Sub-Seasonal Prediction over the Mediterranean

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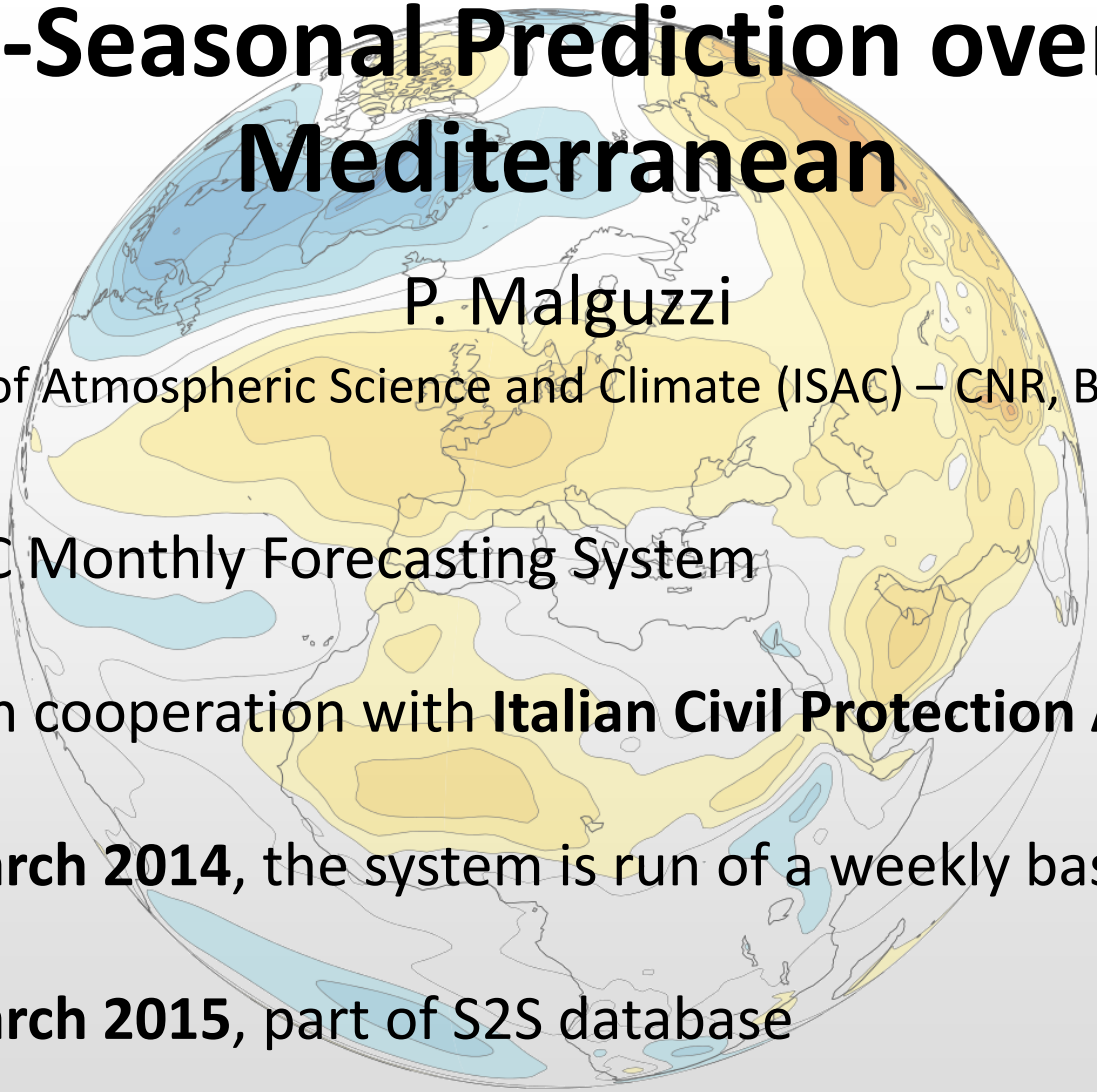
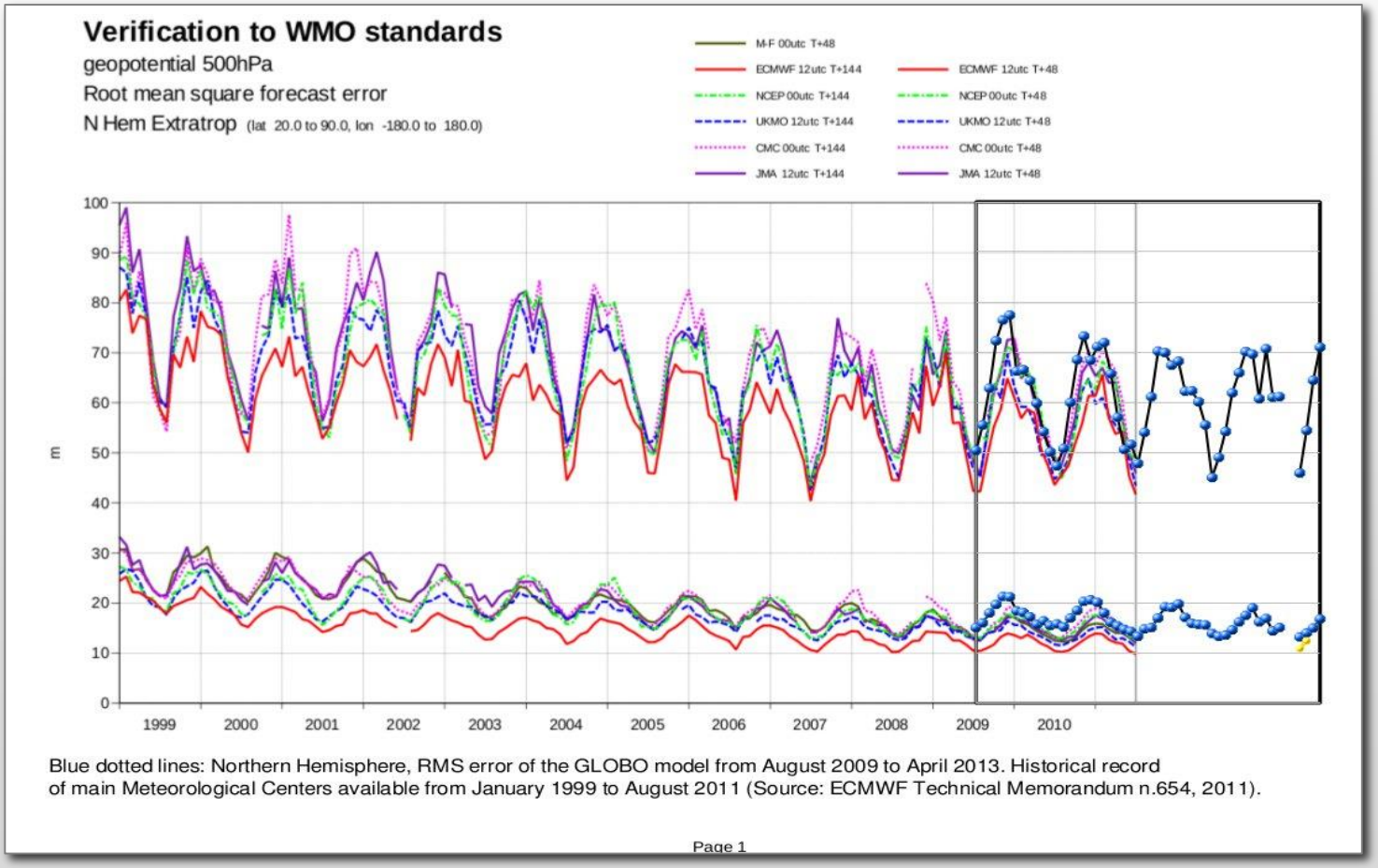


- CNR-ISAC Monthly Forecasting System
- Started in cooperation with **Italian Civil Protection Agency**
- Since **March 2014**, the system is run of a weekly basis
- Since **March 2015**, part of S2S database

Global modeling at CNR-ISAC

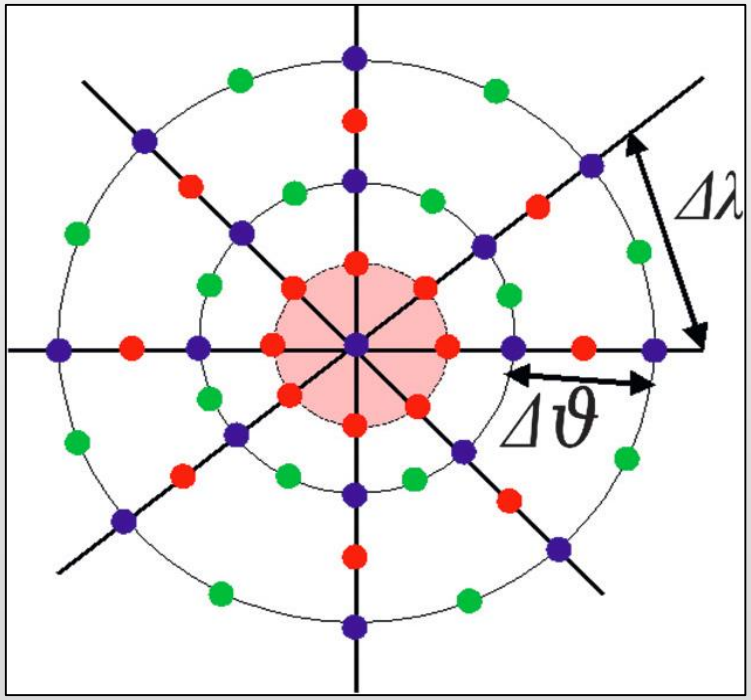
- **Ensemble forecasting system** based on the **atmospheric general circulation model GLOBO** (derived from the **BOLAM** model).
- Used for daily, **real time**, deterministic **medium range** forecast with IC from **00 UT analysis of GFS**.



