The importance of short duration wind events on intrusions of Circumpolar Deep Water onto Antarctic continental shelves

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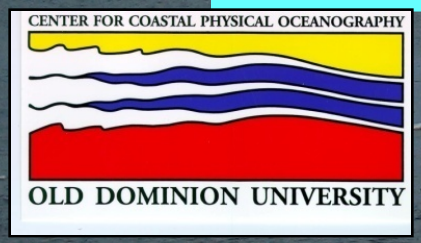


Outline of Presentation

- Introduction
- Recent time series observations of Circumpolar Deep Water (CDW) intrusions
- Description of a regional ocean circulation model
- Timing of CDW intrusions w.r.t. wind forcing
- Conclusions

Introduction

- Relatively warm (up to 2°C), nutrient-rich CDW found at shelf break around much of Antarctica

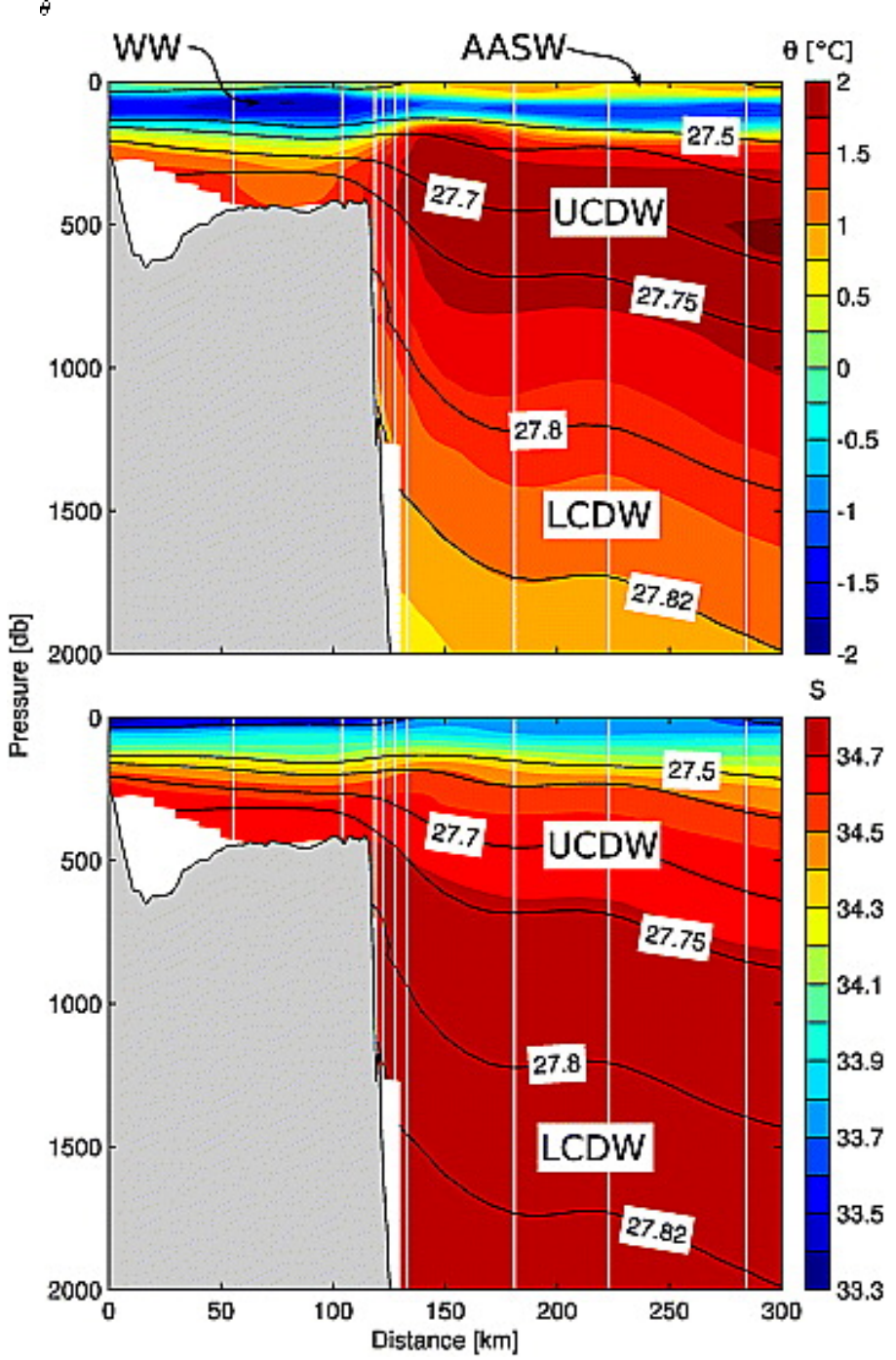
- CDW exchange provides heat and macro (and perhaps micro) nutrients that can stimulate primary production

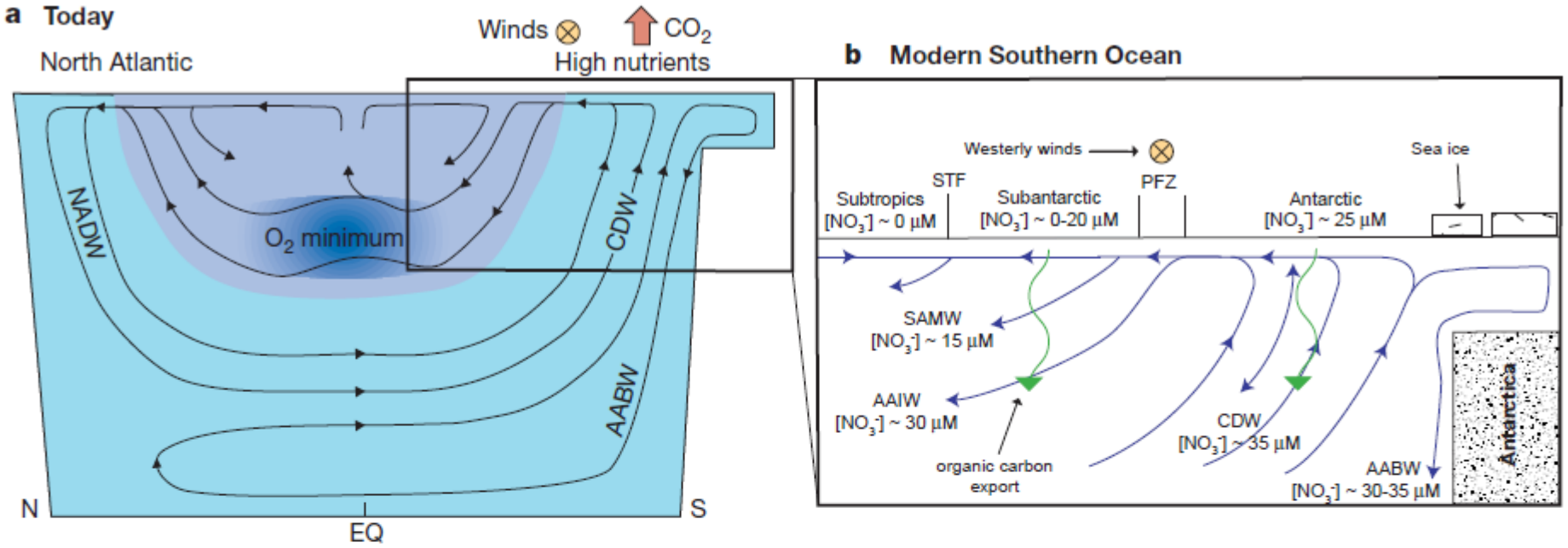
- Changes in either the temperature or quantity of warm CDW entering the ice shelf cavities have been proposed as a reason for the increased volume loss of the West Antarctic Ice Sheet

- Modifications in the wind forcing have been proposed as a mechanism for changes in the flux of CDW onto the continental shelf and to the cavities beneath the ice shelves

Potential temperature and salinity from the SO4P WOCE section (includes the West Antarctic Peninsula (WAP) shelf).

