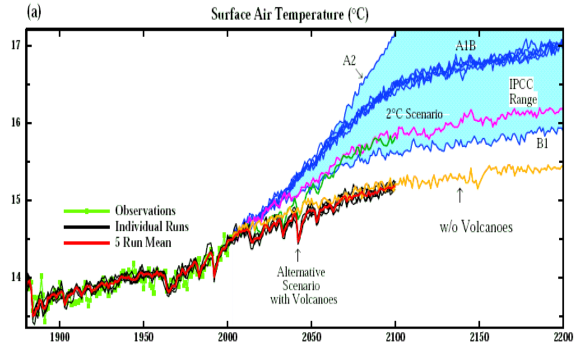
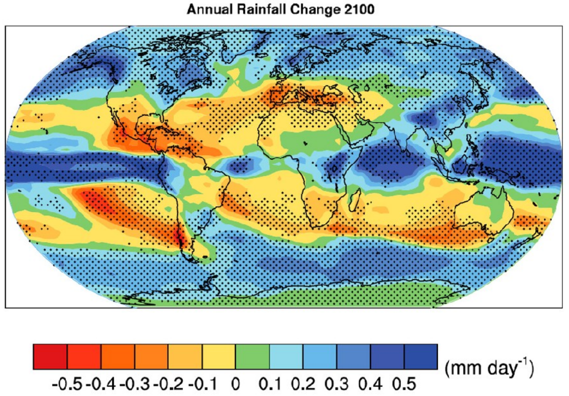
CERES Science Team
Oct 2008

After IPCC AR4: Remaining uncertainties and strategies for reducing them





Gavin Schmidt
NASA Goddard Institute for Space Studies and
Center for Climate Systems Research, Columbia University

Q. What's the difference between an ice core and a MODIS retrieval?

The IPCC perspective

- Very strongly focussed on detection and attribution of current climate change and potential future scenarios
- Projections using 'IPCC-class' models dominate assessments of future risk
- Uncertainties are tied to:
    - credibility of climate models
    - robustness of projections
    - quality of long-term datasets
    - impacts of various policies

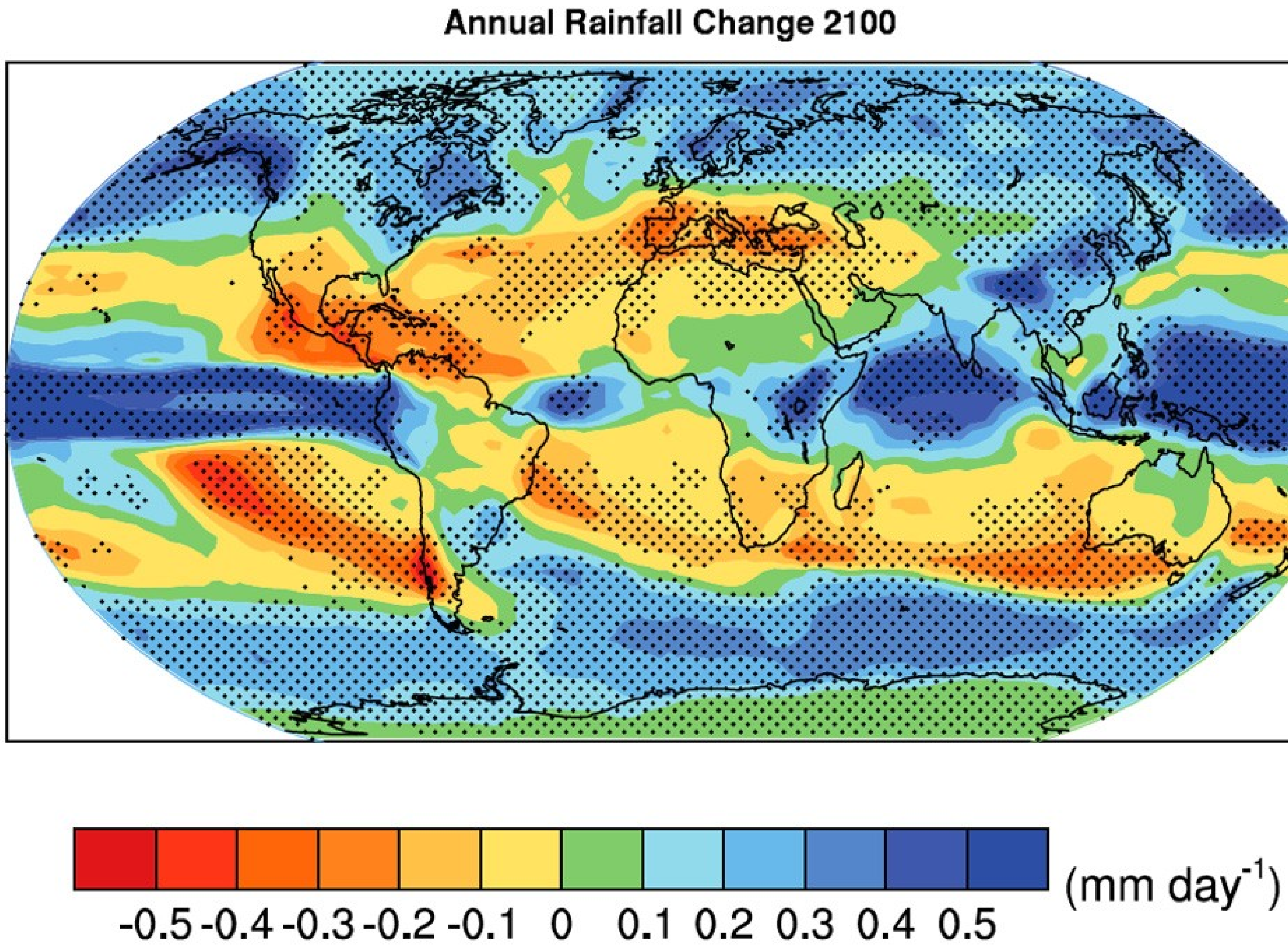
Three kinds of model output

Predictions: Estimated outcomes under highly specific conditions – not restricted to the future!

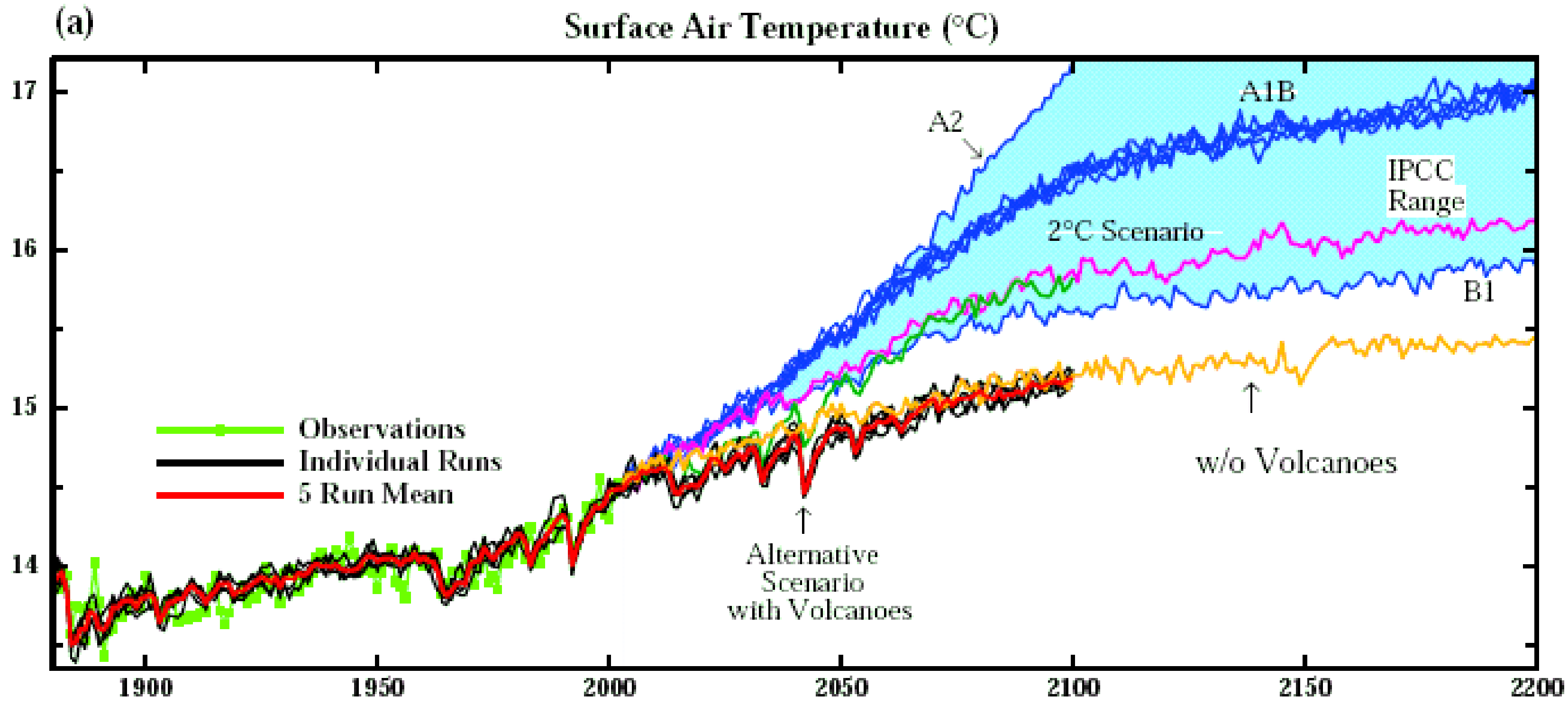
Projections: Predictions conditional on a future scenario (forced component)

