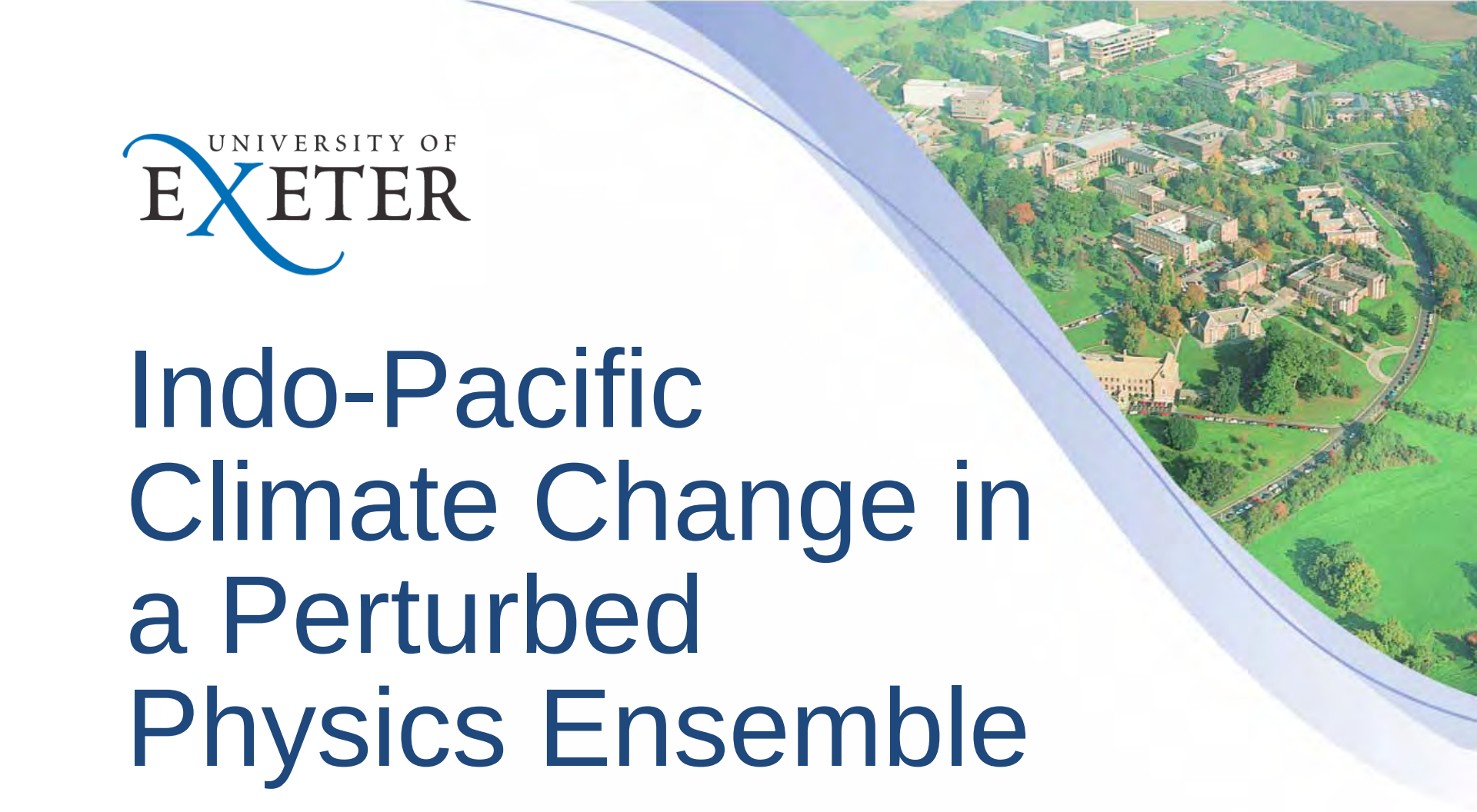

# Indo-Pacific Climate Change in a Perturbed Physics Ensemble

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# Perturbed Physics Experiments

- HadCM3 experiments with flux adjustments used to prevent drift
- Standard model parameters
- 16 members with perturbations to atmosphere parameters
- 16 members with perturbations to ocean parameters
- 33 in total
- Scenarios: 1x$CO_2$ control, 1%/year $CO_2$ increase, historical forcing, SRES A1B
- Also, multi-century unforced 1x$CO_2$ run with non-flux-adjusted HadCM3

