Use of Wind Stress and Altimetric Data to Detect the Anomalous Loss of SVP Drifter's Drogue

M-H Rio

DBCP-XXVII
27th session of the Data Buoy Cooperation Panel
26 - 30 September 2011, Geneva, Switzerland

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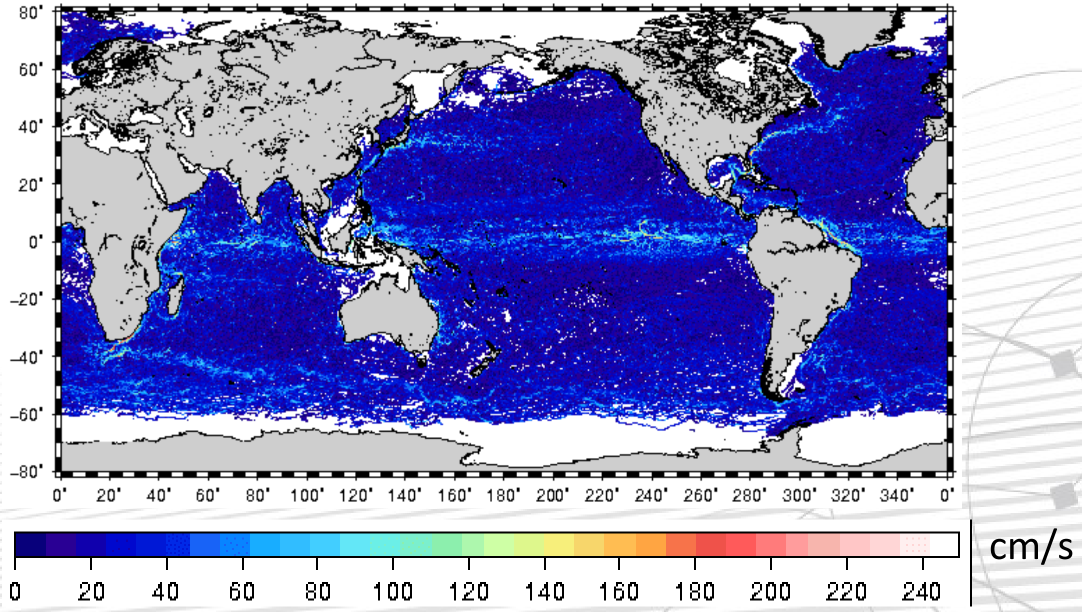
Context of the study:

Drifting buoy velocities are used together with altimetric and wind data to estimate the Ekman response of ocean currents to wind stress
(*Rio et al, 2003,2011*)

$$\vec{V}_{drifter} = \vec{V}_{geost} + \vec{V}_{ekman} + \vec{V}_{tide} + \vec{V}_{inertial} + \vec{V}_{ageo/hf}$$

15m-drogued drifting buoy velocities distributed by AOML for the period 1993-2010



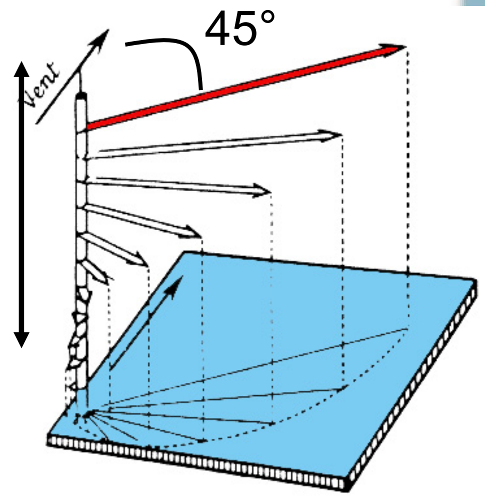
Modelling Ekman currents

Ekman theory

$$u_e = \pm \frac{\pi\sqrt{2}}{\rho f D_e} e^{\frac{\pi}{D_e}z} * \tau * \cos\left(\frac{\pi}{4} + \frac{\pi}{D_e}z\right)$$

$$v_e = \frac{\pi\sqrt{2}}{\rho f D_e} e^{\frac{\pi}{D_e}z} * \tau * \sin\left(\frac{\pi}{4} + \frac{\pi}{D_e}z\right)$$

β θ



Model

Rio and Hernandez, 2003

$$\vec{u}_e = \beta \vec{\tau} e^{i\theta}$$

$\vec{u}_{buoy} - \vec{u}_{alti}$

Band pass filtered 30 hours – 20 days

Wind stress from ERA INTERIM

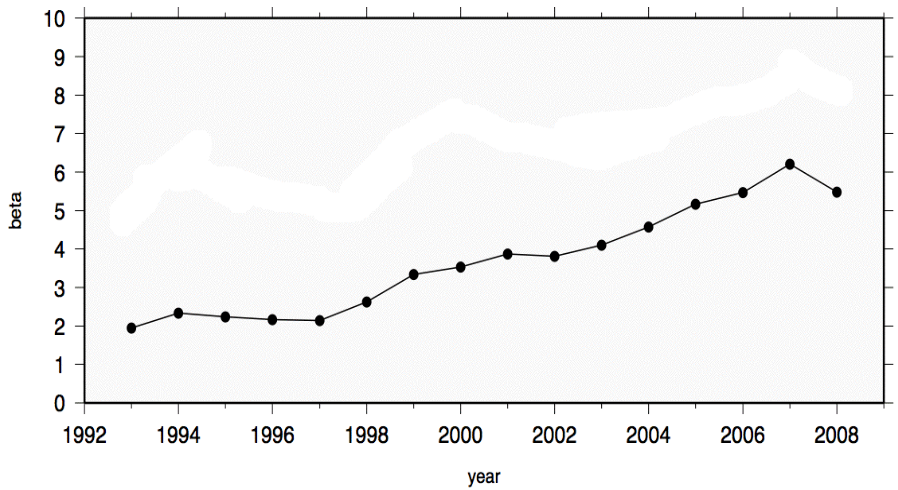
β and θ are estimated through least square fit
Dependency to De: spatial and seasonal variability expected due to change in stratification

