Prediction of Arctic sea ice on subseasonal to seasonal time scales

Lorenzo Zampieri
lorenzo.zampieri@awi.de

Alfred Wegener Institute for Polar and Marine Research

8th International Workshop on Sea Ice Modelling Data Assimilation and Verification

November 3rd, 2017

Overview

- Research Motivation and Objectives
- S2S Forecasts and Observations
- The Verification Metrics
- Predictive Skills of S2S Forecasts Systems
- Comparison of Predictive and Prescriptive Systems
- Considerations on Metrics Behavior

Research Motivations and Objectives

Key Questions

- **Do (sub)seasonal forecast systems have predictive skills for the sea ice edge position?**

Key Questions

- **Do (sub)seasonal forecast systems have predictive skills for the sea ice edge position?**

- **Are we able to properly verify the sea ice distribution in the Arctic?**

Forecasts and True State

The Forecasts - S2S Database

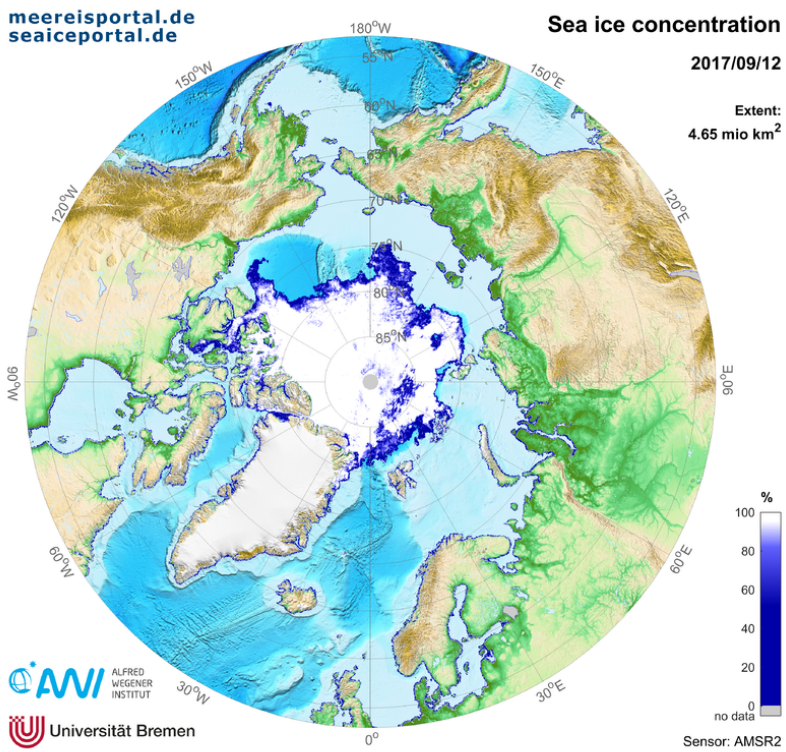
Op. Centers	Ocean	Sea Ice	Frequency	Ens. Size	Length
BoM	✓		twice a week	33	62 days
ECCC			weekly	21	32 days
ECMWF[1]			twice a week	51	46 days
HMCR			weekly	20	61 days
ISAC-CNR			weekly	41	31 days
JMA			twice a week	25	33 days
CMA	✓	✓	daily	4	60 days
ECMWF[2]	✓	✓	twice a week	51	46 days
KMA	✓	✓	daily	4	60 days
Météo France	✓	✓	weekly	51	32-61 days
NCEP	✓	✓	daily	16	44 days
UKMO	✓	✓	daily	4	60 days

Vitart et al. (2015)

The "True State"

ASI sea ice concentration data produced by **University of Bremen**.

The resolution is $\sim$ 6 km.

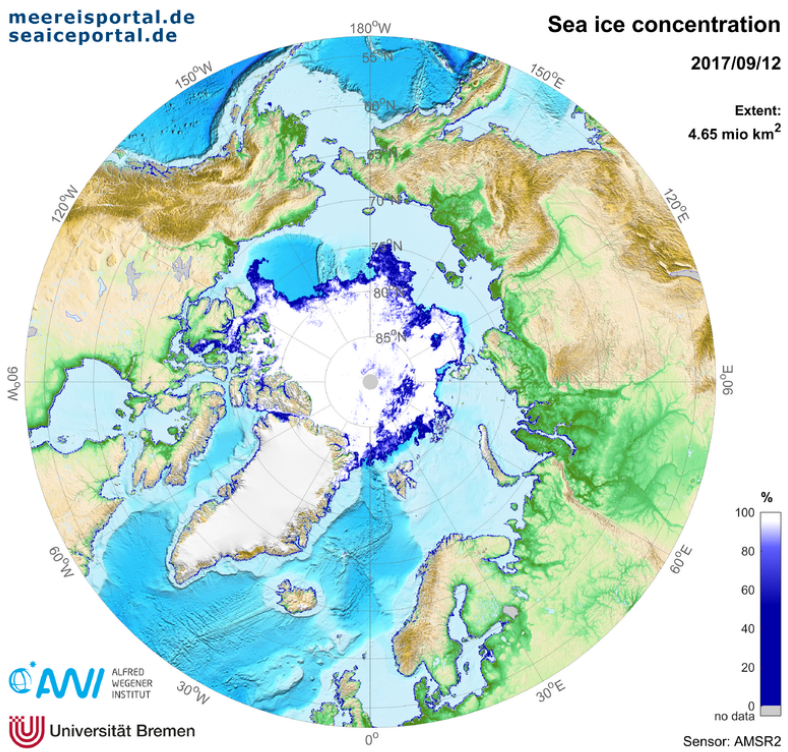


Spreen et al. (2008)

The "True State"

ASI sea ice concentration data produced by **University of Bremen**.

The resolution is ~ 6 km.



Models own analysis

The idea behind the models own analysis is to approximate the real sea ice conditions with the control forecasts evaluated at $t = 0$.

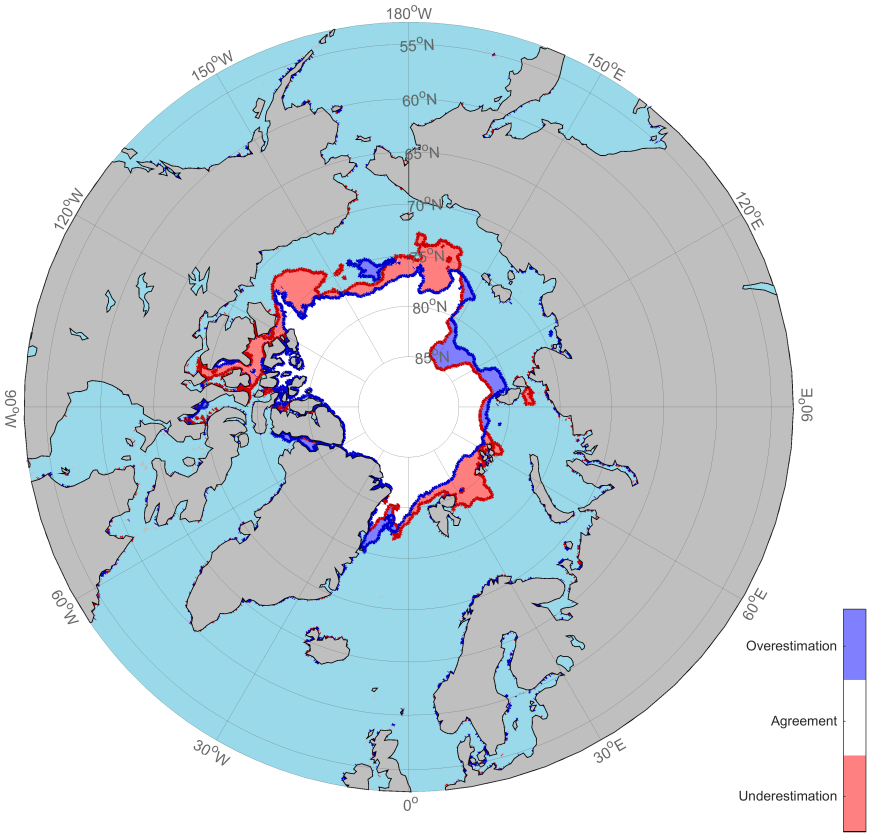
Assuming that the initialization process is handled properly!

Verification Metrics

IIEE - Integrated Ice Edge Error

Observation edge

Forecast edge



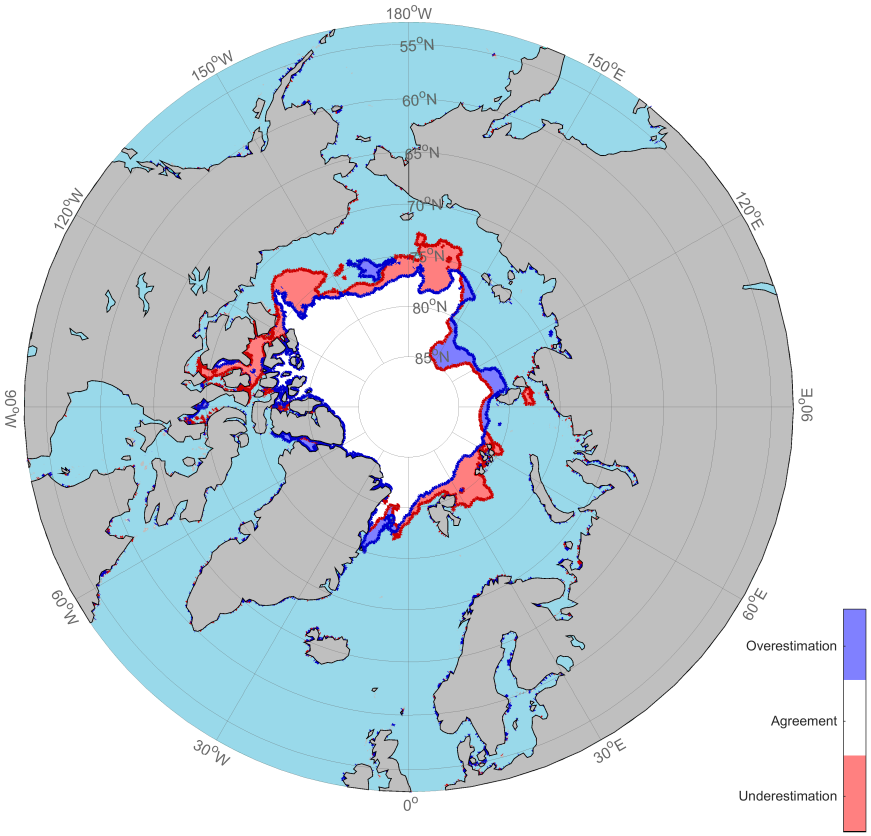
$$IIEE = O + U$$

Goessling et al. (2016)

IIEE - Integrated Ice Edge Error

Observation edge

Forecast edge



$$IIEE = O + U$$

$$IIEE = AEE + ME$$

Absolute Extent Error

$$AEE = |O - U|$$

&

Misplacement Error

$$ME = 2min(O, U)$$

SPS - Spatial Probability Score

SPS is the evolution of **IIEE** in the probabilistic forecasts world.
SPS is defined as the spatial integration of the local (Half) Brier Score.

$$SPS = \int_S \left(p_o\left[sic \geq 15\%\right](\vec{x}) - p_f\left[sic \geq 15\%\right](\vec{x})\right)^2 dS$$

- SPS can be applied to deterministic forecast, in this case $SPS = IIEE$
- It allows a probabilistic description of the observations
- SPS is an area (m^2)
- Dividing the SPS (or the IIEE) by the climatological length of the edge we obtain an estimation of the mean distance between the edges

