



Enhancing the skill of sea ice prediction in the Arctic using novel observations and data assimilation methods

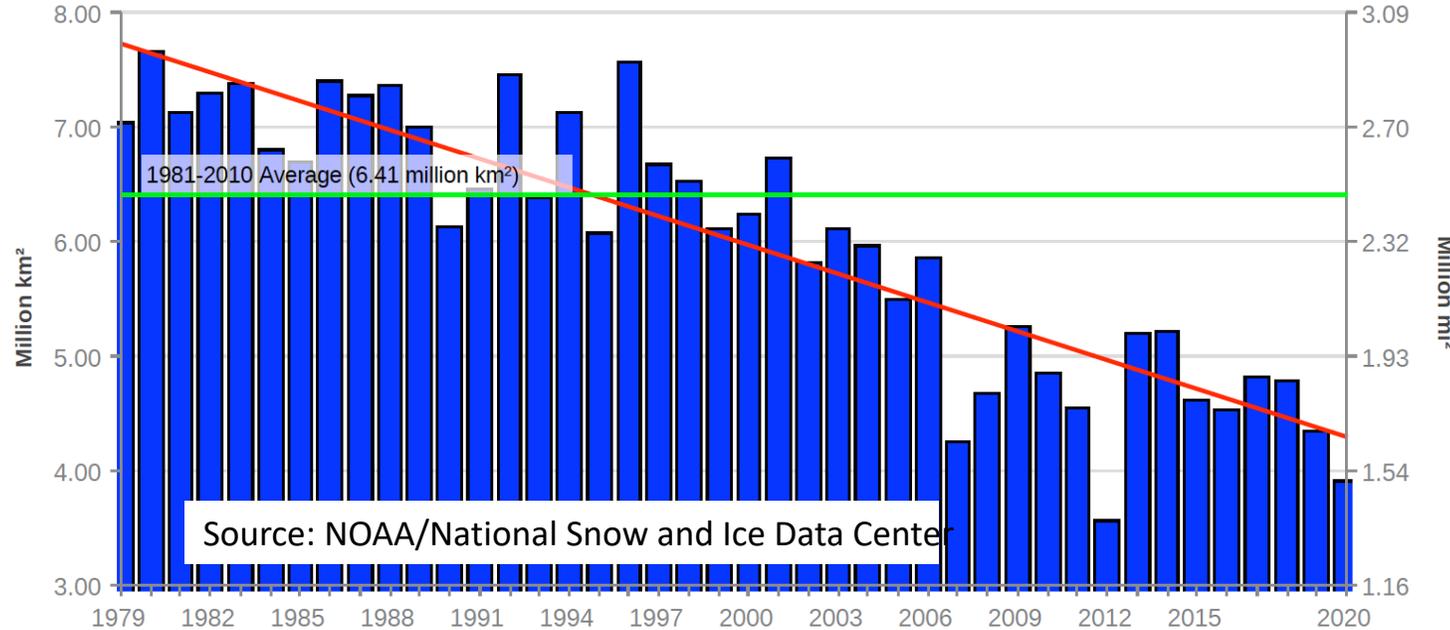
François Counillon



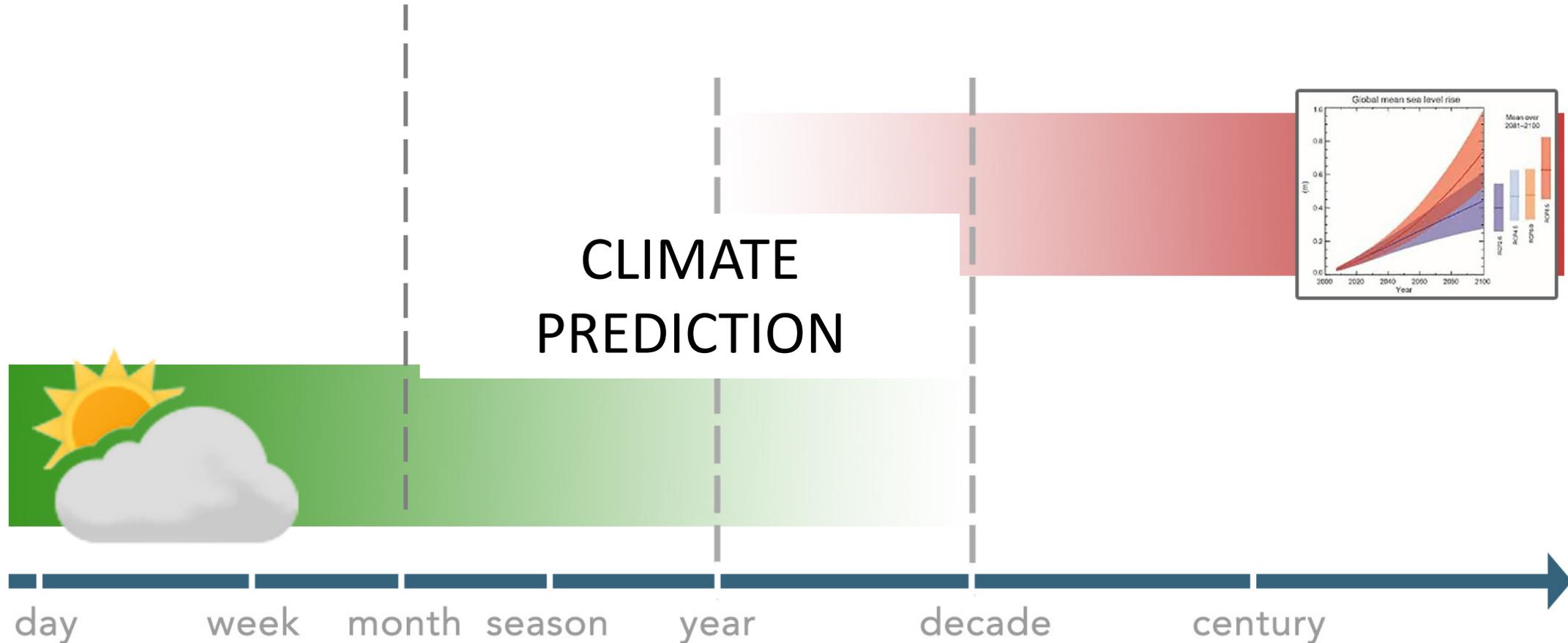
Information needed on Arctic changes over the next few years

