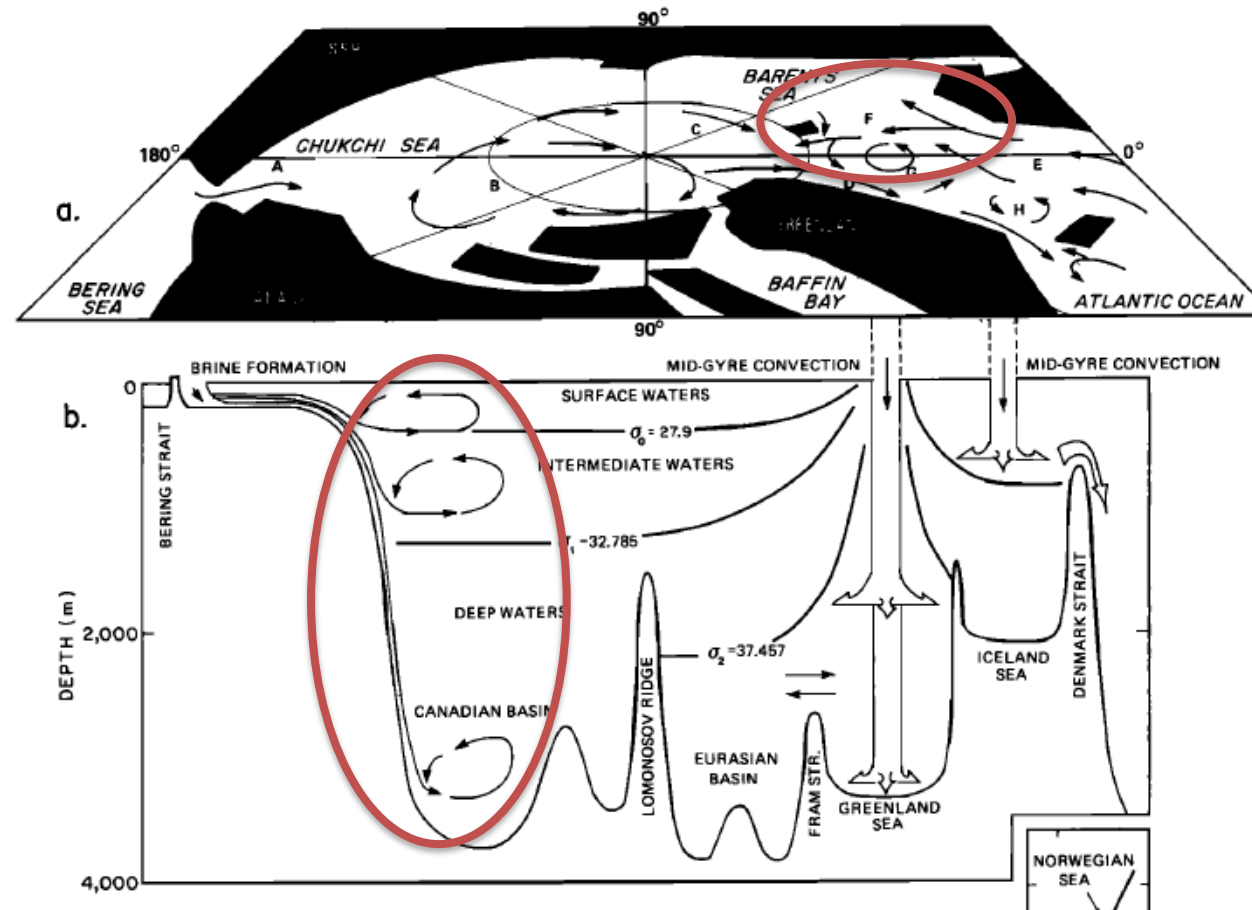# Impact of SLP and Wind Bias on Arctic Ocean Deep Circulation

