Dominance of Eastward Currents in Southern Hemisphere Oceans: the Impact of GOCE Data

Viviane Menezes, vivianev@utas.edu.au

Rory Bingham, rory.bingham@ncl.ac.uk

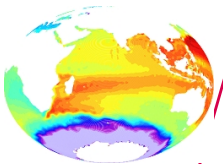
Marcio Vianna, marcio@vmoceanica.com.br

Helen Phillips, h.e.phillips@utas.edu.au

IMAS INSTITUTE FOR MARINE AND ANTARCTIC STUDIES

UTAS

translating**nature**into**knowledge**



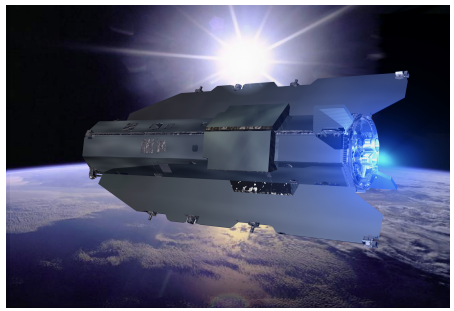
September 27, 2012

OSTST-2012, Venice, Italy

Outline

Introduction

- One of the main goals of the Gravity and **steady-state Ocean Circulation** Explorer (GOCE) satellite mission, launched in March 2009, is to improve the previous estimates of the global ocean circulation structures determined from Mean Dynamic Topographies (MDTs)



- Several studies published to date (e.g. Bingham et al, 2011; Knudsen et al, 2011; Janjic et al, 2012; Farrel et al, 2012; Volkov and Zlotnicki (2012)) $\Longrightarrow$ suggest that the GOCE-based MDTs/MGCs are **superior** to those obtained from GRACE (Gravity Recovery and Climate Experiment)-only data

Introduction

- Most studies using GOCE data focus on the ocean circulation of the North Hemisphere with emphasis on strong WBC systems $\longrightarrow$ In the Southern Hemisphere: focus only on the energetic Agulhas Current and ACC
- It is frequently recognized that the SH mean circulation is still not well established even at large scales
- Therefore, the new GOCE and GRACE products **can contribute** to increase our understanding of the dominant currents of these regions, which may have greater impact on the global climate system

Objective

- Evaluate the GOCE/GRACE products and Analysis of the SH upper-ocean circulation especially in mid-latitudes
- **Our interest:** Recently $\Rightarrow$ Subtropical eastward currents have been found as **permanent features** of SH upper ocean circulation:
  - South Atlantic: Maximenko and Niiler (2006); **Juliano and Alves (2007)**; Vianna et al (2007); Vianna and Menezes (2011)
  - South Indian: Siedler et al (2006); **Palastanga et al (2007)**
  - South Pacific: Qiu and Chen (2004); Qiu et al (2008)
- Note: these currents have been largely ignored, but have been noticed before (Connection Current in South Atlantic by Rennel (1832); Tropical Counter-Current in SI by Sharma (1976) and Tropical Counter-Current SP by Merle (1969) ...)

Objective

- Here, we will show some preliminary results based on GOCE/GRACE focusing the South Indian and Pacific oceans since a good description of the South Atlantic circulation patterns has already been made based on satellite-derived MDTs (Vianna and Menezes, 2011 JGR)

Data & Processing

Data

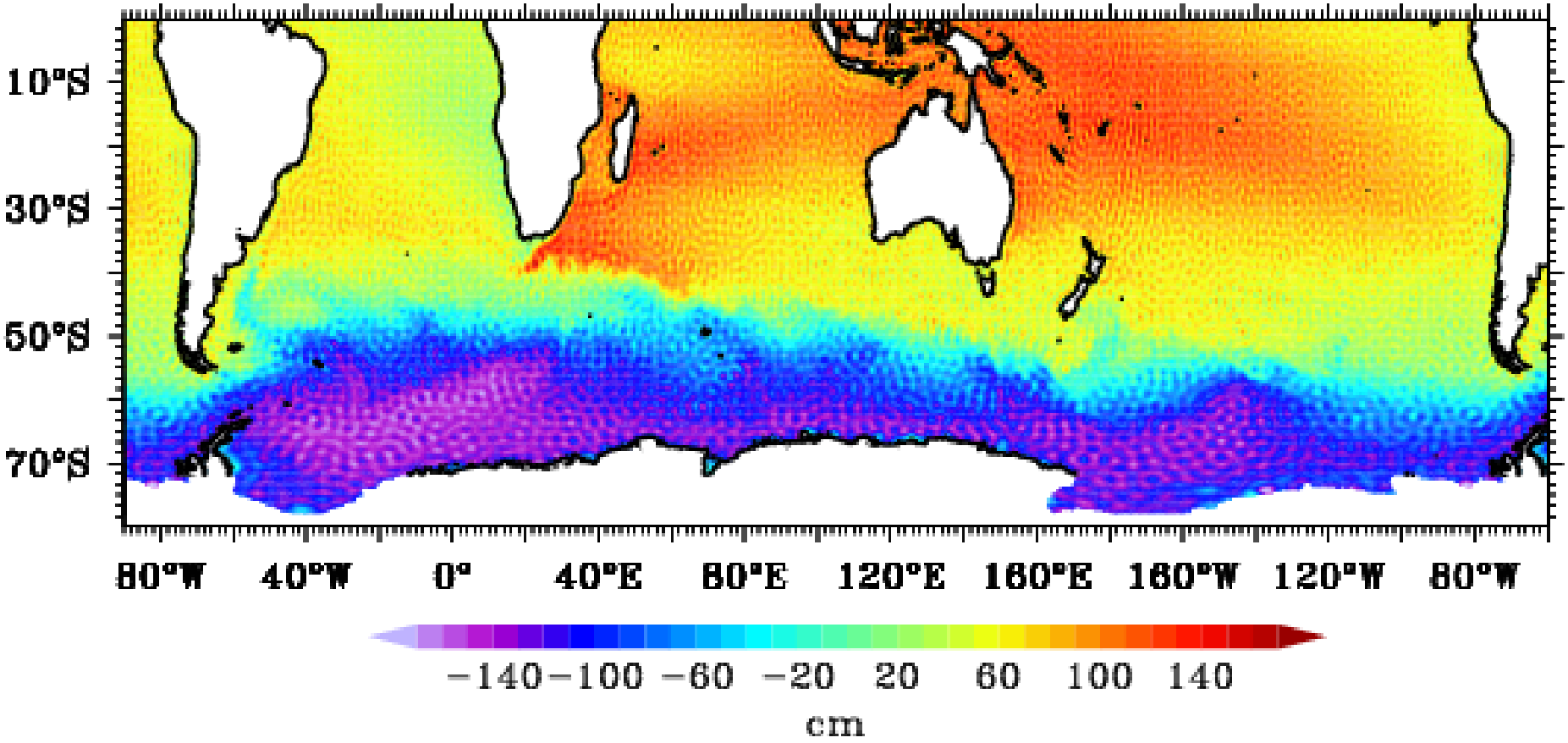
- ✓ Geoid ▶ GOCO03S (Gravity Observation Combination; satellite-only product) $\longrightarrow$ 18 months of GOCE gradiometry data (Nov. 2009 – April 2011); GRACE (7.5 years); CHAMP (8 years)
- ✓ MSS ▶ DTU-10 (17 years of altimetric data - 1993-2009)

