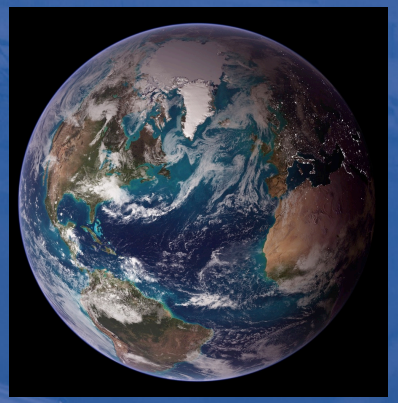
www.bsc.es

Earth Sciences Department



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# Arctic research activities at BSC

&

# On Arctic sea ice thickness clusters

Neven S. Fučkar (neven.fuckar@bsc.es), Virginie Guemas, François Massonnet, Javier García-Serrano, Ruben Cruz Garcia and Francisco J. Doblas-Reyes

Earth Sciences Department, Barcelona Supercomputing Center (BSC), C. Jordi Girona 29, 1D, 08034 Barcelona, Spain

Arctic ECRA Workshop, Helmholtz Association, Brussels, Belgium
25-26 February, 2016

# BSC-CNS

**Barcelona Supercomputing Center – Centro Nacional de Supercomputación (BSC-CNS)** is the premium HPC center in Spain located on **UPC** campus in Barcelona

More than 400 members (from more than 30 countries) are organized in 5 departments:

- → Computer Sciences
- → **Earth Sciences**
- → Life Sciences
- → Computer Applications
- → Support and Services

**MareNostrum III** (housed in Torre Girona) is one of the most powerful supercomputers in Europe (48,128 processors with 1.1 Pflops peak performance) ➠ this year it will be replaced with **MareNostrum IV**



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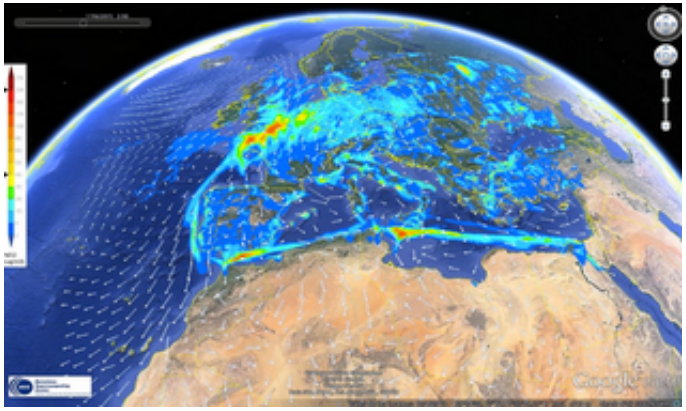
# Earth Sciences Department

**Earth Sciences Department** → conduct research in **Earth System Modeling** and is structured in 4 groups:

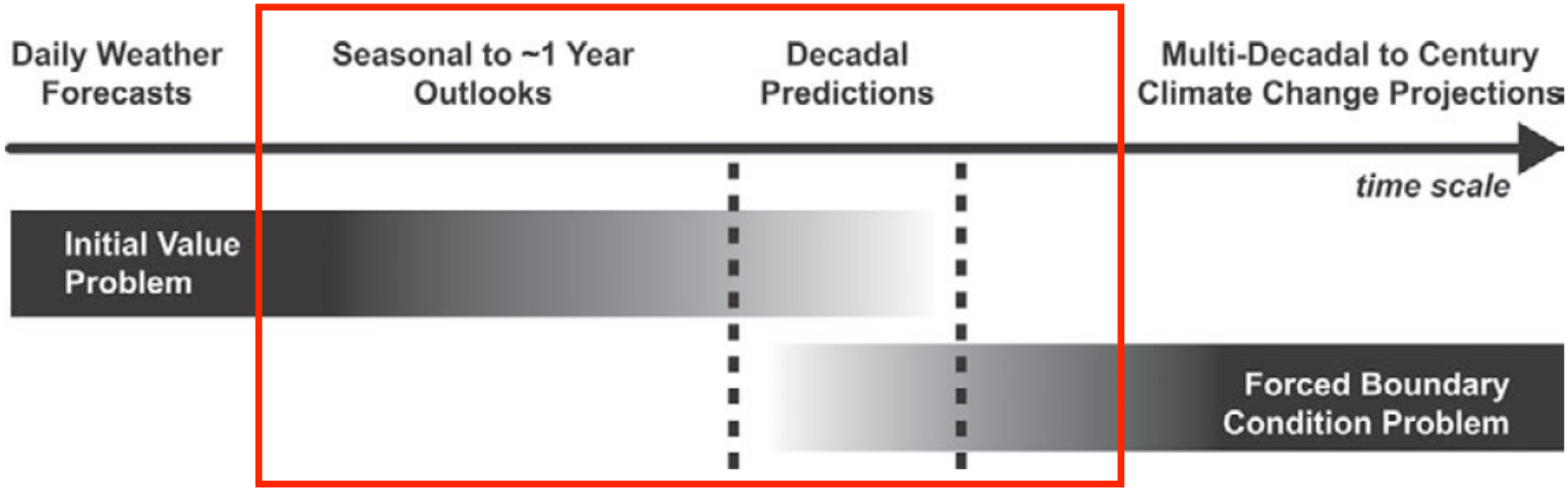


- **Atmospheric Composition** → regional and global weather chemical predictions, air quality, dust emissions, ..
- **Climate Prediction** → regional and global climate predictions from sub-seasonal to multi-decadal timescales, climate analysis, ..
- **Earth System Services** → facilitate knowledge and technology transfer, via tailored services, between science and its end users, aim to maximize value of air quality and climate predictions to society, ..

- **Computational Earth Sciences** → support and development of software and IT infrastructure for Earth Sciences Department

# Climate Prediction Group (CPG)

**Climate predictions group focuses on weekly to annual forecasts on subseasonal (<3 months), seasonal (3-6 months), interannual (multi-year) and multi-decadal times scales (up to 30 years ahead)**

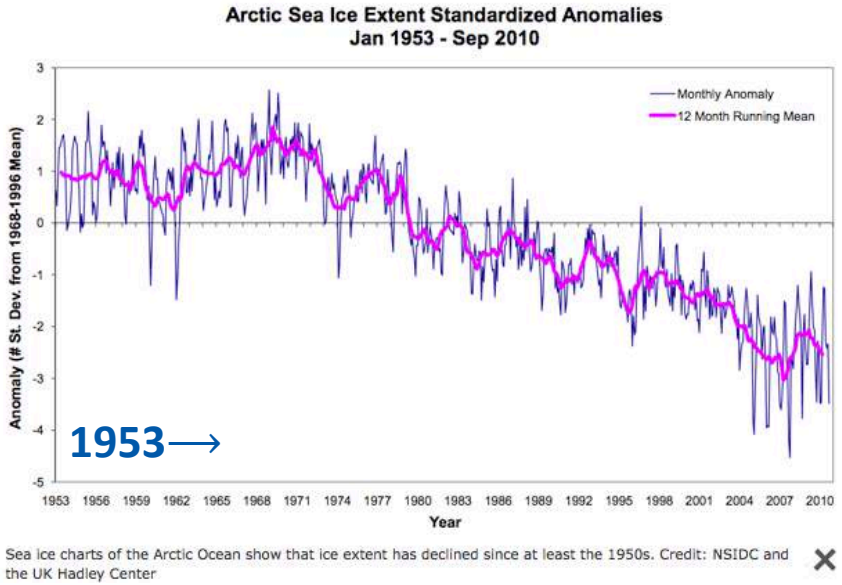



**Range where memory of the initial state (IC) and boundary forcing (BC) are both critical**

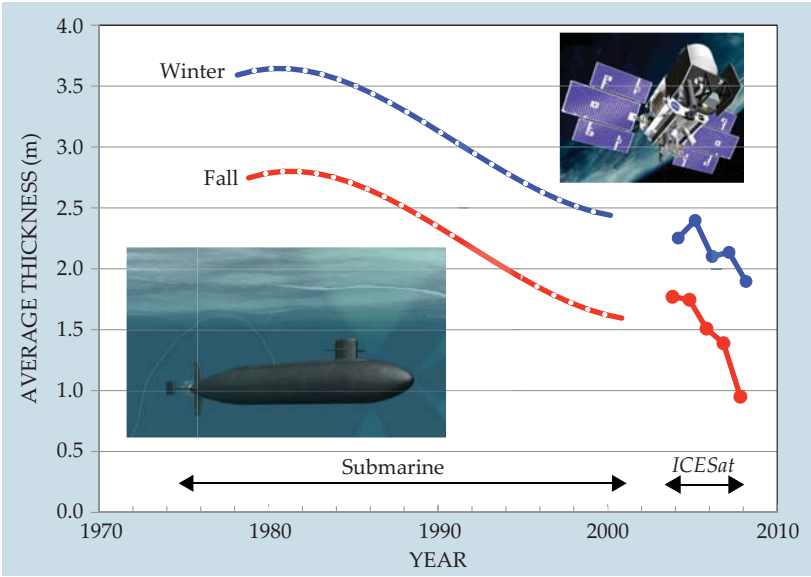


# Arctic variability and change

- NH sea ice cover has experienced a long-term decline superimposed on a strong internal variability → what is the impact on Arctic predictability?