Malguzzi *et al*, *Weather and Forecasting*, Dec 2011, **26**

GLOBO model: dynamical scheme

- Hydrostatic, primitive equations, grid points in lat-lon coordinates
- Arakawa C grid; terrain-following hybrid coordinates
- Time split, forward-backward for gravity modes (with polar filter)
- TVD - 3D advection (Hubbard and Nikiforakis, 2003)
- Parallelization technique based on domain decomposition



GLOBO model: physics

- Radiation : Ritter-Geleyn (rapid update); ECMWF (slow update)
- Kessler-type, bulk microphysics with 5 water species
- Moist convection based on Kain-Fritsh (Kain, 2004)
- Mountain wave drag
- Soil and vegetation hydro-thermal processes with 7 soil layers
- Vertical diffusion (*E-l*: explicit TKE)

‘Slab’ Ocean - Sea ice

$$\frac{\partial}{\partial t} T_{SEA} = -\frac{1}{C}(F_{SH} + F_{LH} + F_{SW} + F_{IR}) - \frac{1}{t}(T_{SEA} - T^{*})$$

$$C = \rho_{W} C_{W} h$$

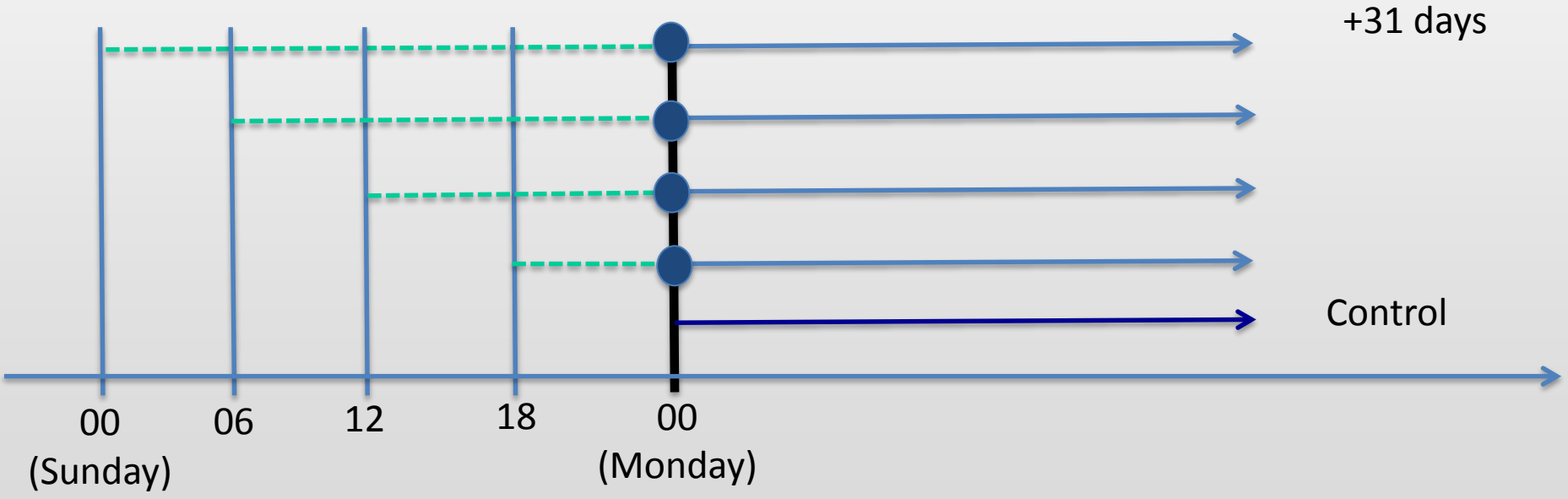
- sea-ice cover fixed if > (<) than climatology in the fall-winter (spring-summer) season; relaxed to climatology otherwise

GLOBO numerical set up

- Horizontal grid spacing of 0.56 deg. lat x 0.8 deg. lon, 54 vertical levels
- Time step of 360 s
- SST and sea-ice cover climatological values are computed from ECMWF ERA-Interim re-analyses over the 30-year period 1981-2010
- 1 simulation of 31 days on 8 nodes (cluster Debian Gnu Linux), 128 cores ≈ 13 min

Mixed lagged-ensemble forecast

- 40 members + 1 control taken from GEFS of NCEP
- Initial time on 00 UT every Monday



Reforecast

Reforecasts are used to:

- diagnose model drift (bias) as a function of calendar and validity day
- calibrate forecasts
- Evaluate forecast skill

"Fixed" set of simulations with 31-day lead time

1981-2010 reference climate, with initial conditions from ECMWF ERA-Interim re-analyses

One simulation every 5 days, starting on January 1, 00UT -> 73 fixed "calendar days" → a total of 2190 simulations

Model climate

Define a (smooth) model climate (*MC*) as function of longitude, latitude, *ID*, *V* by averaging over reforcasts with calendar day C_j nearby the initial date of forecast.

$$p_j \sim e^{-(ID-C_j)^2/d^2}$$

Let R denote the single reforecast:

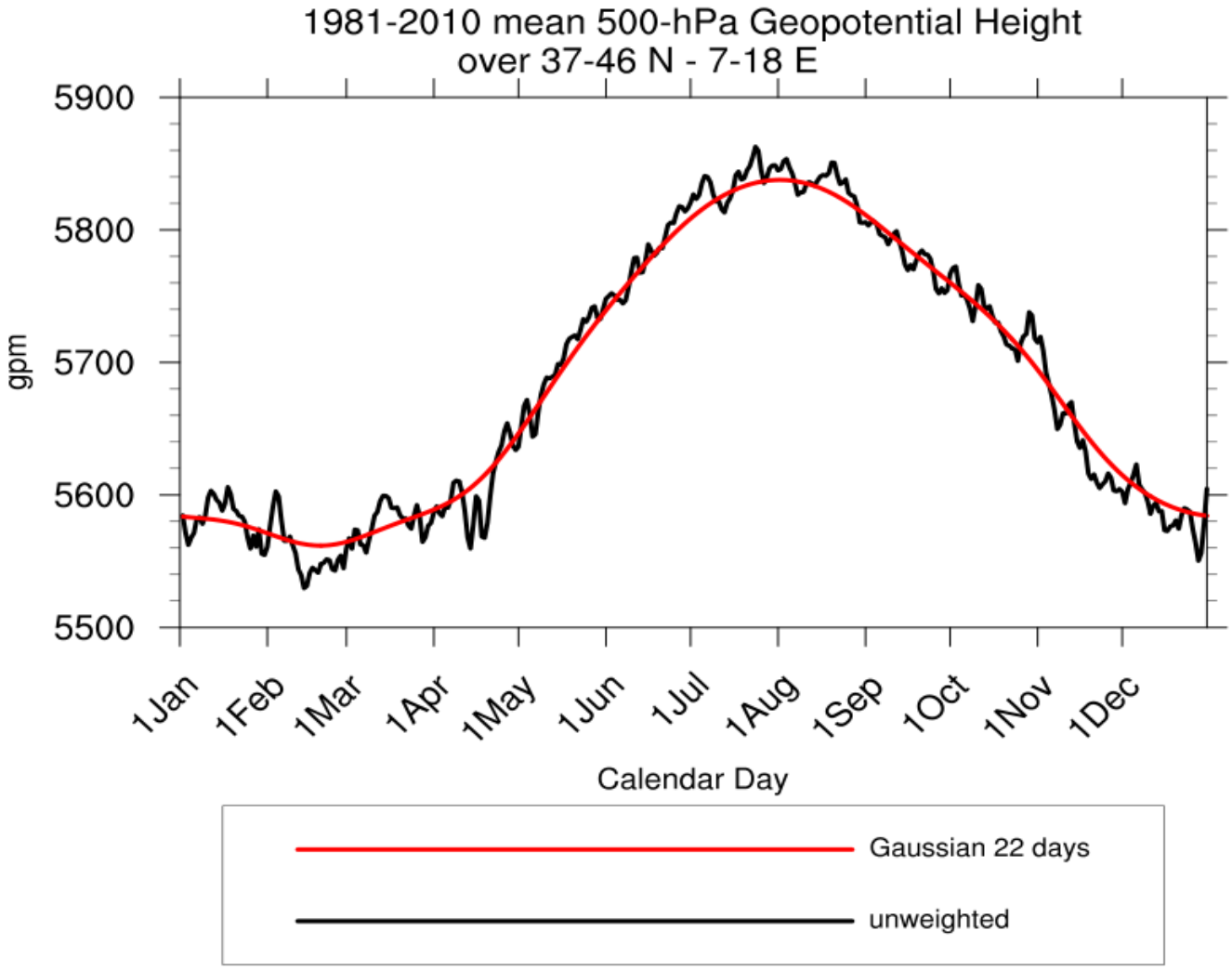
$$R_y(l, f, C_j, V), \quad y \in [1981, 2010], \quad j = 1, .., 73$$

