OSCAR Surface Currents

Kathleen Dohan

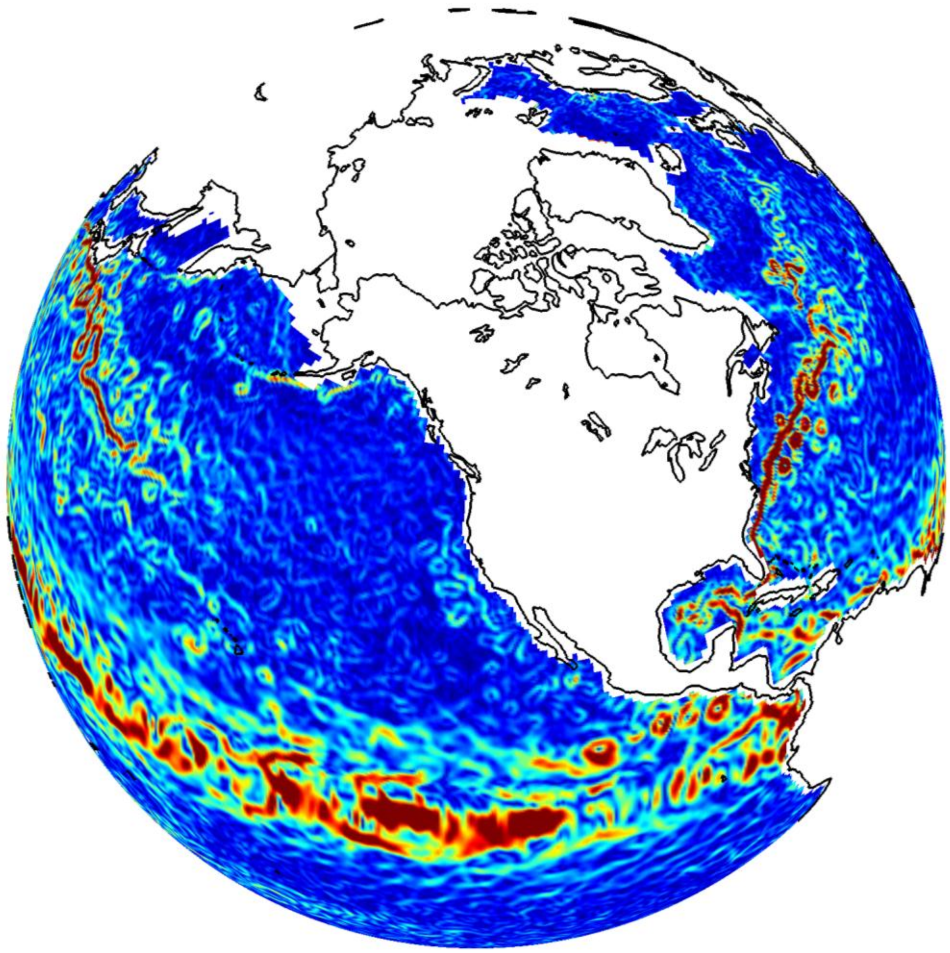
Earth and Space Research, Seattle, WA

- OSCAR = Ocean Surface Current Analyses-Realtime

- Describe OSCAR today and changes in the upcoming version of OSCAR

- Research areas for the project:
  - Vertical and time dependence
    - Inertial oscillations
  - Small-scale features

- Surface currents for ENSO

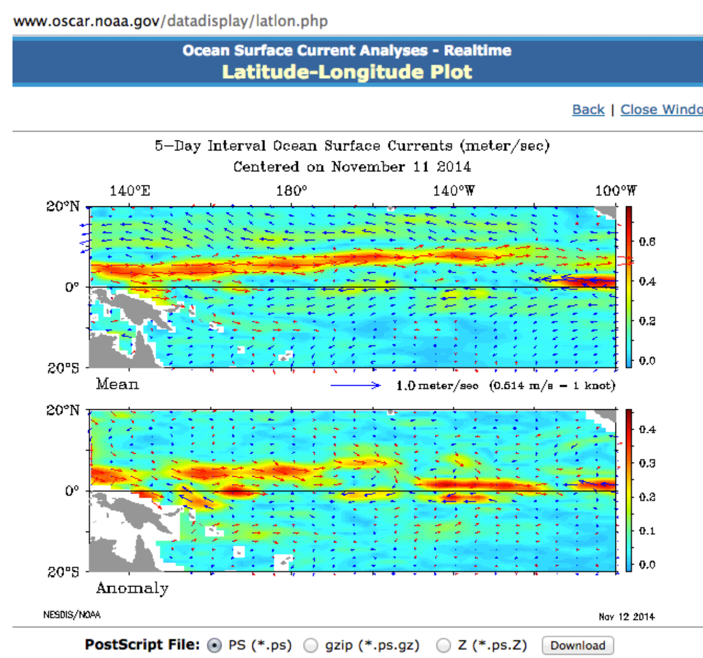


OSCAR Surface currents from satellite fields

- **OSCAR** = **O**cean (mixed layer) **S**urface **C**urrents **A**nalyses - (near) **R**ealtime
  - Satellite-derived global surface current database provided in near-real time based on geostrophy, Ekman dynamics, and thermal wind
- **WIND**: SSM/I, QuikSCAT, ERA Interim, NCEP
- **SSH**: AVISO MADT
- **SST**: GHRSST Reynolds OI SST 0.25^o grid. Not yet using Aquarius.
- Global surface currents
  - $\Delta x = 1/3^o$, $\Delta y = 1/3^o$
  - $\Delta t = 5$ days
  - Near-real-time = between 1-day and 5-day latency
  - Averaged velocities in the top 30m
  - 1993: present day (within about 5 days)
  - 10 day temporal smoothing

OSCAR Surface currents from satellite fields

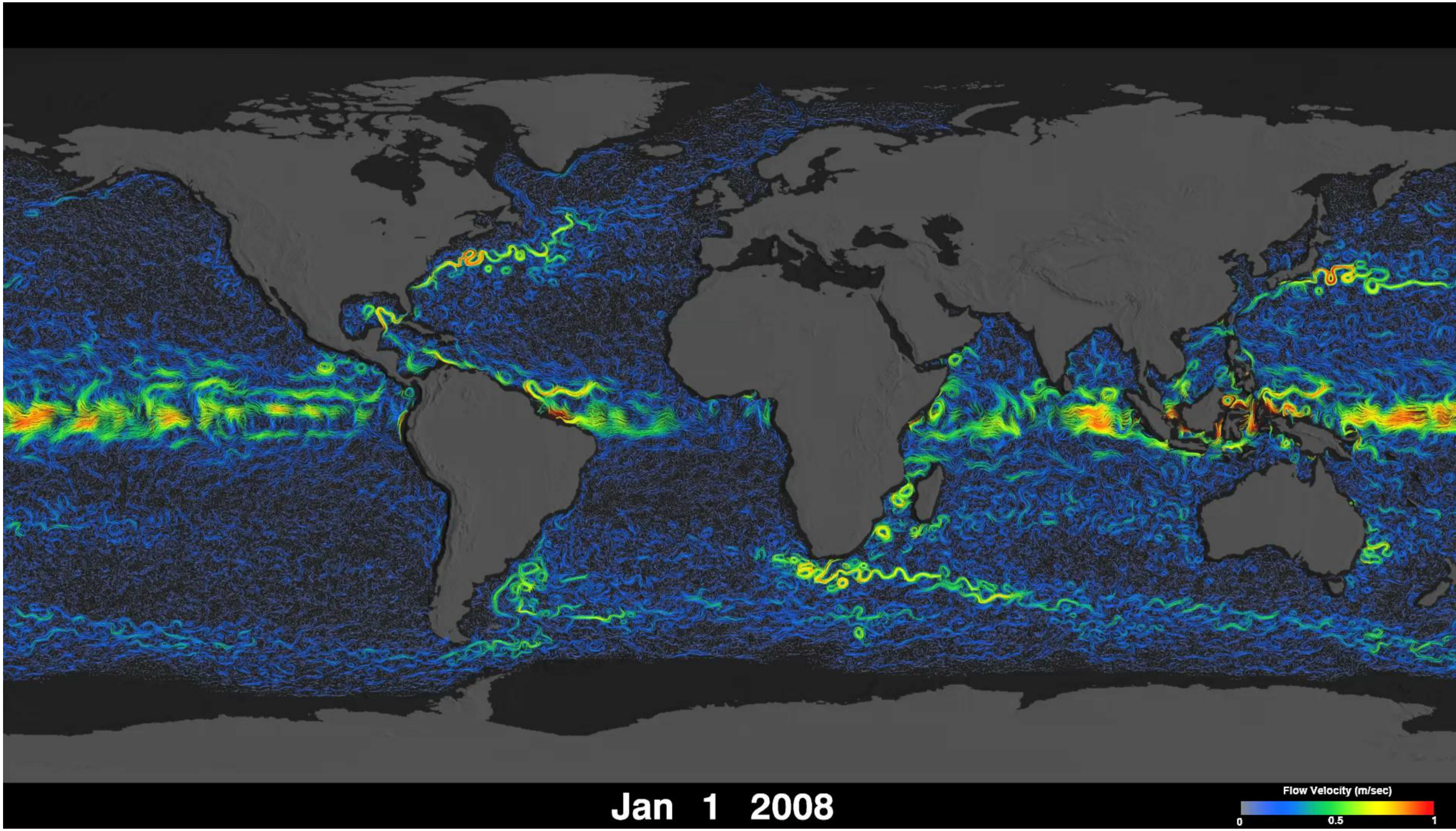
- Supported by NASA
- Hosted at the PO DAAC
- podaac.jpl.nasa.gov



