Time series of SST anomalies off Western Africa

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Supported by ONR through the MISST for IOOS project

GHRSST XV

2-6 June 2014 Cape Town, South Africa

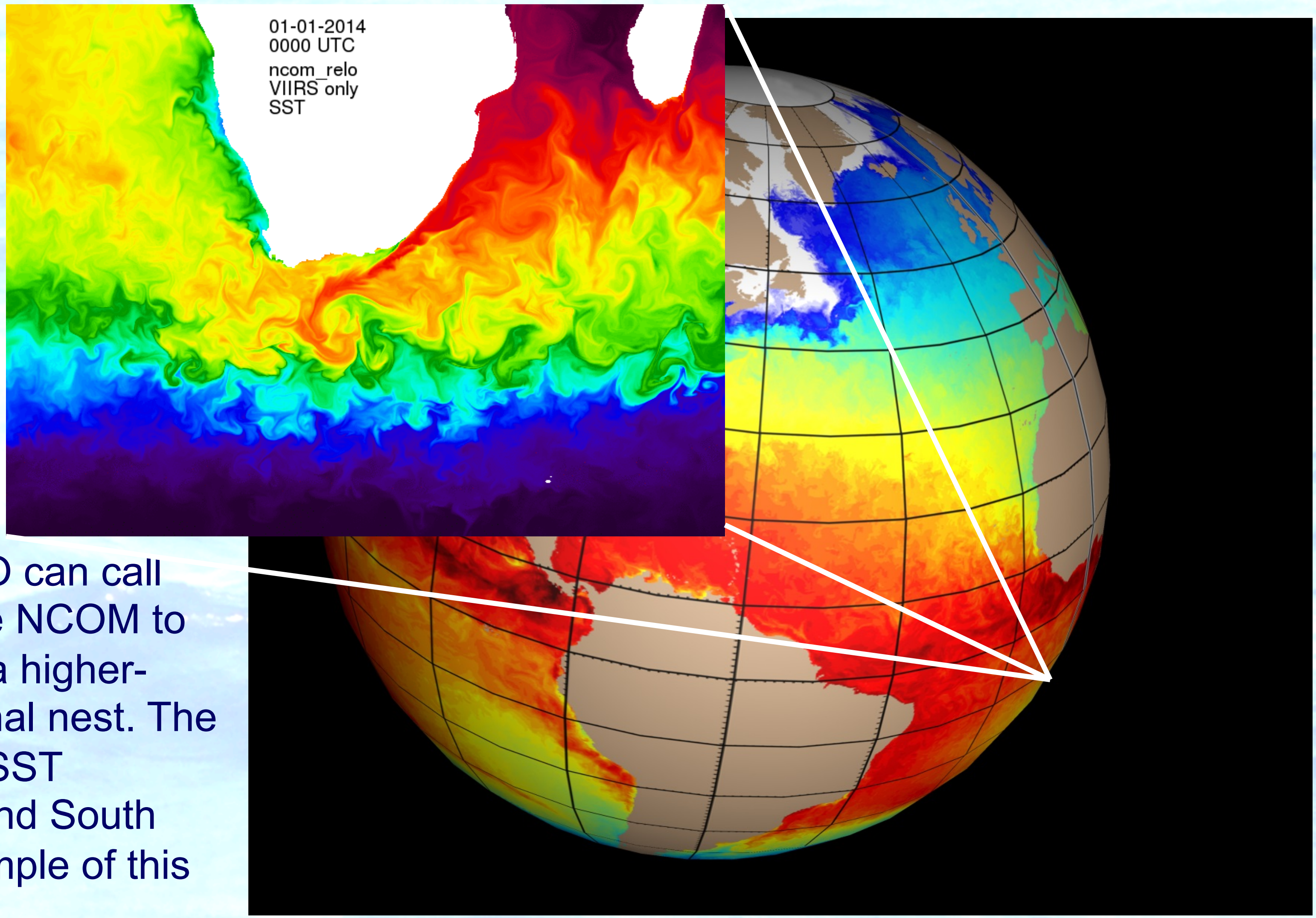
Assimilative forecasts of SST around South Africa

- Assimilative ocean models provide a tool to understand SST variability around southern Africa
  - What causes the variability?
  - What causes spatial and temporal differences in variability?
  - How are other ocean properties changing?

- To be considered:
  - Assimilative model evaluation
  - Diurnal warming
  - Upwelling

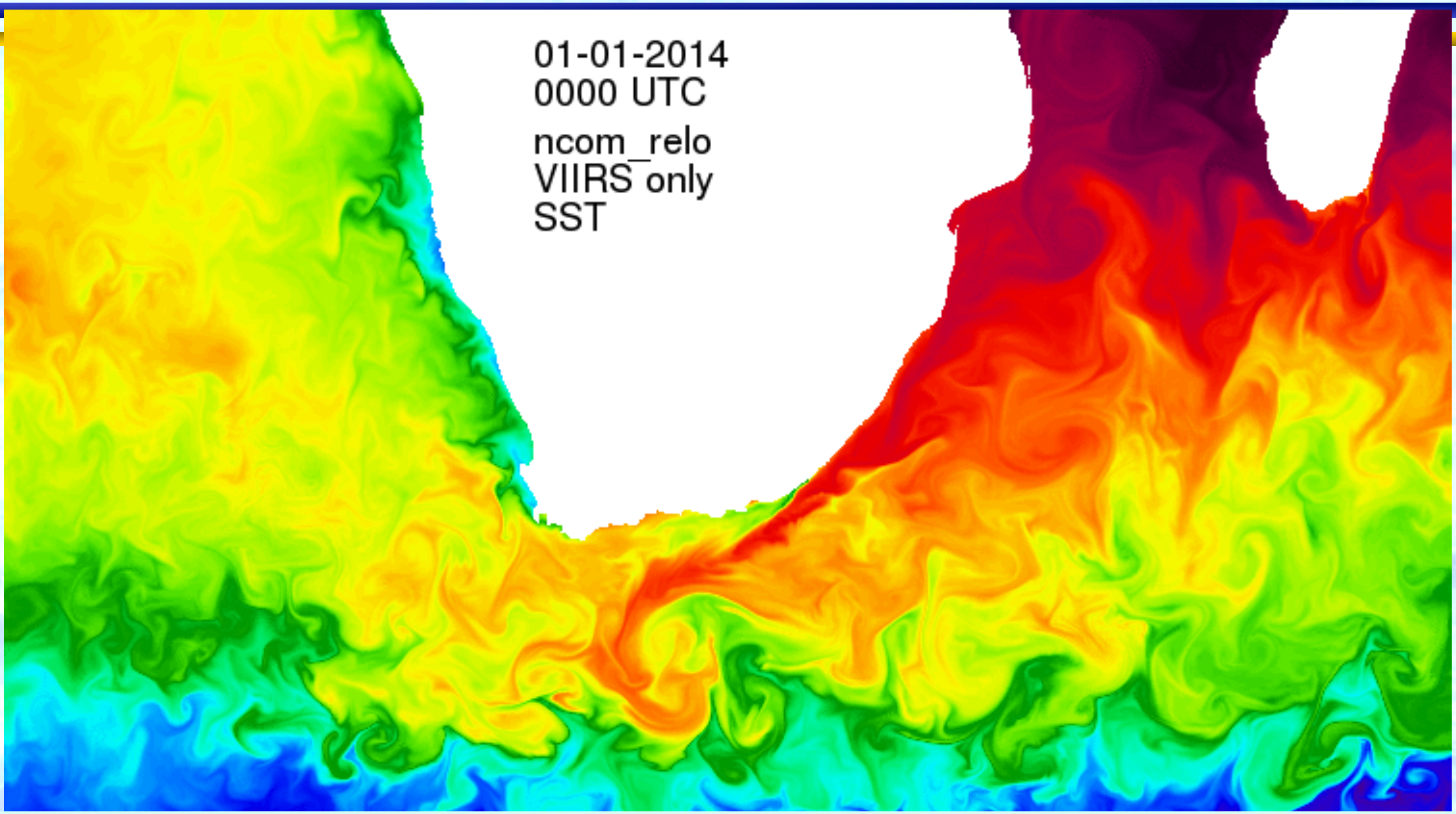
Example of the Navy's capability to implement relocatable ocean model

When mission support requires more detail than is provided by the global ocean forecast system (GOFS; Global HYCOM) …



… NAVOCEANO can call upon relocatable NCOM to rapidly prepare a higher-resolution regional nest. The model used for SST predictions around South Africa is an example of this capability.

Use a standard relocatable NCOM for forecast January-April 2014 SST South Africa



- model: Navy Coastal Ocean Model (NCOM; Barron *et al.*, 2006) 3km grid
- assim: Navy Coupled Ocean Data Assim. (NCODA 3DVAR FGAT; Cummings, 2005)
- atmosphere: Navy Global Environmental Model (NAVGEM 1.1)
- lateral boundaries: GOFS 3.0 (HYCOM 7 km global; Chassignet, *et al*., 2007)
- rivers: monthly river climatology; (Barron and Smedstad, 2002)

What observations are normally assimilated in US-Navy ocean forecasts?

Satellite SST

Polar	Geostationary
AVHRR	GOES
VIIRS	MSG
MetOP	MTSAT
AMSR-2	COMS-1

Use these two SST sources, exclude the rest

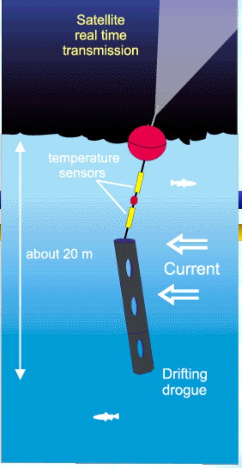
Additional Satellite

Altimetry	Other
Altika	Ice
Jason	Waves
Cryosat	Color
	Salinity

In Situ

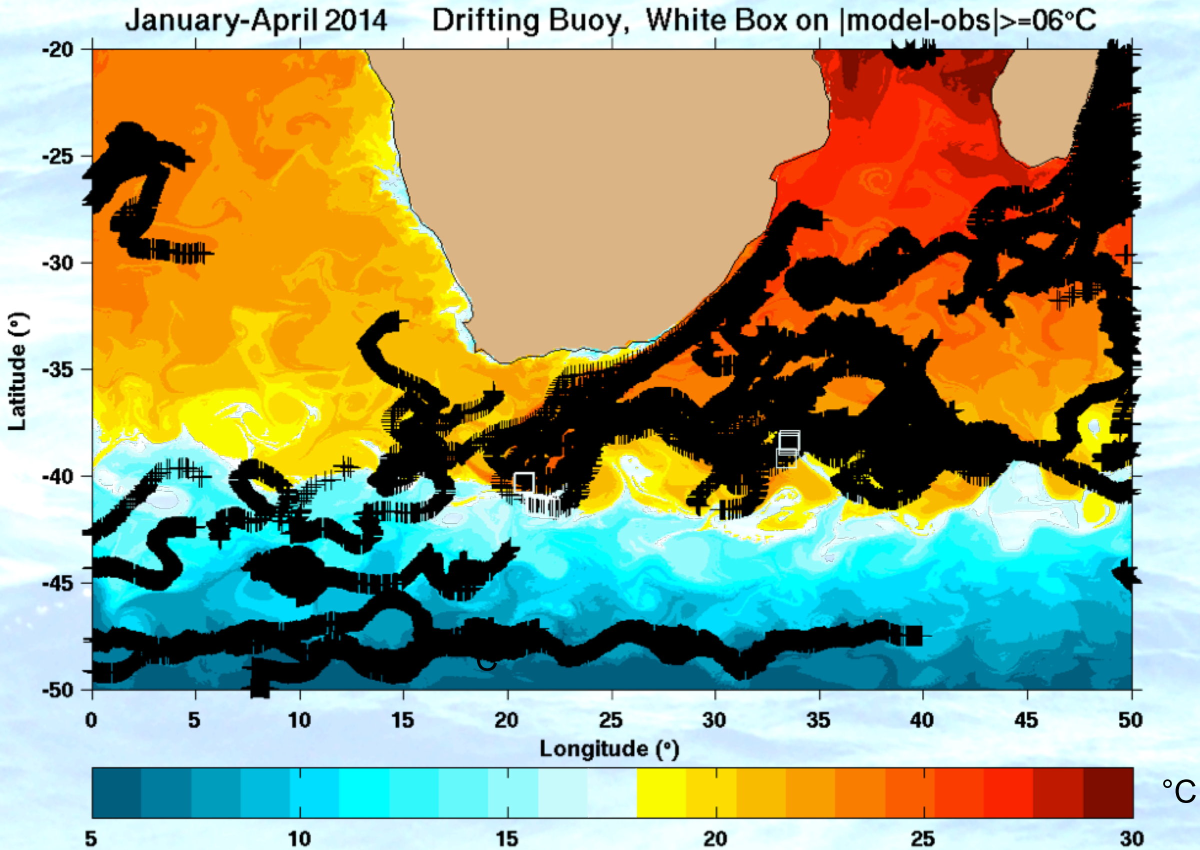
Surface	Profiles
shipboard	XBT/CTD
drifters	Argo
moored	moored
waveglider	glider/UUV
	seals

Assimilative Navy Ocean Models (NCOM/NCODA)

