

# ECMWF Long Range Forecast

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- **The Seasonal Forecasting system and its evolution**
- **Performance**
  - **El Nino Forecast**
  - **Predictions of atmospheric anomalies**
- **Developments and future implementations**
  - **Multi-model ensembles a way to deal with model error**
  - **Monthly Forecast**



# The Seasonal Forecasting system and its evolution:

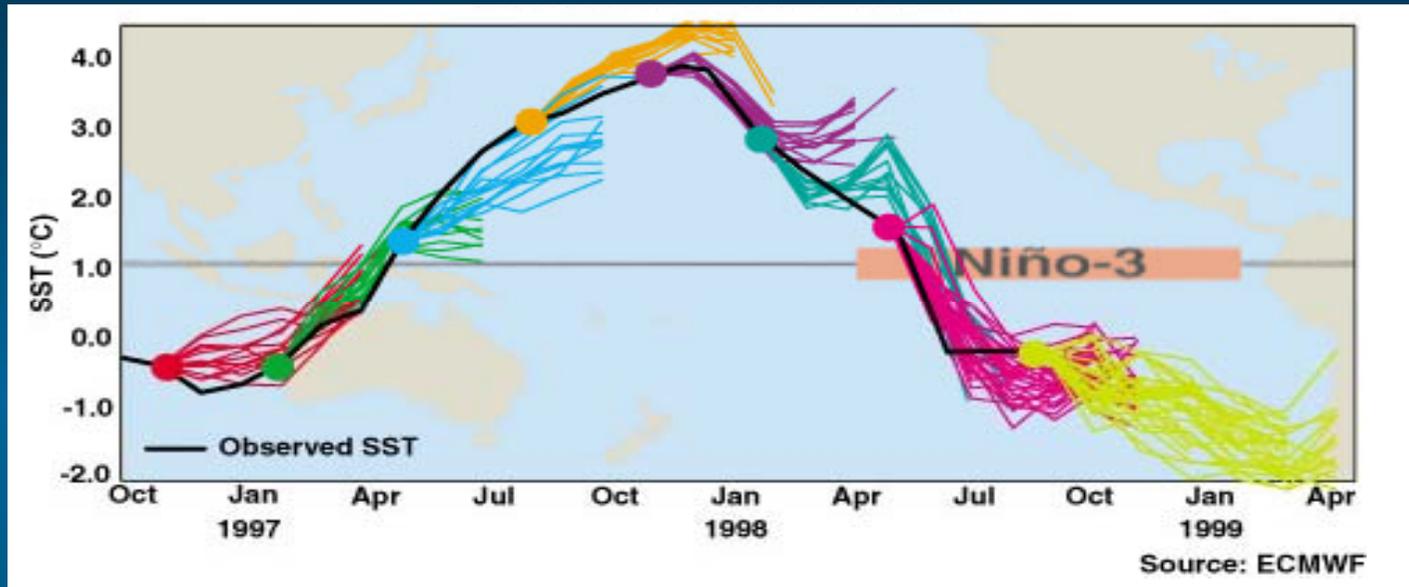
**In 1995 started an experimental programme in seasonal forecasting. The ECMWF atmospheric model used for the NWP was coupled to an ocean model.**

**September 1996- February 1997 seasonal forecast was in semi-operational production (System 1).**

**Successful predictions of the exceptional El Nino event of 1997 encouraged the seasonal forecast activity.**



# El Nino 1997



# The Seasonal Forecasting system and its evolution:

Since then a range of seasonal products was issued routinely on <http://www.ecmwf.int/products/forecasts/seasonal/forecast>.

Since mid-2000 some products are available to all WMO members.

January 2002 operational implementation of an upgraded system (System 2) was introduced.

April 2003 System 1 was dismissed.



## System 1

Atmosphere (IFS):  
Cy 15R8, T63, L31, Eulerian  
Ocean (HOPE):  
L20, ~0.5 eq. ~2 midlat.

## The coupled model

## System 2

Atmosphere (IFS):  
Cy 23R4, T95, L40, semi-  
Lagrangian Ocean (HOPE):  
L29 ~0.3 eq. ~1 midlat.

## Ocean analysis

A daily ocean analysis

5 member ensemble of ocean  
analysis (wind perturbations)

## Ensemble generation

Lag average ensemble

40 forecasts start 1<sup>st</sup> of month

## Calibration period

From 1991 to 1996

From 1987 to 2001



## Ocean Initialization

- Relaxation to observed SST (~2 days)
- OI of subsurface T, every 10 days
- 10 days assimilation window
- Improved treatment of salinity
- Daily forcing from NWP fluxes
- 5 ocean analysis

## Ensemble Generation

- 40-member ensemble forecast
- 5 different ocean analysis
  - Perturbations to the subsurface
- 40 SST perturbations
  - Reynolds 2dvar-OI
- Stochastic physics

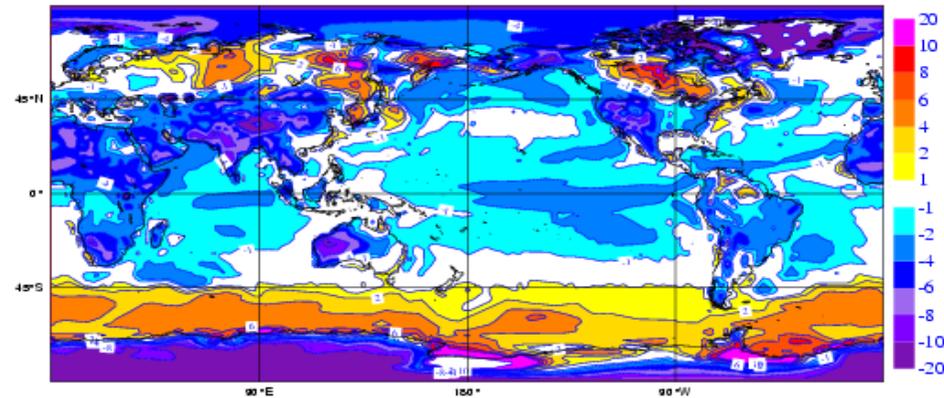
## Atmospheric Initialization

- ERA 15 (1987-1993)
- NWP 1994 onwards

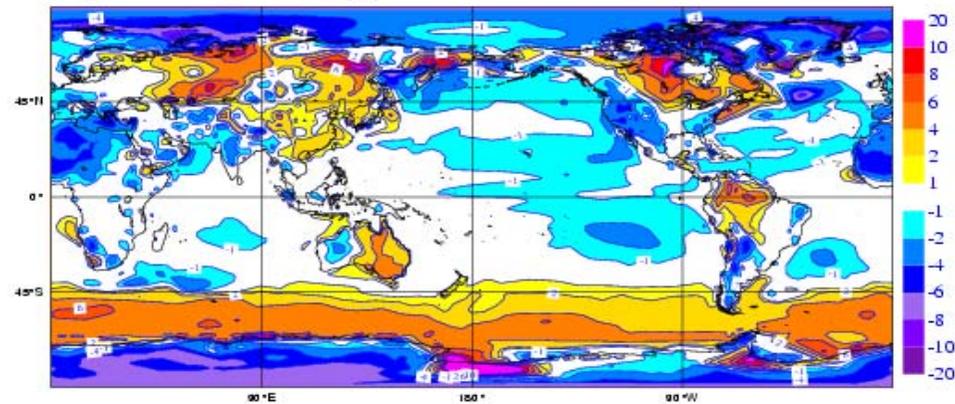


# Biases:

System 1 coupled - month 6 - sstbias

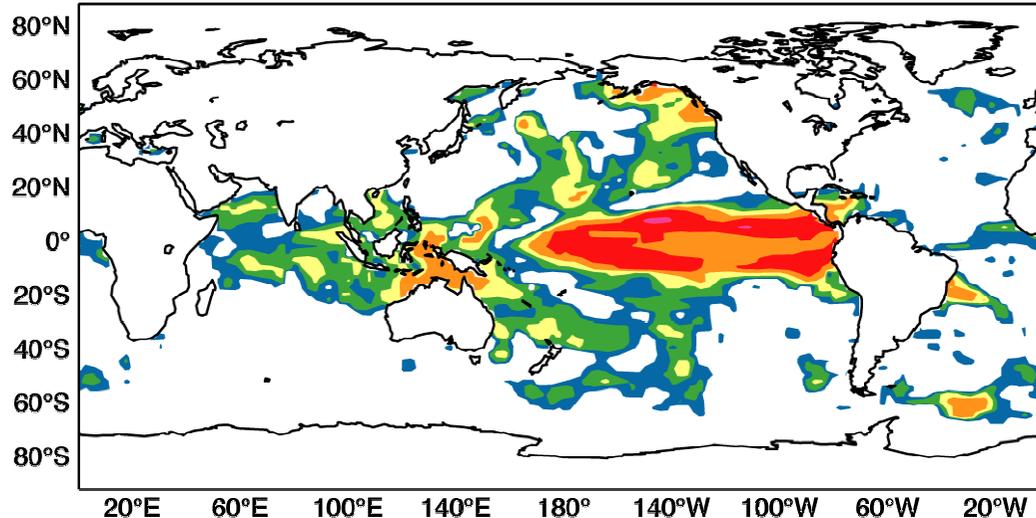


System 2 coupled - month 6 - sstbias

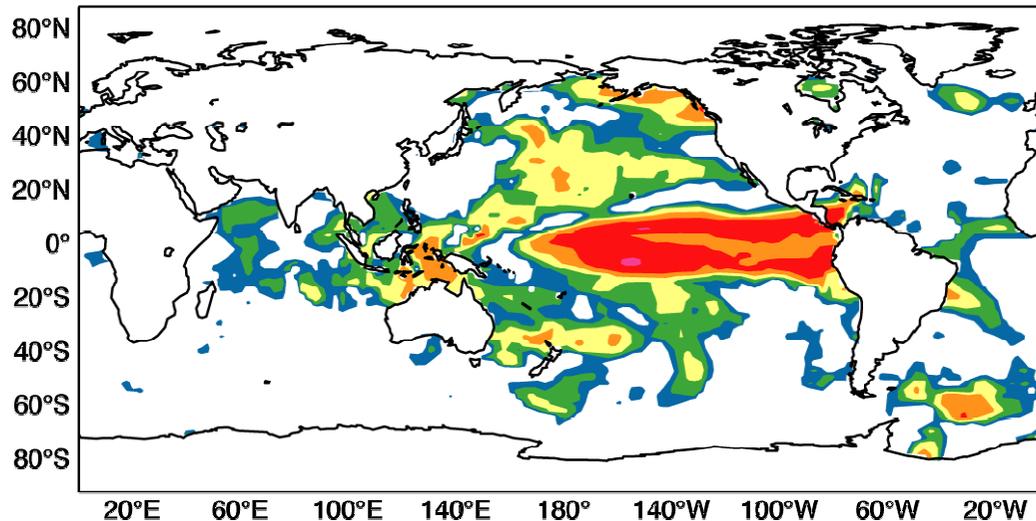


a) ECMWF Monthly Forecasting System 1

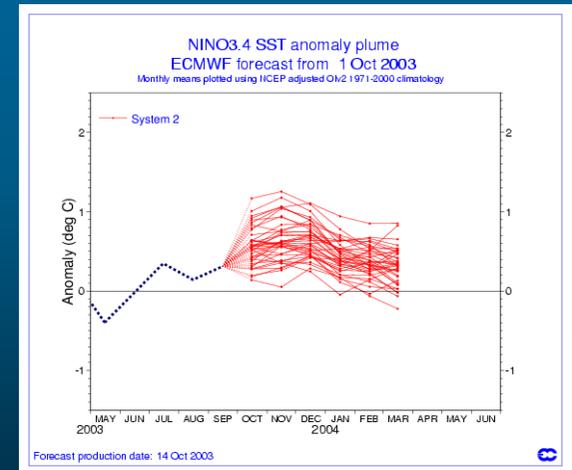
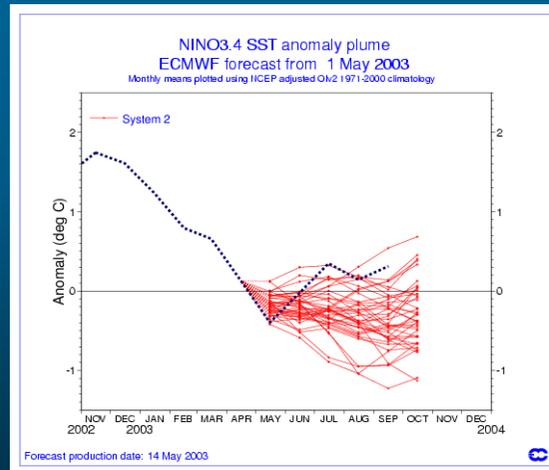
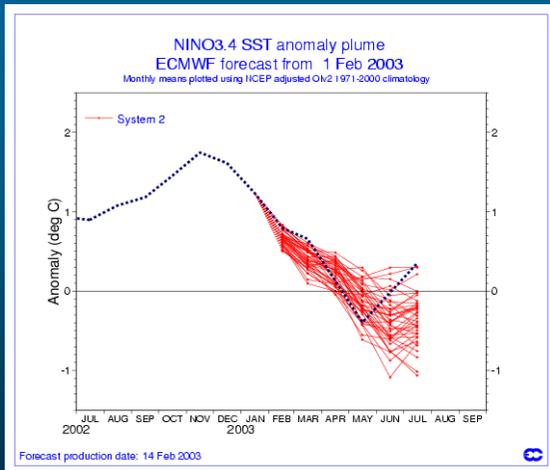
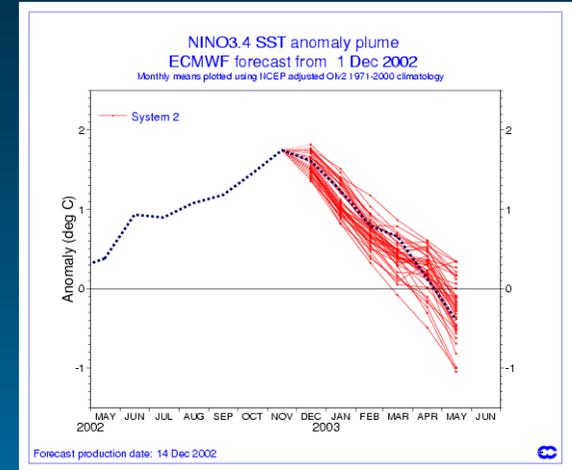
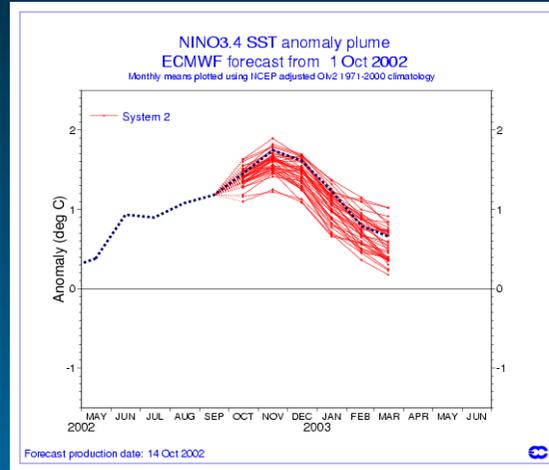
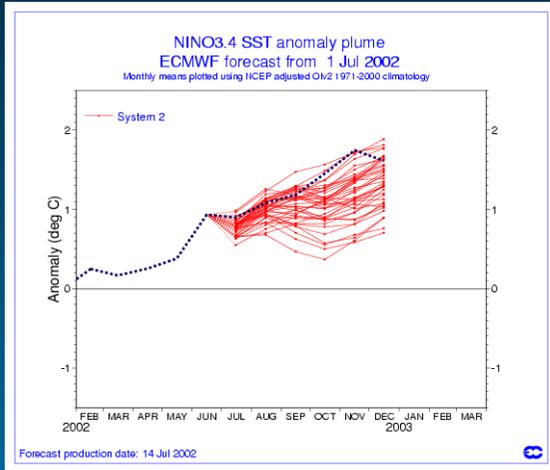
□ <0.4   ■ 0.4 - 0.5   ■ 0.5 - 0.6   ■ 0.6 - 0.7   ■ 0.7 - 0.8   ■ 0.8 - 0.9   ■ 0.9 - 1.0

