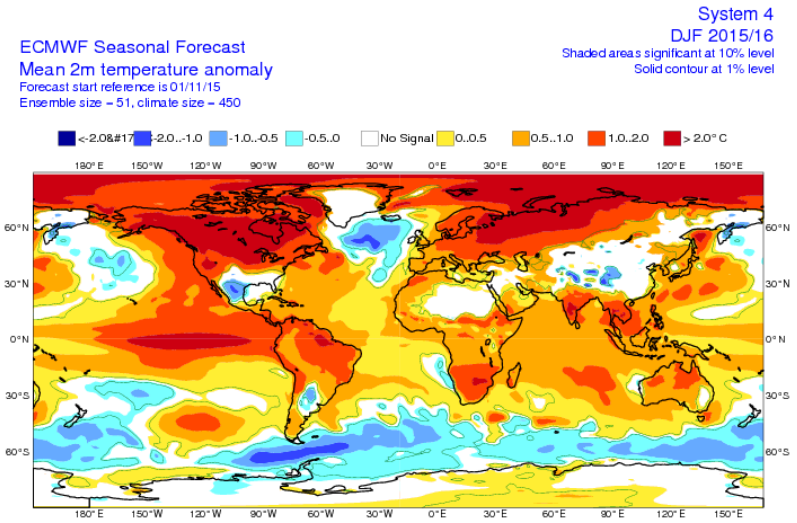
Sub-seasonal time scales: a user-oriented verification approach

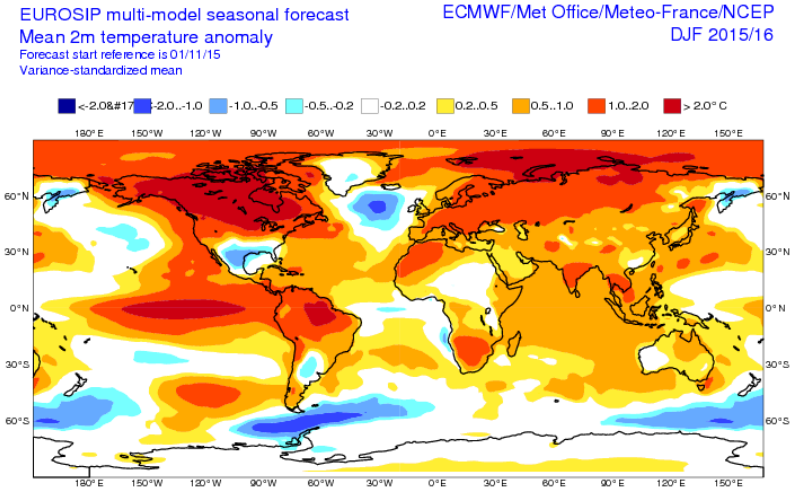
How far in advance can we forecast cold/heat spells ?

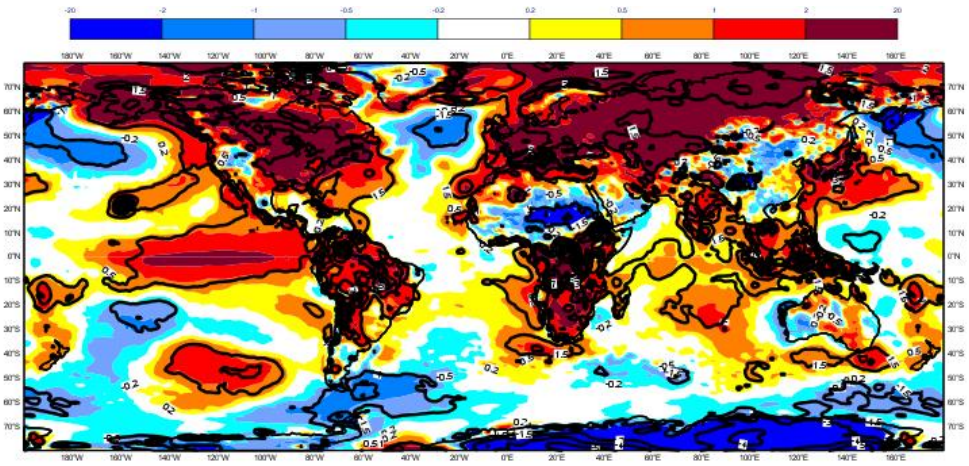
Laura Ferranti , L. Magnusson, F. Vitart, D. Richardson, M. Rodwell

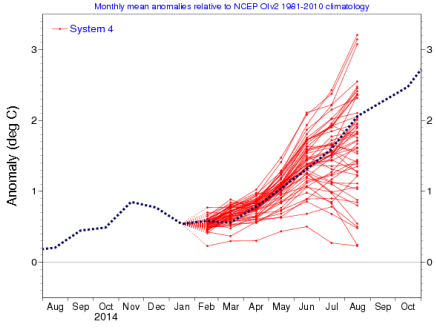
Danube, Feb 2012

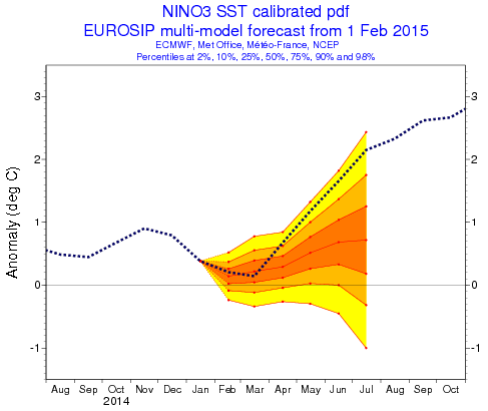
2mt anomalies for DJF 2016: analysis



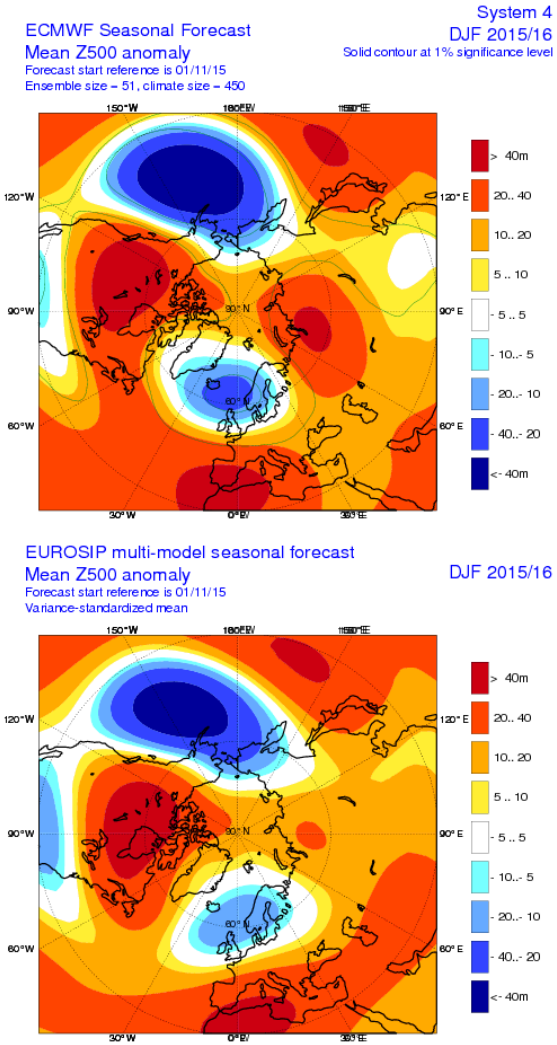




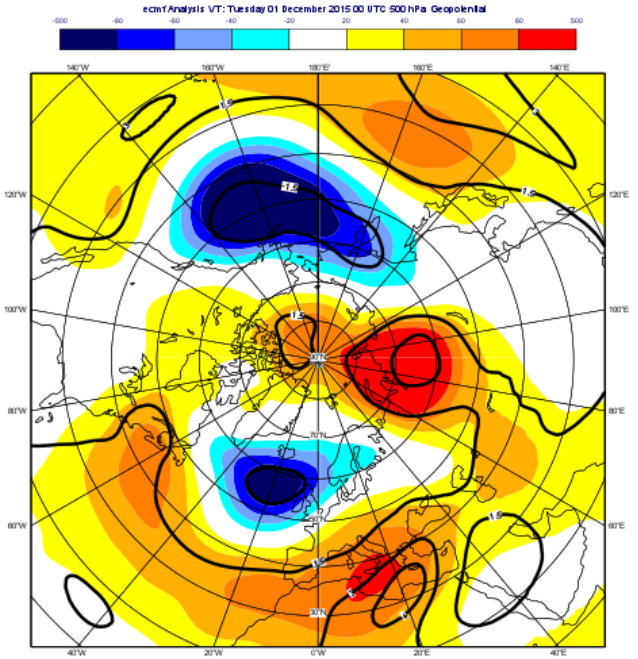




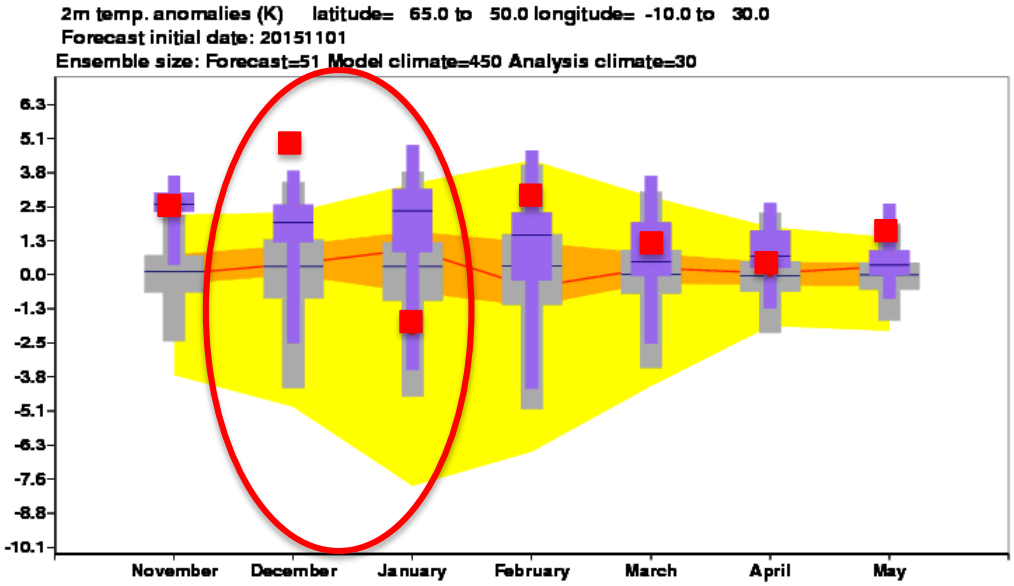
2015 was the hottest year in the modern record, global temperature was well over 0.4 C warmer than the 1981-2010 average, and almost 0.1 C warmer than the previous warmest year. To what extent El Niño contributed to the record-breaking warmth is still a matter of debate.

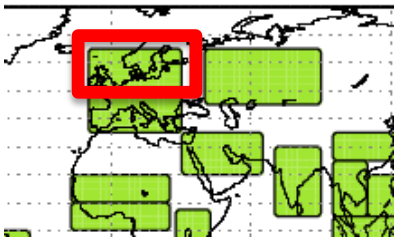


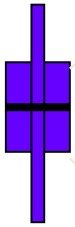
Z500 anomalies for DJF 2016 : analysis



Monthly means anomalies:
2m temp. over Northern Europe



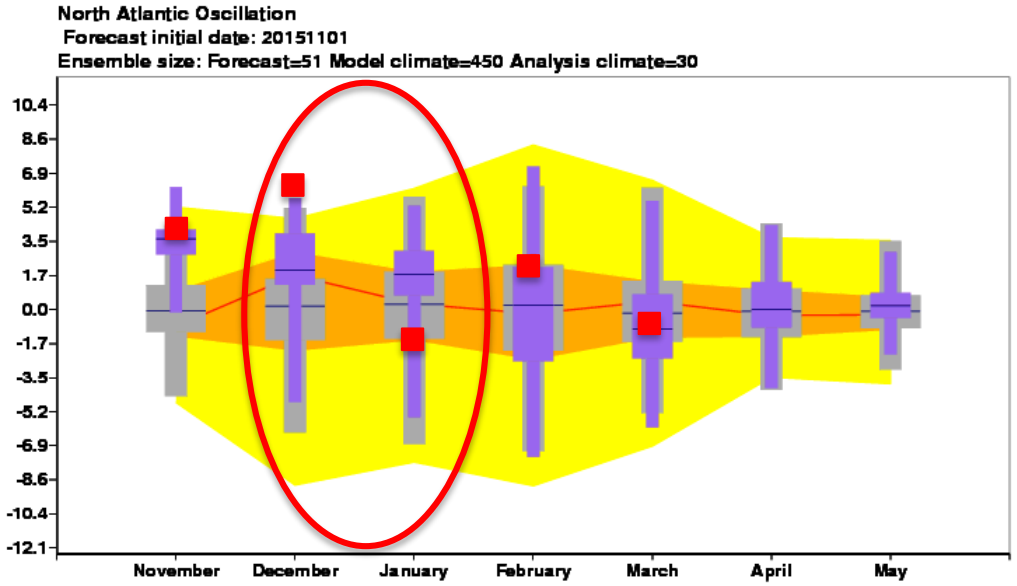




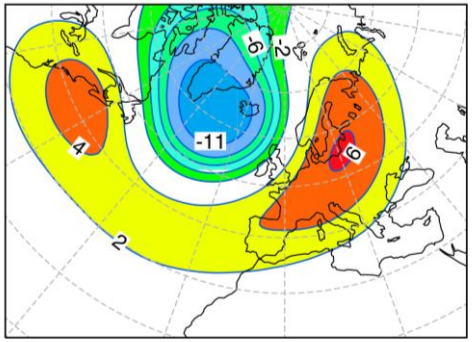
66%

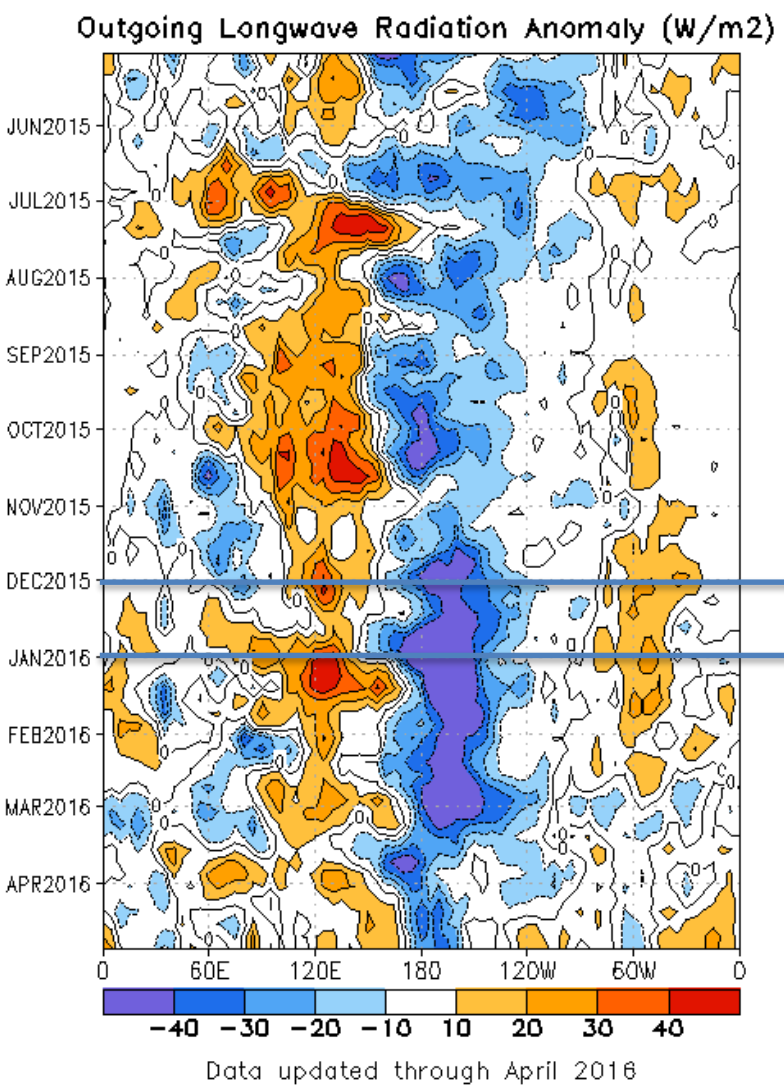
median

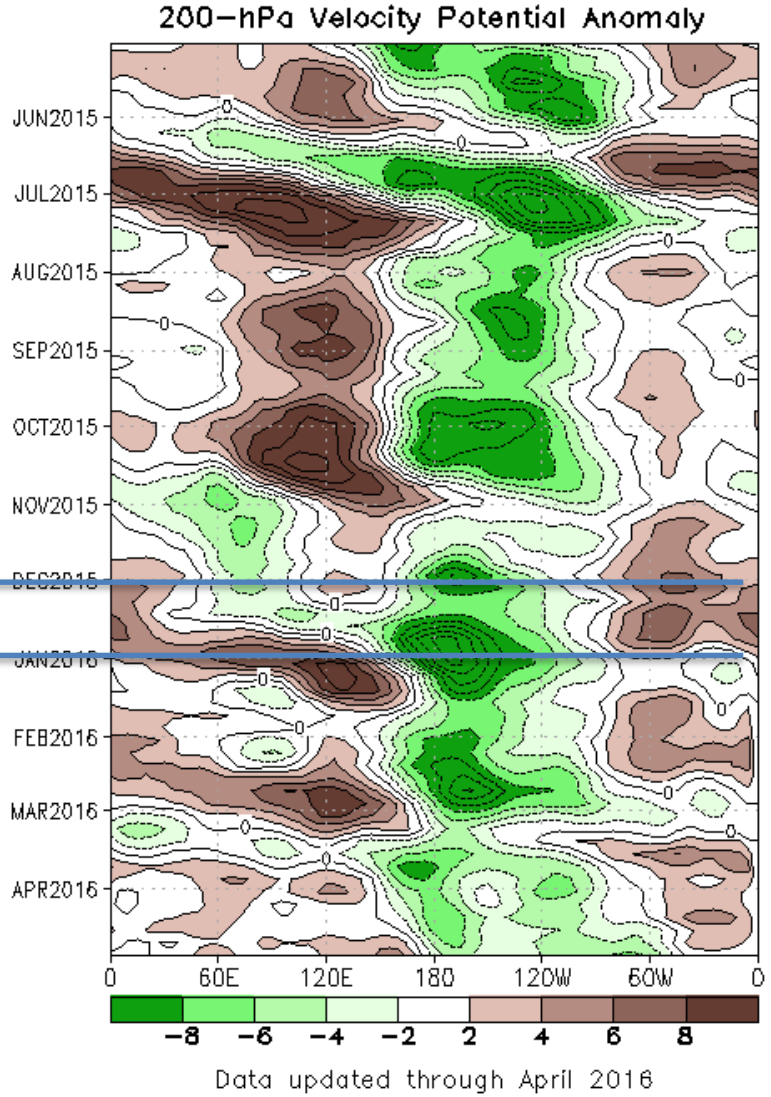
33%



NAO pattern




Outgoing Longwave Radiation Anomaly (W/m2)
JUN2015
JUL2015
AUG2015
SEP2015
OCT2015
NOV2015
DEC2015
JAN2016
FEB2016
MAR2016
APR2016
0
60E
120E
180
120W
60W
0
−40 −30 −20 −10 10 20 30 40
Data updated through April 2016

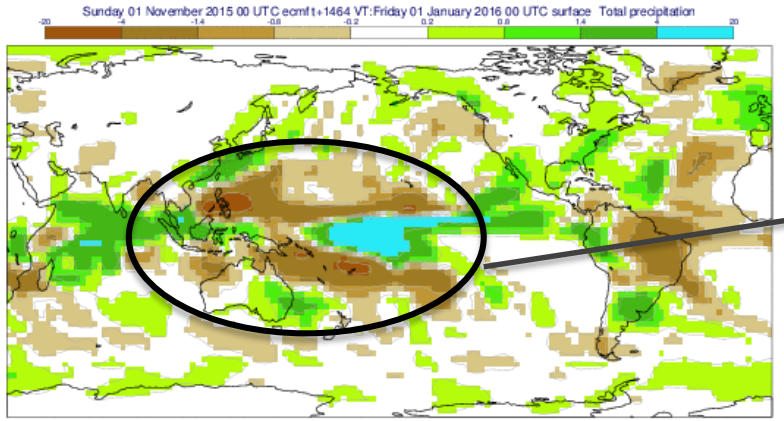

200−hPa Velocity Potential Anomaly
JUN2015
JUL2015
AUG2015
SEP2015
OCT2015
NOV2015
DEC2015
JAN2016
FEB2016
MAR2016
APR2016
0
60E
120E
180
120W
60W
0
−8 −6 −4 −2 2 4 6 8
Data updated through April 2016

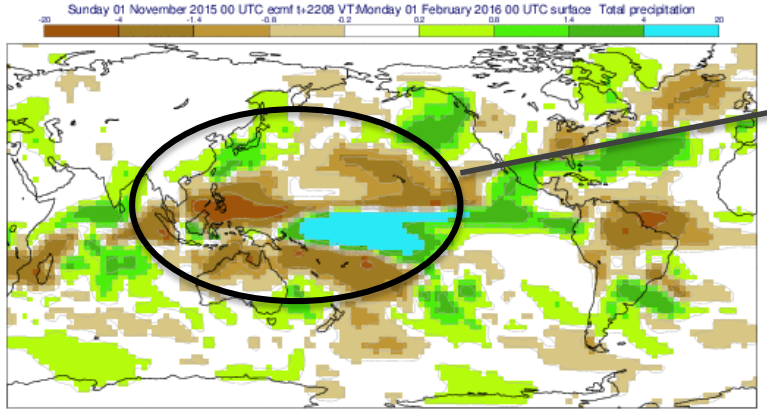
Best members precipitation composites:

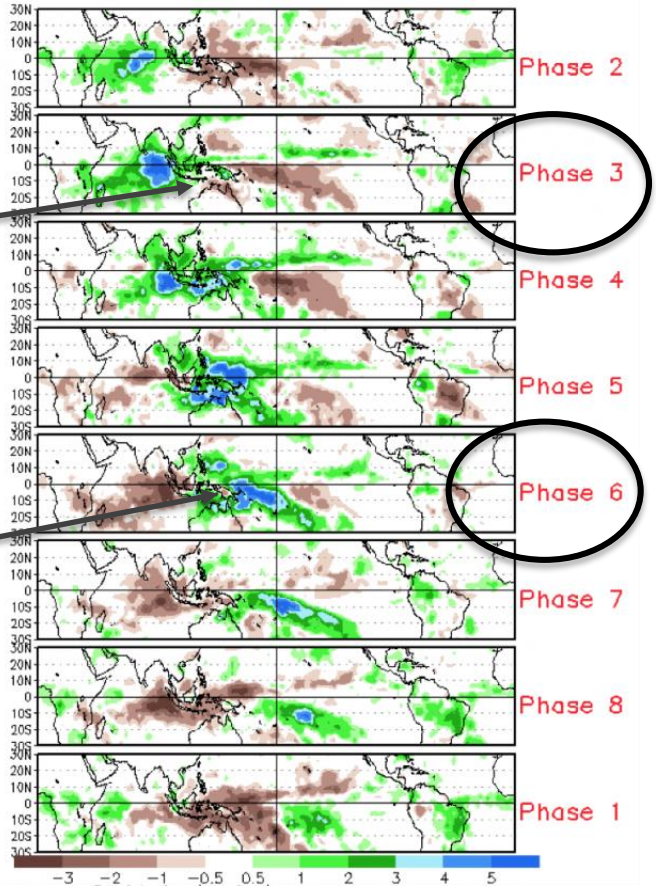
the best members are the ones showing the strongest change in NAO between December to January

December
NAO +

January
NAO-

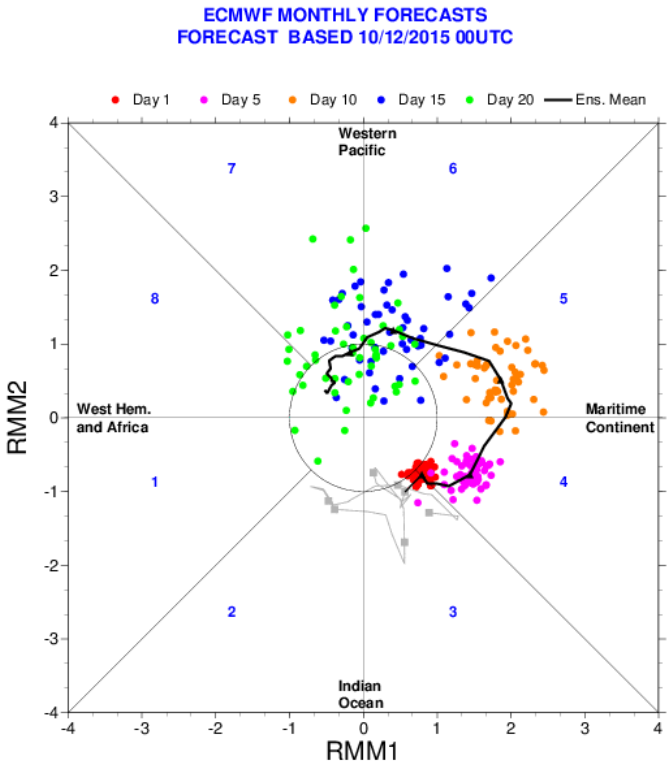




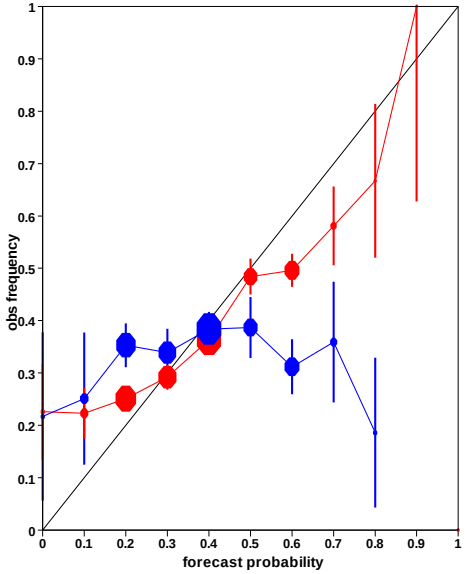


Can the extended range forecast provide useful indication of the cold/warm spell?

The sub-seasonal forecasts have potential since are able to represent the MJO and its teleconnections on the extra-tropics.



Reliability Diagram for EUROPE
Probability of 2-m temperature in the upper tercile Day 19-25



MJO in IC no MJO in IC

The Sub-seasonal to Seasonal (S2S) Prediction Project

- improve forecast skill and understanding on the sub-seasonal to seasonal time scale

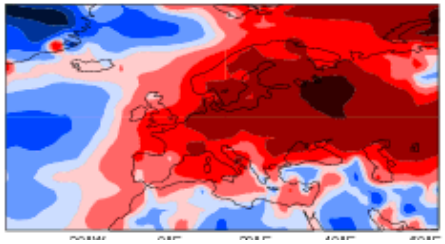
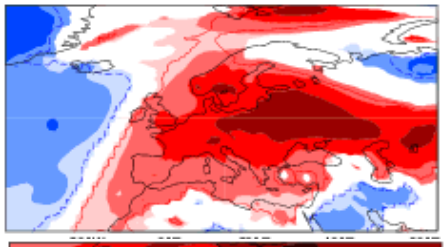
- promote its uptake by operational centres and exploitation by the applications community

- special emphasis on high-impact weather events

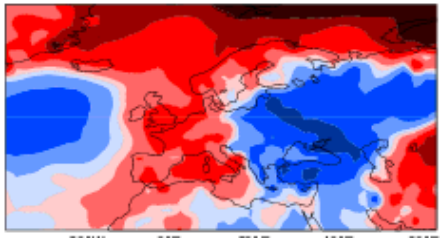
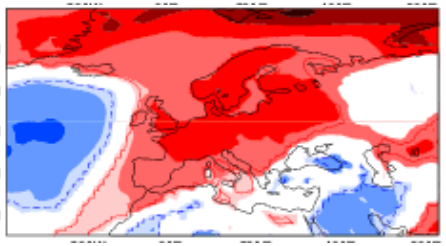
- S2S data is available to everyone https://software.ecmwf.int/wiki/display/S2S/Models

2m temperature weekly mean anomalies

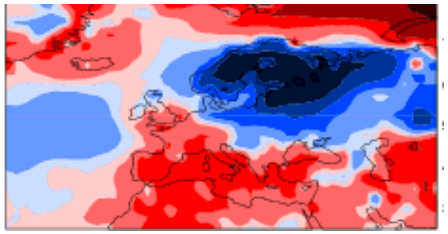
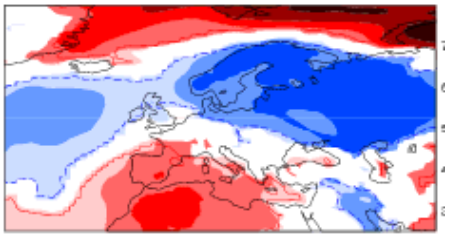
Analysis Forecast 8-14days

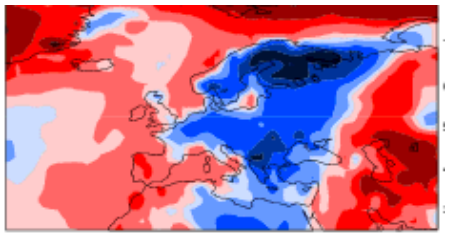
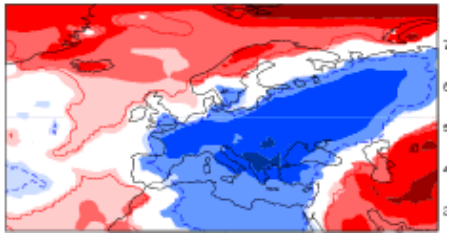
21 Dec 2015

28 Dec 2015

4 Jan 2016

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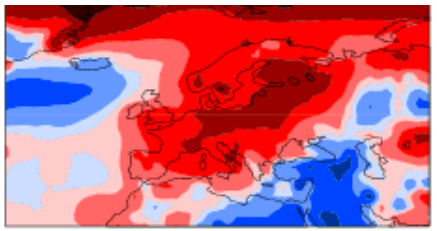
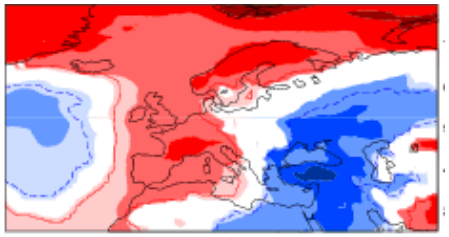



25 Jan 2016

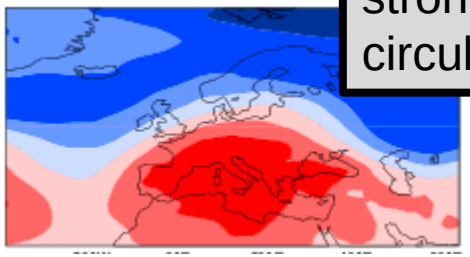
Not good performance for the onset

better performance for the demise

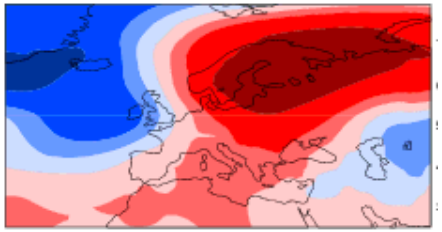
Mslp weekly mean anomalies:

Analysis

The ability to forecast the onset and demise of cold/heat waves is strongly linked to the model ability to predict transitions between circulation patterns such as blocking and NAO



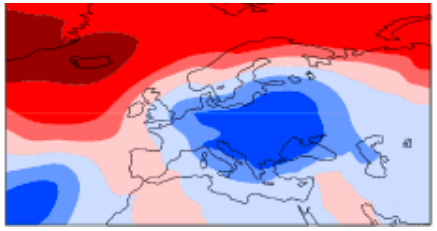
21 Dec 2015



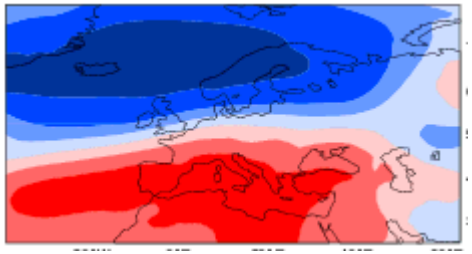
28 Dec 2015

The cold spell onset was associated with a transition to a Sc. Blocking

Sc. Blocking -> NAO-



11 Jan 2016



25 Jan 2016

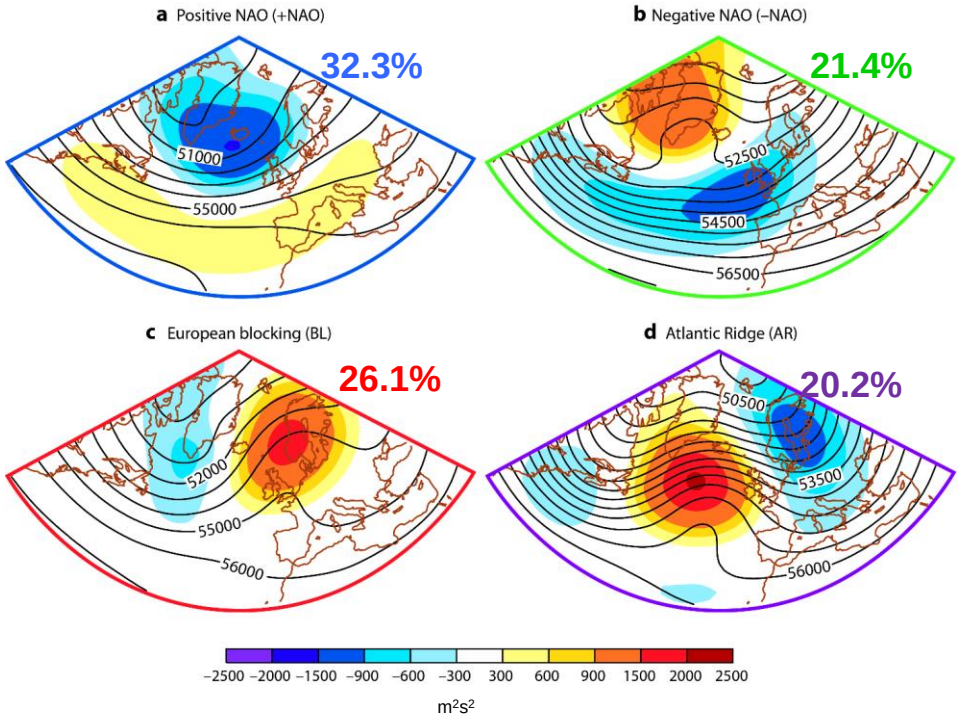
The demise of the cold spell is associated with NAO- -> NAO+

Regimes based on clustering of daily anomalies for 29 cold seasons (October to March1980-2008)

500 hPa geopotential

- Obtain well-known Euro-Atlantic regime patterns

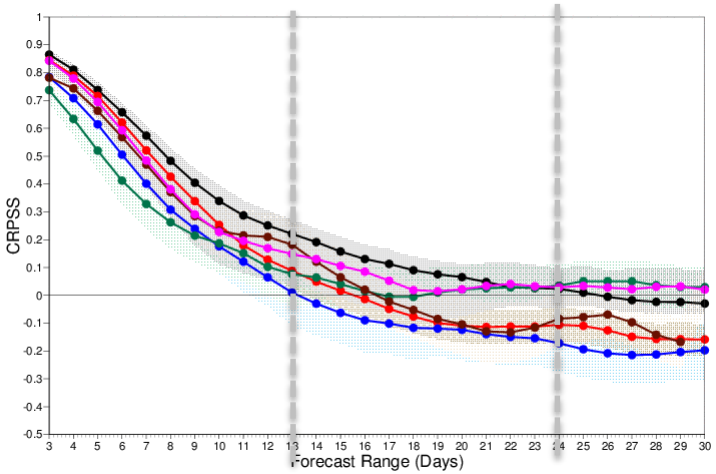
'k means' clustering applied to EOF pre-filtered data (retaining 80% of variance)



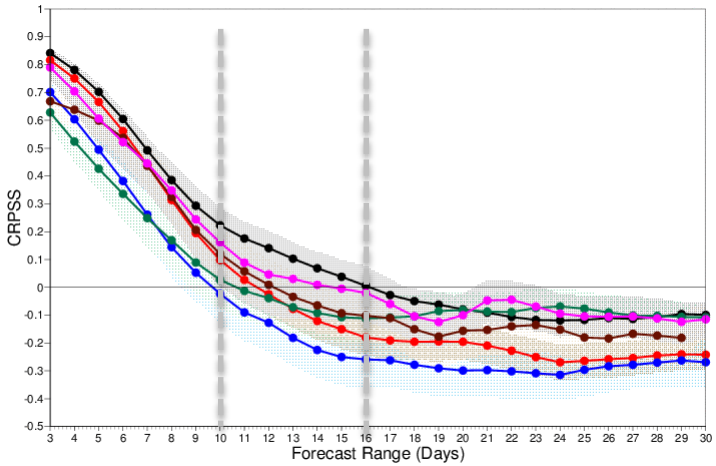
Assessing the forecast ability to predict persistence and transitions of large-scale flow regimes generally associated with cold spells over Europe.

Predicting skill associated with the Euro-Atlantic Regimes:

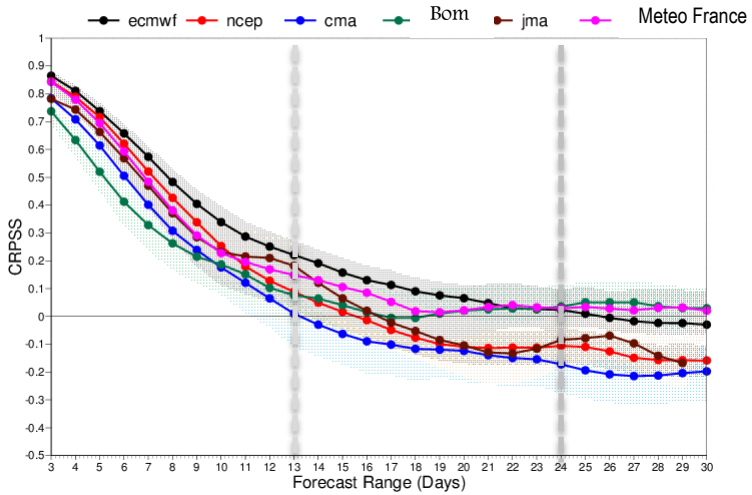
NAO +



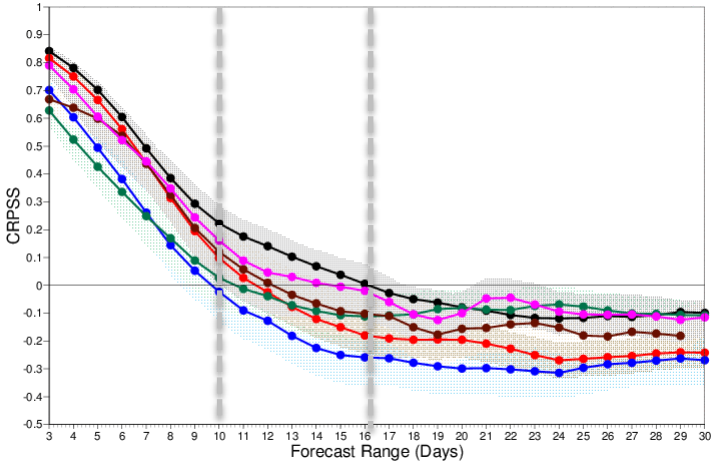
Sc. Blocking



NAO -



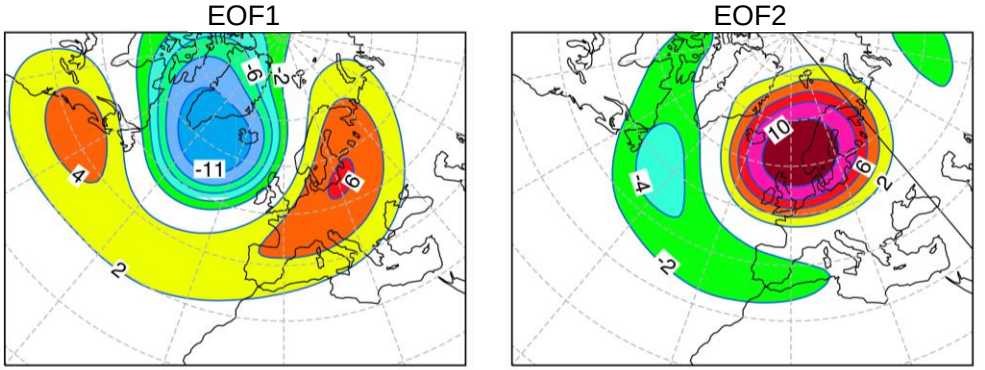
Atl. Ridge

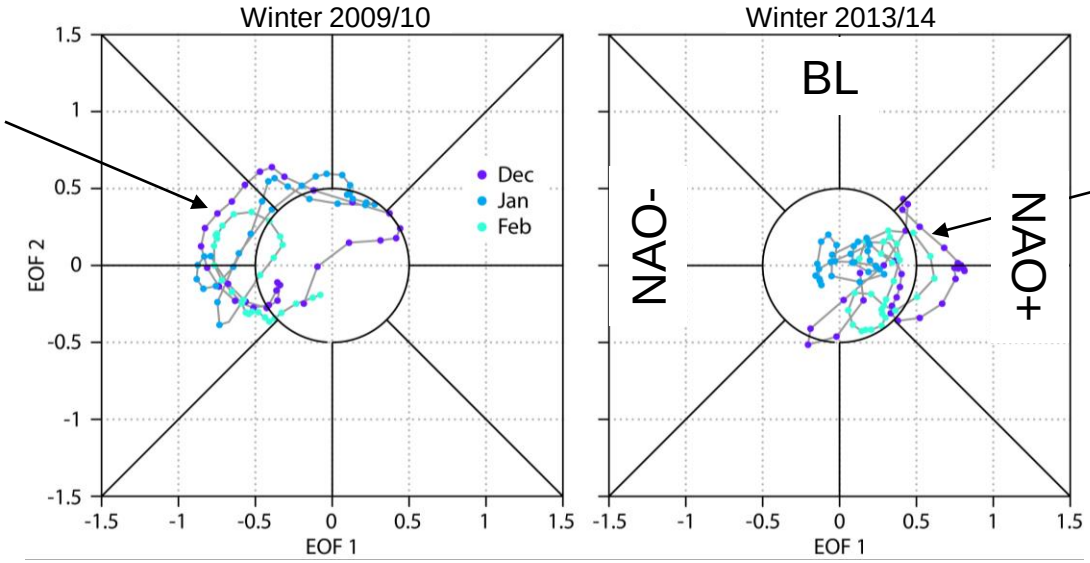


Trajectories in phase space (*c.f.* MJO propagation)

- ±EOF1 and +EOF2 represent quite well ±NAO and BL
- Trajectories in phase space summarise regime evolution
- Unlike MJO, no preferred direction

