Seasonal prediction: opportunities and challenges

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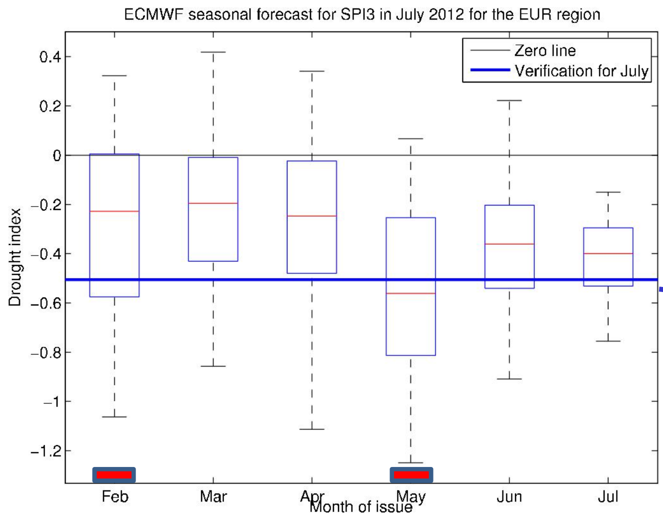
Summer 2012: weather-related risk and seasonal fcs

- **Global food prices have leapt by 10%** in July, raising fears for the planet's poorest, the World Bank has warned. A drought in parts of **Eastern Europe** and a **US** heat wave were partly to blame (BBC, 31/8/12).

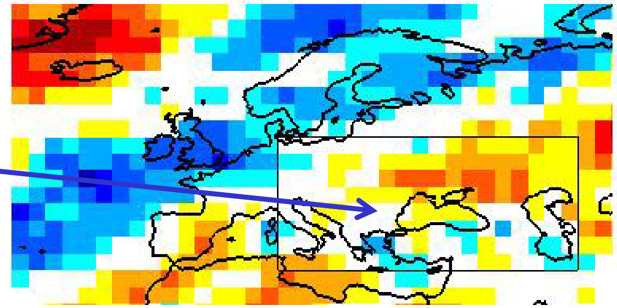
- The **worst drought in over 50 years** in the **U.S. Midwest** has trimmed crop prospects, sent livestock water supplies to critically low levels, and hampered transportation on the Mississippi River (Reuters, 22/8/12). The USDA has allowed farmers to cut hay and graze on conservation areas (FT, 22/8/12).

- A prolonged failure of rains, which began in late 2010, is now taking its toll. **The 2010-11 drought** (the worst drought in 60 years, the UN says) in the **Horn of Africa** affected about 10 million people (BBC, June 2011)**.** It resulted from a precipitation deficit in the October-December 2010 associated with strong La Nina conditions.

Summer 2012: seasonal forecasts for Europe



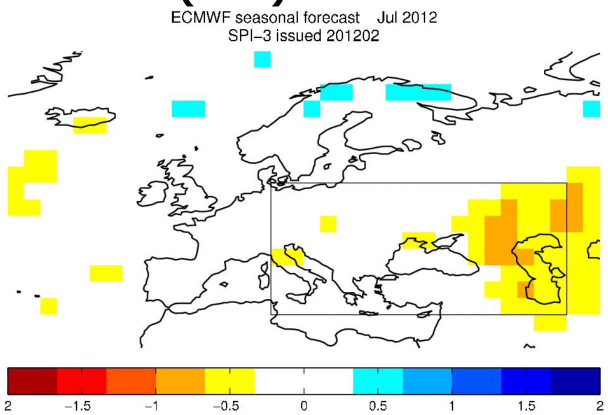
SPI(MJJ) – ERA-I



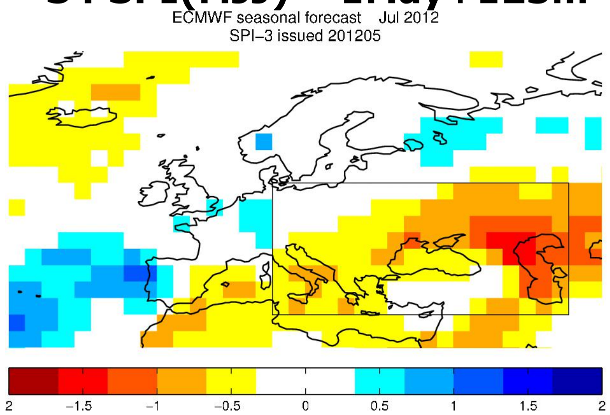
Est EU MJJ12.

Since Feb S4 predicts 75% probability of below normal conditions.

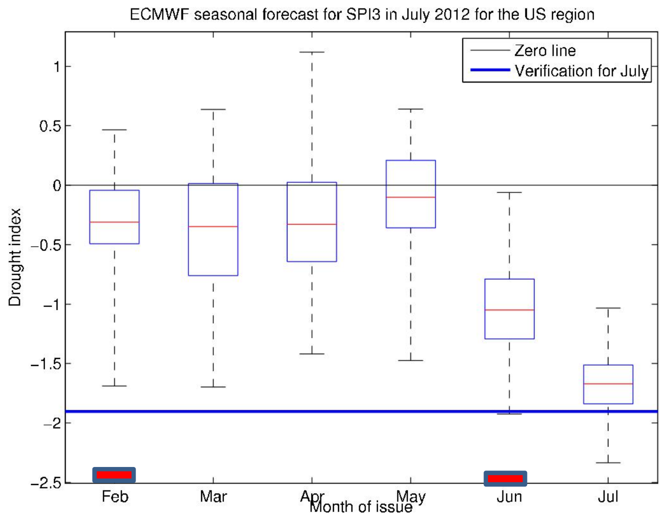
S4 SPI(MJJ) – 1Feb+456m



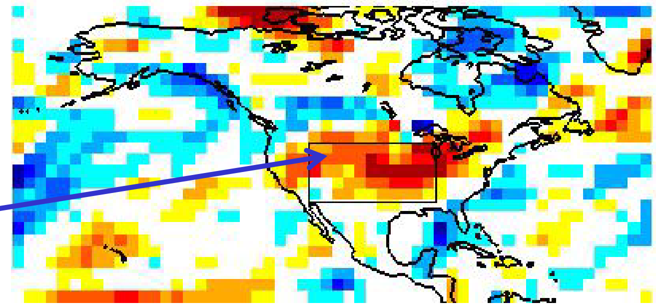
S4 SPI(MJJ) – 1May+123m



Summer 2012: seasonal forecasts for US



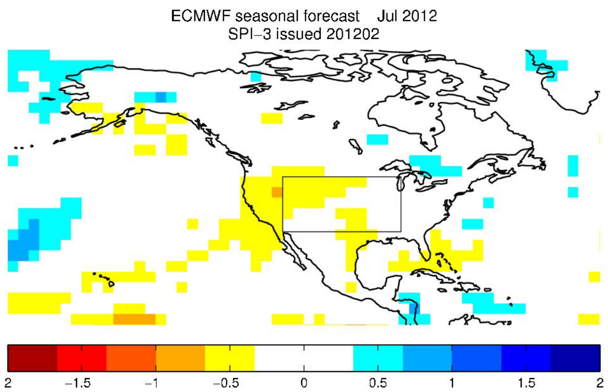
SPI(MJJ) – ERA-I (AAA)



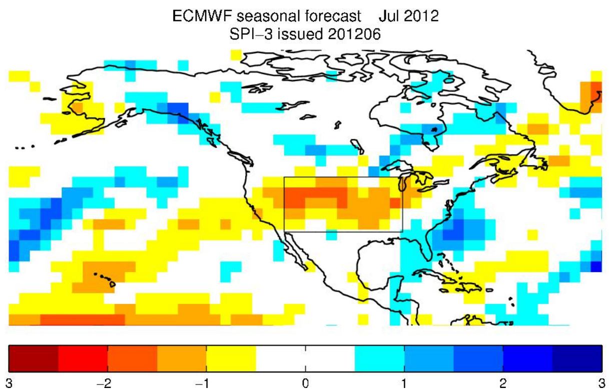
US MidW MJJ12.

Since Feb S4 predicts 75% probability of below normal conditions.

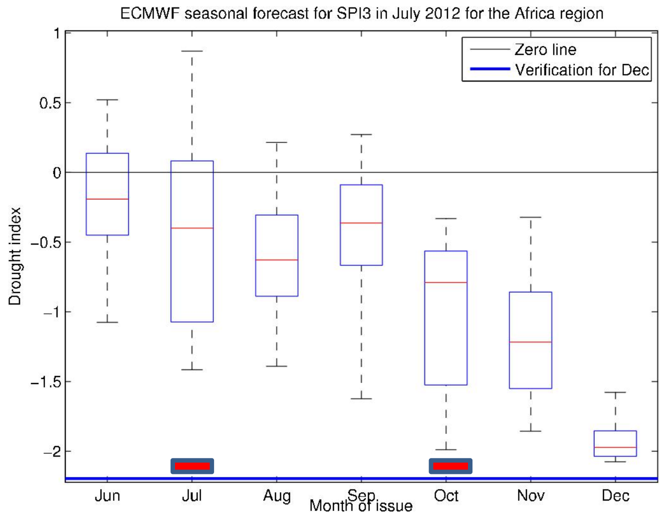
S4 SPI(MJJ) – 1Feb+456m



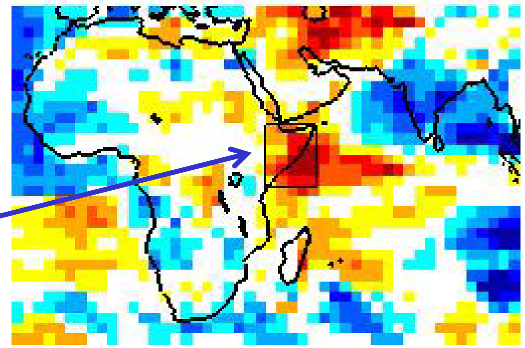
S4 SPI(MJJ) – 1JunA+12m



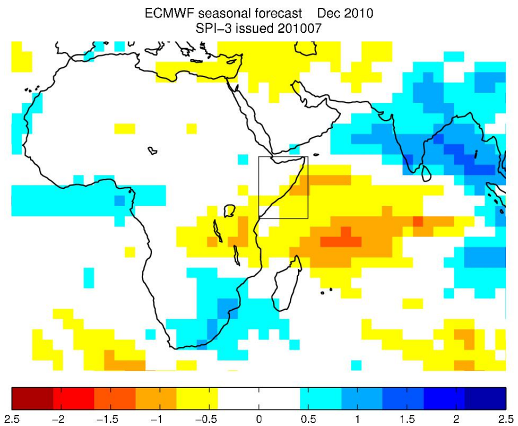
Fall 2011: seasonal forecasts for Horn of Africa



