

Rise and Fall of Ice production in the Kara and Laptev Seas

Sam Cornish, Helen Johnson, Yavor Kostov,
Robbie Mallet, Jakob Dörr, Alice Richards

sam.cornish@earth.ox.ac.uk

Twitter: @sbcornish



Arctic sea ice in decline, winter growth in ascendance?

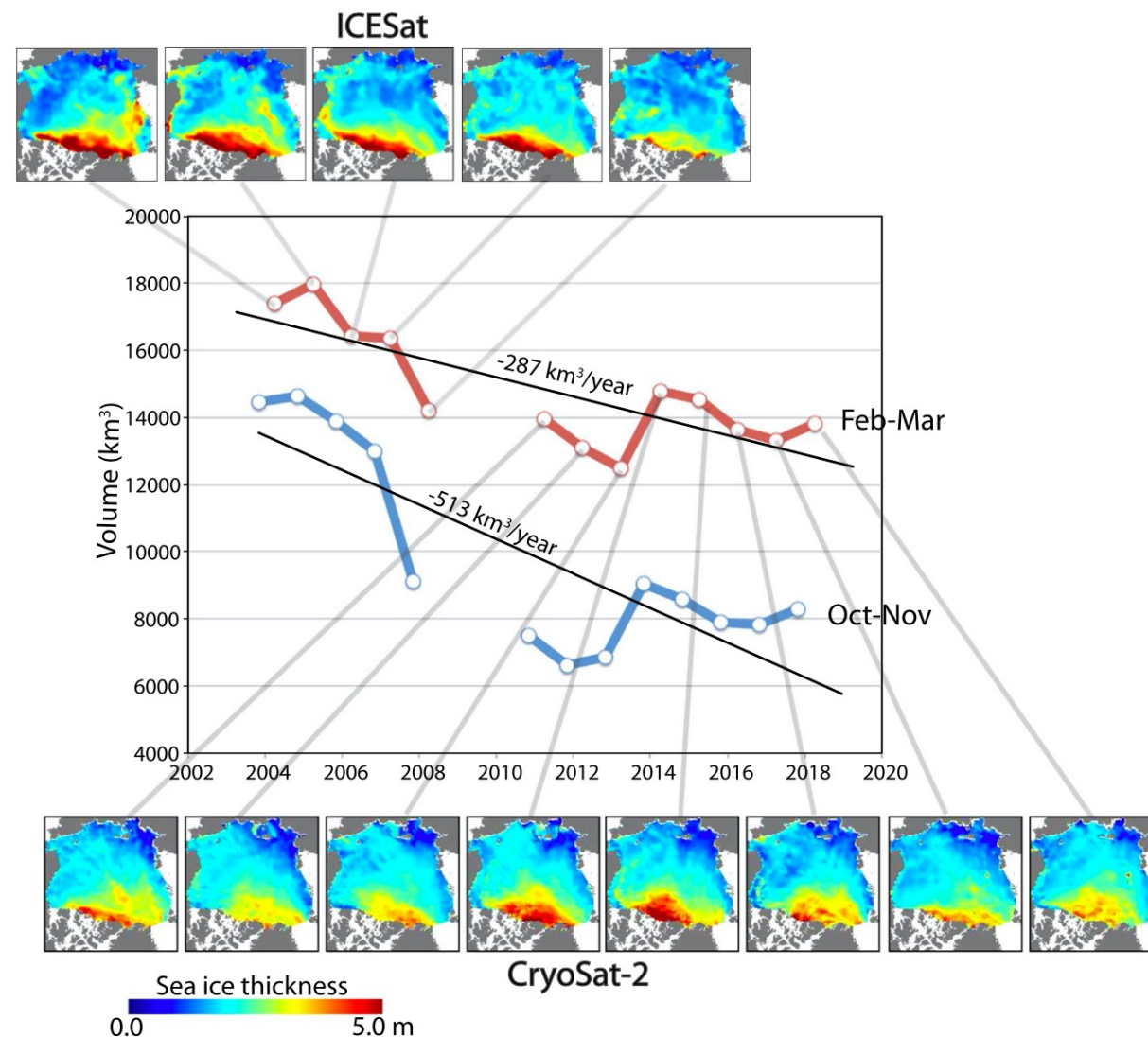
Ice production appears to have been increasing

- Why?
- For how long can we expect this to continue?