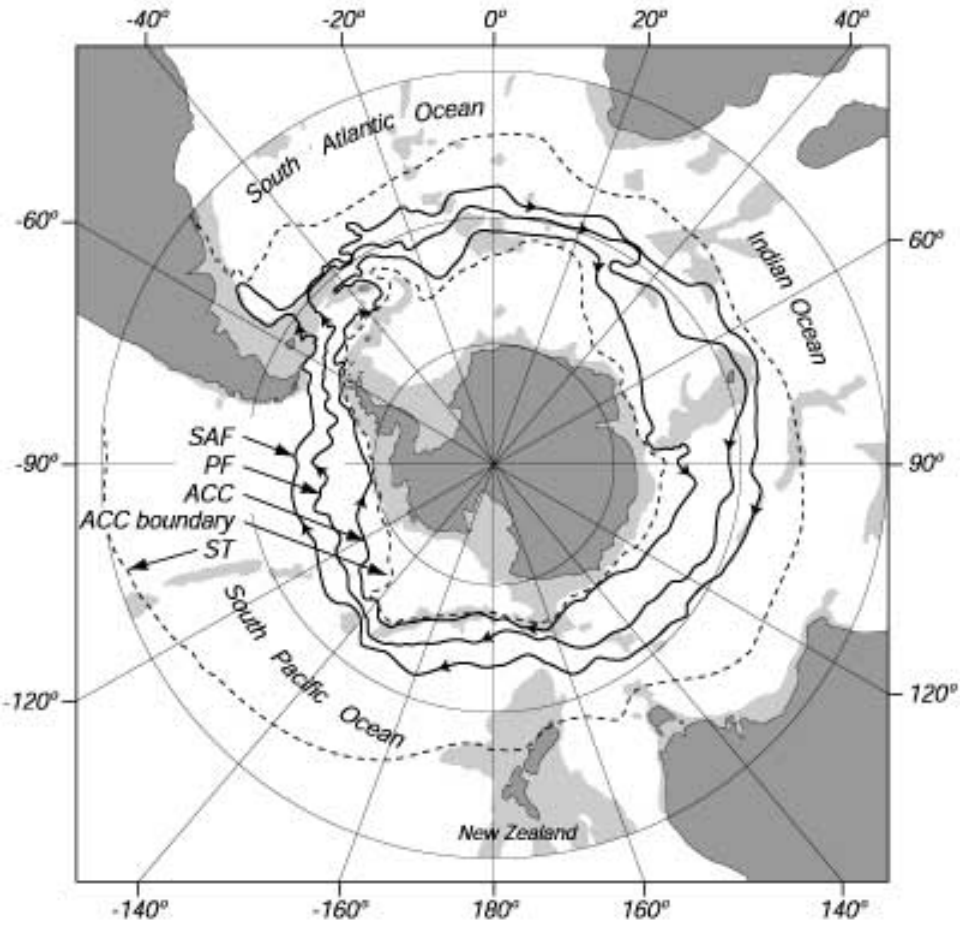
Moffat et al, 2009



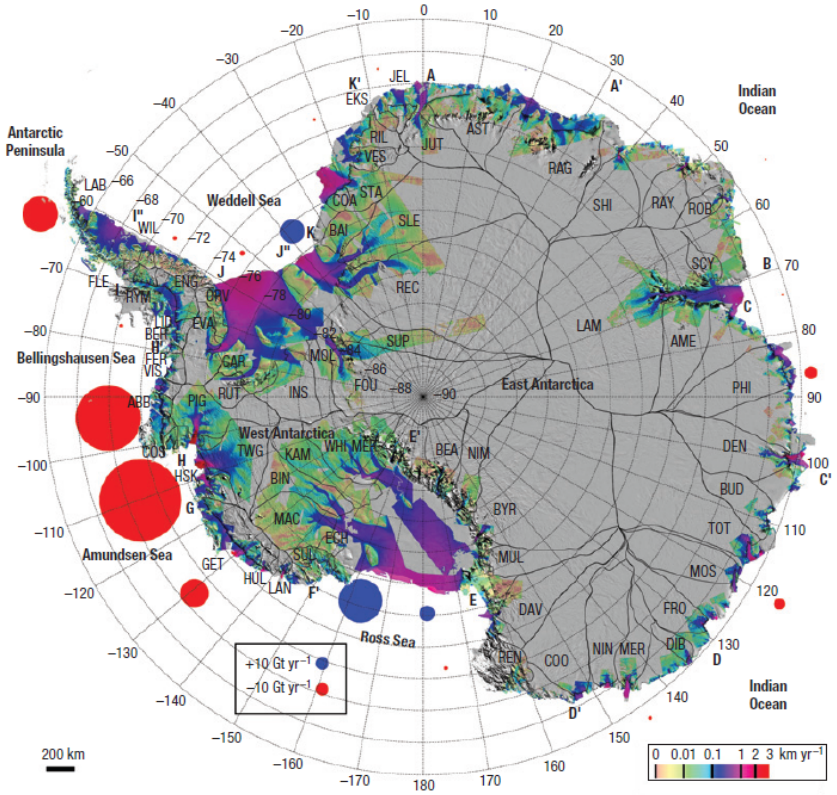


(N.B. LCDW comes from modified NADW, but UCDW is thought to be created in the Pacific and Indian Oceans)

(Figure from Sigman and Boyle, 2000)



