Physical Oceanography

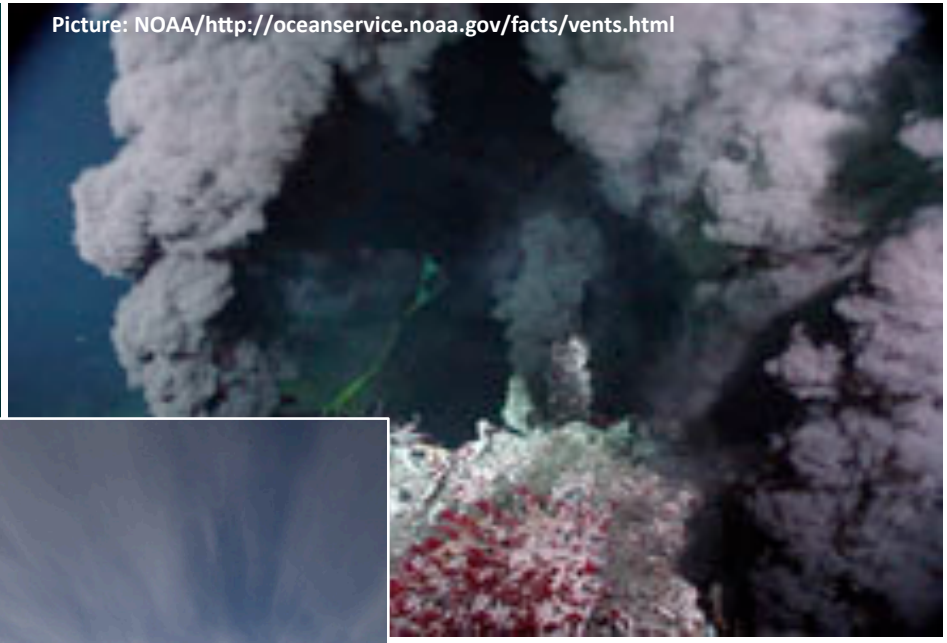
Susan Howard & Daria Halkides

Earth & Space Research

http://www.publicdomainpictures.net/view-image.php?image=18485

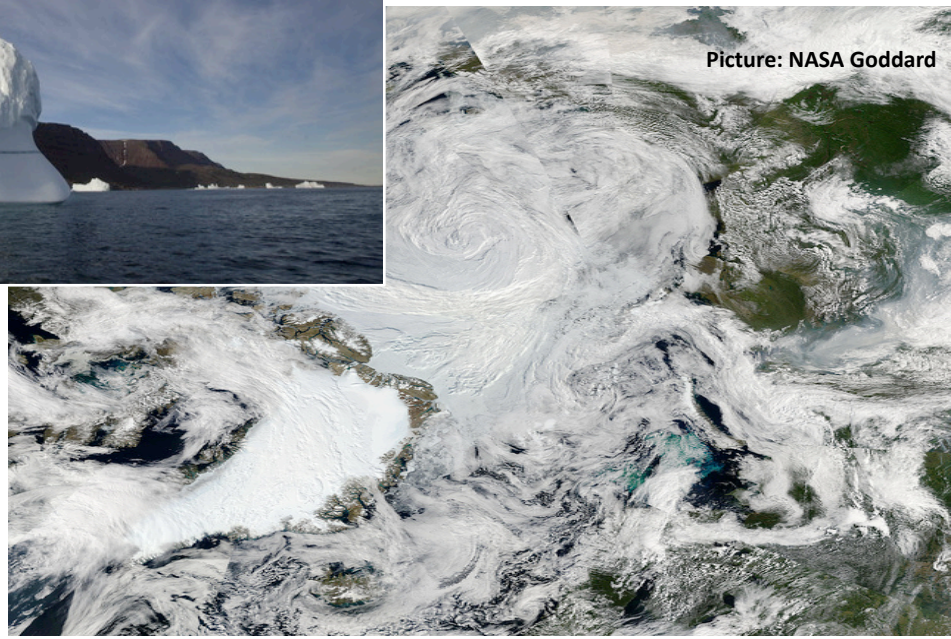
What do you think of when you hear the word "Oceanography"?

