Ocean Geostrophy from Satellite Altimetry and GOCE Data.

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Abstract

The geostrophic currents are the result of the geostrophy balance between the pressure gradient force and the Coriolis force. In lack of direct observations, the surface geostrophic currents (SGC) can be derived from the ocean dynamic height as a function of space and time. The dynamic height is the current-induced deviation of the actual sea level (e. g. observed by satellite altimetry) from the Earth's geoid (e. g. estimated from satellite gravimetry). In this paper, we evaluate the capabilities of a "full-potential" geoid estimated from the first 61-days cycle of the GOCE mission in estimating the global mean SGC that are derived and analyzed against a combined solution of several altimetric satellites (T/P, Jason 1/2, ERS-1/2, GEOSAT). Results are compared with those obtained from a GRACE-induced mean geoid for the period 2002/08-2009/08, as well as with mean circulation patterns from drifter buoys and from simulations of the ECCO Ocean General Circulation Model. We found GOCE clearly leads to significant improvements in determination and resolution of SGC globally except at the Equator (where special filtering of data is needed), with velocities and spatial patterns much closer to in-situ measurements of currents than those from GRACE data or ECCO model simulations.

Data sets and processing

Drifter Buoys

Data type: grids of 1 degree.
Geographical coverage: [-73, 85]x[0, 360]
Server: The GDP Drifter DAC (www.aoml.noaa.gov)

ECCO model

Data type: grids of 1 degree.
Geographical coverage: [-80, 79]x[0, 360]
Server: MITgcm (ecco.jpl.nasa.gov)
Time-span: 1993/01 to 2010/12

GOCE

Data type: release 01, direct solution , Nmax=240
Server: ESA (eo-virtual-archive1.esa.int)
Time-span: 61-days cycle

GRACE

Data type: ITG-Grace2010S
Server: Univ. Bonn (www.igg.uni-bonn.de/apmg)
Time-span: 2002/08 to 2009/08

Sea Surface Height

Data type: grids 1/4 degree
Geographical coverage: [-80, 82]x[0, 360]
Server: AVISO (www.aviso.oceanobs.com)
Time-span: 1992/10-2010/12

