The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

1956-6

Targeted Training Activity: Seasonal Predictability in Tropical Regions to be followed by Workshop on Multi-scale Predictions of the Asian and African Summer Monsoon

4 - 15 August 2008

Obstacles to Seamless Prediction

Sarachik Edward Stuart

Joint Institute For the Study of the Atmosphere and Ocean, JISAO
University of Washington
3737 Brooklyn Ave. NE, Box 355672
Seattle WA 98195-5672
U.S.A.

OBSTACLES TO SEAMLESS PREDICTION

E.S. Sarachik, University of Washington

1. **What is Seamless Prediction?**
2. **Weather Prediction**
3. **Seasonal-to-Interannual Prediction**
4. **Decadal Prediction**
5. **Prediction of the Response to the Addition of Radiatively Active Constituents (Greenhouse Warming)**
6. **The State of Coupled GCMS**
7. **What Needs to be Done?**

1. What is Seamless Prediction?

Seamless prediction is based on the idea that physical processes span the time scales and predicting shorter term variability better helps predict longer term variability better.

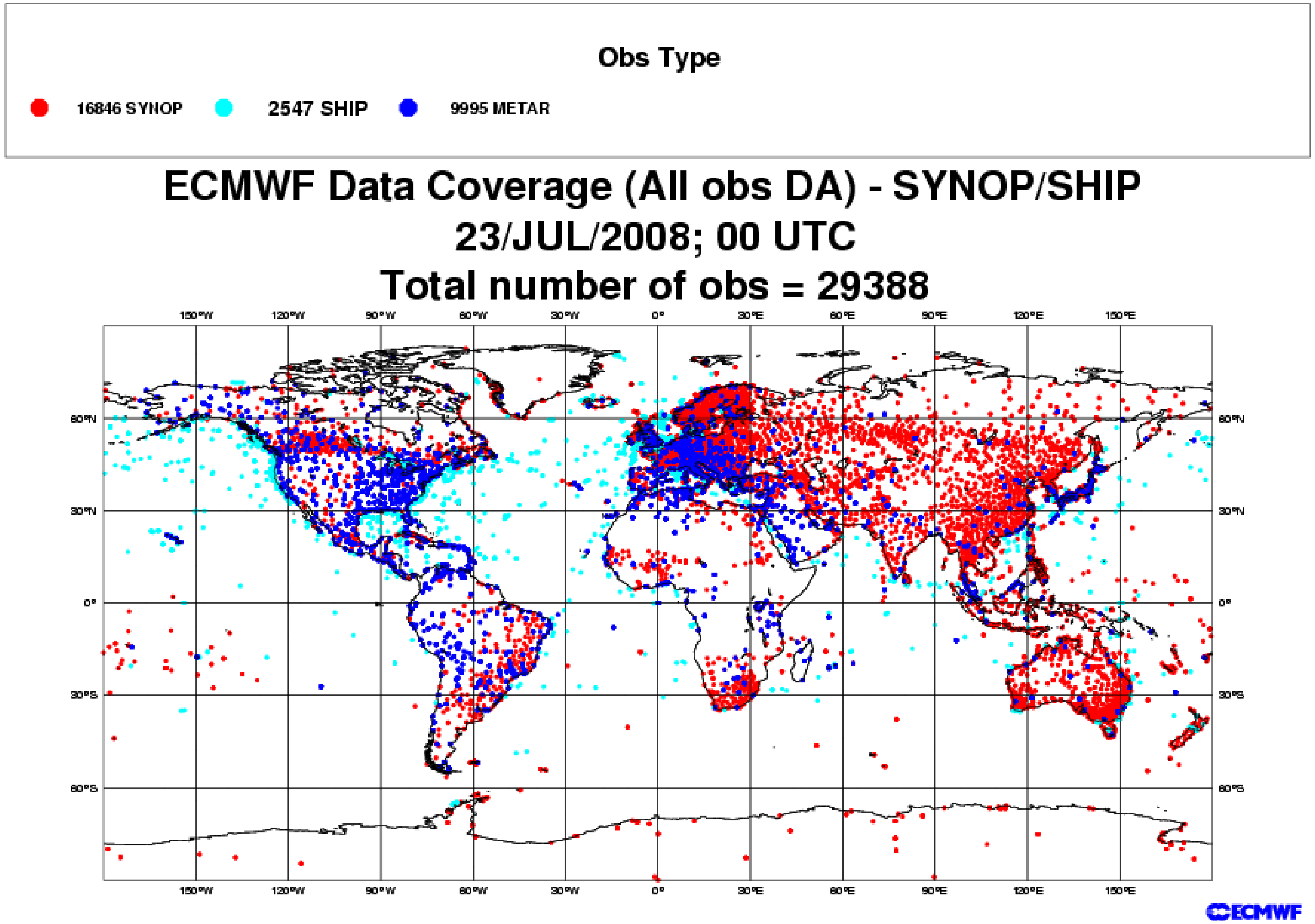
e.g. predicting MJO on weekly times scales would be would be useful for ENSO seasonal-to-interannual prediction.

A corollary to this is that prediction across the time scales should be made with the same model components.

2. Weather Prediction

1. Observations of the atmosphere, both direct and remotely sensed, are collected within a few hours of the initial time (i.e. within the initial time *window*). In general, the weather services of the world send their data to the Global Telecommunication System (GTS) which then makes the global collection of data available to all weather services.

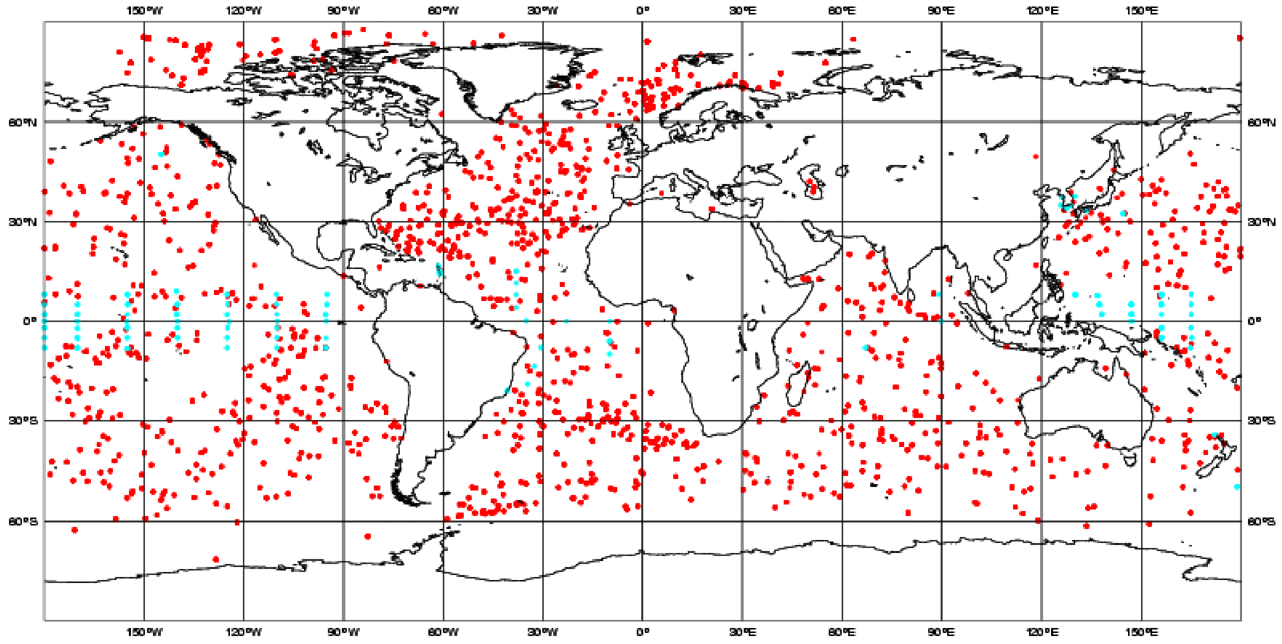
   - Upper Air Balloons (T, p, q, winds)
   - Satellite Radiances (Temperature, constituents)
   - Cloud Winds, Pilot Balloons
   - Surface Obs. (land, ship, buoy)


