Validation of Climate Models

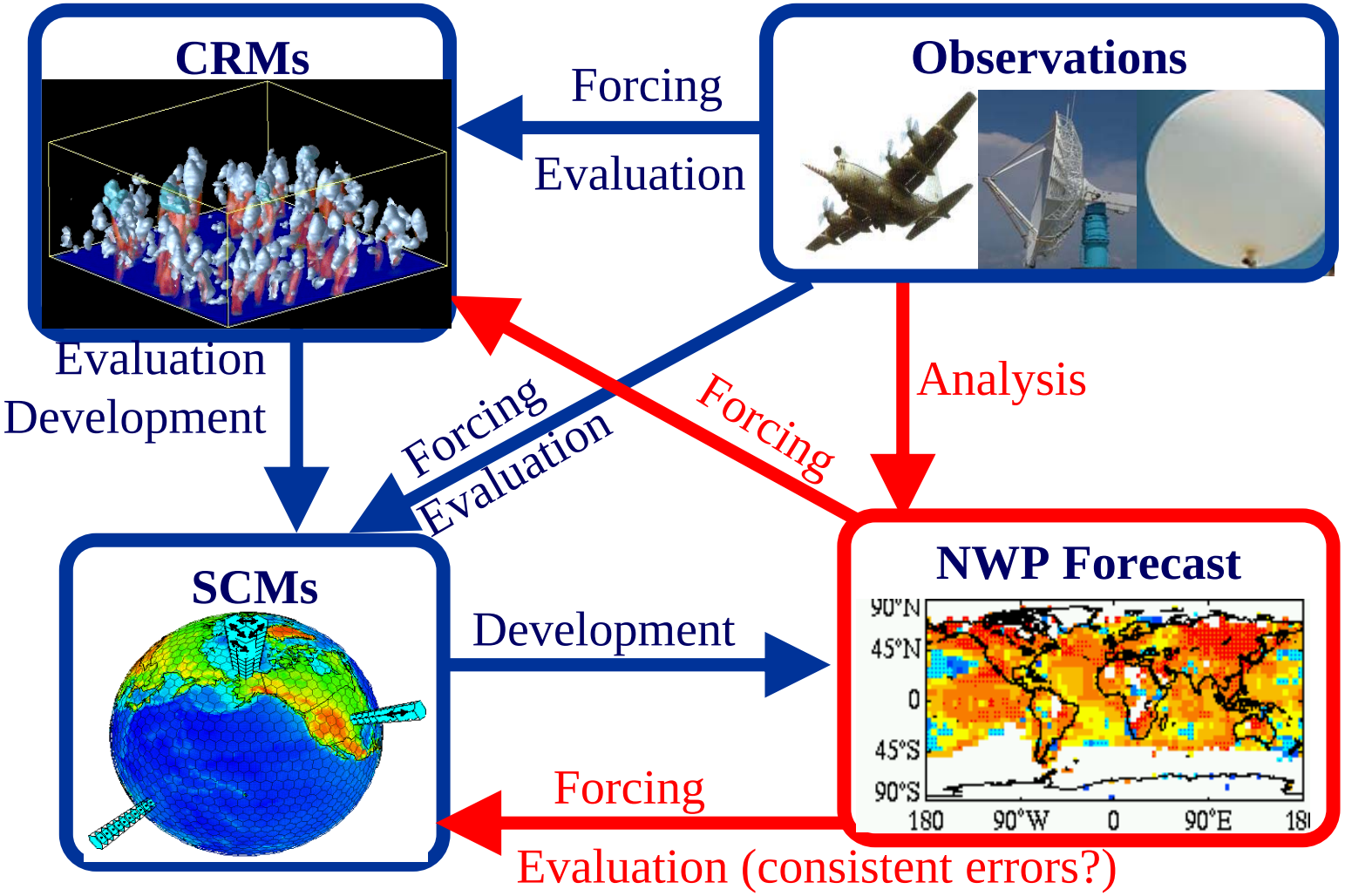
Simon Tett 19/6/06 with thanks to:

Keith Williams, Mark Webb, Mark Rodwell, Roy Kershaw, Sean Milton, Gill Martin, Tim Johns, Jonathan Gregory, Peter Thorne, Philip Brohan & John Caesar

Approaches

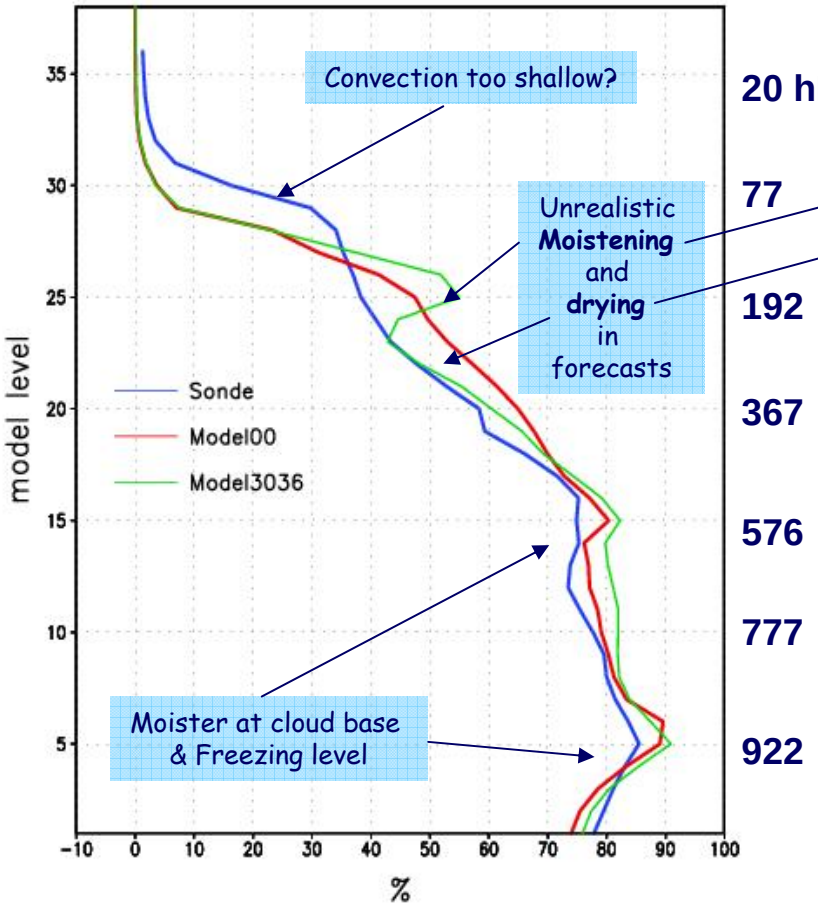
- Parameterisation & Forecast error
- Climatology's
- Climate Variability
- Climate Change.

Methodology for improving parametrizations



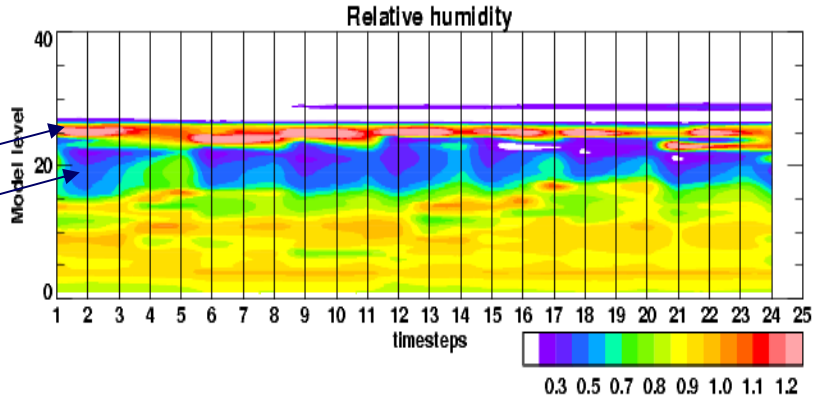
Tropical Systematic Biases in NWP

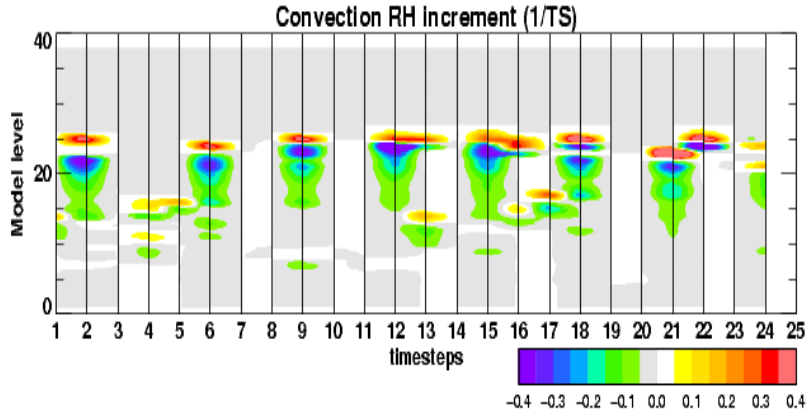
Thermodynamic (RH) Profile Errors Vs ARM Manus Sondes JAS 2003- Errors in convection?



20 hPa
77
192
367
576
777
922

Moisture balance from Idealised Aquaplanet – suggest convection largest contributor to humidity biases

