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On separating the forced response from variability in circulation changes over Europe

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MARIE CURIE ACTIONS

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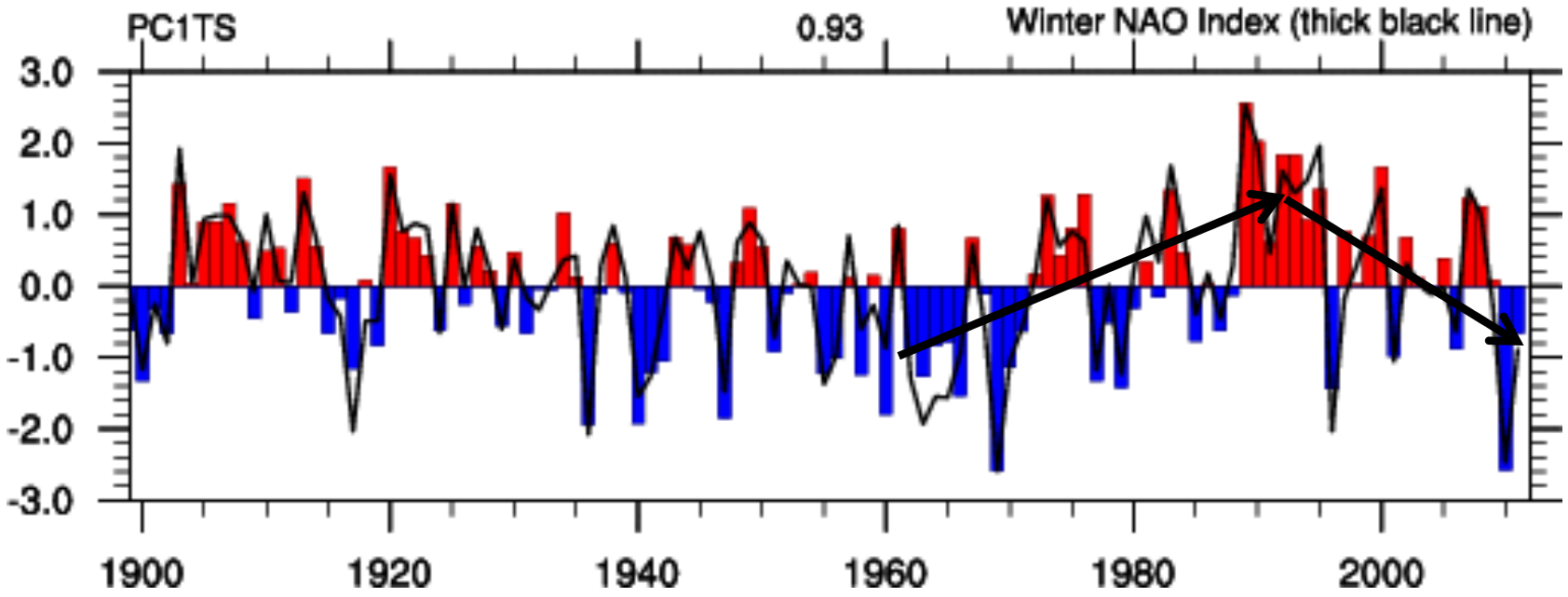
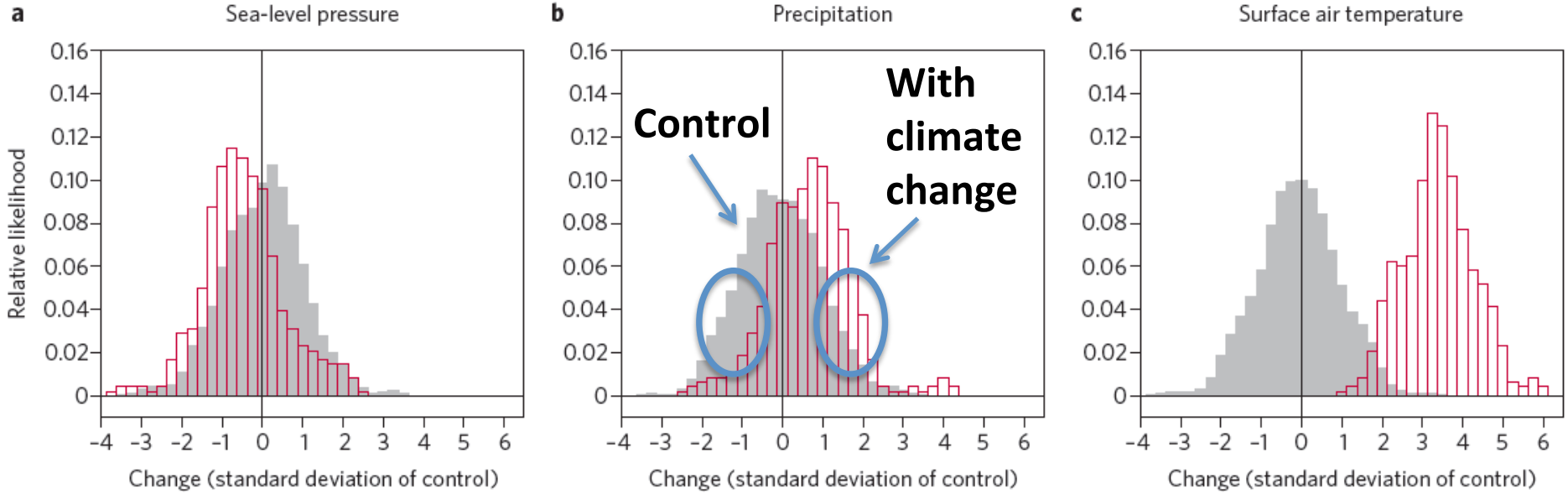
EXCELLENCE IN SCIENCE

