The Importance of High Spatial Resolution for Models of Antarctic Coastal Circulation

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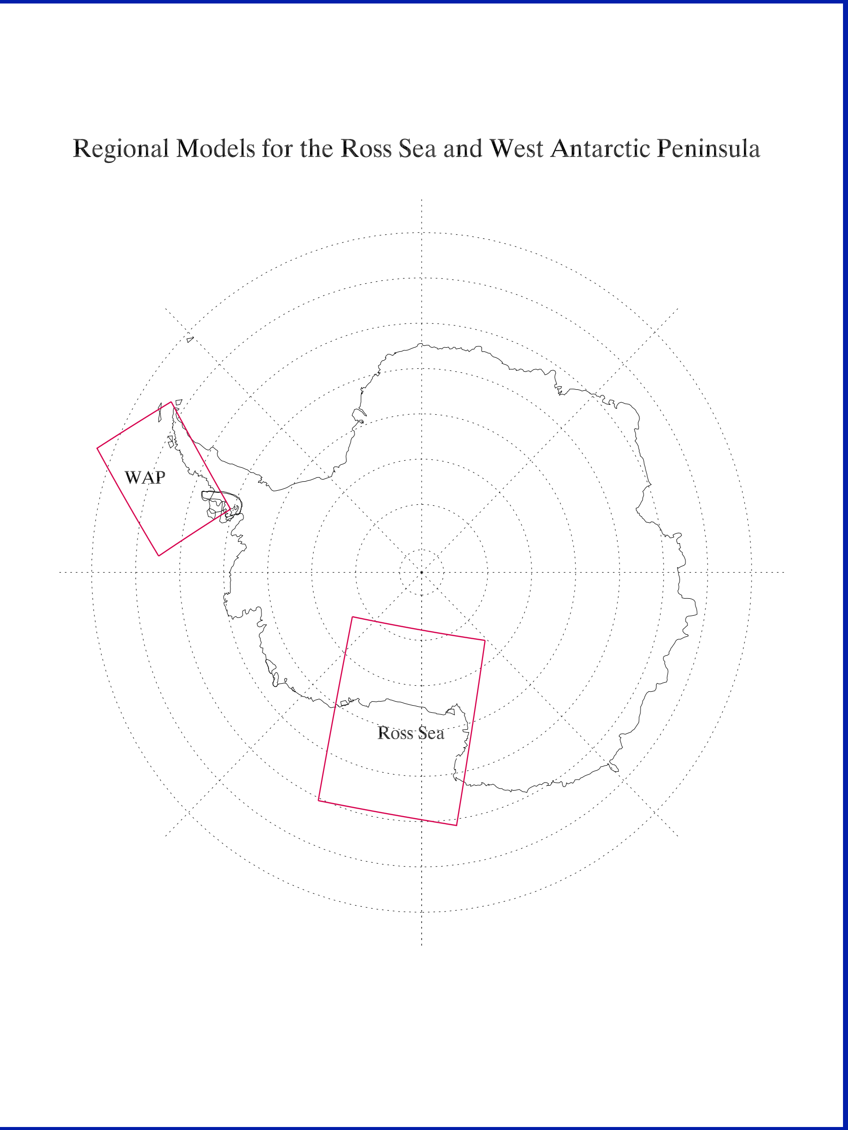
Introduction

- Development of high resolution (5 km) regional ocean circulation models to examine physical environment and marine ecosystems
- Much of the atmospheric forcing data has coarse horizontal resolution (~2.5°) => problems
- 2 regions: west Antarctic Peninsula, Ross Sea



