Sea ice and subseasonal predictability

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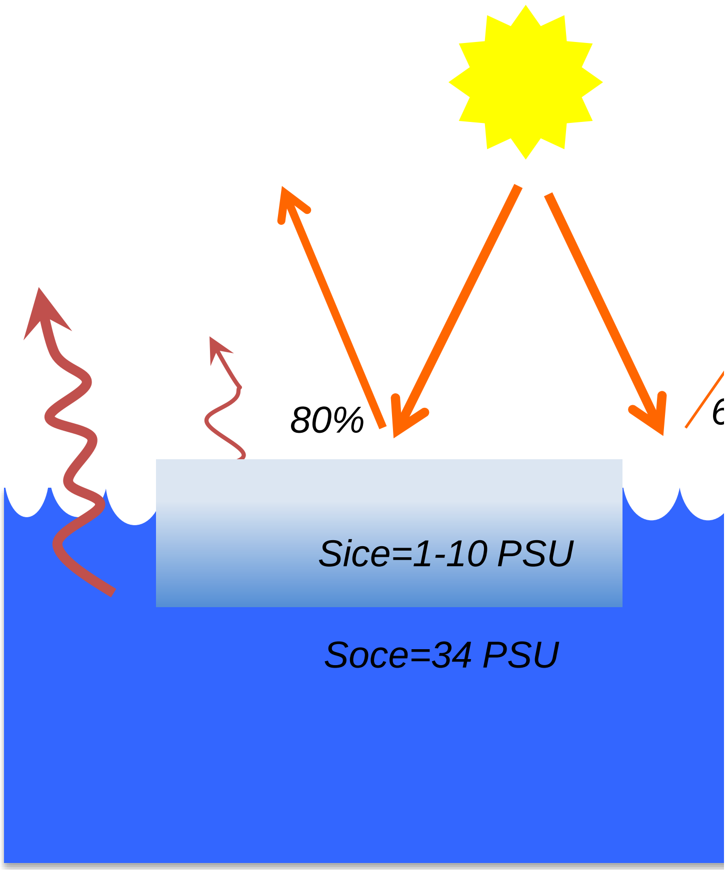
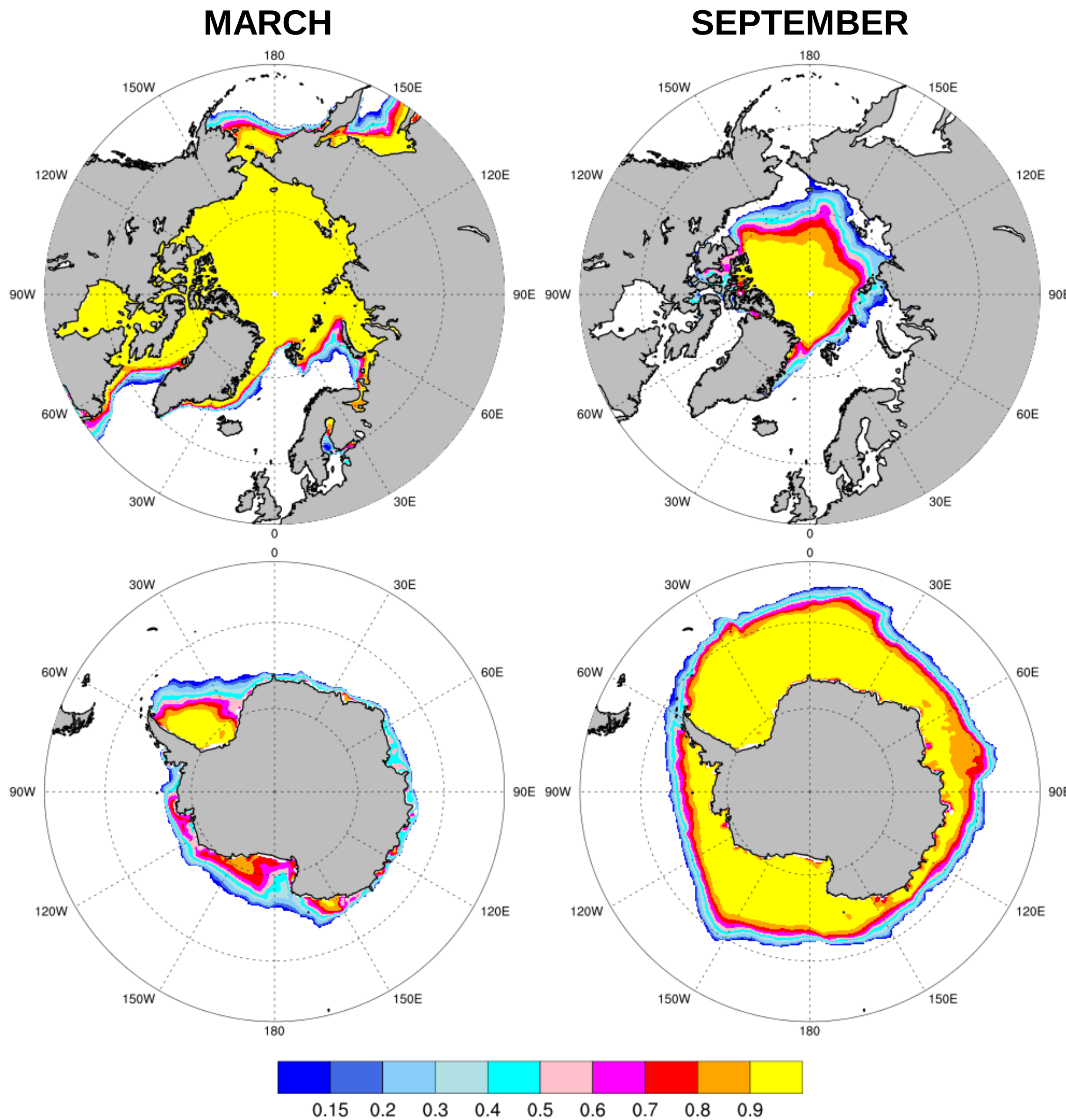
With valuable contributions from: Lauriane Batté, Constantin Ardilouze (CNRM-GAME), Virginie Guémas (BSC, Spain), Greg Smith (Environment Canada) and Thomas Jung (AWI, Germany).