- Phasing out the NOAA site
- Keeping the plotting functionality at ESR
- Will have up to date validation

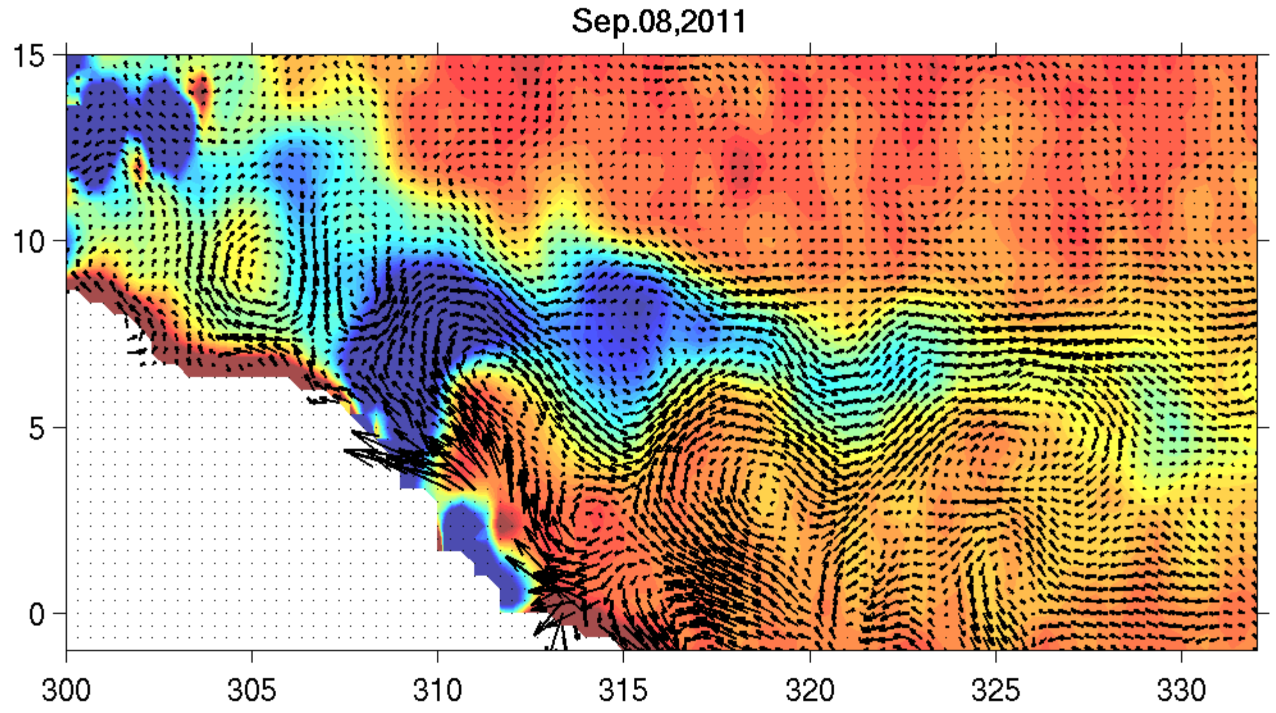
2015

OSCAR Surface currents from satellite fields

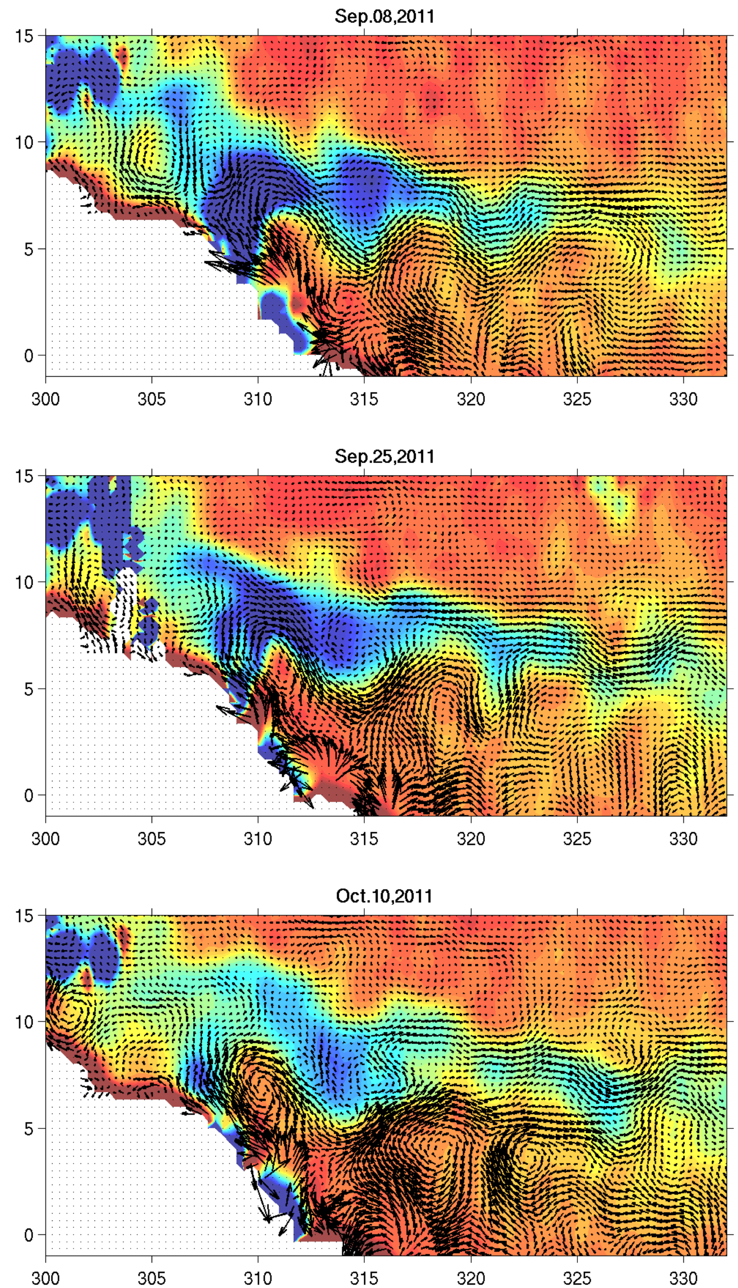


Aquarius SSS and OSCAR

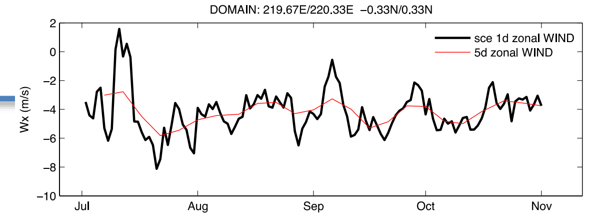
Aquarius sea surface salinity (color) for the Amazon plume, with OSCAR surface currents (vectors).

