Skillful seasonal forecasts of Arctic sea ice retreat and advance dates in a dynamical forecast system

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Context

• Seasonal forecasting of sea ice a young field
  
  \textit{first systems with coupled sea ice component operational in} \textit{~2010}
  
• First studies: area-integrated quantities such as Sea Ice Extent\textit{Of little relevance to end-users (e.g. transport, tourism, Coast Guard, Northern Communities, resource extraction)}
  
• Community is moving toward (monthly mean) regional or local sea ice concentration/sea ice edge
  
• This study: quantifying skill of local dates at which ice melts (retreat) or forms (advance date)
  
  \begin{itemize}
  \item Based on daily data
  \item Directly relevant to end users
  \end{itemize}
Outline

1) How far in advance can local sea ice retreat/advance date be skillfully predicted?  

2) What are the sources of skill?  

3) Initial attempts to produce operational forecasts  

Model, data and method:

- **Model:** Canadian Seasonal to Interannual Prediction System
  - based on 2 GCMs: CanCM3 and CanCM4
    - Same ocean and sea ice
    - Different atmosphere
  - 10 ensemble members for each GCM
  - 12 month forecast range
  - SI concentration initialized with (re)analyses (nudging)
  - SI thickness initialized with climatology (nudging)

- **Data:** Hindcasts initialized every month between 1979-2010

- **Retreat date:** First calendar day with SIC < 50%

- **Maximum lead time with skill:**
  
  \[\text{climatological date} - \text{earliest initialization month with skill}\]

  \[
  \uparrow
  \]

  ACC > 0.3 (p=0.05)
Forecast skill (ACC)
Forecast skill (ACC)
Sources of skill: Trend

With trend

Retreat

2.9

Advance: Even larger contribution (36%)
Even after detrending: advance skill > retreat skill
Sources of skill: Persistence

- Retreat: most of obtained model skill explained by persistence
- But our model beats persistence

Maximum lag with skill of retreat date forecasts made by persisting initially observed SIC anomaly
Sources of skill: Persistence

- **Retreat:** Most of obtained model skill explained by persistence
  - But our model beats persistence

- **Advance:** Almost no skill from persistence
  - Due to absence of sea ice prior to advance (no anomaly to persist \( \rightarrow \) persist. = clim.)
  - Additional value considerable!
Sources of skill (advance): Reemergence
Sources of skill (advance): Reemergence

Hudson Bay

ACC

0.8
0.6
0.4
0.2
0.0

Model
Sea Ice persis.
SST regr.

Retreat
Advance

Corr (initial SST, advance date)

Sea-ice ini.
ocean ini.

Initialization month

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr

melt Summer growth
Initial steps towards operational forecasts

- Problem: real-time CanSIPS forecasts not usable due to inconsistency between hindcasts and forecasts initial conditions
- Solved this by producing historical dataset that is closer to that used to initialize forecasts, and redoing the hindcasts
- Also improved SIT initialization

→ Usable sea ice forecasts
→ More skillful retreat/advance date forecasts

\[\text{retreat: } 3 \rightarrow 5 \text{ month in advance}\]
\[\text{advance: } 5 \rightarrow 7 \text{ month in advance}\]
Advance date forecasts skillful at 5 month lead
• Drops to 3.3 months for detrended anomalies
• Sea ice persistence provides no skill
• Model skill stems from skillful SST predictions

First experimental forecast: 2018 retreat date anomaly (cf 2009-2017)
Advance date forecasts skillful at 5 month lead
Drops to 3.3 months for detrended anomalies
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First experimental forecast:
2018 retreat date anomaly (cf 2009-2017)
Summary:

• Skillful seasonal forecasts of socio-economically relevant sea ice events

• Advance dates predictions more skillful (~5-7 months) than retreat dates (~3-5 months)

• Sources of skill: trend, persistence and re-emergence (SSTs)

• Working towards implementation into operations

• Working with end users (future: probabilistic forecasts)

Thanks!

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Extra slides
Climatology (1979-2010)

- Hindcast climatologies of retreat dates correspond well with obs
Methodology

Retreat
First calendar day with SIC<0.5 for at least 10 days

Model hindcasts

Initialization date

Advance
First calendar day with SIC>0.5 for at least 10 days

Model hindcasts

Initialization date

- Skill metric: Anomaly correlation coefficient (stat. significant: >0.3)

- Maximum lead time with skill:
  [climatological date] – [first initialization date with skill]
Initialization (hindcast/forecast):

<table>
<thead>
<tr>
<th></th>
<th>Current</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIC</td>
<td>HadISST1/CMC</td>
<td>Had2CIS/CMC</td>
</tr>
<tr>
<td>SIT</td>
<td>Clim./Clim.</td>
<td>SMv3/SMv3</td>
</tr>
<tr>
<td>Subsurface ocean temp</td>
<td>GODAS/GIOPS</td>
<td>ORAp5/GIOPS</td>
</tr>
</tbody>
</table>
Forecast skill for retreat date (ACC)
Forecast skill for advance date (ACC)

Current

ACC Nov init.  | Earliest  | Max. lag

NEW

ACC Nov init.  | Earliest  | Max. lag

4.7

6.7