Obs Type
16846 SYNOP
2547 SHIP
9995 METAR
ECMWF Data Coverage (All obs DA) - SYNOP/SHIP
23/JUL/2008; 00 UTC
Total number of obs = 29388
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
60°N
30°N
0°
30°S
60°S
ECMWF

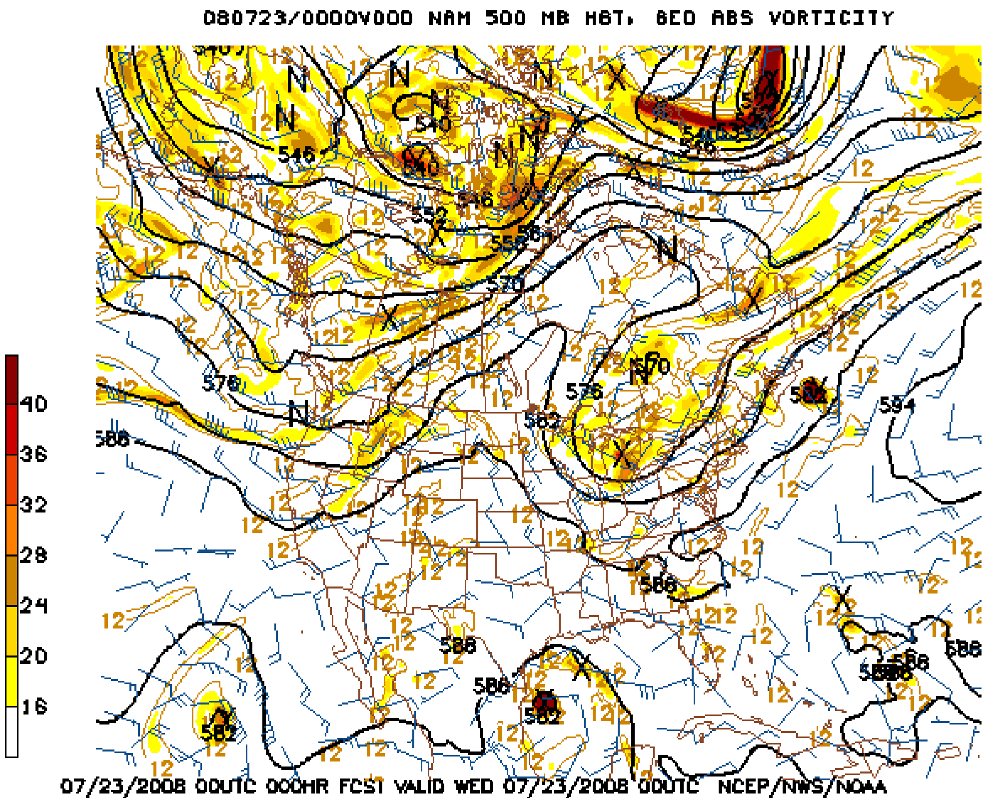
Obs Type

8515 DRIFTER 278 MOORED

ECMWF Data Coverage (All obs DA) - BUOY
23/JUL/2008; 00 UTC
Total number of obs = 8791



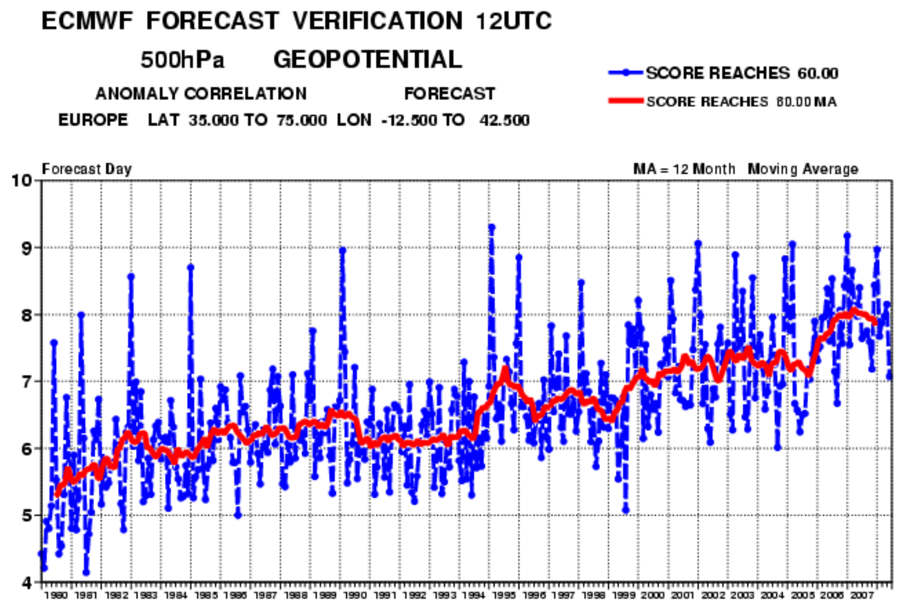
2. The observations are assimilated into a numerical model of the atmosphere by a data assimilation procedure. This ***model-based analysis*** of the atmosphere is performed by combining the observations with the output of the forecast system for the initial time.
    - Optimum estimate of the state of the atmosphere



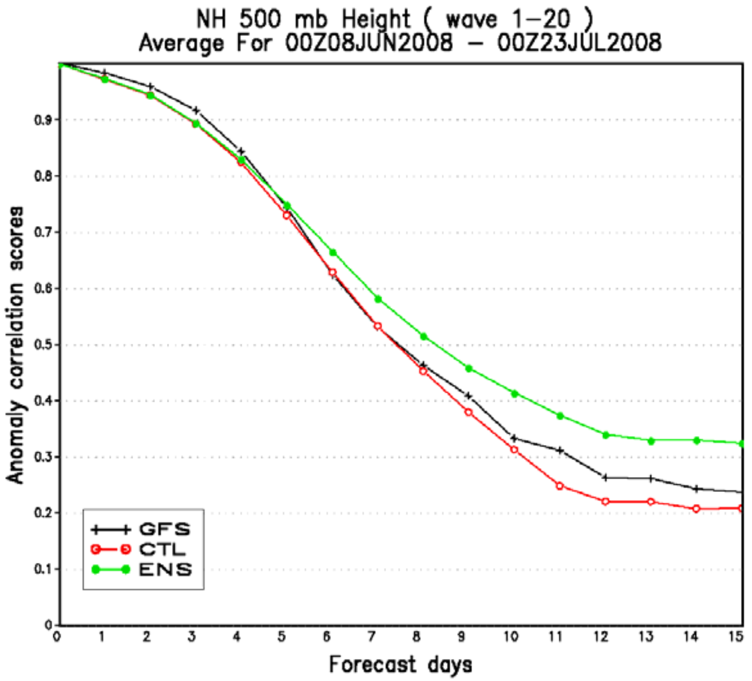
3. The initial state for the forecasts is produced, essentially the model based analysis at the initial time plus some subsidiary adjustments (removing gravity waves, adjusting the envelope of mountains, adjusting for shocks, etc.).

