

What is the thermodynamic versus dynamic sea ice response during a warm moist air intrusion event?

Evelien Dekker

Thanks to:

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Johan Nilsson, Gunilla Svensson*

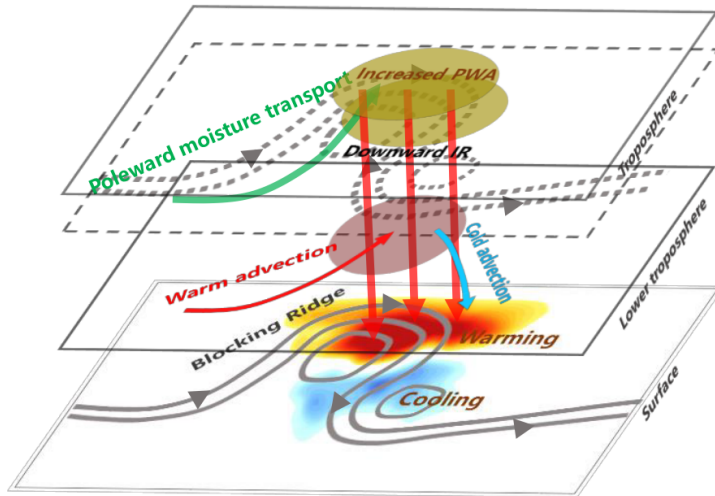


*Knut och Alice
Wallenbergs
Stiftelse*

What is the thermodynamic versus dynamic sea ice response during a warm moist air intrusion event?

Moist warm air intrusions events have been related to sea ice decline and melt in winter. (Woods and Cabellero 2016, Messori et al. 2018, Binder et al. 2017, Yao et al. 2018) in reanalyses studies, based on analyzing sea ice concentration (SIC) fields.

Point observations at SHEBA (Jan 1998) likely show the sea ice growth rate is slowed down after advection of warm moist air. (Persson et al. 2017).



Atmospheric blocking events allow for the advection of warm moist air. In this study, we look at warm moist air transported towards pole.

This illustration comes from Yao et al. 2018 “Effects of Northern Hemisphere Atmospheric Blocking on Arctic sea ice decline in Winter at Weekly timescale”

Figure 10. Schematic diagram of the physical process by which the blocking circulation affects the regional sea ice decline. At the surface (bottom layer), the red (blue) shading represents a positive (negative) SAT anomaly. The streamlines represent the blocking circulation, which is a deep system from the surface to the top of the troposphere. Other processes are indicated in the figure.

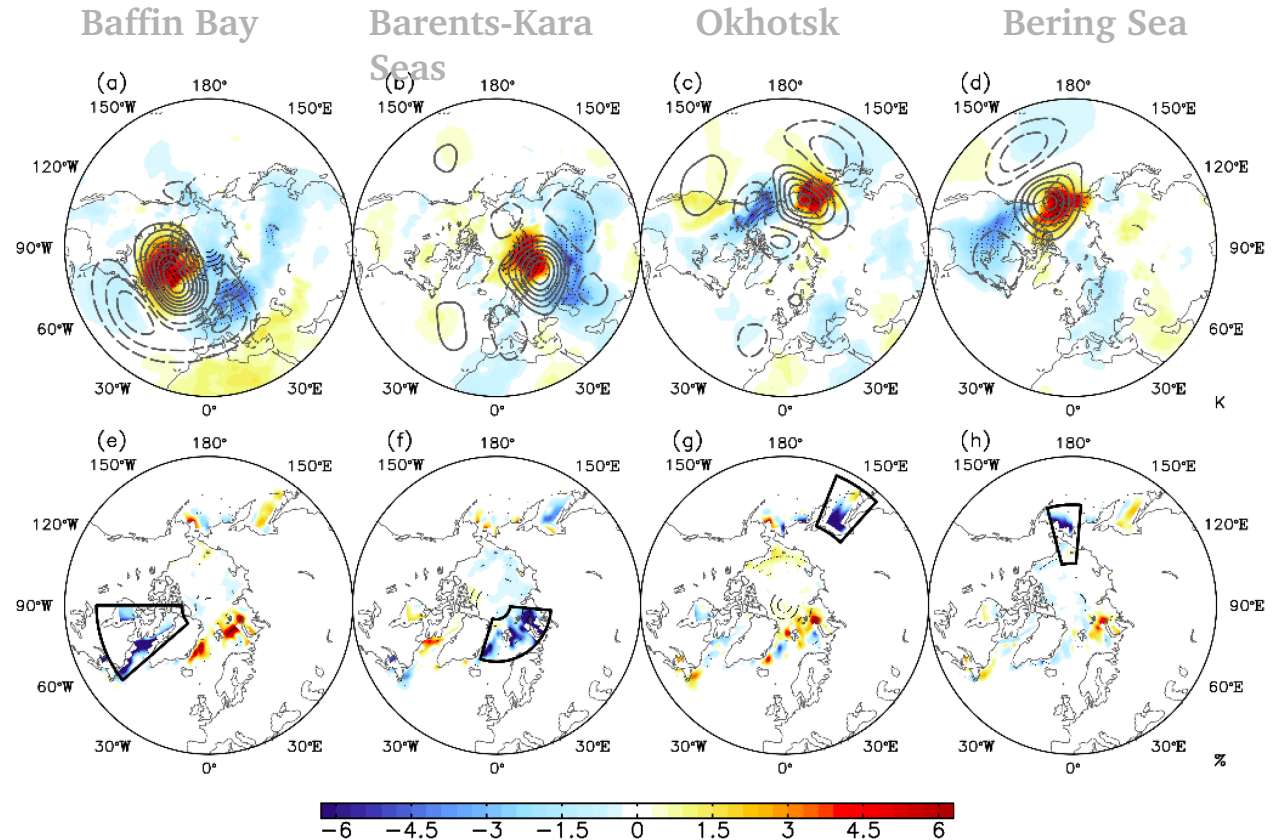
Atmospheric blocking events allow for the advection of warm moist air. In this study, we look at warm moist air transported towards to pole. To illustrate what such blocking events associated with warm moist air intrusions look like, here is a figure from Yao et al. 2018.

