Core Theme 1

Predictability of core ocean and atmosphere quantities

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Introduction

THOR final report: *Initialization of climate models with observations leads to improved skill of predictions of variability of North Atlantic sea surface temperatures and subsurface ocean temperature and salinity variability up to 6-9 years.*
There are indications of skilful multiyear predictions of climate variables associated with North Atlantic surface ocean variability, such as Atlantic tropical storm frequency (…) following the rapid warming of the sub-polar gyre in the mid 1990s

…deliver new generation of climate prediction systems(…) and provide actionable climate information

…exploit emerging capability from the climate community (…) to help decision makers make better informed decisions

…investigate and **quantify** the **predictability** of climate in the North Atlantic/European sector **related to NA/ Arctic** variables

NACLIM Core theme 1: Predictability of key oceanic and atmospheric quantities

Aims of CT1:

- *Quantify the uncertainties in forecasts of the North Atlantic and Arctic Ocean states*

WP1.1: Predictability of the North Atlantic/Arctic Ocean state and key oceanic quantities controlling it

- *Identify North Atlantic and Arctic Ocean surface state changes that most impact the atmosphere and the related atmospheric predictability*

WP1.2: Predictability of the Atmosphere related to the North Atlantic/ Arctic Ocean surface state

- *Identify mechanisms underlying North Atlantic and Arctic Ocean surface state changes and the related atmospheric variability as well as the most relevant feedbacks between the North Atlantc/Arctic Ocean and the atmosphere*

WP1.3: Mechanisms of ocean surface state variability

WP1.1: Predictability of the North Atlantic / Arctic ocean surface state and key oceanic quantities controlling it

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Aims of WP1.1:

- *quantify predictability and skills in various climate variables*
- *assess mechanisms of variability and predictability*
- *quantify the uncertainties in forecasts of the North Atlantic and Arctic Ocean states*

Methods:

analyse existing (mostly CMIP5) simulations,

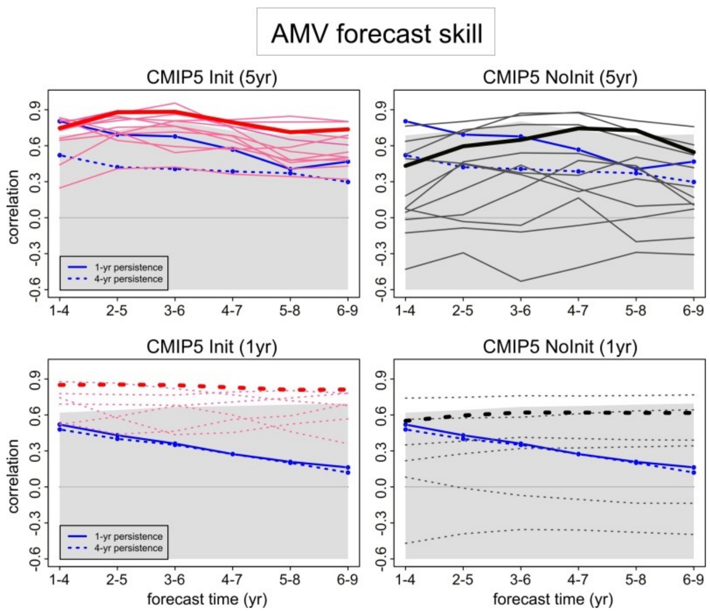
carry out sensitivity studies to dissect certain processes

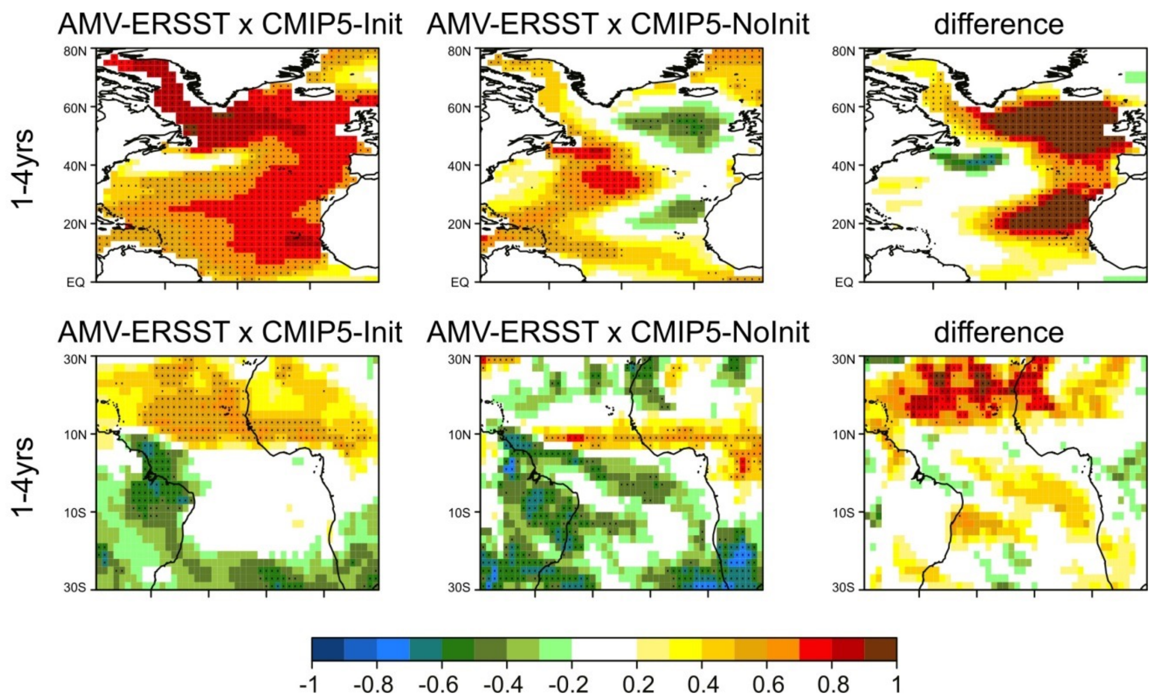
assess benefit of multi-model predictions

analyse model (and methodological) differences

WP1.1: Predictability of the North Atlantic / Arctic ocean surface state and key oceanic quantities controlling it:

Predictability of the Atlantic Multidecadal Variability (AMV)





