

The new ECMWF seasonal forecast system (system 4)

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Met. Application - Met. Oper. - Data services

ECMWF, Reading, U.K.

In 1995 ECMWF started an experimental programme in seasonal forecasting. Successful predictions of the exceptional El Nino event of 1997 encouraged the Council to support the seasonal forecast activity

- Operational phase started in 2002 with S.F. System 2
- EUROSIP multi-model system with MF and UKMO (2005)
- In 2007 was implemented S.F. System3

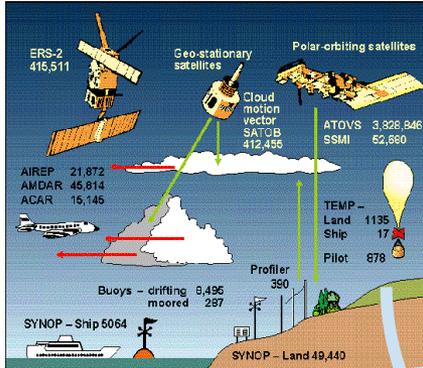
Coupled model IFS-OASIS-HOPE, OI ocean d.a.

November 2011 System 4 is the new operational S.F.

**New coupled system: IFS-OASIS-NEMO, 3D-var
(NEMOVAR) ocean d.a.**

ECMWF Seasonal Forecasting System

Observations



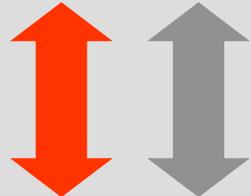
Data Assimilation

Current state of the atmosphere

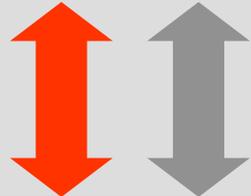
Current state of the ocean

Coupled model

Atmospheric model



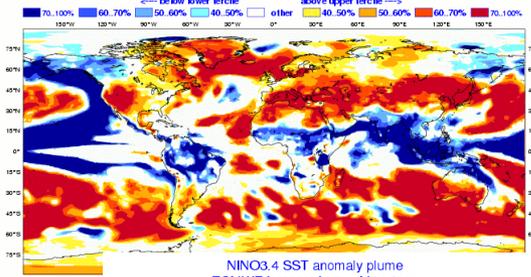
Coupler



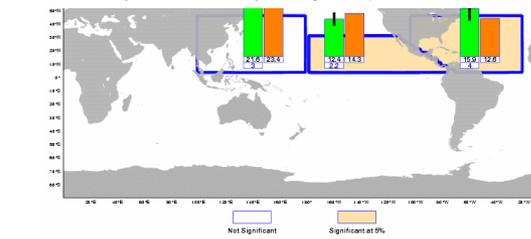
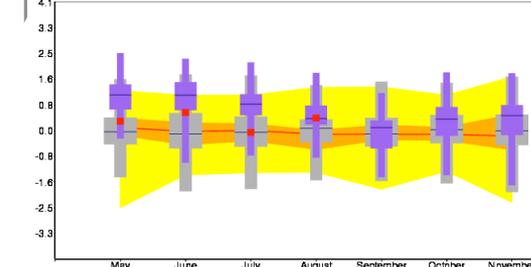
Ocean Model

Forecast Products

ECMWF Seasonal Forecast
Prob(most likely category of 2m temperature)
Forecast start reference 01/01/2008
System 3
JJA 2008
No significance test applied
Ensemble size = 41, climate size = 275



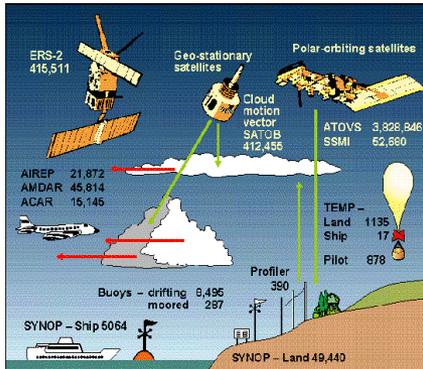
2m temp anomalies (K) latitude= 50.0 to 35.0 longitude= -10.0 to 30.0
Forecast initial date: 2008 501
Ensemble size: Forecast=41 Model climate=275 Analysis climate=25



