Climate change and the Earth's hydrologic cycle: Increased hydroclimatic intensity with global warming

Filippo Giorgi
Abdus Salam ICTP, Trieste, Italy

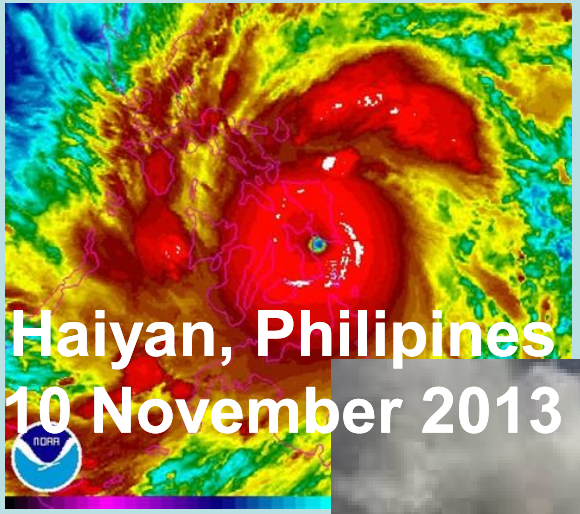
Zagreb, 21 November 2013

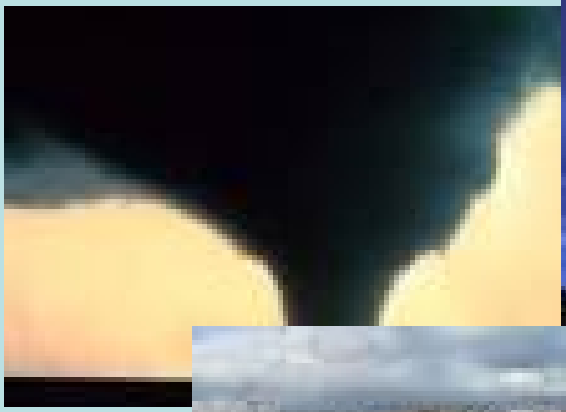
Contributors

- F. Giorgi (ICTP, Italy)
- E. Coppola (ICTP, Italy)
- F. Raffaele (ICTP, Italy)
- E.S. Im (ICTP, Italy)
- N.S. Diffenbaugh (U. Stanford, USA)
- X.J. Gao (CMA, China)
- L. Mariotti (ICTP, Italy)
- Y. Shi (CMA, China)

- Giorgi, F., E.S. Im, E. Coppola, N.S. Diffenbaugh, X.J. Gao, L. Mariotti, and Y. Shi, 2011: Higher hydroclimatic intensity with global warming. J. Climate, 24, 5309-5324.
- Giorgi, F., E. Coppola, F. Raffaele: Some consequences of increasing hydroclimatic intensity with global warming: Reduced precipitation area and increased minimum precipitation predictability. Submitted to Climatic Change Letters.

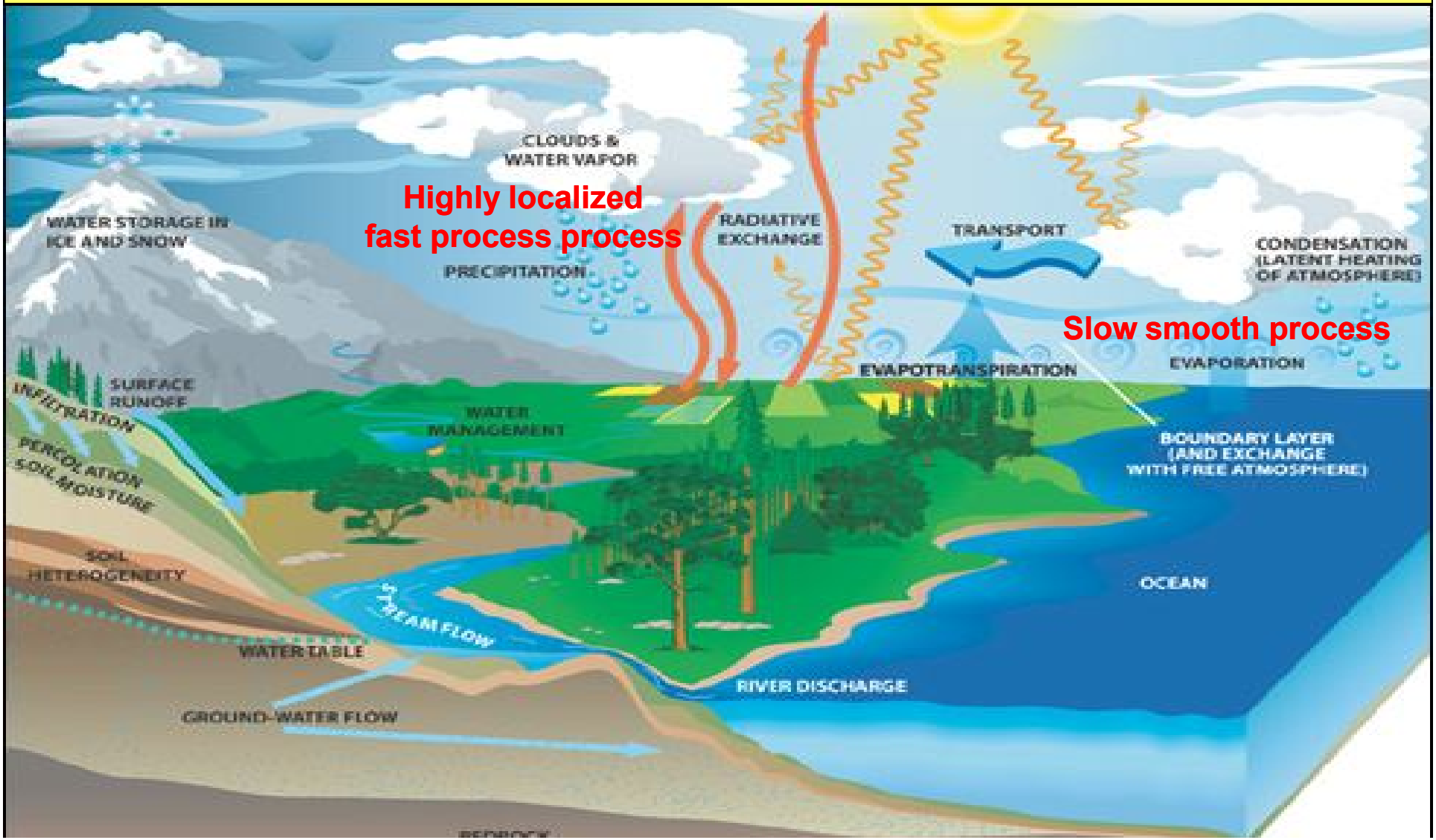
Just Happened !!



