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Suorganizatori

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Kvaliteta zraka kao bitno svojstvo atmosfere neprestano se mijenja te ovisi o prirodnim procesima, ali i ljudskim aktivnostima. Istovremeno ljudske aktivnosti, zdravlje i kvaliteta života ovise o kvaliteti zraka. Kakvo je stanje danas, koliko je pandemija koronavirusa utjecala na kvalitetu zraka? Koja je uloga meteorologije u toj temi i ima li poveznica između kvalitete zraka i klimatskih promjena?

Ciljevi skupa su: razmjena najnovijih znanstvenih rezultata i istraživanja na području meteorologije, zaštite okoliša i održivog razvoja; jačanje komunikacije s korisnicima meteoroloških podataka i produkata, općom javnošću i medijima; promicanje i popularizacija meteorologije.

Očekivani rezultati skupa su uža interdisciplinarna suradnja meteorologa s korisnicima iz svih područja društvenih i gospodarskih djelatnosti gledana kroz prizmu održivog razvoja i poboljšanja kvalitete zraka.

Pozvani predavači su Winfried Schröder (Sveučilište u Vechti, Njemačka), Astrid Manders (TNO, Nizozemska), László Haszpra (Sveučilište Eötvös Loránd, Mađarska), Josipa Milovac (Sveučilište u Kantabriji, Španjolska) i Jadranka Šepić (Sveučilište u Splitu, Hrvatska).

PREDAVANJA
PRESENTATIONS

CONTRIBUTIONS OF LANDSCAPE ECOLOGY TO CHALLENGES IN METEOROLOGY

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Meteorology is one of the disciplines of atmospheric sciences and involves the study of physical and chemical processes in the atmosphere. Climatology is the scientific study of the Earth's climate, usually defined as meteorological conditions in the atmosphere averaged over a period of at least 30 years, and their interactions with the Earth's ecosystems. As such, climatology is a part of physical geography, especially landscape ecology. As the holder of a chair in landscape ecology, I would like to present three examples that show how landscape ecology explores meteorological challenges quantitatively.

The first example concerns the monitoring and mapping of atmospheric deposition accumulation in mosses. This type of monitoring has been carried out every five years throughout Europe since 1990. Mosses have been collected from up to 7300 sites in up to 34 European countries and analysed for heavy metals since 1990, for nitrogen since 2005, for persistent organic compounds since 2010 and for microplastics since 2020. In Germany, heavy metal enrichments in mosses have decreased significantly between 1990 and 2015, although this trend is not continuous for each element, but is associated with an interim standstill or increase for some elements. The nitrogen content of mosses remained high between 2005 and 2015 (Schröder et al., 2019 a).

The second example deals with the correlation between meteorologically modelled atmospheric concentrations and deposition of Cd, Hg and Pb and the measured bioaccumulation of the corresponding heavy metals in mosses (Schröder and Nickel, 2021). The modelling carried out by MSC-W included emission data and meteorological data. Statistical analyses revealed predominantly statistically significant low to high positive correlations. The discrepancies between EMEP data and moss data are likely due to the quality of emission data reporting and the small number of EMEP deposition monitoring sites across Europe used to validate the modelling results. The same applies to the correlations of LOTOS-EUROS atmospheric deposition modelling results with atmospheric deposition accumulation in mosses (Schaap et al., 2018; Schröder et al., 2018).

The third example deals with the measured and modelled impacts of nitrogen deposition and climate change on forests in Germany. For this purpose, a quantitative approach was developed that enables the spatially explicit assessment and classification of forest ecosystem integrity. Based on six ecological functions, the methodology enables a comparison of ecosystem type-specific integrity at different levels of the ecological hierarchy for a reference state (1960-1990) with the further development of forest ecosystem types as measured for the years 1991-2010 and modelled for the period 2011-2070 (Schröder et al., 2019b).

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KVALITETA ZRAKA U ZAGREBU I ZATVARANJE ZBOG PANDEMIJE COVID-19

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Kvaliteta zraka prati se u Zagrebu kontinuirano od šezdesetih godina prošlog stoljeća. U okviru lokalne mjerne mreže grada Zagreba mjerenja se trenutno provode na šest lokacija (Ksaverska cesta, Đorđićeva ulica, Prilaz baruna Filipovića, Susedgrad, Siget, Peščenica). Dosadašnja mjerenja pokazala su da je zrak, ovisno o karakteru lokacije, onečišćen lebdećim česticama PM_{10}, $PM_{2,5}$, benzo(a)pirenom (BaP), dušikovim dioksidom (NO_2) te povremeno ozonom (O_3). Pandemija COVID-19, koja je započela početkom 2020. godine, uzrokovala je do sada neviđene promjene u aktivnostima i navikama ljudi. Mjere djelomičnog ili potpunog zatvaranja (engl. lockdown) koje su kroz određena razdoblja primijenile brojne zemlje u svrhu suzbijanja širenja bolesti, odrazile su se i na kvalitetu zraka. U Zagrebu stroge mjere obustave rada škola, fakulteta i vrtića kao i javnog prijevoza te svih djelatnosti, osim najnužnijih, trajale su od sredine ožujka do sredine svibnja 2020. godine.

U ovom istraživanju proučavani su podaci o kvaliteti zraka s mjernih postaja lokalne mjerne mreže grada Zagreba u razdoblju 2017. – 2020. Uspoređene su koncentracije izmjerene tijekom zatvaranja zbog COVID-19 s prosjekom za isto razdoblje tijekom 2017., 2018. i 2019. godine. Masene koncentracije NO_2 bile su statistički značajno niže na svim mjernim postajama tijekom razdoblja zatvaranja, a najveće razlike utvrđene su na lokacijama izloženim prometu. Suprotno tome, koncentracije ozona su bile statistički značajno više na svim mjernim postajama. Razine lebdećih čestica PM_{10} bile su niže na svim postajama, ali je razlika bila statistički značajna jedino na mjernim postajama Peščenica, Siget i Črnomerec (promet, industrija) dok se koncentracije frakcije lebdećih čestica $PM_{2.5}$ nisu statistički značajno razlikovale. Koncentracije BaP u PM_{10} bile su povišene tijekom razdoblja zatvaranja, ali se ta razlika nije pokazala statistički značajnom. Masene koncentracije metala bile su niske te su varirale ovisno o karakteru mjerne postaje i aktivnostima na lokaciji. Statistički značajno niže masene koncentracija Cu, Zn i Fe (metala povezanih s trošenjem kočnica i automobilskih guma) na prometnim mjernim postajama Đorđićeva ulica i Siget tijekom perioda strogog zatvaranja u usporedbi s trogodišnjim prosjekom za isto razdoblje mogu se povezati s manjim prometom tijekom strogog zatvaranja. Na urbano-industrijskoj mjernoj postaji Susedgrad masene koncentracije metala bile su u rasponima koncentracija iz ranijih godina, što upućuje da su se osnovne aktivnosti na toj lokaciji uglavnom provodile jednakim intenzitetom. Zatvaranje zbog pandemije COVID-19 pokazalo je da su mjere drastičnog smanjenja mobilnosti stanovništva imale kratkotrajni utjecaj na kvalitetu zraka i to samo na razine nekih onečišćujućih tvari te ne uvijek u smjeru smanjivanja koncentracija. Učinak je u pravilu bio izraženiji na mjernim postajama opterećenim prometom u odnosu na lokacije gdje su značajnije zastupljeni i drugi izvori (kućna ložišta, resuspenzija s tla, industrija).

ELEMENTAL ANALYSIS OF PARTICULATE MATTER IN METAL WORKSHOPS AND OF BIOLOGICAL SAMPLES FROM EXPOSED WORKERS

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Metal processing techniques such as welding, cutting, grinding, and polishing produce significant levels of particulate matter (PM) in metal workshops. PM from these sources, especially from welding, is typically less than 2.5 μm in diameter ($PM_{2.5}$), so it can easily enter human respiratory system. It is, therefore, very important to monitor PM levels in metal workshops, but also to monitor health status of the workers exposed to high levels of PM.

Analysis of $PM_{2.5}$ was performed in six metal workshops in the vicinity of the city of Rijeka, Croatia. Two of them are dealing with the aluminium components and four of them are mainly dealing with the steel and stainless steel components. The samples of $PM_{2.5}$ were collected on thin polytetrafluoroethylene (Teflon) filters with a cyclone sampler. Overall, 234 samples were collected on the filters, including 134 hourly samples, 26 2-h samples, 29 4-h samples, 15 8-h samples and 30 12-h samples. Mass concentrations were obtained gravimetrically and elemental analysis was performed with X-ray fluorescence (XRF) and particle induced X-ray emission (PIXE) techniques. Concentrations of Na, Mg, Al, Si, P, S, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Pb and Bi were obtained.

As a first step to estimate possible health impacts of PM, samples of hair and nails were taken from 34 workers who agreed to participate in the study. Additionally, 34 unexposed persons were included in the control group. Elemental analysis of biological samples was performed with inductively coupled plasma mass spectrometry (ICP-MS) and concentrations of Al, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd and Pb were determined.

Although $PM_{2.5}$ and elemental concentrations did not exceed limit values for indoor working places, concentrations of Al, Ti, Mn, Fe and Pb in biological samples of the workers were significantly higher than in the control samples, which indicates that these metals were deposited in analysed tissues after being inhaled as particulate matter.

HOW POLLUTED IS THE AIR IN DUGAVE (ZAGREB, CROATIA)?

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During winters, residents of Dugave, Zagreb are according to media, frequently upset about the air quality in the quarter. Therefore, we investigated the air quality there with respect to particulate matter with aerodynamic diameter less than 10 μm (PM_{10}). Hourly mean PM_{10} concentrations were measured over three years (2018–2020) at Dugave measuring site (ZG3, ϕ = 45.765°N, λ = 16.006°E). The site belongs to the National Network for Continuous Air Quality Monitoring (NNCAQM) and it is supposed to be representative for urban background conditions. Concentrations measured at ZG3 were compared with PM_{10} values that were observed at NNCAQM measuring site exposed to urban traffic (Miramarska, ZG1, ϕ = 45.800°N, λ = 15.974°E). The influence of meteorological conditions on PM_{10} levels at both sites was assessed based on modelled atmospheric variables, where a numerical weather prediction model ALADIN was employed.

The results showed that although overall median and maximum hourly concentrations were slightly lower at ZG3, the mean concentration at ZG3 was somewhat higher than at ZG1 (30.28 and 29.28 μgm^{-3}, respectively). During spring, summer and fall, PM_{10} concentrations at ZG3 were generally similar to or slightly lower than those at ZG1, while during the winter, they were higher. This suggests that in comparison with ZG1 site, ZG3 was more exposed to: 1) effects of fossil fuel and/or biomass burning due to heating; and/or 2) atmospheric inversions. At both sites and for all four seasons, PM_{10} concentrations decreased with an increase in a wind speed, where this decrease was the most pronounced for wintertime at ZG3. For both sites, an increase in the air temperature resulted in a decrease in PM_{10} concentrations in all seasons except summer. A decrease of concentration with an increase in temperature was most prominent for winter, and this drop was more significant for ZG3 in comparison with ZG1 site. This further confirms our hypothesis that wintertime pollution at ZG3 was more affected by emissions associated with burning due to heating and/or unfavorable microclimatic conditions than ZG1 site. Conversely, in summer, PM_{10} concentrations at both sites increased with an increase in the air temperature. This points to the role of photochemical reactions in particle formation. Accordingly, this increase was more pronounced at the urban traffic site, that is, at the site where higher emissions of particulate matter precursors is expected. At both sites, the daily PM_{10} concentration limit value given by EU legislative (50 μgm^{-3}) was exceeded more frequently than permitted, that is, more than 35 times in a year. Thus, at ZG1, 59 and 36 days with the mean concentration above the limit were observed in 2018 and 2019, respectively. At ZG3, the exceedance was even more frequent and it was found for all three years. Daily values above the limit were observed 56 and 63 times for 2018 and 2019, respectively. For 2020, the November and December data were missing. Still, during the available 10-month period, daily concentrations above the 50 μgm^{-3} limit were observed 37 times.

SPECIFIČNI MARKERI ZA GORENJE BIOMASE U PM_{10} FRAKCIJI LEBDEĆIH ČESTICA U ZRAKU ZAGREBA

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Biomasa kao alternativni oblik energije posljednjih godina sve je popularnija obzirom da postoji globalni interes za smanjenjem široke upotrebe fosilnih goriva. Kao prednosti korištenja biomase istaknute su njena dostupnost, obnovljivost, cijena te kružni ciklus ugljikova dioksida zbog kojeg nema porasta u ukupnoj bilanci atmosferskog CO_2. Upotreba biomase manje je povoljna s aspekta oslobođenih lebdećih čestica te toksičnih i kancerogenih produkata koji nastaju nepotpunim izgaranjem biomase. Kako bi se utvrdio udio gorenja biomase u oslobođenim lebdećim česticama do sada su najčešće ispitivani kalijevi ioni te policiklički aromatski ugljikovodici, no pokazalo se da nisu dovoljno specifični obzirom da nastaju i iz drugih značajnih izvora (kuhanje i prženje mesa, spaljivanje otpada, promet, upotreba ugljena, obrada nafte, ...). U posljednjih nekoliko godina se za indikaciju onečišćenja gorenjem biomase koriste celulozno specifični ugljikohidrati poznatiji kao anhidrošećeri. Anhidrošećeri su dehidrirani derivati monosaharida koji nastaju isključivo pirolizom celuloze i hemiceluloze što ih čini preciznim i jedinstvenim indikatorima za onečišćenje zraka gorenjem biomase. Glavni predstavnik anhidrošećera je levoglukozan koji je ujedno i najzastupljeniji, no gorenjem se formiraju i njegovi izomeri; manozan i galaktozan, koji također imaju važnu ulogu jer se iz njihova omjera može dobiti informacija o vrsti biomase. Određivanje ovih specifičnih markera za gorenje biomase po prvi puta se provodi u Republici Hrvatskoj i od iznimne je važnosti jer upotpunjuje sliku o ukupnom sastavu lebdećih čestica, a samim time omogućuje precizniju interpretaciju rezultata o prisutnim izvorima onečišćenja u zraku.

