EUROSIP: seasonal forecasting with ocean-atmosphere models

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Seasonal Forecasting Section

ECMWF

Outline

- **Seasonal forecasting**
  - Success of coupled ocean-atmosphere model forecasts
  - Limitations of model forecasts
- **EUROSIP multi-model system**
  - Benefits of multi-model approach
  - European organization
- **Implications for the models**
  - Initialization
  - Number of integrations
  - Need for and test of model quality

Sources of seasonal predictability

- KNOWN TO BE IMPORTANT:

• El Nino variability	- biggest single signal
• Other tropical ocean SST	- important, but multifarious
• Climate change	- especially important in mid-latitudes
• Local land surface conditions	- e.g. soil moisture in spring

- OTHER FACTORS:

• Volcanic eruptions	- definitely important for large events
• Mid-latitude ocean temperatures	- always controversial
• Remote soil moisture/ snow cover	- not well established
• Sea ice anomalies	- local effects, but remote??
• Dynamic memory of atmosphere	- most likely on 1-2 months
• Stratospheric influences	- various possibilities

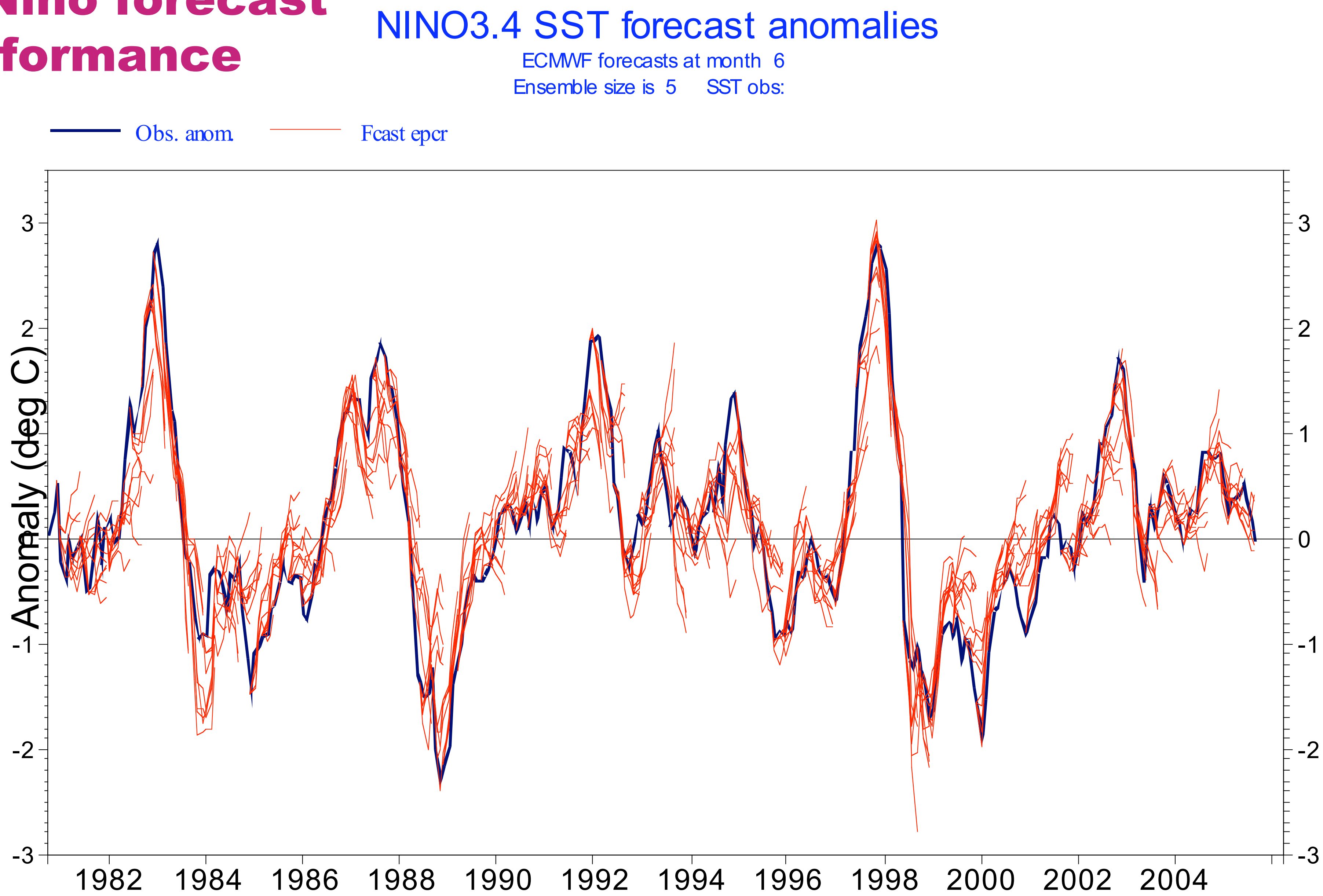
Step 1: Build a coupled model

- **IFS (atmosphere)**
  - T_L159L62 Cy31r1, 1.125 deg grid for physics (operational in Sep 2006)
  - Full set of singular vectors from EPS system to perturb atmosphere initial conditions (more sophisticated than needed …)
  - Ocean currents coupled to atmosphere boundary layer calculations
- **HOPE (ocean)**
  - Global ocean model, 1x1 mid-latitude resolution, 0.3 near equator
  - A lot of work in developing the OI ocean analyses, including analysis of salinity, multivariate bias corrections and use of altimetry.
- **Coupling**
  - Fully coupled, no flux adjustments, except no physical model of sea-ice