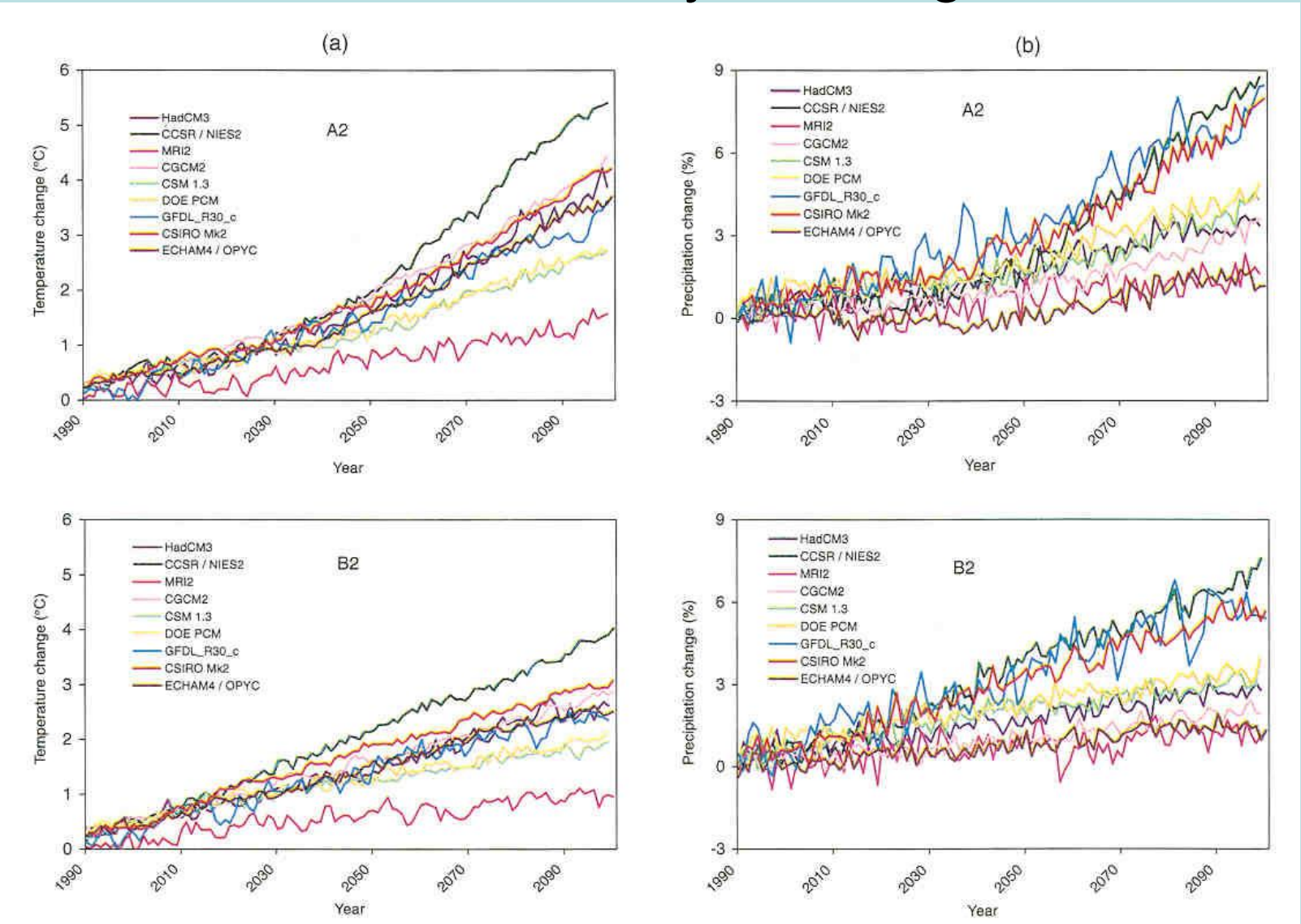


… but it has been happening for a while
August 2010

Climate change can profoundly affect the Earth's hydrologic cycle



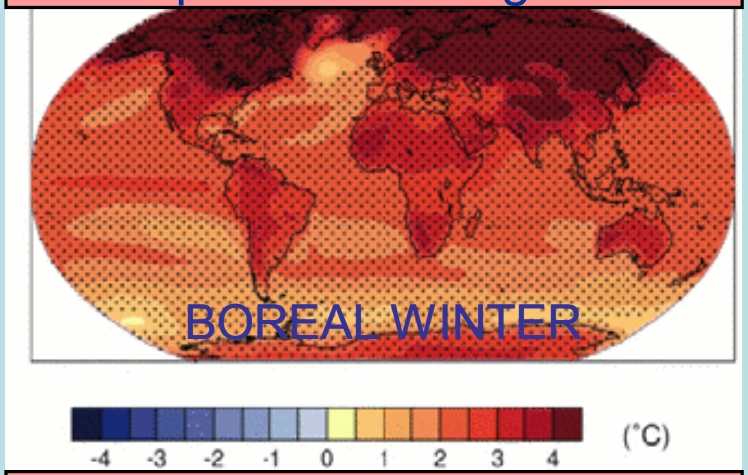
Global warming is generally expected to lead to increased global precipitation while relative humidity remains relatively unchanged



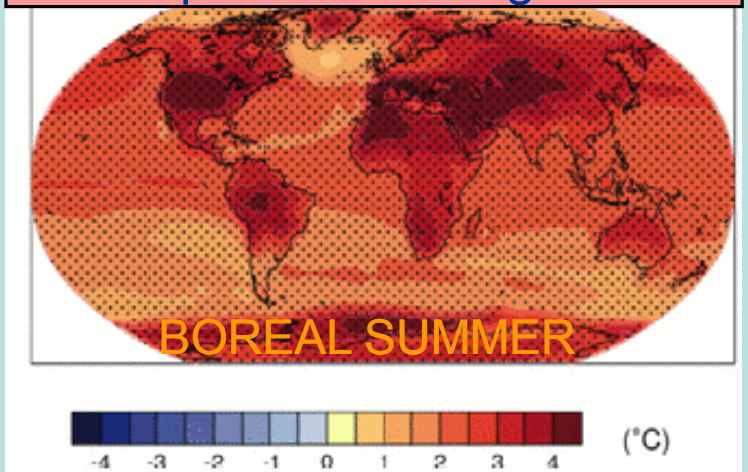
Projected changes in temperature and precipitation show a high degree of spatial variability

(A1B scenario, 2090-2100)