Composite blocking events from lag -2 to lag 2 days at different locations of the 500 -hPa geopotential height and surface temperature (K) anomaly (top row) are associated with an anomaly of sea ice concentration.

Composite blocking events 500 hPa GpH and SAT anomaly

Associated SIC anomalies.

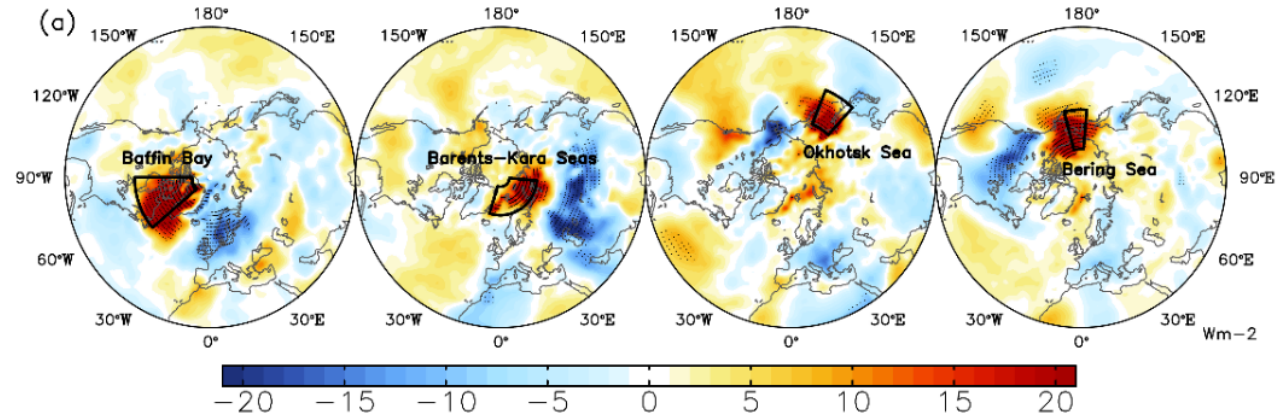
Does this suggest that sea ice concentration decline is caused by the sea ice melting?



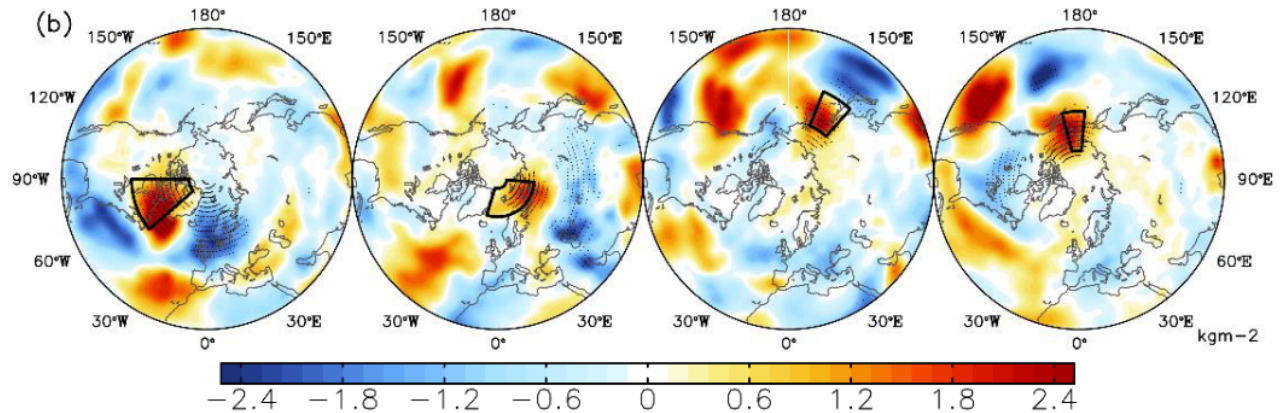
Does this suggest that sea ice concentration decline is caused by the sea ice melting?

