Barcelona Supercomputing Center
Centro Nacional de Supercomputación

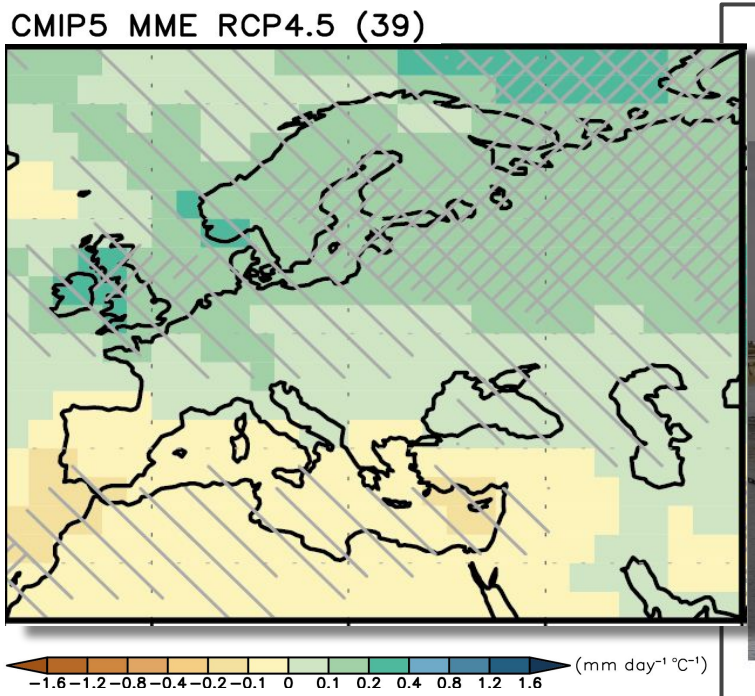
PRIMAVERA

Is winter precipitation change over Europe underestimated in current climate projections?

Eduardo Moreno-Chamarro
Louis-Philippe Caron, Pablo Ortega,
Saskia Loosveldt Tomas, Malcolm Roberts

AGU Fall Meeting 2020

Increased winter precipitation over Northern Europe by 2100 (IPCC AR5)

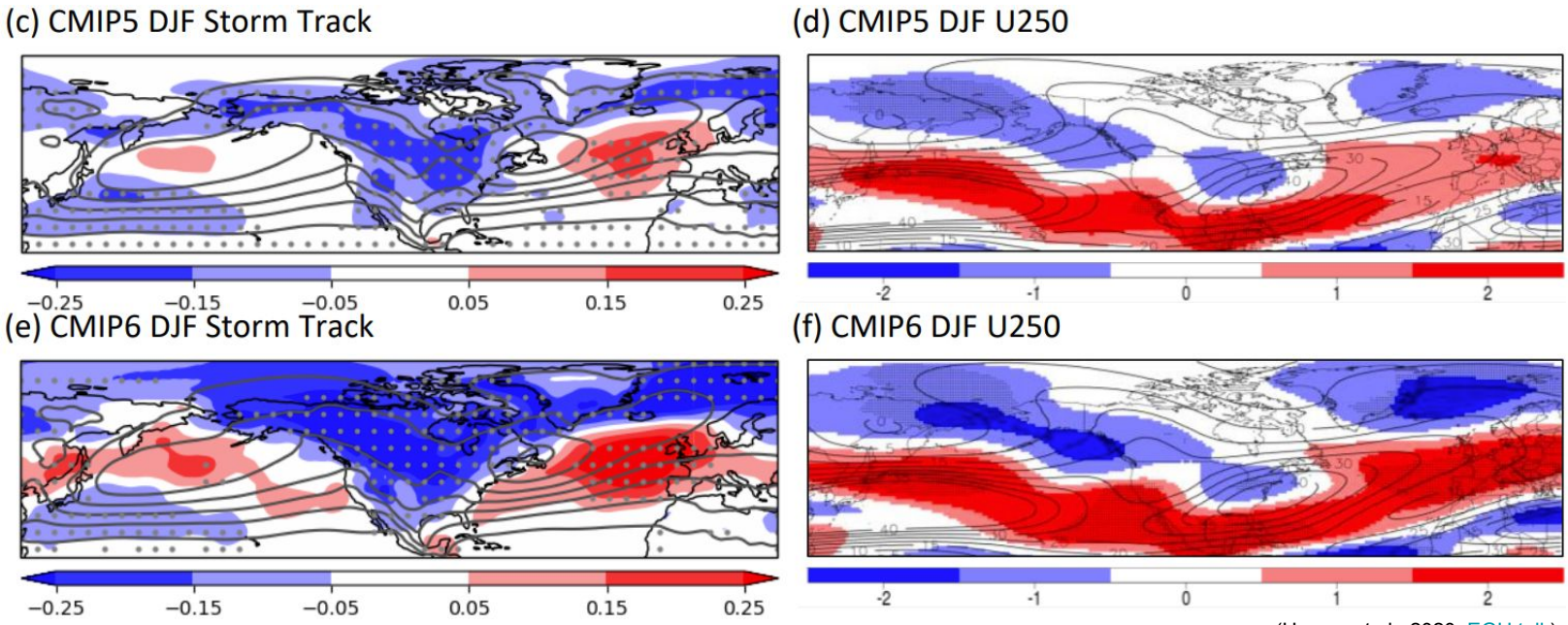


(IPCC, 2013)

eduardo.moreno@bsc.es

Increase in North Atlantic extratropical cyclone activity in CMIP5 and CMIP6

Multimodel mean of the difference between the most recent 30-year period from the present-day simulations and the final 30 years of the 21st century from the future simulations in CMIP5 RCP4.5 and CMIP6 SSP2-4.4



(Harvey et al., 2020; EGU talk)

Black contours: model climatology
Dots: change significant at the 5% based on a Student's t-test