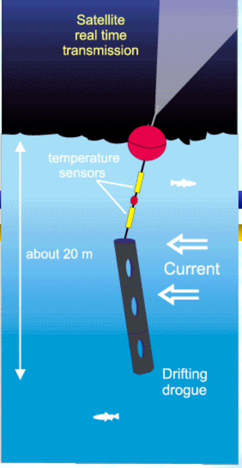


matchup SST data from drifting buoys

Matchup data is irregularly distributed
in space and time

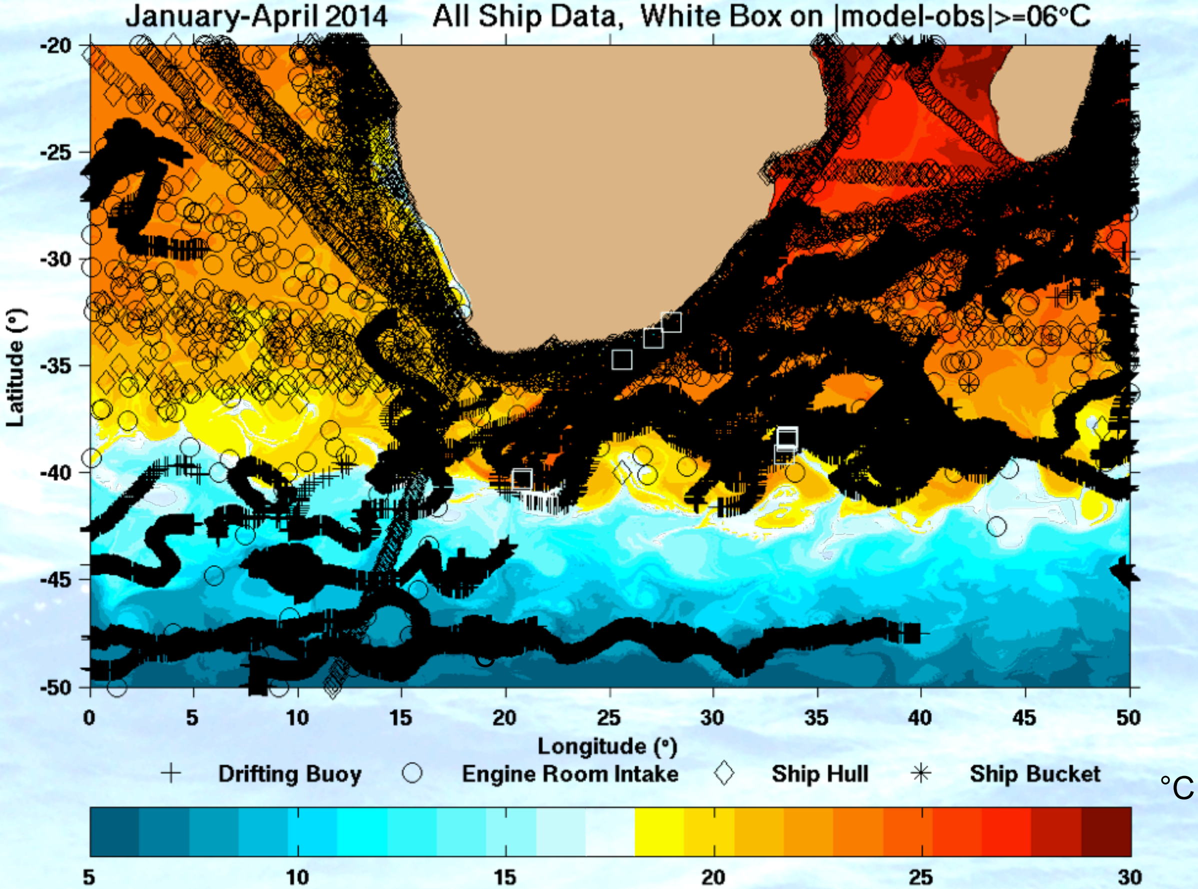


Analyses and forecasts from models assimilating satellite observations are compared with independent SST measurements from drifting buoys



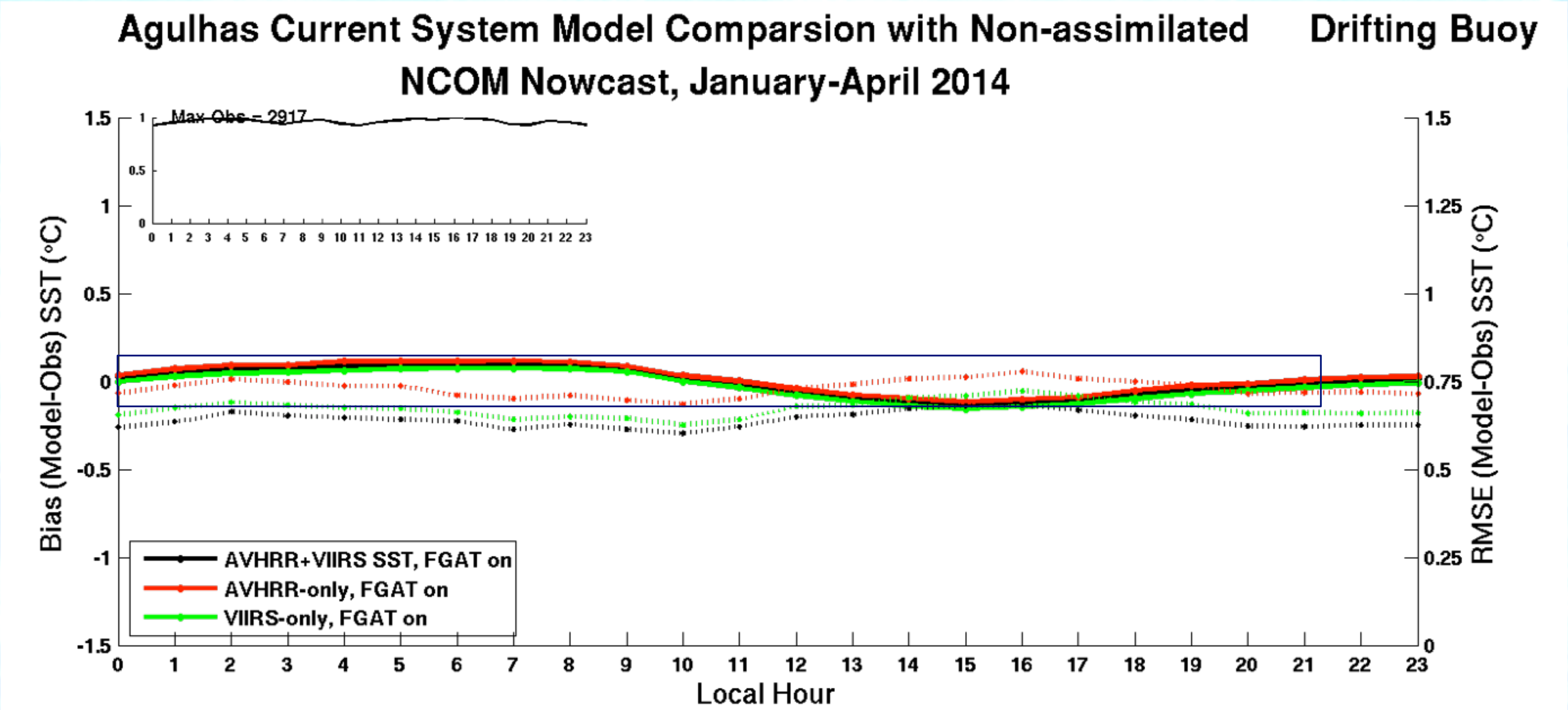
matchup SST data from all surface in situ sources

Matchup data is irregularly distributed in space and time



Potential matchup coverage is improved when all available in situ sources are considered, but standard error of engine room, hull, and bucket sst are too high.

Evaluations show benefit from combined assimilation of AVHRR and VIIRS



Comparison of 0000 UTC analysis with observations on same day reveals mean diurnal signal with amplitude of ~0.3˚C

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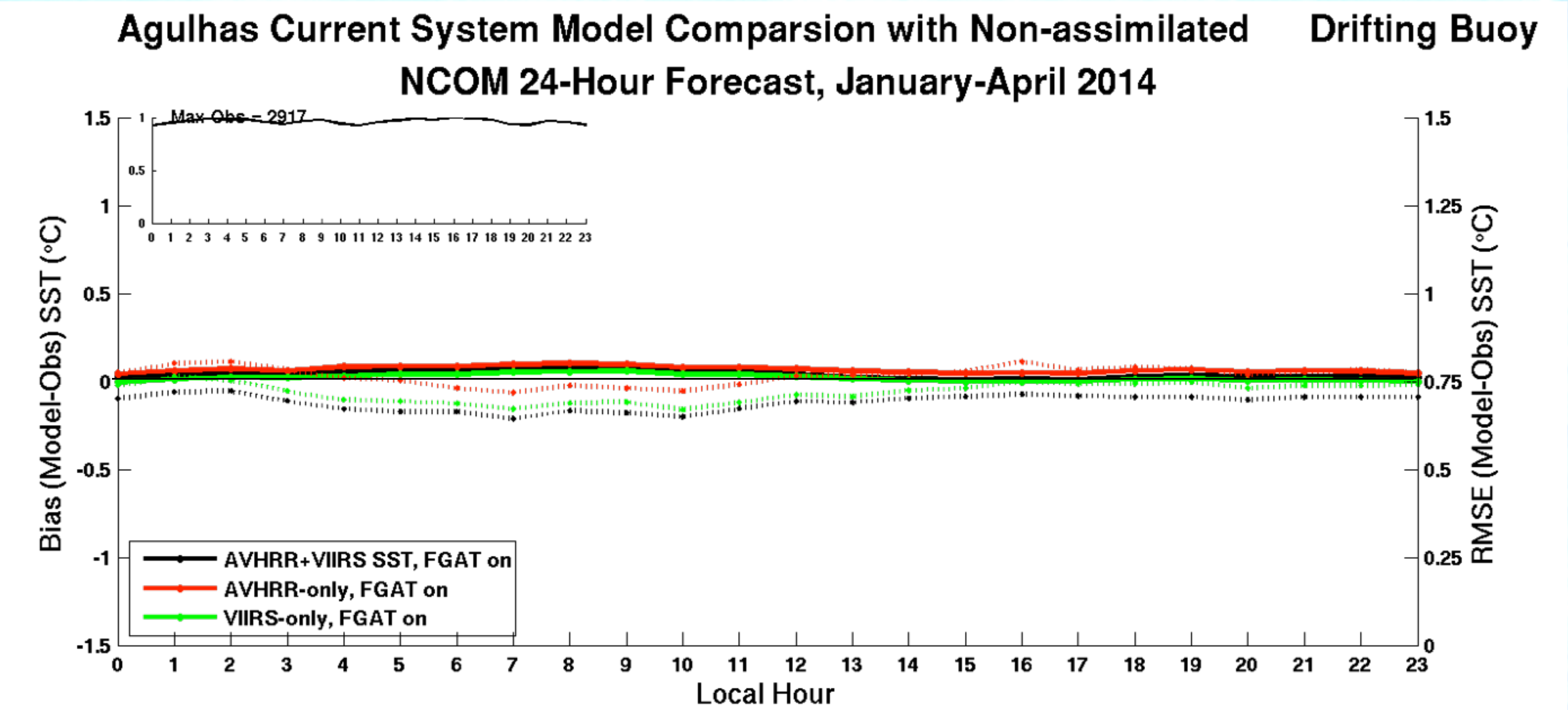
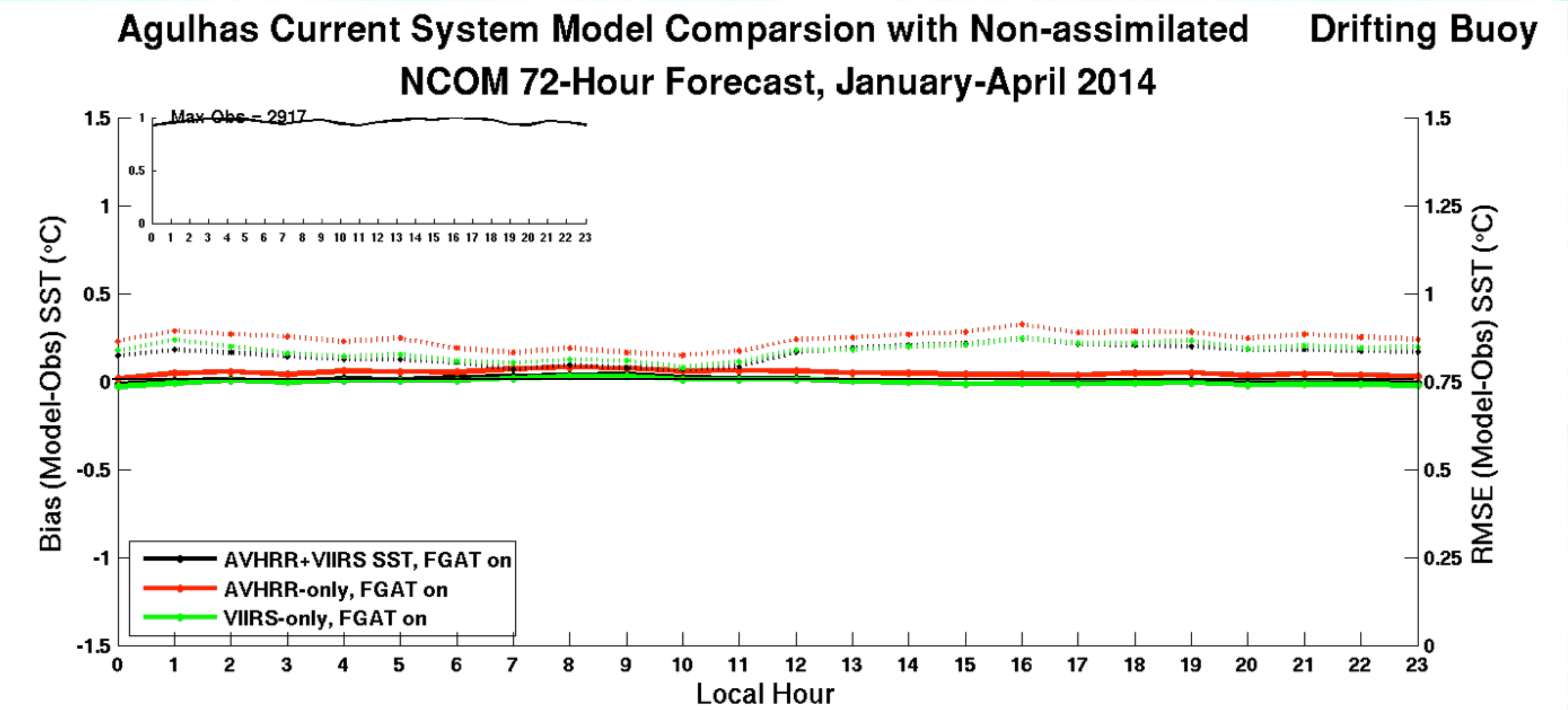


Comparison of NCOM 0-24 hour forecasts with observations on same day/time reveals mean diurnal signal is well represented by forecasts with some indication of insufficient cooling and slight warming bias before local noon. Bias is small overall and RMSE is reduced in the mid-morning hours.