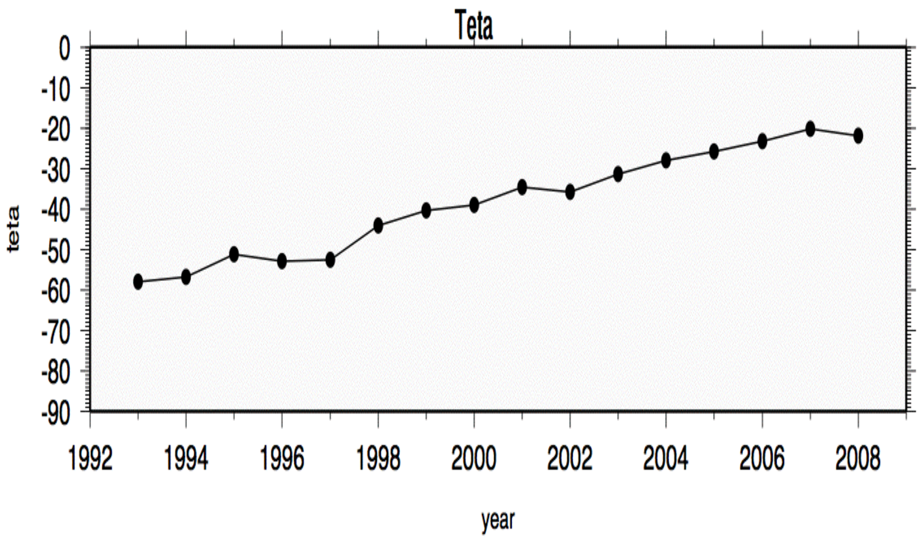
Modelling Ekman currents

Rio et al, 2011

β and θ computed over the global ocean by year

β





Strong dependency of β and θ parameters with time

✓ Increase with time of parameter β – Ekman currents at 15m getting stronger

✓ Decrease with time of |θ| - Direction of Ekman currents getting closer to wind direction

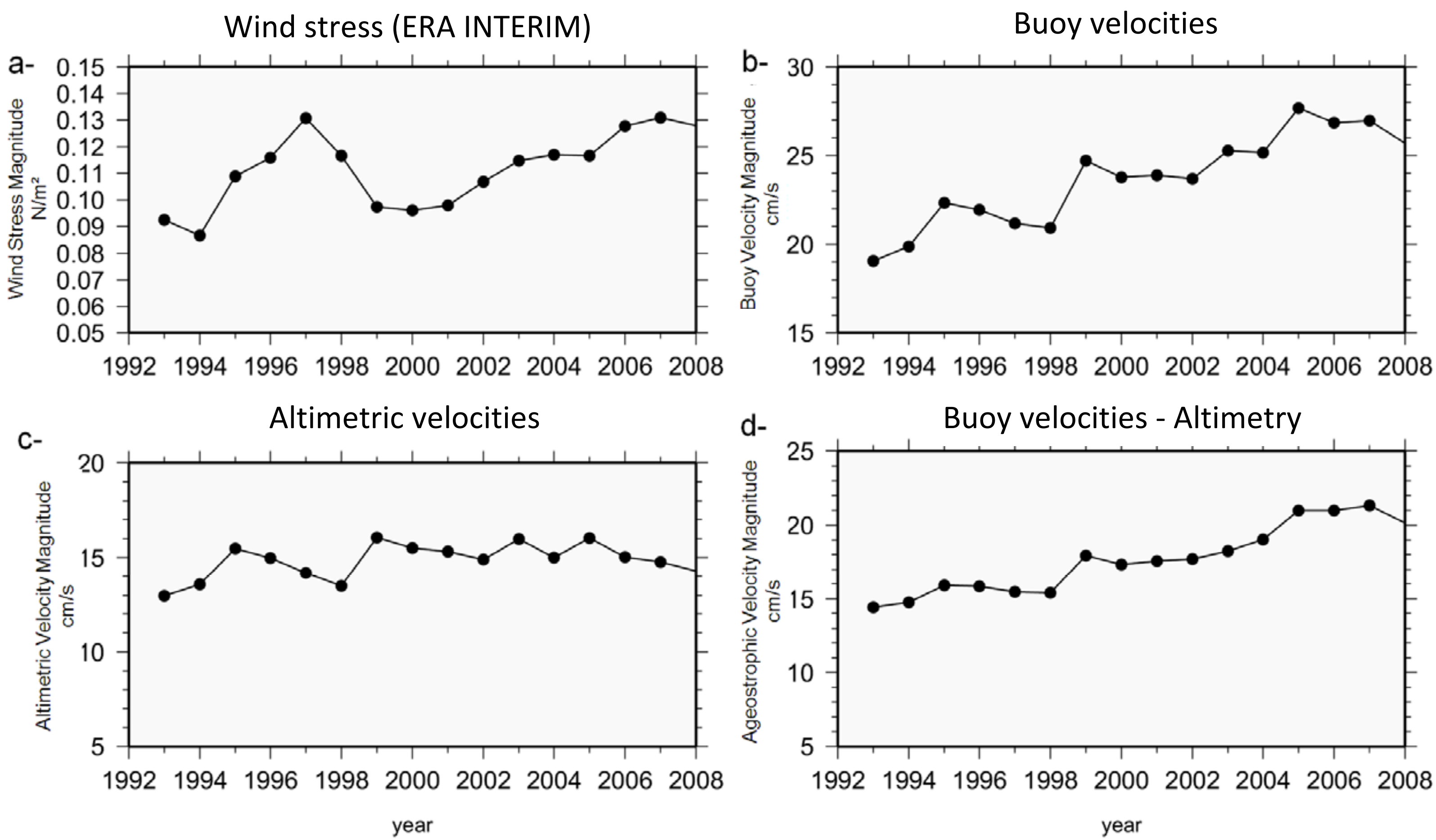
✓Can not be explained by a change in stratification

De decrease => β and |θ| increase

Modelling Ekman currents

Rio et al, 2011

Global yearly means



GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L10606, doi:10.1029/2011GL047393, 2011

Spurious trends in global surface drifter currents

Semyon A. Grodsky,[1] Rick Lumpkin,[2] and James A. Carton[1]

Received 7 March 2011; revised 13 April 2011; accepted 14 April 2011; published 26 May 2011.