Workshop on subseasonal predictability
2-5 November 2015, ECMWF, Reading

Sea ice 101

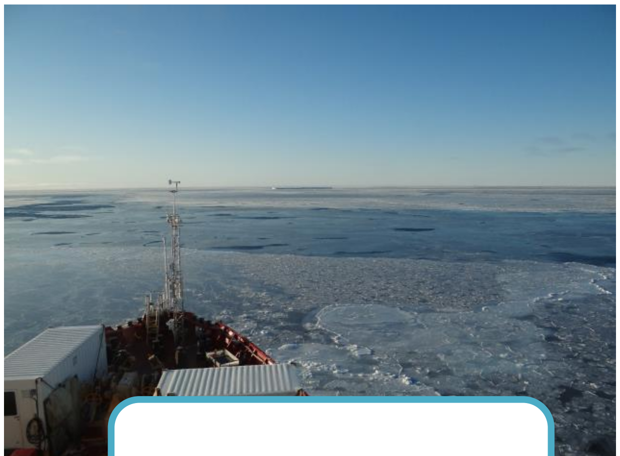




Sea ice concentration (areal fraction, 0-1), mean 1993-2014

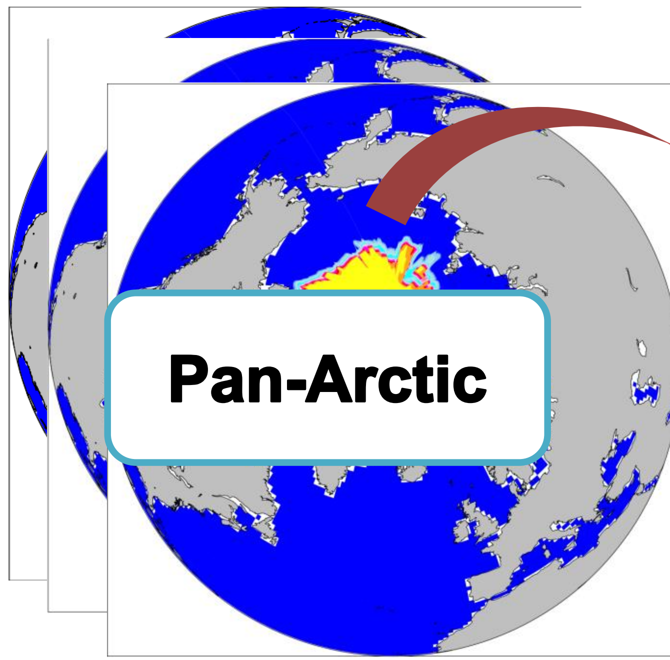
Motivations

USERS



Regional

CLIMATE CHANGE



Pan-Arctic

LINKAGES

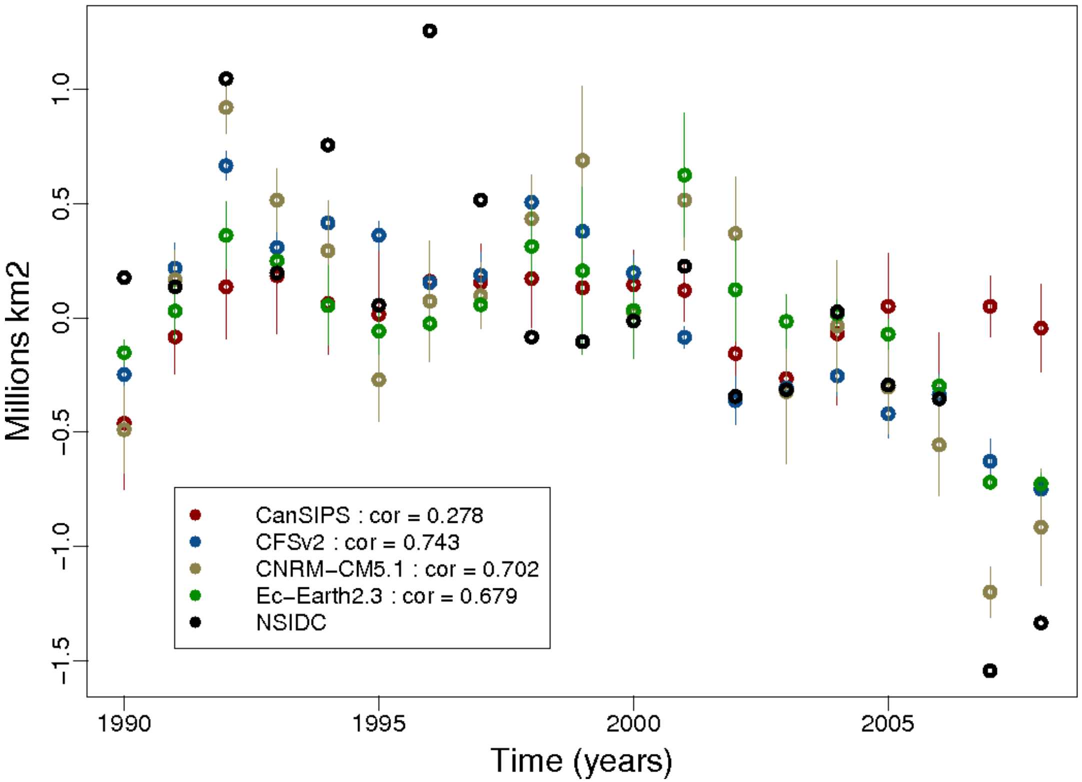
Global

Initial conditions problem

Boundary conditions problem

Arctic seasonal sea ice forecasts

- **Hindcast: May 1 → September (5 months)**
- **In 4 coupled models: CanSIPS, CFSv2, CNRM-CM5.1 and EC-Earth2.3**
- **Predicted mean September Arctic sea ice area**



→ Large differences between coupled systems

→ Not necessary better than statistical models (Sea Ice Outlook)

→ Lot of works to quantify the role of
- **initialization**
- **model physics / parameters**
- **chaotic atmospheric fluctuations**

→ Ex: idealized model simulations ("perfect model"): **APPOSITE** gang

Guémas et al., 2014, QJRMS

Tietsche et al., 2014, GRL

Outlines

Sources of sea ice subseasonal predictability

Sea ice skill in CNRM S2S

Sea ice in S2S prediction systems

Example of case study with sea ice

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Sources of Arctic sea ice predictability

- **On seasonal-to-interannual time scales…**

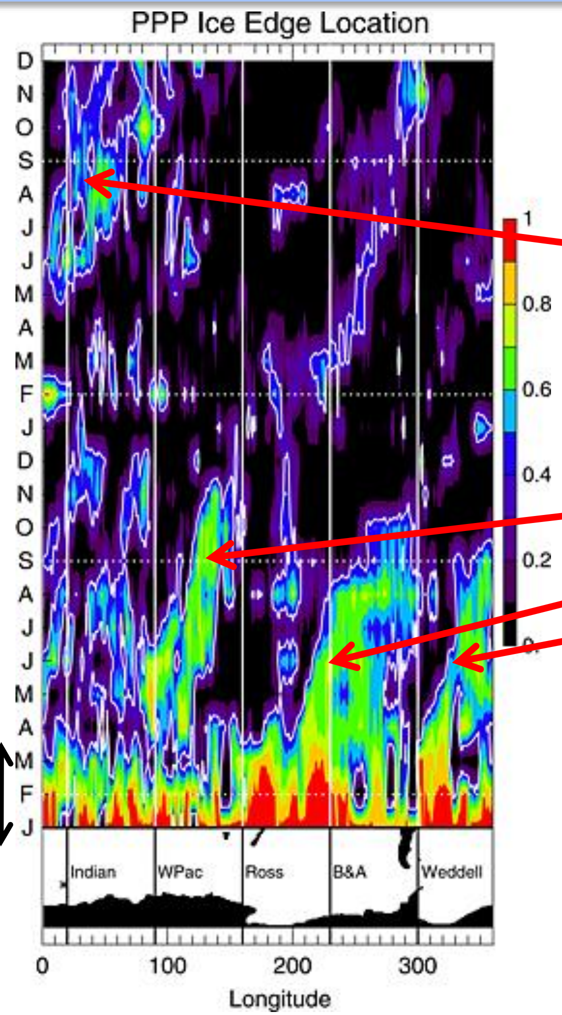
- **Persistence** (2-5 months for sea ice extent, change with the season)
- Advection of local sea ice anomalies by the mean Arctic circulation
- **Atmosphere** (link with NAO/AO?)
- **Ocean** (main source beyond a few months)
- **Re-emergence** (based on persistence of another variable)

➞ **Which one is relevant for the subseasonal time scale?**

Guémas et al., 2014, QJRMS

Antarctic sea ice predictability

- Initial-value predictability of Antarctic sea ice in the CCSM 3
- Perfect model approach – 2-year ensemble integrations started January 1



~3 months **persistence**

Ice edge location = northernmost latitude with SIC>15% (in the SH)

Re-emergence associated to **ocean** heat anomalies

Eastward **advection** of sea ice anomaly

➡ Potential predictability

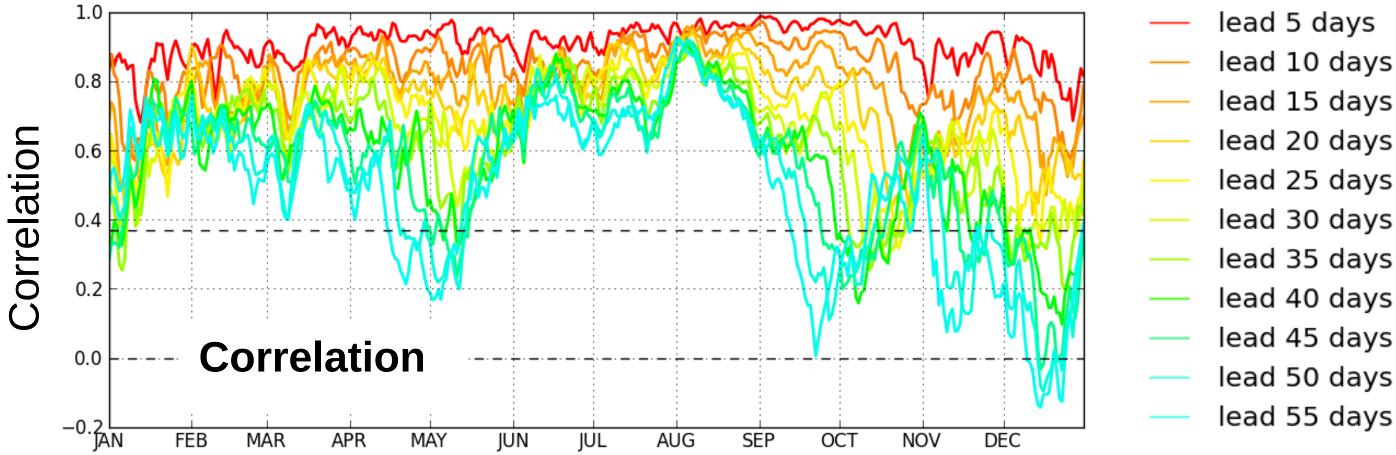
➡ Connections with Tropical Pacific variability

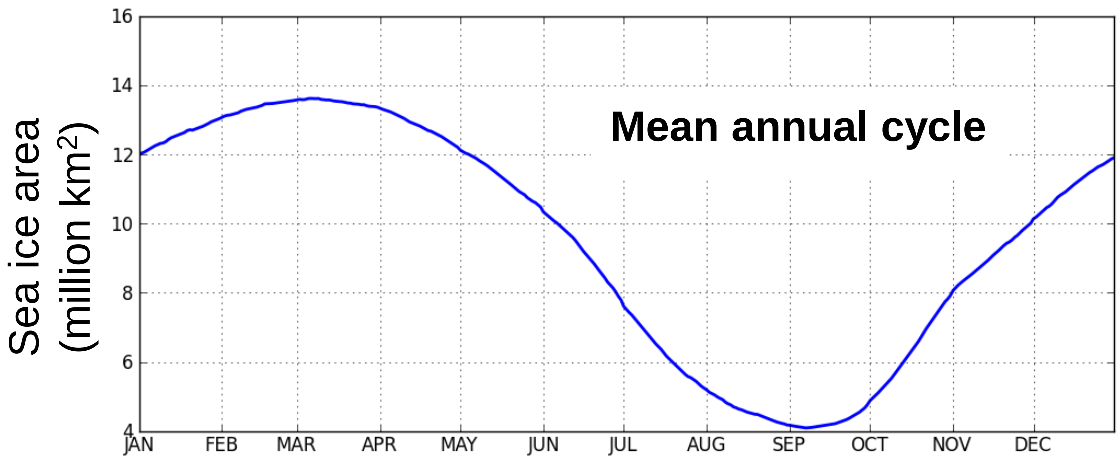
Chen and Yuan, 2004, JCLIM

Holland et al., 2013, GRL

Persistence: Arctic

- **Arctic sea ice area: lagged correlation (daily data, detrended), 1990-2014**





Data: NASATEAM sea ice concentration (NSIDC)

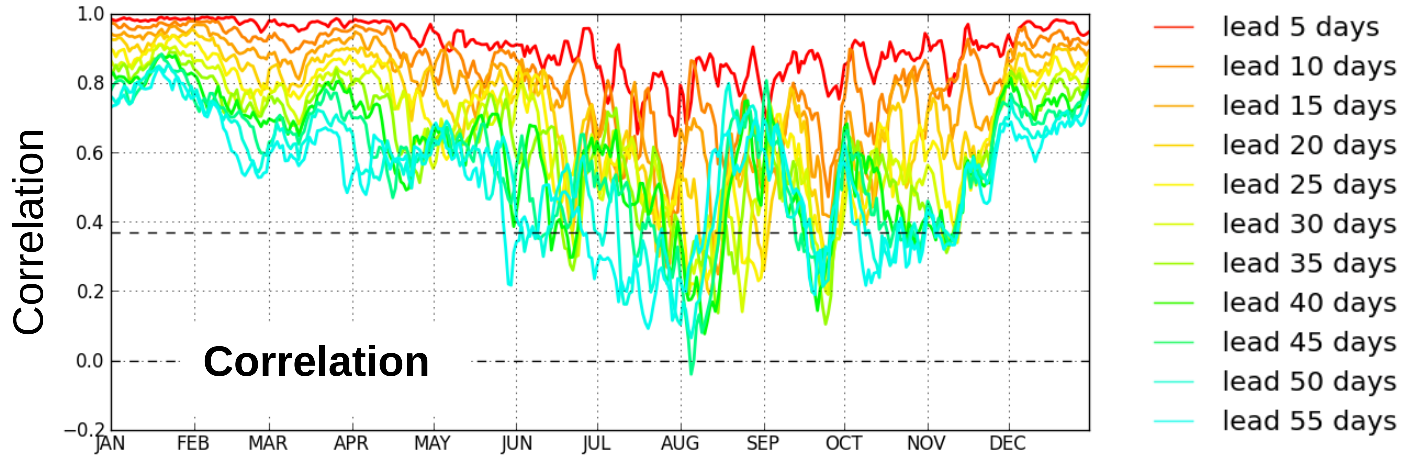
➡ Persistence changes with time of the year