Global Mean Geostrophic Currents

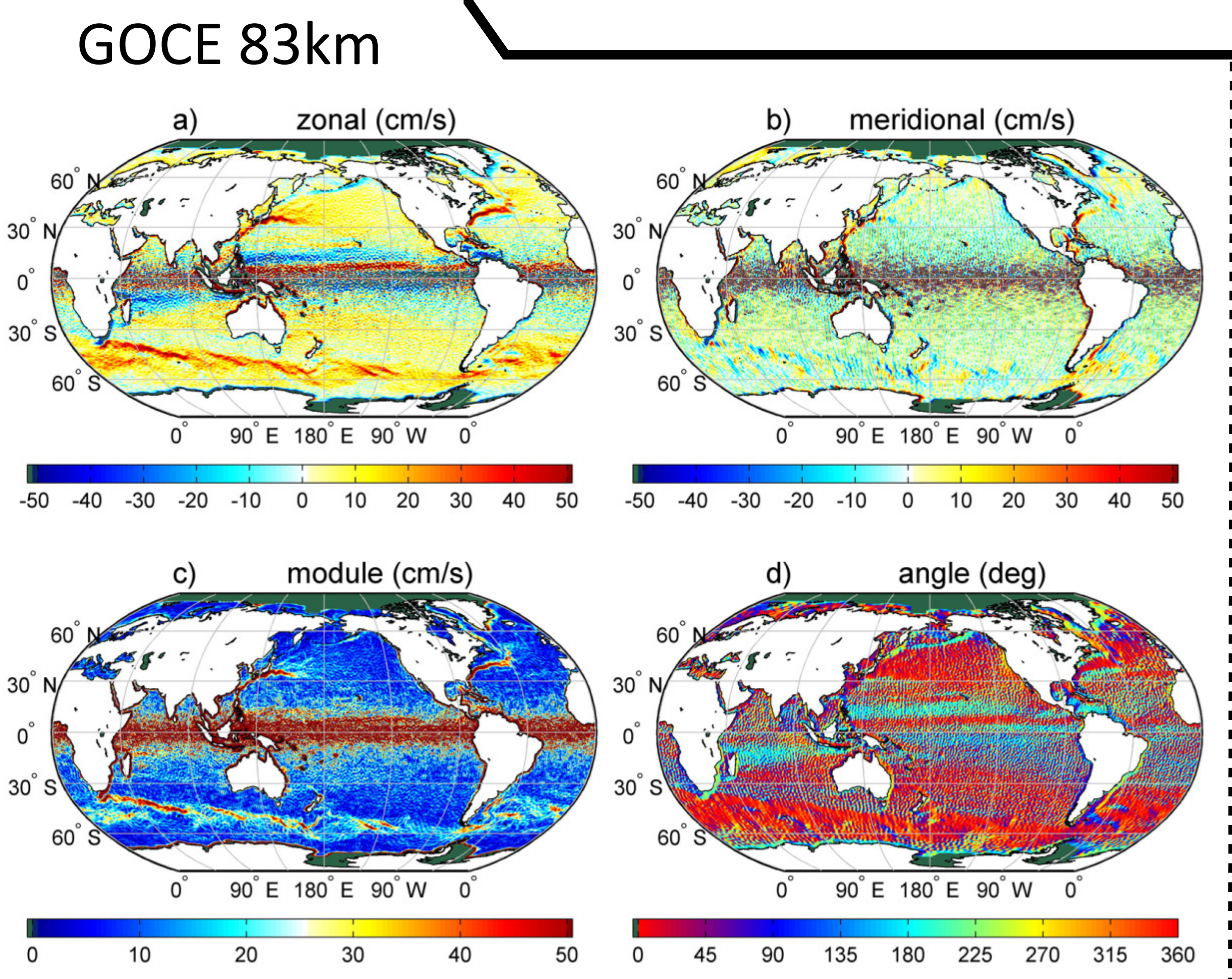

Figure 1: SGC as estimated from a GOCE geoid model.