4. The model is run from the initial state out to n days thereby providing forecasts for all times up to and including n days.

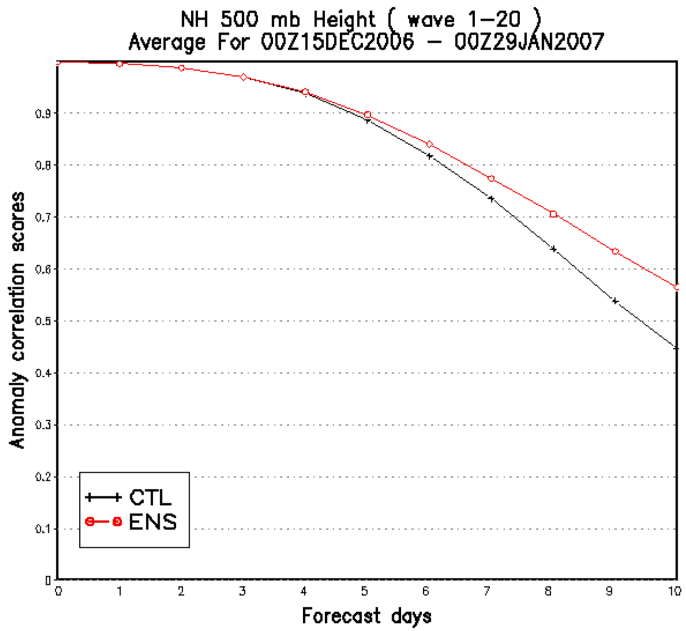
5. As each real forecast time is reached, the forecast is compared to the analysis for that time in order to score the forecast.



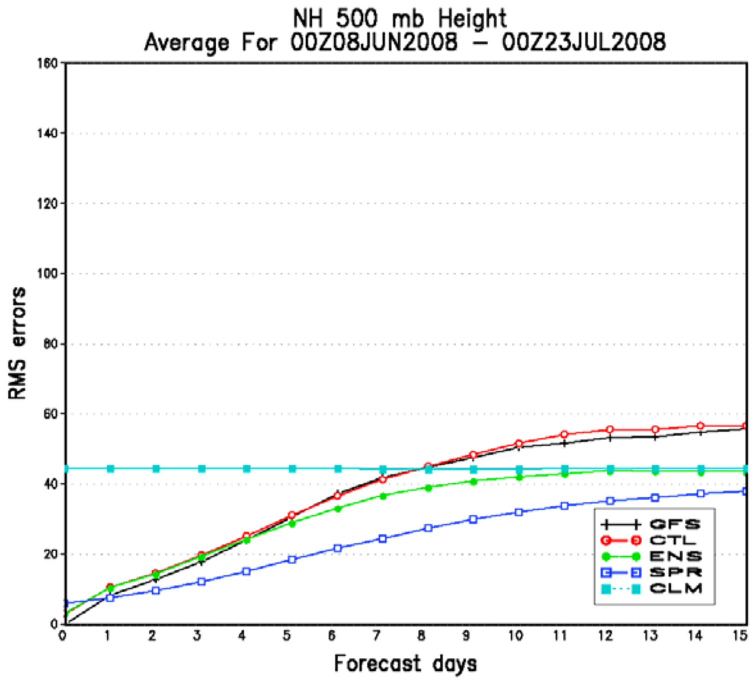
6. The forecast cycle is continually repeated and a series of forecasts is built up and verified by the series of analyses. The long series of forecasts is used to determine the overall skill, to analyze the dependence of skill on season and synoptic conditions, and to examine the forecasts for persistent biases in specific regions.



