Modeling Beaufort-Chukchi Sea Ice-Ocean Ecosystem Using Coupled CIOM-PhEcoM

Jia Wang
NOAA/GLERL

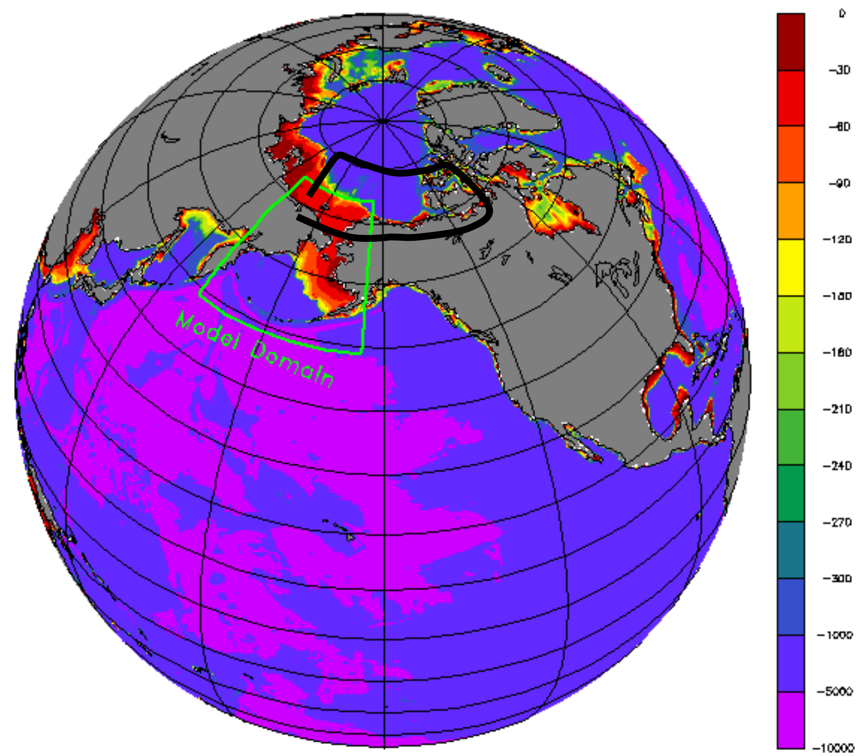
Haoguo Hu and Xuezhi Bai
CILER/UMich

- CIOM with fully dynamics and thermodynamics, multiple category ice thickness (ridging) ***(Wang et al. 2002, Manual/users' guide)***
- 3.8km and 21 level
- 6-hourly or daily forcing
- 3 configurations:

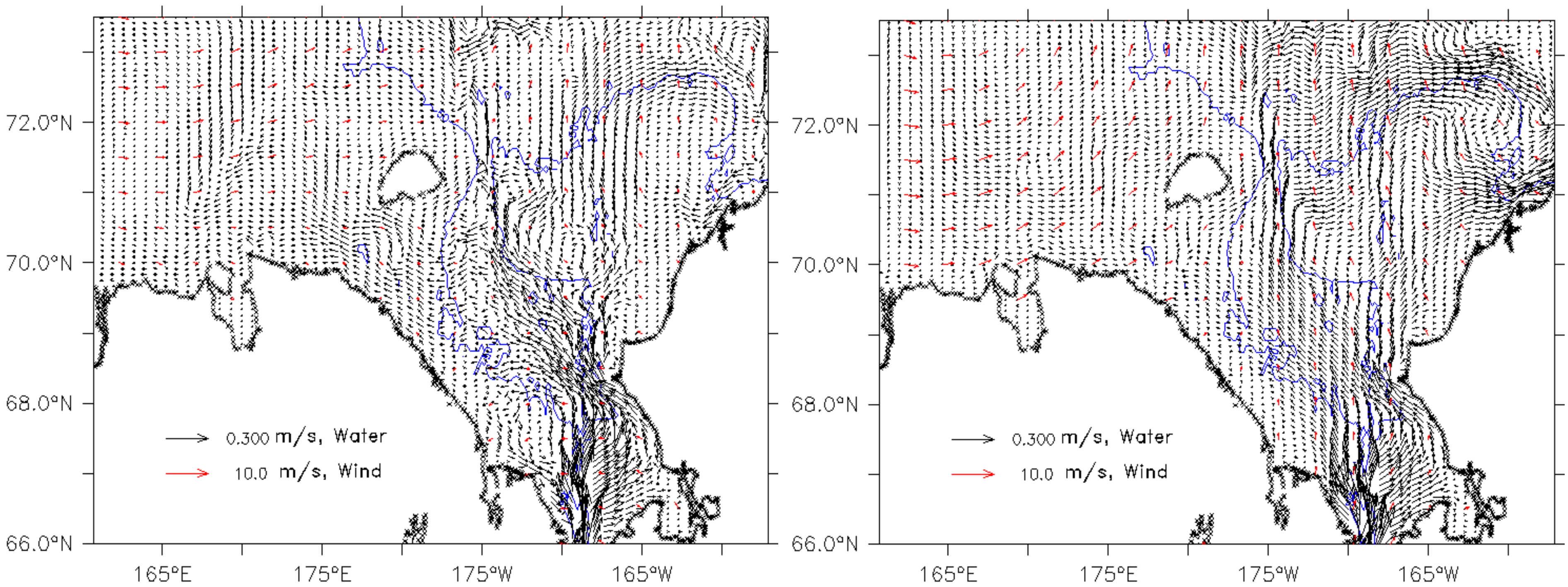
Bering Sea only (7-12km),
Beaufort-Chukchi only (3.8-7km),
Bering-Chukchi Sea (3.8-12km)

- Hypotheses test/RUSALCA synthesis
- Realistic simulation
- PhEcoM—***Ph***ysical-***Eco***system ***M***odel-NPZD

(Wang et al. 2003, manual/user's guide)

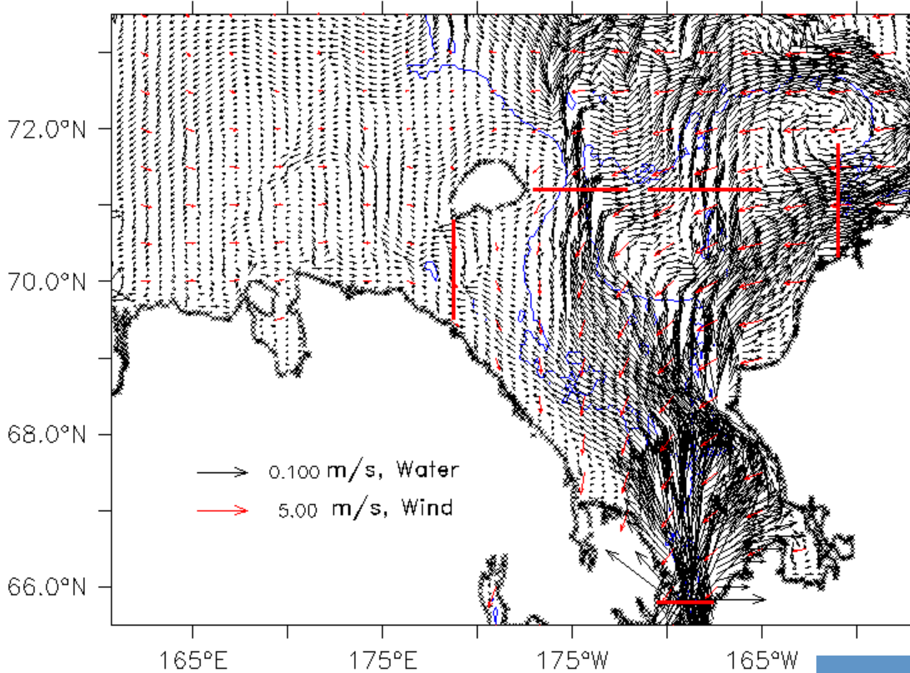


View From Space



RUSALCA 2004 2009

CIOM-simulated August depth-averaged currents in the Chukchi Sea ***(Hu et al, in prep)***



