Seasonal predictability of the Arctic sea-ice in a coupled GCM: a diagnostic approach

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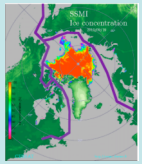
Abstract

- Potential predictability of the Arctic sea-ice area is investigated in a 400-year preindustrial simulation (FP6/ENSEMBLES Stream 2) with CNRM-CM3.3 coupled AOGCM.
- We build predictors integrating information on the subgrid ice thickness distribution (ITD).
- The winter sea-ice area is potentially predictable in late fall/early winter using the amount of young ice formed from the onset of freeze-up in the margins.
- The August-September sea-ice area is potentially predictable using the area covered by ice thicker than 0.9-1.5m up to 6 months in advance.

1.Context of the study

- Recent acceleration of Arctic sea ice retreat and thinning:
  - ⇨growing interest in information on summer marine accessibility of the Arctic seas.
  - ⇨Outlooks of winter/spring ice conditions (ice thickness, onset of melt season…).
- **SEARCH/Sea-Ice Outlook**: since 2008, requests on seasonal outlooks of the September sea ice cover (statistical, empirical, model-based methods).
  - ⇨ emphasize the role of winter preconditioning of the sea ice cover (thickness).
- Influence of sea ice anomalies on mid-to-high latitude weather patterns at seasonal time scales? (e.g. *Francis et al., 2009, Petoukhov and Semenov, 2010*)



The ITD theory (e.g. Bitz et al., 2001)

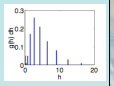
- In winter, thin ice grows faster than thick ice.
- In spring-summer, thin ice melt creates local ice-albedo feedback within the ice pack: accelerates sea-ice melt.
- Thin ice more likely to deform compared to thick ice.

⇨Diagnostic of an **ITD** function $g(h,x)dh$: fraction of ice in x whose thickness lies between h and $h+dh$.

⇨ Discretization of g: ice thickness categories (in CNRM-CM3.3, **8 ice cat.**: 0-0.2,0.2-0.5,0.5-0.9,0.9-1.5,1.5-2.5,2.5-4,4-6,>6m).

⇨Each category: thickness h varying in response to growth, melt, advection, deformation.

⇨When ice in a certain category outgrows thickness limits: transfered from one category to another.



Subgrid scale parametrization for multiple ice thicknesses

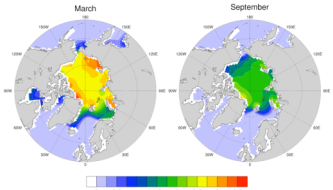
2.Model and data description

CNRM-CM3.3 (Salas et al., 2005, Johns et al., 2011)

- Atmosphere: ARPEGE-Climat (2.8°x2.8°)
- Ocean: OPA8 (2° long., 0.5° to 1.5° lat.)
- Sea-ice: GELATO
- Land: ISBA
- River: TRIP
- Coupling: OASIS

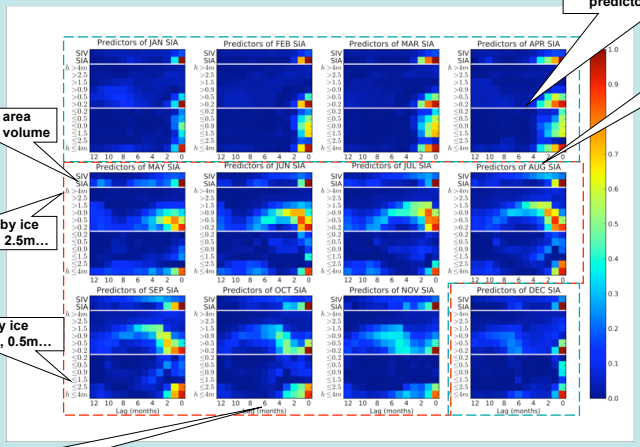
ENSEMBLES/Stream 2 Preindustrial exp.

- 400 years, 1860 Aerosols/GHG concentration. **Negligible climate trends.**



March and September average Arctic sea-ice thickness (m).