- Circulation aspects of climate exhibit pronounced **chaotic variability** on multi-decadal timescales, with generally no clear long-term trend (here the North Atlantic Oscillation, NAO)
  - Similar behaviour is seen in circulation-related extremes
- This confounds the detection of anthropogenic changes
  - In the early 2000's the NAO trend since 1960 was "attributed" to climate change; what would we say now?



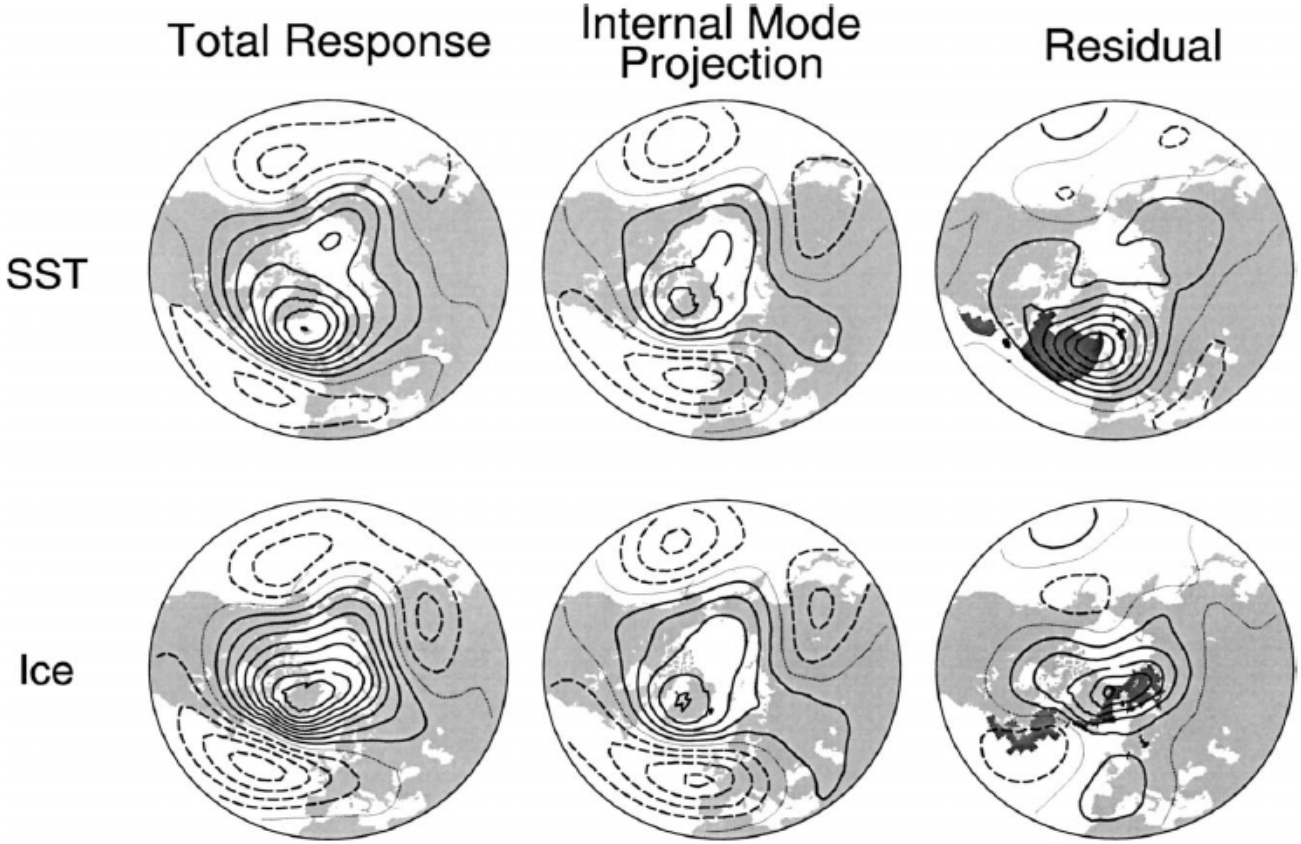
- In many regions, precipitation seems to be controlled much more by circulation than by pure thermodynamics, and **the signal-to-noise of the forced response is comparatively small**
- For Eurasia/North Atlantic, there is about a 30% chance (for this model) of 55-year trends in SLP or precip being of opposite sign to the anthropogenic signal; **yet the change in risk is not small**

PDFs of DJF trends from 2005 to 2060 in the Eurasian/North Atlantic sector



Adapted from Deser et al. (2012 Clim. Dyn.)