Northern Hemisphere Sea Ice
September, 1979-2020

Rapid warming and decline of sea ice



Climate Prediction



Weather predictions

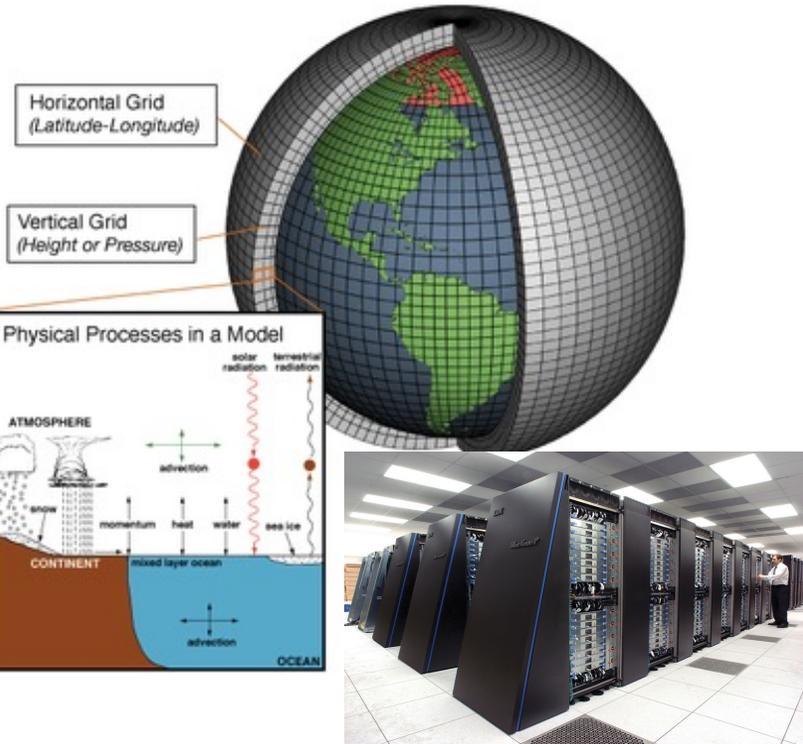
Seasonal to interannual predictions

Long term climate change projections

Adapted from Meehl et al. 2009

Dynamical predictions system

Numerical Models



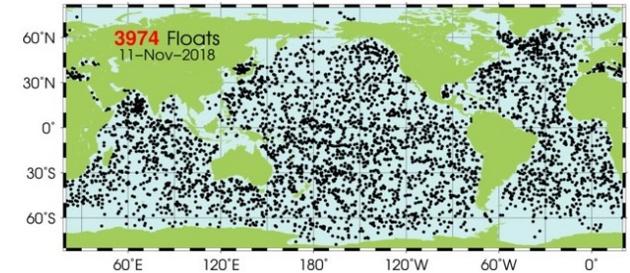
Data assimilation



Statistical methods that bridge a model with observations