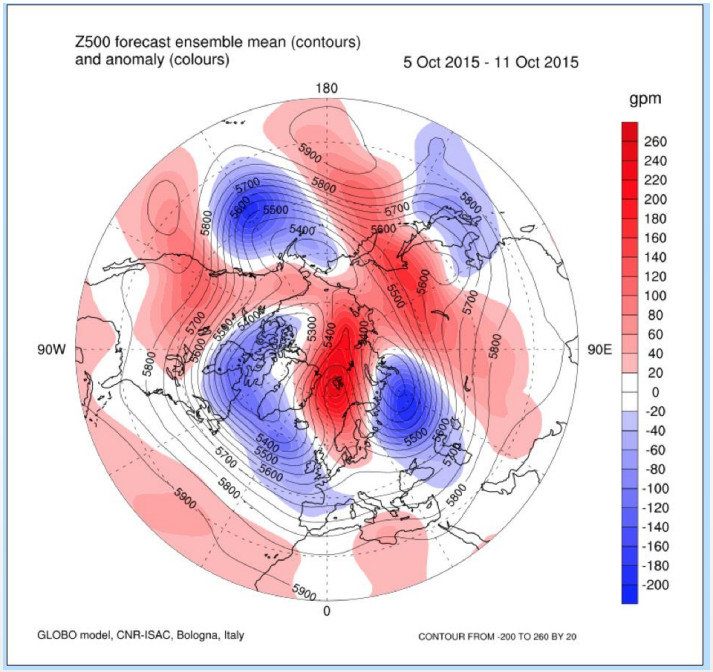
$$MC(l, f, ID, V) = \frac{1}{30} \sum_{y=1981}^{2010} \sum_{j=1}^{73} p_j R_y(l, f, C_j, V)$$

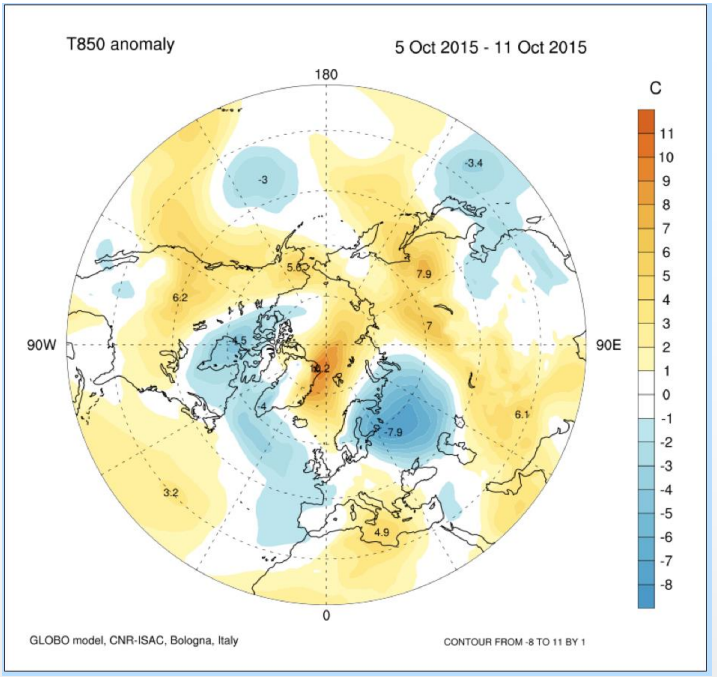
$$MV(l, f, ID, V) = \frac{1}{30} \sum_{y=1981}^{2010} \sum_{j=1}^{73} p_j (R_y - MC)^2$$

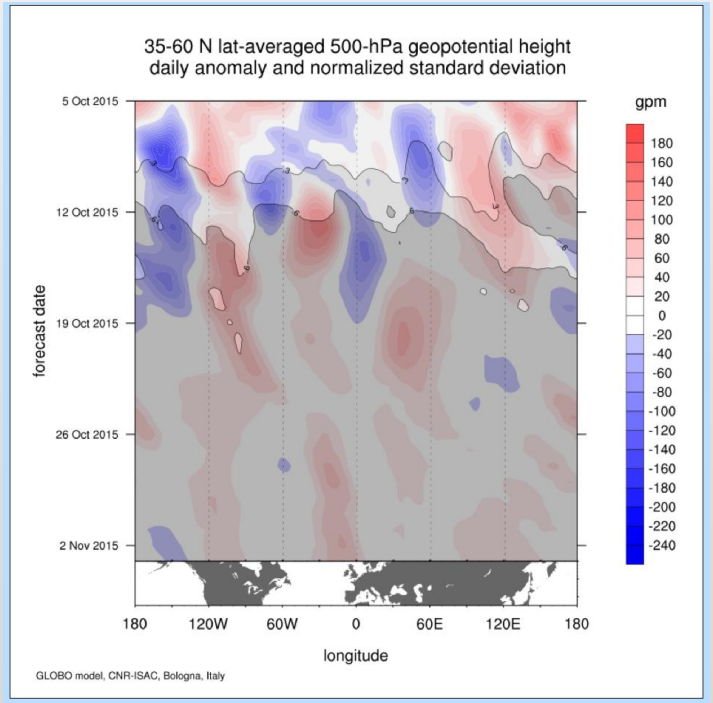
.....