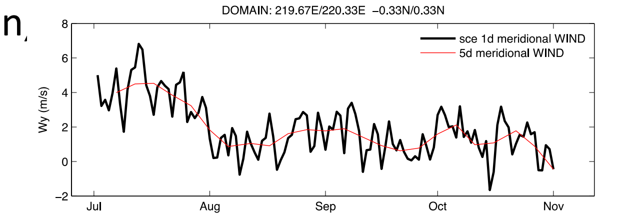


Aquarius SSS and OSCAR

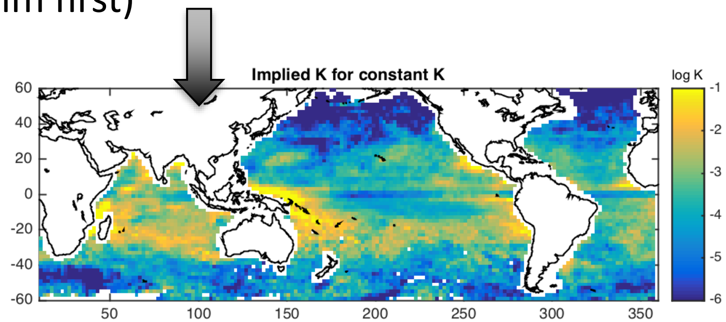


NEW version of OSCAR -- DAILY

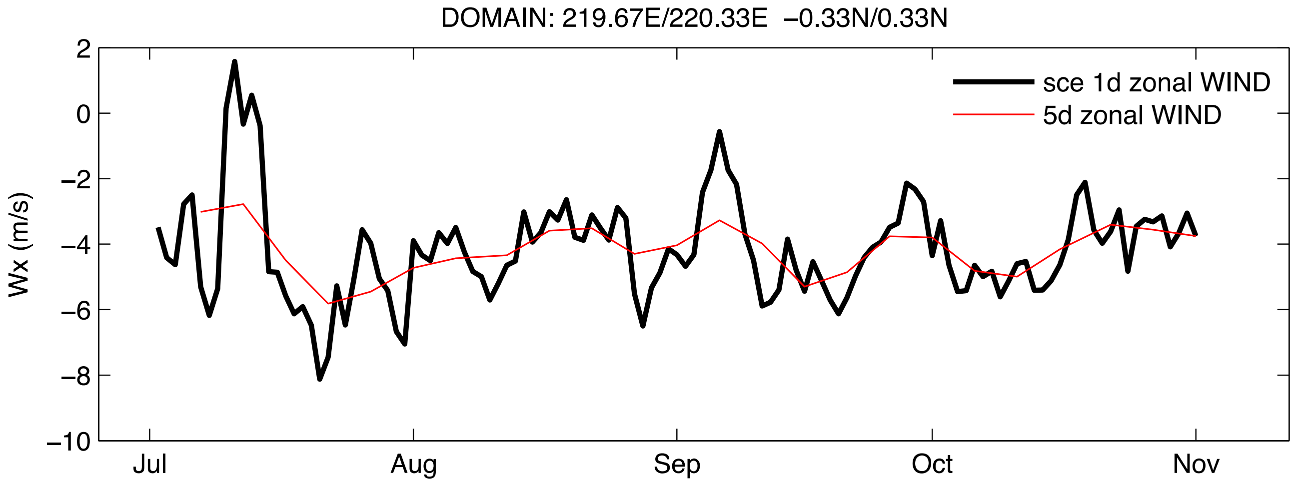


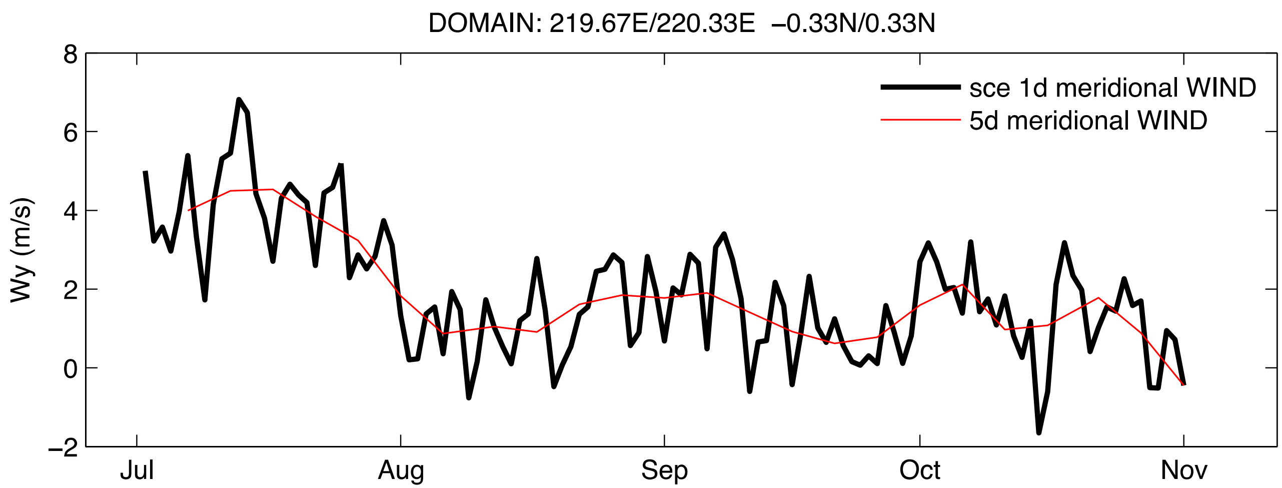


- New version by end of year
- Daily OSCAR, ¼ degree grid, separate geostrophic, wind-driven, thermal wind components, **no temporal smoothing**
- Metadata
  - Spent some time at PO.DAAC in April setting up metadata practices. (This is more involved than I thought… e.g. their sample netcdf header is 6 pages long at 10pt font.)
- **Final OSCAR and interim OSCAR** (NCEP winds, NRT SSH)
- Large data sets: will be producing daily files (how much will users object?)
  - Can easily record what data sources went into that day's file
- Hosted at the PO DAAC, http://podaac.jpl.nasa.gov/ (note: this version will have a DOI).
- (Revised eddy viscosity, Stokes drift … not in this version, or perhaps I'll release an interim first)



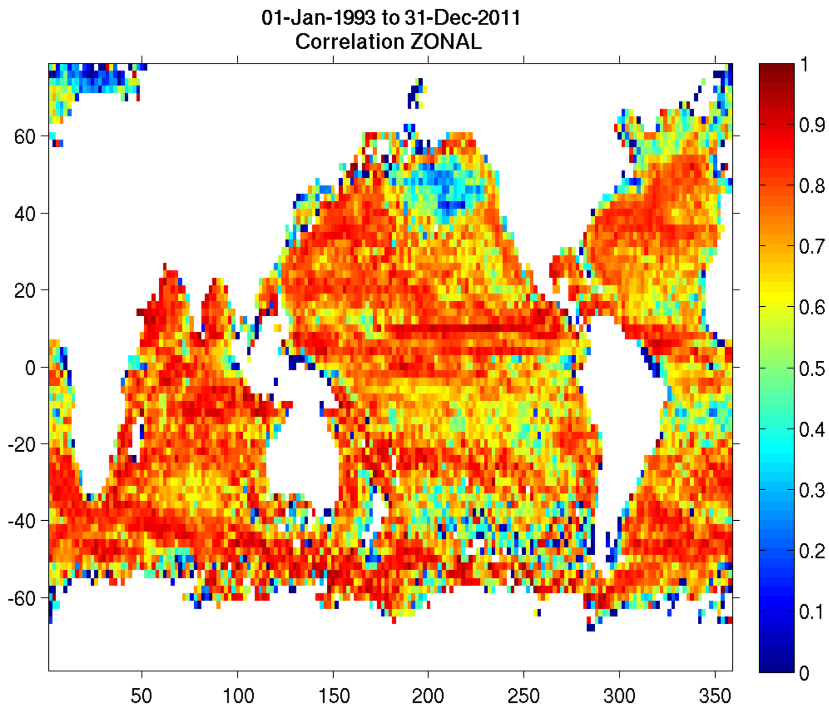
NEW version of OSCAR -- DAILY

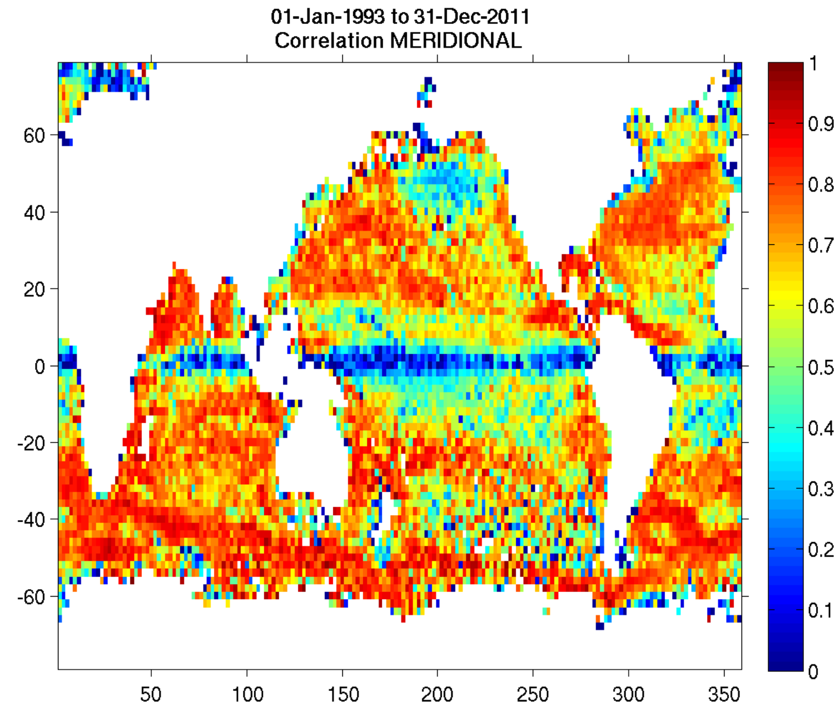




Results: CORRELATIONS with Drifting Buoys

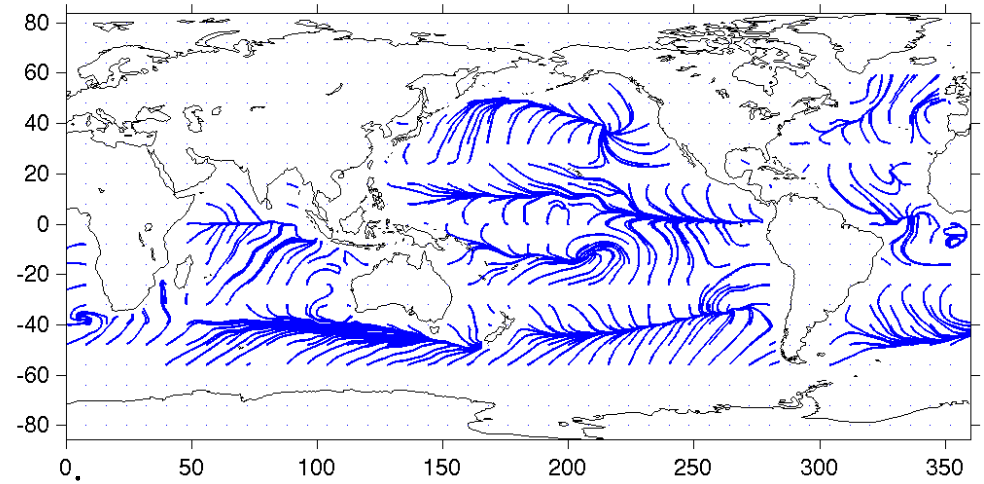
- Correlations with 20 years of global drifting buoys, NOAA/AOML www.aoml.noaa.gov/phod/dac/gdp.html
- OSCAR performs well in most places, with some trouble spots
- OSCAR is interpolated onto daily binned drifters, correlations are made over all data within 2 degree boxes over 1993:2011.
- Possible reasons for the poor correlations:
  - Too smooth and missing scales in the wind forcing, both temporal and spatial
  - Missing physics in the OSCAR model, particularly the wind-driven term: time dependence, nonlinear terms, turbulence treatment
  - Not capturing all of the geostrophic component or ageostrophic such as filaments





Wind Driven Mixed Layer

- Main research on OSCAR: improvement of the wind-driven component
  - We're capturing long-term dynamics
  - Typically poor correlations with drifters for daily/hourly wind-driven motions