Evaluations show benefit from combined assimilation of AVHRR and VIIRS

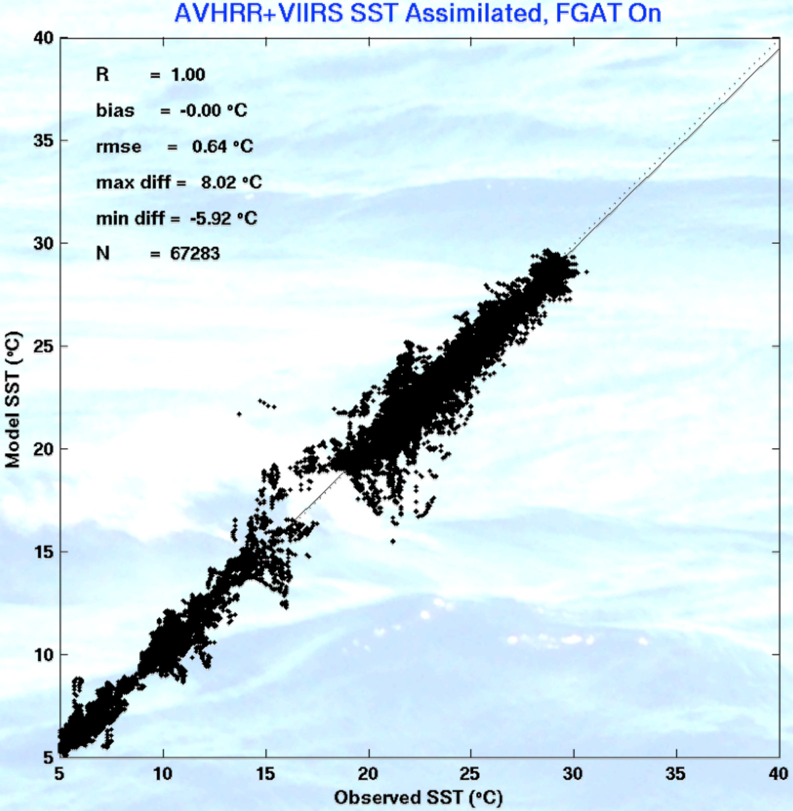


Comparison of NCOM 48-72 hour forecasts with observations on same day/time reveals mean diurnal signal is well represented by forecasts with some indication of insufficient cooling and slight warming bias before local noon. Forecast bias remains small but slightly warm. RMSE is smaller in mid-morning hours and increases about 0.05˚C per forecast day.

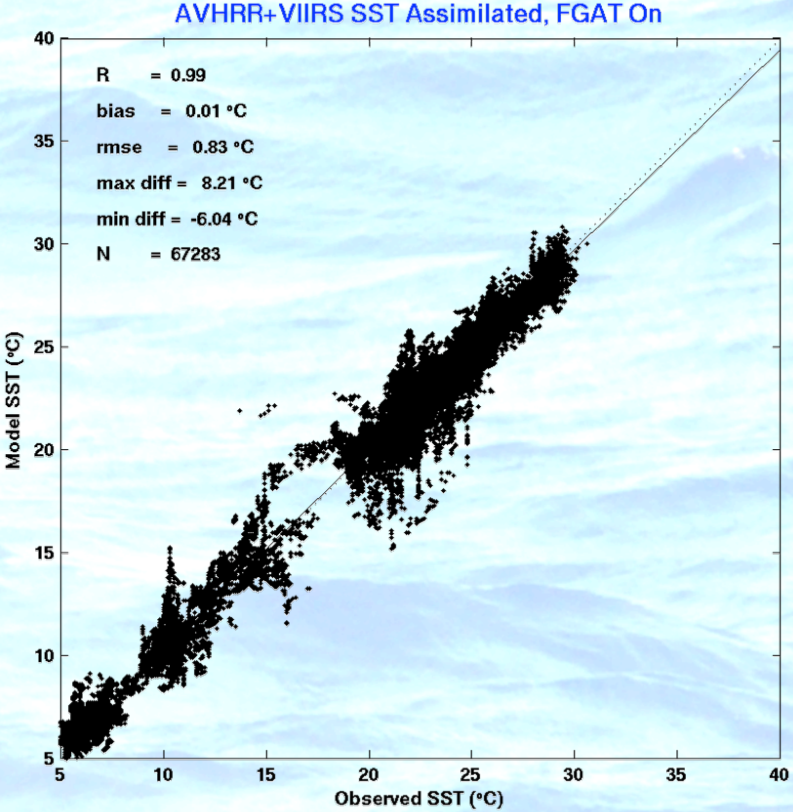
Matchups indicate slight forecast bias, bimodal distribution of SST

Comparison of South African NCOM SST relative to independent drifting buoy SST.

SST analysis

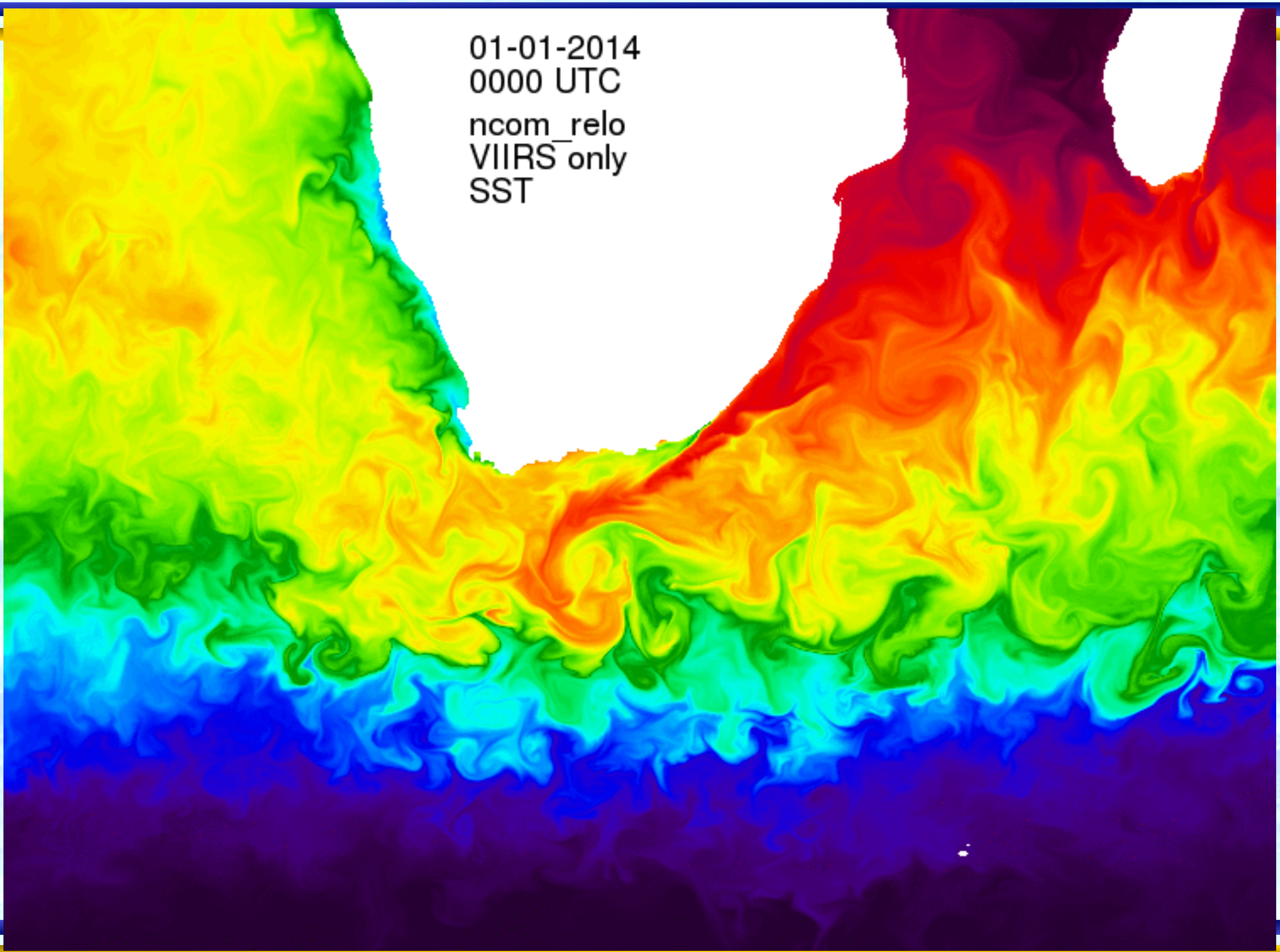


SST 72 hr. forecast

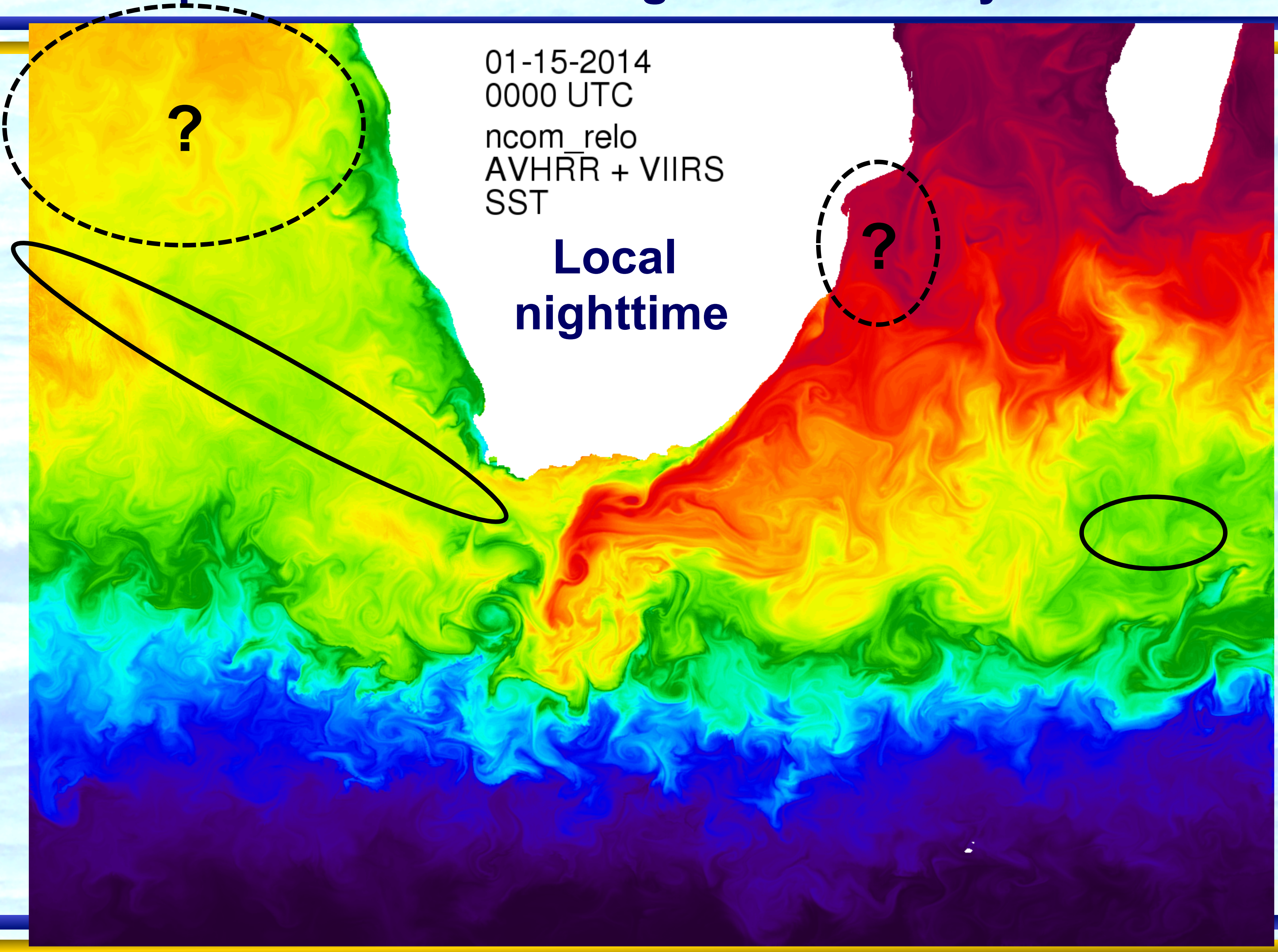


Comparison of SST observations and matching values from NCOM analyses and 51-72 hour forecasts using South Africa regional NCOM assimilating AVHRR and VIIRS. The largest RMSE tend to occur within the interface between bimodal warm and cold distributions. NCOM has a warm bias in this cap. Overall the simulations show little (<0.005˚C amplitde) analysis bias and slightly warm (~0.01˚C) 72-hour forecast bias.

