Vertical Structure in Satellite Wind Derived Ocean Currents

Kathleen Dohan

Gary S. E. Lagerloef, and John T. Gunn

Earth & Space Research
Seattle, Washington

Introduction

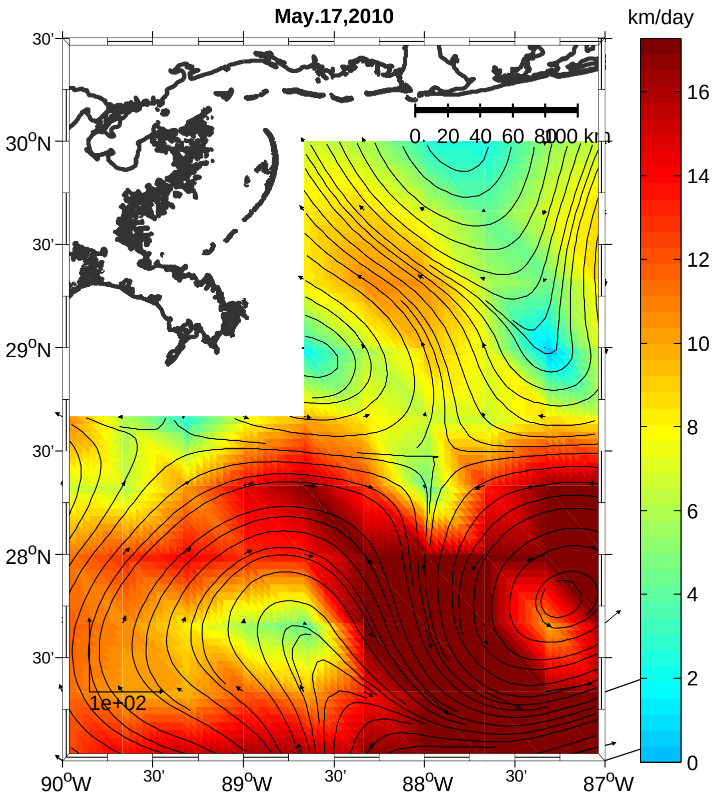
- Incorporating vertical structure to the OSCAR wind-driven component
- Description of the basic OSCAR equations with the turbulence parameterization
  - Stommel model boundary conditions
  - Generalized Ekman boundary conditions
- Compare results from OSCAR and Generalized Ekman to in situ data
- Future directions for OSCAR

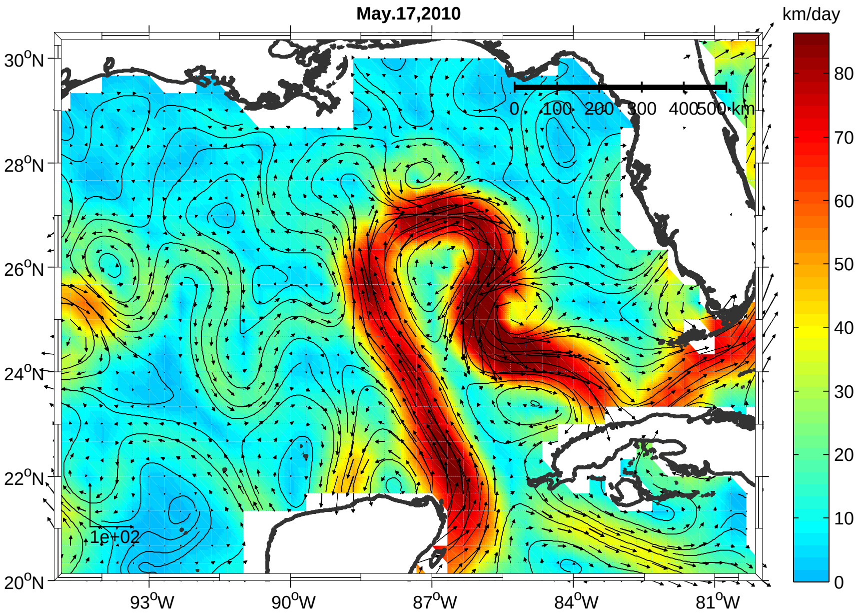
Introduction

Ocean Surface Currents Analyses-Realtime processing system (OSCAR) is a satellite-derived surface current database provided in near-real time based on a combination of quasi-steady geostrophic and locally wind-driven dynamics (Bonjean and Lagerloef, 2002).