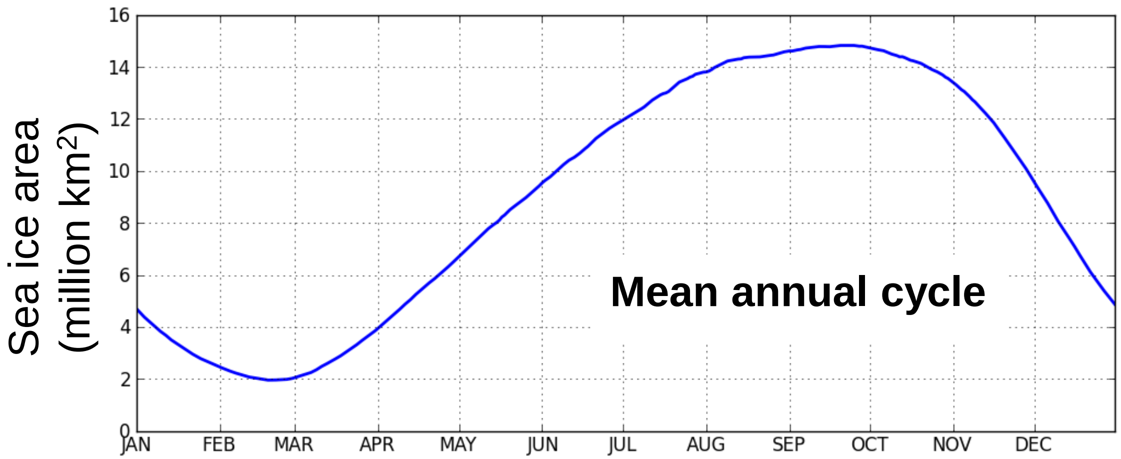
➡ Longest *e*-folding times during the summer (JJAS) and in winter (FM)

➡ Lowest persistence when sea ice area changes the most (May, October) and in December-January

Persistence: Antarctic

- **Antarctic sea ice area: lagged correlation (daily data, detrended), 1990-2014**





➞ Longest *e*-folding times during the summer (DJFMA)

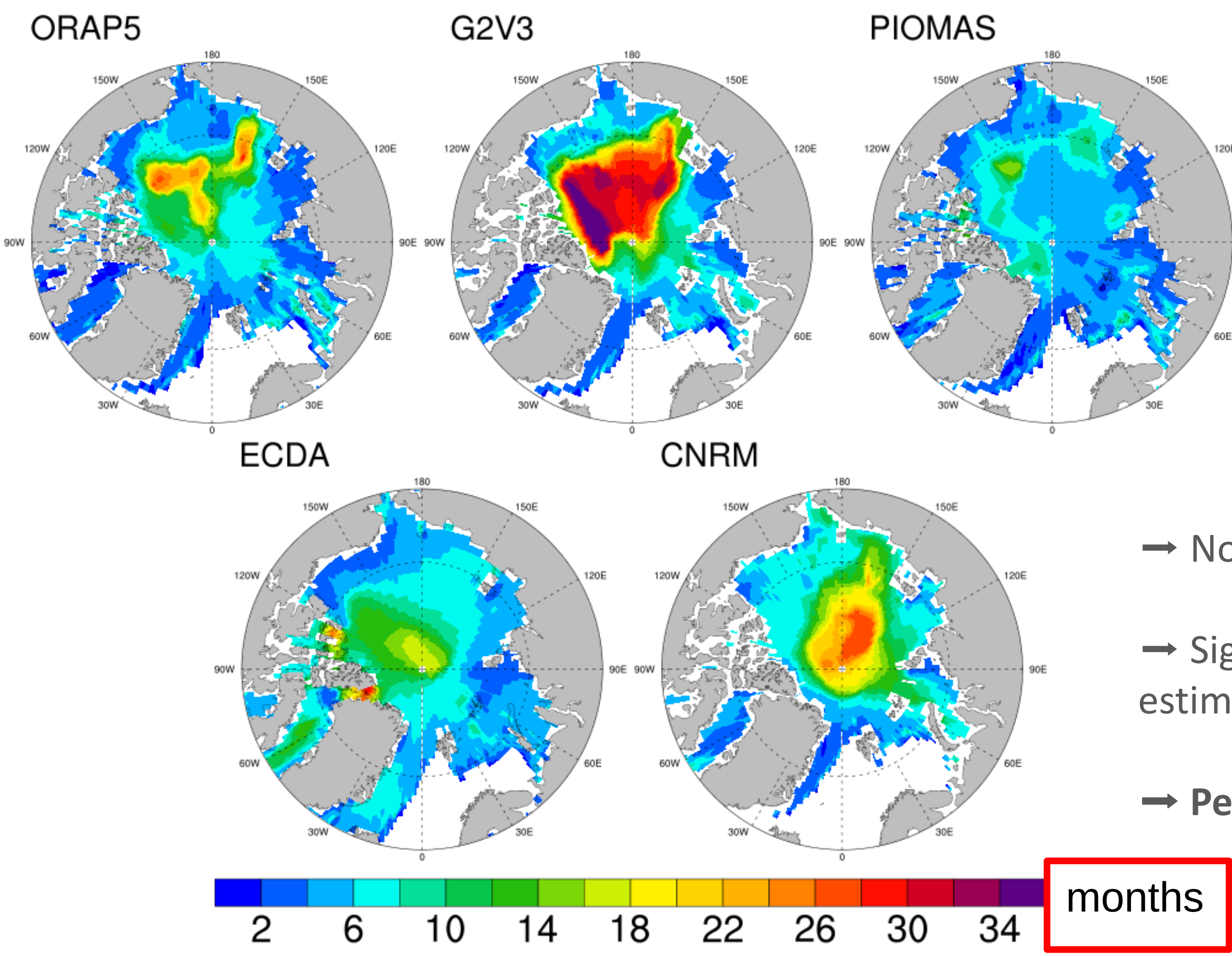
➞ Lower the rest of the year

➞ Re-emergence around the annual maximum (September)

Data: NASATEAM sea ice concentration (NSIDC)

Persistence of sea ice thickness

- Arctic sea ice thickness: e-folding time in reanalyses



- ORAP5 (ECMWF), G2V3 (Glorys2v3, Mercator Océan), ECDA (GFDL), CNRM: global ocean-sea ice reanalyses
- PIOMAS (UW): regional ocean-sea ice reanalysis

→ No long-term observations

→ Signal not consistent among different estimates (modelling+DA issues)

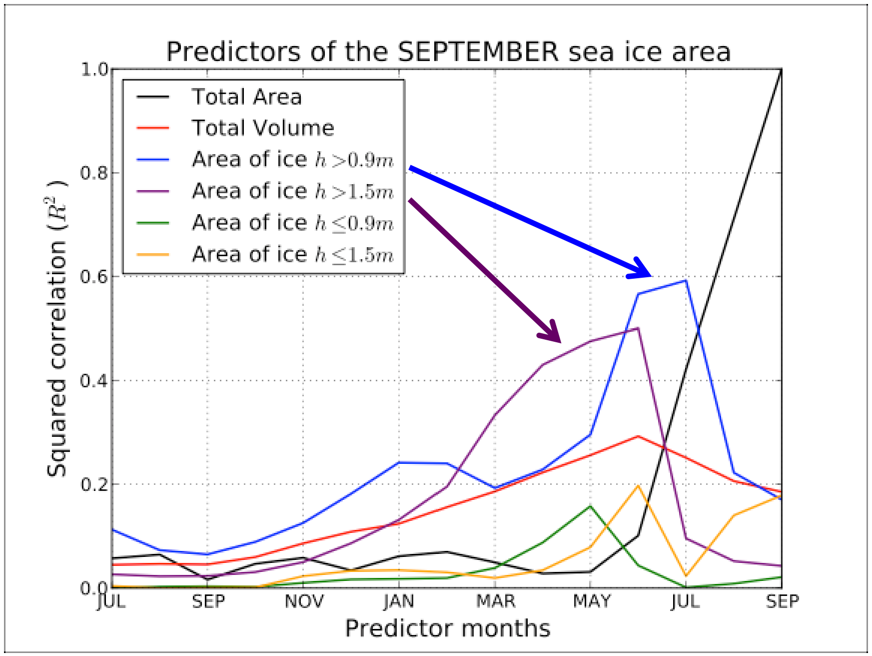
→ **Persistence on longer time scales**

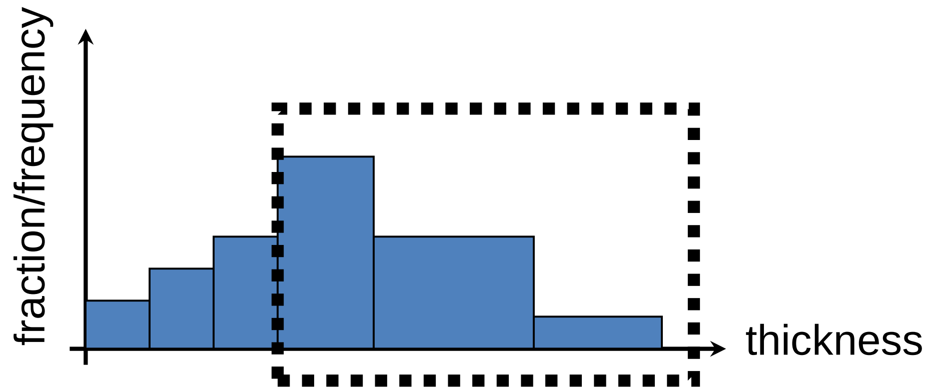
Blanchard-Wrigglesworth and Bitz, 2014, JCLIM