ECMWF Seasonal Forecasting System

Data Assimilation

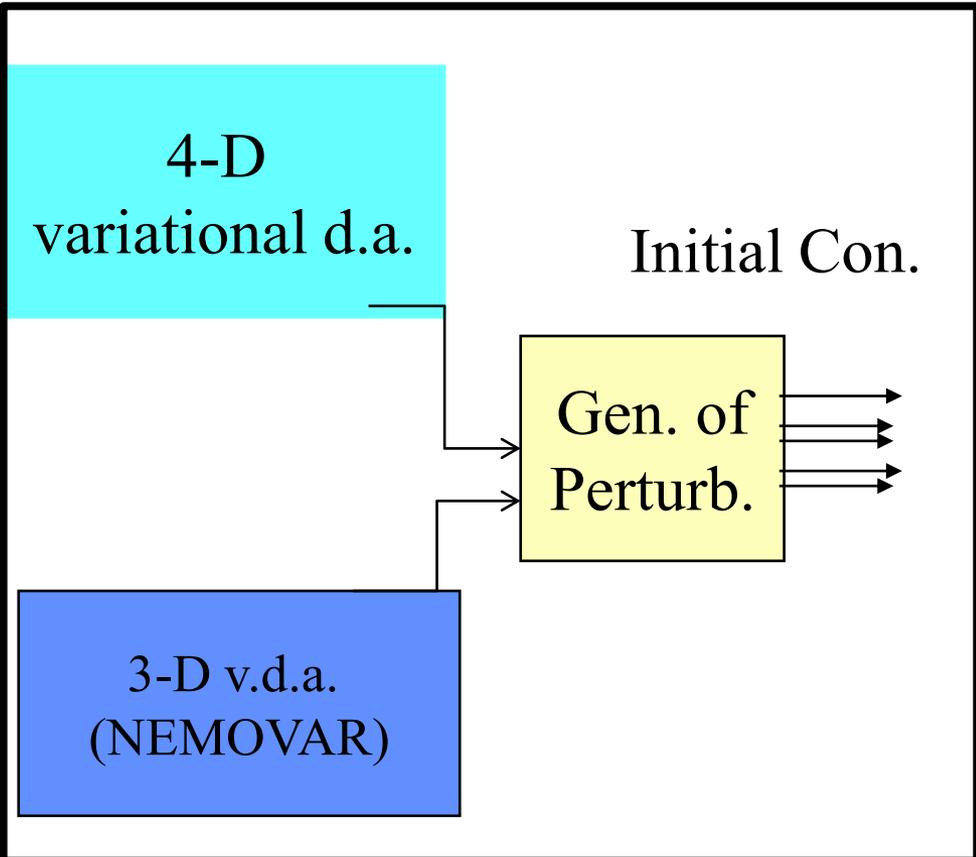
Observations



Current state of the atmosphere

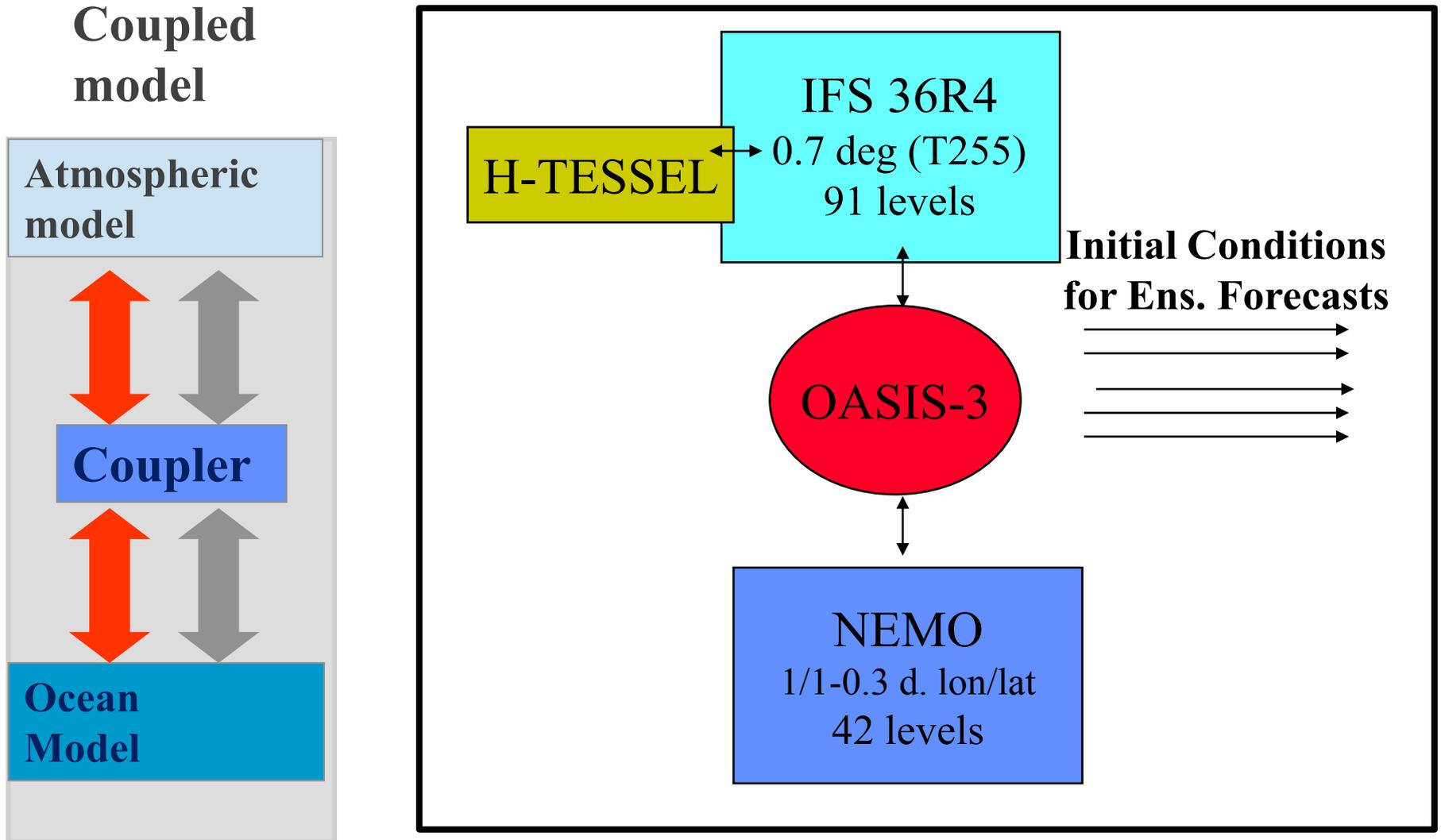
Current state of the ocean

System 4



The ECMWF Seasonal fc. system

System 4



ECMWF System 4: main features

- **Operational forecasts**

- 51-member ensemble from 1st day of the month
- released on the 8th
- 7-month integration

- **Re-forecast set**

- 30 years, start dates from 1 Jan 1981 to 1 Dec 2010
- 15-member ensembles, 7-month integrations
- 13-month extension from 1st Feb/May/Aug/Nov

- **Experimental ENSO outlook**

- 13-month extension from 1st Feb/May/Aug/Nov
- 15-member ensemble

Bias in S4 re-forecasts: SST (DJF)

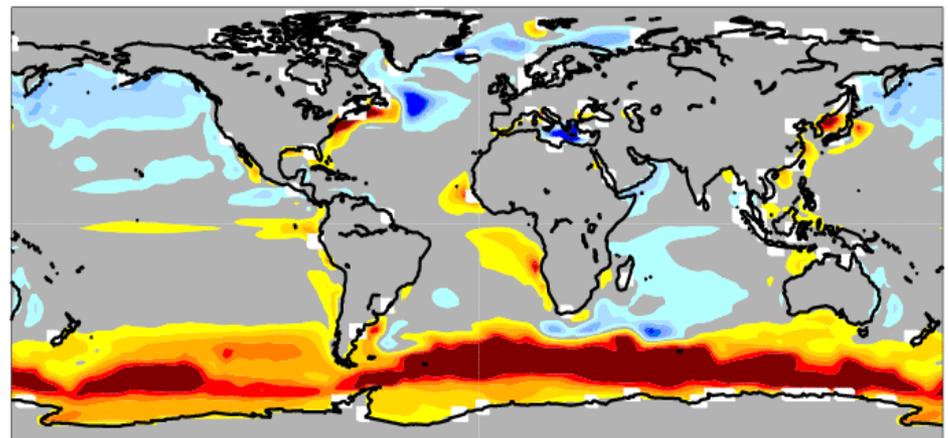
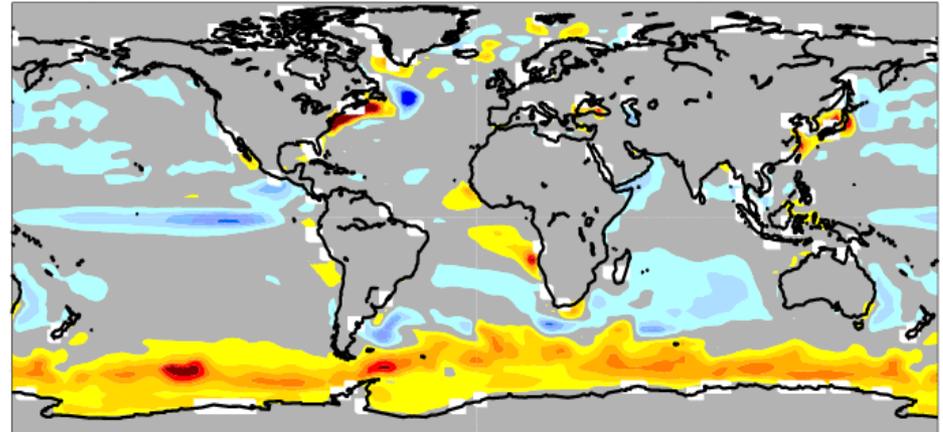
Start: 1 Nov.

1981/2010

Verify: Dec-Feb

System 4

Sea Surface temperature
Hindcast period 1981-2010 with start in November average over months 2 to 4



System 3

Bias in S4 re-forecasts: MSLP (DJF)

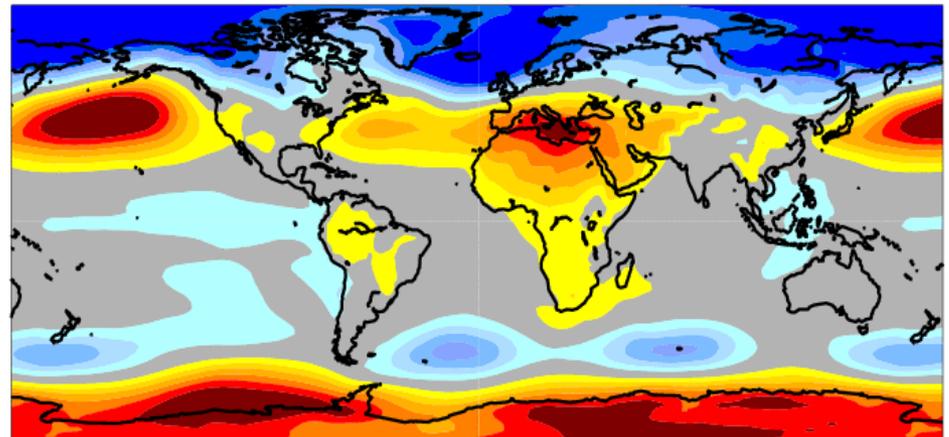
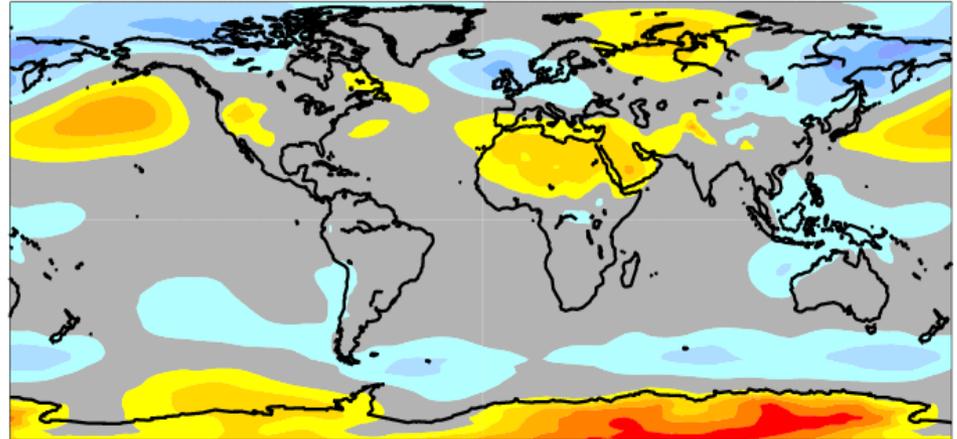
Start: 1 Nov.

