The ECMWF Extended range forecasts

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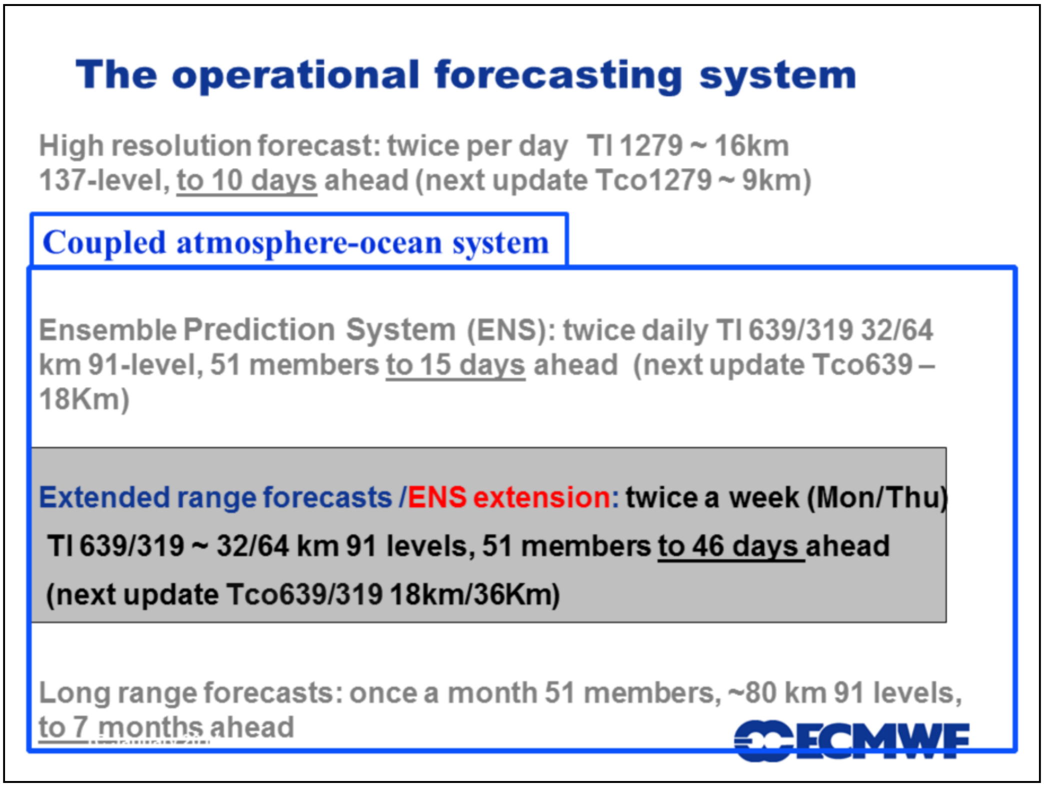


The operational forecasting system at ECMWF consists of:

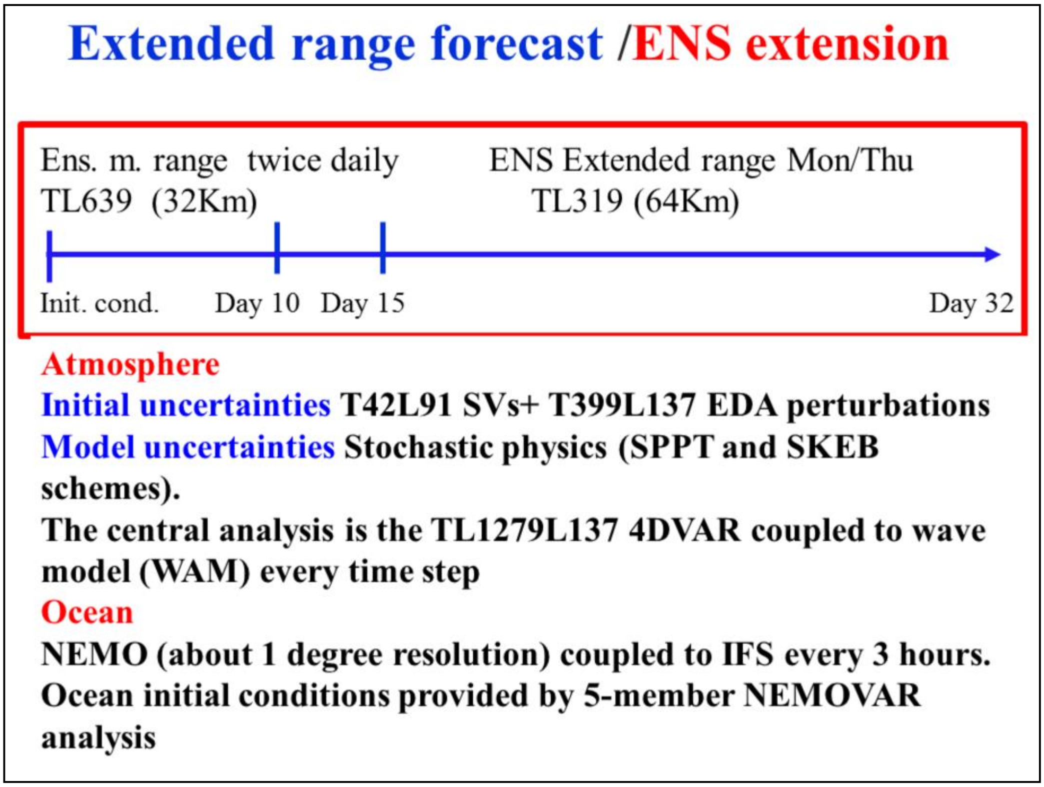
- An high resol. Forecast

- An ENSEMBLE of 51 forecasts that also run twice a day up 15 days --- covering the Medium range predictions: beyond 72 hours and up 240.

- The Extended forecast system: These forecasts are issued twice a week (Mon/Thu) and run up to 32 days and they are an extension of the ENSEMble forecasting system

-Long range ensemble forecast issued once a month that run up to 7 months.

-This presentation is meant to be an introduction to the Extended range forecast: Currently extended range products are provided to the ECMWF Member and Co-operating States and to commercial users



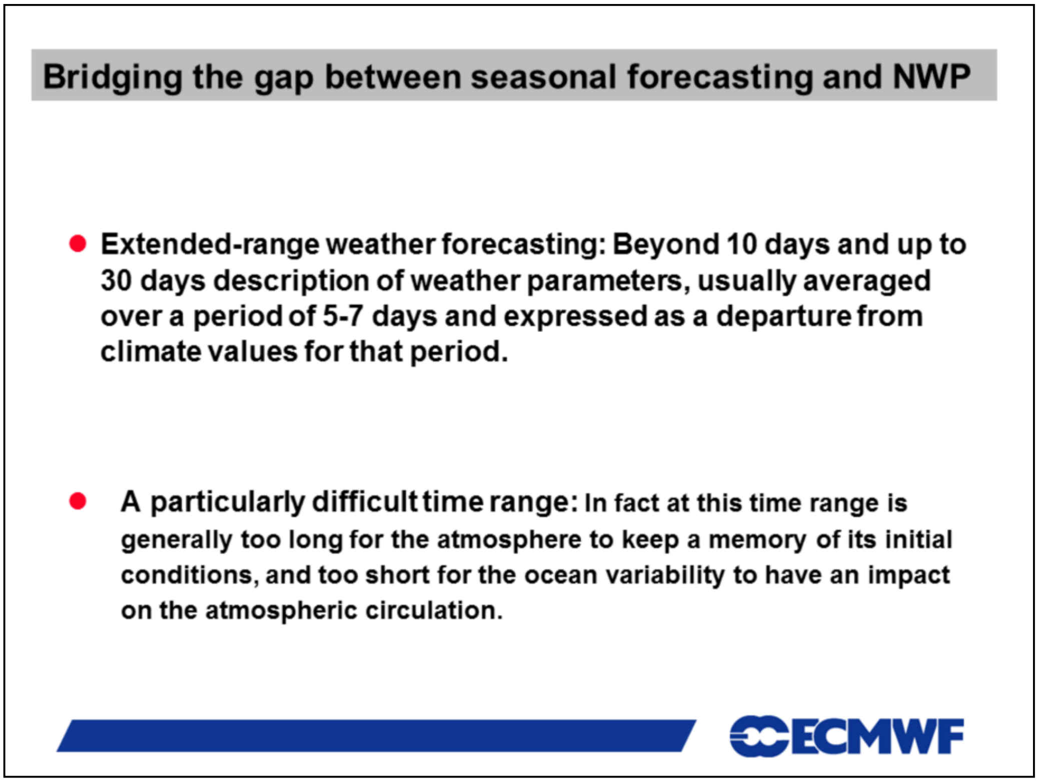
The extended range forecast system is an extension of the Ensemble Prediction. The first 10 days are performed with the atmospheric model running at TL639L62 resolution and forced by persisted SST anomalies (updated every 24 hours). After day 10, the atmospheric model is coupled to the ocean model and has a resolution of TL319L62. The extension to 32 days is performed every Thursday and Monday.

Oceanic component: NEMO with a zonal resolution of about 1 degree (same as in SYSTEM 4). 42 vertical levels

Coupling: OASIS (from CERFACS, France). The atmospheric fluxes of momentum, heat and fresh water are passed to the ocean every 3 hours. In exchange, the ocean surface temperature (SST) is passed to the atmosphere.

CY38R1 since 21/6/2012 (included): 20 years of hindcasts (instead of 18 years) + new soil reanalysis in the hindcasts.

Before January 2008, the monthly forecasting system was a separate system from EPS. The first operational real-time monthly forecast was realized on Thursday, 7 October 2004.



So to start few words about the nature of such forecasts.

May be we need to clarify what we intend for extend range predictions: these are forecast beyond 10 days and up to 30 days. Because at this range we cannot predict the exact daily variability the forecasts typically are presented to the users averaged over a period of 5 to 7 days and they are expressed in terms of anomalies.

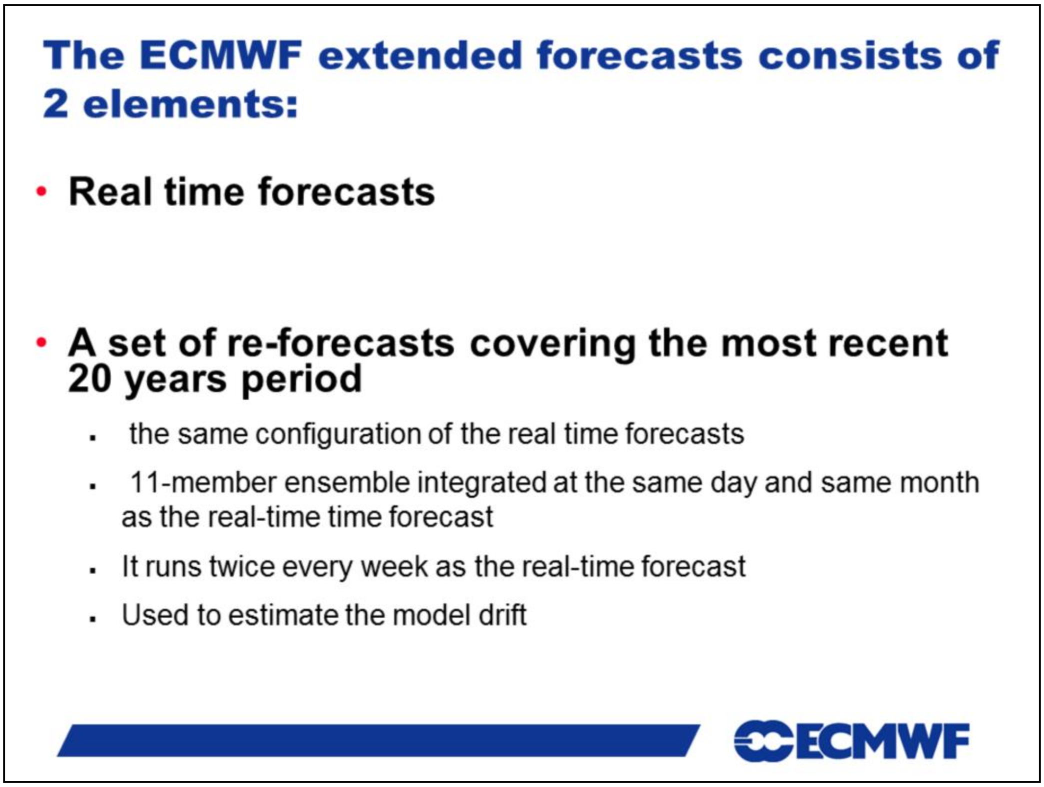
Making predictions from 10 to 30 days ahead is a very difficult task. In fact at this time range is probably too long for the atmosphere to keep a memory of its initial conditions, and too short for the ocean variability to have an impact on the atmospheric circulation. Therefore, for a long time, it was assumed that there was almost no predictability in this time scale.