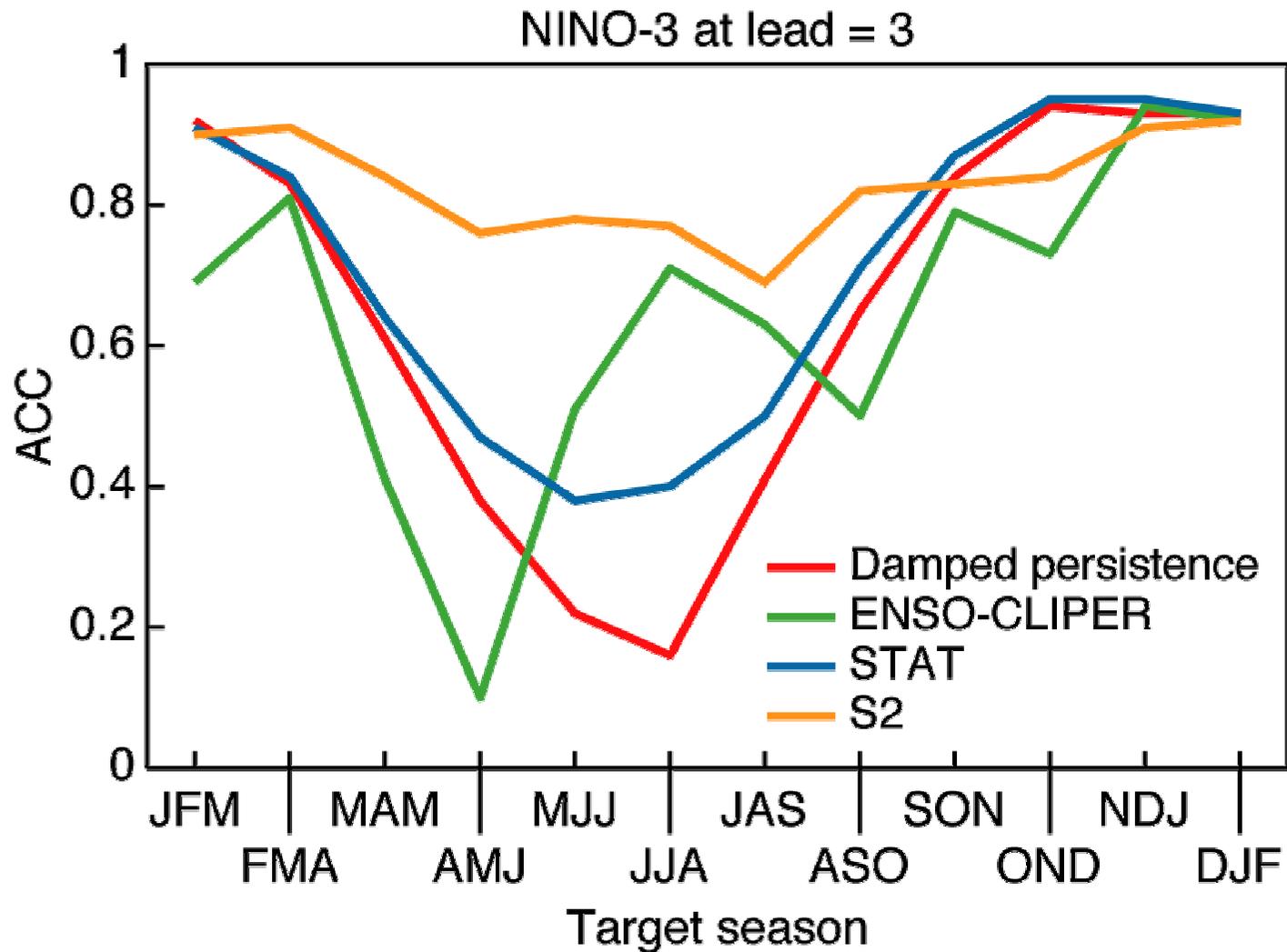


b) ECMWF Monthly Forecasting System 2



# Nino 3.4 past forecasts:





From Oldenborgh et al. submitted to MWR



## Products and Validation :

- **Additional products:**
  - **Forecasts for Nino3, Nino3.4 and Nino4**
  - **Spatial plots terciles, 15%iles**
- **Documentation of skill levels is provided to the users:**
  - **The measure of skill conforms to a common standard defined by the WMO**
  - **The verification sampling for seasonal forecast is limited, importance of significance levels in the verification statistics**

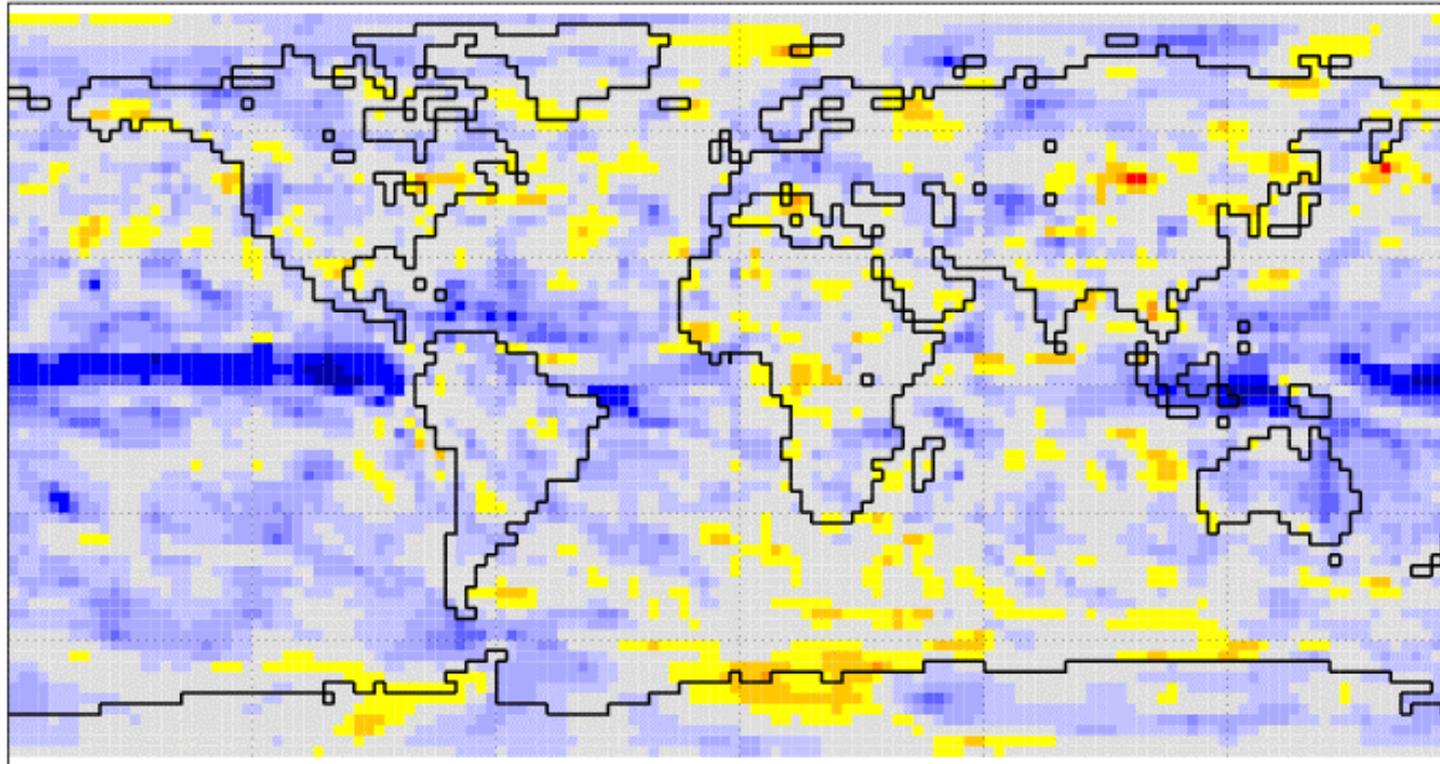


## Total Precipitation

Anomaly Correlation Coefficient: EXP(ECMWF\_oper) with GPCP

Forecast start month and years: May / 1987-2002

FC period: months 2-4 (JJA), ens: 0-39

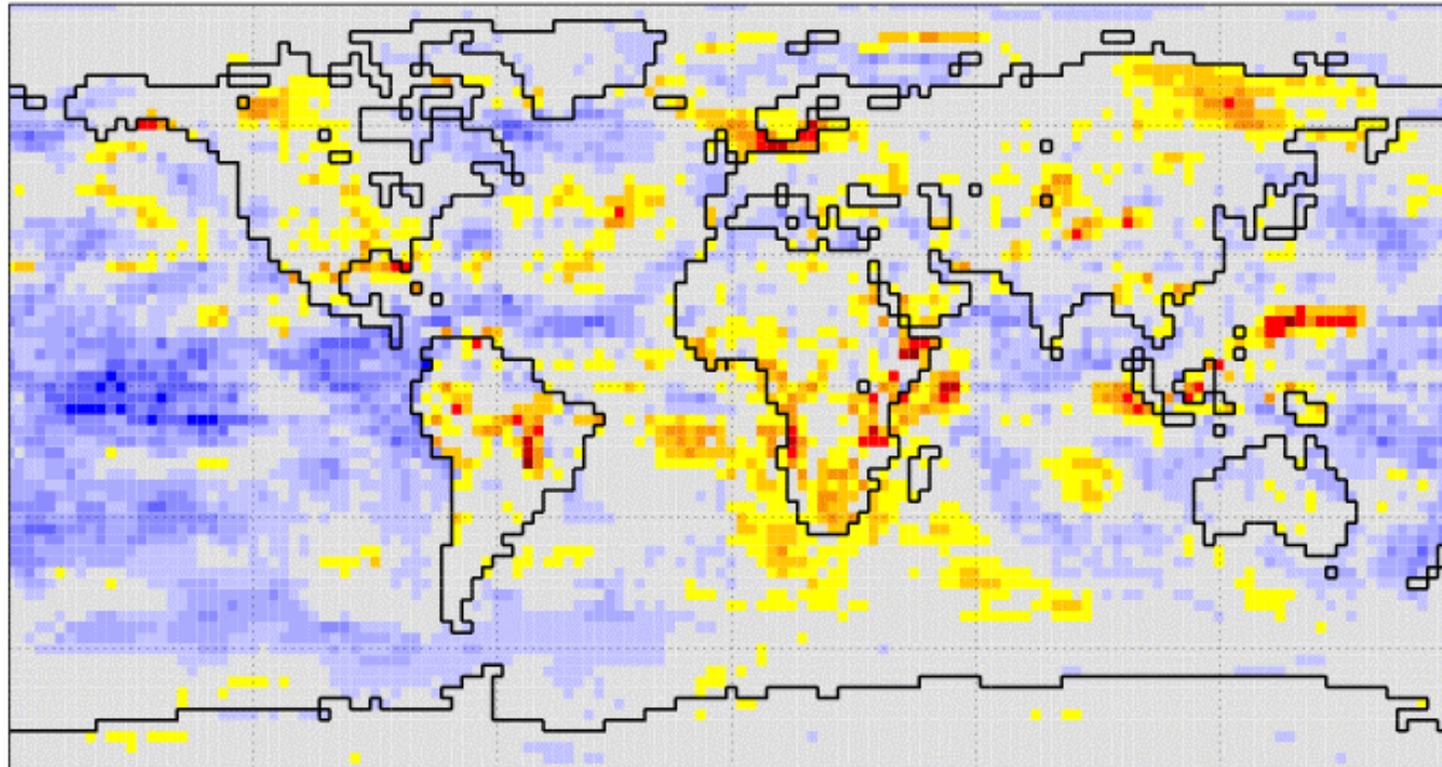


## 2m-Temperature

Ranked Probability Skill Score: EXP(ECMWF\_oper) with respect to ERA-40 and op.analysis

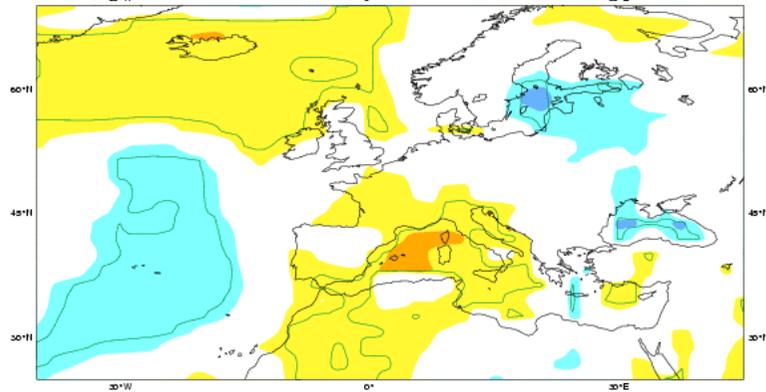
Forecast start month and years: May / 1987-2002