Claudia Hinrichs, Qiang Wang, Tido Semmler, Longjiang Mu, Thomas Jung

Schematic Arctic Circulation

Aagaard, Knut, J. H. Swift, and E. C. Carmack. "Thermohaline circulation in the Arctic Mediterranean seas." *Journal of Geophysical Research: Oceans* 90.C3 (1985): 4833-4846. Figure 11
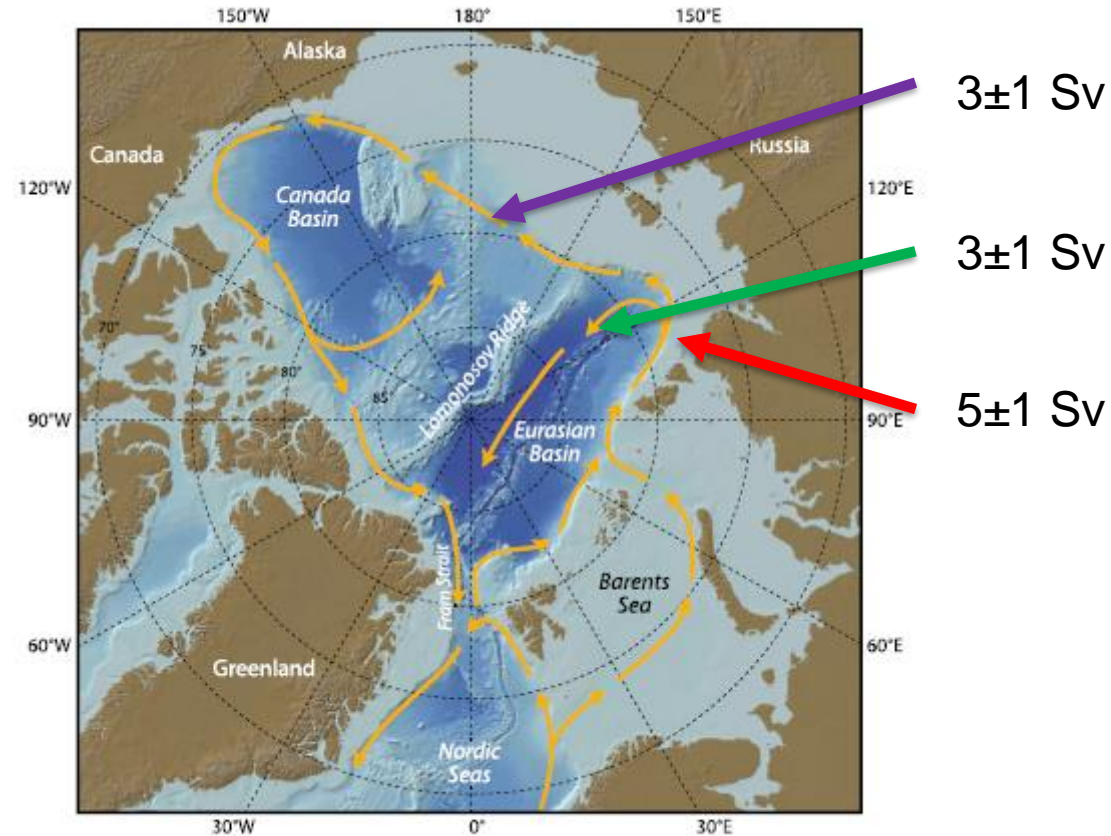
Transport estimates

FIG. 1. Bottom topography and schematic of the Atlantic Water circulation in the Arctic Basin [modified from Rudels et al. (1994) and Rudels (2012)].

Woodgate, Rebecca A., et al. "The Arctic Ocean boundary current along the Eurasian slope and the adjacent Lomonosov Ridge: Water mass properties, transports and transformations from moored instruments." *Deep Sea Research Part I: Oceanographic Research Papers* 48.8 (2001): 1757-1792.

Spall, Michael A. "On the circulation of Atlantic Water in the Arctic Ocean." *Journal of Physical Oceanography* 43.11 (2013): 2352-2371

Topostrophy

- Quantifying velocity as a scalar - topostrophy:

$$\tau = (\boldsymbol{V} \; x \; \boldsymbol{\nabla}D)z$$

  where V is the velocity vector, $\boldsymbol{\nabla}$D the gradient of total depth and z the unit vertical vector

- Positive τ indicates flow with shallower water to right (NH)
- In the case of the deep Arctic boundary current: cyclonic flow

Holloway, G., et al. "Water properties and circulation in Arctic Ocean models." Journal of Geophysical Research: Oceans 112.C4 (2007).
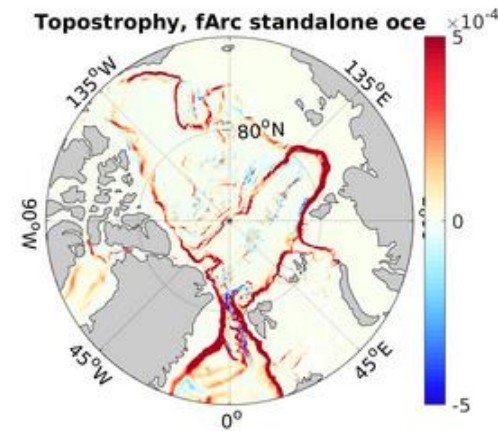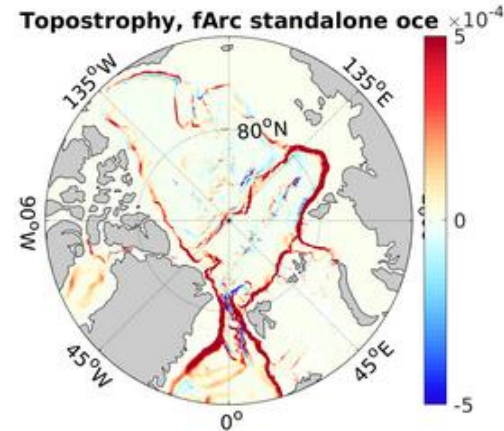
APPLICATE.eu
Advanced prediction in
polar regions and beyond

