An Overview of European Union-Funded Project **APPLICATE**

Pablo Ortega, on behalf of APPLICATE partners

APPLICATE.eu
Advanced prediction in polar regions and beyond

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727862.

The Consortium

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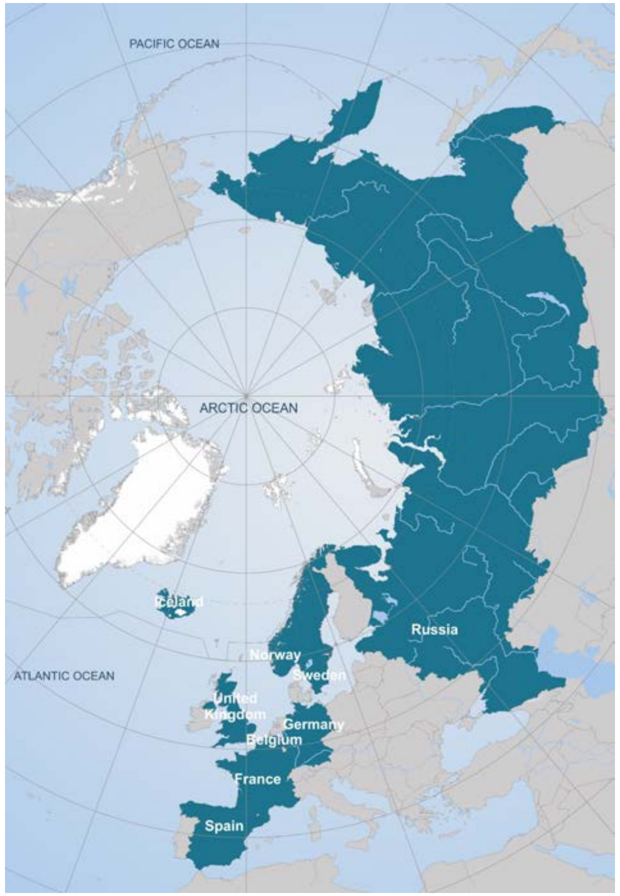
16 partners and 1 third-party from 9 countries



... and many collaborators!

Budget and duration

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- € 8 Mio + separate Russian contribution
- 1st November 2016–31st October 2020 (4-years)
- 6 month no-cost extension requested

Mission statement

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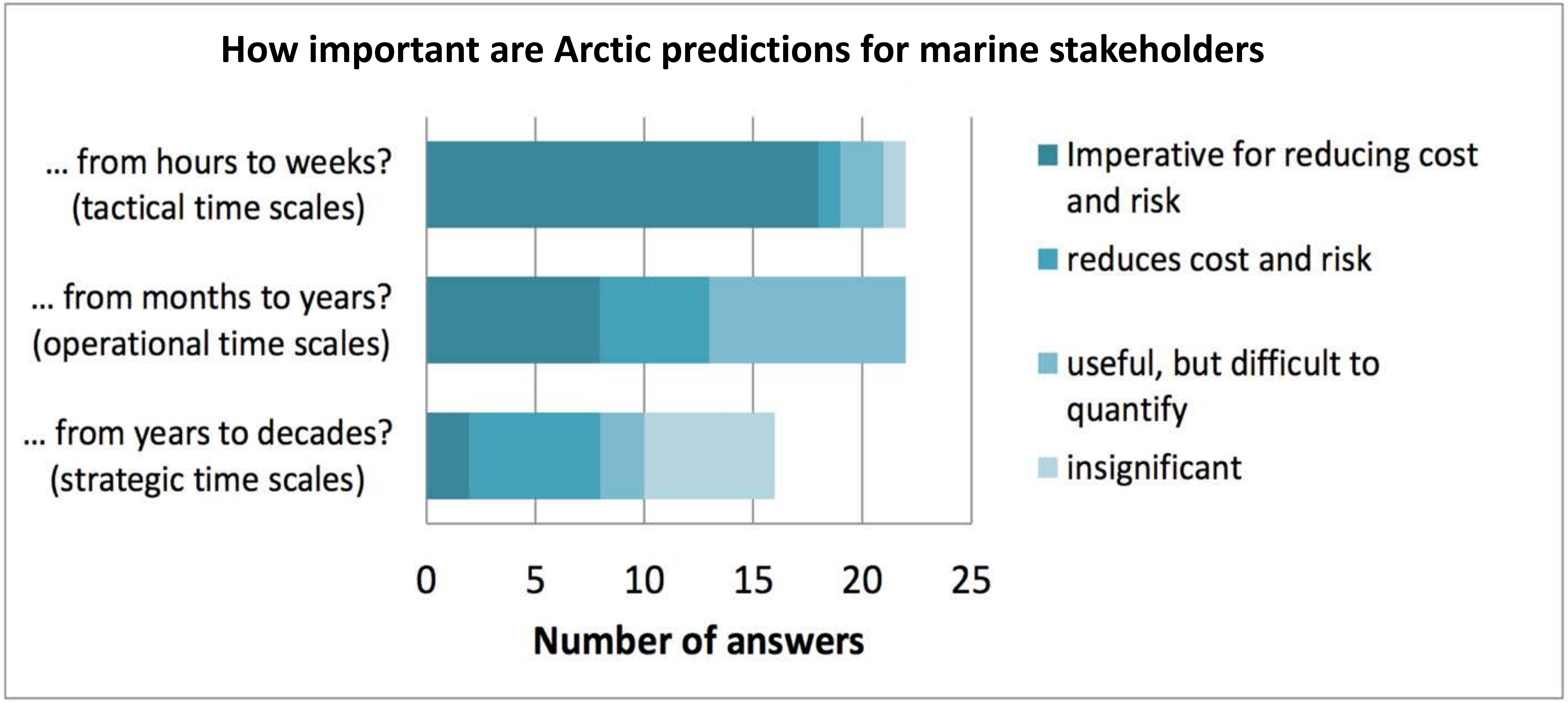
Advanced prediction in polar regions and beyond

Develop enhanced predictive capacity for weather and climate in the Arctic and beyond, and determine the influence of Arctic climate change on Northern Hemisphere mid-latitudes, for the benefit of policy makers, businesses and society.

General approach

➢ Bringing together the NWP and climate communities



Survey: EC-PHORS Services Task Team

General approach

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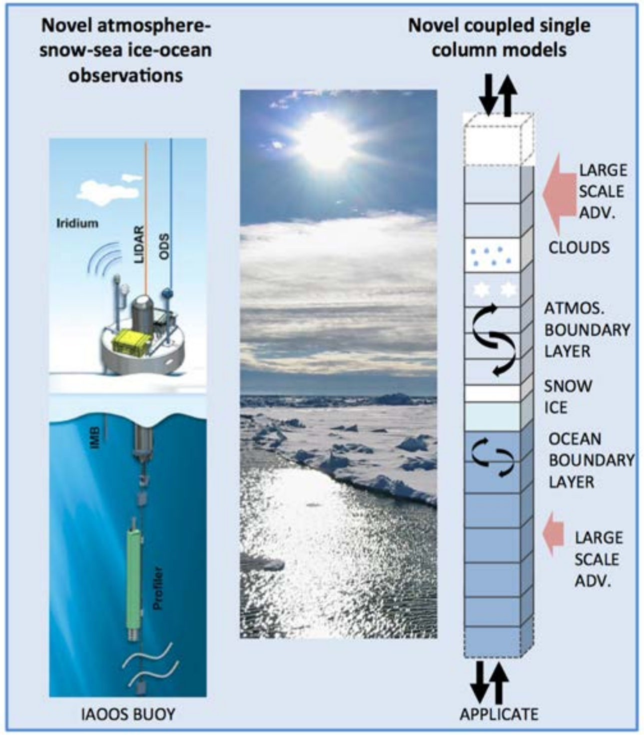
- Involving experts on the Arctic and midlatitudes
- Engaging operational centres for maximizing impact
- Effectively combining models and observations



MOSAiC
International Arctic Drift Expedition

General approach

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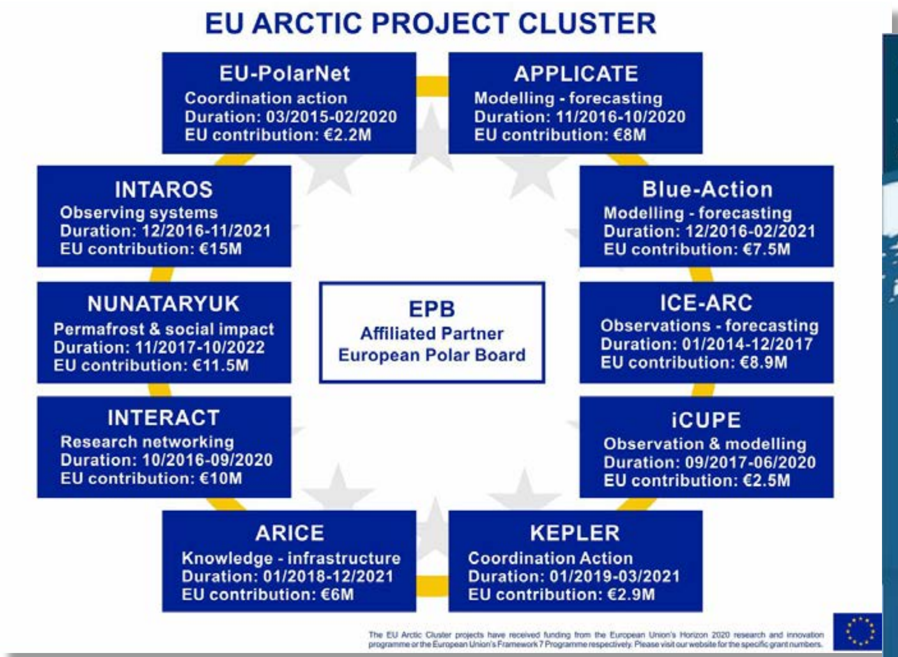
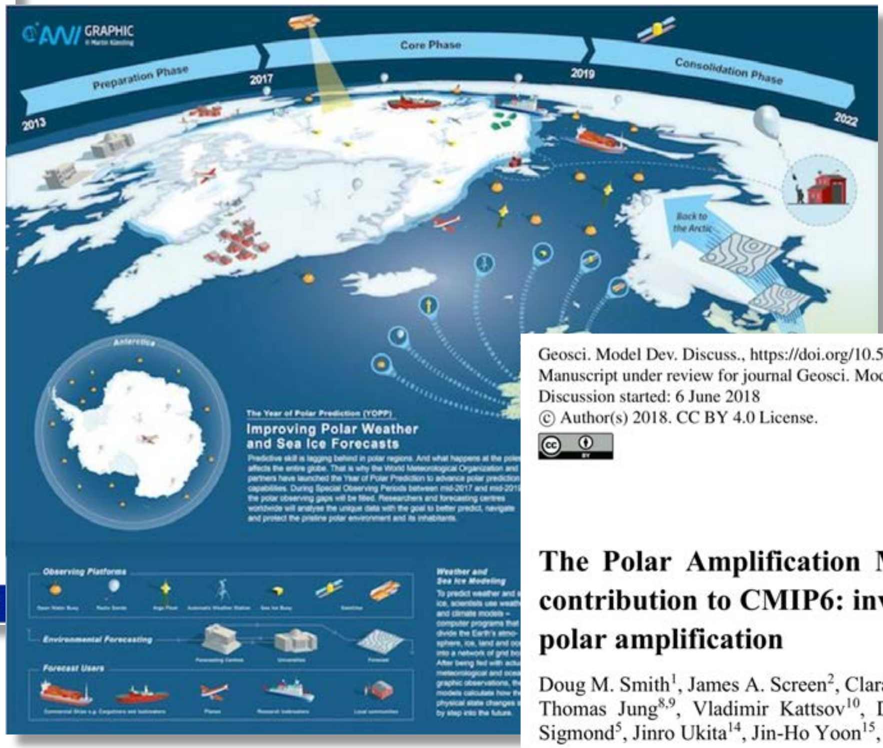
- Exploiting European and international collaboration (e.g. Arctic Cluster, YOPP and PAMIP)





Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2018-82
Manuscript under review for journal Geosci. Model Dev.
Discussion started: 6 June 2018

Geoscientific Model Development Discussions

The Polar Amplification Model Intercomparison Project (PAMIP) contribution to CMIP6: investigating the causes and consequences of polar amplification

Doug M. Smith[1], James A. Screen[2], Clara Deser[3], Judah Cohen[4], John C. Fyfe[5], Javier García-Serrano[6,7], Thomas Jung[8,9], Vladimir Kattsov[10], Daniela Matei[11], Rym Msadek[12], Yannick Peings[13], Michael Sigmond[5], Jinro Ukita[14], Jin-Ho Yoon[15], Xiangdong Zhang[16]

Strategy

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Delivering enhanced predictions

Establish Baseline
- New metrics and diagnostics
- NWP
- Subseasonal to seasonal prediction
- CMIP5/6

Develop Enhancements
- Enhanced models
- Optimized Arctic observing systems
- Improved initial and boundary conditions

Test Enhancements
- Enhanced NWP
- Enhanced Subseasonal to Seasonal Prediction
- Enhanced CMIP6

Recommen-dations
- Presentations
- Reports
- Publications
- Contribution to assessment reports

Enhanced Predictions
- CMIP6-Interim and CMIP7
- Enhanced operational:
  - NWP
  - Subseasonal to Seasonal Prediction
  - Interannual to Decadal Prediction

Project structure

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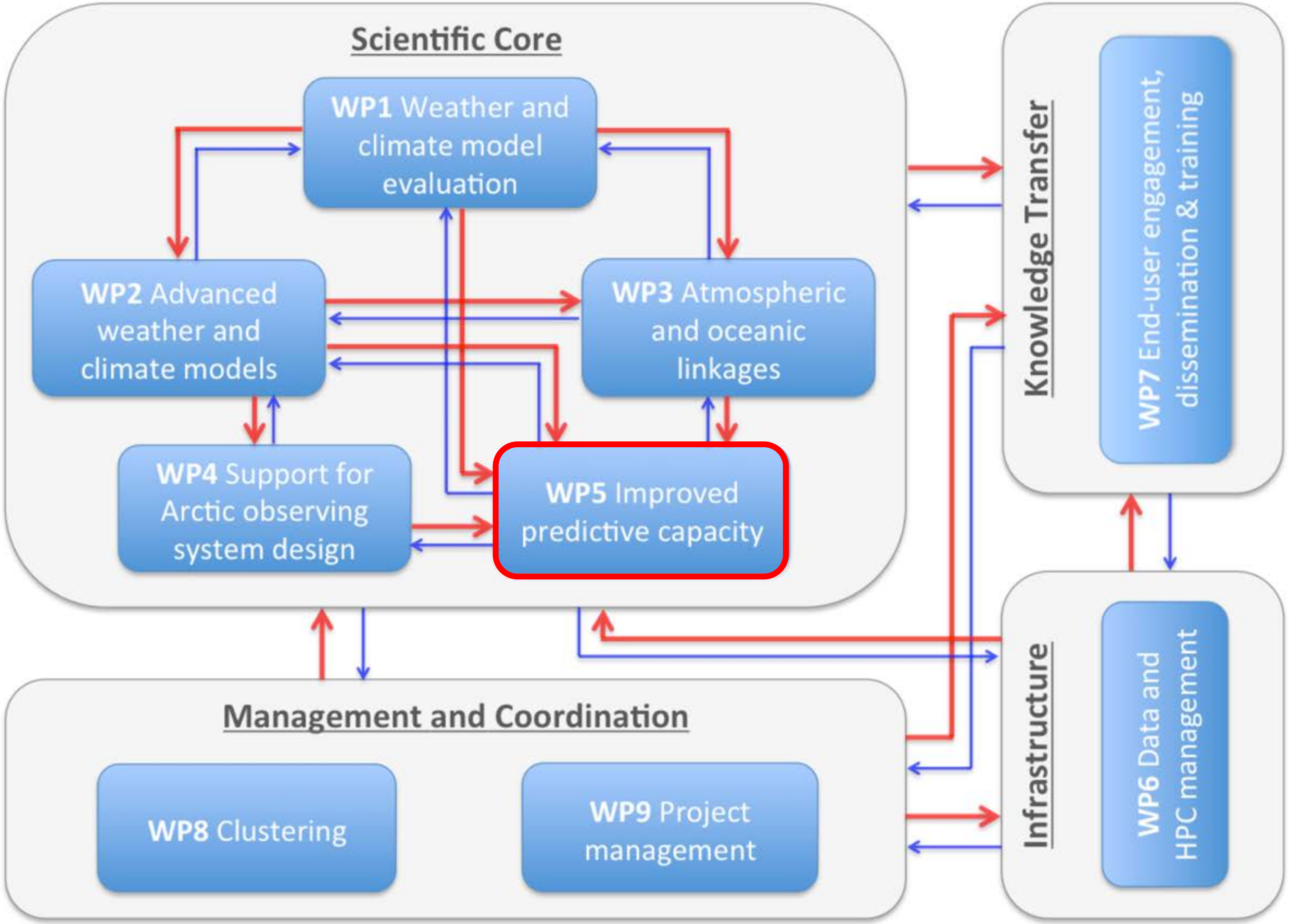

WP5: Main goals

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Advanced prediction in polar regions and beyond

1. Advance our understanding of **predictability mechanisms** operating at 3 different timescales:

NWP	–	Seasonal Prediction	–	Climate Projections
CRNS (CNRM)		*CRNS (CNRM)*		*AWI*
Met Norway		*Met Office*		*BSC*
ECMWF		*BSC*		
		UCL		
deterministic/ensemble		10 members		**HiResMIP:**
global/limited area models		1993-2014 period		1950 fixed forcing control
focus on YOPP period		May/November ICs		1950-2050 transient

WP5: Main goals

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Advanced prediction in polar regions and beyond

1. Advance our understanding of **predictability mechanisms** operating at 3 different timescales:

   NWP – Seasonal Prediction – Climate Projections

2. Investigate whether and how **linkages between the Arctic and mid-latitudes contribute to prediction skill**

3. Assess the **added-value of APPLICATE developments on prediction skill** in the Arctic and beyond

WP5: Main goals

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APPLICATE TIMELINE

NWP – Seasonal Prediction – Climate Projections

STREAM 1
Baseline skill of APPLICATE prediction systems

STREAM 2
Skill after including APPLICATE developments

3. Assess the **added-value of APPLICATE skill** in the Arctic and beyond

Improved **Initialization** (WP4, WP5)
Improved **Models**/Components (WP2,WP5)
Better **ensemble generation** (WP5)
New **diagnostics** (WP1)

WP5: Main tasks

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Task 5.1: Production of Stream 1 experiments

Task 5.2: State-of-the-art of weather/climate prediction and projections
(sources of predictability, links with mid-latitudes, forecasts of extremes,...)

Task 5.3: Added-value of improved process representation on predictive skill
(enhanced sea ice models, increased resolution, improved ensemble generation)

Task 5.4: Production and evaluation of Stream 2 Experiments

Task 5.5: Recommendations for future forecasting system development

WP5: Stream 1 baseline skill

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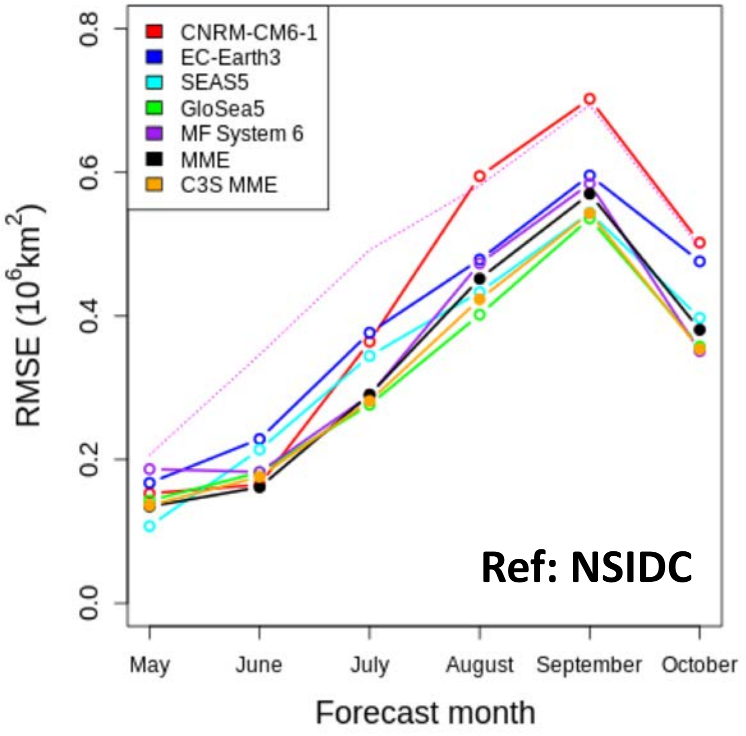
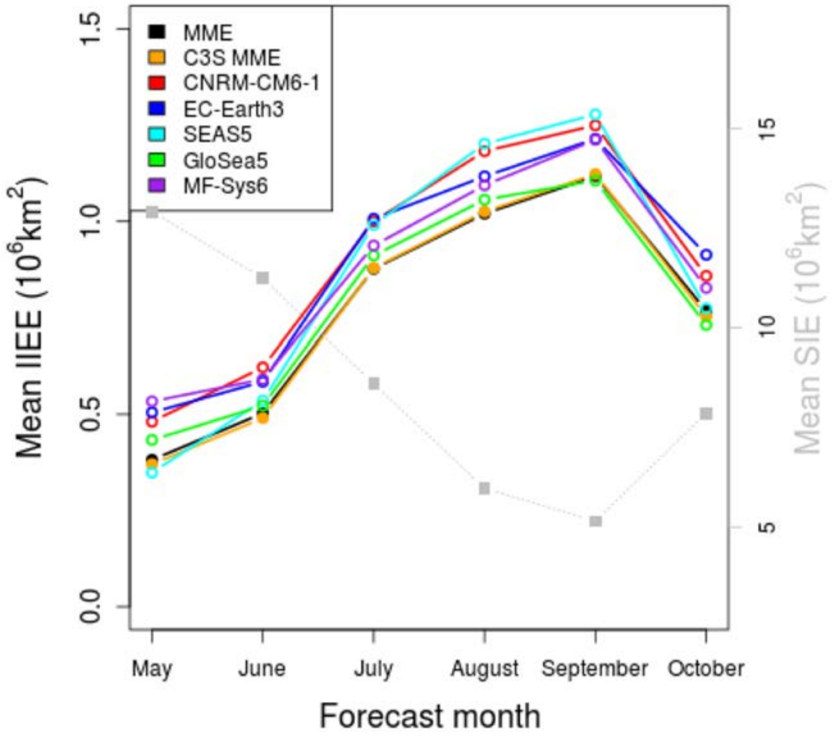
Lauriane Batté

STREAM 1 + C3S systems

RMSE of total Arctic SIE



Pan-Arctic IIEE



Integrated Ice Edge Error

Goessling et al. 2016

1st May Initialized Forecasts (1993-2014)