FC period: months 2-4 (JJA), ens: 0-39



ECMWF Seasonal Forecast  
Mean 2m temperature anomaly

Forecast start reference is 01.05.03  
Ensemble size = 40, climate size = 75

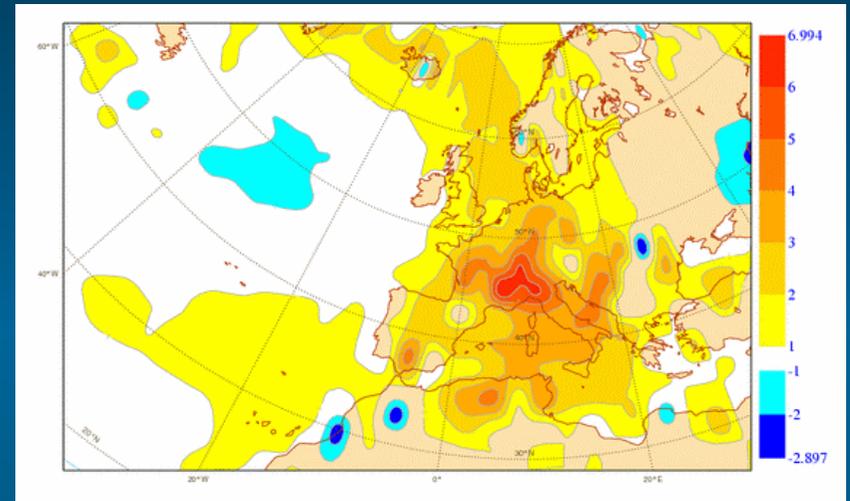


Forecast production date: 14.05/2003



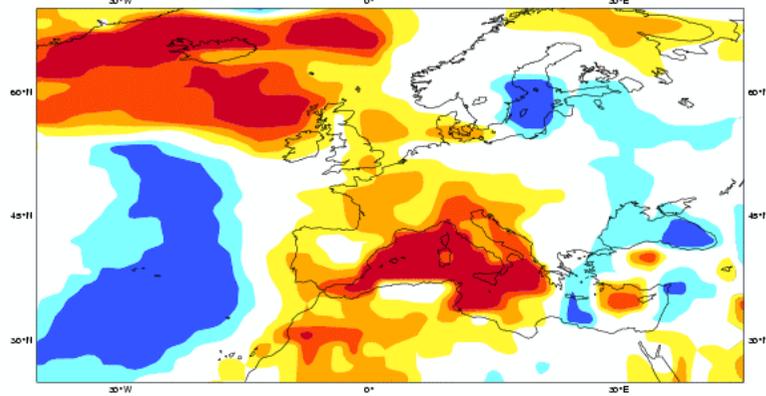
System  
JJA 2003

# 2 m temperature anomalies JJA 2003



ECMWF Seasonal Forecast  
Prob(upper tercile) - 2m temperature

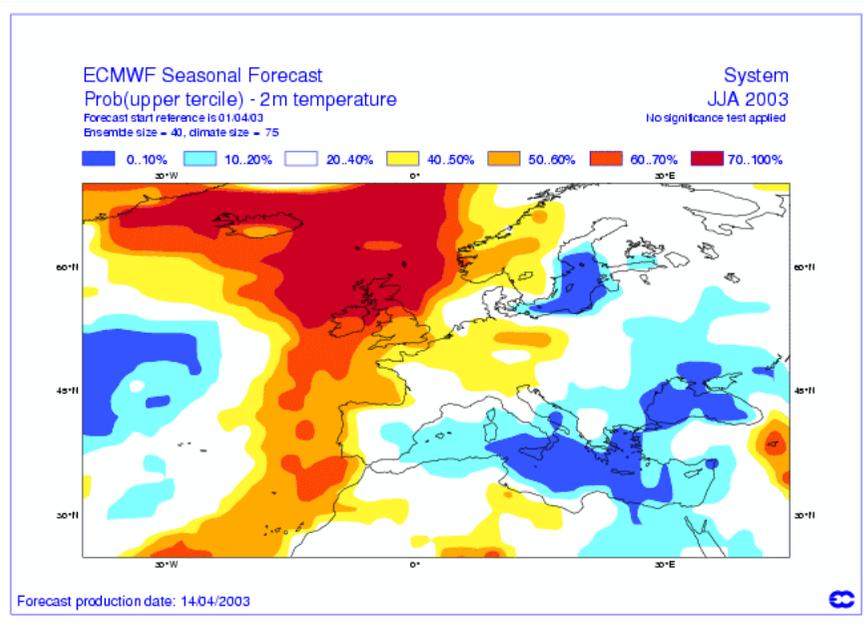
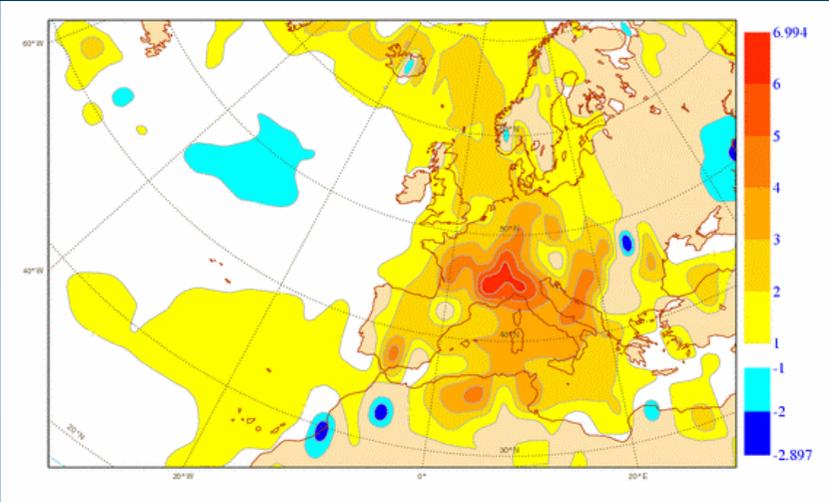
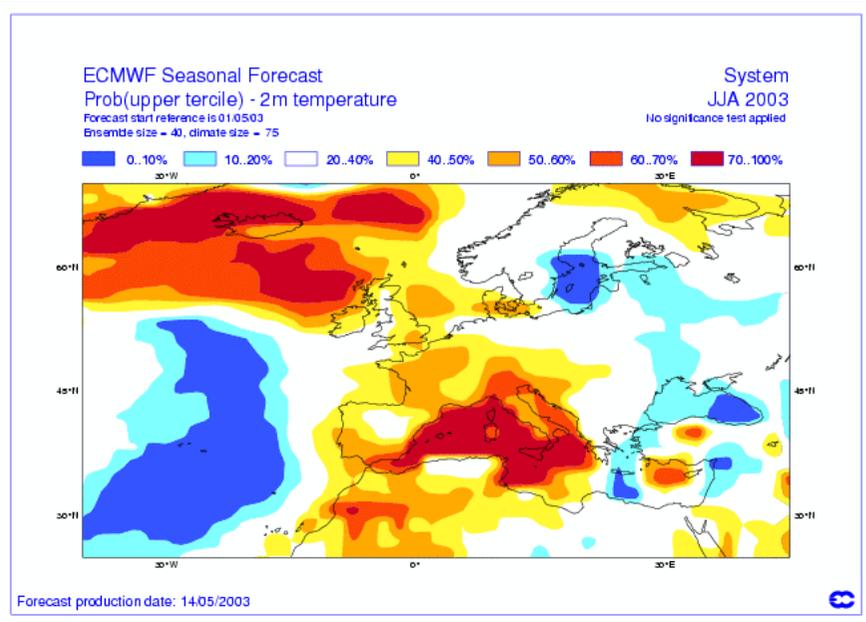
Forecast start reference is 01.05.03  
Ensemble size = 40, climate size = 75



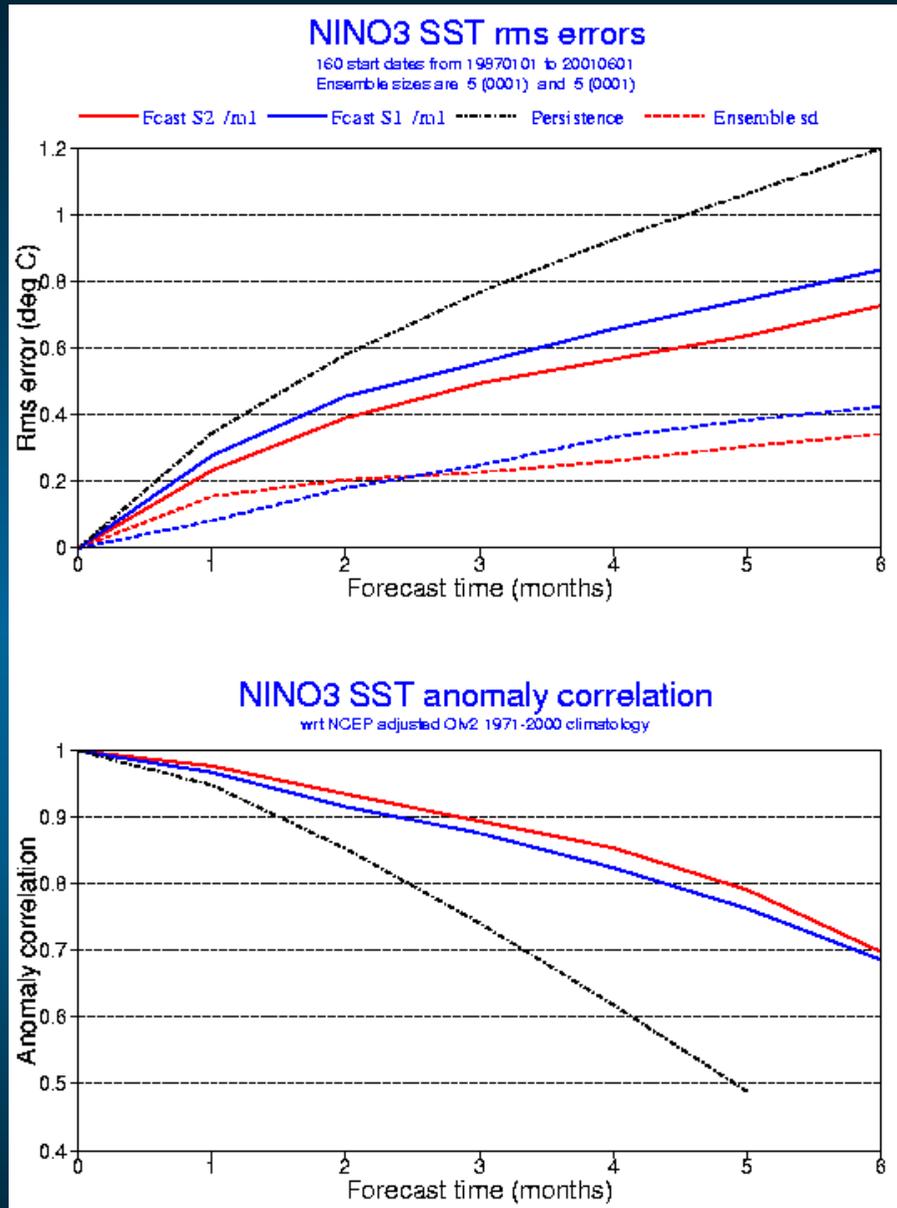
Forecast production date: 14.05/2003



# 2 m temperature anomalies JJA 2003



# Forecast is not reliable: RMS > Spread

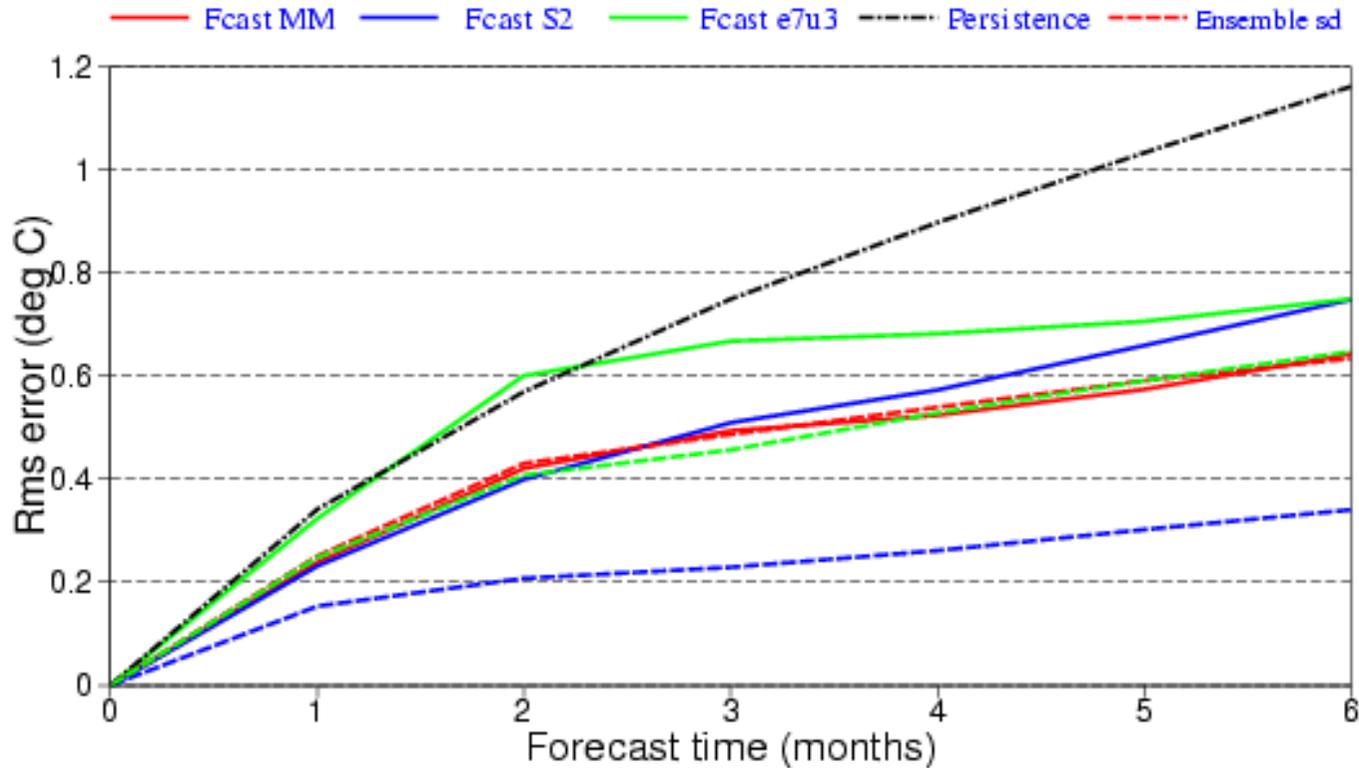


↓ reduce the error  
↑ Increase the spread



# NINO3 SST rms errors

176 start dates from 19870101 to 20010601  
Ensemble sizes are 10 (MM), 5 (0001) and 5 (e7u3)



ECMWF

UKMO

Multi-Model

Multi-model:

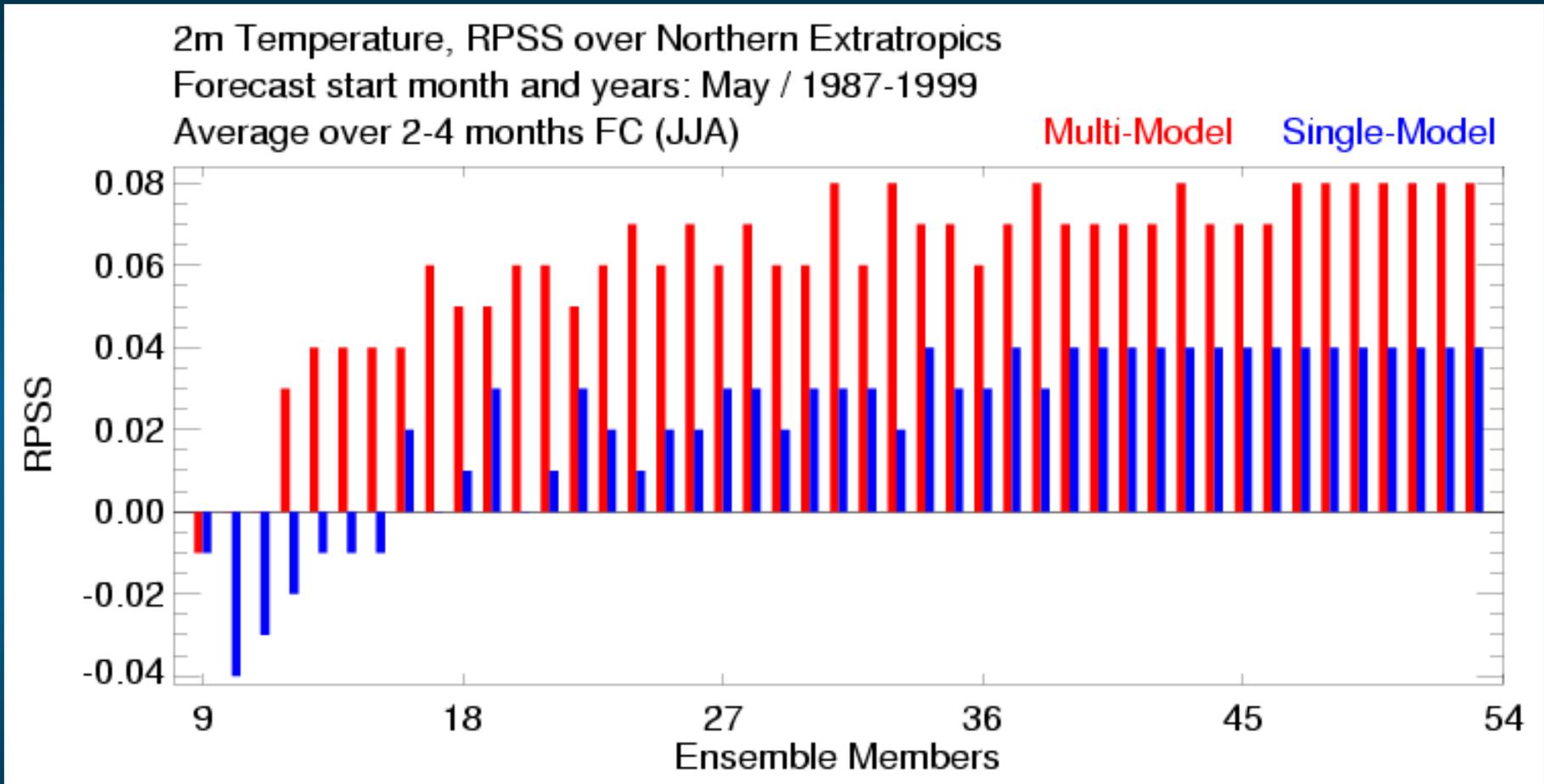
**RMS=SPREAD !!**

and RMS is reduced





# Impact of ensemble size



From Demeter

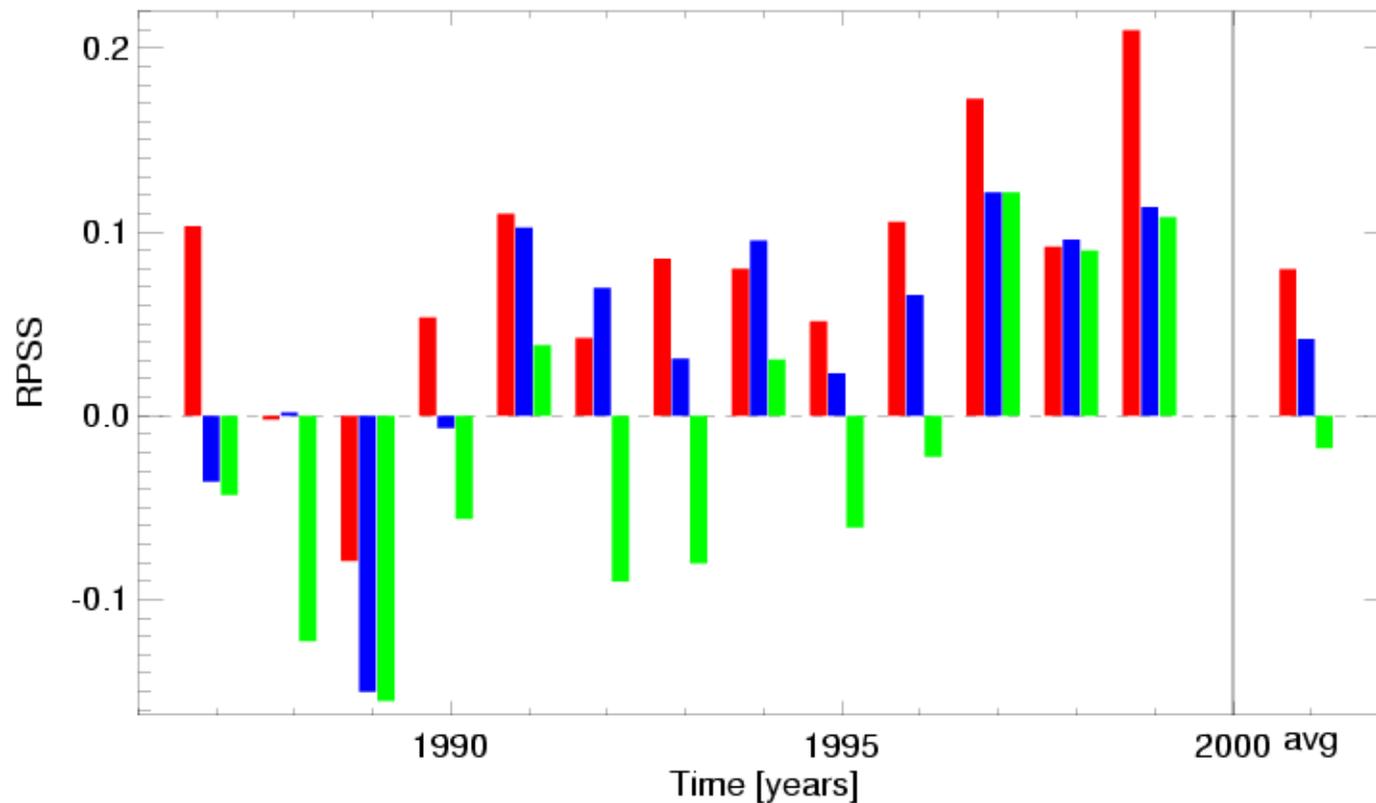


2m Temperature, RPSS over Northern Extratropics (land+sea)

Model: DEMETER (54 members) ECMWF (54 members) ECMWF (9 members)

Start dates: May

Avg. over 2-4 months FC (JJA)



- **Coupled ocean-atmosphere integrations:** a 51-member ensemble is integrated for 32 days every 2 weeks.
- **Atmospheric component:** IFS with the latest operational cycle and with a TL159L40 resolution. Initial conditions: ERA40 or operational analysis. Perturbations: singular vectors +stochastic physics.
- **Oceanic component:** HOPE (from Max Plank Institute) with a zonal resolution of 1.4 degrees and 29 vertical levels. Same perturbations as in seasonal forecasting.
- **Ocean-atmosphere coupling:** OASIS (CERFACS). Every time step (1 hour)



## Background statistics:

- 5-member ensemble integrated at the same day and same month as the real-time time forecast over the past 12 years. It is running every 2 weeks (alternatively with real time forecast)

## Verification:

- The monthly forecasting system is running in real-time since 27 March 2002
- 30 cases have been verified.



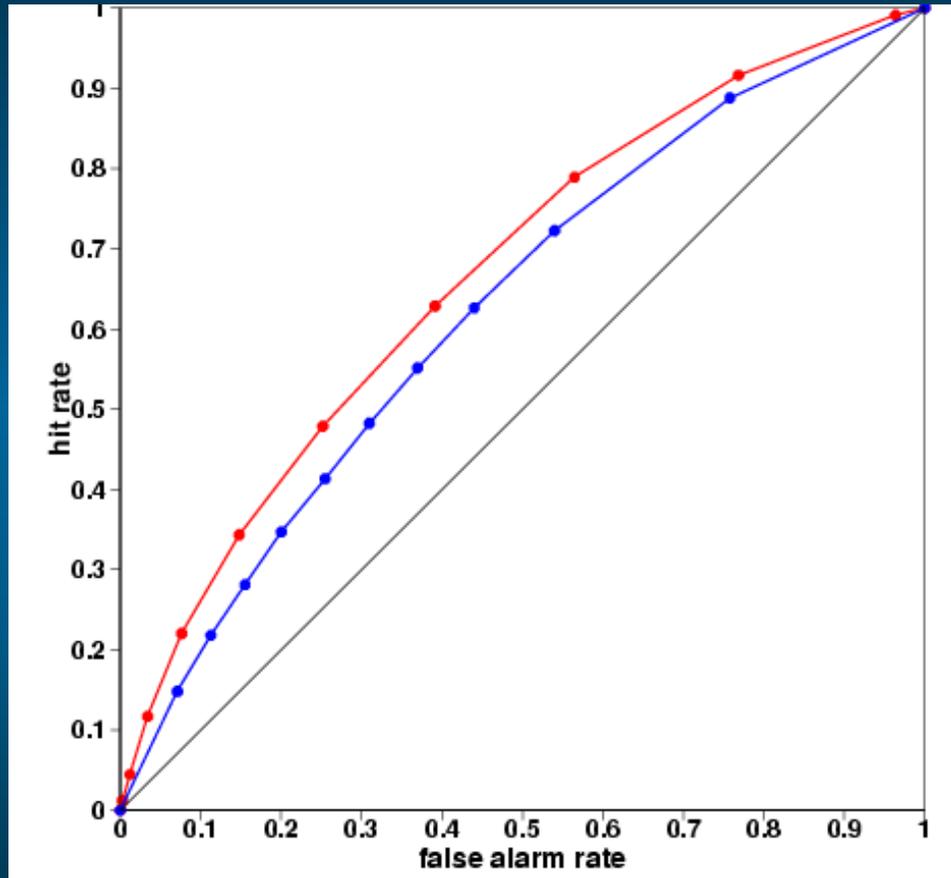
# Comparison with Persistence of day 5-11 probabilities

Days 12-18

Northern Extra-tropics

2mtm in upper tercile

ROC score: 0.67 0.62



Monthly Forecast

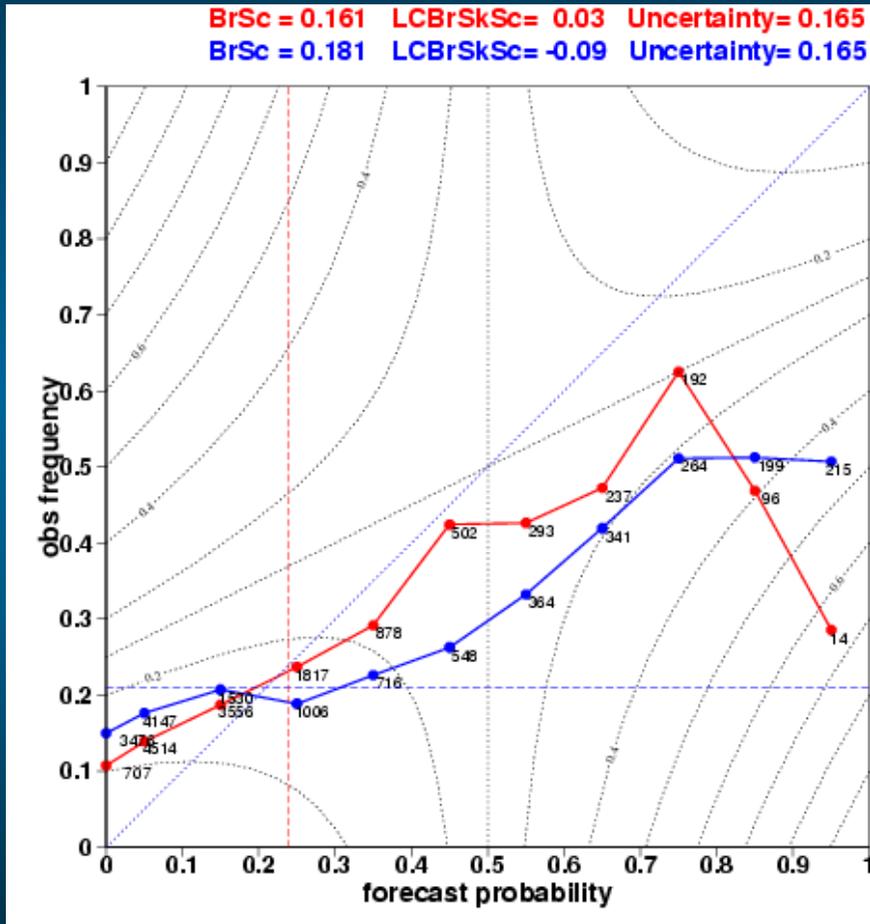
Persistence



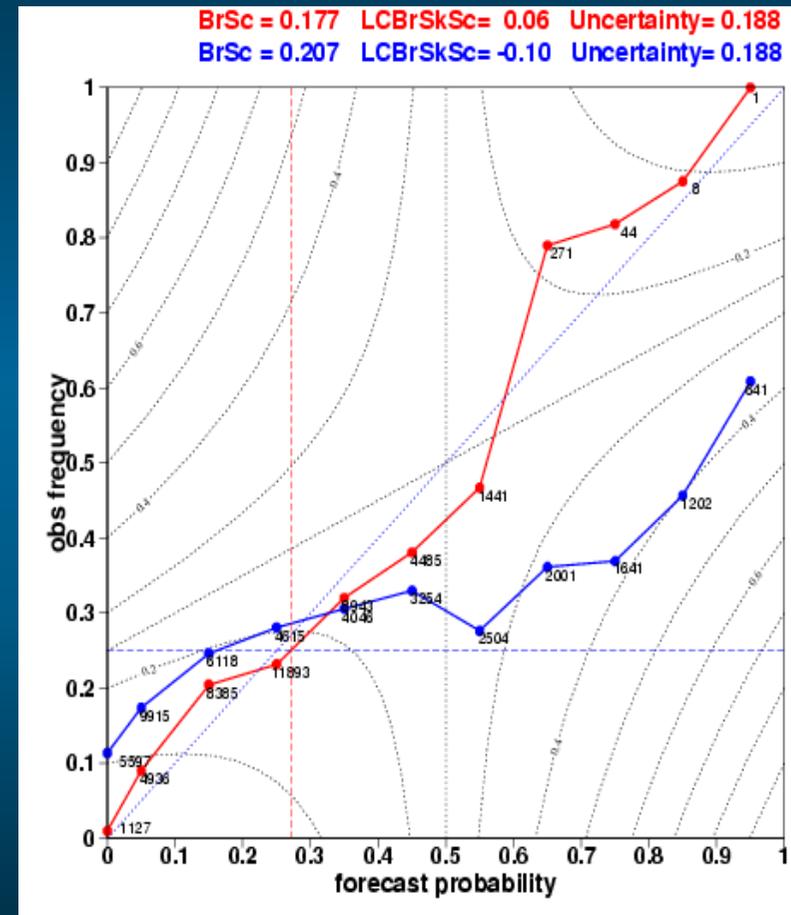
# Days 19-32

2m-temperature weekly anomaly > 2K.

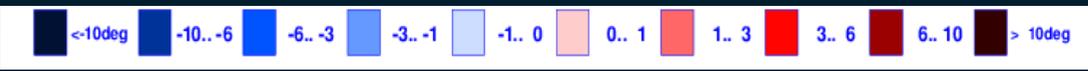
## North America



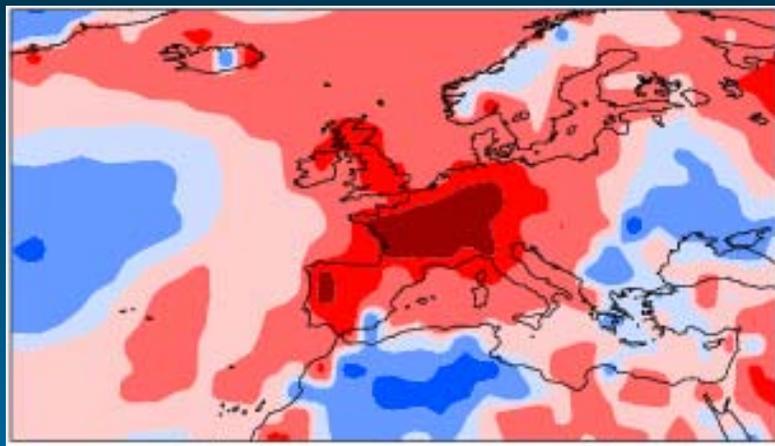
## Southern Hemisphere



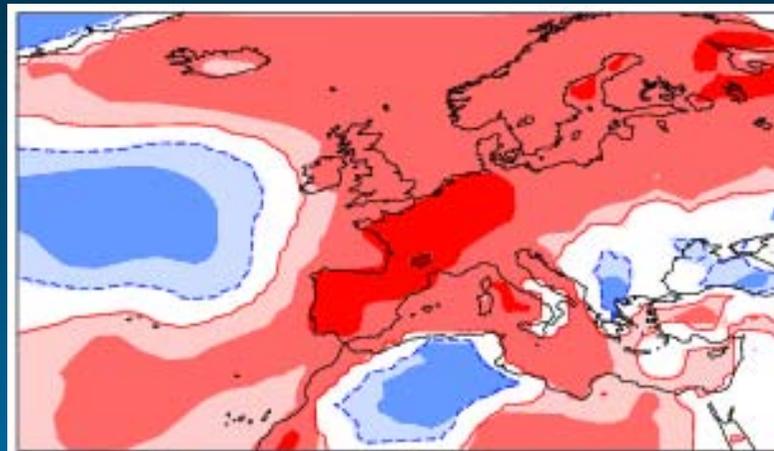
# Last summer heat wave: 2m temp. anomaly