MDT computation

- ✓ MDT = MSS - Geoid
- ✓ Spectral Approach (d/o = 220; $\approx$ 90 Km)
- ✓ Grid Resolution: $0.25^{\circ} \times 0.25^{\circ}$

Data & Processing

"RAW" MDT



SH $\longrightarrow$ AMPL=[-196.1;171.1] cm $\triangle$= 367.2cm; STD = 73.65 cm

Data & Processing

Filtering Strategies

We employed 2 different approaches:

- ✓ Non-linear diffusive filter (Bingham, 2010; Bingham et al., 2011) $\dashrightarrow$ conducted by Rory (the degree of smoothing is primarily controlled by the number of iterations; this number was chosen to minimise the root mean squared (RMS) difference between the currents derived from the geodetic GOCO03S-DTU-10 and the hybrid CLS09 MDT for the South Pacific);
- ✓ Singular Spectrum Analysis filter (Vianna et 2007; Vianna and Menezes, 2010) $\dashrightarrow$ conducted by myself and Marcio (The SSA filter is made through expansion of the input data signal in a series of so-called reconstructed component (RC) modes; the degree of smoothing depends on the choice of the Reconstructed Modes (RC); We implemented slight modifications in relation to our previous works)

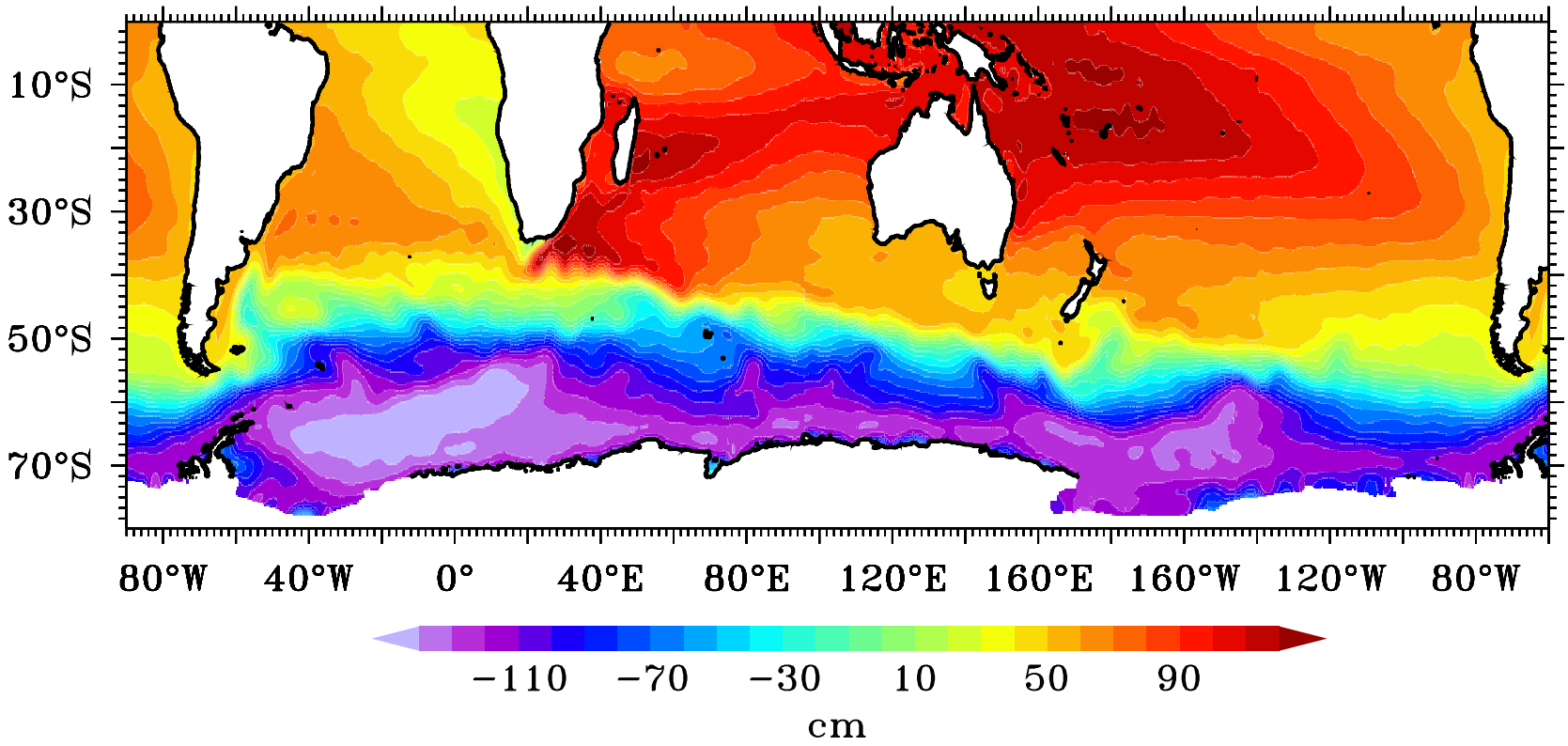
Data & Processing

The Mean Geostrophic Circulation fields (MGCs) were calculated by use of the Anderssen-Hegland averaging scheme for estimation of derivatives, which is able to filter out the well-known high amplitude noise of the standard finite-difference method:

- Anderssen, R.S. and Hegland, M. For numerical differentiation dimensionality can be a blessing! Mathematics of Computation, American Mathematical Society, v.68, number 227, 1121-1141, 1999