Sea ice charts of the Arctic Ocean show that ice extent has declined since at least the 1950s. Credit: NSIDC and the UK Hadley Center

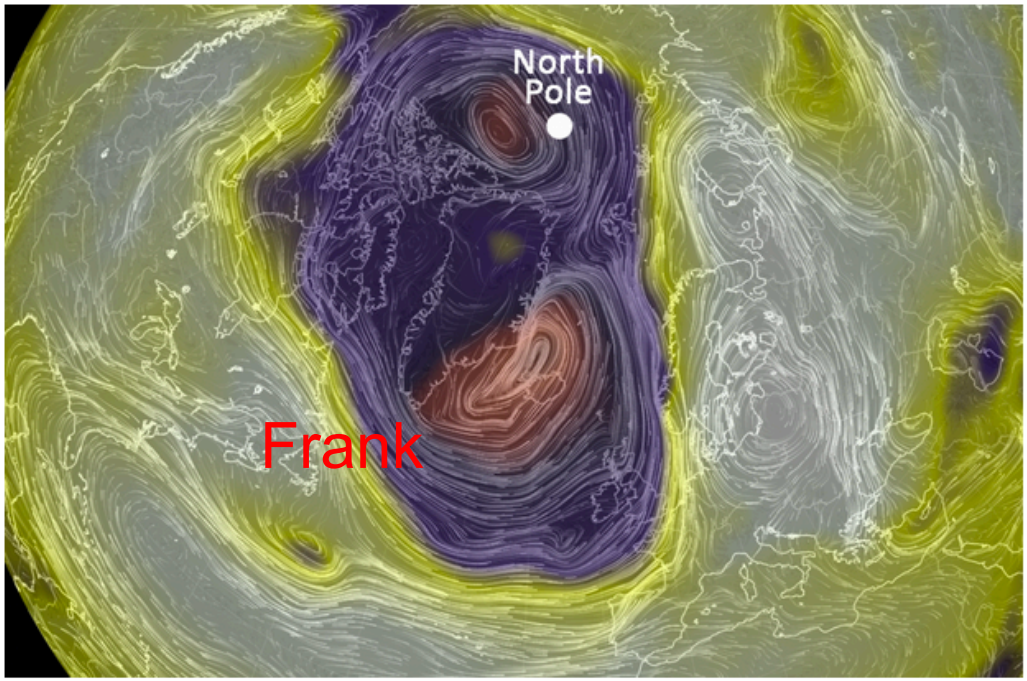


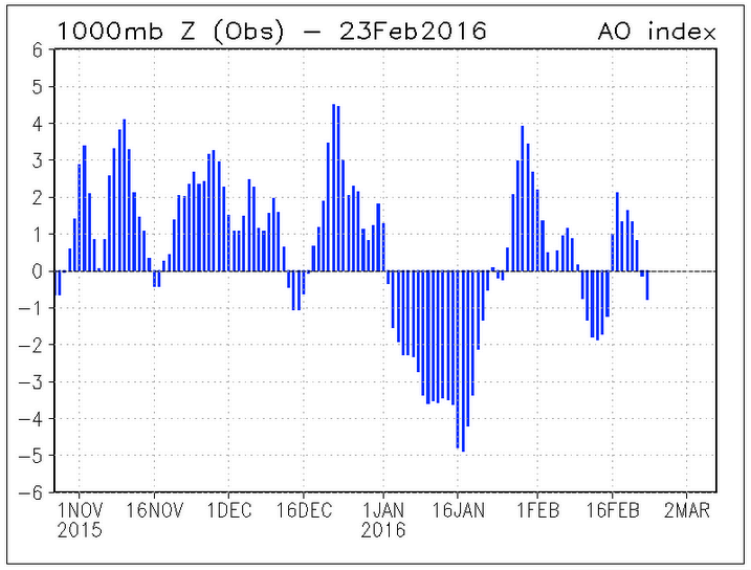

- Key climate memory (IC=initial conditions) resides in the ocean (SST, ML heat content, …), **sea ice – critical on subseasonal to interannual timescale (sea ice concentration, SIC, and thickness, SIT, ..)** and land surface (snow cover, soil moisture, ..)