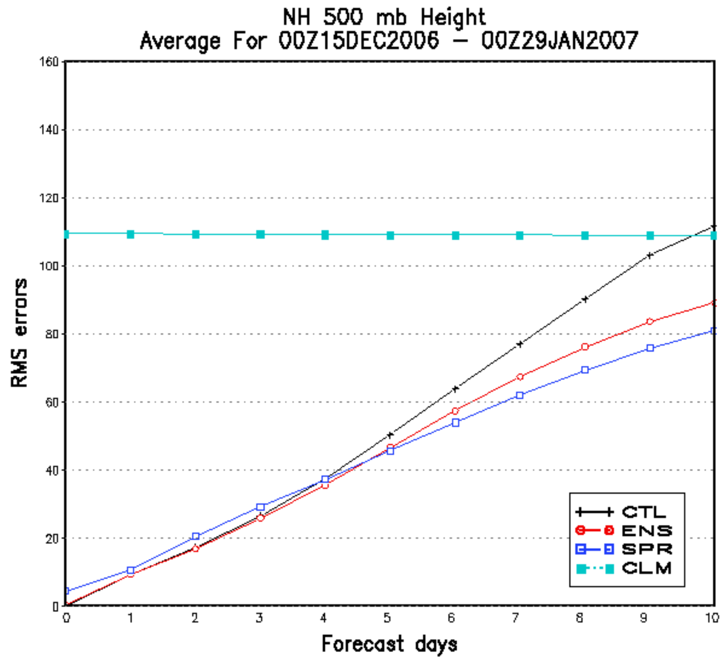
NCEP



ECMWF



NCEP

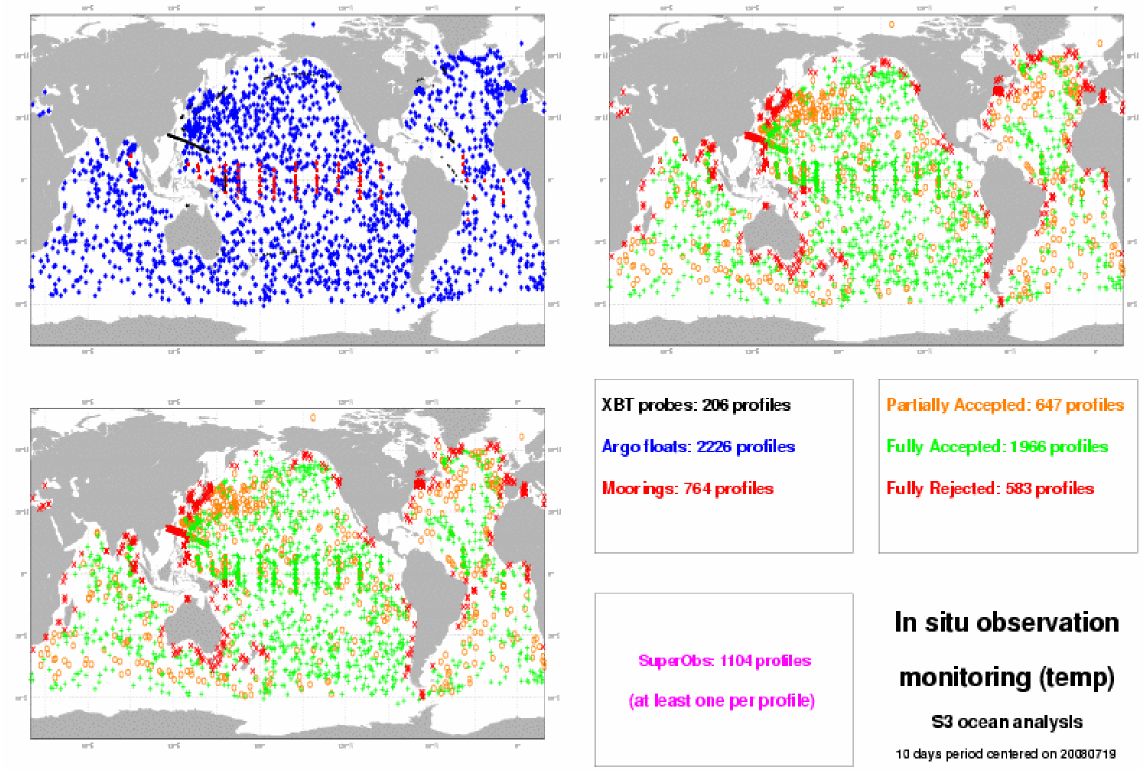


ECMWF

7. The initial conditions are slightly perturbed (consistent with all observations) and an ensemble of forecasts are made leading to a probability distribution function for the future. The ensembles of many models are combined (MMEs).

3. Seasonal-to-Interannual Prediction

1. Data is gathered in the atmosphere and ocean and at the land and ice surface and assimilated into a coupled climate model.

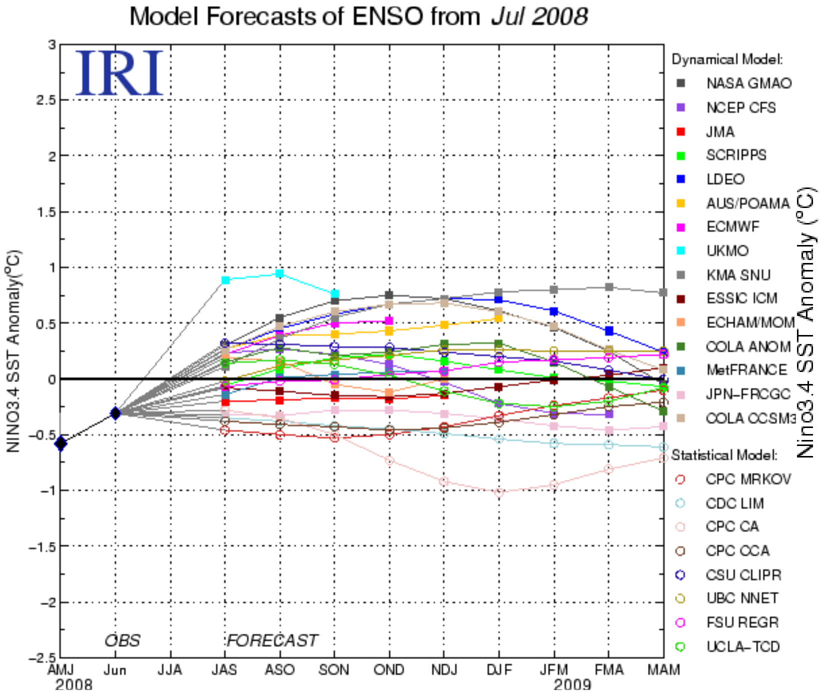


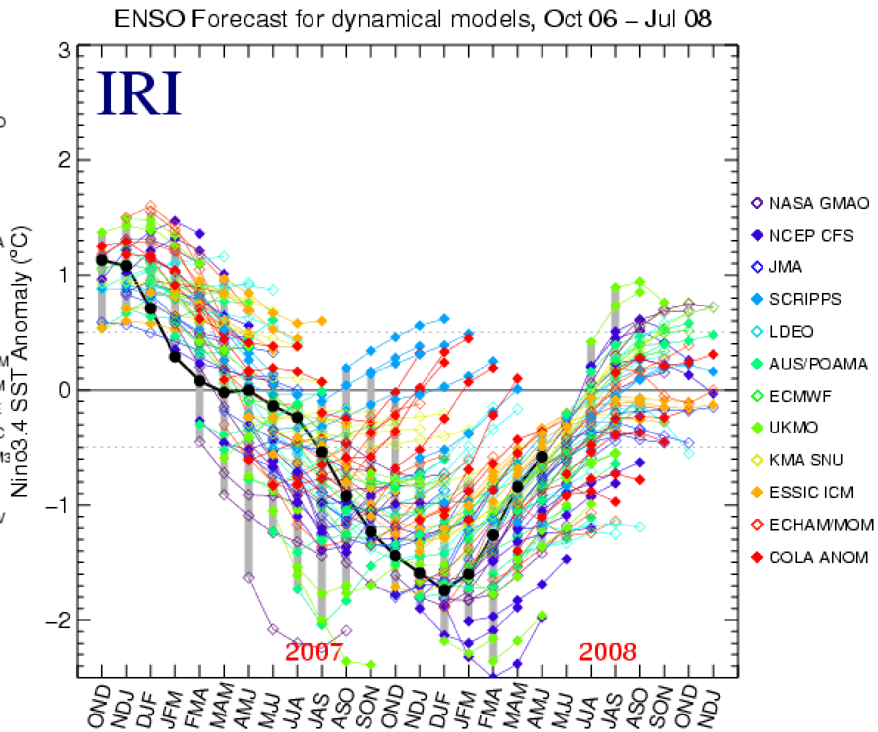
July 19, 2008 ECMWF

2. The data is combined with the forecast for the initial time (the so-called “first guess”) and an analysis of the whole climate system is made.

3. This analysis, plus whatever practical adjustments need to be made, form the initial state of the forecasts. A number of possible perturbed initial conditions are produced for the construction of forecast ensembles.