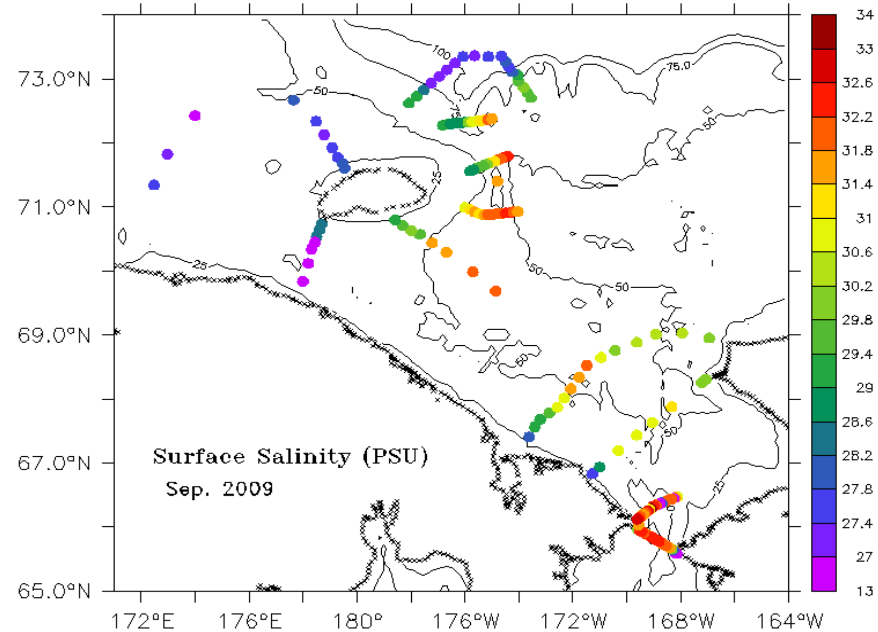


Table: Water transports in the Chukchi Sea in 2009, positive and negative values denote flowing into and out of Chukchi Sea, respectively.

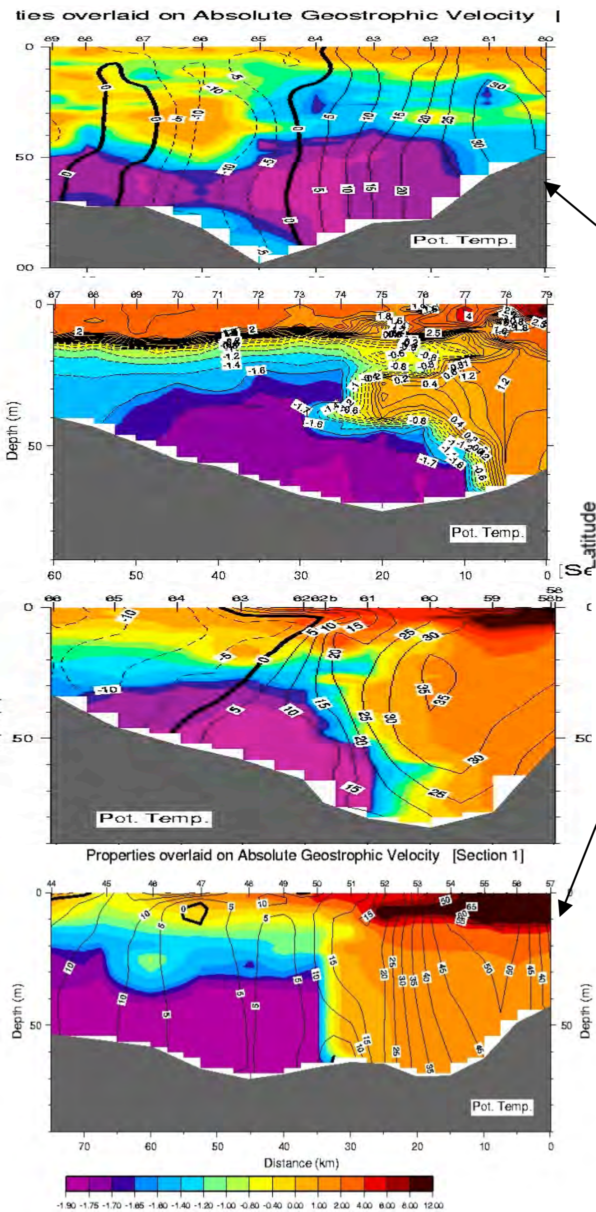
(freshwater flux and heat flux can be calculated and compared to JAMSTEC moorings)

Unit: $x10^6$ m^3	Mean	STD	Max	Min	Observations
Barrow Canyon	0.443	0.606	1.373	-1.419 (westward)	0.48 (itoh et al 2013)
Central Valley	0.269	0.302	1.120	-0.568 (southward)	0.2 ± 0.1 (Weingartner et al. 2005)
Herald Valley	0.248	0.364	0.835	-0.909 (southward)	0.1~0.3 (Woodgate et al 2004)
Long Strait	0.056	0.420	1.128	-1.147 (eastward)	??
Bering Strait	0.997	0.791	2.465	-0.982 (southward)	0.8 ± 0.2 (Woodgate et al. 2004)

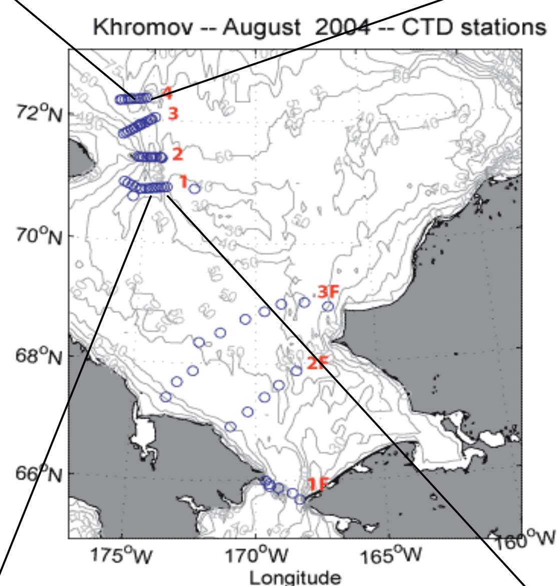
Verification of CIOM using 2004 RUSALCA Data (T&V) in the Bering-Beaufort-Chukchi Seas

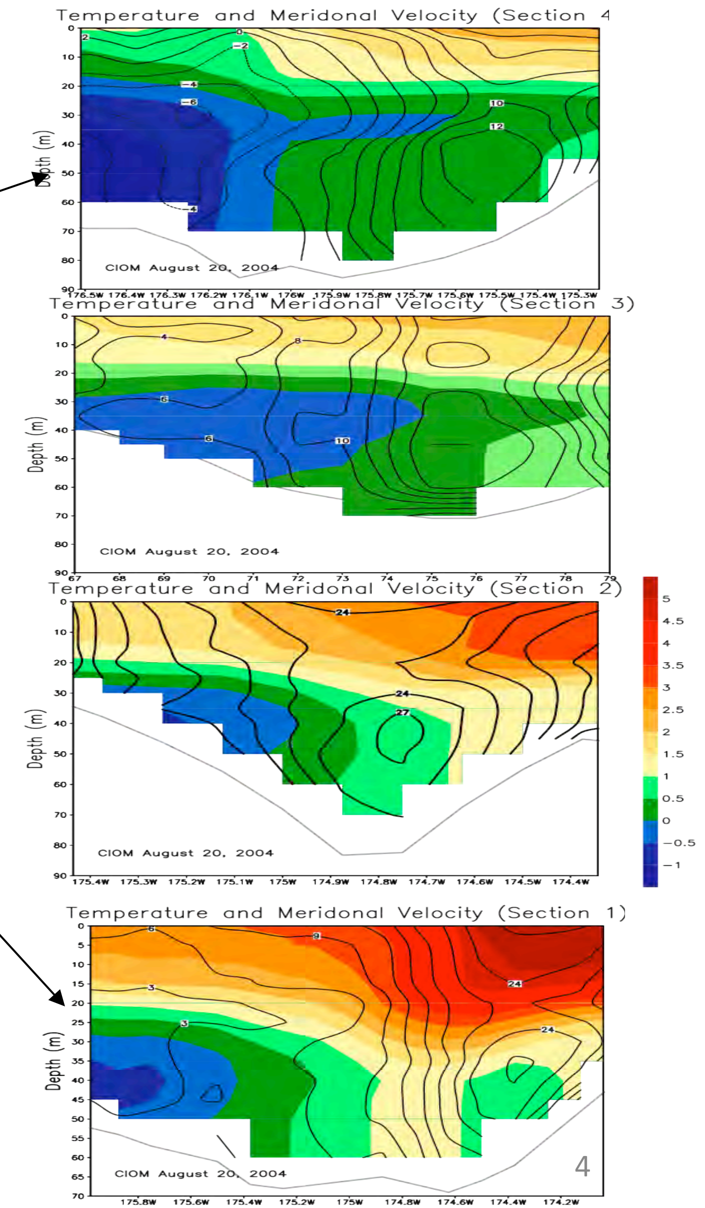
Observed (Pickart 2009)

