KOPRI's interests on the Arctic sea ice study with international collaborations

1) Melting season excursion to the marginal ice zone in the Arctic Ocean

2) Freezing season observations of the high heat flux event

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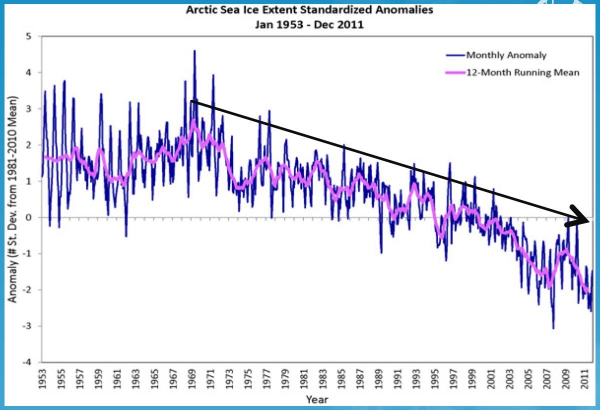
Goals of the Arctic sea ice study

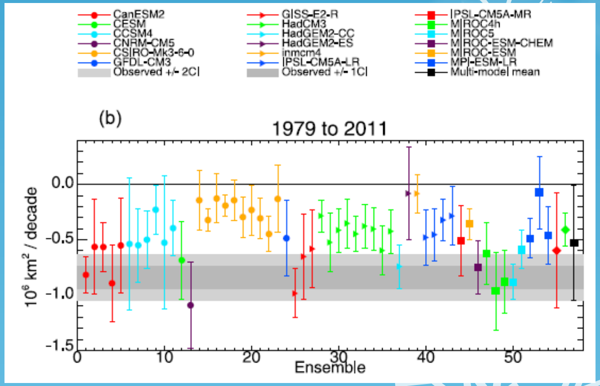
- Successful collaboration of the field scientists and the modelers
- Understanding the physical processes of the seasonally-varying ice state
- Develop improved and generalized parameterizations of the sea ice model of global climat e models
- Bring up a young expert on the sea ice theory and modeling through the collaboration with world-class experts

1) Melting season excursion to the marginal ice zone (MIZ)

- Our common interest in the Arctic Ocean
  - The rapid decline of Arctic sea ice
    - The result from the complex interaction of the whole climate systems a nd the additional ingredients from global warming
    - The increase of the portion of seasonal ice (first year ice)
    - A contributing factor for Arctic amplification?
  - Performance of the global climate models
    - The sea ice thickness model
      - A key component of global climate models
      - Considers atmospheric heat fluxes, conduction through sea ice an d ocean heat flux
      - Provides us with a reasonable seasonal cycle of sea ice thickness
    - Underestimate the recent decline of sea ice and fail to agree on the ti ming of the disappearance in summer
    - The models are not equipped with a proper parameterization of variou s processes controlling the status of seasonally-varying ice
  - Understanding and predicting the future status of Arctic sea ice
    - An efficient combined network of observation, theory, and numerical si mulation, connecting various scale physical systems
    - The importance of in-situ observations leading to a generalized param eterization in the climate models



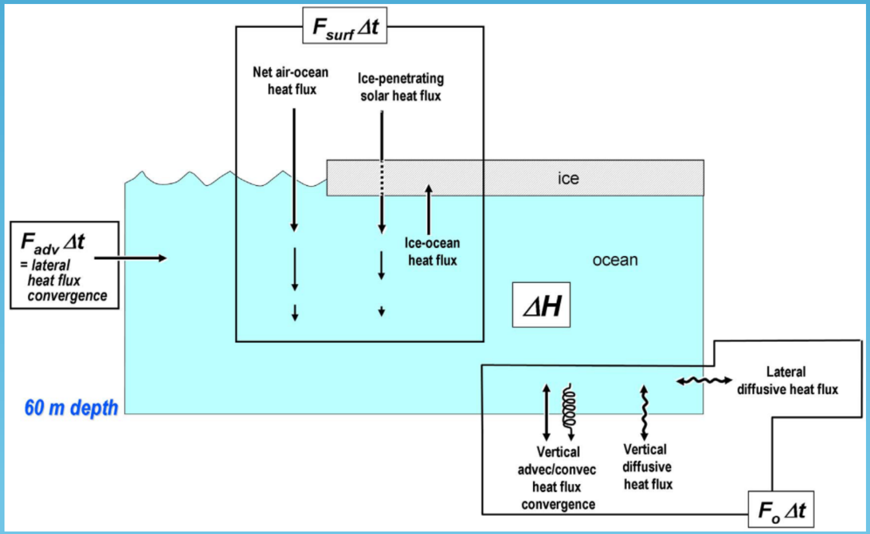
Mean sea ice anomalies, 1953-2011♪



September trends from 1979–2011 for all indi vidual model ensembles as well as the multi-model ensemble mean with confidence interv als (vertical lines). The 1σ and 2σ observed tren ds are shown in dark gray shading (1σ) and light gr ay shading (2σ). (Stroeve et al., 2012)♪

1) Melting season excursion to the marginal ice zone (MIZ)