HELMHOLTZ

Topostrophy in uncoupled runs
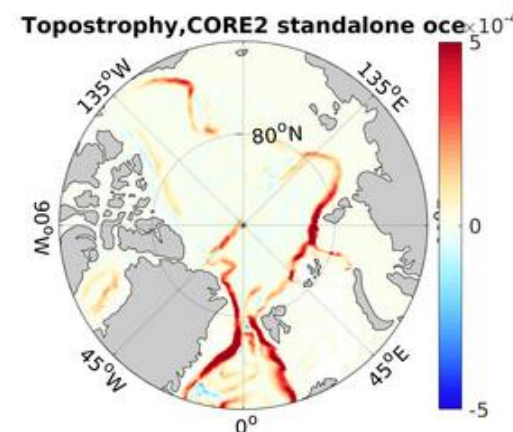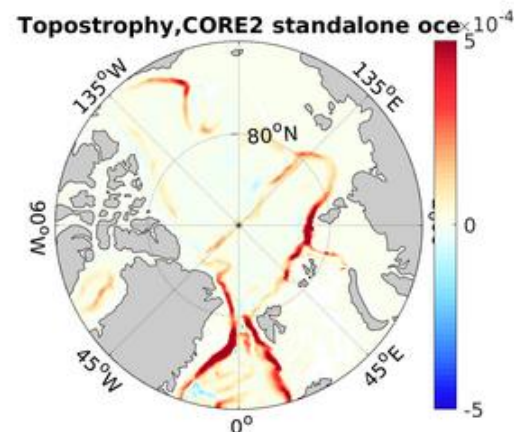
Integrated over 300m - 3000 m depth

1980s   1990s

High-Res ocean

Low-Res ocean

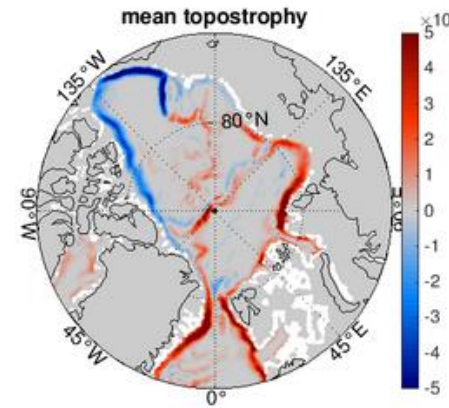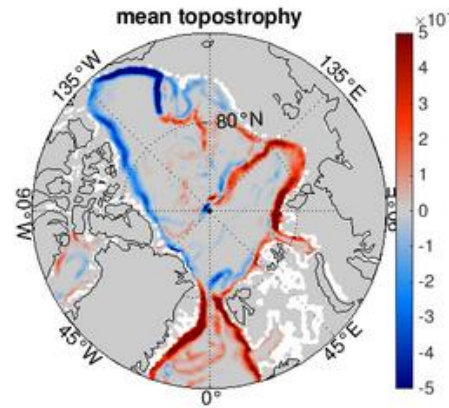red = anticlockwise = correct

blue = clockwise = not correct

Topostrophy in coupled runs
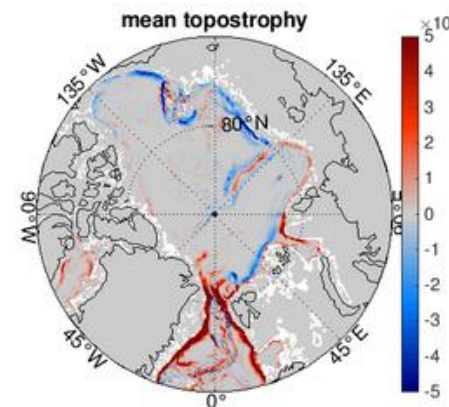
Integrated over 300m - 3000 m depth
Mean 1980-1999

red =
anticlockwise =
correct
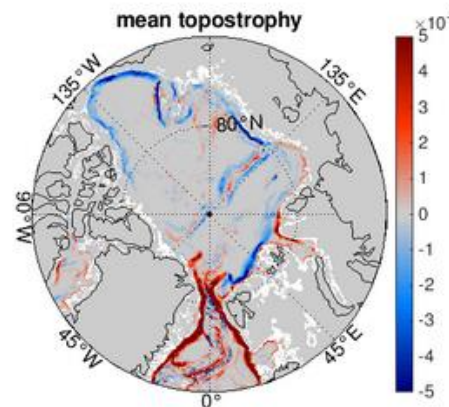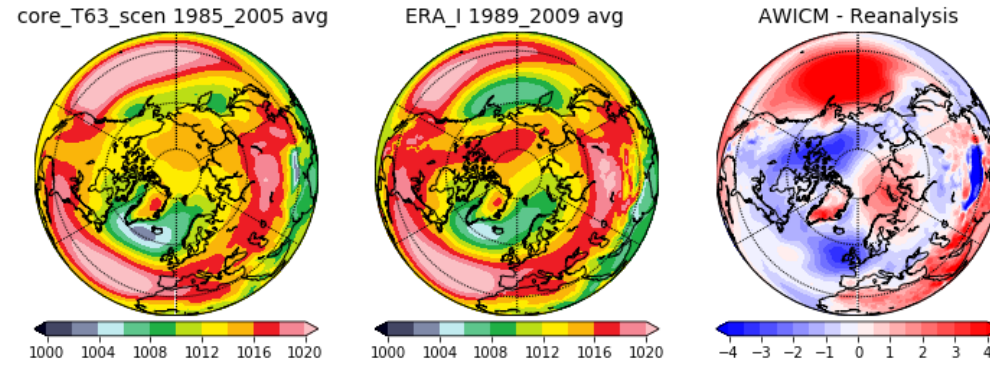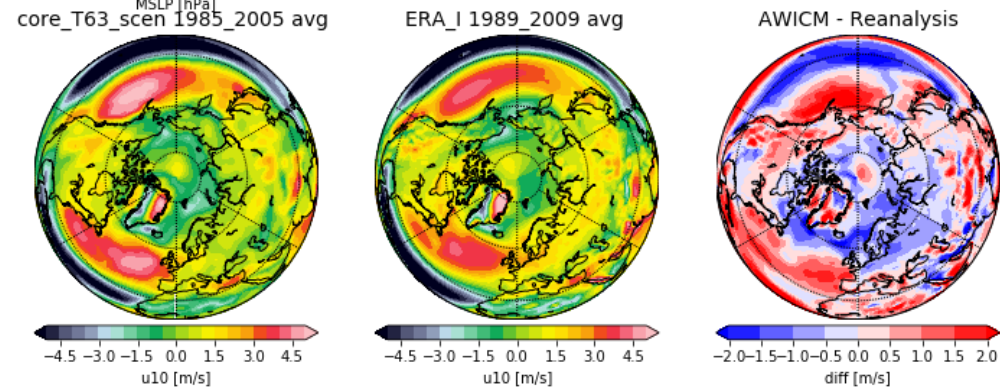
blue =
clockwise =
not correct