# Recent Arctic highlights

## From Arctic perspective we certainly live in “interesting times”



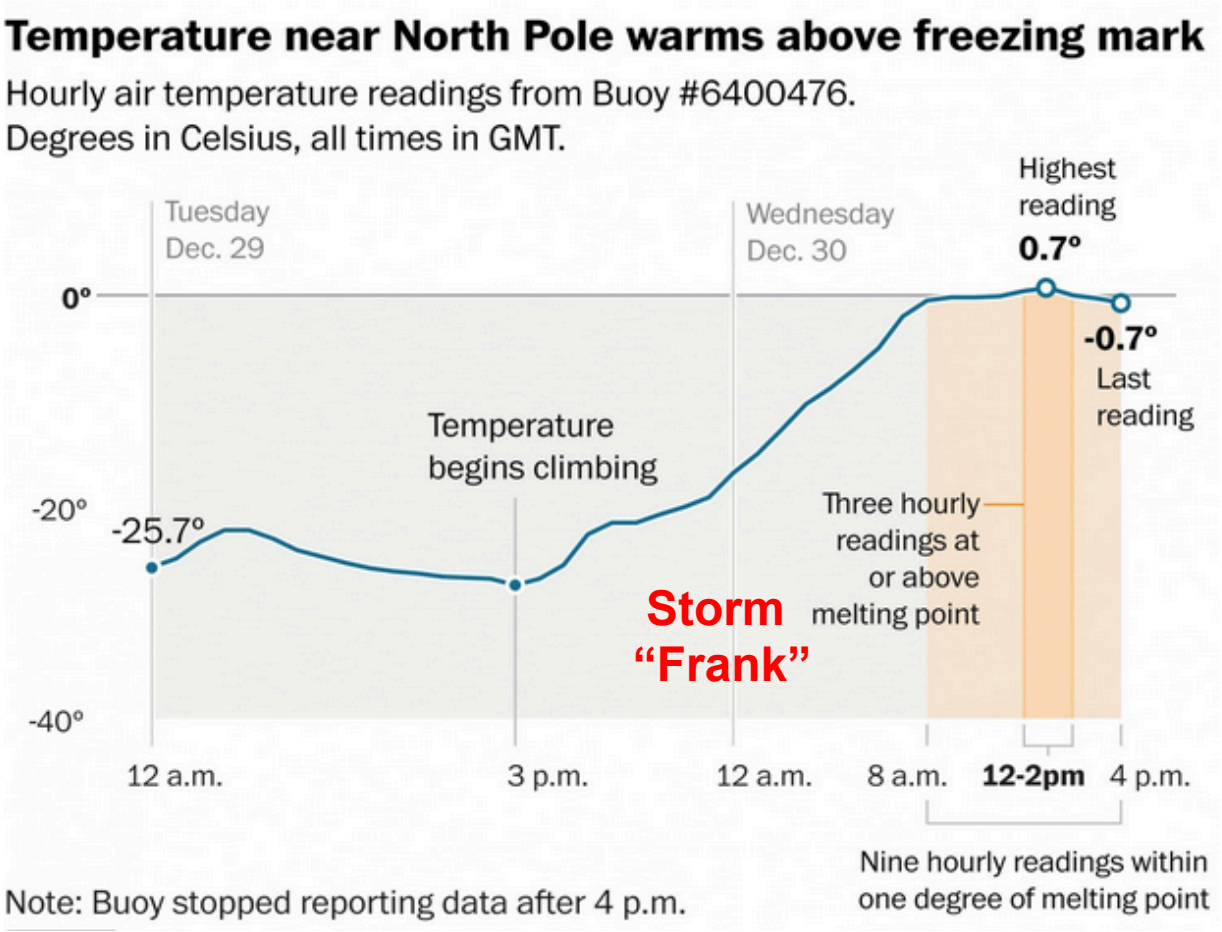

NCEP/NOAA

≈ 30 Dec, 2015



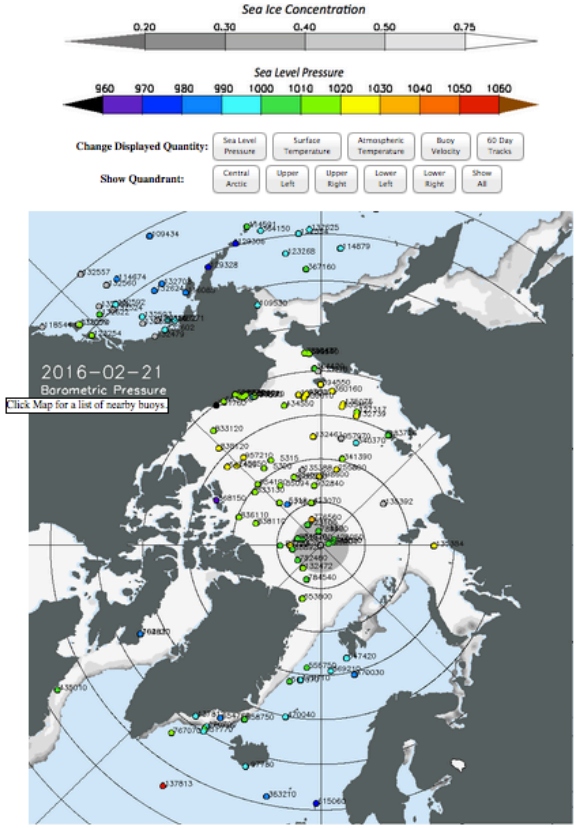
# Recent Arctic highlights

## → short-term variability



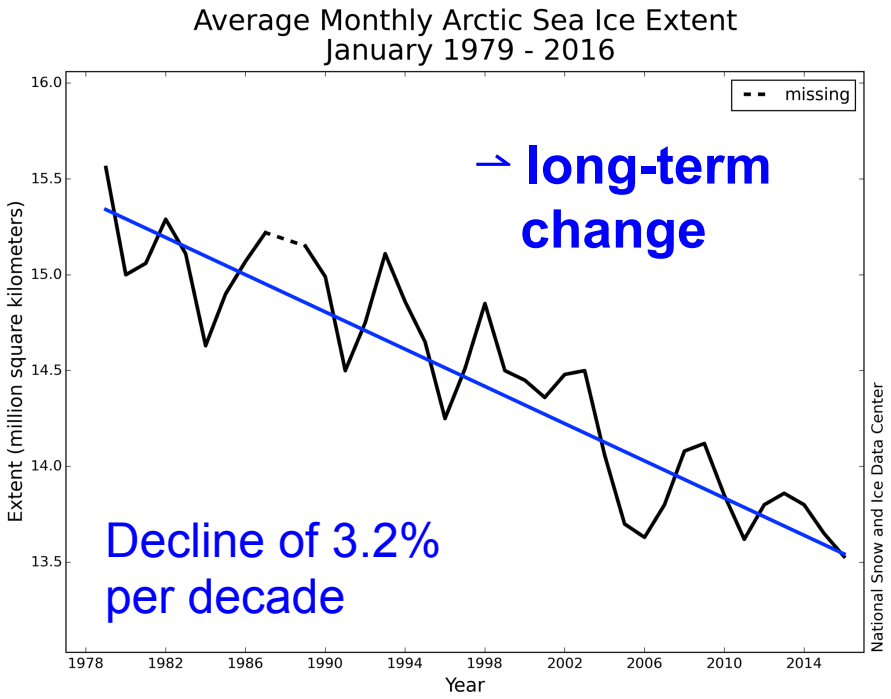

## International Arctic Buoy Program

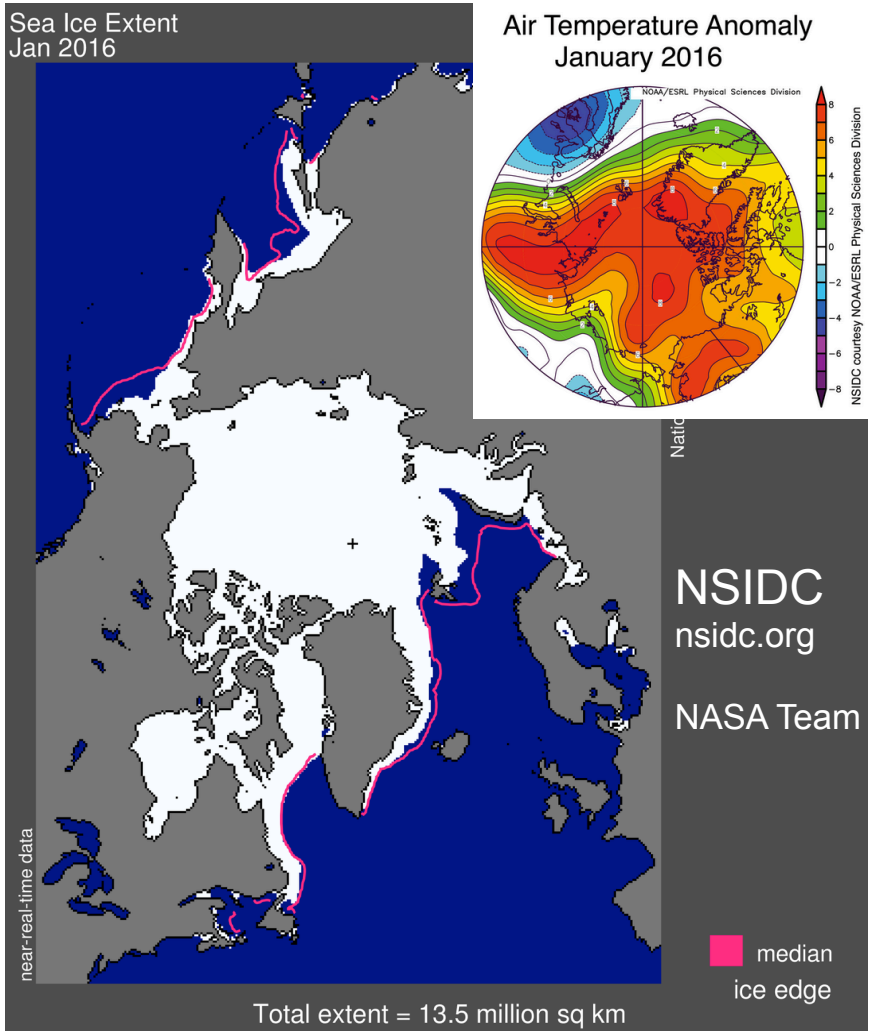
iabp.apl.washington.edu



# Recent Arctic highlights

- **The lowest NH January SIE in the satellite record (since 1979)**
  - → unusually high SAT
  - → persistent negative AO phase



# Arctic research in CPG

- **Sea ice ESM reconstruction and initialization**

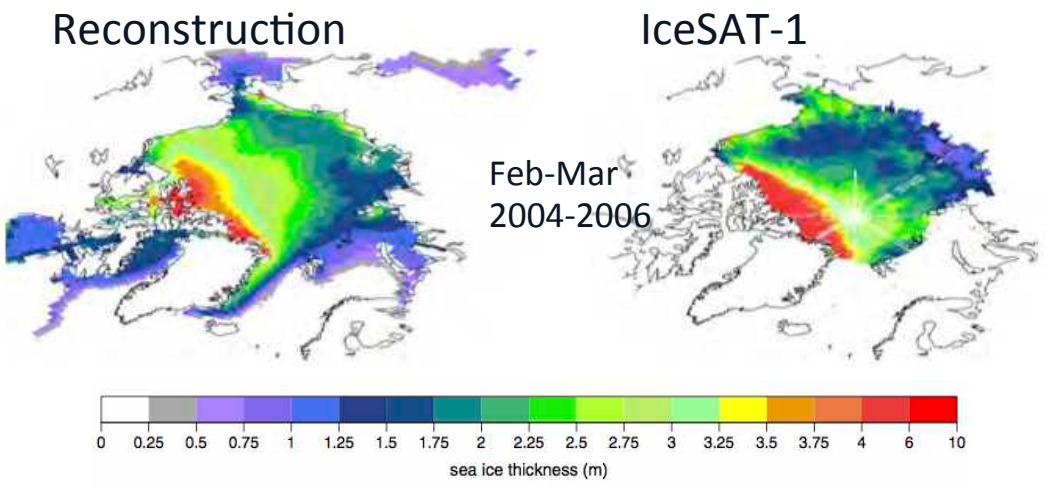
Quality of climate forecast depends on developement of a model (numerical methods and **inclusion of expanding set of physical and biogeochemical processes**) and the associated **data assimilation** routine for **production of different observationally based IC**

→ **SIT** is likely a key medium for the sea ice system memory on longer time scales

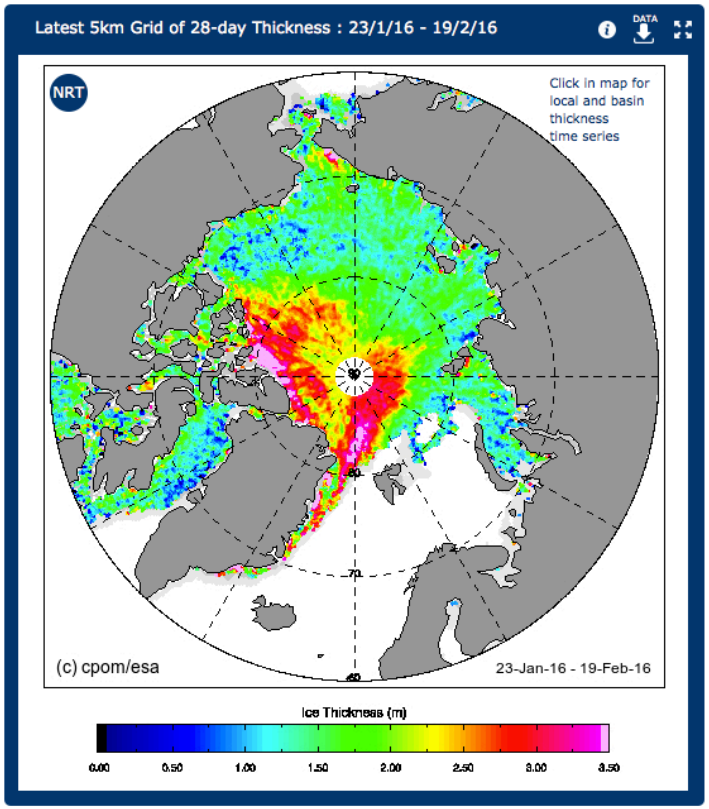
# Arctic research in CPG

Measuring **SIT** is a demanding task at any scale ⇒ use **reconstruction = GCM + data assimilation**

For example: multi-member NEMO3.2-LIM2 reconstructions (surface forcings: DFS4.3 and ERA-Int, and ocean restoring/nudging: ORAS4) utilized to get continuous **SIT** from 1958 to 2013




**CryoSat-2**



# Sea ice initial conditions for EC-Earth climate predictions

Source: GLORYS2v1, ORAP5, ... Reanalysis

* interpolation and extrapolation to different grids (resolutions)

Source: BSC reconstructions

LIM2:

* ORCA1 : 5-member sea ice reconstructions obtained by running NEMO-LIM2 nudged toward ORAS4 monthly-mean 3D T and S and forced by
  1. DFS4.3 over the 1958-2006 period = b02s
  2. ERA-interim over the 1979-2013 period = i00v

LIM3 – 1 category:

* ORCA1 : 5-member sea ice reconstructions obtained by running NEMO-LIM3 nudged toward ORAS4 monthly-mean 3D T and S and forced by
  1. DFS4.3 over the 1958-2006 period = i056
  2. ERA-interim over the 1979-2013 period = i057

LIM3 – 5 category:

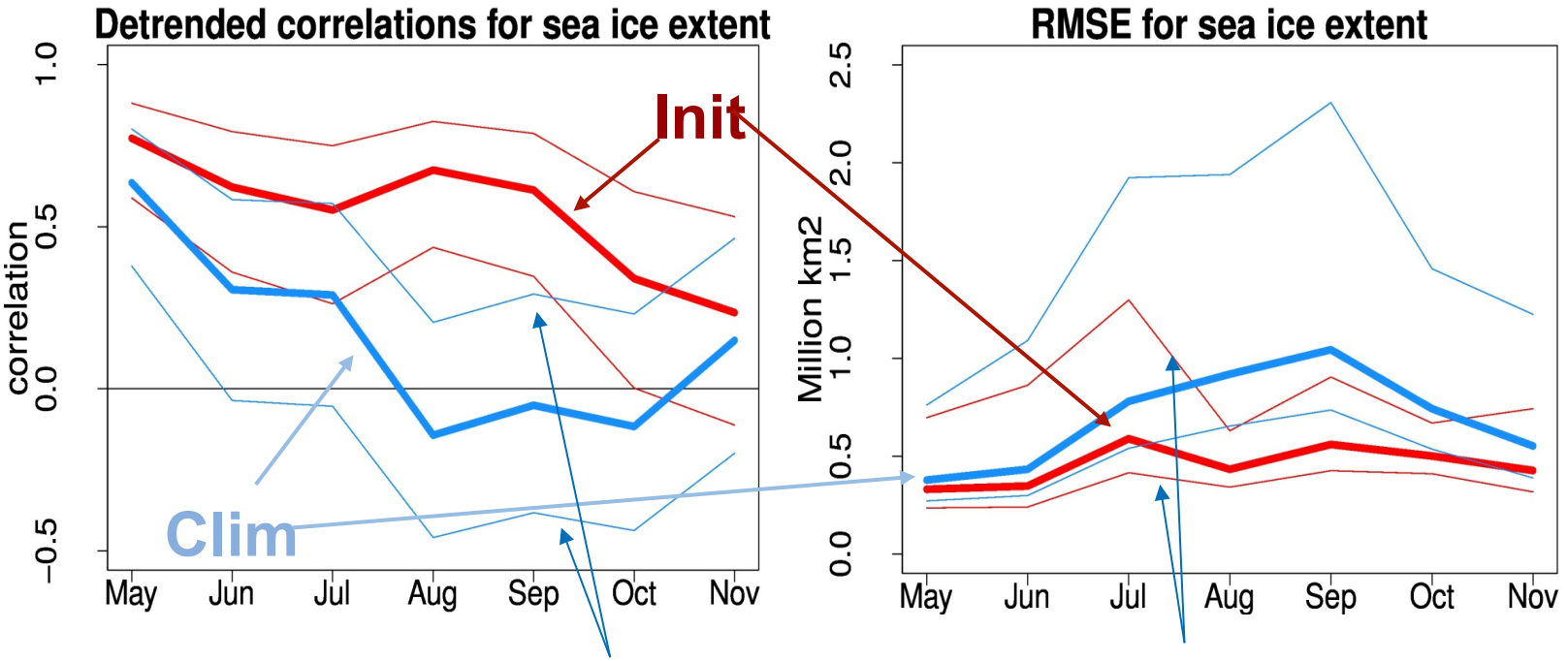
* ORCA1 and ORCA025 … → **data available to community and stakeholders**

More information : https://dev.ec-earth.org/projects/ecearth3/wiki/Sea_Ice_initial_conditions_for_climate_predictions



# Arctic research in CPG

- Arctic ESM predictions from May 1st start dates



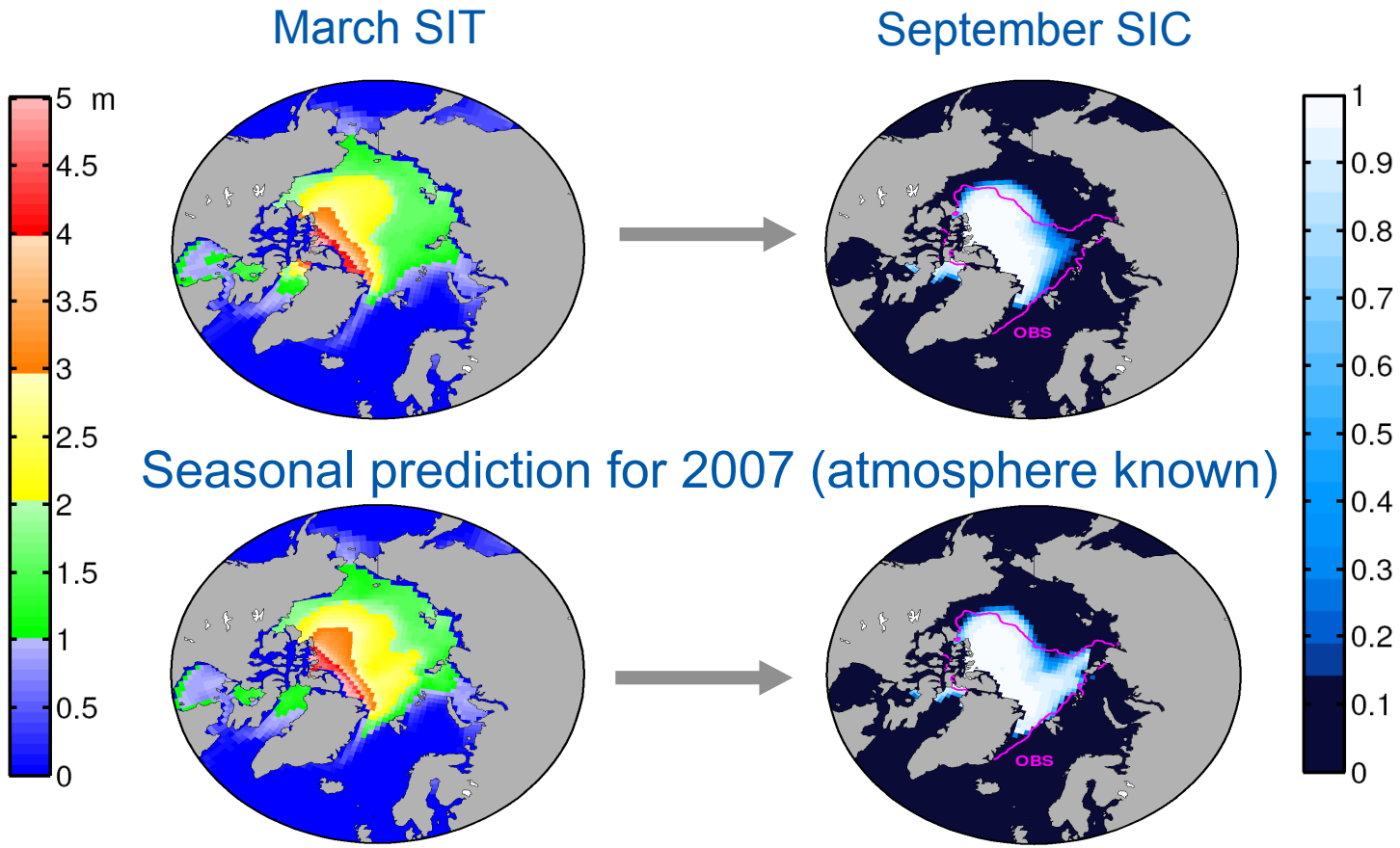

95% confidence interval

**Skill increases** with sea ice **initialisation** using **nudging method** (not due to the long-term trend)



# Arctic research in CPG

- The ensemble Kalman filter (EnKF): a multivariate data assimilation method for smoother initialization



# Arctic research in CPG

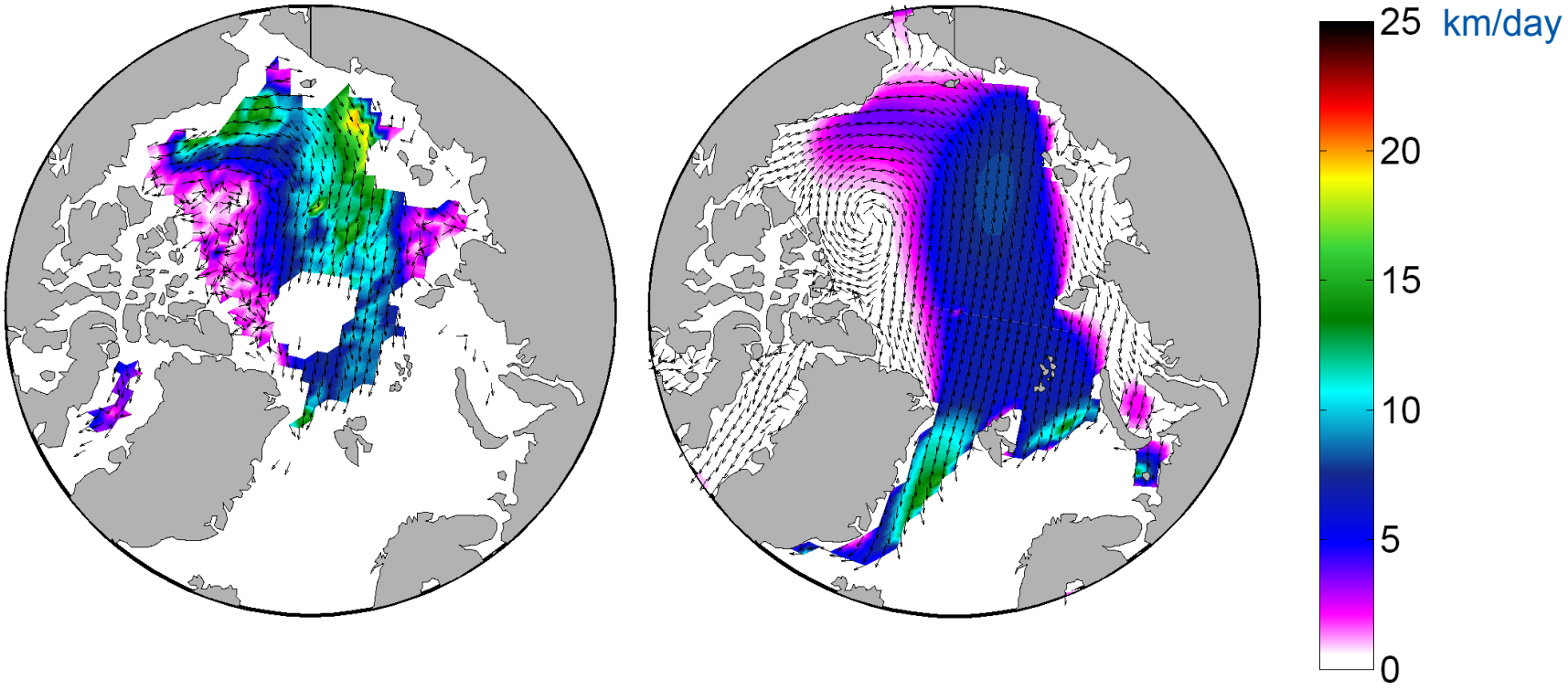
$$F\downarrow air/ice + F\downarrow ocean/ice + F\downarrow ice/ice \approx 0$$