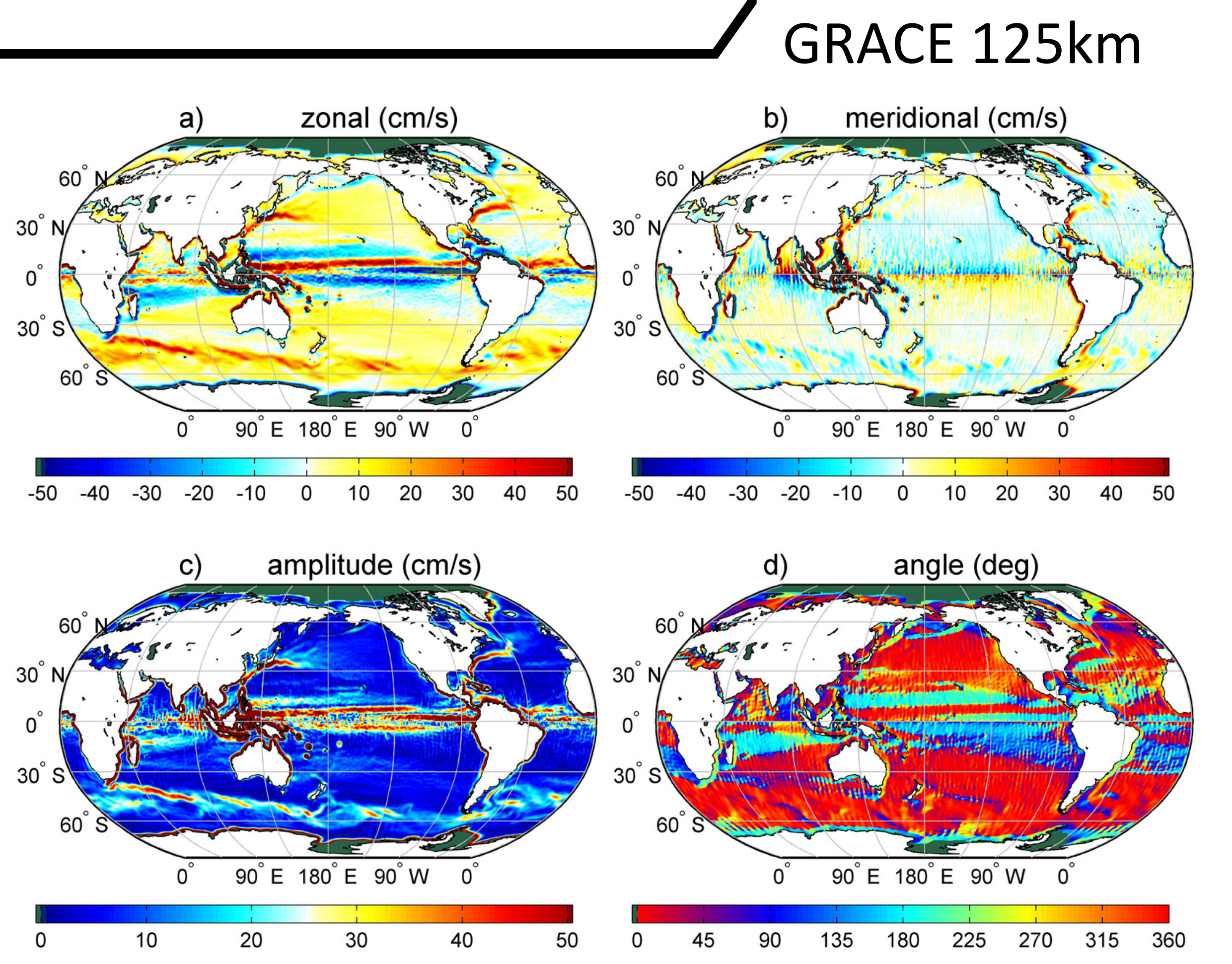

Figure 2: SGC as estimated from a GRACE geoid model.

