Dynamical response of the Arctic atmospheric boundary layer process to uncertainties in sea ice concentration

Hyodae Seo (hseo@whoi.edu)
Woods Hole Oceanographic Institution
Woods Hole, MA

12th Conference on Polar Meteorology and Oceanography
April 30, 2013, Seattle, WA

In collaboration with Jiayan Yang (WHOI)

Thanks to K. Hines (BPRC, OSU) and S. Tressel (NSIDC)

Uncertainties in SIC estimates

- Derived from the satellite passive microwave data
- Processed with different algorithms:
  - Atmospheric absorption/emission, wind roughness, surface emissivity, etc
- Diversities in spatio-temporal variability

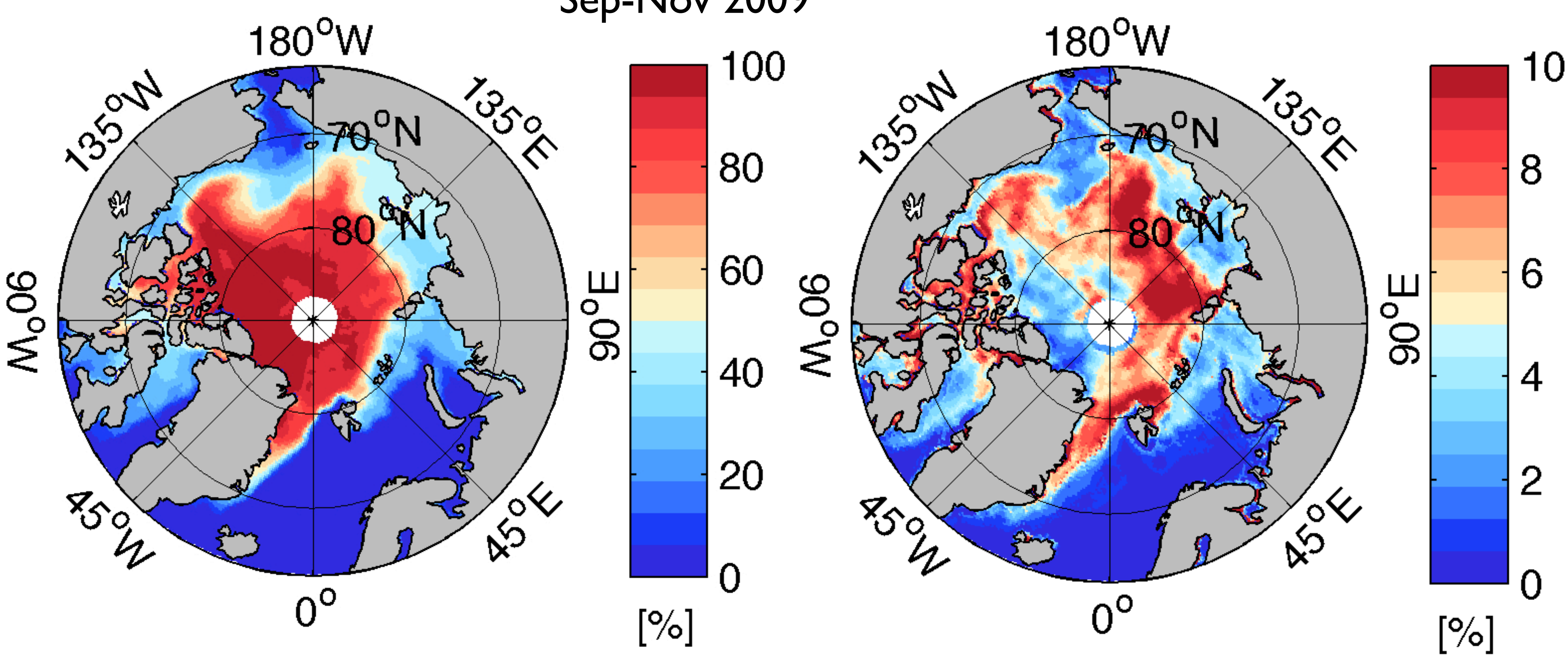
SIC dataset used in this study

1) NASA/TEAM algorithm, 25km, Swift and Cavalieri (1985): **NT**
2) Bootstrap algorithm, 25km, Comiso (1986): **BT**
3) EUMETSAT hybrid algorithm, 12.5 km, Tinboe et al. (2011): **EU**