CNRS METEO FRANCE

WP5: Stream 1 baseline skill

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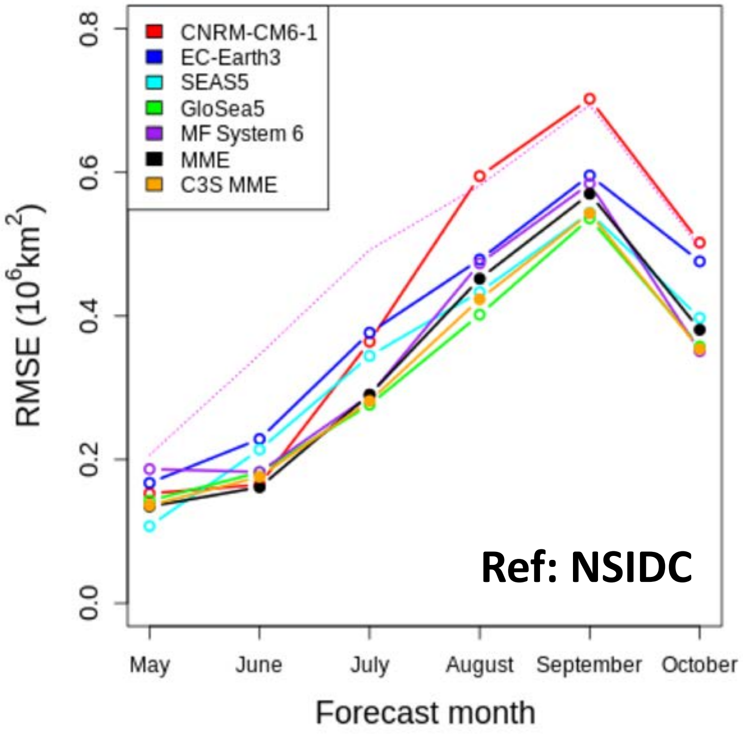
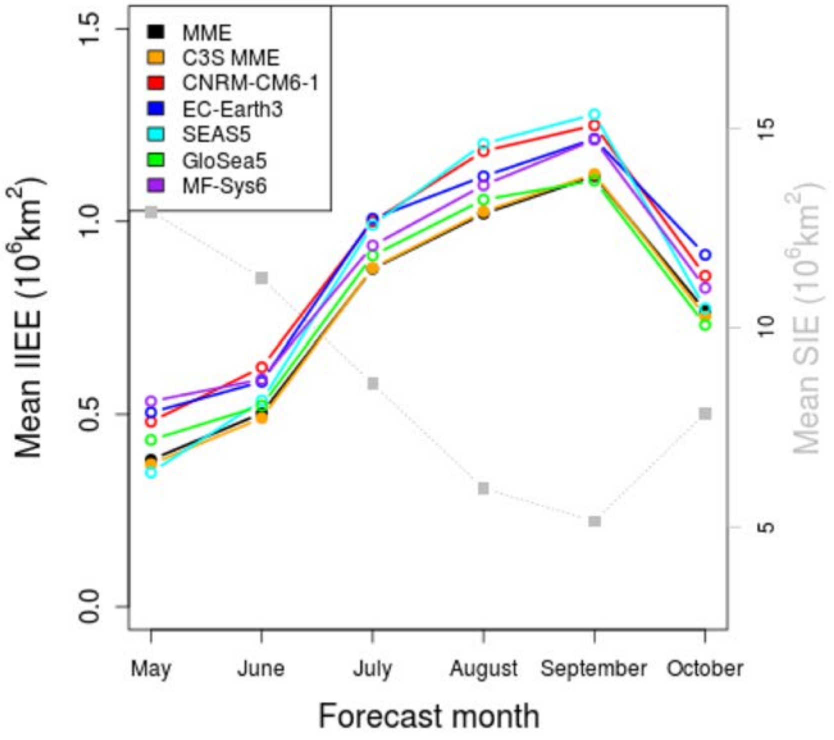
STREAM 1 + C3S systems

RMSE of total Arctic SIE



Pan-Arctic IIEE



Inter-model **differences** are **smaller in IIEE**

Multi-models are **better** than individual models

1st May Initialized Forecasts (1993-2014)

WP5: Stream 1 baseline skill

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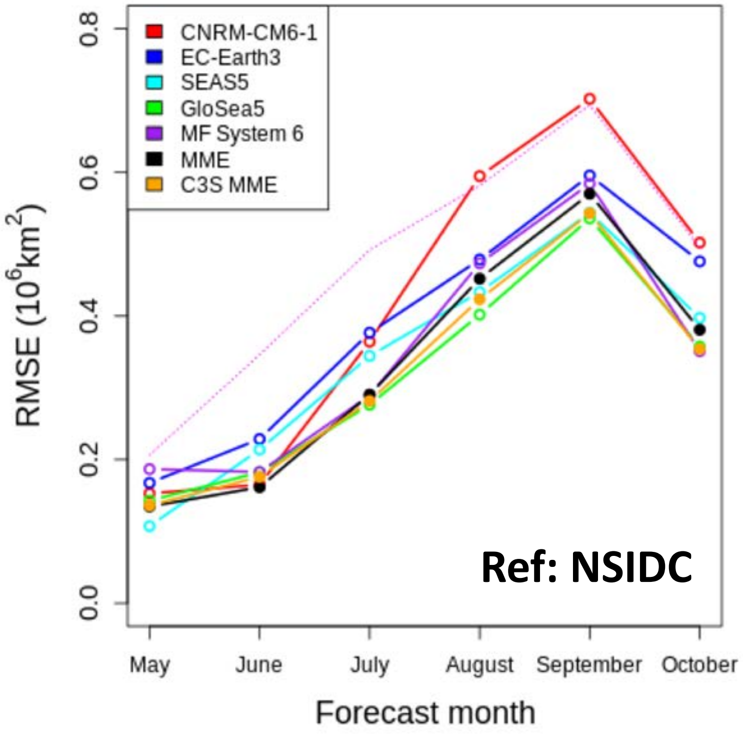
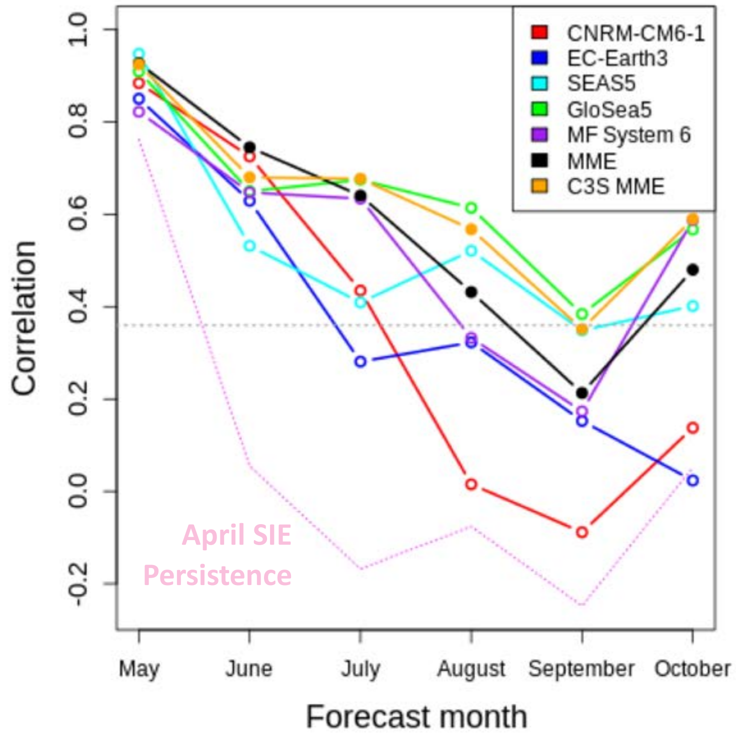
STREAM 1 + C3S systems

RMSE of total Arctic SIE



ACC of total Arctic SIE



Most models exhibit **skill up to 3-4 months** lead

Forecasting **September SIE minimum** is still **challenging**

1st May Initialized Forecasts (1993-2014)

WP5: Role of Initialization

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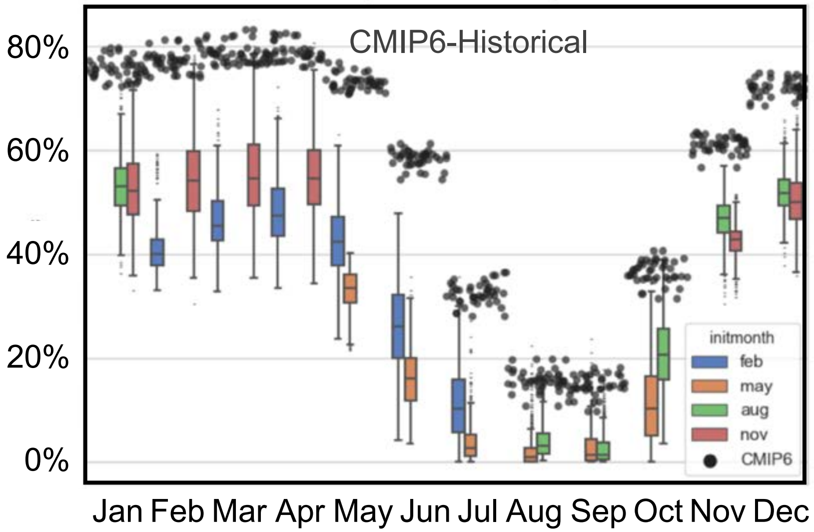
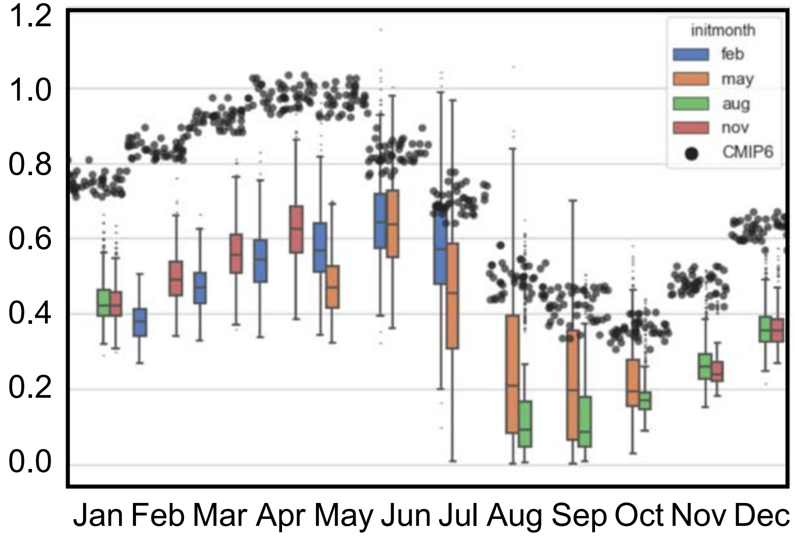
Ilona Valisuo

Greenland Sea

Sea Ice Concentrations



Sea Ice Thickness



CMIP6-Historical has **too much and too thick** ice in Greenland Sea

Forecasts show **huge spread in thickness** during the **melt season**

Systematic error not fully developed by the end of the forecasts

CNRM-CM6-1 Seasonal Forecasts (1993-2014)

CNRM cnrs METEO FRANCE

WP5: Role of Initialization

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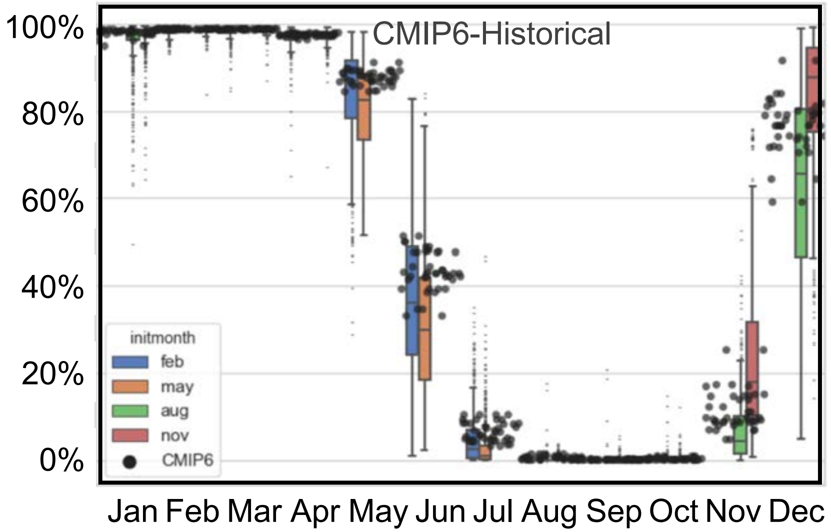
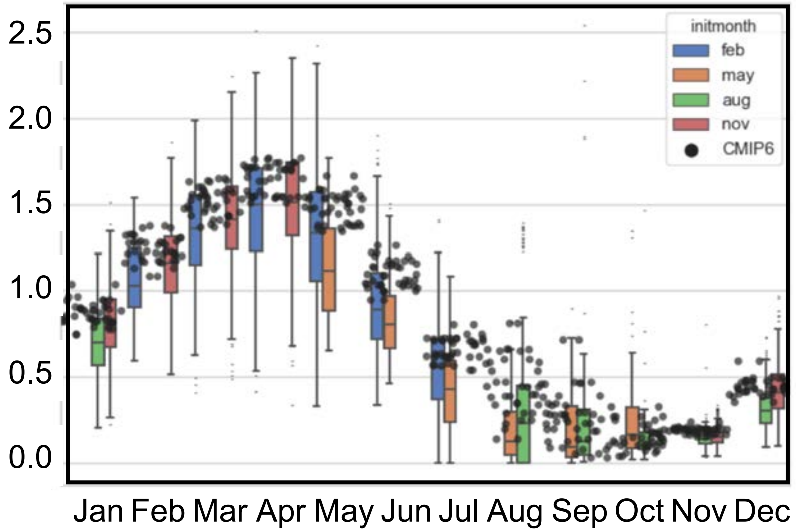
Chukchi Sea

