Investigating the thermohaline variability of the ACC using a GEM proxy technique

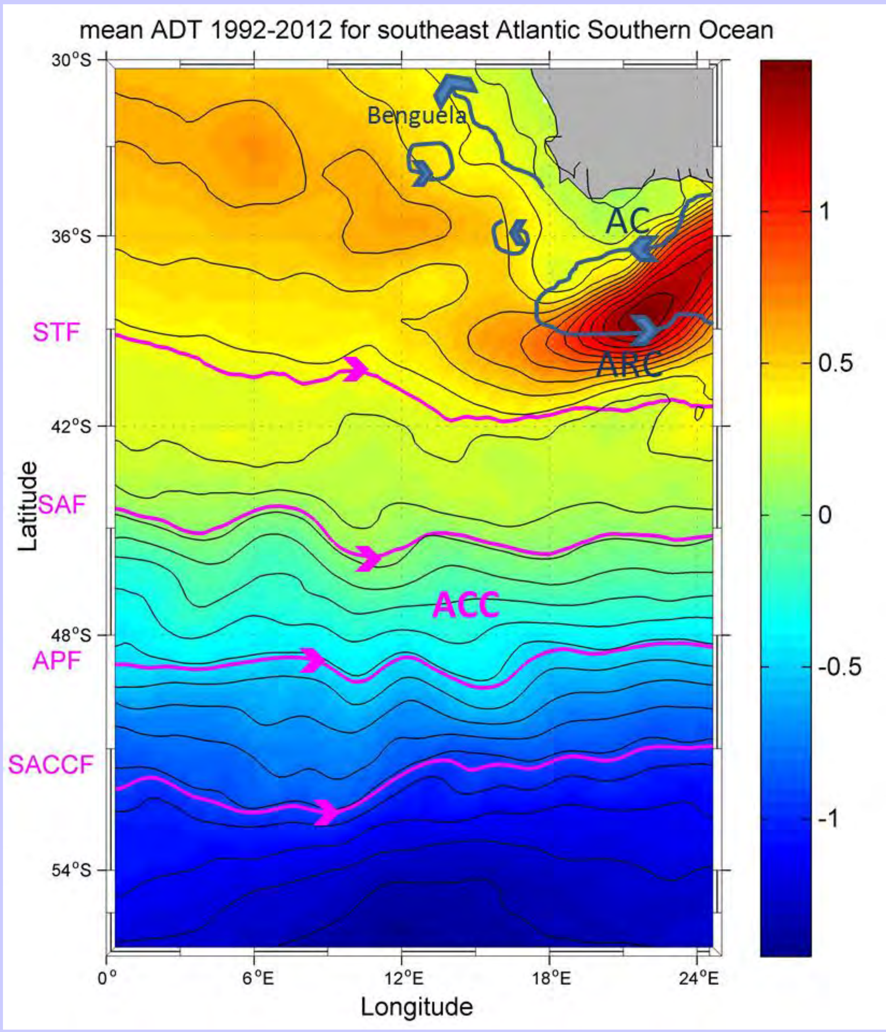
Katherine Hutchinson[1,3], Seb Swart[1,2], Isabelle Ansorge[1], and Sabrina Speich[3]

[1] Department of Oceanography, Marine Research Institute, University of Cape Town, Rondebosch, South Africa.
[2] CSIR - Southern Ocean Carbon & Climate Observatory 5 Lower Hope Street, Rosebank 7700, South Africa
[3] Laboratoire de Physique des Océans (LPO), 6, av Le Gorgeu C.S. 93837, 29238 Brest Cedex 3 France

ABSTRACT

The southeast Atlantic sector of the Southern Ocean acts as a major conduit within global circulation as this is where the Antarctic Circumpolar Current (ACC) links the Atlantic, and Indian Oceans. Yet, the water mass variability in this area is poorly understood due to a lack of hydrographic observations and verified model simulations. In order to obtain a better understanding of the thermohaline changes at the African sector of the ACC, an enhanced Gravest Empirical Mode (GEM) is developed.