….weak smoothing of the climatological annual cycle

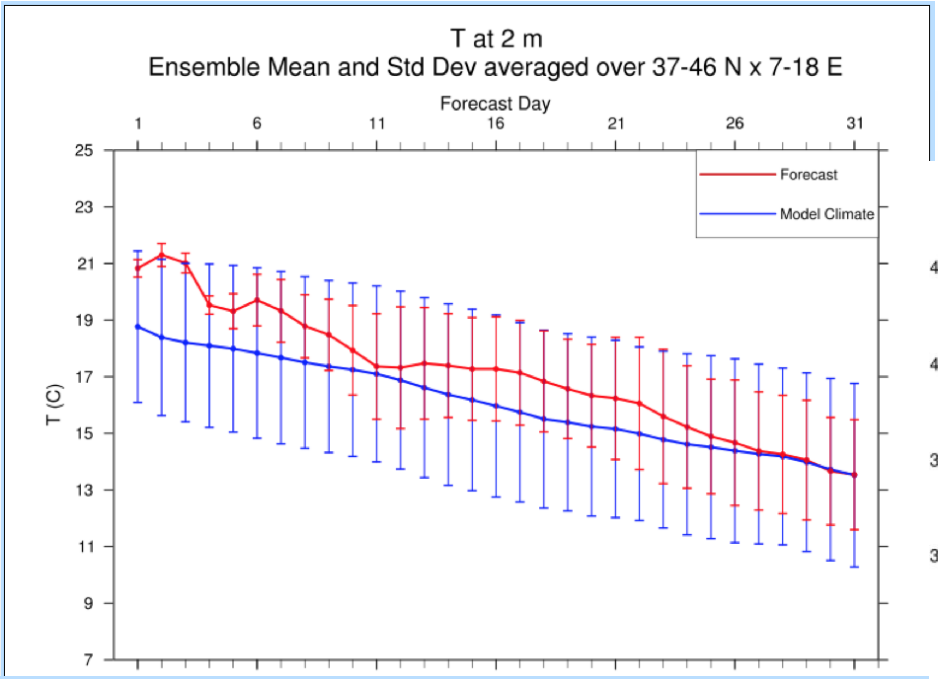


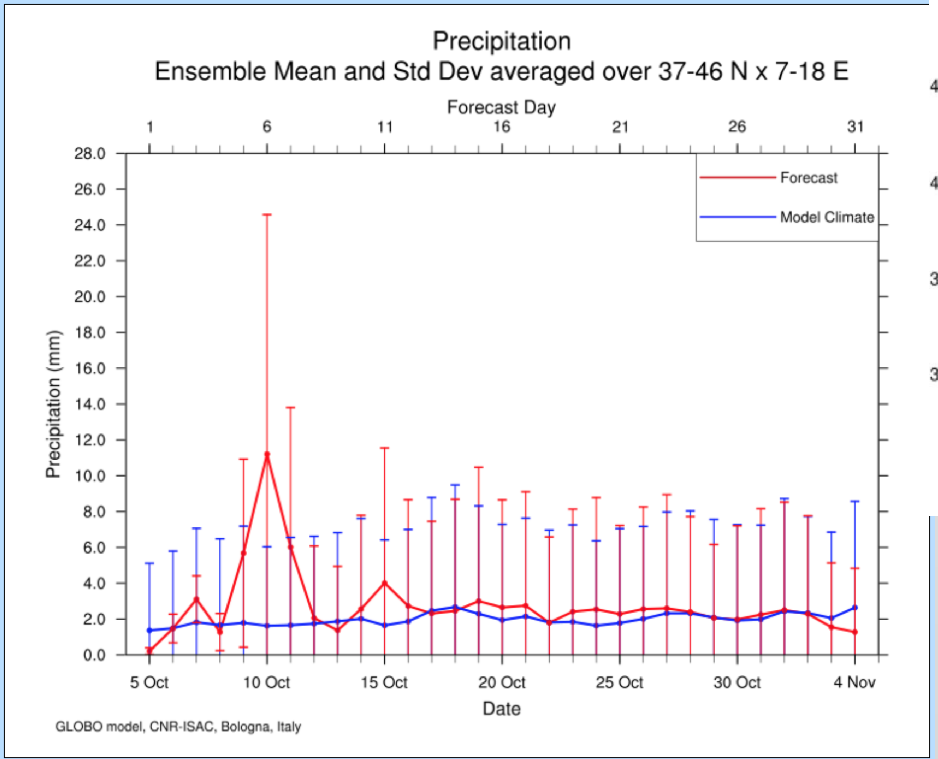


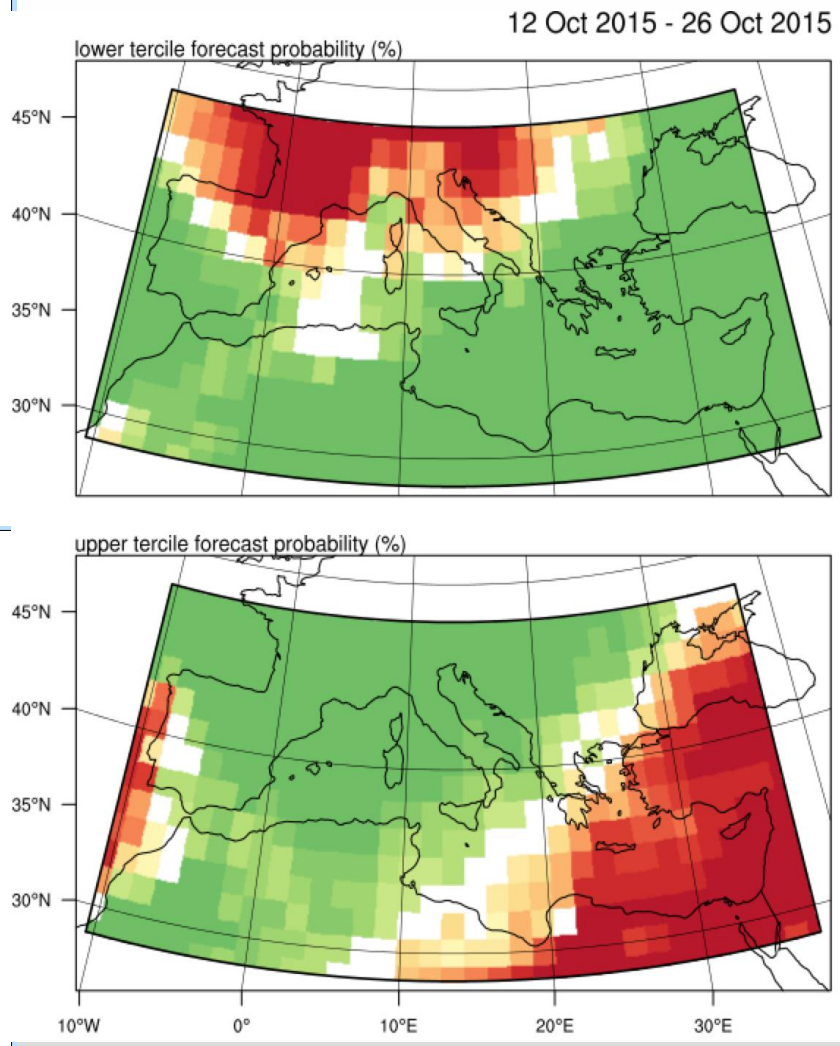




Web page:
http://www.isac.cnr.it/~dinamica/projects/forecasts/


T at 2 m
Ensemble Mean and Std Dev averaged over 37-46 N x 7-18 E
Forecast Day
1
6
11
16
21
26
31
25
23
21
19
17
15
13
11
9
7
T (C)
Forecast
Model Climate


Precipitation
Ensemble Mean and Std Dev averaged over 37-46 N x 7-18 E
Forecast Day
1
6
11
16
21
26
31
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Precipitation (mm)
Forecast
Model Climate
5 Oct
10 Oct
15 Oct
20 Oct
25 Oct
30 Oct
4 Nov
Date
GLOBO model, CNR-ISAC, Bologna, Italy


12 Oct 2015 - 26 Oct 2015
lower tercile forecast probability (%)
upper tercile forecast probability (%)
45°N
40°N
35°N
30°N
10°W
0°
10°E
20°E
30°E
%
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5

S2S project

Geopotential height
Temperature
U-velocity
V-velocity
10 metre u-velocity
10 metre v-velocity
Mean sea-level pressure
Snow depth water equivalent
Soil temperature top 20 cm
Surface air temperature at 2m
Surface air dewpoint temperature at 2m
Sea surface temperature
Sea ice cover
Total cloud cover
Time-integrated top net thermal radiation
Surface air maximum temperature
Surface air minimum temperature
Total precipitation

- March 29, 2015, uploaded to S2S archive
- Model changes
- Surface parameters plus 10 pressure levels: 1000, 925, 850, 700, 500, 300, 200, 100, 50, 10 hPa

Verification

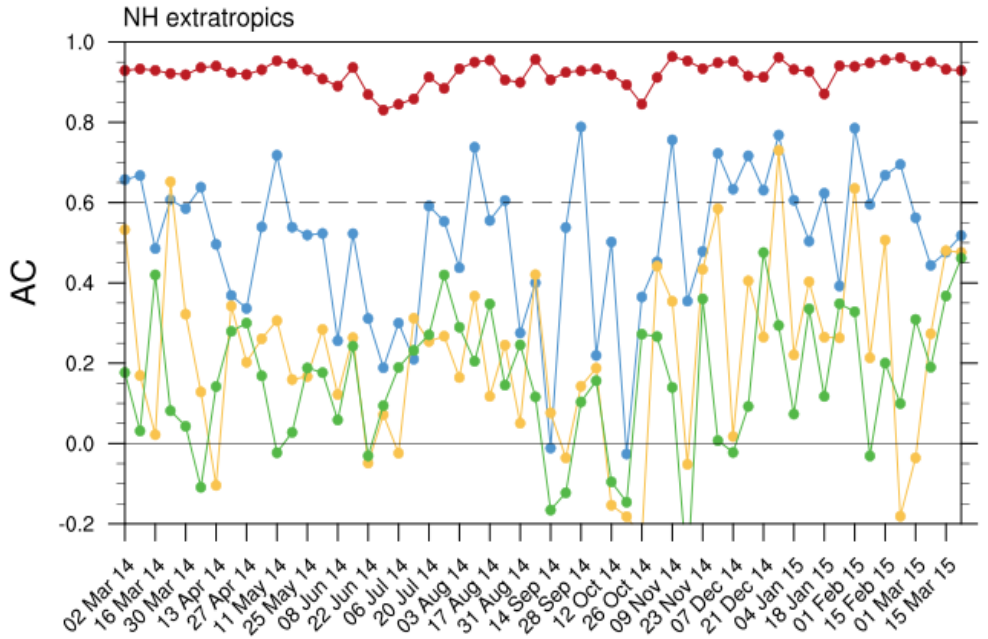
- Verifying observations taken from ERA Interim reanalysis – observed anomalies relative to the 1981-2010 climate

- Verification period: from March 2 (2014) to March 22 (2015)

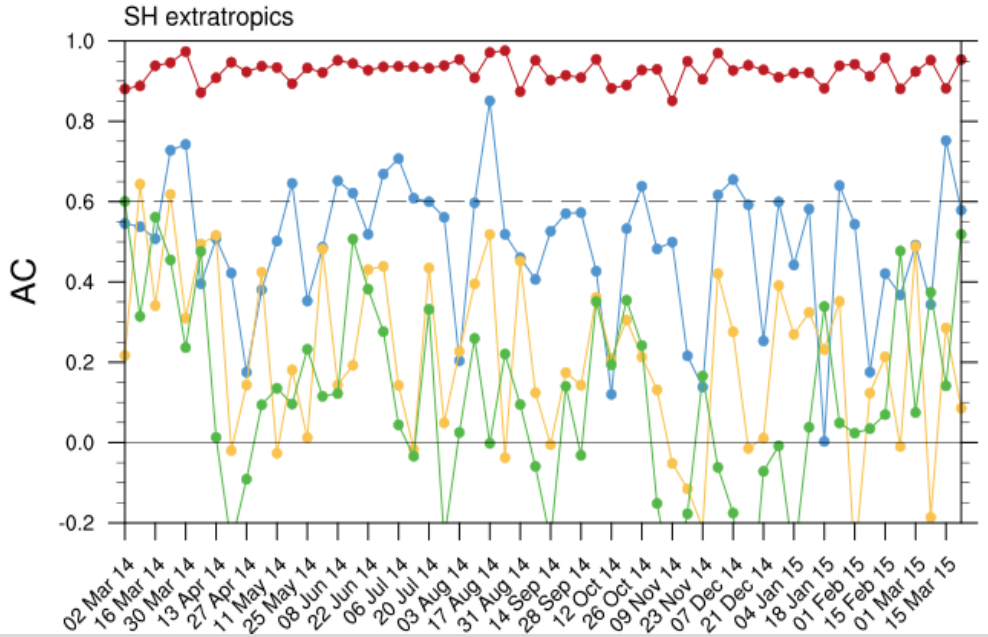
- ACC of (weekly averaged) 500 hPa geopotential and 850 hPa temperature anomalies

