CLIVAR/CliC/SCAR Southern Ocean Panel

Panel Members:

- Matthew England (co-chair)
- Kevin Speer (co-chair)
- Teresa Chereskin
- Yasushi Fukumachi
- Stephen Griffies
- Hartmut Hellmer
- Nicole Lovenduski
- Gareth Marshall
- Alberto Naveira Garabato
- Alex Orsi
- Seb Swart
- Dave Thompson

CLIVAR IPO Officer: Catherine Beswick

SCAR Liaison: Mike Sparrow

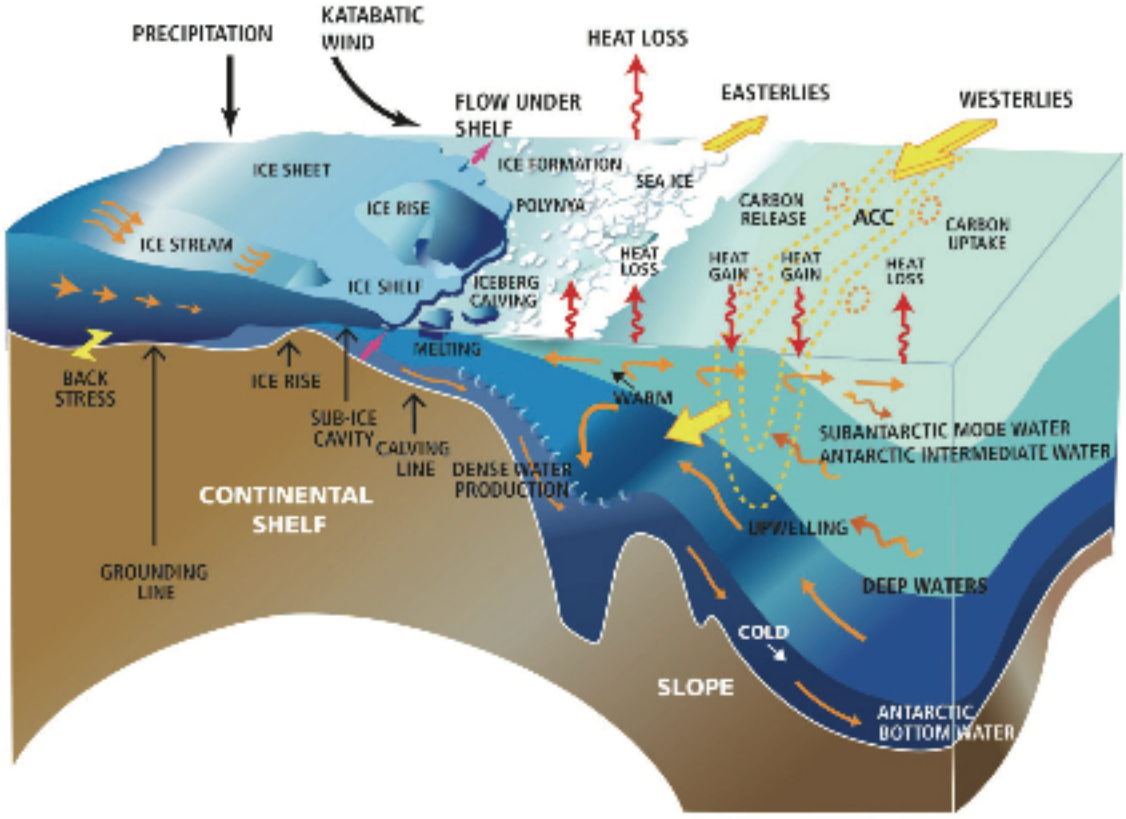

FIGURE 2.5 Cartoon of Southern Ocean circulation and glaciological processes occurring on the coast of Antarctica.

Role of the Southern Ocean in the Earth system

The Southern Ocean:

- Acts as a valve controlling exchange between the surface and the deep ocean;
- Stores more heat and anthropogenic carbon than any other latitude band and is the primary return path for nutrients;
- Influences rate of mass loss by the Antarctic ice sheet and therefore the rate of sea-level rise;
- Is home to unique ecosystems + biodiversity, potentially vulnerable to environmental change.