Why do we care?

- Important for replenishment of sea ice
- Important for halocline stability

See also:
Stroeve et al. *Warm winter, thin ice?* (2018)
Petty et al. *Warm winter, increased sea ice growth?* (2018)



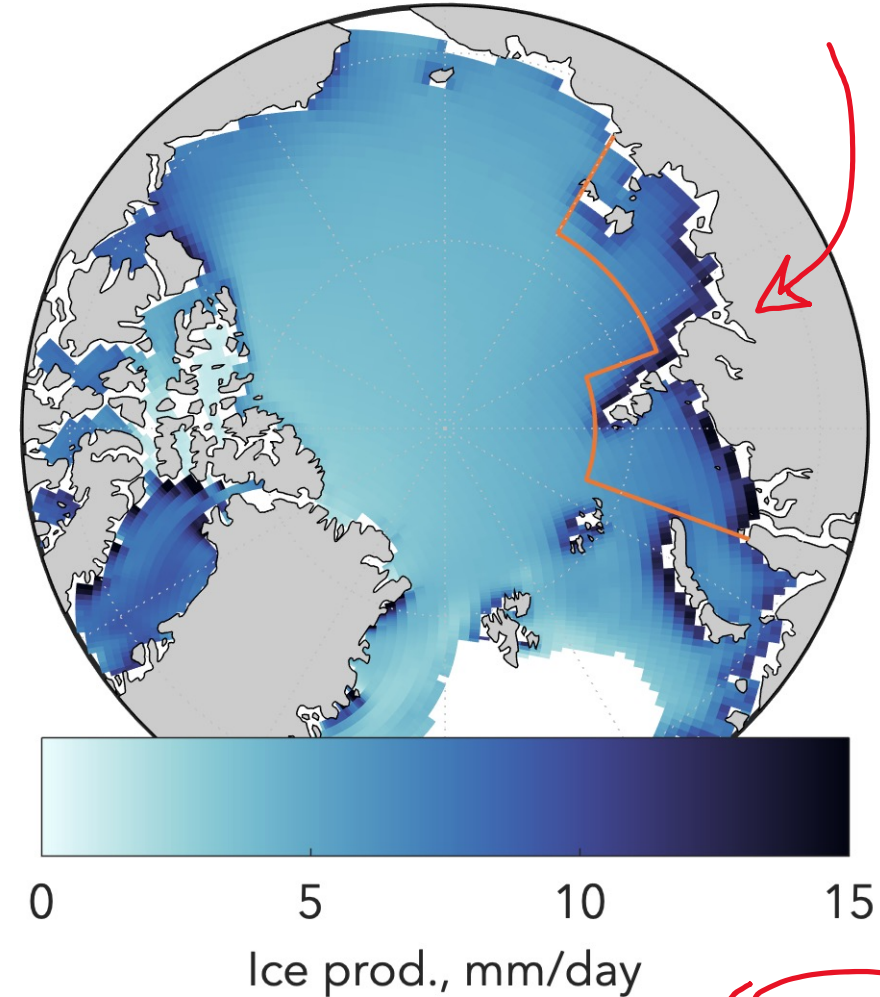
We focus on the 'ice factories' of the Arctic