# Perturbed Physics Experiments

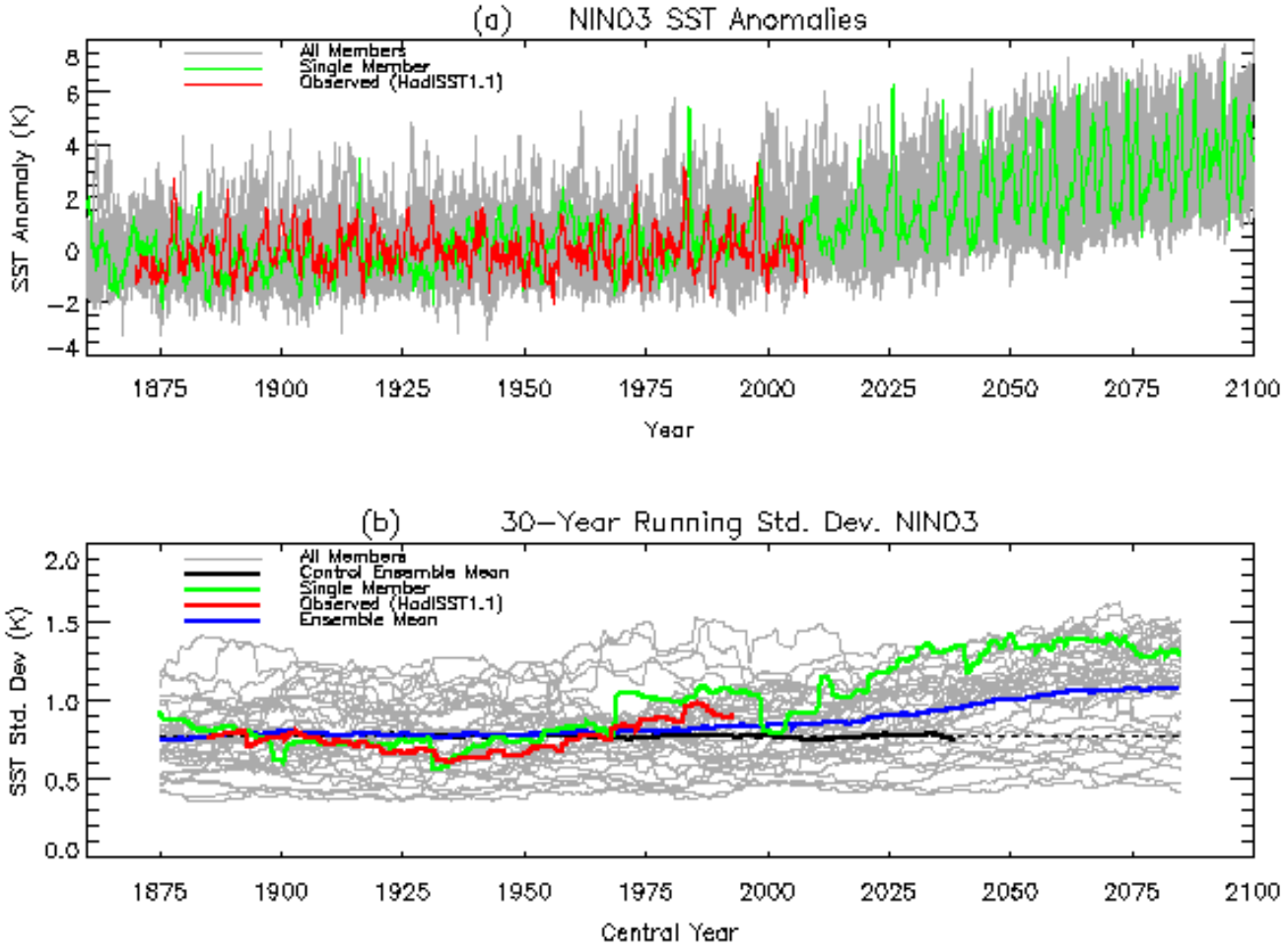
**Advantages:**

- Systematic investigation of uncertainties
- Can increase signal-to-noise for some problems

