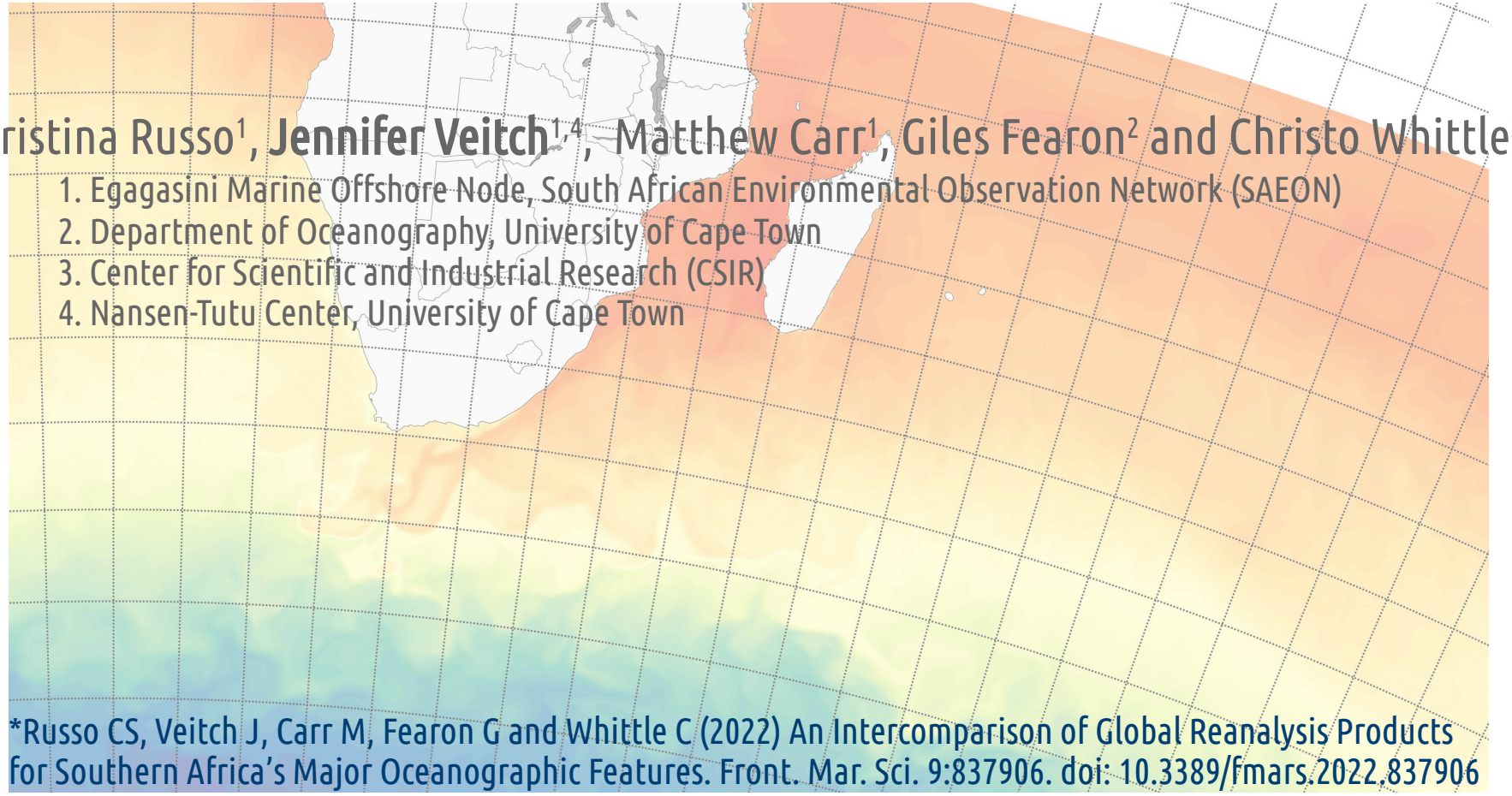
An intercomparison of global reanalysis products for South Africa's major oceanographic features*



Cristina Russo[1], **Jennifer Veitch**[1,4], Matthew Carr[1], Giles Fearon[2] and Christo Whittle[3]

1. Egagasini Marine Offshore Node, South African Environmental Observation Network (SAEON)
2. Department of Oceanography, University of Cape Town
3. Center for Scientific and Industrial Research (CSIR)
4. Nansen-Tutu Center, University of Cape Town

*Russo CS, Veitch J, Carr M, Fearon G and Whittle C (2022) An Intercomparison of Global Reanalysis Products for Southern Africa's Major Oceanographic Features. Front. Mar. Sci. 9:837906. doi: 10.3389/fmars.2022.837906

SOMISANA

Sustainable Ocean Modelling Initiative: a South African Approach

VISION

A sustained and transformed critical mass of internationally recognized South African numerical ocean modelling experts who provide accurate information about the changing state of the ocean for enhanced impact.

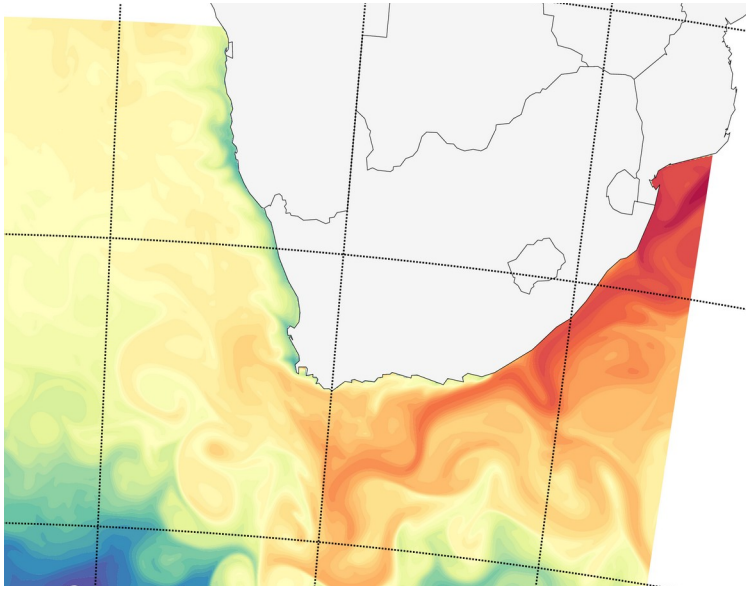
MISSION

Demonstration satellite and model-derived operational products.

Capacity development

GOAL

A limited domain regional operational forecast system, downscaled from global systems.



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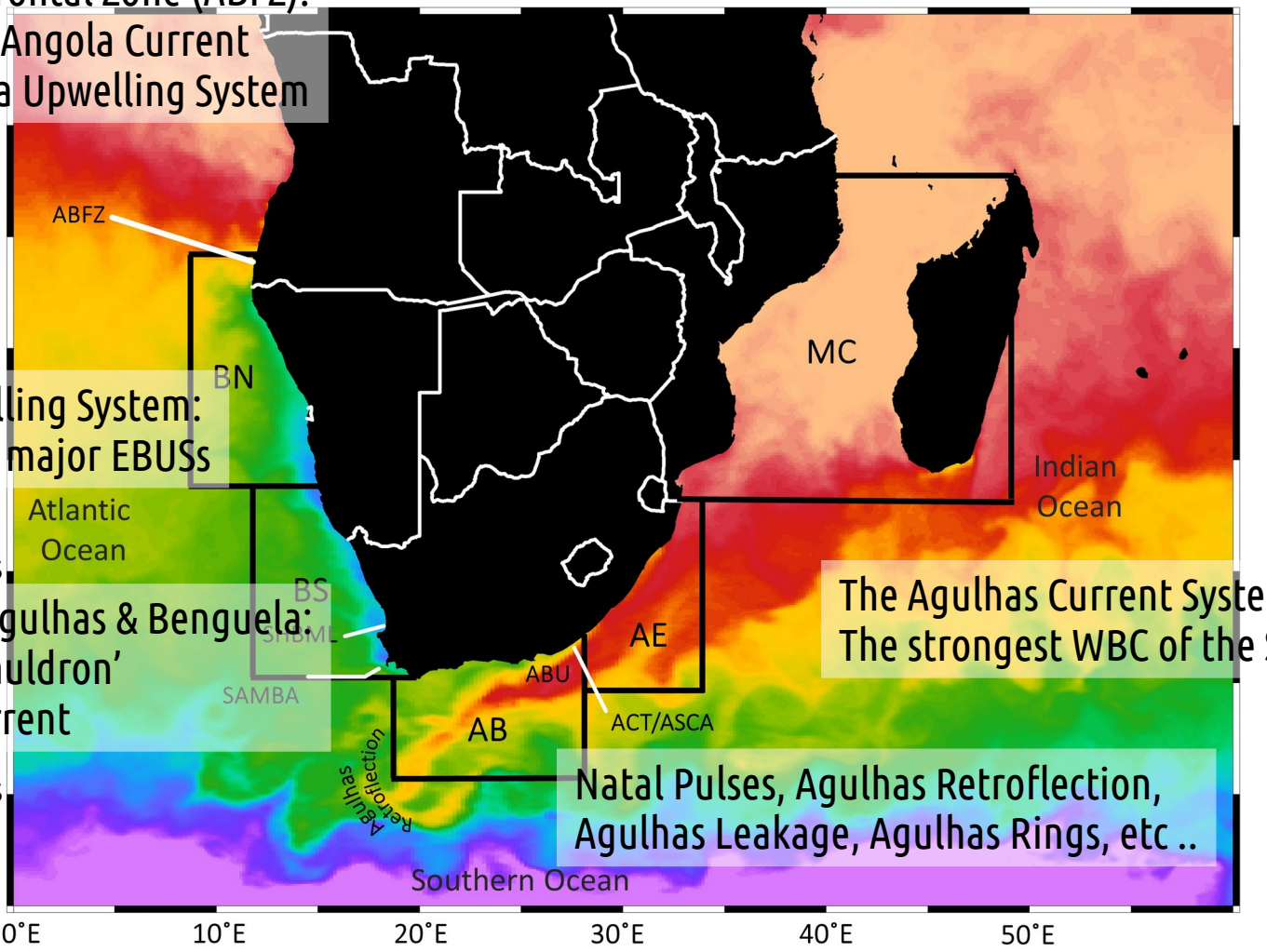
NRF National Research Foundation
SAEON South African Environmental Observation Network

South Africa's 'regional' ocean setting: the boundaries of the coastal ocean

Angola-Benguela Frontal Zone (ABFZ):
Where the tropical Angola Current
Meets the Benguela Upwelling System



The Benguela Upwelling System:
One of the Worlds 4 major EBUSs

Interaction of the Agulhas & Benguela:
- Turbulent 'Cape Cauldron'
- Good Hope Jet Current

The Agulhas Current System:
The strongest WBC of the SH

Natal Pulses, Agulhas Retroflection,
Agulhas Leakage, Agulhas Rings, etc ..