4. The coupled model is run into the future for each of these initial conditions.





5. **At each forecast time, the forecast is compared to the analysis at that time and statistics of skill are gathered.**

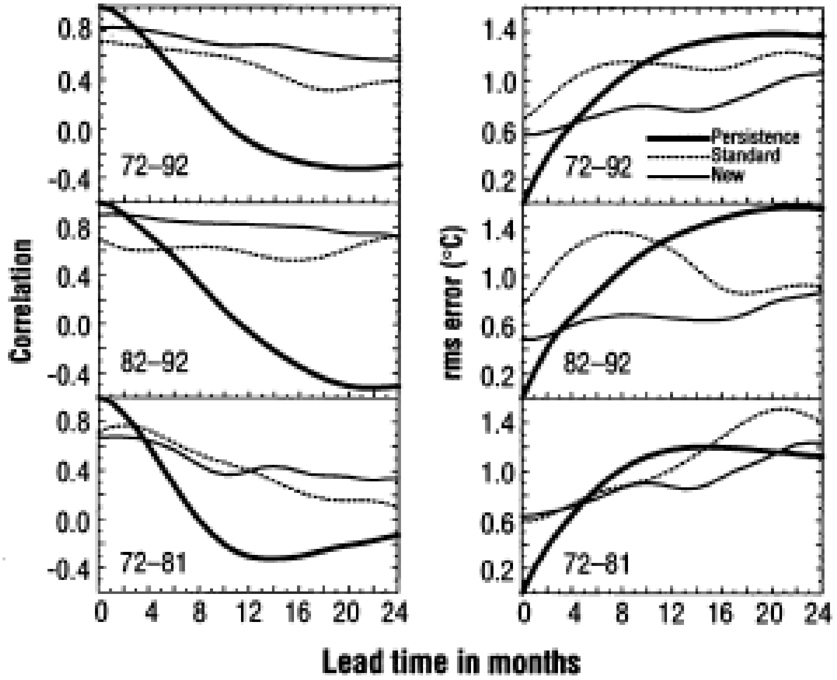
6. **The initial conditions in the atmosphere and ocean are perturbed and an ensemble of forecasts is obtained leading to a probability distribution function of future outcomes. Ensembles from many models are combined.**

7. The cycle is continually repeated.

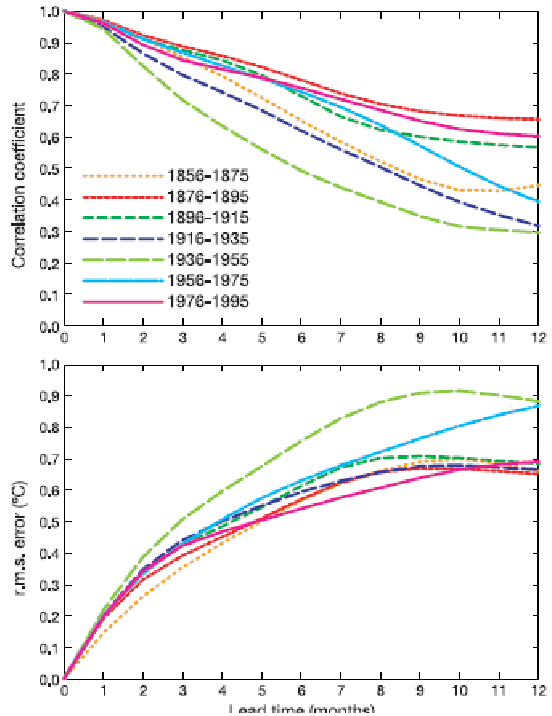
Because the climate evolves so slowly that it would be impractical to determine skill in real time, an additional step is needed:

8. A series of retrospective forecasts is performed using the longest possible series of past analyses (or reanalyses) used both for initialization and for scoring (a retrospective forecast is one performed and scored on past data). Using this long series of retrospective forecasts, the overall skill of the forecast system is determined, the regional and seasonal stratification of skill can be assessed, and any systematic biases can be determined. Using the knowledge of biases obtained from the retrospective forecasts, forecasts can be corrected (so called post-processing).

The physical basis of S-to-I prediction is that the memory of the initial conditions is encoded in the dynamics of thermocline variability.

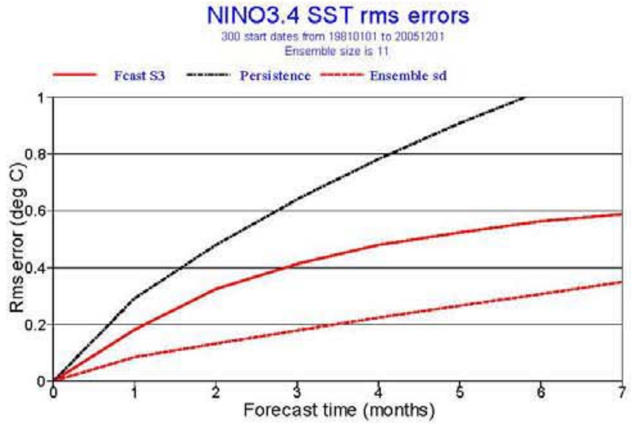


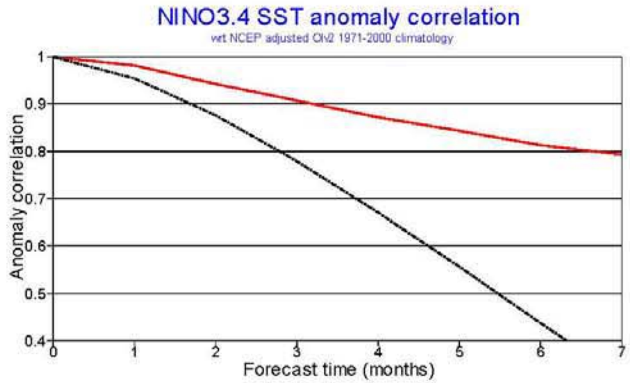
Chen et al 1995



Chen et al, 2004

ECMWF System 3



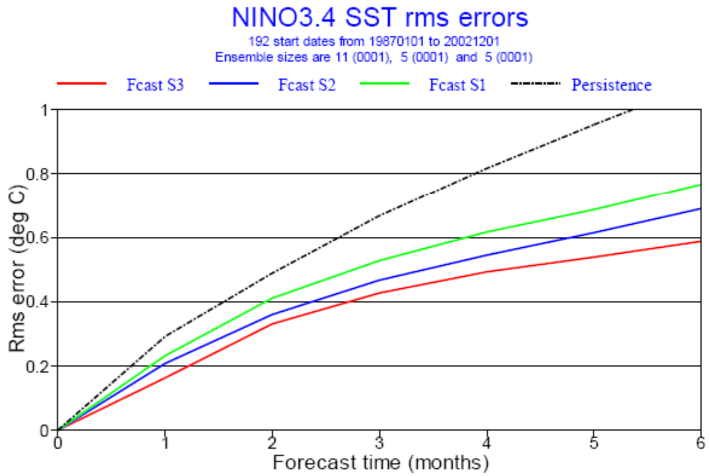


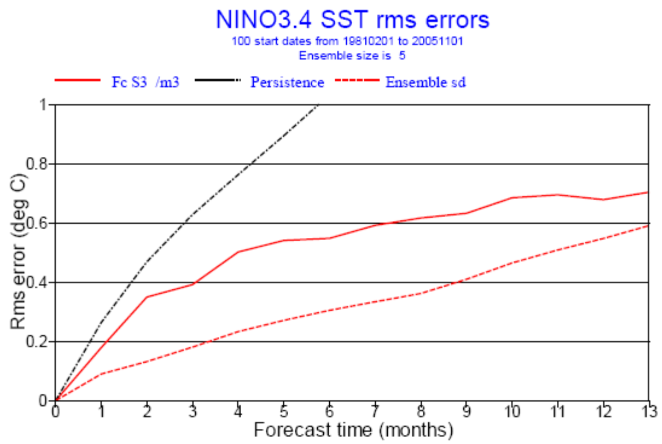
- **1981-2005 hindcasts**
  - 11 member ensembles
  - Every calendar month
  - From 1960 for Feb/May/Aug/Nov
- **Real-time forecasts**
  - 41 member ensemble
  - 7 months long
  - Operational dissemination of products
  - 4 times year, extension of 11 members to 13 months (ENSO outlook)
- **T_L159L60 model**

