West Florida Shelf Mean Circulation Observed with Long-Term Moorings

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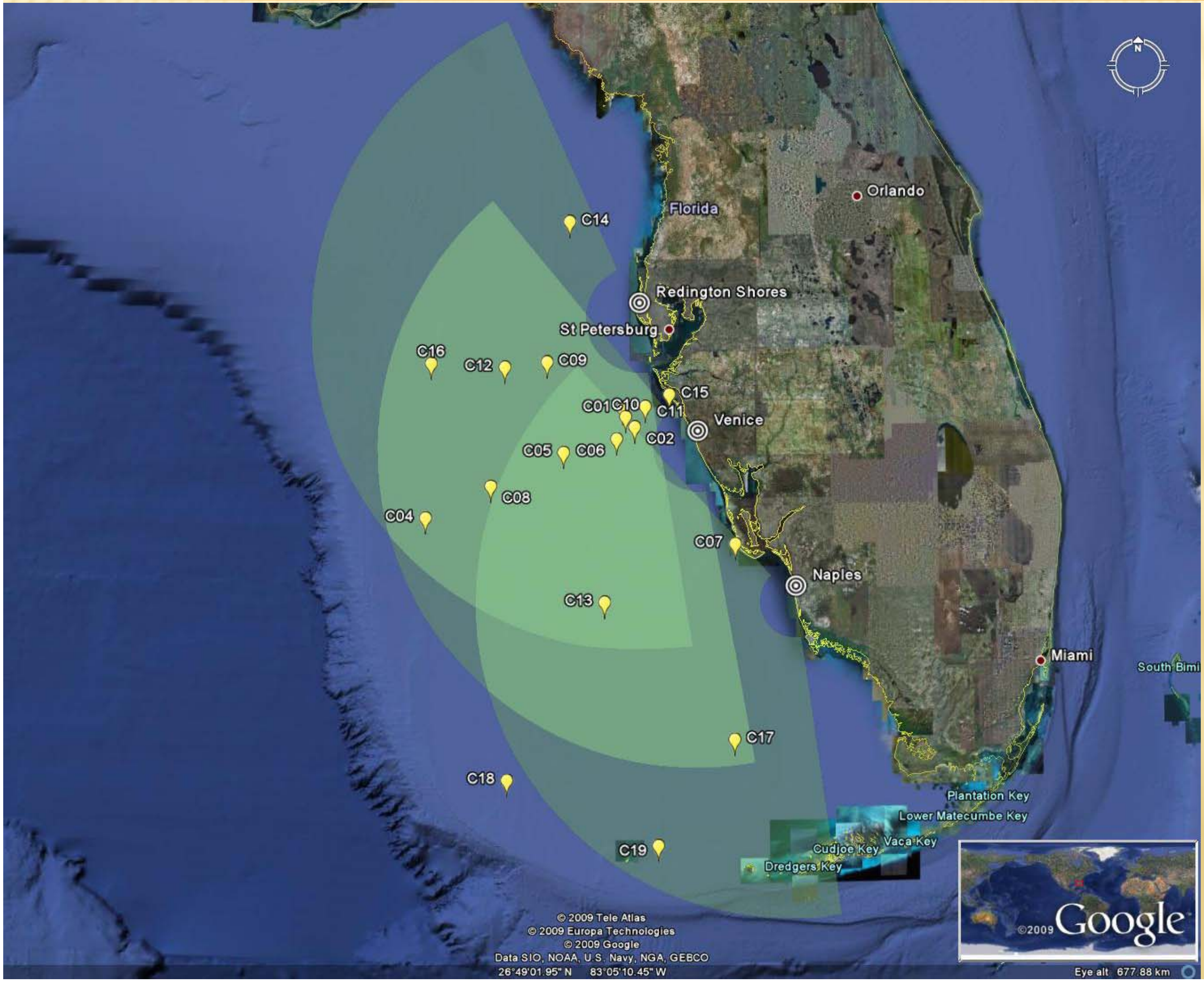
WFS observation systems