[1] The Global Drifter Program (GDP) has been measuring near-surface ocean currents with surface drifters since 1979. At least half of the World Ocean now has drifter velocity time series longer than 15 years. The availability of this data opens new opportunities to explore observationally how ocean circulation responds to changing surface forcing. In this paper we report evidence of an apparently spurious acceleration of global surface drifter currents. This rapid acceleration occurs in a pattern reflecting the geographic distribution of mean surface winds. For example, in the westerly wind region of the Southern Ocean this strengthening is at least 0.5 cm/s per year eastward, while in the easterly trade wind region of the tropics this strengthening is on average 0.25 cm/s per year westward. One possible explanation we explore is that the bias is due to the presence of some undrogued drifters whose frequency of occurrence changes in time and whose windage is significantly greater than that of the drogued drifters. This paper is dedicated to the memory of Professor Peter Niiler, who first suggested this explanation. **Citation:** Grodsky, S. A., R. Lumpkin, and J. A. Carton (2011), Spurious trends in global surface drifter currents, *Geophys. Res. Lett.*, *38*, L10606, doi:10.1029/2011GL047393.

[3] The SVP drifters consist of a spherical surface buoy connected to a submerged nylon 'holey sock' drogue which allows the drifter to track the horizontal motion of water parcels at a nominal depth of 15 m. Most of these devices have been manufactured by four companies, Technocean, Metocean, Pacific Gyre, and Clearwater. In 2002, in order to reduce manufacturing costs, a new, more compact design was presented in the Data Buoy Cooperation Panel Specification revision 1.2. In this mini-drifter redesign, the non-dimensional ratio of the drag exerted by the drogue to the drag exerted by all other components was maintained at a constant value of 40:1 in order to try to constrain wind-forced downwind slip relative to the 15 m current to be less than 0.1% of wind speed [*Niiler et al.*, 1987, 1995].

[4] One well-known source of systematic error in drifter currents results from a mechanical failure of the buoy-drogue connection which is vulnerable to breakage because of constant flexing. When the drogue is lost, wind slippage increases from O(0.1%) to about 1% of the wind speed [*Niiler and Paduan*, 1995; *Poulain et al.*, 2009] through a combination of wind drag on the exposed portions of the buoy, and the impact of vertical shears of wind-driven

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be attributed to differences in the vertical scale of wind-driven currents in the tropics and mid-latitudes (easterly and westerly winds, respectively).

[17] Examination of α^d for different years shows that the problem of unidentified undrogued drifters in the "drogue-on" data set arose sometime around late 2003 to early 2004 and steadily become worse until 2006–2007 (Figure 3). Then, very likely due to the phase-in of tether strain gauge technology, the problem gets better by end 2009. Interestingly, the time series of anomalous currents in Figure 2 also indicates significant changes in drifter currents during that same time period. Ultimately, these drifter current changes during the 2000s are the major cause of the spurious temporal trends evaluated over longer periods. Also note that the anomalous behavior of drifter currents does not seem to depend on the particular drogue manufacturer. We suspect, although cannot yet verify, that the reduced effectiveness of the submergence drogue detection technique is in fact a result of the switch to the smaller mini-drogue design.

4. Summary

[18] The Global Drifter Program has been providing

authors will focus on the reasons for the 2000s drogue detection failure and exploring ways to correct these data. Until this reassessment is complete, we recommend that users interested in exclusively drogue-on data use only the first 90 days of data for drifters in the time period January 2004 through December 2008.

[21] **Acknowledgments.** This research is supported by the NOAA/CPO/CCDD. We appreciate comments by P.-M. Poulain and anonymous reviewer.

[22] The Editor thanks Pierre-Marie Poulain and an anonymous reviewer for their assistance in evaluating this paper.

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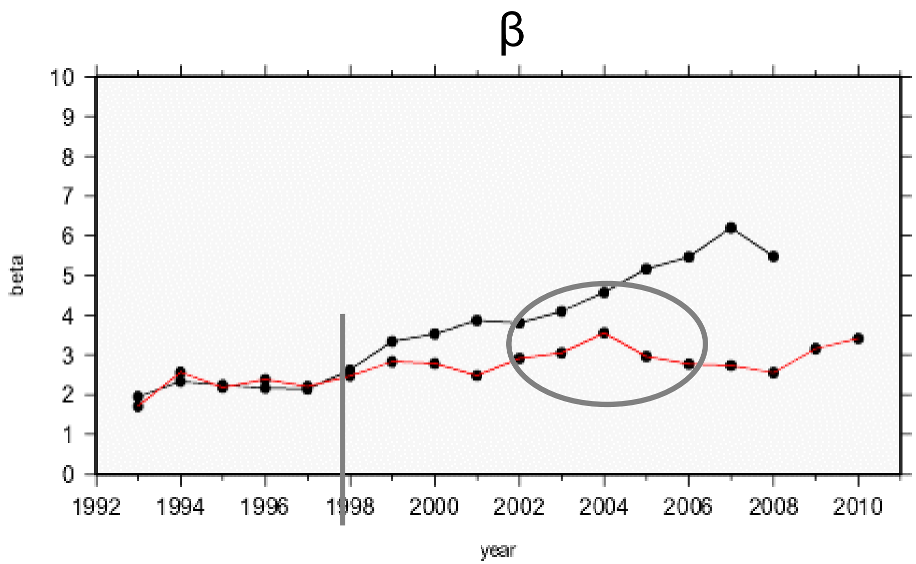
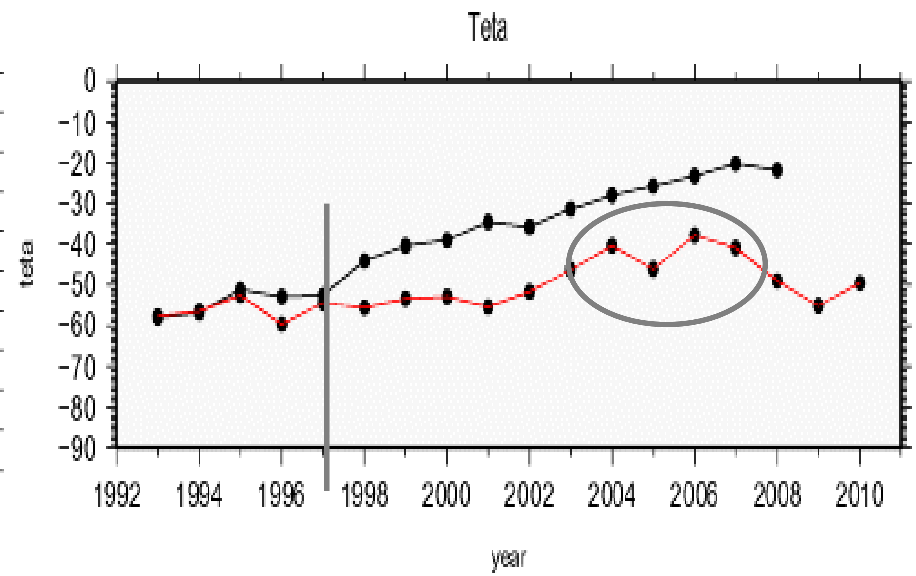
Bonjean, F., and G. S. E. Lagerloef (2002), Diagnostic model and analysis of the surface currents in the tropical Pacific Ocean, *J. Phys. Oceanogr.*, *32*, 2938–2954.