- List of scientific topics of interest (tentative!)
  - The variability of atmospheric turbulent heat and radiative fluxes with cloud forcing
  - The eddy activity in the atmospheric boundary layer over the heterogeneous sea ice surface
  - The response of the atmospheric geostrophic motions over sea ice depending on the status of sea ice
  - The lateral heat flux from ocean mixed layer to sea ice
  - The evolution of lateral boundary of sea ice
  - The structure of the oceanic boundary layer below sea ice associated with brine rejection
  - The effect of sub-mesoscale ocean eddies upon the ocean heat flux



Schematic heat budget of the upper 60 m of the Arctic Ocean Steele et al. (2010)

1) Melting season excursion to the marginal ice zone (MIZ)

- A plan to carry out a pilot study in summer of 2014…
  - Not enough funds in 2014
  - Focusing on localized small-scale processes with limited participants and instruments
  - The plan will be developed in the near future... (within October)

- Can we initiate a large-scale study of sea ice in the MIZ after 2015?
  - Limitations
    - Limited in-house man power
    - Lack of experiences: the KOPRI's first plan targeting in-situ observations of Arctic sea ice
    - The region of ARAON's Arctic excursion as well as our funding is not yet decided.
  - Opportunities
    - Probability of funding: governmental high interest on the Arctic study
    - The utility of the ARAON and the Arctic Dasan Station in Svalbard, Norway
    - The expertise of potential international collaborators

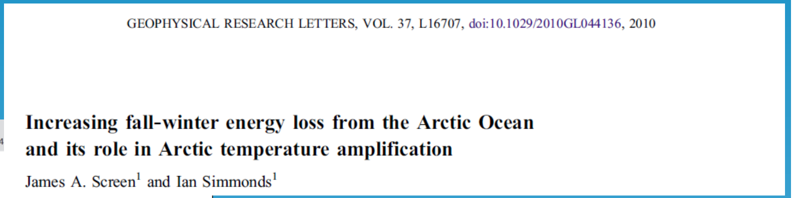
1) Melting season excursion to the marginal ice zone (MIZ)

- Potential external participants
  - John S. Wettlaufer: Prof. of Applicable Mathematics in the Univ. of Oxford & Bateman Prof. of the Dept. of Geophysics, Physics and Applied Mathematics in Yale Univ.
  - Mary-Louise Timmermans: Assistant Prof. of the Dept. of Geology & Geophysics in Yale Univ.
  - Grae Worster: Prof. of the Dept. of Applied Mathematics and Theoretical Physics in the Univ. of Cambridge
  - Woosok Moon: Postdoc of the Dept. of Applied Mathematics and Theoretical Physics in the Univ. of Cambridge
  - Phil Hwang: Research Associate in Sea Ice Remote Sensing in the Scottish Association for Marine Science
  - Edgar L. Andreas: North West Research Associate

  - There will be more field observation and modeling experts…

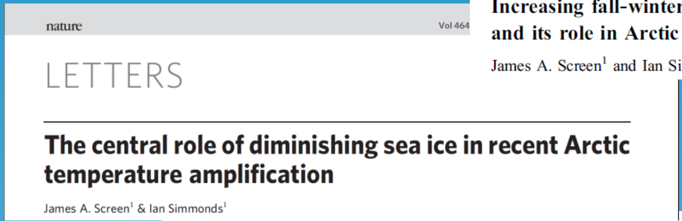
2) Freezing season observations of the high heat flux event (HHFE)

- Why the air-sea boundary heat flux in the freezing season?


GEOPHYSICAL RESEARCH LETTERS, VOL. 37, L16707, doi:10.1029/2010GL044136, 2010

Increasing fall-winter energy loss from the Arctic Ocean and its role in Arctic temperature amplification

James A. Screen[1] and Ian Simmonds[1]


nature Vol 464

LETTERS

The central role of diminishing sea ice in recent Arctic temperature amplification

James A. Screen[1] & Ian Simmonds[1]