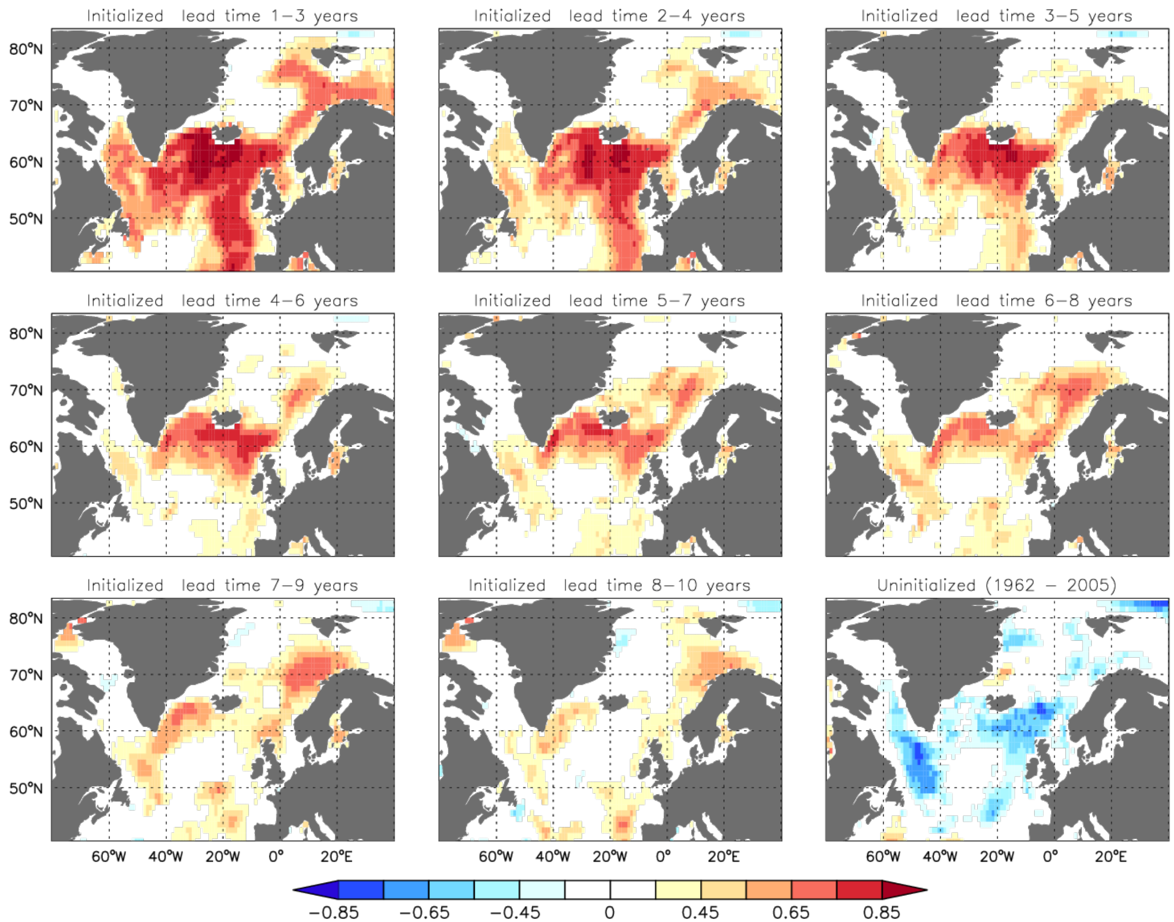
- initialization reduces inter-model spread when estimating the level of AMV skill, thereby reducing its uncertainty
- the added skill from initialization is robust under start-date frequency until 3-6 years ahead

- initialization enhances skill in forecasting the horseshoe-like AMV signature
- initialized hindcasts are skilful at reproducing the AMV teleconnection to the WAM/Sahel

García-Serrano et al., Clim Dyn., 2015

WP1.1: Predictability of the North Atlantic / Arctic ocean surface state and key oceanic quantities controlling it:

Predictive skill of quantities other than SSTs: Upper ocean salt



- Initialized hindcasts (CMIP5 7-model ensemble) can predict evolution of upper ocean salt content (assessed against Ishii et al., 2003)

Lohmann et al., to be submitted

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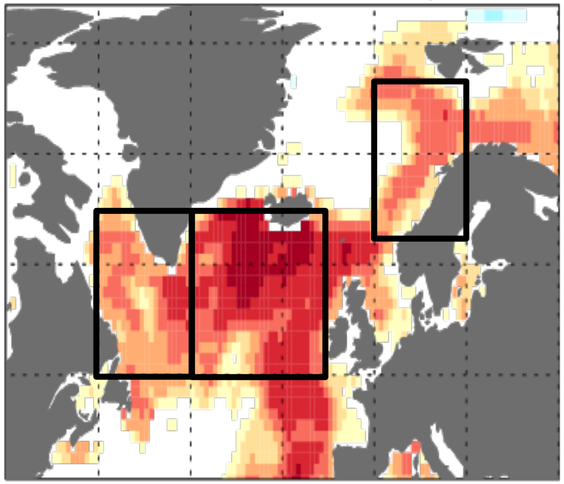
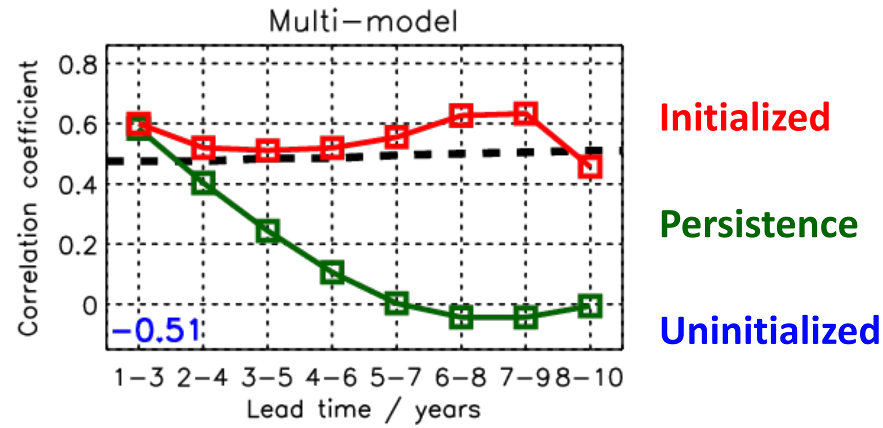
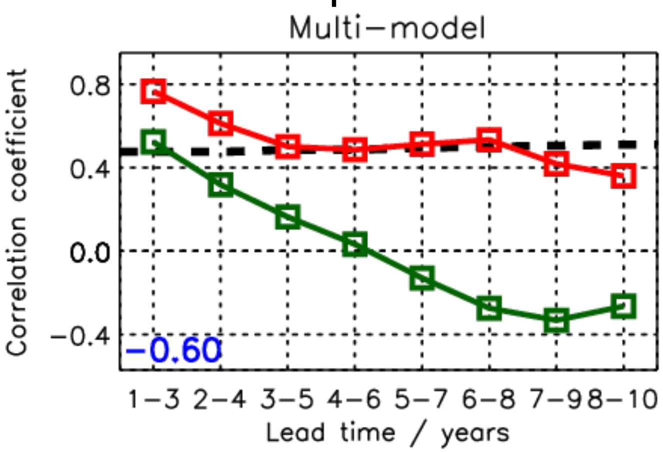