$C_a$ $C_w$ $P^*$

- Parameter calibration via EnKF

Sea ice drift (observed)

Sea ice drift (model)



# Arctic research in CPG

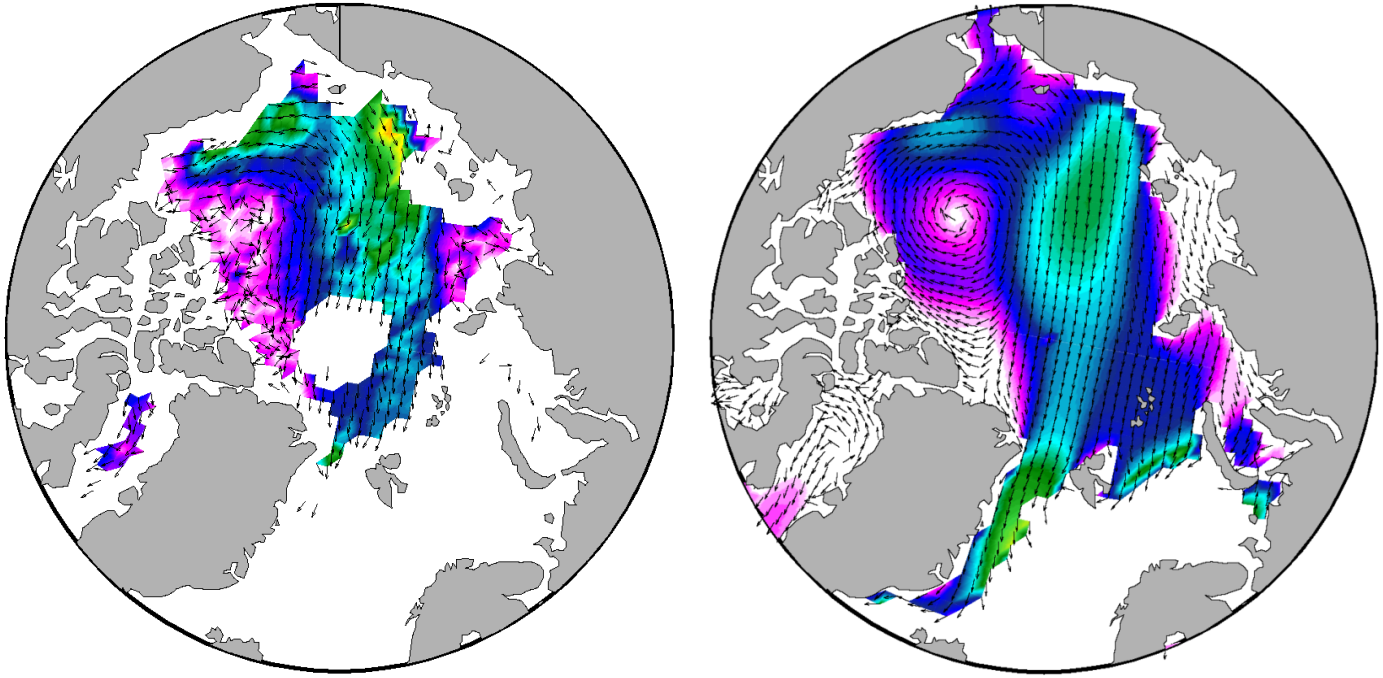
$$F\downarrow air/ice + F\downarrow ocean/ice + F\downarrow ice/ice \approx 0$$

$C_a$ $C_w$ $P^*$

- Parameter calibration via EnKF

Sea ice drift (observed)

Sea ice drift (model, parameters calibrated)





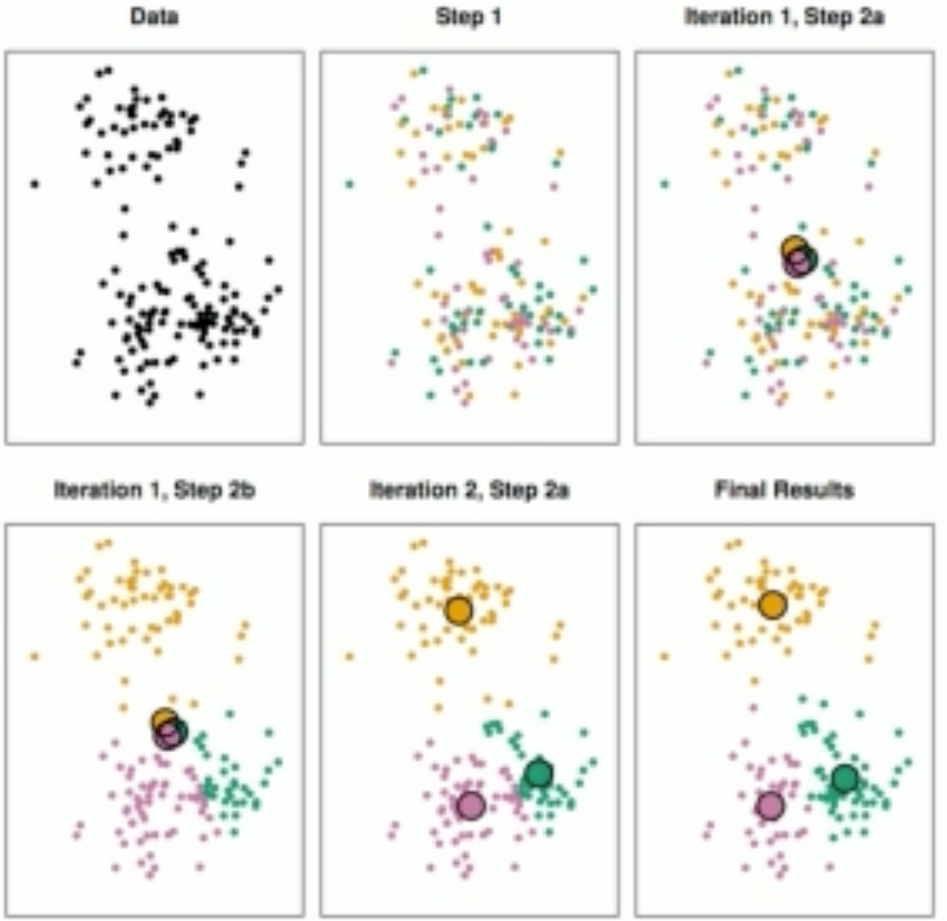

# SIT K-means cluster analysis

**K-means method** is a clustering analysis that simultaneously minimize the distance between members of a given cluster and maximize the distance between the centers of the clusters

→ **optimal number of clusters K** (typically determined via hierarchical clustering) **has to be specified in advance**

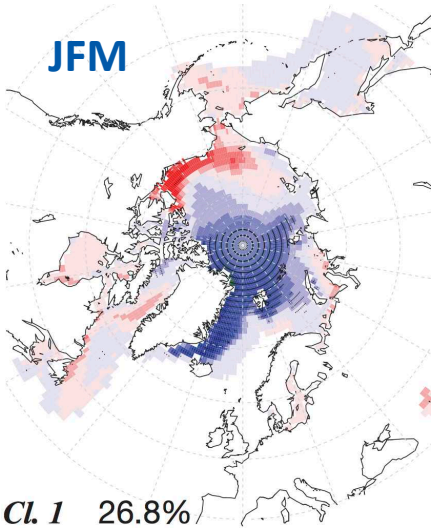
→ **produces** representation of the spatial and temporal variability with **K patterns of cluster centers and time series of cluster occurrences**

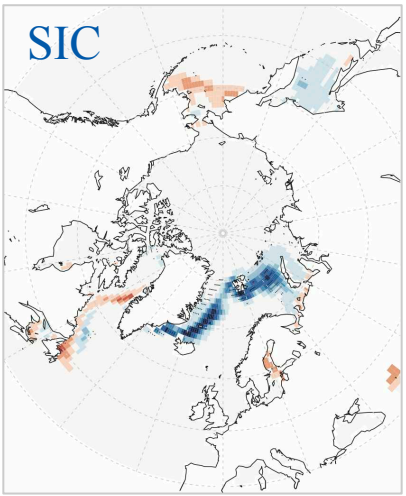
E.g. iterative procedure for K=3 with data($x_1$,$x_2$,t)



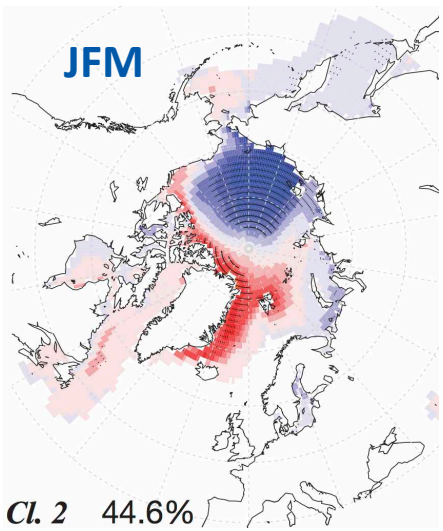
# SIT cluster centers & SIC comp.