Across-data mean

Sep-Nov 2009

Across-data standard deviation



Goal of this study:

1. Assess impact of SIC uncertainties on simulation skill

2. Examine dynamical response in surface wind (Wg and W10)

Polar WRF simulation

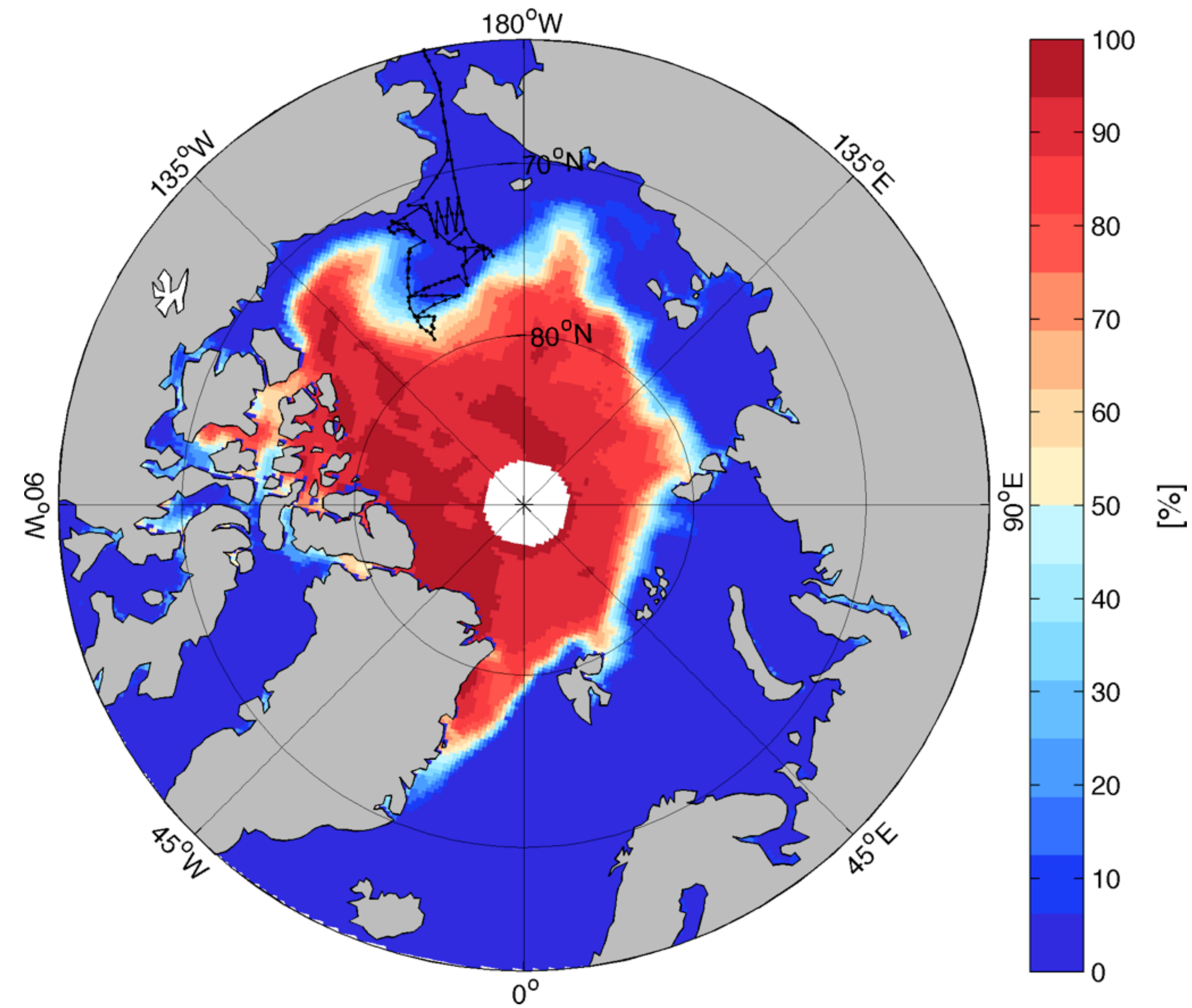
Model

- Polar WRF: Hines and Bromwich (2008)
- Polar stereographic domain, 25 km
- ERA-Interim IC/BCs