Results

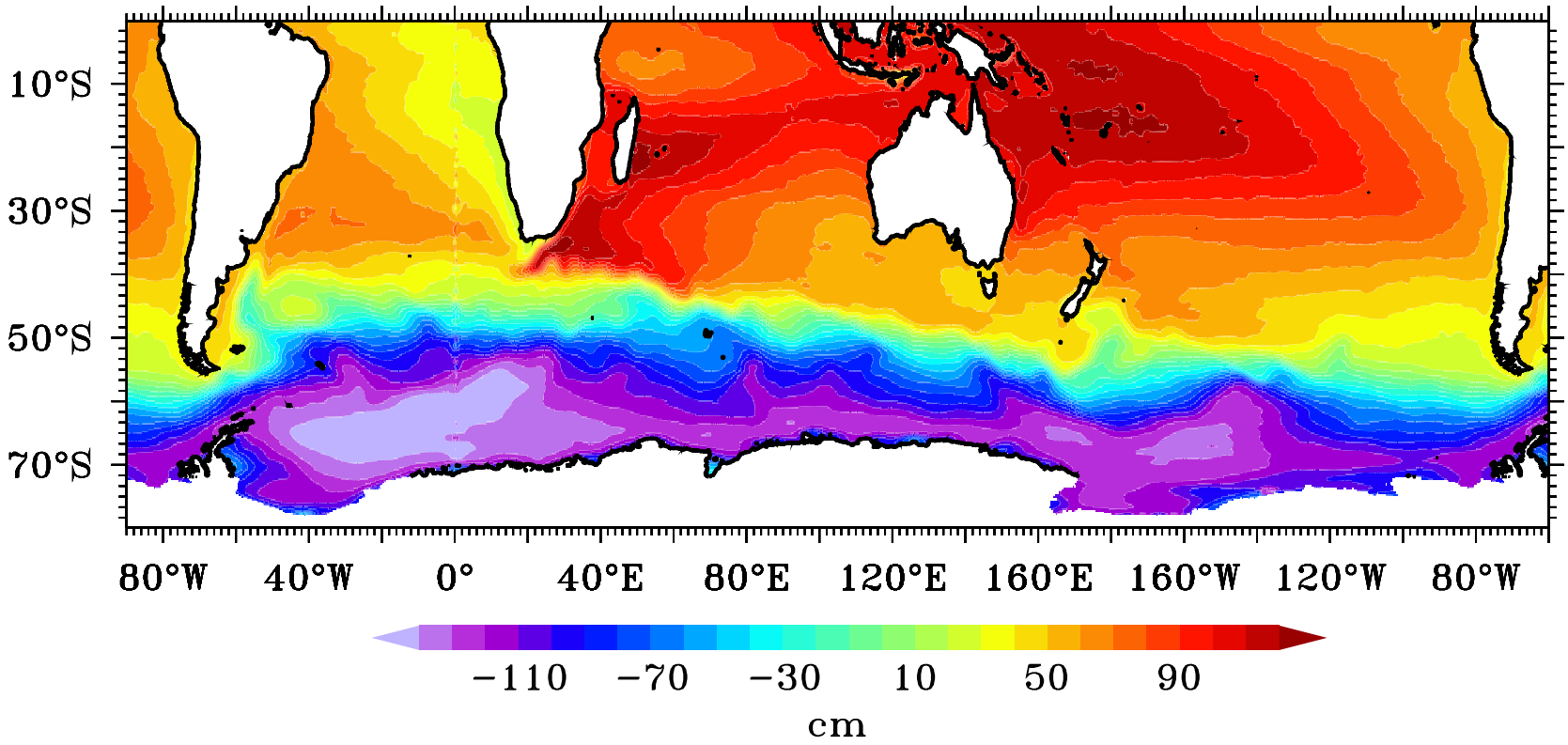
GOCO03S-DTU10 SSA filter



SH $\longrightarrow$ AMPL=[-153.7;127.4] cm $\triangle$=281.1cm; STD = 72.77 cm

Results

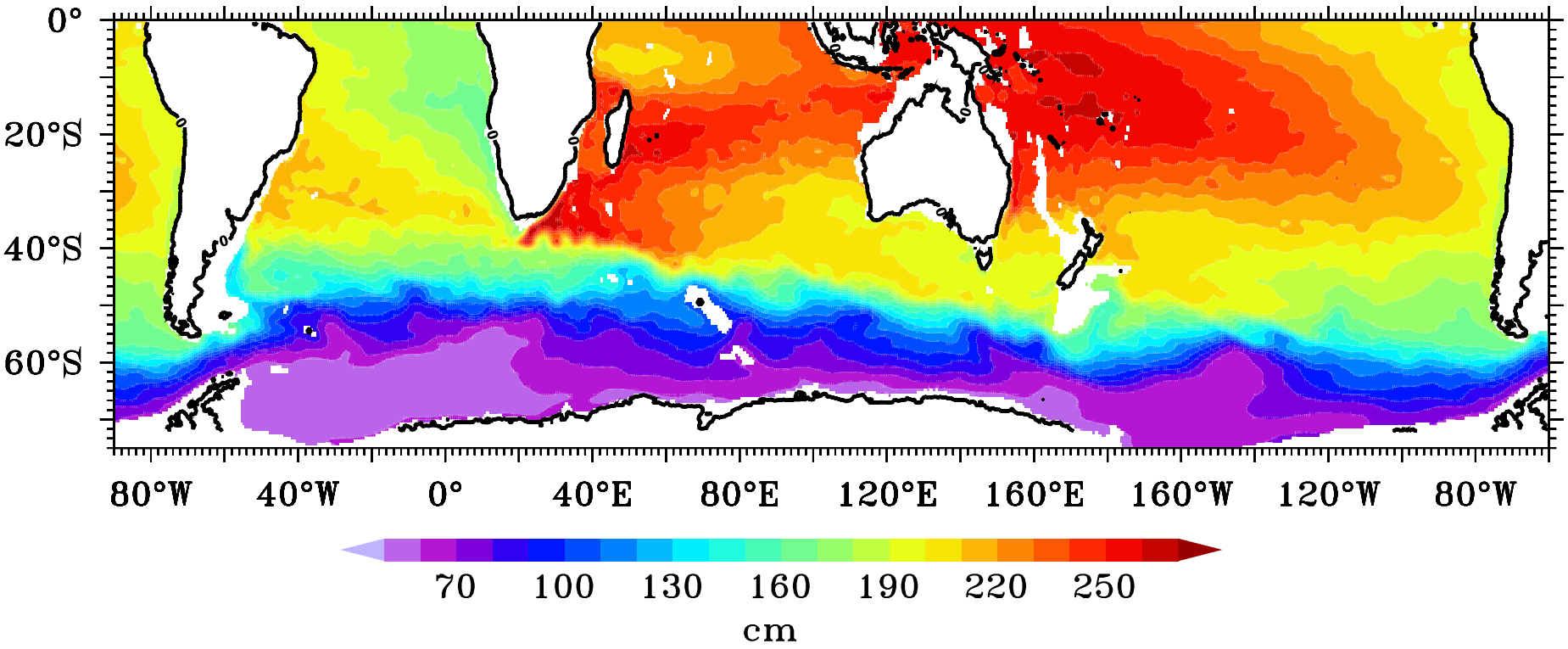
GOCO03S-DTU10 Diffusive filter; RMS DIFF = 2.36 cm



SH $\longrightarrow$ AMPL=[-162.0;129.3] cm $\triangle$=287.3cm; STD = 72.50 cm

Results

CARS2009 DH Ref. 2000m; 0.5°× 0.5°



SH $\longrightarrow$ AMPL=[48.22;268.8] cm $\triangle$=220.6cm; STD = 56.65 cm

South Pacific: What we known?

"The region in the 21–29°S band corresponds to none of the commonly recognized currents presented in Figure 2"

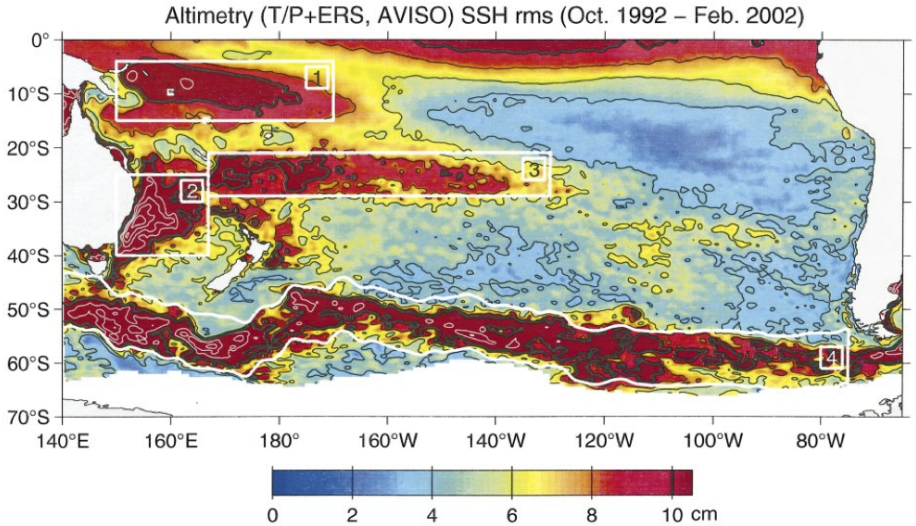


FIG. 1. Map of the rms sea surface height variability in the South Pacific Ocean. Based on the combined T/P and *ERS-1/2* altimetric data from Oct 1992 to Feb 2002. Thick solid lines denote the 0.1-m contour. In regions above 0.1 m, thin white lines denote contours at a 0.05-m interval.