Changes in precip./cyclones sensitive to model resolution

Sensitivity studies mainly based on atmosphere-only regional and global models

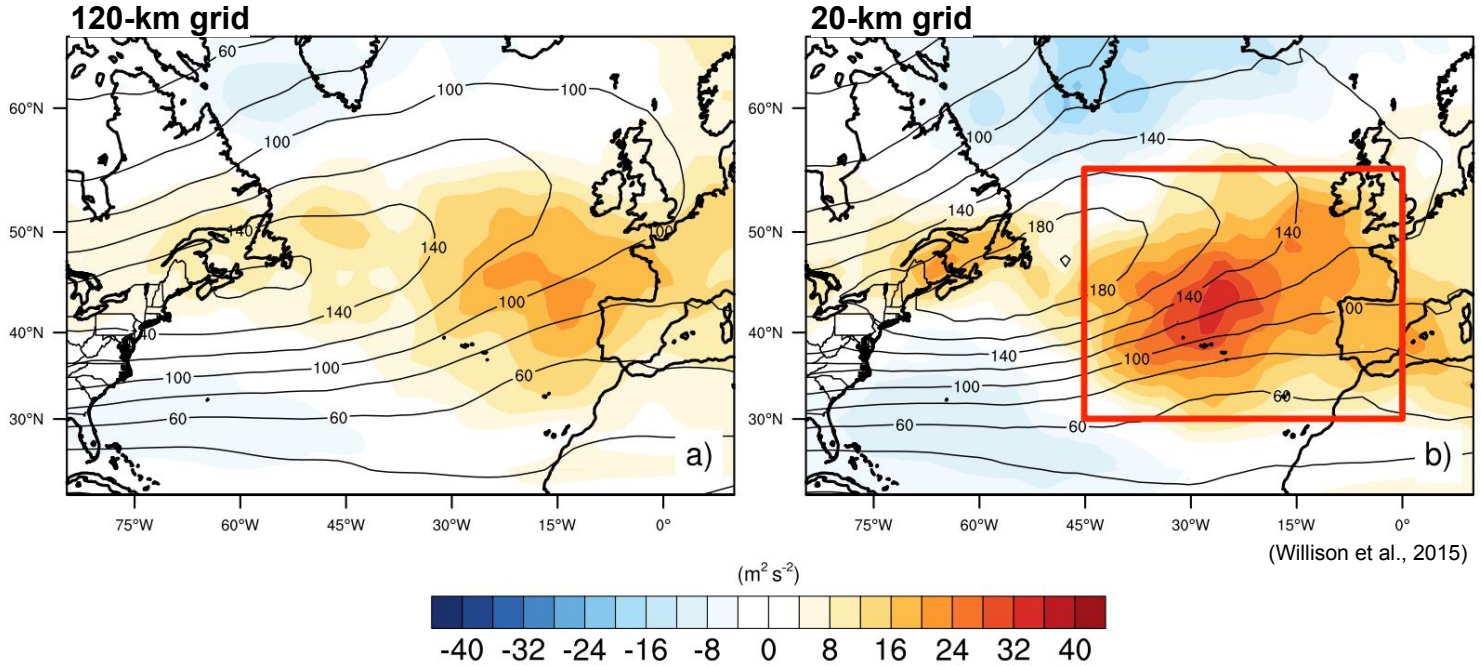
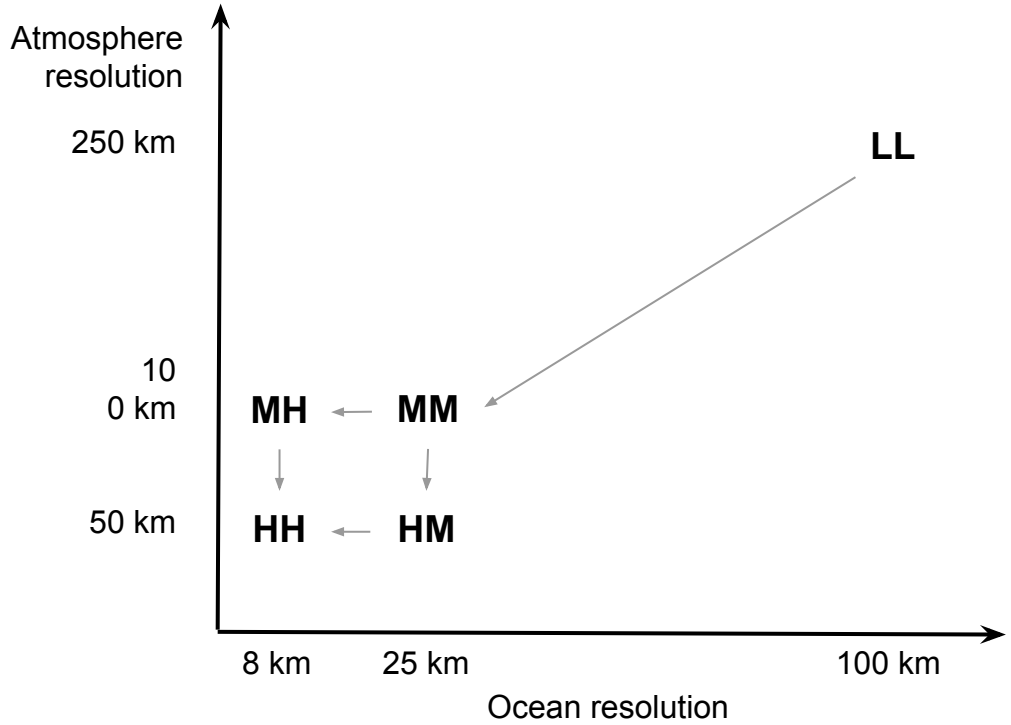


FIG. 2. Change in EKE with warming at 300 hPa (shaded) for (a) 120-km grid spacing and (b) 20-km grid spacing. Current-day values shown in contours (interval 20 $m^2 s^{-2}$).

Increased winter precipitation over Northern Europe by 2100 (IPCC AR5): How sensitive to model resolution is it?

- ➔ CMIP6 HighResMIP/PRIMAVERA simulations
- ➔ Coupled model HadGEM3-GC3.1

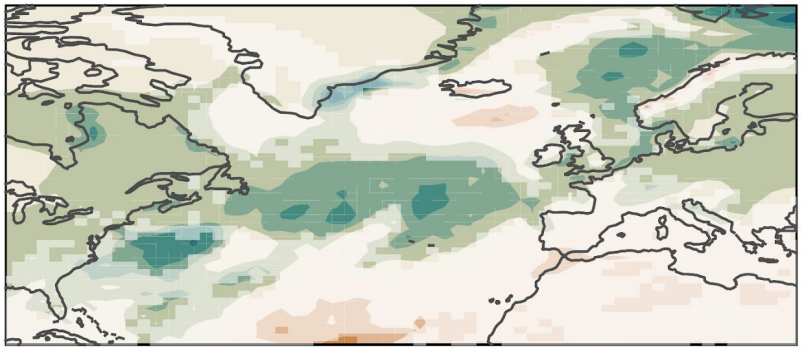


	Ensemble size	
	historical (1950–2014)	SCP5-8.5 (2015–2050)
LL	8	4
MM	3	3
HM	3	3
MH	1	1
HH	1	1

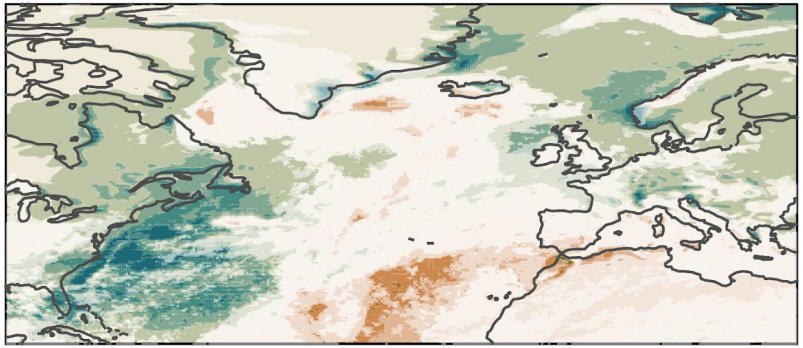
Winter precip. increases much more in HH than at lower resolutions