However, two main sources of predictability in this timescale have been isolated in the recent years:

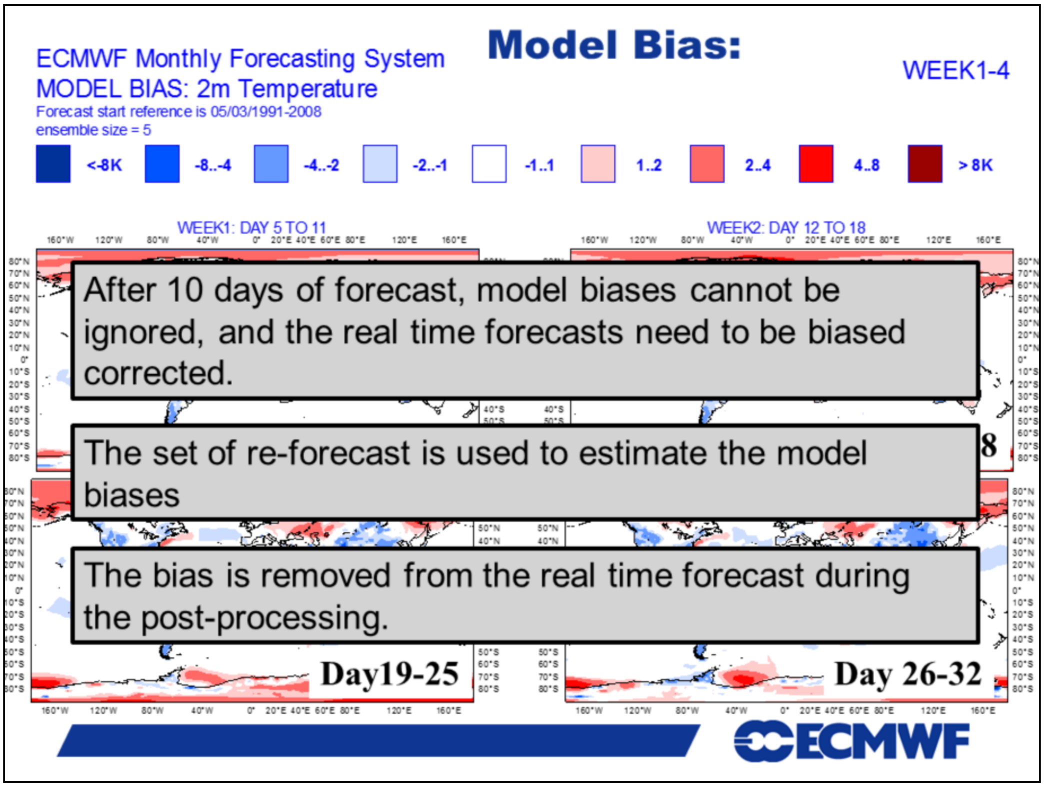
- The impact of the stratosphere on the troposphere

-The Madden-Julian Oscillation (MJO)

-As well as the effect of surface initial conditions

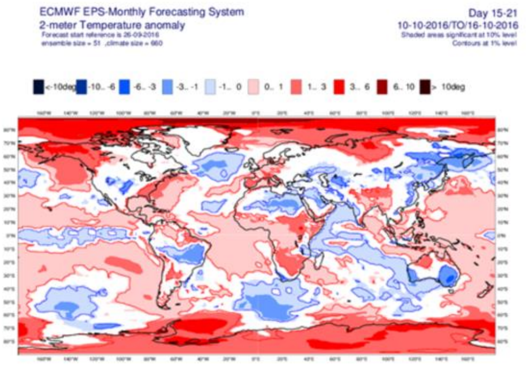


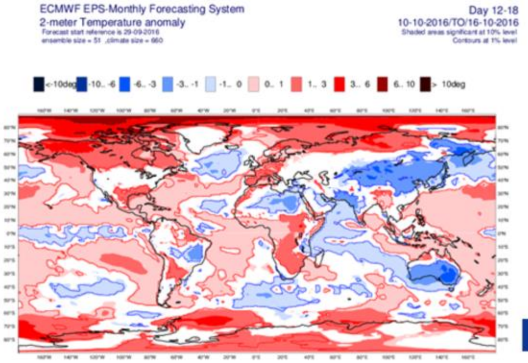
The re-forecasts are created once a week and are ready 3 weeks before the real-time forecasting suite starts. The real-time monthly forecasts produced on Thursdays are calibrated using only the back-statistics associated to the date of the real-time forecasts. The real-time monthly forecasts produced on Mondays are calibrated using the back statistics associated to the previous and next Thursdays, and a weight averaging is applied.



After 10 days of forecast, model error cannot be ignored, so that the forecast needs to be biased corrected.

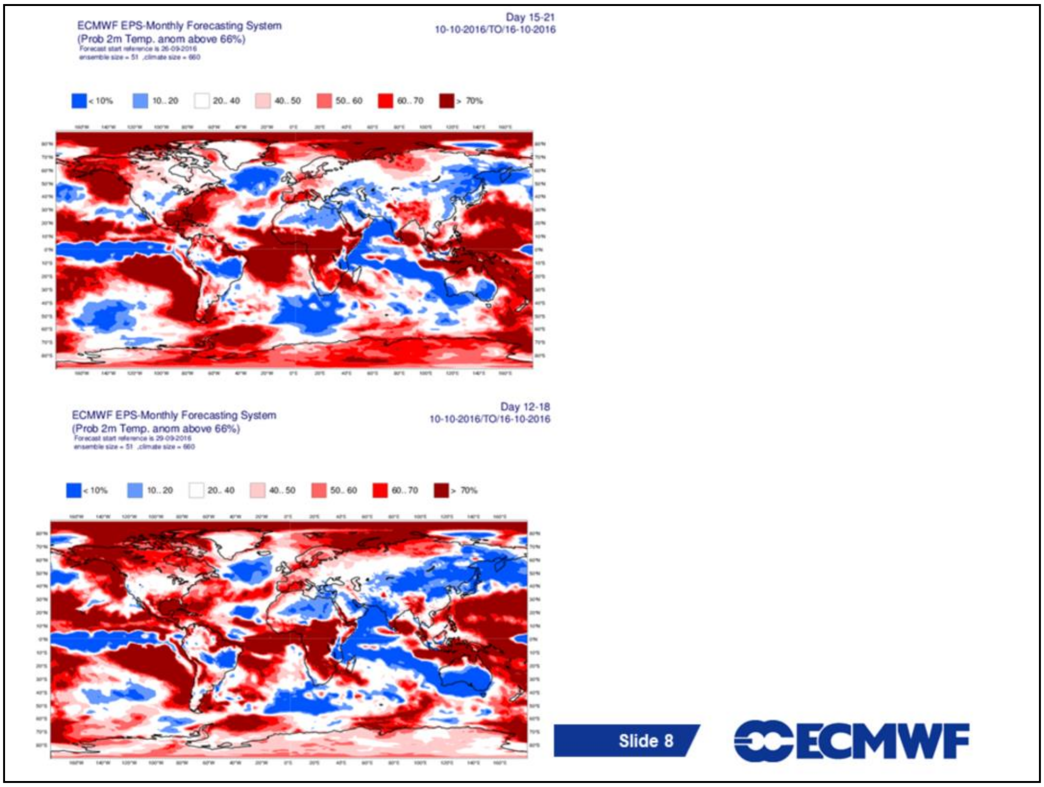
This figure shows the evolution of the model bias of 2-meter temperature week by week. The patterns of the model bias are roughly the same during the 4 weeks, but the intensity increases almost linearly in some areas. After 10 days of forecast, such model error cannot be ignored, and the model needs to be biased corrected as for the long range forecasts.





Slide 7

ECMWF


ECMWF EPS-Monthly Forecasting System
(Prob 2m Temp. anom above 66%)
Forecast start reference is 26-09-2016
ensemble size = 51 ,climate size = 660
Day 15-21
10-10-2016/TO/16-10-2016
< 10%
10.. 20
20.. 40
40.. 50
50.. 60
60.. 70
> 70%
ECMWF EPS-Monthly Forecasting System
(Prob 2m Temp. anom above 66%)
Forecast start reference is 29-09-2016
ensemble size = 51 ,climate size = 660
Day 12-18
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10.. 20
20.. 40
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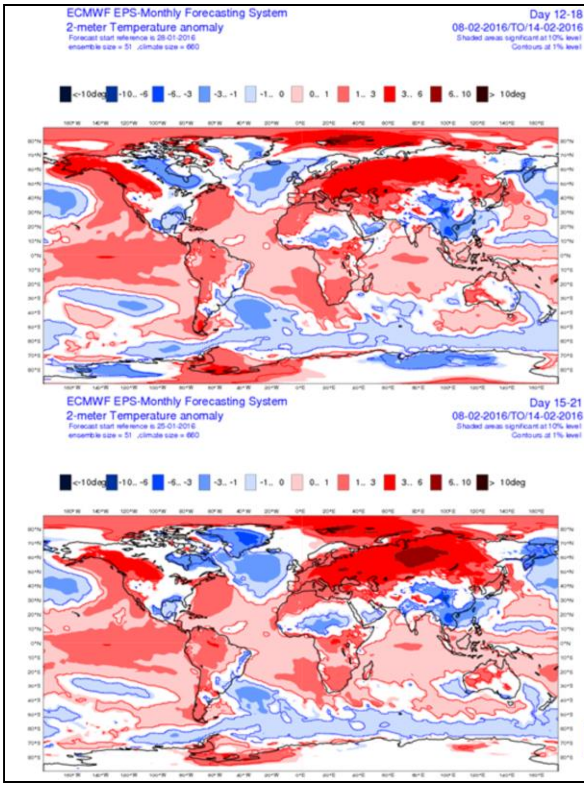
Slide 8
ECMWF



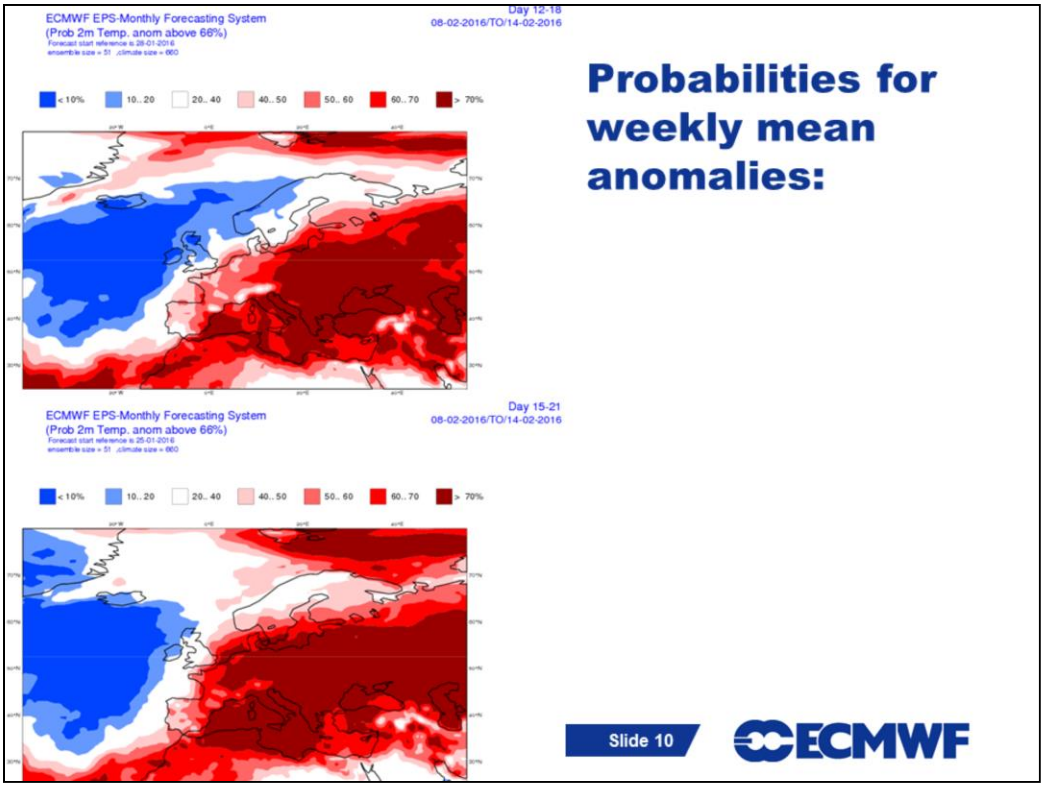
Weekly mean anomalies

Slide 9

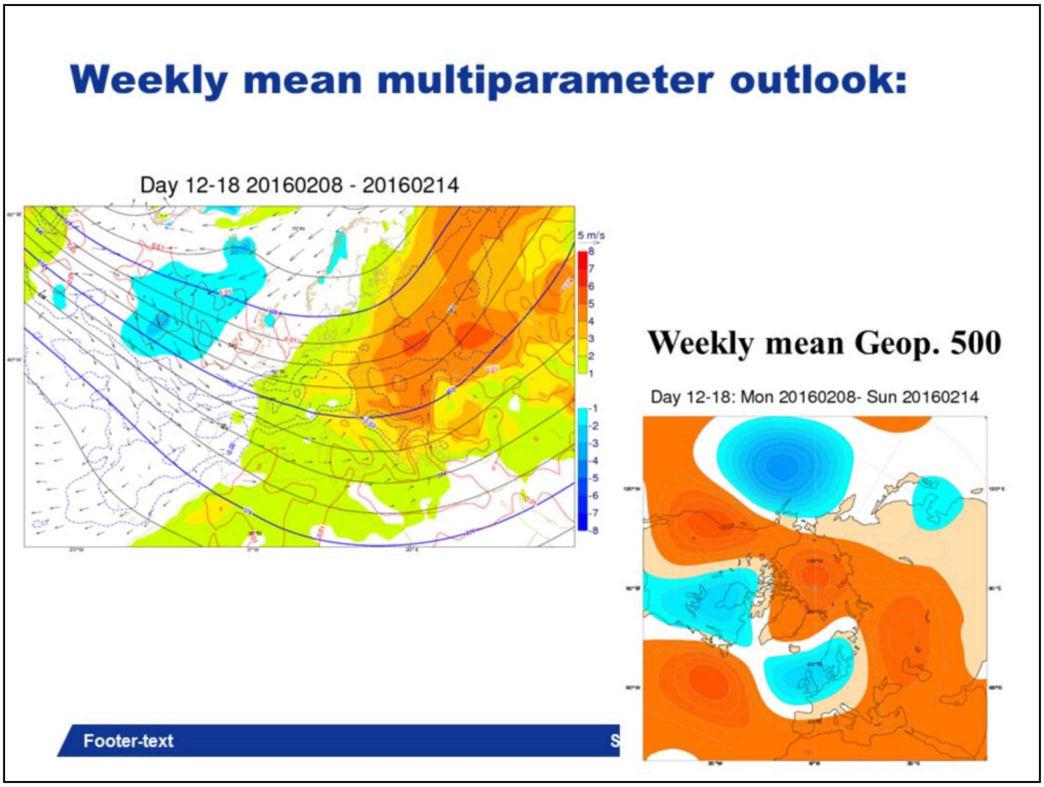
Here we have an example of the 2 m temperature forecast for next week over Europe.

