

Klimatski sustav – od globalnih utjecaja do lokalnog odziva

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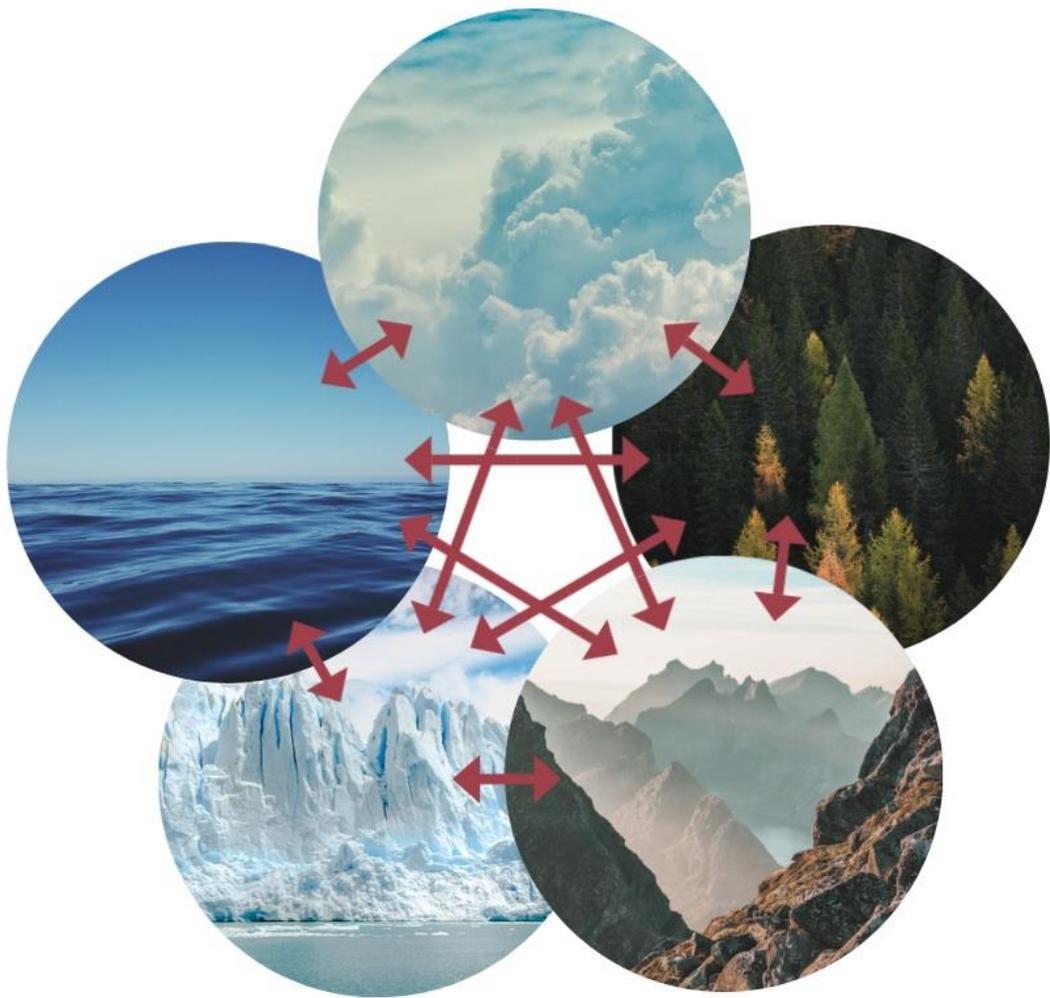
Geofizički odsjek Prirodoslovno-matematičkog fakulteta
Sveučilište u Zagrebu

Marijana Boras
Sara Ivasić
Irena Nimac
Matej Žgela



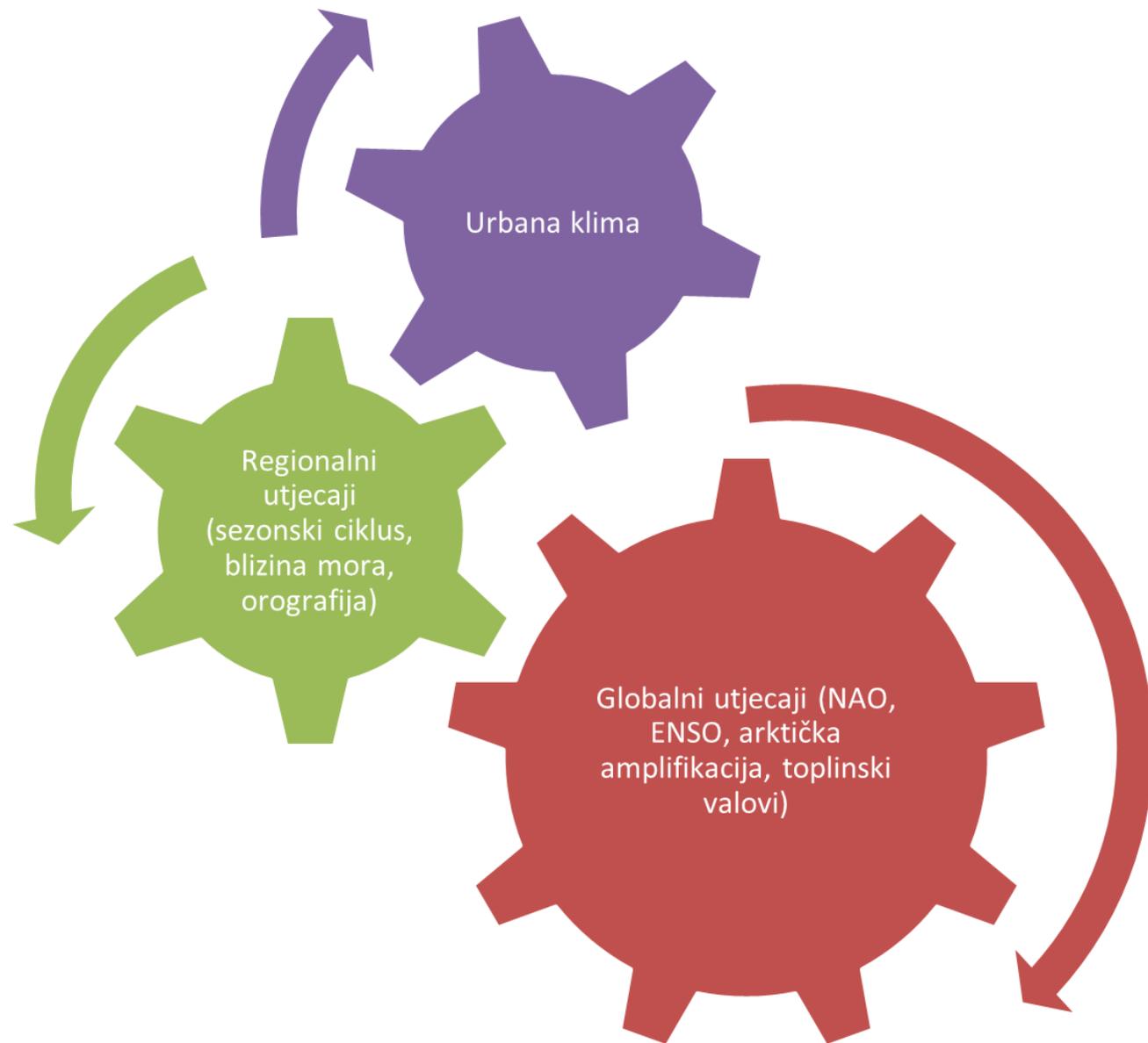
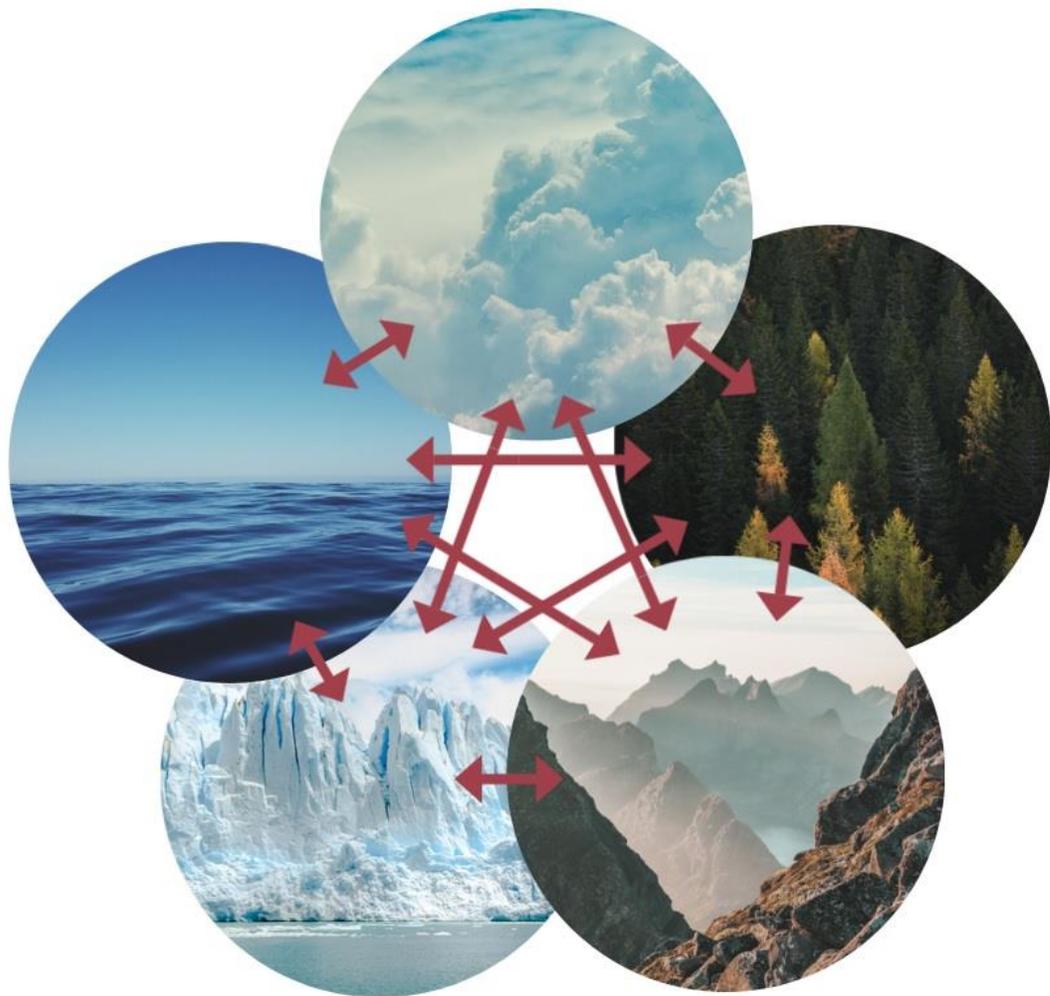
Rad je financirala Hrvatska zaklada
za znanost (projekt CroClimGoGreen
UIP-2017-05-6396)

Klimatski sustav



- atmosfera, hidrosfera, kriosfera, litosfera, biosfera
- dinamički interaktivni sustav
- uzajamno-povratne sprege

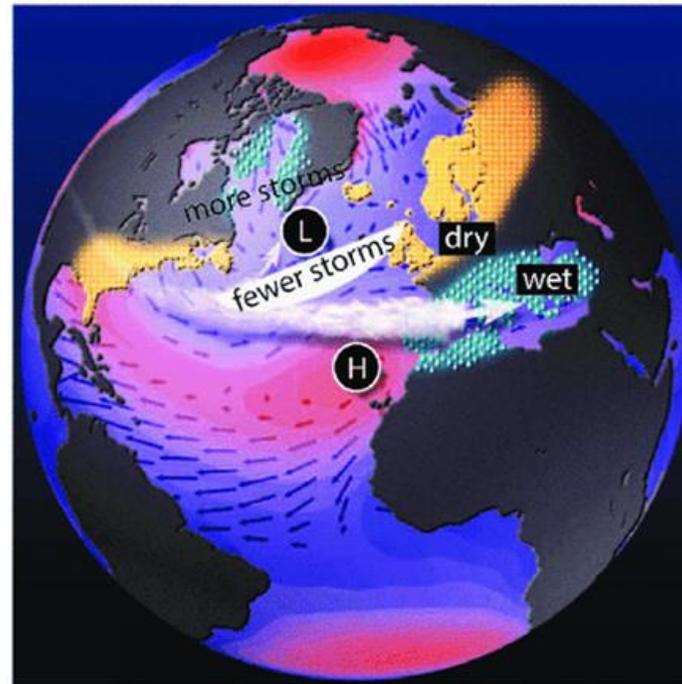
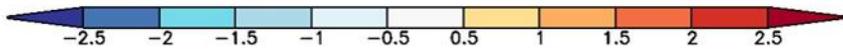
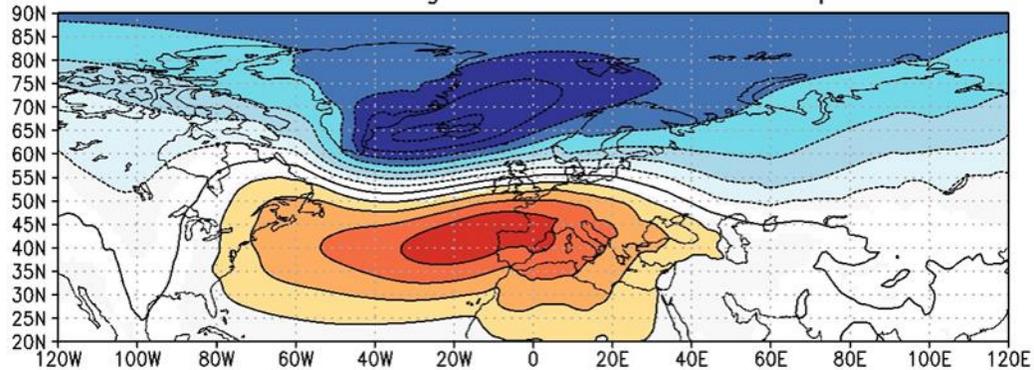
Klimatski sustav