The southeast Atlantic Southern Ocean



- Globally one of the most dynamic ocean domains – convergence of Indian, South Atlantic and Southern Ocean waters [1]
- Widely accepted the upper branch of the AMOC originates in this region [2]
- African choke point most variable of the ACC [3]
- Least investigated of all three passages to the south of the Southern Hemis. continents

The traditional method of observation of the ACC has been through the acquisition of CTD profiles from research vessels. However, the financial and human resource intensive nature of gathering this data means that it is very challenging to monitor the current with sufficient resolution. [4]

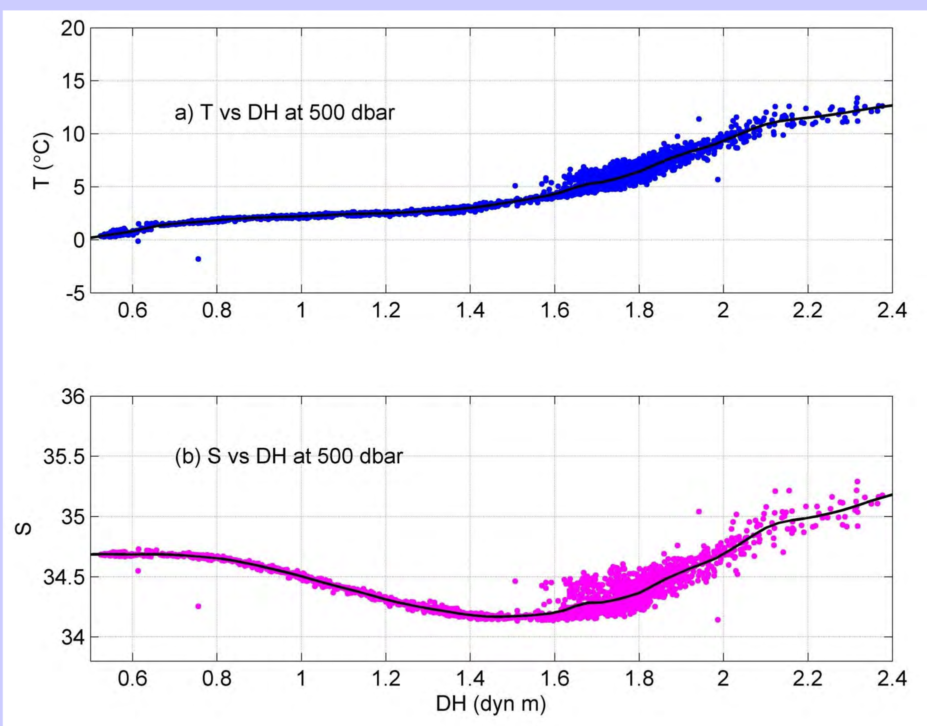
SOLUTION? ⇨ a Gravest Empirical Mode

A Gravest Empirical Mode (GEM) is a type of proxy technique that allows for the deduction of one variable that has not been sampled through the knowledge of its relationship with another observed variable.[5] The ACC is ideal for the implementation of proxy methods.

How does it work?

The *in situ* measurements are plotted against dynamic height and the relationship fitted with a spline.