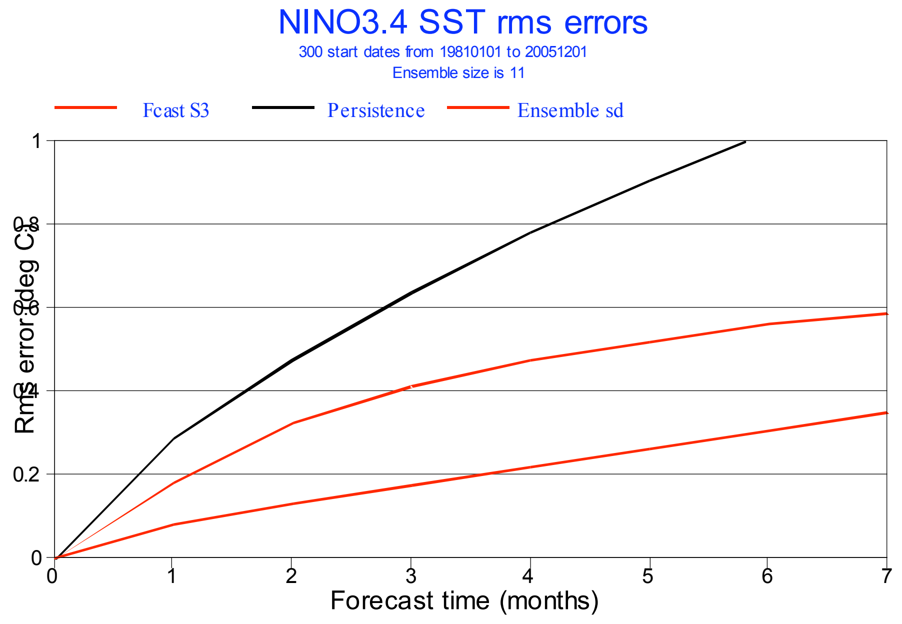
Step 2: Make some forecasts

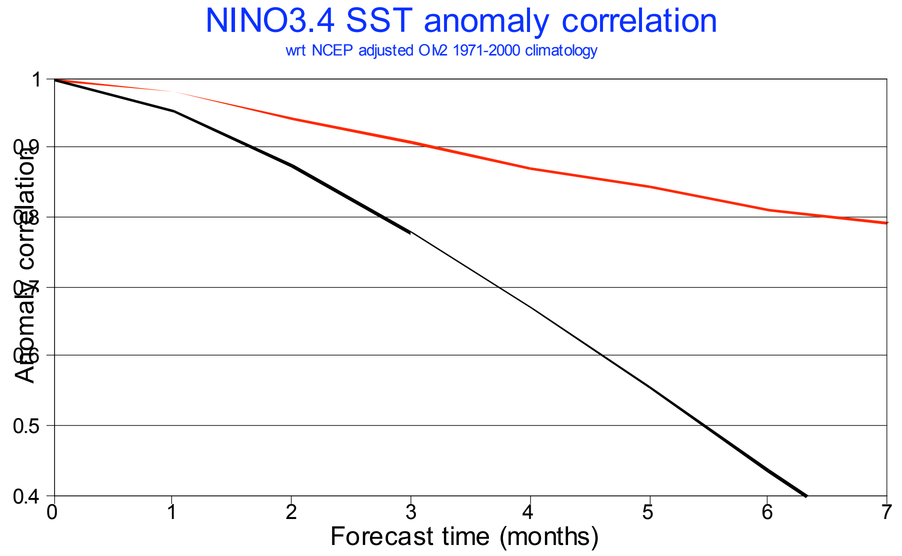
- **Initialize coupled system**
  - Aim is to start system close to reality. Accurate SST is particularly important, plus equatorial ocean sub-surface.
- **Run an ensemble forecast**
  - Explicitly generate an ensemble on the 1st of each month, with perturbations to represent the uncertainty in the initial conditions; run forecasts for 7 months
- **Remove systematic error**
  - Forecasts have considerable systematic error; estimate this error from a set of previous forecasts, which define the model climatology.
  - Model climatology is a function of date *and* forecast lead-time.
  - Linear assumption is not correct, but seems to work remarkably well.