Highlight: Two distinctly different types of major ocean current systems,
an eastern and western boundary current system that directly interact (globally unique)

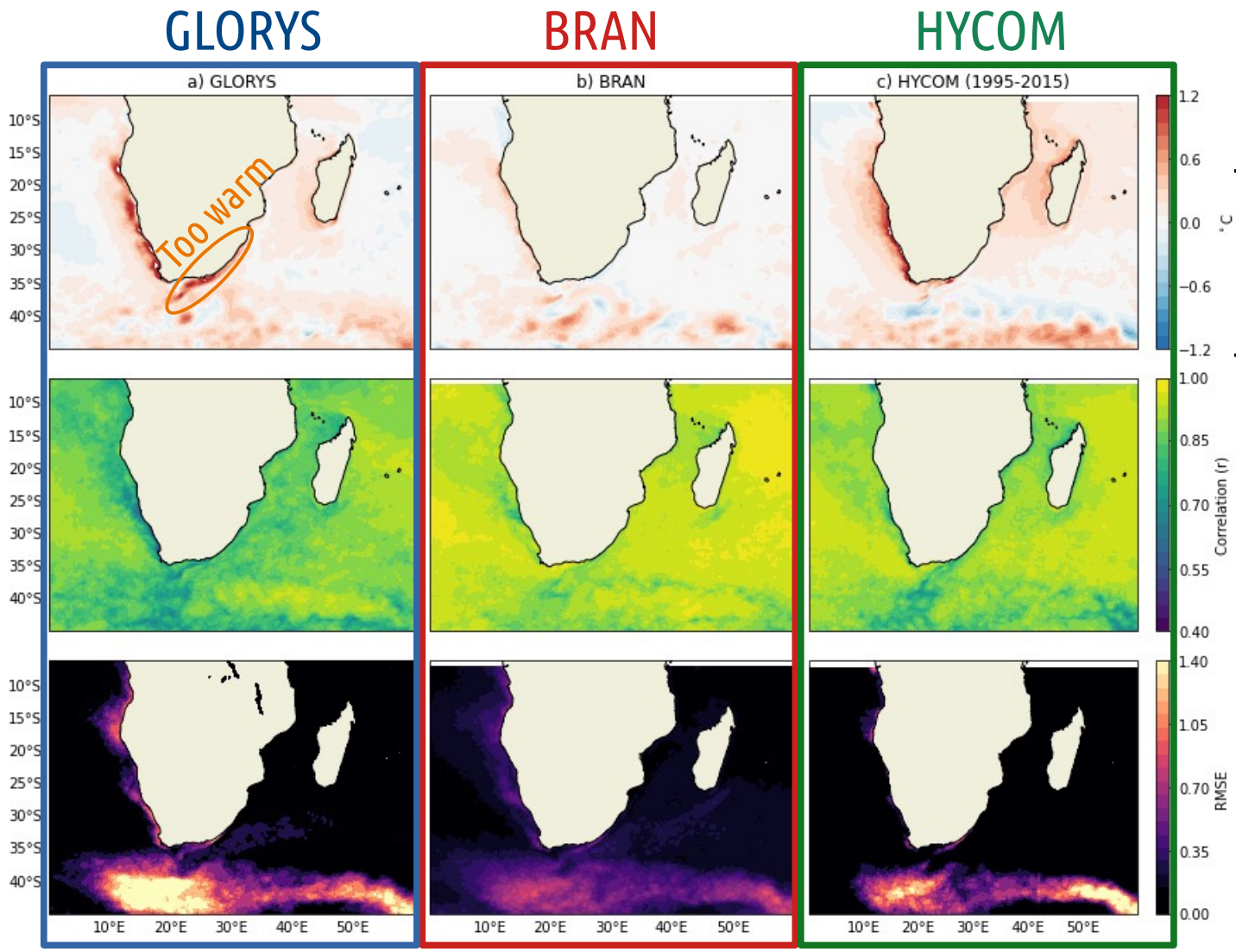
The Global Reanalysis Systems

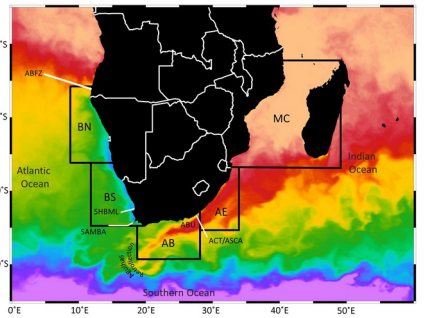
	BRAN2020 Bluelink	**GLORYS12V1** Mercator Ocean	**GOFS 3.1** NRL
Model	MOM v5	NEMO v3.1	HYCOM v2.2.99
Domain	75°S – 75°N (no sea-ice)	Global (including sea-ice)	Global (including sea-ice)
Time	Jan 1993 – Dec 2019	Jan 1993 - Dec 2019	Jan 1994 – Dec 2015
Resolution	0.1^0 50 vertical levels	0.083° 50 vertical levels	0.083° (40°S-40°N) 41 vertical levels
Atmospheric Forcing	JRA-55 (~55 km res.)	ECMWF ERA-Interim (~79 km res.), ERA5 (~31 km res.) from 1/01/2019	NCEP CFSR (~38 km)
Data Assimilation	Multi-scale Ensemble Optimal Interpolation	Multivariate Kalman filter & 3D-VAR for large-scale biases.	NCODA 3DVAR
Link	https:// 10.25914/6009627c7af03	https://doi.org/10.48670/ moi-00021	https://www.hycom.org/dataserver
Reference	Chamberlain et al., 2021	Lellouche et al., 2021	Cummins et al., 2013

NOTE: All models have a similar resolution and are eddy-resolving (~10 km), but vary in most other aspects