Observations

From ships, float



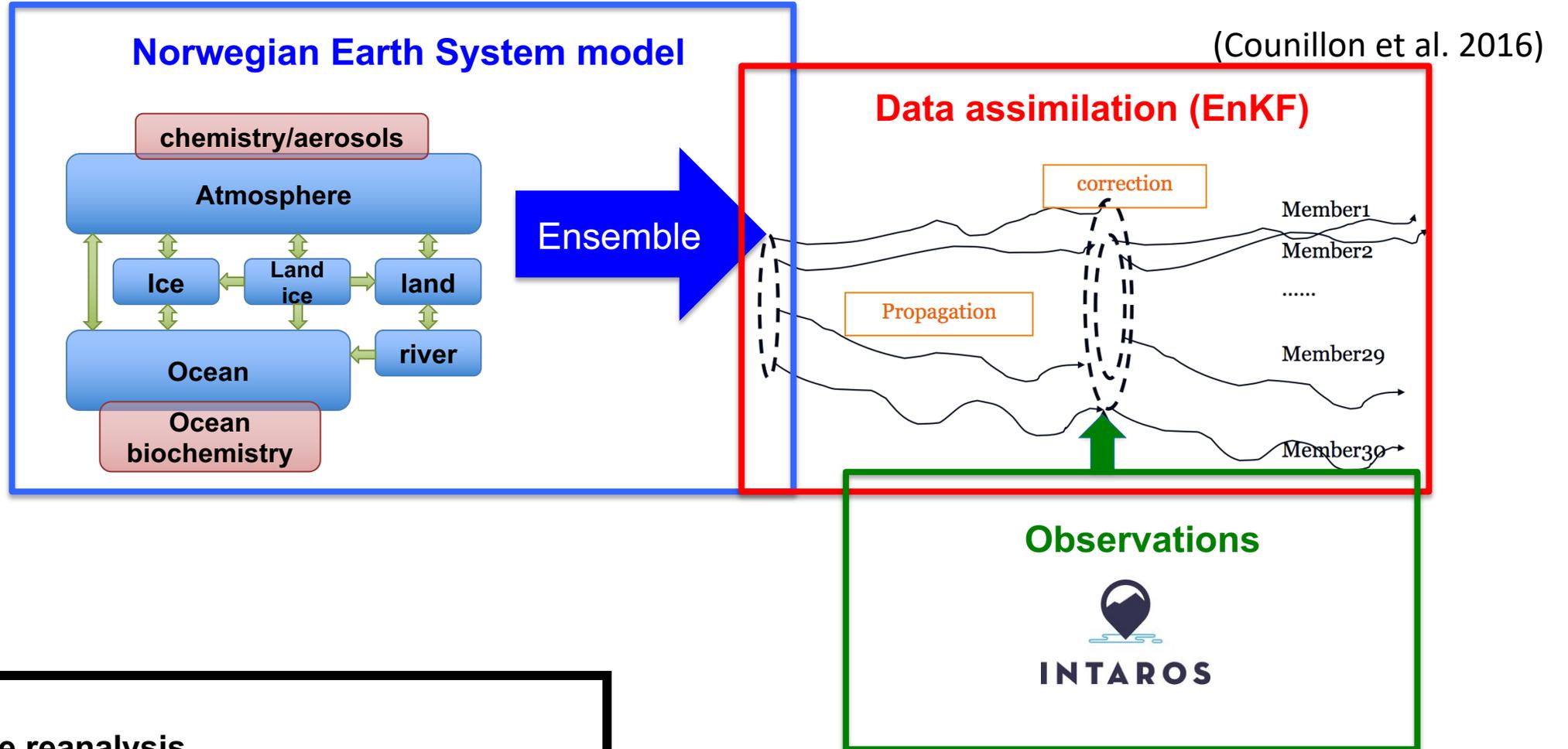
Satellites



Enhanced predictions expected from improved models, observations and data assimilations methods



Norwegian Climate Prediction Model (NorCPM)



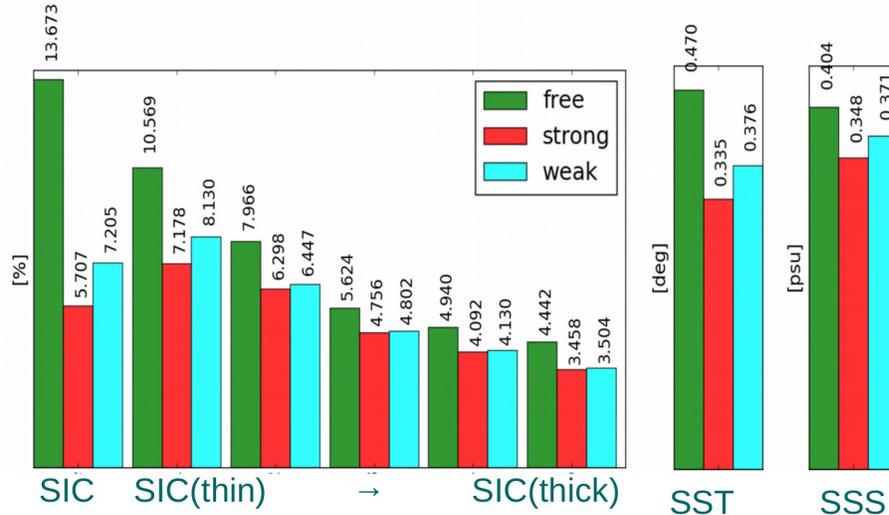
Objectives:

- Long climate reanalysis
- Skillful and reliable climate prediction
 - Seasonal time scale
 - Annual-to-decadal time scale