El Nino forecast performance



ECMWF System 3



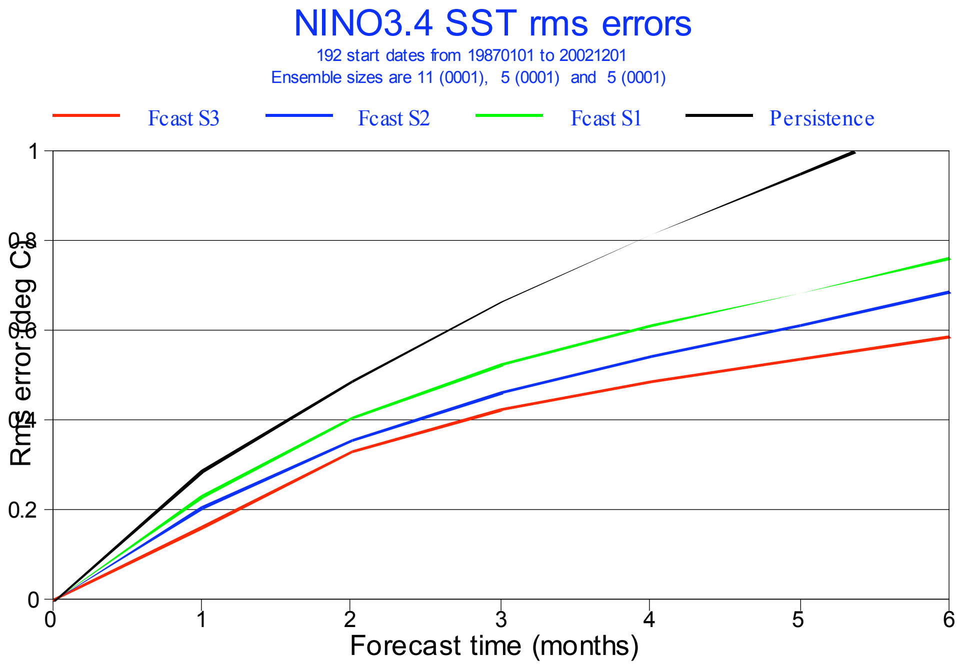


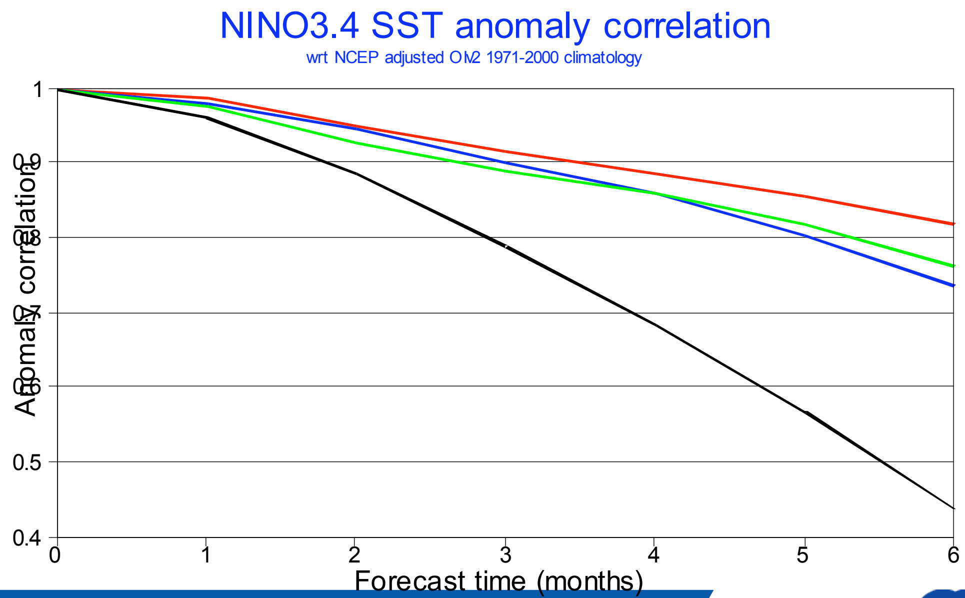
Progress S1 -> S2 -> S3

S1: 1997

S2: 2002

