Decadal Climate Prediction:

Overview of progress and issues

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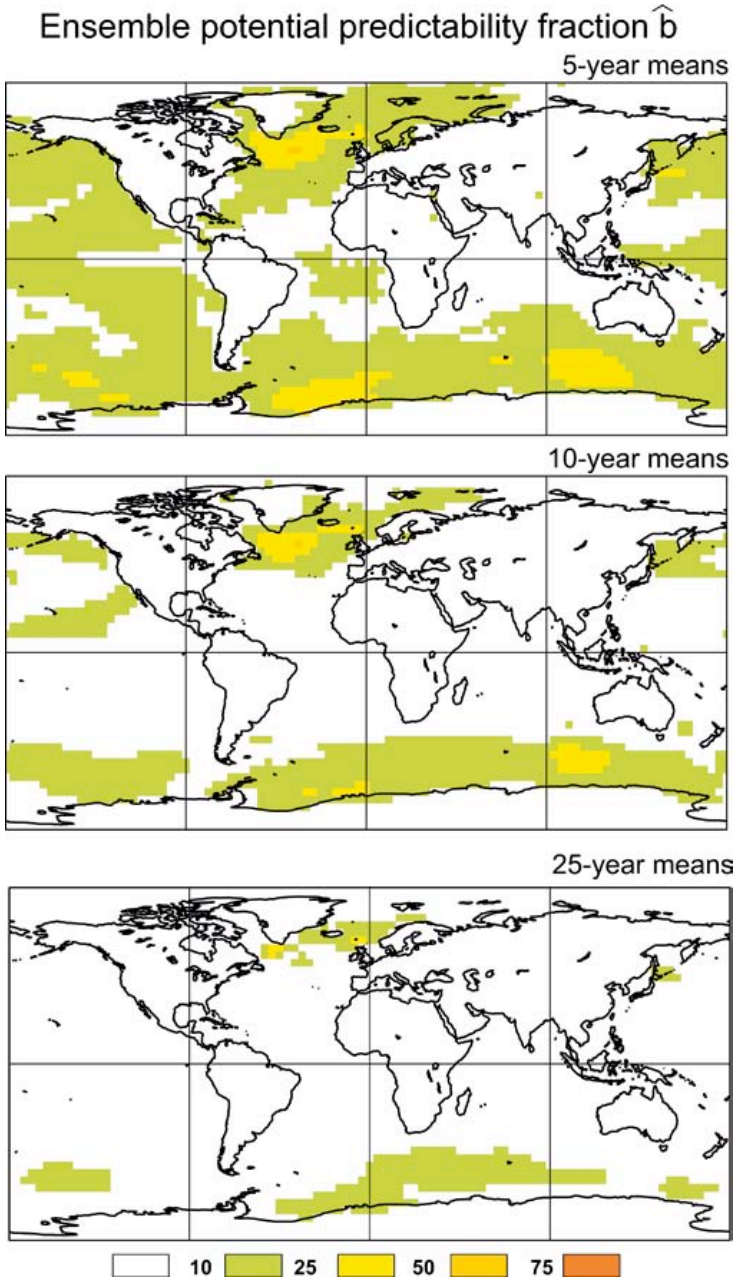
Contents

- Motivation for near-term climate prediction
- Survey of early attempts
- Some points for the AR5 experiments



Potential predictability of surface temperature, diagnosed from CMIP1 multi-model ensemble of control simulations (Boer, 2004)

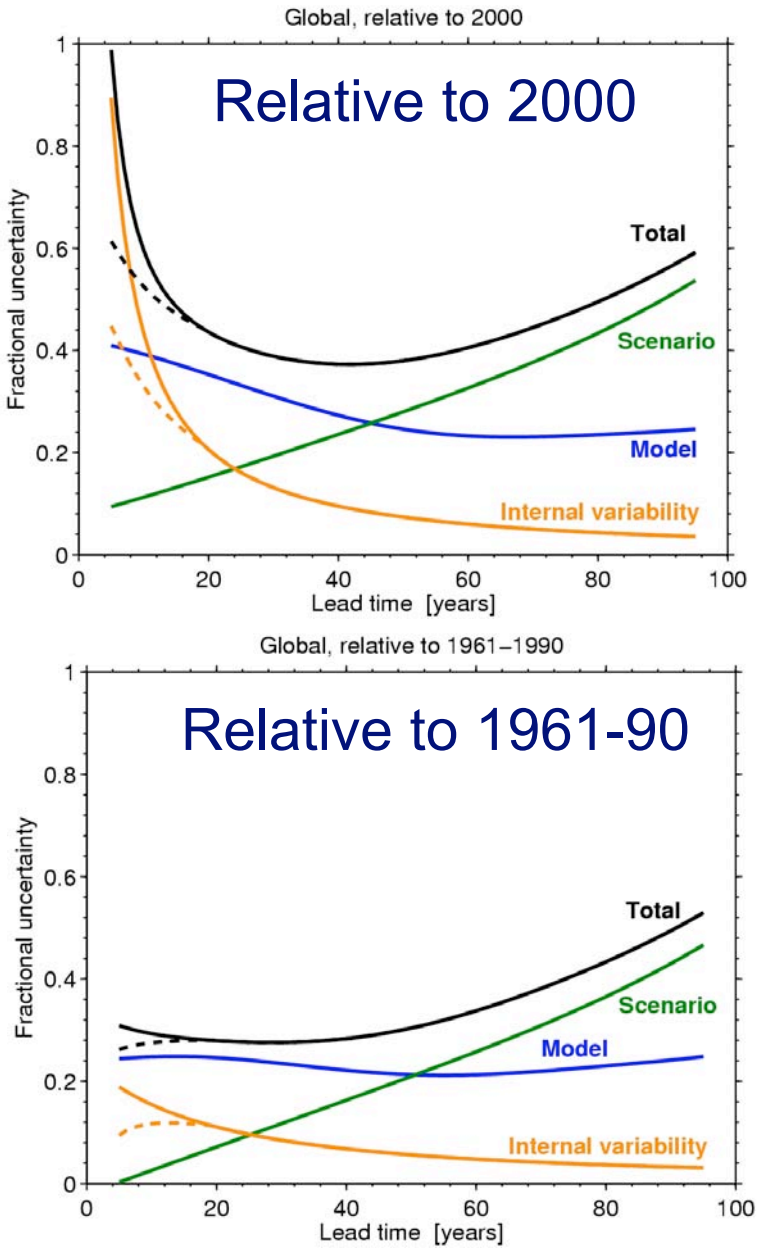
Potential predictability defined as variance of multiannual means as a fraction of total variance of annual mean values

Predictability topics (signal to noise, studies of modes of low frequency variability) covered in subsequent talks

Sources of uncertainty in projections of global mean decadal mean temperature, derived from IPCC AR4 multi-model ensemble