CIOM-simulated (GLERL)



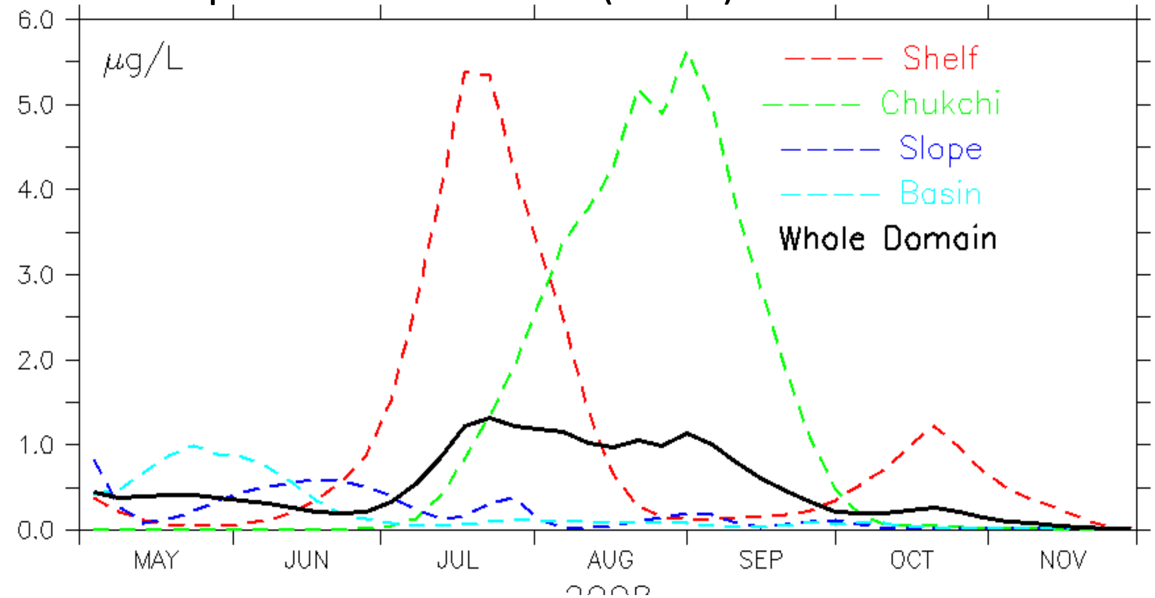
Aug 2004



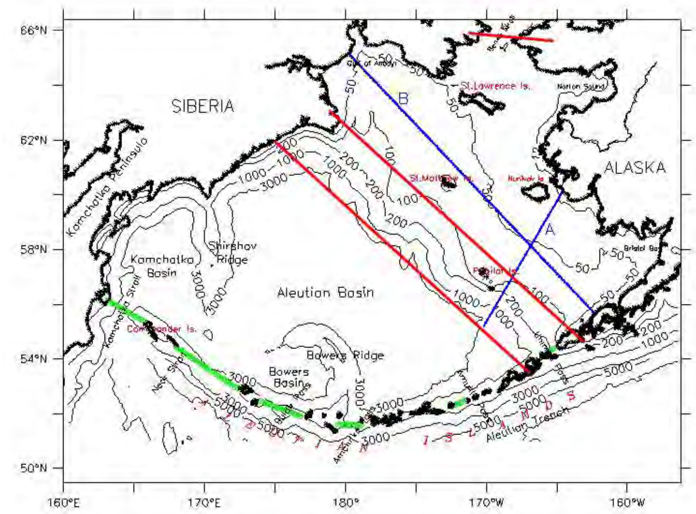


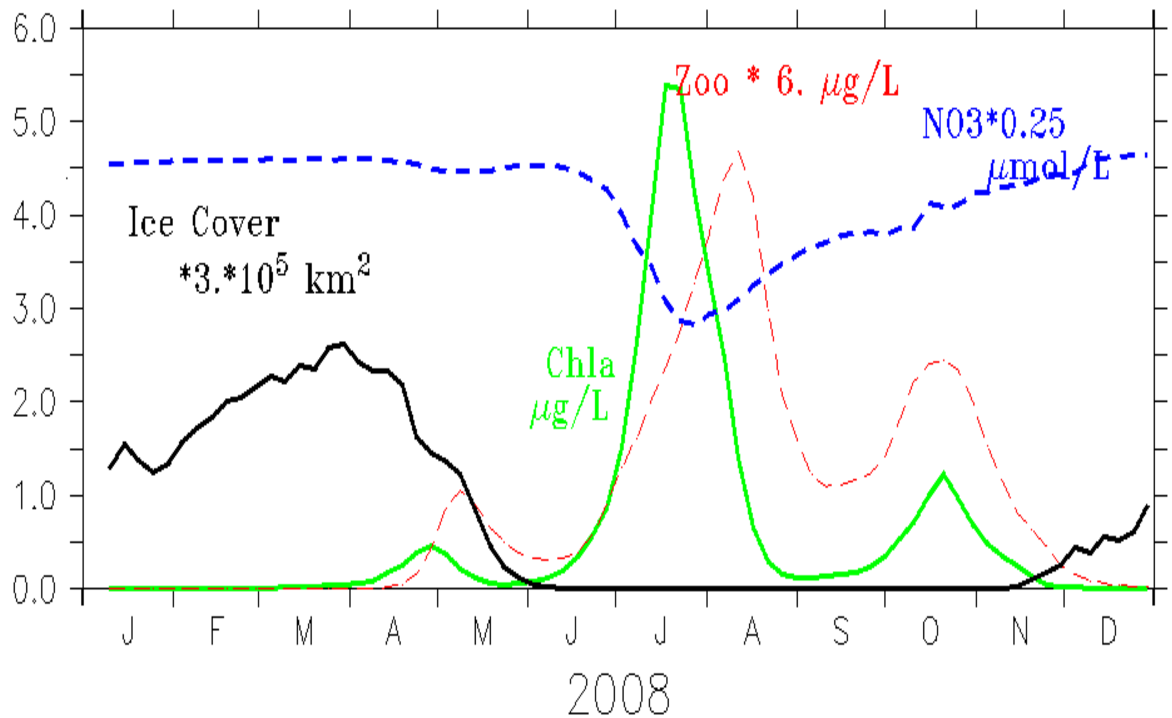
(Bai et al, in prep)

Coupled CIOM-PhEcoM (NPZD) model results



Regional Average



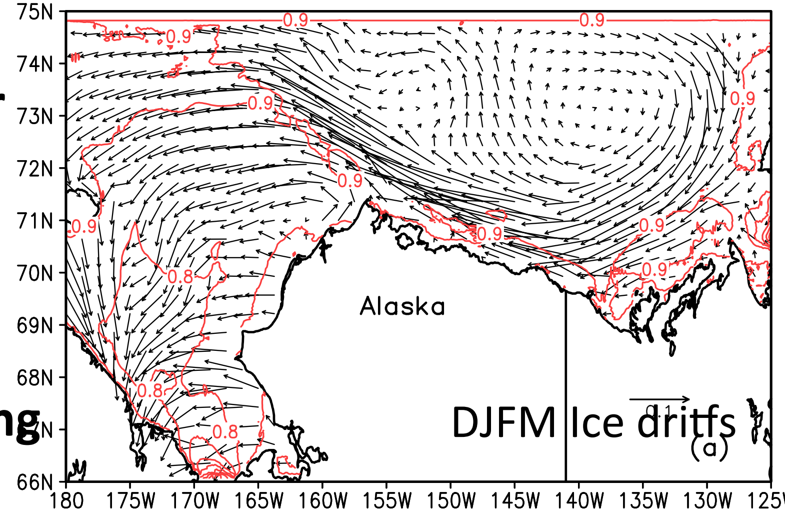


Wang et al. (2013, JGR)