Picture: Brian J. Skerry/National Geographic


Picture: NOAA/http://oceanservice.noaa.gov/facts/vents.html

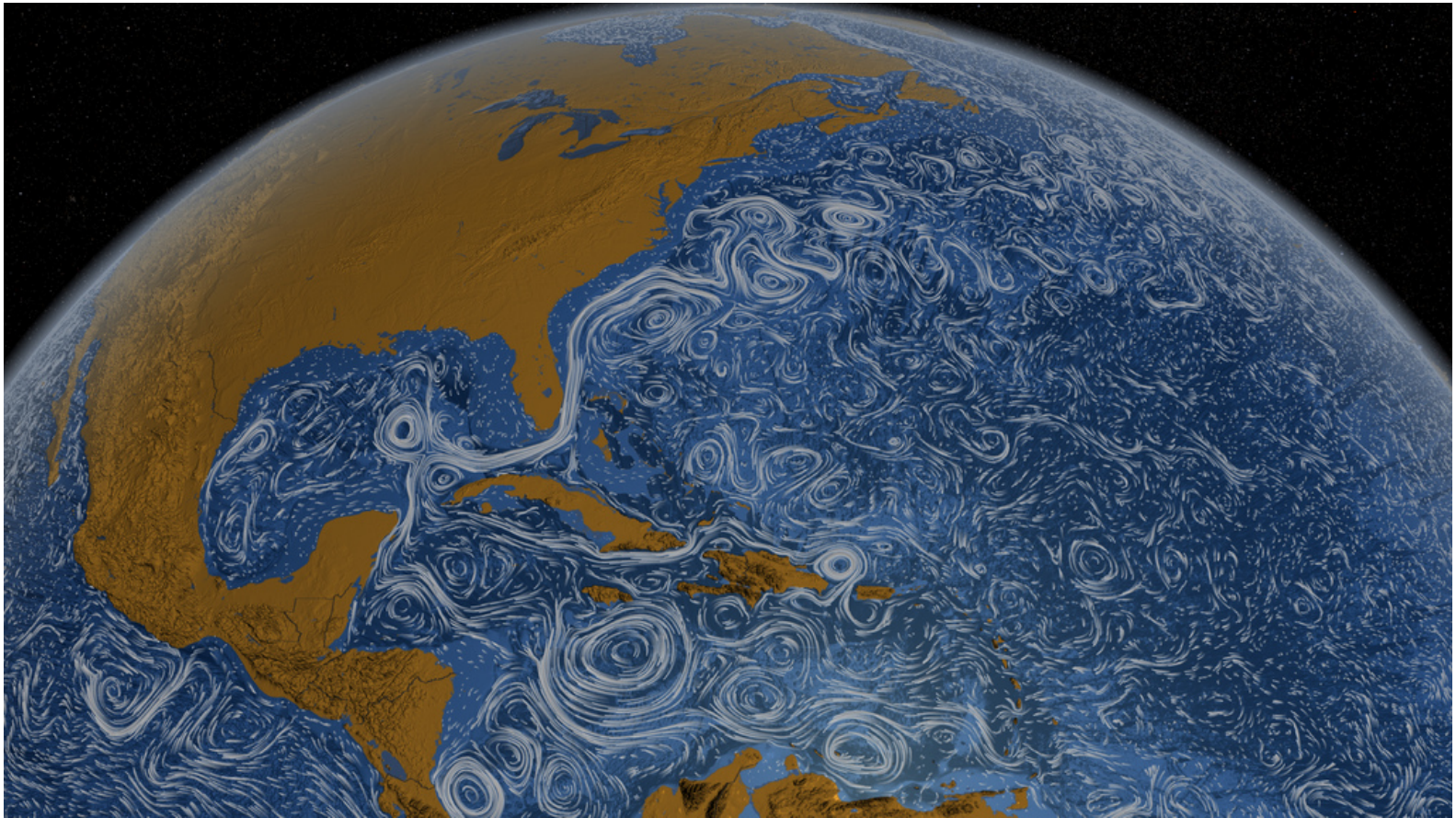
Picture: Brennan Linsley/AP

Picture: REUTERS/Mainichi Shimbun

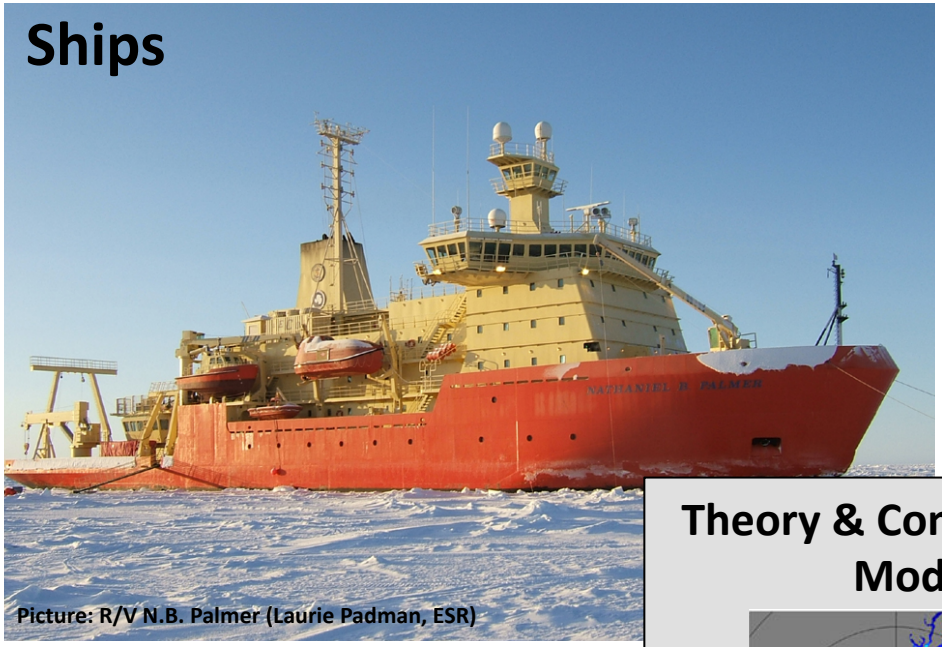

Picture: NASA Goddard

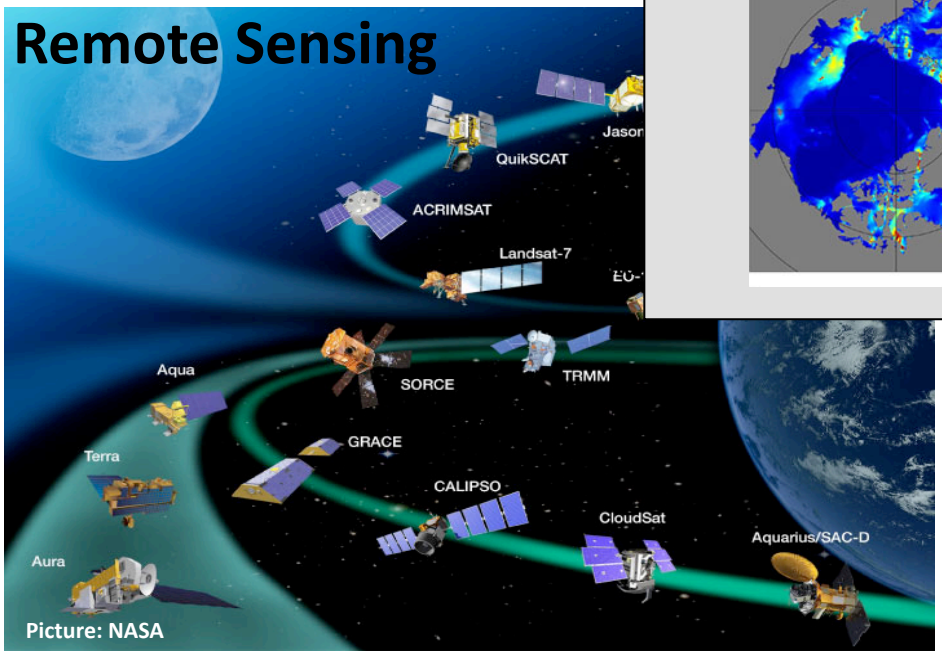
Physical Oceanography?

- **A branch of physics** focused on the transfer of mass & energy in the ocean, especially through fluid motions, as well as interactions of the ocean with the atmosphere, cryosphere, lithosphere & biosphere, & the impacts of these interactions on climate…