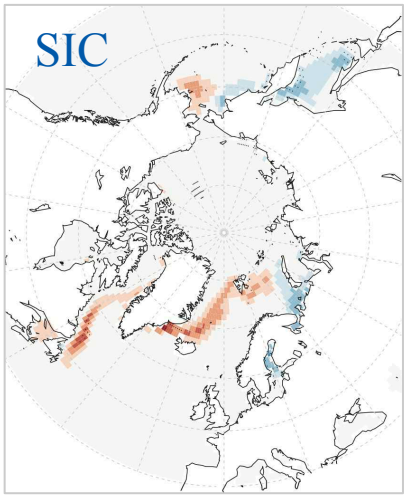
**CAT** mode



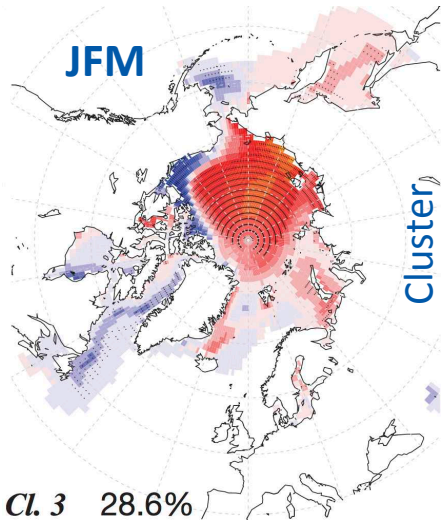



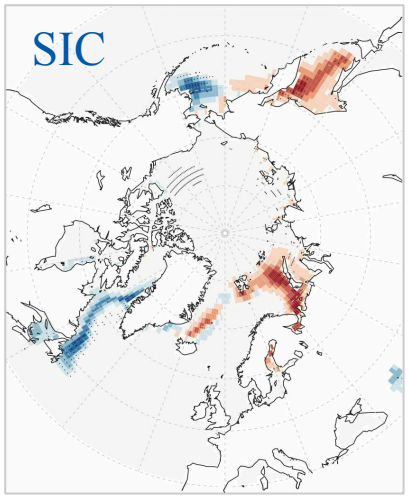

**APD** mode

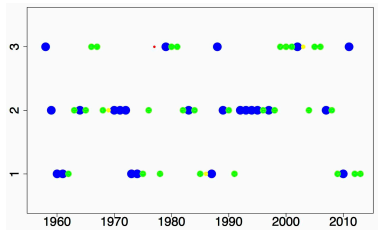



**CSD** mode




**CAT** mode = Central Arctic Thinning mode

**APD** mode = Atlantic Pacific Dipole mode

**CSD** mode = Candian Siberian Diploe mode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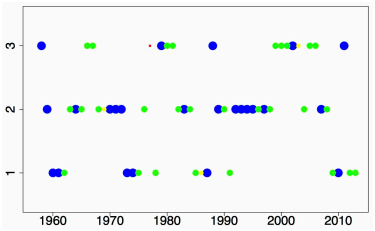
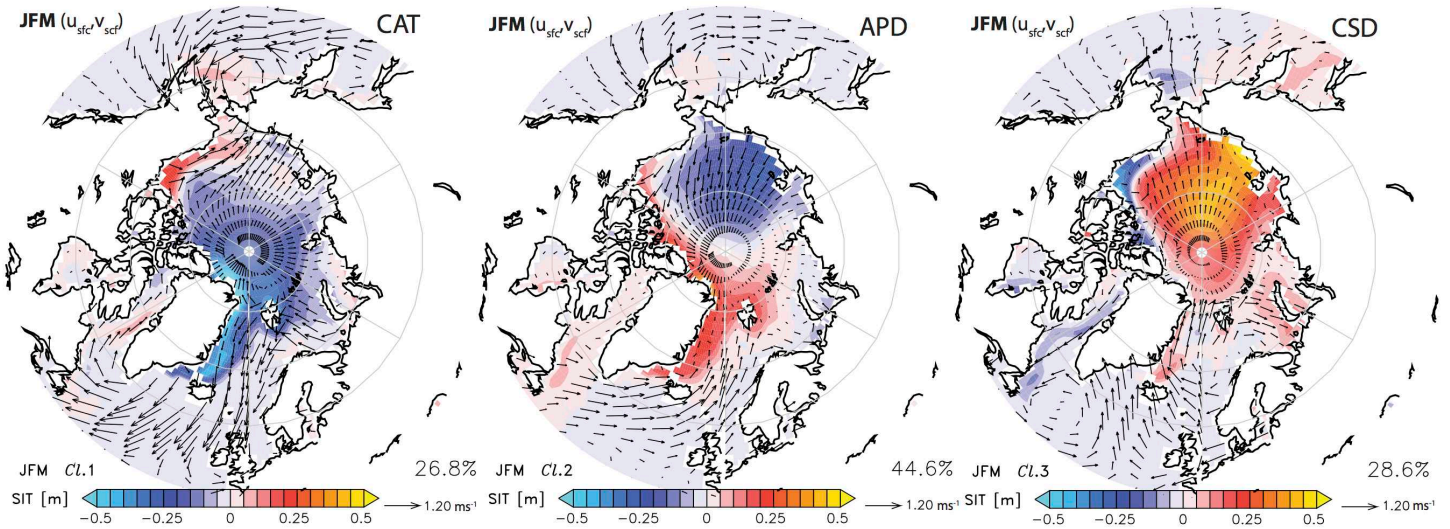
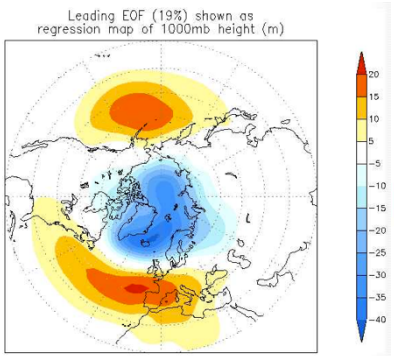
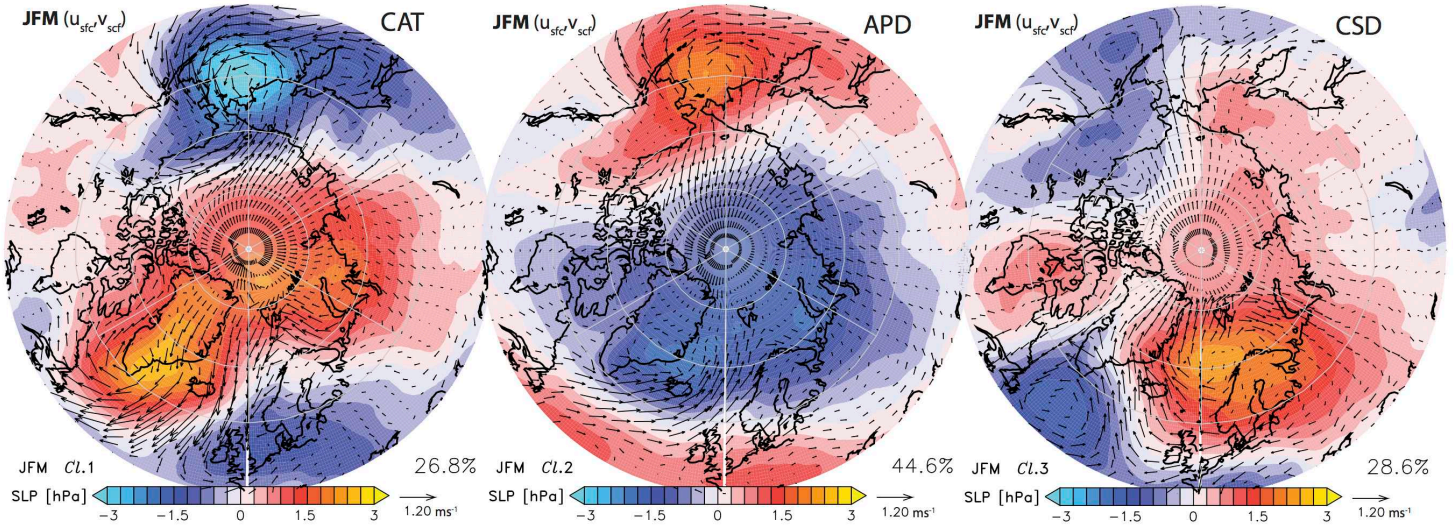
# Key influence of surface winds