Forecasts: Predictions dependent on scenario and initial conditions

How do you define robustness?

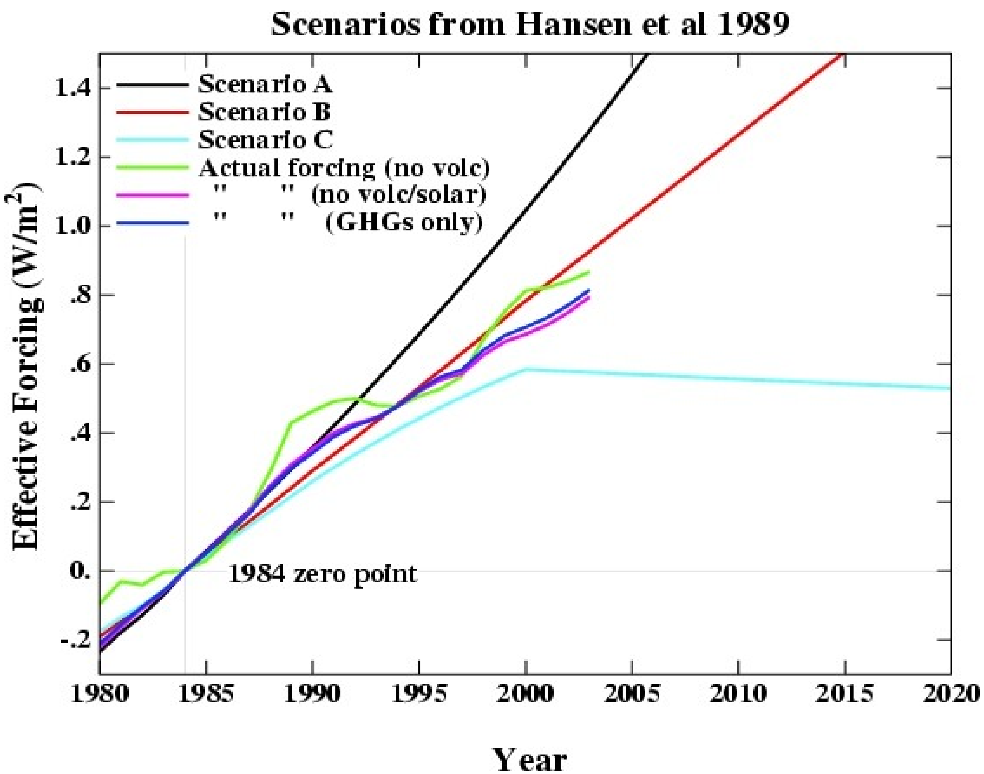


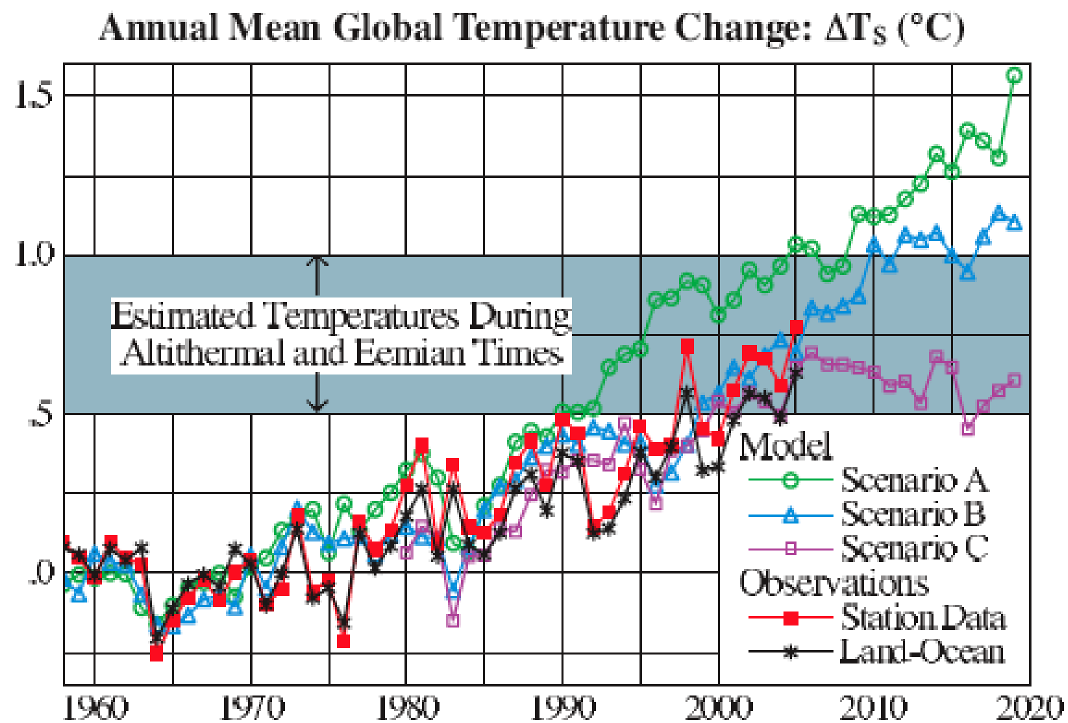
Future temperatures?



