



**Barcelona  
Supercomputing  
Center**

*Centro Nacional de Supercomputación*

# Improving the representation of sea ice variability and seasonal prediction

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**APPLICATE.eu** 

Advanced prediction in  
polar regions and beyond

# Improving the representation of sea ice variability and seasonal prediction

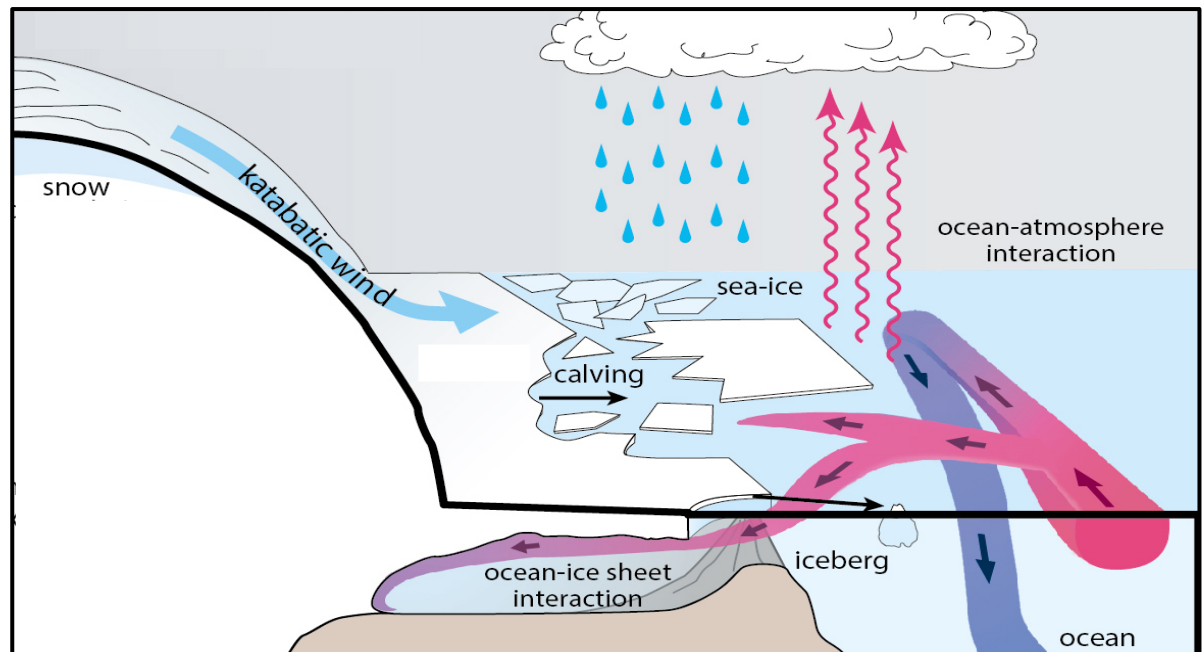
Following APPLICATE's overarching aim:

“Improvements in predictability of weather and climate in the NH” (especially in Arctic)

Two pronged approach:

- Improving the representation of sea ice in EC-Earth (LIM3)
- Improving assimilation and initialization of sea ice

→ Assess the impacts of such improvements on sea ice variability and mid-latitude weather and climate



Adapted from 5<sup>th</sup> IPCC report

# Improving the representation of sea ice variability and seasonal prediction

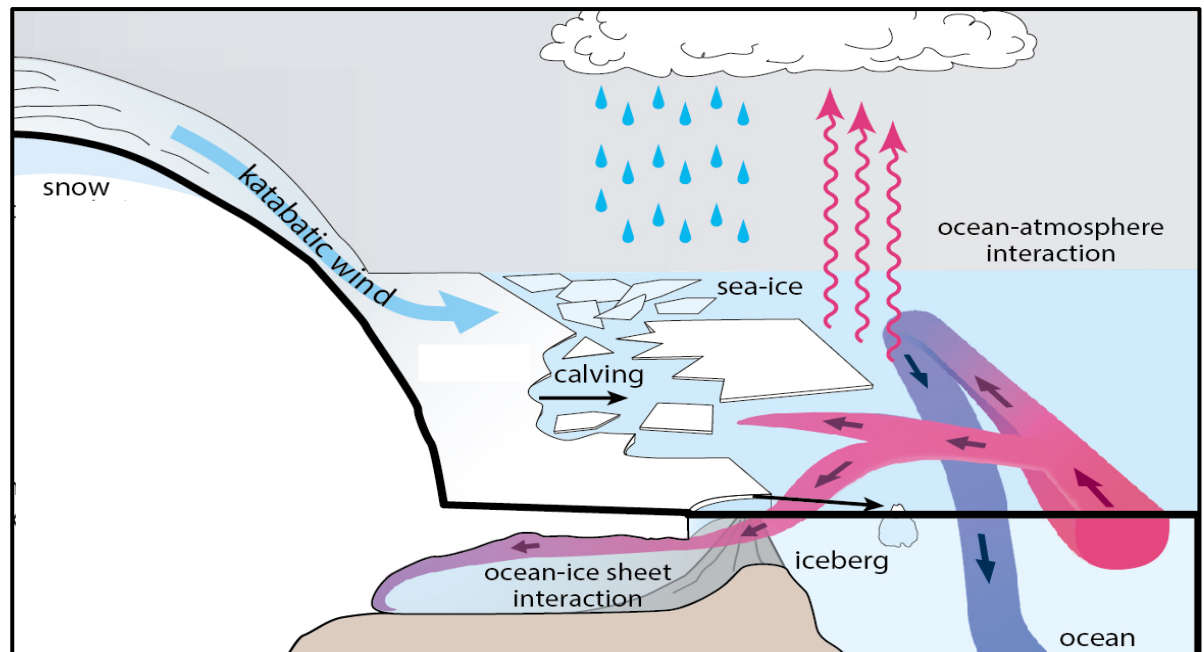
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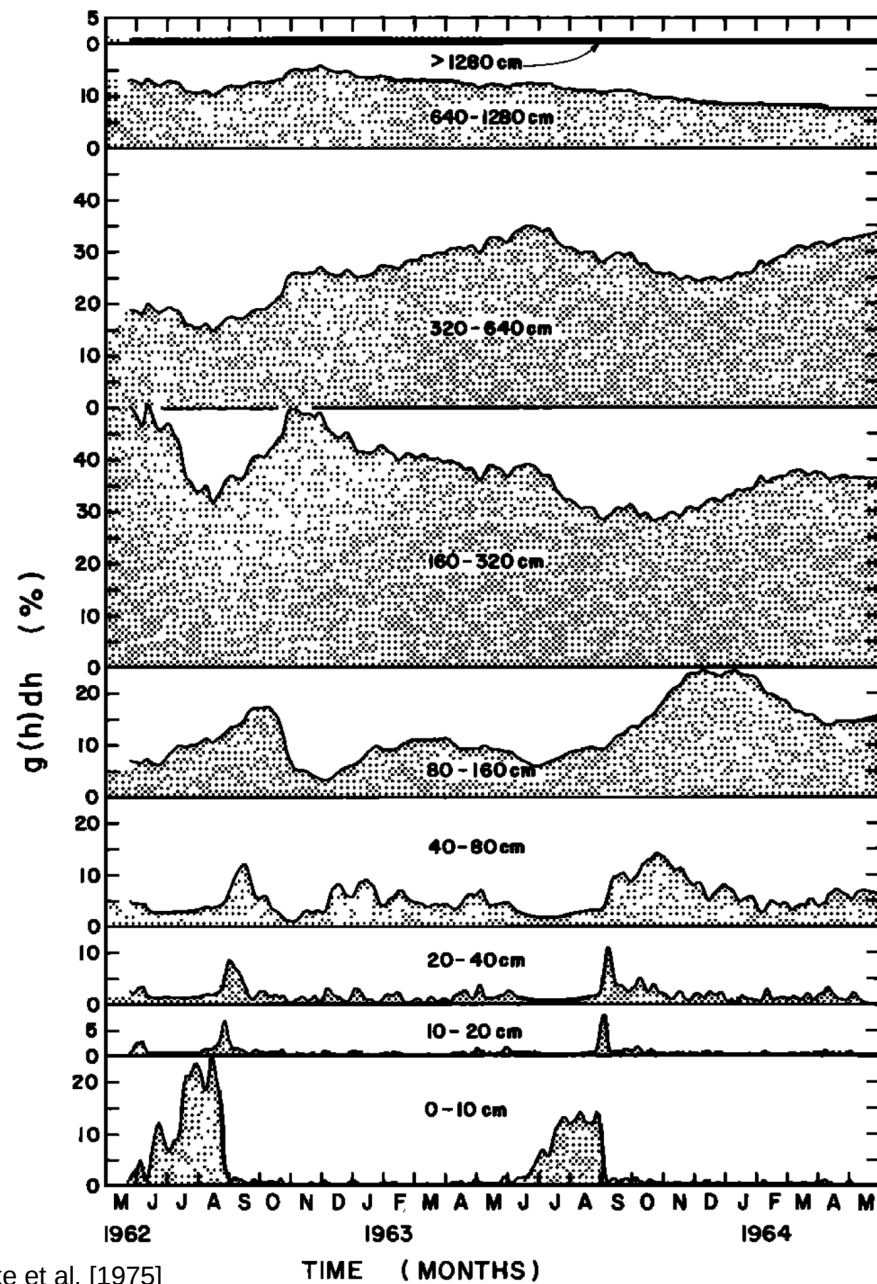


