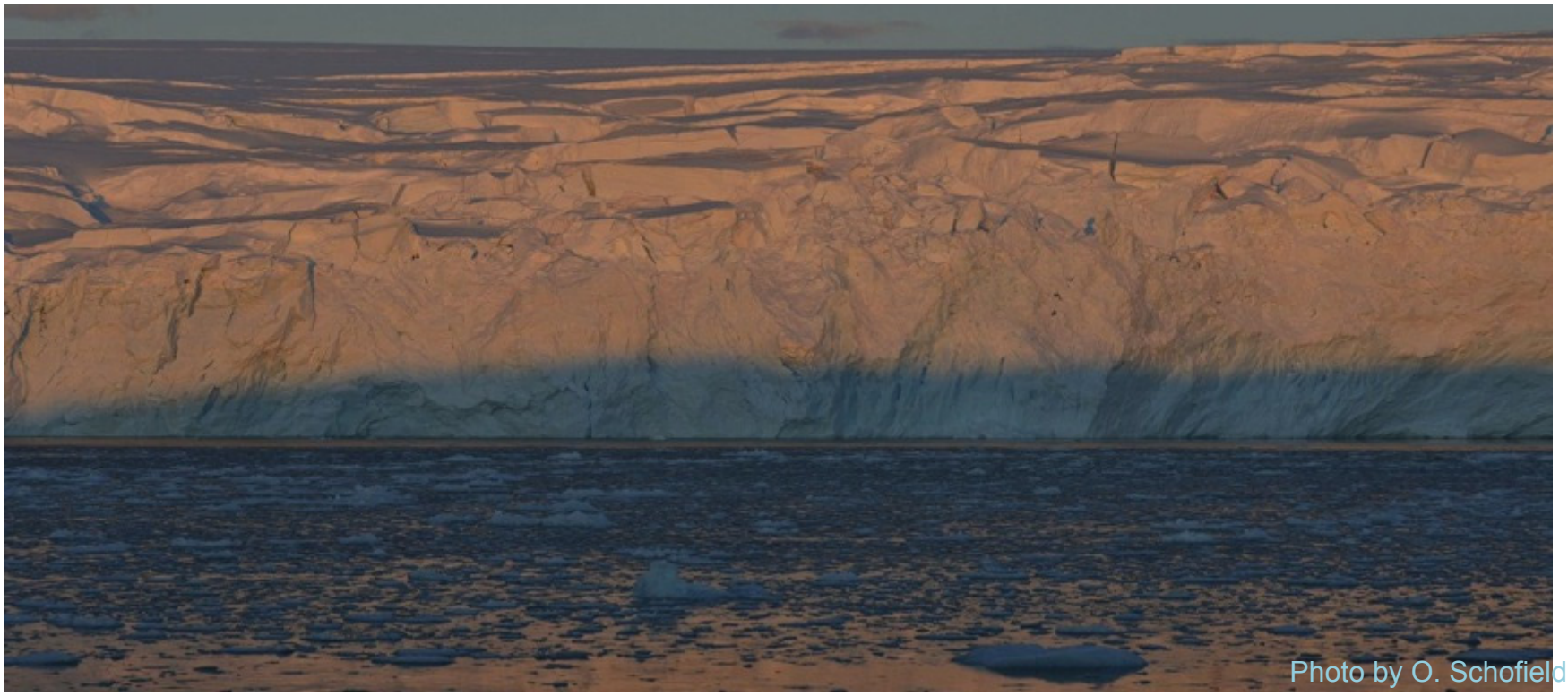
US CLIVAR/OCB Joint Workshop and Working Groups



Joellen Russell (U. Arizona)
Igor Kamenkovich (U. Miami)

Ocean's Carbon and Heat Uptake: Uncertainties and Metrics
December 12-14 | San Francisco, CA

This workshop, organized jointly by the Ocean Carbon Uptake and Southern Ocean Working Groups of US CLIVAR and OCB, aims to catalyze progress toward understanding the ocean's role in carbon and heat uptake by strengthening communication and collaboration across traditional disciplinary boundaries to facilitate the exchange of results from recent studies and discuss the most promising directions for future research.

During this workshop, participants will focus on the following topics:

- Oceanic regions critical for heat and carbon uptake (e.g., Southern Ocean, North Atlantic, tropics)
- Processes governing the heat and carbon uptake in these regions and the main challenges of representing these processes in climate models
- Critical observational targets in these regions
- Development of data/model metrics, which will help to improve the models and guide future observational campaigns

Including a special session sponsored by the **WCRP Polar Climate Predictability Initiative** on *Southern Ocean: Circulation and Carbon Cycle.*

Registration Deadline: September 30, 2014

https://usclivar.org/meetings/2014-ocean-carbon-workshop

The workshop is open to interested scientists across observational, process study, and modeling communities. Participants must apply to attend this joint workshop. The number of participants will be limited to 75 scientists, so a brief application and advance registration is required. Notifications will be sent in early October.