Past projections: Hansen 1988

3 Scenarios: A - exponential growth,
B - business as usual 'most plausible'
C - no further GHG growth after 2000

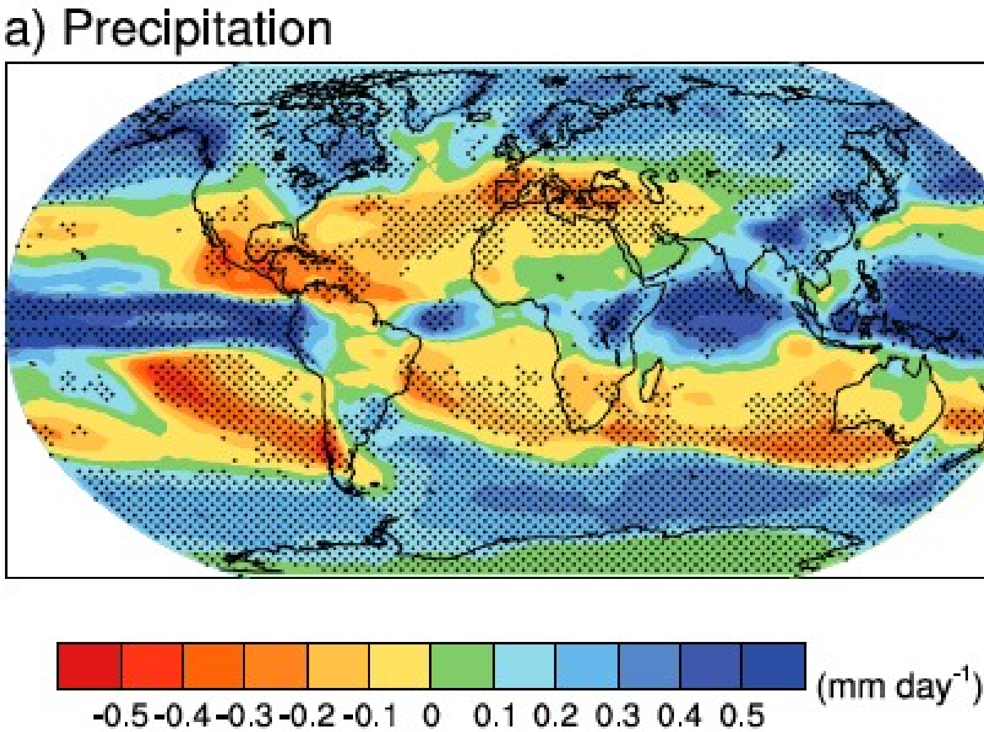


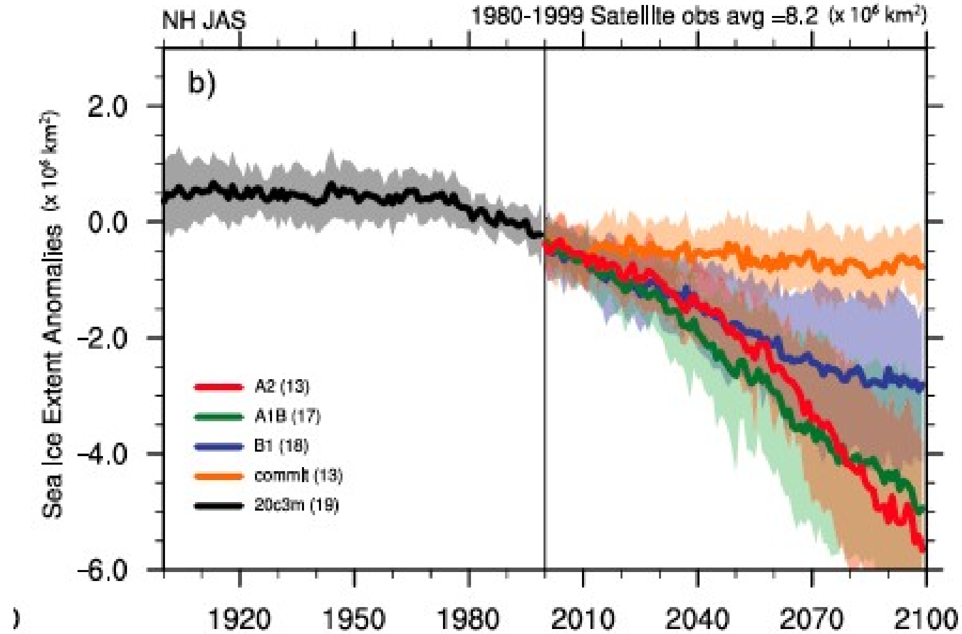


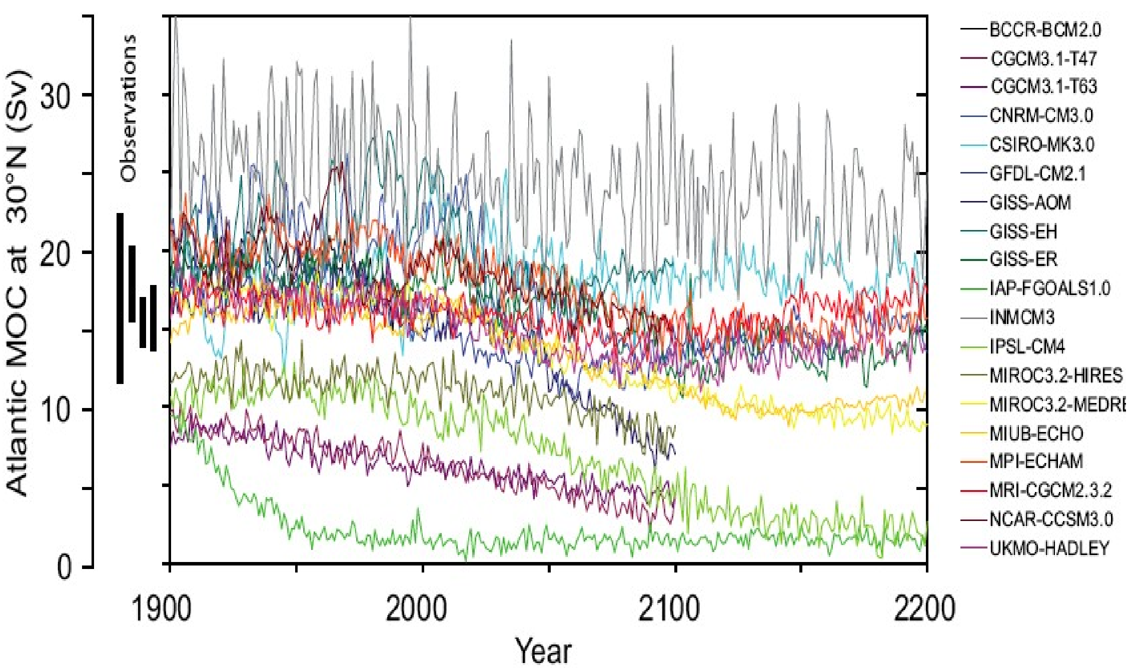
SAT Trends 1984-2005:

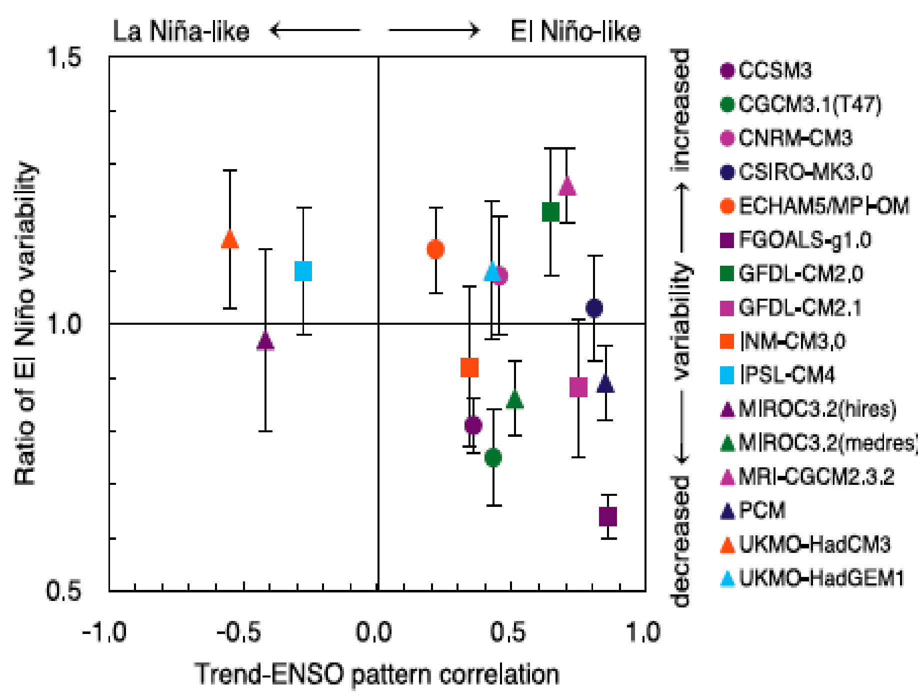
OBS: 0.23±0.04/0.20±0.03 (different indices)

Scen. B: 0.23±0.06


a) Precipitation
-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5
(mm day^{-1})