Cilj istraživanja bio je odrediti doprinos gorenja biomase onečišćenju zraka u gradu Zagrebu praćenjem koncentracija levoglukozana, manozana i galaktozana u lebdećim česticama. Ispitivanja su provedena na lebdećim česticama aerodimaničkog promjera manjeg od 10 µm (PM_{10}) paralelno sakupljenima na mjernim postajama u sjevernom i južnom dijelu grada Zagreba. Masene koncentracije lebdećih čestica određene su gravimetrijskom metodom, dok su masene koncentracije anhidrošećera određene analitičkom metodom anionske izmjenjivačke kromatografije visoke djelotvornosti s pulsnom amperometrijskom detekcijom. Rezultati su pokazali značajnu sezonsku i prostornu razliku u raspodjeli koncentracija lebdećih čestica i koncentracija anhidošećera. Pronađeno je da su koncentracije lebdećih čestica i koncentracije anhidrošećera veće na mjernoj postaji u južnom dijelu grada u odnosu na sjeverni dio grada. Masene koncentracije anhidrošećera pratile su sezonski trend: zima, jesen, proljeće, ljeto što je u skladu sa sezonom grijanja u kućanstvima. Promatrajući zimski dio godine kada su koncentracije anhidrošećera najveće, dobiveno je da je njihov udio u PM_{10} lebdećim česticama manji od 10 %. Na oba mjerna mjesta masena koncentracija levoglukozana znatno je veća u odnosu na manozan i galaktozan, neovisno o godišnjem dobu.

UPOTREBA PODNICOMJERA (CEILOMETER) ZA ODREĐIVANJE KONCENTRACIJE AEROSOLA

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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 Zagreb-Maksimir tijekom 2017. godine. Uređaj radi vertikalna skeniranja do 15000 m svakih 15 sekundi. Detaljna vizualizacija vertikalnih profila odraza omogućuje lakšu dijagnozu tipičnih meteoroloških situacija, pogotovo u atmosferskom graničnom sloju.

U radu će se prezentirati situacije u kojima se jasno razlikuju situacije s različitim koncentracijama aerosola nad Zagrebom. Kvalitativno se može ocijeniti čistoća zraka, visina sloja zasićenog česticama i njegove promjena tijekom dana, promjene svojstava zraka nakon prolaska fronti i drugo. Analizirajući gradijent povratnog signala, uređaj prepoznaje slojeve aerosola u nižim slojevima atmosfere. Sve navedeno može se koristiti kod prognoze magle i niskih oblaka.

NAČINI MJERENJA INTENZITETA INFRAZVUKA U ATMOSFERI

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Infrazvuk prisutan u atmosferi dijelom nastaje zbog prirodnih razloga, dijelom zbog utjecaja ljudi. Raspodjela intenziteta infrazvuka vremenski je i prostorno ovisna. Budući da trajnija izloženost infrazvuku većeg intenziteta negativno utječe na zdravlje ljudi potrebno je znati glavne karakteristike te raspodjele, što se postiže kombinacijom mjerenja i računalnih simulacija. Podacie za određivanje raspodjele intenziteta infrazvuka dobivaju se višestrukim mjerenjima dovoljne preciznosti, provođenim na dovoljno gustoj mreži mjernih točaka.

U radu su izloženi načini mjerenja intenziteta infrazvuka. Uz postojeće načine, bit će izložen i koncept planiranog mjerenja intenziteta infrazvuka primjenom bespilotnih zrakoplova. Razmotreni su početni problemi koje treba riješiti za realizaciju koncepta. U slučaju realizacije, koncept omogućava dobivanje trodimenzionalne raspodjele intenziteta infrazvuka.

AIR QUALITY MODELLING OVER EUROPE: TRENDS AND PERSPECTIVE

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Emissions of air pollutants over the European continent have decreased considerably over the past decades. This has resulted in considerable improvement in air quality. However, not for all air pollutants a linear reduction with emission reductions is found, due to chemical interactions. Therefore, air quality models are needed to link emission changes to changes in observed concentrations. Such models are also indispensable for assessing the impact of future emission changes and the assessment of the potential impact of climate change. Climate change is expected to partially offset the effect of emission reductions.

In this presentation, I will give an overview of modelled trends, highlighting the lessons learned. Also for current-day air quality modelling, the status and challenges will be presented, including the use of sensor data and assessment of black carbon. Modelling source attribution and BC monitoring with separation of traffic and residential combustion can help to reduce the uncertainties for this component that is relevant for both health and climate. With the new AR6 climate scenarios, countries would like to investigate the implications for air quality in the coming decades. A brief overview of modelling approaches and their benefits for climate impact assessment will be given.

PRIMJENA REGIONALNOG KEMIJSKOG TRANSPORTNOG MODELA LOTOS-EUROS NAD PODRUČJEM REPUBLIKE HRVATSKE ZA PROCJENU ONEČIŠĆENJA PM_{10}

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Državni hidrometeorološki zavod u partnerstvu s Institutom za medicinska istraživanja i medicinu rada od 2017. provodi projekt AirQ − Proširenje i modernizacija državne mreže za trajno praćenje kvalitete zraka. Jedan od ciljeva AirQ projekta je uspostava sustava za modeliranje kvalitete zraka u Republici Hrvatskoj. To uključuje razvoj i primjenu LOTOS-EUROS modela za proračun prizemnih koncentracija onečišćujućih tvari s ciljem osiguravanja potrebnih podataka za procjenu razine onečišćenja (posebno u područjima gdje ne postoje mjerenja).

LOTOS-EUROS model je „open-source“ kemijski transportni model regionalne skale koji je već dugi niz godina u regulativnoj i znanstvenoj upotrebi diljem svijeta. LOTOS-EUROS modelira sve bitne procese od emisije onečišćujućih tvari u zrak, transporta onečišćujućih tvari kroz atmosferu, kemijskih reakcija u atmosferi te uklanjanje onečišćujućih tvari iz zraka procesima taloženja.

U ovom radu pokazat će se napredak u primjeni LOTOS-EUROS modela za procjenu prizemnih koncentracija PM_{10} nad područjem Republike Hrvatske usporedbom vremenskih nizova mjerenih i modeliranih podataka. Usporedba podataka je provedena uz pomoć R programskog paketa „openair“ dok su prostorne karte napravljene uz pomoć ArcGIS programa. Analizom više simulacija pokazat ćemo osjetljivost modela na razne ulazne parametre. Postavke različitih simulacija su identične u znatnom broju elemenata (emisijski inventar, meteorološki podaci, definirane kemijske reakcije itd.). Bitne razlike su promjena horizontalne rezolucije s 0.25°x 0.125° na 0.1° x 0.05° geografske dužine i širine. Druga razlika je promjena vertikalne rezolucije s 5 vertikalnih nivoa („mixing layer“ shema) na 15 vertikalnih nivoa definiranih meteorološkim podacima („metlevel“ shema). Zadnja razlika uključuje primjenu Corine seta podataka za zemljišni pokrov („land use“) visoke rezolucije.

Cilj napravljenih izmjena je bolja reprezentacija gradijenata prizemnih koncentracija. Napredak dobiven zadnjim postavkama modela jasno je vidljiv na statističkim pokazateljima te opravdava veću potrošnju računalnih resursa u odnosu na prvu postavku modela. Najveće razlike između mjerenih i modeliranih prizemnih koncentracija PM_{10} javljaju se u gusto naseljenim urbanim sredinama gdje model u načelu podcjenjuje izmjerene koncentracije. Takav rezultat je očekivan, jer su ulazni podaci modela na regionalnoj skali (~5 km) te ne mogu dobro reprezentirati fenomene na manjim prostornim skalama (~0,5 km) koji utječu na lokalna mjerenja. Rad na poboljšanju LOTOS-EUROS modelarskog sustava je i dalje u tijeku, te još nisu iscrpljene sve mogućnosti za potencijalna poboljšanja.

INVESTIGATION OF ADMS-URBAN AND LOTOS-EUROS MODEL RESPONSES TO EMISSION REDUCTIONS IN THE ZAGREB REGION

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One of the main advantages of air quality models is their usage in planning future strategies for air quality, considering EU and national legislation (e.g., the National Emission Ceilings Directive) and, at the same time, meeting local compliance. Since every mathematical air quality model comes with uncertainties, before giving any recommendations on the methods to assess the robustness attached to the potential impact of a modelled measure, it is important to assess the sensitivity of the model's responses to emission reductions when input data (such as emissions or/and meteorology) or the model itself is changed. For that purpose, the CT9 group was formed at FAIRMODE (Forum for Air Quality Modelling), as part of the Joint Research Centre (JRC), the European Commission's science and knowledge service. Croatian Meteorological and Hydrological Service is a part of the FAIRMODE community, and as such, we participate in various exercises and experiments where modelling systems are tested and continuously developed with the aim of gaining a better understanding of air quality and air quality modelling capacities. One of our latest contributions was to the CT9 group, within which we continuously investigate the robustness of air quality projections.

For this purpose, the ADMS-Urban dispersion model and Lotos-Euros chemical transport model were used over the Zagreb region domain. The experiment included 26 different simulations (13 simulations per modelling system): base case (BC) scenario (with full emissions), and 25% and 50% emission reductions over the domain for pollutants: NO_x, SO_x, NMVOC, NH_3, PPM, and ALL (simulations where all these pollutants were reduced to 25% and 50%, respectively). Simulations were set for the year 2015. The ADMS-Urban model uses meteorological data from the Zagreb-Maksimir meteo-site (hourly sequential met-data), background data from the Desinić rural-background site (hourly sequential air quality data), and emission on 500 m x 500 m resolution obtained from the Croatian National Emission Inventory (source: Ministry of Economy and Sustainable Development). Two large point sources were explicitly modelled. The LotosEuros model uses ECMWF IFS (F1280 grid) meteorological data. The Zagreb region domain (15.63°E – 16.33°E, 45.56°N – 46.16°N) with resolution lon-lat: 0.1° x 0.05° was nested within the European domain (10°W – 45°E, 30°N – 60°N) with the resolution being lon-lat: 0.5° x 0.25°. The LE CTM uses a 5-level mix layer scheme and the CAMS-AP-v2.2 (2015) emission inventory. Concentrations of PM and O_3 were investigated as a result of these reductions for every scenario performed. For analysis, FAIRMODE's new „Delta“ benchmarking tool was used and tested. The linearity of the modelling systems was investigated and performances of the two modelling systems were compared and analyzed.

AVIATION ENVIRONMENTAL IMPACTS

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In this research, we focused on understanding the influence of aircraft emissions on local air quality using air quality measurements and modeling results. 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. 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. The AIRMODE model was applied in order to calculate local concentrations of CO, PM_{10} and NO_2 around the Zagreb airport in Croatia. Further on, the WRF-Chem, EMEP, and WRF-CAMx models were used to estimate the contributions of aviation emissions with several different emission scenarios.

NUMERICAL SIMULATIONS OF DESERT DUST EPISODES IN THE NORTHERN ADRIATIC; IMPACT OF ASIAN AND AFRICAN SOURCES

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Airborne mineral dust affects the climate by modifying radiation budget, formation of clouds and marine biogeochemical cycles. It's most abundant global source, the Saharan desert, has strong and frequent influence on the Mediterranean countries which is well documented in scientific papers. However, less attention from the scientific community is on the transport from Asian deserts towards European countries.

Here, we present the simulations of one 'typical' Saharan dust outbreak and another one originating from deserts east to the Caspian Sea.

In the first case, the increase of PM_{10} hourly values due to the Saharan dust outbreak was observed at the Italian and Croatian Adriatic coast in September 2015. The 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. The temporal evolution of spatially averaged dust emission at source locations shows strong morning peaks characteristic for NLLJ breakdowns. Although the chosen model's horizontal resolution is too coarse for grid-resolved simulation of convective processes detected by the NASCube method, the model exhibits a 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.

In the second case, the untypically extreme dust outbreak was observed over the Balkan region from 27 to 30 March 2020. The anticyclone north of Croatia and cyclone over Anatolia formed a strong pressure gradient driving a transport from desert sources east to the Caspian Sea. The backward trajectories as well as satellite products indicated the Aral and surrounding deserts as major sources of dust.

WRF-Chem based research is still in progress. At this stage the model shows high correlation with PM_{10} hourly values from regional air quality stations but it underestimates the observations. The peak hourly PM_{10} value was 612 μgm^{-3} measured in Belgrade. However the PM_{10} chemical (Pb, Cd, Cu, Zn, Fe, Mn, PAHs) and morphological (SEM analyses) composition at the site in the northern Adriatic indicate mainly the presence of the Saharan dust. Preceeding the Asian dust advection, the presence of Saharan dust transport towards Balkan driven by Sharav cyclone was observed. Modeling results indicate that the transport from Asia was below ~2 km, while the Saharan was up to ~8 km amsl. The mixing of the Asian and Saharan dust plume over Balkan was favored by subsidence due to anticyclonic high pressure conditions, and it is the most plausible explanation for the observed PMs chemical and morphological results.

The authors acknowledge the financial support from the project "Marine Rogoznica Lake as a model for ecosystem functioning in the changing environment" (MARRES, IP-2018-01-1717).

REGIONAL MODELING AND ASSESSMENT OF SO_2 CONCENTRATIONS IN A COMPLEX ENVIRONMENT

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Temporal and spatial variability of sulfur dioxide (SO_2) concentrations were investigated using measurements from available rural and urban stations and satellite data in the Central and Eastern parts of Croatia. Many complex urban and industrial areas are located within this area where SO_2 measurements frequently exceed the daily averaged concentration limit value. This is usually observed in the cities with dominant industry activities, such as Slavonski Brod and Sisak.