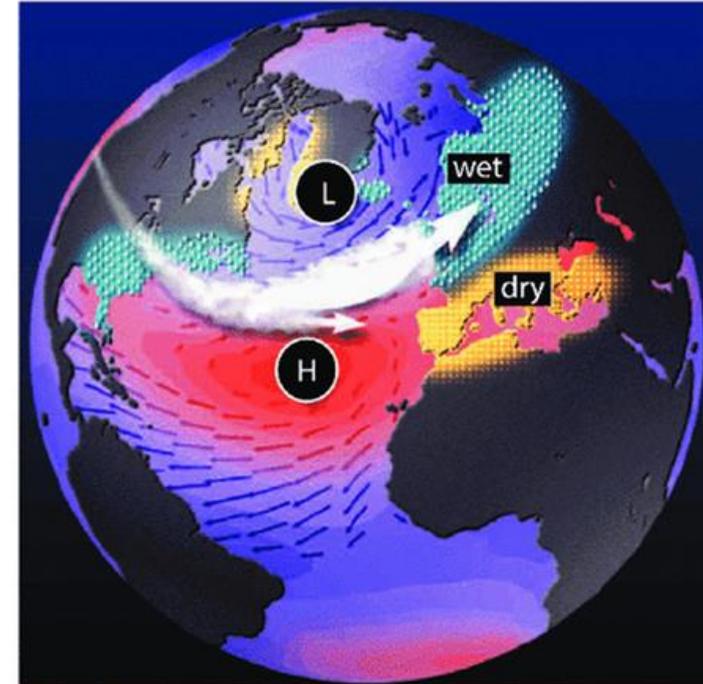
Sjeverno-atlantska oscilacija

North Atlantic Oscillation - NAO

regr Jan-Mar averaged NAO-Gibraltar index
with Jan-Mar averaged 20CRv3 SLP 1836:2015 $p < 10\%$



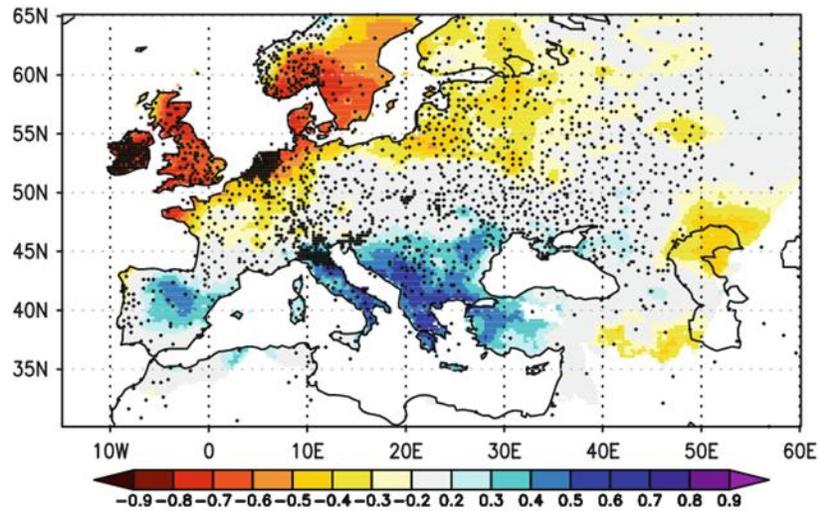
Negativni NAO (zima)



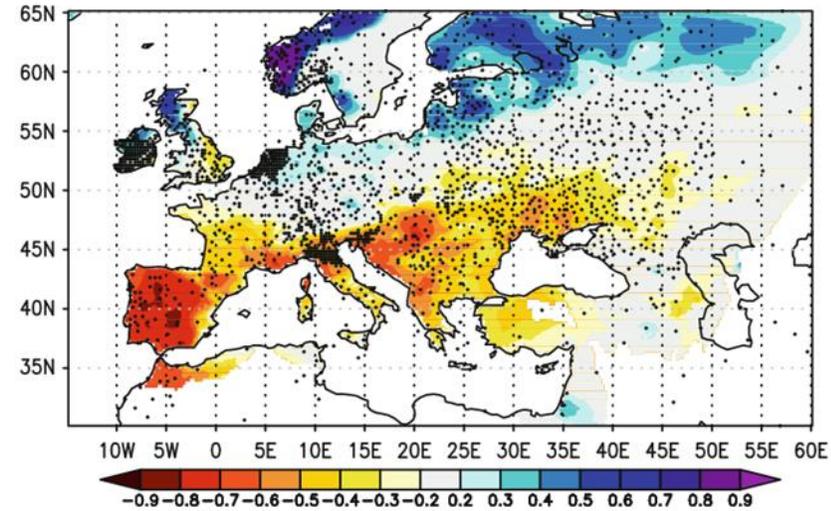
Pozitivni NAO (zima)

Utjecaj NAO-a na Europu

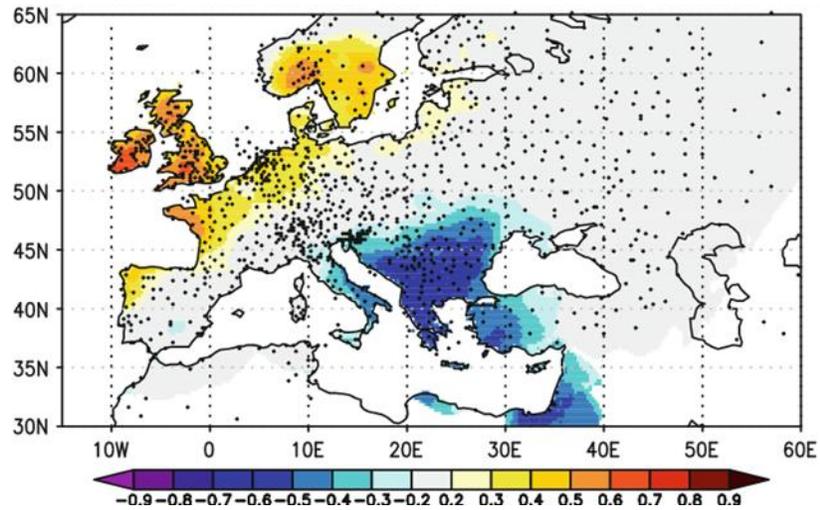
Ljetni NAO: utjecaj na oborinu



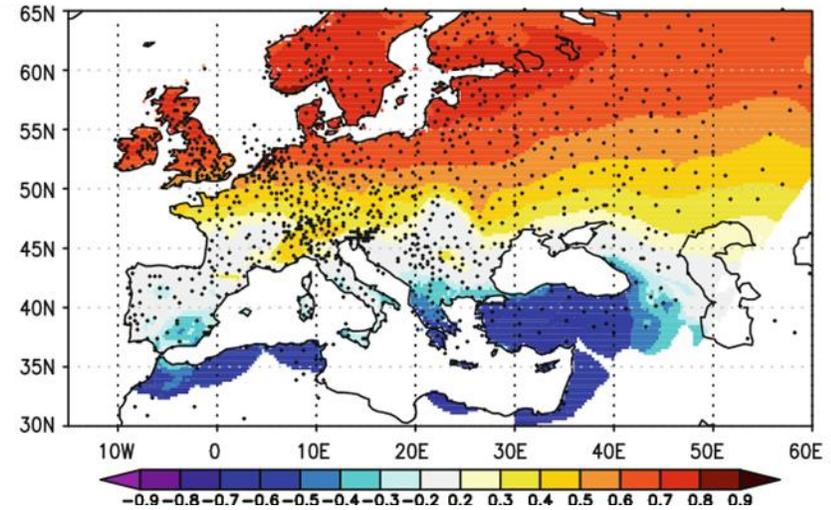
Zimski NAO: utjecaj na oborinu



Ljetni NAO: utjecaj na temperaturu



Zimski NAO: utjecaj na temperaturu



El Niño - Južna oscilacija

El Niño Southern Oscillation - ENSO

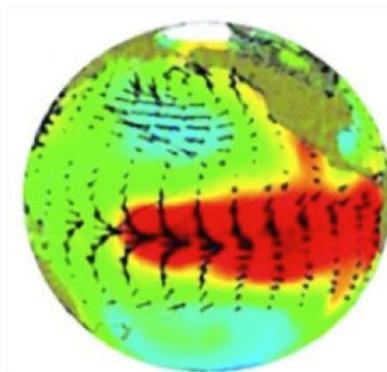
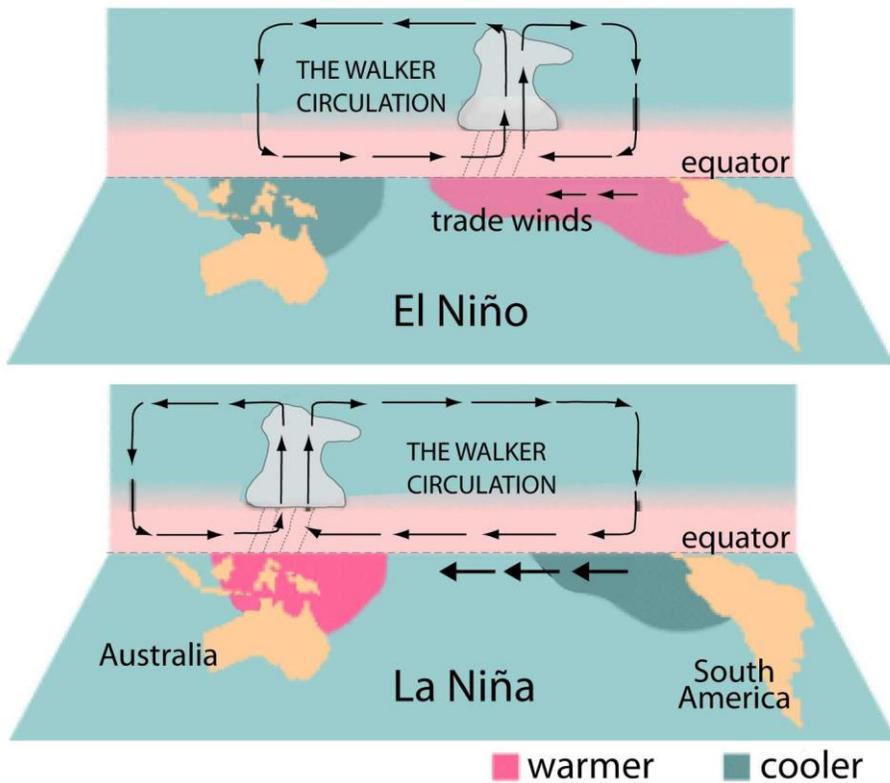
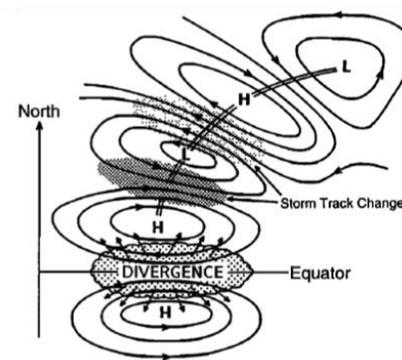
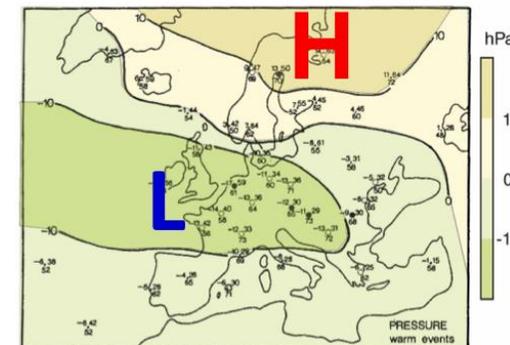


Image courtesy of University of Washington
El Niño Southern Oscillation



Trenberth et al. 1998
North Pacific-North America



Fraedrich and Müller [1992]
North Atlantic-European

Daljinske veze

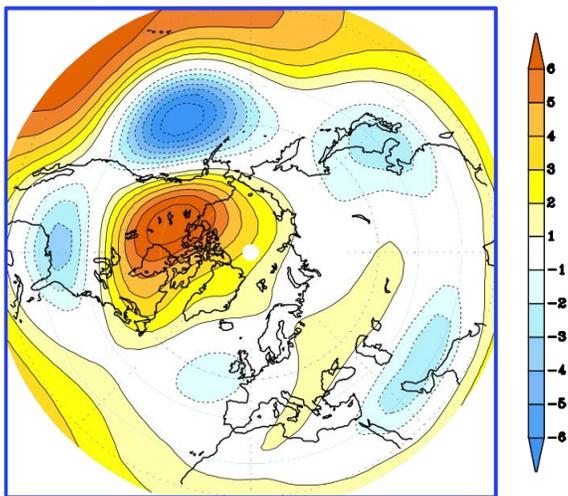
Polja daljinskog odziva

Prinudno djelovanje ekvatorskog Pacifika
(eng. *equatorial Pacific forcing*)