**Real sea ice can be this complex ...**



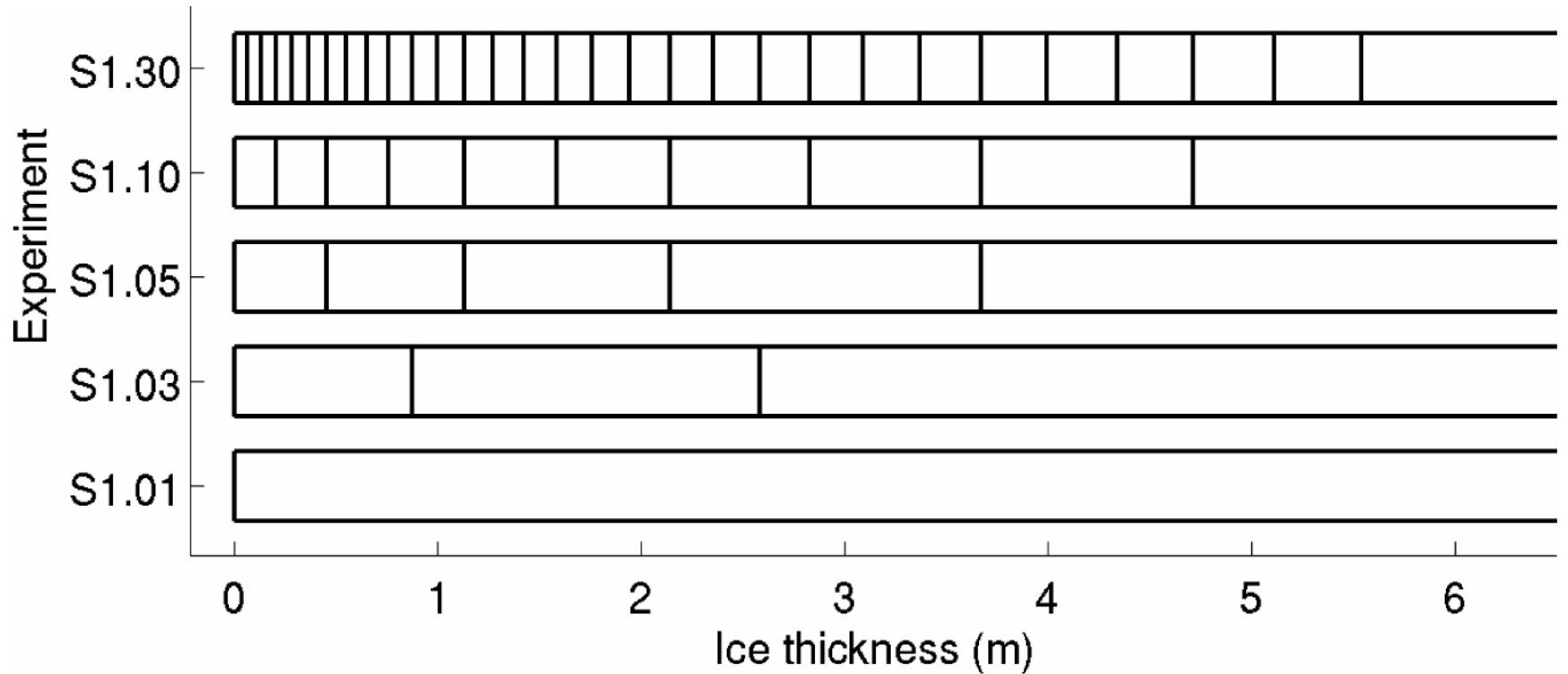


# A distribution of sea ice thicknesses



# What is the effect of having a coarser or a finer thickness distribution on the simulated sea ice variability?

LIM3 default configuration: 5 categories



Massonnet et al. [in review]



# What is the effect of having a coarser or a finer thickness distribution on the simulated sea ice variability?

Pan-Arctic sea ice concentration (SIC) variability in  
Winter (Jan–Mar)  
Summer (Jul–Sep)

→ NEMO-only simulations (1958–2015)  
Between 1 and 40 categories

→ Satellite observations of sea ice concentration  
NSIDC (0051)  
OSI SAF (reprocessing OSI-409)  
HadISST (2.2)

K-means clustering for the overlapping period 1980–2014:

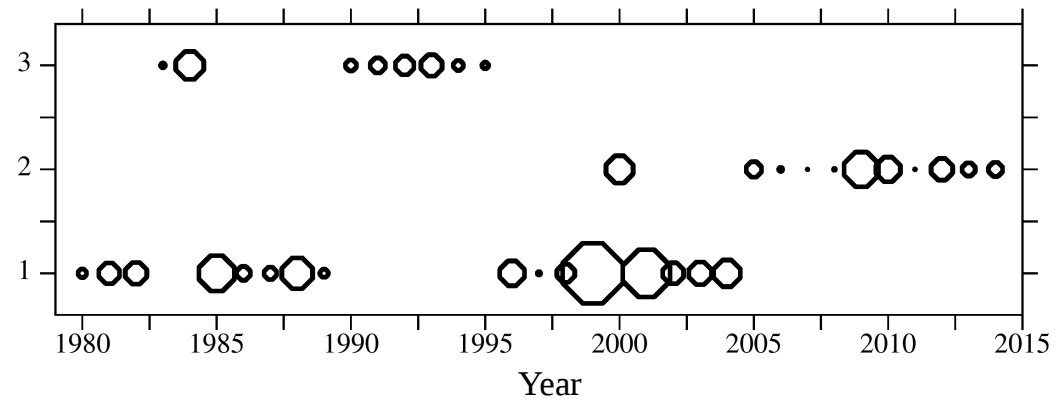
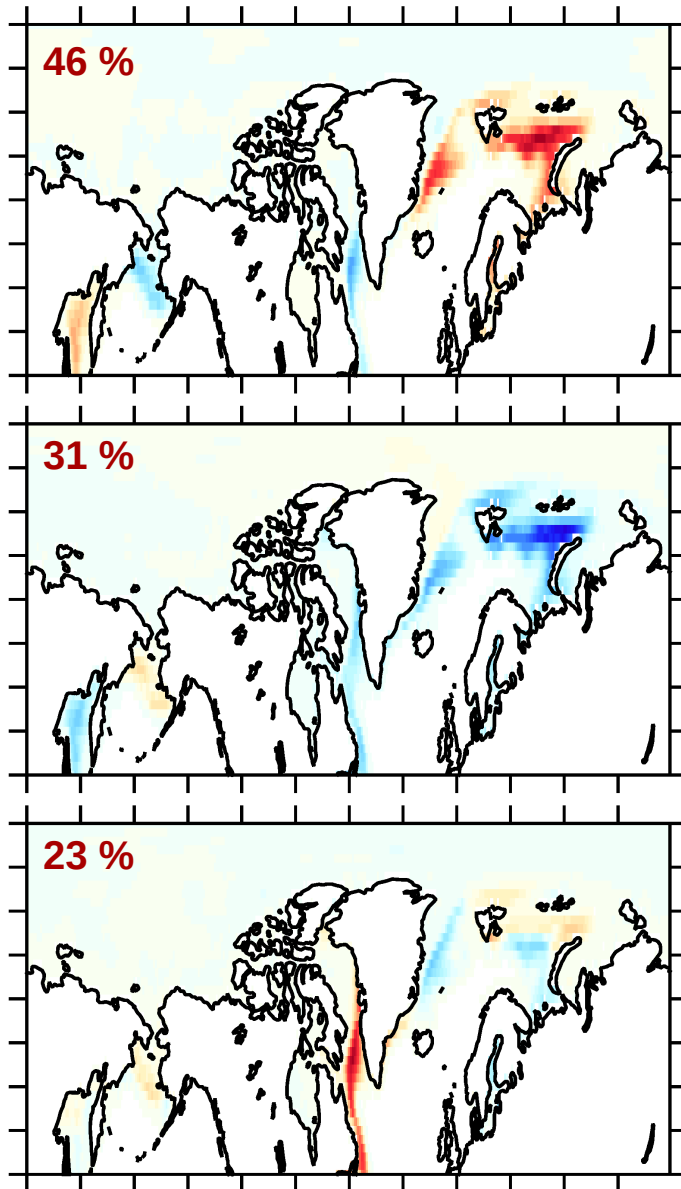
3 modes as optimal number