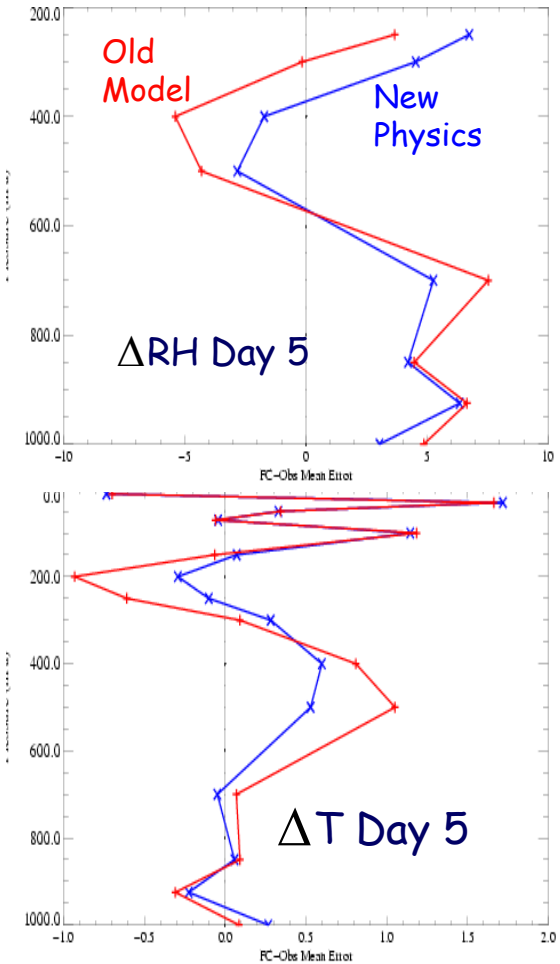




NWP Tropical T, RH, and Wind Errors vs Sondes

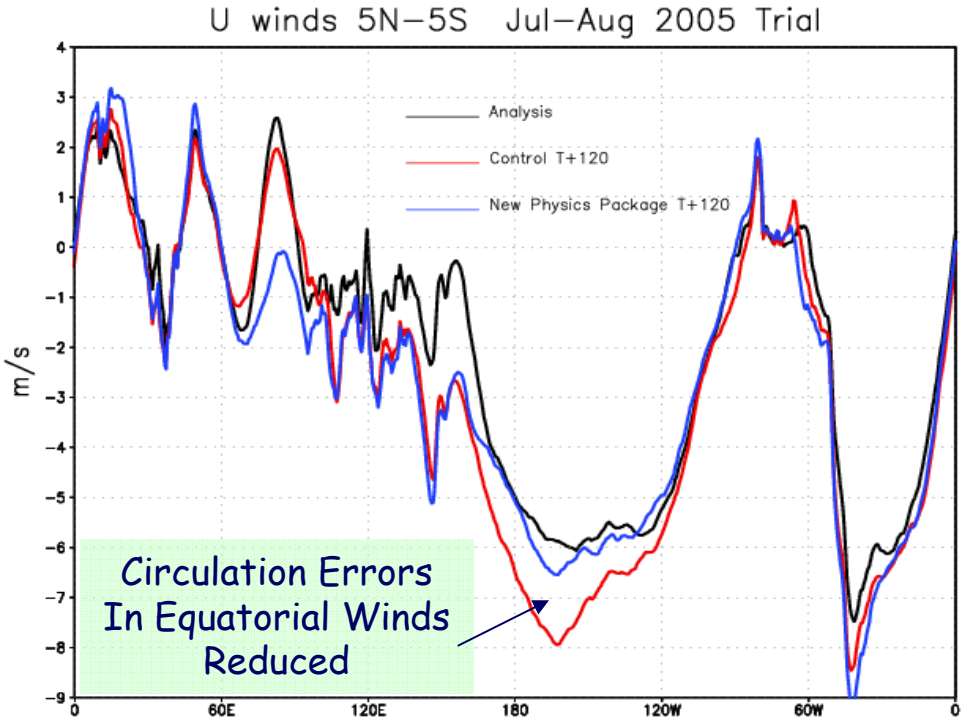
Summer 2005 – Impact of new Physics

Improved Thermodynamic Profiles



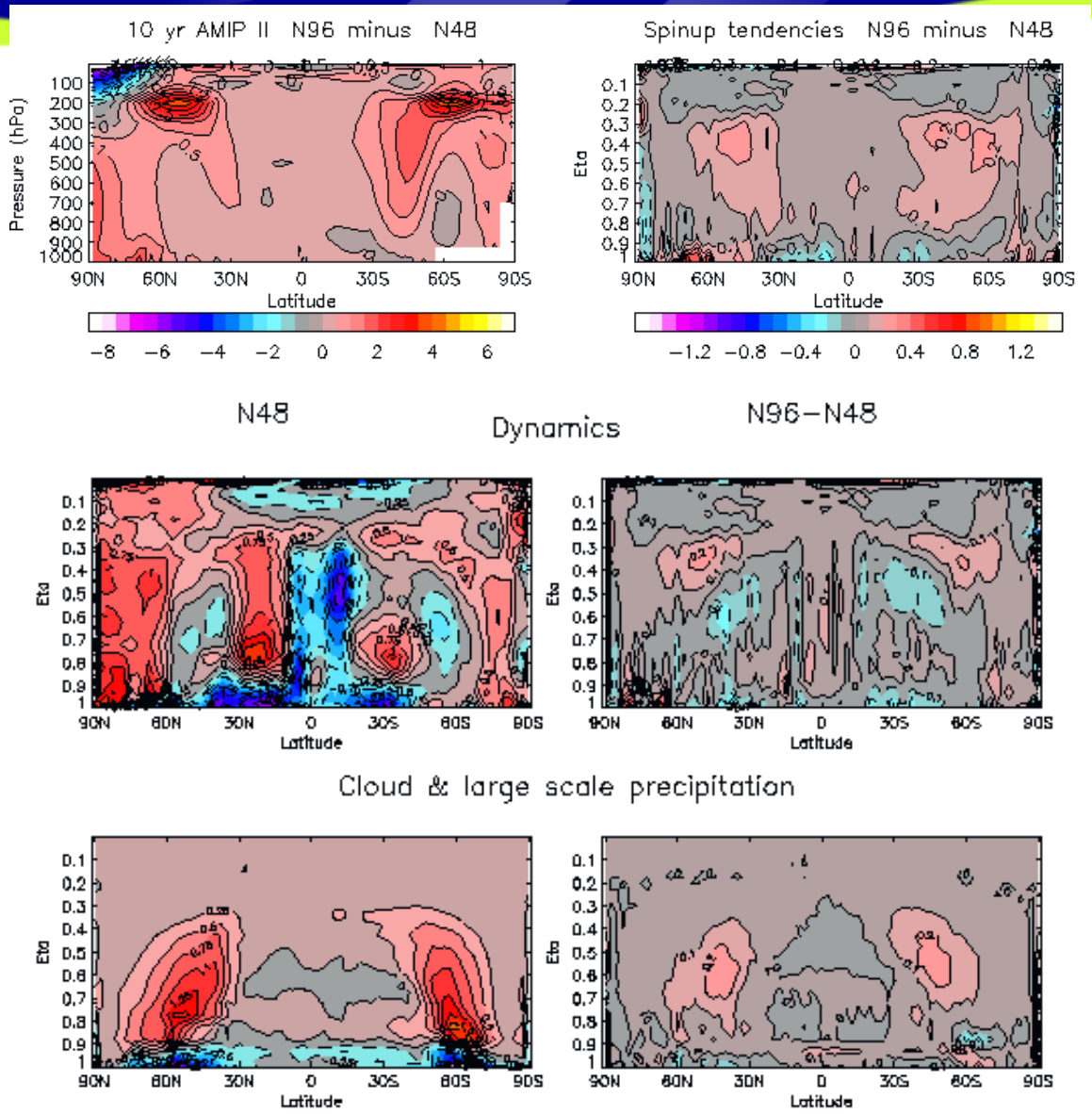
A package of physics improvements introduced in March 2006

- Adaptive detrainment (conv) -> improve detrainment of moisture.
- Changes to marine BL -> reduce LH fluxes
- Non-gradient momentum stress. -> Improve low level winds



S. Derbyshire, A. Maidens, A. Brown, J.Edwards, M.Willett & S.Milton

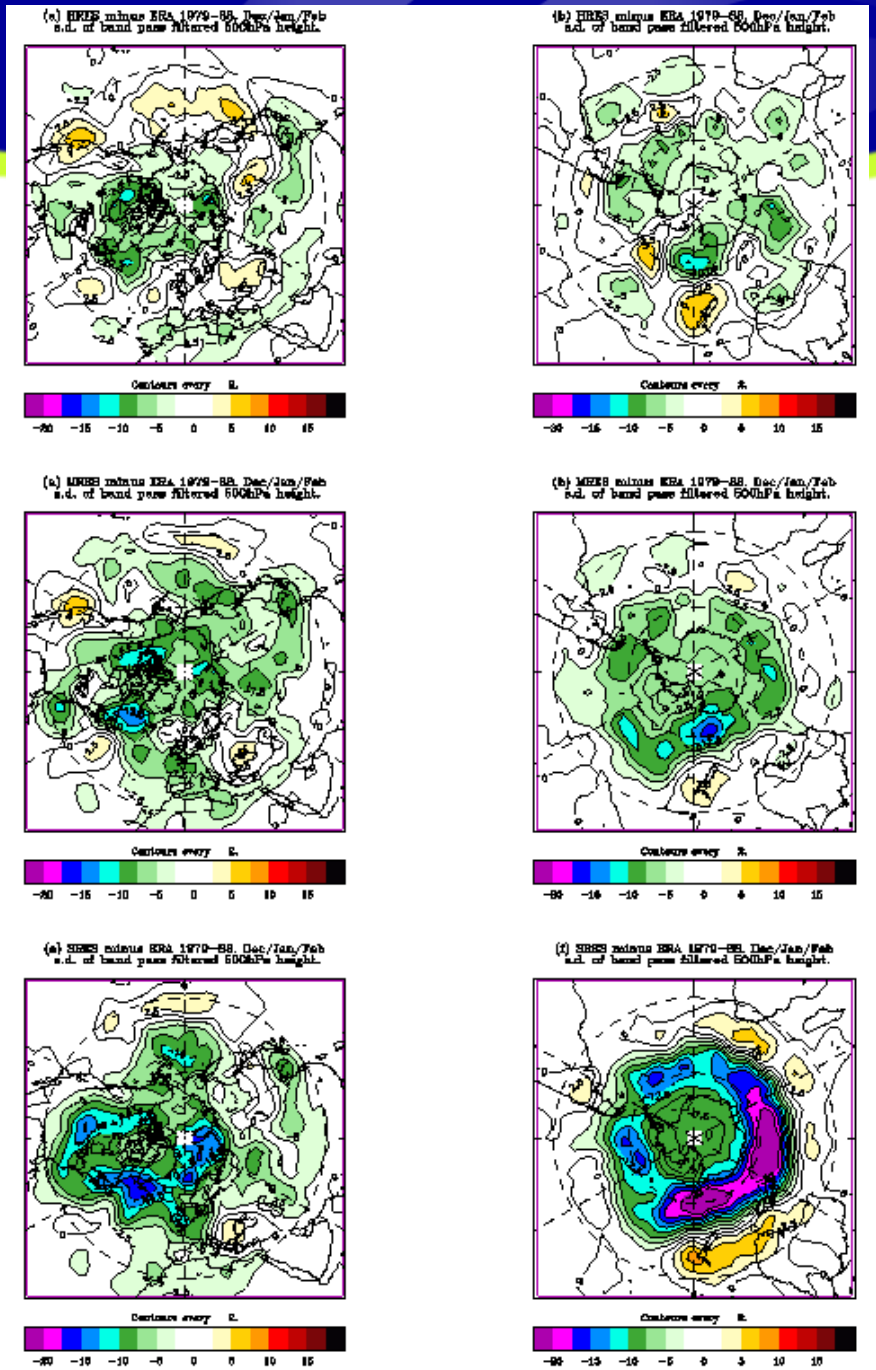
Spinup Tendencies



- Used to assess the contribution of individual physical parametrisations and dynamics to systematic errors.
- Run a ~60-member ensemble of 1 to 5 day integrations started from operational NWP analyses scattered evenly over a period e.g. December to February.
- Useful only when total spin-up tendency resembles model bias in full simulation.
- Total tendency shows warming 30 to 60 N/S between 800 and 250 hPa, similar to change in full model.
- Upper level warming attributed to dynamics.
- Mid-tropospheric warming attributed to changes in cloud and precipitation: intensified hydrological cycle

Climatology

Storm tracks Climatology



N144

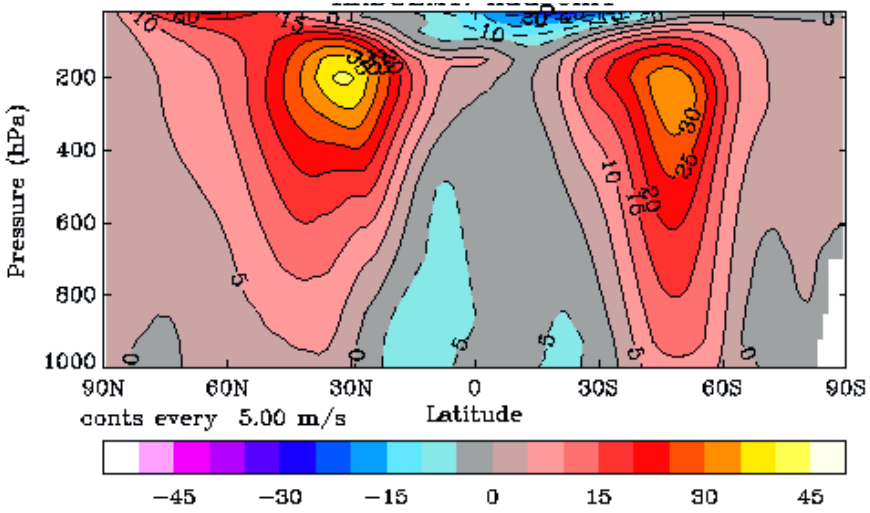
N96

N48

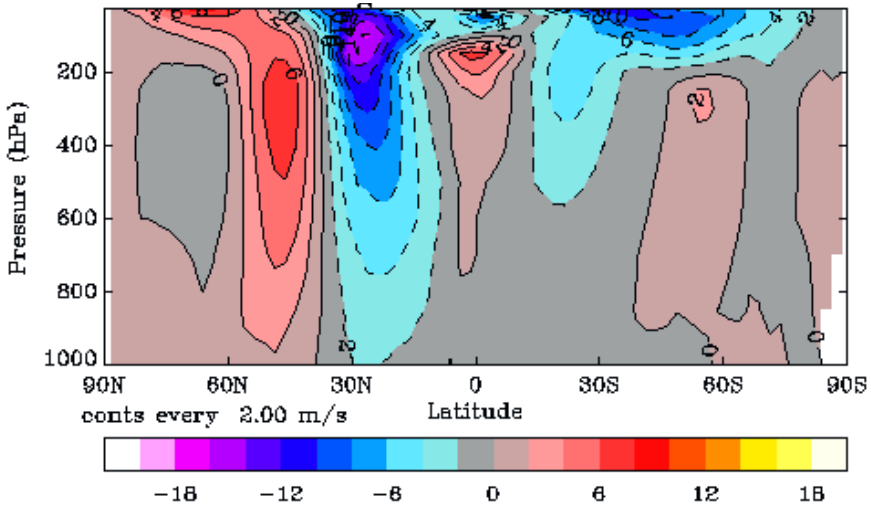
- Plots show differences in the standard deviation of band-pass filtered 500 hPa height in DJF, between different resolution runs and ERA, for the northern and southern hemispheres.
- As resolution increases, the storm tracks strengthen and move polewards.
- Agreement with ECMWF reanalyses improves with resolution.