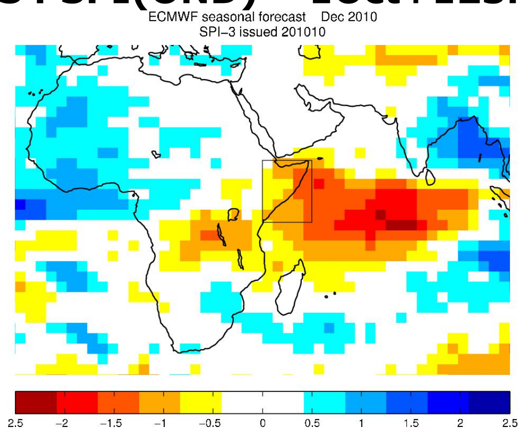
SPI(OND) – ERA-I



S4 SPI(OND) – 1Jul+456m



S4 SPI(OND) – 1Oct+123m



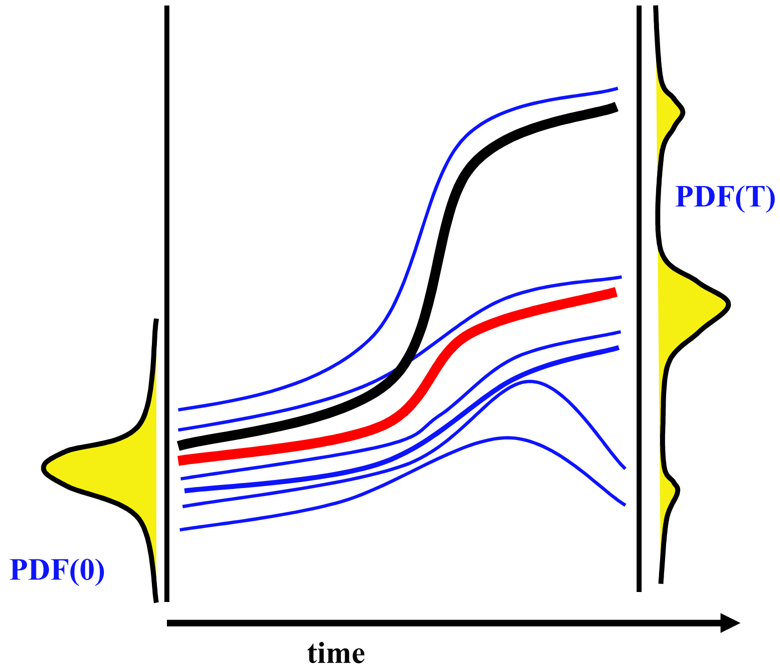
Horn Af OND11.

Since July S4 predicts 75% probability of below normal conditions.

Seasonal prediction can only be probabilistic

- Seasonal prediction has to take uncertainties and approximations into account. The only feasible way to do it is by building reliable ensemble systems

- The use of ensemble techniques have the advantage to allow users to predict a range of possible alternatives (in other words the most likely scenario and its uncertainty)

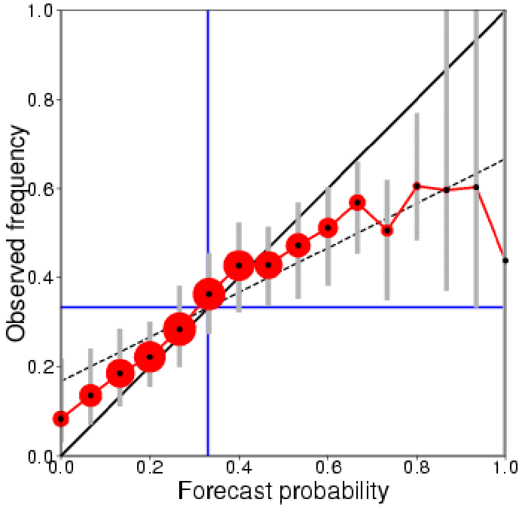


To be valuable, ensemble predictions must be reliable

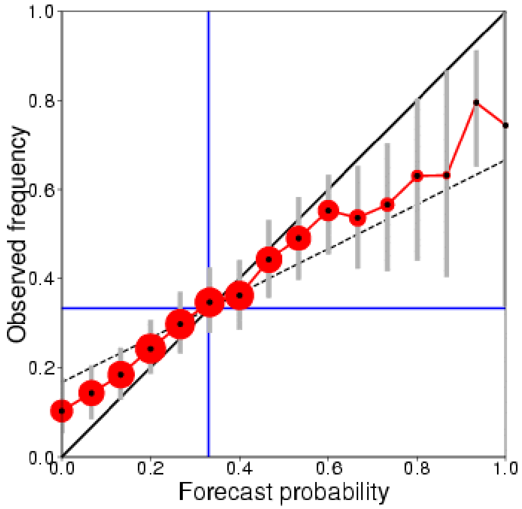
On average (30 years), 4-6 month probabilistic predictions of 2mT over Africa, North America and Europe started in Feb for MJJ (t+4-6m) are reliable and skilful compared to climatology (BSS>0).

BSS PR(2mT>U3)	EU	NA	AF
1 Feb > MJJ (t+ 4-6m)	0.064	0.050	0.116
1 Apr > MJJ (t+2-4m)	0.058	0.074	0.141

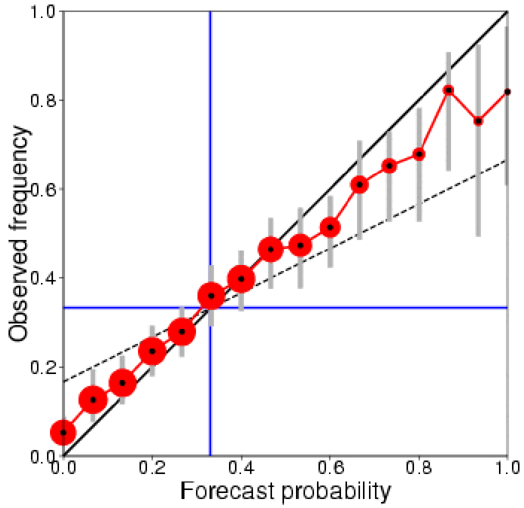
EU – 1 Feb + 4-6m



NA – 1 Feb + 4-6m



AF – 1 Feb + 4-6m

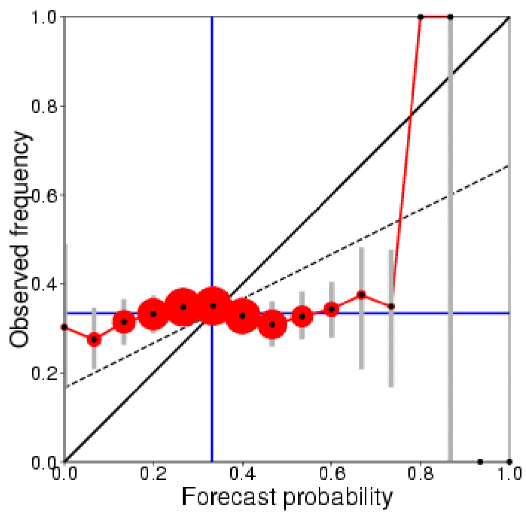


For precipitation, reliability is poor

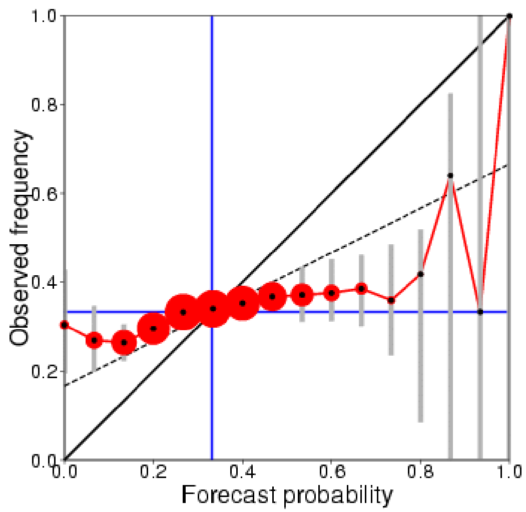
On average (30 years), even shorter-range 2-4 month probabilistic predictions of TP over Africa, North America and Europe started in Apr for MJJ (t+2-4m) are **not** reliable and **less** skilful than climatology.

BSS PR(TP<L3)	EU	NA	AF
1 Feb > MJJ (t+ 4-6m)	-0.049	-0.052	-0.049
1 Apr > MJJ (t+2-4m)	-0.072	-0.052	-0.046