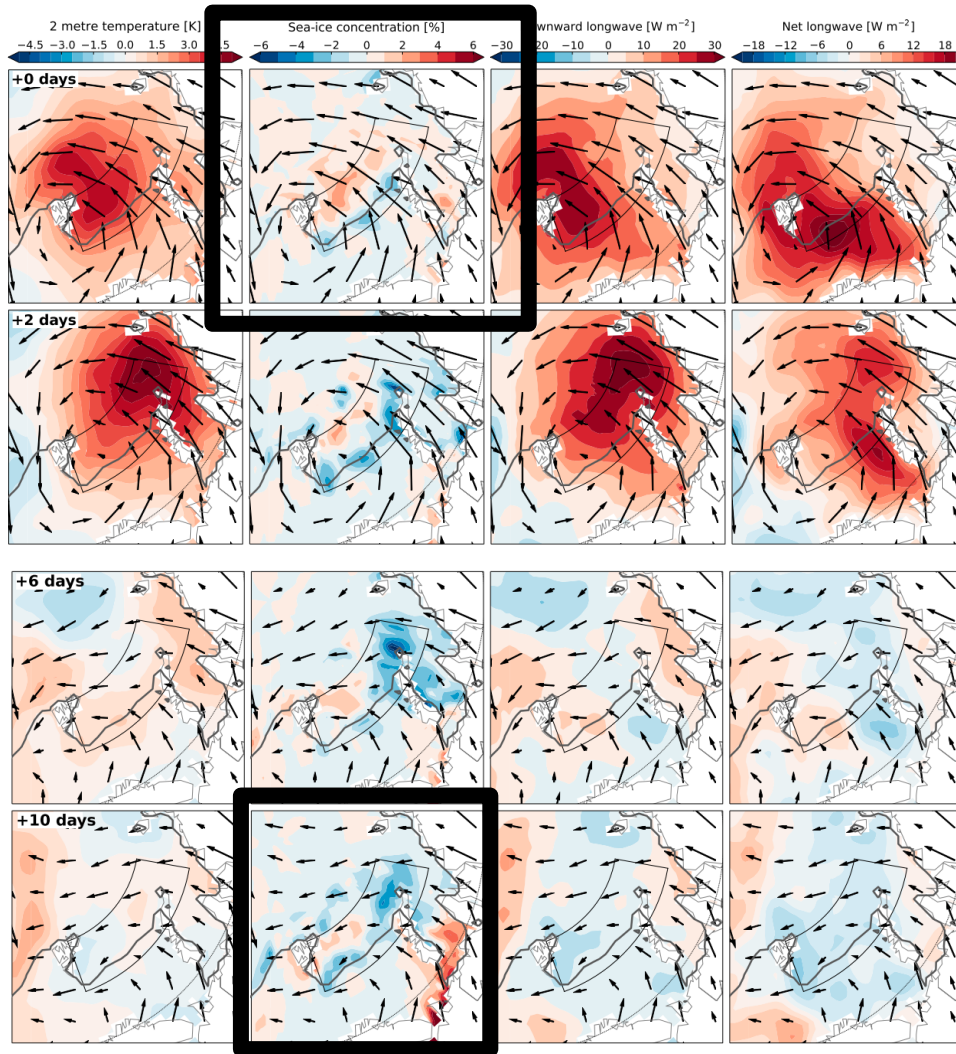
Yao and Yao 2018 follow up by showing the associated net downward longwave anomaly (first row) and the precipitable water (column integrated specific humidity). These blocking events impose a surface forcing, but does that directly translate into sea ice melt?

precipitable water
for blocking
composites



precipitable water





In a study by Woods and Cabellero 2016, moist air intrusions in the Barents sea are studied. Here is an example of a composite of all moist air intrusion over the Barents Sea box in ERA -Interim winter 1979-2016. At lag 0 days the northern part of the box has increased SIC, while the southern part has decreased SIC.

Later, at lag 2, 6 and 10, there is actually an increase of sea ice concentration (blue), which could imply that the wind opened up the ice field, which allows for more ice growth.

It could be argued that here is no ice melt but advection of ice from the south to the north by the winds associated with the moist air intrusion event.

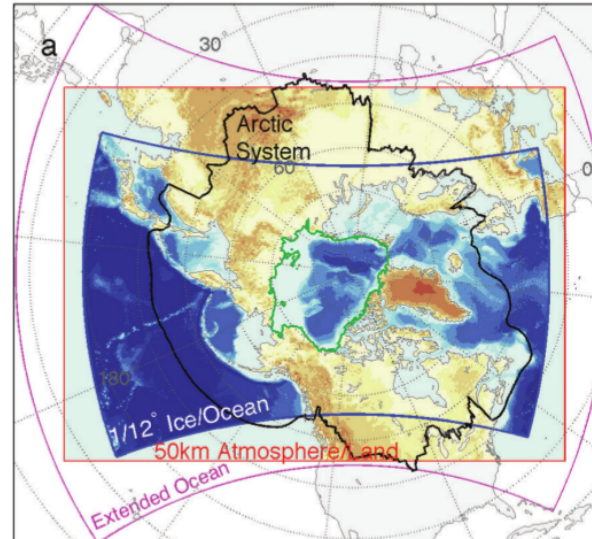
What is the role of ice transport (advection) versus ice (bottom) melt during such warm moist air intrusion events?

These events are associated with strong wind events... what is the net local effect on the ice? Stronger winds → lead opening → more ice growth?