Goessling and Jung

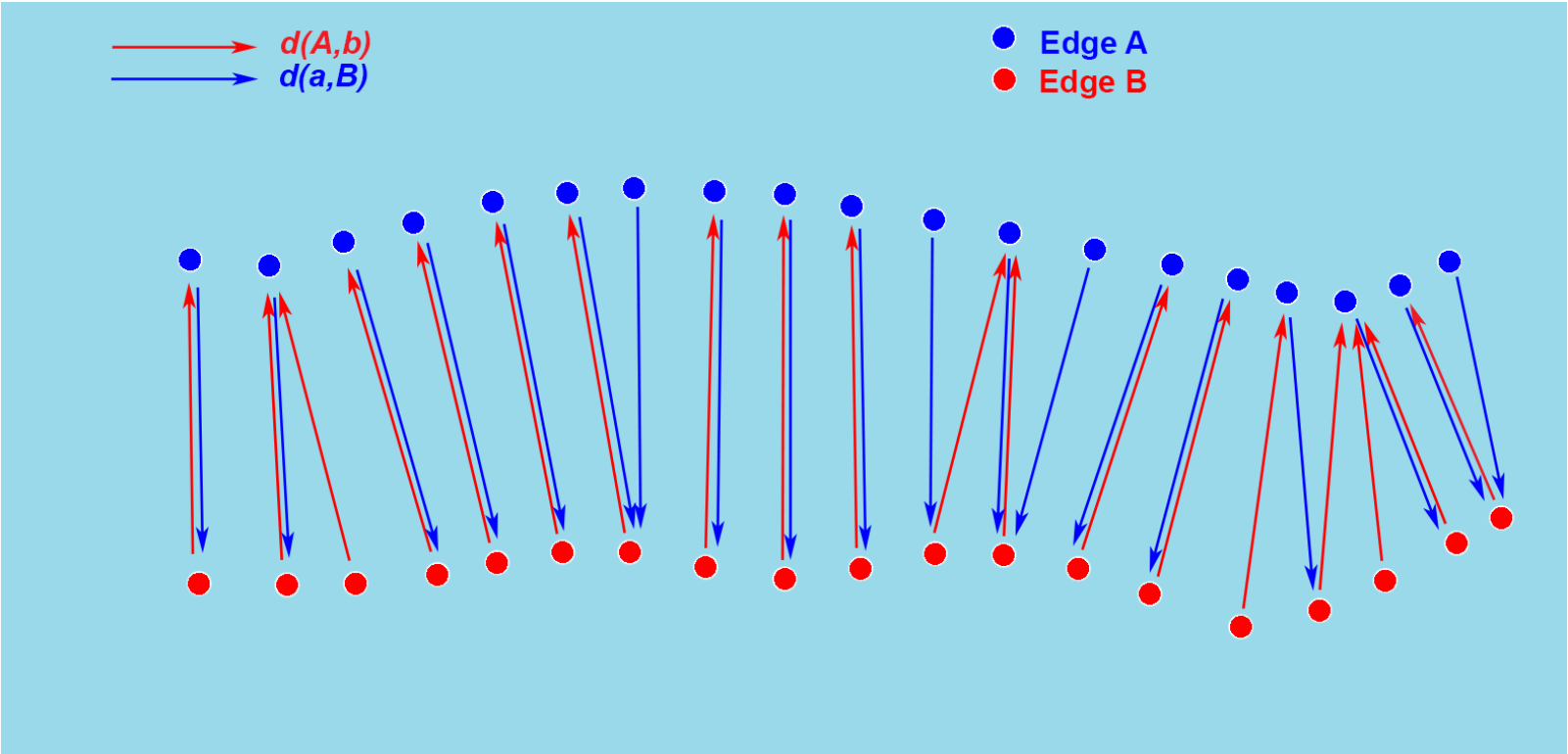
MHD - Modified Hausdorff Distance

$$\mathrm{MHD}(A,B) = max\left\{\frac{1}{|A|}\sum_{a\in A} d(a,B),\ \frac{1}{|B|}\sum_{b\in B} d(A,b)\right\}$$

$$d(a,B) = \inf_{b\in B}\ [d(a,b)]$$

$$d(A,b) = \inf_{a\in A}\ [d(a,b)]$$

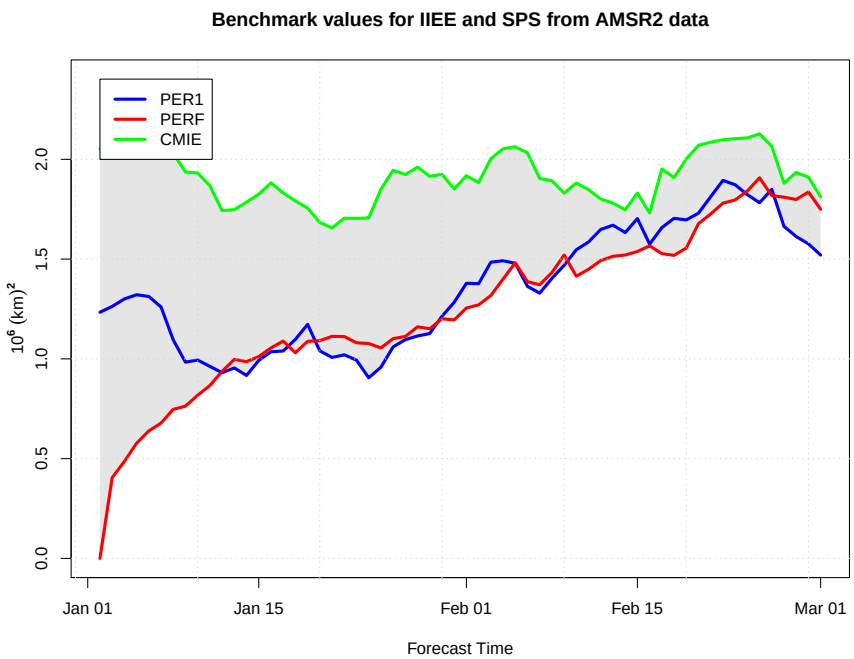
Dukhovskoy et al. (2015)

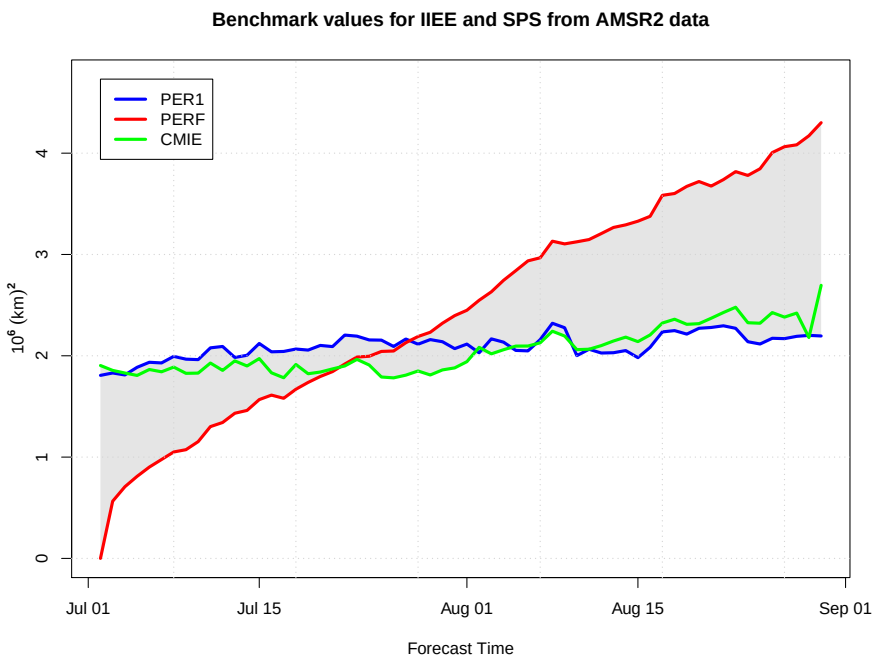


Benchmark values for IIEE and SPS

IIEE and SPS are not straightforward to interpret without reference values. Those have been calculated using the observed sea ice concentration

- **Persistence from the previous year** (PER1)
- **Persistence from forecast beginning** (PERF)
- **Climatological median ice edge** (CMID)



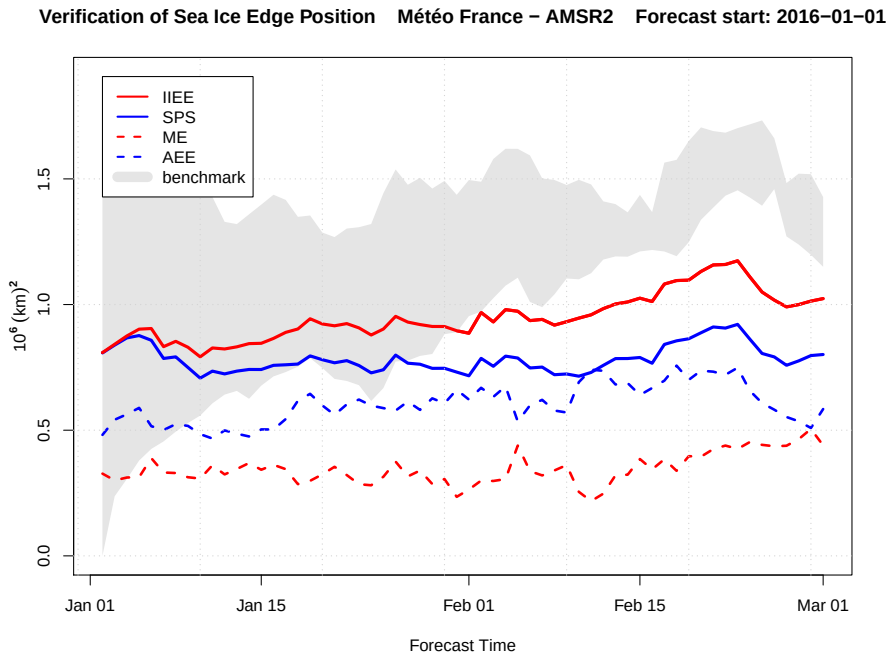


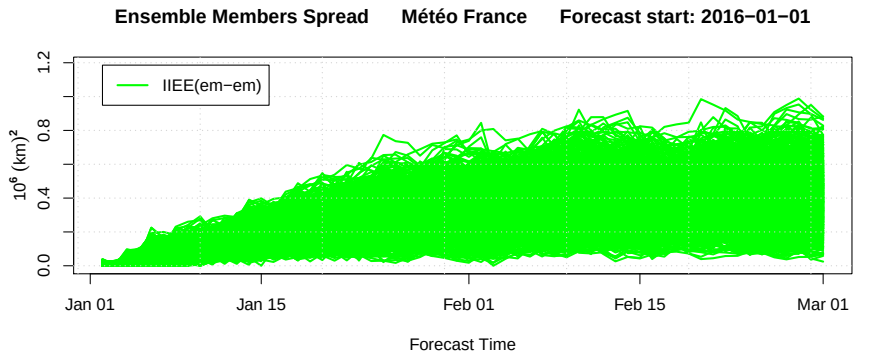
Predictive Skills of S2S Forecast Systems