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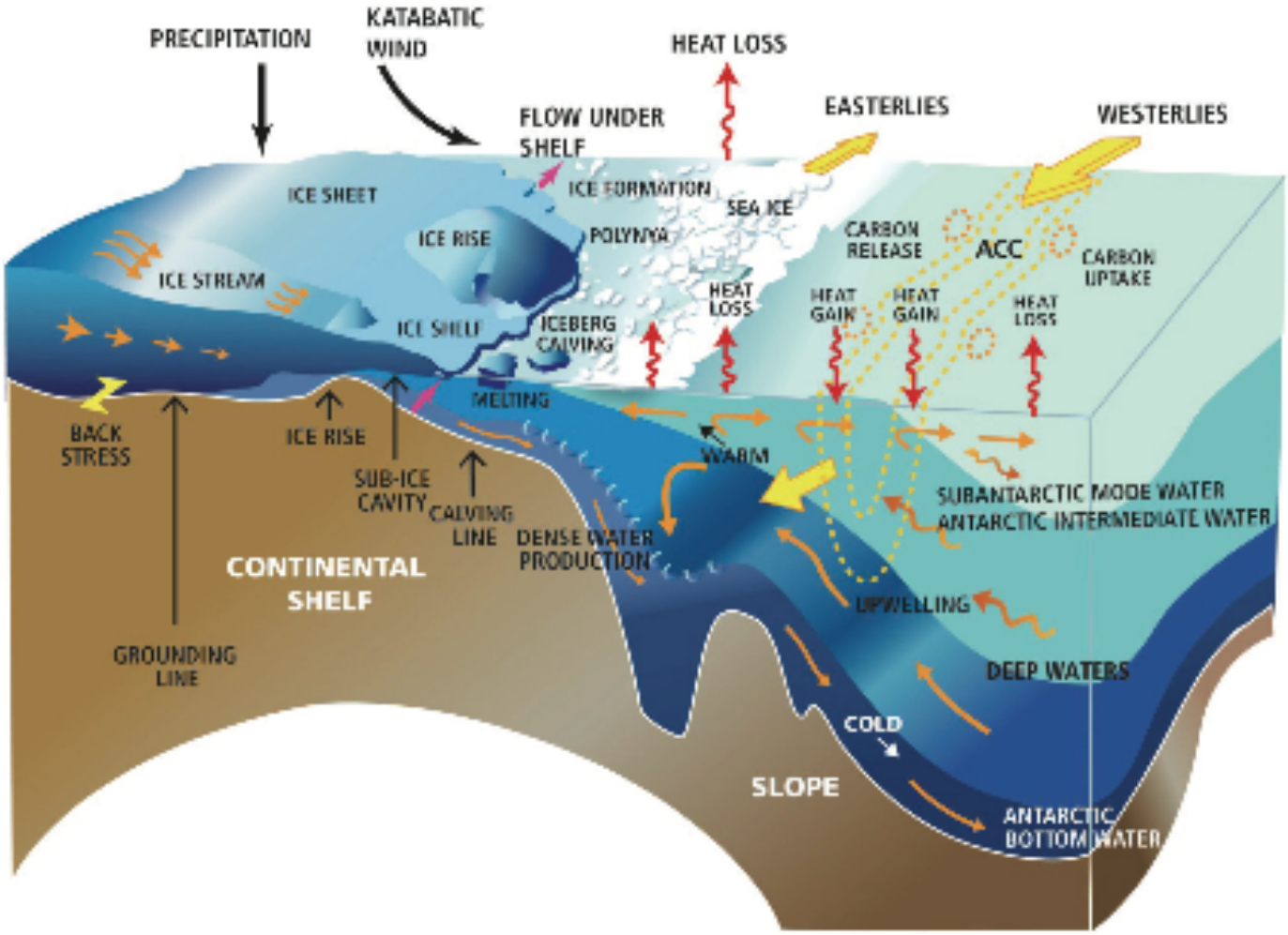
Schematics (based on Speer et al, Rintoul, iterated for an NAS study and then for the SOBOM proposal)



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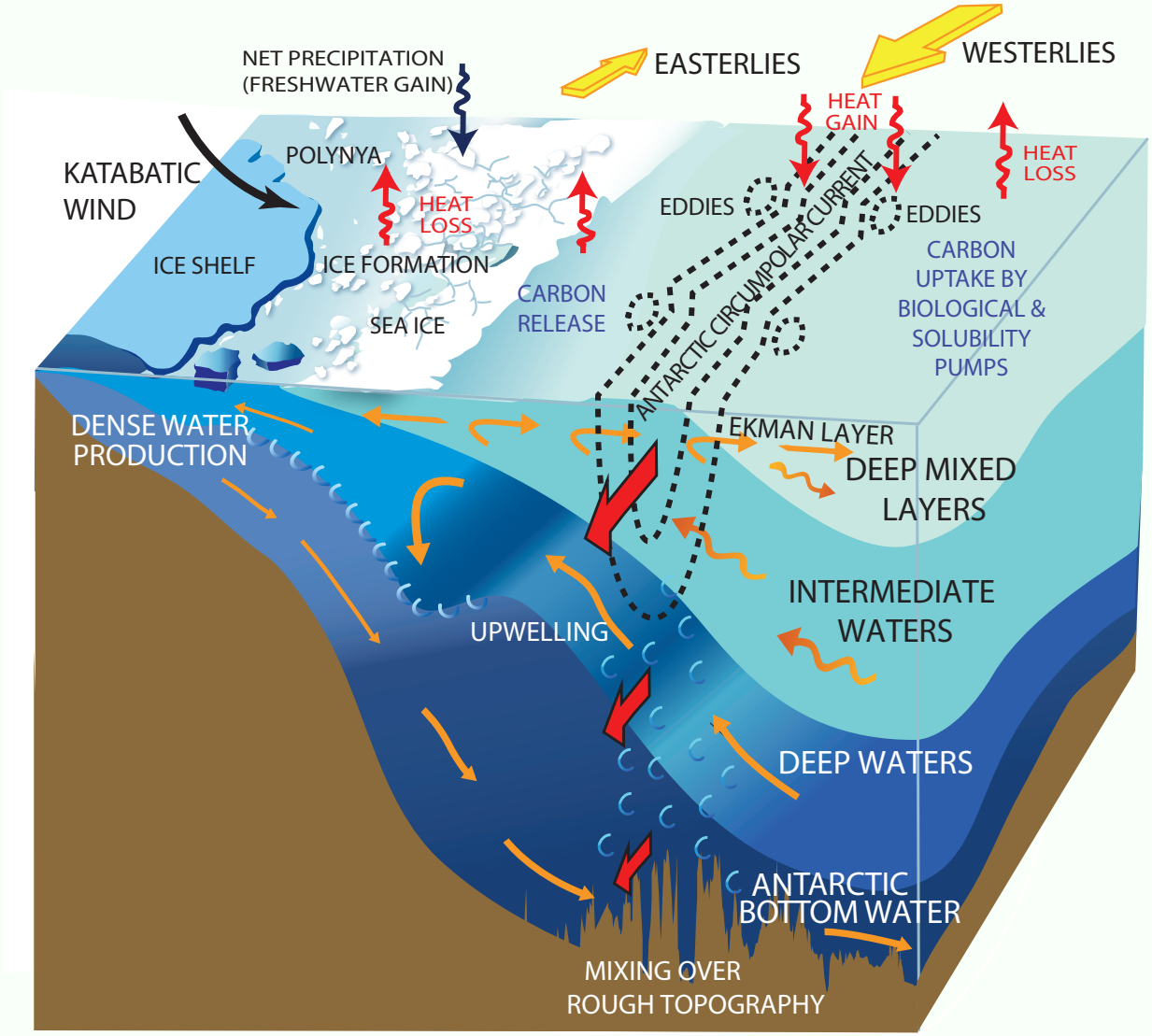