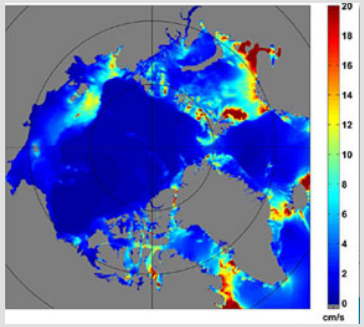


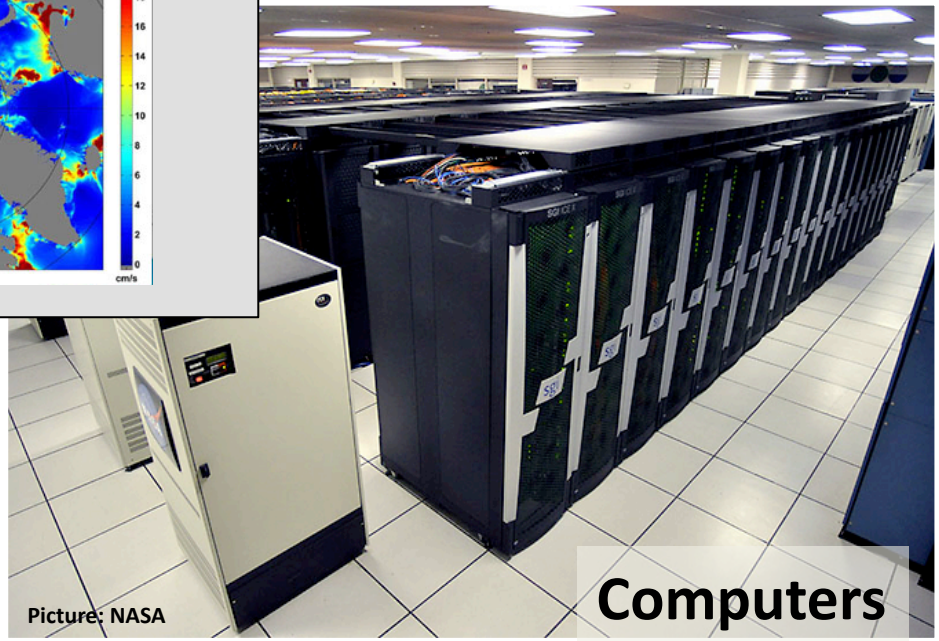
What Tools Do Physical Oceanographers Use?





Theory & Computational Models





Education?

- **High School**
  - Physics, chemistry, calculus (or at least pre-calculus) usually prerequisites for physical science majors
  - Computer science/programming skills a big plus
  - Summer programs?
- **College**
  - Major: general **(Physics, Math)** or specific (**Oceanography, Environmental/Marine Science, etc.)**?
  - Highest ranked school not always best school for an individual, personally or professionally
- **Graduate School**
  - Time commitment for terminal MS is 1-3 years, PhD is 4 - 8 years (5-6 years typical)
  - MS vs. PhD: Oceanography differs from some physical sciences (e.g. Astrophysics) in that there are terminal MS programs; many of the same things can be accomplished without going PhD route, including career in research
  - Take the time to find out what you love before entering a program (Common myth: "Get your degree, then you can study whatever you want" – not easily done in the current job market!)
  - Look at specific program, research of faculty you may want to work with & geographic location
- **Postdoctoral Positions (1-3 years)**
  - Advisor compatibility & topic area most critical
  - Write proposals!

Types of jobs?

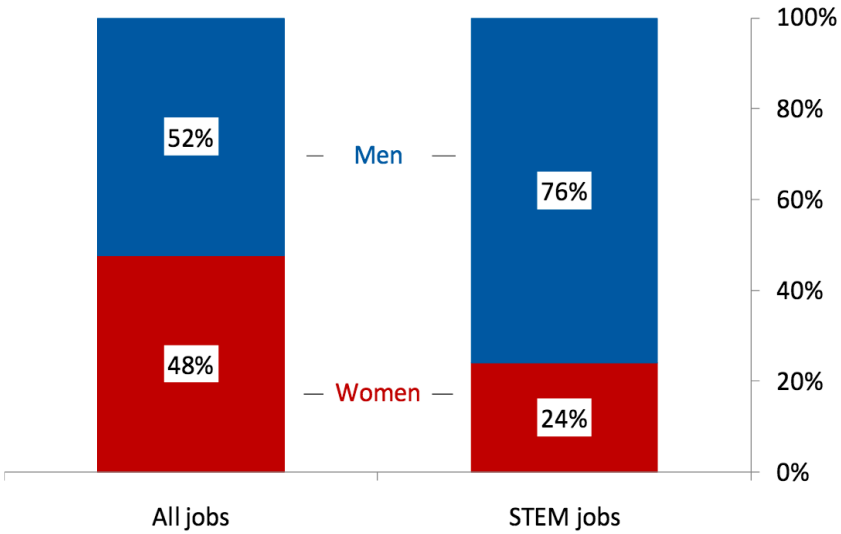
- **Academia**
  - Professor (teaching + research)
  - Research faculty
- **Pure Research**
  - Government research institutions (NASA, NOAA, NCAR, DOE, NRL)
  - Private non-profit institutes (large/college affiliated: WHOI, Scripps; small: **ESR**, NWRA)
  - Independent researcher (rare but possible, e.g., Theiss Research)
- **Military (Navy)**
- **Industry**
  - Oil/mining companies
  - Fishing industry
- **Media**
  - TV meteorologist
  - Science journalist
- **Education**
  - K-12 science teacher or science education specialist
  - College instructor (teaching only)
  - Science museum curator
- **Public Service**
  - Resource manager
  - Science advisor (e.g., for congress person)
  - Public educator for environmental activist groups (e.g., Union of Concerned Scientists)

Is There A Gender Gap?

NSF: In 2012, women accounted for…

- > half of undergraduates STEM majors!
- ~44% (52%) of STEM PhD (MS) degrees
- ~40% (46%) of Oceanography PhD (MS) degrees
- But only ~21% of full professors in STEM fields (~15% in Physical Oceanography)
- Numbers are similar for non-academic, upper management positions in STEM fields….

- **Active Workforce?**



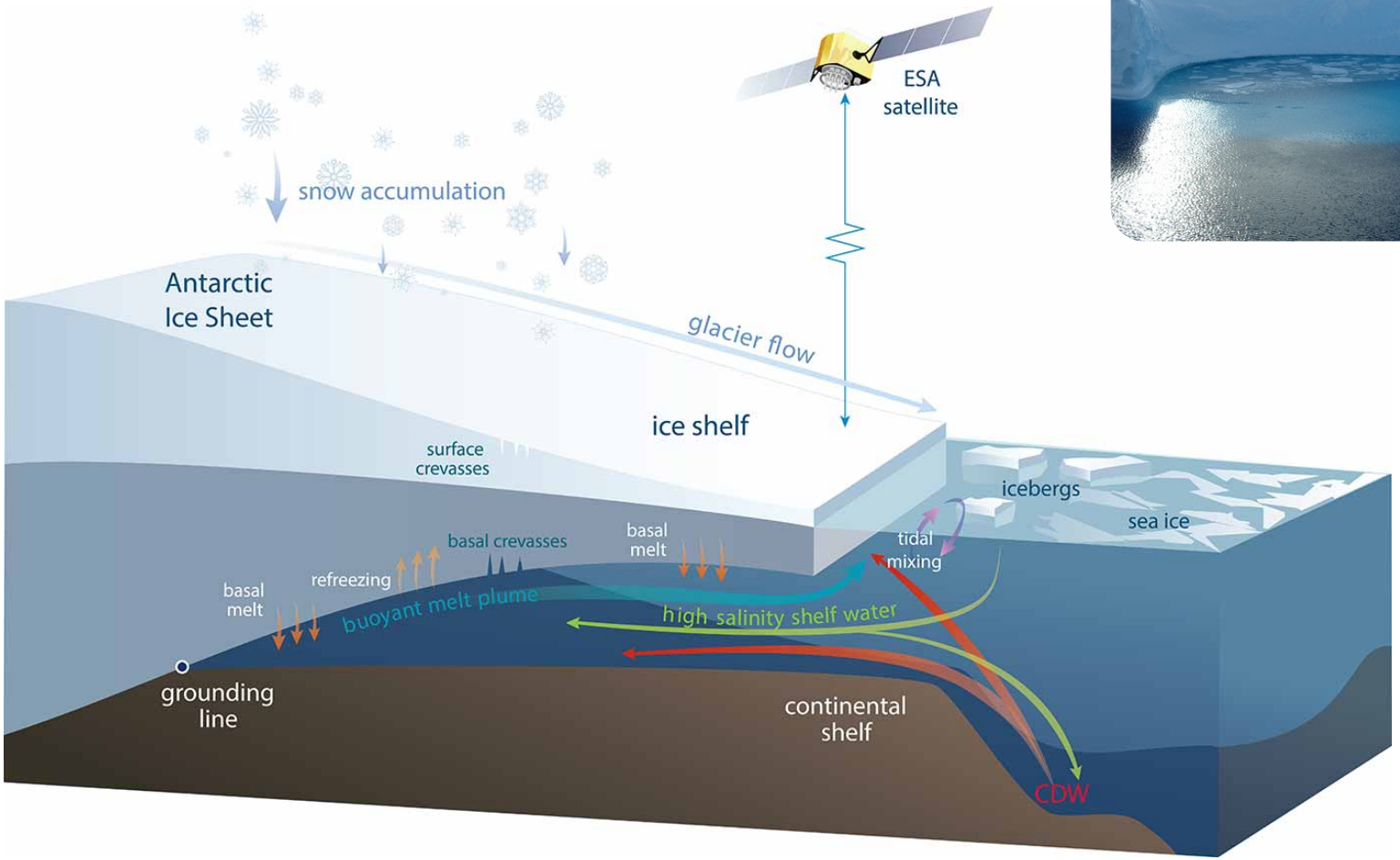
Source: ESA calculations from American Community Survey public-use microdata.
Note: Estimates are for employed persons age 16 and over.