Single Forecast Verification

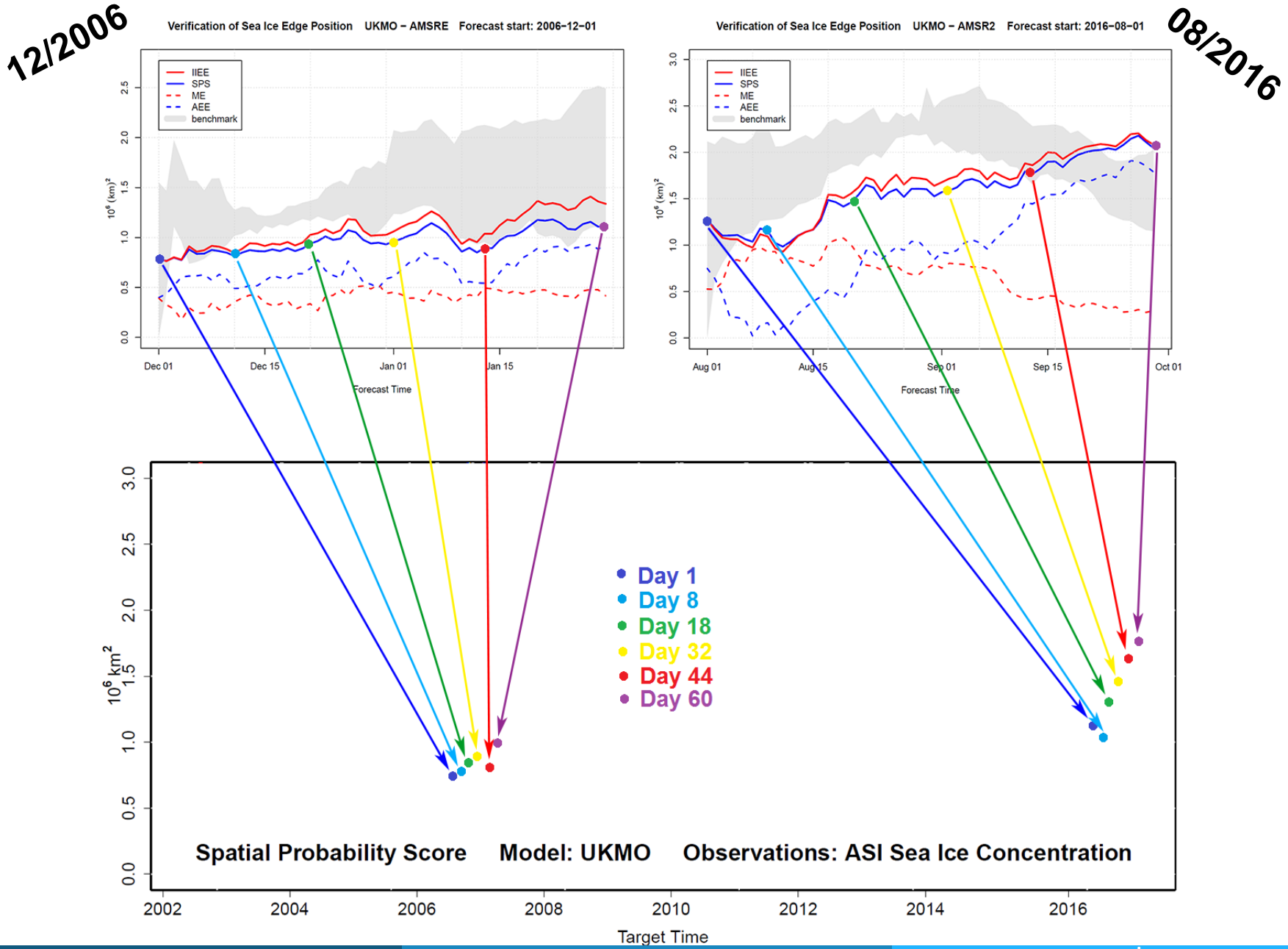
Ens. members: 50
Start: 01.01.2016

Forc. length: 60 days

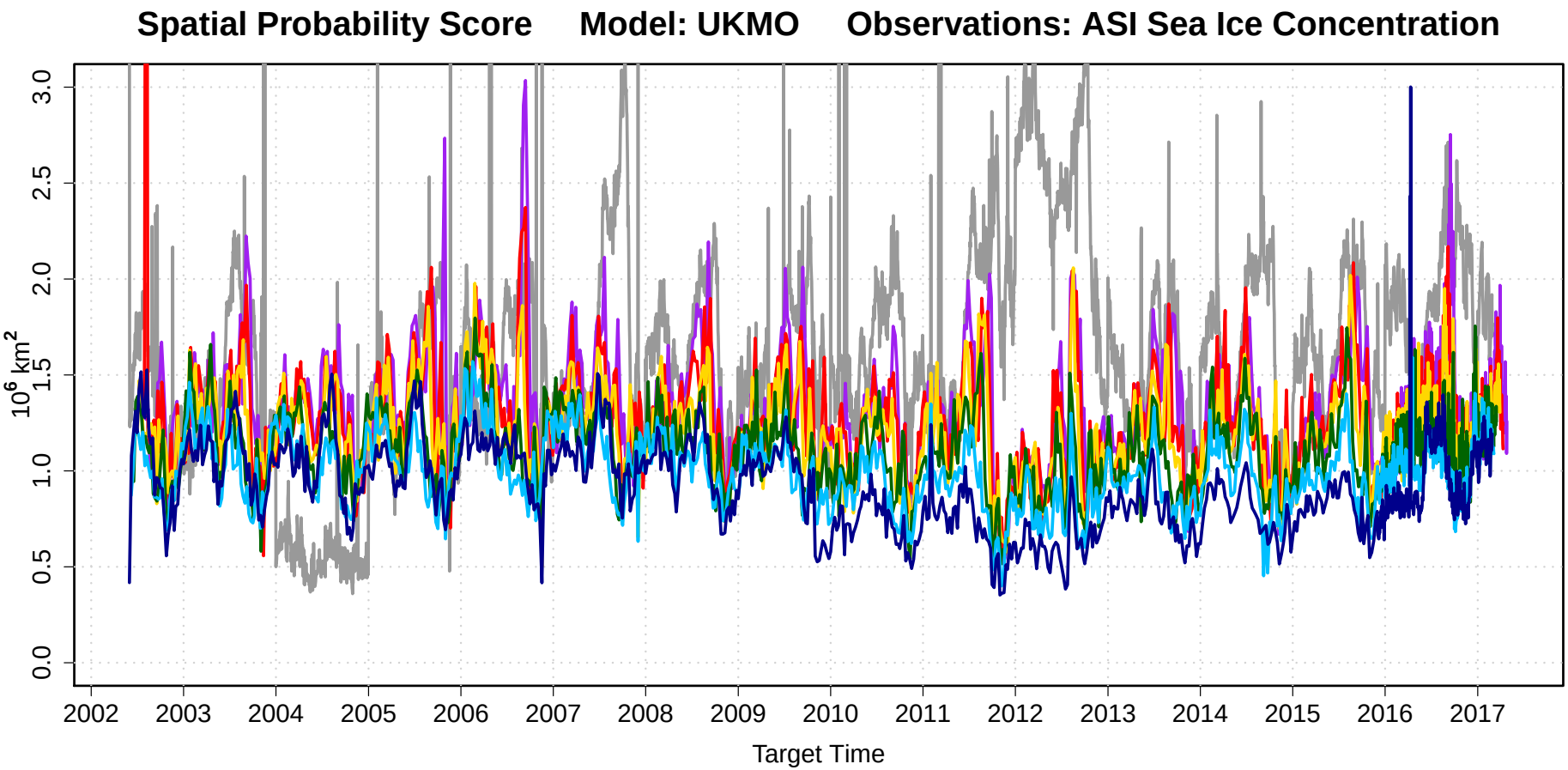




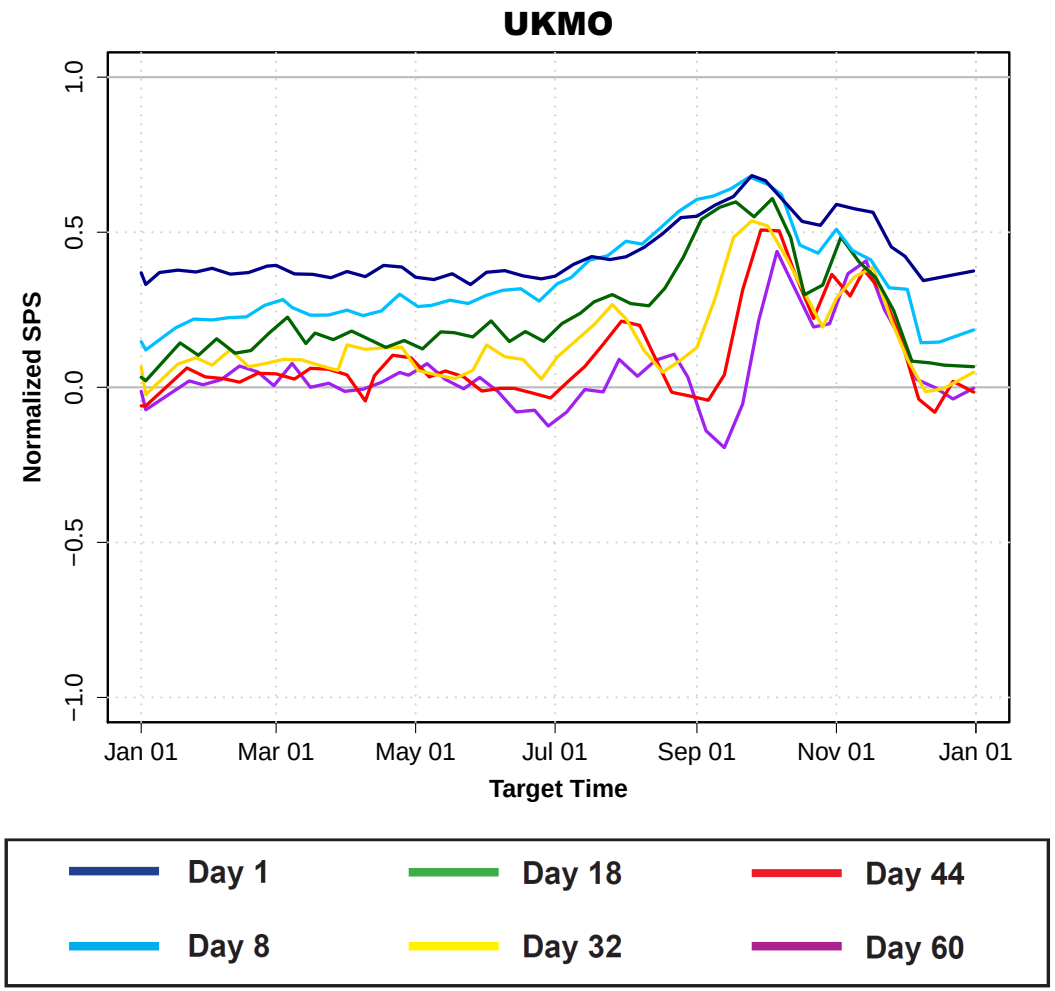
Extensive visualization of the results

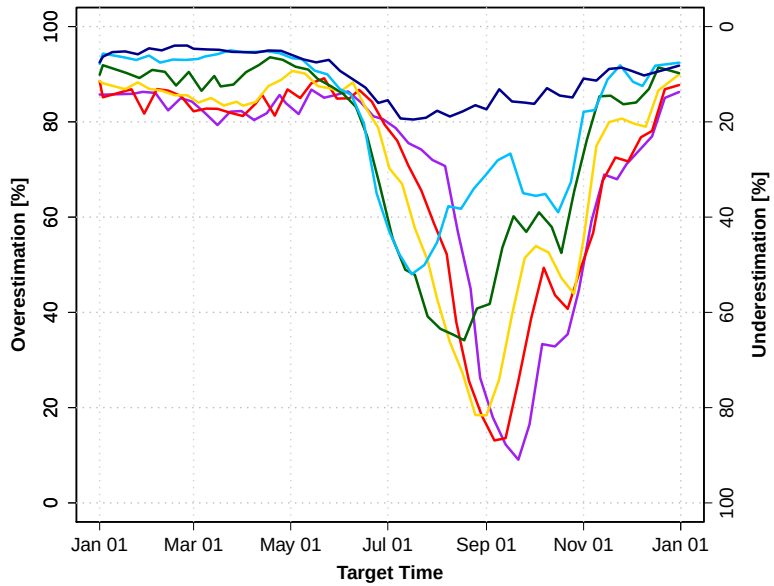


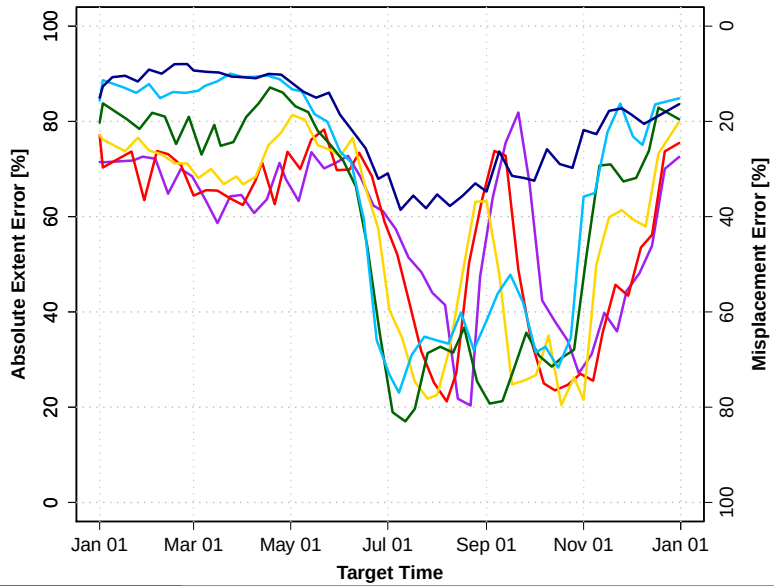
Extensive visualization of the results