Recent panel activities

- **Panel meeting** in Boulder, CO, Oct 2011, hosted by UCAR
- **New membership** (Teresa Chereskin, Stephen Griffies, Hartmut Hellmer, Alex Orsi, Seb Swart)
- **Engagement with Observation Initiatives** e.g. DIMES (Diapycnal and Isopycnal Mixing Experiment in the Southern Ocean) and SOBOM (Southern Ocean Biogeochemical Observations and Modelling) programme (proposed)
- **Exchanges 58** reporting on initiatives through the recent ocean basin themed issue
- **WCRP Open Science Conference** poster cluster on Southern Ocean Hydrography and Circulation
- **Further development of Vision Document** including three themes 1) Southern Ocean carbon; 2) atmospheric processes over the Southern Ocean; and 3) Southern Ocean physics
- ("A Vision for Climate Variability Research in the Southern Ocean-Ice-Atmosphere System")

Recent panel activities

- **Highlight: 2 review papers, co-authored by the co-chairs of the SOP**

- Thompson, D.W.J., S. Solomon, P.J. Kushner, M.H. England, K.M. Grise and D.J. Karoly, 2011: Signatures of the Antarctic ozone hole in Southern Hemisphere surface climate change, Nature Geoscience, 4, 741-749 (doi: 10.1038/ngeo1296).

- Marshall, J., Speer, K.: 2012, Closure of the meridional overturning circulation through Southern Ocean upwelling, Nature Geoscience 5, 171-180 (doi:10.1038/ngeo1391).

Key Science Questions

- **What is the future of Antarctic ice?** Including sea ice, ice shelves, and land ice.
- **What is the impact of acidification?** And how will the Southern Ocean store of CO2 change in the future?
- **How will the ongoing projected trend in the SAM impact on air-sea heat, moisture, and carbon fluxes?** And what will be the impact on Southern Hemisphere regional climate?
- **What is the future of the Antarctic continental margin?**

CLIVAR/CliC/SCAR Southern Ocean Region

WCRP Grand Challenges

Provision of skillful future climate information on regional scales

- Close engagement with WGOMD on SO modeling activities (e.g. joint Hobart panel meeting Feb. 2013)
- Evaluation and synthesis of CMIP5 model projections spanning atmosphere, oceans, sea-ice

Regional sea level rise

- Ongoing input on the role of the southern hemisphere cryosphere on sea level
- 2013 workshop being co-organised with WGOMD on sea level rise, amongst other topics

Cryospheric response to climate change

- Activities towards the development of SOOS
- 2013 workshop will also focus on ocean/ice-shelf interaction, and ice sheets
- SOP7 addressed Southern Ocean physics (and ice)

Improved understanding of the interactions of clouds, aerosols, precipitation, and radiation and their contributions to climate sensitivity

- Atmospheric processes over the Southern Ocean was one of the key topics of SOP7

Past and future changes in water availability (with connections to water security and hydrological cycle) And Science underpinning the prediction and attribution of extreme events

- Focus on atmospheric processes over the Southern Ocean during SOP7, which highlighted e.g. SAM influence on precipitation/drought events in Southern Hemisphere regions
- Support extending the observing under ice, for better cryosphere predictions, glacial ice melt processes

Observing System Issues and Challenges and the development of the SOOS

The Southern Ocean Observing System

- Design and implementation of an observing system that encompasses *physical, biogeochemical* and *ecological* processes is therefore a formidable challenge
- Requires multiple nation and agency involvement since the region is vast, remote and logistically difficult to access and thus is one of the least sampled regions on Earth

Observing gaps?

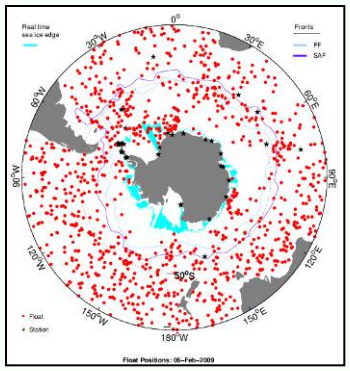
- Ecosystem monitoring on Argo profiling
- CO2 gas fluxes
- Must expand ocean coverage within sea-ice zone
- Must include atmospheric boundary layer
- Must include ice interaction regions

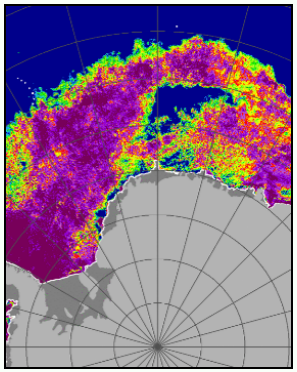
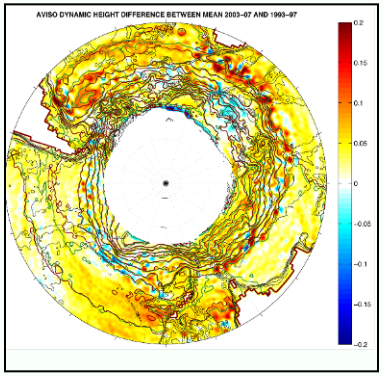
International SOOS office to carry forward this work

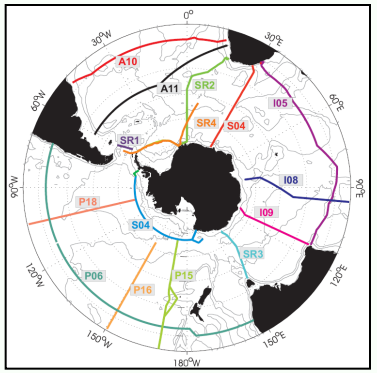
A Southern Ocean Observing System – SOOS