NH JAS
1980-1999 Satellite obs avg =8.2 (x 10^6 km^2)
b)
Sea Ice Extent Anomalies (x 10^6 km^2)
2.0
0.0
-2.0
-4.0
-6.0
A2 (13)
A1B (17)
B1 (18)
commit (13)
20c3m (19)
1920 1950 1980 2010 2040 2070 2100

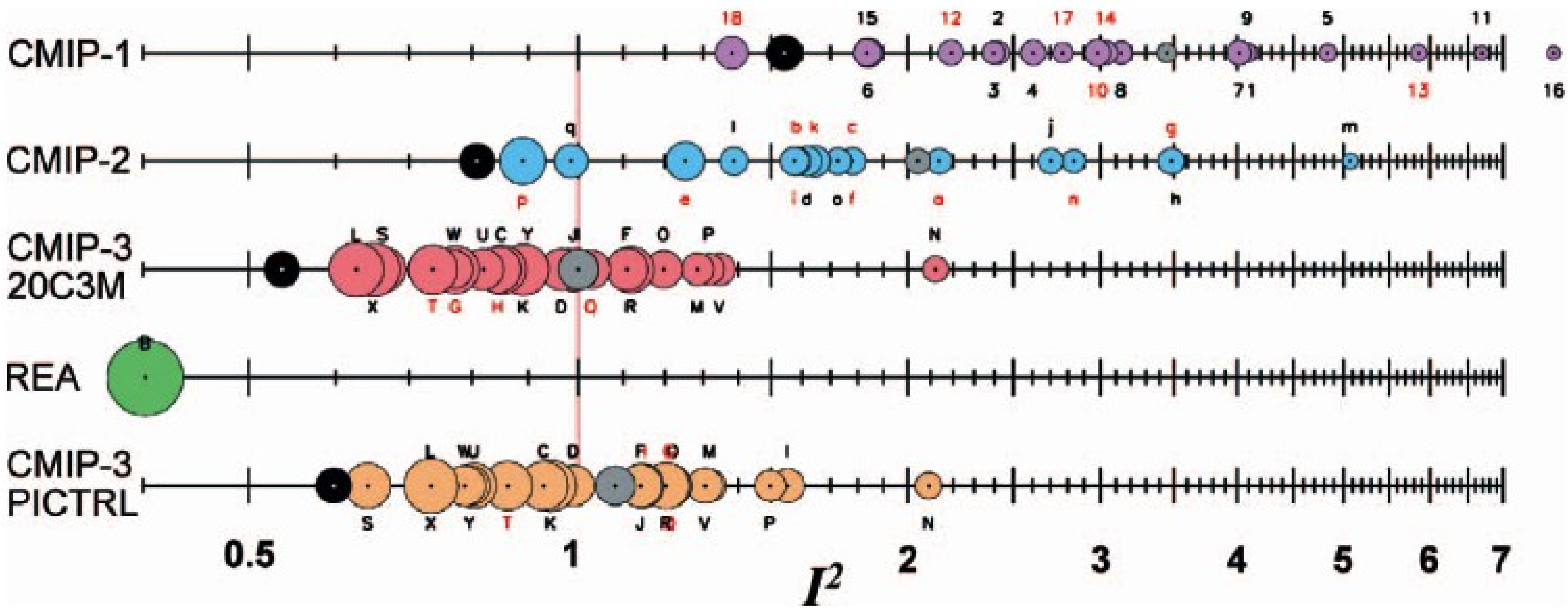

Atlantic MOC at 30°N (Sv)
Observations
0 10 20 30
1900 2000 2100 2200
Year
BCCR-BCM2.0
CGCM3.1-T47
CGCM3.1-T63
CNRM-CM3.0
CSIRO-MK3.0
GFDL-CM2.1
GISS-AOM
GISS-EH
GISS-ER
IAP-FGOALS1.0
INMCM3
IPSL-CM4
MIROC3.2-HIRES
MIROC3.2-MEDRE
MIUB-ECHO
MPI-ECHAM
MRI-CGCM2.3.2
NCAR-CCSM3.0
UKMO-HADLEY


La Niña-like
El Niño-like
Ratio of El Niño variability
1.5
1.0
0.5
-1.0 -0.5 0.0 0.5 1.0
Trend-ENSO pattern correlation
decreased ← variability → increased
CCSM3
CGCM3.1(T47)
CNRM-CM3
CSIRO-MK3.0
ECHAM5/MPI-OM
FGOALS-g1.0
GFDL-CM2.0
GFDL-CM2.1
INM-CM3.0
IPSL-CM4
MIROC3.2(hires)
MIROC3.2(medres)
MRI-CGCM2.3.2
PCM
UKMO-HadCM3
UKMO-HadGEM1

Major remaining uncertainties

- Climatology
  - Double ITCZ, Cloud distributions
- Regional climate change
  - ENSO variability – no credibility, no robustness
  - Hadley circulation
    - – robustness, uncertain credibility
  - Sub-tropical precipitation
    - – robust in zonal mean, not locally
- Extremes
  - Hurricane activity
    - – not modelled, not robust, no credibility
- Ice sheets (and sea level rise)
  - All models totally inadequate

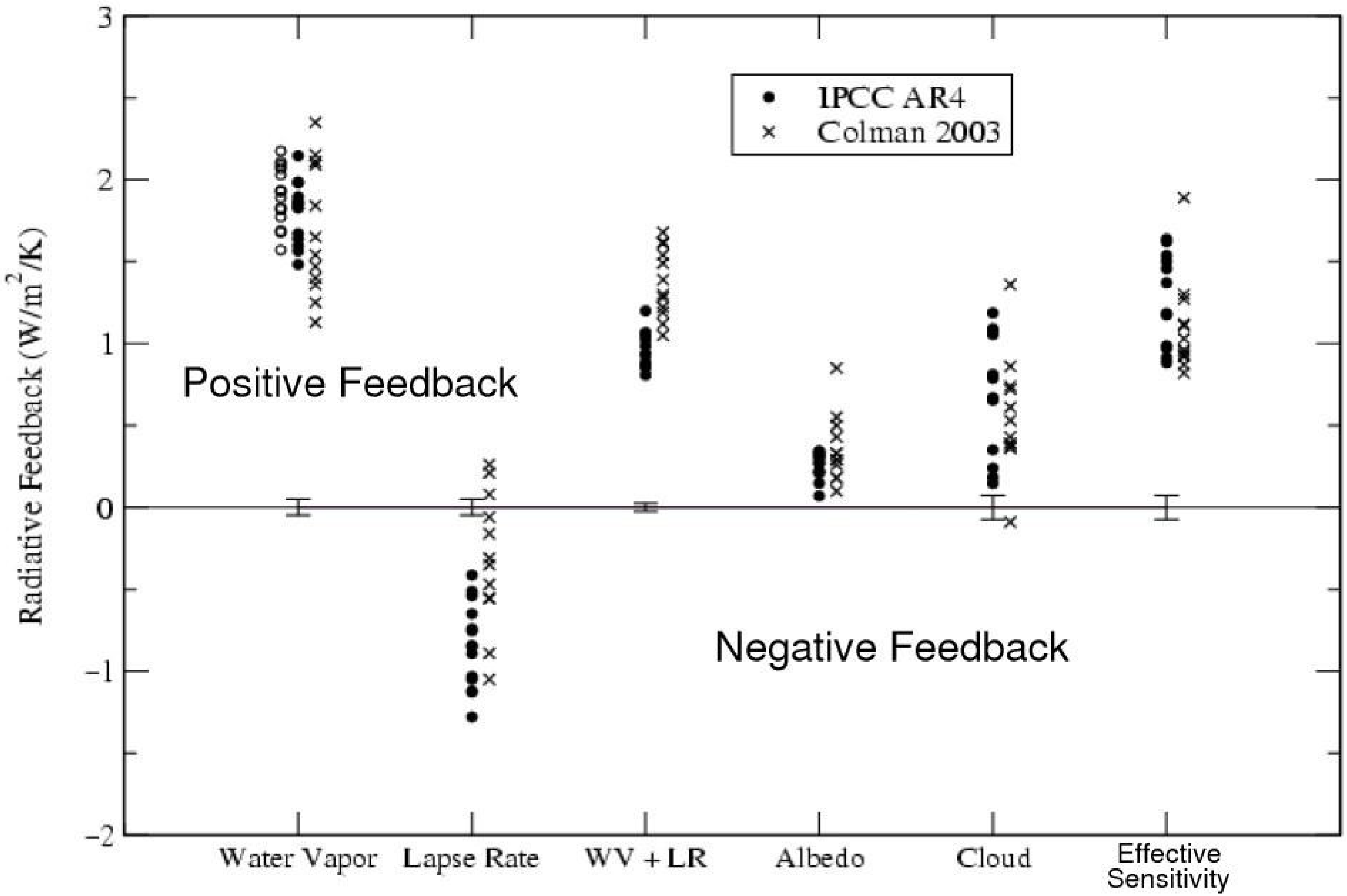
Climate models have got better



← Skill score

Reichler and Kim, BAMS 2008

But big differences in feedbacks...