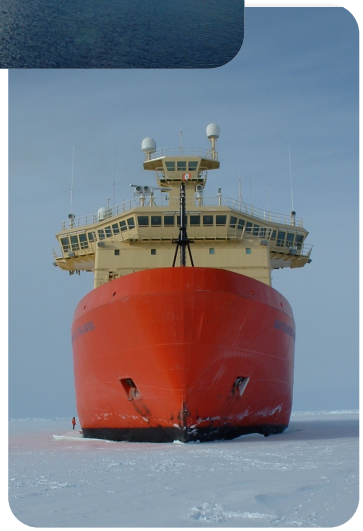
Useful references:

- **Women In Oceanography: A Decade Later**, in *Oceanography,* vol. 27, Number 4, Supplement: http://www.tos.org/oceanography/archive/27-4_supplement.pdf
- **Women Oceanographers.Org**: http://www.womenoceanographers.org/Default.aspx
- **National Academies Committee on Women in Science, Engineering & Medicine**: http://sites.nationalacademies.org/PGA/cwsem/index.htm

Susan's Work

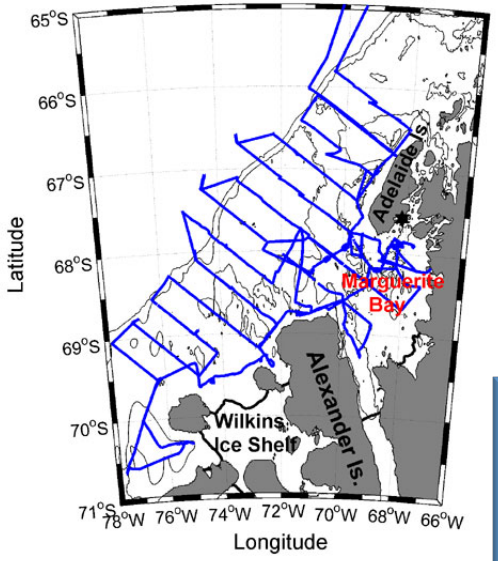
- Polar Oceanography
- Tides, Mixing, Ocean-Ice Interactions