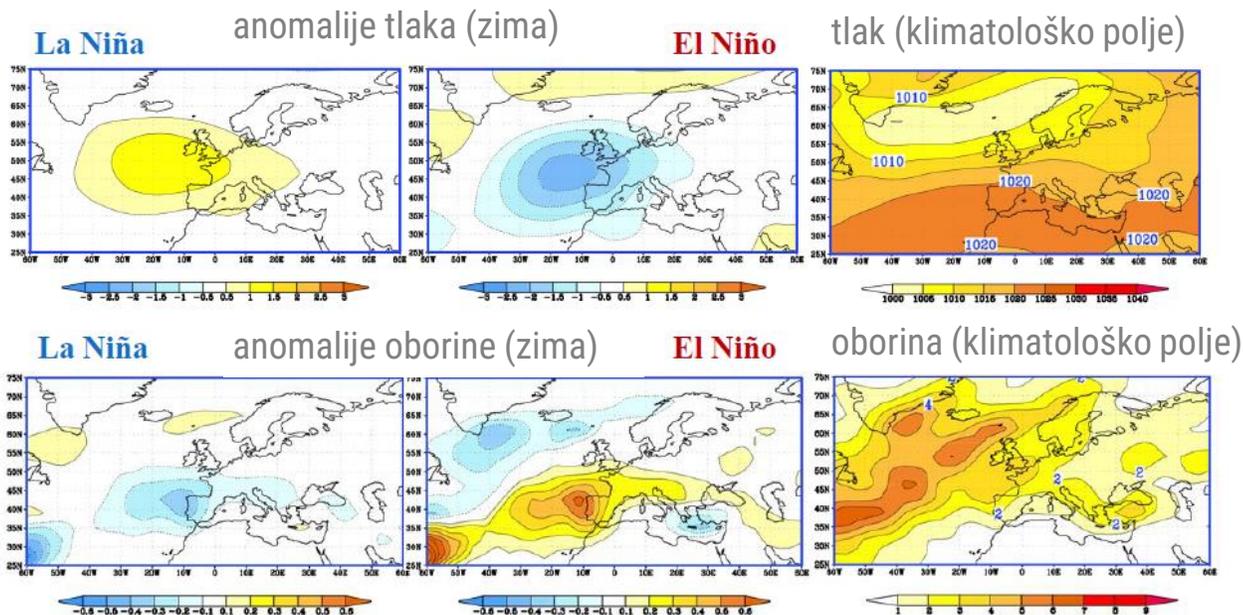
Daljinske veze (eng. *teleconnections*) →
polja daljinskog odziva (eng. *teleconnection patterns*)

Utjecaj zimskog ENSO-a na umjerene zemljopisne širine

Z200 (dam), El Niño (zima)



Područje sjevernog Pacifika i Amerike:
Jaki atmosferski odziv
(tlak, vjetar, temperatura, oborina...)
PNA polje atmosferskog odziva



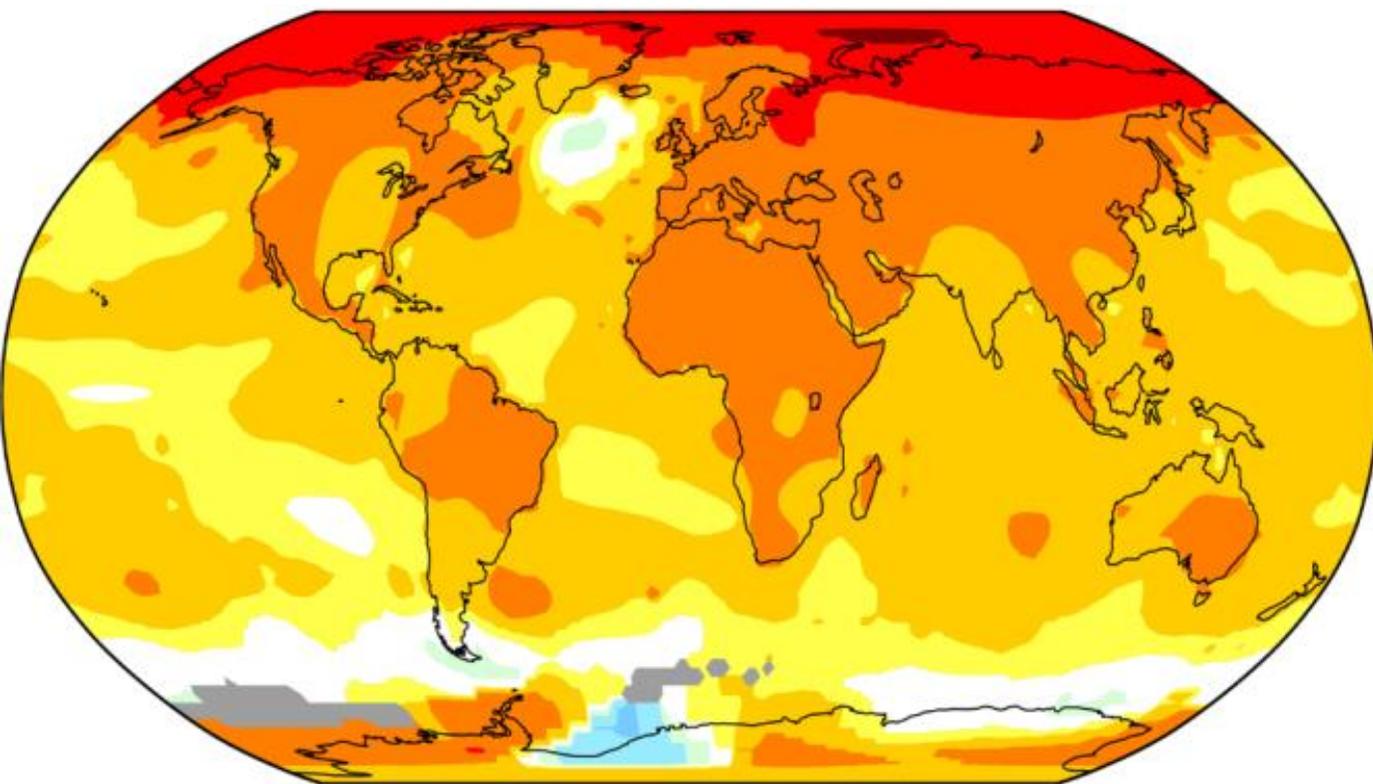
Područje sjevernog Atlantika i Europe:
Slabi atmosferski odziv
(tlak, vjetar, temperatura, oborina...)

El Niño: ciklonalni tip vremena
La Niña: anticiklonalni tip vremena

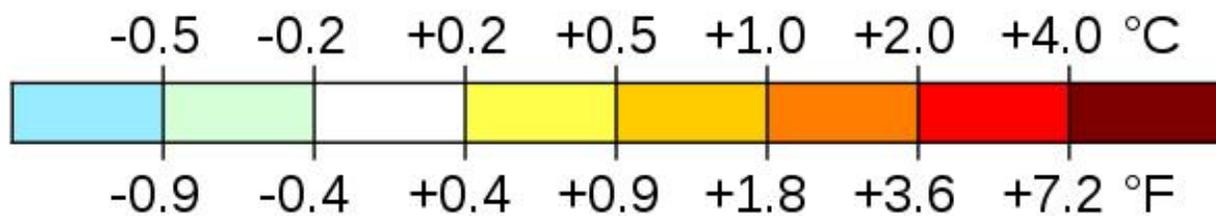
Herceg Bulić i Branković, Clim. Dyn. (2012)

Globalno zatopljenje

Globalne promjene temperature

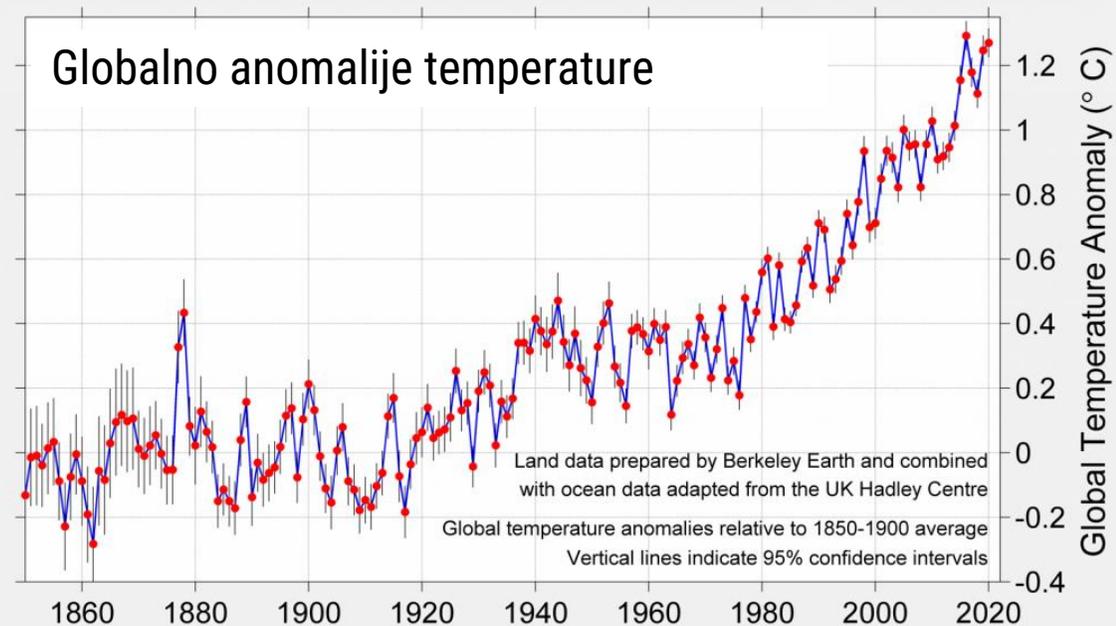


Odstupanja (2011.-2020.) – (1951.-1980.)

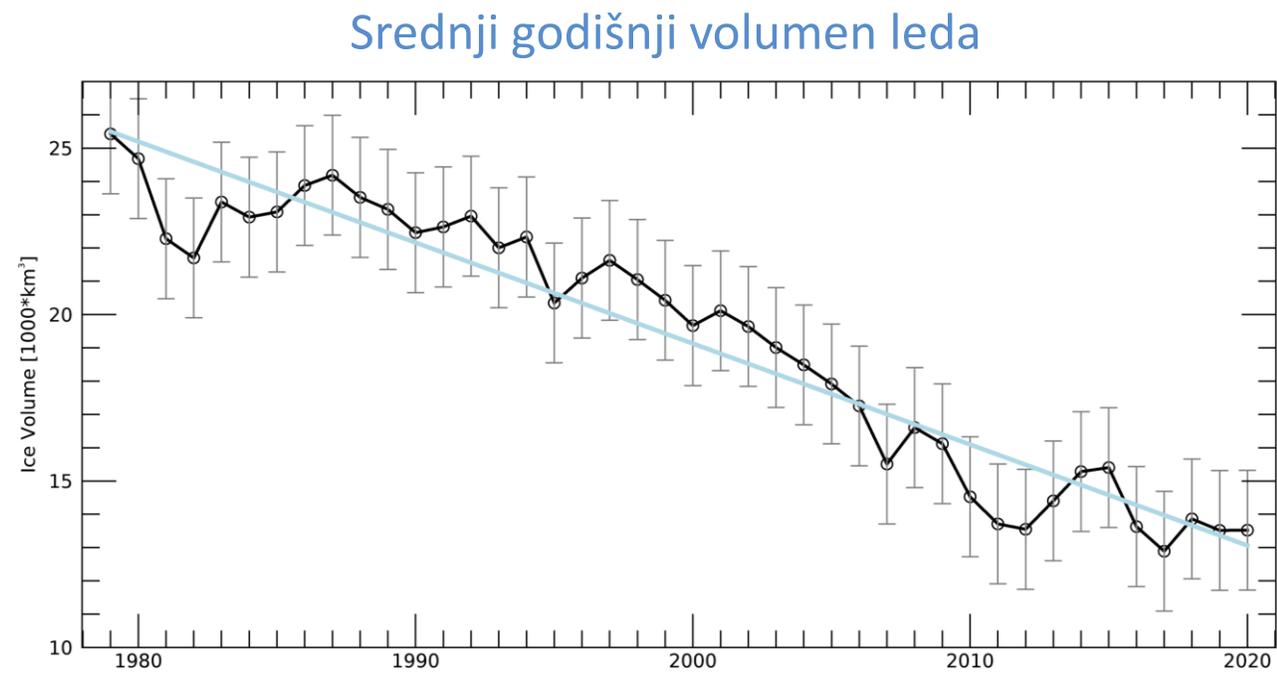
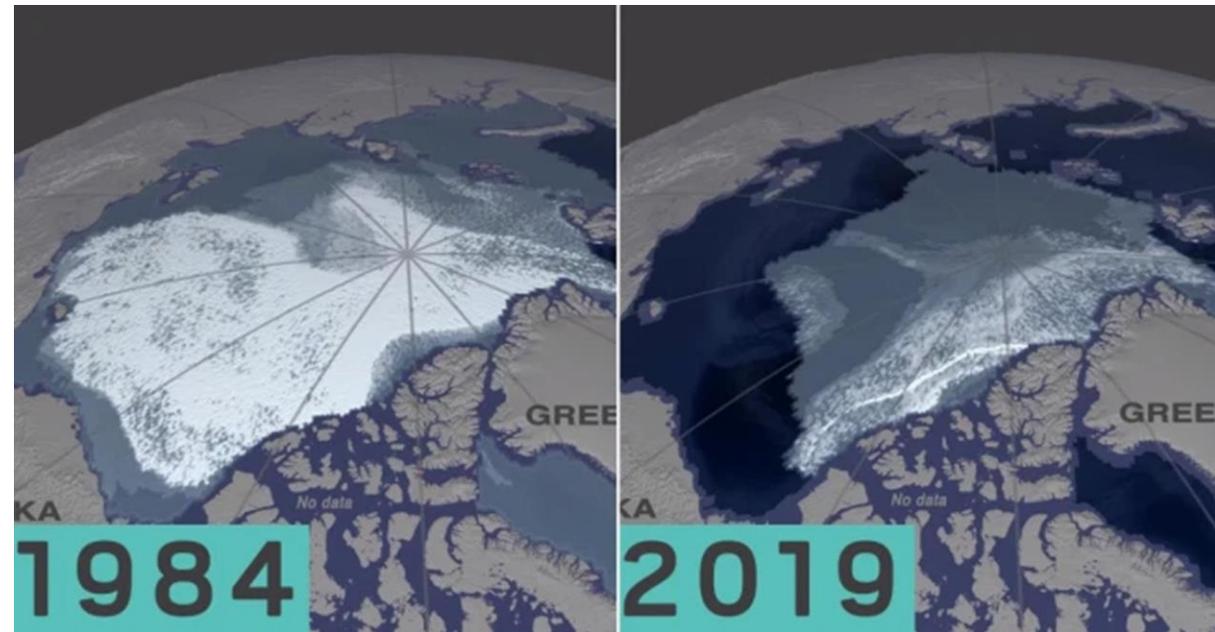