Soden and Held, 2006

How can we make projections more credible and robust?

1) Bottom up

Test process parameterisations against observations of that process

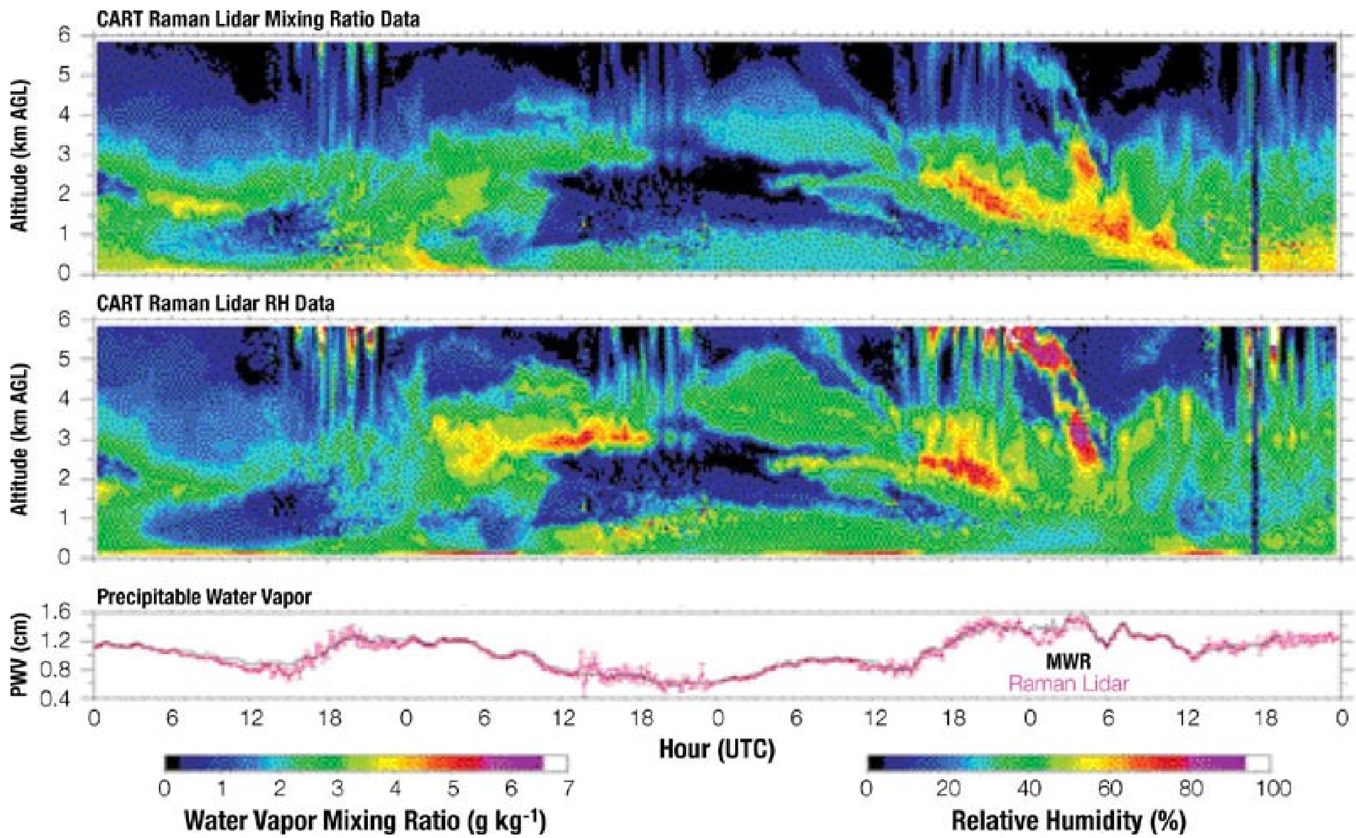
2) Top down

Test emergent properties – variability, large scale coherent patterns, overall sensitivity

3) Middle-ware

Improve conformability of modelled variables and observations

Bottom up observations

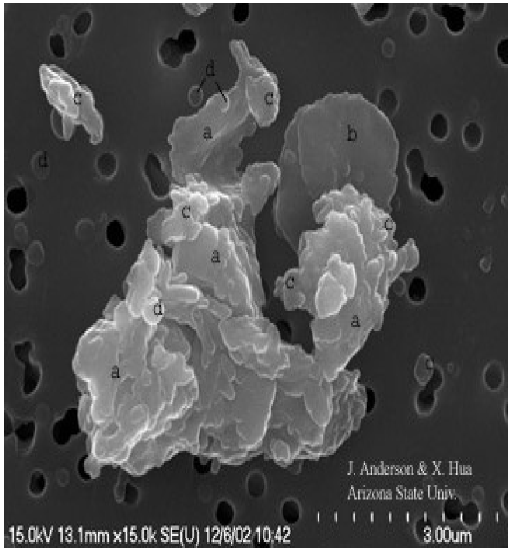


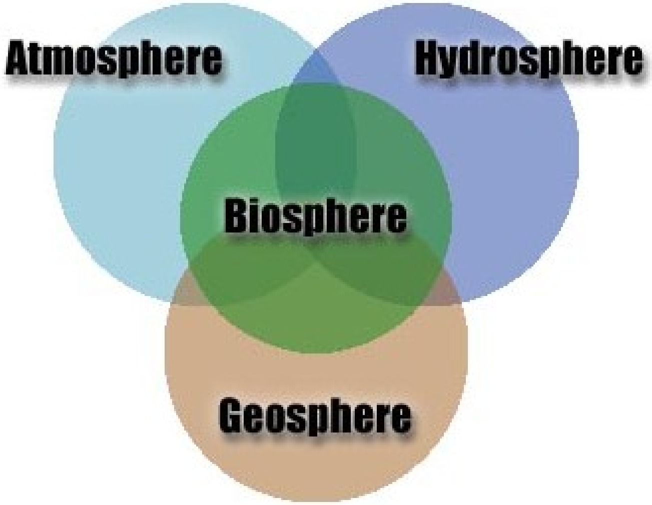
Short time scale, multi-parameter

- useful for parameter/parameter relationships
- need as many parameters in the models as are measured
- forward models for direct observables

Towards fully interactive ESMs...