The Kara and Laptev seas

A region of sea ice divergence

These shelf seas make an outsized contribution to Arctic sea ice production

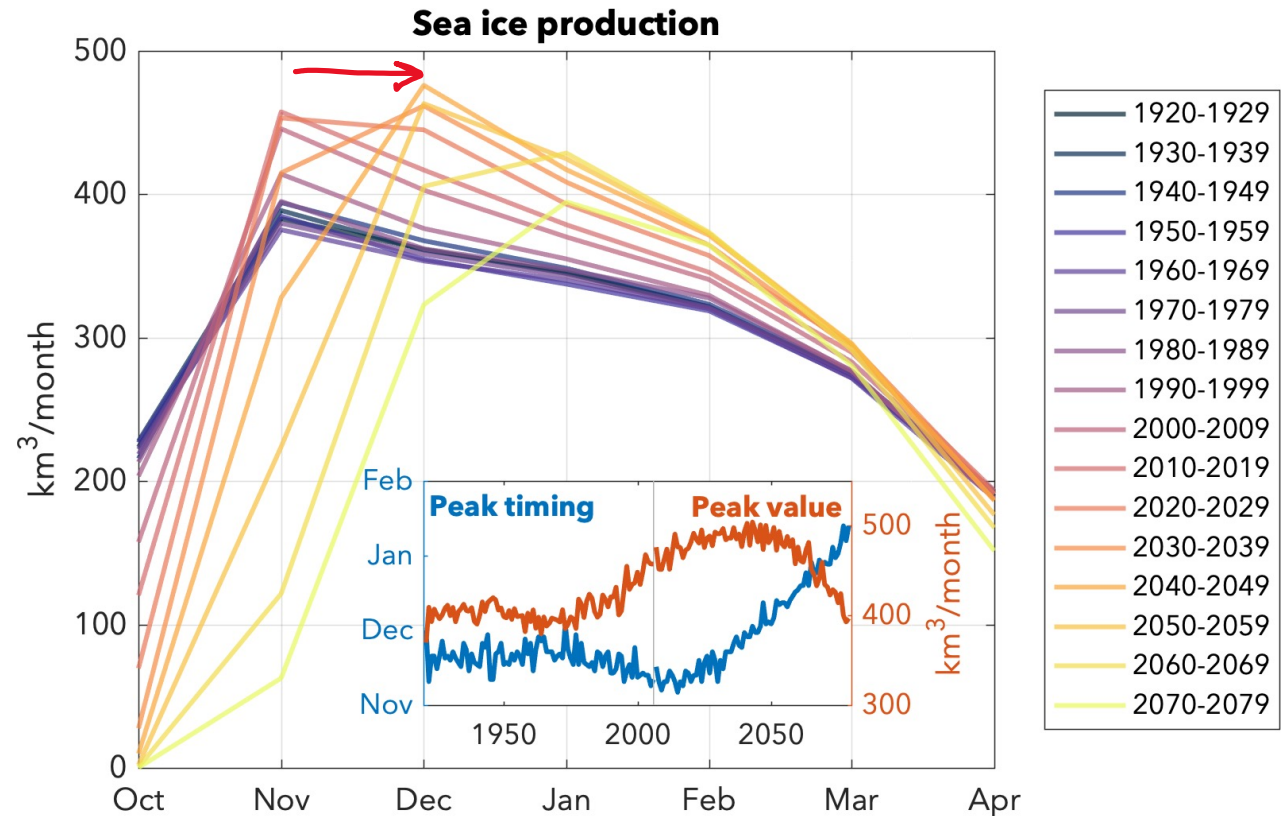
Winter ice production, 1980-1999



CESM-LE

Shrinking growth season, rising growth rate

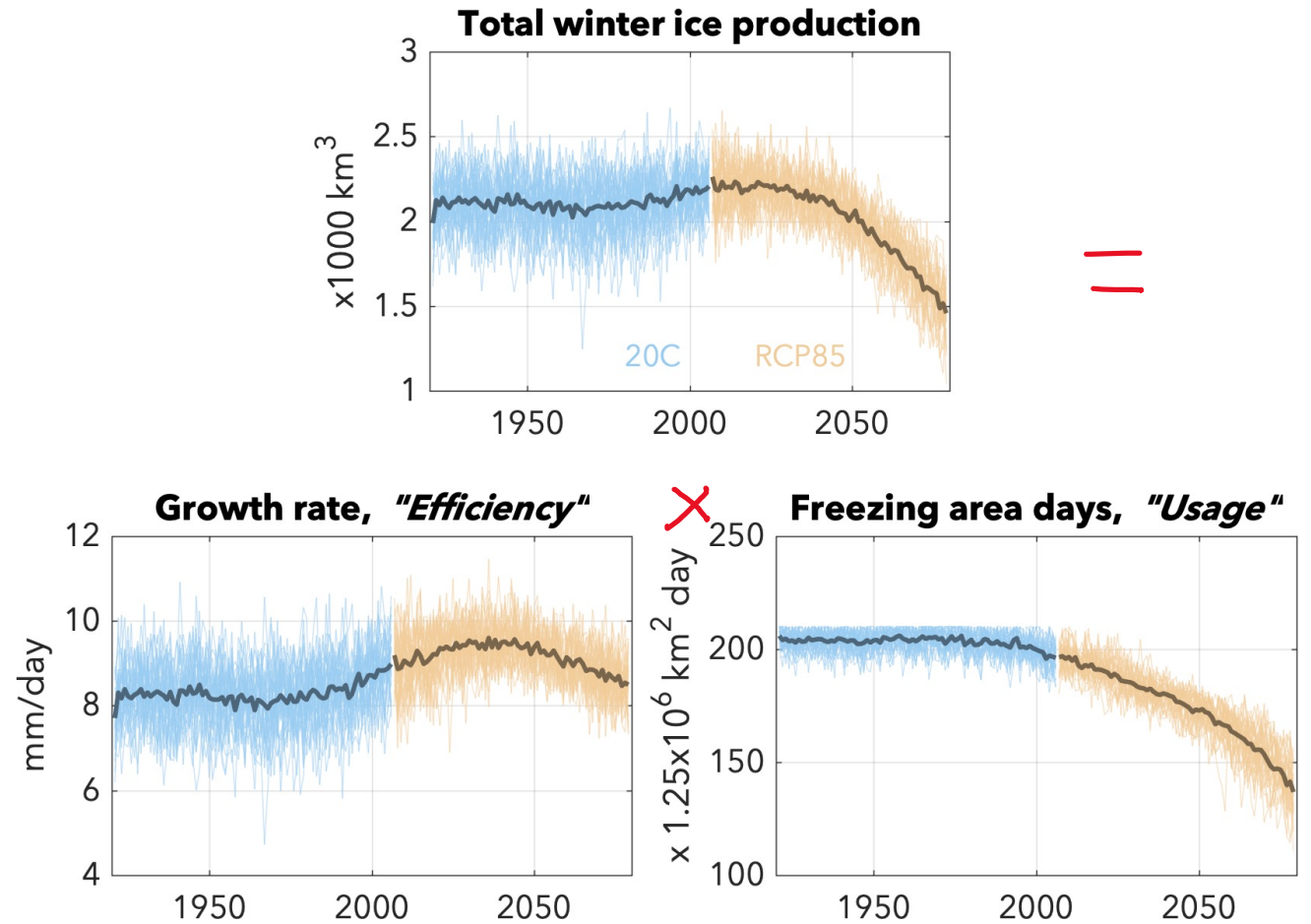
- Ice production (only the freezing part of thermodynamic ice-ocean freshwater exchanges)
- Winter freezing season gets shorter, but more intense
- We can understand this by separating ice production into two parts (next slide)



Decomposing ice production into 'usage' and 'efficiency'

$$\text{Ice prod.} = \text{mean growth rate} \times \text{freezing area days}$$

To extend the 'ice factories' metaphor, we can consider ice production as resulting from *usage* of the factory (where and when it is freezing) and *efficiency* (how quickly ice is being made at those points in time and space)



We can construct skillful linear models for *usage* and *efficiency*

Growth rate/*efficiency*

Governed by heat flux balance

If F_w is small, F_c determines growth rate

Usage

Reflects time taken for upper ocean to cool to freezing (-1.8°C)

Principally determined by September SSTs

$$\rho_i L_i \frac{dH}{dt} = F_c - \cancel{F_w}$$

Generally small!

$$\rho_i L_i \frac{dH}{dt} = F_c$$

$$F_c = \frac{\Delta T}{\frac{1}{k} + \frac{H}{\lambda_i} + \frac{h_s}{\lambda_s}}$$