Carton, J. A., and B. S. Giese (2008), A reanalysis of ocean climate using Simple Ocean Data Assimilation (SODA), *Mon. Weather Rev.*, *136*, 2999–3017, doi:10.1175/2007MWR1978.1.

Modelling Ekman currents

β and θ computed over the global ocean by year





ALL

First three months of each trajectory only (Grodsky et al, 2011)

11 000 703 data

Only 10% of the data kept!

1 107 262 data

Need for cleaning the AOML drifting buoy dataset for undetected undrogued drifter

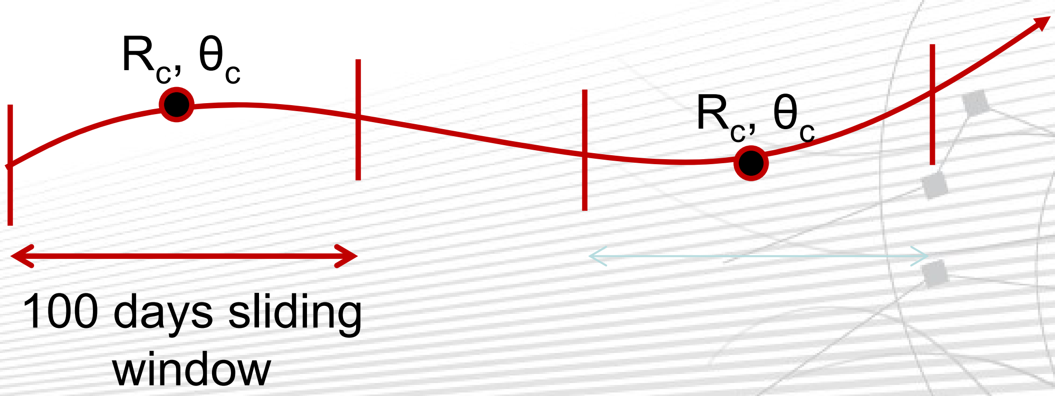
Detecting the drogue loss: Method

✓A new Ekman model is computed based on the first three months of the AOML drifter trajectories (by latitudinal band and by month to take into account the spatial and seasonal change in stratification)

✓Altimetric geostrophic currents (AVISO) are subtracted from the drifter velocity
-> 'Ageostrophic' drifter velocity

✓Ekman currents are subtracted fom the drifter currents -> 'residual' drifter velocity

✓Vectorial correlation between the 'residual' drifter velocity and the wind is computed along the drifter trajectories (only trajectories longer than 200 days are considered)