- General areas of research and development:
  - Time-dependent wind-driven dynamics
  - Turbulent mixing scheme
  - Vertical variation
  - "Mesoscale"

- Ultimate purpose: Better understanding of the transfer of momentum between the atmosphere and ocean
  - Depth of penetration of direct wind-driven motions
  - Loss of inertial energy to deep

Development of the OSCAR Model

- OSCAR today:
  - Geostrophic balance, steady Ekman
  - OSCAR is an analytical solution for shear with Stommel boundary conditions
  - Thermal wind shear due to horizontal gradients of SST
  - Eddy viscosity depends on wind speed W, parameters a& b set once by drifter climatology
  - H=125m, τ_0=surface wind stress

OSCAR Equations

$$\begin{aligned} if\mathbf{u} &= -\frac{1}{\rho}\nabla p + \frac{1}{\rho}\frac{\partial \tau}{\partial z} \\ \tau &= K\frac{\partial \mathbf{u}}{\partial z} \\ \frac{\partial p}{\partial z} &= -\rho g \end{aligned}$$

$$\frac{\partial \mathbf{u}}{\partial z}(z=0) = \frac{1}{\rho_0 K}\tau_0 \qquad \frac{\partial \mathbf{u}}{\partial z}(z=-H) = 0$$

$$K = a\left(\frac{|\mathbf{W}|}{W_0}\right)^b$$

Modifications to OSCAR Equations

Time and Vertical Dependence: Linear Unsteady Ekman

$$\frac{\partial \mathbf{u}(t,z)}{\partial t} + if\mathbf{u}(t,z) = \frac{1}{\rho}\frac{\partial \tau(t,z)}{\partial z}$$

Turbulence parameterized by an Eddy Viscosity

$$\tau = K(z)\frac{\partial \mathbf{u}}{\partial z}$$

$$\frac{\partial \mathbf{u}(t,z)}{\partial t} + if\mathbf{u}(t,z) = \frac{1}{\rho}\frac{\partial}{\partial z}\left(K(z)\frac{\partial \mathbf{u}(t,z)}{\partial t}\right)$$

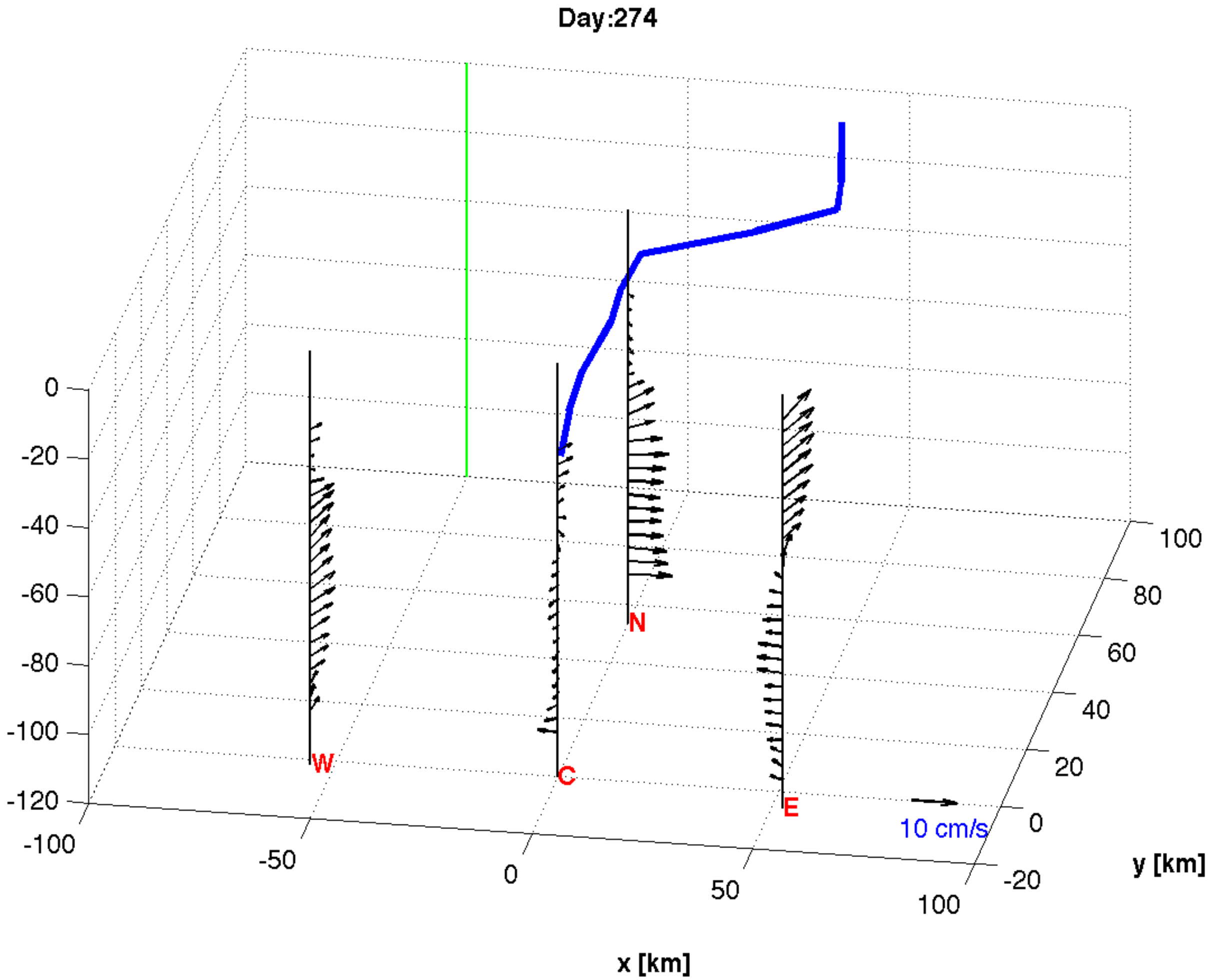
Damped Slab with turbulence as a Rayleigh drag

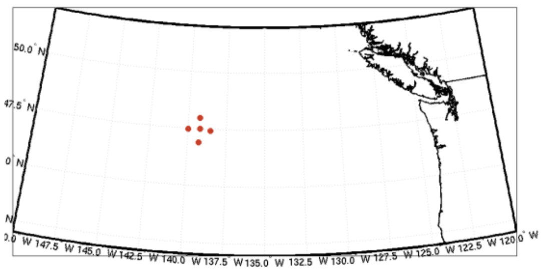
$$\frac{d\mathbf{U}(t)}{dt} + if\mathbf{U}(t) = \frac{\tau(t)}{\rho MLD} - r\mathbf{U}(t)$$

Pollard and Millard, 1970

Adding time dependence means inertial oscillations

- Ocean Storms Experiment: the upper ocean response to storm events
- Collection of papers in J. Phys. Ocean., 1995, 25, pp. 2817-2971.
- Here: data from Dohan and Davis, JPO, 2011.
- Velocity, temperature and wind stress from up to five moorings.
- Storm events at Day 257 (Sept 14, 1987) and Day 277 (Oct 4, 1987).

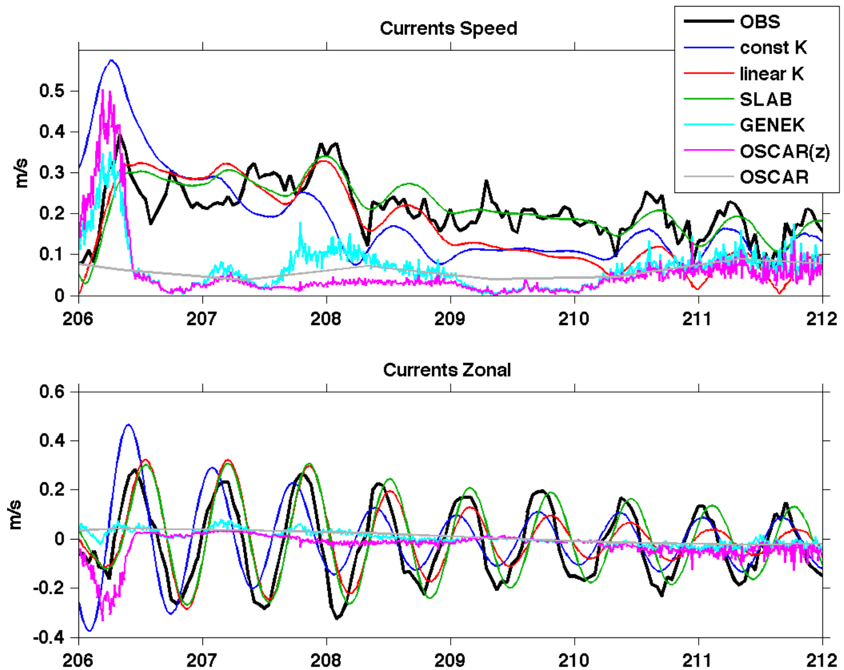




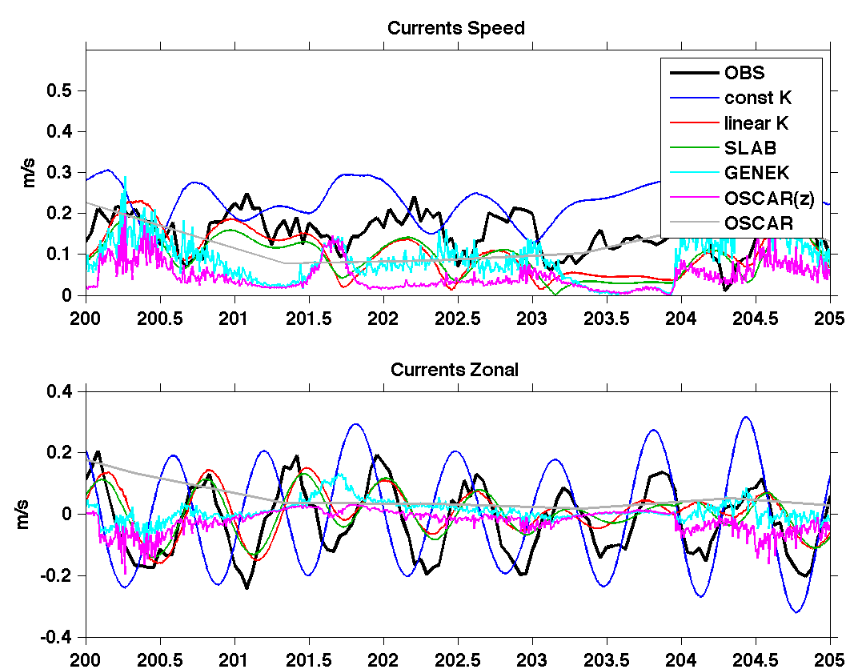
Model Performance for K(z) and d/dt

- Different turbulence parameterizations at Ocean Station Papa (50N, 145W).
- Models averaged from 0-30m, like OSCAR.
- Values and vertical profile of K can significantly impact surface currents.
- Slab model performs quite well