Global and regional maps of weekly mean anomalies are available on the web.

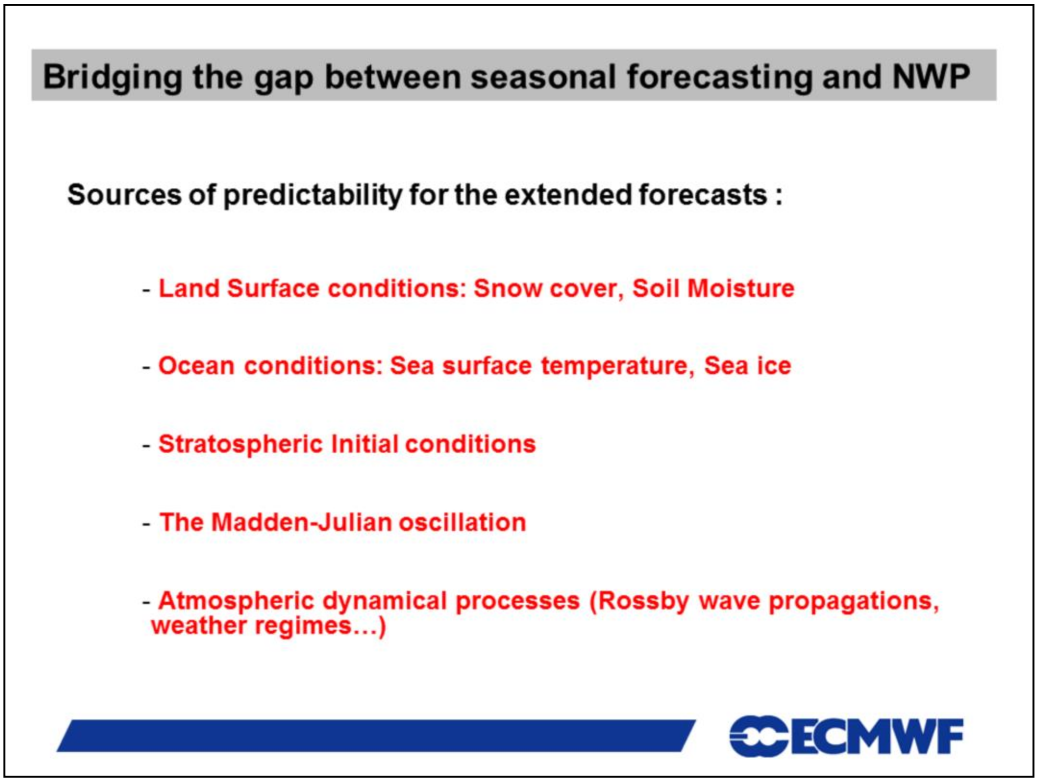
The anomalies have been calculated relative to an 20-year model climatology produced each Thursday. For the forecasts produced on Monday, the climatology used to produce the anomalies is a weighted average of the climatology of the previous and following Thursdays. The areas where the ensemble forecast is not significantly different from the climatology, according to a WMW-test (Wilcoxon-Mann-Whitney), are blanked.



Probabilities for the weekly mean anomalies to be in the lower or upper third of the model climate distribution. Three equally probable categories are calculated from the 20-year model climatology produced each Mon/Thursday. The forecast probabilities are calculated from the proportion of ensemble members in each category.



Weekly averages of the monthly forecast ensemble mean. Solid lines (black and blue) represent the geopotential height at 500 hPa (contour every 6 dam). Anomalies of 2-metre temperature, sunshine and 10-metre wind are represented respectively by colour shading, red/blues (positive/negative) thin contours and arrows. Anomalies are computed with respect to 20 years of model climate. Weekly-mean 500hPa geopotential anomaly for the ensemble mean. Contour intervals of 2dam (zero line not shown).



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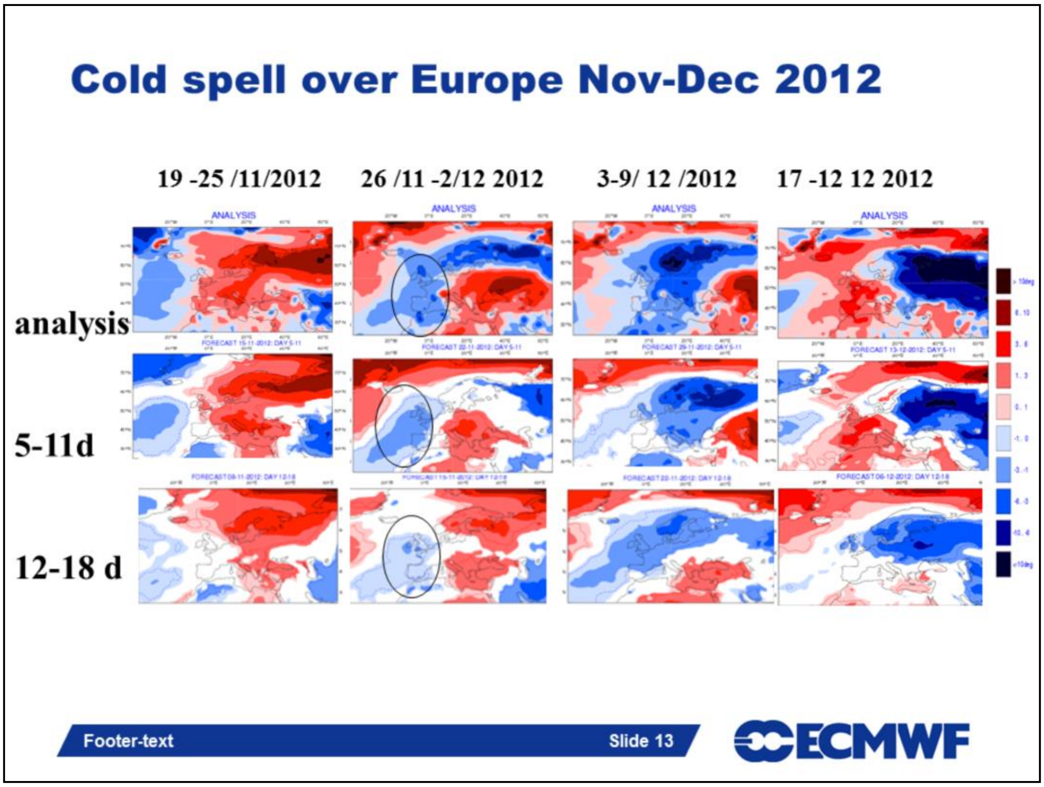
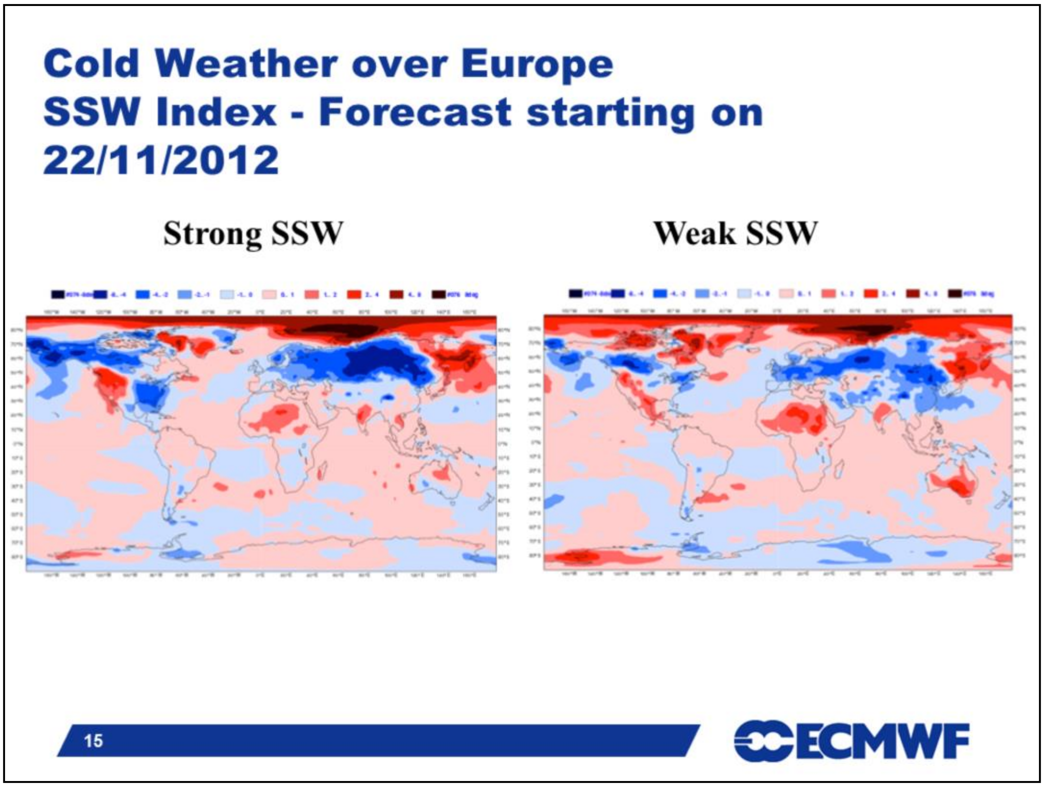


Here we have an example of how the extended range forecast performed during the cold spell in No-Dec2012

The maps are weekly mean of 2m temp anomalies. First row is the veryfing analysis, second and third row the forecast at 5-11 and 12-18 days.

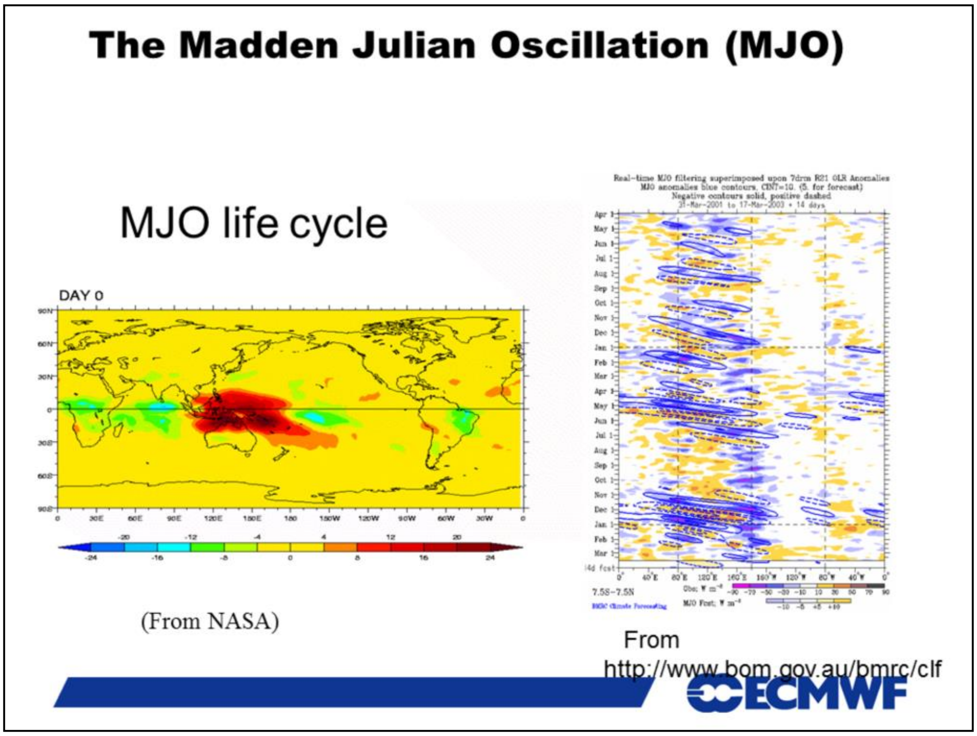
This was a period were there was a clear transition from warm to cold conditions over Europe. The cold conditions developed in the week of 26 over western Europe and later on moved over Central Europe and Scandinavia.