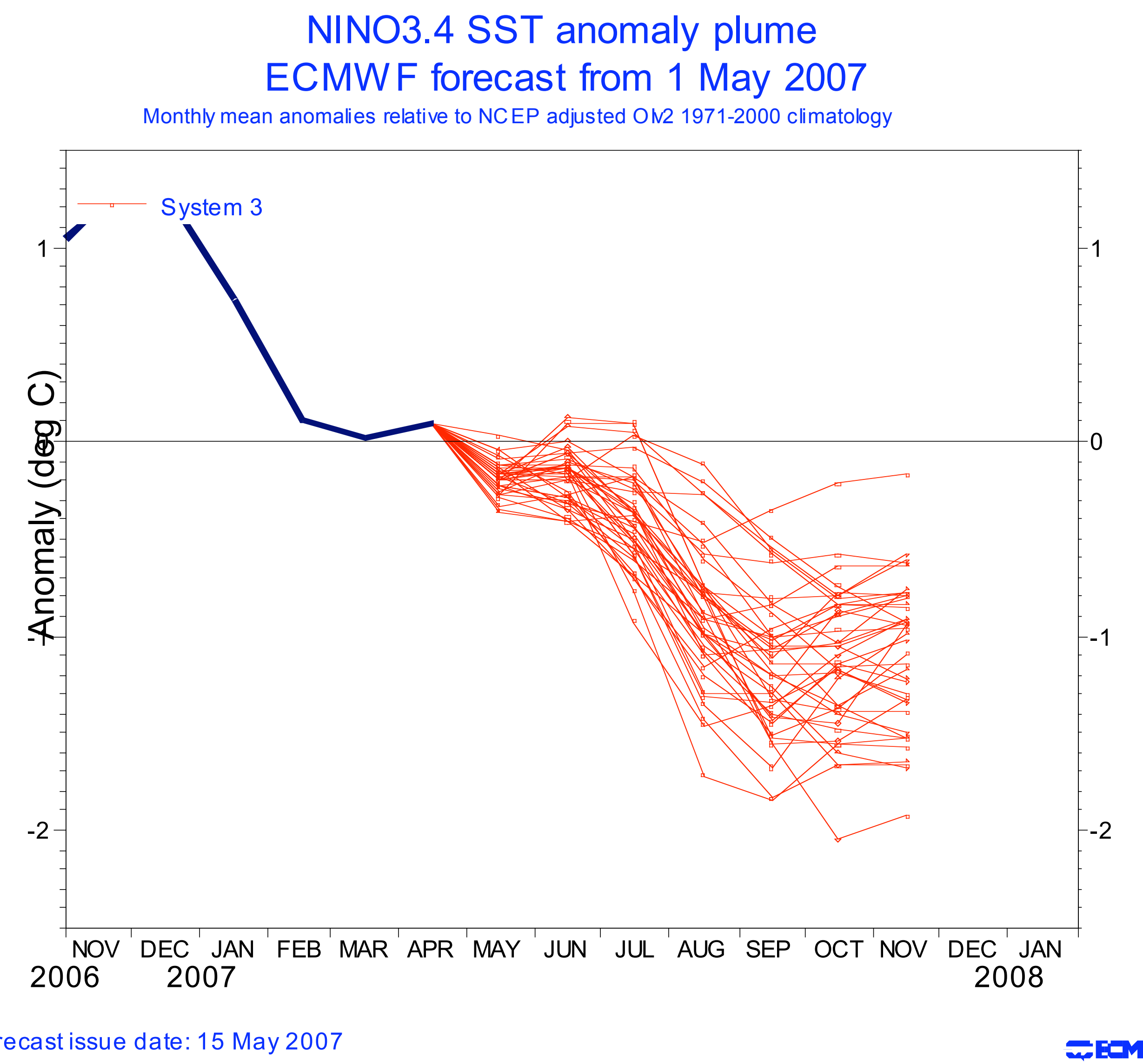
S3: 2007





ECMWF

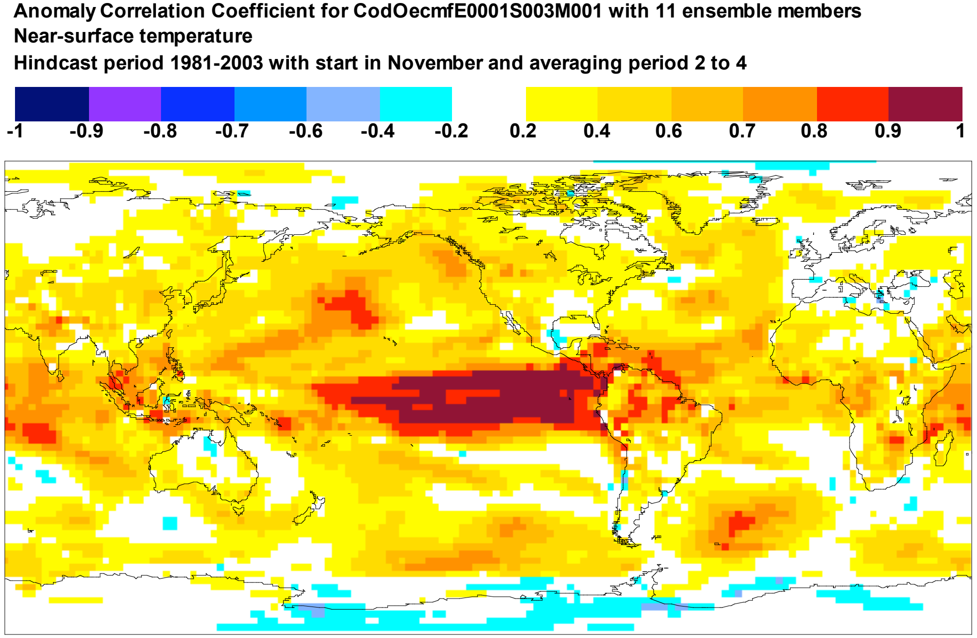
Latest forecast



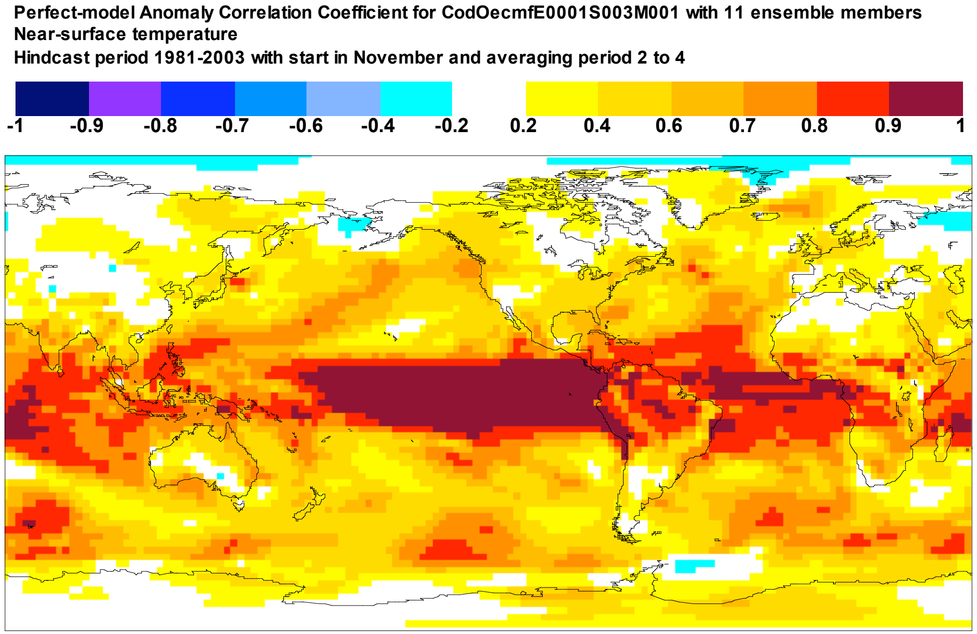
Atmospheric skill (provisional)