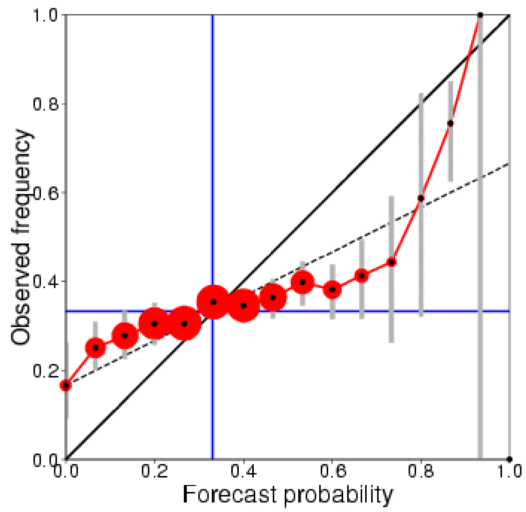
EU – 1 Apr + 2-4m



NA – 1 Apr + 2-4m

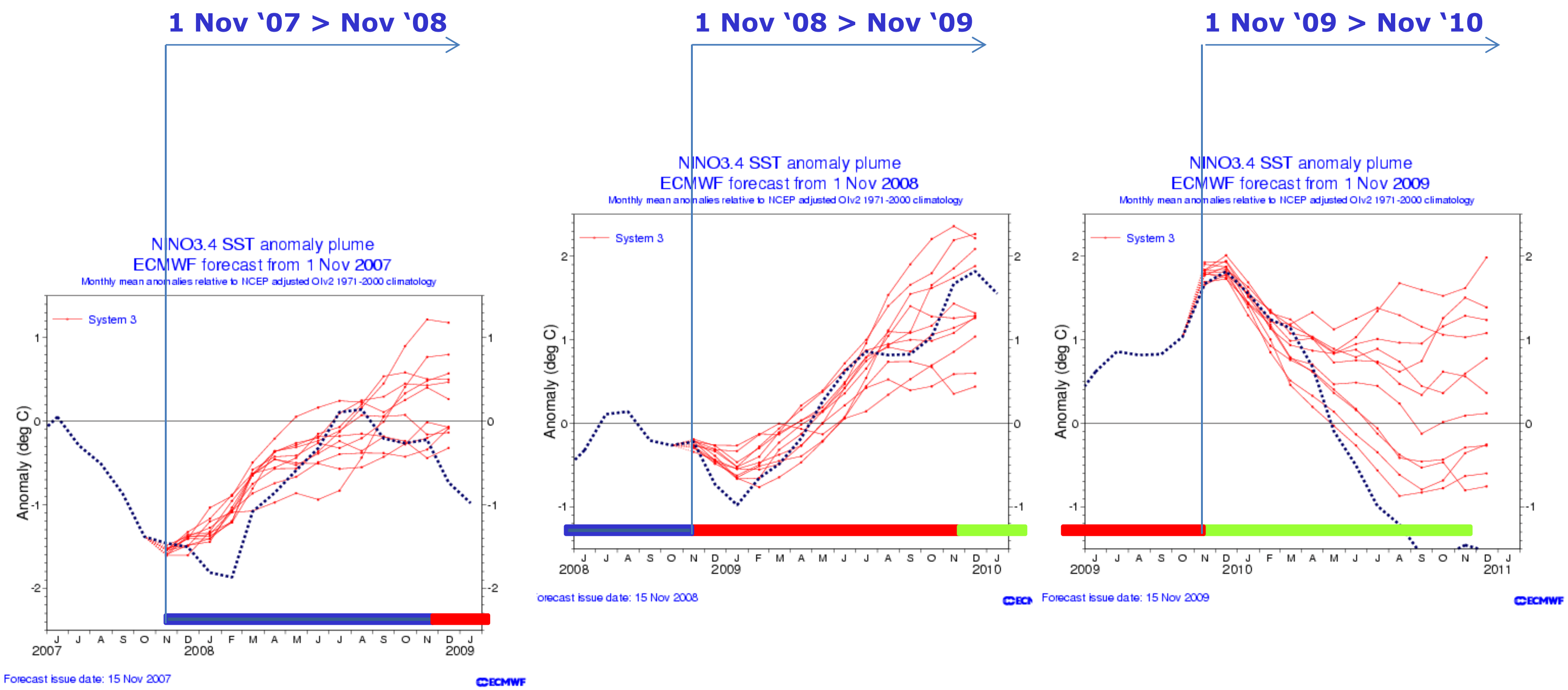


AF – 1 Apr + 2-4m



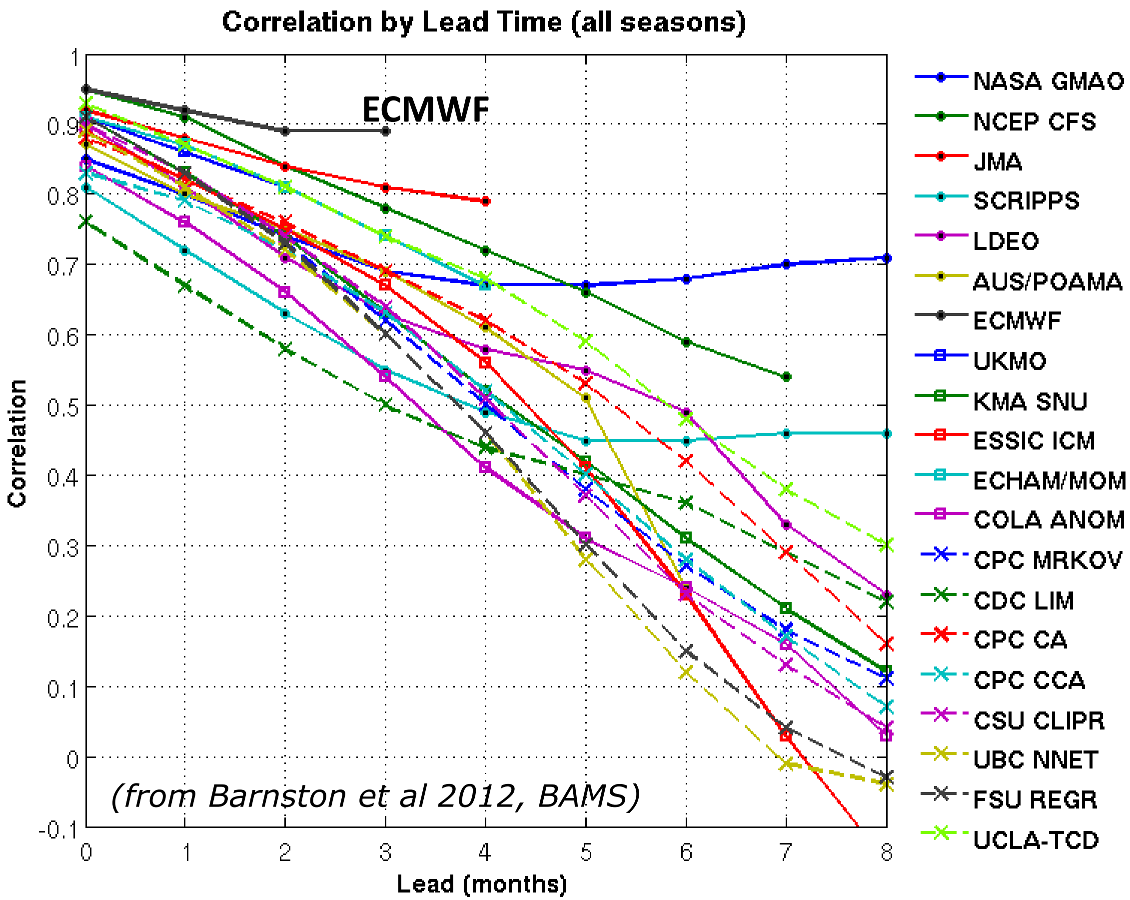
For El-Nino, reliability and skill are very high up to 1 year

The tropics remain the area where seasonal prediction has the highest skill, as indicated e.g. by the accuracy of 1-year forecasts of SST anomaly in the Nino3.4 area.



Today dynamical predictions provide best seasonal fcs

Based on the earth-system equations, dynamical coupled systems give us better forecasts than statistics.

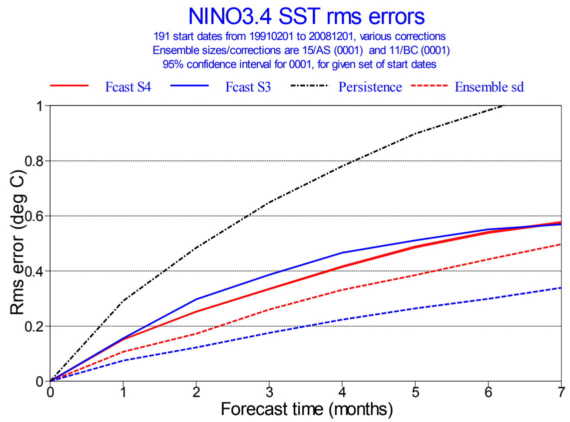


Why is it so difficult?

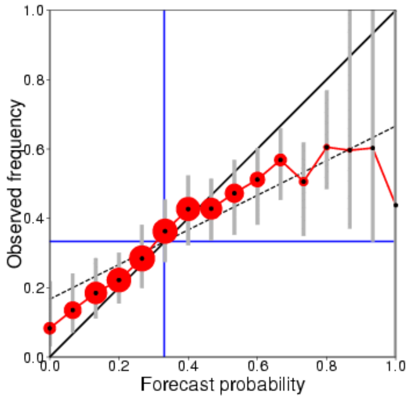
We have seen that:

- In few cases we forecasts are good months ahead
- El-nino forecasts are rather good
- Forecasts for Europe (xTr in general) remain poor

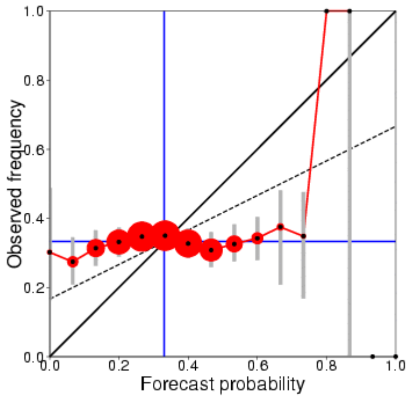
Why is it so difficult?

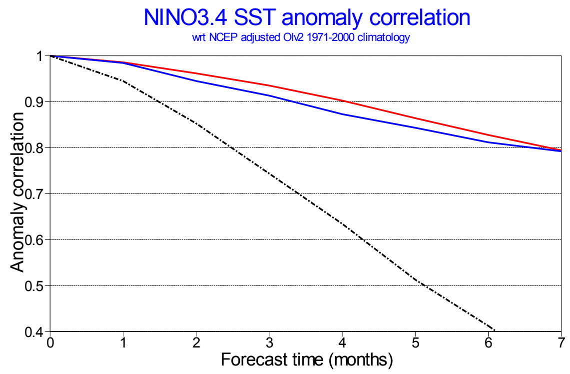


EU – 2mT 1 Apr+4-6m



EU – TP 1 Apr+2-4m





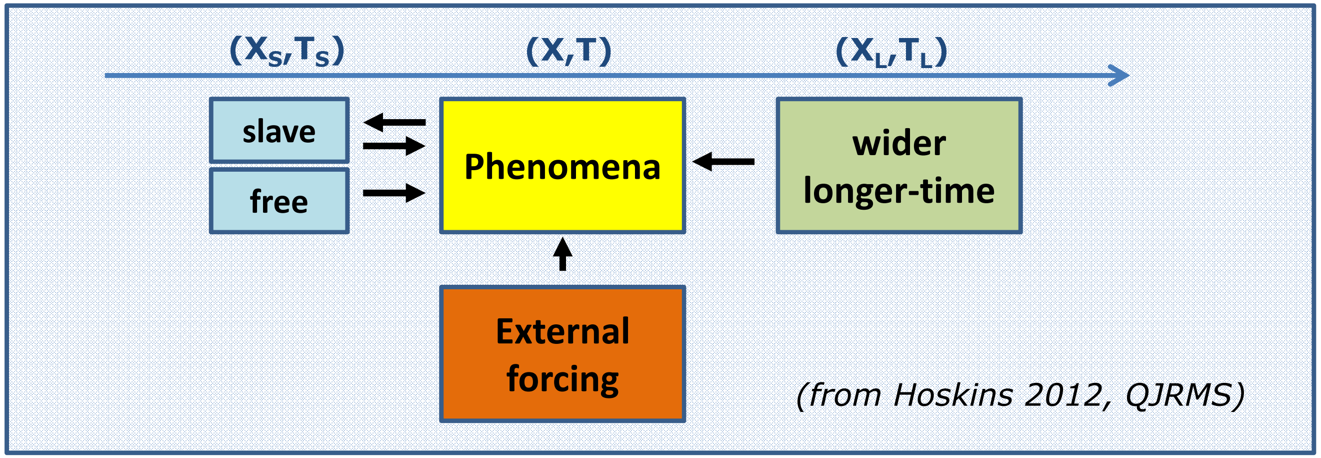
The main challenges: model processes and initialization

The main **challenges** that seasonal prediction is facing are:

a) to design systems that simulate many scales and include all relevant processes, and

b) to initialize the forecast integrations with accurate initial conditions.