The amplitude of the anomalies were not realistic but at this forecast range we do not expect to get a very large signal and the ensemble mean is bound to reduce the amplitude of the anomalies. The cold signal over Scandinavia at day 5-11 appears to be not significant (that why is white) but at day 12-18 is replaced by warm anomalies. Over Scandinavia the forecast was not so great in picking up the change from warm to cold and the signal became clear only a week later. This seems to be a typical behaviour and we are trying to investigate further. For example several studies have shown that some transitions to cold in winter are associated to a stratospheric sudden warming event.



The plot here show the signal in 2m temp from the forecasts with strong SSW and from the forecasts with weak SSW.

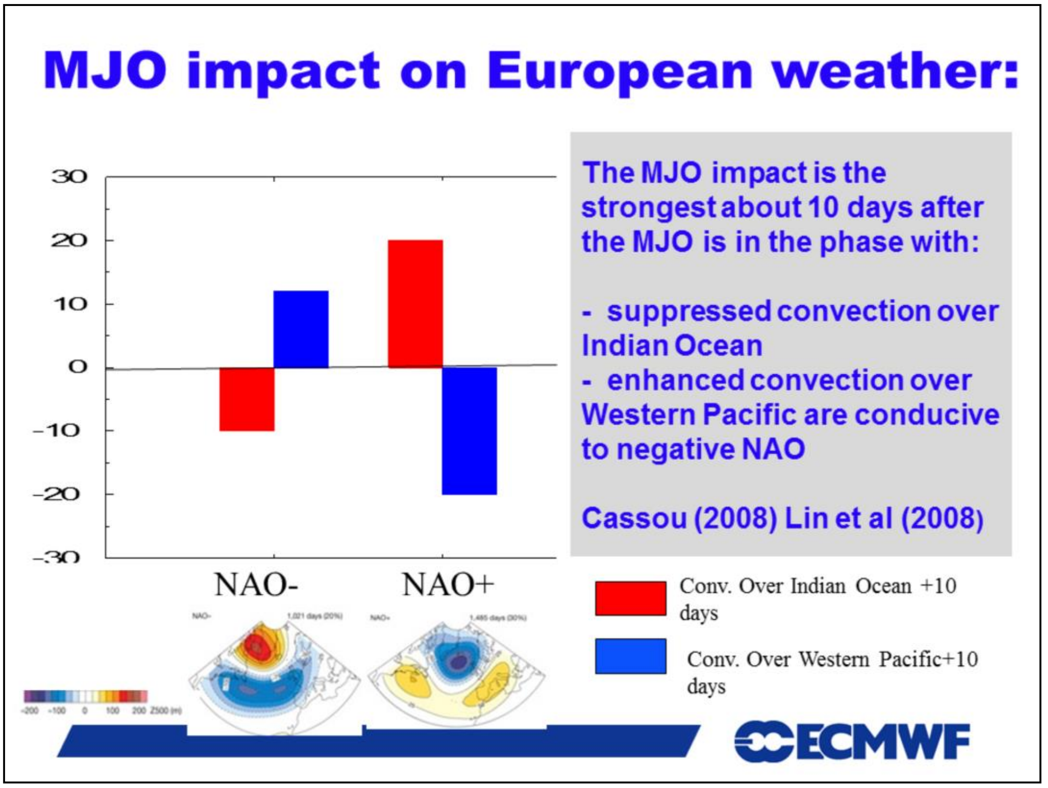
It is clear that the forecast that had a stronger signal in simulating the SSW are also better in reproducing the extension of the cold anomalies particularly over Scandinavia. This implies that if improve the model in representing the SSW and its propagation downwards we can also improve the forecast skill of winter temperature over Europe at day 12-18.



An important source of predictability over Europe in the 10-30 day range originates from the Madden-Julian Oscillation (MJO). The MJO is a 40-50 day tropical oscillation. The MJO is the main intra-seasonal fluctuation that explains weather variations in the tropics. The MJO affects the entire tropical troposphere but is most evident in the Indian and western Pacific Oceans. The MJO involves variations in wind, sea surface temperature (SST), cloudiness, and rainfall. Because most tropical rainfall is convective, and convective cloud tops are very cold (emitting little longwave radiation), the MJO is most obvious in the variation of outgoing longwave radiation (OLR), as measured by an infrared sensor on a satellite.

Several papers suggest that the ocean-atmosphere coupling has a significant impact on the speed of propagation of an MJO event in the equatorial Indian and western Pacific oceans. Therefore, the use of a coupled ocean-atmosphere system may help capture some aspects of the MJO variability.

The left panel shows the evolution of OLR anomalies during a typical MJO. The blue colour indicates increased convection (positive phase of the MJO) and the red colour indicates suppressed convection (negative phase of the MJO). The MJO starts with increased convection in the Indian Ocean. This convection propagates eastwards, and it reaches the Maritime continent by about day 9. It reaches the western Pacific by day 15, and stops at the dateline (180E). Then, the negative phase of the MJO starts, with suppressed convection over the Indian Ocean propagating eastward. The right panel shows the time evolution of OLR anomalies over a period of 3 years from observations (2001 to 2003). In this Hovmoeller diagram, MJO episodes are well visible, but they are not regular. There are periods of strong MJO activity, and periods with low MJO activity. The different MJO events display a lot of variability in intensity and main characteristics, in the same way as ENSO events do not look all the same. The non-regularity in the occurrence of the MJO, makes the forecast of the MJO non trivial.

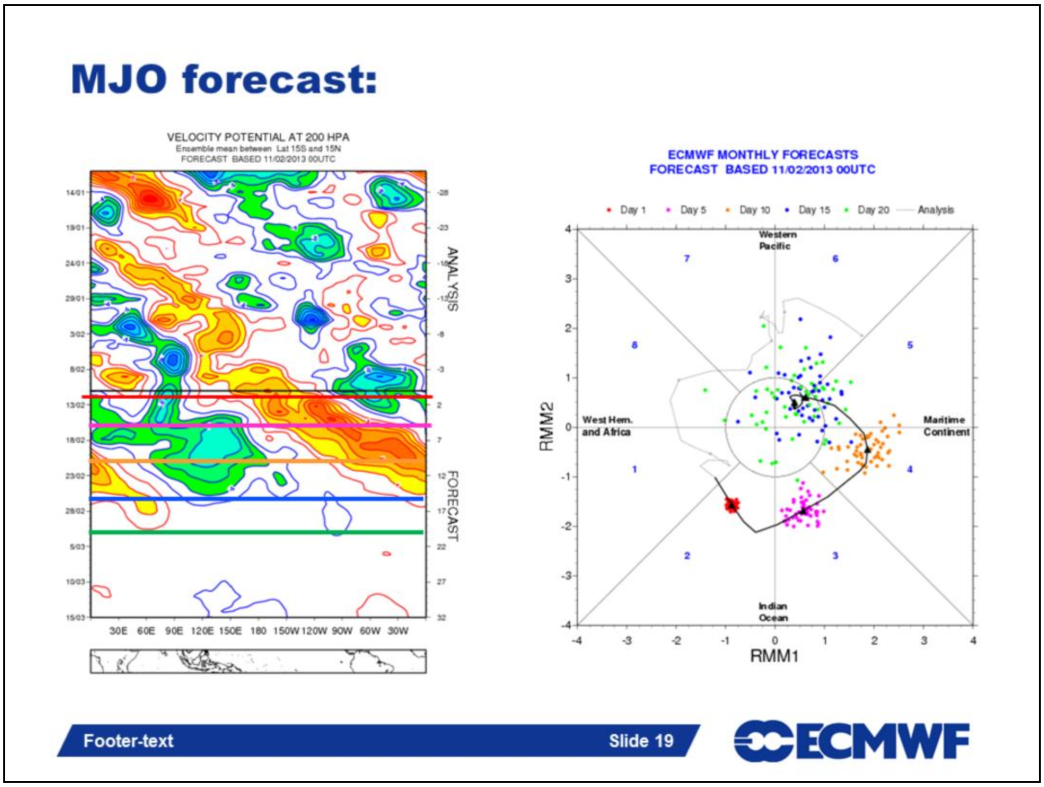


In this slide we show the model is able to reproduce the relationship between the 2 MJO phases and the frequency of NAO. This relation has been well documented by several authors looking at observations.

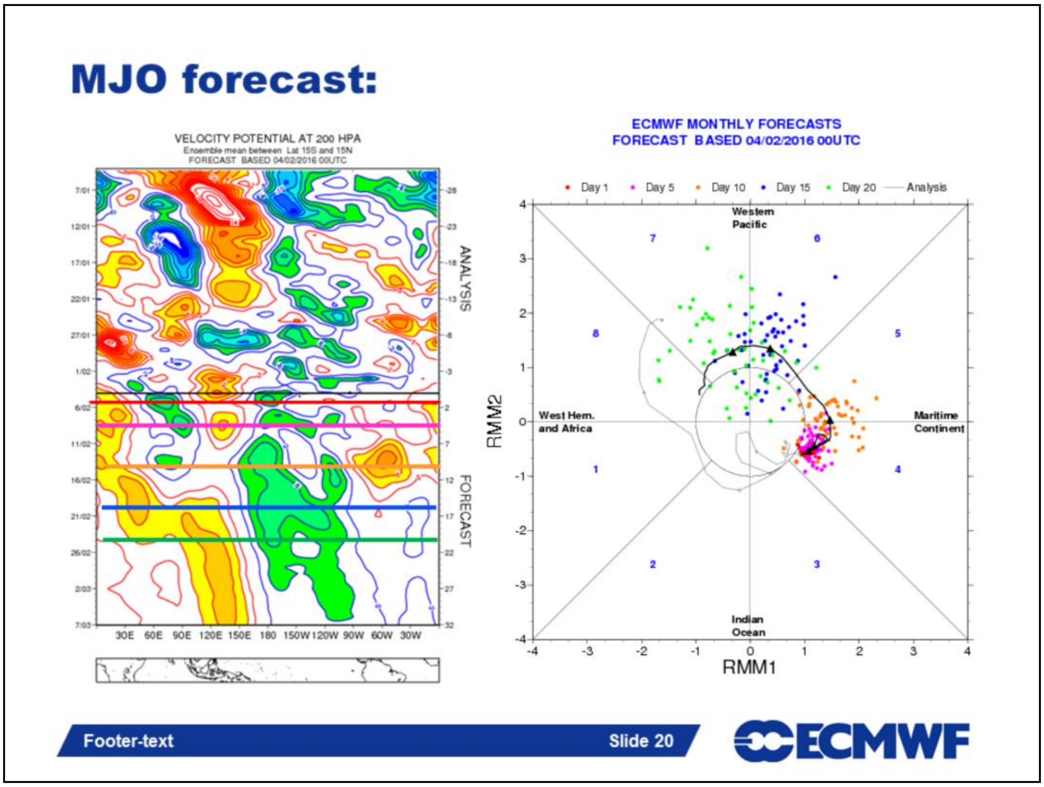
The diagram tell that when there is an MJO phase with enhanced conv. over Indian Ocean 10 days later there is higher frequency of Nao- events with easterly conditions.

Red bars are for Phase 3 + 10days and blue bars are for Phase 6 + 10 days. This plot shows that the strongest impact of the MJO is on the frequency of NAO+. After 10 days the MJO phase exhibits enhanced conv over the Indian Ocean the probabilities of a NAO+ is increased.

When we prepare a forecast over Europe especially for winter/spring it is a good idea to look at the tropical anomalies and check if there in an MJO event. If there is an MJO event we can be more confident about the forecast.



The time evolution of the MJO predicted by the EPS is described by a multivariate MJO index (Wheeler and Hendon 2004 Mon. Wea. Rev. vol. 132, 8 p 1917-1932). The diagram represents 8 regions of the two dimensional phase space defined by the first two principal components (RMM1 and RMM2) of a combined fields (OLR zonal wind at 850 hPa and 200 hPa) averaged between 15S and 15N. Individual ensemble member values at day 1, 5, 10, 15 and 20 are represented respectively by a red, pink orange blue and green circles. The ensemble mean values (black triangles) are joined by a solid black line and the analysis values of the preceeding 30 days are joined by a grey line. The grey squares represent the analysis values of the preceeding 5, 10, 15, 20, 25 and 30 days. Points representing sequential values trace anticlock-wise trajectories around the origin,indicating systematic eastward propagation of the MJO. Large amplitudes (outside of the circle) signify strong cycles of the MJO, while weak activity appears as rather random motion near the origin.