Dynamics – Zonal mean zonal winds (DJF)

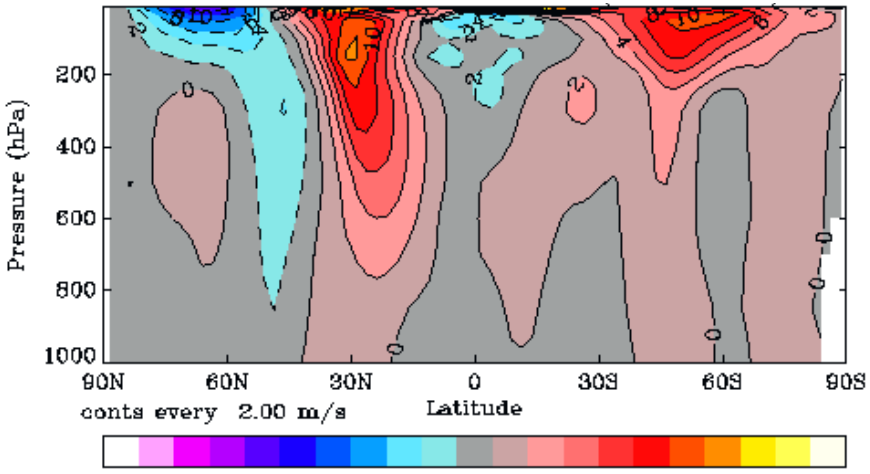
HadGEM1



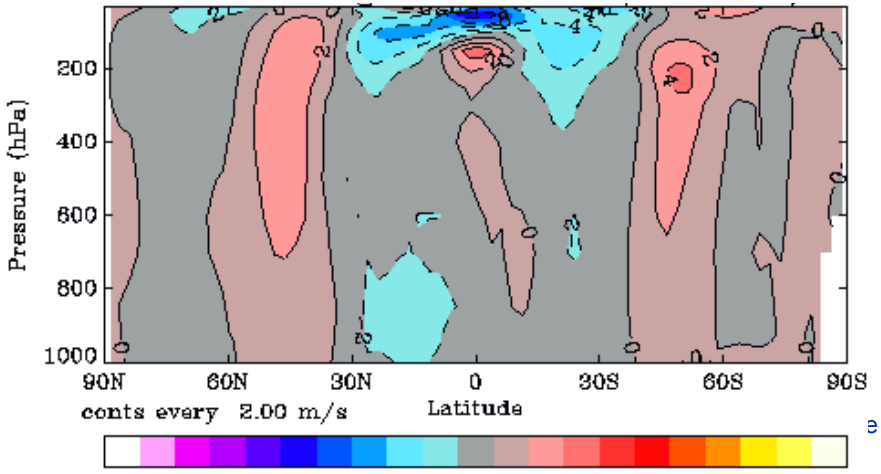
HadGEM1 – HadCM3



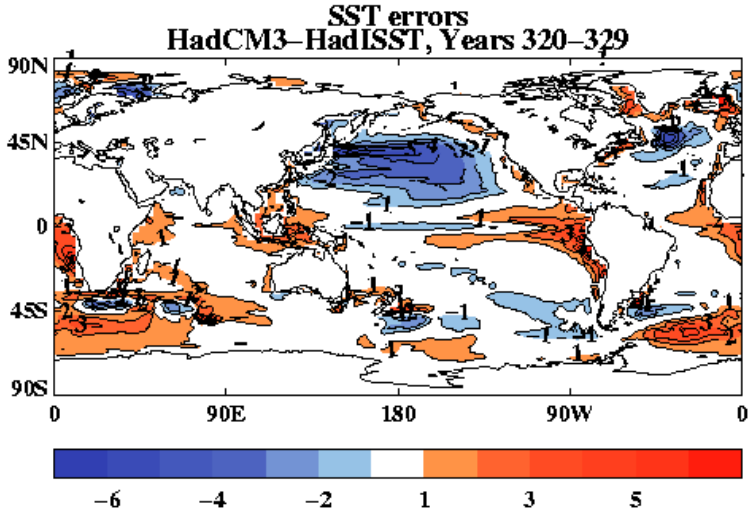
HadCM3 – ERA

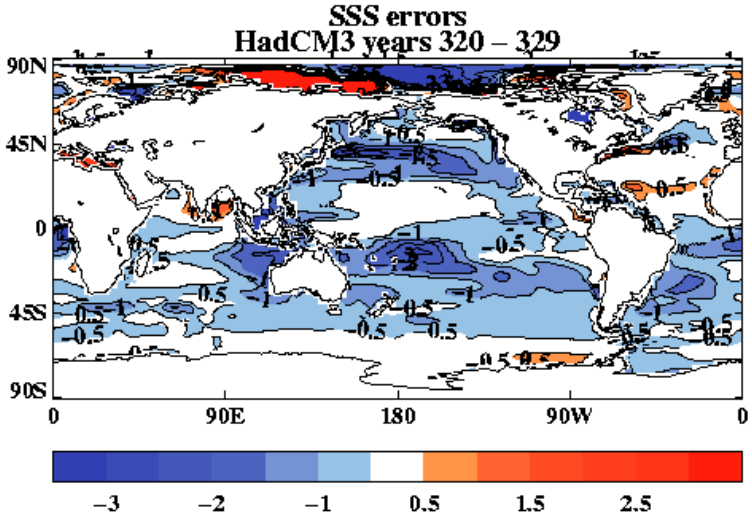


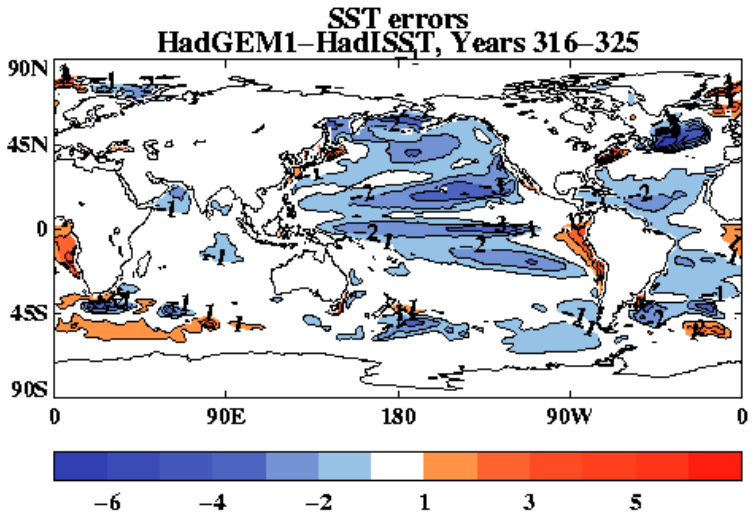
HadGEM1 – ERA

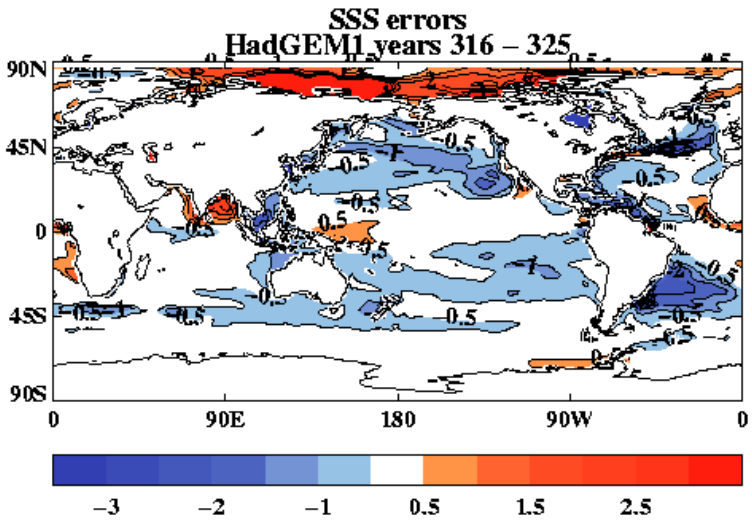


SST and SSS errors after ~300 years: HadGEM1 and HadCM3









Simulation of HIRS water vapour channel

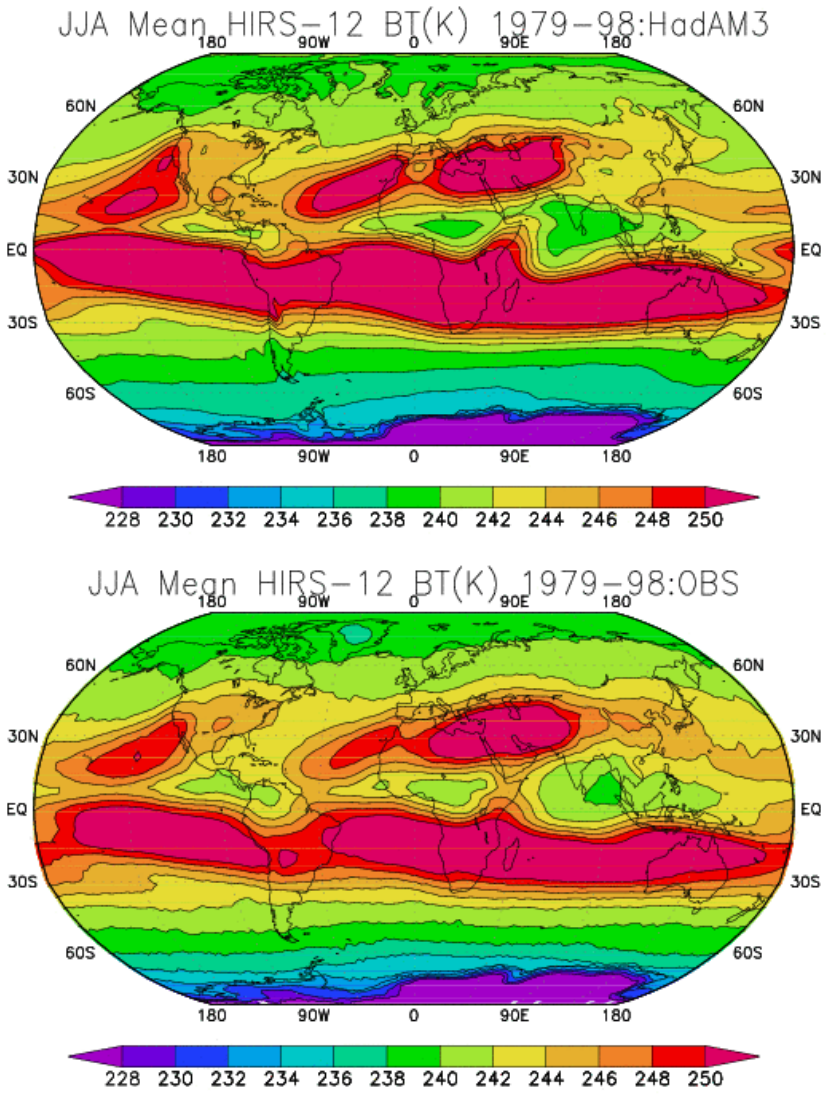
HIRS-12 channel used extensively in studies of upper tropospheric water vapour

Shows 20-year mean fields for JJA

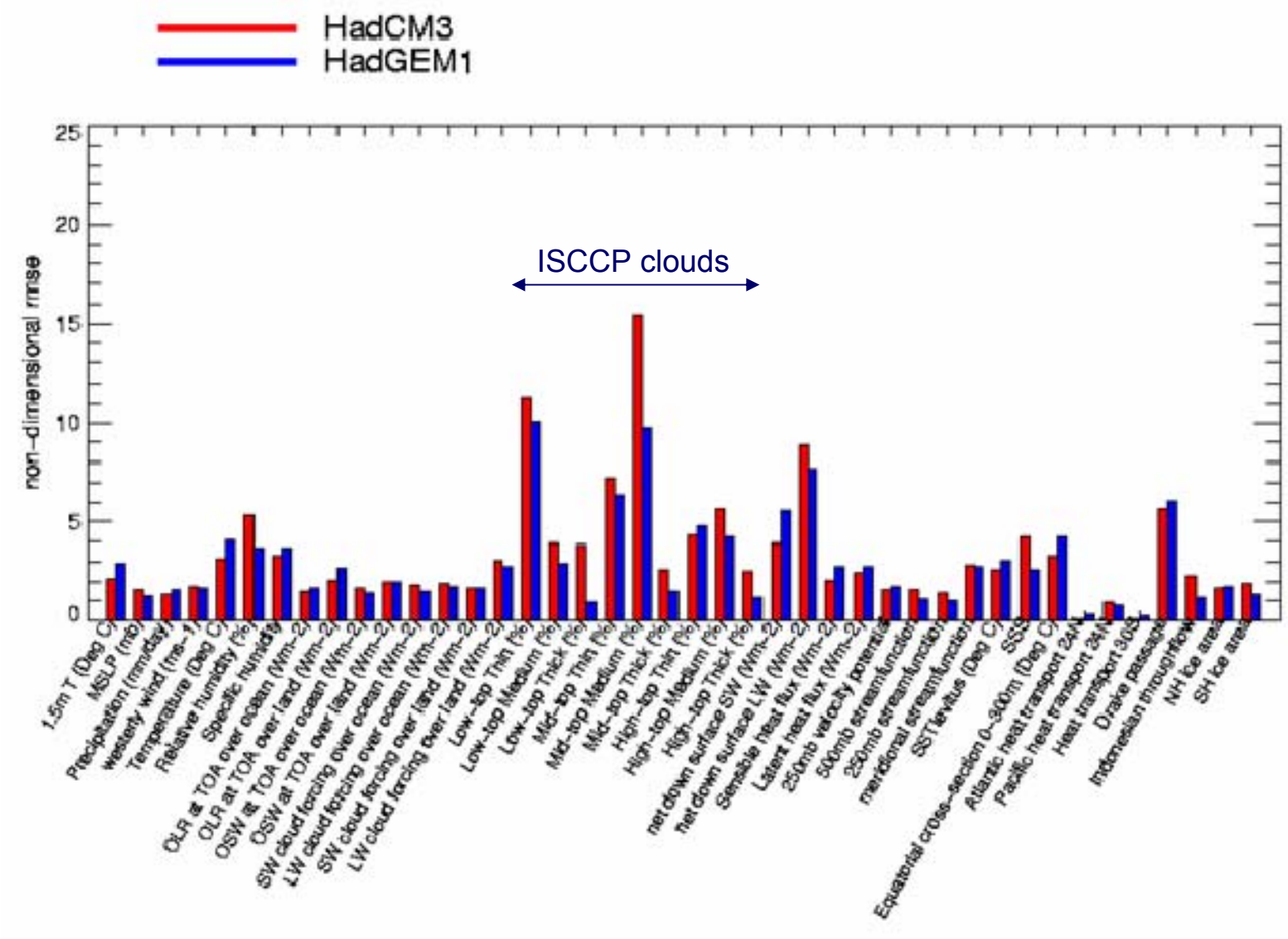
Model forced with observed SSTs

Main features well reproduced – model has a tendency to be too dry in sub-tropics, corresponding to an over vigorous Hadley circulation