US-Navy Model SST forecasts: South Africa
SST variability over many time/space scales and processes



SST shows a band and other patches with peak diurnal warming on 15 January 2014



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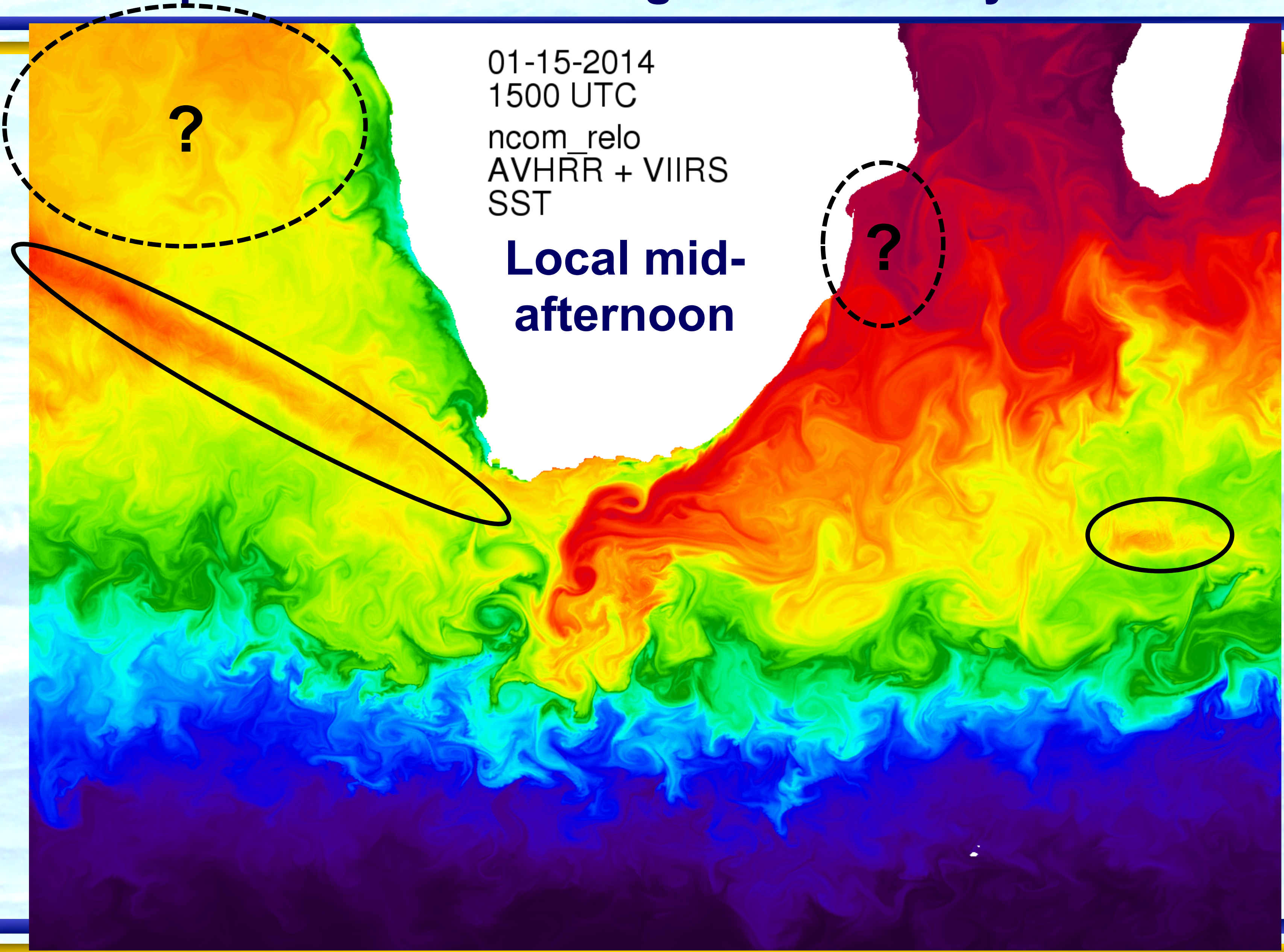

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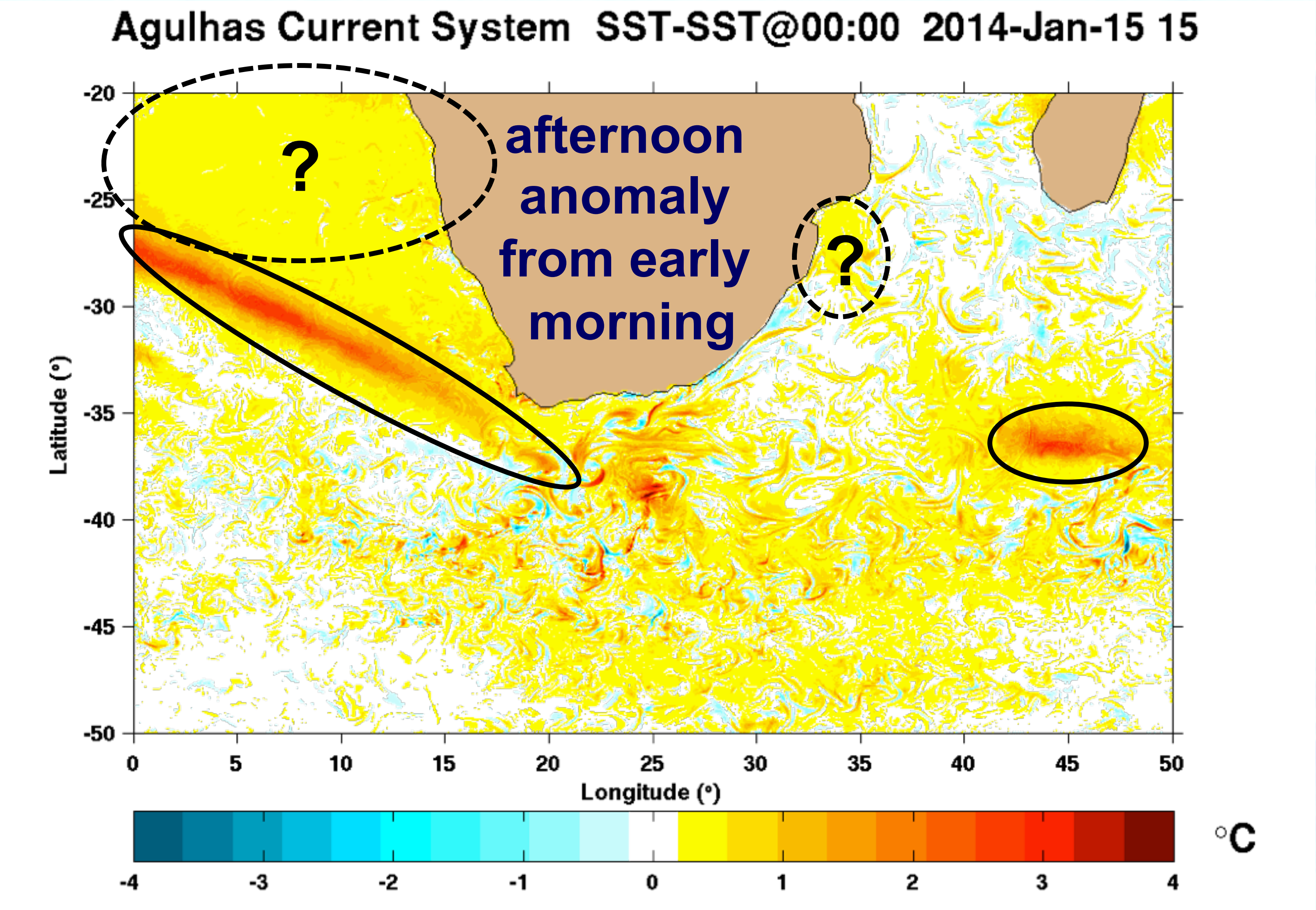

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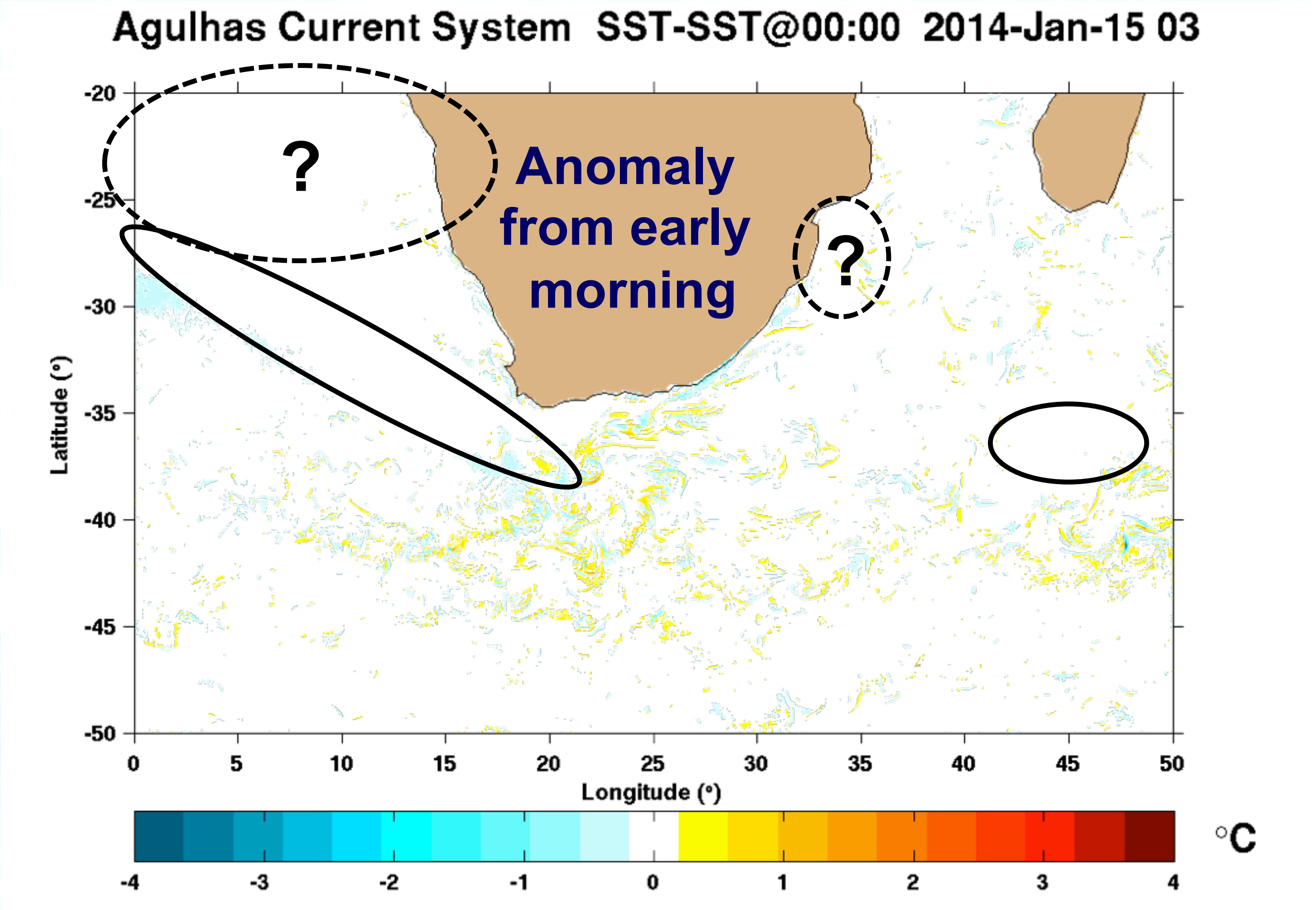
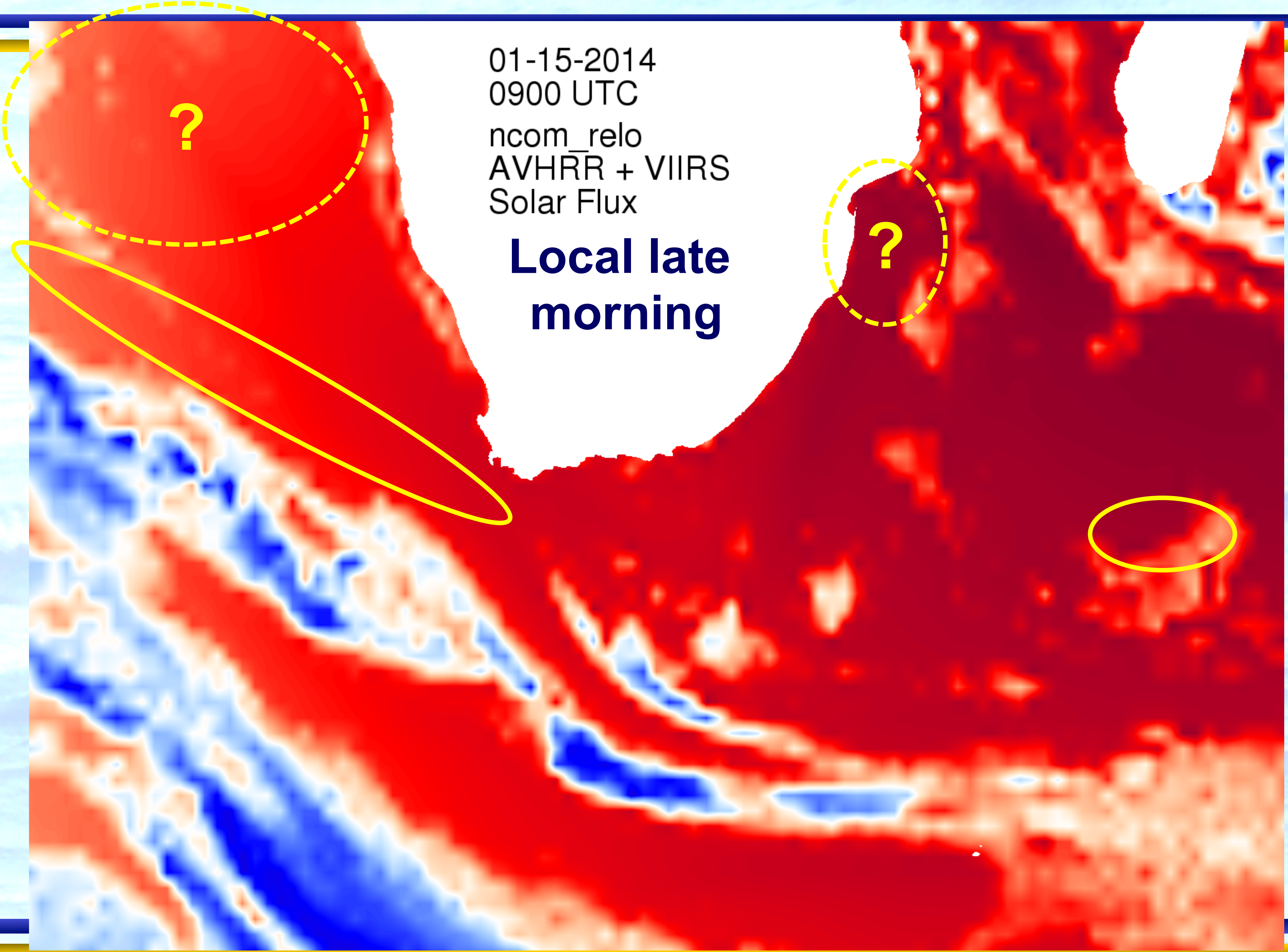