In this study, we used a high-resolution WRF-Chem model with enhanced emissions and land cover data over areas of interest. Furthermore, within the METHANE-To-Go project, a series of airborne field experiments were performed in autumn 2020 in Croatia and neighboring countries with the focus on trace gas emissions (especially SO_2, but also methane) and aerosols from power plants. By using airborne measurements the first kind of model validation over this particular domain was performed which provided information on model performance in upper levels of the atmosphere and on processes that contributed to enhance concentrations.

The results from this comprehensive analysis contribute to a better understanding of the regional air quality model's performance in simulating SO_2 concentrations, especially over industrial areas and at higher altitudes of the atmosphere. The systematic and continuous evaluation of the model abilities is very important, as models are inherently scientific and regulatory tools for air quality assessment and management.

THE ROLE OF GREENHOUSE GAS MEASUREMENTS IN CLIMATE RESEARCH

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The near-future evolution of Earth's climate depends on the amount of greenhouse gases (GHG) in the atmosphere. Due to the numerous feedbacks and interactions in the climate system emissions alone do not determine the amount of GHGs in the atmosphere. We need to measure their concentration to feed the climate models with realistic input data. The official emission estimations, the basis of the international climate protection treaties, are based on statistics on activity data and emission factors. The emission factors cannot perfectly characterize all emission processes, which introduce significant uncertainty into the resulted emission values, especially in the case of methane and nitrous oxide.

The lecture presents how the atmospheric measurements can help the identification and quantification of the emission sources/processes, how they help the localization of the source areas. The lecture also presents the forming pan-European greenhouse gas monitoring network, the Integrated Carbon Observation System (ICOS), which supports the climate protection strategy of the European Union. It helps the better understanding of the atmospheric processes and validates the emission estimations providing a controlling mechanism for the emission reduction agreements. In addition, it serves as a warning system alarming when unexpected changes occur in the composition of the atmosphere.

CHANGES IN THE ONSET OF THE RAINY SEASON IN CALIFORNIA

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Californian hydroclimate is strongly seasonal and prone to severe water shortages. Recent changes in climate trends have induced shifts in seasonality, thus exacerbating droughts, wildfires, and adverse water shortage effects on the environment and economy. Previous studies have examined the timing of the seasonal cycle shifts mainly as temperature driven earlier onset of the spring season.

In this paper, we address quantitative changes in the onset, amounts, and termination of the precipitation season over the past 6 decades, as well as the large-scale atmospheric circulation underpinning the seasonal cycle changes. We discover that the onset of the rainy season has been progressively delayed since the 1960s, and as a result the precipitation season has become shorter and sharper in California. The progressively later onset of the rainy season is shown to be related to the summer circulation pattern extending into autumn across the North Pacific, in particular, a delay in the strengthening of the Aleutian Low and later southward displacement of the North Pacific westerlies.

ASSESSMENT OF EXTREME RAINFALL THRESHOLDS FOR AN EARLY WARNING SYSTEM IN CROATIA

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The changes in rainfall extremes due to climate change may have negative consequences in the engineering designs, particularly for urban infrastructure that relies on the short-term rainfall amounts. In Croatia, the early warning system aside on the official web page is also integrated into the Meteoalarm severe weather alert system for Europe. The current alerts for heavy rain are issued for eight regions in Croatia with the thresholds based on 6 and 24 hours return values associated with 1, 2 and 5 years return periods for yellow, orange and red alarming categories, respectively. The corresponding return values were estimated by fitting the Generalized Extreme Value distribution (GEV) to the series of the annual maxima of 6 and 24 hours precipitation amounts for the 1959-2005 period. Eight regions were covered by 17 meteorological stations from DHMZ station network.

The main goal of this study was to upgrade the alarm system by means of improving thresholds due to a longer period of measurements and moving from the regions defined by the climatological characteristics to the county level (21 counties). To that end, new rainfall thresholds are estimated by employing ombrographic data from 58 stations covering the period 1961-2020. Different scales of sub-daily rainfall amounts, from 10 minutes to 24 hours, are analysed by means of extreme value theory. Both stationary and non-stationary GEV models are tested and the results revealed the adequacy of the stationary one for estimation of the return values. The spatial distribution of the corresponding 1, 2, 5, 10, 25, 50 and 100 years return values showed a clear distinction between the continental and Adriatic regions with a pronounced maximum in the northern Adriatic (Kvarner) region. The new proposal for the warning rainfall thresholds in Croatia is discussed. It would be still based on the 6 and 24 hours duration, but considering higher return periods than in the current system by shifting to 1, 5 and 25 years for yellow, orange and red colours, respectively. Generally, the new threshold values are higher in each category than in the current system, especially for orange and red warnings along the coast and in the mountain region. Following the international standards and procedures for using the longer data sets as well as spatially smaller warning regions, the current warning system will be refined.

CroMonthlyGrids - MJESEČNI RASTERI TEMPERATURE ZRAKA I KOLIČINE OBORINE ZA POTREBE PRAĆENJA KLIME, KLIMATSKIH PROMJENA I NJIHOVOG UTJECAJA NA RANJIVE SEKTORE

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Homogenizirani klimatološki nizovi i interpolirani rasteri – CroMonthlyGrids, temelj su za praćenje klime i klimatskih promjena i njihovog utjecaja na ranjive sektore. U radu predstavljamo nizove homogenizirane srednje mjesečne temperature zraka i količine oborine i mjesečne rastere visoke rezolucije za razdoblje 1981. – 2018. Prekidi homogenosti utvrđeni su standardnim normalnim testom homogenosti. Regresijski kriging primjenjen je za izradu mjesečnih karata i karata normaliziranih pogrešaka za svaki mjesec analiziranog razdoblja. Kvaliteta interpolacije procijenjena je meteodom poprečne validacije ispuštanjem po jednog elementa. Izvedeni homogenizirani podaci na postajama i mjesečne karte nužne su za nacionalno praćenje klime, izradu klimatskih normala i procjenu trendova. Primjerice, nakon 2000. prosječne godišnje anomalije temperature zraka u odnosu na 30-godišnju klimatsku normalu 1981. – 2010. bile su pozitivne i do 1,4 °C toplije od prosjeka, a tek povremeno negativne. Godišnji trendovi temperature zraka bili su značajni i na području Hrvatske kretali su se od 0,3 °C po desetljeću do 0,7 °C po desetljeću.

CITIZEN SCIENCE IN SERVICE OF THE CLIMATE CHANGE ADAPTATION

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TeRRIFICA project has developed an innovative approach to science communication open to individuals and groups to take an active part and influence climate change institutional, governmental and policy adaptations. In a system defined by RRI policy, SDGs, citizen science and climate adaptation and mitigation measures, TeRRIFICA operates in six European regions with very distinctive challenges. A practical outcome of this co-creation process is locally focused but globally empowered climate actions, based on the collected and visually represented data. TeRRIFICA crowd-mapping tool demonstrates actual geographical spread of climate changes by showcasing effects which citizens encountered and marked on a daily basis.

Center for the Promotion of Science (CPN) acts as a regional project hub and coordinator of activities across South-East Europe – from Croatia to Romania and from Albania to Hungary. Together with local partners belonging to diverse professional and social groups, the CPN has been organising numerous project presentations, advocacy meetings, educational activities etc., with a goal to define common regional framework and foster future partnerships and joint actions.

This presentation will also announce further activities and announce collaborative opportunities at the regional level, including an experimental, mobile and modular platform entitled Climate Capsule.

A WALK THROUGH INTERACTIVE ONLINE CLIMATE RESEARCH AND BEYOND

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The Interactive Atlas (IA, http://interactive-atlas.ipcc.ch) is a novel contribution of the IPCC Working Group I (WGI) to the recently released Sixth Assessment Report (AR6, Masson-Delmotte et al., 2021). It is an outstanding outcome from 3 years of intense collaboration between WGI and contributing authors from CSIC (Consejo Superior de Investigaciones Científicas), Universidad de Cantabria and the SME Predictia (https://predictia.es/en), supported by the Spanish government. IA is one of the most innovative interactive online tools to visually explore past, present, and future climate on a regional scale, available to everybody with access to the internet. A comprehensive set of information on observed and modelled climate, with multitude of variables and derived climate indices (including extremes) from more than 30 global (CMIP5 and CMIP6) and regional (CORDEX) climate models, have been made accessible to everybody through this framework in a user-friendly way and following the FAIR guiding principles.

Two different interfaces of IA are available to meet the requirements of various groups of end users, from scientific professionals to stakeholders, and the public in general, with the initial purpose to support and extend the information of various chapters and summaries in the AR6 WGI report, as well as to encourage users to extend their research to their own region of interest. The latter can be accomplished through the Atlas repository (Iturbide et al., 2021), which provides data and scripts behind IA. Furthermore, it includes well-documented Jupyter notebooks and uses freely available online computational resources from BinderHub, which allows users to interact directly in a web browser with the provided data and scripts using standard programming languages (R and Python).

In this presentation, we will walk together through the immense possibilities of IA by exploring the past, current, and future climate of a specific region of interest (e.g. Mediterranean). Furthermore, it will be demonstrated how this tool can be used as a baseline for detailed scientific research through an example where the scaling properties of sea surface temperature are explored for different global warming levels in a set of global models.

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RAZVOJ I PRIMJENA KLIMATSKOG MODELA VISOKE REZOLUCIJE HARMONIE-CLIMATE

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Konzorcij za razvoj klimatskog modela visoke rezolucije HARMONIE-Climate (HCLIM) osnovan je zbog potrebe više državnih meteoroloških zavoda za pružanjem poboljšanih klimatskih usluga na lokalnoj skali. Konzorcij trenutno čini sedam zemalja. Rad konzorcija bazira se na prilagođavanju postojećeg operativnog modela za numeričku prognozu vremena klimatskim potrebama, uz usku suradnju s kolegama koji razvijaju prognostički model.

Predstavit će se konfiguracija modelskog sustava i primjeri primjene, te dodana vrijednost klimatskog modeliranja visoke rezolucije.

ADDED VALUE OF KILOMETER-SCALE COUPLED ATMOSPHERE-OCEAN CLIMATE MODELLING IN THE ADRIATIC REGION

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The Adriatic climate – strongly affected by complex orography and ocean geomorphology, land-sea contrasts, intense air-sea interactions, etc. – is extremely challenging to adequately simulate with climate models. Global and regional climate models at a relatively coarse spatial resolution (from 100 to 10 kilometers) are generally not suitable to reproduce atmospheric processes in the Adriatic, while coupling with the ocean represent another challenge in terms of numerical cost. However, kilometer-scale coupled atmosphere-ocean models, principally developed for operational and process-oriented purposes have the advantage to better capture critical processes such as orographically-driven variations in precipitation, winds, surface energy balance, etc., particularly during extreme events. The Adriatic Sea and Coast (AdriSC) kilometer-scale modelling suite has thus been recently developed to accurately reproduce the atmospheric and oceanic processes at different temporal and spatial scales over the Adriatic and northern Ionian Sea, ranging from the impact of climate change on extreme events to the operational forecast of extreme sea-levels along the Croatian coasts.

Within the AdriSC modelling suite, the climate component is dedicated to the study of long-term kilometer-scale atmospheric and oceanic processes occurring in the Adriatic region. Two approaches have been applied. First, long-term AdriSC climate simulations have been set-up to cover the present climate for the 1987-2017 period (evaluation run) and a far-future high-emission climate under the Representative Concentration Pathway (RCP) 8.5 scenario for the 2070-2100 period. Second, short-term simulations over a significant number of extreme events under present (1977-2017 period, evaluation runs) and projected future climates (RCP4.5, RCP8.5, 2060-2100 period) have been used to prove the added value of the AdriSC model. All far-future simulations were derived with the pseudo-global warming (PGW) methodology – recently extended to coupled atmosphere–ocean models – which imposes an additional climatological change (e.g., a temperature change representative of the increase in temperature between past and future climate) to the forcing used to produce the evaluation runs.

In this presentation we will present an overview of the AdriSC climate applications: (1) evaluation of the long-term AdriSC climate simulation, (2) quantification of the bora wind and the associated ocean cooling in far-future climate, (3) assessment of ocean waves during extreme bora and sirocco events in far-future climate, and (4) modes of the decadal variability in the Adriatic-Ionian system. In addition to the presentation of these unique results, we will also demonstrate that the AdriSC kilometer-scale model can be used to study a wide range of atmospheric and oceanic processes in the Adriatic region as its resolution captures enough details to accurately reproduce even the most extreme events.

NEXT-GENERATION ATMOSPHERIC-OCEAN CLIMATE MODELLING FOR EXTREME SEA-LEVEL HAZARD PROJECTIONS IN THE ADRIATIC SEA

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Today, about 10% of the world population lives not more than 10 km from the coastline, being extremely vulnerable to coastal floods and extreme sea-levels. Aside from mean sea-level rise, extreme sea-levels are strongly influenced by local processes driven by coastal topographies and geomorphologies. For example, in the Adriatic Sea, sirocco-driven storm surges may vary substantially within the lagoons (e.g. Venice Lagoon) or meteorologically-driven tsunami waves may change for several times over a few kilometres, like in Vela Luka Bay. Adriatic storm surge models are nowadays capable to provide coastal flood forecasts (with some reliability) at (sub-) kilometre-scale resolution in operational mode. However, till recently, climate projections of extreme sea-levels at kilometre-scale (or higher) resolutions, were relying on atmospheric forcing coming from regional climate models available at about 10 km resolution and thus, strongly underestimating local processes, such as the bora wind, in the Adriatic Sea.