- Porast temperature nije jednak na cijeloj Zemlji
- Arktičko područje se zagrijava dvostruko brže od ostalih dijelova – **Arktička amplifikacija**

Globalno anomalije temperature



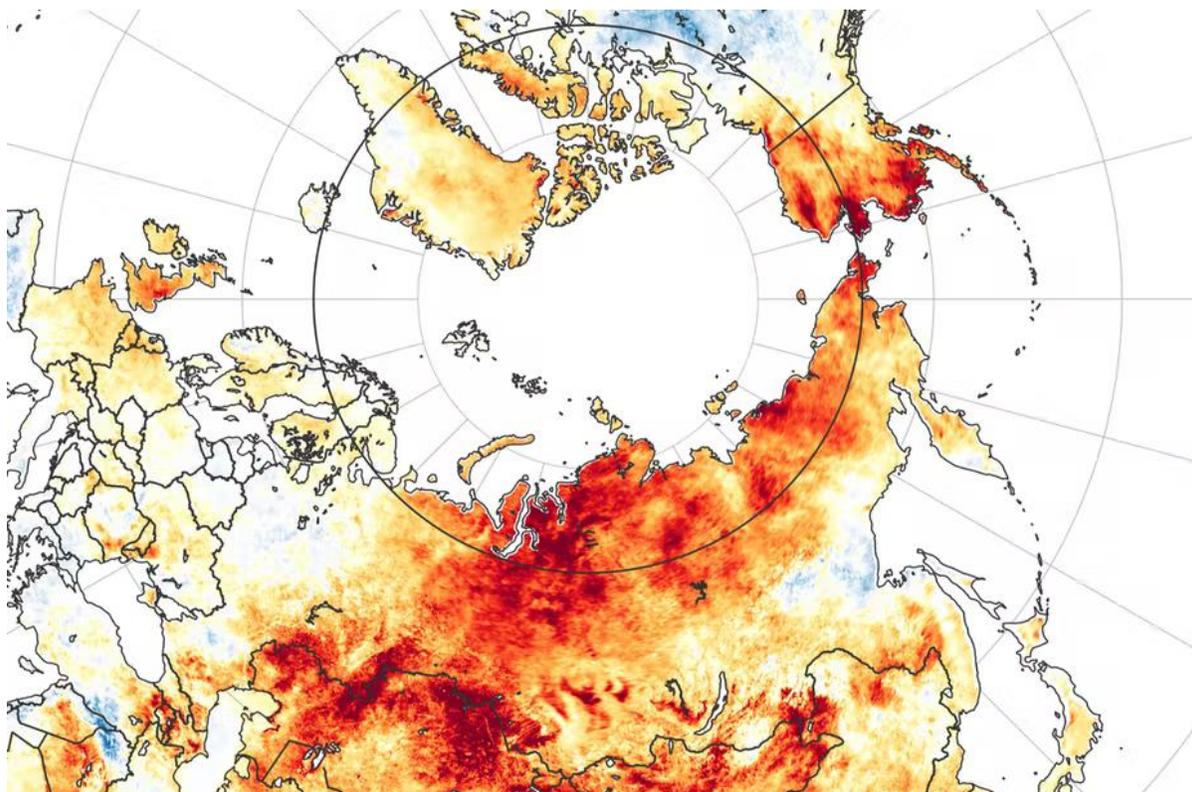
Arktička amplifikacija



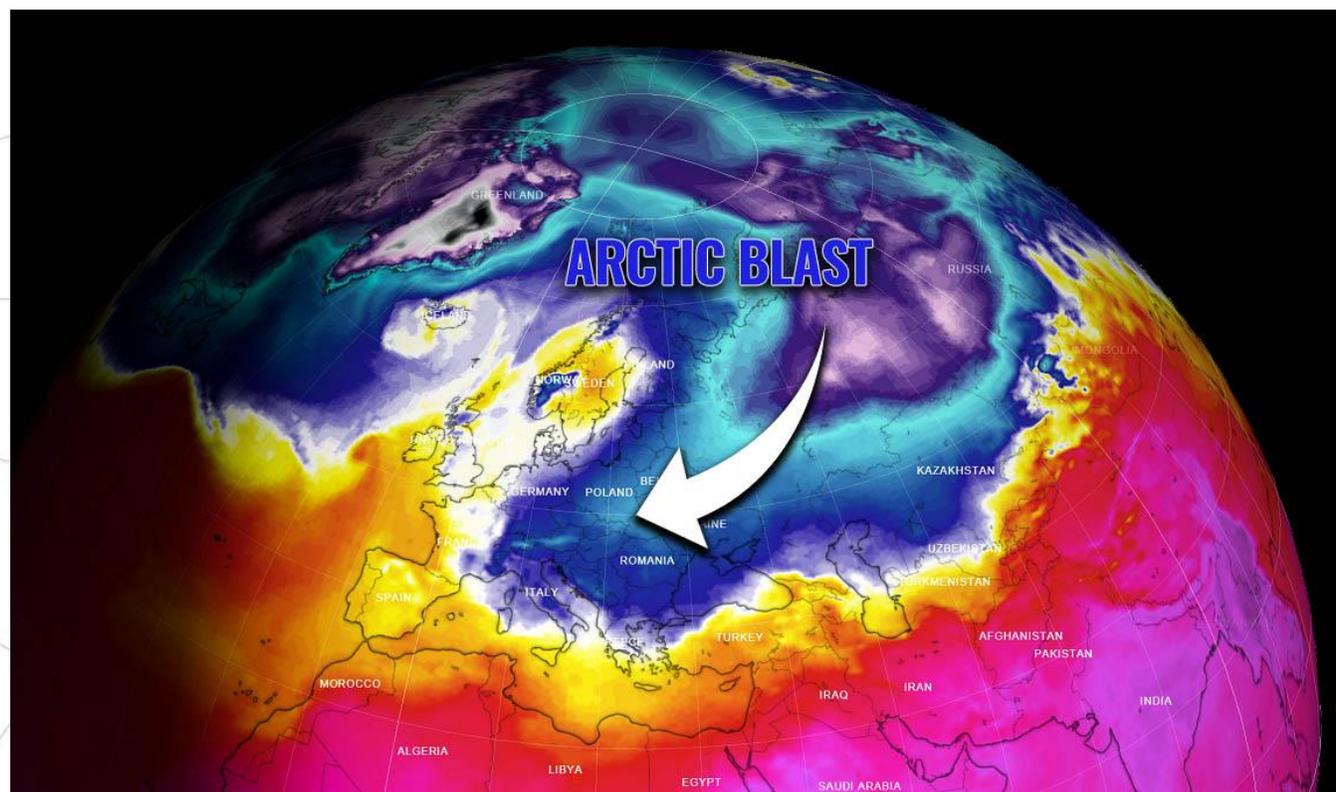
Arktička amplifikacija

Topljenje arktičkog leda – globalni utjecaj

Toplinski valovi (ljetno)

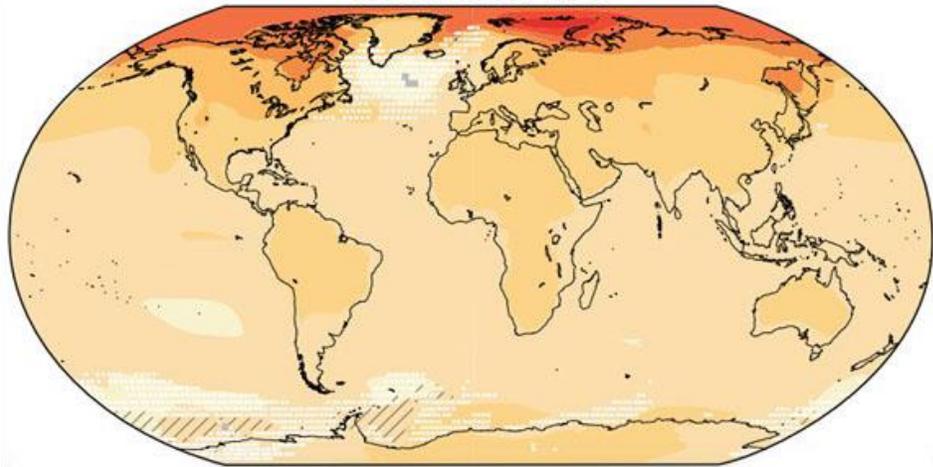


Prodori polarnog zraka (zimno)

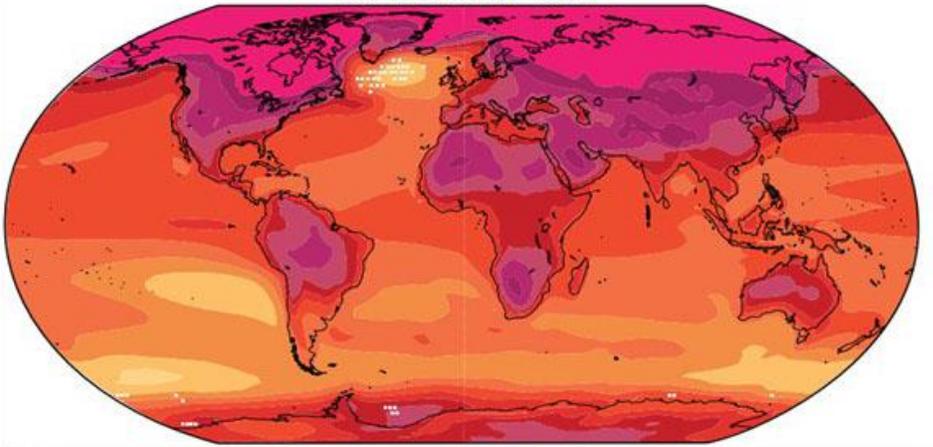


Što nas čeka u budućnosti?

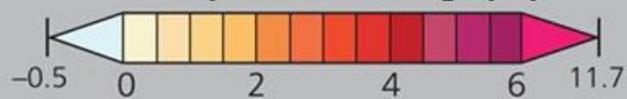
RCP2.6 2081–2100



RCP8.5 2081–2100

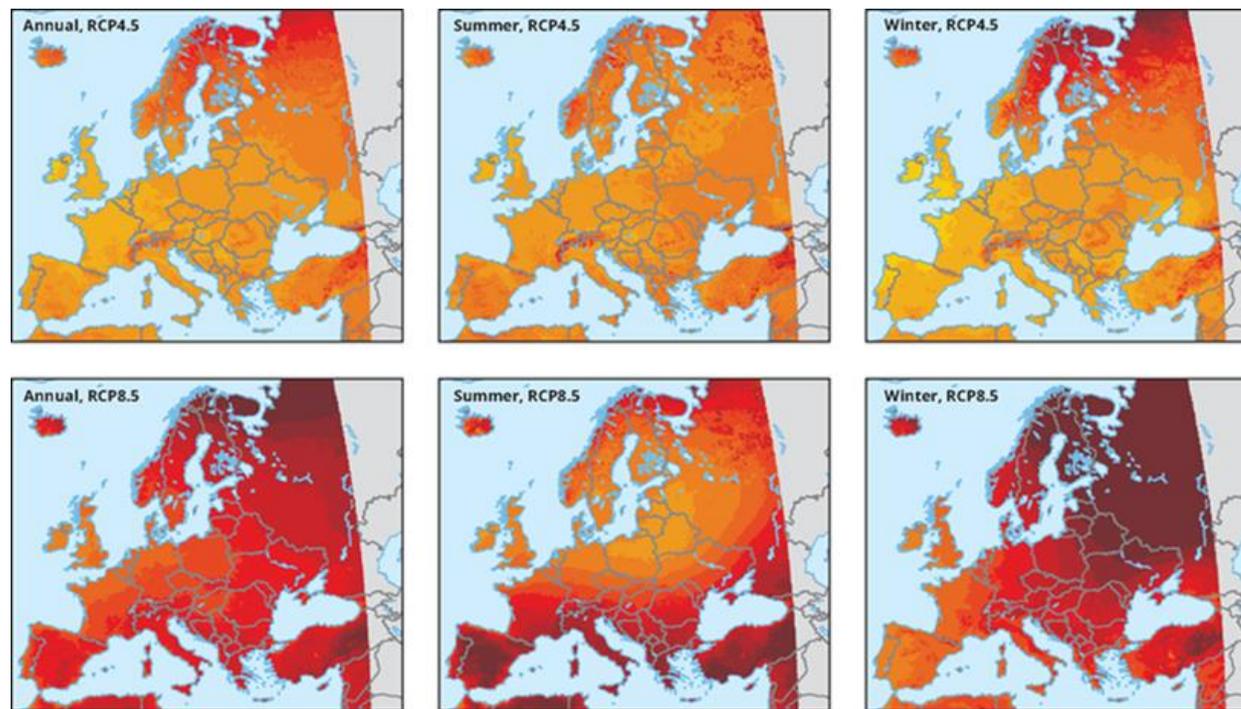


Temperature Change (°C)



Source: IPCC

Klimatske projekcije



Projected change in annual, summer and winter temperature for the forcing scenarios RCP4.5 and RCP8.5



