The Monthly Forecast system at ECMWF

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European Centre for Medium-Range Weather Forecasts

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Use of monthly forecasts in applications

Main sources of predictability on the monthly time-scale

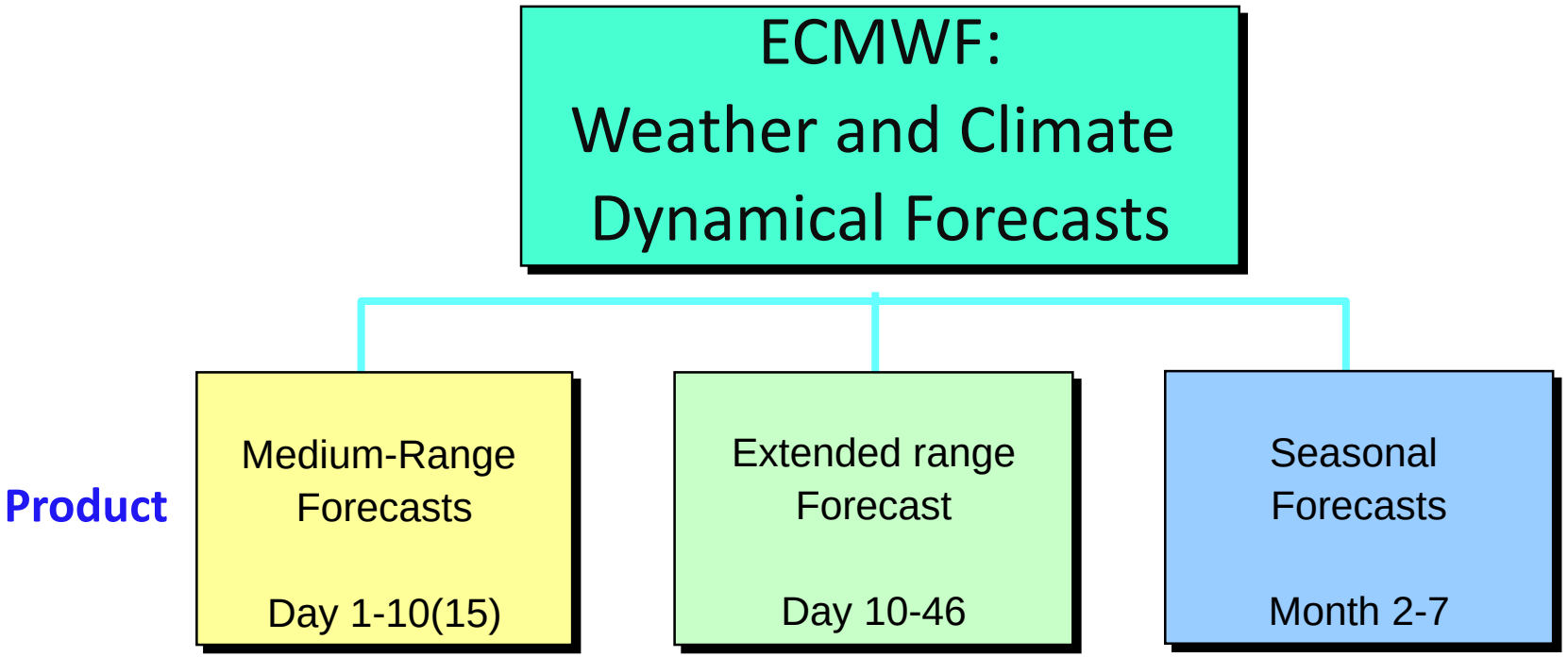
- *Madden Julian Oscillation*
- Soil Moisture
- Stratospheric Initial conditions
- Rossby waves
- SSTs/Sea-ice

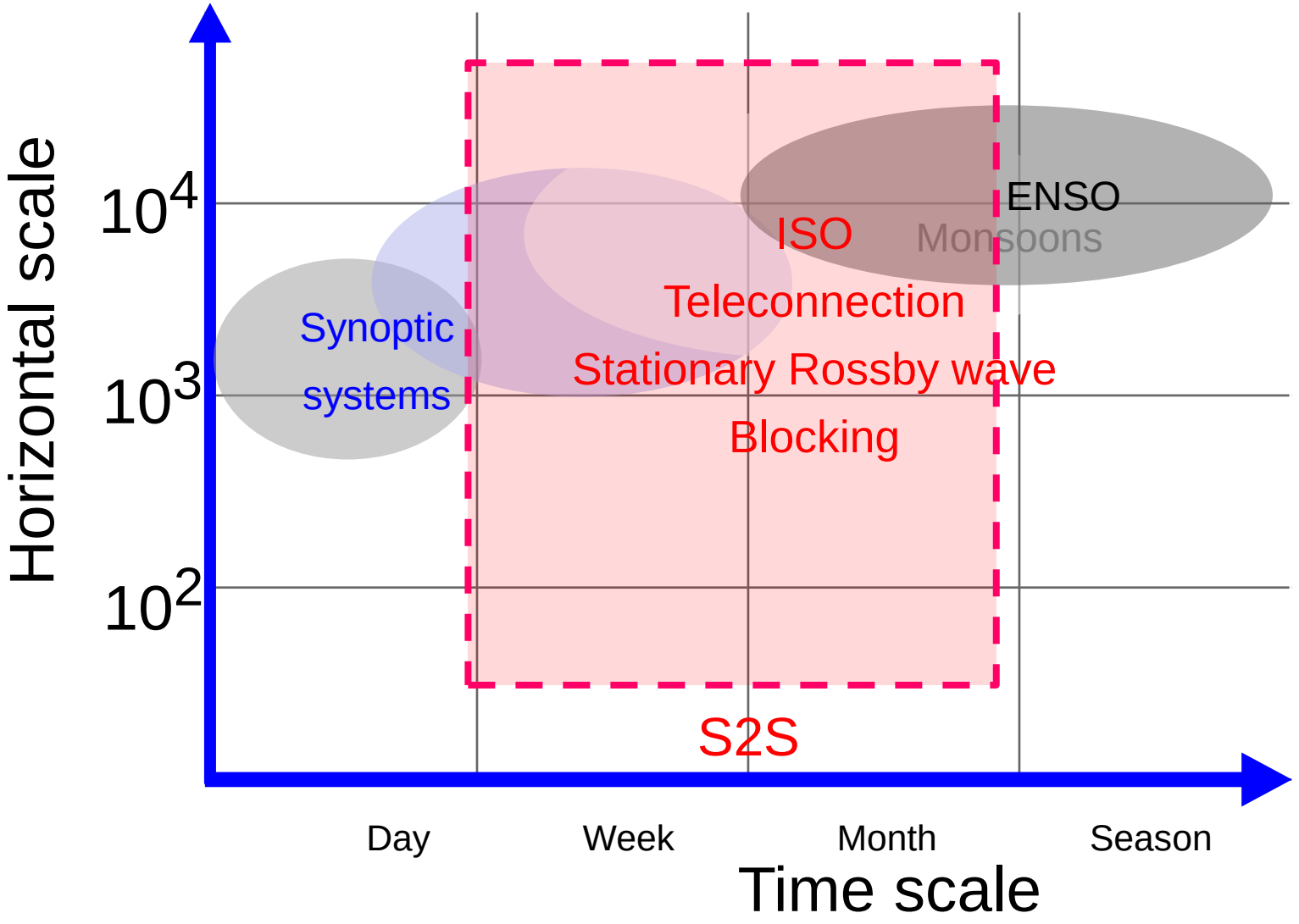
The ECMWF extended range forecast system

- Description
- Some examples of forecasts
- Skill

S2S database

Forecasting systems at ECMWF



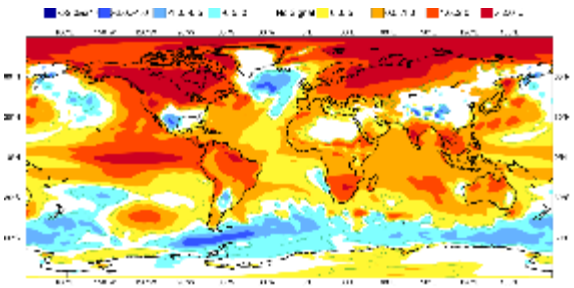

Horizontal scale
10^4
10^3
10^2
ENSO
Monsoons
ISO
Teleconnection
Stationary Rossby wave
Blocking
Synoptic
systems
S2S
Day
Week
Month
Season
Time scale

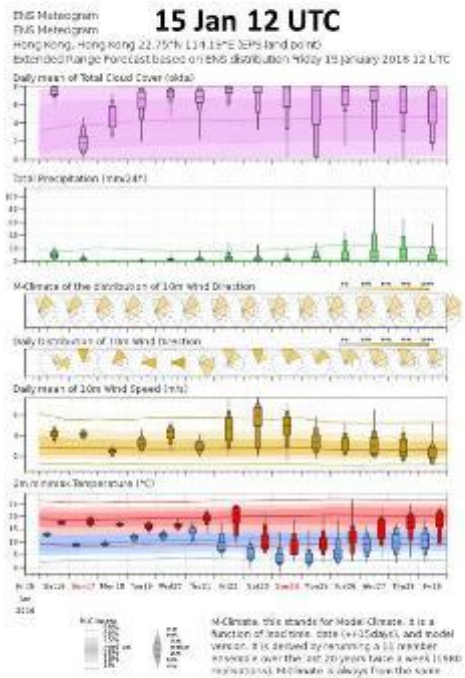
From medium-range to seasonal to extended range

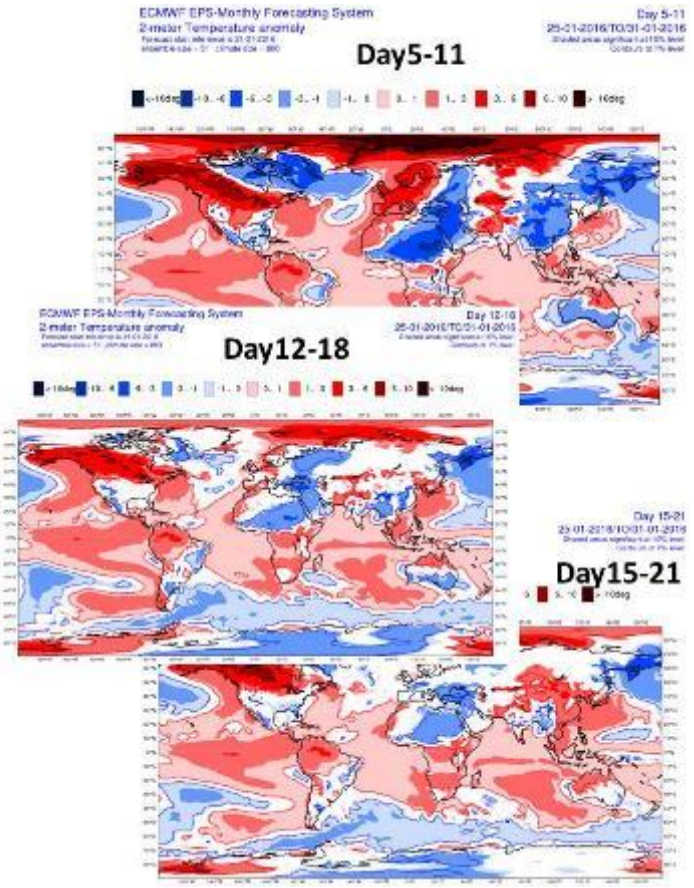
Extended-range

Medium-range

Seasonal Forecast







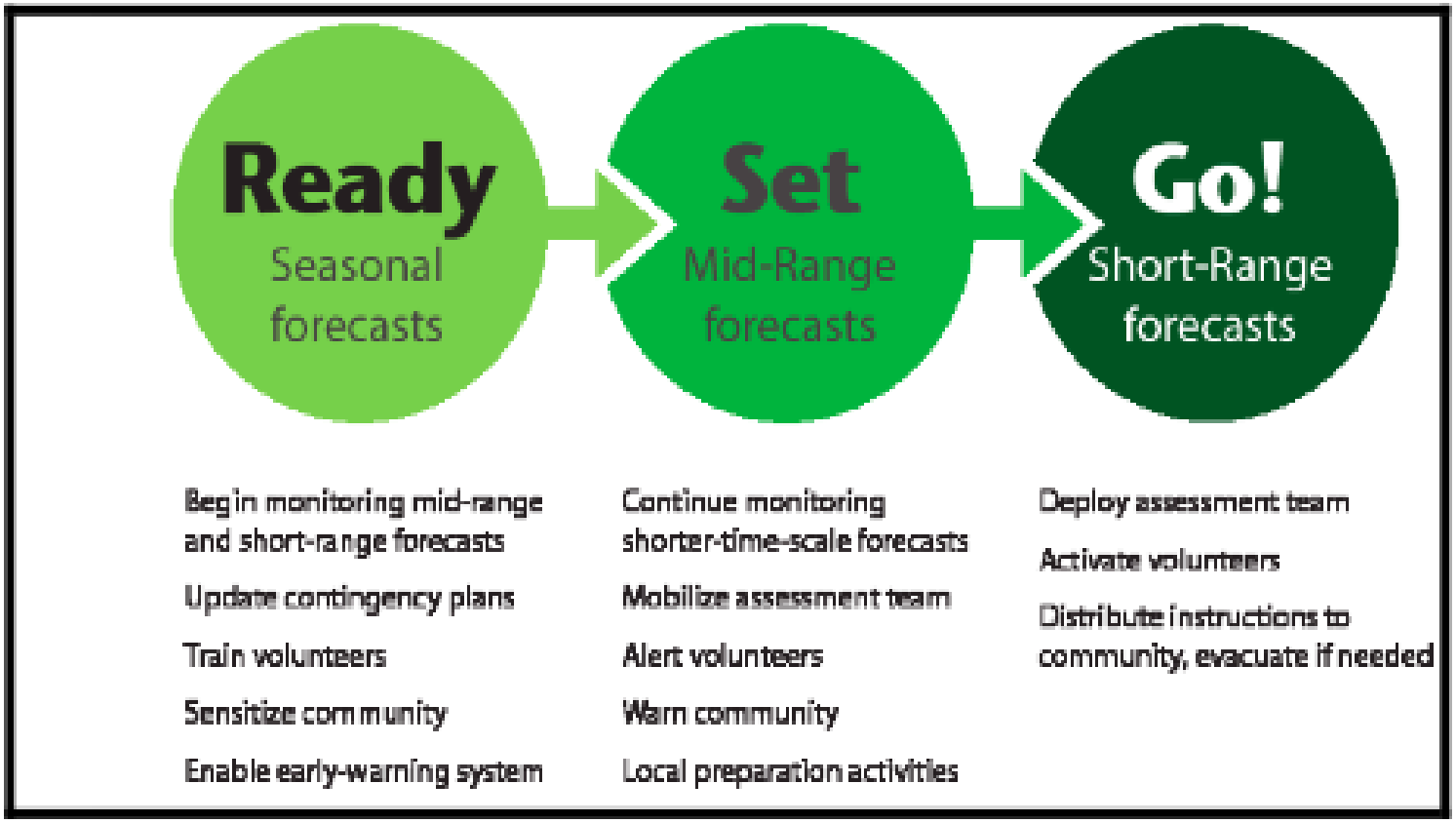
European Centre for Medium-Range Weather Forecasts

Use of sub-seasonal forecasts in applications

Growing, and urgent, requirement for the employment of sub-seasonal predictions for a wide range of societal and economic applications which include:

- Warnings of the likelihood of severe high impact weather (droughts, flooding, wind storms etc.) to help protect life and property
- Humanitarian Planning and Response to disasters
- Agriculture particularly in developing countries — e.g. wheat and rice production
- Disease planning/control — e.g. malaria, dengue and meningitis
- River-flow — for flood prediction, hydroelectric power generation and reservoir management for example

Opportunity to use information on *multiple* time scales



Red Cross - IRI example

Sub-seasonal prediction

- Bridges the gap between weather and climate forecasting.