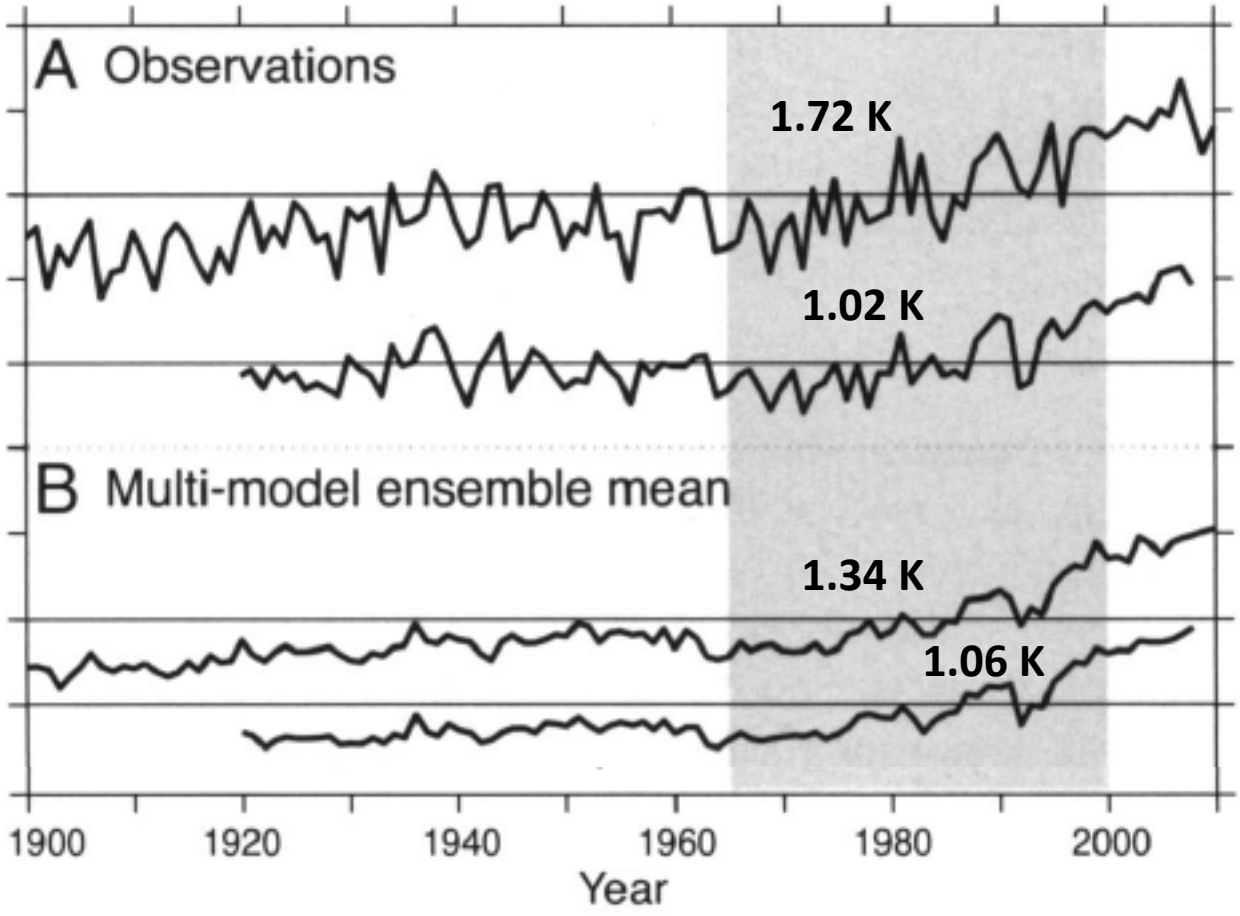
- **There is a connection between the circulation response to forcing and variability**
  - The wintertime 500 hPa geopotential height response to thermodynamic forcings (here SST or sea-ice anomalies) consists of a direct baroclinic response and an indirect barotropic response which projects on modes of variability



Detection of the latter will be challenging!

Deser et al. (2004 J. Clim.)

- Some have proposed making a **"dynamical correction"** to observed changes, removing the component congruent with internal variability; this tends to bring models closer to obs
  - But what if part of a dynamically congruent trend is forced?