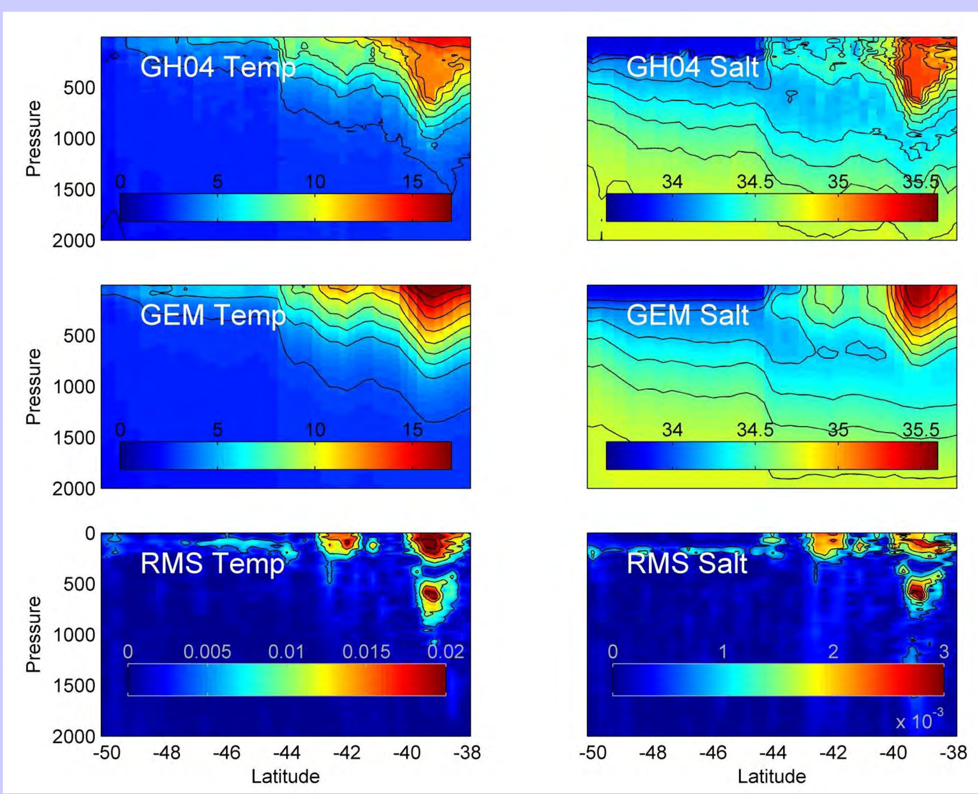
This spline is then used as a type of lookup table to obtain the T and S measurements that corresponds to a DH reading.



Testing the GEM proxy technique

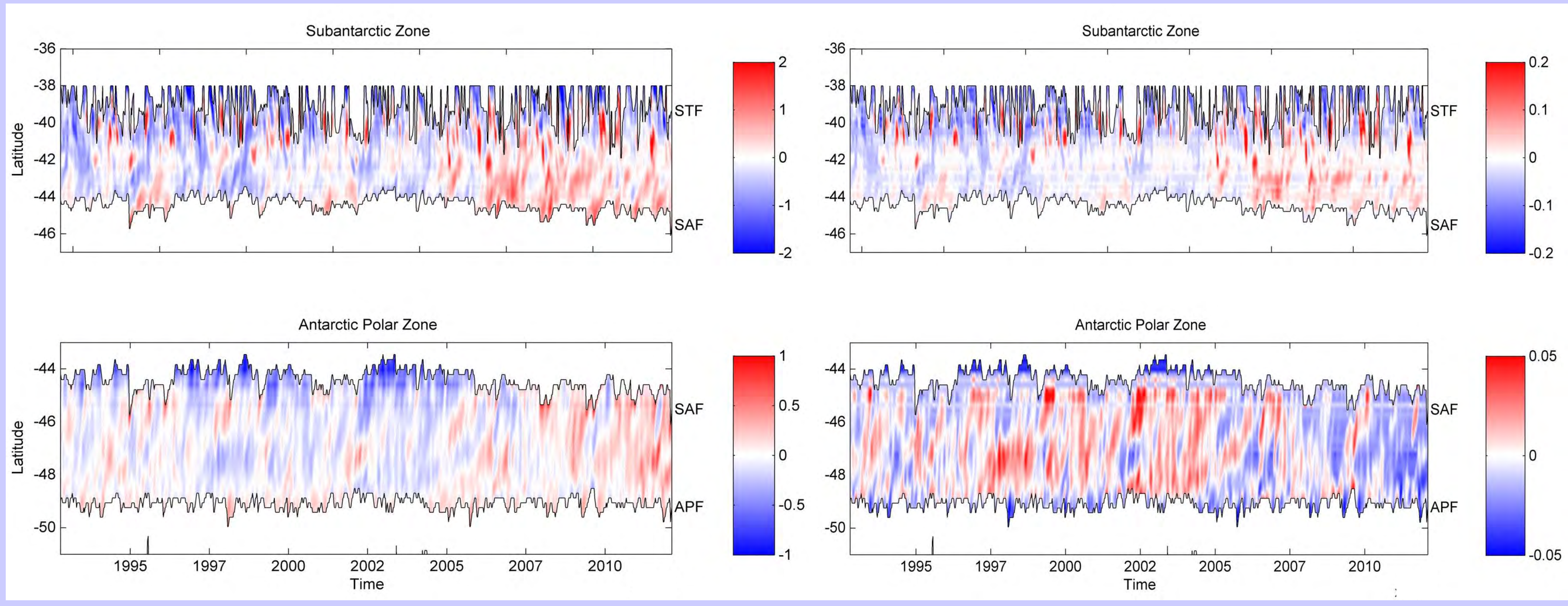
It is important to ensure that the GEM is reliable and can proficiently reproduce observed conditions, therefore extensive testing is performed. The figure below illustrates the results from the testing of the GEM generated fields against *in situ* hydrographic observations from the GoodHope 2004 cruise.