- First attempts of sub-seasonal forecasting started in the 1980s (Miyakoda, Molteni..)

- A particularly difficult time range:

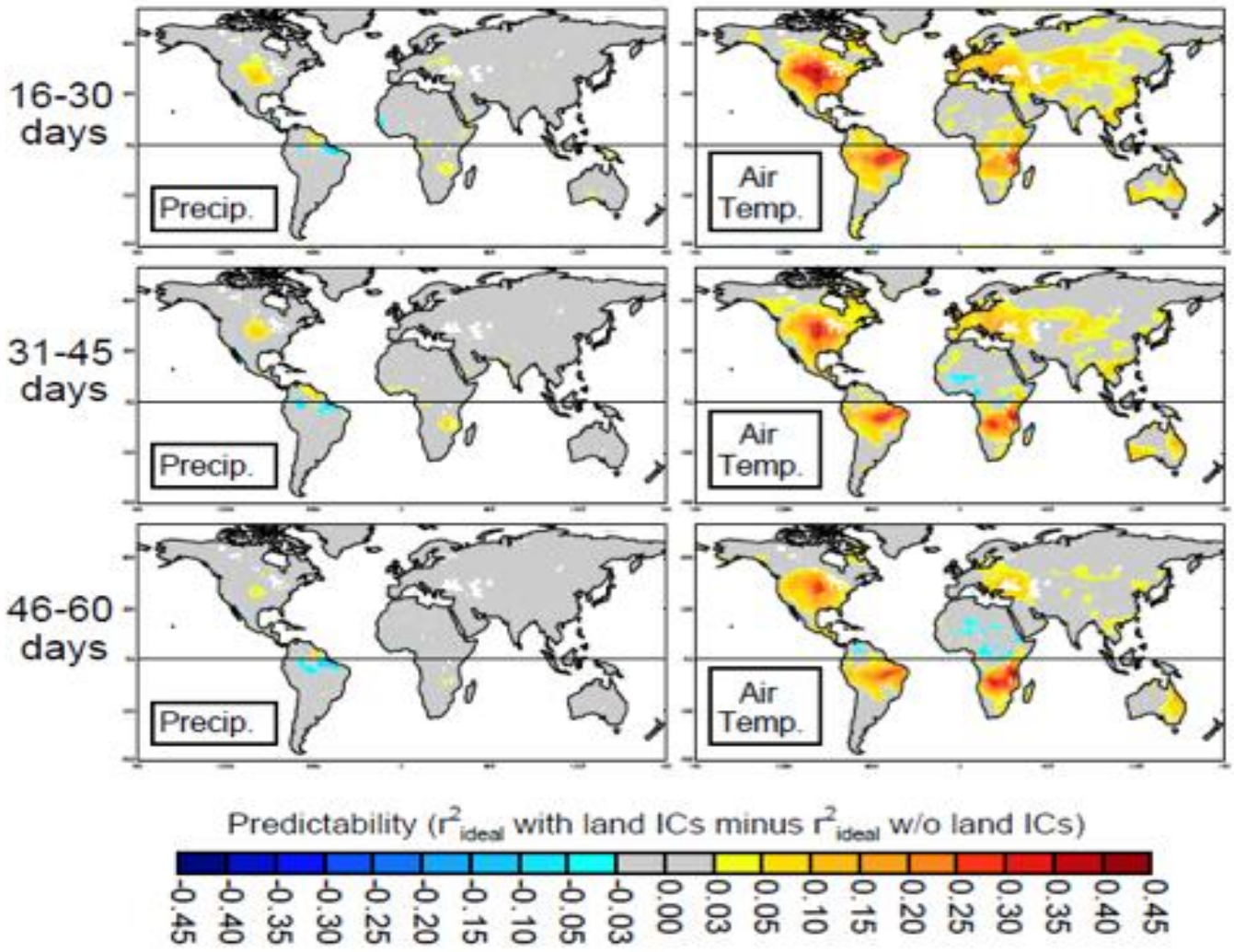
Is it an **atmospheric initial condition problem** as medium-range forecasting or is it a **boundary condition problem** as seasonal forecasting? Is it a “Predictability Desert” ?

Sources of sub-seasonal predictability

- Madden-Julian Oscillation
- Extra-tropical modes (weather regimes: blockings, NAO, PNA, SAM..)
- Stratospheric Sudden Warming
- Quasi-Biennal Oscillation
- ENSO
- Slowing varying processes: Soil moisture/vegetation, snow, sea ice, ocean SSTs/heat content
- Chemistry: Ozone, aerorols…
- Others?

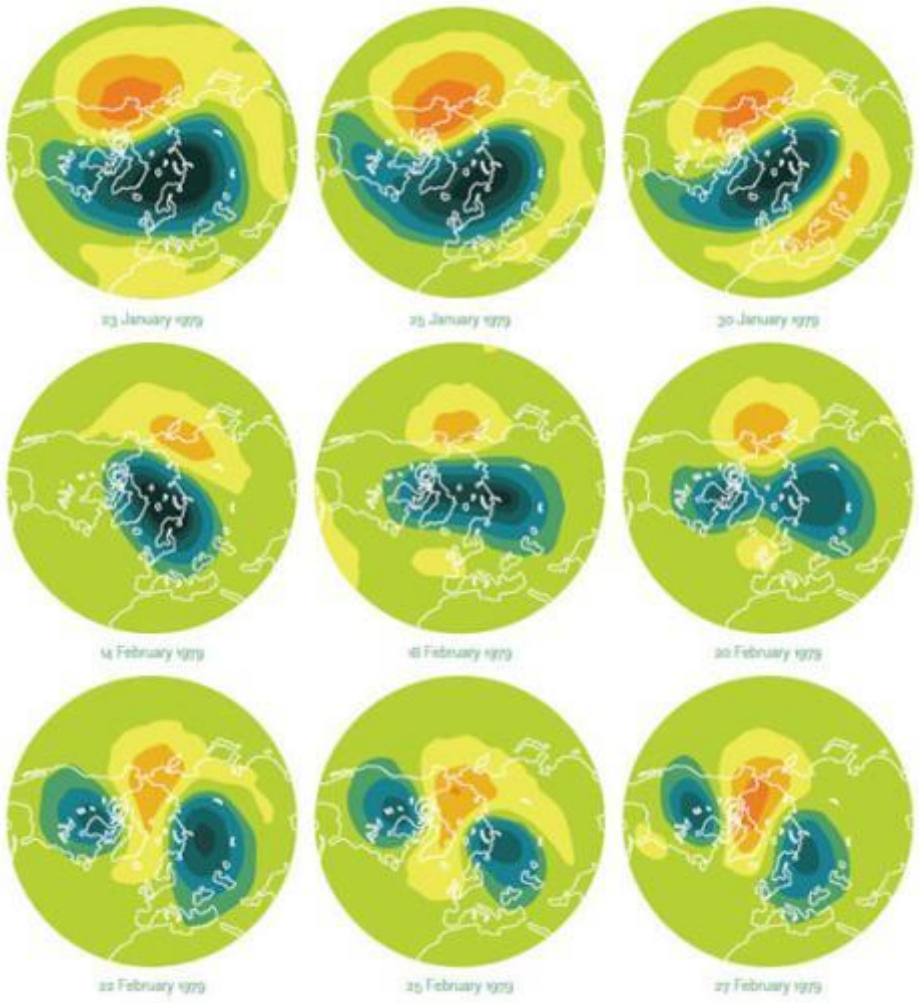
Sub-seasonal skill is strongly flow-dependent

Impact of soil moisture



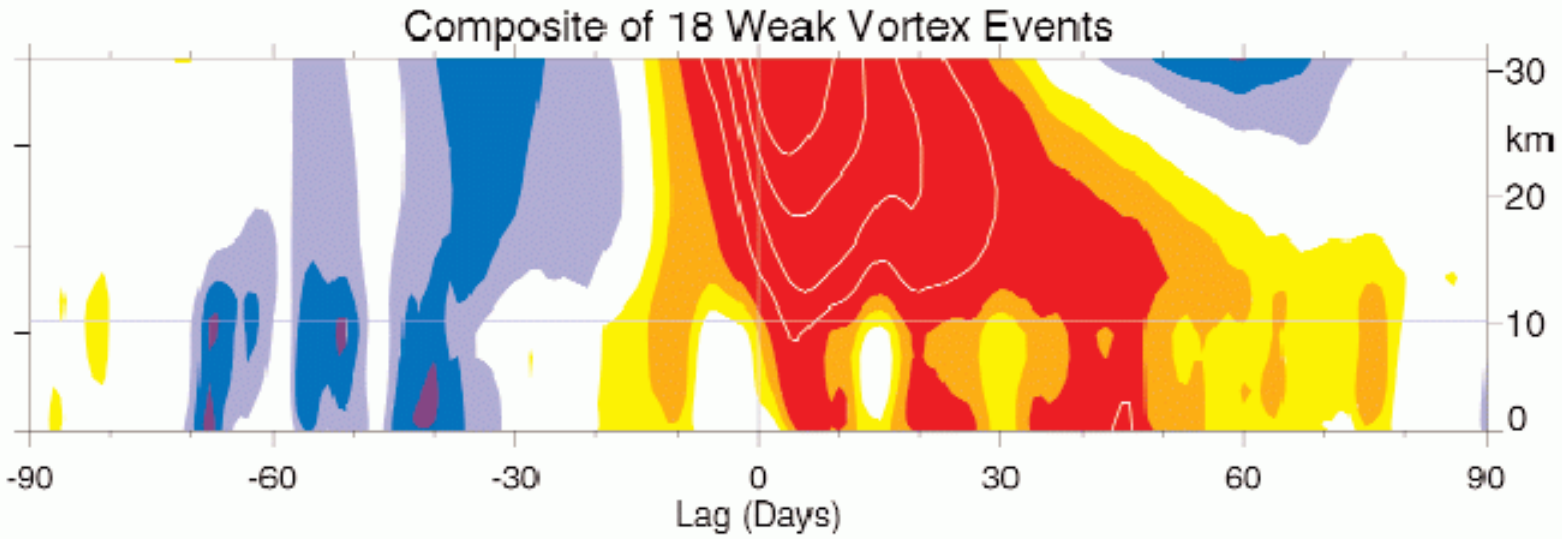
Koster et al, GRL 2011

Sudden Stratospheric Warmings



Chui and Kunz, 2009

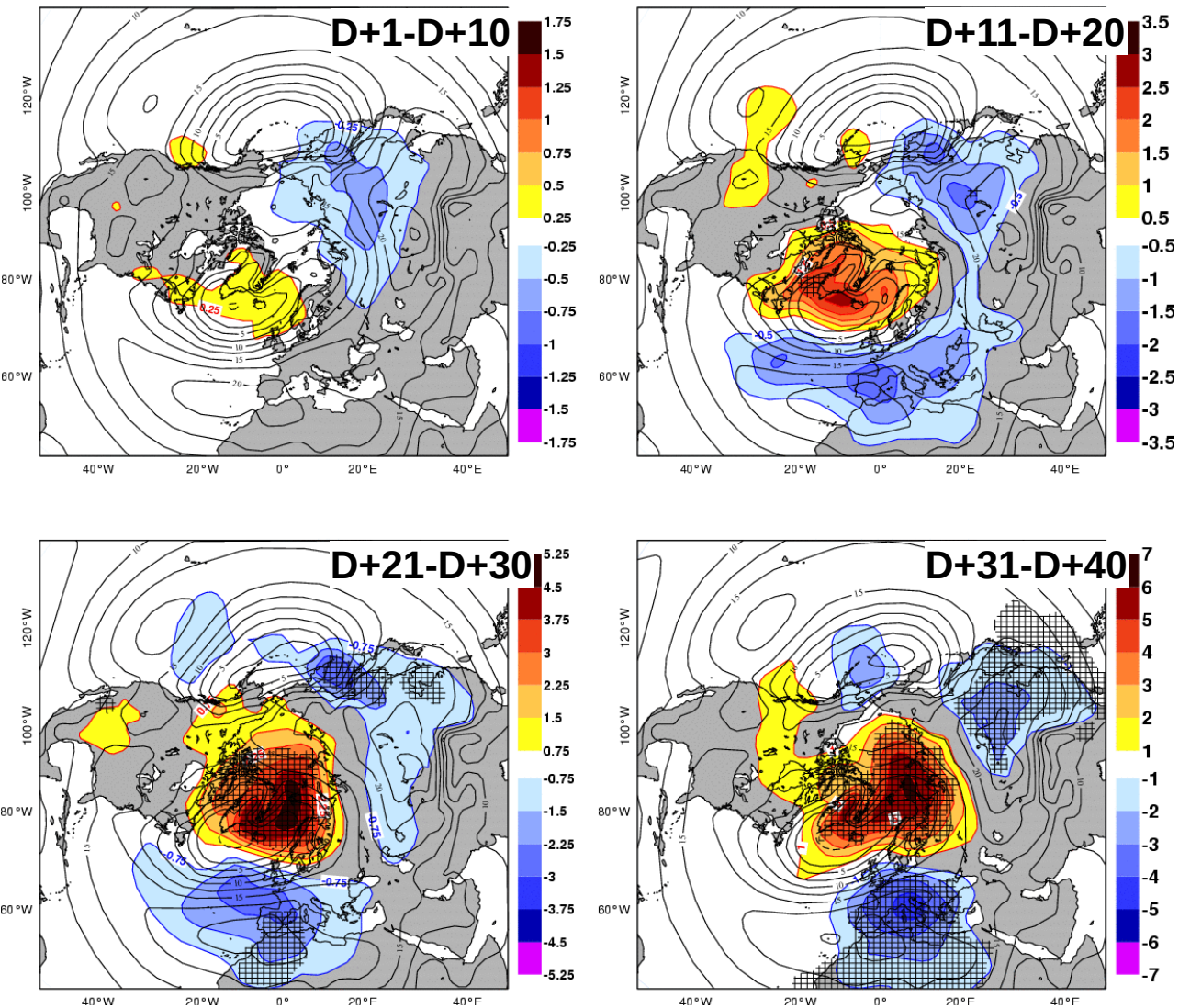
Stratospheric influence on the troposphere?