Consequently, we developed the AdriSC (Adriatic Sea and Coast) coupled atmosphere-ocean kilometre-scale climate model to better assess extreme sea-level hazards along the Adriatic coast. The AdriSC climate modelling suite is composed of two modules, which can be used independently or together to quantify a variety of climate-related processes. The general circulation module – coupling online an atmospheric model (Weather Research and Forecasting, WRF) at up to 3 km resolution and an ocean model (Regional Ocean Modelling System, ROMS) at up to 1 km resolution – has been run for 31-year long periods at an extreme computational cost (i.e. each simulation took 18 months using 260 CPUs on the European Centre for Middle-range Forecast (ECMWF) supercomputing facility). Further, the extreme event module – coupling offline the WRF model downscaled to 1.5 km resolution and the unstructured ADCIRC-SWAN storm surge model at up to 10 m resolution – has been used for the most extreme sea-level events previously extracted from the long-term simulations following classical hazard assessment techniques (i.e. about 80 short-term simulations).

In this talk, we will present (1) the evaluation of the extreme sea-levels provided by the AdriSC model, (2) the changes in kilometer-scale extreme sea-levels under extreme climate warming over the whole Adriatic, inside some vulnerable sub-basins, and along the coastline, (3) the present and projected kilometer-scale extreme sea-level hazard assessments and finally, (4) the resulting sub-kilometer scale distributions of wind speed, wind direction, sea-level, significant wave-height, peak wave-period, etc. With this study we will also demonstrate the importance of using higher resolution climate model to help local decisionmakers better mitigate the impact of extreme sea level under climate warming.

OČEKIVANO TOPLINSKO OPTEREĆENJE DUBROVNIKA, OSIJEKA, RIJEKE, ZADRA I ZAGREBA PREMA PROJEKCIJAMA REGIONALNIH KLIMATSKIH MODELA

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U ovom radu ispitano je buduće stanje klime u pet hrvatskih gradova: Dubrovniku, Zadru, Rijeci, Zagrebu i Osijeku. To je napravljeno analiziranjem klimatskih indeksa FD, ID, SU, TR, DTR i ETR te srednjih, maksimalnih i minimalnih dnevnih temperatura dobivenih klimatskim simulacijama korištenjem dvaju različitih regionalnih klimatskih modela, DHMZ-RegCM4 i SMHI-RCA4 horizontalne rezolucije 12,5 km, u kombinaciji s dva globalna klimatska modela, EC-EARTH i MPI-ESM-MR, za dva različita scenarija buduće klime, RCP4,5 i RCP8,5. Uspoređivanjem ovih varijabli u razdoblju 2041. – 2070. u odnosu na dosadašnju klimu, iz razdoblja 1991. – 2020., uočen je značajan porast srednjih, maksimalnih i minimalnih temperatura u svim korištenim kombinacijama regionalnih i globalnih klimatskih modela za sve promatrane gradove, a najveći je uglavnom u toplom dijelu godine. U Dubrovniku i Rijeci ovaj se porast pokazao najbržim, a zbog malih vrijednosti trendova u rasponu temperatura možemo zaključiti da se minimalne i maksimalne temperature u promatranim gradovima povećavaju podjednakim brzinama. U uvjetima toplije klime u svim se promatranim gradovima povećava broj dana s maksimalnom temperaturom zraka iznad 25 °C (posebice u Dubrovniku) i minimalnom iznad 20 °C (osobito u Rijeci i Zadru). Nadalje, u svim je gradovima dobiveno smanjenje broja dana s maksimalnom i minimalnom temperaturom ispod 0 °C.

ATMOSPHERIC FORCING OF EXTREME SEA LEVEL EVENTS

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Coastal floods related to extreme sea levels generated by tropical cyclones (hurricanes, typhoons and cyclones) are the leading natural disaster when it comes to death toll and economic damage.

Various mechanisms of generation of extreme sea level by tropical and extratropical cyclones will be discussed. Impact of tropical cyclones will be demonstrated by show-casing two recent examples: Typhoon Songda that affected the western coast of the northern USA and Canada in October 2016, and Typhoon Maysak that destructively affected coasts of South and North Korea, Japan and Russia in September 2020. It will be shown how spatially and temporally varying atmospheric processes, related to typhoon and to its propagation track, generate multitude of sea level responses, including wind waves, infragravity waves, storm seiches and storm surges. Impact of extratropical cyclones will be demonstrated by using the Adriatic extreme sea level events.

Atmospheric processes related to tropical and extratropical cyclones and associated ocean processes occur on spatial scales ranging from sub-kilometre to thousands of kilometres, and on temporal scales ranging from seconds to hours. Maximum sea levels are thus usually a combination of multitude of individual responses to atmospheric forcings. Conclusively, to estimate the true hazard of coastal floods, one needs to consider all components of atmospheric forcings.

INTRODUCTION TO NEW THUNDERSTORM INTENSITY INDEX (TSII)

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Lightning data provide very high spatial and temporal resolution allowing us to decompose thunderstorms into smaller segments. By using those segments, we introduce a new Thunderstorm intensity index (TSII). Based on the mathematical background of the lightning jump, TSII aims to identify areas that are most affected by the storm. Such index captures location in space and time where a thunderstorm experienced a sudden positive change in lightning activity, using the Eulerian standpoint. The advantage is independence to a total number of flashes produced by the storm (which can vary significantly), and high temporal monitoring (2 min). TSII was established within the SWALDRIC project using a period of 11 years of lightning data and in a study area of the NE Adriatic region. Validation is done against precipitation, wind, hail, waterspouts, and a comparison with ERA5 instability indices is made.

Results show very good agreement between higher rain intensities and total precipitation in the vicinity of TSII. Good agreement with hail occurrence, waterspout presence within 15 km radius. Also, TSII turned out to be invariant on the size of the system thus allowing us to recognize small-scale intense thunderstorms. The main goal is to present background principles of TSII computations as well as key verification results considering precipitation and hail. Due to the nature of TSII, it has the potential to be used in nowcasting, model verification, and climatological studies.

CONVECTION-PERMITTING SIMULATIONS OF HAILSTORMS AND LIGHTNING ACTIVITY OVER THE ALPINE-ADRIATIC REGION USING COSMO AND WRF MODELS

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Hail is a significant convective weather hazard, often causing considerable crop and property damage across the world. Although extremely damaging, hail still remains a challenging phenomenon to model and forecast given the gaps in understanding the processes involved in hail formation. Recently, a physically-based one-dimensional hail model called HAILCAST was developed. HAILCAST forecasts the maximum expected hail diameter at the ground using a vertical profile of the updraft, temperature, liquid and ice water content and can be embedded within a convection-permitting model (CPM). Furthermore, lightning activity is a characteristic phenomenon that often accompanies severe weather, and especially hailstorms, as well as a damaging phenomenon in itself. One of the ways to diagnose the areas prone to lighting activity is by using a Lightning Potential Index (LPI). LPI is a measure of the potential for charge generation and separation inside a thundercloud, which results in lightning flashes during convective thunderstorms. Therefore, LPI maps the area with the potential for electrical activity based on the model's dynamical and microphysical fields.

Here, eight hailstorms occurring over the Alpine-Adriatic region are analyzed using Weather Research and Forecasting (WRF) and Consortium for Small Scale Modeling in Climate Mode (COSMO) simulations with embedded HAILCAST and LPI at convection-permitting resolution (~2.2 km). In addition, a model intercomparison study is performed to investigate the ability of different modeling systems in reproducing such convective extremes and to further assess the uncertainties associated with simulations of such local-area phenomena. The results are verified by direct hail observations from Croatia (hailpad network), radar estimates of hail from Switzerland (probability of hail, maximum expected severe hail size) and lightning measurements from the LINET network using neighborhood and spatial verification methods.

The analysis revealed that both HAILCAST and LPI are able to reproduce the observed hail and lightning activity. Namely, both models are able to reproduce the areas affected by hail and lightning as well as its intensity. Moreover, the fields produced by both models are remarkably similar, although, a slight tendency of WRF to produce smaller hail swaths with larger hailstone diameters and larger LPI values seems to be present. Overall, the analysis revealed promising results and indicates that both HAILCAST and LPI could be valuable tools for real-time forecasting and climatological assessment of hail and lightning occurrence in current and possibly changing climate.

HYDRO-METEOROLOGICAL ANALYSIS OF SUMMER 2020 URBAN FLOOD IN ZAGREB

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Extreme weather situations are of great interest due to their damaging effect on society, ecosystem, infrastructure, etc. In a world with a changing climate, increase in occurrence and intensity of such events might be expected.

In this study, extreme precipitation event on 24 July 2020 which resulted in urban flood in Zagreb area, is analyzed from hydro-meteorological point of view. First, a general climatology of the short-term (from 5 to 120 min) extreme precipitation amount is analyzed in terms of its timing and correlation with other durations for the Zagreb-Grič station in the period 1908–2020. Temporal changes in the amplitude of extreme precipitation are examined by trend analysis, as well as non-stationary generalized extreme value distribution (GEV). Trend results revealed an intensification in short-term extreme precipitation up to 2.9% per 10 years, which is significant for durations longer than 20 min. Together with the results of analysis of occurrence and correlogram analysis, these findings point to changes in the occurrence of corresponding weather types responsible for heavy rainfall events. Summer 2020 rainfall event analysis showed that 120-min extreme precipitation was an exceptional event over the city center with return period higher than 100 years. All available data, measurements and numerical weather prediction models revealed that all ingredients for deep moist convection were present before the event, together with a deep layer shear. Additionally, the formation of cutoff low, the presence of an intense positive potential vorticity anomaly and the surface convergence line appear to be the main processes which further enhanced triggered deep convection, consequently also heavy precipitation. The hydrological analysis revealed that the sewerage system of Zagreb city could not drain the stormwater from the streets, pointing out the need for its redesign and adaptation to climate change. The results obtained from this study might serve for better preparedness of the city and society to future similar events.

HEAT WAVE PROTECTION WITHIN METEOALARM IN CROATIA

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A large number of human sufferings as a consequence of summer heat and heat waves in the recent past, requires continuous research on this topic in order to improve heat warning protocol and human health protection. The current Croatian heat wave alert system is carried out under the Ministry of health which has established working group for heat health protection. According to the Protocol, which is a part of the Action Plan for heat protection in Croatia, Croatian Meteorological and Hydrological Service (DHMZ) is issuing warnings regarding different levels of heat threat. Warnings are issued for eight different areas in Croatia which are defined as to cover all climate characteristics, but also to include available mortality data sets needed to define moderate, high, and very high heat risk.

As Croatia is a small but geographically quite diverse country, there is a need and interest in defining criteria for issuing warnings on more detailed spatial scale. The problem is that mortality data are not available on the same spatial scale and for all needed areas. To overcome that problem, DHMZ is working on introducing the new heat alarm system, based on different thresholds for extreme temperatures.

With the new algorithm we want to cover 20 counties, but also daily, seasonal and annual temporal variability. In this work we are testing the new algorithm on the summer period (1st June to 31st August) for three selected years (2003, 2019 and 2021) for current eight locations, by comparing the warnings (start date, end date, risk level) that would issue the current vs. the new algorithm.

The new algorithm hits well the term of the first heat wave, but underestimates the total number of heat waves issued by the current algorithm. On the other side, the advantage of the new algorithm is that it can issue heat warning throughout the whole year. Nevertheless, before implementing it into the heat wave warning protocol, the new algorithm requires further research.

IMPACT OF TROPICAL SSTS ON THE LATE-WINTER SIGNAL OVER THE NORTH ATLANTIC-EUROPEAN REGION

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Sea surface temperatures (SSTs) in the tropics can act as a source of boundary-forced predictability for the atmosphere in the extratropics, which is characterized by its large internal variability and poor predictability. However, if the SST forcing is strong and persistent enough to establish the boundary-forced circulation and overcome this chaotic intrinsic variability of the extratropical atmosphere, potential predictability can be increased. Among the strongest events with such an influence on the climate variability throughout the world is the El Niño-Southern Oscillation (ENSO).

Here, the potential impact of tropical SSTs on the signal of geopotential heights at 200 hPa (GH200) was tested based on the results of four different ensembles of numerical simulations. Using an intermediately complex AGCM (ICTP AGCM) we designed experiments with SST anomalies serving as AGCM lower boundary forcing prescribed globally, in the tropical zone of all oceans, only inside the tropical Atlantic area, and limited to the tropical Pacific. Additionally, the fifth AGCM experiment containing global SST forcing and double the amount of imposed CO_2 concentration was added to the analysis for comparison of the results to warmer climate conditions. All of the simulations within each of the experiments extended over the 156-year long period between 1855 and 2010.

Signal over the North Atlantic-European region (NAE; 30° N-60° N; 50° W-30° E) was selected as the main focus of the analysis. This monthly GH200 signal was calculated based on the difference between the ensemble mean of each experiment and the climatological mean for the considered time period. To detect the extent of the ENSO influence on the signal over the NAE region, ENSO years were selected based on the value of the standardized Niño3.4 index in the late-winter season. Signal in different AGCM experiments was then averaged over the NAE region and over the whole time period for ENSO years, non-ENSO years and all years, respectively.

Results have shown that the signal is the strongest in the late-winter months (January-March) in all of the experiments. The AGCM experiment with SST boundary forcing prescribed only in the tropical Atlantic consistently yielded the least amount of signal among the rest of the experiments. Overall, the GH200 signal is more pronounced and persists in strength and pattern throughout the late winter months when only the ENSO years are taken into account. The strongest signal linked to ENSO events is found in the experiment with the SST forcing prescribed only in the tropical Pacific. Comparing the results from the two ensembles forced with global SST anomalies, larger values of signal were found in the experiment with the two times higher CO_2 concentration.