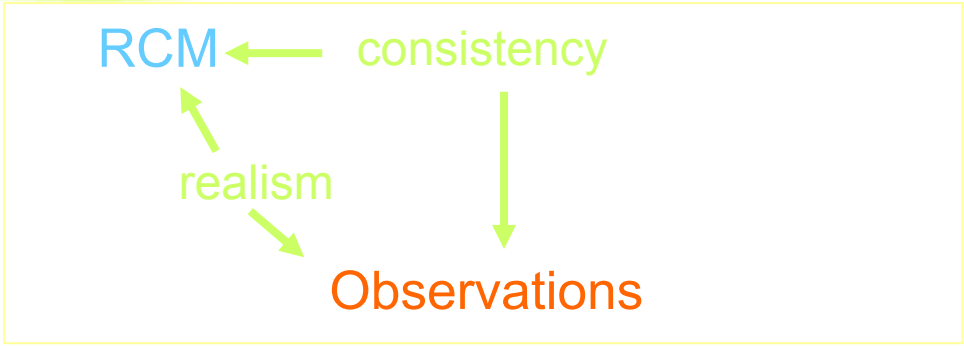
Key: Like-with-like comparison



Climate Prediction Index skill scores: HadGEM1 vs. HadCM3



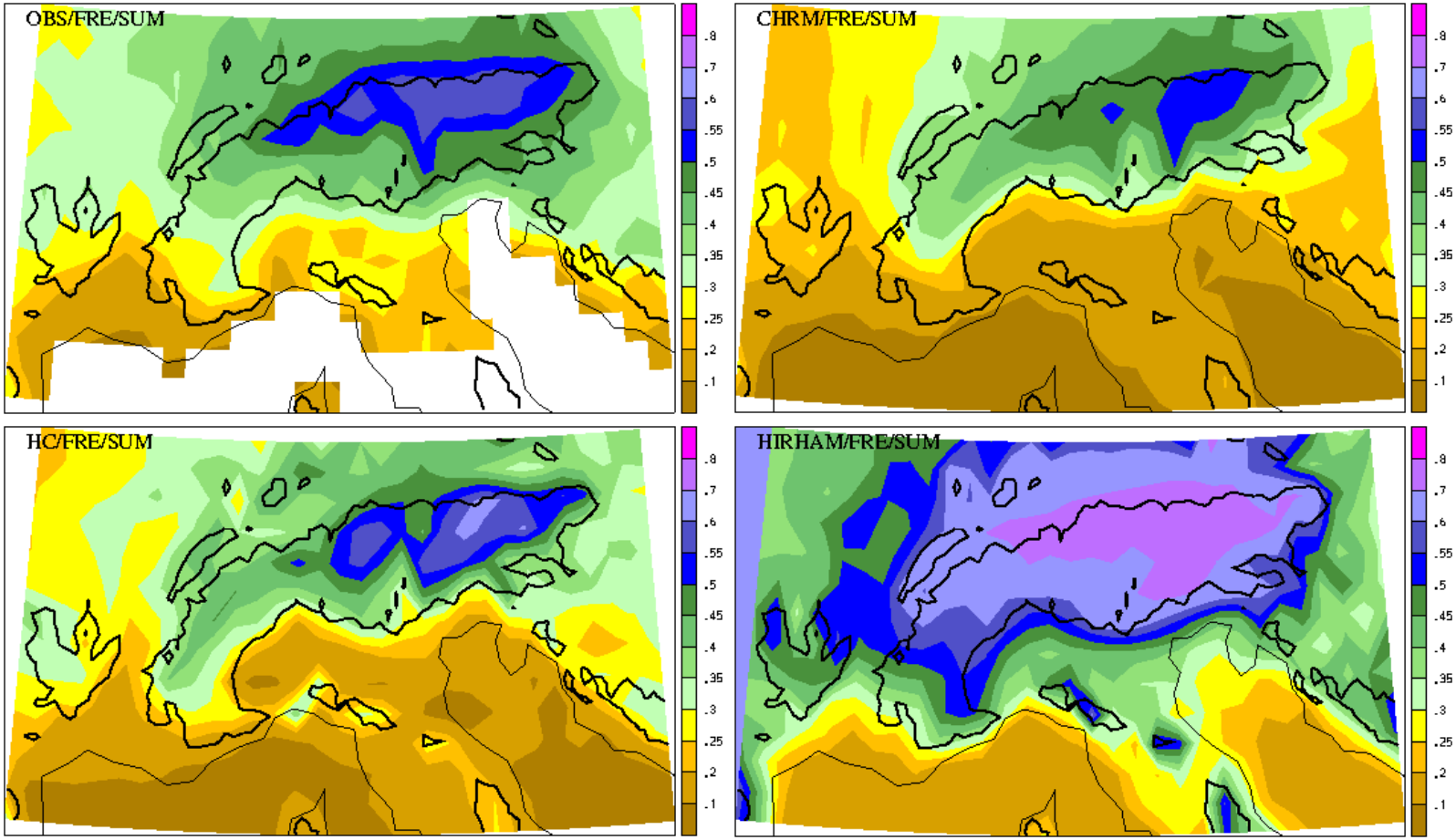
Validating Regional Climate Models



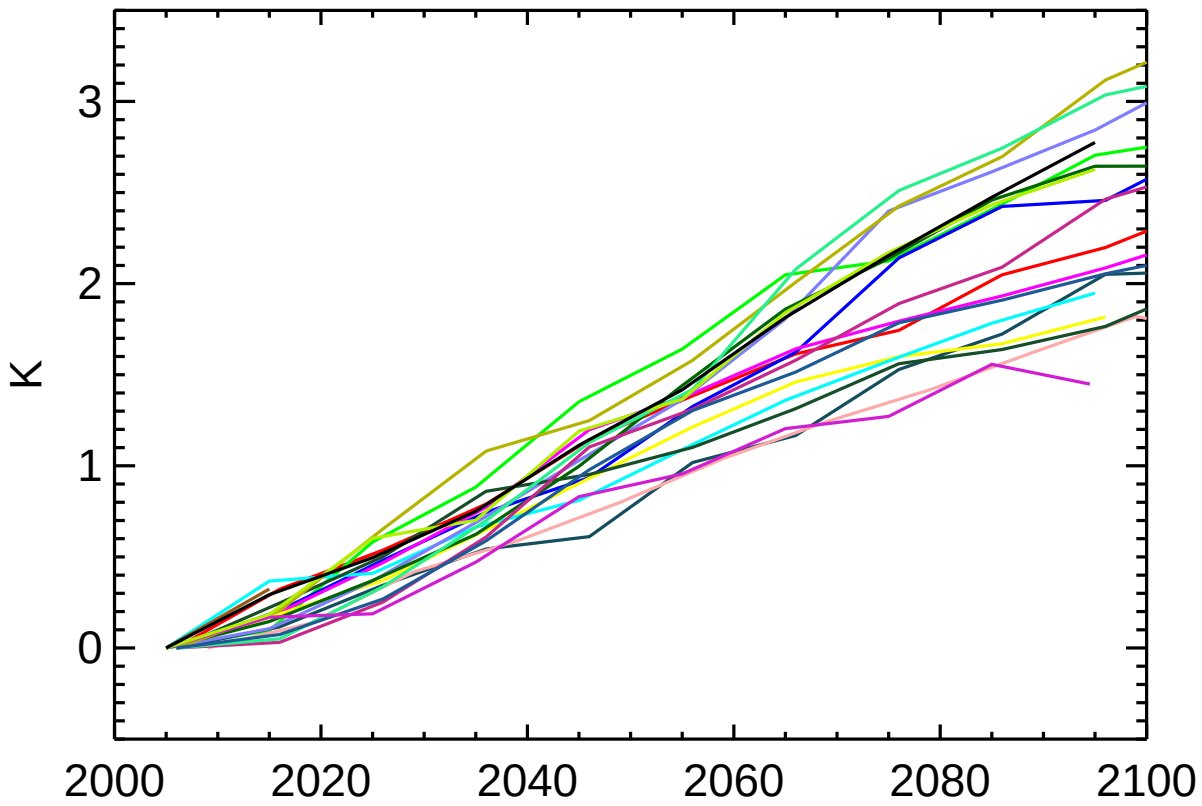
- "*Quasi-observational*" BCs ("re-analysis") allow us an alternative validation of the RCM
- BCs are from an atmosphere-only GCM which was constrained to observations from satellites, sondes, land stations, ships, buoys, *etc*.
- The RCM is forced by representations of reality both externally (e.g. observed SST) and internally (quasi-observed BCs)
  - Thus allowing the possibility of RCM vs. observations comparisons for particular time periods or events

Summer Wet day frequency over the Alps

O
B
S



Good Climatology not very strong constraint on future change

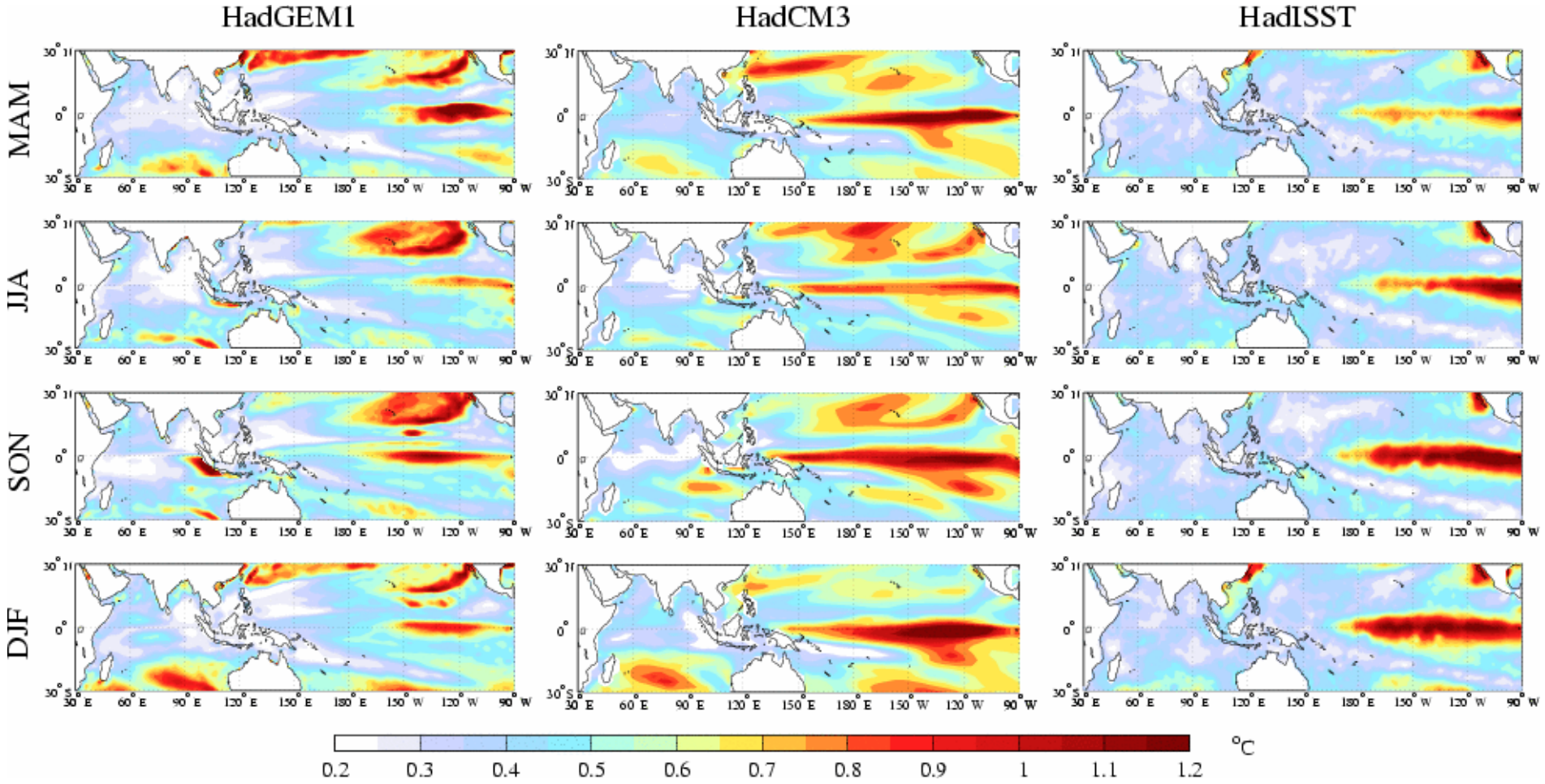


- CCSM3
- CGCM3.1(T47)
- CGCM3.1(T63)
- CNRM-CM3
- CSIRO-Mk3.0
- ECHAM/MPI-OM
- ECHO-G
- FGOALS-g1.0
- GFDL-CM2.0
- GFDL-CM2.1
- GISS-AOM
- GISS-EH
- GISS-ER
- INM-CM3.0
- IPSL-CM4
- MIROC3.2(hires)
- MIROC3.2(medres)
- MRI-CGCM2.3.2
- PCM
- UKMO-HadCM3
- UKMO-HadGEM1