- The geostrophic term is computed from the gradient of surface topography fields (AVISO/CLS and NRL/MODAS).
- Wind-driven velocity components are computed from an Ekman/Stommel formulation with variable viscosity using QuikSCAT winds (FSU/COAPS) and NCEP winds
- with a thermal wind adjustment using Reynolds SST data.
- Data available at http://podaac.jpl.nasa.gov and http://www.oscar.noaa.gov.

OSCAR Gulf of Mexico





- OSCAR product extended to daily output for the latest 20 days of data using real time products (AVISO RT and NCEP). Image from NASA's Terra Satellite on May 17.

OSCAR Real Time Gulf of Mexico

(Loading Gulf.mpg)

- OSCAR product extended to daily output for the latest 20 days of data using real time products (AVISO RT and NCEP).

Calculating Surface Currents

Quasi-steady linear flow in a surface layer with turbulent mixing parameterized by a constant vertical eddy viscosity. Frontal model: buoyancy force θ is a function of SST horizontal gradients only. Surface layer velocity $\bar{\mathbf{U}}$ by averaging over the top h=30m.

$$\text{(1)} \qquad if\bar{\mathbf{U}} = -g \bigtriangledown \zeta + \frac{h}{2} \bigtriangledown \theta + \frac{\tau_0 - \tau(-h)}{h}$$

$$\text{(2)} \qquad \tau = \nu \frac{\partial \mathbf{U}}{\partial z}.$$

Use Stommel model boundary conditions in a second order differential equation for shear:

$$\text{(3)} \qquad \frac{\partial \mathbf{U}}{\partial z}(z=0) = \tau_0/\nu$$

$$\text{(4)} \qquad \frac{\partial \mathbf{U}}{\partial z}(z=-H) = 0$$

where: $\mathbf{U} = u + i \times v$, τ_0 is surface wind stress, ζ is SSH, θ is buoyancy, based on SST ($\theta = g\chi_T SST$), and ν is a vertical eddy viscosity, calculated as a function of wind

$$\text{(5)} \qquad \nu = a(\frac{|\mathbf{W}|}{W_0})^b.$$

Calculating Surface Currents: Generalized Ekman

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

Optimal choice for a in OSCAR blends from 8×10^{-5} m^{2}s^{-1}, $b = 2.2$ at the equator as in Santiago-Mandujano & Firing (JPO 1990), to 2.85×10^{-4} m^{2}s^{-1}, $b = 2$ for the global value.

Rather than solve for the shear, Cronin and Kessler (JPO 2009) solved for stress, using the Generalized Ekman boundary conditions and a vertically varying eddy viscosity which decays with depth so that the stress becomes zero at depth H, while the shear can remain nonzero.