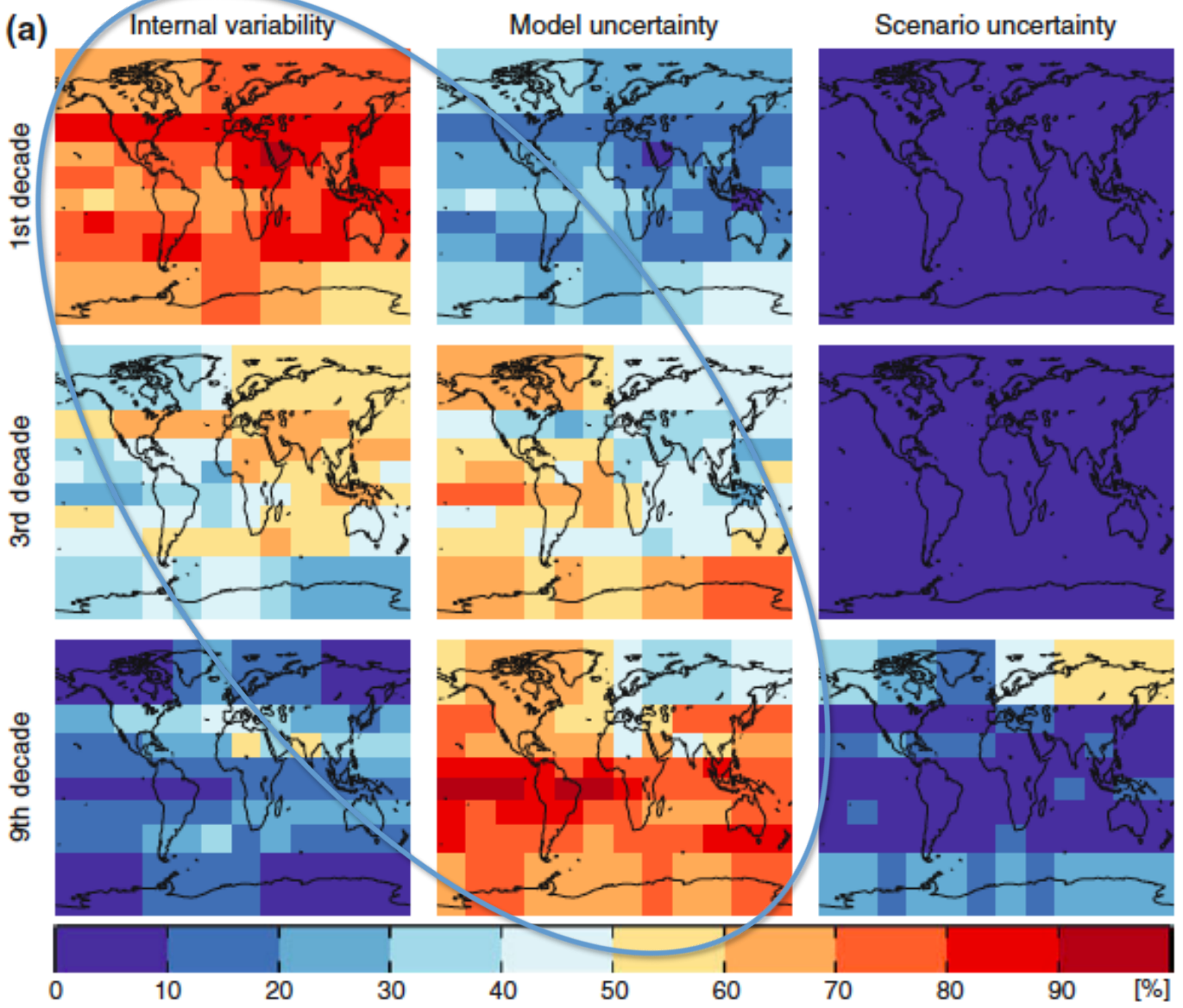


Changes in annual mean SAT over land, 40°N-90°N; raw (top curves) and dynamically adjusted (bottom curves)

Tick marks are 1K

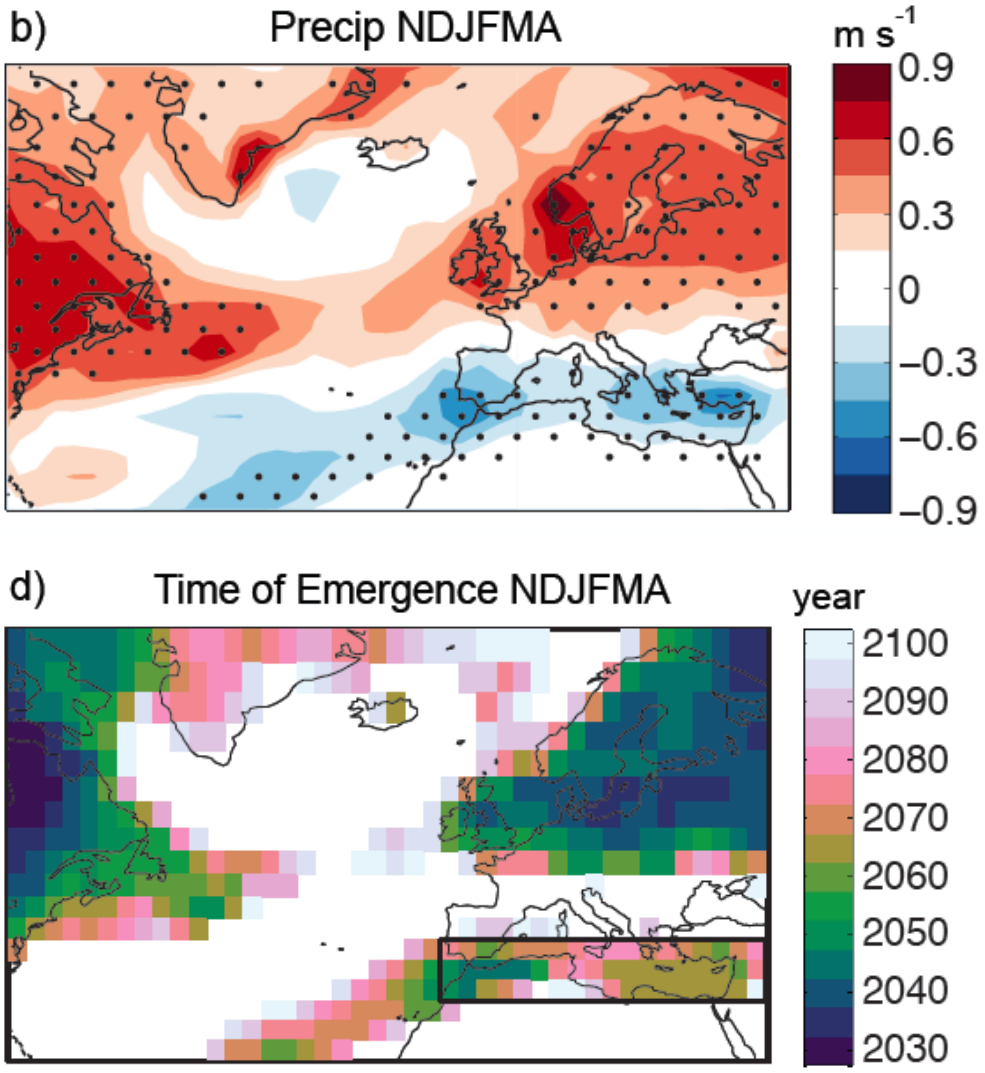
Wallace et al. (2012 PNAS)