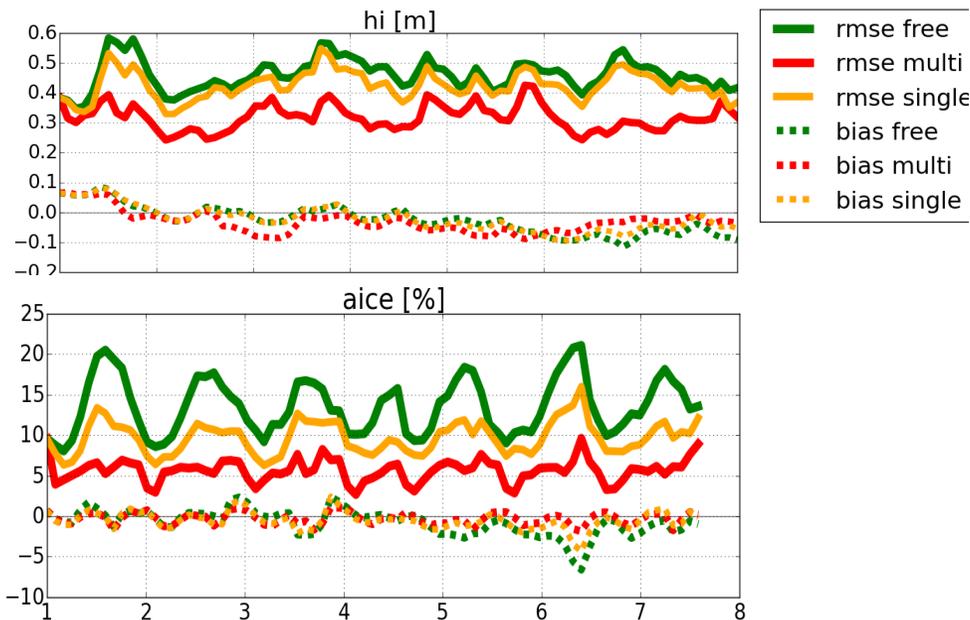
INTAROS brought us novel and more accurate observations

Can we enhance prediction skill by further initialising sea ice ?

Twin experiment



With flow dependent DA, strongly coupled DA (SCDA) of ocean and sea ice yields improvements over weakly CDA.



Assimilating the **multicategory** sea ice model state **outperforms** assimilation of **aggregated thickness and concentration**

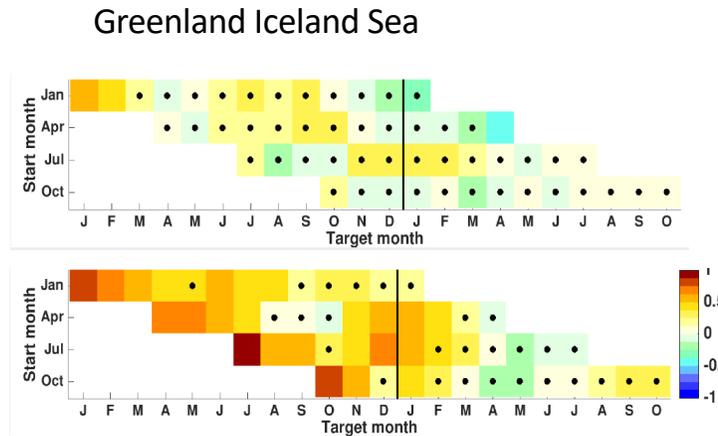
Enhancing seasonal prediction in the Arctic

