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
- EUROSSIP 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

Coupled model

Forecast Products

Current state of the atmosphere

Atmospheric model

Coupler

Current state of the ocean

Ocean Model

Current state of the atmosphere

Data Assimilation

Observations

Forecast Products

Coupled model
ECMWF Seasonal Forecasting System

Observations

Current state of the atmosphere

Current state of the ocean

Data Assimilation

4-D variational d.a.

Initial Con.

3-D v.d.a.
(NEMOVAR)

System 4

Gen. of Perturb.
The ECMWF Seasonal fc. system

Coupled model

Atmospheric model

Coupler

Ocean Model

System 4

IFS 36R4
0.7 deg (T255)
91 levels

Initial Conditions for Ens. Forecasts

H-TESSEL

OASIS-3

NEMO
1/1-0.3 d. lon/lat
42 levels
ECMWF System 4: main features

- **Operational forecasts**
  - 51-member ensemble from 1\textsuperscript{st} day of the month
  - released on the 8\textsuperscript{th}
  - 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 1\textsuperscript{st} Feb/May/Aug/Nov

- **Experimental ENSO outlook**
  - 13-month extension from 1\textsuperscript{st} Feb/May/Aug/Nov
  - 15-member ensemble
Bias in S4 re-forecasts: SST (DJF)

Start: 1 Nov.

1981/2010

Verify: Dec-Feb

System 4

System 3
Bias in S4 re-forecasts: MSLP (DJF)

Start: 1 Nov.
1981/2010
Verify: Dec-Feb

System 4

System 3
Bias in S4 re-forecasts: rainfall (JJA)

Start: 1 May
1981/2010
Verify: Jun-Aug

System 4

System 3

System 3

System 4

S4 shows:
• Marginally higher correlation
• Better ratio spread/ RMSE
• Too large amplitudes anomalies

<table>
<thead>
<tr>
<th>NINO 3.4</th>
<th>Corr</th>
<th>Spread/rmse</th>
<th>Sd m/Sd obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>System 3</td>
<td>0.89</td>
<td>0.46</td>
<td>0.85</td>
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<tr>
<td>System 4</td>
<td>0.92</td>
<td>0.68</td>
<td>1.47</td>
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</table>
Calibration of ENSO SST indices

NINO3 SST anomaly amplitude ratio

NINO3 SST mean square skill scores

150 start dates from 19910201 to 20081101, various corrections
Ensemble sizes are 15 (0001), 11 (0001) and 11 (0001)

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 1971-2000 climatology

System 4

NINO3.4 SST anomaly plume
ECMWF forecast from 1 Oct 2011
Monthly mean anomalies relative to NCEP adjusted 1971-2000 climatology

System 4
**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

**EQATL SST rms errors**
- 95% confidence interval for 0001, for given set of start dates

### Solid:
- S4 error
- S3 error

### Dashed:
- S4 spread
- S3 spread

### NINO3.4 SST anomaly correlation
- wrt NCEP adjusted Ok02 1971-2000 climatology

### EQATL SST anomaly correlation
- wrt NCEP adjusted Ok02 1971-2000 climatology

**MAGICS 6.12 nautilus - net Tue Jul 26 13:52:00 2011**

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

Start: 1 May

1981/2010

Verify: Jun-Aug

System 4

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)

Sys 3
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
Variability of tropical rainfall: EOF comparison

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

Not Significant
Significant at 5%
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

Track density for the July-Dec. period from fc. started on 1 May 1990-2010
ENSO skill: comparison with other seasonal fc. systems

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

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