Joint Workshop

Workshop Organizing Committee:

- **Joellen Russell**, Chair, University of Arizona
- **Heather Benway**, OCB/Woods Hole Oceanographic Institution
- **Annalisa Bracco**, Georgia Tech
- **Curtis Deutsch**, University of Washington
- **John Fyfe**, Environment Canada/ WCRP Polar Climate Predictability Initiative
- **Taka Ito**, Georgia Tech
- **Igor Kamenkovich**, RSMAS/ University of Miami
- **Mike Patterson**, US CLIVAR Project Office
- **Kristan Uhlenbrock**, US CLIVAR Project Office

The goals of this workshop were to:

- Build upon and synthesize the Working Groups efforts to develop metrics for evaluating biases in CMIP-5 model simulations;
- Estimate uncertainties in model projections of heat and carbon uptake;
- Inform future observations, model development, and analysis strategies for addressing biases and uncertainties (including protocols of CMIP-6)

The workshop was organized into five main sessions covering the following themes:

- **Model Biases and Uncertainties in CMIP5 Models**
- **Observational Gaps and Uncertainties**
- **Process Studies: Gaps, New Measurements, and Parameterizations**
- **Southern Ocean: Circulation and Carbon Cycle**
- **New Initiatives**

The 82 attendees included academic, government and non-governmental scientists and program managers including at least 20 from non-US organizations representing 9 different countries.

Recommendations from the Workshop:

Modeling Session Recommendations

- **Derive observational metrics** that cross boundaries between atmosphere, ocean, land and cryosphere and can identify biases in coupled dynamics and associated feedbacks
- **Evaluate and address model biases** by identifying processes/mechanisms, not simply documenting the model errors. Among the important properties mentioned are the hydrologic cycle amplification, water mass structure (SAMW/AAIW, AMOC), continental shelf processes (upwelling and outflows/overflows), large-scale tropical features (cold tongue, ITCZ, upwelling), spatial variations in carbon uptake and atmospheric biases
- **Need comprehensive CMIP5 analysis packages** (CMIPVAL tool, PCMDI metrics), such as newly established CMIP panel within GFDL, CLIVAR REOS webpage for one-stop shop (observational data sets/metrics to evaluate ocean models)
- **The community should conduct idealized sensitivity simulations** to establish key processes; the results can be used to validate the parameterization of these processes before adding more complexity to climate models
- **Coordinated observations and modeling efforts** can go a long way toward identifying biases and reducing uncertainty in climate simulations

Recommendations:

Observations Session Recommendations

- **Calibration, calibration, calibration** – it's critical and newly emerging programs like OOI don't have readily available, well documented procedures. It's difficult to calibrate rates, and there is a strong need to fully document methodologies and changes in methodologies
- **Need standardized** climate-quality biological measurements
- **More data synthesis/analysis efforts** – these are critical to fully exploiting rich data sets but many of efforts to date have been done on shoestring (e.g., GLODAP and GLODAP2), agencies need to prioritize this to get full return on their investment in the observations!!
- **More coordinated efforts** to observe atmospheric and oceanic process concurrently
- **More deep ocean measurements** (Expand Deep Argo!)
- **Measurements under the ice**

Recommendations:

Southern Ocean Session Recommendations

- The use of **observationally-based standardized metrics** is the best way to evaluate and compare models and to move toward reducing uncertainty in out projection of future climate.
- A **rigorous assessment of input of wind energy** into the ocean and the uncertainties (spatial and seasonal) associated with the observing system is needed.
- A **coordinated program to observe and model** both oceanic and atmospheric biogeochemical parameters at the same place and time is needed for both improved understanding and for model validation.
- There is an increasing need for both **top-down tracers** that reveal sinking (like CFCs) and **bottom-up tracers** that reveal ventilation (like radiocarbon).
- We need to **assess the role of the winds in changes in the strength of the Antarctic Circumpolar Current and the role of eddies both in the ocean and in the models**; why variability in the strength and position of the simulated winds is larger than observed across models and within individual models; and how carbon uptake is sensitive to the interaction between the simulated winds and the simulated (or parameterized) eddies.

Recommendations:

Process Studies Session Recommendations

- The **role of eddies** at low and high latitudes
- The **dynamics in coastal upwelling zones**, including the role of Eastern Boundary Currents
- **Ocean convection, overflows** from marginal seas and shelf, and the interior pathways of dense water masses
- **Mechanisms** of iron (Fe) input to the ocean

The workshop report is being edited by the organizing committee, and should be available this summer

Ocean Carbon Uptake Working Group:
Joint U.S. CLIVAR/OCB Working Group

Ocean Carbon Uptake Working Group	
Annalisa Bracco, co-chair	Georgia Tech University
Curtis Deutsch, co-chair	University of California, Los Angeles
Taka Ito, co-chair	Georgia Tech University
Scott Doney	Woods Hole Oceanographic Institute
John Dunne	NOAA/GFDL
Markus Jochum	University of Copenhagen
Matthew Long	NCAR
Nicole Lovenduski	University of Colorado
Damon Matthews	Concordia University, Canada
Galen McKinley	University of Wisconsin
Ralph Milliff	Colorado Research Associates
Jaime Palter	McGill University, Canada
Shang-Ping Xie	University of California, San Diego/SIO

Goals:

- Foster and promote collaboration between members of the US CLIVAR and OCB communities and between modelers and theoreticians within each community.
- Advance our understanding of the processes responsible for the oceanic carbon uptake and their representation in climate models.

