An Overview of European Union-Funded Project APPLICATE

Pablo Ortega, on behalf of APPLICATE partners

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

16 partners and 1 third-party from 9 countries

... and many collaborators!
Budget and duration

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

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

How important are Arctic predictions for marine stakeholders

- ... from hours to weeks? (tactical time scales)
- ... from months to years? (operational time scales)
- ... from years to decades? (strategic time scales)

Survey: EC-PHORS Services Task Team
General approach

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

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

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

Doug M. Smith1, James A. Screen2, Clara Deser3, Judah Cohen4, John C. Fyfe5, Javier García-Serrano6,7, Thomas Jung6, Vladimir Kattsov8, Daniela Matei9, Ryn Maudek10, Yannick Peings11, Michael Sigmond12, Jinro Ukita13, Jin-Ho Yoon14, Xiangdong Zhang15

10.5194/gmd-2018-82
Manuscript under review for journal Geosci. Model Dev.
Discussion started: 9 June 2018

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Delivering enhanced predictions

**Strategy**

**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

**Recommendations**
- Presentations
- Reports
- Publications
- Contribution to assessment reports

**Enhanced Predictions**
- CMIP6-Interim and CMIP7
- Enhanced operational:
  - NWP
  - Subseasonal to Seasonal Prediction
  - Interannual to Decadal Prediction
WP5: Main goals

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

- **NWP**
  - **CRNS (CNRM)**
  - Met Norway
  - ECMWF

- **Seasonal Prediction**
  - **CRNS (CNRM)**
  - Met Office
  - BSC
  - UCL

- **Climate Projections**
  - **AWI**
  - BSC

**Deterministic/ensemble**

**Globallimited area models**

Focus on YOPP period

10 members

1993-2014 period

May/November ICs

**HiResMIP:**

1950 fixed forcing control

1950-2050 transient
WP5: Main goals

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

1. Advance our understanding of predictability mechanisms operating at 3 different timescales:
   - NWP
   - Seasonal Prediction
   - Climate Projections

2. Enhance the exploitation of Arctic Observations, and advance our understanding of linkages between the Arctic and mid-latitudes

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

APPLICATE TIMELINE

STREAM 1
Baseline skill of APPLICATE prediction systems

STREAM 2
Skill after including APPLICATE developments

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

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

STREAM 1 + C3S systems

RMSE of total Arctic SIE

Pan-Arctic IIEE

Ref: NSIDC

1st May Initialized Forecasts (1993-2014)

Goessling et al. 2016
WP5: Stream 1 baseline skill

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

Ref: NSIDC

1st May Initialized Forecasts (1993-2014)
WP5: Stream 1 baseline skill

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)
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.
WP5: Role of Initialization

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

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

EC-Earth3.2 Seasonal Forecasts (1993-2008)
WP5: Impact of model resolution

NEMO/LIM3 (ORCA1)

Ocean ICs: forced run nudged to ORAS4

NEMO/LIM3 (ORCA025)

Ocean ICs: forced run nudged to ORAS5

ACC in Sea Ice Concentration in DJF (ORCA1)

Ref: NSDIC

ACC in Sea Ice Concentration in DJF (ORCA025)

Ref: NSDIC

EC-Earth3.3 November Forecasts (1993-2014)
WP5: Impact of model resolution

Ocean ICs: forced run nudged to ORAS4

NEMO/LIM3 (ORCA025)

ACC difference in DJF SLP (ORCA025 – ORCA1)

Ocean ICs: forced run nudged to ORAS5

Ref: ERA-Interim

EC-Earth3.3 November Forecasts (1993-2014)
WP5: Impact of model resolution

NEMO/LIM3 (ORCA025) vs NEMO/LIM3 (ORCA1)

Ocean ICs: forced run nudged to ORAS4
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

Ocean ICs: forced run nudged to ORAS4

Ocean ICs: forced run nudged to ORAS5

Systematic Analysis with three GCMs

EC-Earth3.3 November Forecasts (1993-2014)
WP5: Statistical climate predictions

7 different predictors

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIV</td>
<td>Sea Ice Volume</td>
</tr>
<tr>
<td>OHT</td>
<td>Ocean Heat Transport</td>
</tr>
<tr>
<td>SIC</td>
<td>Sea Ice Concentration</td>
</tr>
<tr>
<td>SID</td>
<td>Sea Ice Drift</td>
</tr>
<tr>
<td>SIA</td>
<td>Sea Ice Area</td>
</tr>
<tr>
<td>SIT</td>
<td>Sea Ice Thickness</td>
</tr>
<tr>
<td>SST</td>
<td>Sea Surface Temperature</td>
</tr>
</tbody>
</table>

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)
WP5: Optimal sampling locations

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)
WP5: Optimal sampling locations

4 predictors (easily observable)

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

Statistical Predictions: Perfect model (1950-2014)

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
Summary of APPLICATE

- 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
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
Thanks for your attention!!
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)
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

Chukchi Sea

Sea Ice Concentrations

Mean bias in monthly mean sea ice concentration with NSIDC

CNRM-CM6-1 Seasonal Forecasts (1993-2014)
Summary – APPLICATE ...

- 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
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

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 existing “channels” from APPLICATE partners
<table>
<thead>
<tr>
<th>Name</th>
<th>Area of expertise</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cecilia Bitz</td>
<td>Model development and sea ice prediction</td>
<td>USA</td>
</tr>
<tr>
<td>Clara Deser</td>
<td>Arctic-midlatitude linkages</td>
<td>USA</td>
</tr>
<tr>
<td>Veronika Eyring</td>
<td>Model evaluation and CMIP</td>
<td>Germany</td>
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<tr>
<td>Inger Hansen-Bauer</td>
<td>Climate and weather services</td>
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<td>Bill Merryfield</td>
<td>Climate prediction</td>
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<tr>
<td>Jean-Noel Thepaut</td>
<td>Copernicus Climate Change Services</td>
<td>UK</td>
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<tr>
<td>Tero Vauraste</td>
<td>Stakeholder representative</td>
<td>Finland</td>
</tr>
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Sea ice loss enhancing likeliness of climate extremes

J. Acosta et al

Lowest sea ice cover since 1979

Observed Precipitation

Forecasted Odds

Only when 2016 sea ice is initialized