Sea Ice Concentrations



Sea Ice Thickness



Better agreement between **initialized/non initialized** forecasts

CNRM-CM6-1 Seasonal Forecasts (1993-2014)

WP5: Development of forecast errors

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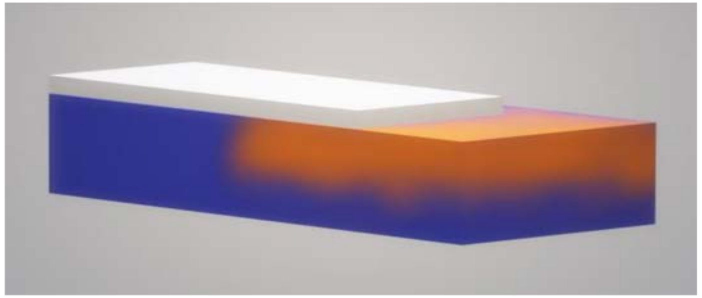
Ruben Cruz-García

Inconsistency of ICs



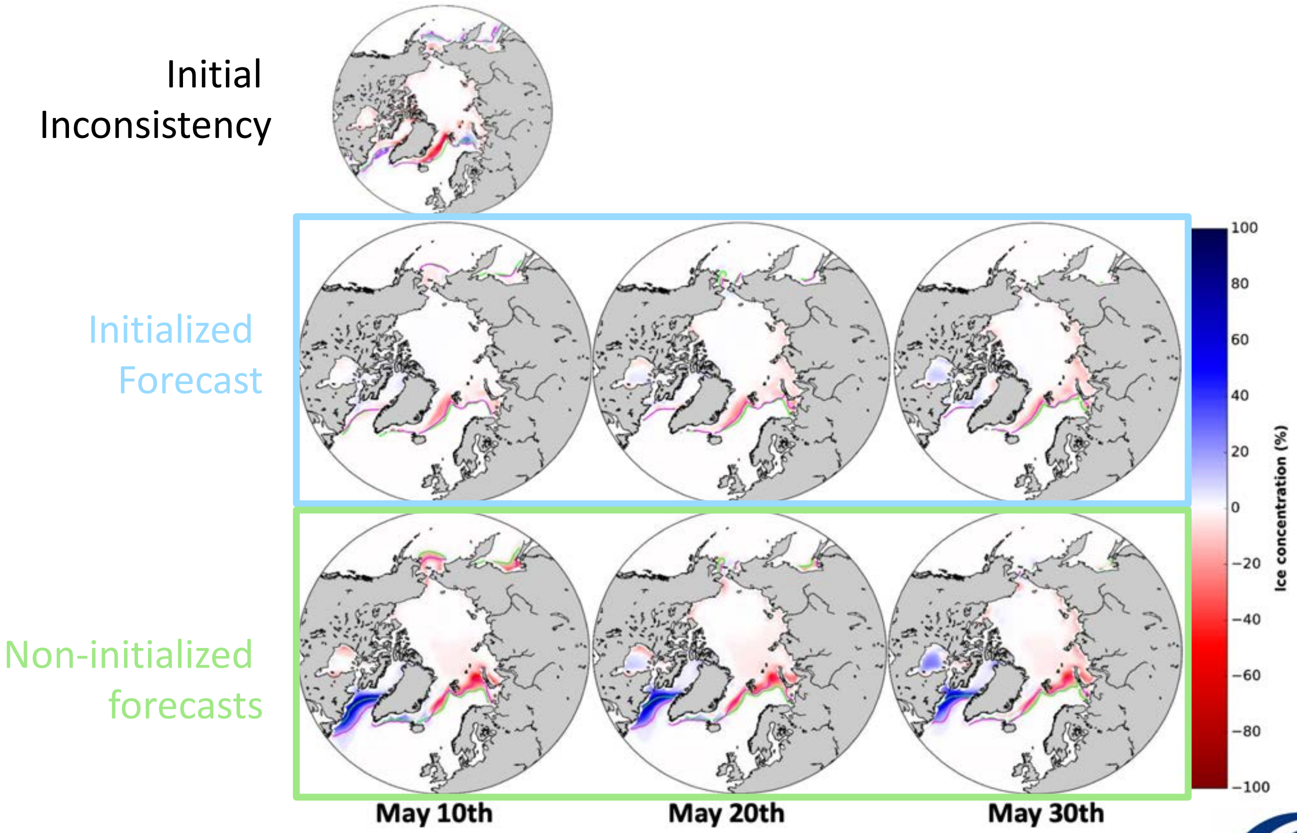
Initialization Strategy

Sea Ice: NEMO-LIM3 forced w. ERA-Interim
ENKF assimilation of SICs from ESA

Ocean: ORAS4

Atmos: ERA-Interim

Evolution of errors with forecast day



EC-Earth3.2 Seasonal Forecasts (1993-2008)

WP5: Development of forecast errors

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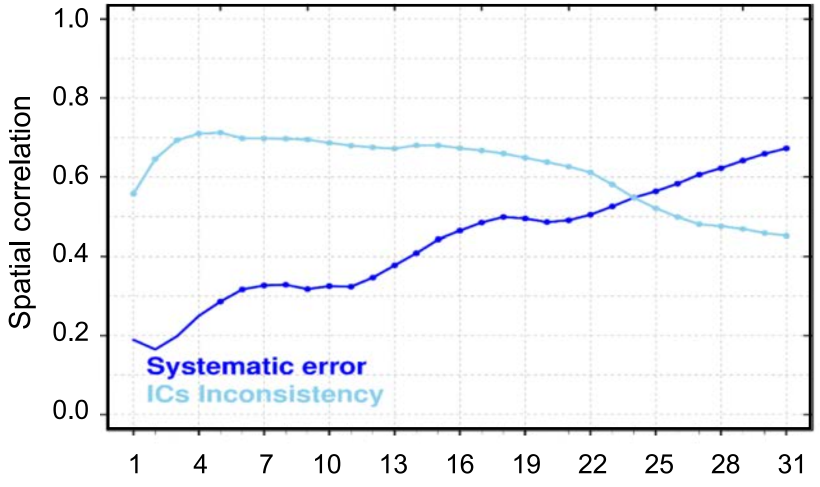
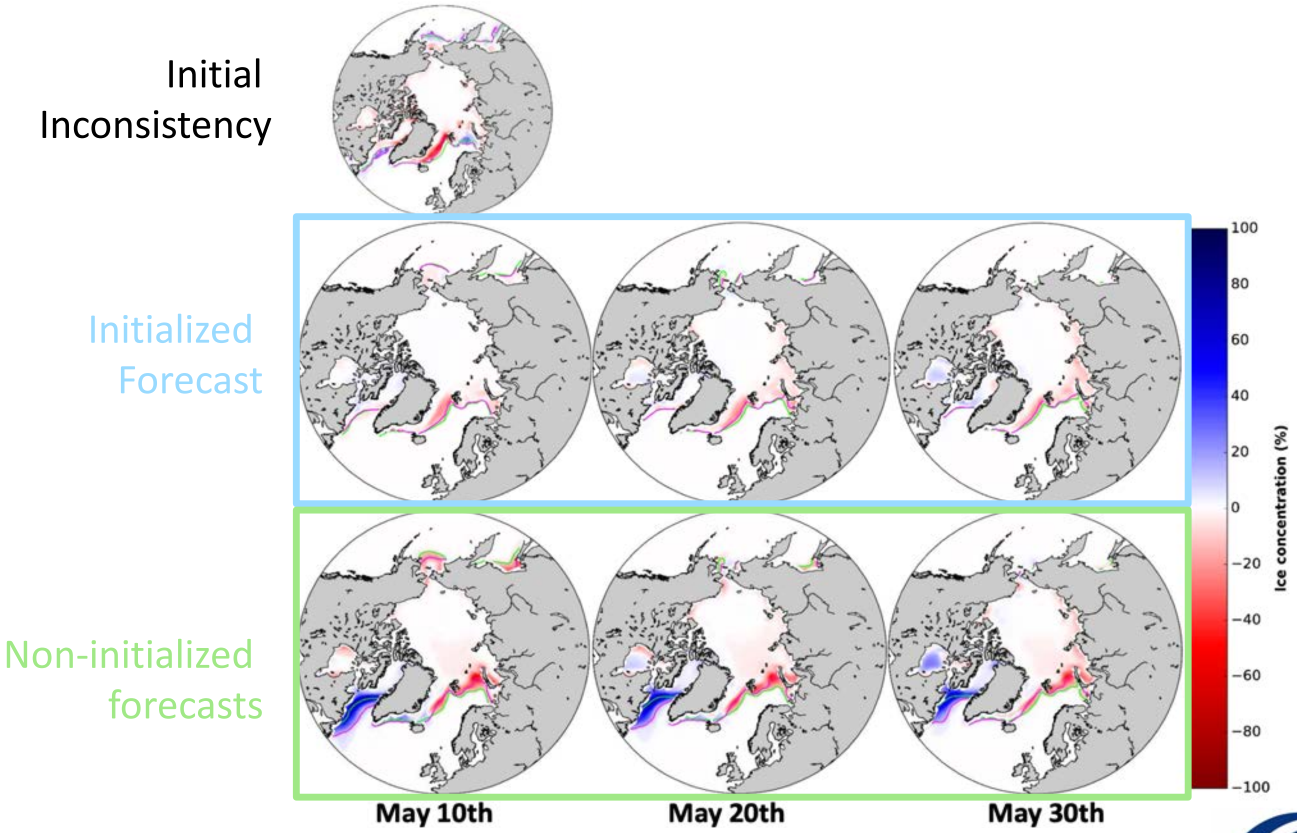
IC inconsistency vs systematic error



Evolution of errors with forecast day



EC-Earth3.2 Seasonal Forecasts (1993-2008)

WP5: Impact of model resolution

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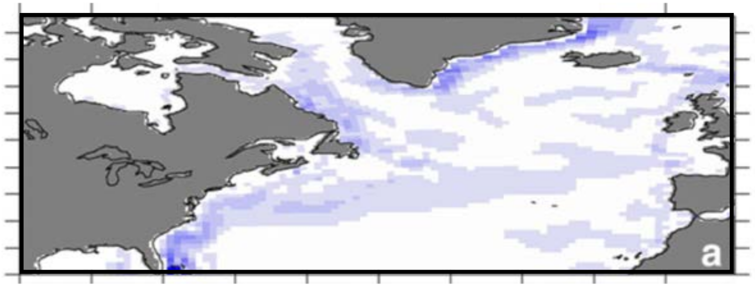
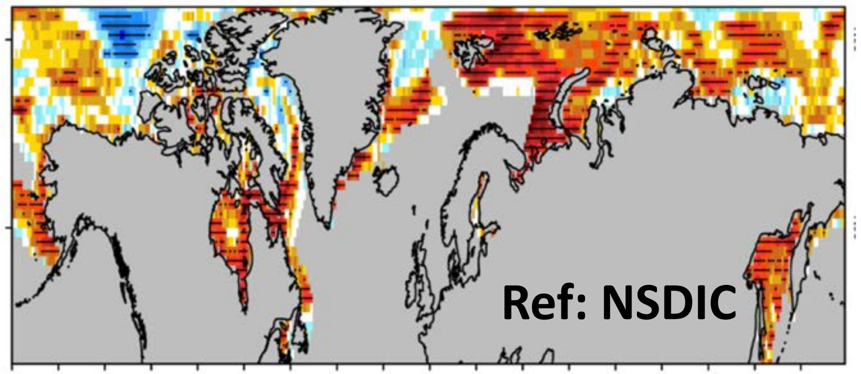
NEMO/LIM3 (**ORCA1**)