- Aerosols <=> Chemistry <=> Radiation
  - Dust/Sea salt, heterogenous chemistry
  - Cloud-aerosol indirect effects
  - RH-aerosol effects
  - aerosol microphysics
- Dynamic vegetation => Emissions
  - Dynamic plant physiology/type
  - Ozone, secondary organic aerosols, isoprene
  - Ecosystems <=> temperature, precipitation
  - Methane
- Chemical deposition <=> Vegetation
  - Nitrogen/Surface ozone impact veg.
  - Other nutrients to plankton
- Ocean biology => Albedo/Emissions
  - Ocean plankton/ecosystem model
  - Carbon cycle



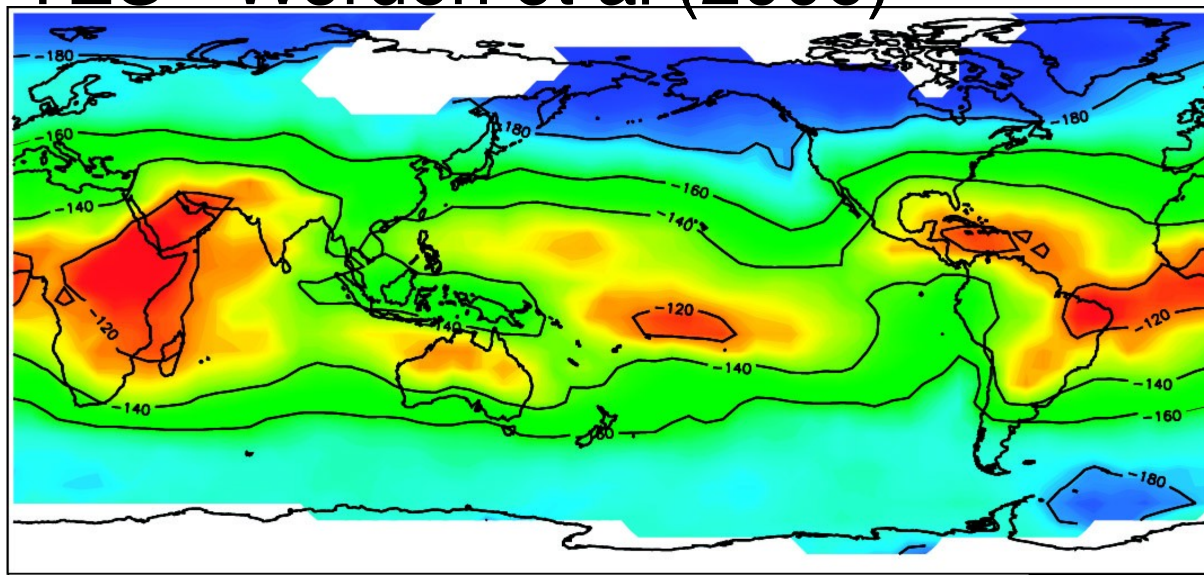


Water isotopes – a new remote-sensed tracer

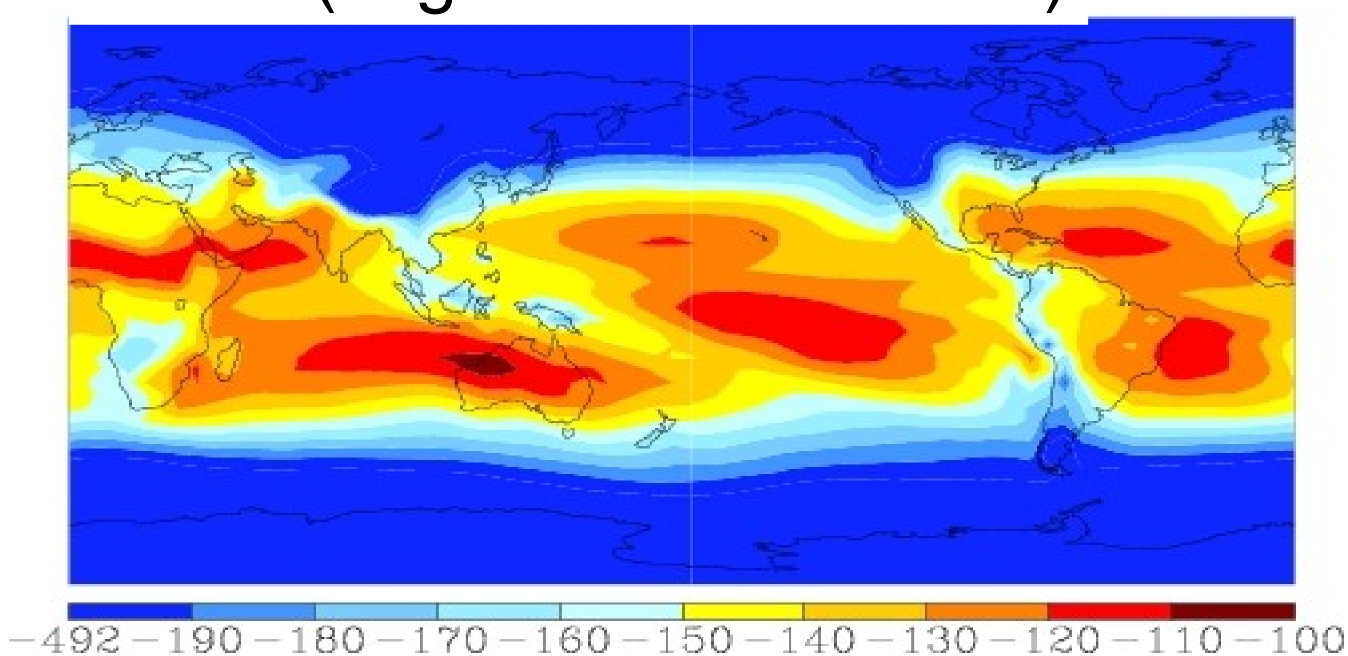
Satellite retrievals of dD

Since water isotopes differentiate between different sources of water, they can be used to separate out evaporative fluxes from atmospheric convergence etc.

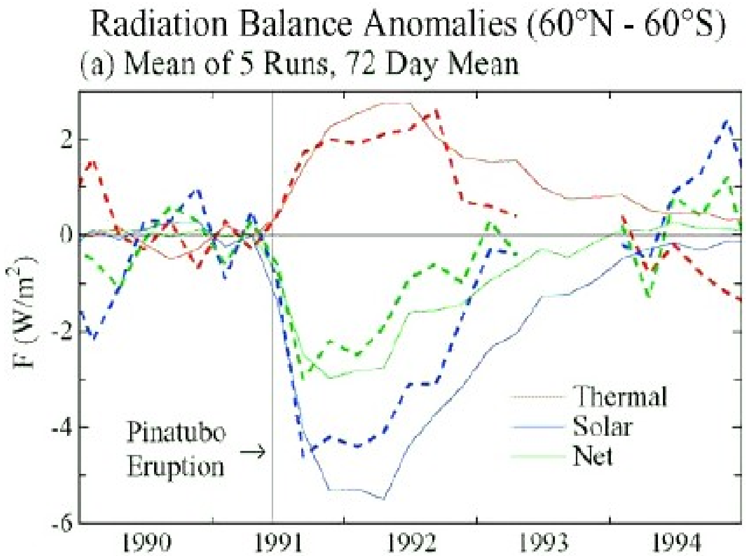
TES - Worden et al (2006)

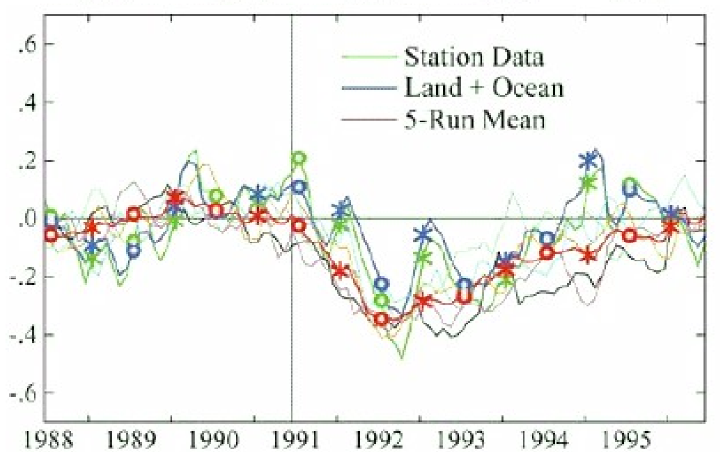


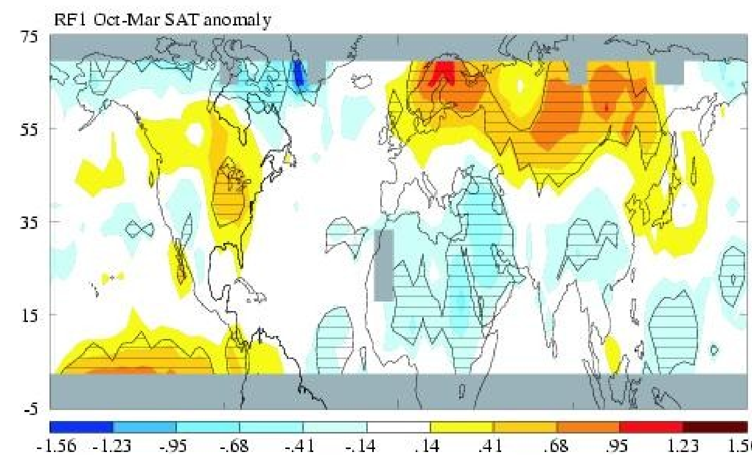
Model (avg of 934mb-550mb)