OCUWG Outcomes and Deliverables

- - CLIVAR and OCB Newsletter Article
- - Website, periodically updated by WG and linked to both US-CLIVAR and OCB websites
- - ASP Summer Colloquium on 'Carbon and Climate' targeted to graduate and postgraduate students.
- - Final Workshop and white paper describing source of uncertainties, recommending strategies to improve model representation, and addressing observational needs.
- - At least one peer-review publication (possibly two) on Global Biogeochemical Cycles (and/or Journal of Climate) summarizing findings from model intercomparison effort.

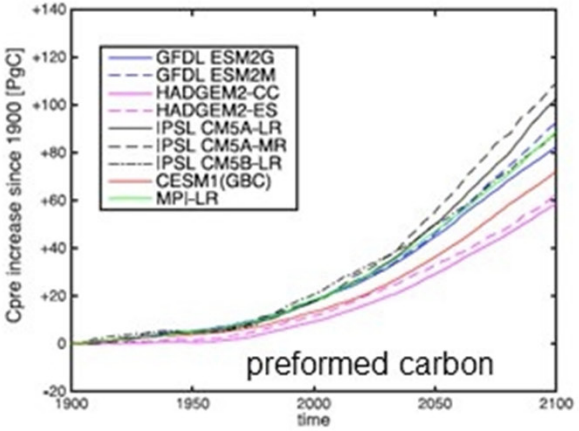
- The OCUWG final report is available as a Webinar at:
  - https://usclivar.org/sites/default/files/documents/2015/OCU-WG-Webinar-30Jun2015.mp4

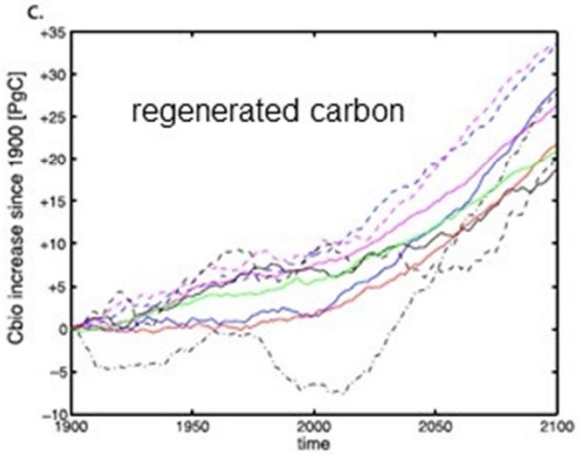
Accomplishments

- July 29 – August 16, 2013 NCAR ASP Summer Colloquium on 'Carbon-climate connections in the Earth system' and Research Workshop on Key Uncertainties in the Global Carbon-Cycle: Perspectives Across Terrestrial and Ocean Ecosystems
- EOS article, Examining Uncertainties in Representations of the Carbon Cycle in Earth System Models, 2013
- BAMS article, NCAR's Summer Colloquium: Capacity building in Cross-disciplinary Research of Earth System Carbon-climate Connections, In Press
- Input to US CLIVAR Science Plan
- Input to CMIP6 planning
- Workshop held in San Francisco, December 2014 together with Southern Ocean WG
- Workshop report in final stages of preparation
- Special Issue of CLIVAR Variations and OCB newsletter (Spring
- 2015)

The future of the Southern Ocean carbon storage in CMIP5 models by Takamitsu Ito, Annalisa Bracco, Curtis Deutsch

According to CMIP5 models the ability of the Southern Ocean to store CO_2 will continue to increase during this century despite slowdown of total ocean uptake