Detecting the drogue loss: Example

— 'Ageostrophic' drifter velocity vs Wind

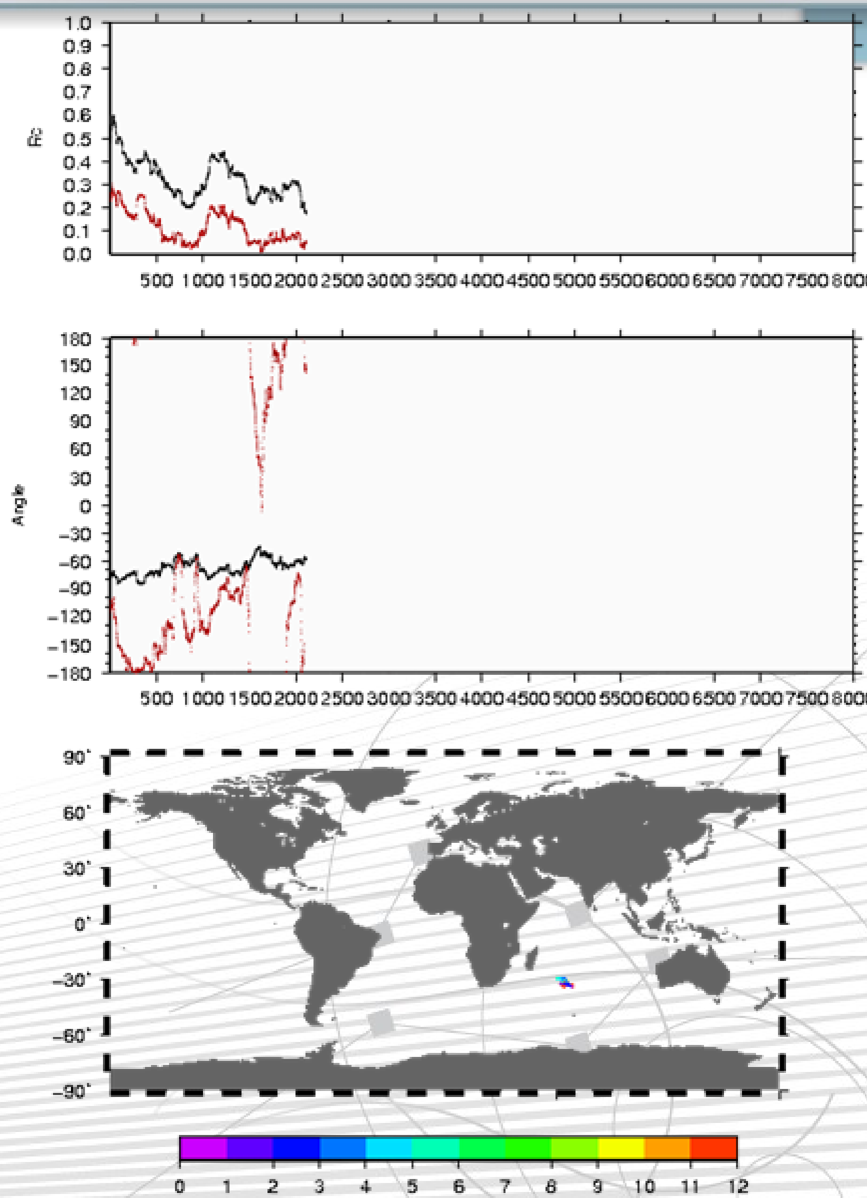
Correlation > 0.3
Ekman angle ~70°

— 'Residual' drifter velocity vs Wind

Correlation coefficient drops (<0.2)
Correlation angle uncoherent

⇩

We are confident that the drogue is still ON



Detecting the drogue loss: Example

— 'Ageostrophic' drifter velocity vs Wind

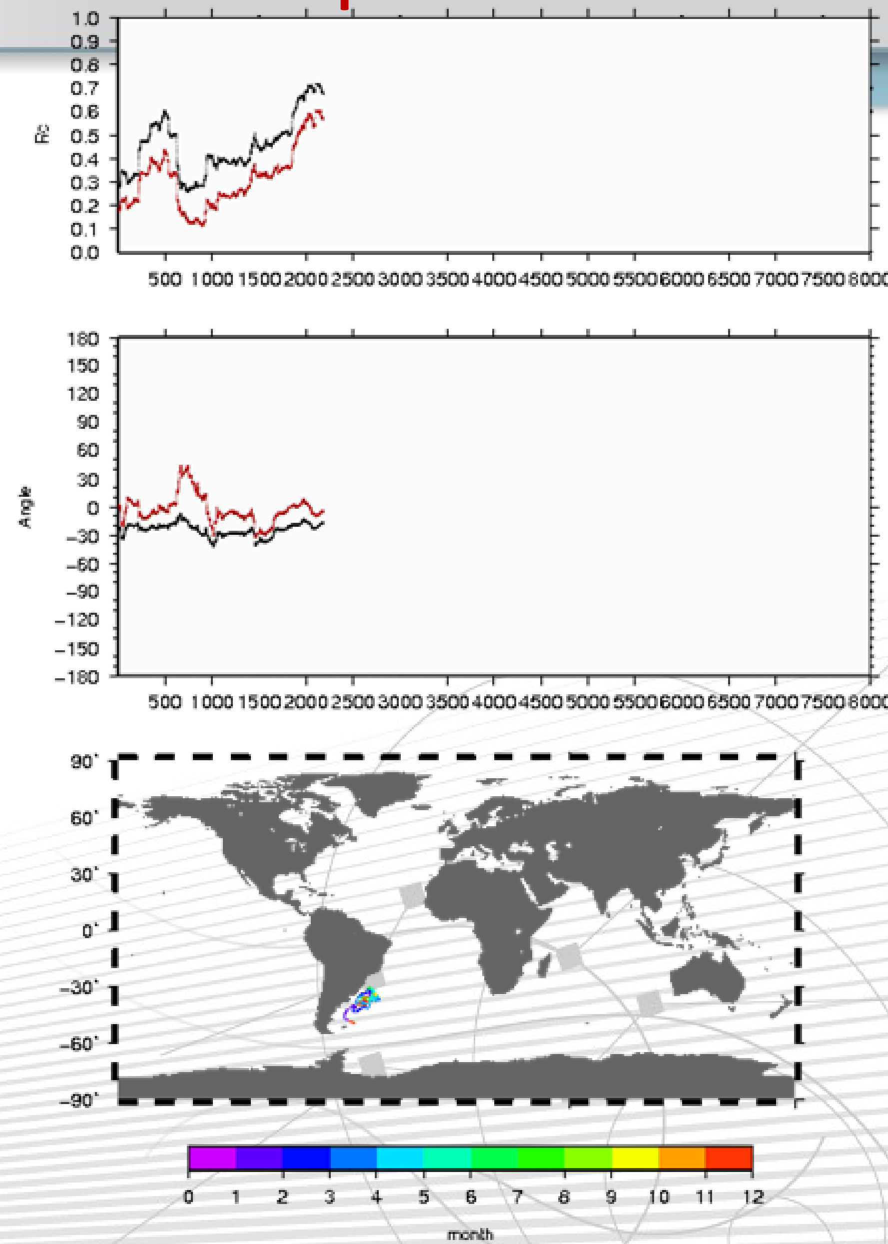
Correlation > 0.3
Ekman angle ~30°

— 'Residual' drifter velocity vs Wind

Correlation coefficient still high (>0.3)
Correlation angle nearly 0°

⇩

We are confident that the drogue has been lost



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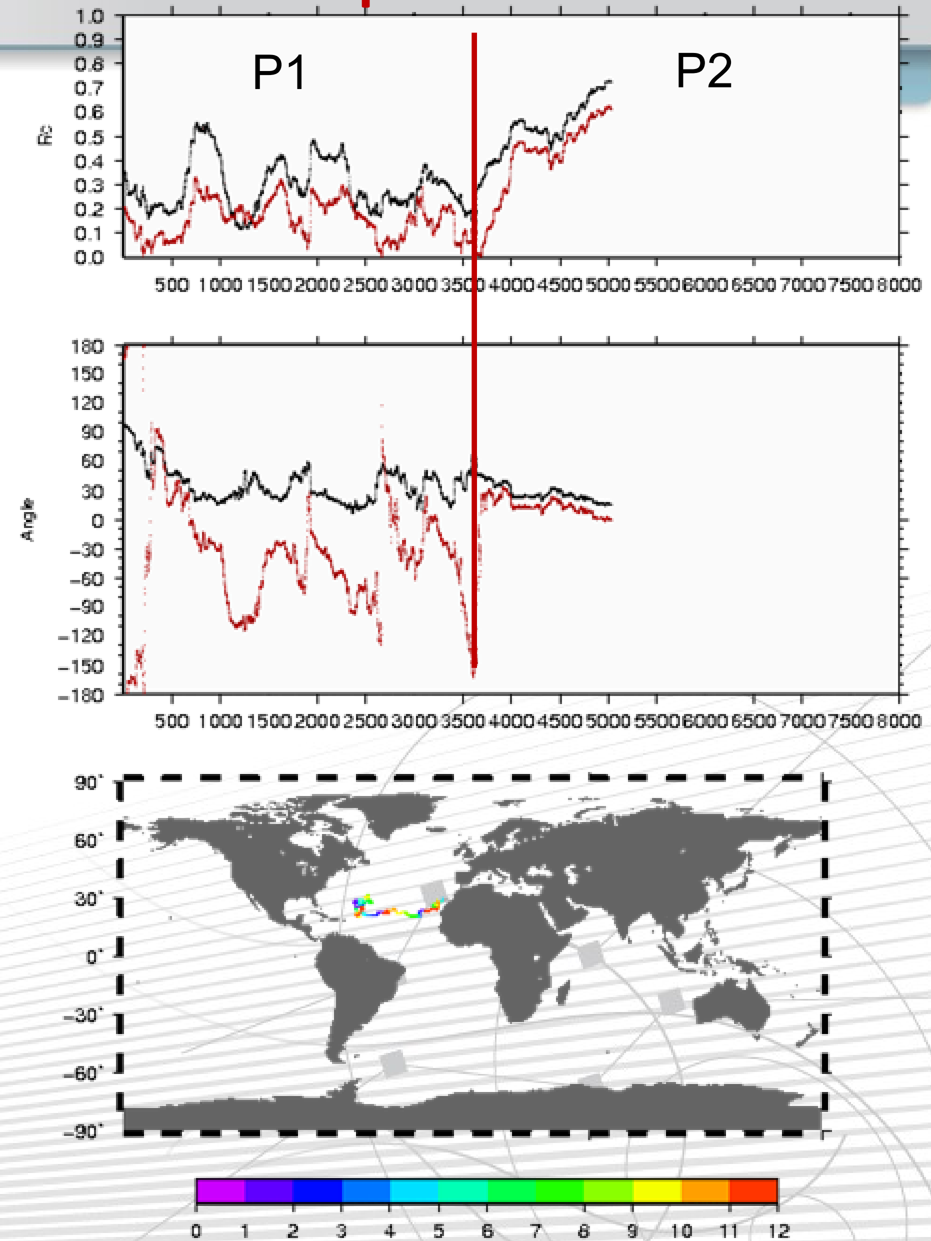