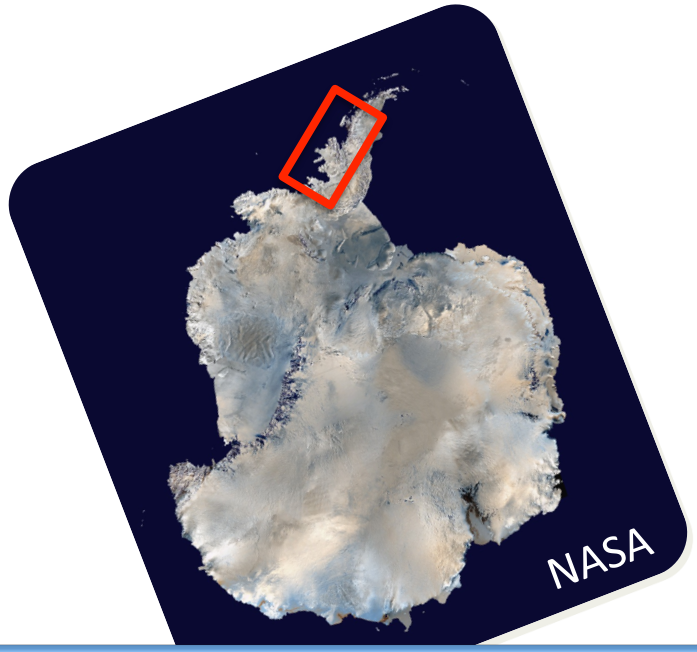




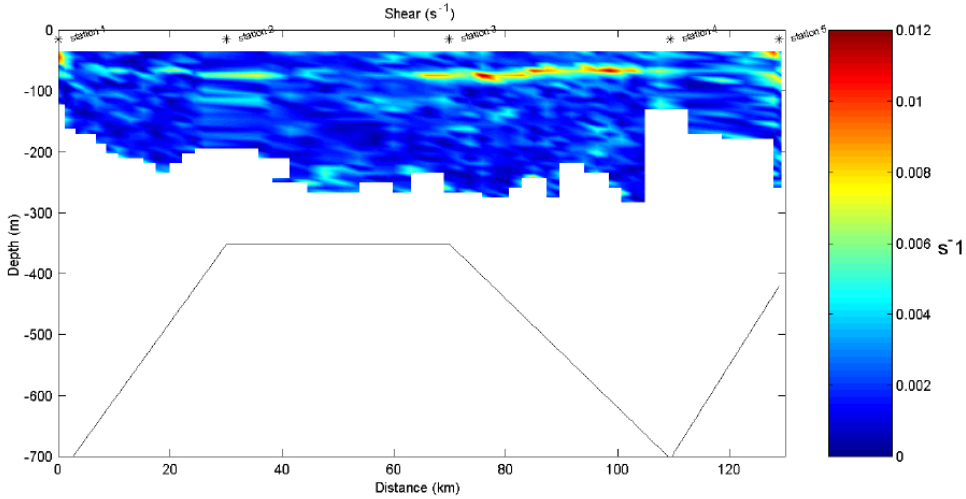
Susan's Work

- U.S. Southern Ocean GLOBEC



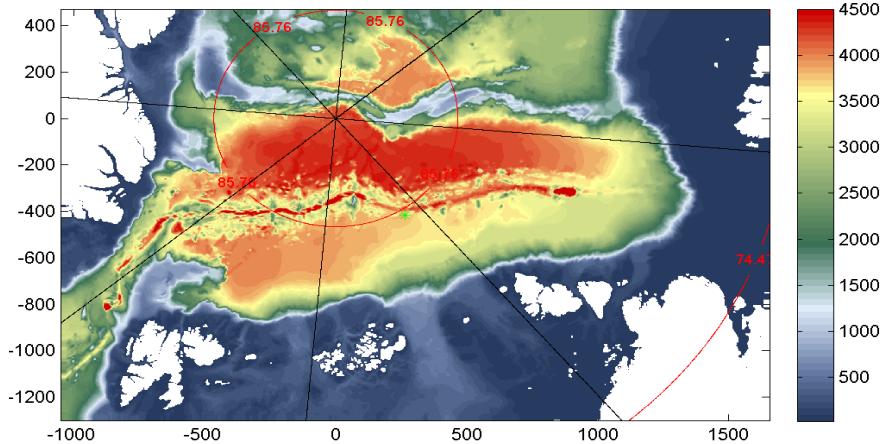


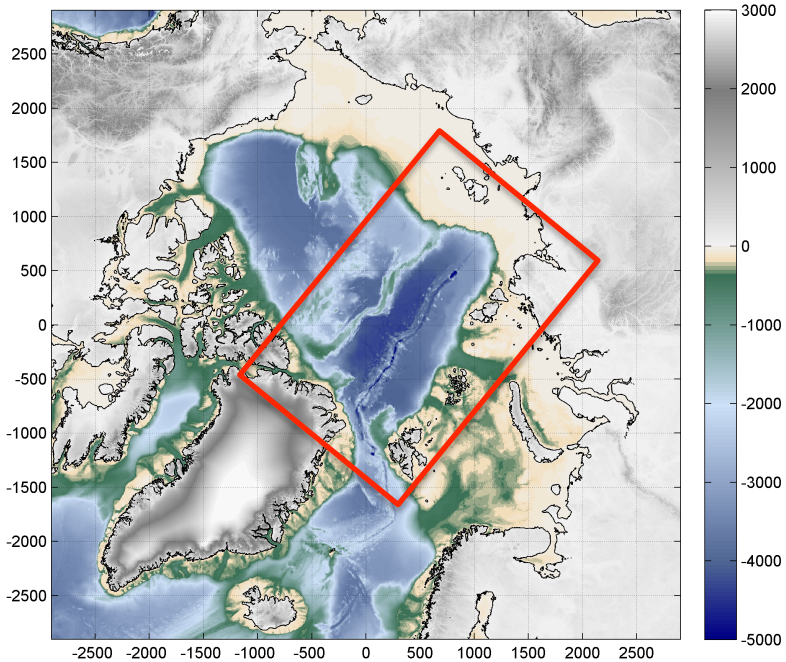
- Mapping currents
- Mapping temperature & salinity
- Determining amount of mixing by looking at shear



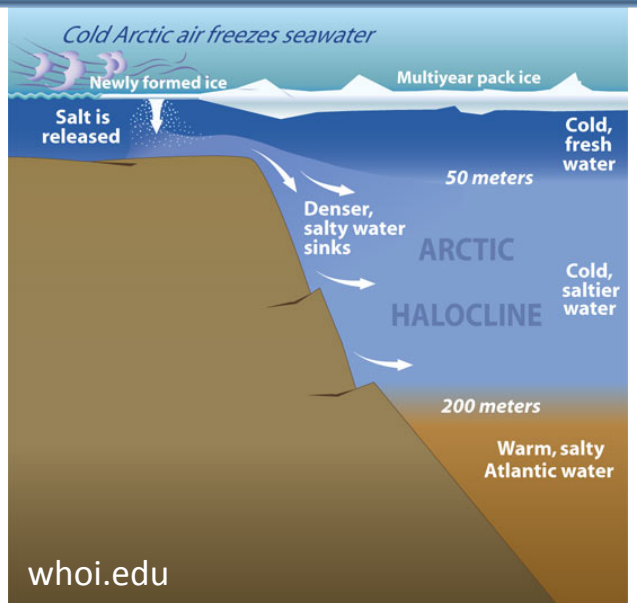
Susan's Work

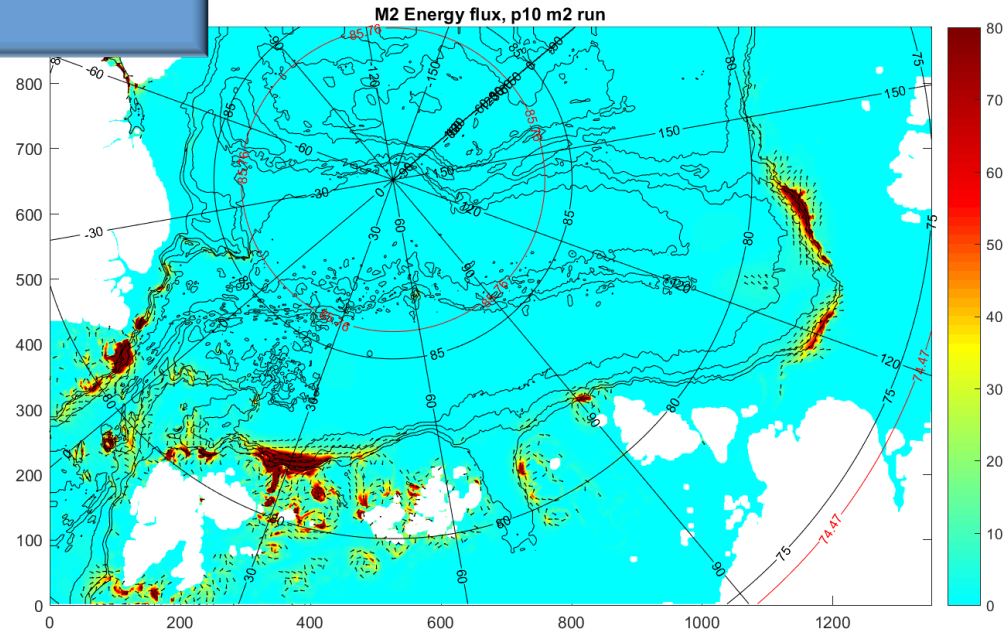
- High resolution Arctic Tide model





Determine how tides affect the climate by mixing the water column & altering heat fluxes.