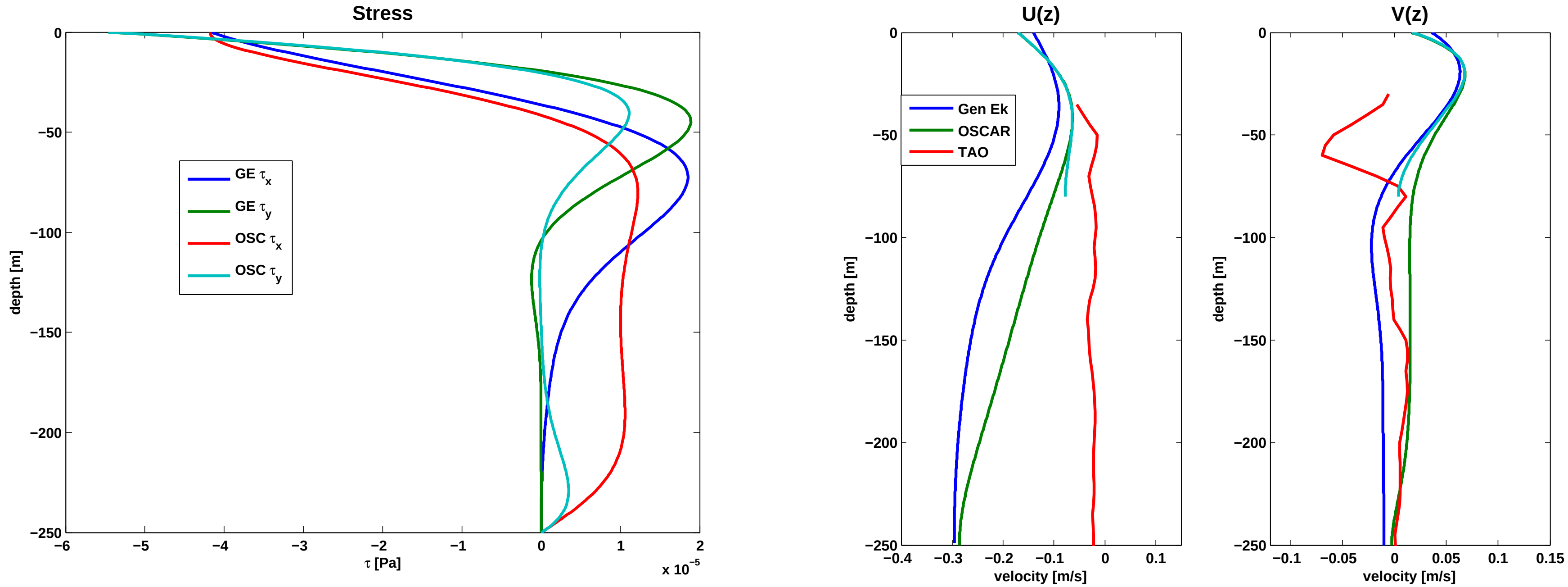
Generalized Ekman boundary conditions

(7) $$\tau(z=0) = \tau_0$$

(8) $$\tau(z=-H) = \nu(z)\frac{\partial \mathbf{U}}{\partial z}(z=-H) = 0.$$

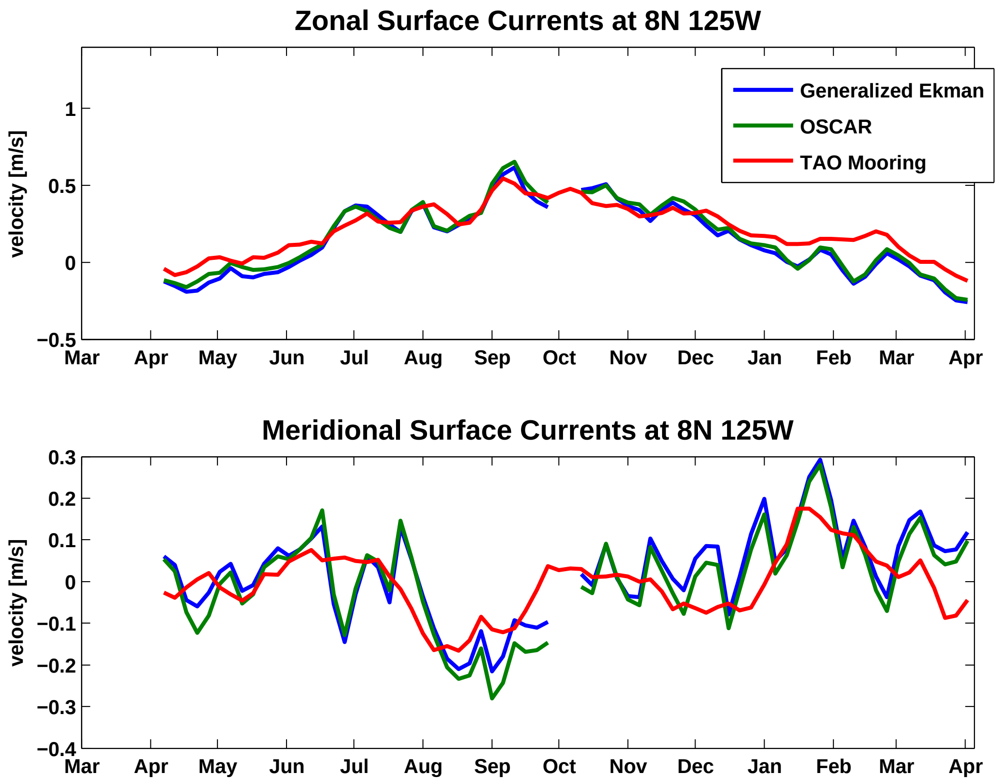
where: $\nu = A\exp(z/D) - B$, $D = 125$m and $\nu = 16e - 03$ m^{2}s^{-1} at 10m and zero at 250m.