- The GEM temperature and salinity sections compare well with the original cruise plots.
- The GEM fields adequately capture the thermohaline structure with depth and latitude.
- RMS errors are two orders of magnitude smaller than comparable GEM Southern Ocean studies. [6,7,8]



Generating 20 years of thermohaline data

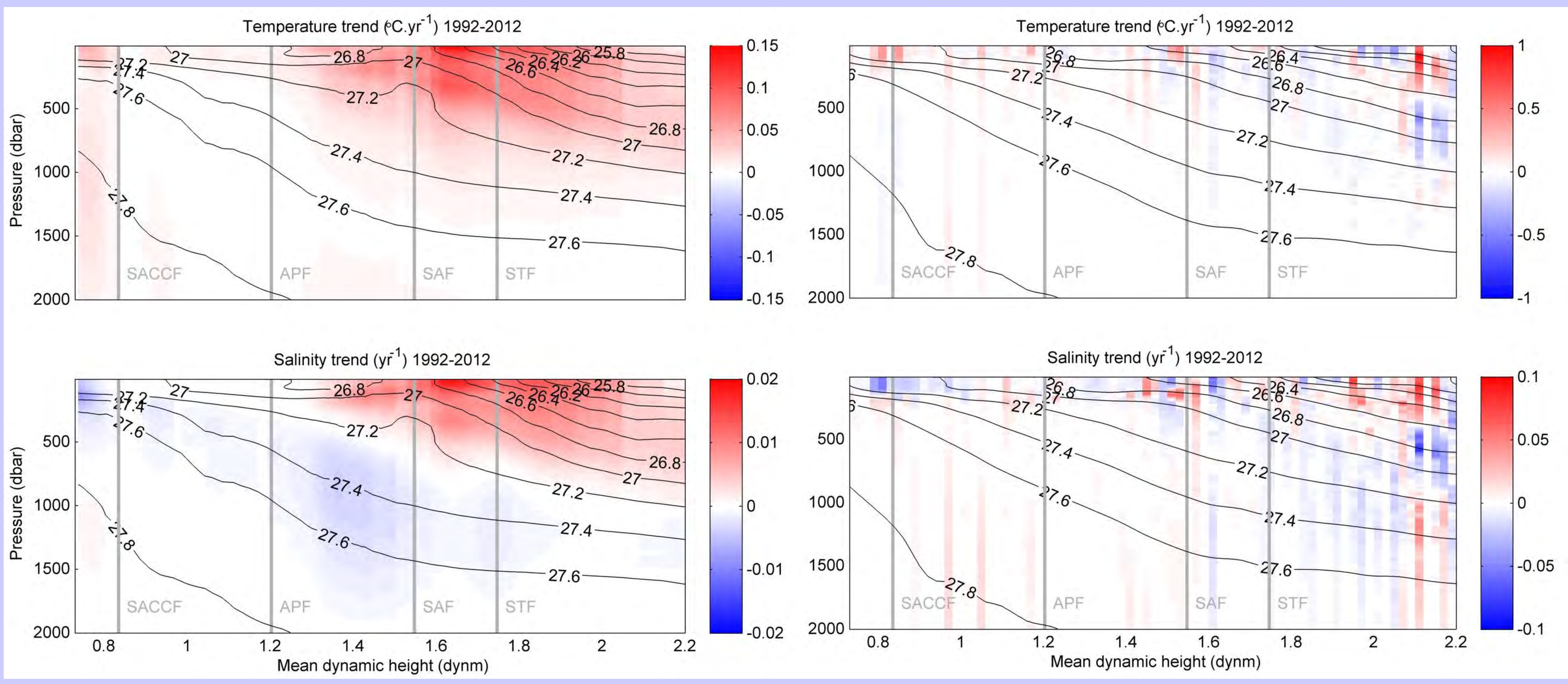
Weekly satellite altimetry measurements of sea surface height are available for the ACC south of Africa. By uniting this remotely sensed data with the GEM relationships, an Altimetry GEM (AGEM) is created. This AGEM is able to generated weekly updated temperature (T) and salinity (S) sections, thereby providing great insight into the property changes occurring over time.