1981/2010

Verify: Dec-Feb

System 4

Mean sea level pressure
Hindcast period 1981-2010 with start in November average over months 2 to 4



System 3

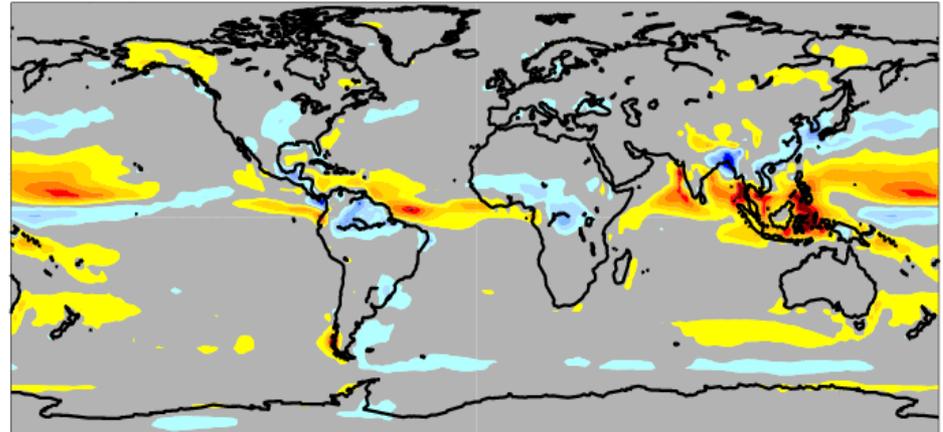
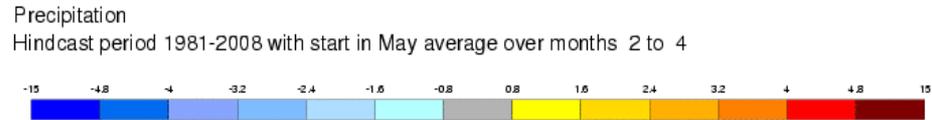
Bias in S4 re-forecasts: rainfall (JJA)

Start: 1 May

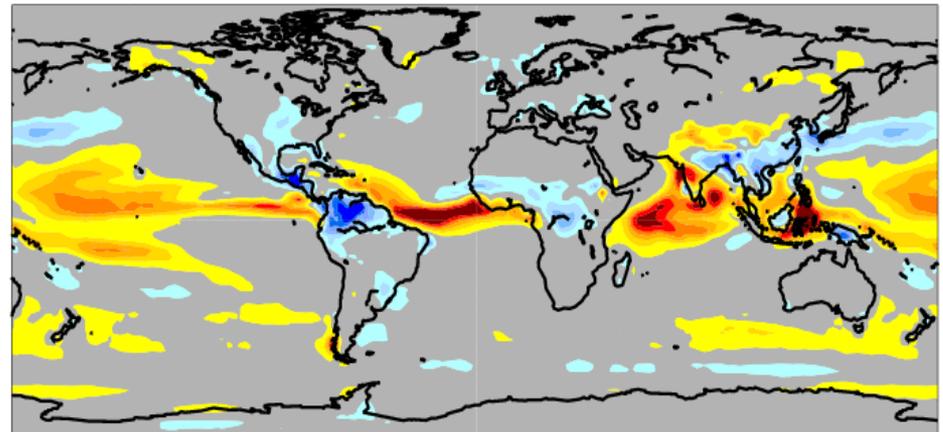
1981/2010

Verify: Jun-Aug

System 4



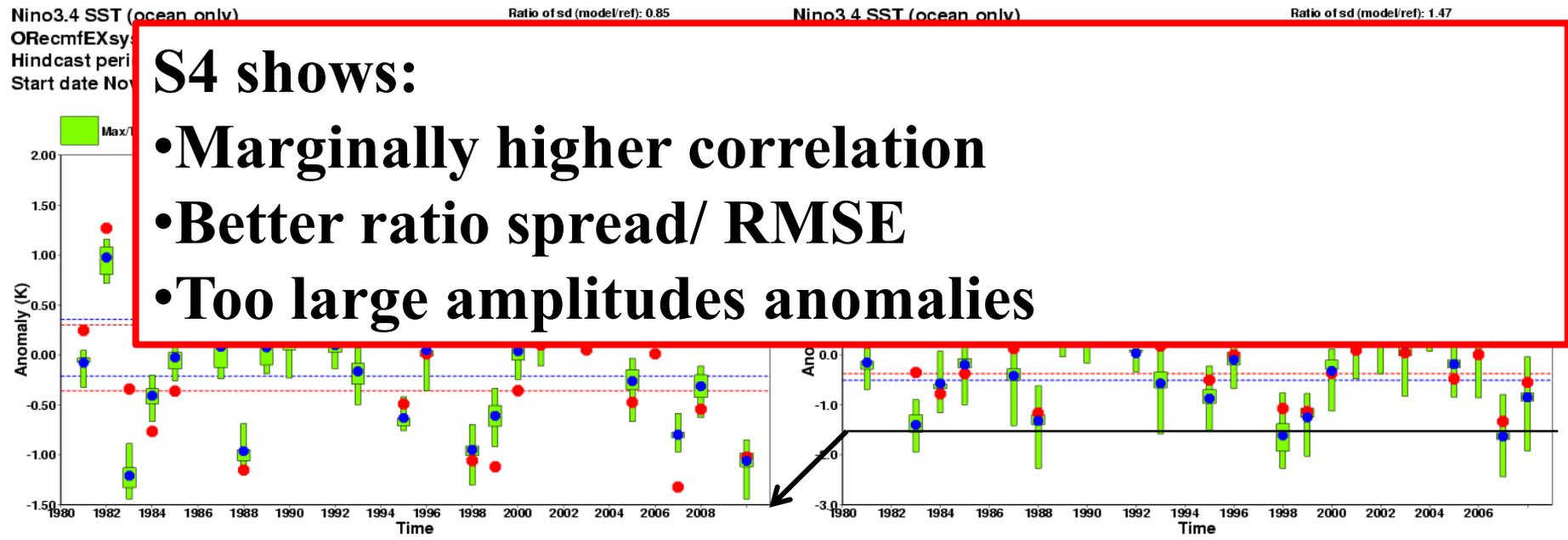
System 3



NINO 3.4 performance: verifying FMA (1989-2008)

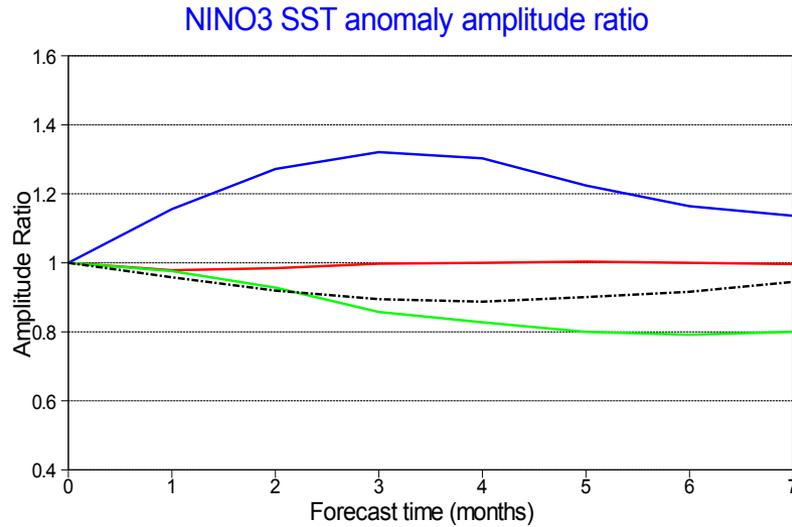
System 3

System 4

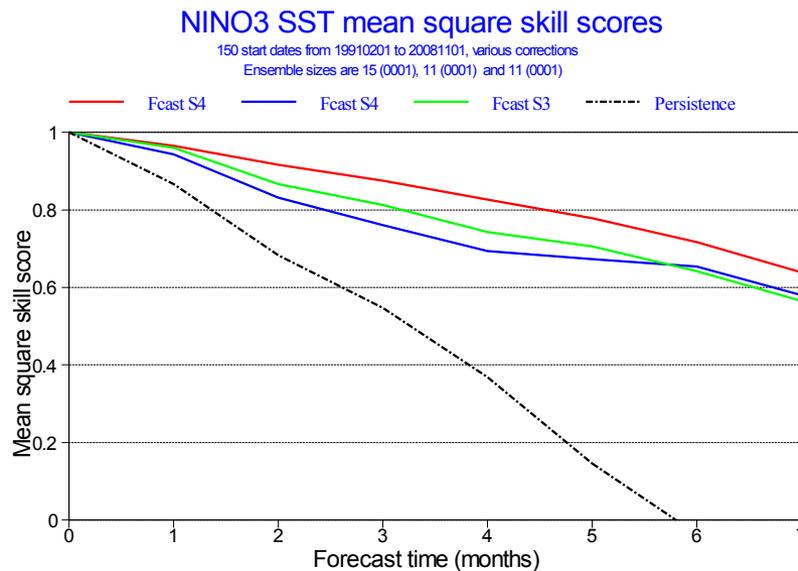


NINO 3.4	Corr	Spread/rmse	Sd m/Sd obs
System 3	0.89	0.46	0.85
System 4	0.92	0.68	1.47