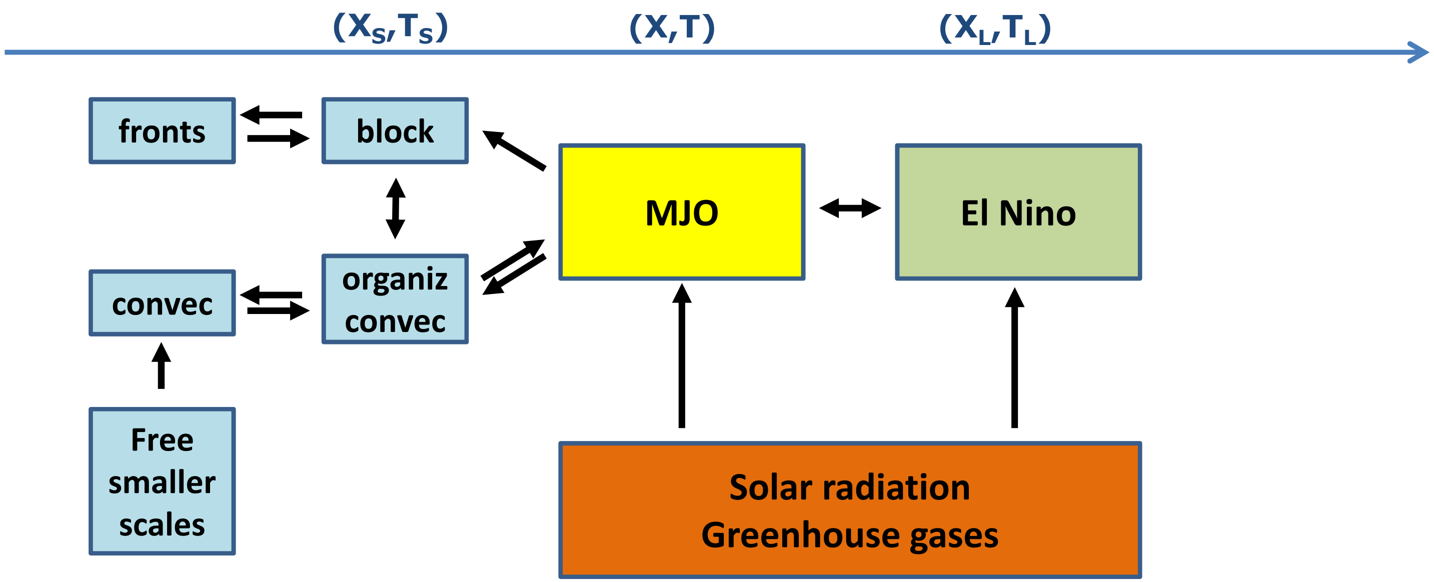
These challenges provide us a clear indication on where the **opportunities** are!



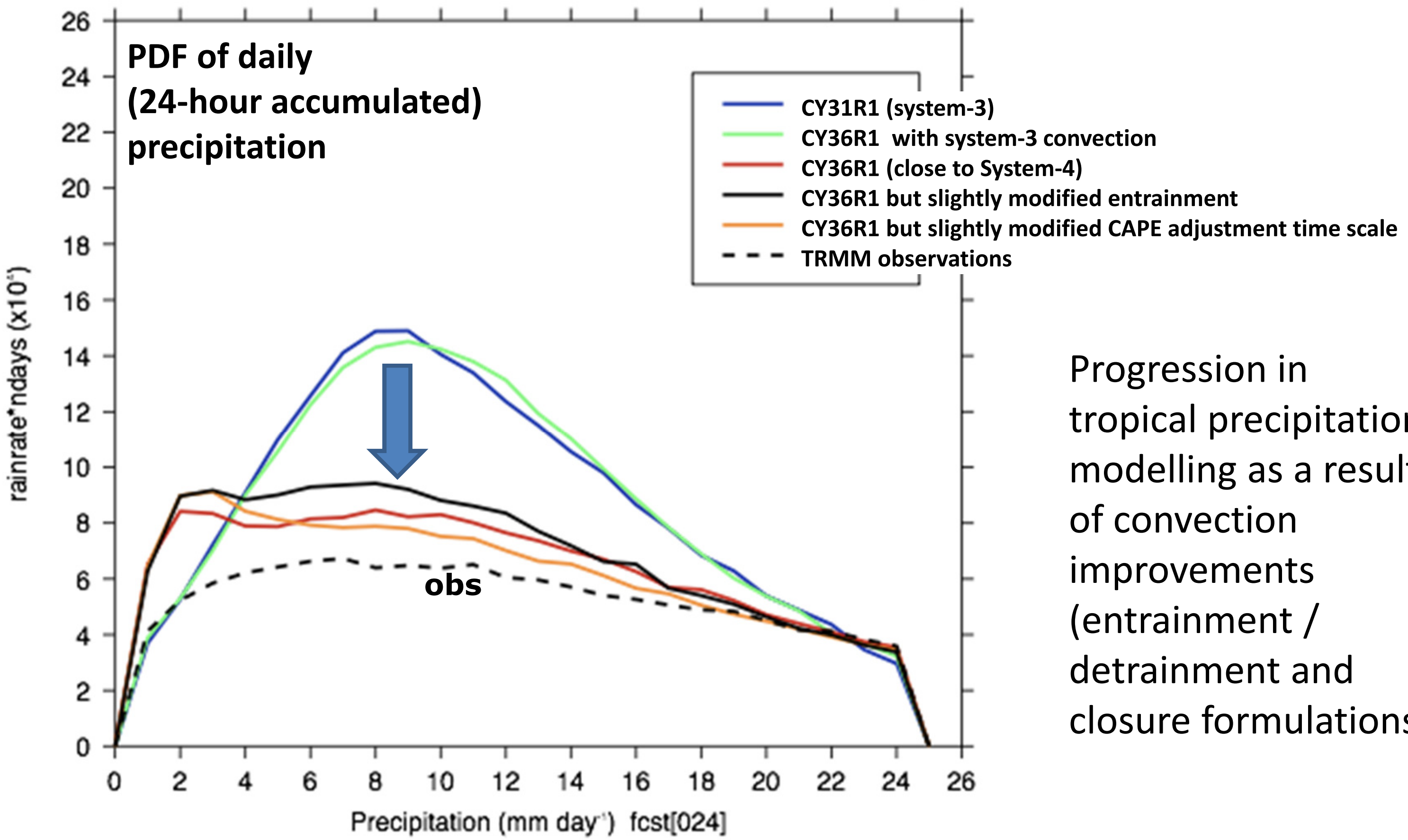
(from Hoskins 2012, QJRMS)

a) Scales interaction: El Nino, the MJO, convection, …

- Diurnal tropical convection influences organized convection and the MJO
- The MJO propagates and interacts with El Nino
- El Nino and the MJO are affected by variations in solar radiation and greenhouse gases
- The MJO can affect extra-tropical, low-frequency phenomena such as blocking
- Blocking influences synoptic scales, fronts



a) Changes in convection improves tropical precipitation

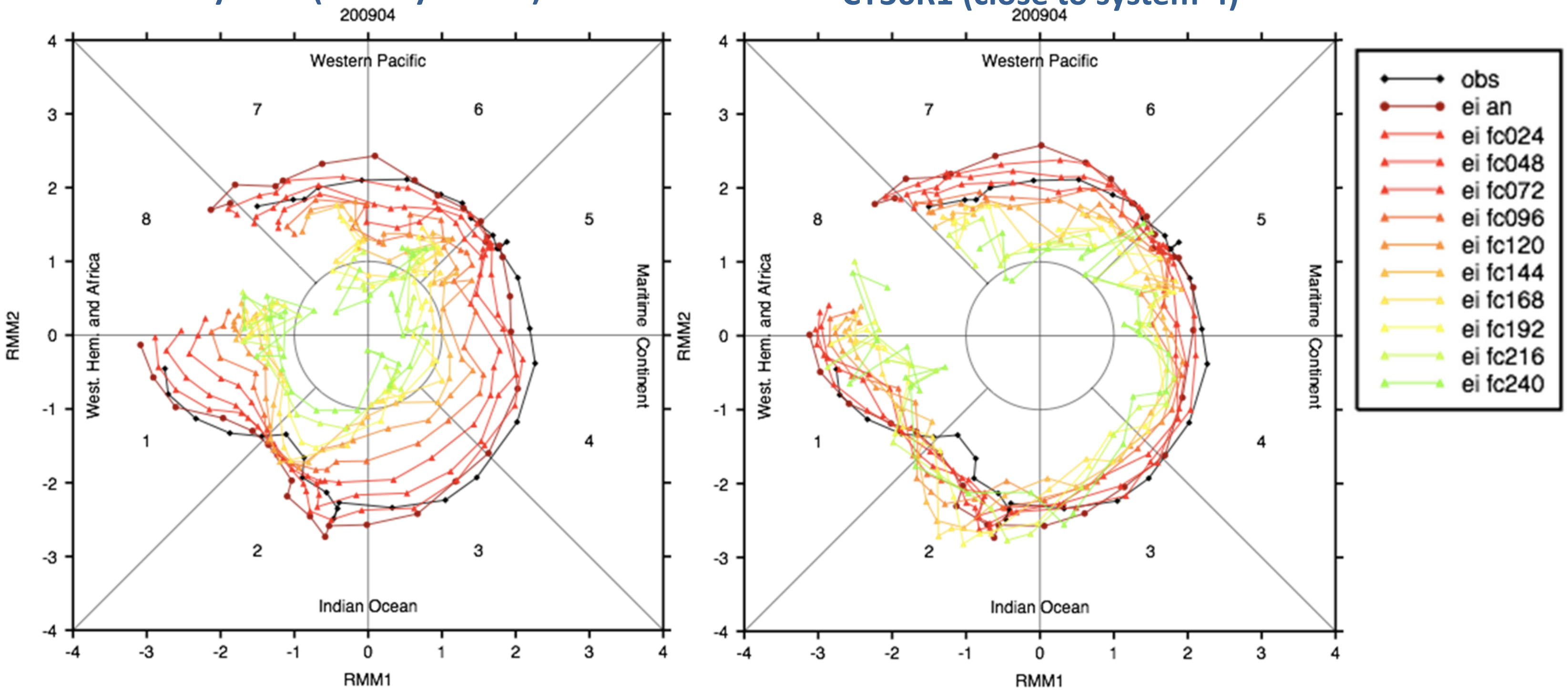


Progression in tropical precipitation modelling as a result of convection improvements (entrainment / detrainment and closure formulations)

