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Znanstveni časopis *Hrvatski meteorološki časopis* nastavak je znanstvenog časopisa *Rasprave* koji redovito izlazi od 1982. godine do kada je časopis bio stručni pod nazivom *Rasprave i prikazi* (osnovan 1957.). U časopisu se objavljuju znanstveni i stručni radovi iz područja meteorologije i srodnih znanosti.
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HRVATSKO METEOROLOŠKO DRUŠTVO

organizira

ZNANSTVENO-STRUČNI SKUP S MEĐUNARODNIM SUDJELOVANJEM

Prvi poziv

Meteorološki izazovi 7

Meteorologija kao podrška tijelima javne uprave

1. - 3. travnja 2020.

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Ovaj skup je od posebne važnosti za Hrvatsku u vrijeme kad će preuzeti predsjedanje Vijećem Europske unije. Meteorologija kao struka je uvijek bila podrška svim društvenim i gospodarskim aktivnostima, ali i tijelima javne uprave koja također koriste meteorološke informacije i proizvode u obavljanju svojih svakodnevnih aktivnosti.

Ciljevi skupa su razmjena najnovijih znanstvenih rezultata i istraživanja na području meteorologije, jačanje komunikacije s korisnicima meteoroloških podataka i produkata te s javnošću i medijima, jačanje suradnje među meteorolozima i znanstvenicima srodnih znanosti te promicanje i popularizacija meteorologije.

Očekivani rezultati skupa su uža interdisciplinarna suradnja meteorologa s korisnicima iz svih područja društvenih i gospodarskih djelatnosti, posebice s tijelima javne uprave na svim razinama.

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Meteorološki izazovi 7: Sekcija 1
SURADNJA S TIJELIMA JAVNE UPRAVE

THE WEATHER WARNING SYSTEM IN WEATHER ANALYSIS AND FORECASTING DEPARTMENT OF THE CROATIAN METEOROLOGICAL AND HYDROLOGICAL SERVICE

TANJA RENKO, PETRA MIKUŠ JURKOVIĆ, LOVRO KALIN, MARIJA MOKORIĆ, TOMISLAVA HOJSAK and TOMISLAV KOZARIĆ
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Issuing of weather warnings is one of the primary tasks of the Croatian meteorological and hydrological service (DHMZ). Towards this end systematic and continuous effort is focused on the development and quality of information on hazardous weather events. The established alert system has undergone many changes and improvements over the recent years, especially with the development of internet and other technologies by means of which information is delivered quickly. The timely issued weather warnings are very important in protecting the citizens and their property. The DHMZ is the only organization responsible for issuing official meteorological warnings in the country. To fulfill this task the DHMZ must communicate and cooperate with all the services and partners responsible for the security of citizens of RH. This paper aims to give an overview of the DHMZ Weather Warning System, from the Standard Operating Procedures, to development of the system that has been extensively upgraded in the last few years, as well as to the explanation of the final product, vizual information made available to all citizens on DHMZ website. In addition, we also present the statistical features of the warnings in the period from 2009 to 2018 and the method of verification of individual warnings. A part of the paper is devoted to forest fire protection, i.e. the role of DHMZ in the implementation of fire protection measures of interest to the croatian authorities and citizens.

Key words: DHMZ, weather warnings, impact, security, Republic of Croatia

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METEOROLOŠKI PODACI U DOKUMENTIMA I AKTIMA PROSTORNOGA UREĐENJA I ZAŠTITE OKOLIŠA NA PODRUČJU PRIMORSKO-GORANSKE ŽUPANIJE

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S obzirom da o vremenu i klimi ovise sve životne i gospodarske aktivnosti čovjeka, meteorološki i klimatski podaci su neizostavan dio svih dokumenata prostornoga uređenja i zaštite okoliša, kao i akata njihove provedbe. U radu se stoga iznose primjeri prostornih planova, kao i planskih dokumenata iz područja zaštite okoliša donesenih za područje Primorsko-goranske županije te provedenih postupaka strateške procjene utjecaja na okoliš i pojedinačnih postupaka procjene utjecaja na okoliš u kojima su upravo meteorološke, odnosno klimatske prilike od presudnog značaja za realizaciju planiranih zahvata. Zaključuje se o nužnosti izrade kvalitetnih podloga iz područja meteorologije od strane ovlaštenih stručnih institucija i osoba jer u suprotnom može doći do velikih problema tijekom korištenja pojedinih građevina i/ili zahvata s obzirom na utjecaj na okoliš te kvalitetu života stanovništva.

Ključne riječi: meteorološki podaci, dokumenti prostornoga uređenja, dokumenti zaštite okoliša, Primorsko-goranska županija

INVOLVEMENT OF STAKEHOLDERS DURING THE HEAT-SHIELD PROJECT DEVELOPMENT IN SLOVENIA

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Global warming causes more extreme weather, and climate change will exacerbate the negative effects of heat stress on individuals. Climate projections for Slovenia show that at the end of the century, in the case of a moderately optimistic scenario of greenhouse gas emissions, we will have on average at least one heat wave per year, which is comparable to or worse than the heat wave we had in the summer of 2003 (Bertalanič et al., 2018). According to ILO (International Labor Organization) projections, more than 2% of working hours per year are expected to be lost globally by 2030, either because of poor working conditions or slower work with increased heat load (Kjellstrom et al., 2019). In Europe, workers in agriculture, construction, transport, industry and tourism are the most exposed to heat and represent about 50% of the workforce. Increasing heat points to the need to be prepared for the excessive heat load of people in general and especially for workers in more exposed workplaces.

The HEAT-SHIELD project brings together scientists from various research institutions with knowledge of climatology, physiology, medicine and experts in public health, environmental policy and occupational safety. During the project, the WBGT (Wet Bulb Globe Temperature) indicator was selected as an appropriate indicator of heat load. In order to keep employers, consultants and workers in Europe aware of the increased heat load and the negative effects of heat stress on health and productivity, a platform was created (Morabito et al., 2019) within the Heat-Shield project (https: //heatshield.zonalab.it) with heat stress forecast and personal alerts and tips. Timely preparedness for heat stress greatly enhances our potential for mitigation, so we encourage businesses and individuals to come up with an action plan for the heat, register on the platform, and follow up on forecasts and alerts. The response of employers and occupational safety and health organizations to global warming should include adaptation policies and measures to protect workers.

We will present how we have continued from the first analysis of the workers' situation in Slovenia through two symposia for various stakeholders like employers, environmental agency, national institute for public health, trade unions representatives, ministries, etc. trying to get the topic the attention it deserves and to put some solutions to practice.

Key words: heat-shield, heat stress, workers, stakeholders, occupational health

MARINE METEOROLOGY FOR MARITIME ACTIVITIES AND PUBLIC SAFETY IN CROATIA

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The Croatian meteorological and hydrological service (DHMZ) provides marine meteorological services for the offshore, coastal areas, ports, coastlines and land-based support operations for the area of Adriatic Sea. On demands, the services are provided for the Mediterranean areas and other seas. The duties of DHMZ are described at Croatian law of the sea.
Marine meteorological services includes activities of atmospheric and sea surface observations and monitoring, numerical analyses and forecasting and applied forecasts and warnings for dangerous weather phenomena.
Met-ocean (atmospheric, sea surface and sea state) observing systems are part of global observing system coordinated by World Meteorological Organization (WMO), Joined Commission for Oceanography and Marine Meteorology Observations Programme (JCOOM OPS). DHMZ is contributing to global and regional observing systems with surface observations, moored met-ocean buoys and voluntarily observing ships (VOS) observations. The met-ocean observing system is a part of the modernization of state meteorological observing system and also a part of European automatic VOS system.
The specific duties for the marine forecasting and warnings are provided by DHMZ Marine meteorological center (Pomorski meteorološki centar – PMC) that operates in Split and Rijeka. PMC is working as 24/7 call center and issues forecasts and warnings for navigational safety (maritime transport) in line with the international SOLAS convention. The PMC monitor and forecast severe meteorological phenomena, creates weather surveys, severe weather phenomena warnings and marine weather forecasts.
The products of PMC work are: marine meteorological bulletins and warnings for ships, bulletins and warnings for ports and anchoring sites, weather notifications for the Search and Rescue, weather notifications for nautical tourism, sport activities and tourism in general (in English, German and Italian), special meteorological notifications for marinas, shipyards, marine constructions, for towing and dangerous goods shipping, other maritime works, research and exploitation of the sea, seabed and the undersea, for roads and bridges constructions, salt pans, electric power industry, fishering, etc.
DHMZ issues and publish marine meteorological forecasts and warnings (www.meteo.hr) for numerous public, civil and governmental institutions and at the marine broadcasting system.
The warnings are disseminated immediately after they are prepared to the authorities of the national early warning system (EWS):
• Ministry of the interior – Civil Protection Directorate (SCZ)
• Ministry of the sea, transport and infrastructure
• Croatian firefighting association (HVZ)
• Ministry of defense – Marine and coast guard.
The specific marine meteorological product – NAVTEX marine messages are part of worldwide met-ocean information and warning service provides Maritime Safety Information (MSI) to mariners in the form of marine forecast and warning products. NAVTEX messages in English are radio broadcasted via national marine radio operators on 518 kHz of MSI by means of narrow-band direct-printing telegraphy.
Ministry of sea, transport and infrastructure incorporated PMC marine meteorological messages as a part of Navigational Information System (nIS) mobile phone application that is designed for the small and recreational craft crews and marine tourists.
PMC marine meteorological messages will be part of new AIS AToN Messages for Adriatic Sea that will be developed at Italy-Croatia Vessel Traffic information System (VTS).

Key words: marine meteorology, warnings, national authorities, MSI, NAVTEX

PRIMJENA REZULTATA ALADIN PROGNOSTIČKOG SUSTAVA: POTPORA DRUŠTVU I GOSPODARSTVU

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Razvoj i primjena ALADIN sustava za numeričku prognozu vremena je djelatnost koja ostvaruje jasan javni interes jer doprinosi normalnom odvijanju društvenog života zemlje. Osnovna svrha ALADIN prognostičkih produkata je rana najava na opasne vremenske, klimatske i hidrološke uvjete, s ciljem ublažavanja nerijetko katastrofalnih posljedica na cjelokupno društvo. S druge strane, izravna povezanost postoji i s gospodarskim aktivnostima jer je na temelju prognostičkih produkata moguće stvoriti dodatnu vrijednost odnosno dobit od pruženih usluga na tržištu. Primjena ALADIN prognostičkog sustava u javnoj upravi, javnim tvrtkama i društvu u cjelini stoga ima kako negospodarsku tako i gospodarsku svrhu.
S ciljem potpore prognostičarima i unapređenju sustava upozorenja na DHMZ-u, ALADIN prognostički sustav nedavno je dopunjen s modulima naknadne obrade za lokalno-specifičnu prognozu vremena te probabilističkog pristupa prognozi. Izrađena je i analiza režima vjetra te proračun povratnih perioda maksimalnih očekivanih brzina vjetra na 60-ak lokacija u Hrvatskoj. S druge strane, jača i primjena prognostičkih informacija u društvu i gospodarstvu: energetici, prometu, turizmu i drugim djelatnostima, kako putem dostupnosti novih produkata, tako i putem osuvremenjenog načina izlaganja konačnih prognostičkih produkata, npr. putem ALADIN web aplikacije. Nadalje, primjena rezultata modela ALADIN uključuje i potporu izgradnji ključnih infrastrukturnih projekata, poput cesta, žičara itd., za što se koriste kako povijesni prognostički podaci ALADIN modela tako i podaci mjerenja sa promatranih lokacija, te odnedavno i meteorološko modeliranje ultravisoke razlučivosti (~10 m). Kroz izlaganje će se dati specifični primjeri nedavnog razvoja i primjene novih tehnologija odnosno unapređenja ALADIN prognostičkog sustava.

Ključne riječi: ALADIN prognostički sustav, primjena prognostičkih informacija u društvu i gospodarstvu, nove tehnologije

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ZAŠTITA ZRAKA: IZGRADNJA ZAKONODAVNOG OKVIRA KOJI ZADOVOLJAVA ZAHTJEVE STRUKE, GOSPODARSTVA I JAVNOSTI UKLJUČUJUĆI MEĐUNARODNE STANDARDE I OBVEZE

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Izgradnja zakonodavnog okvira u svakom području ljudske djelatnosti predstavlja izazov. U području zaštite zraka i okoliša općenito to je osobito izraženo jer se moraju pomiriti interesi i potrebe brojnih interesnih skupina, različitih sektora gospodarstva i općih interesa populacije. Možda jedno od „najmlađih“ područja koje je ušlo u regulatorni ciklus, ne samo kod nas, nego i u svijetu, područje zaštite okoliša se za uspostavu regulatornog okvira moralo snažno osloniti na znanstvene podloge i rezultate znanstvenih istraživanja. To je ponajprije zbog činjenice da se gotovo sva uspostavljena regulativa može svesti na ograničavanje gotovo apsolutne slobode i nedostatku kontrole u mnogim sektorima gospodarstva i industrije koji su vladali do sredine šezdesetih godina prošloga stoljeća. Pokazatelji propadanja i narušavanja ravnoteže u okolišnim ekosustavima (vode, jezera, šume, tlo, zrak itd.) iznjedrili su sintagmu „održivi razvoj“ i malo pomalo omogućili „evidence-based policy development“.
Znanstveni pristup i znanje pomažu razumijevanju uzroka i učinaka promjena u okolišu. Znanost nam pomaže osmišljavanje strategija za upravljanje resursima, iznalaženje učinkovitih rješenja za probleme negativnih utjecaja na zdravlje, sigurnost i kvalitetu života i osiguravanje prijelaza na resursno učinkovito gospodarstvo. Više znanja pomaže nam da prepoznamo važne trendove i

osmislimo odgovarajuće politike za zaštitu i očuvanje kvalitete zraka i okoliša.
U ovome radu bit će prikazan pregled učinkovitosti međudjelovanja i sprege znanstvenih dostignuća, strategija i politika koje su dovele do razvoja zakonodavnog okvira u području zaštite okoliša s posebnim naglaskom na ulogu meteorologije, mjerenja i modeliranja atmosferskih procesa. Bit će prikazani primjeri dosadašnjih rezultata ovih procesa kao i izgledi za njihov daljnji razvoj u vremenu koje je pred nama.

Ključne riječi: zakonodavni okvir, znanost, kvaliteta zraka, zdravlje, okoliš

ULOGA METEOROLOGA U IZRADI NACIONALNIH DODATAKA EUROPSKIM NORMAMA

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Djelovanje ekstremnih vremenskih prilika uz djelovanje potresa, čini dominantno djelovanje kojem su izloženi građevinski objekti u svom vijeku trajanja. Poseban značaj ovog djelovanja je što je ono promjenjivo u vremenu, a po intenzitetu varira i ovisi o meteorološkim karakteristikama pojedinog područja, te se ne može unificirati.
Velikom broju građevinara pri projektiranju jedini kontakt s informacijama o proračunu opterećenja građevinskih konstrukcija vjetrom, snijegom ili ekstremnom temperaturom su postojeći standardi, odnosno norme. Iako se ti standardi zasnivaju na opsežnim istraživanjima, oni nužno, zbog zahtjeva praktične primjene, pojednostavljuju modele proračuna opterećenja vjetrom, snijegom ili ekstremnom temperaturom. Proces globalizacije ima za posljedicu i nastojanje da se broj postojećih standarda za proračun tog opterećenja smanji, te da se postigne ujednačenost u njihovom sadržaju i formatu.
Prihvaćanjem europskih normi za projektiranje konstrukcija Hrvatska je prihvatila i načelo da u pojedine norme ugradi nacionalne specifičnosti koje se prvenstveno odnose na prirodne pojave, tj. da izradi posebne nacionalne dodatke za pojedinu normu koji sadrže sve određene parametre koji će se upotrebljavati pri projektiranju zgrada i inženjerskih građevina koje se grade u Hrvatskoj.
Značajni dijelovi tehničke regulative koja se odnosi na djelovanje meteoroloških uvjeta na građevine su minimalna i maksimalna temperatura zraka i maksimalna brzina vjetra za povratno razdoblje od 50 godina i karakteristično opterećenje snijegom. Procjene ekstremnih vrijednosti osnova su za kartiranje tih parametara, a karte su dio ili osnova za izradu nacionalnih dodataka u normama koje izdaje Hrvatski zavod za norme. Stoga meteorološka ekspertiza u izradi nacionalnih dodataka hrvatskim normama ima izuzetan značaj.
Meteorolozi Državnog hidrometeorološkog zavoda sudjelovali su znanstveno-istraživačkim radom u izradi nekoliko normi: Djelovanja vjetra: HRN EN 1991-1-4:2012/NA:2012; Opterećenja snijegom: HRN EN 1991-1-3:2012/NA:2012; Toplinska djelovanja: HRN EN 1991-1-5:2012/NA:2012.
Isto tako izrađena je i analiza ugroženosti ledom i ekstremnom brzinom vjetra koja je dala nužnu osnovu za kompletiranje podloga za usklađivanje prakse projektiranja, izgradnje i održavanja nadzemnih vodova iznad 1 kV u Republici Hrvatskoj s normativnom praksom u Europskoj uniji (EN 50341-1:2012). Trenutno je u izradi analiza specifičnih nacionalnih klimatskih parametara za potrebe izrade nacionalnog dodatka normi koja se odnosi na projektne parametre potrebne za dizajn i konstrukciju staklenika (EN 13031-1).
Pri izradi svih nacionalnih dodataka i podloga za njihovu izradu susretali smo se s mnogim znanstveno-istraživačkim izazovima čije je rješavanje moralo rezultirati konkretnim, jasno i nedvosmisleno primjenjivim rezultatom prikazanim u jednostavno razumljivom formatu.
Ovaj rad ima za cilj prikazati neke od tih izazova i pristup njihovom rješavanju.

Ključne riječi: nacionalni dodatak europskoj normi, meteorološki ekstremi

METEOROLOŠKA POTPORA IZGRADNJI KRITIČNE PROMETNE INFRASTRUKTURE U HRVATSKOJ

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Državni hidrometeorološki zavod (DHMZ) pruža potporu tijelima javne uprave kroz različite primjene meteorologije i hidrologije u područjima klimatologije, pomorske meteorologije, agrometeorologije, zrakoplovne meteorologije, energetike, prometa, prostornog planiranja i projektiranja i ostalih primjena. U sektoru prometa, DHMZ pruža potporu izgradnji i upravljanju kritičnom prometnom infrastrukturom putem i) izrade meteoroloških podloga u fazi planiranja i projektiranja ii) prognostičke potpore tijekom izgradnje iii) prognostičke potpore za rad sustava za upravljanje kritičnom prometnom infrastrukturom i osiguranju sigurnosti prometa.
Planiranje izgradnje i optimalna funkcionalnost žičare Labin – Rabac zahtijeva analizu podataka mjerenja osnovnih meteoroloških elemenata jer je poznavanje klimatskih obilježja lokaliteta gradnje od izuzetnog značaja u fazama njegovog planiranja, projektiranja, izgradnje i korištenja. Sve radove na elementima građevine potrebno je isplanirati i obraditi tako da se izvedbom radova postigne proračunata i predviđena funkcija svih elemenata. Kako smjer i brzina vjetra značajno utječu na funkcionalnost i trajnost predviđene građevine, studija "Analiza meteoroloških prilika na području planirane izgradnje žičare Labin – Rabac" sadrži detaljnu analizu ovih meteoroloških parametara, s posebnim naglaskom na jaki vjetar. Da bi građevinski objekt izložen olujnom vjetru bio siguran i otporan, potrebno je projektne parametre prilagoditi maksimalnom očekivanom opterećenju vjetrom koje u prvom redu ovisi o procjeni zone opterećenja proračunatoj na temelju maksimalne očekivane brzine vjetra na lokaciji građevine.
Na području planirane izgradnje žičare Labin – Rabac, DHMZ ne raspolaže višegodišnjim nizovima kontinuiranih mjerenja meteoroloških parametara. Uzimajući u obzir složenu konfiguraciju terena područja za koje se traži analiza i prostornu promjenjivost klimatskih prilika, najbliža meteorološka postaja reprezentativna za ocjenu klimatskih prilika na području buduće žičare je Monte Kope. U analizi su korišteni podaci mjerenja smjera i brzine vjetra s meteorološke postaje Monte Kope u razdoblju 2015. – 2018. godine. U svrhu ocjene režima strujanja na području bez mjerenja koristi se numerički model atmosfere ALADIN koji je u DHMZ-u operativni prognostički model. Detaljnija prostorna slika strujanja za područne zone mjerenja vjetra, dobit će se modelom visoke rezolucije – tzv. WRF-LES (large eddy-simulation) za reprezentativan slučaj olujnog vjetra u području određen na temelju podataka s mjerne postaje.

Ključne riječi: DHMZ, prometna infrastruktura, vjetar, ALADIN, WRF

25 GODINA GLOBE PROGRAMA

DIJANA GARAŠIĆ i VLADIMIR RIBIČIĆ
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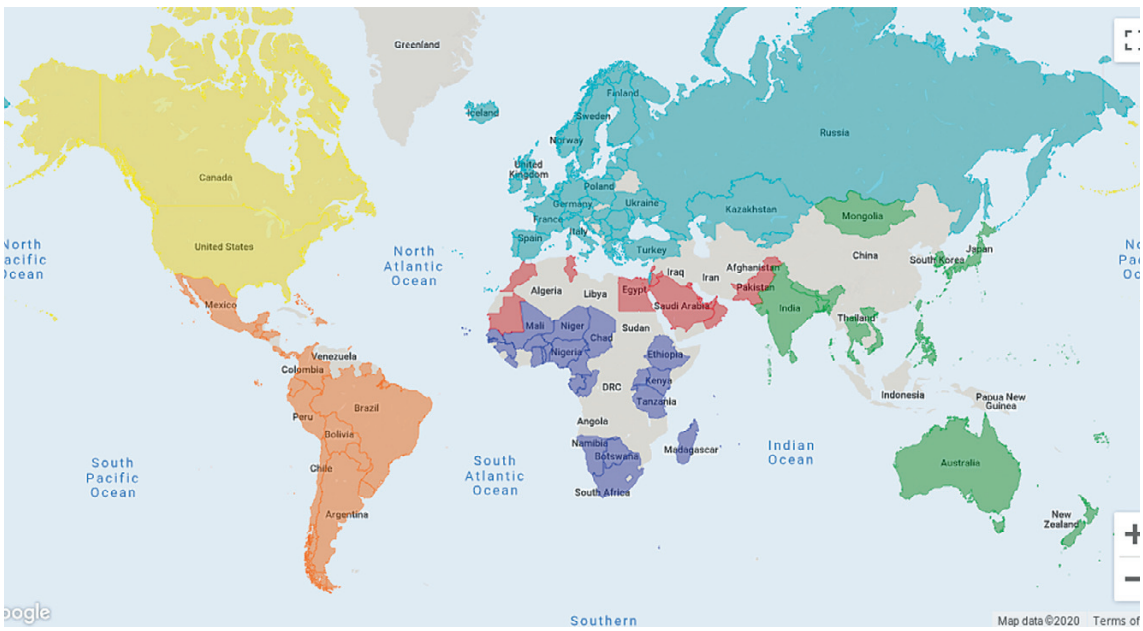
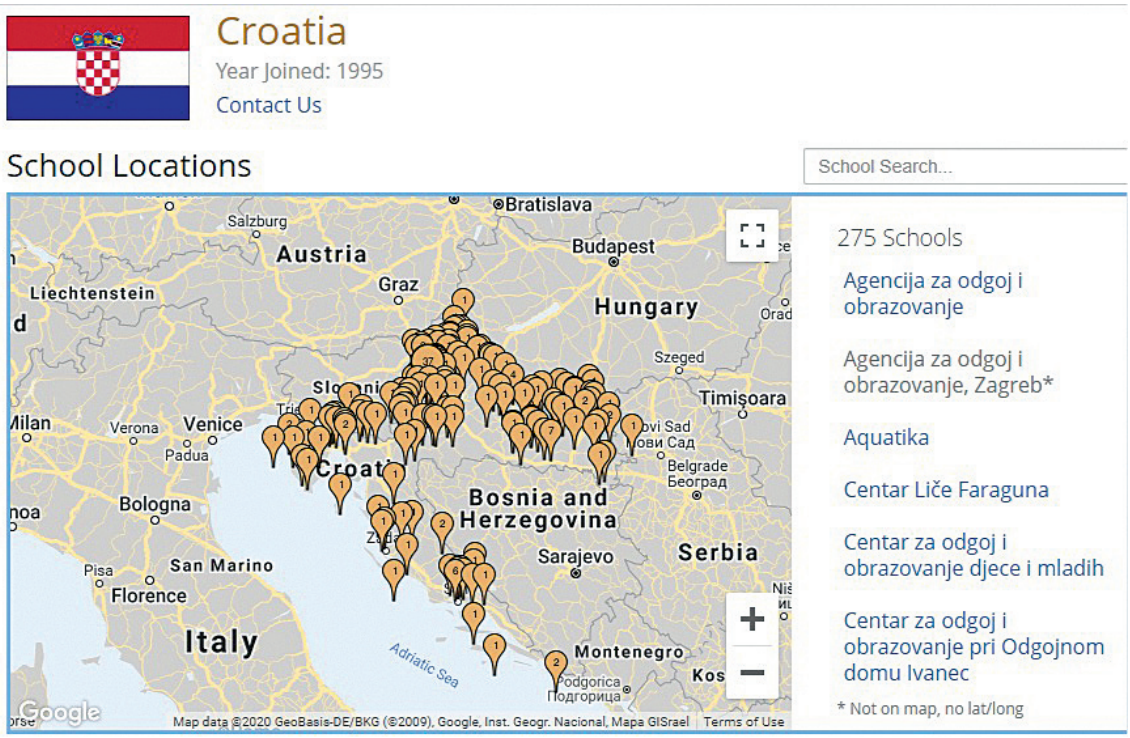
GLOBE (Global Learning and Observations to Benefit the Environment = Cjelovito učenje i opažanje za dobrobit okoliša) znanstveno je obrazovni program, namijenjen učenicima osnovnih i srednjih škola, koji u svom neposrednom okolišu obavljaju različita mjerenja, primjerena svojoj dobi i interesima te mogućnostima škole. Prikupljeni se podaci unose u jedinstvenu svjetsku bazu podataka. Mjereći i opažajući značajke okoliša u istraživačkom području škole, učenici upoznaju i na neposredan način doživljavaju svoje okruženje, upoznaju znanstvene metode mjerenja, prikazivanja i tumačenja podataka, povezuju školska znanja s praktičnim i terenskim radom te razvijaju osjetljivost i pozitivan odnos prema okolišu. GLOBE ostvaruje zamisao: „Misli globalno, djeluj lokalno".