Detecting the drogue loss: Example



— ‘Ageostrophic’ drifter velocity vs Wind

P1: Correlation > 0.3 P2: Correlation ↗
Ekman angle ~60°

— ‘Residual’ drifter velocity vs Wind

P1: Correlation coefficient low(<0.3)
Correlation angle uncoherent

P2: Correlation coefficient increases
Correlation angle nearly 0

⇩

We are confident that the drogue is ON during P1 and is off during P2

Detecting the drogue loss and computing a slippage correction

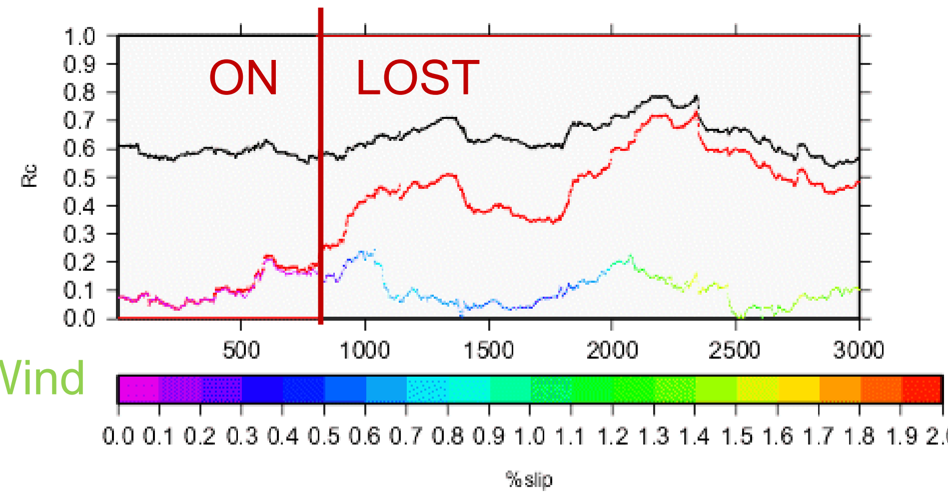
'Residual' velocities = Vbuoy-Valti-Vekman-αWind   α ranging from 0% to 2%

We determine α= α_{best} that minimizes the vectorial correlation between the 'residual' velocity and the wind.

