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Arctic Research Programme
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The Arctic sea ice forecast horizon: how do we get there?

Jonny Day

Thanks to:
Steffen Tietsche, Mat Collins, Helge Goessling, Virginie Guemas, Sarah Keeley, Daniela Matei, Rym Msadek, Hiroaki Tatebe, M. Sigmond and **Ed Hawkins**

@jonnyday

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Sea ice variability

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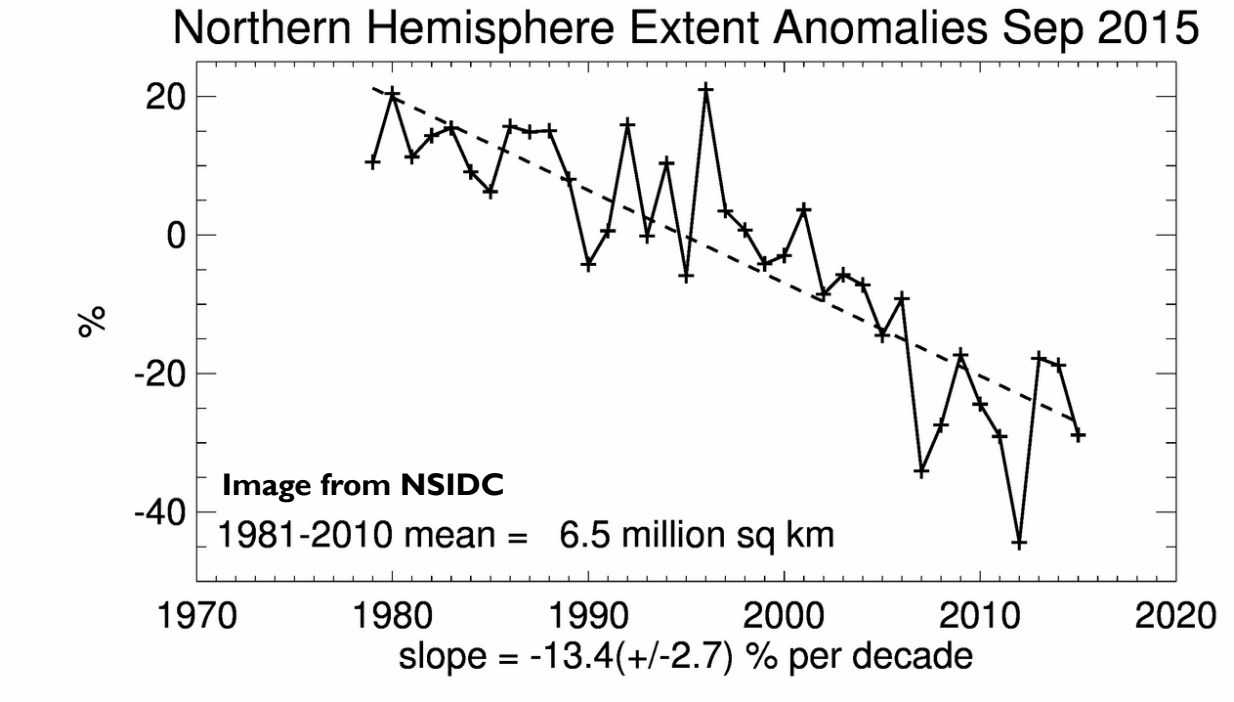

Can we predict the inter-annual variability?

Arctic Marine Access

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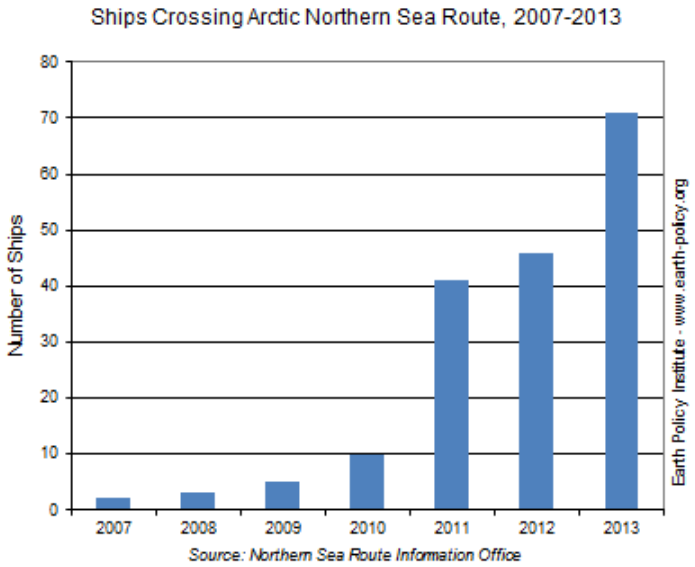