Hrvatska je bila među prvim zemljama koje su pristupile svjetskoj mreži Programa GLOBE, na temelju Sporazuma koji su u travnju 1995. potpisali hrvatski dužnosnici s predstavnicima američke vlade. Danas je u GLOBE program uključeno preko 120 zemalja sa svih kontinenata (sl. 1). Samo područja na slici 1 obojena sivo ne pripadaju GLOBE zajednici.



Slika 1. Karta svijeta i GLOBE regije.

Zemlja-partner obvezuje se provoditi Program u svojim školama, na način koji sama odabere, ali poštujući strogo propisane protokole mjerenja što je nužno zbog vjerodostojnosti i usporedivosti rezultata mjerenja.
Škola / institucija postaje dio GLOBE zajednice na temelju edukacije učitelja / nastavnika, čime se oni osposobljavaju za provedbu programa. Obveznom edukacijom nastoji se osigurati znanstvena korektnost postupaka pri izvođenju mjerenja i opažanja.



Slika 2. GLOBE škole u Hrvatskoj.

2. SADRŽAJ PROGRAMA GLOBE

Program GLOBE obuhvaća mjerenja i opažanja u području atmosfere, površinskih voda, tla i zemljišnog pokrova. Za svaku vrstu mjerenja i opažanja postoji propisani protokol, instrumentarij definiranih karakteristika i odgovarajuća dinamika mjerenja (tab. 1).

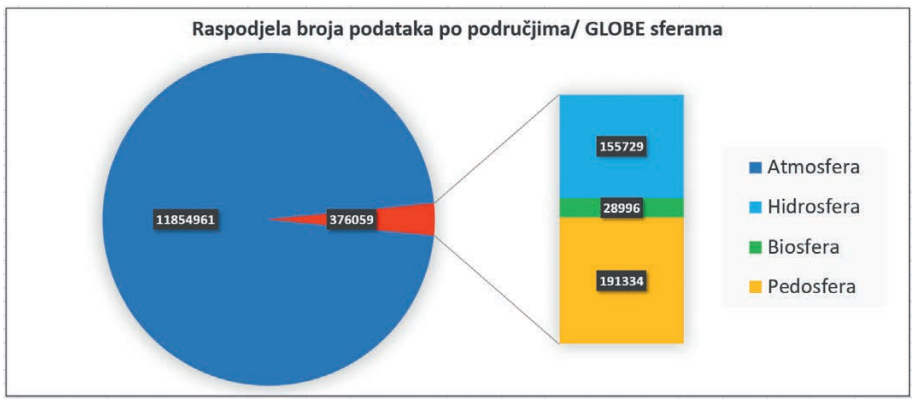
Tablica 1. Dinamika mjerenja i opažanja.

Područje mjerenja i opažanja	**Učestalost prikupljanja podataka**
Atmosfera (meteorologija)	Svaki dan u solarno podne (± 1 sat)
Hidrosfera (kopnene vode i more); fizikalno-kemijske analize	Tjedno (češće u vrijeme promjene uvjeta)
Biosfera (pokrov)	Dva puta godišnje
Fenološka opažanja (pupanje i listanje; promjene boja lišća)	Tijekom proljetnog i jesenskog perioda
Pedosfera (tlo) – karakterizacija tla	Jednom na svakoj lokaciji
Pedosfera (tlo) – vlažnost i temperatura tla	Svaki dan u solarno podne (± 1 sat)

Osim što će učenici prikupljajući podatke učiti o okolišu, važno je probuditi njihovo zanimanje za razumijevanje rezultata mjerenja i praćenja u širem kontekstu, poticati korištenje baze podataka za vlastita istraživanja te surađivati s drugim GLOBE školama u zemlji i inozemstvu.
U hrvatskim se školama program GLOBE ostvaruje poglavito kao dodatna nastava ili izvannastavna aktivnost najmanje jedne grupe učenika, koja obavlja redovita mjerenja i putem interneta unosi prikupljene podatke u jedinstvenu GLOBE bazu podataka. Dio periodičkih mjerenja i opažanja, a posebno njihova tumačenja i teoretska podloga te istraživanja u okolišu, mogu se dobro povezati uz redovite ili izborne programe različitih predmeta, primarno STEM područja, ali veze su moguće i s jezično-komunikacijskim, kao i s društveno-humanističkim područjem.

3. ATMOSFERSKA MJERENJA I OPAŽANJA

Većina hrvatskih škola za početak svojeg rada bira meteorološka mjerenja i opažanja, posebno protokole za koje nije potrebna posebna mjerna oprema – određivanje boje neba, pokrivenosti neba oblacima i tipova oblaka. U sljedećem koraku obično postavljaju GLOBE (malu) meteorološku kućicu s minimalnim i maksimalnim termometrom, uz koju se smješta i kišomjer. To su i najčešća mjerenja koja se provode u našim školama i provode se svakodnevno pa iz tog područja ima i najveći broj podataka (sl. 3).

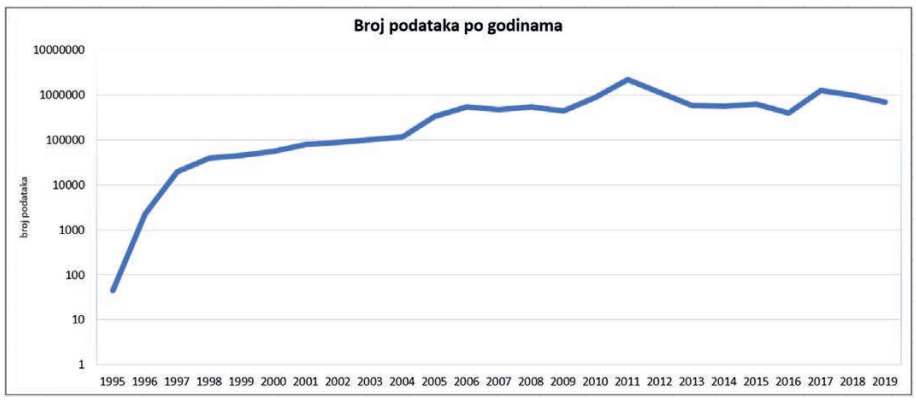


Slika 3. Raspodjela broja podataka po područjima / GLOBE sferama.

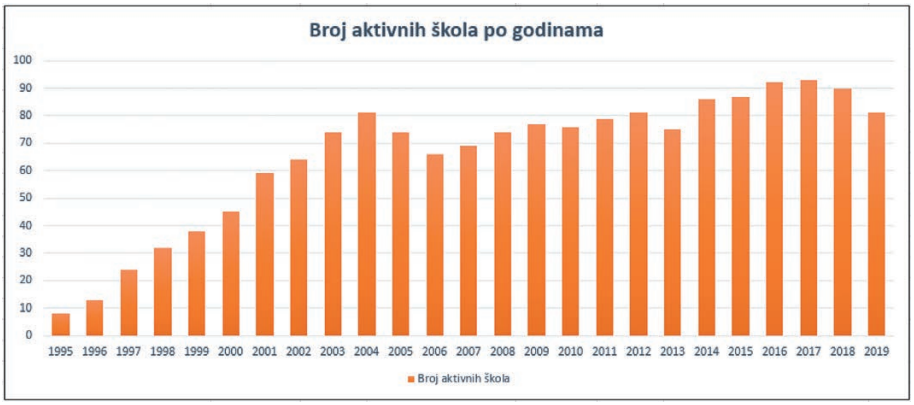
Veliki broj škola provodi još i mjerenja vlažnosti zraka, manji broj provodi mjerenja atmosferskog tlaka i pH vrijednosti oborine, a dio škola primjenjuje protokole koji se odnose na snijeg. Svega nekoliko škola provodi mjerenja aerosola jer je za to potrebno nabaviti baždareni instrument – fotometar.

4. BROJ GLOBE PODATAKA IZ HRVATSKIH ŠKOLA

Tijekom 25 godina hrvatskog sudjelovanja u Programu GLOBE, hrvatske su škole u međunarodnu razmjenu poslale preko 10 milijuna podataka atmosferskih, hidroloških, pedoloških i fenoloških mjerenja i opažanja.
Broj upisanih podataka za svaku godinu pokazuje manje varijacije između 2011. i 2017. godine (sl. 4). Vjerojatni uzrok tome je što neke škole prestaju s mjerenjima iz raznih razloga ili smanjuju opseg mjerenja vezano uz trenutačne interese (sl. 5). Istodobno se aktiviraju nove škole, ali imaju u početku manji opseg mjerenja.

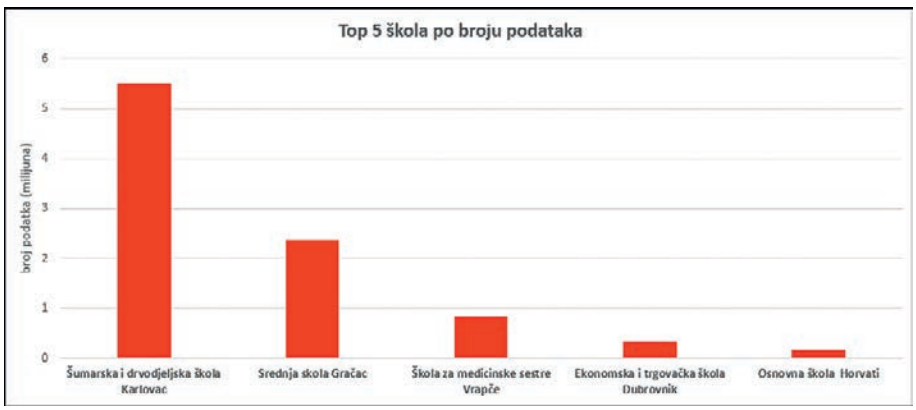


Slika 4. Godišnji broj podataka koje su hrvatske škole upisale u GLOBE bazu.



Slika 5. Broj aktivnih škola u Hrvatskoj po godinama.

Ako se pogleda koje škole imaju najveći broj upisanih podataka (sl. 6) može se primijetiti da su na prvih 5 mjesta škole koje imaju automatske meteorološke postaje. Premda se korištenjem automatskih postaja gubi značajni aspekt praktičnog učeničkog rada u baratanju s instrumentima, razvijanju urednosti, točnosti i odgovornosti, rješava se problem održavanja kontinuiteta mjerenja, odnosno problem dežurstava tijekom vikenda i praznicima. Budući da su automatske postaje još uvijek relativno skupe, veliki broj škola i dalje obavlja mjerenja klasičnim načinom.

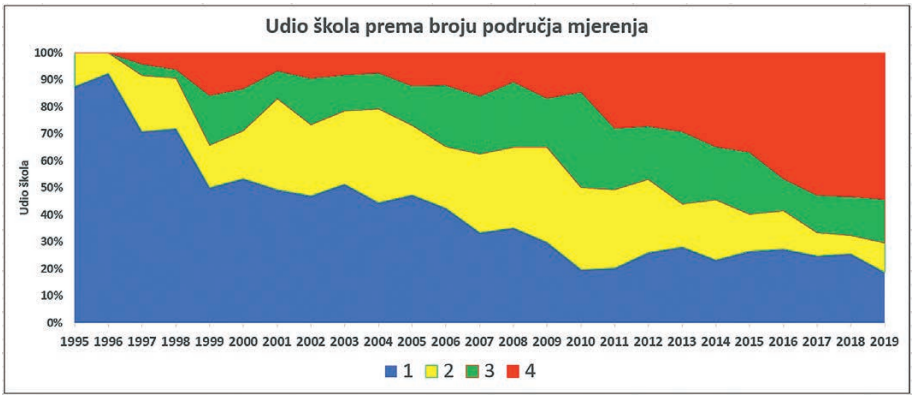


Slika 6. Škole s najvećim upisanim brojem podataka (prvih 5).

Kad se primjena odabranih protokola uhoda i učenici se uvježbaju u njihovoj provedbi, škola prema vlastitim interesima i mogućnostima može proširiti broj protokola koje primjenjuje. S godinama provedbe, u Hrvatskoj možemo primijetiti trend porasta broja škola koje provode mjerenja i opažanja u više područja (sl. 7). Taj se trend, između ostaloga, može dovesti u vezu s kriterijima za selekciju škola koje se pozivaju na državnu smotru učeničkih projekata i GLOBE orijentacijsko natjecanje.

5. SMOTRE I NATJECANJA GLOBE ŠKOLA

Na Državnu smotru i natjecanje GLOBE škola pozivaju se škole koje aktivno ostvaruju program, a broj i raspon podataka utječu na ocjenu aktivnosti. Smotra istraživačkih projekata i orijentacijsko natjecanje školskih timova zamišljeni su kao način stimuliranja aktivne provedbe GLOBE programa, ali i poticanja integriranog pristupa poučavanju, poticanju timskog rada te međusobnom zbližavanju i povezivanju škola, učitelja i učenika.



Slika 7. Udio škola koje prikupljaju podatke iz jednog, dva, tri ili četiri područja.

Učenički, odnosno školski projekti izrasli iz programa GLOBE najviša su razina njegove obrazovne komponente. Oni potiču analizu i dublje razumijevanje dobivenih rezultata, povezivanje i primjenu temeljnih školskih znanja u rješavanju konkretnih problema u svojoj sredini, kroz njih se razvija prosuđivanje i ostvaruje istraživački, djelatni i multidisciplinarni pristup učenju, unapređuje se vještina komuniciranja i vježba timski rad (sl. 8).
Stručna povjerenstva procjenjuju učeničke istraživačke radove pristigle na državnu razinu Smotre i natjecanja pa se oni uspješni objavljuju na hrvatskim internetskim GLOBE stranicama, a najuspješniji dobivaju priznanja.
Sve veći broj hrvatskih škola odlučuje prijaviti svoje istraživačke projekte na međunarodnu GLOBE smotru (International Virtual Science Symopsium – IVSS).
Za IVSS 2020. pristiglo je ukupno 268 projekata, od čega 22 iz regije Europa i Euroazija, a od tog broja 12 ih je bilo iz hrvatskih škola. Nakon stručne procjene nezavisnih ocjenjivača, ukupno je 76 projekata dobilo priznanja i značke, od čega 8 iz naše regije, a od toga je 5 bilo hrvatskih.

Slika 8. GLOBE natjecateljski tim.

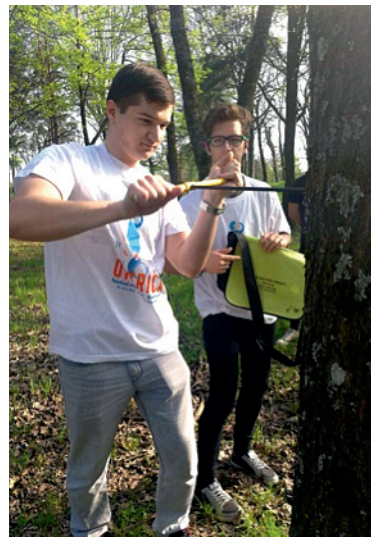
6. HRVATSKA U MEĐUNARODNOJ GLOBE MREŽI

Zahvaljujući aktivnostima i kvalitetnom radu naših škola od samih početaka provedbe GLOBE programa, Hrvatska je odabrana za domaćina nekoliko međunarodnih konferencija i sastanaka.

1999. u Splitu je održan međunarodni simpozij o daljinskim istraživanjima.
2003. u Šibeniku je održana svjetska učenička konferencija (GLOBE Learning Expedition – GLE – 2003. na kojoj je sudjelovalo više od 400 sudionika iz tridesetak zemalja cijelog svijeta.
2007. u Dubrovniku je održan međunarodni sastanak koordinatora i GLOBE trening.

Naše su učeničke delegacije sudjelovale na konferencijama GLE Helsinki (Finska), 1998., GLE – Cape Town (JAR), 2008., GLE – Killarney (Irska), 2018. te na nekoliko svjetskih godišnjih sastanaka Programa GLOBE (GLOBE Annual Meetings).
Nekoliko naših škola sudjelovalo je u međunarodnim projektima, koji su bili financirani sredstvima norveške vlade, a oba su uključila područje meteoroloških mjerenja.
The Tree Rings je projekt u kojem su učenici uspoređivali klimatska obilježja različitih dijelova Europe i povijesne varijacije atmosferskih parametara s godovima stabala bora (sl. 9).
Aerosols in Europe – u projektu je sudjelovalo 6 zemalja, a cilj je bio prikupiti i usporediti podatke o koncentracijama aerosola u različitim dijelovima Europe, usporedno s ostalim relevantnim meteorološkim parametrima.

Ugledu Hrvatske u međunarodnoj GLOBE zajednici, osim redovitosti mjerenja te broja i raspona podataka, značajno pridonosi odaziv hrvatskih škola na sudjelovanje u kampanjama prikupljanja podataka vezano uz pojedine satelitske misije (Trees Around the GLOBE, GLOBE Mission Mosquito, Urban Heat Island Effect, SMAP, Global Precipitation Measurement (GPM)) te uz europsku fenološku kampanju Growapp (https://www.growapp.today/).



Slika 9. Uzimanje uzoraka godova.

7. SURADNJA S INSTITUCIJAMA

Provedba GLOBE programa u Hrvatskoj ne bi bila moguća bez potpore mnogih institucija kao što su Ministarstvo znanosti i obrazovanja, Agencija za odgoj i obrazovanje, Državni hidrometeorološki zavod, Prirodoslovno matematički fakultet, ali i mnoge druge. Suradnja s Državnim hidrometeorološkim zavodom (DHMZ) ponajprije se očituje sudjelovanjem u osposobljavanju učitelja i nastavnika za provedbu meteoroloških mjerenja i opažanja te u radu državnog povjerenstva za Smotru i natjecanje.
Od samih početaka provedbe Programa GLOBE, važnu je ulogu imala mr. sc. Janja Milković, koja je osim brojnih edukacija zadužila program i prevođenjem opsežnog GLOBE priručnika za učitelje. U novije vrijeme suradnja s DHMZ-om ostvaruje se sudjelovanjem Dubravke Rasol, dipl. ing. i Vladimira Ribičića u edukaciji učitelja/nastavnika te u radu državnog povjerenstva za smotru i natjecanje.
U osposobljavanju učitelja/nastavnika za područje meteoroloških mjerenja i motrenja značajnu su ulogu odigrali profesori *Šumarske i drvodjeljske škole u Karlovcu*, smjera *Meteorološki tehničar*: mr. sc. Marina Grčić, mr. sc. Mladen Matvijev i Zrinko Bahorić, dipl. ing.
Agencija za odgoj i obrazovanje (AZOO) je institucija službeno zadužena za provedbu Programa GLOBE u Hrvatskoj. AZOO oglašava i organizira početne tečajeve, seminare za uključene GLOBE učitelje, u suradnji s Ministarstvom znanosti i obrazovanja organizira i financira državnu smotru i natjecanje GLOBE škola te koordinira radom međužupanijskih GLOBE vijeća.
U sklopu GLOBE tečajeva od 1996. godine redovito se organizira i radionica za osposobljavanje polaznika za rad s računalom, korištenje interneta i GLOBE baze podataka. U počecima provedbe programa za mnoge je učitelje/nastavnike to bio prvi susret s ICT područjem. Svakako možemo zaključiti da je GLOBE značajno pridonio razvoju digitalne pismenosti u hrvatskom školskom sustavu. Tu također treba naglasiti potporu koju je od početka provedbe pružao CARNet, omogućavajući školama besplatan pristup internetu. Suradnja se ostvaruje i danas, jer CARNet pruža uslugu smještaja GLOBE web stranice na svom poslužitelju.
Projektni rad u nastavi i istraživačko učenje od samih su početaka zauzimali važno mjesto u edukaciji nastavnika u sklopu GLOBE tečajeva i seminara, puno prije nego je takav način rada uveden kao standard na razini školskog sustava. Stoga je i u pogledu suvremenog pristupa poučavanju GLOBE odigrao pionirsku ulogu.
Putem GLOBE programa naši su učenici i nastavnici, još krajem 20. stoljeća proširili spoznaje u području korištenja modernih tehnologija, poput satelitske navigacije i principa GIS-a te daljinskog istraživanja. Naime, znanstvena misija Programa GLOBE je povezivanje satelitskih podataka s podacima prikupljenim na površini Zemlje. Stoga svaki podatak koji ulazi u GLOBE bazu mora biti prostorno definiran. Da bi sudionici lakše povezivali svoja opažanja na površini Zemlje sa satelitskim snimkama, NASA je (kao glavni sponzor programa GLOBE) u prvim godinama provedbe, dostavljala školama satelitske snimke njihova istraživačkog područja. Danas se to više ne šalje budući da su satelitske snimke svima dostupne putem interneta.
U osposobljavanju nastavnika za primjenu daljinskog istraživanja i interpretiranje satelitskih snimaka, važnu je ulogu odigrao dr. sc. Vladimir Kušan iz Instituta za primijenjenu ekologiju OIKON.
U počecima programa GLOBE, posebno u nabavci osnovne mjerne opreme, značajnu su ulogu odigrali Grad Zagreb i tvrtka ZGO, a mnogim su školama individualnu potporu pružile jedinice lokalne uprave, šumarije, geodetske uprave, zavodi za javno zdravstvo, kao i mnoge tvrtke.

U stručnom aspektu edukacije za provedbu ovog programa te u radu prosudbenih povjerenstava za učeničke istraživačke radove svakako valja istaknuti stručni doprinos i sustavnu suradnju s Biološkim odsjekom Prirodoslovno-matematičkog fakulteta Sveučilišta u Zagrebu.

8. ZAKLJUČAK

Tijekom 25 godina provedbe, Hrvatska se ističe kao jedna od najaktivnijih GLOBE članica na svijetu. Hrvatske škole svake godine osvajaju brojna priznanja, a mnogi učenici uključeni u ovaj program odabiru nastavak obrazovanja u nekom od STEM područja, što je jedan od značajnih pokazatelja važnosti i uspješnosti tog programa. Jedan od najvećih doprinosa Programa GLOBE svakako je podizanje razine prirodoslovne pismenosti učenika i učitelja, a posebice podizanje razine meteorološke pismenosti.

INTERNETSKE STRANICE:

Program GLOBE: www.globe.gov
Hrvatski program GLOBE: http://globe.hr
Udruga ZNAM: https://pubweb.carnet.hr/znanstvenici-amateri/
FB – GLOBE Hrvatska https://www.facebook.com/GLOBE-Hrvatska-871742226188908/?ref=page_internal&path=%2FGLOBE-Hrvatska-871742226188908%2F

Izvori podataka:

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SAHARAN DUST EMISSION PROCESSES DURING DUST OUTBREAK ON NORTH ADRIATIC

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The most abundant global source of the airborne mineral dust, Saharan desert, has strong influence on Mediterranean countries. It affects climate by modifying radiation budget, formation of clouds and marine biogeochemical cycles. The increase of PM_{10} hourly values due to Saharan dust outbreak was observed at several ground based air quality stations located on Italian and Croatian Adriatic coast in September 2015. According to previous studies, two major mechanisms contribute to dust emissions: the Nocturnal Low Level Jet (NLLJ) morning breakdown and convective dust storms, Haboobs. WRF-Chem model was applied to simulate the dust emission, transport and deposition and two major sources of dust in Algeria and Tunisia were detected during the episode. According to coarse grid simulations, the temporal evolution of spatially averaged dust emissions at sources locations show strong morning peaks characteristic for NLLJ breakdowns. However, using North African Sandstorm Survey (NASCube) method, development of several Haboobs is observed during the episode and possibly contributing to dust source emissions. In order to simulate Haboobs, the finer grid resolution was found to be required and still the model frequently collocates the storm or fails to simulate one, or misses the initiation time or duration. Although the model's coarse resolution is not sufficient to simulate convective processes, the model shows good agreement with AOD measured at 8 African and European AERONET stations and with PM_{10} measured at 10 Italian and Croatian air quality stations. This provides evidence that the overall result in this case depends mostly on NLLJ mechanism and not on individual convective storms.

Key words: Saharan dust, Haboob, Nocturnal Low Level Jet, WRF-Chem

SYNERGY OF POLICIES FOR MORE EFFICIENT TACKLING OF CLIMATE CHANGE AND AIR POLLUTION IN CROATIA

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Abstract: Air pollution and climate change, although they have different physical manifestations, are both closely linked to similar causes and concerns. Fossil fuel and biomass burning are the main anthropogenic sources of greenhouse gas and air pollutants emissions that change the composition of the atmosphere. Some of pollutants that are responsible for air quality deterioration are also responsible for the global warming. The question is whether current policies to address climate change and air pollution in Croatia are in synergy, or if they have some contradictions (e.g. biomass combustion in the residential sector). This paper gives an overview of greenhouse gas (GHG) emissions projections and primary air pollutants (NO_x, PM) emissions projections in Croatia, it discusses the interconnections and the importance of the residential sector and road transport sector as key sources of urban air pollution. An overview of the current state of emissions and air quality in the case of particulate matter in Croatia is also given. The importance of black carbon (BC) is highlighted as one of the components of fine particulate matter ($PM_{2.5}$) and also as short-lived

climate pollutants (SLCP). In addition, some funding mechanisms for implementing climate change and air protection policies in Croatia are considered.

Key words: air pollution, climate change, policy, emission, black carbon (BC), funding

1. INTRODUCTION

Air pollution and climate change are linked in many ways. They have similar causes which can be generated by humans, like burning fossil fuels, cutting down rainforests, farming livestock [1], or natural (for example, forest and wildfires, eruptions of volcanos, wind-blown sand and dust and emissions from vegetation). Climate change and air pollution are a result of the current energy model. Both are aggravated by the burning of fuel, increasing the CO_2 emissions that cause global warming, and generating air pollutants, such as nitrogen oxides, sulphur oxides and particulate matter, which are the main reason of air pollution.