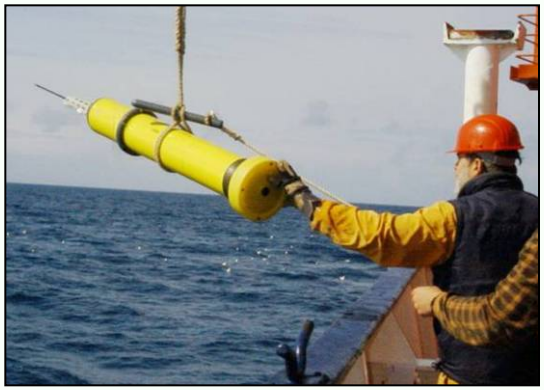








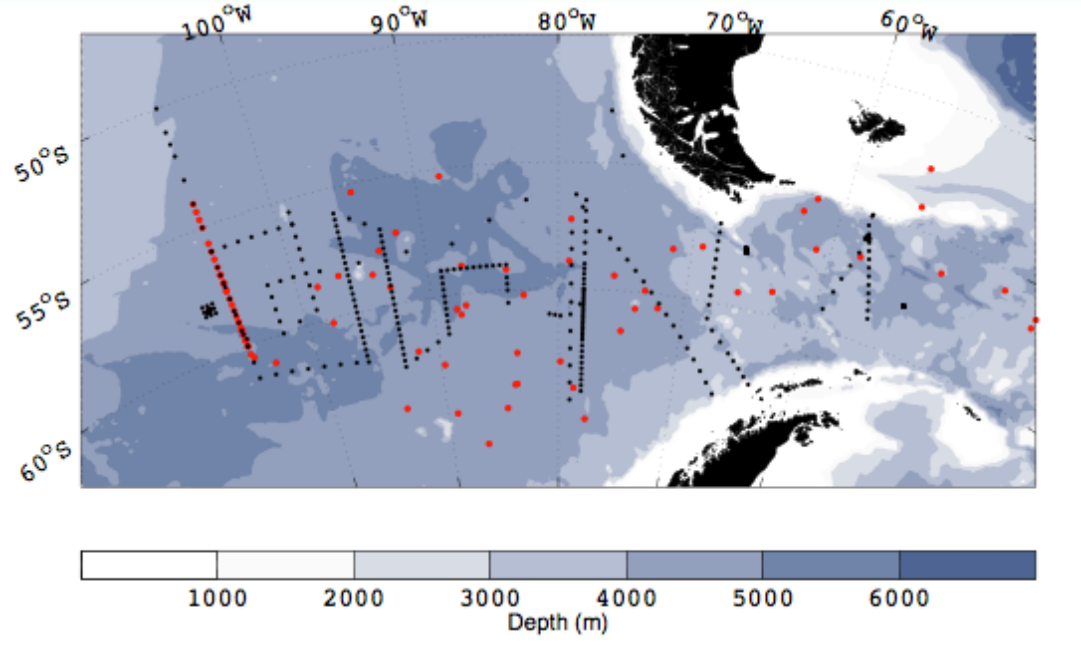


Future Activities

- **SOBOM (Notes from LDT: proposed to NSF – second round decisions to be reported before June 30; if successful, site visit in fall, 2012 for final decision). If successful, field work will commence nearly immediately.**
- **Southern Ocean Panel meeting Hobart, Australia, Feb 2013**
- **Workshop co-organised with WGOMD on sea-level rise, ocean/ice-shelf interaction and ice sheets** (coincident with the SOP meeting)
- **Develop a review paper on the state of southern climate system (underway with panel co-authors)**

Some DIMES results

- **UK/US program, continuing in UK**
- **Tracer release, mixing experiment in southeastern Pacific/ACC region**
- **Goal to quantify eddy diffusivity and mixing processes at mid-depth**



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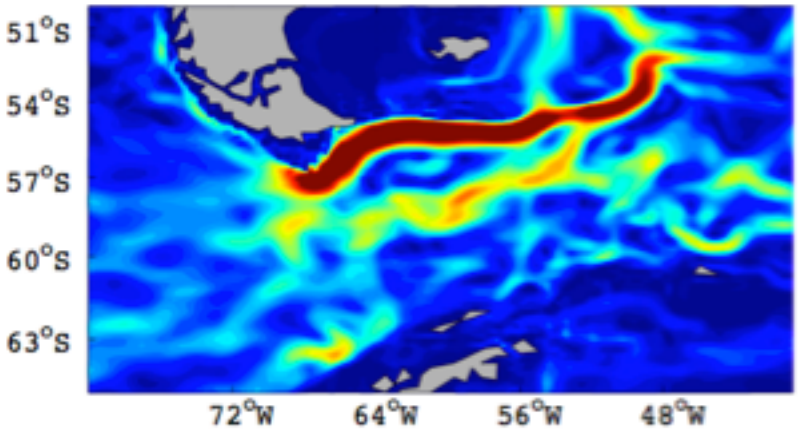
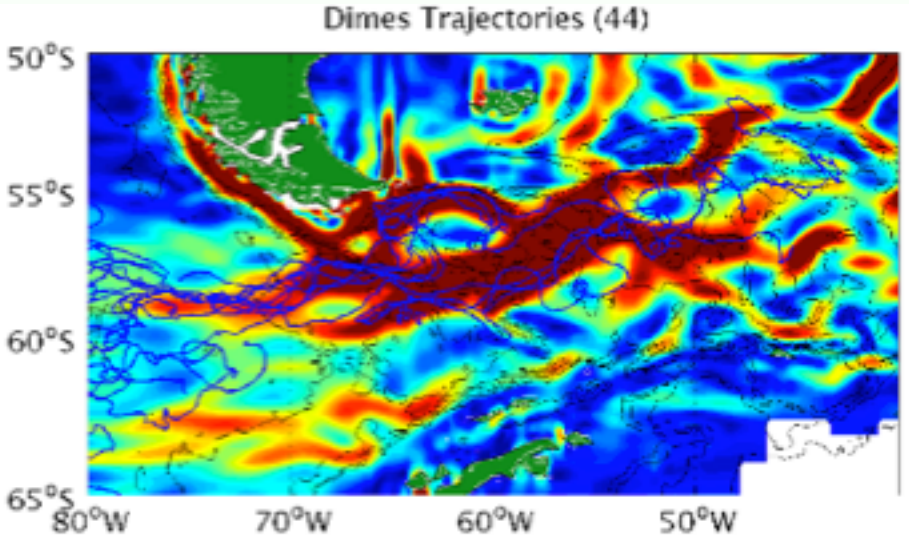