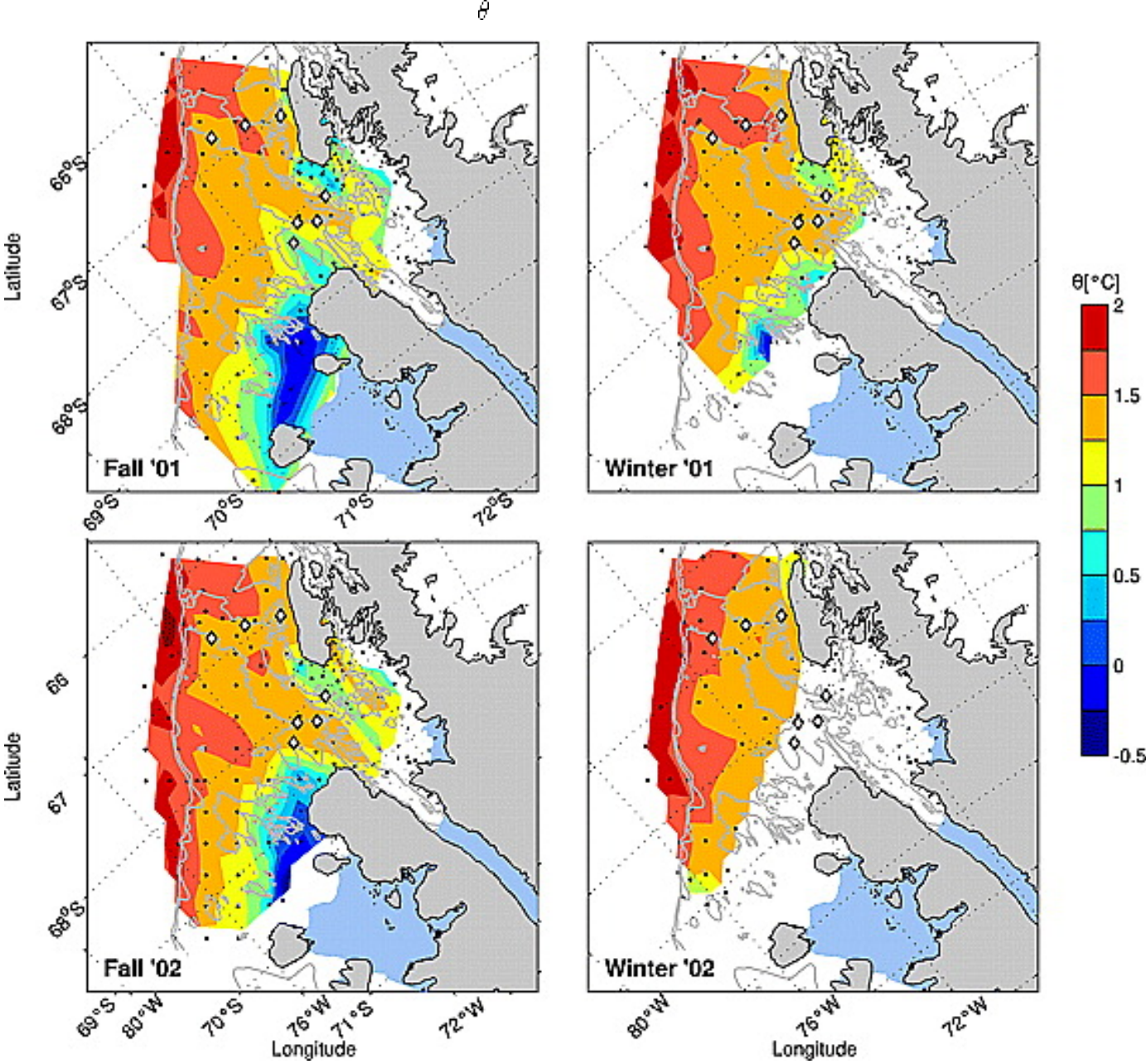
Orsi, 1995



Rignot et al., 2008

Tmax below mixed layer for the West Antarctic Peninsula (WAP) shelf

Moffat et al., 2009

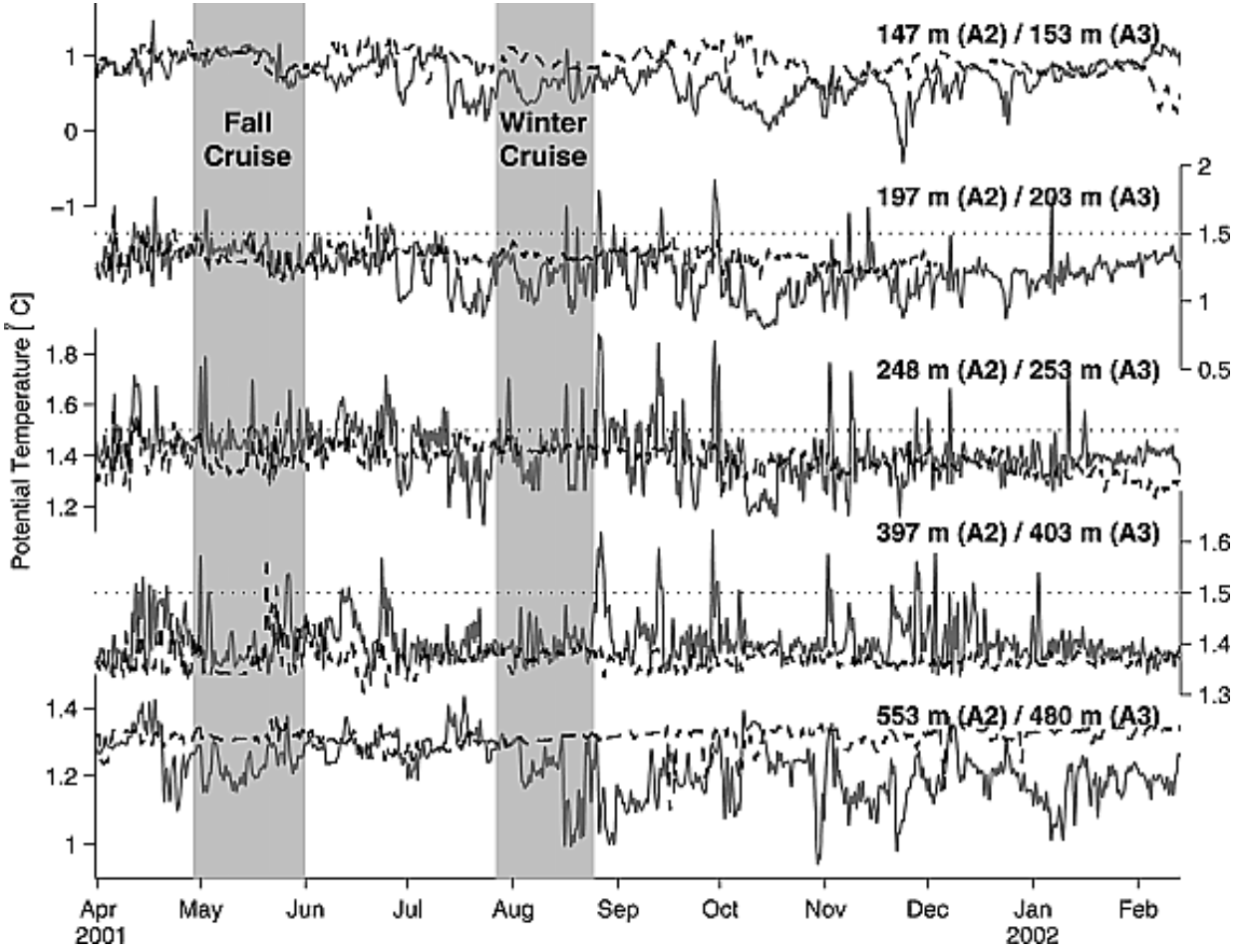


Previous view of WAP intrusion frequency: 4-6 events/year

However, this was based on broad scale hydrographic surveys

Detided, low-pass filtered time series of potential temperature at two moorings within Marguerite Trough => shows much higher intrusion frequency

Moffat et al, 2009

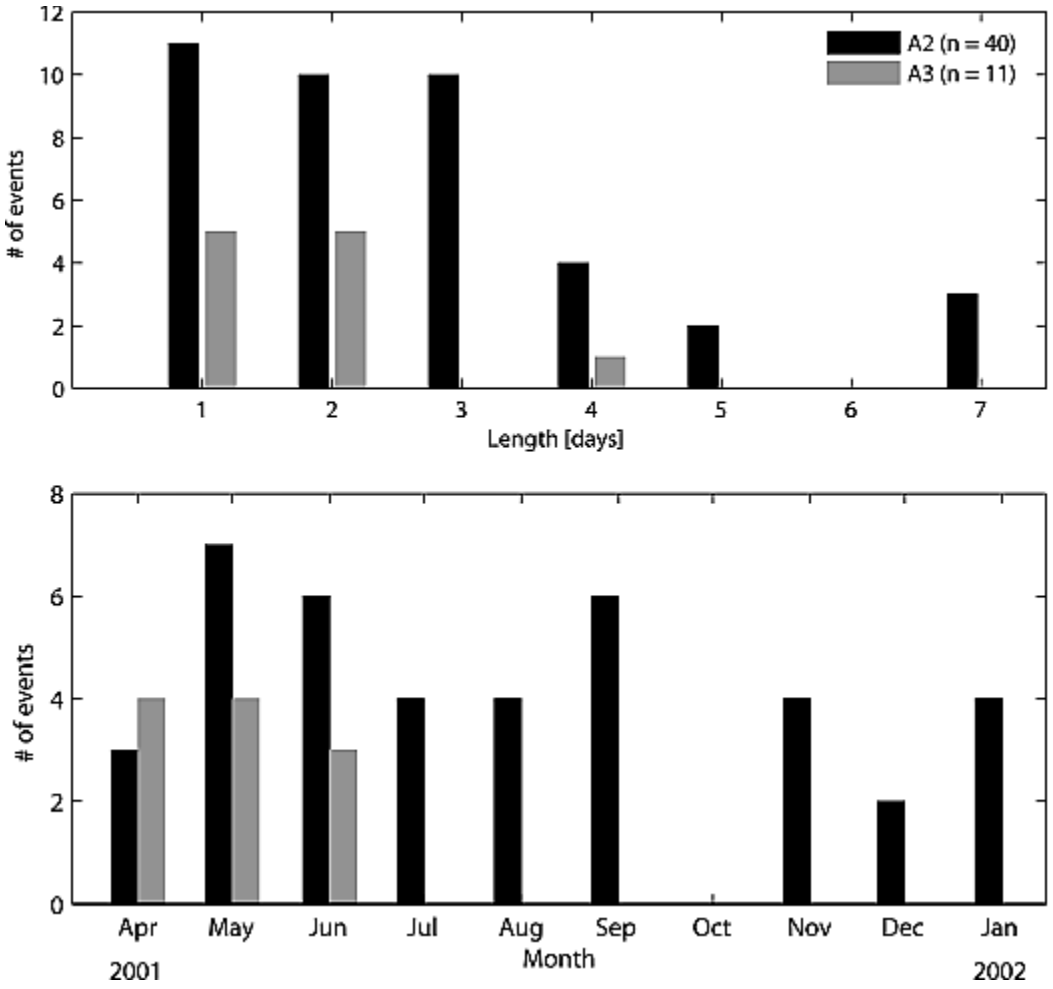


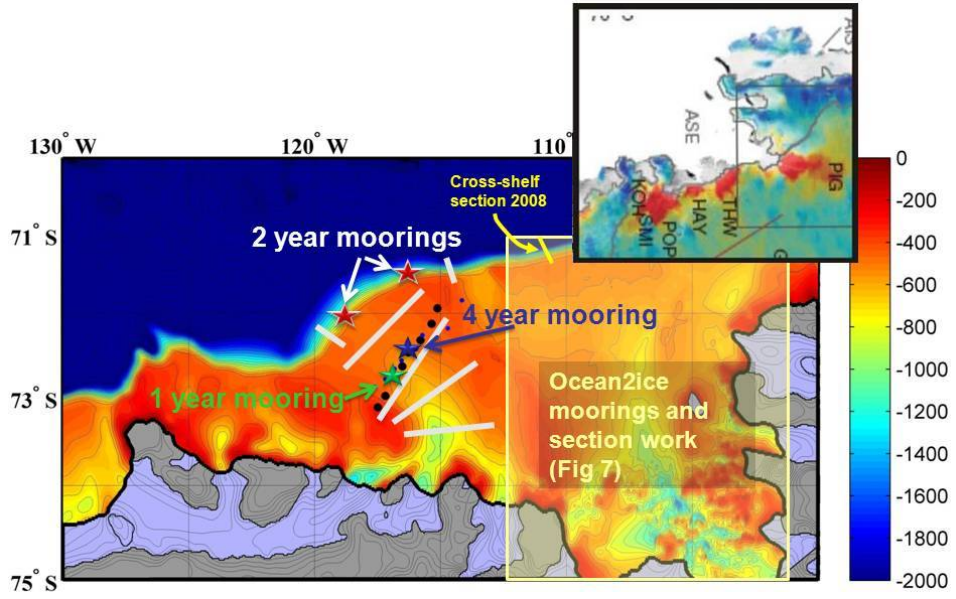
Solid line: A2 – north side of MT
Dashed line: A3 – south side of MT

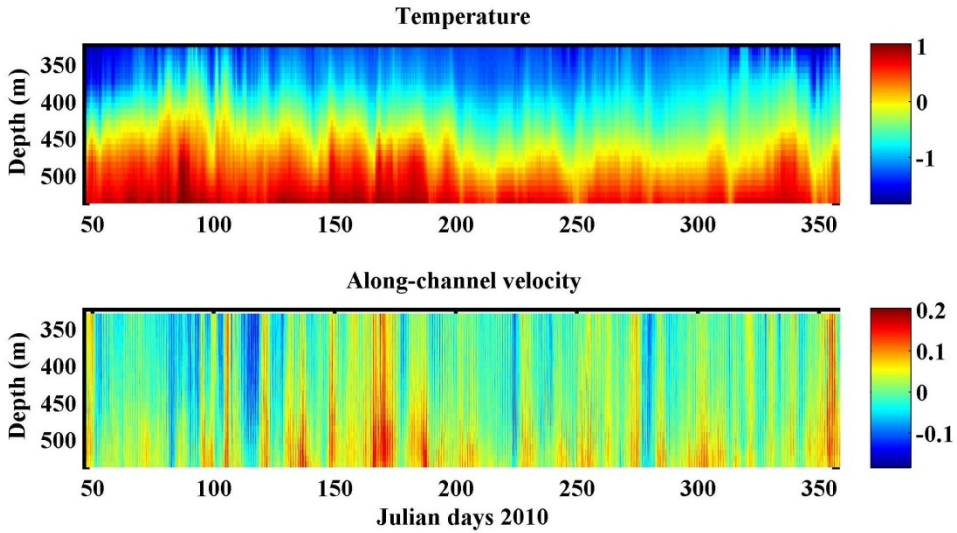
Histogram of the UCDW events' (top) duration and (bottom) number of intrusions per month throughout the 2001/2002 SO GLOBEC mooring deployment