NAM/AO





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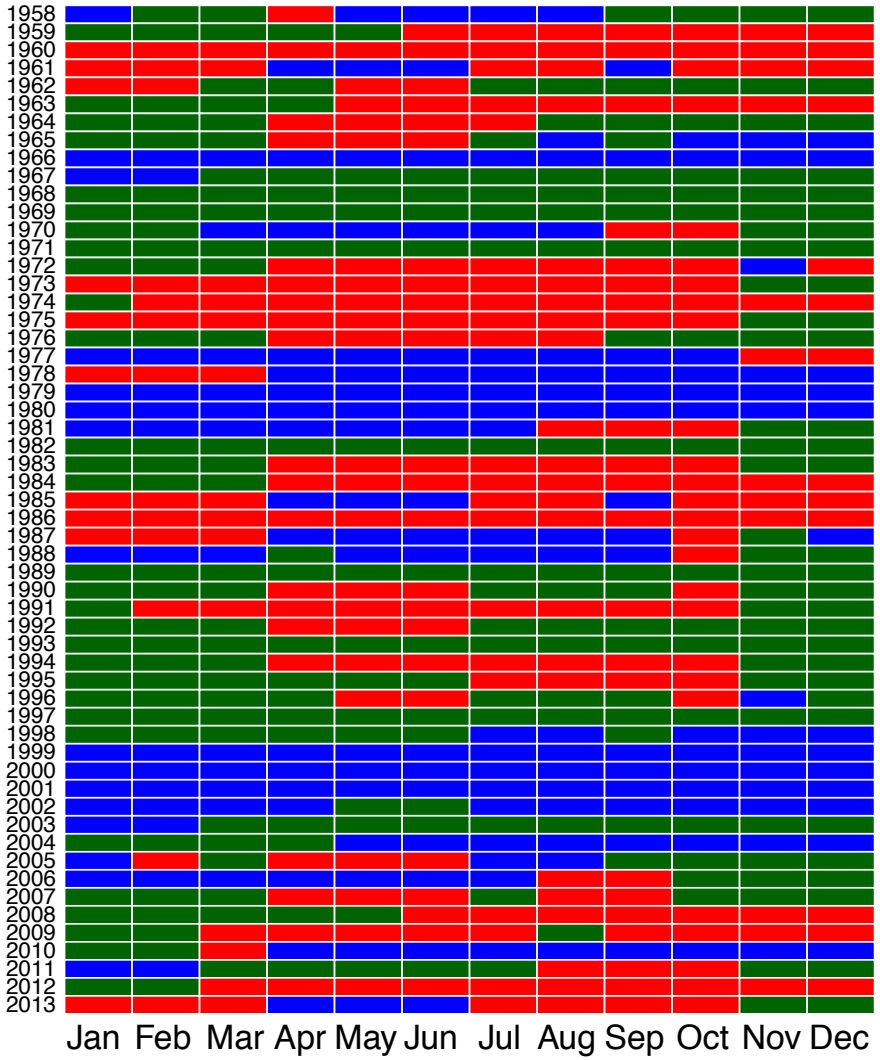
# Persistence of SIT clusters




**→ 3 identified SIT clusters (CAT, APD and CSD) often show persistence reaching into interannual time scales**

← monthly SIT cluster occurrences

| X(t+1) | CAT | APD | CSD |
|---|---|---|---|
| P{ X(t+1) \| CAT(t) } | 81.36% | 13.18% | 5.45% |
| P{ X(t+1) \| APD(t) } | 10.69% | 85.12% | 4.20% |
| P{ X(t+1) \| CSD(t) } | 6.87% | 5.82% | 87.30% |

Conditional probability of the transition between Arctic SIT clusters (1958-2013)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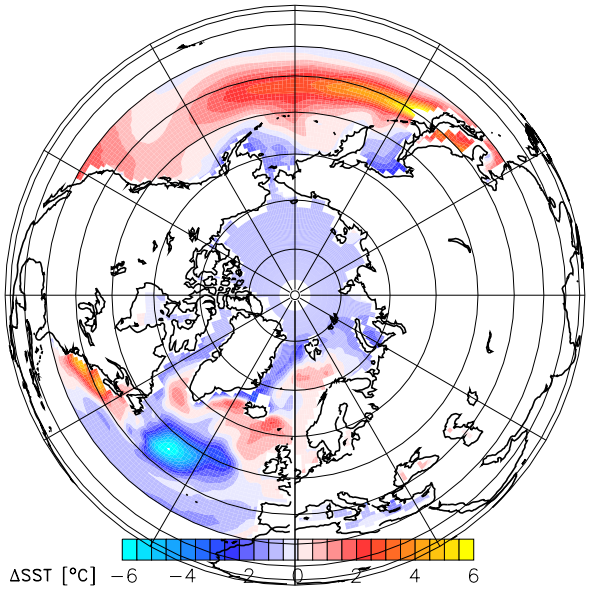
# EC-Earth2.3 seasonal prediction

## Seamless Earth-System Model

→ aims to forge weather and climate forecasting, and climate change studies in a single framework

**Atmosphere**: ECMWF's Integrated Forecasting System (IFS) T159 and L62 (up to 5 hPa)
**Land**: H-TESSEL (part of IFS)
**Ocean**: Nucleus for European Modeling of the Ocean (NEMO) v3.2 in ORCA1L42
**Sea ice**: Louvain-la-Neuve sea Ice Model (LIM) V2 (part of NEMO)




EC-Earth2.3 <1979-2012>
- ERSSTv3b <1979-2012>

→ 5-member seasonal (12-month) prediction using full-field initialization (using ERA-Interim for atmospheric IC, ORAS4 for oceanic IC and sea ice IC from reconstruction used to identify SIT clusters) with **May 1st** and **November 1st** start dates from **1979 to 2010**

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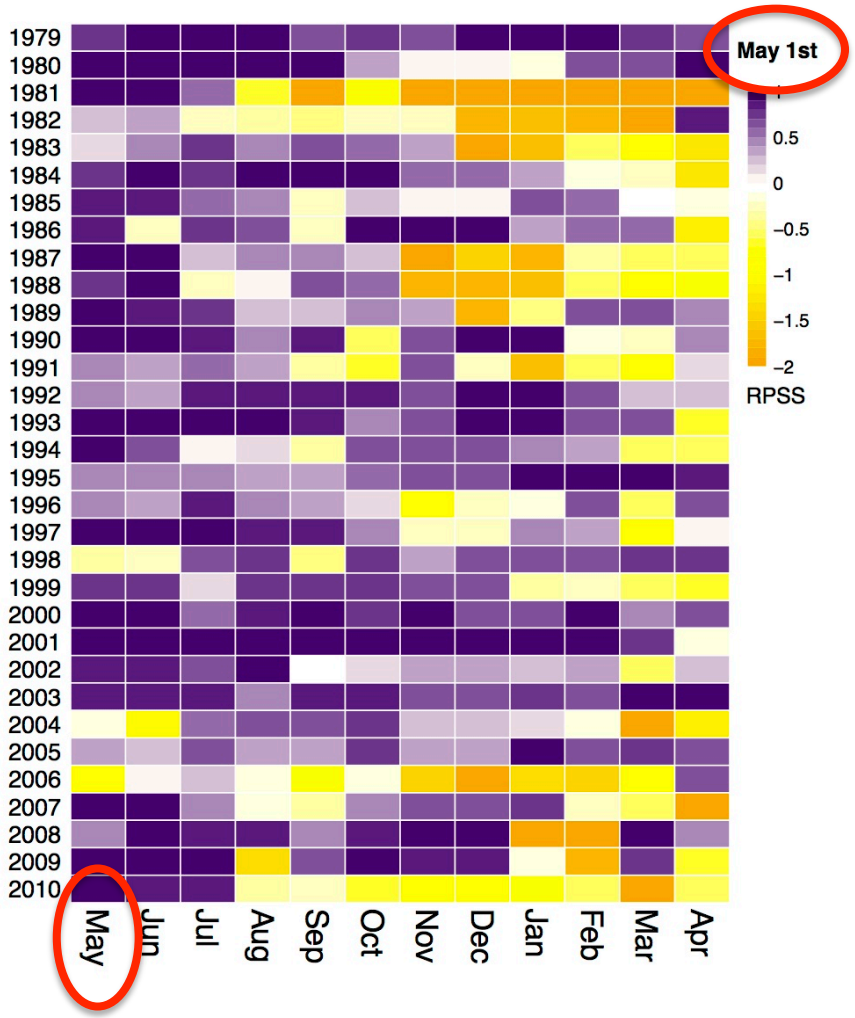
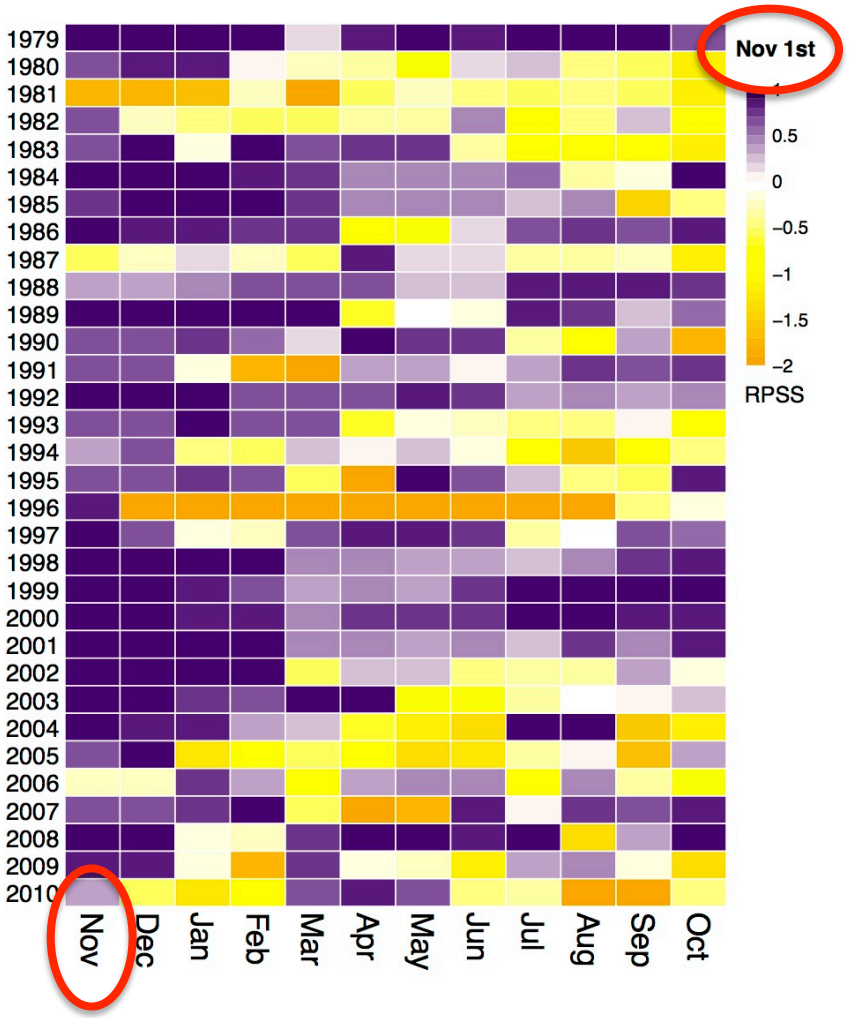
# SIT cluster prediction skill score