Detrended correlation skill of sea ice extent in real framework

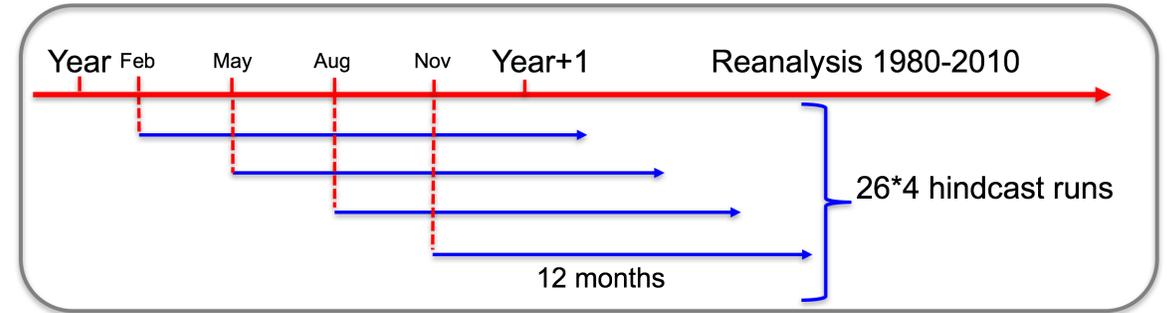
- means not significant

1985:2010

ocean
obs



ocean
+sea ice



*Improved sea ice
export*

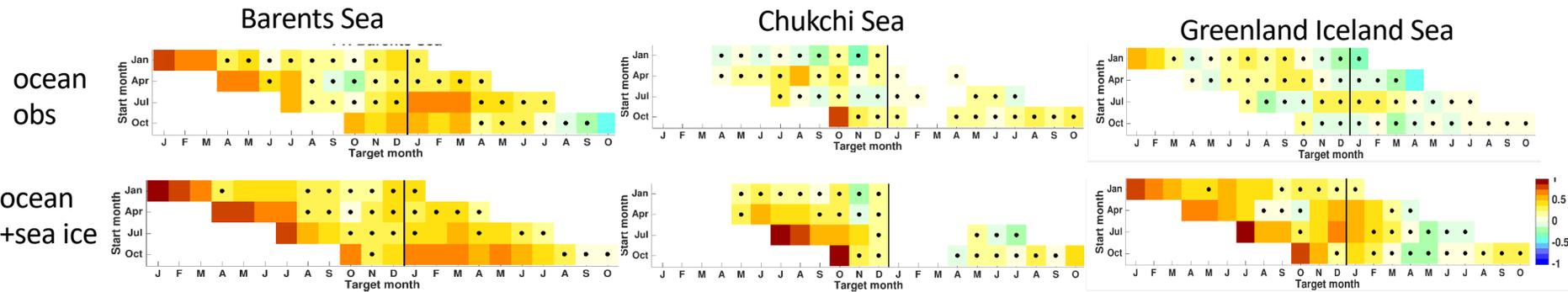
Complementing our system with sea ice concentration data greatly improved prediction skill of sea ice extent

(Kimmritz et al. 2019)

Improving prediction with new observations

1985:2010

- means not significant



*Initialisation of
heat content*

*Initialisation of
SIT in may*

*Improved sea ice
export*

Complementing our system with sea ice concentration observation greatly improves seasonal prediction of Arctic sea ice extent

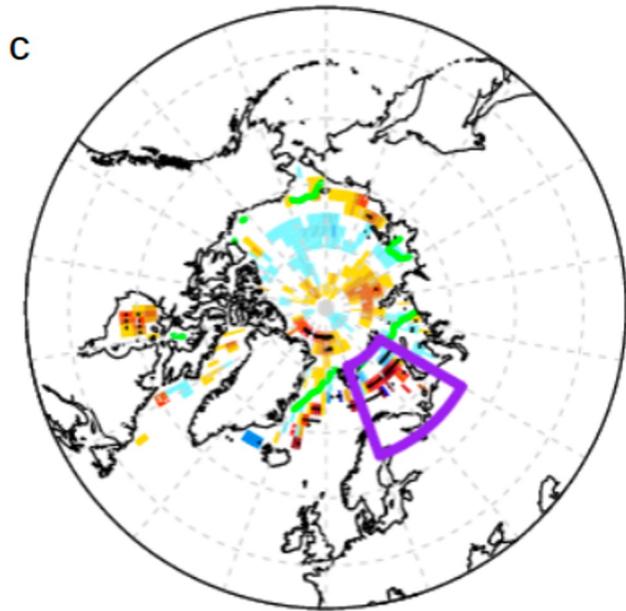
Benefits of assimilating INTAROS sea ice data in BSC EC-Earth3.3

Impact on July-September predictions from May start (lead month 3-5)

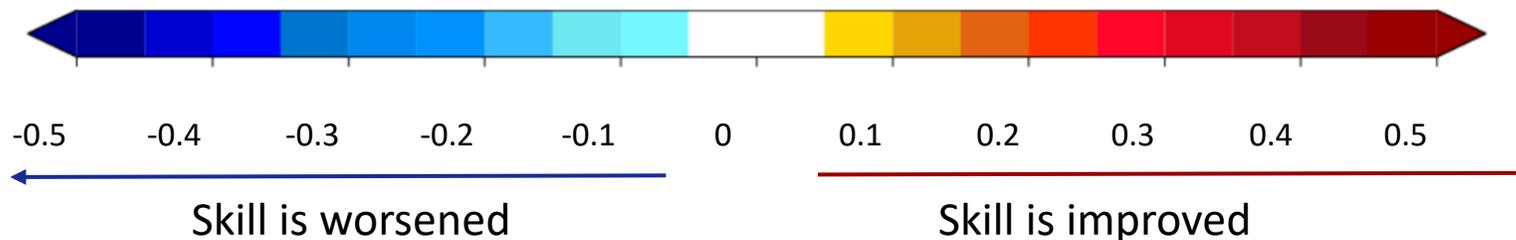
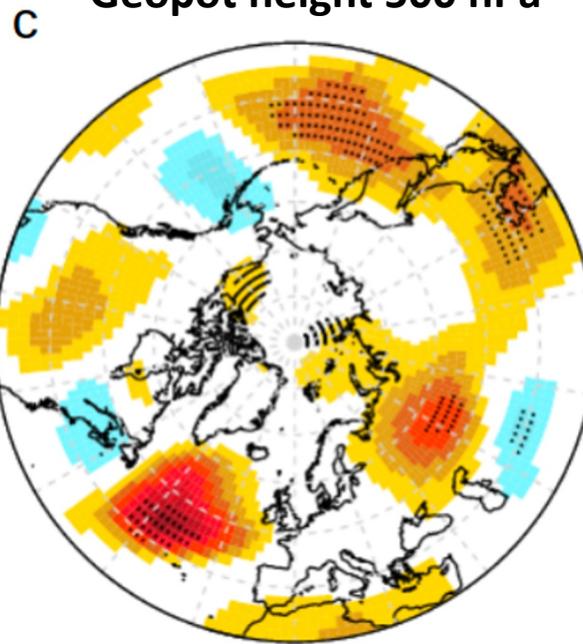
*Acosta-Navarro et al
(in review)*