a) Better physics > more realistic MJO propagation

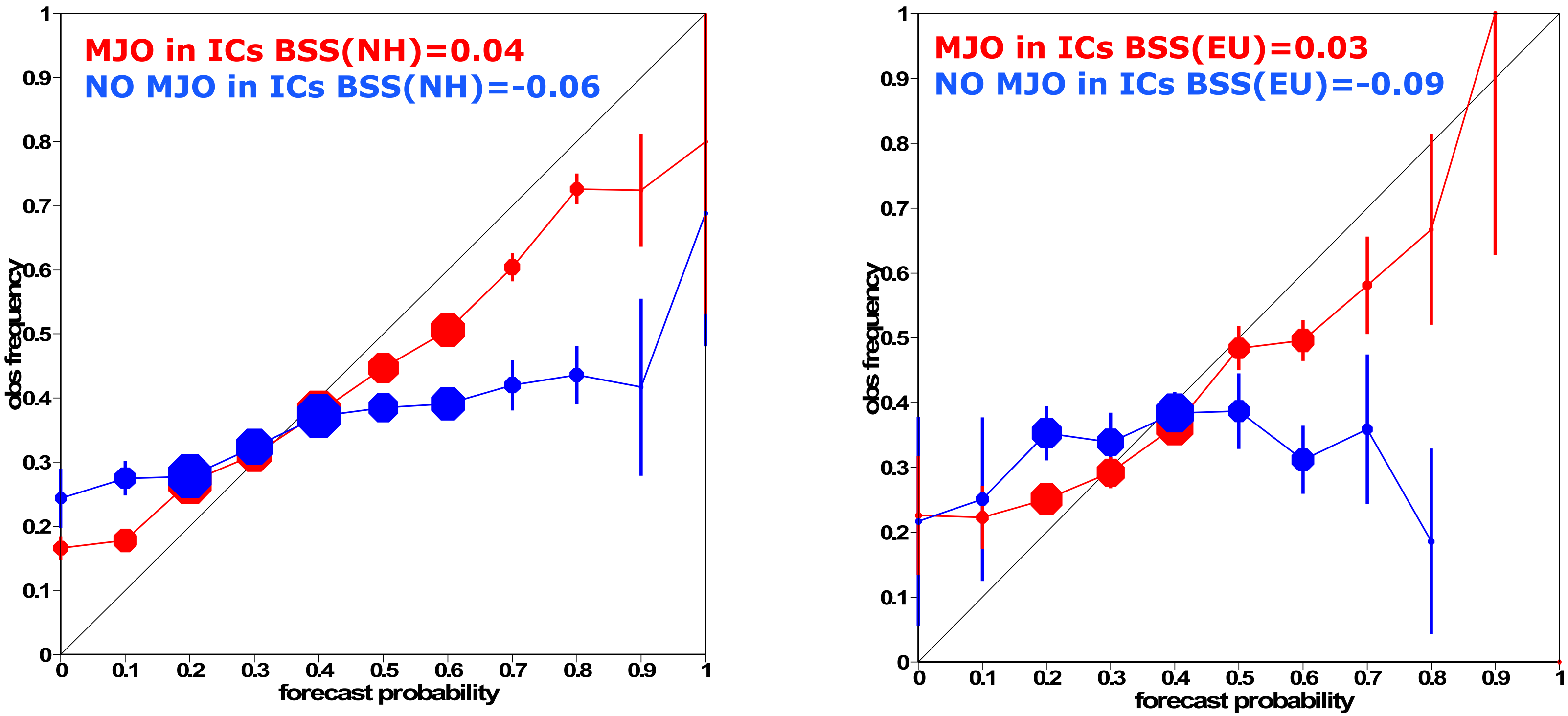
Progression in MJO modelling as a result of convection improvements (entrainment / detrainment and closure formulations).

Cy 31r1 (as in system-3) **CY36R1 (close to system-4)**



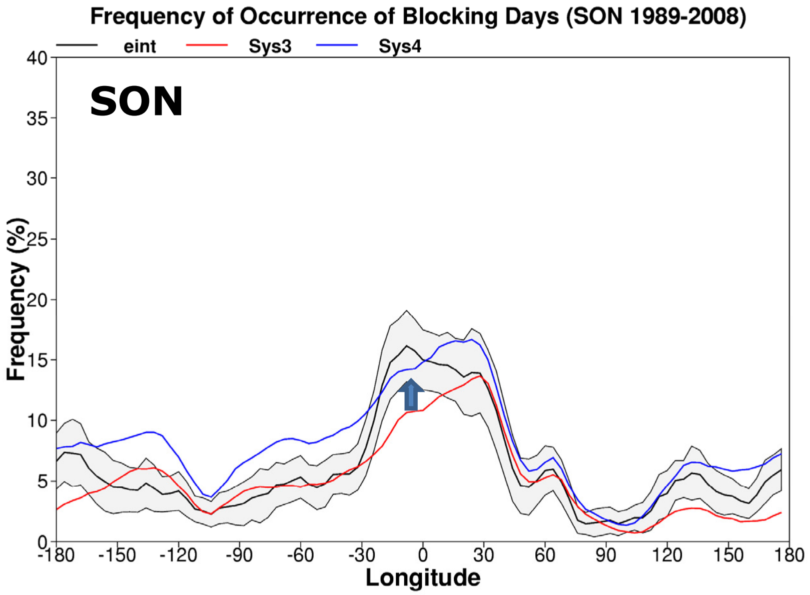
a) Better MJO propagation > higher skill over Europe

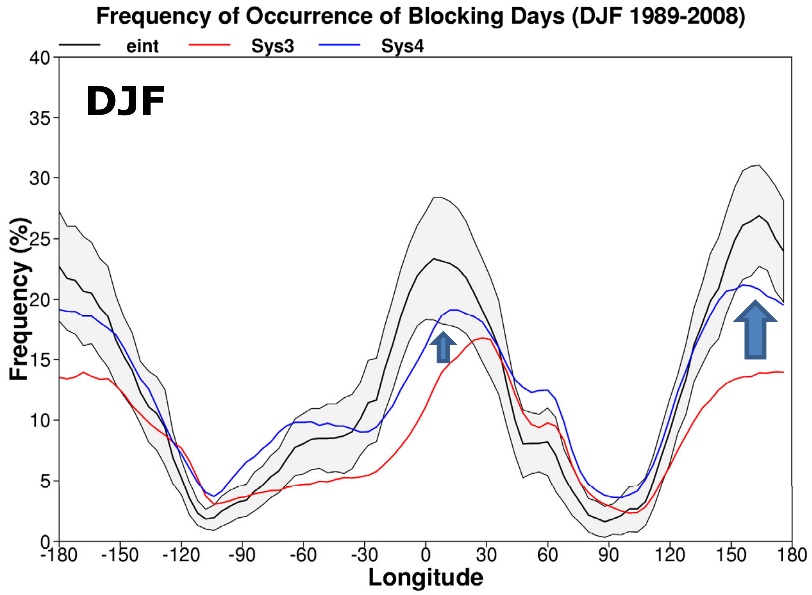
The skill of d19-25 PR(2mT>Upp3) forecasts is higher if there is an active MJO in the Ics. (results based on 45 cases, 1989-2008).



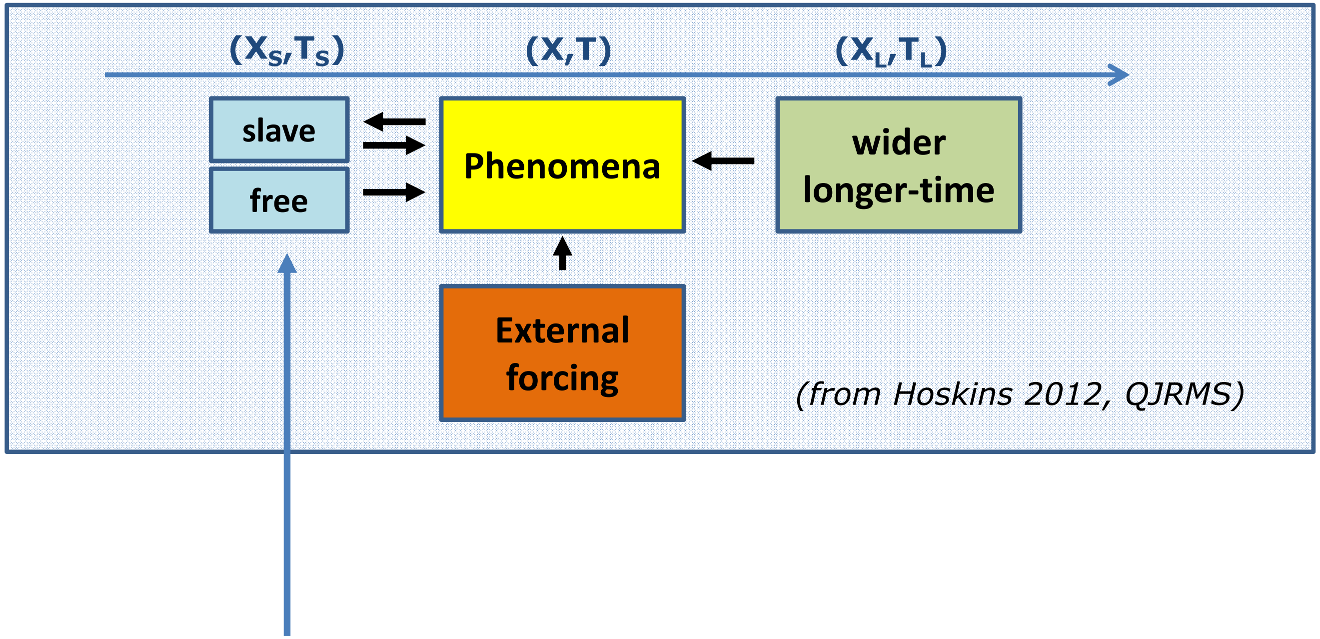
a) Better physics > more realistic blocking statistics

S4 (blue lines) shows better blocking statistics than S3 (red lines) over both the Euro-Atlantic and the Pacific sectors (verified against ERA-I).