BIVARIJATNA KOREKCIJA PRISTRANOSTI ANSAMBLA REGIONALNIH KLIMATSKIH MODELA NA ŠIREM PODRUČJU JADRANSKOG MORA

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Glavni cilj analize je dati ocjenu ansambla regionalnih klimatskih modela (RCM) na širem jadranskom području. Analiza se temeljila na skupu od 12 kombinacija, tri RCM-a i četiri globalna klimatska modela (GCM) od 1971. do 2004., podijeljenih u dijelove za kalibraciju i validaciju. Korekcija klimatskih modela je izvršena prema E-OBS podacima na mreži 0.1°. Provedena je usporedba jedne univarijantne i tri verzije bivarijatnih metoda korekcije pristranosti ljetne i zimske mjesečne temperature zraka i oborine. Za ispitivanje utjecaja metoda korekcije pristranosti koristili smo različite marginalne razdiobe i razdiobe međuovisnosti (kopule). Bivarijantna korekcija pristranosti provedena je uz korištenje parametarskih i empiričkih marginalnih razdioba. U mapiranju kvantila (univarijantnom (QM)) i parametarskoj bivarijatnoj metodi korištene su gama (oborina) i normalna (temperatura) razdioba, te u bivarijatnoj dodatno su korištene Gaussova i Student t kopula. Dokumentirana je pristranost i utjecaj metoda korekcije na oborinu i temperaturu, uključujući i signale klimatskih promjena u povijesnim podacima. Razmatrane metode zadržale su prostornu razdiobu trendova iz nekorigiranog ansambla. Provedena su i dva eksperimenta o tome kako metode korekcije pristranosti utječu na statističke mjere razmatranih varijabli i njihovih odnosa. Pokazano je da bivarijatna metoda s empiričkim razdiobama (eeG) nešto uspješnije zadržava odnos među varijablama detektiran u mjerenim podacima.

SEASONAL VARIATIONS OF LAND SURFACE TEMPERATURE IN THE CITY OF DUBROVNIK, CROATIA

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Land cover properties are the key driver of differences in land surface temperature (LST), what is especially important in the temporal analysis of LST. Moreover, the heterogeneity of land cover in urban areas indicates a specific spatial distribution of LST thus allowing areas with high heat load to be identified.

This study investigates the spatial and temporal variation of LST in Dubrovnik for land use/land cover (LULC) classes in four seasons of years 2020 and 2021 using remote sensing techniques, GIS and statistical analysis. Each season is represented by one cloud-free Landsat-8 satellite image taken as close as possible to the middle of the season. LST and spectral indices for selected images were derived using Google Earth Engine, a cloud-based geospatial analysis platform. LST was retrieved from the Landsat-8 Thermal Infrared Sensor (TIRS) Band 10 data using a mono-window algorithm, while spectral indices were calculated from bands of the Operational Land Imager (OLI) sensor. LULC classes were grouped based on the dominance of urban or natural morphological features in order to assess the impact of urban form and natural properties on LST. For natural LULC classes, seasonal changes in land cover were quantified using Landsat-8 spectral indices, such as normalized difference vegetation index (NDVI), while urban ones were considered unchanged during analyzed seasons. Additionally, Copernicus data was used to signify differences between natural LULC classes.

The results for all seasons show the highest LST in urban LULC classes, emphasizing the surface urban heat island (SUHI) of Dubrovnik, and in a barren land outside of the city, mostly on slopes of hills where the growth of vegetation is prevented by strong bora winds. Lowest LST is recorded for natural LULC classes: forests, urban parks, and other green surfaces. Dominant karst topography in the city's hinterlands also shows a profound influence on spatial variation of LST. A strong correlation is found between LST and NDVI, indicating that seasonal change in vegetation is influencing LST, e.g. seasonal change in leaf cover for broad-leaved forests.

TEMPERATURE CHARACTERISTIC AND HEAT LOAD IN THE CITY OF DUBROVNIK

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In this study temperature characteristics and heat load in the city of Dubrovnik are investigated by using temperature data observed at local meteorological station in Dubrovnik for the time period 1961-2019, satellite data collected by LANDSAT5 satellite for the time period 2001-2010 and climatic indices data obtained from simulations of urban climate model MUKLIMO_3 for the period 2001-2010. Dubrovnik belongs to the Mediterranean touristic cities. Mediterranean region is recognized as one of the most vulnerable region to climate changes as well as the tourism, one of the main industries in Dubrovnik. Therefore, this work was intended to examine changes of the observed temperature data as well as spatial distribution of heat load according to Land use/land cover classification. Trends of daily mean temperatures and seasonal daily mean, maximum and minimum temperatures were analysed by using two independent methods, linear regression method and Mann-Kendall test.

Derived results reveal that mean daily temperatures are increasing accelerated. Analysis of seasonal temperatures shows positive trends of temperature rise for all analysed seasons, where the biggest rise of temperatures is obtained for all summer seasons. However, summer maximum daily temperatures are rising the most. Linear regression method and Mann-Kendall test were also applied for examining trends of climatic indices calculated from observed temperature data (summer days and tropical nights). These results show as well rise of daily maximum and minimum temperature, where minimum temperature are growing accelerated what suggests that nocturnal heating in the city is intensified. Results of satellite data of mean summer land surface temperatures for the period 2001-2010 indicate that urban surfaces are heated more than natural surfaces with vegetation. Climatic indices (summer and hot days, warm evenings and tropical nights) obtained by simulations of model MUKLIMO_3 reveal as well that urban surfaces are heated more than sparse built-up areas or than natural surfaces with vegetation.

THE EFFECT OF WINTER AND SUMMER NAO ON SUMMER URBAN HEAT LOAD IN ZAGREB

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In this study the effect of North-Atlantic Oscillation (NAO) over Zagreb area is investigated. Specifically, the role of indirect (lagged) and direct NAO effect are analyzed by different combinations of winter (wNAO) and summer (sNAO) NAO index. Based on the measurements at station Zagreb-Maksimir in the period 1949-2019, significant correlation is obtained between sNAO index and number of summer days (Tx25). However, when wNAO index was additionally included in multiple linear regression (MLR), even stronger correlation is found with all MLR coefficients being significant. It is demonstrated that the combination of positive wNAO followed by negative sNAO results in the strongest increase in heat load compared to the reference situation, while the opposite combination leads to the strongest decrease. Combinations of the same polarity of wNAO and sNAO phases are generally associated with weak response due to their opposing effect on temperature and precipitation over area under the study. This change in the amplitude of the heat load is also confirmed in simulations made by urban climate model. However, modelling approach enabled us to investigate the spatial variability of the Tx25 field over Zagreb. It is found that NAO combination leading to longer dry conditions results in weaker spatial gradient of the Tx25 due to decreased cooling efficiency of vegetation.

Mentioned results indicate the importance of slower components of climate system, in this case soil. The assumption that soil moisture is significant link between wNAO and summer heat load is confirmed by analogue analysis based on standardized precipitation evapotranspiration index (SPEI) determined for station Zagreb-Maksimir. Furthermore, impact of drought conditions on spatial variability of the urban heat load is confirmed by the analysis of Landsat-8 land surface temperature data.

The results of this research might be useful for urban climate mitigation purposes, especially for planning of irrigation of vegetation in situations when seasonal forecasts indicate warmer and drier conditions.

Full paper:

Nimac, I., I.Herceg-Bulić, M. Žuvela-Aloise and M. Žgela, 2022: Impact of North Atlantic Oscillation and drought conditions on summer urban heat load – a case study for Zagreb. *International Journal of Climatology*, 1–18. https://doi.org/10.1002/joc.7507.

URBAN HEAT ISLAND OF ZAGREB – FIRST MOBILE MEASUREMENTS

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As a result of urbanisation, cities develop a special type of climate called urban climate, which is characterized by occurrence of Urban Heat Island (UHI), a significantly higher temperature in densely built part of the city than in the rural surrounding areas. Resulting heat difference can lead to negative health consequences and the impairment of quality of life of the population. Additionally, impacts of UHI are seen through decreased air quality, formation of less dense fog, increased smog occurrence, shifting of phenological phases (occurring earlier), etc. Also, UHI can play a significant role in energy management throughout the year as we would expect less energy needed in winter for heating, but more in summer for cooling. The anthropogenic heat sources in densely built cities are not negligible. All cities including Zagreb develop UHI. To better determine characteristics of UHI, its intensity and spatial distribution, it is necessary to have as much as possible of data collected from a city area.

For that reason, first mobile measurements of air temperature were organised in Zagreb. The measurements were done using bicycles to increase spatial coverage. The air temperature of the UHI was measured at the height of approximately 2 m from the ground level. Here we will show how the measurements were organised and performed. Collected temperature data and their comparison with land surface temperature (LST) obtained from Landsat-8 satellite are presented. A more detailed analysis of LST in the domain of the city of Zagreb was also made, with the purpose of identifying additional heat sources in the city.

The aim of the study is to show the difference in heat load between different morphological features in the city. This study emphasizes the importance of green areas to mitigate the UHI effect

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HAIL CLIMATOLOGY ALONG THE CROATIAN COAST

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Hail is a weather phenomenon that can cause material damage and hence, knowledge of national hail climatology may contribute to reduced future losses. Unlike a number of countries in the region/Europe that have developed national hail climatology, most of the coastal part of Croatia has not yet been sufficiently researched or analyzed. Therefore, in order to supplement the existing knowledge, the observed hail data from the weather logs from 55 stations were used. They provided a creation of database for the coastal area for the period from 1973 to 2019. The data analysis was accompanied with instability indices obtained from ERA5 data

EXPLORING USEFULNESS OF DROUGHT INDICES TO DETECT AGRICULTURAL DROUGHT IN SLOVENIAN ALPINE REGION

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In the last decade(s) drought has become more frequent in the Alpine region, too. Due to specific climate and mountainous terrain, drought monitoring in this region is particularly challenging. Drought indices are essential for tracking and warning about the potential impacts of drought. To use a specific drought index, it is necessary to evaluate the performance of the index in detecting and monitoring different types of drought. Droughts can cause significant economic losses in agriculture. Information derived from indices is useful to measure the qualitative status of droughts and to support risk management in drought-affected areas.

The study had two objectives: 1) to compare the calculation of drought indices (SPI – Standardized Precipitation Index, SPEI – Standardized Precipitation Evapotranspiration Index , VHI – Vegetation Health Index) from regional datasets (ERA5) with indices derived from ground observations and 2) to verify the ability of different drought indices to detect drought impacts on agricultural crops using different data sources (LINGRA-N model, yield) in alpine grasslands and crops in two climatically different regions of the Alps in Slovenia (e.g. Podravska and Gorenjska region).

Evaluation of SPI and SPEI values calculated from ERA5 reanalysis (within the Alpine Drought Observatory project) versus SPI and SPEI values calculated from ground observations at meteorological stations in Slovenia showed that indices calculated in the Alpine region are relevant at the national level and suitable for operational use.

Validation of SPI and SPEI values (2- and 3-month indices) against annual yield data for different crops and grassland types was averaged to statistical regions (NUTS3 level) due to the availability of impact data. In general, the 2-month indices show better agreement with annual yield data than the 3-month indices, suggesting that the 2-month indices may be more suitable for monitoring agricultural drought in Slovenia. The SPI shows relatively good agreement with yield data in the Gorenjska region, which may suggest that in mountainous regions the evapotranspiration component in drought indices is less relevant.

Due to the lack of impact data at smaller spatial scales that would allow a more detailed analysis, the second part of the study is based on the comparison of drought indices SPEI and VHI with yield values calculated with the grassland productivity model LINGRA-N for two farms at a higher altitude site and one farm at a lower altitude site in the Alpine region. The LINGRA-N model calculates the ratio of actual to potential transpiration (TRANRF), actual root zone water content (SMACT), leaf area index (LAI), reserve dry weight (WRE), and root dry weight (WRT), all of which can be used to detect drought.

Comparison of modeled data with drought indices showed that for the selected years with the highest drought impacts (2003, 2013, and 2017), the two SPEI indices (SPEI-2, SPEI-3) showed the best agreement. The TRANRF, SMACT, and WRT model variables also showed statistically significant correlation with the lower-elevation farm indices in 2013. For 2003 and 2017, the correlation was less significant.

PERFORMANCE OF SEVERAL MODELS FOR PREDICTING START DATE OF PHENOLOGICAL STAGES OF GRAPEVINE IN CROATIA

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As many studies shows, temperature is key element that affects grapevine growth. Global warming and temperature rise shifted grapevine phenology in many vineyard regions worldwide. In Croatia, viticulture represents one of the most important branches of agriculture in the economical and traditional sense. Therefore, it is important to study changes in vine growth, as well as impact of meteorological parameters on it, so that it can be used to predict suitability and growth under future climate.

In this study, dates of beginning of 3 phenological phases (budburst, flowering and veraison), as well as harvest dates, collected from wineries across country, were analyzed. Different statistical methods, that use daily temperature and temperature sum (Growing degree day with base 10°C or 5°C) are used to determent beginning of these phases. Results show earlier appearances of almost all phases, regardless of variety. With rise of temperature, the duration between two phases is shorted and that leads to an earlier harvest.

Statistical methods generally predict dates well. The best prediction is for budburst and harvest dates with correlation coefficient higher then 0.7. Temperature correlation is worse for predicting flowering and veraison, but shorter period between flowering and budberst as well as between veraison and flowering can correlated with higher temperature.

SEZONSKO PROGNOZIRANJE U POLJOPRIVREDI

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Sezonske prognoze od velike su važnosti za potporu donošenju odluka u različitim sektorima, kao što su poljoprivreda i energetika. Iako je uspješnost sezonskih prognoza općenito ograničena u Europi, ona se u nedavnoj prošlosti poboljšala kao rezultat boljeg predstavljanja različitih fizičkih procesa u modelima, veće prostorne rezolucije i prikaza početnih uvjeta. Posljedično tome, sezonske prognoze se sve više koriste u Europi, ali i diljem svijeta, kao alat koji pomaže poljoprivrednicima u donošenju odluka o odabiru pravih agrotehničkih mjera u poljoprivrednoj proizvodnji.

Kako dosadašnja istraživanja sezonskih prognoza u Hrvatskoj nisu bila usmjerena na poljoprivredni sektor, pregledom literature i rezultata iz Europe i regije predstavit će se koncept metodologije primjene ansambla sezonskih prognoza Europskog centra za srednjoročne vremenske prognoze (ECMWF) u agrometeorološkom modeliranju prinosa usjeva te kako se prinosi mogu povezati s izvorima predvidljivosti, kao što su El Niño južna oscilacija i Sjeverno atlantska oscilacija na regionalnoj razini.