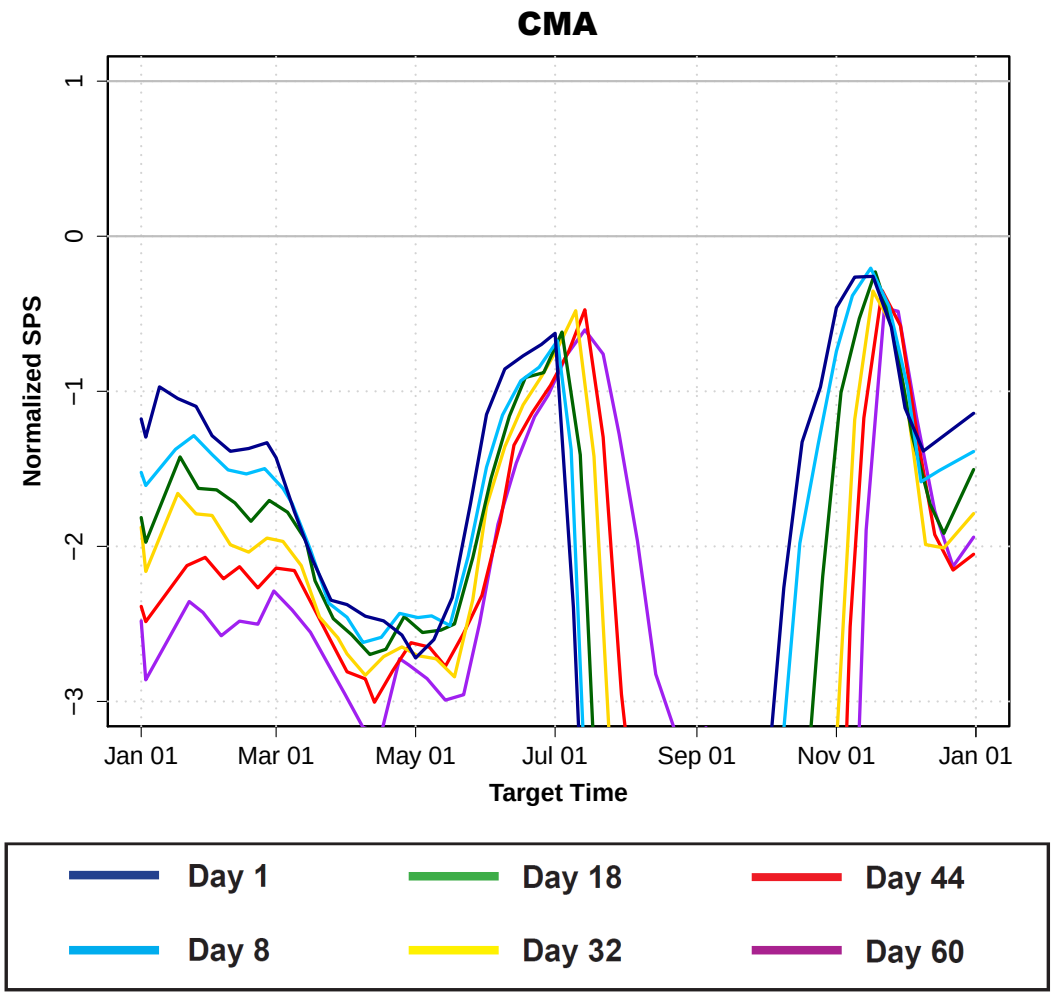
UKMO Predictive Skills

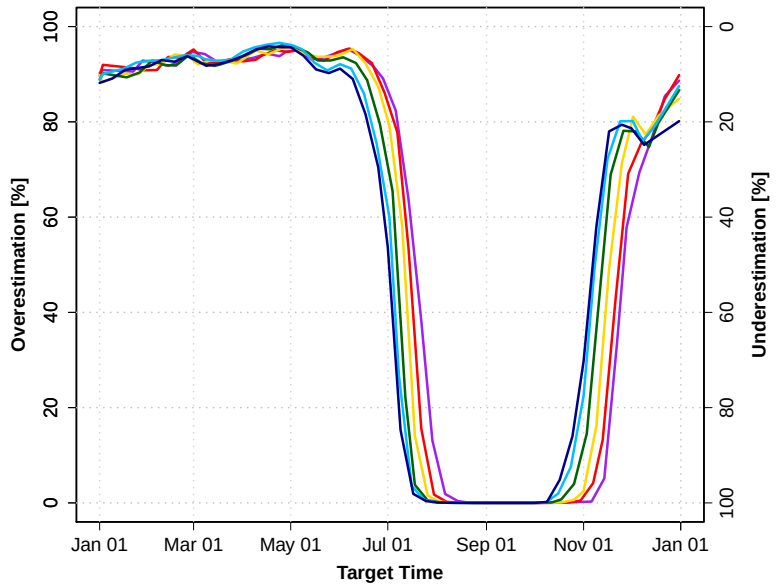


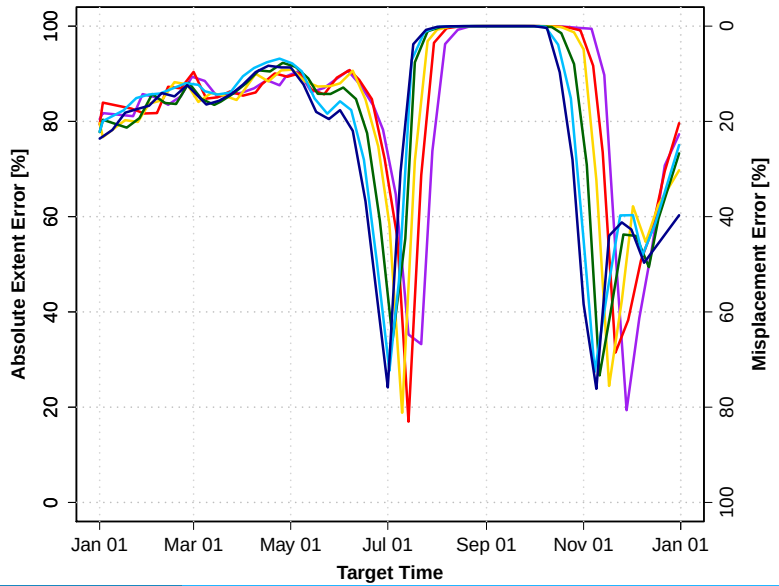




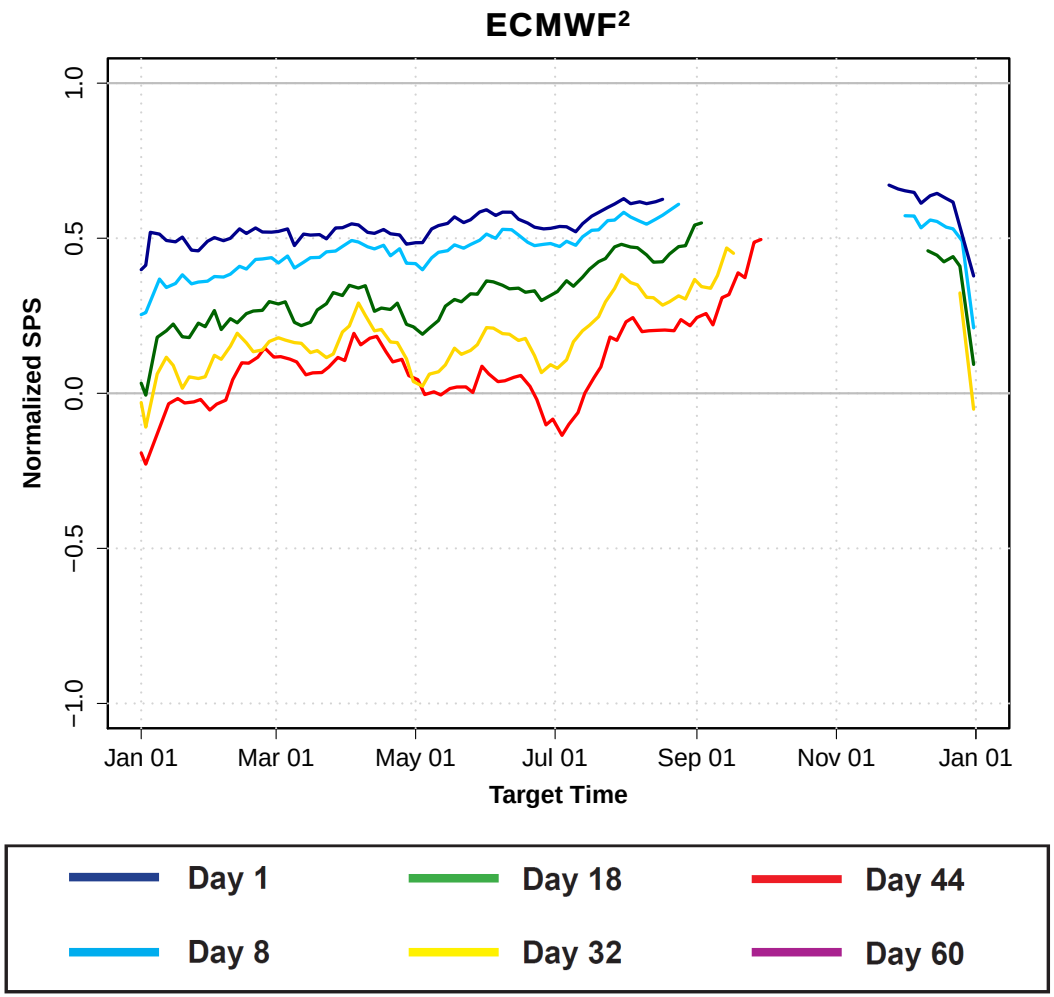
CMA Predictive Skills

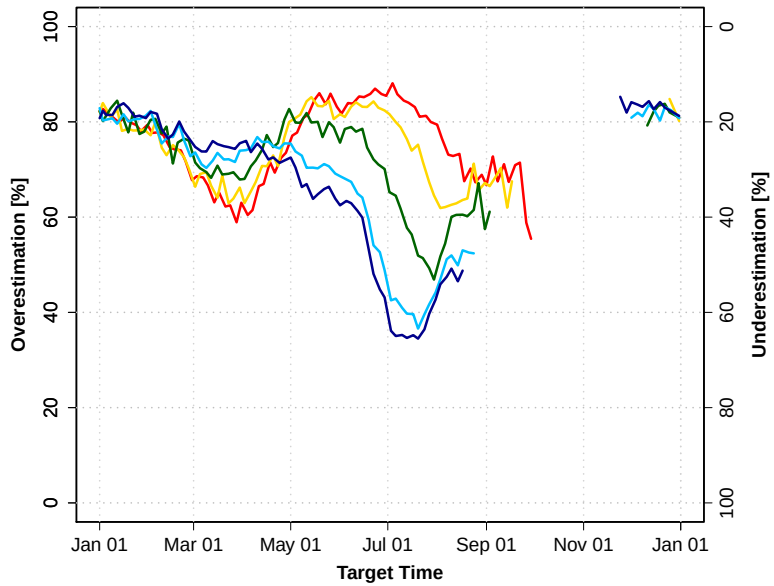


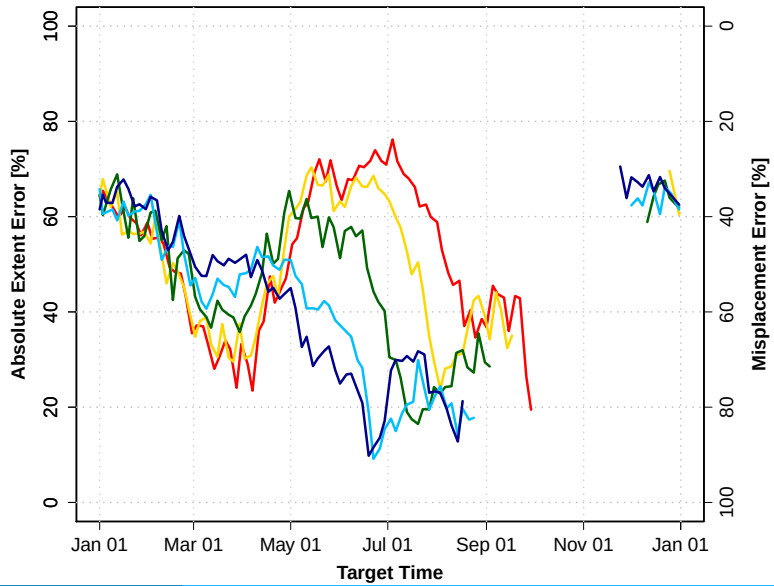




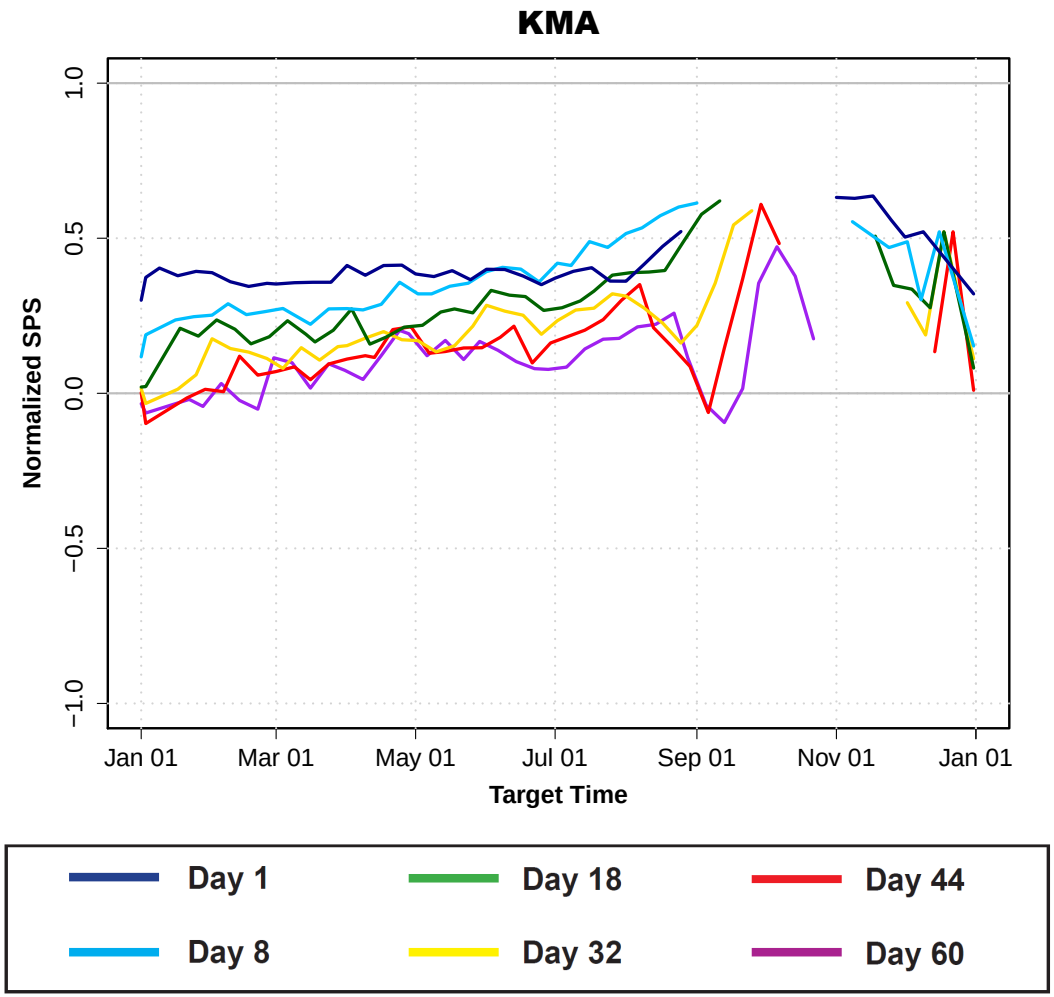
ECMWF^2 Predictive Skills

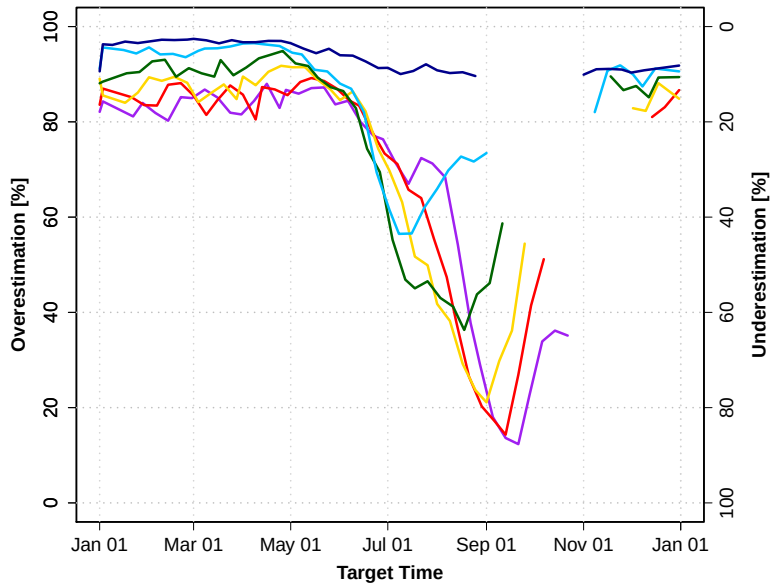