Source: CORDEX

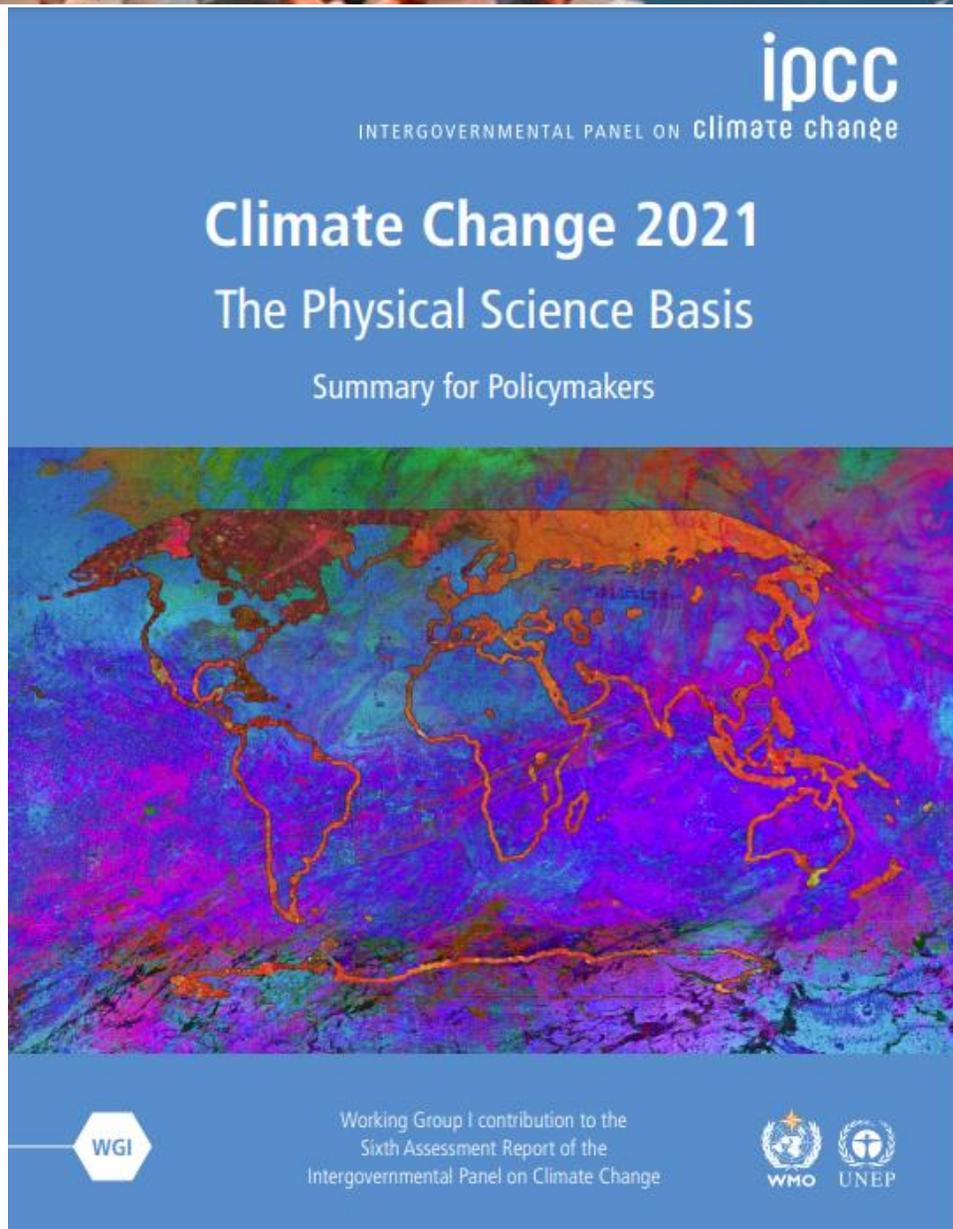
Što nas čeka u budućnosti?



Klima ekstrema...



Što nas čeka u budućnosti?



- **Porast temperature** će se nastaviti barem do polovine stoljeća bez obzira na scenarij stakleničkih plinova
- **Globalno zatopljenje** će premašiti **1.5 °C** osim ako se ne poduzmu drastične mjere smanjenja emisija stakleničkih plinova
- **Porast učestalosti i intenziteta toplinskih valova** (u atmosferi i moru), porast intenziteta oborine, poljoprivredne i ekološke suše u nekim područjima, učestalije intenzivne tropske ciklone, topljenje arktičkog leda, snježnog pokrivača i permafrosta

Što nas čeka u budućnosti?

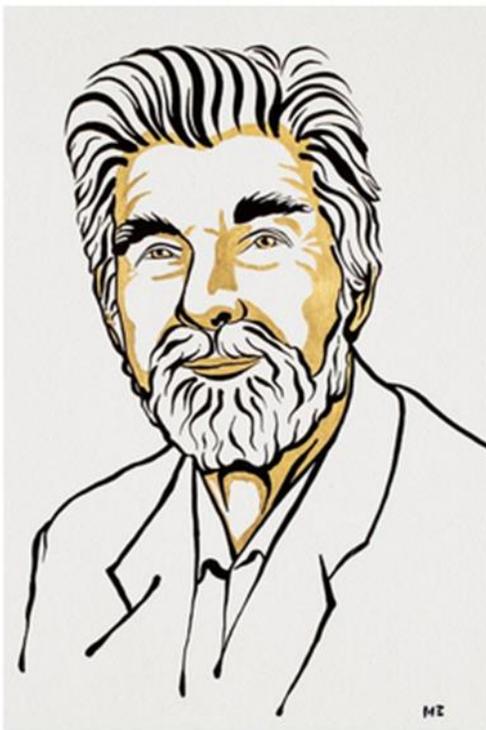
The Nobel Prize in Physics 2021



Ill. Niklas Elmehed © Nobel Prize Outreach

Syukuro Manabe

Prize share: 1/4



Ill. Niklas Elmehed © Nobel Prize Outreach

Klaus Hasselmann

Prize share: 1/4



Ill. Niklas Elmehed © Nobel Prize Outreach

Giorgio Parisi

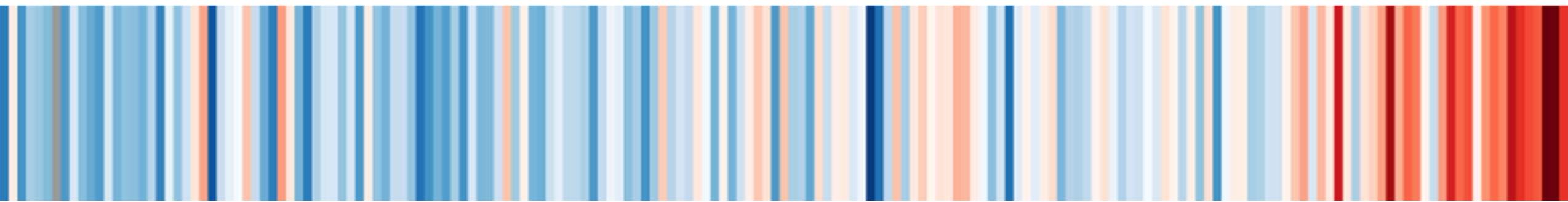
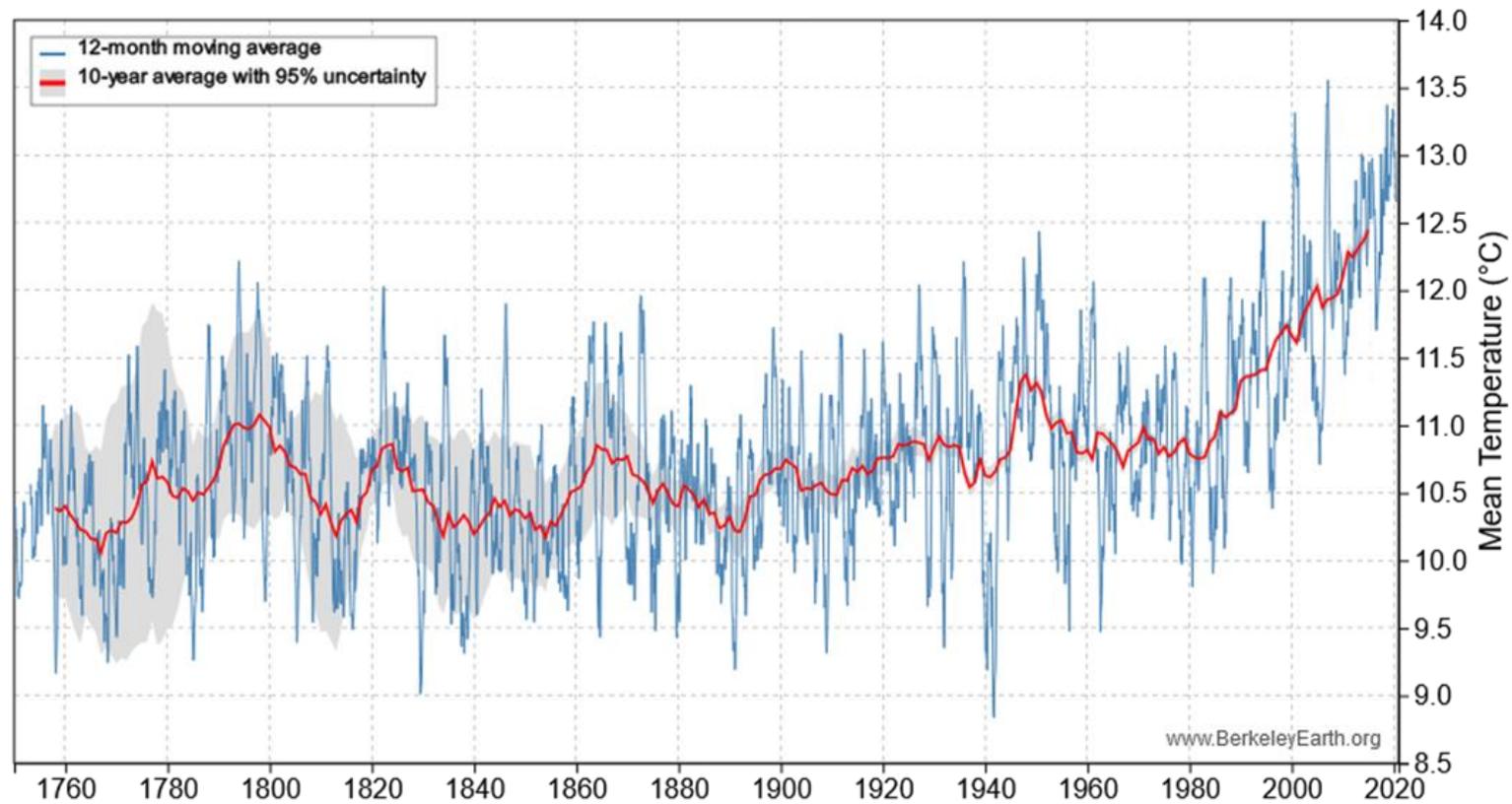
Prize share: 1/2

Syukuro Manabe – povišene koncentracije CO_2 u atmosferi uzrokuju povećanje temperature na Zemlji. Postavio je temelje za razvoj klimatskih modela klimatskog sustava Zemlje (1960.).

Klaus Hasselmann – razvio klimatski model na temelju fundamentalnih zakona atmosferske fizike. Ukazao je na važnost oceana kao tromije komponente klimatskog sustava te na nužnost združivanja atmosfere i oceana u klimatskim modelima. Njegova istraživanja su ukazala na pouzdanost klimatskih modela usprkos promjenjivosti i kaotičnosti atmosferskih procesa, Njegove metode su pomogle u povezivanju antropogenih emisija CO_2 i globalnog zatopljenja.

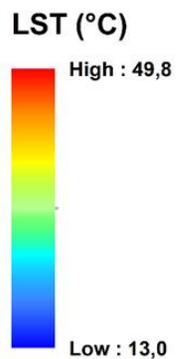
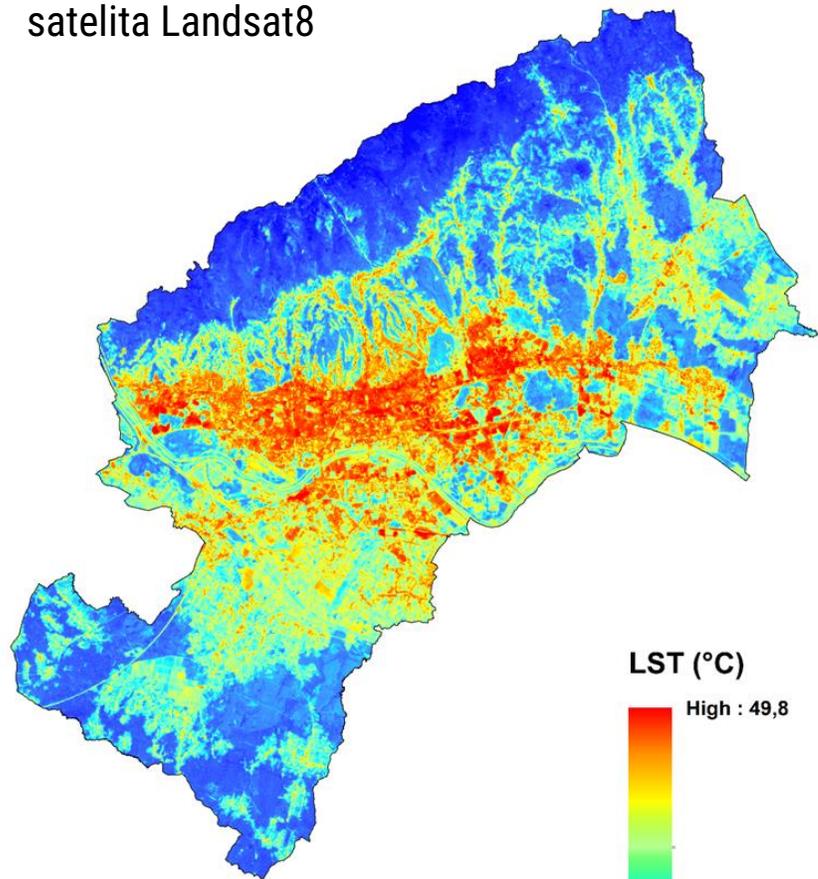
Hrvatska – klimatske promjene