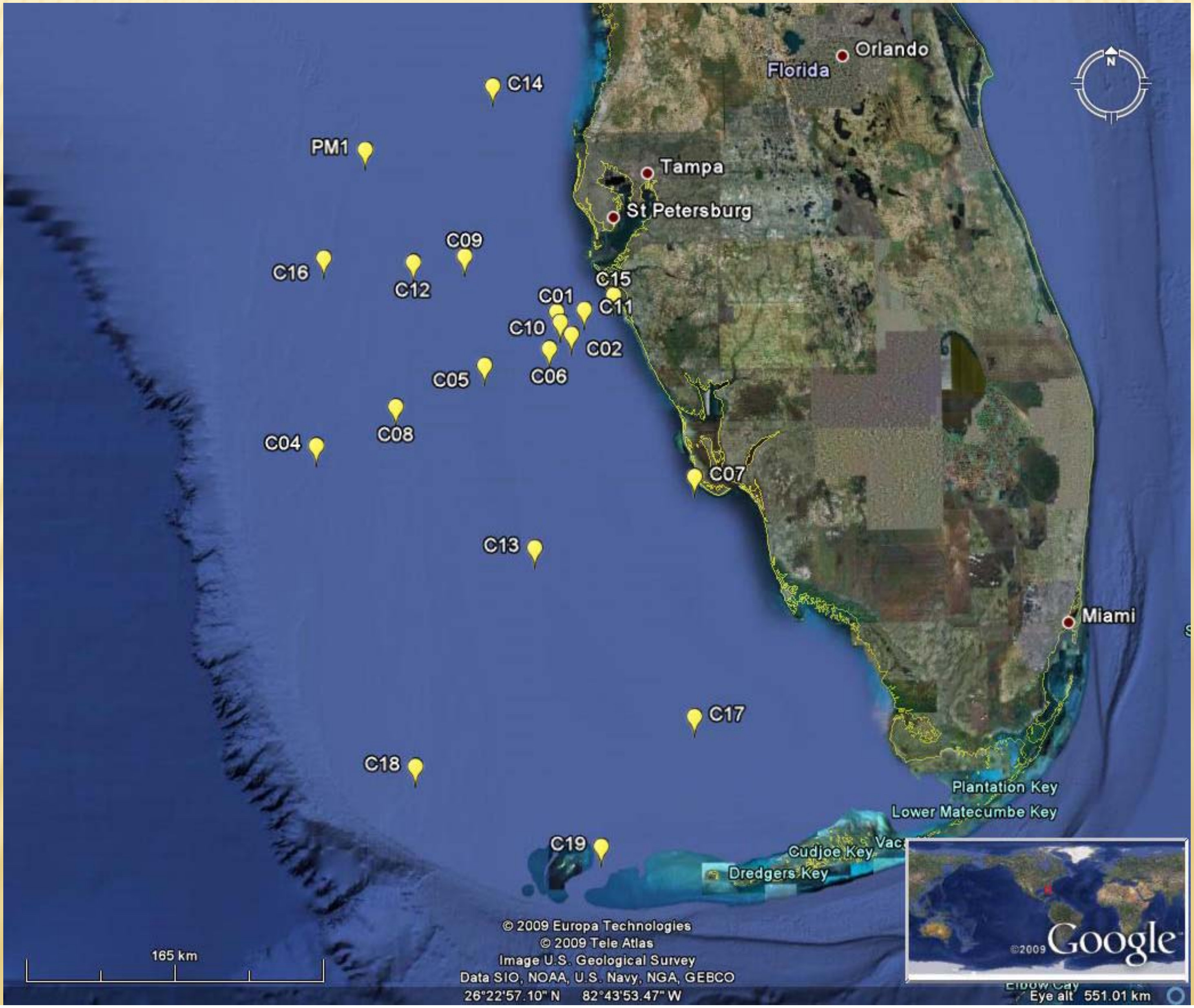


- ADCP array
- HF radar array
- Gliders
- BSOP

Outline

- Moored observations
- Depth-averaged mean flow pattern
- Vertical profiles of the mean flow
- Velocity vertical veering
- The physics
- Summary

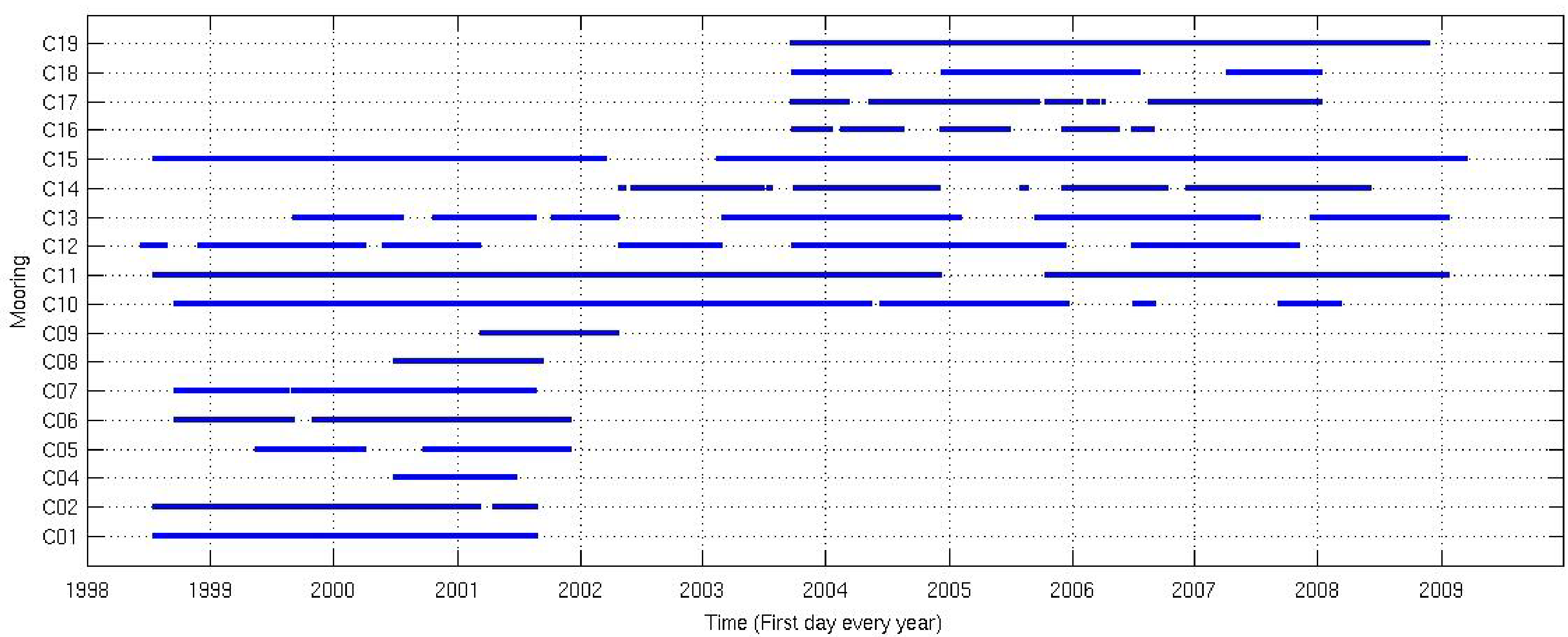
ADCP Moorings on the West Florida Shelf



Timeline of the ADCP Moorings

Record length

- \> 3 yrs: 12 moorings
- \> 7 yrs: 4 moorings
- \> 10 yrs: 2 moorings



Standard error ε of mean velocity

$$\varepsilon = \sigma / \sqrt{n}$$

$\sigma \rightarrow$ the standard deviation of the vel component (36-hr lowpass filtered)
$n \rightarrow$ the number of independent observations