Experimental design

- 1-year period: Nov 2008 - Oct 2009
- Forced with NT, BT, and EU
- A successive 48-hour hindcast runs

Across-data mean SIC 09/09-10/19 2009

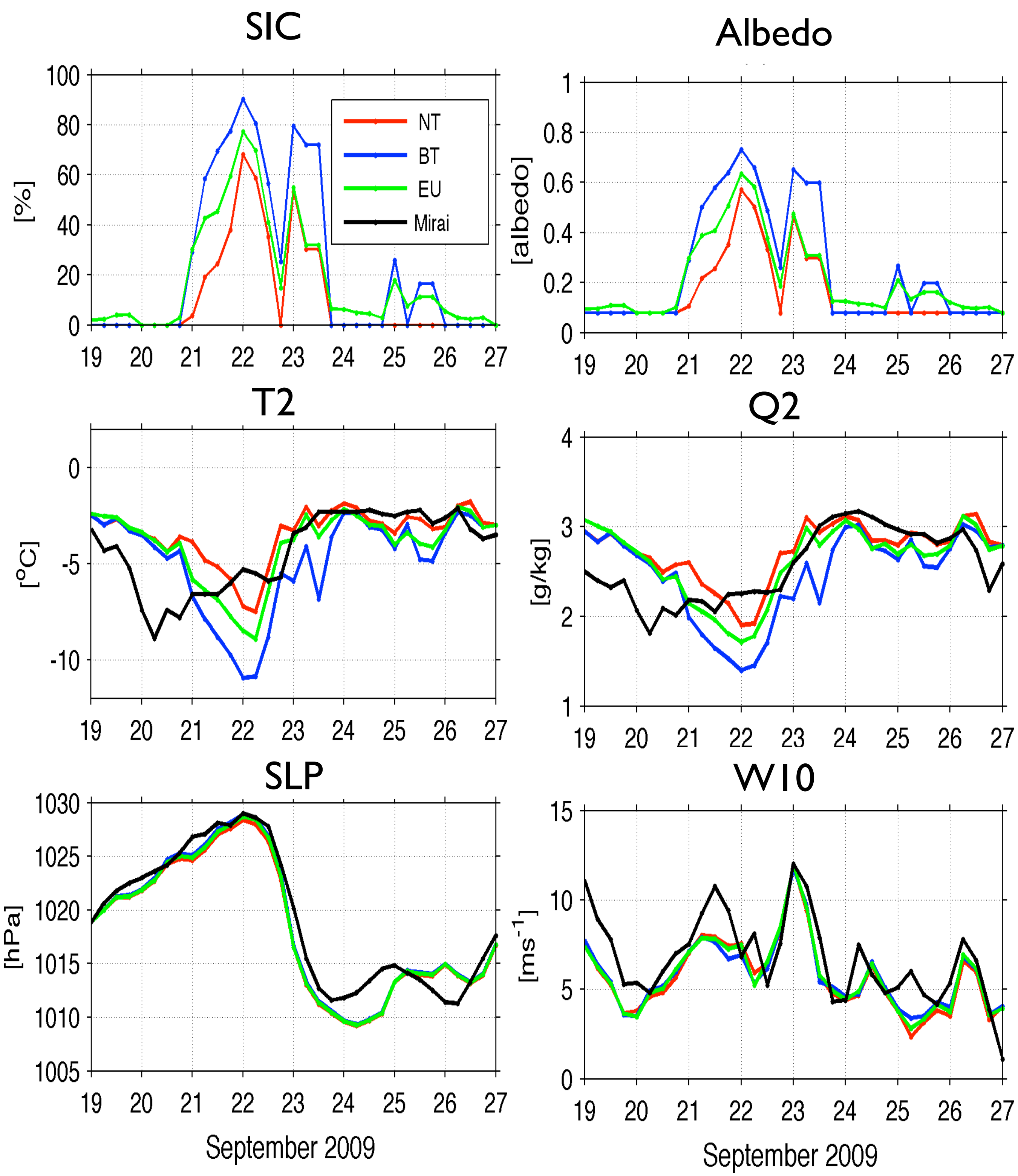


In situ observations

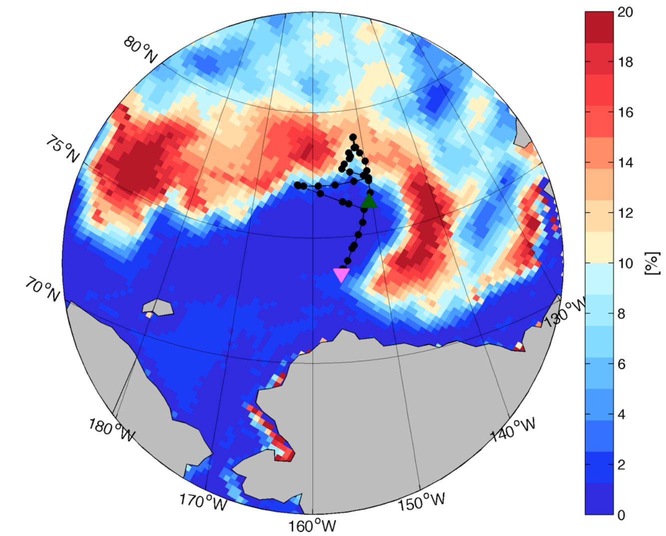
- Ship-board measurements of ABL and sounding by R/V Mirai (Inoue and Hori, 2011)
  - Sep 9 - Oct 14, 2009 in the Beaufort Sea ice margin

- High skill is "guaranteed" due to high quality ICs.
