Wind-Driven Surface Currents

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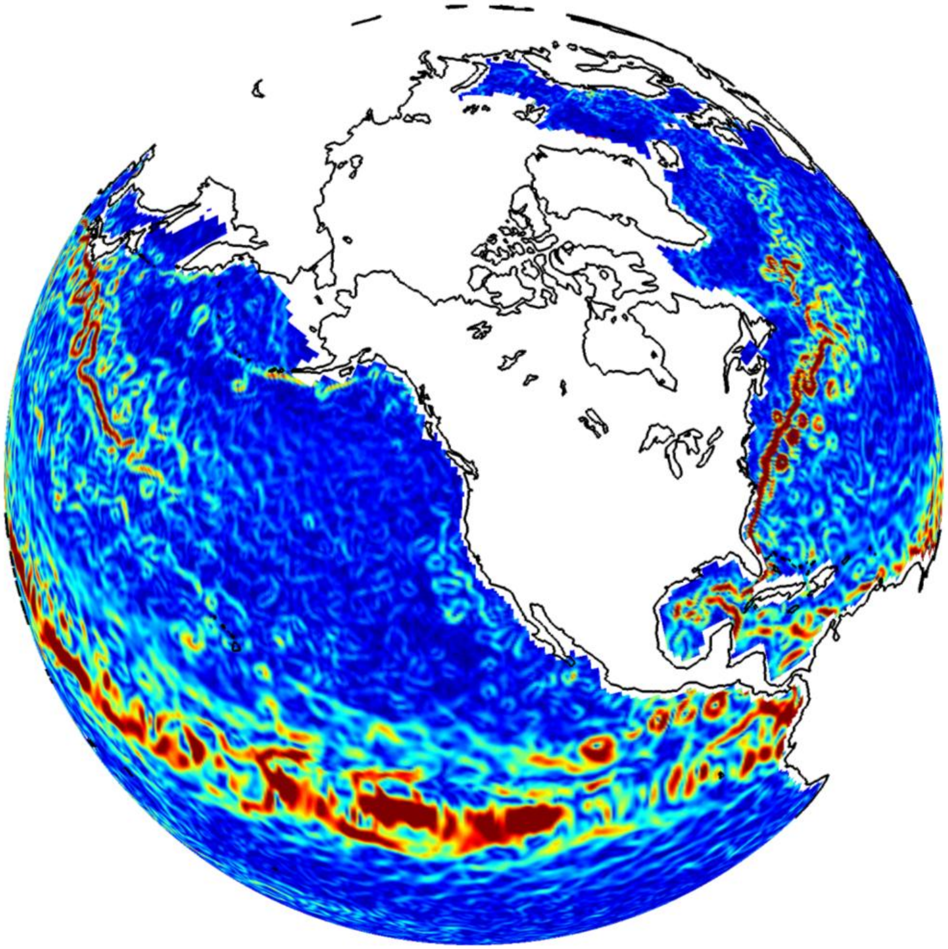
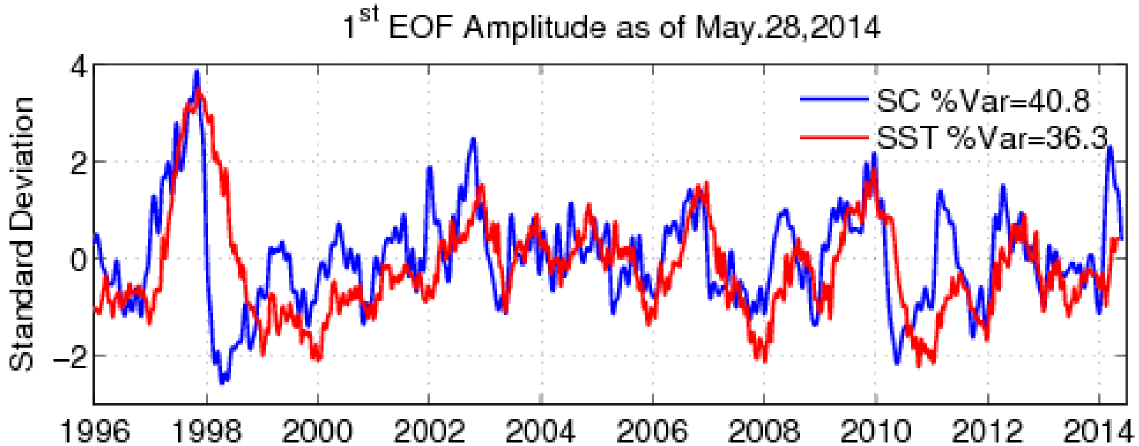
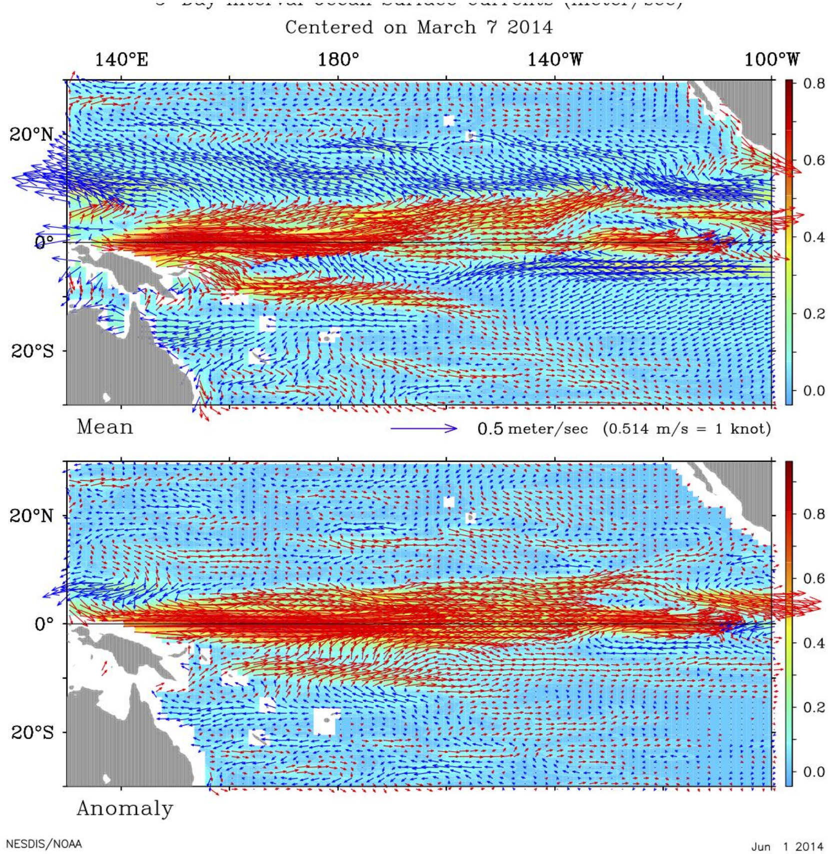
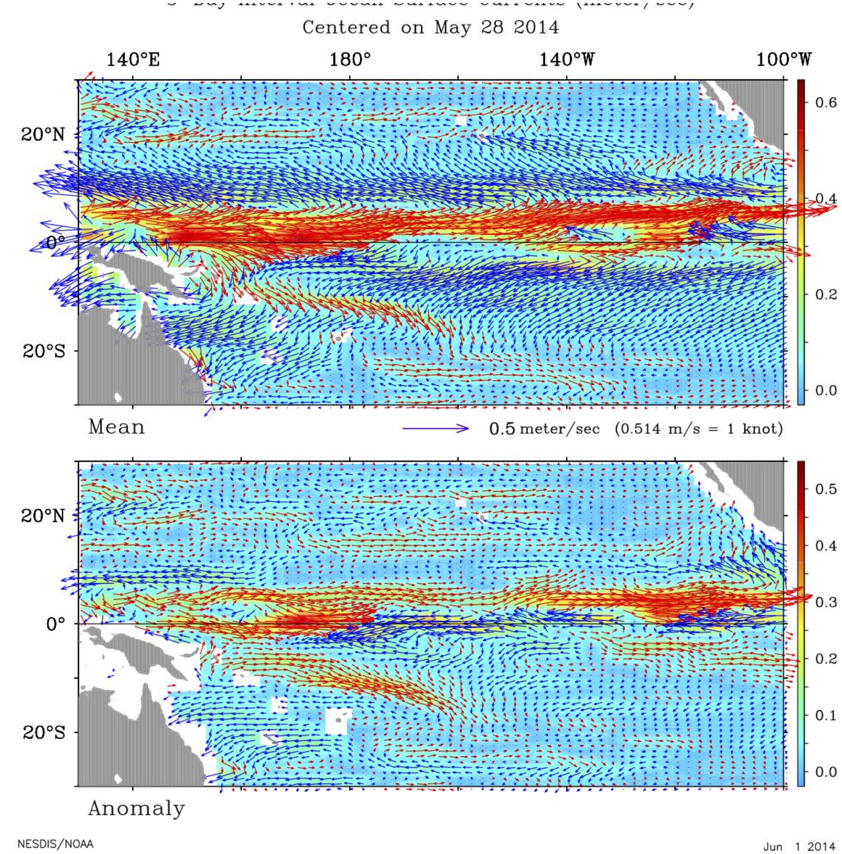
- Updates to OSCAR and challenges with capturing the wind-driven currents.



ENSO


1st EOF Amplitude as of May.28,2014
Standard Deviation
SC %Var=40.8
SST %Var=36.3
4
2
0
−2
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


Centered on March 7 2014
140°E
180°
140°W
100°W
20°N
0°
20°S
Mean
0.5 meter/sec (0.514 m/s = 1 knot)
Anomaly
NESDIS/NOAA
Jun 1 2014


Centered on May 28 2014
140°E
180°
140°W
100°W
20°N
0°
20°S
Mean
0.5 meter/sec (0.514 m/s = 1 knot)
Anomaly
NESDIS/NOAA
Jun 1 2014

OSCAR Surface currents from satellite fields

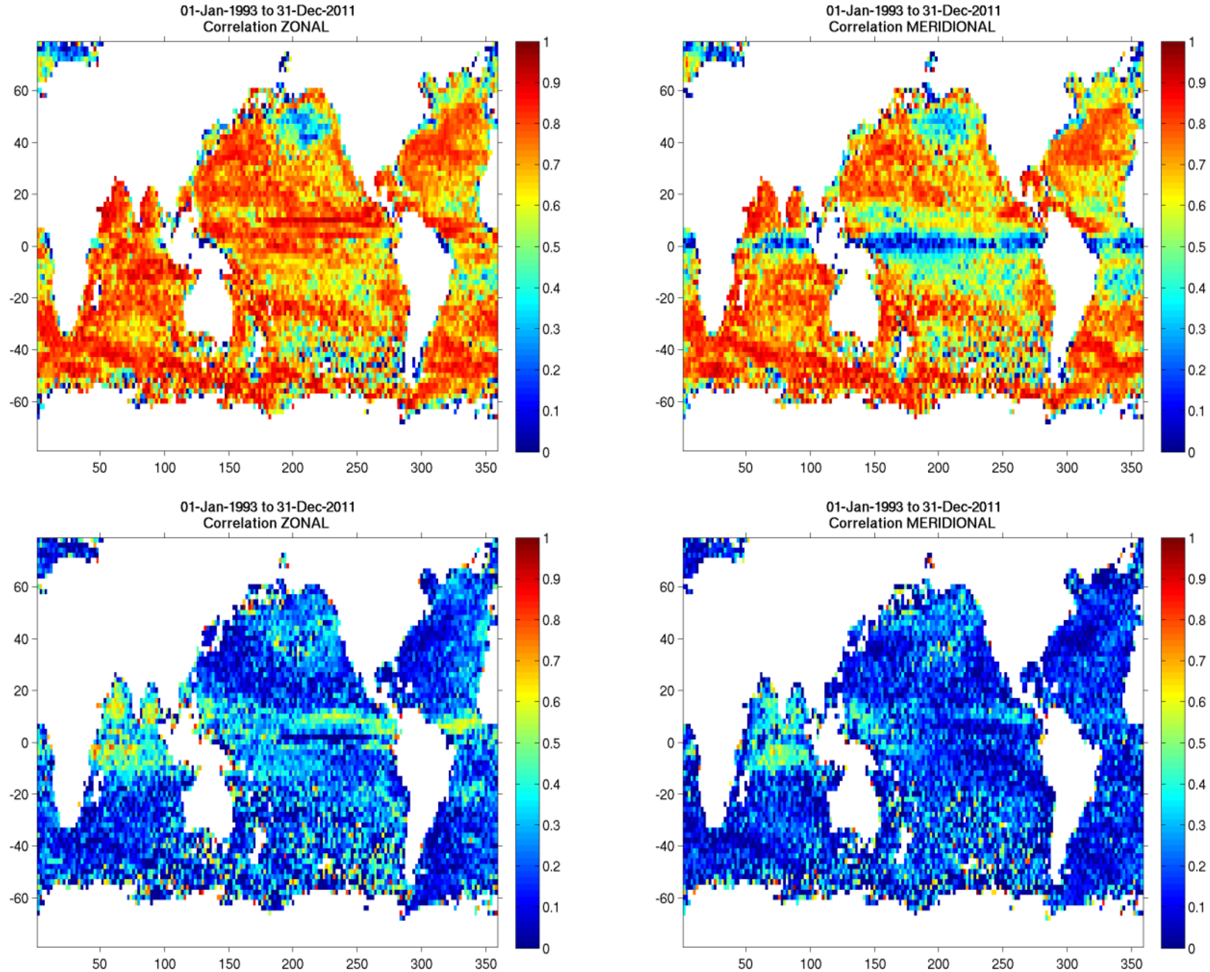
- Ocean Surface Currents Analyses-Realtime processing system (OSCAR) is a satellite-derived global surface current database hosted at the NASA PO DAAC, http://podaac.jpl.nasa.gov/
  - Phasing out the NOAA site
- **WIND**: Still using ERA Interim winds + NCEP
- **SSH**: AVISO has changed its format to daily delayed-time and 0.25^{o} grid, from 7-day and Mercator grid. With this change will come a daily 0.25^{o} OSCAR, no temporal smoothing, CF compliant. (very very soon)
- **SST**: GHRSST Reynolds OI SST 0.25^{o} grid. Not yet using Aquarius.

CORRELATIONS with Drifting Buoys

- Correlations with 20 years of global drifting buoy dataset
- Full OSCAR performs well in most places, with some trouble spots
- Correlations between wind-driven components are poor, where “wind-driven component” = full velocity-(geostrophic + thermal wind)

OSCAR all components

OSCAR wind component



CORRELATIONS with Drifting Buoys

- Possible reasons for the poor correlations for the wind-driven components:
  - Missing physics in the OSCAR model: Time dependence, nonlinear terms, turbulence treatment
  - Missing scales in the wind forcing, both temporal and spatial
  - Not removing all of the geostrophic component, filaments

Extensions to the OSCAR Model

- Geostrophic balance, steady Ekman, K constant in vertical depends on wind speed
- The simplest progressions from the existing model are:
  - **VERTICAL VARIATION OF EDDY VISCOSITY**: Generalized Ekman, which has b.c. such that stress goes to zero at depth and a vertically varying eddy viscosity but no time dependence
  - **TIME DEPENDENCE**: Damped slab model which has time dependence but assumes all properties are uniform throughout the mixed layer and uses a Rayleigh drag to treat the damping effects of turbulence
  - **BOTH**: Time dependence and varying forms of the eddy viscosity and boundary conditions

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

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

Turbulence Parameterizations

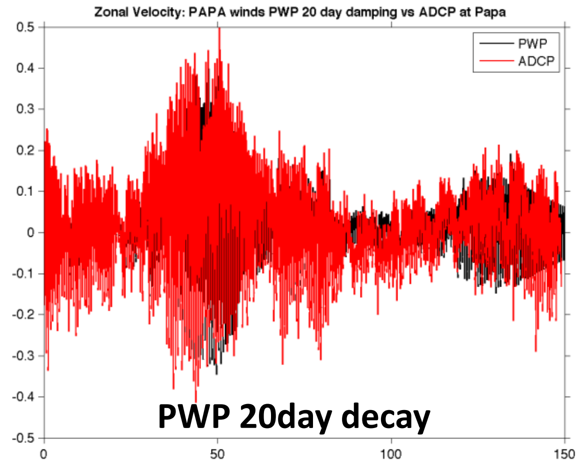
- Last year: results at Ocean Station Papa. Quite different results between the models both in phasing and speed. Need d/dt for inertial oscillations, which dominate the signal.

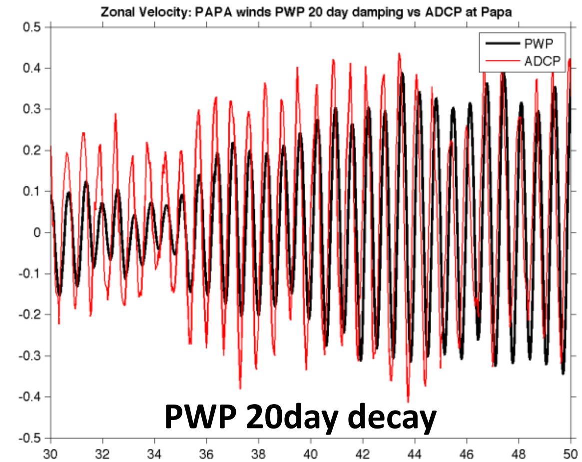
- Conclusion: Slab model performs the best out of these models

- Here: Look at Price Weller Pinkel (PWP) and K-Profile (KPP) parameterizations for turbulence
- PWP is damped slab plus convective instability mixing, and shear-driven mixing from bulk and gradient Richardson numbers
- KPP is more complicated with boundary layer mixing based on bulk Richardson number boundary layer depth, turbulent velocity scale (from atmospheric observations) and a shape function along with gradient Richardson number mixing, internal wave mixing, and double diffusive mixing.
- Both use surface fluxes, which I am not including here. Instead I initiate with T/S profiles from Argo and only use surface winds.
- Essentially, both solve for unsteady Ekman + turbulence terms

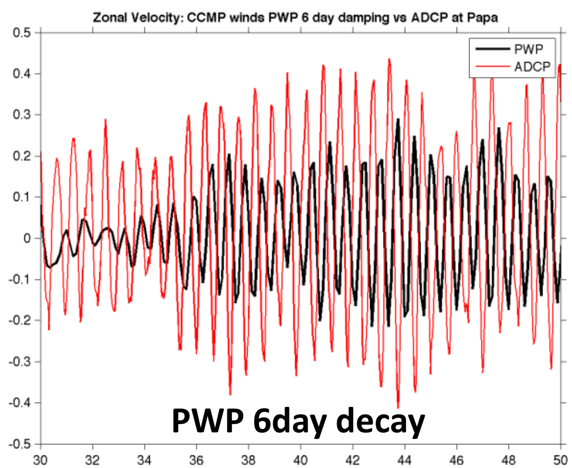
PWP and KPP Performance at PAPA

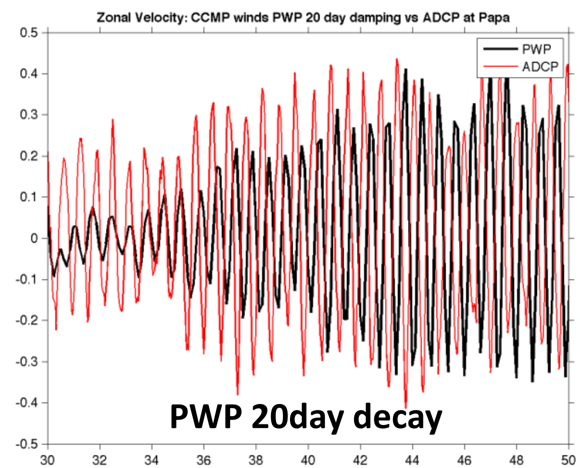
10 minute PAPA WINDS

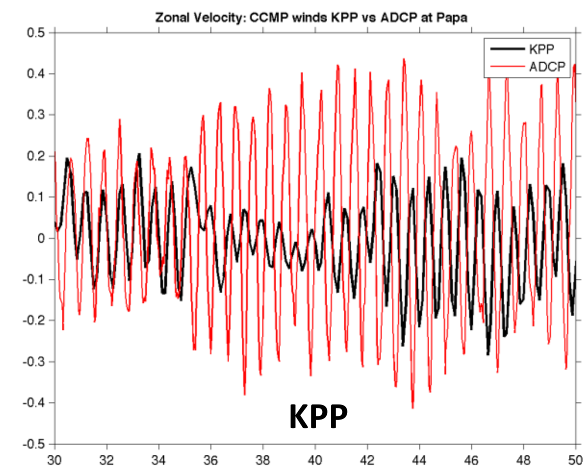




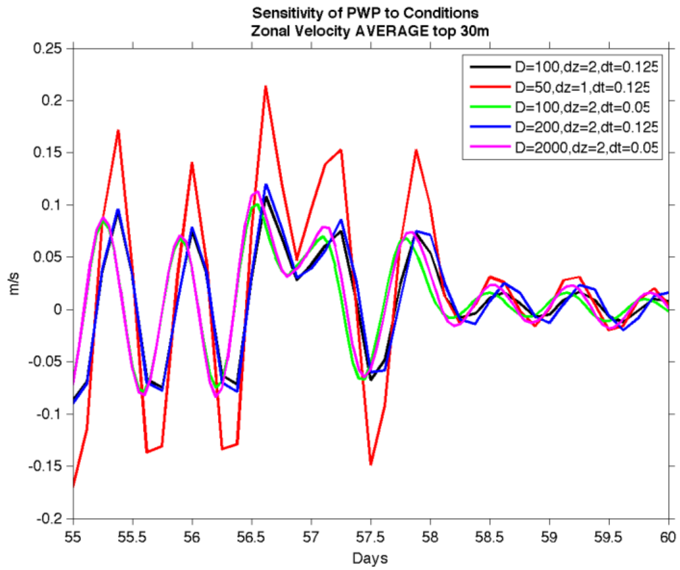
6hr CCMP WINDS



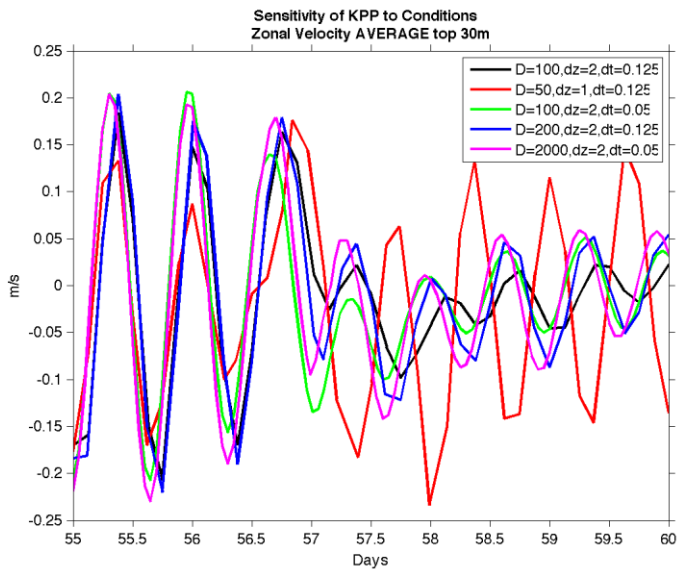


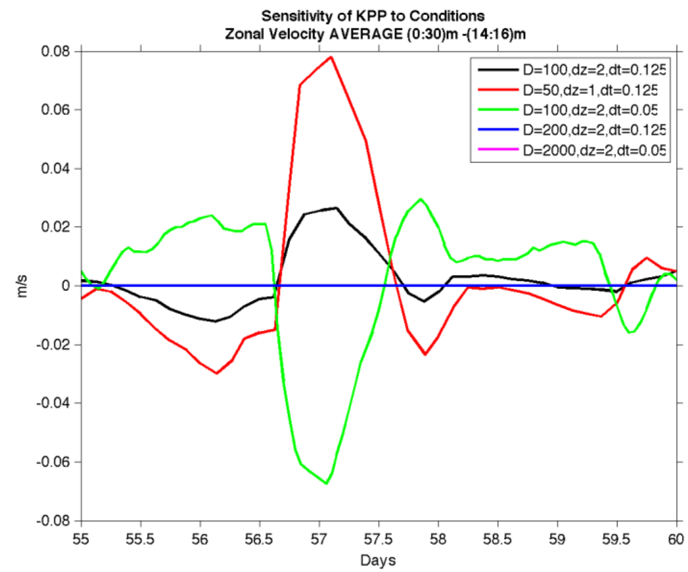


Sensitivity to model configuration

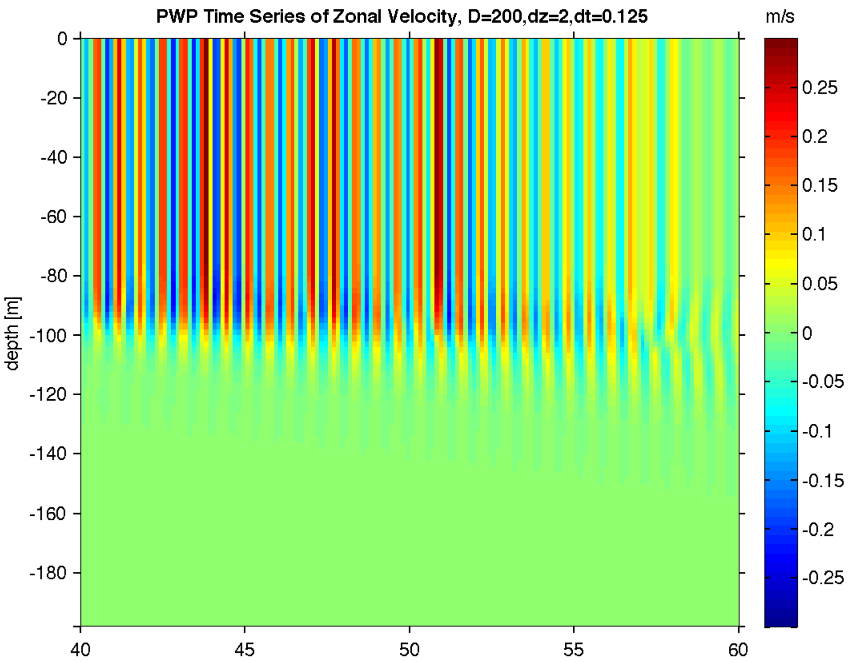


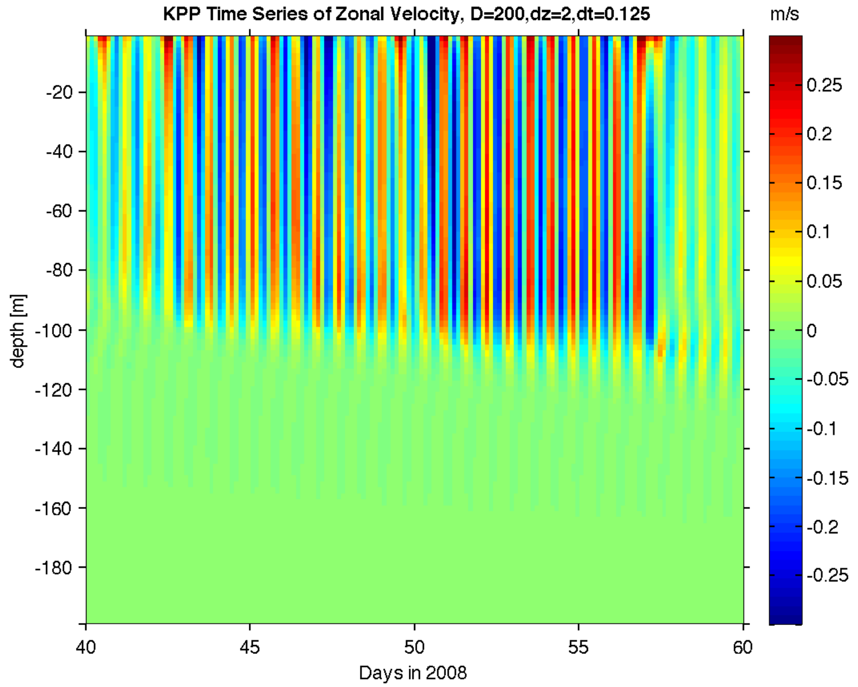
- KPP is too dependent on grid spacings and time steps
- KPP varies in the vertical, which means “surface current” depends on averaging area, however, it also depends on model configuration

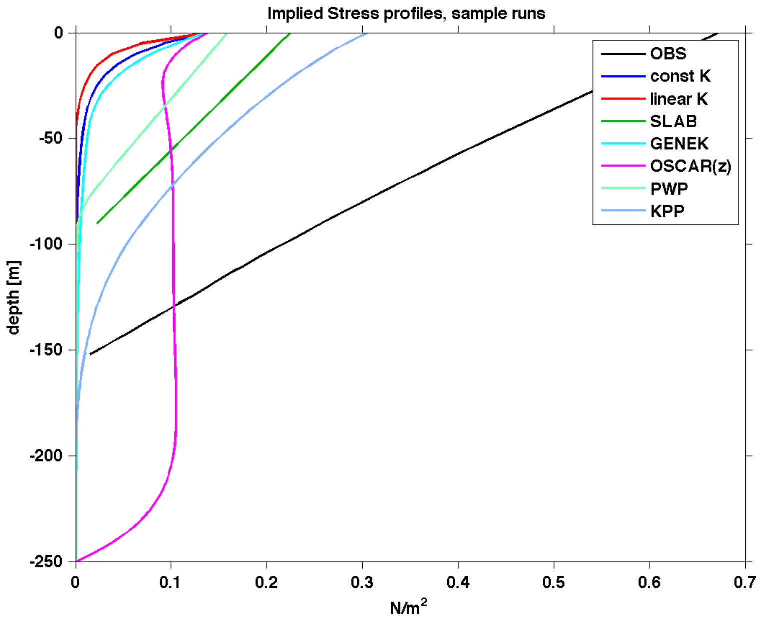




Advantage: Vertical Transport of Momentum

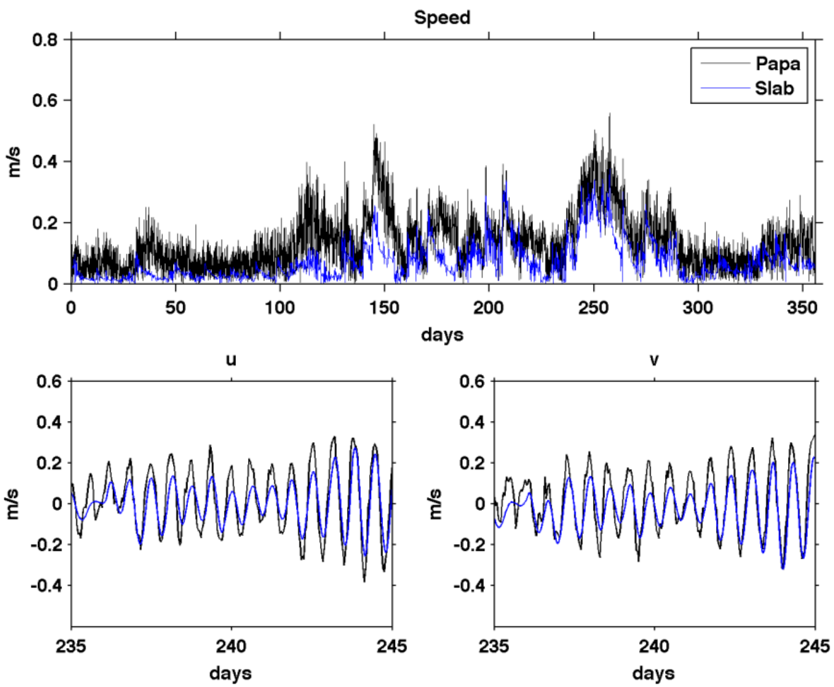


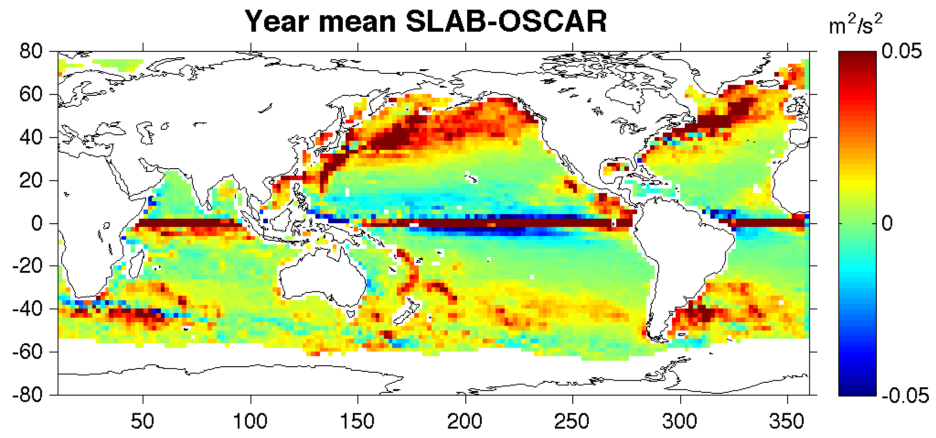




Return to Slab

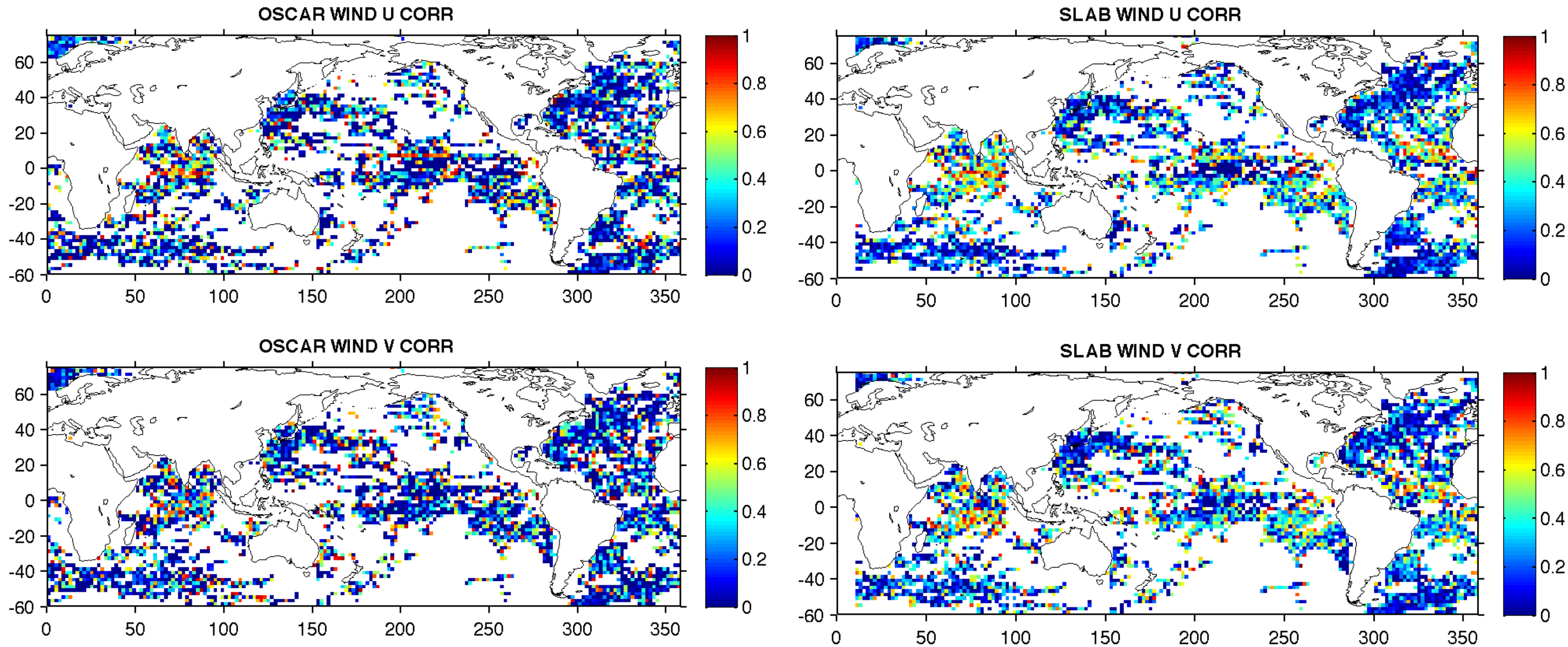
- For the purposes of improving OSCAR currents, the damped slab is looking to be the most viable option.
- Note: great agreement using winds at Papa, even if use 6hr CCMP winds. Off mooring winds in the models (CCMP or ERA/I) will likely not perform as well
- Results for slab model run for 2008. Velocities are binned to daily values (imperfect way of removing NIO signal).
- Amplitudes are improving with slab. 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





Comparison of Wind-driven Component with Drifters

- Correlations with drifters improve with SLAB



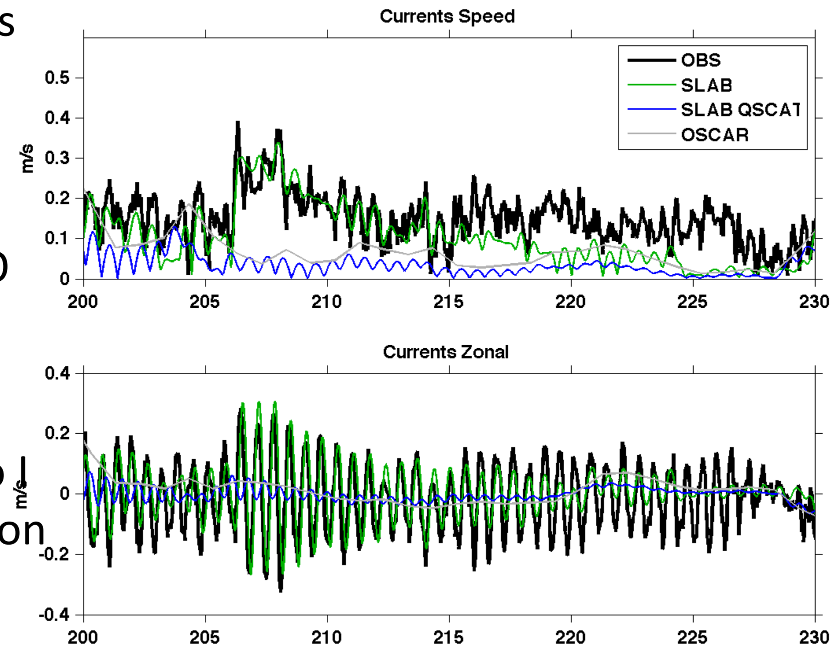
Summary

- Wind-driven surface currents are both underestimated in strength and not well correlated with drifting buoys values
- Better results in areas with higher winds
- Investigating 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 (most robust, more to be investigated with variable terms in the complicated models)
- Much to be learned from the vertical momentum transfer as is varies between models still, including the effects of internal wave drag and mixed layer deepening on the surface currents

Issues and Next Steps

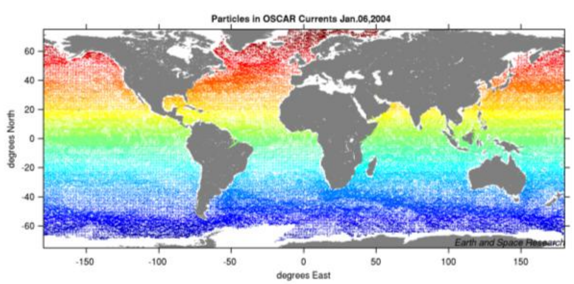
- Going to need to continue using model winds at 6hr minimum to use the slab model. Can't just use interpolated daily winds.
- Likely will end up using the slab formulation with NIO filtered out, plus a value-added NIO energy term. The phasing is just not reliable enough to include in OSCAR.
- Is it sufficient to use simple 1D models, or do I need density profiles, surface inputs, transition layer mixing and nonlinear terms? No horizontal propagation of NIO.

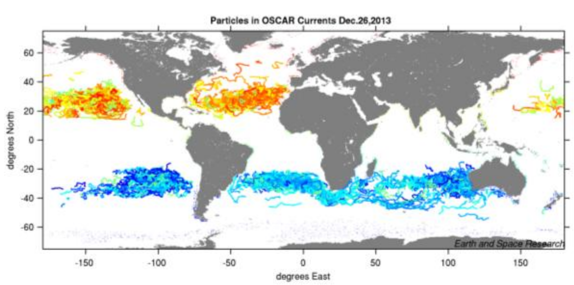


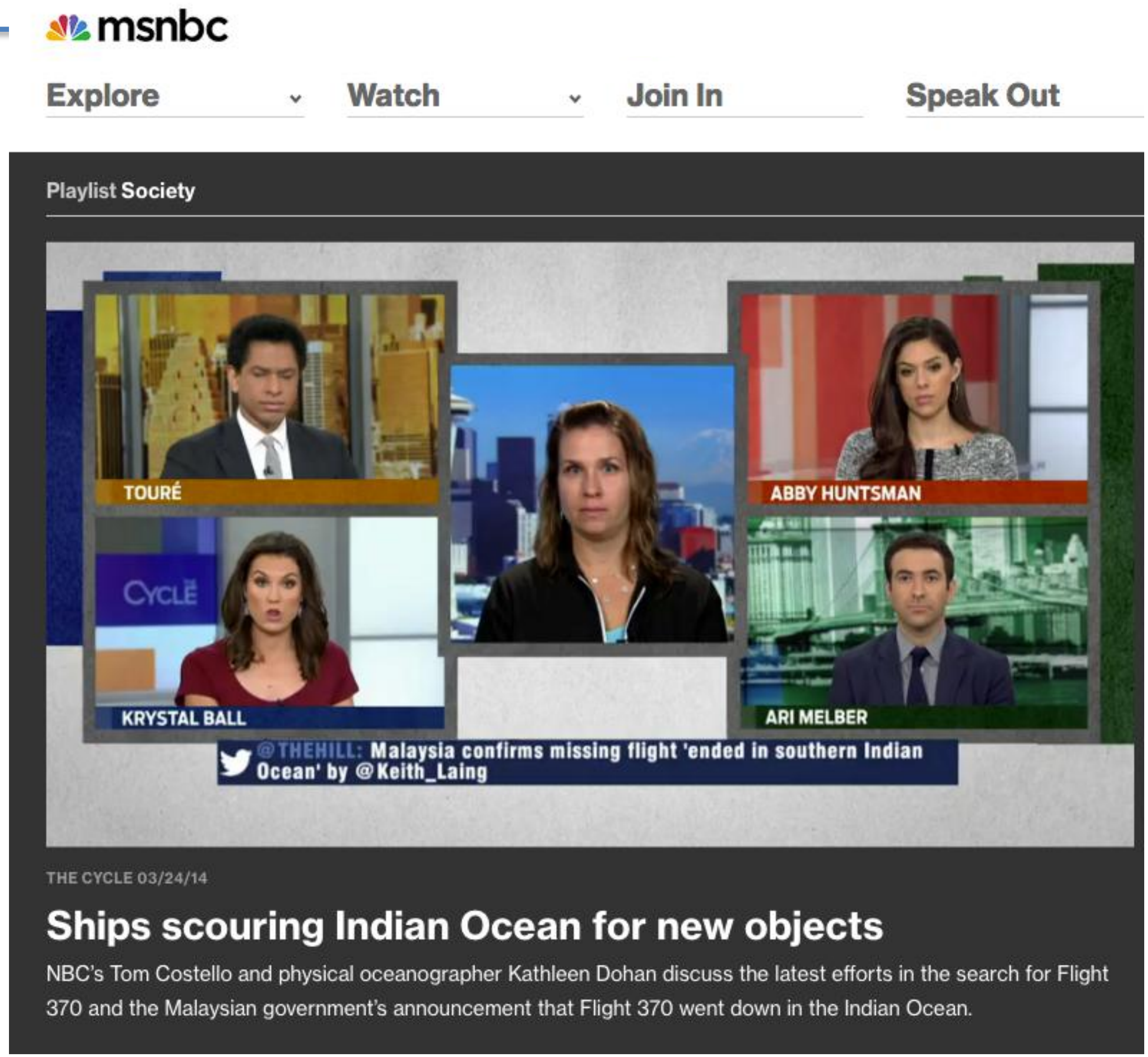
- Need to look at level 2 fields
  - SSH to see what is being misdiagnosed as error in the wind term
  - Winds to see the small scales
  - Exploit more moorings and fields like HF radar as much as feasible (too near the coast) for fast timescales

OSCAR in the news

- New Republic article
- several MSNBC Appearances
- NBC Nightly News with Brian Williams
- NBC 30 seconds on the hour
- CNN
- National Geographic
- NBC News

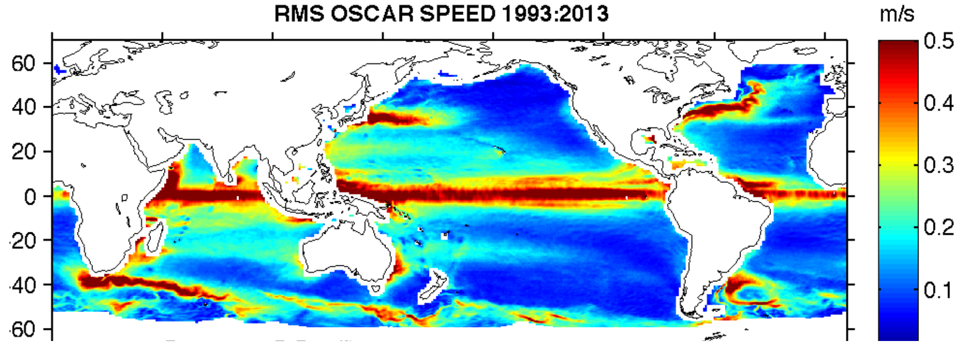


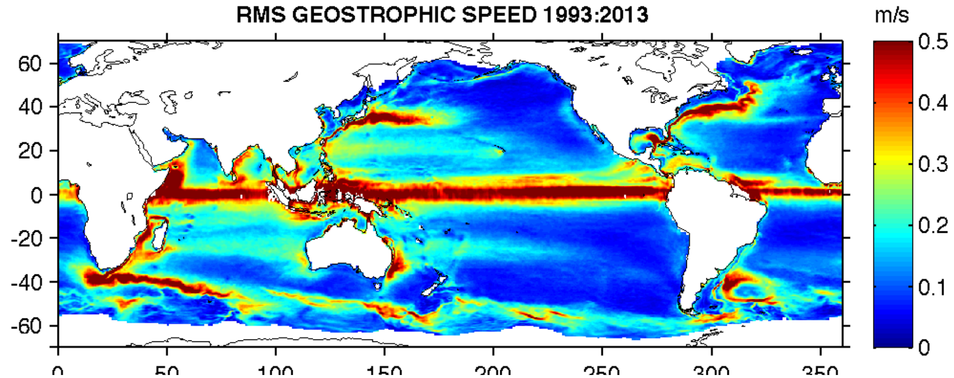


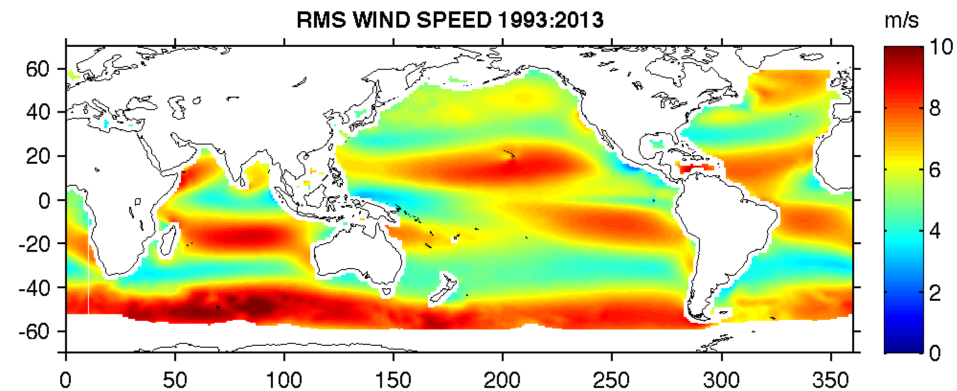


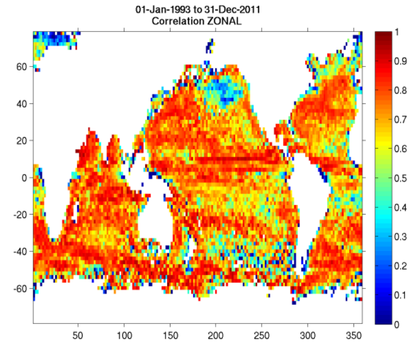
OSCAR Performance

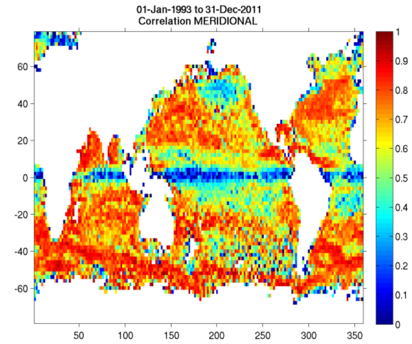
- However, areas of poor correlations are also areas with weaker currents

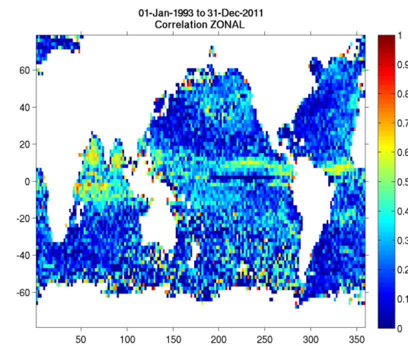


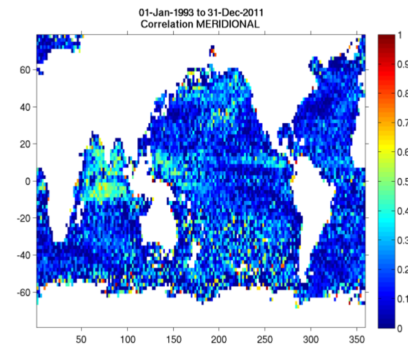








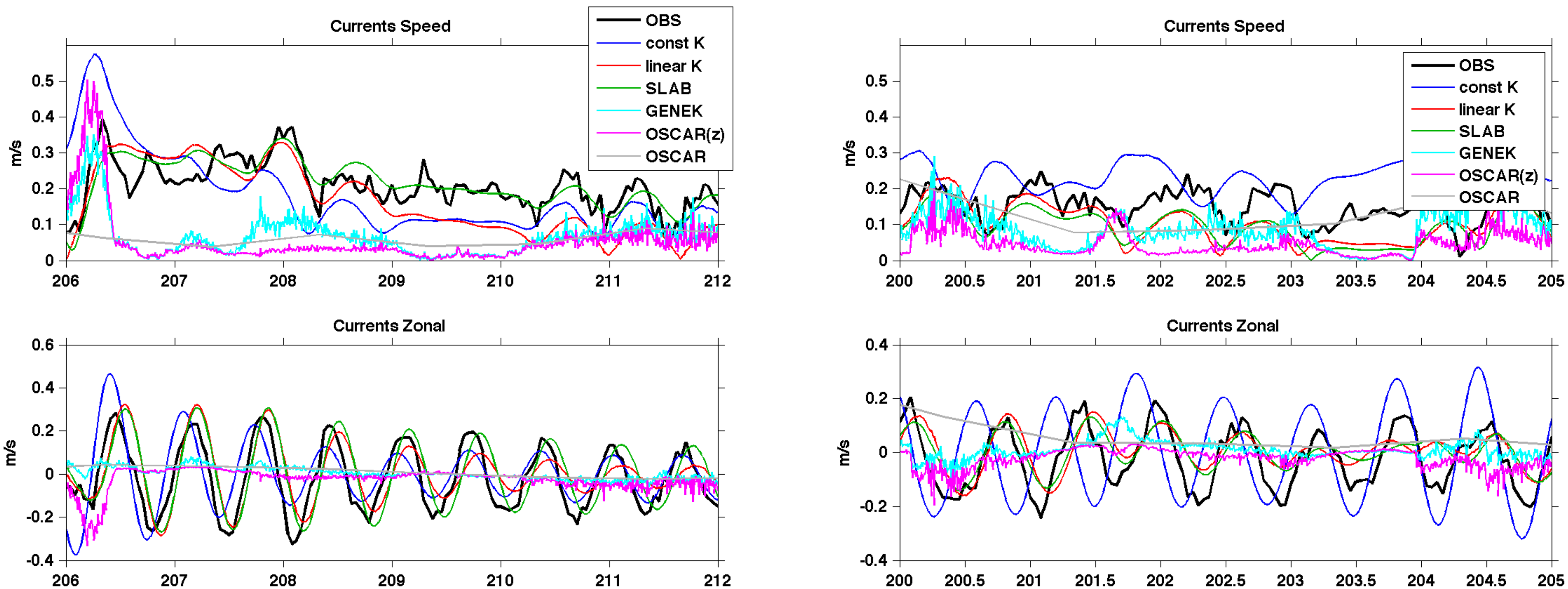




Model Performance for K(z) and d/dt

- At Ocean Station Papa. Quite different results, phasing and speed.
- Note: these are averaged over the top 30m – K models vary with depth.

- Conclusion: Slab model performs the best out of these models



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

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

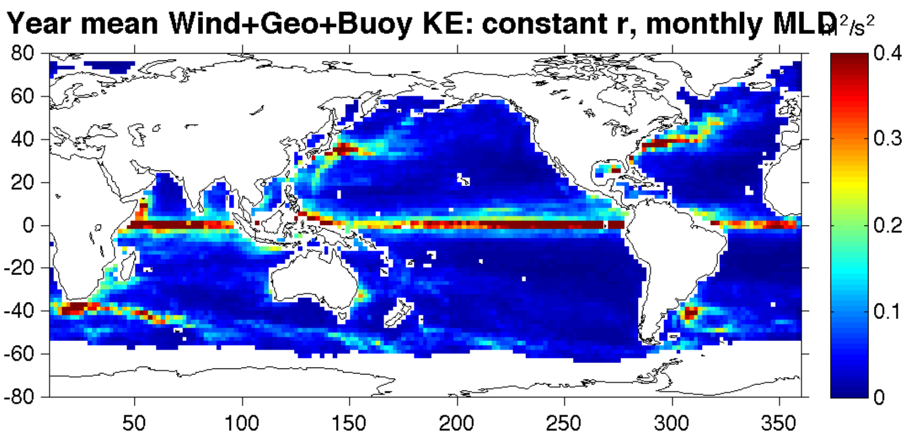
SLAB: r, constant properties in mixed layer, $\frac{\partial}{\partial t}$ term

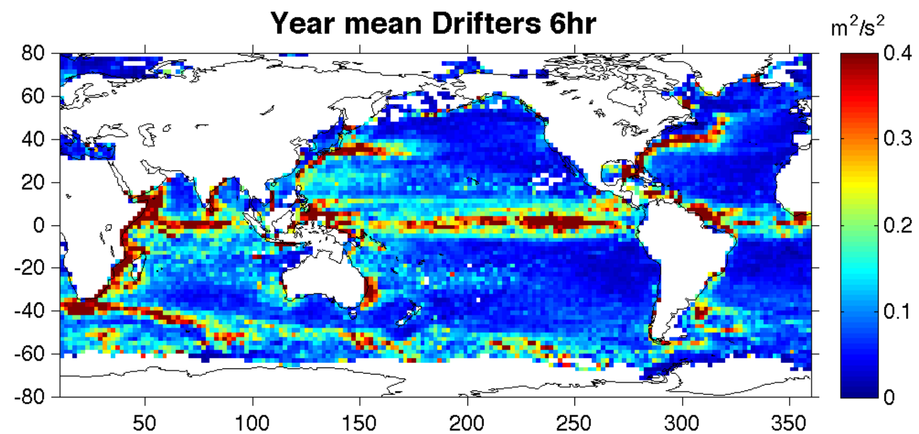
CONSTANTK: $K(z) = K0$, $\frac{\partial}{\partial t}$, infinite b.c.

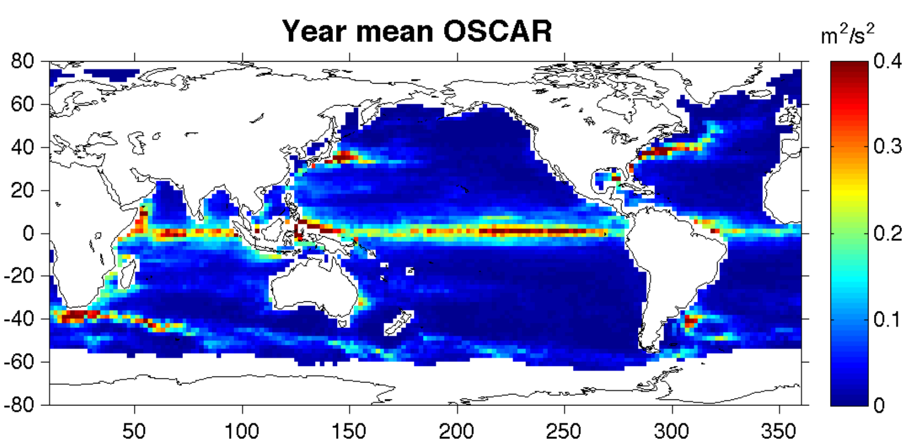
LINEARK: $K(z) = K0 + K1z$, $\frac{\partial}{\partial t}$, $\frac{\partial u}{\partial z}$ b.c.

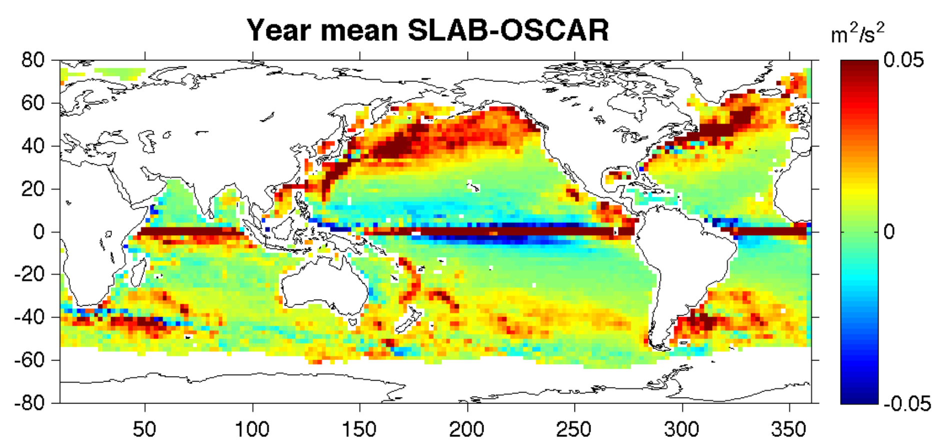
Comparison of SLAB and OSCAR with Drifters

- For the purposes of improving OSCAR currents, the damped slab is looking to be the most viable option.
- Results for slab model run for 2008. Velocities are binned to daily values (imperfect way of removing NIO signal).
- Amplitudes are improving with slab. 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



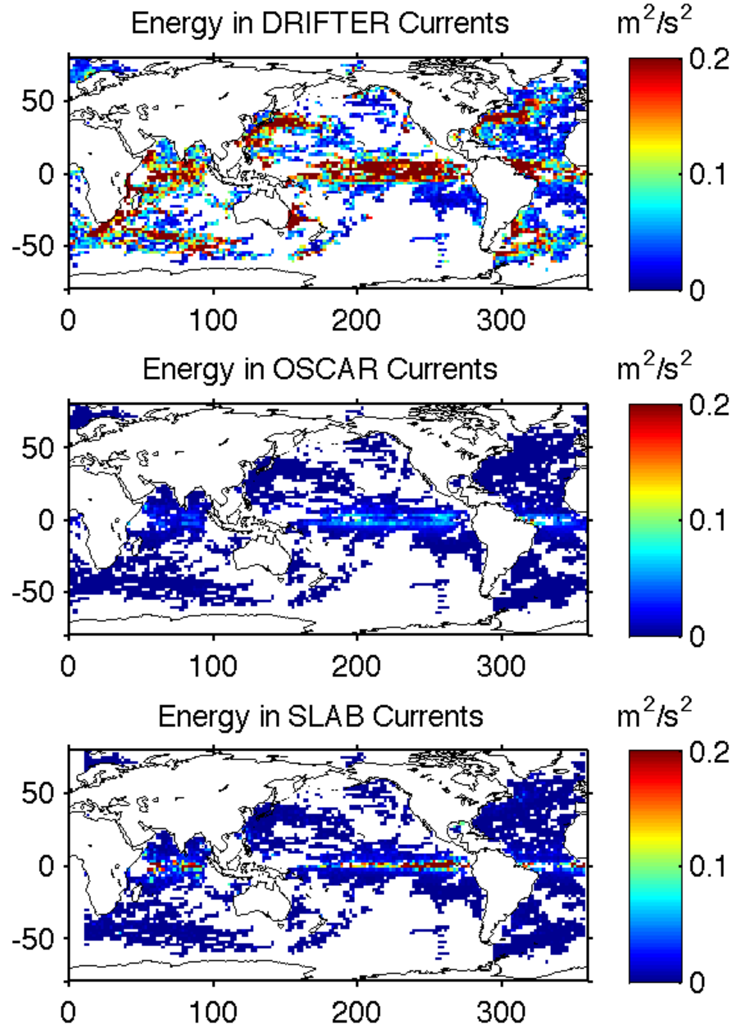






Comparison with Drifters, Energies

- Energies are improving but need 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.



Separate out NIO

- Here: 2 test cases of global slab models for the year 2008 using 6hr CCMP winds and mixed layer depths from Argo
- Separate the inertial band from the signal to see what fast wind-driven motions are captured other than NIOs. Note the change in color scale, with NIO signal an order of magnitude higher.