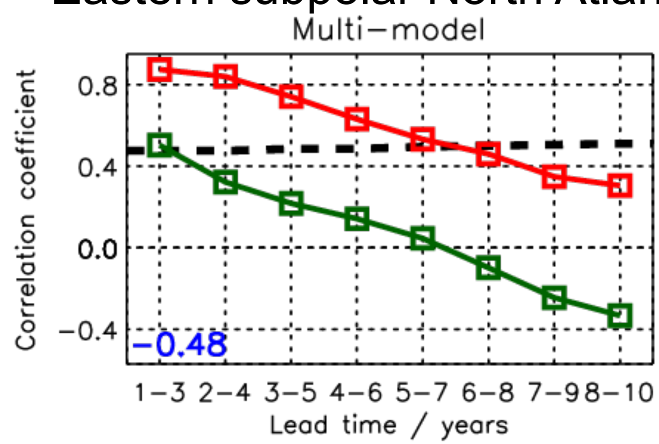
Eastern part of Nordic Seas



Western subpolar North Atlantic



Eastern subpolar North Atlantic



- …but there are regional differences as well as model-to-model differences

Lohmann et al., to be submitted

WP1.2: Predictability of the atmosphere related to the North Atlantic/Arctic ocean surface state

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Aims of WP1.2:

- *identify the space-time patterns of the North Atlantic/Arctic surface state that most impact the atmosphere*
- *assess the ability of climate models to reproduce response to boundary forcing*
- *assess the link between weather regimes and Polar Low developments in present and future climate*
- *quantify the sensitivity of land temperatures to ocean state variables*

Methods:

analyse existing (mostly CMIP5) simulations, observations and reanalysis data

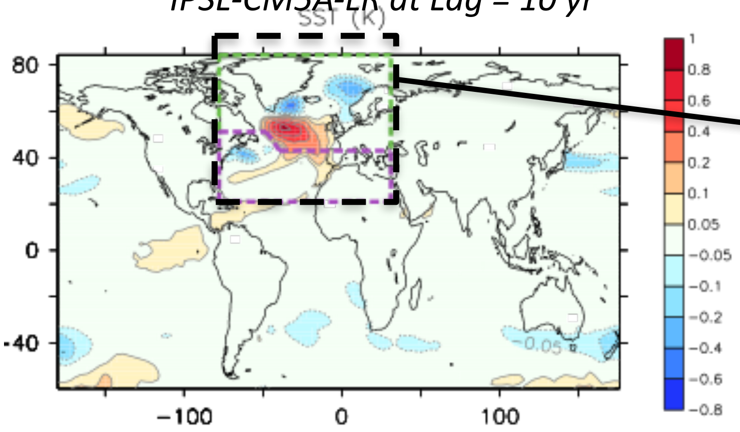
ensemble simulations with atmosphere models

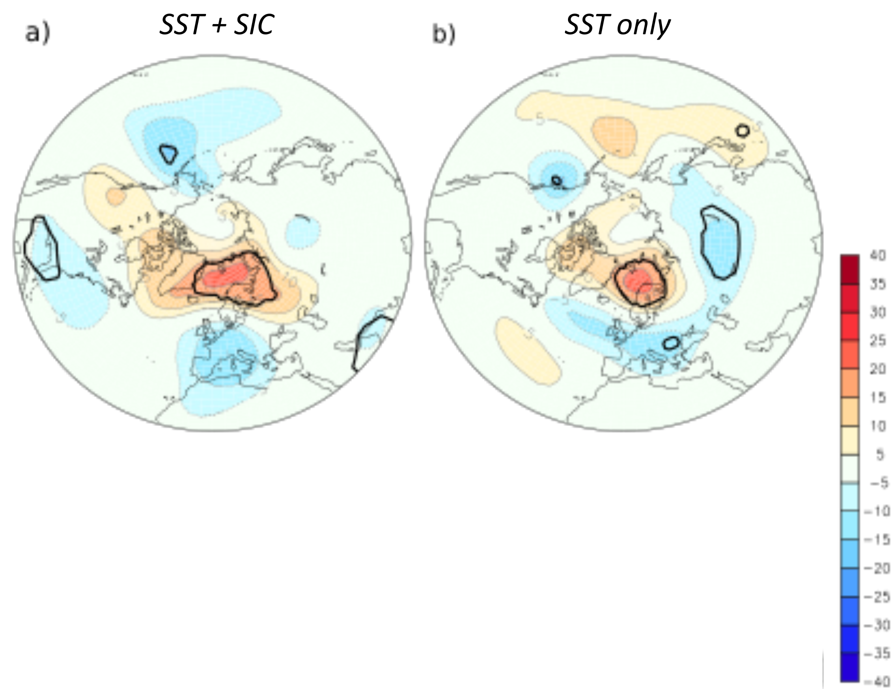
apply coupled atmosphere-ocean model (CESAM) and its adjoint

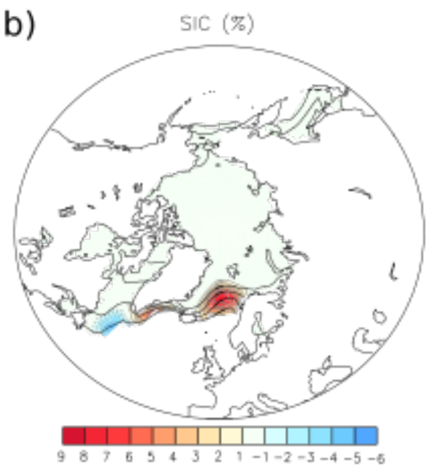
WP1.2: Predictability of the atmosphere related to the North Atlantic/Arctic ocean surface state

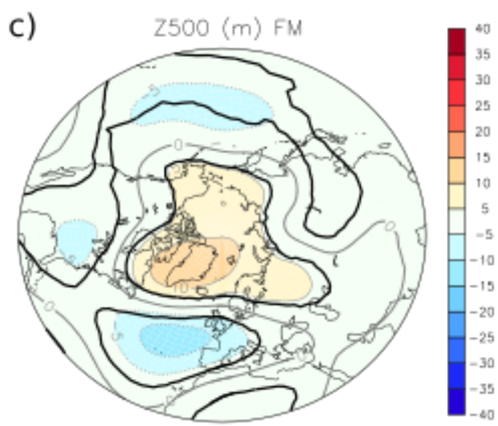
SST influence on the North Atlantic/European sector