The diurnal warming regions have high solar flux with low clouds – note clouds to south



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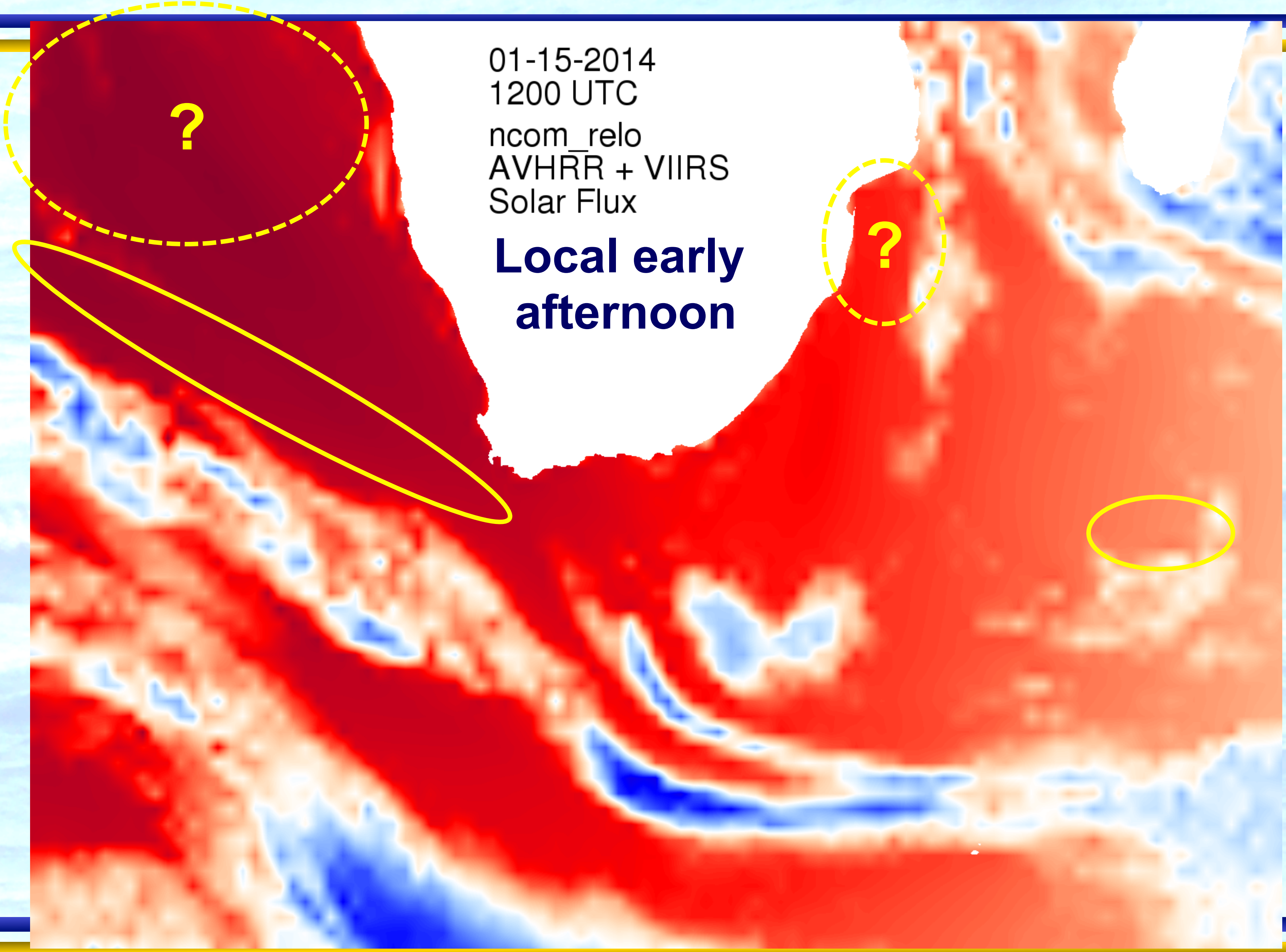
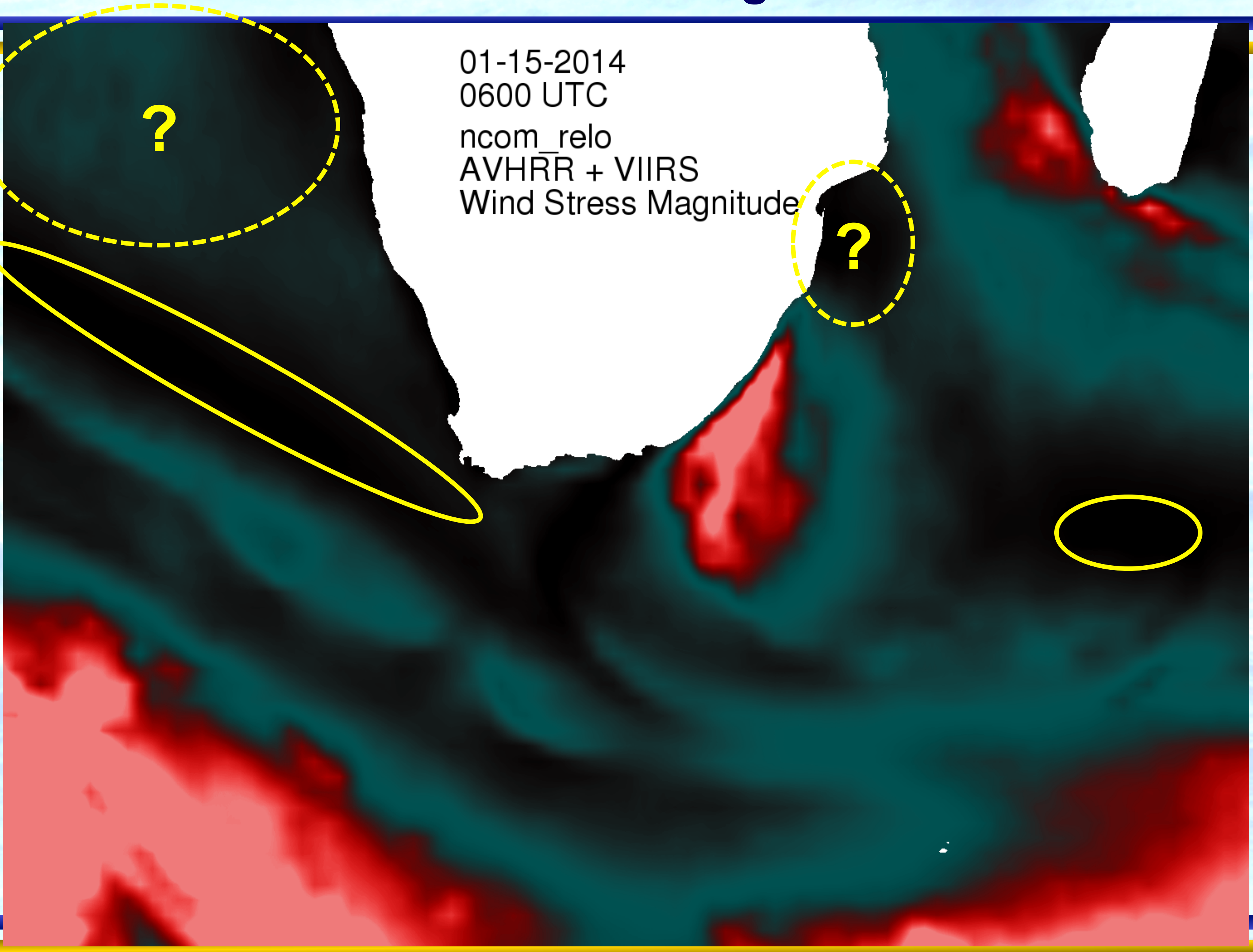


The diurnal warming regions consistently have very low wind stress from morning to mid-afternoon



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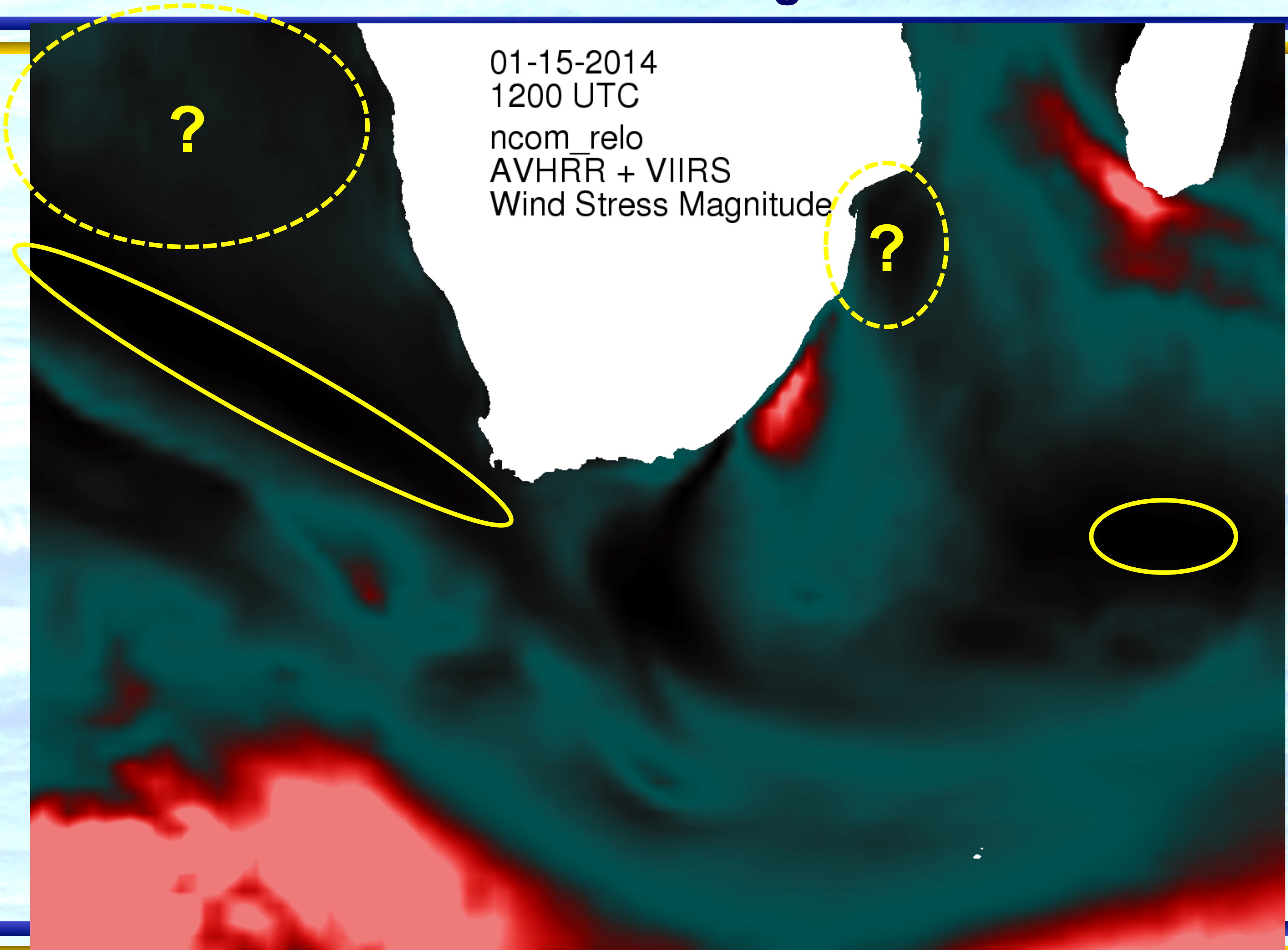