The changing climate has modified weather patterns, which in turn have influenced the levels and location of air pollutants such as ground-level ozone (O_3) and fine particulate matter. Increasing carbon dioxide (CO_2) levels also promote the growth of plants that release airborne allergens, which will not be discussed in this paper. Climate change influences air pollutant concentrations in many ways. The climate influences temperatures, cloudiness, humidity, the frequency and intensity of precipitation and wind patterns, each of which can influence air quality. Over longer time scales, human responses to climate change may also affect the amount of energy that humans use, as well as how land is used and where people live. These changes would in turn modify emissions (depending on the fuel source) and thus further influence air quality. Some air pollutants such as ozone, sulphates and black carbon also cause changes in climate [2].

Climate change affects all regions around the world. Polar ice shields are melting and the sea level is rising. In some regions extreme weather events and rainfall are becoming more common while others are experiencing more extreme heat waves and droughts [3]. Air pollution leads to poor air quality, which in turn influences human health and environment.

Policies that address climate change and air pollution on international level are for now regulated under two separate regulations. Change in climate is addressed by the United Nations Framework Convention on Climate Change (UNFCCC), while air pollution is regulated through the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP). Both policies have the main challenge to limit future emissions, even though the CLRTAP does not have global coverage. By implementing air quality and climate policies, mutual benefits can be provided: climate change mitigation actions can help reduce air pollution, and clean air measures can help reduce GHG emissions leading to reductions in global warming [4].

The paper presents the position of Croatia as a party of both conventions and as one of the EU-28 Member States and also one of 41 European countries considering the state of emissions and emissions projections, and the current state of air quality in the case of particulate matter.

The overview of the policies and measures in place in Croatia is given, along with most effective ones, which require intensive implementation to combat poor air quality and climate change.

Some contradictions observed in current policies addressing climate change and air pollution in Croatia are a reminder that more needs to be done. One way for resolving existing contradictions is through the funding mechanisms for implementing climate change and air protection policies in Croatia.

2. AIR POLLUTION AND CLIMATE CHANGE – PHYSICAL MANIFESTATIONS, LINKAGE, CAUSES AND CONCERN

Air pollution and climate change influence each other through complex interactions in the atmosphere. Although two different topics and separated by different policies, in the reality they are quite related [5, 6].

Greenhouse gases absorb and emit radiant energy within the thermal infrared range. They trap heat in the atmosphere and contribute to climate change. The primary greenhouse gases are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Water vapor

accounts for the largest percentage of the greenhouse effect, between 36% and 66% for clear sky conditions and between 66% and 85% when including clouds [7]. Water vapor concentrations fluctuate regionally, but human activity does not directly affect water vapor concentrations except at local scale. The average residence time of a water molecule in the atmosphere is only about nine days, compared to years or centuries for other greenhouse gases such as CH_4 and CO_2. The most common greenhouse gases, after H_2O is carbon dioxide (CO_2). The atmospheric lifetime of CO_2 is estimated of the order of 30–95 years [8]. Although more than half of the CO_2 emitted is removed from the atmosphere within a century, some fraction (about 20%) of emitted CO_2 remains in the atmosphere for many thousands of years [9]. At current emission rates, temperatures could increase by 2°C, which the United Nations' Intergovernmental Panel on Climate Change (IPCC) designated as the upper limit to avoid "dangerous" levels, by 2036 [10].

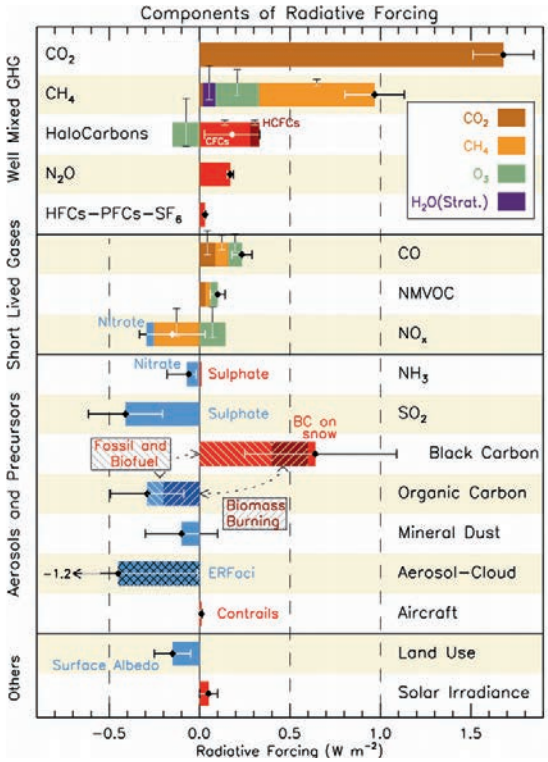

Figure 1. Radiative forcing of climate change during the Industrial Era shown by emitted components from 1750 to 2011 (Source: Figure TS.7, p. 57 [11]).

Many air pollutants contribute to climate change by affecting the amount of incoming sunlight that is reflected or absorbed by the atmosphere, with some pollutants warming and others cooling the Earth. These short-lived climate-forcing pollutants (SLCPs) include methane (CH_4), black carbon (BC), ground-level ozone (O_3) and sulphate aerosols [6]. Figure 1 shows radiative forcing (RF) of climate change during the Industrial Era shown by emitted components from 1750 to 2011. After CO_2 and CH_4, BC is the third top component of positive radiative forcing [11].

Methane (CH_4) is the second most prevalent greenhouse gas emitted by human activities [12] and approximately one-third of those emissions come from oil production and the production, processing, transmission and storage of natural gas [13]. Methane does not have any direct effects on human health in the sense that inhaling typical ambient concentrations of methane is not harmful to human health but has a very important indirect impact on human health as a precursor to ground-level O_3.

Tropospheric or ground-level ozone (O_3) is produced by photochemical reactions between nitrogen oxides (NO_x) and volatile organic compounds (VOCs), where UV rays from the Sun are the catalyst for these reactions. Ozone is of high concern in Europe due to its effects on human health, vegetation and materials. It is also a short-lived climate pollutant, since it is a greenhouse gas and contributes to the warming of the troposphere [14]. According to EEA Indicator assessment [15] future climate change is expected to increase O_3 concentrations, due to changes in meteorological conditions, as well as due to increased emissions of specific ozone precursors and/or emissions from wildfires that can increase under periods of extensive drought.

The impact of particulate matter (PM) on climate change is complex because PM is made up of many different chemical components with different physical properties [16], with either warming or cooling effects on the climate. For example, black carbon, a particulate pollutant from combustion, contributes to the warming of the Earth, while particulate sulphates cool the Earth's atmosphere [17]. According to the NASA fact sheet on atmospheric aerosols [18], both stratospheric (volcanic) and tropospheric aerosols have the same climatic effect: “Stratospheric SO_2 aerosols reflect sunlight, reducing the amount of energy reaching the lower atmosphere and the Earth’s surface, cooling them”. Human-made sulphate aerosols “absorb no sunlight but they reflect it, thereby reducing the amount of sunlight reaching the Earth’s surface” [19].

Some of air pollutants and the main greenhouse gas, which are the main cause of air pollution and

climate change, are presented at Figure 2 along with their impact on climate and human health, the ecosystem, scale of their impact, and lifetime in the atmosphere.

Figure 2. Some of air pollutants and greenhouse gases, their impact on climate and health/ecosystem, scale of impact and lifetime in the atmosphere (Source: *Ekonerg Ltd, 2020*).

3. CONCERN – CONSEQUENCES

The consequences of climate change are melting ice and rising sea level, more frequent extreme weather events like heavy rain, which can lead to floods and decreasing water quality, and also more frequent heat waves, forest fires and droughts. The Mediterranean area is becoming drier, making it even more vulnerable to drought and wildfires. Urban European areas are exposed to heat waves, flooding or rising sea level, but are often poorly equipped and ill-prepared for adapting to climate change [2].

Air pollution affects the environment and human health. In many cases it can impact the process of plant evolution by preventing photosynthesis, with serious consequences on the purification of the air we breathe. The accumulation of polluting gases in the atmosphere also generates environmental problems such as: acid rain, depletion of the ozone layer, global warming, the greenhouse effect, etc. [20].

Our continued exposure to air pollutants is responsible for the deterioration of human health and can cause cardiovascular problems, allergies, asthma attacks, conjunctivitis, bronchial diseases, lung or skin cancers, vision problems, blood problems in the mental development of the child, among others. Numerous studies have shown cause-and-effect relationship between air pollution and human health. Some of the conclusions of the studies that confirm this are as follows: the increase of polluting particulate matter in cities and the thickening of the internal wall of the arteries or atherosclerosis are in direct relationship, people living in large urban areas with high traffic volumes have more respiratory problems than average and are more likely to develop disease, in large cities, cases of children with bronchitis and delayed pulmonary development are much more common [20].

According to Air quality in Europe – 2019 report [21], air pollution continues to have significant impacts on the health of the European population, particularly in urban areas. Europe's most serious pollutants, in terms of harm to human health, are PM, NO_2 and ground-level ozone (O_3, also known as tropospheric ozone). Air pollution also has considerable economic impacts, cutting lives short, increasing medical costs, and reducing productivity through working days lost across the economy. Estimates of the health impacts attributable to exposure to air pollution indicate that $PM_{2.5}$ concentrations in 2016 were responsible for about 412 000 premature deaths originating from long-term exposure in Europe (over 41 countries), of which around 5 300 were in Croatia.

The estimated impacts of exposure to NO_2 and O_3 concentrations on the population in these 41 European countries in 2016 were around 71 000 and 15 100 premature deaths per year respectively, and in Croatia around 260 and 190 premature deaths per year, respectively.

4. THE IMPORTANCE OF BLACK CARBON (BC) ON AIR POLLUTION AND CLIMATE CHANGE

Black carbon (BC, also known as soot and black smoke) is a component of fine particulate matter (PM) ≤ 2.5 μm in aerodynamic diameter. Chemically, black carbon consists of pure carbon in several linked forms. It is formed through the incomplete combustion of fossil fuels, biofuel and biomass, and is emitted in both anthropogenic and naturally occurring soot. Black carbon causes human morbidity and premature mortality [22].
In climatology, black carbon is a climate-forcing agent. Black carbon warms the Earth by absorbing sunlight and heating the atmosphere and by reducing albedo when deposited on snow and ice (direct effects) and indirectly by interaction with clouds, with the total forcing of 1.1 Wm^{-2}. [23, 24] Black carbon stays in the atmosphere for only several days to weeks, whereas carbon dioxide (CO_2) has an atmospheric lifetime of more than 100 years [25].
Major source of black carbon is a major component of diesel engine exhaust–the black, sooty smoke that spews from tailpipes of diesel cars and heavy-duty vehicles and busses. The World Health Organization has determined that diesel exhaust, outdoor air pollution and particulate matter (which includes black carbon) cause cancer. Black carbon is also not climate friendly. In fact, scientists have identified black carbon as the second most powerful contributor to climate change after carbon dioxide. As a short-lived climate pollutant (SLCP), black carbon emissions last a matter of days in the atmosphere, meaning its effects can be felt almost immediately [26].
Reducing BC emissions, particularly from combustion sources such as cooking and heating stoves and engines, delivers combined health and climate change benefits. This is because BC is estimated to be responsible for approximately 15% of the current excessive warming of global temperatures. In addition, short-term reductions in BC can potentially delay the impact of global warming by approximately 10 years, "buying" time for more research and action. Efforts to reduce BC emissions should not replace measures to reduce CO_2 emissions, which in the long term will dominate climate change [27]. Several studies suggest that, in addition to health benefits, reducing black carbon sources would lead to cooling of global atmosphere. On the other hand, other studies point out that reducing air pollution could worsen climate change in the short-term by contributing to an increase in global temperatures [27].

5. FOSSIL FUEL AND WOOD BURNING AS THE MAIN ANTHROPOGENIC EMISSION SOURCES

Fossil fuel and wood (biomass) burning play a crucial role in the total primary energy supply in Croatia. According to IEA Bioenergy country report for Croatia [28] Croatia`s target to increase the share of renewable energy to 20% in the annual gross energy consumption of the country by 2020 is defined in the National Energy Strategy 2009–2020 and implemented according to the National Renewable Energy Action Plan's (NREAP) dynamics. The total primary energy supply of Croatia in 2016 amounted to 355 petajoule (PJ) and is dominated by fossil fuels (70%). Renewable energy sources have a share of 24.6% or 84 PJ – 15.3% bioenergy and 8.3% other renewable energy sources. The total primary energy supply of renewable energy sources is mostly covered by energy from biomass, with 65% (54 PJ).
Fossil fuel and wood burning as the main anthropogenic sources of greenhouse gases and air pollutants emission in Croatia are associated with climate change and air quality with negative impact on human health. When carbon-based fuels are burned, combustion causes the emission of carbon dioxide (CO_2) and other pollutants, including particulate matter (PM) (aerosols), which include particles that can cool or heat the atmosphere by reflecting or absorbing the radiation of the Sun. BC remains in the atmosphere for a relatively short time (one week), but strongly absorbs solar radiation. BC emitted from domestic burning of solid fuels, particularly indoors, and high-emitting diesel engines is likely to contribute to warming of the atmosphere [27].

Wood burning is very popular in many homes and is commonly used as a primary or secondary home heating fuel in Croatia [29, 30]. Popularity comes from lower price in comparison to other types of energy source, the ability to warm a place in a short time, market availability of wood and fireplaces and stoves in homes give a cosy feeling. It is a general belief that wood is natural, that wood smoke is a natural substance, and these cannot be harmful. However, it is scientifically well established that wood burning and wood smoke result in health-harmful pollutants, including several carcinogenic compounds [31, 32, 33].
According to Lelieveld, 2019. [34], the switch from fossil to renewable, clean energy sources has the potential to prevent morbidity and mortality from aerosol pollution. Because the particles have a net cooling effect, removing them will lower the prospects of meeting the goals of the Paris Agreement, but the public health gain is nevertheless a strong motivation for emission controls [35, 36].

6. POLICIES THAT ADDRESS CLIMATE CHANGE AND AIR POLLUTION

The issue of climate change on a global scale is addressed by the United Nations Framework Convention on Climate Change (UNFCCC). The Republic of Croatia has been a party to the UNFCCC since 1996, and a party to the Kyoto Protocol[1] and the Paris Agreement[2]. The most important regulation of the Republic of Croatia governing climate change is the Act on Climate Change and Ozone Layer Protection (OG 127/19). Strategies that address decarbonisation and climate change issues and also determine Croatia's "roadmap" for future energy orientation are: The Energy Development Strategy of the Republic of Croatia until 2030 with an outlook to 2050, The Long-Term Strategy to Encourage Investment in the Renovation of the National Building Stock of the Republic of Croatia by 2050, Low-Carbon Development Strategy of the Republic of Croatia until 2030 with an outlook to 2050, and Climate Change Adaptation Strategy in the Republic of Croatia until 2040 with an outlook to 2070 with the action plan. These strategies are directly influencing future air quality and air pollution.
Air pollution on an international level is regulated through the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP Convention)[3]. Eight protocols under the LRTAP Convention identify specific measures to be taken by Parties to cut their emissions. The LRTAP Convention provides access to emission, measurement and modelling data, and information on the effects of air pollution on ecosystems, health, crops and materials. It is implemented by the European Monitoring and Evaluation Programme (EMEP).
To improve air quality, the European Union adopted in 2013 a Clean Air Policy Package[4], including a Clean Air Programme for Europe setting objectives for 2020 and 2030, and accompanying legislative measures. Implementing the clean air package would result in improved air quality for all EU citizens and lower healthcare costs for governments. The proposals would also benefit industry, as measures to reduce air pollution should boost innovation and enhance EU competitiveness in the field of green technology [37]. The main legislative instrument to achieve the 2030 objectives of the Clean Air Programme for Europe is the National Emission Ceilings Directive (NEC Directive)[5]. The NEC Directive was formed on the basis of the original Gothenburg Protocol under LRTAP Convention. It sets national emission reduction commitments for Member States and the EU for the five pollutants (sulphur dioxide, nitrogen oxides, volatile organic compounds, ammonia and fine particulate matter) responsible for acidification, eutrophication and ground-level ozone pollution, which lead to significant negative impacts on human health and the environment. The NEC Directive requires Member States to draw up National Air Pollution Control Programmes that should contribute to the successful implementation of air quality plans established under the EU's Air Quality Directive. The most important regulation of the Republic of Croatia governing air pollution is Air Protection Act (OG 127/19).

[1] Pursuant to the Act on the Ratification of the Kyoto Protocol along with the United Nations Framework Convention on Climate Change (International Treaties, OG No. 5/07) and the Act on the Ratification of the Doha Amendment to the Kyoto Protocol (International Treaties, OG No. 6/15)
[2] Pursuant to the Act on the Ratification of the Paris Agreement (International Treaties OG No. 3/17)
[3] The 1979 Geneva Convention on Long-range Transboundary Air Pollution entered into force in 1983, now has 51 Parties. Based on the notification of succession, the Republic of Croatia is a party to the Convention of 8 October 1991 (NN-MU no. 12/93)
[4] Includes the Clean Air Programme for Europe, as well as a proposal for Directives on the reduction of national emissions of certain atmospheric pollutants (the NEC Directive) and on limitation of emissions of certain pollutants into the air from medium combustion plants (the MCP Directive).
[5] Directive 2016/2284/EU entered into force on 31 December 2016, replacing earlier legislation (Directive 2001/81/EC).

7. THE STATE OF EMISSIONS AND EMISSIONS PROJECTIONS IN CROATIA

The main challenge of international climate change policy and air pollution policy is to limit future emissions. Projections of emissions trends strongly depend on assumptions such as economic and population trends and the rate of technology development and diffusion. As a Party of UNFCCC, LRTAP Convention and EU, Croatia is obligated to prepare emissions inventory and emission projections. Results of recent reported emissions of GHG and air pollutants NO_x and $PM_{2.5}$ detected as primary pollutants responsible of air quality deterioration and global warming, the pollutants along with emission projections are shown at Figures 3–5.

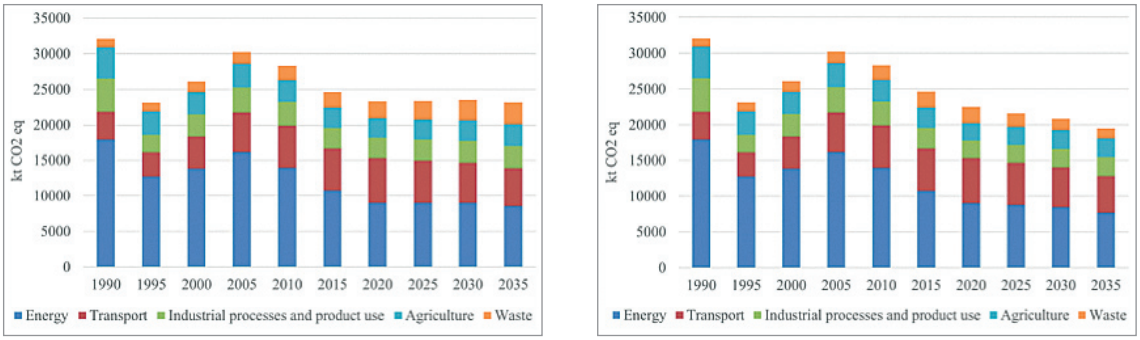

Figure 3. Historical and projected GHG emissions by sectors, with measure (WM) scenario (left graph) and with additional measures (WAM) (right graph) scenario in Croatia (Source: [38]).

Concerning greenhouse gas (GHG) emissions, the most significant contributor is energy at 71%, followed by industry at 12%, agriculture at 11% and waste at 6% (Fig. 3). Projections of GHG emissions show that in the "with measure" (WM) scenario, the emissions in 2035 in comparison to 1990 are reduced by 27.6%, and in the "with additional measure" (WAM) scenario, emissions are reduced by 39.2%. In the WM scenario, projections show a decrease of emissions until 2020. In the period from 2020 to 2035, this scenario shows just a slight decrease of emission. In the WAM scenario, projections show a steady downward trend of emissions. In the WAM scenario in relation to the WM scenario in 2035, GHG emissions will be reduced by 16.0% [38].
Figures 4 and 5 show historical (2005–2018) and projected NO_x and $PM_{2.5}$ emissions, WM scenario (left graph) and WAM (right graph) scenario. The NO_x emission trend has an overall decreasing character since 2007. The key sector of NO_x emissions is the road transport sector with contribution of 42%–60% in national total in the period 2005–2018. Projections of NO_x emissions show that in the WM scenario, the emission in 2050 in comparison to 2005 is reduced by 84.2%, and in the WAM scenario emission is reduced by 92.4%. In scenario WAM in relation to the scenario WM in 2050, NO_x emissions will be reduced by 8.2%.

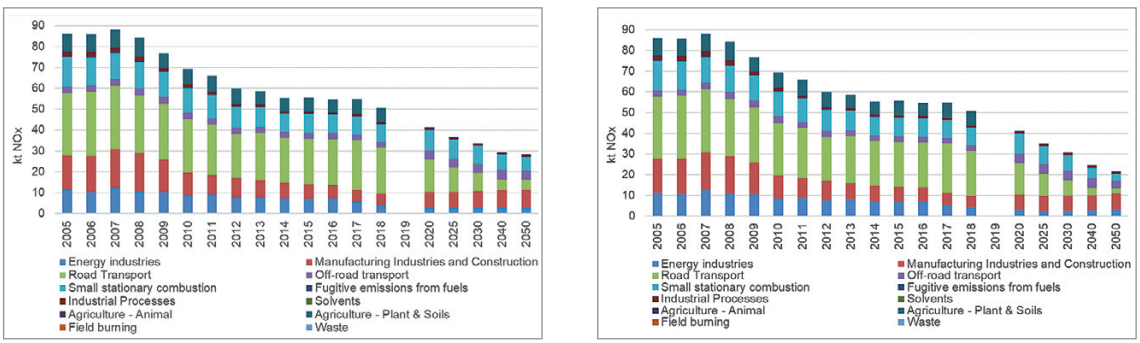

Figure 4. Historical and projected NO_x emissions, with measure (WM) scenario (left graph) and with additional measures (WAM) (right graph) scenario in Croatia (Source of emission data: [39, 40]).

An overview of the current state of emissions in the case of $PM_{2.5}$ is presented because it is regulated and measured in SB. The $PM_{2.5}$ emission in 2018 amounted 28.7 kt. The $PM_{2.5}$ emission trend has overall decreased since 2005 by 31.4%. The key sector of $PM_{2.5}$ emissions is the small stationary combustion with contribution of 42%-60% in national total in the period 2005–2018. The small combustion sector is dominated by wood combustion in the residential sector [11]. Projections of $PM_{2.5}$ emissions show that in the WM scenario, the emission in 2050 compared to 2005 is reduced by 80.3%, and in the WAM scenario the emission is reduced by 91.2%. In the WAM scenario in relation to the WM scenario in 2050, $PM_{2.5}$ emissions will be reduced by 11%. The residential sector is responsible for the biggest reduction in historic and projected $PM_{2.5}$ emissions. The reduction occurs due to the replacement of traditional wood stoves and open fireplaces with new technologies that have significantly lower emissions.

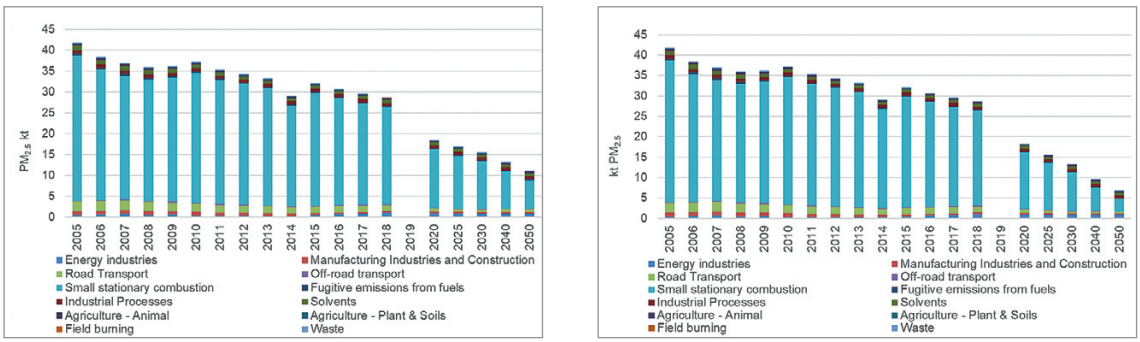

Figure 5. Historical and projected $PM_{2.5}$ emissions, with measure (WM) scenario (left graph) and with additional measures (WAM) (right graph) scenario in Croatia (Source of emission data: [39, 40]).

Projected GHG, NO_x and $PM_{2.5}$ emissions in Croatia are based on the same policy and measures (PaMs). The biggest reduction in GHG, NO_x and $PM_{2.5}$ emissions is expected in the road transport sector and residential sector as these are key sectors in current GHG, NO_x and $PM_{2.5}$ emissions. Some of PaMs for reduction of emissions in the road transport sector are:

- Financial incentives for the purchase of plug-in hybrid and electric vehicles,
- Promotion of integrated and intelligent transport systems and alternative fuels in urban areas,
- Promotion of clean and energy efficient vehicles in road transport,
- Development of the infrastructure for alternative fuels,
- Special environmental fee for motor vehicles and special tax on motor vehicles.

Some of PaMs for reduction of emissions in the residential sector [41, 42] are:

- Programme for energy renovation of apartment buildings,
- Programme for the increase of energy efficiency and use of renewable energy sources in commercial non-residential buildings,
- Programme for energy renovation of family houses,
- Promotion of the use of renewable energy sources and energy efficiency by EPEEF (the Environmental Protection and Energy Efficiency Fund) resources,
- Integration of measures for pollutant emission mitigation into planning documents and projects for road transport and
- Integration of measures for pollutant emission mitigation into planning documents and projects for energy renewal of buildings.