Calibration of ENSO SST indices



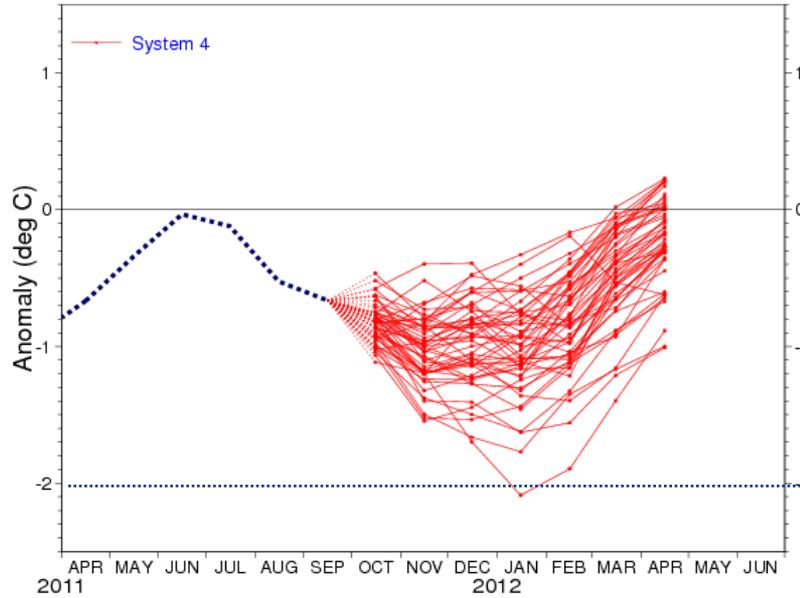
S4 non calib.
S4 calibrated
S3



NiNO3.4 plumes: calibrated vs non calibrated

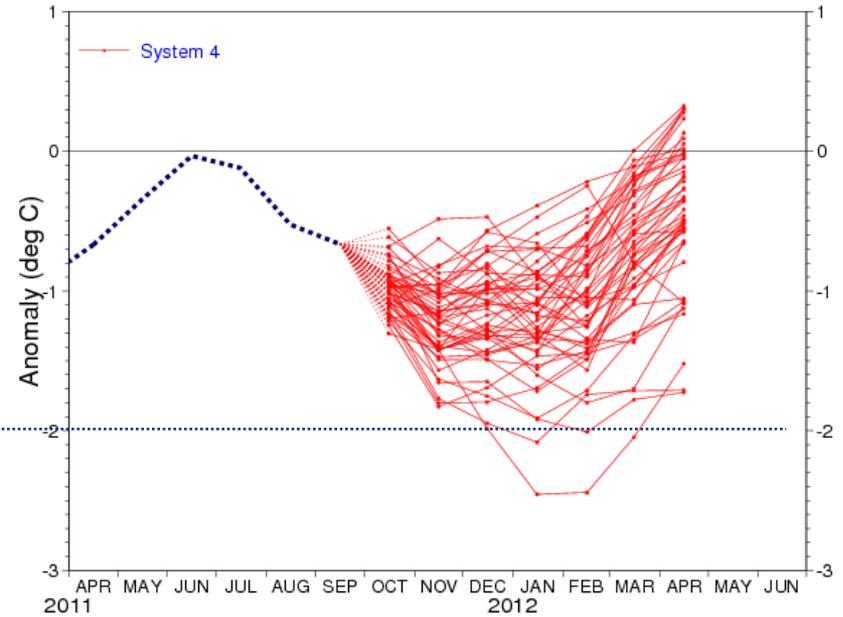
NiNO3.4 SST anomaly plume
ECMWF forecast from 1 Oct 2011

Monthly mean anomalies relative to NCEP adjusted Olv2 1971-2000 climatology



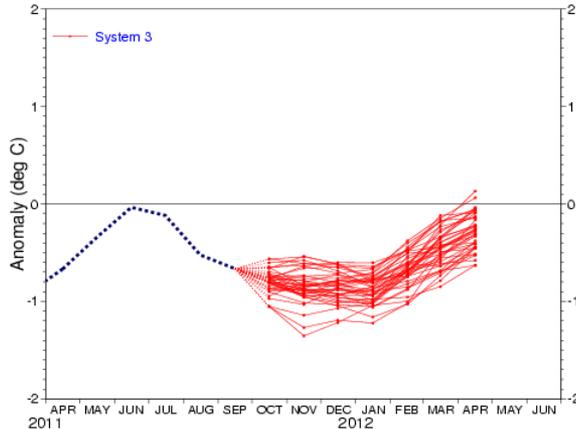
NiNO3.4 SST anomaly plume
ECMWF forecast from 1 Oct 2011

Monthly mean anomalies relative to NCEP adjusted Olv2 1971-2000 climatology



NiNO3.4 SST anomaly plume
ECMWF forecast from 1 Oct 2011

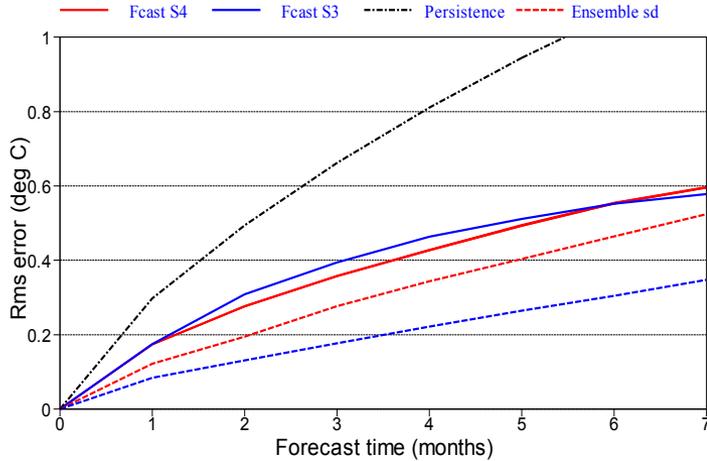
Monthly mean anomalies relative to NCEP adjusted Olv2 1971-2000 climatology



SST scores: Nino 3.4 and Eq. Atlantic

NINO3.4 SST rms errors

360 start dates from 19810101 to 20101201, various corrections
 Ensemble sizes/corrections are 15/AS (0001) and 11/BC (0001)
 95% confidence interval for 0001, for given set of start dates