Comparison of OSCAR with TAO mooring



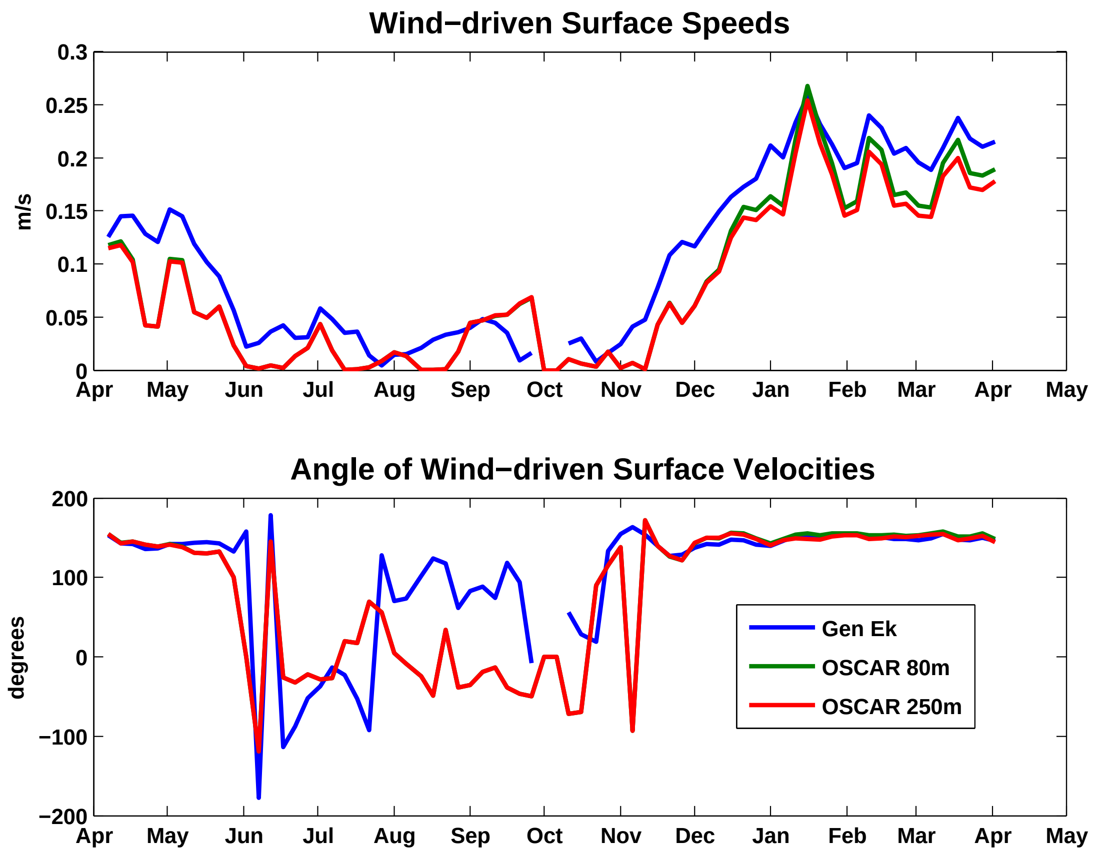
- Vertical profiles of stress and velocity at a single day given a variable eddy viscosity $\nu(z)$ (Generalized Ekman) and a constant eddy viscosity (OSCAR).
- Comparison of surface currents with 8N 125W TAO mooring ADCP.
- The stress profile should depend on the wind and stratification, and has been observed to decrease to zero at the base of the transition layer (Dohan and Davis 2010).

Comparison of OSCAR with TAO mooring



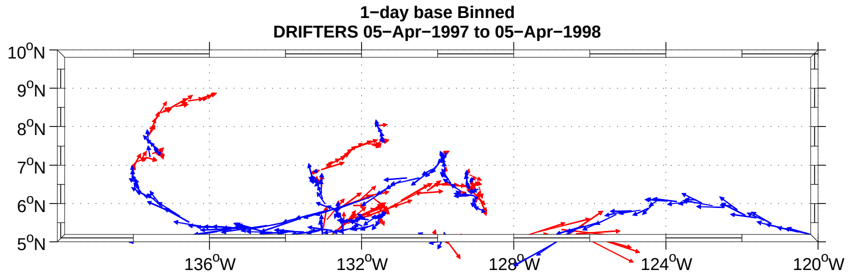
- Comparison of surface current solutions with 8N 125W TAO mooring ADCP velocity at 30m depth, 10-day smoothed onto 5-day timebase.
- Currents are calculated with Generalized Ekman $\nu(z)$ and OSCAR constant ν to 250m depth.
- Moored data is distributed by NOAA/PMEL at http://www.pmel.noaa.gov/tao.