  - Pros: No need for ensemble simulation, easier to identify rapid ABL response.
  - Cons: May not capture slower adjustment process in large-scale circulation.

Low skill due to errors in SIC during September 19-27, 2009



Across-data SIC STD



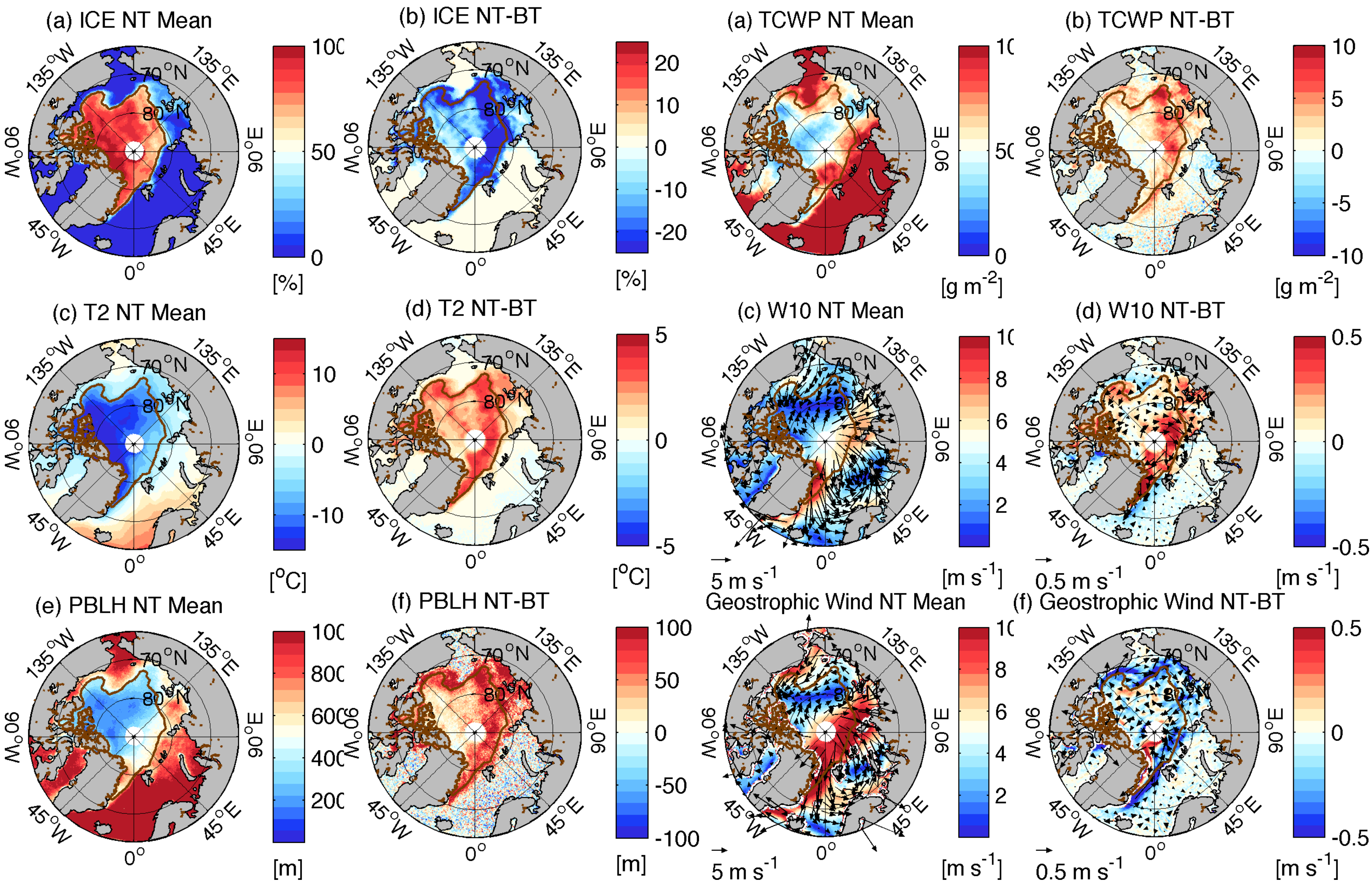
- SICs peak on 9/22-23.
  - BT up to 90%
  - EU ; 77%
  - NT; 68%.
- A large across-model spread in T2/Q2,
  - Reflects the sea ice evolution.
- Bias in T2/Q2 stems from the delayed peak.
  - The true peak in SIC was probably on 9/20.