SST, SIC and Z500 in winter following the AMOC in IPSL-CM5A-LR at Lag = 10 yr







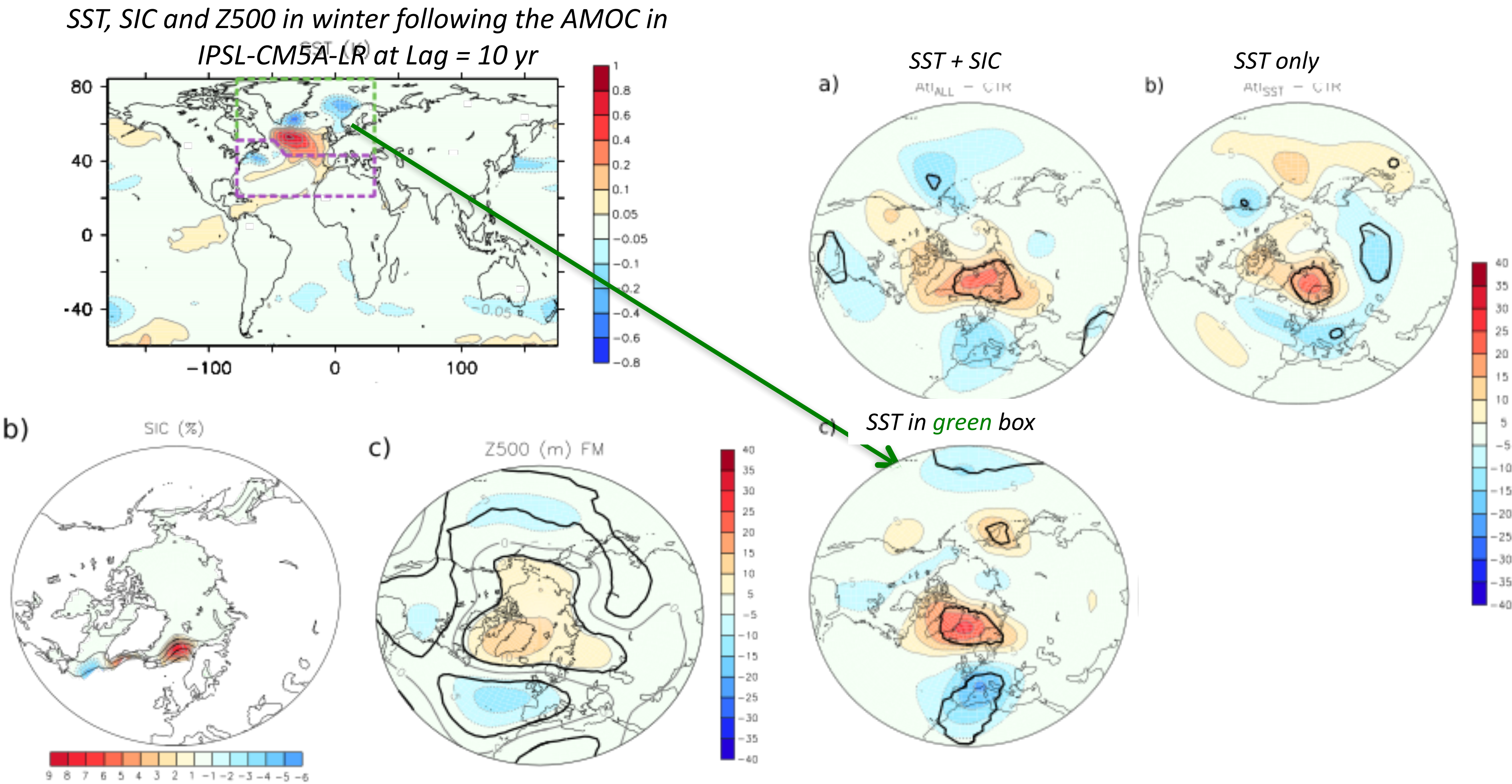


Discriminate between the effects of SST and sea ice edge

Gastineau et al., J. Cim., 2016

WP1.2: Predictability of the atmosphere related to the North Atlantic/Arctic ocean surface state

SST influence on the North Atlantic/European sector



Gastineau et al., J. Clim. 2016

WP1.2: Predictability of the atmosphere related to the North Atlantic/Arctic ocean surface state