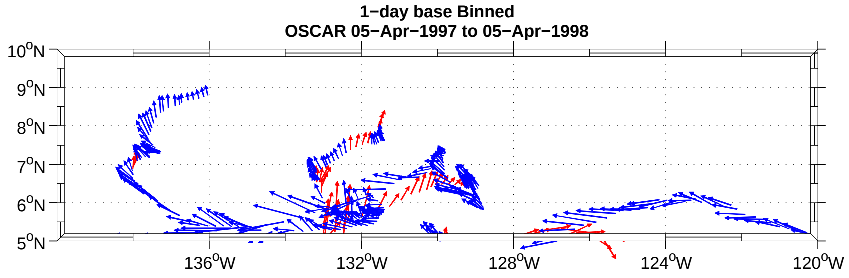
Surface current differences



- Difference in magnitude and angle of surface currents using Generalized Ekman $\nu(z)$, constant ν to 80m depth, and constant ν to 250m depth.

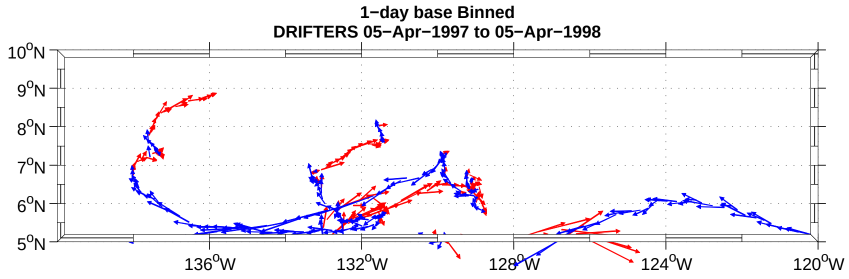
Comparison of OSCAR with Drifters

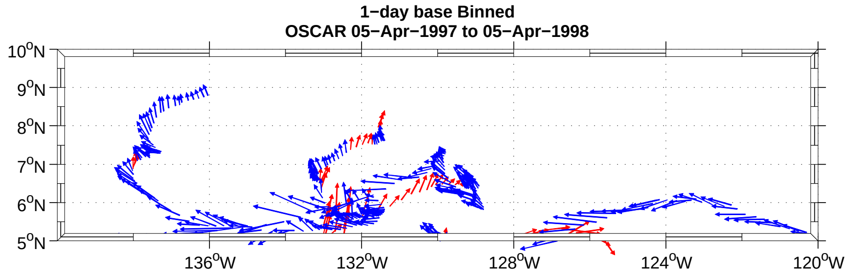




- OSCAR surface velocities are interpolated onto drifter locations (which have been averaged over 1 day).
- **Generalized Ekman** solution.

Comparison of OSCAR with Drifters





- OSCAR surface velocities are interpolated onto drifter locations (which have been averaged over 1 day).
- **OSCAR constant viscosity** solution.