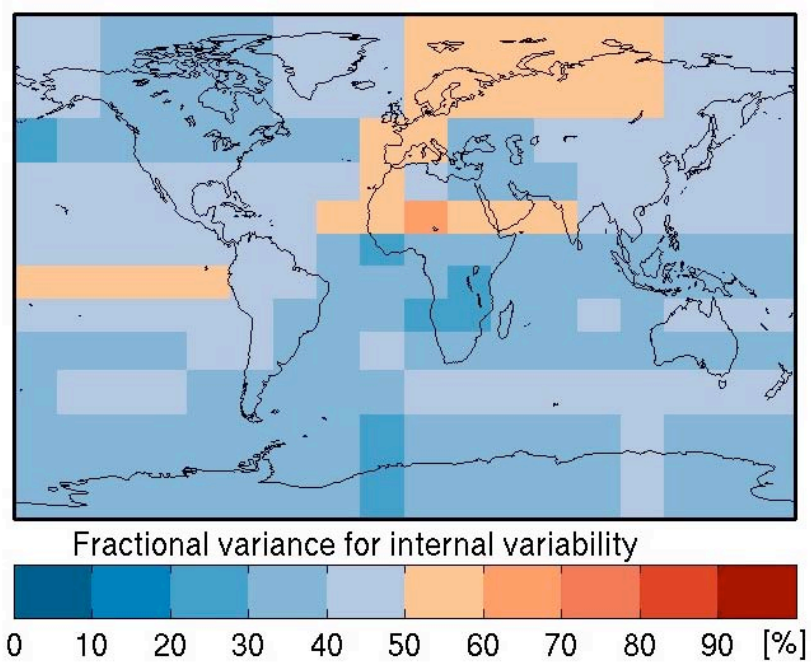
- Fractional uncertainty = total uncertainty divided by mean response averaged over models and scenarios.
- A minimum in fractional uncertainty indicates a relative maximum in robustness of projections
- Caveats: e.g. results depend on choice of reference period; multi-model ensemble does not sample carbon cycle feedbacks

Hawkins & Sutton, Univ. Reading, submitted

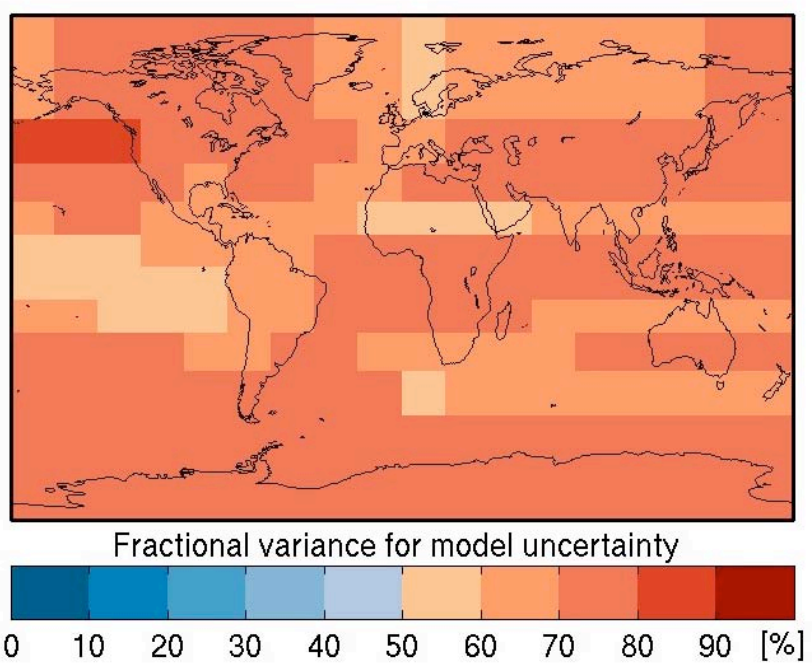


Sources of uncertainty in projections of *regional* decadal mean temperature wrt 1961-90

Fraction of total variance explained by internal variability for predictions of the first decade ahead



Fraction of total variance explained by model uncertainty for predictions of the second decade ahead



- For projections of the first decade ahead internal variability and model uncertainty account for a similar fraction of the total variance
- For projections of the second or third decade ahead, model uncertainty is the larger contribution

Hawkins & Sutton, submitted

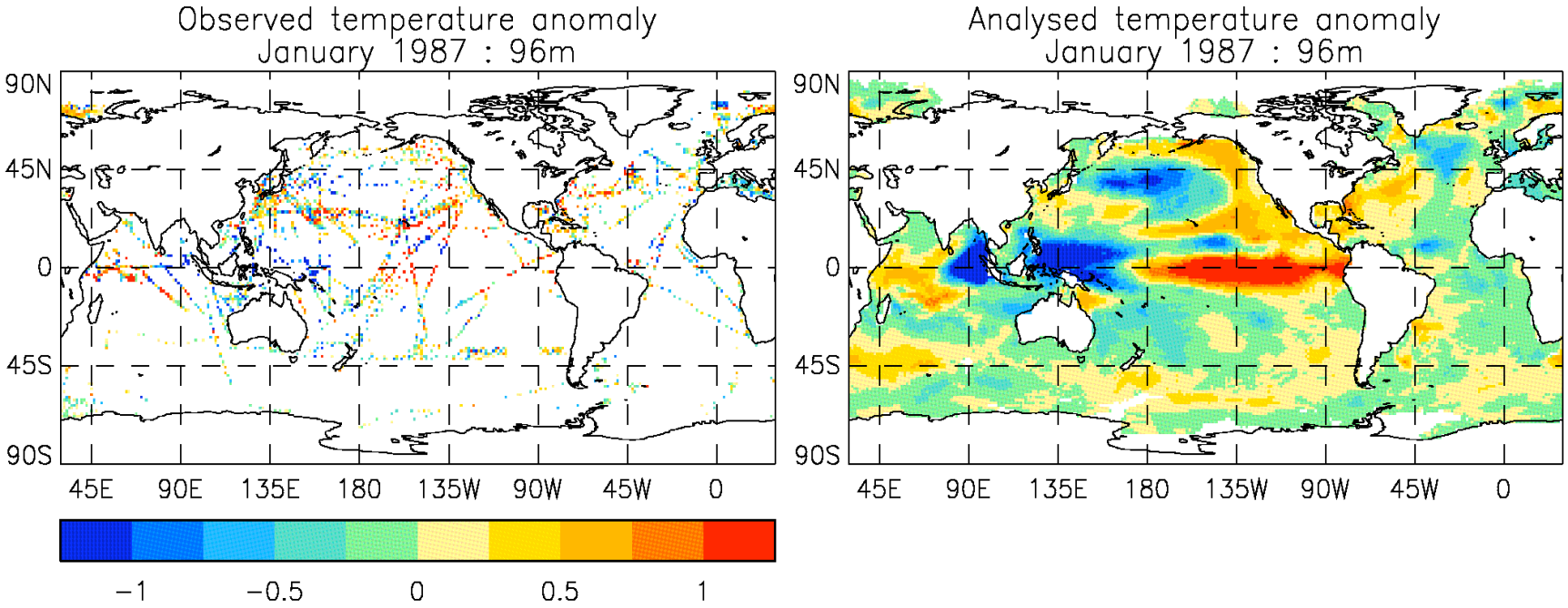
Decadal prediction system (DePreSys)

- HadCM3
- Include changes in greenhouse gases and sulphate aerosols (SRES B2 scenario)
- Repeat previous 11-year solar cycle in forecasts
- Decay volcanic aerosol from the start of a forecast
- Include initial condition information:
  - Atmospheric winds, temperature and surface pressure
  - Ocean temperature and salinity
  - **Assimilate as anomalies to avoid model drift**