Weather from above. A weakening stratospheric vortex (red) can alter circulation down to the surface, bringing storms and cold weather farther south than usual.

Baldwin and Dunkerton, 2001

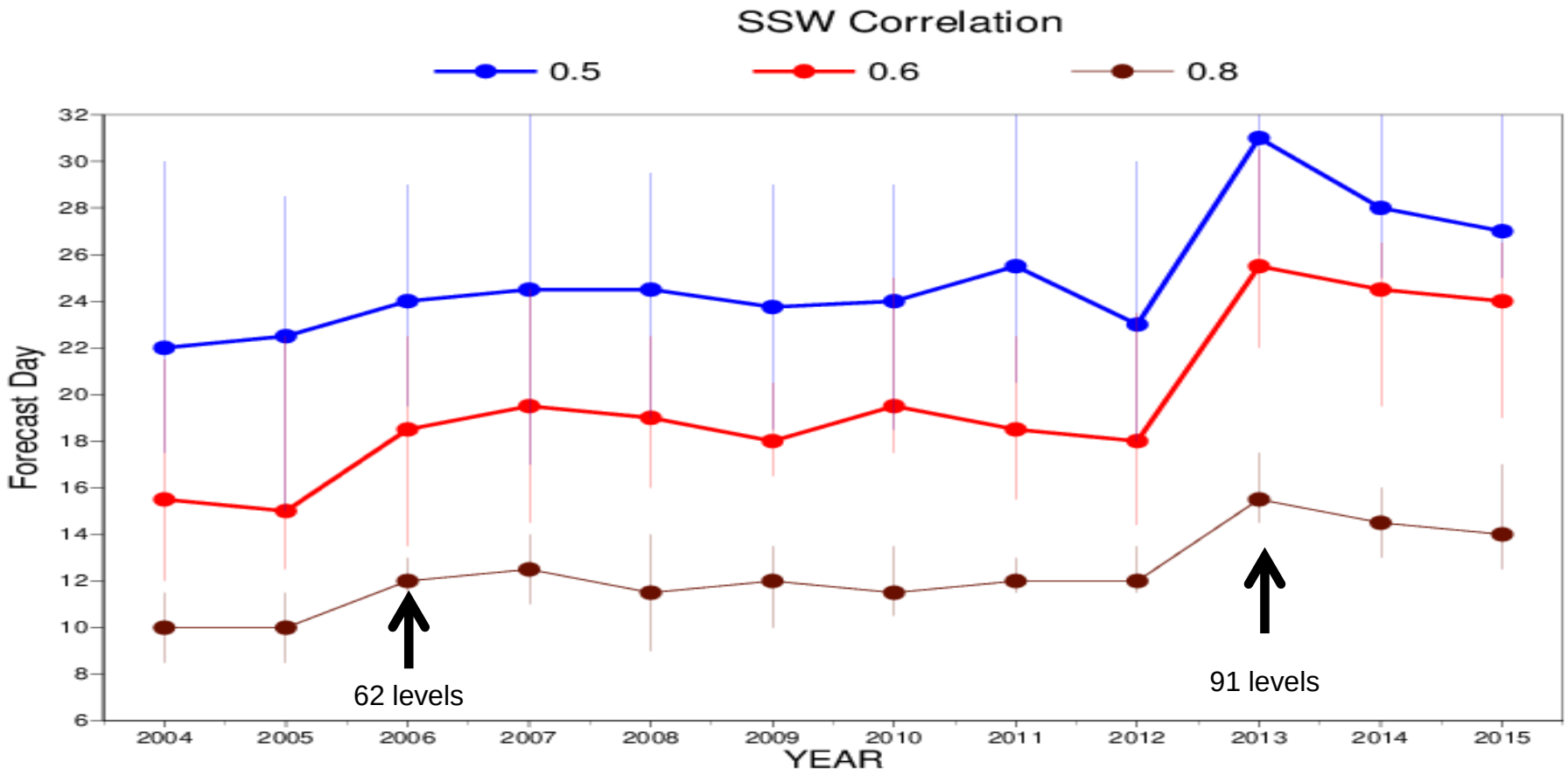
Stratospheric influence on the troposphere?



Z1000 Response (Weak vortex-CTL)

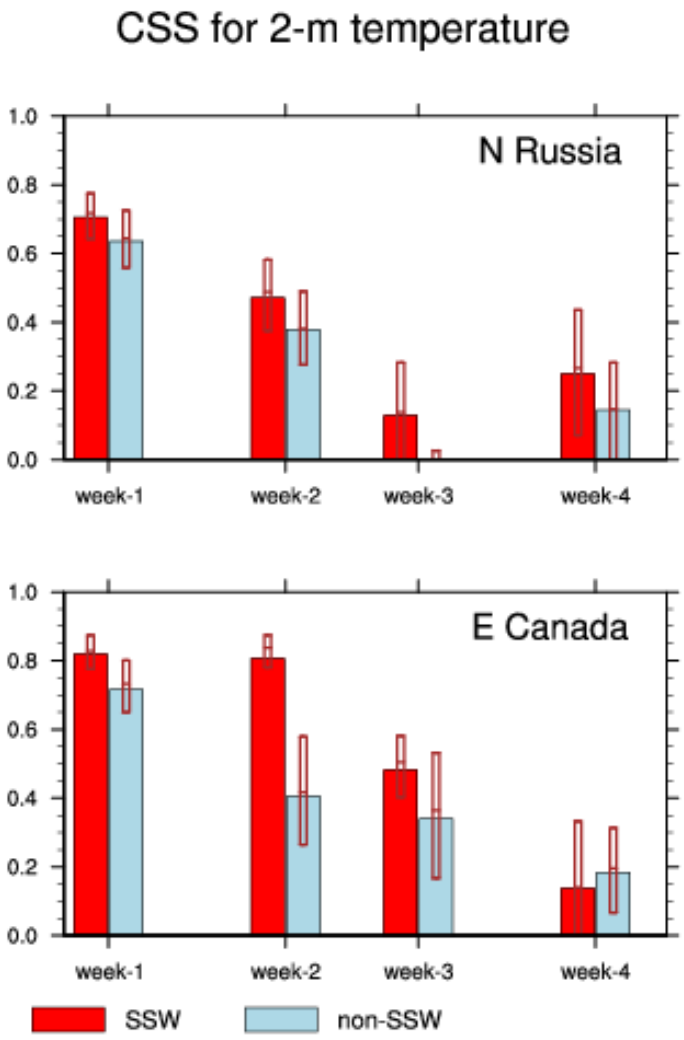
From T. Jung et al 2005

Prediction of Sudden Stratospheric Warming Index



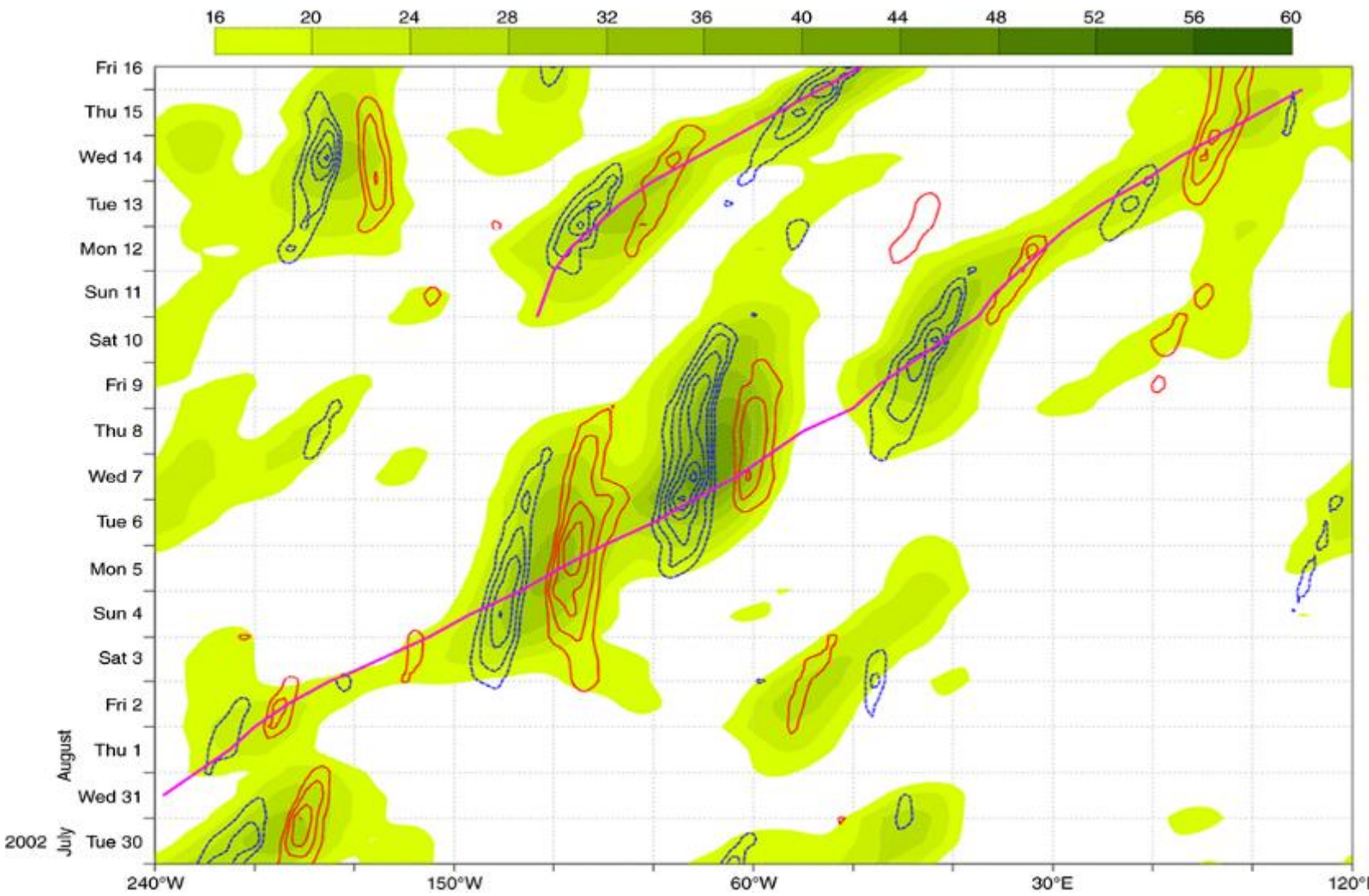
Improvements in SSW Prediction mostly due to changes in stratospheric resolution

Impact of SSWs on skill scores

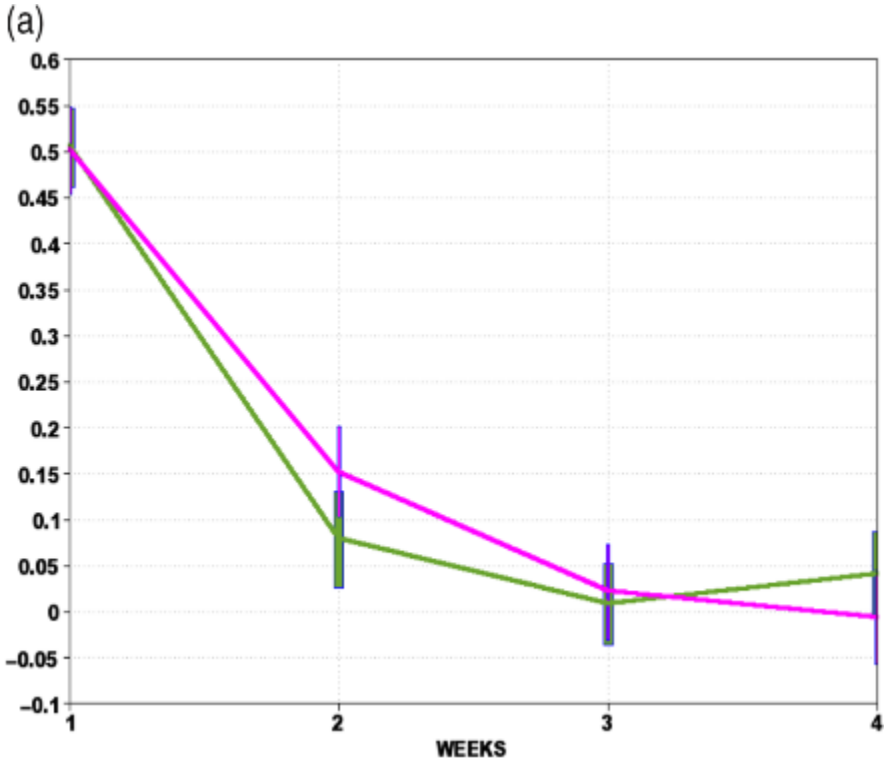


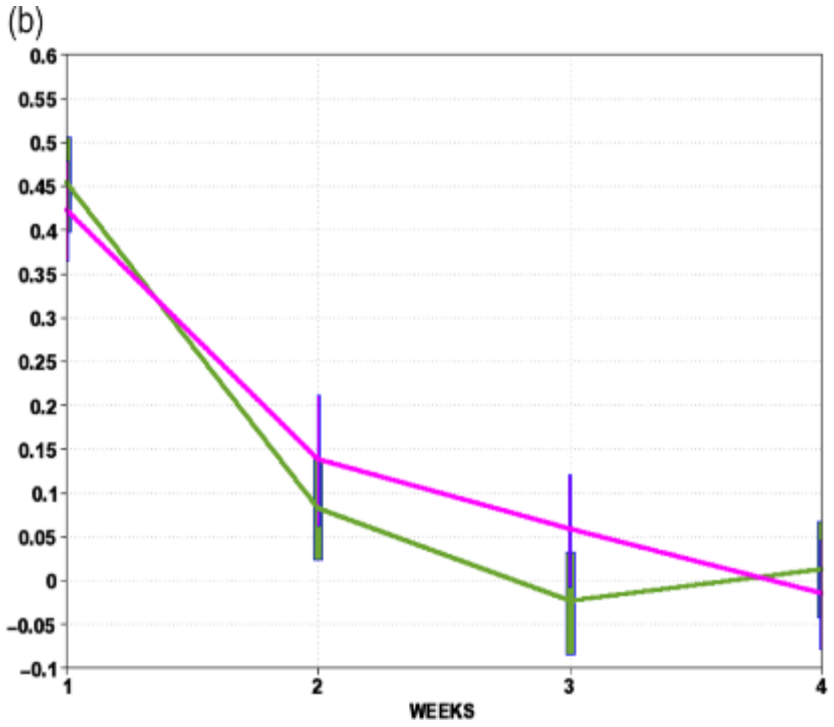
From Tripathi et al. (2015)