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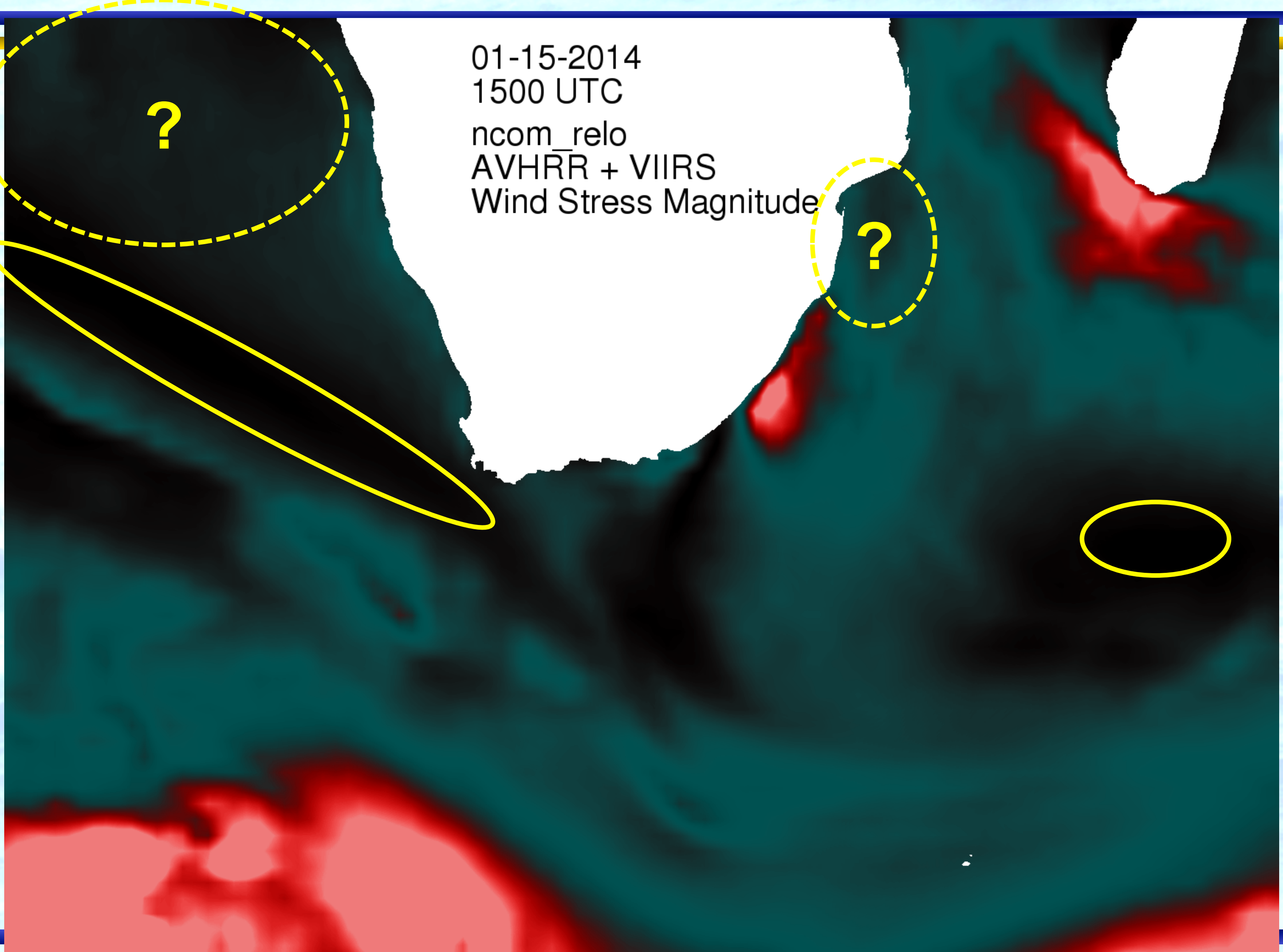
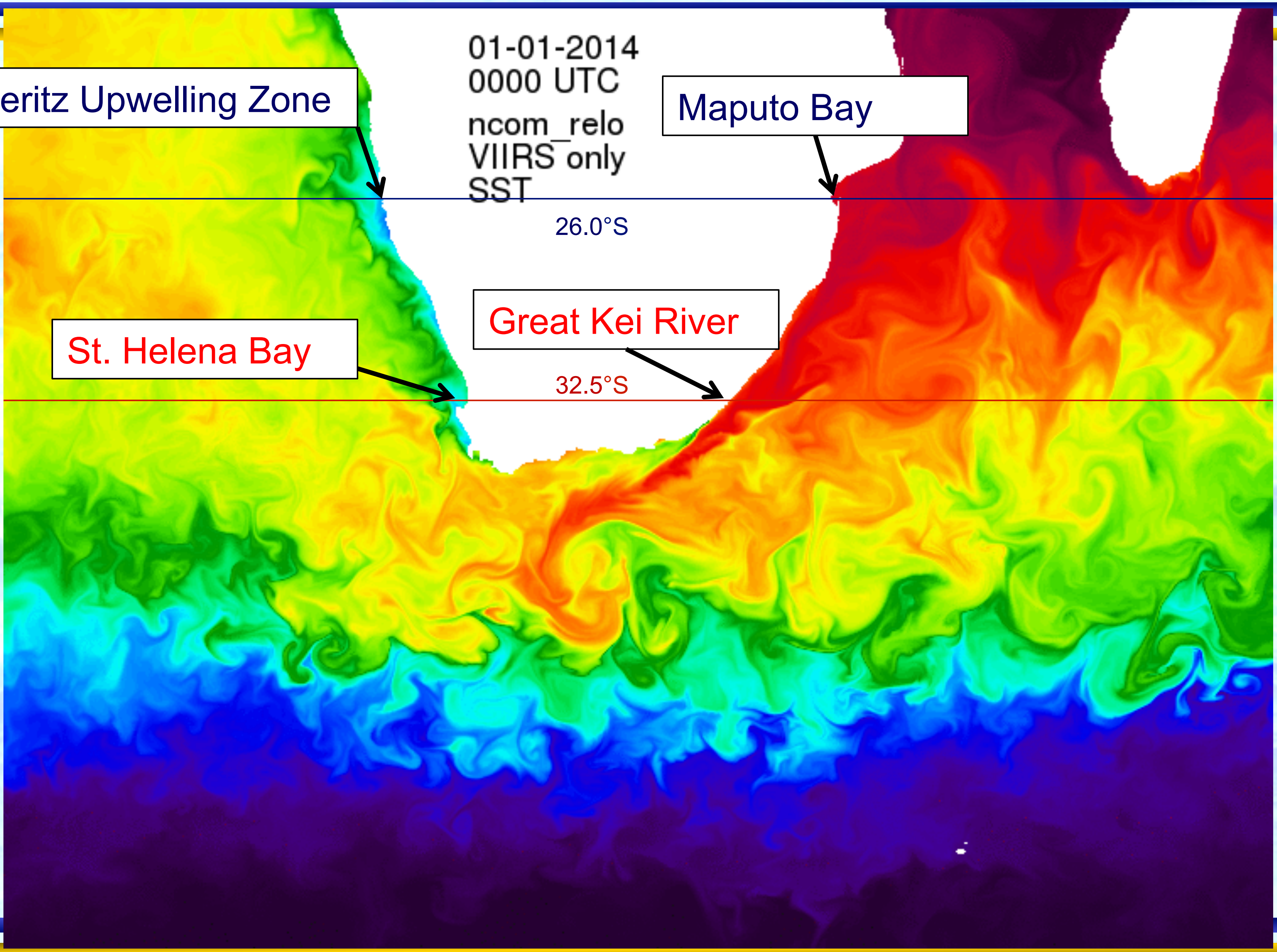
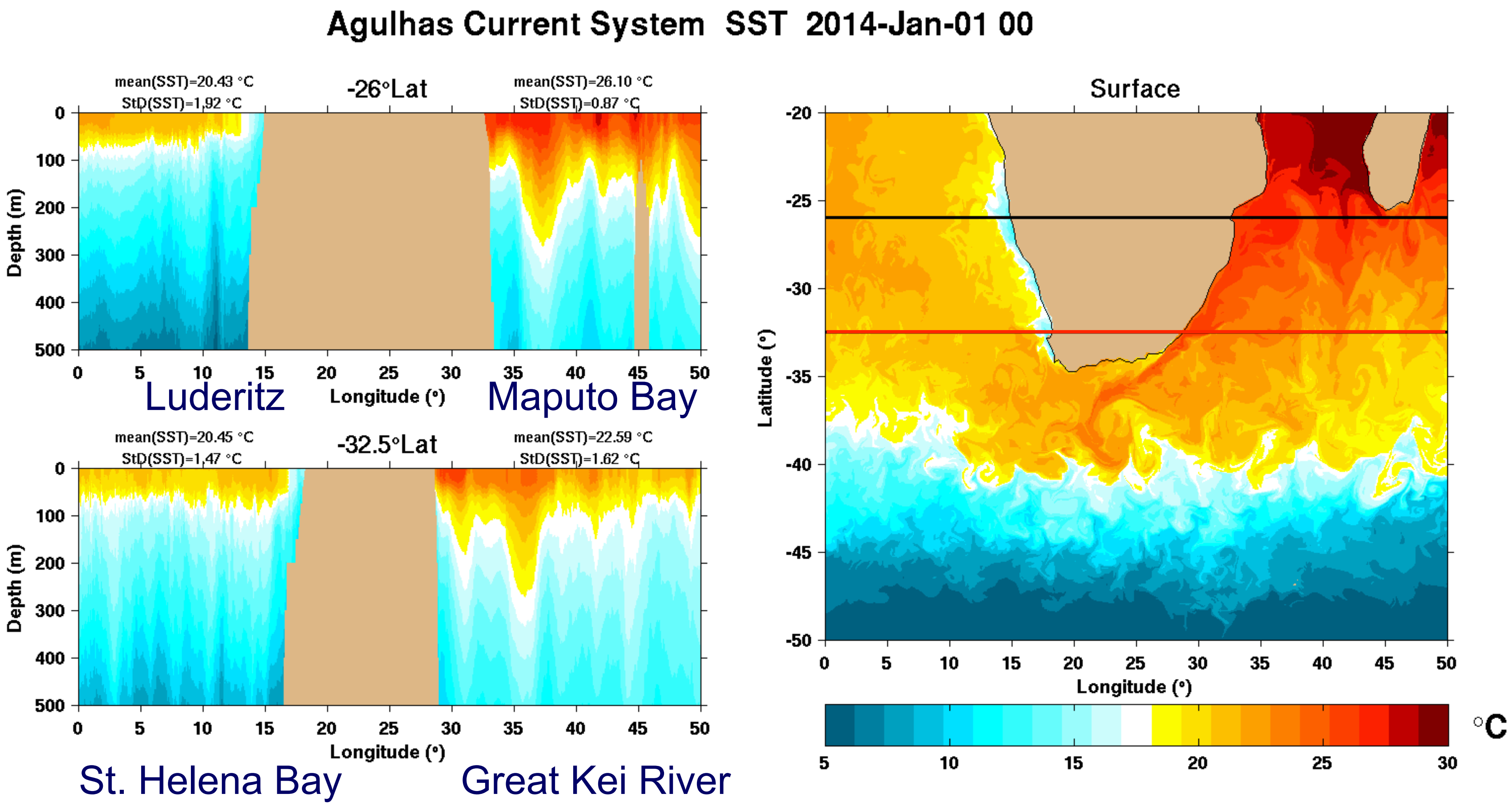


US-Navy Model SST forecasts: South Africa
SST variability associated with upwelling