OR

longwave down anomaly, sea ice growth stagnation, less ice?

Needed: distinction between thermodynamic and dynamic response during a case study in a model:
RASM, the Regional Arctic System Model R2200aRBRcaaa01a



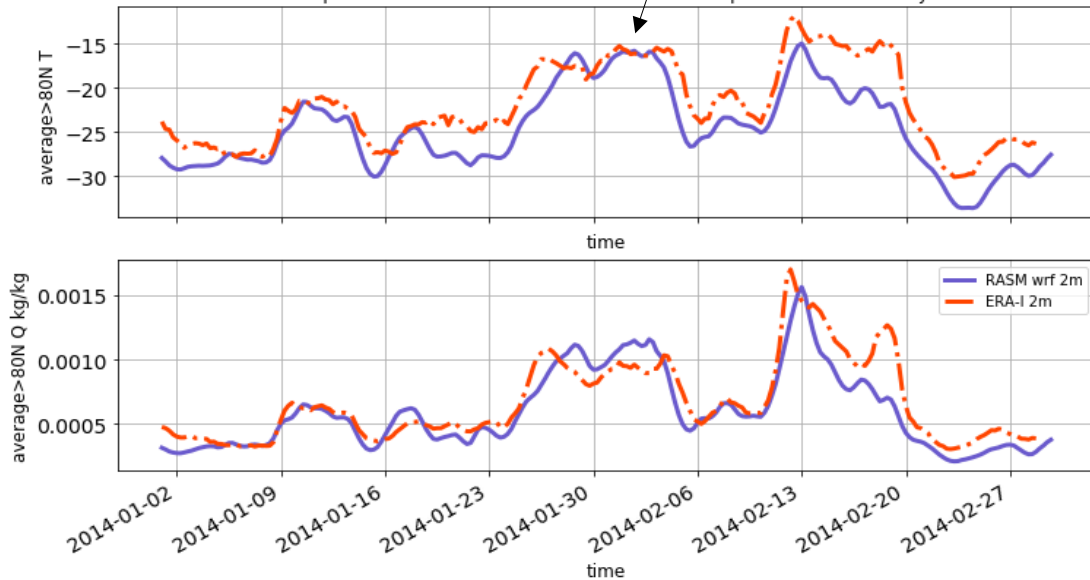
Ocean resolution ~9km (1/12 degree)
Atm resolution 50 km
Coupling every 20 min (instead of hourly)
Which impact greatly on the sea ice movement frequency spectrum and therefore ocean heat flux reaching the ice

The RASM model group provided daily atmospheric data, ocean and ice data. I selected one case study. Based on Arctic temperature extremes in ERA-Interim(Messori et al. 2018) associated with warm moist air intrusions that provide an extreme vQ flux @ 70 degrees North (Woods et al. 2016) and model data availability, I picked a case in january-feburari 2014.

The test case is chosen based on one of the 50 extreme warm events in ERA-Interim over the period of January 1979 – December 2016. The moist common moisture intrusion happen on the Atlantic side. This particular case is interesting because it is follow up of moist air intrusions on the Atlantic and the Pacific side. Pacific moist air intrusions are more rare.

Because the case was picked based on ERA-Interim data, here a comparison between ERA-I and RASM is shown.

Comparison RASM and ERA-I of >80 N surface temperature and humidity



This video show the precipitable water in the atmosphere from 2014-01-23 to 2014-02-05.

In a dry winter Arctic, the central Arctic would be blue. Around 2014-01-30, one can spot moisture flowing on though the Pacific side in the red box

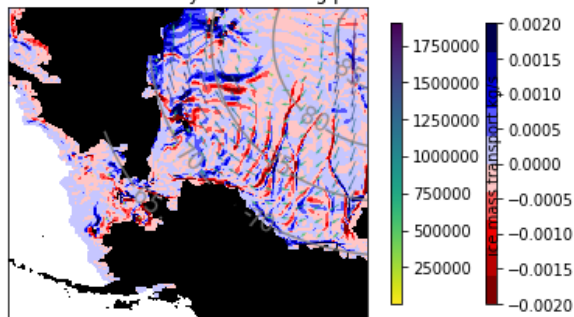
VIDEO:

https://drive.google.com/open?id=1dAtdg50LLWj1jJFcf_Lo9ayz5sOHh-Zu

The following three slides show a follow up of the dynamics and thermodynamic mass tendencies with the associated longwave down field for **three time slices: before, during and after the moist air intrusion event in Bering strait.**

Dynamic sea ice tendency ($\text{kg s}^{-1} \text{m}^{-2}$)

dynamic ice mass tendency $1.82\text{E}+08 \text{ kg per second}$

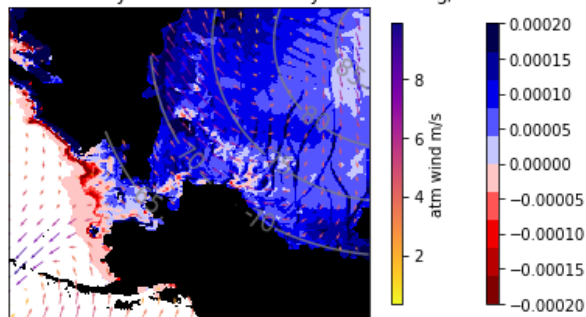


Dynamic mass tendencies show advection of ice. In this case leads open from east to west (red indicates a loss of ice due to dynamics, blue a gain). The green/yellow arrows represent ice mass movement in kg/s .