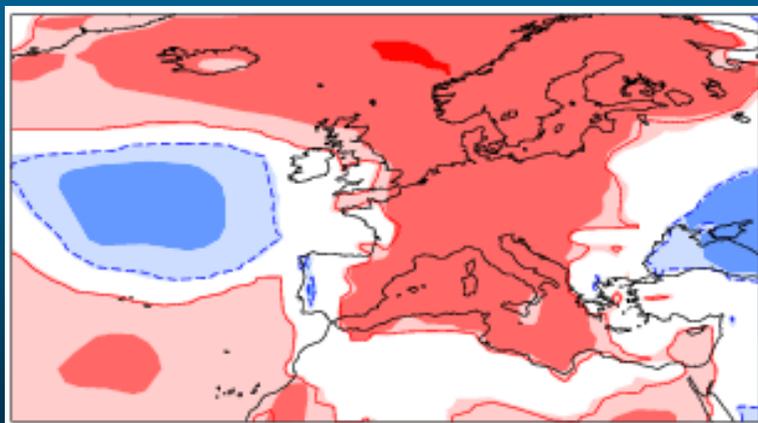
Verification : 3-9 August 2003



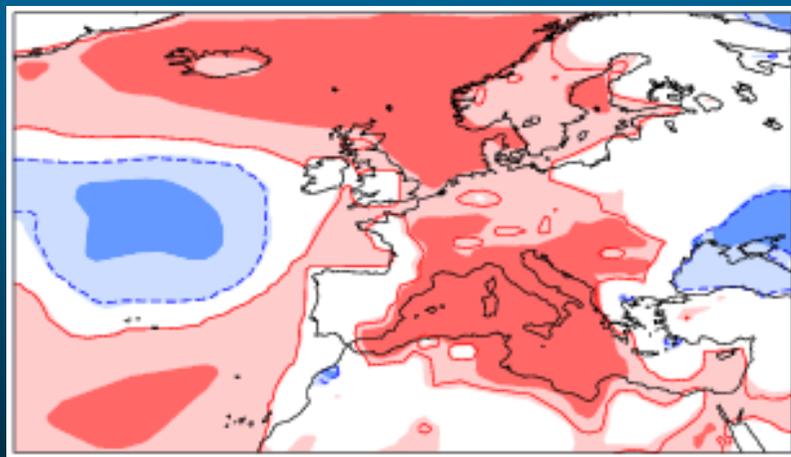
Forecast 30/07: DAYS 5-11



Forecast 25/07: DAYS 12-18



Forecast 16/07: DAYS 19-25

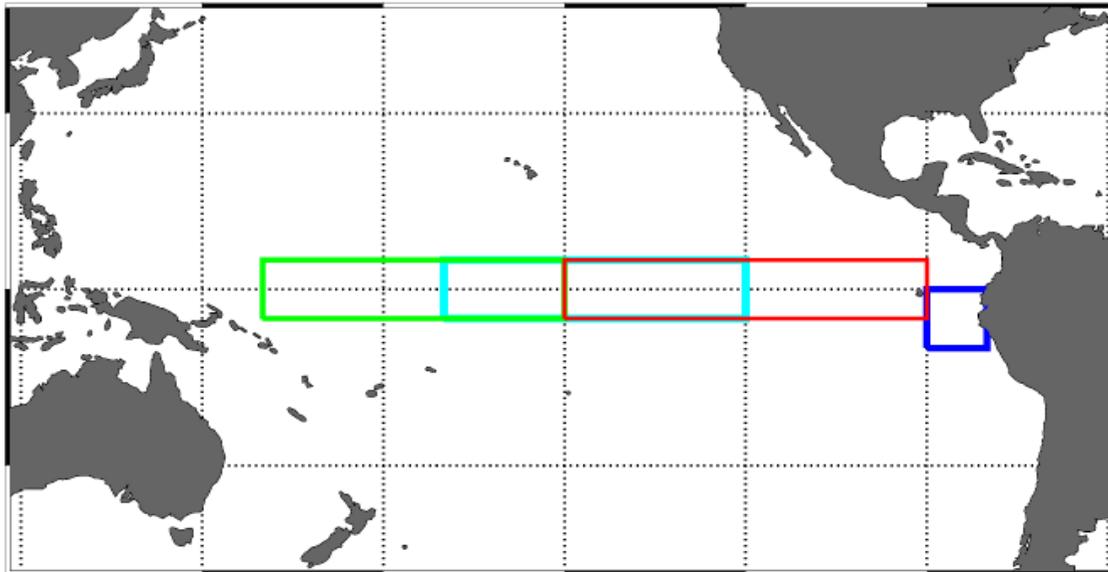


# Summary

- **The current operational seasonal forecast system provide a better data set to the users. Its skill is overall comparable to System 1.**
- **The ECMWF seasonal forecast is a good system for El Nino predictions.**
- **Seasonal forecast predictions, particularly over mid-latitudes, should be used in combination with some estimate of the forecast skill. Various skill estimates are available to the users.**
- **Multi-model approach: a way to deal with model error (model calibration) and to enhance forecast reliability.**
- **Monthly forecast: bridging the gap between the medium and long range forecasts**



Nino3.4, Lon = [-170, -120], Lat = [ -5, 5]  
Nino12, Lon = [ -90, -80], Lat = [-10, 0]  
Nino4, Lon = [ 160, -150], Lat = [ -5, 5]  
Nino3, Lon = [-150, -90], Lat = [ -5, 5]



# IFS/HOPE coupled model (1)

## HOPE

- High resolution ( $0.3^\circ$  meridional at equator, and  $1^\circ \times 1^\circ$  in midlatitudes)
- 1 h time step
- SST coming from NCEP (Reynolds OI version 2)
- Relaxation to climatological SSS (~1 year)
- PGT vertical mixing
- Damped persistent sea-ice anomalies relaxed in 2 months to SSMI climatology

## OASIS

- No flux correction
- 24 h coupling

## IFS

- Cycle 23R4
- T95L40
- 1 h time step
- Semi-Lagrangian advection
- Tiling scheme
- New snow scheme
- Monthly albedo evolution
- Improved vegetation characteristics
- RRTM longwave radiation scheme
- Jakob and Klein cloud and precipitation scheme



# Generation of Perturbations

## Wind

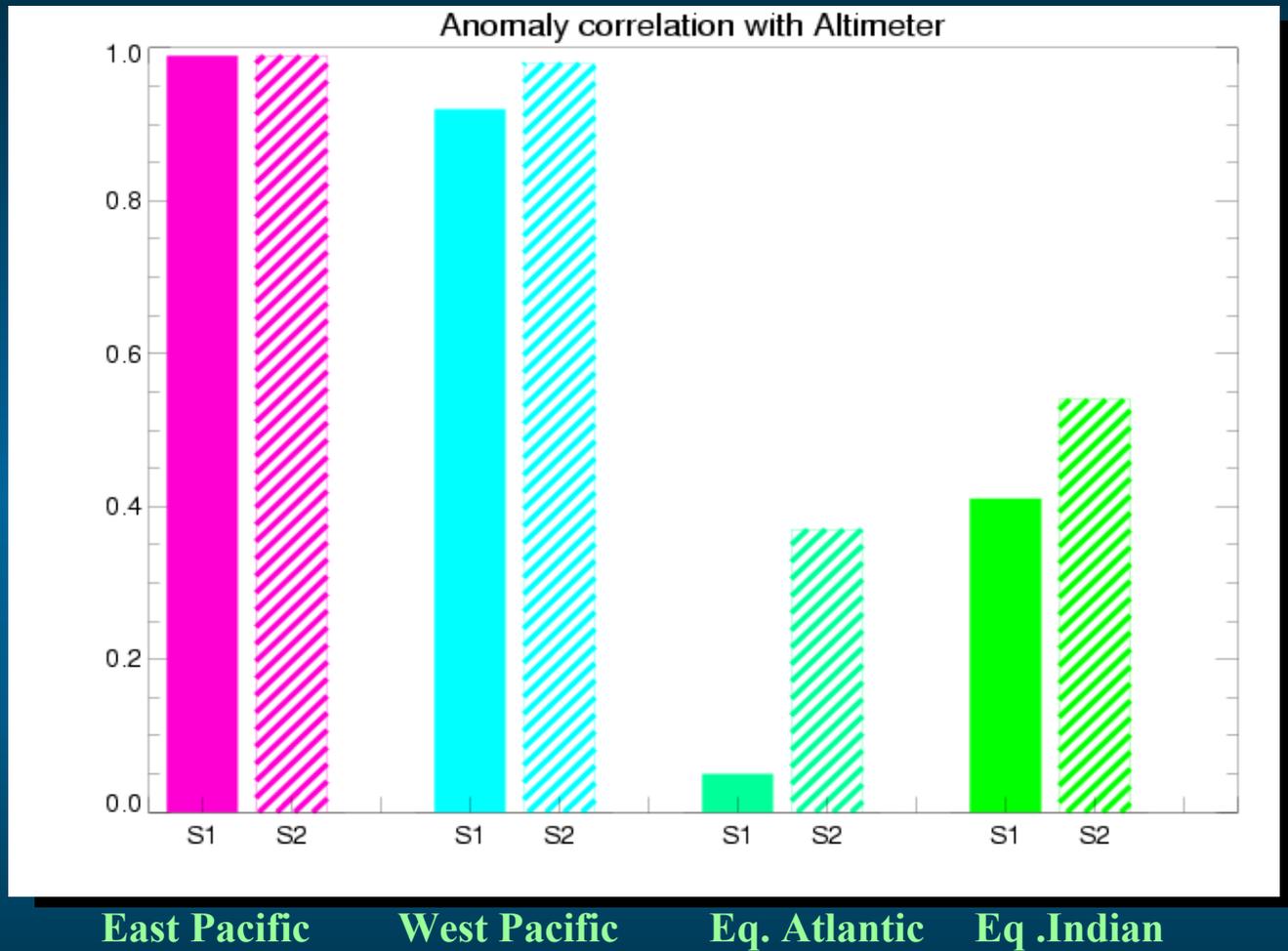
- Represent uncertainties in the wind stress analysis:
  - SOC - ECMWF monthly means (1980-2000)
- 1 month decorrelation scale
- Applied during ocean analysis
  - They affect the subsurface structure of the ocean

## SST

- Represent uncertainty in SST analysis:
  - Reynolds OI - Reynolds 2Dvar
- Represent error in temporal resolution:
  - 1 week persistence error
- Perturbations represent weekly values
  - Weekly climatology removed
- Applied at forecast initial time over the mixed layer



# Ocean Analysis

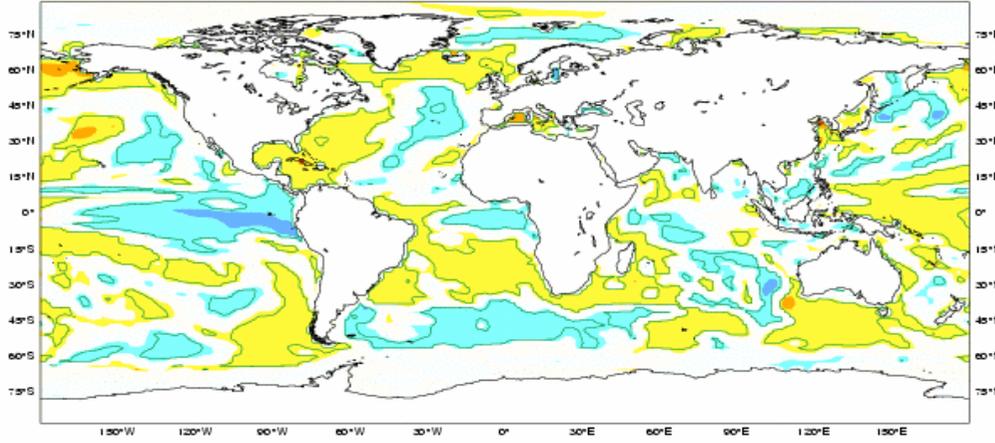


ECMWF Seasonal Forecast  
Mean forecast SST anomaly

Forecast start reference is 01/05/03  
Ensemble size = 40, climate size = 75

System  
JJA 2003

Shaded areas significant at 10% level  
Solid contour at 1% level

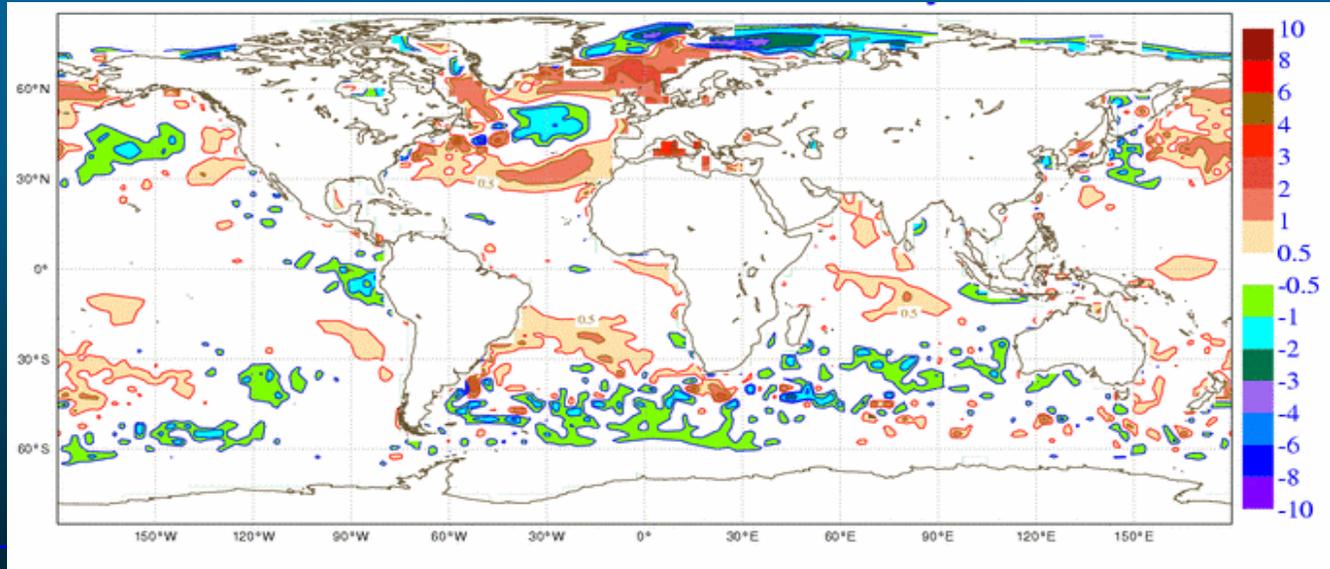


Forecast production date: 14/05/2003



# SST anomalies from Analysis (1987-2001)

## SST forecast



# UKMO predictions for JJA 2003

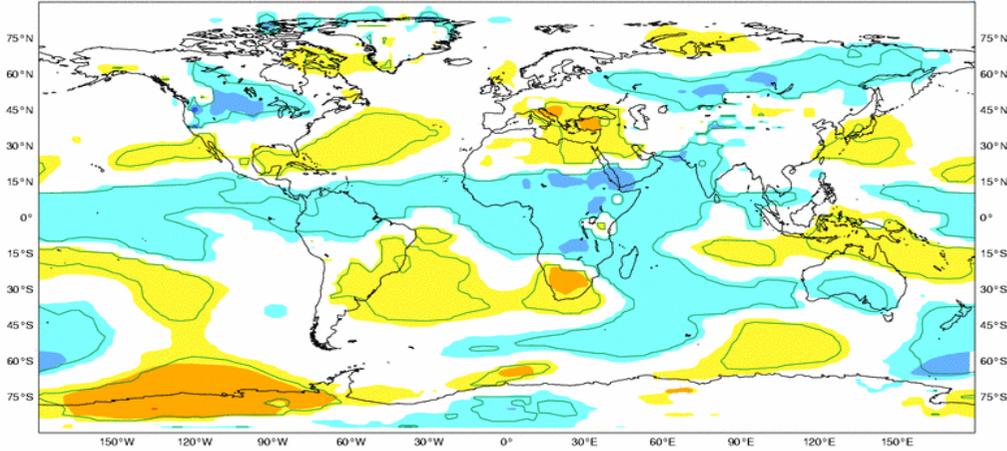
eaqk

Mean T850 anomaly

Forecast start reference is 01/05/03  
Ensemble size = 40, climate size = 75

JJA 2003

Shaded areas significant at 10% level  
Solid contour at 1% level



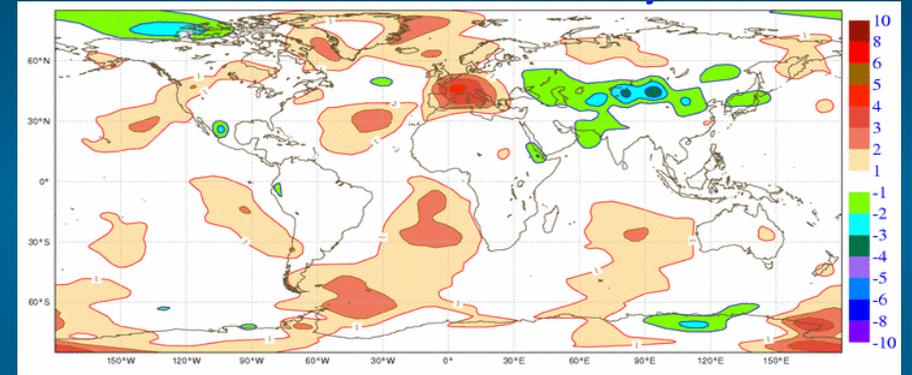
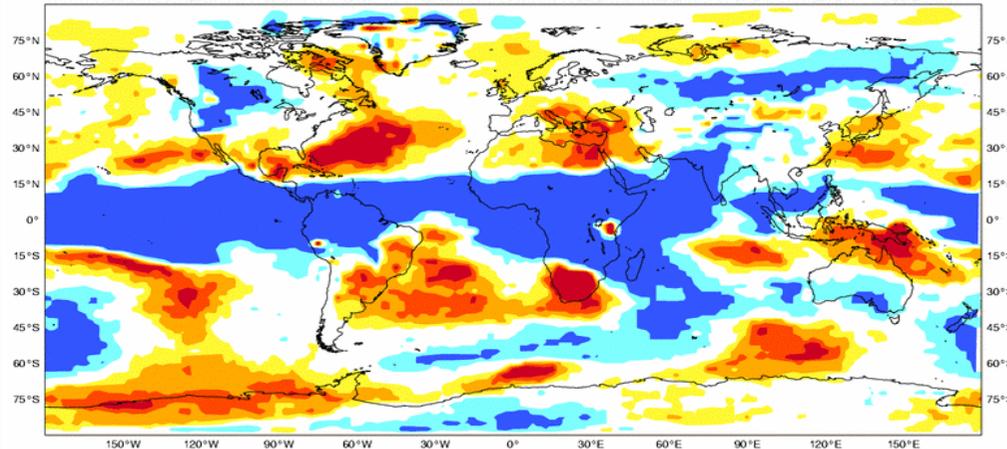
eaqk