SOSE mean speed



AVISO 7 yr mean speed + real floats + bathymetry

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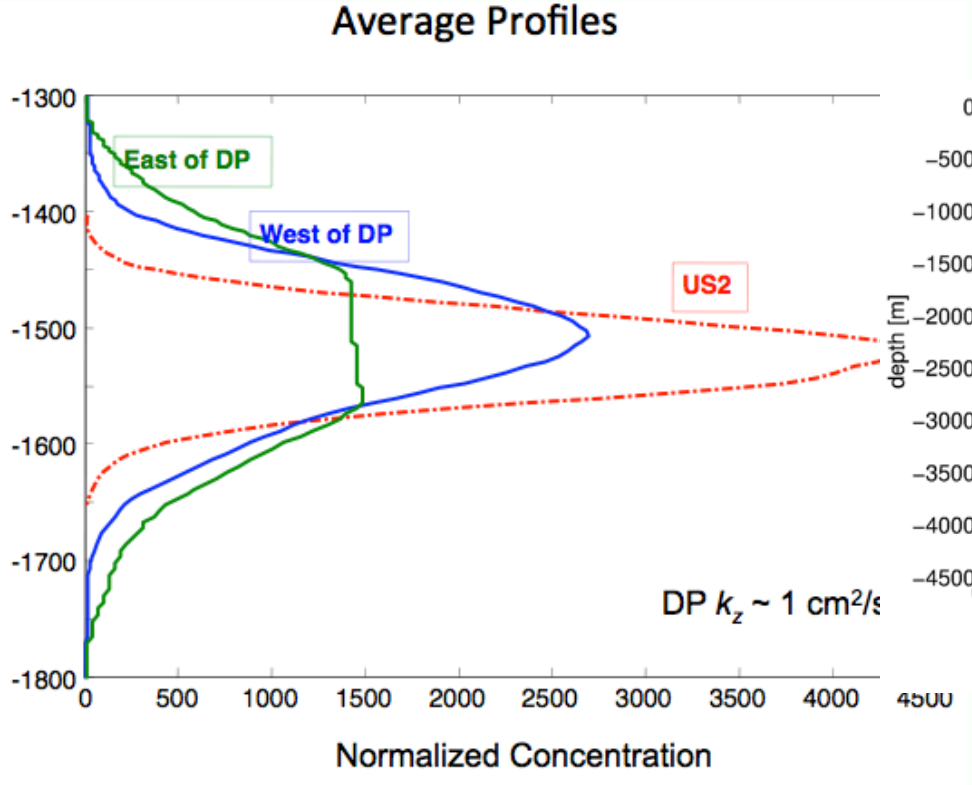
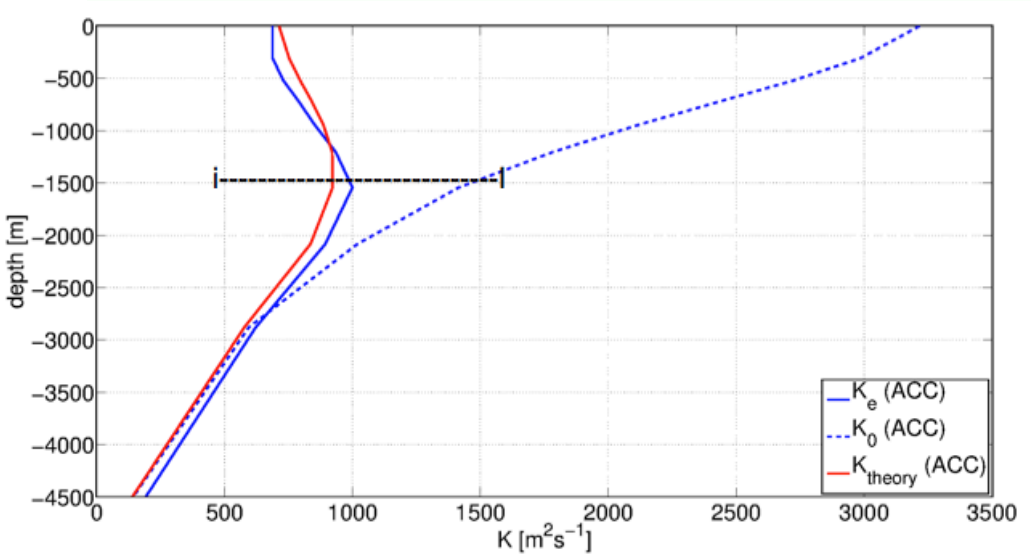


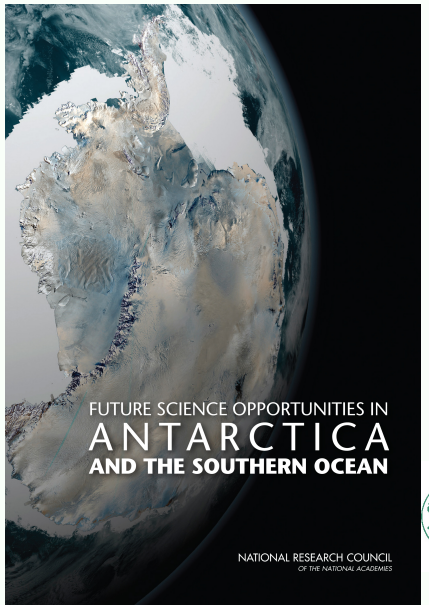


Klocker et al; Speer et al.

Side information from U.S. activities

- **Establishment of a Southern Ocean Working Group within U.S. CLIVAR**
  - **Co-chairs: Joellen Russell and Igor Kamenkovich**
  - **U.S. CLIVAR support: Mike Patterson and Jennifer Mays, Heather Benway**

- **NSF has a "blue ribbon" panel now working on recommendations for long-term investment in Antarctic science. This follows a National Academy study of key questions for Antarctic science.**