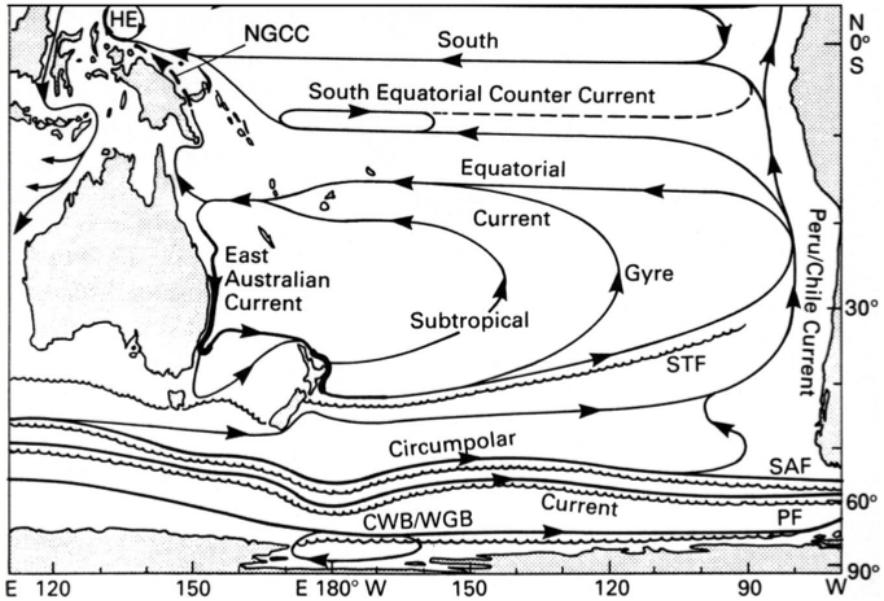
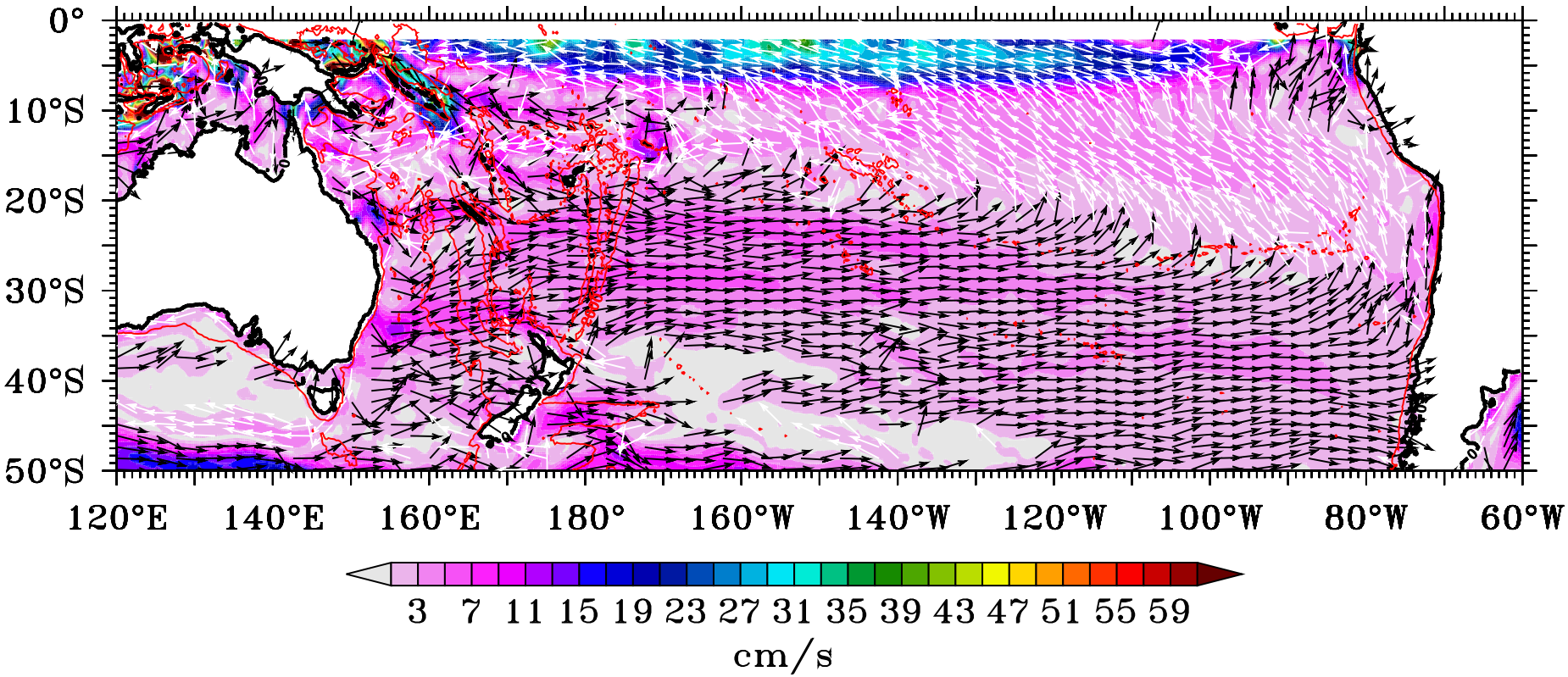


FIG. 2. Surface current system of the South Pacific Ocean from Tomczak and Godfrey (1994). Abbreviations in the figure are as follows: Halmahera Eddy (HE), New Guinea Coastal Current (NGCC), Subtropical Front (also called the South Pacific Current) (STF), subantarctic front (SAF), polar front (PF), and continental water boundary/Weddell gyre boundary (CWG/WGB).