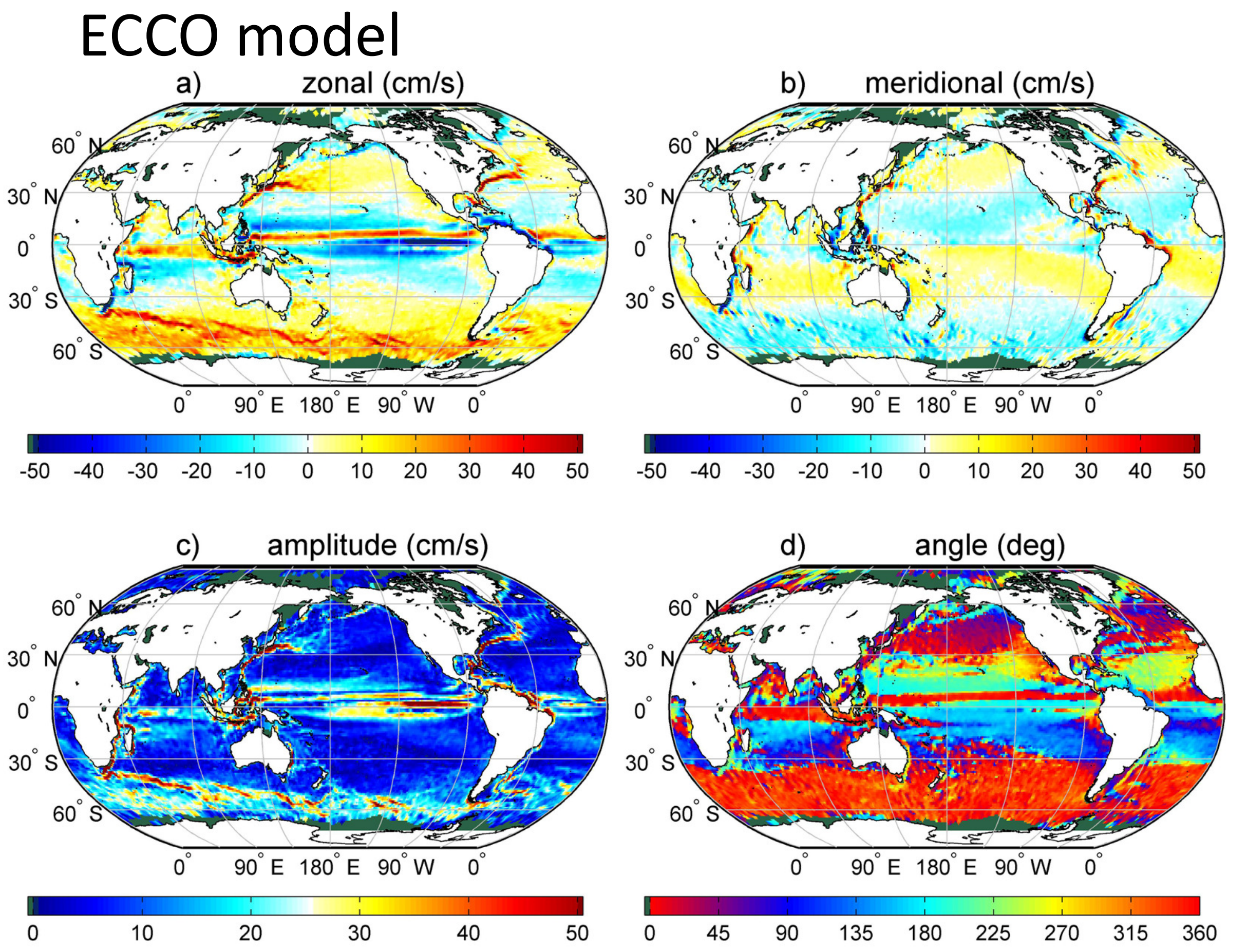

Figure 3: SGC as output from a general circulation model (ECCO).