BL: record-breaking cold temperatures over Europe



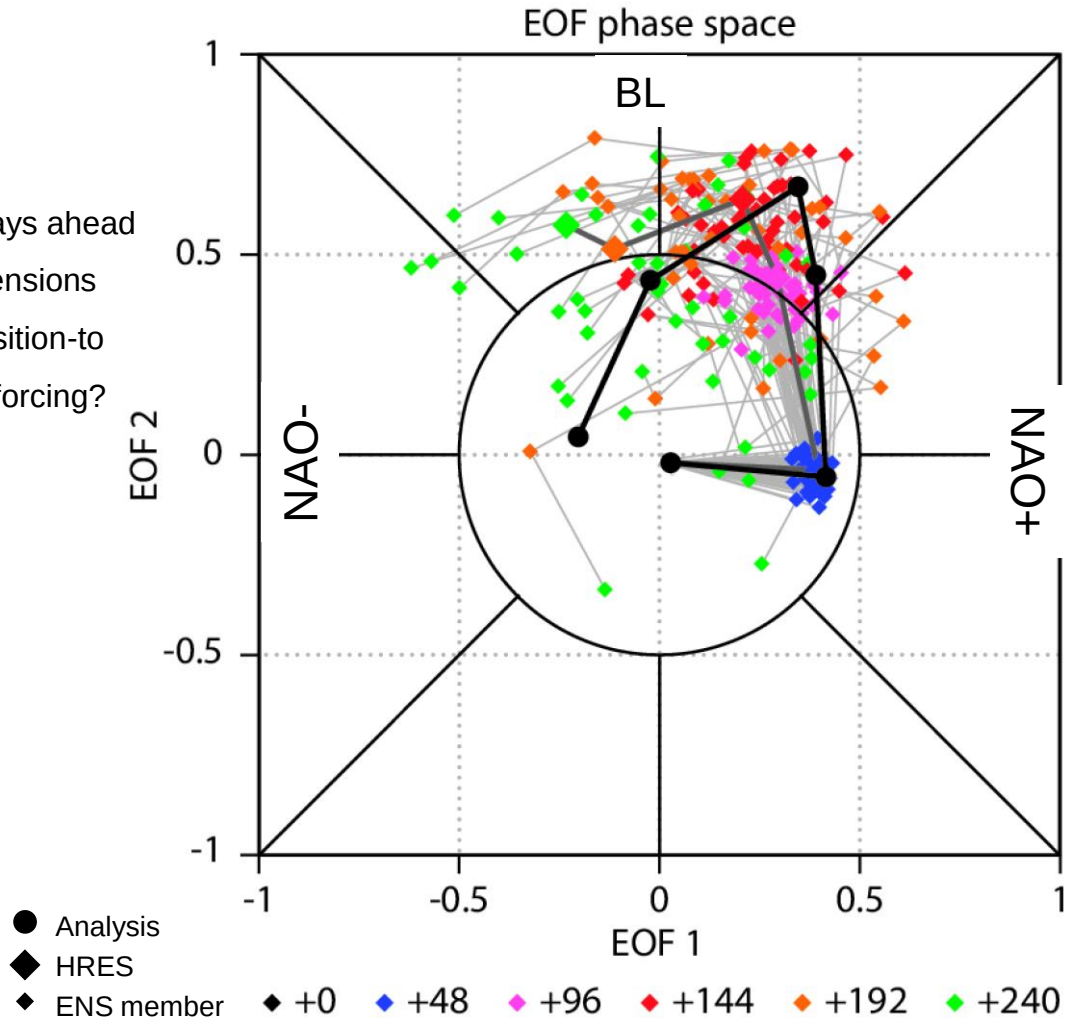


+NAO: exceptional storminess, but mild temperatures over Europe

Based on 5-day running means

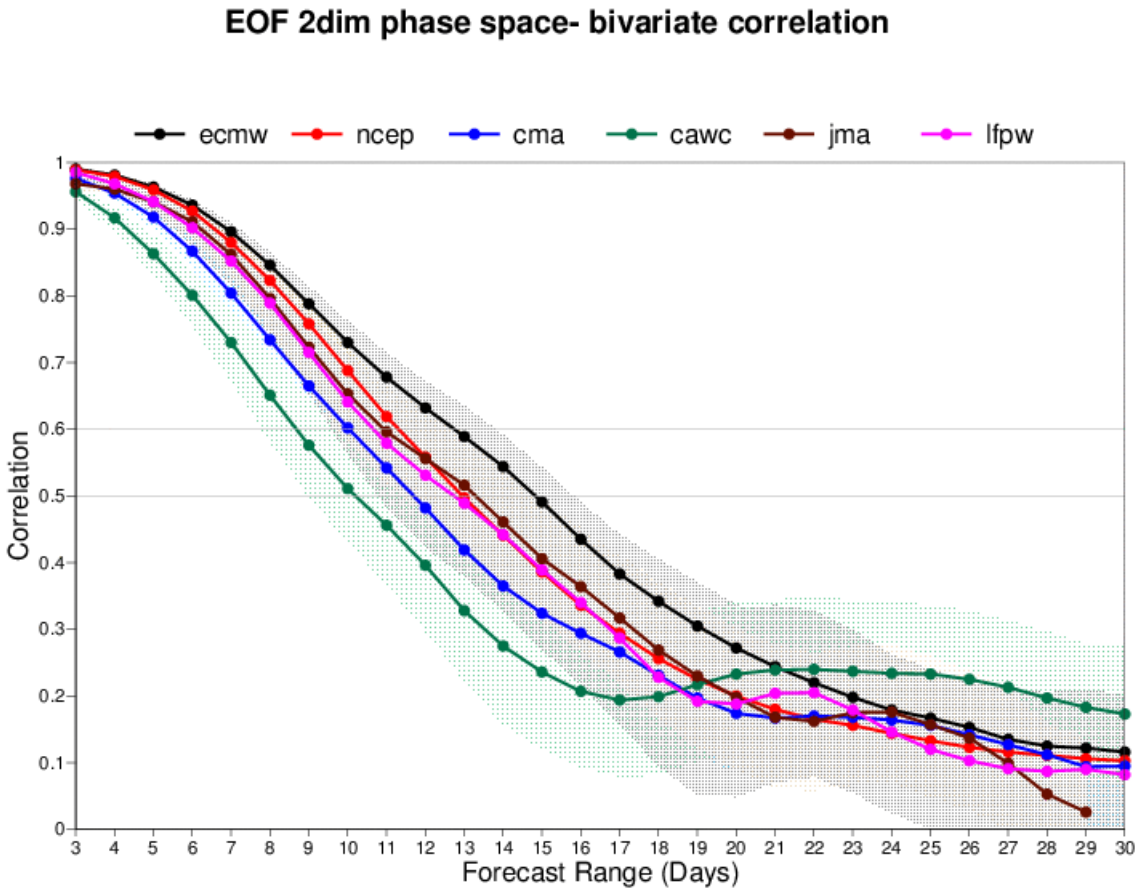
Ensemble evolution in phase space

- Transition to blocking well-predicted 4 days ahead
- Nice way to summarise ENS in two dimensions
- Future: What processes involved in transition-to and maintenance-off blocking? Tropical forcing?

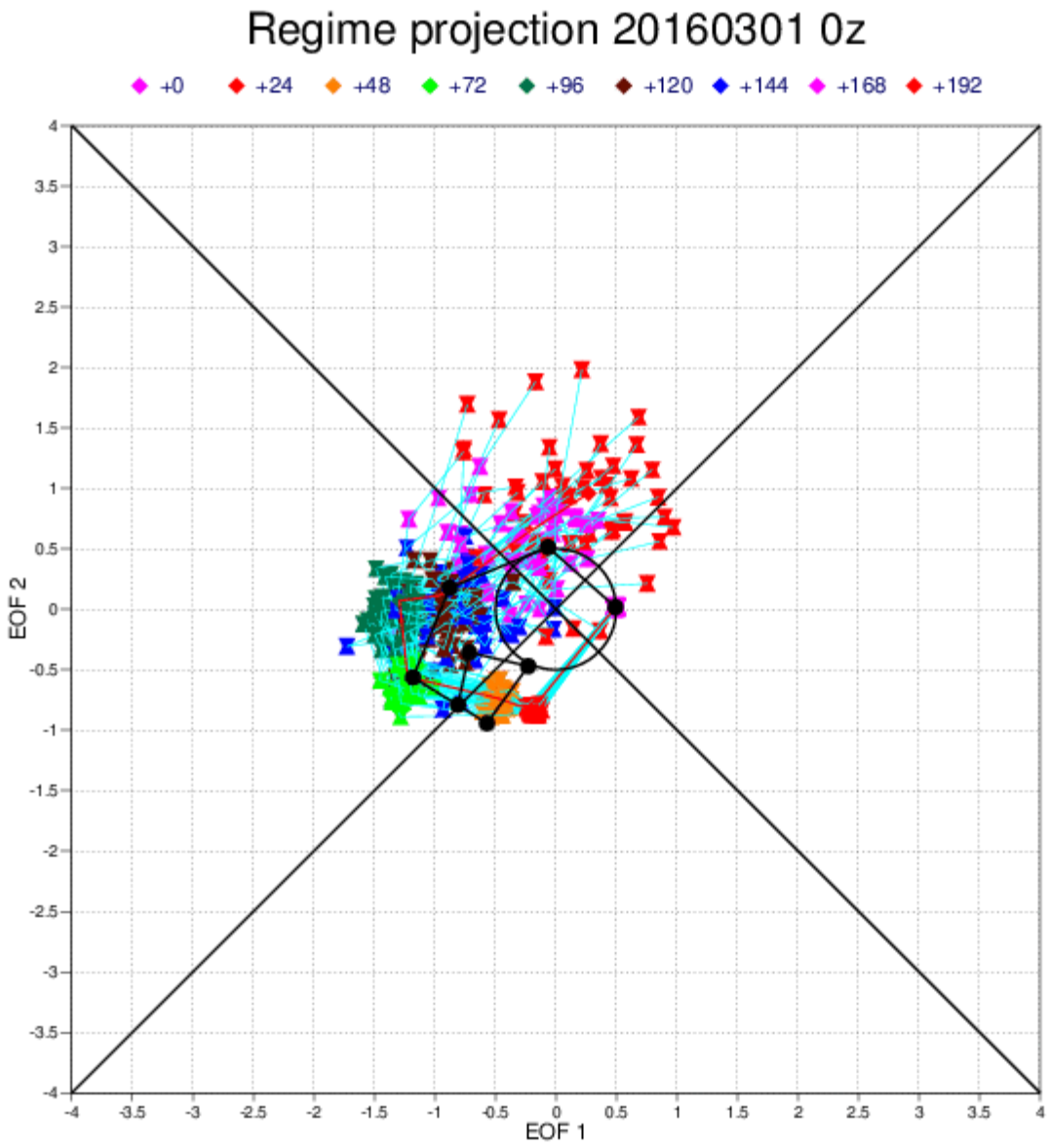


Initial date: 22 September 2015 0UTC

Predictive skill of transitions between NAO+/- and Sc. Blocking (*in analogy of the* MJO skill measure)



Novel approach to verify and visualize transitions to and from the circulation regimes associated with high-impact temperature anomalies over Europe


Regime projection 20160301 0z
+0
+24
+48
+72
+96
+120
+144
+168
+192
EOF 2
EOF 1
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4

ECMWF

- Strong and persistent large scale high pressure systems are often associated with dry-spells, and with heat-waves in summer and cold-spells in winter.

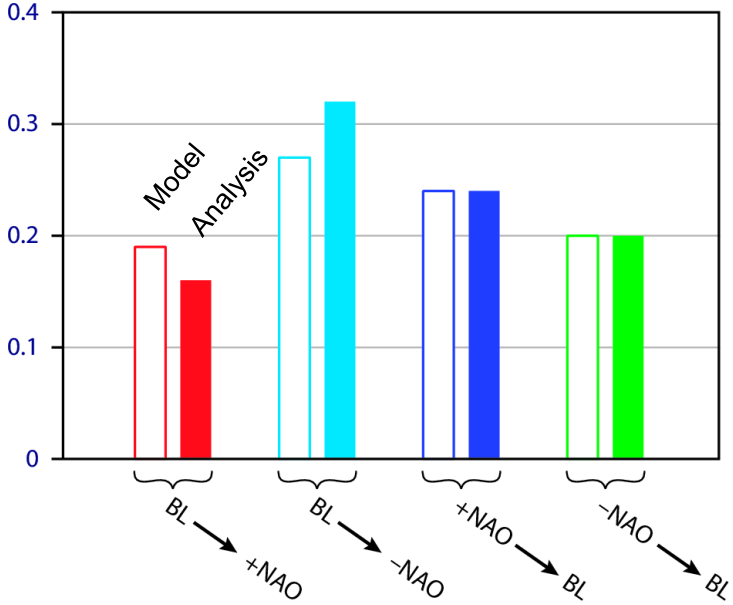
- The persisting anti-cyclonic circulation characterized the extreme hot summer in 2003. While the severe cold winter in 2009/10 was associated with record persistence of the negative phase of the NAO.

- Circulation patterns like the NAO are often associated with global teleconnections through propagation of Rossby wave trains.

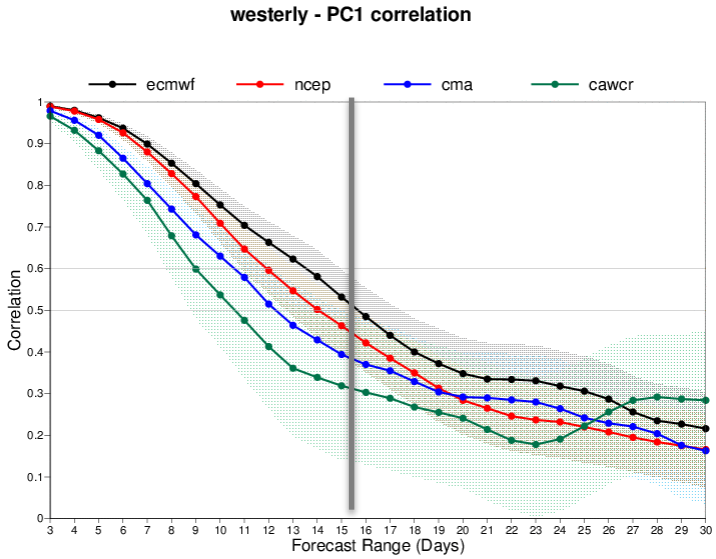
- It is therefore important to assess the ability of the forecast model to predict, at the extended range, persistence and transitions of large scale flow regimes. Here we explore the ability of the ENS to predict the extended range evolution of the large-scale circulation patterns that are generally associated with cold spells over Europe.

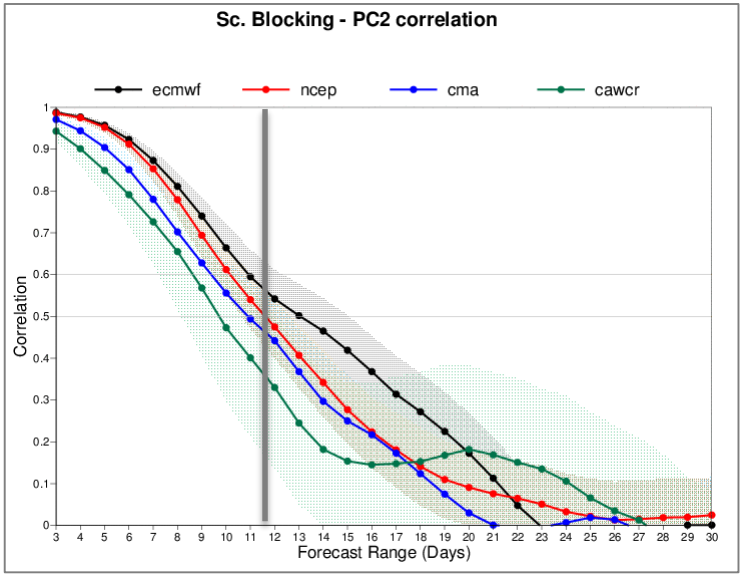
Regime transition-frequencies and predictability (*c.f.* MJO predictability)

Frequencies of transitions between persistent regimes (>5 days)



- Transition frequencies good. Slight over-preference for BL → +NAO
- ECMWF has 1-2 days better skill than NCEP
- PC1 is ~2 days better than PC2 (due to high persistence of –NAO?)

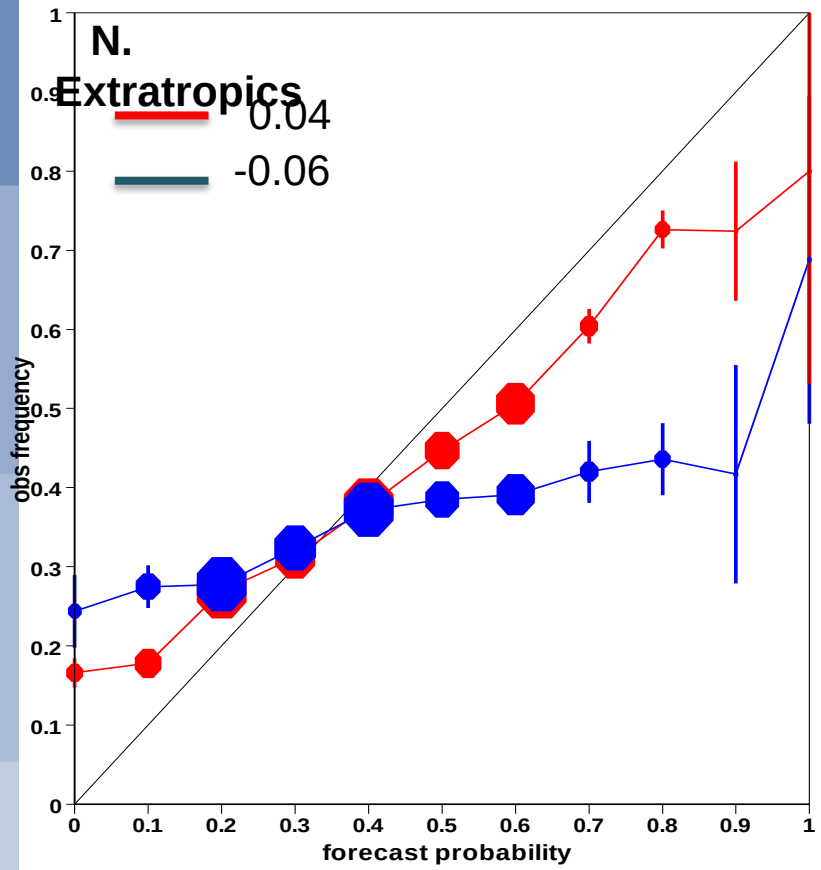


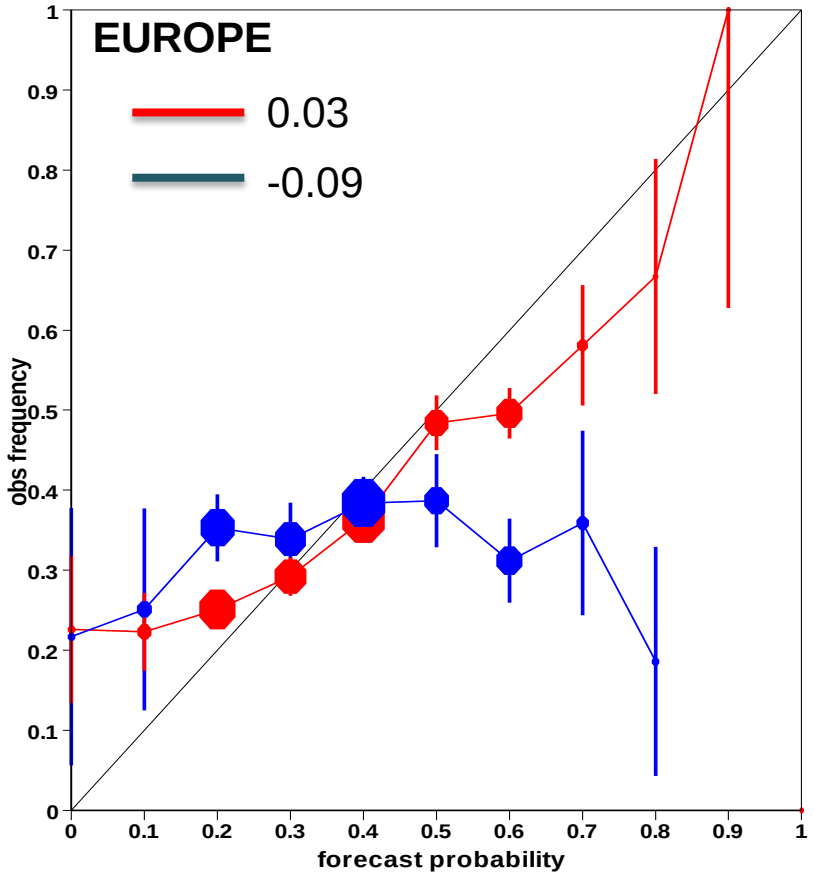


5-day running mean applied prior to correlation calculation

Probabilistic skill scores – NDJFMA 1989-2008

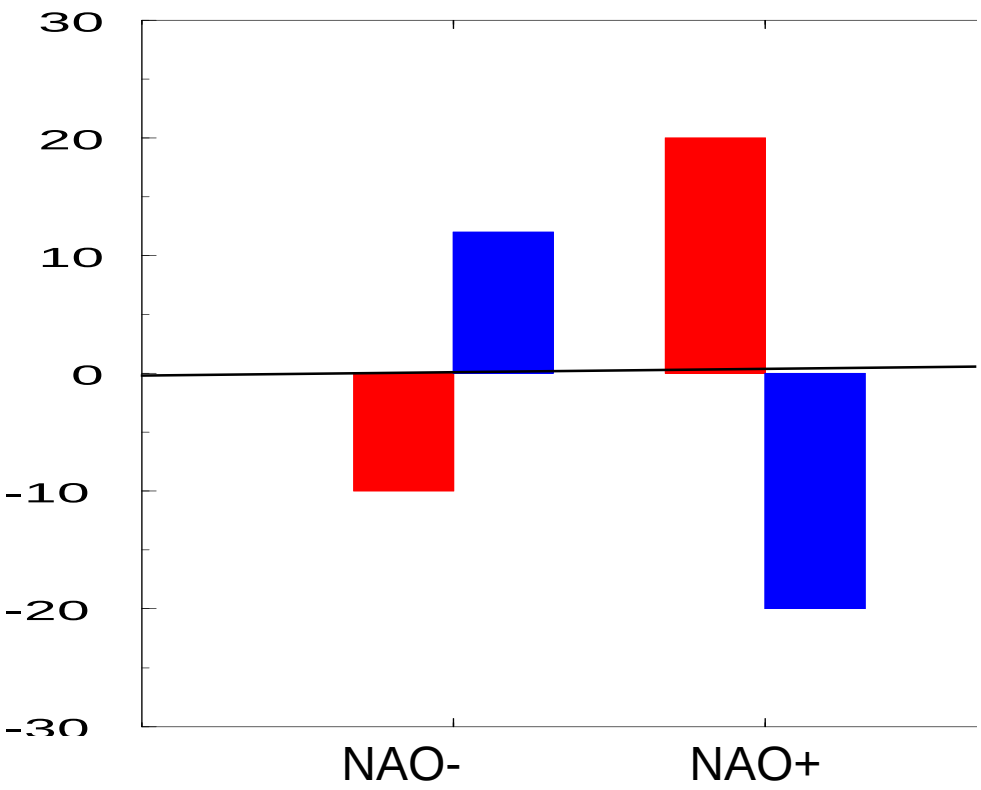
Reliability Diagram
Probability of 2-m temperature in the upper tercile
Day 19-25

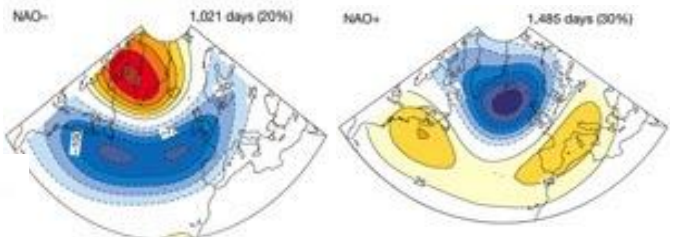




MJO in IC NO MJO in IC

MJO impact on European weather:





The MJO impact is the strongest about 10 days after the MJO is in the phase with:

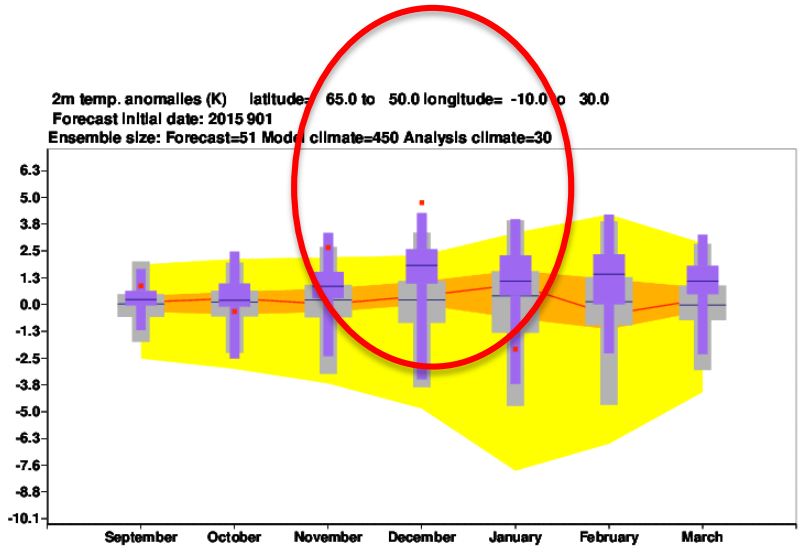
- suppressed convection over Indian Ocean
- enhanced convection over Western Pacific are conducive to negative NAO

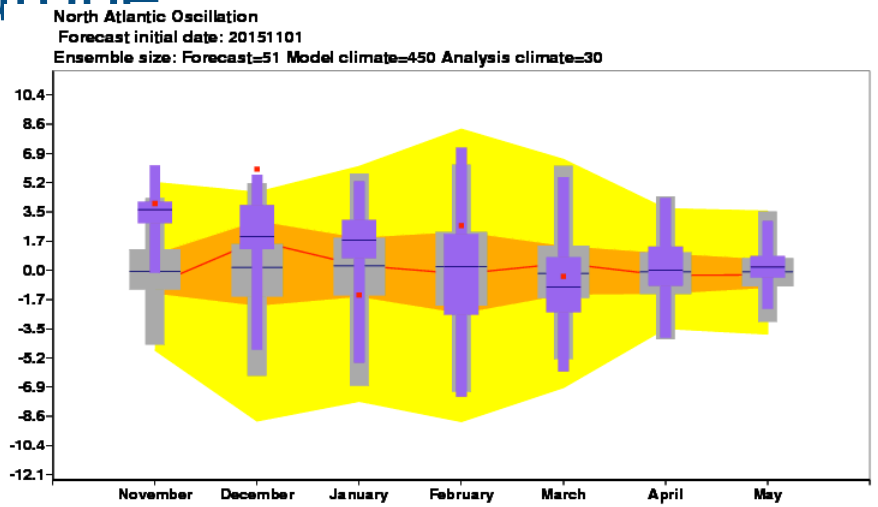
Cassou (2008) Lin et al (2008)

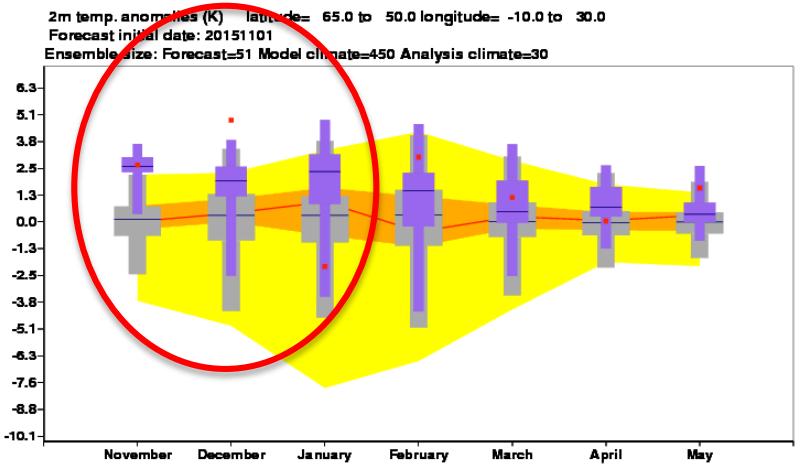
Conv. Over Indian Ocean +10 days

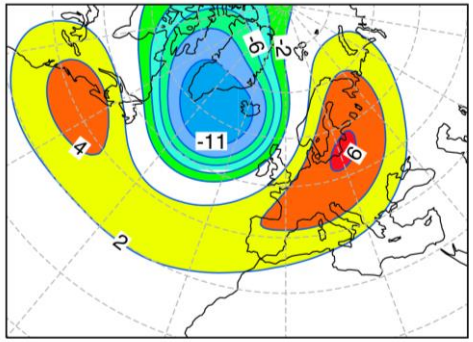
Conv. Over Western Pacific+10 days

Monthly means anomalies:
2m temp. over Northern Europe



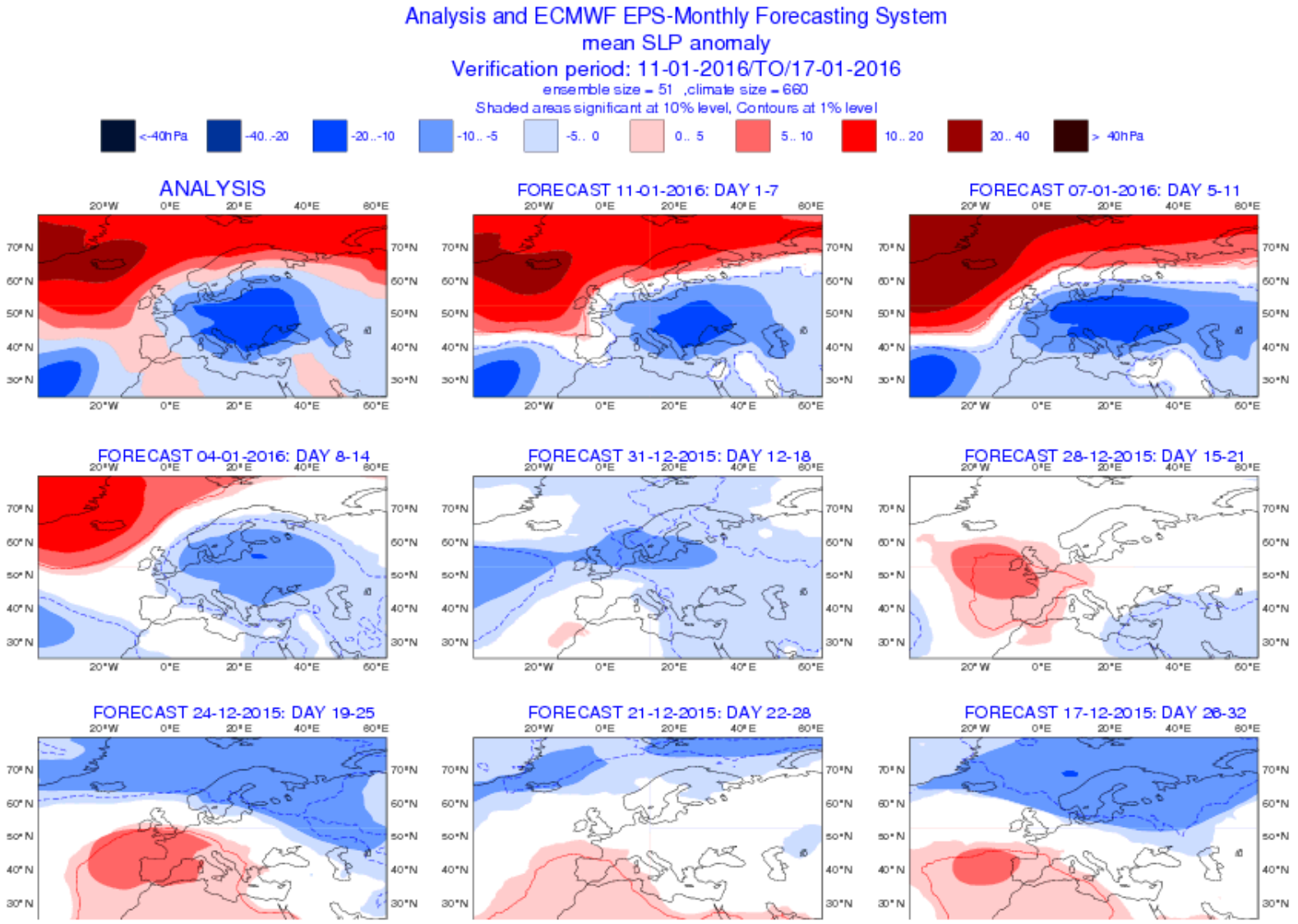


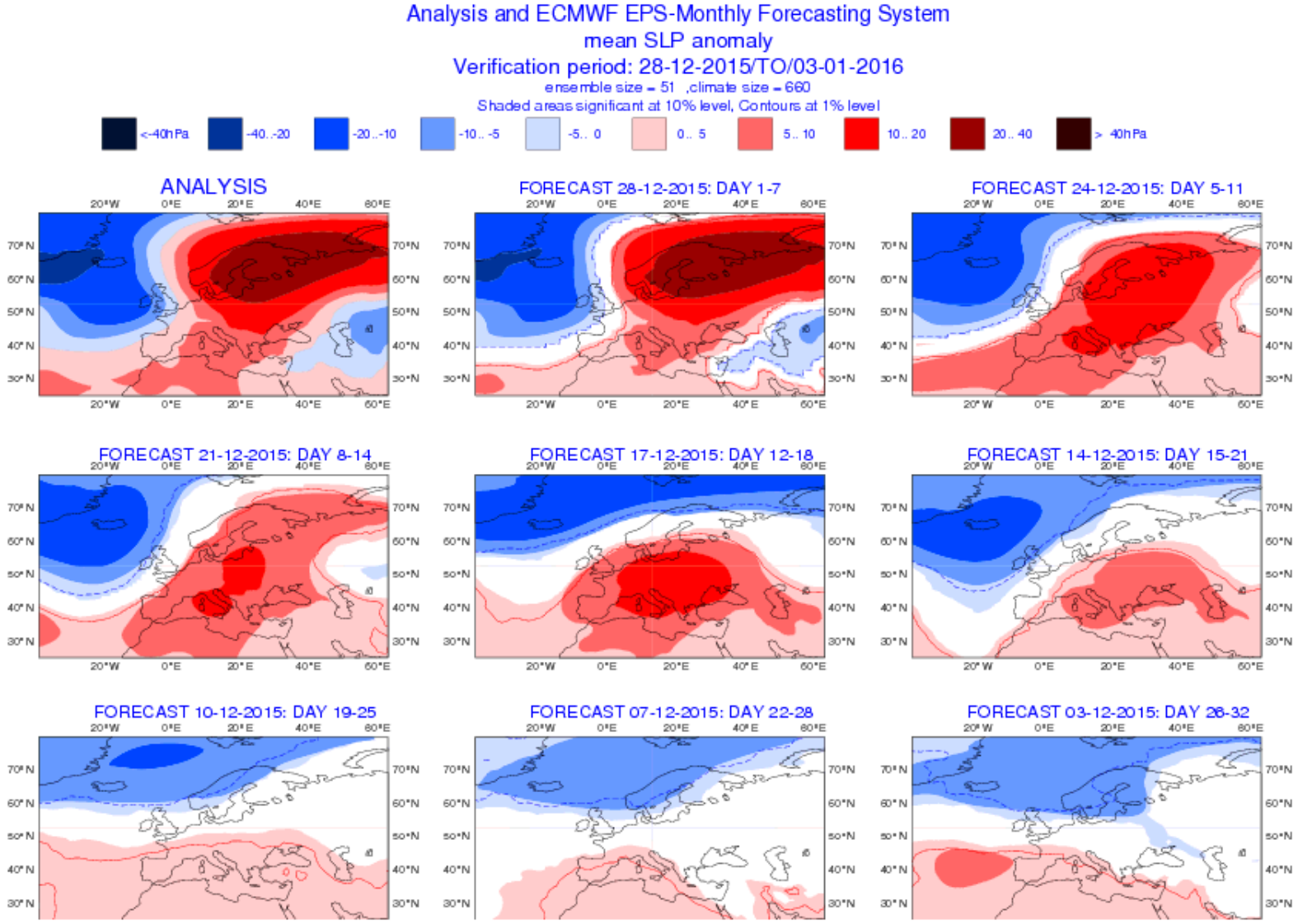




…uring El Niño (La Niña) winters (Fraedrich and Müller 1992). This effect is …y winter the ENSO influence over European temperature can be reversed …effect over Europe, when averaged over the canonical winter season (Dec …variation.

…Southern and Northern Europe issued on the 8th of September. The figure shows the extent of the warm anomalies in the analysis indicating that both November and December months were much warmer than the 30 year climate based on 1981-2010. Forecasts issued in September gave an accurate indication of the extent of such warm conditions with the median of the forecast distribution exceeding the upper third of the model climate (grey box). Predicted temperatures over Northern Europe provided some indications of the relative cooling in January according with the ENSO modulation.


Analysis and ECMWF EPS-Monthly Forecasting System
mean SLP anomaly
Verification period: 11-01-2016/TO/17-01-2016
ensemble size = 51 ,climate size = 660
Shaded areas significant at 10% level, Contours at 1% level
<-40hPa
-40..-20
-20..-10
-10..-5
-5.. 0
0.. 5
5.. 10
10.. 20
20.. 40
> 40hPa
ANALYSIS
FORECAST 11-01-2016: DAY 1-7
FORECAST 07-01-2016: DAY 5-11
FORECAST 04-01-2016: DAY 8-14
FORECAST 31-12-2015: DAY 12-18
FORECAST 28-12-2015: DAY 15-21
FORECAST 24-12-2015: DAY 19-25
FORECAST 21-12-2015: DAY 22-28
FORECAST 17-12-2015: DAY 26-32


Analysis and ECMWF EPS-Monthly Forecasting System
mean SLP anomaly
Verification period: 28-12-2015/TO/03-01-2016
ensemble size = 51 ,climate size = 660
Shaded areas significant at 10% level, Contours at 1% level
<-40hPa
-40..-20
-20..-10
-10.. -5
-5.. 0
0.. 5
5.. 10
10.. 20
20.. 40
> 40hPa
ANALYSIS
FORECAST 28-12-2015: DAY 1-7
FORECAST 24-12-2015: DAY 5-11
FORECAST 21-12-2015: DAY 8-14
FORECAST 17-12-2015: DAY 12-18
FORECAST 14-12-2015: DAY 15-21
FORECAST 10-12-2015: DAY 19-25
FORECAST 07-12-2015: DAY 22-28
FORECAST 03-12-2015: DAY 26-32