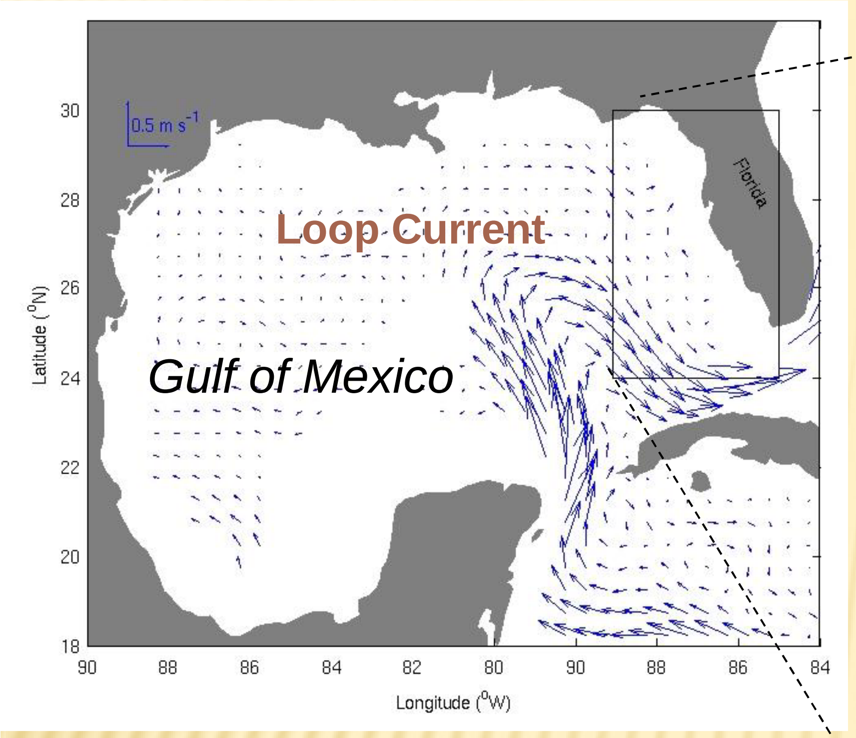
$$n = T/\tau$$

$T \rightarrow$ the record length
$\tau \rightarrow$ the decorrelation time scale

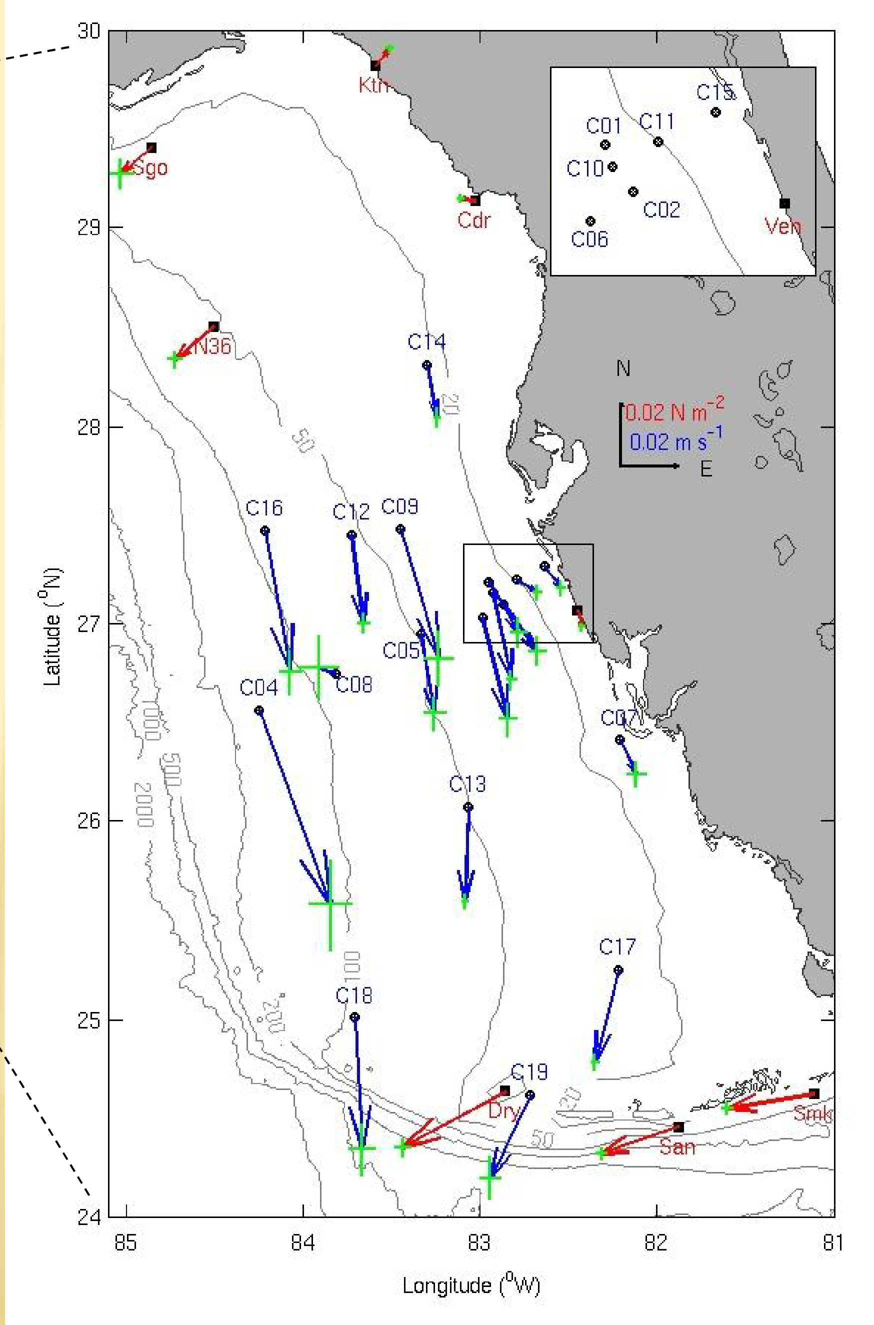
$\tau \approx 2 \sim 4$ days, for WFS
$\tau \approx 2 \sim 3$ days, for MAB (*Beardsley & Boicourt* 1981; *Lentz* 2008)

τ = 5 days → conservative estimates

Mean surface geostrophic velocity
(*Rio et al.* 2005)