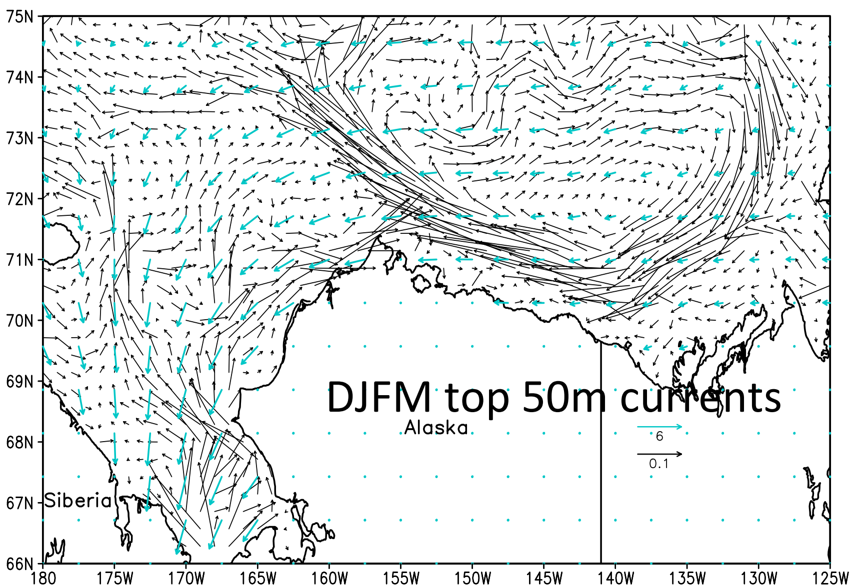
Shelf

Responses of the Chukchi-Beaufort Sea to storm passages during winter 2006/2007

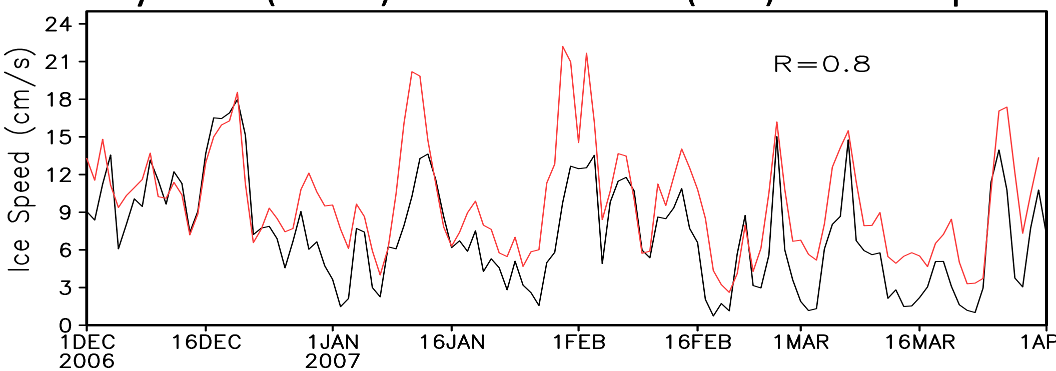
Xuezhi Bai and Jia Wang
U of Michigan, NOAA/GLERL

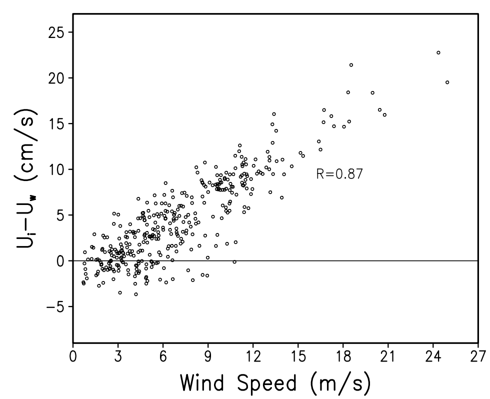


CIOM forced by NCEP2 6-hourly forcing



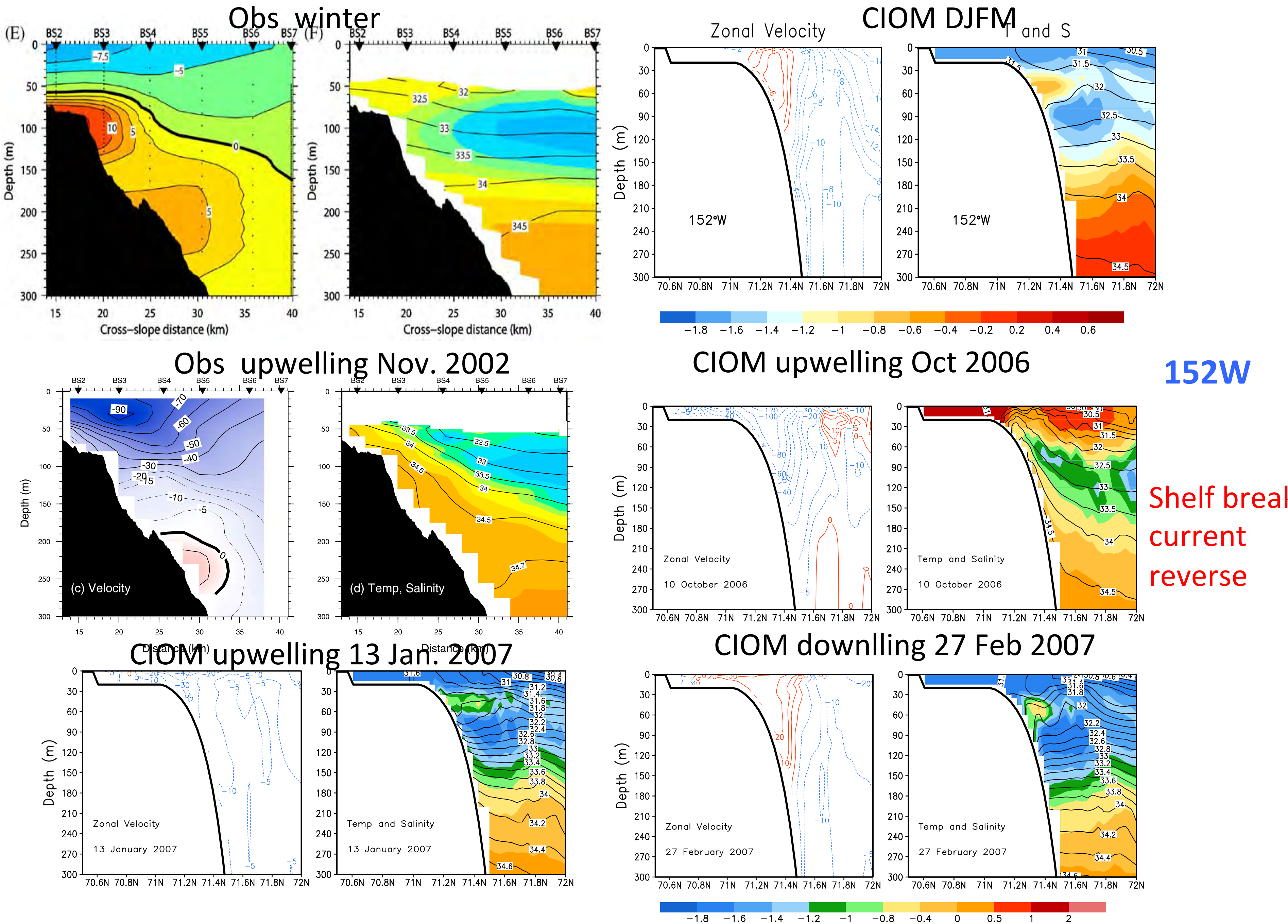
Daily Obs. (black) vs. simulation (red) sea ice speed