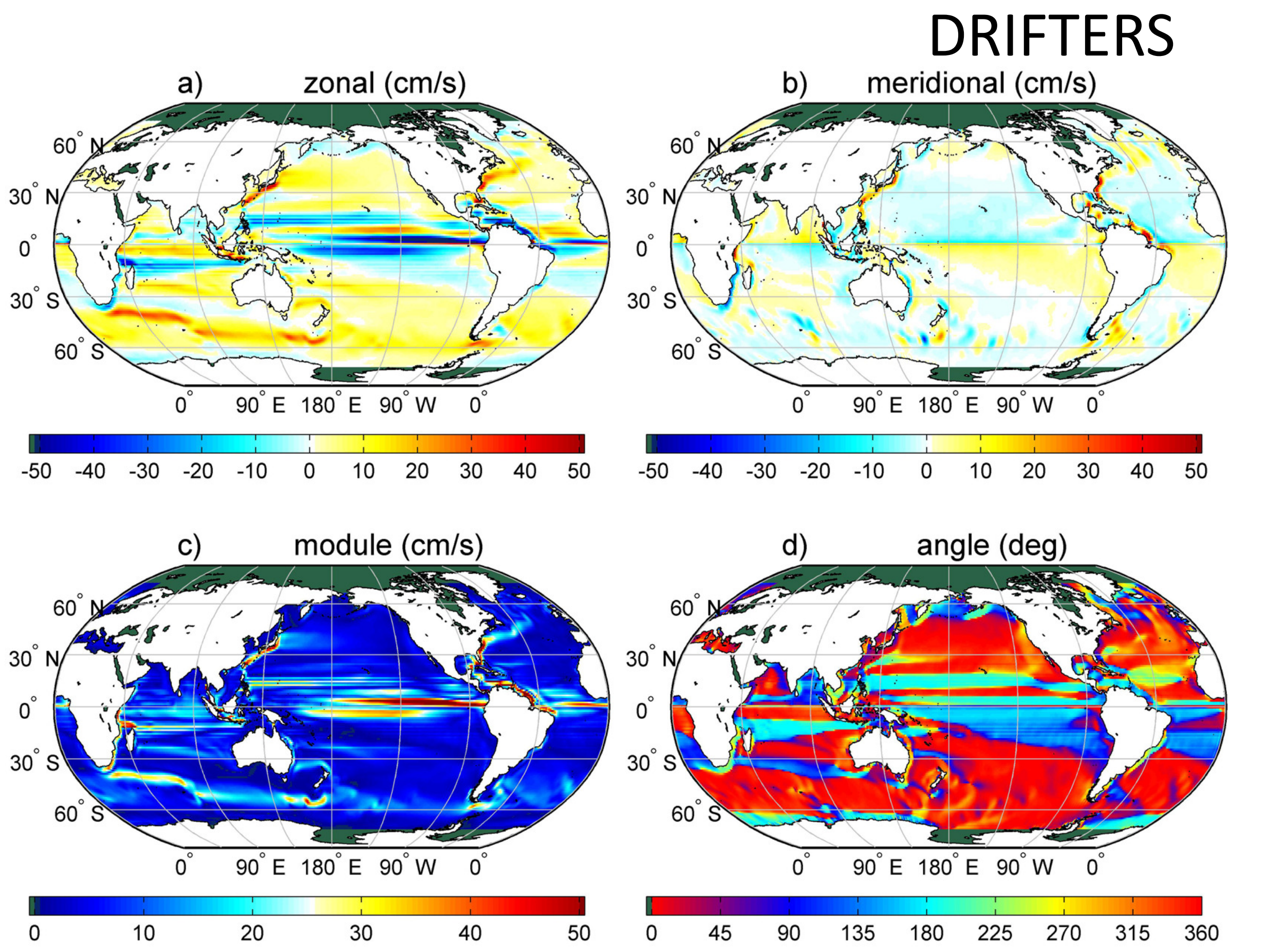

Figure 4: SGC as measured by drifter buoys.

A Mean Dynamic topography (MDT) is obtained using a geoid from GOCE and a geoid from GRACE. Geostrophic currents component are estimated as the gradient of such MDTs,

$$u_s = -\frac{g}{f}\frac{\partial MDT}{\partial \varphi} \qquad v_s = \frac{g}{f}\frac{\partial MDT}{\partial \lambda}$$

Equator band [5ºS 5ºN] is determined following [Largerloef *et al.* (1999)].

Discussion

Figure 1 shows the SGC components derived from GOCE geoid and the figure 2 the corresponding from the GRACE geoid model. Surfaces involved in the process were filtered with a Gaussian filter of 20000/Nmax km of half-wave length.

Either the GOCE and the GRACE induced results represent quite well the general circulation pattern. However, when comparing both patterns, it is clear the increasing in resolution given by GOCE which has a potential resolving power of 83 km.

Because of the noise affecting the meridional component is much higher for GOCE (since the spherical expansion is twice the GRACE one), it shows less detailed equator band than the GRACE-induced one. This last implies further filtering is needed to resolve signals in such area, leading into a signal attenuation at higher latitude currents.

It is known the currents are completely zonal at the equator band for seasonal and long-term averaged estimations [Huang et al. (2007)]. In this sense a fairer assessment of the real improvement by GOCE relative to GRACE would be the comparison of the zonal components. In figure 1,a and figure 2,a it can be observed the similarities in the longer term SGC with an increased detail in amplitude and delimitation when focused on shorter space scales.

GOCE resolution increases in higher latitudes since GOCE tracks become closer to each other. This implies filter degree exigencies are weaker when further from the equator. In this way, the study of the SGC at such areas can be carried out from the most optimistic filtering degree, that is 83 km for GOCE data.

Figures 5-7 show zooms into the major currents areas as estimated from GOCE and GRACE geoids models, respectively (figures 1,2) and they are compared with velocities coming from outputs of the ECCO model and in-situ drifter measurements (figures 3,4).

Figures 5-7a illustrate the high resolving power of GOCE that leads to such amazing displays. When compared with GRACE, figure 5-7b, it is evident the great improvement that GOCE supposes to the SGC study, since currents are shown much better delimited in space as well as more powerful in magnitude. Figure 5-7c illustrate the still low resolution of the GCM.

Figures 5-7d illustrate how GOCE is close to balance the velocity magnitudes estimation given by in-situ measurements. In this sense, GOCE provides a great advantage in relation with such in-situ measurements based in the data from monitoring in almost continuous time and homogeneous in space.