Contributions to uncertainty of decadal-mean DJF precipitation projections

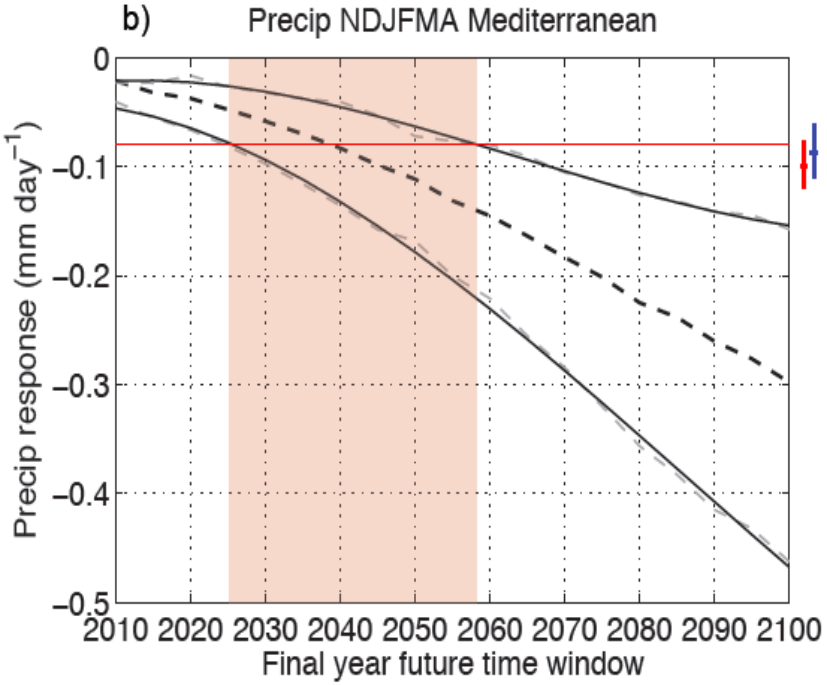


Hawkins & Sutton (2011 Clim. Dyn.)

- A consistent prediction of climate models is **wintertime drying over the Mediterranean**