Assimilating
Sea Ice Concentrations

Sea ice concentration



Geopot height 500 hPa

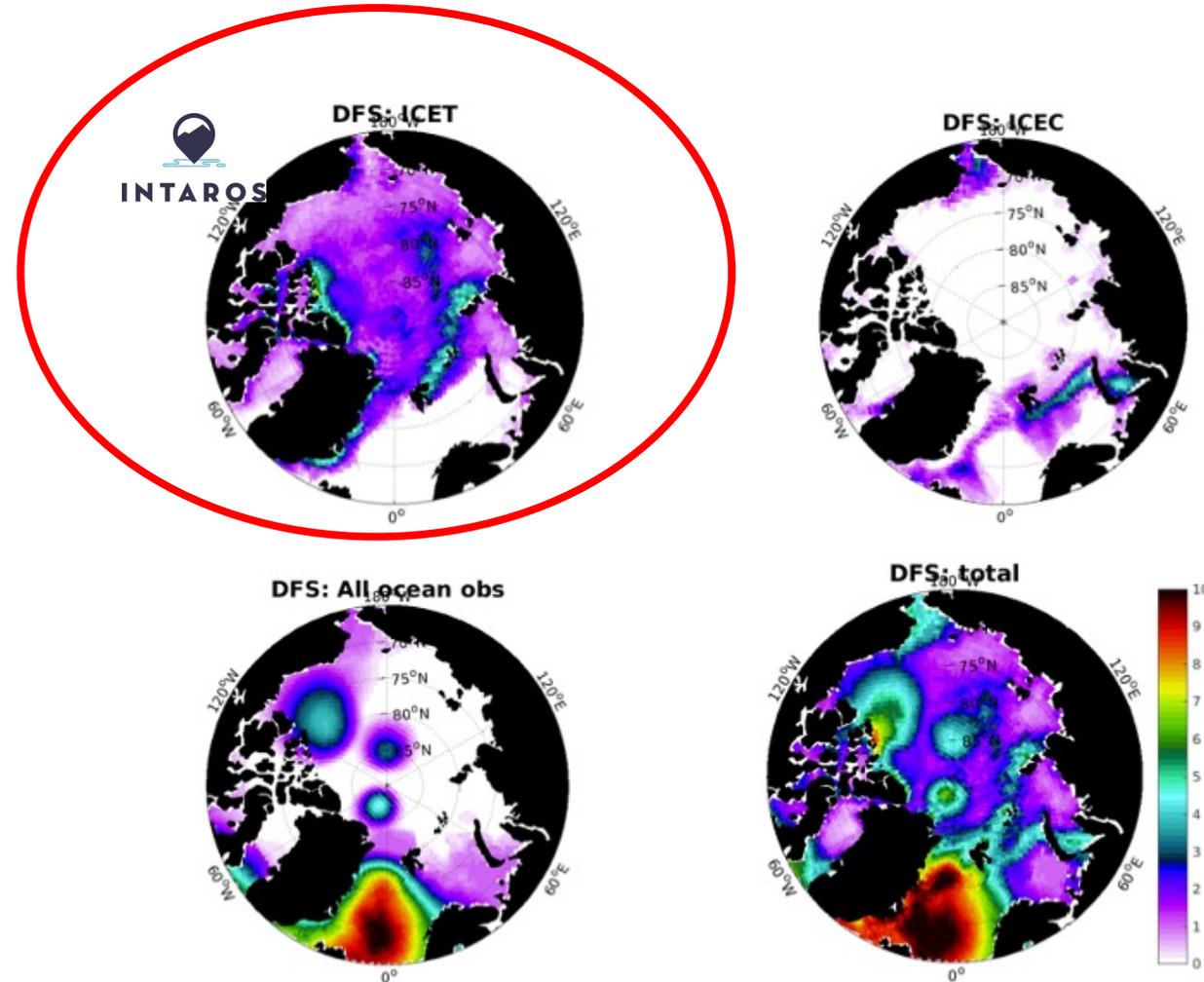


Forecast improvements extend to other climatic variables beyond the Arctic, like the atmospheric circulation in the North Atlantic and Eurasia