Southern Ocean carbon inventory change (in PgC) since 1900

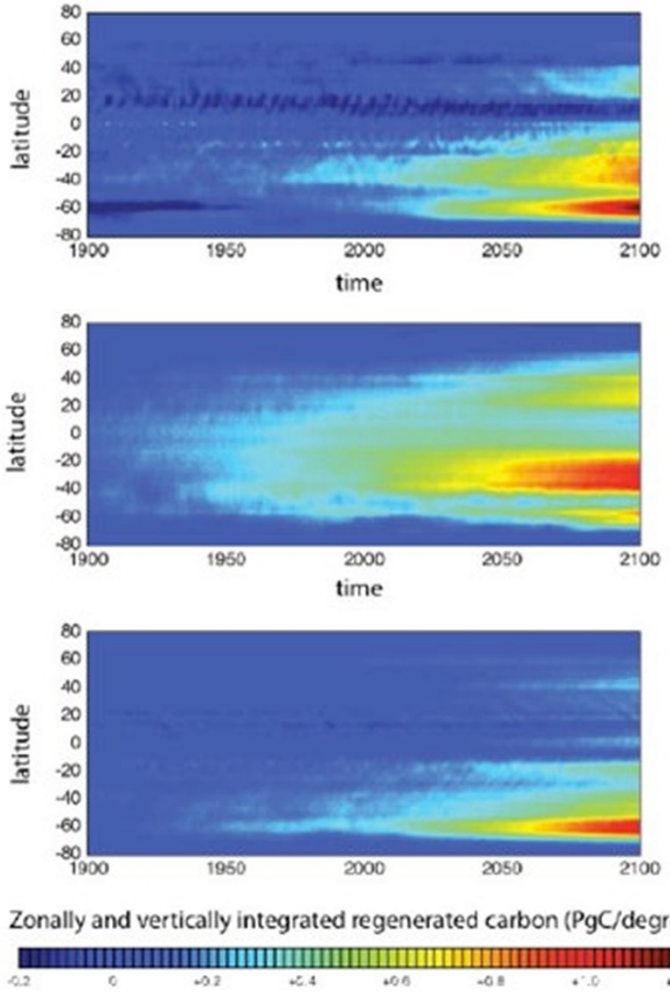


Figure 4: Zonally and vertically integrated annual mean regenerated carbon anomaly (PgC/degree) from 1900-2100 relative to 1860 in three of the models analyzed. Top: GFDL-ESM2M; Middle: IPSL-A-LR; Bottom: MPI-LR.

Ocean heat and carbon uptake in transient climate change: Identifying model uncertainty by Anastasia Romanou and John Marshall

In CMIP5 models the Atlantic meridional overturning circulation (AMOC) controls transient ocean heat uptake through regulating deep ocean ventilation. Kostov et al. (2014) found that the AMOC depth sets the depth to which heat is sequestered, and hence the effective heat capacity of the ocean in transient climate change ⟶ the spread in heat uptake across CMIP5 models could be largely explained by differences in their AMOC properties.

CORE-like experiments can help attributing regional warming patterns.

- Ocean biogeochemistry in the fifth Coupled Model Intercomparison Project (CMIP5) by John P. Dunne, Charlotte Laufkötter, and Thomas L. Frölicher

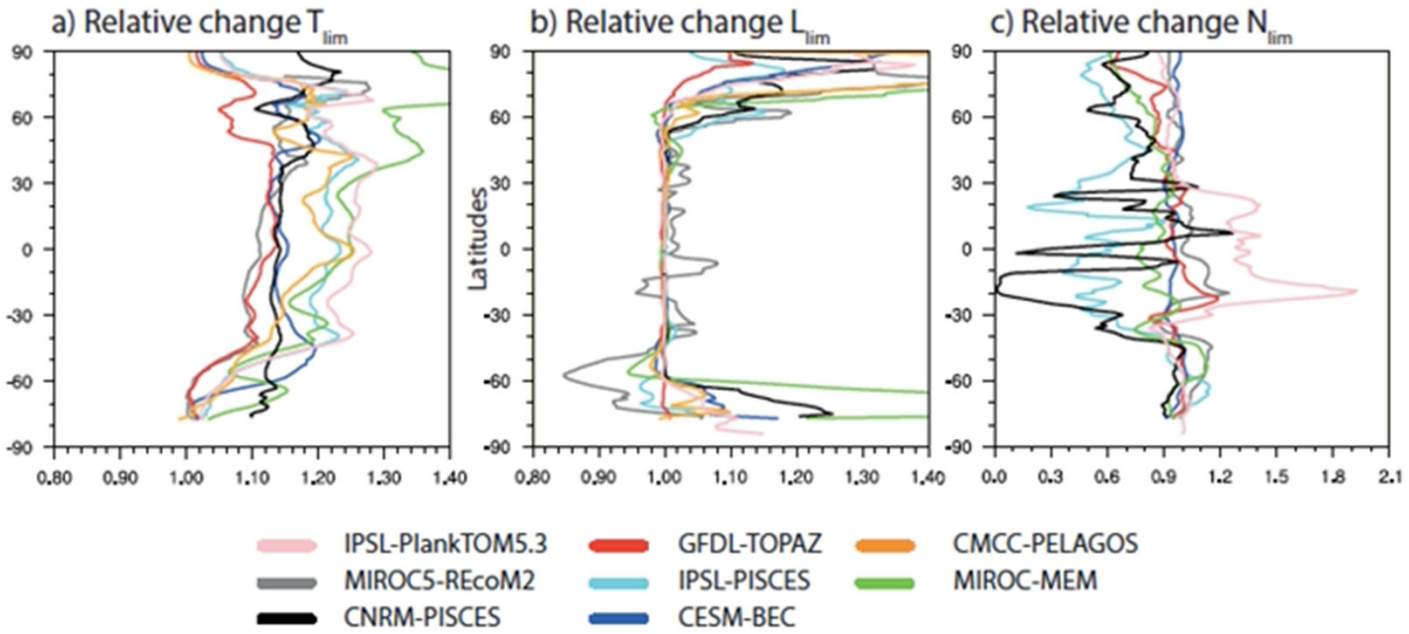


Figure 3: Zonal mean of the relative change in (a) temperature, (b) light, and (c) nutrient limitation factors for nine marine biogeochemistry models. Relative change is calculated as the 2081–2100 average divided by the 2012–2031 average. Based on Figure 6 of Laufkötter et al. (2015).