Bias AWI-CM vs ERA Interim
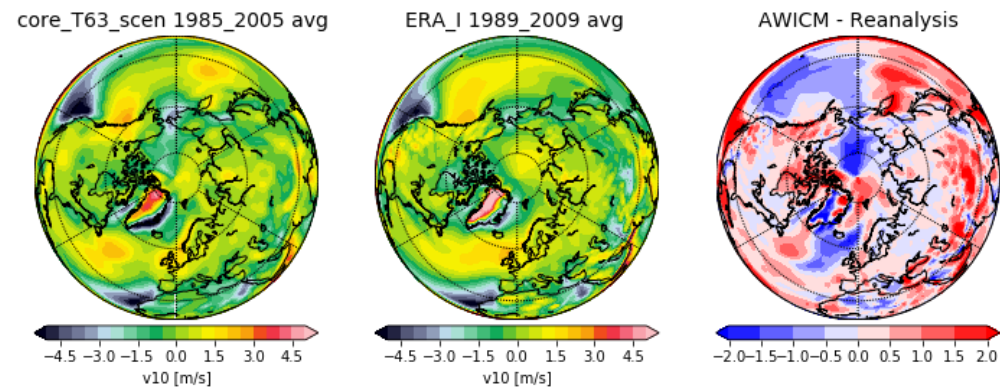
Trying to tune the atmosphere

Description	Who?	Where is the data	Atmospheric Parameter	Ocean parameter	Comment on result
Atmo only, PAMIP set-up, T63	Tido	/work/ab0995 /a270062/PAMIP /g??t63	double gk_wake (low level blocking due to sub-grid orography)		slight improvement, could be stronger in T127 set-up
Atmo only, PAMIP set-up, T63	Tido	/work/ab0995 /a270062/PAMIP /gd??t63	double gk_drag (gravity wave drag)		no improvement
Atmo only, PAMIP set-up, T63	Tido	/work/ab0995 /a270062/PAMIP /gl??t63	activate gk_lift (orographic lift)		no improvement
Atmo only, PAMIP set-up, T63	Tido	/work/ab0995 /a270062/PAMIP /gwd??t63	double gk_wake, half gk_drag		no improvement
Atmo only, PAMIP set-up, T63	Tido	/work/ab0995 /a270062/PAMIP /gw5??t63	increase gk_wake by factor of 5		bias halved
Atmo only, PAMIP set-up, T127	Tido	/work/bk0988/awicm /a270062/PAMIP /gw5??t127	increase gk_wake by factor of 5		bias reduced but not halved

Trying to tune the atmosphere

Description	Who?	Where is the data	Atmospheric Parameter	Ocean parameter	Comment on ...
Atmo only, PAMIP set-up, T63	Tido	/work/ab0995 /a270062/PAMIP /g??t63	double gk_wake (low level blocking due to sub-grid orography)		slight improvement, could be stronger in T127 set-up
Atmo only, PAMIP set-up, T63	Tido	/work/ab0995 /a270062/PAMIP /gd??t63	double (g...		no improvement
Atmo only, PAMIP set-up, T63	Tido	/work/ab0995 /a27006... /gl...	...e gk_lift ...orographic lift)		no improvement
Atmo only, PAMIP set-up, T63	Tido	...2/PAMIP ...wd??t63	double gk_wake, half gk_drag		no improvement
Atmo only, PAMIP set-up, T63		/work/ab0995 /a270062/PAMIP /gw5??t63	increase gk_wake by factor of 5		bias halved
Atmo only, PAMIP set-up, T127	Tido	/work/bk0988/awicm /a270062/PAMIP /gw5??t127	increase gk_wake by factor of 5		bias reduced but not halved