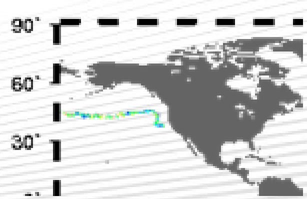
— Vbuoy-Valti vs Wind

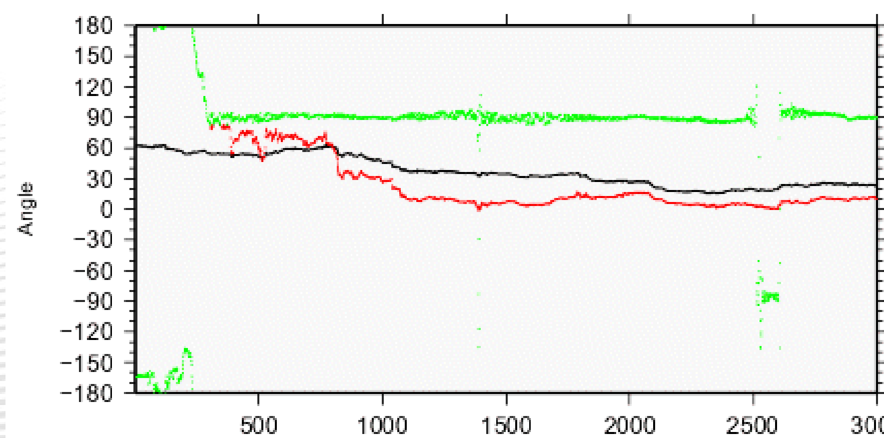
— Vbuoy-Valti-Vekman vs Wind

— Vbuoy-Valti-Vekman-α_{best}Wind vs Wind



<u>α>0.1% => the drogue has been lost</u>

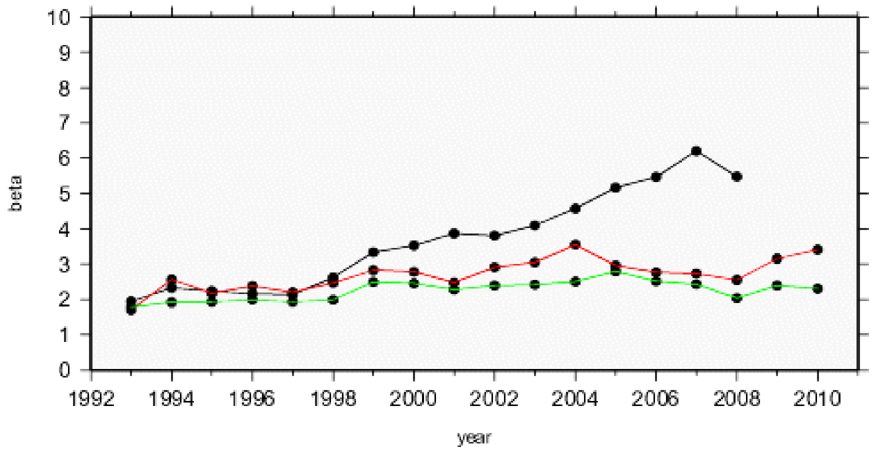




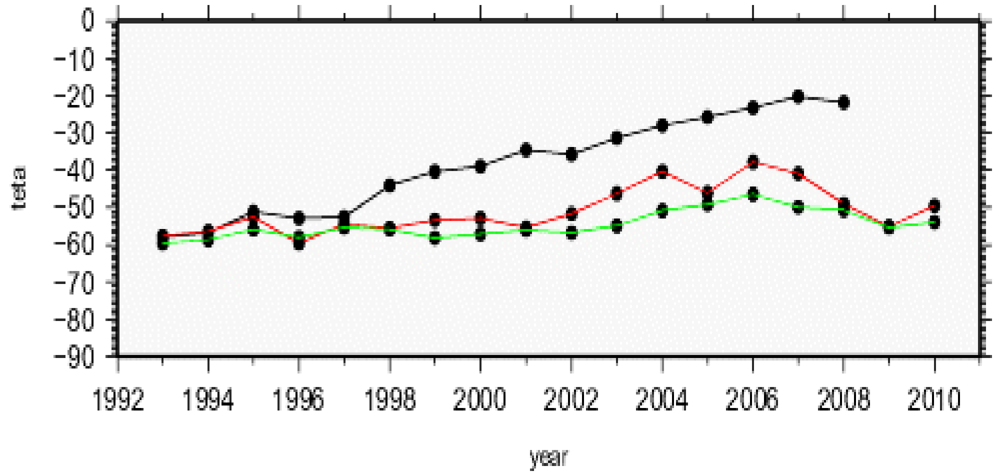
Modelling Ekman currents

β and θ computed over the global ocean by year

β



θ



ALL (black line)		11 000 703 data
First three months of each trajectory only (Grodsky et al, 2011) (red line)		1 107 262 data
Only drogued drifters (green line)		1 873 443 data (out of ~7 000 000 Data from more than 200 days long trajectories)=~27%

Conclusion

- As described in Grodsky et al, 2011, the present global drifter array suffers for a problem of drogue loss detection.

- As a consequence, the physical content of the velocities measured by the drifter array has changed over time: Instead of measuring the ocean currents at 15m depth, a growing number of drifters measure the current at the surface + a velocity component due to the direct action of the wind on the surface buoy

- Ekman model based on drogued drifter start to differ from Ekman model based on all drifters (drogued and undrogued) in 1997-1998