500-hPa Geopotential Height weekly averaged AC

w 1 = .93
w 2 = .51
w 3 = .22
w 4 = .16



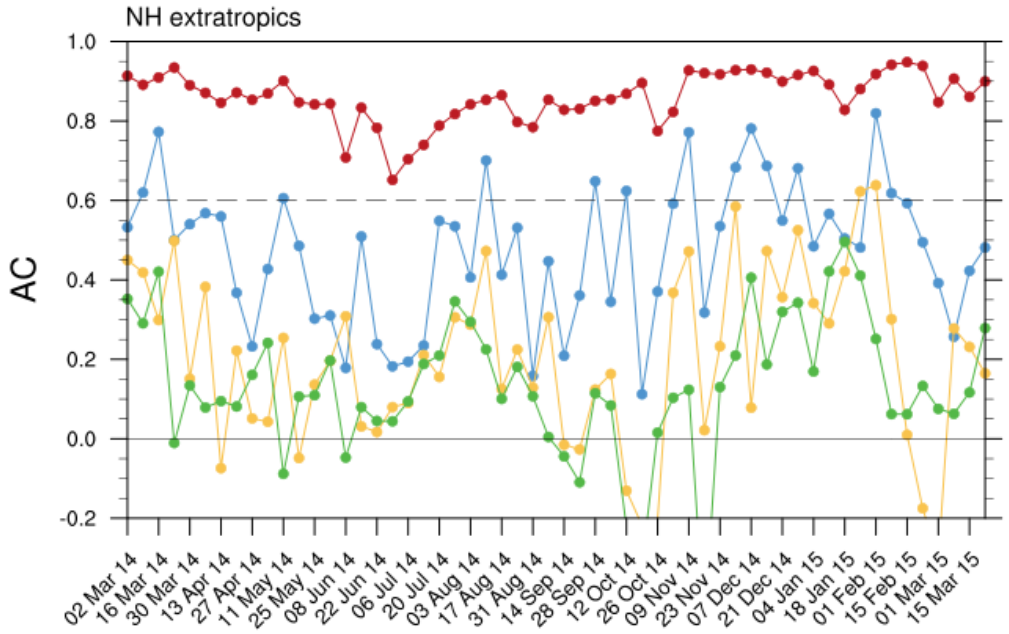
w 1 = .93
w 2 = .49
w 3 = .21
w 4 = .11



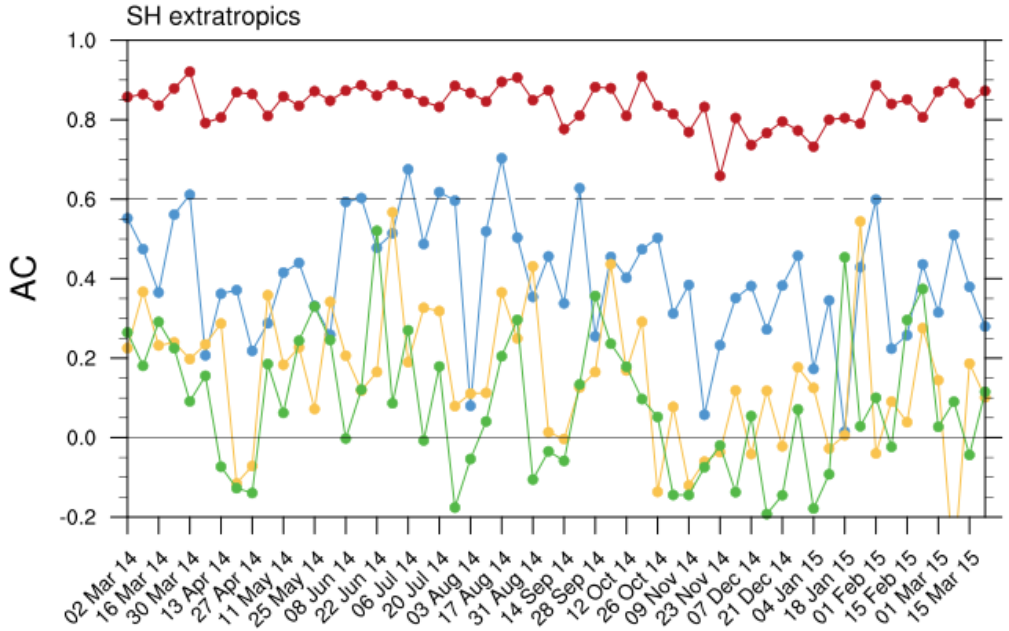
ISAC

850-hPa Temperature weekly averaged AC

w 1 = .88
w 2 = .48
w 3 = .23
w 4 = .15



w 1 = .85
w 2 = .42
w 3 = .17
w 4 = .11



ISAC

Verification of probability forecasts

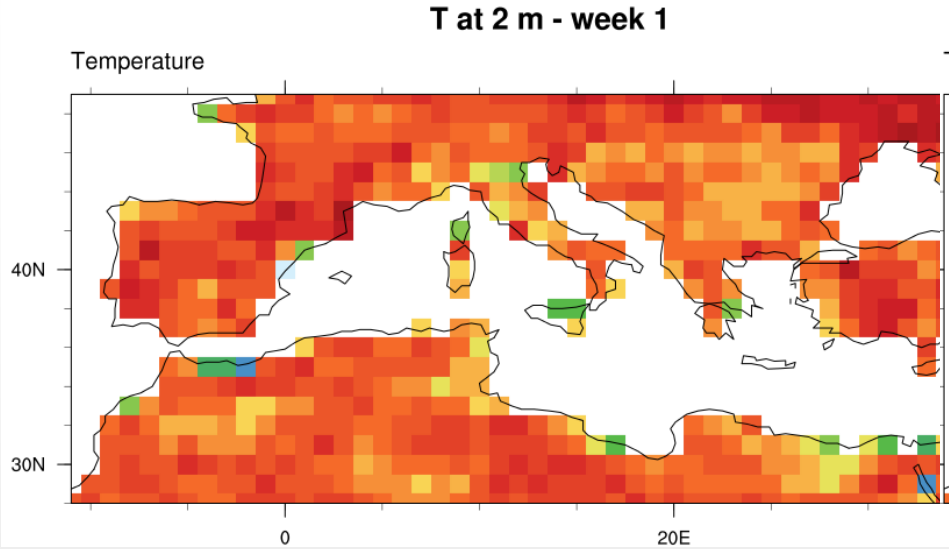
Verification of the probability forecast of T at 2 m (over land) and precipitation

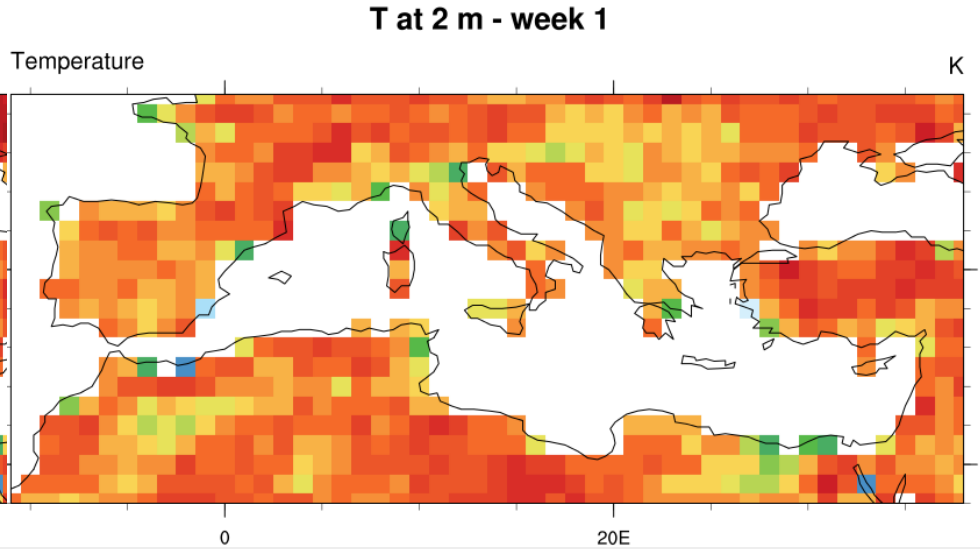
Era Interim is used to define the climate terciles and as verifying observation

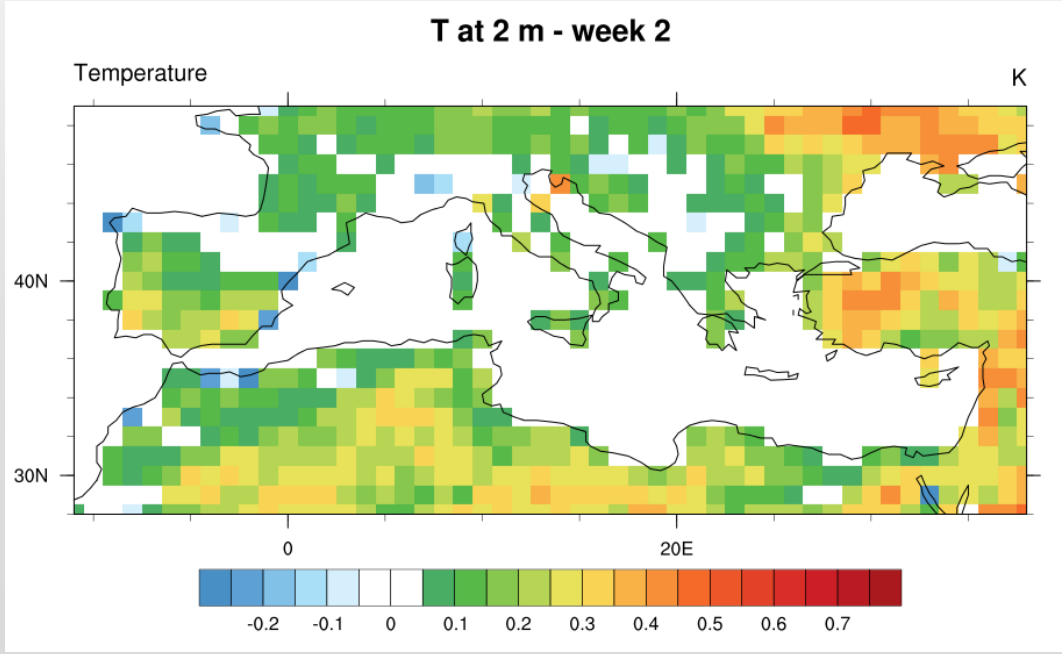
Observation is transformed in a dicotomic signal and then compared with predicted probabilities

The Ranked Probability Score is computed for model and climatological forecast, and the RPSS is computed (Hamill et al, 2004)