Modes: spatial maps + occurrence frequency

Cluster occurrence: which mode is the closest to SIC anomalies in a year

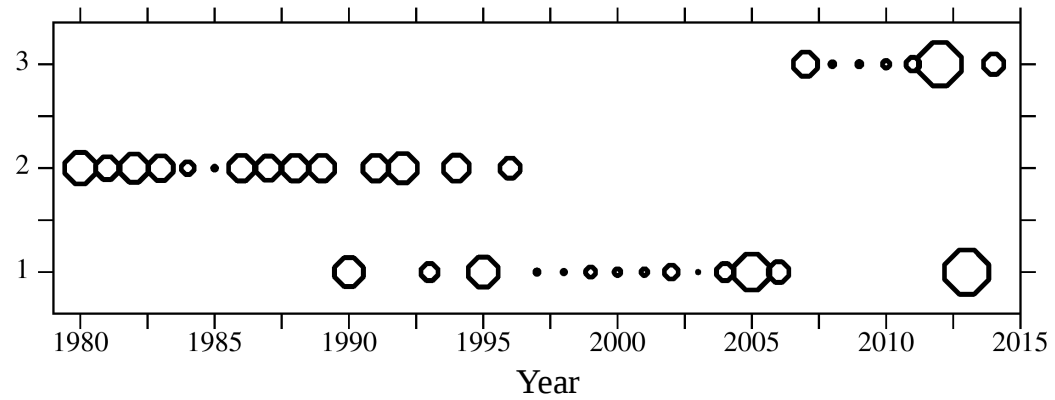
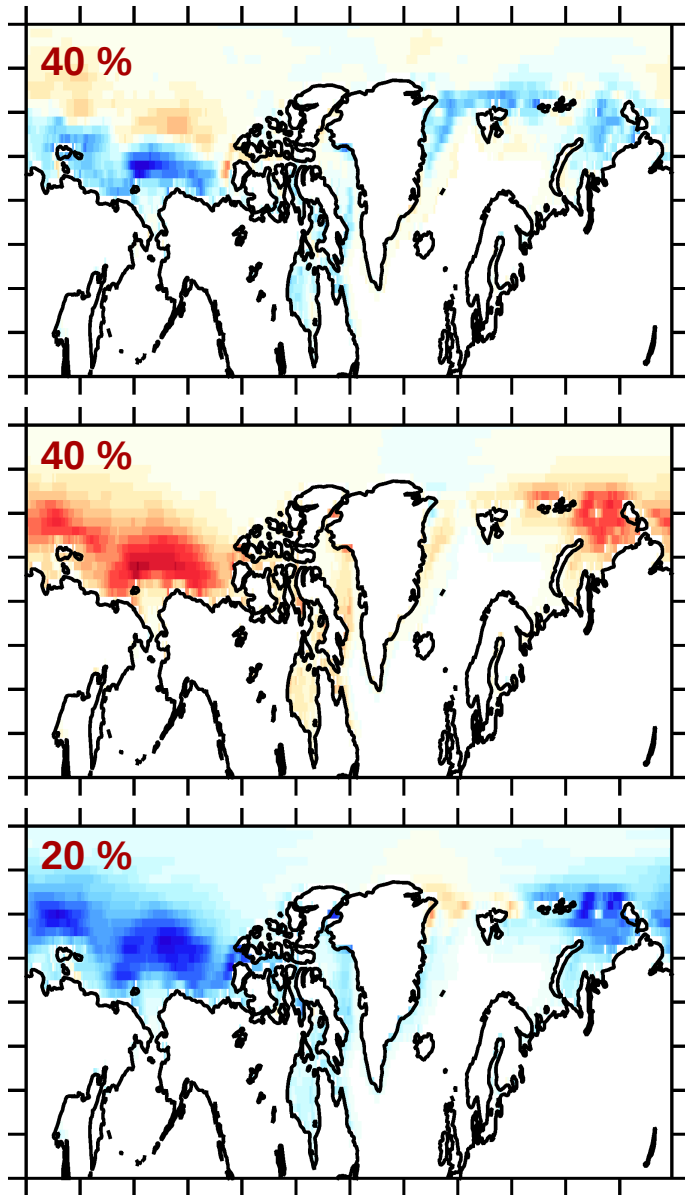
Root-mean-square difference between the anomaly and the closest mode