AGROKLIMATSKI ATLAS HRVATSKE U RAZDOBLJU 1991. – 2020.

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Agroklimatski atlas Hrvatske u razdoblju 1991. – 2020. prvi je hrvatski agroklimatski atlas u kojem su dani tablični i kartografski prikazi određenih agroklimatskih parametara i indeksa za dva klimatska razdoblja: 1981. – 2010. i 1991. – 2020. Atlas se sastoji od šest poglavlja, a nakon tekstualnog uvoda na početku svakog poglavlja slijede karte i tablice za novije razdoblje 1991. – 2020. Za starije razdoblje 1981. – 2010 na jednak način prikazane su tablice i karte, ali samo u digitalnom obliku.

Promatrani agroklimatski elementi izračunati su na temelju terminskih i dnevnih meteoroloških podataka sa 109 meteoroloških postaja na kojima je pokrivenost mjerenjima u razdoblju 1991. – 2020. bila veća od 70 %. Za prostornu interpolaciju primijenjena je geostatistička metoda kartiranja regresijski kriging, a kao prostorna interpolacijska mreža poslužio je digitalni elevacijski model horizontalne razlučivosti od 1 km iz kojeg su preuzeta četiri prediktora – nadmorska visina, udaljenost od mora, geografska širina i geografska duljina. Uspješnost predviđanja modela ispitana je metodom poprečne validacije izostavljanjem po jednog elementa (Leave One Out Cross Validation, LOOCV).

Nakon povijesnog pregleda u prvom poglavlju slijedi drugo poglavlje u kojem je prikazana prostorna razdioba agroklimatskih parametara i indeksa koji se baziraju na temperaturi zraka (negativne i pozitivne temperaturne sume za određeni temperaturni prag, Huglinov indeks, indeks hladnih noći, maksimalna duljina trajanja toplih i hladnih razdoblja u zraku te najraniji i najkasniji datumi s temperaturom zraka ispod 0°C. U trećem poglavlju analizirana je temperatura tla na različitim dubinama (2, 5, 10 i 20 cm), maksimalna duljina trajanja toplih i hladnih razdoblja u tlu te maksimalna dubina smrzavanja. Tema četvrtog poglavlja su komponente vodne ravnoteže prema Palmerovom modelu (potencijalna i stvarna evapotranspiracija, sadržaj vode u tlu, gubitak vode iz tla, procjeđivanje i otjecanje) i maksimalna trajanja kišnih i sušnih razdoblja iznad, tj. ispod tri oborinska praga 1, 5 i 10 mm. Peto poglavlje bavi se indeksima meteorološke opasnosti od nastanka požara raslinja (pokazatelj vlažnosti finog goriva, indeks početnog širenja vatre, indeks ukupnog goriva, indeks meteorološke opasnosti od požara raslinja te srednje mjesečne i sezonske žestine) koji su određeni prema kanadskom modelu Fire Weather Index (FWI). U posljednjem poglavlju opisana je metoda prostorne interpolacije te je dan pregled mjera uspješnosti interpolacijskog modela.

Rezultati atlasa mogu poslužiti kao priručnik agrometeorolozima, agronomima, šumarima i drugim znanstvenicima te vatrogascima i poljoprivrednicima.

NEW CONVECTION FORECASTS FOR AIR TRAFFIC MANAGEMENT

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Deep moist convection is one of the main causes of air traffic delays in the warm season. Airplanes navigate around convectively active areas, deviating from their planned flight paths, causing congestion and increased workload on air traffic controllers in airspaces around the active convection. EUROCONTROL Network Manager (NM) coordinates and optimizes air traffic flow over the whole Europe and must be able to plan when affected airspace may have to close (and reopen) a day ahead of a convective event. In addition NM should be able to take action at least 2-3h before an event on the day of operations.

To assist NM in their planning and tactical operations EUMETNET has created a new probabilistic Cross-Border Convection Forecast (CBCF). The forecast consists of convective risk polygons created by local meteorological service providers for their own area of responsibility, harmonized across state borders. The risk matrix is a function of likelihood and extent/severity of convective weather with additional CB-top height information and a descriptive briefing text. The forecast is collaboratively made in web application EuFoCs developed by German DWD. In 2019 only five participants from EUMETNET participated in this forecast, covering just a part of Europe. In 2020 eight more met services joined the project, including Croatia Control. It is expected to have 23 met providers in the project in 2022 season, covering the whole Europe.

To complement this forecast and help Croatia Control air traffic controllers in local decision making and planning, in 2020 Croatia Control met department has created a similar product on a smaller scale which allows forecasters to be more precise about convection risk in Croatian and neighboring airspaces. Both products are a step forward in probabilistic forecasting of convection, because all previous products were just deterministic.

This presentation will explain both forecasts in more detail and share some experiences from the 2021 convective season.

SYSTEMATIC DIFFERENCES IN MODERATE TO SEVERE BORA UPWIND AND DOWNWIND TURBULENCE

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Turbulence statistics are analyzed for *Bora* wind episodes that occurred simultaneously in the town of Senj and at the Vratnik pass at the northern Croatian Adriatic coast, for a large dataset spanning over nine months and 800 hours of moderate to severe bora wind record.

Our goal is to address the systematic differences in characteristics of the near-ground turbulence statistics between Senj, located at the shoreline leeward of the main mountain peaks and Vratnik, located at the mountain ridgeline "above", approximately 7.5 km away from Senj. Special focus was on the difference in turbulence kinetic energy (TKE) and its dissipation rate between those two sites. Through these two quantities, we explore how well the TKE balance at either site adheres to a simple shear-dissipation model. Finally, turbulence intensity is compared to values measured elsewhere at the Croatian coast and to the values recommended in various engineering codes. Such patterns of turbulence, which affect the onset, duration and cessation of *Bora* wind, are often not adequately parametrized in operational numerical model.

ANALYSIS OF CROATIAN BURNT AREA IN COMPARISON WITH THE FIRE WEATHER INDEX

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Forest fires cause environmental and economic damages every year, especially in the southern part of Europe. Estimation of the fire risk can vary from practical to scientific approach since different professions like firefighters, meteorologists, soldiers and foresters are involved. For fire risk assessment in Croatia (as in many other countries as well), Canadian Fire Weather Index (FWI) is calculated daily.

The aim of this presentation is to relate the burnt area and FWI in Croatia in recent years. In order to investigate new ideas for forest fire risk assessment, different data sources should be used. Although many open access data are available, only trusted data sources should be used for this work. One of the trusted data providers is Copernicus, which is the European Union's Earth observation programme, implemented by the European Centre for Medium-Range Weather Forecasts (ECMWF) on behalf of the European Commission.

Copernicus Climate Change Service (C3S) is one of the six thematic information services within Copernicus. Inside Climate Data Store, C3S currently offers four products closely related to fires. Fire burnt area is available at different horizontal (from 250 m to 25 km) and temporal (from 15 days to 1 month) resolutions, with different temporal coverage (from 2001 to 2020). Copernicus Emergency Management Service provides daily fire danger indices at the finer horizontal (from 8 km to 10 km) and temporal (daily) resolutions. C3S provides Canadian, American and Australian fire danger indices at horizontal (25 km) and temporal (daily) resolutions with temporal coverage from 1979 to 2022.

The amount of overall burnt area in Croatia for the time period 2017-2020 will be presented together with a comparison of Continental with Adriatic Croatia. We will also present which land cover was the most endangered and compare burnt areas inside and outside of the fire season. Analysis of Canadian FWI will be presented for the time period 2017-2021. The danger levels will be compared in time and space since the aim is to estimate how endangered is Croatia inside and outside of the fire season and how huge is the difference between the Continental and Adriatic parts.

In spite of the limitations of C3S products (e.g. coarse horizontal and temporal resolutions, temporal coverage, different models, model setup), this study highlights possible advantages of using the open-access data, like enabling a deeper understanding of mechanisms related to the forest fires in Croatia and developing new approaches for forest fire risk assessment.

SIMPLE ONE-DIMENSIONAL LAKE TEMPERATURE PREDICTION MODEL (SIMO V1.0)

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Water temperature directly influences a range of lake properties such as the solubility of gases and minerals or the rate of chemical reactions. The vertical water temperature profile determines the water column stability and has a significant role in the vertical transport of gases and nutrients, consequently affecting the biological activity and diversity in the lake. The thermodynamic behavior of lakes is affected by many processes including shortwave and longwave radiation, attenuation of light, sensitive and latent heat flux, sediment heat flux, phase change of water, convective and turbulent mixing, and wind sheltering. However, the main driver are the meteorological conditions determining the heat flux at the lake surface.

Here, a simple 1-D energy budget model (SIMO) for the prediction of the vertical temperature profiles in small, monomictic lakes is proposed. The goal was to develop a model that estimates the net heat flux and vertical thermal diffusion using only routinely measured hourly mean meteorological variables. Namely, the proposed model employs carefully chosen parameterizations to calculate surface heat flux components, such as longwave and shortwave radiation, using only the air temperature, relative humidity, atmospheric pressure, wind speed, precipitation and ultraviolet B radiation (UVB). The only additional data needed are the climatological yearly mean air temperature data. Except for the initial vertical temperature profile, the model does not use any lake-specific variables.

The model performance was evaluated against lake temperatures measured continuously during an observational campaign in two lakes belonging to the Plitvice Lakes, Croatia (Prošće and Kozjak). Temperatures were measured at 15 and 16 depths ranging from 0.2 to 27 in Prošće (maximum depth of 37.4 m) and 0.2 to 43 m in Kozjak (maximum depth of 46 m). Common bivariate measures were used: mean bias error, mean absolute error, root mean square error and maximum absolute error, as well as index of agreement. Results from simulations of different lengths, ranging from 1 to 30 days, were used to evaluate the model performance sensitivity to the simulation length. The model performed reasonably well and it was able to satisfactorily reproduce the vertical temperature profile at the hourly scale, the deepening of the thermocline with time, and the annual variation in the vertical temperature profile.

The ability of the model to predict the springtime onset of lake stratification and autumn convective overturn was also examined by running a yearlong simulation initiated with an approximately constant vertical profile of the lake temperature (~ 4°C). The model was able to reproduce the lake stratification. The upper limit of the metalimnion was well captured while it's thickness was overestimated. The epilimnion temperature was also somewhat overestimated. Nevertheless, the values of the model performance measures of the yearlong simulation were comparable with those reported for other more complex models. This shows that the presented model can be used for assessment of the onset and duration of lake stratification periods when no water temperature data are available, as well as for long term simulations for climate change impacts assessment.

UJEDNAČAVANJE RAZLIČITIH KLASIFIKACIJA ATMOSFERSKIH TIPOVA CIRKULACIJE

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Usporedba velikog broja postojećih metoda za klasificiranje atmosferskih tipova cirkulacije pokazala je potpuno neslaganje rezultata različitih metoda primijenjenih na iste ulazne podatke. Potencijalna je implikacija tog rezultata da je klasificiranje tipova cirkulacije proizvoljno, što ograničava upotrebljivost tih metoda. Ovaj rad istražuje načine za pronalaženje konzistencije između različitih metoda.

Metode se baziraju na kvantificiranju stupnja sličnosti između različitih ulaznih polja, npr. prostornih raspodjela tlaka ili geopotencijala na određenoj domeni. Većina metoda može se podijeliti u dvije glavne kategorije, ovisno o tome koju mjeru stupnja sličnosti koriste: euklidsku udaljenost ili prostornu korelaciju. Ovdje pokazujemo da metode koje koriste istu mjeru stupnja sličnosti pokazuju veću međusobnu konzistenciju u konačnim rezultatima. Dodatno, prikladnom prilagodbom ulaznih podataka ostvaruje se konzistentnost i između metoda koje koriste različite mjere stupnja sličnosti, te se može ciljano odrediti željenu prirodu konačnih klasa. Zaključno se može ustvrditi da većina metoda daje adekvatan rezultat te da je prilagodba ulaznih podataka ključ za postizanje željenog rezultat.

POST-PROCESSING OF ALADIN FORECASTS USING NEIGHBORHOOD TECHNIQUES

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It is important to understand that the model grid size is not the same as the model resolution.

The second is sometimes referred to as the model effective resolution and is generally, at least 5 times lower than the first. 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. Therefore, all point predictions within that area (i.e., neighbourhood) should be considered equally likely and the output of the model should be viewed as the spatial and (or) temporal function of that neighbourhood.

To alleviate before-mentioned difficulties, neighbourhood methods were developed for:
a) The use in the forecast verification as spatial verification methods where they generally share a common trait of relaxing the traditional requirement that forecast and observed events exactly match at the grid scale to account for observation and model uncertainties.
b) To extend an EPS by increasing the number of its members and (or) to provide a way to calculate ensemble probabilities which better reflect the model's true resolution.

In this work, we apply neighbourhood method to a deterministic ALADIN forecast. Selected neighbourhood contains both spatial and temporal dimension and its size varies with the forecast range to account for increasing forecast uncertainty. By using neighbourhoods, 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 neighbourhood approach will be presented.