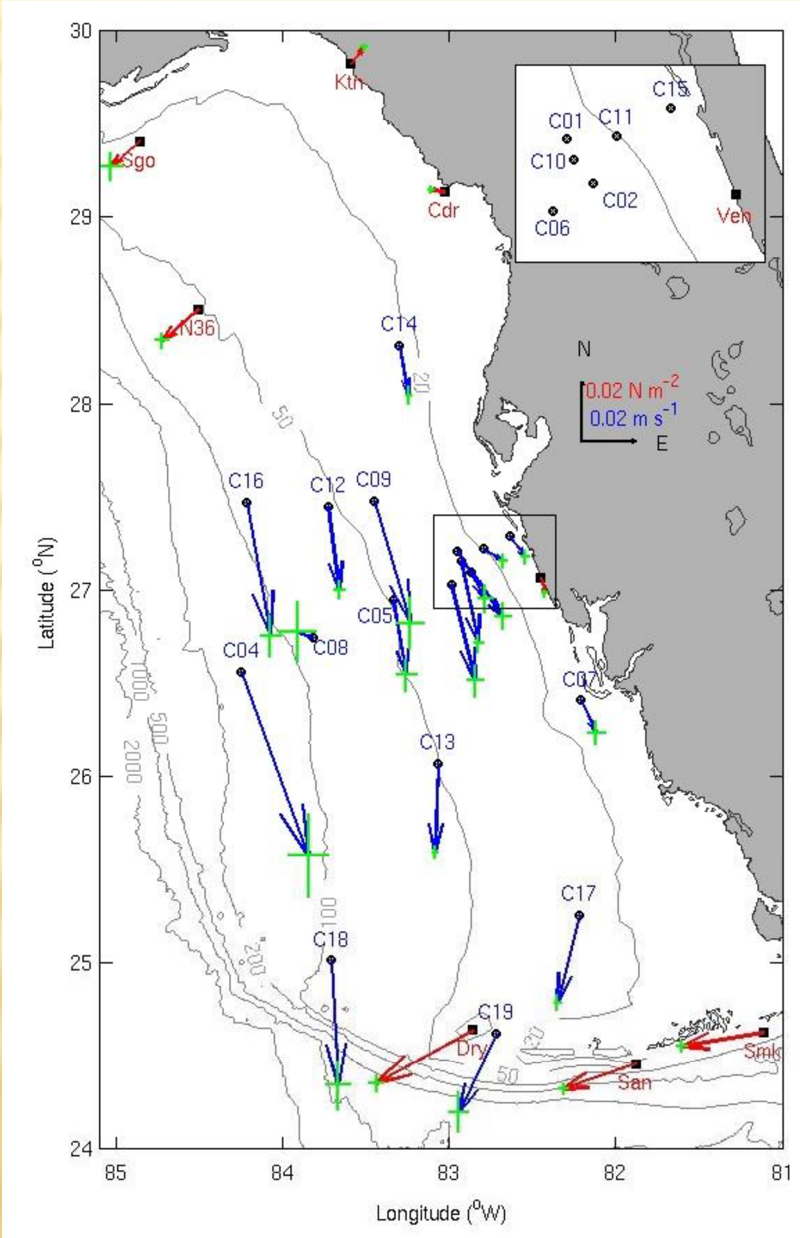


Mean winds & depth-averaged vel



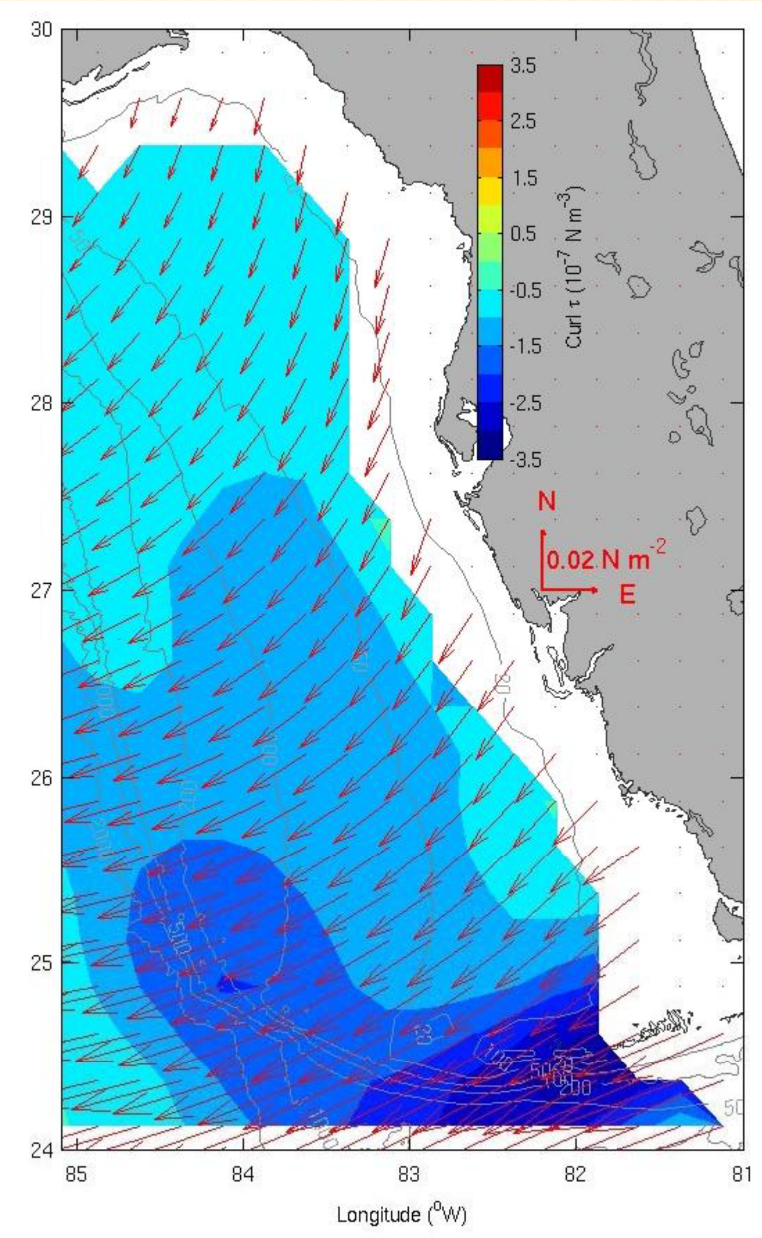
Mean wind stress
Mean currents (μ)
Standard errors ($\mu \pm \varepsilon$)