No success

APPLICATE.eu
Advanced prediction in polar regions and beyond

HELMHOLTZ

Trying to tune the ocean

| Description	Who?	Where is the data	Atmosphere Parameter	Ocean parameter	Comment on result
Atm (T63) no changes	Longjiang	/work/ab0995/a270112/awicm1/core		Kv=1e-5, K_GM=200, Ah_bg=3.0e13, Smagorinsky = true, restart from Tido's 1951 ocean and atm state	T/S (Arctic) distribution impro... Halocline deeper th... Circulation ... Bea... ...asin after 10 years with ...EB
Atm (T63) no changes	Longjiang	/work/ab0995/a270112/awicm1/core		Kv=1e-5, K_GM=200, add tb4 ver... mixing scheme to KPP (glob... Ah_bg=3.0e13, Smagor... restart from Tido's ... state	...n improved ...per than obs ...ation wrong after 10 years Beaufort High extends to Eurasian Basin after 10 years with freshwater also extending to EB
Atm (T63) no changes	Longjiang	/work/ab0995/a270112/awicm1/core		...b4 vertical ...(global), ...magorinsky = true, ...Tido's 1951 ocean and atm	T/S (Arctic) distribution improved Halocline deeper than obs Circulation wrong after 10 years Beaufort High extends to Eurasian Basin after 10 years with freshwater also extending to EB
Atm (T63) no changes	Longjiang	/work/ab0995/a270112/awicm1/core		Kv=1e-7, K_GM=366, add tb4 vertical mixing scheme to KPP (exclude sea ice area), Ah_bg=2.7e13, Smagorinsky = true, restart from Tido's 1951 ocean and atm state	T/S (Arctic) distribution improved Halocline deeper than obs Circulation wrong after 15 years Beaufort High extends to Eurasian Basin after 15 years with freshwater also extending to EB
Atm (T63) no changes	Longjiang	...core		Kv=1e-7, K_GM=366, add tb4 vertical mixing scheme to KPP (exclude sea ice area), Ah_bg=2.7e13, Smagorinsky = true, restart from Tido's 1951 ocean and atm state	T/S (Arctic) distribution improved Halocline deeper than obs Circulation wrong after 15 years Beaufort High extends to Eurasian Basin after 15 years with freshwater also extending to EB
Atm (T63) no changes		/work/ab0995/a270112/awicm1/core		Kv=1e-7, K_GM=50, add tb4 vertical mixing scheme to KPP (exclude sea ice area), Ah_bg=2.0e13, Smagorinsky = true, restart from Tido's 1951 ocean and atm state	T/S (Arctic) distribution improved Halocline deeper than obs Circulation wrong after 15 years Beaufort High extends to Eurasian Basin after 15 years with freshwater also extending to EB

No success

...

Test if wind bias is (solely) to blame

- Compare topostrophy in FESOM standalone forced with CORE2 forcing to same simulation but with wind bias added

- Added wind bias for now: constant annual mean bias

- Expectation: CORE 2 forcing gives correct circulation, adding the bias will result in wrong circulation as seen in coupled run