Satellite SST: OSTIA L4 1/20°

Large-scale: SST patterns





BIAS

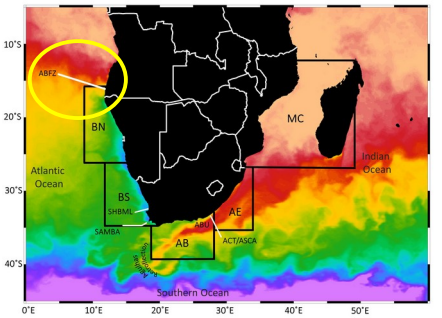
CORRELATIONS

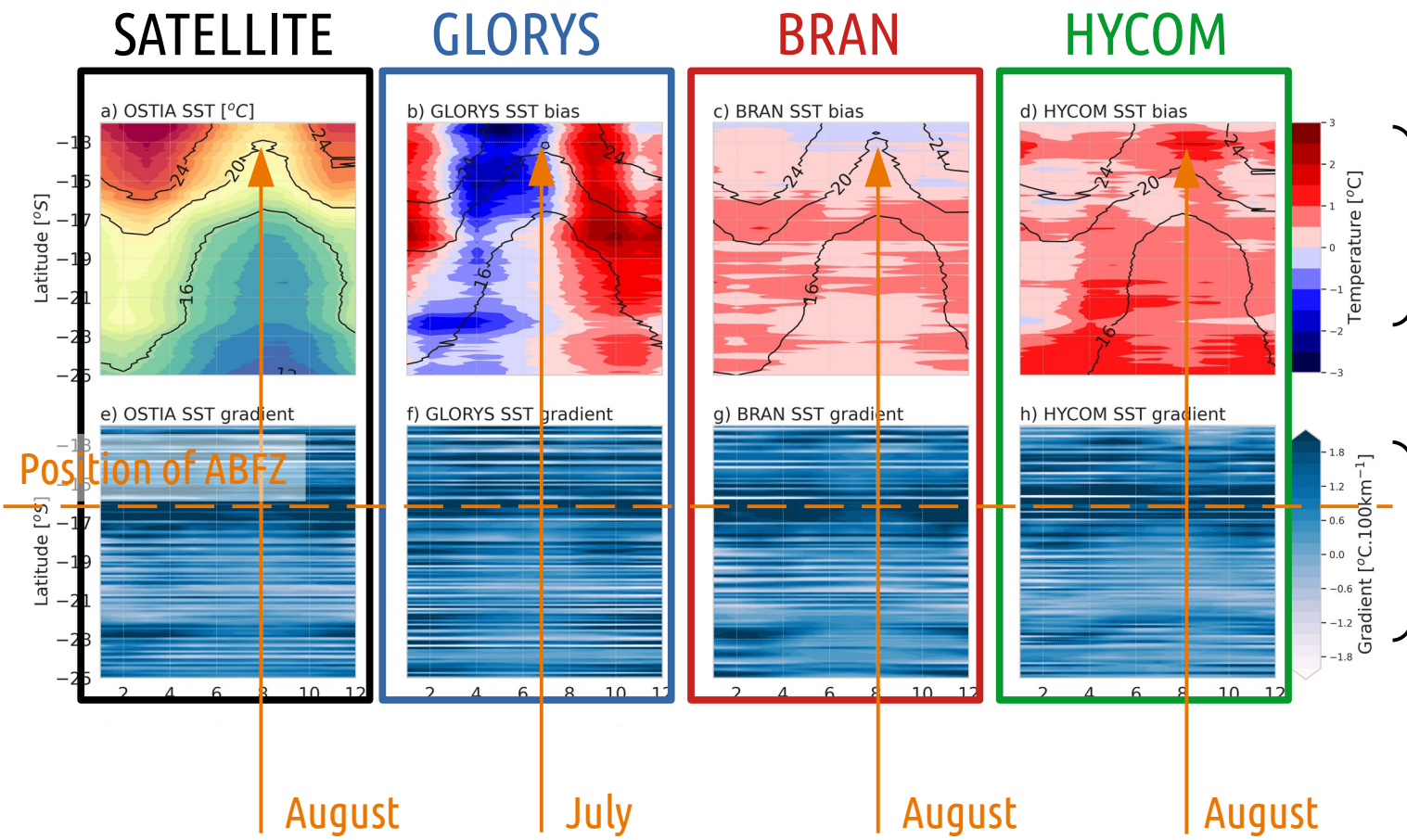
RMSE

NOTE: All models struggle to accurately capture regions of intense frontal activity. Could this be related to satellite data used as 'truth'? BRAN is doing something right wrt SSTs!

The the Angola Benguela Frontal Zone (ABFZ)

Satellite SST: OSTIA L4 1/20°



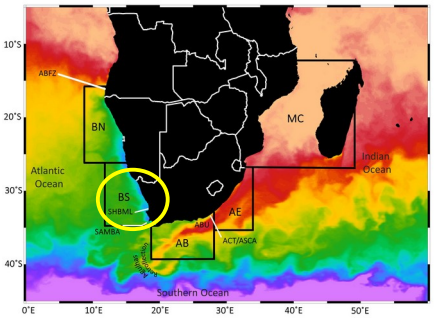


SSTs and model SST biases

Meridional SST gradient

NOTE: All models capture the position of the ABFZ well. GLORYS's seasonal cycle is offset by 1 month.

In Situ Data: SHB Monitoring Line



The southern Benguela upwelling system

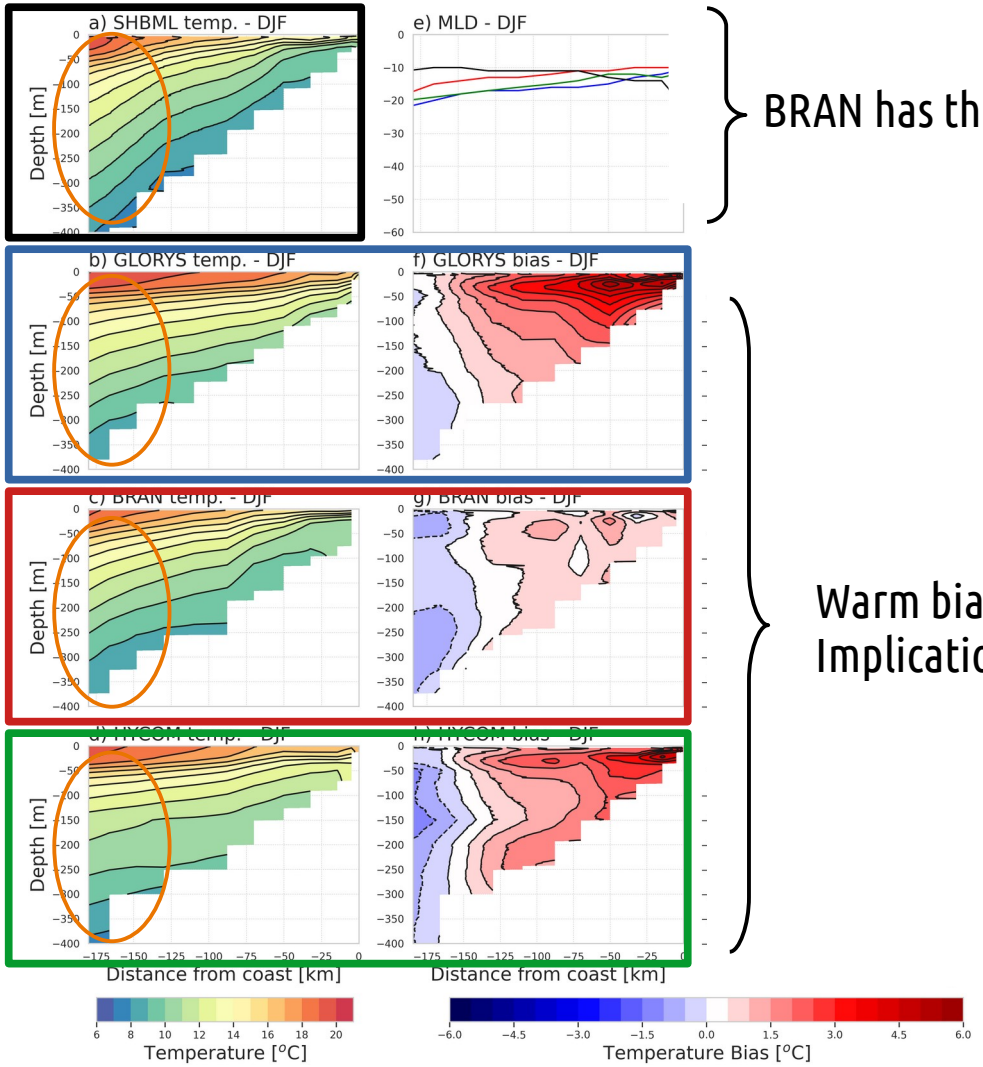
SUMMER (DJF) MEAN SECTION

IN SITU

GLORYS

BRAN

HYCOM



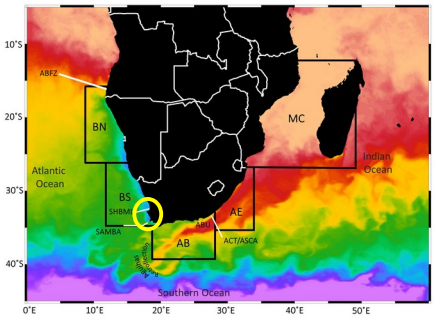
BRAN has the shallowest MLD

Warm bias on the shelf, cool bias offshore
Implications for shelf-edge jet?

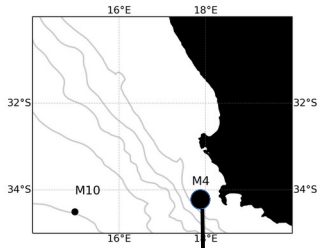
NOTE: All models underestimate the upward tilt of isotherms toward the shelf-edge. BRAN has the shallowest MLD and most accurate from mid-shelf offshore.

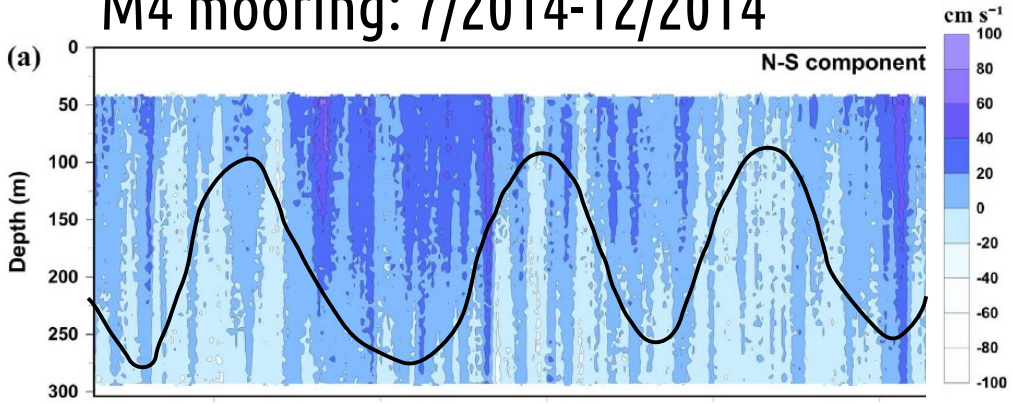
Where the Agulhas meets the Benguela: The Good Hope Jet

In Situ Data: SAMBA array



M4 mooring: 7/2014-12/2014



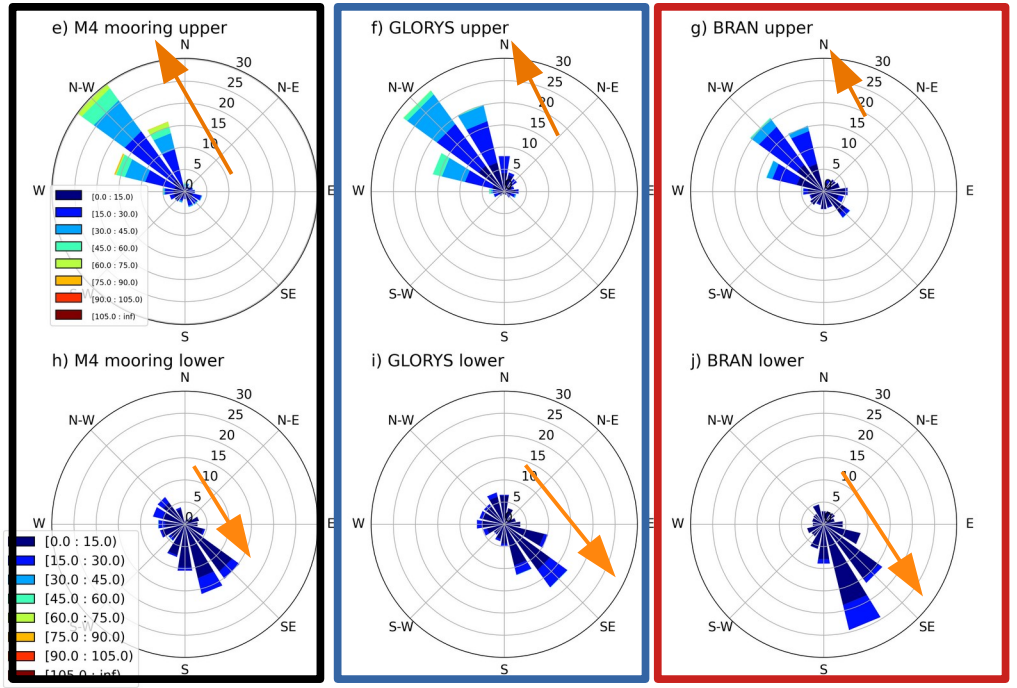


Strong equatorward (Good Hope Jet)

Weak poleward

NOTE: Equatorward shelf-edge jet is underestimated in both models, more so in BRAN. Strength of the Poleward undercurrent is well reproduced in both, but variability reduced in BRAN.