# Modes of variability in winter (JFM) in OSI SAF SIC

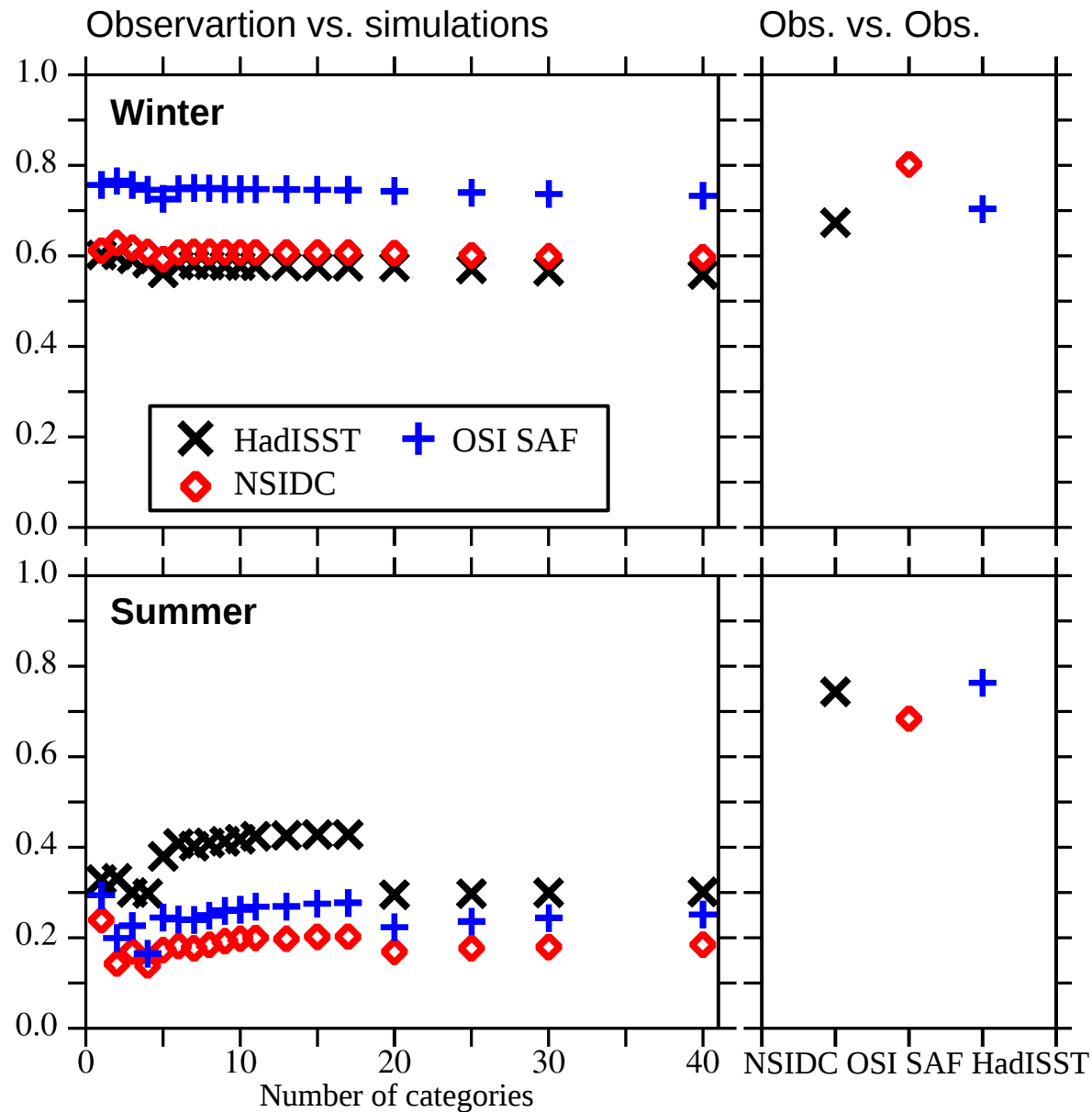




# Modes of variability in winter (JAS) in OSI SAF SIC

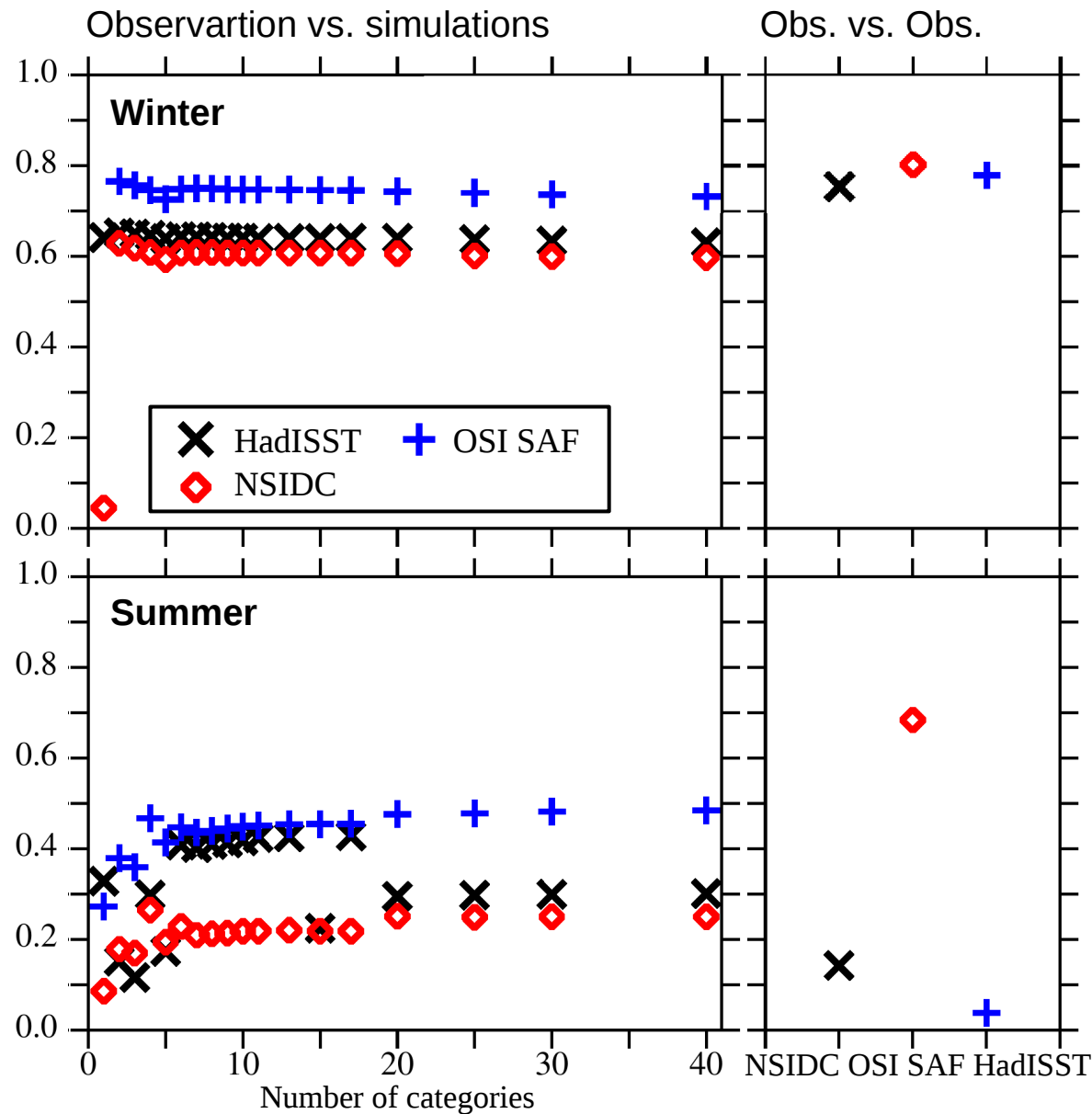


# Spatial correlation with respect to the observed 1st mode





# Spatial correlation with respect to the observed 3rd mode



## Summary: Impact of number of thickness categories on sea ice concentration variability

- Massonet et al. [in review]: on average, including more categories leads to unrealistic, thicker sea ice, with no convergence (+ being computationally heavier)
- Model–data comparison of the first three modes of variability in Arctic SIC in winter (JFM) and summer (JAS):
  - No big gains or losses in winter
  - Largest effect in the 2nd and 3rd summer modes, but no evident magic number of categories
  - Uncertainty in the observed variability affects comparison



# Improving the representation of sea ice variability and seasonal prediction

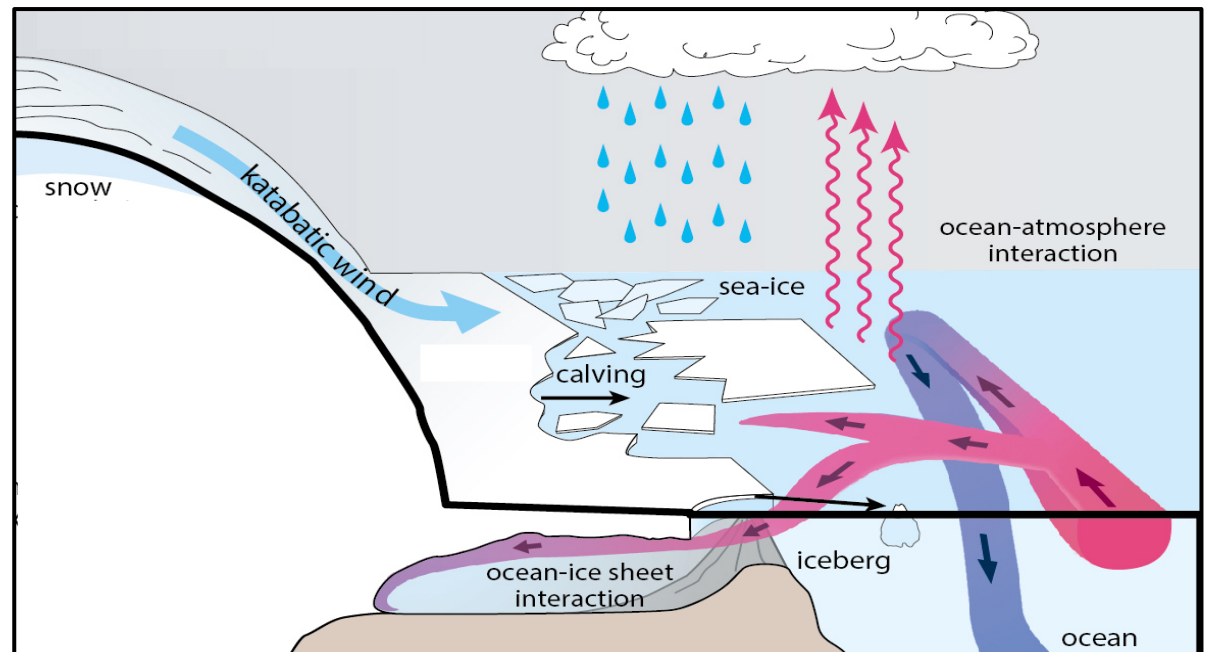
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Two pronged approach:

- Improving the representation of sea ice in EC-Earth (LIM3)
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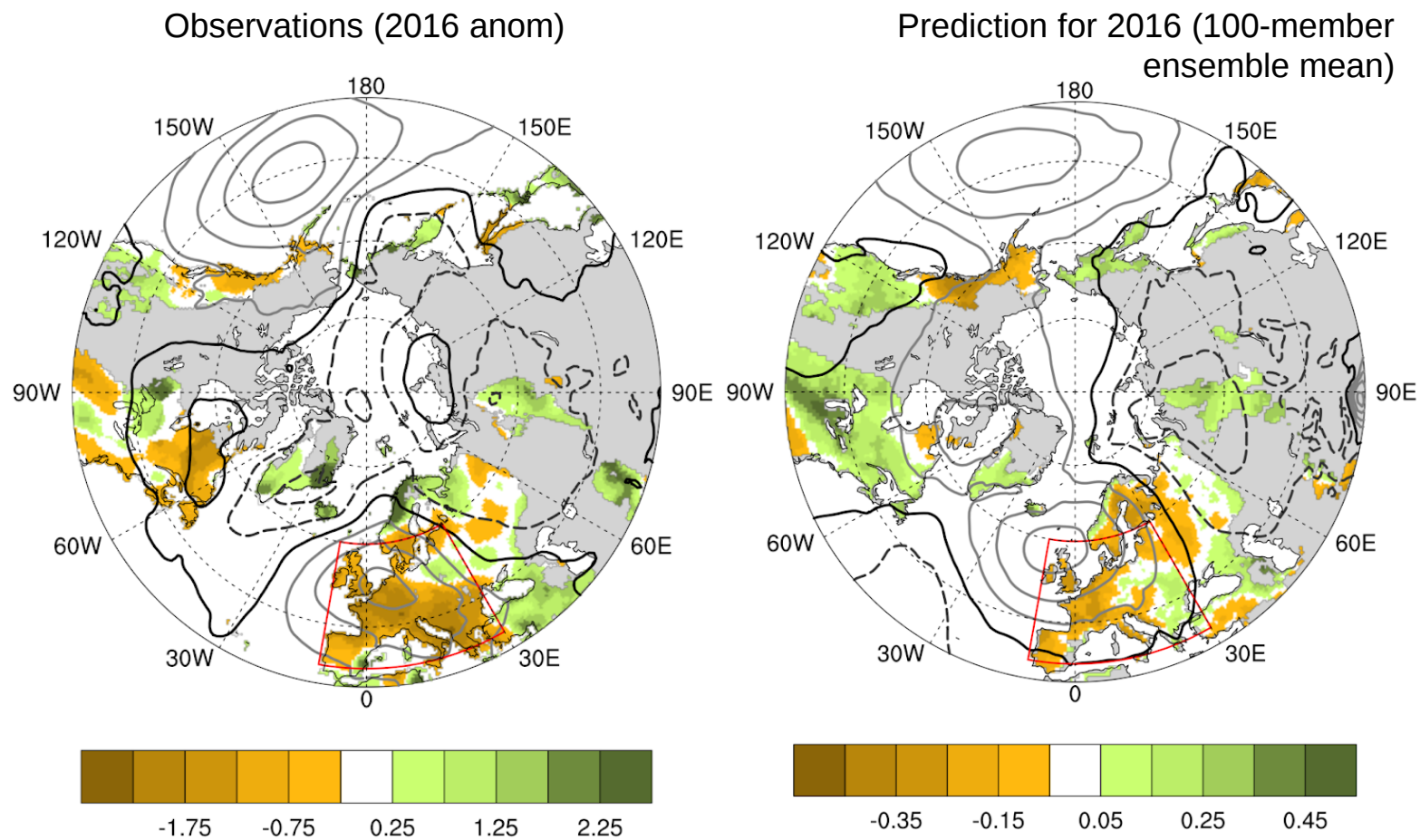
→ Assess the impacts of such improvements on sea ice variability and **mid-latitude weather and climate**



Adapted from 5<sup>th</sup> IPCC report

# Impact of sea ice initialization to capture extreme events on mid-latitudes

Case of study: December 2016, lowest observed December precip in Europe since 1901



# Impact of sea ice initialization to capture extreme events on mid-latitudes

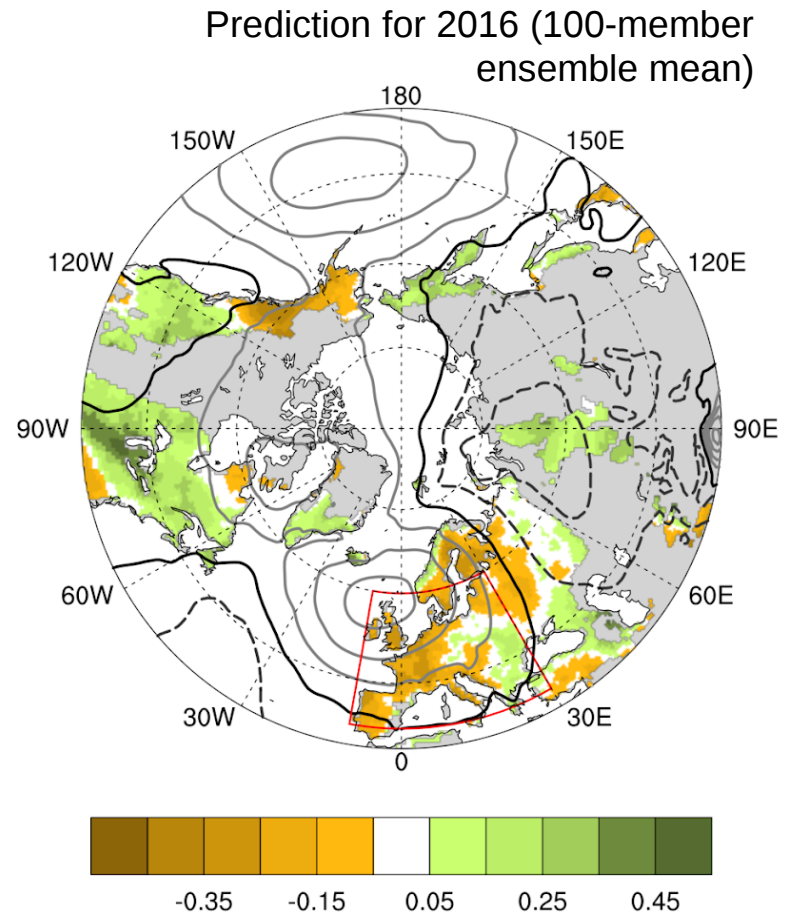
Case of study: December 2016, lowest observed December precip in Europe since 1901

## Forecast:

Fully coupled EC-Earth  
Starting in November 1

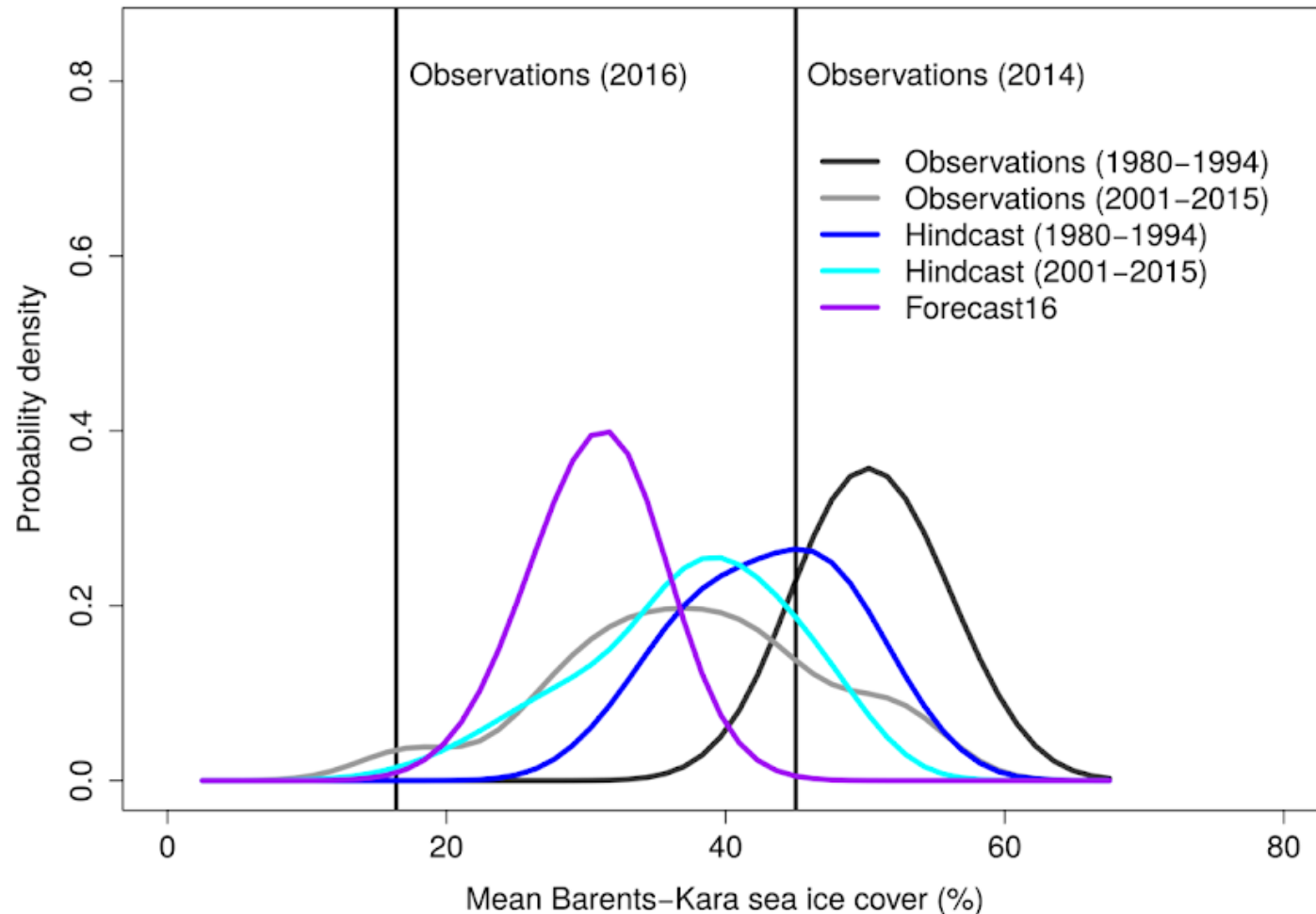
## Initial Conditions:

Atmosphere: ERA-Interim  
Ocean: ORAS4  
Sea ice: NEMO-only historical  
simulation assimilating ESA sea ice every  
month's last day



# Impact of sea ice initialization to capture extreme events on mid-latitudes

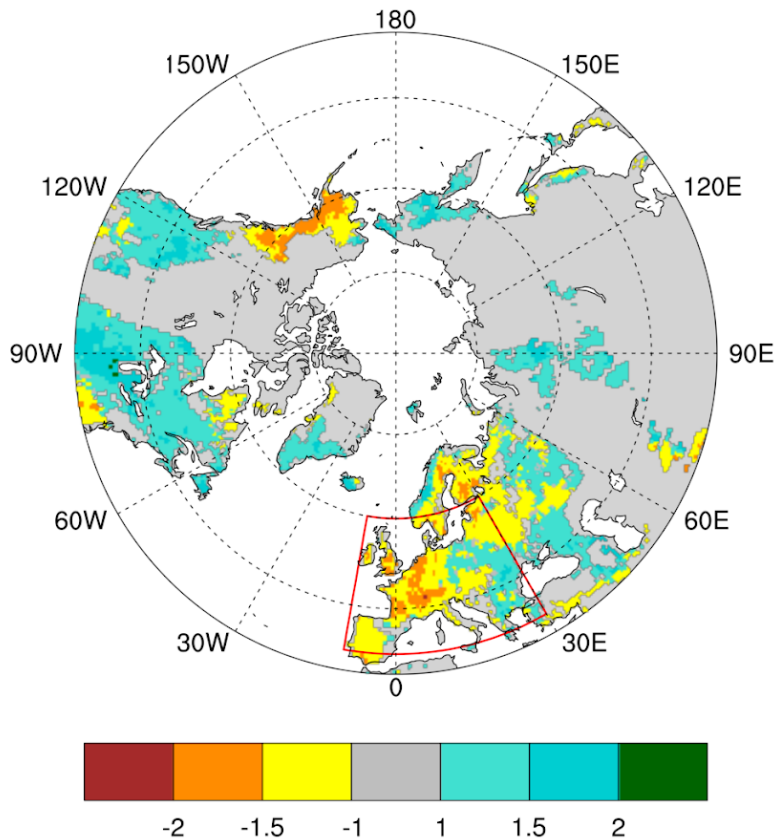
Case of study: December 2016, lowest observed December precip in Europe since 1901  
Nov–Dec 2016, lowest monthly sea ice cover (pan Arctic & Barents–Kara) since 1979



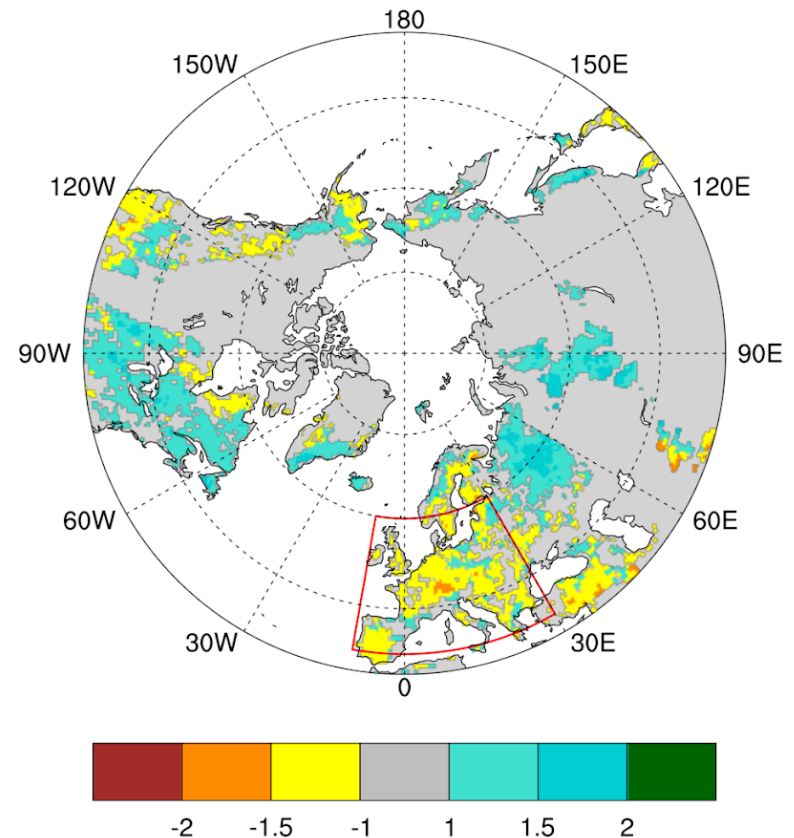
# Lowest sea ice cover in Barents and Kara seas in fall 2016 favored the likelihood of low December 2016 precip in Europe

In a 100-retrospective forecast of Nov 2016, extreme low precip better predicted if using correct low sea ice initial conditions

Forecasts with fall 2016 low sea ice



Forecasts with sea ice closer to climatological values (here, 2014)





## **Summary: Impact of sea ice initialization to capture extreme events on mid-latitudes**

→ Forecasting extreme events on mid-latitudes more likely if initializing sea ice

# Impact of sea ice initialization to capture extreme events on mid-latitudes

Case of study: December 2016, lowest observed December precip in Europe since 1901