Little agreement in relation to processes that generate regional structure in projected changes among models

Ocean Carbon Uptake in CMIP-5 Models

- CMIP-5 models have provided wealth of resources to advance our understanding of global carbon and biogeochemical cycling under changing climate

- Representations of key physical/biogeochemical still **vary widely** across the models

- There are also **robust features** in the CMIP-5 ensemble involving climate – biogeochemical feedback and its regional expression → opportunity for improved understanding

Southern Ocean Working Group:
Joint U.S. CLIVAR/OCB Working Group

Southern Ocean Working Group	
Igor Kamenkovich, co-chair	University of Miami
Joellen Russell, co-chair	University of Arizona
Cecilia Bitz	University of Washington
Raffaele Ferrari	Massachusetts Institute of Technology
Sarah Gille	University of California, San Diego/SIO
Bob Hallberg	NOAA/GFDL
Ken Johnson	Monterey Bay Aquarium Research Institute
Irina Marinov	University of Pennsylvania
Matt Mazloff	University of California, San Diego/SIO
Jorge Sarmiento	Princeton University
Kevin Speer	Florida State University
Lynne Talley	University of California, San Diego/SIO
Rik Wanninkhof	NOAA/AOML

Goals:

- Improve understanding of the role of mesoscale eddies in the heat and carbon uptake by the Southern Ocean.
- Improve understanding of how the Southern Ocean stratification, circulation and heat and carbon uptake will respond to a changing climate.

SOWG Outcomes and Deliverables

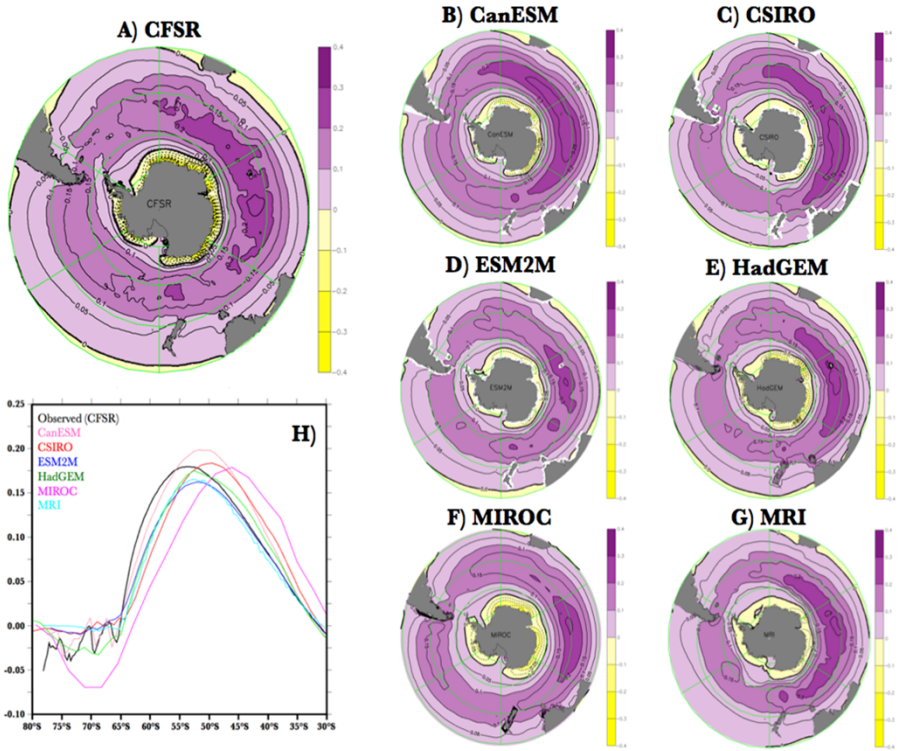
- Observationally-based data/model metrics for the consistent evaluation of modeling efforts by Southern Ocean and Antarctic scientists. Will be available on UA-hosted Southern Ocean Climate Model Atlas website. (available this summer)