Chevallier et al., 2015, CLIMDYN Special issue 'ocean reanalyses'

Sea ice thickness vs sea ice area

- CNRM-CM3.3 400-year control simulation (PI)
- Potential predictors of the Arctic sea ice area
- Based on the ice thickness distribution / ice thickness categories





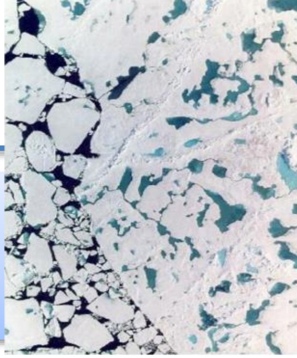
➞ Role of the ice thickness distribution on seasonal time scale

➞ Preconditioning of September sea ice anomaly by **thick ice anomaly in March**

➞ **Not necessary better than persistence on shorter time scale…**

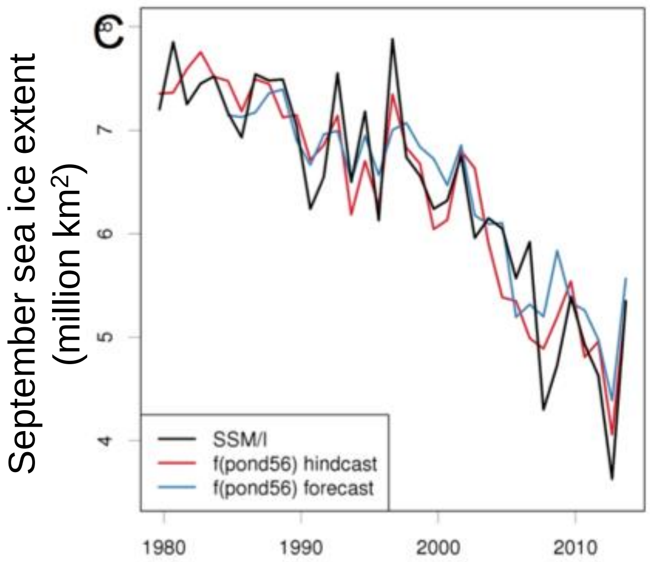
Chevallier and Salas y Mélia, 2012, JCLIM

Radiative processes: role of melt ponds

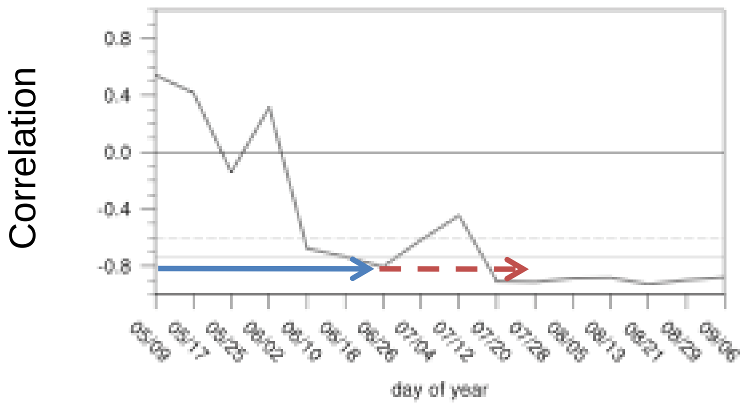


- **Statistical predictions of the Arctic September sea ice extent**
- Using **model** or **observational** estimates of melt pond fraction

Model: Schröder et al



MODIS: Liu et al



➞ Melt ponds over Arctic sea ice in May-June is a promising predictor of Sep sea ice extent (*R=-0.8*)

➞ Predictor is a model estimate

➞ Strong relationship as melt pond fraction is integrated over May-June

➞ Persistent strong relationship only occuring after **late July**

Schröder et al., 2014, NCC

Liu et al., 2015, ERL

Outlines

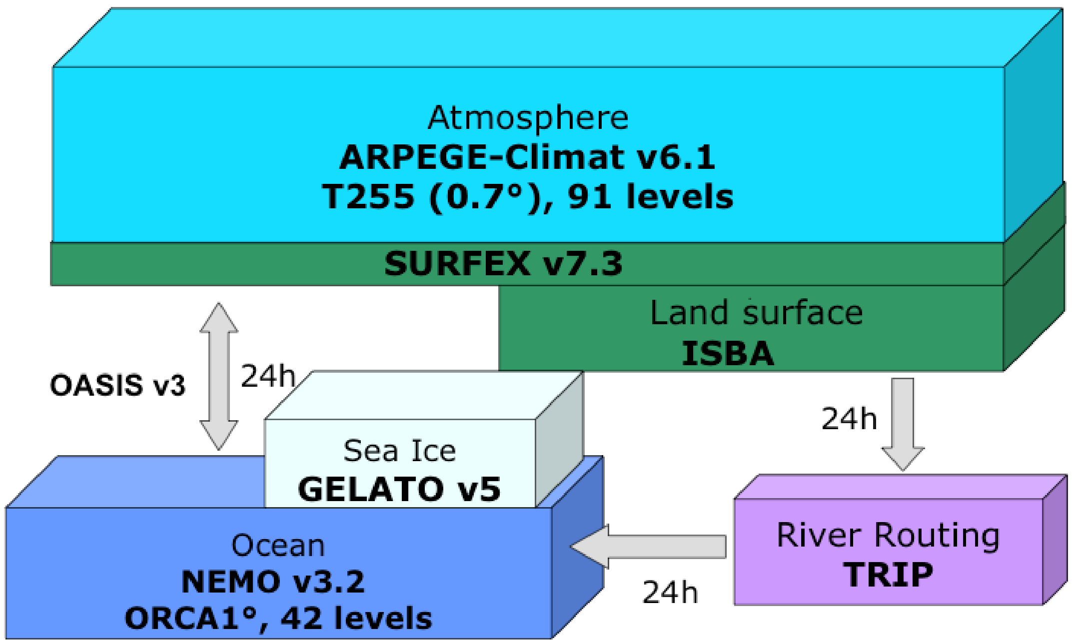
Sources of sea ice subseasonal predictability

Sea ice skill in CNRM S2S

Sea ice in S2S prediction systems

Example of case study with sea ice

CNRM S2S system



- **Hindcast (1993-2014)**
- 2 start dates per month: 1st and 15th
- 60-day forecasts
- 15 members
- Stochastic dynamics in ARPEGE

- Dynamic/thermodynamic multi-category sea ice model

- Initial conditions:
  - ✓ atm/land: **ERA-Interim**
  - ✓ oce/sea ice: **Mercator Océan PSY2G2V3 upscaled**

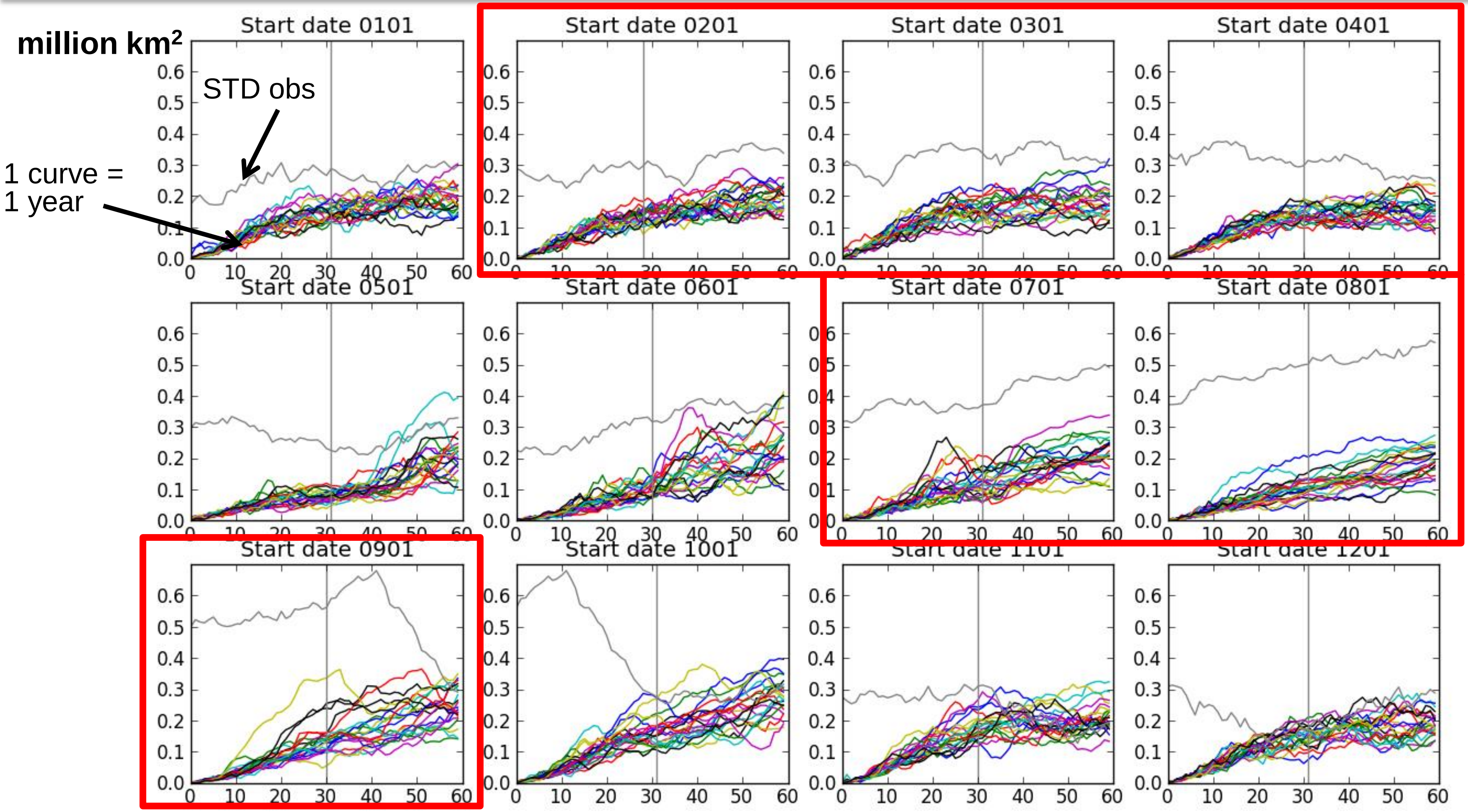
Voldoire et al., 2013, CLIMDYN
Batté and Déqué, 2012, GRL
Chevallier et al., 2013, JCLIM