Anomalies in winter precip. (mm/day) between 2030–2050 and 1960–1980

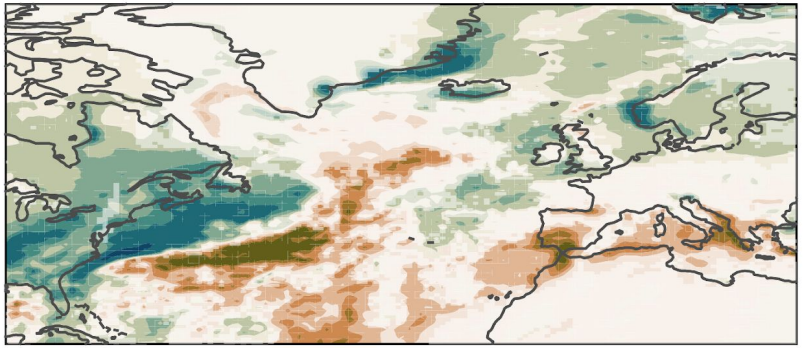
LL



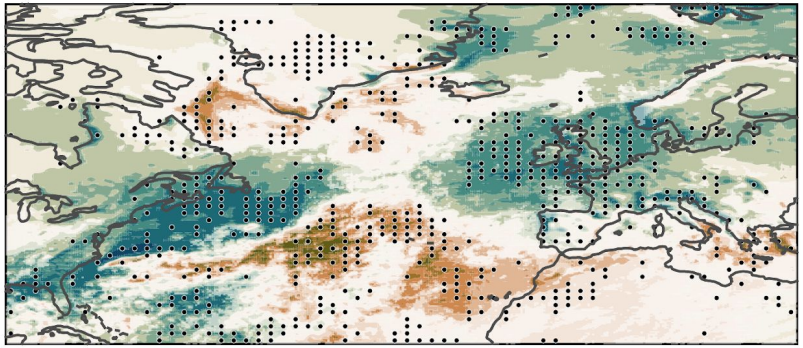
HM (highest atmosphere resolution)



MH (highest ocean resolution)

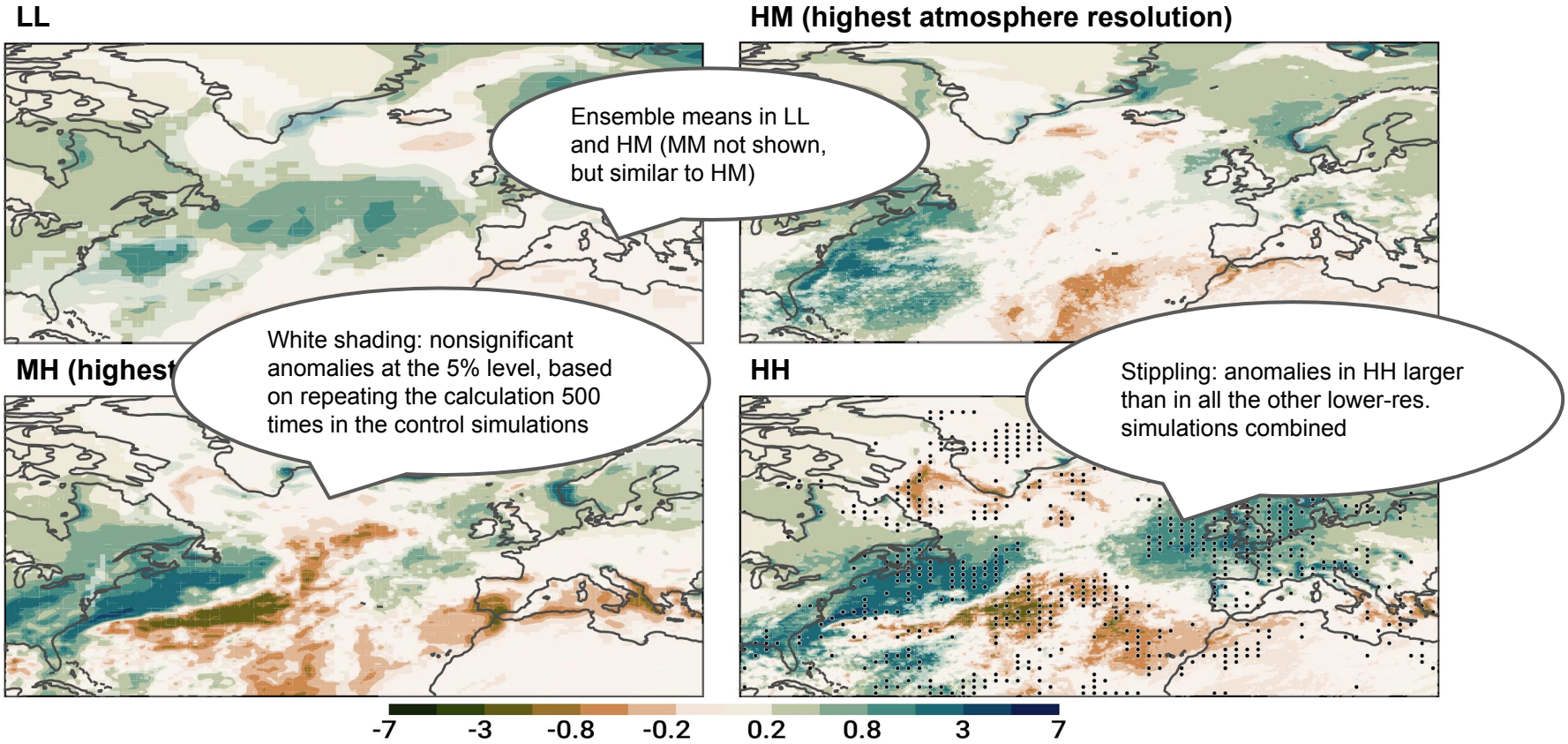


HH



Winter precip. increases much more in HH than at lower resolutions

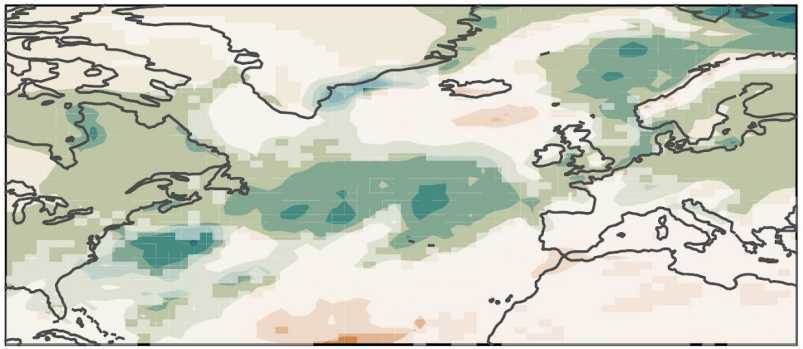
Anomalies in winter precip. (mm/day) between 2030–2050 and 1960–1980