THE OPERATIONAL LAUNCH OF eGAFOR FORECAST

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eGAFOR is a new joint meteorological forecast for general aviation. eGAFOR is produced simultaneously and in the coordinated and harmonized way in Croatia, Bosnia and Herzegovina, Hungary, Montenegro, Romania, Slovakia, Slovenia and Serbia. It is a graphical forecast made four times a day, and its six hours period of validity is divided into three two-hour time intervals. eGAFOR is developed through an EU co-funded project initiated and managed by CCL, while other partners in the project were ARSO, BHANSA, OMSZ, ROMATSA, SHMU and SMATSA. The eGAFOR was already presented at the Challenges in Meteorology conference in 2018 during the projects' implementation. eGAFOR system is an interactive webpage on the address *www.egafor.eu*, and it consists of a section for forecasters and a section for general aviation users. The users section is called eGAFOR Viewer and is optimized for both mobile devices and computers. Registered users can modify some of their settings. The forecasters section is called eGAFOR Editor; it is used by the forecasters from the participating countries to jointly create a forecast. Five weather phenomena hazardous for general aviation are probabilistically forecasted: clouds, visibility, cumulonimbus clouds, turbulence and freezing precipitation. The forecasters input the forecasts as polygons of a certain severity class and probability class. According to the previously defined criteria, a meteorological impact on general aviation routes is determined from these forecasts. On the users interface the routes are intuitively colour-coded for each time interval of the forecast, depending on the forecasted meteorological impact. Before the operational launch of eGAFOR, all the aviation forecasters from all partner countries had participated in training. The training consisted of using the system and of collaborative forecasting. Training methods, training material and the best practice were developed through the project as well. eGAFOR was operationally launched on May 20th 2021 as a module in the Aviation Support Program of EUMETNET.

SENSITIVITY TESTS OF KALMAN FILTER ALGORITHM FOR FORECAST POST-PROCESSING

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Modern weather forecasting, for a long time, is based on the Numerical Weather Prediction (NWP) models. But, although the capabilities of such models are constantly improving, the errors that they exhibit are still noteworthy. This is especially the case in complex terrain, even for the highresolution mesoscale models. Computational resources are also an important factor in operational weather forecasting. The answer to the further forecast improvement could be found in the usage of statistical post-processing methods. Some of the popular methods, that improve NWP forecast on the locations where measurements are available, are the analog-based method and the method inspired by the Kalman filter (KF). Although some of the authors have performed sensitivity tests, there has not been any paper in current literature that performs detailed sensitivity tests of ratio *r* for various KF methods. For that reason, we present the results of a detailed sensitivity test performed to find the optimal value of the variance ratio *r* for different KF-based post-processing forecasts.

The KF method is applied to the point-based predictions of wind speed and wind gust. The forecasting range is 72 hours. The measurements include 61 locations across the Republic of Croatia. The wind is analyzed as both a continuous and a categorical variable. The continuous verification conducted here relies on RMSE decomposition, spectral analysis and quantile-quantile plot. The appropriate categorical verification measures are used to gain better insight, such as equitable threat score, frequency bias measure, extremal dependence index and frequency measure. Even though the usage of different *r*-values always comes with certain trade-offs, the proposed *r*-values are considered optimal since they lead to excellent results for the overall data, and the results remain satisfactory even for strong wind.

THE IMPROVEMENT OF TAF FORECAST OVER THE YEARS

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Terminal aerodrome forecast (TAF) is a standard ICAO product used worldwide for flight planning. Written by a forecaster, it contains wind, visibility, weather phenomena, cloud conditions and temperature forecasts for the airport for a 24 hours period. The verification procedure of TAF forecasts in Croatia Control Ltd. produces regular seasonal verification reports for winter and summer. Verification follows the approach proposed by Mahringer (2008), used in Austro Control and all MetAlliance members within Europe. The forecasted conditions in TAF are verified with observed ones (METAR reports) for each hour of the TAF and each weather element.

Looking at the results for the last 12 years, improvement in verification results has been achieved for most of the parameters for 9 airports in Croatia. Particular improvement of verification results is most likely the result of investment in education, staff, the technology of work in Meteorological watch office in Croatia control, and overall progress in knowledge, observations and particularly atmospheric models. Better forecasts are good news for the customers, flight planning staff, pilots, etc. Also, this is very encouraging for meteorology because it is generally hard to objectively prove the progress of forecast products to customers, which we all subjectively observe and work on in the meteorological community.

OPERATIONAL FORECASTS OF UNIVERSAL THERMAL CLIMATE INDEX IN CROATIAN METEOROLOGICAL AND HYDROLOGICAL SERVICE

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With an increase in frequency and intensity of extreme events due to global warming, the Croatian Meteorological and Hydrological Service (DHMZ) is always looking to improve its algorithms and warning system for such events. Part of the current biometeorological forecast and the Meteoalarm warning system are forecasts of heat waves and cold spells. In an attempt to improve these forecasts, DHMZ analyzed several thermal indices and implemented them operationally in test mode. Although there is no agreement on single comfort or physiological strain index to be used, Physiologically Equivalent Temperature (PET) and Universal Thermal Climate Index (UTCI) are well accepted worldwide. For example, the UTCI has been used in many countries for over 10 years. It integrates contemporary science to simulate the human response (physiological stress) to meteorological conditions by a sophisticated model. The meteorological data used for the calculation of UTCI are hourly NWP model values of air temperature, relative humidity, wind speed and mean radiant temperature. These predictions are calculated using NWP model ALADIN's export cycle 43, which is currently being tested at DHMZ. The UTCI is calculated for 30 locations in Croatia. The cases include heat waves and normal weather conditions. Strong wind episodes, such as local bora and jugo wind in coastal regions both in cold and warm seasons are also included, as well as moderate/strong wind in continental regions.

Results for the cases of strong wind, especially in the cold season, show UTCI sensitivity to the wind. Finally, the UTCI values are compared with other biometeorological indices which are operational in DHMZ (e.g., Thermal comfort index and Physiological equivalent temperature) and simpler biometeorological indices (e.g., Heat Index in the warm season and Wind Chill index in the cold season).

POSTERI
POSTERS

AIR QUALITY SIMULATIONS OF PM_{10} AND NO_2 FOR ZAGREB USING ADMS-URBAN DISPERSION MODELLING SYSTEM

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This study aims to improve the knowledge of air quality in Zagreb, the capital of Croatia. It gives insight into the spatial distribution of concentrations of the main city pollutants (fraction of particulate matter <10 µm and nitrogen dioxide) within the process of developing an air quality modelling system in high resolution. The work is a part of an ongoing AIRQ project (AIRQ – Expansion and Modernisation of the National Network for Continuous Air Quality Monitoring) funded by the European Regional Development Fund and Environmental Protection and Energy Efficiency Fund (FZOEU).

Air pollution is perceived as the second biggest environmental concern for Europeans, next to climate change, as quoted by European Commission in 2017, and it is the most important environmental risk to human health. Over the last three decades, policies to reduce air pollution have led to improved air quality; nevertheless, in some European cities air pollution still poses risks to health. Zagreb is, unfortunately, one of them. Based on the levels of fine particulate matter measured in the air in 2019. and 2020., among 323 European cities, Zagreb is ranked as 256th, and air quality in the city is categorized as „poor“ (EEA, 2022).

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 representative for a specific street, authorities are encouraged to use dispersion models to complement the observations for a city.

In this study, the ADMS-Urban model was set up for the Zagreb agglomeration. Within the model, measurement data from the Desinić site 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 (source: Ministry of Economy and Sustainable Development). Since emission sectors with low emission heights, such as traffic and household emissions, generally make larger contributions to surface concentrations and health impacts in urban areas than emissions from high stacks, special attention was given to road emissions, their spatial distribution and time profiles, taking into consideration the limitation of available data. The meteorology data used within the model were from the Zagreb-Maksimir measurement site and are representative of the whole modelling domain.

The focus of the analysis was the main pollutants usually found to exceed EU limit values within the city and the surrounding area PM_{10} and NO_2. The performance of the model is assessed against measurements from 14 urban, urban-background and near-traffic sites using a range of metrics concerning annual averages, high hourly average concentrations and diurnal cycles. The model shows good performance compared to measurements for PM_{10}, although it underestimates concentration values during high pollution winter episodes. First NO_2 results show characteristic high concentrations at the traffic hot spots and next to the main roads.

DUST DEPOSITION IN THE ADRIATIC SEA; CLIMATOLOGY AND POSSIBLE IMPACT ON MARINE PRODUCTION

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Atmospheric mineral dust deposition plays an important role in providing nutrients to marine ecosystems. In this study, the climatology of dust deposition in the Adriatic Sea area was determined for the first time based on MERRA-2 reanalysis from 1989 to 2019. The annual cycle of deposition exhibits two maxima: a stronger in March–April and weaker in November. Wet deposition is a dominant process with a relative contribution to overall deposition from 67.35% to 88.53%. Deposition hot spots are along the Montenegrian coast and Otrant. The average contribution of dust deposition events (DDEs) is 16.5% (60.2 dy yr^{-1}), with the strongest deposition during the 1999-2009 and positive trend in deposited mass during study period. Dust deposition effect on primary production is observed by a high level of oxygen saturation up to 250% (usually is lower, up to 150%) in the stratified middle water layer (5-8 m) of the central Adriatic marine system (Rogoznica Lake) during intense wet deposition episode. Such extreme values of oxygen saturation can be taken as an indication of biological activity related to increase in phytoplankton abundance and activity, diatoms in particular.

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VIŠEKORISNIČKA BAZA PODATAKA KVALITETE ZRAKA IZRAĐENA U GIS-U ZA PODRUČJE REPUBLIKE HRVATSKE

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Izrada baze podataka započinje kreiranjem konceptualne sheme gdje se određuju entiteti, atributi i veze. Zatim slijedi izrada logičke sheme gdje se određuju relacije tablica, a nakon toga se izrađuju tablice za bazu podataka u nekom od programskih alata. Tablice unutar baze izrađene su po određenom ključu, odnosno grupirane su prema utvrđenoj potrebi kako bi se održao smisao i unutarnja povezanost samih podataka. Nakon izrađenih tablica u programskom alatu u njih se unose finalni podaci. Geodatabase (višekorisnička baza podataka) je sastavni dio GIS-a koji pruža podršku raznim aplikacijama unutar sustava. U bilo kojoj GIS aplikaciji mogu se koristiti podaci iz baze podataka za izvođenje različitih željenih naredbi.

ArcGIS je omogućio izradu harmonizirane georeferencirane baze podataka, a osiguran je iz sredstava AirQ projekta. Glavna karakteristika višekorisničke baze podataka je da sadrži prostorne slojeve i atributne tablice za pohranu podataka mjerenja kvalitete zraka. Na prostorne slojeve koji prikazuju prostornu raspodjelu postaja kvalitete zraka na području Republike Hrvatske vežu se atributne tablice s karakterističnim vrijednostima za svaku pojedinu postaju. Nekoliko je izrađenih atributnih tablica u bazi, opći podaci postaje, kalibracija uređaja, karakteristike mjerenja i podaci mjerenja, i sve tablice su međusobno povezane. Tablica opći podaci postaje sadrži opće i glavne podatke o svakoj postaji pojedinačno, kao što su geografske koordinate, nadmorska visina, klasifikacija postaja, popis mjerenih onečišćujućih tvari i drugo. Tablice karakteristike mjerenja i podaci mjerenja, sadrže popis parametara koji se mjere na postajama, odnosno brojčane vrijednosti svih popisanih parametara koje se mjere na postajama. Vrijednosti koje su definirane unaprijed nalaze se u domenama. Nekoliko je tablica domena, kao što su: mjerna jedinica, vrsta postaje, mreža postaje, nivo validacije i druge. Povezanost atributnih tablica omogućuje lakše provođenje operacija potrebnih za izradu studija, analiza i drugih oblika izvješća o kvaliteti zraka. U GIS portalu koriste se podaci iz geodatabase baze podataka koji se automatikom vizualno prikazuju (dashboard) uz unaprijed određen način izračuna statističkih parametara i graničnih vrijednosti za parametre kvalitete zraka. Izradom ovakve baze postiže se željeni cilj, postiže se djelomična automatizacija i ubrzava proces izrade različitih znanstvenih i stručnih podloga.

OCJENA KVALITETE ZRAKA NA PODRUČJU REPUBLIKE HRVATSKE NA OSNOVI REZULTATA MJERENJA I MODELIRANJA 2016. – 2020. S OBZIROM NA ONEČIŠĆENJE LEBDEĆIM ČESTICAMA (PM_{10} I $PM_{2,5}$) TE NO_2 I OZONOM

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Kvaliteta zraka značajno utječe na ekosustave i zdravlje ljudi te se prati pomno prije svega radi poboljšanja kvalitete života, ali i planiranja budućih regionalnih i globalnih ljudskih aktivnosti, obzirom da onečišćenje atmosfere izravno doprinosi i klimatskim promjenama. Složenost atmosferskih čimbenika te njihova međusobna ovisnost čini sustav praćenja kvalitete zraka vrlo izazovnim. Zbog toga su uloženi značajni napori i velika novčana sredstva kako bi se osigurala sustavna mjerenja kvalitete zraka na području Republike Hrvatske. Direktivom 2008/50/EK o kvaliteti zraka i čišćem zraku za Europu iz 2008. godine te Direktivom o teškim metalima i policikličkim aromatskim ugljikovodicima u zraku iz 2004. godine (2004/107/EK) propisani su standardi kvalitete zraka kojima se uvode zajednička mjerila i metode za procjenu kvalitete zraka. Zemlje članice Europske Unije dužne su izrađivati godišnja izvješća, jednogodišnju ocjenu kvalitete zraka kao i cjelovitu petogodišnju studiju kvalitete zraka na svojem teritoriju i dostavljati ih Europskoj Komisiji zbog analize postojećih problema i trendova, provjere učinkovitosti provedenih politika, planiranja zajedničkih mjera te izrade novih srednjoročnih planova za očuvanje i daljnju zaštitu zraka. Ocjena je izrađena na osnovi raspoloživih podataka mjerenja na postajama Državne mreže za trajno praćenje kvalitete zraka na postajama gradskih i županijskih mreža za praćenje kvalitete zraka uz potporu numeričkog atmosferskog kemijskog modela LOTOS-EUROS koji se koristi za proračun i procjenu daljinskog prijenosa, prostorne razdiobe i taloženja onečišćujućih tvari u prizemnom sloju zraka. Kao ulazni podaci za primjenu modela potrebni su meteorološki podaci i podaci o emisiji onečišćujućih tvari za područje na kojem se razmatra prijenos, disperzija i taloženje onečišćujućih tvari.