Continental parts of Croatia have a pronounced particulate air pollution problem during heating seasons. The air quality standard is mostly exceeded because of frequent occurrence of high daily PM_{10} concentrations during wintertime. The overview of local sources of PM_{10} emission is presented below. In 2018, PM_{10} emission was 37.8 kt (Fig. 6) and was down by 28.5% compared to 2005. The energy sector is the sector with the highest contribution to the total PM_{10} emission (in 2018 with 74.3%). The key category in the Energy sector is Small stationary combustion (63.2% in the national total in 2018). Industrial processes and product use sector is the second largest source (14.4% in 2018), followed by agriculture, which contributed to the overall emissions in 2018 with 11% [29].

The historic state of emissions in the case of BC is also presented because it is an indicator of the impact of traffic on air quality and it was measured earlier. In 2018, BC emission was 3.9 kt (Fig. 6) and was down by 33.3% compared to 2005. The energy sector is the sector with the highest contribution to the total of BC emission (in 2018 with 95.3%). The key category in the energy sector is small stationary combustion (73% in the national total in 2018). The second dominant sector is road transport (18% in the national total in 2018).

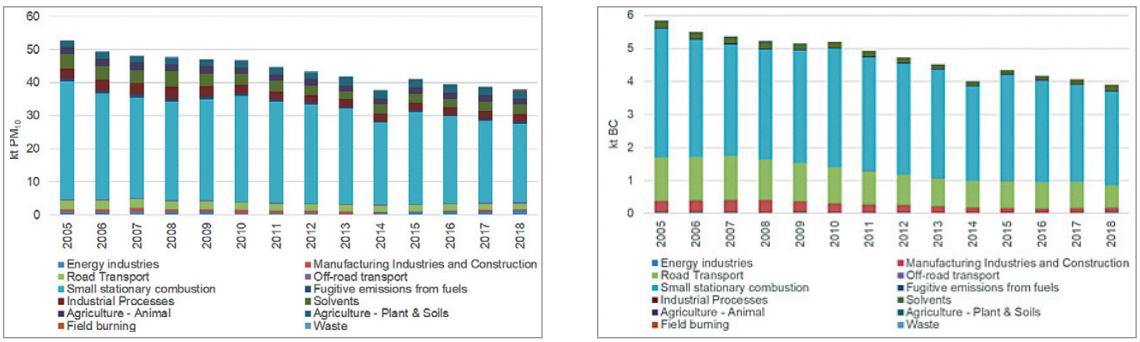

Figure 6. Historic emissions for PM_{10} (left graph) and BC (right graph) in Croatia (Source of emission data: [39]).

It can be concluded that the small stationary combustion with the domination of residential wood combustion and road transport sector are the key sources of GHG, NO_x, PM_{10}, $PM_{2.5}$ and BC emissions. In compliance with EU goals to reduce GHG emissions and considering growing air pollution, it is essential to emphasise the importance of green transportation, i.e. energy efficiency in transport, and to encourage the projects aimed at increasing energy efficiency of transportation systems and use of more efficient vehicles (vehicles using RES, which emit less CO_2 and electric vehicles) [43]. Croatia has prescribed and set policies and measures packages to meet international and EU obligations. Since their implementation is mandatory, it can be considered that Croatia contributes to the global effort to climate change mitigation and improvement of air quality by reducing its greenhouse gas emissions, decarbonizing economy and reducing air pollution.

Diesel vehicles and especially diesel cars could be a significant source of NO_2 and PM air pollution in the busy urban streets. Even though the majority of new cars in Croatia run on petrol, a large share of old diesel cars had been imported to Croatia over the last seven years. For example, 55,686 used cars were imported into Croatia in 2017 and as many as 87% had diesel engines and they were produced from 2005–2015 which means their emissions are according to old Euro 4 and Euro 5 emission standards [44], [45]. Average age of passenger cars in Croatia increased from 9.89 years in 2008 to 12.58 years of age in 2019. The impact of economic crises and the effect of import of old used diesel cars result that after the year 2014, reduction in emission of PM_{10} has been stopped as can be seen in Figure 7.

The emission of PM_{10} from the transport sector consists of exhaust emissions and non-exhaust emissions such as tyre wear, brake wear and road abrasion. Stricter EURO emission standards for vehicle emissions led to reduction of non-exhaust emissions so they have limited impact on the total transport emissions, but they have a major impact on BC emission. Namely, BC is a major part of exhaust particulate emissions from vehicles, but it is not a major constituent of particles that originated from road transport. A closer look at the road transport PM_{10} emissions in Croatia shows that in the year 2018 less than half of PM_{10} emission comes from vehicles' exhaust gases (Fig. 7). It could be expected that urban driving leads to higher automobile tyre and brake wear as well as road abrasion, while exhaust emissions are continuously dropping by the "rejuvenation" of the vehicle fleet.

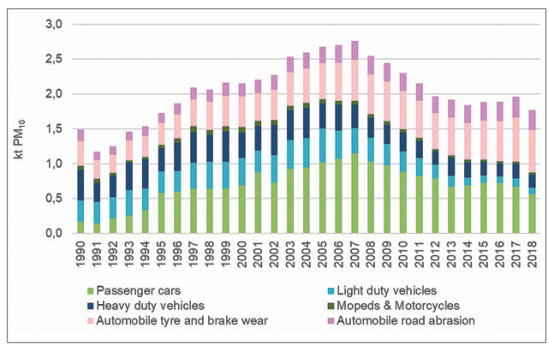

Figure 7. Historic trend of PM_{10} emission from road transport in Croatia (Source of emission data: [39]).

8. THE CURRENT STATE OF AIR QUALITY IN THE CASE OF PARTICULATE MATTER IN CROATIA

The territory of Croatia is divided into 5 zones (HR 1, HR 2, HR 3, HR 4, HR 5) and 4 agglomerations (HR ZG, HR OS, HR RI, HR ST) for air quality assessment (Fig. 8). The air quality monitoring network, for compliance assessment, consist of 9 monitoring stations in agglomeration and 13 monitoring stations in zones (Fig. 8). There are 7 rural background monitoring stations (Višnjan, Hum, Žarkovica, Parg, Plitvička jezera, Desinić, Kopački rit) sited in 4 zones (HR1, HR3, HR4, HR5).

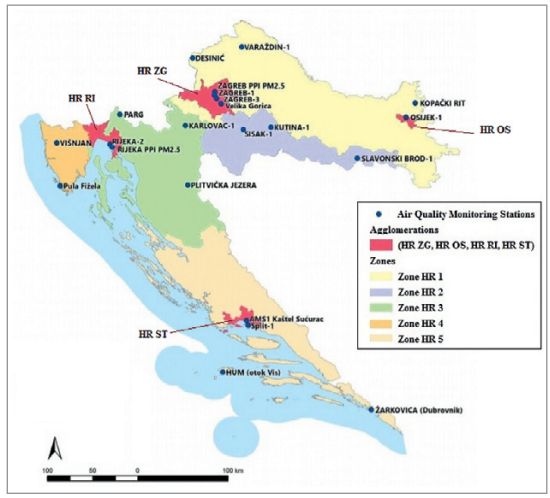

Figure 8. Air quality monitoring stations in zones and agglomerations of the Republic of Croatia (Source: Figure adopted from *Croatian Environment Agency*: [48]).

The compliance assessment, based on national air quality report [47] for the year 2017 is summarised below:

- The limit value for NO_2 was exceeded in one agglomeration (HR ZG),
- The limit value for PM_{10} was exceeded in two agglomerations (HR ZG, HR OS) and one zone (HR 2),
- The limit value for $PM_{2.5}$ was exceeded in one agglomeration (HR ZG) and one zone (HR 2),
- The target value for benzo(a)pyrene was exceeded in one agglomeration (HR ZG) and one zone (HR 2),
- The target value for ozone was exceeded in two agglomerations (HR ZG, HR RI) and four zones (HR 1, HR 3, HR 4, HR 5).

The NO_2 pollution is localized in one agglomeration (HR ZG) and is caused by road traffic emission. On the other hand, the ground level ozone pollution is widely spread over Croatia and it is mostly under the influence of transboundary transport of ozone and ozone precursors. The highest number of exceedances for ozone target value in the year 2017 were measured in the coastal zones (HR 3, HR 4, HR 5).

The air quality standards for particulate matter (PM_{10} and $PM_{2.5}$) and benzo(a)pyrene are only exceeded in continental parts of Croatia. Non-compliance for all three pollutants were assessed in the year 2017 for one agglomeration (HR ZG) and one zone (HR 2) but not necessarily at the same monitoring stations. Only the non-compliance for PM_{10} is assessed for agglomeration HR OS but it should be mentioned that $PM_{2.5}$ and benzo(a)pyrene are not measured in that agglomeration.

Compliance with annual and daily limit values for PM_{10}, presented in Figure 9, shows that exceedance of limit value for PM_{10} daily concentration are major cause of non-compliance for that pollutant in the year 2017.

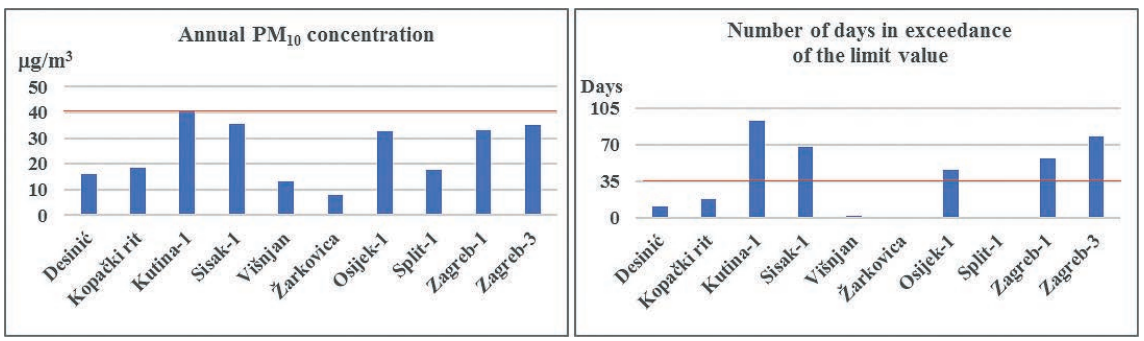

Figure 9. Compliance with limit values for PM_{10} in the Croatia for the year 2017 (Source: Data from *Croatian Environment Agency* [48]).

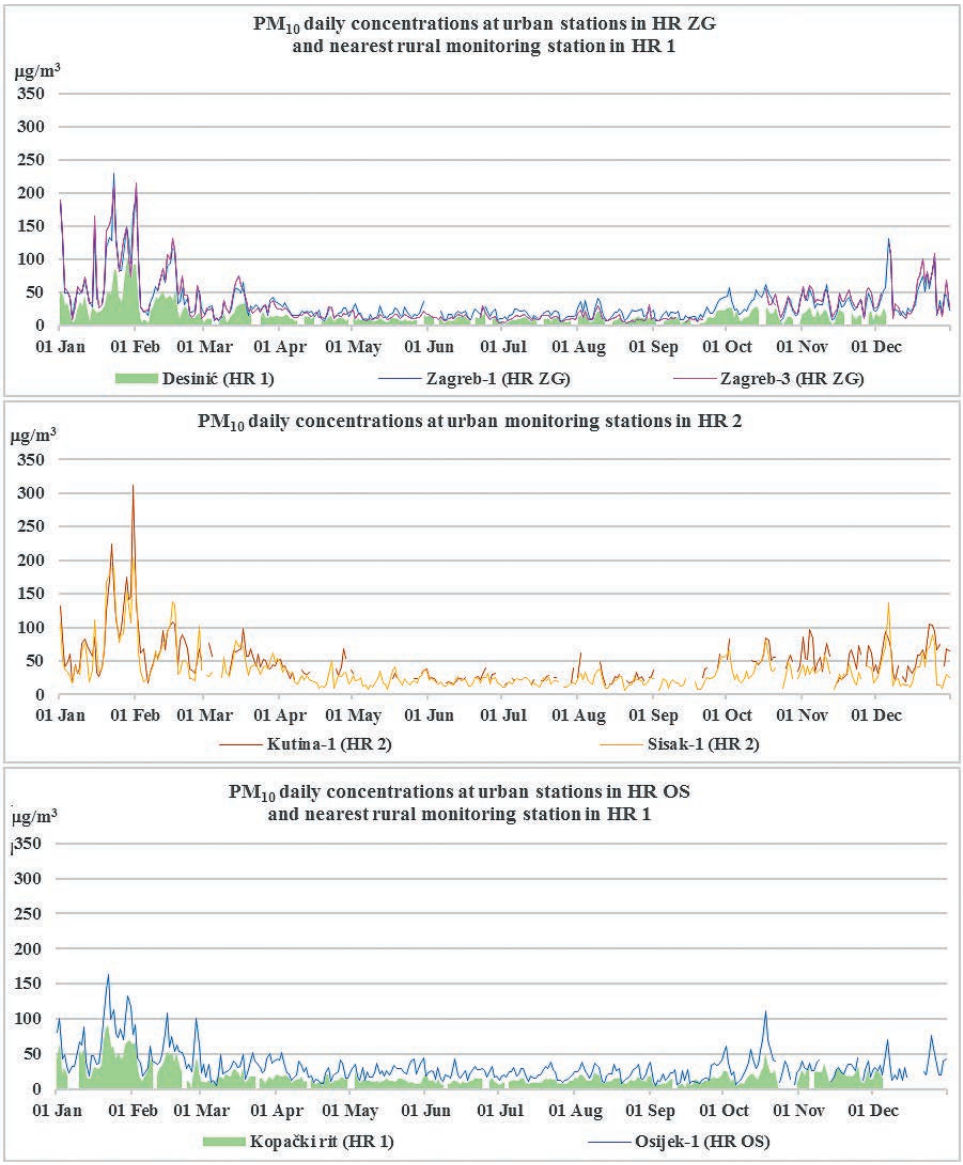

Figure 10. Urban and rural background daily concentrations of PM_{10} for the year 2017 (Source: Data from *Croatian Environment Agency* [48]).

Seasonal variation of daily concentrations for urban and rural background air quality monitoring stations are presented in Figure 10. Rural background monitoring stations (Desinić, Kopački rit) are less than 50 km from the monitoring stations in the nearest agglomeration (HR ZG, HR OS). The PM_{10} pollution episodes mostly occur at the same time at all monitoring stations during winter. The pollution episodes are most pronounced in zone HR 2 where there is no rural background monitoring station.
Emission and air pollution maps of PM_{10} based on EMEP data [49] in the year 2017 are presented in Figure 11. The PM_{10} concentration map (Fig. 11, right) shows that eastern parts of continental Croatia are exposed to transboundary particulate pollution.

9. LOCAL AIR POLLUTION POLICY AND CLIMATE POLICY

At the municipality level, mitigation measures to reduce air pollution are set out by the obligatory *air quality plans*, while the measures to reduce GHG emissions are set by voluntary policies, such as *Sustainable Energy (and Climate) Action Plans* (SE(C)AP). All Croatian municipalities, which have developed air quality plans because of particulate pollution, also have SEAPs as presented in Table 1.

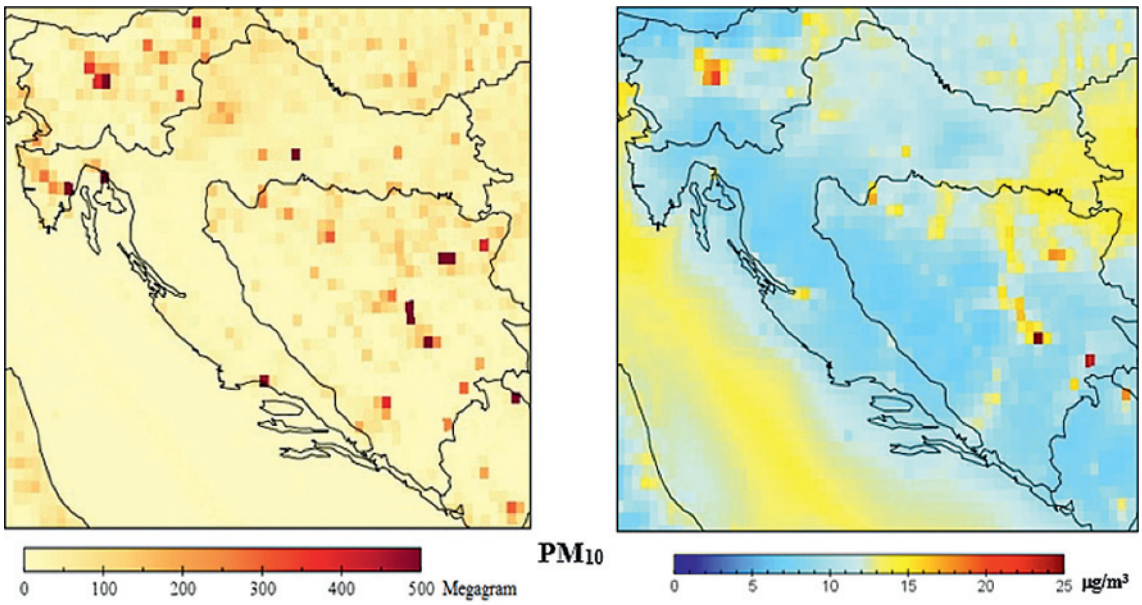

Figure 11. Map of annual primary PM_{10} emission (left) and concentrations (right) for the year 2017 (Source: Data from The Norwegian Meteorological Institute [49]).

According to air quality plans listed in Table 1, the major source of particle pollution are household emissions and road transport. All measures to improve energy efficiency and promotion of public transport and the shift to environmentally friendly ways of transport set by SEAPs, are integrated in air quality plans. Since air quality plans aim at reducing particle emissions as soon as possible, there is the question about the use of natural gas instead of GHG-neutral wood stoves for heating, which is in contradiction to the goals set by SEAPs.

Table 1. The overview of air quality plans and SEAPs in continental parts of Croatia.

Municipality	Air quality plan	Sustainable Energy (and Climate) Action Plan
Zagreb	✓ NO_2, O_3, $PM_{2,5}$, PM_{10}, BaP	✓
Slavonski Brod	✓ $PM_{2,5}$	✓
Sisak	✓ PM_{10}	✓
Kutina	✓ PM_{10}	✓
Osijek	✓ PM_{10}	✓
Vinkovci	✓ $PM_{2,5}$, PM_{10}	✓

10. FUNDING MECHANISMS FOR IMPLEMENTING CLIMATE CHANGE AND AIR PROTECTION POLICIES IN CROATIA

The Government of the Republic of Croatia, the Ministry of Construction and Physical Planning, and the Ministry of Environmental and Nature Protection, adopted on 27 March 2014 the Programme of energy renovation of family houses, which is implemented by the Environmental Protection and Energy Efficiency Fund. The goal of the Programme is to increase energy efficiency of the existing houses, to reduce energy consumption and emissions of CO_2 into the atmosphere, and to reduce the monthly costs for the energy generating products, with the overall improvement of the quality of living. At the same time, the planning of such interventions implies the engagement of the local companies and experts, meaning it promotes economic activities. The first Amendments to the Programme were adopted in 2015, and the Second amendments in 2020. After the adoption of the Amendments to the Programme, the Environmental Protection and

Energy Efficiency Fund will continue with the national financing of the Programme of energy renovation of family houses in 2020. On 25 June 2020, the Public Call was invited for the citizens (co)owners of the existing family houses falling in the minimum energy category (according to $Q_{H,nd}$, the specific annual thermal energy required for heating, the Ordinance on energy audit of buildings and energy certification OG 88/17, 90/20) D or below in the continental part of Croatia, or in the energy category C or below in the coastal part of Croatia [46].
For the Programme of energy renovation of family houses in the period 2015–2020, the Fund has secured the amount of HRK 836 million, and additional funding was invested in the Programme of energy renovation of multi-apartment buildings in the amount of HRK 195 million, while HRK 204 million for the Programme of energy renovation of public buildings, all in the same timeframe.
The Environmental Protection and Energy Efficiency Fund co-financed the measures for enhancing energy efficiency in transportation through 3 programmes:

- co-financing the purchase of electric and plug-in hybrid vehicles for citizens, companies and trades, and co-financing the construction of charging stations for electric vehicles
- co-financing eco-driving training
- co-financing other measures for energy efficiency in traffic [43].

The Fund provided HRK 325 million for the implementation of the above measures in the period 2015–2020.
Investment of the Fund in renewable energy sources (RES) for the mentioned 5-year period amounts to HRK 192 million. Part of the investment was allocated for co-financing the replacement of the conventional wood-burning stoves and boilers with high particle emissions with the new devices, which ensure low particle emissions in the burning of biomass, i.e. using better combustion technology.

11. CONCLUSION

This paper provides a brief overview of what is causing air pollution and climate change at global and local level, and what can be done to tackle both. An overview of the latest status of air quality and emissions of the main polluters in Croatia with policies in place to combat both are presented. It should be emphasized that the implementation of both air and climate quality policies can bring mutual benefits to both health and climate. Reducing ambient air pollution can reduce the incidence of diseases attributable to air pollution, but it can also reduce CO_2 and SLCP (such as black carbon) emissions, thus contributing to short-term and long-term climate change mitigation.
Sustainable energy path with energy efficiency and renewable energy is imposed as an overall path for tackling climate change and air pollution. By adopting the Energy development Strategy[6] in March 2020, Croatia is a step closer towards realizing the vision of low-carbon energy. But more synergy of policies is needed for tackling climate change and air pollution more efficiently. Coordination among ministries with different authorities is getting better, but activities should be continuously intensive, both on horizontal and vertical level with local authorities.
This paper shows that the residential wood combustion and road transport sector are the key sources of GHG, NO_x, PM_{10}, $PM_{2.5}$ and BC emissions in Croatia. Historical trends of pollutants along with their projected emissions and air quality plans in Croatia are one of the proofs of the above. With that in mind, Croatia has prescribed and set policies and packages of measures to meet international and EU obligations, implementation of which is mandatory, and Croatia will take part in the global effort to reduce greenhouse gas emissions, decarbonise its economy and reduce air pollution and improve air quality. Increasing Green transportation, energy efficiency of transportation systems and use of more efficient vehicles, along with replacing conventional wood-burning stoves and open wood fireplaces with new stoves and boilers with low PM emissions will ensure combined health and climate benefits compared with costs.
The observed contradictions in current policies to address climate change and air pollution in Croatia mentioned in this paper, is a reminder that more needs to be done. One way for resolving the existing contradictions is through the funding of joint mechanisms for implementing climate change and air protection policies in Croatia.

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DEVELOPMENT OF AN AIR QUALITY MODELING SYSTEM FOR ZAGREB, CROATIA

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Poor air quality has been recognized as an important factor in causing adverse health effects for a long time. While concentrations of particulate matter and nitrogen oxides continue to exceed EU limit values, it is important to improve information about air quality, especially in the cities where the exposure of the population is the largest. Zagreb is the capital of Croatia with a population of nearly 800,000 and as such comprises 18% of the Croatian population. In cities, pollutant concentrations have strong gradients, in particular those related to traffic. Since continuous air quality measurements are usually representative of several square kilometers for urban background locations, or for a specific street, authorities are encouraged to use dispersion models to complement the observations for a city.

This study combines knowledge gained from analysis of 14 urban, urban-background and near-traffic sites with the first results of the high resolution modeled data. Measurements were fully analyzed, seasonal and diurnal cycles were investigated, yearly averages and exceedances regulated by the EU were calculated. For the first time, the ADMS dispersion model was set up for Zagreb agglomeration. Within the model, measurement data from Desinić site (40 km NE from Zagreb) were used as background data representing the contribution of long-range transport to the city. Gridded emissions (500 m by 500 m resolution) were obtained from the Croatian National Emission Inventory. Also, emissions using the detailed road-level emissions using a street map were used. Meteorological parameters from the Zagreb-Maksimir measurement site were used in the model and there were considered as representative for the whole modeling domain. The focus of this analysis were main pollutants usually found to exceed EU limit values within the city and the surrounding area: particulate matter and nitrogen oxides.

In Zagreb, clear decreasing trend in concentration of PM_{10} was found (roughly 2 $\mu gm^{-3}year^{-1}$) through the period 2003–2018, although, exceedances are still present. Exceedances for PM_{10} are mainly related to wintertime episodes with stable conditions due to low boundary layer heights combined with high emissions caused by wood combustion. Spatial distribution given by the model for the year 2017 shows high gradients of concentrations near the sources, as well as influence of meteorological parameters on pollution dispersion.

The observed concentrations of PM_{10} and NO_2 are increased over the city within the range of 6–11 μgm^{-3} and 22–37 μgm^{-3} respectively. Modelled concentrations for the year 2017 show characteristic high values representing the main roads.

The next step will imply the coupling of ADMS with the LOTOS EUROS CTM that is currently being tested for the regional area.

Key words: air quality, city, Zagreb, ADMS, particulate matter, nitrogen oxides

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MJERENJA U ATMOSFERI POMOĆU BESPILOTNIH LETJELICA KOJE ZAJEDNIČKI NOSE SENZOR

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U radu je predstavljen koncept mjerenja atmosferskih veličina pomoću grupe bespilotnih letjelica. Izdvojena je konfiguracija u kojoj grupa rotokoptera zajednički nosi jedan ili više senzora. Istaknute su prednosti i nedostaci takvih mjerenja u usporedbi s mjerenjima u kojima jedna bespilotna letjelica nosi jedan senzor. Kao poseban slučaj razmotreno je mjerenje razine infrazvuka na opisani način.

Ključne riječi: bespilotne letjelice, atmosfera, infrazvuk, sintetska apertura

IMPACTS ON AIR QUALITY DUE TO AVIATION EMISSIONS

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One year of air quality data obtained at Zagreb airport has been analyzed to assess the level of air pollution due to air traffic. Air transportation growth has rapidly increased over the years and notable influences of aviation emissions on local and regional air quality as well as on climate are identified. The environmental impacts of atmospheric emissions from aircraft have been addressed in two separate ways: aircraft pollutant emissions occurring during the landing and take-off (LTO) phase (local pollutant emissions), and the non-LTO phase (global/regional pollutant emissions). Aircraft pollutant emissions are an important source of pollution and directly or indirectly harmfully affect human health and ecosystems.
In this work harmonized methodology for emissions estimation as well as recently estimated emissions for Croatia will be presented in relation to European and global trends. The WRF-Chem model is applied with modified aviation emissions in order to calculate local air concentrations of CO_2, PM_{10}, NO_x and SO_2 around the Zagreb airport in Croatia. The Gaussian type model is also used to estimate the maximum contributions along the runway. The management of air quality have to include major sources within the urban area and the application air quality models is essential in the identification of environmental impacts.