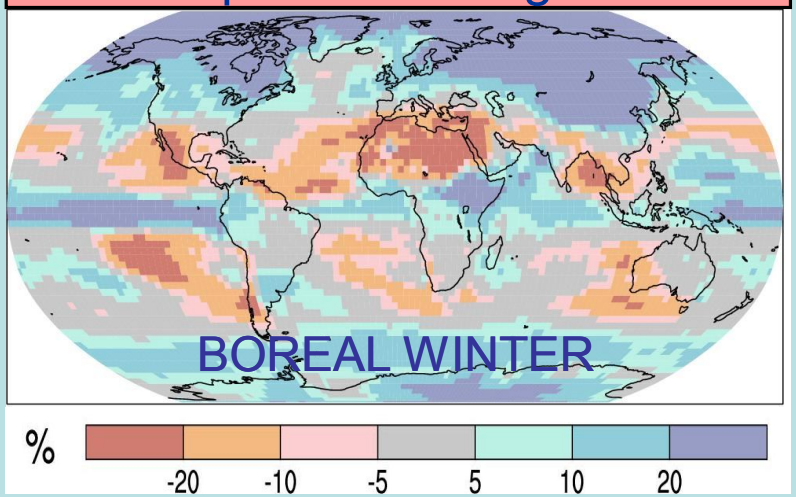
Temperature change DJF



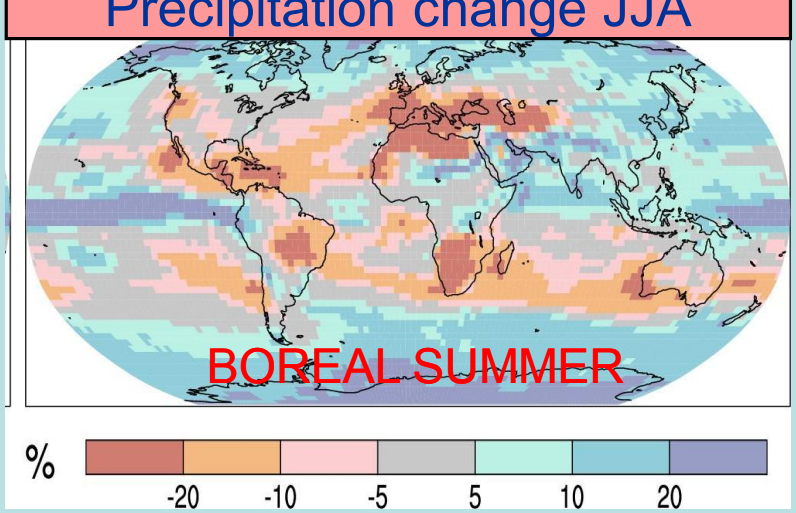
Temperature change JJA

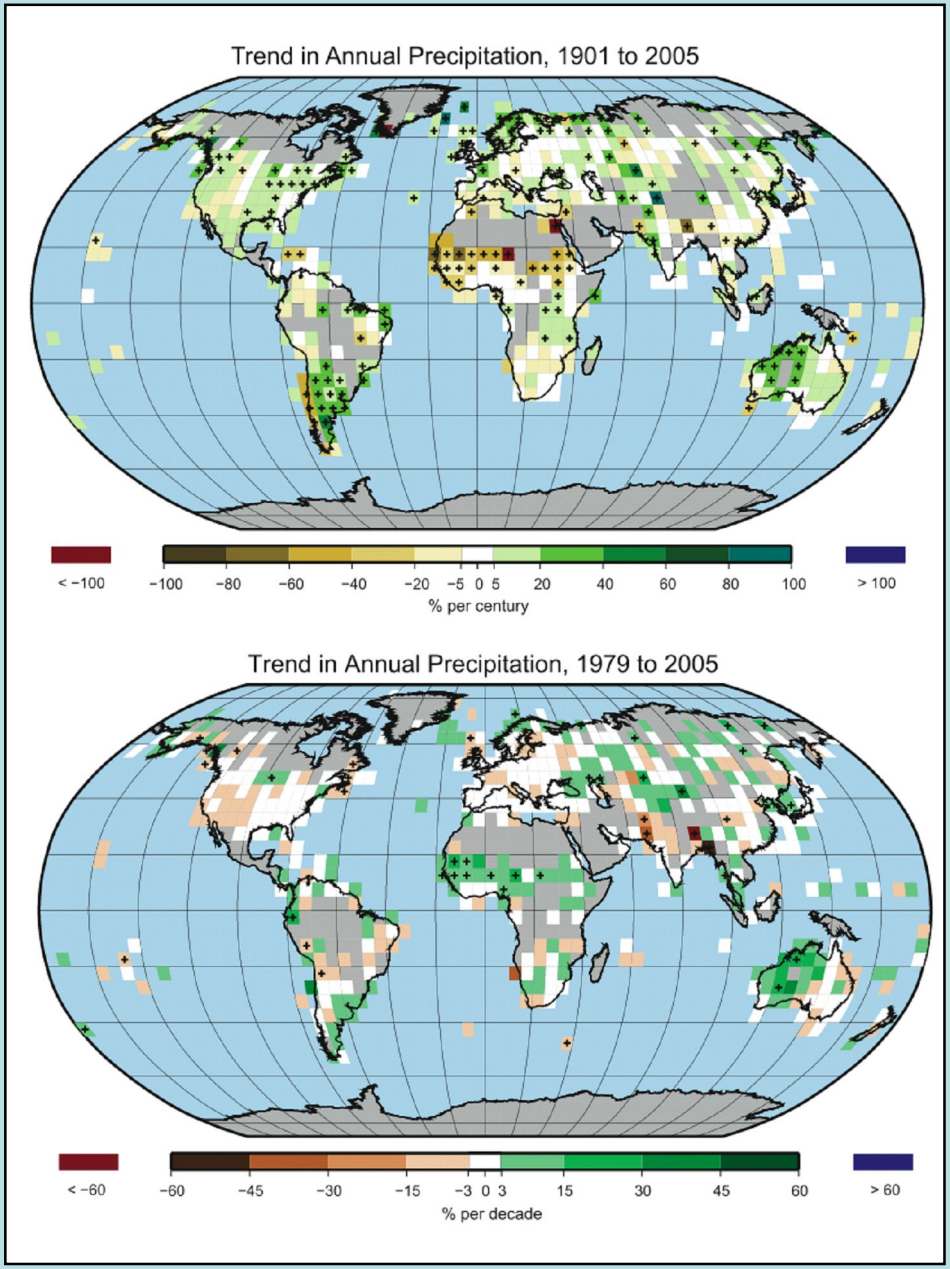


Precipitation change DJF

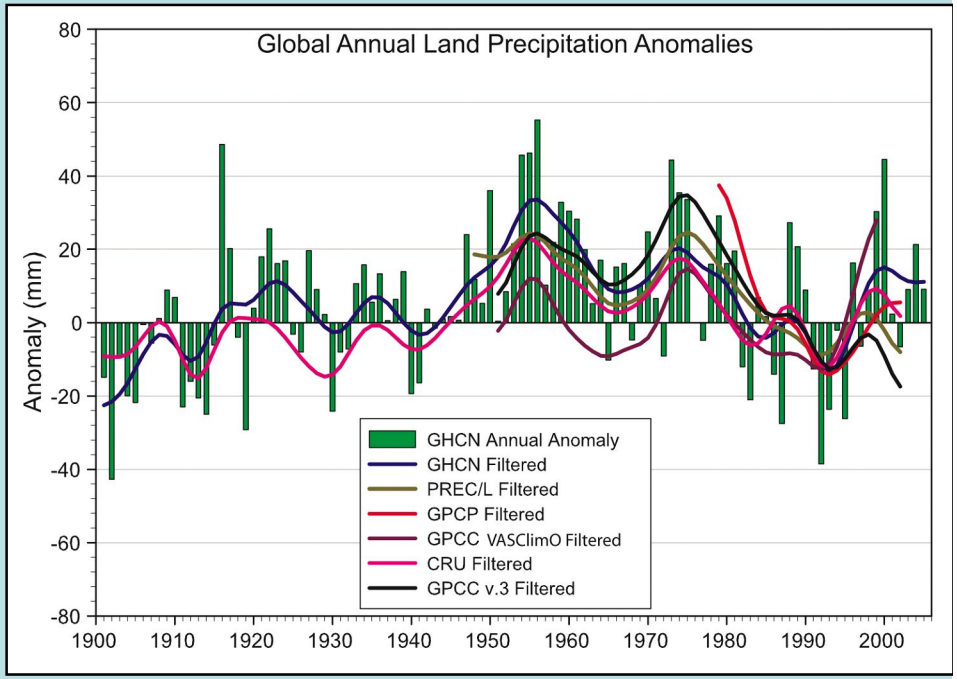


Precipitation change JJA





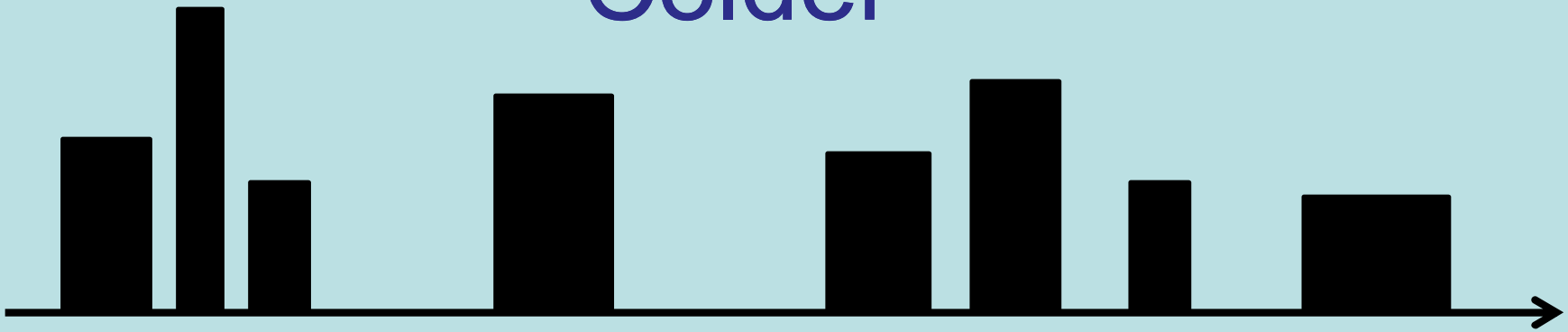
Observed precipitation trends are still unclear




Is it possible that changes in the hydrologic cycle due to global warming might manifest themselves primarily as changes in hydroclimatic regimes?