Thermodynamic sea ice tendency ($\text{kg s}^{-1} \text{m}^{-2}$)

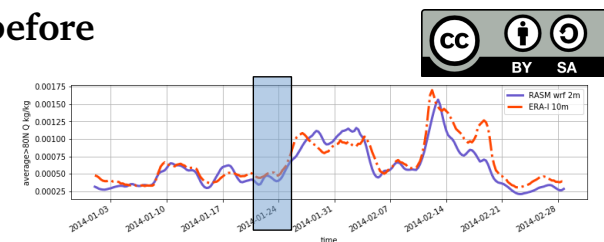
(10x smaller than dynamic tendency colorbar)

2014/01/24 thermodyn ice mass tendency $4.11\text{E}+08 \text{ kg/s}$

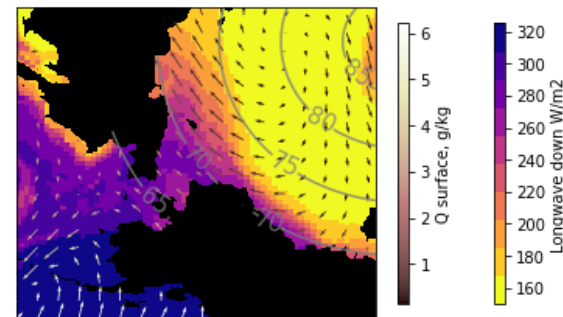


In the middle the thermodynamic mass tendencies are positive for ice growth, just before the event the deep blue colors indicate ice growth in the lead and along the Siberian coast. Ice exported through Bering Strait is colored red, which means it melts. Note that the sum of these thermodynamic tendencies over the ice area at the top of the figure is larger than of the dynamic tendencies

before



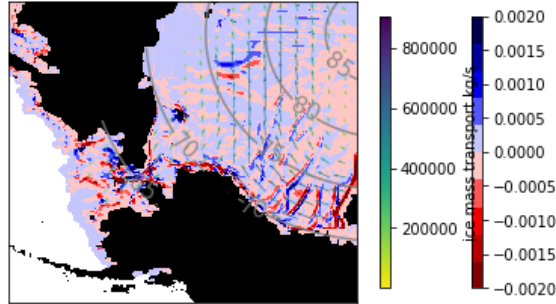
Longwave down with 10m wind field.



Before the Pacific intrusion event, the longwave down field is “calm”. In this plot one can see latitude lines.

Dynamic sea ice
tendency ($\text{kg s}^{-1} \text{m}^{-2}$)

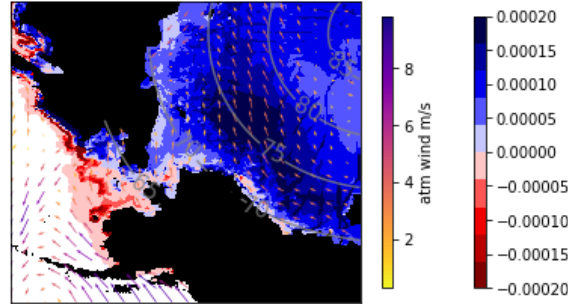
dynamic ice mass tendency $-3.08\text{E}+07$ kg per second



The ice transport slowed down
because the wind field turns with
the incoming moisture event.

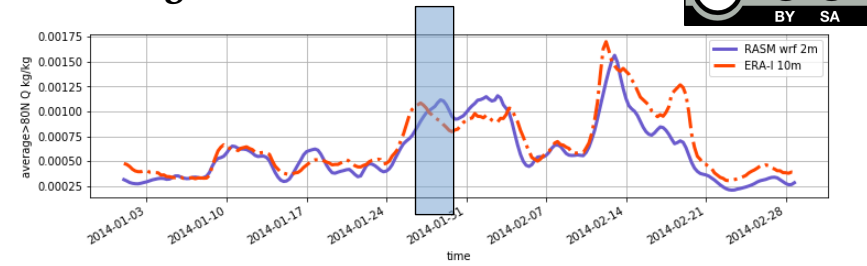
Therodynamic sea ice
tendency ($\text{kg s}^{-1} \text{m}^{-2}$)

2014/01/28 thermondyn ice mass tendency $4.30\text{E}+08$ kg/s

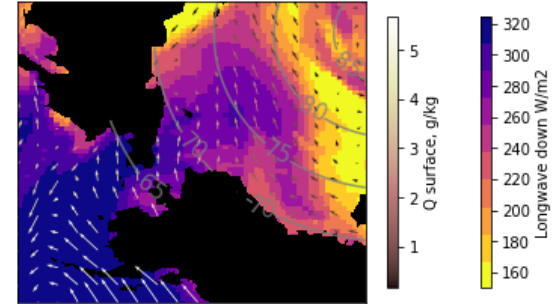


The longwave down field shows the influence
of the incoming water vapor. The
thermodynamic ice tendency is still negative so
there is not instanteneous melt response
because the ice internal balance (T,S) first
needs to adapt.

during

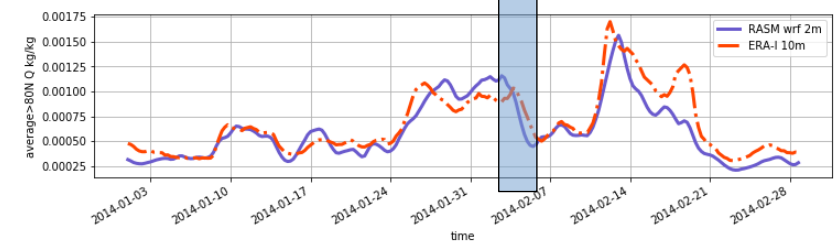


Longwave down
with 10m wind field.