3.Summary of results



Squared lagged anomaly correlation (SLAC): predictor vs. sea-ice area.

Month of prediction of the sea-ice area (lag 0)

SIA: sea-ice area
SIV: sea-ice volume

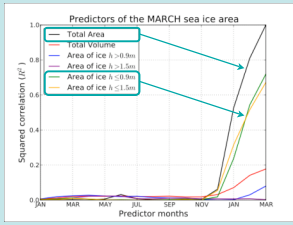
Area covered by ice thicker than 4, 2.5m…

Area covered by ice thinner than 0.2, 0.5m…

Lead time of the prediction

- In SLAC, anomalies are calculated relative to a 15-year moving average.
- SIA: potential predictability of about **3 months** (consistent with previous studies: e.g. Blanchard et al. (2010).
- SIV: longer potential predictability (5 months), but weaker skills (not greater than 50%).
- Cumulative categories are used (rather than individual categories): identify thin/thick ice.
- We identify two regimes for the prediction of sea ice area of:
  - **December-April (« winter »)**
  - **May-November (« summer »)**

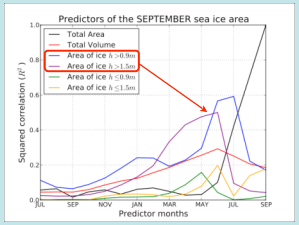
4.Winter sea-ice area predictability



⇨***"Persistence regime"***

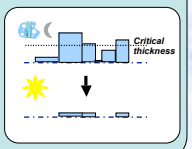
- For the prediction of late winter sea ice area, the predictive skills of area covered by relatively thin ice in late fall/early winter is comparable to those of the sea ice area itself (persistence).
- The amount of relatively thin ice in late fall/early winter (November-February) is an indicator of the severity of the freeze-up season: upper ocean preconditioning?

5.Summer sea-ice area predictability



⇨***"Memory regime"***

- An anomaly of September SIA is potentially predictable **up to 5 months in advance**, using the amount of ice thicker than h, where h lies between 0.9-1.5m.
- Relatively thick ice contains the **memory** of the system.



6.Future works

⇨ Perform seasonal forecast ensemble experiments with the fully coupled CNRM-CM climate model, based on historical cases.

- Impact of sea ice initialization: using the ITD information for the perturbation (+ensemble of sea ice/ocean hindcasts: **Poster EGU2011-1923**, Friday 08 April, CR9.1).
- Impact of the atmosphere: WGSIP/Ice-HFP program (impact of a « real » sea ice initialization on atmosphere seasonal predictability).

⇨ Investigation on the ability of ITD-resolving sea ice GCM components in allowing a memory to emerge (enhancing predictive skills).

References:

Bitz, C., Holland, M., Weaver, A. and Eby, M., 2001: Simulating the ice-thickness distribution in a coupled climate model. *J. Geophys. Res.*, **106**.

Blanchard-Wrigglesworth, E., Armour, K., Bitz, C. and DeWeaver, E., 2010: Persistence and inherent predictability of Arctic sea ice in a GCM. *J. Climate*, **24**.

Chevallier, M. and Salas-Y-Mélia, D., 2011: The role of sea ice thickness distribution in the Arctic sea ice potential predictability: a diagnostic approach with a coupled GCM. *J. Climate, submitted*.

Francis, J.A., et al., 2009: Winter Northern Hemisphere weather patterns remember summer Arctic sea-ice extent. *Geophys. Res. Lett.*, **36**.

Johns et al., 2011: Climate change under aggressive mitigation: The ENSEMBLES multi-model experiment. *Climate Dyn., in press.*

Petoukhov, V. and Semenov, V., 2010: A link between reduced Barents-Kara sea ice and cold winter extremes over northern continents. *J. Geophys. Res.*, **115**.

Salas-Y-Mélia,D., et al., 2005: Description and validation of the CNRM-CM3 GCM. Note de centre CNRM 03 (http://cnrm.meteo.fr/scenario2004/paper_cm3.pdf).