The above figures illustrate the mean T and S anomalies of the top 2000m for the frontal regions south of Africa using the 20 years of AGEM generated data.

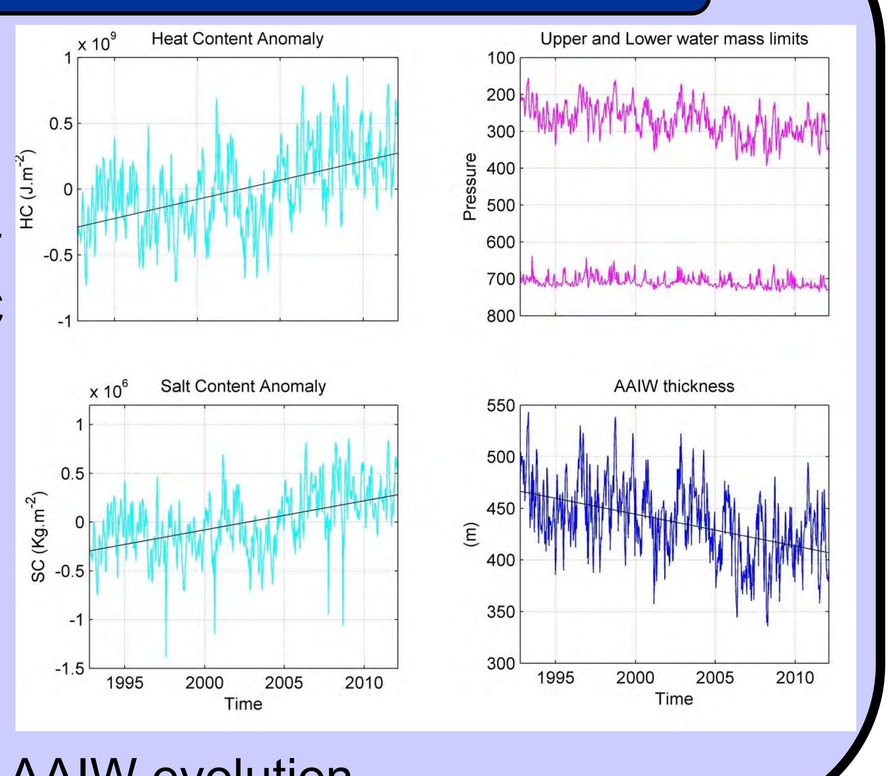
SAZ: T ⇧, S ⇧ APZ: T ⇧, S ↷ What is driving these changes?