Analysis and ECMWF EPS-Monthly Forecasting System

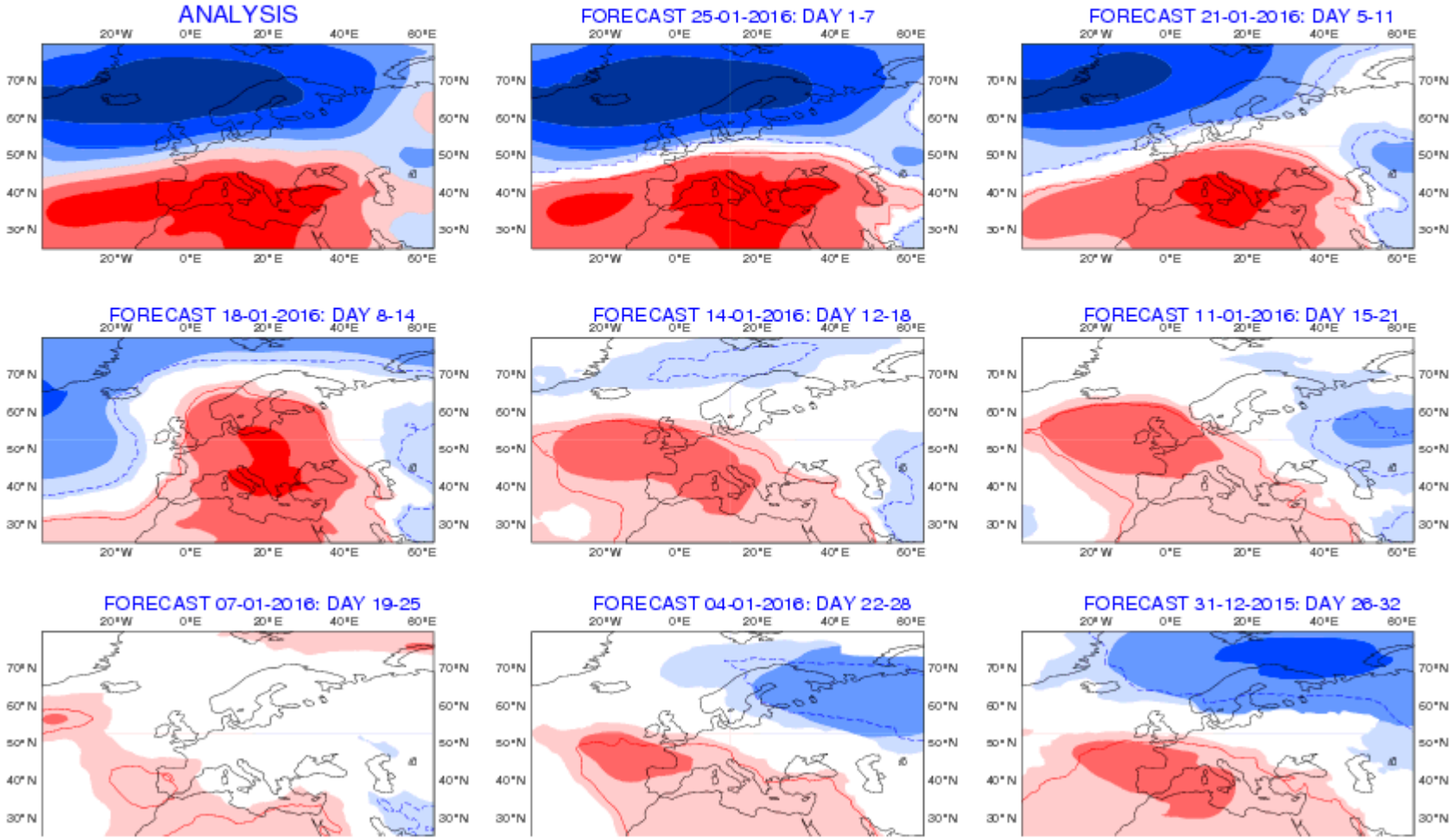
mean SLP anomaly

Verification period: 25-01-2016/TO/31-01-2016

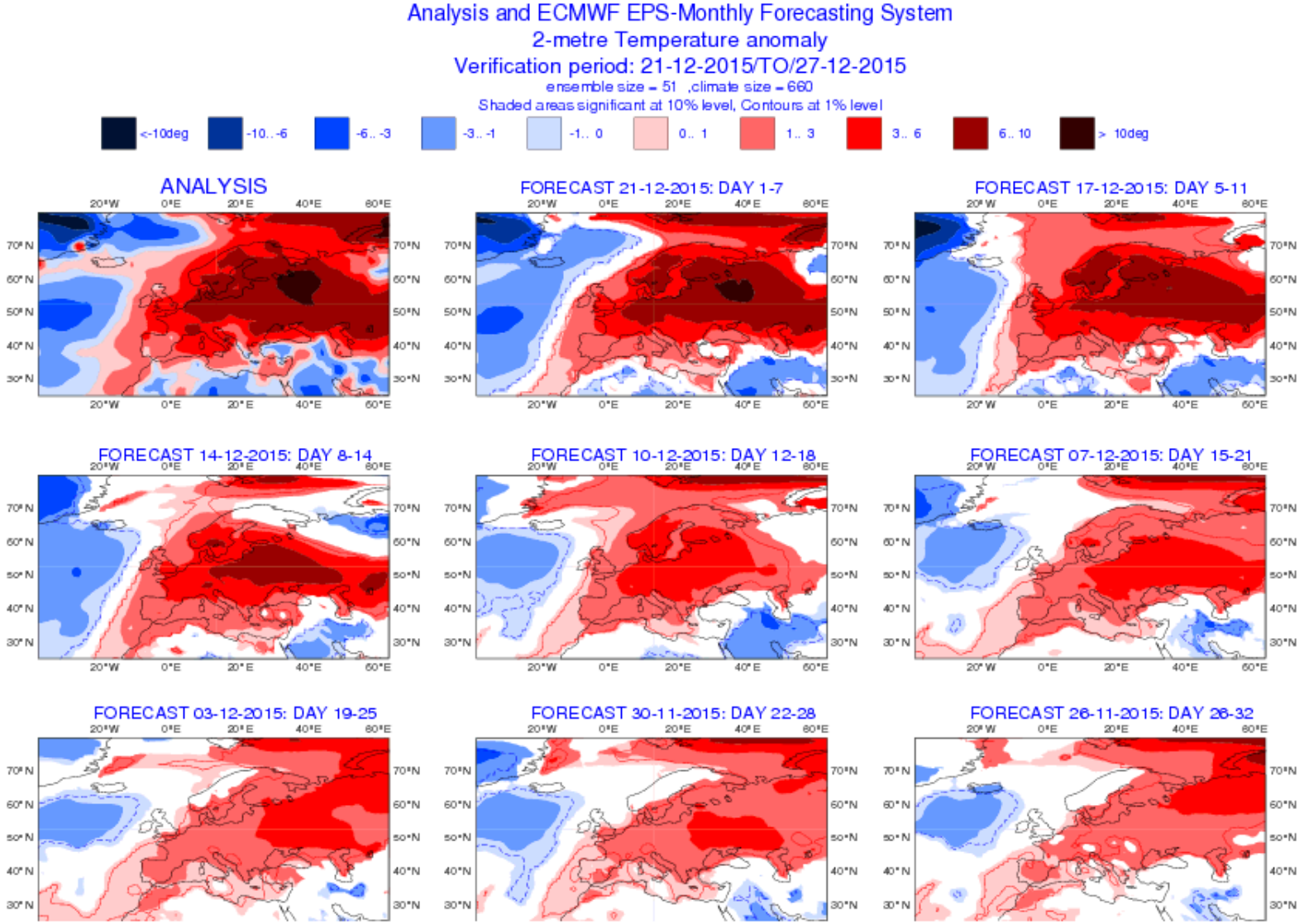
ensemble size = 51 ,climate size = 660

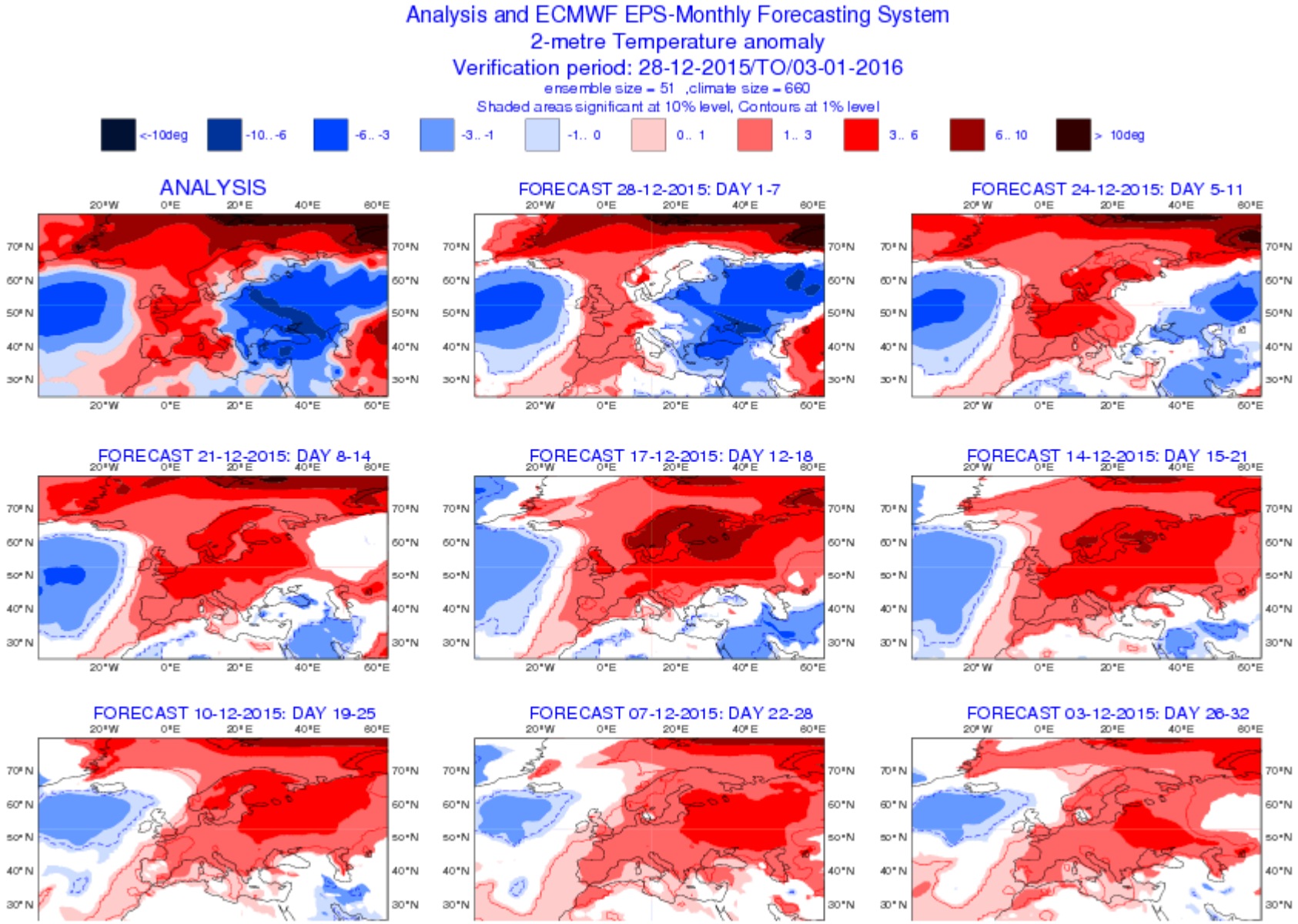
Shaded areas significant at 10% level, Contours at 1% level

<-40hPa | -40..-20 | -20..-10 | -10.. -5 | -5.. 0 | 0.. 5 | 5.. 10 | 10.. 20 | 20.. 40 | > 40hPa



ECMWF


Analysis and ECMWF EPS-Monthly Forecasting System
2-metre Temperature anomaly
Verification period: 21-12-2015/TO/27-12-2015
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 21-12-2015: DAY 1-7
FORECAST 17-12-2015: DAY 5-11
FORECAST 14-12-2015: DAY 8-14
FORECAST 10-12-2015: DAY 12-18
FORECAST 07-12-2015: DAY 15-21
FORECAST 03-12-2015: DAY 19-25
FORECAST 30-11-2015: DAY 22-28
FORECAST 26-11-2015: DAY 26-32


Analysis and ECMWF EPS-Monthly Forecasting System
2-metre Temperature anomaly
Verification period: 28-12-2015/TO/03-01-2016
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 28-12-2015: DAY 1-7
FORECAST 24-12-2015: DAY 5-11
FORECAST 21-12-2015: DAY 8-14
FORECAST 17-12-2015: DAY 12-18
FORECAST 14-12-2015: DAY 15-21
FORECAST 10-12-2015: DAY 19-25
FORECAST 07-12-2015: DAY 22-28
FORECAST 03-12-2015: DAY 26-32

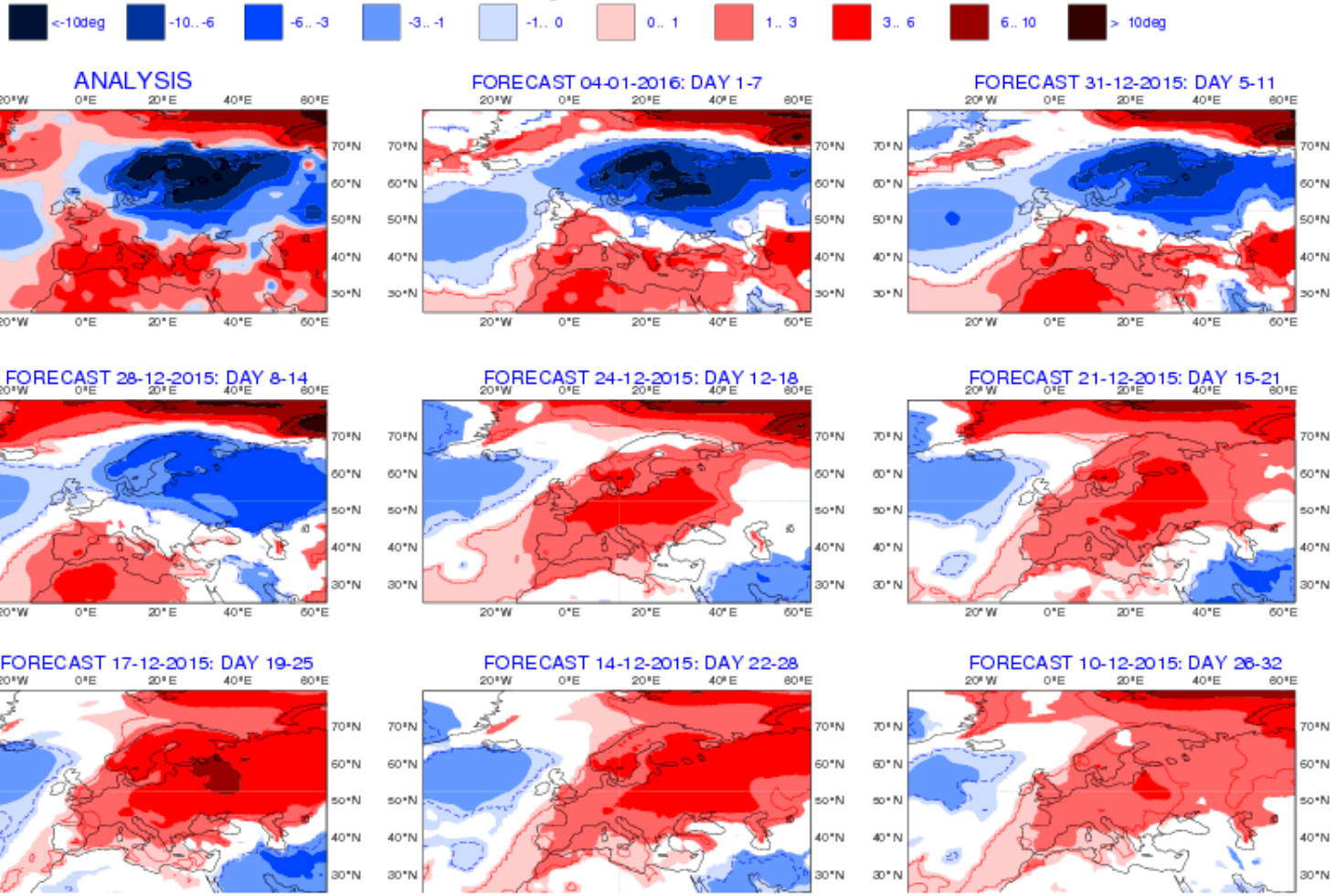
Analysis and ECMWF EPS-Monthly Forecasting System

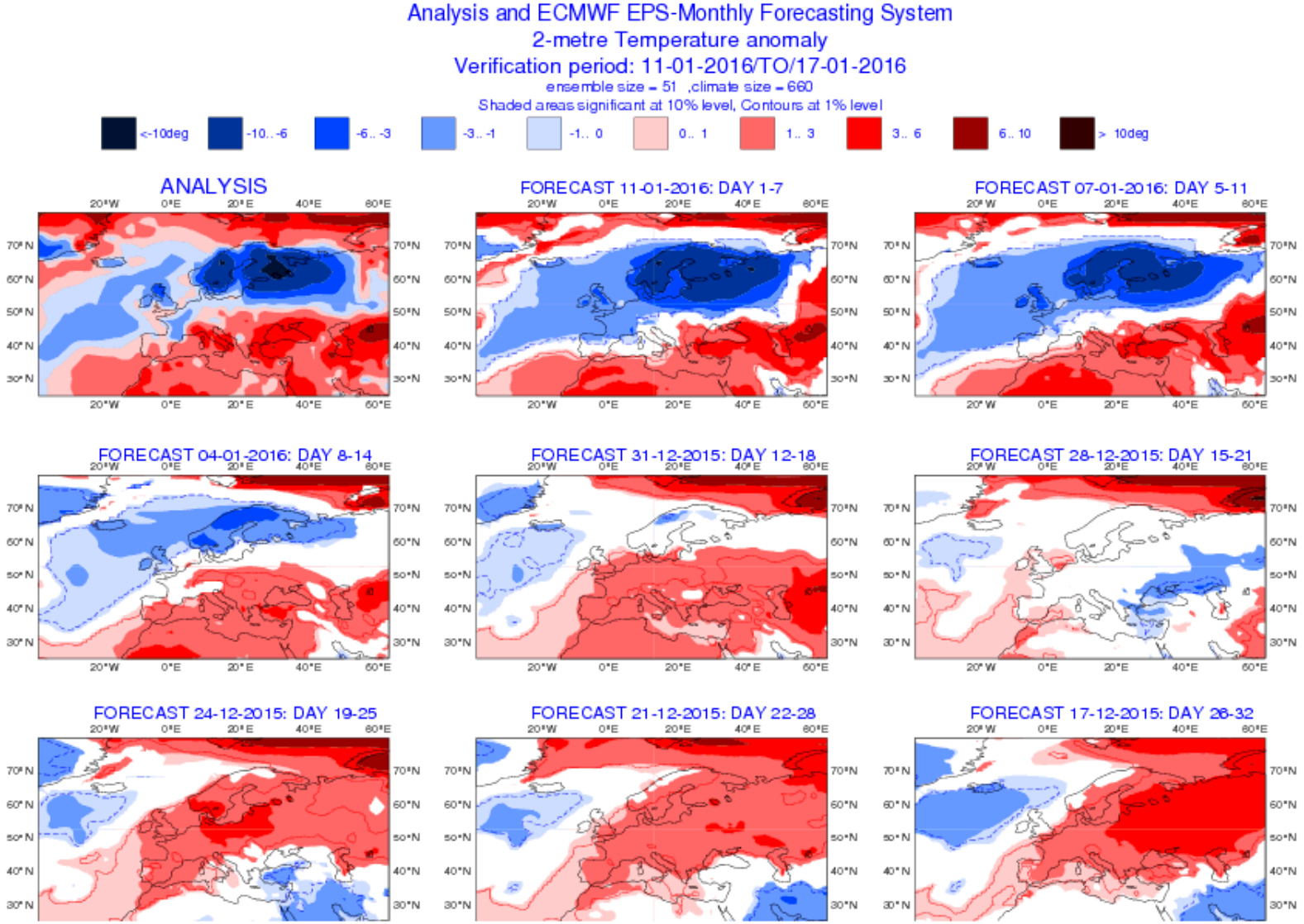
2-metre Temperature anomaly

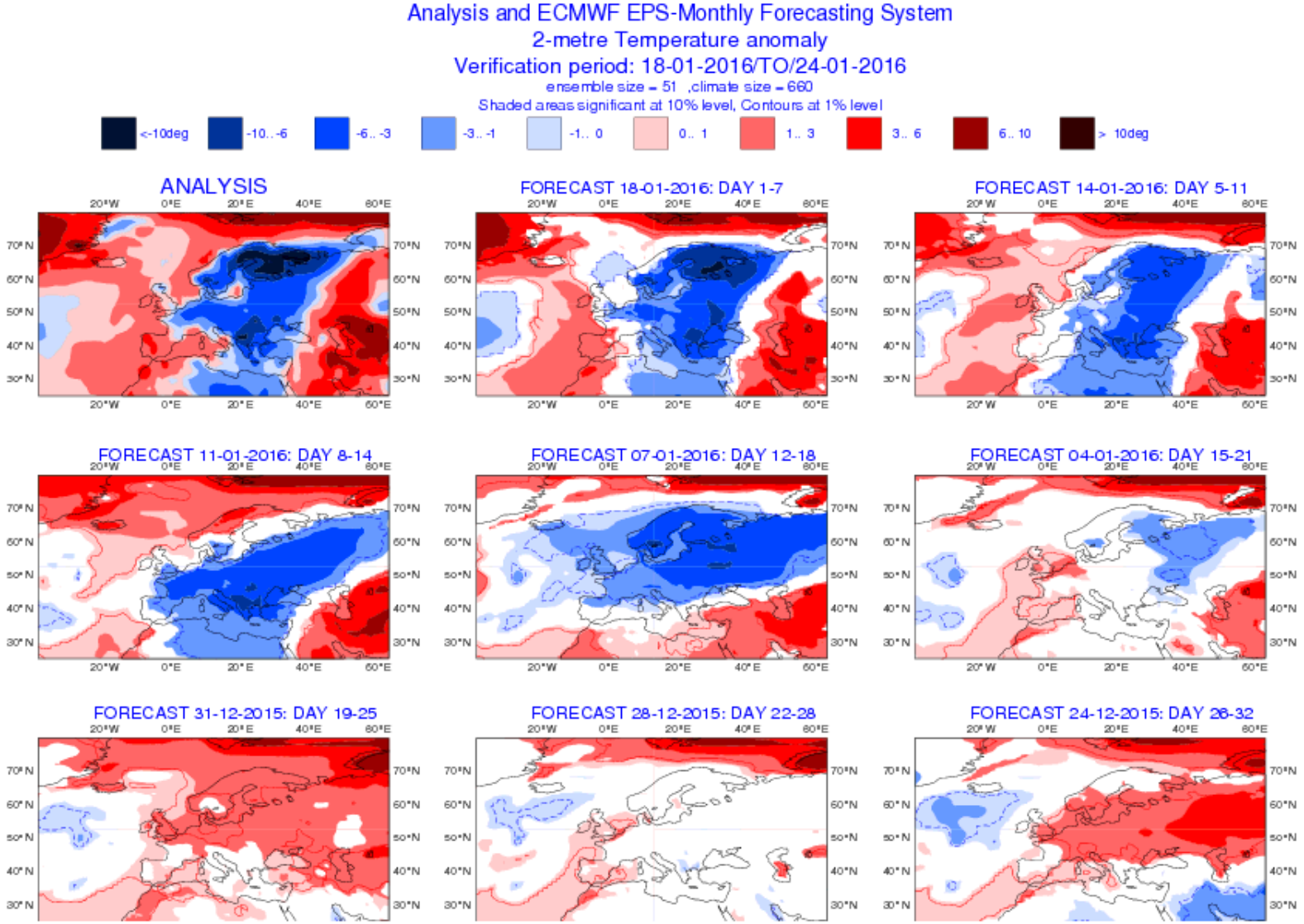
Verification period: 04-01-2016/TO/10-01-2016

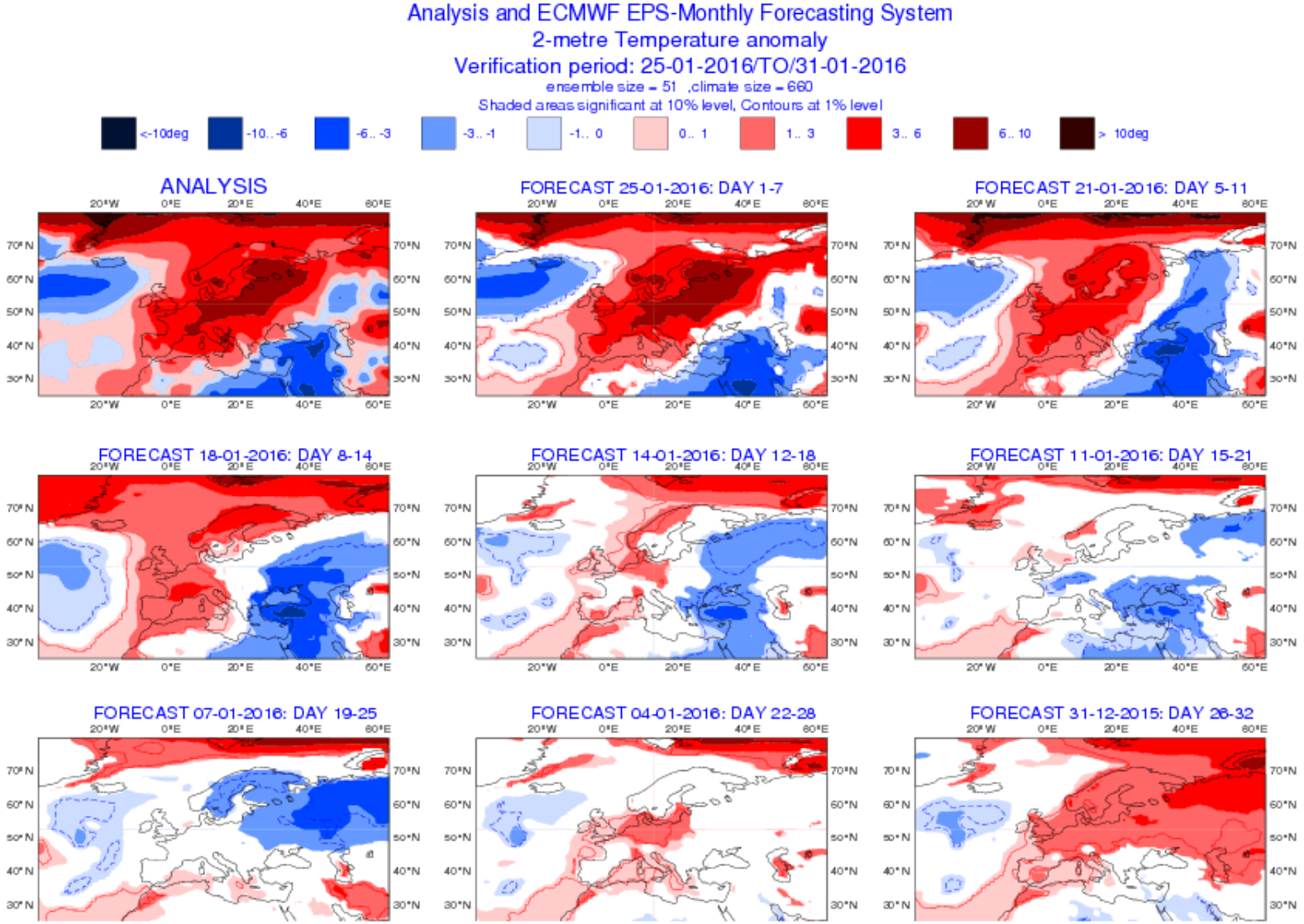
ensemble size = 51 ,climate size = 660

Shaded areas significant at 10% level, Contours at 1% level




Analysis and ECMWF EPS-Monthly Forecasting System
2-metre Temperature anomaly
Verification period: 11-01-2016/TO/17-01-2016
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 11-01-2016: DAY 1-7
FORECAST 07-01-2016: DAY 5-11
FORECAST 04-01-2016: DAY 8-14
FORECAST 31-12-2015: DAY 12-18
FORECAST 28-12-2015: DAY 15-21
FORECAST 24-12-2015: DAY 19-25
FORECAST 21-12-2015: DAY 22-28
FORECAST 17-12-2015: DAY 26-32


Analysis and ECMWF EPS-Monthly Forecasting System
2-metre Temperature anomaly
Verification period: 18-01-2016/TO/24-01-2016
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 18-01-2016: DAY 1-7
FORECAST 14-01-2016: DAY 5-11
FORECAST 11-01-2016: DAY 8-14
FORECAST 07-01-2016: DAY 12-18
FORECAST 04-01-2016: DAY 15-21
FORECAST 31-12-2015: DAY 19-25
FORECAST 28-12-2015: DAY 22-28
FORECAST 24-12-2015: DAY 26-32
20°W
0°E
20°E
40°E
60°E
70°N
60°N
50°N
40°N
30°N