bias on 9/22	NT	BT	EU	model-mean
T2	-0.2	-3.4C	-1.3C	-1.6

- SLP/W10: Little sensitivity to SIC
  - The delayed peaks are not apparent.

Representation of the daily sea ice near the ice margins is critical to hindcast skill.

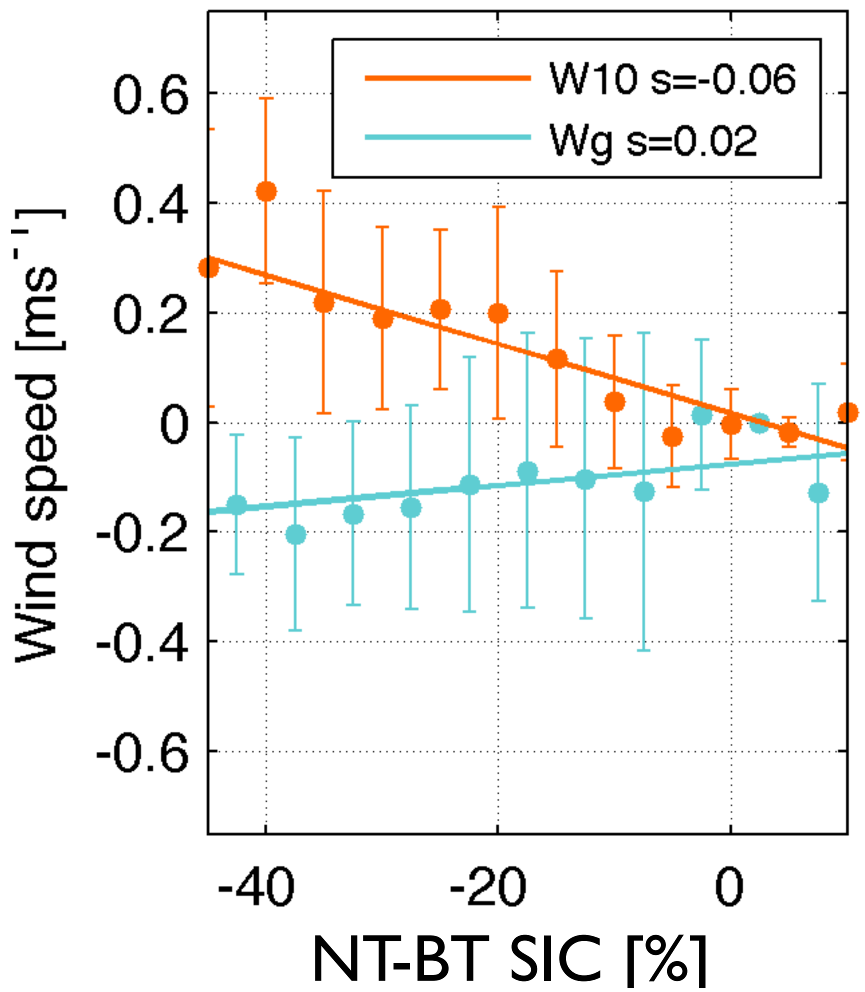
The pan-Arctic response pattern to SIC difference: September 2009



- On the basin scale: Lower SIC in NT ➜ higher T2, PBL, TCWP, W10
- Stability adjustment to surface temperature (*Overland, 1985; Wallace et al., 1989*).