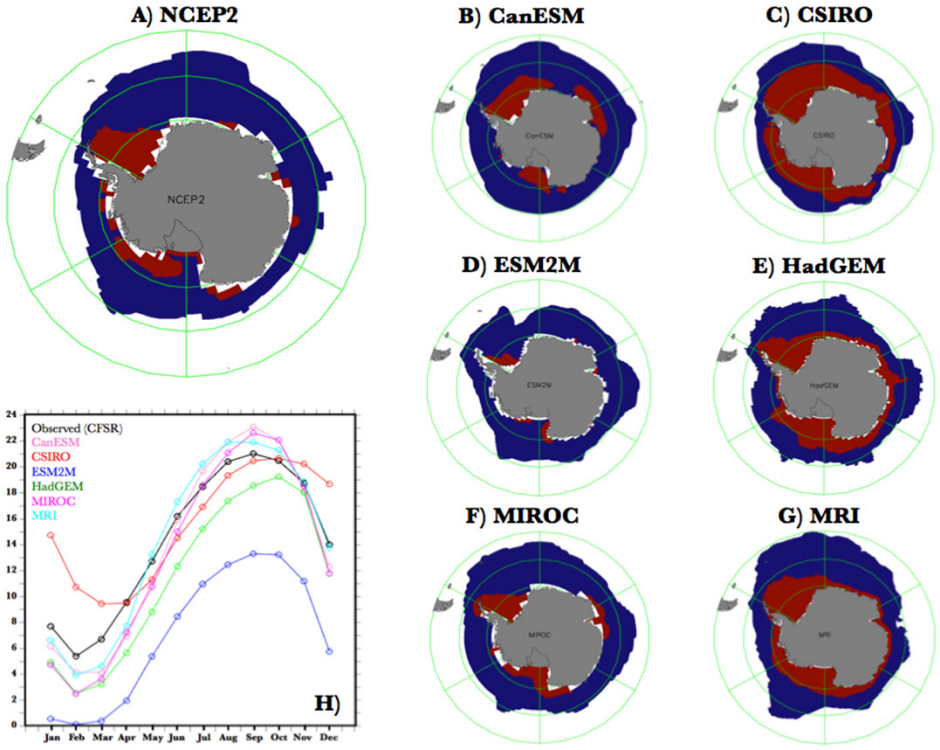
- A Manuscript for the Journal of Climate that:
  (i) assesses the state of our understanding of the role of eddies in the Southern Ocean in both the data and the models;
  (ii) identifies the most critical observational targets needed to fill in gaps in our understanding of the role of the Southern Ocean in present and future climate.

- A Workshop/Conference jointly sponsored with the Oceanic Carbon Uptake Working Group at **Fall AGU 2014**, with the goal of:
  (i) sharing the developed metrics for model evaluations;
  (ii) identifying important biases in the AR5/CMIP5-type model simulations of present and future climate, stemming from the lack of mesoscale eddies;
  (iii) providing guidance for estimating and reducing uncertainty in climate projections.

Person	Affiliation	Area of Interest	Metric(s)
Cecilia Bitz	U. Washington	Role of Sea Ice in Climate	Sea Ice Extent/Volume/Seasonality
Raffaele Ferrari	MIT	Ocean Turbulence	Eddy Kinetic Energy; Eddy-induced diffusivities and heat transport/uptake
Sarah Gille	UCSD/SIO	Air/Sea Exchange	Mixed-layer depth; Heat Content (400m) Non-solubility pCO_2 variance
Robert Hallberg	NOAA/GFDL	Ocean Dynamics	Water mass properties (upper 2000m and abyssal); Age tracer distribution; Drake Passage transport
Ken Johnson	MBARI	Chemical Sensors/ Biogeochemical Cycles	Seasonal cycle of nitrate
Igor Kamenkovich	U. Miami	Mesoscale Eddies/ Role of SO in global MOC	Stratification at the northern flank of the SO; Eddy-induced diffusivities
Irina Marinov	U. Pennsylvania	Carbon Cycle/Ecology	Oxygen, Temperature, Salinity Precipitation; Background nutrients
Matt Mazloff	UCSD/SIO	State Estimates	Mean dynamic topography; Temperature transport through the Drake Passage
Joellen Russell	U. Arizona	Role of Ocean in Climate	Strength and position of SO Westerly Winds Area of deep-water outcrop; Depth of AAIW isopycnal
Jorge Sarmiento	Princeton U.	Biogeochemical Cycles	Fractional uptake of heat and carbon by the SO
Kevin Speer	Florida State U.	Large-Scale Circulation	Stratification north and south of ACC (esp. SAMW) Mean flow/shear in SE Pacific; tracer spreading rates
Lynne Talley	UCSD/SIO	Physical Oceanography	Repeat hydrography inventories
Rik Wanninkhof	NOAA/AOML	Inorganic Carbon Cycle	Aragonite saturation state

Observationally-based Climate Model Metrics (examples)





Integrated area is given in 10^6 km^2

The ice edge is defined as the 15% coverage contour (NSIDC)