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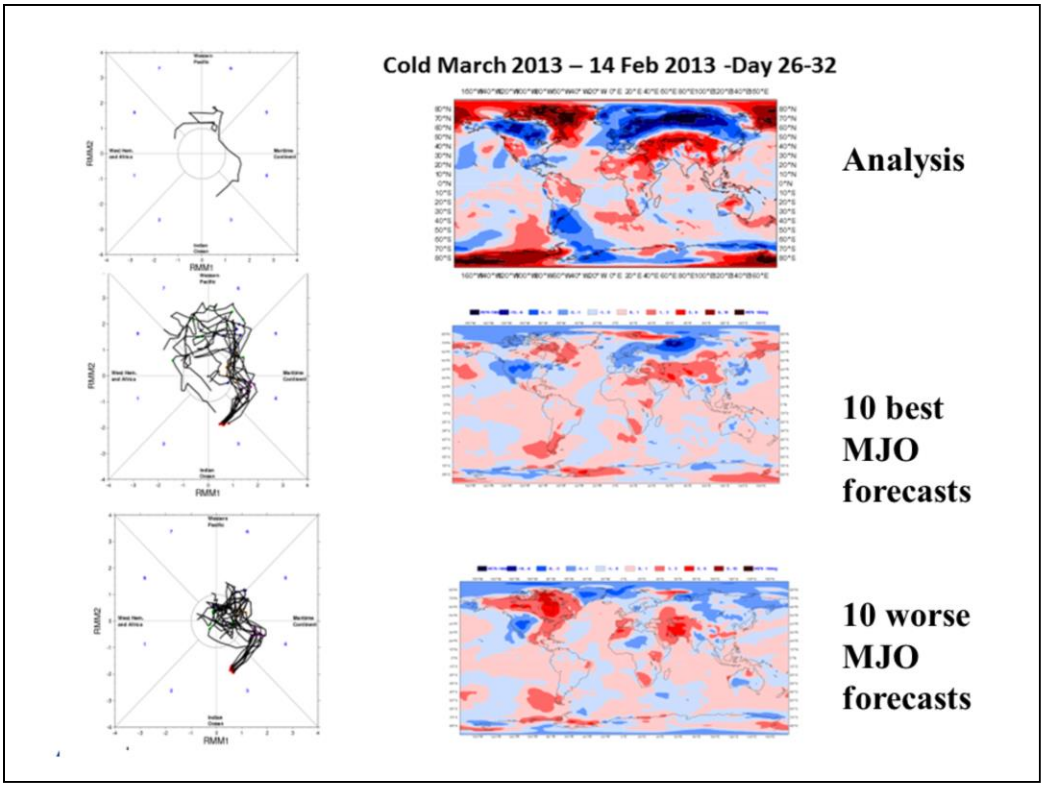
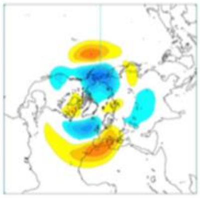

Cold March 2013 – 14 Feb 2013 -Day 26-32
Analysis
10 best MJO forecasts
10 worse MJO forecasts
RMM1
RMM2
Western Pacific
Indian Ocean
West. Hem. and Africa
Maritime Continent

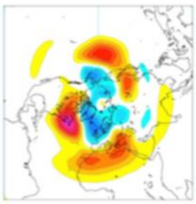
MJO Teleconnections

Evolution of NAO skill scores day 19-25

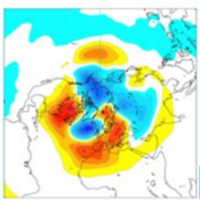
2002 MOFC hindcasts



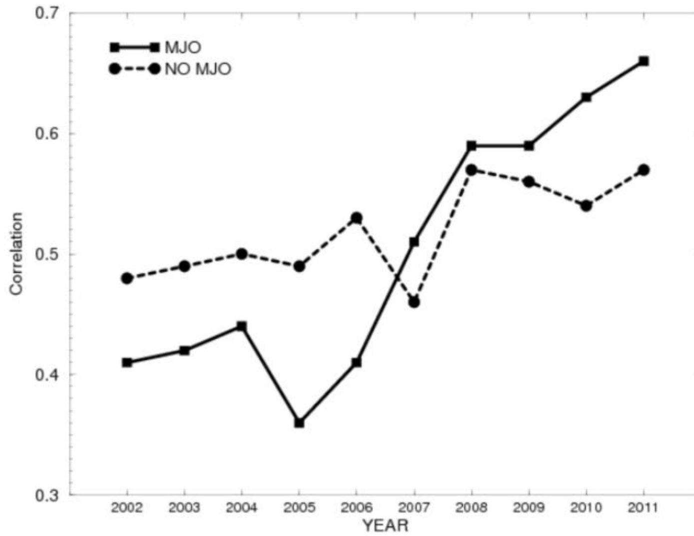
2013 MOFC hindcasts

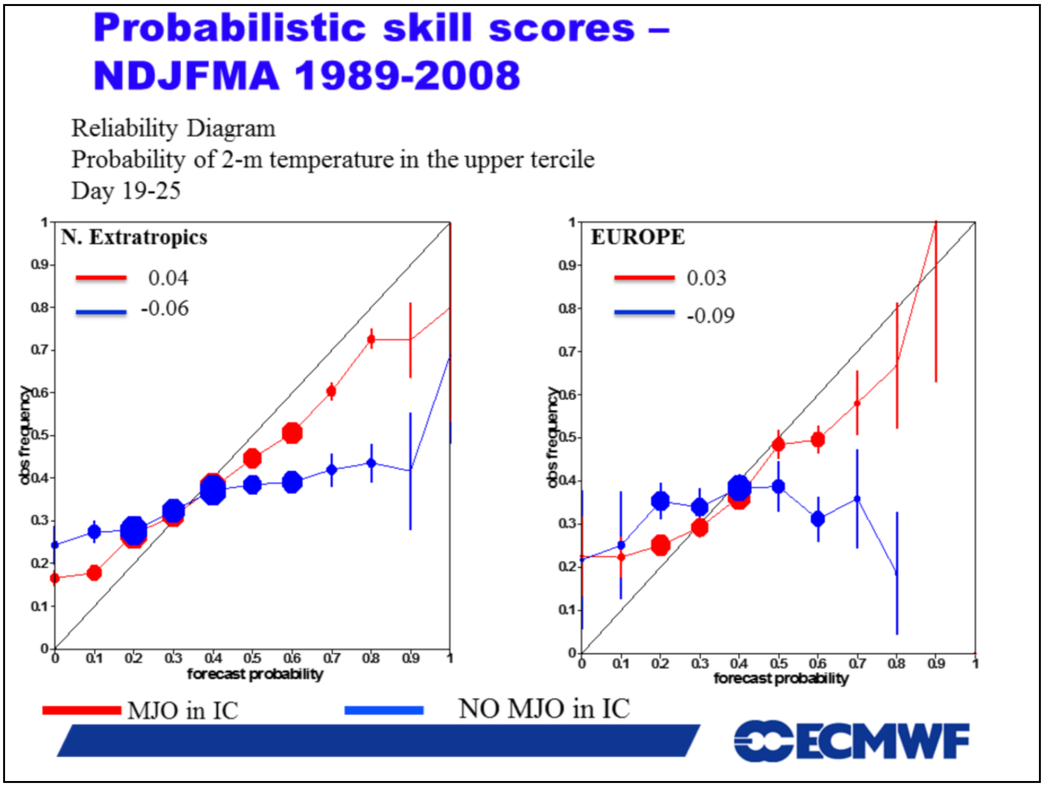


ERA Interim

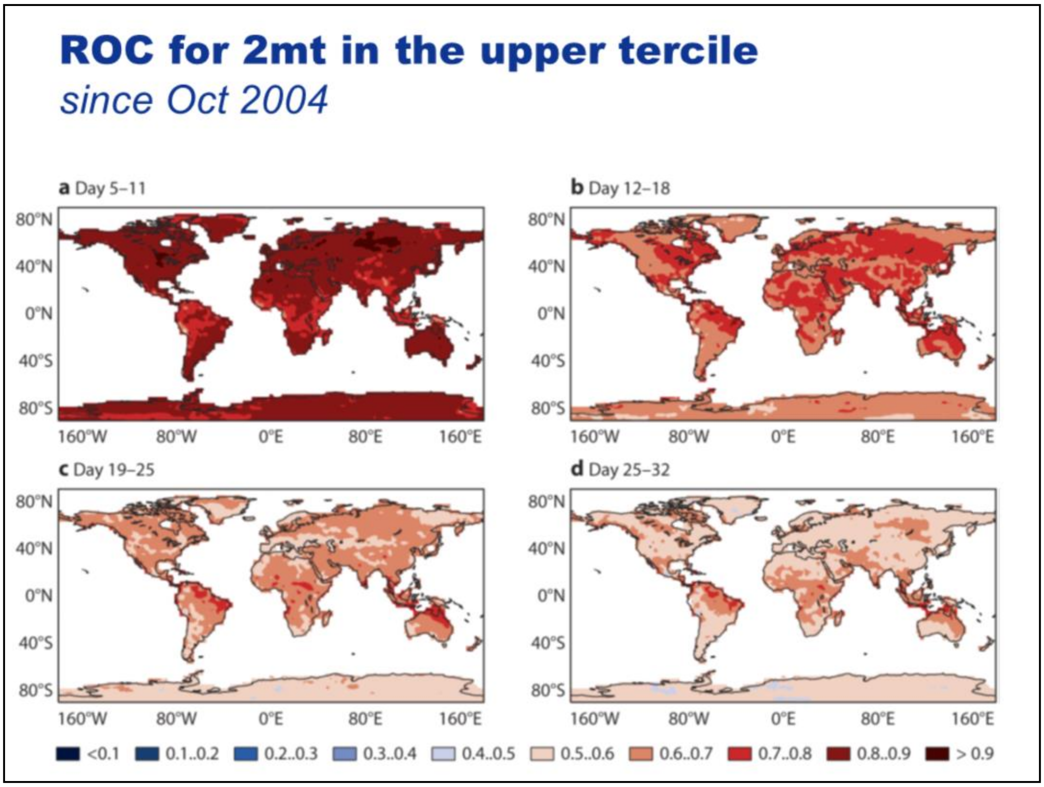


NAO index is computed as projection onto a reference pattern

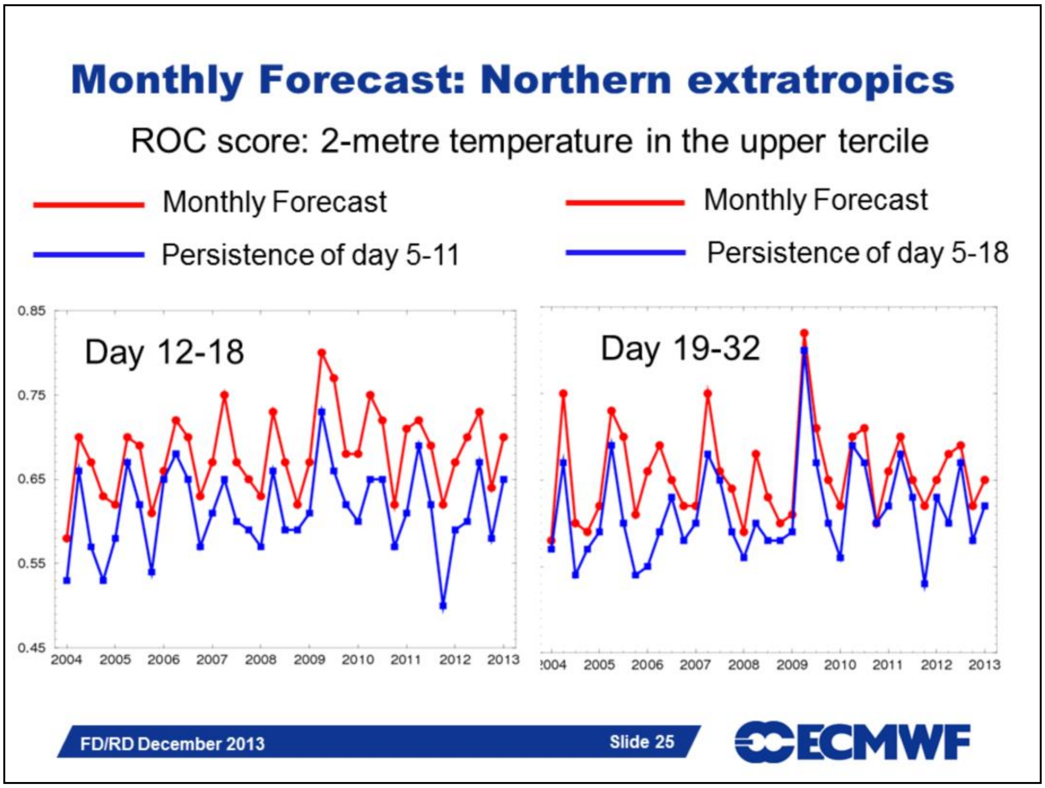




Slide 47: Reliability of the probability that 2-metre temperature anomalies are in the upper tercile for the period day 19-25 for the Northern Extratropics (left panel) and Europe (right panel). The red (blue) line represents the reliability diagram obtained with all the cases with an MJO (no MJO) in the initial conditions. The numbers represent the Brier Skill Scores. Only land points have been included in the calculation of the reliability diagram and the Brier skill scores. This figure shows that the MJO has a major source of predictability for the time range day 19-25 in the ECMWF forecasting system.



