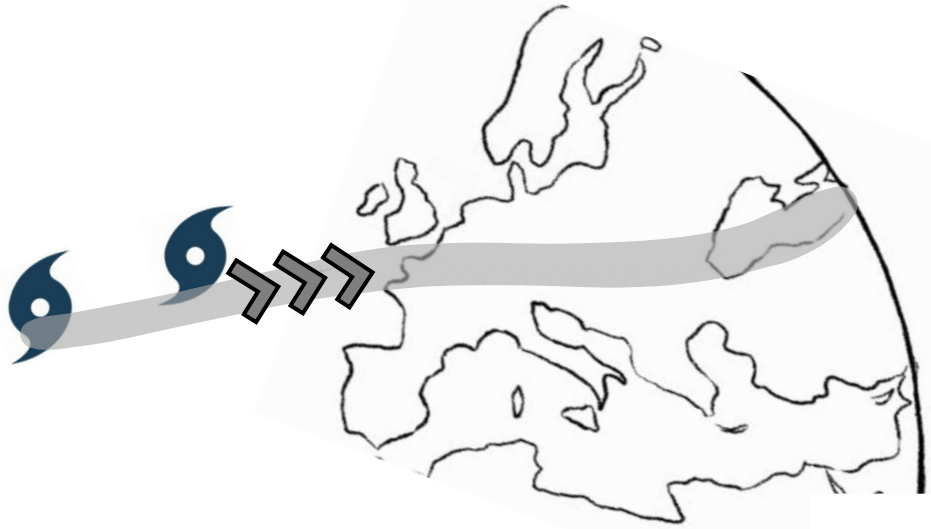
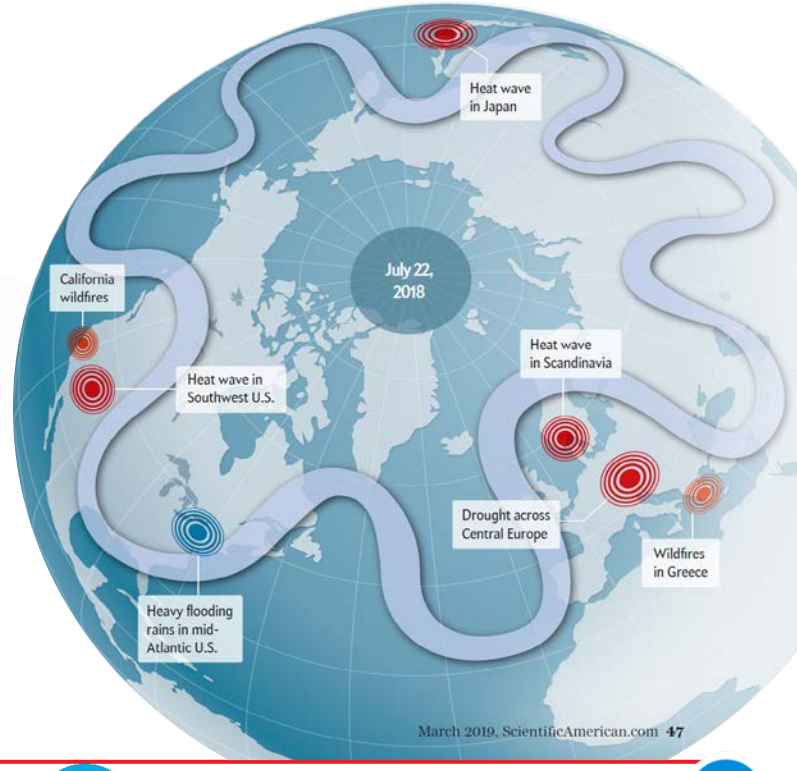
Three arguments for increasing weather persistence in boreal summer – and why we should care

Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu

VU VRIJE UNIVERSITEIT AMSTERDAM

Dim Coumou, Paolo de Luca, Kai Kornhuber, Efi Rousi, Rebecca Scholten, Paolo Scussolini, Fei Luo, Sem Vijverberg





10-02-2022

ECRA European Climate Research Alliance

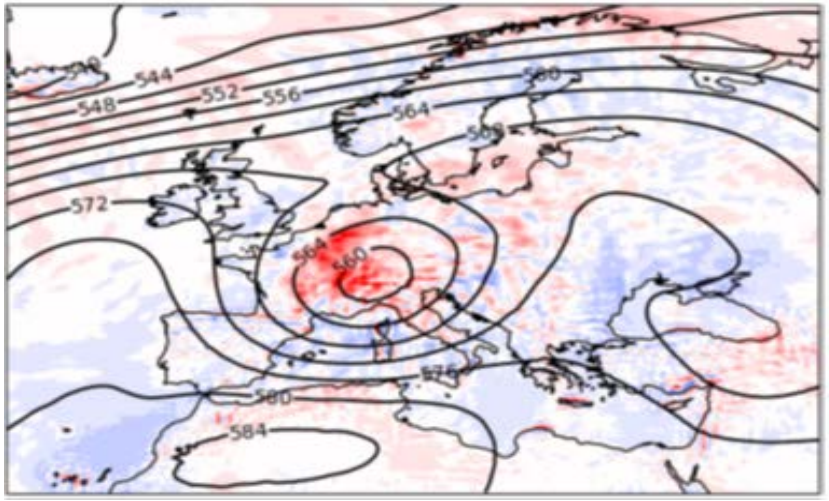
CLIMATE EXTREMES

Three arguments for increasing weather persistence in boreal summer – and why we should care

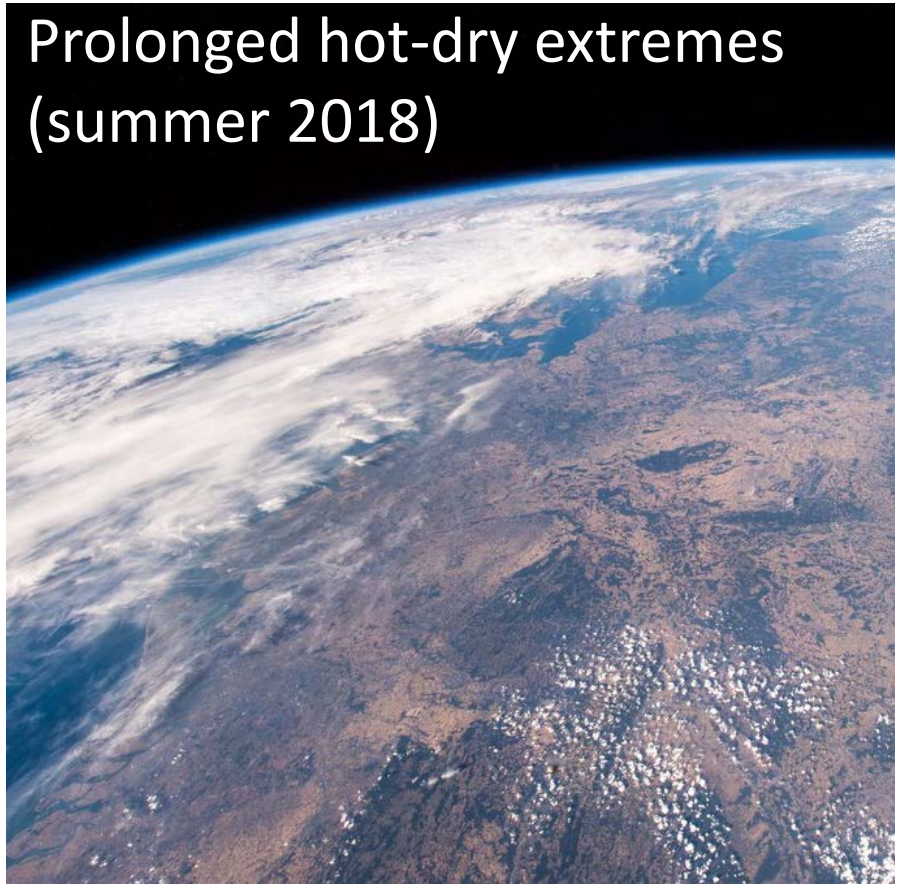
1. We see it in observations
2. We see it in climate models
3. Things are physically consistent

Why should we care? Persistent extremes

Stalling cut-off low (July 2021)

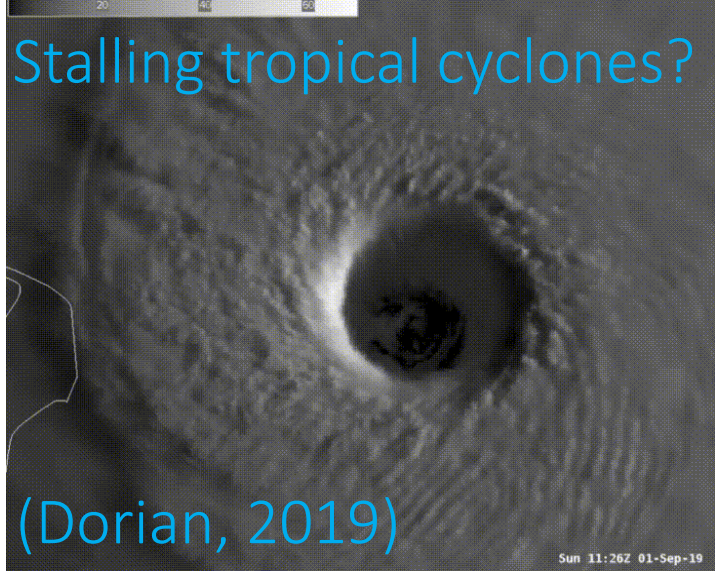


Prolonged hot-dry extremes (summer 2018)



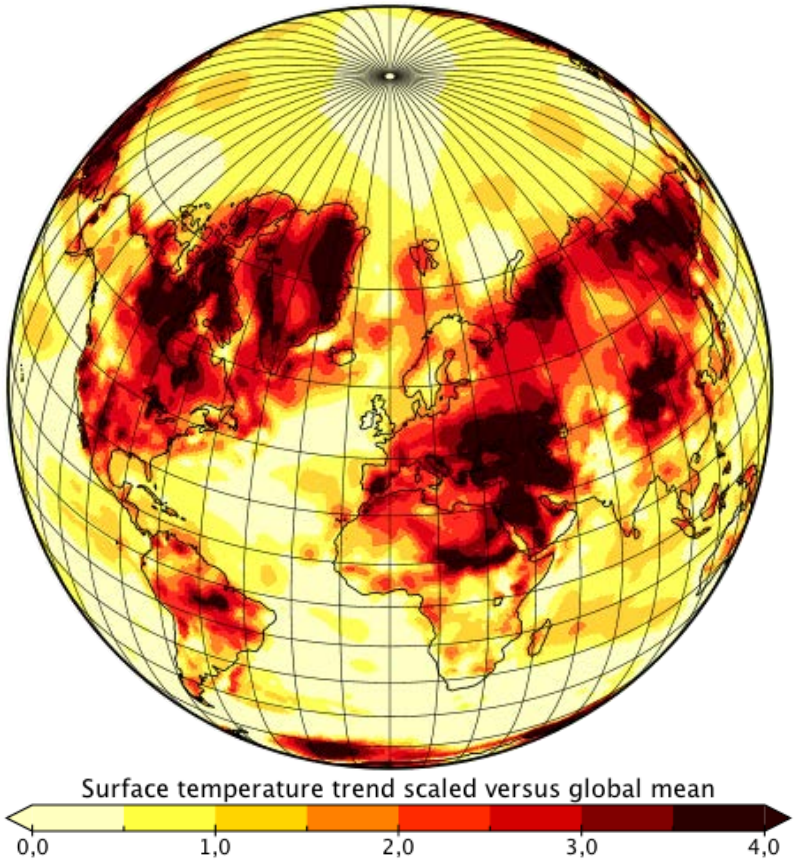
Agricultural impacts, wild fires, etc

Stalling tropical cyclones?