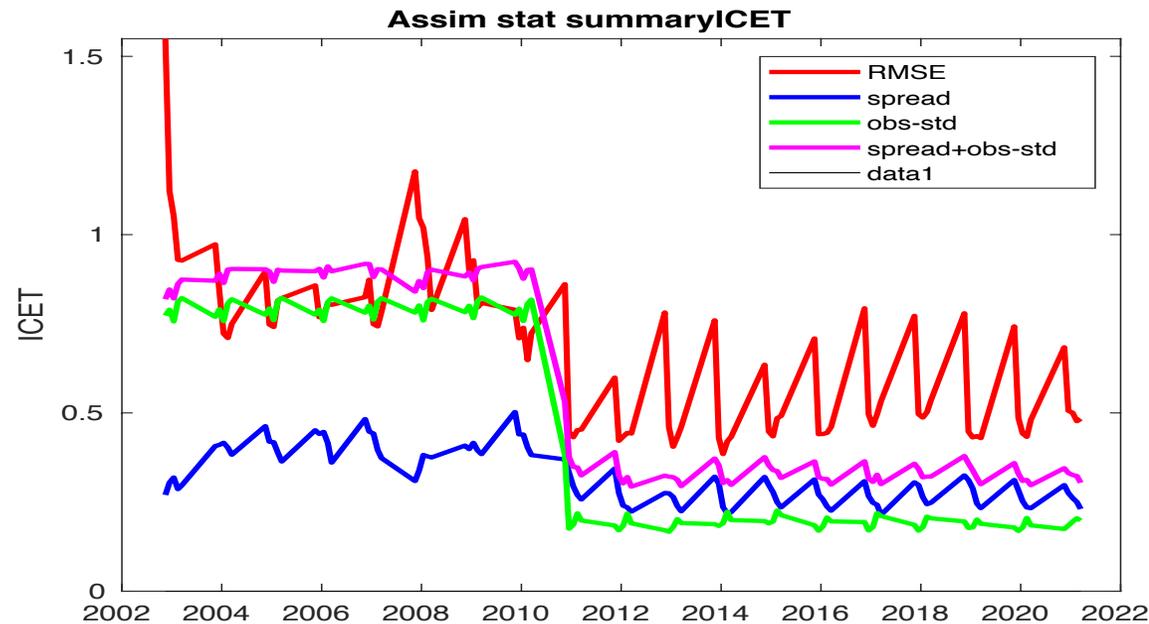
Relative impact of each observation type

Degree of Freedom of Signal of the ice thickness in Nov 2011



C2SMOS SIT is important to constrain the error in our system

Reanalysis with sea ice thickness assimilation



- ESA CCI 2.2 (From 2002 Nov → Nov 2012)
 - C2SMOS (combined SMOS and CRYOSAT2) Ricker et al. 2017
 - Available from Nov 2011
- Data in October and April were discarded by precaution (partial and more inaccurate,; e.g. Xie et al.18)

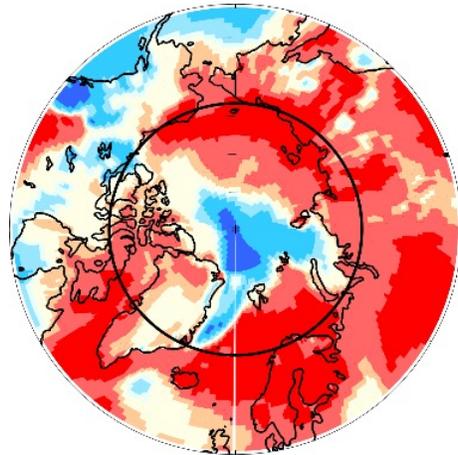
Assimilation of ice thickness constrains well error of ice thickness :

- > 1.5 m without assimilation
- ~ 1 m during ESA CCI period
- ~0.6 m with C2SMOS

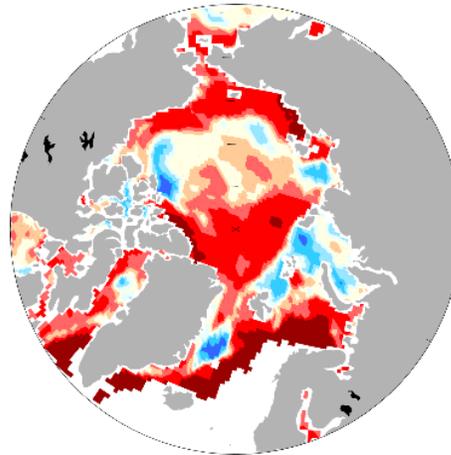
Comparable developments with *EC-Earth3 Climate Prediction system*