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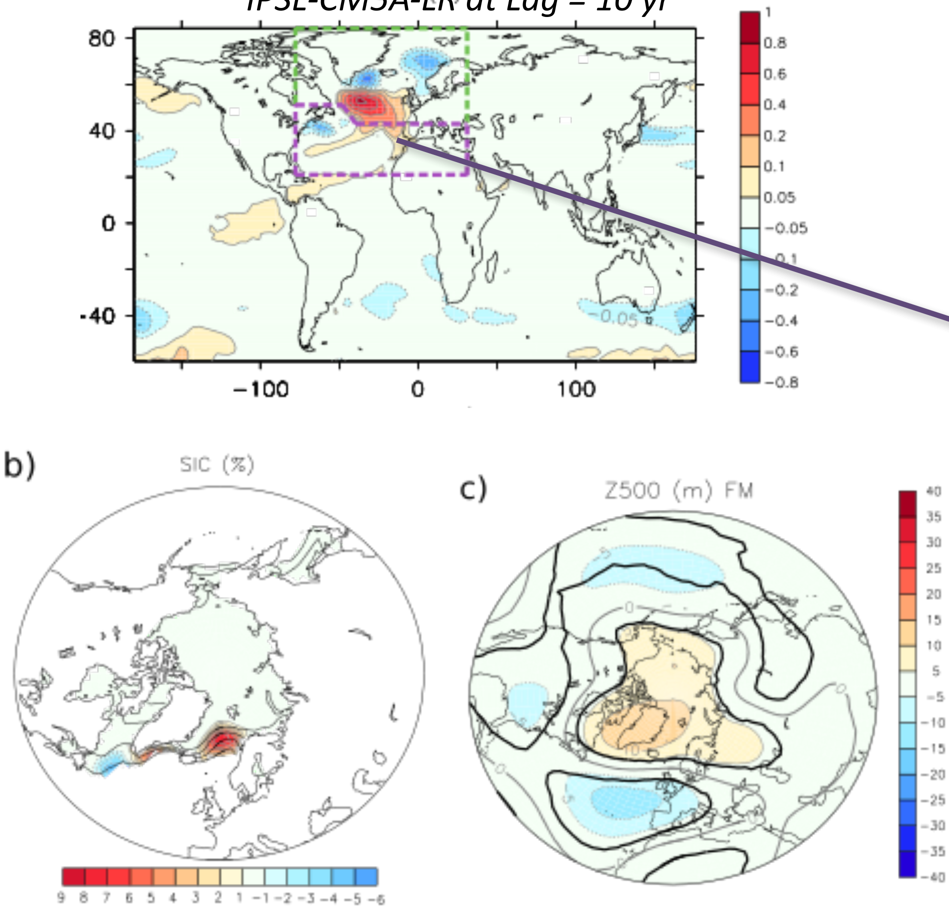
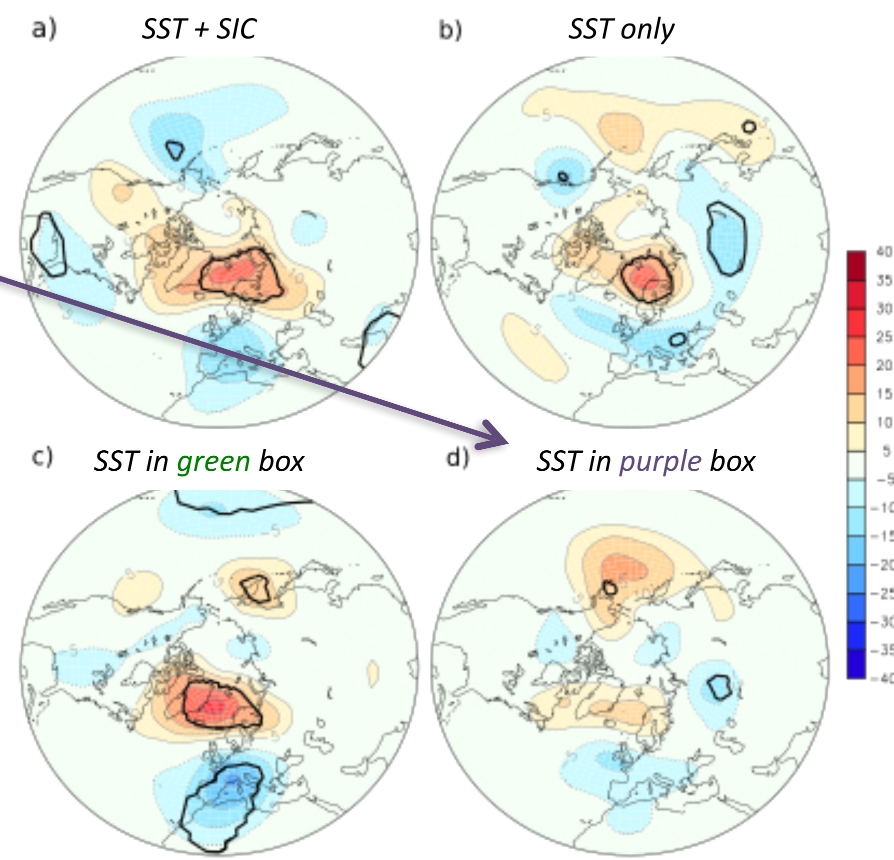


Z500 anomalies in FM in sensitivity atmosphere-only experiments



- *Response to sub-polar SST through baroclinicity changes in the Atlantic stormtrack.*
- *Sea ice anomalies act as a positive feedback.*

Gastineau et al., J. Clim. 2016

WP1.2: Predictability of the atmosphere related to the North Atlantic/Arctic ocean surface state

Impact of the projected autumn sea-ice free Arctic on climate

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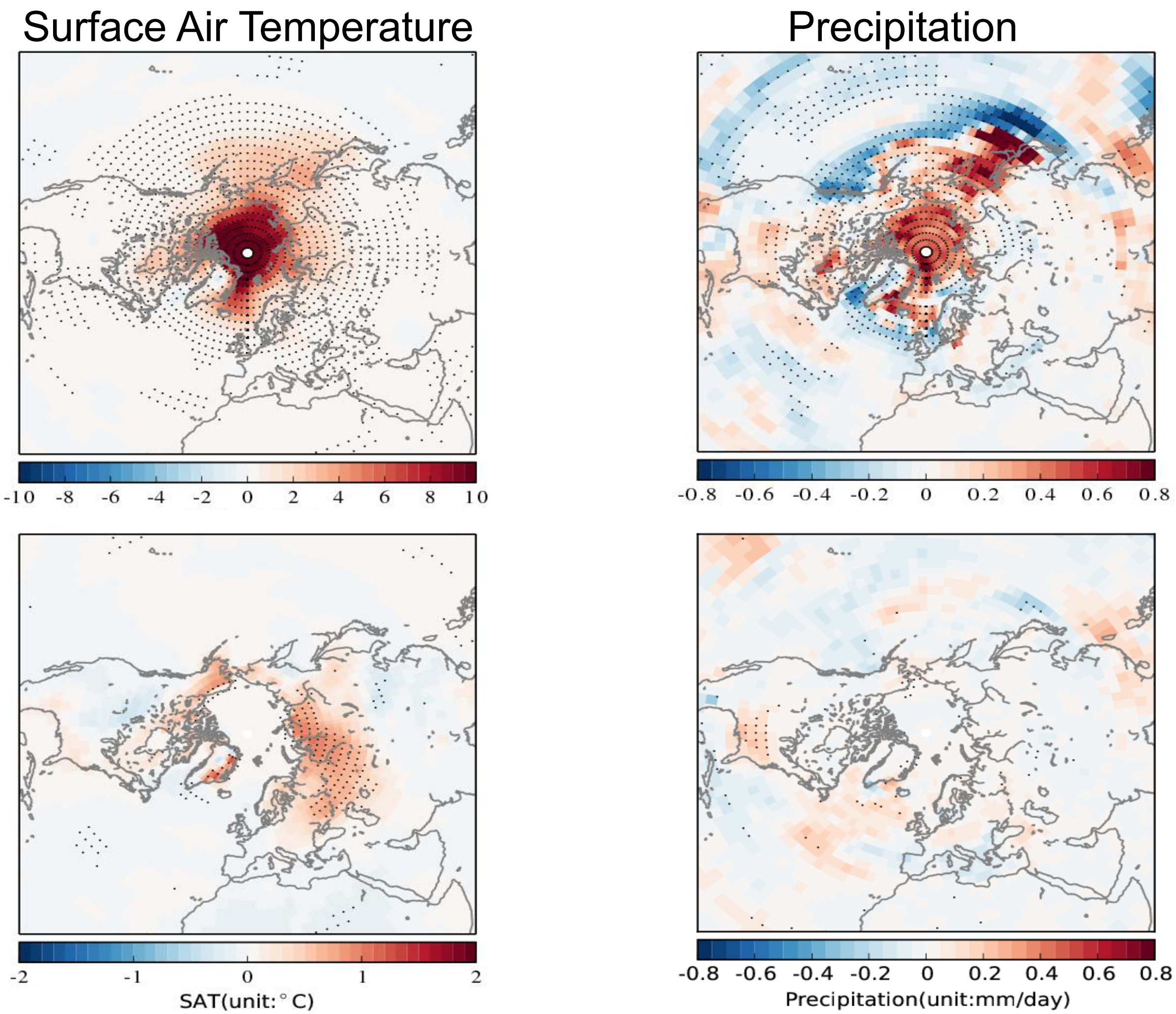
Large (300 member) AGCM simulations