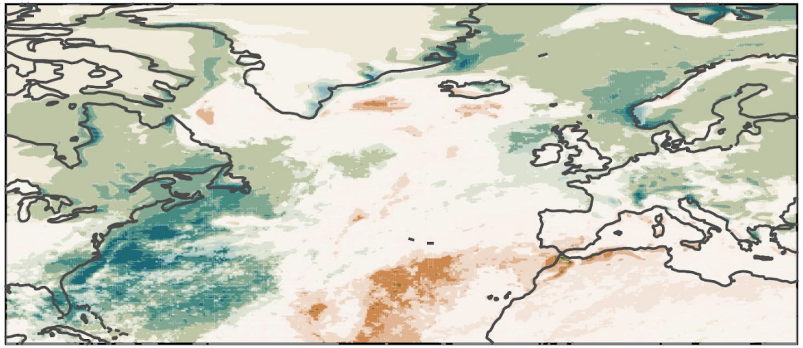
Winter precip. increases much more in HH than at lower resolutions

Anomalies in winter precip. (mm/day) between 2030–2050 and 1960–1980

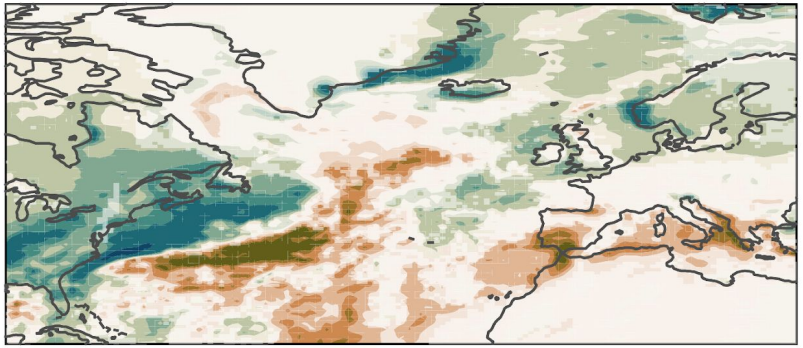
LL



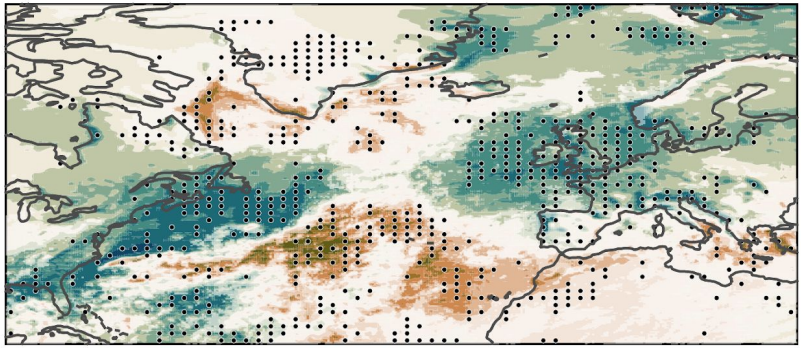
HM (highest atmosphere resolution)



MH (highest ocean resolution)