The skill of the monthly forecasts is routinely evaluated by scoring the 51-member real time forecasts, mainly against analyses, using a range of measures. For instance, Figure 2 shows skill scores of 2-metre temperature anomalies based on all the real-time forecasts since October 2004, when the monthly forecasts became operational. The skill score is the area under the Relative Operating Characteristic (ROC; see Wilks 2011 for a general introduction of probabilistic verification metrics), a measure of the capability of the ensemble to discriminate between occurrence and non-occurrence of events. A ROC score larger than 0.5 indicates that the model is more skilful than climatology. Figure 2 shows a drop of skill with increased time range as expected. For the 12–18 day forecast, the ROC area exceeds 0.7 over large portions of the northern extra-tropics. One week later (i.e. the 19–25 day forecast), the northern extra-tropics still display some skill in predicting 2-metre temperature anomalies, but the highest skills scores are in the tropics. At days 26–32, the skill in the northern extra-tropics is low, although larger than climatology, while skill is largest in the Tropics. An issue with this type of verification is that it mixes forecasts which have been produced using different versions of the IFS since 2004



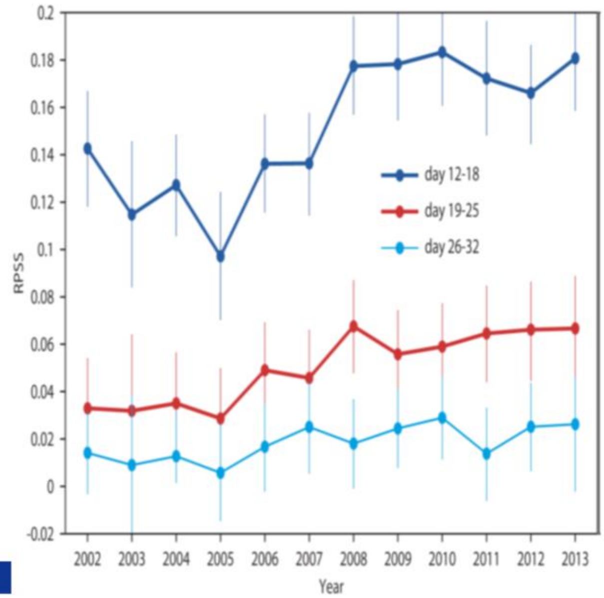
Latest points are SON 2013. The scores of the monthly forecast (seasonal means) for day 12-18 and day 19-32. At both ranges the forecast is better than the persistence.

Evolution of skill scores based on the re-forecasts

RPSS – Probability of 2mt in upper tercile NDJFM

All the re-forecasts produced since 2002 have the period 1995-2001 in common.

RPSS scores have been computed for all the re-forecasts produced between April of a given year and March of the following year and covering the period 1995-2001 (once a week, 5-member ensemble).

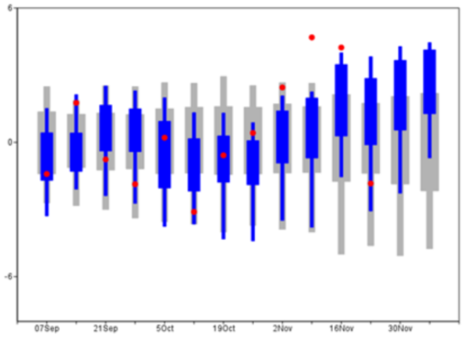


Footer-text

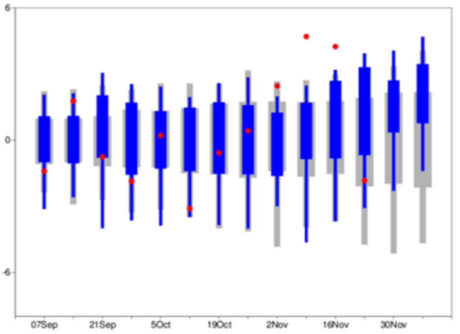
Although there is a drop in the probabilistic skill score between days 12–18 and days 19–25, the monthly forecasts still display better skill than climatology (positive RPSS). These results also suggests that there have been improvements in the RPSS scores of 2-metre temperature anomaly re-forecasts over the northern extra-tropics for all three time ranges (days 12–18, days 19–25 and days 26–32) since 2002. The values of the discrete RPSS for days 26–32, although still very low, are now close to the values for the previous week (days 19–25) re-forecasts that were produced in 2002. The skill scores of days 19–25 have also improved almost linearly in time and get close to the skill scores of days 12–18 in the early years of the ECMWF monthly forecasts.

September to December 2015
2m temp weekly anomalies
(55-45N 5-15E):

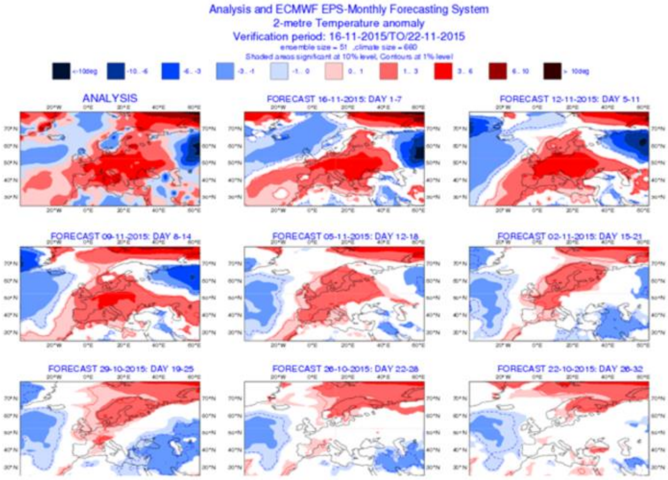
For. range 12-18 days days



For. range 19-25



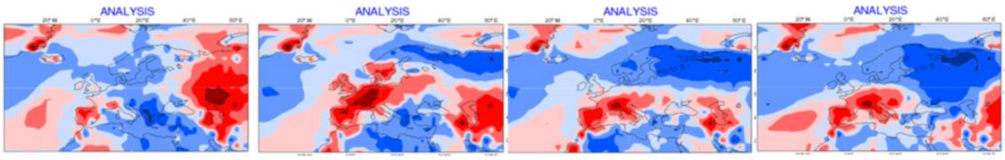
ECMWF



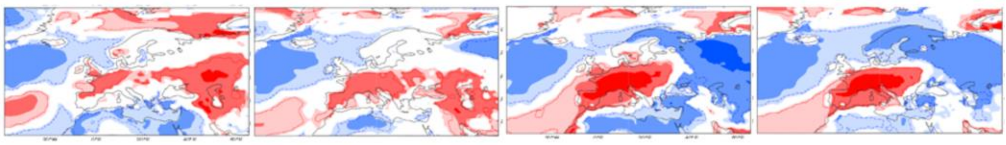
Analysis and ECMWF EPS-Monthly Forecasting System
2-metre Temperature anomaly
Verification period: 16-11-2015/TO/22-11-2015
ensemble size = 51 ,climate size = 660
Shaded areas significant at 10% level, Contours at 1% level
ANALYSIS
FORECAST 16-11-2015: DAY 1-7
FORECAST 12-11-2015: DAY 5-11
FORECAST 09-11-2015: DAY 8-14
FORECAST 05-11-2015: DAY 12-18
FORECAST 02-11-2015: DAY 15-21
FORECAST 29-10-2015: DAY 19-25
FORECAST 26-10-2015: DAY 22-28
FORECAST 22-10-2015: DAY 26-32

ECMWF

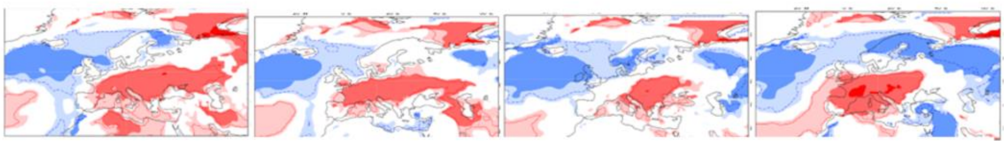
Heat wave over Central-southern Europe: 2mt weekly mean anomalies



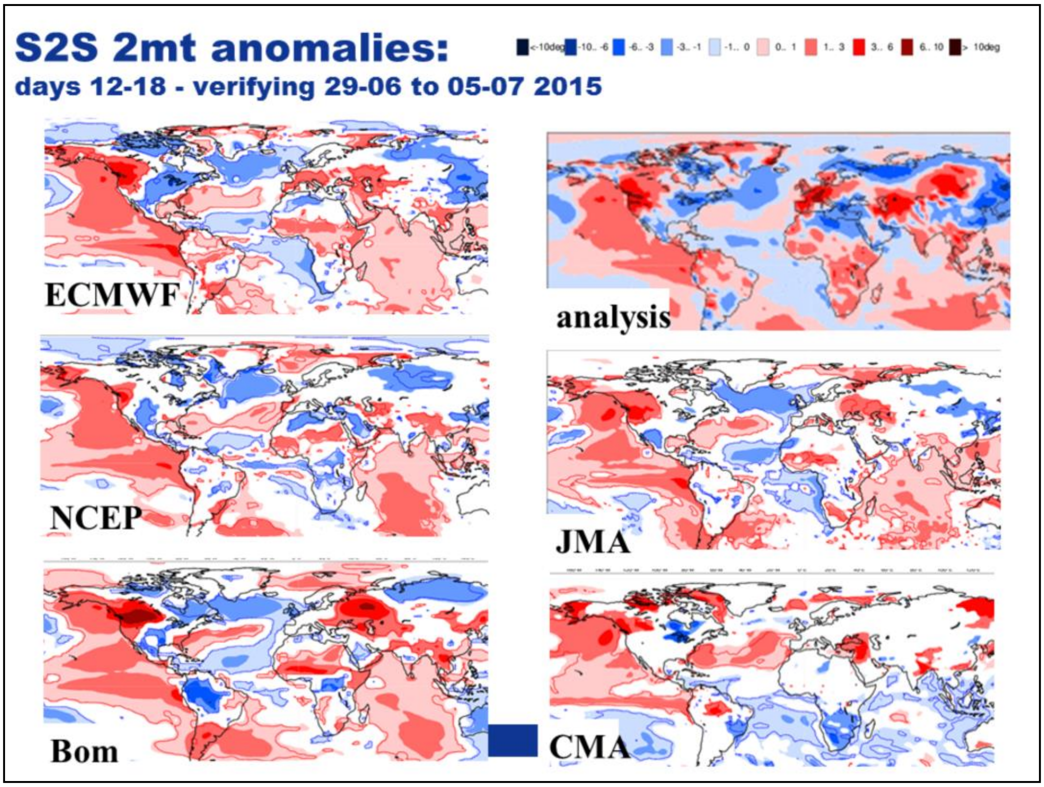
22-28 Jun   29-5Jul   6-12Jul   13-19Jul