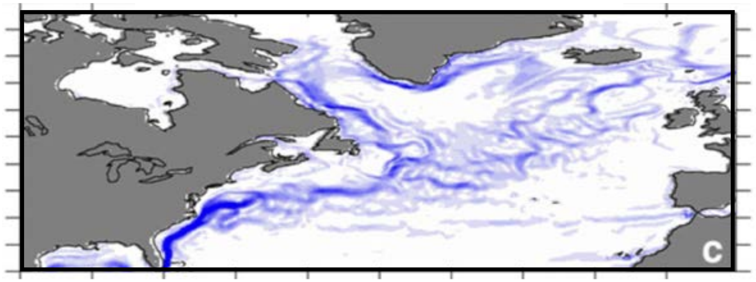


Ocean ICs: forced run nudged to **ORAS4**

ACC in Sea Ice Concentration in DJF (ORCA1)

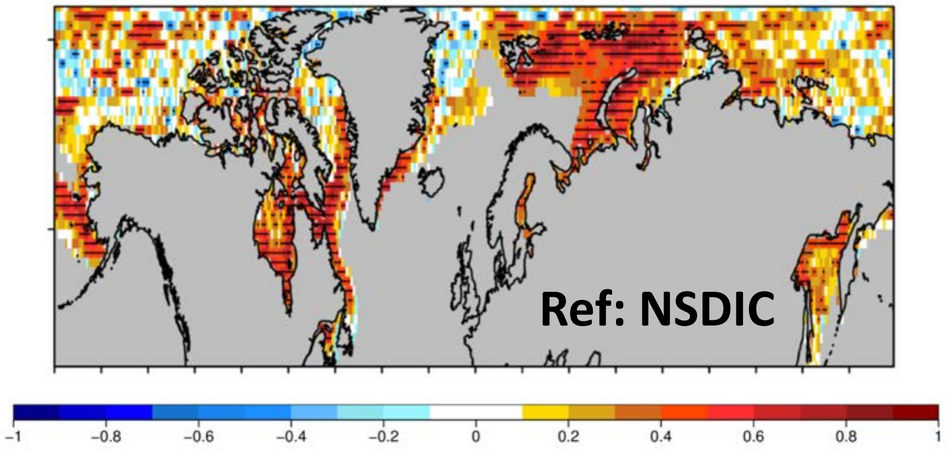


NEMO/LIM3 (**ORCA025**)



Ocean ICs: forced run nudged to **ORAS5**

ACC in Sea Ice Concentration in DJF (ORCA025)

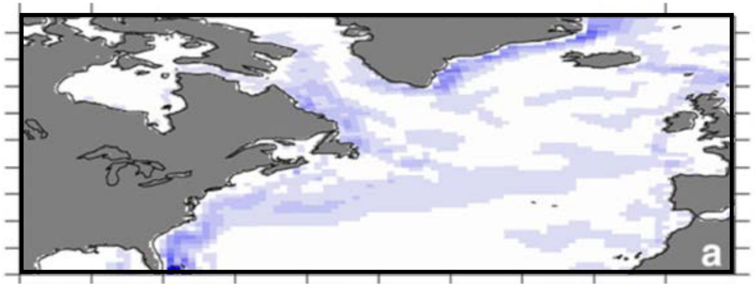


EC-Earth3.3 November Forecasts (1993-2014)

WP5: Impact of model resolution

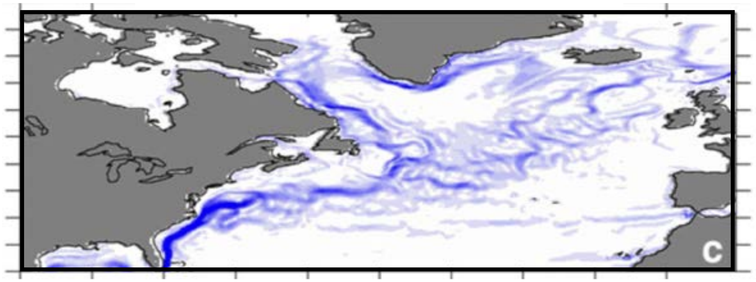
Juan C. Acosta-Navarro

NEMO/LIM3 (**ORCA1**)



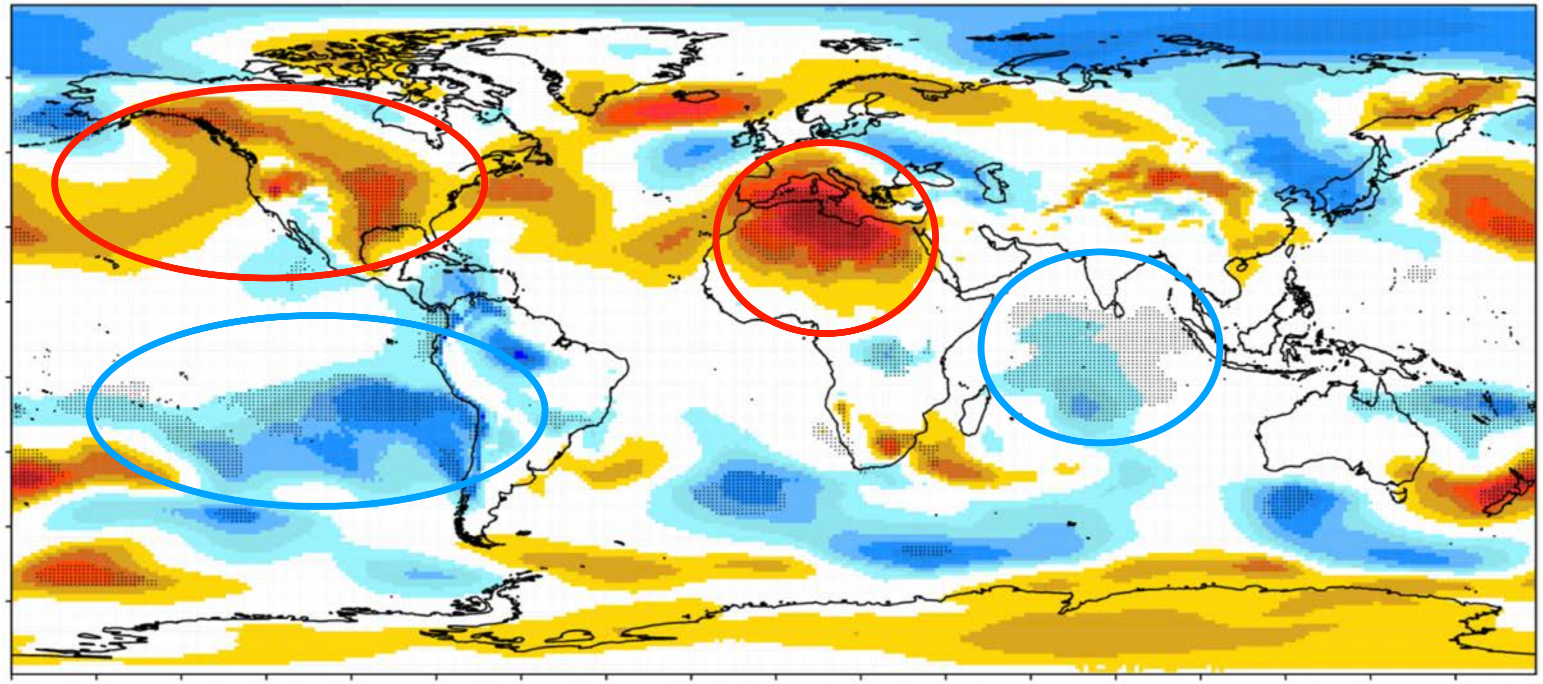
Ocean ICs: forced run nudged to **ORAS4**

NEMO/LIM3 (**ORCA025**)



Ocean ICs: forced run nudged to **ORAS5**

ACC difference in DJF SLP (ORCA025 – ORCA1)



Ref: ERA-Interim

EC-Earth3.3 November Forecasts (1993-2014)

WP5: Impact of model resolution

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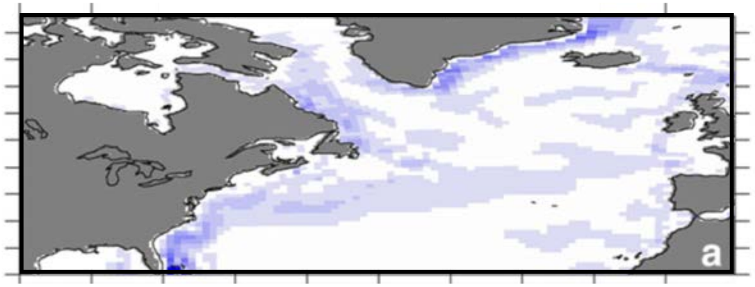
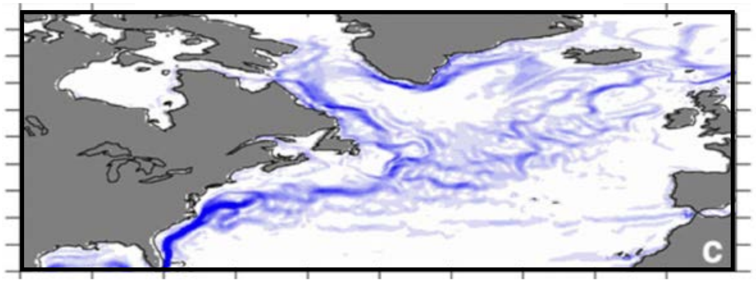
NEMO/LIM3 (**ORCA1**)



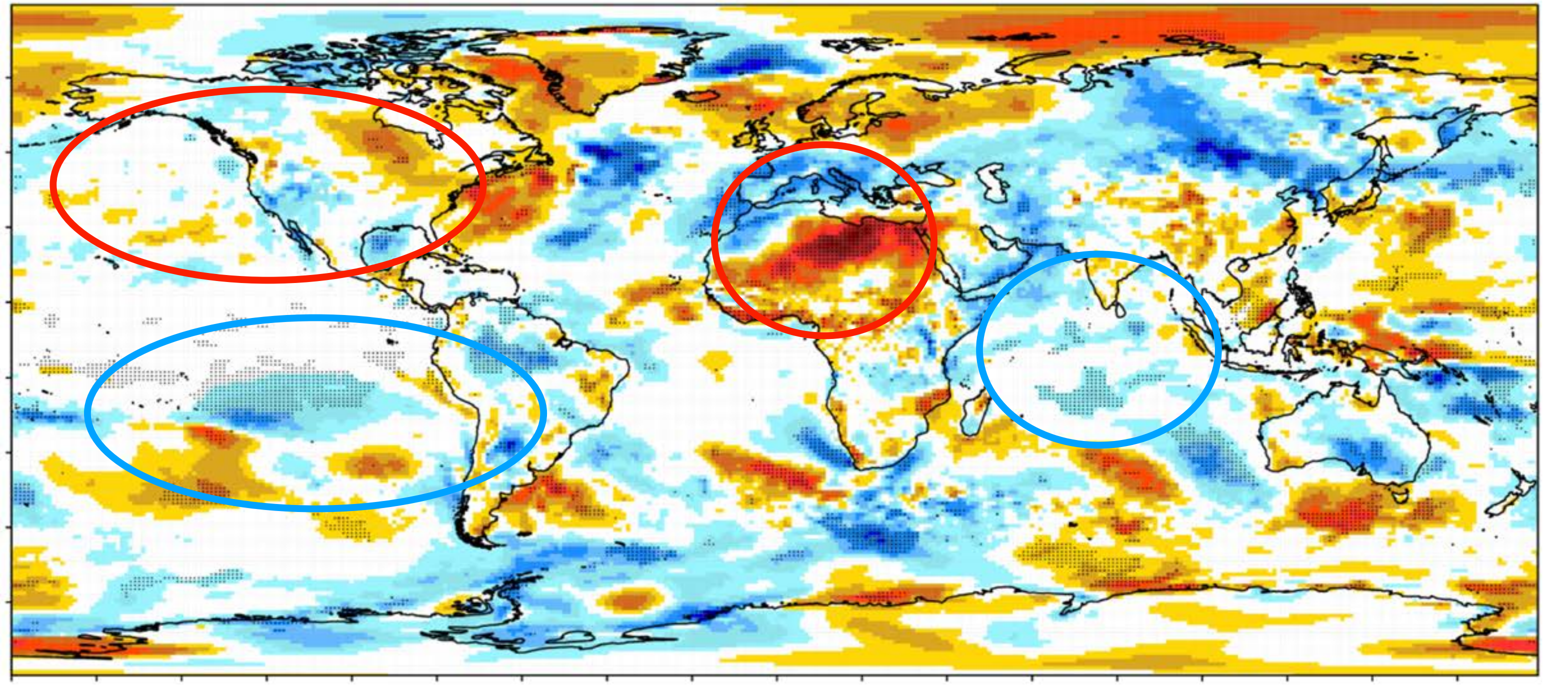
Ocean ICs: forced run nudged to **ORAS4**