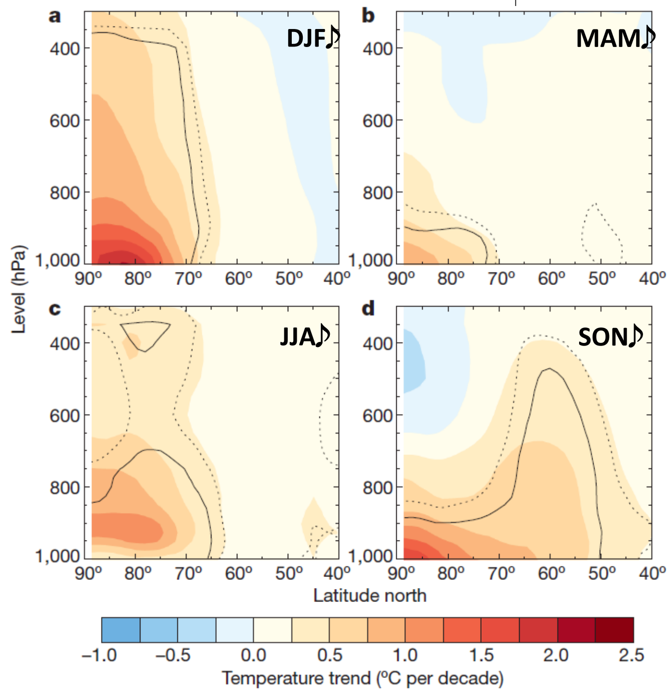
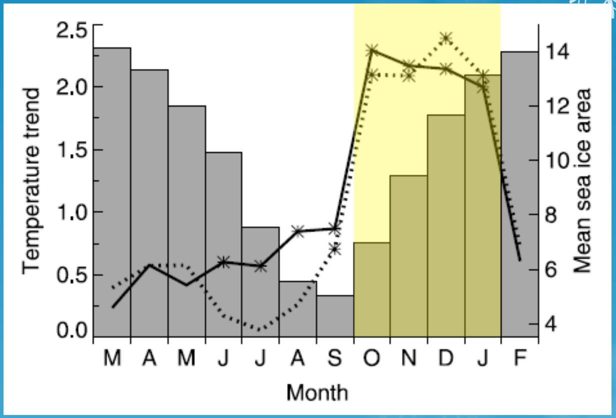
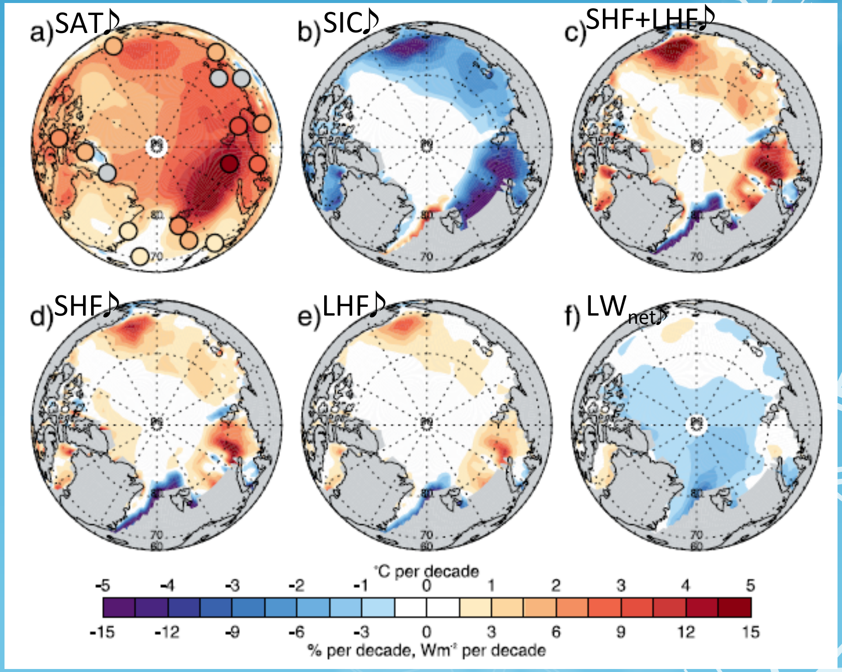


Figure 2 | Temperature trends linked to changes in sea ice. Temperature



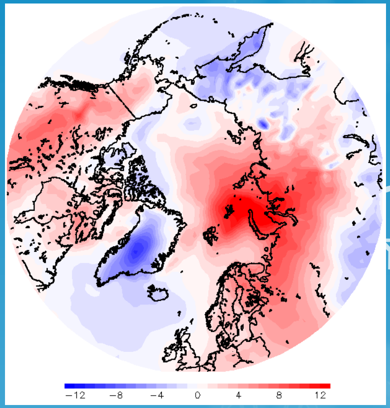
October-November-December (1989-2009)



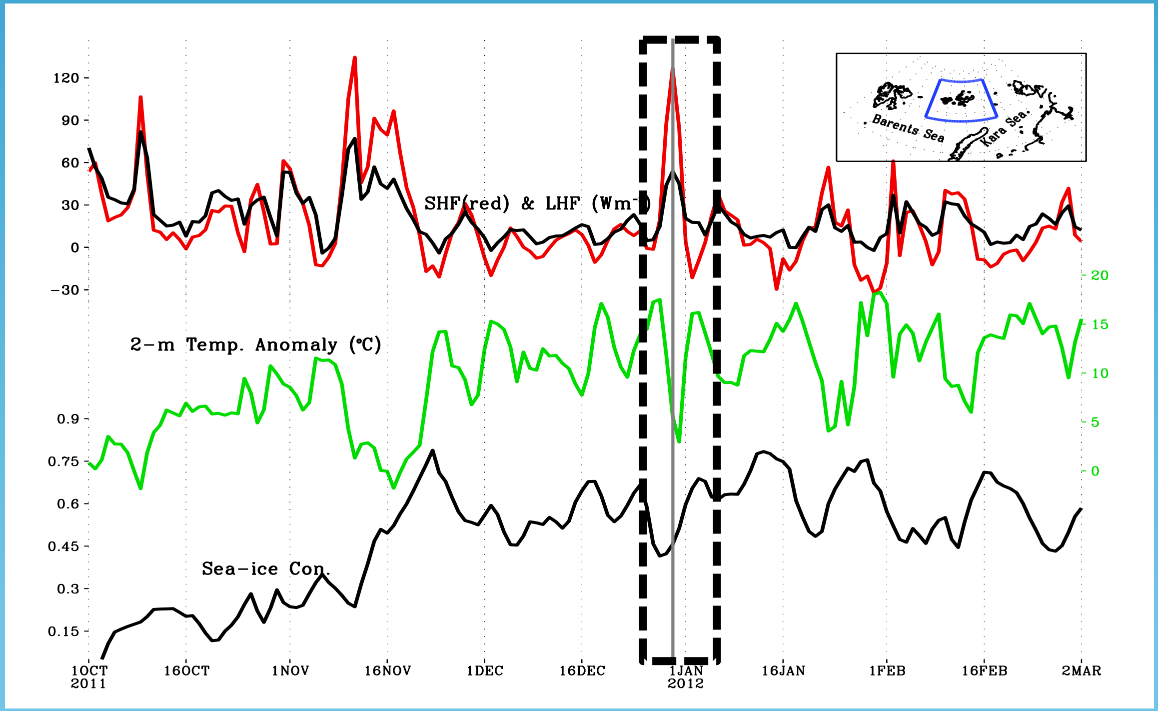
2) Freezing season observations of the high heat flux event (HHFE)