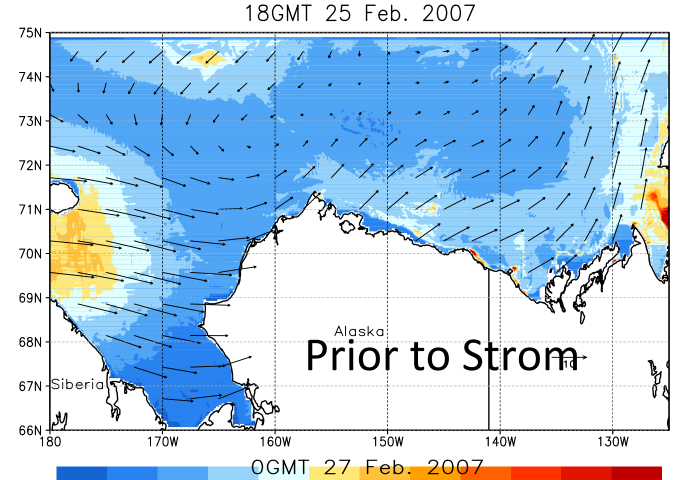


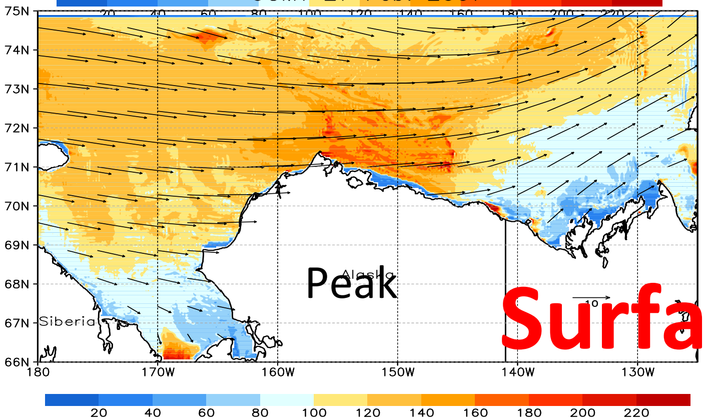
Difference of ice and water speed increases along with wind speed

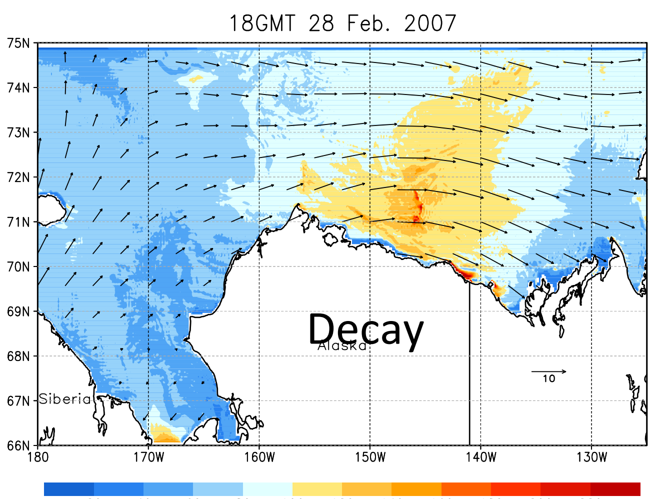
(Bai et al, submitted)

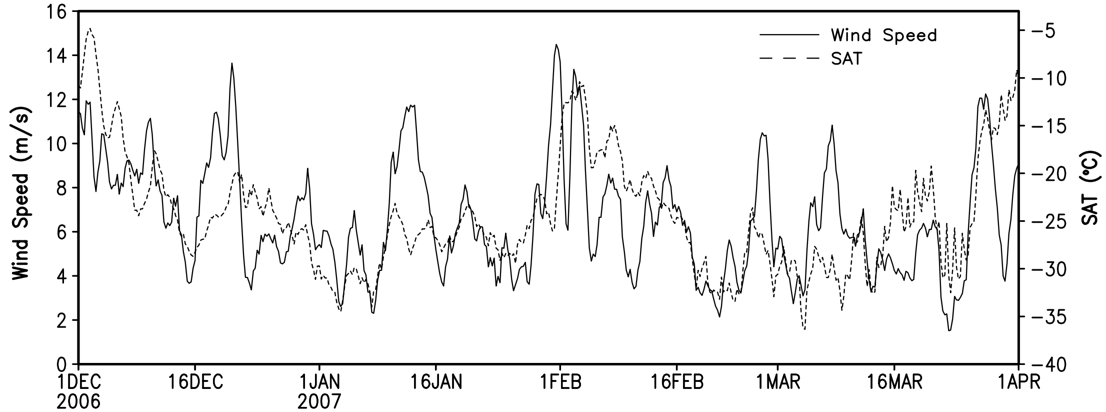

Obs winter
(E)
(F)
BS2
BS3
BS4
BS5
BS6
BS7
Depth (m)
Cross–slope distance (km)
CIOM DJFM
Zonal Velocity
T and S
152°W
Depth (m)
70.6N 70.8N 71N 71.2N 71.4N 71.6N 71.8N 72N
−1.8 −1.6 −1.4 −1.2 −1 −0.8 −0.6 −0.4 −0.2 0.2 0.4 0.6
Obs upwelling Nov. 2002
(c) Velocity
(d) Temp, Salinity
Distance (km)
CIOM upwelling Oct 2006
152W
Zonal Velocity
10 October 2006
Temp and Salinity
10 October 2006
Shelf break
current
reverse
CIOM upwelling 13 Jan. 2007
Zonal Velocity
13 January 2007
Temp and Salinity
13 January 2007
CIOM downlling 27 Feb 2007
Zonal Velocity
27 February 2007
Temp and Salinity
27 February 2007
−1.8 −1.6 −1.4 −1.2 −1 −0.8 −0.4 0 0.5 1 2