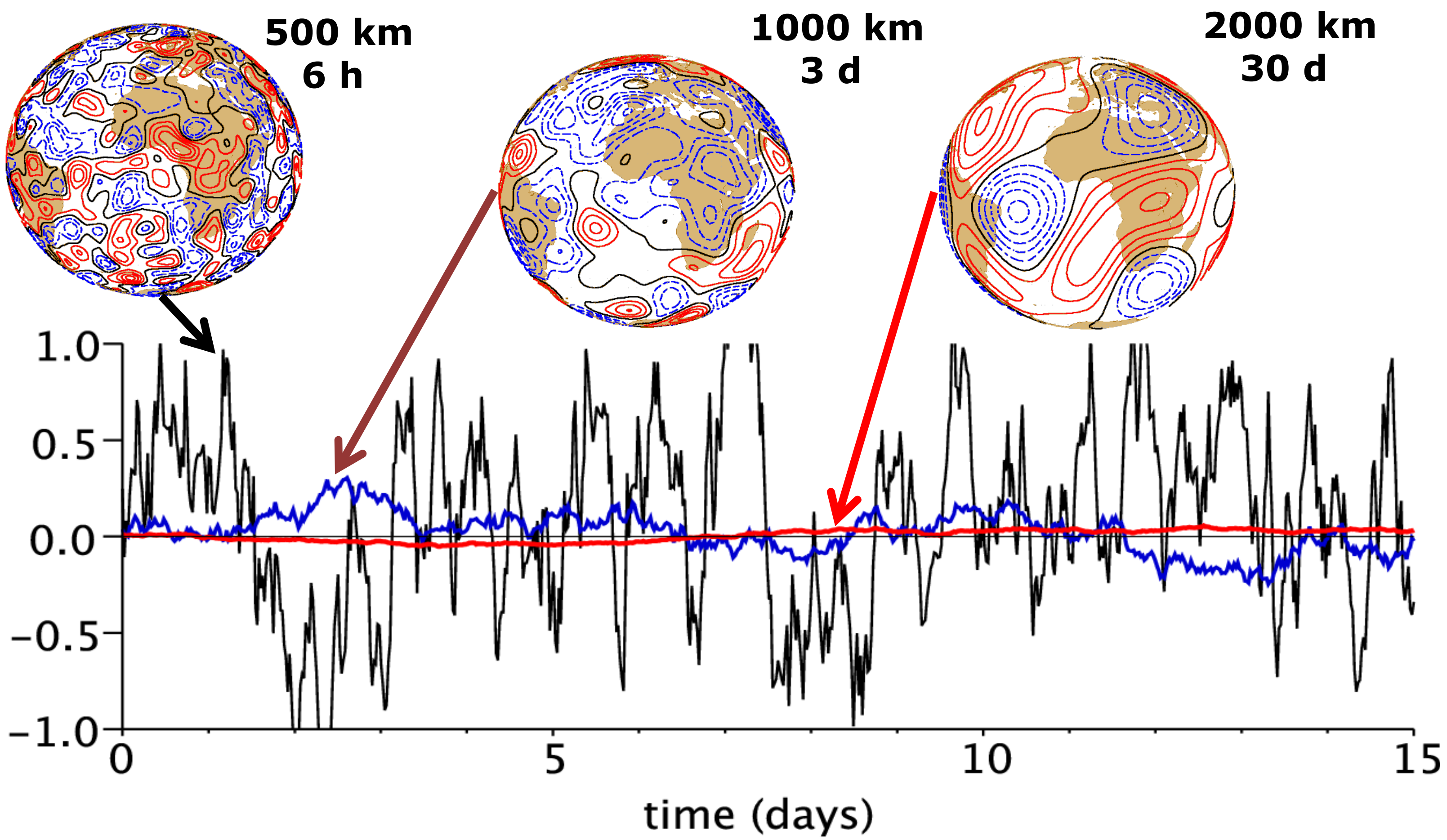


a) The free scales and stochastic schemes



How can we simulate the effect of the 'unresolved scales'?

a) Sub-grid scale (stochastic) processes simulation

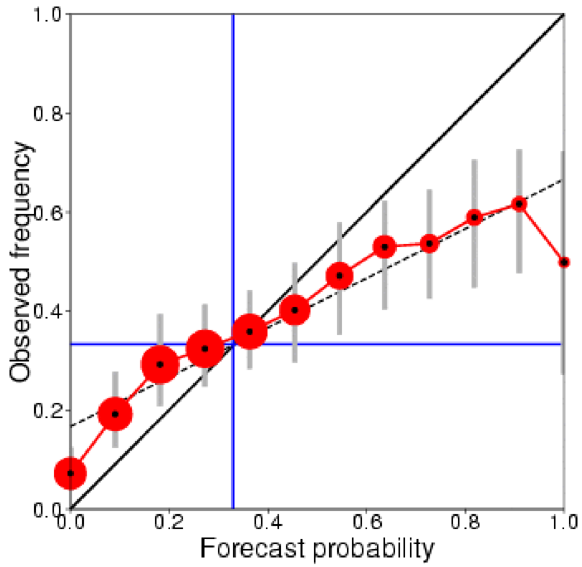


a) Improved sub-grid scale processes > better reliability

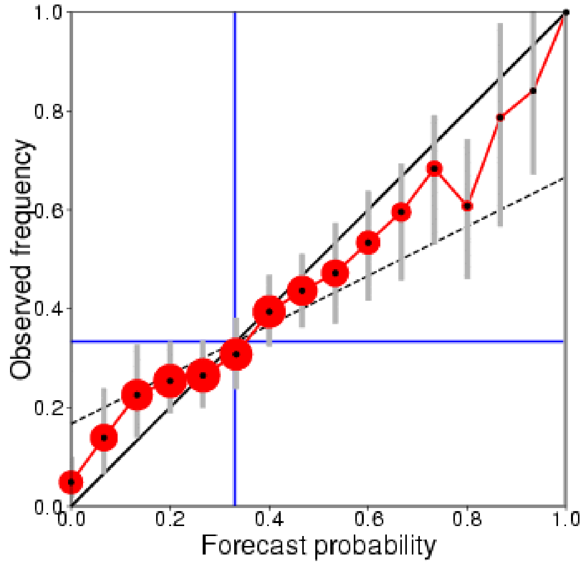
Improvements in the simulation of model uncertainties lea to enhanced internal variability, better reliability and higher skill.

BSS PR(2mT>U3)	S3	S4
1 May > JJA (t+2-4m)	0.031	**0.092**

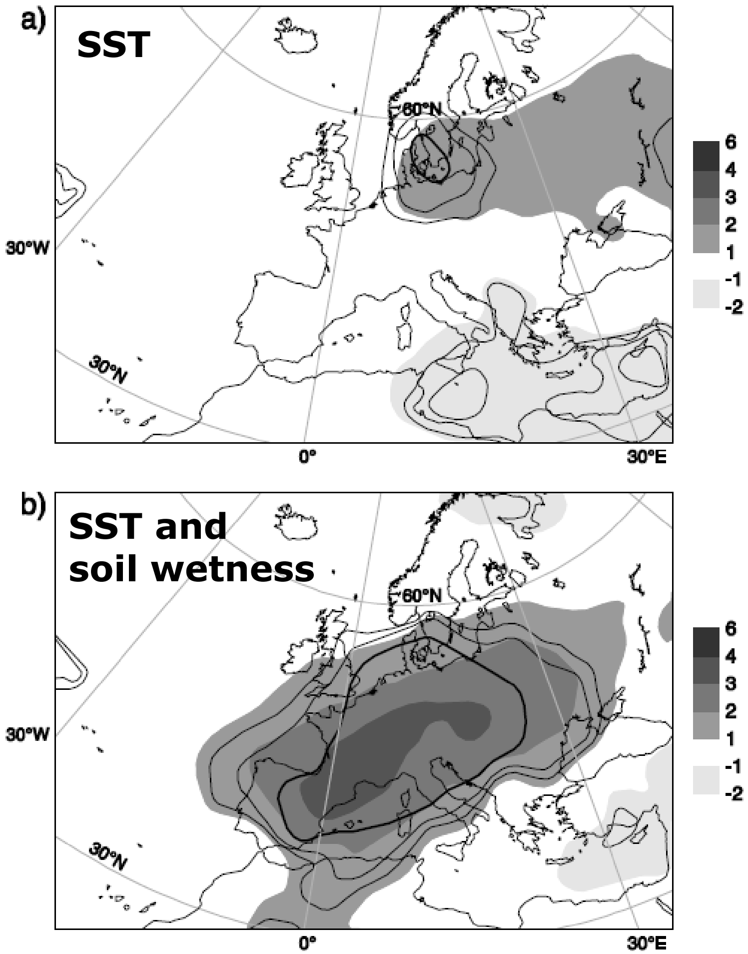
S3 (2007-2011)



S4 (now operational)



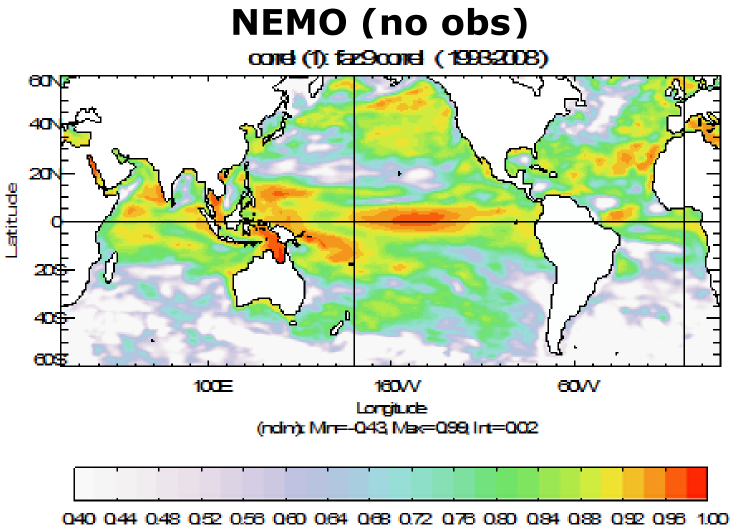
a+b) Better land-surface modelling and ICs

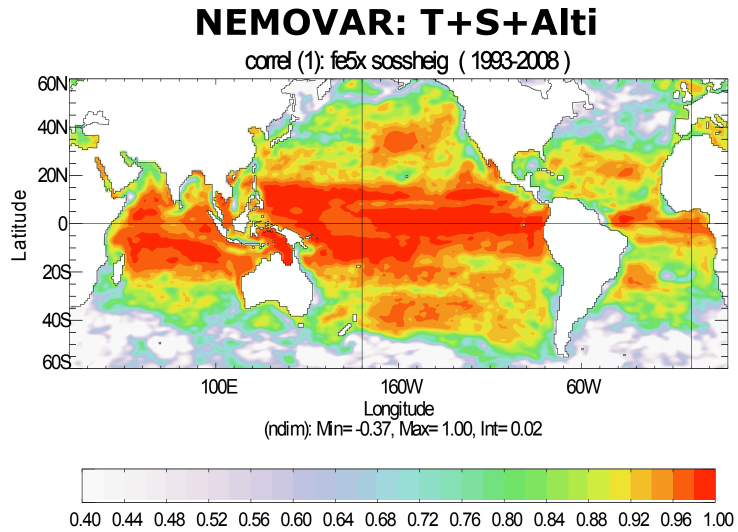


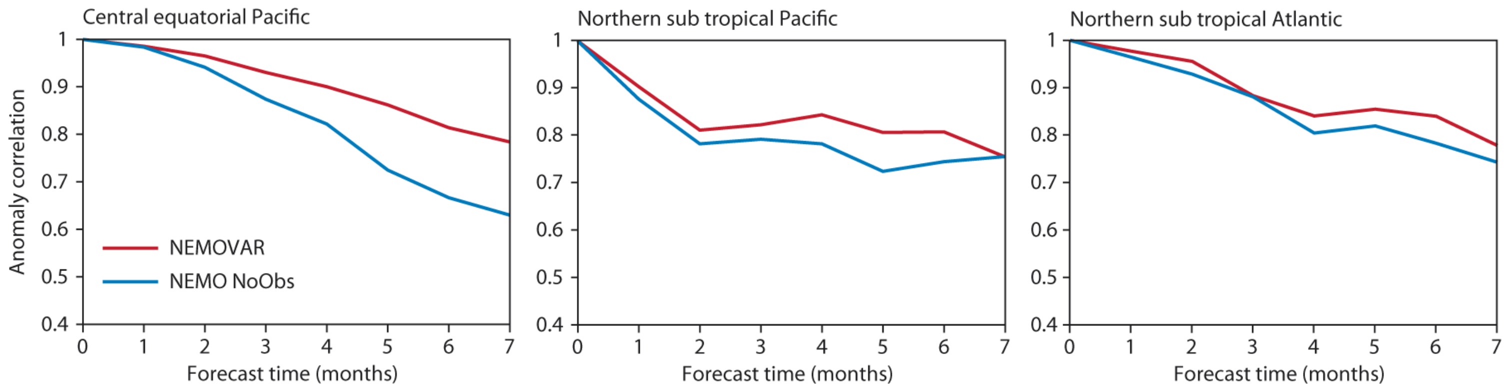
More accurate land-surface modelling and initializations lead to improved skill.