Side information from U.S. activities

Some graphics from the NAS study

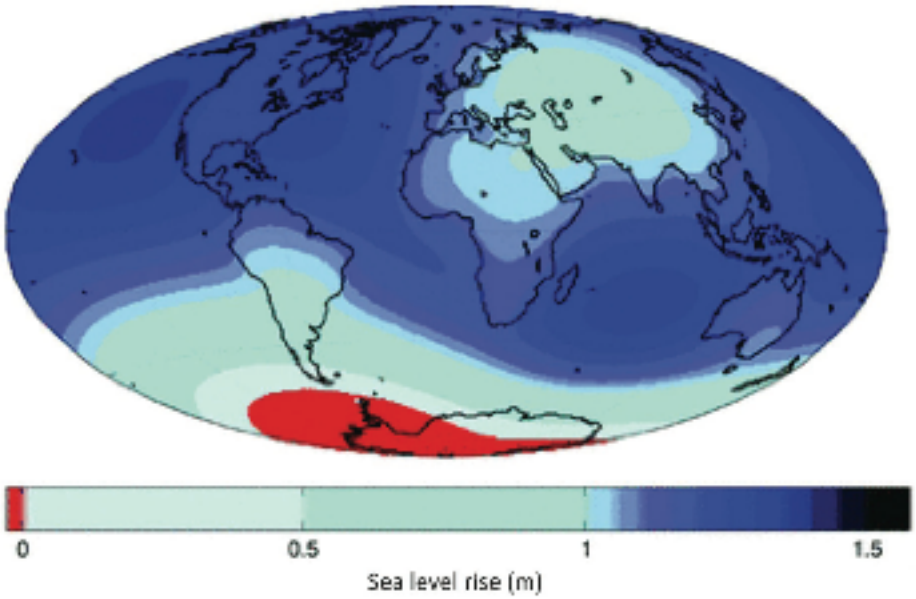
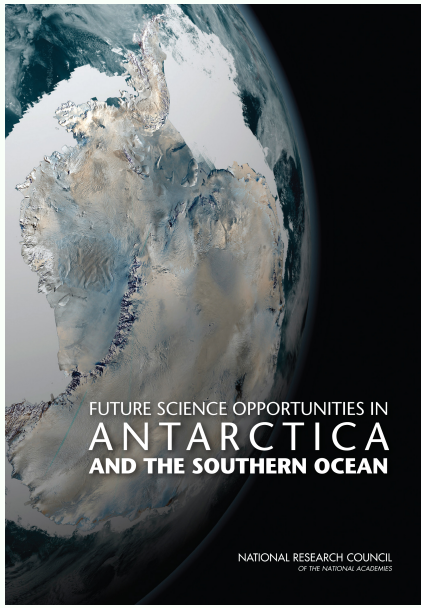


FIGURE 2.2 Sea level changes in response to a collapse of the West Antarctic Ice Sheet represented as an additional change relative to the global average of 5 meters; this highlights the significant local deviations. Sea level rise is 15 percent higher than the global average along the U.S. coast line. Changes over land can be ignored. SOURCE: Mitrovica et al., 2009, reprinted with permission from AAAS.



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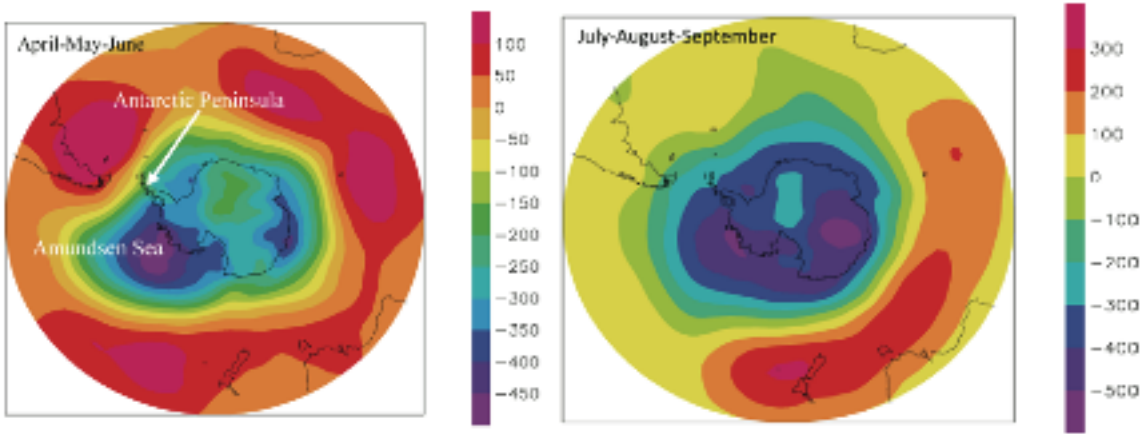
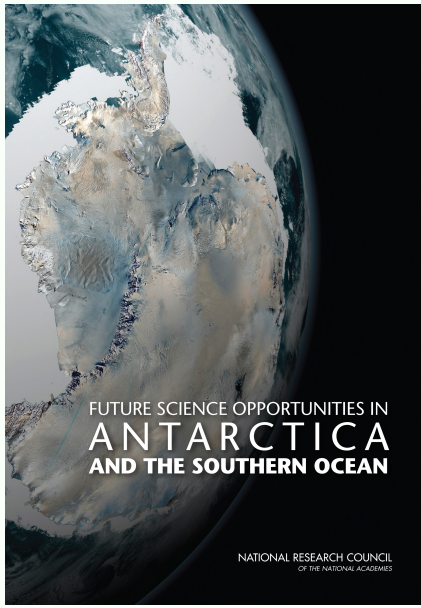


FIGURE 2.4 Spatial patterns of atmospheric surface pressure change associated with the Southern Annular Mode in Pascals for (left) the average of April, May, and June and (right) July, August, and September. The Southern Annular Mode describes variability of the surface atmospheric pressures or atmospheric flow that is not associated with the seasonal cycle. In the pressure field, the annular modes are characterized by north-south shifts in atmospheric mass between the polar regions and the middle latitudes; the figure shows the positive phase where pressures are lower over polar regions (cool colors) and higher in middle latitudes (warmer colors). In the wind field, the annular modes describe north-south vacillations in the extratropical zonal wind with centers of action located ~55-60 and ~30-35 degrees South latitude; the positive phase has stronger westerly winds along ~55-60 degrees latitude. SOURCE: Goosse et al., 2011, data from NCEP-NCAR reanalyses (Kalnay et al., 1996).