Lebdeće čestice obje frakcije ($PM_{2,5}$ i PM_{10}) karakteriziraju povišene vrijednosti u zimskom razdoblju, osobito u kontinentalnom dijelu zemlje, što je najvećim dijelom posljedica emisije iz malih ložišta na kruta goriva (ogrjev), uz pojačano onečišćenje koje prate stabilni atmosferski uvjeti. Ozon predstavlja značajan problem kvalitete zraka, ponajprije u područjima s izraženom fotokemijskom aktivnosti (Jadranska obala). Dušikov dioksid najznačajnija je onečišćujuća tvar iz sektora cestovnog prometa, čija žarišta, poput centra Zagreba i dalje predstavljaju izazov za kvalitetu zraka u gradu.

Cilj studije je osigurati što iscrpnije informacije za potrebe ocjene kvalitete zraka na području Republike Hrvatske, ocijeniti učinkovitost sustava za praćenje kvalitete zraka i dostatnost mjerenja koja su se provodila u promatranom razdoblju, osigurati pouzdanu, znanstveno utemeljenu podlogu za donošenje troškovno učinkovitih politika i mjera zaštite zraka i okoliša, te dati naputke za unaprjeđenje praćenja kvalitete zraka.

PROJECTED CHANGES IN PRECIPITATION IN THE LATEST EURO-CORDEX ENSEMBLE UNDER RCP4.5 SCENARIO OVER THE EASTERN ADRIATIC AND DINARIC ALPS

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The topographically complex coastal-mountainous region of the eastern Adriatic and Dinaric Alps is one of the rainiest areas in the Mediterranean and particularly vulnerable to climate change. Although there are studies that classify this region as the area with a "zero-change" line between the wetter north and drier south, which shifts northward towards the end of the century, the research of future precipitation changes over this region is still limited. We use the climate projections for the RCP4.5 scenario from the latest EURO-CORDEX ensemble of 11 regional climate models (RCMs) driven by six CMIP5 global climate models (GCMs), a total of 25 members at 0.11° resolution. We focus on the climate change signal for the far future period (2071-2100) compared to the historical period (1971-2000).

The results show a reduction of total precipitation amount in the summer over the southern areas with no signal change over the northern parts of the region. In the winter, an increase in total precipitation amount is shown for the whole domain, highest over the northern parts. The projections show a decrease in the number of rainy days for all seasons over the southern parts of the region and with the highest agreement in the sign of the change in summer. However, an increase in precipitation intensity can be expected by the end of the century, especially during the autumn and winter months. Furthermore, the 99th percentile of precipitation amount, along with one and five-day maximum precipitation amount, are projected to increase in all seasons over northern areas, especially in winter and autumn. The projections do not show a clear signal over the southern parts in summer. We plan a more detailed analysis for multiple future periods and greenhouse gas concentration scenarios.

WINDWARD MEASUREMENTS AND WRF SIMULATION OF A LONG-LASTING SEVERE BORA EVENT

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An exceptionally long-lasting (more than 20 days) and strong bora event (winter of 2012) was captured by instruments on a 100-m meteorological mast, located upwind of the coastal mountains. This data is used to validate a high-resolution Weather Research and Forecasting (WRF) simulation (finest grid resolution of 300 m). Based on the agreement between the model and the measurements, which validates the WRF-ARW model suitability for numerical simulations of transient winds in windward areas, this approach is intended to be deployed for future studies with the aim of exploring the severe Bora upwind of the coastal mountains. In this context, we outline some of the preliminary results.

FIRST ANALYSIS OF THE JUGO WIND MICROSCALE PROPERTIES

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At the eastern Adriatic coast, there are different types of winds, the most prominent of which are *bura* and *jugo* winds. The complex orographic configuration contributes to the frequent occurrence of severe and gusty winds in the area, which is why they are the subject of numerous studies. While *bura* has been intensively explored for decades, *jugo* has not received as much attention. *Jugo* is the wind from southeast, but it can reach *bura*-like wind speeds and create problems in human activities such as traffic, tourism, infrastructure, agriculture, engineering and firefighting.

In this work, the microscale characteristics of the *jugo* wind are analyzed for the first time. Until now, within the Department of Geophysics of the Faculty of Science in Zagreb, only *bura* have been studied. The study of *jugo* turbulence is important because important processes of moisture, momentum and heat transfer in the atmospheric boundary layer take place on this scale as part of the interaction of airflow with the ground.

We study a *jugo* event that was measured near the Maslenica bridge at the beginning of October 2020. We determine the turbulence averaging scale based on Fourier spectra of wind speed components, which allows us to estimate turbulent kinetic energy (TKE) and its dissipation rate (ε). We test the relationship between TKE and ε, and their agreement with the parameterization used in numerical weather prediction models.

LAKE-LAND BREEZES OVER KOZJAK, PLITVICE LAKES, CROATIA

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The aim of the study was to investigate if a small, elongated lake (Kozjak, Plitvice Lakes, Croatia; 2.3 km by 0.1-0.6 km; maximum depth of 46 m) can produce atmospheric thermal circulation systems, that is, lake-land breezes (LLBs). The lake temperature was measured during summertime over three years (2018-2020) at the depth of 0.2 m at temporal resolution of 1h. Simultaneous standard meteorological variables were obtained from nearby meteorological site. Days with persistent LLBs were identified based on 7 prescribed criteria in which the atmospheric and lake conditions were taken into account. Specifically, these criteria take into account air and lake temperature, wind speed and direction, air pressure and precipitation. The results show that despite of the small lake size, LLBs were established. Thus, 17.7% of the investigated days were associated with persistent LLB events. As these events were accompanied by elevated energy in the normalized wavelet spectra for the wind speed at period of 24 hours, it was concluded that the prescribed criteria well define persistent LLB events. However, it was noted that the observed LLBs were most likely superposed with the thermally induced up- and downslope winds, as Kozjak Lake is confined by nearby mountains. While during the nighttime, land breezes were characterized with a clear clockwise wind rotation, during the daytime, lake breezes were frequently channeled in the along-lake direction due to the surrounding topography. Finally, the results showed a clear relationship between the lake-land temperature difference and the strength of the LLBs.

TEMPERATURNE PRILIKE NA PODRUČJU VELEBITA

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Velebit je najduža i četvrta najviša hrvatska planina. Svojim položajem razdvaja kontinentalni dio od priobalja čineći granicu između dviju klimatskih zona u kojima prevladavaju različiti temperaturni režimi. Kako bi se što bolje opisale prostorne razlike u klimatskim karakteristikama ovog područja, korišteni su podaci s tri meteorološke postaje smještene na različitim lokacijama – Senj, koja je na obali mora, Gospić koja je u središnjem dijelu Like te Zavižan koja se nalazi na planinskom vrhu koji čini granicu tih dviju zona.

Klima nekog područja opisuje se prosječnim vrijednostima različitih klimatskih elemenata, njihovom varijabilnošću te ekstremima u dužem vremenskom razdoblju. U ovoj analizi naglasak je na temperaturi zraka. Za prikaz prosječnih temperaturnih prilika velebitskog područja korišteno je referentno 30-godišnje klimatološko razdoblje 1981. – 2010., dok je za analizu parametara koji predstavljaju ekstremne situacije te procjenu trenda korišteno dulje razdoblje 1953. – 2020. Analizirani su godišnji hodovi temperature zraka i karakterističnih dana s temperaturom ispod/iznad određenog praga (hladni, studeni i ledeni dani, topli i vrući dani te tople noći) te su izračunati pripadni trendovi, a njihova statistička značajnost je ocijenjena pomoću Mann-Kendalovog testa. Izračunati su i rangovi temperatura zraka te je napravljena procjena ekstrema dnevne temperature zraka.

Rezultati pokazuju porast godišnje temperatura zraka na svim postajama, kao i porast broja toplih dana, dok broj hladnih dana ima negativan trend.

KLIMATSKA PODLOGA ZA RAZVOJ ZDRAVSTVENOG TURIZMA

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Pravilnikom o pojedinim oblicima zdravstvenih usluga koje se pružaju u djelatnosti zdravstvenog turizma te standardima i normativima za njihovo obavljanje (NN 79/19) postavljeni su standardi za klimatske ljekovite činitelje koji uključuju potrebu analize klime u svrhu razmatranja mogućnosti korištenja klime kao prirodnog ljekovitog činitelja. Navedena analiza klime zahtjeva „…obilazak mjesta te analizu mjerenja i opažanja klimatskih parametara (temperatura zraka, vlažnost zraka, insolacija, vjetar, oborina, naoblaka, toplinsko opterećenje) s postaje za praćenje klime minimalno tijekom dvije godine“, a „…u razmacima od najviše 10 godina treba provjeravati jesu li se promijenile pretpostavke za analizu i ocjenu klime.“

Studija „Klima i bioklima Rovinja“ izrađena je kao klimatska podloga za potrebe utvrđivanja uvjeta za ispunjavanje kriterija za klimatsko lječilište Rovinj. U studiji su analizirane klimatske prilike u Rovinju na temelju meteoroloških podataka iz razdoblja 1981. – 2010. s meteorološke (klimatološke) postaje Rovinj. Analiza je pokazala da područje Rovinja ima umjereno toplu kišnu klimu, prema Koppenovoj klasifikaciji, oznake *Cfsax''*. Da bi se potvrdila prikladnost Rovinja kao lokacije za obavljanje djelatnosti zdravstvenog turizma, pomoću fiziološke ekvivalentne temperature (PET), veličine koja ukazuje na toplinski osjet ugode čovjeka, analizom učestalosti pojavljivanja određenih kategorija osjeta ugode, razmotrene su i biometeorološke značajke Rovinjskog područja. Za potpuniju ocjenu prikladnosti klimatskog mjesta za klimatsko lječilište potrebno je analizirati čistoću i uređenost okoliša, količinu svjetlosnog onečišćenja i buke te kvalitetu zraka koji udišemo.

IMPLEMENTATION OF DOUBLE GROWING NEURAL GAS FOR WIND DATA CLASSIFICATION

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Characteristic wind time patterns were classified using growing neural gas (GNG) and double growing neural gas (DGNG) trained by unsupervised learning. We used ERA5 reanalysis wet points over the Mediterranean Sea, 10-m wind magnitudes and mean sea level pressure data with a spatial resolution of 0.25×0.25 on the hourly time scale. GNG was applied only to the wind data, leaving the MSLP data for post-analysis validation to check if the averaged pressure fields align with the extracted wind patterns. GNG is probably easiest to explain by relating it to Self-organising map (SOM) algorithm. While SOM tries to preserve the topological structure, GNG is more flexible in this regard, i.e., it does not require prior knowledge of the network topology to learn the similarity relationships between input signals. GNG can be observed as a clustering algorithm that reduces the dimensionality of the data space to an arbitrary number of neurons by assigning them to relevant parts of the data space while minimising the representation error.

We introduce double growing neural networks as a model for compressing already compressed data. Before time patterns could be extracted via GNG, the input data had to be reshaped and organised in a specific way because the algorithm is sensitive to the shape of the input. Simply transposing the input data results in vastly different physical interpretations of the output. To achieve this data structure, the original data had to be split into north and south wind components. The resulting 2D arrays of data at a given time were smoothed into row-major order before being stacked and transposed together. At the end of this single step, the data had the form (1, 63162) – i.e. (one hour, (latitude points * longitude points)*2). This procedure was then repeated for each hour on each day of each month from 1979 to 2019.

The result was an array of the form (n, 63162), where *n* is the total number of hours elapsed in 41 years in each month, accounting for the variable duration of months while distinguishing between leap years and nonleap years. The MSLP data were transformed in the same way, resulting in an array of the form (n, 31581), since there is only a single pressure component. While this is an impressive reduction in time scale, the sum of 108 patterns, or 9 patterns for each of the 12 months, are still too many, at least for human perception. Drastically reducing the number of patterns can potentially cause oversmoothing issues, meaning some otherwise prominent patterns might overlooke due to their lower-than-average frequency of occurrence. To deal with this problem we decided to cluster the patterns again. This way, we can not only reduce the number of patterns to a manageable number, but also pick out important signals that would be over-smoothed when analysing the bulk data. The process is identical to GNG, except that the input data is now of the form (108, 63162). The supporting parameters for GNG remain the same. The result of the double clustering is 9 unique time patterns. The model was able to extract frequent episodes of low and high-speed NW winds, as well as several types of Bora and Scirocco winds affecting large parts of the Mediterranean.

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TLO KOJE DIŠE, ZRAK KOJI UDIŠEMO

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Kvaliteta zraka neprestano se mijenja, a ovisi o prirodnim procesima i ljudskim aktivnostima. Ugljikov dioksid (CO_2), plin koji se nalazi u Zemljinoj atmosferi i jedan od najvažnijih stakleničkih plinova, utječe na kvalitetu zraka i procese globalnog zagrijavanja. Ugljikov dioksid oslobađa se iz tla u atmosferu prirodnim procesom disanja tla. Tlo sadrži najveće globalne zalihe ugljika koje su gotovo tri puta veće od zaliha ugljika u nadzemnoj biomasi. Pravilnim gospodarenjem poljoprivrednim tlom može se utjecati na disanje tla u poljoprivredi odnosno emisiju CO_2 iz tla, a samim time i na kvalitetu zraka. Zbog nedostatka istraživanja i vlastitih nacionalnih podataka vezanih uz tematiku disanja tla, 2012. godine započela su se provoditi mjerenja koncentracije CO_2 iz tla u različitim agroekološkim uvjetima RH i različitim načinima korištenja poljoprivrednih tala.

U ovome radu biti će prikazani rezultati mjerenja koncentracije CO_2 iz tla metodom zatvorenih statičkih komora tijekom vegetacija različitih jednogodišnjih i višegodišnjih poljoprivrednih kultura.