Westerly winds –

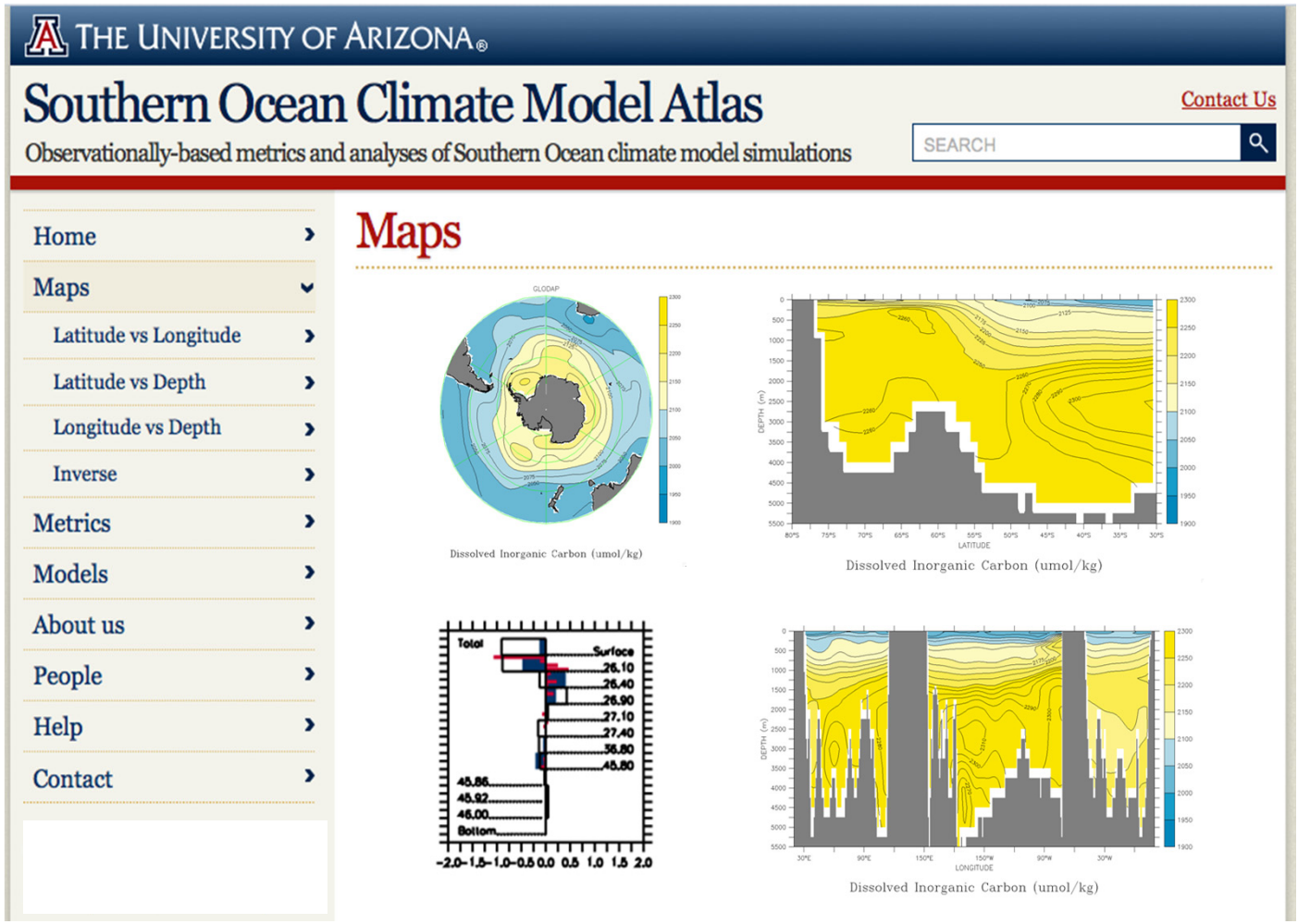
- source of virtually all of the momentum in the Southern Ocean (ACC)
- effects depends critically on the latitudinal structure
- drives upwelling/downwelling
- play a key rome in balancing density structure: act to weaken stratification
- models continue to exhibit a northward bias in the location of the maximum of the wind stress.

Sea Ice Extent (max/min) –

- forms a physical barrier to the air/sea exchanges of heat and carbon
- brine rejection believed to be an essential part of Antarctic Bottom Water formation
- biases in the sea-ice cover most likely caused by errors in the simulated heat budgets of the upper ocean