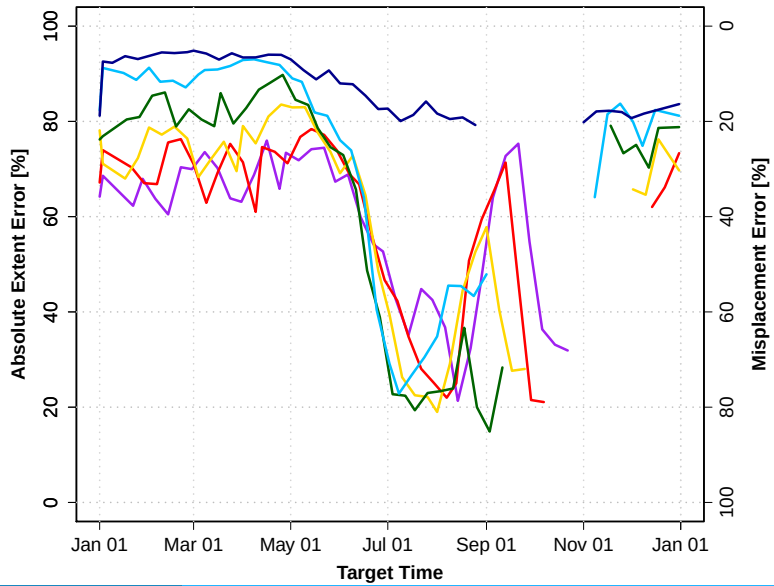




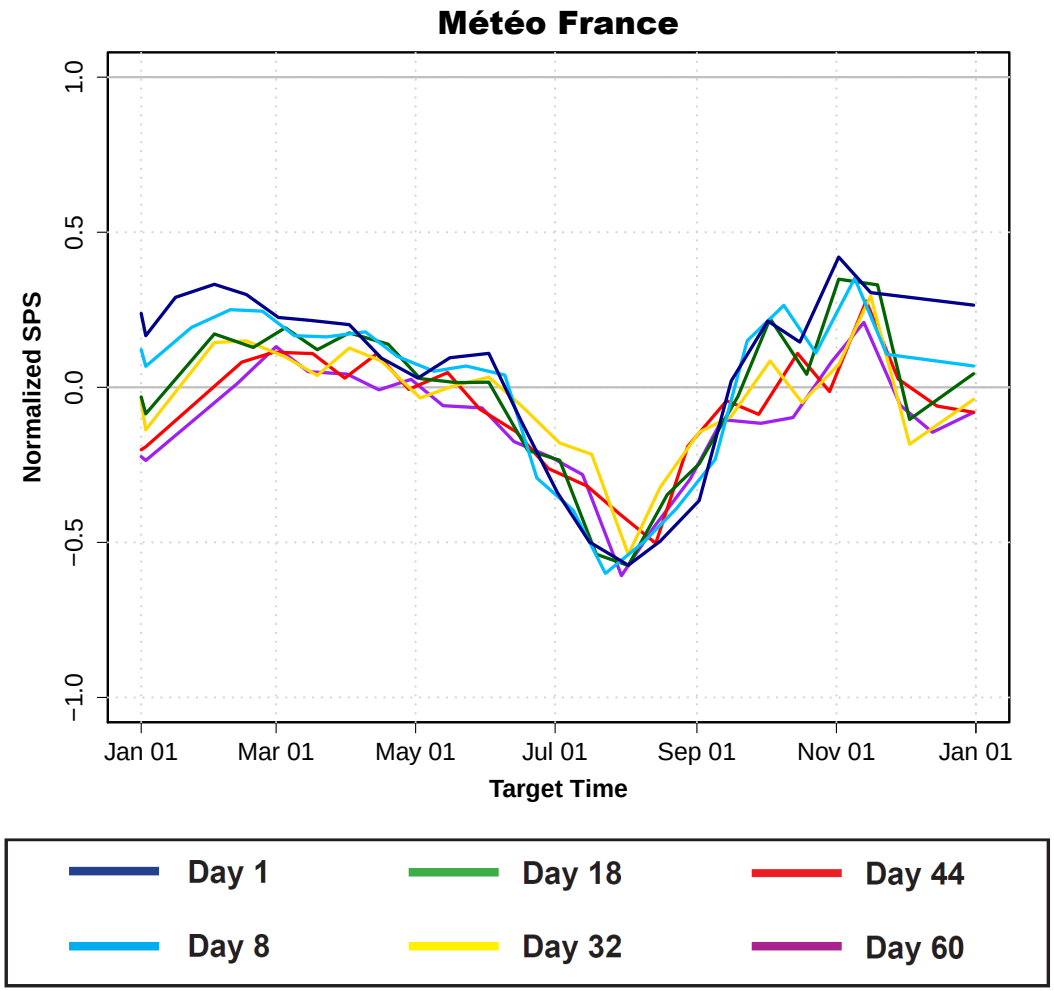
KMA Predictive Skills

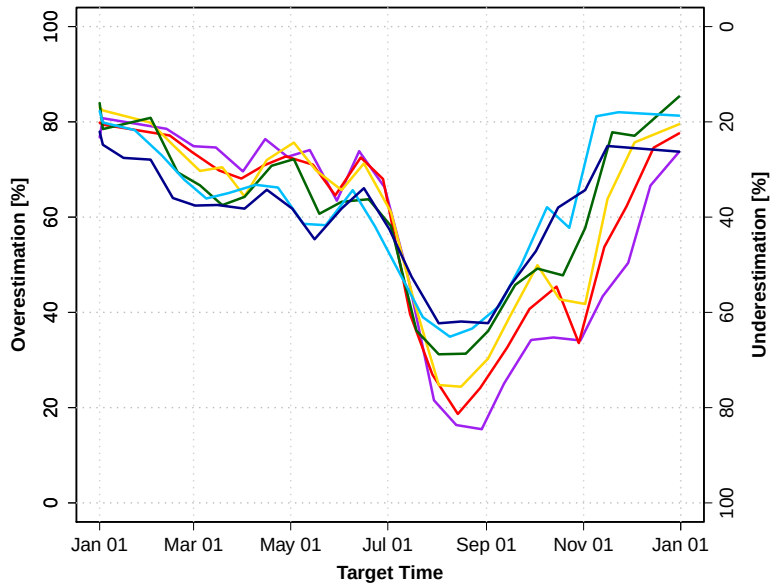


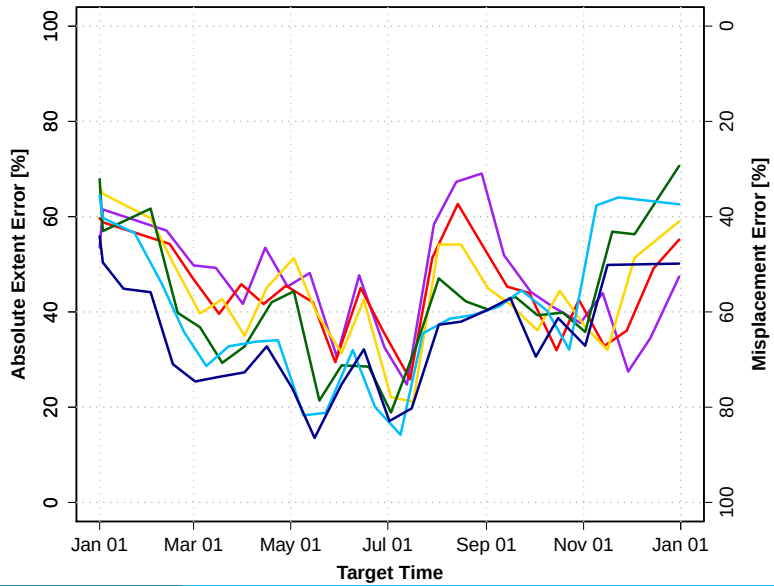




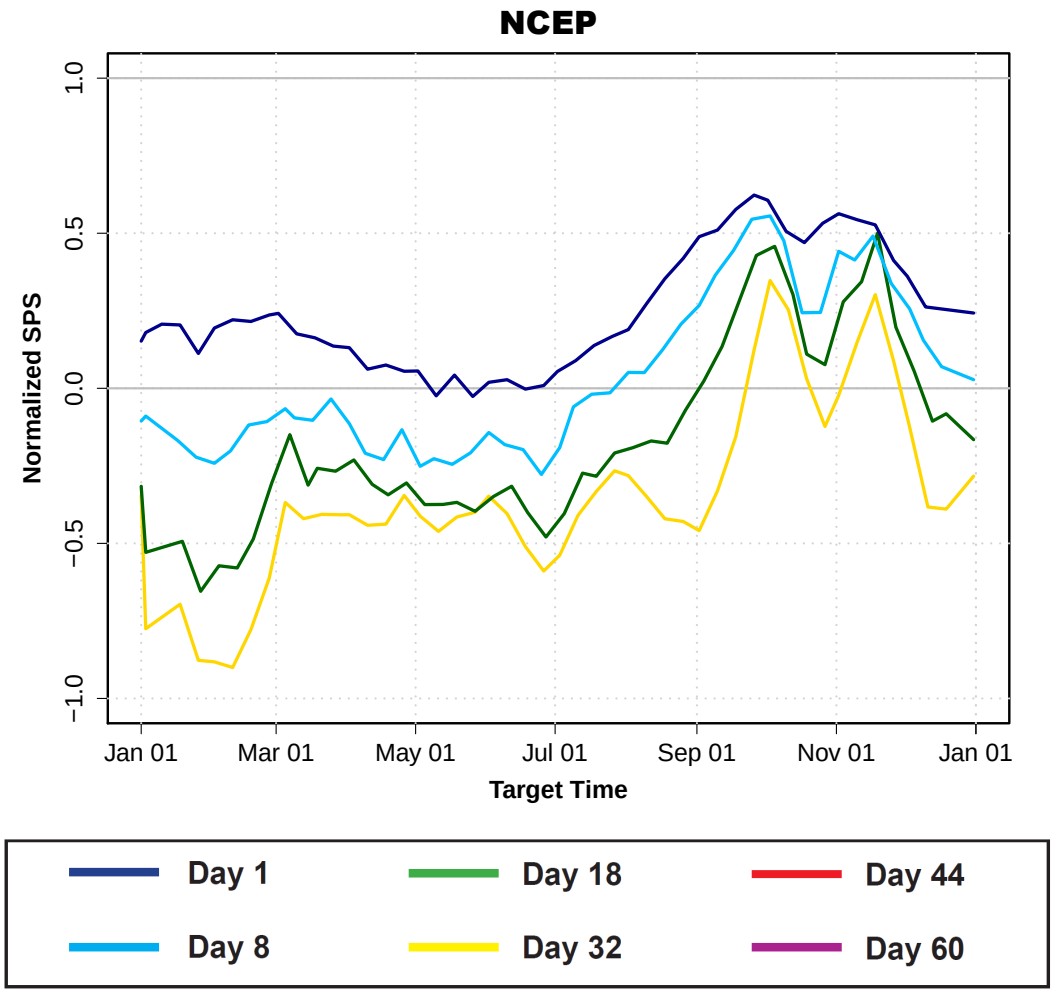
Météo France Predictive Skills

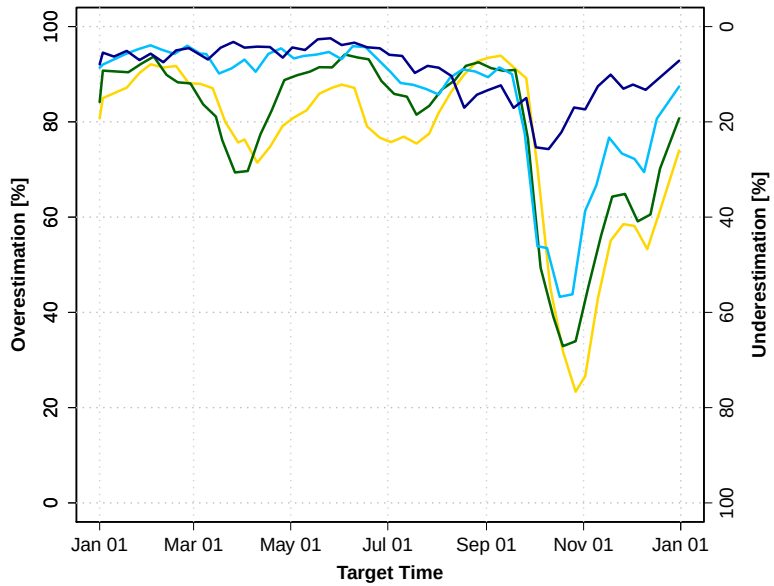


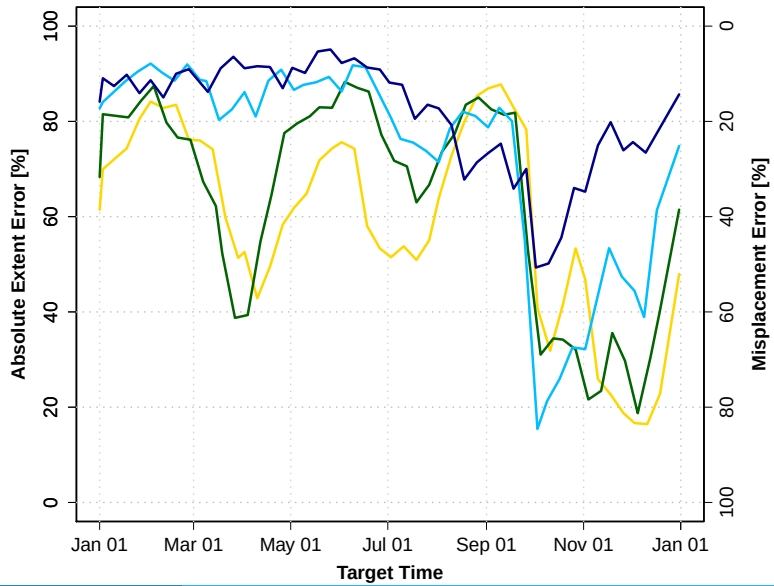