**Disadvantages:**

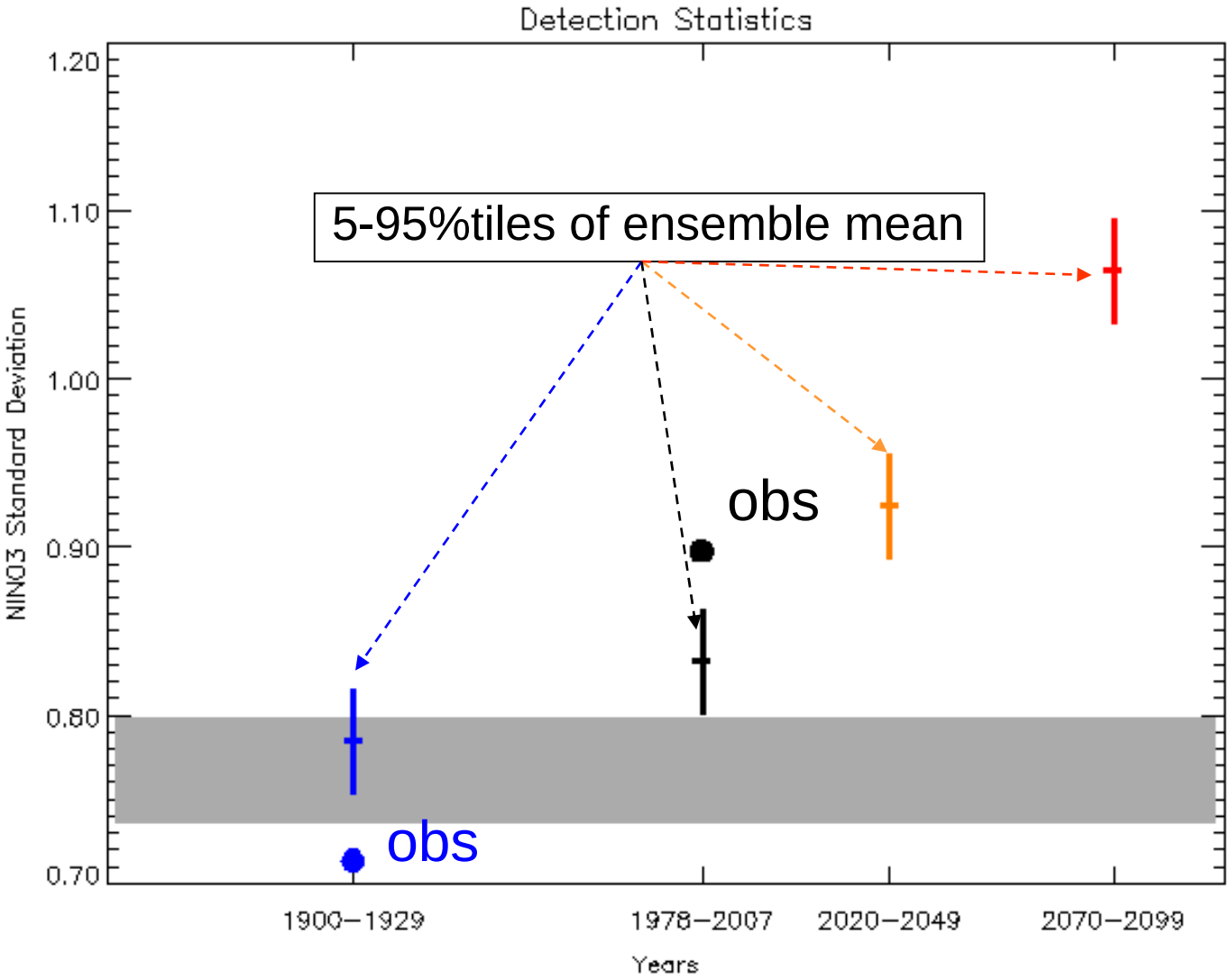
- Cannot sample “structural” uncertainties
- Not enough ensemble members for full Bayesian statistical treatment