EXAMPLE OF GOOD RESULTS



EXAMPLE OF WORSE RESULTS



Year Day

OSCAR: $K(z) = K0$, no $\frac{\partial}{\partial t}$

GENEK: $K(z) = A\exp(z/D) - B$, no $\frac{\partial}{\partial t}$

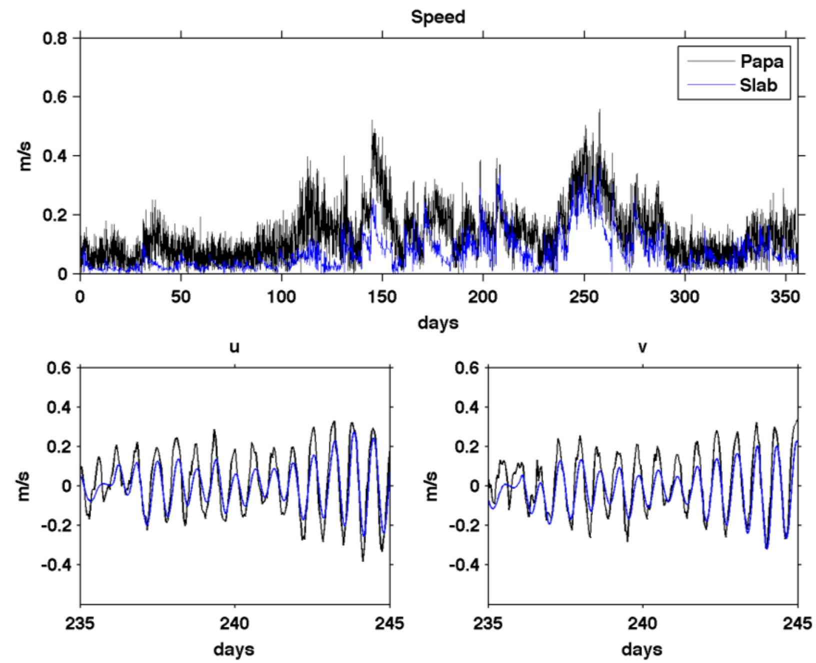
SLAB: r, constant properties in mixed layer, $\frac{\partial}{\partial t}$ term

CONSTANTK: $K(z) = K0$, $\frac{\partial}{\partial t}$, infinite b.c.

LINEARK: $K(z) = K0 + K1z$, $\frac{\partial}{\partial t}$, $\frac{\partial u}{\partial z}$ b.c.

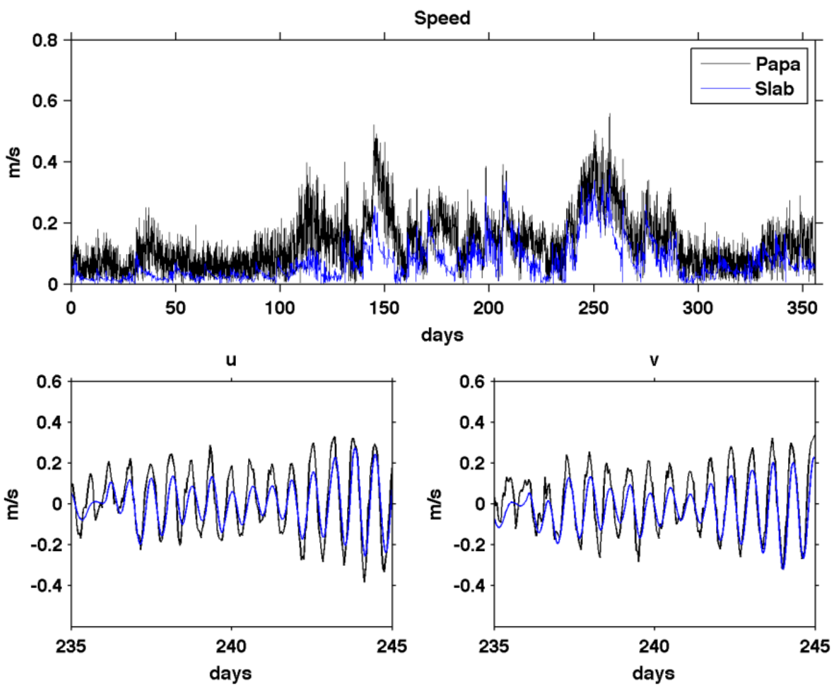
Wind Driven Ocean Mixed Layer (OML) Research with OSCAR

- A hierarchy of increased complexity to the wind-driven component of OSCAR
  - Vertically varying eddy viscosity K(z)
  - d/dt + either Rayleigh damping or K(z)
  - PWP
  - KPP
- For the purposes of surface currents, damped slab performs best so far at Ocean Station Papa
  - Captures amplitude and phase more reliably
  - Vertically uniform
- Much to be learned from the vertical momentum transfer as is varies between models still

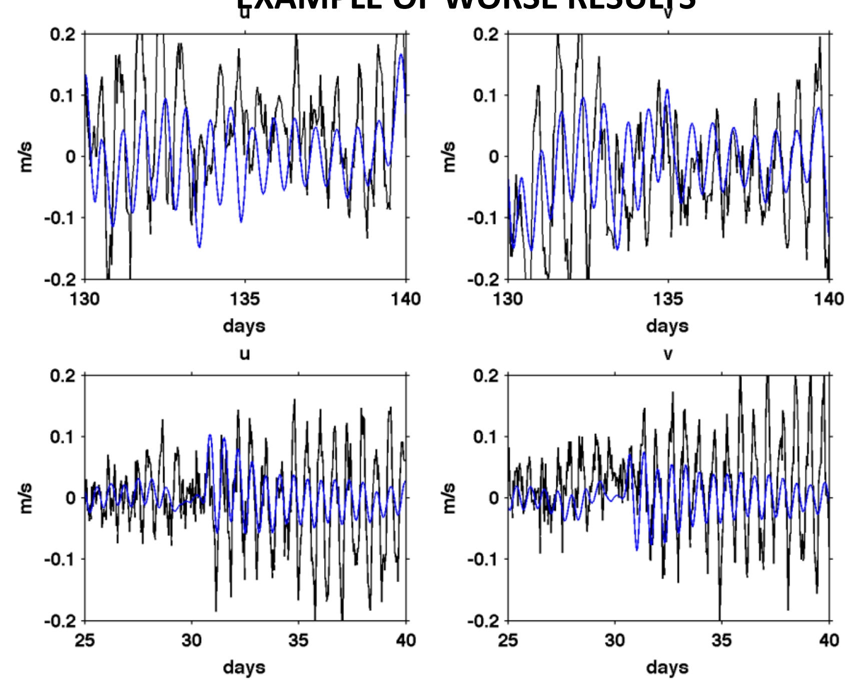


Capturing phasing and amplitude of waves like NIOs and TIWs.

- **Mooring example**. Inertial oscillations are very difficult to reproduce exactly. Filter out? It's a large part of the signal.