Deterministic skill: DJF ACC

Temperature: actual forecasts

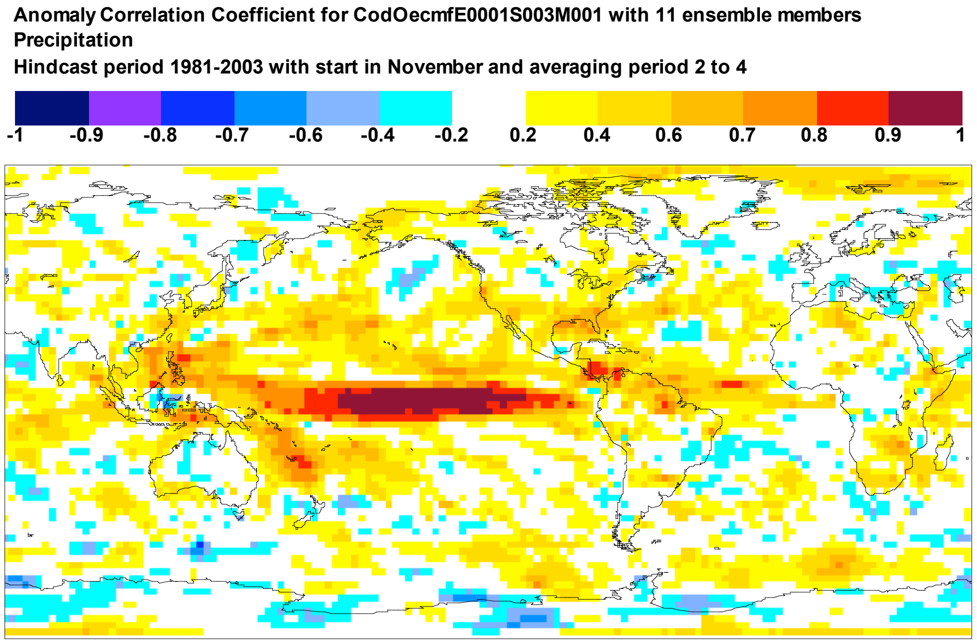


Temperature: perfect model

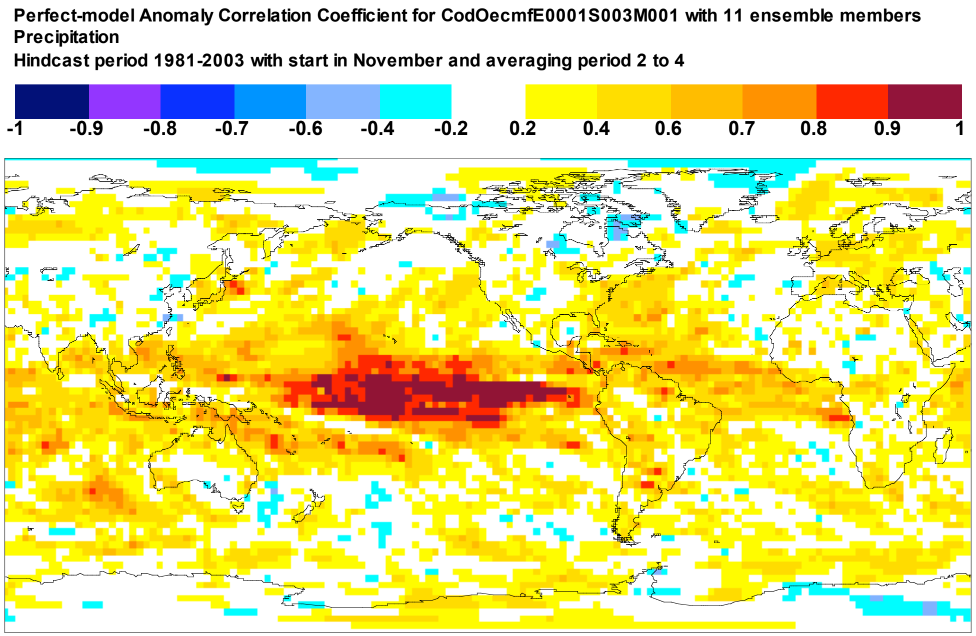


Deterministic skill: DJF ACC

Precip: actual forecasts

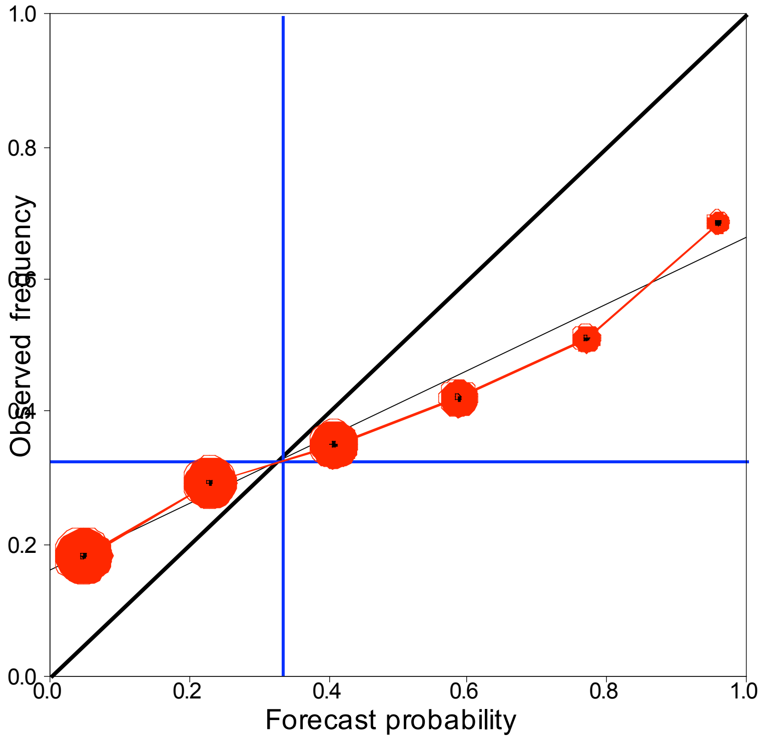


Precip: perfect model

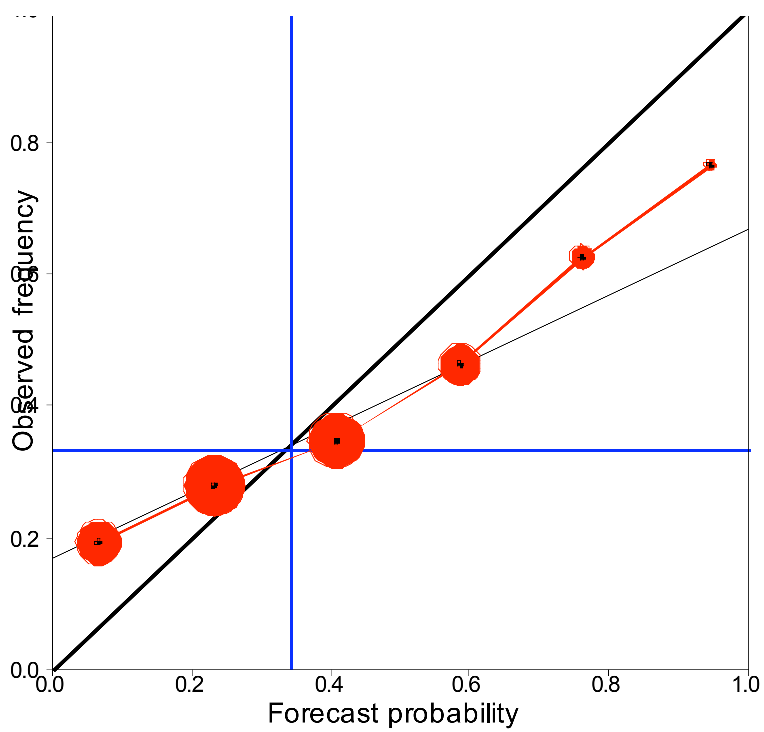


Probabilistic skill: Reliability diagrams

Tropical precip < lower tercile, JJA



NH extratrop temp > upper tercile, DJF



Why multi-model seasonal forecasts?