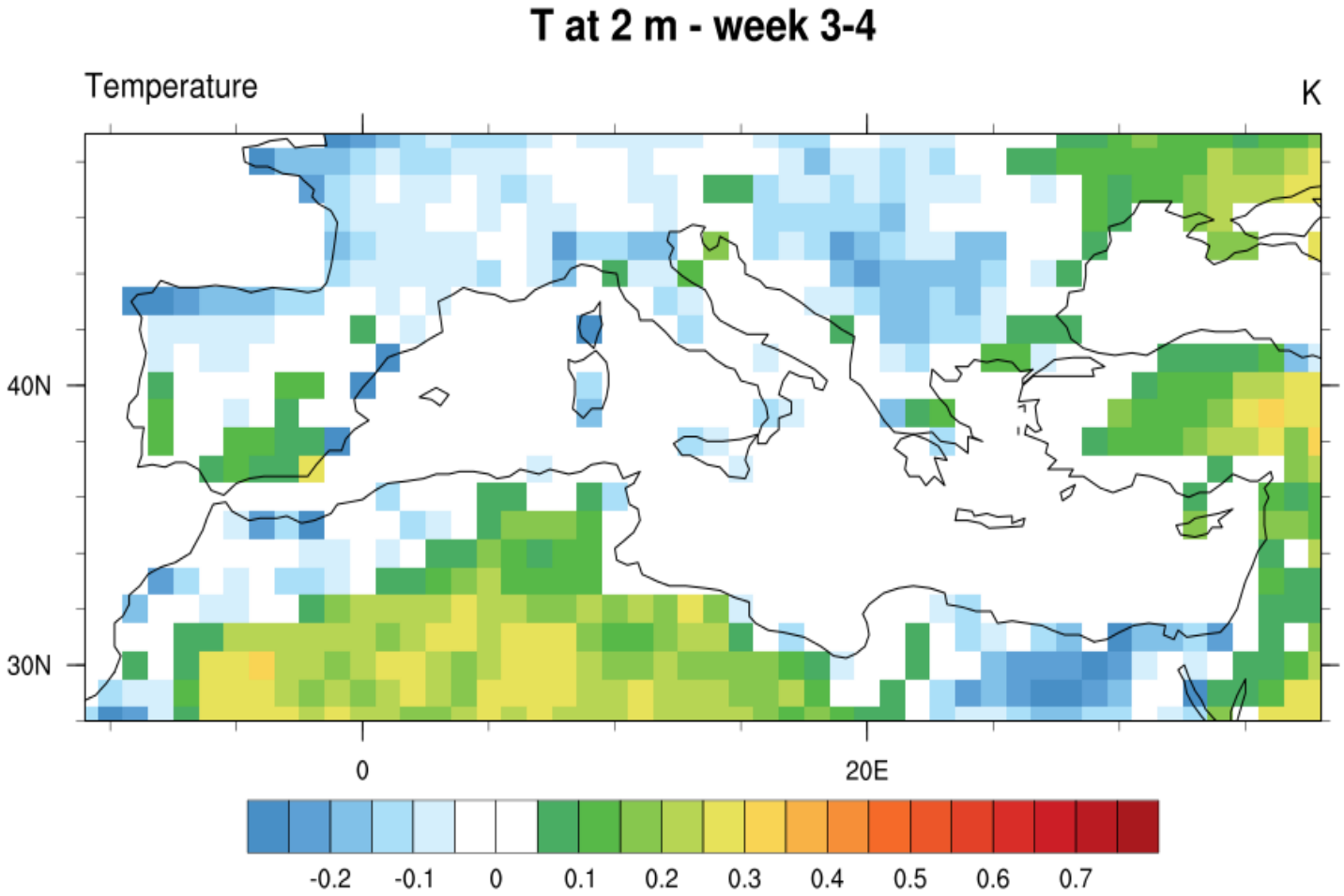
Verification: RPSS







Verification: RPSS



Comparison with IFS control runs

Exploit the large reforecast set to compare GLOBO and ECMWF-IFS past predictions.

The ECMWF monthly forecasting system includes a set of reforecasts performed "**on the fly**", on a weekly basis every Thursday, covering the past 20 years. It includes also 4 ensemble members.

GLOBO has a "**fixed**" set of reforecast, one every five days starting 1st of January.

A quite large number of **common dates** can be found for the **winter season**. Over the 17 winters from 1994 to 2010 there exists an average of more than 14 cases per year having coincident initial dates, giving a total of **249** runs per model that can be directly compared.

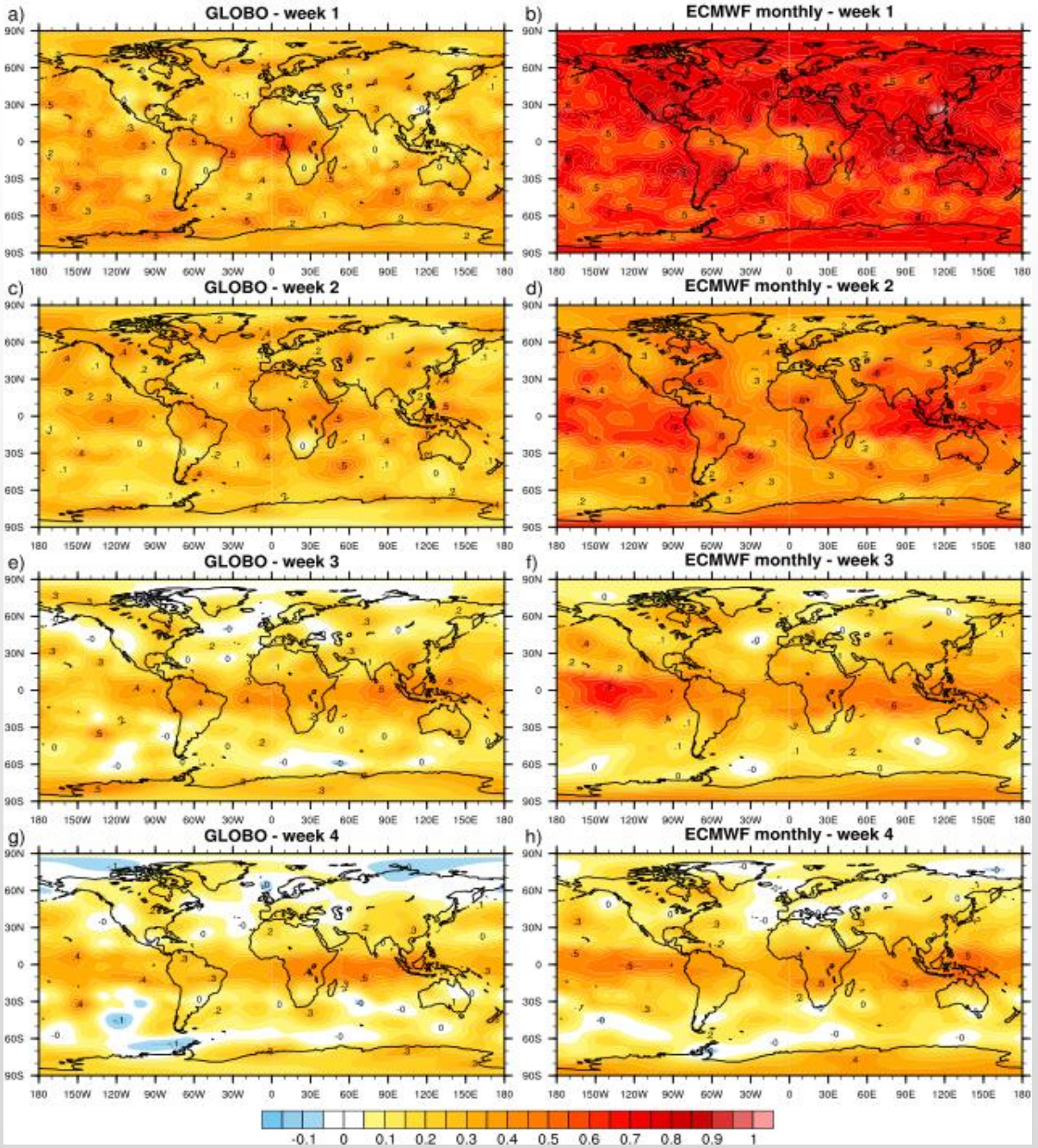
Multi Model GLOBO- IFS

- 500 hPa geopotential and 850 hPa temperature (T850) as meteorological parameters.
- The fields are interpolated on a common verification grid of 1.0 degree and averaged in time over the first, second, third, and fourth week of forecast
- For each grid point i, j the multi-model prediction (MM) for week w =1,..,4 and initial date d=1,…,249 is defined as:

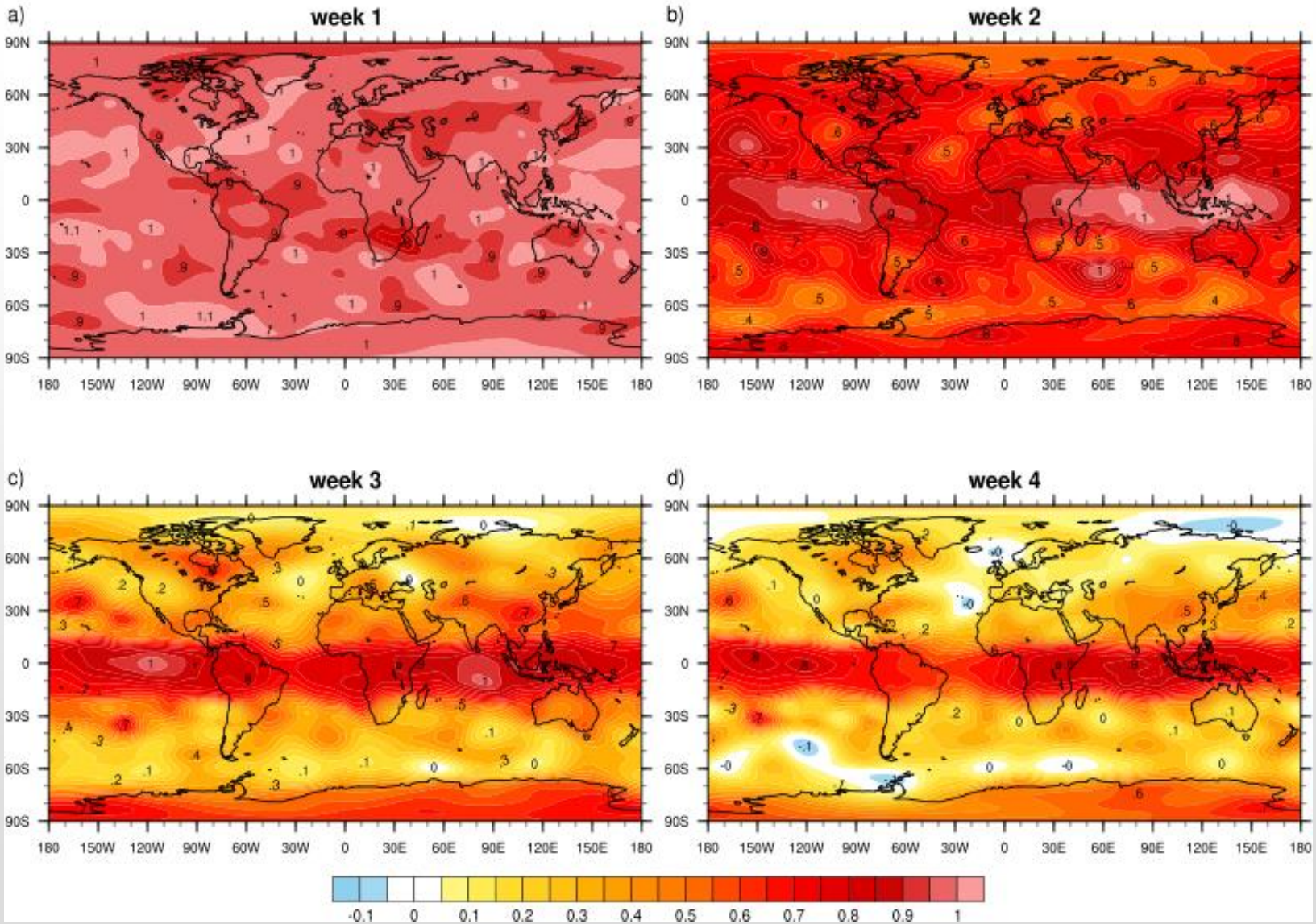
$$MM(i,j,w,d) = c_0(i,j,w) + c_1(i,j,w)M_1(i,j,w,d) + c_2(i,j,w)M_2(i,j,w,d)$$

- The weights c_1 and c_2 are computed by a linear regression over a training period.
- Verification is done in cross-evaluation mode

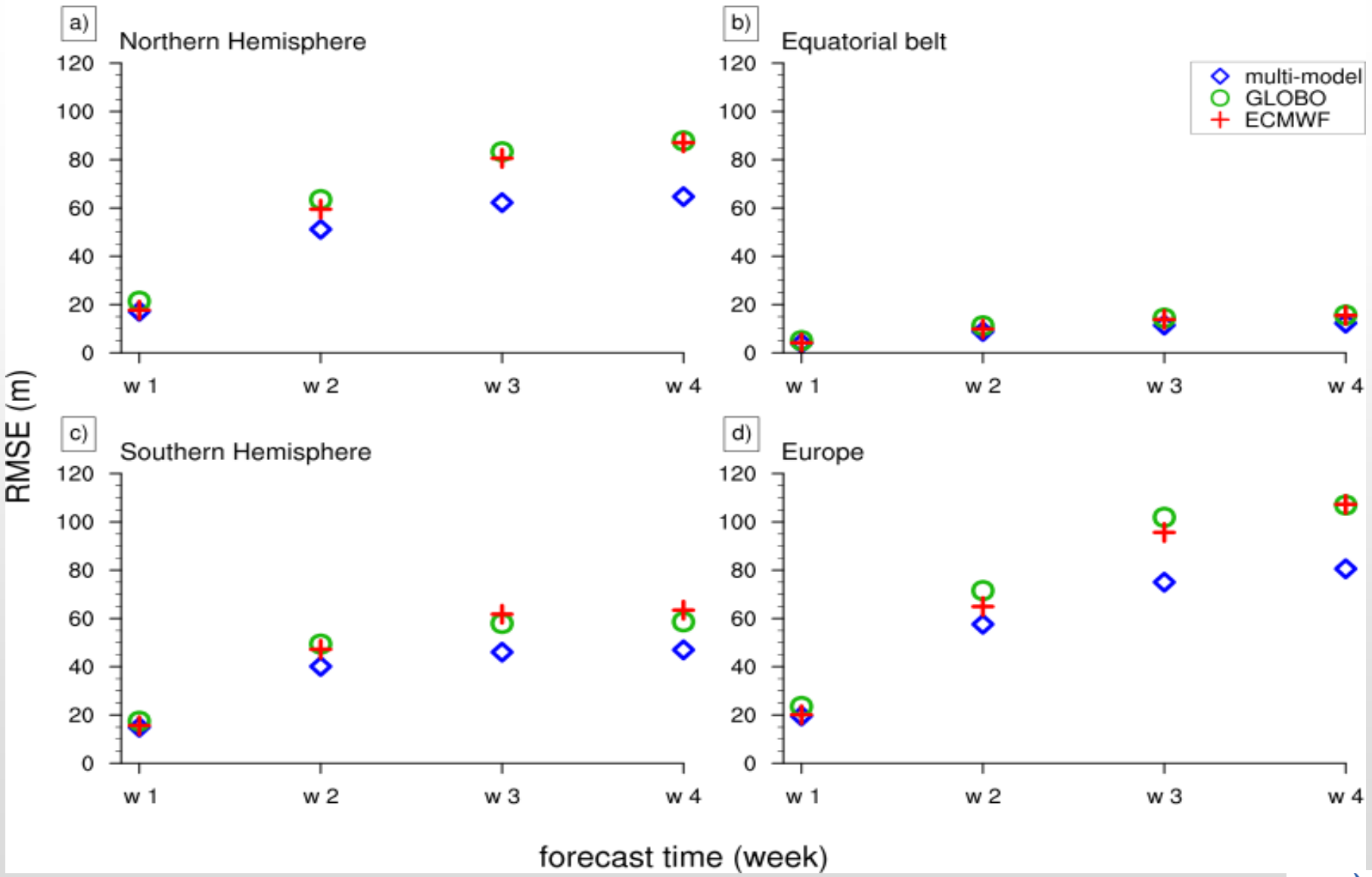
Regression coefficients for Geopotential Height at 500 hPa