- We carried out some preliminary works for the early winter of 2011 when th e surface air temperature over the Arctic Ocean was excessively warmed u p.
  - ERA-interim reanalysis data
  - Radiosonde vertical sounding
  - Polar WRF model

2-m temperature anomaly (DEC2011)♪

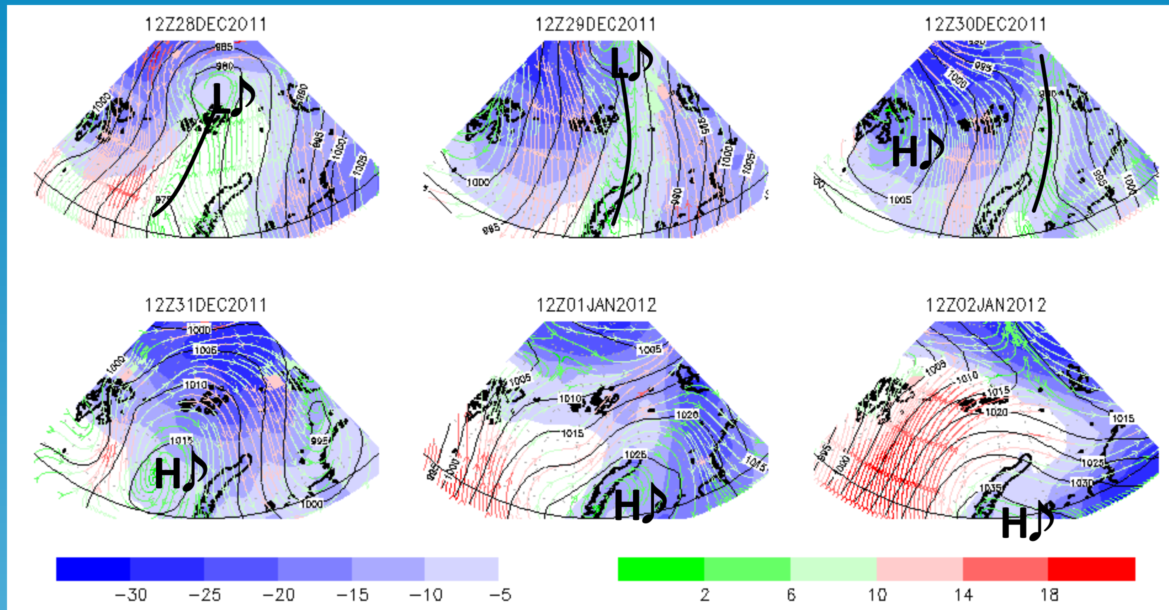


ERA-interim reanalysis♪



2) Freezing season observations of the high heat flux event (HHFE)