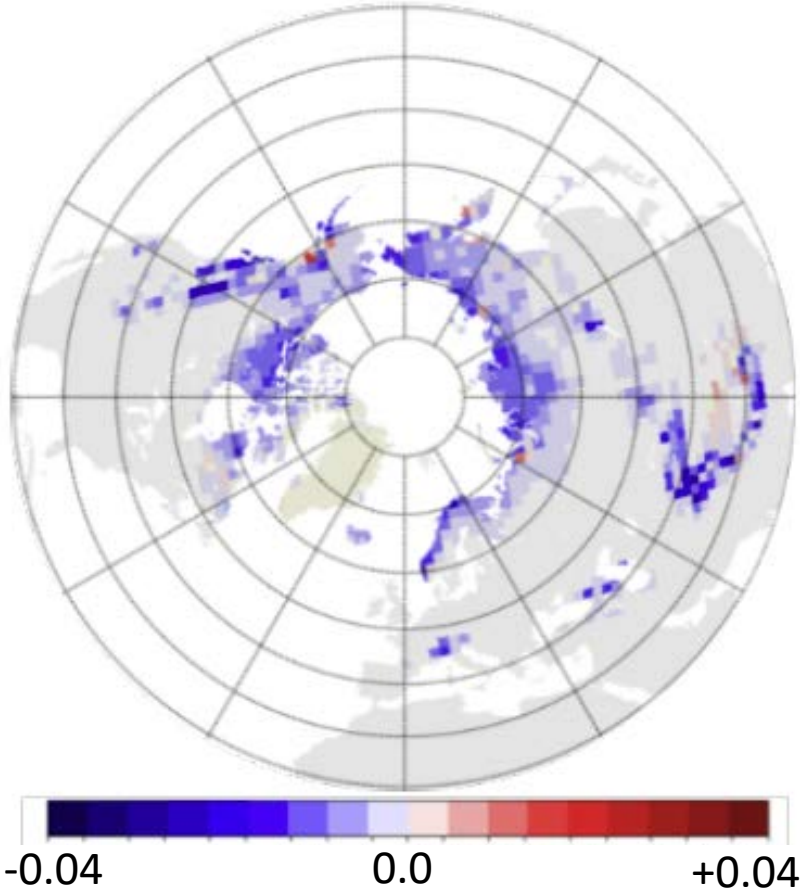


e.g. Kossin et al

Enhanced warming of high-latitude land in summer



ERA5, JJA trends 1979-2018



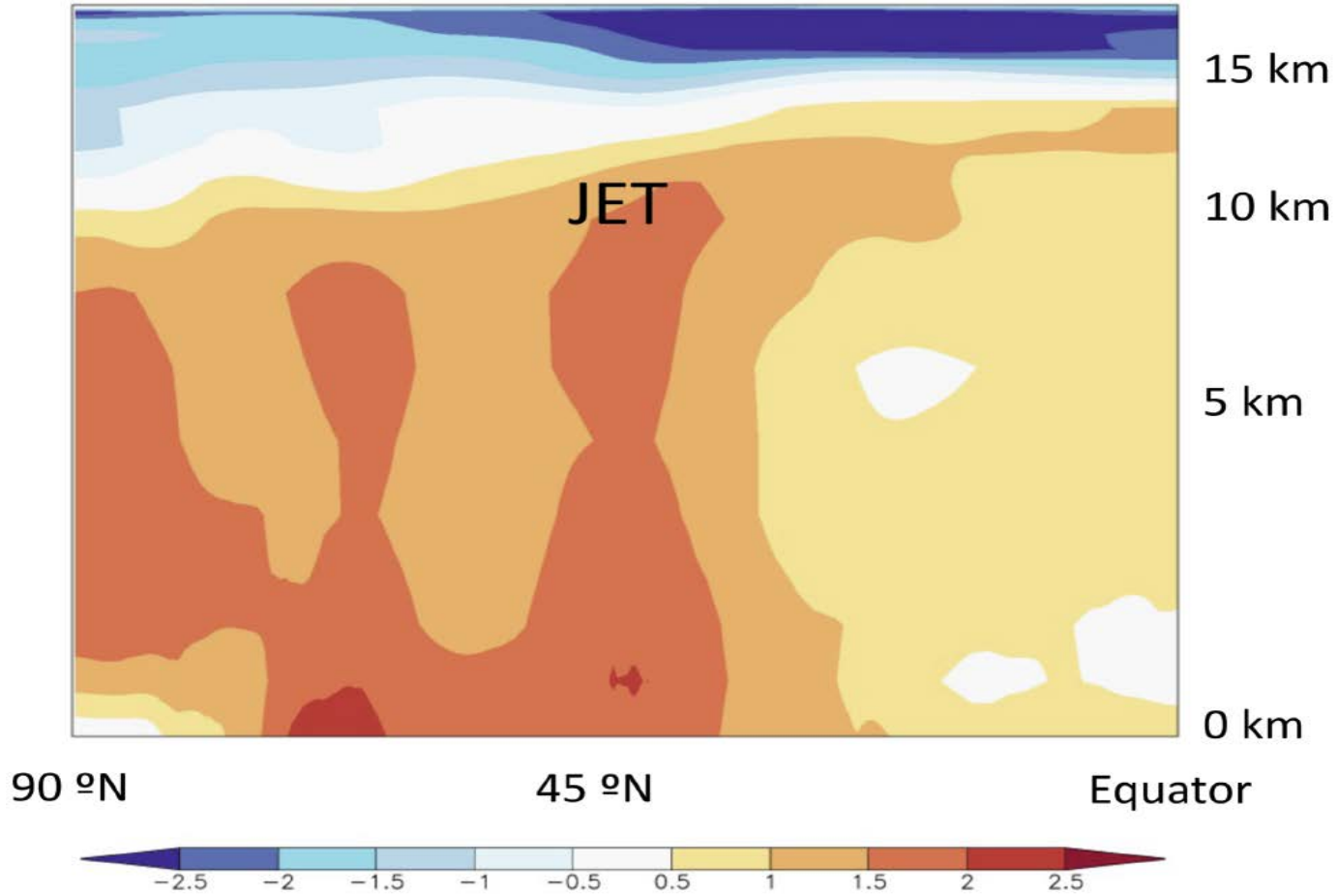
June snow cover trend (per-year) (1979-2018)

- Arctic ocean: No warming as all extra energy goes into melting sea-ice
- Arctic land: Rapid snow retreat associated with very strong warming

CLIMATE EXTREMES

Vijverberg; Coumou et al. (in review)

Enhanced warming of high-latitude land in summer



ERA5, JJA trends 1979-2018 (per degree of global warming)

- Arctic ocean: No warming as all extra energy goes into melting sea-ice
- Arctic land: Rapid snow retreat associated with very strong warming
- Warming penetrates to higher levels

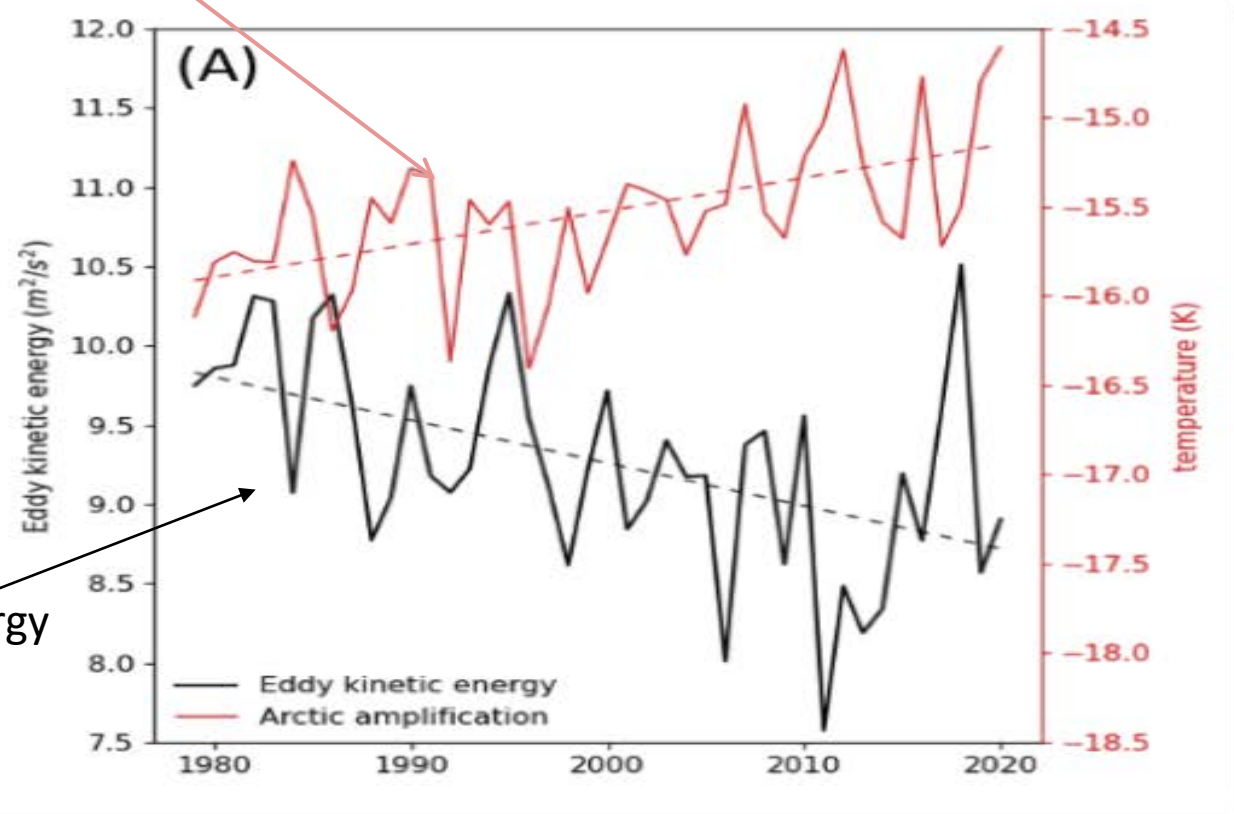
Philip et al (2021)