Climate Variability

HadGEM1 tropical behaviour

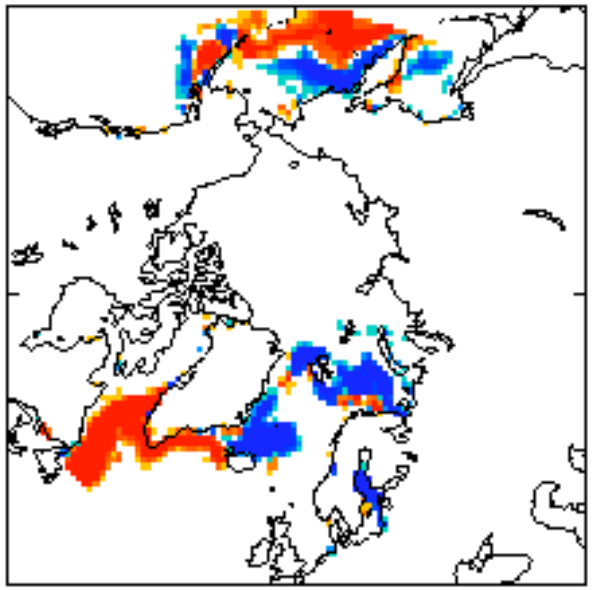
Interannual standard dev of seasonal mean SSTs



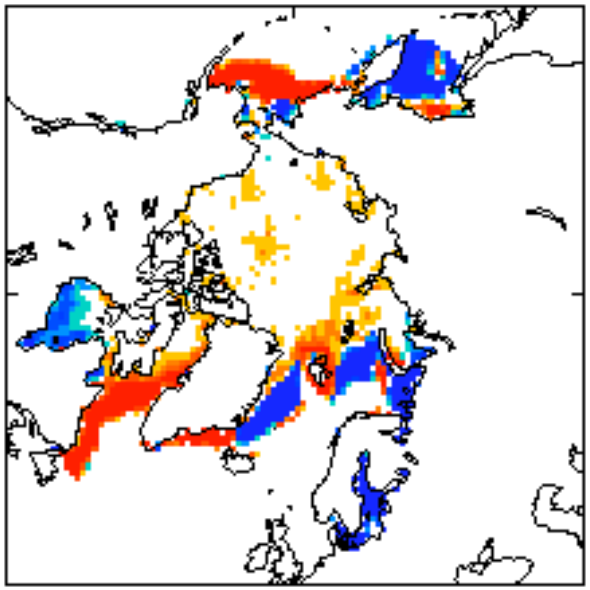
HadGEM1 wintertime sea ice variability related to NAO

March Ice Concentration Anomalies

HadGEM1



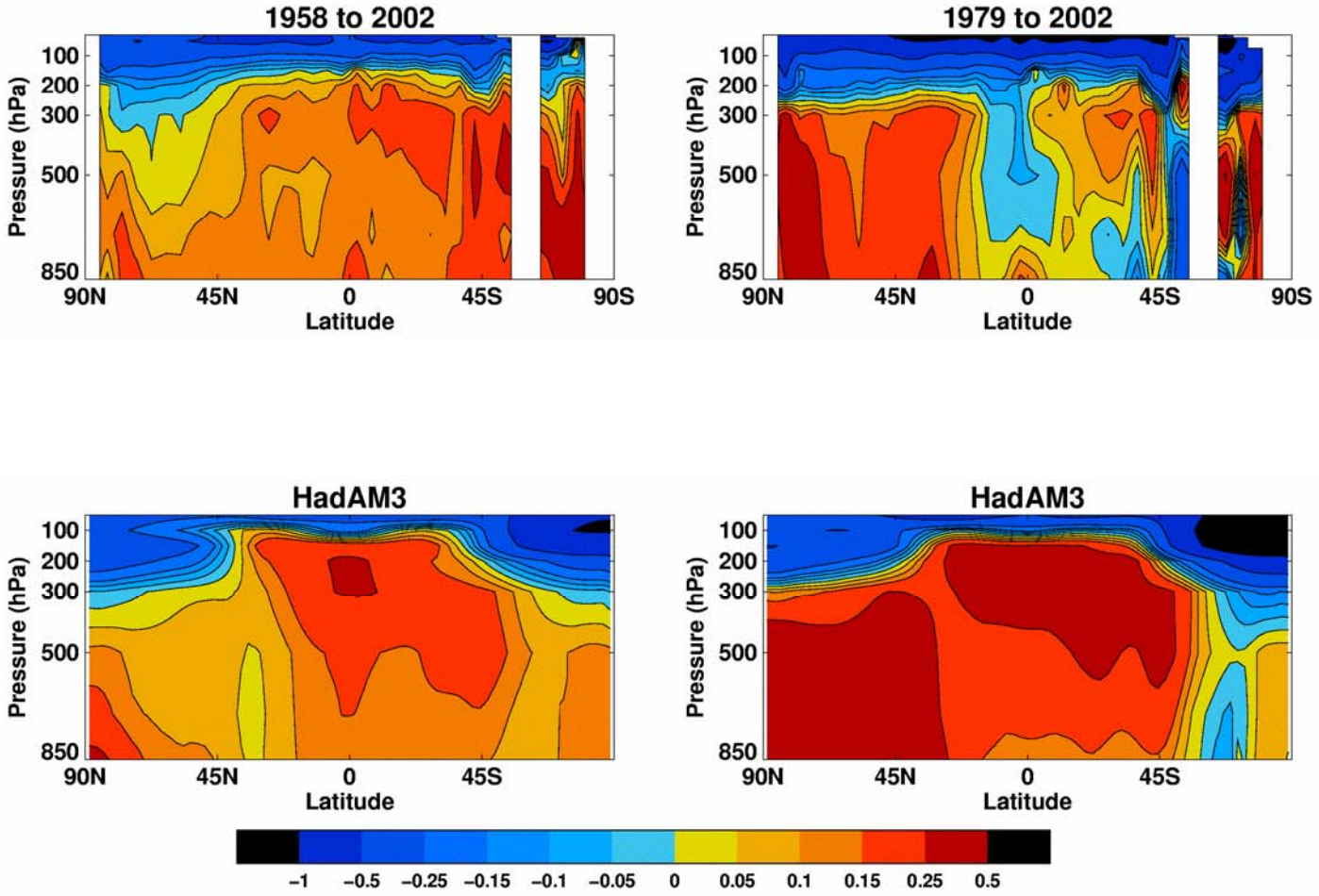
HadISST (from ERA40 PMSL)



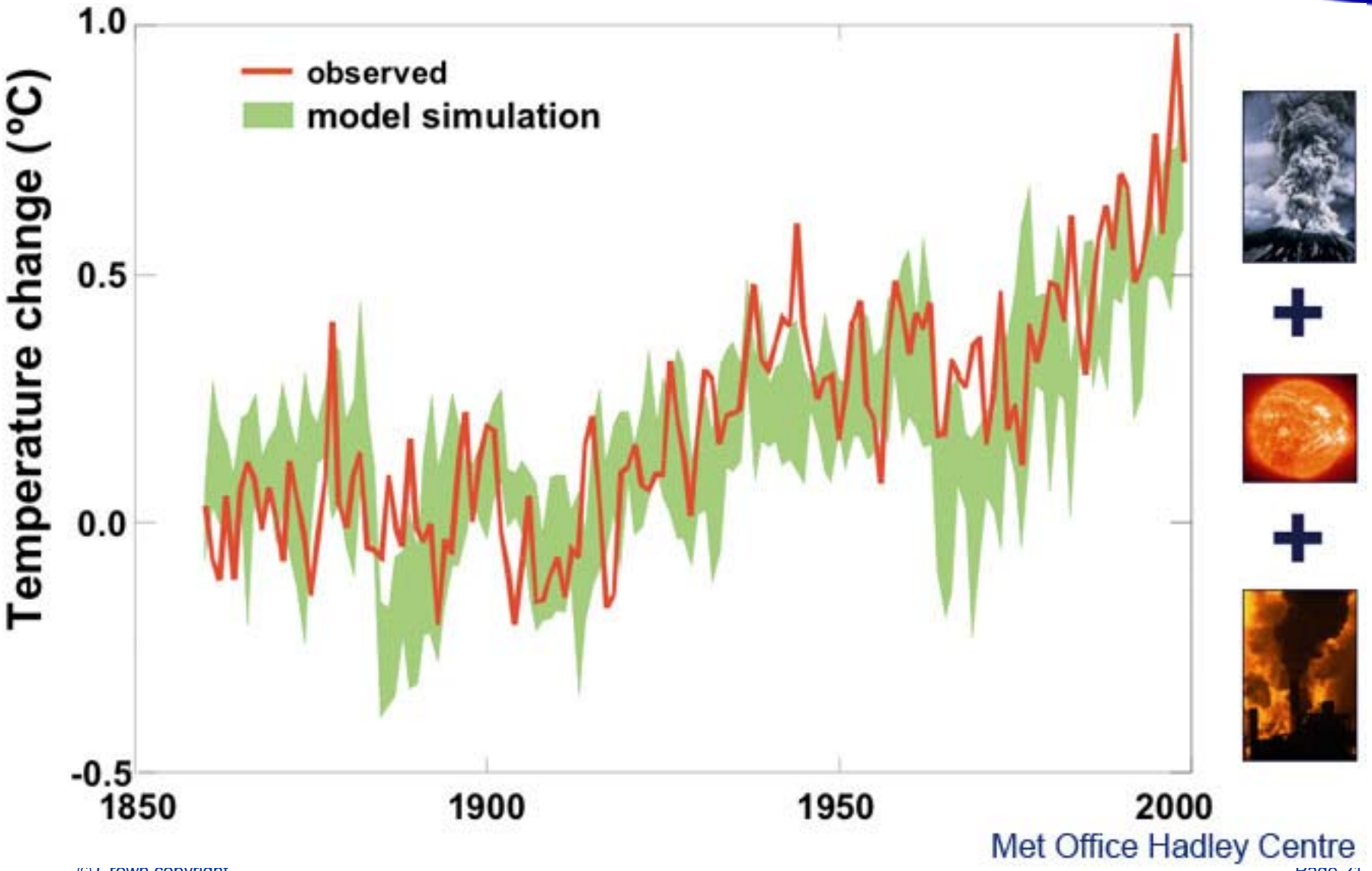
Climate Change

- Direct test.
- But what matters?

Free-atmosphere temperatures

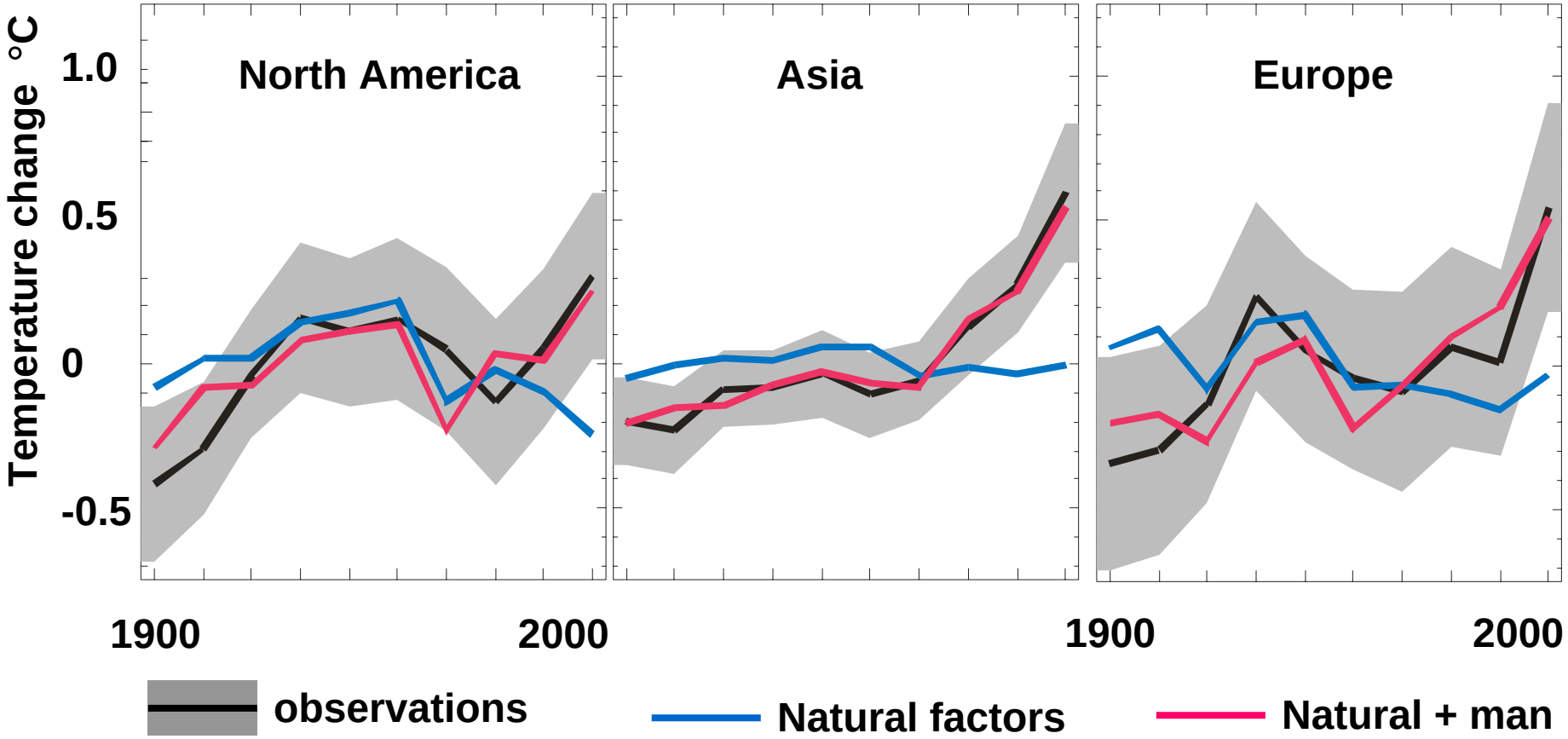


Recent warming can be simulated when man-made factors are included



Observed temperature change over North America, Asia and Europe and model simulation with natural and man-made factors