# ENSO and Climate Change



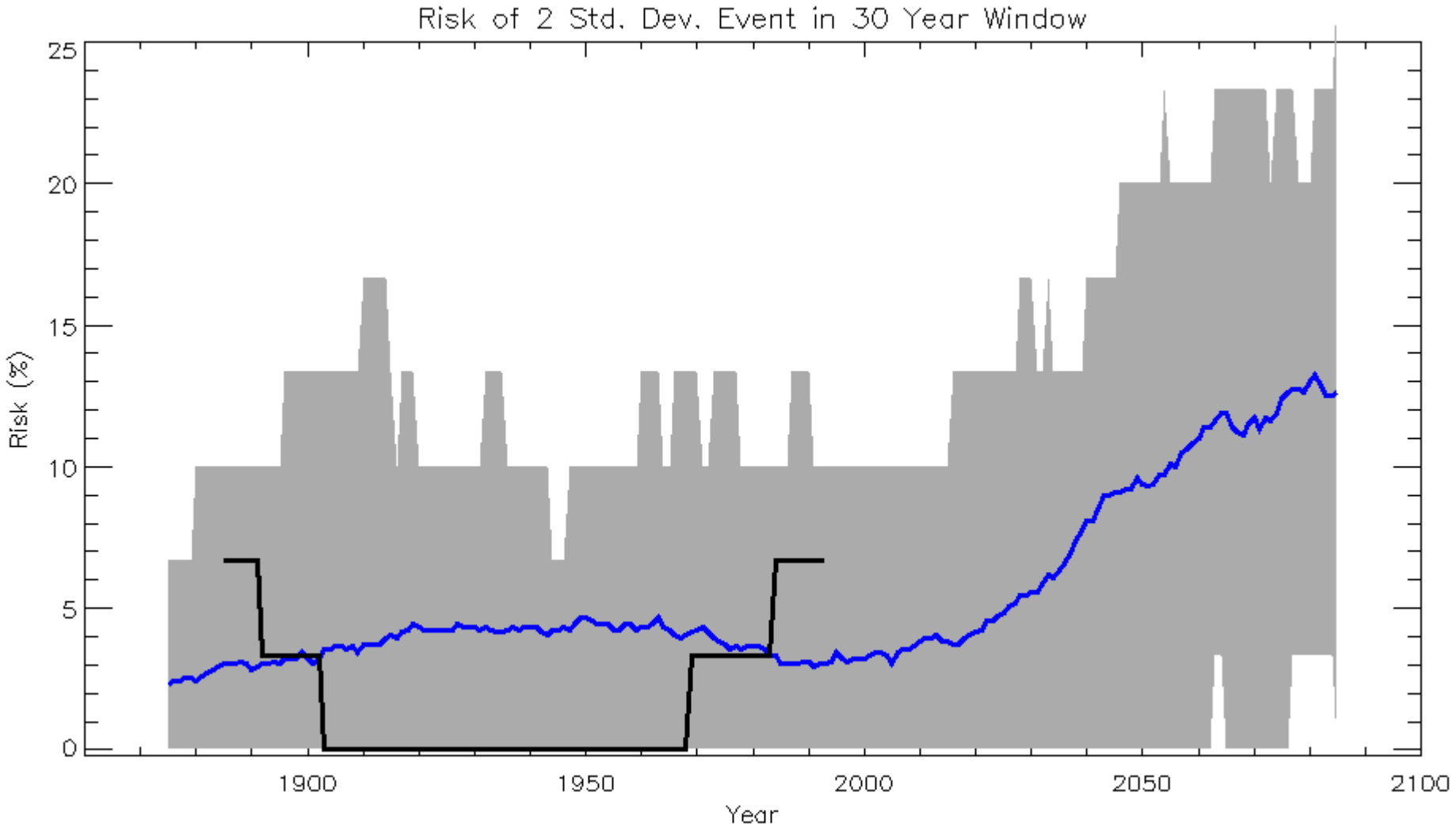

- 33 ensemble members
- Anthro and natural forcings
- SRES A1B
- Mean ENSO strength and frequency is sensitive to forcing in 20th and 21st centuries