Temperature cross sections: Upwelling concentrated along western coast

Sections:	Luderitz	Maputo Bay
	St. Helena Bay	Great Kei River



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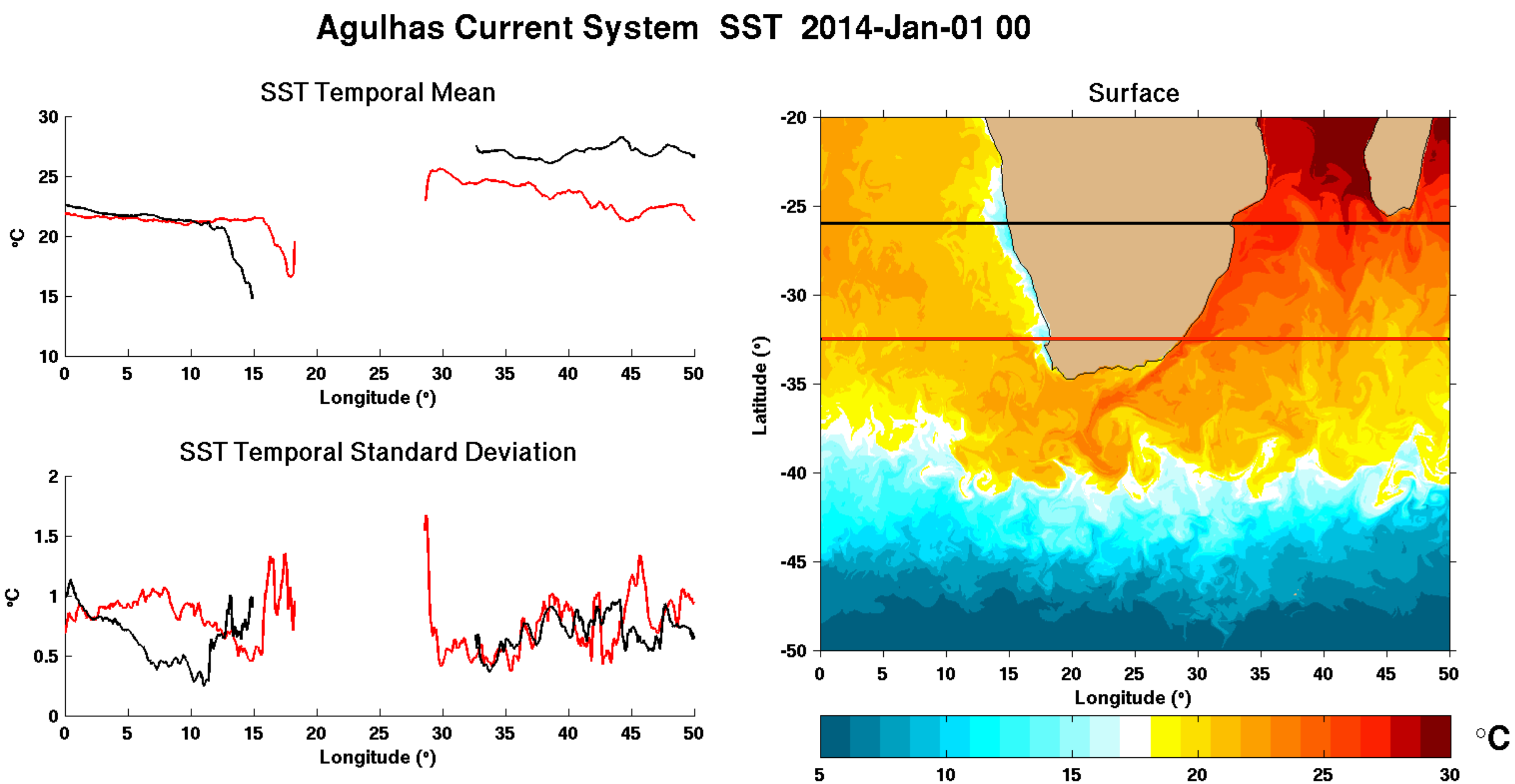
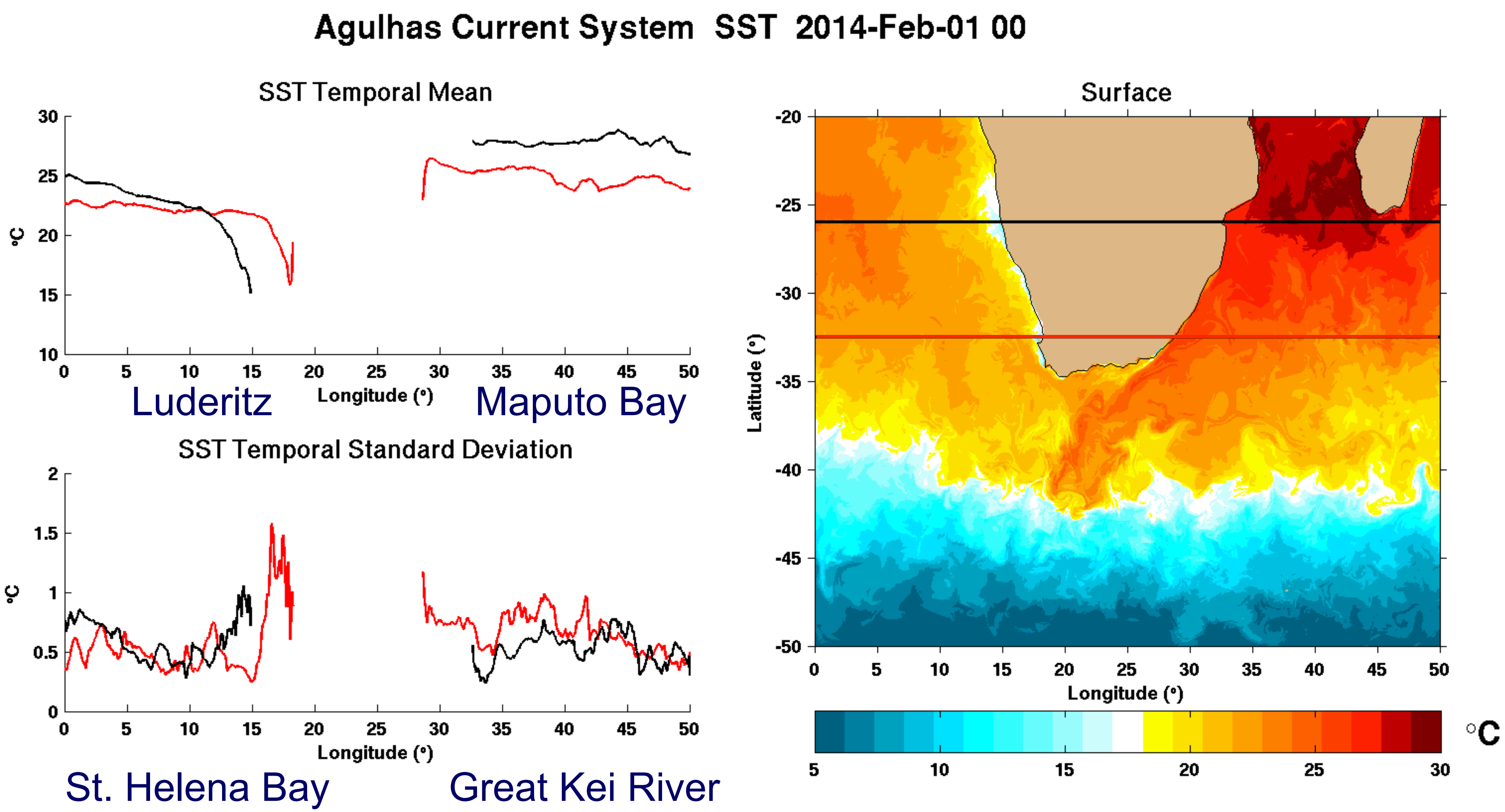


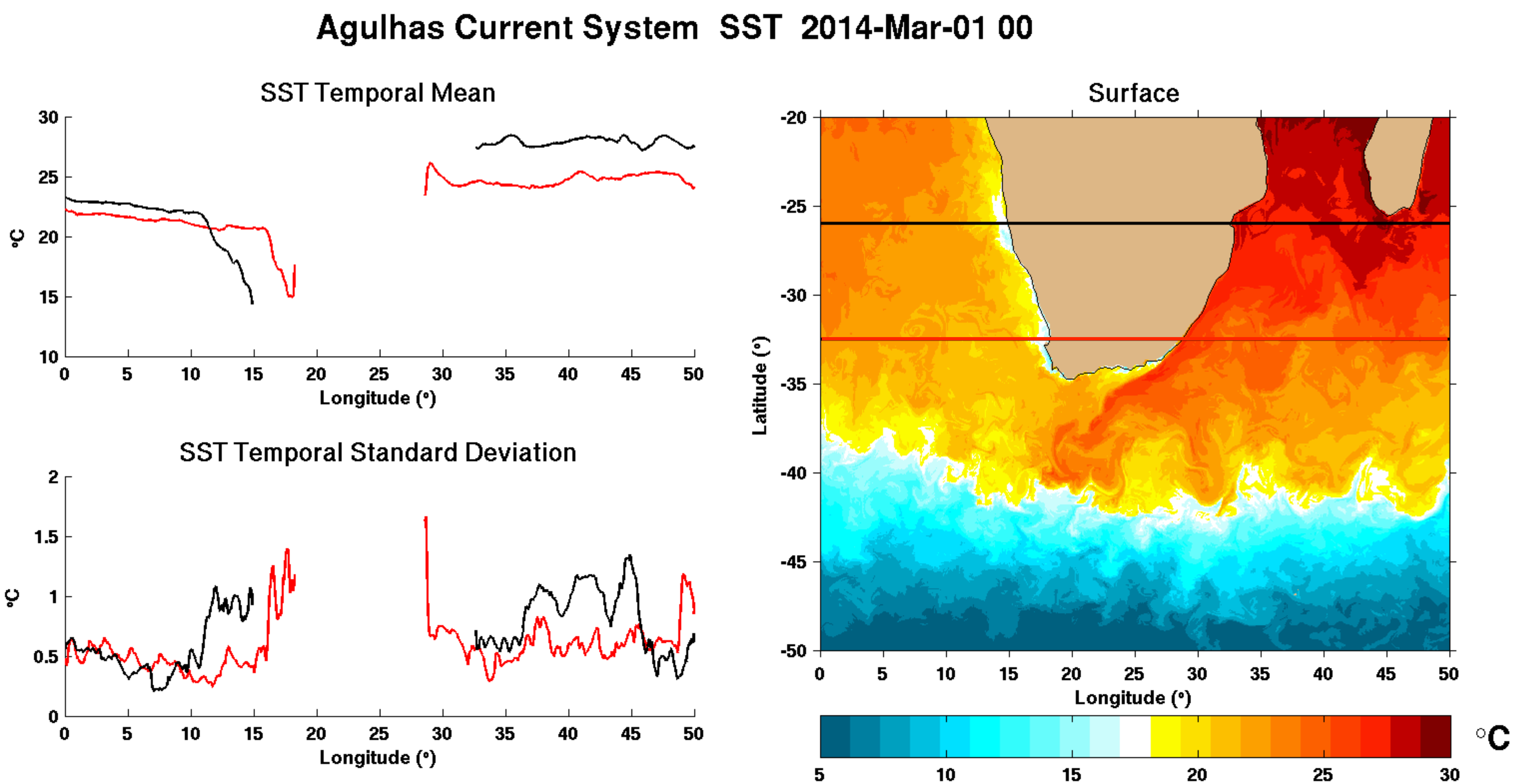
Temperature cross sections: mean SST increases into February

Sections: **Luderitz** **Maputo Bay** **St. Helena Bay** **Great Kei River**



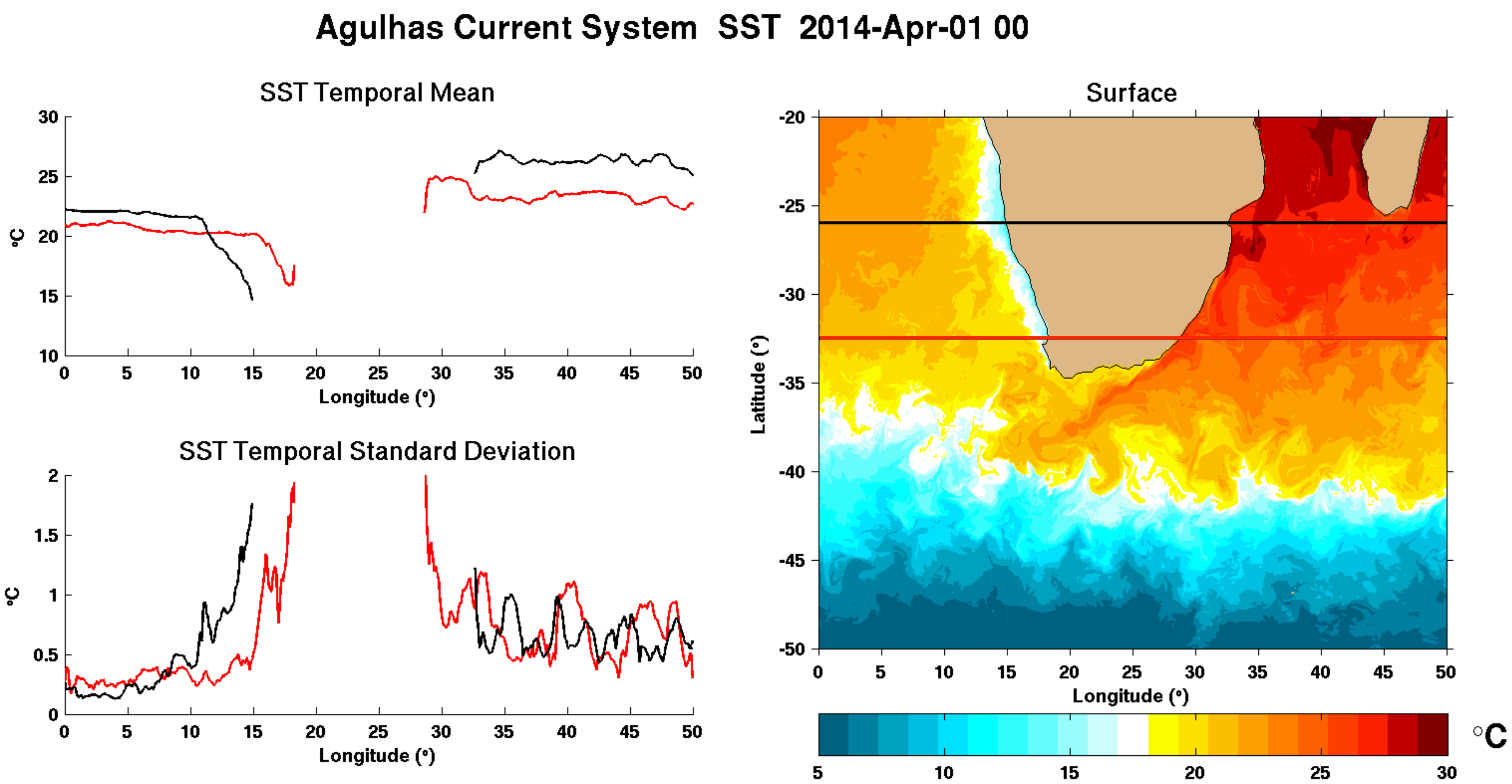
Temperature cross sections: high variability at Great Kei River in March