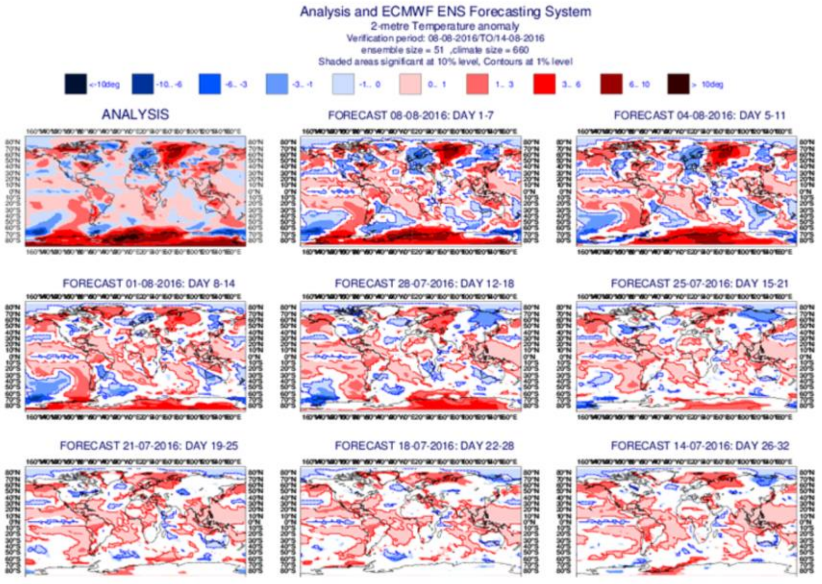
Forecasts: 12-18 days

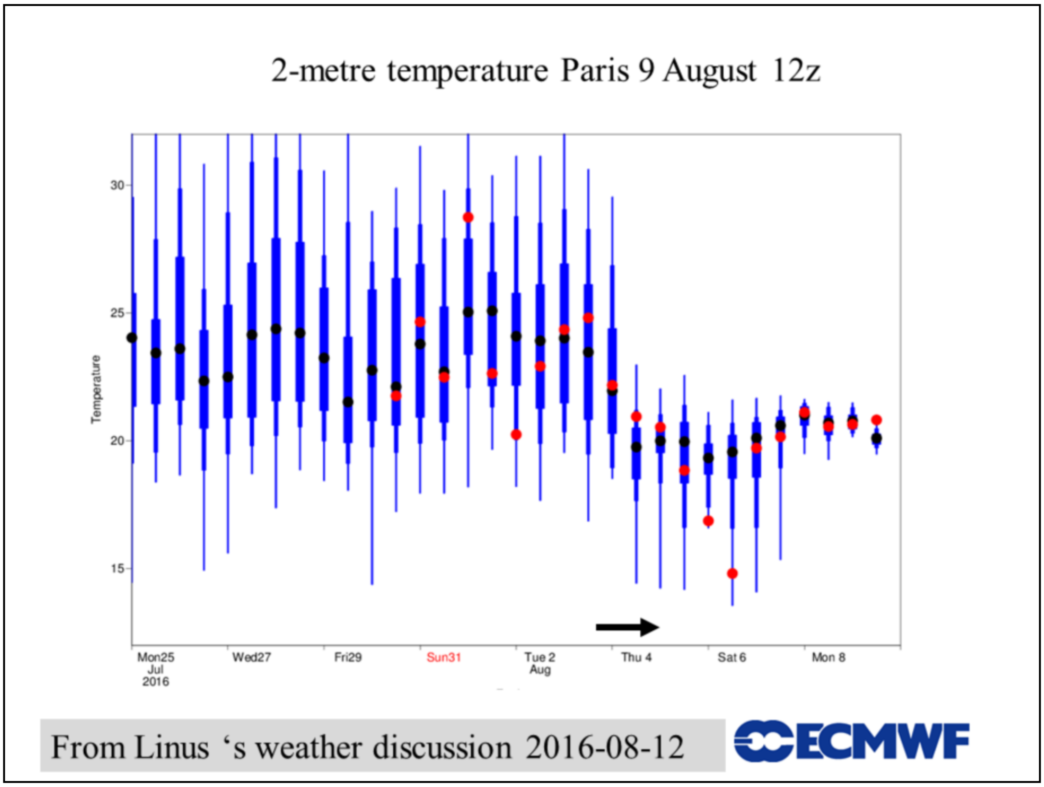


Forecasts: 19-25 days

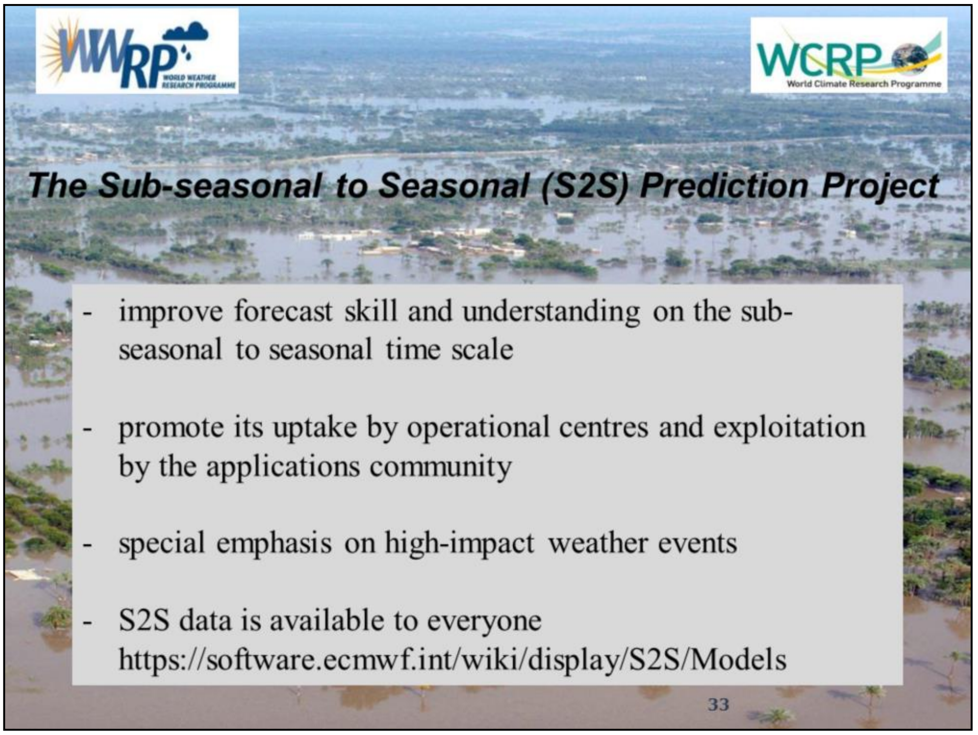


ECMWF ens-size 51 Clim size 60 jma ens 60 clim25 ncep ens 16 clim 48
cma ens 4 clim 48 Bom ens 33 clim 396

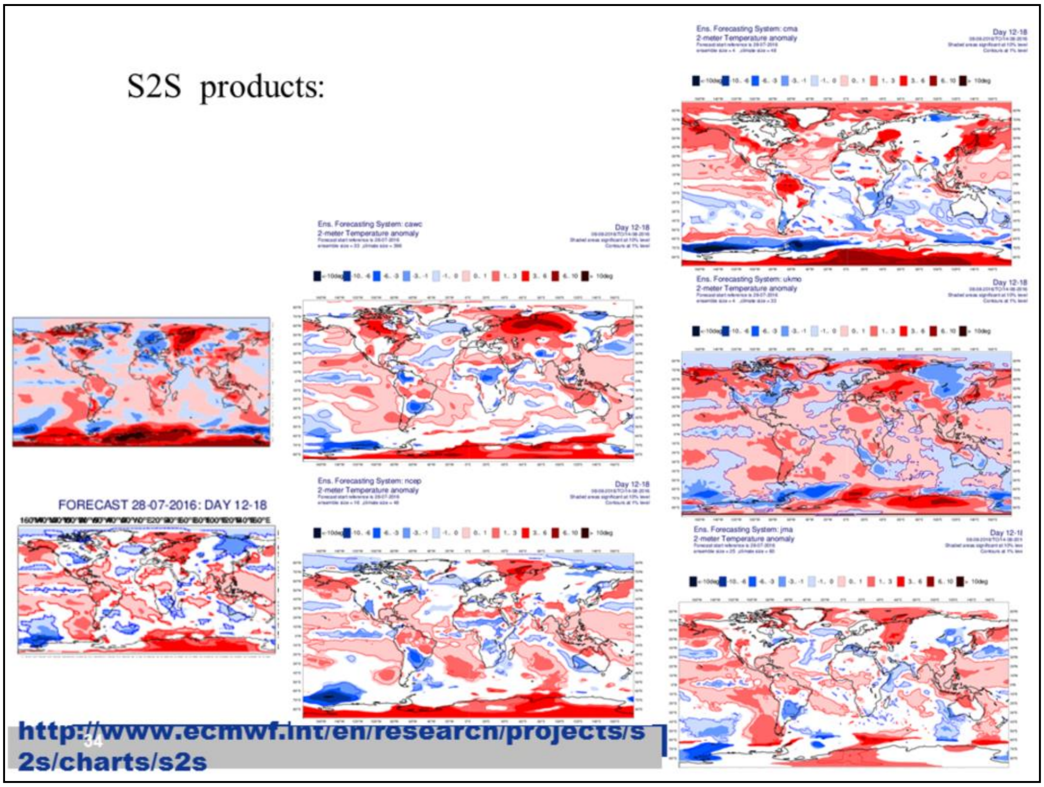

Analysis and ECMWF ENS Forecasting System
2-metre Temperature anomaly
Verification period: 08-08-2016/TO/14-08-2016
ensemble size = 51 ,climate size = 660
Shaded areas significant at 10% level, Contours at 1% level
<-10deg
-10..-6
-6..-3
-3..-1
-1..0
0..1
1..3
3..6
6..10
> 10deg
ANALYSIS
FORECAST 08-08-2016: DAY 1-7
FORECAST 04-08-2016: DAY 5-11
FORECAST 01-08-2016: DAY 8-14
FORECAST 28-07-2016: DAY 12-18
FORECAST 25-07-2016: DAY 15-21
FORECAST 21-07-2016: DAY 19-25
FORECAST 18-07-2016: DAY 22-28
FORECAST 14-07-2016: DAY 26-32



Verification is about 20Celsius



S2S, sub-seasonal to seasonal prediction project, is a WWRP/THORPEX-WCRP joint research project



Warm conditions over west Siberia are associated with the anticyclonic the summertime height anomalies regressed onto the ENSO phase during November to January reveal enhanced anticyclonic circulation

Conclusion

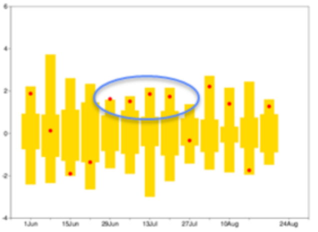
- SSTs, Soil moisture, stratospheric initial conditions and MJO are source of predictability at the intra-seasonal time scale. In particular the MJO has a significant impact on the forecast skill scores beyond day 20.

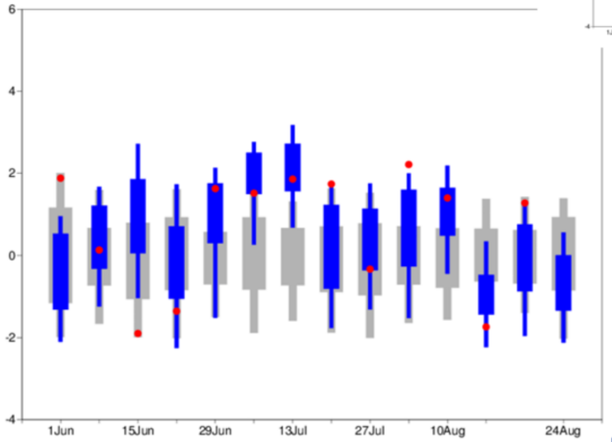
- The ENS produces forecasts for days 12-18 that are generally better than climatology and persistence of day 5-11. Beyond day 20, the skill is marginal but for some applications and some regions has some interest.

- Making improvements to sub-seasonal predictions, assessing their skill and uncertainty, and exploring ways to communicate their benefits to decision-makers are significant challenges. The S2S WWRP/THORPEX-WCRP joint project (http://s2sprediction.net) is embracing all these challenges and, to promote this research, has created a new database with a set of multi-model S2S reforecasts and forecasts freely available to the community.

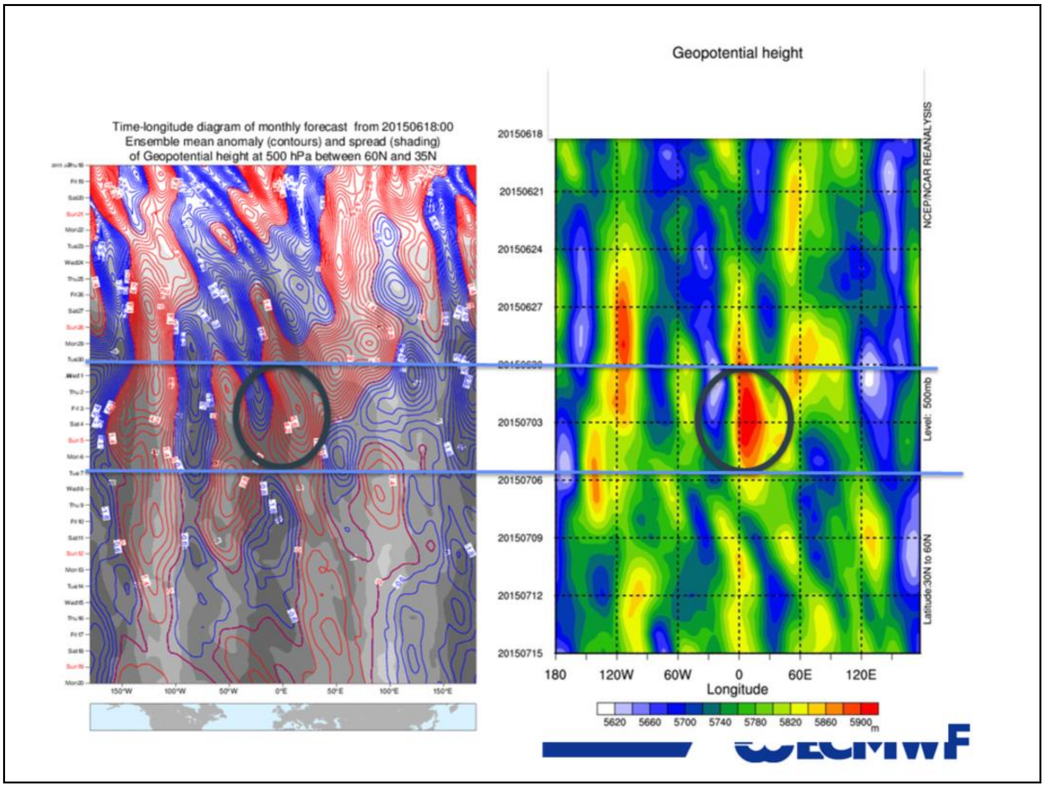
ECMWF

weekly mean anomalies over Southern Europe: 2mt forecast 12-18





ECMWF


Time-longitude diagram of monthly forecast from 20150618:00
Ensemble mean anomaly (contours) and spread (shading)
of Geopotential height at 500 hPa between 60N and 35N
Geopotential height
NCEP/NCAR REANALYSIS
Level: 500mb
Latitude:30N to 60N
20150618
20150621
20150624
20150627
20150703
20150706
20150709
20150712
20150715
180
120W
60W
0
60E
120E
Longitude
5620
5660
5700
5740
5780
5820
5860
5900
m

Stochastic Perturbed Parametrization Tendency (SPPT) scheme

Uncertainties in the model physical parametrizations can be a significant source of random error. This led to the development SPPT. It has been used in the since October 1998 there has been an increase in ensemble spread in the EPS and improved probability skill scores.