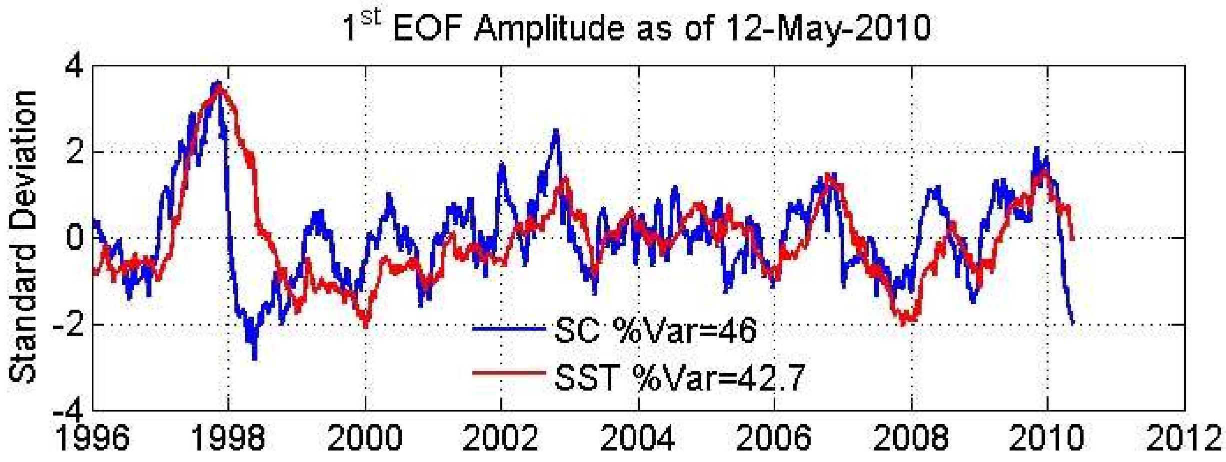
Summary

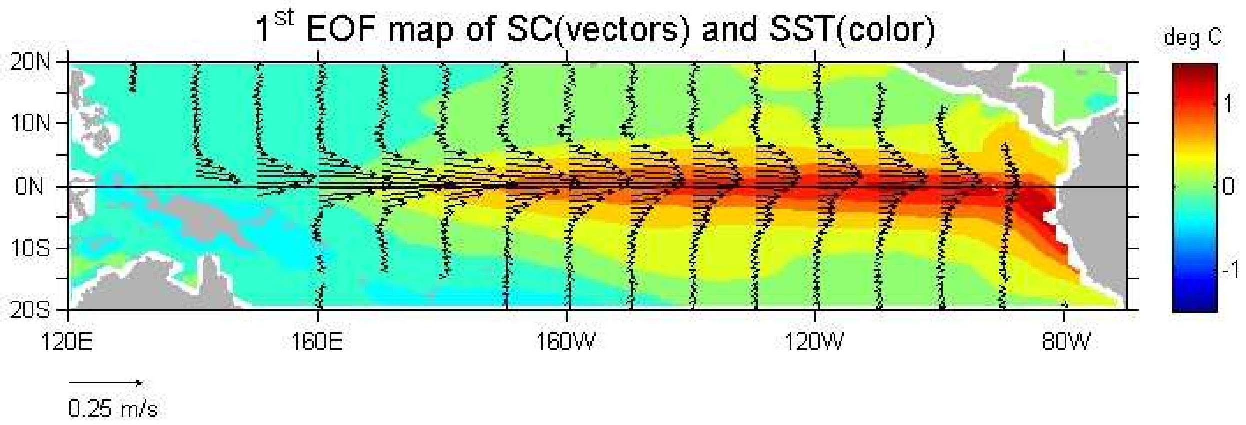
- OSCAR as a test-bed for surface information-based turbulence parameterizations
  - Global dataset dating back to 1992.
  - Validation of surface currents from the global drifting buoy array and subsurface currents from moored arrays.
- The Generalized Ekman formulation, with a vertically varying eddy viscosity has more flexibility and is more physically realistic.
- The profiles of velocity at depth do not agree with in situ data (not surprisingly).
- Surface velocities are similar between viscosity choices, although with enough variation in magnitude and direction to distinguish between parameterization types.

Future Work

- Improve the wind-driven turbulent mixing scheme
  - vertically varying eddy viscosity
  - include a mixed layer and transition layer
    - account for the shear-driven mixing in the transition layer (i.e. below mixed layer)
    - incorporate ARGO mixed layer depths
  - vary models according to dynamical regions
    - equatorial, ACC, high winds, near coasts, compensation layers/ salt fingers, deep convection, eddies ...
- Develop time-dependent dynamics in OSCAR to include high-frequency wind-driven currents.
- Extend OSCAR capability to nowcast and forecast.

La Nina

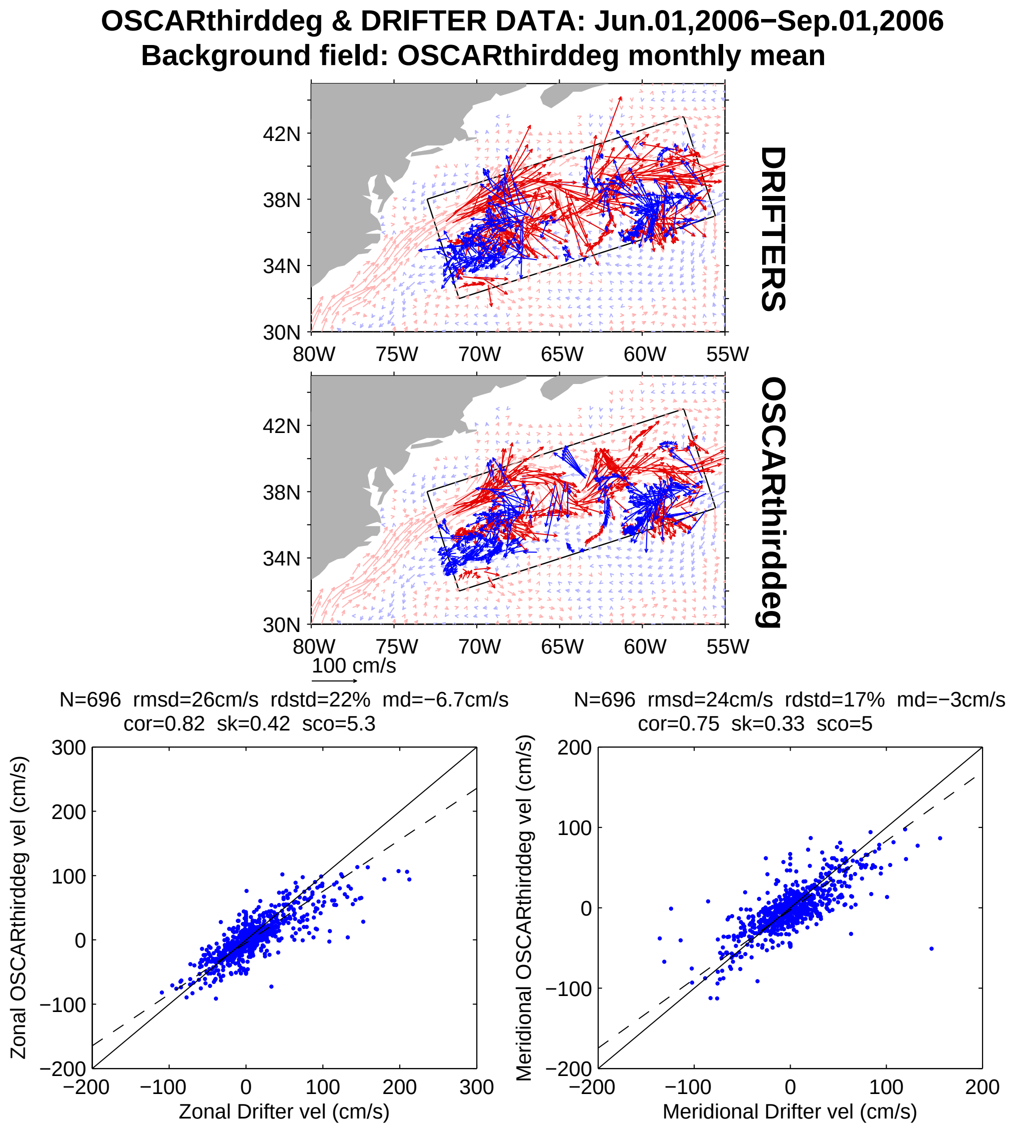




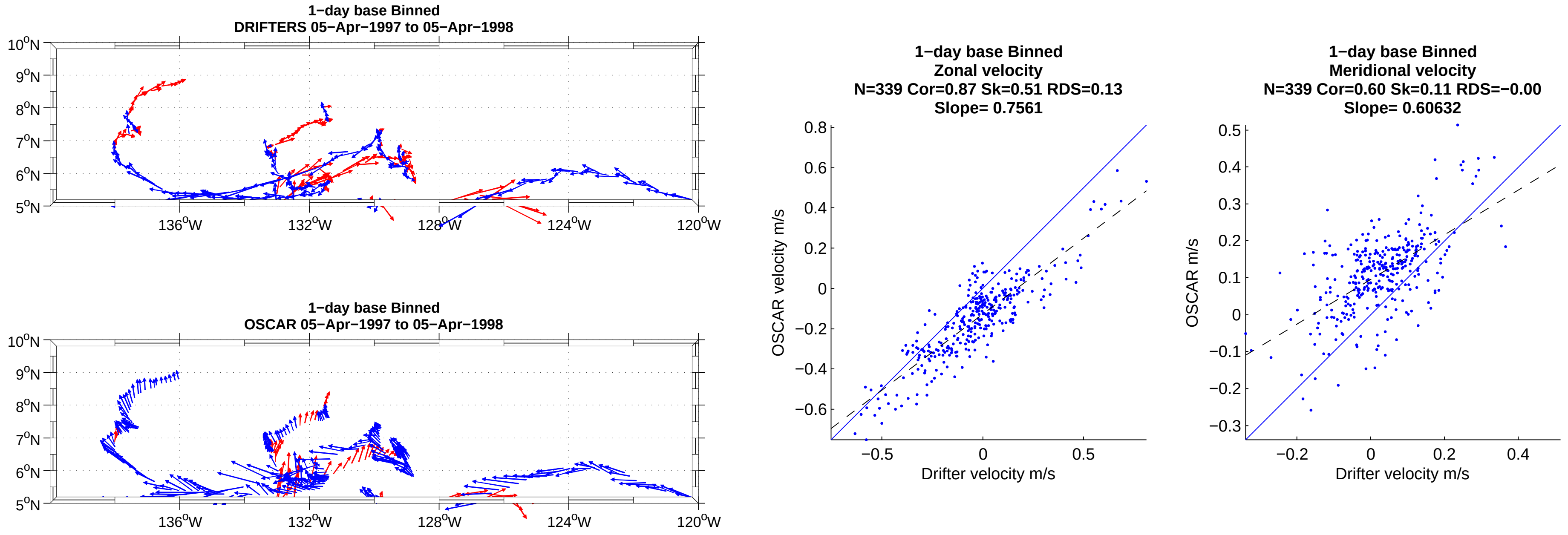
- ENSO cycle as indicated by 1st EOF of surface current and SST anomalies.

Comparison with Drifters Gulf Stream

- OSCAR surface velocities are interpolated onto drifter locations (which have been averaged over 1 day). Zonal and meridional currents *vs* drifter velocities are plotted on the scatter plot.
- Drifter data distributed by NOAA/AOML www.aoml.noaa.gov/phod/dac/gdp.html



Comparison of OSCAR with Drifters



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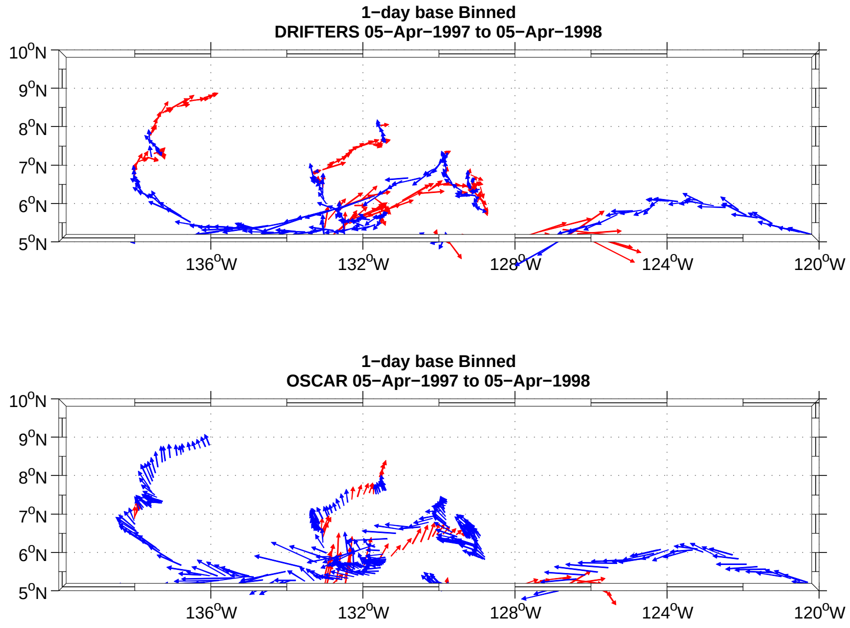

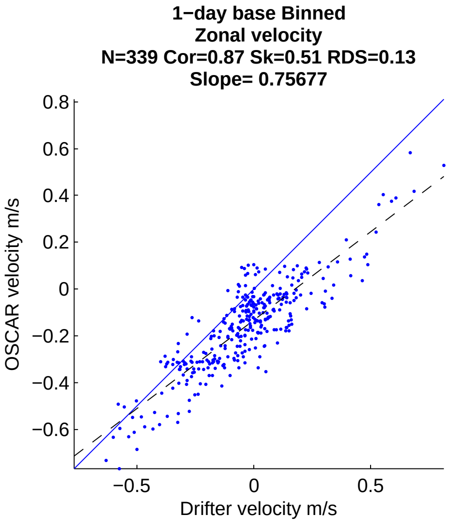

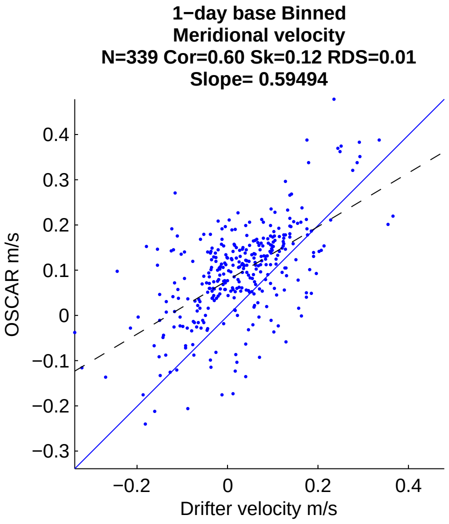

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- **OSCAR constant viscosity** solution.