This is shown here for the case of summer 2003. Sensitivity experiments (*Ferranti and Viterbo*, 2006) indicate that using the observed SST (top) and a drier soil wetness lead to a more accurate 2mT prediction.

b) Better ocean analysis > better ocean ICs and higher skill

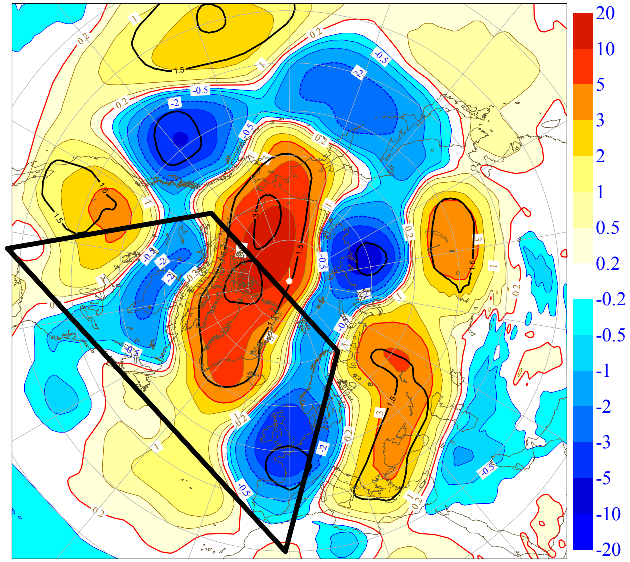




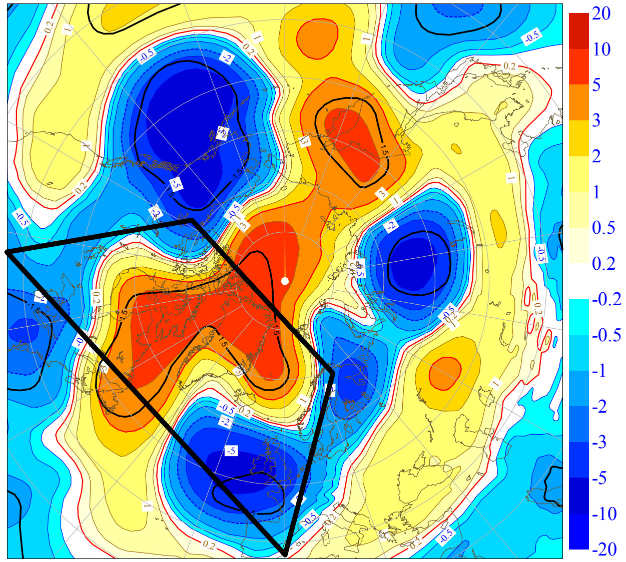


a+b) Impact of the N Atlantic SST on the atmosphere

Z500 anomalies JA 2007 (1979-2001)

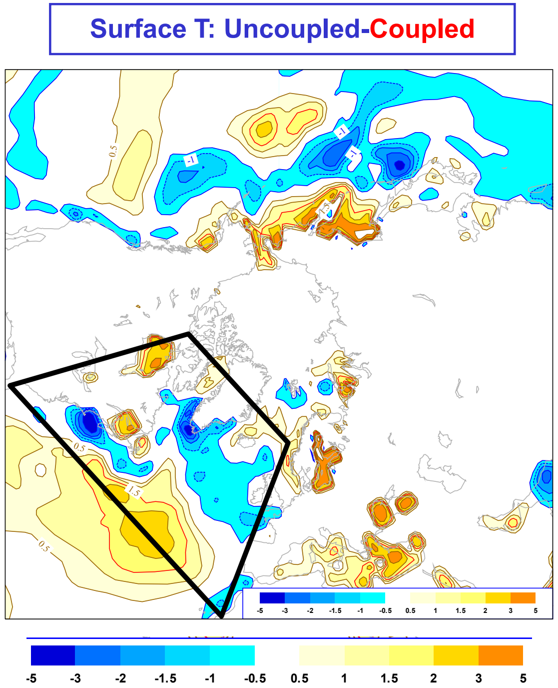


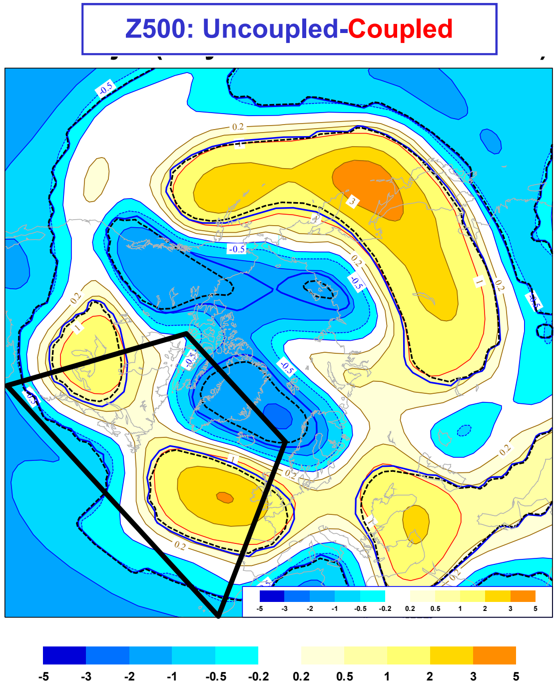
Z 500 anomalies JA 2008 (1979-2001)



The summers of 2007 and 2008 were cold and wet for western Europe. These summers were characterized by strong Arctic high and low pressure over western Europe. Did the ocean (and the sea-ice) play any role?

a+b) Impact of the N Atlantic SST on the atmosphere





Sensitivity experiments (with S3):

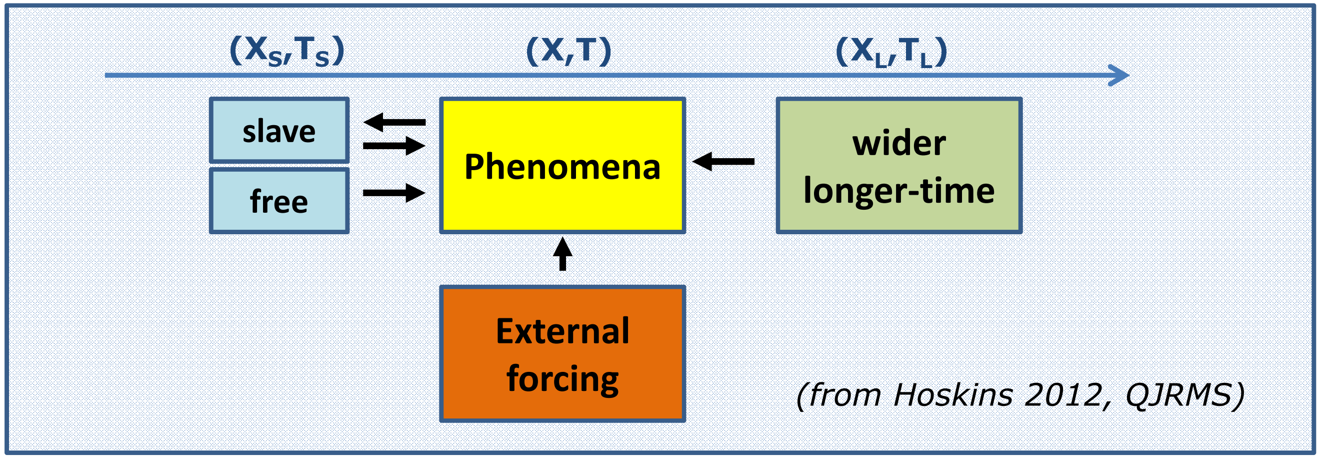
- **Uncoupled**: fixed SST
- **Coupled**: HOPE SST (predicted)

Uncoupled/coupled/partially-coupled integrations can be compared to assess the impact of the Atlantic SST on the atmospheric circulation. Results show that coupling induces large SST differences in the north western Atlantic, and this induces a higher arctic ridge and a lower trough over Europe (right).

The opportunities lie where the main challenges are

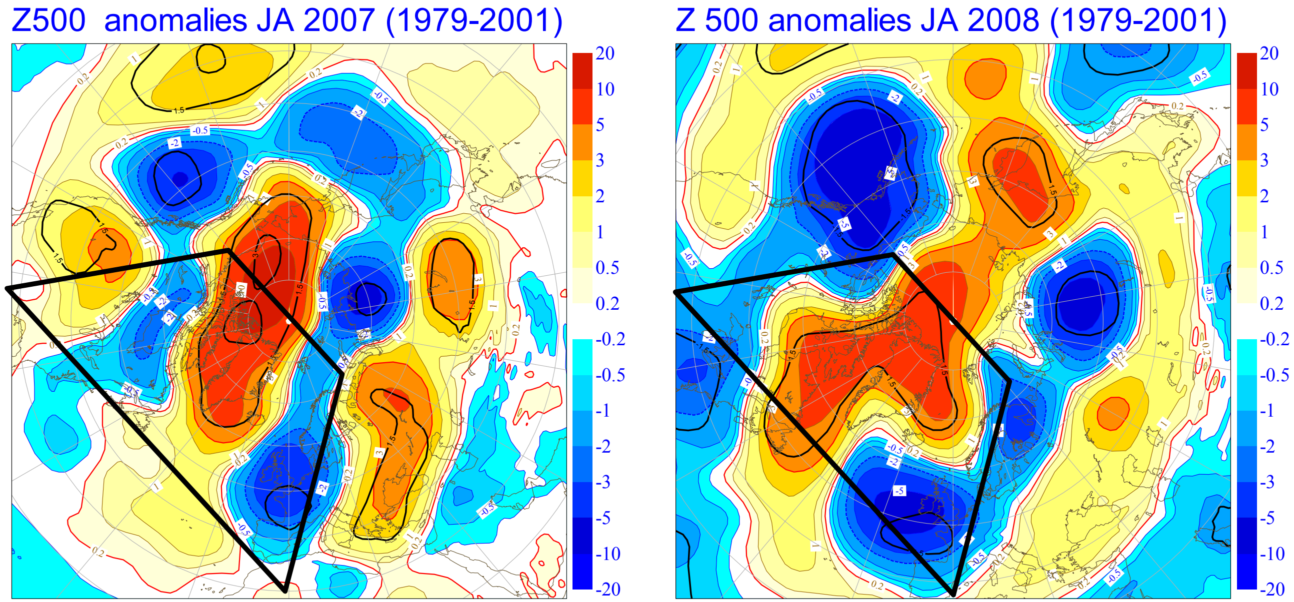
Our opportunities are to address the two key challenges by:

- Improving the design of simulated processes,
- including the missing processes, and
- Initializing accurately all model components (ocean, land, atmosphere).