NEMO/LIM3 (**ORCA025**)



Ocean ICs: forced run nudged to **ORAS5**

ACC difference in DJF TAS (ORCA025 – ORCA1)



Ref: ERA-Interim

EC-Earth3.3 November Forecasts (1993-2014)

WP5: Impact of model resolution

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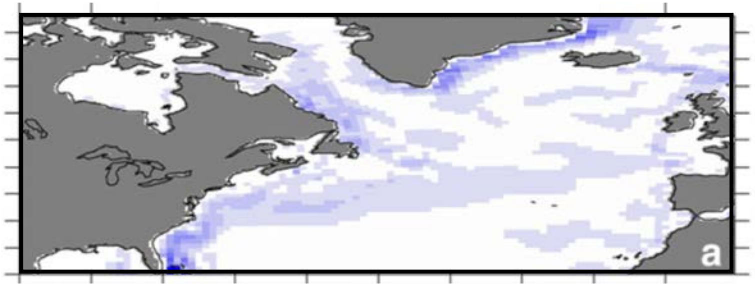
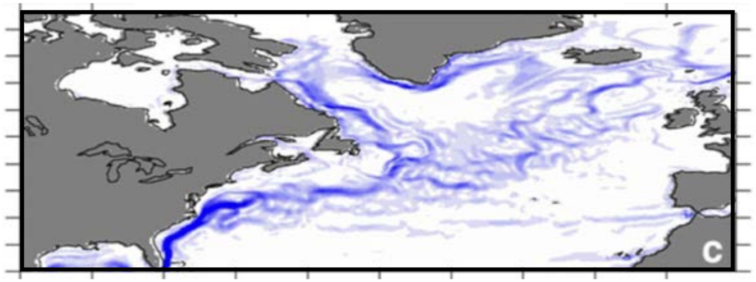
NEMO/LIM3 (**ORCA1**)



Ocean ICs: forced run nudged to **ORAS4**

NEMO/LIM3 (**ORCA025**)



Ocean ICs: forced run nudged to **ORAS5**

Systematic Analysis with three GCMs

METEO FRANCE
CNRM-CM6

Environment Canada
CanCM

BSC
EC-Earth3

EC-Earth3.3 November Forecasts (1993-2014)

EC-EARTH3 BSC

WP5: Statistical climate predictions

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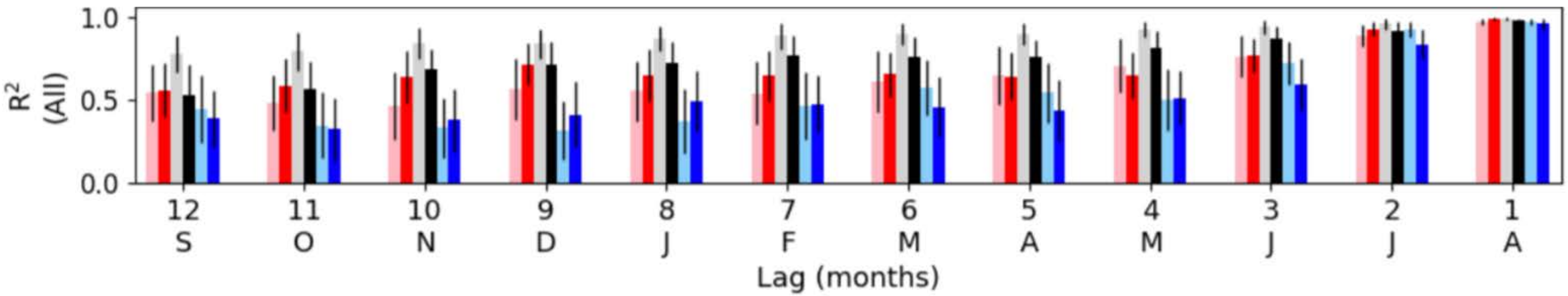
7 different predictors

SIV: Sea Ice Volume
OHT: Ocean Heat Transport
SIC: Sea Ice Concentration
SID: Sea Ice Drift
SIA: Sea Ice Area
SIT: Sea Ice Thickness
SST: Sea Surface Temperature

Outputs from 6 models

HadGEM3-LL
HadGEM3-MM
ECMWF-LR
ECMWF-HR
AWI-LR
AWI-HR

Statistical predictability of September SIV Anomaly for 1 to 12 preceding months



Statistical Predictions: Perfect model (1950-2014)

UCLouvain

WP5: Optimal sampling locations

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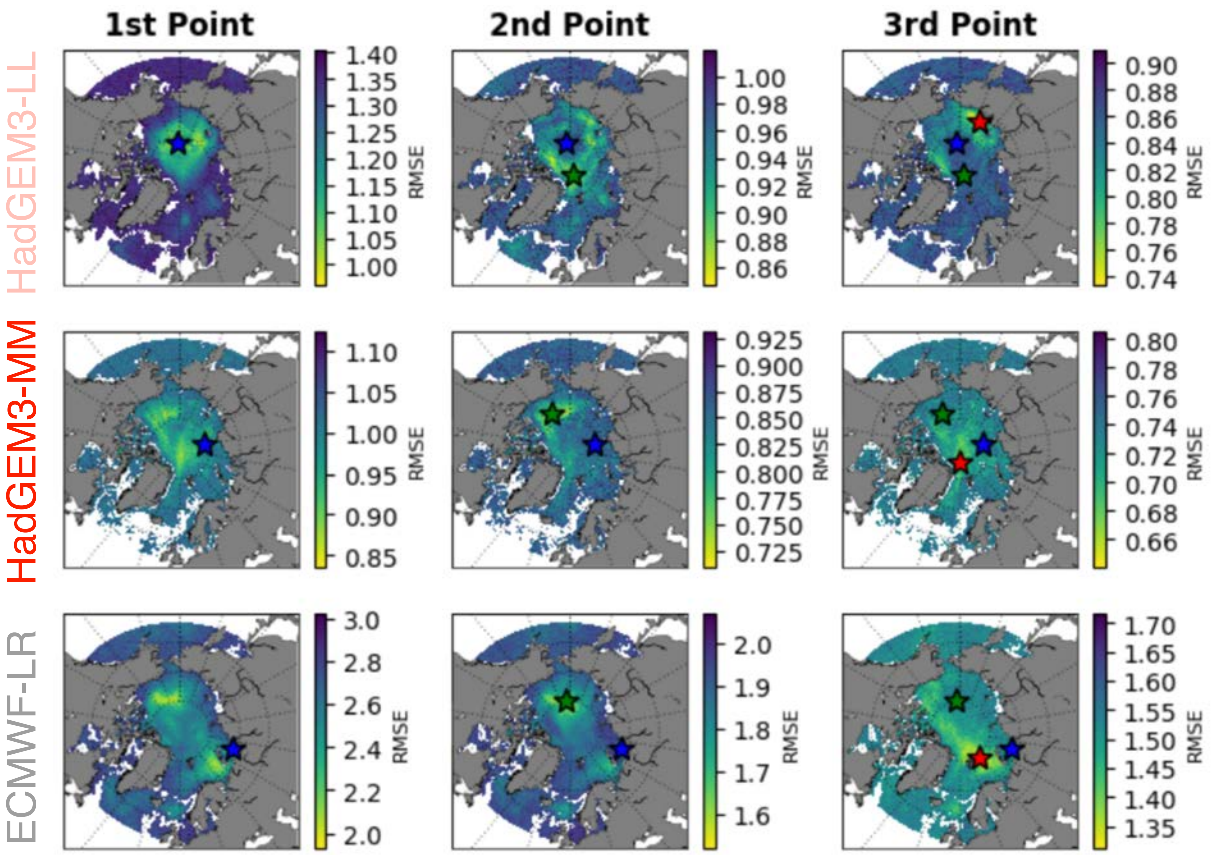
RMSE of Sea Ice Volume



4 predictors (easily observable)

Sea Ice Drift	(in-situ)
Sea Ice Thickness	(in-situ)
Sea Ice Concentration	(satellite)
Sea Surface Temperature	(in-situ)

Optimal locations:

Placed at the grid points where predictors minimise RMSE in SIV

Statistical Predictions: Perfect model (1950-2014)

UCLouvain

WP5: Optimal sampling locations

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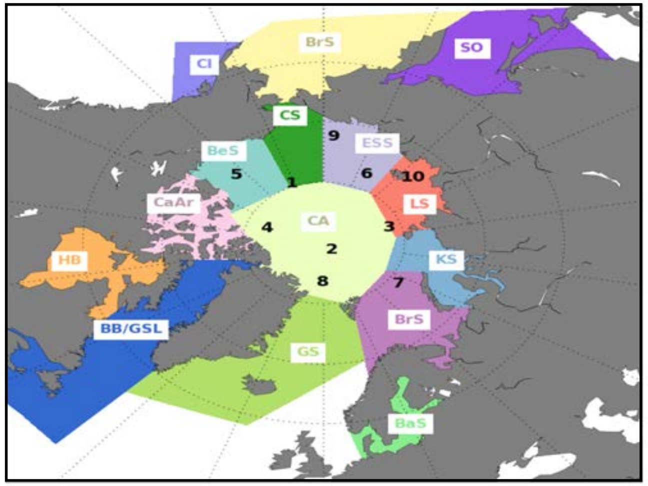
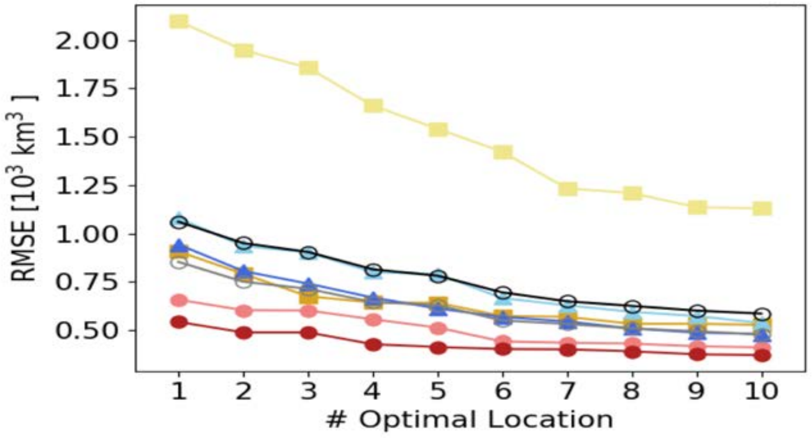
4 predictors (easily observable)