Qiu and Chen (2004)

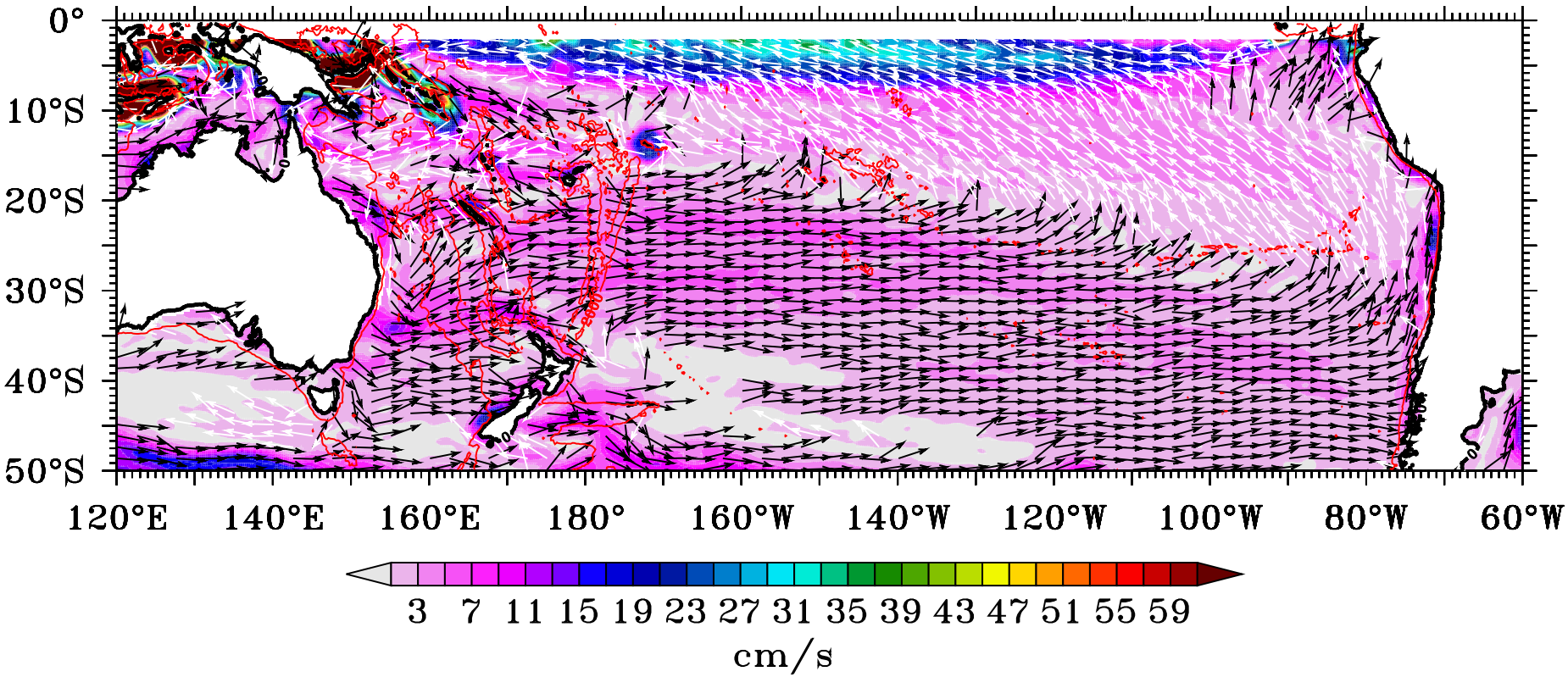
South Pacific from GOCE

SSA filter: eastward currents (Black); westward currents (White); lon 1 vector/10 pts; lat 1 vector/5 pts



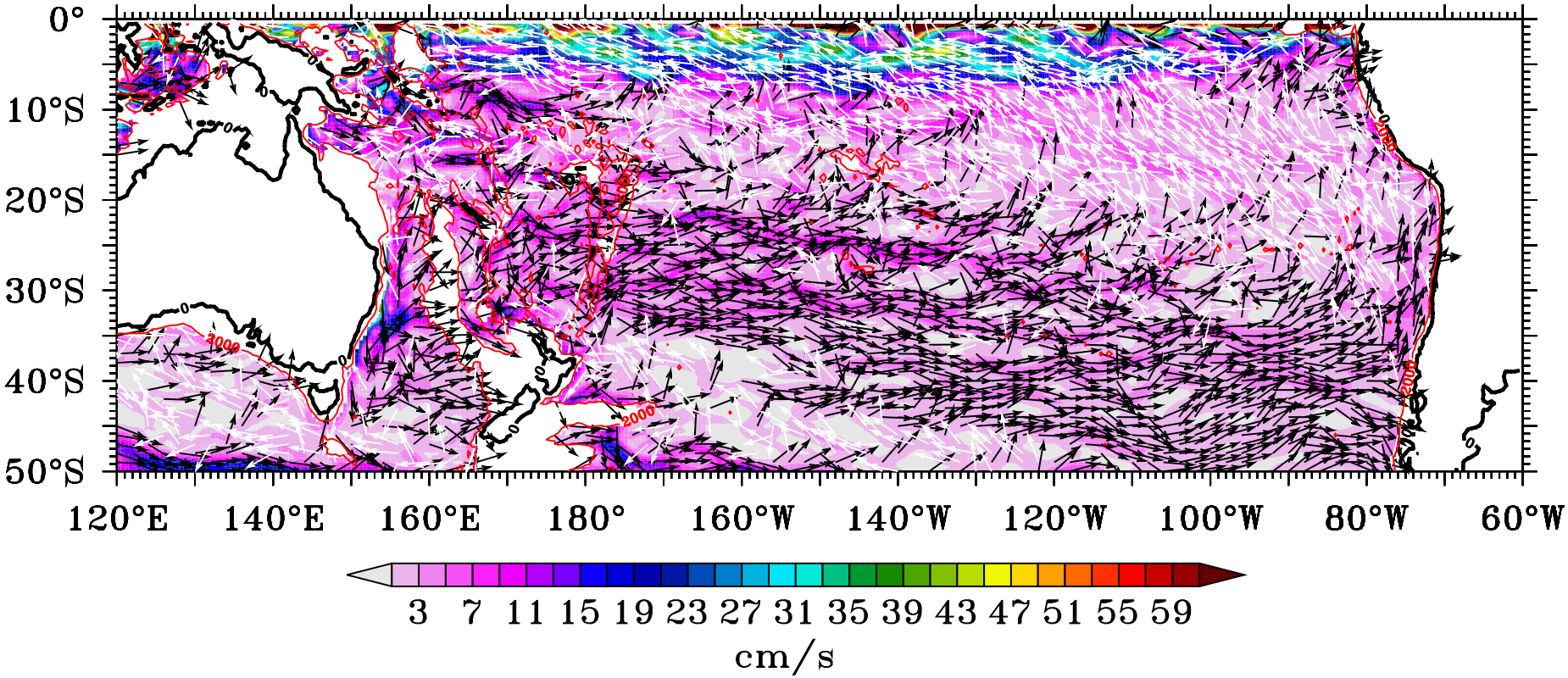
South Pacific from GOCE

Diffusive filter: eastward currents (Black); westward currents (White); lon 1 vector/10 pts; lat 1 vector/5 pts



South Pacific from CARS2009

Ref.2000m; Eastward currents (Black); westward currents (White); lon 1 vector/4 pts; lat 1 vector/2 pts