Prob(upper tercile) - T850

Forecast start reference is 01/05/03  
Ensemble size = 40, climate size = 75

JJA 2003

No significance test applied



# Multi-model predictions for JJA 2003

## ECMWF Multi-model Seasonal Forecast

Prob(lower tercile) - T850

Forecast start reference is 01/05/03

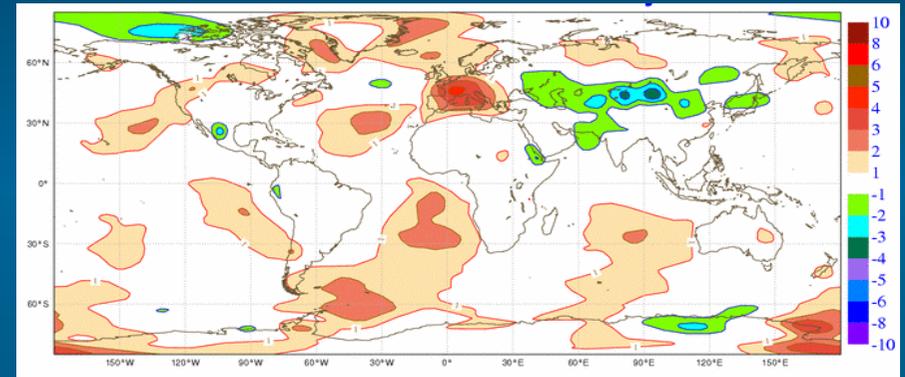
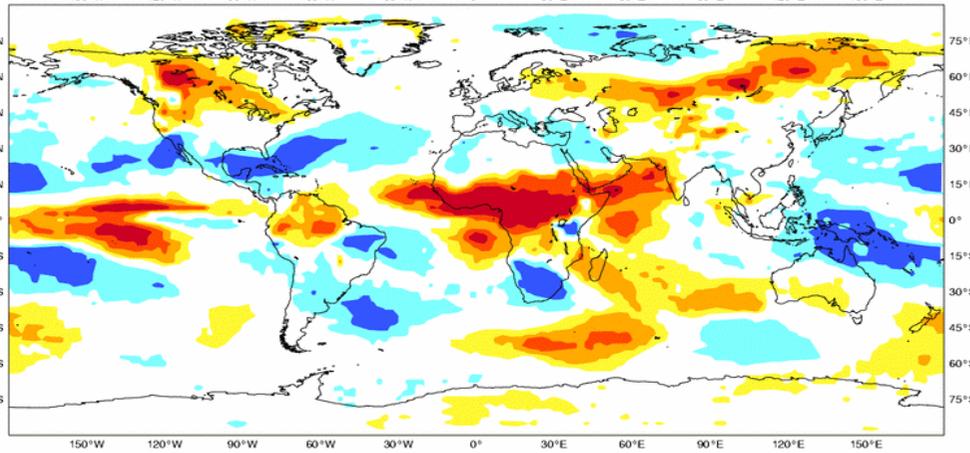
Ensemble size = 40, climate size = 75

ECMWF(S2)/UKMO

JJA 2003

No significance test applied

0..10% 10..20% 20..40% 40..50% 50..60% 60..70% 70..100%



## ECMWF Multi-model Seasonal Forecast

Prob(upper tercile) - T850

Forecast start reference is 01/05/03

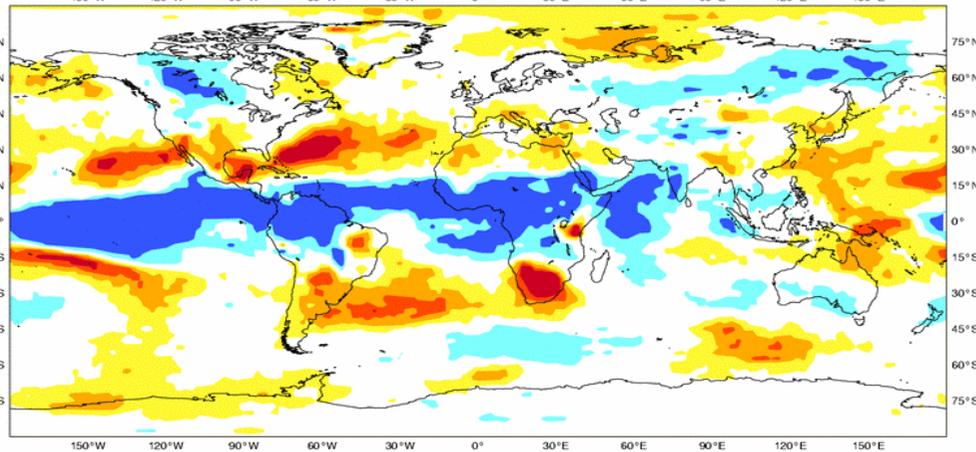
Ensemble size = 40, climate size = 75

ECMWF(S2)/UKMO

JJA 2003

No significance test applied

0..10% 10..20% 20..40% 40..50% 50..60% 60..70% 70..100%



### ECMWF Seasonal Forecast

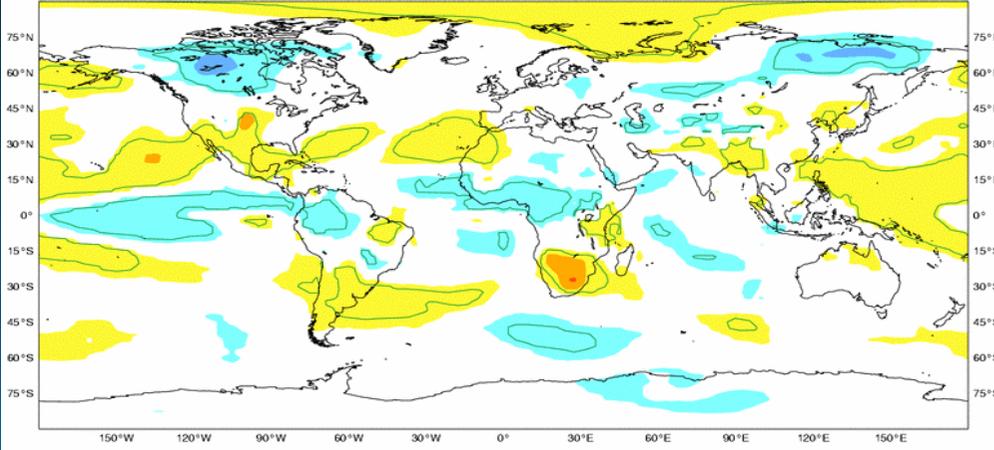
#### Mean T850 anomaly

Forecast start reference is 01/05/03  
Ensemble size = 40, climate size = 75

### System 2

#### JJA 2003

Shaded areas significant at 10% level  
Solid contour at 1% level



# Temperature 850 anomalies JJA 2003

### ECMWF Seasonal Forecast

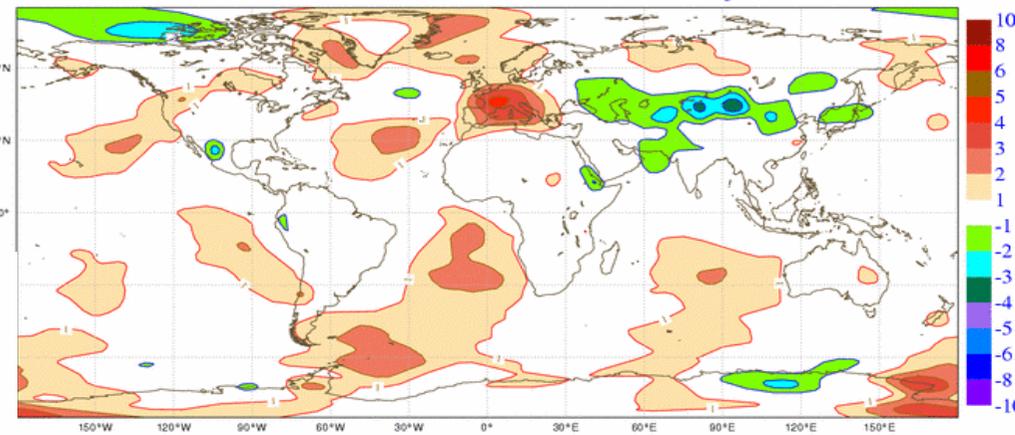
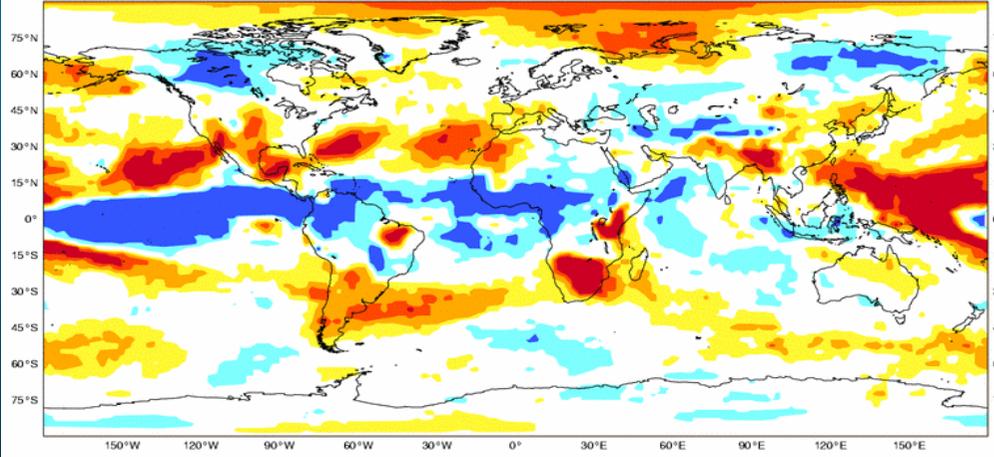
#### Prob(upper tercile) - T850

Forecast start reference is 01/05/03  
Ensemble size = 40, climate size = 75

### System 2

#### JJA 2003

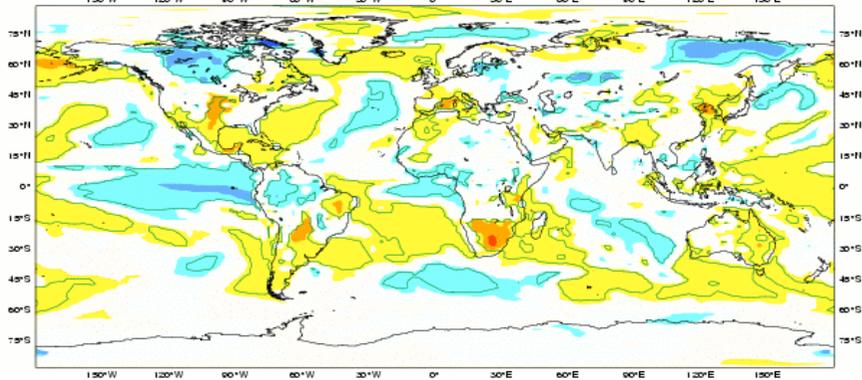
No significance test applied



ECMWF Seasonal Forecast  
 Mean 2m temperature anomaly  
 Forecast start reference is 01/05/03  
 Ensemble size = 40, climate size = 75

System  
 JJA 2003  
 Shaded areas significant at 10% level  
 Solid contour at 1% level

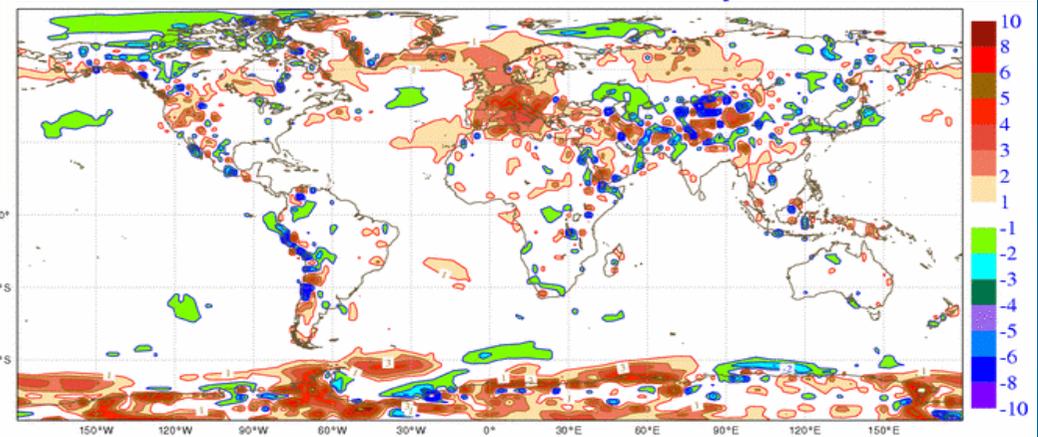
Legend: < -4 °C, -4 .. -2, -2 .. -1, -1 .. 0, No Signal, 0 .. 1, 1 .. 2, 2 .. 4, > 4 °C



Forecast production date: 14.05/2003



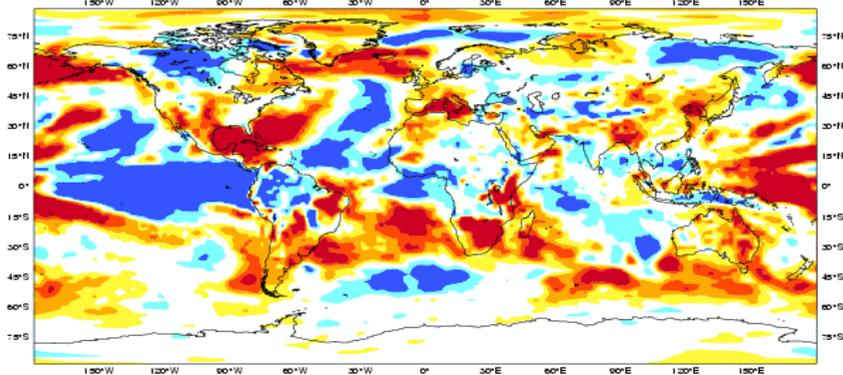
## 2m Temperature anomalies JJA 2003



ECMWF Seasonal Forecast  
 Prob(upper tercile) - 2m temperature  
 Forecast start reference is 01/05/03  
 Ensemble size = 40, climate size = 75