Global warming might lead to more intense, more frequent events

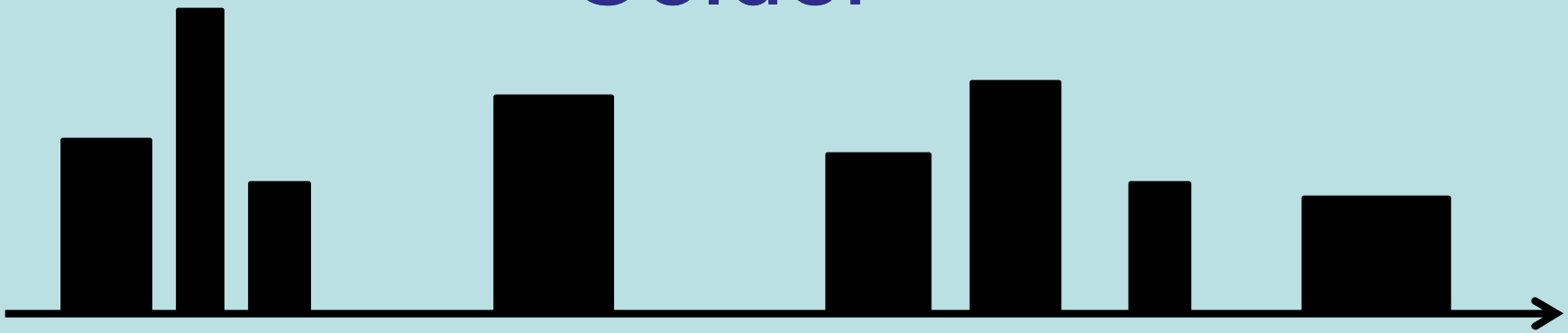
Colder



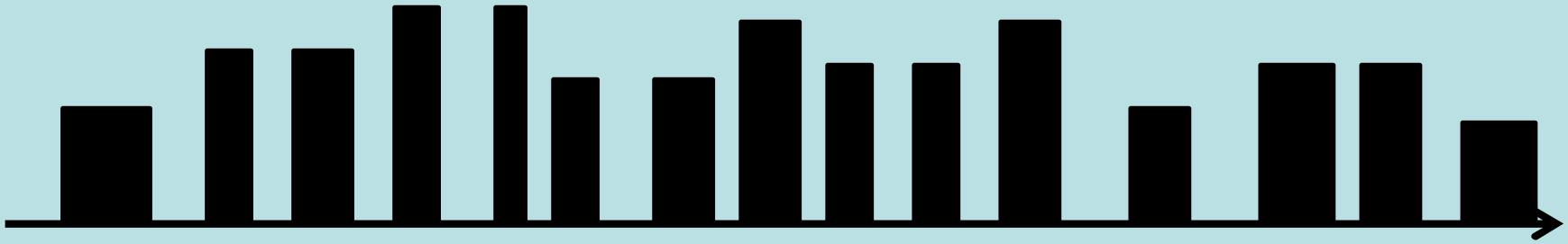
Warmer

… or to
less intense, more frequent events

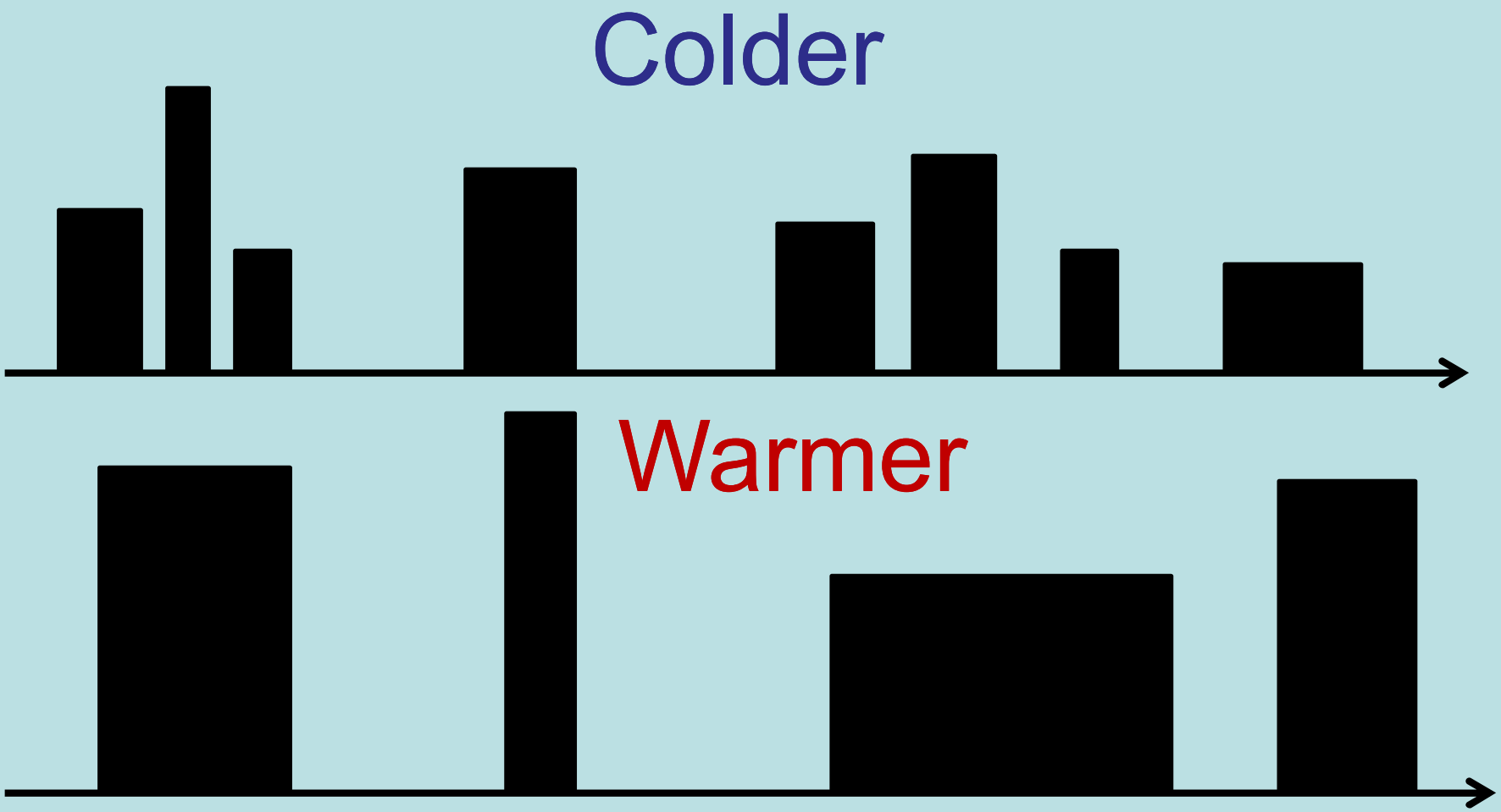
Colder



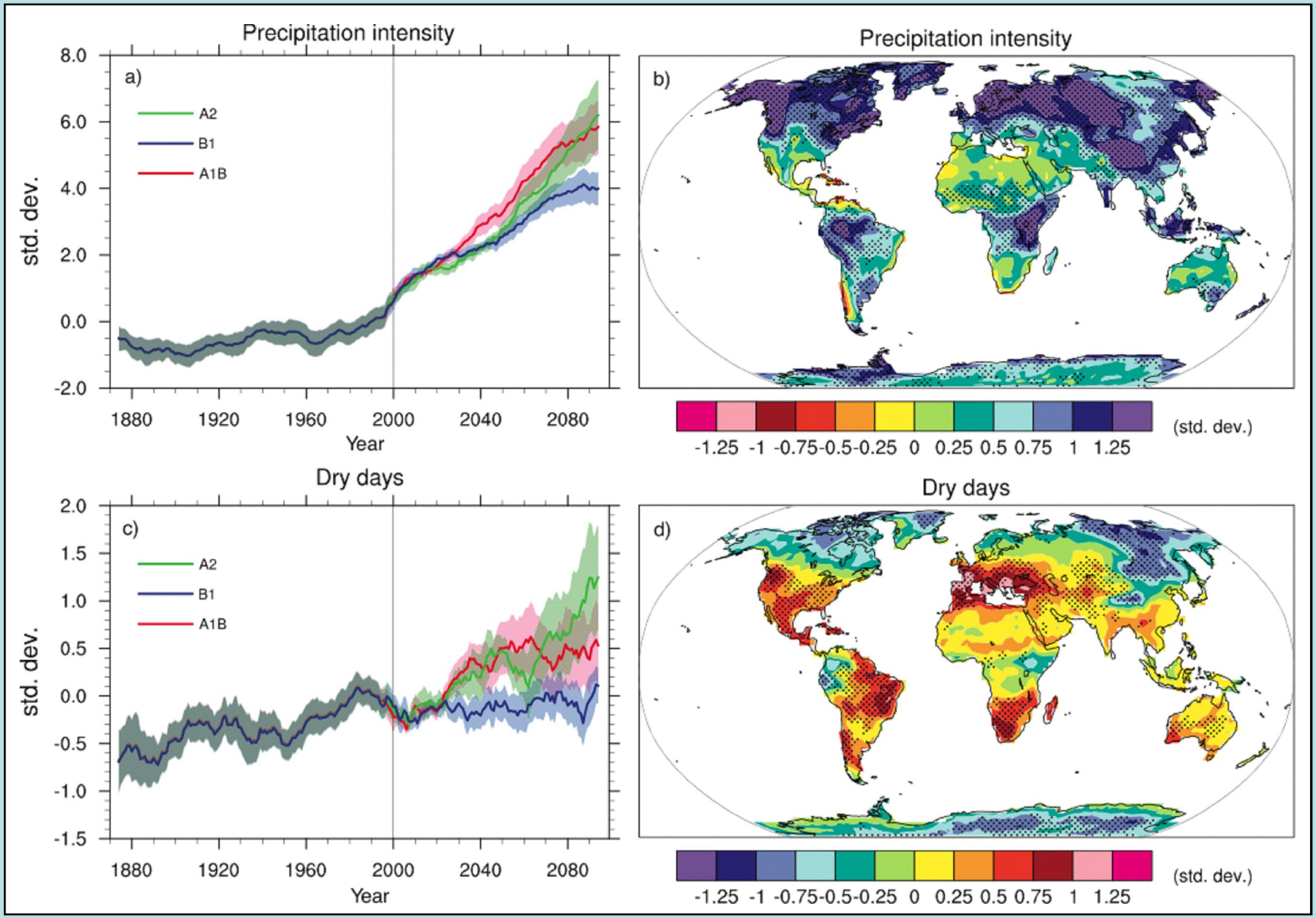
Warmer



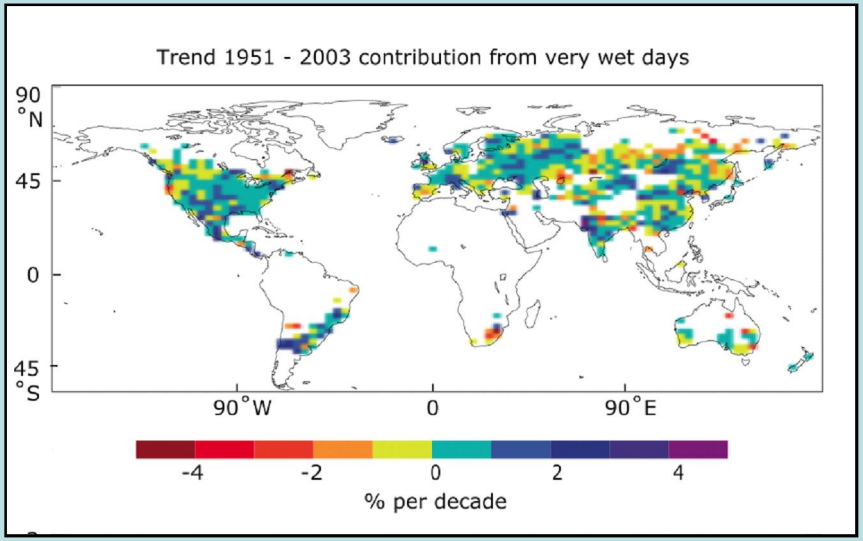
… or yet to more intense, less frequent events



Projected changes in precipitation characteristics IPCC (2007)



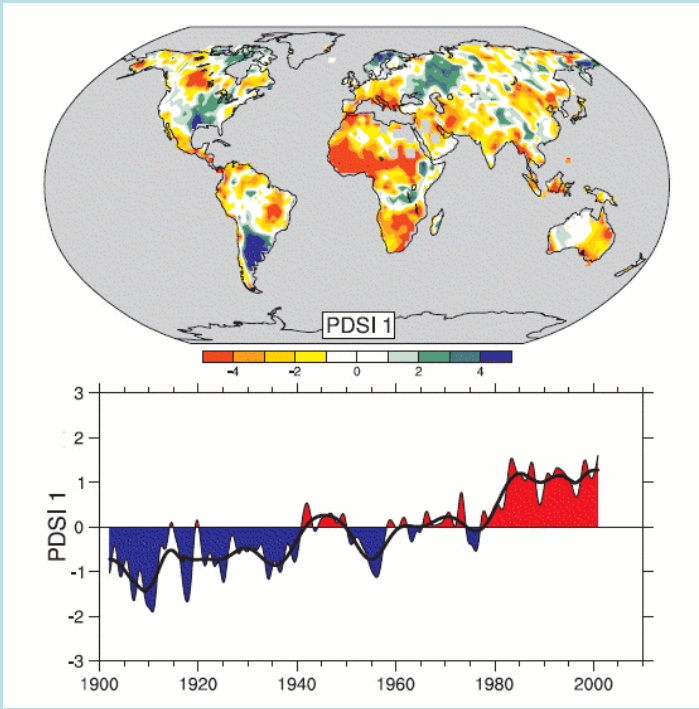
Observed trends in precipitation characteristics IPCC (2007)



It rains less frequently but more intensely

IPCC 2007: “More intense and longer droughts have been observed over wider areas since the 1970s”

IPCC 2007: “The frequency of heavy precipitation events has increased over most land areas”



Hypothesis: The increases in dry day frequency and precipitation intensity are deeply interconnected and can be seen as a combined hydroclimatic signature of global warming