Susan's Work

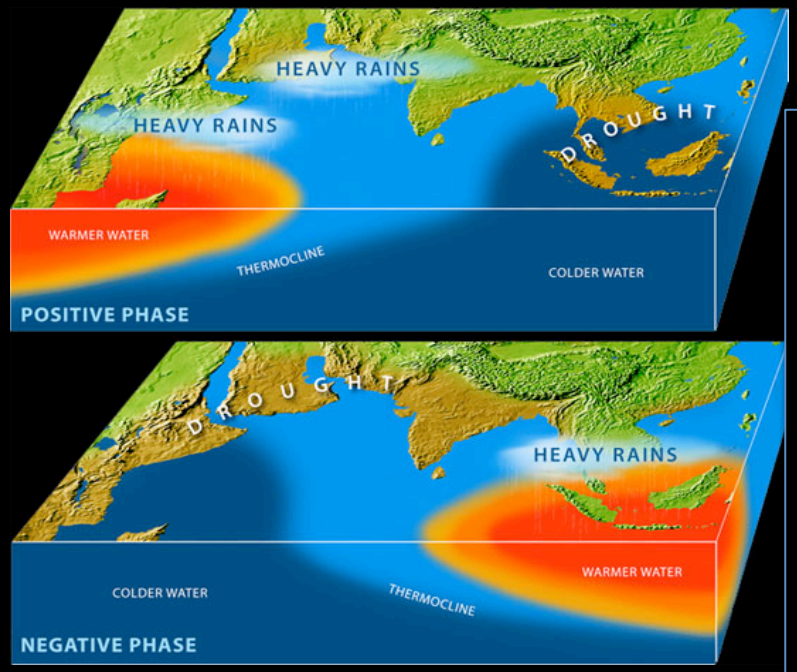
- Fluid Dynamics
- Physics
- Programming
- Problem solving

Daria's Work

- Air-sea interactions (Indian Ocean variability, El Niño)
  - Ocean surface mixed layer processes
- High latitude – low latitude 'exchange'
- Virtual Ice Sheet Laboratory (VISL)

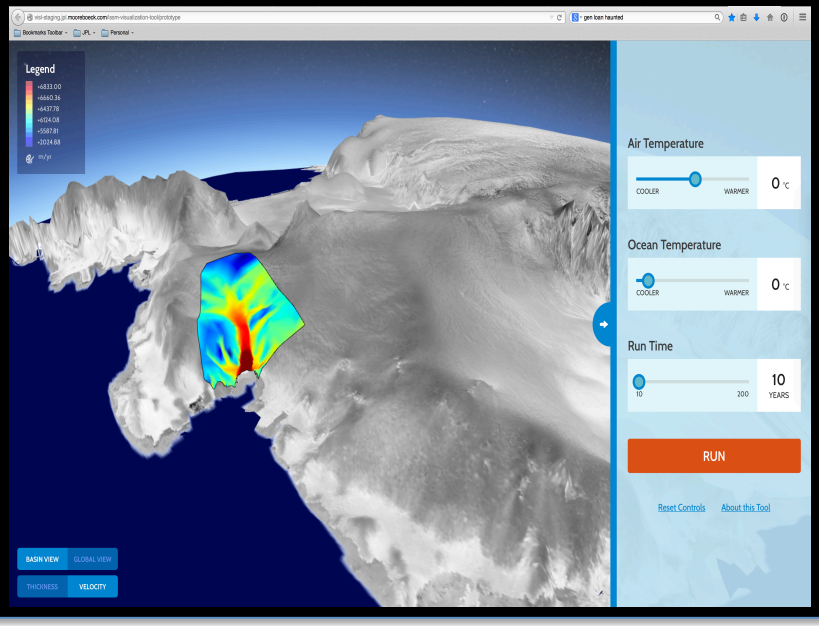
Global Ocean Mixing Depth from MITgcm
Map: Courtesy of Dimitris Menemenlis (JPL)

Indian Ocean Zonal/Dipole Mode (IOZDM)



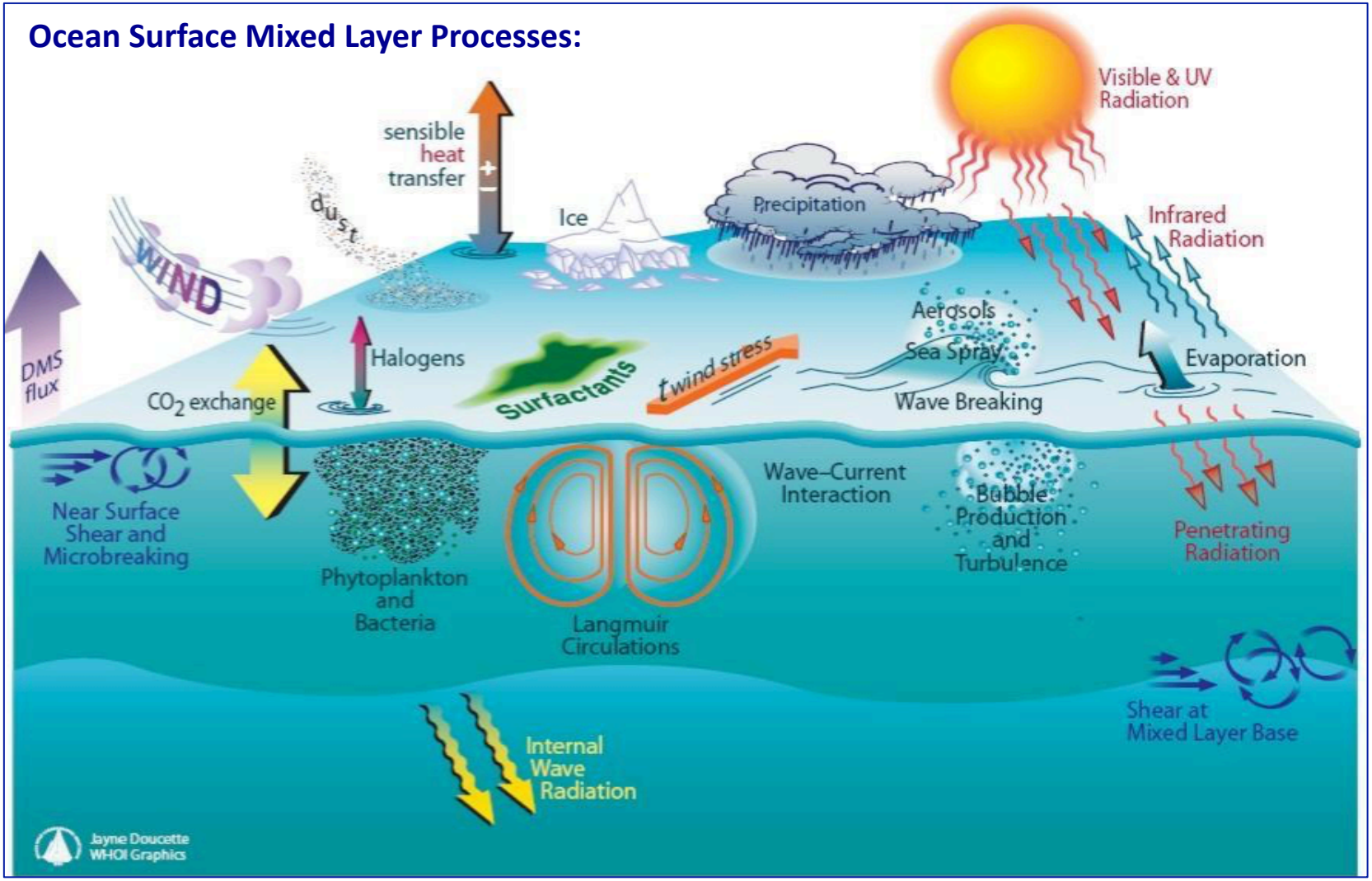
Schematic Credit: Woods Hole Oceanographic Institute