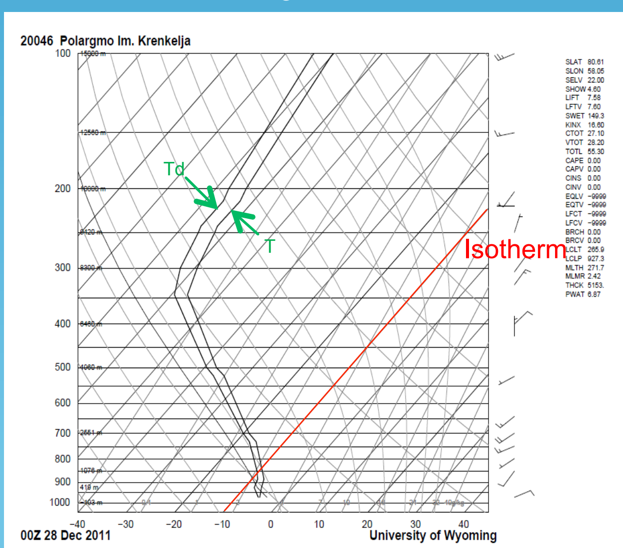
ERA-interim reanalysis

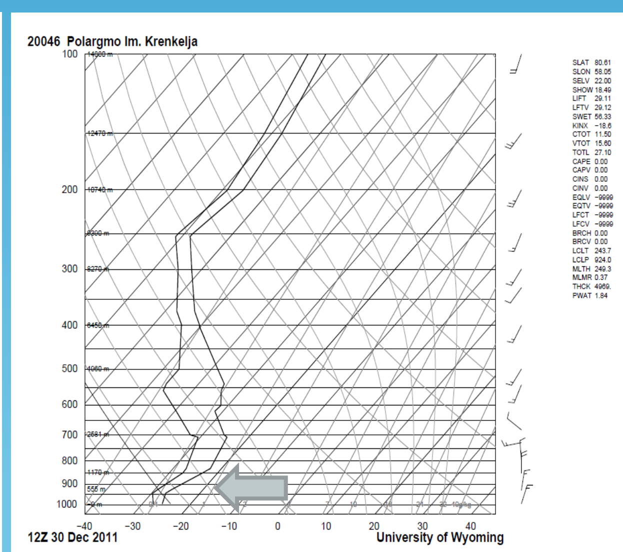


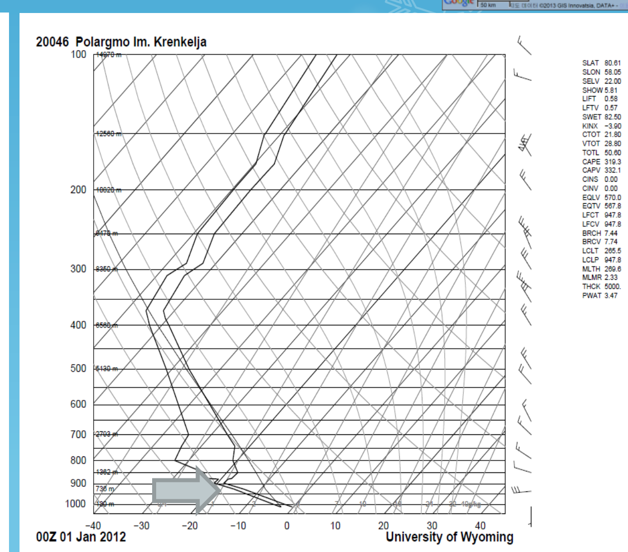
2-m Air Temperature (°C)

10-m Horizontal Wind Speed (m/s)