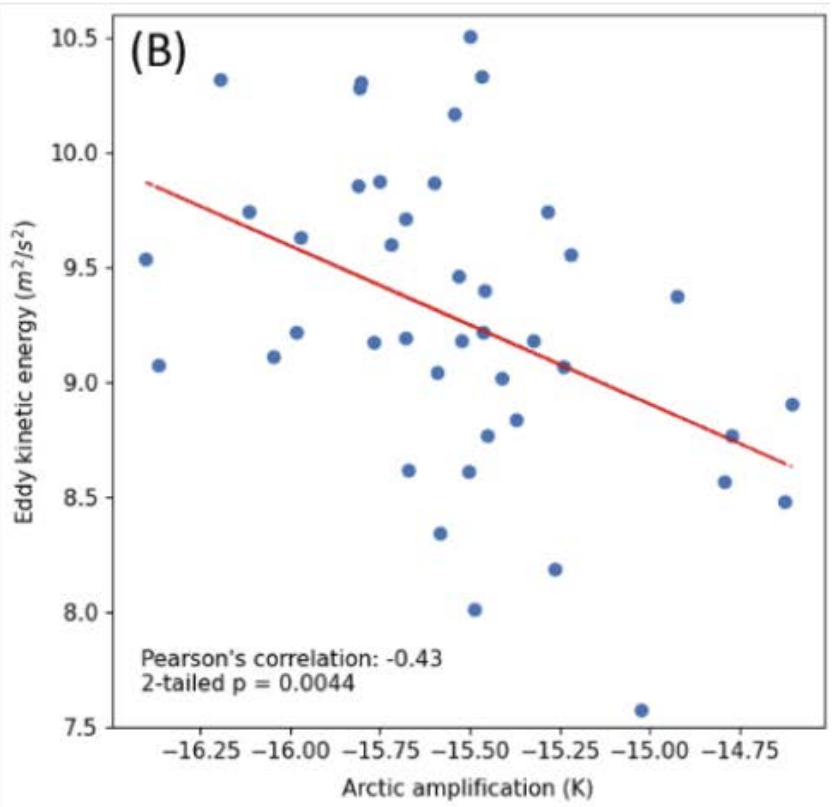
High-lat. land warming: Weakening of summer circulation

Weakening of westerlies and storm tracks in mid-latitudes since 1979, consistent with thermal wind balance

Arctic Amplification:
Above 65N – full northern hemisphere

Eddy Kinetic Energy
(35N-65N)





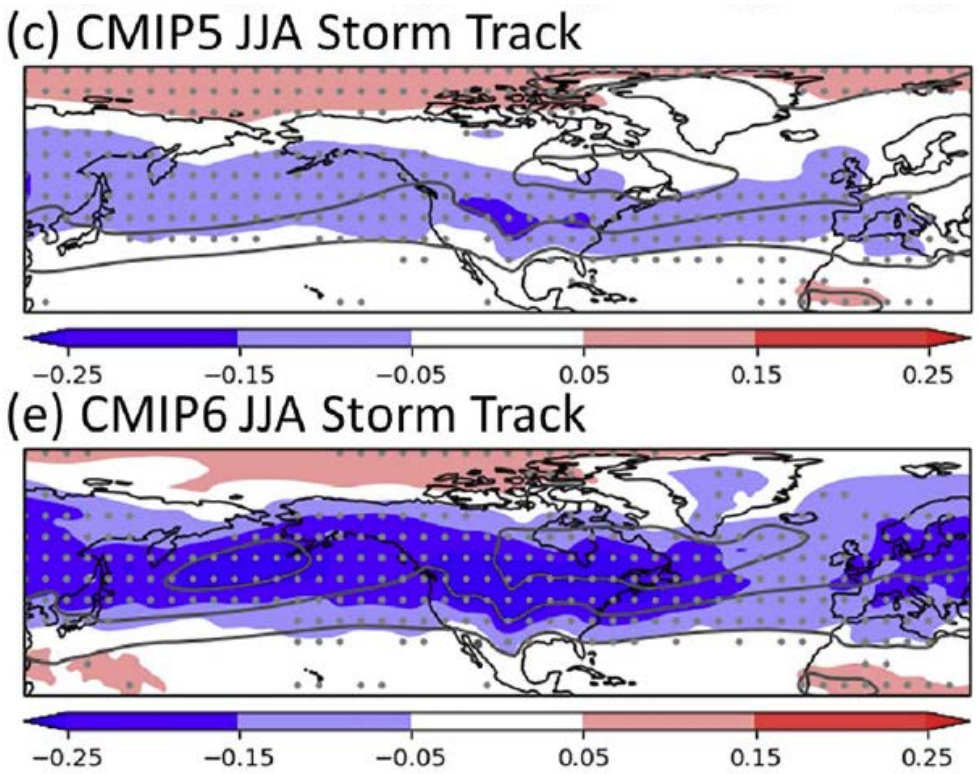
CLIMATE EXTREMES

Coumou et al, *Science* (2015); Coumou et al, *NCC* (in review)

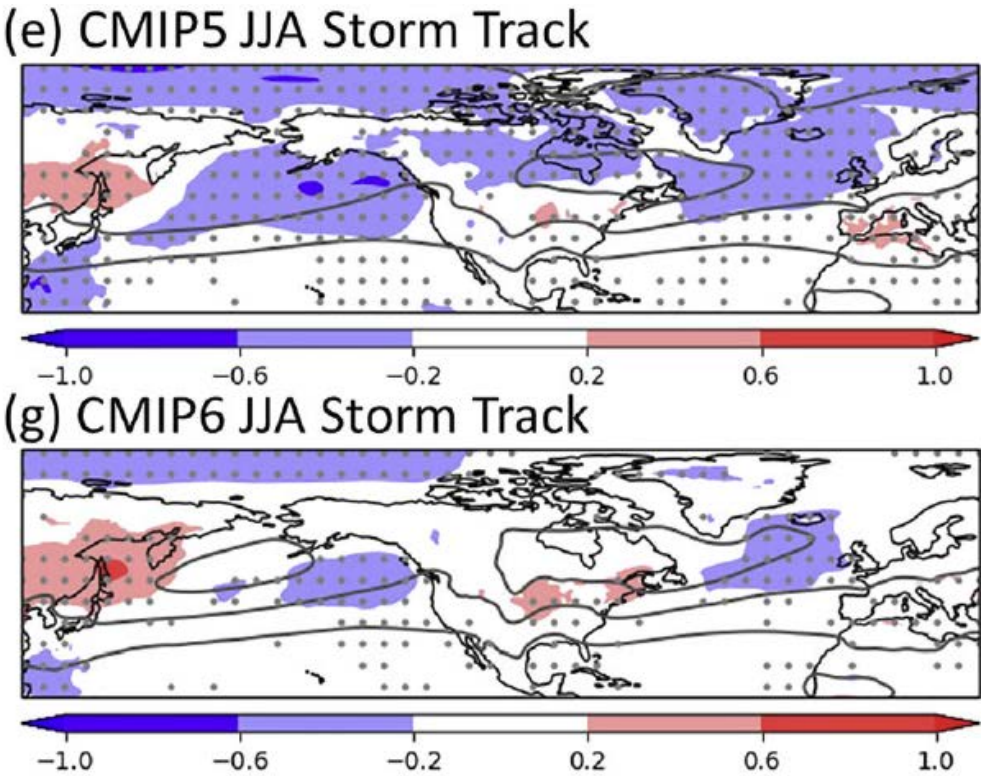
High-lat. land warming: Weakening of summer circulation

Climate models project same storm track weakening under future emissions

CMIP6: Improved storm track representation & <u>stronger climate signal</u>



JJA multimodel mean future minus present (RCP4.5)



JJA multimodel mean present minus ERA5

CLIMATE EXTREMES

Harvey et al, JGR (2020)

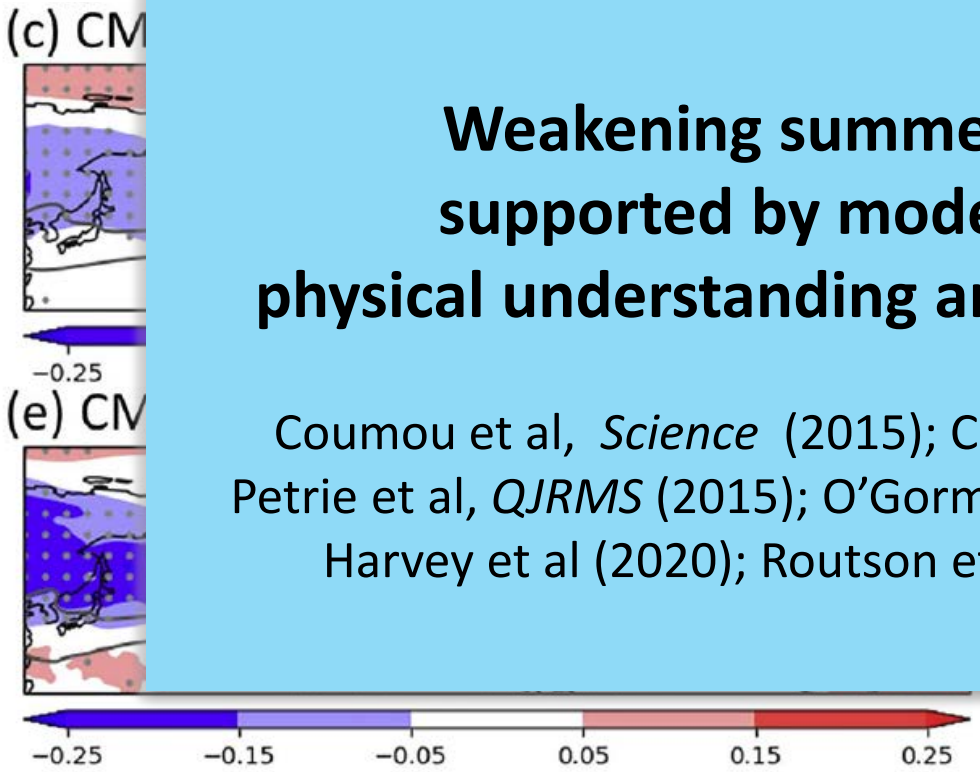
High-lat. land warming: Weakening of summer circulation