SAM pattern

Side information from U.S. activities

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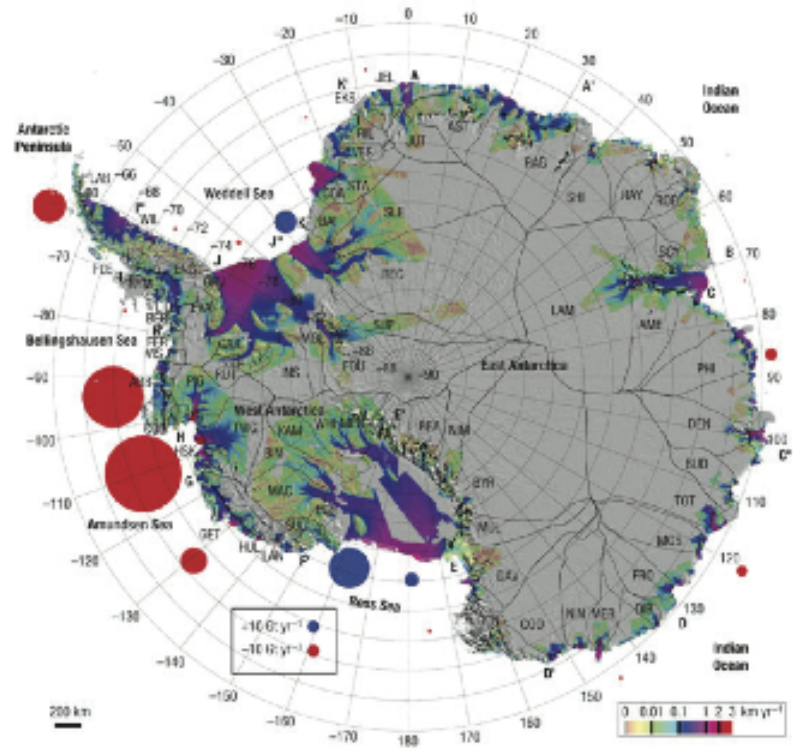
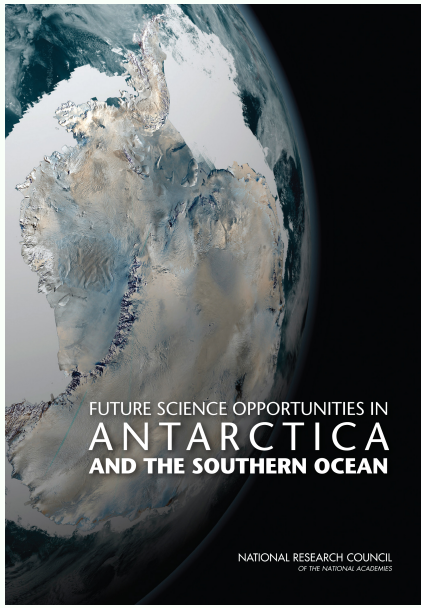


FIGURE 2.6 This image indicates the glacial surface velocities along the periphery of Antarctica and the mass loss (red circles) or gain (blue circles) of various Antarctic glaciers in gigatonnes per year. Data from satellite interferometric synthetic-aperture radar observations from 1992 to 2006 to estimate the total mass flux into the ocean, and mass fluxes from large drainage basin units with interior snow accumulation calculated from a regional atmospheric climate model for 1980 to 2004. The largest mass losses are from the glaciers from the West Antarctic Ice Sheet where it enters the Bellingshausen and Amundsen Seas. SOURCE: Reprinted by permission from Macmillan Publishers Ltd: Nature Geoscience (Rignot et al., 2008), copyright 2008.



Mass loss (red circles) and glacial surface velocities (colors)

Side information from U.S. activities

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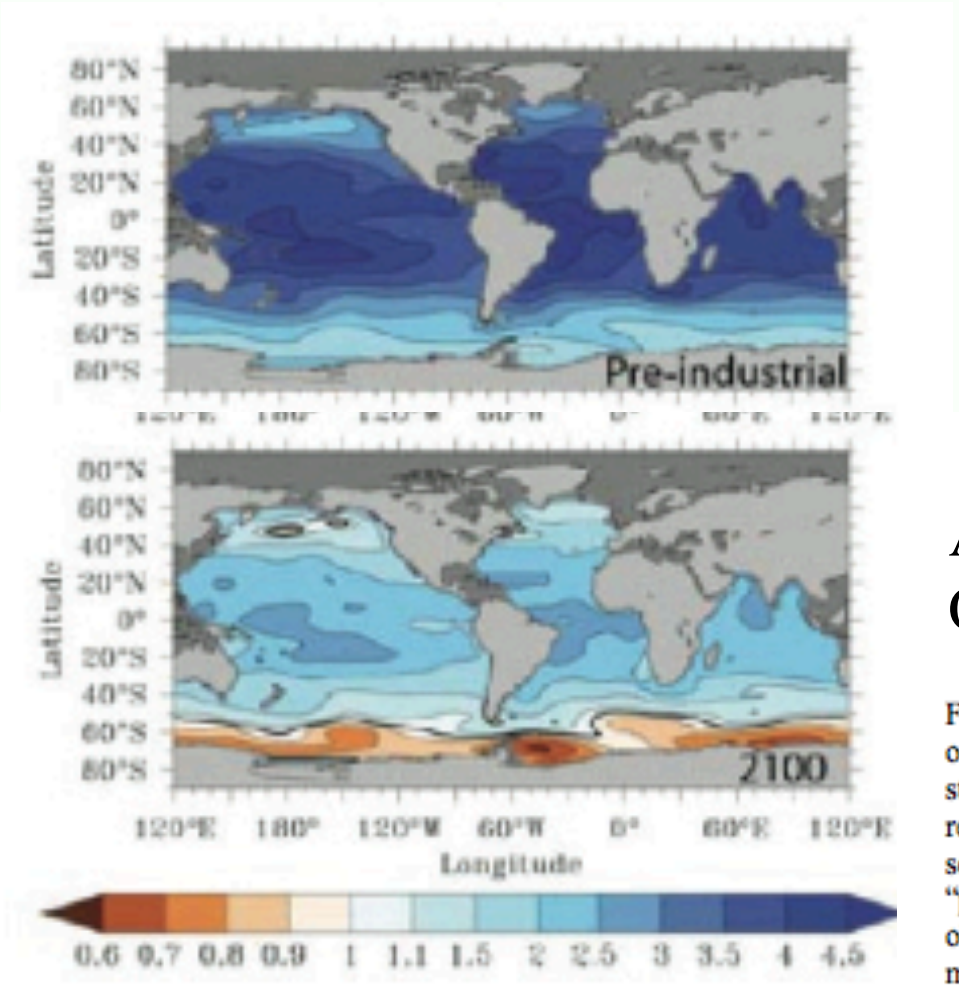