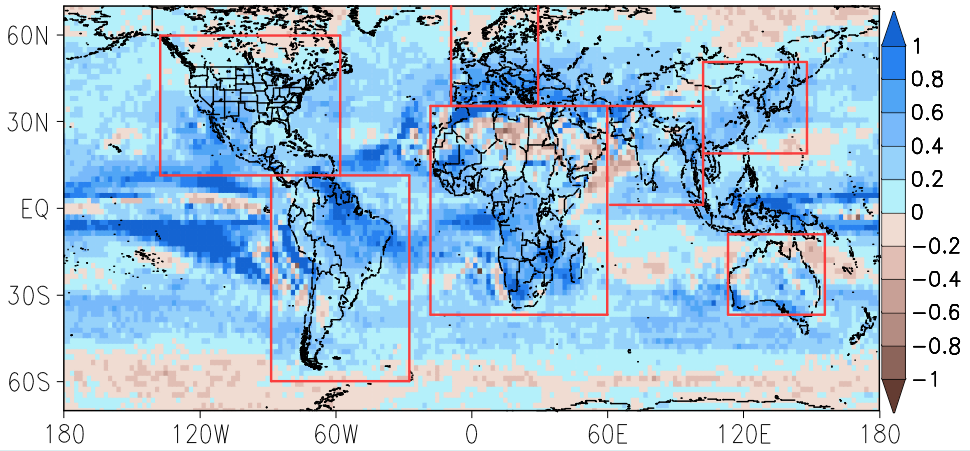
Define an index of hydroclimatic intensity that combines precipitation intensity and dry spell length

$$\text{HY-INT} = I \bullet DSL$$

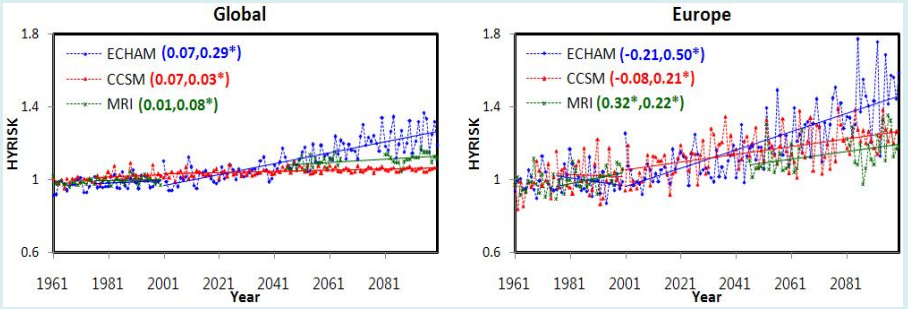
I = Normalized Precipitation Intensity
DSL = Normalized Dry Spell Length

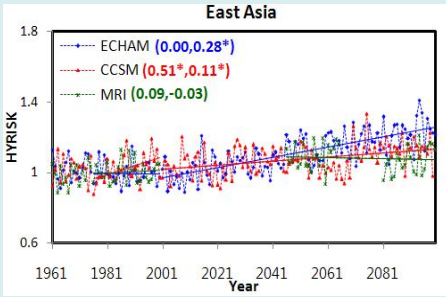
HY-INT is NOT an index of extremes
HY-INT is calculated from daily precipitation on an annual basis

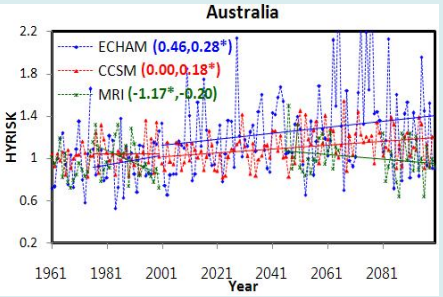
21st Century trend of HY-INT for three GCM projections, A1B Scenario Giorgi et al. (2011)