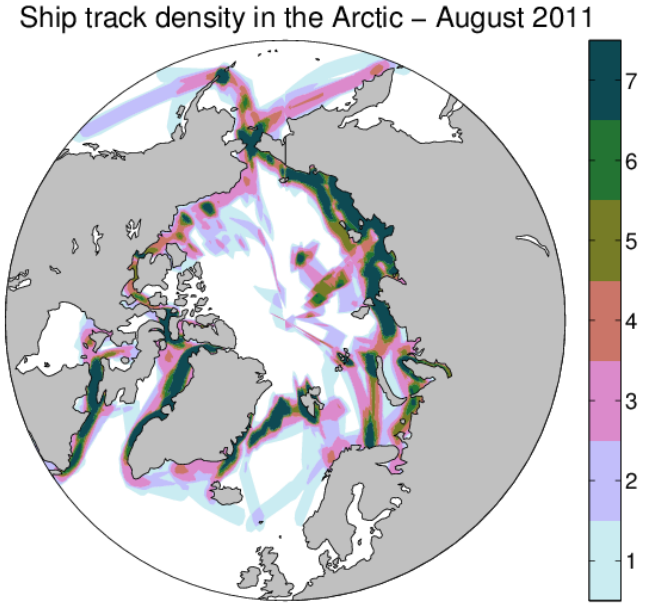

An operational forecast system

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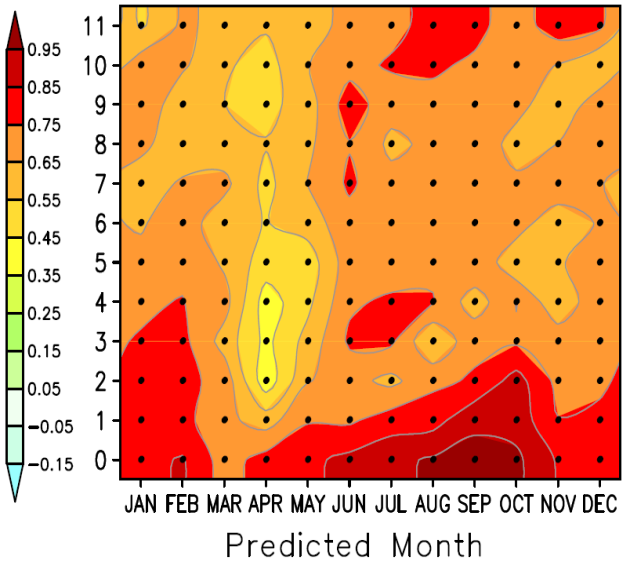
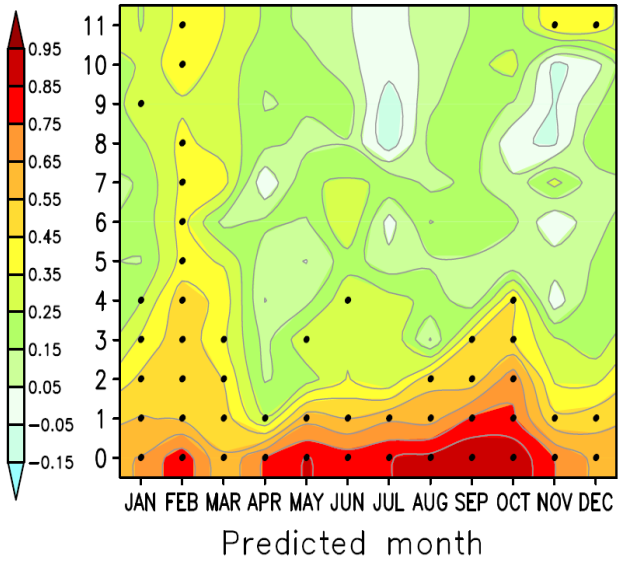
Correlation skill for extent from retrospective forecasts