A quasi-linear relationship in surface winds to SIC

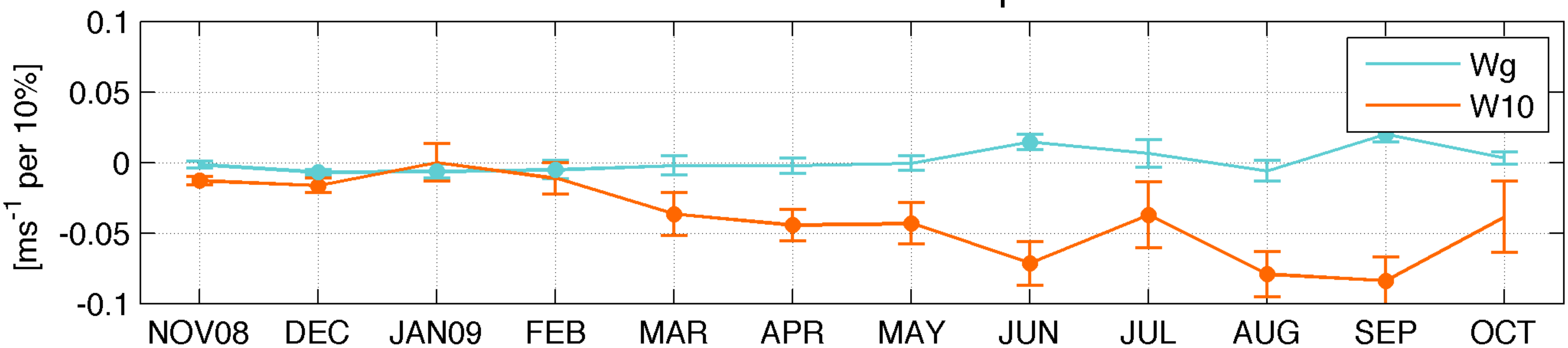
September 2009 W10 and Wg

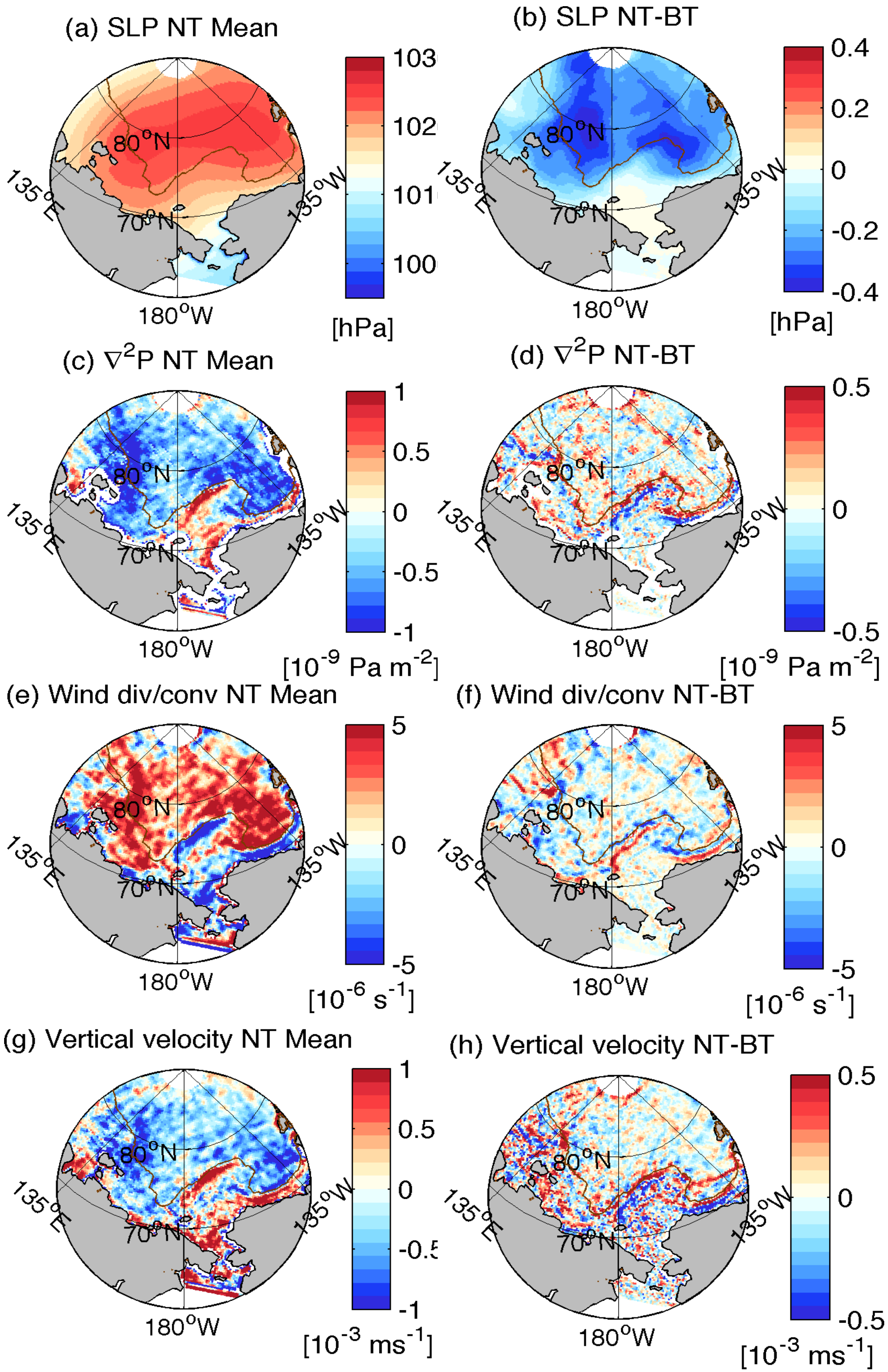


- Arctic-averaged difference (NT-BT).
- The linear slope *s* is a measure of effect of SIC (≈a coupling coefficient of *Chelton et al. 2011*).

- SIC-W10: A negative relationship
- SIC-Wg: Either a positive or no correlation
- Difference largest in summer-autumn.