➞ **Contributes to the S2S database!**

➞ **Poster "Sub-seasonal to seasonal predictions with the CNRM-CM global coupled model" by Lauriane Batté et al.**

Sea ice in CNRM S2S

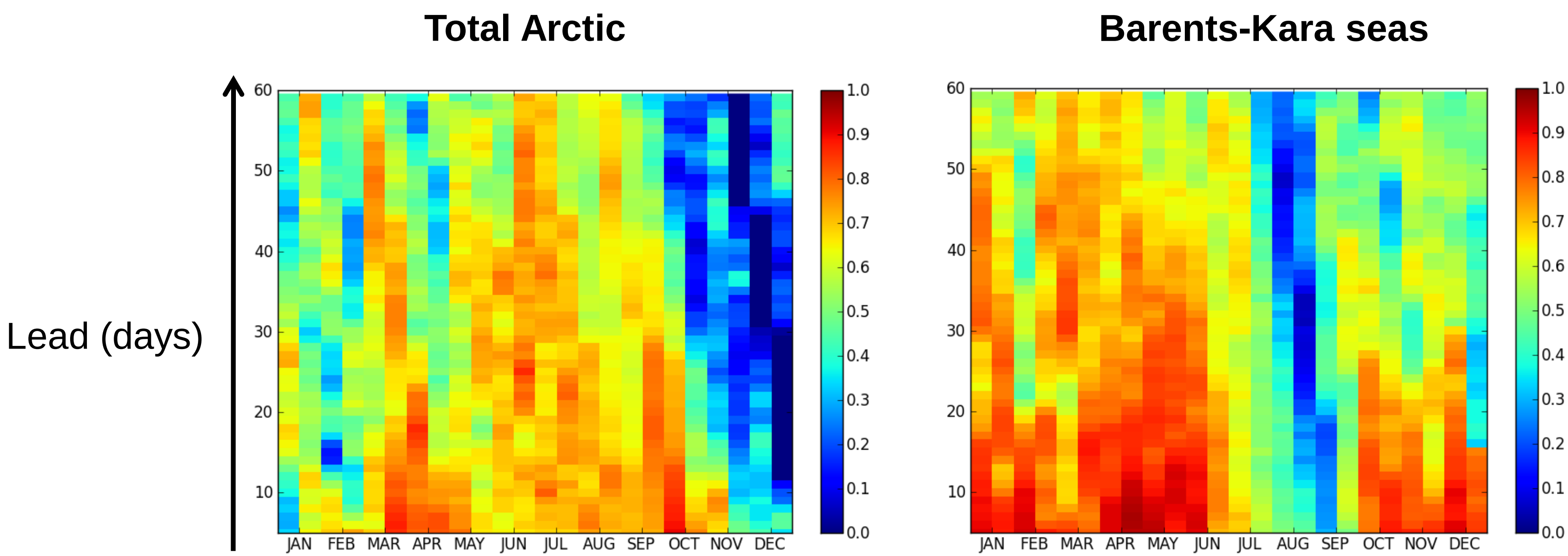
- Spread (STD) of 15-member ensemble forecasts of Arctic sea ice area
- Compared to natural variability in the observations: potential predictability



➡ Potential predictability for 2 months in Feb, Mar, Apr, Jul, Aug, Sep

Sea ice in CNRM S2S

- Sea ice area
- Anomaly correlation (detrended), reference: NSIDC (NasaTeam), 1993-2013

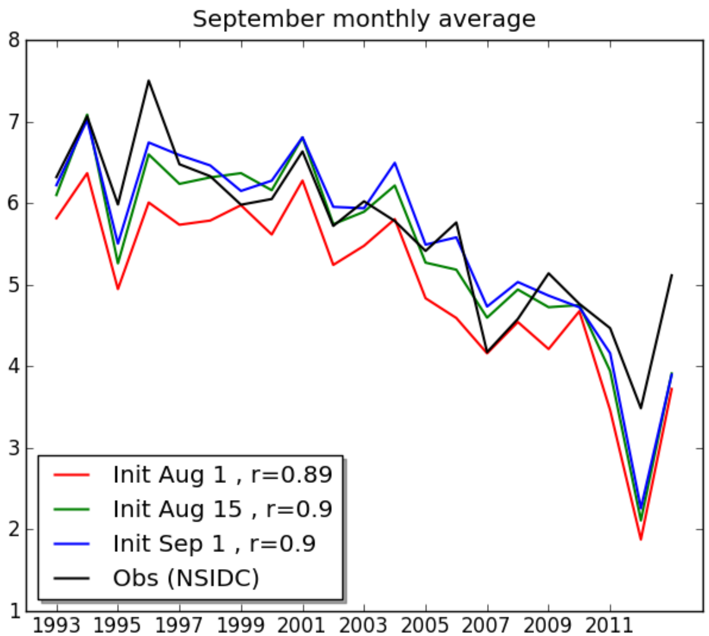


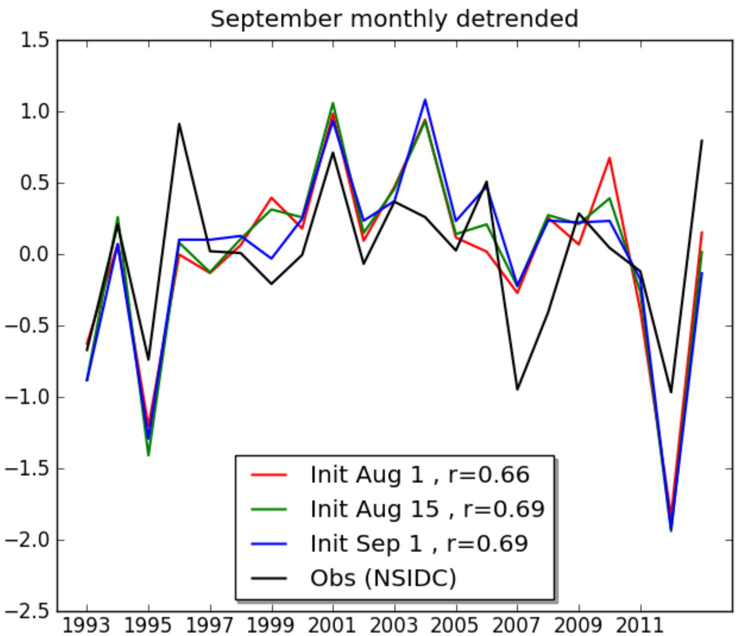
➞ Better predictive skill in spring, summer, early fall for pan-Arctic sea ice area

➞ Regional contrasts: predictive skill in winter/spring and fall in the Barents-Kara seas

Sea ice in CNRM S2S

▪ **September pan-Arctic sea ice extent**





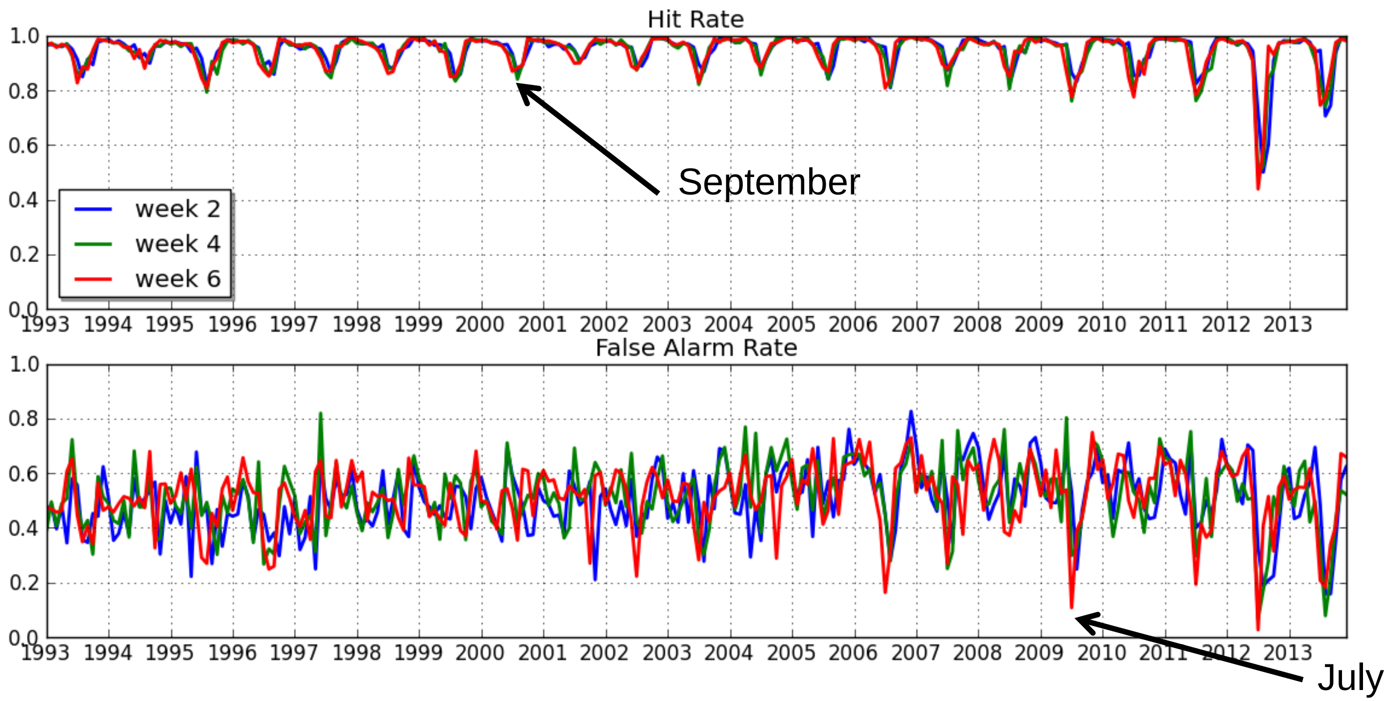
➡ **Reasonable skill with and without the trend**

➡ **Not significantly better than persistence of July anomalies**

➡ Is it interesting?