Rossby Wave Packets



Rossby Wave Packets

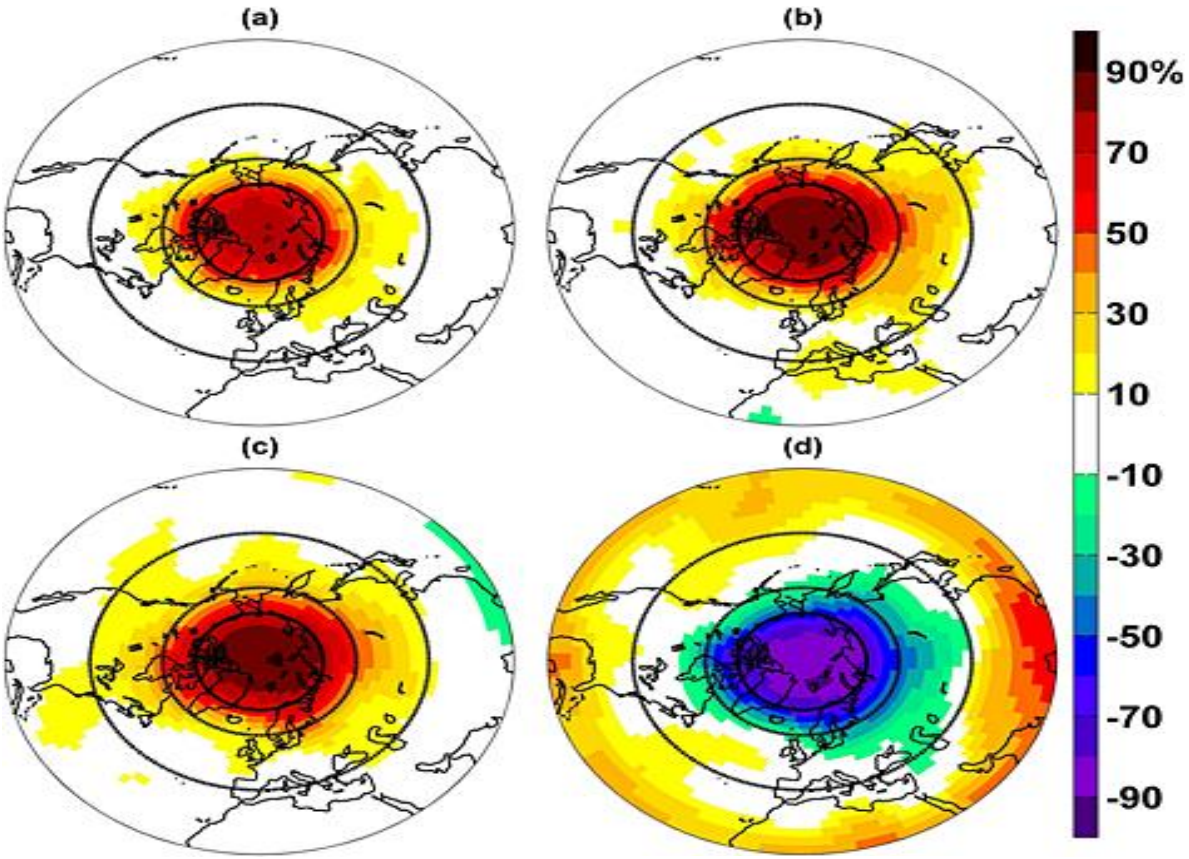




Impact of Arctic relaxation (north of 70N) on sub-seasonal RMS error

Day 1-5

Day 5-10



Day 11-30

Day 11-30
Arctic-tropical relaxation

Jung et al., 2014

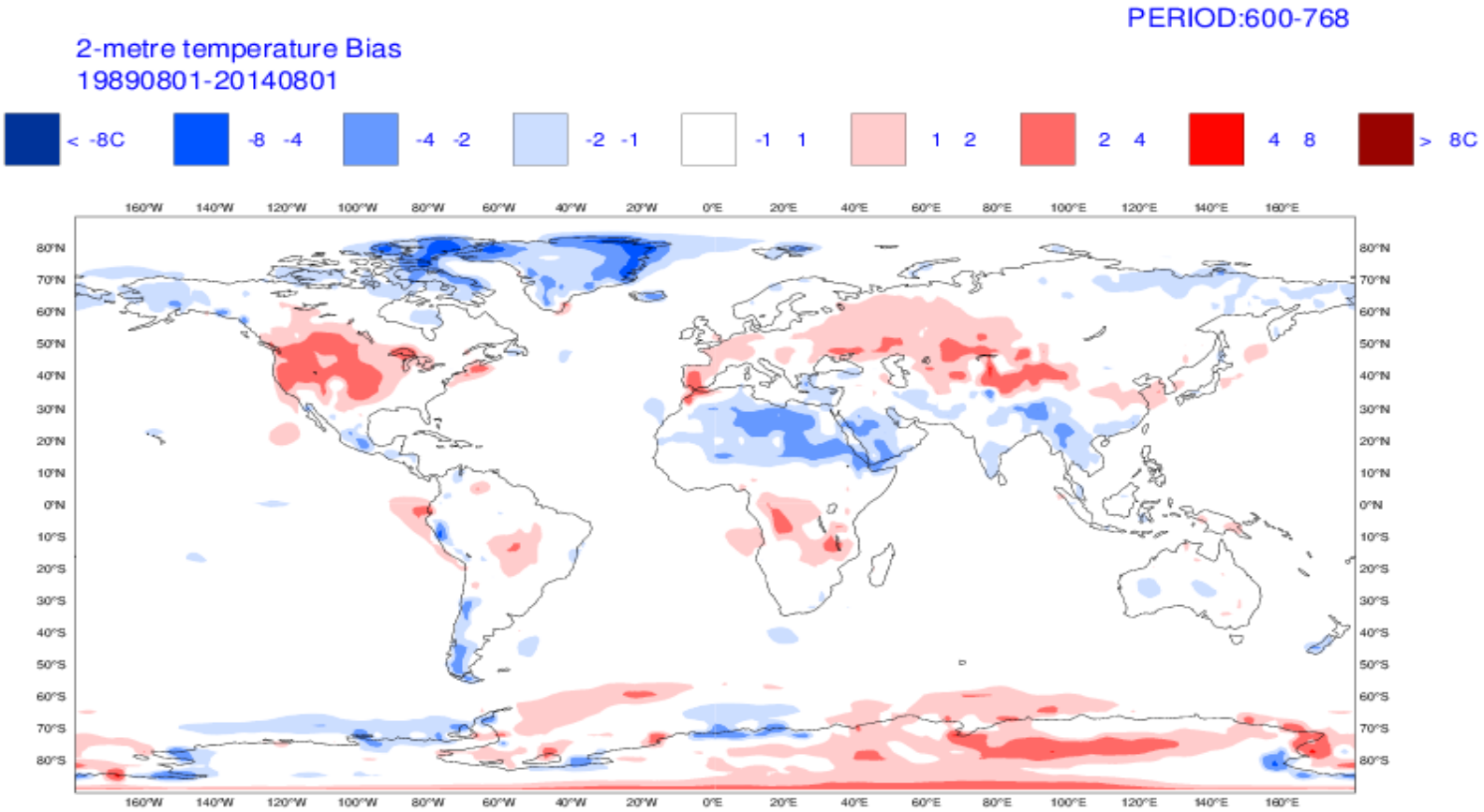
ECMWF monthly forecasts

- A 51-member ensemble is integrated for 46 days twice a week (Mondays and Thursdays at 00Z)
- Atmospheric component: IFS with the latest operational cycle and with a Tco639L91 resolution up to day 15 and Tco319L91 after day 15.
- Ocean-atmosphere coupling from day 0 to NEMO (about 1/4 degree) every hour.

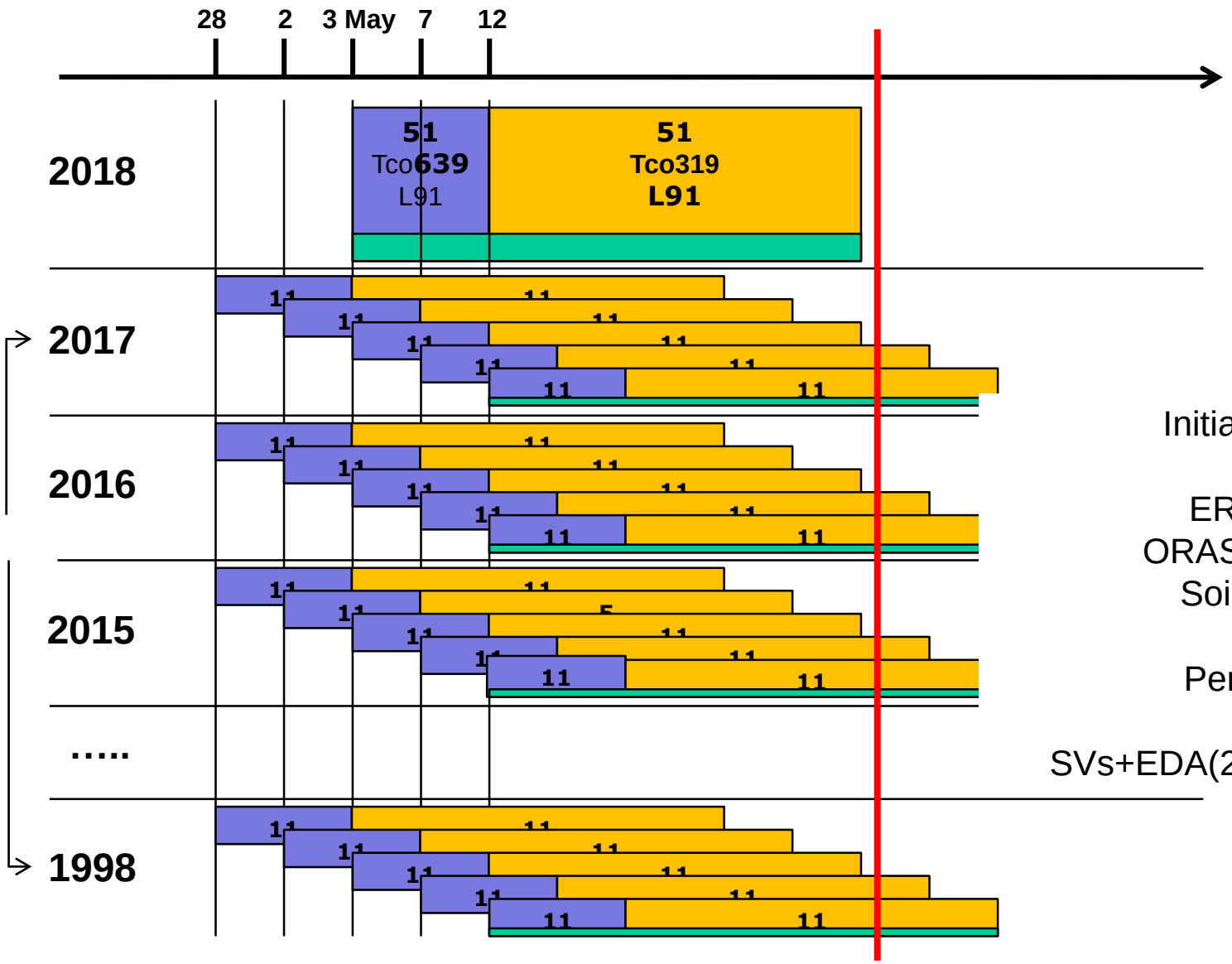
Initial conditions:

- Atmosphere: Operational 4-D var analysis + SVs+ EDA perturbations
- Ocean: 3D-Var analysis (NEMOVAR) + wind stress perturbations

Biases (eg 2mT as shown here) are often comparable in magnitude to the anomalies which we seek to predict