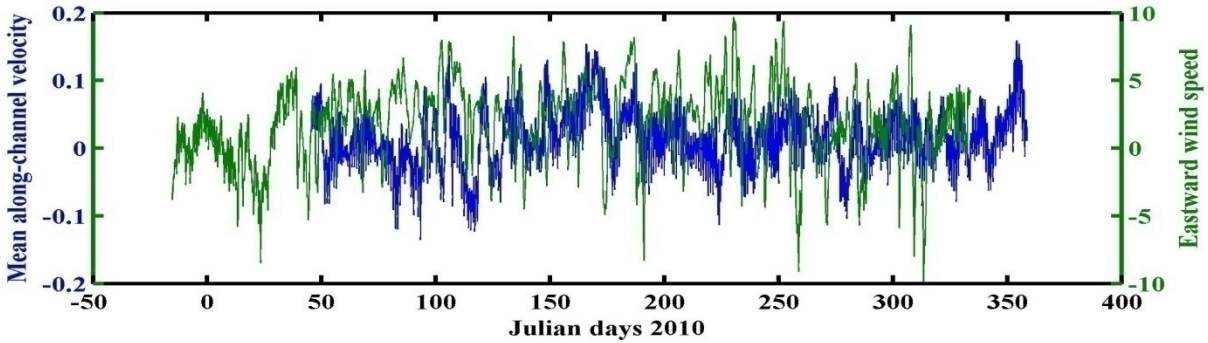
A2: 3.8 events/month
Typical duration: 1-3 d

Moffat et al., 2009





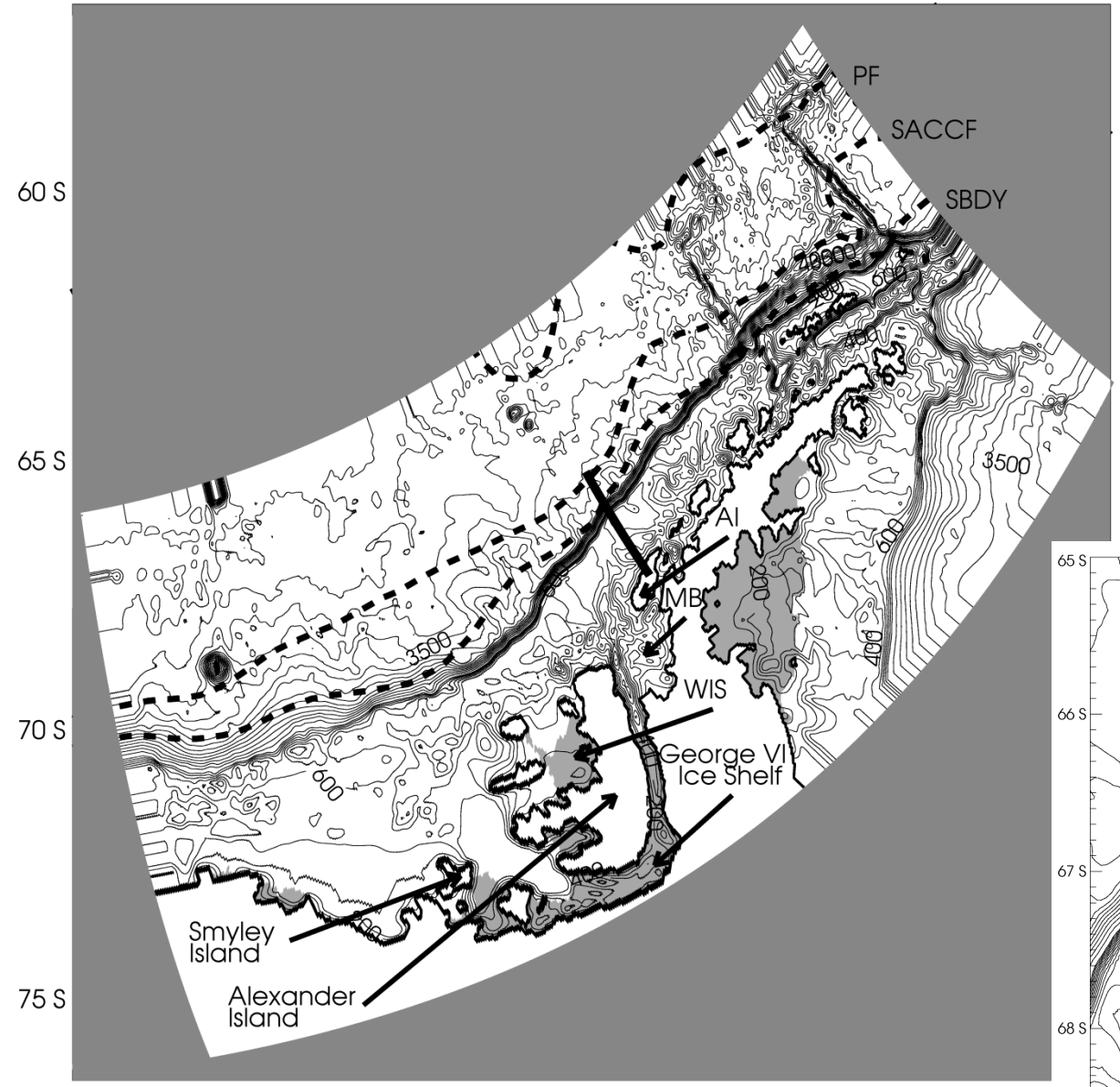


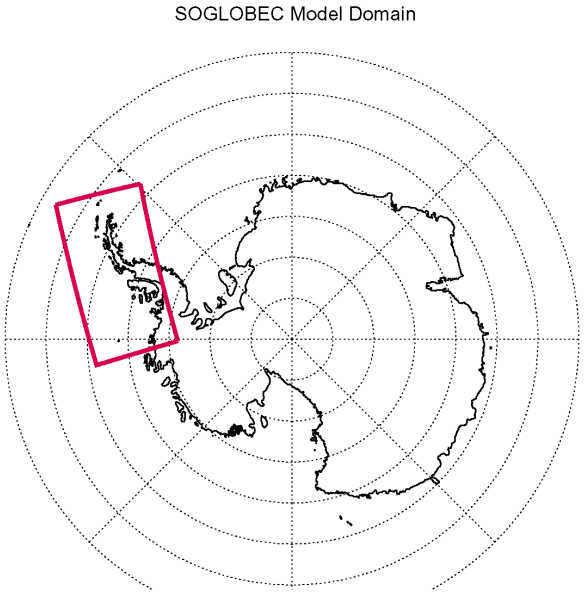


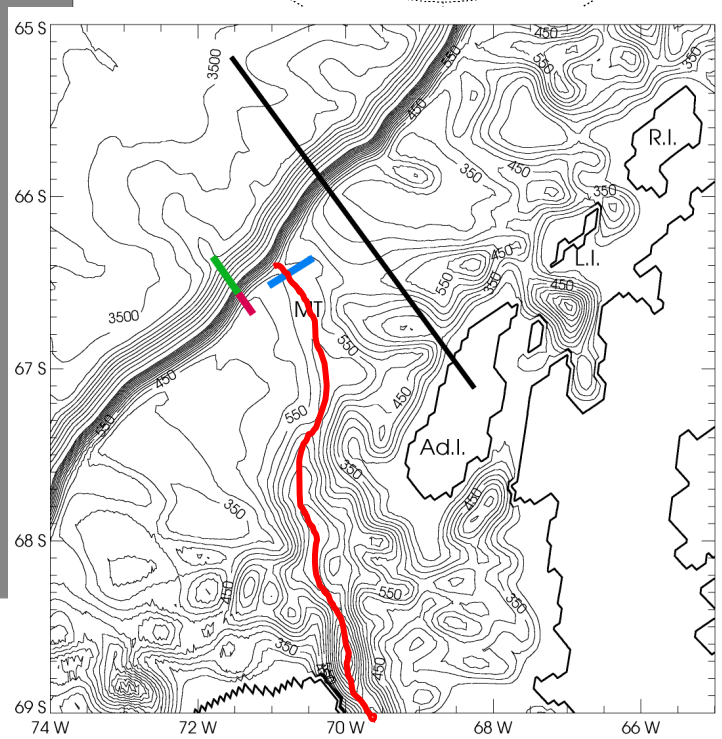
Correlation between eastward wind speed (ERA-Interim) at shelf break (green) and detided depth averaged along-channel velocity (blue) = 0.6