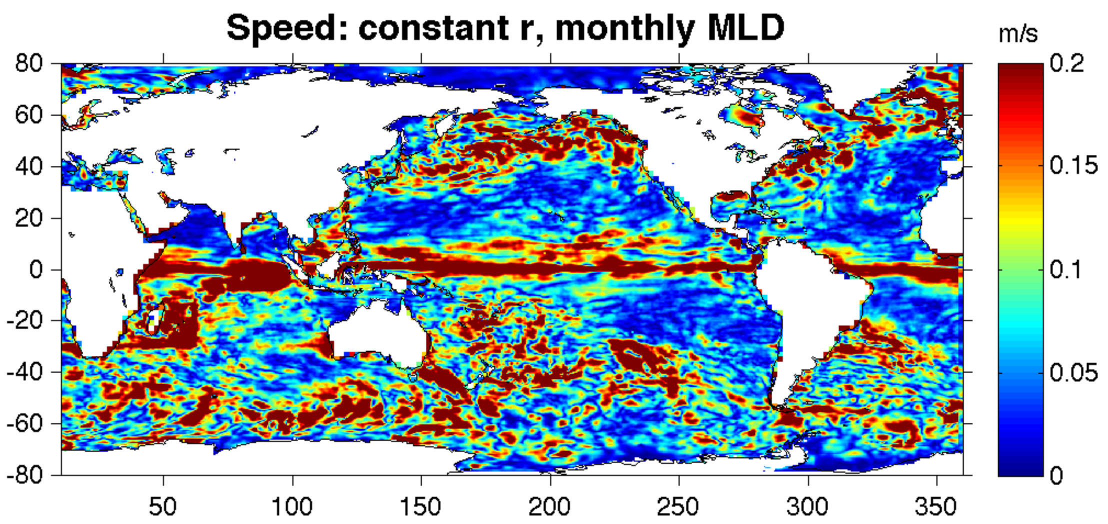


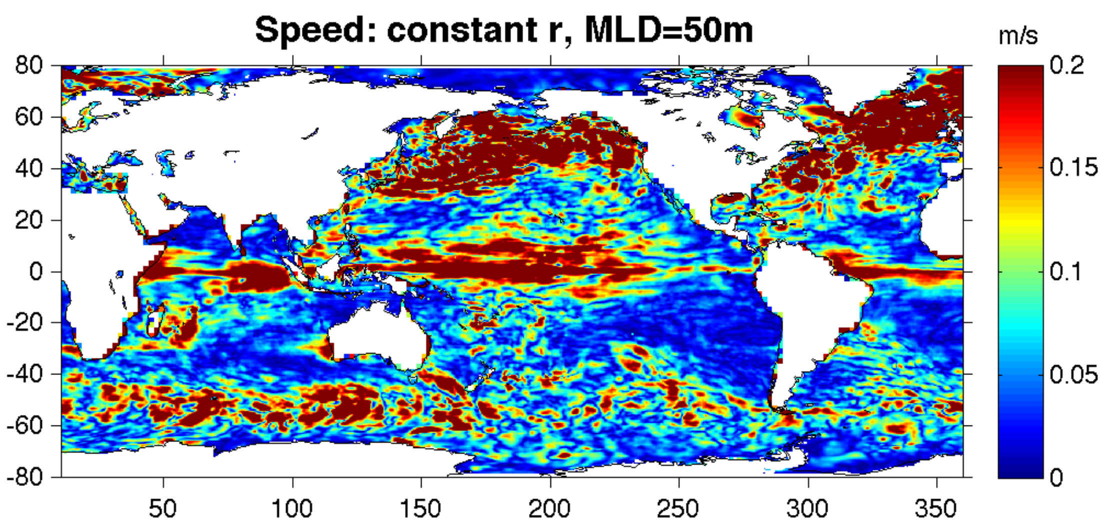
EXAMPLE OF WORSE RESULTS



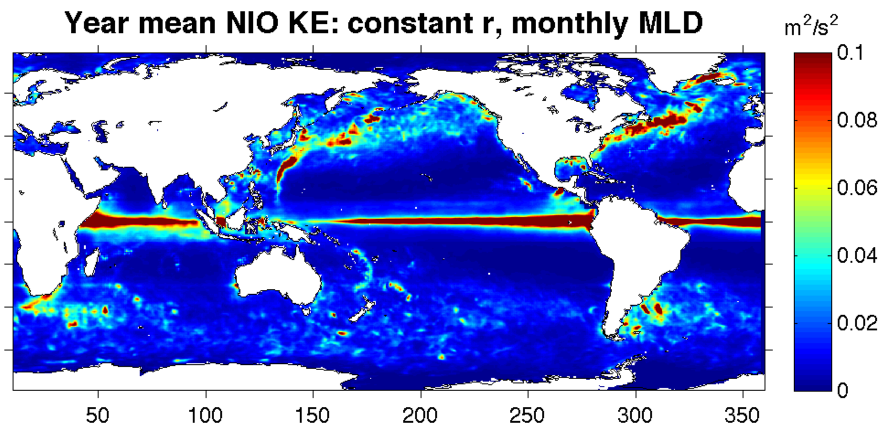
- In general, slab performed really well at Papa, look global
- 2 sample test cases for the year 2008, CCMP winds
  - 1) Rayleigh damping optimized for Papa performance, using mixed layer depths from monthly climatology
  - 2) Rayleigh damping optimized for Papa performance, using mixed layer depth =50m

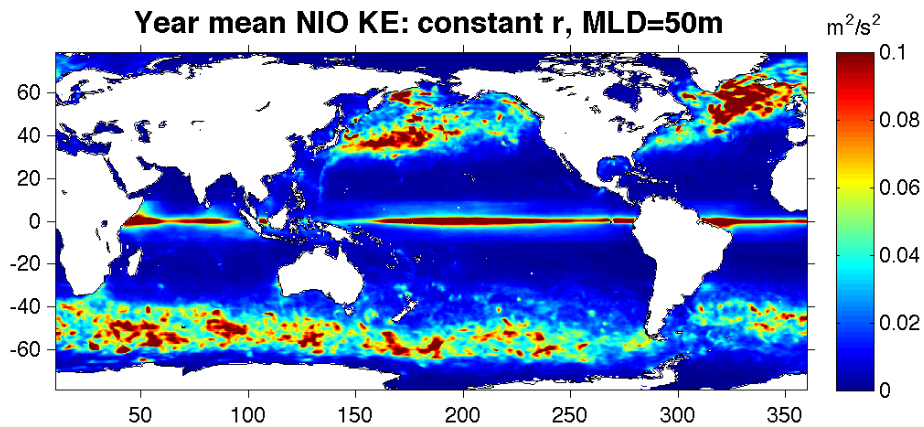
Slab Model Results Snapshot View of Speed



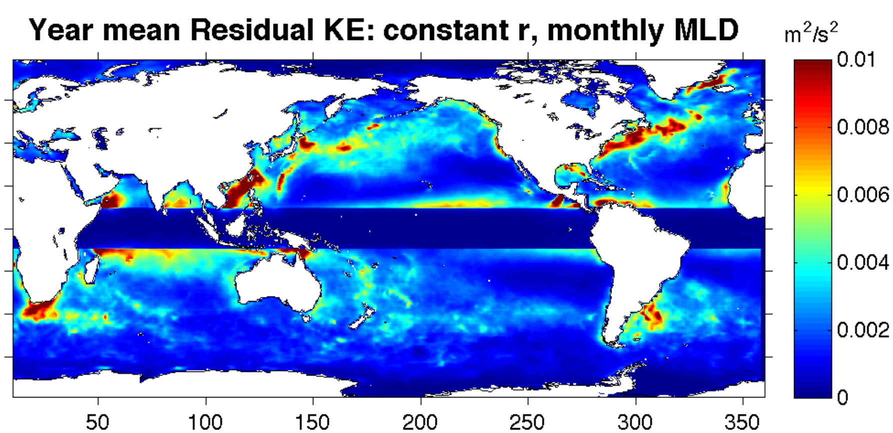


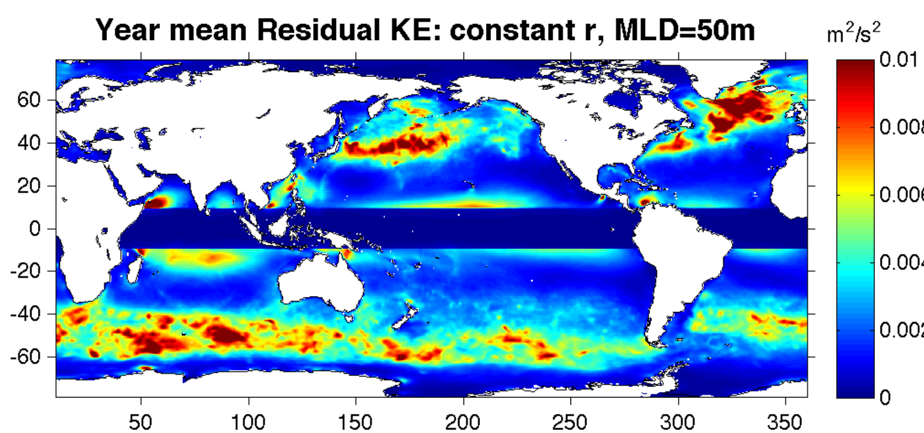
Energy in Near-Inertial Oscillations, Year Average





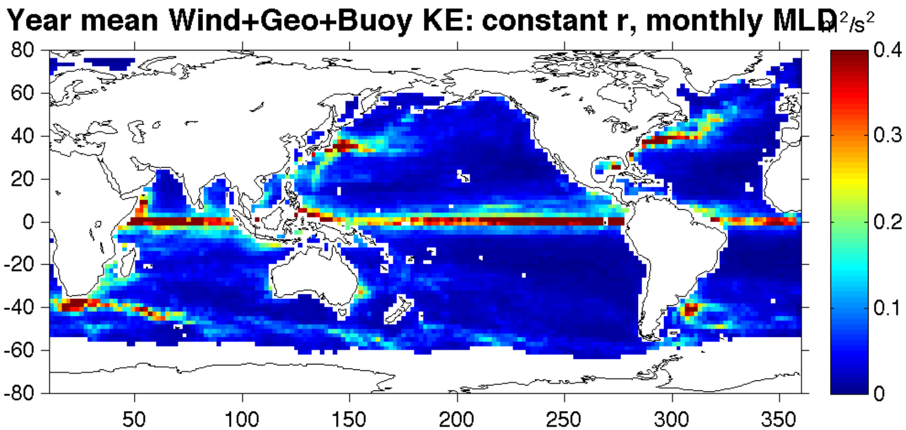
Energy in Residual from NIO, Year Average