# Detection: Ensemble Mean Std. Dev. 30-year NINO3

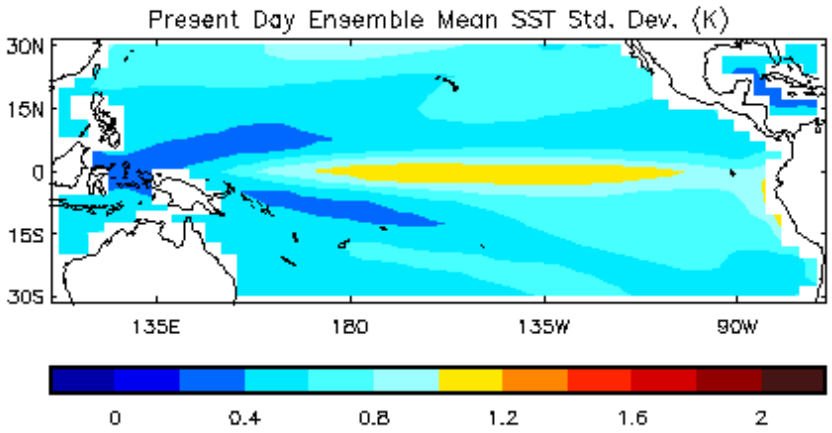


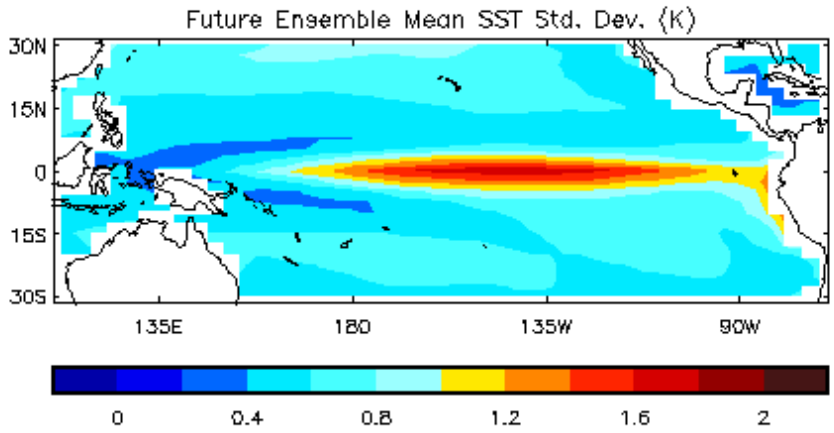

Natural variability
5-95%tiles

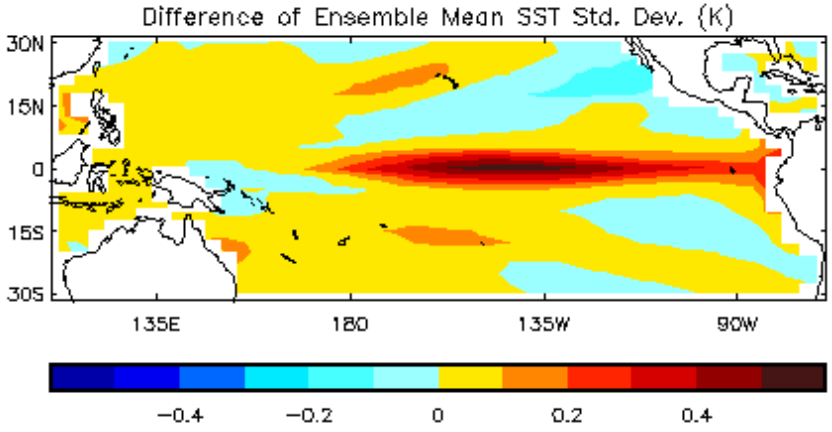
# Risk of Large El Nino Event

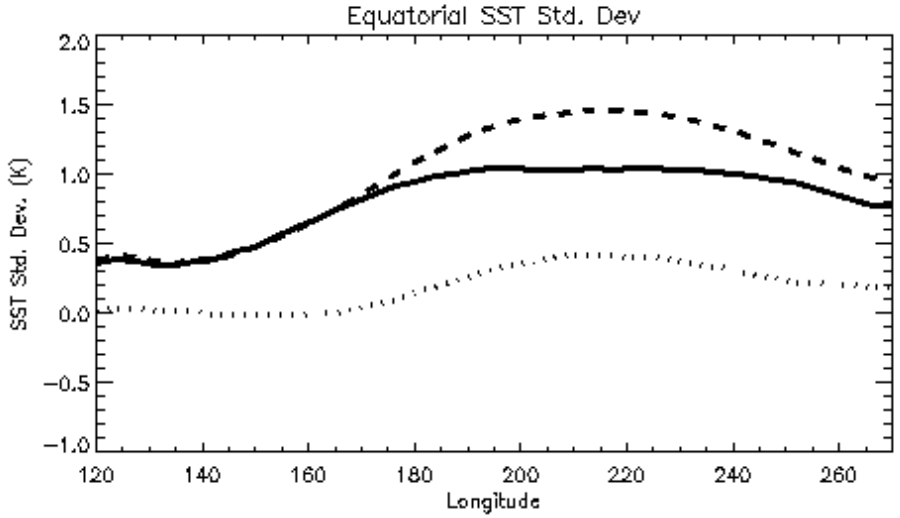