Sea ice in CNRM S2S

- Contingency tables
- Event: ice presence (sea ice concentration > 15%)



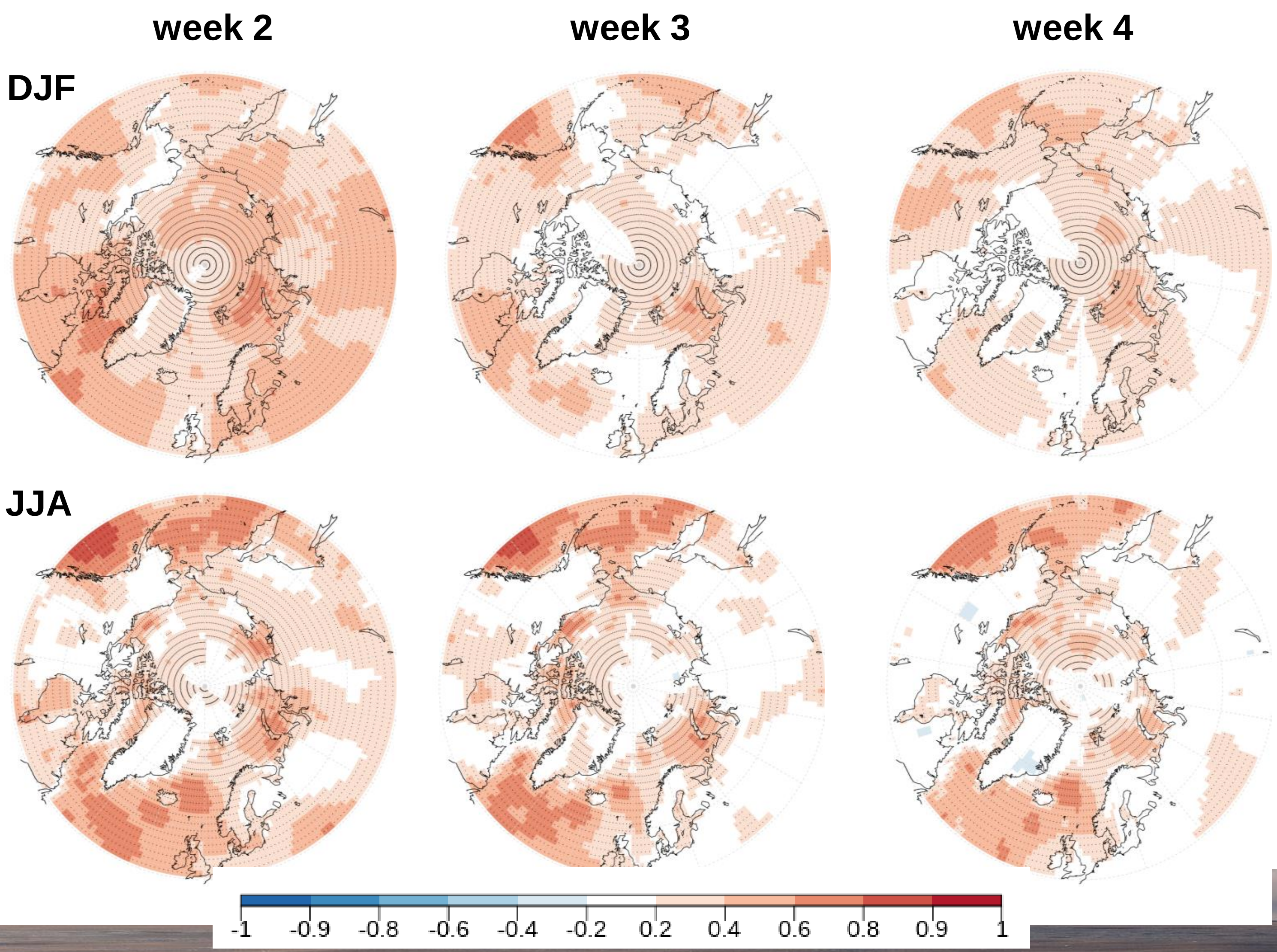
➞ Both spatial and integrated information
➞ Relevant for end-users (shipping)
➞ Sensitivity to the threshold (in obs)

Outlines

- Sources of sea ice subseasonal predictability
- Sea ice skill in CNRM S2S
- **Sea ice in S2S prediction systems**
- Example of case study with sea ice

CNRM S2S skill in the Arctic

- Anomaly correlation 2m-temperature, reference: ERA-Interim, DJF/JJA 1993-2014



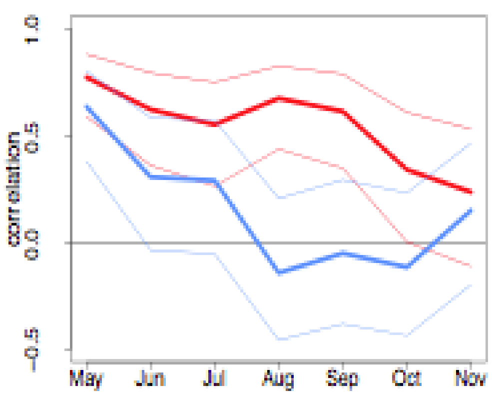
Sea ice initialization in seasonal forecasts

- CNRM-CM5, hindcast: May 1 → September (5 months)
- **Impact of sea ice initialization on seasonal forecasts**

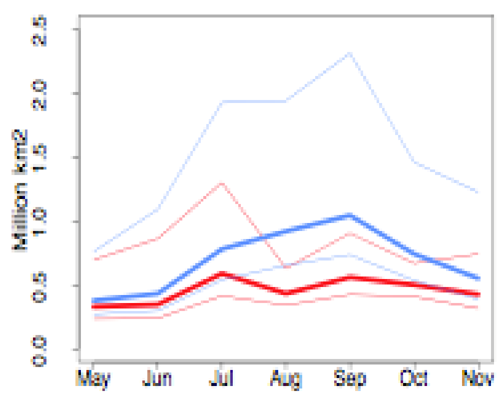
Init: realistic sea ice initialization

Clim: climatological sea ice initialization

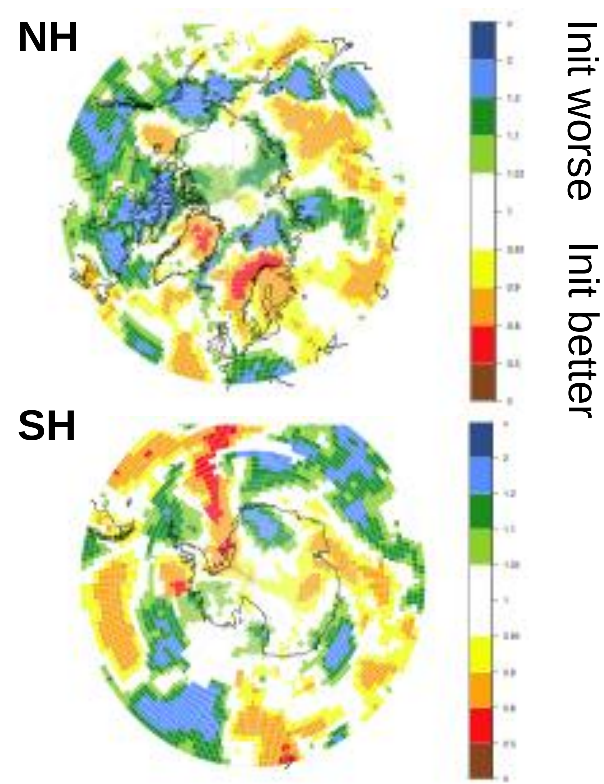
Detrended ACC Arctic SIE



RMSE Arctic SIE



Ratio RMSE Init/Clim (JJA) **T2m**



→ **Sea ice initialization improves sea ice forecasts (not in winter…)**

→ **JJA forecasts are not significantly improved**

→ **Same with EC-Earthv2.3**

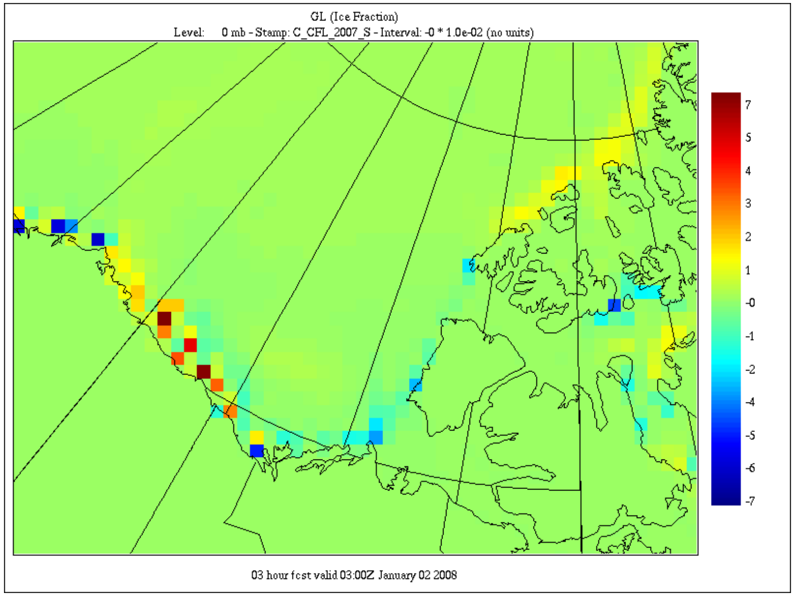
→ **Modelling + Initialization issues**

Guémas, Chevallier et al., 2015, submitted

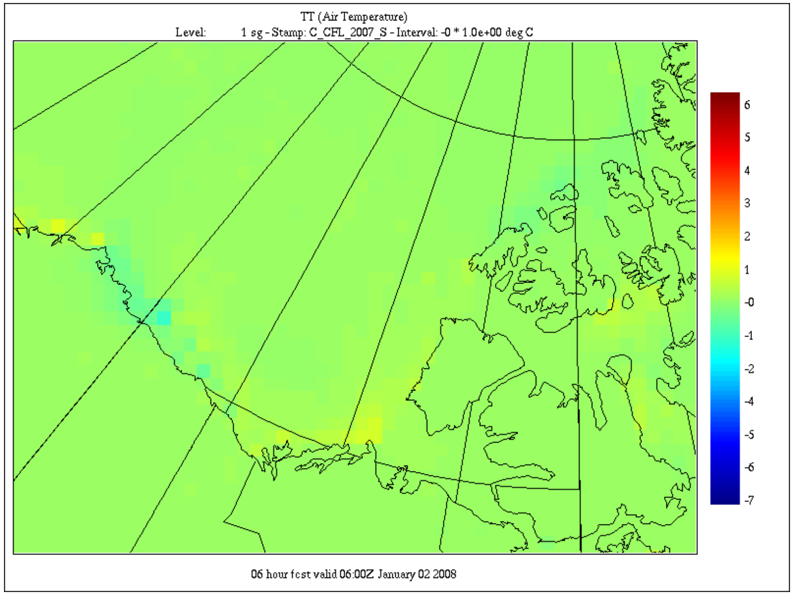
Sea ice models in medium-range forecasts