Mean winds and depth-averaged velocity

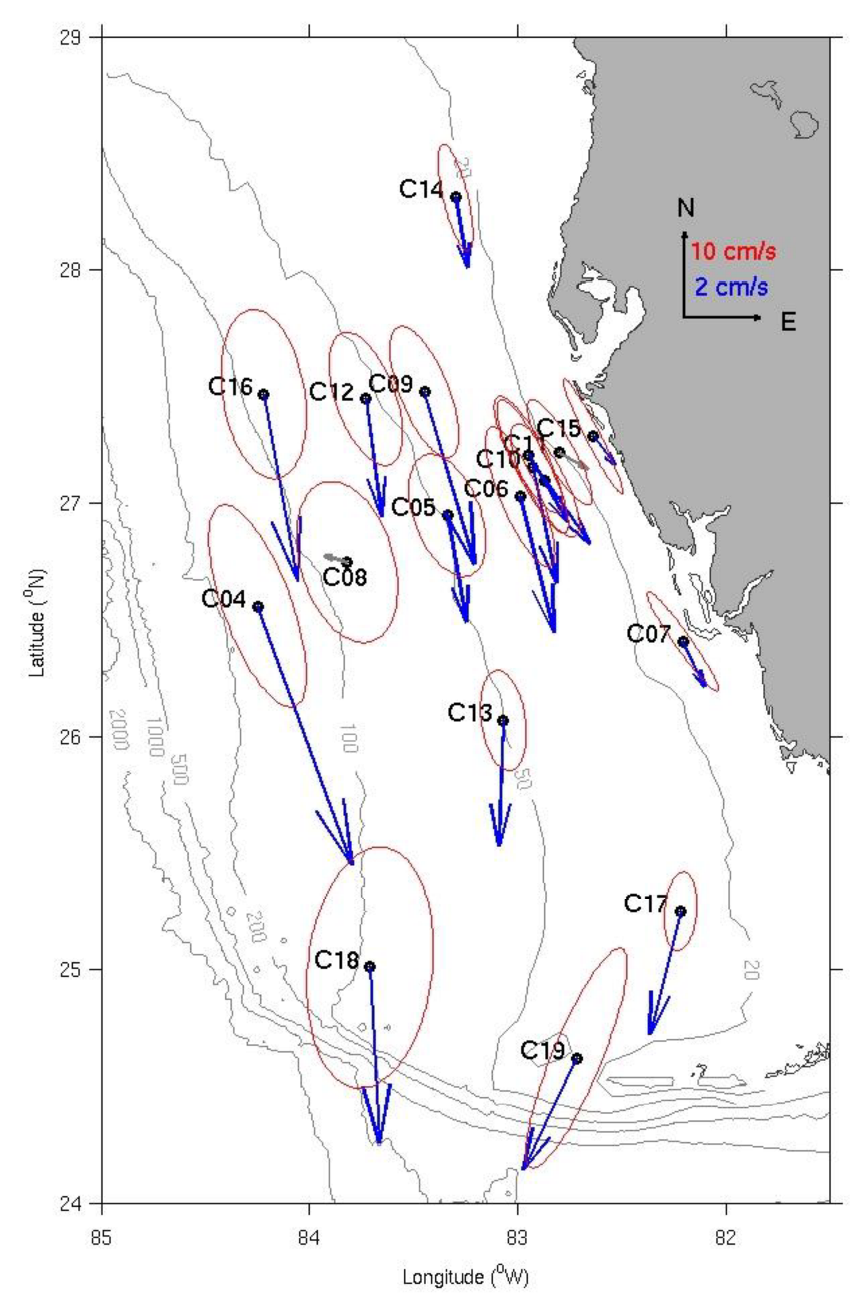


Mean wind stress τ_w & curl τ_w

(SCOW, *Risien & Chelton* 2008)