Key words: air traffic, emissions, WRF-Chem, air quality management, pollution

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IDENTIFICATION OF DIVERSE AIR POLLUTION SOURCES IN A COMPLEX URBAN AREA OF CROATIA

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Pinpointing the contribution of sources in complex urban areas, affected by large point sources such as oil refineries, is important for developing emission control strategies. Receptor models based on the chemical composition of particulate matter (PM), such as chemical mass balance (CMB) and positive matrix factorization (PMF), are useful means for source apportionment, but the inclusion of other gaseous pollutants need further consideration. The results of the multipollutant analyses using temporal variations in pollutant concentrations, chemical PM speciation and receptor modelling, PMF and conditional bivariate polar plots (CBPF), were used for determination of major pollutant sources of fine particulate matter ($PM_{2.5}$) and less represented pollutants – hydrogen sulfide (H_2S), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) in an urban area in Slavonski Brod, Croatia influenced by a large point source (an oil refinery) in Brod, Bosnia and Herzegovina. It is found that the composition of $PM_{2.5}$ is dominated by carbonaceous combustion particles, mainly organic carbon (OC), with maximum values appearing during winter. Summer $PM_{2.5}$ levels were dominated by sulfate and ammonium, which can be related to the industrial activities i.e., oil refinery. According to PMF analysis, the majority of OC is coming from biomass burning with ~ 50% contribution to observed species concentration followed by ~ 30% from industry/refinery and ~10% from traffic. CPBF model showed that urban and highway traffic was the main source of NO_2 concentrations while oil refinery was identified as the dominant source of SO_2 and H_2S. The CBPF receptor model combines concentrations of pollutants and meteorological parameters and emerged as a reliable complementary tool for the identification of sources for considered gaseous pollutants. Limitations of CBPF method are in the application in stable atmospheric boundary layer conditions (SABL) as wind direction is not representative. Also, larger uncertainty is related to the representation of peak concentrations transported with higher wind speeds (> 8 ms^{-1}) due to the lower number of events. Moreover, a

high resolution WRF-Chem model was applied over the area of Slavonski brod. It was used to describe and understand the influence of a complex urban environment and meteorology on high pollution events, daily variability of PM_{10} and peaks of SO_2 during the day.
This work uses various methods in the assessment of PM and gaseous pollutants, such as NO_2, SO_2 and H_2S that are less represented in the e.g. source apportionment studies and can be used for future scientific applications and to assure more efficient air quality management which is important for decision-makers and other public authorities.

Key words: oil refinery, source apportionment, bivariate polar plot, positive matrix factorization, WRF-Chem

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IMPLEMENTATION OF ATMOSYS MODULES FOR CROATIA IN THE FRAMEWORK OF THE AIRQ PROJECT

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ATMOSYS is a LIFE + Environmental Policy and Governance project co-financed by European Commission. Within the AIRQ project, implementation of ATMOSYS modules will be done for Croatia. The main objectives are: (1) Near real-time air quality maps based on the observations, (2) Air quality forecasts for the whole territory of Croatia up to 3 days ahead, (3) Historical air quality maps service for Croatia including a high-resolution assessment for the city of Zagreb.
For the first objective, RIO mapping module is used allowing to derive real-time, daily and yearly concentration maps from air quality monitoring network. It is able to account for the local character of the air pollution phenomenon at locations where no monitoring stations are available. As input RIO requires spatially representative concentration measurements together with metadata, geospatial data as proxy data in the mapping (CORINE land cover data, population data, road network data, altitude information). So far annual maps for O_3, PM_{10} and NO_2 are calculated. For ozone, we can observe the regional scale decrease of concentration values from seaside towards inland. Local decreases in O_3 are noticeable for some urban areas such as Zagreb and Kutina. In terms of PM_{10}, the lower concentration values towards the sea are still noticeable, but the major variability occurs at local scale with visible peaks in Zagreb, Kutina, Sisak and several other eastern cities. As for NO_2, the most variability occurs in densely populated cities like Zagreb or Split.
For the second objective OVL forecast module with neural network is trained with concentration measurements from January 2016 to June 2017. In almost all test cases, the NN outperforms the chemical transport models from CAM services.
For the third objective, ATMO-Street chain model is used. It combines a traffic emission model (FASTRACE) and a Gaussian dispersion model coupled to a street-canyon module (IFDM-OSPM). The final outputs are 10 m resolution maps. Traffic input data for Croatia were used from COPERT model. In addition, 24 emission point sources are taken into account as well as 3D buildings model that allows street canyon dispersion calculations. Meteorological data are used from ALADIN numerical model on a 2 km wind field resolution. Results show that the highest concentrations are observed around the city centers of Zagreb and Split. In addition to the higher background concentrations in the urban areas (modelled by the RIO model), the effect of the road traffic emissions on the air quality is clearly visible, both in rural areas and around the city centers. Much higher concentrations are observed in the modelled street canyons: whereas the open street concentration close to the mean roads reaches 45 μgm^{-3}, the highest values in the street canyons are above 55 μgm^{-3}. This highlights the importance of applying a street canyon module such as OSPM in combination with Gaussian dispersion model (IFDM).
Acknowledgment:
This work was done within the scope of the project "AIRQ – Expansion and Modernization of the

National Network for Continuous Air Quality Monitoring" (KK.06.2.1.02.0001) and is supported by the EU from the European Regional Development Fund.

Key words: AIRQ, ATMOSYS, air quality forecast

USE OF CHEMICAL TRANSPORT MODELS FOR DEVELOPMENT OF EMISSION CONTROL STRATEGY

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Implementation of cost-efficient emission control strategies is one of the main goals of air quality protection policies for which testing of different methodologies is useful. To assess the impact of emission changes on surface concentration levels, the chemical transport model (CTM), as well as the screening methodology SHERPA (Screening for High Emission Reduction Potential on Air) developed by Joint Research Centre can be used.
In this study LOTOS-EUROS chemical transport model with a source apportionment module with a labeling approach was used for emission reduction scenarios of NO_2, PM_{10} and $PM_{2.5}$ for Croatia (the year 2018). ECMWF meteorological data (F1280 grid, resolution of 0.07°x0.07°) and CAMS-REG-AP version 2.2 emission data aggregated by GNFR sectors provided by TNO were used. Outer domain (0.5°x0.25° resolution) covered 10° W–45° E; 30° N–60° N while nested domain covered the area 13° E–23.5° E; 41.5° N–47° N, with spatial resolution 0.1°x0.05°. Emission reduction scenarios (10, 20, 30, 40, 50, 60, 80 and 100%) were used for the traffic sector (F), residential combustion sector (C) and both sectors (C and F) combined. Hence, 25 model runs were made: the base model run without emission reductions and model runs with three scenarios. The base case is run with a source apportionment module. In run, chosen labels are sectors C and F for Croatia and for outside Croatia. These results were compared with 100% reduction runs. Afterwards, the same scenarios approach was used with the SHERPA tool and results were compared. To complete the LOTOS-EUROS scenario runs took more time then the SHERPA tool runs. Both methodologies provide comparable results with respect to annual average concentration values, however, spatial distributions differ considerably. Spatial distribution differences show that both SHERPA and CTM are highly sensitive to the underlying emission gridding assumptions (proxies). Since CTM used the latest update of the emission inventory results for areas of highways and roads, especially for NO_2 compared to SHERPA look much more realistic. SHERPA overestimates the influence of population density in rural areas and does not depict the road traffic influence. As expected, surface concentrations of NO_2 are more affected by reductions of road transport emissions while PM concentrations are more affected by reductions in the sector of other stationary combustion. Combined scenario results show that linearity is conserved in case of emission reduction by 10 and 20%. SHERPA tool provided semi-adequate general screening results but should be used with caution in case of need for specific and detailed spatial analysis.

Key words: LOTOS-EUROS, source apportionment, emission reduction

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Meteorološki izazovi 7; Sekcija 3:
METEOROLOŠKI EKSTREMI I NJIHOV UTJECAJ

APPLICATION OF THE WRF-HAILCAST MODEL TO THE CROATIAN AREA – SENSITIVITY TO PBL SCHEMES

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The existing analysis of measurements showed that western and central regions of Croatia have the highest frequency of hail occurrence, characterized by large intensity. Due to the long history of hail suppression activities in the aforementioned regions, hailpads were placed at main meteorological stations, locations used for hail suppression activities, as well as on the specially designed polygon in the northwestern region of Croatia. Parameters that can be determined by hailpads are: (i) diameter and the number of hailstones and (ii) the kinetic energy (KE) of hailstones.
Despite its frequent occurrence, hail still remains a difficult phenomenon to model or forecast as the processes involved in producing hail are not fully resolved by current convection-allowing models (CAM). One of the ways to address this issue is by embedding a physically based one-dimensional hail model called HAILCAST within a CAM. Here, the HAILCAST model is embedded within Weather Research and Forecasting (WRF) model since the WRF model, when run at a horizontal grid spacing of approximately 4 km or finer, can reproduce dominant, large-scale circulations and hydrometeor fields associated with organized storms and convective systems.
Selected hail events are analyzed using the WRF-HAILCAST model simulations. HAILCAST consists of a one-dimensional steady-state cloud model coupled with a time-dependent hail growth model. The vertical updraft, liquid and ice water content, and temperature profiles from a given WRF timestep and grid columns are passed to the time-dependent WRF-HAILCAST model which forecasts maximum hail diameter at the surface. A set of numerical convection-permitting experiments are performed to assess the sensitivity of the results to five (two non-local and three local) planetary boundary layer (PBL) parametrization schemes and to provide guidance for WRF-HAILCAST tuning. The results are verified by observational (hailpad, hail observations) data as well as with radar and lightning measurements where available.

Key words: hail, WRF-HAILCAST, planetary boundary layer

TWENTY-FIRST CENTURY PROJECTED CHANGES IN EXTREME TEMPERATURE OVER CÔTE D'IVOIRE (WEST AFRICA)

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The projection of the future climate change is of paramount importance in as much as it contributes to provide useful information for adaptation planning worldwide to local scales. This study investigated the future changes using four temperature related indices such are: the warm extreme indices such as the warm spell days index (HWFI), the very warm days frequency index (TX90P), the warm nights frequency index (TN90P) and the intra period extreme temperature range (ETR) index, based on an ensemble of 14 CORDEX-Africa simulations at 0.44° × 0.44° (~50 km) of resolution under the RCP4.5 and RCP8.5 scenarios. These indices describe moderate extreme of ETCCDI based on temperature investigated over Côte d'Ivoire.
The results of this study show a general increase in HWFI, TX90P and TN90P indices over the entire country under both emission scenarios. The increase in these indices was higher under RCP8.5 sce-

nario, especially in the period 2071–2100 and reached about 85, 72, and 90% for HWFI, TX90P, and TN90P respectively. In addition, the magnitude of the changes is relevant along the coastal areas in the periods 2031–2060 and 2071–2100. Thus, the coastal areas might be vulnerable to heat wave episodes. Moreover, ETR index shows future decrease following a south-north gradient with values in the range [-0.5; 1.5°C] over the country during January–March (JFM) and October–December (OND) seasons whereas an increase (~0.5°C) is projected for April–June (AMJ) and July–September (JAS) seasons, particularly in the central and northern parts. This situation leads to a projected faster increase of the minimum temperature than the maximum, except in AMJ and in JAS seasons in the central and the northern regions. On the other hand, the changes in the different indices with respect to the mean value of the reference period (1976–2005) are in concordance to the expected warming at the end of the twenty-first century in west African region with significant increasing trends. The trends in the future period (2006–2100) under the RCPs forcing scenarios are generally more important than those in the historical period (1976–2005). Thus, significant modification mostly occurs in future climates under both mid-level (RCP4.5) and high-level (RCP8.5) Green House Gas (GHG) forcing scenarios albeit trends under RCP8.5 are higher compared to those under RCP4.5 scenario. The HWFI, TX90P and TN90P trends' consistently increase even in the historical and future periods. The projected changes are, however, subject to uncertainties, which are higher under RCP8.5 than under RCP4.5 scenarios and higher in the future period (2006–2100) than in the historical period (1976–2005). Overall, these changes are robust as all the 14 CORDEX-Africa simulations agree to an increase of warm extreme temperature for the end of the twenty first century.

Key words: West Africa, Côte d'Ivoire, extreme temperature, projected changes, RCPs scenarios, CORDEX

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VREMENSKA NEPOGODA NA JADRANSKOM MORU KAO UZROČNIK POGREŠKE SATELITSKOG ODREĐIVANJA POLOŽAJA

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Satelitska navigacija predstavlja temeljnu tehnologiju određivanja položaja, brzine i vremena u pomorstvu. Narušavanje kvalitete određivanja položaja satelitskim sustavom predstavlja izvor rizika za primjene (sustave i usluge) koje koriste satelitsku navigaciju.
U izlaganju razmatramo vremensku nepogodu na zapadnoj obali Jadranskog mora 10. studenog 2019. kao uzrok narušavanja točnosti određivanja položaja satelitskim sustavom GPS. Narušavanje točnosti određivanja položaja prouzročeno je pojavom troposferskog kašnjenja satelitskog signala, koje je prevedeno u pogrešku određivanja položaja. Doprinos troposferskih poremećaja na ukupnu točnost satelitskog određivanja položaja razmotren je na temelju eksperimentalnih opažanja na referentnoj GNSS stanici Padova u Italiji, koja je tijekom dana svakih 30 sekundi biježila opažene vrijednosti pseudoudaljenosti vidljivih satelita. GPS pseudoudaljenosti su naknadno analizirane primjenom programski određenog GNSS prijamnika RTKLIB, koji je kao rezultat naknadne analize dao procijenjene vrijednosti položaja i procjene pogrešaka određivanja položaja u 30-sekundnim intervalima. Analiza je obavljena u dva scenarija procjena položaja istim ulaznim podatcima: (1) potpuno ispravljene pseudoudaljenosti (uključene sve dostupne ispravke), (2) pseudoudaljenosti ispravljene za sve poznate uzroke narušavanja točnosti osim troposferskog kašnjenja. Razlika vremenskih nizova scenarija (1) i (2) dala je vremenski niz pogrešaka određivanja položaja koje su nastale isključivo uslijed djelovanja troposferskog kašnjenja. Očitane su značajne vrijednosti udjela troposferskog kašnjenja u ukupnoj pogreški GPS određivanja položaja: RME u smjeru sjevera od 0,65 m i RME u smjeru istoka od 0,4 m, što upućuje na zaključak o potrebi razvoja i operativne primjene posebnih modela ispravaka troposferskog kašnjenja u razdobljima značajnih promjena

vremena. Dobiveni vremenski niz udjela pogreške uslijed troposferskog kašnjenja u ukupnoj pogreški GPS određivanja položaja analiziran je i interpretiran sa stajališta nenavigacijske i navigacijske primjene u pomorstvu.

Ključne riječi: GPS, troposfersko kašnjenje, pogreška određivanja položaja, vremenska nepogoda, Jadransko more

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KARTA KOEFICIJENTA DODATNOG TERETA OD LEDA NA NADZEMNIM ELEKTRIČNIM VODOVIMA

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Za potrebe izrade nacionalnog dodatka norme "HRN EN 50341-1:2012 Nadzemni električni vodovi izmjenične struje iznad 1 kV – 1. Dio: Opći zahtjevi – Uobičajene specifikacije" zahtijeva se analiza klimatskih podataka na području Hrvatske s naglaskom na klimatološkim parametrima koji predstavljaju opterećenja za funkcioniranje sustava, a to su vjetar i led. U nedostatku specijalnih mjerenja tereta od leda na vodovima koji bi pružili najtočniju informaciju o opterećenju, uvjeti za zaleđivanje predviđaju se pojavom niske temperature zraka i oborine. Na lokaciji meteorološke postaje računa se 98. percentil godišnjeg broja dana s uvjetima za zaleđivanje. Procjena na lokacijama meteoroloških postaja se geostatističkom metodom regresijskog kriginga interpolira na pravilnu mrežu s ciljem izrade karte ugroženosti ledom i definiranja klimatskih zona za procjenu s ciljem dodatnog tereta od leda na nadzemne vodove.

Ključne riječi: teret od leda, nadzemni električni vodiči, multilogistička regresija

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ESTIMATION OF HAIL USING LIGHTNING VS RADAR DATA, CASE STUDY OF 25 JUNE 2017

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In the past decade new approach was developed based on lightning data to investigate hail, severe wind and tornadoes. It demonstrated good capabilities to nowcast severe effects and it has been used in Catalonia operationally for several years now. The method is based on a mathematical model which is detecting sudden increases in lightning activity known as a lightning jump. We expanded current use from nowcasting towards diagnostics and climatological assessments. Such approach uses fixed grid, which observes lightning activity as the storm is passing over. Lightning jump is computed independently in each of the grid points providing locations in space and time over which the storm was most active. Such method is well suited for archive data of lightning activity allowing us to examine potential hail activities in areas without direct measurements of hail.
In our case we consider total lightning activity (cloud to cloud, cloud to ground, intra cloud and both positive and negative discharges) to ensure enough lightning strikes per grid point since the size of the point is 3x3 km.
Here we will present the case study where we inspect capabilities of such approach to represent hail measured on hail pads in continental parts of Croatia and compare it with radar estimates of hail. The goal is to find best suited parameters for both radar and lightning jump which will correspond well with measured hail. Such method can be a potential source of severe weather information with focus on hail, especially in areas lacking radar coverage and/or direct measurements.

Key words: hail, lightning

Extreme coastal flooding on the eastern Adriatic coast on 28/29 October 2018 documented at I-STORMS project

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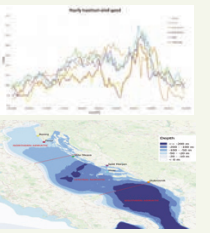
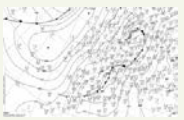
Introduction

Flooding induced by storm tides, high waves and meteotsunamis is the major coastal hazard. Within the framework of the I-STORMS (**Integrated Sea sTORm Management Strategies**) project we are aiming to identify the most vulnerable hotspots in the Adriatic-Ionian area and to design the catalogue of the sea flooding events. Reanalysis of the low frequency but high impact severe weather events is crucial for developing a risk reduction strategies and hazard maps. In this study we present the recent flooding event from the end of October 2018 when very high sea levels and waves were recorded along the Adriatic basin. The series of Mediterranean cyclones and the presence of the anticyclone eastern of the Adriatic sea determined a very strong zonal pressure gradient and favoured intense prevailing southeasterly winds. The funnelling of the wind between the mountain chains surrounding the Adriatic basin further increased the wind speed. Retrospective analysis by means of measurements on the stations along the Croatian eastern part of the Adriatic Sea is shown for this case of persistent strong and gale force southerly wind. During the 28th and 29th October, the precipitation was extreme only in some locations, the pressure minimum was not particularly deep, the peak gusts were between 25 and 40 m/s and the waves were exceptionally high. The wind, wave and sea level analysis for the city of Rovinj and Dubrovnik area is presented to highlight the differences between the deeper southern and very shallow northern part of Croatian coast, which is particularly vulnerable to high magnitude storm surges. The main reason for damaging high sea levels and waves was the first stage of the event on the 26th when jugo (southeasterly) wind started and generated the waves with significant height over 1 meter prior to the cyclone and associated cold front passage on the 29th October.



Synoptic overview and data analysis



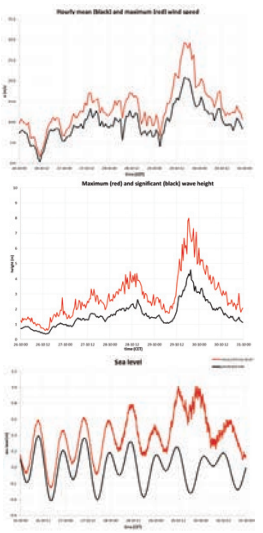
27th October, 18 UTC

- First shallow surface low was moving on 26-27th October northern of Italy, it was reabsorbed by a large system passing above central Europe; strong zonal gradient with anticyclone on the east (≈ 15hPa)
- simultaneously on the 27th October the new cyclogenesis started over the western Mediterranean and the new surface low was rapidly deepening while moving to the east; deep trough with cold air intrusion
- cyclone's maximum intensity was reached on 29th October with surface pressure around 980 hPa near Sardinia and then it followed a more northern unusual path; severe storms formed on the cold front

29th October, 12 UTC — 26-30th October

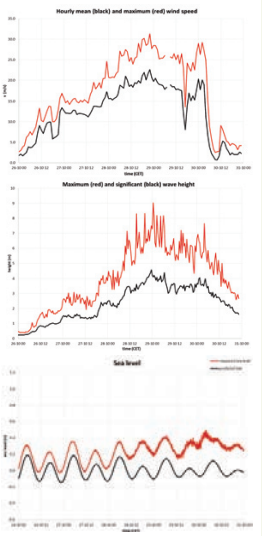
Rovinj

- during the 26-28th October sustained SE winds of about 10 m/s build up waves with SWH>1 m
- short decrease in wind speed and change of direction to E while the new surface low was deepening
- sudden sharp increase in wind speed and wave heights with cyclone and the associated cold front rapidly approaching
- first maximum of the sea level (**1.01 m** above average) reached around the same time as the Acqua Alta happened in Venice
- during the frontal passage peak wind speed gusting up to **29.4 m/s** and highest wave height of **8.0 m** (SWH=**4.34 m**) was recorded which luckily coincided with the low tide, but still the sea level reached **1.73 m** over the predicted
- very rough sea (SWH>4 m) lasted **2.5 h**
- secondary maximum sea level (**1.02 m**) after the frontal passage when the wind and waves were decreasing, but the tide was rising (at 21:20 CET on 29th October reaching **1.17 m** over the predicted)



Dubrovnik

- during the 26-28th October steady increase of SE winds reaching peak values of average speed **22.6 m/s** with gusts up to **31.3 m/s** around 23 CET on the 28th that build up the highest wave of **9.03 m** (SWH=**4.11 m**) and the sea level of **0.20 m** above average which was **0.30 m** over predicted
- very rough sea (SWH>4 m) lasted **9.5 h**
- short decrease in wind speed and change of direction to ESE while the new surface low was deepening
- secondary maximum of wind speed ahead and during the frontal passage reaching around **29 m/s** between 00 and 03 CET on the 30th October coinciding with the half way up the rising tide, and the maximum sea level of **0.49 m** was recorded at 3:38 CET which exceeded by **0.49 m** the negative values that was predicted
- rough sea conditions (SWH>2.5 m) lasted **57 h**
- due to the deeper water, amplitudes and residuals sea levels are much lower as compared to those in the shallower northern Adriatic Sea



Impact

Opatija
(Credit: Nel Pavletić / Pixsell)

- widespread damages to coastal infrastructure; many buildings wrecked by pounding waves and seawalls heavily destroyed
- coastal lowlands were flooded, the sand and rocks washed onto shore roads and many boats sunken
- disruption of marine traffic during the 27-30th October; ferry service cancelled almost all of the scheduled sailings on 29th October because of the rough sea conditions so the many islands were cut off from the mainland for more than a day
- the highest sea level measured in the Bakar bay (1.27 m above average) and the fourth highest Acqua Alta in Venice (1.56 m)*
- extremely high waves measured near the city of Rovinj (8.0 m) and Dubrovnik (9.03 m)*
- the second highest waves ever recorded on Italian stations in the Adriatic sea*
- weak meteotsunamis recorded in the Central Adriatic

Promenade between Ičići and Ika
(Credit: Eduard Kličić / HR Radio Rijeka)

Conclusion*

The growing coastal population and infrastructure and the likely impact of climate change on the occurrence of extreme weather events and expected sea level rise, makes the coastal flooding a significant and increasing hazard. The long lasting strong and gale southeasterly winds are forming high waves in the Adriatic Sea and push the water in the same direction along the basin. Since the most pronounced storm surges generally arise in relatively shallow sea, the northern Adriatic is more prone to coastal flooding. The study of this recent event from October 2018 reveals that it had a similar synoptic pattern of the historical extreme wave and storm surges cases in the Adriatic Sea. We would like stress out that the reanalysis of the severe weather phenomena is crucial for risk assessment along the diverse Adriatic coastline and that the integrated approach is needed. Our goal is to make a series of region specific hindcast studies and the I-STORMS projects new Transnational Multi Model Ensemble System (TMES) will give us the opportunity to prepare it.

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Acknowledgments to the Hydrographic Institute of the Republic of Croatia for providing the wave and the sea level data.
*as of May 2019

Sensitivity of atmospheric stratification to physical parameterizations in a regional climate model

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1 INTRODUCTION

During the first HyMeX Special Observation period heavy precipitation affected the coastal mountainous region in Croatia causing flash floods and severe damage. Our focus is on the six heavy precipitation events (**HPEs**) during intensive observation periods (**IOPs**) over the Adriatic target area.

AIM → examine the impact of parameter change in parameterization schemes of regional climate model (RCM) on atmospheric stratification

Dates, location and maximum 24 h accumulated rainfall for each IOP over the Adriatic target area (Ivančan-Picek et al., 2016). →

IOP	DATE	LOCATION	PRECIPITATION (mm)
2	12-13 Sep	Rijeka	220.2
4	13-14 Sep	Pelješac	101.4
13	14-16 Oct	Hvar, Mljet, Rijeka, Karlobag, Imotski	118.6, 145.4
16	26-28 Oct	Rijeka, Rijeka inland	180.1, 173.5
18	31 Oct-2 Nov	Istria, Rijeka	171.4
19	4-5 Nov	Rijeka inland	177.0

2 MODEL

- RCM ALADIN-Climat version 6.3 (ALD6)
- the spectral nudging technique applied
- atmosphere-only, driven by ERA-Interim reanalysis
- Med-CORDEX domain (MED-11)
- spatial resolution of 11.0° (~12.5 km)

Daniel et al. (2018)

Experiments

in terms of a prior sensitivity to convection:

I. entrainment and aerodynamical drag (increased), marginal microphysics and radiation modifications
II. turbulence modifications (increased in presence of convection)
III. marginal dynamics modifications

ALD63n-t0	ALD63n-t1	ALD63n-t2	ALD63n-t3
Control run	I.	I. + II.	I. + II. + III.