RMS DIFF (cm/s) in the South Pacific

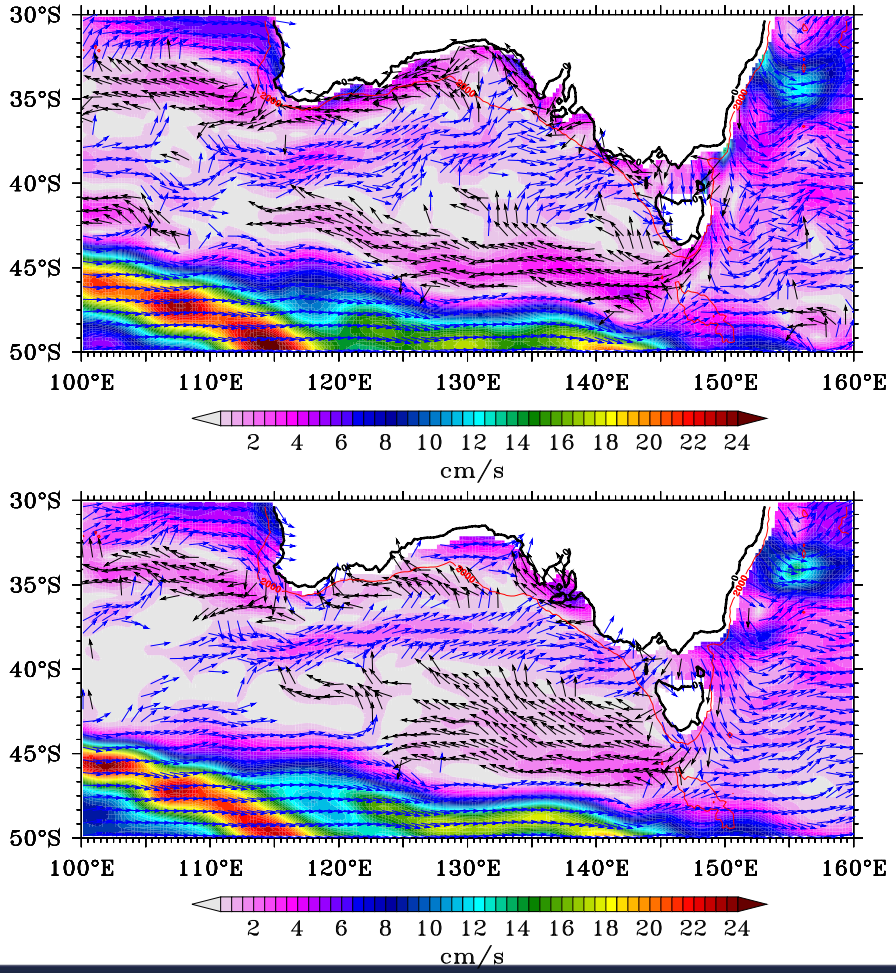
	SSA-FILT [U,V,VEL]	DIF-FILT [U,V,VEL]	CARS09 [U,V,VEL]
SSA-FILT		8.63, 5.56, 8.21	3.63, 2.44, 13.12
DIF-FILT	8.63, 5.56, 8.21		3.69, 2.40,13.00

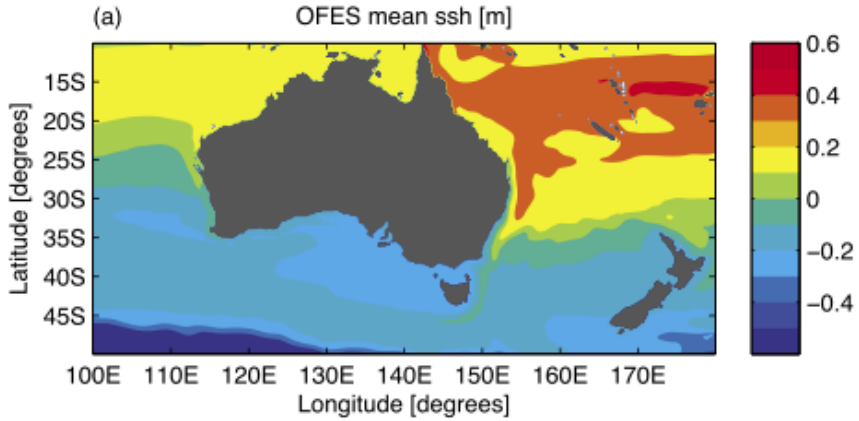
Tasman Leakage?

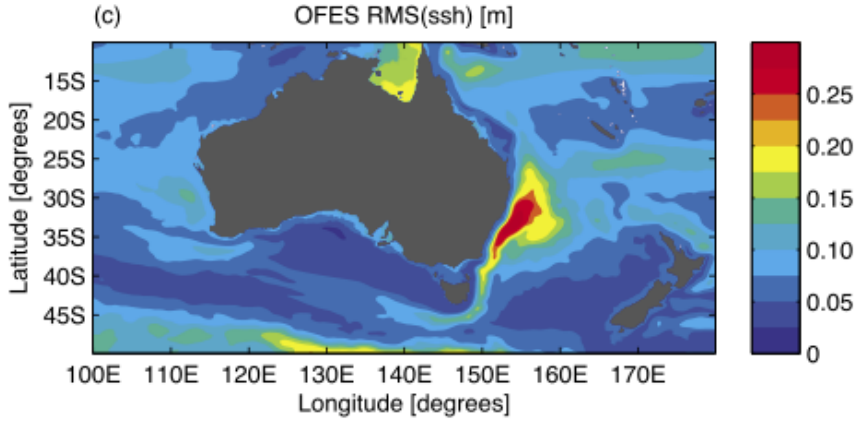
Eastward currents (Blue); Westward currents (Black); lon/lat 1 vector/3 pts

✓ SSA Filter (A) and Diffusive Filter (B)

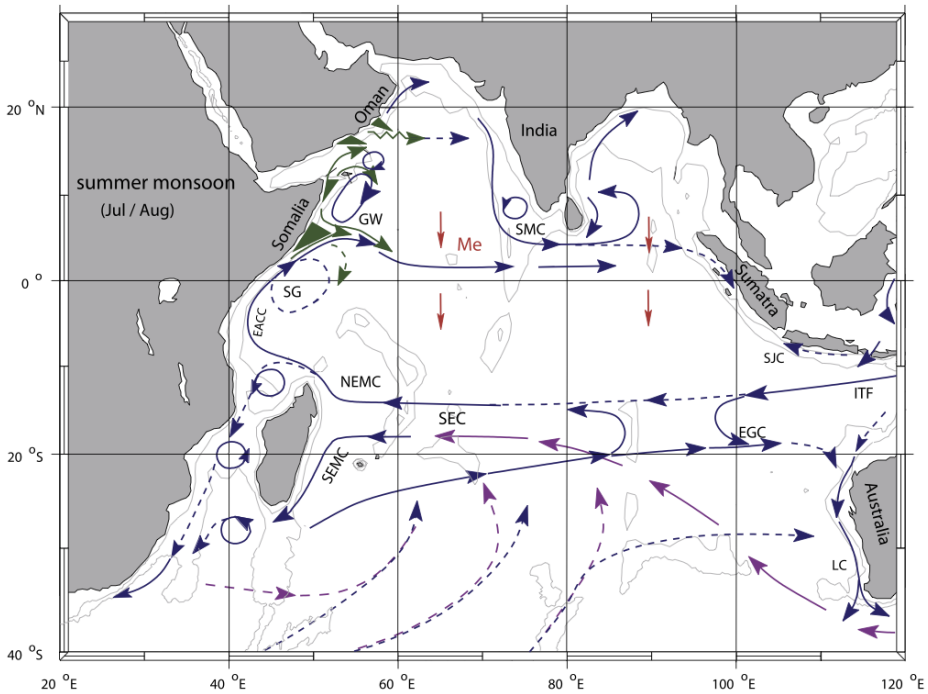
✓ Van Sebille et (2011)