- **Impact of a dynamical sea ice model on coupled forecasts over the Beaufort Sea**
- **5-day forecasts with GEM (10km) – NEMO-CICE (1/4°)**
- Difference dynamical vs persistent sea ice

Difference in ice fraction (%)



Difference in 2m temperature (°C)



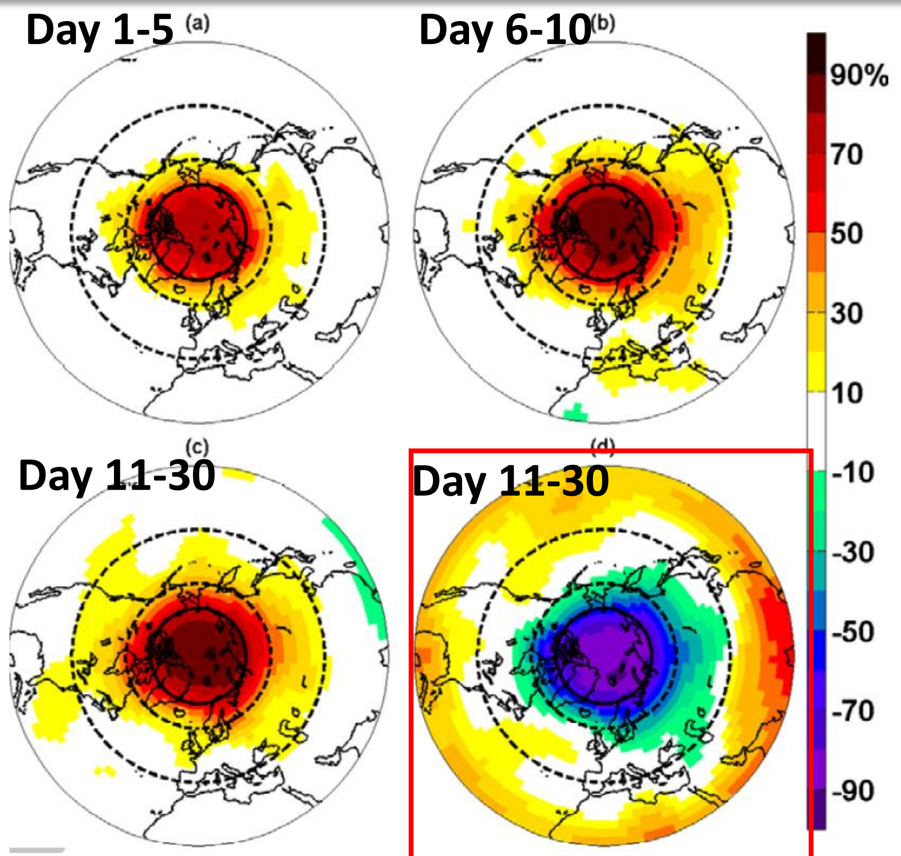
➡ **Clear impact of sea ice dynamics on atmospheric simulation**

➡ **Modelling issues: air-ice coupling, high resolution sea ice features (leads)**

Courtesy Greg Smith (Environment Canada)

Sea ice/Arctic processes in S2S forecasts

- **ECMWF T159L60, prescribed SST/sea ice**
- **Relaxation of u, v, T, log(p) towards ERA-40 north of 70°N and below 300hPa (ARC)**
- **Comparison with experiment with relaxation in the tropical belt (20°S-20°N) (TRP)**



Negative values = ARC > TRP

Relative reduction (in %) of the RMSE of 500hPa geopotential height due to Arctic nudging.
Winter forecasts 1980/81-2000/01

➡ **Potential of improvement of S2S forecasts assuming a perfect representation of Arctic processes**

Jung et al., 2014, GRL

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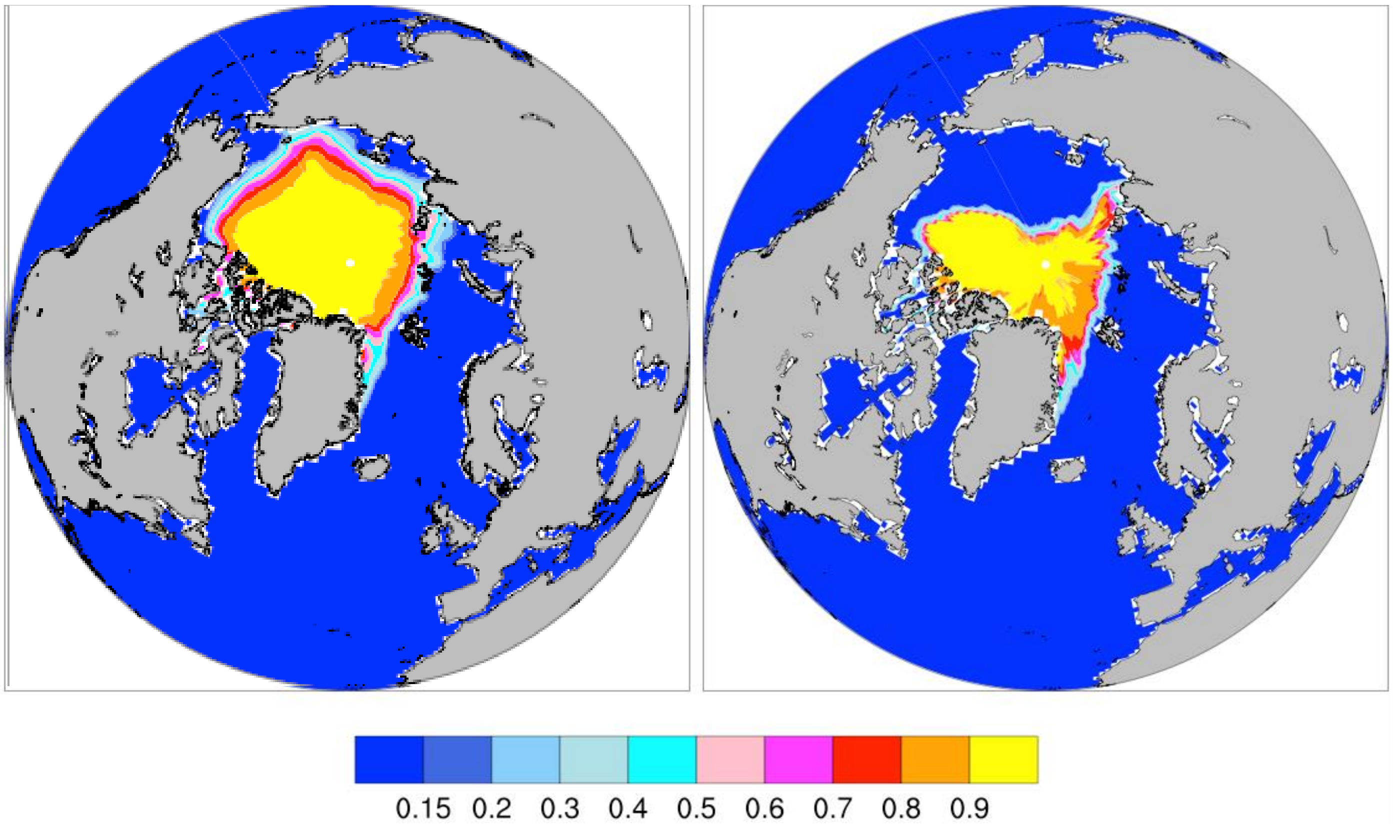
Example of case study with sea ice

Case study: September 2007 (1)