Including trend



Without trend

Sigmund et al. 2013, GRL

An operational forecast system

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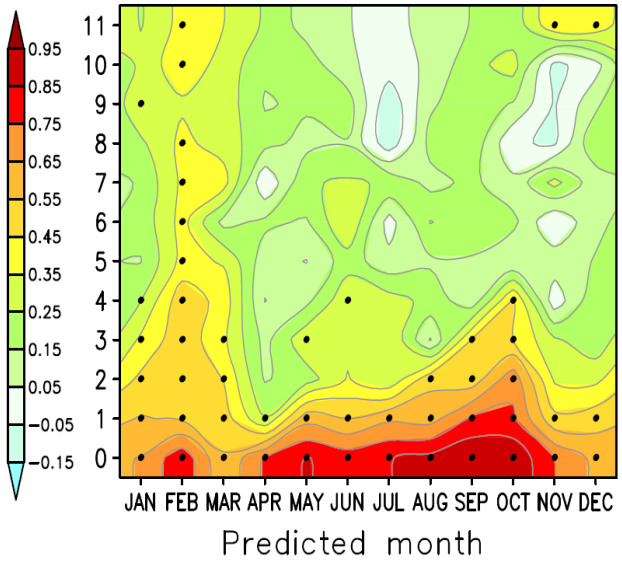
Correlation skill for extent from retrospective forecasts

Questions:

1) Are these features due to observation and/or model inadequacies?

2) Or, have we reached the limit of predictability?



Without trend

Sigmund et al. 2013, GRL

APPOSITE approach

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AIMS:

- Quantify the limits of predictability of the Arctic environment on inter-annual timescales
- Determine the physical processes and mechanisms that determine Arctic predictability (in simulations)
- Provide recommendations on developments for operational prediction systems

Hierarchy for predictability studies

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- Predictor-predictand relationships
  - e.g. Kapsch et al (2013,2014), Chevallier and Sales-Melia 2012.
- Perfect model *predictability* experiments
  - e.g. Griffies and Bryan (1997)
- Observing system experiments
  - see Day et al. (2014)
- Hindcast *skill* analysis
  - All seasonal forecast centres

(see Hawkins et al., 2015)

Methodology

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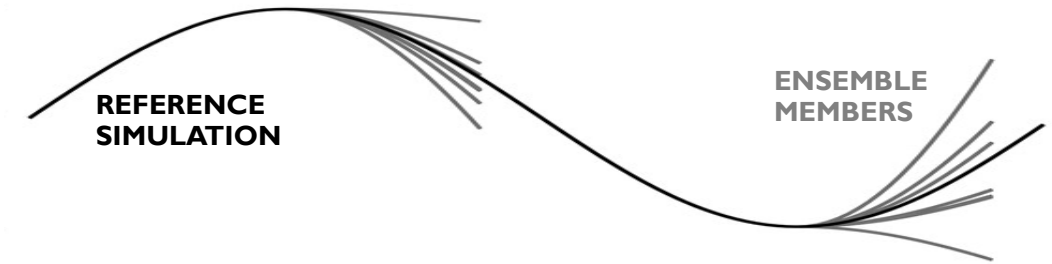
'Perfect model' framework:

- Examine how well a GCM can predict itself (Griffies and Bryan, 1997; Collins, 2002).
- Predicting the real world with the same GCM is a harder problem
- The estimated 'perfect' skill is therefore an upper limit for the skill of that GCM to



Methodology

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Ensemble design:

- 7 GCMs (HadGEM1, EC-EARTH2, MPI-ESM, GFDL-CM3, ECHAM6-FESOM, CanCM4 & MIROC5)
- Experiments started on 1st July in at least 8 different years from reference control simulation
- Range of initial conditions chosen to sample different states of the Arctic, e.g. neutral, high, low sea-ice
- Between 8 and 16 ensemble members, generated by making tiny perturbations to atmospheric initial conditions
- Run for 3 years