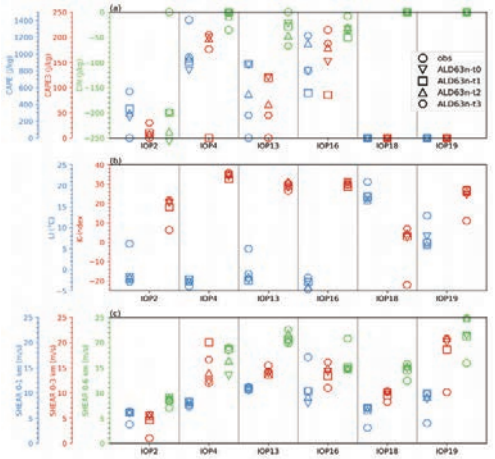
CONVECTION SCHEME	CLOUD SCHEME	LARGE-SCALE MICROPHYSICS	RADIATION SCHEME	LAND-SURFACE MODEL	TURBULENCE SCHEME
PCMT - Piriou et al. (2007); Guérémy (2011)	Ricard and Royer (1993)	Lopez (2002)	LW → Mlawer et al. (1997) SW → Morcrette et al. (2008)	SURFEX v8 platform (includes tile)	Cuxart et al. (2000)

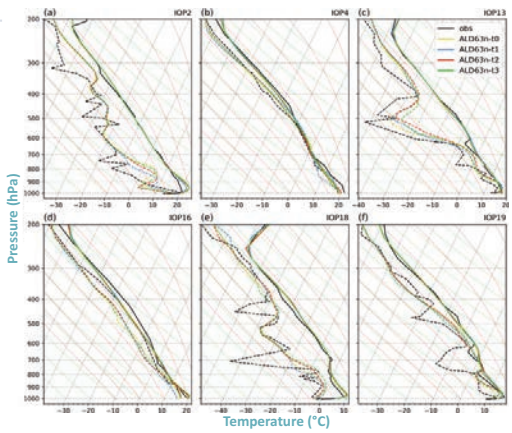
3 OBSERVATIONS

- radiosounding measurements from the station Zadar-Zemunik (station ID = 14430)
- available at 0000 and 1200 UTC
- only 0000 UTC soundings used on the IOP day with maximum precipitation

4 METHOD

- vertical profiles of temperature and humidity from RCM are compared with the radiosounding measurements for each IOP
- vertical profiles of temperature, specific humidity, wind and pressure extracted from RCM and radiosounding measurements → input for Sounding and Hodograph Analysis and Research Program in Python (SHARPpy) software (Blumberg et al., 2017)
- derived thermodynamic quantities: CAPE, CAPE3, CIN, Lifted Index (LI) and K-index
- derived kinematic quantities: bulk wind shear between the surface and 1 km (SHEAR 0-1 km), surface and 3 km (SHEAR 0-3 km) and surface and 6 km (SHEAR 0-6 km)





6 CONCLUSION

- ALD63n sensitivity tests show realistic results for integrated stability diagnostics and indices
- good agreement with observed vertical wind shear in several layers
- the largest discrepancies are found for vertical moisture profiles (not so much for temperature)
- ALD63n simulations show robustness to the parameter changes → further improvement of physical parameterization schemes could be the next thing for the developers' community to address
- the evaluation of a larger number of HPE cases is preferable as the evaluation results can be highly event dependent

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VERIFYING PRECIPITATION: AN IMPORTANT TASK OF SOUTH-EAST MULTI-HAZARD EARLY WARNING ADVISORY SYSTEM PROJECT

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The main goal of the South-East Multi-Hazard Early Warning Advisory System project (SEE-MHEWS-A) is to provide the support for the National Meteorological and Hydrological Services in Southeast Europe in order to produce timely and accurate warnings of hazardous weather and hydrological events. The reliability of such a warning system largely depends on the accuracy and adequate performance of numerical weather predictions (NWP). Therefore, verification of numerical models and comparison of their results in a structured, region-wide forecast verification procedure is a necessary component of the process for building such a system. Overall verification methodology is developed for the SEE-MHEWS-A project using ALADIN-HR and ECMWF 24-hour cumulative precipitation products. The available forecasts are verified at 42 stations in Croatia during one-year time period. The nearest model grid point over land is used for the comparison with the observations.

The goal of the verification procedure is to summarize the information of the forecast quality in only a few measures, while still keeping the objective evaluation on its skill and value. This is a complex issue, since every measure has its benefits and imperfections. The verification methodology consists of several building blocks, starting with the analysis of the missing observations and climatology analysis for the target area. Taking proper account of the missing observations is necessary to improve the quality of verification procedure. Additionally, climatology analysis is essential to design the exact details of the verification procedure and to provide proper interpretation of the verification results. After the preparatory steps, methodology includes the following:

- The verification of a continuous predictand, which takes into account exactly how much the values of the forecasts differ from the values of the observations. Conventional verification measures include Pearson correlation coefficient, systematic error, mean absolute error and root mean square error.
- The verification of a categorical predictand, which evaluates whether or not forecasts take predefined categories. The categories in this work are determined by several thresholds, describing different precipitation intensities. For the more frequent events the measures such as frequency bias, hit rate, false alarm ratio, false alarm rate and equitable threat score are used to evaluate the forecast accuracy. The extremal dependence index is shown to access the performance for rare events.

The included verification measures, when interpreted together, provide meaningful information of the NWP model forecasts performance. Therefore, this work is a comprehensive insight into the strengths and weaknesses of the NWP models being evaluated and as such may be a useful backup in a future advisory system.

Key words: verification, precipitation, verification scores, extreme event

Meteorološki izazovi 7; Sekcija 4:
KLIMATSKE PROMJENE I PRILAGODBA

KLIMATSKO MODELIRANJE JADRANA ZDRUŽENIM MODELSKIM SUSTAVOM ADRISC

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AdriSC (Adriatic Sea and Coast, www.izor.hr/adrisc) predstavlja združeni modelski sustav atmosfere i mora visoke razlučivosti, razvijen u Institutu za oceanografiju i ribarstvo za potrebe operativne prognoze stanja mora i pojedinih ekstremnih procesa (meteorološki tsunamiji), kao i za potrebe klimatskog modeliranja sadašnje i buduće klime. Sustav sačinjavaju dva osnovna modula – atmosferski, koji koristi ugniježđeni Weather Research and Forecast (WRF) model, razlučivosti od 15 do 1,5 km, te oceanski, koji koristi ugniježđeni Regional Ocean Modelling System (ROMS) model razlučivosti 3 i 1 km i nestrukturirani model ADCIRC razlučivosti do 10 m u obalnom području. Trenutno, AdriSC modelski sustav je implementiran za: (1) operativnu dvodnevnu prognozu stanja Jadrana, napose za prognozu pojave meteoroloških tsunamija, (2) klimatsku analizu površinskih valova u Jadranu temeljenu na reproduciranju 36 izabranih ekstremnih događaja valova bure i juga, kao i njihovu manifestaciju u budućoj klimi temeljenu na RCP4.5 i RCP8.5 scenarijima emisije stakleničkih plinova i metodologiji tzv. surogatnog klimatskog modeliranja te (3) višedekadsku klimatsku simulaciju Jadrana u razdoblju 1987. – 2017. U prezentaciji će biti prikazane (i) same karakteristike modelskog sustava, (ii) njegova primjena u studijama (2) i (3), (iii) verifikacija rezultata modela u navedenim istraživanjima, (iv) buduća istraživanja i planirane studije te (v) ideje i mogućnosti za istraživanja i primjenu u studijama klimatskih i drugih rizika u Hrvatskoj i Jadranu u cjelini.

Ključne riječi: klima, Jadran, numeričko modeliranje, atmosfera, more

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METEOROLOŠKA PODRŠKA LOKALNIM ZAJEDNICAMA U PRILAGODBI NA KLIMATSKE PROMJENE

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Lokalne zajednice na obali Jadrana su izložene klimatskim promjenama koje se javljaju u atmosferi i moru. Porast temperature zraka i mora, promjene u hidrološkom sustavu te porast srednje razine mora su samo dio izazova s kojima se ove zajednice susreću. Početkom 2019. godine započela su dva Interreg Italija – Hrvatska projekta, *RESPONSe* (Strategije prilagodbe na klimatske promjene u jadranskim regijama) i *Adriadapt* (Informacijska platforma o otpornosti na klimatske promjene za jadranske lokalne zajednice), kojima je cilj podržati gradove i općine u izradi planova i strategija za lokalnu prilagodbu. Analizom najnovijih simulacija opažene i buduće klime pripremit će se podloge koje mogu poslužiti kao tehnička podrška donositeljima odluka. Za odabrana pilot područja testirat će se provedba alata i metodologija pri izradi lokalnih strategija. U predavanju će biti izloženi ciljevi i struktura oba projekta te primjeri doprinosa DHMZ-a i ostalih hrvatskih partnera u njihovoj izvedbi.

Ključne riječi: klimatske promjene, Interreg projekti, prilagodba

ASSESSING BIAS CORRECTION METHODS FOR EURO-CORDEX PROJECTIONS (TEMPERATURE AND PRECIPITATION)

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Climate models make an incomplete representation of reality, currently they don't succeed to simulate all temporal and spatial scales or all processes in the atmosphere. The processes in the climate system occur on spatial-temporal scales ranging from tens of thousands of kilometres to less than 1 kilometre and from centuries scales to the sub-daily temporal scales. Several processes and interactions such as turbulent exchanges under stable conditions or aerosol life cycles are not yet fully understood and, therefore, are not directly quantifiable in explicit terms. Thus, to improve the quality of the information provided by climate models, statistical techniques are used to adjust systematic errors.

In this study, two categories of bias correction (BC) methods of climate scenarios data were tested: univariate and multivariate. The BC methods were calibrated for the period 1971–2005 using as reference the ROCADA dataset. The temperature and precipitation data provided by three EURO-CORDEX models were analysed in this paper.

The calibration of the BC methods was performed for each grid point with daily ROCADA data of temperature (average, minimum and maximum) and precipitation. By comparing the calibrated data with the ROCADA data set, the results of the two methods of climate scenario adjustment were evaluated. For a detailed analysis of the results, three indicators of measurement of the estimation errors were calculated: the mean absolute error (MAE), the mean square error (RMSE) and the Pearson's correlation coefficients (CORR).

It was found that regardless of the climatic scenario, for the temperature data both categories applied methods obtain similar results, with the meaning that the multivariate method corrects better the extreme negative values. The analysis of the precipitation data revealed an obvious differentiation between the results of the two categories of BC methods, the data calibrated with the multivariate method having statistical properties closest to those of the reference data.

Acknowledgment
This work was supported by a grant of the Romanian National Authority for Scientific Research and Innovation, CCCDI – UEFISCDI, project number COFUND-SUSCROP-SUSCAP-2, within PNCDI III.

Key words: climate models, bias correction, calibration, errors

METMONIC – Podaci u realnom vremenu za praćenje klime i prilagodbu klimatskim promjenama

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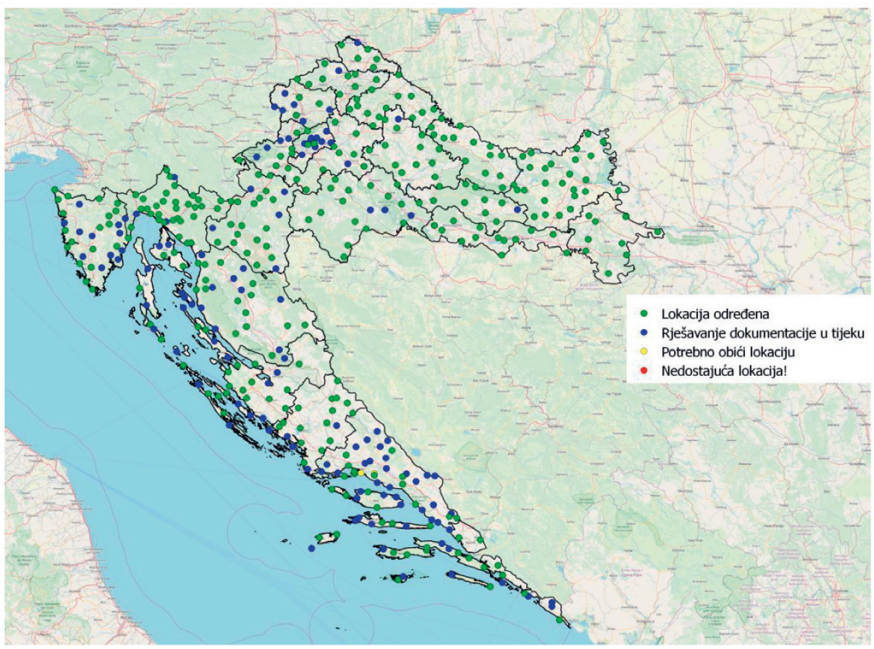
Projekt modernizacije meteorološke motriteljske mreže u RH - METMONIC

Osnovni cilj projekta – uspostava suvremenog sustava automatskih prizemnih meteoroloških postaja, meteorološko-oceanografskih plutača i daljinskih sustava mjerenja atmosfere uključivši sustav meteoroloških radara, čime će se omogućiti praćenje klime i klimatskih promjena te izdavanje pravovremenih upozorenja na opasne vremenske prilike.
Trajanje je produženo do kraja lipnja 2023. godine.

Ključne komponente projekta su:

1. Modernizacija i unaprjeđenje prizemnih meteoroloških mjerenja

Modernizacija postojećih ili uspostava novih automatskih meteoroloških postaja. Pronađeno je i potvrđeno 435 od 437 lokacija za prizemne meteorološke postaje u suradnji s jedinicama lokalne samouprave i RH.



Slika 1. Planirani položaj automatskih meteoroloških postaja nakon provedbe projekta.

U tijeku je:

- izrada Tehničke dokumentacije za gradnju postaja (nedostaje dokumentacija za cca. 60 lokacija),
- ocjenjivanje ponuda za osjetnike,
- ocjenjivanje ponuda za Nadzor gradnje i Voditelja projekta gradnje.

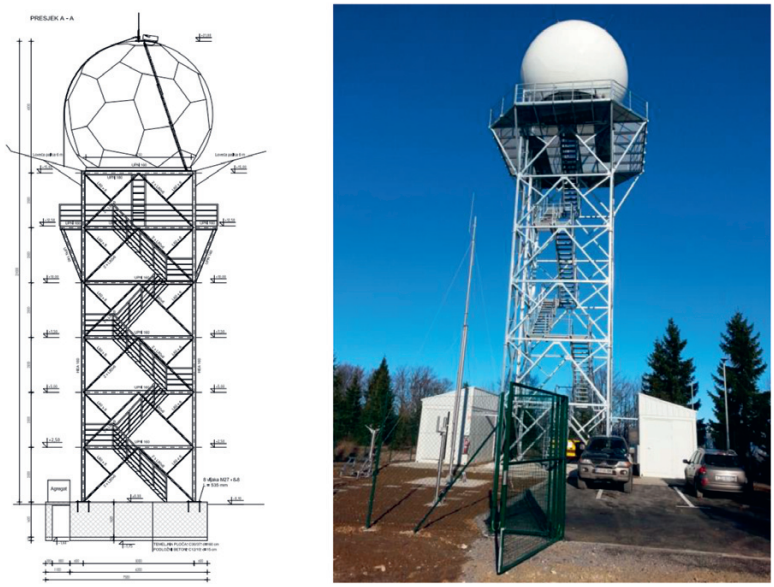
Nakon izrade tehničke dokumentacije potrebno je provesti nabavu građevinskih radova te početi s gradnjom.

2. Modernizacija i unaprjeđenje visinskih meteoroloških mjerenja

Uspostavit će se visinska mjerenja u Slavonskom Brodu i na lokaciji Monte-Kope na južnom vrhu Istre.
Slavonski Brod: 3D scanning lidar (vjetar nad lokacijom, transport aerosola i naoblaka),
Monte Kope: wind profiler (profil vjetra po visini) i mikrovalni radiometar (temperatura i relativna vlažnost zraka po visini).

3. Modernizacija i unaprjeđenje mreže radarskih mjerenja

Lokacije: Gradište, Bilogora, Puntijarka, Goli kod Labina, Debeljak kod Sukošana, Uljenje na Pelješcu.



Slika 2. Projekt za radare na moru i slika instaliranog radara u Sloveniji kakav će se instalirati u RH.

Nabavlja se šest novih C-band dual-pol meteoroloških radara. Bit će instalirani na tri obnovljena radarska centra u unutrašnjosti i tri nova radarska centra na obali.

4. Uspostava meteorološko-oceanografskog sustava mjerenja

Nabavlja se pet meteorološko-oceanografskih plutača. Bit će instalirane na pet lokacija duž cijelog Jadrana.
Više detalja u prezentaciji Dijane Klarić.

5. Unaprjeđenje i modernizacija sustava prihvata, obrade, kontrole i pohrane podataka i osiguranje dostupnosti podataka

Nakon nabave i instalacije sustava za skeniranje u tijeku je skeniranje arhivske građe.
Također je u tijeku izrada Centralne integracijske platforme. Centralna integracijska platforma služit će za prihvat i pristup podacima koji će poslužiti za jednostavniji pristup podacima u realnom vremenu kao i arhivskim podacima, s ciljem podrške procesima prilagodbe na klimatske promjene i ublažavanja njihovih posljedica.
Još slijedi nabava sustava za automatsku kontrolu podataka s automatskih postaja.

6. Unaprjeđenje umjernog meteorološkog laboratorija

Uređen je novi prostor za umjerni meteorološki laboratorij i servis za automatske meteorološke postaje. Prostor je nakon potresa dio vremena korišten kao privremeni smještaj DHMZ-a.

Slika 2. Instalirani wind tunel za umjeravanje osjetnika brzine i smjera vjetra.

Instalirana je i puštena u rad oprema za umjeravanje mjerila strujanja, temperature, relativne vlažnosti i tlaka zraka te količine oborine.

Instaliranom opremom u umjernom laboratoriju DHMZ će moći umjeravati veliku većinu svojih osjetnika. Preostaje još nabaviti opremu za umjeravanje osjetnika za mjerenje Sunčevog zračenja.

7. Unaprjeđenje praćenja opterećenja ekosustava elementima u tragovima

Instaliran je i pušten u rad ICP-MS uređaj u svrhu praćenja koncentracije elemenata u tragovima u oborini kao jednog od indikatora kvalitete zraka.

Umjesto zaključka: po završetku provedbe projekta planirano je da DHMZ kao nositelj projekta osigura sljediv, reprezentativan, visokokvalitetan, pouzdan i pravovremeni podatak o stanju atmosfere i mora na čitavom području RH, neophodan za kontinuirano praćenje vremena i klime te za ostvarivanje meteorološke podrške procesima prilagodbe na klimatske promjene i ublažavanja njihovih posljedica. S dostupnim pravovremenim meteorološkim podacima poboljšat će se kvaliteta upozorenja na prirodne nepogode i katastrofe.

Projekt modernizacije meteorološke motriteljske mreže u RH – METMONIC, KK.05.1.1.01.0001, financira se u iznosu od 85 % iz bespovratnih sredstava Europskog fonda za regionalni razvoj te 15 % iz Fonda za zaštitu okoliša i energetsku učinkovitost.

OBSERVED AND FUTURE CHANGES OF DRY SPELLS IN CROATIA

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Drought in Croatia causes the highest economic losses inflicting serious damages, especially in agricultural and water management sector. In this study dry spells (DS) in Croatia are analyzed. DS are defined as consecutive sequences of days having daily precipitation less than a given precipitation-per-day threshold (5 mm in this study). Daily precipitation data from a dense national rain-gauge network (grouped into seven climatological regions) and spanning the time period 1961–2015 are employed. Spatial and temporal characteristics of mean and maximum seasonal and annual DS are analyzed as well as recent changes in DS using the trend estimations by means of Kendall' tau method.
Additional period 1971–2000 is defined. For this period both observation based DS and regional climate models' based DS analysis is performed. Three regional climate models, RegCM4, CLM and RCA4, cover the EURO-CORDEX domain, and they are forced at the lateral boundaries using four CMIP5 global climate models. Regional climate models are applied at the 12.5 km horizontal resolution, resulting in a realistic orography and land-sea fields over Croatia. For the 1971–2000 period, models' systematic errors in terms of the DS climatology are examined.
Finally, projections and future changes in the DS are based on the simulations under the high and medium greenhouse gases concentration scenarios (i.e., RCP8.5 and RCP4.5). The focus is on the climate change signal between 1971–2000 and the two future periods, 2011–2040 and 2041–2070.
Reports on drought impacts for the period 2000–2018 were collected from the national newspapers and analyzed. The severity of drought impacts for the few selected years is linked to the satellite products available on the drought monitoring web platform – Drought Watch (mainly to the soil moisture and vegetation status) and Standardized Precipitation Index (SPI).

Key words: drought, dry spell, climate model, impacts, Drought Watch

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PRISTRANOST U REZULTATIMA TEMPERATURE I OBORINE IZ ANSAMBLA REGIONALNIH KLIMATSKIH MODELA NA ŠIREM PODRUČJU JADRANSKOG MORA

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Sustavne pogreške, odnosno, odstupanje varijabli modeliranih globalnim i regionalnim klimatskim modelima nazivaju se pristranost modela, a javljaju se zbog ograničene prostorne rezolucije, pojednostavljene fizike i termodinamike u modelu, numeričkih shema, itd. Korištenje klimatskih projekcija u različitim modelima utjecaja zahtijeva podatke gotovo bez ikakvih pristranosti.
U ovom radu je dokumentirana pristranost u regionalnim klimatskim modelima RegCM4, RCA4 i CLM s rubnim uvjetima iz četiri CMIP5 globalna klimatska modela na širem području Jadranskog mora. Pristranost je određena prema E-OBSv19e podacima na mreži razlučivosti 0,1° x 0,1°. Promatrane su srednje sezonske vrijednosti temperature zraka i ukupne količine oborine za razdoblje 1971. – 2004. Analizirani su osnovni obrasci ponašanja pristranosti te je istražena ovisnost pristranosti o nadmorskoj visini ćelije mreže u pojedinačnim modelima i medijanu ansambla (12 modela) pristranosti. Prije korištenja rezultata klimatskih modela u primijenjenom istraživanju, njihove rezultate je potrebno statistički korigirati stoga je dan i pregled, te mane i prednosti najčešće korištenih metoda korekcije pristranosti uz poseban osvrt na bi- i viševarijatne metode.

Ključne riječi: pristranost, regionalni klimatski modeli, ovisnost o visini, temperatura, oborina

Meteorološki izazovi 7; Sekcija 5:
PROGNOZA VREMENA

METEOROLOGICAL SUPPORT FOR FOREST FIRE PROTECTION

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Forest fires are a growing threat to the natural environment and human communities, and major fires can also become a serious crisis with potentially catastrophic consequences. This has been particularly pronounced in the last twenty years due to climate change and global warming. For more than thirty years, the Croatian Meteorological and Hydrological Service has been involved in forest fire protection by making analyzes and weather forecasts. This paper gives an overview of the activities that are being carried out, particularly during the main fire season – which are defined by the Government's Activity Program.
The most important product that indicates the drying of the plant cover, or combustible material, is the Canadian Fire Weather Index (FWI), which takes into account air temperature, air humidity, wind and precipitation. For stations in the Adriatic and inland, the real value of the index and its forecast for the next two days are calculated daily and submitted to the fire authorities. The index, its properties and the results of forecast verification will be displayed.
In addition to these short-term forecasts, medium-range (semi-weekly and weekly), and long range (monthly and special seasonal forecasts with an emphasis on the risk of forest fires) will be presented.
Due to the increasing danger and damage from fires, especially extreme ones, special warnings have been introduced from 2012 on the risk of potentially large, catastrophic fires and specific criteria for the occurrence and spread of such fires have been developed. In addition to the high value of the fire index, they are: strong wind (with increased values of turbulent kinetic energy) or instability in dry air (for which the Haines index was introduced as a measure). In accordance with these criteria, three hazard levels – yellow, orange and red – have been introduced since this year, similar to other alert systems. Alert statistics and their verification will be discussed.
At the end of the month – and especially at the end of the season – additional statistics, analyzes of the average classes of danger and their deviation from the climatological mean are calculated, and the observed trends and changes in the atmospheric circulation are investigated. The weather and the synoptic situation in large, catastrophic fires are specifically analyzed.
Finally, plans for the future development of new tools and methods will be presented.

Key words: forest fires, forecast, warnings

IS PRECISE NOWCASTING OF SEA BREEZE ONSET POSSIBLE?

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Maestral is a very important wind for Split international airport. It is basically a sea breeze combined with prevailing synoptic flow, modified by the local orographic effects. Runway orientation and complex air traffic approach pattern – due to a nearby mountain Kozjak – make changing takeoff and landing pattern quite complicated for Split airport. For this reason, air traffic controllers require very precise forecasts of the beginning of maestral. Terminal Aerodrome Forecast (TAF) verification shows that forecasters do a good job in forecasting maestral beginning within two hours precision, but air traffic controllers need even more precise maestral timing, which can be provided in the form of TREND forecast. The main question to

answer is: „Is it possible to nowcast maestral beginning with higher precision?“
To answer this question, an experiment was performed during 2019 summer season. An anemometer was placed 6 km upwind (southwest) from the runway, taking into account local experience that maestral wind usually spreads over sea surface from the southwest or west direction. If this hypothesis is correct, the upwind anemometer should catch the beginning of maestral sooner than the one at the airport. Objective analysis of data from both anemometers should reveal if there is any lead time in upwind anemometer and if it could help forecasters to more precisely nowcast maestral beginning at the airport.
The preliminary results show that in 90% of the cases maestral starts sooner at the upwind anemometer. Moreover, the upwind anemometer most frequently registers the beginning of maestral between 40 and 70 minutes sooner than the one at the airport. These results are promising and show that forecasters can use the upwind anemometer data to improve maestral nowcasting.