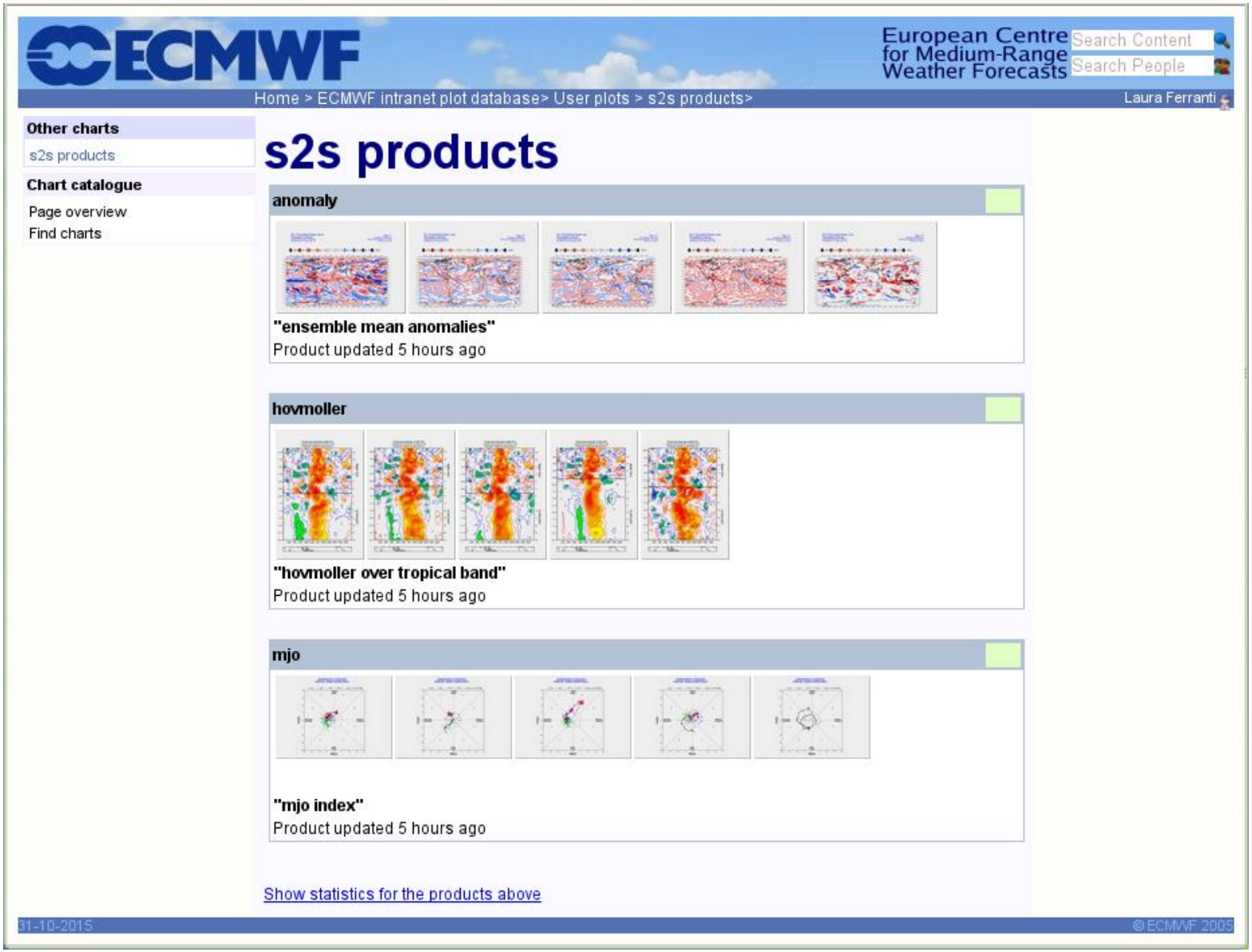

Analysis and ECMWF EPS-Monthly Forecasting System
2-metre Temperature anomaly
Verification period: 25-01-2016/TO/31-01-2016
ensemble size = 51 ,climate size = 660
Shaded areas significant at 10% level, Contours at 1% level
<-10deg
-10..-6
-6..-3
-3..-1
-1.. 0
0.. 1
1.. 3
3.. 6
6.. 10
> 10deg
ANALYSIS
FORECAST 25-01-2016: DAY 1-7
FORECAST 21-01-2016: DAY 5-11
FORECAST 18-01-2016: DAY 8-14
FORECAST 14-01-2016: DAY 12-18
FORECAST 11-01-2016: DAY 15-21
FORECAST 07-01-2016: DAY 19-25
FORECAST 04-01-2016: DAY 22-28
FORECAST 31-12-2015: DAY 26-32

S2S reforecasts data used for the skill assessment:

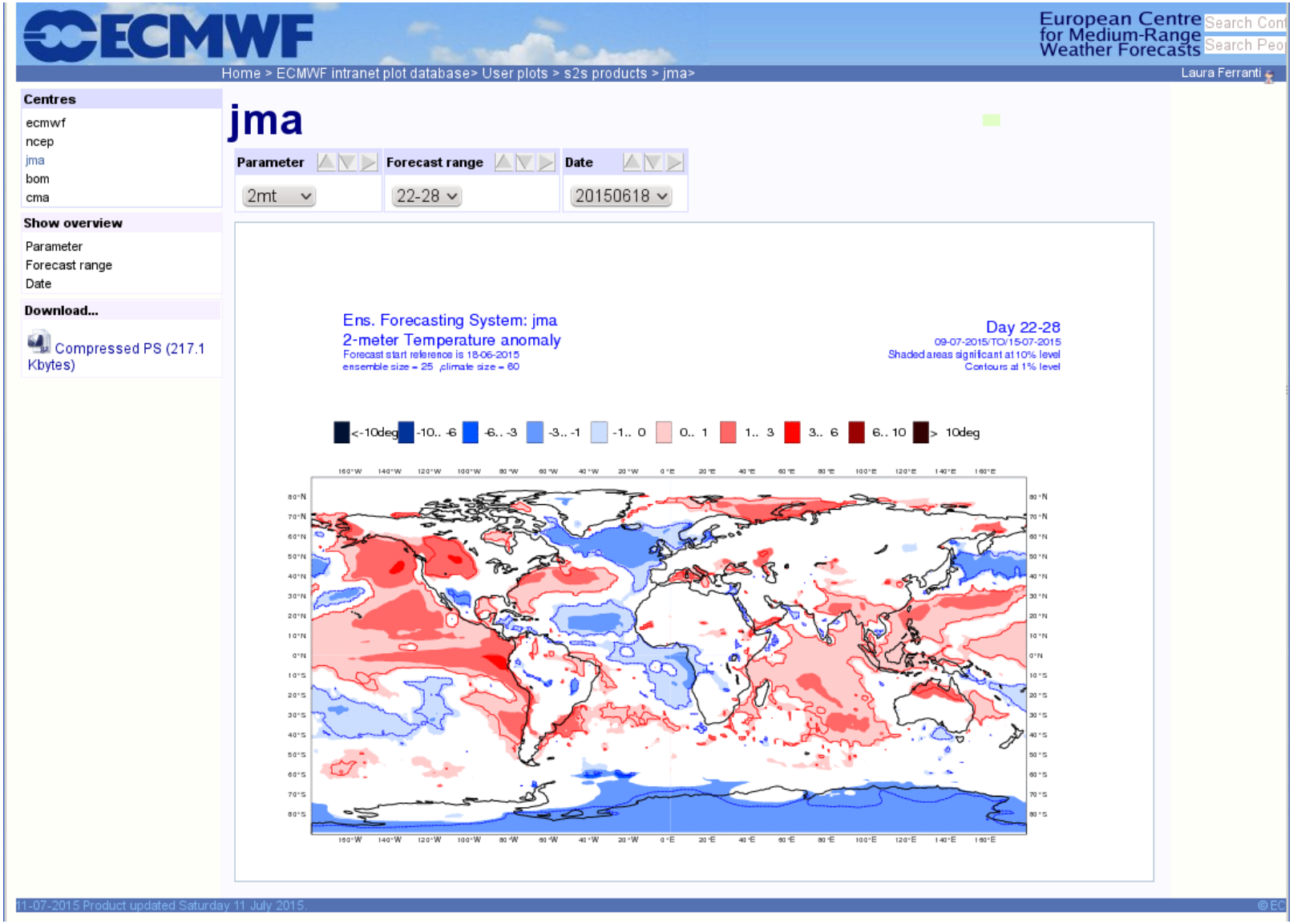
model	Bom	Cma	Ecmwf	Ncep
Rfc. lenght	0-60 days	0-60days	0-46 days	0-44 days
Resol.	T47L17	T106L40	T639/319 L91	T126L64
Rfc. size	33	4	11	4
Rfc. period	1981-2013	1994-2014	1994-2014	1999-2010
Rfc. Freq.	6/months	daily	2/weekly	daily

In order to increase the Cma and Ncep ensemble size, we have combined 3 ensemble forecasts (initiated on consecutive days) into a single 12-member ensemble. (We define the initial date to be that of the central sub-ensemble; this has little effect on results at extended leadtimes).

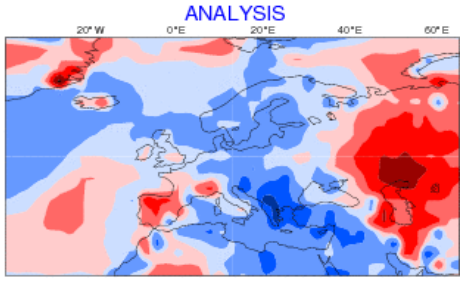
Monitoring S2S quasi real-time forecasts:



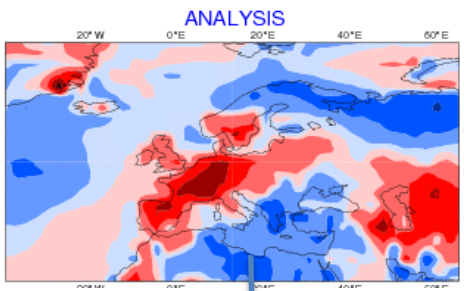
Monitoring S2S quasi real-time forecasts:



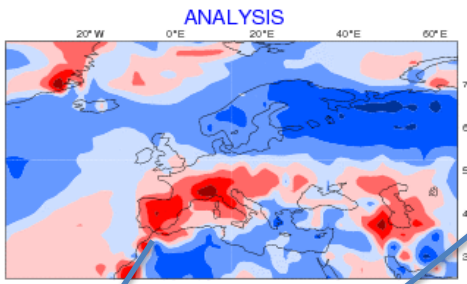
Heat wave over Central-southern Europe: 2mt weekly mean anomalies



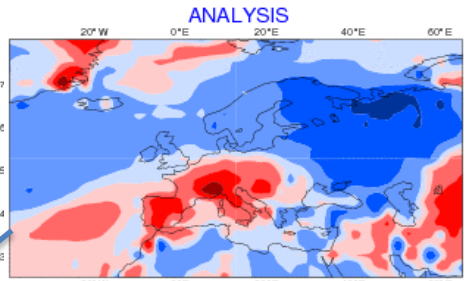
22-28 Jun



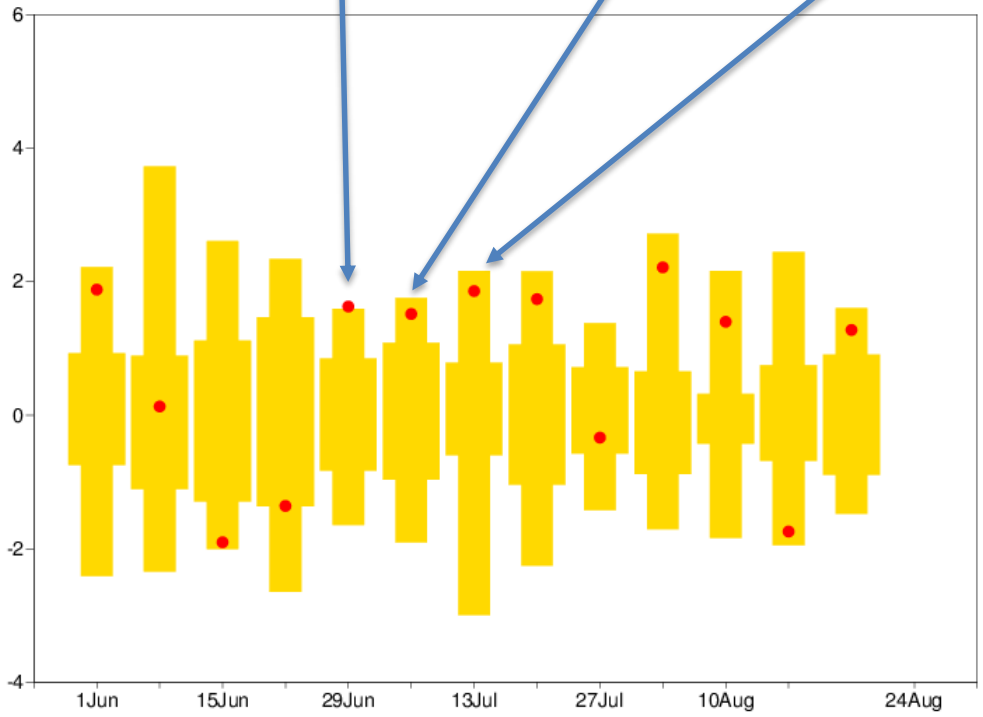
29-5Jul



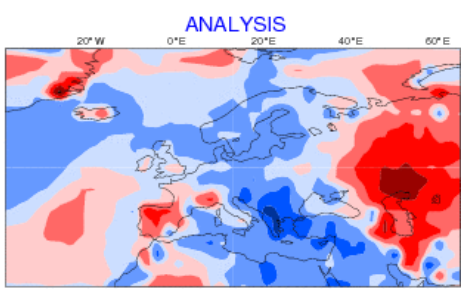
6-12Jul



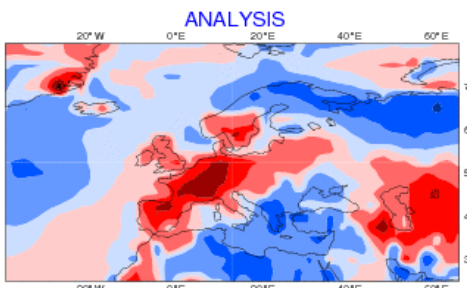
13-19Jul



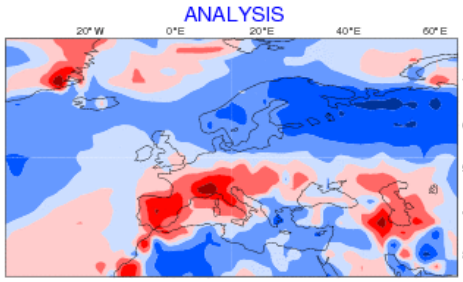
Heat wave over Central-southern Europe: 2mt weekly mean anomalies