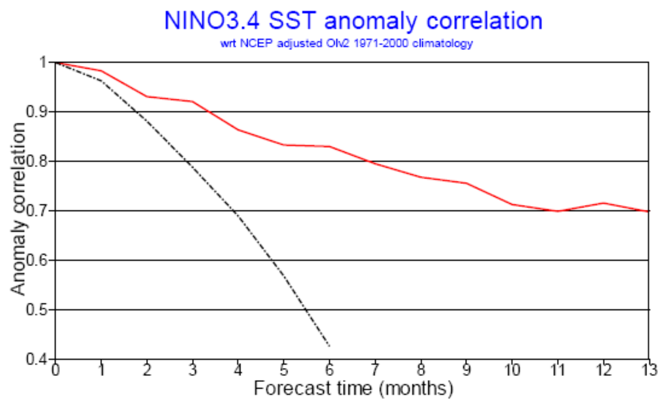
ECMWF System 3

Systematic improvement from S1 > S2 > S3

This figure represents 10 years' progress.





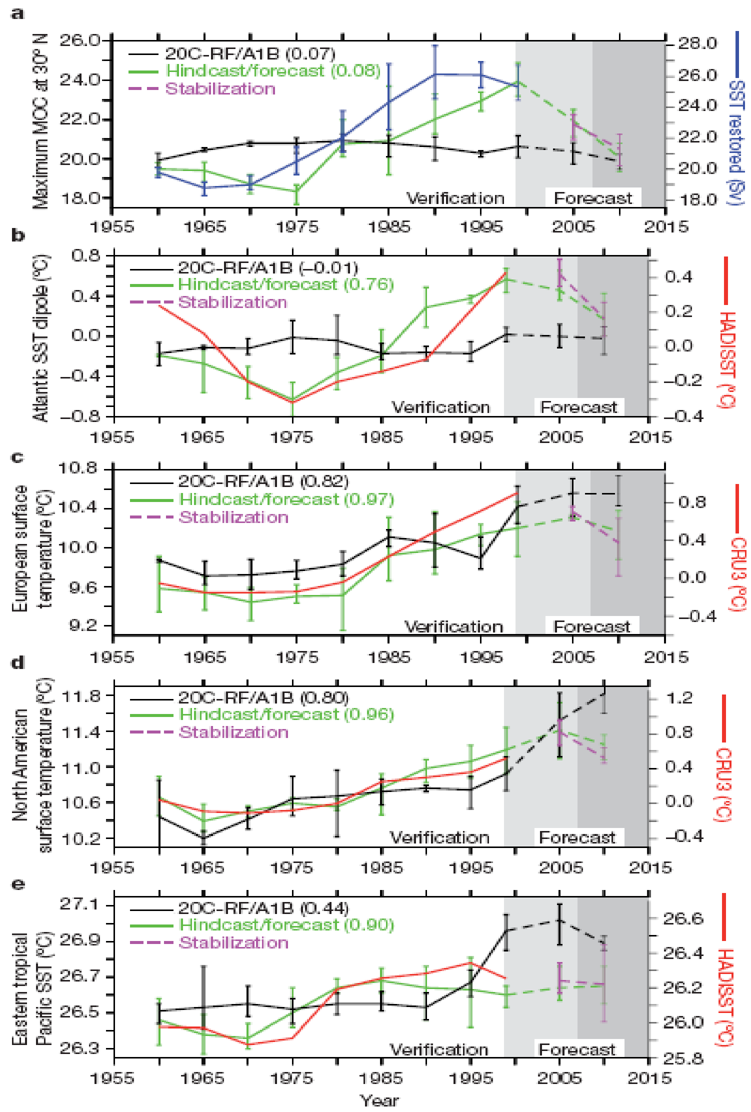


13 month forecasts look reasonable

4. Decadal Prediction

The physical basis for decadal prediction in the Atlantic ocean is that the decadal variability of the thermohaline circulation has such huge inertia that an initialization of the state of the Atlantic can detect future changes and allow a decadal prediction.

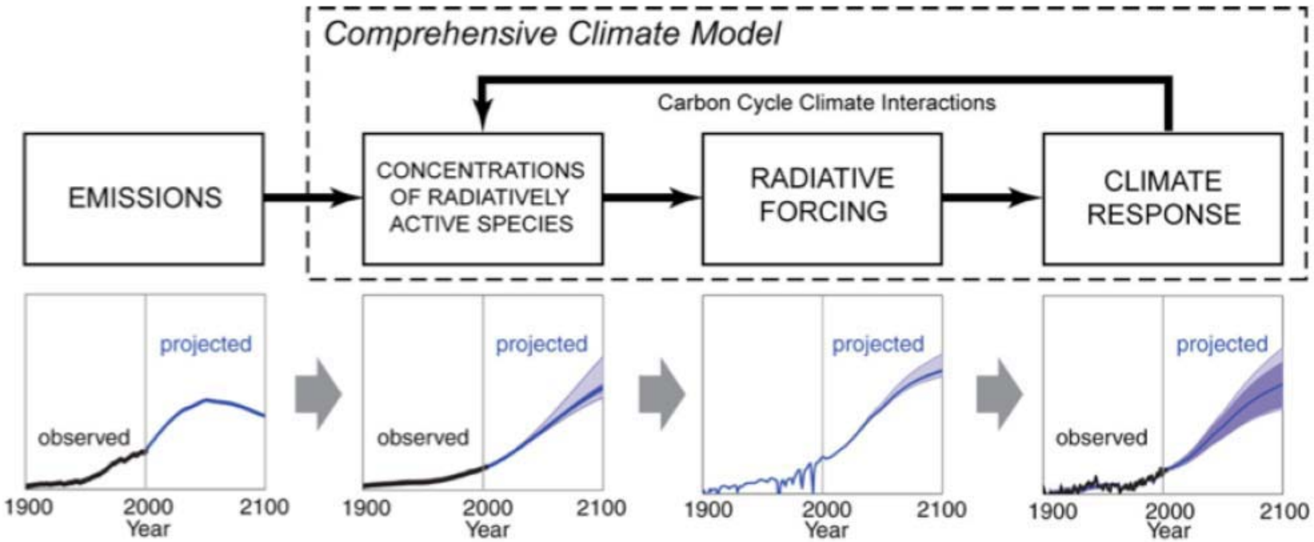
Keenlyside et al., 2008, initialized only with SST and predicted that the THC in the next decade will slow down to its historical mean thereby cooling the North Atlantic.