The ENS re-forecast suite to estimate the M-climate



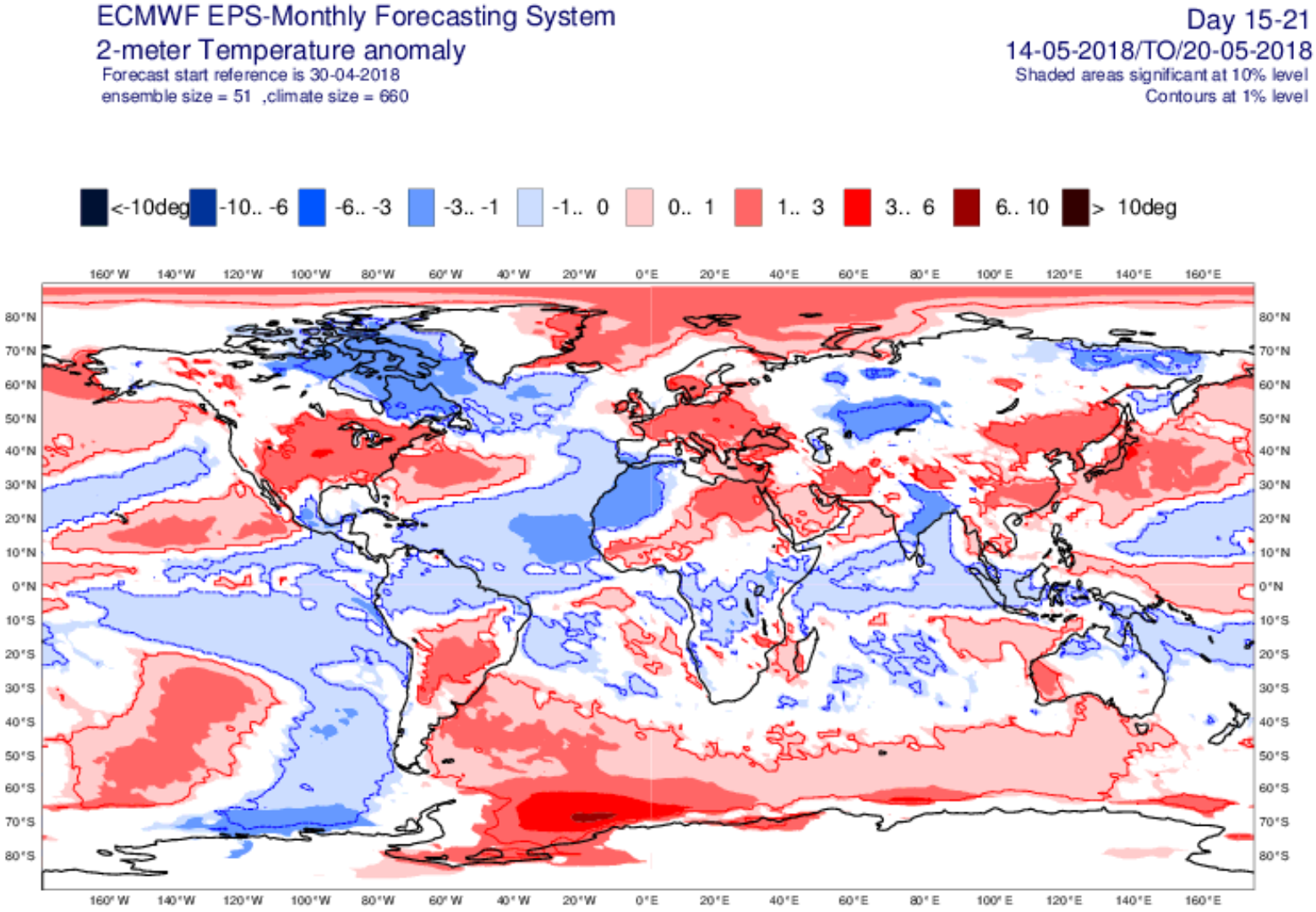
Initial conditions:

ERA Interim+
ORAS4 ocean Ics+
Soil reanalysis

Perturbations:

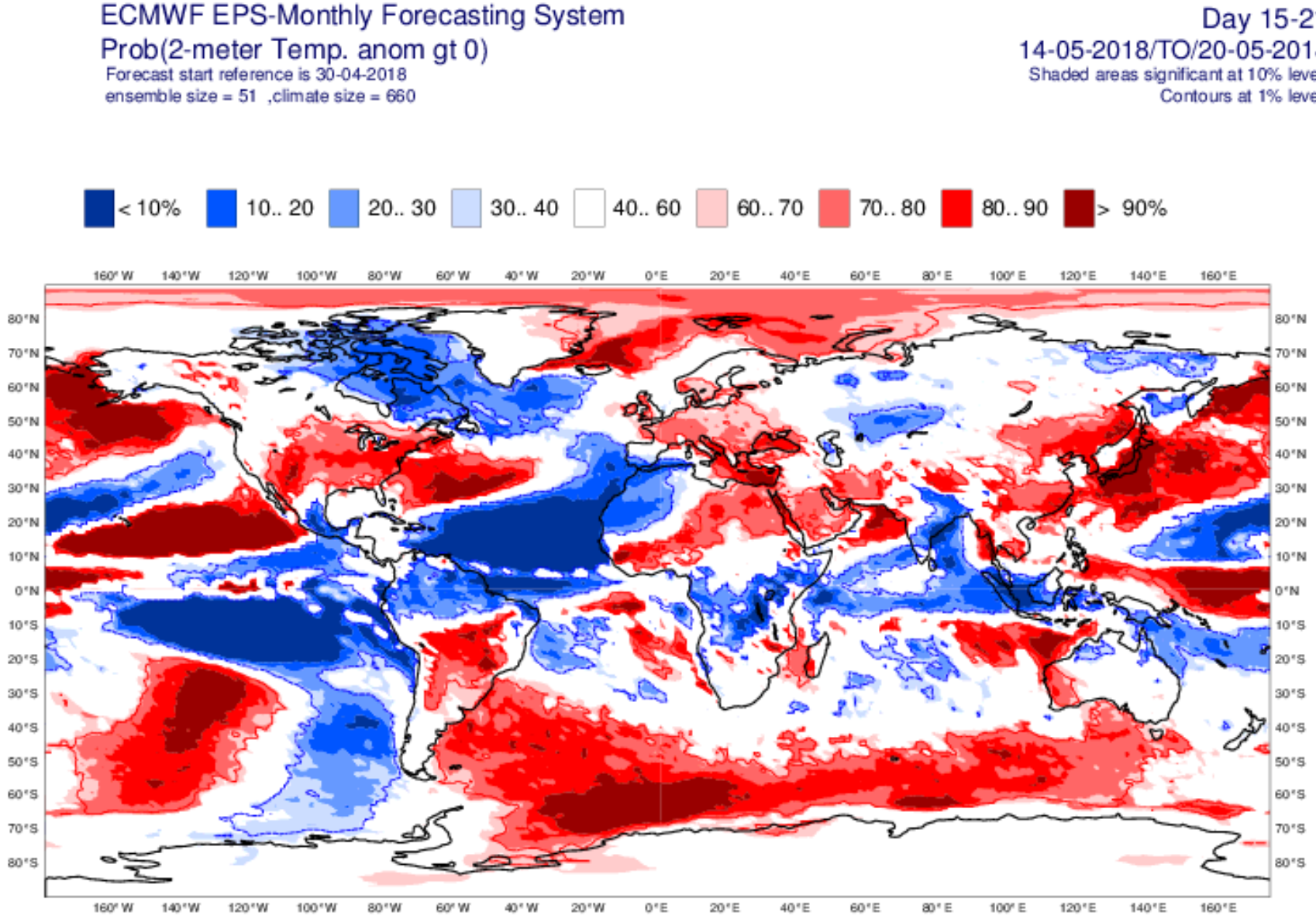
SVs+EDA(2016)+SPPT+SKEB

The ECMWF monthly forecasts

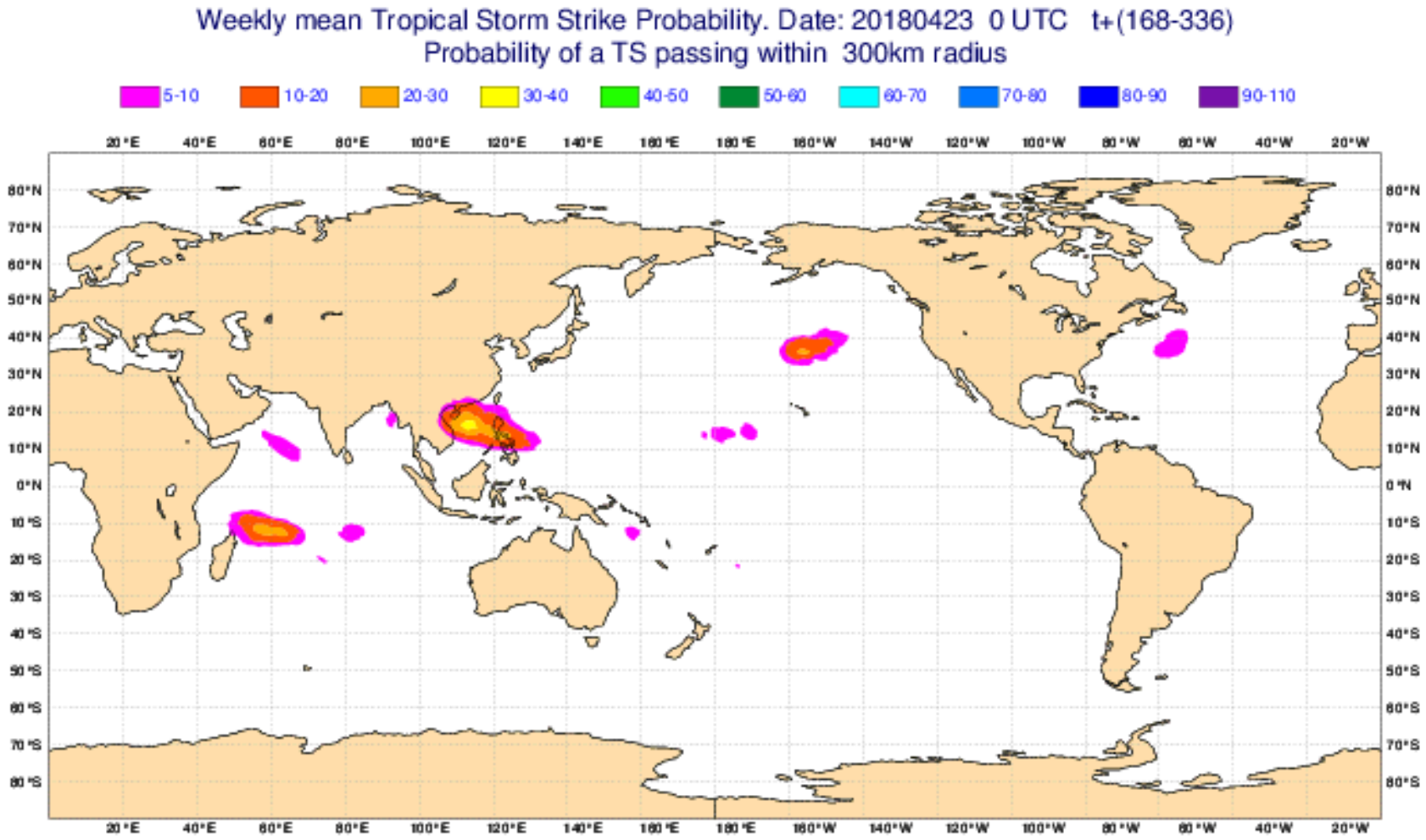


Anomalies (temperature, precipitation..)