Climate models project same storm track weakening under future emissions

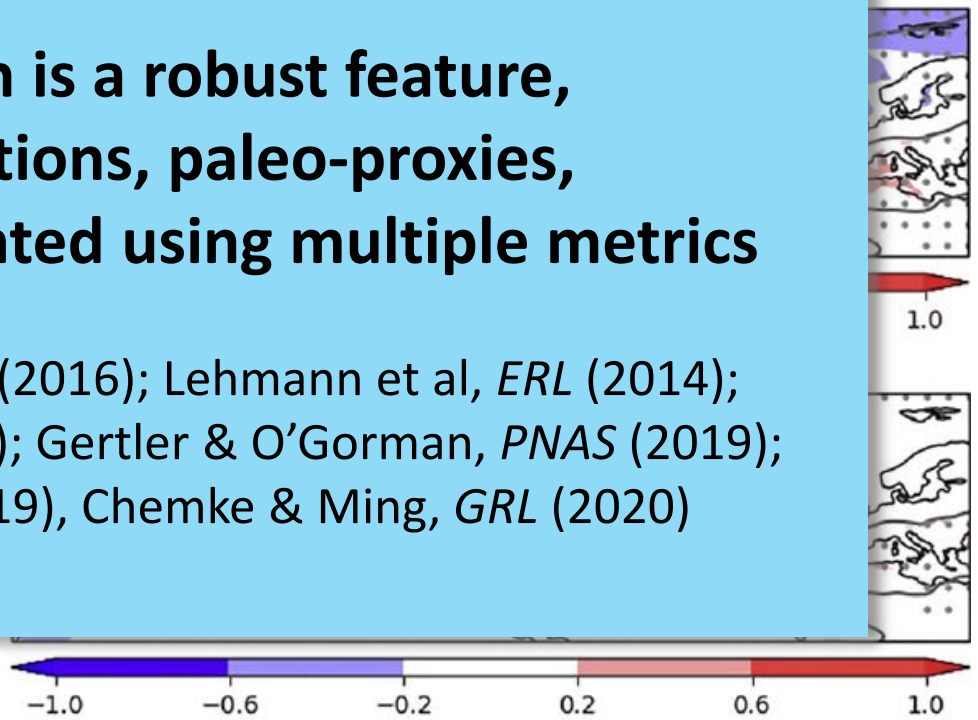
CMIP6: Improved storm track representation & stronger climate signal

Weakening summer circulation is a robust feature, supported by models, observations, paleo-proxies, physical understanding and documented using multiple metrics

Coumou et al, *Science* (2015); Chang et al, *GRL* (2016); Lehmann et al, *ERL* (2014); Petrie et al, *QJRMS* (2015); O'Gorman *PNAS* (2010); Gertler & O'Gorman, *PNAS* (2019); Harvey et al (2020); Routson et al, *Nature* (2019), Chemke & Ming, *GRL* (2020)



JJA multimodel mean future minus present (RCP4.5)



JJA multimodel mean present minus ERA5

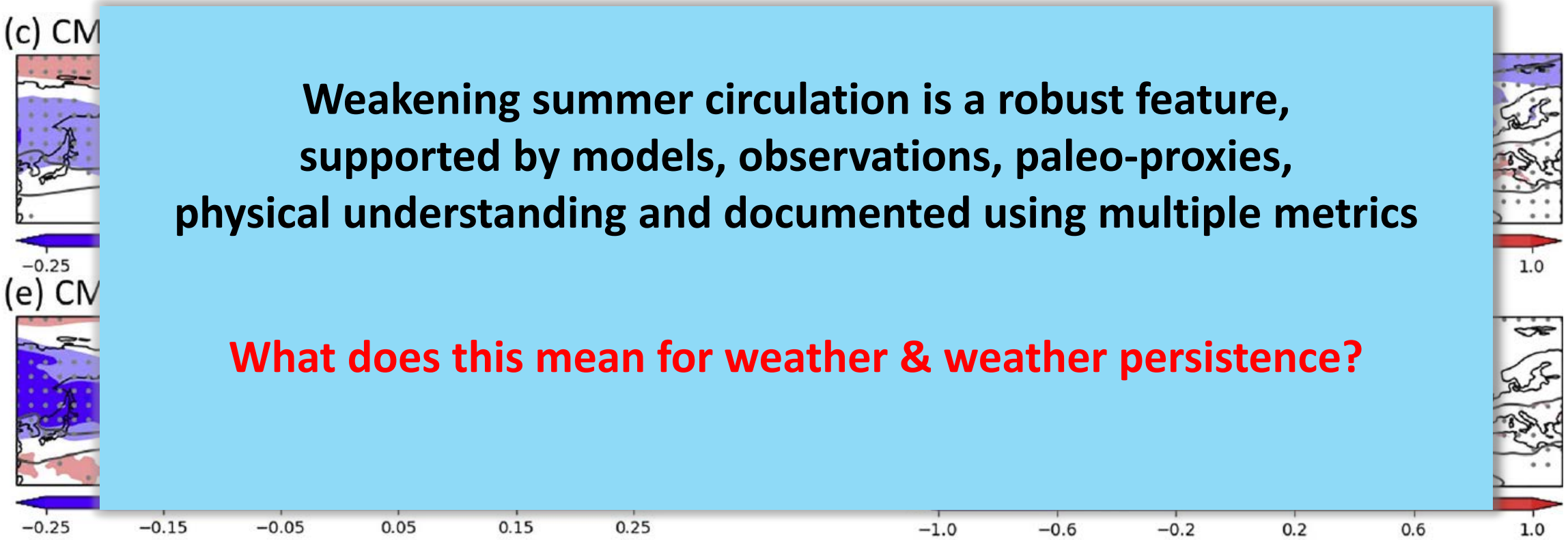
CLIMATE EXTREMES

Harvey et al, JGR (2020)

High-lat. land warming: Weakening of summer circulation

Climate models project same storm track weakening under future emissions

CMIP6: Improved storm track representation & stronger climate signal



Weakening summer circulation is a robust feature, supported by models, observations, paleo-proxies, physical understanding and documented using multiple metrics

What does this mean for weather & weather persistence?

JJA multimodel mean future minus present (RCP4.5)

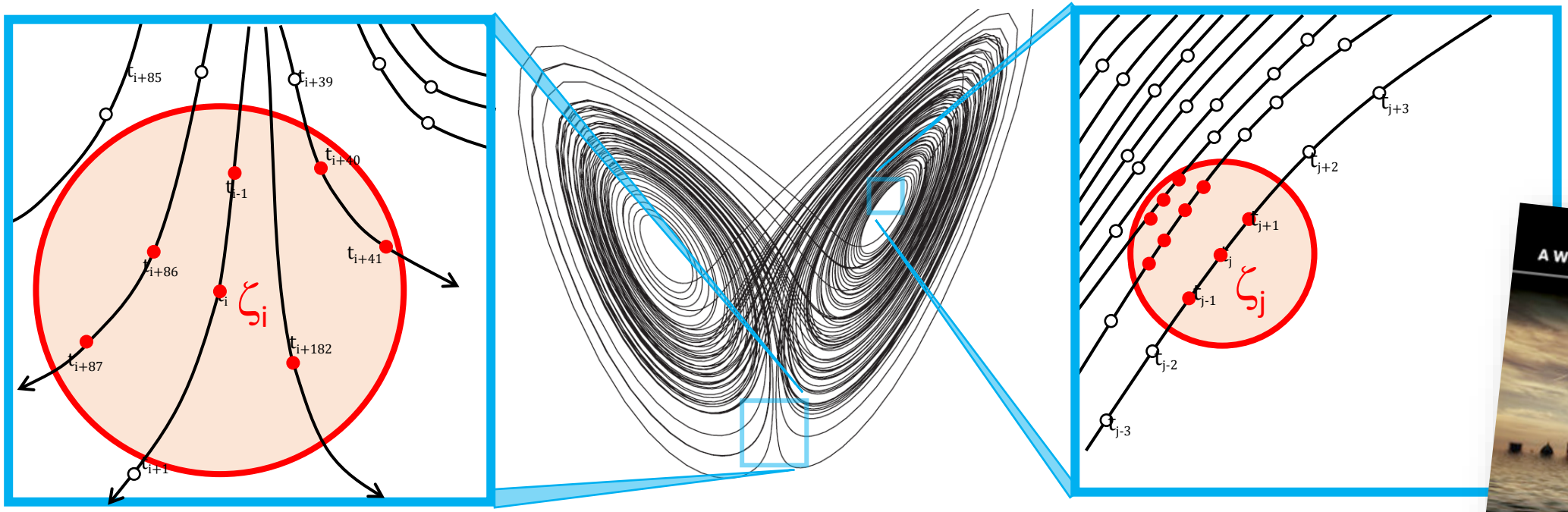
JJA multimodel mean present minus ERA5

CLIMATE EXTREMES

Harvey et al, JGR (2020)

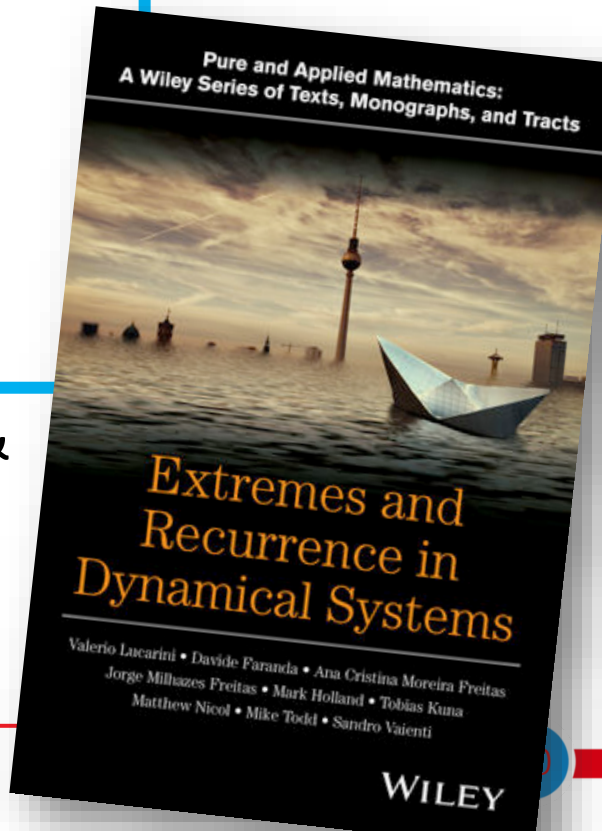
Defining weather persistence: A Dynamical Systems Approach