Met Office Hadley Centre

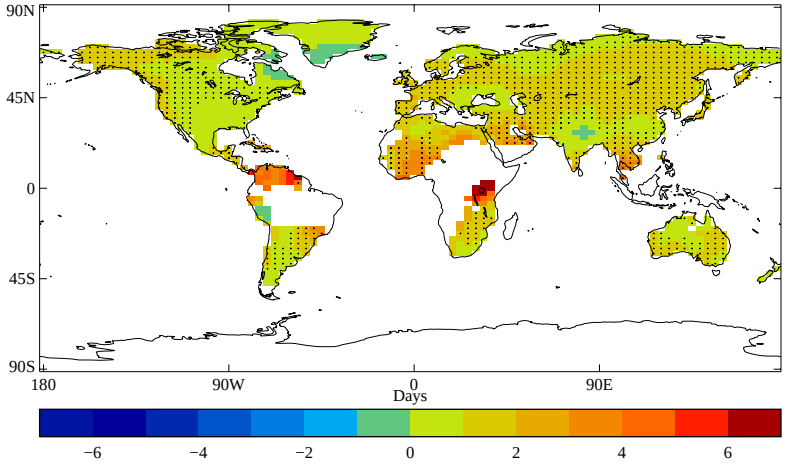


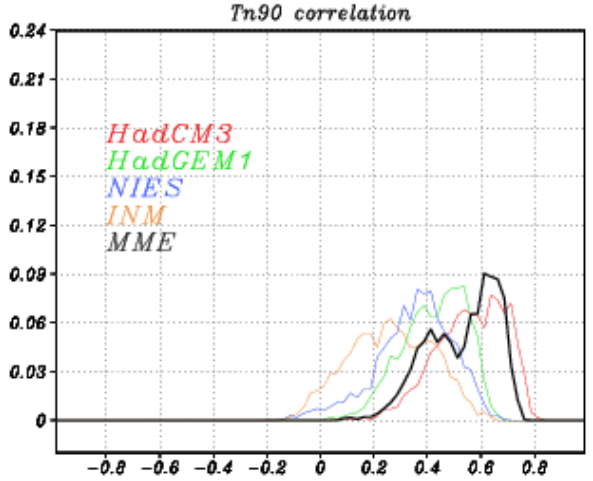
Forcing is important!

Observed & simulated climate extremes

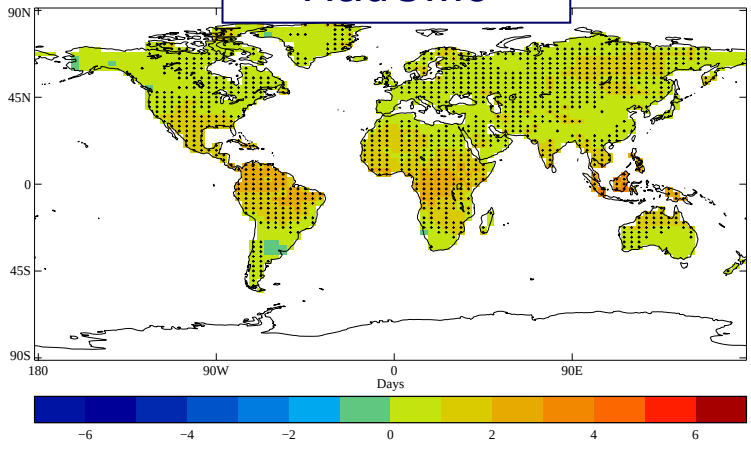
Warm nights (above 90th percentile of minimum temperature), 1951-2003

Obs trend

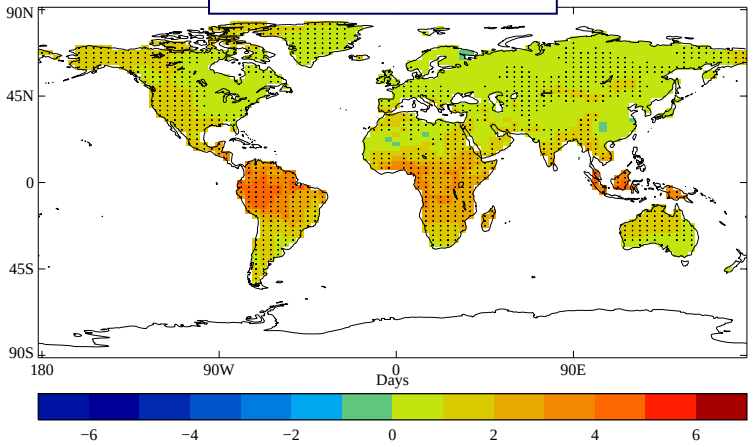




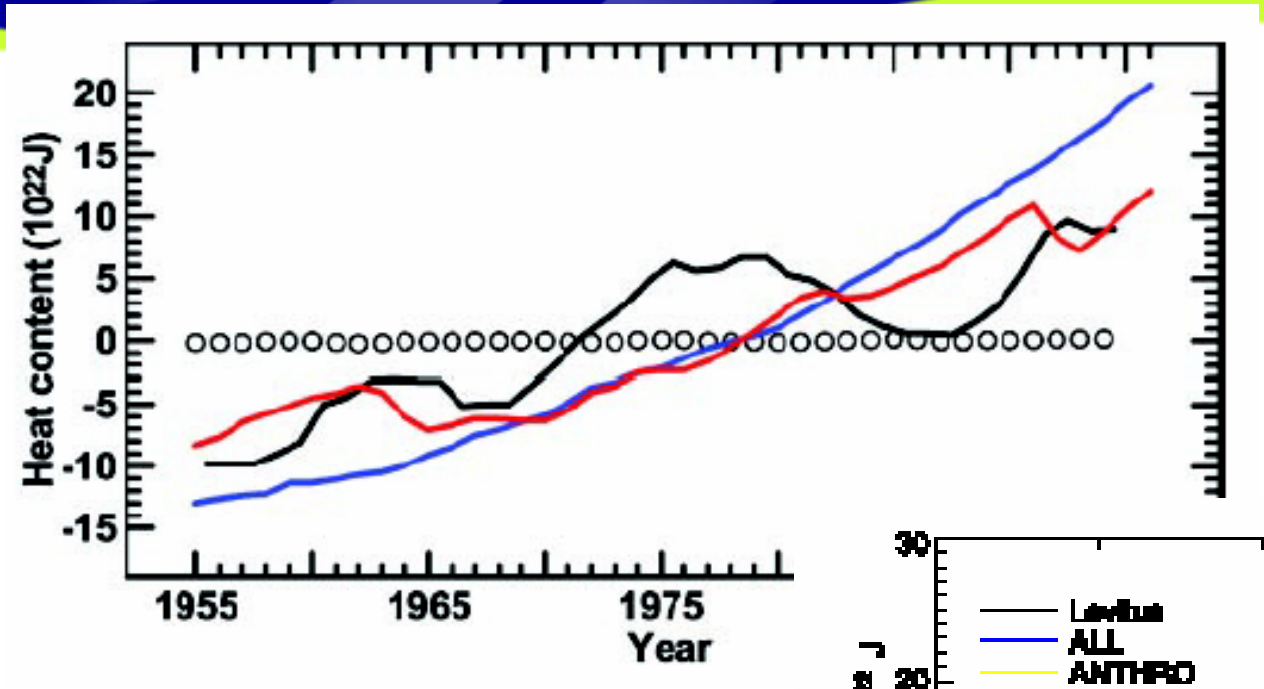
HadCM3

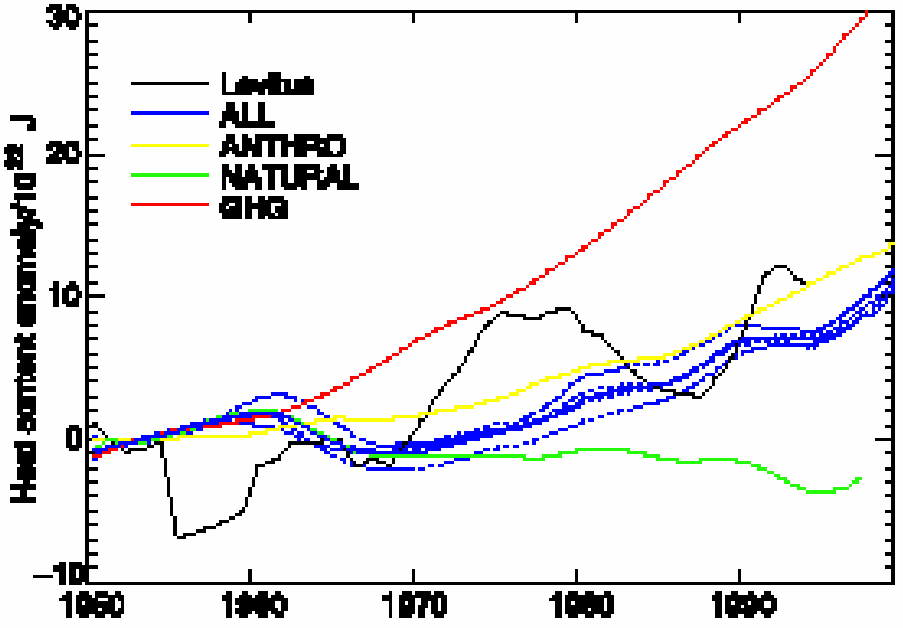


HadGEM1



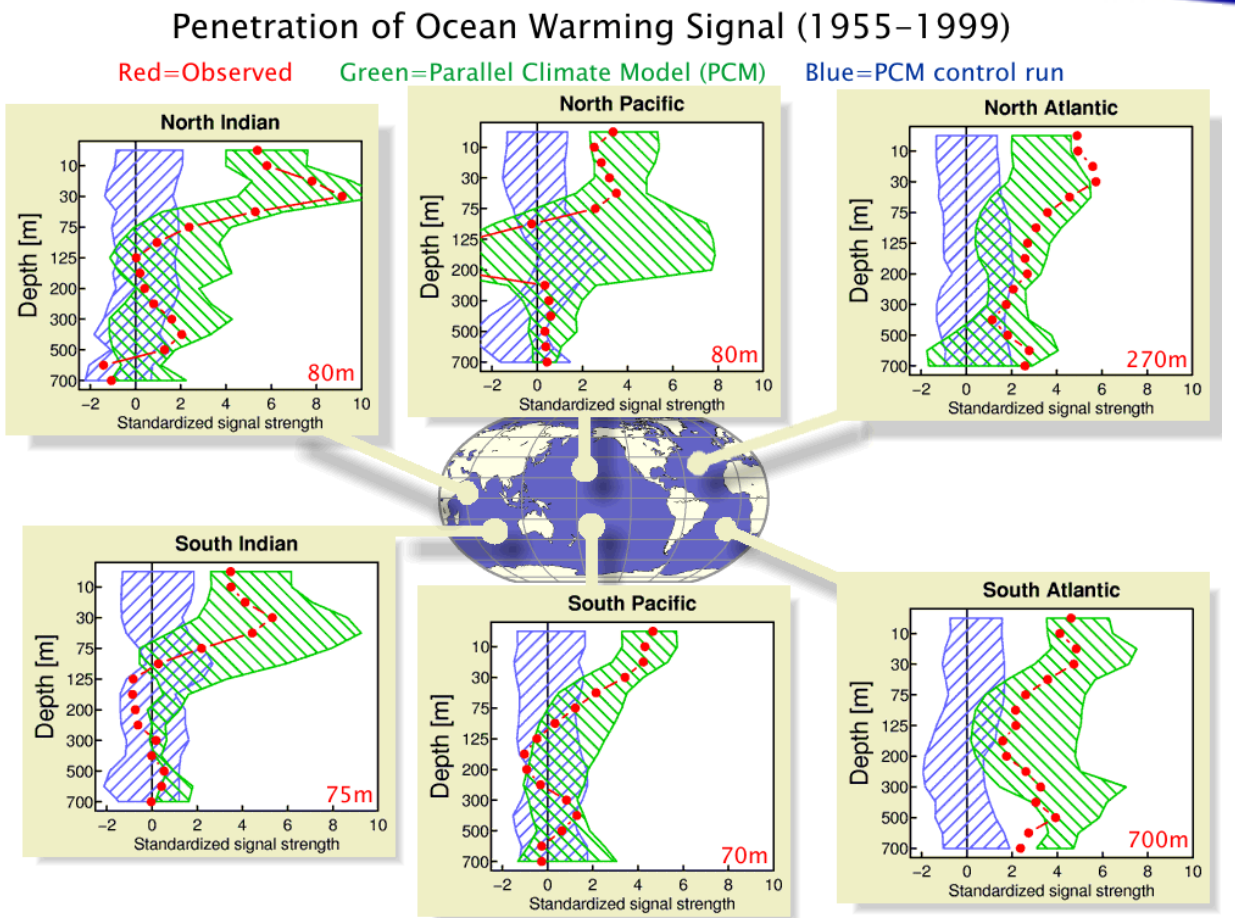
Ocean Heat Content





Human-induced warming of the ocean has been detected

Whereas natural internal variability (blue range) is not consistent with the observed signal (red circles), simulated ocean warming due to anthropogenic factors (green range) is consistent with the observed changes and reproduces many of the different responses seen in the individual ocean basins.