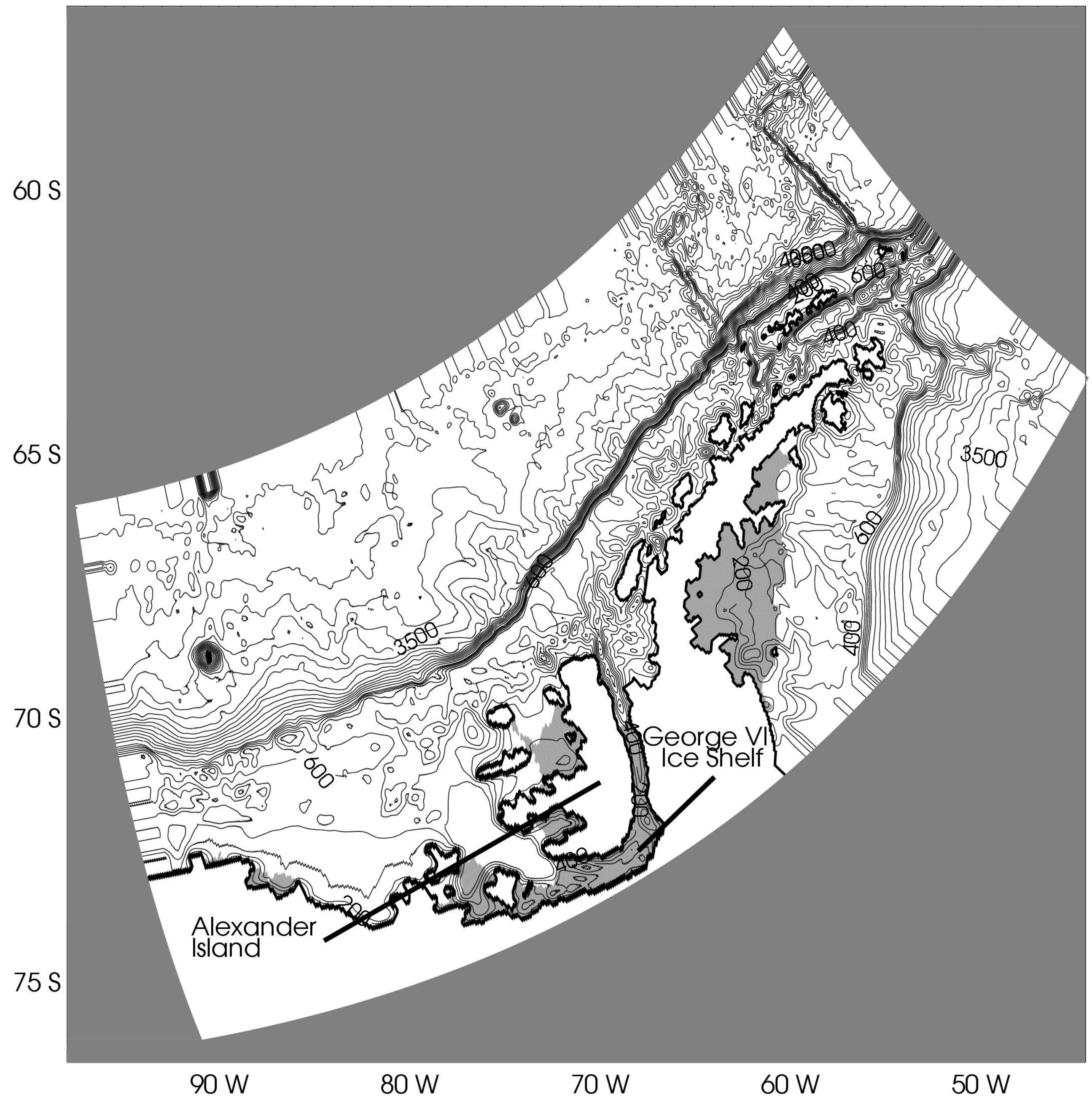
High Resolution for Ocean Models

- Dynamic scale (deformation radius) is ~5 km
- Sets the width scale of eddies, frontal jets and coastal currents
- Weak stratification means that bottom topography has strong control over circulation (flow follows f/h)
- Land elevation creates small scales in atmosphere which affects the ocean (coastal jets, katabatic winds, lee eddies)

West Antarctic Peninsula Model

- Previous model has 5 km grid, imposed sea ice, no ice shelf processes.
- New model has 4 km grid, expanded domain, sea ice (imposed or dynamic) and ice shelves.
- Future plans are to use WRF/AMPS to estimate higher resolution atmospheric conditions

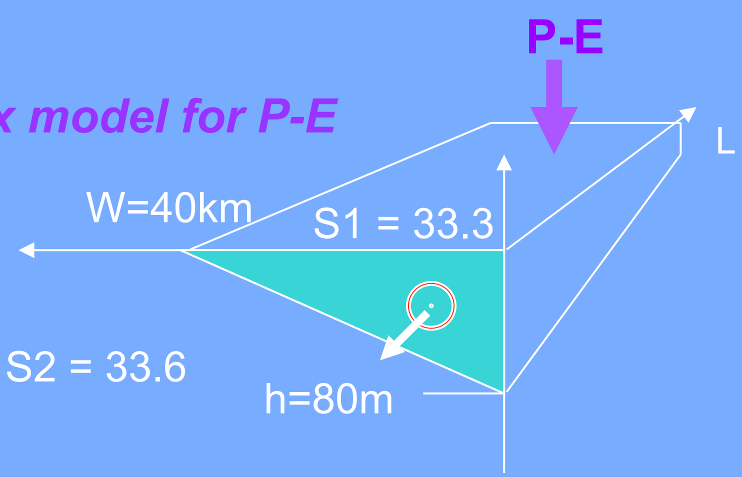
West Peninsula model domain



Potential freshwater sources for coastal current:

- **Surface: sea ice melt, P – E**
- **Lateral: runoff, glacier calving**

Box model for P-E

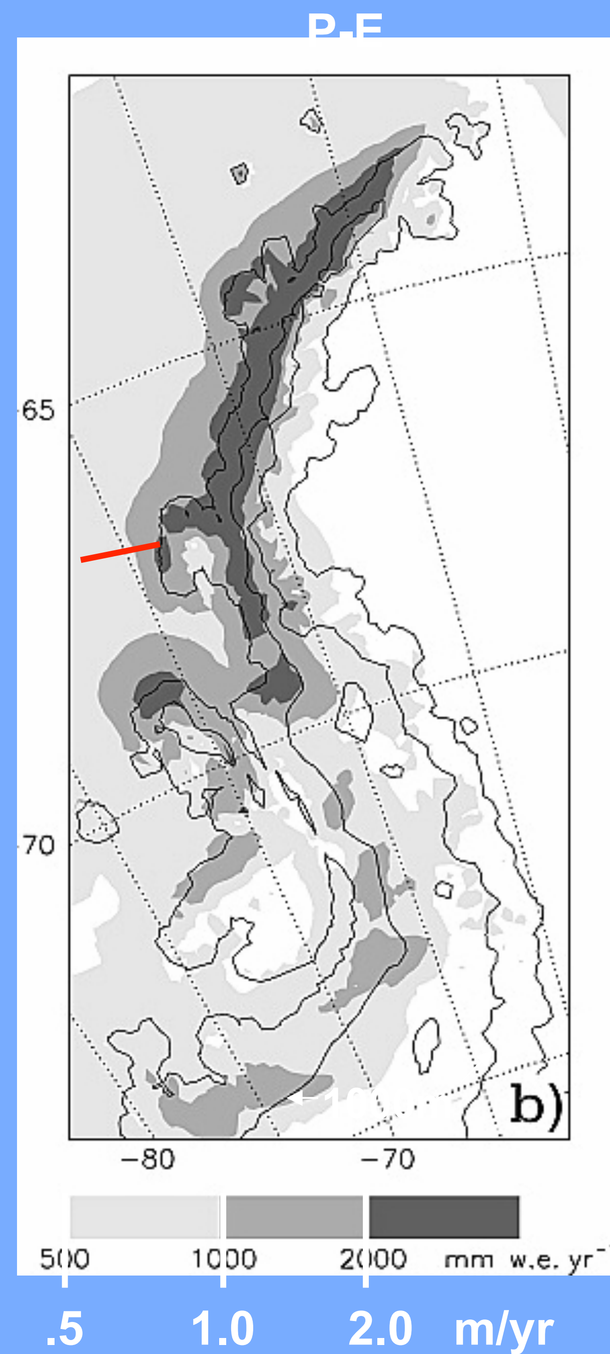


$T = g'h^2/2f = 0.7 \times 10^5$ m³/s

$u = g'h/fW = 4$ cm/s

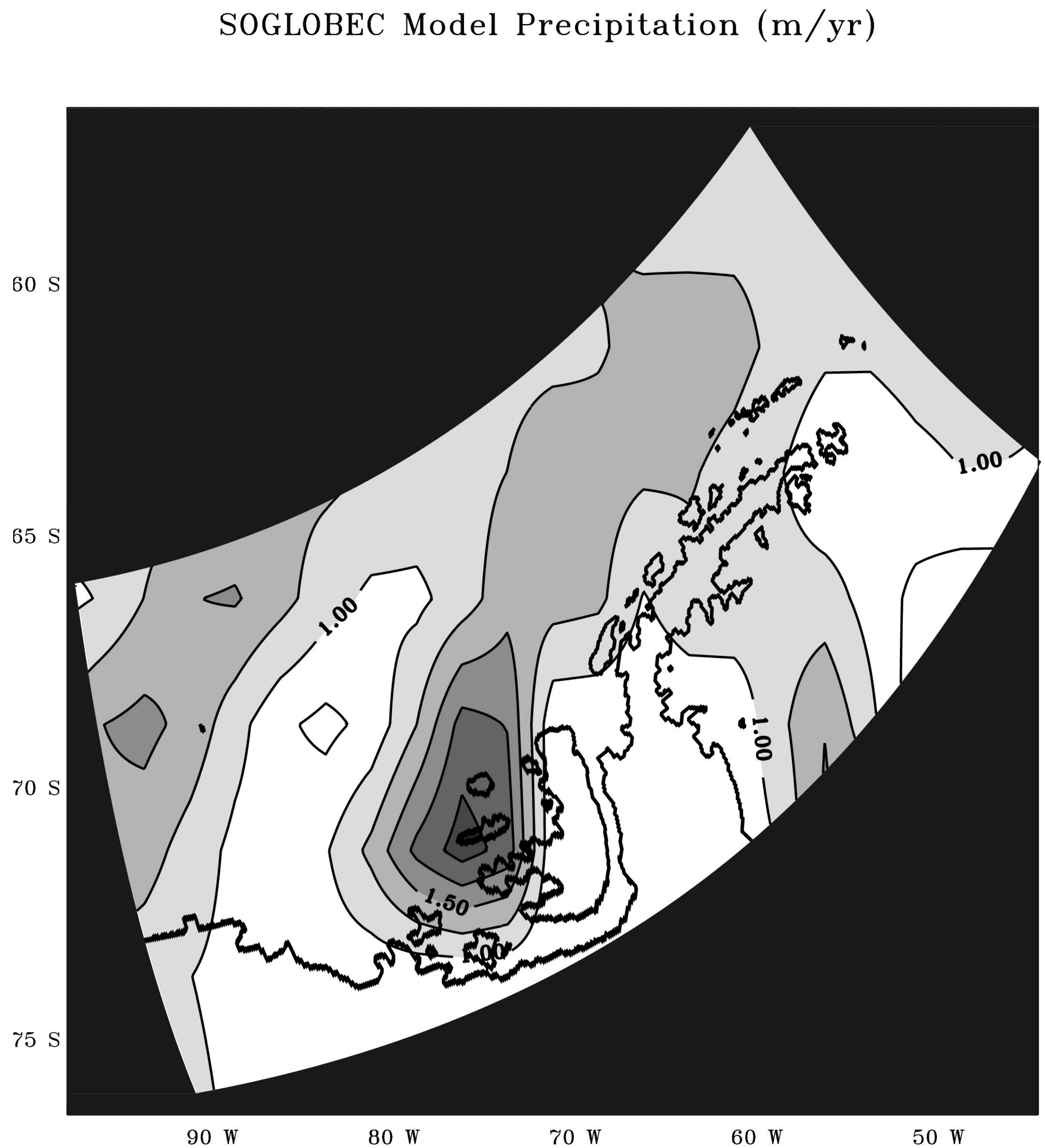
P-E = 1.5 m/yr

L = (ΔS/S)T/(W*(**P-E**)) ~ 330 km



Estimated precip from Xie and Arkin (1997) global climatology

Compare to van Lipzig et al 2004 result from a precip model (previous slide).



Circulation Model

- ROMS (Rutgers/UCLA Regional Ocean Modeling System)

  - Free surface, hydrostatic, primitive equation ocean general circulation model in terrain-following coordinates
  - Horizontal finite difference (Arakawa C-grid) and vertical finite volume discretization
  - full heat budget at ocean surface
  - Mechanical and thermodynamic effects of ice shelves on the water underneath

Atmospheric Surface Forcing

- Daily wind stress and wind speed calculated from 6-hr winds from a blend of QSCAT data and NCEP analyses (0.5° res., sort of…)
- Monthly climatology of precipitation from Xie and Arkin 2.5° CMAP (gauges, satellite and NCEP reanalysis) data
- Monthly cloud climatology from ISCCP
- Monthly climatology of surface pressure, air temperature and humidity from NCEP reanalysis (some experiments w/ ERA-40 reanalysis air temperature)
- Open-water heat flux computed w/ COARE 2.0 bulk flux algorithm
- Model heat and freshwater fluxes a linear combination of open water and sea ice terms based on ice concentration