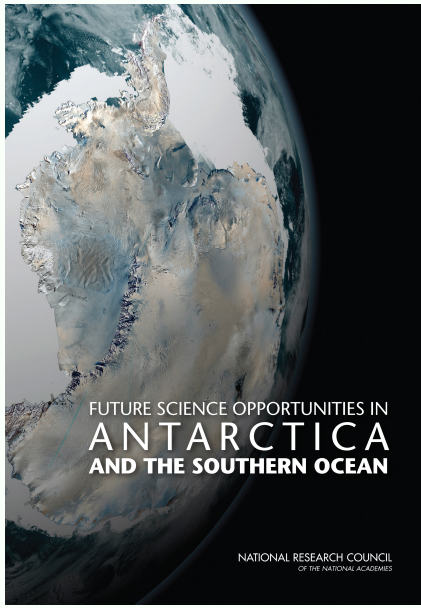

Acidification affects the Southern Ocean preferentially

FIGURE 2.7 The effects of ocean acidification at the sea surface are illustr
of the surface water aragonite saturation state showing where calcium-carb
structures (like shells) would be dissolved: values <1 are undersaturation o
respect to aragonite, indicating that there would be dissolution. These maps
sensitivity of the Southern Ocean under greenhouse gas forcing scenarios.
"pre-industrial" (1765) and 1994 are based on observations and extrapolati
observations; maps for 2050 and 2100 are the average of 13 ocean general
models under an IPCC "business-as-usual" scenario (Orr et al., 2005). SO
et al., 2008 by permission of Oxford University Press.

Side information from U.S. activities

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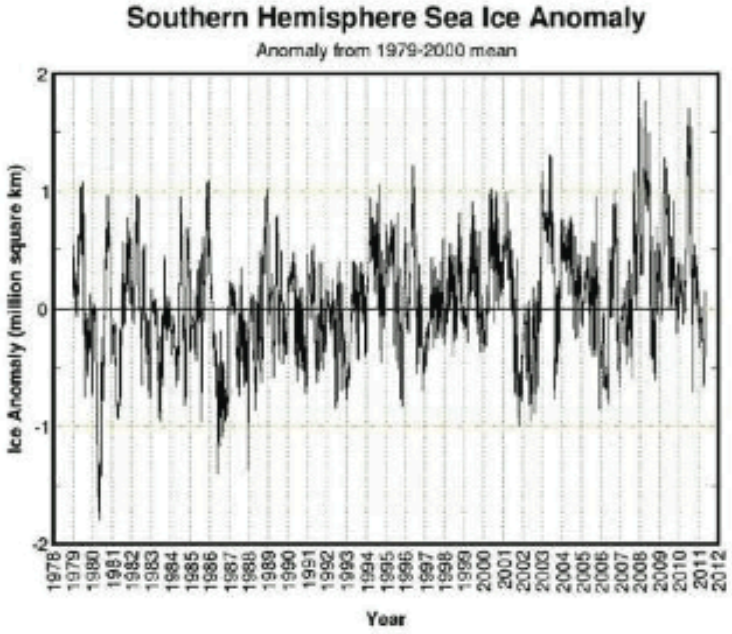

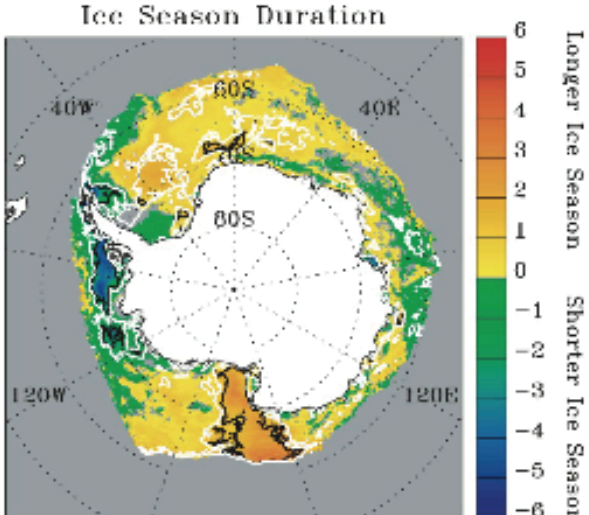

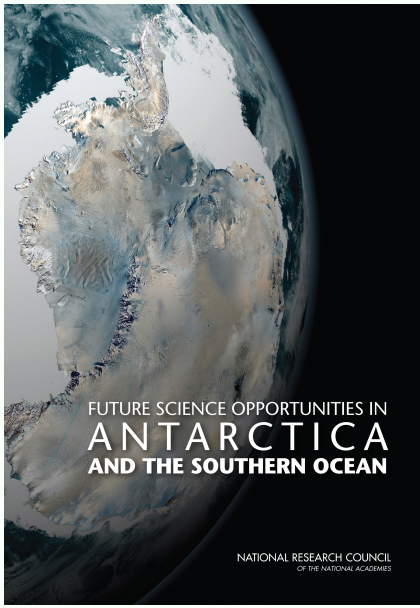

Sea ice anomalies: regional variability and little long-term trend (slight increase)

FIGURE 2.9 Unlike the Arctic, sea ice trends in Antarctica have strong regional variability and winter sea ice cover has slightly increased over the past 30 years. (top) Antarctic sea ice cover anomalies (difference from the 1979-2000 mean). (bottom) Trend in ice season duration (days/year) for 1979-2004. SOURCES: (top) Cryosphere Today, University of Illinois at Urbana-Champaign, (bottom) Stammerjohn et al., 2008, Copyright 2008 American Geophysical Union, reproduced by permission of American Geophysical Union.