To gain insight into the phenomena that may be causing these property changes, we look at the portion of trend due to a shift in circumpolar fronts (adiabatic), and the component due to changes in water masses (diabatic).



Focusing on Antarctic Intermediate Water

- AAIW plays a vital role in ocean circulation and climate regulation
- In the South Atlantic, it forms part of the returning upper limb of the MOC
- Recent warming of AAIW has been suggested, however due to the scarcity of data south of Africa, the extent of warming in this region is poorly understood.



⇨ Use the AGEM to investigate AAIW evolution

CONCLUSIONS

- GEM and AGEM fields successfully represent observations
- The resultant 20 years of thermohaline sections showed positive trends in T, an increase in S pre 2005, and S decrease thereafter.
- A southward shift in the Southern Ocean fronts is likely responsible for a large component of the warming (adiabatic).
- The changes in S over time are not uniform with depth, with adiabatic salt increases in the top 500m, and freshening below.
- The diabatic changes are not as spatially uniform, however the magnitude of change is larger than that of the adiabatic trends.
  ⇨ Indicates an important evolution of water masses in the area.
- The variability of AAIW south of Africa is found to most notably be driven by a large increase in heat and salt content.

CONTACT DETAILS

Katherine Hutchinson

Email: kath.hutchinson@gmail.com

Tel: 0741385527

ACKNOWLEDGEMENTS

We would like to thank the South African National Research Foundation (NRF), the South Atlantic Meridional Overturning Circulation (SAMOC), and the International Centre for Marine and Atmospheric Sciences over Africa (ICEMASA) for providing the essential funds that facilitated this research. This study would not have been possible without the CTD hydrographic data collected by the Shirshov Institute of Oceanology, the Alfred Wegener Institute, and Laboratoire de Physique des Oceans. We are most grateful for the continued support from the South African National Antarctic Program (SANAP). The Argo float data was supplied by the Coriolis Operational Oceanography Centre, and the altimeter products used were distributed by AVISO. Finally the corresponding author would like to show deep appreciation to the co-authors for their invaluable support and guidance, without which this research would not have been possible.

REFERENCES

1. Lutjeharms, J. 1996. The exchange of water between the South Indian and South Atlantic Oceans. In The South Atlantic. Springer. 125-162.
2. Banks, H.T., Wood, R.A., Gregory, J.M., Johns, T.C. and Jones, G.S. 2000. Are observed decadal changes in intermediate water masses a signature of anthropogenic climate change? *Geophysical research letters*. 27(18):2961-2964.
3. Swart, S., Speich, S., Ansorge, I.J., Goni, G.J., Gladyshev, S. and Lutjeharms, J.R. 2008. Transport and variability of the Antarctic Circumpolar Current south of Africa. *Journal of geophysical research: Oceans* (1978–2012). 113(C9).
4. Sokolov, S., King, B.A., Rintoul, S.R. and Rojas, R.L. 2004. Upper ocean temperature and the baroclinic transport stream function relationship in Drake Passage. *Journal of geophysical research: Oceans* (1978–2012). 109(C5).
5. Watts, D.R., Sun, C. and Rintoul, S. 2001. A two-dimensional gravest empirical mode determined from hydrographic observations in the Subantarctic Front. *Journal of physical oceanography.* 31(8):2186-2209
6. Sun, C. and Watts, D.R. 2001. A circumpolar gravest empirical mode for the Southern Ocean hydrography. *Journal of geophysical research.* 106(C2):2833-2855.
7. Swart, S., Speich, S., Ansorge, I.J., Goni, G.J., Gladyshev, S. and Lutjeharms, J.R. 2008. Transport and variability of the Antarctic Circumpolar Current south of Africa. Journal of geophysical research: Oceans (1978–2012). 113(C9).
8. Meijers, A., Bindoff, N. and Rintoul, S. 2011a. Estimating the four-dimensional structure of the Southern Ocean using satellite altimetry. *Journal of atmospheric and oceanic technology*. 28(4):548-568.