- Run on Core grid, coldstart 1958 from EN4

Test results - Topostrophy

Control

With wind bias added

Topostrophy,CORE2 standalone oce $\times 10^{-4}$

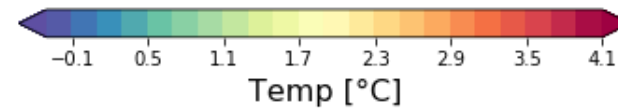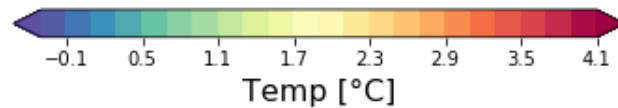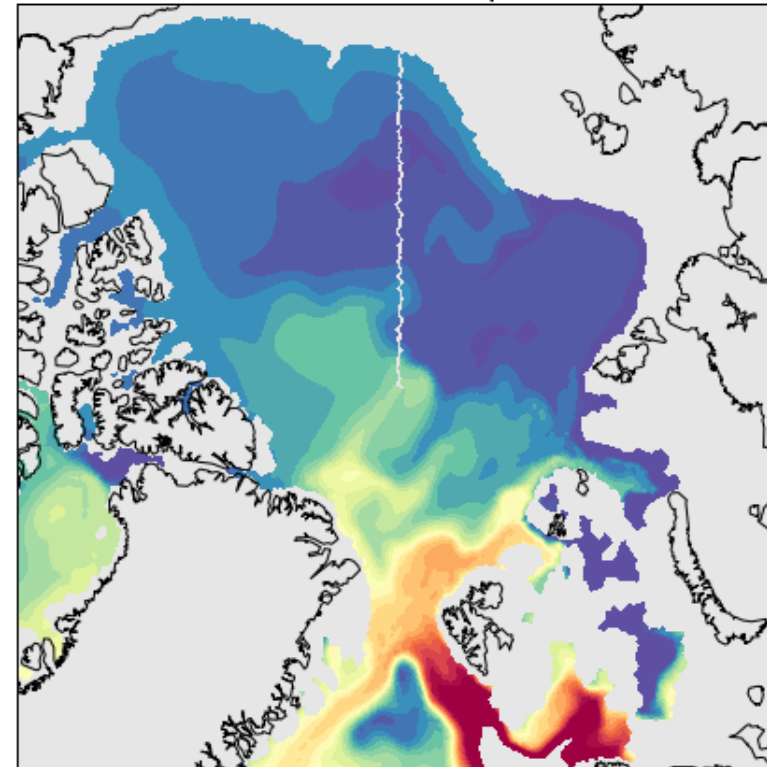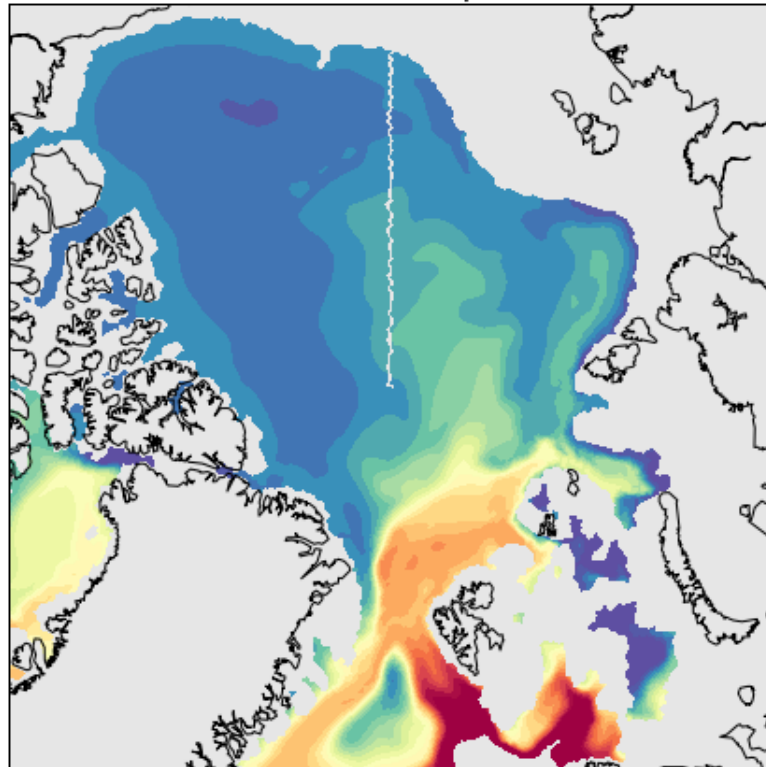mean topostrophy 1975 - 1985 $\times 10^{-4}$
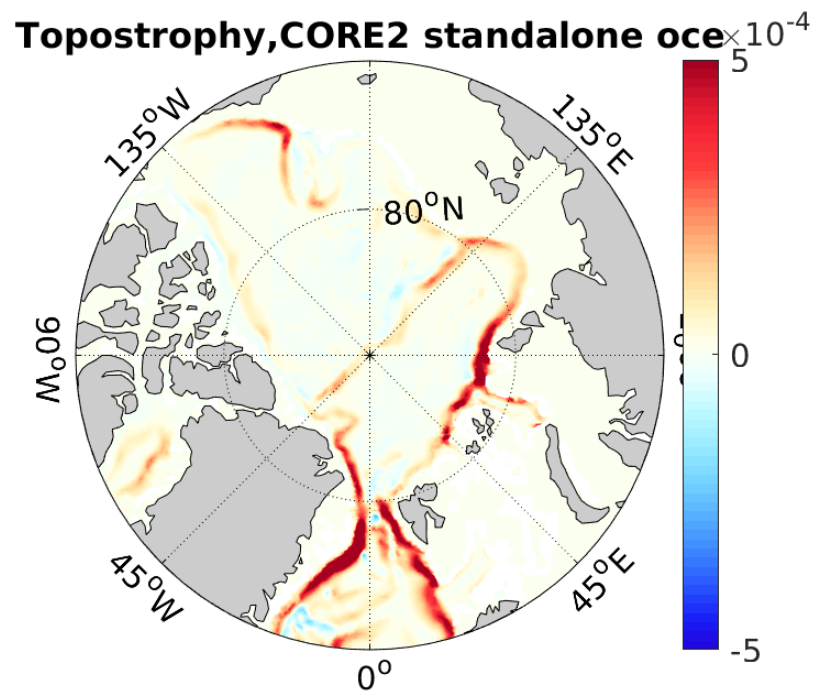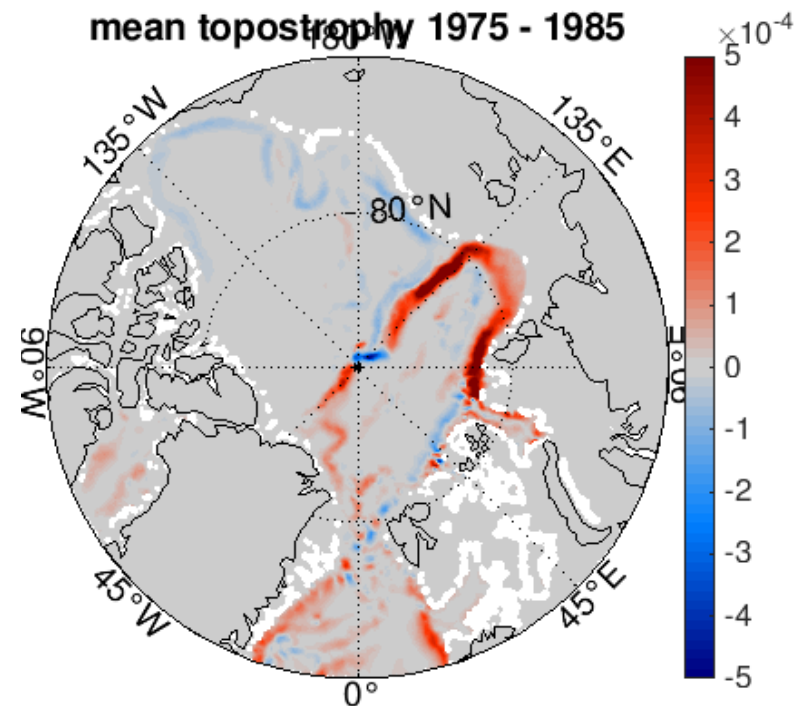
Test results – Atlantic Water