Key words: sea breeze, maestral, nowcasting, wind, air traffic

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POST-PROCESSING OF ALADIN FORECASTS USING NEIGHBORHOOD ENSEMBLE TECHNIQUES

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The traditional or point based verification of model forecasts is problematic because i) grid averaged values (model forecasts) cannot simply be compared to the point values (observations), as representativeness error can be as high as 50% of the total error, especially given the fact that model effective resolution is 5–6 times higher than its grid spacing, ii) it has been shown in the past that point verification is unable to show benefit of increasing model resolution and iii) it is very sensitive to the double-penalty effect. This led to the development of so-called spatial verification techniques. The spatial evaluation accounts for structure errors, spatial displacements and field deformations. Through different approaches (i.e. scale separation, neighborhood, object or feature-based approach, etc.) spatial verification is reducing the double-penalty effect and is able to more correctly compare different resolution models.
In addition, lowering the grid spacing leads to faster error growth and saturation on the smallest resolved scales. For kilometric grid sizes, error saturation can occur after only a couple of hours of integration. This means that model forecasts on those scales become uncertain very quickly. That is why the ensemble and probabilistic forecasts are becoming more and more important.
In this work, we try to alleviate before-mentioned problems by generating a neighborhood ensemble from a deterministic ALADIN forecast. Selected neighborhood contains both spatial and temporal dimension and its size varies with the forecast range in order to account for increasing forecast uncertainty. By using neighborhoods, we can include probabilistic information to and reduce representativeness error of a deterministic forecast. We apply this technique to precipitation, temperature and wind variables. The results show increased forecast accuracy for all variables, especially for min/max temperatures and it gives us an elegant way to account for double-penalty effect for precipitation. In addition, various forecast products based on the neighborhood approach will be presented.

Key words: ALADIN, neighborhood, ensemble, post-processing

TURBULENCE INTEGRAL SCALES AND DATA FILTERING FOR BORA WIND

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Bora is a strong, gusty wind, whose microscale characteristics, especially its turbulence, are not fully explored yet. Integral scale is a good indicator of the size of the eddies that dominate the turbulence spectrum. It is estimated from the atmospheric wind speed measurements using autocorrelation function (ACF) and Fourier spectrum. In theory, their ratio should be a constant. Besides being a fundamental property in the theory of turbulence, the integral scale is used as an important variable in numerical weather prediction (NWP) and climate models. Therefore, it is of essential importance to estimate properly the integral scale from the atmospheric wind speed measurements using ACF and Fourier spectrum, in order to be able to validate NWP and climate models. However, the values of integral scale obtained from ACF and Fourier spectrum are very sensitive to preprocessing of the data, such as the data filtering, so one has to be very careful in preparing the data for ACF and Fourier spectrum analysis. In this work, we study the sensitivity of integral scale values for bora flows (obtained using ACF and Fourier spectrum analysis) on the data filtering, which is in practice a first step in the analysis of the atmospheric turbulence in general.
The measurements that were used were performed on a micrometeorological tower installed near the Maslenica Bridge north of the city of Zadar, Croatia, with a sampling frequency of 20 Hz. The 10 m tall tower was equipped with three levels of Gill WindMaster ultrasonic anemometers (2, 5 and 10 m) gathering the 3D wind speed and sonic temperature. For the period from October 9, 2015, to October 9, 2016, 48 events of bora flow were abstracted.
The main objectives of this work are to examine the effect of data filtering on integral scale values for bora flows, obtained from ACF and Fourier spectrum, the effect on their ratio and to try to find out a suitable high-pass filtering period. The results show that integral scales obtained by the filtered data using filter periods close to averaging time scale (30 min) are not significantly sensitive to filtering. When using shorter filter periods, it is better to estimate integral scales from the Fourier spectrum. Given that the ratio is relatively conserved over the length of the filter, it is difficult to say, for bora flows, whether the raw data should be filtered or not.

Key words: numerical weather prediction, averaging time scale, autocorrelation function, Fourier spectrum, micrometeorological tower, Maslenica bridge

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OPERATIONAL WAVE MODELLING IN THE ADRIATIC SEA WITH THE WIND WAVE MODEL

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The accurate modelling of sea surface gravity waves is essential for accurate oceanic forecasting with high sea waves being a major concern for navigation and coastal activities. It is also very important for oceanic modelling, with the wave input being key to the accurate modelling of oceanic surface stress, sediment resuspension and also to oceanic current modelling.
In the Croatian Meteorological Institute, we have implemented the Wind Wave Model III (WWM-III) as an operational model. The wind forcing used is based on the numerical weather prediction model ALADIN/HR. The model is using near-surface winds dynamically adapted to 2 km grid spacing over the 3-day forecast range. The boundary condition at the Otranto strait is obtained from the WWM model forecasts computed at ECMWF. The model setup uses an unstructured grid to make the forecasts. The numerical modelization uses an implicit scheme that we describe.
We found an underestimate of significant wave height by 8 cm, an absolute error of 21 cm and a

correlation of 91% when comparing with the altimeter of the SARAL satellite. Comparison with wave radar and buoys show no underestimate and smaller absolute errors.
We will also present results related to the coupling of the ALADIN model with the WWM-III model.

Key words: altimeter, wave model, model coupling

RECENT RESEARCH AND DEVELOPMENT WITHIN TURBULENCE PARAMETRIZATION OF THE ALARO CANONICAL MODEL CONFIGURATION (CMC)

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ALARO-CMC utilizes the Third Order Moments Unified Condensation Accounting and N-dependent Solver for turbulence and diffusion (TOUCANS), which is an integral part of the ALARO-1 package of physical parametrizations. TOUCANS is a 1D scheme with 2.5 level type of closure, which unifies several ideas into its framework: non-existence of the critical Richardson number, inclusion of the impact of unisotropy of turbulence, prognostic treatment of Turbulence Kinetic Energy (TKE) and Turbulence Total Energy (TTE), treatment of moisture impact on turbulence, Third Order Moments (TOMs) parametrization enabling counter-gradient transport, as well as the possibility of prognostic treatment of mixing length and 3D turbulence parametrization (1D+2D).
Key component of the scheme is a solver for a pair of the above mentioned turbulence energies, whose ratio is used as a stability parameter instead of gradient Richardson number. The scheme is quite sensitive to the selection of mixing length formulation. Currently TOUCANS utilizes Geleyn-Cedilnik Prandtl type formulation, which is basically a smooth Planetary Boundary Layer (PBL) height-dependent function. Its shape in the PBL and asymptotic behaviour at the model top can be adjusted by modification of three additional tuning parameters. Here we focus on testing the performance of a newly implemented TKE-based buoyancy-shear (BS) formulation, where mixing length is computed as a displacement of an air parcel from particular model level initialized by TKE and stopped by joint buoyancy and shear effects. The latter one enables the usage of BS formulation across different stability regimes and it is expected to improve the model performance in stable stratification, as well as near the neutrality. The model configuration we utilized is a hydrostatic version of the ALARO-CMC at 4.7 km grid spacing, with 87 vertical levels of the hybrid-pressure coordinate and time-step of 180 s. The simulations were run throughout the 72-hour forecast window for a summer convection case and a stable winter case, wherein the verification is done using available surface and upper-air measurements.
With most of the RC LACE countries moving towards 2 km grid spacing, or even less, there is an emerging question of the adaptability of current turbulence parametrization, as well as its compliance with the grid-point part of the Semi-Lagrangian Horizontal Diffusion which mimics the horizontal effects of turbulence. Moreover, around 1 km grid spacing and less we should enter the "grey zone" of turbulence or "terra incognita", where turbulent motions are partly resolved and partly still sub-grid. Within the "grey zone", 1D turbulence schemes should be converted to 3D and carefully adapted to interact properly with the resolved turbulence (model dynamics). As a first step we need to identify where the ALARO-CMC is in the context of the "grey zone". For this reason we created four different meshes, covering the same area and differing only in grid spacing, which was set to 4, 2, 1 and 0,5 km respectively. Preliminary analysis of the post spin-up part of 24-hourly non-hydrostatic simulations showed that the resolved part of TKE becomes important already at 1 km grid spacing, i.e. the "grey zone" is reached.

Key words: ALARO-CMC, TOUCANS, turbulence parametrization, mixing length, grey zone, resolved turbulence

POST-PROCESSING OF THE WIND SPEED NUMERICAL WEATHER PREDICTION USING ANALOG-BASED METHOD

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The analog approach is a statistical post-processing method used to generate deterministic and probabilistic forecasts. The analogs are past numerical weather predictions similar to the current prediction across several variables (i.e. predictors). The measurements corresponding to the analogs form an analog ensemble. The predictors can be deterministic and / or ensemble NWP forecast output.
The analog method is first applied to the deterministic ALADIN NWP model, producing a point-based wind speed forecast 10 m above the ground. The performance is tested in climatologically and topographically different regions of Croatia. It is shown that the deterministic analog-based predictions (ABPs) improve the correlation between predictions and measurements while reducing the forecast error (with respect to both the starting model predictions and the Kalman filter based correction). All ABPs improve prediction of larger than diurnal motions while the application of the Kalman filter in so-called analog space is the superior among all ABPs in predicting alternating wind regimes on shorter-than-diurnal time scales.
Additionally, the austrian ALADIN-LAEF system ensemble forecasts are used as a starting model. The results show that there is often no need to use all ensemble members as predictors. It might be enough to use only summarized information (such as ensemble mean and spread), which is computationally less demanding. Further improvements can be achieved by optimizing and adapting the analog searching procedure (i.e. the predictor-weighting strategy). Finally, an analog-based method is comparable to (or even outperforms) an ensemble model output statistic (EMOS) approach, even for high wind speed thresholds.
Overall, the results encourage the use of analog approach in an operational environment.

Key words: statistical post-processing, NWP, wind speed forecast, analog-based method

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ŠTO SE DEŠAVA IZNAD ZAGREBA?

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Podnicomjer (eng. ceilometer) je uređaj za mjerenje visine donje granice oblaka. Državni hidrometeorološki zavod postavio je Lufft ceilometer CHM15k na meteorološkom opservatoriju Maksimir tijekom 2017. godine.
Napravljena je detaljna vizualizacija vertikalnih profila odraza zadnjih šest sati s uzorkovanjem svakih pet minuta. Ona omogućuje praćenje profila vlage (i čestica) u atmosferskom graničnom sloju i slobodnoj atmosferi. Izdvojeno je nekoliko karakterističnih vremenskih situacija: razvoj konvektivnog graničnog sloja, padanje oborine, usporeno padanje suhog snijega, snižavanje stratusa, nestanak magle, advekcija slojeva različite vlažnosti i drugo.
Zaključuje se kako je detaljna vizualizacija vertikalnih profila korisna kao dodatan alat u dijagnozi i prognozi vremena.

Ključne riječi: Ceilometer, Zagreb-Maksimir

ZRAKOPLOVNA PROGNOSTIČKA SLUŽBA – NAPREDAK TIJEKOM PROTEKLOG DESETLJEĆA

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Zrakoplovna prognostička služba unutar Hrvatske kontrole zračne plovidbe pruža usluge prognoza i upozorenja za zrakoplovne korisnike. Tijekom proteklog desetljeća bilo je promjena u organizaciji rada, tehnologiji i ljudskim resursima koje su utjecale na operativni rad. Uvođenje promjena, upravljanim od službi koje pružaju podršku operativi, bilo je izazovno i doprinijelo je napretku prognostičkih produkata za zrakoplovne korisnike.
Velike promjene napravljene su u tehnološkom razvoju. U operativni rad prognostičara uvedene su nove radne stanice koje su omogućile znatno brže pregledavanje i analizu meteoroloških mjerenja i modela te izradu produkata. Praćen je razvoj meteoroloških mjerenja – od zračnih luka do satelitskih podataka. Primjerice, sustav mrežnih kamera na ciljanim lokacijama iz cijele Hrvatske omogućio je kontinuirani pregled vremenskih uvjeta na područjima koje imaju manjak standardnih meteoroloških mjerenja, ali su bitne za podršku letova na niskim razinama (npr. policiji i vojsci). Korištenje novih i napredak meteoroloških modela (i ansambala) omogućilo je bolje i pouzdanije prognoziranje opasnih meteoroloških pojava na malim skalama.
Glavna promjena u upravljanju ljudskim potencijalima bila je optimiziranje organizacija smjena i radnih zadataka u središnjem uredu i u podružnicama. Tijekom navedenog razdoblja izmijenila se i gotovo polovina stalnih prognostičara. Također, svi su sudjelovali na edukacijama pohađanjem redovnih seminara i/ili posebnih radionica. Najveći iskoraci u razumijevanju i prognoziranju postignuti su u prognoziranju grmljavinskih oluja, bure i magle.
Sve navedeno omogućilo je da prognostičari naprave bolju analizu, dijagnozu i prognozu te izdaju kvalitetnije produkte. Dodatno uz standardne međunarodne produkte (dostupne na met.crocontrol.hr) uvedeni su i ciljani produkti za potrebe upravljanja zračnim prometom ili za korisnike za letove na niskim razinama. Navedene promjene omogućit će nam napredak i praćenje svjetskih trendova razvoja u tehnološki još izazovnijem narednom desetljeću.

Ključne riječi: zrakoplovna meteorologija, Hrvatska kontrola zračnog prometa, napredak

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EKSTREMAN SLUČAJ BURE – PROGNOZA I KOMUNIKACIJA

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Prognoziranje ekstrema uvijek je izazovan operativni zadatak. Velika je odgovornost i hrabrost u prognoziranju odmaka od standardnog raspona meteorološkog parametra za određenu lokaciju. Istovremeno, potrebna je posebna pažnja i dodatna pozornost u konzultacijama s korisnicima.
Analiziran je slučaj orkanske bure, tzv. "bure desetljeća", 22. i 23. veljače 2019. Poseban naglasak je na utjecaju bure na zračne luke u Dalmaciji.
Bura se, kao bočni vjetar na određenim zračnim lukama, smatra jednim od najopasnijih fenomena u zrakoplovstvu i kao takva ima značajan utjecaj na sigurnost zrakoplovnih operacija. S obzirom da je uzrok ove epizode bio poremećaj sinoptičkih razmjera, dobro se prognozirala i do nekoliko dana unaprijed. Kao prognostička podloga korišteni su, između ostalog, ansambli i indeks EFI (The Extreme forecast index) Europskog centra za srednjoročnu prognozu ECMWF, te vertikalni i horizontalni podaci ALADIN 8 km modela DHMZ-a, koji su se uspoređivali s već poznatim jakim ekstremnim epizodama bure. Indeks EFI definiran je kao mjera odstupanja raspodjele ansambl prognoza u odnosu na raspodjelu klime modela (M-climate). Ne zahtijeva definiranje prostornih i/ili vremenskih kriterija, zbog čega je EFI vrlo koristan u alarmiranju ekstremnih vremenskih pojava nad bilo kojim područjem.

Zanimljivost ove epizode orkanske bure je i u dva različita tipa bure. Tako je Sjeverni Jadran obilježio tip duboke bure karakterističan po rotorima i manjim vrijednostima brzine srednjeg vjetra i udara u odnosu na klasični tip plitke bure na južnom Jadranu. Maksimalna vrijednost udara vjetra izmjerena je tako u noći 23. veljače na zračnoj luci Dubrovnik, a iznosila je rekordnih 82 kt.
U drugom dijelu prezentacije naglasak je na operativnom radu Službe meteorološkog bdjenja (SMB), kako su izgledale prognoze za zračne luke u Dalmaciji (Split, Dubrovnik, Zadar), koji su produkti izdani i koje su mjere poduzete. Dan ranije, održana je proširena interna konzultacija s dežurnim prognostičarima. S obzirom na očekivani razmjer ekstremnog događaja, zaključeno je, da je uz već propisane, potrebno poduzeti i mjere dodatnog upozoravanja zračnih prijevoznika i korisnika na zračnim lukama.
S obzirom da su medijski prostori vrlo često prepuni članaka o ekstremnom vremenu, ovakav slučaj ukazao je na važnost dobre, jezgrovite kumunikacije s našim korisnicima, kako ni oni sami ne bi postali previše tolerantni na riječi orkanska bura.

Ključne riječi: bura, komunikacija, ekstremi, EFI

OPERATIVNI PROGNOSTIČKI SUSTAV DHMZ-A: STATUS I PERSPEKTIVE

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Operativni prognostički sustav (OPS) Državnog hidrometeorološkog zavoda (DHMZ) temelji se na numeričkom modelu atmosfere *Aire Limitée Adaptation dynamique Développement InterNational* (ALADIN). Da bi prognoza bila pouzdana i pravovremena, OPS je potrebno redovito održavati i unaprjeđivati. U okviru međunarodne suradnje više meteoroloških instituta, razvija se i sam model ALADIN. Svaki značajniji znanstveni i tehnički razvoj implementira se u jedinstvenu novu verziju modela, tzv. ciklus.
Trenutno na DHMZ-u postoji nekoliko operativnih konfiguracija modela ALADIN koje se međusobno razlikuju po rezoluciji (ALADIN-HR8 i ALADIN-HR4), postavkama i ciklusu. Također, operativno se izvršava i posebna konfiguracija modela, dinamička adaptacija (ALADIN-DA2), koja na računalno „jeftin" način unaprjeđuje prognozu vjetra te daje izlaz na mreži točaka s korakom od 2 km. Navedena konfiguracija modela združena je s valnim modelom *Wind Wave Model III* (WWM3) te daje prognozu značajne visine i smjera valova na Jadranu do 72 sata unaprijed. OPS DHMZ-a dodatno sadrži i sustav vrlo kratkoročne prognoze *Integrated nowcasting through comprehensive analysis* (INCA). Sustav INCA izrađuje korekcije izlaznih satnih polja modela ALADIN te ih ekstrapolira u vremenu, dobivajući time statistički bolju prognozu do 6 sati unaprijed. Izlazna polja OPS-a DHMZ-a na kraju se prilagođavaju za upotrebu krajnjih korisnika.
Računalni resursi na DHMZ-u, kao jedna od najvažnijih komponenti prognostičkog sustava, trenutno su u potpunosti iskorišteni. U 2020. g. očekuje se nabava novog superračunala, čime se otvaraju nove mogućnosti unaprjeđenja OPS-a. Trenutno je na DHMZ-u u tijeku priprema za preseljenje kompletnog sustava na novo superračunalo, implementacija najnovijeg ciklusa modela ALADIN (cy43) te operacionalizacija novog sustava crtanja produkata za korisnike. Trenutni status gore navedenih komponenti OPS-a te planiranih unaprjeđenja biti će prezentirani na skupu.

Ključne riječi: ALADIN, DHMZ, prognoza, numerički model

OVERVIEW OF DHMZ NWP ACTIVITIES ON THE WMO PROJECT SOUTH-EAST EUROPEAN MULTI-HAZARD EARLY WARNING ADVISORY SYSTEM – SEE-MHEWS-A

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Since 2017, the World Meteorological Organization (WMO) has been coordinating development of the *South-East European Multi-Hazard Early Warning Advisory System (SEE-MHEWS-A)* supported by the World Bank, European Union and USAID. SEE-MHEWS-A aims to provide operational forecasters from National Meteorological and Hydrological Services of the South-East Europe (17 countries) with effective and tested tools for forecasting hazardous weather events and their possible impacts in order to improve the accuracy of warnings and their relevance to stakeholders and users. On a single virtual platform, the system will collect information, products and tools for the provision of accurate forecasts and warnings to support hazard-related decision-making by national authorities. Furthermore, the SEE-MHEWS-A will function as a regional cooperative platform where forecasters from different countries can work together on the identification of potential hazards and their impacts, especially when impending weather hazards may have potential impacts in many countries.

The main overall objectives of the project are i) Strengthened regional cooperation through leveraging of national, regional and global capacities to develop improved hydrometeorological forecasts, advisories and warnings, which will contribute to saving lives and reducing economic losses and damage and ii) Strengthened national early warning systems by making regional and sub-regional observing, monitoring and forecasting tools and data available to the participating countries and other beneficiaries.

In this contribution we describe in more details the role of DHMZ related to NWP, which is two-fold. First, DHMZ is a key partner for verification of numerical weather prediction models. DHMZ leads elaboration of methodology for meteorological verification in the SEE MHEWS region and will apply the methodology to assess the skill of several NWP models, such as ALADIN, IFS, COSMO and WRF. DHMZ also assists ARSO in implementing ALADIN numerical weather prediction for the entire region on ECMWF high-performance computing system. In addition to presenting the project and DHMZ activities, we will discuss some early results as well as remaining technical and professional challenges of the project.

Key words: multi-hazard, early warning, southeast Europe

Meteorološki izazovi 7; Sekcija 6:
PRIMIJENJENA METEOROLOGIJA

TESTING OF NONSTATIONARITY USING THE EOF METHOD

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Stationarity is a fundamental assumption in the statistical investigation of turbulence and the development of similarity functions that are widely used in e.g. surface-layer parameterization schemes for NWP and climate modeling. Non-stationary time series should, therefore, be removed from the analysis before assessing turbulence statistics used in similarity functions. Many approaches have been developed over the years to determine non-stationarity of means and (co-)variances. Here we investigate the possibility of using EOF analysis to detect non-stationarity. First, we test EOF analysis on artificially created perfectly stationary and non-stationary time series and contrast the results with existing methods. After concluding that it is indeed possible to detect non-stationarity with EOF analysis, we apply this method together with other approaches to near-surface time series of wind and temperature means collected during bora events near Maslenica bridge, near the city of Zadar, Croatia. Measurements are taken with a frequency of 20 Hz at 2 m, 5 m, and 10 m elevation. In the end, we investigate the differences and similarities between the approaches.

Key words: non-stationarity, EOF analysis

FIRST FINDINGS FROM THE CROSSINN CAMPAIGN ON THE STRUCTURE AND VARIABILITY OF CROSS-VALLEY CIRCULATIONS IN THE INN VALLEY, AUSTRIA

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Over flat and horizontally homogeneous terrain, vertical exchange mechanisms govern the coupling between the surface and the free troposphere. However, over sloping terrain and heterogeneous land-use, this coupling takes a three-dimensional character across a range of spatial scales, introducing uncertainties when attempting to parameterize resulting flow structures in operational numerical weather prediction. Superposition of these spatial scales is particularly pronounced in mountain valleys, for which a theoretical framework capable of explaining such alteration of exchange mechanisms does not currently exist. The resulting flow structures may assume several different properties and formations, ranging from asymmetrical cross-valley circulation cells to curvature-induced circulations accompanied with marked turbulence. To date, such flow structures have been sampled only during a few selected ambient conditions and with limited spatio-temporal resolution, leaving many open-ended questions as to their persistence and their effect on the coupling between the surface and the free troposphere. To address these questions and improve our understanding of the evolution of such cross-valley flow, we conducted the CROSSINN (Cross-valley flow in the Inn Valley investigated by dual-Doppler lidar measurements) field campaign in the Inn Valley, Austria, from 1 August to 13 October 2019.
In this talk, we present preliminary findings from one Intensive Observation Period (IOP). The thermodynamic state of the mountain boundary layer during this IOP was sampled with a rich suite of measurements, including five Doppler LiDARs, a Raman LiDAR, a ceilometer, a microwave radiometer, surface energy balance measurements, as well as frequent radiosoundings. To sample the cross-valley flow structure with adequate spatio-temporal resolution, three Leosphere Doppler LiDARs Windcube 200s, which are part of the mobile integrated atmospheric observation platform

KITcube, were set up in two dual-Doppler configurations covering each one half of the valley atmosphere in a single vertical plane. Such a configuration enabled the retrieval of two components of the wind field along this single vertical plane, giving us desired insight into the structure of the cross-valley flow. The spatial coverage, with the extent of 5x3 square kilometers on average, was resolved with a 50-m grid spacing throughout the entire duration of CROSSINN, sufficiently fine to assess the spatial extent of the cross-valley flow observed during this IOP. During this IOP, we observed several features of interest, including a twice daily transition from nighttime downvalley to more intense daytime upvalley flow and vice versa, as well as a shallow daytime convective boundary layer. Owing to the intense upvalley flow, the cross-valley flow structure, as obtained from the dual-Doppler algorithm, resembled an asymmetrical, single closed cell restricted to altitudes below the surrounding Alpine ridgetops.

Key words: complex terrain, cross-valley flow, Doppler LiDAR, turbulence, atmospheric boundary layer

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VALIDATION OF SUNSHINE DURATION OF THE SURFACE SOLAR RADIATION DATA SET – HELIOSAT (SARAH-2.1) FOR CROATIA

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Solar radiation components and sunshine duration are used in the assessment and monitoring of climate conditions, in the estimation of the potential for using renewable solar energy and in the calculation of parameters for energy consumption for heating and cooling of buildings. Here, validation of the satellite-based climate data record Surface Solar Radiation Data Set – Heliosat (SARAH-2.1) derived from satellite-observations onboard the geostationary Meteosat satellites is made. The validation is performed using ground sunshine duration observations from 27 meteorological stations in Croatia with less than 10% of missing data in the period 1983–2017. Meteorological stations used for validation are covering different climate regions: five stations are located in a continental part of Croatia, four in the mountain region, while the rest are on the coast of the northern, middle and southern Adriatic. Average monthly bias is ~7 h, with the largest mean bias in January and March (~13 h) and the lowest in May (~0.1 h). At the highest station Zavižan (height ~1600 m) satellite data underestimate measurements in all months, especially in summer which may be the effect of convective clouds in the surrounding area as well as high albedo. Significant positive bias is found in winter at continental stations, as well as at the valley stations, probably due to fog occurrence in those areas. Overall good agreement of satellite data compared to in-situ measurements is found, however due to larger differences at specific locations additional correction would be needed.

Key words: sunshine duration, satellite data

ON DOWN-SLOPE WINDSTORMS – AN ATMOSPHERIC BOUNDARY-LAYER PERSPECTIVE

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A chapter from a newly coming textbook: “Handbook of Non-Synoptic Wind Storm Hazards”, edited by Kareem and Hangan, and published by Oxford University Press will be presented. The chapter deals with certain meteorological and engineering aspects of severe down-slope wind-storms such as Bora, Foehn, Chinook, Santa Ana and more. Effects of those vigorous winds on constructions will be addressed as well as the corresponding meteorological backgrounds.