Sea Ice

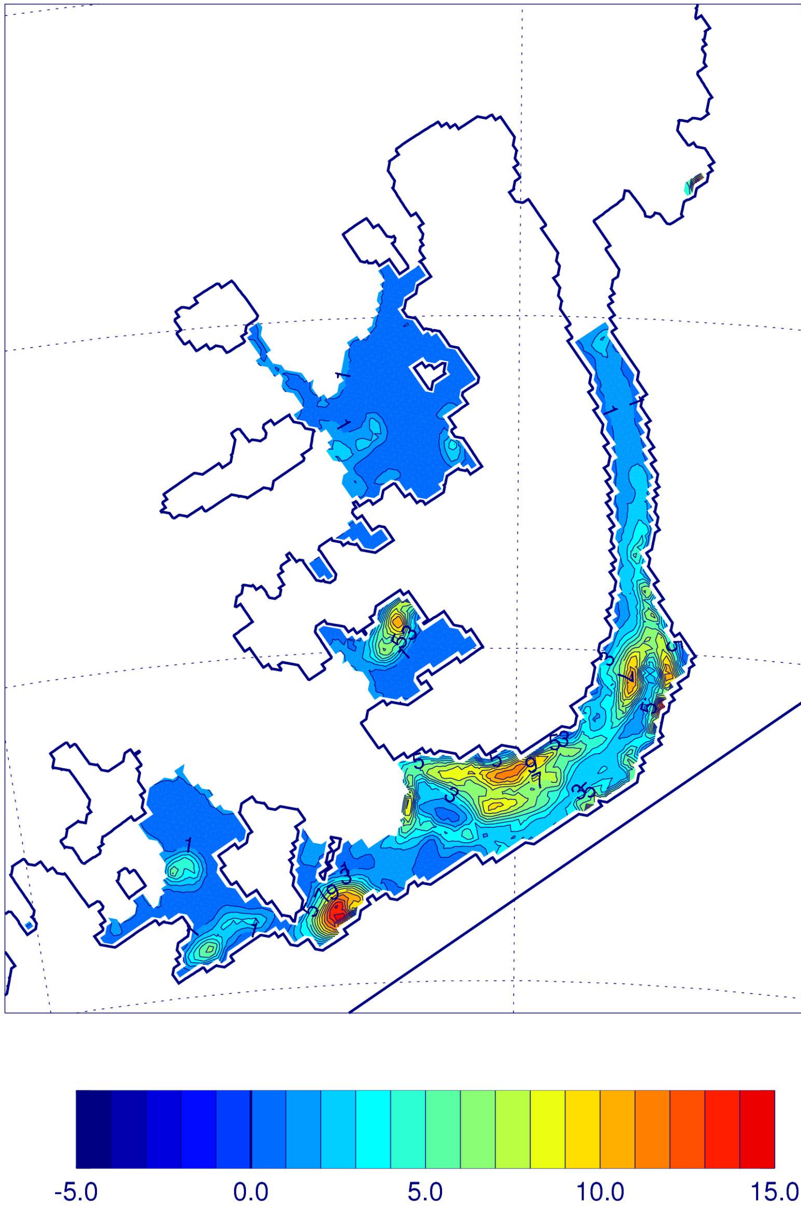
- Imposed
  - Set model ice concentration to SSM/I 25km data
  - Heat and salt fluxes computed from thermodynamic calculation of ice freezing or melting, but ice is not accumulated or transported
  - Easy to implement, mimics extent of polynyas w/o the correct winds, handles changes in open water due to iceberg blocking (e.g. Ross Sea)
- Dynamic model
  - Los Alamos CICE (thermodynamics, dynamics, transport and ridging)
  - Tougher to implement, but can provide insight into polynya dynamics (e.g. relative importance of atmosphere vs. ocean for Ross Sea polynya)

Melting under George VI Ice shelf

Average over first 2 years

Average is 3.8 m/yr from model.