# Switch to Modoki/Central Pacific ENSO?

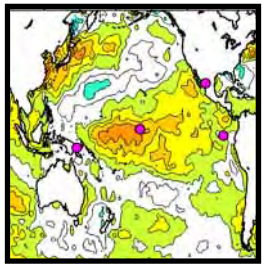


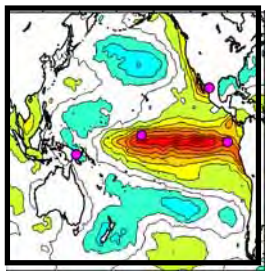



# Unforced variability in ENSO ‘modes’

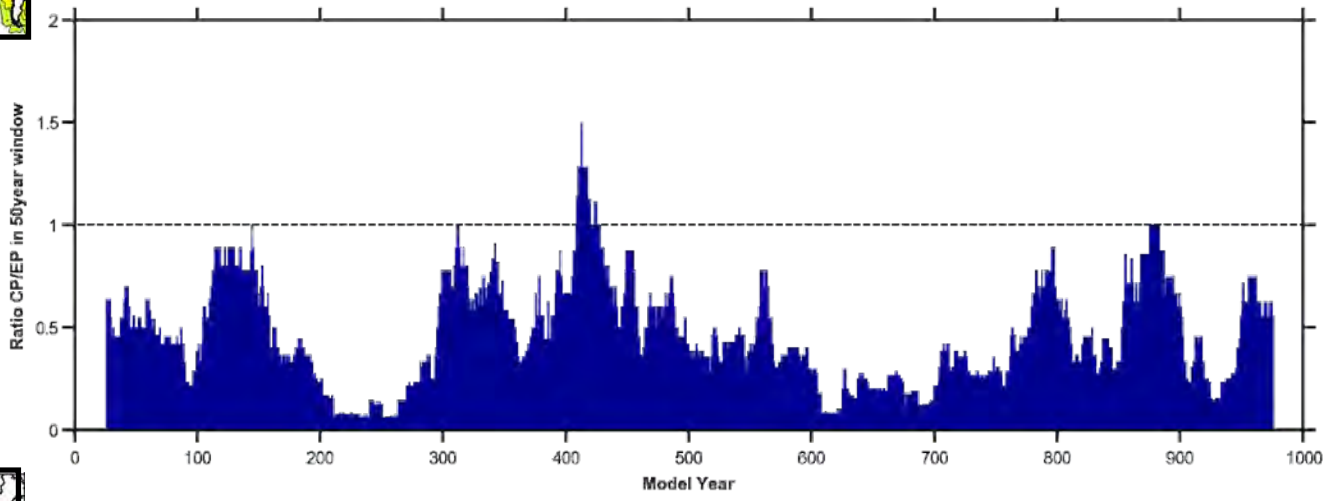


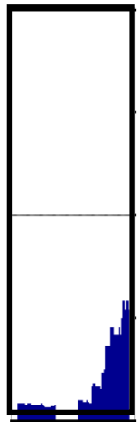
‘CP’

‘EP’