GCMs: mean state & variability

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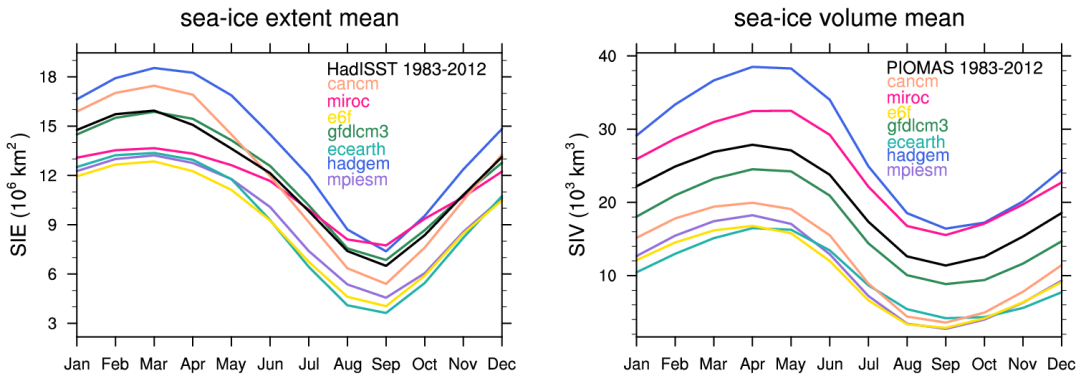

Day et al., (submitted; GMDD);updated from Tietsche et al., (2014; GRL)

Potential predictability estimates

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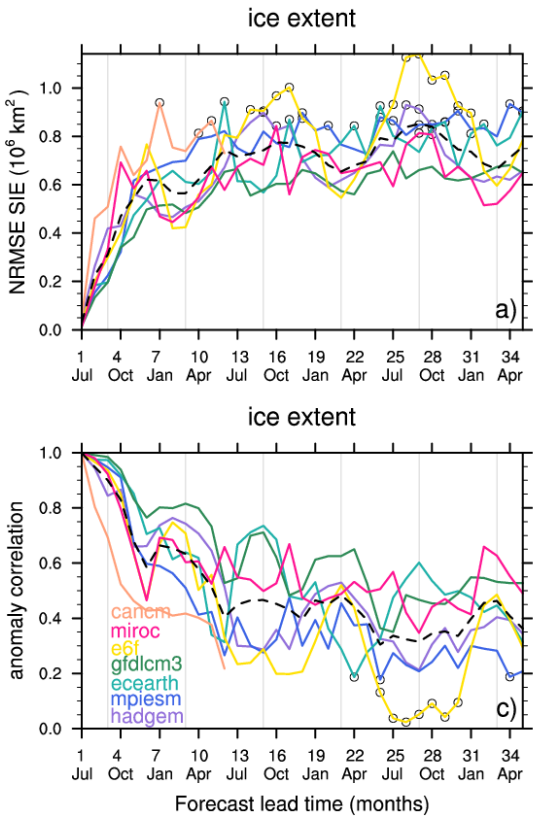

Day et al., (submitted; GMDD);updated from Tietsche et al., (2014; GRL)

RMSE for September (3 month lead)

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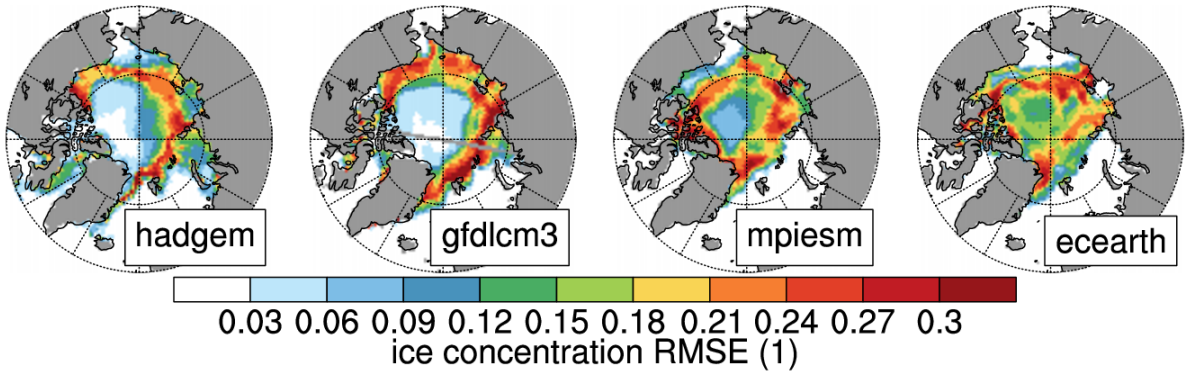