Observed is 2-4 m/yr



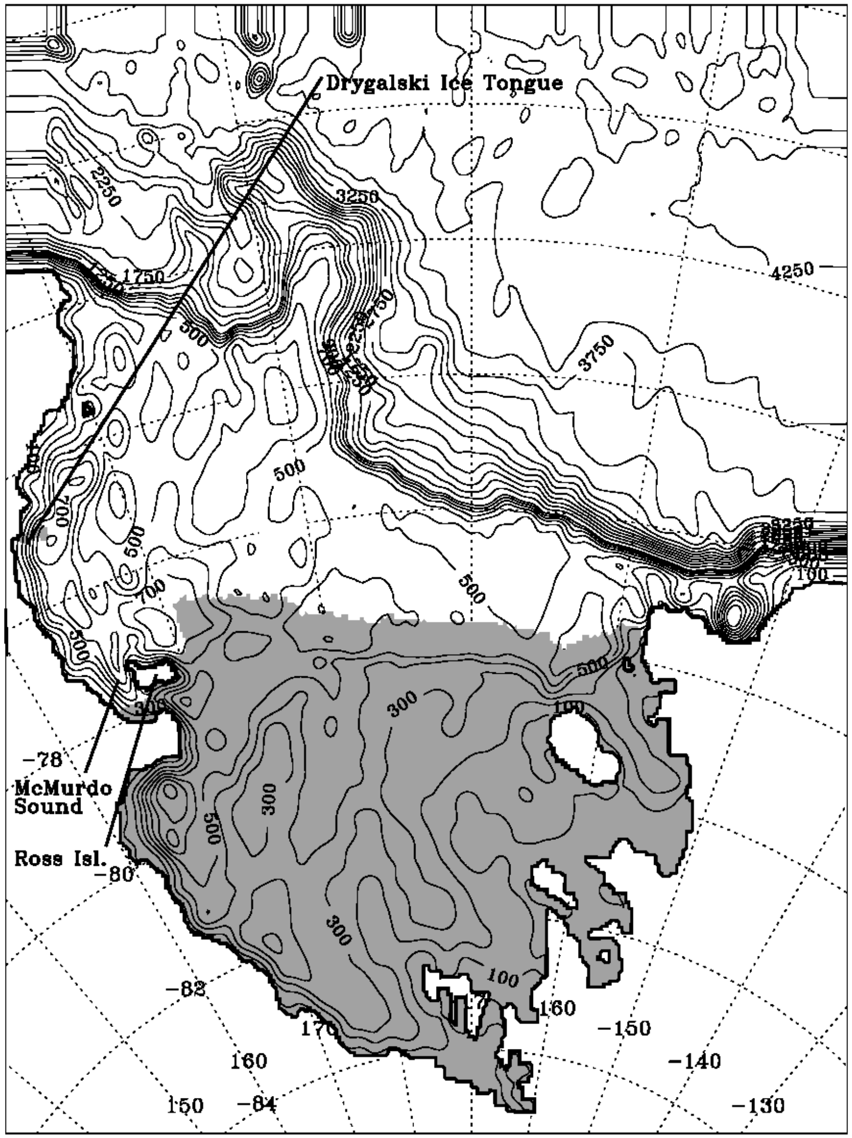
Ross Sea model

5 km spacing

Ross Ice Shelf, sea ice, various Atmospheric fields

Adding AWS winds at 1 point near TNB to ERA-40 winds changes HSSW production with dynamics sea ice (Kamel poster)