Antarctic Peninsula Model

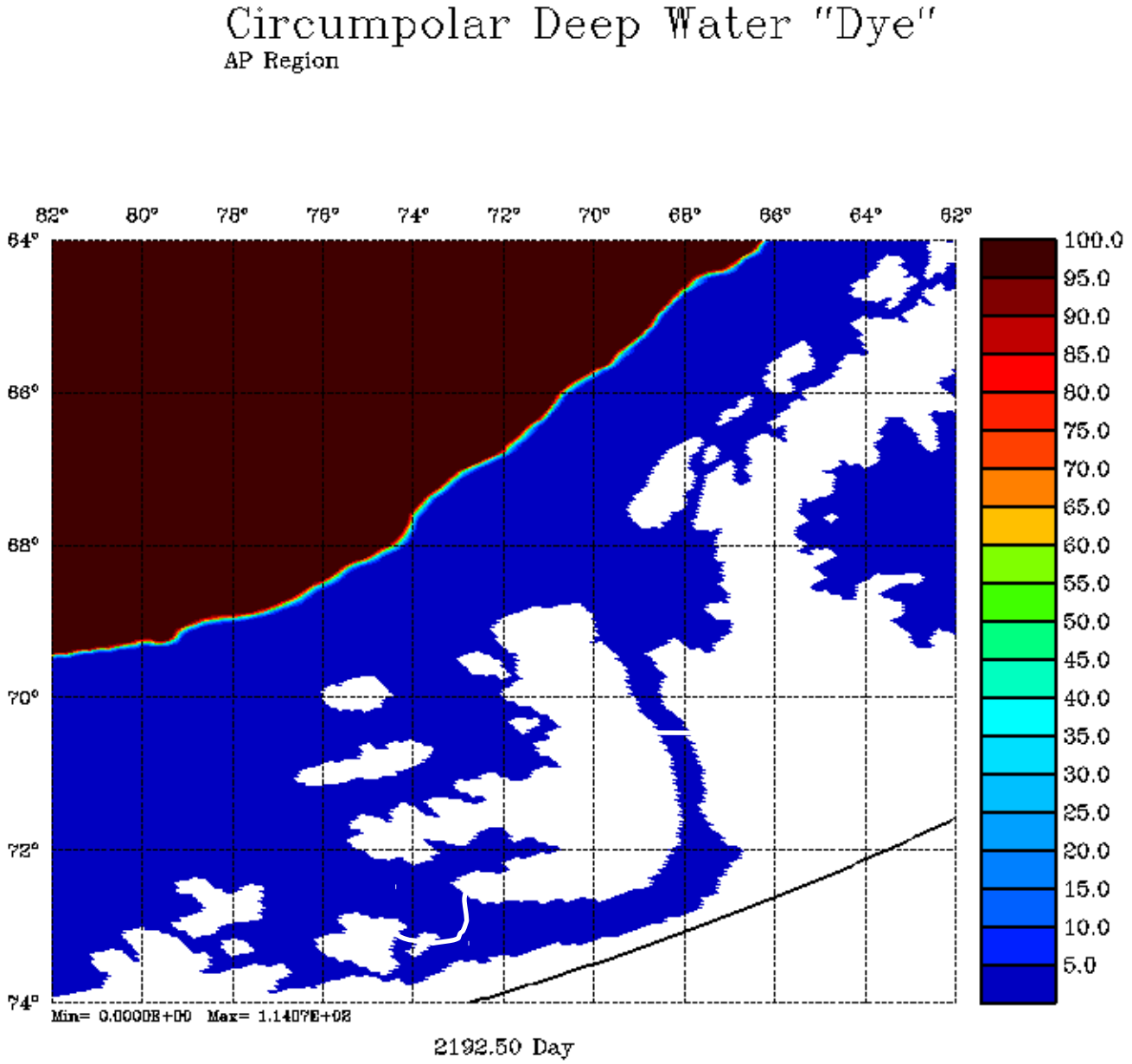
- ROMS: 4 km horizontal resolution, 24 levels
- Ice shelves (mechanical and thermodynamic)
- Dynamic sea ice
- Twice daily wind forcing from AMPS winds
- Lateral boundary conditions from SODA ocean reanalysis and SSM/I ice concentrations
- Experiments w/ dye representing CDW

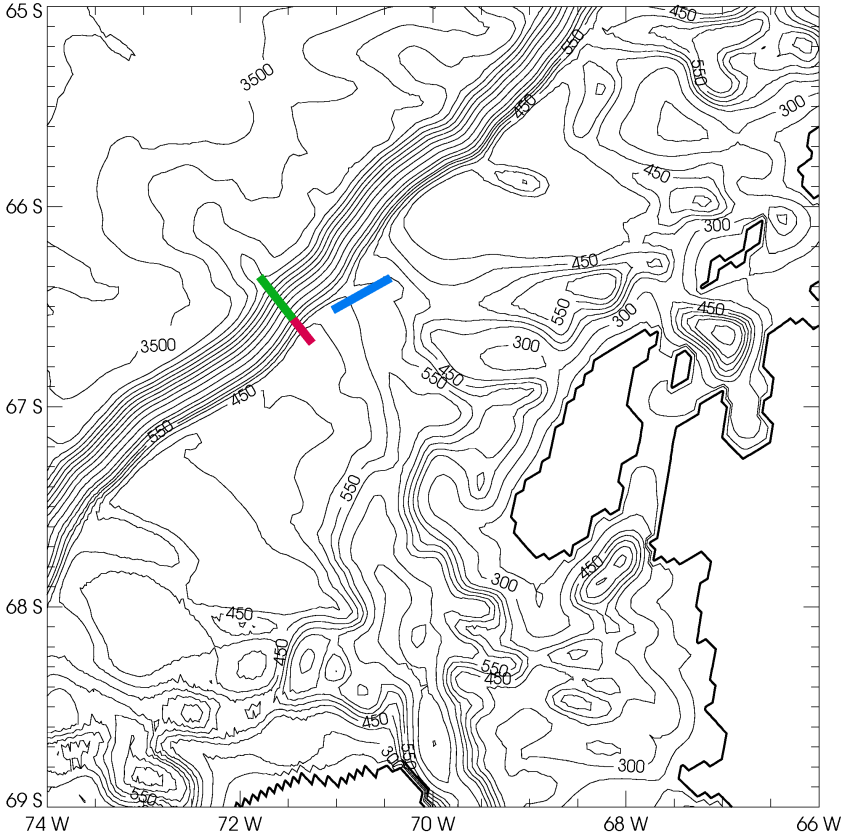

PF
SACCF
SBDY
AI
MB
WIS
George VI
Ice Shelf
Smyley
Island
Alexander
Island
60 S
65 S
70 S
75 S
90 W
80 W
70 W
60 W
50 W
3500
600
450