Analyze state changes along the trajectory in phase-space



High-dimensional & rapidly evolving

Low-dimensional & slowly evolving

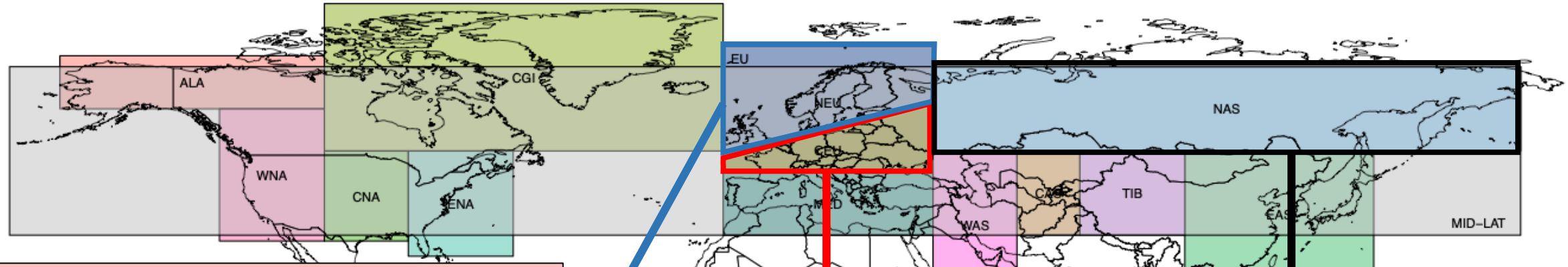


θ^{-1} : the average residence time of trajectories in the neighbourhood of ζ.
If large: Preceding and future states likely to resemble the current state

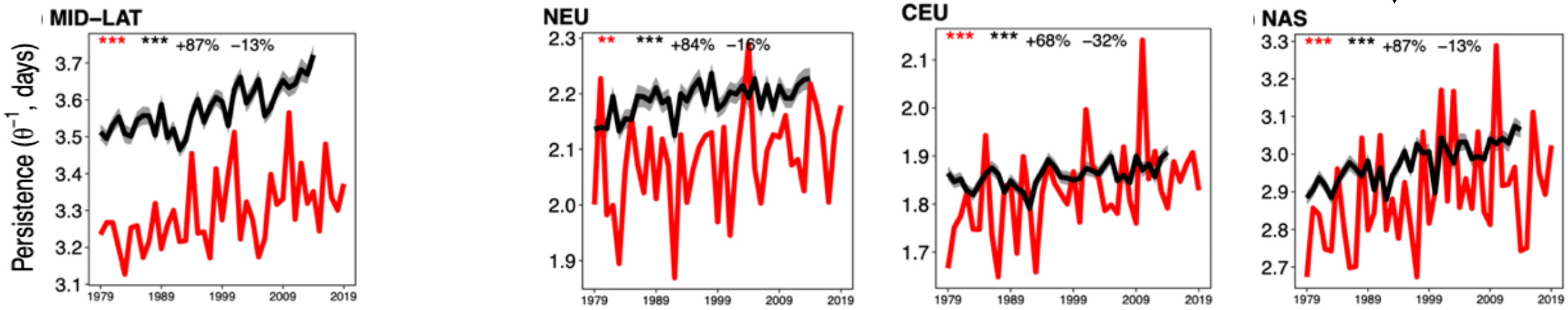
CLIMATE EXTREMES

Faranda, Lucarini, Messori, Freitas, Yiou, *et al*

Systematic increase in persistence in reanalyses & climate models



USE 500mb Streamfunction!

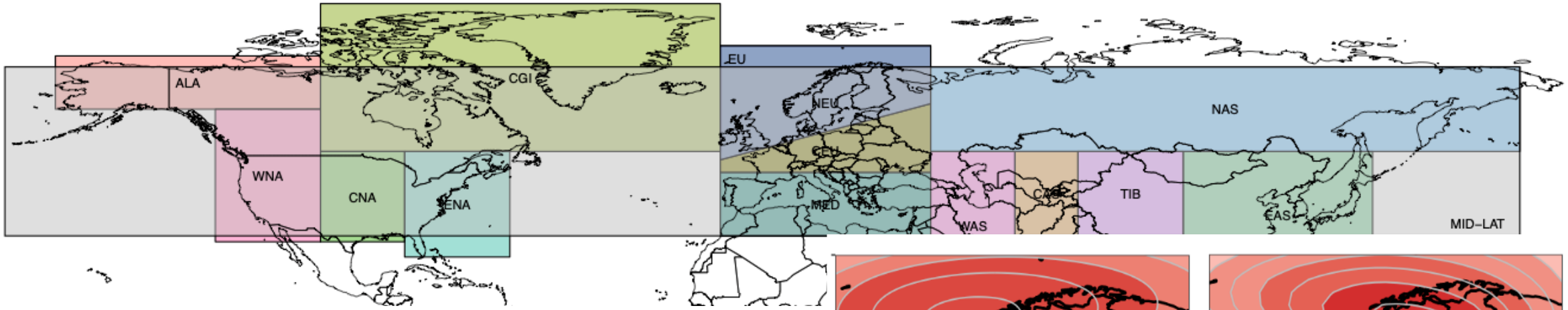


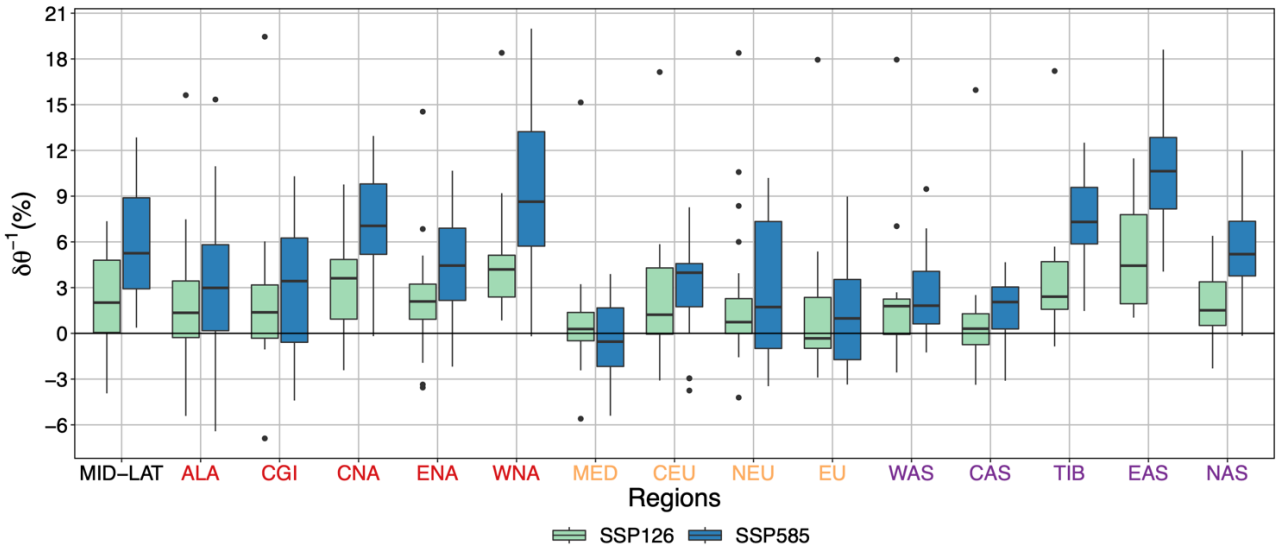
Most significant increases over Eurasian sector

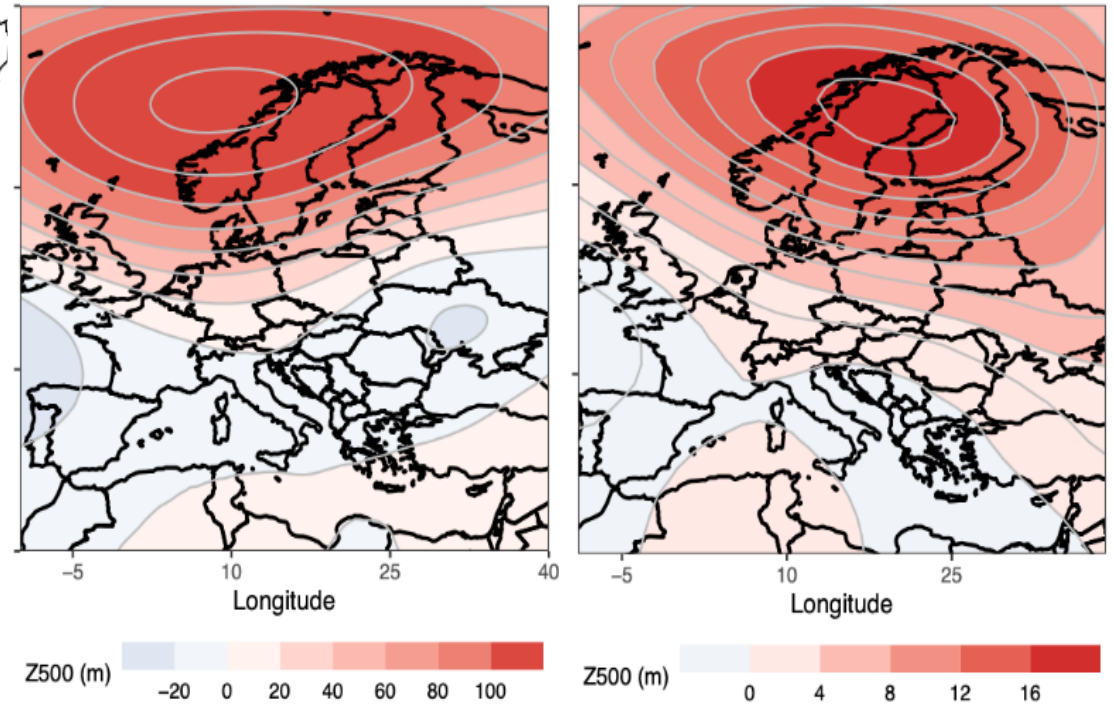
CLIMATE EXTREMES

De Luca et al, QJRMS (in review)

Further increase in persistence under future warming



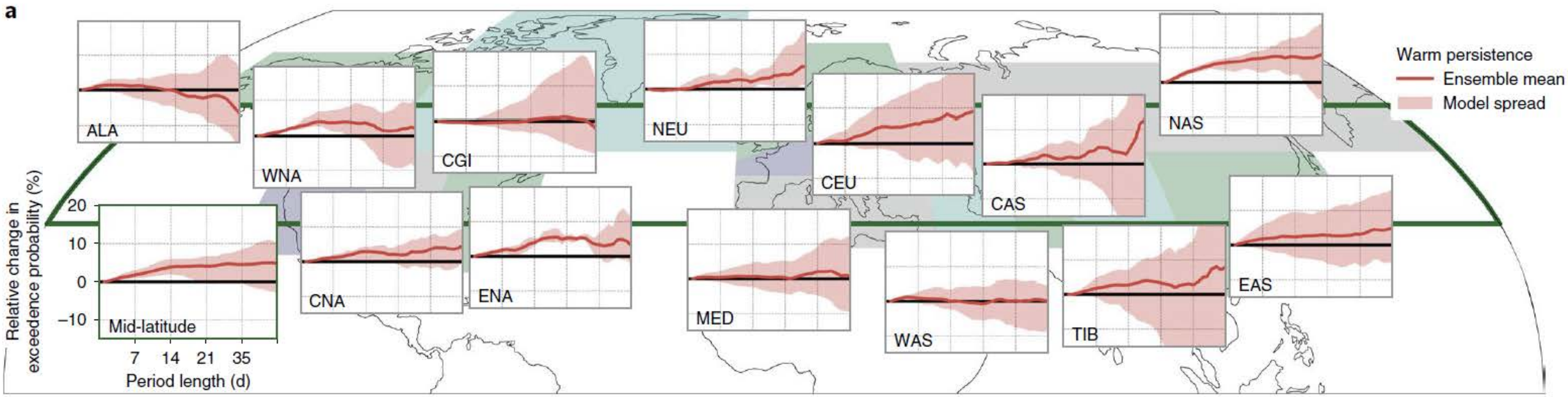




Most persistent states: Scandinavian blocking

De Luca et al, QJRMS (in review)

Surface weather: Increasing warm persistence



2ºC – present day (~1ºC):

Consecutive warm days, defined as warmer than the median temperature in the new climate (HAPPI ensemble).