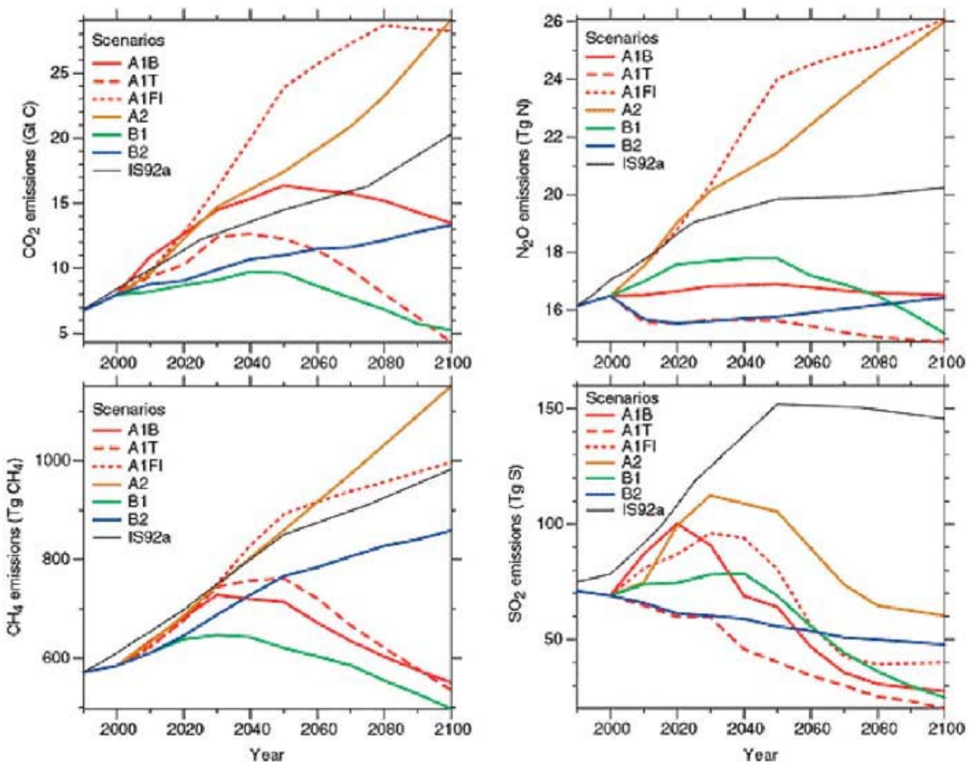


Keenlyside et al., 2008

5. Prediction of the Response to the Addition of Radiatively Active Constituents

The prediction is the scenario of future emissions of radiatively active gases. The model gives the response to this prediction.





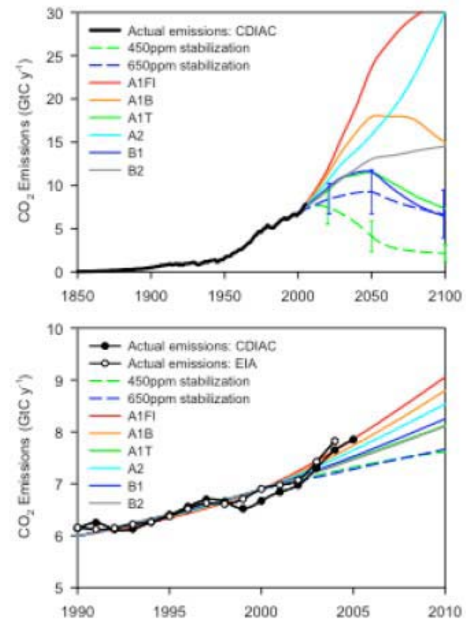


Fig. 1. Observed global CO_2 emissions including all terms in Eq. **1**, from both the EIA (1980–2004) and global CDIAC (1751–2005) data, compared with emissions scenarios (8) and stabilization trajectories (10–12). EIA emissions data are normalized to same mean as CDIAC data for 1990–1999, to account for omission of F_{Cement} in EIA data (see *Materials and Methods*). The 2004 and 2005 points in the CDIAC data set are provisional. The six IPCC scenarios (8) are spline fits to projections (initialized with observations for 1990) of possible future emissions for four scenario families, A1, A2, B1, and B2, which emphasize globalized vs. regionalized development on the A,B axis and economic growth vs. environmental stewardship on the 1,2 axis. Three variants of the A1 (globalized, economically oriented) scenario lead to different emissions trajectories: A1FI (intensive dependence on fossil fuels), A1T (alternative technologies largely replace fossil fuels), and A1B (balanced energy supply between fossil fuels and alternatives). The stabilization trajectories are spline fits approximating the average from two models (11, 12), which give similar results. They include uncertainty because the emissions pathway to a given stabilization target is not unique.