Time-series of linear-slopes



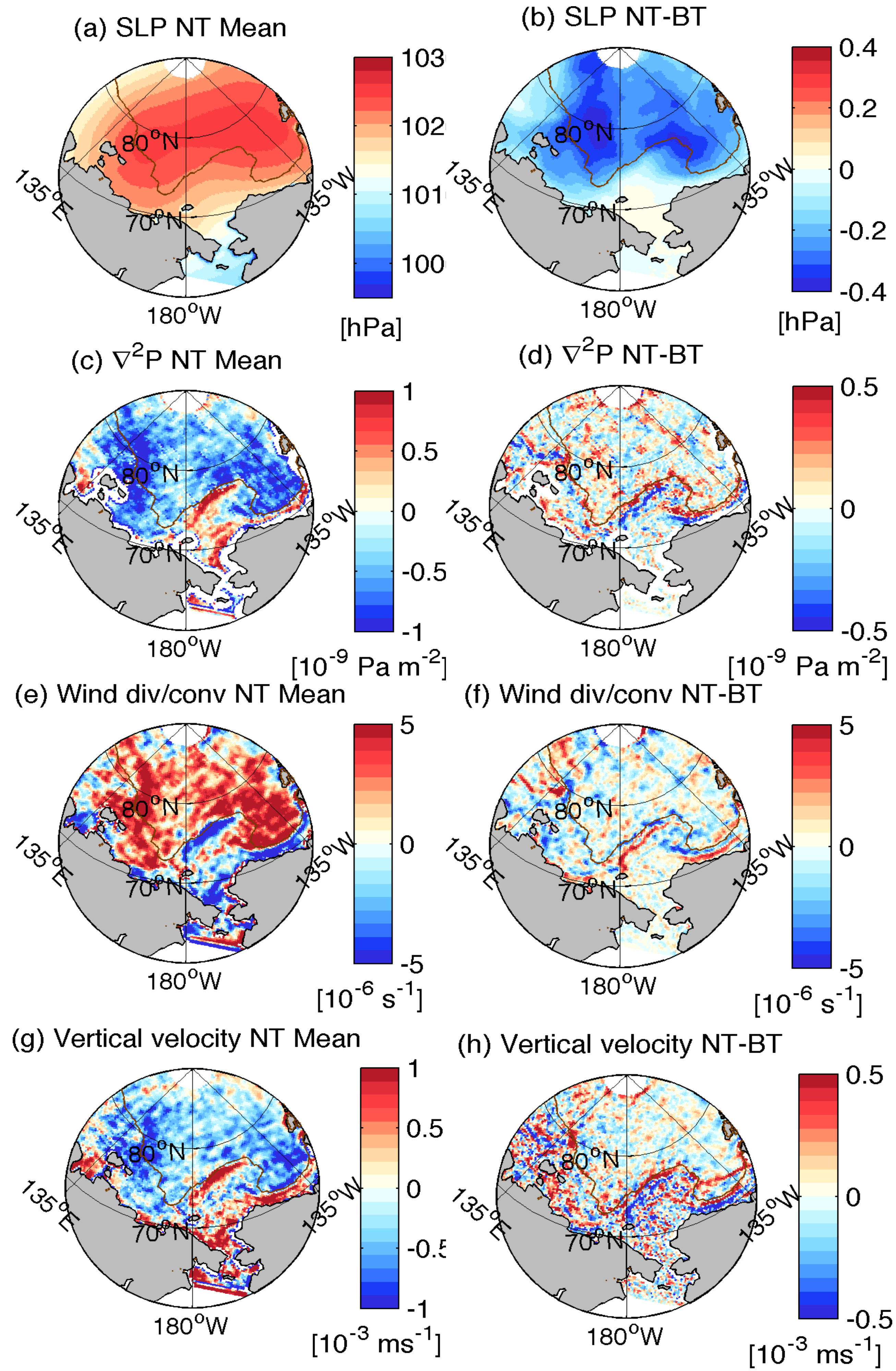


Impact of SIC on SLP-induced wind

- A simple marine boundary layer model of *Lindzen and Nigam (1987)*: steady flow, no advection, linear friction, etc.

$$\rho_o\left(\nabla\cdot\vec{u}\right) = -\left(\nabla^2 P\right)\varepsilon/\left(\varepsilon^2+f^2\right)$$

- Div. /Conv. of surface wind is linearly proportional to SIC-induced Laplacian of SLP
  - e.g., *Minobe et al. (2008); Small et al. (2008)*



Impact of SIC on SLP-induced wind

- A simple marine boundary layer model of *Lindzen and Nigam (1987)*: steady flow, no advection, linear friction, etc.

$$\rho_o\left(\nabla\cdot\vec{u}\right) = -\left(\nabla^2 P\right)\varepsilon/\left(\varepsilon^2 + f^2\right)$$

- Div. /Conv. of surface wind is linearly proportional to SIC-induced Laplacian of SLP
  - e.g., *Minobe et al. (2008); Small et al. (2008)*

$$w(z) = \frac{1}{\rho_o}\left(\frac{\varepsilon z}{\varepsilon^2 + f^2}\right)\nabla^2 P$$

- SIC-induced vertical velocity is proportional to $\nabla^2 P$.
- ∇^2 effectively highlights small-scale response,
  - e.g., along the sea ice margins.

Conclusion

- Enhanced uncertainties in satellite-based SIC
  - along the sea ice margins and the inner ice pack
  - during the onset of freeze-up.

- A reasonable skill of Polar WRF is obtained when SIC uncertainty is small.

- Stability of ABL adjusts to broad-scale uncertainties in SICs
  - producing an anomalous W10 on the same spatial scales.
  - via stability adjustment and vertical mixing of momentum.
  - e.g., Overland (1985), Wallace et al. (1989)

- SLP adjusts to SIC changes,
  - generating anomalies in div/conv and vertical motions
  - via the Laplacian of SLP along the sea ice margins
  - e.g., Lindzen and Nigam (1985)

- Use of the Wg-based surface wind stress may underestimate the effect of broad-scale SIC change (or uncertainties).

Thanks!

hseo@whoi.edu