Conclusion

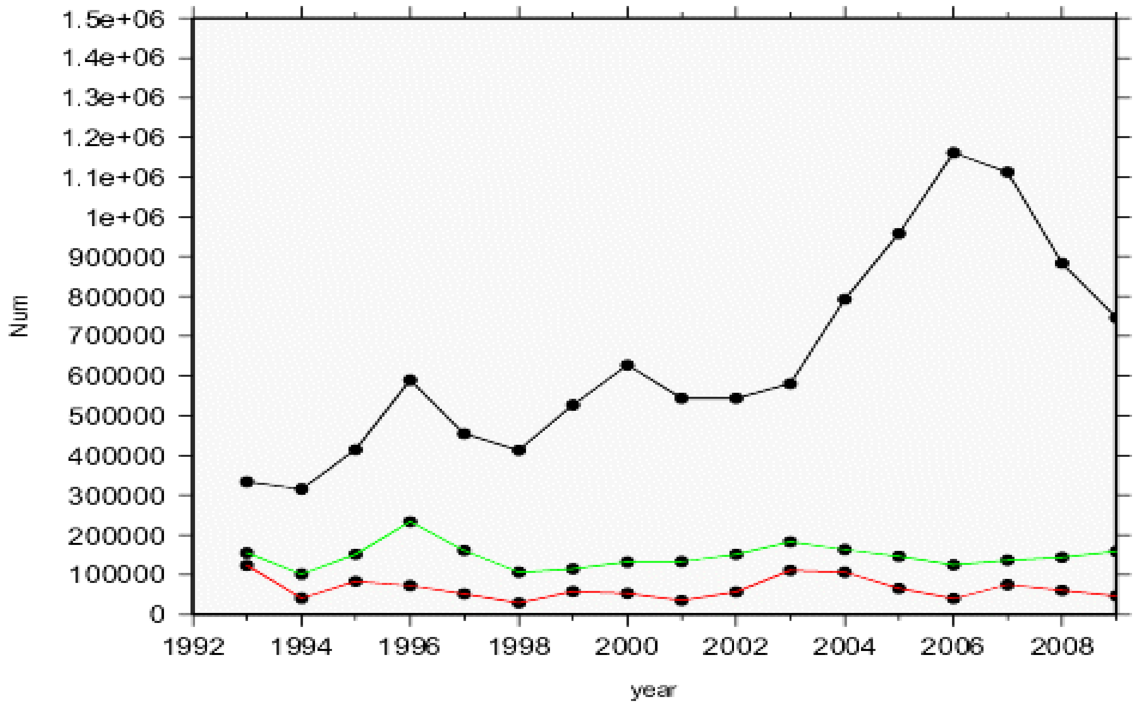
- This is a key issue for oceanographic studies – mainly interannual to decadal climate studies

- The oceanographic community urgently needs a cleaned dataset (both delayed-time and real time)

- Both a robust flag is needed (drog is on or off) and a slippage correction for undrogued buoys

- The combined use of altimetric data (geostrophic component of the current) together with wind data (Ekman component of the current) allows to detect the time of drogue loss

Number of data per year



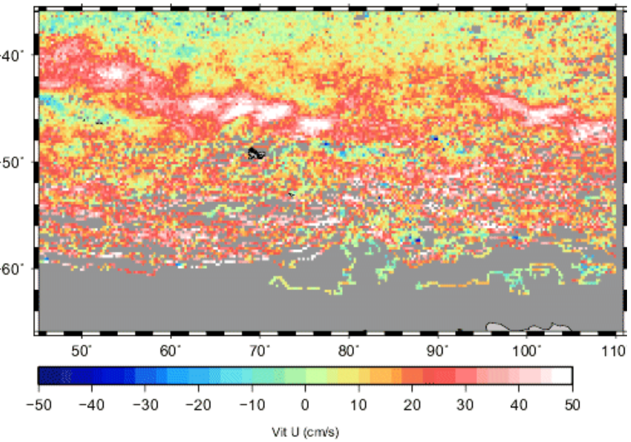
ALL

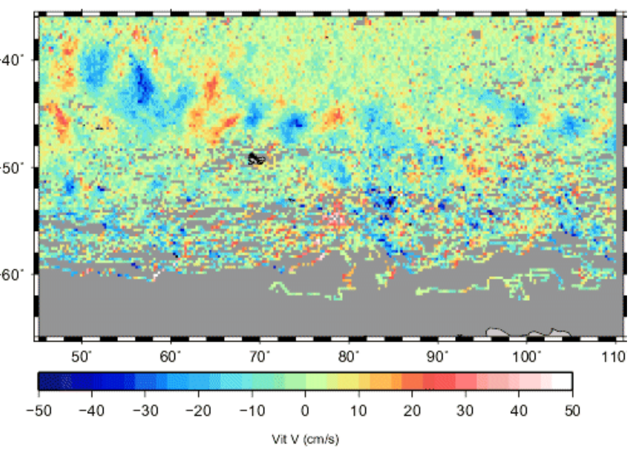
First three months of each trajectory only)

Only drogued drifter

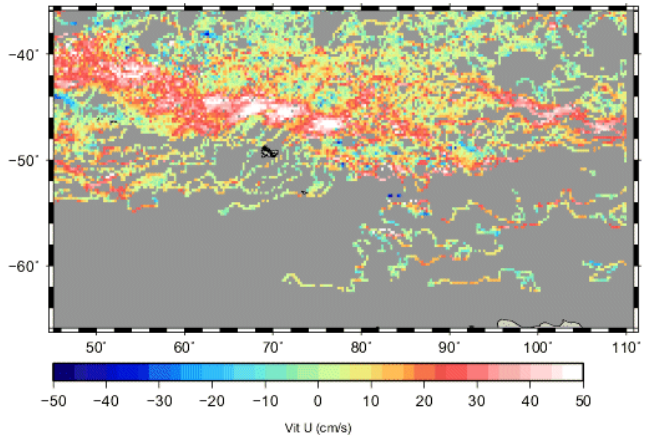
Impact on ocean mean currents:
Example in the Antarcic Circumpolar Current

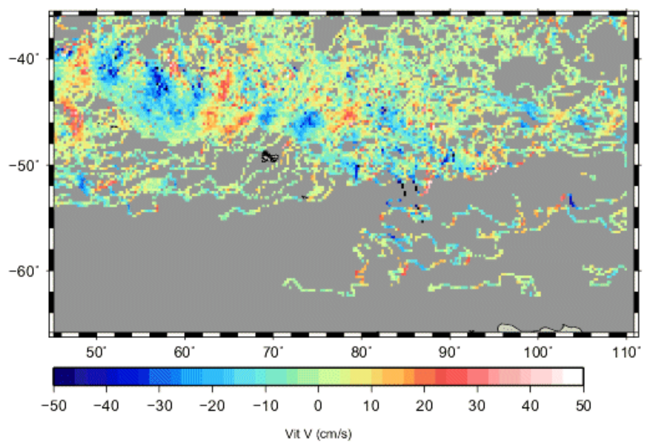
New Ekman model
ALL BUOY (drog ON and OFF)





New Ekman model
BUOY with drog ON only





New Ekman model
+ Slip correction
ALL BUOY (drog ON and