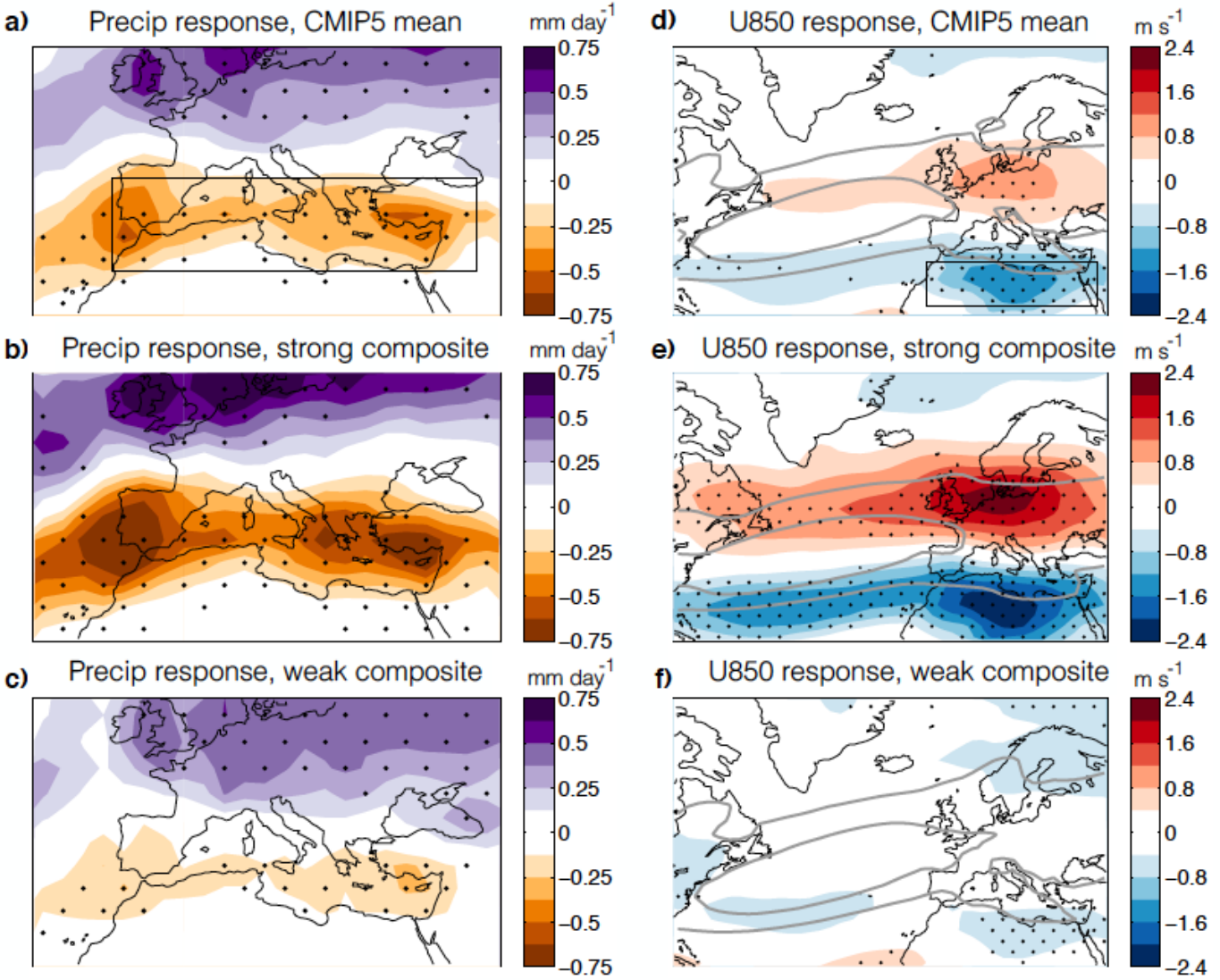


- The signal (in 30-year means, relative to 1960-1990) could emerge within the next 10 years!



Zappa, Hoskins & Shepherd (2015 J. Clim.)

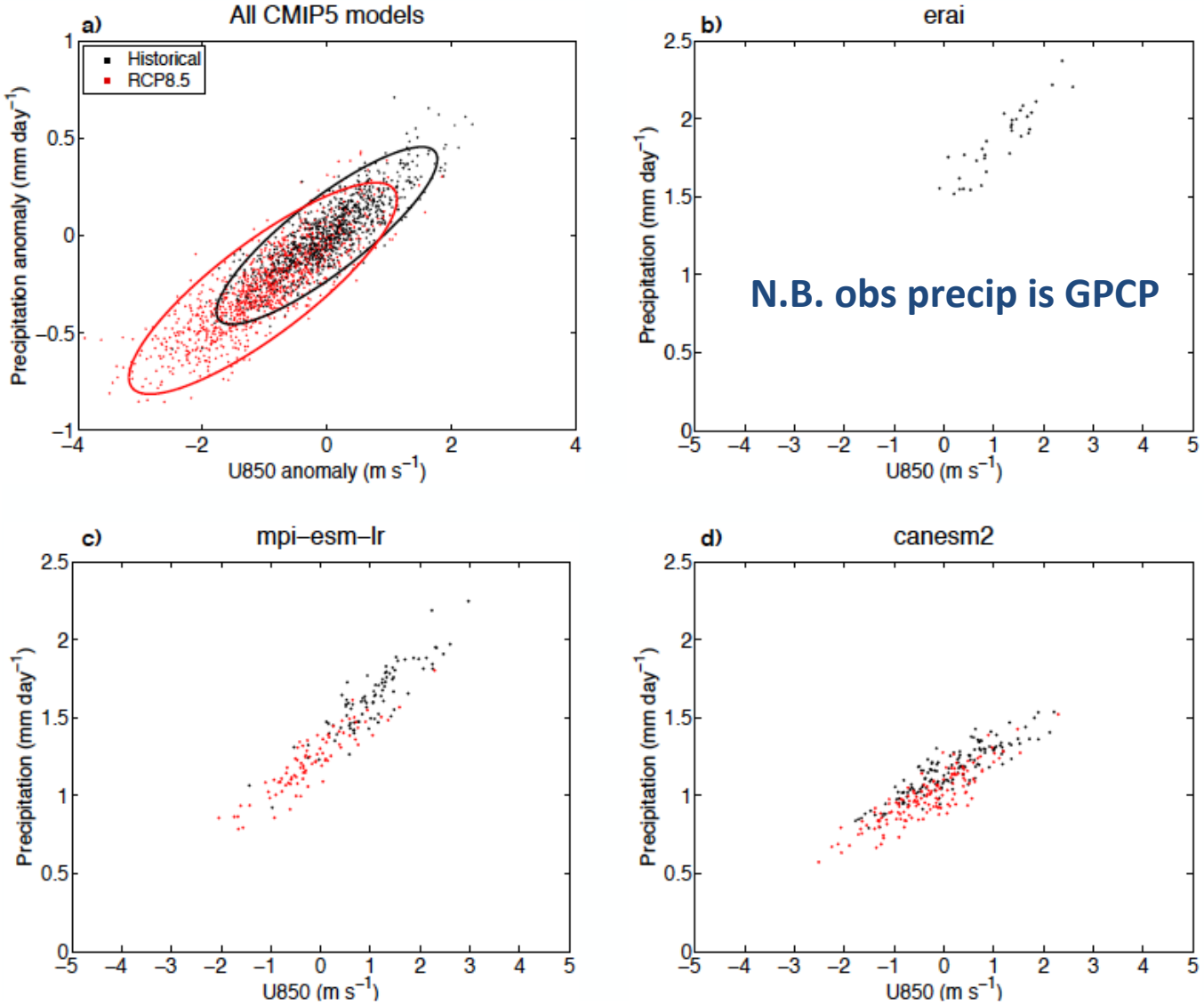
- A strong/weak trend in Mediterranean drying is associated with a strong/weak trend in circulation, related to storm track