NCEP Predictive Skills







UKMO - CMA Comparison

Ens. members: 3
Start: 01.07.2016

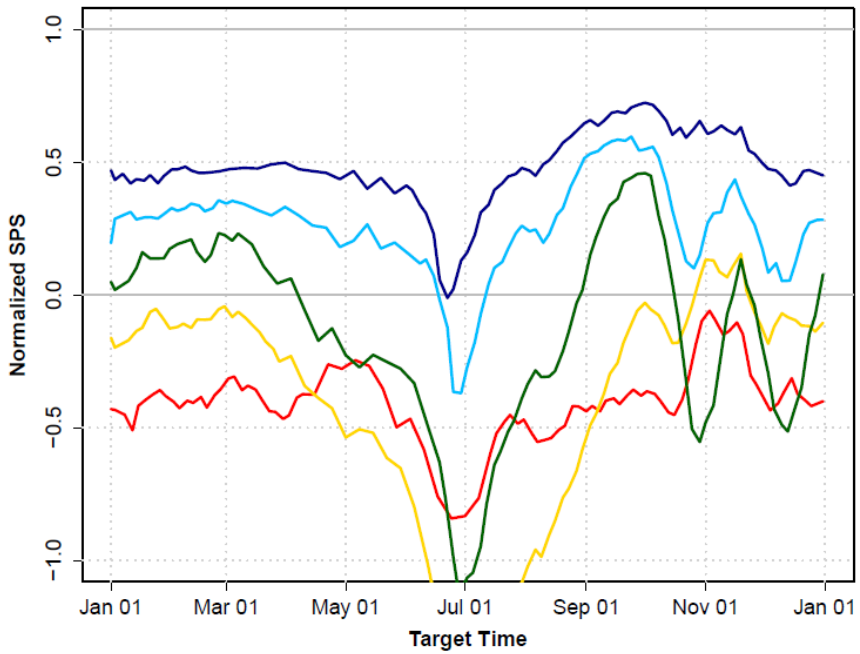
Ens. members: 3
Start: 01.07.2016

S2S Forecasts Systems Predictive Skills

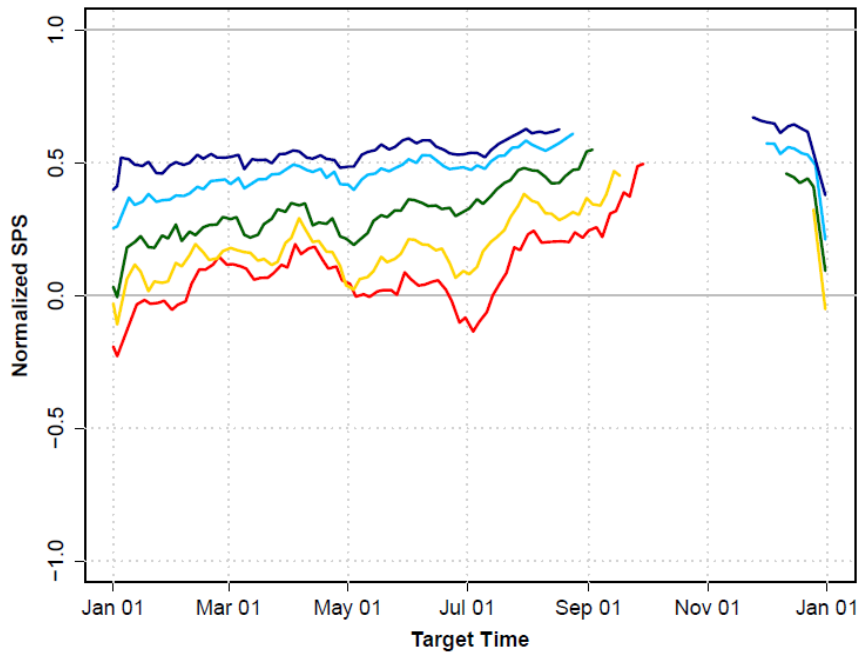
Forecast System	Season		Issues		
	Winter	Summer	Assimil.	Mlt.	Frz.
CMA	🔴	🔴	✗	✗	
ECMWF 2	🟢	🟢		✗	
KMA	🟢	🟢		✗	
Météo France	🟠	🔴	✗	✗	
NCEP	🔴	🔴	✗		✗
UKMO	🟢	🟢		✗	