IN SITU | GLORYS | BRAN



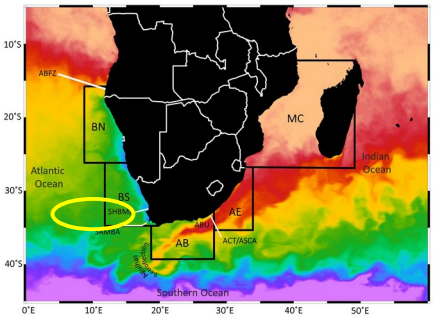
0-100m

250-300m

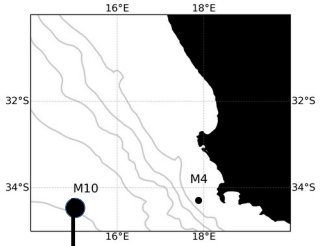
* HYCOM GOFS 3.1 does not cover this period.

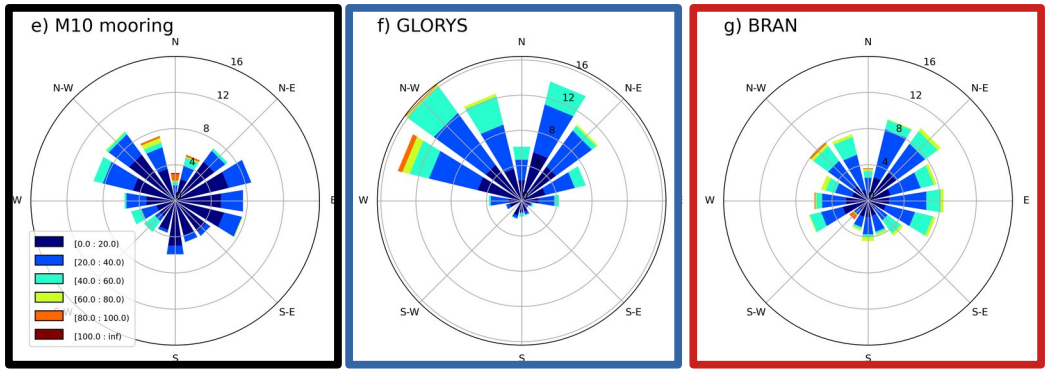
Where the Agulhas meets the Benguela: The Cape Cauldron

In Situ Data: SAMBA array



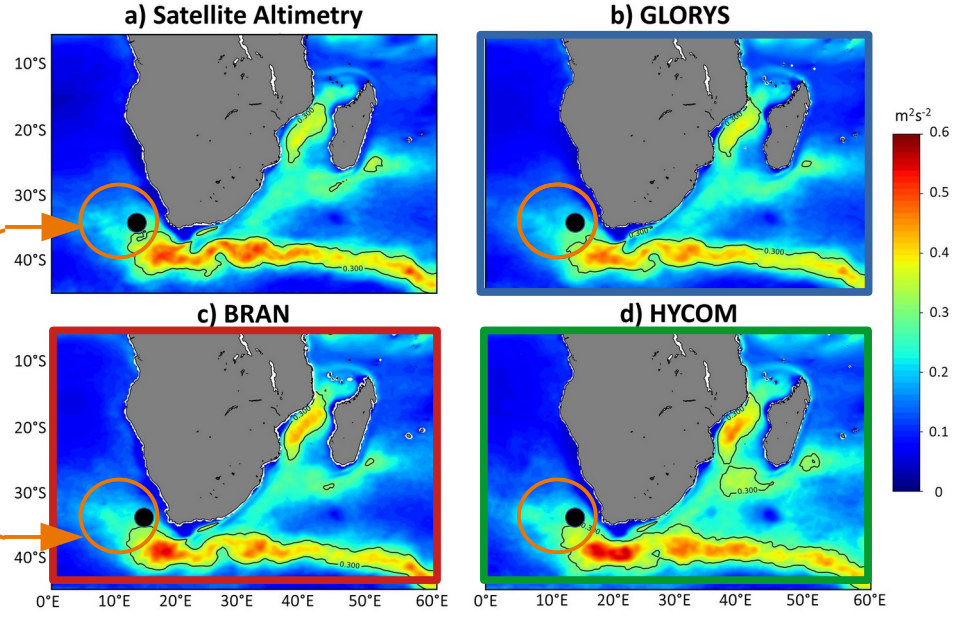
IN SITU GLORYS BRAN





0-450m

Surface Eddy Kinetic Energy



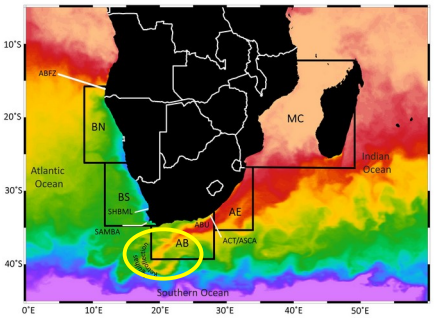
NOTE: Both models reproduce a highly variable/turbulent current field (however GLORYS tends to be too northward). Both overestimate current speeds. Lack of mesoscale-submesoscale interactions in the models?

Approx. position of Cape Cauldron

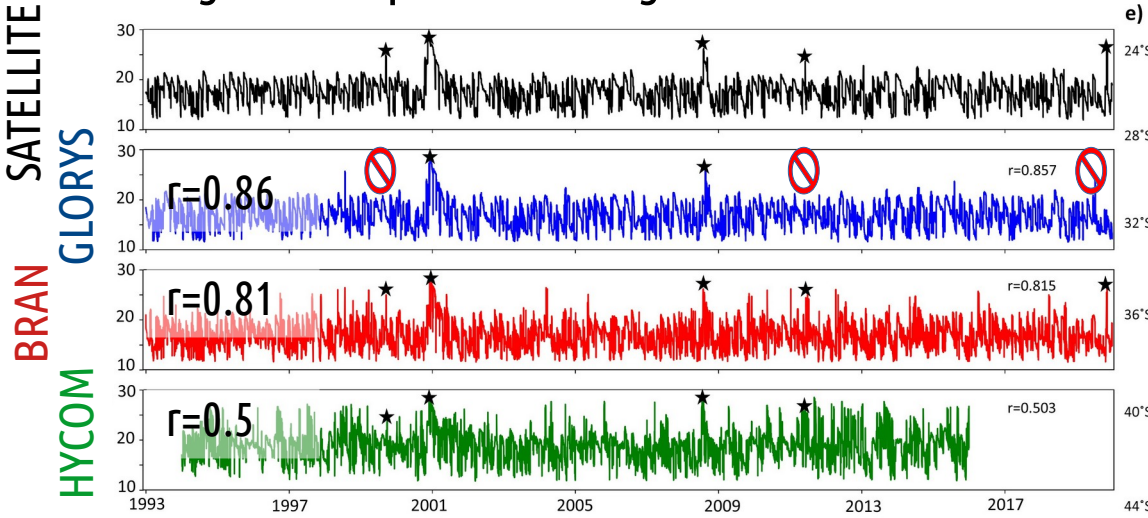
* HYCOM GOFS 3.1 does not cover this period.

The Agulhas Current: Its retroflection

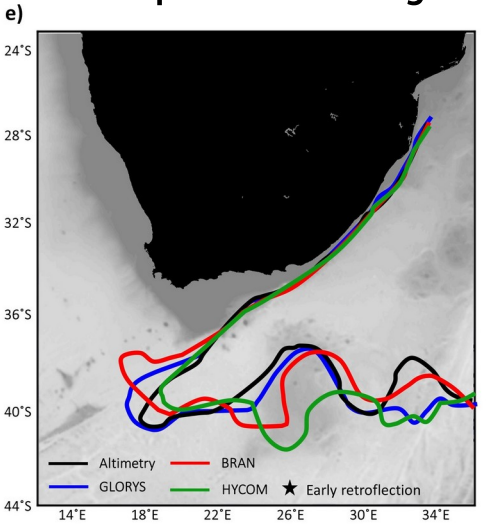
Satellite Altimetry



Longitudinal position of Agulhas Retroflection



Mean position of Agulhas

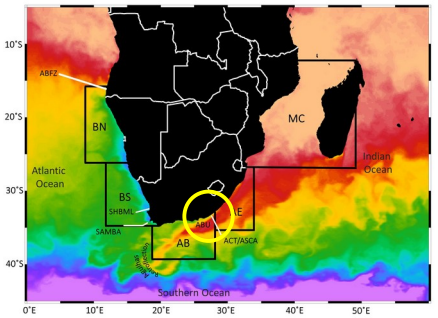


★ Early retroflections

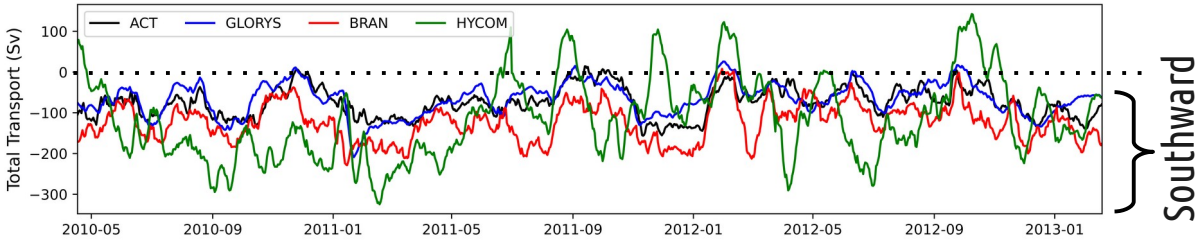
NOTE: While GLORYS correlates best with the satellite-derived retroflection position, it does not capture all of the early retroflection events. Too stable in the southern part of the Agulhas?