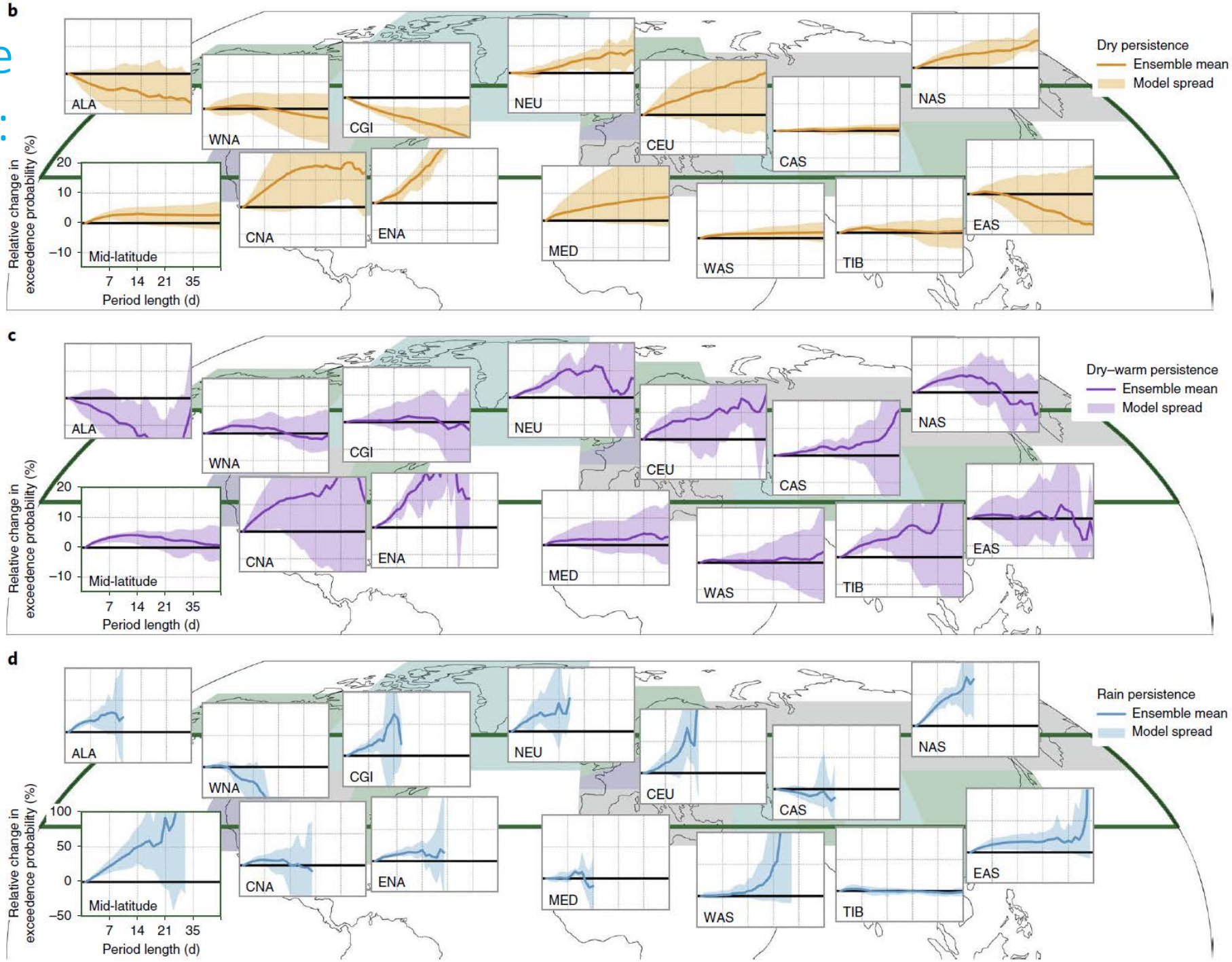
CLIMATE EXTREMES

Pfleiderer et al (2020); Pfleiderer & Coumou (2018)

Increasing persistence for compound events:

- dry persistence
- dry & warm
- rain

Pfleiderer et al, *NCC* (2020)



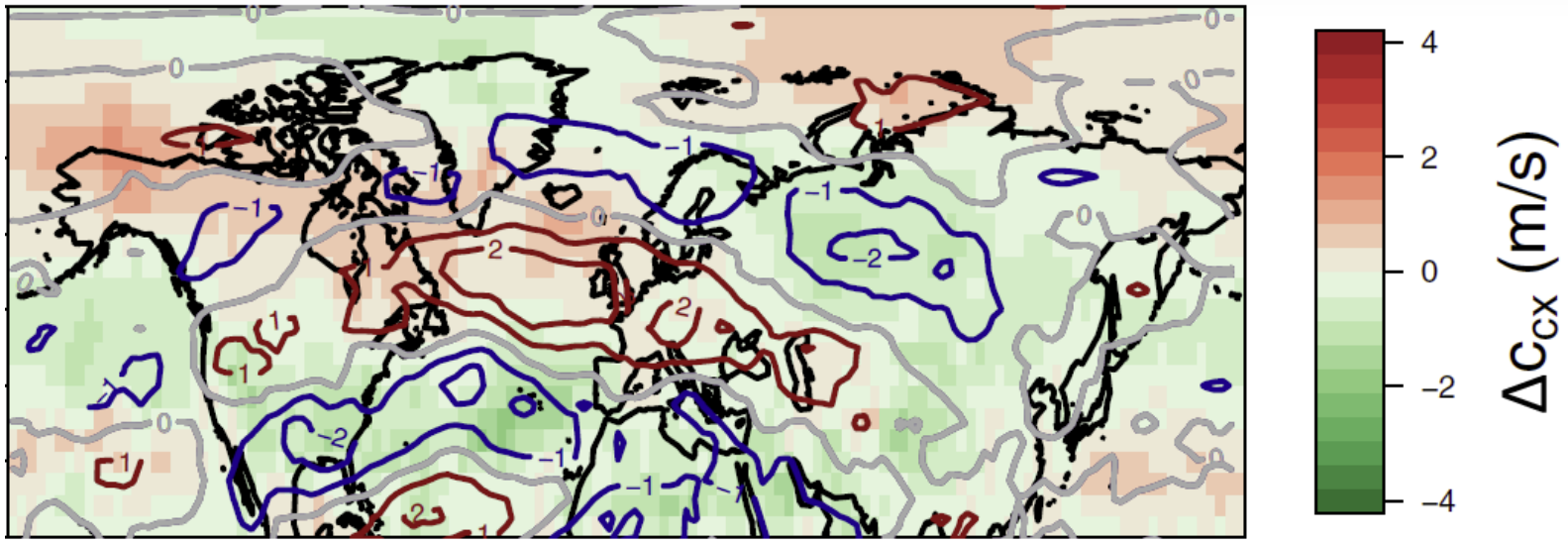
CLIMATE EXTREMES

Surface weather: Slowdown in propagation of anticyclones

Geophysical Research Letters

Future Changes in Northern Hemisphere Summer Weather Persistence Linked to Projected Arctic Warming

Kai Kornhuber[1,2] and Talia Tamarin-Brodsky[3]



Change in anti-cyclone propagation speed in summer (RCP8.5)

Use tracking algorithm to determine propagation speed (Kevin Hodges)

Significant links between slower propagating weather systems and weaker equator-to-pole temperature difference in observations and models.