Control

With wind bias added

Control, mean temp at 300m

Windbias, mean temp at 300m

Influences on AW layer and circulation

- Remote wind forcing (Nordic and Barents Sea)

  ➢ *volume transport through Fram Strait* (e.g. Chafik et al. 2015; Lique et al. 2015)

  ➢ *dense water formation in Barents Sea and export through St. Anna Trough* (e.g. Karcher et al. 2007)

- Local wind forcing (Beaufort Sea)

  ➢ *modification of halocline depth -> PV* (e.g. Karcher et al. 2007)

- Ocean vertical mixing (e.g. Zhang and Steele 2007)

Where we are at

- Discovered a bias in the direction of Arctic deep circulation
- Potentially important for
  - *Arctic basin heat content,*
  - *location of warm AW,*
  - *exchange of water masses between basins*
- Impact on climate prediction ??

Where we are at

- Discovered a bias in the direction of Arctic deep circulation
- Potentially important for
  - *Arctic basin heat content,*
  - *location of warm AW,*
  - *exchange of water masses between basins*
- Impact on climate prediction ??

- Experiment suggests wind bias causes change in current direction
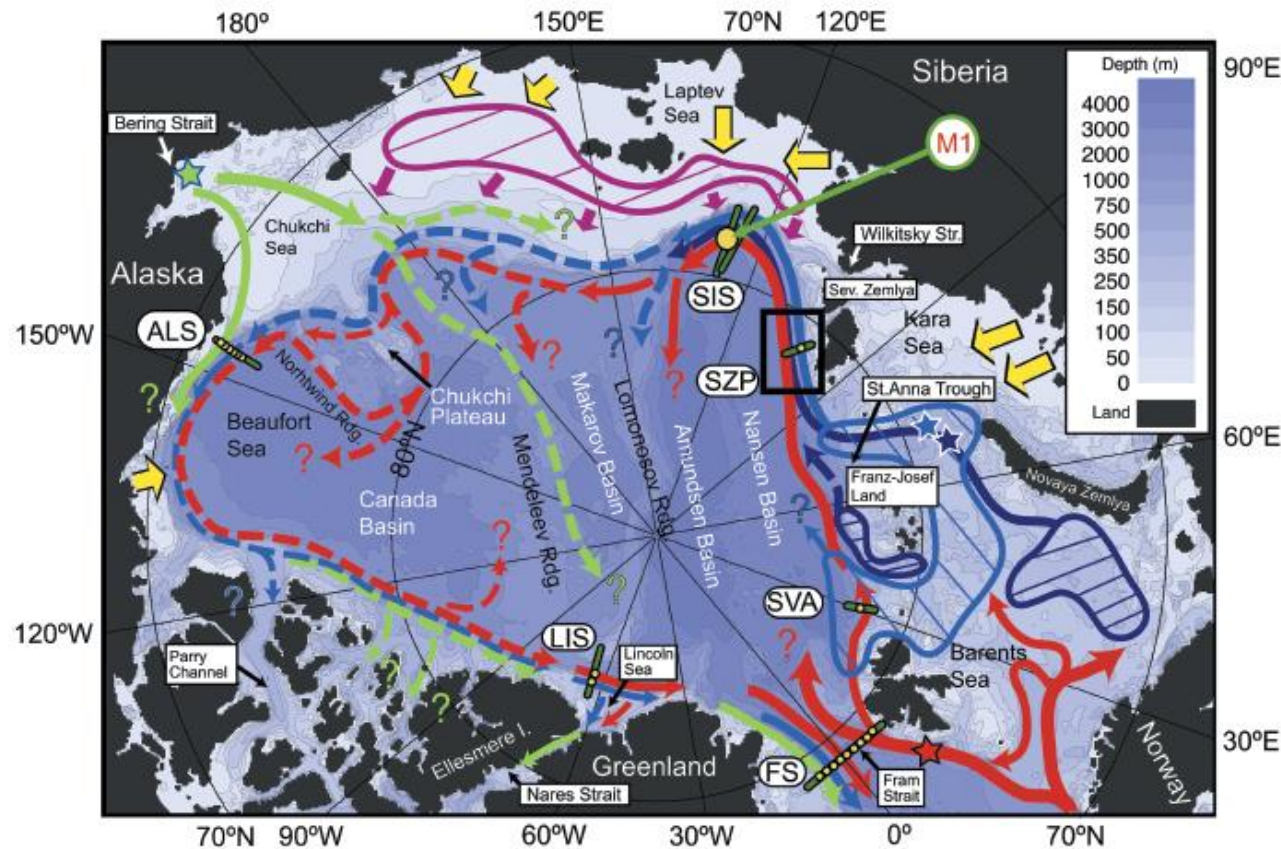- Constrain atmosphere in coupled model ? Change atmosphere model ?