AMPS winds with imposed sea ice changes circulation

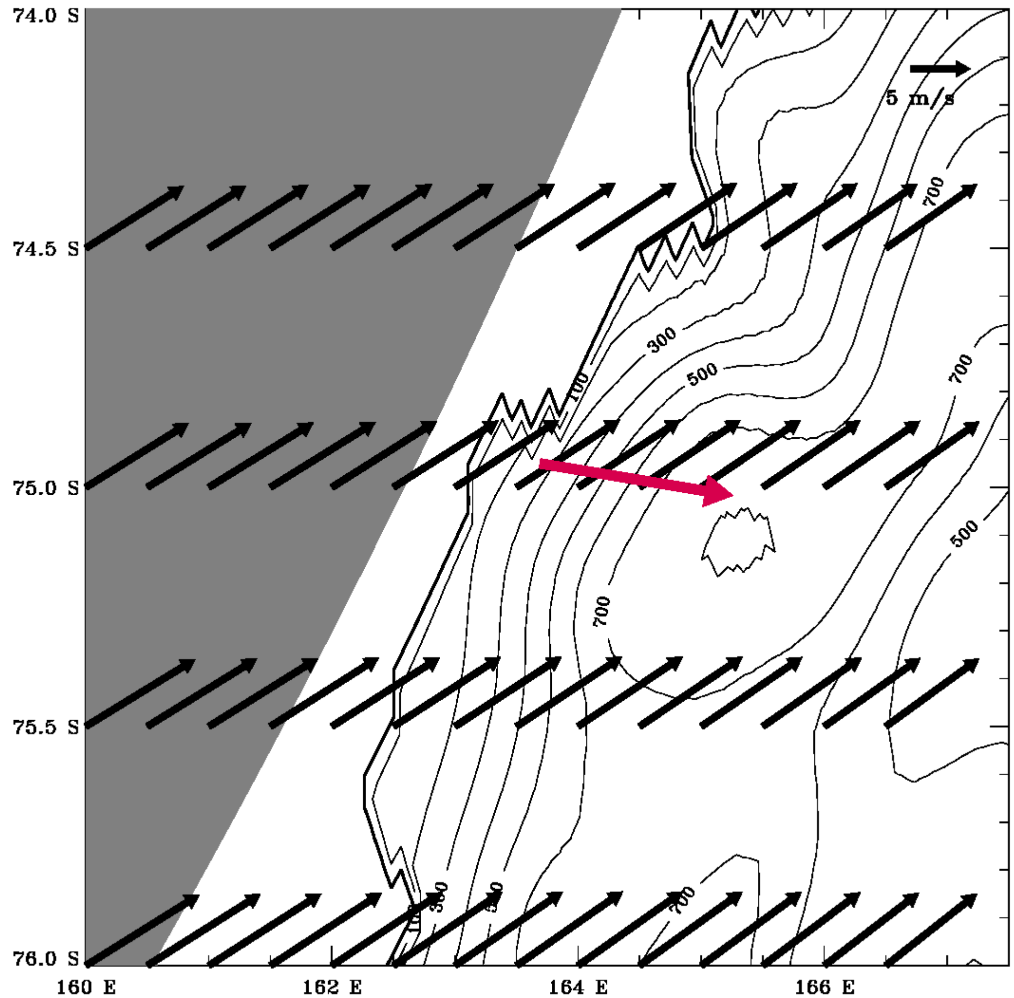


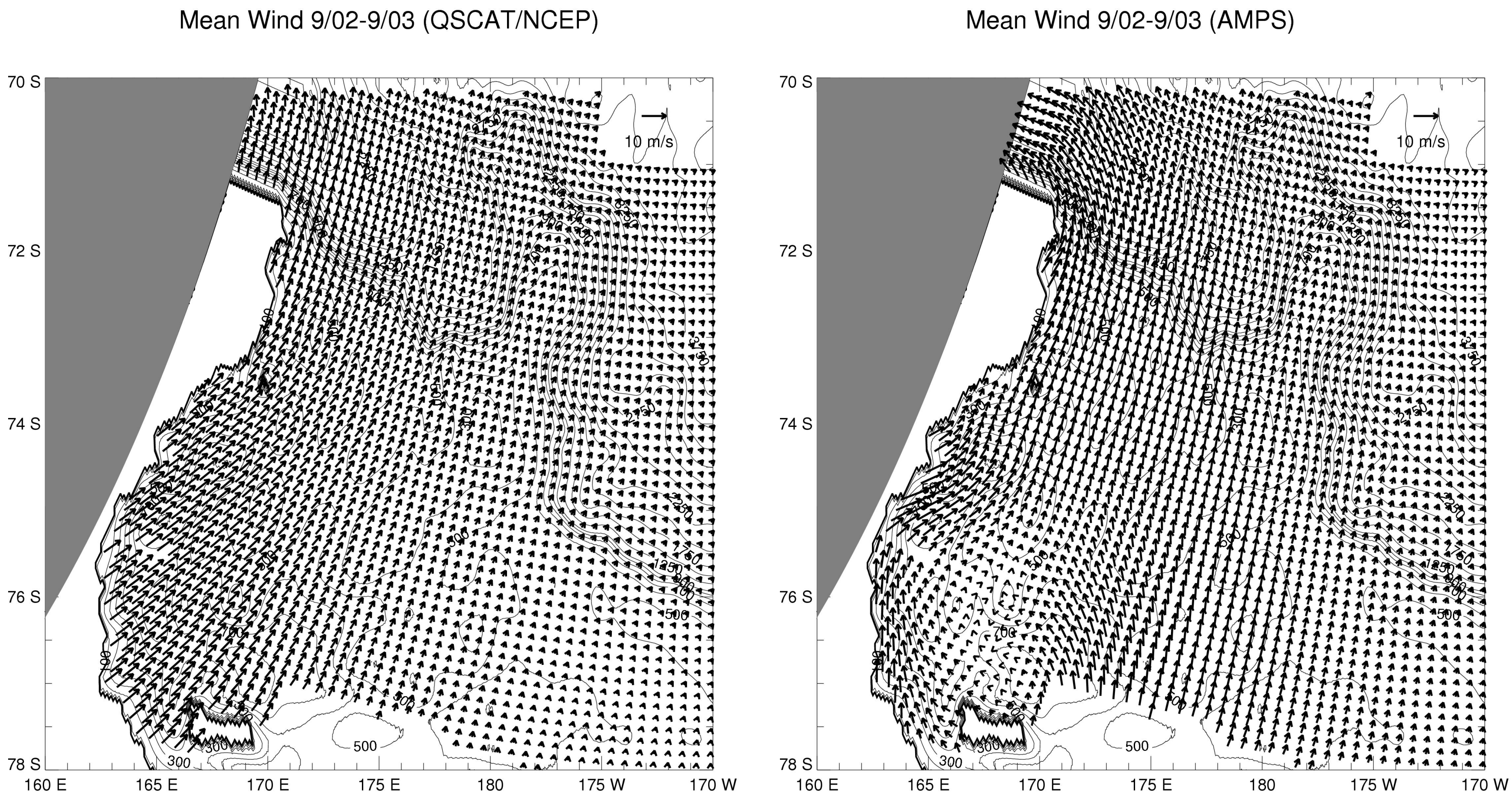
Polynyas in the Ross Sea

- Ross Ice Shelf Polynya
  - Largest regular polynya around Antarctica (~27,000 km^2)
  - Many reasons proposed for formation including southerly katabatic airflow surges and upwelling of warm CDW onto the shelf (upwelling limb of global circ.)
- Terra Nova Bay Polynya
  - Oriented N/S along the coast with winds blowing from the west and the Drygalski Ice Tongue to the south blocking advection of sea ice from the south
  - Much smaller than RISP (~1300 km^2), but winter ice production is estimated at 40-60 m and is very important in the production of High Salinity Shelf Water that flows down the slope to become Antarctic Bottom Water

Comparison of larger Scale winds with AWS observations (averaged over 3 winters)