Radiosonde sounding

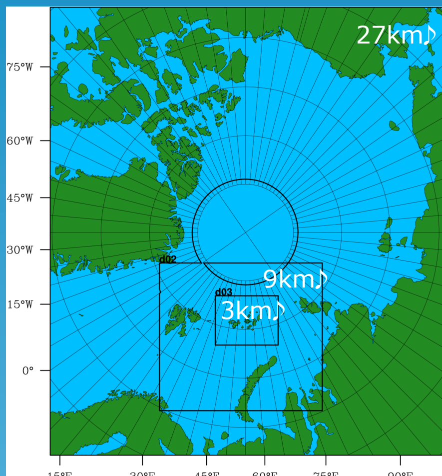


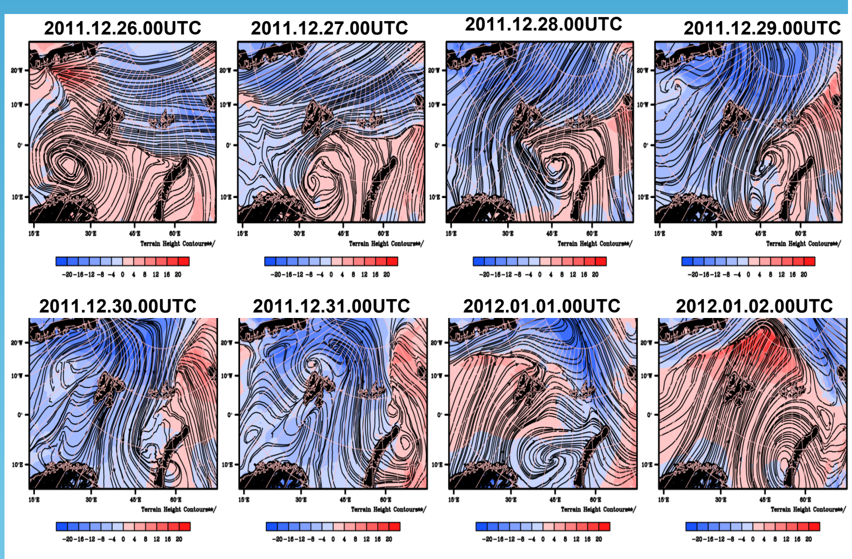


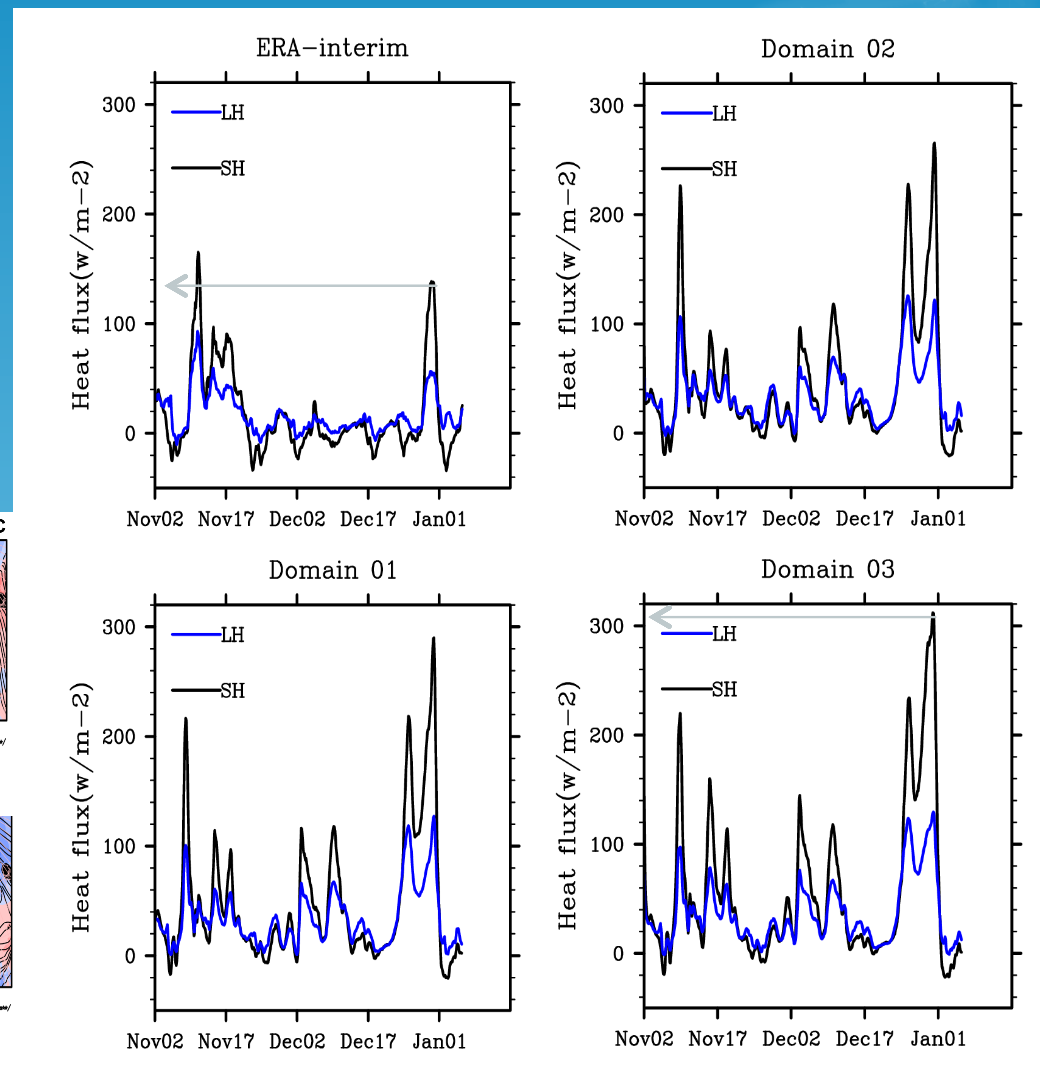


2) Freezing season observations of the high heat flux event (HHFE)

Polar WRF simulation (w/ two-way nesting, w/ grid nudging above PBL)♪







◆Heat flux in Polar WRF ♪

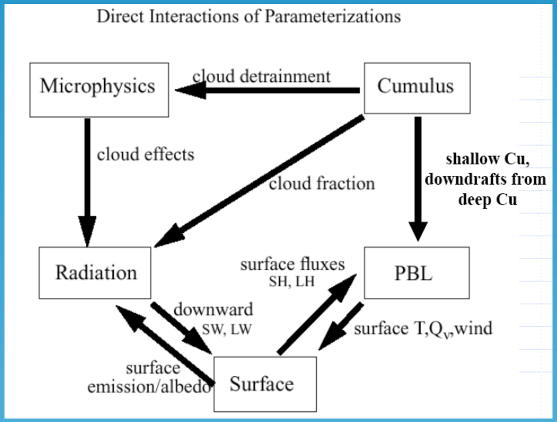
• **Parameterization for sensible heat flux**

♪

$$\theta_* = -\overline{\theta' W'} / u_*$$

$$\theta_* = \frac{k(\theta - \theta_0)}{\Pr\left[\ln(\frac{z}{z_0}) - \psi_h\right]}$$

The turbulent Prandtl number Pr is set to 1 in the model, as suggested by Webb(1970).
Ψh has its own equations.♪



▶ **Weather Research and Forecasting model (WRF)**
♪

• **Parameterization for latent heat flux**
follows Carlson and Boland (1978)

♪

$$q_* = -\overline{q' w'} / u_*$$

(where q' represent fluctuations of humidity from the mean Q)
♪

$$q_* = \frac{Mk(Q - Q_s(\theta_0))}{\ln(\frac{ku_* z}{k_a} + \frac{z}{z_1}) - \psi_h}$$

- z1 (top is the molecular sublayer) is set to 0.01.
- M is a moisture availability parameter defined by land-use category.
- Ka is the background molecular diffusivity set to 2.4x10-5 m2/s.