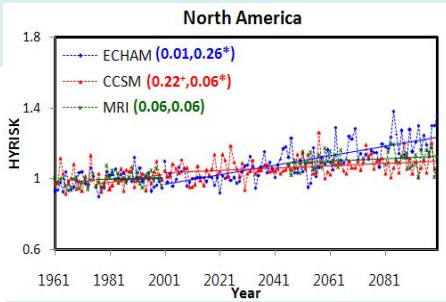


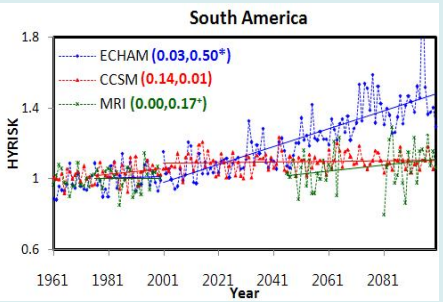
ECHAM5

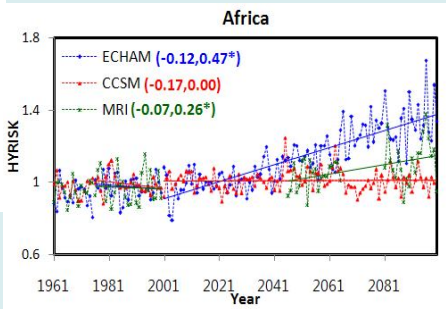


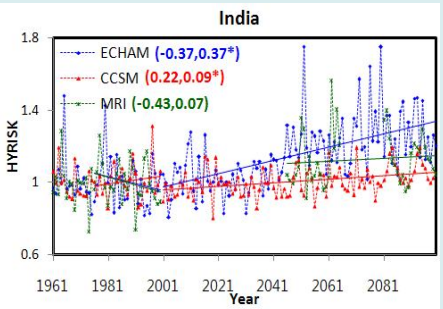


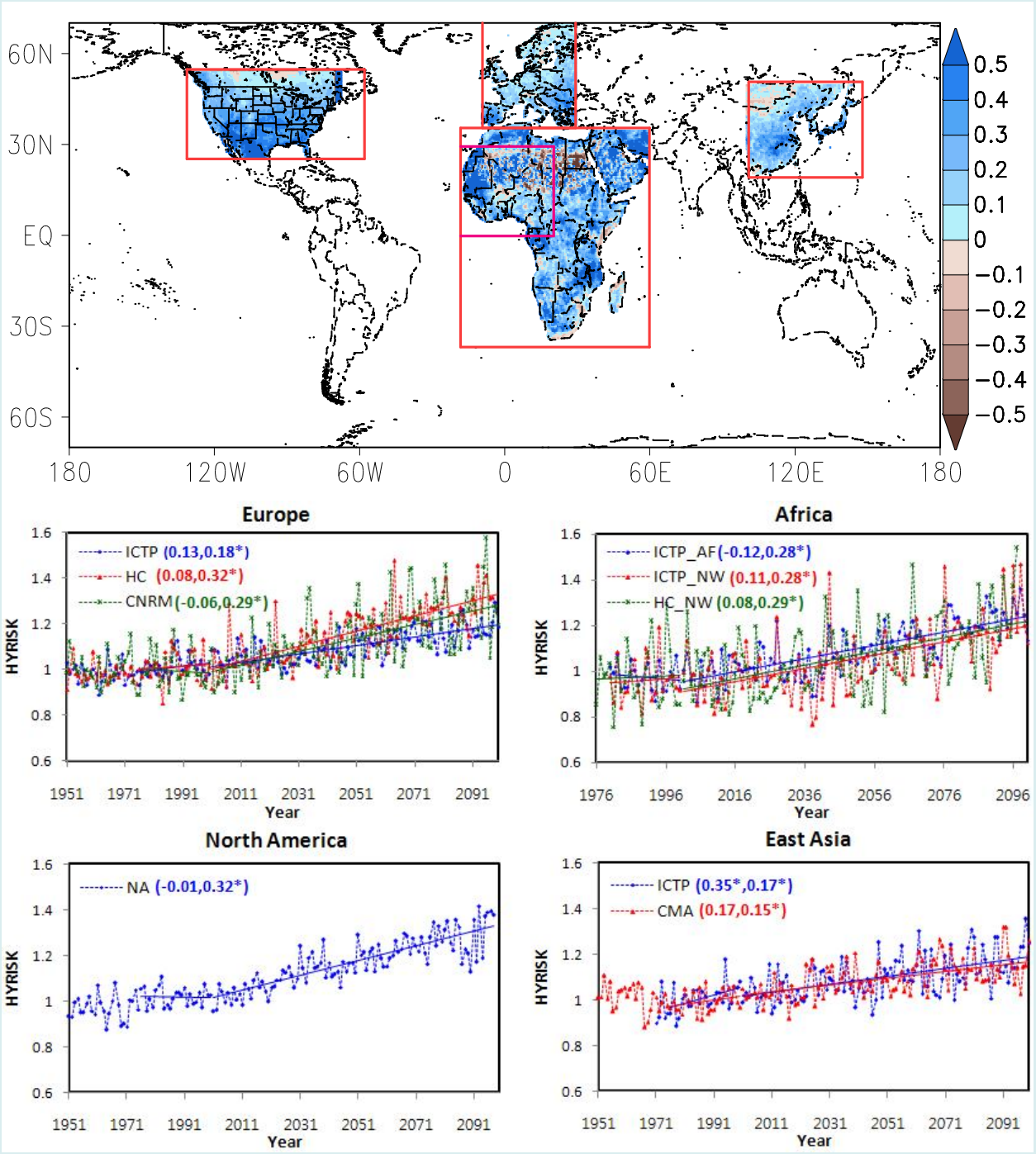






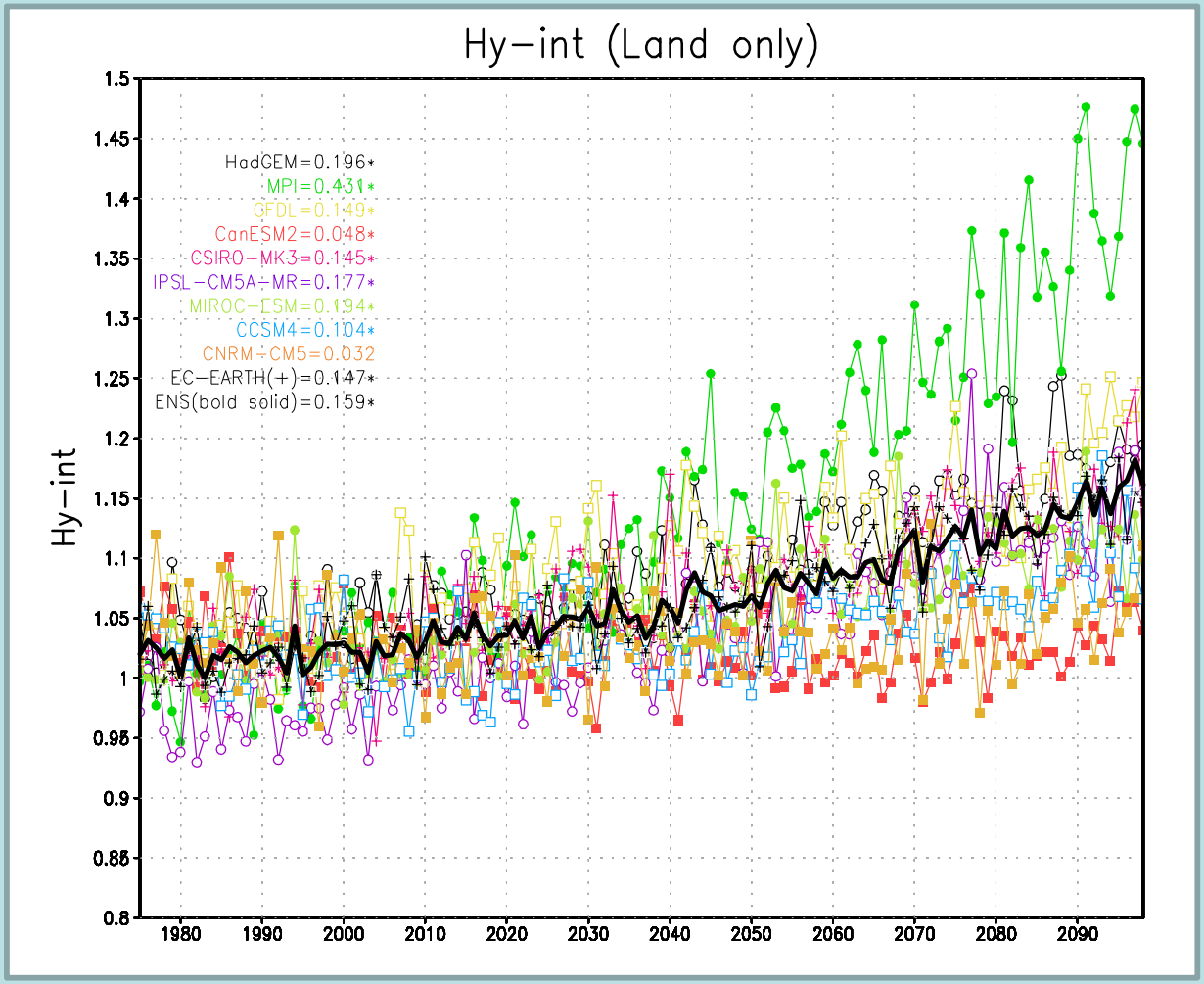


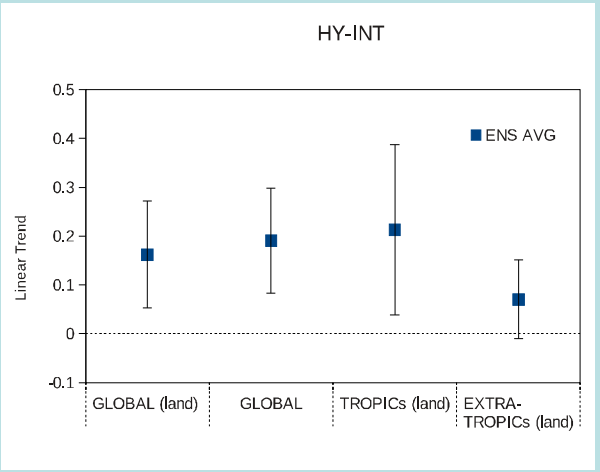




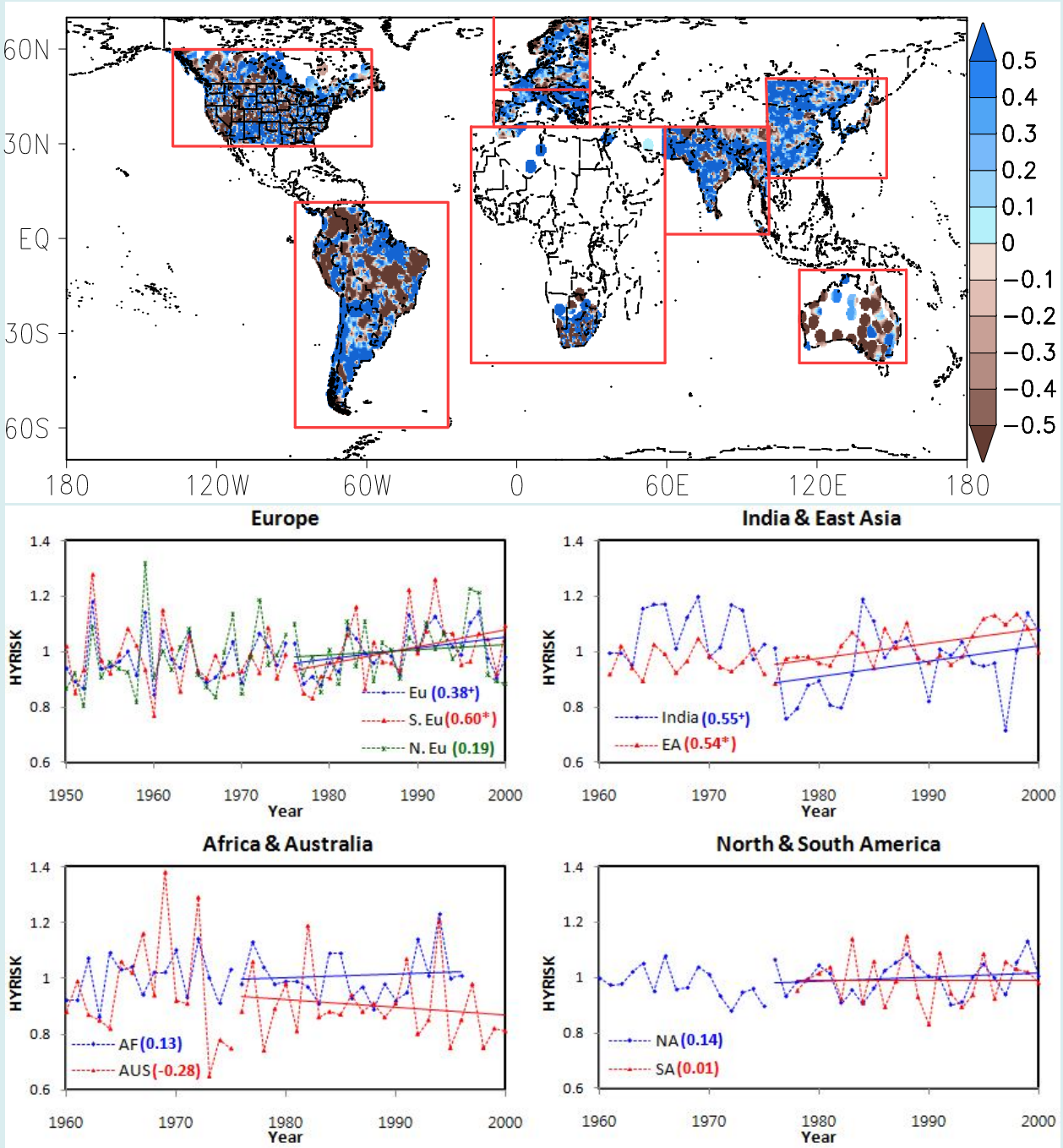
21st Century trend of HY-INT for three RCMs Giorgi et al. (2011)

21st Century trend of HY-INT for ten GCM projections from CMIP5, RCP8.5, Land Only Giorgi et al. (2013)