Winds (JJA 2000-2002) QSCAT/NCEP



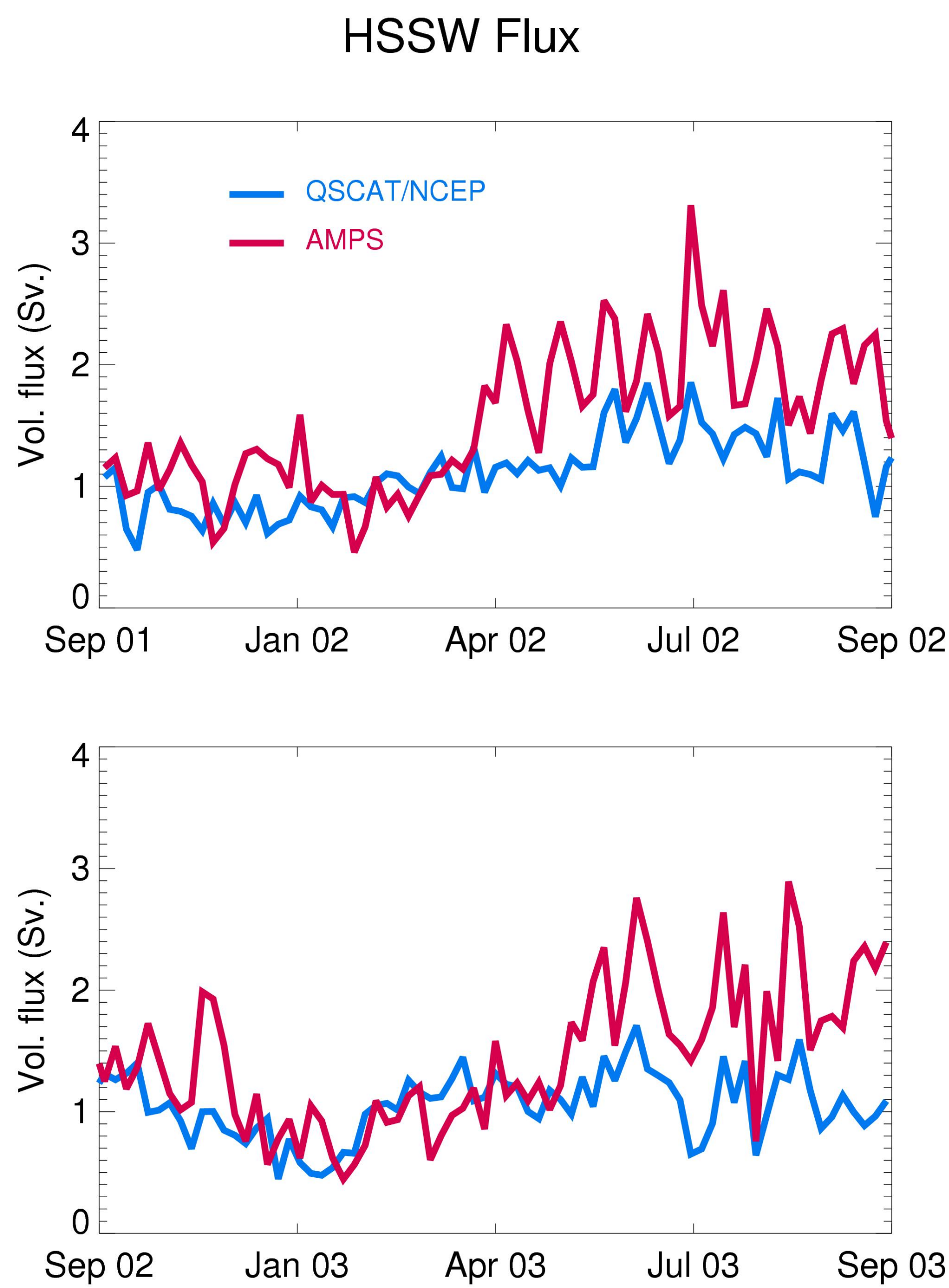


Improvement due to AMPS downscaling

These subtle changes affect ocean.

High Salinity shelf water is made in winter in TNB polynya. The modified winds produce stronger circulation near the coast, which exports more dense shelf water.

[imposed sea ice, so HSSW production is the same between cases]



Summary

- Finer resolution in the atmospheric forcing fields is needed for several critical physical processes in the ocean model
  - Improved winds help create TNB polynya
  - Improved winds create better ocean circulation
  - Improved precip helps with coastal currents
- Plan to hindcast high resolution atmospheric conditions for Ant Peninsula for 2000-2003 to drive ocean model to compare to ocean obs from SO GLOBEC program.


Thank you
Questions or comments?
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