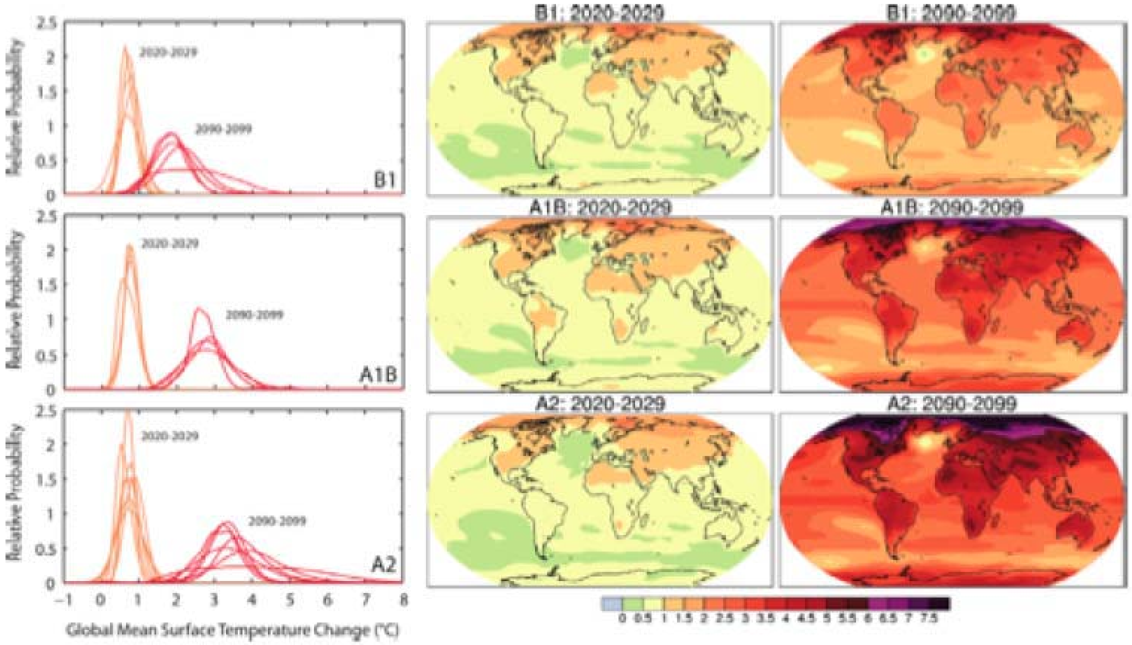
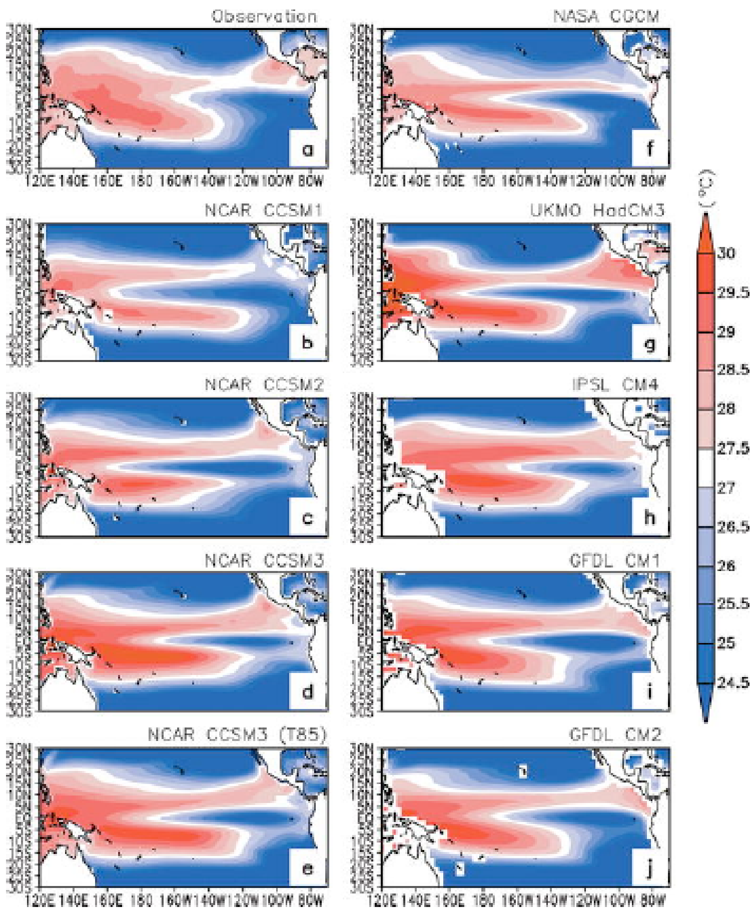
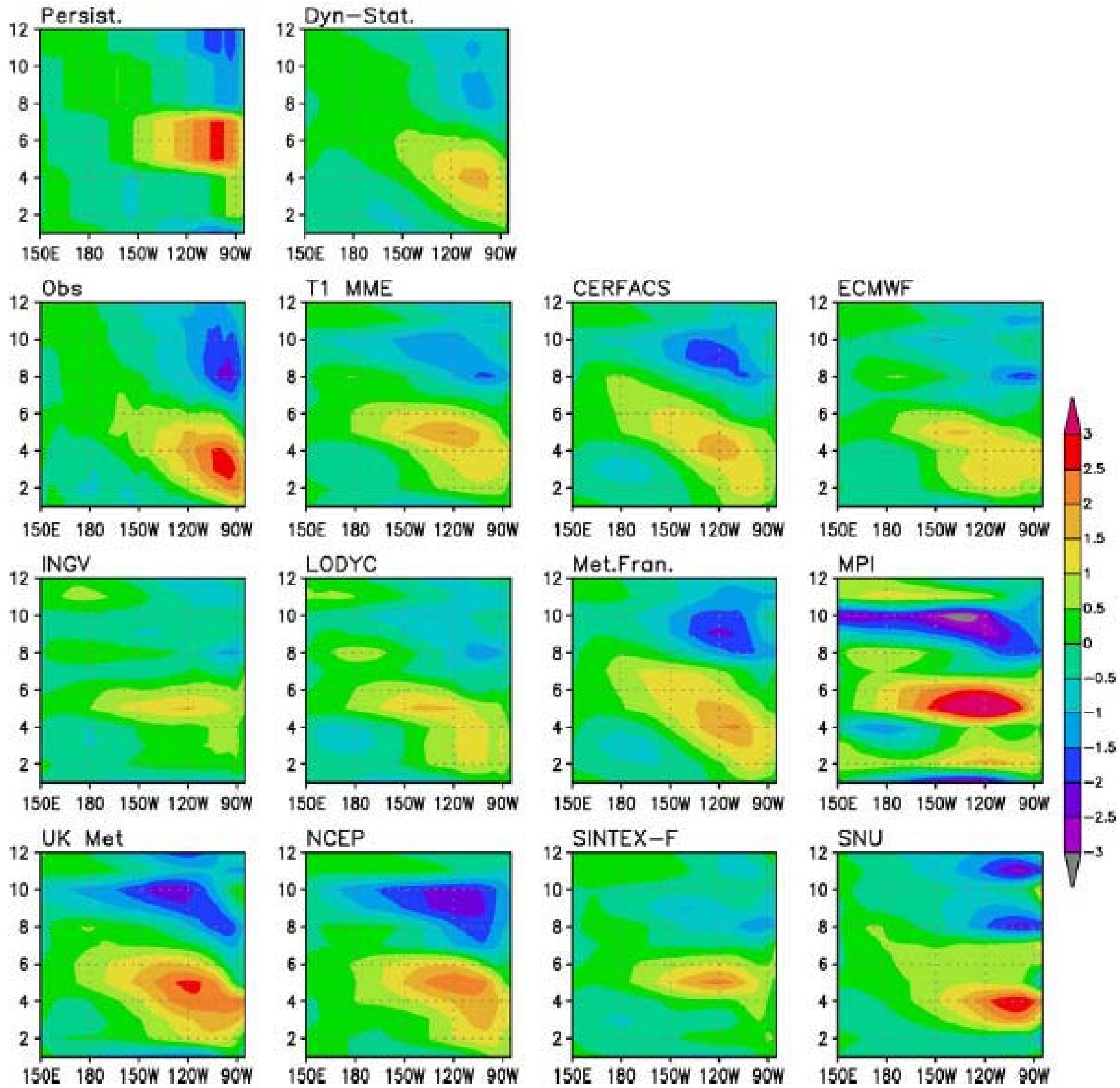


Figure TS-28. Projected global average temperature changes for the early and late 21st century relative to the period 1980–1999. The central and right panels show the multi-model average projections for the B1 (top), A1B (middle) and A2 (bottom) SRES scenarios averaged over decades 2020–2029 (centre) and 2090–2099 (right). The left panel shows corresponding uncertainties as the relative probabilities of estimated global average warming from several different studies for the same periods. {Figures 10.8 and 10.28}

6. The State of Coupled GCMS

Sun et al.,2004





Jin et al, 2008

7. What Needs to be Done?

1. **The mean biases in the models are not intrinsic and need to be fixed.**
2. **As we move towards longer prediction, the lack of a climate observing system needs to be addressed. Without a climate observing system:**
   - **A model based climate analysis becomes impossible.**
   - **The initialization data for predictions is compromised.**
   - **The validation data for predictions is compromised.**
3. **A monthly (initially seasonal) model based climate analysis needs to be researched, designed and implemented.**
4. **We need to know the mechanisms for the various large scale climate patterns (annual cycle, ENSO, PDO, NAO) so that**

- **some scientific basis for prediction may be given**
- **the ultimate limit of predictability be determined.**

5. **The variability (annual cycle, ENSO, PDO, NAO) in coupled climate models needs to be fixed.**

6. **Higher frequency variability (MJO) needs to be initialized and predicted in the models.**