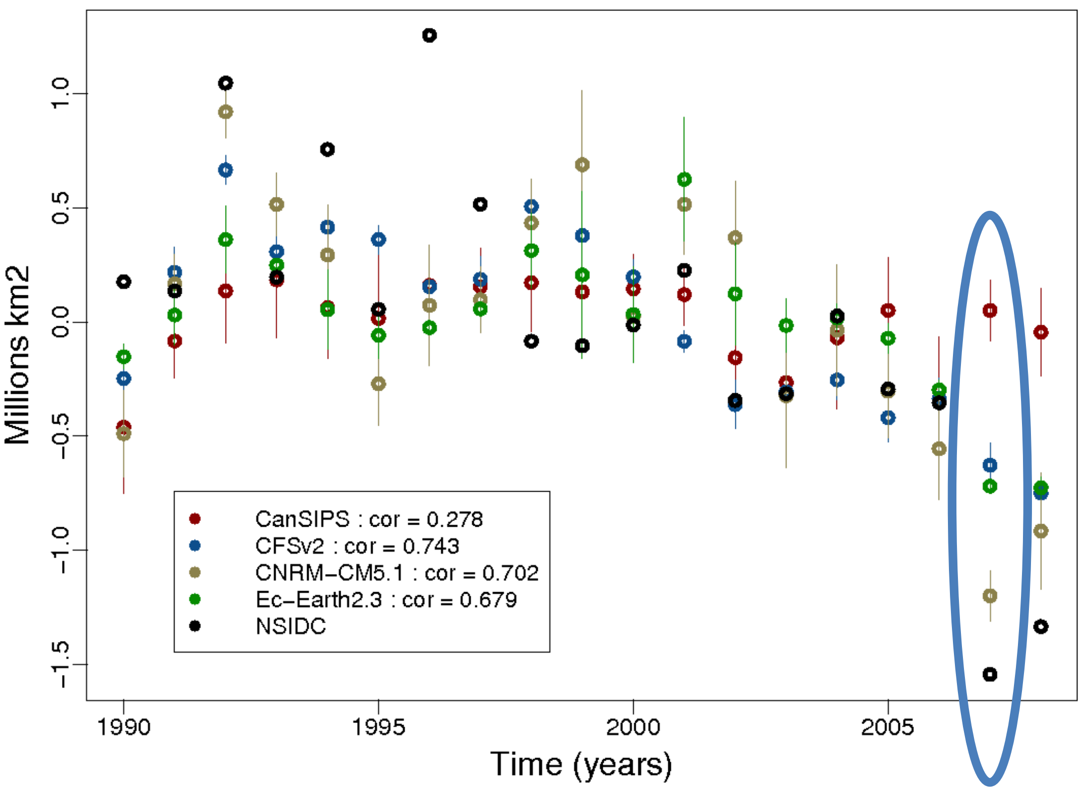
SEPTEMBER 1979-2000 **SEPTEMBER 2007**

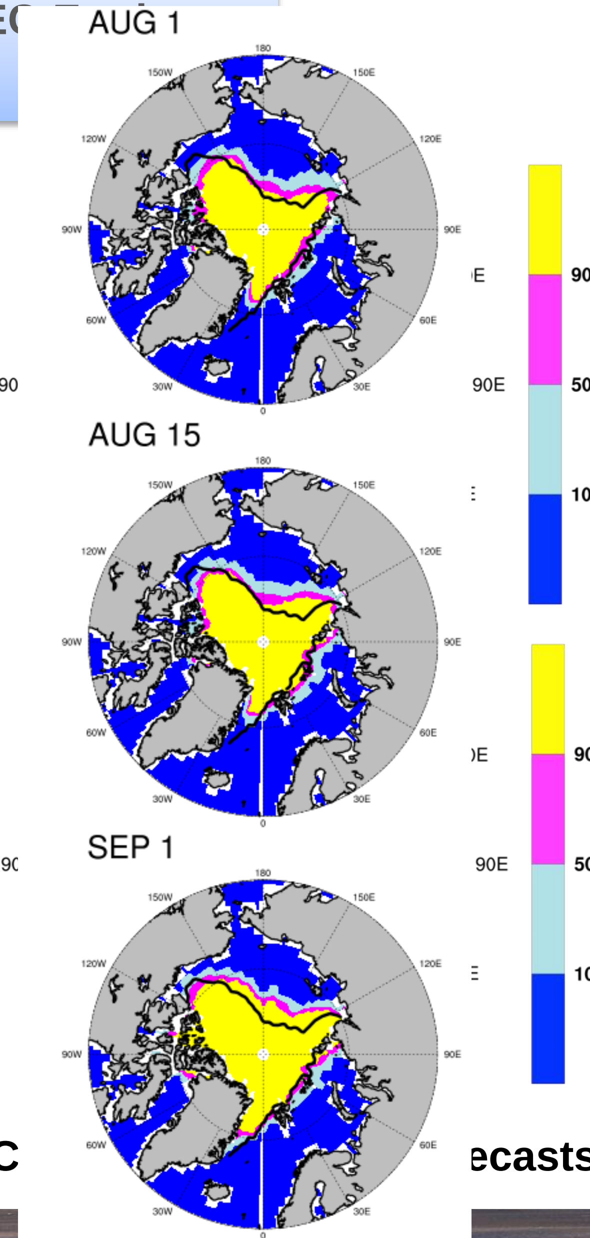


➡ **Drivers of the September sea ice anomaly?**
➡ **Atmospheric response to the September sea ice anomaly?**

Case study: September 2007 (2)

- 5-month May 1 hindcasts with CanSIPS, CFS, CNRM-CM, EC
- CNRM-CM S2S initialized Aug 1, Aug 15 and Sep 1





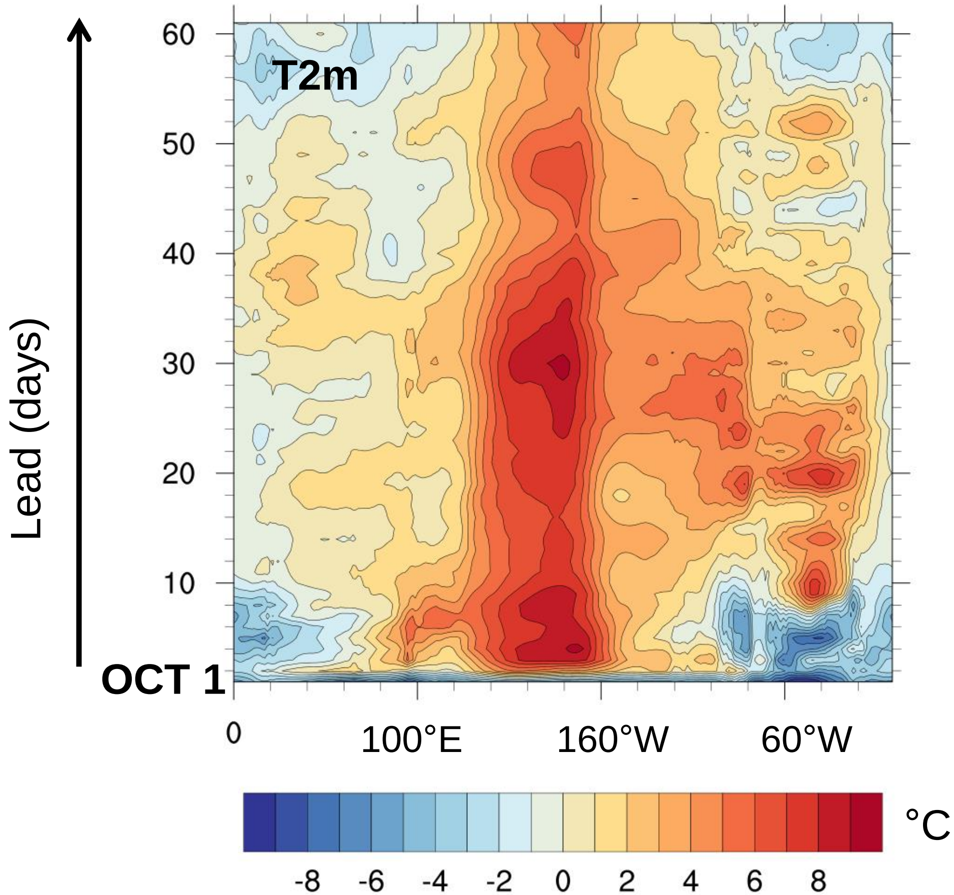
C ... ecasts

➞ Seasonal: The more information, the better the forecast

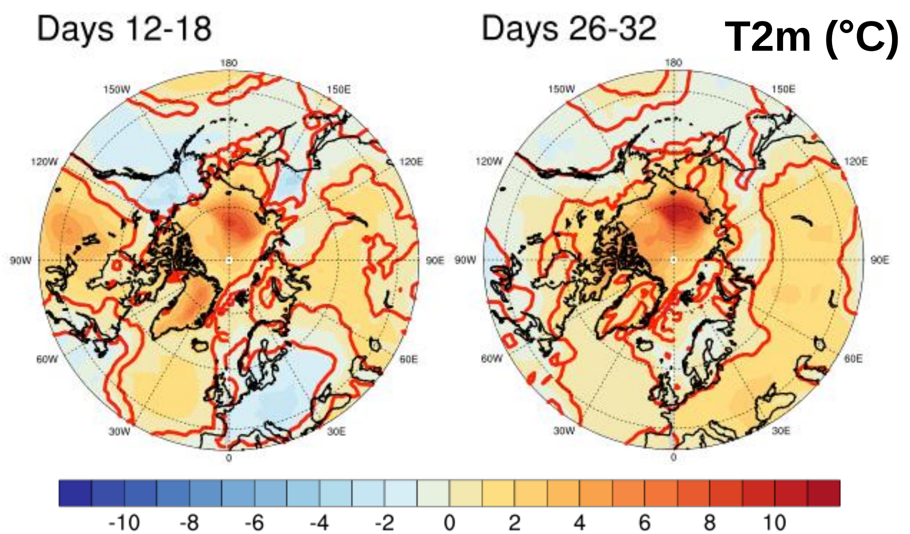
➞ S2S: AUG 1 is already a good forecast!

Case study: September 2007 (3)

- CNRM S2S hindcast initialized on 1 October 2007
- Anomaly relative to 1993-2013



Average over the latitude band 75°N-85°N



Kumar et al., 2010, GRL

Orsolini et al., 2011, CLIMDYN

Summary

This is the end!

Summary

- ✓ **For end-users**, the subseasonal time scales is the relevant time scale.

- ✓ **Persistence** is the main source of predictability at subseasonal time scales for sea ice area.
- ✓ Longer persistence of sea ice area in the summer and late winter in both hemispheres.
- ✓ Sea ice thickness potentially plays a role for longer time scales (still important for users!)

- ✓ **CNRM S2S system** has some reasonable skill in the summer and spring for pan-Arctic sea ice area. Predictability is limited in transition seasons.
- ✓ There are regional contrasts: better skill in winter-spring in the MIZ.

- ✓ Including dynamical sea ice in S2S systems has potentially a strong **impact on atmospheric predictions** inside and outside the polar regions.
- ✓ Coupled air-ice processes as potential sources of predictability (fluxes, leads, melt ponds)
  ➞ well represented in models?

- ✓ **Case studies** (as summer-fall 2007) could address:
  - Drivers of sea ice anomalies (sea ice = **predictand**)
  - Response to sea ice anomalies (sea ice = **predictor**)

➞ Connections with the Polar Prediction Project (WWRP) and the Year Of Polar Prediction (2017-2019): improve hourly-to-seasonal environmental forecasts in the Polar regions (+ linkages)

Thank you for your attention

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