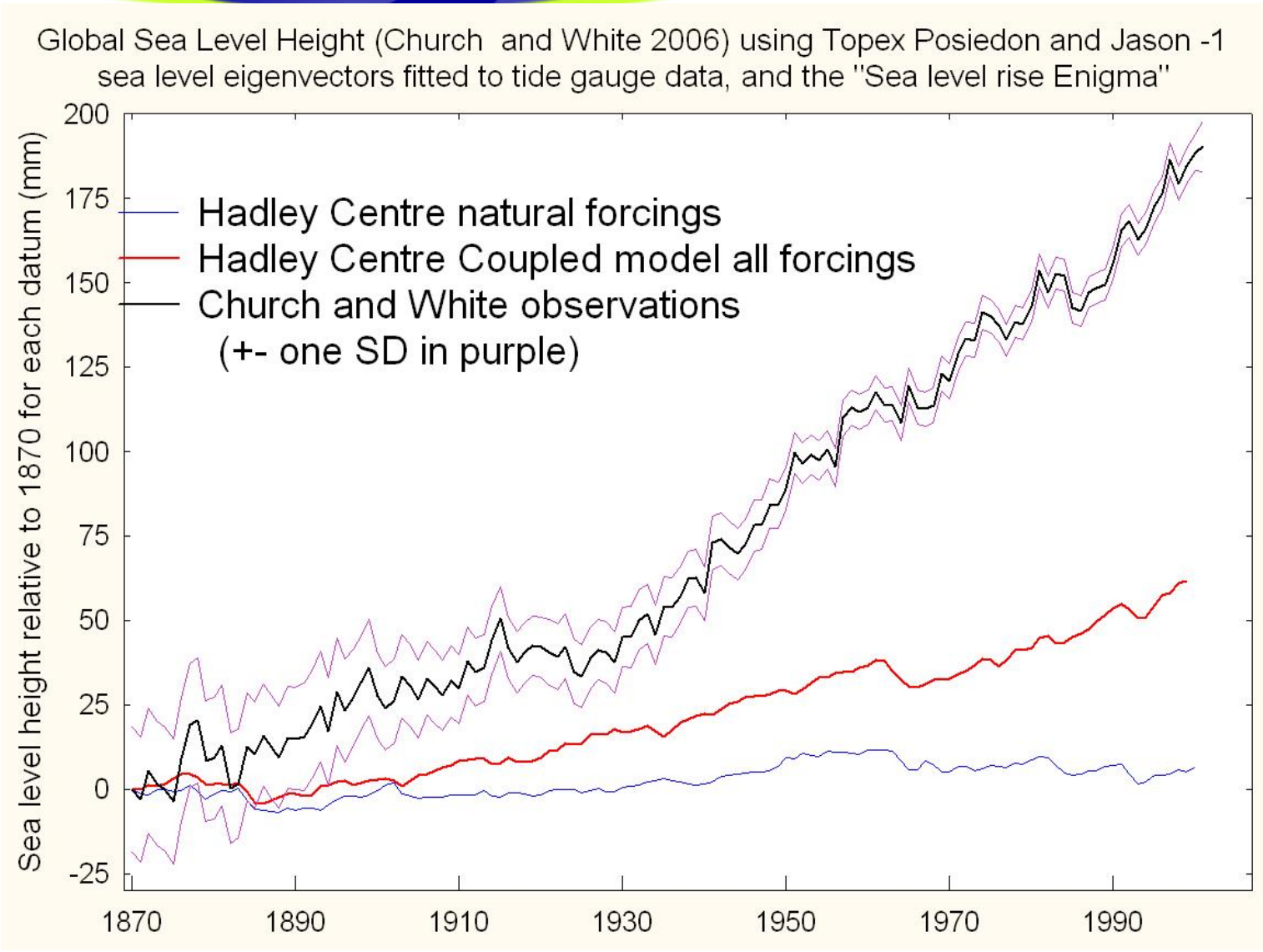


Penetration of Human-Induced Warming into the World's Oceans

Tim P. Barnett,[1]* David W. Pierce,[1] Krishna M. AchutaRao,[2] Peter J. Gleckler,[2] Benjamin D. Santer,[2] Jonathan M. Gregory,[3] Warren M. Washington[4]

Barnett *et al.*, *Science* (2005)

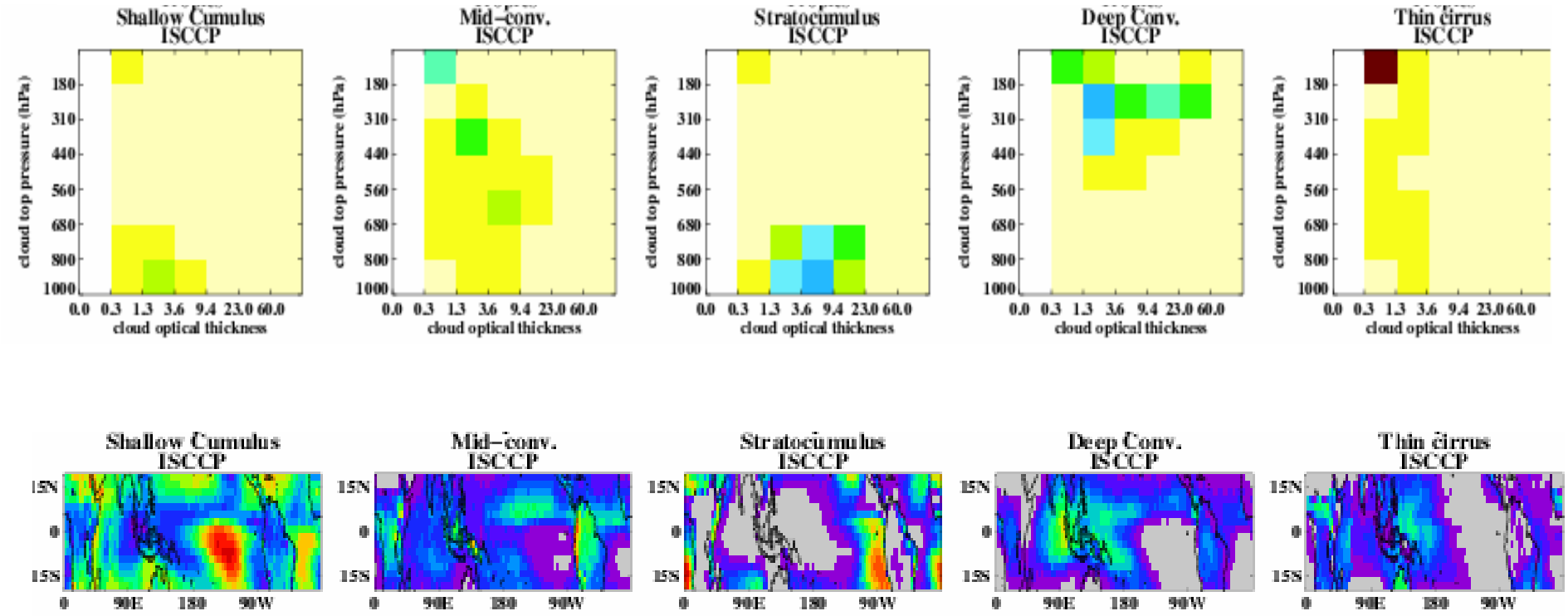
Sea Level



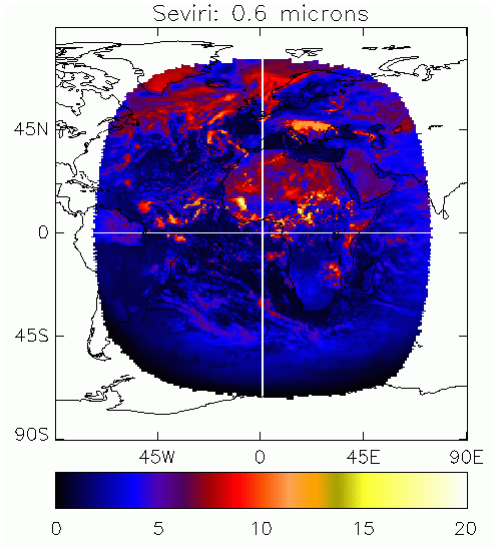
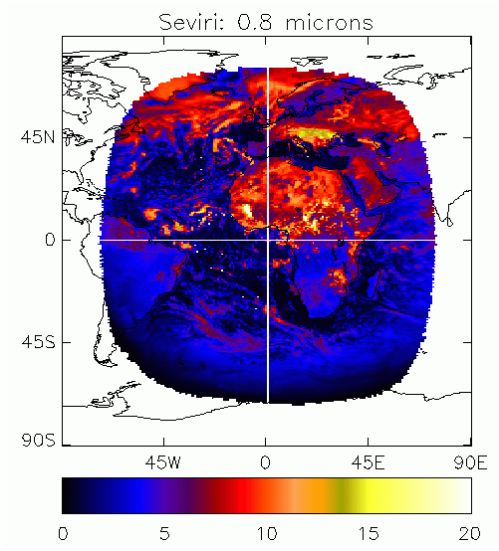
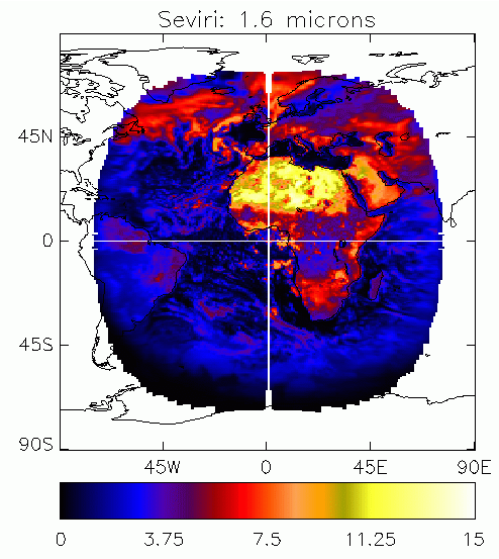
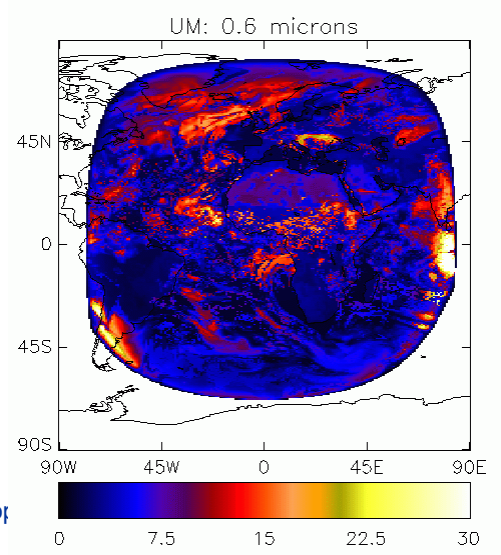
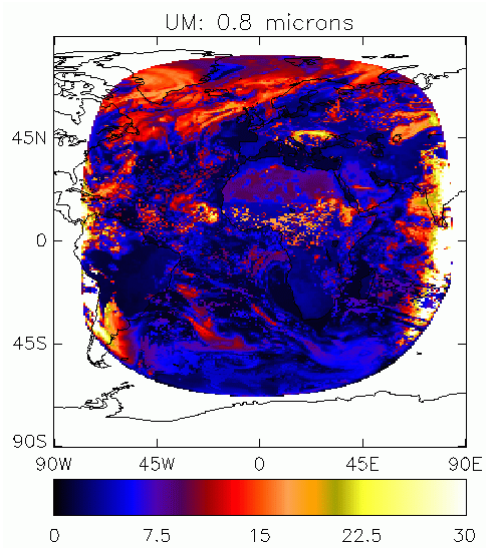
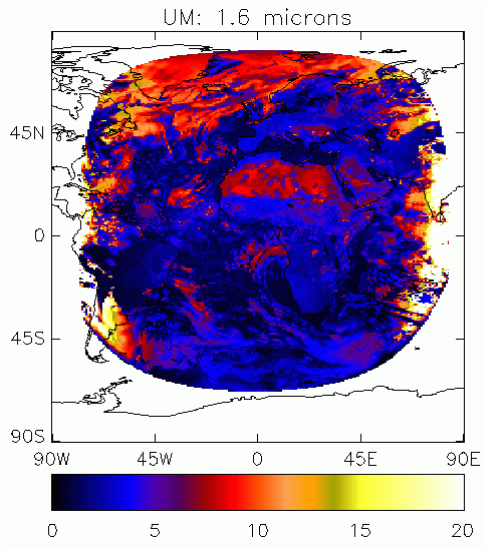
Using satellite data

- ISCCP
  - Need ISCCP simulator – clouds are seen from space.
- Direct simulation of radiances.