Gulf Stream

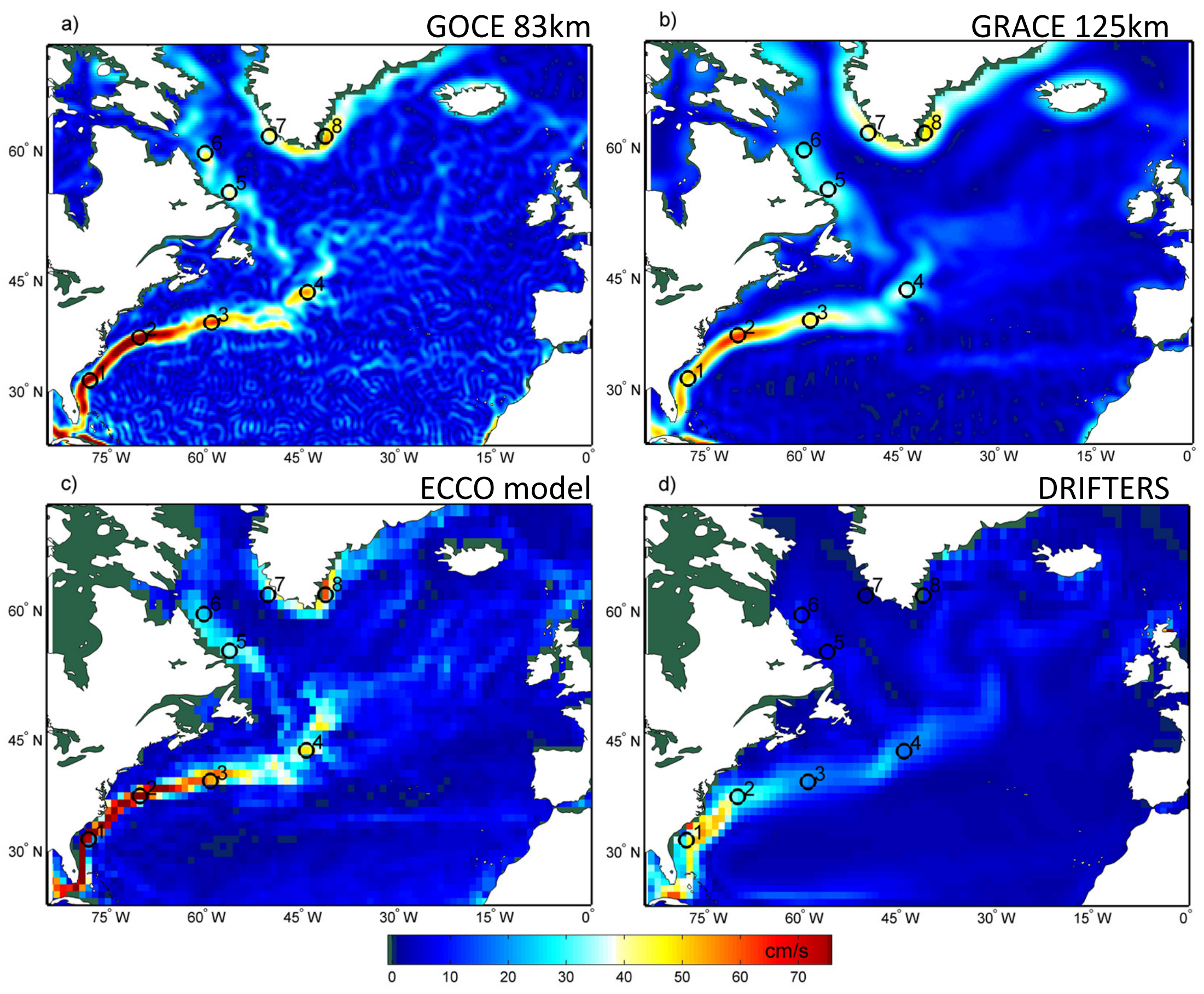

Figure 5: Zoom into the Gulf Stream from a) GOCE geoid model; b) GRACE geoid model; c) ECCO model ; and d) in-situ measurements