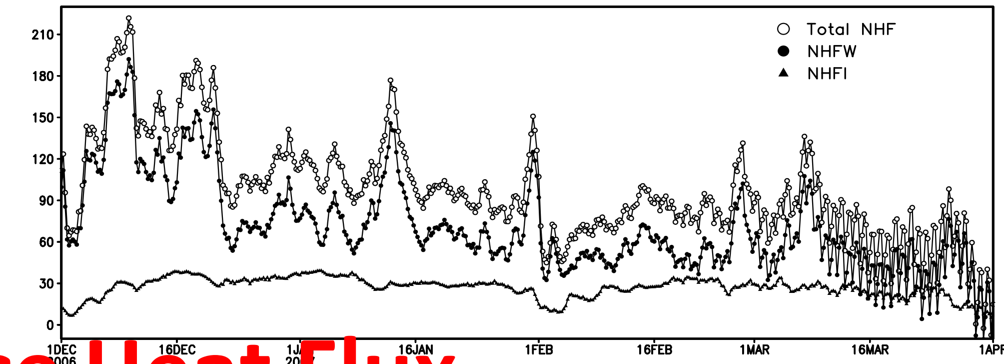
Surface Heat Flux

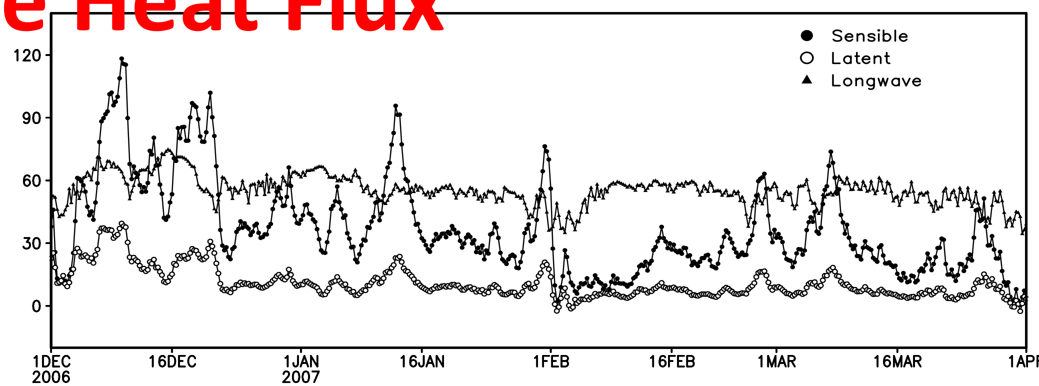








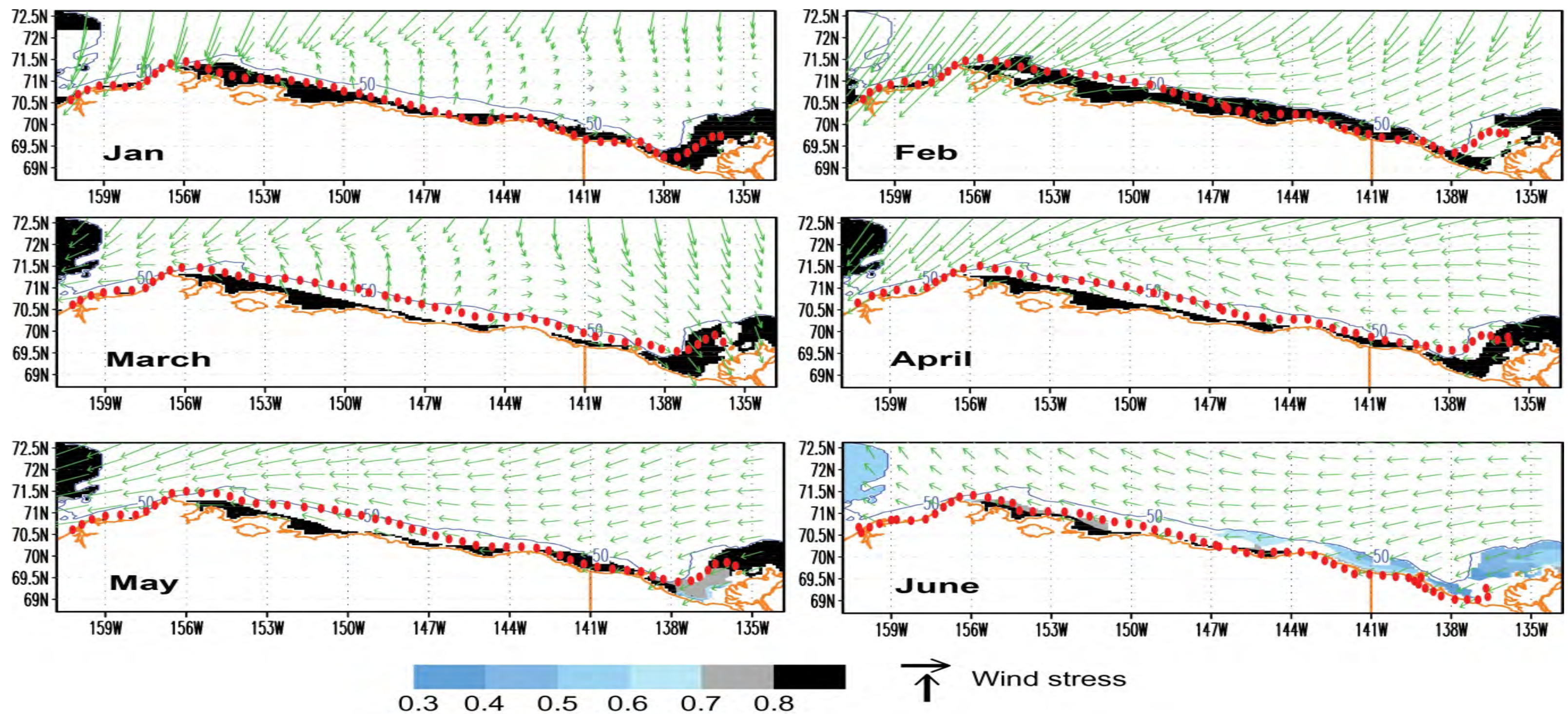




Surface Heat flux increases dramatically during storm passage

Mainly from the sensible flux over the open water

CIOM reproduces Beaufort-Chukchi Seas landfast ice

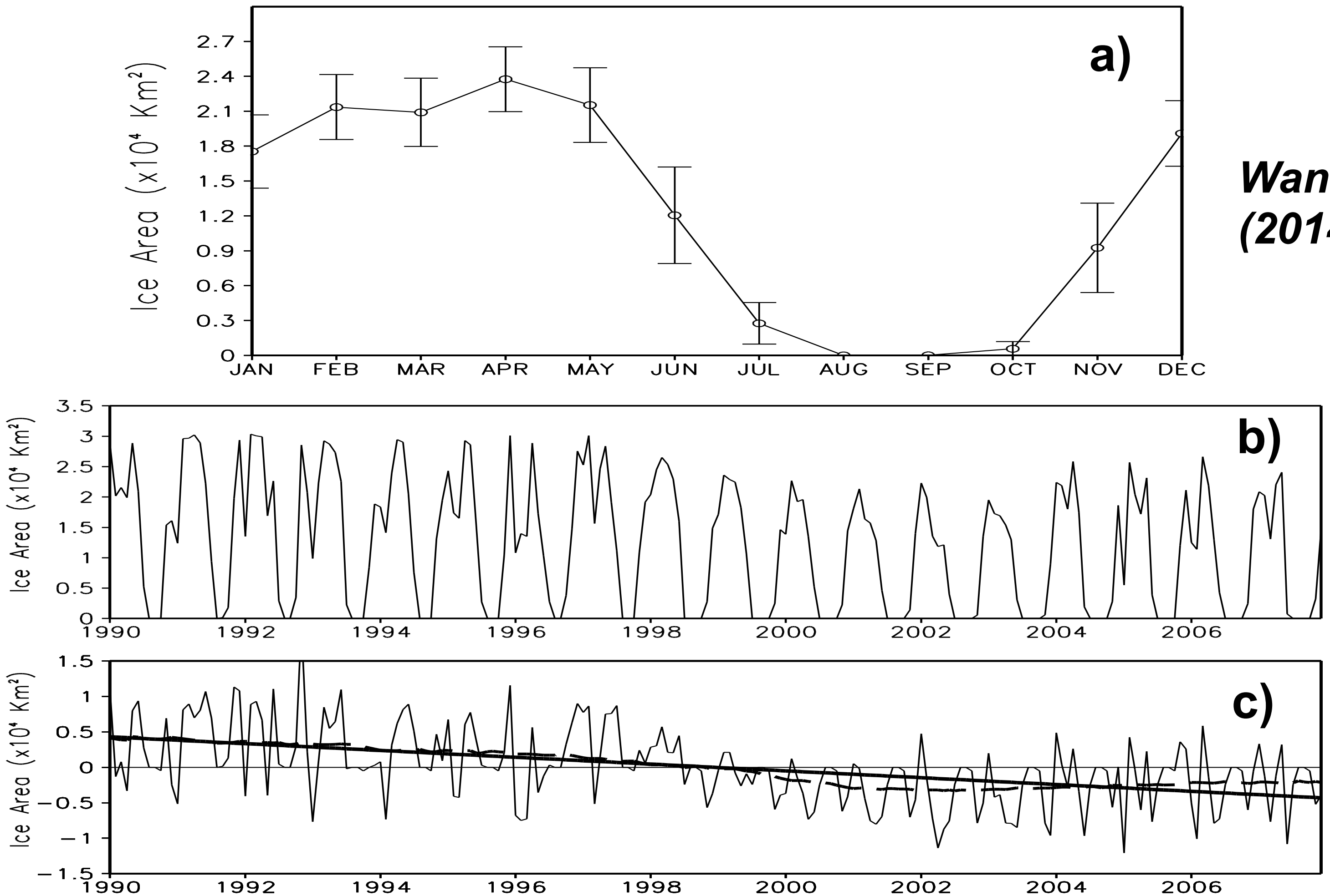


Wang et al. (2014a, JGR)

The CIOM-simulated January to June climatological landfast ice extent (from 1996-2004, black shaded) compared to landfast ice edge locations derived from synthetic aperture radar satellite data (red dots) averaged for the period 1996-2004. Green vectors are wind stress in units of 10^{-5} N m^{-2}.