- **Seasonal forecasts dominated by model error**
  - Ocean initialization is important too, especially for El Nino
  - However, with state-of-the-art systems model error dominates even for SST forecasts
  - For atmospheric response, model error even more of an issue
- **Different models have different errors**
  - We do not expect errors to be orthogonal or independent
  - But at least *some* part of model error will differ and can be averaged out
  - Averaging over models improves both skill and reliability
- **Research shows multi-model approach works well**
  - Eg DEMETER project

Theory of multi-model forecasting

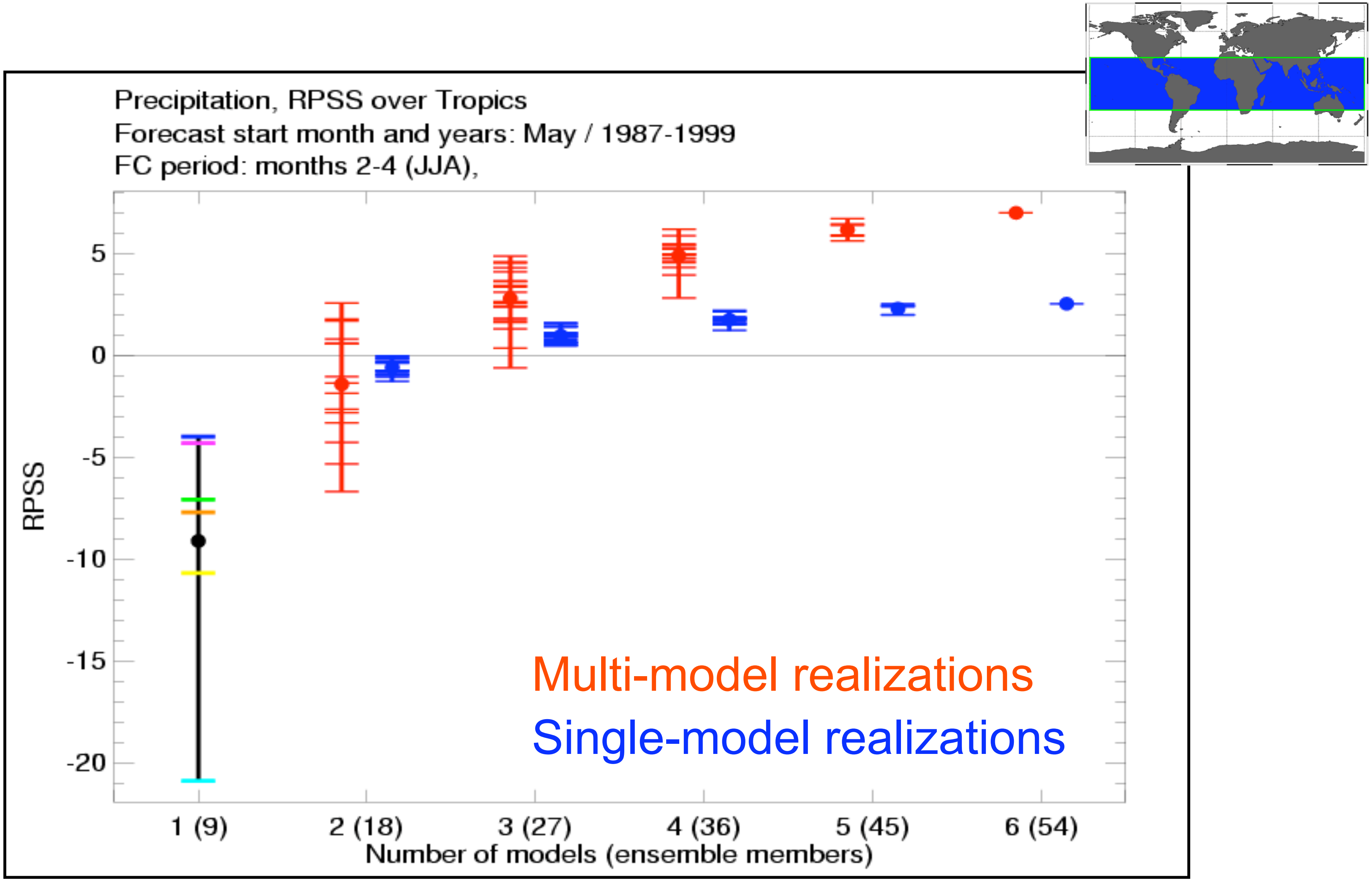
- **NOT sampling equally likely outcomes**
  - We expect all models to be wrong, none of them to be possible solutions
  - ARE sampling model-induced errors in predicted outcomes of individual events
  - If these errors are independent, then a large multi-model ensemble might have a *small* error in the ensemble mean, much smaller than the inter-model spread

  -> Optimistic view of multi-model forecasts

- **Model errors can easily be highly dependent**
  - Under-represented processes (eg complexity of aerosols)
  - Anything related to not having a 10km resolution …

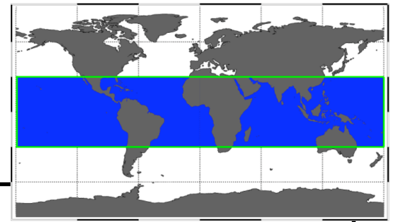
  -> Pessimistic view of multi-model forecasts