Smith et al., 2007

Sub-surface ocean analysis

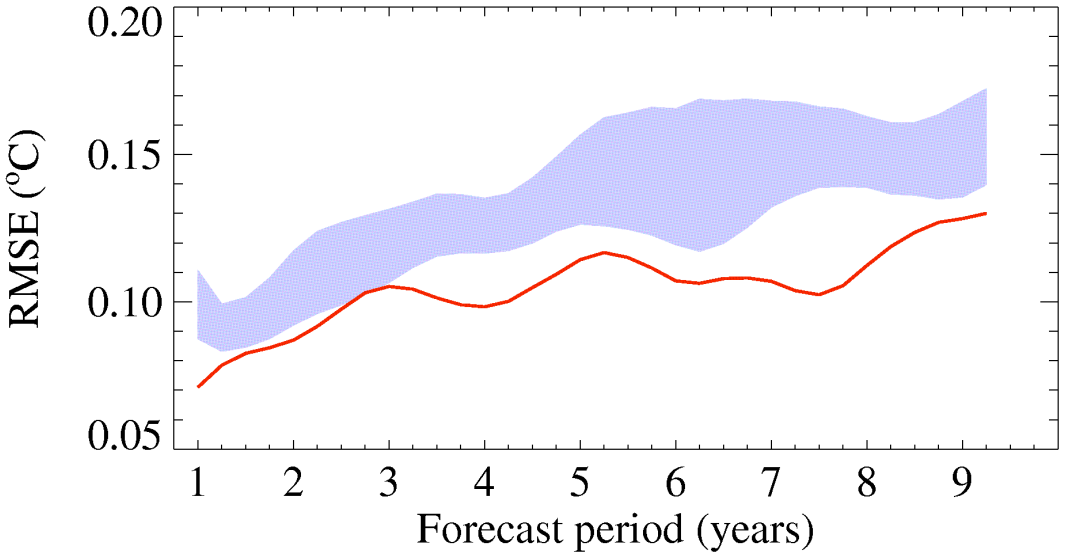
- Optimal interpolation using covariances computed directly from HadCM3 transient integration
- Analyses computed off-line, stored in ancillary files
- Relax model to analyses (6 hour timescale)



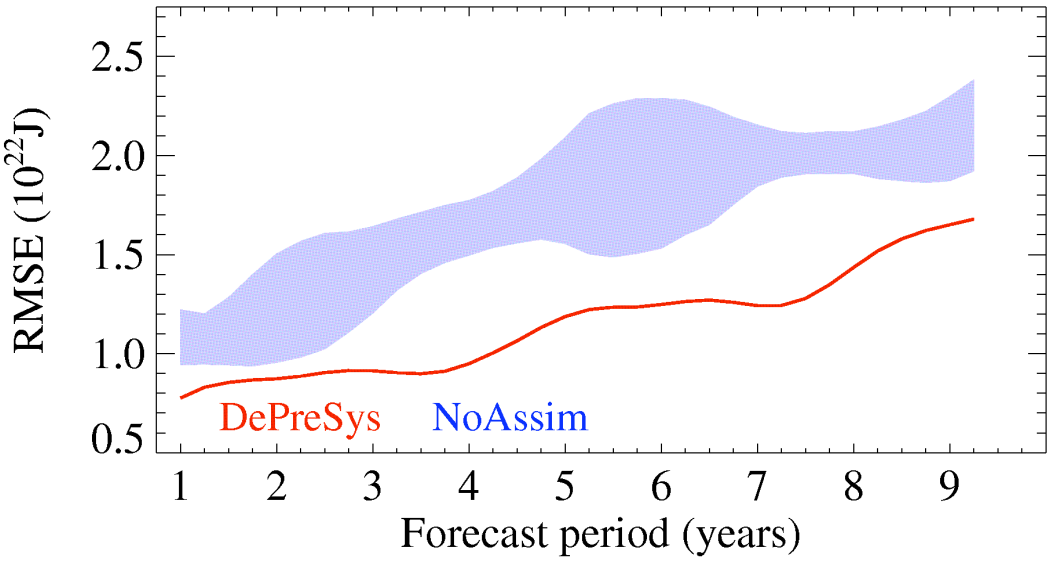
Hindcast experiments to assess skill

- 10 year hindcasts started from 1st March, June, September and December in each year from 1982 to 2001 (80 start dates)
- 4 ensemble members, starting from consecutive days
- Do we achieve additional skill by starting the model from observed initial conditions ?
- Test by making a set of hindcasts (NoAssim) parallel to DePreSys
- NoAssim includes the same external forcings as DePreSys but omits the assimilation of observed initial conditions.

Improved skill is found in hindcasts of global mean surface temperature, explained mainly by ENSO in first year, and by better predictions of upper ocean heat content at longer lead times

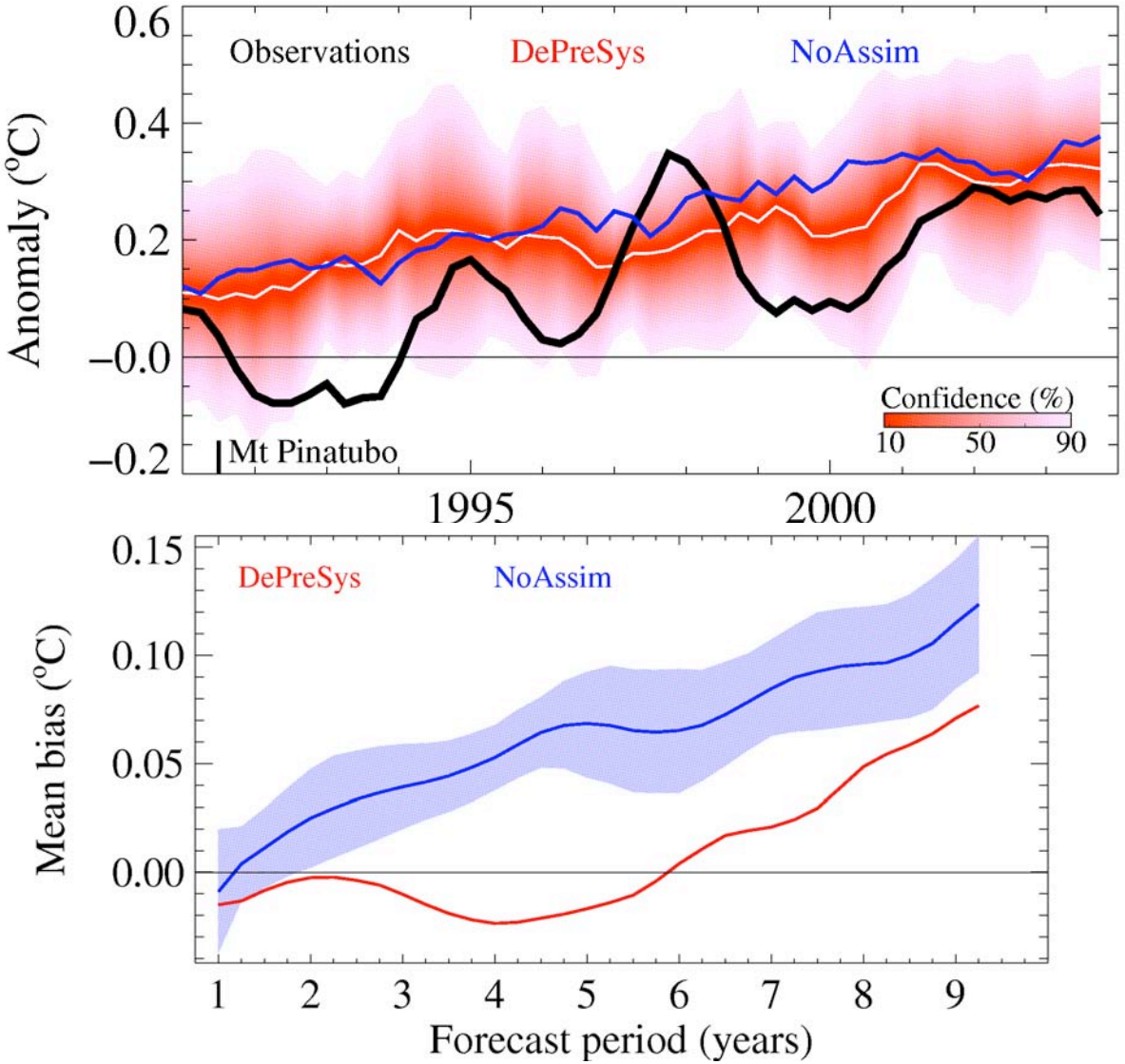


Global annual mean surface temperature (T_S)