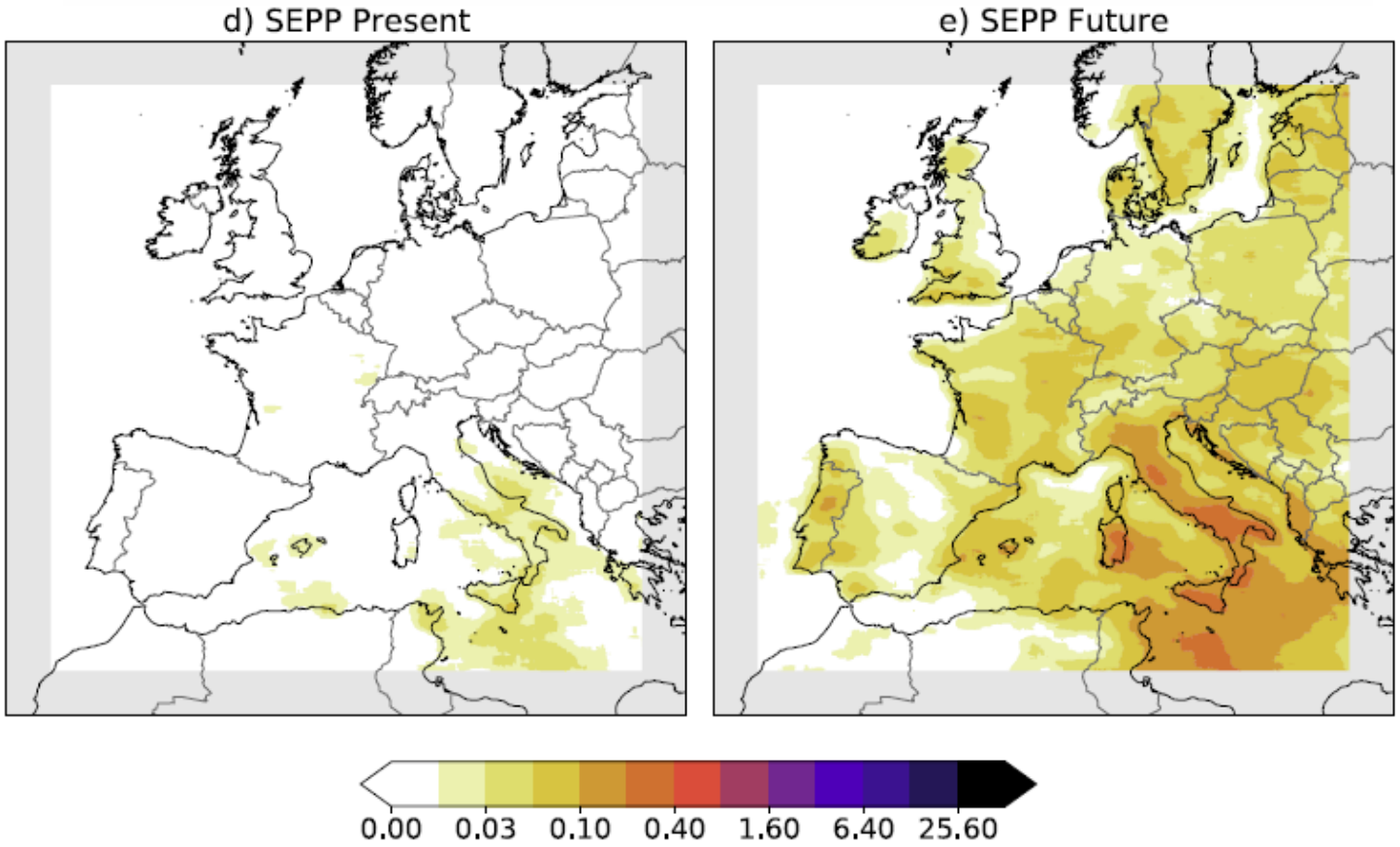
CLIMATE EXTREMES

Surface weather: Slowdown in propagation of convective storms

Geophysical Research Letters

Quasi-Stationary Intense Rainstorms Spread Across Europe Under Climate Change

Abdullah Kahraman[1,2], Elizabeth J. Kendon[3], Steven C. Chan[1,2], and Hayley J. Fowler[1]

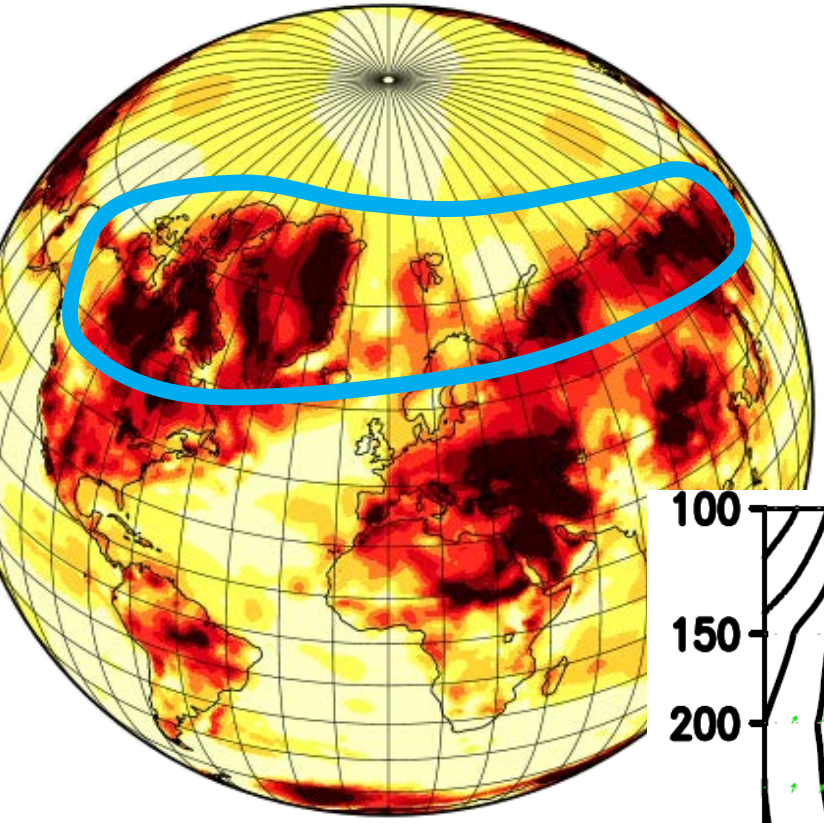


Slow-moving Extreme Precipitation Potential (SEPP):

Co-occurrence of high moisture, high vertical velocity, *and* slow movement

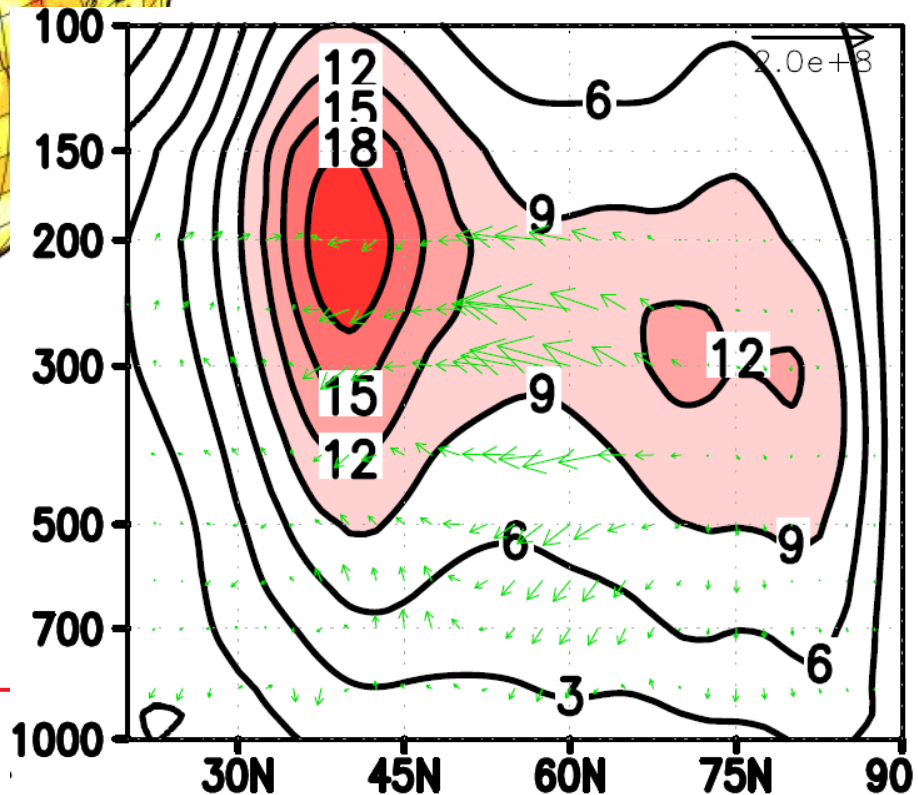
"Environments favoring high rainfall rates are projected to be 7× more frequent by 2100, while the figure for quasi-stationary ones is 11×"

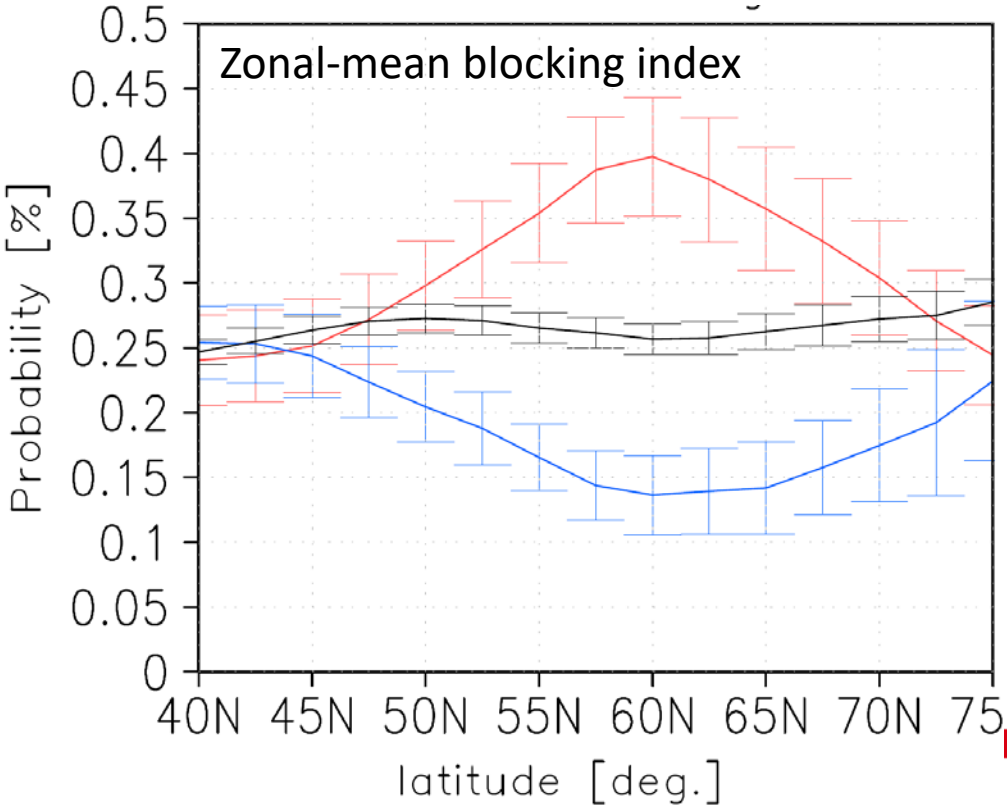
High-latitude land-warming favors double jets



- Weakening mid-lat gradient but strengthening land-ocean gradient → Formation of Arctic front jet / double jets
- Associated with enhanced mid-latitude blocking