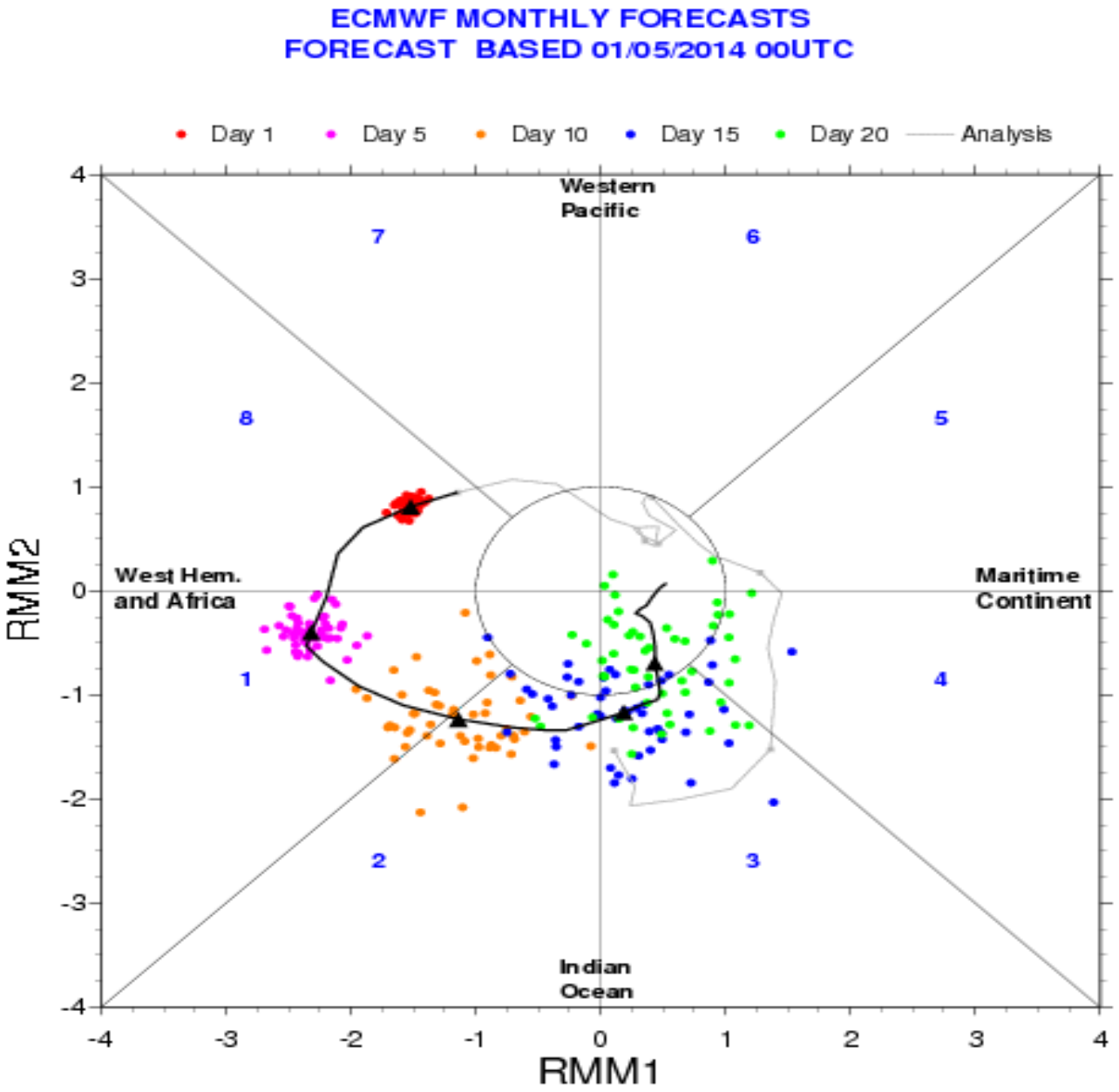
The ECMWF monthly forecasts



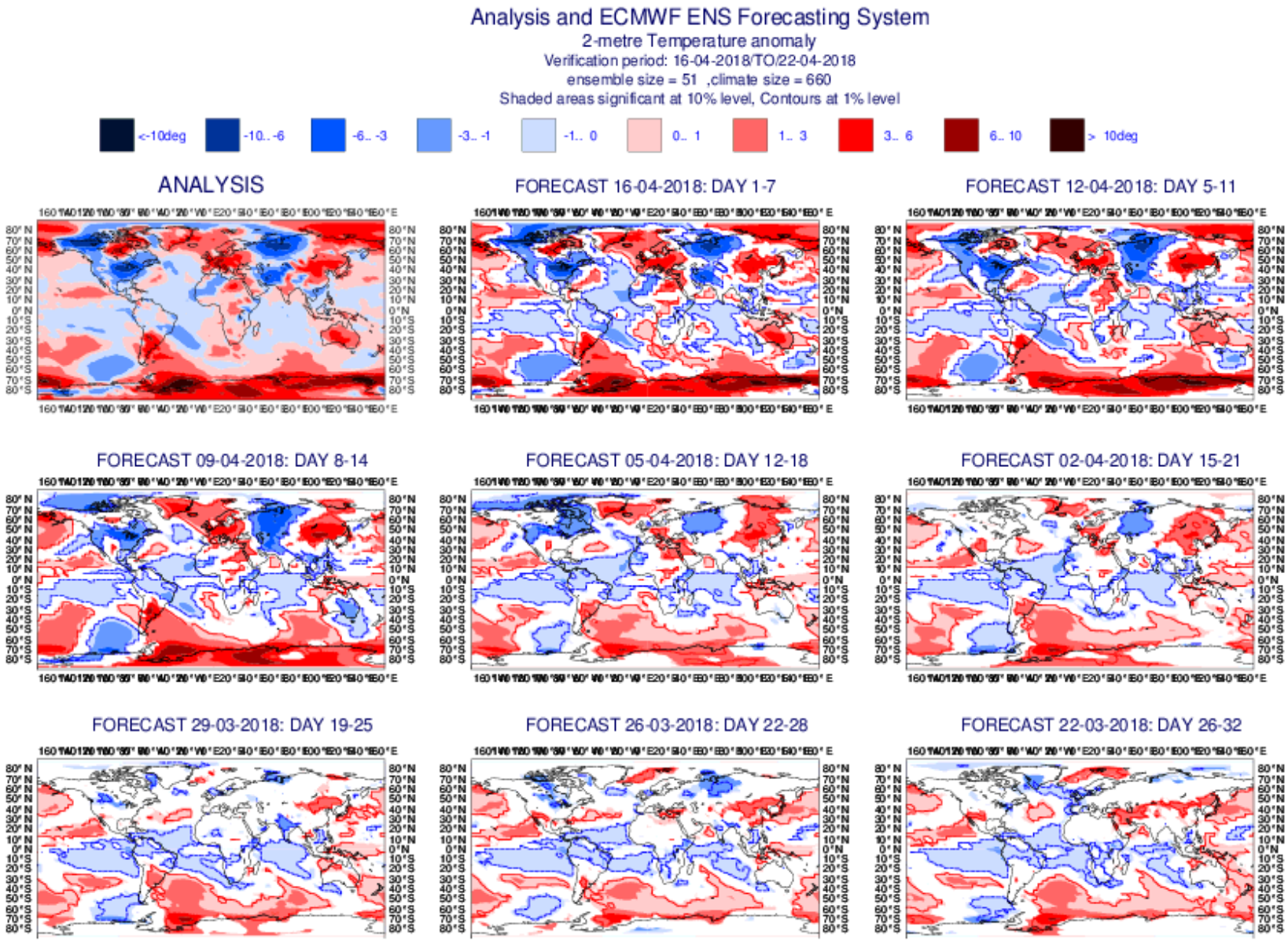
Tropical cyclone activity



MJO Forecasts



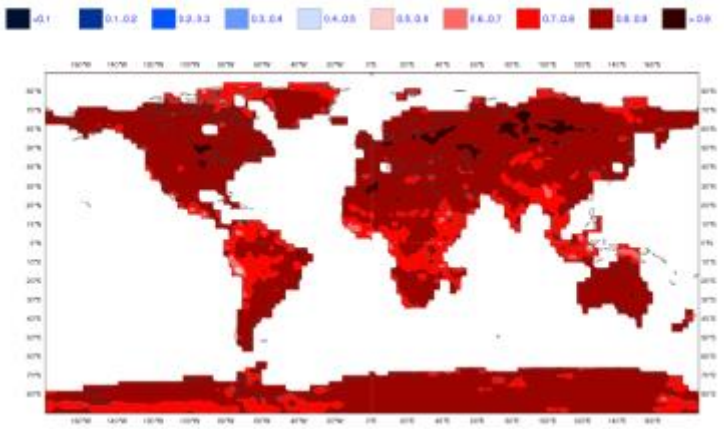
ECMWF Extended-range forecasts



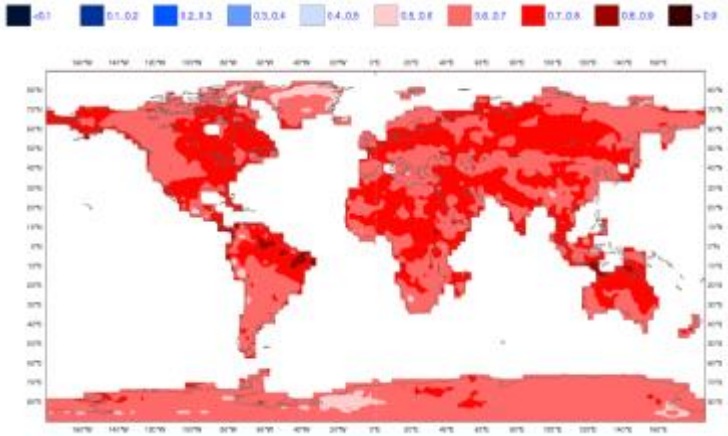
Skill of the ECMWF Monthly Forecasting System

ROC score: 2-meter temperature in the upper tercile

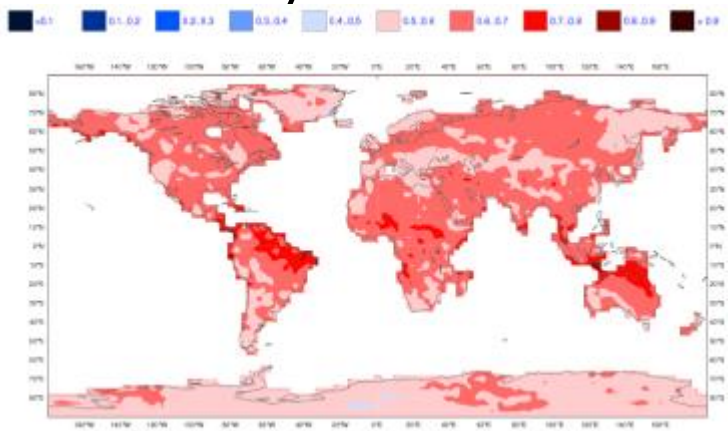
Day 5-11



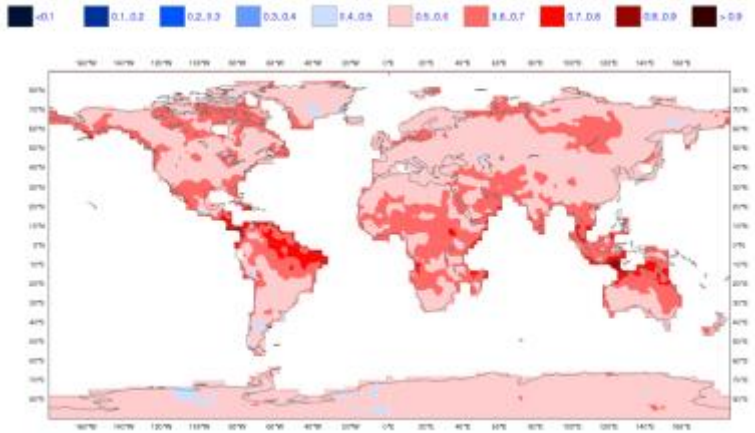
Day 12-18



Day 19-25



Day 26-32

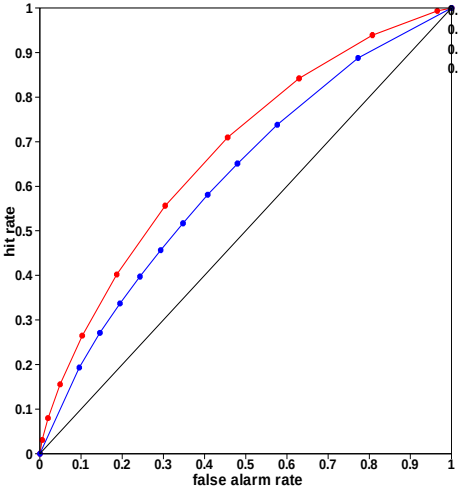


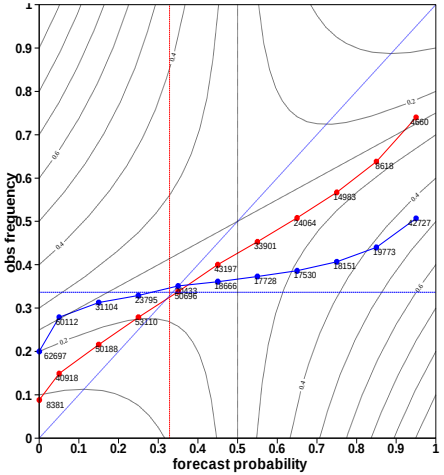
Skill of the ECMWF Monthly Forecasting System

