Importance of Surface Current Measurements in the Equatorial Belt for the Understanding of Ocean and Climate Dynamics

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Tropical Atlantic Variability

- Climate modes: zonal mode (JJA) and meridional mode (MA)

Strong ocean-atmosphere interaction with great importance of ocean dynamics: Heat advection and upwelling important for the zonal mode (Bjerknes feedback) and likely for the termination of the meridional mode (e.g. Sverdrup transport).

e.g. Chang et al., 2006
Importance of Surface Velocity

- SST affected by heat advection associated with low-baroclinic mode waves (Kelvin and Rossby waves) and Ekman/Sverdrup flow

- High baroclinic mode waves:
  - Equatorial deep jets generated in the deep ocean propagate energy upward: 4.5-yr cycle
  - Potential impact on surface velocity and near-surface mixing

- Wind power, ocean circulation

- Mixed layer (ML) heat budget varying on time scales from diurnal to decadal

- Similar role of ML freshwater budget (e.g. barrier layers)

- ML budgets strongly influenced by mean and eddy advection, surface divergence and upwelling, and shear induced mixing

Bourles et al., 2019
About half of wind power, \( \langle \tau v \rangle \), required to maintain global ocean circulation (1.1 TW) is provided in the tropical ocean.

Calculation using geostrophic velocity largely underestimate wind power input in the tropics as obtained from model simulations.

Surface current feedback on winds: damping of mesoscale possibly scale dependent.

Intraseasonal wave generation.

Brown and Fedorov, 2008
Mixed Layer Heat Budget

\[ \frac{\partial T}{\partial t} = \frac{q_{net}}{\rho c_p h} - \nabla \cdot (\rho c_p h \bar{v} T) - \rho c_p w_e \Delta T - q_{-h} \]

- \( h \) - mixed layer depth
- \( \bar{v} \) - horizontal velocity
- \( T \) - Temperature
- \( w_e \) - entrainment velocity
- \( \rho \) - density
- \( c_p \) - specific heat capacity

Ocean Dynamics

- Heat tendency
- Surface heat flux
- Horizontal heat advection
- Entrainment
- Diapycnal heat flux

e.g. Foltz et al., 2003
Residual is an estimate of the sum of horizontal heat advection and diapycnal heat flux (mixing) and entrainment.
At PIRATA buoys with velocity measurements (still more than 50% missing data, filled with OSCAR), largest errors for horizontal heat advection

RMS(correlation) between daily 10-m velocity from PIRATA buoy and OSACAR:
- zonal velocity: 25.5 cm/s (0.5)
- merid. velocity: 19.4 cm/s (0.4)

Daily velocity errors range from 5 to 30 cm/s in the equatorial belt between 4S/N
Cooling by zonal advection, warming by eddy advection

Diapycnal heat flux of same order or larger than advection

Hummels et al., 2014

Only few shipboard microstructure measurements; mixing parameterization using near-surface shear data
Strong Near-Surface Stratification during Equatorial Upwelling 10W

Glider measurements at equator, 10W; diurnal cycle with extremely shallow mixing layer; 15m-drifter velocity mostly below ML base: often not adequate for ML budget calculations
Diurnal Cycle of Temperature and Velocity at the Equator, 23W

Diurnal shear layers are regularly observed descending into the marginally unstable Equatorial Undercurrent

Wenegrat and McPhaden 2015
SSH and SST variability not synchronous: improved dynamical understanding of forced ocean waves

Jochum et al., 2003

What is the role of surface velocity divergence and mixing in biological productivity?

Jochum et al., 2003
Tropical Atlantic Observing System: Limitations of velocity observations

- Only few buoys with direct velocity observations in the upper meter/mixed layer (excellent temporal but very poor horizontal resolution)
- Subsurface moorings have typically upward looking ADCPs missing the top 10% of the measurement range due to surface reflection
- Shipboard velocity measurements typically miss the upper 20m (installation depth, blanking distance, potential flow around ships hull)
- Surface Drifter measure velocity centered at 15m depth; experience strong equatorial divergence (only few measurements at the equator); strong stratification in the upper 15m in upwelling regions result in near-surface velocity shear: drifter do not measure mixed layer velocities
- Argo floats measure surface drift (upper 1m) with some impact of wind; they are (almost) not affected by equatorial divergence; surface time about 12-20h, but reduces with change from Argos to iridium transmission making velocity data more noisy in the future
Tropical Atlantic Observing System: Circulation und Upwelling

Foltz et al., OceanObs'19, 2019
Possible Achievements of Surface Velocity Measurements

- Monitoring of ocean surface currents have great potential to aid research, data assimilation, and forecasts.
- Direct observations of an important component of oceanic energy balance: wind power input by nearly simultaneously measuring wind and surface velocity.
- Significant improvements in mixed layer heat, salt, and tracer budgets on intraseasonal to interannual timescales expected.
- Discoveries expected: not much known about details of equatorial surface currents from direct observations:
  - Frontal dynamics with upwelling/subduction and associated productivity.
  - Role of smaller scale equatorial waves in driving advection/mixing.
  - Possibly resonant generation of equatorial waves.
  - Temporal and spatial distribution of near-surface shear.
Near-Surface Current Mapping by Shipboard Marine X-Band Radar

Lund et al., 2018