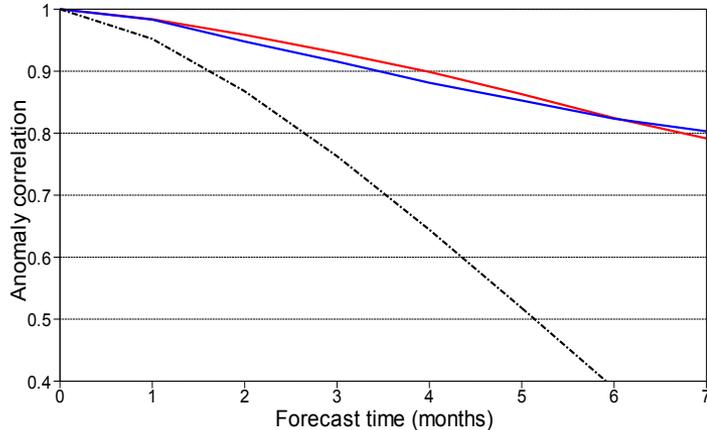


Solid:
 S4 error
 S3 error
 Dashed:
 S4 spread
 S3 spread

S4 ACC
 S3 ACC
 Pers. ACC

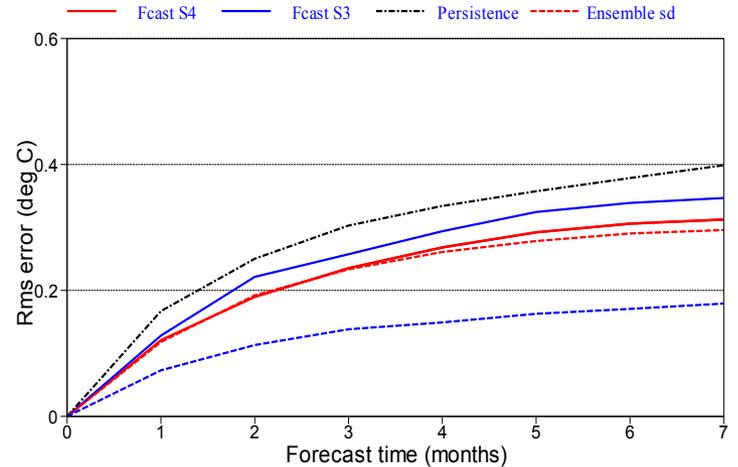
NINO3.4 SST anomaly correlation

wrt NCEP adjusted OI2 1971-2000 climatology



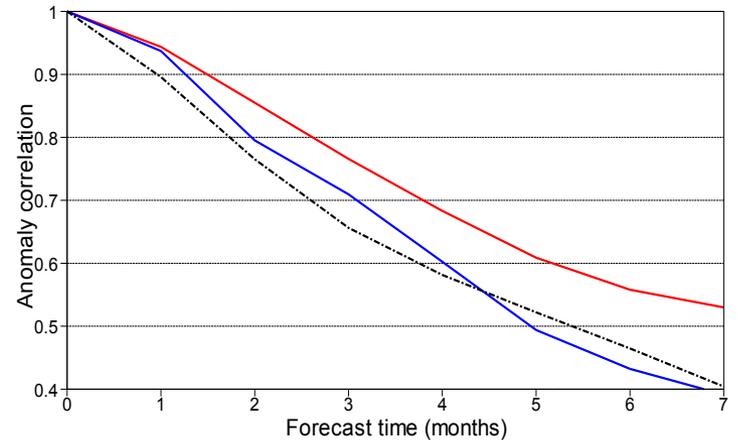
EQATL SST rms errors

360 start dates from 19810101 to 20101201, various corrections
 Ensemble sizes/corrections are 15/AS (0001) and 11/BC (0001)
 95% confidence interval for 0001, for given set of start dates



EQATL SST anomaly correlation

wrt NCEP adjusted OI2 1971-2000 climatology



Ens-mean ACC in S4 re-forecasts: 2m T (JJA)

Start: 1 May

1981/2010

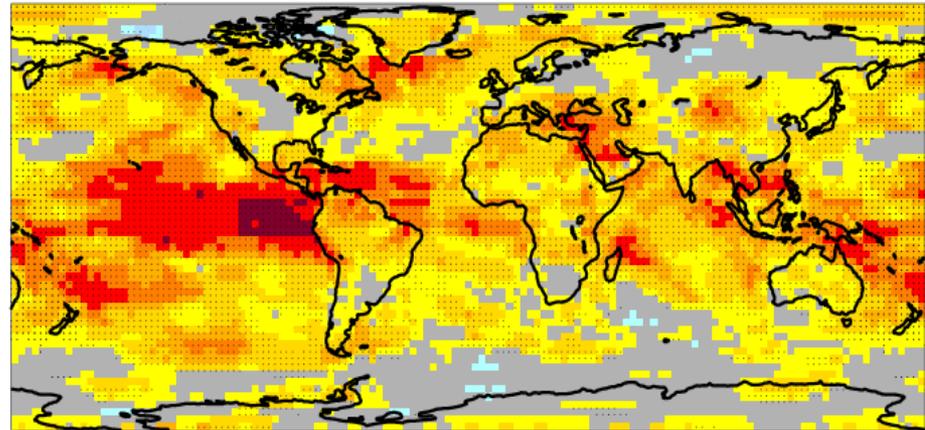
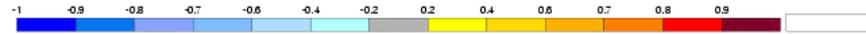
Verify: Jun-Aug

System 4

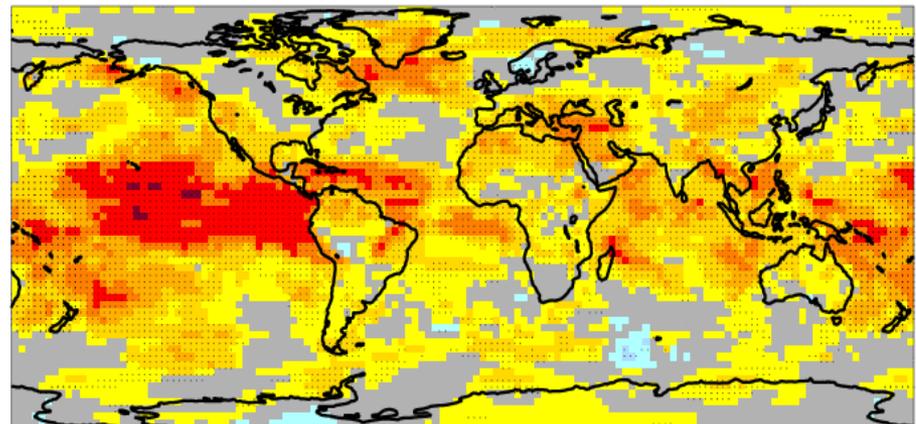
Near-surface air temperature

Hindcast period 1981-2010 with start in May average over months 2 to 4

Black dots for values significantly different from zero with 95% confidence (1000 samples)



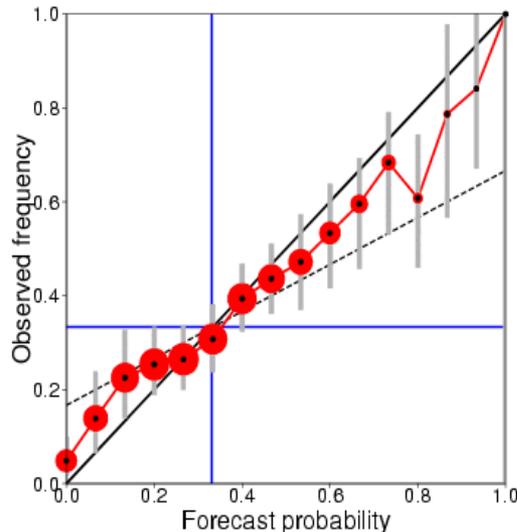
System 3



Reliability: 2m T > upper tercile over Europe, JJA

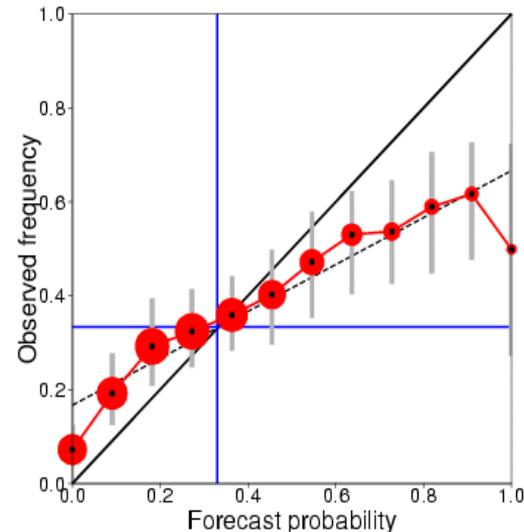
Sys 4

Reliability diagram for ECMWF with 15 ensemble members
Near-surface air temperature anomalies above the upper tercile
Accumulated over Europe (land and sea points)
Hindcast period 1981-2010 with start in May average over months 2 to 4
Skill scores and 95% conf. intervals (1000 samples)
Brier skill score: 0.092 (0.007, 0.162)
Reliability skill score: 0.986 (0.950, 0.994)
Resolution skill score: 0.106 (0.056, 0.173)



Sys3

Reliability diagram for ECMWF with 11 ensemble members
Near-surface air temperature anomalies above the upper tercile
Accumulated over Europe (land and sea points)
Hindcast period 1981-2010 with start in May average over months 2 to 4
Skill scores and 95% conf. intervals (1000 samples)
Brier skill score: 0.031 (-0.045, 0.094)
Reliability skill score: 0.943 (0.891, 0.965)
Resolution skill score: 0.089 (0.056, 0.133)



Ens-mean ACC in S4 re-forecasts: rainfall (JJA)