The Agulhas Current: Its transport

In Situ Data: ACT/ASCA array

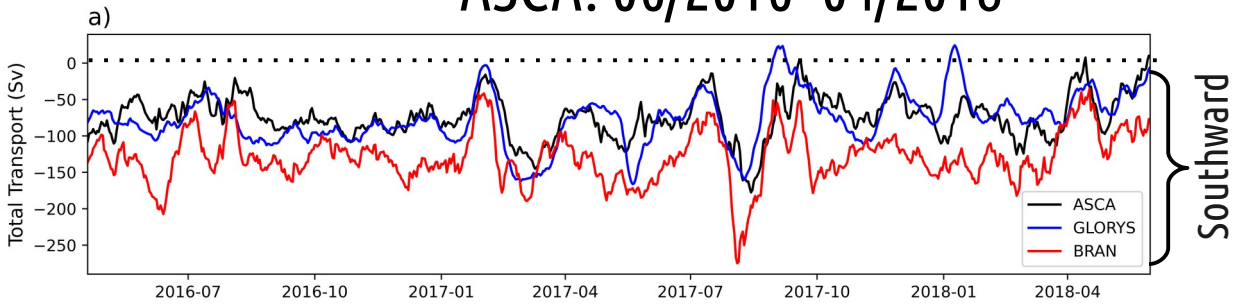


ACT: 05/2010- 01/2013



Mean transport		r-value
ACT Data:	74.5 ±1.5 Sv	
GLORYS:	65.8 ± 1.2 Sv	0.75
BRAN:	123.7 ± 1.4 Sv	0.72
HYCOM:	116.3 ± 2.7 Sv	not significant

ASCA: 06/2016- 04/2018

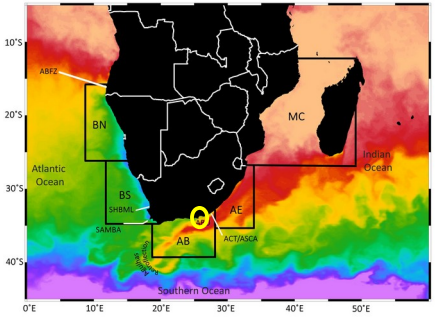


Mean transport		r-value
ACT Data:	73.2 ±1.1 Sv	
GLORYS:	75.6 ± 1.3 Sv	0.61
BRAN:	128.6 ± 1.3 Sv	0.72

NOTE: HYCOM is too strong and too variable, which is consistent with too high EKEs in the Agulhas Current region. BRANs Agulhas Current is consistently too strong, but it captures the variability well. GLORYS captures its transport best.

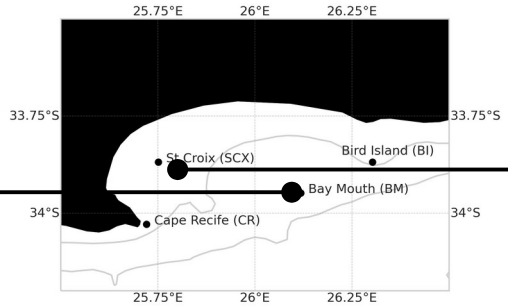
Inshore of the Agulhas: Algoa Bay temperatures

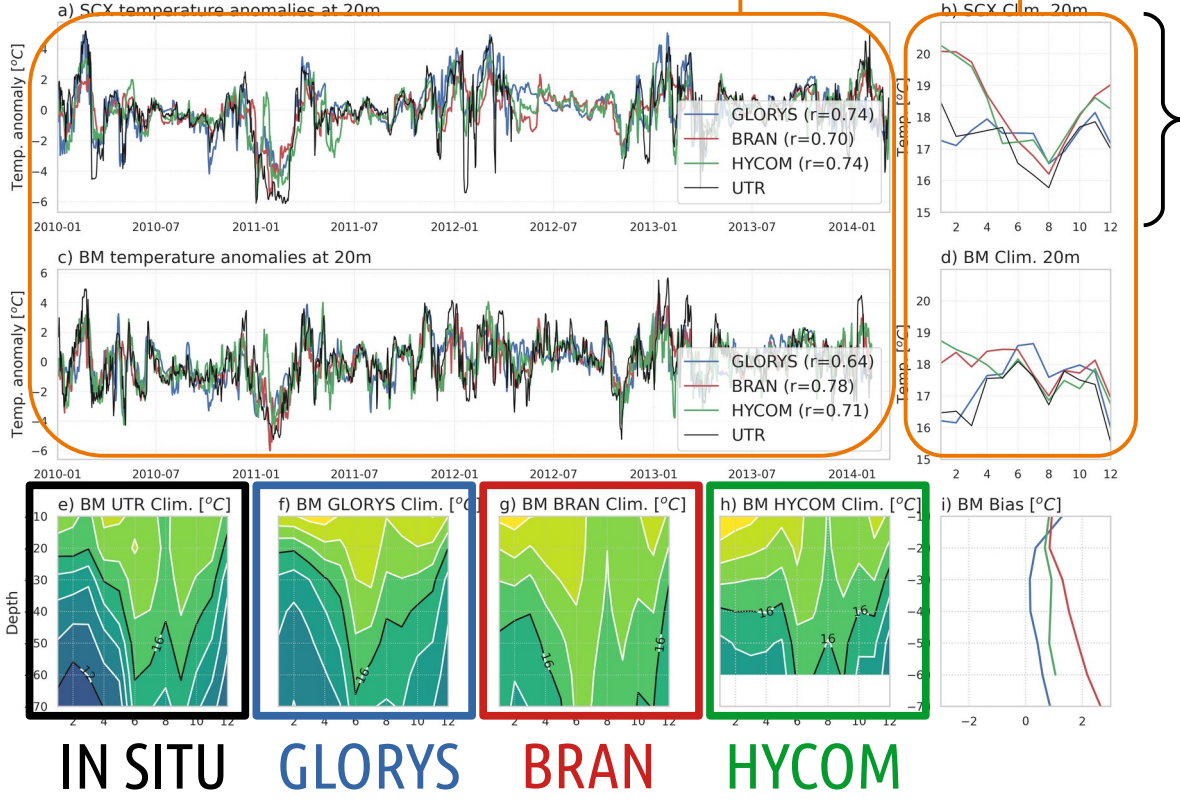
In Situ Data: Algoa Bay UTRs



Event-scale ✓

Seasonal cycle ✗

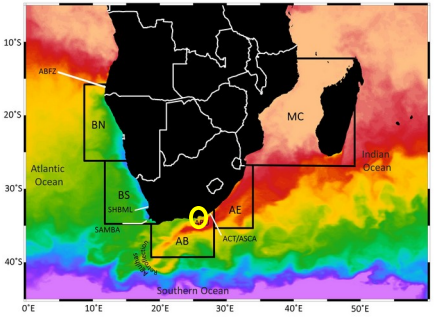


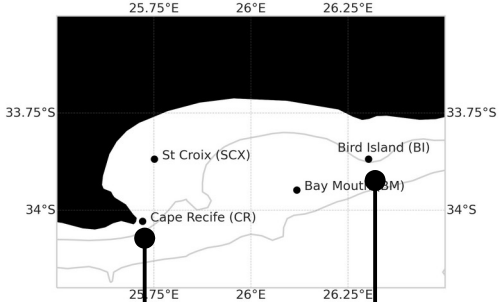


NOTE: All models capture the event-scale subsurface temperature anomalies well, but all struggle to accurately capture the seasonal cycle. GLORYS does well in summer, but fails to capture winter cooling. BRAN and HYCOM do better in winter, but do not capture the summer cooling.