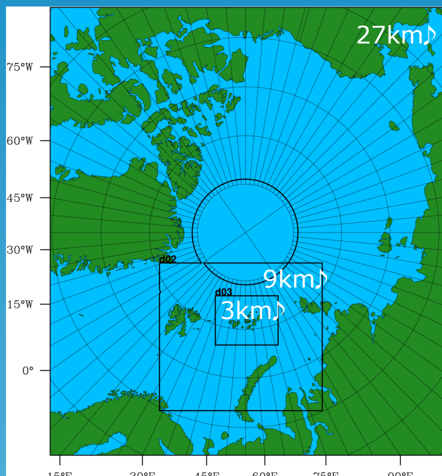
- Equations for u*, θ*, and q* are derived empirically from surface-layer data.♪

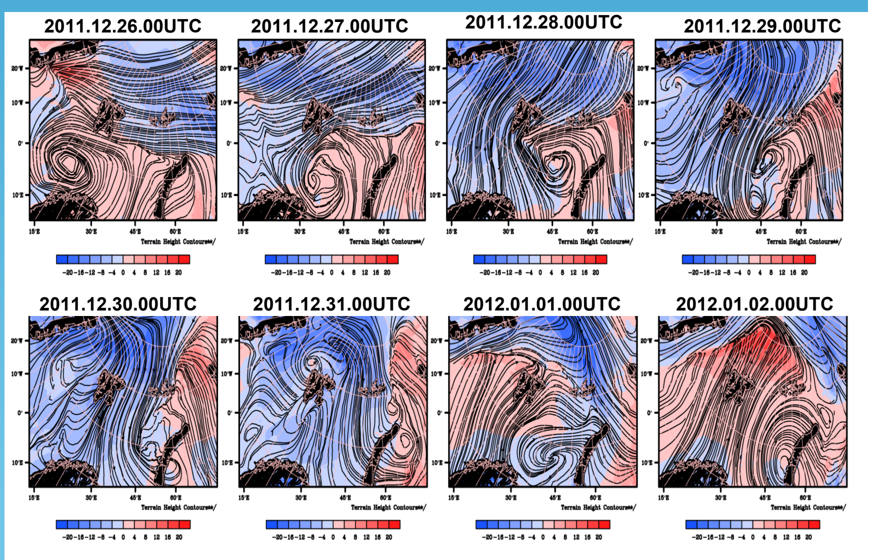
Domain	Domain 1	Domain 2	Domain 3
Horizontal grid	170 x 192	214×190	241×187
Resolution	27㎞	9㎞	3㎞
Vertical layers	44 Layers		
Geog data resolution	10m′	5m′	2m′
Initial data	ERA-Interim (6-hour intervals with a spatial resolution of 0.25°×0.25°)		
Time period	2011.11.01. 00 UST ~ 2012.01.06.00 UST		
Grid nudging	O	X	X
Nudging coefficient for u, v, temp, qvapor	0.0003	X	X

Physics scheme	
mp_physics	WRF Single-Moment 6-class
ra_lw_physics	RRTMG scheme
ra_sw_physics	RRTMG shortwave
sf_surface_physics	Noah Land Surface Model
sf_sflay_physics	MM5 similarity
bl_pbl_physics	Mellor-Yamada Nakanish and Niino Level 2.5 PBL
cu_physics♪	Grell-Devenyi ensemble
	Fractional sea ice♪

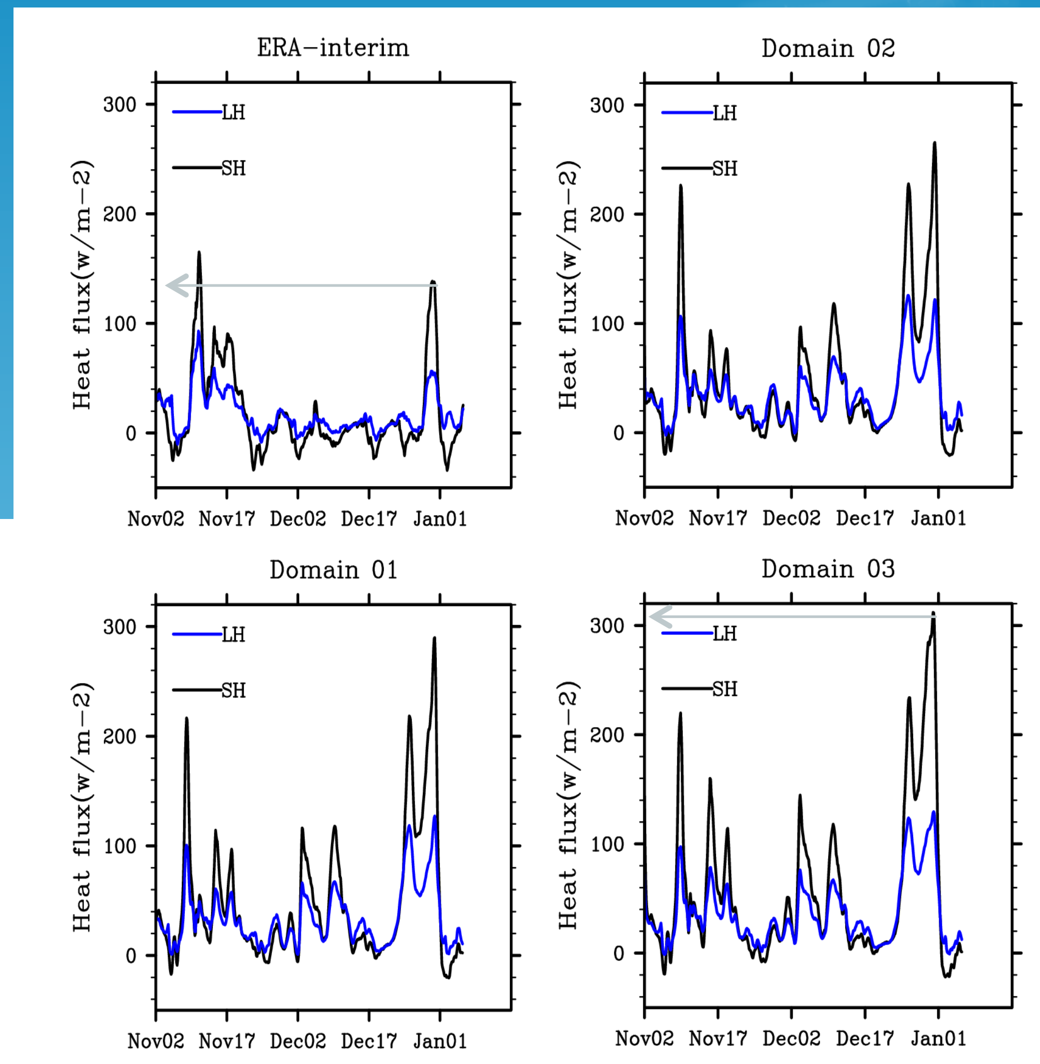
2) Freezing season observations of the high heat flux event (HHFE)