Virtual Ice Sheet Lab (VISL)

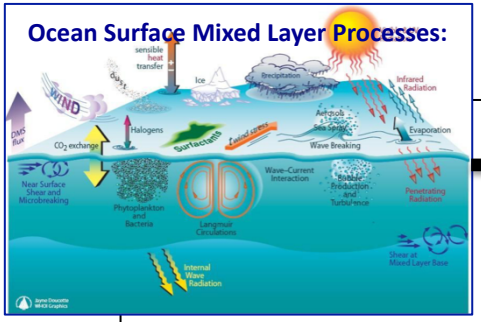


Daria's Work – Example: ML Temperature Budget

Ocean Surface Mixed Layer Processes:



Daria's Work – Example: ML Temperature Budget



The MLT Equation

(Kim et al. 2006)

Ocean Dynamics (OD) Contribution

Net MLT Tendency

Surface Heat Flux (SHF) Contribution

Horizontal Advection

Horiz. Mixing (small)

Subsurface Processes

$$\frac{\partial[T]}{\partial t} = \left[\frac{1}{\rho C_p}\frac{\partial(Q_{net})}{\partial z}\right] - \left[u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right] + \left[\frac{\partial}{\partial x}\left(\kappa_x\frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(\kappa_y\frac{\partial T}{\partial y}\right)\right] + subsurface$$

$$subsurface = -\frac{1}{h}\Delta T\frac{\partial h}{\partial t} - \left[w\frac{\partial T}{\partial z}\right] - \frac{1}{h}\kappa\frac{\partial T}{\partial z}\Big|_{-h}$$

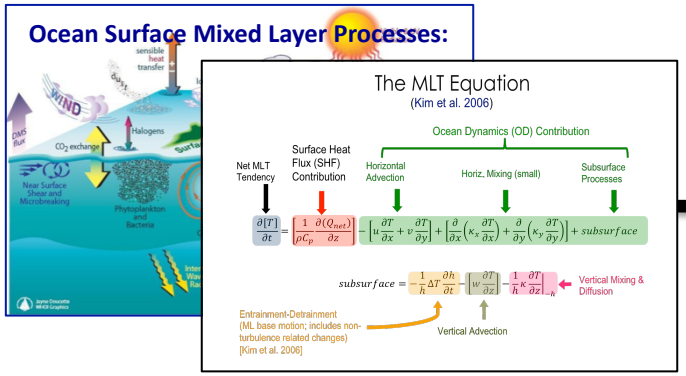
Vertical Mixing & Diffusion

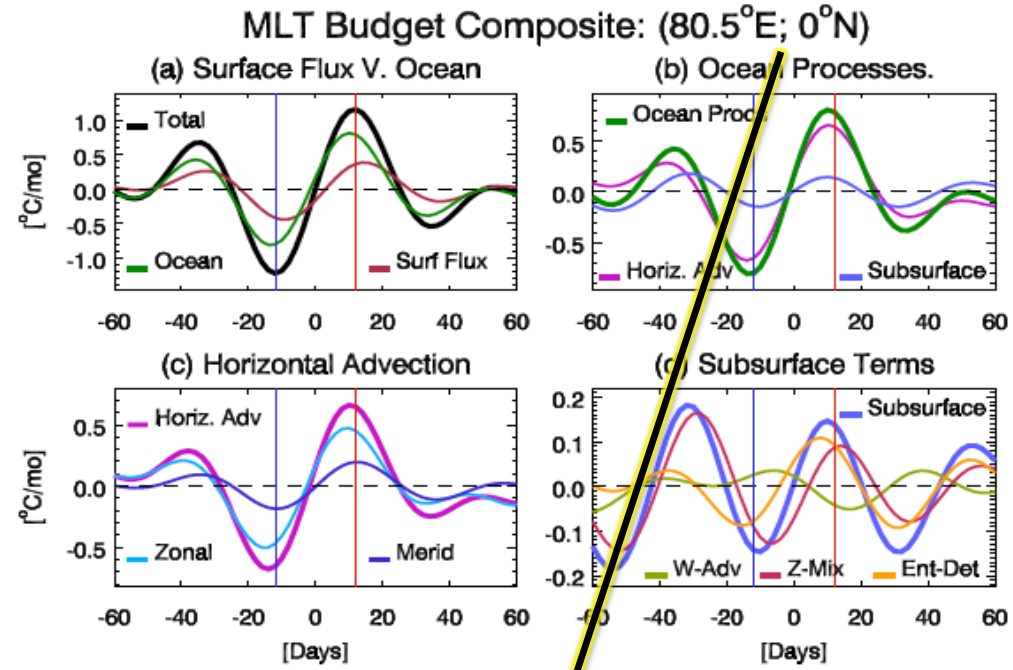
Entrainment-Detrainment (ML base motion; includes non-turbulence related changes) [Kim et al. 2006]

Vertical Advection

Daria's Work – Example: ML Temperature Budget

(Study of cold events on 35-95 day timescale in Indian Ocean from Halkides et al. 2015)

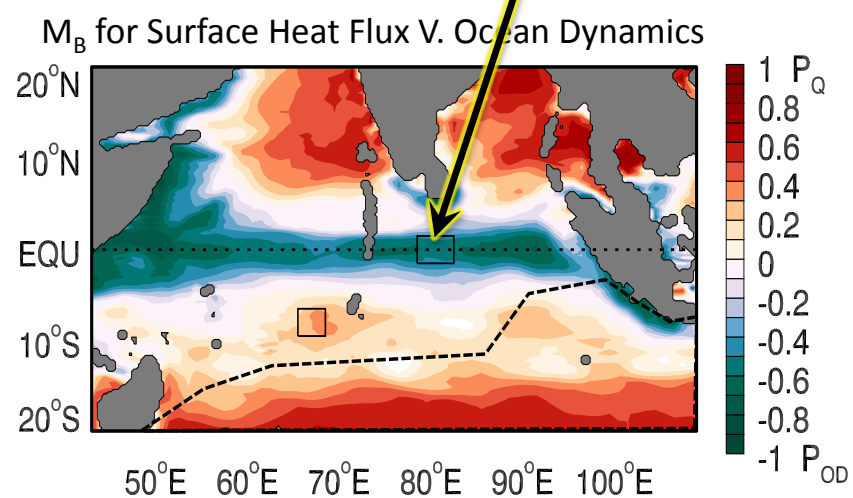




Balance Metric….