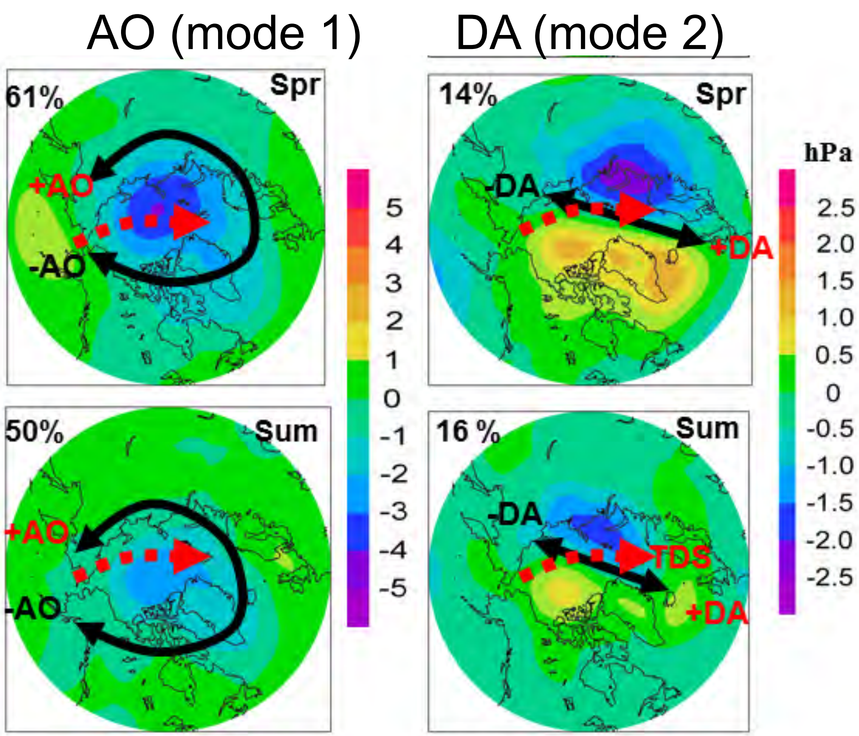
CIOM-simulated Beaufort-Chukchi Seas landfast ice seasonal/interannual variability

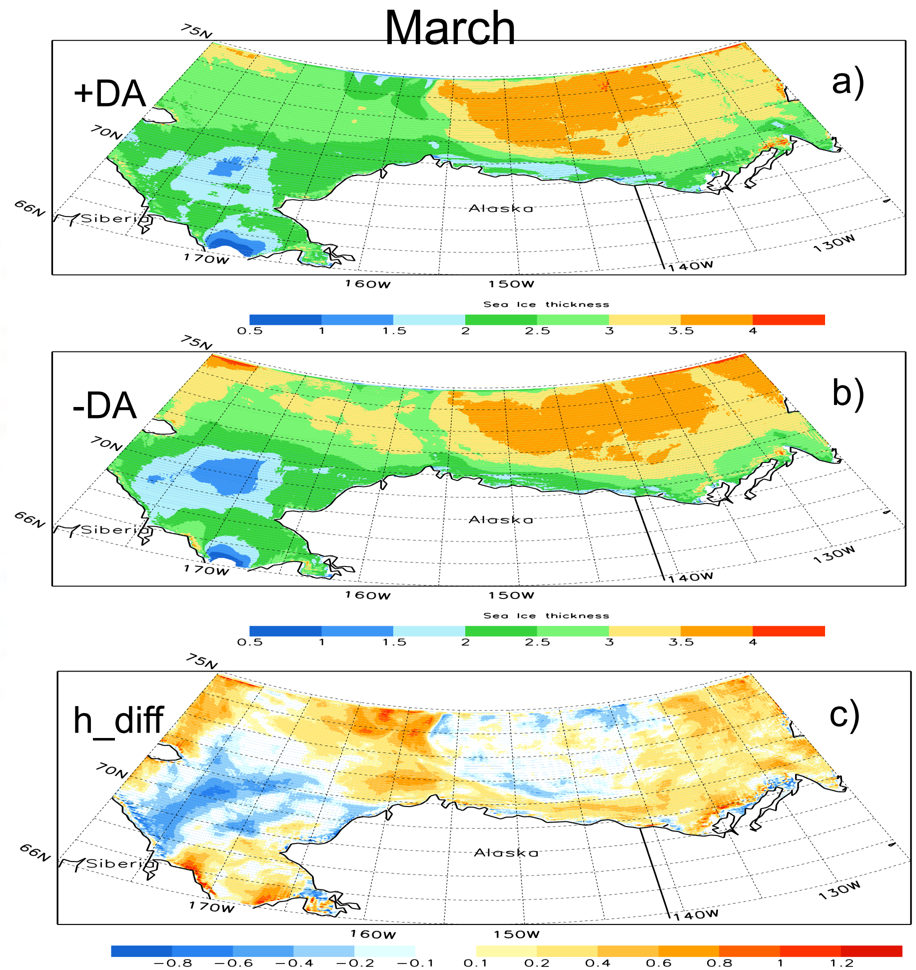
Wang et al. (2014a, JGR)



a) Modeled seasonal climatology of landfast ice area with standard deviations (the vertical bars denote one standard deviation) for the period of 1990-2007; b) Modeled monthly landfast ice area from 1990 to 2007; and c) Modeled monthly landfast ice area anomalies from 1990-2007. A 5-year running mean (thick dashed line) and a downward trend (thick solid line) are also given. The linear regression line is presented by Ice Area=0.4344-0.0040M, where units are in 10^4 km^2 and M is in months).The landfast ice area is calculated within the Beaufort and Chukchi coastal region between 160^oW and 134^oW.