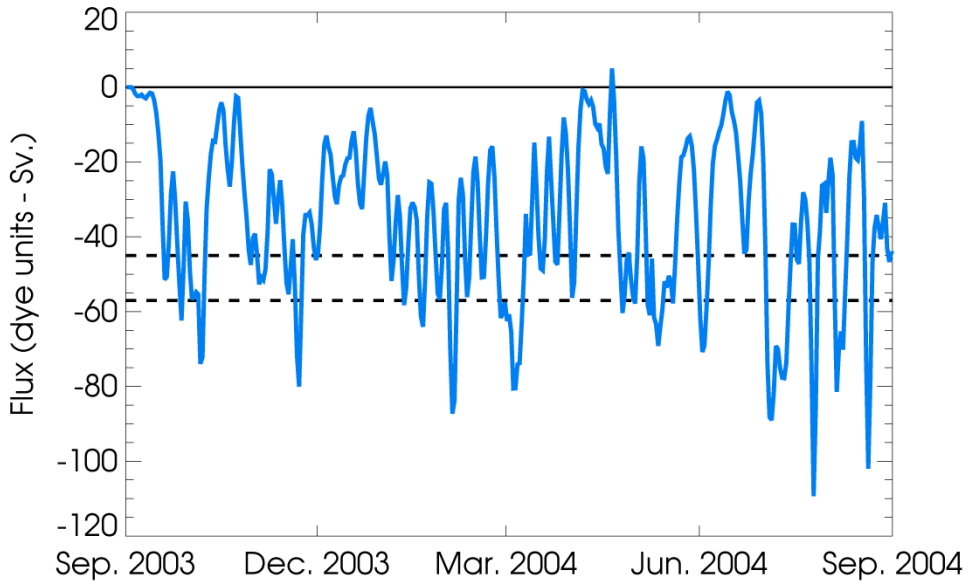

SOGLOBEC Model Domain

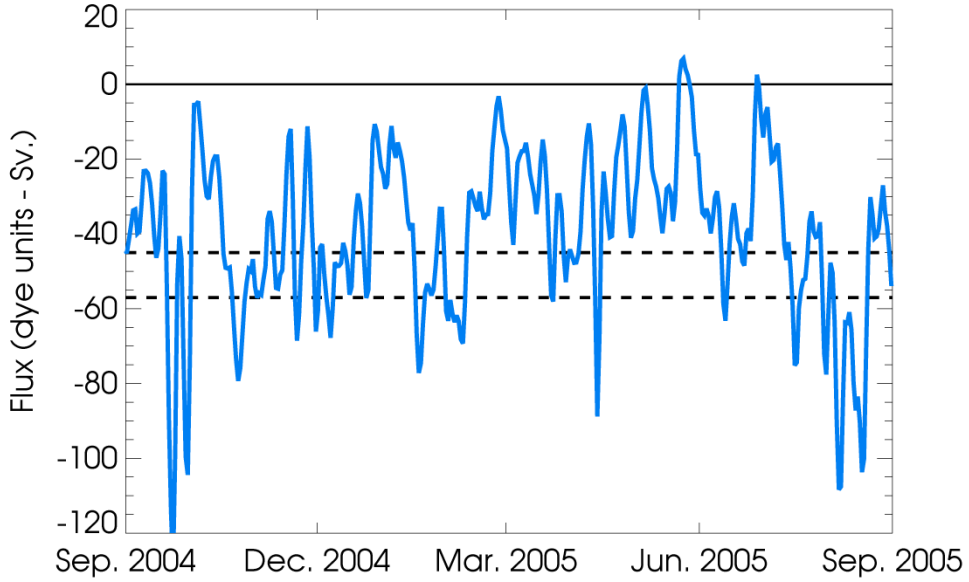

65 S
66 S
67 S
68 S
69 S
74 W
72 W
70 W
68 W
66 W
3500
450
550
350
R.I.
L.I.
Ad.I.
MT

Dye concentration at depth (model level 4): 9/15/2003 – 9/15/2005



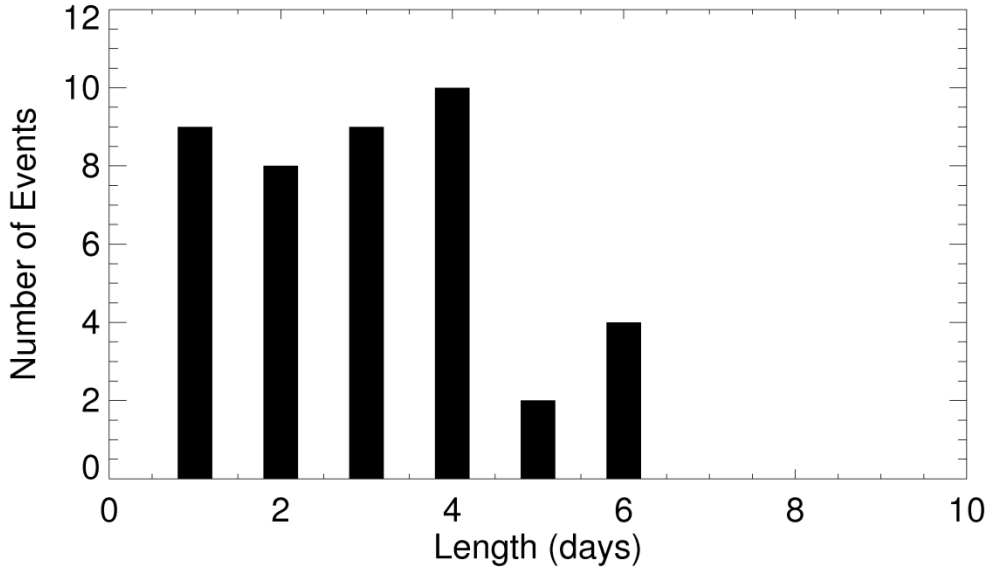






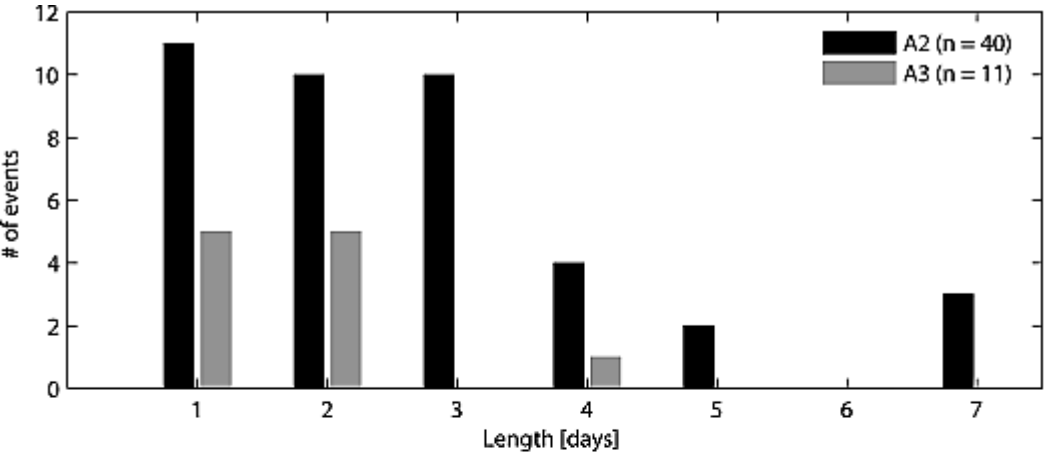
Left: Gate for measuring CDW intrusions (blue) and upstream cross-section (green-red)

Right: Model dye flux across Marguerite Trough “gate” and intrusion thresholds



Model histogram of the intrusion duration (57 dye unit-Sv. threshold) for the entire model run

Model: 1.8 events/month
(3.0 events/month w/ 45 dye unit-Sv. threshold)
Typical duration: 1-4 d



Observed histogram of the intrusion duration

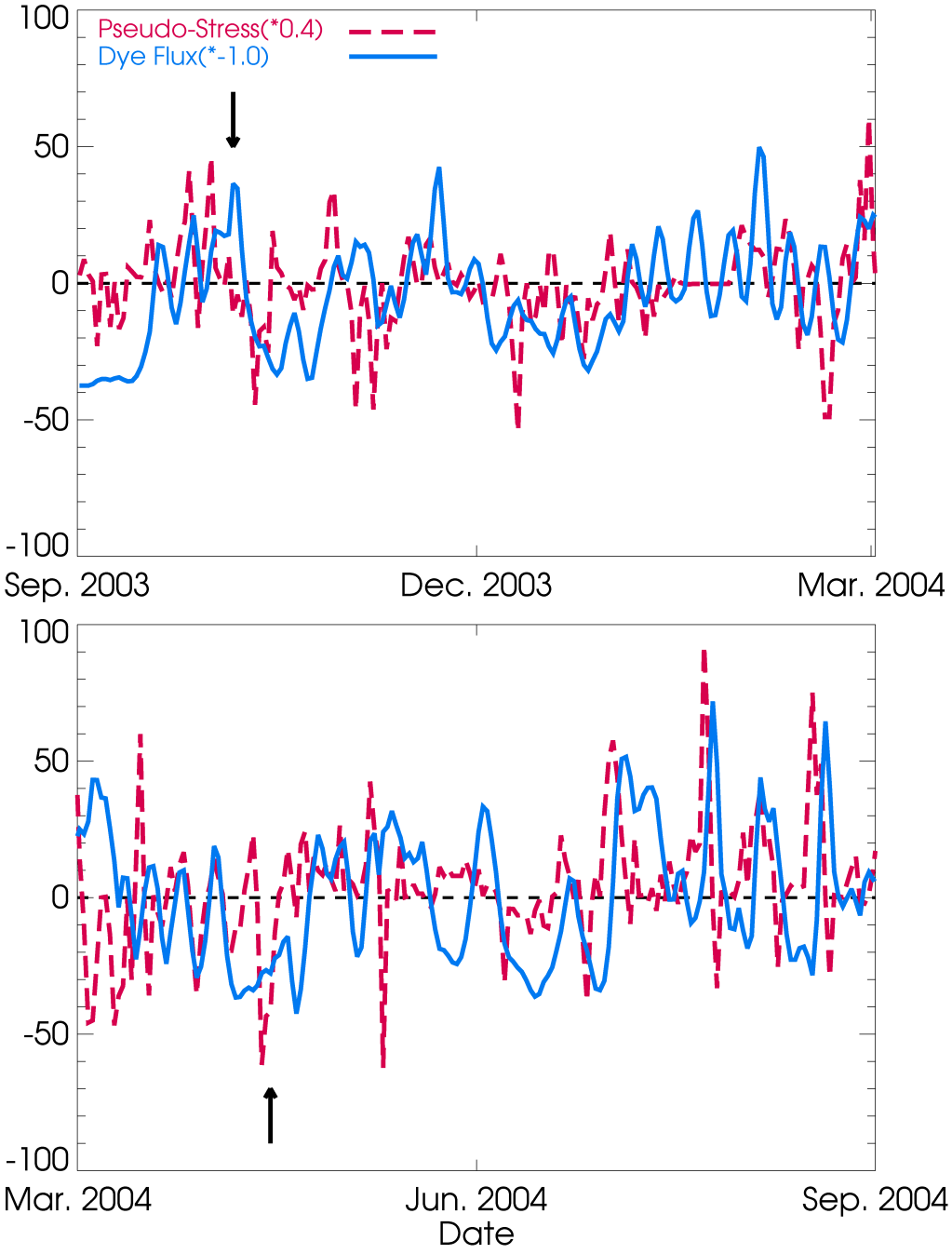
A2: 3.8 events/month
Typical duration: 1-3 d

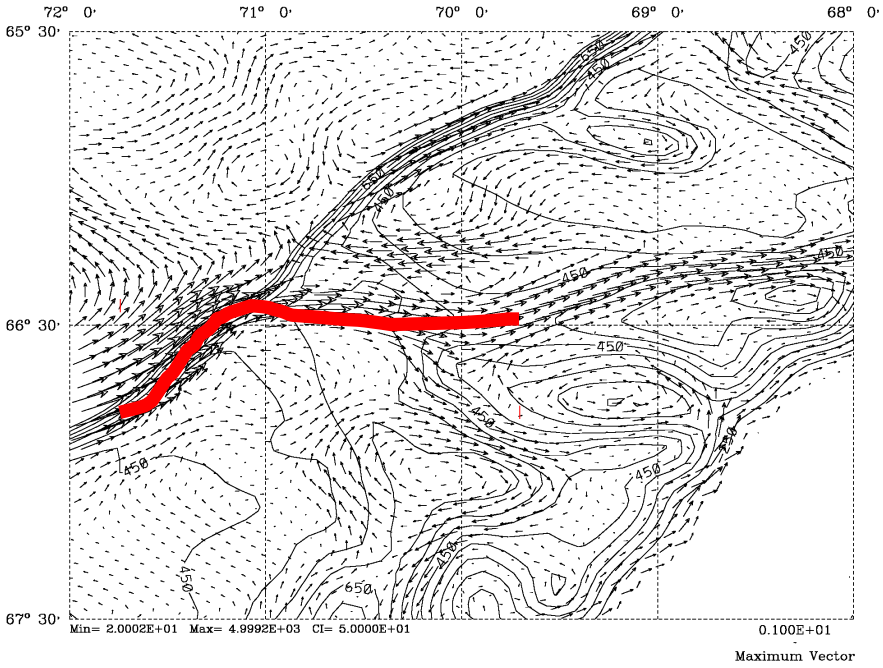
Definition of intrusion is arbitrary, but model is much closer to mooring data than previous survey based picture of 4-6 intrusions per year