ISCCP observational cloud regimes (20N-20S)



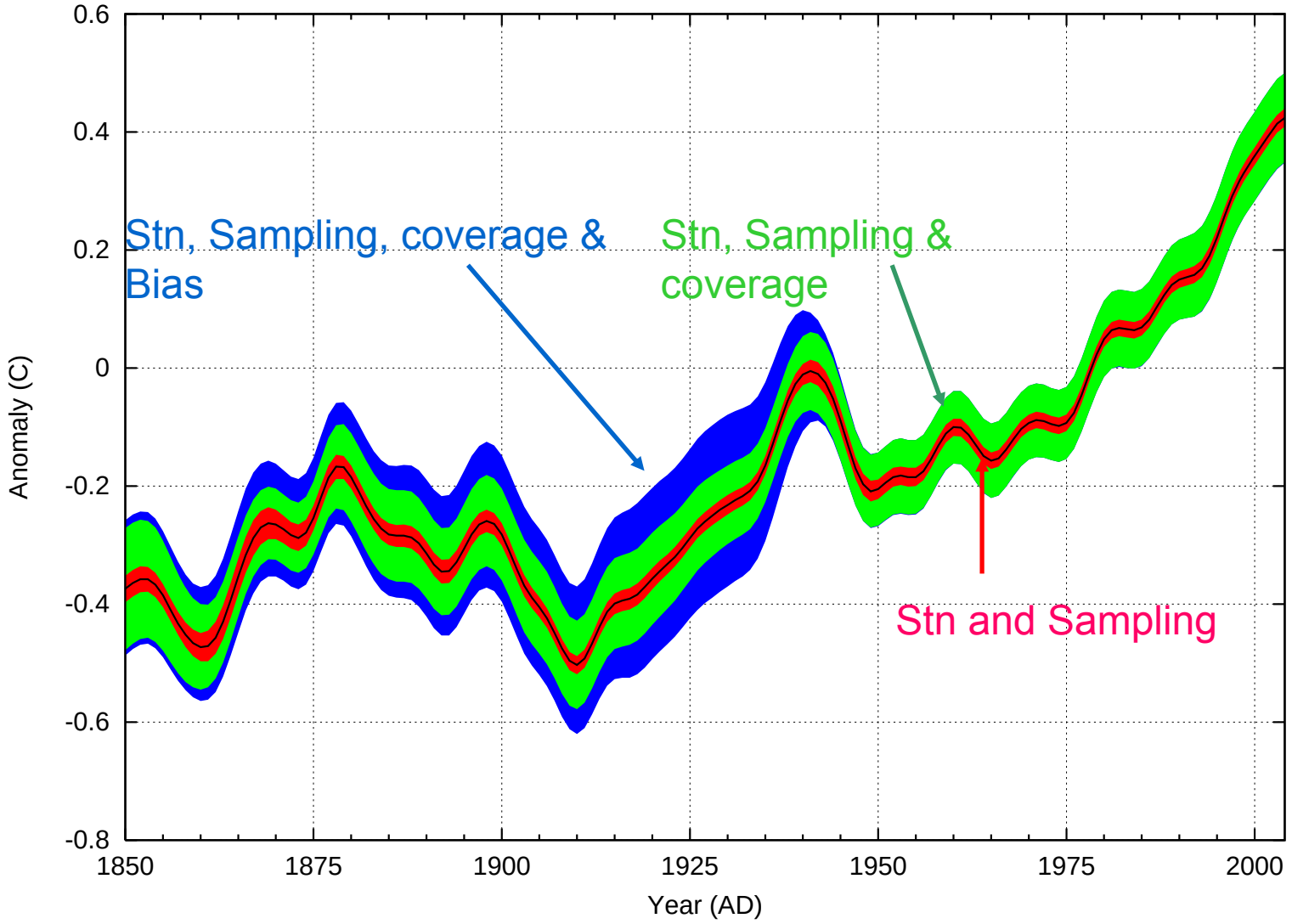
Simulation of SEVIRI shortwave channels

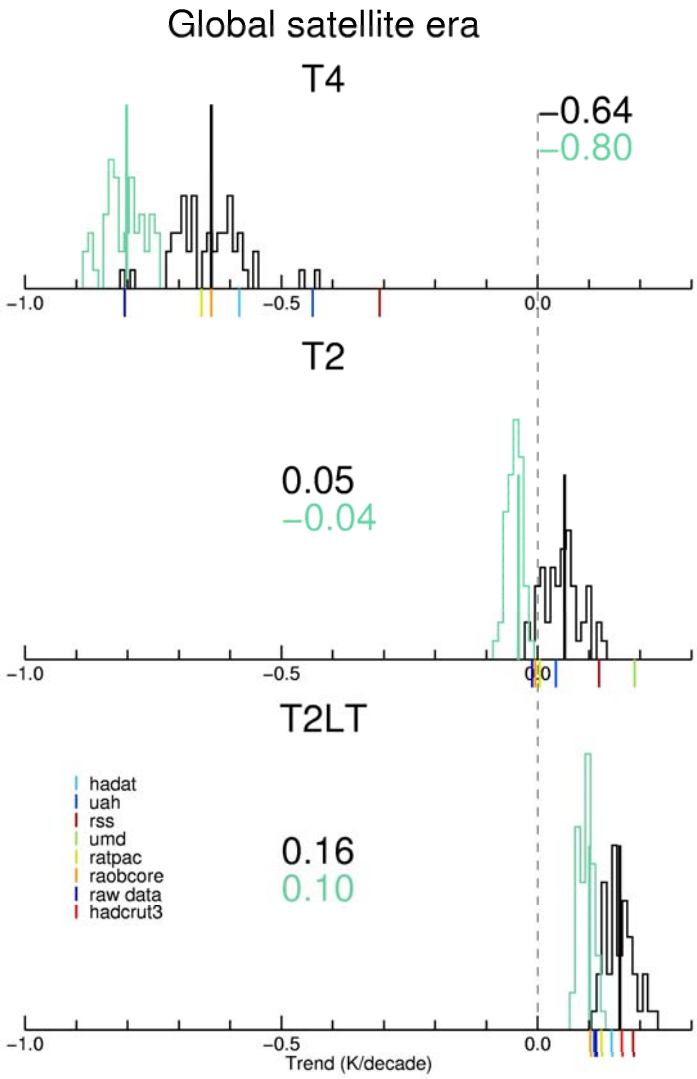
	0.6 microns	0.8 microns	1.6 microns
Observed			
Model			

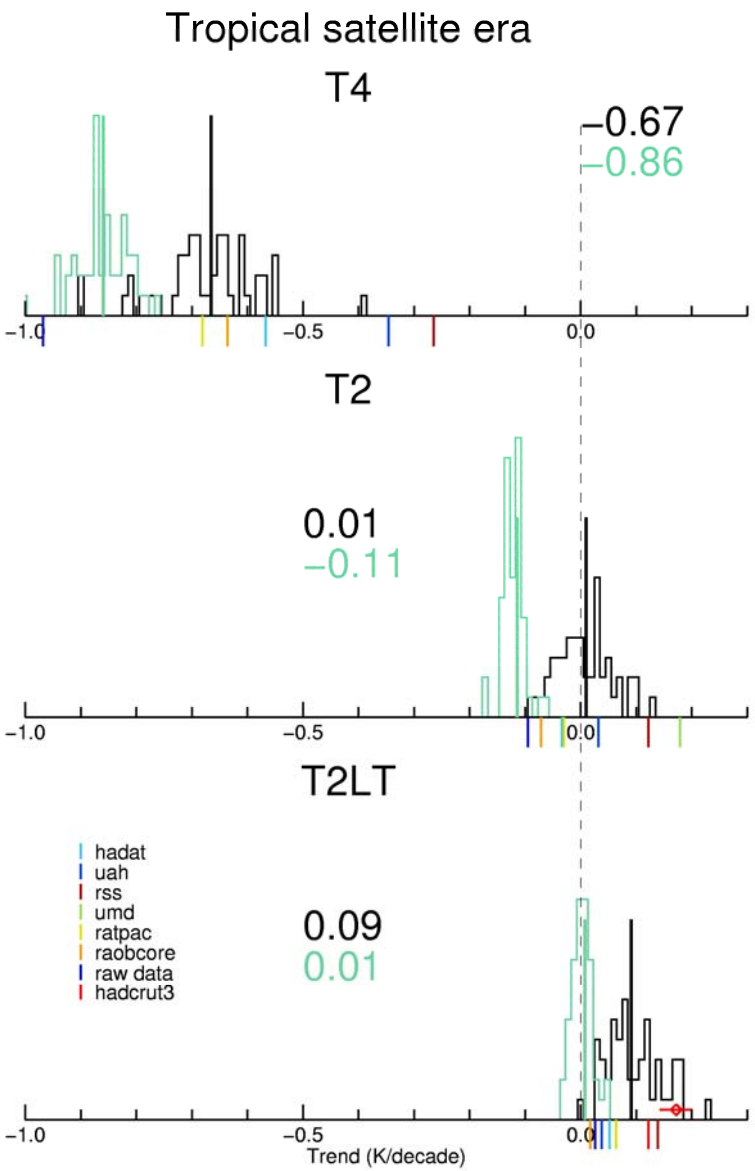
Observational Uncertainty

- Climate Records are corrected.
- Correction is uncertain.
- *In situ* data are point measurements and have error.
- Need to develop methods to use these uncertainties which have complex structure.

Global time-series at smoothed annual resolution



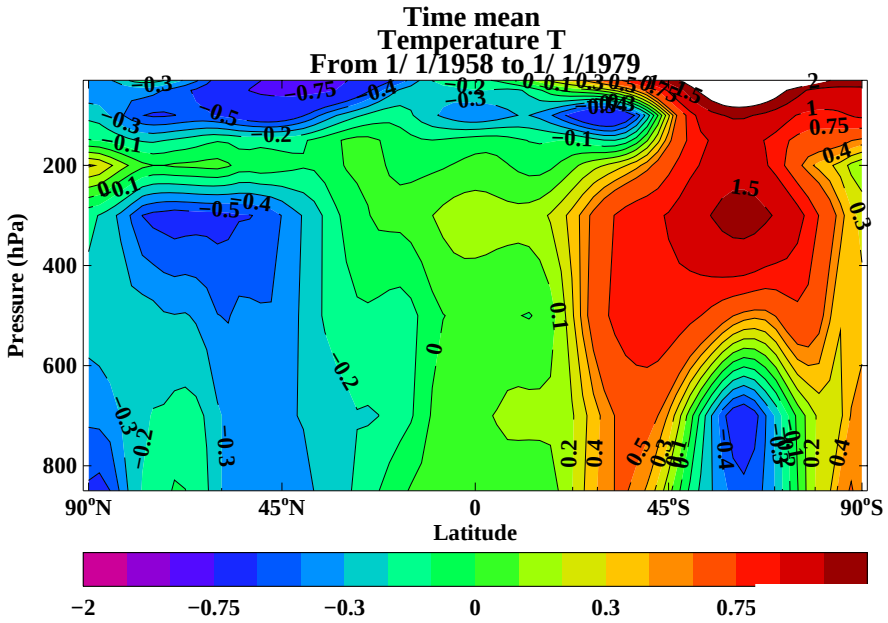




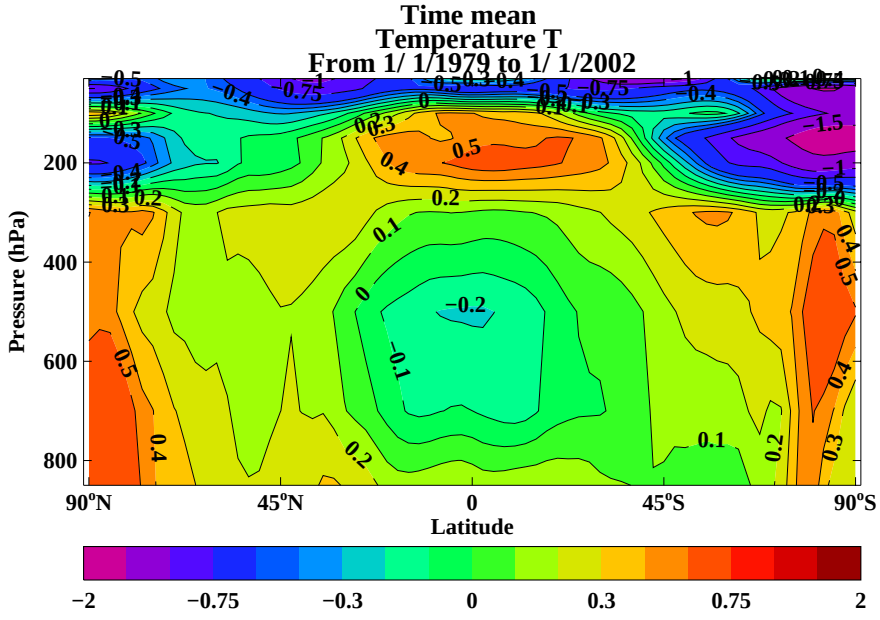
How could climate-quality reanalysis help.

- Allow broader range of validation studies
  - Particularly for low-frequency variability and change.
  - Issues:
    - Model Bias
    - Data homogenisation.
- Needs error estimates.
- Or at least subjective views on reliability & Uncertainty. Red/Amber/Green lights ???
- Provide initial conditions for “Transpose AMIP”
- And Boundary Conditions for regional models
  - Would like to test their ability to downscale climate change.

Do we have it now?



58-79



79-02