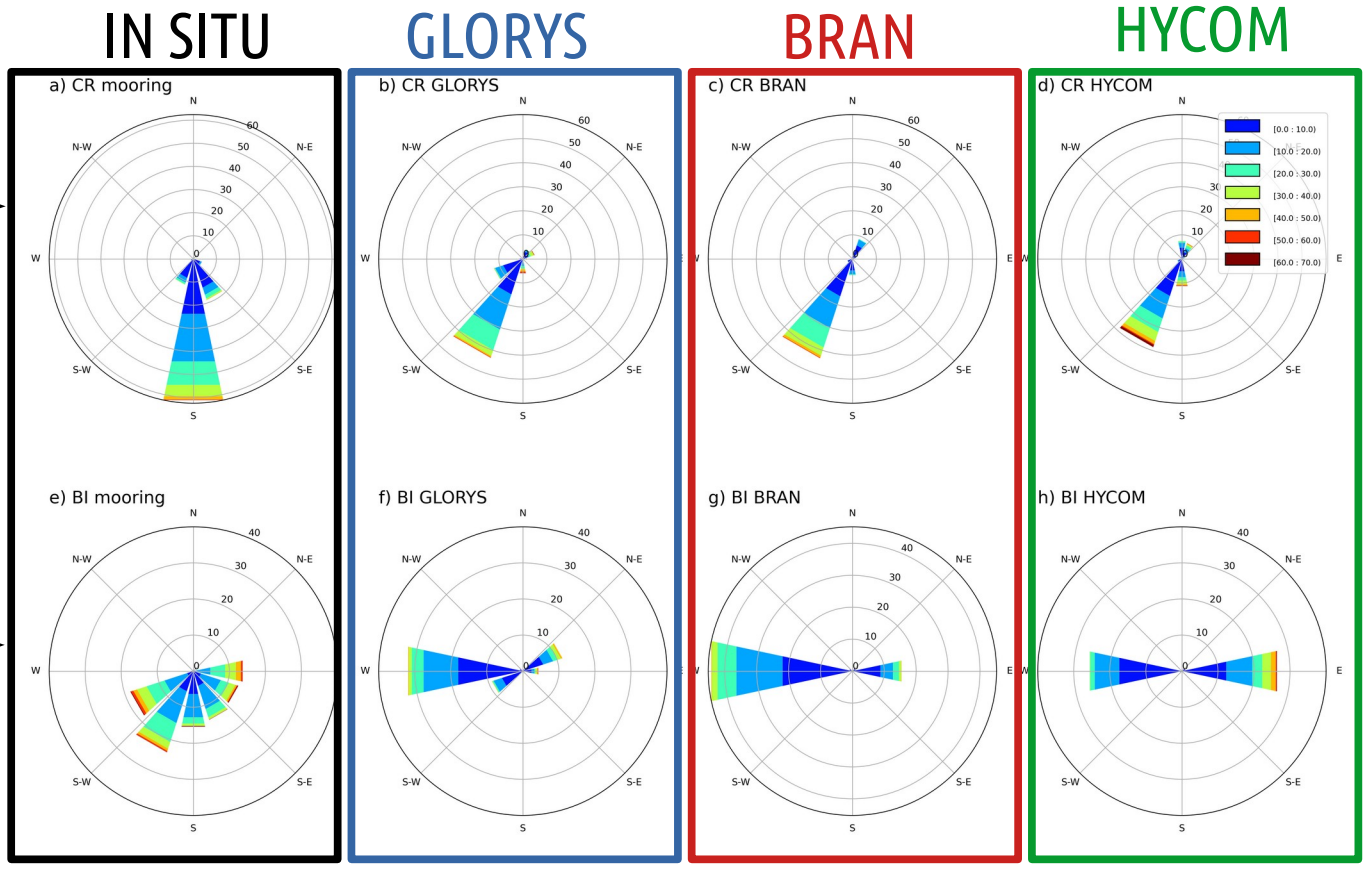
Inshore of the Agulhas: Algoa Bay currents

In Situ Data: Algoa Bay ADCPs



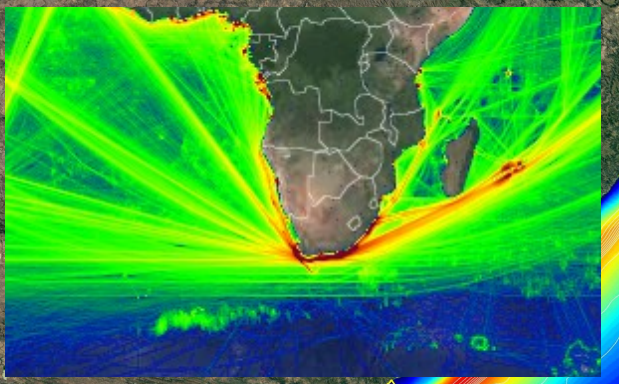


NOTE: All models struggle to accurately resolve nearshore currents!



What is happening within South Africa's EEZ?

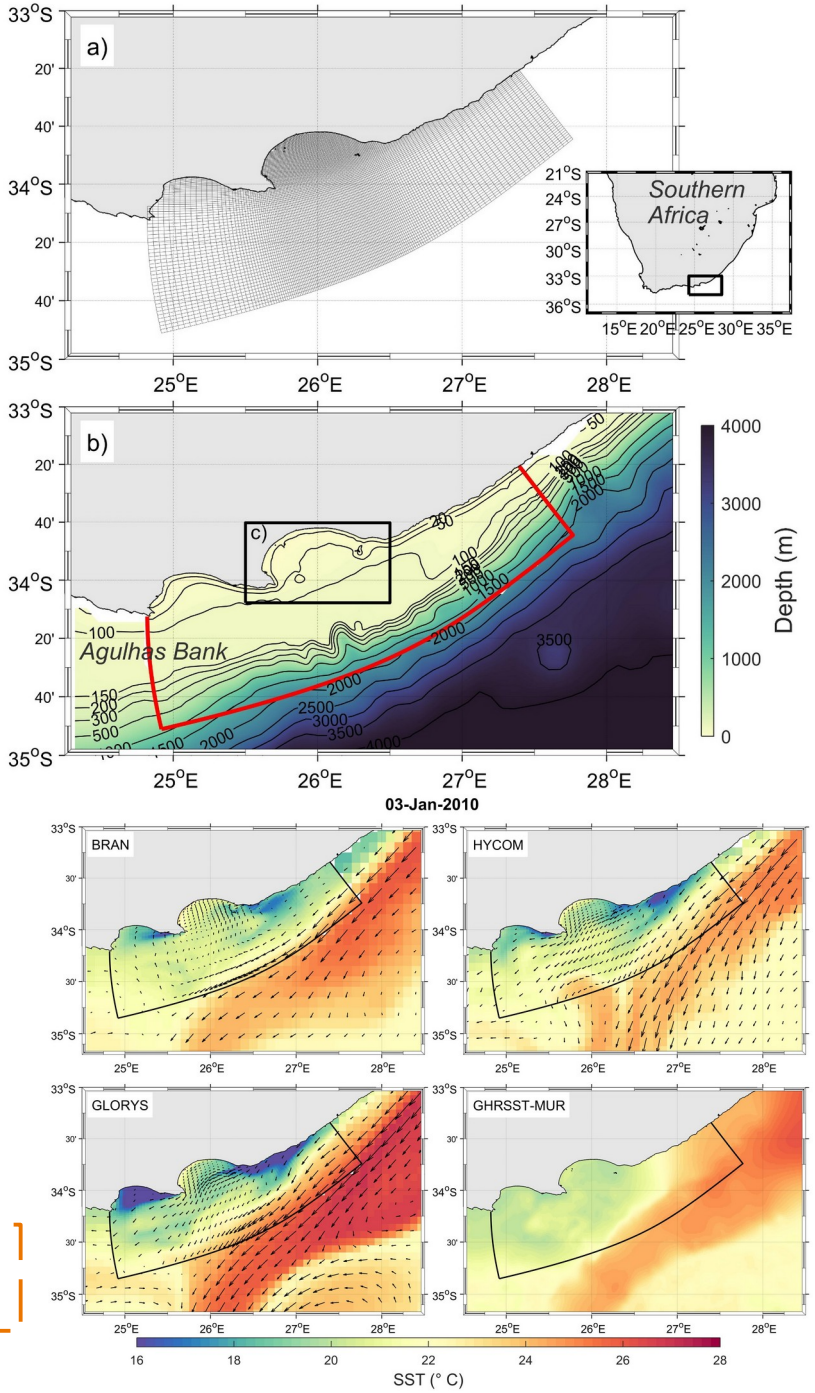
A. Several Marine Protected Areas
B. Extreme oceanographic conditions, globally relevant science and long term monitoring lines
C. Deep-sea drilling
D. Oil bunkering
E. All of the above …. and more!



NOTE: Due to the various activities, high conservation value and that it is realtively well-monitored, Algoa Bay chosen as 'pilot' site for development of bay-scale forecast system.

Downscaling Approach: Algoa Bay

- Developed with the Coastal and Regional Ocean COmmunity model (CROCO)
- High resolution curvilinear grid (~500 m in Algoa Bay)
- Atmospheric forcing – tested sensitivity to winds of different resolutions:
  - 3 km resolution WRF model from Climate Systems Analysis Group (CSAG)
  - ~30 km reanalysis from CFSR
- Boundary forcing – tested sensitivity to different global ocean reanalysis products:
  - HYCOM
  - GLORYS
  - BRAN*
- Our model 'downscales' these coarse resolution (1/10˚ to 1/12˚) products to high resolution over Algoa Bay