System  
 JJA 2003  
 No significance test applied

Legend: 0..10%, 10..20%, 20..40%, 40..50%, 50..60%, 60..70%, 70..100%



Forecast production date: 14.05/2003



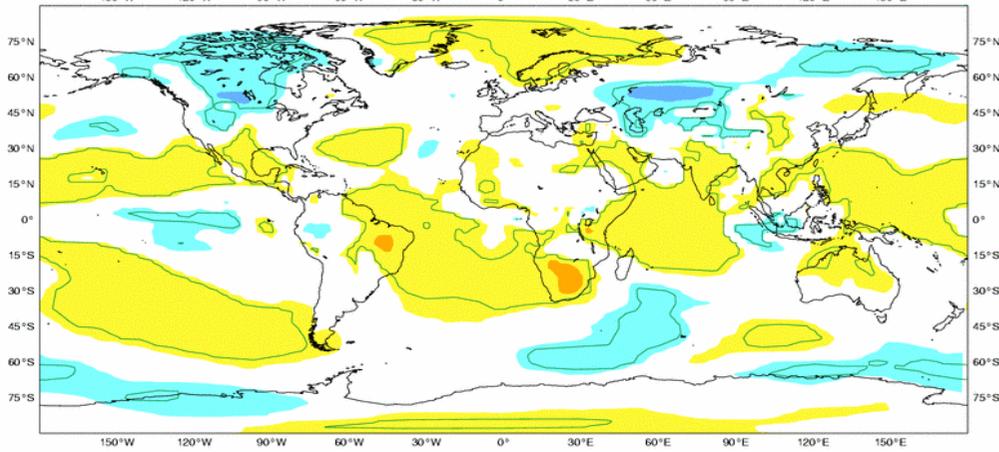
ecrm

### Mean T850 anomaly

Forecast start reference is 01/05/03  
Ensemble size = 40, climate size = 225

JJA 2003

Shaded areas significant at 10% level  
Solid contour at 1% level



**Temperature 850 anomalies from an uncoupled run forced by observed SST JJA 2003**

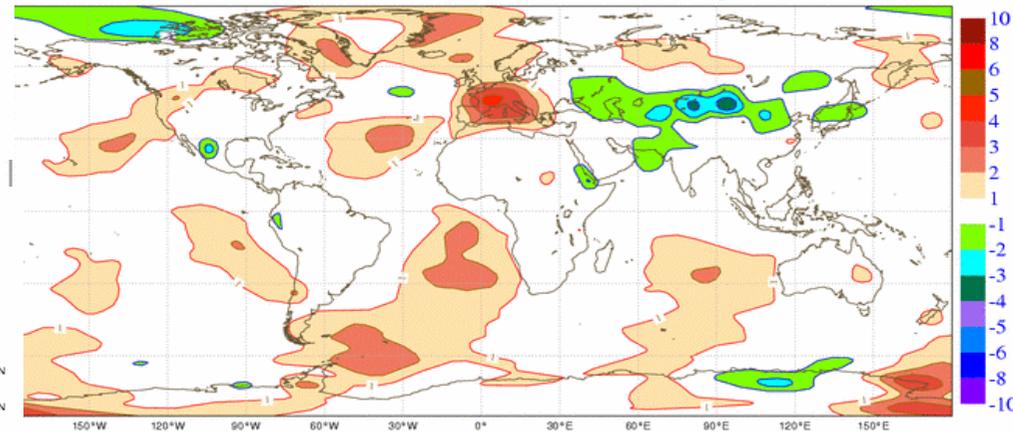
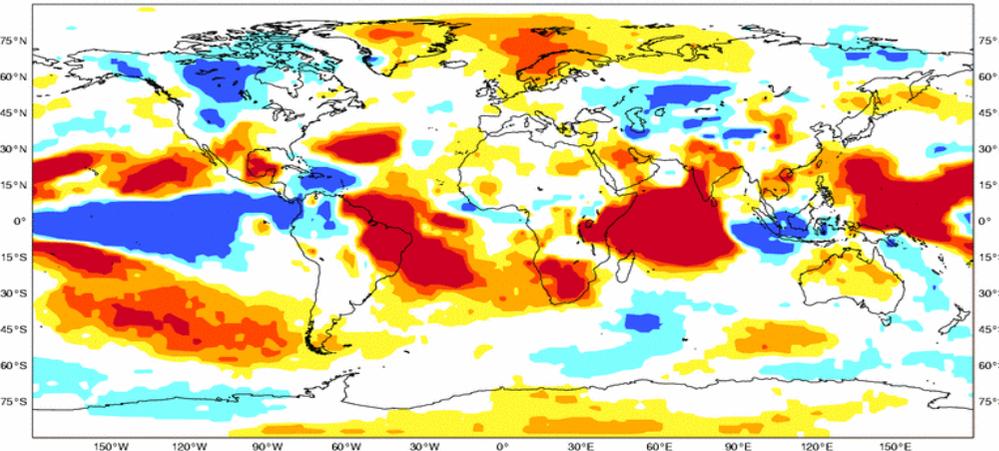
ecrm

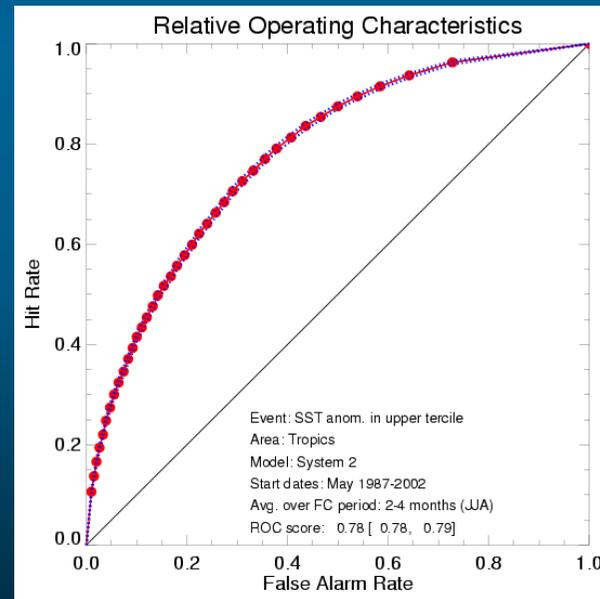
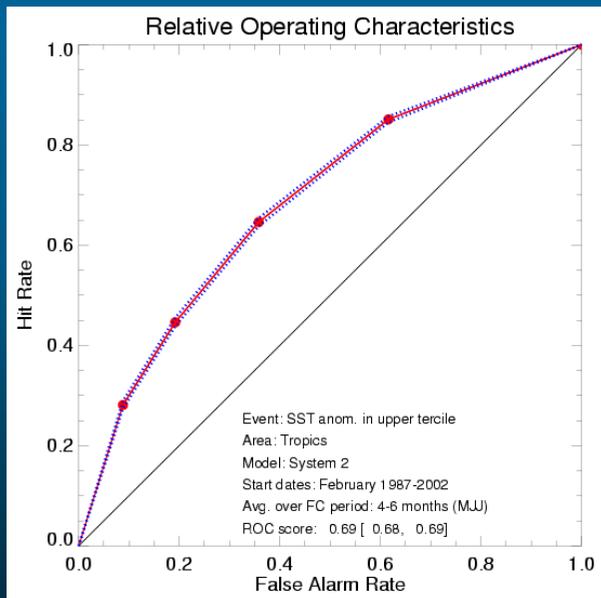
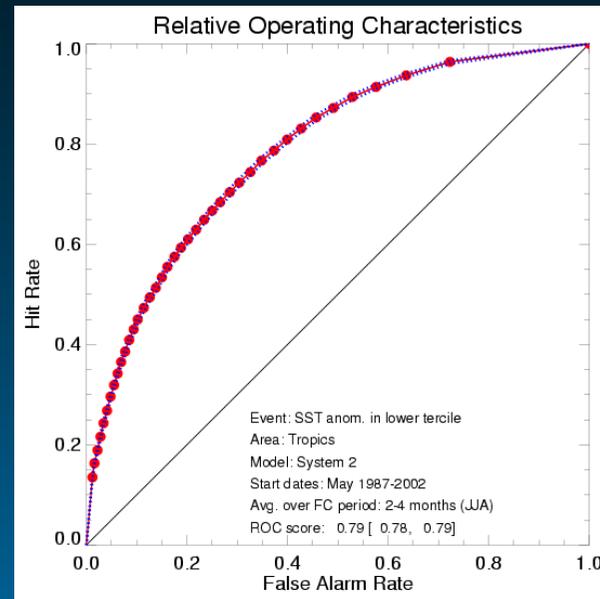
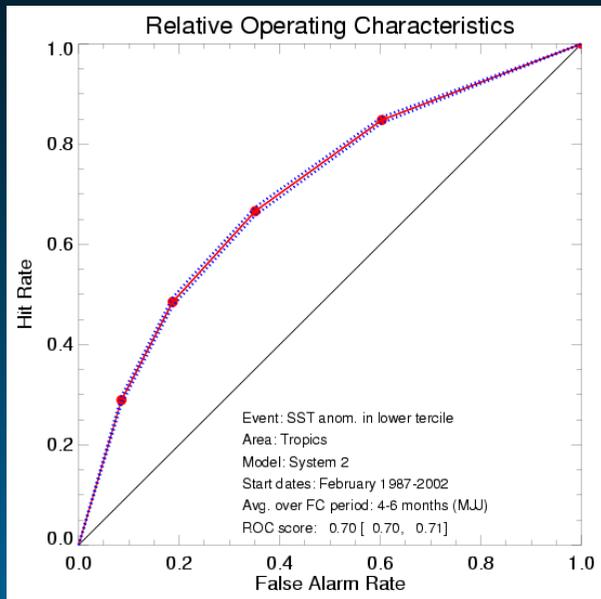
### Prob(upper tercile) - T850

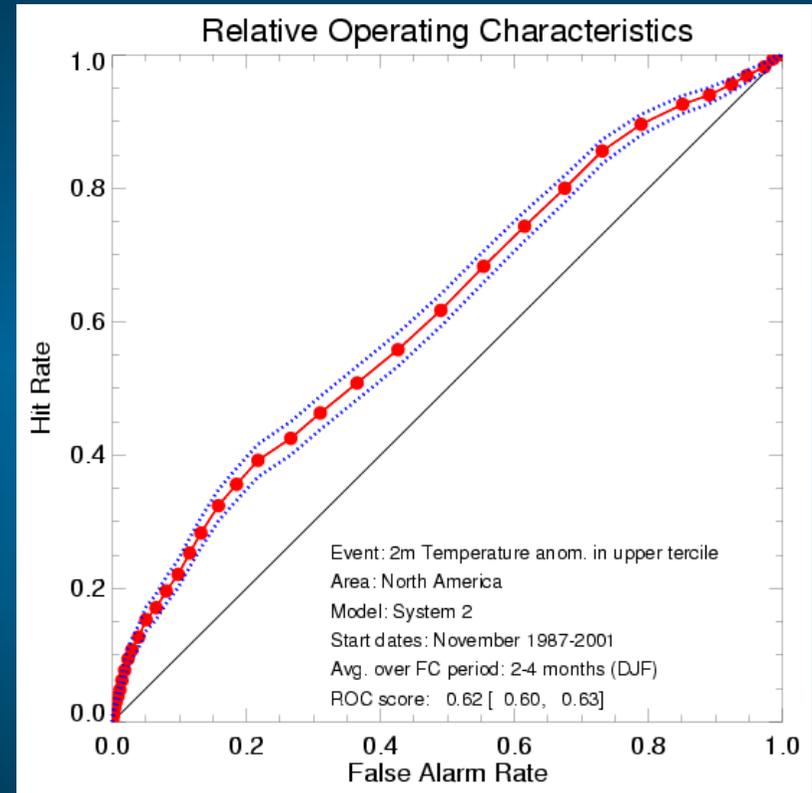
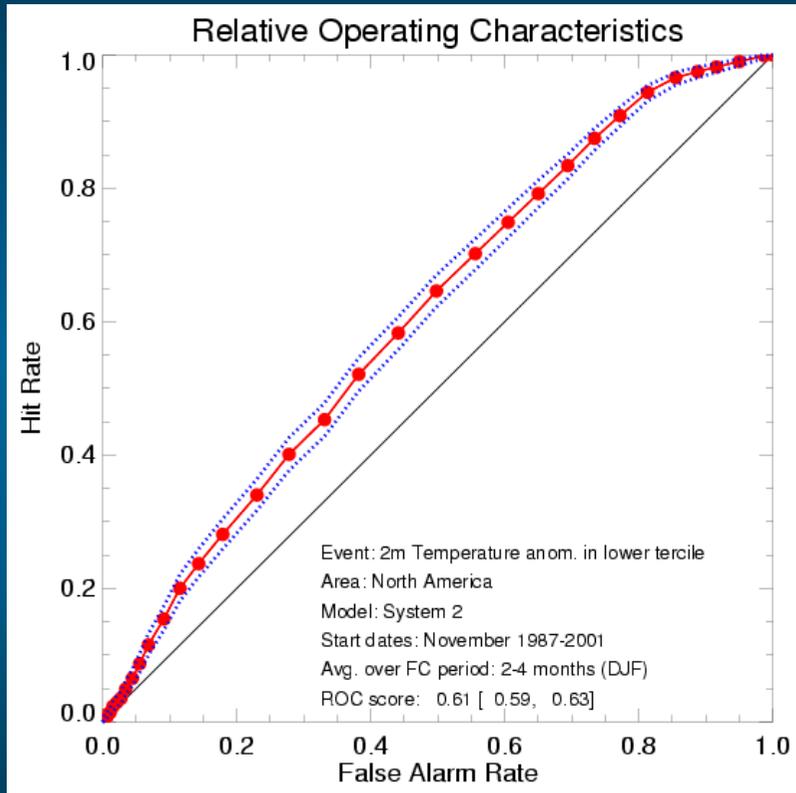
Forecast start reference is 01/05/03  
Ensemble size = 40, climate size = 225

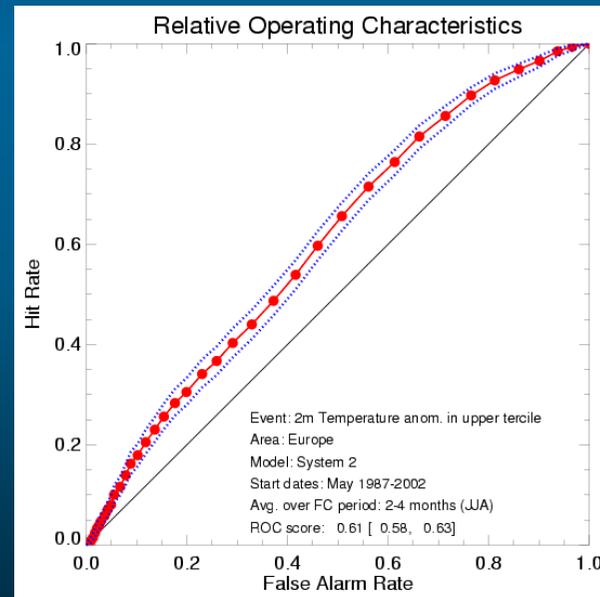
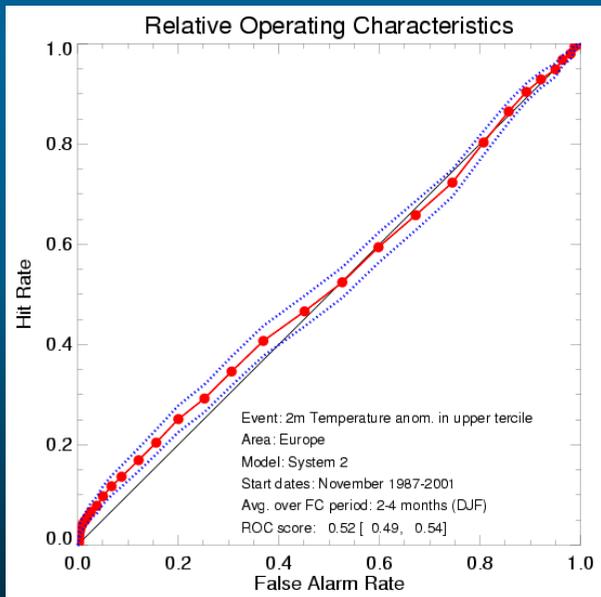
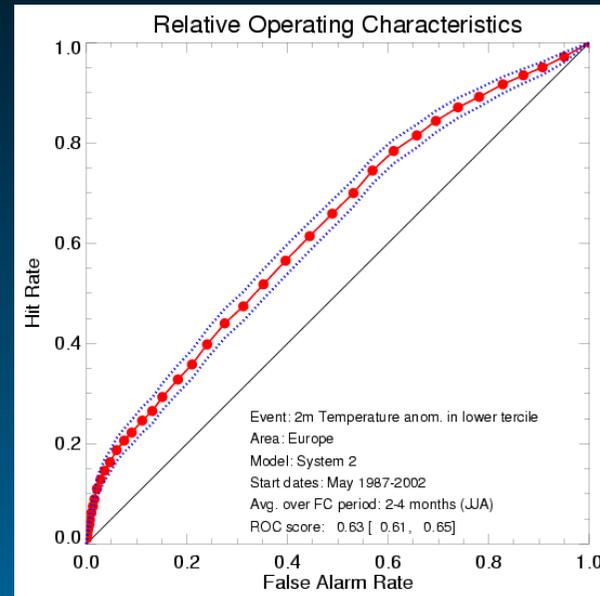
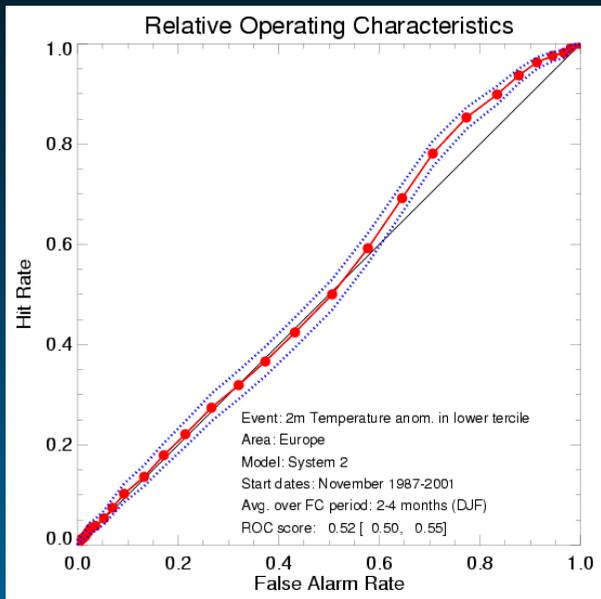
JJA 2003