predictions for lead-year 2-9

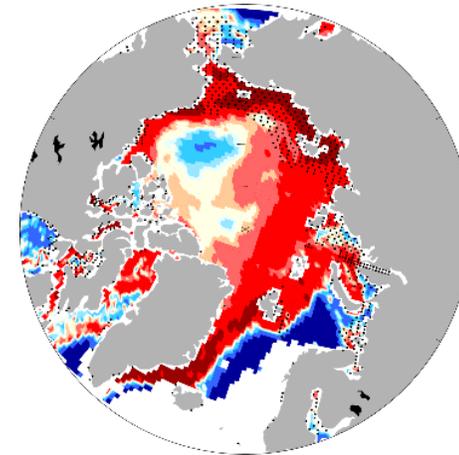
Surface air temperature



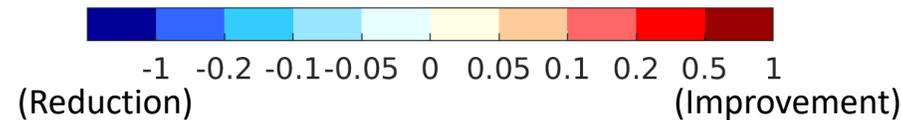
Sea Ice concentration



Sea Ice thickness

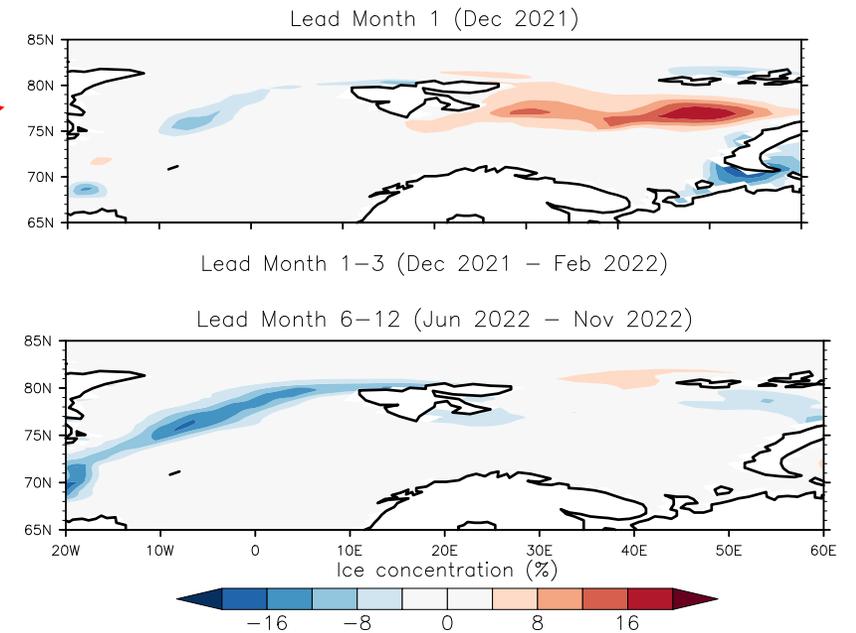
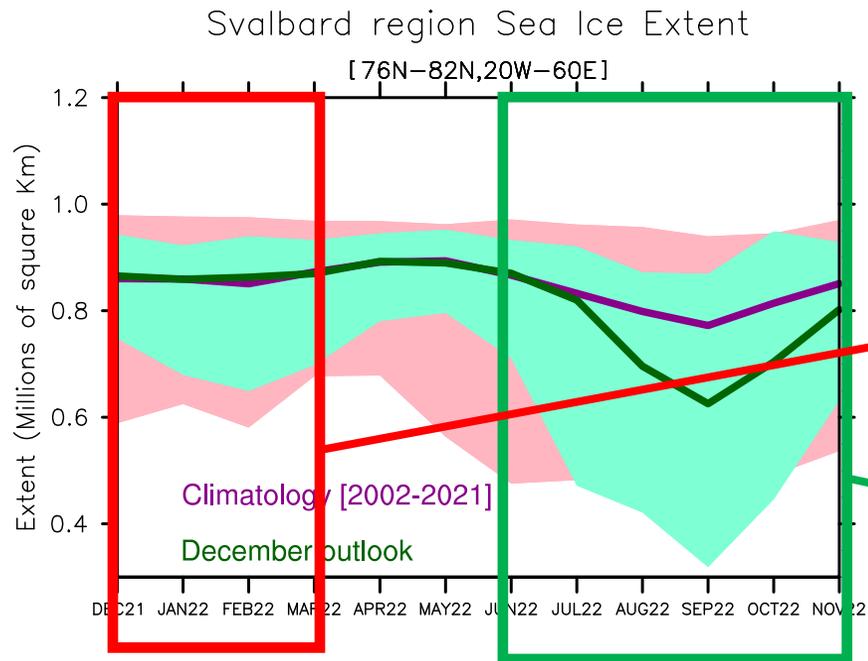


RMSE skill score



Prediction of sea ice concentration in the Svalbard region

Delivered in ctober 2021 prediction



Courtesy of T. Singh

Conclusions

- Several prediction systems has been further developed in INTAROS and show the benefit of the novel data sets (All contribute to CMIP6 DCPD)
- Such tools will play a key role in development of climate services and building a resilient society
- The added value of SIT data for prediction skill in NorCPM still remains to be tested (in 4SICE)
- Snow thickness and more measurements of ocean interior are needed to enhanced Arctic prediction further. Can be tested in observing system simulation experiment (OSSE)