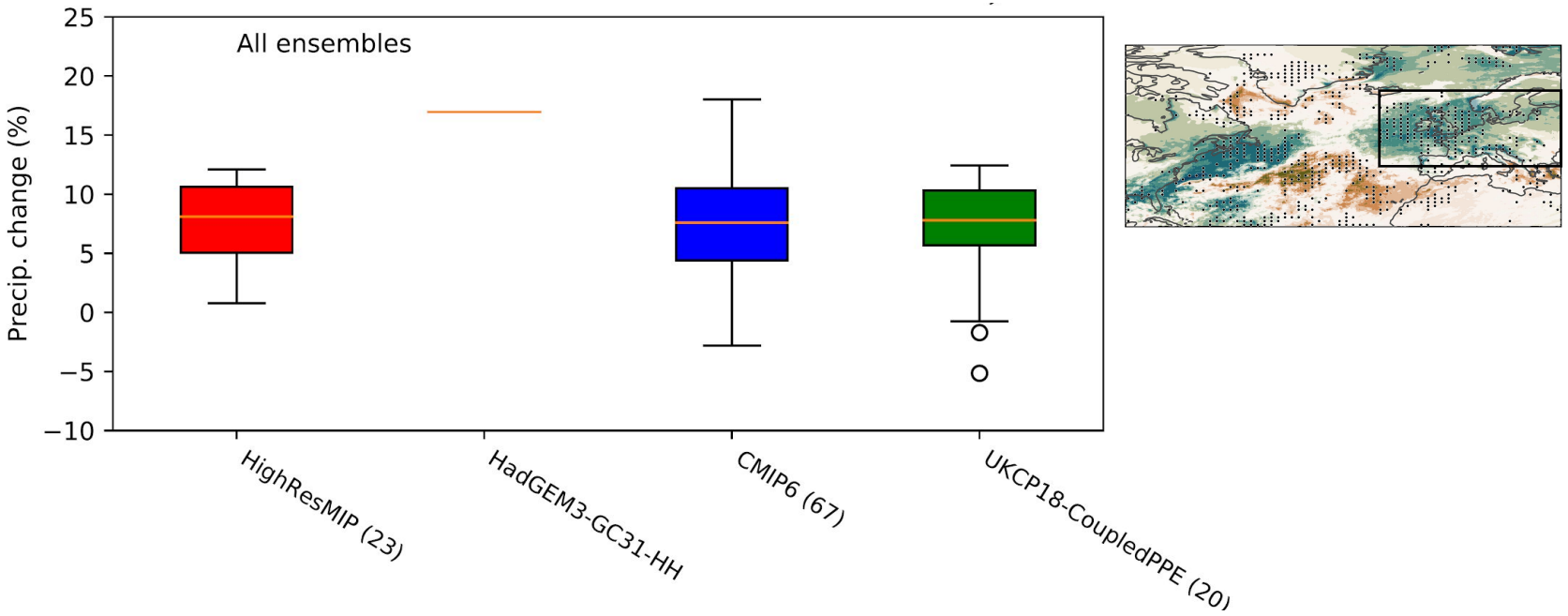


HH



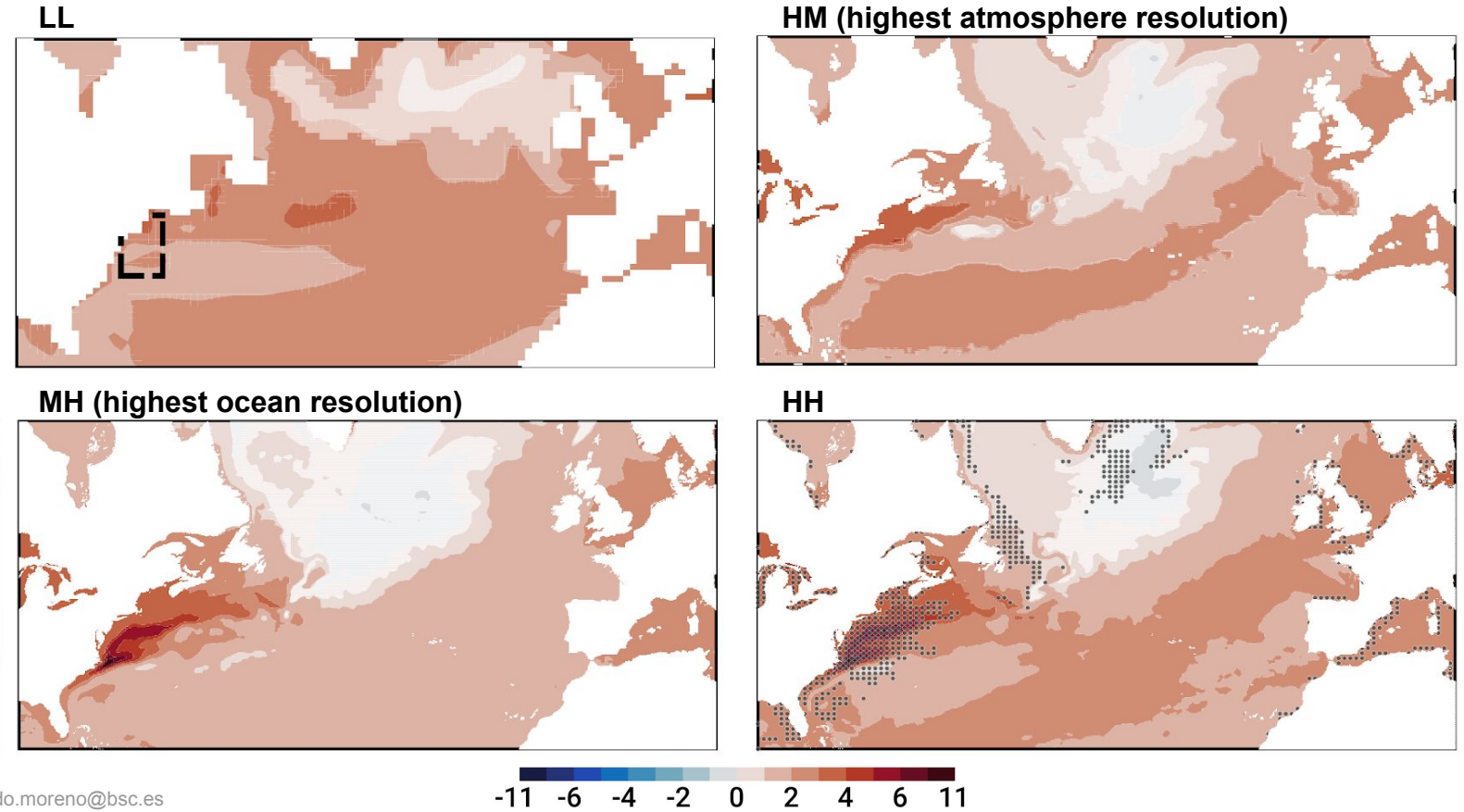
Winter precip. increases much more in HH than at lower resolutions and nearly all other projections in HighRESMIP and CMIP6

Percentage of change in winter precip between 2030–2050 and 1960–1980 over northern Europe



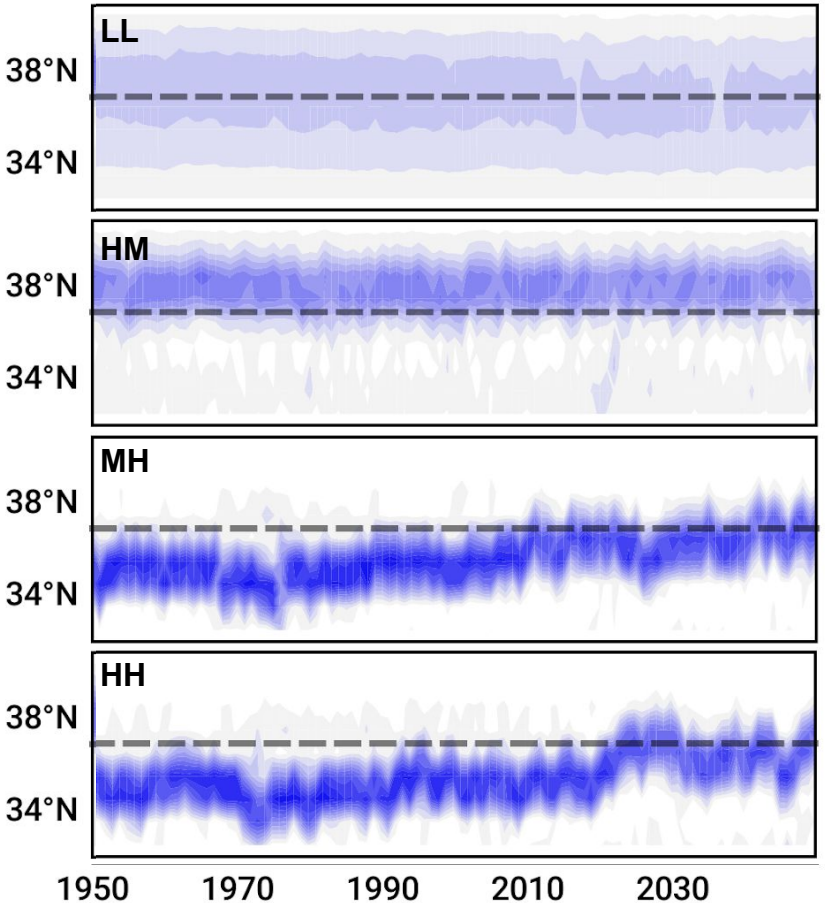
Gulf Stream surface warming only in the eddy-rich (H) ocean model

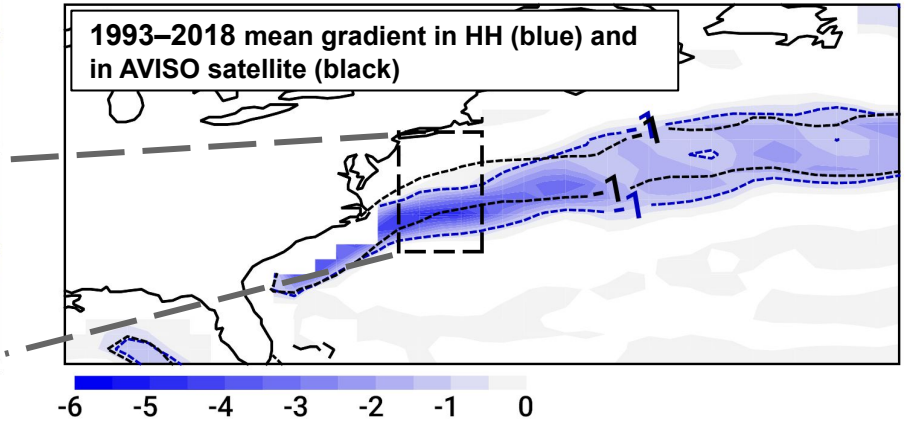
Anomalies in SST (K) between 2030–2050 and 1960–1980