DA's Impact on Beaufort-Chukchi Seas ice: interannual variability

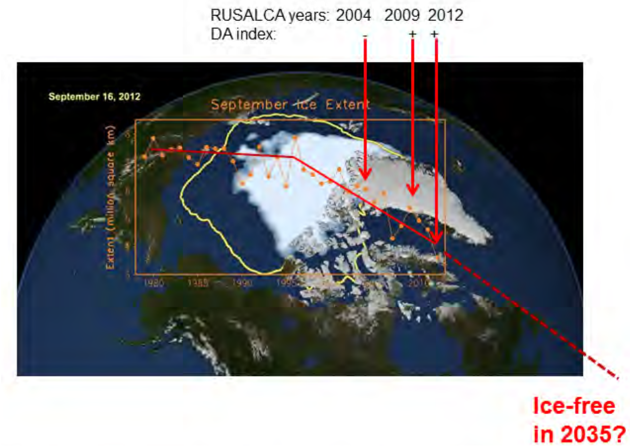


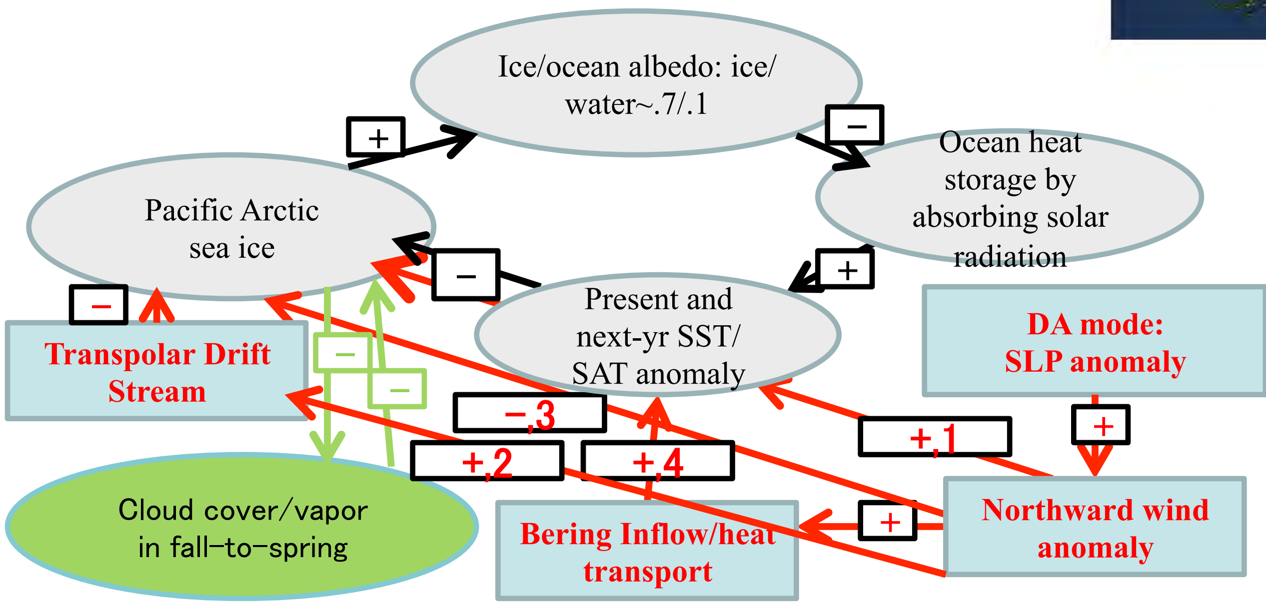


Wang et al. (2014a, JGR)

Composite sea ice thickness (in meters) composite mean in the Beaufort and Chukchi seas in March during +DA (a) and –DA (b) phases, simulated by the CIOM. h_diff denotes the sea ice thickness difference between the -DA (b) and +DA (a) composite means. Unit of color bars for thickness difference is in meters.

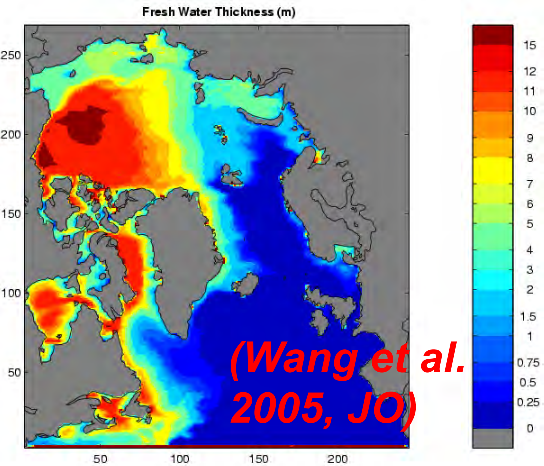
DA accelerates the ice/ocean albedo feedback annual loop/wheel/cycle by intermittent impulses



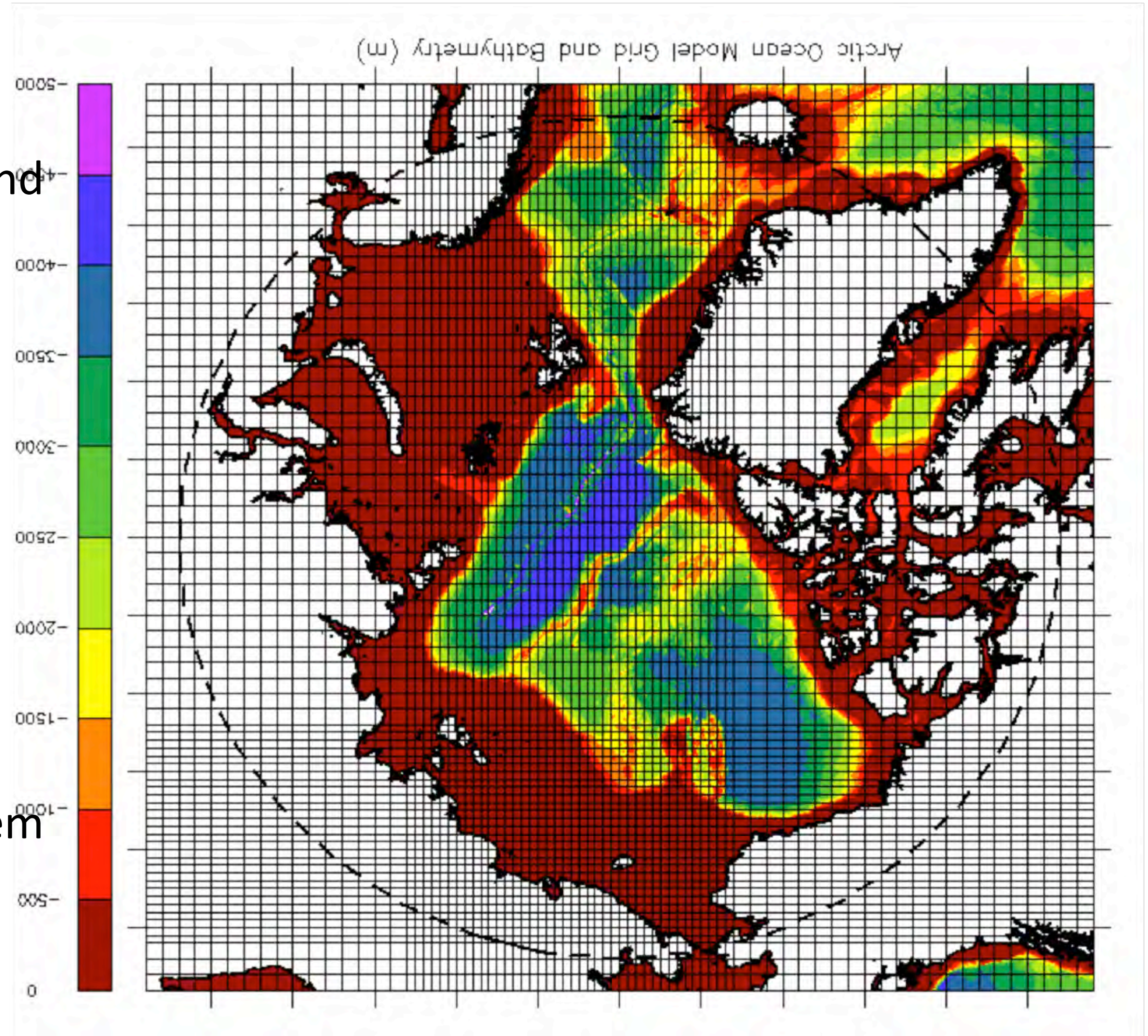


Wang et al. (2014b, Springer Book, chapter 4)

An ice/ocean albedo feedback loop and ice/cloud feedback loop are accelerated by a series of intermittent +DA forcings. The red arrows are associated with +DA forcing, which applies the positive feedback to the SST/SAT, or negative feedback to the sea ice, causing the unprecedented loss of Arctic summer sea ice and a series of record-breaking ice minima. + and – signs denote the positive and negative feedback, respectively. The positive feedback means that a change in one item (say *A*) affects the other item (say *B*), which feeds back so that *A* makes the change in the same direction as the original change. Note that associated with +DA, red arrow 1 indicates the northward advection of warmer SAT in the northern North Pacific to the Arctic by the anomalous meridional wind; Red arrow 2 denotes that anomalous meridional wind directly accelerates the TDS, which promotes export of more ice out of the Arctic; Red arrow 3indicates the direct advection of sea ice by the anomalous meridional wind; and red arrow 4 denotes the warming impact of the ocean heat transport from the Bering Sea promoted by the anomalous northward (or meridional) wind.



Proposed New Arctic-CIOM Configuration for RUSALCA's Northward Expansion, 2015-2020



- CIOM with fully dynamics and thermodynamics, multiple category ice thickness (ridging)
- ~4/12km in ESS/elsewhere
- 36 level
- 6-hourly or daily forcing
- Hypotheses test/RUSALCA synthesis
- Realistic simulation
- PhEcoM—***Ph***ysical-***Eco***system ***M***odel-NPZD