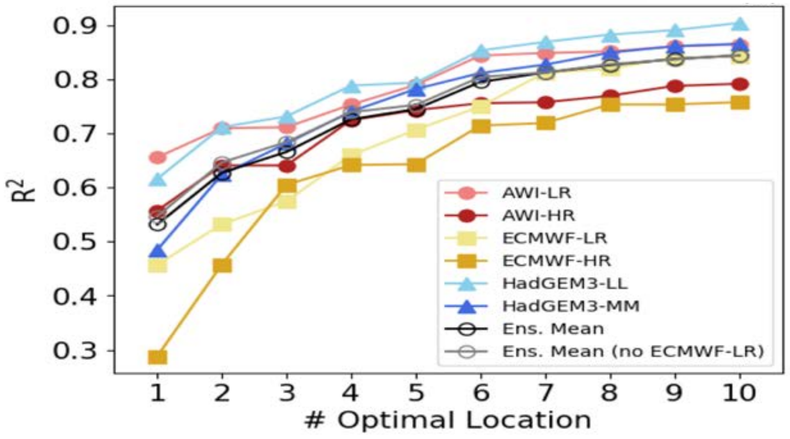
Sea Ice Drift	(in-situ)
Sea Ice Thickness	(in-situ)
Sea Ice Concentration	(satellite)
Sea Surface Temperature	(in-situ



RMSE of Total SIV



R^2 of Total SIV



5 to 6 locations can guarantee a relatively **low RMSE and high R**

ECMWF-LR has a **strong RMSE bias**, which creates too thick sea ice

Statistical Predictions: Perfect model (1950-2014)

UCLouvain

Summary of APPLICATE

APPLICATE.eu
Advanced prediction in polar regions and beyond

- Advances predictive capacity in polar regions and beyond:
  - Develops models with enhanced representation of Arctic processes
  - Contributes to improving the Arctic observing system

- Enhances our understanding of Arctic-midlatitude linkages (also from a prediction perspective)

- Brings different communities closer together

Highlights of APPLICATE WP5

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Experimental framework to foster the predictive skill over the Arctic

- APPLICATE Stream 1 seasonal forecasts show **skill to predict summer SIE up to 3-4 months** beforehand
- Increasing the resolution seems to lead to higher predictive skill in the Northern Hemisphere, although it is unclear if the improvement comes from the ICs or from the resolution itself
- Statistical models can achieve high level of skill up to 12 months ahead

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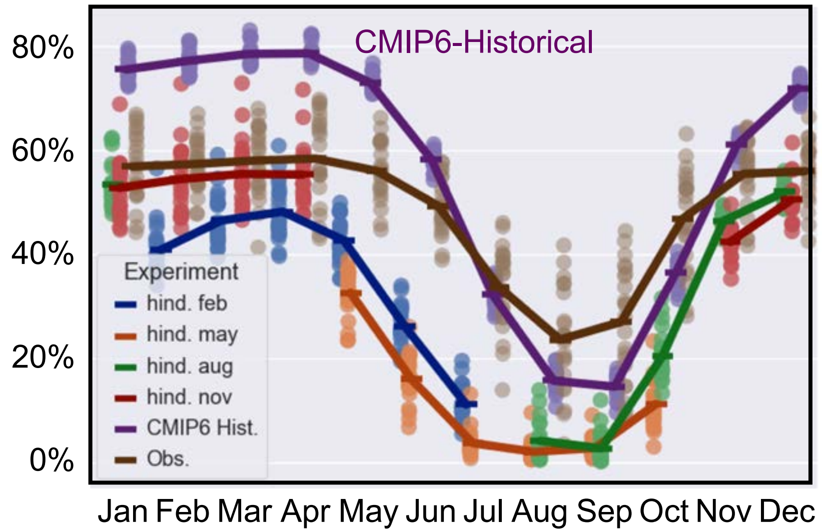
Thanks for your attention!!

WP5: Role of Initialization

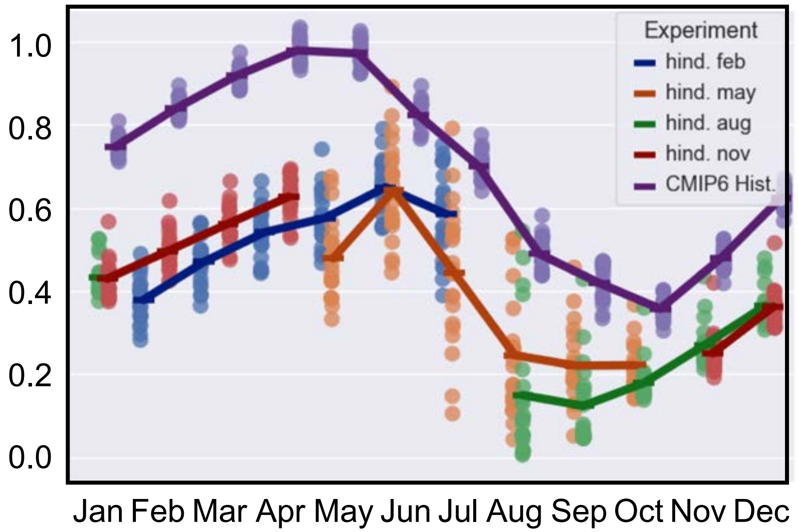
Ilona Valisuo

Greenland Sea

Sea Ice Concentrations



Sea Ice Thickness

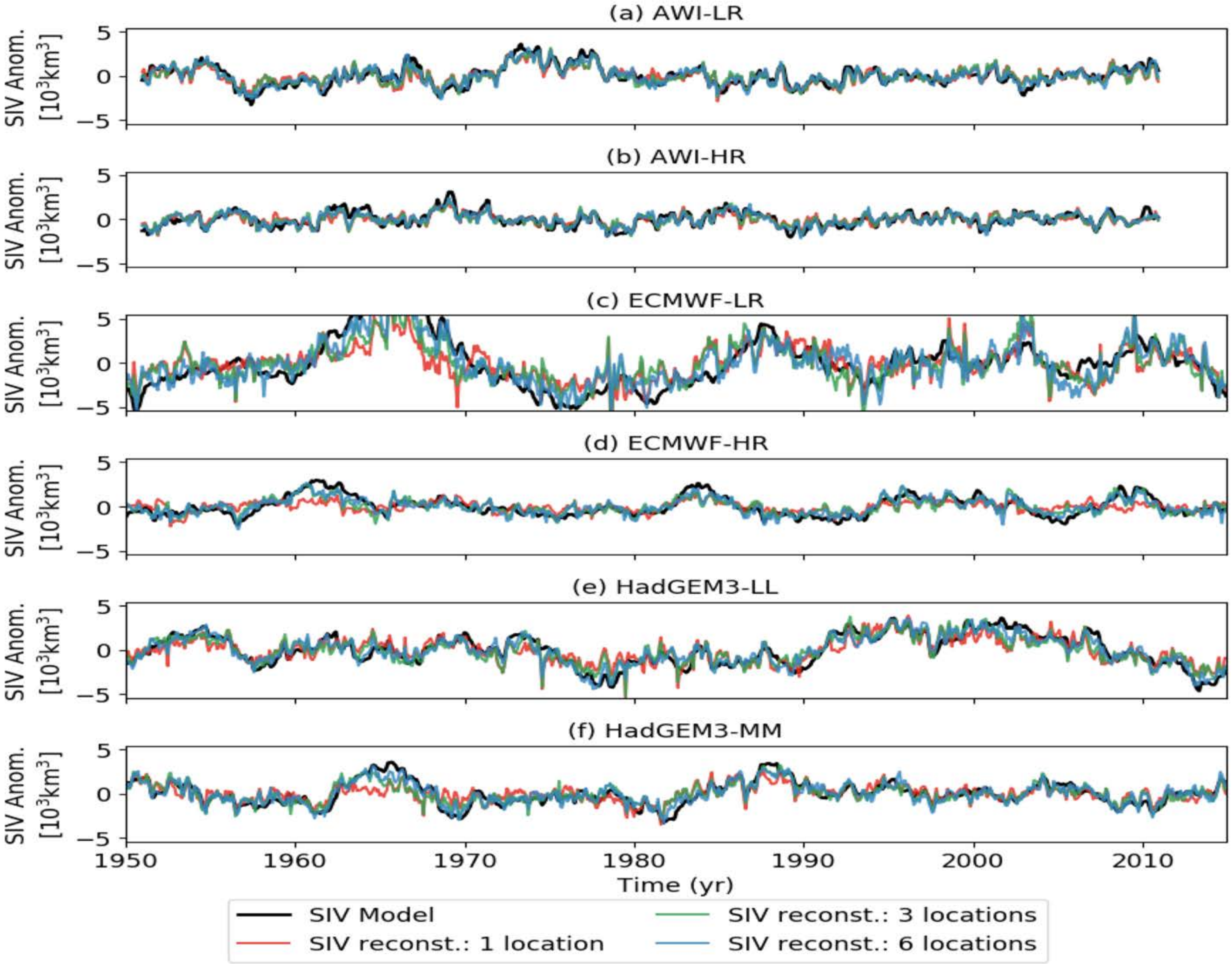


CNRM produces **too much and too thick** ice in Greenland Sea

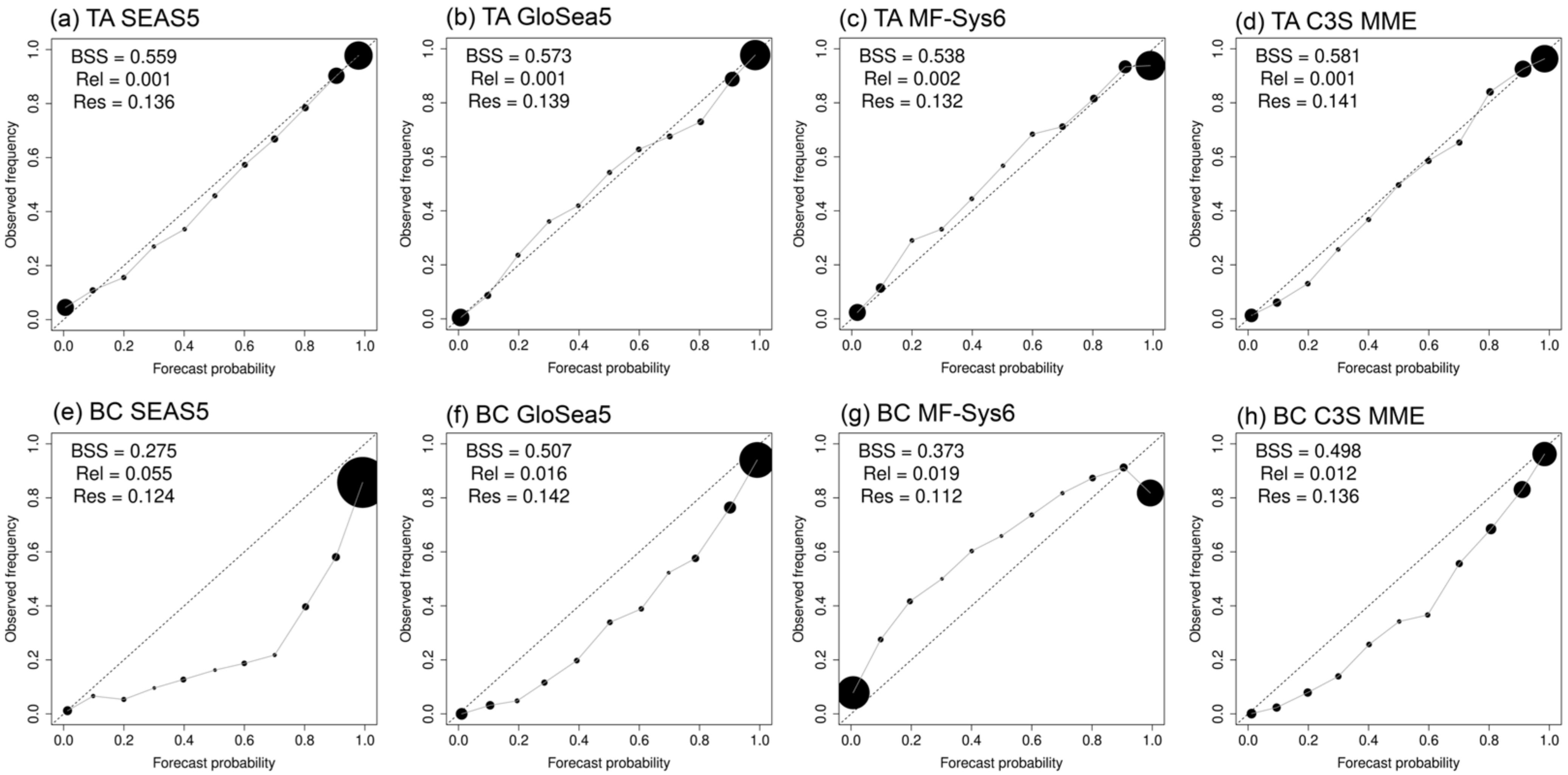
Forecasts show **huge spread in thickness** during the **melt season**