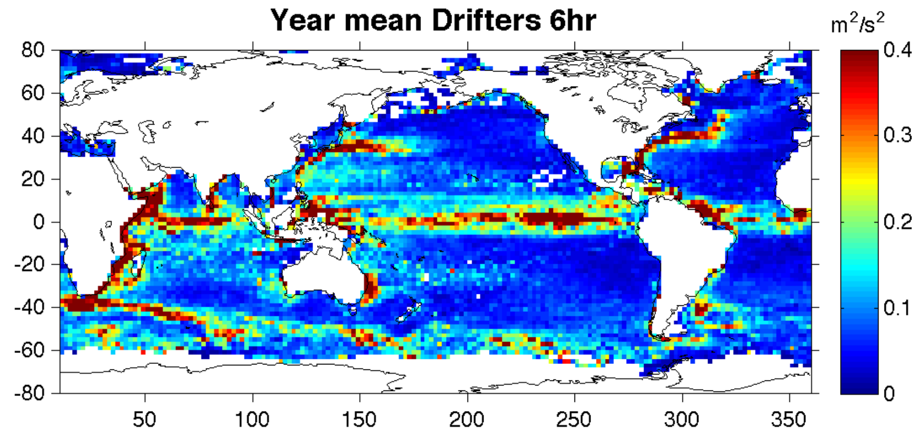


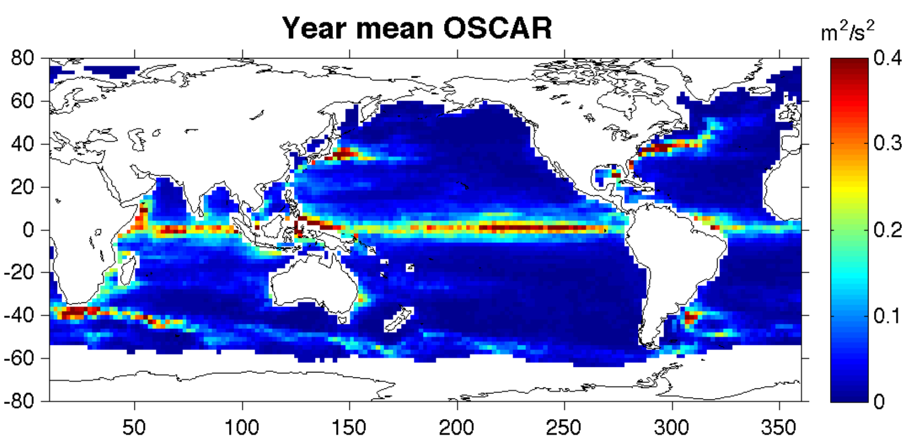


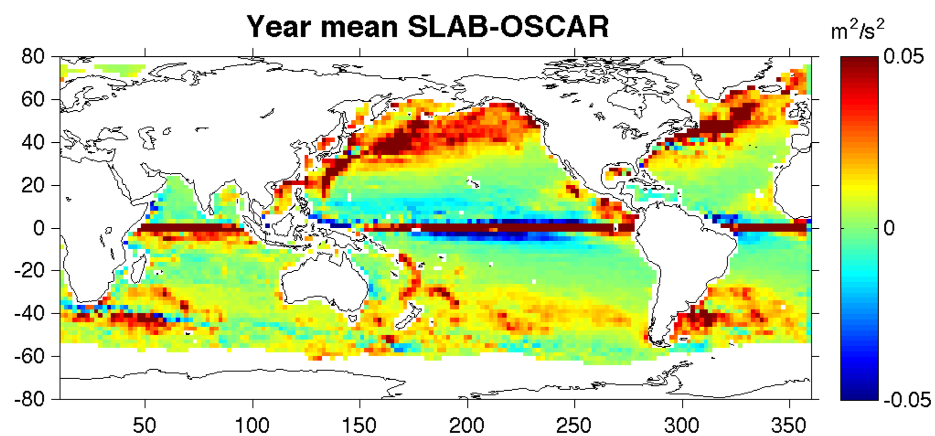
Comparison with Drifters

- Results for slab model run for 2008. Velocities are binned to daily values (imperfect way of removing NIO).
- Amplitudes are improving with slab but needs more work. Still underestimating what is observed in drifters. 20 day damping timescale is better… still needs more work. Will be interesting to see if there is a regional optimal damping timescale



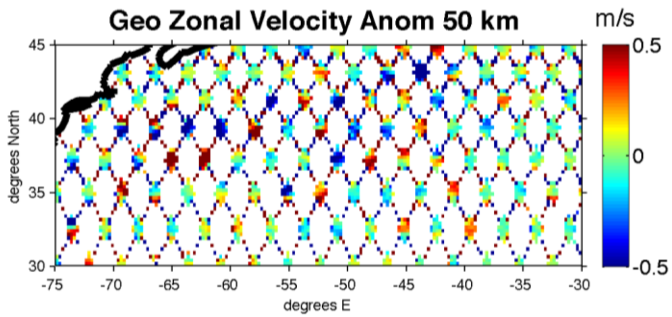


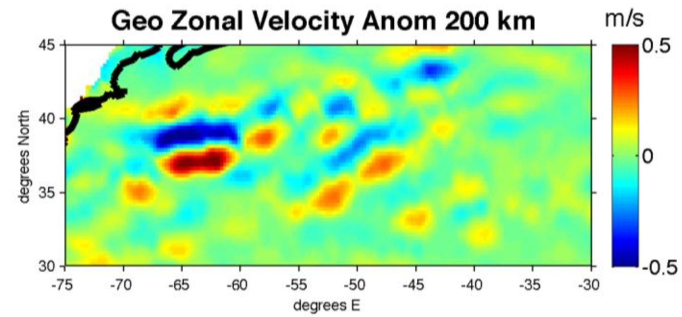




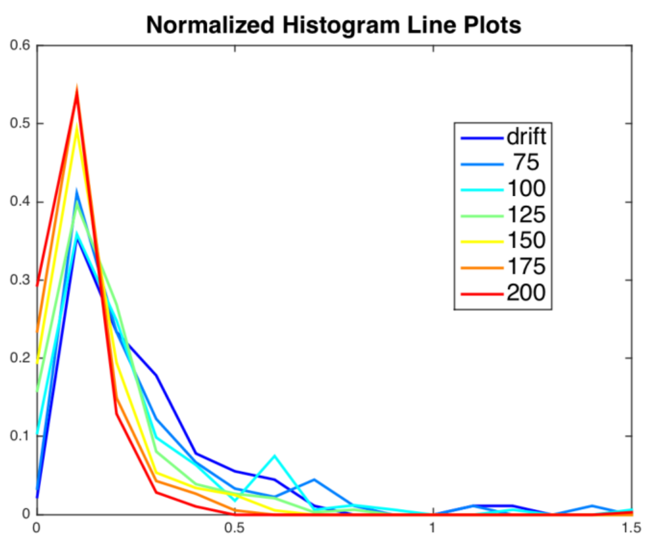
Towards using swath data

- Have begun to look at deriving geostrophic currents from level 2 swath data
- A lot of information is lost in the gridding process, then after which we take gradients





- Redo the gridding process using less smoothing, allow gaps



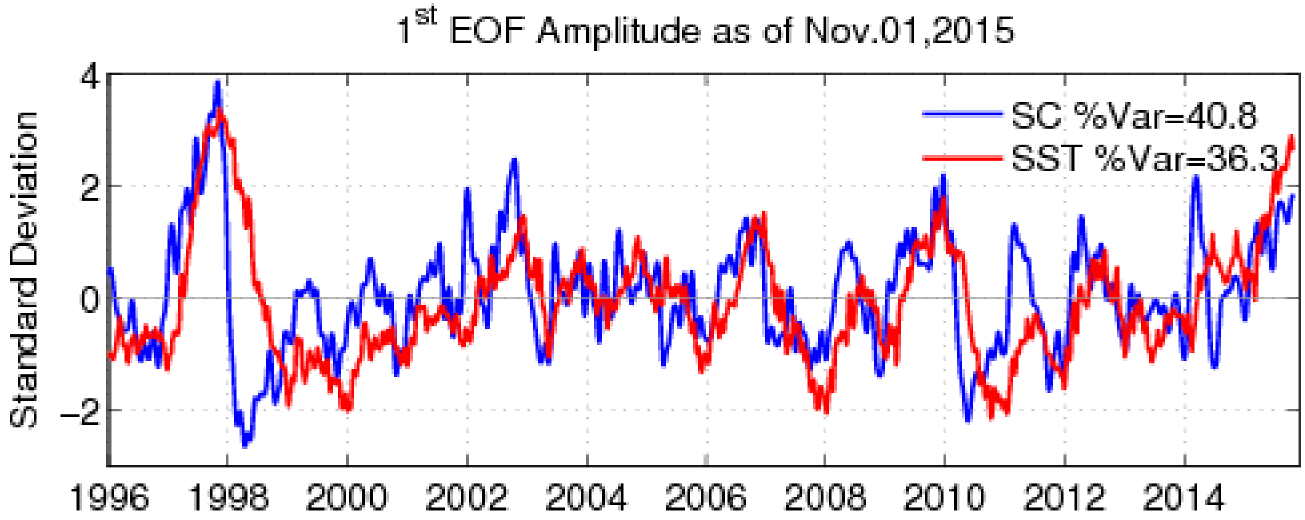
- Histograms of speeds calculated by gridding using search diameters 75km to 200km.
- Comparison with drifters in the same area

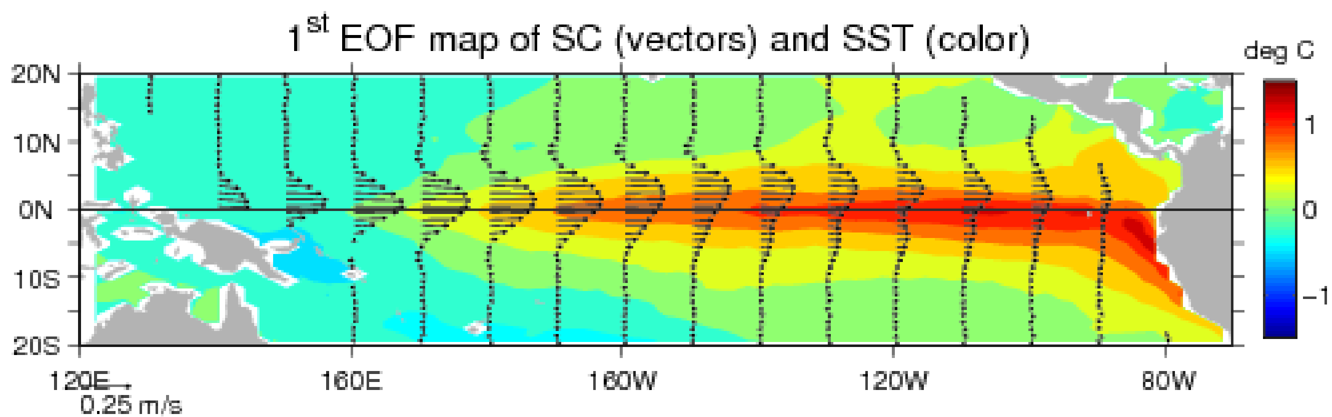
Next Steps

- Continued investigation of time-dependence, explicit vertical variation, and nonlinear versions of OSCAR, while still continuing to provide OSCAR quasi-steady.
- The more complicated models allow us to investigate the wind-driven ocean mixed layer. Will modify future OSCAR with simplest model possible.
- Since I do not have 10-minute winds everywhere, likely will end up using the slab formulation in the time-dependent OSCAR with NIO filtered out, plus a value-added NIO energy term.
- “Mesoscale” OSCAR, both in SSH and winds

Application: Surface Currents index for ENSO

http://www.esr.org/enso_index.html

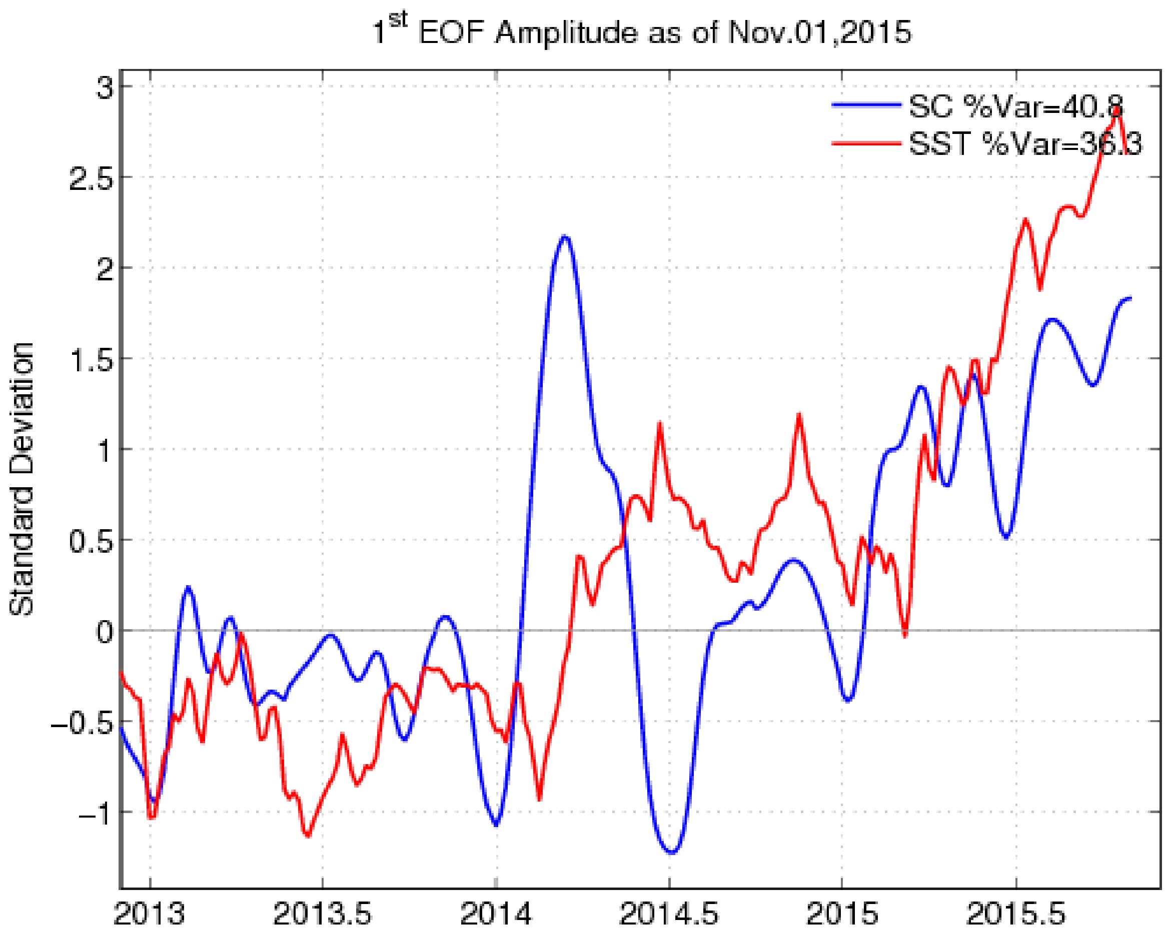




Earth & Space Research

Surface Currents index for ENSO

http://www.esr.org/enso_index.html

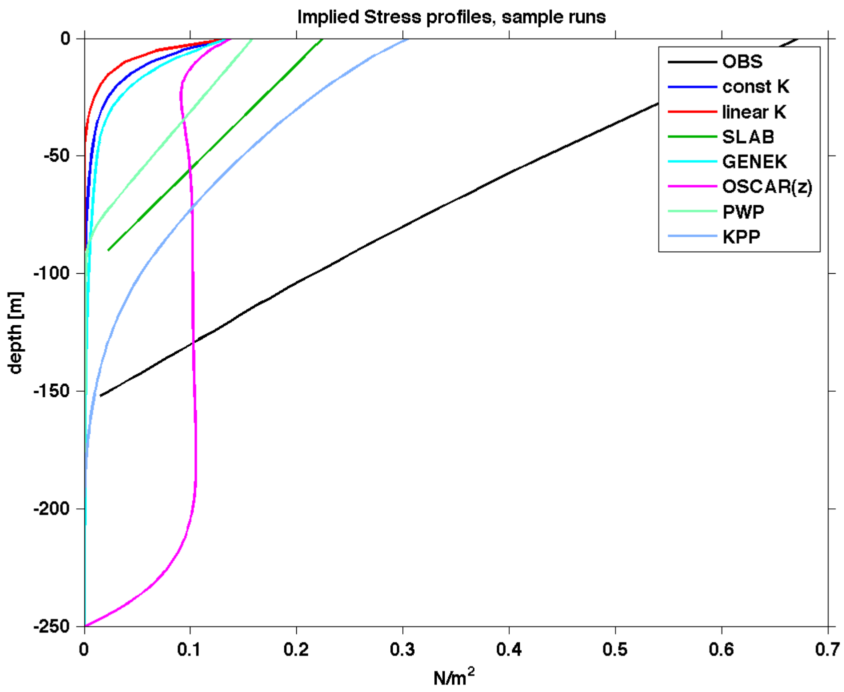


Vertical transfer of stress between the models

- Calculate the stress on the mixed layer, assuming unsteady Ekman, given velocity profiles
- Averaged over a year
- Big difference in models
- Observations look slab-like, although probably not all of geostrophic component has been removed

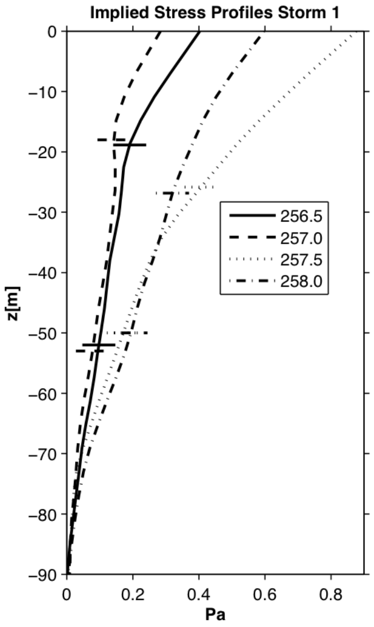
$$\frac{\partial \mathbf{u}(t,z)}{\partial t} + if\mathbf{u}(t,z) = -\frac{1}{\rho}\frac{\partial \tau(t,z)}{\partial z}$$

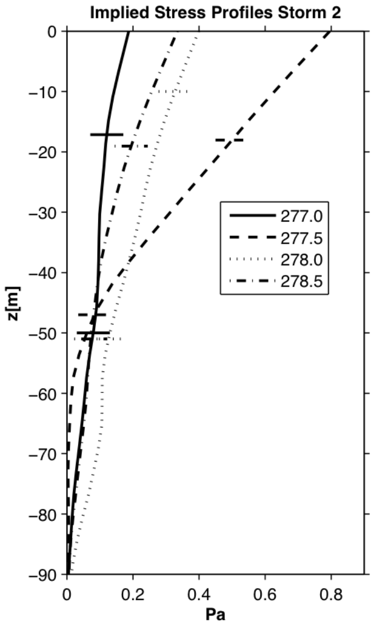
Models



Ocean Storms

sample days





Vertical Dependence: Benefits of DopplerSCAT for OML research

- Damped slab promising so far, as a very simple model, but there is no vertical dependence. Top surface measurements, such as from DopplerSCAT, will really help with validating models.
- Sample model output for currents averaged over the top 30m vs z=0m.