Start: 1 May

1981/2010

Verify: Jun-Aug

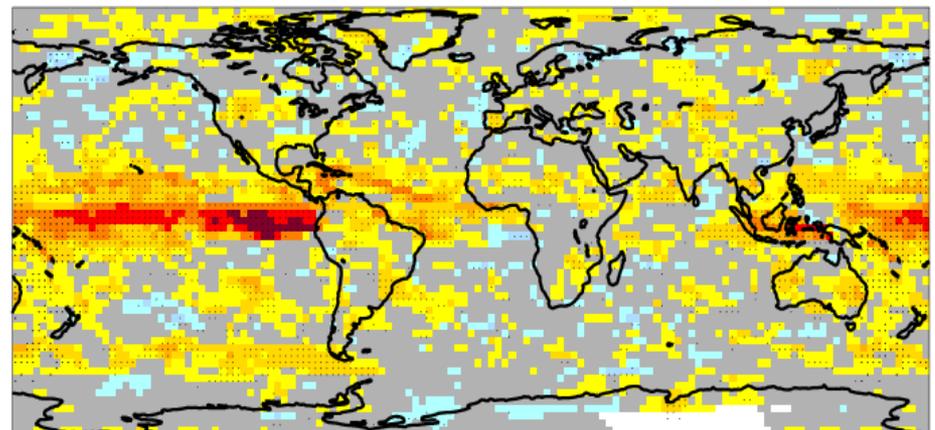
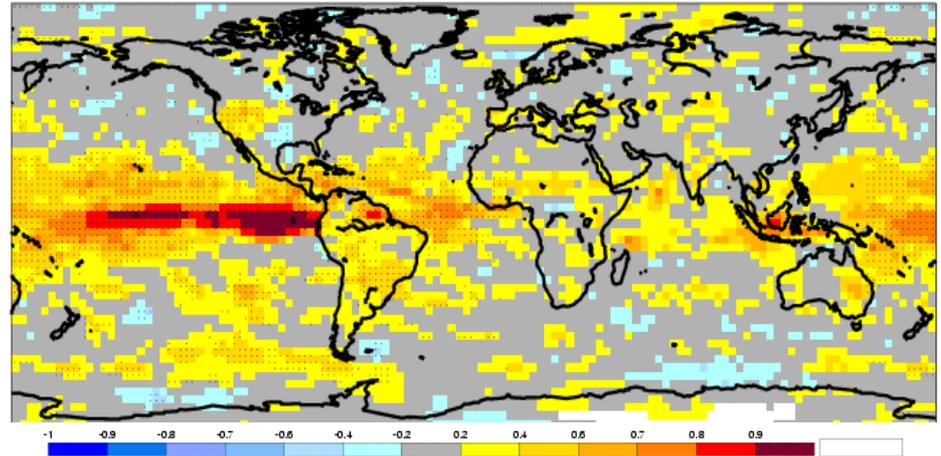
System 4

System 3

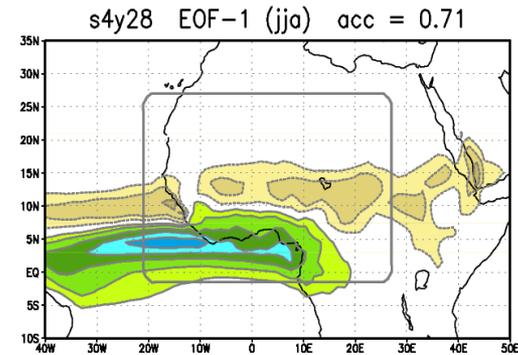
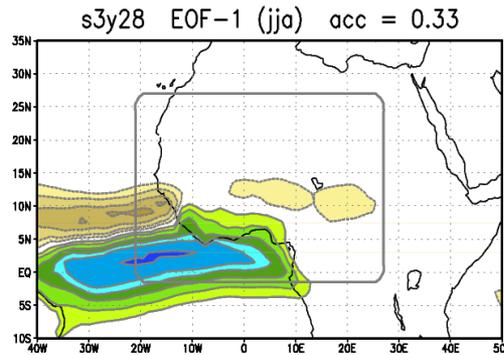
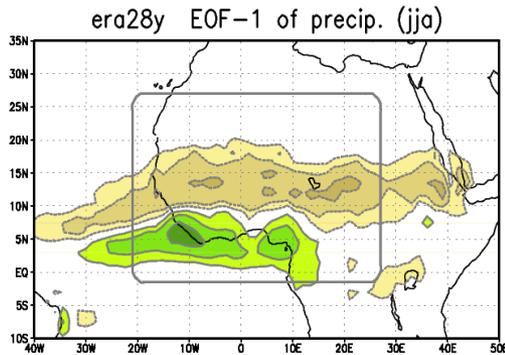
Precipitation

Hindcast period 1981-2008 with start in May average over months 2 to 4

Black dots for values significantly different from zero with 95% confidence (1000 samples)

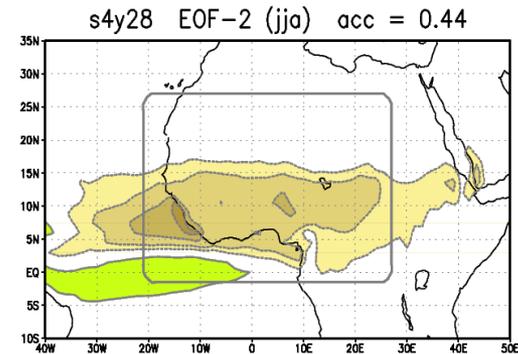
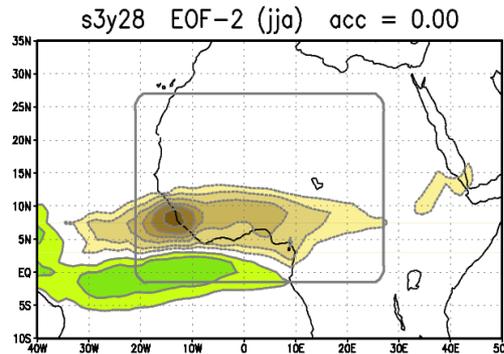


Variability of tropical rainfall: EOF comparison

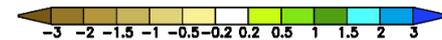
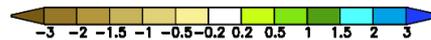