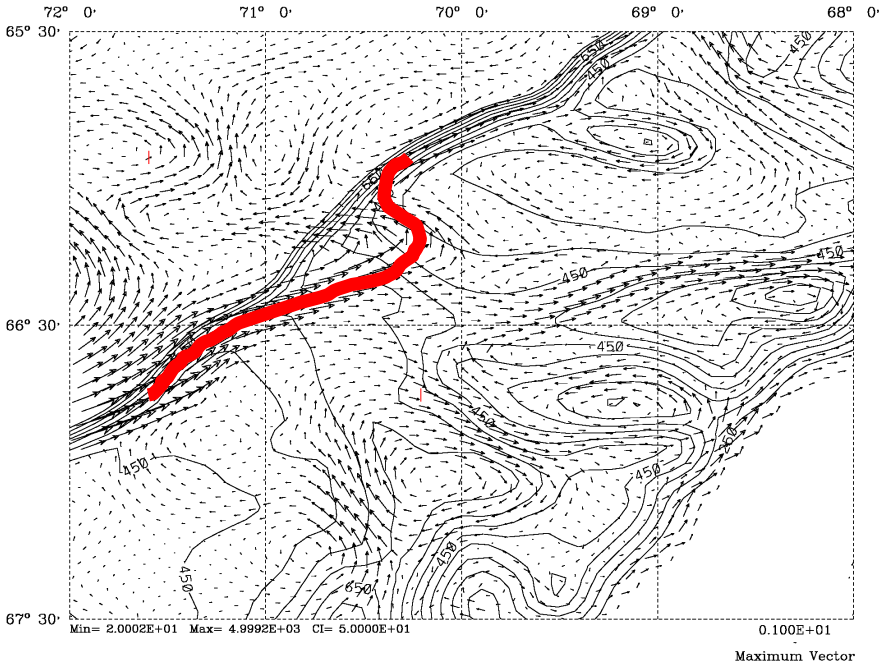
Duration of intrusions suggests wind forcing (weather band frequency: 2-8 days)

No significant correlation between wind perpendicular to flux “gate”, but significant lagged correlation for wind parallel to cross-section:
r = 0.44 (wind leads dye flux by 2-3 days)

Red: Pseudo-stress (x 0.4) parallel to CDW-dye flux cross section
Blue: CDW-dye flux anomaly (reversed sign)







"Intrusion" flow

Non-"Intrusion" flow

No significant correlation between upstream volume flux along continental slope and dye flux, but significant lagged correlation for inner along slope volume flux and dye flux (r = 0.64, volume flux leads dye flux by 2 days)

Physical Mechanism?

Future Plans

- High-resolution (1 km) process model to study cross shelf break intrusion mechanisms
  - Are intrusions mesoscale eddies?
  - Bottom Ekman layer, flow inertia and bathymetry, ACC density variation due to thermal wind, flow dynamic instability, atmospherically forced exchange, ice shelf circulation
- Use realistic model domains to examine impacts of changes in the winds on intrusions

Conclusions

- Intrusions of CDW on to the shelf have a shorter timescale then previously thought and the intrusion timescales seem to be related to wind events

- This could lead to increases in winds leading to increases in the amount of CDW advected onto the continental shelf

Acknowledgements

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- AMPS winds courtesy of John Cassano
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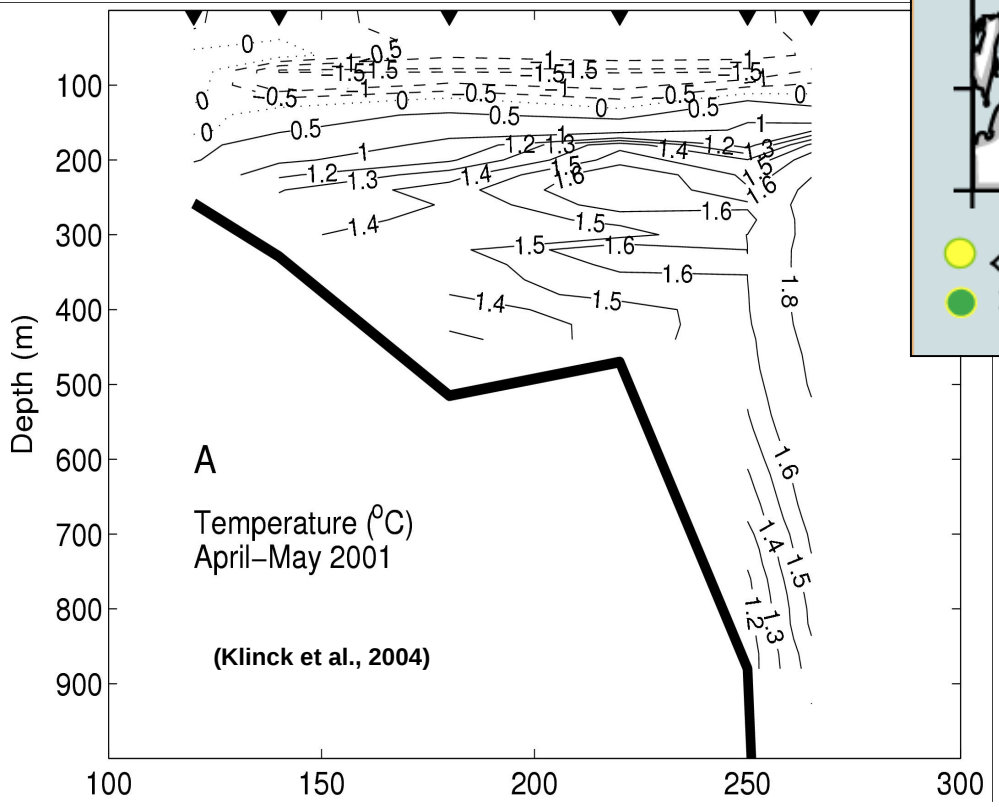
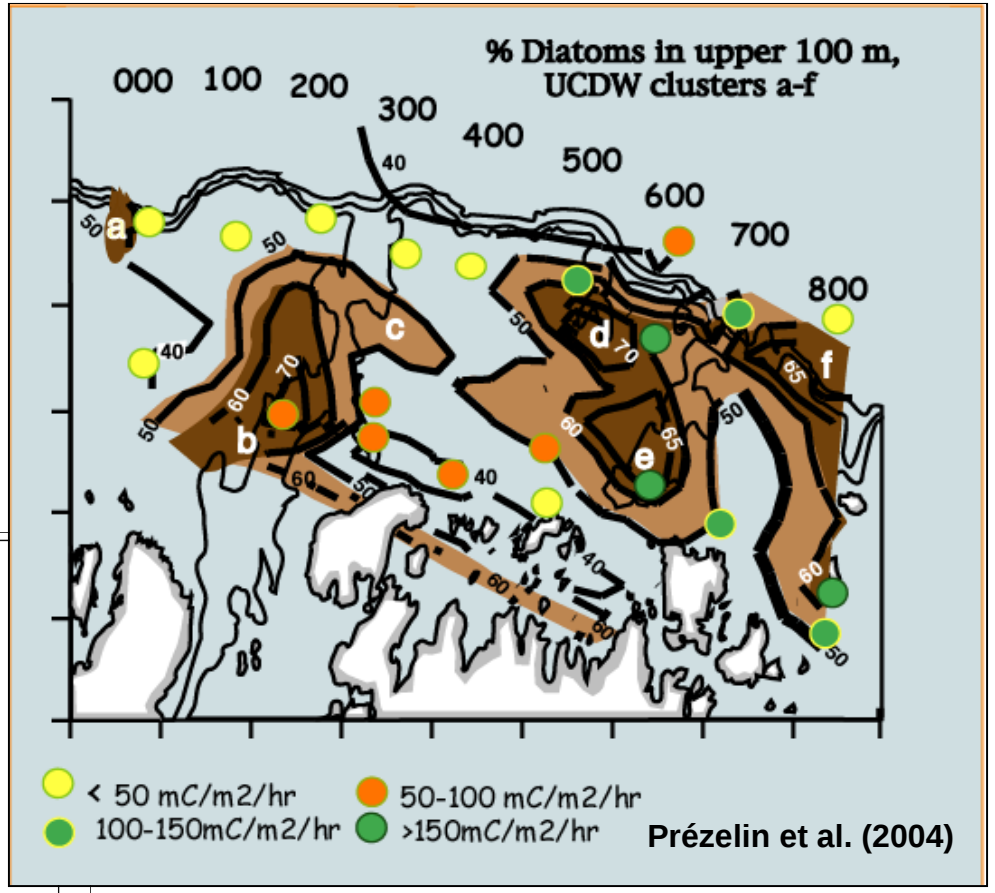
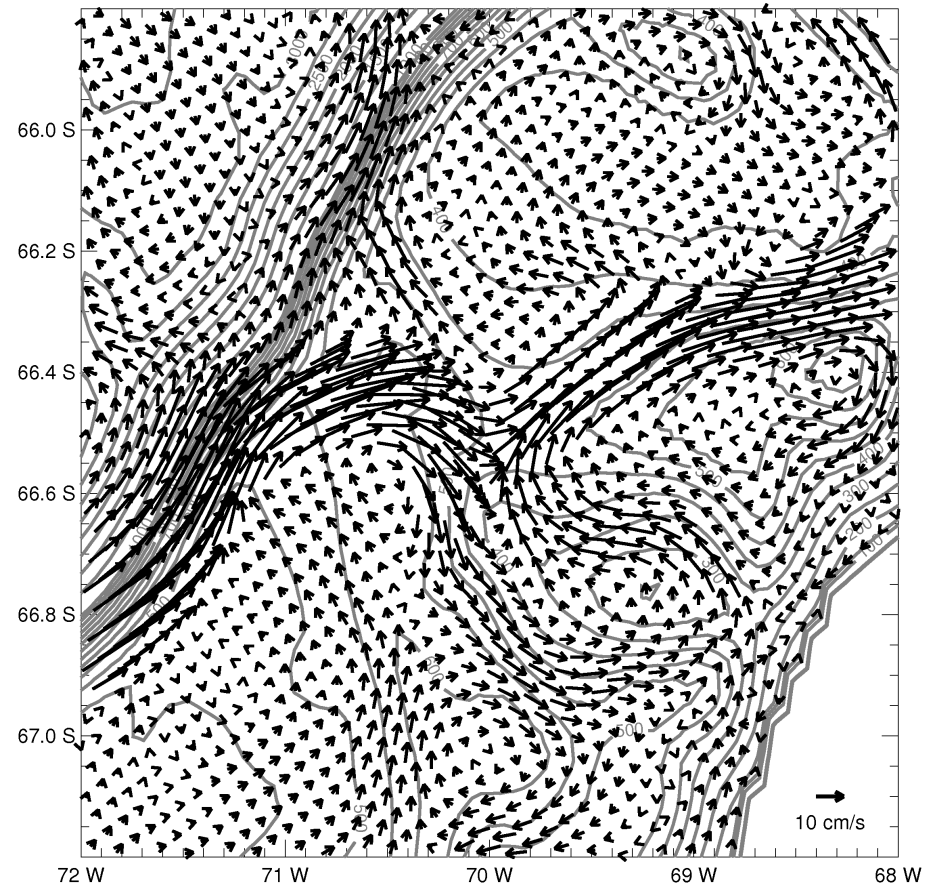
Circumpolar Deep Water