Depth-averaged mean & principal axis currents

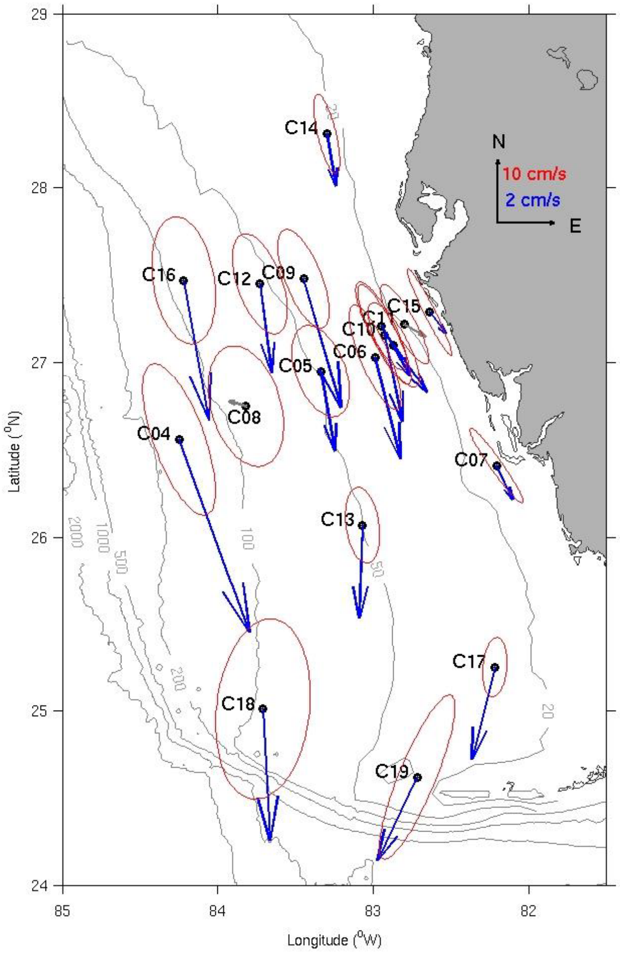


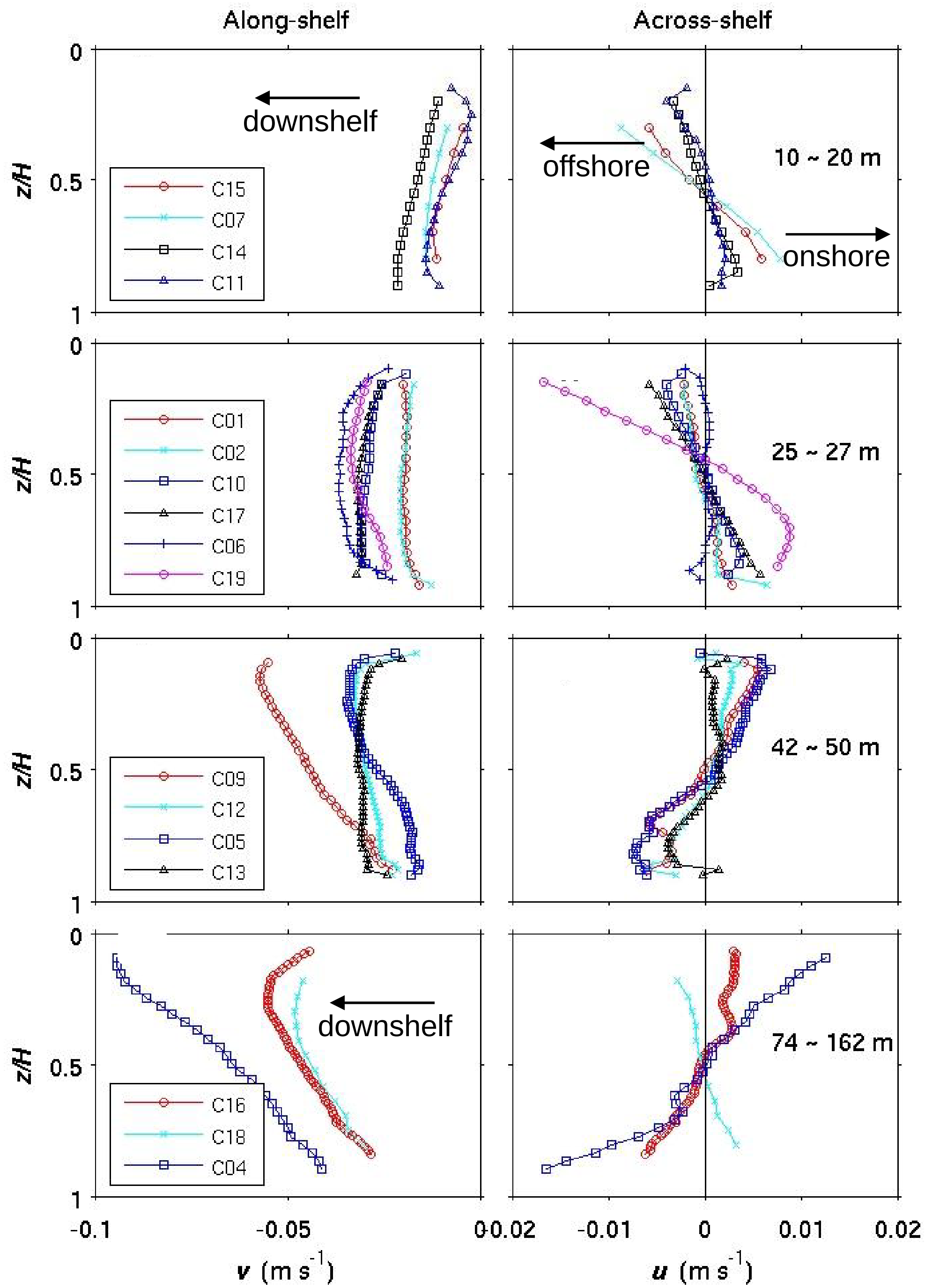
Along-shelf direction

- Direction of the principal axis of the 36-hr lowpass filtered currents
- Direction of depth-averaged mean currents → depth-averaged mean across-shelf flow is zero (*Lentz* 2008)