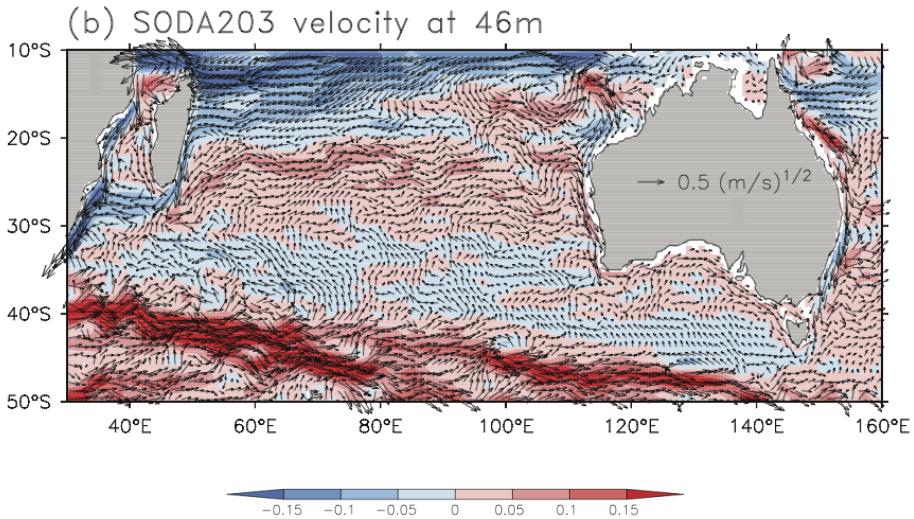






South Indian: What we known?

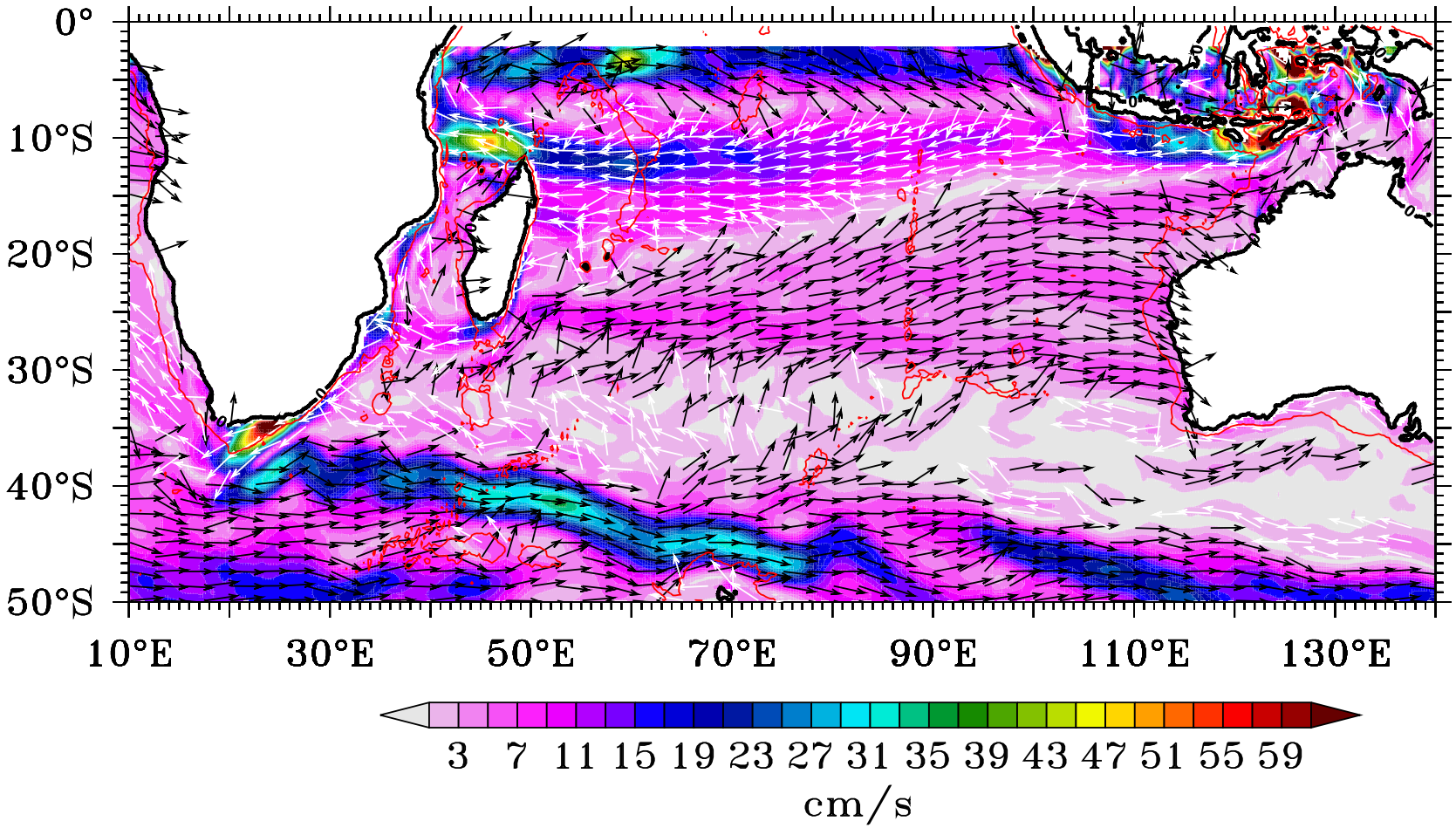




Schott et al. (2009)