Polar WRF simulation (w/ two-way nesting, w/ grid nudging above PBL)





Area-averaged time series of turbulent heat fluxes around the Franz Josef Land, Russia



2) Freezing season observations of the high heat flux event (HHFE)

- The simulated total heat flux (sensible+latent) by the 3-km WRF model reached about 400 W/m^2 near the year-end of 2011, about twice as large as that from the ERA-interim.

- We need a reliable in-situ observation of the magnitude of such an event.

Melting season♪ → Freezing season(?)♪

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Energy budget of first-year Arctic sea ice in advanced stages of melt

Stephen R. Hudson,[1] Mats A. Granskog,[1] Arild Sundfjord,[1] Achim Randelhoff,[1] Angelika H. H. Renner,[1] and Dmitry V. Divine[1]

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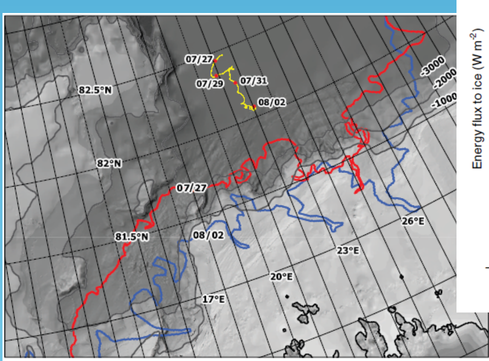
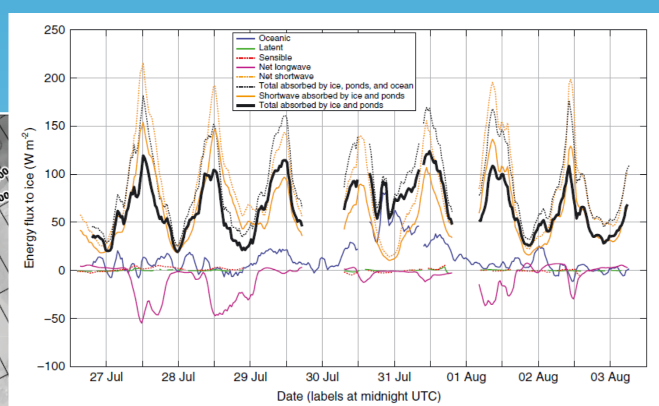
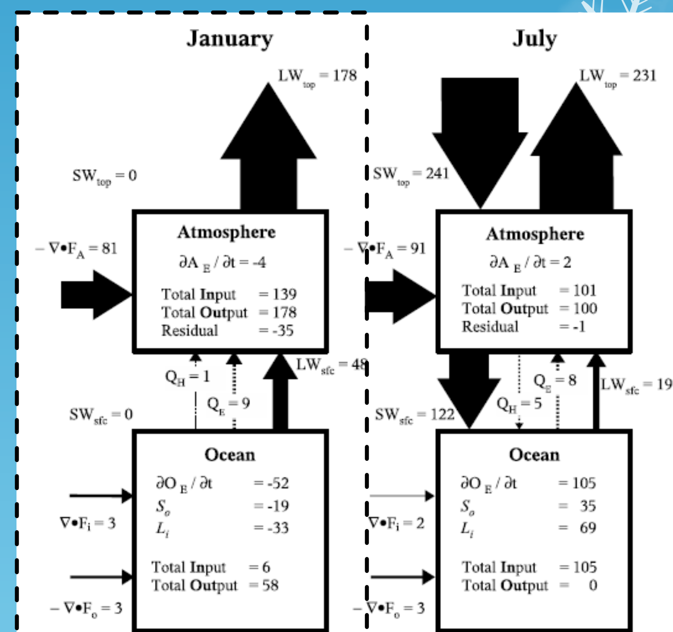


Figure 1: The yellow track shows the drift path of the ice floe during the study; red dots mark locations at noon on the given dates. Bathymetry is shown in the grayscale background, with contours at 1000-m intervals. The red and blue curves show the ice edge on two days, at the beginning and end of the data collection (defined as 40% ice concentration, based on ice charts from the Norwegian Meteorological Institute).





Serreze et al. (2006)♪

Observation strategy