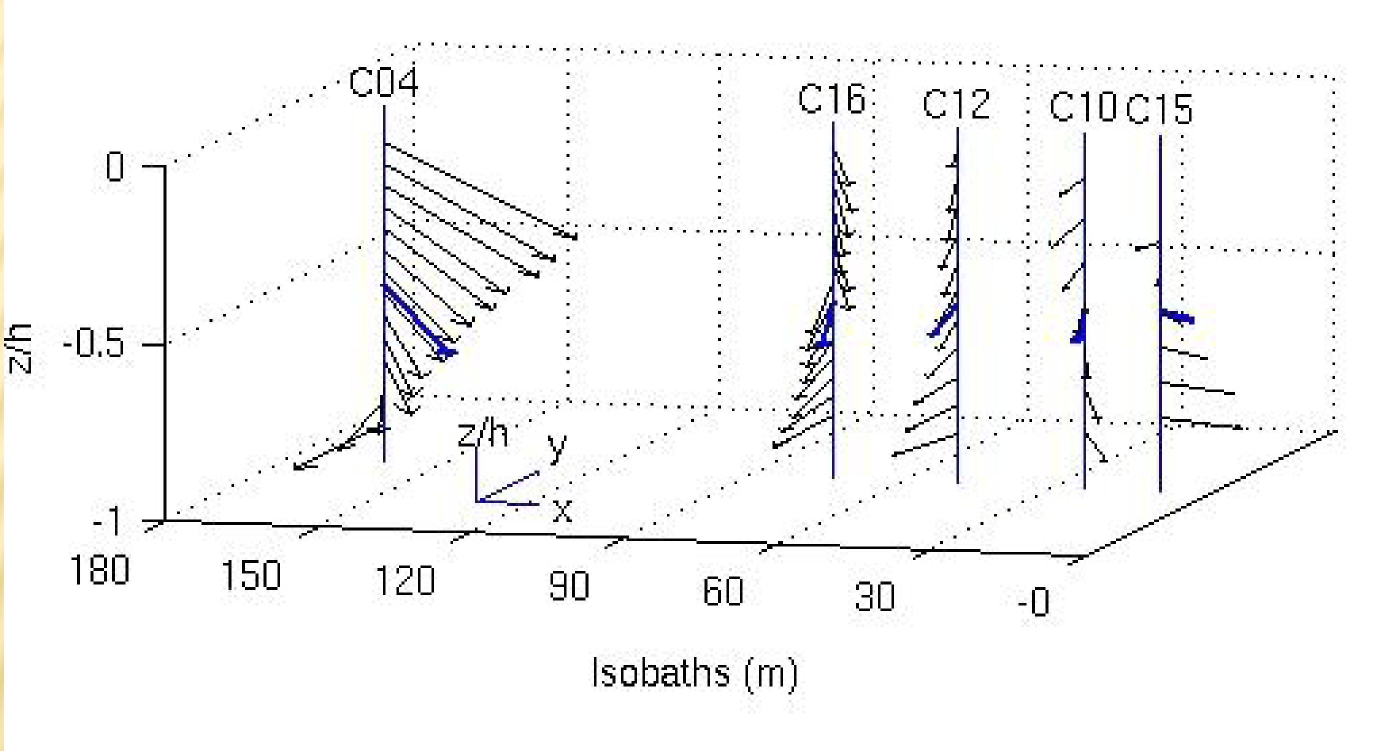
Zonation of mean vel profiles

Depth-averaged mean
& principal axis currents

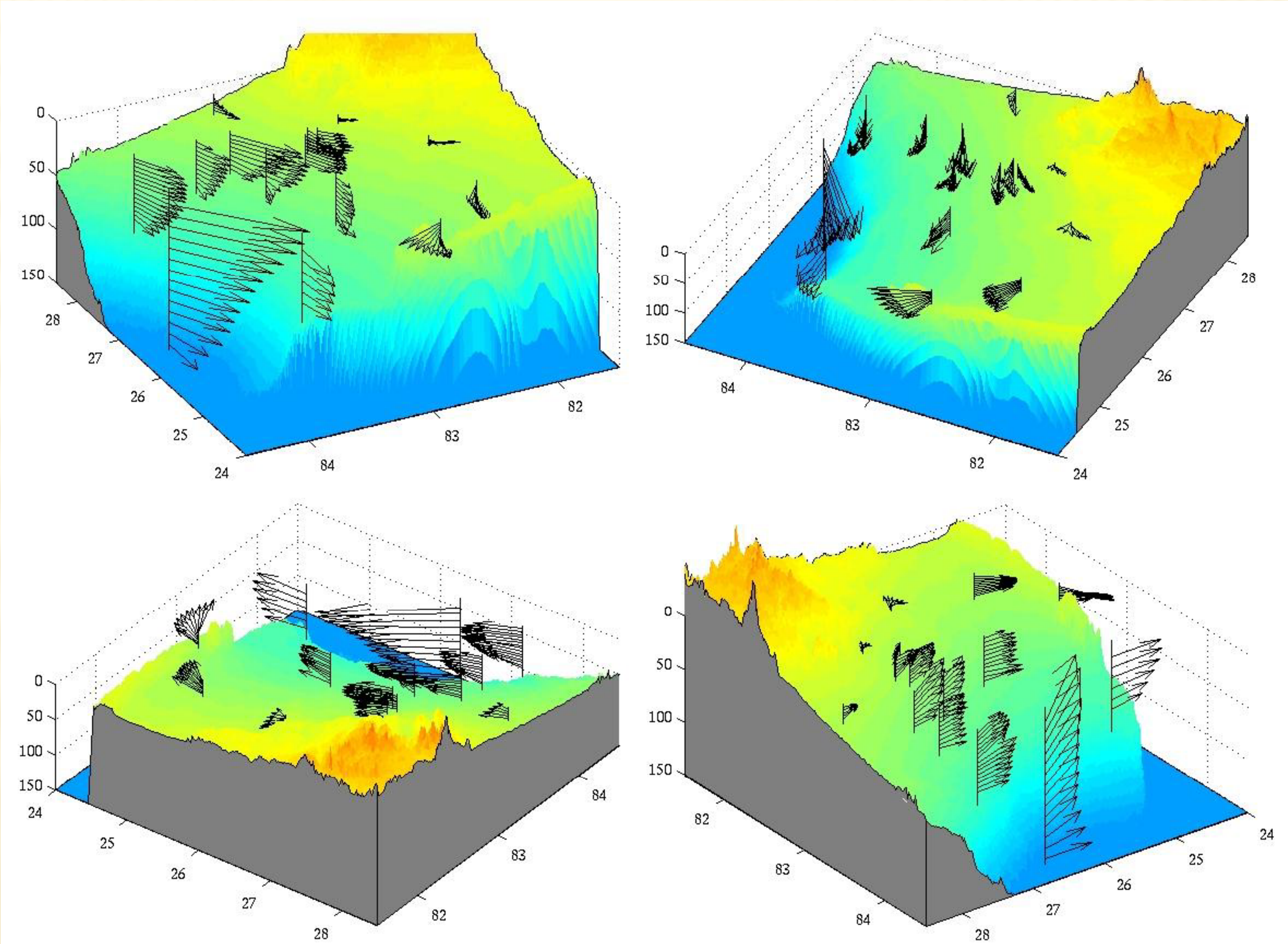


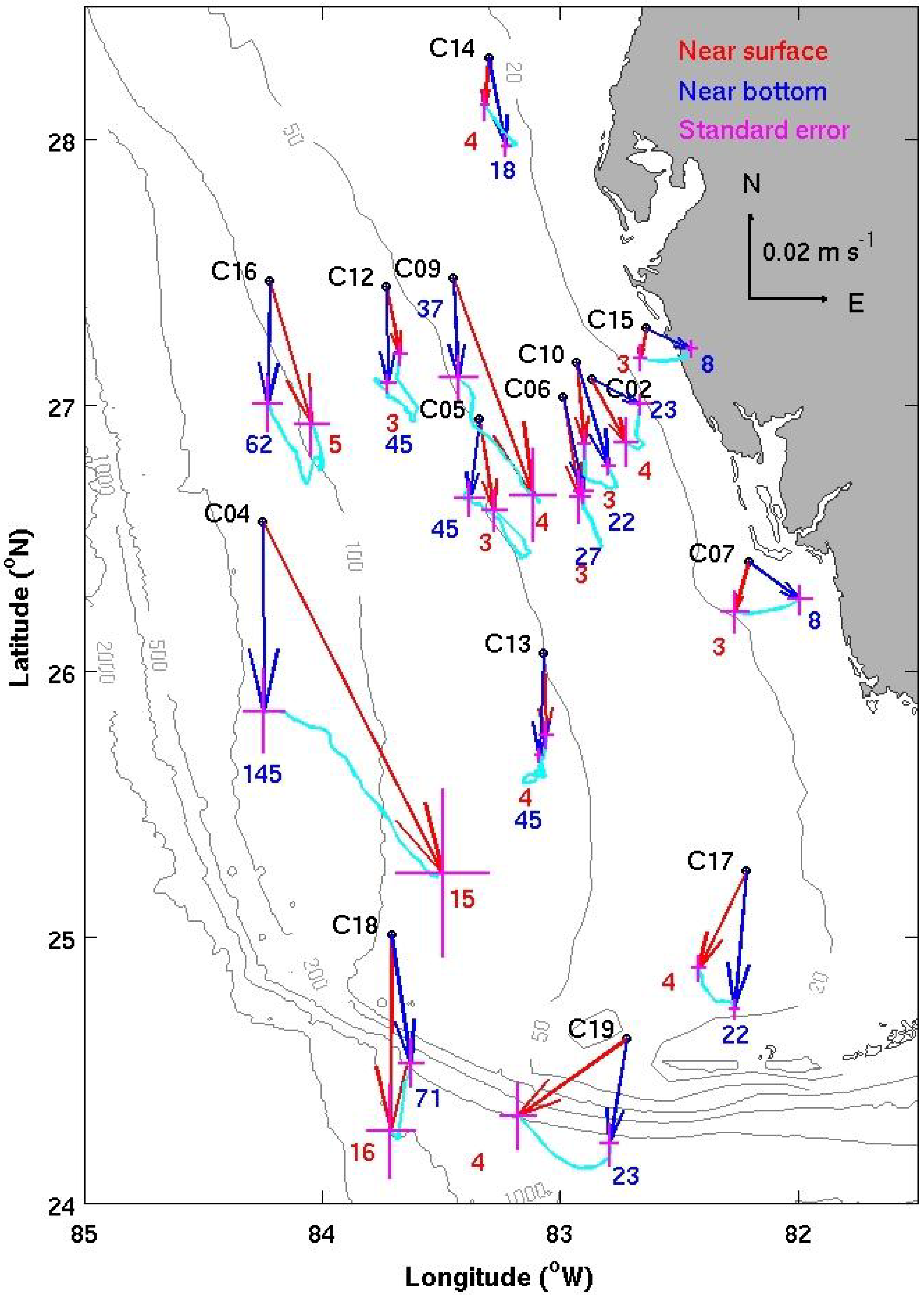


Vertical veering of mean velocity



Vertical veering of mean velocity

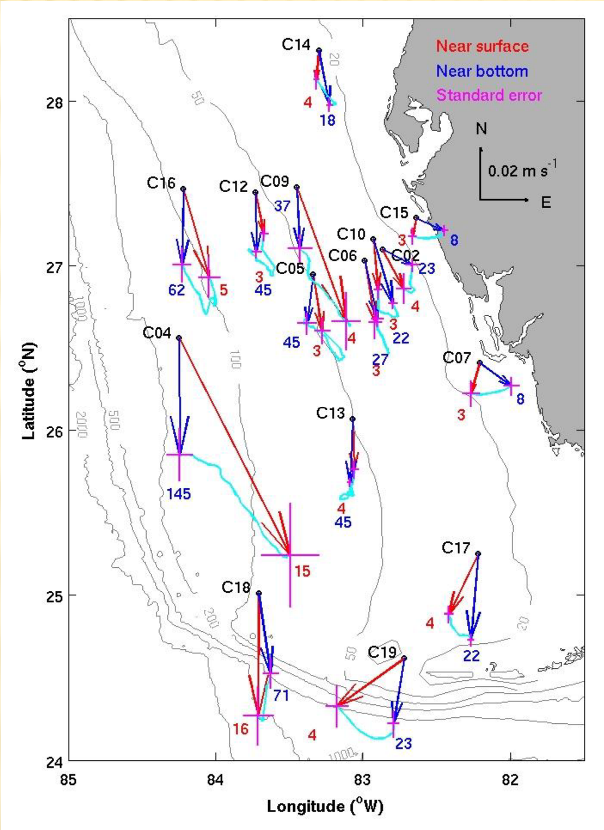




Zonation of mean velocity veering with depth on the WFS

The mean velocity vectors veer systematically with depth, with a change in polarization occurring across the shelf: The velocity vectors veer shoreward over shallow water and seaward over deeper water. Thus, along with its shelf-wide southward orientation, the mean flow is upwelling over shallow water and downwelling seaward from the inner shelf.

The Physics – inner shelf



Vorticity perspective:

$\partial w/\partial z < 0$ across the water column

Stretching of planetary vorticity filaments tends to balance the negative bottom stress torque that is imposed by the alongshore flow.

Vertical velocity w:

Kinematic boundary condition:
$w = u\partial h/\partial x = 3\sim8\times10^{-6}\ \mathrm{m\ s^{-1}}$

Curl of the bottom stress:
$w = (1/rf)\mathrm{curl}\tau_b = 5\sim10\times10^{-6}\ \mathrm{m\ s^{-1}}$

The inner portion of the inner shelf is governed by Ekman/geostrophic dynamics.

The Physics – outer shelf

Mass conservation

$$u\frac{\partial \rho}{\partial x} + v\frac{\partial \rho}{\partial y} + w\frac{\partial \rho}{\partial z} = 0$$

Assuming geostrophy