Hrvatska

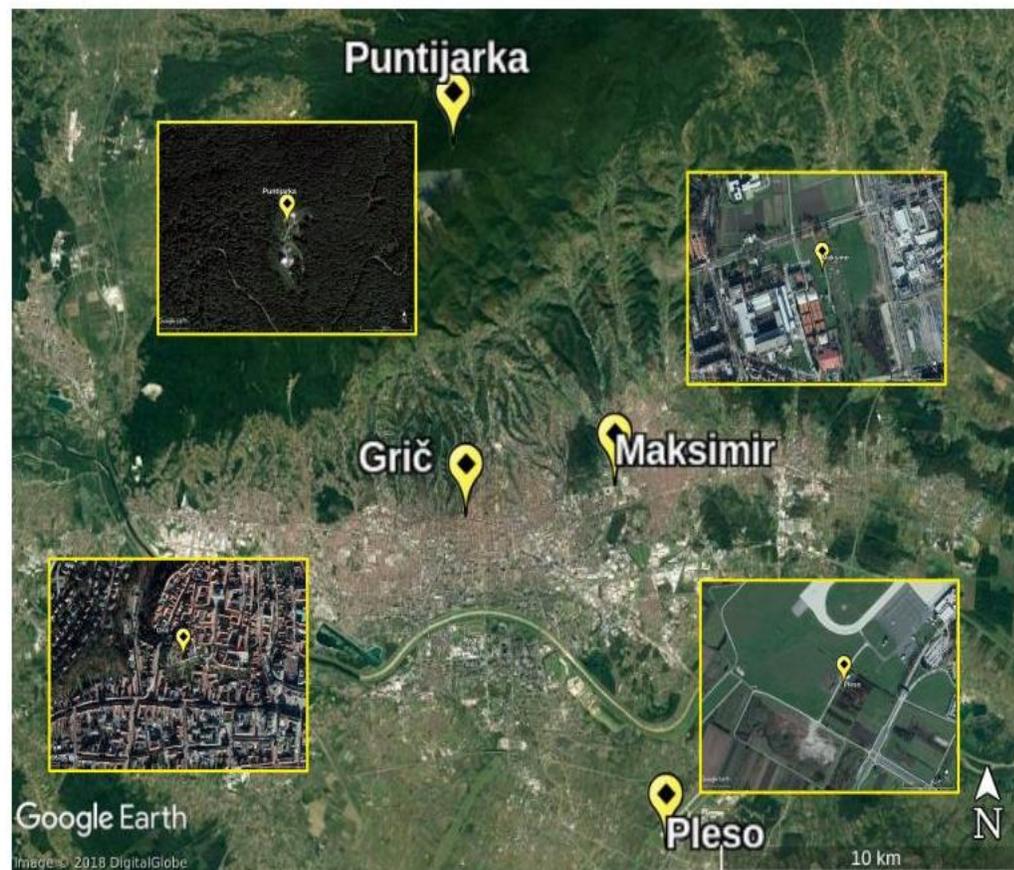


Obilježja klime grada Zagreba

Toplinsko opterećenje (ljetno 2019., površinska temperatura) prema podacima satelita Landsat8



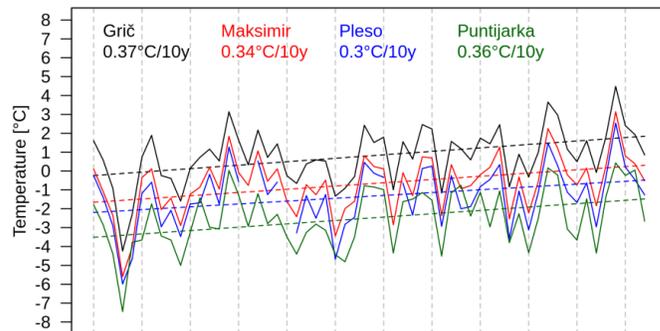
0 7,5 15 km



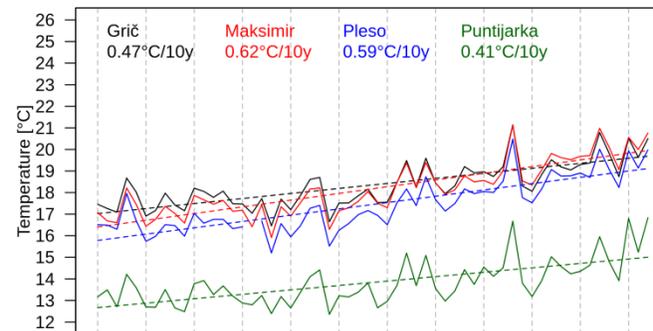
Station name	Type	Alt(m)	Lon (°)	Lat (°)
Puntijarka	Mountain	991	15.9683	45.9075
Grič	Urban	157	15.9719	45.8144
Maksimir	Sub-urban	123	16.0336	45.8219
Pleso	Airport	106	16.0539	45.7292