Global annual mean ocean heat content in upper 113m (H)

Skill at longer lead times due to bias removal

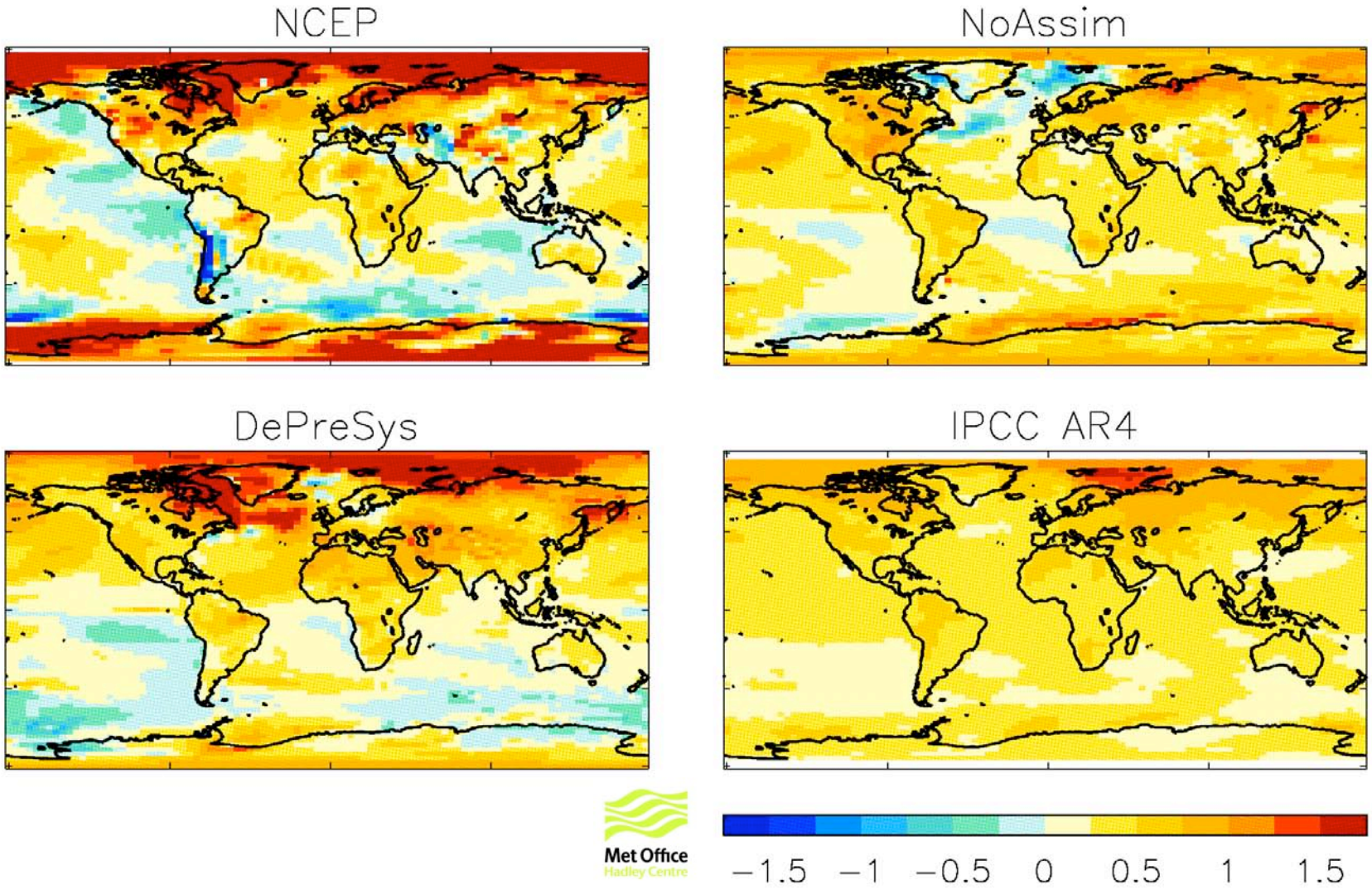


Time series of year 9 hindcast T_S

Mean bias of hindcast T_S

Assessment of forecast from June 2005

Temperature anomalies (wrt 1979-2001) for the period June 2005 to Feb 2008



Initialisation and decadal hindcasts using ECHAM5/MPI_OM coupled model

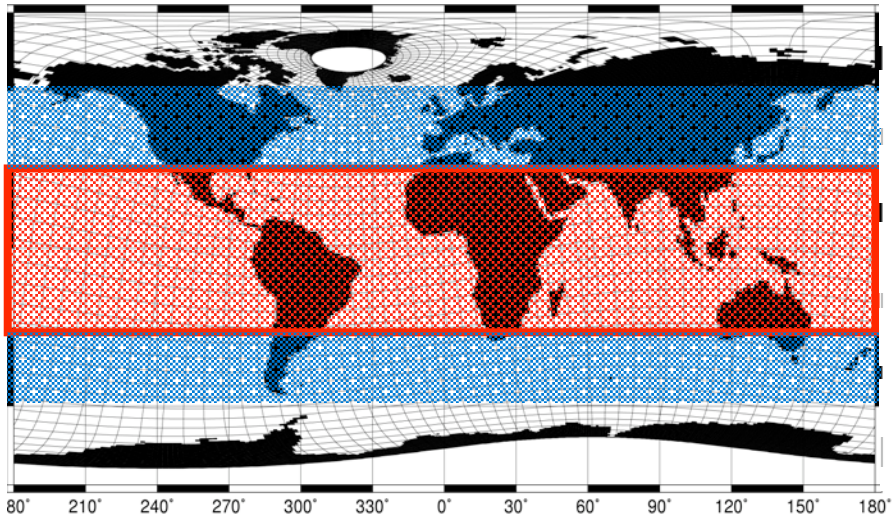
- 3x 20th century transient simulations (anthro, solar, volcanic forcing)
- 3 x 20th century simulations assimilating SST anomalies (same forcing)
- Decadal hindcasts started every 5 years from 1955-2005. 3 ensemble members; (anthro forcing, repeated solar cycle, no volcanoes)
- Keenlyside et al (2008).