$$w\frac{\partial \rho}{\partial z} = \frac{1}{\rho_0 f}\left(\frac{\partial \rho}{\partial x}\frac{\partial p}{\partial y} - \frac{\partial \rho}{\partial y}\frac{\partial p}{\partial x}\right) = \frac{\nabla\rho \times \nabla p}{\rho_0 f}$$

$$w\frac{\partial \rho}{\partial z} = \frac{\rho_0 f}{g}\left(u\frac{\partial v}{\partial z} - v\frac{\partial u}{\partial z}\right)$$

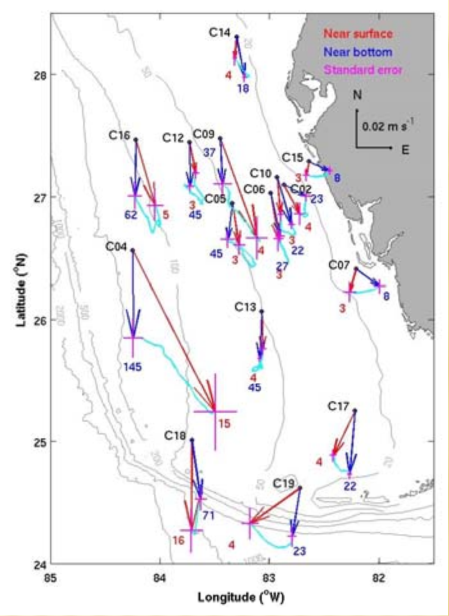
Express in polar form

$(u = V\cos\theta, v = V\sin\theta)$

$$w = -\frac{fV^2}{N^2}\frac{\partial \theta}{\partial z}$$

$$\partial\theta/\partial z > 0 \Rightarrow w < 0$$

→ downwelling across the geostrophic interior



Seaward from the local maximum, the wind stress curl-induced downwelling from the surface Ekman layer is accommodated through the adjustment of the density field, i.e., geostrophic veering.

SUMMARY

- ✓ The mean circulation on the WFS is described using long-term current measurements.
- ✓ The WFS mean flow is oriented approximately along-isobath and southward. The mean velocity vectors veer systematically with depth, shoreward over shallow water and seaward over deeper water.
- ✓ This polarization change implies that the mean flow is upwelling over shallow water and downwelling seaward from the inner shelf.
- ✓ Such a well-organized, three-dimensional coastal ocean circulation pattern, revealed by an unprecedented set of observations, and explained on the basis of wind forcing and density field adjustment, has important implications for both fisheries and red tide occurrences.

Weisberg et al. (2009), *Geophys. Res. Lett.* (submitted & revised)

ACKNOWLEDGEMENTS

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