Kuroshio Current

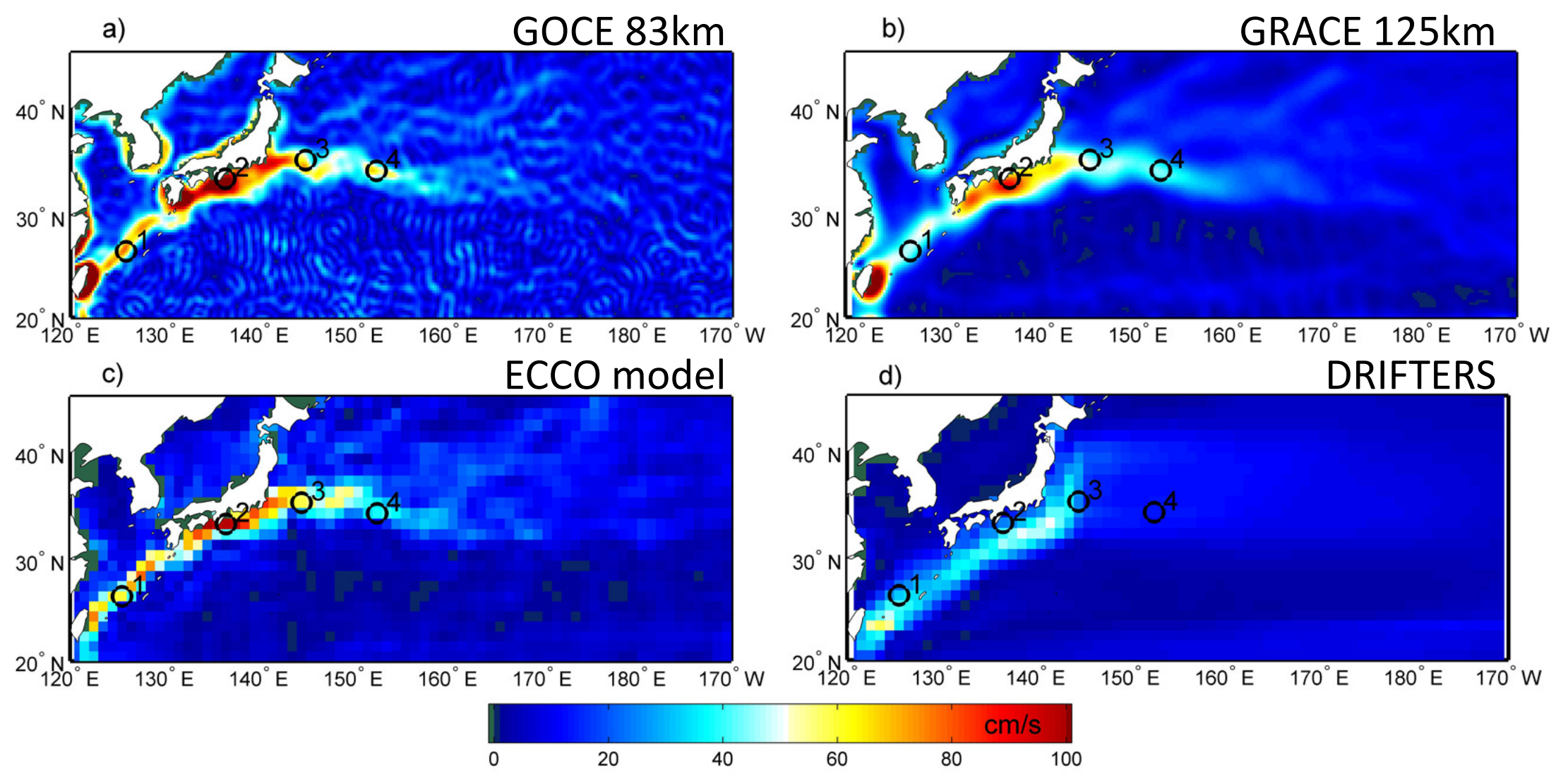

Figure 6: Zoom into the Kuroshio Current from a) GOCE geoid model; b) GRACE geoid model; c) ECCO model ; and d) in-situ measurements