IFM-GEOMAR

A simple decadal hindcast/forecast strategy

- Model: ECHAM5/MPIOM climate model (IPCC AR4 version)
- Initial conditions: Coupled model SST restored to observations
- Boundary conditions: 20th century/A1B radiative forcing

Nudging constant varies with latitude



0 days^{-1} (fully coupled)

Linear transition

0.25 days^{-1}

Linear transition

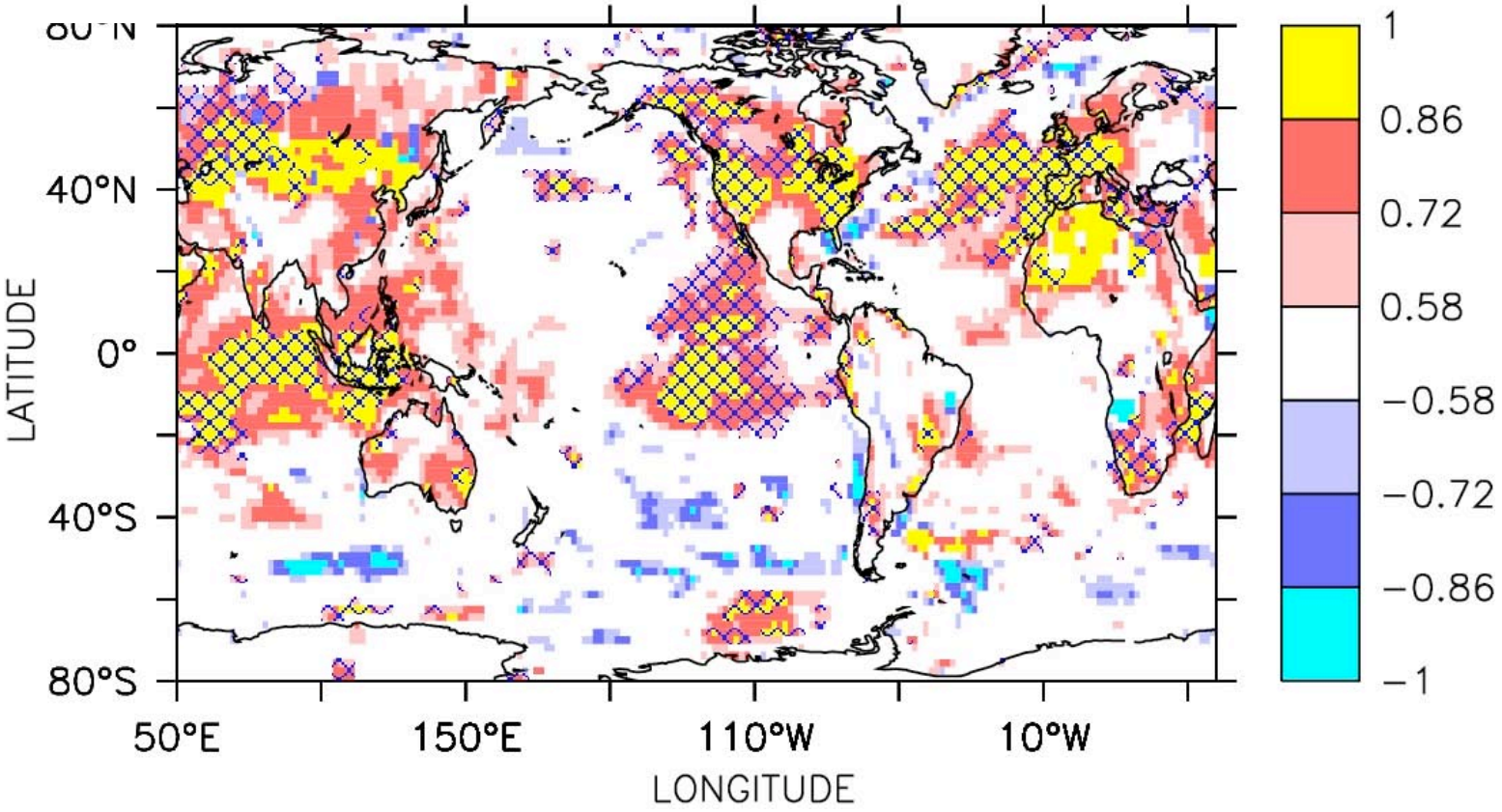
0 days^{-1} (fully coupled)

[Keenlyside et al. 2008]

IFM-GEOMAR

Decadal prediction skill

Correlation with observed surface temperature anomalies
years 1-10; 9 hindcasts, 1955-2005
Hashing indicates skill over radiative forced only simulations



[Keenlyside et al. 2008]

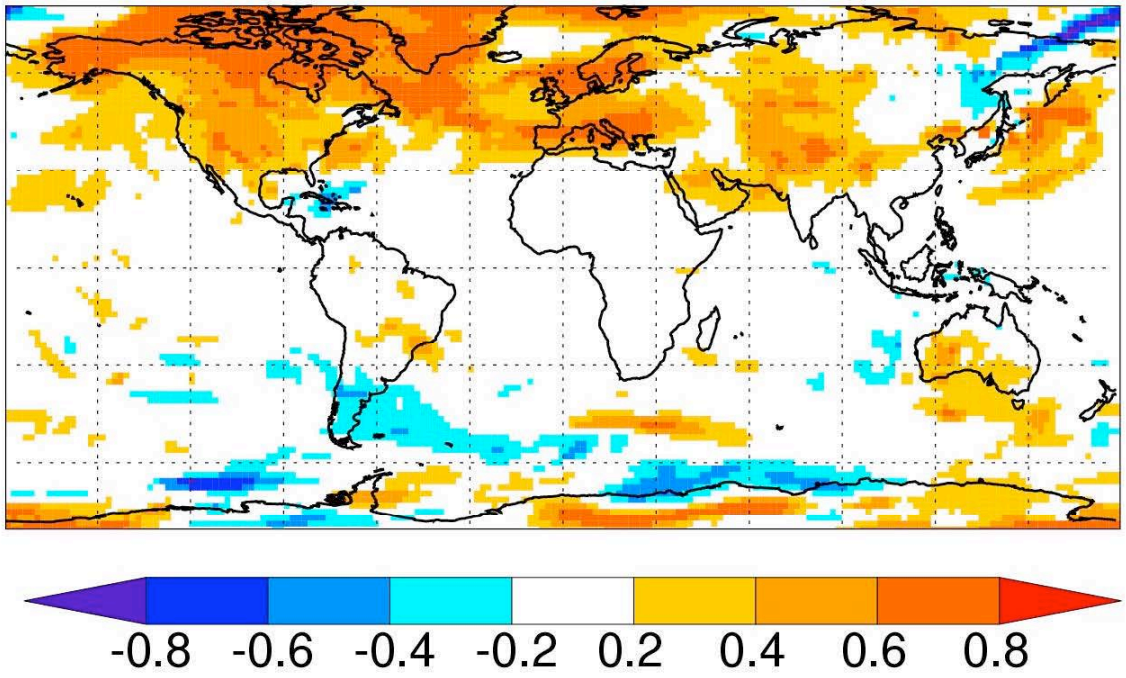
IFM-GEOMAR

More decadal hindcasts using ECHAM5/MPI-OM

- Pohlmann et al (2008) (submitted)
- 3x 20th century transient simulations (GHG, aerosol forcing)
- Simulation from 1952-2001 assimilating 3-D monthly T and S from GECCO analysis
- Decadal hindcasts started every year from 1952-2001, using anomaly initialisation. (same forcing as transient runs)

Result from Pohlmann et al (2008)

- Initialised hindcasts show improved skill in multiyear means of North Atlantic MOC and SST, and global mean SST
- 7-member ensemble hindcast from 2002 shows warmer northern hemisphere than uninitialised simulations