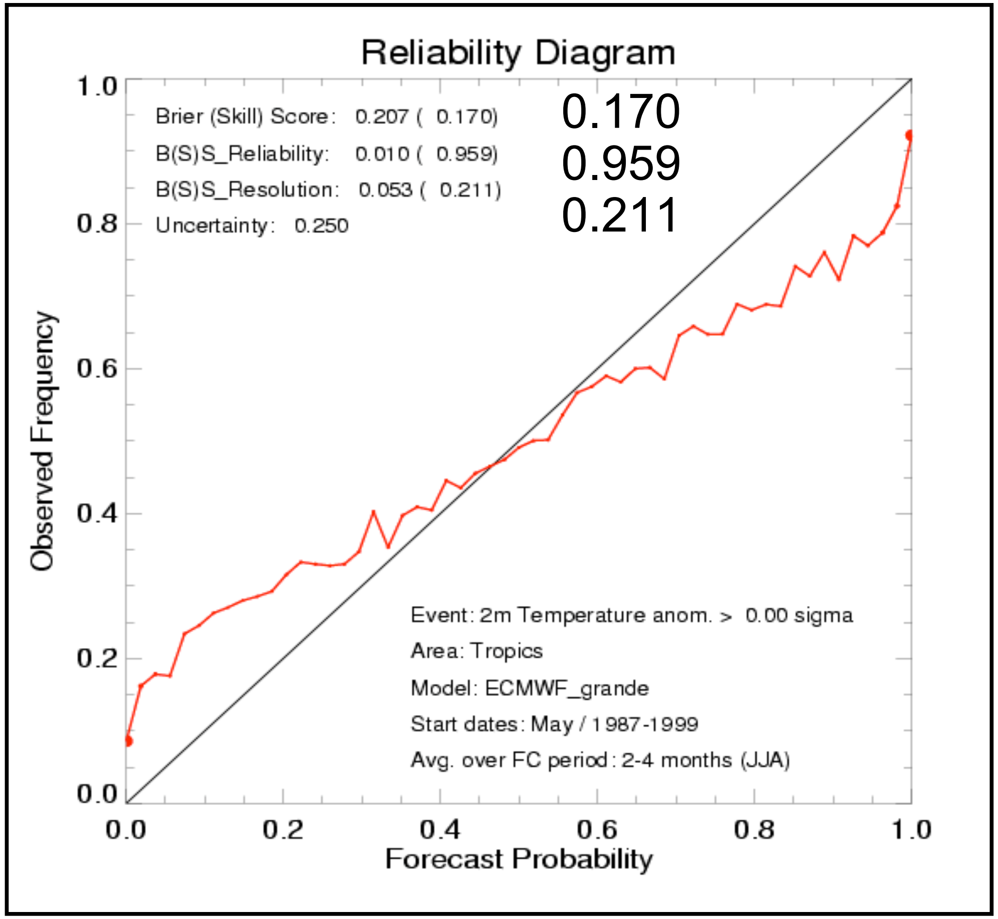
DEMETER: Impact of number of models



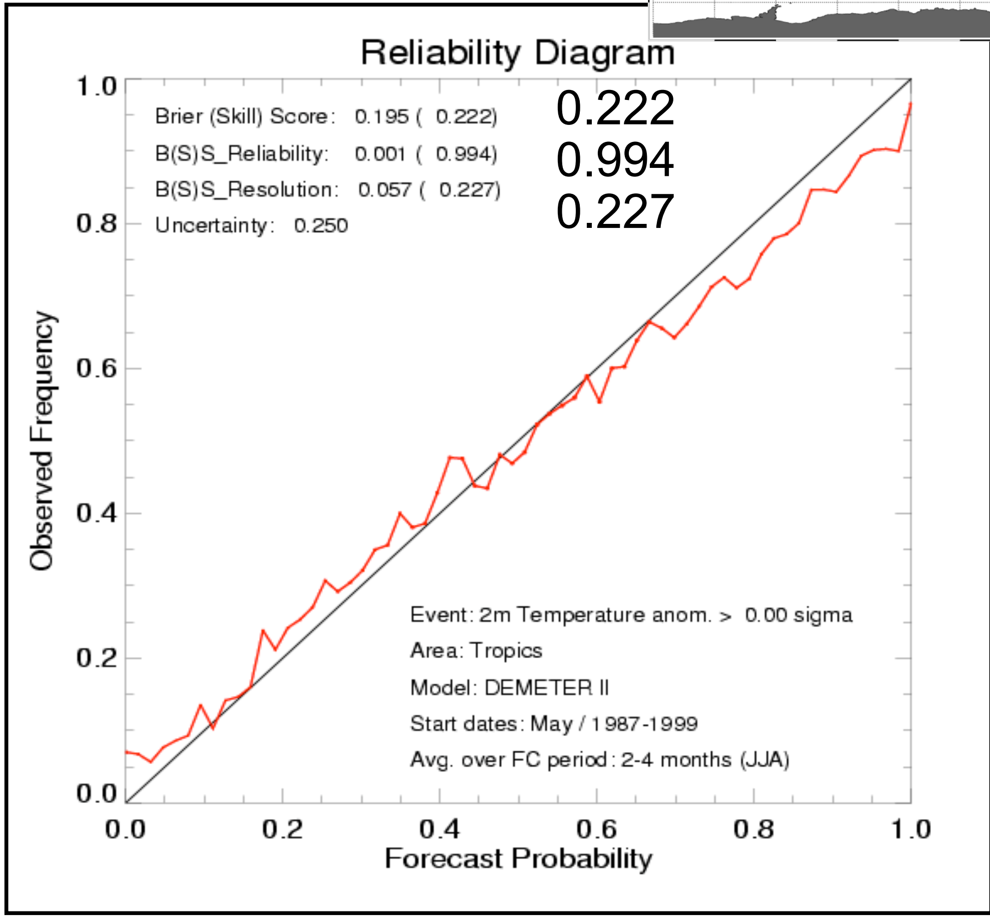
Reliability diagram: 2m-Temp.>0

Benefit of 6 models





single-model (54 members)



multi-model

What is EUROSIP?