Autumn Responses to Autumn Sea Ice

Jan-Feb Responses to Autumn Sea Ice Free Arctic

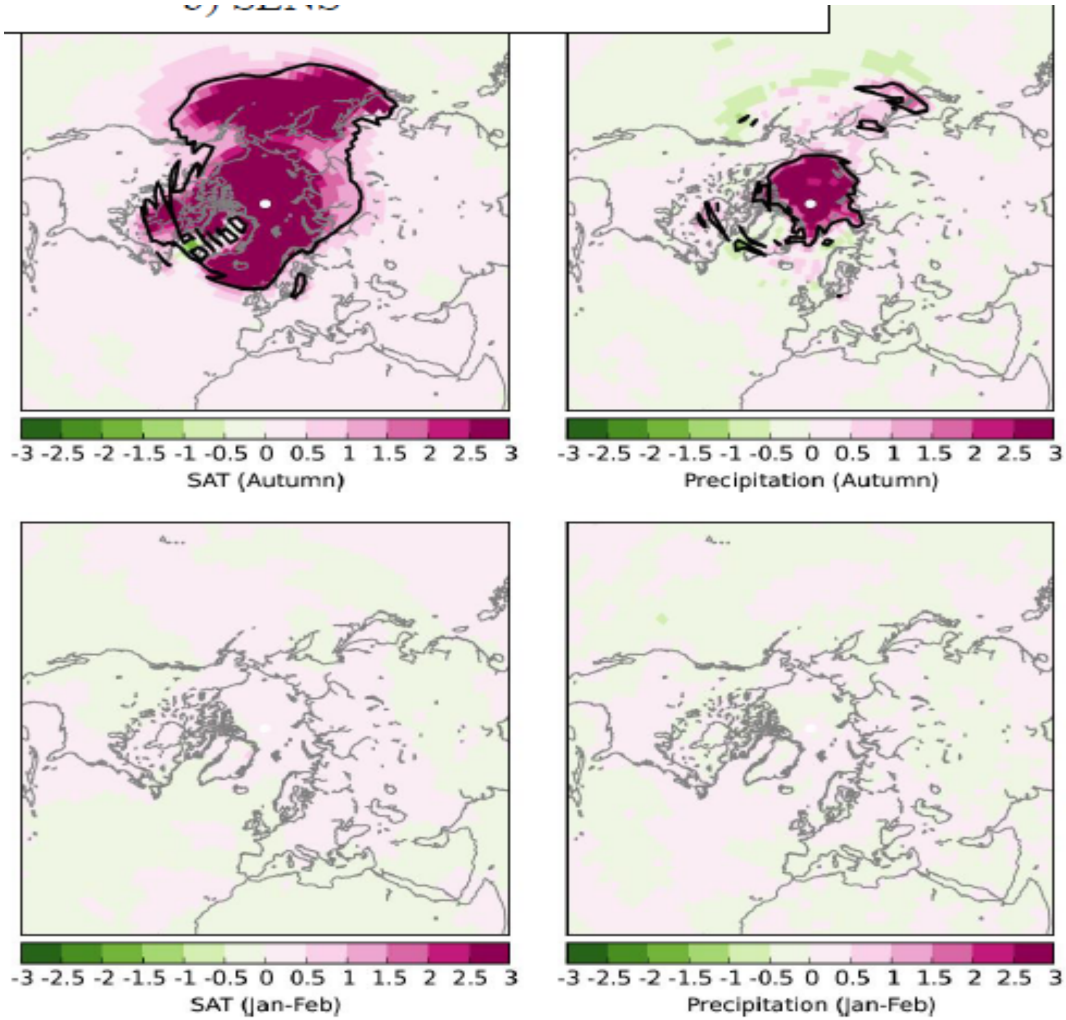
(Blact dots: 95% significant level)

Suo et al., Clim. Dyn. 2015

WP1.2: Predictability of the atmosphere related to the North Atlantic/Arctic ocean surface state

Impact of the projected autumn sea-ice free Arctic on climate

Ratio of the Responses to the Internal Variability



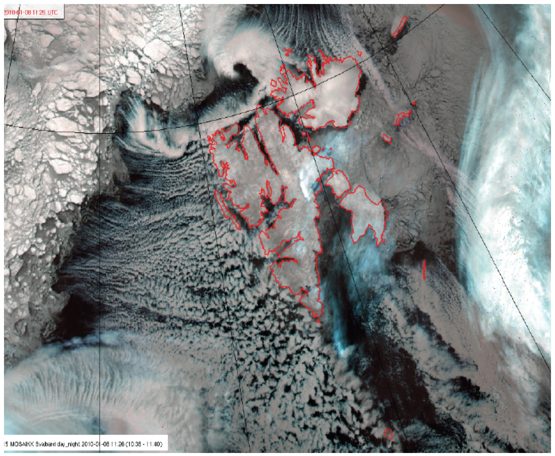
Autumn

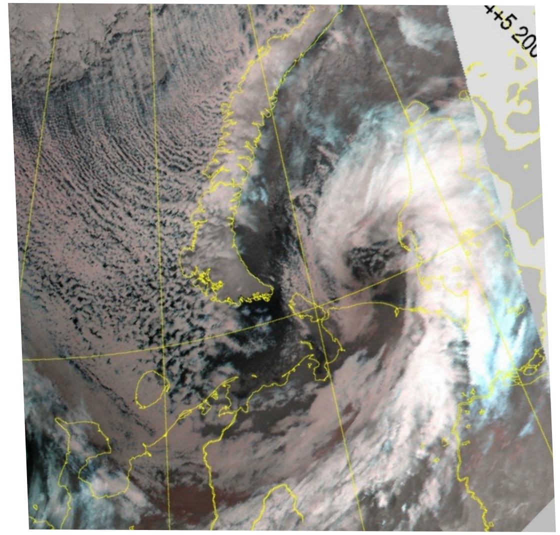
Winter

Suo et al., Clim. Dyn.,2015

WP1.2: Predictability of the atmosphere related to the North Atlantic/Arctic ocean surface state

Impact of Arctic changes on polar mesoscale activity





More open water in formerly ice-covered areas permits PL development in new areas (north of Svalbard, Kara Sea).