## **Rank Probability Skill Score** (ref. forecast: 1st order Markov chain)





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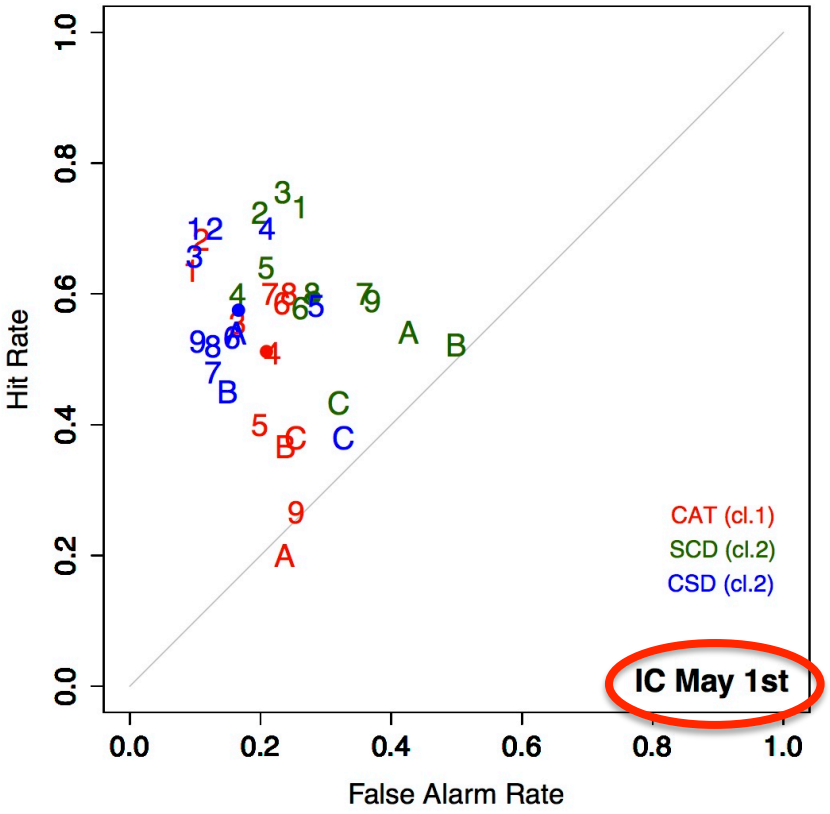
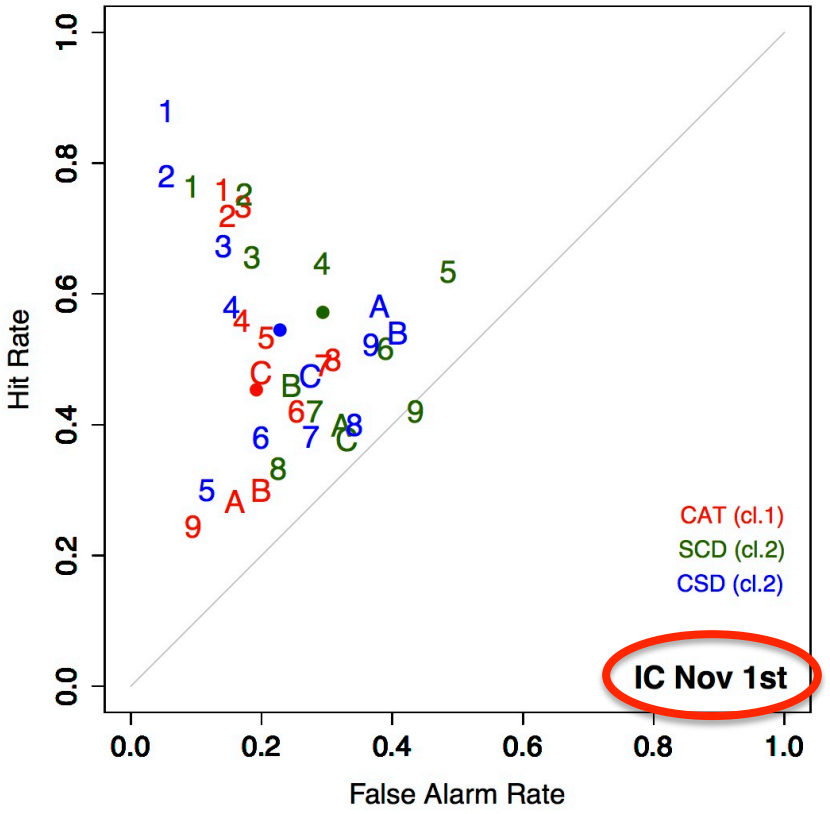
# ROC diagrams of SIT clusters




→ EC-Earth2.3 SIT cluster predictions initialized in summer (May 1st) show initially lower skill that predictions initialized in winter (Nov 1st), but prediction skill in summer is deteriorated at slower rate than in winter

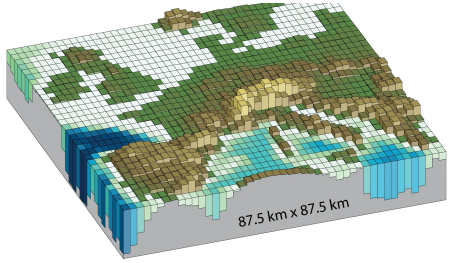


# Overall research aims

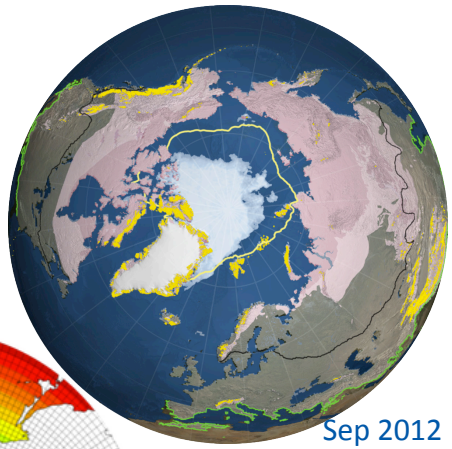
- Research on initialisation: generate a set of initial conditions (for ocean and **sea ice**) and compare different initialisation techniques (e.g. full field versus anomaly initialisation)
- Improving model processes: Inclusion and/or testing of model components (biogeochemistry, vegetation, aerosols, **sea ice)** or new parameterizations, model parameter calibration, increase in resolution
- Bias correction, calibration and combination: *hierarchy of post-processing methods and empirical predictions* (better use of current benchmarks)
- Forecast quality assessment: *provide skill scores practical to the user*, reliability as a main target, process-based verification, *attribution of climate events with successful predictions*, diagnostics of model fidelity including both strengths and weaknesses
- More sensitivity to the users' needs: going beyond downscaling, better documentation, *demonstration of value and outreach → building versatile climate services for stakeholders* as a part of Earth system services



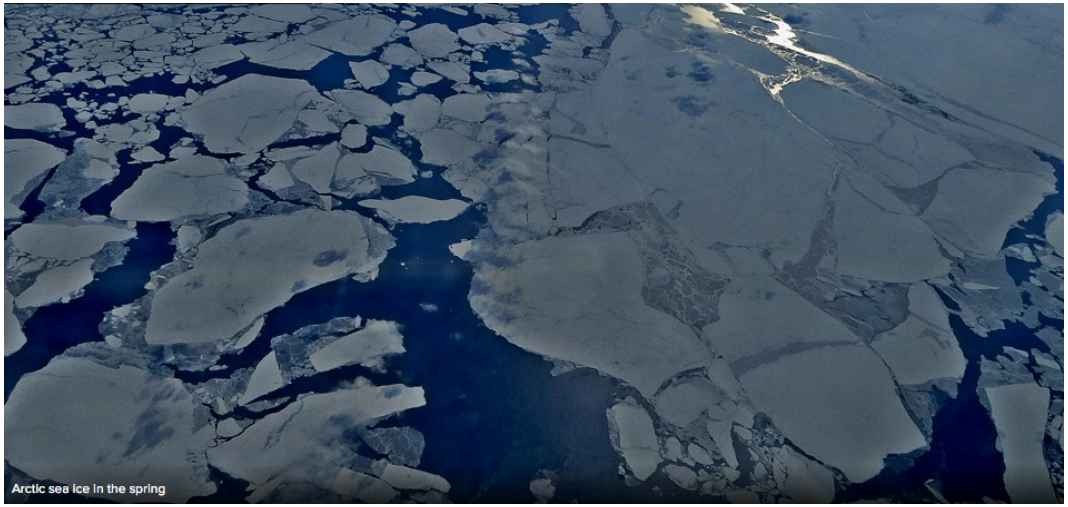
# Thank you for your attention

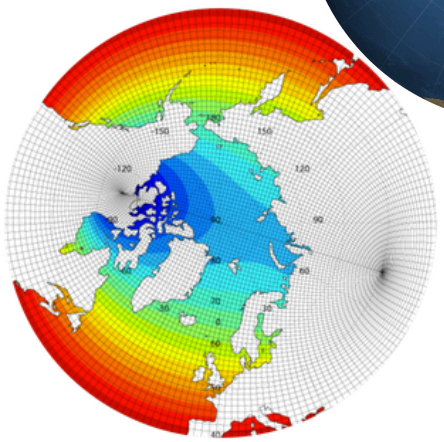


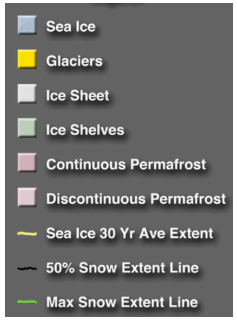

***Merci pour votre attention***
***Bedankt voor uw aandacht***
***Danke für Ihre Aufmerksamkeit***



Sep 2012



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