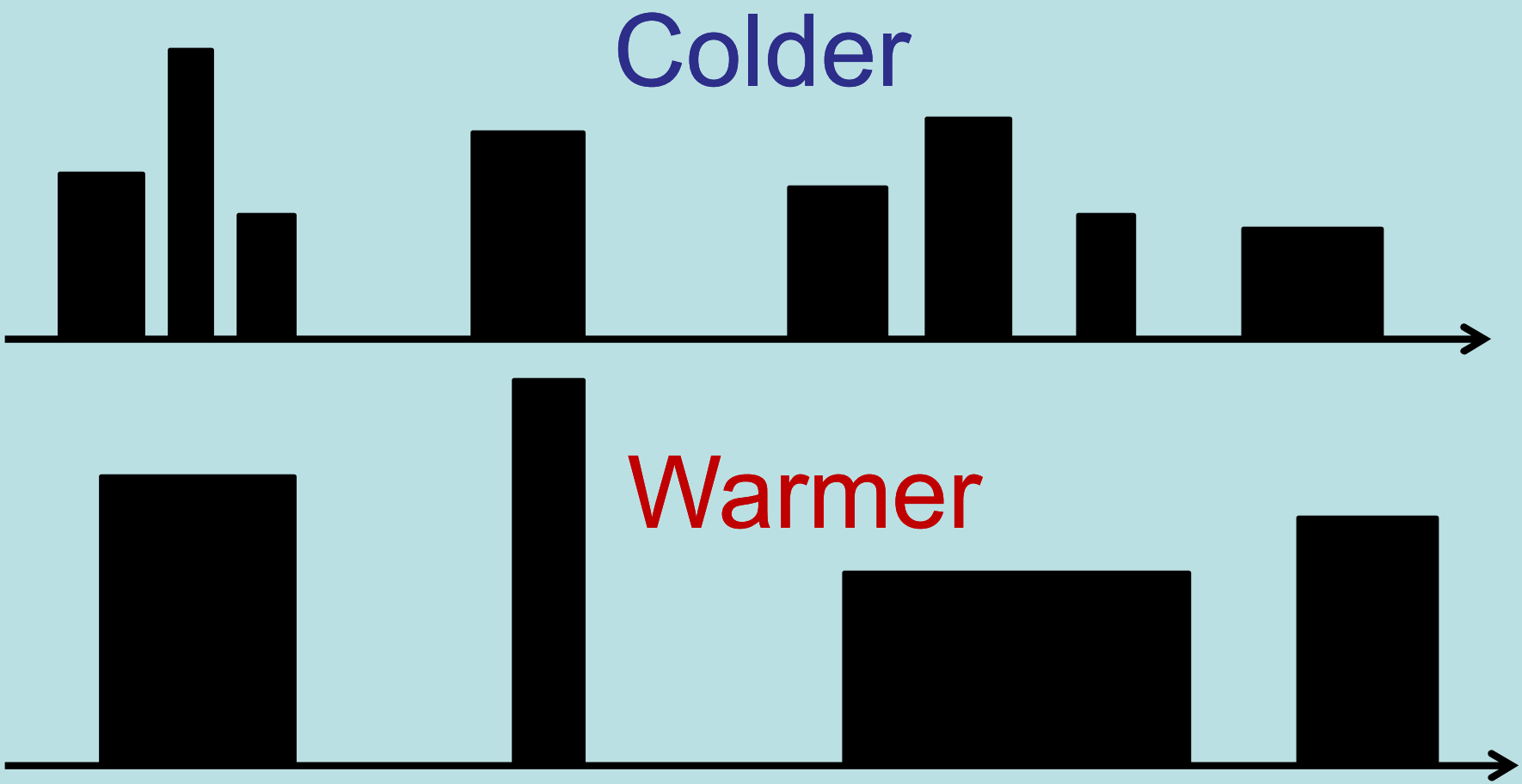


21st Century trend in HY-INT

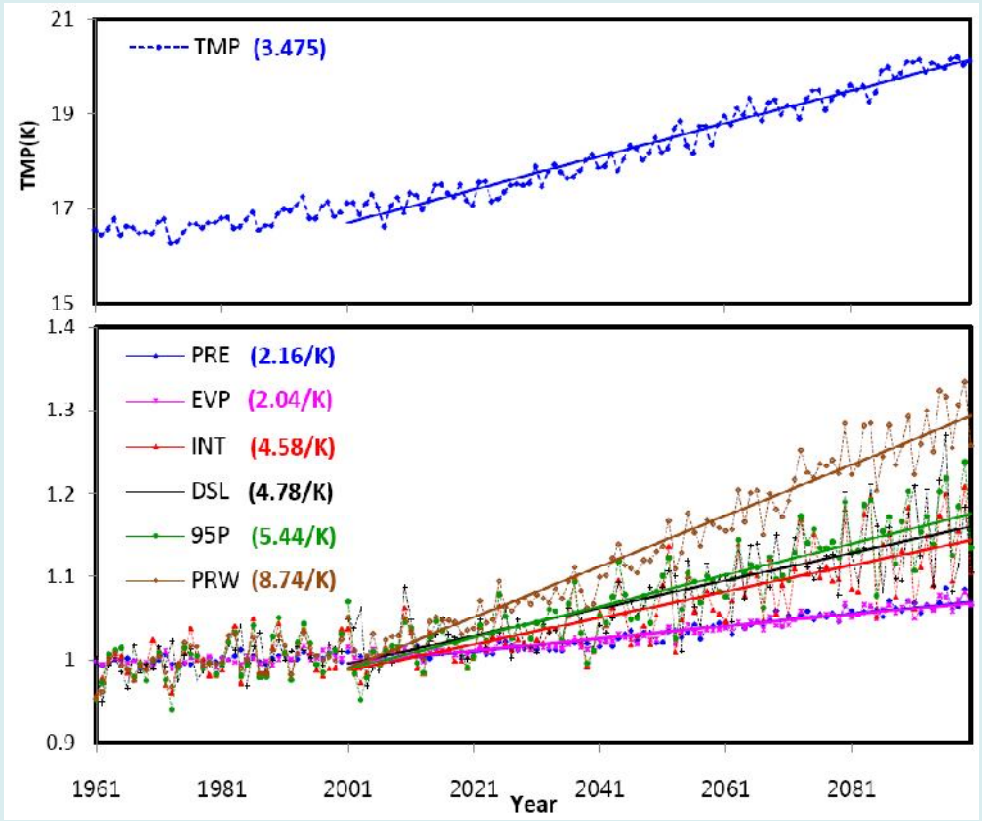


Late 20th Century trend of HY-INT from station Observations Giorgi et al. (2011)

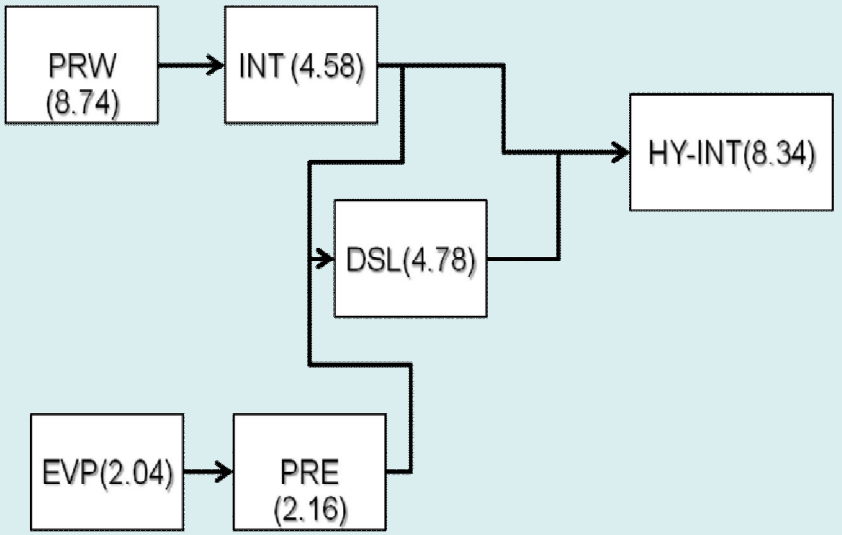
It appears that a robust response of the hydrologic cycle to global warming is a shift to more intense, less frequent events



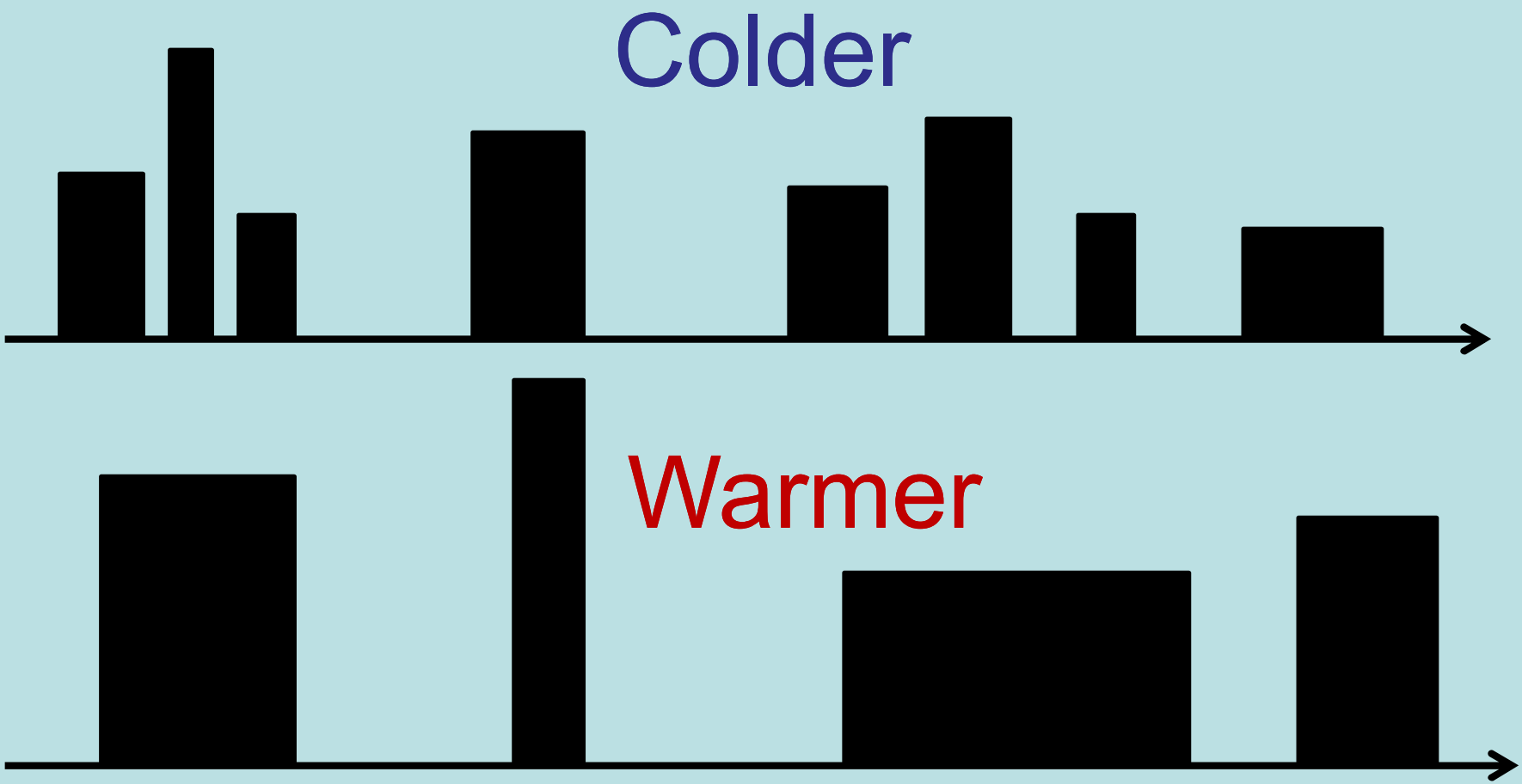
A diagnostic explanation of this response. ECHAM5 model, A1B scenario