Tietsche et al., (2014; GRL)

The Arctic observing System

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- There is a large gap in the density of atmosphere and ocean observations in the polar regions.
- Satellite derived sea ice thickness products are becoming available but:
  - Altimeters have problems with thin ice (CryoSAT-2).
  - Radiometers can't distinguish between thick ice (>0.5m)(SMOS)
  - Gap in observations May-Oct.
- Which component is the largest source of predictability?

Data denial experiments

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How much memory/predictability comes from the sea ice thickness?

- Using HadGEM1
- Rerun perfect model simulations started in January and July.
- Except, replace initial sea ice thickness conditions with model climatology, everything else left

Will sea ice thickness observations improve skill?

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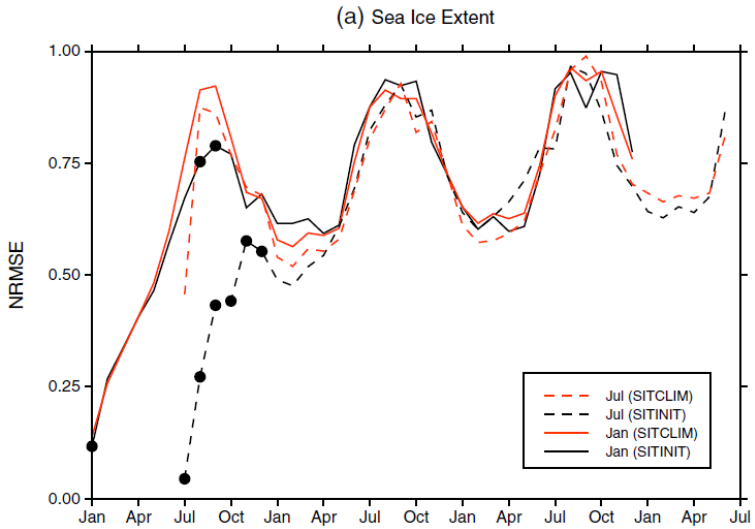

- Large seasonal difference in the impact of thickness initialisation.
- Jan start: very little impact.
- July start: Almost complete removal of skill.

Day et al., (2014; GRL)

Sea Ice fields (January start)

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Day et al., (2014; GRL)

Sea Ice fields (July start)

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Day et al., (2014; GRL)

Atmosphere (January start)

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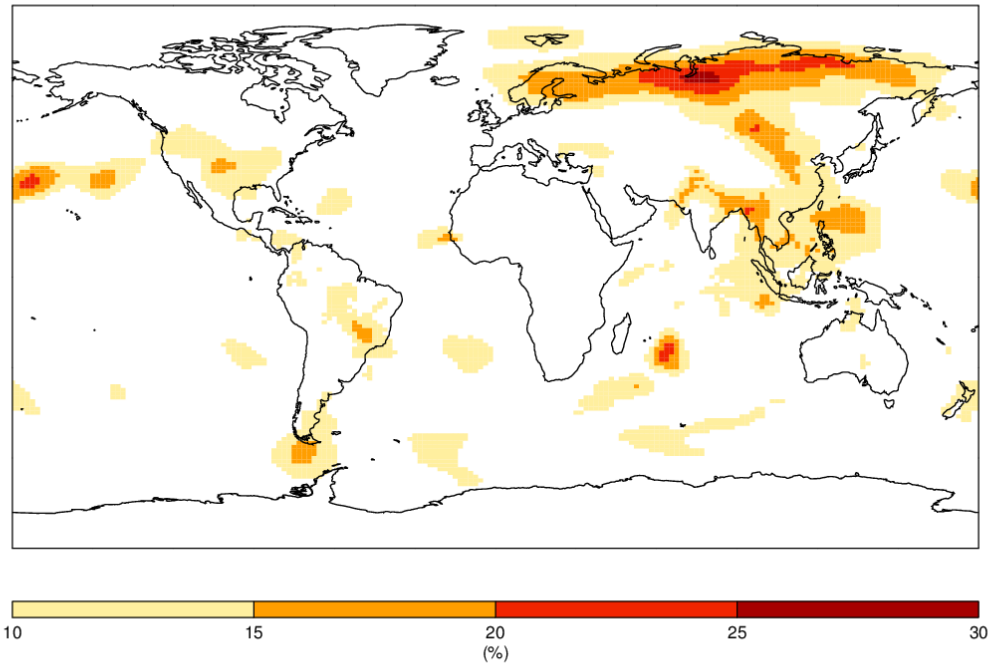
Increase in Jan MSLP error