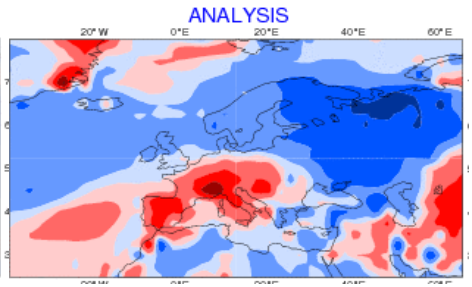
22-28 Jun



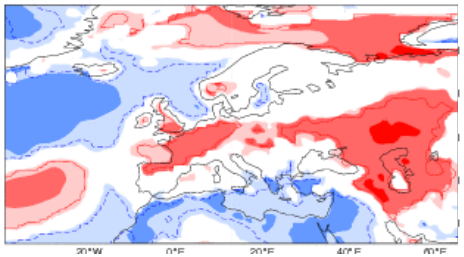
29-5Jul

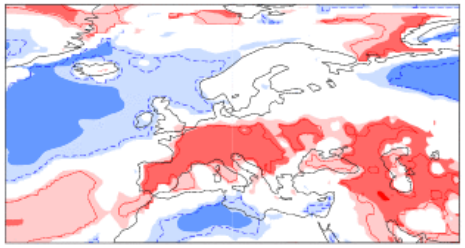


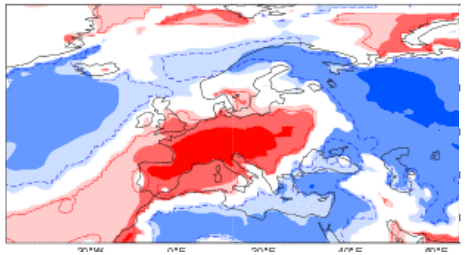
6-12Jul

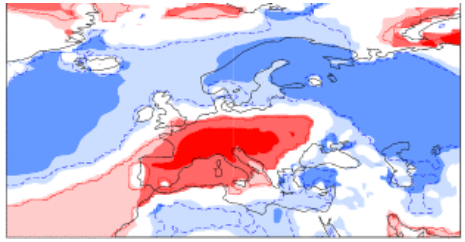


13-19Jul





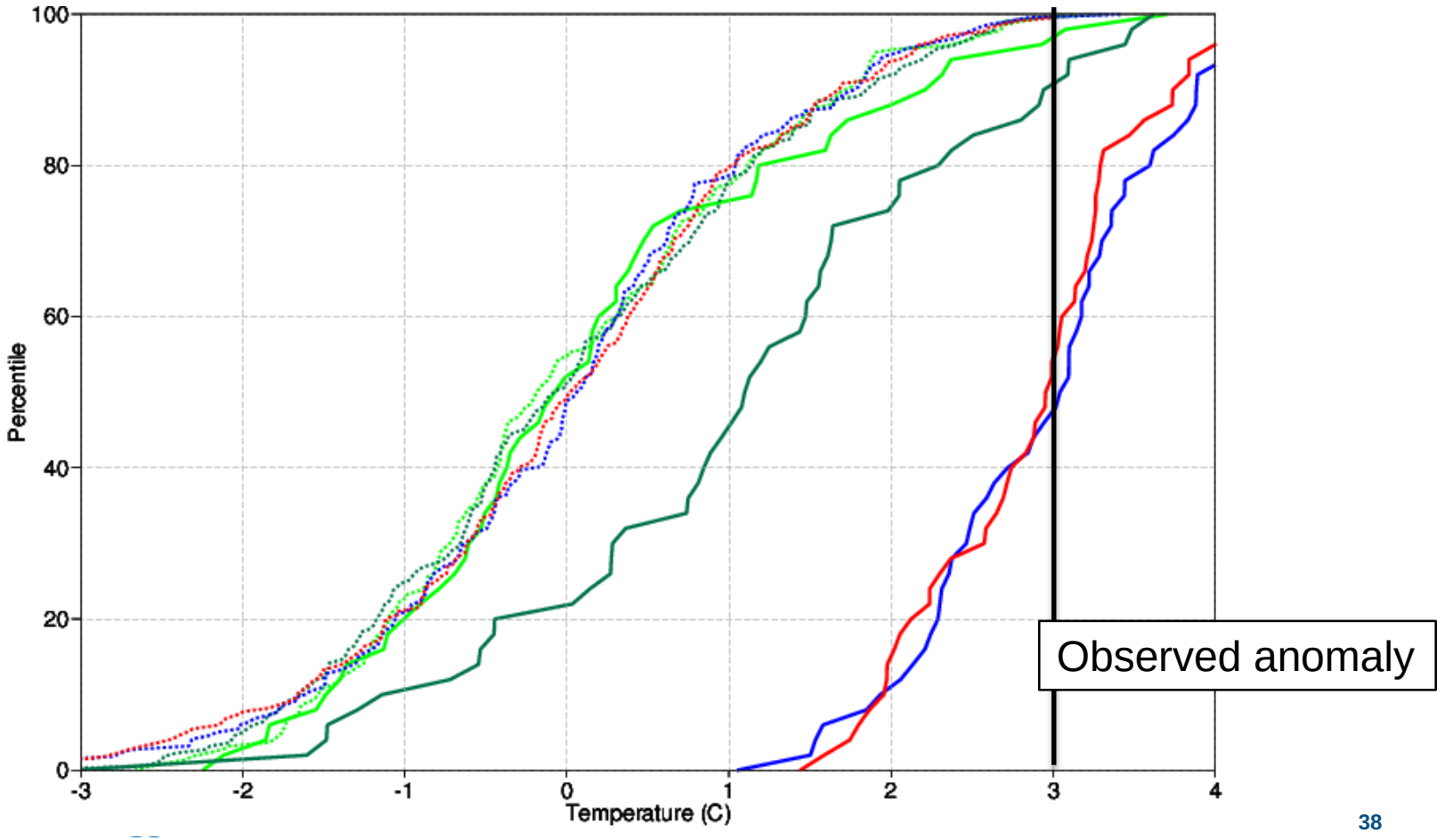


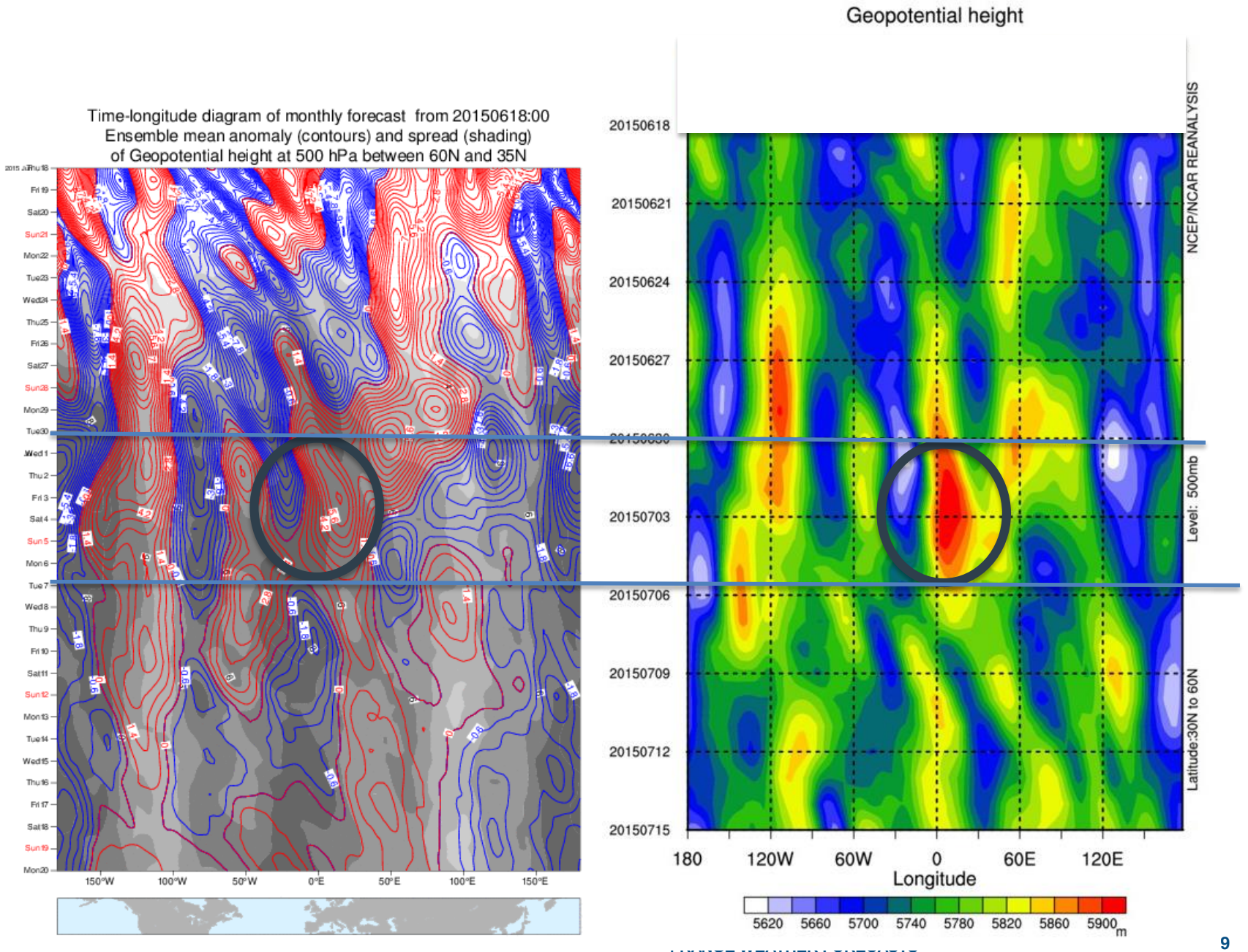


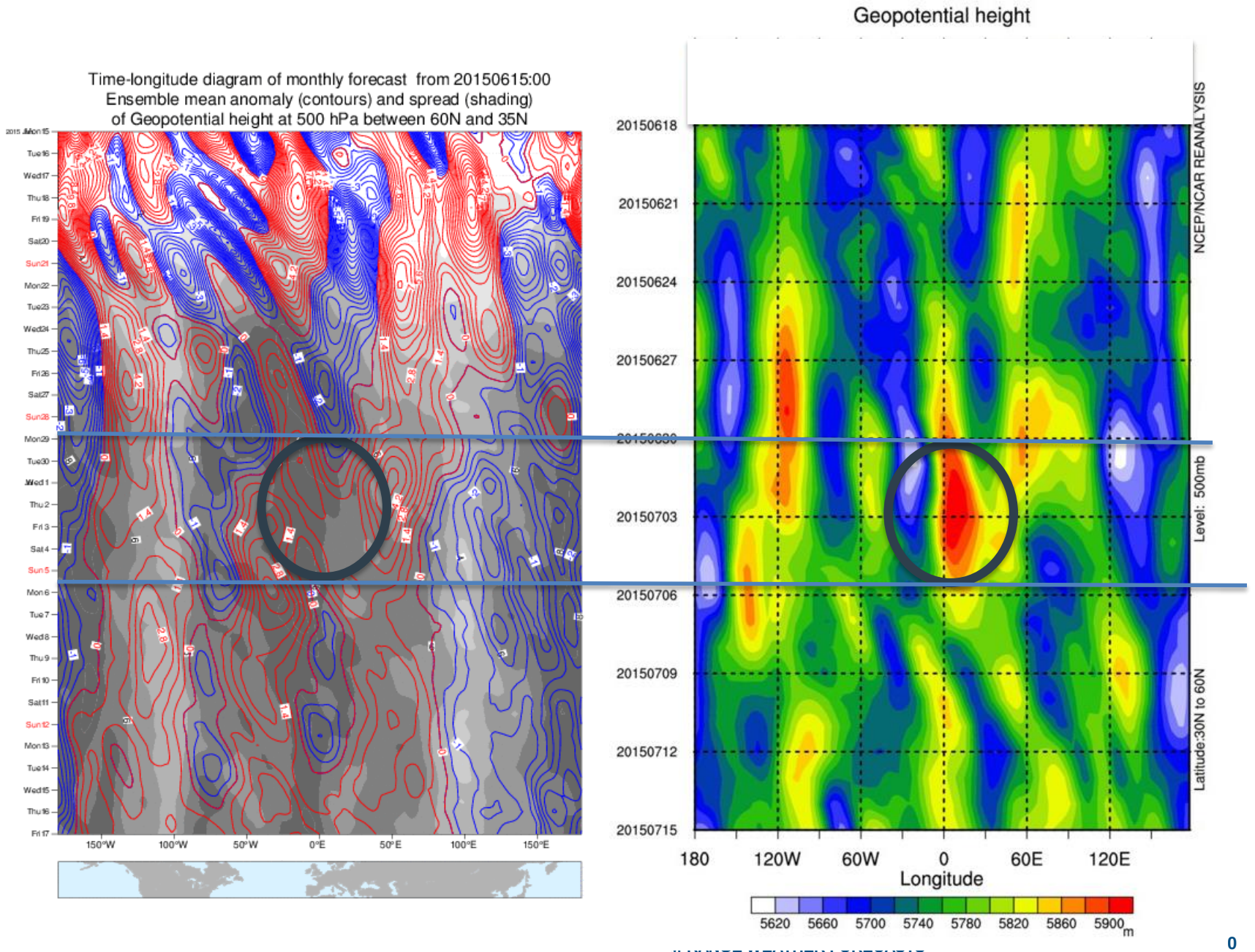
Forecasts: 12-18 days

2m temp CDF: ensemble predictions for 29 June - 5 July 2015

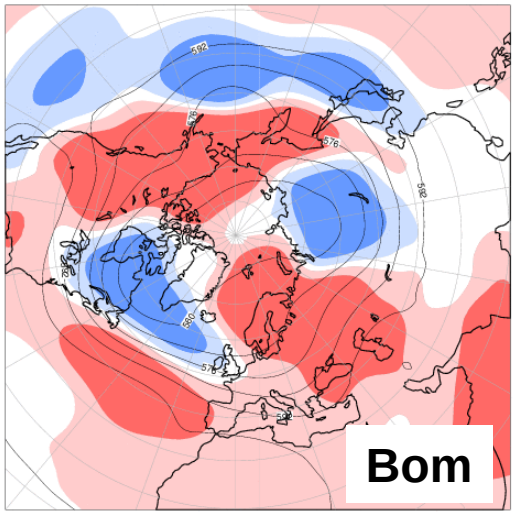
Climate | 15 June 2015 (15-21d) | 18 June 2015 (12-18d) | 22 June 2015 (8-14d) | 25 June 2015 (5-11d)

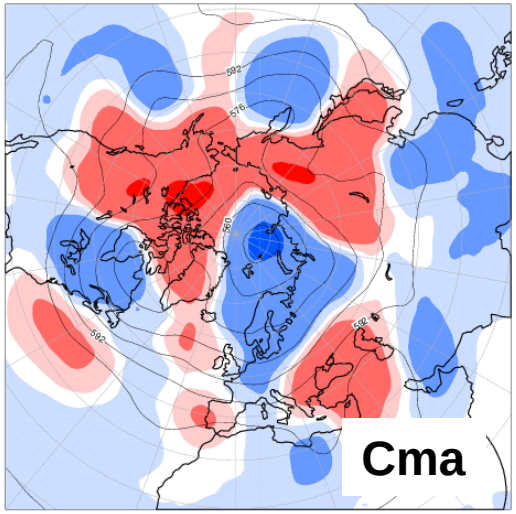


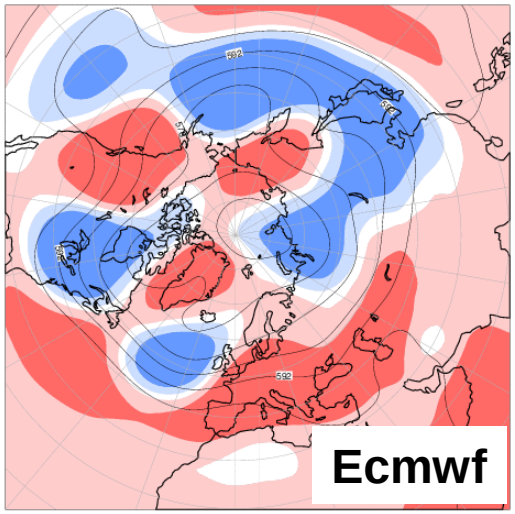

Time-longitude diagram of monthly forecast from 20150618:00
Ensemble mean anomaly (contours) and spread (shading)
of Geopotential height at 500 hPa between 60N and 35N
150°W
100°W
50°W
0°E
50°E
100°E
150°E
Geopotential height
20150618
20150621
20150624
20150627
20150703
20150706
20150709
20150712
20150715
180
120W
60W
0
60E
120E
Longitude
NCEP/NCAR REANALYSIS
Level: 500mb
Latitude:30N to 60N
5620
5660
5700
5740
5780
5820
5860
5900
m

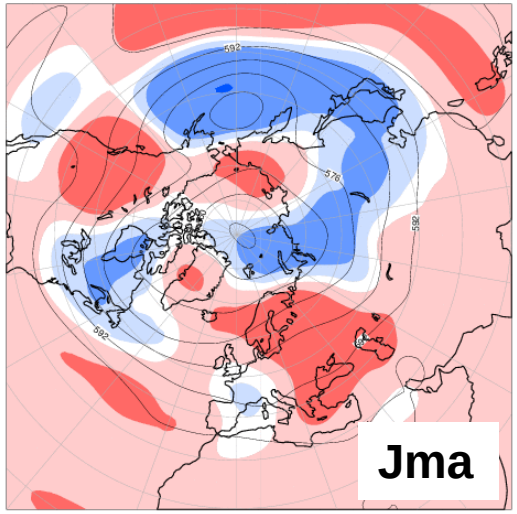

Time-longitude diagram of monthly forecast from 20150615:00
Ensemble mean anomaly (contours) and spread (shading)
of Geopotential height at 500 hPa between 60N and 35N
Mon15
Tue16
Wed17
Thu18
Fri19
Sat20
Sun21
Mon22
Tue23
Wed24
Thu25
Fri26
Sat27
Sun28
Mon29
Tue30
Wed1
Thu2
Fri3
Sat4
Sun5
Mon6
Tue7
Wed8
Thu9
Fri10
Sat11
Sun12
Mon13
Tue14
Wed15
Thu16
Fri17
150°W
100°W
50°W
0°E
50°E
100°E
150°E
Geopotential height
20150618
20150621
20150624
20150627
20150630
20150703
20150706
20150709
20150712
20150715
180
120W
60W
0
60E
120E
Longitude
NCEP/NCAR REANALYSIS
Level: 500mb
Latitude:30N to 60N
5620
5660
5700
5740
5780
5820
5860
5900
m

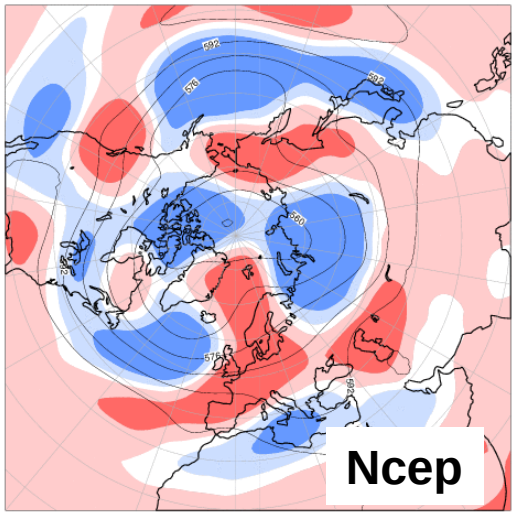
S2S Z500 anomalies: days 12-18 - verifying 29-06 to 05-07 2015

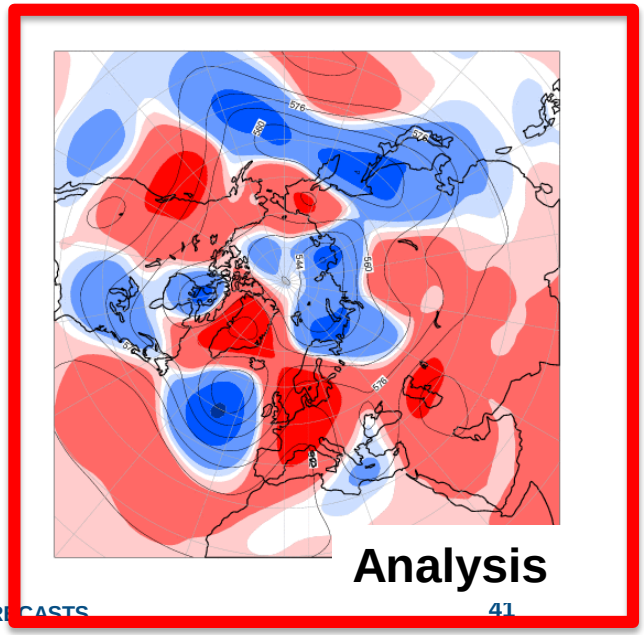




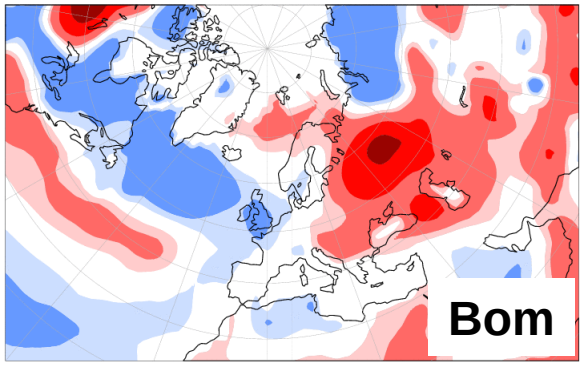


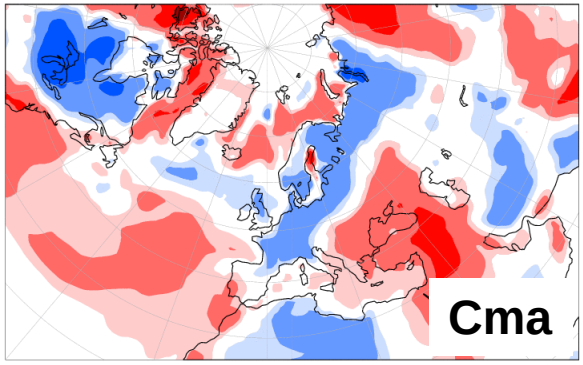


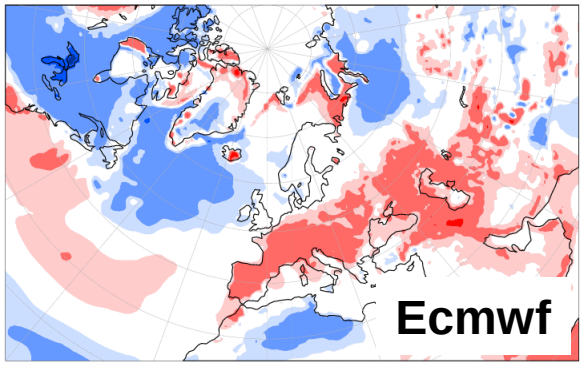


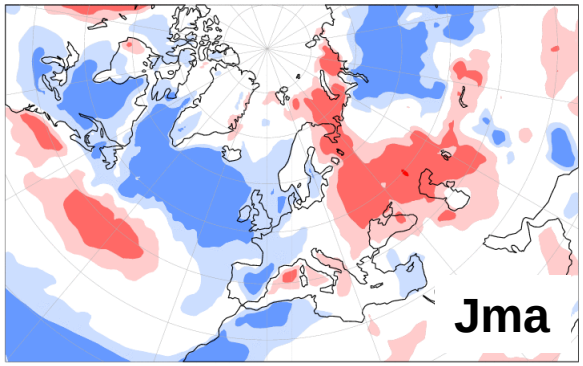


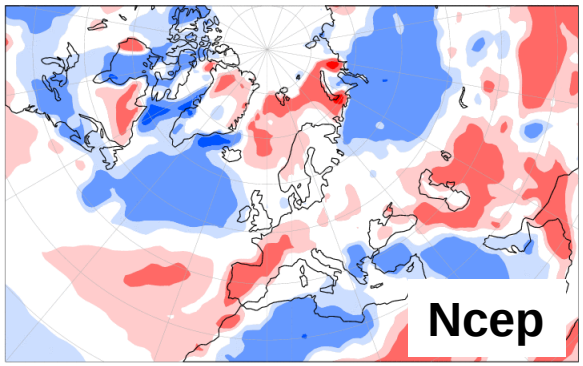
S2S 2mt anomalies: days 12-18 - verifying 29-06 to 05-07 2015

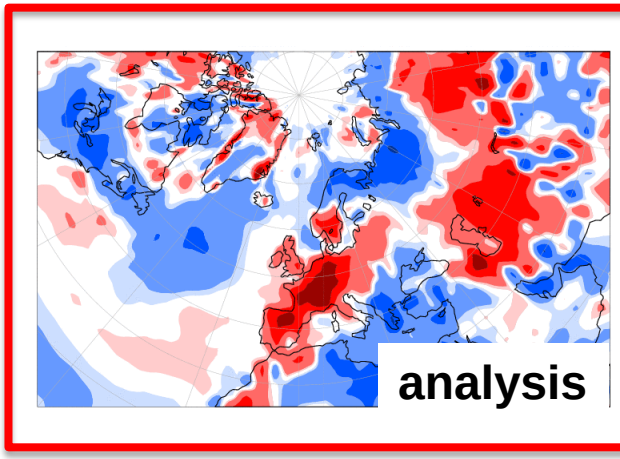












Summary and discussion:

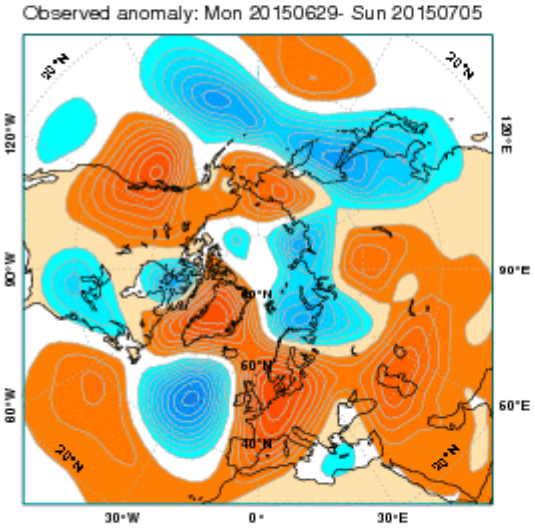
Analysis on the cold events:

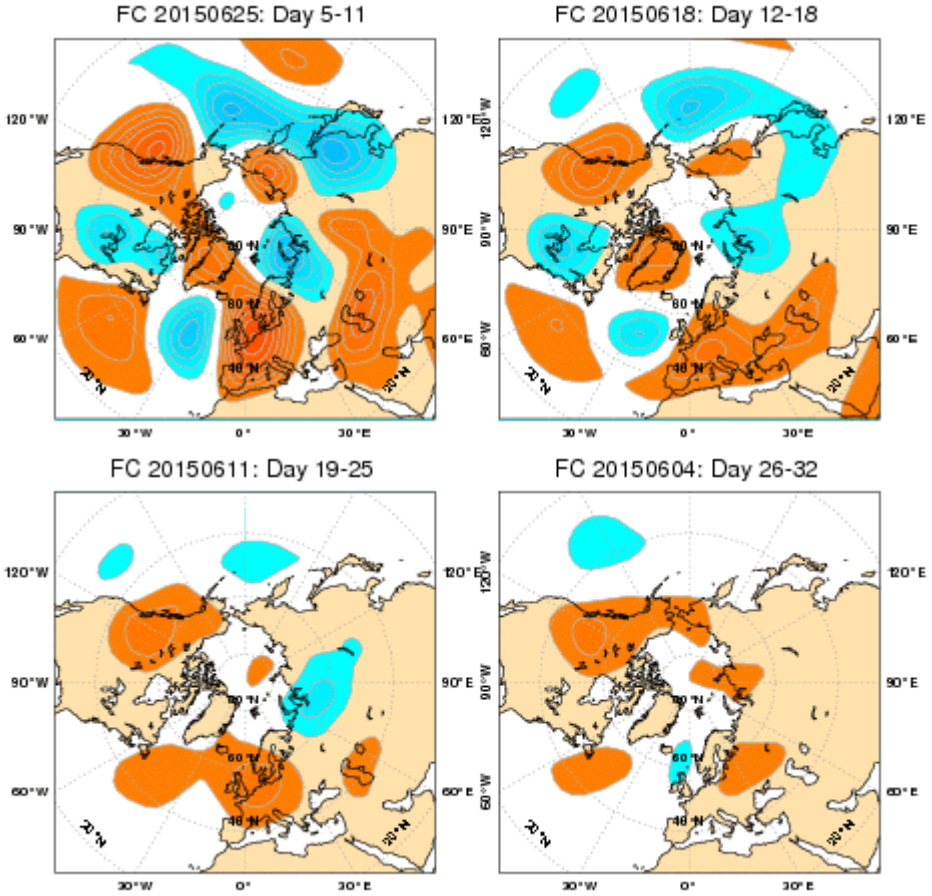
Importance of using re-forecast data to get some
Relevance of the regime transitions.
Possible tools ?