EOF 1

S4 shows higher predictive skill for the Western Africa rainfall than S3

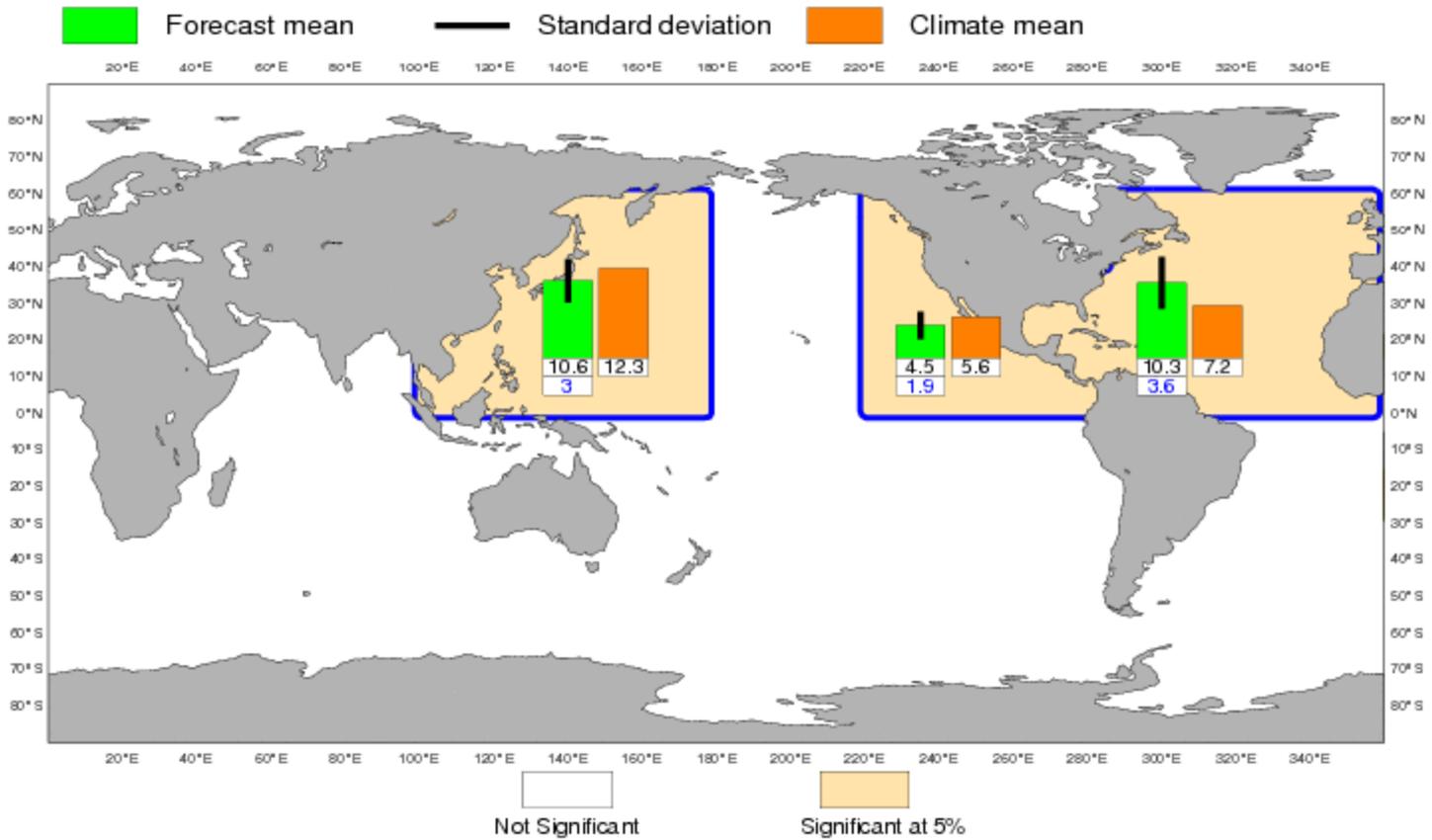


EOF 2

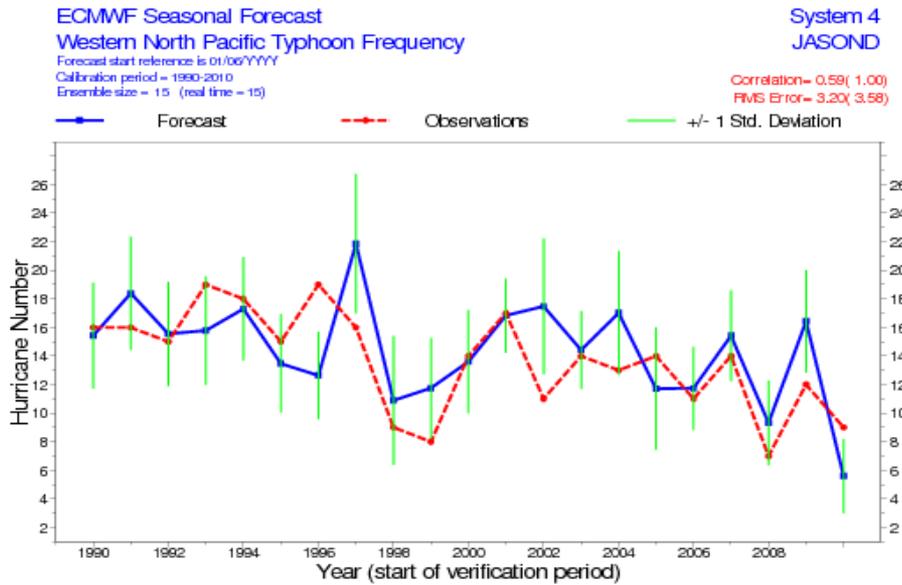


ECMWF Seasonal Forecast
 Tropical Storm Frequency
 Forecast start reference is 01/08/2011
 Ensemble size = 51, climate size = 300

System 4
 SONDJF 2011/12
 Climate = 1990-2009

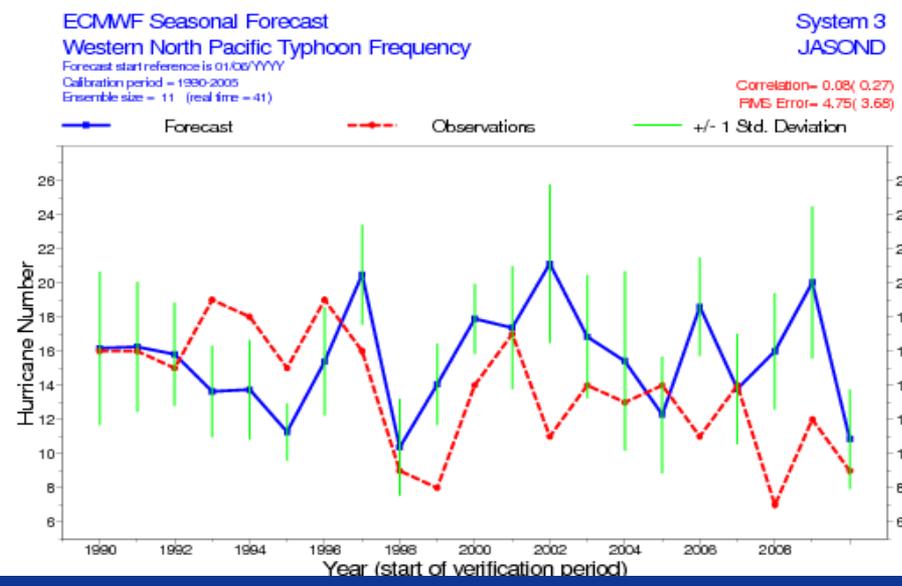


Prediction of tropical cyclone frequency: NW Pacific



System 4
vs. ERA-Int.

July-Dec.
1990-2010

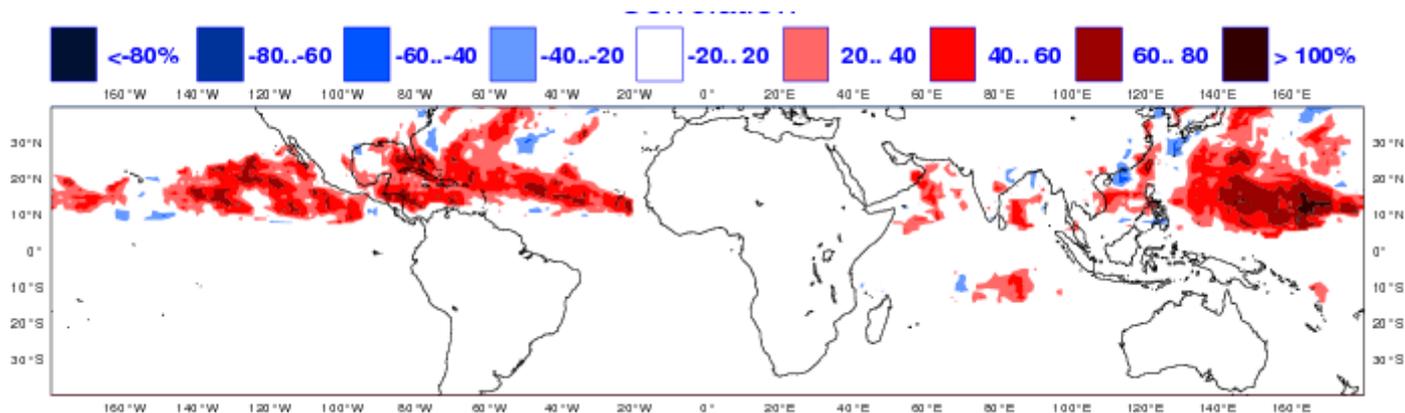
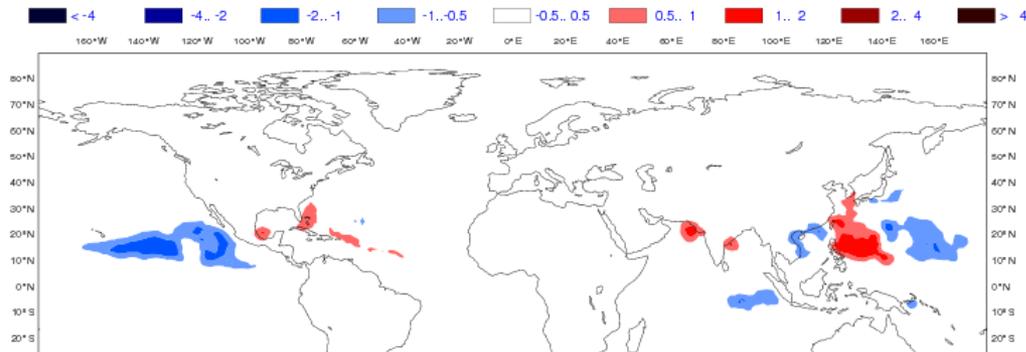


System 3
vs. ERA-Int.

Cyclone track density new product from S4 and its verification

ECMWF Seasonal Forecast
Tropical Storm Density Anomaly
Forecast start reference is 01/05/2011
Ensemble size = 51, climate size = 300