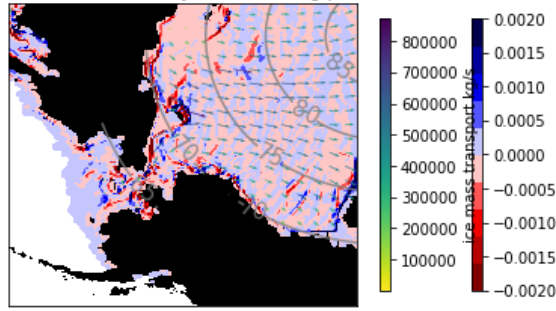


The impact on the internal ice balance takes a couple of days. 5 days after the longwave down forcing, one can observe a zero/negative thermodynamic sea ice tendency (melt), but it is very small

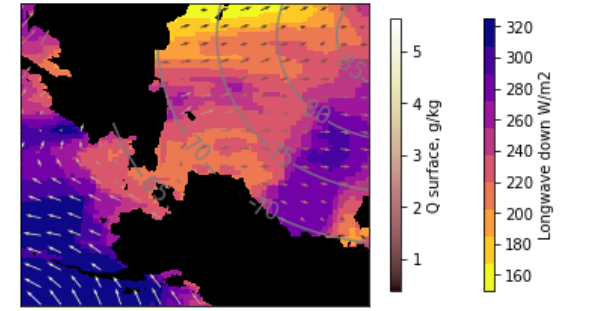
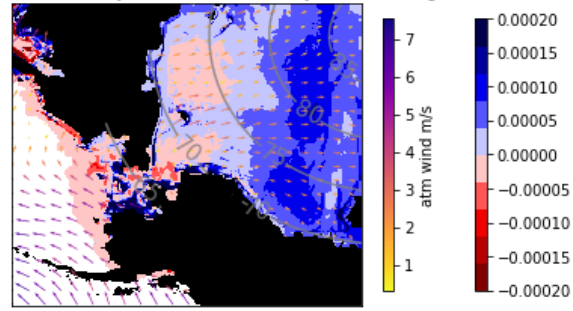
after



dynamic ice mass tendency $-1.42\text{E}+08$ kg per second

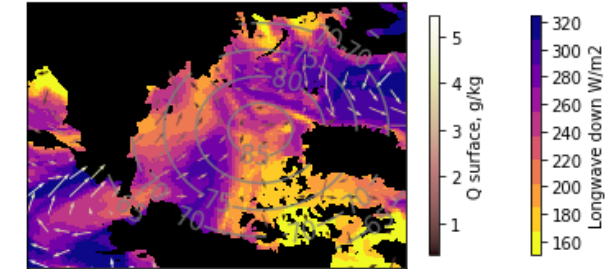
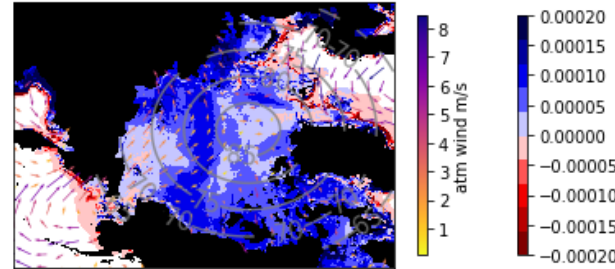


2014/02/04 thermodyn ice mass tendency $2.26\text{E}+08$ kg/s



A similar figure for a larger part of the model domain shows than the day before the figure above, the longwave down field shows that a large part of the Arctic is covered in water vapor rich air. The pacific and atlantic side show almost zero thermodynamic ice tendencies.