Key words: bora, mountain wave, turbulence

Meteorološki izazovi 7; Sekcija 7:
AGROMETEOROLOGIJA

10 YEARS OF EDDY COVARIANCE AND BIOMETRIC CARBON FLUX MEASUREMENTS IN CROATIA

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Water vapor and carbon dioxide are the main atmospheric constituents which are controlling the Earth's climate. The rapid increase in the atmospheric content of carbon dioxide since the beginning of the industrial revolution is considered as one of the main drivers of the recent climate changes on Earth. Only about 40% of the total anthropogenic emissions of CO_2 remain in the atmosphere, while the rest of the emitted CO_2 is stored in oceans and land. The terrestrial sinks of carbon are global soils and forests. Forests sequester CO_2 from the atmosphere and assimilate carbon into above- and belowground biomass and by that partially offset anthropogenic emission of CO_2 and participate in a regulation of climate. Because of these findings, monitoring of CO_2 exchange between atmosphere and underlying forest ecosystems has gained significant importance. Micrometeorological eddy covariance technique has shown as the most accurate way for direct flux measurement of trace gases, and today it is a standard tool for estimating net ecosystem exchange (NEE) of trace gases between the atmosphere and the underlying surface.
Within this research 10-year eddy covariance experiment (2008–2017) was carried out in young pedunculate oak (*Quercus robur L.*) stands (35–44 years old) which are part of the forest complex of the Kupa River basin, about 35 km SW from Zagreb, Croatia. Over the entire study period, Jastrebarsko forest acted as a carbon sink, with an average annual NEE of -319 ± 30 g C $m^{-2}yr^{-1}$. Estimated NEE was partitioned into gross primary production (GPP) and ecosystem respiration (RECO). Furthermore, RECO was partitioned into heterotrophic (Rh) and autotrophic respiration (Ra). Most important carbon flux in forest ecosystems, net primary production (NPP), was estimated by subtracting NEE from heterotrophic respiration. In this study the causes of interannual variability of carbon NEE were investigated. Also, the impact of extreme weather events (droughts and floods) on carbon fluxes was investigated. For validation of EC measurements, a biometric estimate of the net primary productivity (NPPBM), which was built on periodic measurement and simple modelling, was compared with NPPEC. Comparison of NPPEC and NPPBM showed good agreement (R^2=0.46).

Key words: CO_2, eddy covariance, NEE, NPP, GPP, RECO, pedunculate oak

VINOGRADARSKA ZONA CIII U REPUBLICI HRVATSKOJ

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Vinogradarstvo i vinarstvo među najvažnijim su poljoprivrednim i gospodarskim djelatnostima u Hrvatskoj. Vinova loza (*Vitis vinifera L.*) klimatski je osjetljiva kultura, jer na njen rast i razvoj uvelike utječu prevladavajući atmosferski uvjeti u svakoj regiji. Kao takvi, optimalni klimatski uvjeti za rast vinove loze ograničeni su zemljopisno te se uobičajeno smatra da su najpogodnija područja za njezin uzgoj između 30° i 50° paralele sjeverne i južne geografske širine. Vrlo su specifični i uvjeti potrebni za dobivanje željenih prinosa i optimalnog kemijskog sastava grožđa te željene kvalitete i tipa vina. Utjecaj klime očituje se makroklimatskim (regija, podregija) i mezoklimatskim (vinogorje, položaj) djelovanjem, te izborom agrotehničkih i ampelografskih mjera koje poduzimamo u vinogradu.

Gledajući kroz sektor vinogradarstva i vinarstva, agroklimatski indeksi su metode kojima se određuju zemljopisna područja i njihova pogodnost za uzgoj određene sorte vinove loze ili njene podloge, a pomoću njih se izrađuju karte vinogradarskih područja. Utjecaj klime na vinogradarsko zoniranje procijenjen je na temelju projekcija vrijednosti agroklimatskih indeksa poput Huglinovog (heliotermičkog; Huglin, 1978) indeksa, indeksa sume efektivnih temperatura prema Winkleru (Winkler et al., 1974), indeksa hladnih noći (Tonietto, 1999; Tonietto i Carbonneau, 2004) i indeksa prosječne temperature zraka u vegetaciji (Jones, 2006).
Vinova loza vrlo je osjetljiva na klimatske promjene. Iz tog razloga očekuje se da će istraživanja i spoznaje o značajnim klimatskim promjenama predstavljati veliki izazov za vinogradarsku proizvodnju u nadolazećim desetljećima. Štoviše, u većini klimatskih područja poput Mediterana (kojem pripada i Hrvatska), vinogradi su već danas izloženi visokim temperaturnim vrijednostima te vodnim stresovima (maloj količini vode dostupnoj biljci). Stoga, s obzirom na važnost sektora vinogradarstva i vinarstva, istraživanje trenutne klime te potencijalnog utjecaja klimatskih promjena od izuzetne je važnosti za buduću održivost vinove loze u Hrvatskoj.

Ključne riječi: klima, vinogradarska zona, agroklimatski indeks, vinova loza, sorta

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DISANJE TLA U AGROEKOSUSTAVIMA

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Ugljikov dioksid smatra se uzročnikom klimatskih promjena i jednim od najvažnijih stakleničkih plinova koji utječu na procese globalnog zagrijavanja. Granica između pedosfere i atmosfere mjesto je intenzivne razmjene ugljika. Tlo predstavlja važan čimbenik u borbi protiv klimatskih promjena jer je drugo po veličini skladište ugljika i može predstavljati ponor atmosferskog CO_2. Poljoprivredni, šumski i ekosustavi travnjaka interakcijom tlo-biljka-atmosfera mogu sekvestrirati atmosferski ugljik u svoju biomasu i tlo i tako usporiti brzinu klimatskih promjena. Na disanje tla utječu mnogi čimbenici poput agroklimatskih elemenata, agrotehničkih zahvata, prisutnost i vrsta usjeva, itd. Zbog nedostatka podataka vezanih za tematiku disanja tla provedeno je istraživanje u prirodnim agroklimatskim uvjetima u blizini Bistre, Daruvara i Siska s različitim poljoprivrednim kulturama. Koncentracije CO_2 iz tla mjerile su se tijekom jedne vegetacijske godine (2013/2014), in situ metodom statičkih komora tijekom uzgoja jedne energetske (*Miscanthus x giganteus*) i dviju ratarskih (pšenica, kukuruz) poljoprivrednih kultura.

Ključne riječi: emisija CO_2 iz tla, pšenica, kukuruz, *Miscanthus x giganteus*, Hrvatska

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Assessment of agro - climatic resources for agriculture in Ukraine

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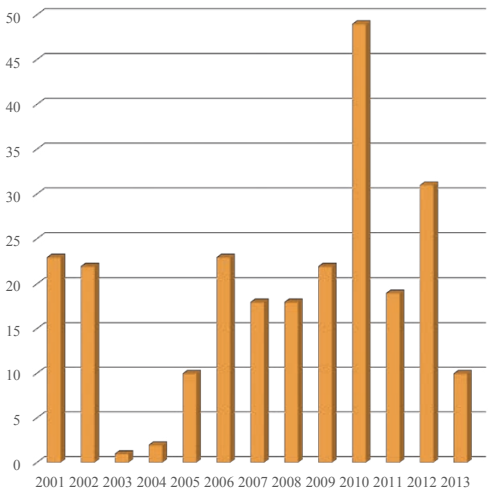
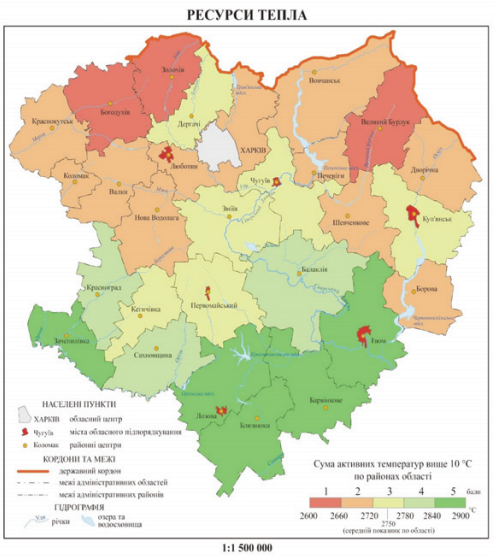
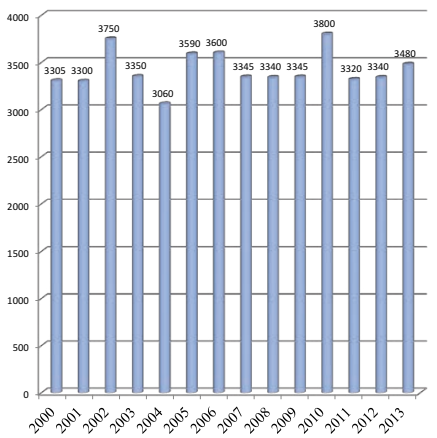


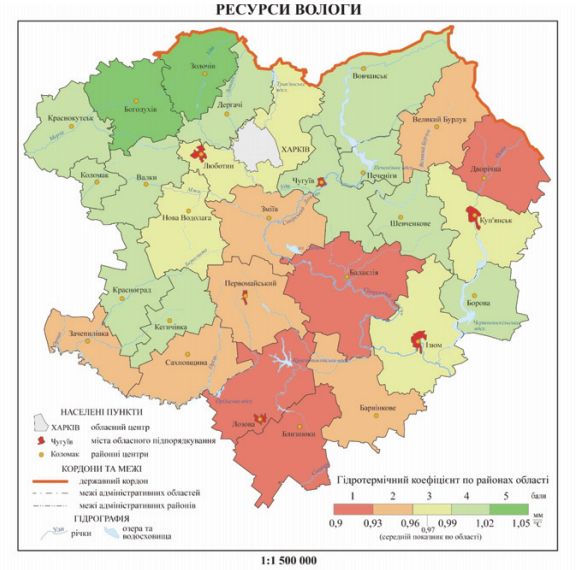
Recurrence of high air temperatures (25.0°C and above, number of days) on the example of Kharkiv station, Ukraine

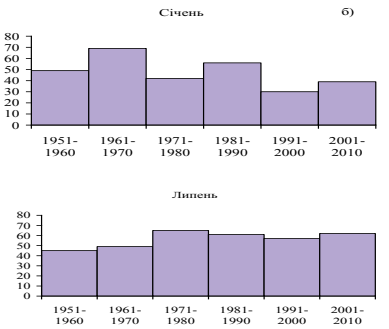
During the entire study period, the highest recurrence of high temperature (more than 25.0°C) occurs in July (116 cases), the lowest - in May (15 cases). In June, 43 cases were recorded, in August - 56 cases.
In total, 248 cases with temperatures above 25.0 °C and very high temperature (more than 30.0 °C) were registered. The same period is characterized by the droughts intensification (atmospheric drought, dry winds), the soil moisture decrease and crops' disappearance and its productivity decrease.



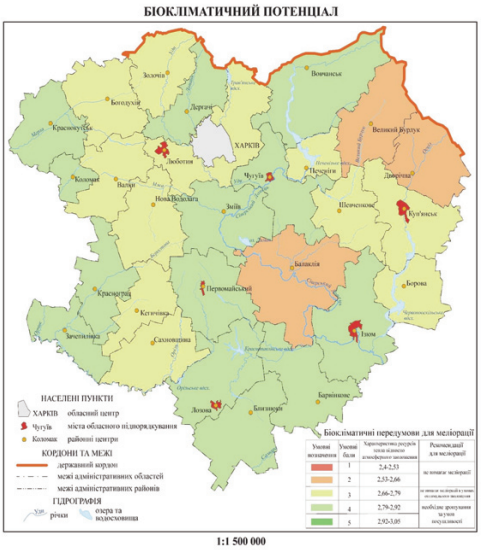
Heat resources *in the region are characterized by growth in the south and southwest. Increased values of the sum of active air temperatures up to 3000 ° C and above, which accelerates the phenological phases of plants.*







Humidification mode *indicates increased dryness in the east and south of the region. Prolonged insufficient moisture causes inhibition of crop growth, reduced productivity and crop failure. In the spring there is a tendency to decrease slightly, and in winter and summer to increase.*



The bioclimatic potential of the territory determines the measures of agricultural production. Due to the increase in heat resources, this figure increases from north to south and requires additional irrigation.

Meteorološki izazovi 7; Sekcija 8:
KLIMATOLOGIJA I BIOMETEOROLOGIJA

IMPACT OF TROPICAL OCEAN SSTS ON THE VARIABILITY AND PREDICTABLE COMPONENTS OF SEASONAL ATMOSPHERIC CIRCULATION IN THE NORTH ATLANTIC–EUROPEAN AREA

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Atmospheric variability and predictable components over North Atlantic–European area were analyzed using an atmospheric general circulation model of intermediate complexity (ICTP AGCM). In order to extract individual modes of variability occurring in the ensemble of numerical simulations, EOF analysis was applied onto the fields of the 200 hPa geopotential height and total precipitation. The same variables were selected for the signal-to-noise optimal patterns method, which identifies the patterns that maximize the signal-to-noise ratio, following Straus et al. (2003).
To detect the potential impact of tropical ocean SSTs, five experiments based on a 35-member ensemble of simulations for the 1855–2010 period were conducted. Each experiment was forced with observed SST anomalies prescribed in different ocean areas: the experiment with climatological SSTs (i.e. no SST forcing), SST anomalies prescribed globally, SST forcing prescribed in the entire tropical zone, SST forcing constrained to the tropical Atlantic and the experiment with SST forcing constrained to the tropical Pacific.
SST forcing impacts the interannual variability of the geopotential height and total precipitation, represented with EOF1 and EOF2 patterns, only in the frequency of occurrence of a certain atmospheric mode. In the winter season the first EOF pattern projects onto the NAO, while the second EOF pattern projects onto the Atlantic ridge.
The signal-to-noise optimal patterns method has shown that the optimal patterns and signal-to-noise ratio are affected by the boundary forcing of the oceans.

Key words: tropical–extratropical teleconnections, signal-to-noise ratio

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UNCERTAINTY OF ENSO TELECONNECTION IN THE NORTHERN HEMISPHERE

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The influences of the El Niño-Southern Oscillation (ENSO) in the Atlantic sector are relatively unclear compared with the Pacific sector. Several studies show an evolution of the ENSO teleconnection from November to February, including King et al. (2018, https://journals.ametsoc.org/doi/full/10.1175/BAMS-D-17-0020.1) who suggest that the Atlantic part of the pattern is more robust in late autumn. Using bootstrapping tests (resampling with replacement) following the approach of Deser et al. (2017, https://journals.ametsoc.org/doi/10.1175/JCLI-D-16-0844.1), we re-evaluate the uncertainty in Atlantic sea level pressure anomalies related to ENSO (based on Niño3,4) according to Nov/Dec and Jan/Feb means. Taylor diagrams are used to effectively show the spatial correlations, amplitudes and other statistical properties of the bootstrap composites relative to the observed composites. The Taylor diagrams allow us to find the bootstrap confidence intervals of the patterns and amplitudes. The analyses here confirm that for Nov/Dec means, El Niño (La Niña) is associated with the positive (negative) East Atlantic pattern, which resembles a southward shifted North Atlantic Oscillation (NAO); while the Jan/Feb El Niño (La Niña) is associated with a pattern that projects on the negative (positive) NAO. Using the bootstrap composites, we also

assess the validity of applying the t-tests on the original composites. It is found that in most cases considered for the current study a t-test is able to adequately indicate (which we would only know after performing the bootstrapping) the statistical significance. We will argue that the uncertainty of the ENSO teleconnection in the North Atlantic is reduced when separated into late autumn and winter. The results extend our knowledge in the uncertainty of ENSO teleconnection which also has implication for predictability and model evaluation.

Key words: ENSO Teleconnection, North Atlantic–Europe climate, North Atlantic oscillation

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CLIMATOLOGY OF BORA TYPES AT DUBROVNIK AIRPORT

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Strong bora events have a significant influence on air traffic at Dubrovnik airport. During the time, forecasters learned to differentiate three main bora types: standard bora, deep bora, and nocturnal gap flow. Standard bora is a typical hydraulic flow that is generally associated with bora flows. Usually, mean wind speeds are higher than 10 ms^{-1}, with occasional gusts. Deep bora is typical for measured average wind speeds <10 ms^{-1}, but occasionally gusts can reach 20 ms^{-1}. Contrary to the standard bora, deep bora is characterized by a variation of wind speed and direction, which is often more than 180°. Nocturnal gap flow is steady wind during the nighttime with mean speed up to 12.5 ms^{-1}, a small variation of wind direction, and absence of gusts.
An algorithm that automatically classifies bora types is developed. Inputs are data of 10 min wind from standard METAR reports. For every METAR reports, each class is estimated from thresholds for mean wind speed, occasional gusts, a variation of wind direction and time of day. Smoothing of individual class bora is applied with M of N method. Finally, the time series of bora class is given in final order: deep bora, standard bora, nocturnal gap flow, unclassified bora, and no bora. Within one bora episode, several types of bora can be classified.
During 11 years, 20% of all METAR reports reveal bora type, and among them, 42% reports are weak bora, 32% nocturnal gap flow, 21% standard bora and 5% deep bora. Standard and deep bora are more frequent during the cold part of the year and have an impact on air traffic (cross-wind gust >17.5 ms^{-1}). Standard bora is more frequent during nighttime and deep bora during daylight. Although empirical, this classification could be useful in nowcasting.

Key words: bora, classification, METAR reports, Dubrovnik

PLANNING OF TOURISM DEVELOPMENT IN MALI LOŠINJ (CROATIA)

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INTRODUCTION Mali Lošinj is one of the most popular Croatian tourist destinations situated on the island of Lošinj in northern Adriatic. Management of the Mali Lošinj Tourist Board is aware of the tourism industry vulnerability to climate change. For their planning of tourism development they ordered the climatological study of suitability of present and future local climate for different types of tourist activities. The study provided such information on the basis of climate index for tourism (CIT) determined for 06 UTC and 12 UTC.

METHODS Taking into account the fact that thermal state, precipitation, wind and solar radiation are the most important parameters for tourism, De Freitas et al. (2008) defined the second generation of climate index for tourism (CIT) that integrates thermal (T), aesthetic (A) and physical (P) facets of atmospheric environment important for tourism:

CIT = f [(T, A) * P]

The thermal component (**T**) is a measure of the body-atmosphere energy balance expressed by some biometeorological index that integrate environmental and physiological thermal variables. It is expressed as thermal sensation rather than an energy value, and here the physiologically equivalent temperature PET is used for the assessment of thermal environment (H□ppe, 1999; Matzarakis et al., 1999). The aesthetic component (**A**) includes sky condition, while the physical components (**P**) are wind and rain which can haThermal and aesthetic states are combined into a weather typology matrix and produce the rating class ranging from 1 to 7. CIT should be a descriptor of the quality of climate conditions for a tourism activity for which the index is specifically designed, as indicated for 3S tourism, cycling and cultural tourism and hiking in examples on the right (Bafaluy et al., 2014).
ve an overriding effect when certain values are exceeded.

3S				
Thermal perception	Cloudiness ≤4/10	Cloudiness ≥5/10	Rain >3 mm	Wind ≥6 m/s
very hot	4	3	2	3
hot	6	5	2	4
warm	7	5	2	4
sligh. warm	6	4	1	4
comfortable	5	3	1	2
sligh. cool	2	2	1	2
cool	1	1	1	1
cold	1	1	1	1
very cold	1	1	1	1

Cycling				
Thermal perception	Cloudiness ≤4/10	Cloudiness ≥5/10	Rain >10 mm	Wind ≥8 m/s
very hot	3	2	3	2
hot	4	3	3	2
warm	6	5	4	2
sligh. warm	7	7	4	3
comfortable	7	6	4	2
sligh. cool	6	5	3	2
cool	6	4	3	1
cold	4	3	2	1
very cold	3	2	1	1

Cultural tourism and hiking				
Thermal perception	Cloudiness ≤4/10	Cloudiness ≥5/10	Rain >5 mm	Wind ≥10 m/s
very hot	3	3	2	2
hot	4	3	3	2
warm	6	5	4	4
sligh. warm	7	6	4	4
comfortable	7	6	4	4
sligh. cool	6	5	4	4
cool	5	4	3	3
cold	4	4	2	1
very cold	3	2	1	1

1	2	3	4	5	6	7
unacceptable			acceptable			ideal

DATA

1. Suitability of present climate for tourism is shown with CIT determined on the basis of observed values of meteorological variables during the period 1981-2010.

2. The changes in climate potential of tourism are estimated by changes of CIT in the future 30-year period 2021-2050, according to the referent present period 1981-2000. Data for both periods are provided by two different downscaled data sets, over European area with 12.5 km horizontal resolution.

The first data sets: downscaled by regional climate model SMHI-RCA4_v1 which was forced by five CMIP5 global atmosphere-ocean circulation models: HadGEM2-ES, CNRM-CM5, EC-EARTH, IPSL-CM5A-MR and MPI-ESM-LR.

The second data sets: downscaled by regional climate model RegCM4, version 4.2, which was forced by four global atmosphere-ocean circulation models: CNRM-CM5, EC-EARTH, MPI-ESM-MR and HadGEM2-ES.

In addition, future climate projections were run under RCP4.5 as well as under RCP8.5 IPCC scenarios. In this way, the uncertainty of simulations of future climate was taken into account.

RESULTS

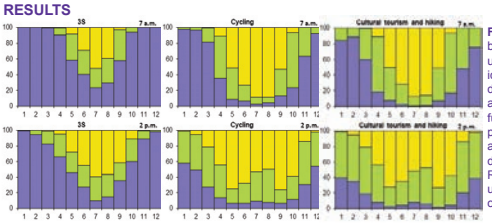


Figure 1. Distribution of CIT (%) at 7 a.m. local time (06 UTC) and 2 p.m. local time (13 UTC) during the year for 3S, cycling and hiking and cultural tourism for Mali Lošinj in 1981-2010.

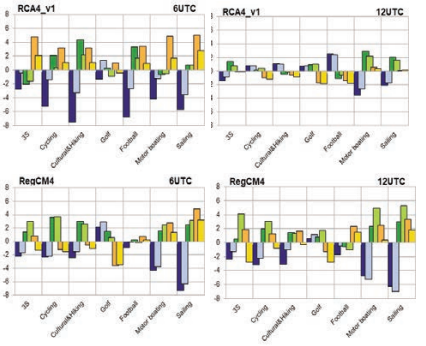


Figure 2. Annual differences between occurences (%) of unacceptable, acceptable and ideal climate conditions for different types of tourism accoding to CIT between future (2021-2050) and present (1981-2000) climates at 06 UTC and 12 UTC, determined with RCA4_v1 and RegCM4 regional models, under IPCC emission scenarios RCP4.5 and RCP8.5.

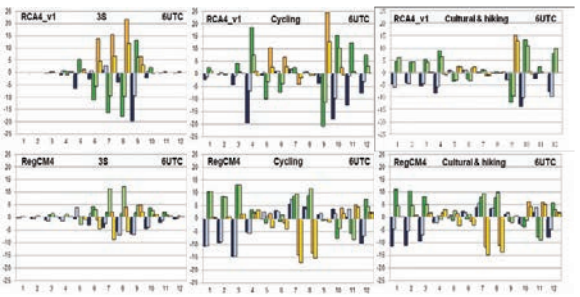
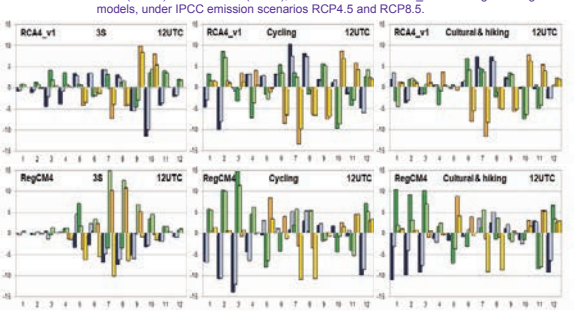


Figure 3. Monthly differences between occurences (%) of unacceptable, acceptable and ideal climate conditions for 3S, cycling and hiking or cultural tourism for Mali Lošinj according to CIT between future (2021-2050) and present (1981-2000) climates at 06 UTC (above) and 12 UTC (below), determined with RCA4_v1 and RegCM4 regional models, under IPCC emission scenarios RCP4.5 and RCP8.5.



CONCLUSIONS

• According to observed data, the distribution of CIT in the morning shows the best conditions in summer. At 2 p.m. there is a bimodal distribution with maxima of ideal conditions in spring and autumn for all kinds of recreation except for typical summer activities 3S (Fig. 1).

• Generally on the annual scale, there is an increase of acceptable and ideal climate conditions for most types of tourism in future climate, especially in the morning (06 UTC). The best conditions could be expected for typical summer activities – beach tourism (3S), motor boating and sailing (Fig. 2).

• Analysing by months (Fig. 3), for beach (3S) tourism the smallest future changes of suitability are in the period from December until April. In future climate the most probable is the increase of ideal or acceptable conditions on the account of reduction of unacceptable conditions in September and October. This indicate that the season of 3S tourism will be prolonged in future.

• Hiking and cultural tourism have an increase in acceptable and decrease in unacceptable future climate conditions mostly from January until March. In future climate ideal conditions are expected to appear less often in July and August whilst more often from October until December than in present climate (Fig.3).

• Common characteristic for all future sport activities tourism is the decrease of acceptable conditions in summer and increase in colder part of year, especially in spring and autumn. For cycling, most probable is that the future climate conditions, both in the early morning and in the afternoon, will be more often acceptable in December-February and less often ideal in July and August (Fig.3). The greatest chances for football in future are the decrease of unacceptable and increase of ideal or acceptable conditions in January-March and decrease of ideal conditions in summer months, both in the early morning and in the afternoon (not shown).

• Applied approach can help in detecting the range of CIT values in future and consequently in the assessment of Mali Lošinj's tourism activities that the future climate will support.

ACKNOWLEDGEMENT: Part of RegCM simulations were supported by the Croatian Science Foundation (CARE Project 2831) and several were performed as a part of the Croatian Ministry of Environment and Energy project (Contract number: *TF/HR/P3-M1-O1-010*) funded by the EU Transition Facility. We wish to thank Grigory Nikulin for providing us subdaily RCA4 modeled data.

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