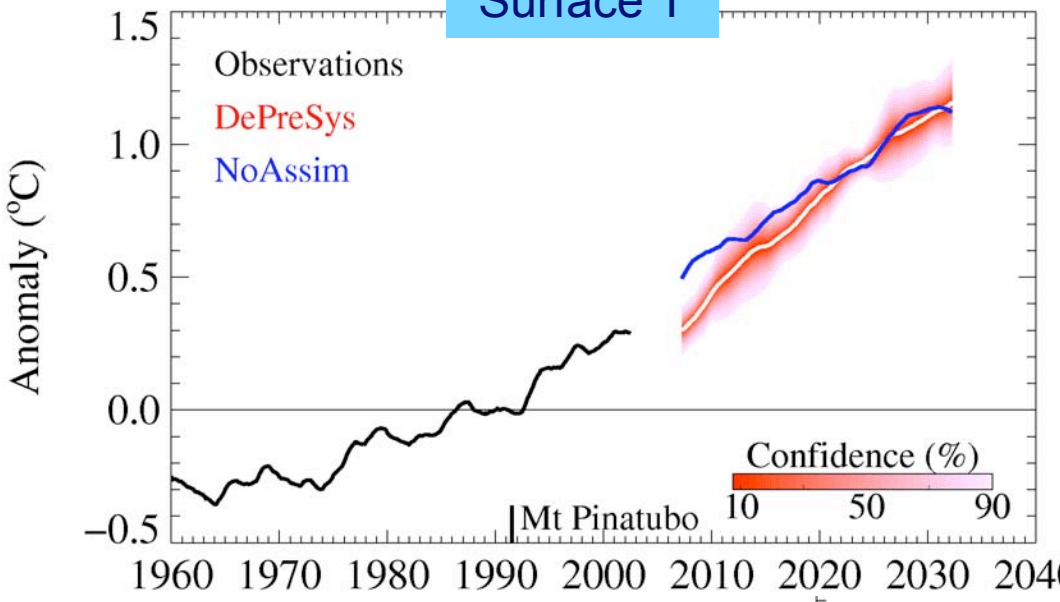


Effect of initialisation on surface temperature, 2002-2006

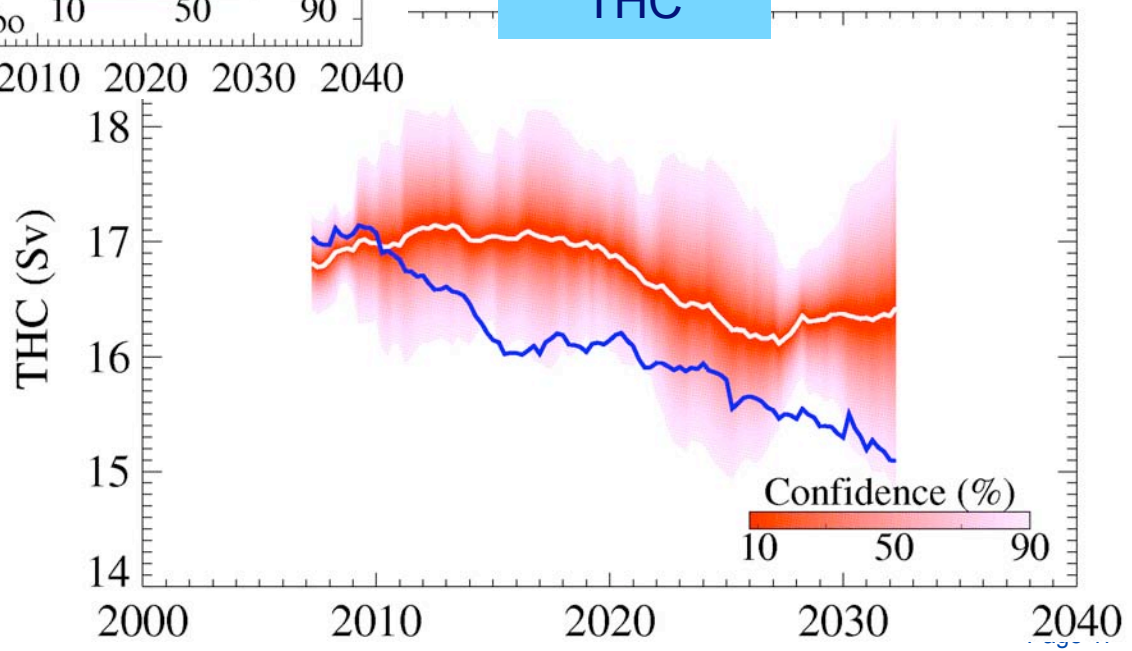
DePreSys 30 year forecasts from Mar 2007

Met Office Hadley Centre

Surface T



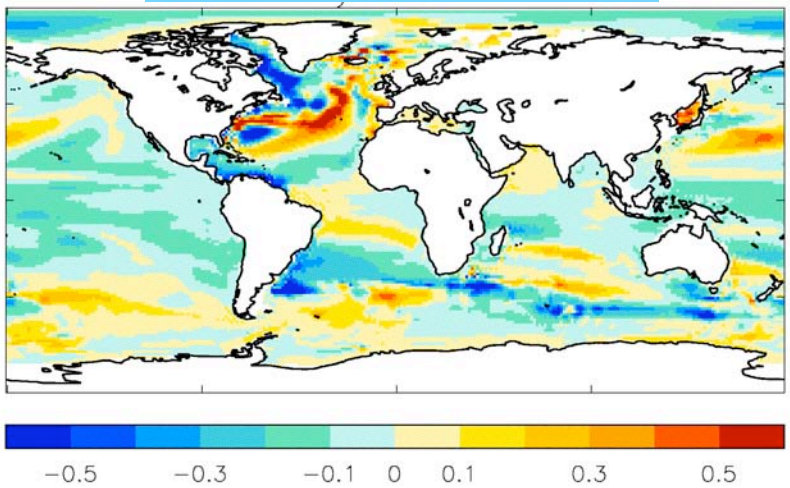
THC



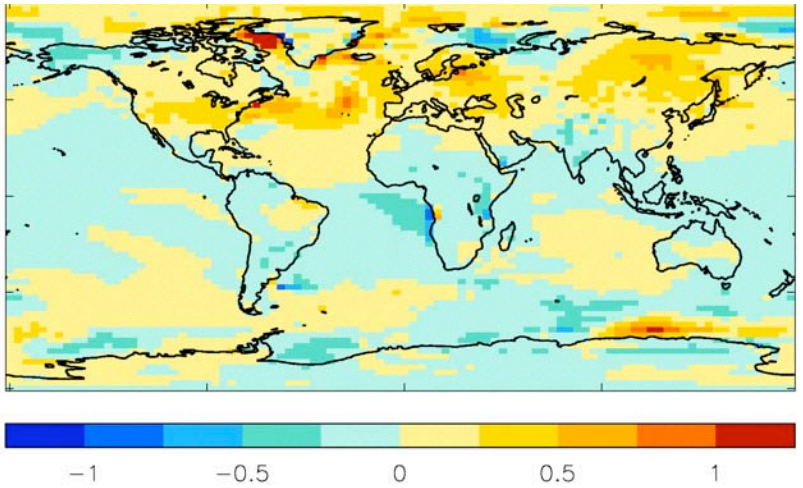
- 5-year means
- 10 members DePreSys
- 4 members NoAssim