ice snow

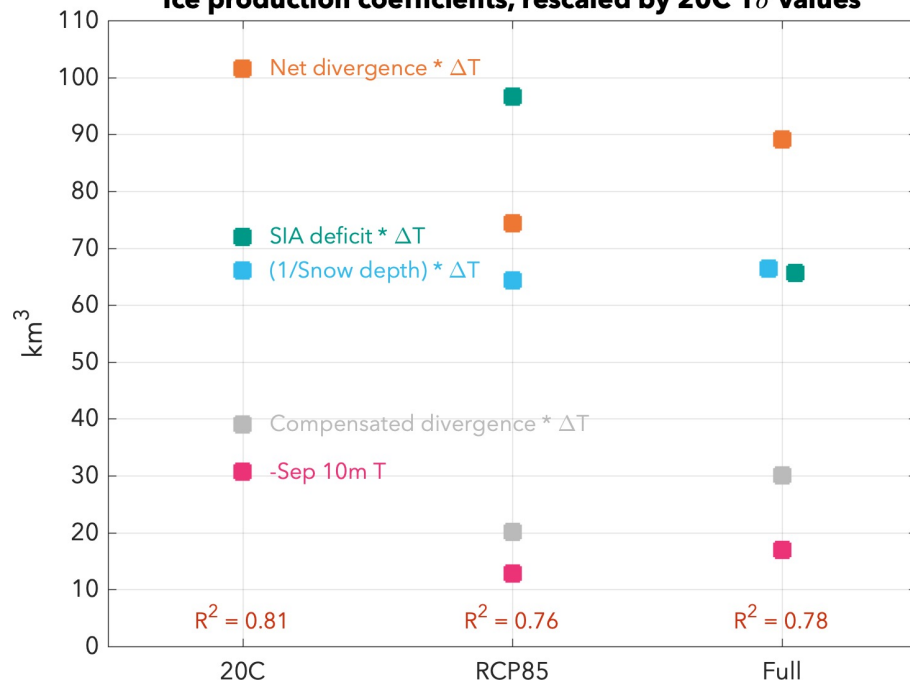


Explanatory variables?

- September sea ice area → area available for freezing
 - Initial thickness? (Could use, but we don't—can explain)
 - Divergence → we split into an export term and a *compensated* divergence. Divergence creates open water available for freezing
 - Snow depth → insulates sea ice, limits F_c
 - For all of the above, **we multiply through by ΔT**
 - **That step is crucial in being able to capture forced changes**
 - We capture *usage* changes with Sep SSTs
- 
- 

A linear model for ice production

(Standardised coefficients) 
Ice production coefficients, rescaled by 20C 1 σ values



$$\text{Ice Prod} = \beta_1 \Delta T / h_s + \beta_2 \Delta T \text{SIA}_{\text{deficit}} + \beta_3 \Delta T A_{\text{net}} + \beta_4 \Delta T A_{\text{comp}} + \beta_5 \text{SST}_{\text{Sep}}$$

Trained on 35 members of the CESM Large Ensemble

We train the regression on internal variability only
(remove ensemble mean)

The resulting regression coefficients are fairly consistent
between the 20C and RCP8.5 runs

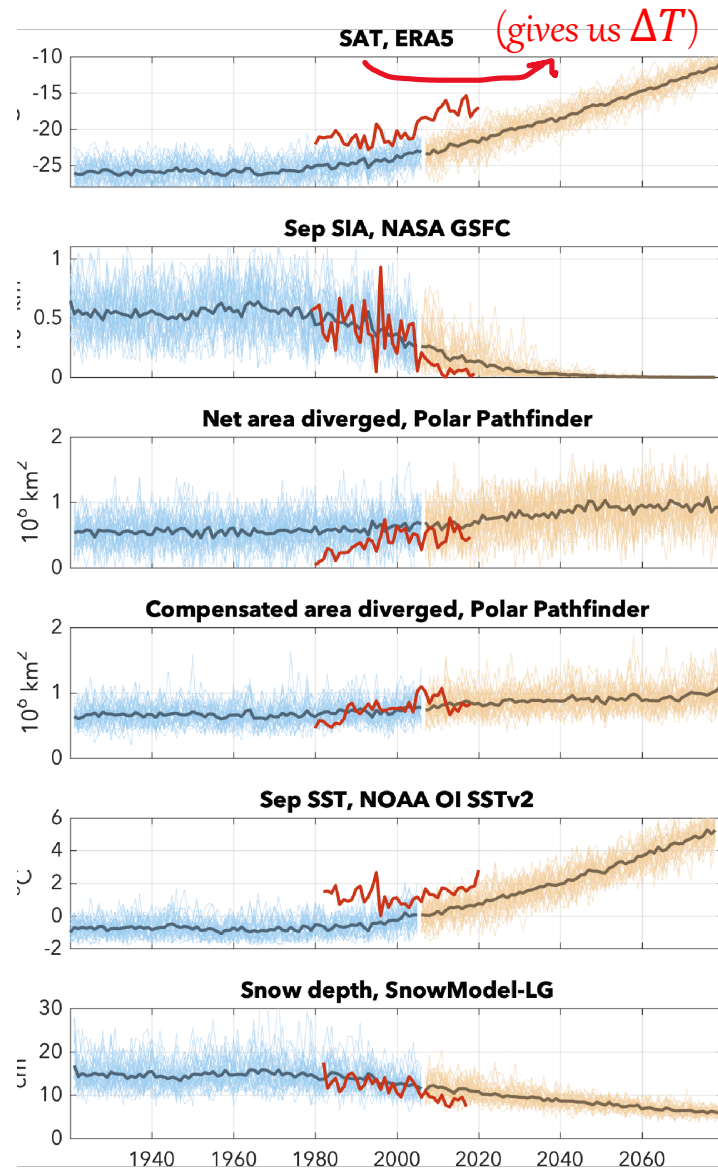
Suggests that the relationships are robust