Temperatura zraka

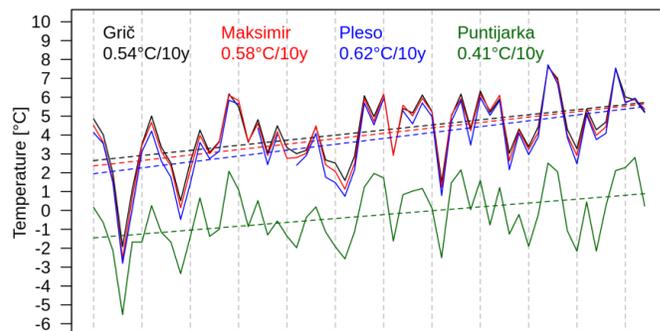
Temperatura 07:00, DJF



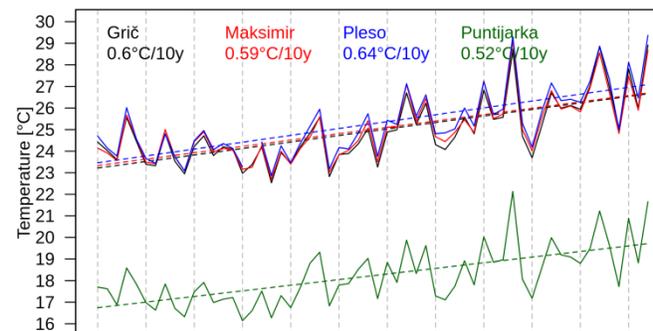
Temperatura 07:00, JJA



Temperatura 14:00, DJF



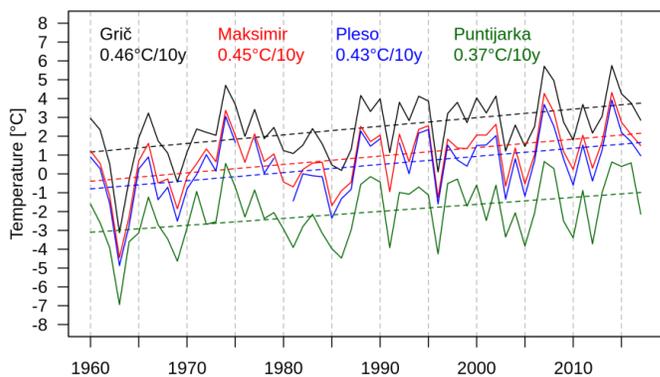
Temperatura 14:00, JJA



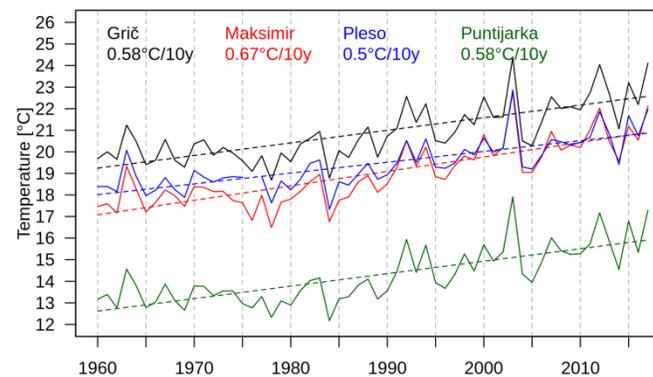
ZIMA

LJETO

Temperatura 21:00, DJF

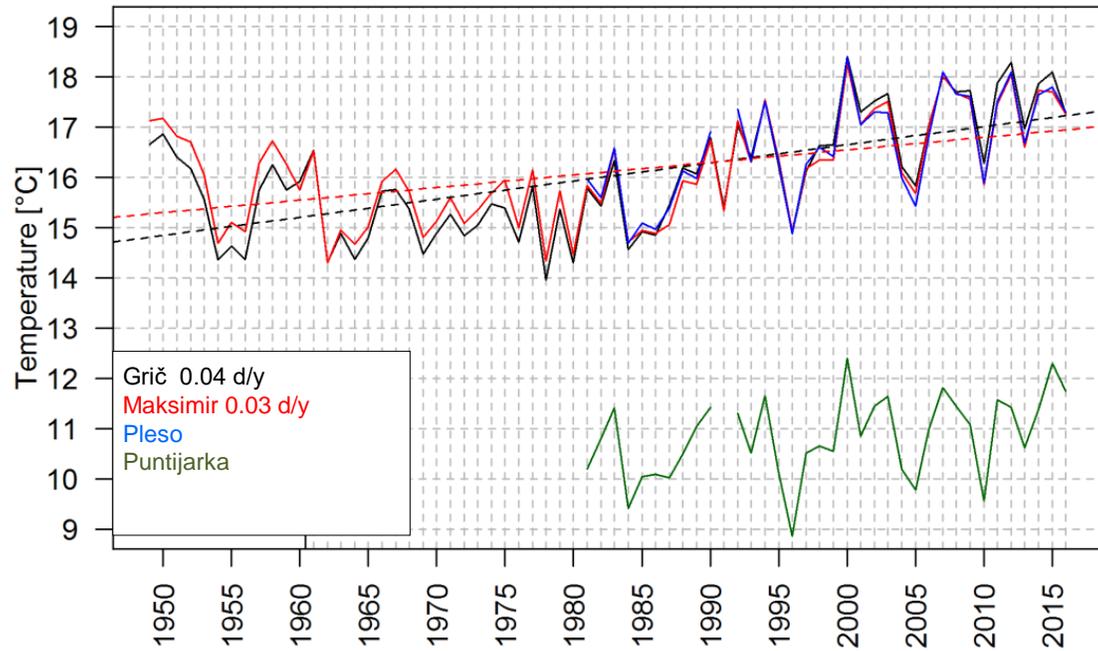


Temperatura 21:00, JJA

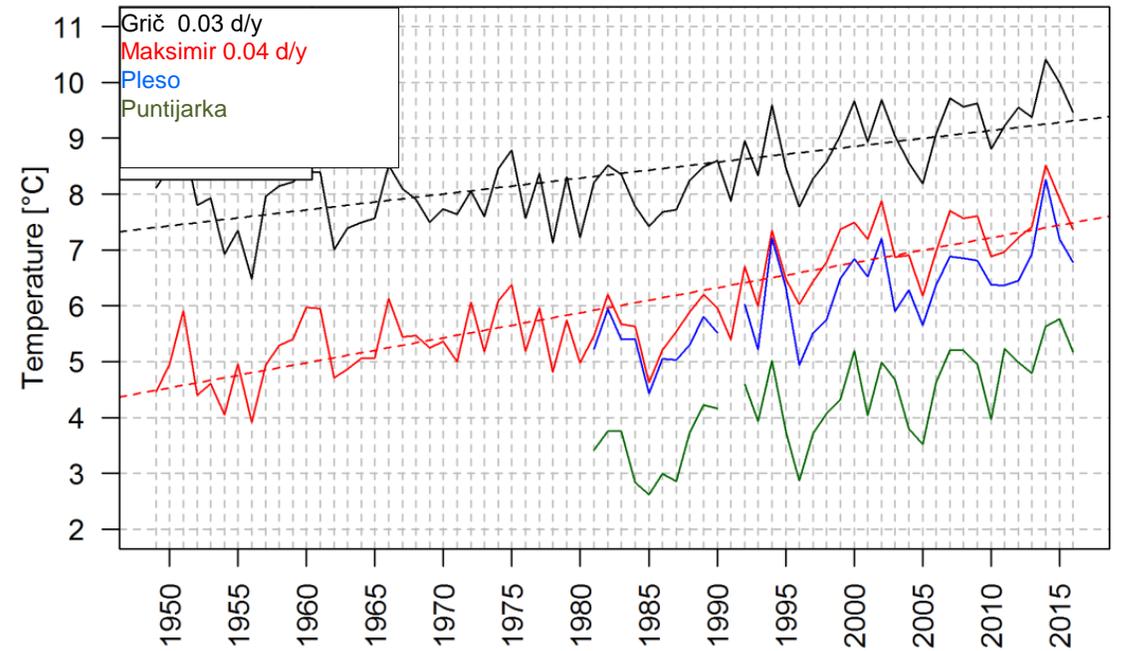


Temperatura zraka - ekstremi

Tmax, Zagreb, 1949-2016

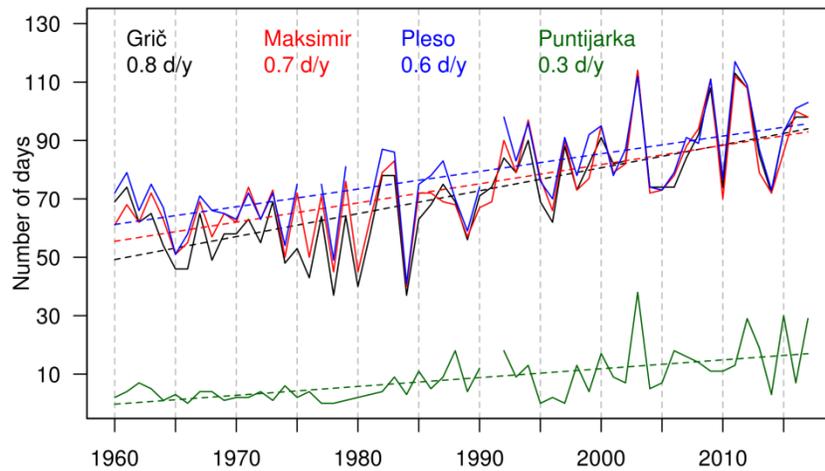


Tmin, Zagreb, 1949-2016

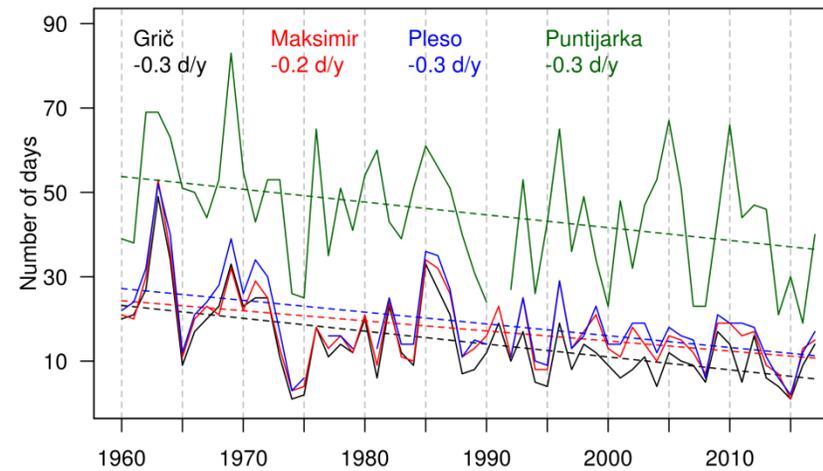


Toplinski indeksi

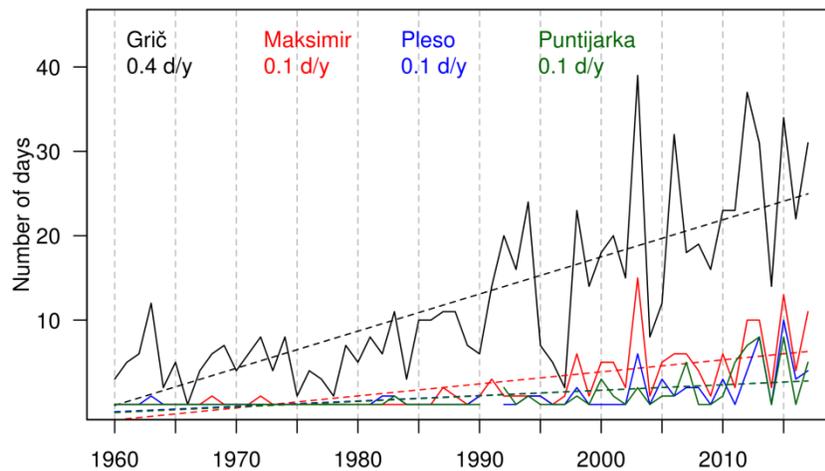
Broj ljetnih dana ($T_{max} > 25^{\circ}\text{C}$)



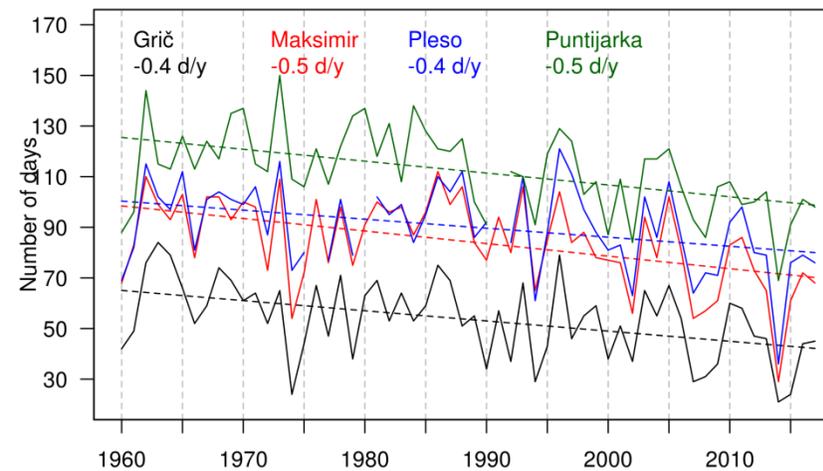
Broj ledenih dana ($T_{max} < 0^{\circ}\text{C}$)



Broj tropskih noći dana ($T_{min} > 25^{\circ}\text{C}$)



Broj dana s mrazom ($T_{min} < 0^{\circ}\text{C}$)



Zagreb – promjena klimatskih klasa

Köppen- Geigerove klimatske klase

Postaja	1960–1989	1988–2017	Razdoblje promjene klimatske klase
Grič	Cf <u>b</u>	Cf <u>a</u>	1978–2007
Maksimir	Cf <u>b</u>	Cf <u>a</u>	1987–2016
Pleso	Cf <u>b</u>	Cf <u>a</u>	1987–2016
Puntijarka	<u>D</u> fb	<u>C</u> fb	1964–1993

Grič, Pleso, Maksimir

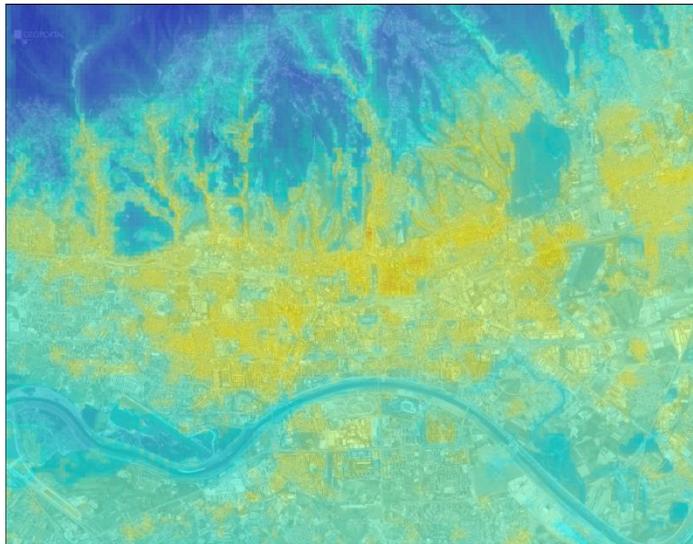
Vlažna **umjereno topla klima (Cfb)** → Vlažna **umjereno topla s vrućim ljetima (Cfa)**
b → a posljedica **porasta srednje mjesečne temperature najtoplijeg mjeseca** (srpanj) koja je sada iznad 22°C.

Puntijarka

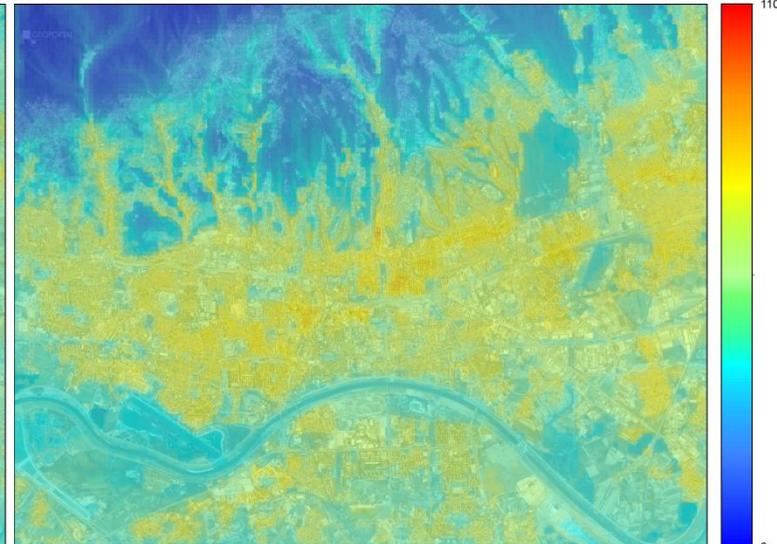
Vlažna **snježno-šumska klima (Dfb)** → Vlažna **umjereno topla (Cfb)**
D → C posljedica **porasta srednje mjesečne temperature najhladnijeg mjeseca** (siječanj) koja više ne poprima vrijednosti manje od -3°C.