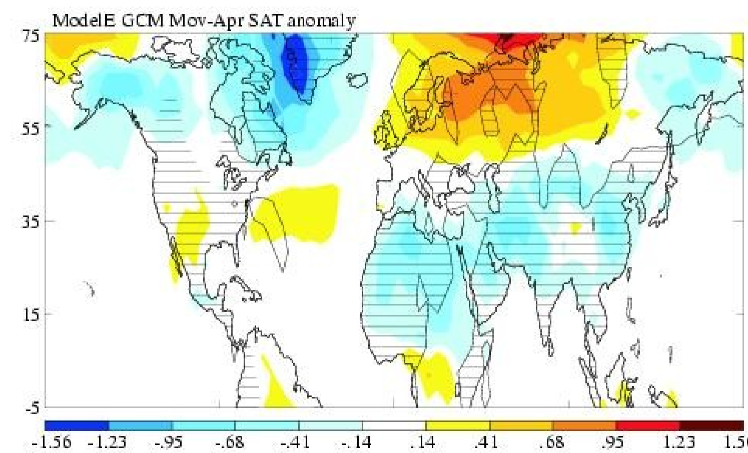
Volcanic forcing and response







Obs

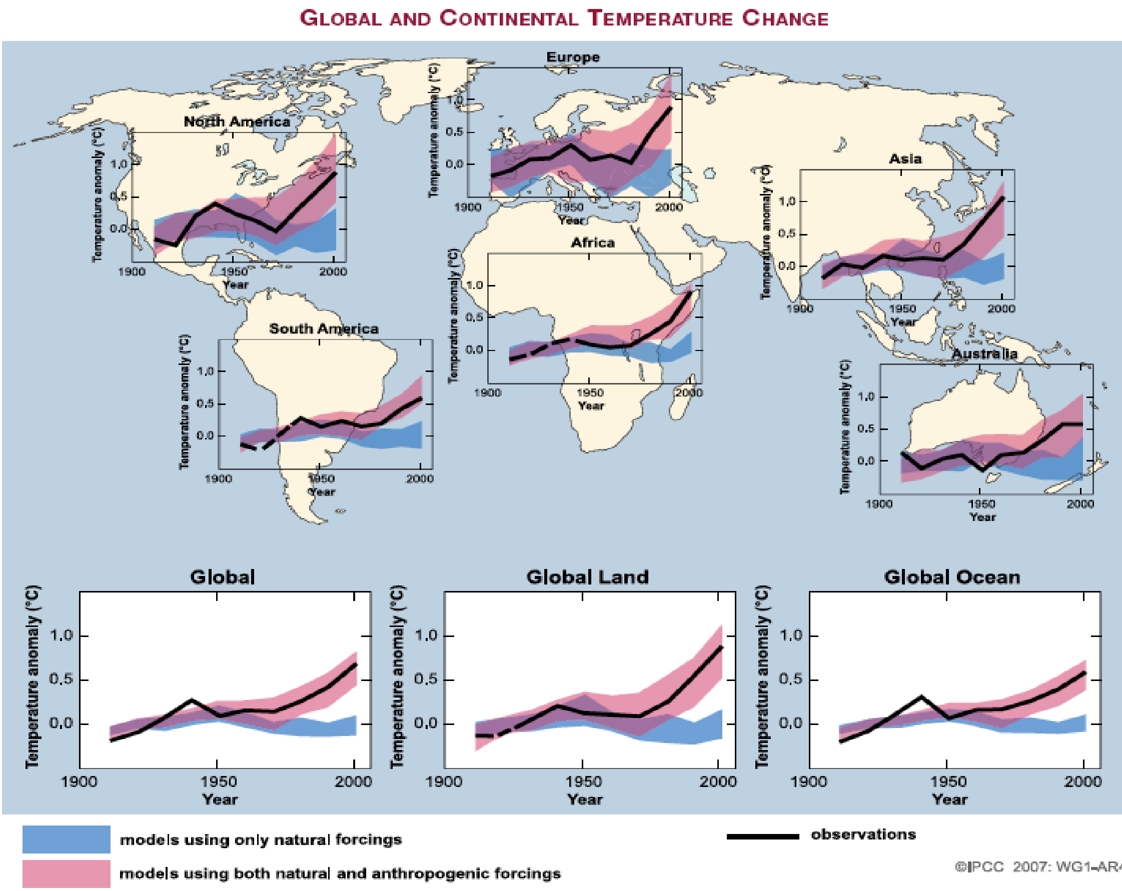


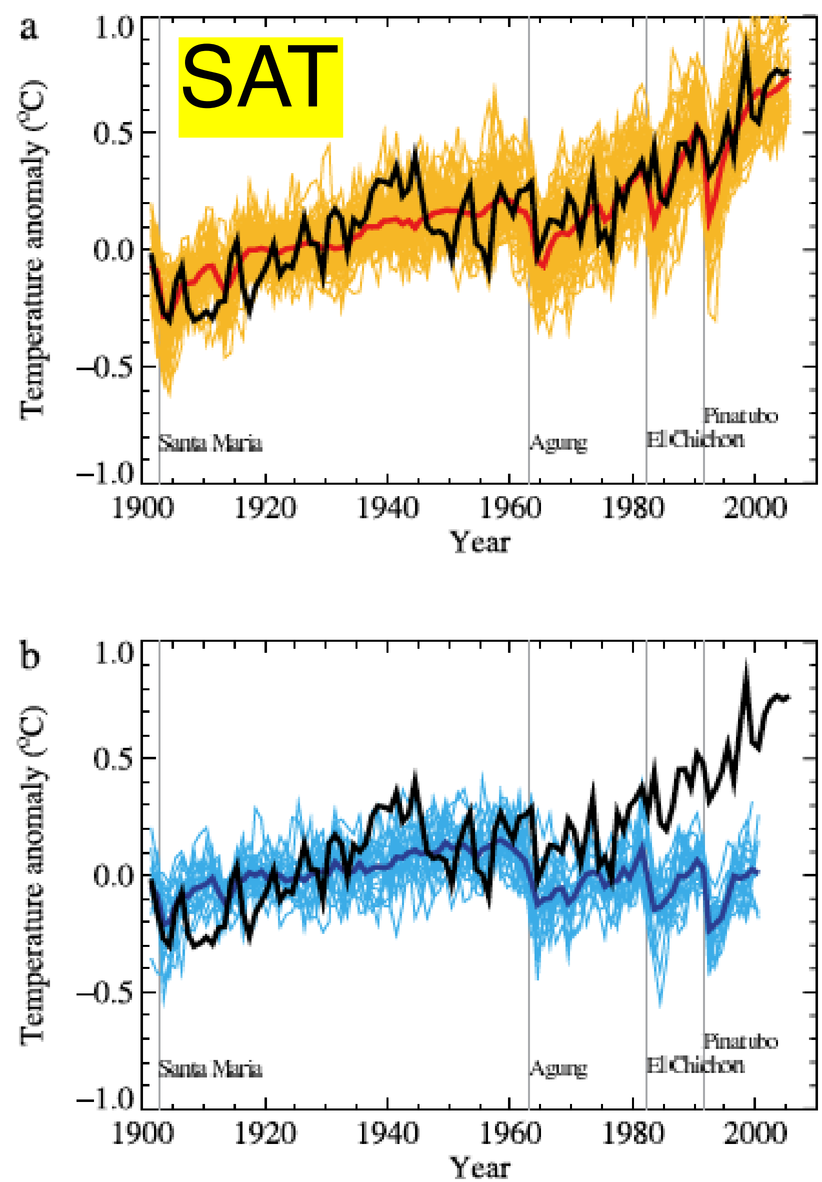
Model

Mt. Pinatubo 1991

"Winter warming"