What does the underlying data look like?

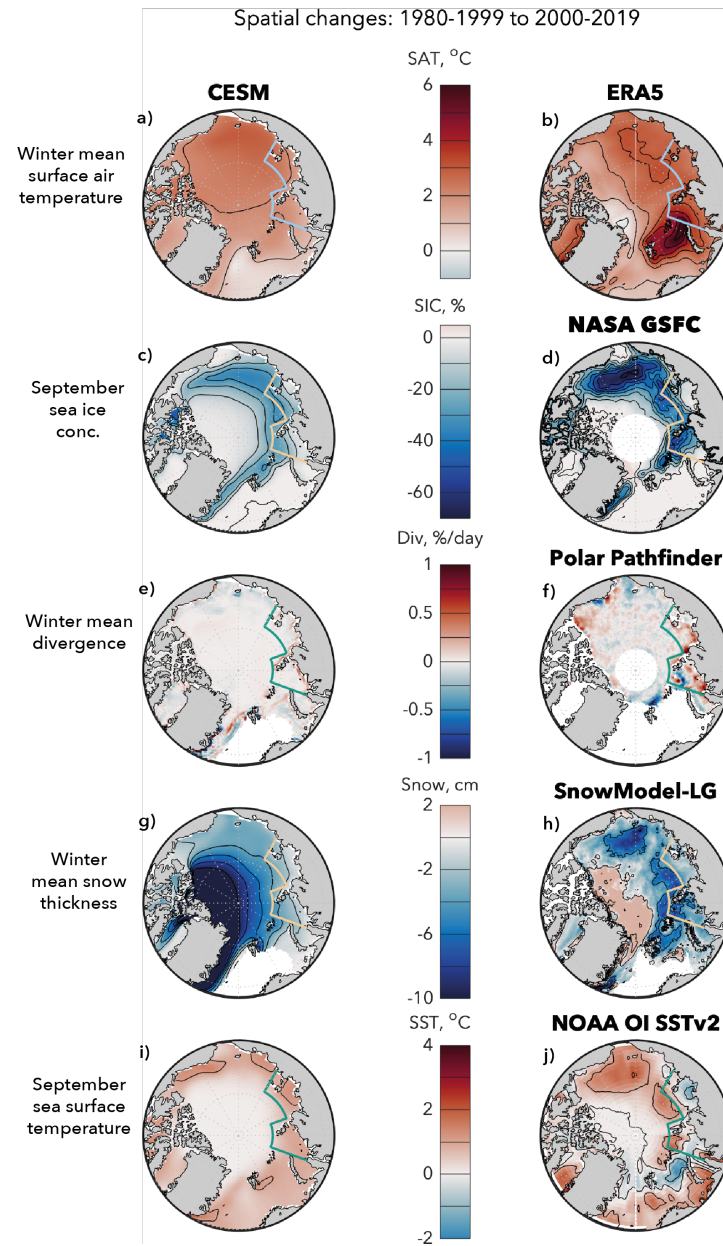
Comparing CESM-LE output to observation-based products here

These are the climate variables used in the regression

$$\text{Ice Prod} = \beta_1 \Delta T / h_s + \beta_2 \Delta T \text{SIA}_{\text{deficit}} + \beta_3 \Delta T A_{\text{net}} + \beta_4 \Delta T A_{\text{comp}} + \beta_5 \text{SST}_{\text{Sep}}$$



What does
the
underlying
data look
like?