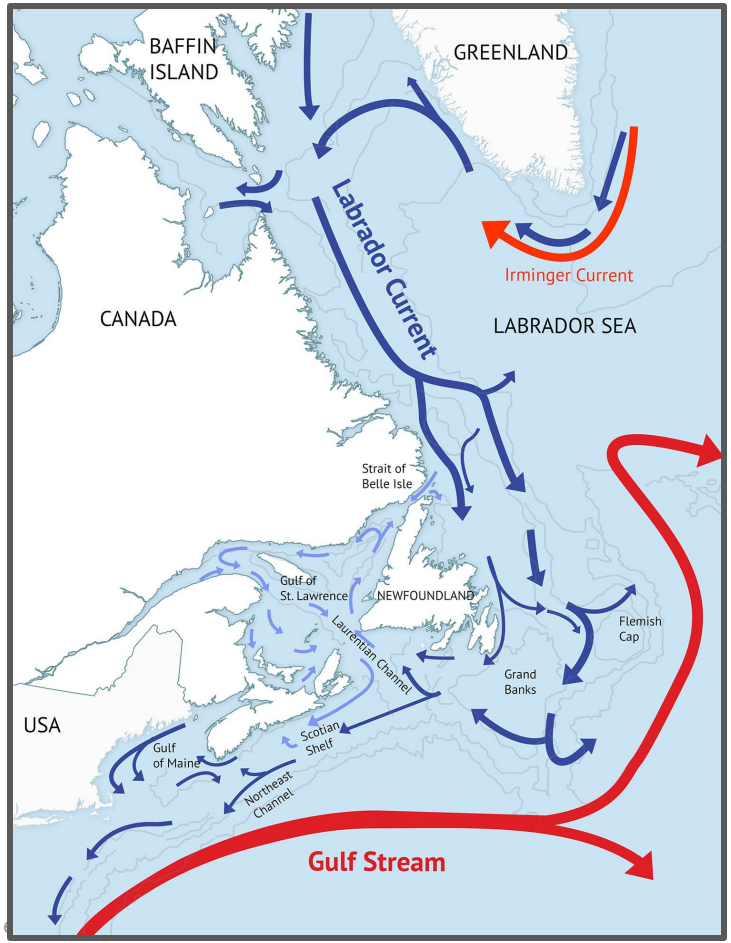
Northward shift of the Gulf Stream drives surface coastal warming

← Change in meridional gradient in sea-surface height (10^{-6} m/m). 1993–2018 AVISO satellite climatology (dashed line)





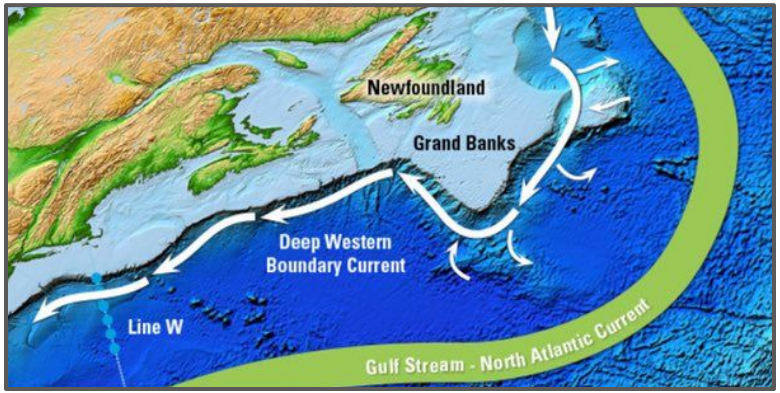
Surface currents



Northward Gulf Stream shift linked to weakening in the AMOC/deep western boundary current

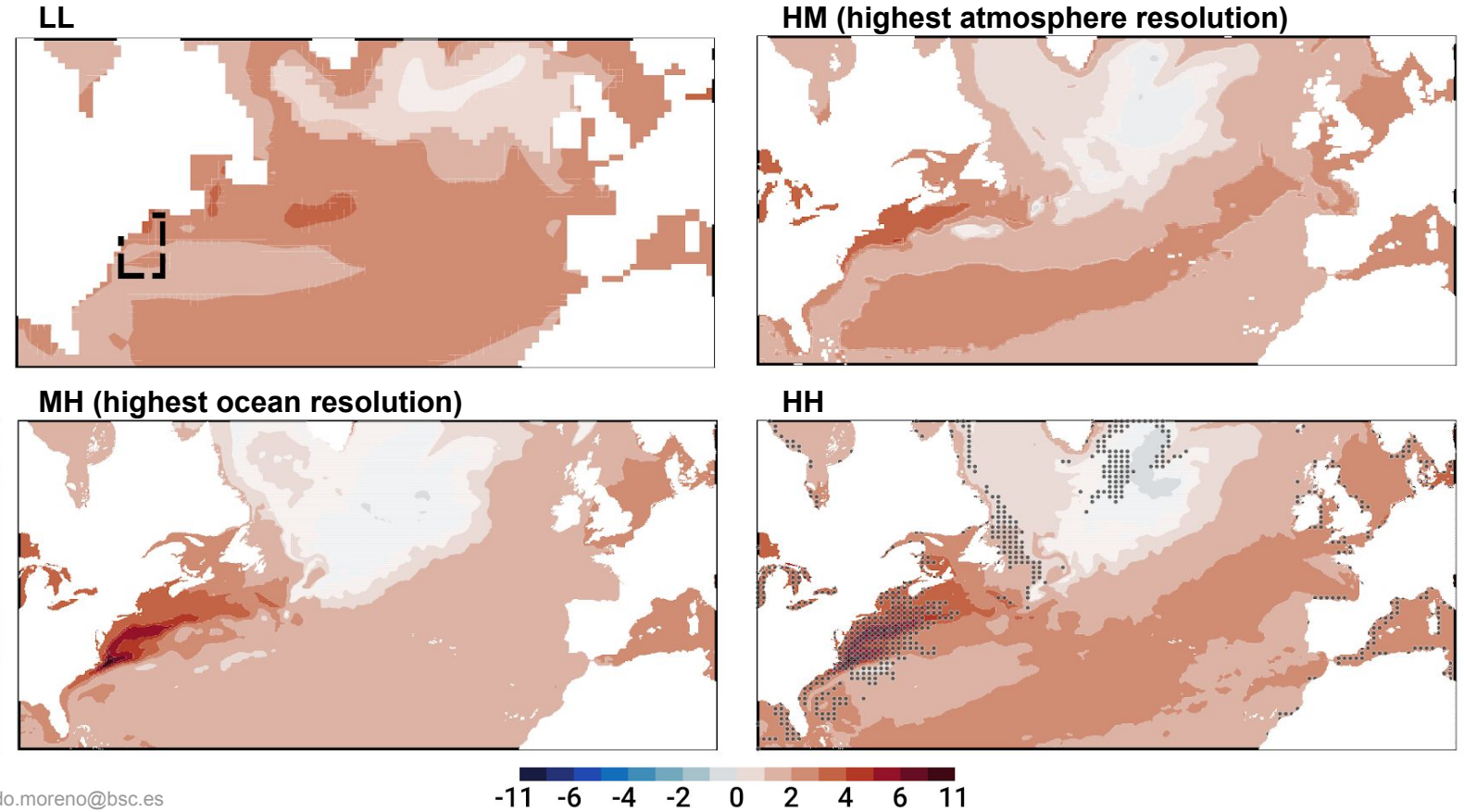
Mechanism first proposed by Saba et al. [2016; J. of Clim]