Arctic sea ice decline at the end of summer may have had impact on the lower activity observed in early/mid winter during the last years (global effect**)**.

At the same time, reduced sea ice over the Barents Sea in mid-winter creates more favourable conditions for PL development at the end of the season (more **local** effect).

In concert with spatial changes, the intra-seasonal distribution of PLs over the adjacent seas could also be modified, in response to decreased baroclinicity, and less frequent occurrence or intensity of Cold Air Outbreaks.

see poster: Claud et al.

WP1.3: Mechanisms of ocean surface state variability

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Aims of WP1.3:

understand the ocean surface state variability with particular focus on ocean regions that are expected to exert a control on, or to be highly sensitive to the Arctic surface (sea ice) conditions

identify recurrent signals of upper ocean variability

identify key modes of atmospheric variability influencing the surface state and evaluate underlying mechanisms

Methods:

analyse existing (mostly CMIP5) simulations, observations (in-situ and satellites) and reanalysis data

ocean state estimates (GECCO2)

specific regional forced ocean model simulations

WP1.3: Mechanisms of ocean surface state variability

Identify oceanic mechanisms involved in the variability of SST and sea-ice concentration

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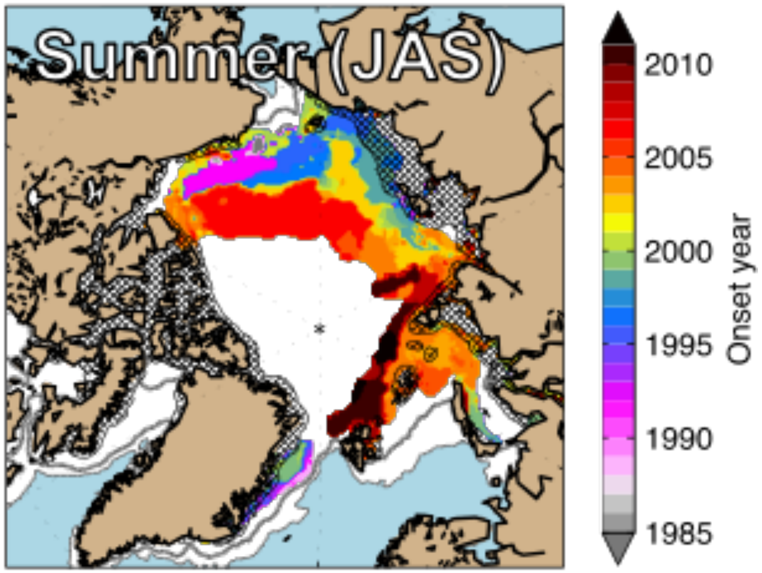
I. Decadal trends in Arctic sea ice concentration : regional contrasts



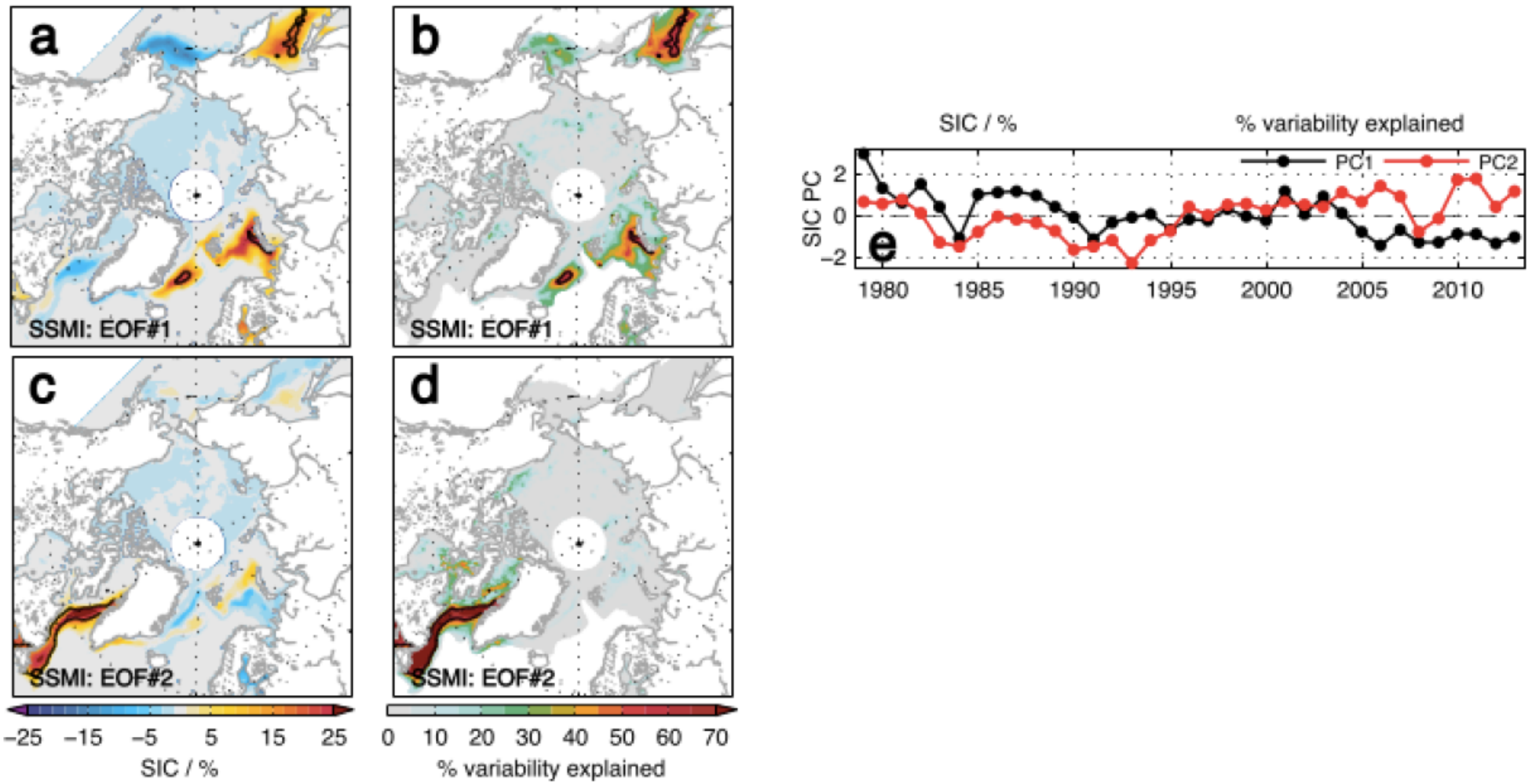
Year of ice loss onset based on SMMR/SSMI summer sea ice concentrations