Antarctica Circumpolar System

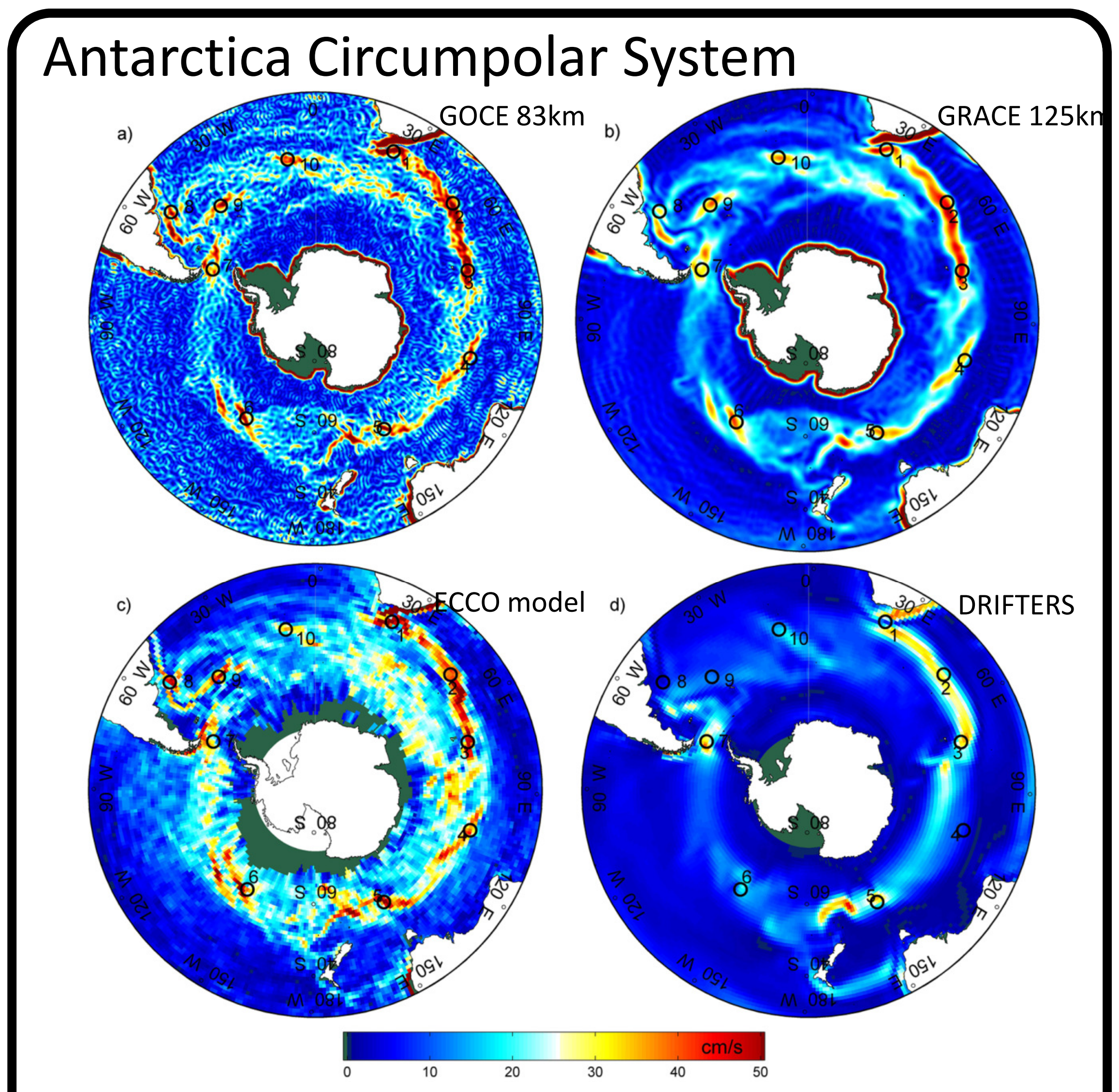

Figure 7: Zoom into the ACC from a) GOCE geoid model; b) GRACE geoid model; c) ECCO model ; and d) in-situ measurements

Conclusions

- ✓ GOCE provides a significant improvement. All major currents are much better defined with intensities significantly increased.
- ✓ Although for the equator band a higher degree of filtering would be preferred, the GOCE-induced SGC can be studied from the most optimistic point of view for higher latitudes.
- ✓ Validation with in-situ measurements for the major currents areas of the Gulf Stream, Kuroshio Currents and ACC show how magnitude of the velocities estimated from GOCE are nicely close to in-situ observations.
- ✓ Geodetic estimation of the SGC starts to be comparable with in-situ measurements.

Sanchez-Reales, JM, Vigo MI, Jin SG and Chao BF, Global Surface Geostrophic Ocean Currents Derived from Satellite Altimetry and GOCE Geoid. Marine of Geodesy. In press

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