(from Hoskins 2012, QJRMS)

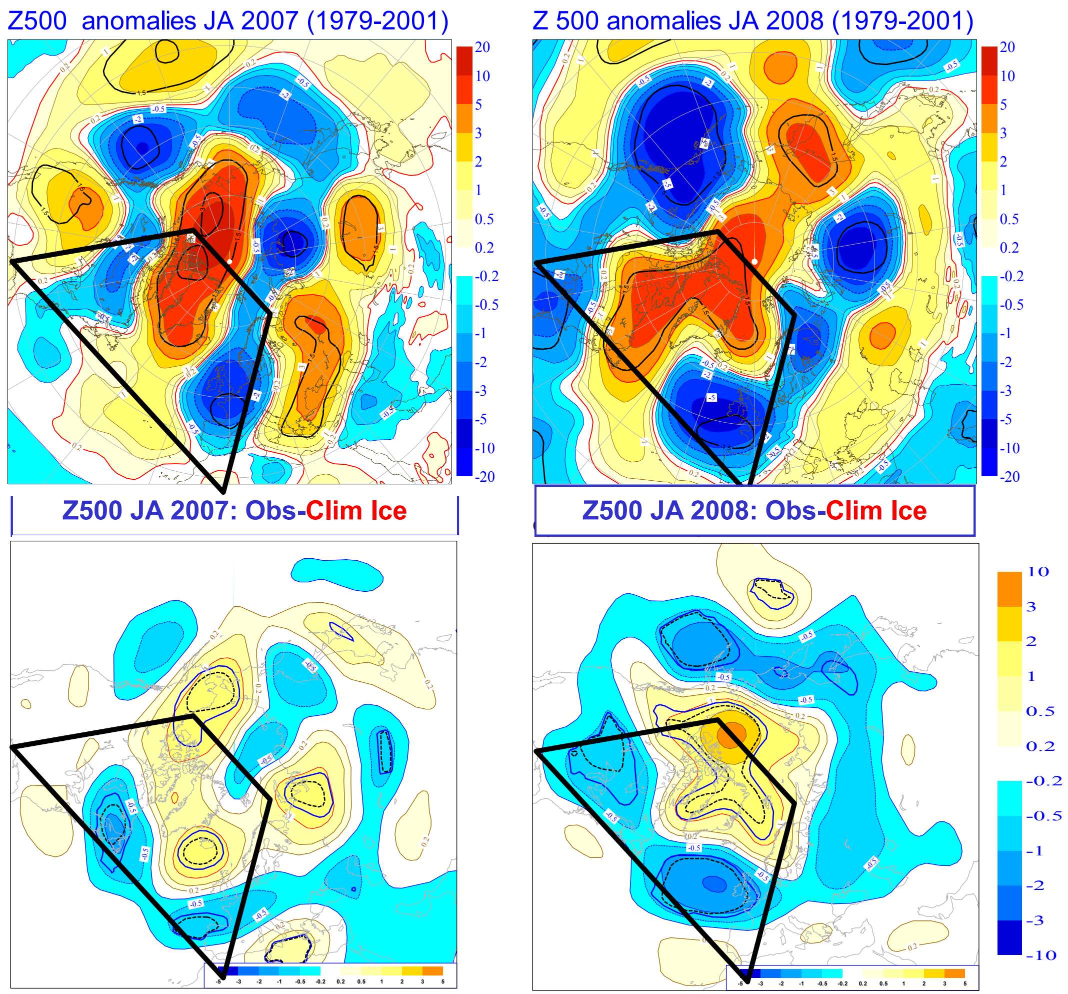
Science/understanding: impact of sea-ice on atmosphere



As already discussed, both summers 2007 and 2008 were characterized by a low over Western Europe and North-East America, and high pressure over the Arctic.

Did sea-ice contribute to the large-scale anomalies?

Science/understanding: impact of sea-ice on atmosphere



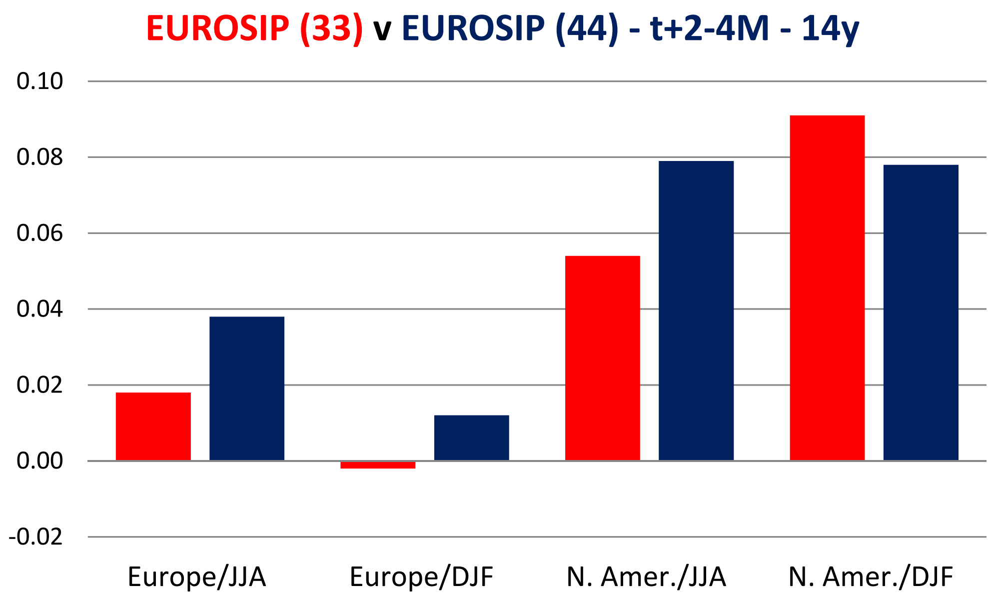
Sensitivity experiments indicate that integrating the atmospheric model forced with the observed sea-ice contributes to the development of the right type of anomaly over the North Atlantic-European.

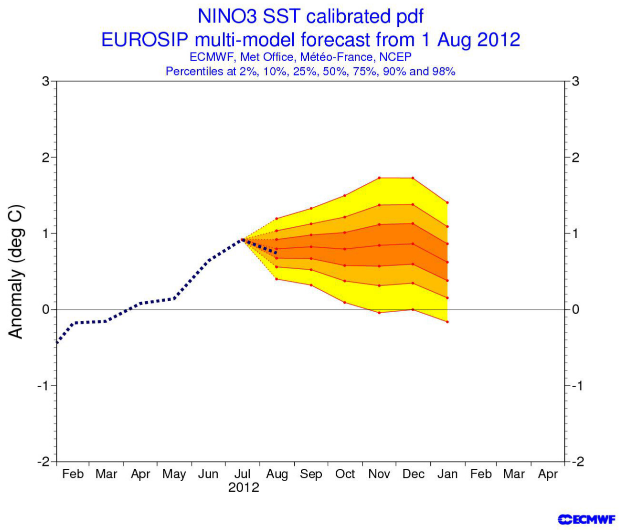
Sensitivity experiments (with S3):

- **obs**: observed sea-ice
- **Clim ice**: climatological sea-ice

Science/understanding: single- v multi-model approach

- Research has consistently shown that better and more reliable seasonal forecasts can be created by combining the output from several models
- Can this approach be used to improve the simulation of model uncertainty and simulate the 'unresolved scales'? EUROSIP is using this approach.

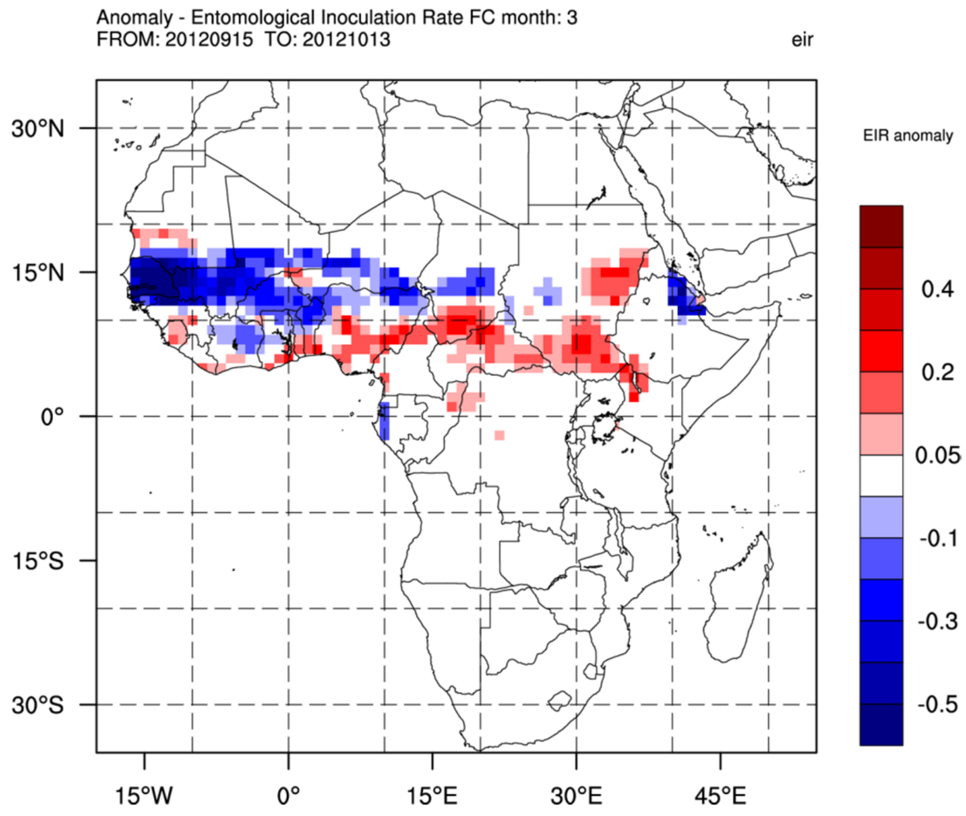




Let’s not forget to build new, target, valuable products!

ECMWF is helping users develop tailored applications in the health sector (**QWECI** project). This figure shows the first malaria outbreak forecast.

The figure shows a prototype 3m forecast for 15 Sep – 13 Oct 2012 of the Entomological Inoculation Rate (EIR) computed using the ICTP malaria model **VECTRI**, driven by S4 t+3m daily TP and T2m.



[from F di Giuseppe & A Tomkins (ICTP)]

Conclusions

- Dynamical, coupled seasonal forecasts are better than statistical ones.

- Further developments of dynamical coupled systems will lead to improvements, especially in the most difficult areas (e.g. Europe).

- At ECMWF, we are working to further improve all aspects of our system:
  - Simulation of all processes (ocean/land/atmosphere)
  - Inclusion of uncertainty estimation in all components
  - Unification of the ocean wave/currents/sea-ice model
  - Coupled analysis (and re-analysis)
  - Resolution
  - Products
  - Diagnostics and verification