**Ratio of El-Niño event types in moving 50yr window**



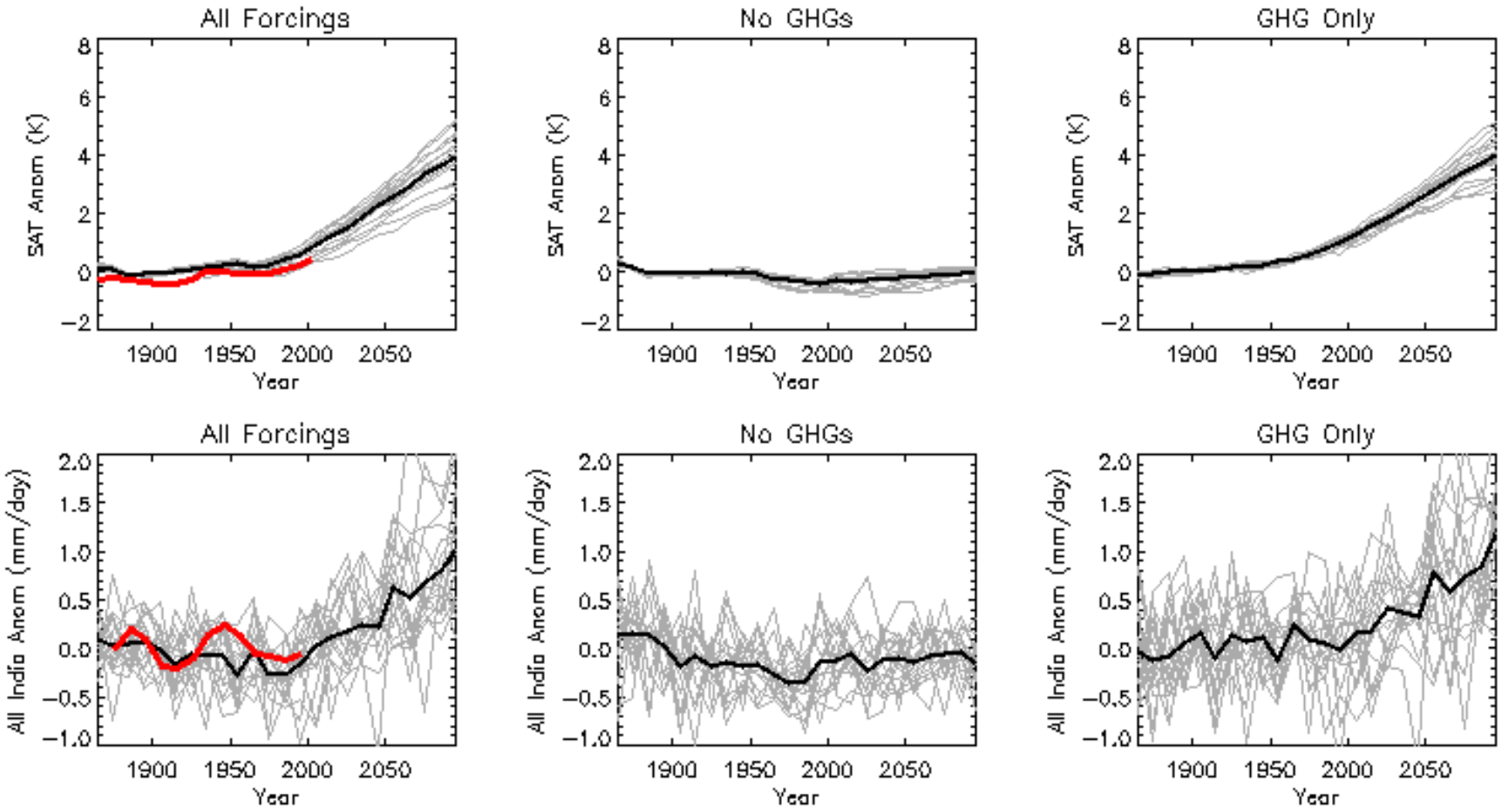



**HadCM3**
**Control run**

**HadISST**

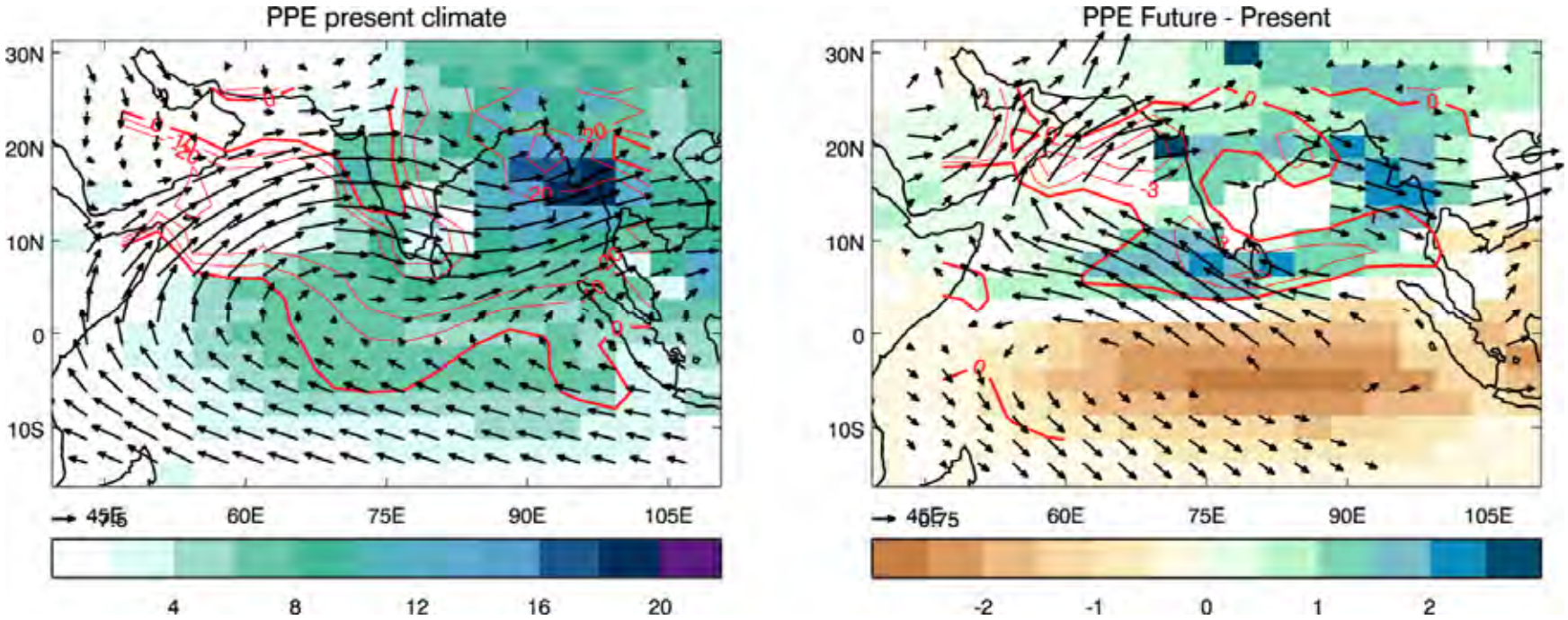
Tom Russon et al.