Utjecaj urbanizacije - utjecaj globalnog zatopljenja

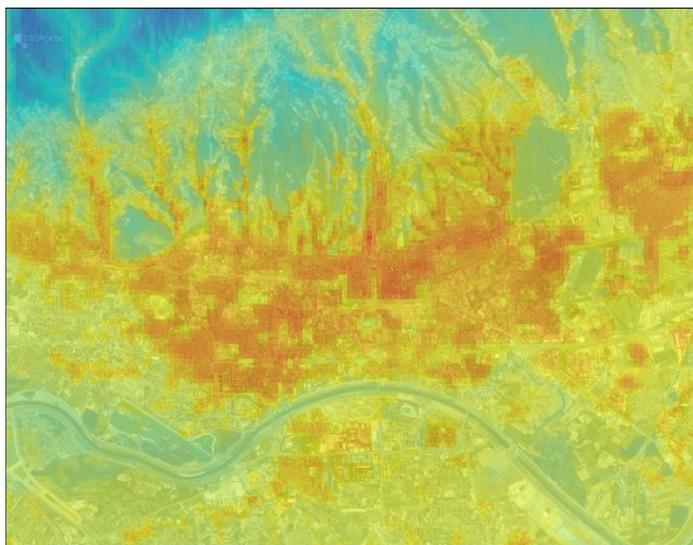
Ljetni dani, klima 1951-1980, grad 1968



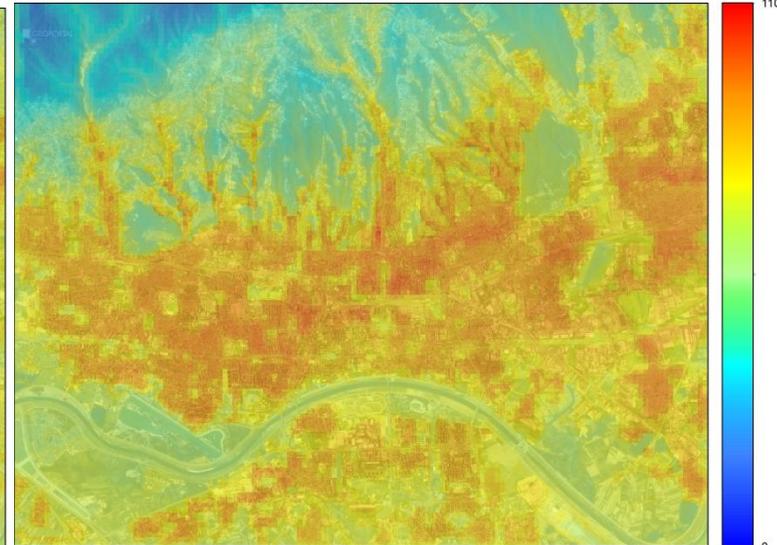
Ljetni dani, klima 1951-1980, grad 2011



Ljetni dani, klima 1981-2010, grad 1968

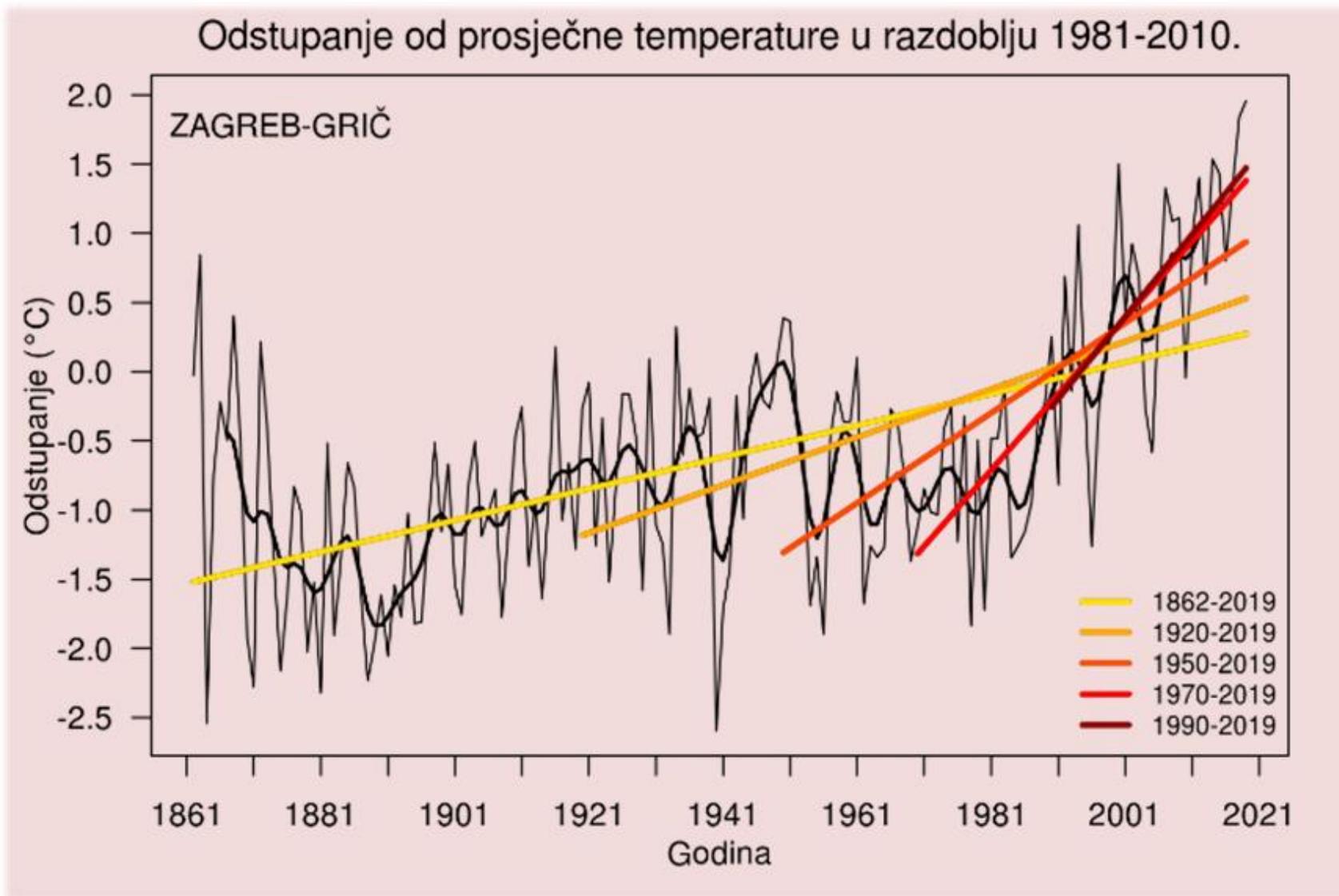


Ljetni dani, klima 1981-2010, grad 2011

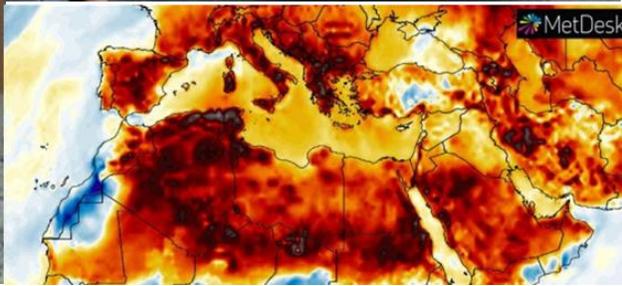


Ciljane numeričke
simulacije
(model MUKLIMO_3)

Zatopljenje grada Zagreba

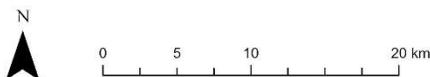
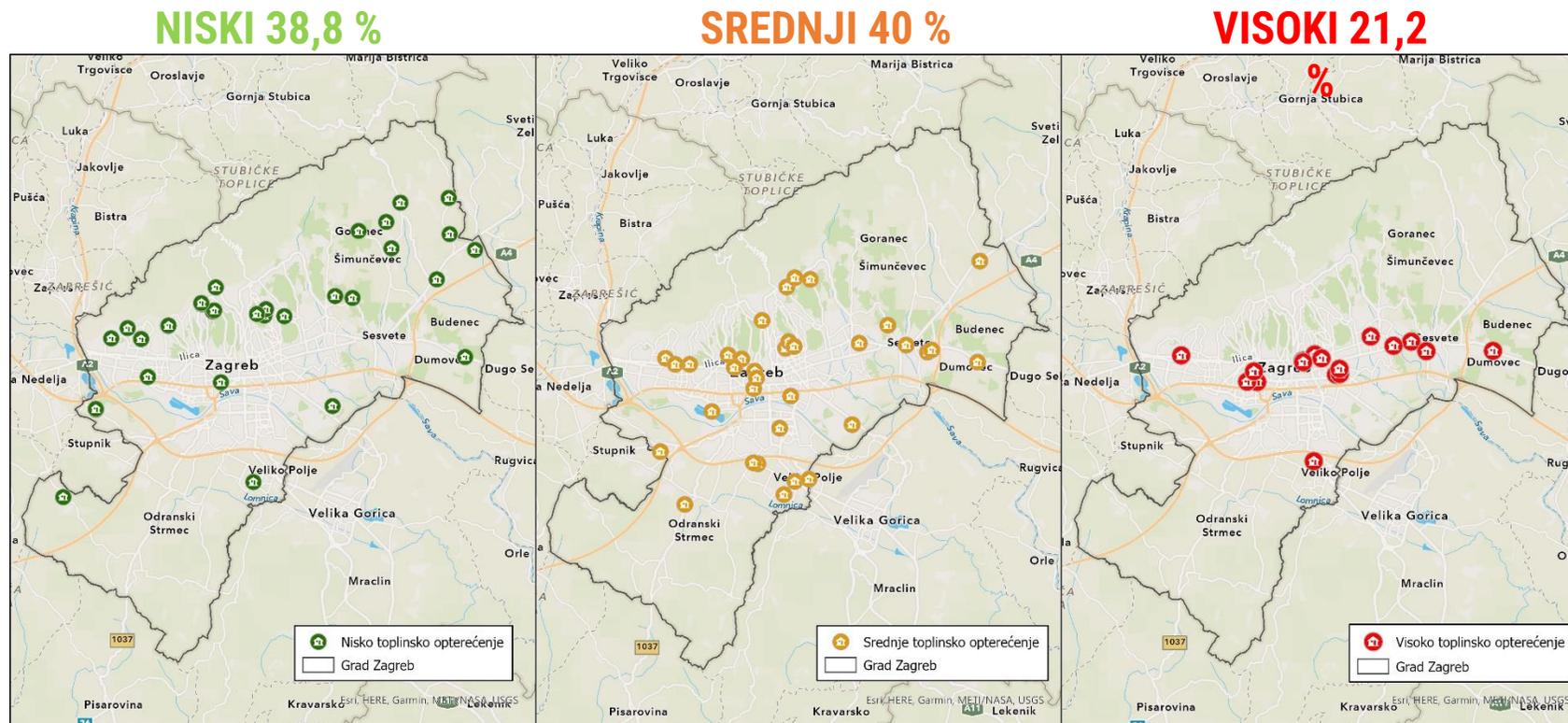


Posljedice...



Utjecaj na građane

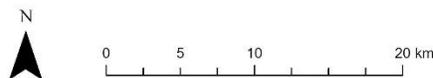
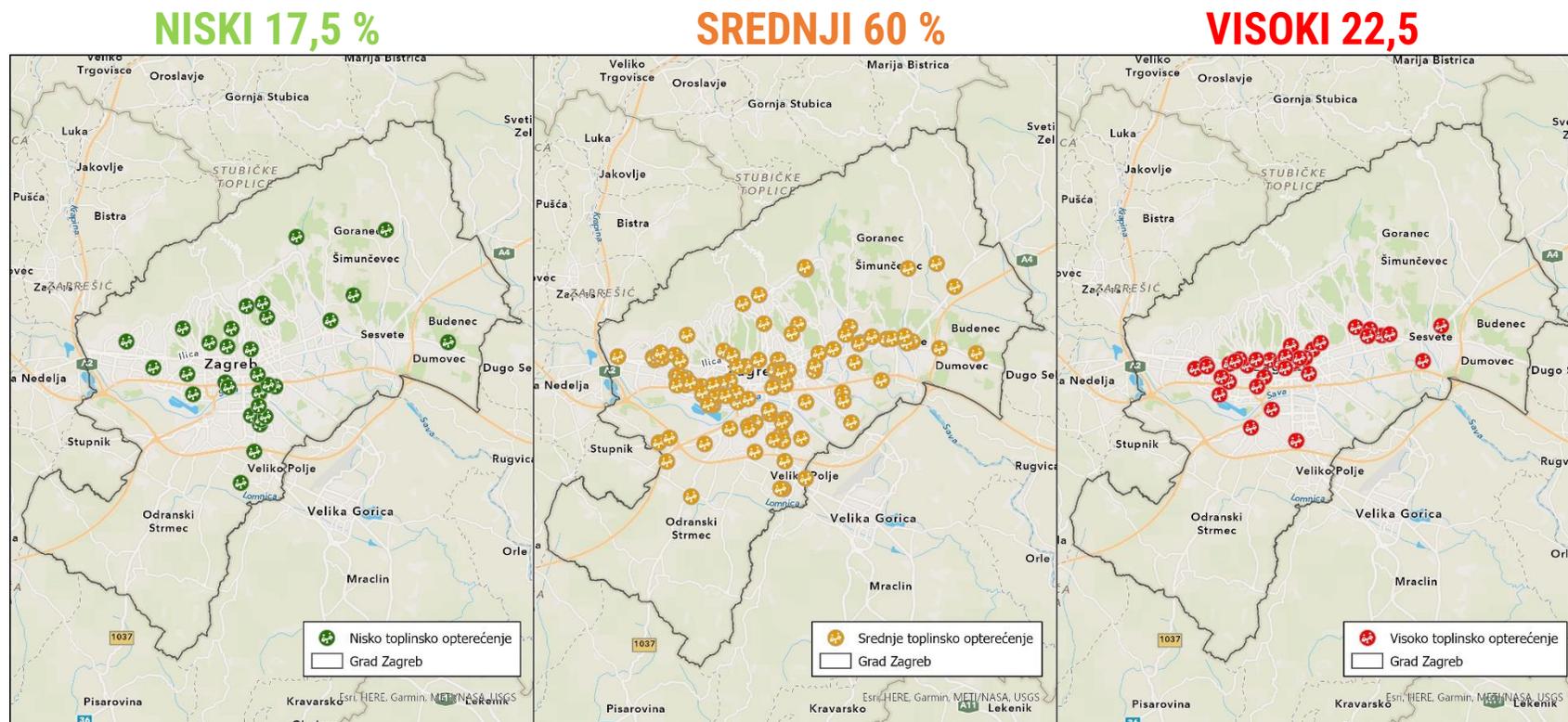
Rizik od toplinskog stresa (utjecaj temperature i dostupnosti zelenih površina)
– domovi za starije i nemoćne



Izvori podataka: Grad Zagreb, Gradski ured za strategijsko planiranje i razvoj Grada;
USGS (Landsat 8)

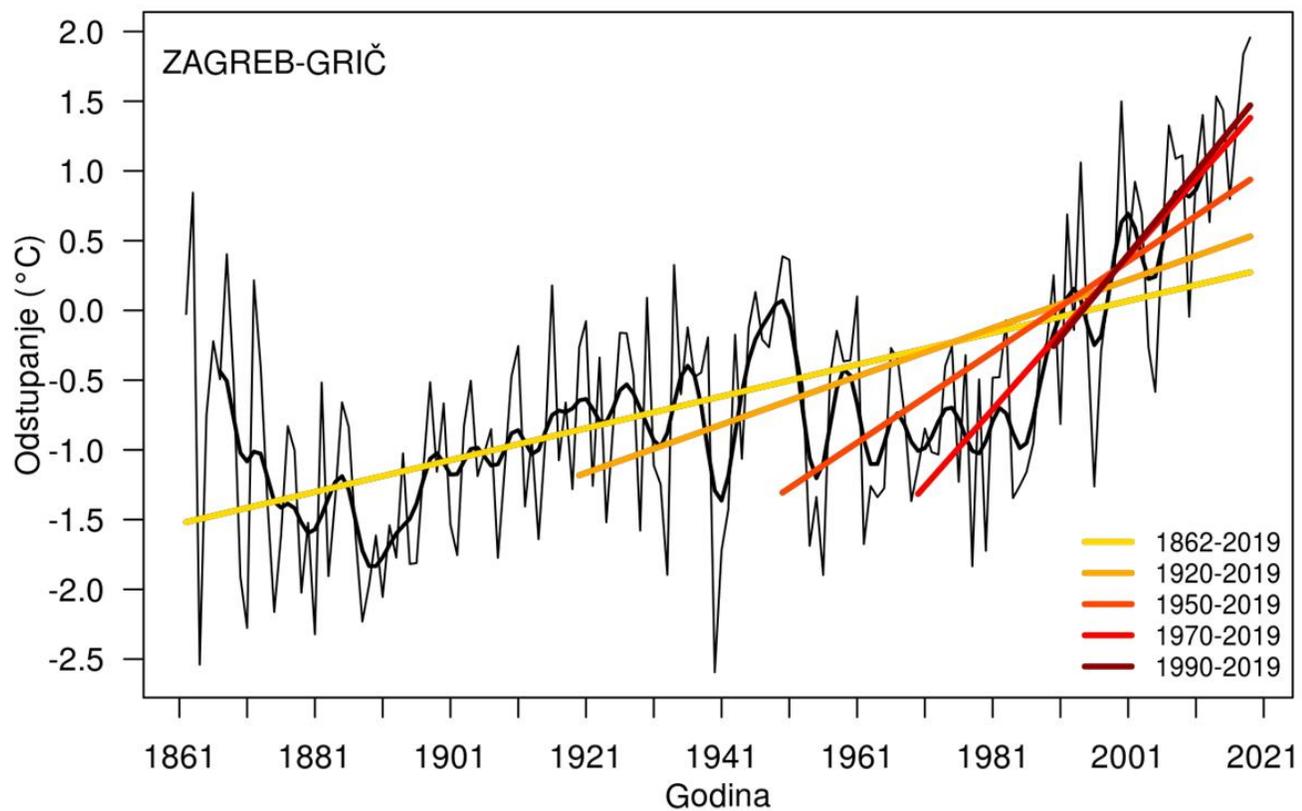
Utjecaj na građane

Rizik od toplinskog stresa (utjecaj tempertaure i dostupnosti zelenih površina)
– dječji vrtići



Izvori podataka: Grad Zagreb, Gradski ured za strategijsko planiranje i razvoj Grada;
USGS (Landsat 8)

Odstupanje od prosječne temperature u razdoblju 1981-2010.



Hrvatska