- **EUROSIP multi-model seasonal forecasts**
  - SIP = seasonal-interannual prediction
  - 6 month forecasts
- **Three models at present**
  - ECMWF: system 3 (IFS/HOPE)
  - Met Office: system 3 (GLOSEA – based on HADCM3)
  - Meteo-France: system 2 (Arpege/OPA)
- **Real-time forecasts since April 2005**
  - Initial agreements with Met Office and Meteo-France were made separately
  - Replaced by recently agreed comprehensive new data policy
  - German contribution now under development ϑ

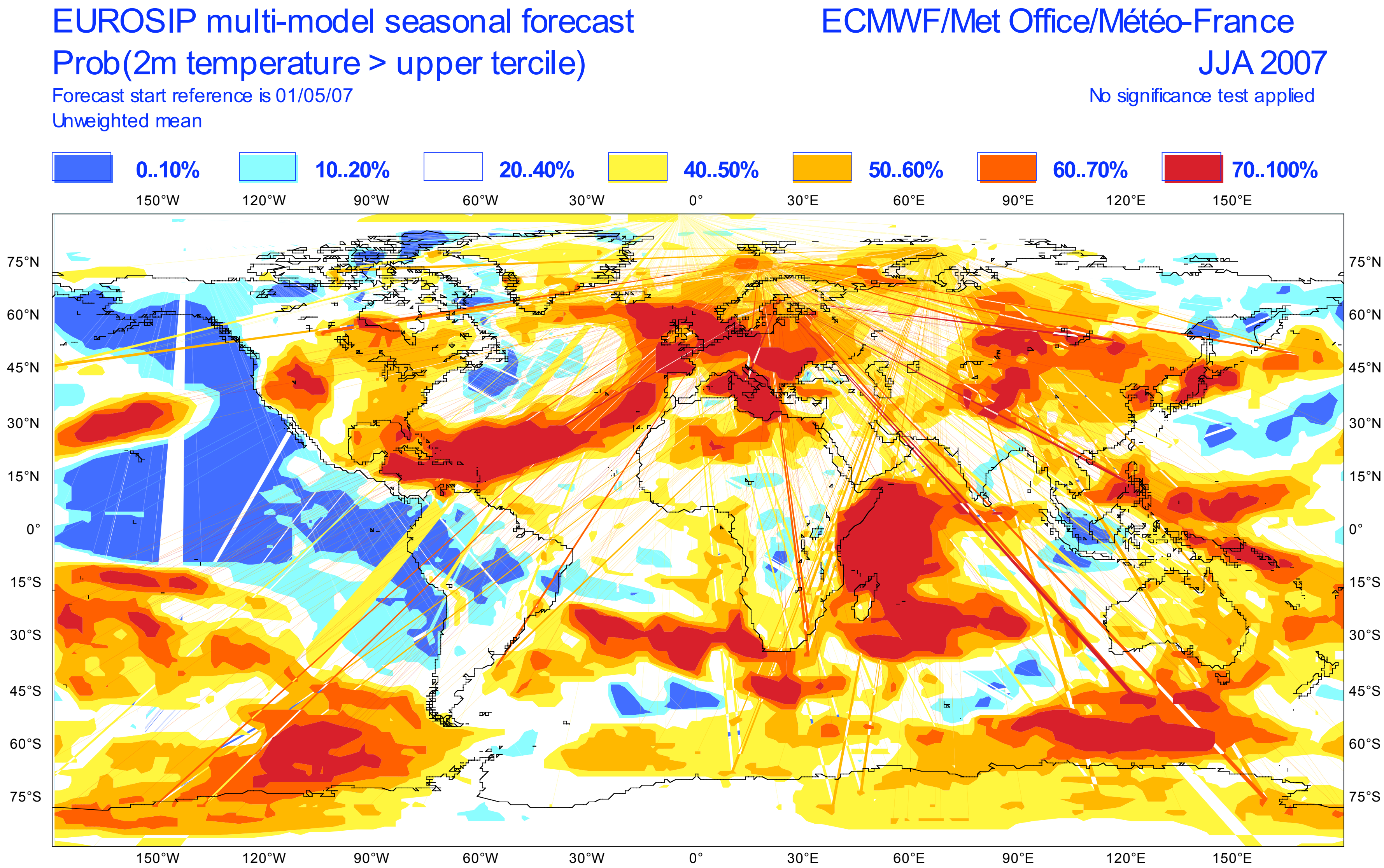
What does EUROSIP give?

- **A coordinated operational system**
  - Production schedule
  - System design (ensemble sizes, back integrations ..)

- **Unified data structures**
  - Based on ECMWF grib, MARS, fdb, and dissemination structures for seasonal forecast data – a relatively mature infrastructure

- **Performance checking of individual models**
  - Analysis of historic performance
  - Checking of real-time forecasts

- **Multi-model products**



Forecast issue date: 15/05/2007

Implications: initialization

- **ECMWF uses sophisticated ocean analysis**
  - Multivariate scheme, OI based
  - Special adjustments for model biases
  - Altimetry

- **But simple wind-forced ocean is also good**
  - Use decent quality wind field (eg ERA-40)
  - Strong relaxation to SST (eg NCEP OIv2)
  - SST forecasts only slightly worse than with high quality analysis
  - Impact on main atmosphere fields is very limited
  - => Benefit of a different atmosphere/ocean model is easily obtained

Implications: number of integrations

- **Real-time forecasts:**
  - 41 member ensemble, once per month
  - 6 or 7 months long => 24 model-years
  - To be completed in 1 day wall-clock (but is very parallel)

- **Re-forecasts for calibration**
  - 5 or more member ensemble (recommended 11)
  - Every month, from 1981-present
  - Say 900 -> 2000 model years
  - Wall-clock time: up to a year
  - Repeated for each new system
  - => Do not change systems very often

Implications: model quality

- **Seasonal forecasting is demanding of model quality**
  - Biggest source of forecast error is model error
  - Tropical convection is particularly tough – multi-scale problem
  - Any error that affects the mean state can be a problem
- **Seasonal forecasting is a good test of model quality**
  - Relatively large number of cases to verify (cf climate)
  - Sensitive to most of the physics of the atmosphere, and faster coupled ocean-atmosphere processes
- **Climate**
  - Seasonal forecasting is unavoidably linked with climate change
  - Ability of models to capture observed trends (even in short range forecasts) can disappoint