30 year forecasts from Mar 2007: Last 10 years

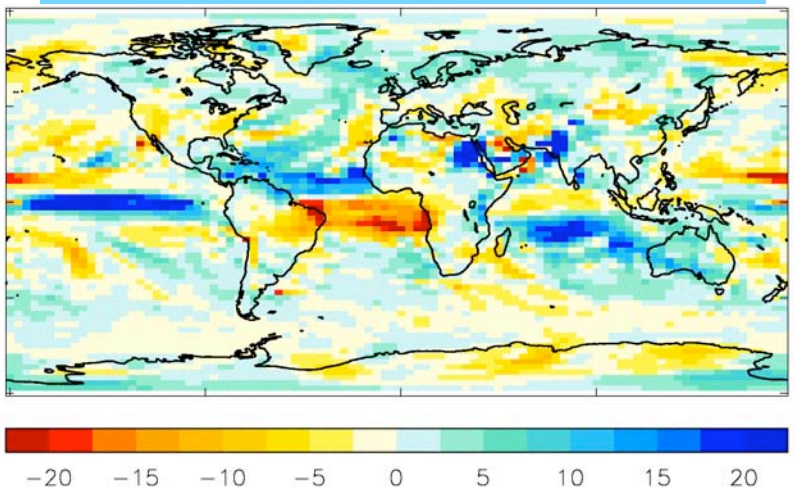
360m upper ocean T



Surface T



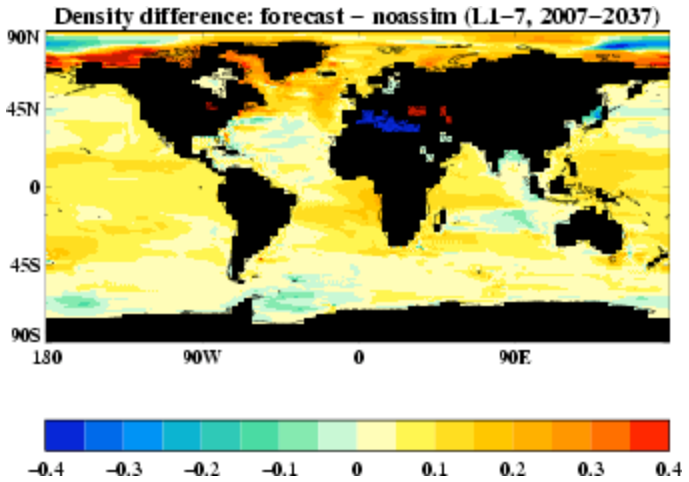
Precip (% of 1979-2001 mean)

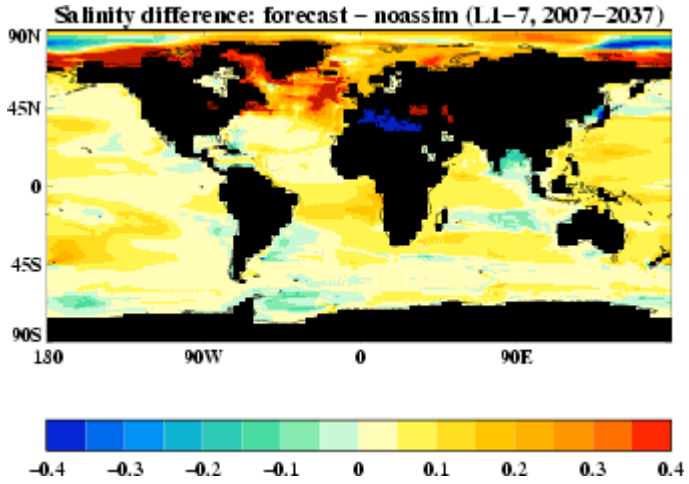


- Mar 2027 to Feb 2037
- DePreSys - NoAssim

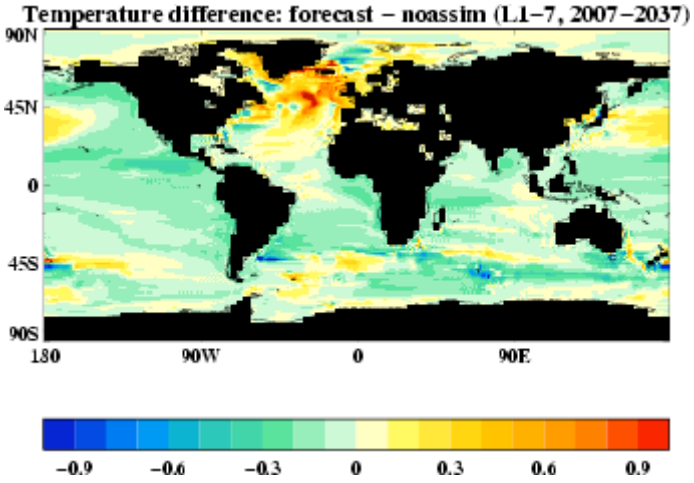
Salinity initialisation important in explaining maintenance of MOC in DePreSys 30 year forecast

Density difference (top 100 metres)