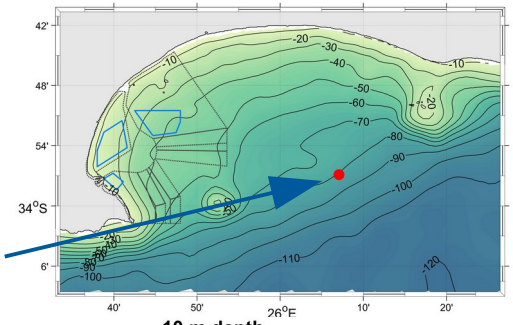


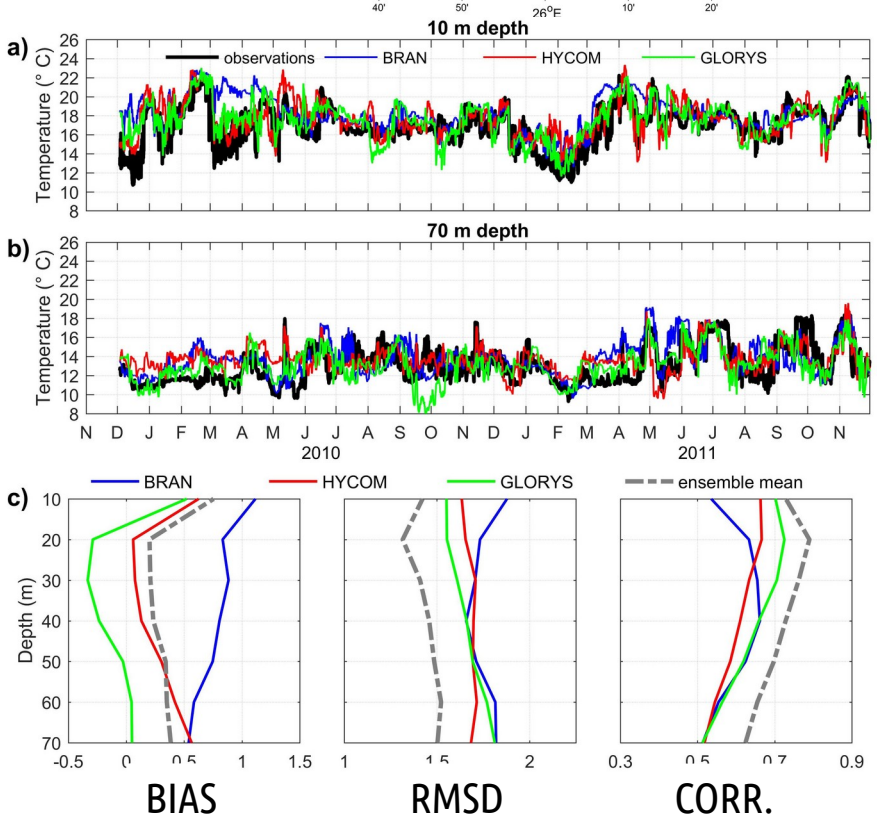
NOTE: The curvilinear grid was produced using Delf3D tools.

Downscaling Evaluation: Algoa Bay

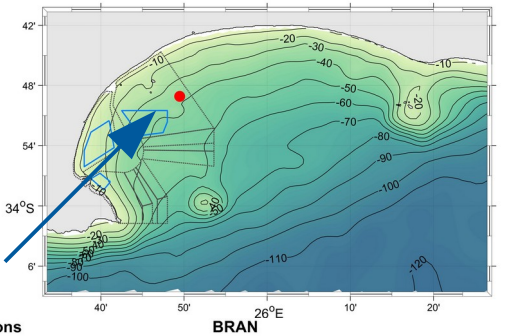
Atmospheric forcing: NCEP CFSR (~38 km), no assimilation

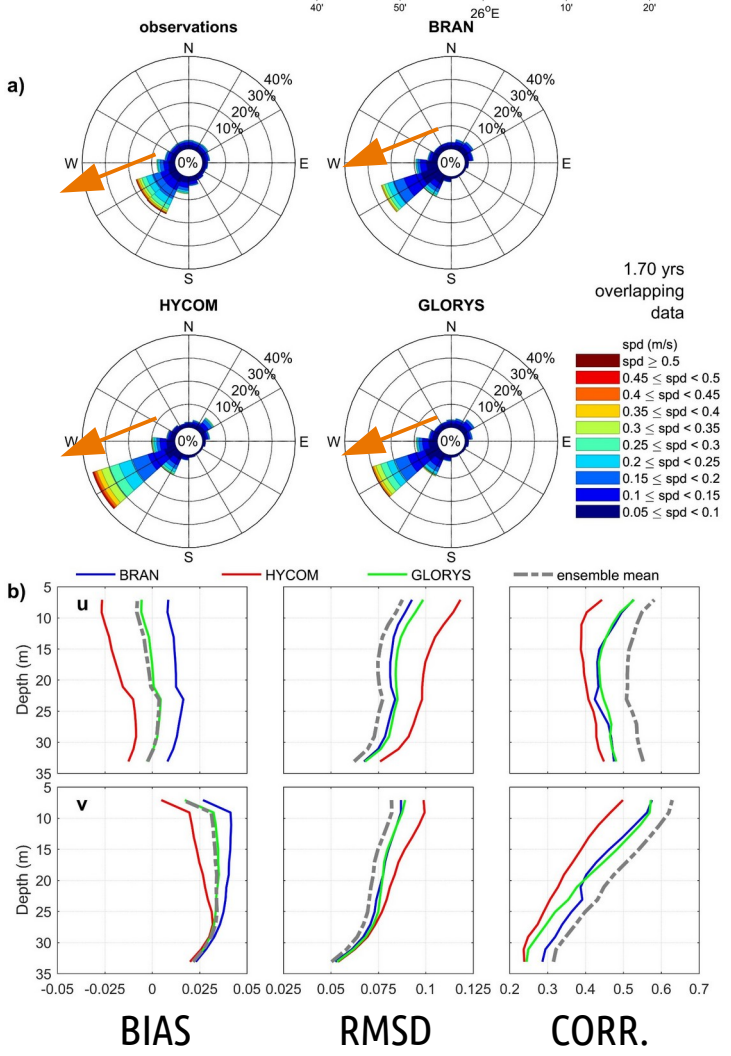
Temperature





Currents

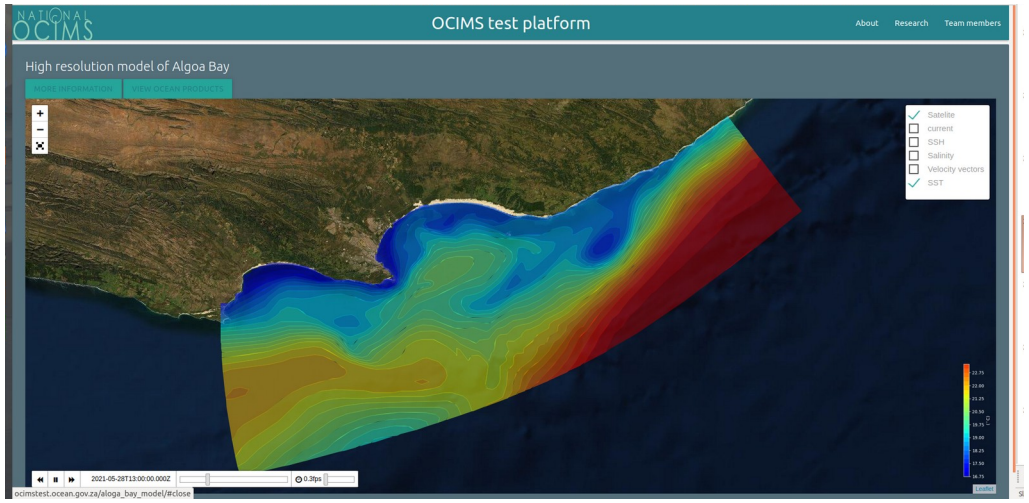


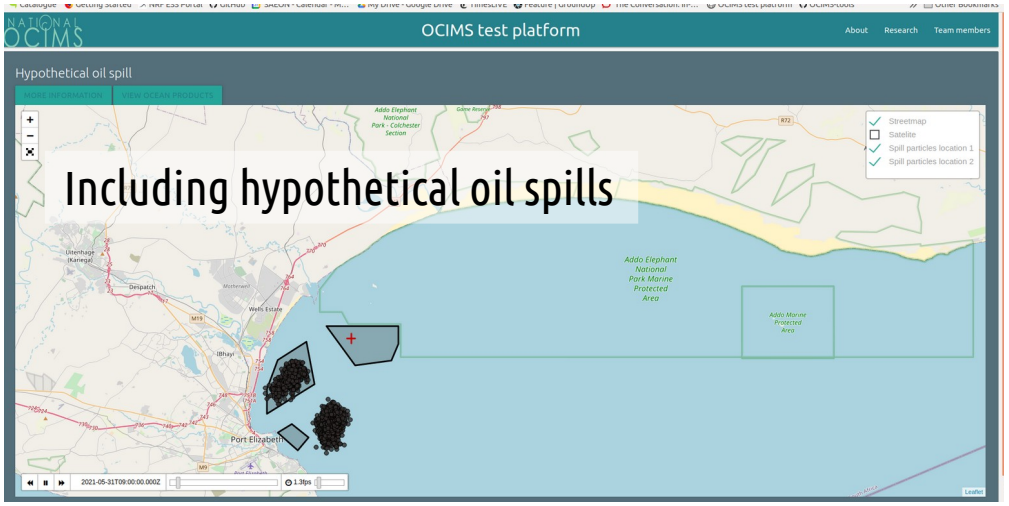


NOTE: Biases are improved for each downscaling experiment (despite low resolution wind forcing) and the ensemble mean performs best. Not shown: higher res. wind forcing improves skill in some places more than others