Systematic error not fully developed by the end of the forecasts

CNRM-CM6-1 Seasonal Forecasts (1993-2014)


(a) AWI-LR
(b) AWI-HR
(c) ECMWF-LR
(d) ECMWF-HR
(e) HadGEM3-LL
(f) HadGEM3-MM
SIV Anom. [10^3km^3]
5
0
−5
1950
1960
1970
1980
1990
2000
2010
Time (yr)
SIV Model
SIV reconst.: 1 location
SIV reconst.: 3 locations
SIV reconst.: 6 locations

Multi-model forecasts improve model reliability



Reliability diagrams and Brier Skill Score for September mean SIC > 0.15 over the Beaufort and Chukchi seas for (a-d) trend-adjusted and (e-h) bias corrected SIC re-forecasts (Copernicus Climate Change Services systems, 1993-2014 May starts)

WP5: Role of Initialization

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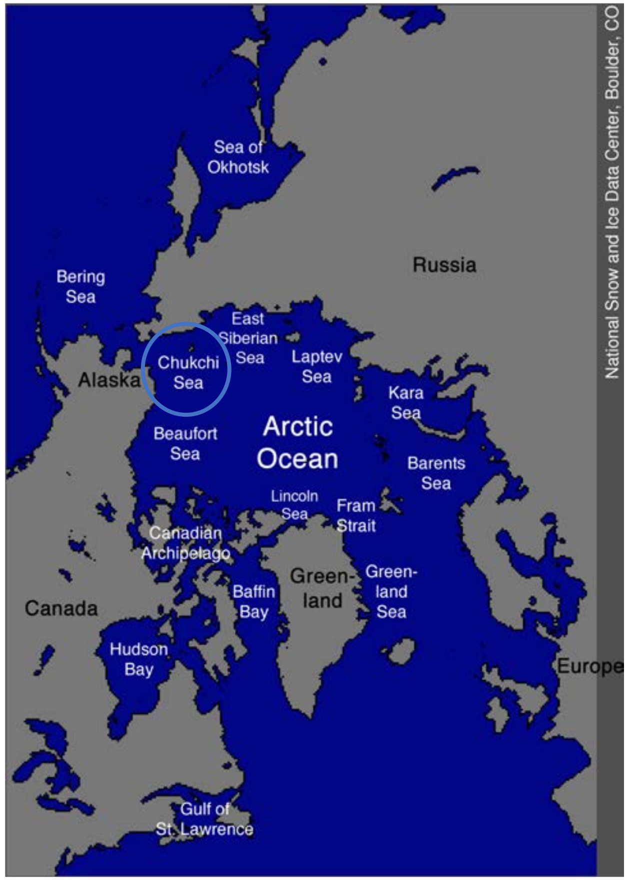
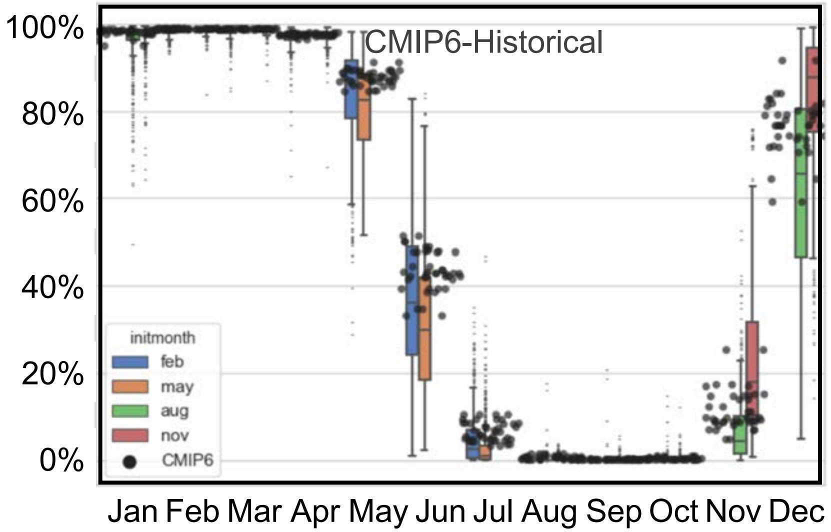
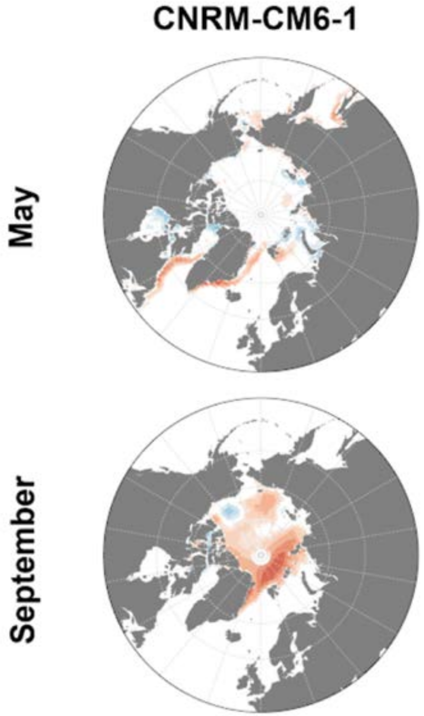
Chukchi Sea



Sea Ice Concentrations



Mean bias in monthly mean sea ice concentration with NSIDC



CNRM-CM6-1 Seasonal Forecasts (1993-2014)

Summary – APPLICATE …

APPLICATE.eu
Advanced prediction in polar regions and beyond

- Advances predictive capacity in polar regions and beyond:
  - Develop models with enhanced representation of Arctic processes
  - Contribute to improving the Arctic observing system
- Enhances our understanding of Arctic-midlatitude linkages (also from a prediction perspective)
- Brings different communities closer together
- Exploits and fosters international collaboration
- Works closely with key users and stakeholders
- Contributes to educating the next generation of scientists

Strategy

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Advanced prediction in polar regions and beyond

Understanding Arctic-midlatitude linkages

- Coordinated multi-model approach (CMIP6-PAMIP)
- Employ atmosphere-only *and* coupled models
- Study linkages also from a short-term prediction perspective
- Repeat some of the experiments with enhanced models

Strategy

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Advanced prediction in polar regions and beyond

Knowledge exchange

Focus on three key areas:

- User engagement
- Dissemination
- Training

Experienced partners taking the lead:

- Arctic Portal
- Barcelona Supercomputing Centre
- Association of Polar Early Career Scientists

Exploit exisiting “channels“ from APPLICATE partners

APPLICATE Advisory Board

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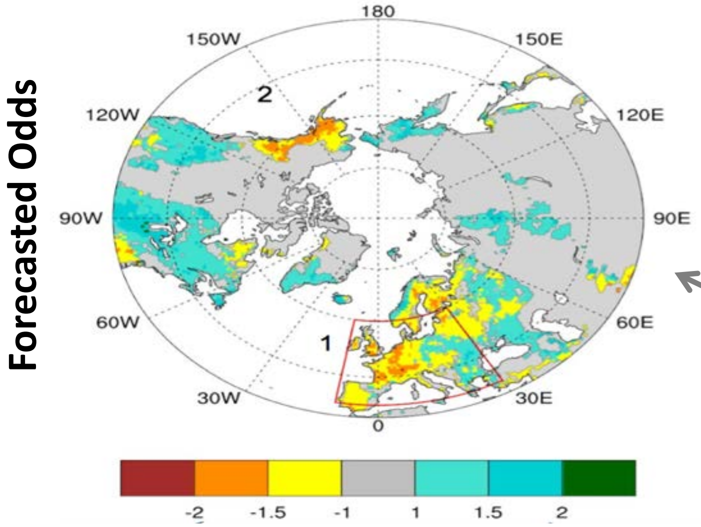
Advanced prediction in polar regions and beyond

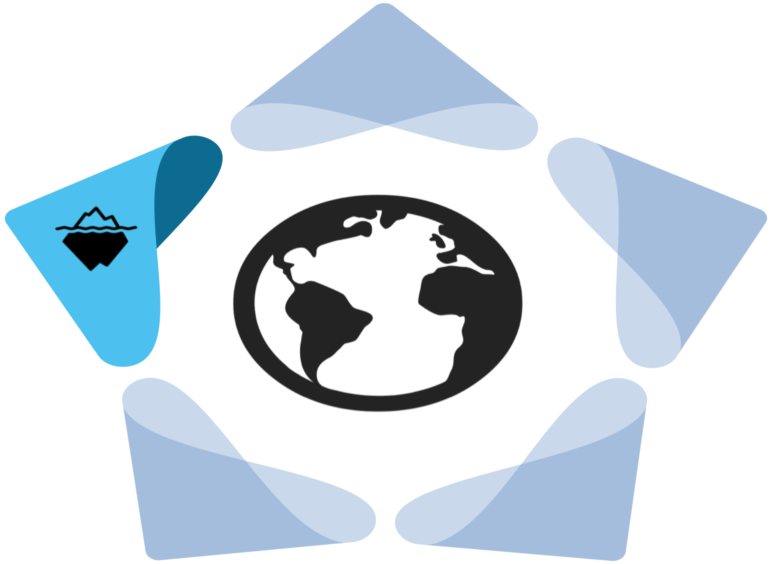
Name	Area of expertise	Country
Cecilia Bitz	Model developent and sea ice prediction	USA
Clara Deser	Arctic-midlatitude linkages	USA
Veronika Eyring	Model evaluation and CMIP	Germany
Inger Hansen-Bauer	Climate and weather services	Norway
Bill Merryfield	Climate prediction	Canada
Jean-Noel Thepaut	Copernicus Climate Change Services	UK
Tero Vauraste	Stakeholder representative	Finland

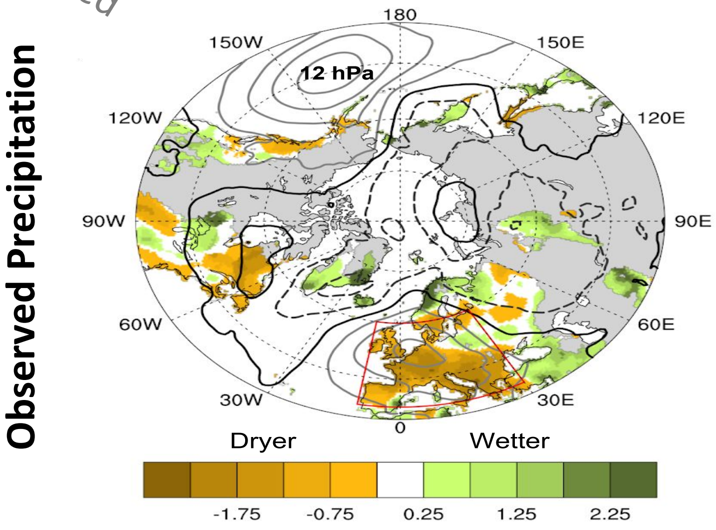
Sea ice loss enhancing likeliness of climate extremes

J. Acosta et al



Only when 2016 sea ice is initialized





Lowest sea ice cover since 1979