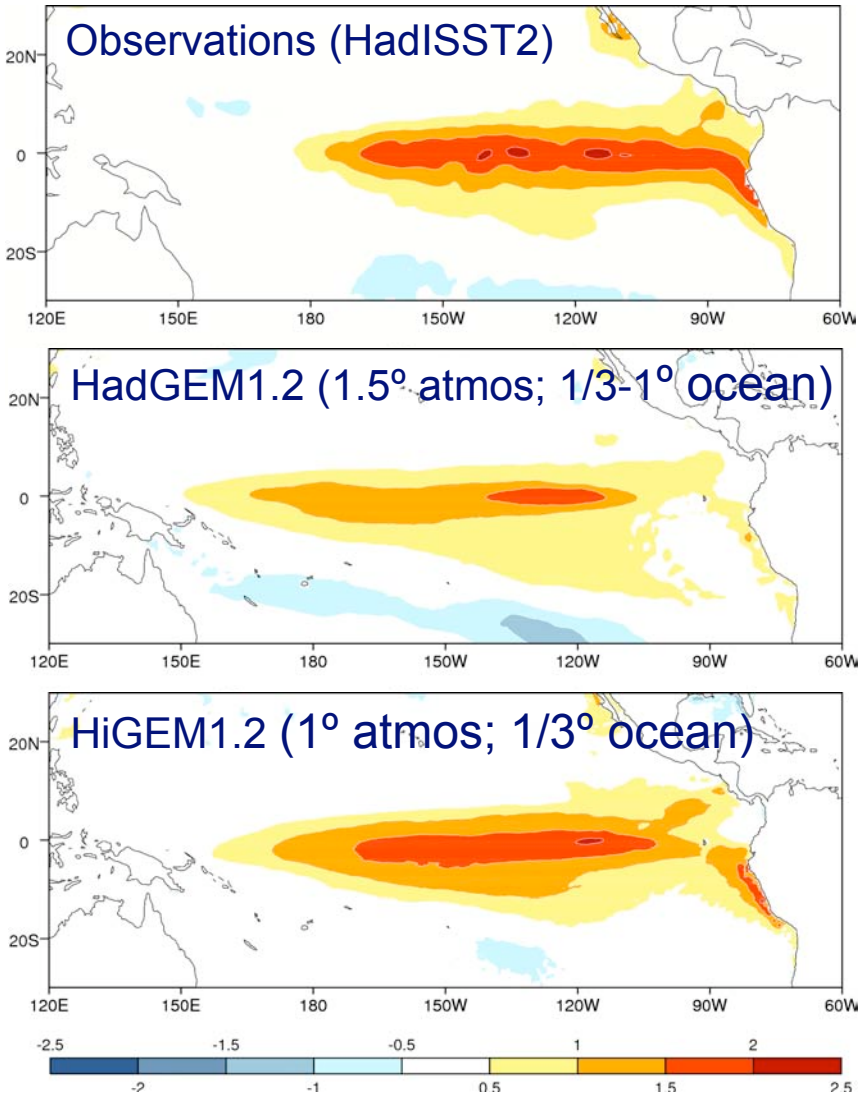
Salinity difference



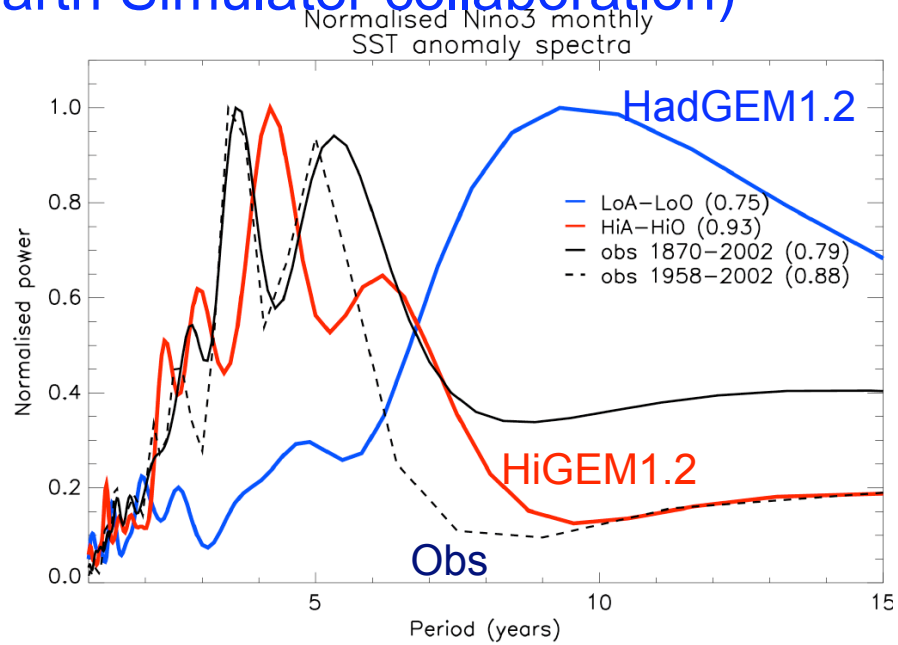
Temperature difference

Impact of better horizontal resolution ?

DJF Sea Surface Temperature Anomalies - El Nino Composites



(Univ Reading, Hadley Centre, CCSR, Earth Simulator collaboration)



Improved ENSO at higher resolution: Impact on decadal variability and predictability under investigation in Reading

Impact of better stratospheric representation ?

PMSL change in response to 4xCO2: HadGAM1 (standard 38 level version, lid at ~40km) coupled to slab ocean

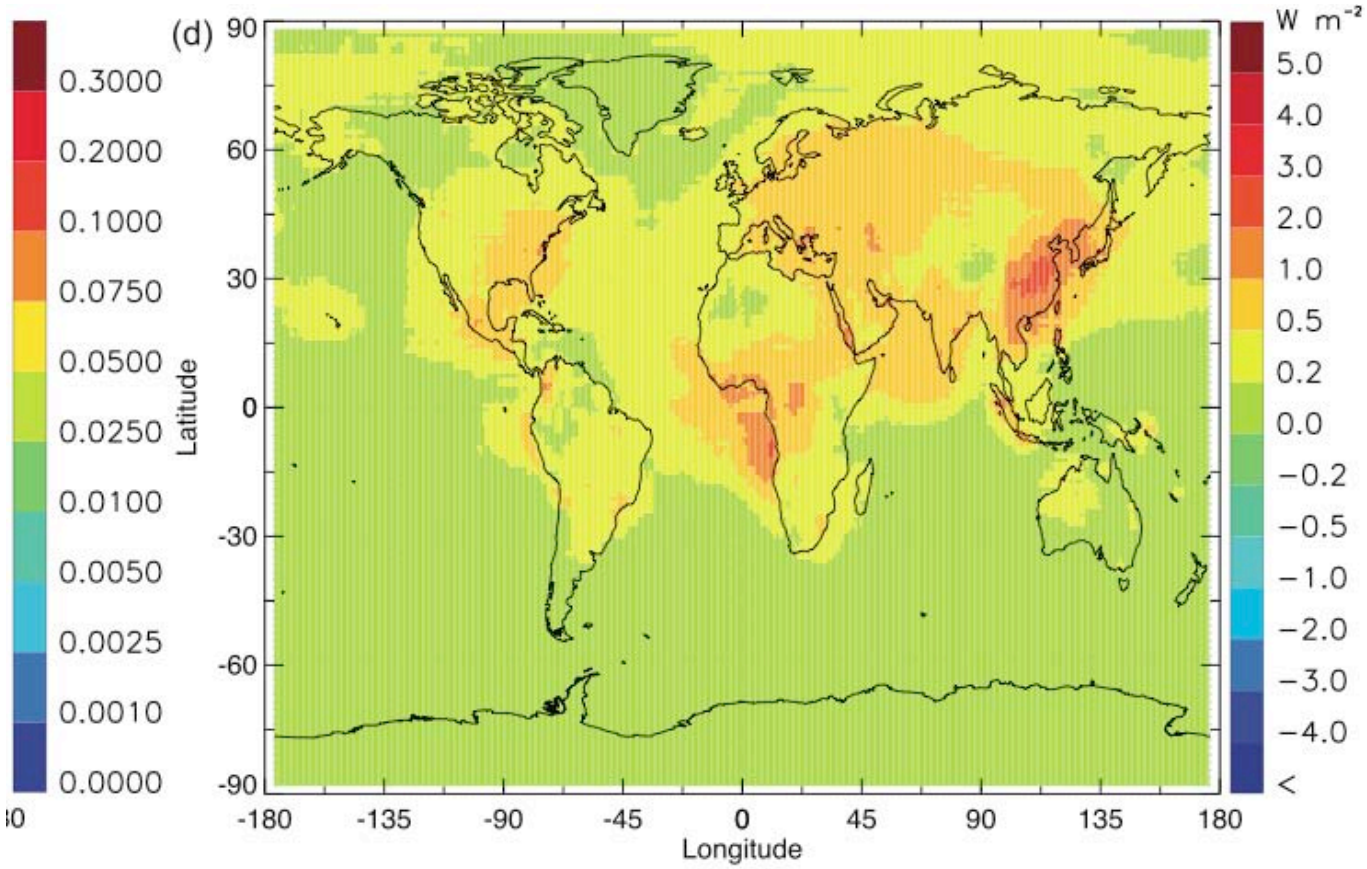
PMSL change in response to 4xCO2: HadGAM1 (60 level version, lid at ~85km) driven by same SST changes as above

Difference in response: Storm track shifts further south than in standard version

Huebener et al (2007) found a similar result in the EGMAM coupled model

Adam Scaife, Met Office

Uncertainty in forcing not so important globally, but could be regionally ?



e.g., Std dev of present-day short-wave forcing from anthropogenic aerosol, from nine Aerocom models (taken from IPCC AR4, Chapter 2)

Summary

- Early studies suggest potential for improved skill in initialised decadal predictions of global and large-scale regional multiyear mean surface temperature, and upper ocean heat content
- Parallel simulations without initialisation, and large hindcast sets, are needed to demonstrate skill robustly
- Early indications of effects of initialisation out to 2-3 decades ahead
- Potential impacts of model refinements (e.g. higher horizontal resolution, better stratospheric representation), regional forcing uncertainties, sampling of model and initialisation uncertainties,…, are all of interest for AR5.

Initialisation issues for AR5 experiments

- If initialise anomalies to avoid drift, need a model climatology form a long 20th century integration
- Initialise what ?
- SST, 3-D ocean T and S, sea-ice, soil moisture, snow cover, atmosphere variables ?
- Several analyses of ocean T and S available
- Simple initialisation (e.g. modify ocean start dumps or a simple relaxation scheme) OK for centres who don't have access to a coupled initialisation method ?
- Forecasts may be influenced by initialisation technique, as well as by differences between models and initial data.