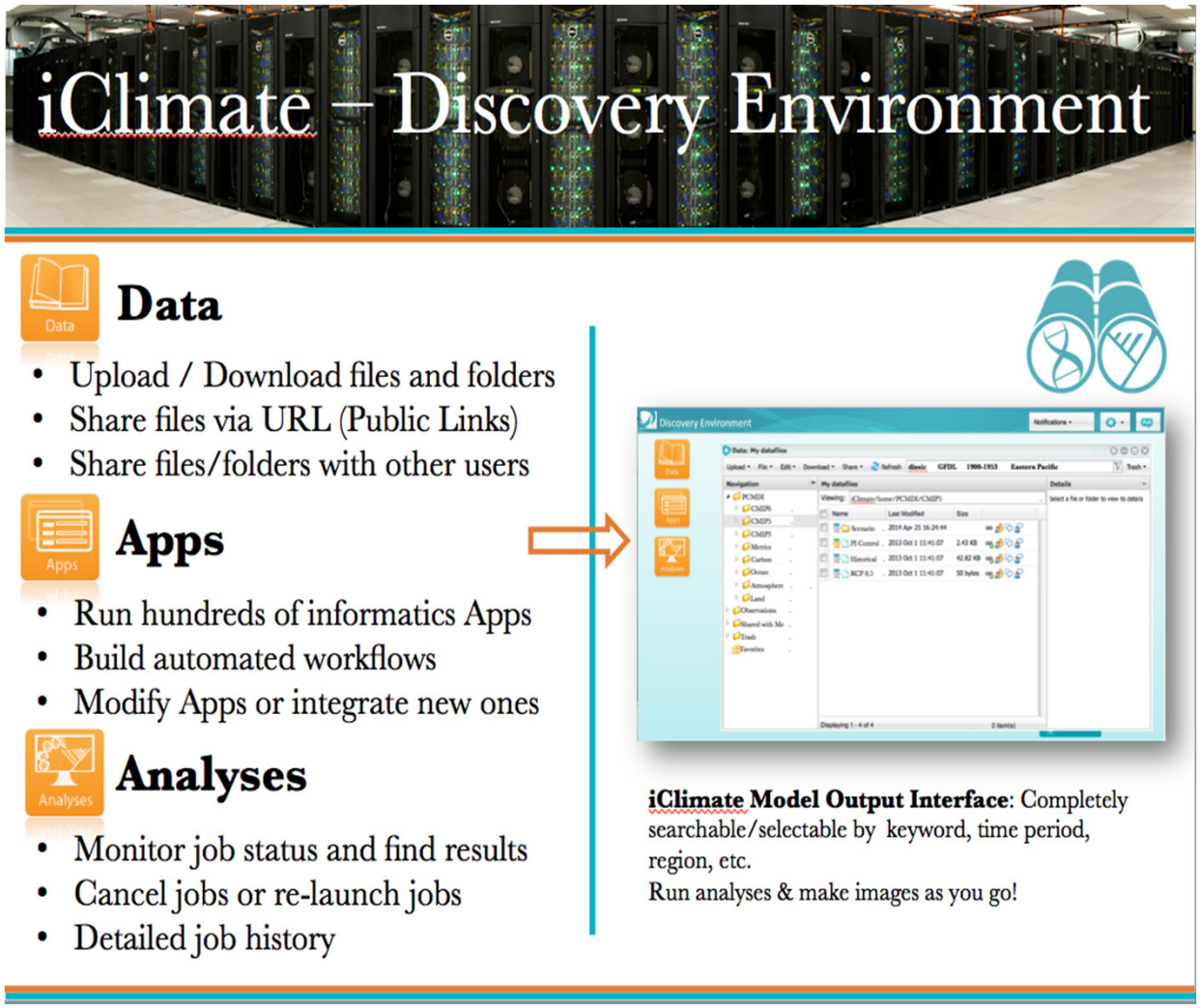
New Resources:

The Southern Ocean Climate Model Atlas will provide standardized images and metrics of the climate model and Earth System Model simulations conducted as part of the IPCC and CMIP processes. These maps, analyses and metrics will be available to researchers of all disciplines and members of the public. The Atlas will be made public shortly.



New Resources:

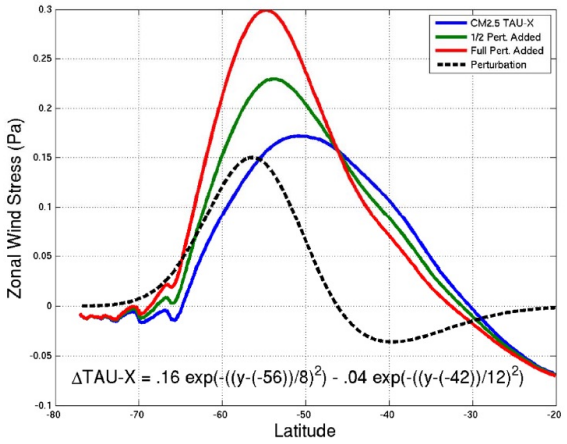
We are creating a climate data and analysis portal called iClimate. iClimate will allow users to upload and share climate model data and the observational datasets against which they are assessed, as well as analysis tools and scripts. iClimate is currently in a testing phase and should be available to the public in the Fall of 2015.



Southern Ocean Model Intercomparison Project

OVERALL GOAL: Reduce uncertainties in climate projections by defining the role of the oceans in climate with regards to the Southern Ocean, especially the role of winds, buoyancy and stratification in determining the global impacts of warming.

OBJECTIVE: Encourage the climate modeling community to use the newly created assessment tools (SOWG) by developing a protocol for an international, model intercomparison program (SOMIP)



Proposal: Zonally uniform wind perturbation, focused on Drake Passage

WCRP World Climate Research Programme
WMO
UNESCO IOC
ICSU International Council for Science

SOWG Conclusions:

We need to reduce the uncertainty in our projections of the Southern Ocean's role in climate.

1) We need more in situ biogeochemical observations of the Southern Ocean, including floats, ships, moorings, etc. (BGC-Argo)

2) We need more Southern Ocean Climate Process Teams

3) We need more Observationally-based climate model metrics

4) We need a Southern Ocean Model Intercomparison Project