Day et al., (2014; GRL)

Summary

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The APPOSITE project is examined the predictability of the Arctic climate system:

- Potential for skillful predictions of sea-ice extent is 1-2 years for summer (longer in winter) and longer than 3 years for volume
- Model biases and lack of complete observations reduce the skill when predicting real world
  - Sea ice thickness particularly important for forecasts of summer sea ice extent.
  - Ocean state more important for winter ice edge.
- Unique dataset openly available at BADC

Discussion points

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- Sea ice thickness initialisation is crucial for summer sea ice prediction.
- Assimilation of Cryosat-2/IceSAT should be a high priority in this area.
- Impact of winter sea ice thickness anomalies on atmospheric circulation is likely to be particularly sensitive to boundary layer parameterisation.

- **Year of Polar Prediction (2017-2019)** is an opportunity to develop capability in these areas.

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Thank You!

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Impact of Barents-Kara sea on storm tracks & circulation

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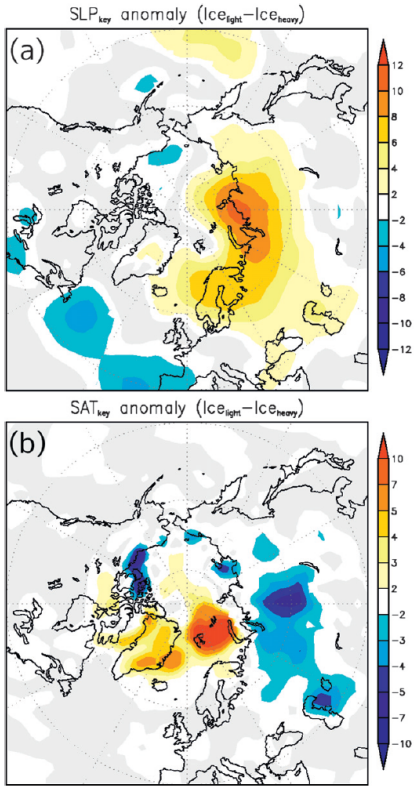
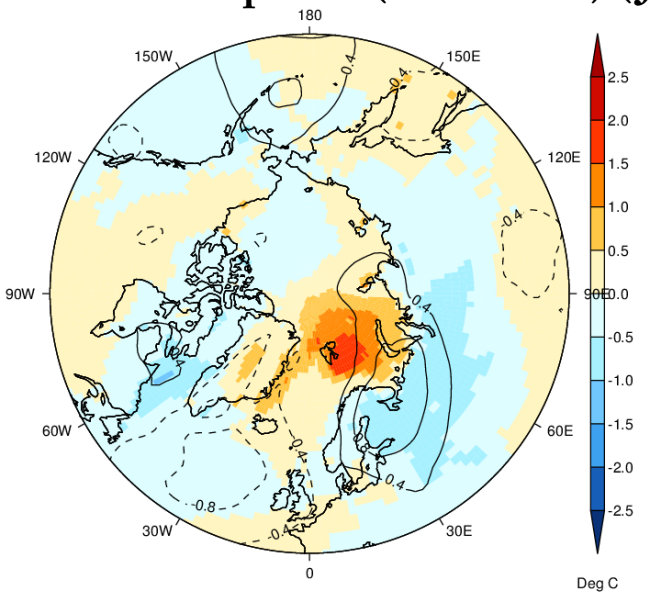


Kara sea composite (thin-thick) (Jan)



Prospects for longer term prediction

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