Deep western boundary current



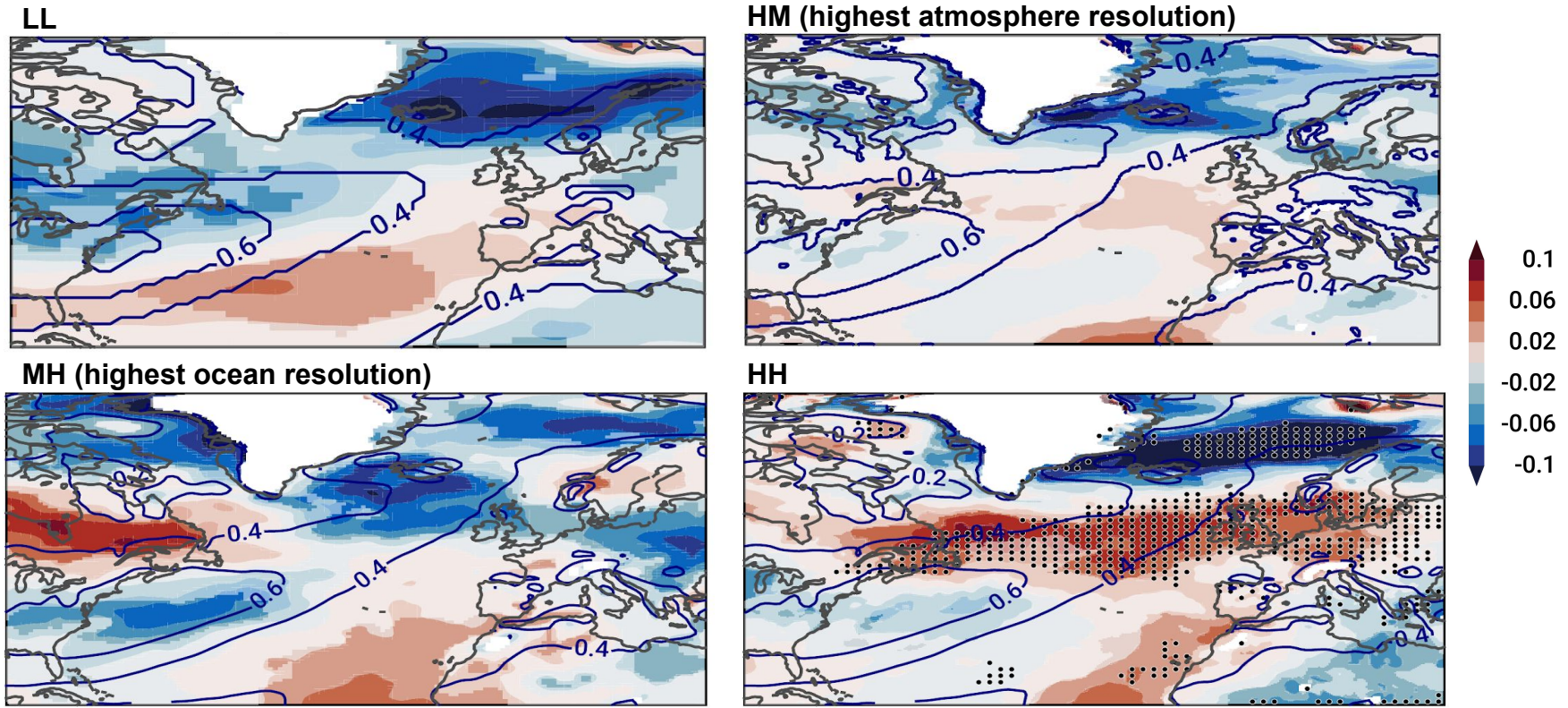
Gulf Stream surface warming only in the eddy-rich (H) ocean model

Anomalies in SST (K) between 2030–2050 and 1960–1980



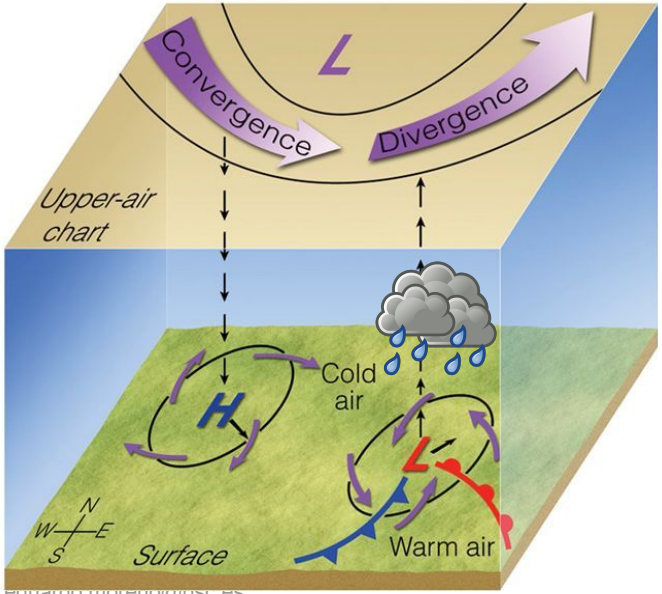
Strongest increase in midlatitude cyclone activity in HH

Anomalies in winter max. Eady growth rate (day^{-1}) between 2030–2050 and 1960–1980

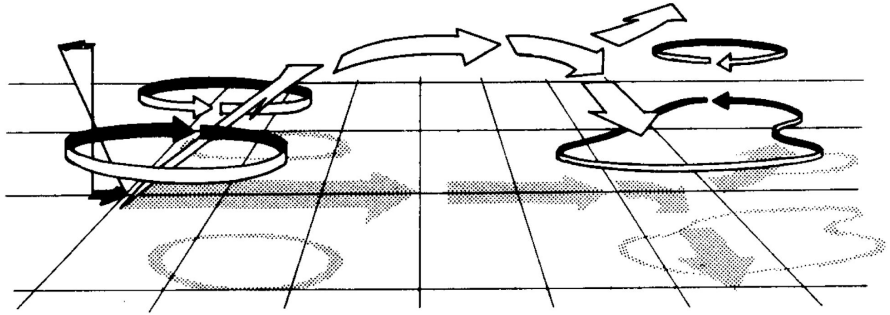


Two mechanisms sustain increased extratrop. cyclone activity in HH

Increased diabatic heating



Accelerated upper-troposphere jet



(Hoskins et al., 1983)