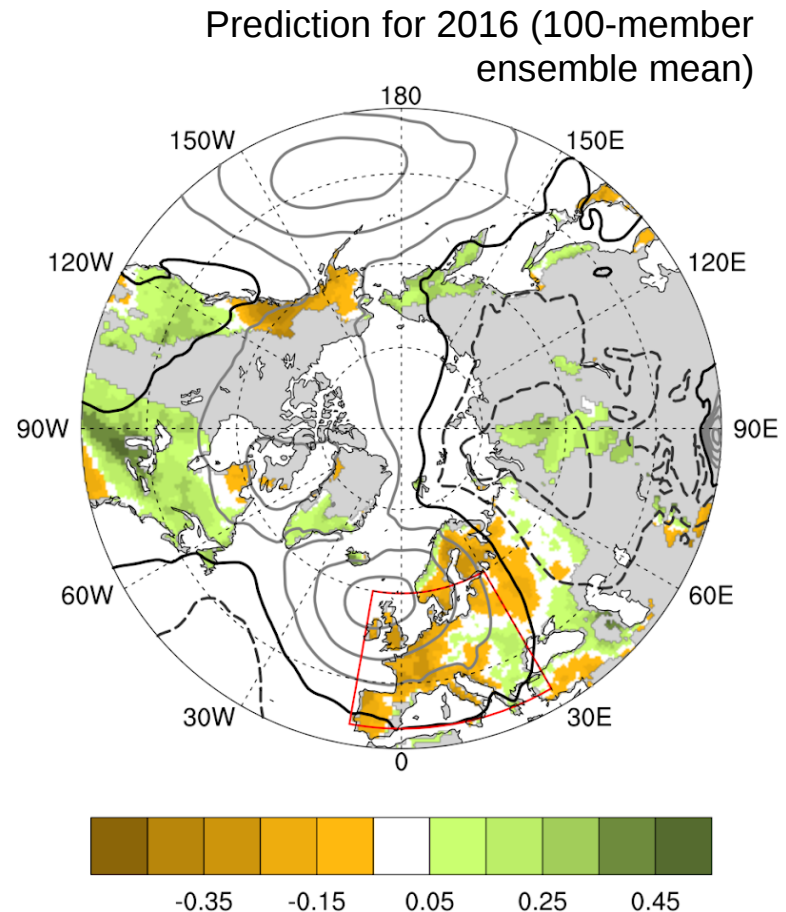
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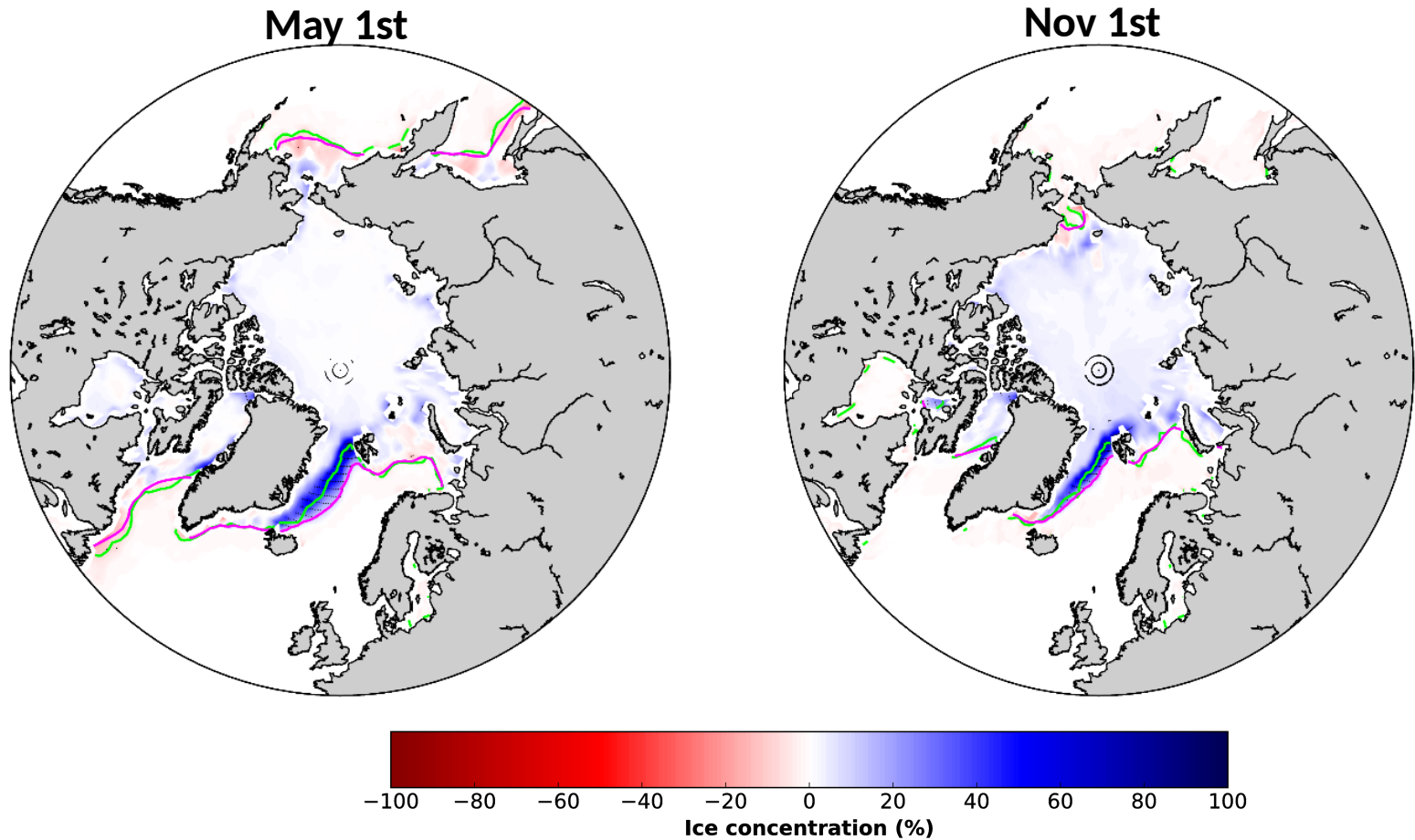
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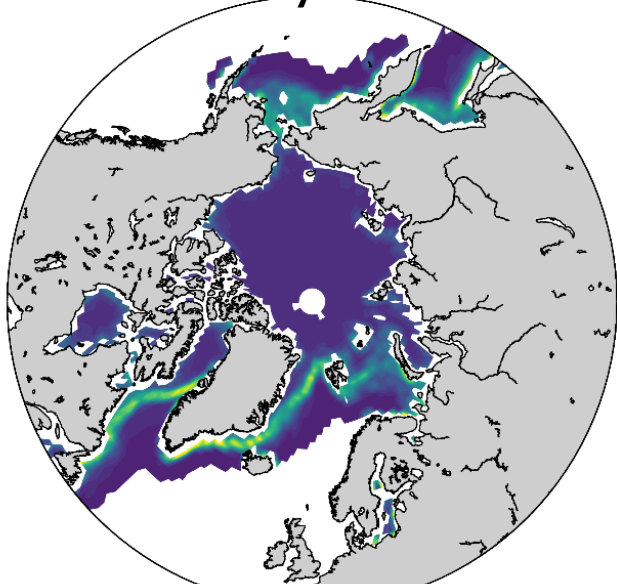
# Large bias in SIC already on the first prediction day

SIC anomaly between an assimilation simulation and ESA observation

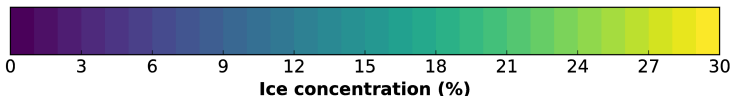


# Large bias in SIC already on the first prediction day: Three potential error sources

May 1st

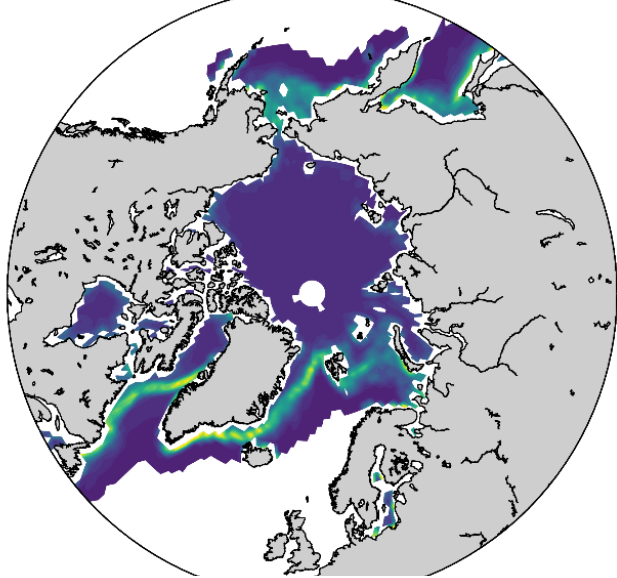


1) Observation uncertainty (taken into account by the Ensemble Kalman Filter)



# Large bias in SIC already on the first prediction day: Three potential error sources

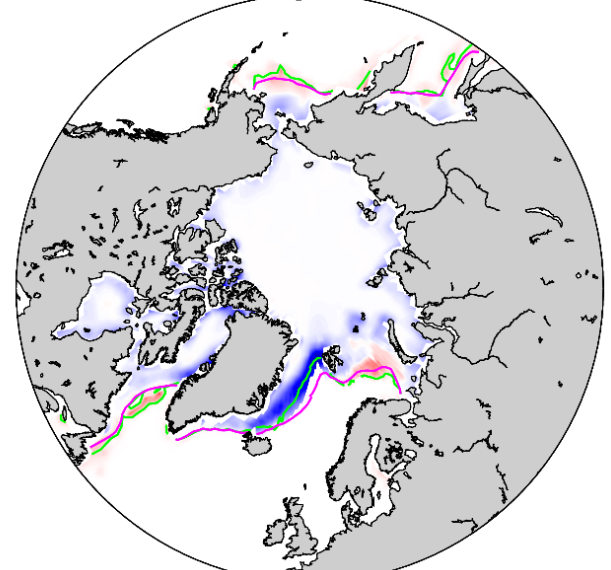
May 1st



Ice concentration (%)