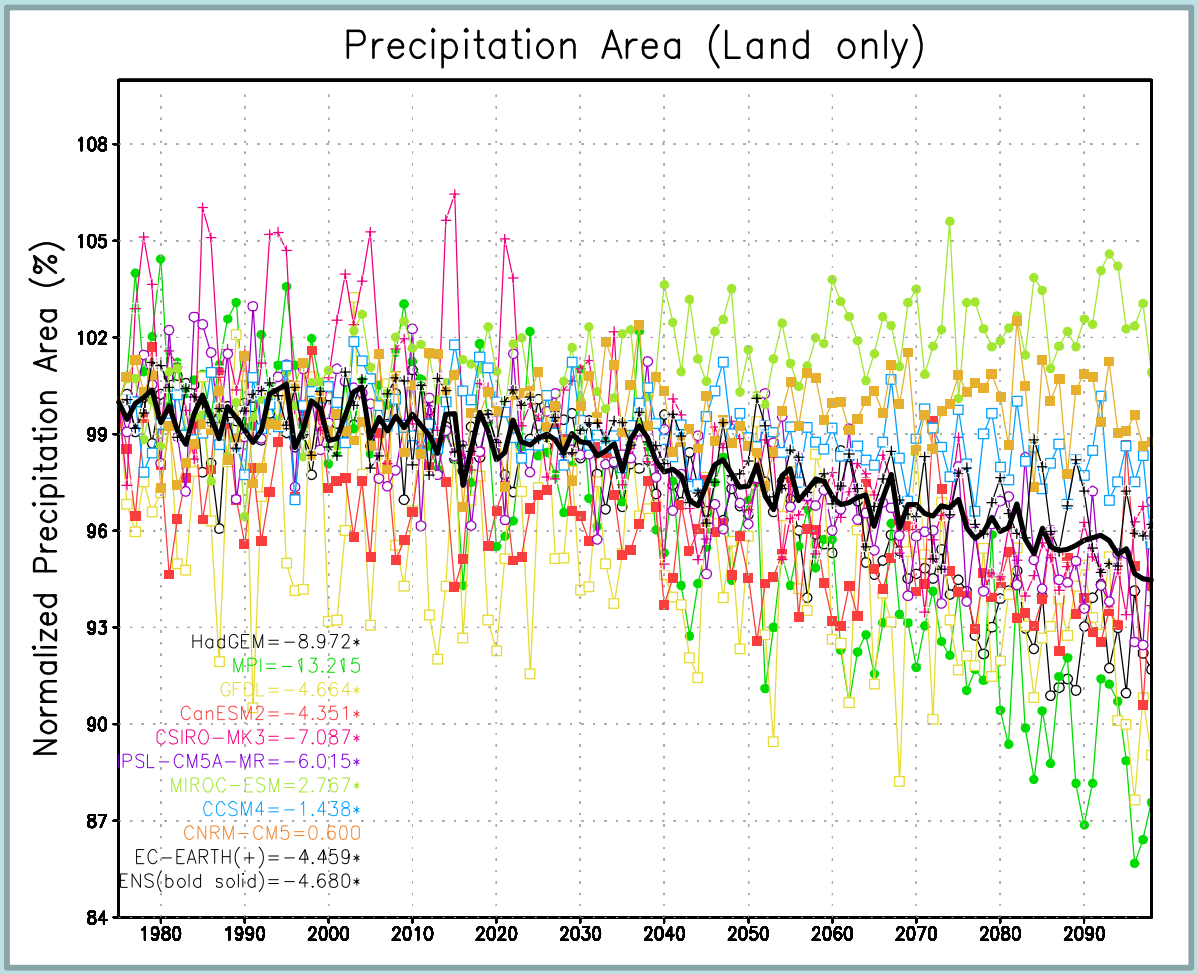
% change per degree of global warming

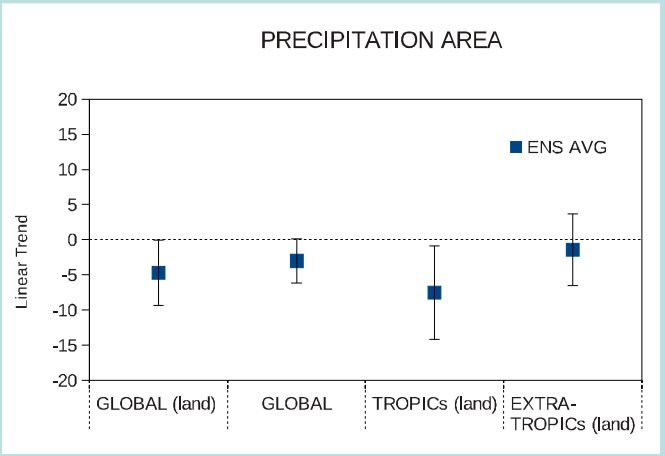


Some interesting consequences of the hydroclimatic regime shift in response to global warming



21st Century trend of precipitation area for ten GCM projections from CMIP5, RCP8.5, Land Only Giorgi et al. (2013)

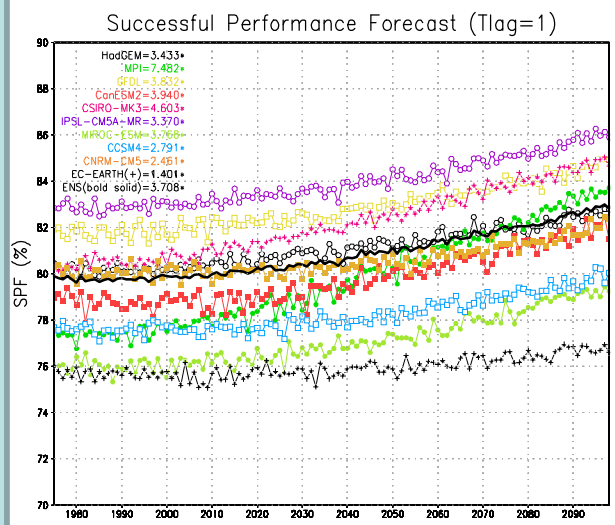


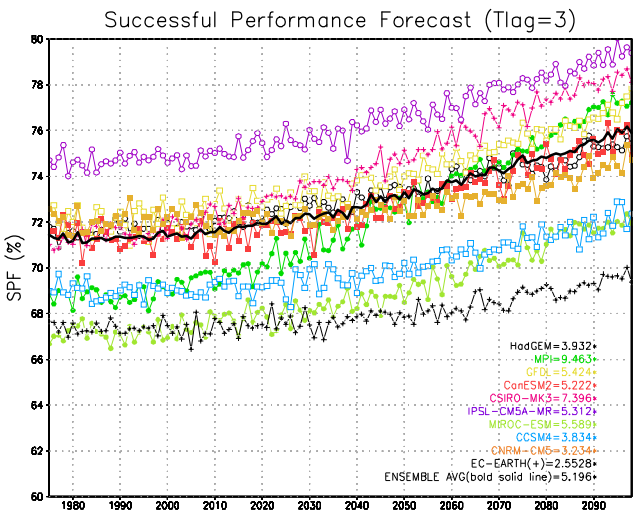


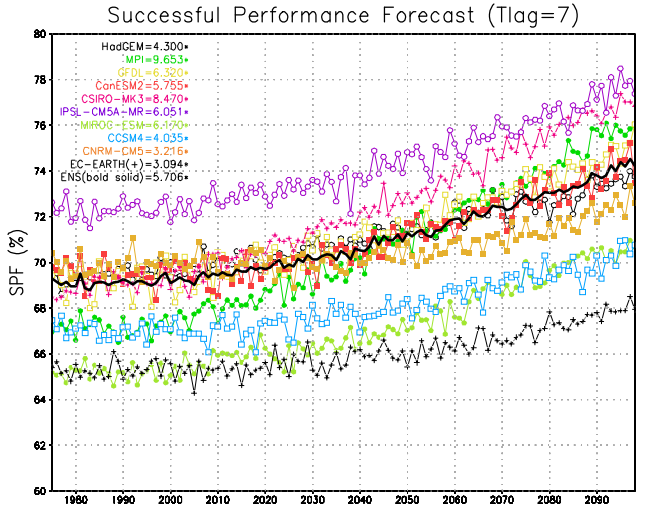
21st Century trend in Precipitation area

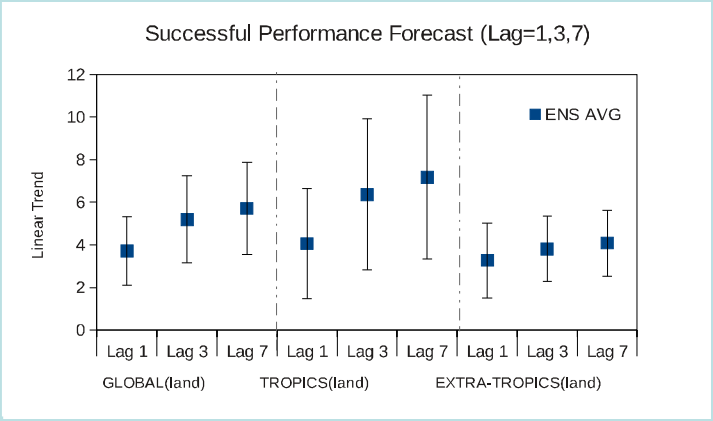
Longer dry seasons shorter and more intense wet seasons

21st Century trend of successful Persistence Forecasts for ten GCM projections from CMIP5, RCP8.5, Land Only Giorgi et al. (2013)









Global warming might lead to an increase in minimum precipitation predictability

21st Century trend in Precipitation area

Summary

- A regime shift towards more intense, less frequent precipitation events appears to be a robust response to global warming
- This response implies greater risk of flood and drought with global warming
- The index HY-INT can be used as an effective measure of this response and can provide a useful hydroclimatic detection and attribution tool
- The increase in hydroclimatic intensity implies a decrease in daily precipitation area and an increase in minimum precipitation predictability (as defined by persistence)
- Understanding of this hydroclimatic shift might provide key information on the inherent behavior of the Earth's hydrologic cycle


HVALA