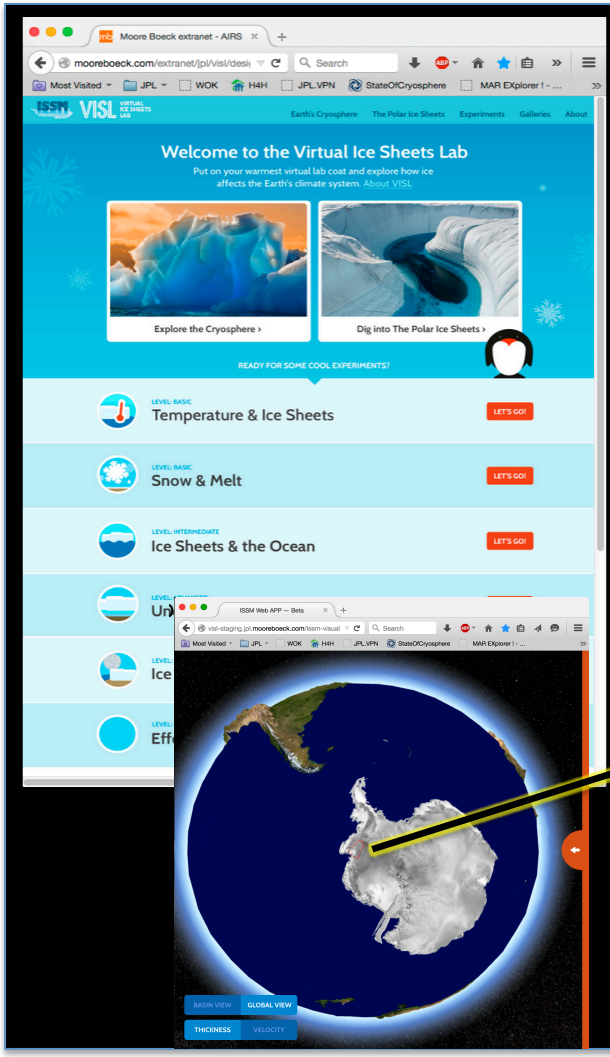
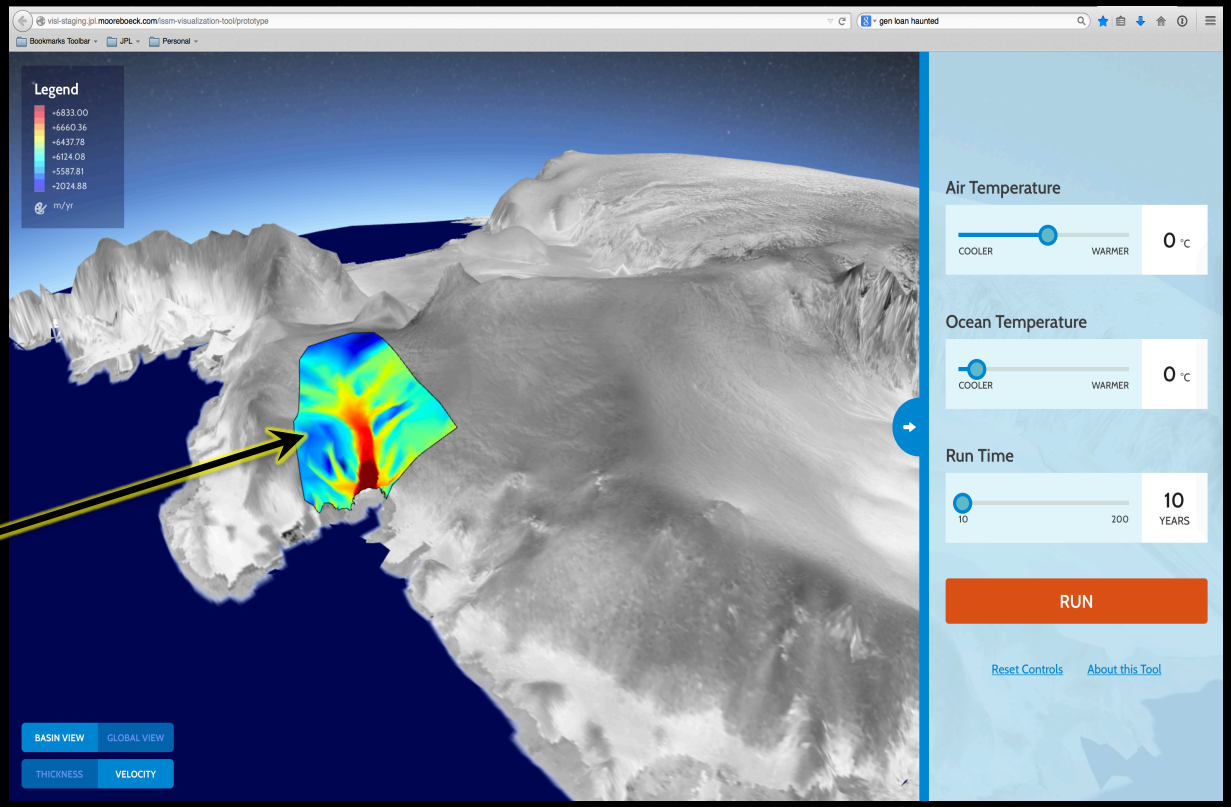
$$M_B = \frac{\langle (P_2{}' - T_t{}')^2 \rangle - \langle (P_1{}' - T_t{}')^2 \rangle}{\langle (P_2{}' - T_t{}')^2 \rangle + \langle (P_1{}' - T_t{}')^2 \rangle}$$

$$\text{where if } \begin{cases} 0 < M_B \le +1 & \ldots \mathrm{P}_1 \text{ most important} \\ 0 > M_B \ge -1 & \ldots \mathrm{P}_2 \text{ most important} \\ M_B = 0 & \ldots \mathrm{P}_1, \mathrm{P}_2 \text{ equal} \end{cases}$$



Daria's Work – Virtual Ice Sheet Lab (VISL)

- Working with ice sheet modelers at Jet Propulsion Lab, graphic designers at Moore Boeck Design & Development & students to develop online lab with adaptations for K-12 education, undergraduate science labs, resource management education & scientific research…



- Students, lay-users & researchers alike will run NASA's state-of-the-art Ice Sheet System Model (ISSM) by moving sliders on a user-friendly graphic interface
- Site will include lesson plans & instructions for table top experiments to illustrate basic physics concepts needed for model interpretation