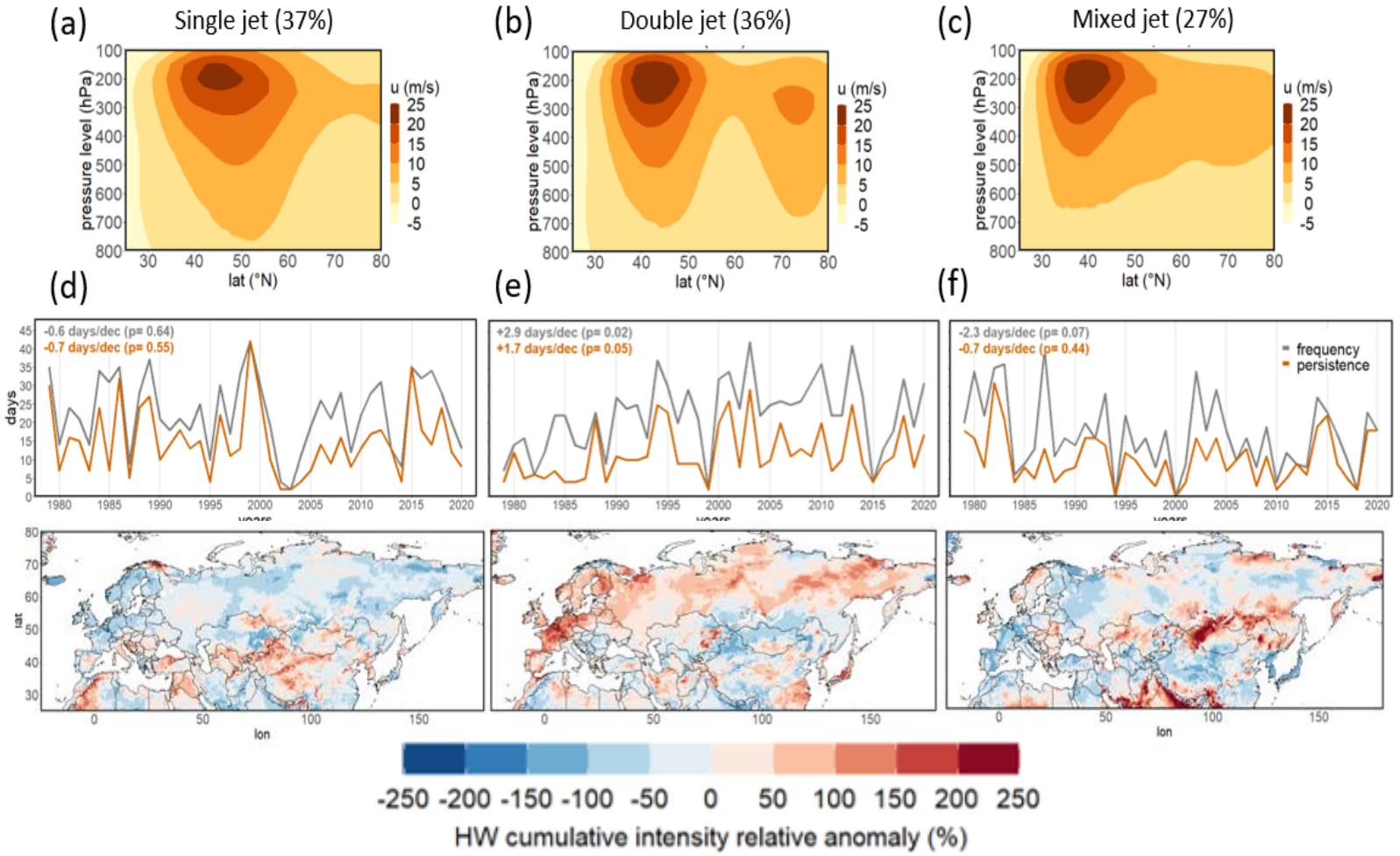
Tachibana *et al.* (2010)





CLIMATE EXTREMES

High-latitude land-warming favors double jets



Doubling in frequency of Eurasian double jets over last 40 years, driven by increase in persistence of double-jet events

Double jets related to heatwaves in western Europe

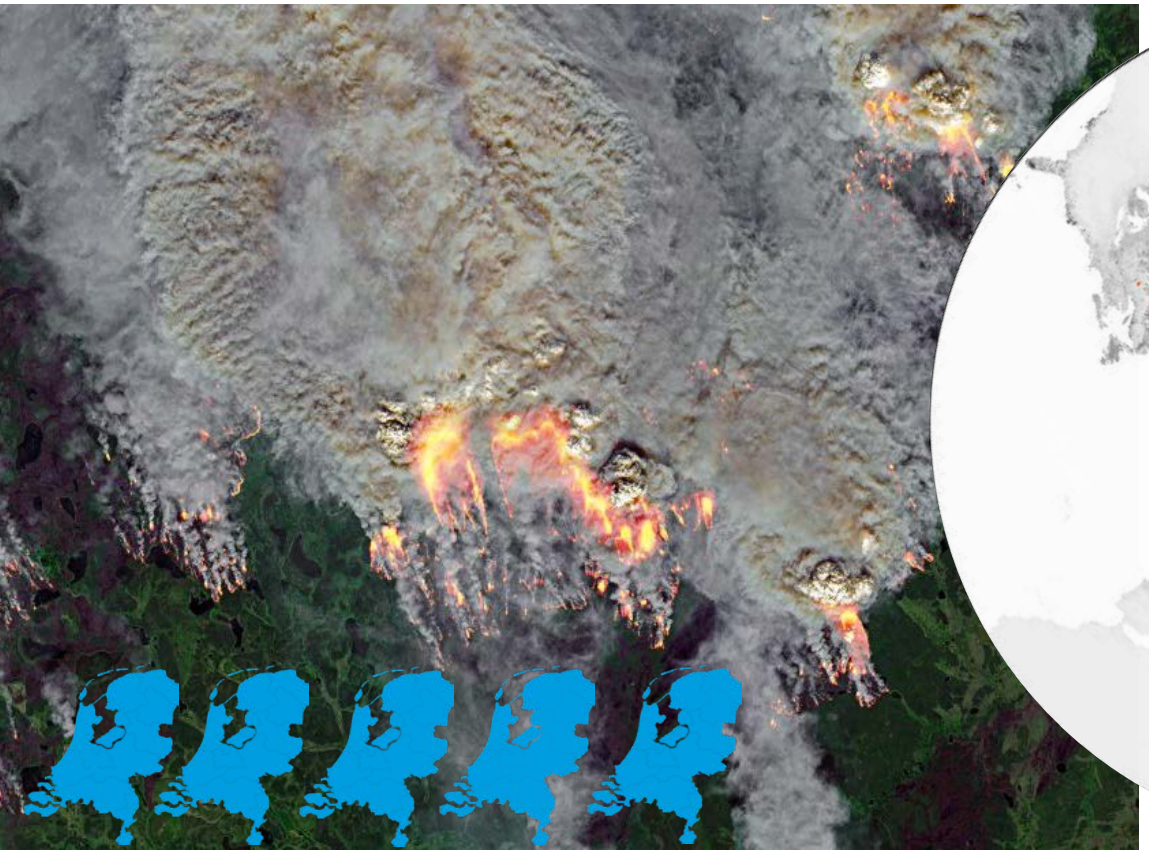
Classic case: Summer 2003

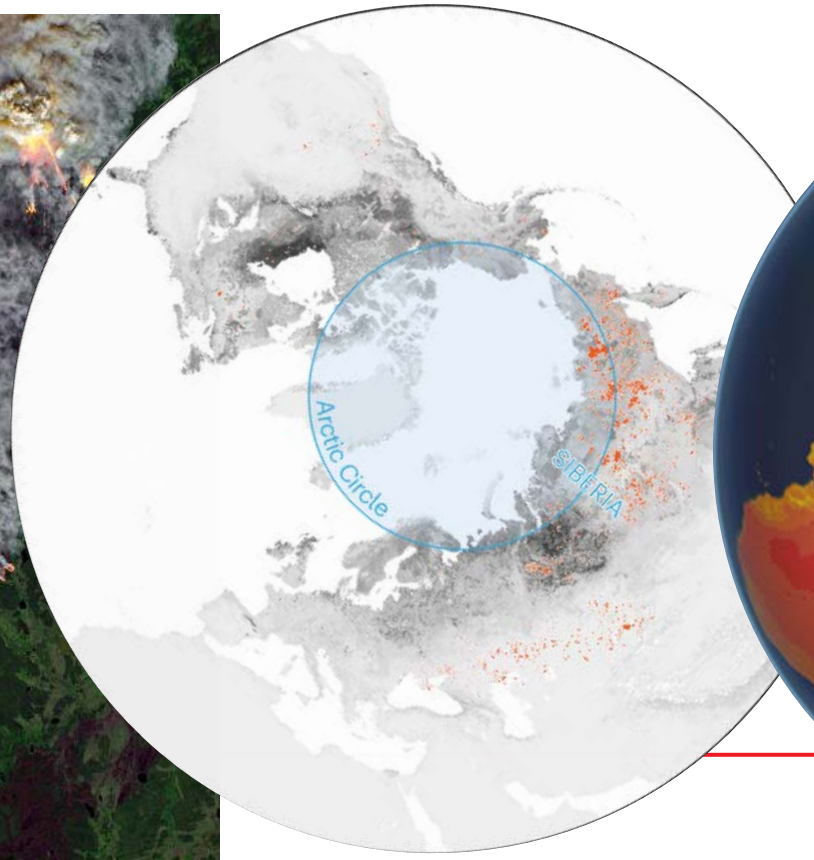
CLIMATE EXTREMES

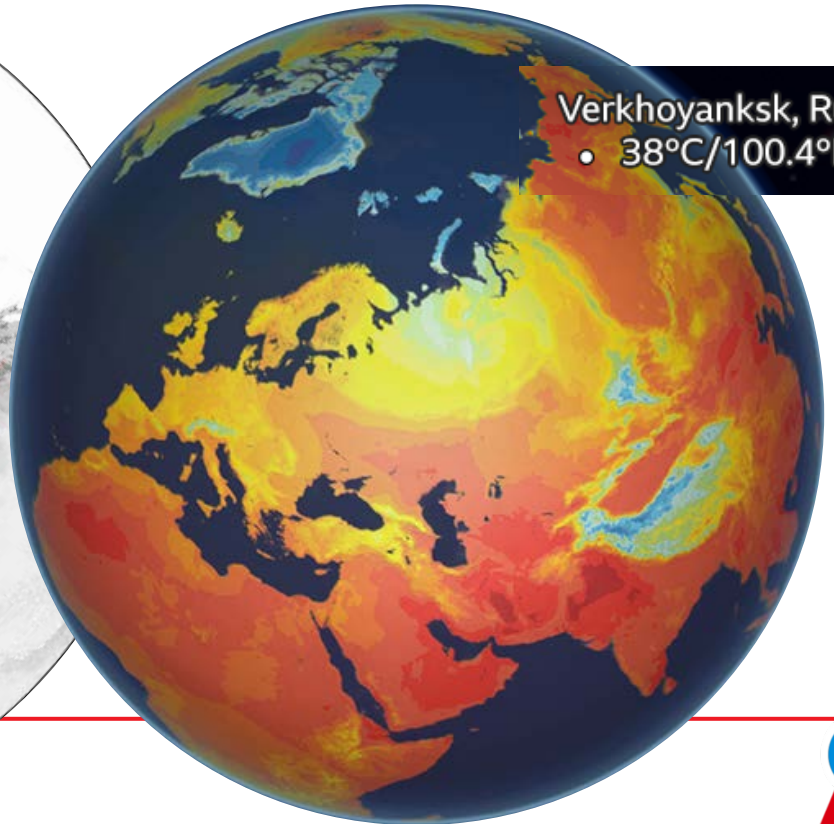
Rousi *et al.* (in review)

Double jet also important for high-latitude extremes

Summers of 2019 and 2020 experienced extreme fire activity in north-eastern Siberia that were driven by record-high spring and summer temperatures







Key messages:

1. High-latitude land warming in summer is associated with weakened storm tracks & more persistent double jets
2. Weakening circulation leads to more persistent weather, supported by multiple metrics in observations and models
3. Causality not strictly proven & model spread is large

CLIMATE EXTREMES