System 4
JJASON 2011
Climate = 1990-2009

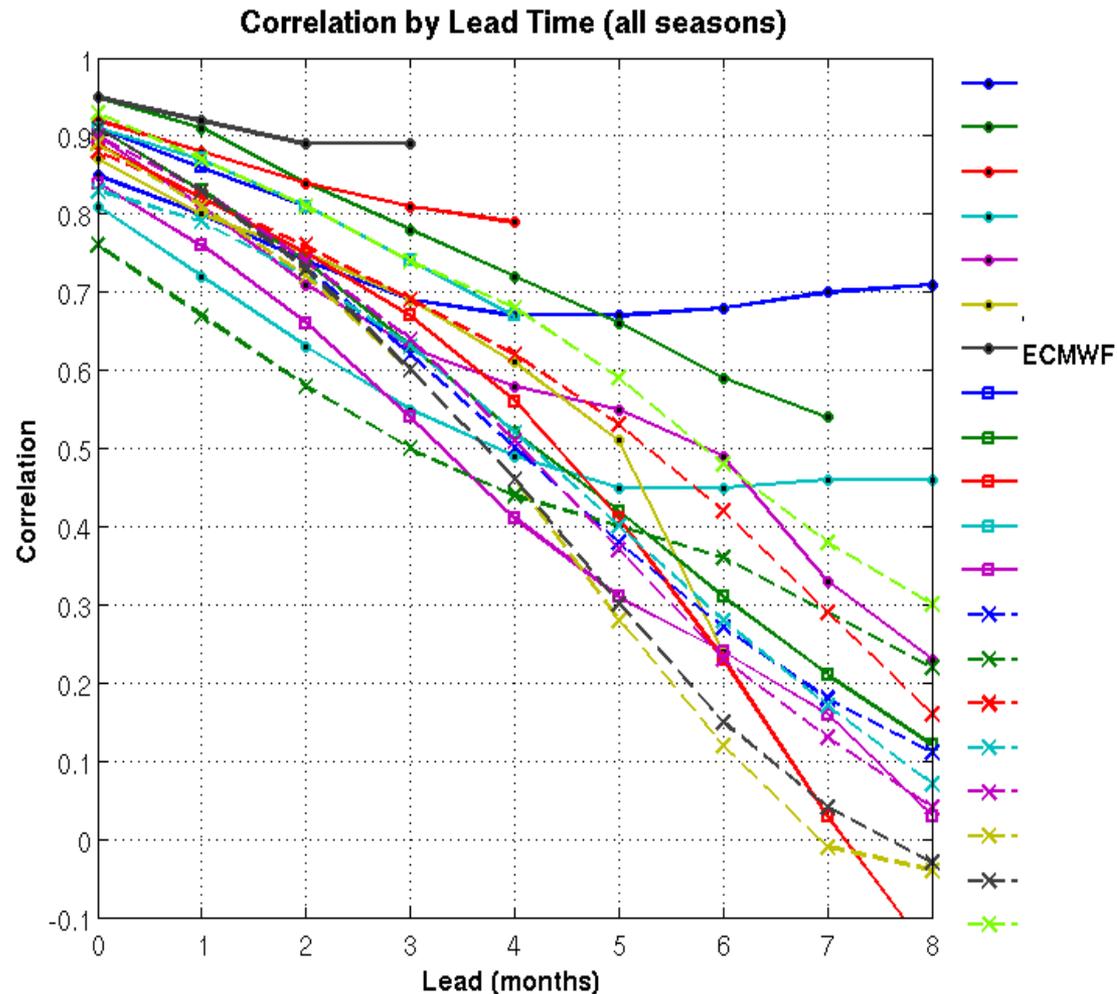


Track density for the July-Dec. period from fc. started on 1 May 1990-2010

ENSO skill: comparison with other seasonal fc. systems

NINO3.4
Anomaly
Correlation

3-month
running means



From: Barnston et al. 2011: Skill of Real-time Seasonal ENSO Model Predictions during 2002-2011—Is Our Capability Increasing? BAMS, accepted

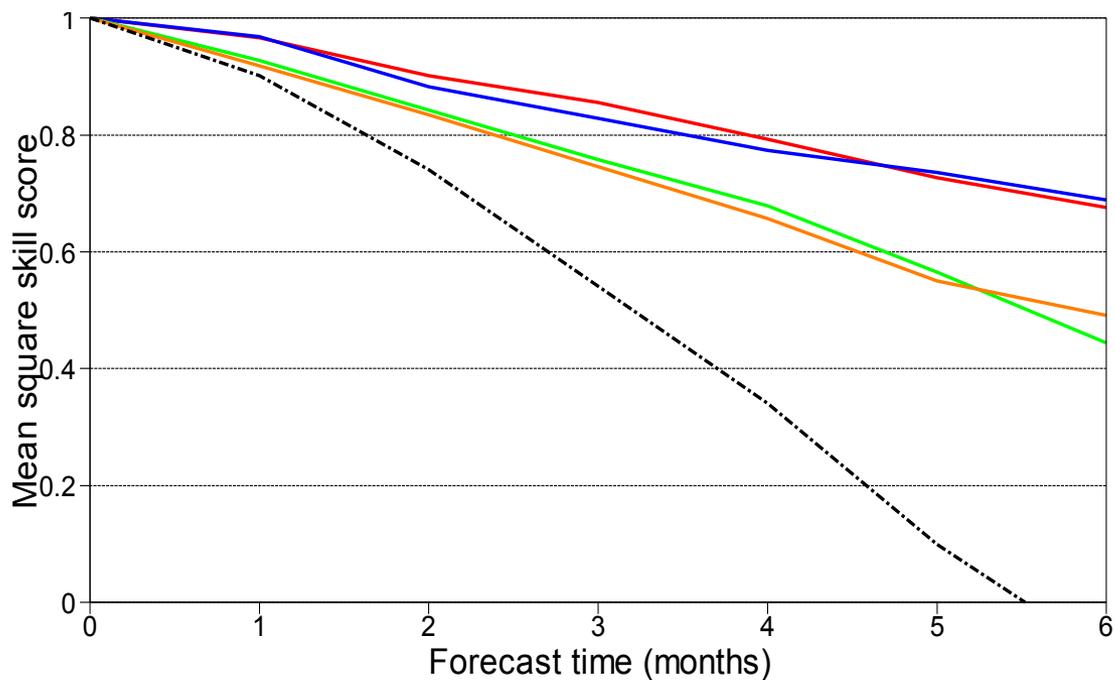
Conclusions

- **Seasonal fc. System-4 (S4):** IFS-NEMO coupled model, 3-D var. ocean data assimilation (NEMOVAR), higher atmos. spatial resolution than S3, larger ensemble size, extended re-forecast set.
- **Model biases:** much reduced extra-tropical biases, too strong trade winds and cold SST bias in the equatorial Pacific. ENSO SST variability is over-estimated.
- **SST forecast skill:** similar to S3 in the NINO regions (better in NINO3, slightly worse in NINO4), increased in the tropical and sub-trop. Atlantic.
- **Skill for atmospheric variables:** spatial averages of ensemble-mean scores are consistently higher than in S3 (NH summer better than winter).
- **Tropical atmospheric variability:** more realistic patterns of rainfall variability, better simulation of the interannual and decadal variation in tropical cyclone frequency.
- **Reliability:** the enhanced internal variability and better match between spread and error lead to more reliable seasonal forecasts w.r.t. S3 in both tropical and extra-tropical regions.

ENSO skill: comparison with EUROSIP partners

NINO3.4 SST mean square skill scores

154 start dates from 19890201 to 20021201, various corrections
Ensemble sizes are 15 (0001), 11 (0001), 11 (0001) and 11 (0001)



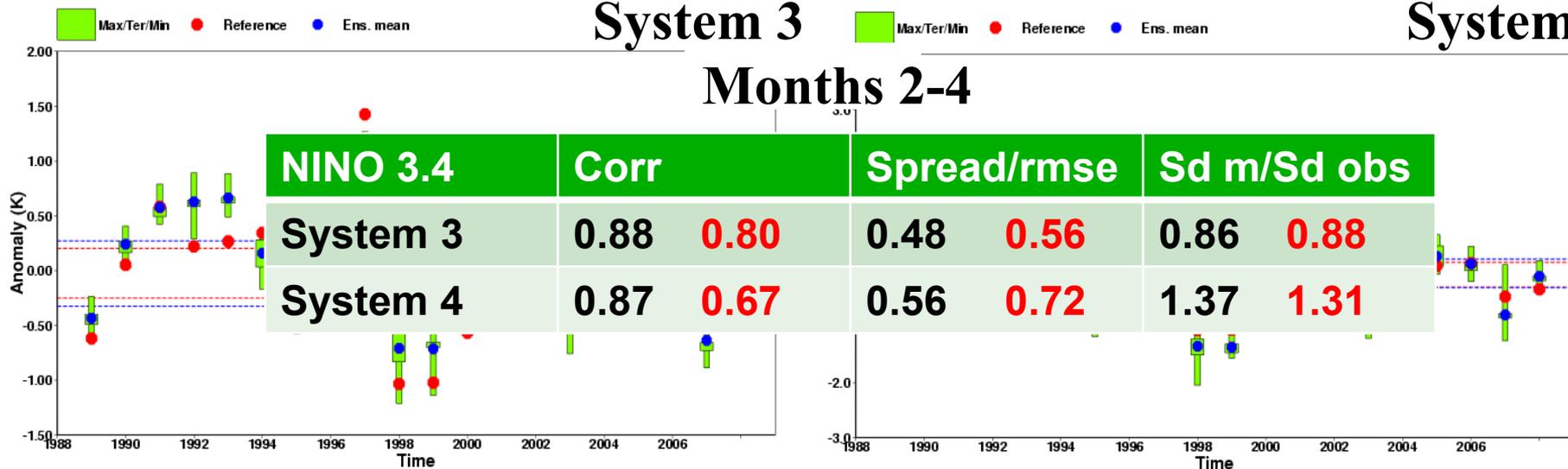
ECMWF S4

ECMWF S3

NINO 3.4 performance: verifying JJA (1989-2008) 11 m

System 3

System 4



- Similar correlation
- Better ratio spread/ RMSE
- Ratio of sd (model/ref) indicates that S4 produces anomalies with too large amplitudes