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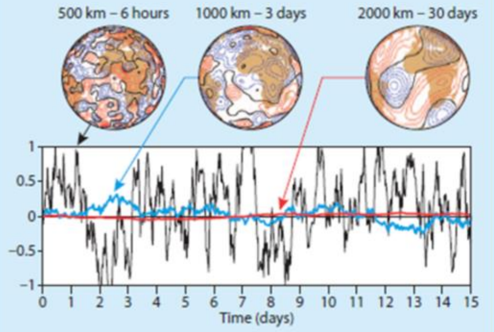
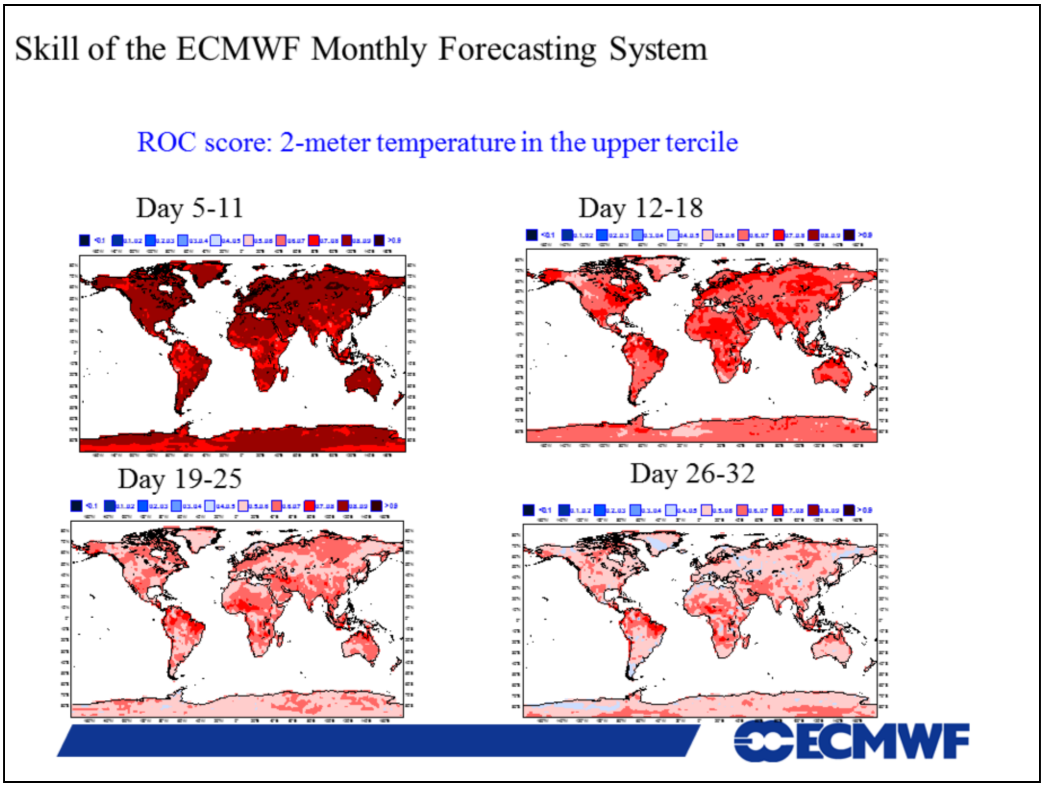


The three patterns underlying the SPPT3 scheme. The numbers next to the spheres indicate the horizontal spatial and temporal correlation scales in kilometres and hours. The three curves on the graph show time series of the pattern values at a point employed in the operational scheme The colour of the arrows relates the patterns to the time series.

Stochastic backscatter scheme (SKEB)

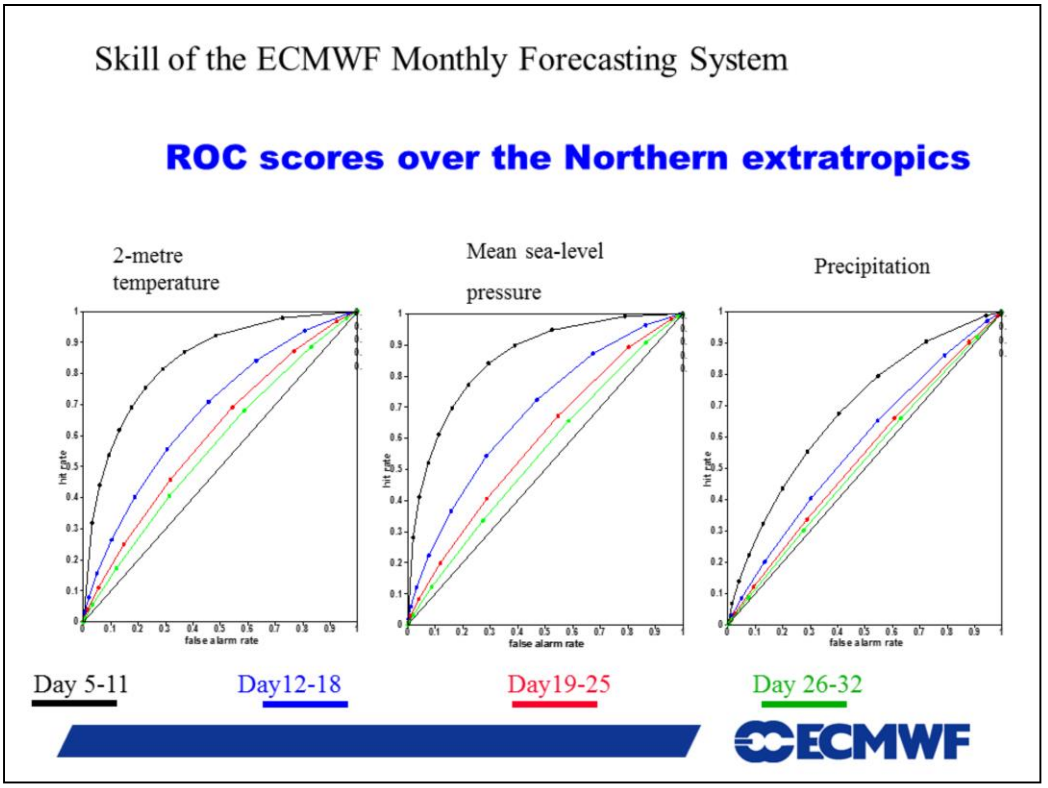
It compensate for the loss of energy in the model due to the Mis-representation of processes at sub-gridscale.

ECMWF



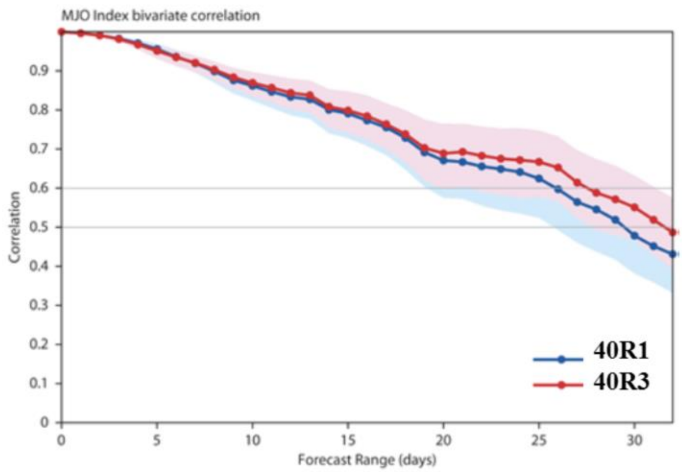
Slide 16 Map of ROC scores of the probability that 2-meter temperature averaged over the period day 12-18 is in the upper tercile. Only the scores over land points are shown. The terciles have been defined from the model climatology. The verification period is Oct 2004-May 2008. Red areas indicate areas where the ROC score exceeds 0.5 (better than climatology). This plot shows that the coupled model performs better than climatology for the period days 12-18.

For the period days 19-26, the skill is much lower than for days 12-18, as expected. The red is largely dominating overall, suggesting that the model generally performs better than climatology at this time scale. Europe seems to be a difficult region, with very low skill at this time range. Tropical regions display the strongest skill after 30 days, suggesting that the coupled model at this time range starts to behave more like seasonal forecasting.

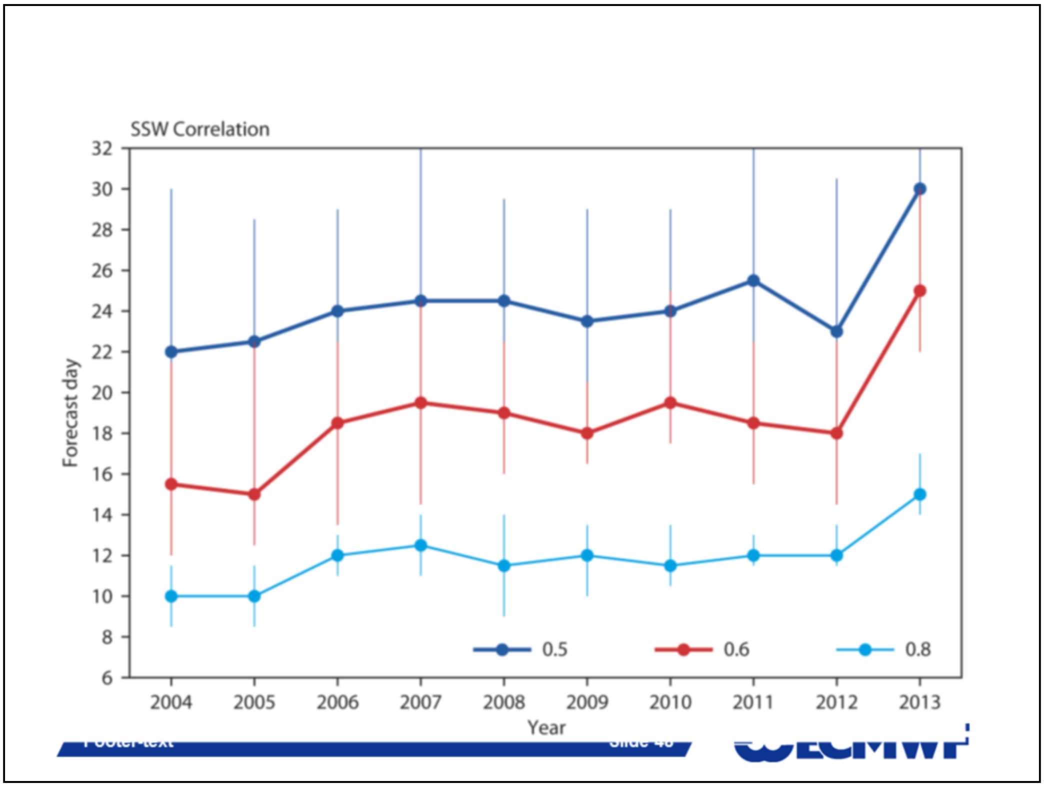


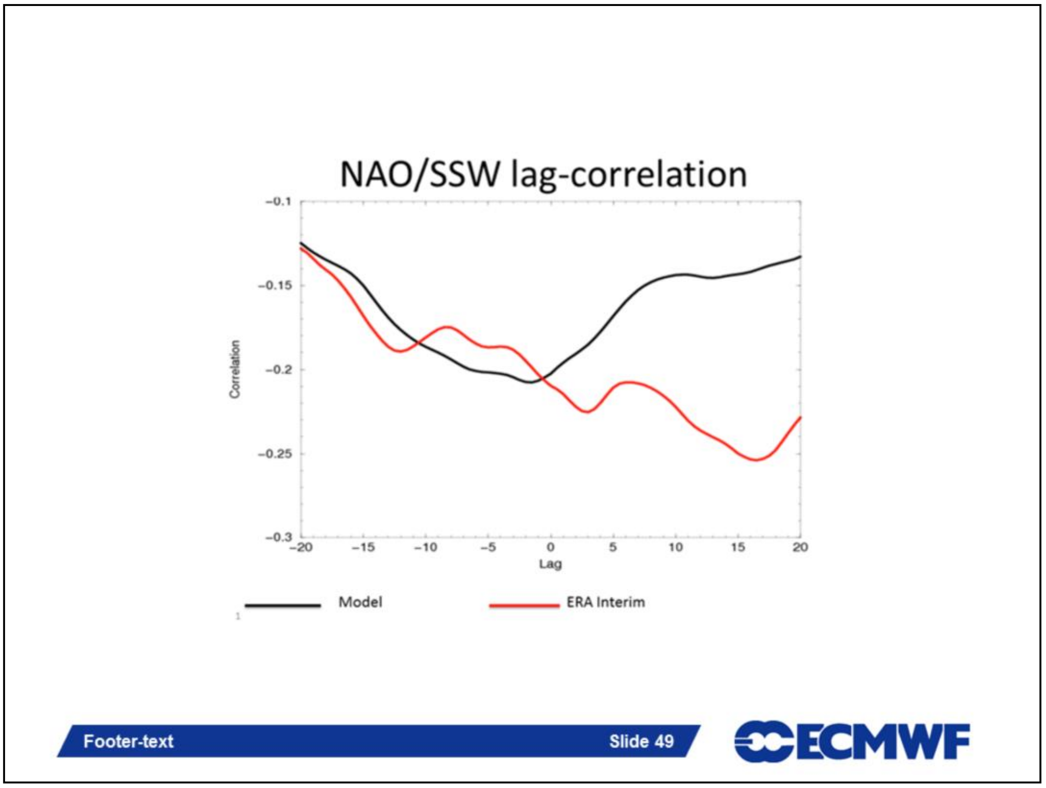
Slide 19: ROC diagrams of the probability that weekly (left) 2-meter temperature, (middle) mean-sea level pressure, and (right) precipitation are in the upper tercile. The diagrams have been calculated over all the land grid points of the Northern hemisphere extratropics (North of 30N) and over the 45 cases. The solid black line represents the period days 5-11, the blue line days 12-18, the red line days 19-25, the green line days 26-32. This plot shows that the ROC score varies a lot from one variable to another. For days 12-18, the ROC score remains sufficiently high to be potentially useful, particularly for temperature.

Madden Julian Oscillation



Improvement due to revised organised convective detrainment term and the revised convective momentum transport.


SSW Correlation
Forecast day
Year
0.5
0.6
0.8
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013


NAO/SSW lag-correlation
Correlation
Lag
−0.1
−0.15
−0.2
−0.25
−0.3
−20
−15
−10
−5
0
5
10
15
20
Model
ERA Interim
Footer-text
Slide 49
ECMWF