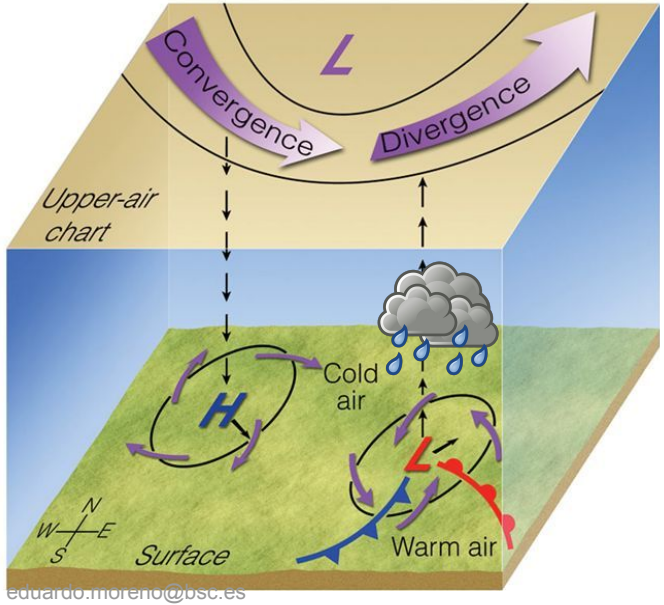
Two mechanisms sustain increased extratrop. cyclone activity in HH

Increased diabatic heating

– In better resolved storm fronts

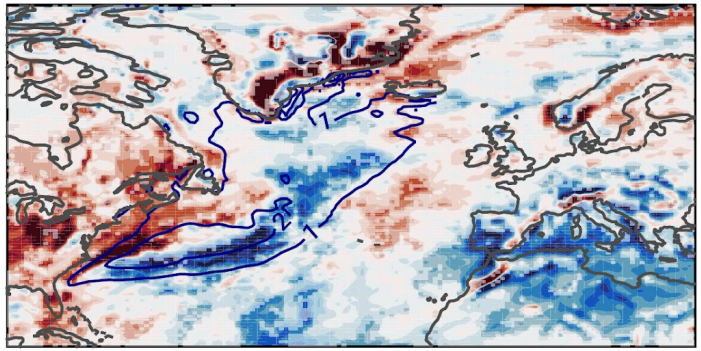
– Reinforces the lower-level cyclonic circulation **(L)** and the upper-level through **(L)**, which fuel farther cyclone development

– Subject to the additional heating from the Gulf Stream warming

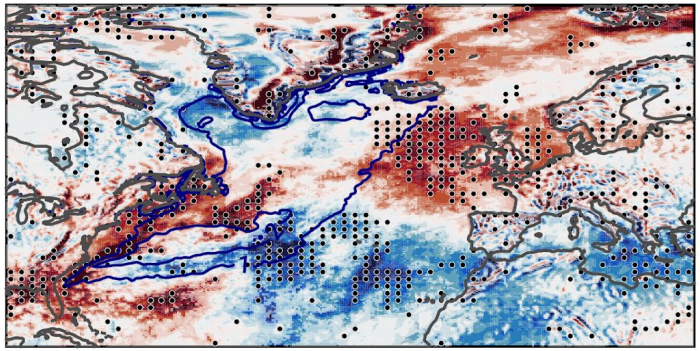


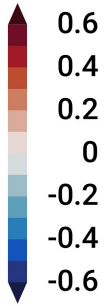
Anomalies in 850–250 hPa diabatic heating (K/day) between 2030–2050 and 1960–1980

MH (highest ocean resolution)



HH

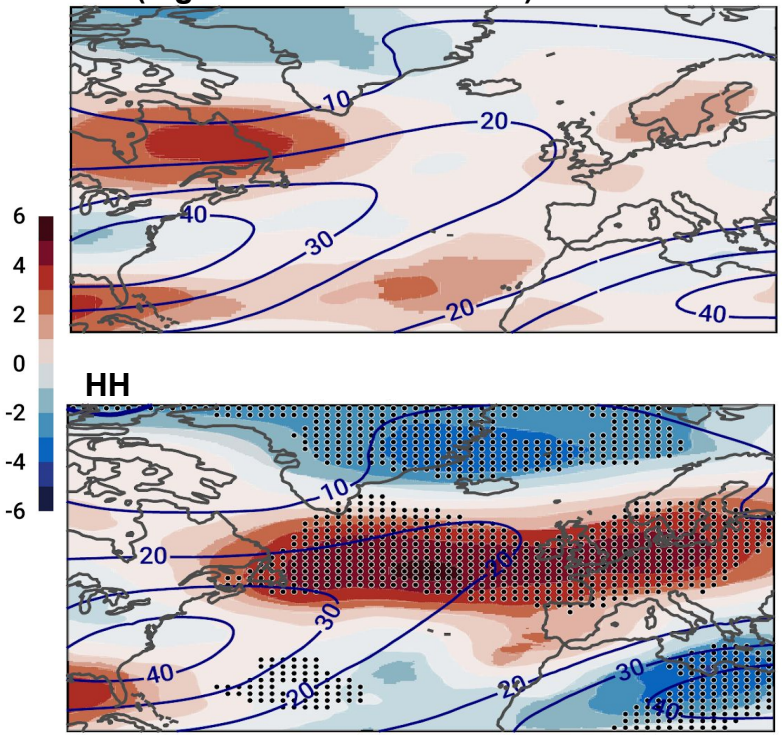




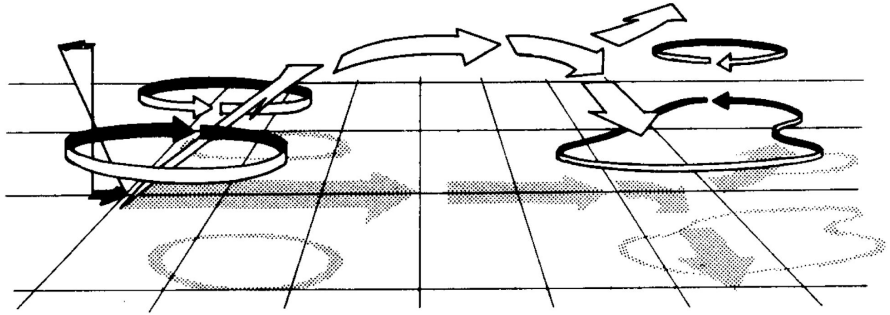
Two mechanisms sustain increased extratrop. cyclone activity in HH

Anomalies in 250 hPa zonal wind (m/s)
between 2030–2050 and 1960–1980

MH (highest ocean resolution)



Accelerated upper-troposphere jet
– weakens atmosphere stability (vertical shear increases)
– due to enhanced eddy–mean flow interactions at higher resolution



(Hoskins et al., 1983)

Is winter precipitation change over Europe underestimated in current climate projections?

- Largest increase in European winter precipitation in a synoptic-scale, eddy-rich model
  - Lower resolutions might underestimate projected future changes (hence, risks!)

- SST warming in the Gulf Stream
  - Related to a northward shift in the Gulf Stream
  - Increased low-level temperature gradient and surface heating increases baroclinicity and fuels atmospheric circulation changes

- More active extratropical cyclones and faster jet stream over the North Atlantic
  - Due to increased atmospheric diabatic heating and eddy–mean flow interactions

- Highest resolution in both the atmosphere and ocean are essential for these mechanisms