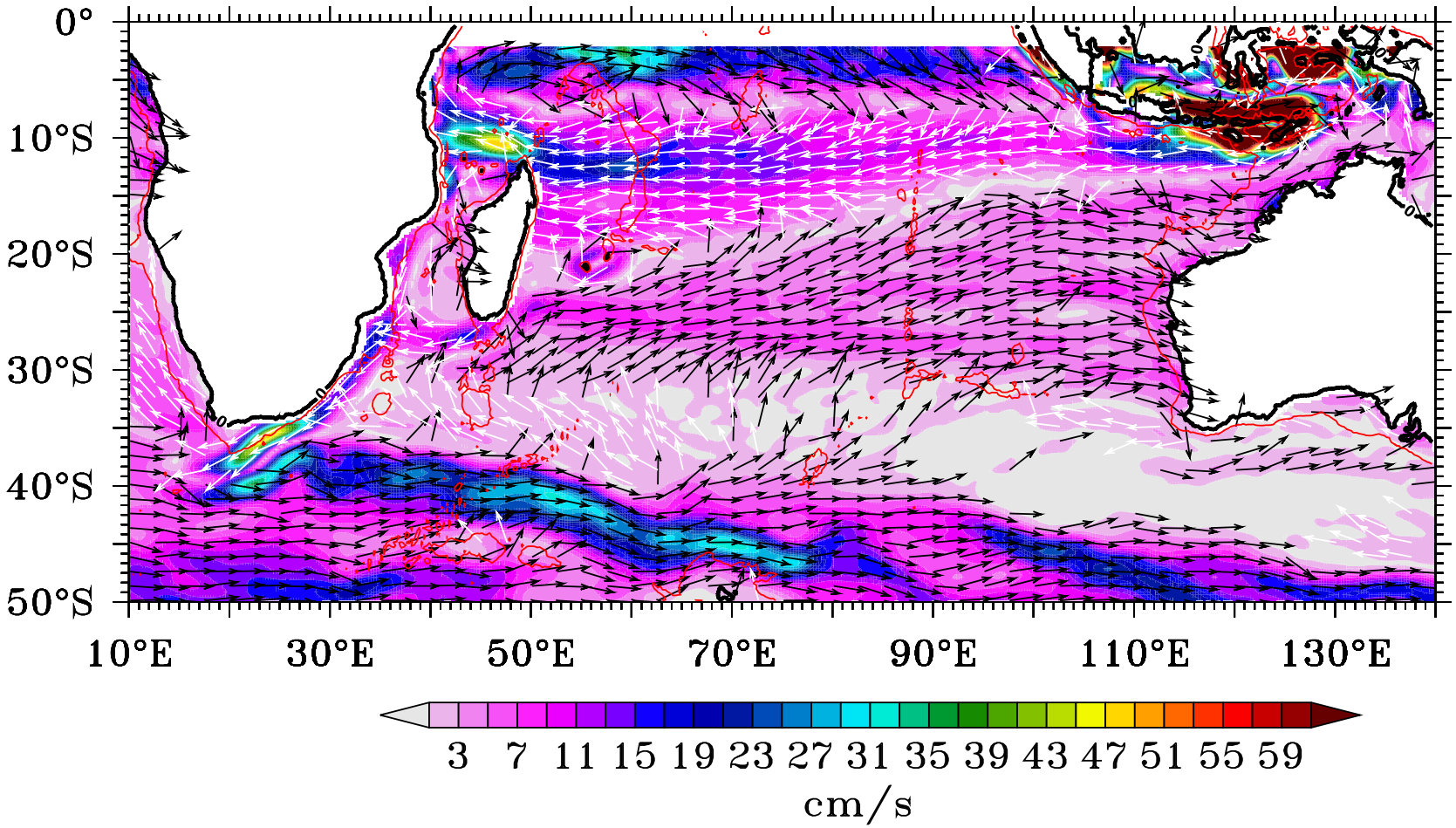
South Indian from GOCE

SSA filter: eastward currents (Black); westward currents (White); lon 1 vector/10 pts; lat 1 vector/5 pts



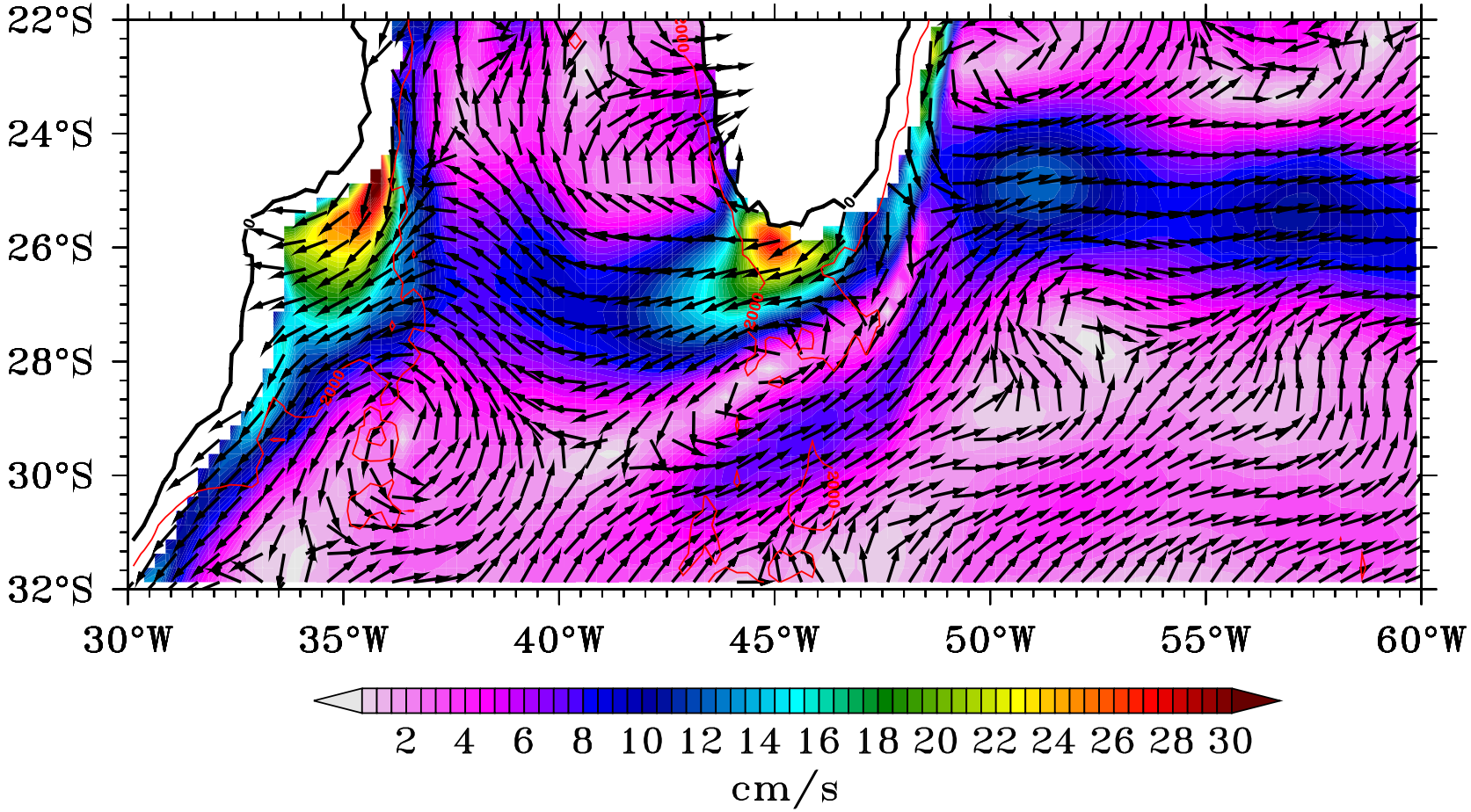
South Indian from GOCE

Diffusive filter: eastward currents (Black); westward currents (White); lon 1 vector/10 pts; lat 1 vector/5 pts



South Indian from GOCE

EMC, SICC and AC



Summary

- Extraction of South Pacific-Indian mid-latitude Geostrophic Currents (MGC) from new satellite-only GOCE/Grace MDT products is shown to be feasible at good resolution.
- This is shown here by applying two different filters: the Bingham Diffusion and the VM SSA/MEM filters.
- Examples of new successes:
  - The Qiu-Chen remark of non-detection of a clear South (Sub)Tropical Pacific eastward flow was raised into a clear detection of a broad eastward zonal flow between latitude interval ...
  - Important spatial meso-scale visible features are: a southern connection current between the Pacific and Indian Oceans are confirmed: the Tasman Leakage (connection) Current suggested by the OFES model (van Sebille et al, 2011)
  - The complex Madagascar area exhibits clearly the EMC retroflection, and the branch into the Agulhas Current.

Summary

- This means that GOCE is already proving its value for mean ocean current mapping even at a modest spectral resolution model.
- This is a preliminary work: statistical inter-comparisons with other MDT products and new applications are being planned for the coming months.

Thank you !