Questions ?

Backup

Schematic Arctic Circulation II

AKSENOV ET AL.: THE ARCTIC CIRCUMPOLAR BOUNDARY CURRENT

solid arrows, known flows; dashed arrows, presumed flows

Red arrows depict Fram Strait Branch (FSB) and pathways of Atlantic Water (AW).

Dark blue arrows show Barents Sea Branch (BSB)

Light green arrows depict flow of Pacific Water (PW).

Aksenov, Yevgeny, et al. "The Arctic circumpolar boundary current." *Journal of Geophysical Research: Oceans* 116.C9 (2011). Figure 1
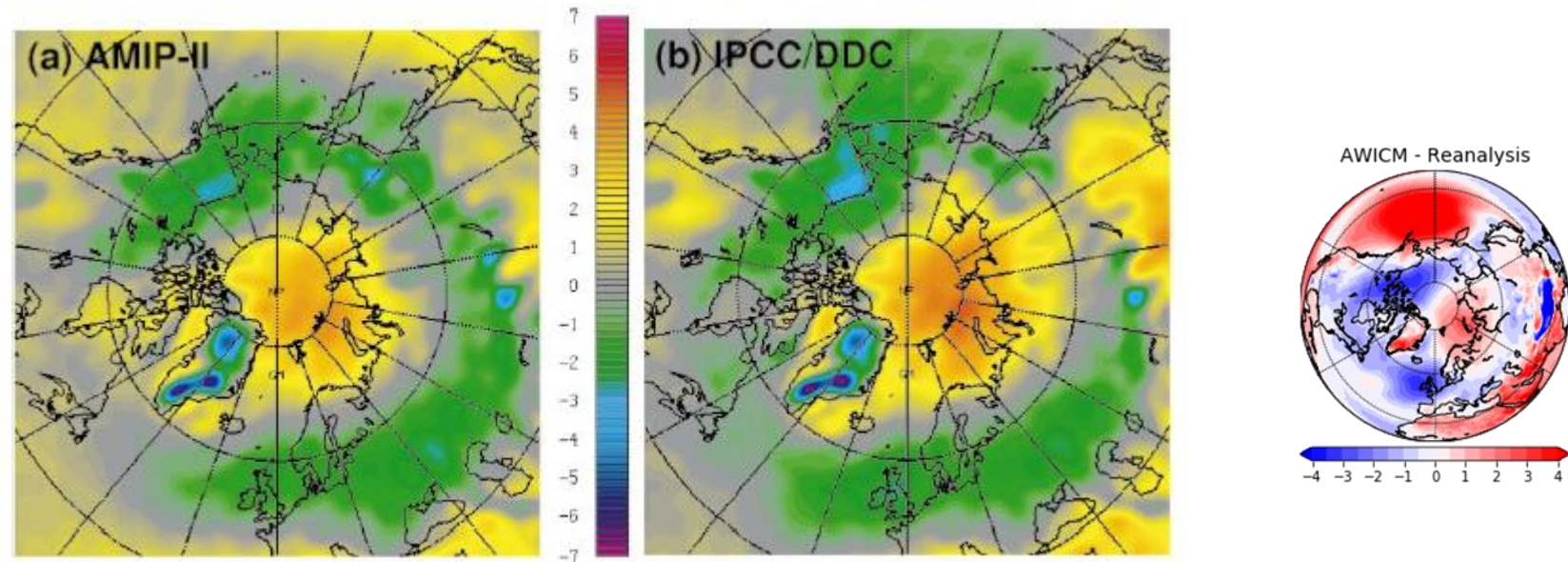
Atmosphere model SLP bias

FIG. 2. Biases, relative to NCEP reanalysis, of the annual mean sea level pressure composited over (a) AMIP-II uncoupled models and (b) IPCC/DDC coupled models. Color scale ranges from negative (blue, green) to positive (yellow, red).

Walsh, John E., et al. "Comparison of Arctic climate simulations by uncoupled and coupled global models." *Journal of Climate* 15.12 (2002): 1429-1446.