2-meter temperature in upper tercile - Day 12-18

ROC score

Day 12-18

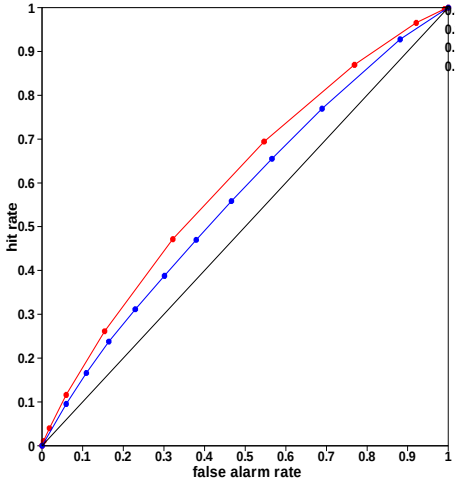


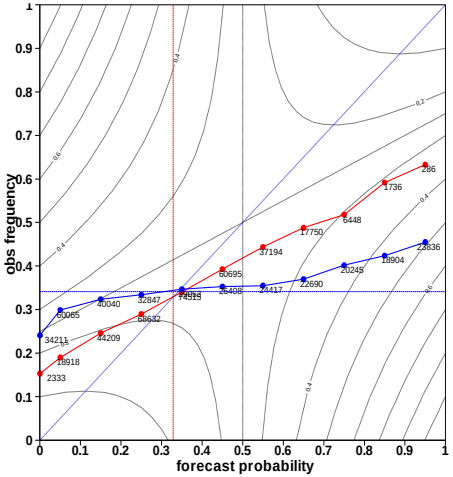


Persistence of day 5-11

Monthly forecast day 12-18

Day 19-25

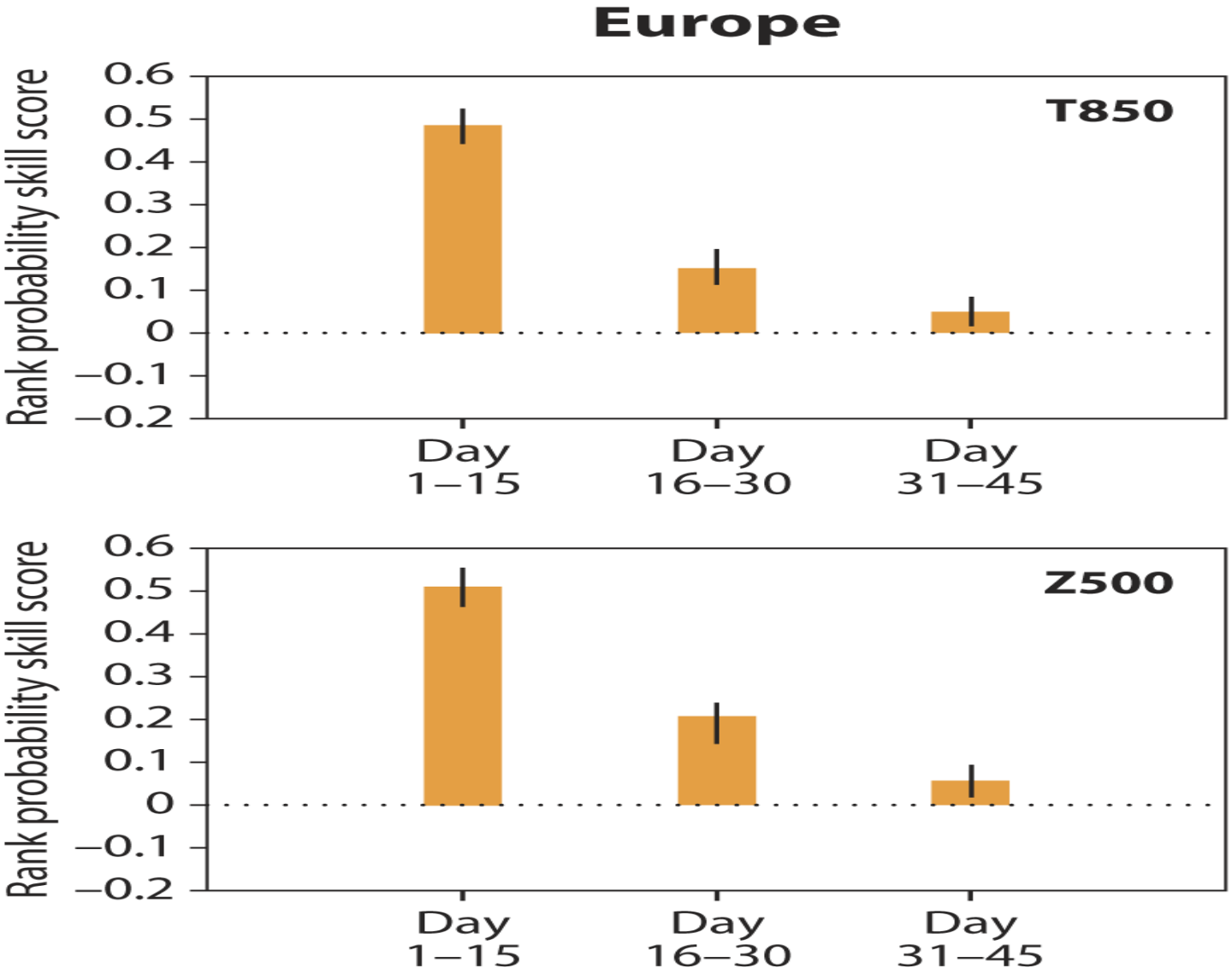




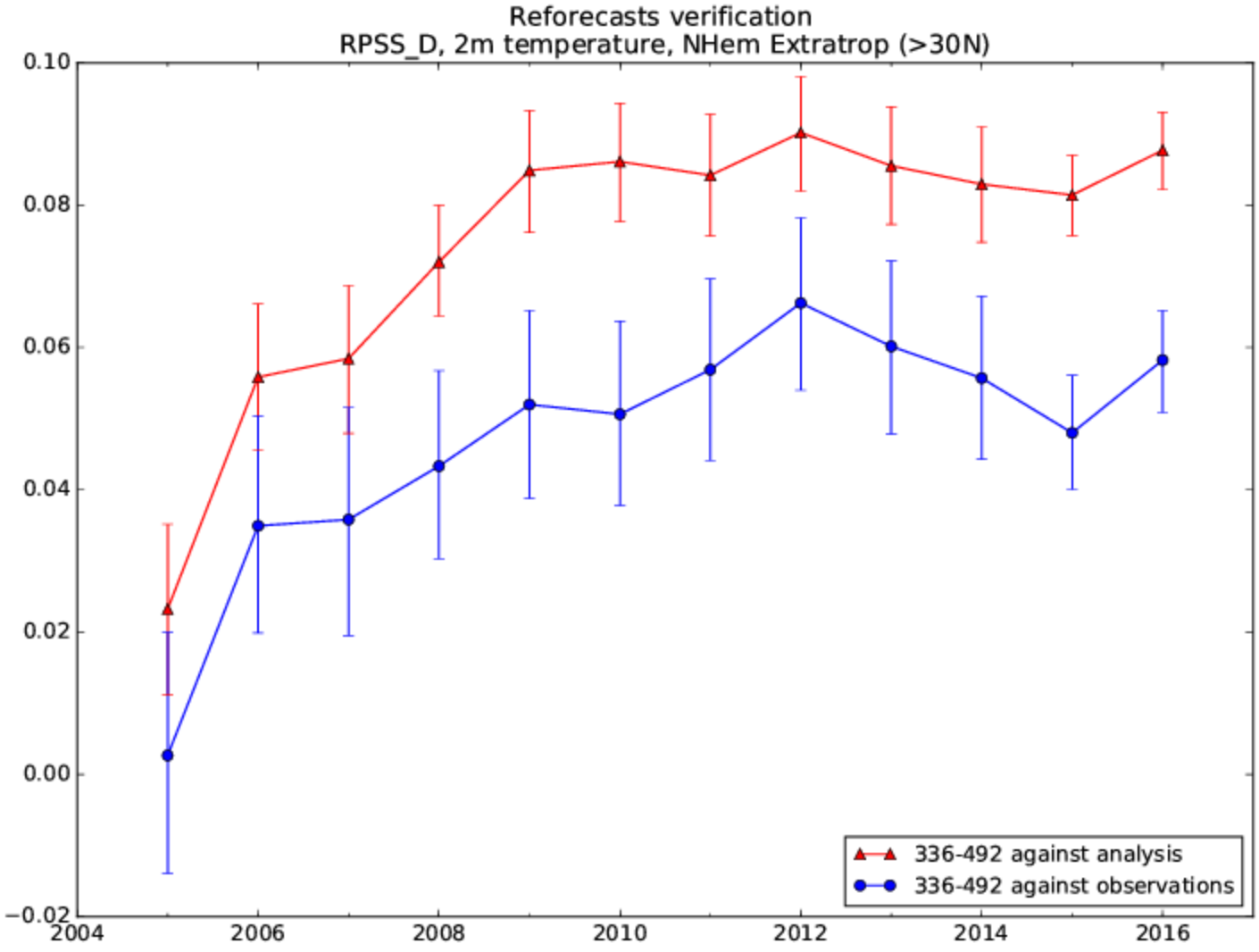
Persistence of day 5-18

Monthly forecast day 19-32

Extension to 46 days

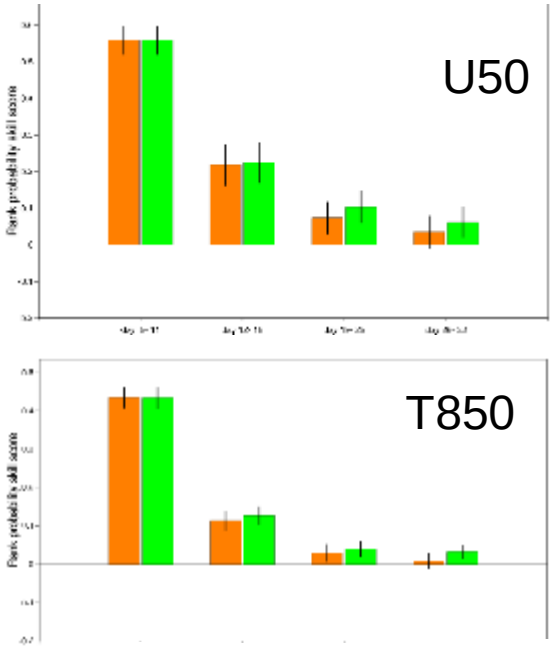


80 case, starting on 1st Feb/May/Aug/Nov 1989-2008

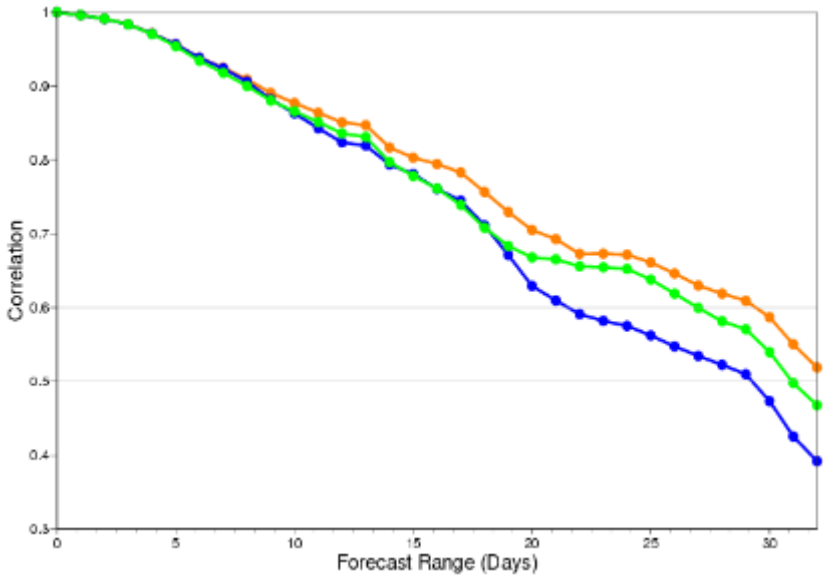

Reforecasts verification
RPSS_D, 2m temperature, NHem Extratrop (>30N)
0.10
0.08
0.06
0.04
0.02
0.00
−0.02
2004
2006
2008
2010
2012
2014
2016
336-492 against analysis
336-492 against observations

Impact of ocean/atmosphere coupling

RPSS over NH



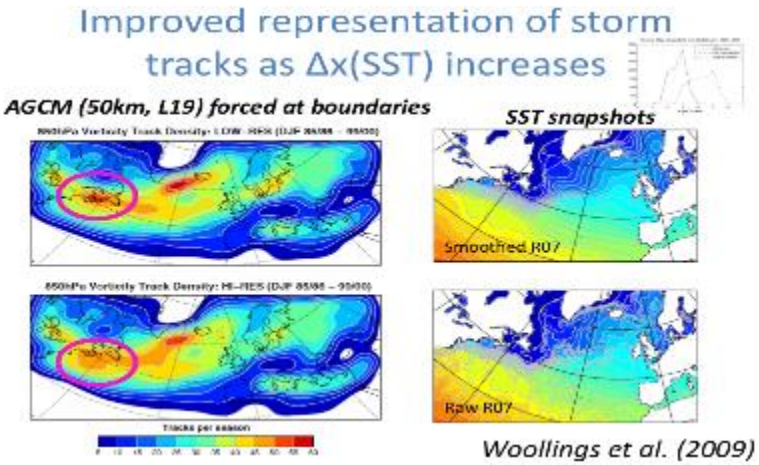
MJO Bivariate Correlation



Obs SSTs Coupled

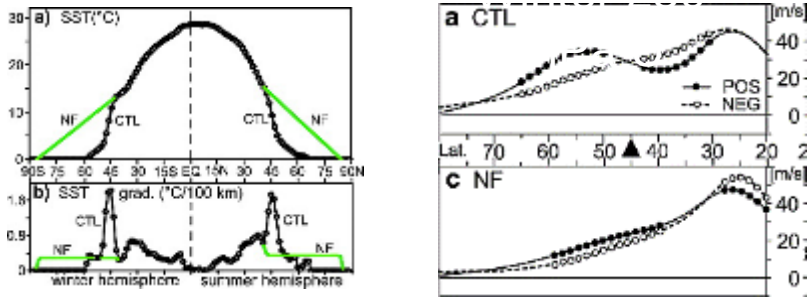
80 case, starting on 1st Feb/May/Aug/Nov 1989-2008

Impact of increasing ocean horizontal resolution



- Impact of storm track – Possible impact on teleconnections
- SST gradient: Ocean resolution of ¼ degree sufficient?
- Problem of Gulf stream separation: Coupled model tend to move the front too much to the North. Issue with ocean parameterization or resolution?
- Publications have so far shown importance of Gulf stream separation for seasonal/climate integrations. We need to explore the impact for sub-seasonal forecasts.

Importance of oceanic mid-latitude fronts



Nakamura et al. 2008

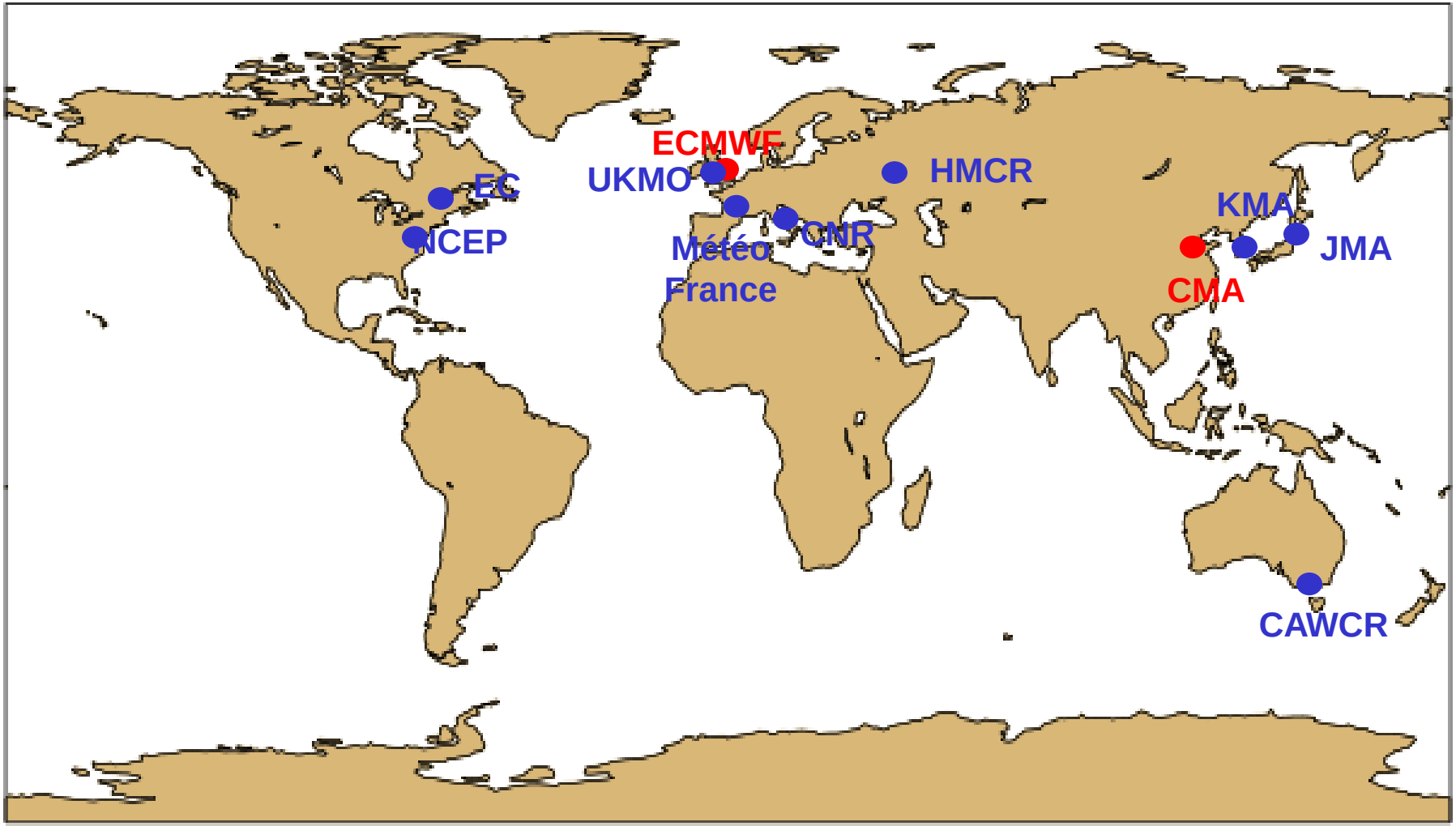
WMO Sub-seasonal to Seasonal Prediction (S2S) database