ECMWF Prescriptive vs. Prognostic System

1st VERSION
Prescribed Sea Ice

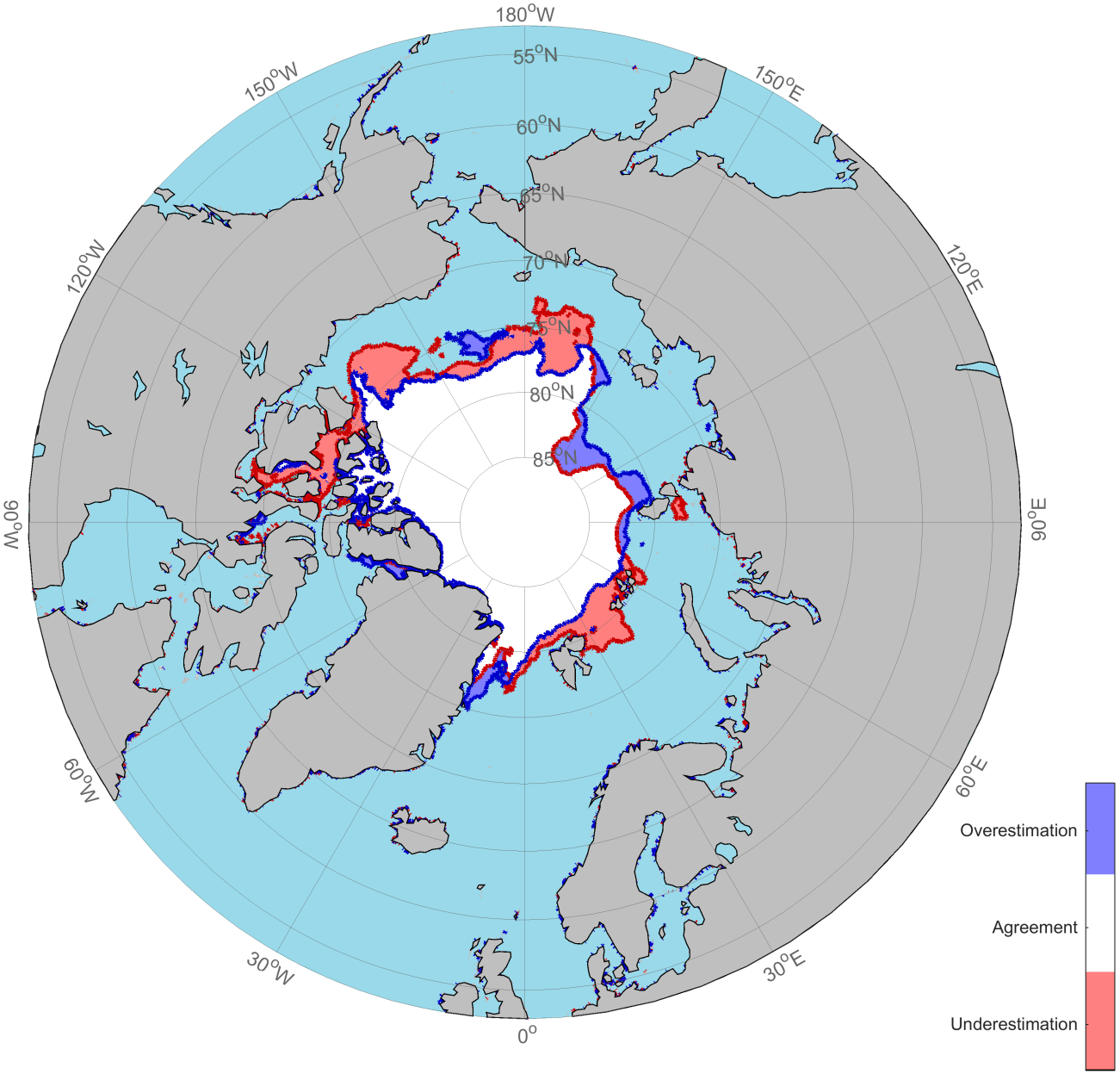


2nd VERSION
Dynamical Sea Ice

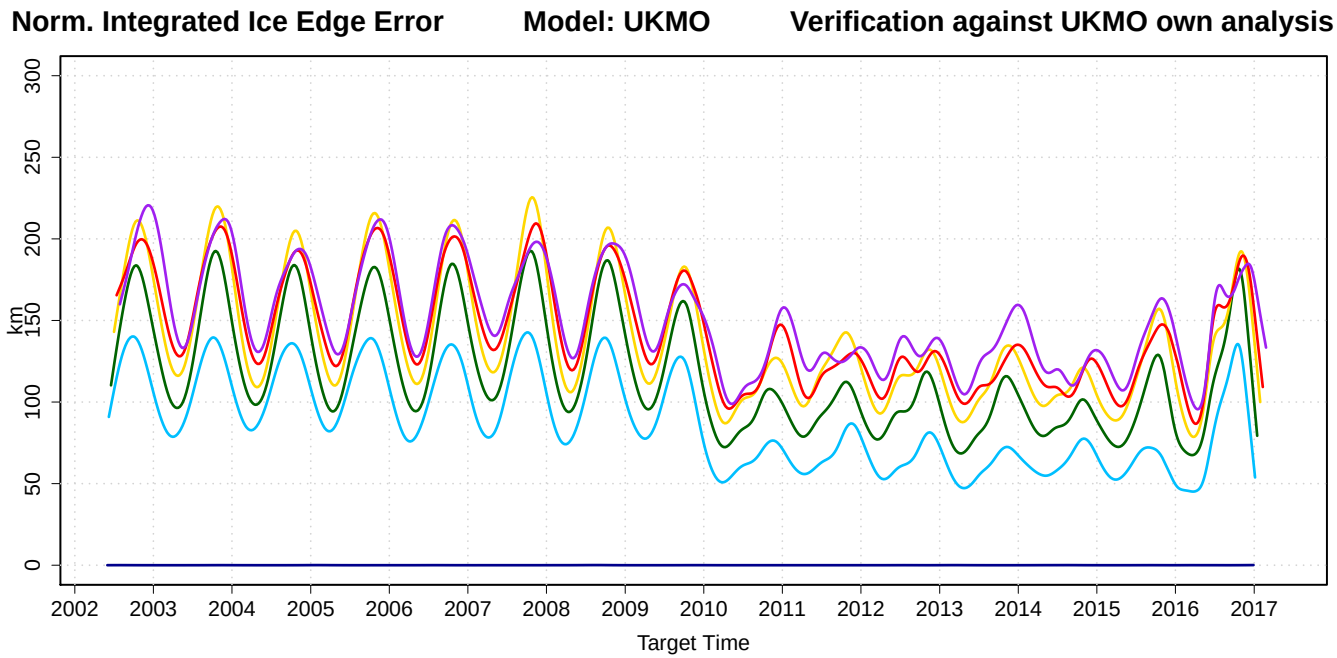


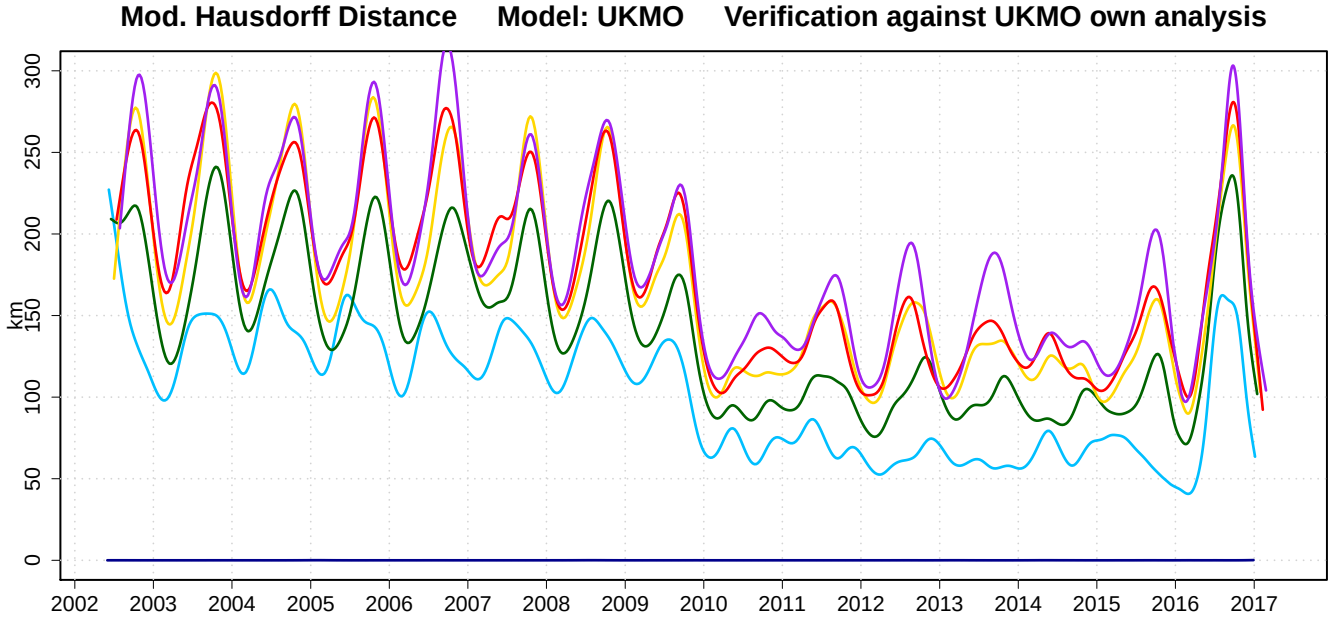
Verification Metrics Behavior

Comparison of MHD and NIIEE



Comparison of MHD and NIIEE





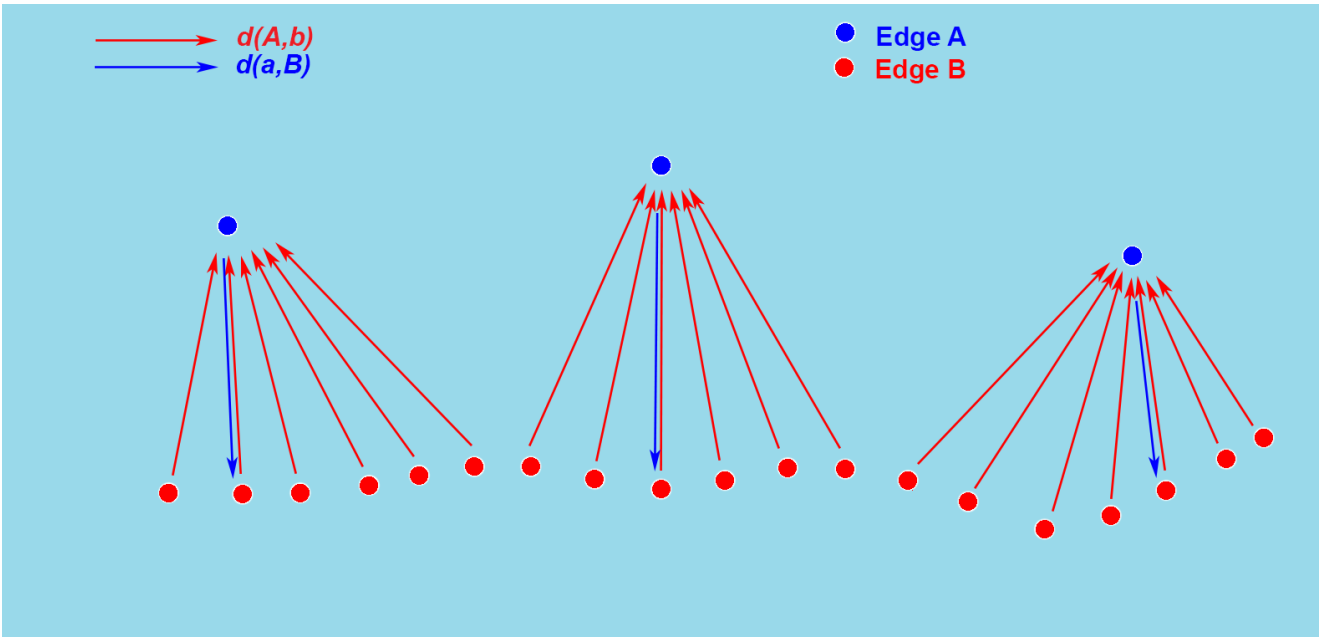
Comparison of MHD and NIIEE

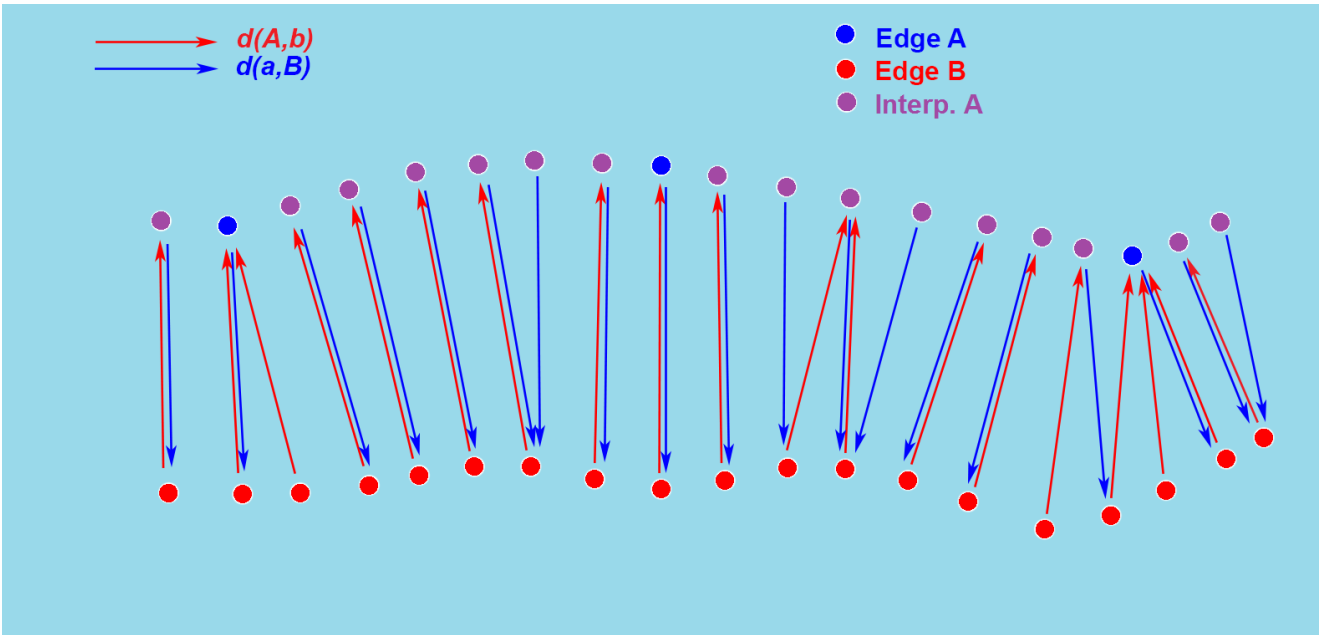
Forecast Lead Time	Correlation Coeff.	Scaling Factor
Day 1	0.915	0.75
Day 8	0.813	1.18
Day 18	0.872	1.23
Day 32	0.860	1.24
Day 44	0.770	1.24
Day 60	0.672	1.23

The NIIEE and the MHD estimations of the mean distance between the edges are comparable! However...

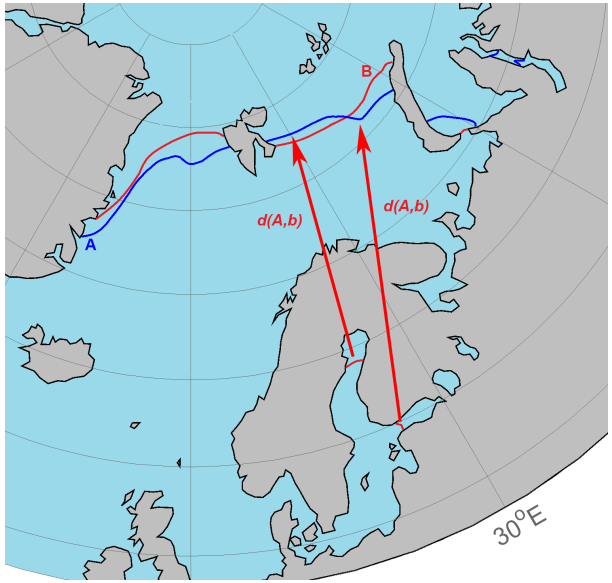
- NIIEE is sensitive to the normalization procedure
- MHD is subject to noise likely caused by outliers
- MHD computation is much more demanding

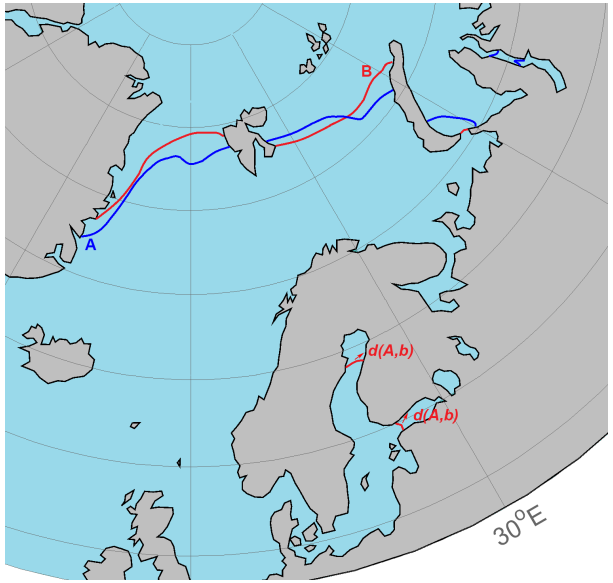
MHD Problems - 1

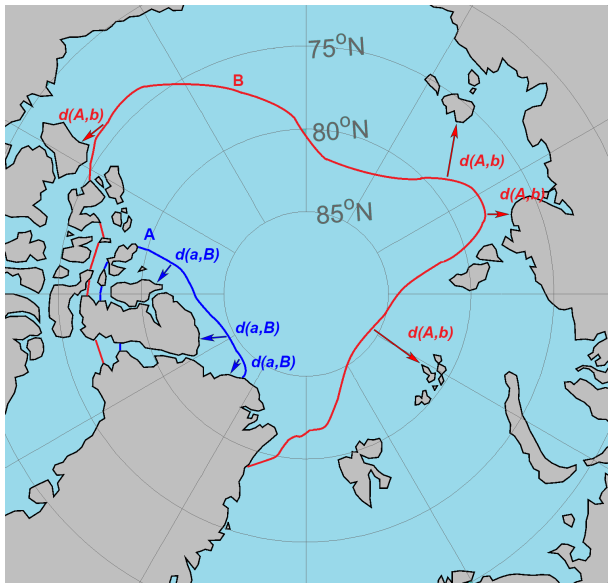




MHD Problems - 2







Conclusions

Features of S2S Forecasts Systems

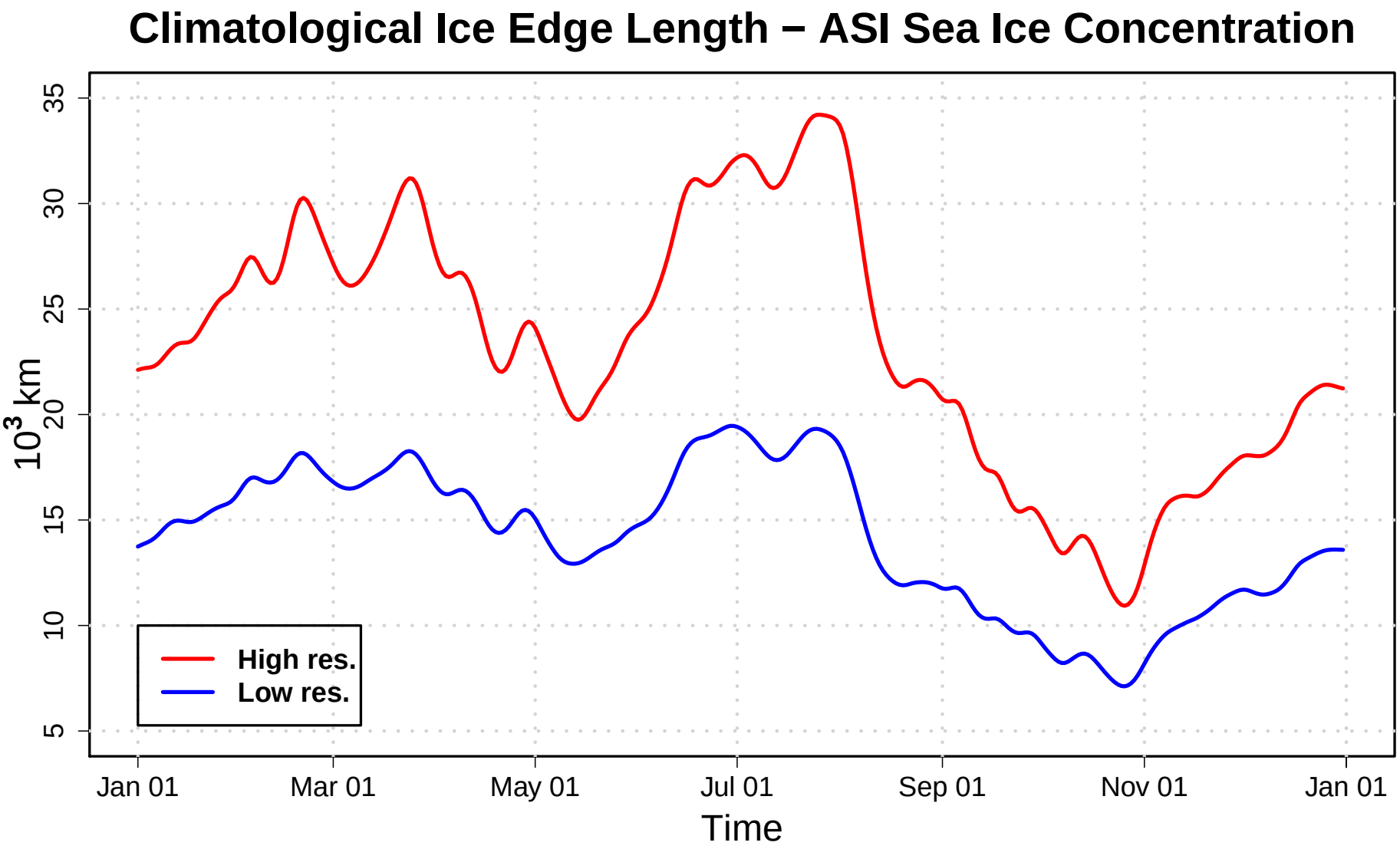
- Despite the early development stage of Arctic sea ice predictions on the seasonal time scale some of the S2S models are promising, exhibiting better predictive skills than the observation-based climatology and persistence during certain periods of the year.
- Evidence of critical aspects concerning the data assimilation procedure and the tuning of the models, which can strongly affect the forecasts quality.
- Expected benefits from an increased ensemble size could not be detected.
- The comparison of different versions of the ECMWF forecast system shows the benefits brought by a coupled dynamical description of the sea ice instead of its prescription based on persistence and climatological records.

Metrics Behavior

- IIEE and SPS are effective verification metrics to describe the quality of the sea ice edge position.
  Simplicity - Comprehensibility - Stability
- MHD is also able to evaluate the quality of the forecasted ice edge position. However it is less flexible than the two previous ones and affected by biases.
- Verification against satellite observation useful to monitor models skills.
- Verification against models own analysis useful to study the model response to modification in data assimilation.


Thank you for your attention

Climatological Ice Edge Length



Alternative applications