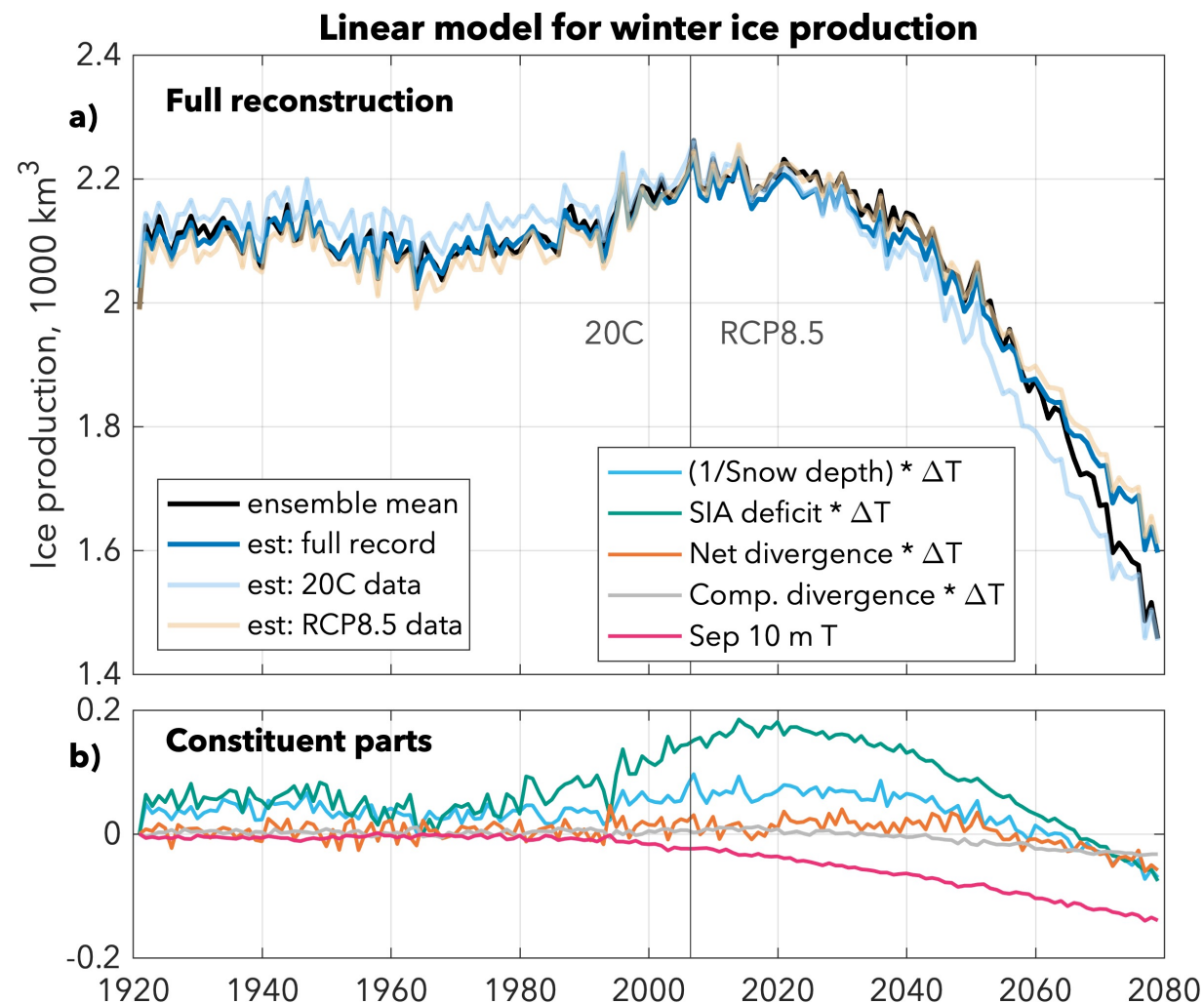


Reconstructing ice production

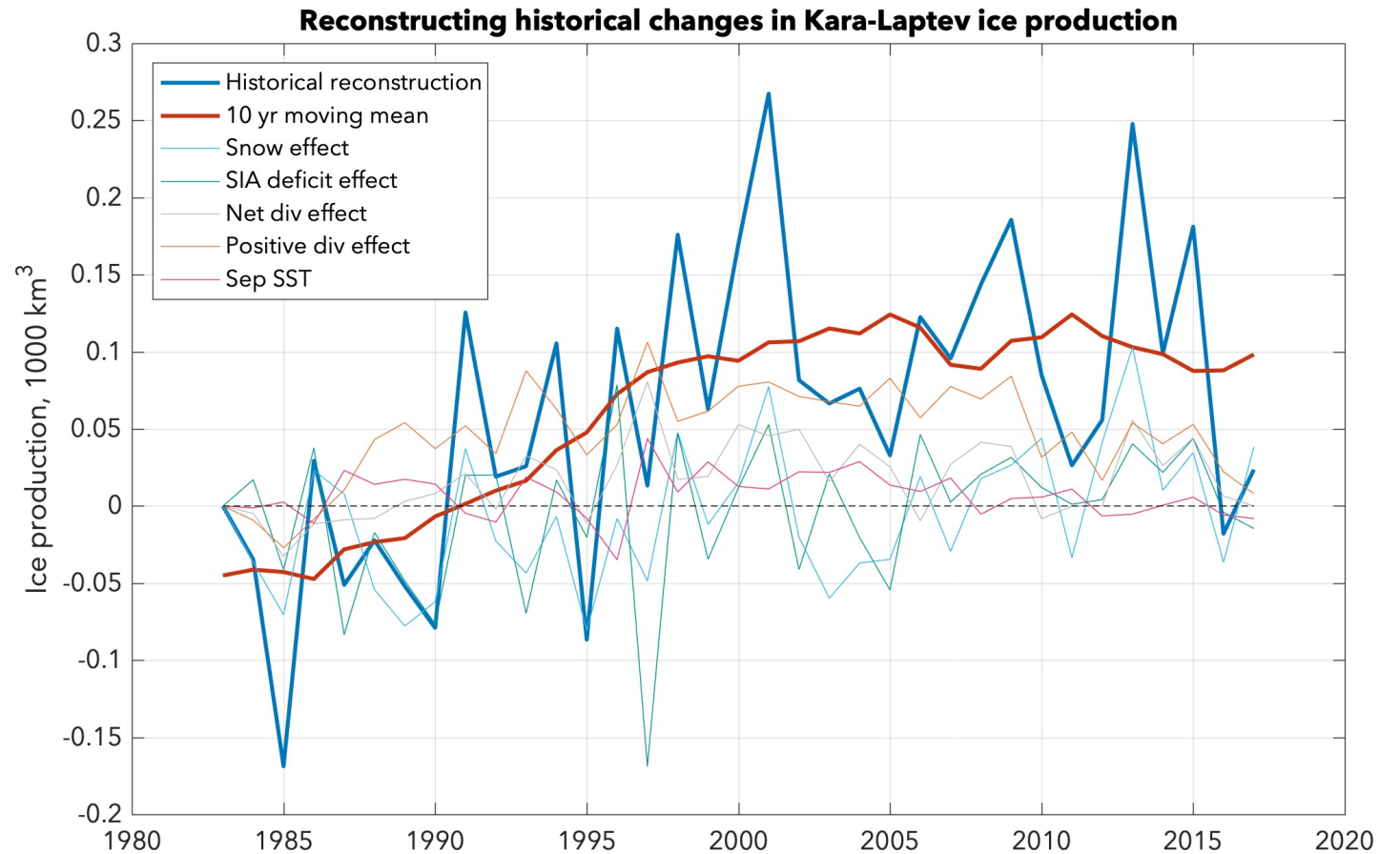
Linear model trained on internal variability successfully captures forced rise and fall

September Sea ice area changes decisive in timing of peak production

Can we apply this to observation-based products?



Reconstructing historical changes



Utilising the linear model with observation-based estimates

Many similarities with CESM-LE

Appears we are passing peak ice production

Shifting patterns of ice production

While the ice factories decline,
the interior basins become
more productive

Implications for stability of the
halocline

Thanks for listening/looking!

Any comments/questions/feedback?

Get in touch!

sam.cornish@earth.ox.ac.uk

@sbcornish