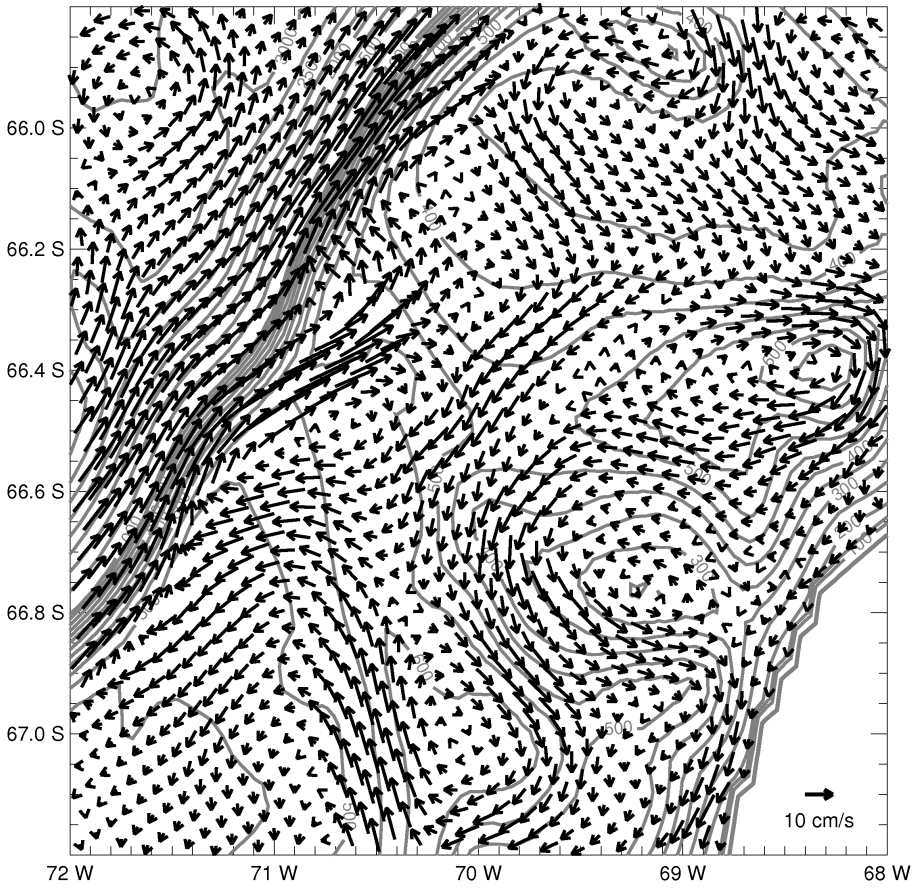
CDW- Floods WAP shelf below 200 m





CDW – correlates with regions of high primary production and high diatom percentage within phytoplankton assemblages





“Intrusion” flow

Non-“Intrusion” flow

No significant correlation between upstream volume flux along continental slope and dye flux, but significant lagged correlation for inner along slope volume flux and dye flux ($r = 0.74$, volume flux leads dye flux by 2 days)

Physical Mechanism?

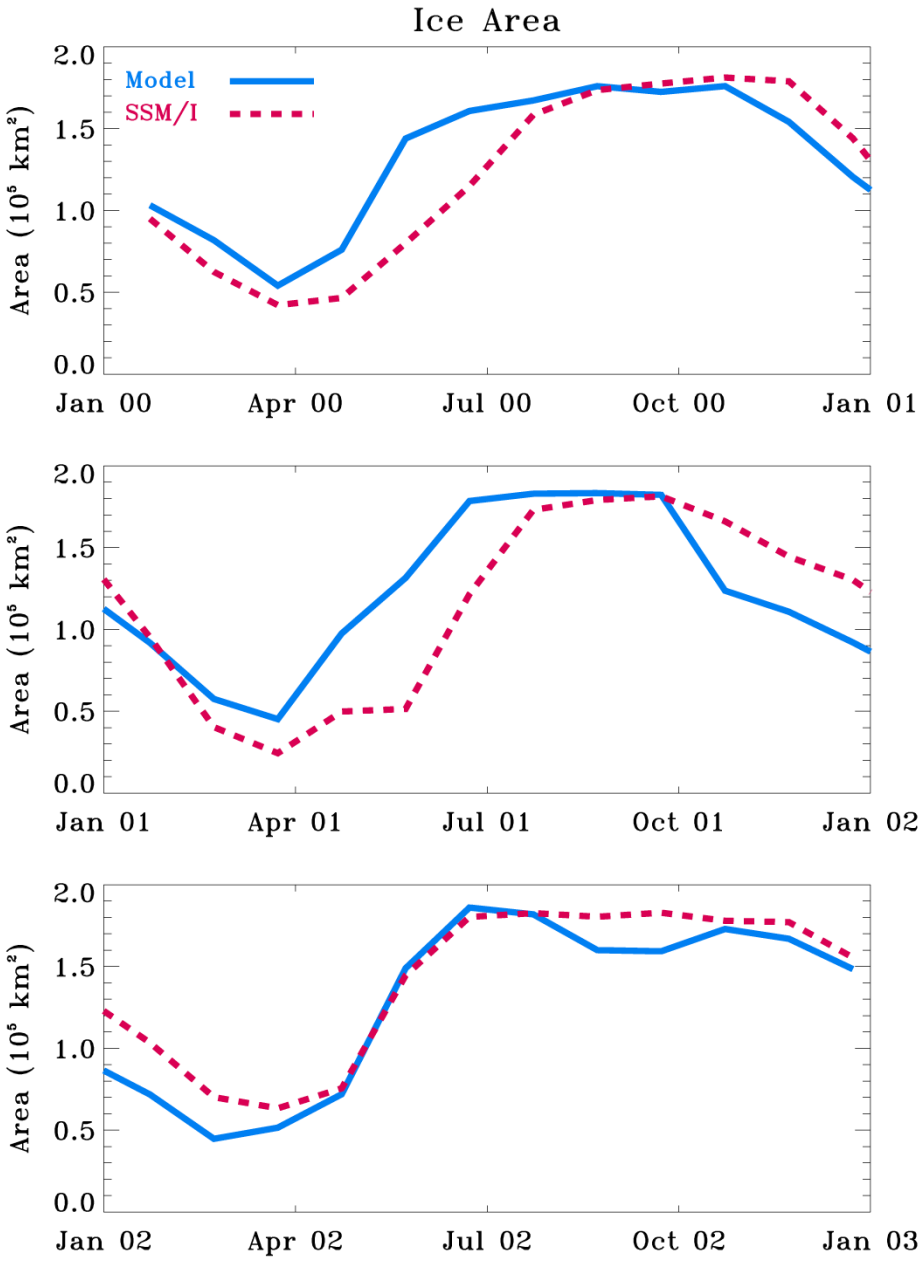
Dynamic Sea Ice Model

- Budgell (2005) model (built into ROMS)
  - Thermodynamics based on Mellor and Kantha (1989) with two ice layers, a snow layer, surface melt ponds and a molecular sub layer at the ice/ocean interface
  - Dynamics based on an elastic-viscous-plastic rheology after Hunke and Dukowicz (1997) and Hunke (2001)

- Los Alamos CICE available, but not using yet due to time constraints

Monthly modeled sea-ice (solid line) vs. SSM/I sea-ice (dashed line) area for the central WAP shelf

(r^2 = 0.72)



Monthly modeled sea-ice (solid line) vs. SSM/I sea-ice (dashed line) area

(r^2 = 0.87)