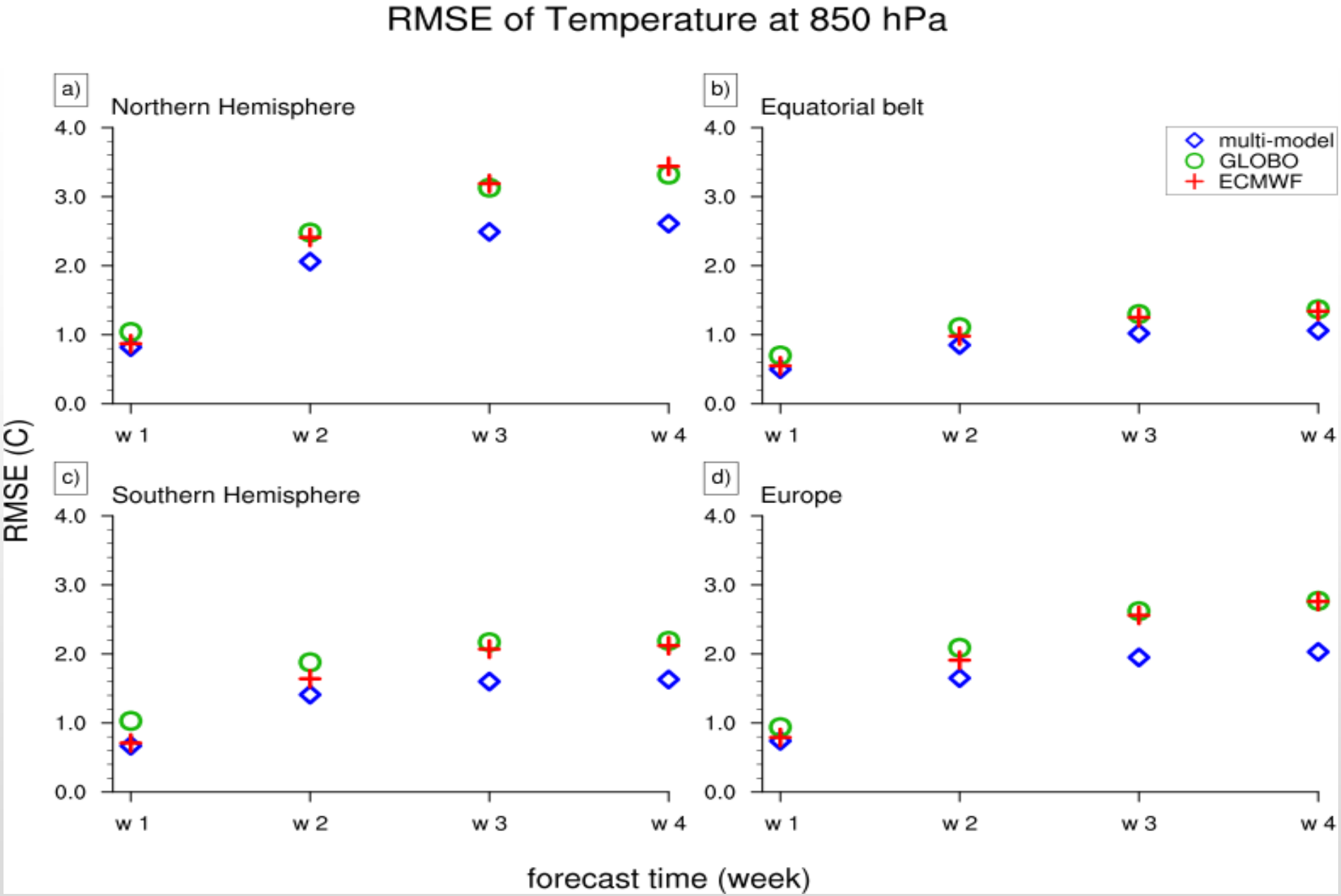


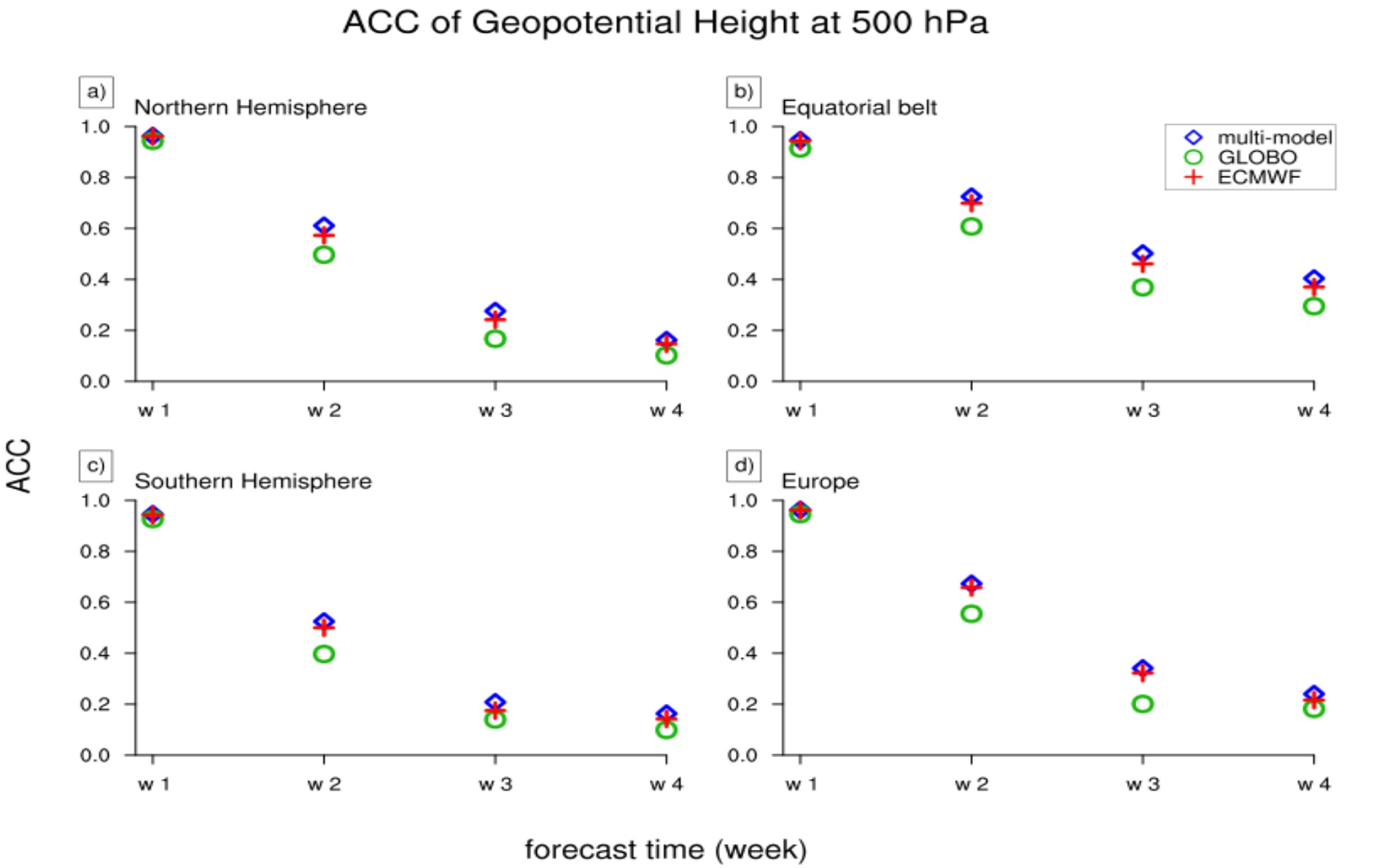
Sum of regression coefficients for Geopotential Height at 500 hPa



RMSE of Geopotential Height at 500 hPa



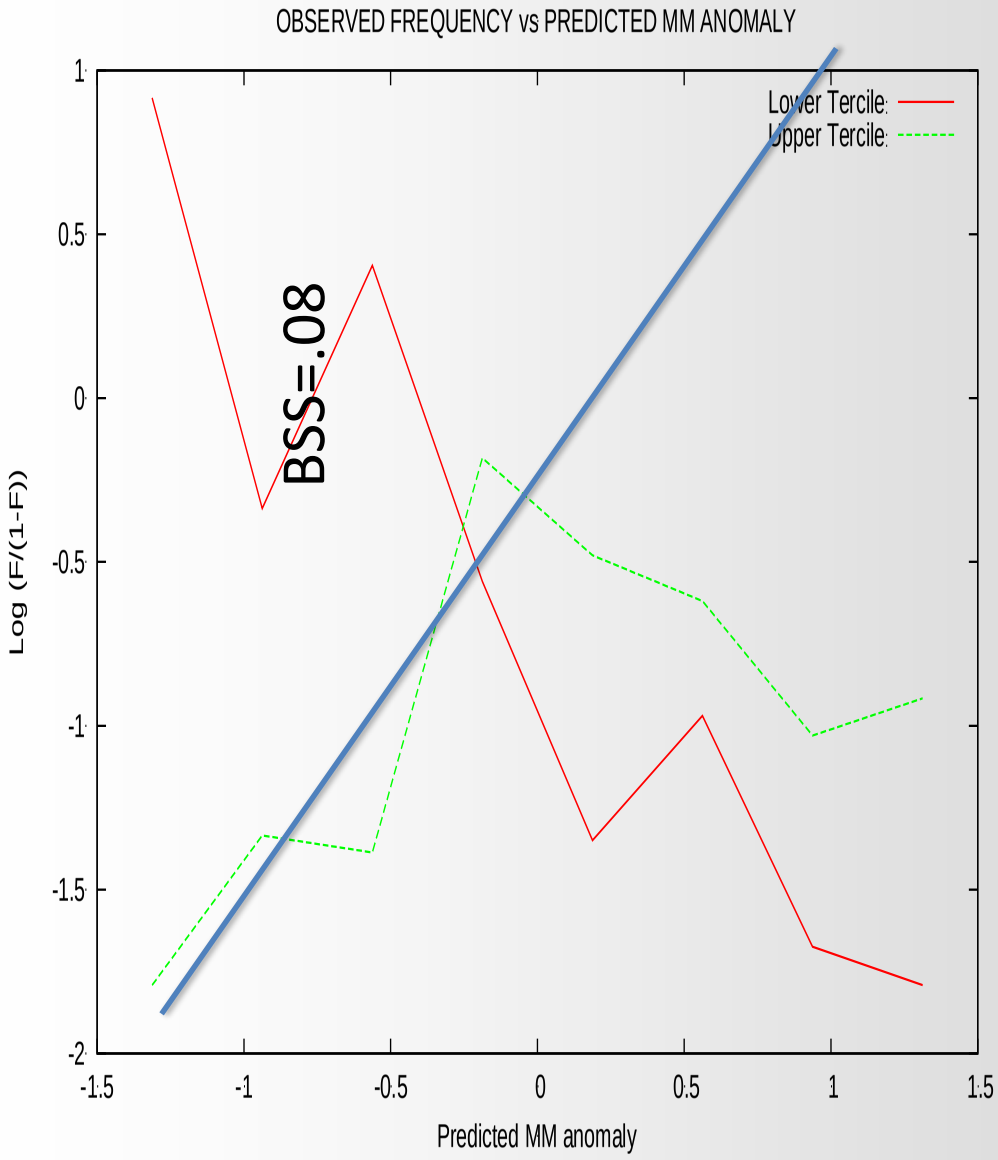

RMSE of Temperature at 850 hPa
a)
Northern Hemisphere
b)
Equatorial belt
c)
Southern Hemisphere
d)
Europe
multi-model
GLOBO
ECMWF
RMSE (C)
forecast time (week)
4.0
3.0
2.0
1.0
0.0
w 1
w 2
w 3
w 4


ACC of Geopotential Height at 500 hPa
a)
Northern Hemisphere
b)
Equatorial belt
multi-model
GLOBO
ECMWF
c)
Southern Hemisphere
d)
Europe
ACC
1.0
0.8
0.6
0.4
0.2
0.0
w 1
w 2
w 3
w 4
forecast time (week)

Model Output Statistics can provide informations on probability forecast

Probability Distribution Function inferred from ensemble average + ensemble spread +…

Test the hypothesis that tercile probabilities can be deduced from MM prediction


OBSERVED FREQUENCY vs PREDICTED MM ANOMALY
Lower Tercile
Upper Tercile
BSS=.08
Log (F/(1-F))
Predicted MM anomaly
1
0.5
0
-0.5
-1
-1.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5

Conclusions

The Monthly Forecasting System of CNR-ISAC has been described

- No interactive ocean → benchmark to assess the role of ocean-atmosphere interaction in the sub-seasonal predictability (15-30 days)

Further verification is ongoing:

- Reliability diagrams
- Run mini-ensembles on the past (winter season only)
- MOS on reforecast set