- Daily real-time forecasts + re-forecasts
- 3 weeks behind real-time
- Common grid (1.5x1.5 degree)
- Variables archived: about 80 variables including ocean variables, stratospheric levels and soil moisture/temperature
- Archived in GRIB2 – NETCDF conversion available

S2S Database

11 data providers and 2 archiving centres

● Data provider ● Archiving centre



S2S partners

	Time-range	Resol.	Ens. Size	Freq.	Hcsts	Hcst length	Hcst Freq	Hcst Size
ECMWF	D 0-46	Tco639/319L91	51	2/week	On the fly	Past 20y	2/weekly	11
UKMO	D 0-60	N216L85	4	daily	On the fly	1993-2015	4/month	7
NCEP	D 0-44	N126L64	4	4/daily	Fix	1999-2010	4/daily	1
ECCC	D 0-32	0.6x0.6L40	21	weekly	On the fly	1995-2014	weekly	4
BoM	D 0-60	T47L17	33	weekly	Fix	1981-2013	6/month	33
JMA	D 0-33	Tl479/Tl319L100	50	weekly	Fix	1981-2010	3/month	5
KMA	D 0-60	N216L85	4	daily	On the fly	1996-2009	4/month	3
CMA	D 0-45	T106L40	4	daily	Fix	1886-2014	daily	4
CNRM	D 0-32	T255L91	51	Weekly	Fix	1993-2014	2/monthly	15
CNR-ISAC	D 0-32	0.75x0.56 L54	40	weekly	Fix	1981-2010	6/month	5
HMCR	D 0-63	1.1x1.4 L28	20	weekly	On the fly	1981-2010	weekly	10

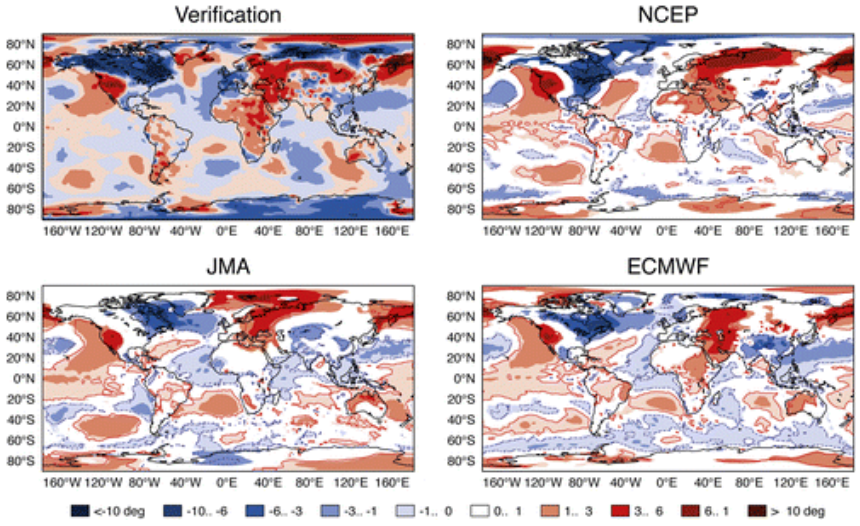
S2S models

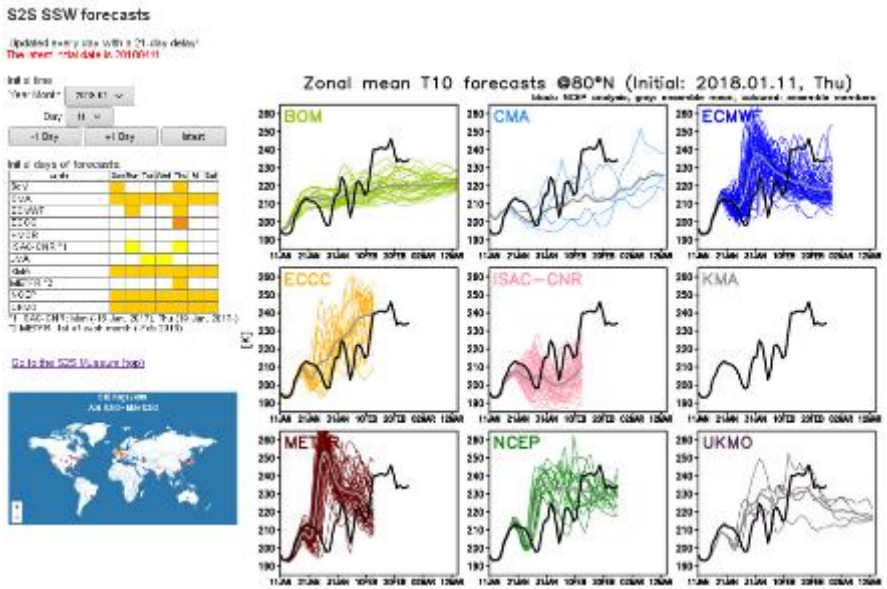
Models	Ocean coupling	Active Sea Ice
ECMWF	YES	YES
UKMO	YES	YES
NCEP	YES	YES
ECCC	NO	NO
BoM	YES	Planned
JMA	NO	NO
KMA	YES	YES
CMA	YES	YES
Met.Fr	YES	YES
ISA-CNR	NO	NO
HMCR	NO	NO

S2S Product Websites (3 weeks behind real-time)

- S2S product website at ECMWF: Contains near real-time products (2mtm precip, Z500 anomaly maps, MJO forecasts, EFI…) from S2S models from 1st January 2016. http://www.ecmwf.int/en/research/projects/s2s/charts/s2s/

- "S2S museum" at university of Tsukuba, Japan: Contains near real time indices (MJO, AO, NAO. SSW…)
http://gpvjma.ccs.hpcc.jp/S2S/S2S_SICmap.html

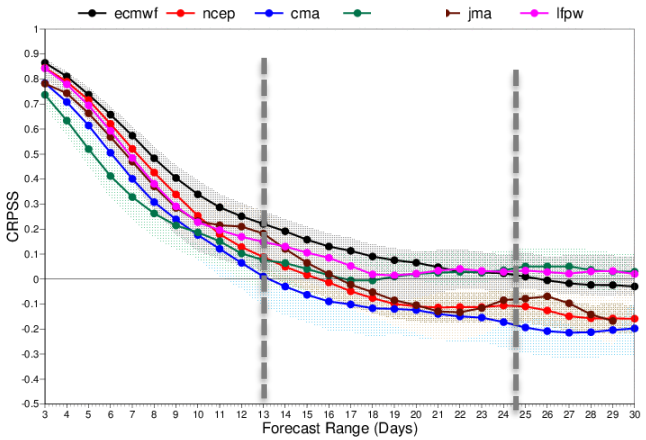




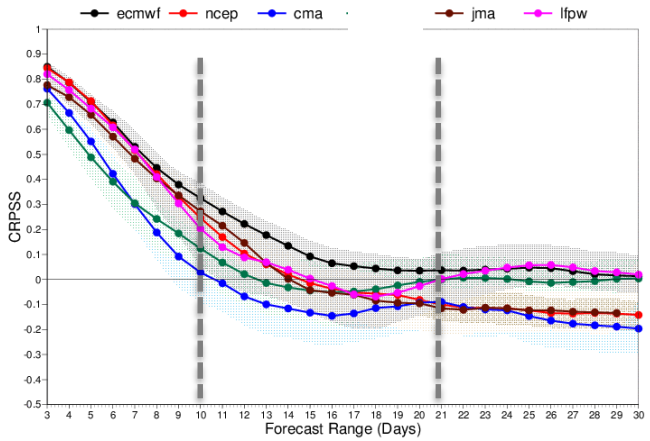
ECMWF

Predicting skill associated with the Euro-Atlantic Regimes:

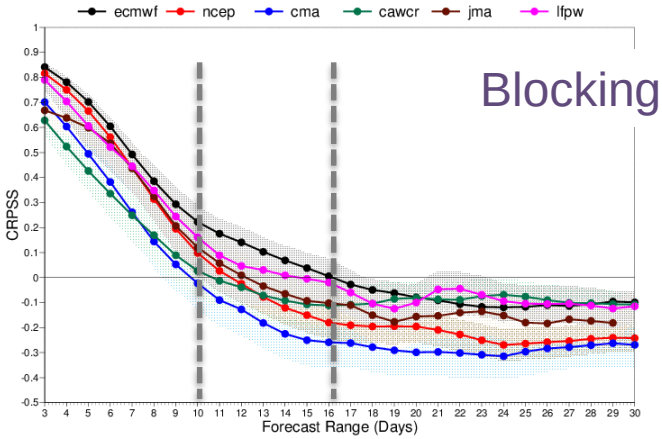
NAO +



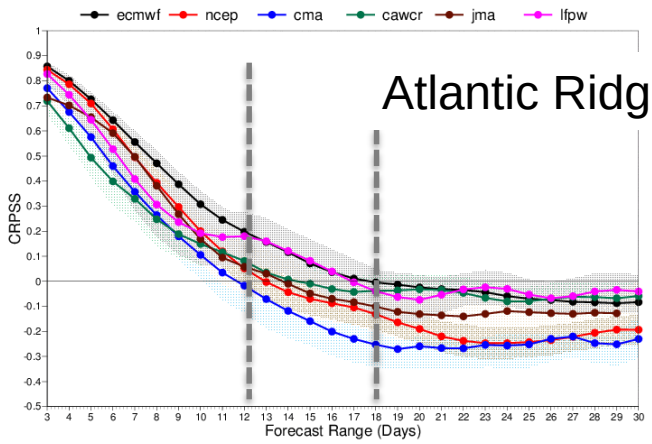
NAO -



Blocking

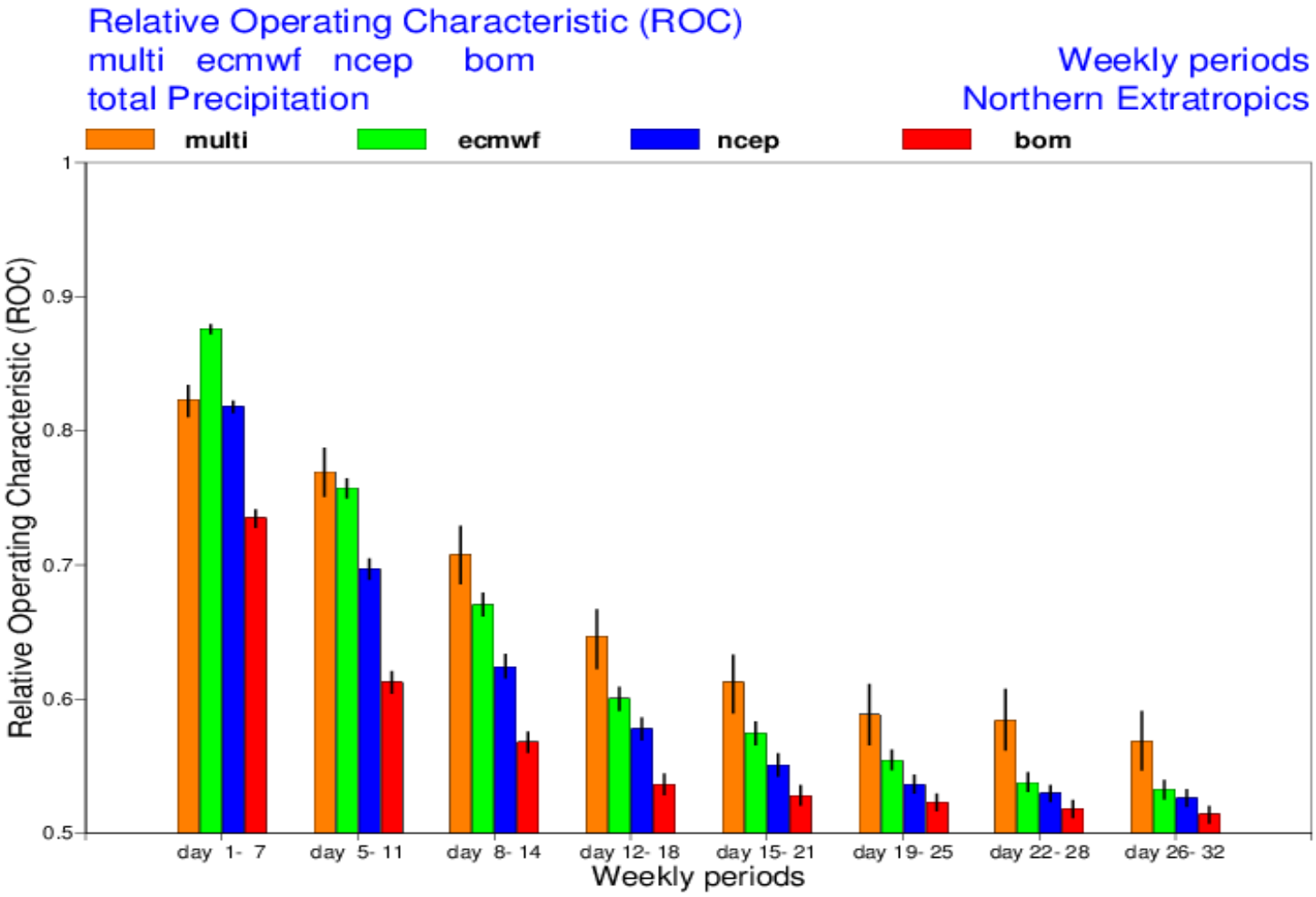


Atlantic Ridge



Ferranti et al, 2018

2015/2016 Real-time Forecast verification



Conclusion

- SSTs, sea ice , Soil moisture, stratospheric initial conditions and MJO are sources of predictability at the intra-seasonal time scale.

- The monthly forecasting system produces forecasts for days 12-18 that are generally better than climatology and persistence of day 5-11. Beyond day 20, the monthly forecast is marginally skilful. For some applications and some regions, these forecasts could however be of some interest.

- There has been a clear improvement in the monthly forecast skill scores since 2002. This improvement is likely to be related to improved prediction in the Tropics and most especially improved MJO prediction.

- S2S database is now available. It is an important tool to better identify model's sources of predictability and teleconnections.