2014/02/03 thermodyn ice mass tendency $7.68\text{E}+08$ kg/s

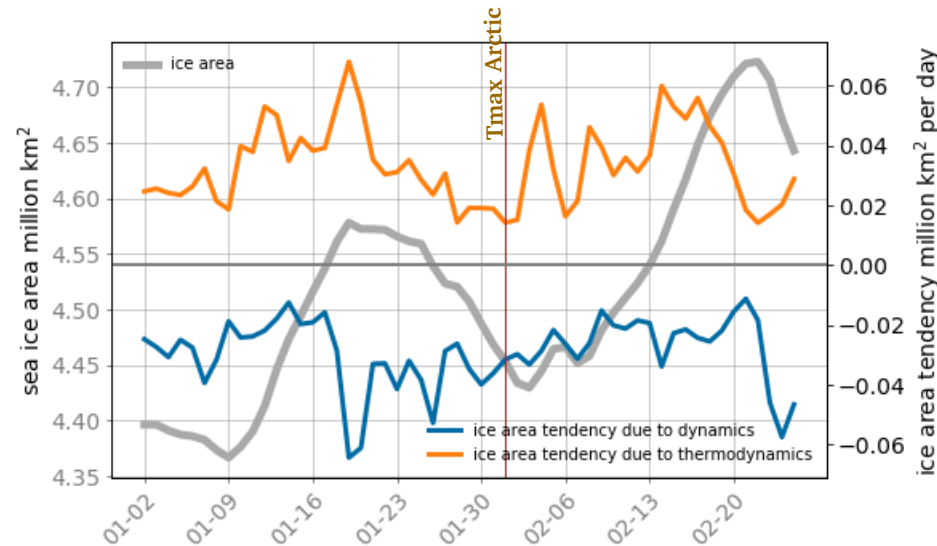


What is the thermodynamic versus dynamic sea ice response during a warm moist air intrusion event?

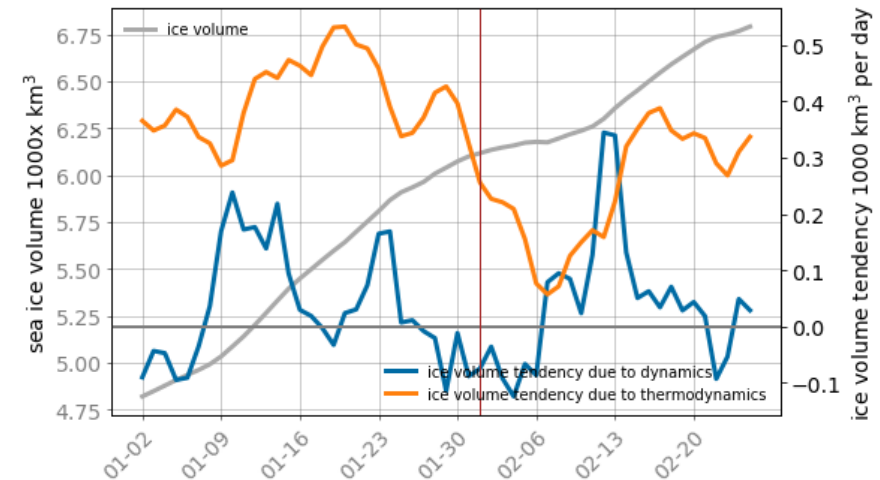


For the region on the Pacific side of the Arctic basin as showed in previous slides the sum over the area is shown :

- The sum of the sea ice tendencies due to DYNAMICS for AREA is always negative, which means that this regions on the pacific side always loses ice likely though Bering strait.
- The sum of the sea ice tendency due to THERMODYNAMICS is always positive, which means that there is still a net growth of sea ice.



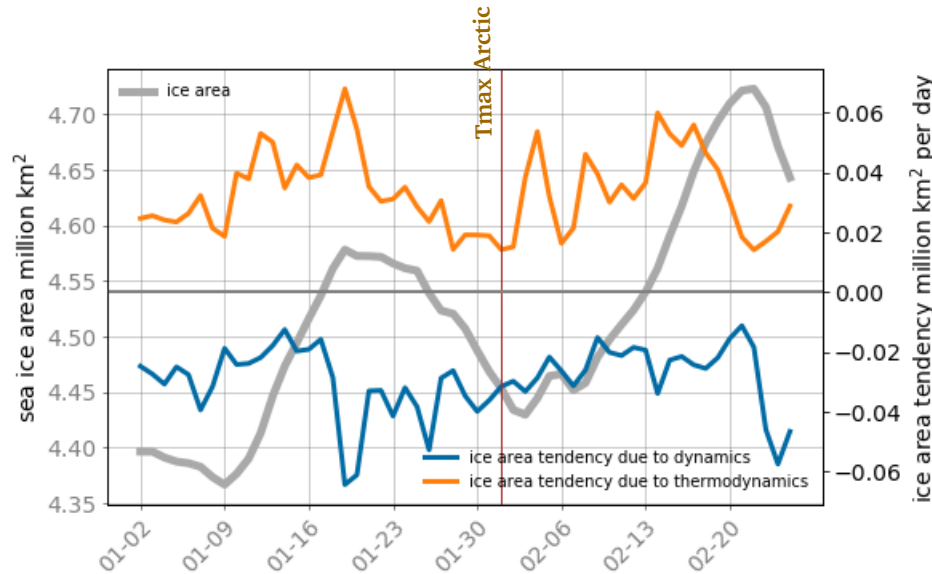
- The sum of the sea ice tendencies due to DYNAMICS for VOLUME (blue) is often positive, which means that even though the tendencies are negative for area, the volume is still increasing due to dynamics (ridging?).
- The sum of the VOLUME sea ice tendency due to THERMODYNAMICS is always positive, but there is a clear dip 5 days after the temperature maximum in the central Arctic. This likely indicates a slow down of the growth rate of sea ice which has an impact ~20 days.