The circulation changes seem to be well characterized by U850 over North Africa

Zappa, Hoskins & Shepherd (ERL, in revision)

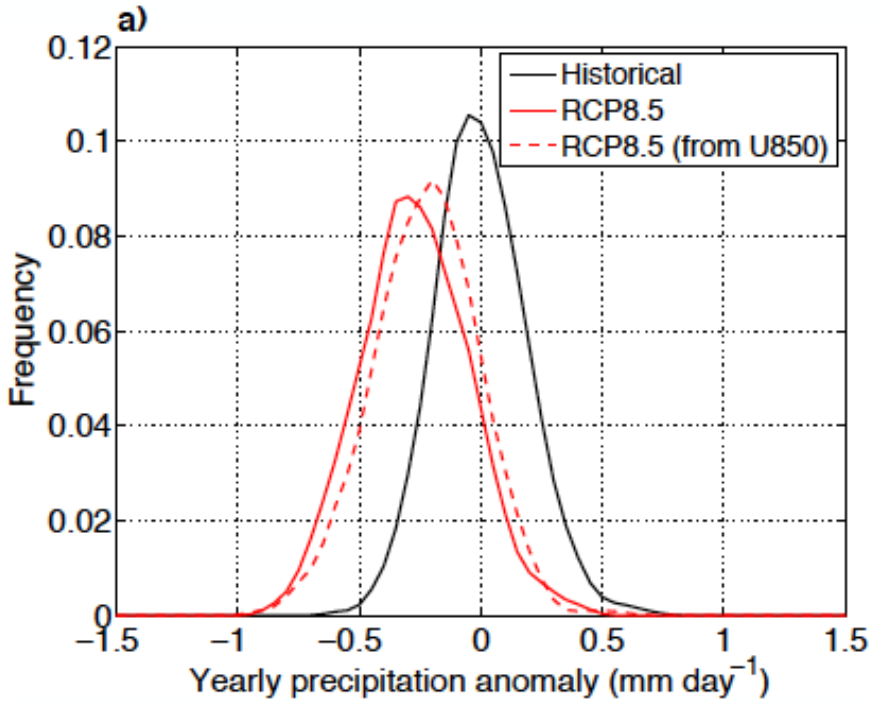
- Year to year variations in Mediterranean precip are correlated with variations in North Africa U850, in both obs and models

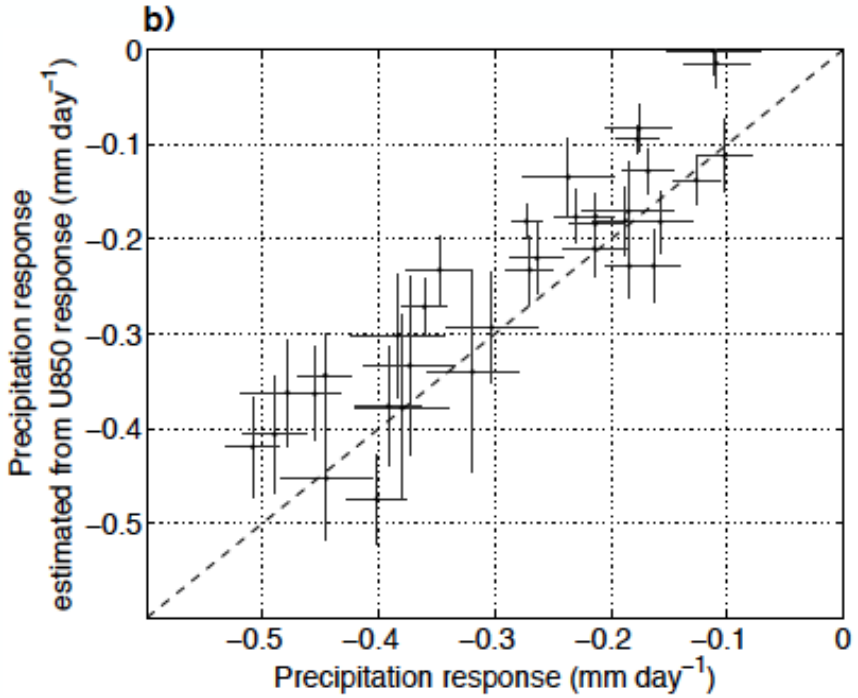


The projected changes (red) seem mainly an extension of this relationship, plus some additional drying

