Seasonal forecasting at ECMWF

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The operational forecasting system

• High resolution forecast: twice per day 16 km 91-level, to 10 days ahead

• Ensemble **Prediction System** (EPS): twice daily 51 members, 30/60 km 62-level, <u>to 15 days ahead</u>

Extended range forecasts /EPS extension: twice a week (Mon/Thursdays)
 51 members, 30/60 km 62 levels, to 1 month ahead

 Long range forecasts: once a month (coupled to ocean model) members, ~80 km 91 levels, <u>to 7 months ahead</u>

WSI, October 2011

Slide 2

Sources of seasonal predictability

Atmospheric predictability arises from slow variations in lower-boundary forcing

KNOWN TO BE IMPORTANT:

- El Nino variability
- Other tropical ocean SST
- Climate change
- Local land surface conditions

OTHER FACTORS:

- Mid-latitude ocean temperatures
- Remote soil moisture/snow cover
- Sea ice anomalies
- Dynamic memory of atmosphere
- Stratospheric influences
- Volcanic eruptions

\rightarrow biggest single signal

- important, but multifarious
- trends in mid-latitudes
- e.g. soil moisture in 2003
- always controversial
- not yet well established
- local effects, but remote??
- most likely on 1-2 months
- downward propagation of anomalies
- potentially predictable if contained in initial conditions

Can the weather be predicted months in advance?

- Predictions may be possible a few months in advance based on the fact that irregular weather variations have been associated with El Niño a warming of the Pacific Ocean near the equator- and La Niña, a similar event caused by the cooling of equatorial Pacific waters.
- The slow changes in the surface temperatures of the oceans are thought to impart a degree of predictability.

THE EL NIÑO/SOUTHERN OSCILLATION (ENSO) CYCLE

December - February Normal Conditions



December - February El Niño Conditions



December - February La Niña Conditions







Equatorial Southern Oscillation Index (SOI):



23/02/2013

Weather-related natural disasters



Societal Impacts from 1997/98 El Niño

Seasonal Forecasting at ECMWF

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.

A range of seasonal products are issued routinely on http://www.ecmwf.int/products/forecasts/seasonal

ECMWF Seasonal Forecasting System



ECMWF Seasonal Forecasting System



Observations

Polar-orbiting sate





Sec.



The ECMWF Seasonal fc. 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

Real Time Ocean Observations

Moorings

XBT (eXpendable BathiThermograh)





Tropical Indian Ocean Moored Buoy Array Surface Mooring = Flux Reference Site = ADCP

ADCP



ARGO floats





Argo Network, as of March 2006

ARGENTINA (6)	OSTA RICA(1)	JAPAN (353)
AUSTRALIA (92)	 EUROPEAN UN. (25) 	 KOREA, REP. OF (83)
BRAZIL (3)	FRANCE (163)	MAURITIUS (2)
CANADA (76)	 GERMANY (123) 	MEXICO (1)
CHILE (4)	 INDIA (74) 	NETHERLANDS (7)
 CHINA (9) 	IRELAND (1)	NEW ZEALAND (6)

2436 Active Floats

NORWAY (9)
 RUSSIAN FED. (3)
 SPAIN (6)
 UNITED KIN6DOM (96)
 UNITED STATES (1293)



Satellite







Ocean Observing System



+ XBT : Subsurface Temperature

Chaotic nature of the atmosphere:

- To deal with the chaotic processes in the atmosphere we use an ensemble of simulations: on the 1st of the month 40 forecasts are run for 6 months. They have initial conditions from 5-member ensemble of ocean analyses (wind perturbations throughout analysis and SST perturbations at start of forecasts)
- Seasonal forecasting does not give exact predictions, but it may allow us to describe the probability that a certain weather event can happen.

Product generation:

 Model drift, estimated by an ensemble of simulations started in previous years, is removed. This is based on the assumption that the atmospheric and oceanic anomalies have a linear behaviour.

Extended range predictions

• Products from Extended range predictions are generally defined with reference to the model climate estimated by the re-forecast data.

• Post-processing/calibration of model data is indispensable for the extended range forecasts.



<L clim >: Model climate upper tercile

Products :

- Ocean Analysis
- Seasonal outlook:

- (up to 6 months ahead)
- Forecasts for Nino3, Nino3.4 and Nino4
- Spatial plots (ens.mean anomaly, terciles ..)
- Climagrams (similar to Epsgrams)
- Tropical storms
- Annual outlook:

(up to 10 months ahead)

- Forecasts for Nino3, Nino3.4 and Nino4
- Spatial plots (ens.mean anomaly, terciles ..)
- Tropical storms

NINO3.4 plumes



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

Forecast time (months)

NINO 3.4 past predictions





Nino 3.4 outlook



CECMWF

Calibration of ENSO SST indices

NINO3 SST anomaly amplitude ratio 1.6 1.4 Amplitude Ratio 0.6 0.4 . Υ 2 3 5 6 Ż Δ Forecast time (months) 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) - Fcast S4 Fcast S4 Fcast S3 ----- Persistence score Mean square skill 0+ 2 3 5 6 Forecast time (months)

S4 non calib. S4 calibrated S3



ENSO skill: comparison with other seasonal fc. systems



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

Seasonal forecast charts :

Spatial maps representing the seasonal forecast in terms of model probabilities stratified by terciles.