# Indian Monsoon Changes



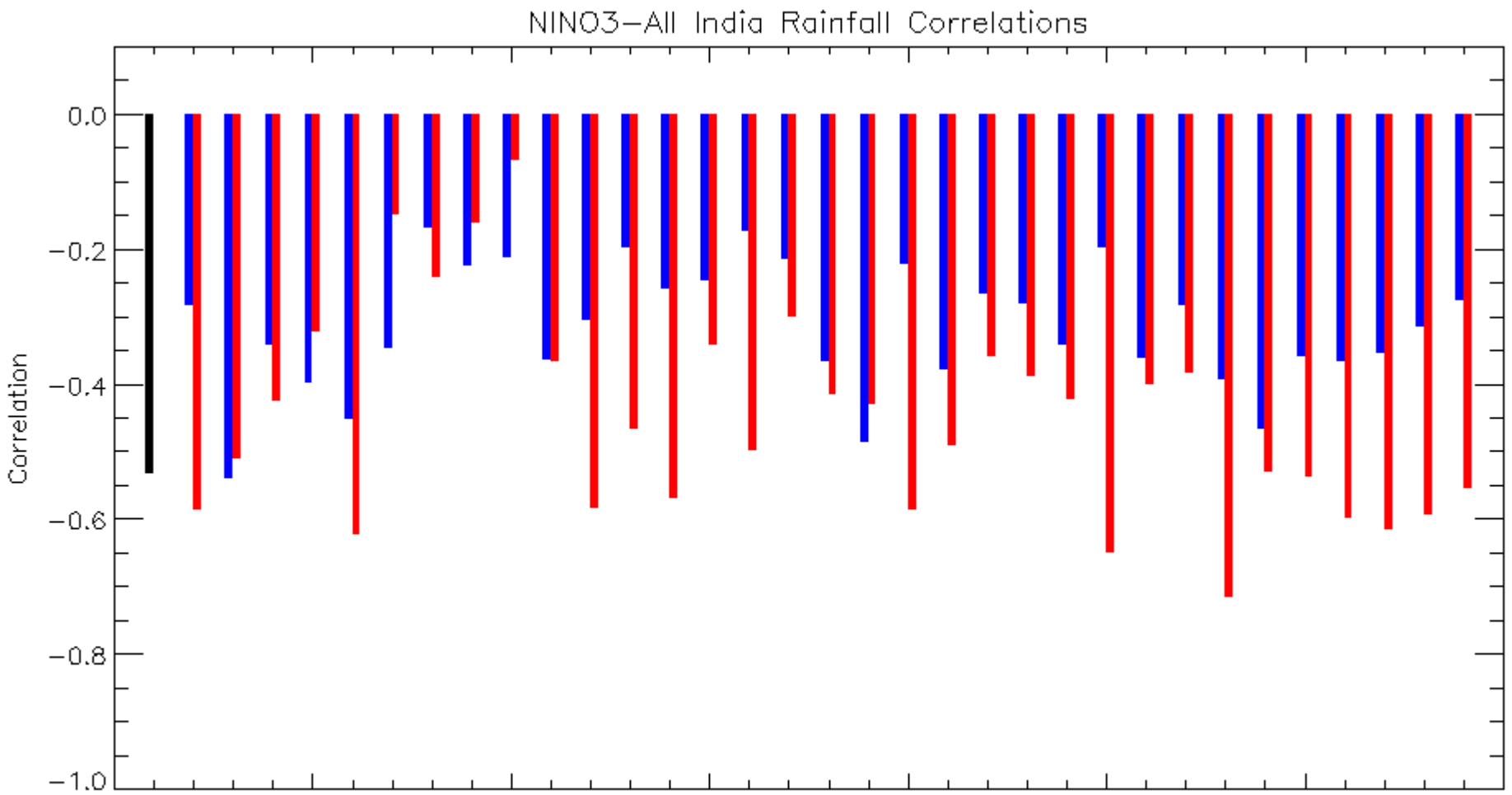

JJAS global mean temperature and All-India rainfall anomalies

# Indian Monsoon Changes




B. Bhaskaran et al. Spatial distribution of PPE mean precipitation (shading), 850hPa winds and convergence (contours) for present day (left panel) and future change (right panel. The change values that are not significant at 95% are omitted. Precipitation is in mm/day, winds are m/s and convergence is in units of $10^{-6}$/s.

# ENSO-Monsoon Teleconnection




JJAS NINO3 All-India rainfall correlations for past (blue) and future (red)

# Summary

- PPE experiments show increasing risk of large El Niño events
- However no clear shift to Modoki/Central Pacific mode
- Long HadCM3 control experiment suggest recent Modoki trends may be natural
- Increases in Indian Monsoon rainfall have been ‘held back’ by aerosol forcing but are now ready to be ‘released’
- Northward shift in monsoon flow pattern and increase in ENSO-monsoon teleconnection

# Notation

$$c = M(p, R)$$

$M$ = model/function
$c$ = climate variable
$p$ = model parameters/inputs
$R$ = radiative forcing
Subscript h=historical, f=future
$o$ = observations

$$c_h = M(p, R_h)$$

$$c_f = M(p, R_f)$$

**General Algorithm:**

- Run model/evaluate function at many different input parameters for historical radiative forcing
- Compute metric of fit between model output and observations
- Weight future projections according to the value of the metric

$$m = (c_h - o)^T (c_h - o) = \sum (c_h - o)^2$$

$$w = \exp\left(-\frac{1}{2}\sum (c_h - o)^2\right)$$