Zappa et al. (ERL, in revision)

- 85% of the CMIP5 mean precipitation response (left), and 80% of the inter-model spread (right), are related to changes in circulation and are congruent with internal variability
- Uncertainty in projected cold-season Mediterranean drying will not be reduced unless the uncertainty in the atmospheric circulation response is reduced



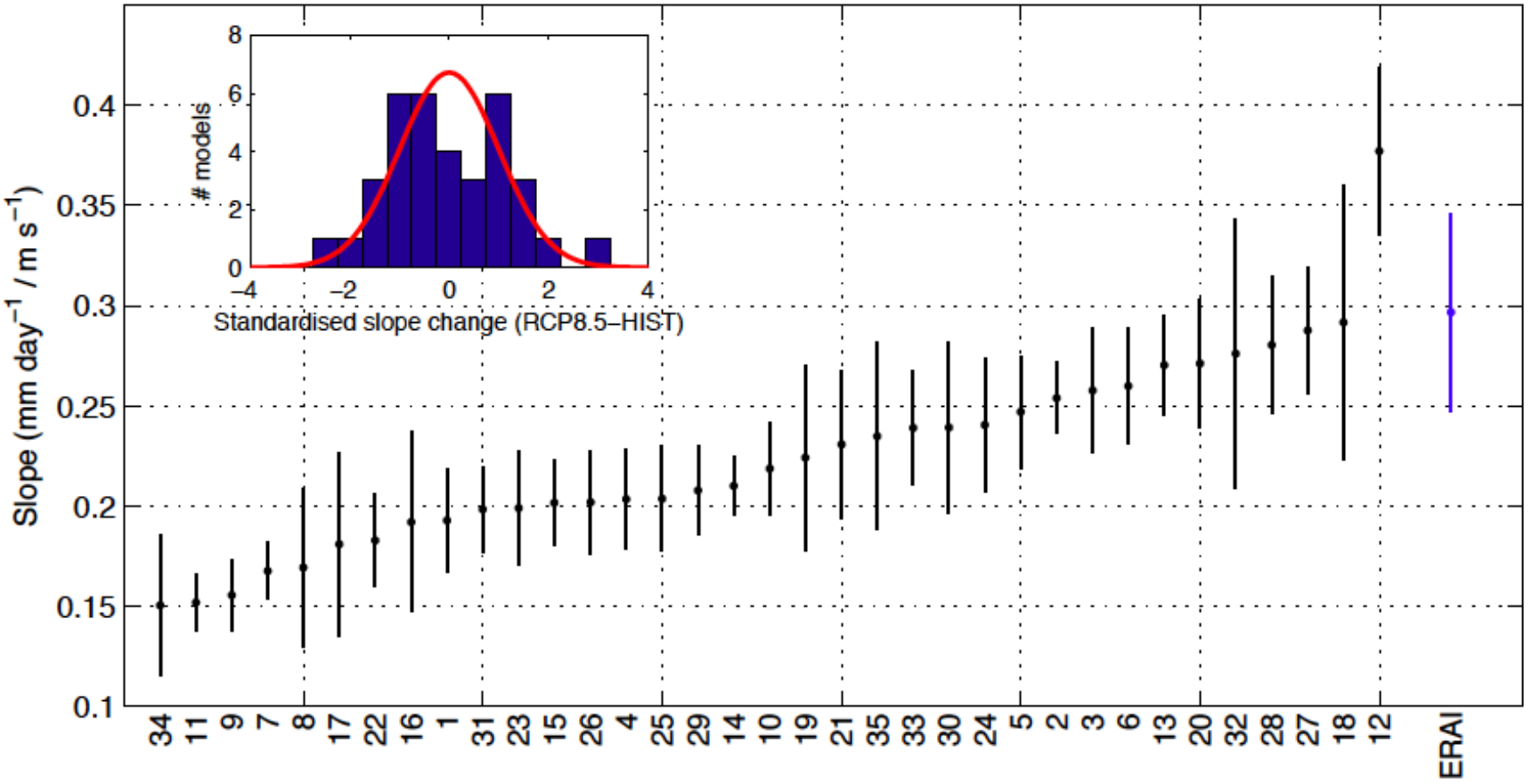


Zappa et al. (ERL, in revision)

Summary

- For circulation-related aspects of climate (including storms), the signal-to-noise ratio of projected changes is generally small, and inter-model differences are large
- It is critically necessary to separate the forced response from the variability, because it affects the change in risk
  - This is challenging because much of the forced response is congruent with variability (so "fingerprinting" is not useful)
- "Dynamical correction" is a reasonable default approach, but may in some cases throw the baby out with the bathwater
  - In the case of cold-season Mediterranean drying, the role of circulation is absolutely dominant, and highly uncertain
- There seems to be little alternative to running large ensembles to accurately determine the forced response for each climate model; only then can the uncertainty be narrowed

- Models generally underestimate the precipitation change for a given circulation change
- There is no evidence of a change in this relationship in RCP8.5



Zappa et al. (ERL, in revision)