Available parameters are:

- 2m Temperature
- Mean sea level pressure
- Precipitation
- Sea surface temperature
- 850 hPa temperature
- 500 hPa geopotential

Forecast is made available on the 8h of each month.

Seasonal forecast charts :

Spatial maps representing the seasonal forecast in terms of model probabilities stratified by terciles.



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Forecast is made available on the 8th of each month

ECMWF Seasonal Forecast

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

Standard deviation Climate mean Forecast mean 340°E 20°E so*E 100°E 140°E 200°E 40°E 60° E 120°E 160°E 180°E 220°E 240°E 260°E 280°E 300°E 320°E so•N 80° N 70° N 70°N 300 60"N 60° N so•N sor N 77 40°N 40° N 30°N 30° N 20"N 20ª N 10.6 12.3 3 4.5 5.6 1.9 10.3 7.2 10° N 10"N 3.6 0"N 0"N 10ª S 10° S 20°S 20° S 30° S 30°S 40° S 40° S 50°S 50° S 60°S 60° S 70" S 70ª S 80°S 80° S 20°E 40°E 60° E 80°E 100°E 120°E 140°E 160°E 180°E 200°E 220°E 240°E 260°E 280°E 300°E 320°E 340°E Not Significant Significant at 5%

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



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

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

-6	-2.4	-2	-1.5	-1.2	-0.8	-0.4	0.4	0.8	1.2	1.5	2	2.4	6





System 3



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)



1 -0.9 -0.8 -0.7 -0.8 -0.4 -0.2 0.2 0.4 0.5 0.7 0.8 0.9

System 3



Reliability diagram for ECMWFwith 15 ensemble membersNear-surface air temperature anomalies above the upper tercileAccumulated over Europe (land and sea points)Hindcast period 1981-2010 with start in May average over months 2 to 4Skill 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)



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)



Validation :

- 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

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23/02

ROC diagram for ECMWF with 11 ensemble members Near-surface temperature anomalies above the upper tercile Accumulated over tropical band (land and sea points) Hindcast period 1981-2005 with start in March average over months 2 to 4 Skill scores and 95% conf. Intervals (1000 samples) ROC score: 0.720 (0.660, 0.770)

ROC diagram for ECMWF with 11 ensemble members Near-surface temperature anomalies above the upper tercile Accumulated over North America (land points only) Hindcast period 1981-2005 with start in March average over months 2 to 4 Skill scores and 95% conf. Intervals (1000 samples) ROC score: 0.640 (0.560, 0.700)



ROC diagram for ECMWF with 11 ensemble members Near-surface temperature anomalies above the upper tercile Accumulated over Europe (land points only) Hindcast period 1981-2005 with start in March average over months 2 to 4 Skill scores and 95% conf. Intervals (1000 samples) ROC score: 0.570 (0.500, 0.640)



Summary (1):

- 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 <u>more reliable seasonal forecasts</u> w.r.t. S3 in both tropical and extra-tropical regions.

Summary (2)

- The current operational seasonal forecast system provides a set graphic products on the web and digital data set to the users.
- 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.
- For further reading see ECMWF Tech Memo N.656, available at <u>http:// www.ecmwf.int/publications</u>

S3 tends to persist the spring conditions in the Subtropical Atlantic

JAS T2m from 1st of May

JAS T2m from 1st of June



May SST Initial Conditions



June SST Initial Conditions



Outlook for Europe

Long-term predictions over Europe are particularly difficult:

- At times during very large El Niño part of Europe seem to be affected.
- However non-linearity of the atmosphere seem to play a relevant role over this region.
- The Atlantic Ocean influence on the weather over Europe is not yet well understood.

Persistence and mixed layer depth

Persistence from April to JJA



ERA-40



MLD in North Subtropical Atlantic

Apr and July starts



- Persistence (from spring to summer) in coupled models is too large in the North-Subtropical Atlantic
- The couple model can not predict the rapid shallowing of the mixed layer from spring to summer.

Nino 3.4 past forecasts:



23/02/2013



JJA 2007 2mt anomalies



EUROSIP multi-model seasonal forecast Mean 2m temperature anomaly Forecast start reference is 01/05/07 Variance-standardized mean

ECMWF/Met Office/Météo-France JJA 2007 No significance test applied



Forecast issue date: 15/05/2007

CECMW Forecast issue date: 15/05/2007

Climate trends, La Nina, or others?

T2m linear trends in S3



•Warming in Central/Eastern Europe is part of the linear trends.

•From the linear teleconnections, La Nina is unlikely to be responsible for the anomalous precipitation and T2m during summer of 2007 in Western Europe.



From van Oldenborgh 2007