- *Characterisation of form of ice loss on seasonal basis and at interdecadal time scales demonstrates striking lack of spatial coherence. Loss onset occurs much earlier in the Pacific sector*
- *Strong role of local atmospheric forcing; often this correlates moderately with large-scale climatic modes, but is notably distinct*
- *Wind-driven ice motion most important factor in interannual variability*
- *Role of the ocean is less tangible: link to time scale of action?*

Close et al., JGR,2015

WP1.3: Mechanisms of ocean surface state variability

Characterisation of the atmospheric forcing patterns, which are linked to the leading modes of winter sea ice variability



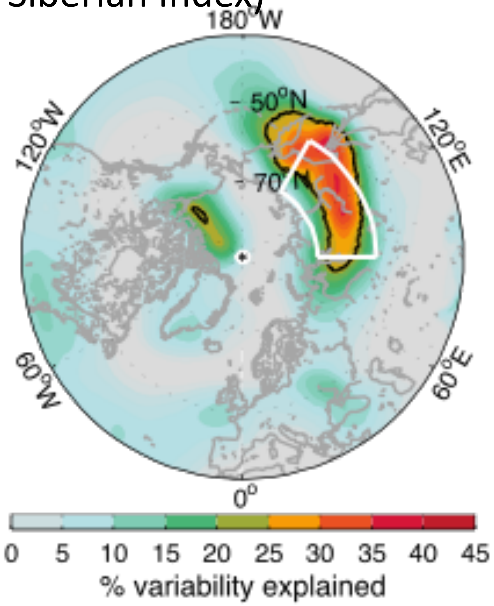
- Leading EOF modes distinct in regional and temporal characteristics

Close et al., in revision

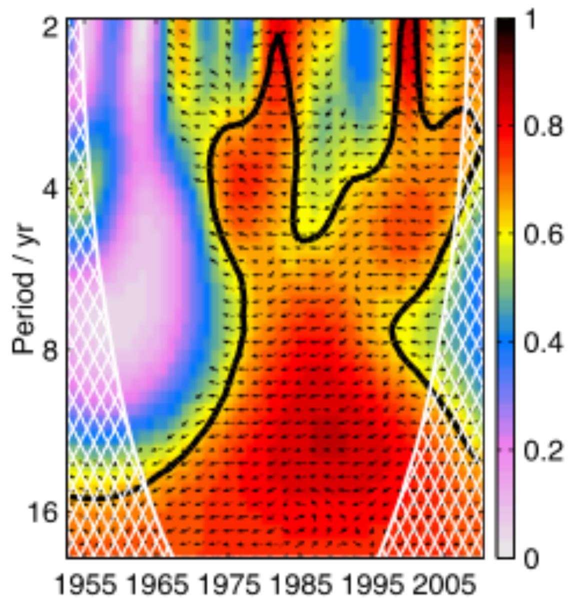
WP1.3: Mechanisms of ocean surface state variability

Characterisation of the atmospheric forcing patterns, which are linked to the leading modes of winter sea ice variability

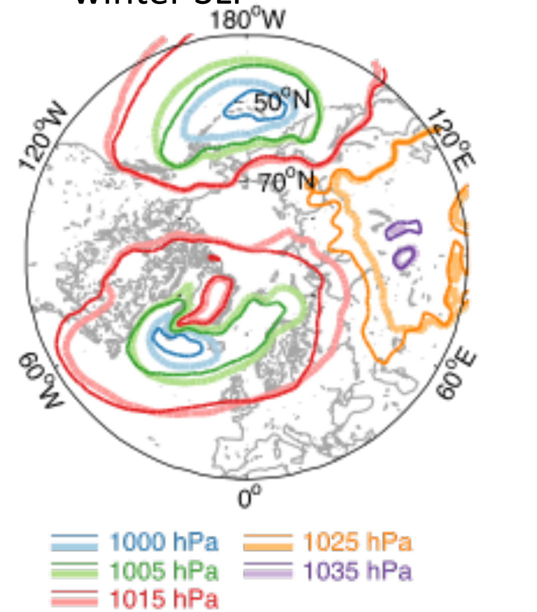
% variability explained by regression of Φ_{700hPa} on to SIC PC1 (white box defines Siberian Index)



Cross-wavelet coherence between SIC PC1 and Siberian Index



Pre- (thick lines) and post-2004 (thin lines) mean winter SLP



- PC1 is correlated at multiple time scales with atmospheric conditions in the region where the Siberian Index (Overland, 2008) is defined
- Large-scale changes in the atmospheric pressure field occur ca. 2004, with a corresponding signal in SIC. The SLP gradient across the Barents Sea is strongly modulated by the Siberian High, leading to a link with SIC PC1

Close et al., in revision

NACLIM CT1 achievements

Predictability of the North Atlantic surface state:

- confirmed predictive skills above persistence of upper ocean temperature and salinity in the sub polar North Atlantic and Nordic Seas
- identified oceanic source of long-lasting predictability
- identified regional, model, and methodological uncertainties

Space-time patterns that most affect the atmosphere

- quantified the roles of SST, SIC, northern snow cover and ocean current changes
- investigated the role of AMOC and AMV in CMIP5 models and reanalyses
- improved understanding of the role of surface conditions in the development of Polar Lows

Arctic Ocean surface state variability

- identified characteristics and regional details of sea ice decline, such as detection of break-points in observed sea-ice time series
- assessed pivotal role of Atlantic Water flow and identified regime shift in the Nordic Seas in the 1990s.

NACLIM CT1 challenges/open questions

Predictability of the North Atlantic surface state:
Space-time patterns that most affect the atmosphere:

- *model and methodological uncertainties:*

remedies: bias corrections, higher resolution? (EU PRIMAVERA),

but also further improved process understanding

Arctic Ocean surface state variability

- *Identify the main drivers of the different modes of Arctic sea ice concentration variability and their expression in the North Atlantic sector.*
- *Identification of the main processes which drive the redistribution of the heat content of the Atlantic Water layer in the Arctic.*

The research leading to these results has received funding from the European Union 7th Framework Programme (FP7 2007-2013), under grant agreement n. 308299

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