1) Observation uncertainty (taken into account by the Ensemble Kalman Filter)

May 1st



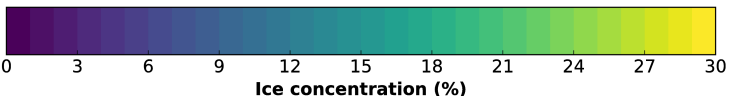
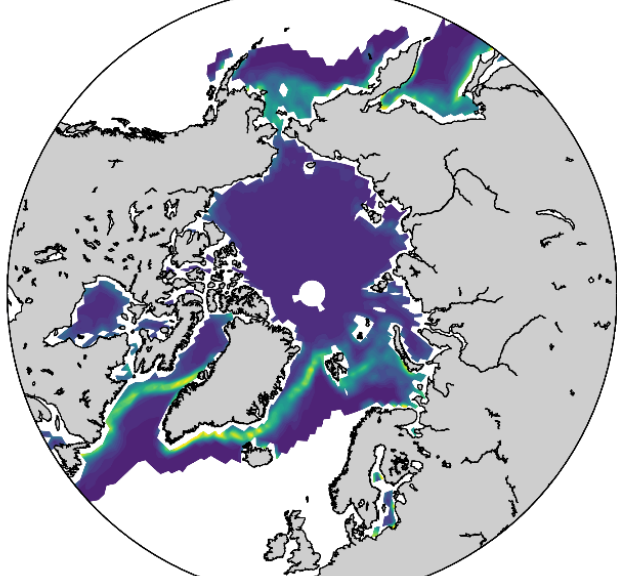
Ice concentration (%)

2) Incompatibility between SIC in assimilation runs and the SIC in ORAS4 (provides ocean initial conditions)



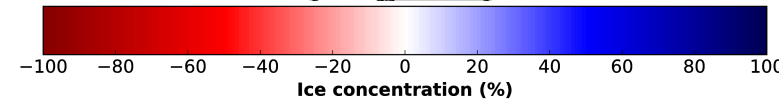
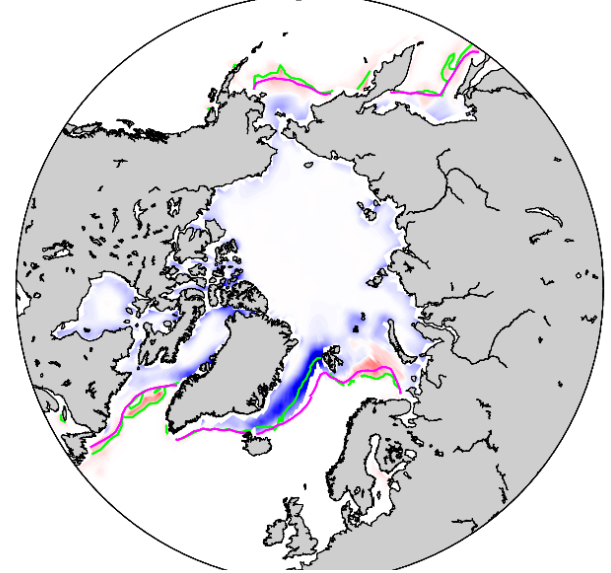
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1) Observation uncertainty (taken into account by the Ensemble Kalman Filter)

May 1st



2) Incompatibility between SIC in assimilation runs and the SIC in ORAS4 (provides ocean initial conditions)

3) Systematic model biases

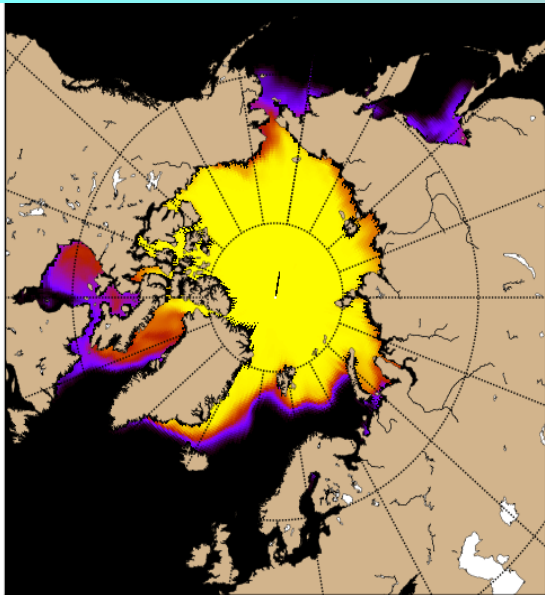
## Summary: Sea ice assimilation

- Large biases in SIC already growing on the first day after assimilation
  - Assimilating observations once a month might not be sufficient
  - Working toward having assimilation + ocean nudging
  - SIC biases after assimilation show seasonal dependence

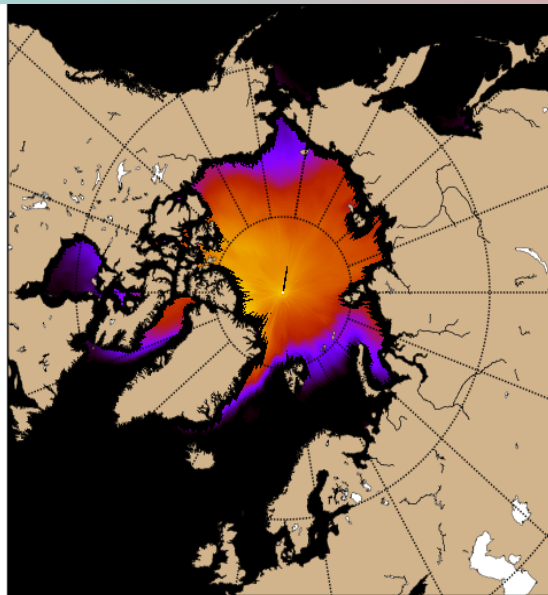
# A novel technique for nudging sea ice concentration: nudging by relaxing SST

Too low SIC compared to a target value → SST relaxed toward lower values →  
→ Ocean heat sink → Sea ice growth (and vice versa)

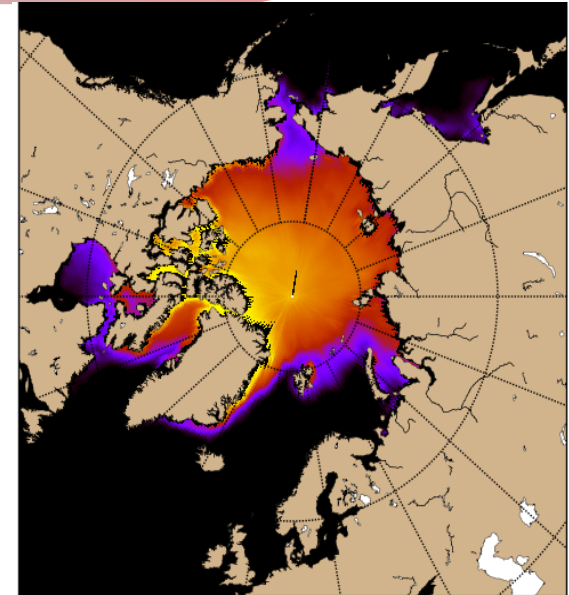
SIC in a control run  
(forcing year 2000, nudging OFF)



SIC mask  
(late 21th century)



SIC in a nudged run  
(forcing year 2000, nudging ON)



## Summary: Improving the representation of sea ice variability and seasonal prediction

- Sea ice thickness categories: model–data comparison of the first three modes of variability in winter (JFM) and summer (JAS) in the Arctic:
  - No big gains or losses in winter
  - Largest effect in the 2nd and 3rd summer modes, but no evident magic number of categories
  - Uncertainty in the observed variability affects comparison
- December 2016 low precip in Europe: forecasting some extreme events on mid-latitudes more likely if initializing sea ice
- Large biases in SIC already growing on the first day after assimilation
  - Assimilating observations once a month might not be sufficient
  - Working toward having assimilation + ocean nudging
  - SIC biases after assimilation show seasonal dependence
- Improvements in prescribed SIC through SST nudging