Monitoring web site useful tool for

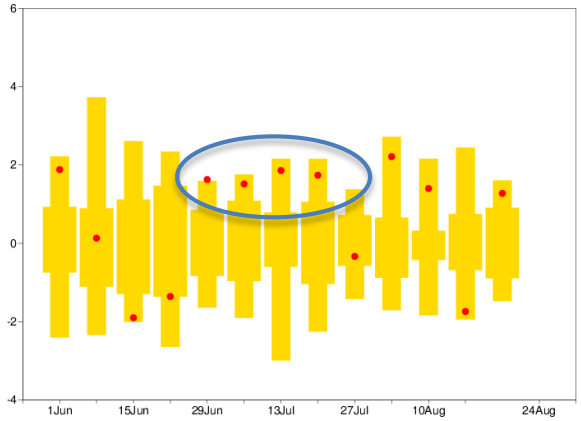
Heat wave case shows the importance of reproducing the transient waves

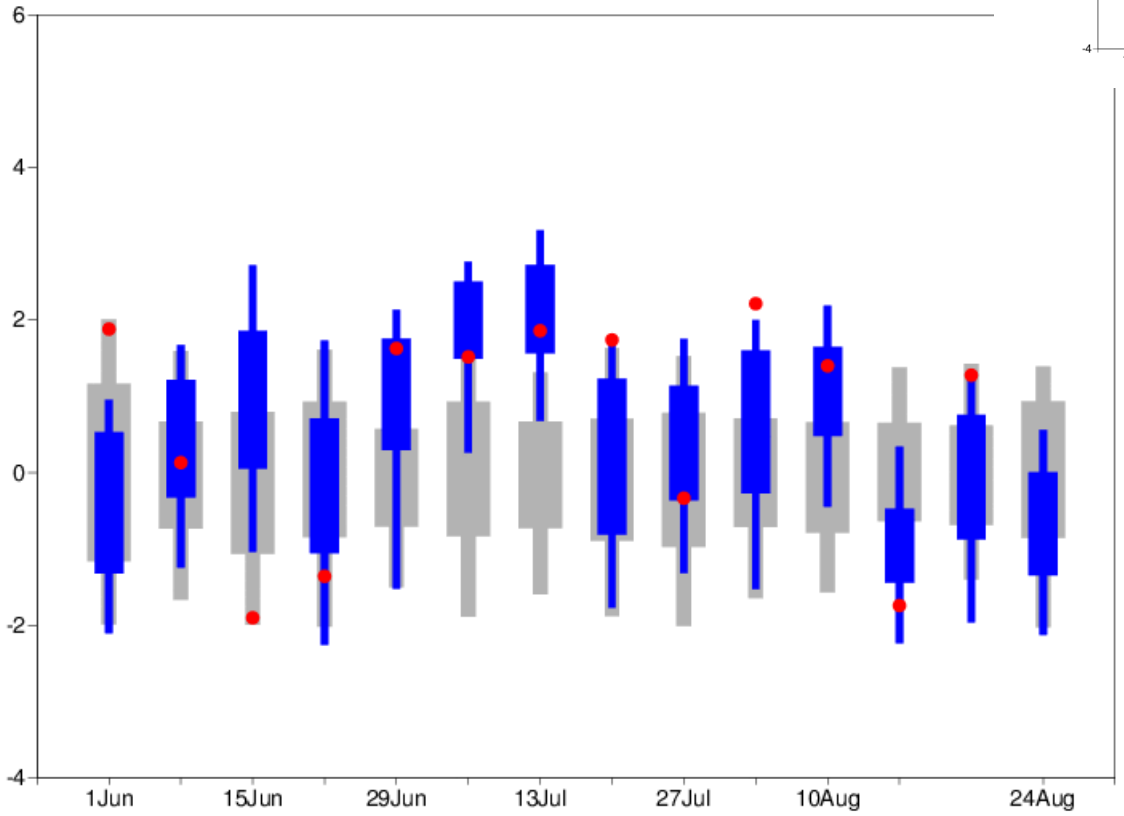
The predictability of this particular case stem from surface conditions our model
In a sense had an advantage …..

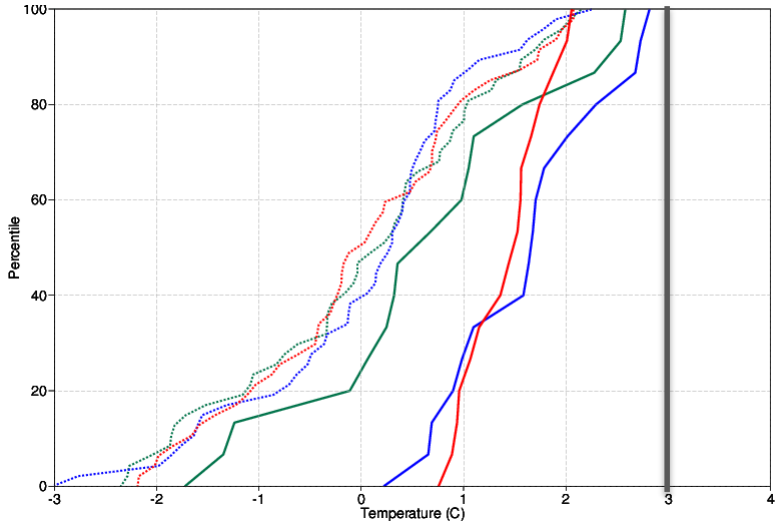

Observed anomaly: Mon 20150629- Sun 20150705
120°W
90°W
60°W
120°E
90°E
60°E
30°W
0°
30°E
80°N
60°N
40°N
20°N

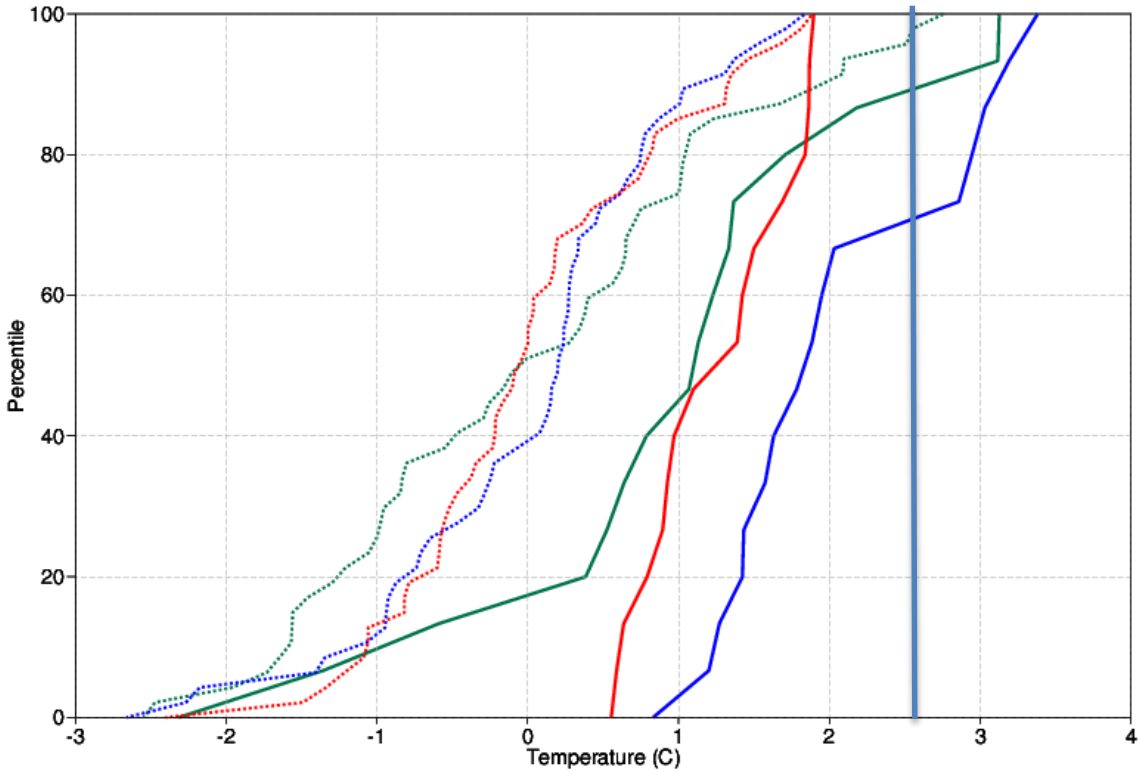

FC 20150625: Day 5-11
FC 20150618: Day 12-18
FC 20150611: Day 19-25
FC 20150604: Day 26-32
120°W
90°W
60°W
120°E
90°E
60°E
30°W
0°
30°E
80°N
60°N
40°N
20°N

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

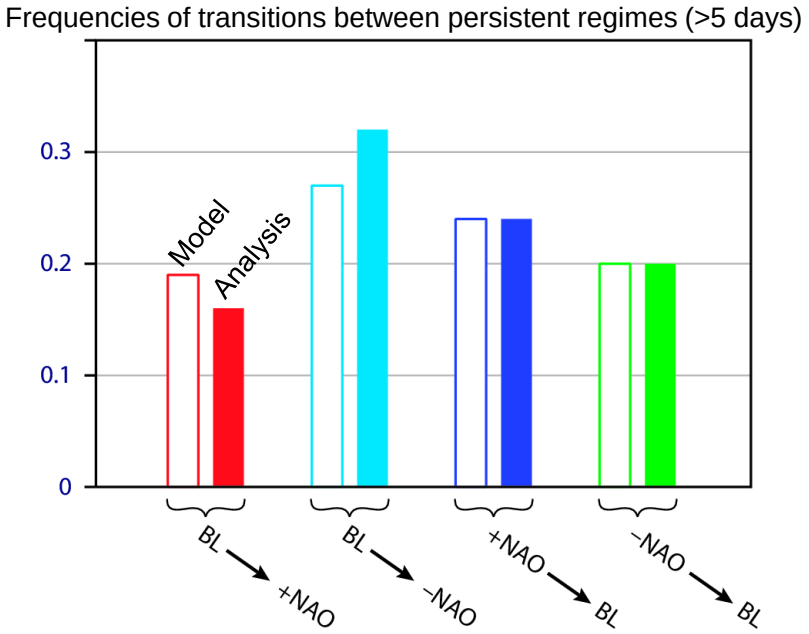


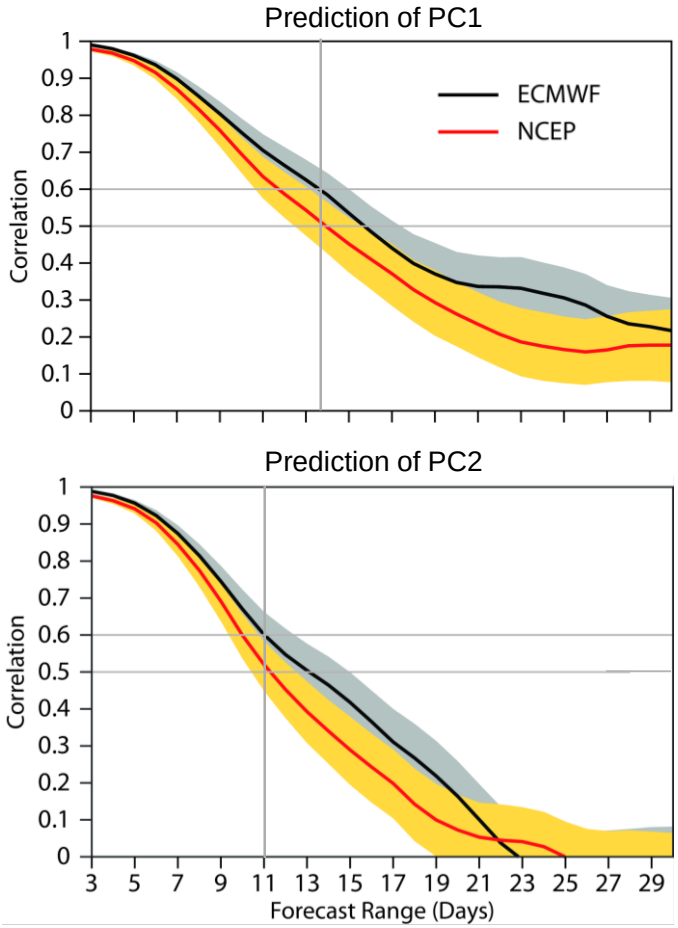



100
80
60
40
20
0
Percentile
-3
-2
-1
0
1
2
3
4
Temperature (C)


100
80
60
40
20
0
Percentile
-3
-2
-1
0
1
2
3
4
Temperature (C)

Regime transition-frequencies and predictability (*c.f.* MJO predictability)





- Transition frequencies good. Slight over-preference for BL → +NAO
- ECMWF has 1-2 days better skill than NCEP
- PC1 is ~2 days better than PC2 (due to high persistence of –NAO?)

5-day running mean applied prior to correlation calculation

Although forecasts at the extended range are not expected to have skill to predict the day to day variability, they might predict cold/warm spells that persist for longer than a week.

Cold/warm spells are generally associated with persistent high pressure systems.

Those systems are sometime associated with global teleconnections linked to tropical organized convection (MJO) (Cassou 2005).

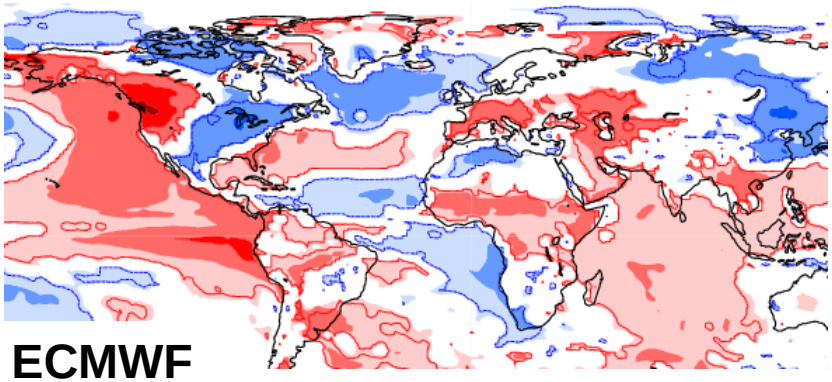
From a recent study on Heat waves predictions at extended range:

- Generally the forecasts identify with a certain degree of accuracy the location of warm anomalies although the amplitude is underestimated

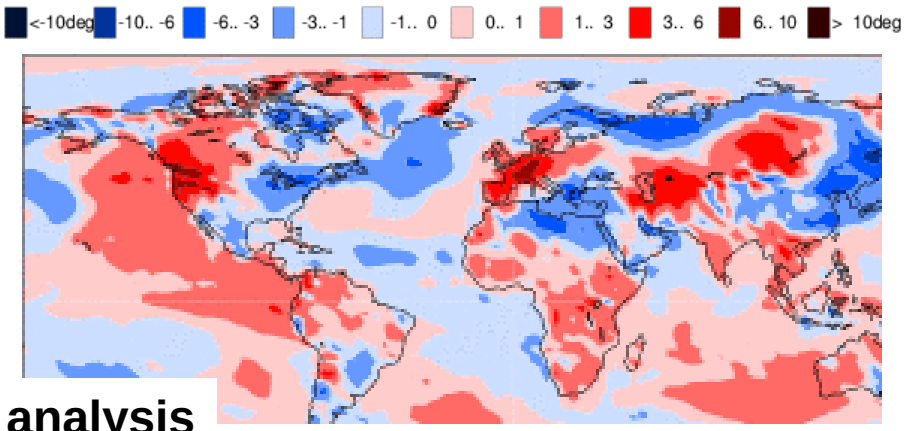
- The successful predictions persisted the anti-cyclonic circulation which was already present in the initial conditions. In contrast most of the non successful predictions did not have an anti-cyclonic circulation in the initial conditions.

The skill in predicting heat waves at the extended range may therefore be limited by the ability of the forecast model to represent transitions to anti-cyclonic circulation regimes.

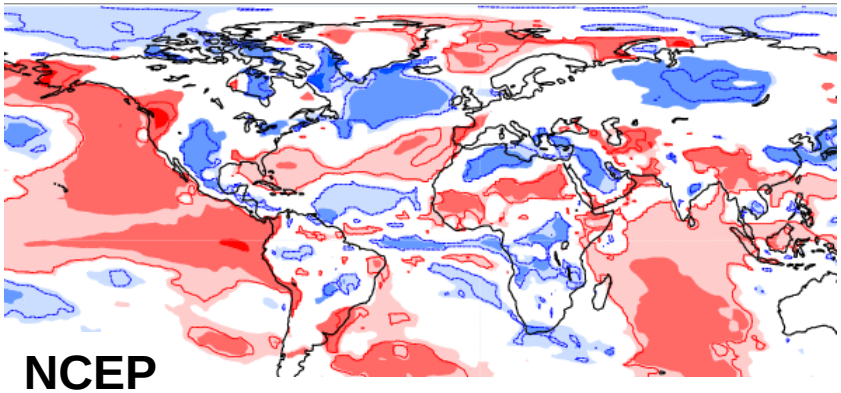
S2S 2mt anomalies: days 12-18 - verifying 29-06 to 05-07 2015



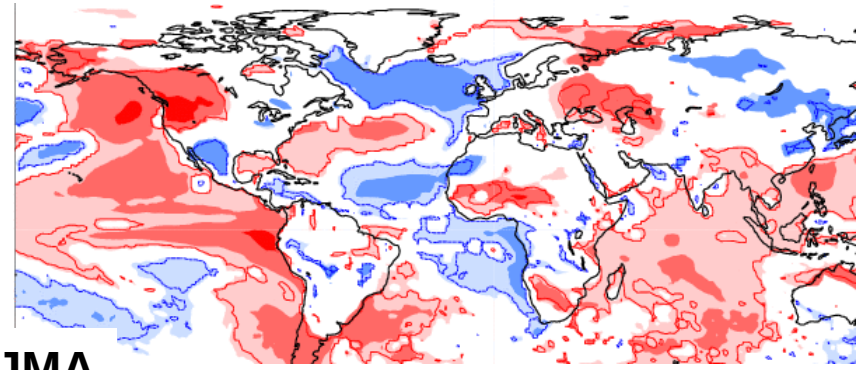
ECMWF



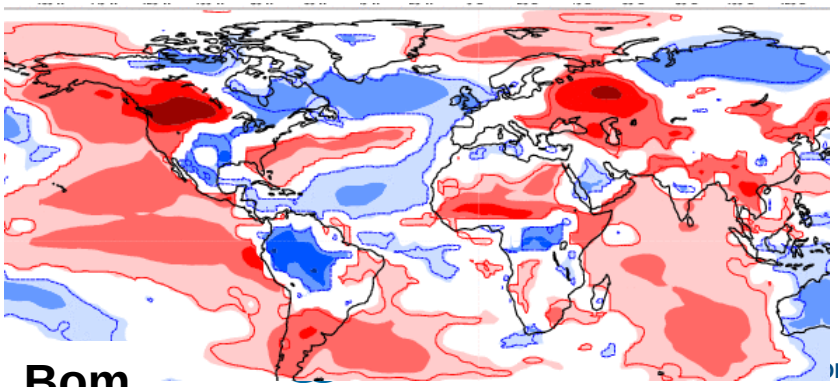
analysis



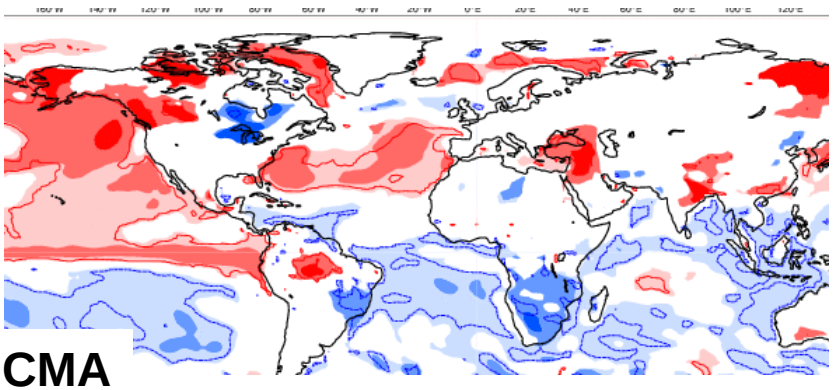
NCEP



JMA

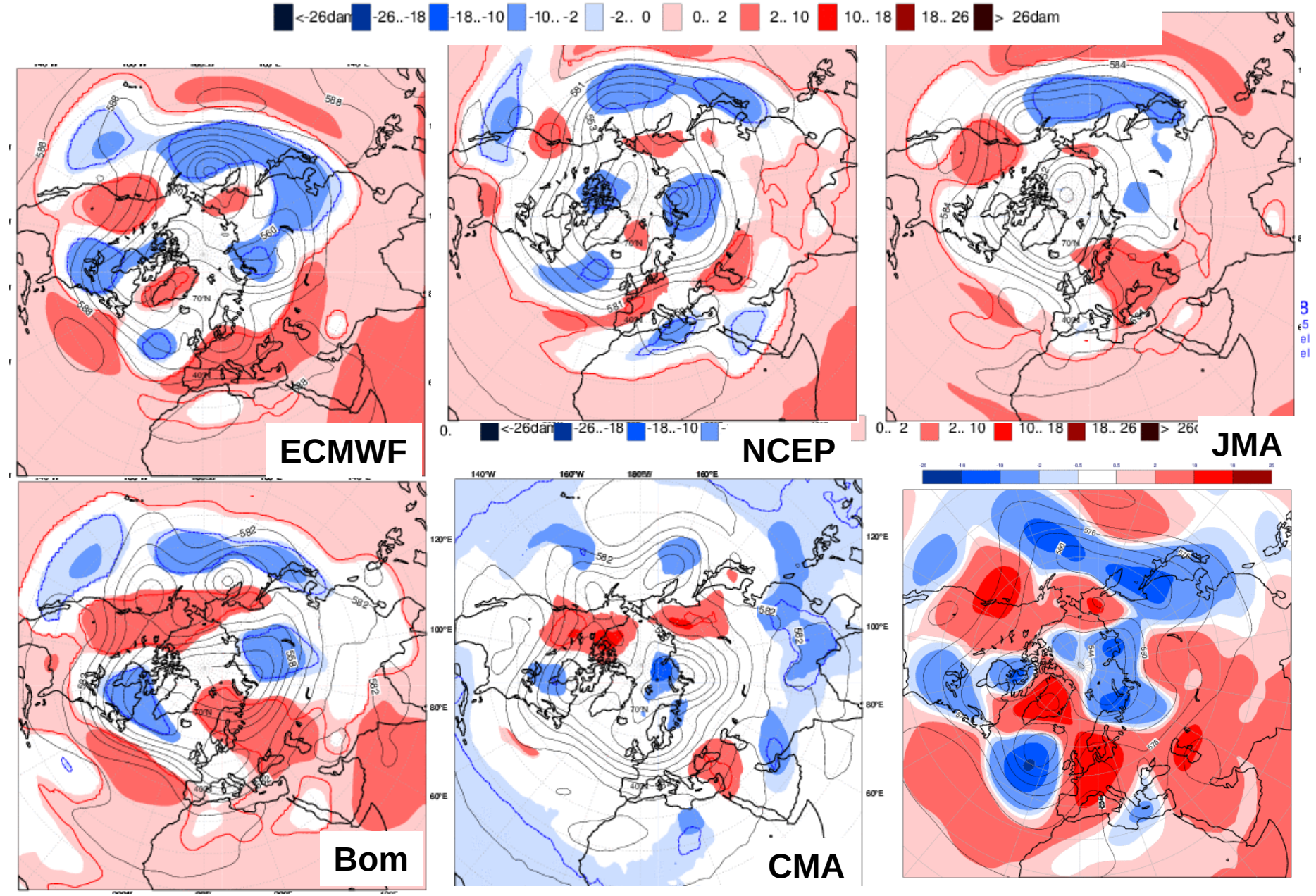


Bom



CMA

S2S Z500 anomalies: days 12-18 - verifying 29-06 to 05-07 2015



Predicting skill associated with the Euro-Atlantic Regimes: