Variability of turbulent mixing and diapycnal solute fluxes in the Peruvian upwelling region: First results from Meteor Cruise M92

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Motivation

A8 - Transport and Fluxes across the Bottom Boundary Layer

- Sediments in the oxygen minimum zones (OMZs) release or take up significant amounts of nutrients (e.g. ammonium, nitrate, nitrite, phosphorus, iron, silicate)
- Sediments represent a sink for dissolved oxygen, nitrate and nitrite

Open Question: Fluxes of solutes of sedimentary origin into the water column, their iso- and diapycnal diffusion and their relative contribution to the total solute budget.
The Peruvian Upwelling Region

- Upwelling is driven by northward winds. The resulting offshore Ekman transport causes an equatorward flow on the shelf.
The Peruvian Upwelling Region?

- Upwelling is driven by northward winds. The resulting offshore Ekman transport causes an equatorward flow on the shelf.

- Observation during the cruise: Light to no winds (mostly below 10kn)
CTD Station during M92

CTD measurements include water column analysis of nutrients, N-isotopes, oxygen, salt, DIC, N2, Argon, CO2, N2O, radium, thorium
Mooring work during M92

A8 - Transport and Fluxes across the Bottom Boundary Layer

- In cooperation with B6 and B9 (8 deployed, 1 more to go)

Planned

Deployed

Mini-Lander and Mooring Positions M92
• In cooperation with B9
(7 released)
Results from M92: Hydrography

Temperature

Salinity

O2

Turbidity
Results: Along-slope currents at 12°S

- Currents show southward transport all along the continental slope (which is thought to be driven by wind-stress curl)
- No northward current on the shelf
Nutrients distribution along 12°S

Nitrite (NO$_2^-$) in μMol/l and density (σ$_0$) in kg/m$^3$ along the 12°S Section
FS Meteor cruise M92, January 2013

Nitrate (NO$_3^-$) in μMol/l and density (σ$_0$) in kg/m$^3$ along the 12°S Section
FS Meteor cruise M92, January 2013

Phosphate (PO$_4^{3-}$) in μMol/l and density (σ$_0$) in kg/m$^3$ along the 12°S Section
FS Meteor cruise M92, January 2013

Silicate (SiO$_4^{4-}$) in μMol/l and density (σ$_0$) in kg/m$^3$ along the 12°S Section
FS Meteor cruise M92, January 2013
Nitrite distribution along 12°S

Nitrite (NO$_2$) in μMol/l and density ($\sigma_\theta$) in kg/m$^3$
along the 12°S Section
FS Meteor cruise M92, January 2013
The Peruvian Upwelling Region?
Internal wave observations

However, take a look at what tides can do when the impinge on a continental shelf

(Animation kindly provided by Sonja Legg, GFDL, Princeton University, USA)
Near surface internal wave trains

Results from ADCP measurements

Target Strength  Shipboard-ADCP (OS75)

Depth [m]  05:21 05:38 05:55 06:12 06:29 06:46 07:03 07:20 07:37

January 6, 2013

db  180 160 140 120 100 80 60 40 20
Measuring the smallest movements in the ocean

Microstructure System (MSS):
- Profiler (loosely-tethered)
- Winch (1100m)
- Deckunit

During M92, 272 MSS profiles were acquired

MicroRider (MR):
- piggybags on a Glider
- measures autonomously
Loosely-tethered Profiler:

Profiler MSS90D (2000m)
- 16 channels that are recorded at a rate of 1000Hz
- 2 or 4 shear sensors (250 Hz, Airfoil)
- fast thermistor (125 Hz, NTC)
- tilt sensors
- acceleration sensor
- standard CTD Sensors (24 Hz) (pressure, conductivity, temperature)

Manufacturer: Sea & Sun Technology and ISW – Wassermesstechnik
What are the oceans’ smallest movements?

Figure 1.7: Two velocity vector maps of the same area, sampled 1 s apart. The instantaneous mean velocity of the sample area (shown at the top of each map) is subtracted from each vector to highlight the turbulence structure. The vertical coordinates represent the actual distance from the bottom. These frames were observed by means of Particle Image Velocimetry (PIV) near the LEO-15 site off the coast of New Jersey in 15 to 21 m depth of water. Figure by Alex Nimmo Smith (Plymouth, England), see also Nimmo Smith et al. [2002].
Shear sensors (airfoil probe):

- 1000 Hz sampling rate
- resolution $10^{-11}$ W/kg
- Zeitkonstante 3ms
Upper ocean turbulence maximum

Results from MSS measurements

M92 Dissipation rate ($\varepsilon$) at 225m depth (Profiles 148–153)

[Graph showing dissipation rate across different depths and times]
Near bottom turbulence maximum

Results from MSS measurements

M92 Dissipation rate ($\varepsilon$) at 350m depth

Depth [m]

Time in UTC

Jan 14 2013

W kg$^{-1}$
Glider vertical velocity (downward)
First results from M92 indicate extensive mixing occurring on the continental slope of Peru.

Despite the strong mixing, nutrient gradients are pronounced on the shelf.

Mixing due to internal wave is likely to strongly contribute sustaining the cold water on the shelf.