Pilot: Algoa Bay Forecast System

Atmospheric forcing: GFS ; Boundary forcing: GLORYS forecasts



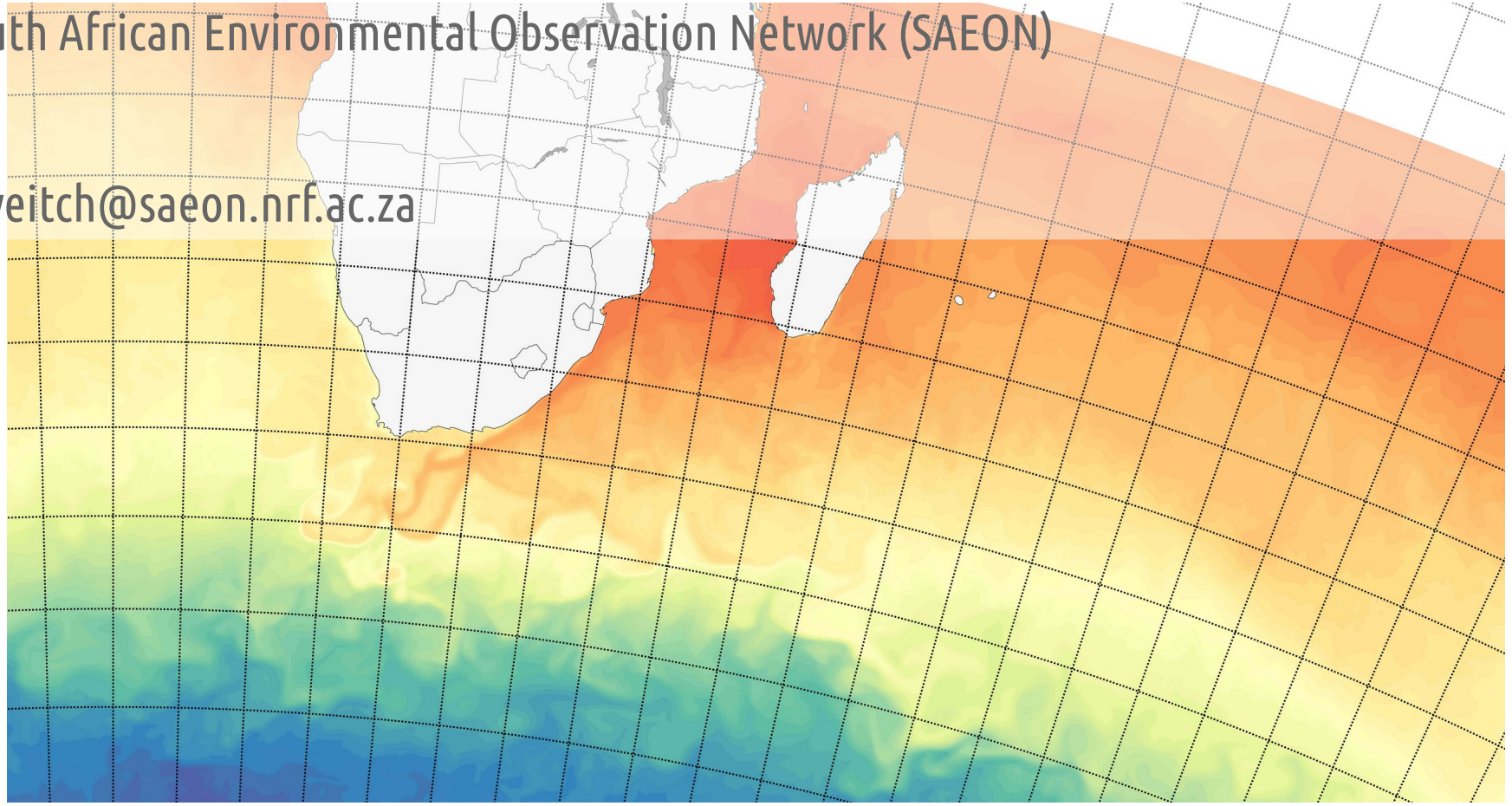


PLAN: Improve this rudimentary OFS, develop new bay-scale OFSs in other contentious/sensitive regions with value added tools geared to our stakeholder needs. Support South Africa's contribution to the CoastPredict program.

Thank you!

Jennifer Veitch
South African Environmental Observation Network (SAEON)

ja.veitch@saeon.nrf.ac.za



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NANSEN-TUTU CENTRE
MARINE ENVIRONMENTAL RESEARCH

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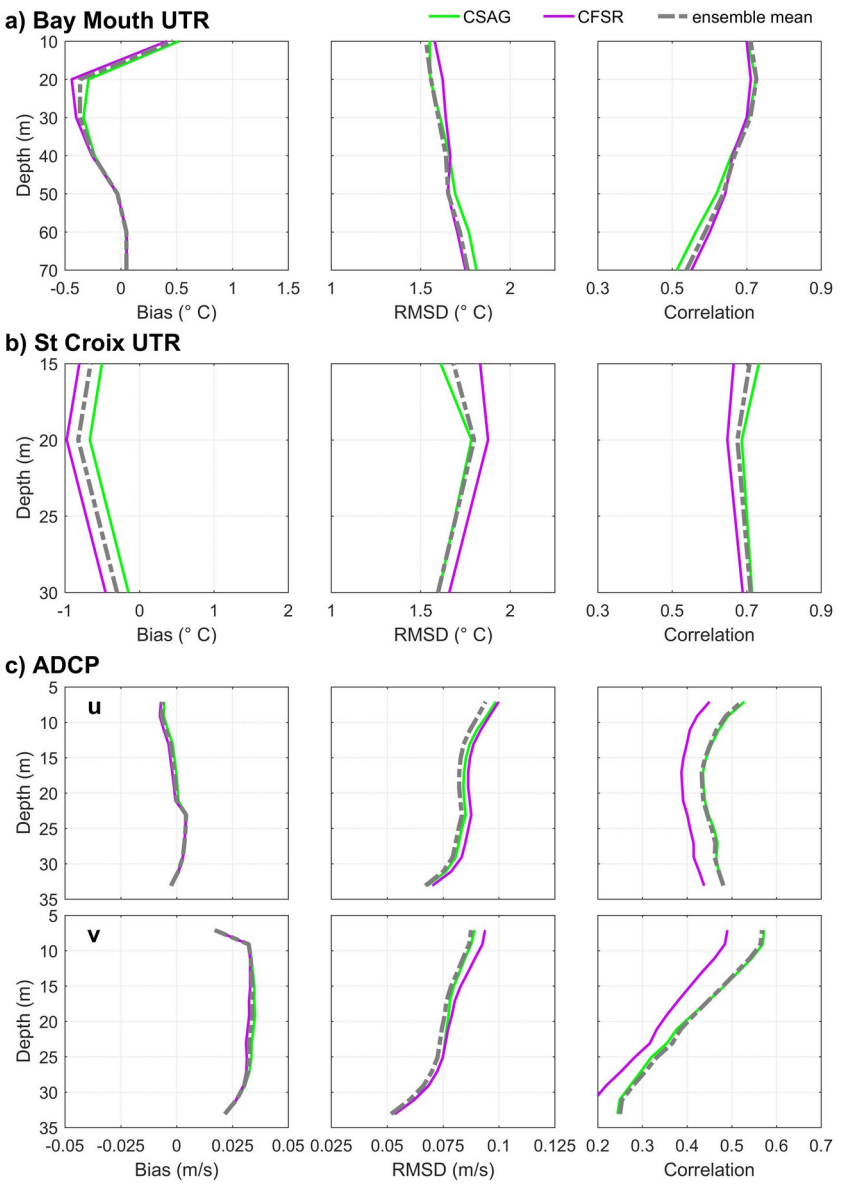
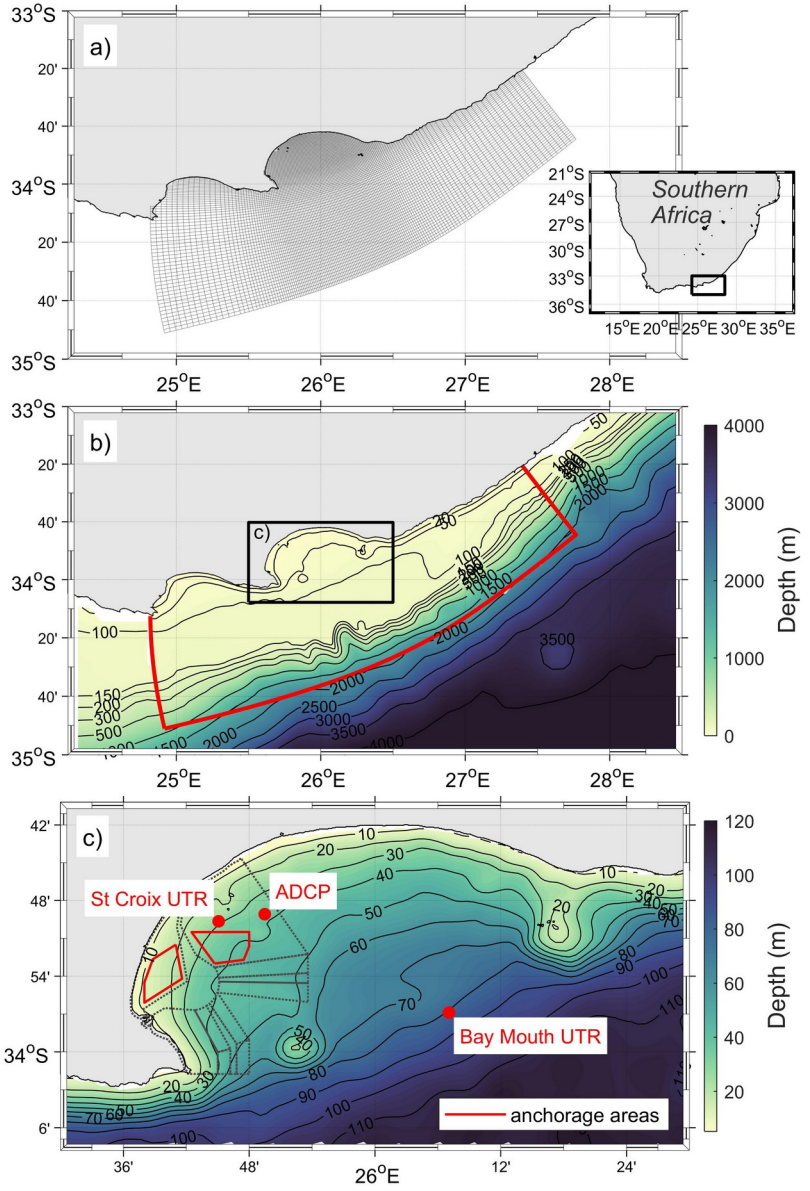
CSIR
our future through science

NRF
National Research Foundation
SAEON
South African Environmental Observation Network


a) Bay Mouth UTR
CSAG
CFSR
ensemble mean
Depth (m)
Bias (° C)
RMSD (° C)
Correlation
b) St Croix UTR
c) ADCP
u
v
Bias (m/s)
RMSD (m/s)


a)
b)
c)
Southern Africa
St Croix UTR
ADCP
Bay Mouth UTR
anchorage areas
Depth (m)