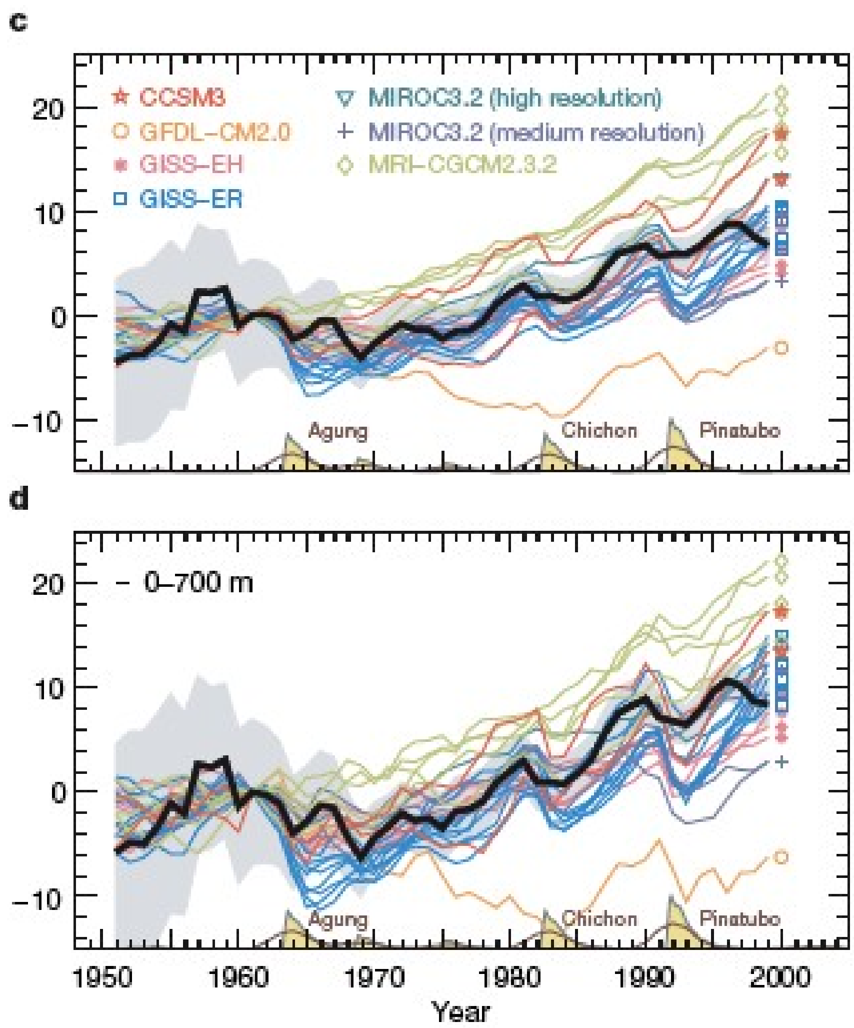
20th Century climate hindcasts





Matches to observed data imply consequences that can be looked for in the real world...

Ocean heat content changes



Domingues et al, 2008

But how can we test sensitivity of the processes to changes outside recent experience?

Paleo-climate!

Mid-Holocene response of rain patterns/ENSO to orbital forcing

8.2kyr event for N. Atl. ocean circulation

Last glacial period for cool climates

Eocene/Pliocene/last interglacial for warm climates

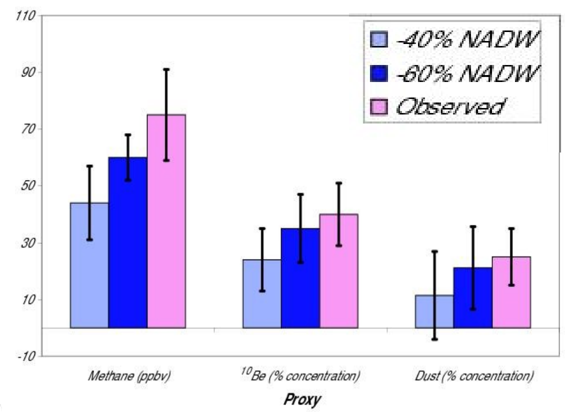
Comparisons are for proxy data though...

...but proxies are often the same Earth System components that are in the models already!

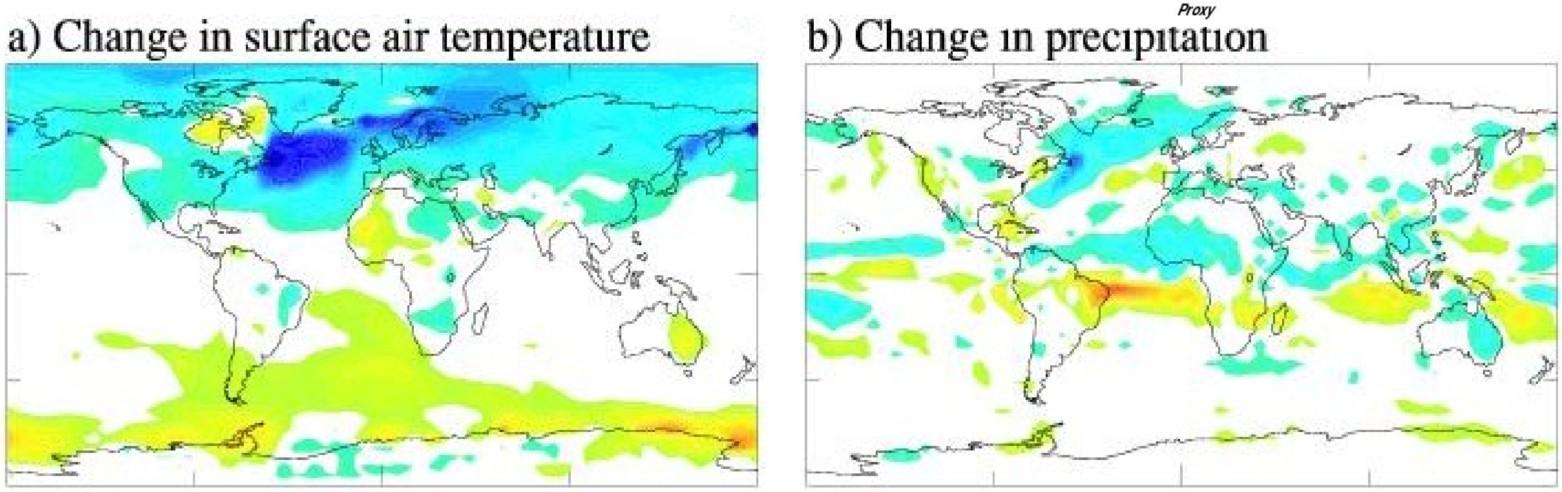
8.2kyr event and North Atlantic circulation

This event was coincident with the final draining of a large ice-dammed lake (Lake Agassiz) and was related to a slowdown in the N. Atlantic circulation. GISS modeling of this event, using the latest Earth System model components, supported this interpretation by matching multiple proxy records (methane, aerosols, isotopes), helping validate the coupled model.

Lake Agassiz Drainage



Matches to multiple ice-core proxies: CH_4, dust and ^{10}Be



Model results associated with 40% slowdown in NADW

LeGrande et al, 2006

Q. So why is an ice core like a MODIS retrieval?

A. Both tell us something indirect about climate processes and climate change.

Models are the bridge between observables and processes. This needs:

- more complete models
- more forward modelling
- more data synthesis
- bottom-up and top-down!