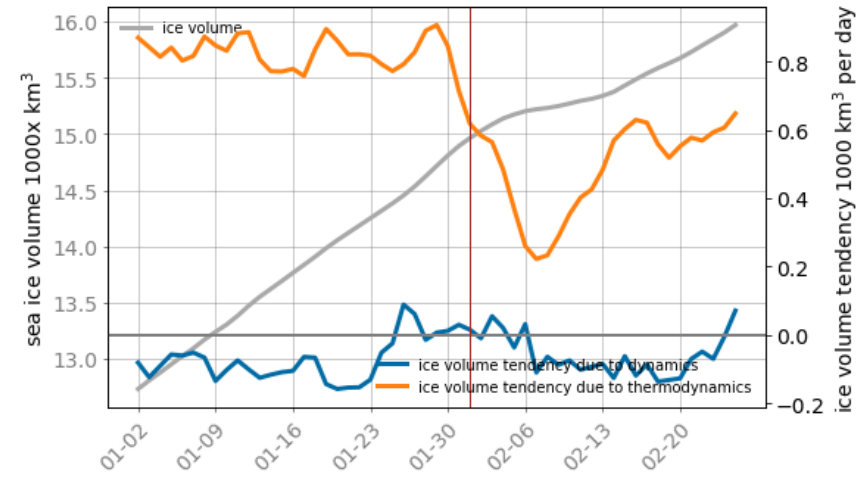
What is the thermodynamic versus dynamic sea ice response during a warm moist air intrusion event?

These figures are for the region Northward of 70 degrees latitude, commonly used as “Arctic”.

- The sum of the sea ice tendencies due to DYNAMICS for AREA is always negative, which means that this regions on the pacific side always loses ice likely though Bering strait.
- The sum of the sea ice tendency due to THERMODYNAMICS is always positive, which means that there is still a net growth of sea ice.



- The sum of the sea ice tendencies due to DYNAMICS for VOLUME (blue) is often negative, which indicates that the “>70N Arctic” loses ice volume by dynamics by export. Interestingly, the period when the intrusion comes in, it seems that the wind divergence is such that there is no net ice loss from this >70N region.
- The sum of the VOLUME sea ice tendency due to THERMODYNAMICS is always positive, but there is a clear dip 5 days after the temperature maximum in the central Arctic. This likely indicates a slow down of the growth rate of sea ice which has an impact ~ two weeks..



The video in the link the net surface heat flux over sea ice

<https://drive.google.com/open?id=1QlvEBKpR7h5uMr0pdvBiSMK5h79o9FGD>

Blue colors indicate a negative heat flux, which means from the surface upwards. As long as the net surface heat flux is negative, one expects growth of sea ice.

At some point, the moist air intrusion on the pacific side leads to positive imprint of the surface heat flux (longwave downward radiation from clouds)

Things to note:

- After the intrusion from the pacific side, the atmospheric field is such that the surface flux turn positive almost in the whole central Arctic. This is also the day that the maximum temperature $>80\text{N}$ is recorded in ERA-Interim (Messori et al. 2018)
- Deep purple colors in leads, where strong sea ice growth is expected.
- The moisture intrusions do not seem to increase the amount of leads.

What is the thermodynamic versus dynamic sea ice response during a warm moist air intrusion event?



Moist warm air intrusions events have been related to sea ice decline and melt in winter. (Woods and Cabellero 2015, 2016, 2018, Messori et al. 2018, Binder et al. 2017, Yao et al. 2018) in reanalyses studies, based on SIC concentration.

During week of 29-01-2014 until 04-02-2014 an event of advection of warm moist air occurred on the Pacific side of the Arctic. This event was picked based on moisture and latent energy advection analysis in ERA-I.

What is the importance of sea ice advection for the sea ice concentration on different spatial scales? Advection seems to dominate the negative terms in the sea ice concentration tendencies. Arctic wide, the thermodynamic terms dominate the total sea ice tendencies.

The sea ice growth is slowed down after the moisture intrusion, there is a delay between the maximum temperature and the thermodynamic sea ice tendency $\sim 5-7$ days (In line with Persson et al 2017). It takes time for forcing signal to affect bottom melt. However, there is no real net melt, it is always a balance between dynamics and thermodynamics.

The sea ice area tendencies due to dynamics are not as clearly related to the moist air intrusion as the volume (thickness). To draw conclusion that a decline in sea ice concentration is thermodynamically driven seems incorrect for this case study.

Future questions:

- what is the net effect on surface energy balance?

- Do these intrusions lead to more leads opening up (what is the imprint on the wind divergence)?

- What is the effect on ice growth on the long term?

- How to compose good budgets over a phenomenon that is moving?

- This is only for one event, what about other events? It would be interesting to look at long term dataset and pick out more events.

Thanks to:

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Robert Osinki*

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*Sonja Murto, Rune G. Graversen, Gabriele Messori,
Pasha Karami, Cian Woods, Richard Bintanja
Johan Nilsson, Gunilla Svensson*

Thanks for your attention!

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Referred literature:

Binder, H., Boettcher, M., Grams, C. M., Joos, H., Pfahl, S., & Wernli, H. (2017). Exceptional air mass transport and dynamical drivers of an extreme wintertime Arctic warm event. *Geophysical Research Letters*, 44(23), 12-028.

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