No significance test applied









# Impact of ensemble size (tropics)

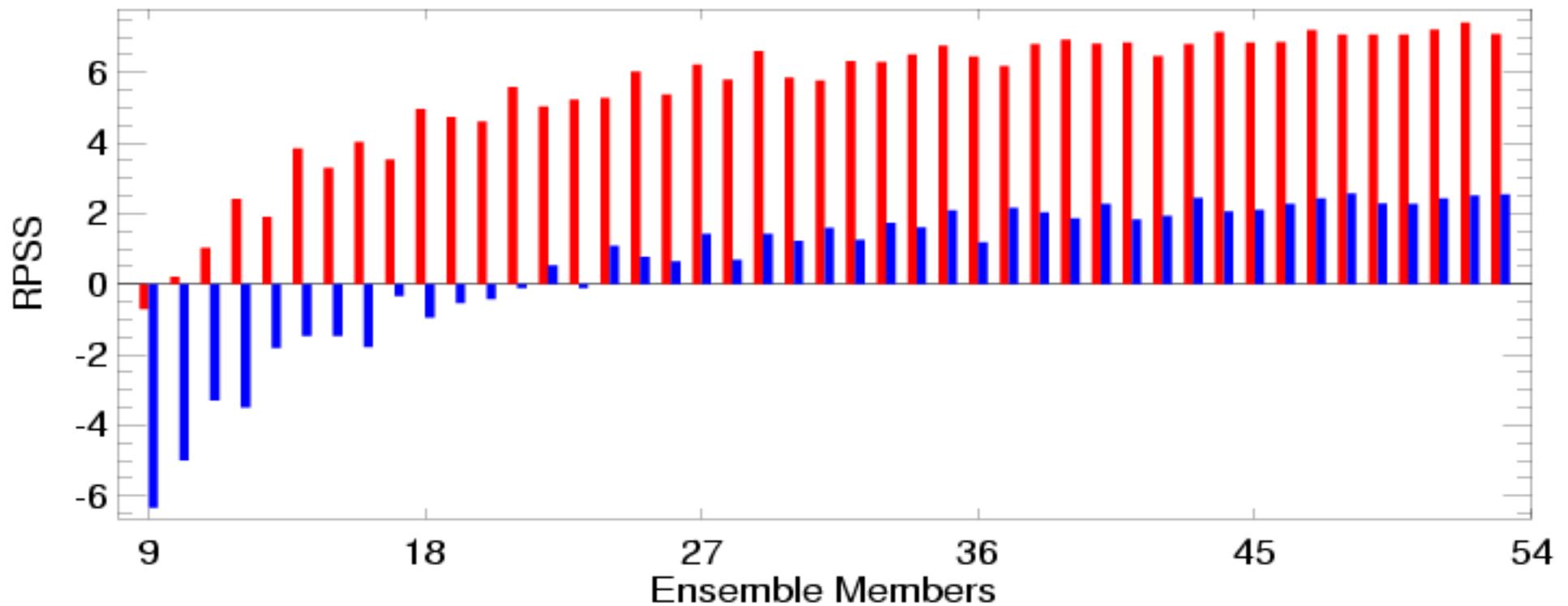
Precipitation, RPSS over Tropics

Forecast start month and years: May / 1987-1999

Average over 2-4 months FC (JJA)

Multi-Model

Single-Model

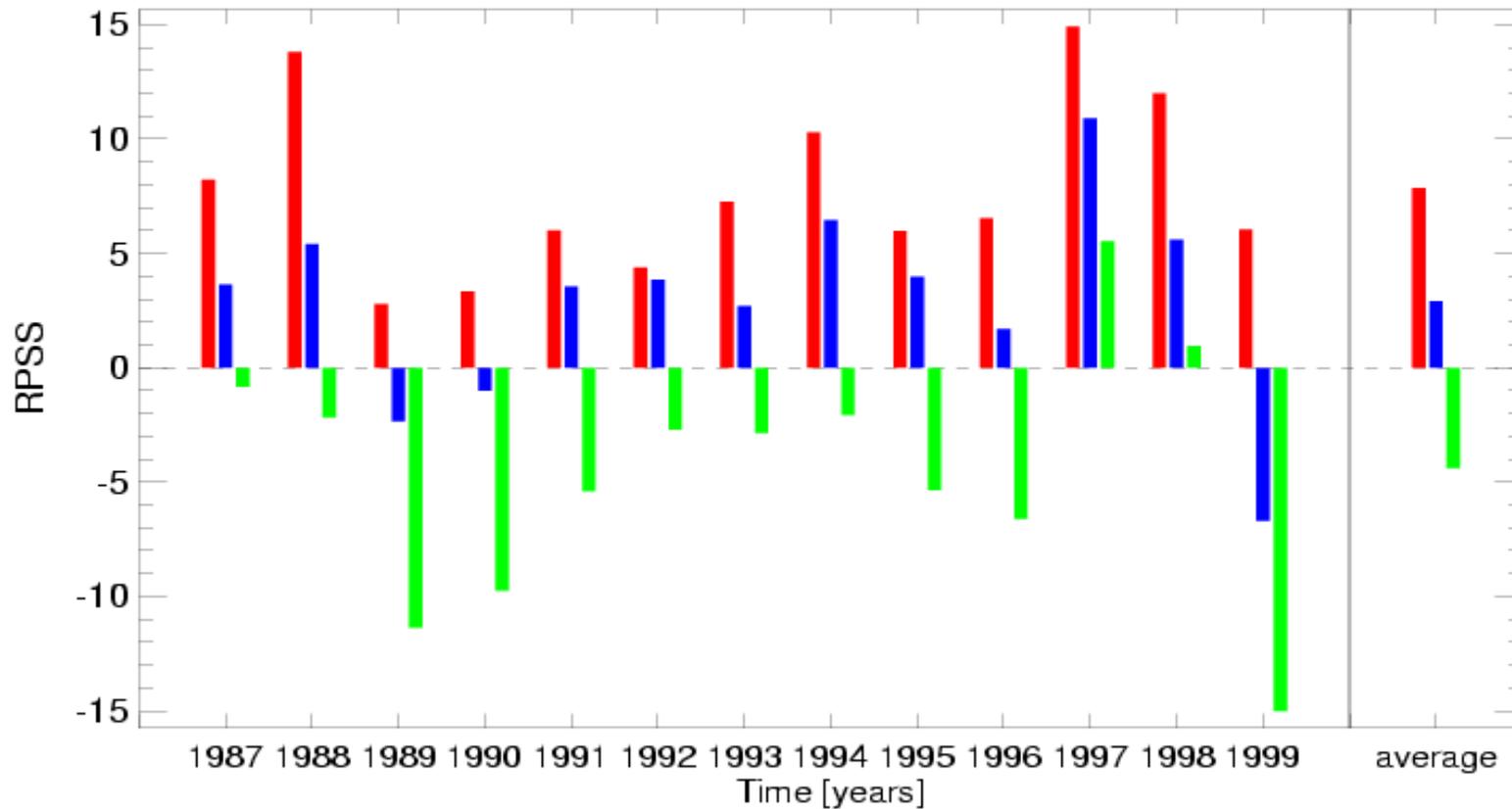


### Precipitation, RPSS over Tropics

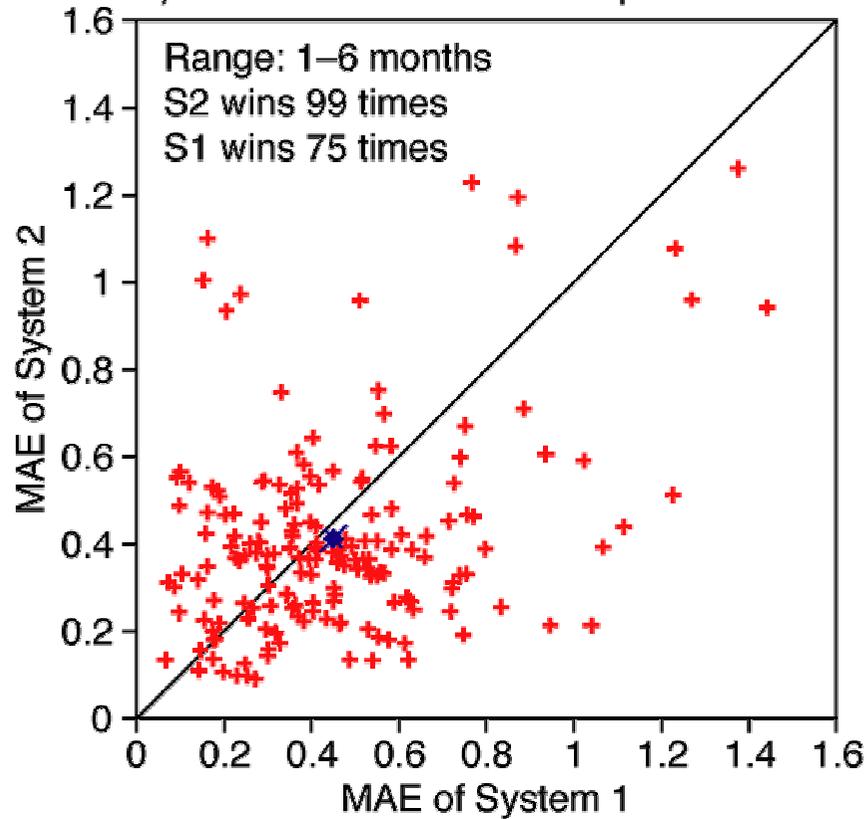
Model: DEMETER II ECMWF\_grande ECMWF\_ctrl

Start dates: May

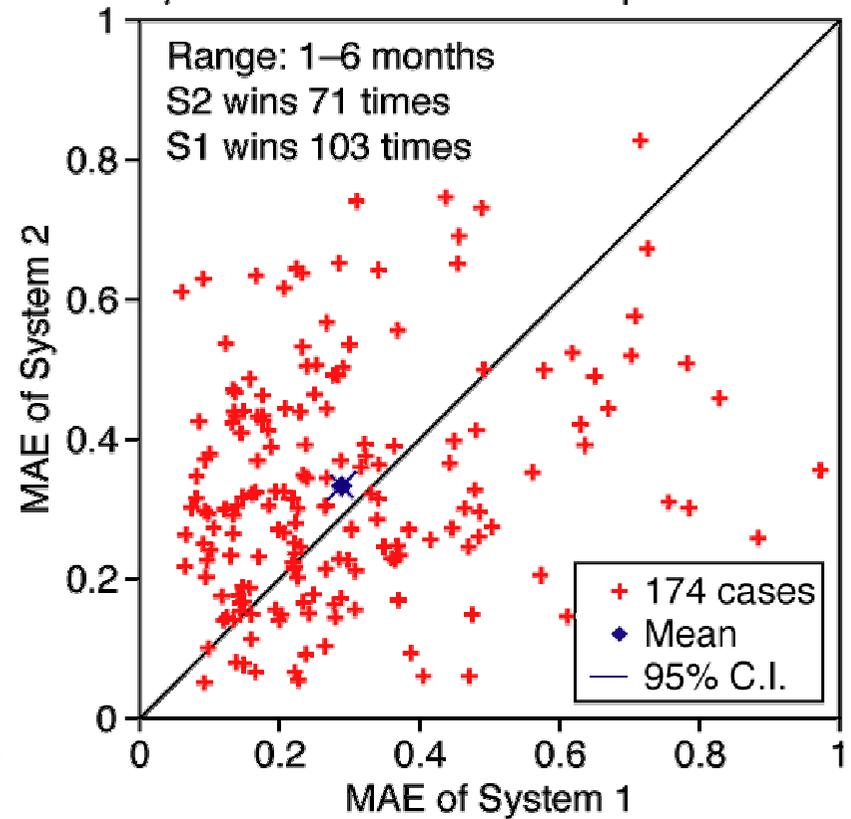
Avg. over 2-4 months FC (JJA)



a) NINO-3 SST error comparison



b) NINO-4 SST error comparison



**Tropical Pacific precipitation**

Model: ECMWF\_oper

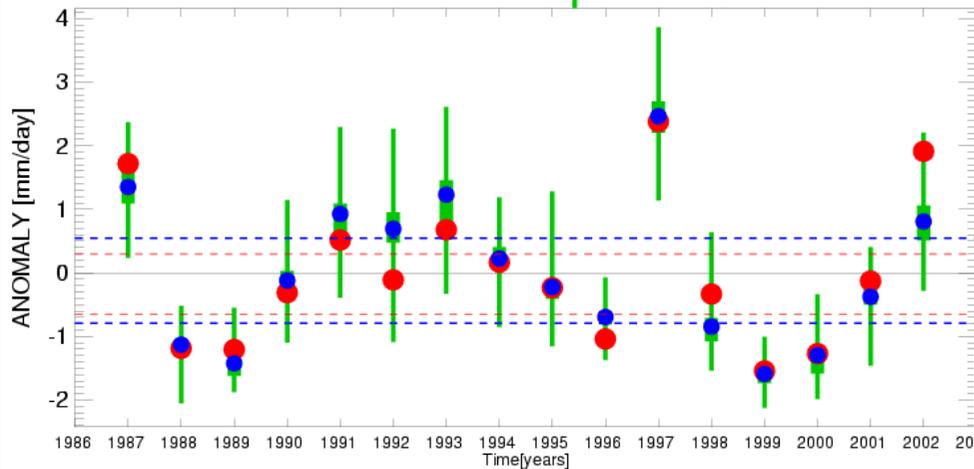
Start dates: May

Avg. over 2-4 months FC (JJA)

Ratio of variance: model/verif.	=	1.03
Signal/Noise ratio [Conf.-Level]	=	2.34 [ 1.00]
RMSE	=	0.65
Correlation [Conf.-Level]	=	0.93 [ 1.00]
RPSS [Conf.-Level]	=	79.59 [ 1.00]

dashed lines: tercile boundaries for whole dataset of GPCP and hindcasts

● GPCP    ● Ensemble-mean    ■ Ensemble Spread / Tercile



**Northern Europe precipitation**

Model: ECMWF\_oper

Start dates: May

Avg. over 2-4 months FC (JJA)

Ratio of variance: model/verif.	=	0.91
Signal/Noise ratio [Conf.-Level]	=	0.49 [ 0.00]
RMSE	=	0.47
Correlation [Conf.-Level]	=	0.45 [ 0.72]
RPSS [Conf.-Level]	=	14.84 [ 1.00]

dashed lines: tercile boundaries for whole dataset of GPCP and hindcasts

● GPCP    ● Ensemble-mean    ■ Ensemble Spread / Tercile