Sections:	Luderitz	Maputo Bay
	St. Helena Bay	Great Kei River



Temperature cross sections: higher nearshore SST variability along all sections in April

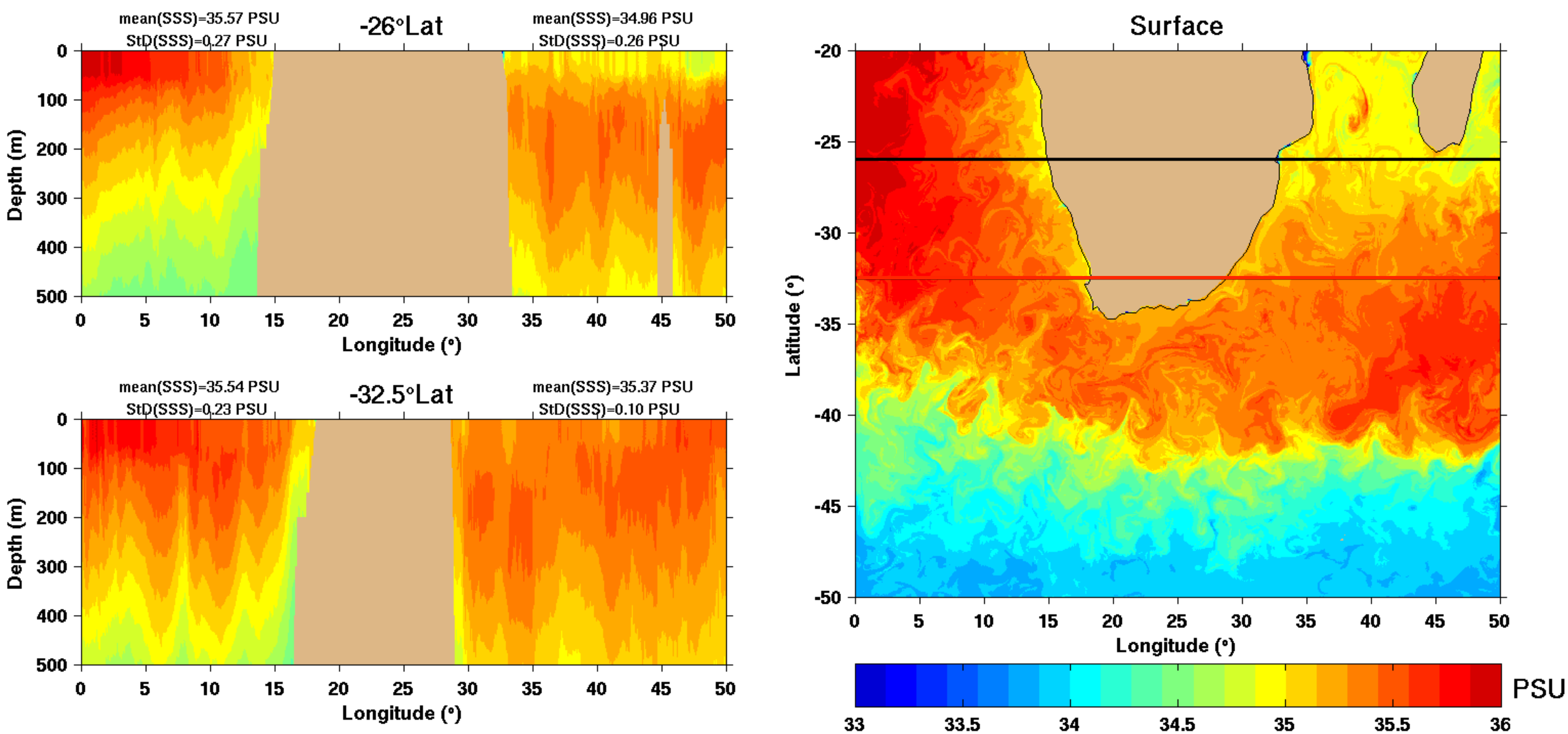
Sections:	Luderitz	Maputo Bay
	St. Helena Bay	Great Kei River



Salinity partially compensates temperature in upwelling density gradients west of South Africa

Sections: Luderitz, Maputo Bay, St. Helena Bay, Great Kei River

Agulhas Current System SSS 2014-Apr-01 00

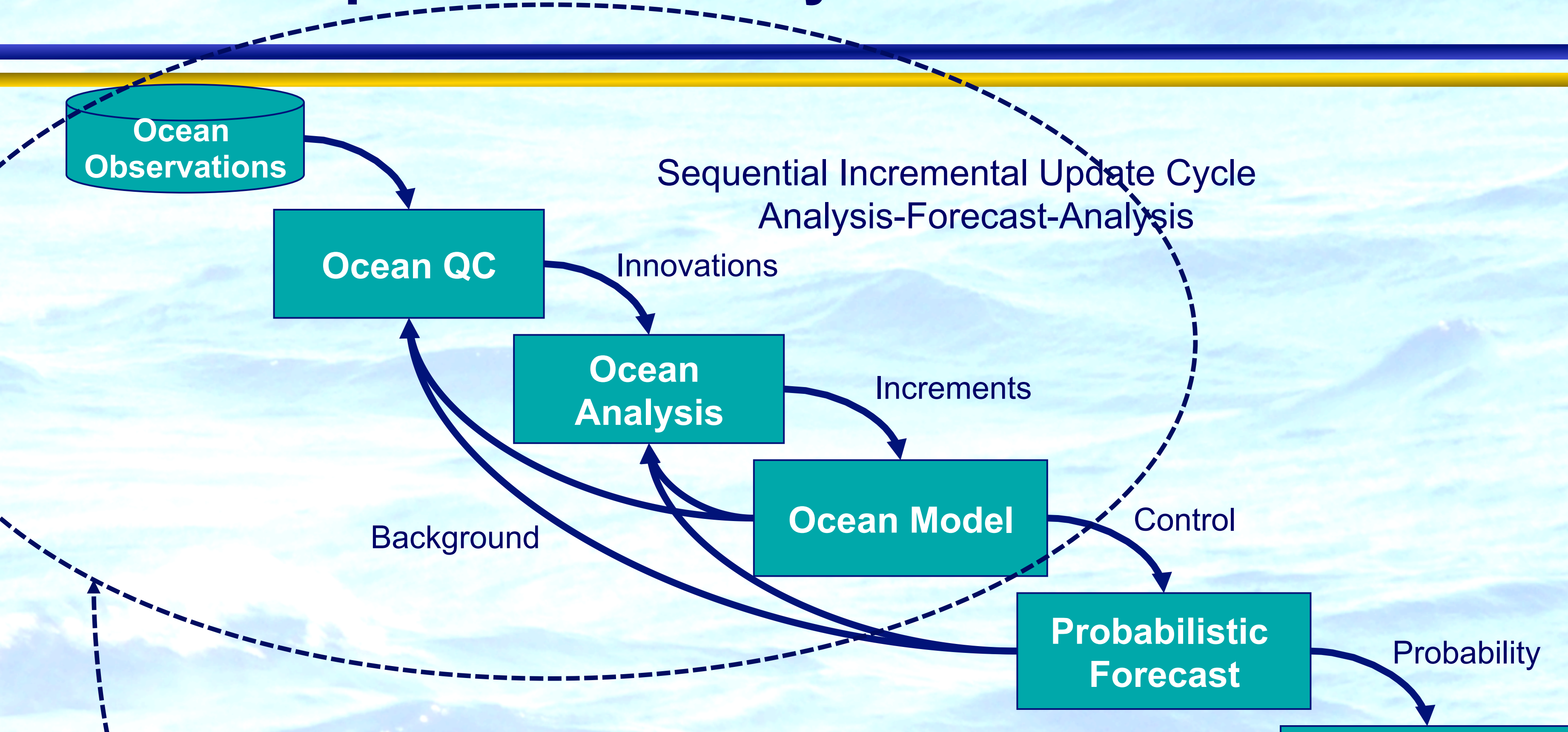


Conclusions

- Rapid setup of RELO NCOM provides a nested assimilative modeling system that gives reasonably accurate SST forecasts in the vicinity of Southern Africa.
- Diurnal warming is forecast in bands and patches with low wind speed and high isolation.
- Upwelling is significantly stronger along western South Africa along the Luderitz and St. Helena Bay sections.
- Along eastern South Africa, smaller episodes of upwelling are predicted off the Great Kei River; very little off Maputo Bay.
- Nearshore SST variability along sections is minimum in February (late summer) and increases into April (Fall). What is source of variability near Maputo Bay? Upwelling or river?

Backup Slides

Components of Navy Ocean Prediction

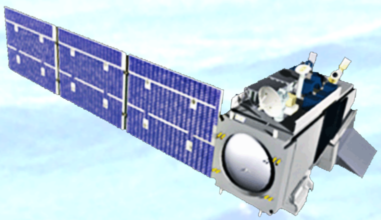


Assimilative ocean forecasts require observations + ocean model + data assimilation

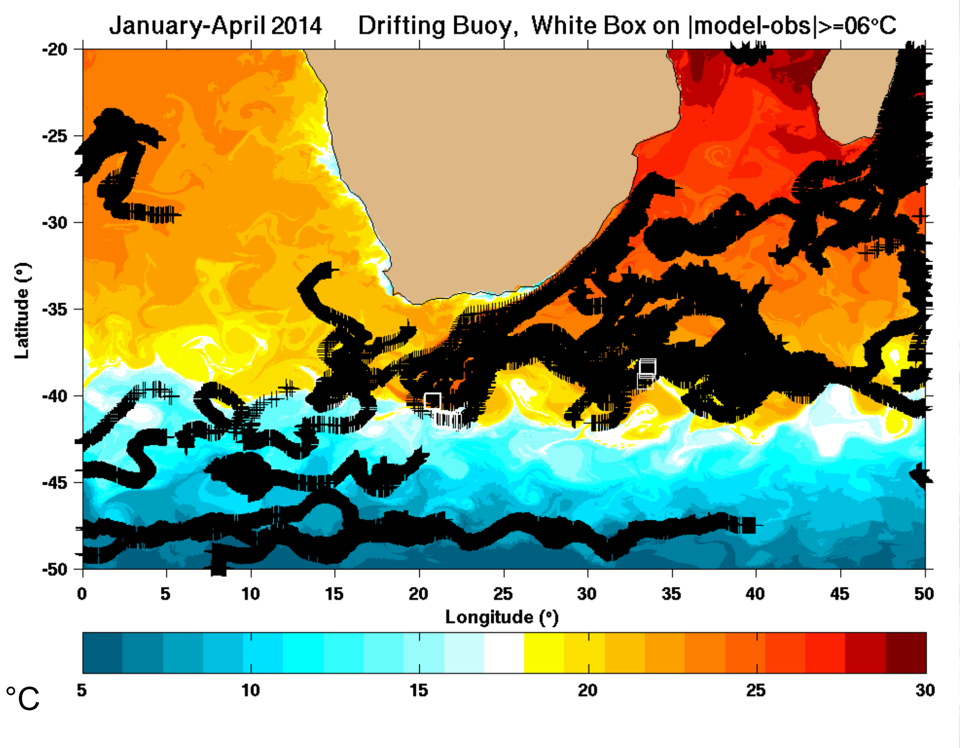
NRL 7320 seeks to develop advancements supporting ocean prediction systems

Impact of NOAA AVHRR and NPP VIIRS SST on assimilative forecasts

Infra-red observations of SST are available globally from polar-orbiting NOAA (AVHRR) and Suomi-NPP (VIIRS) satellites



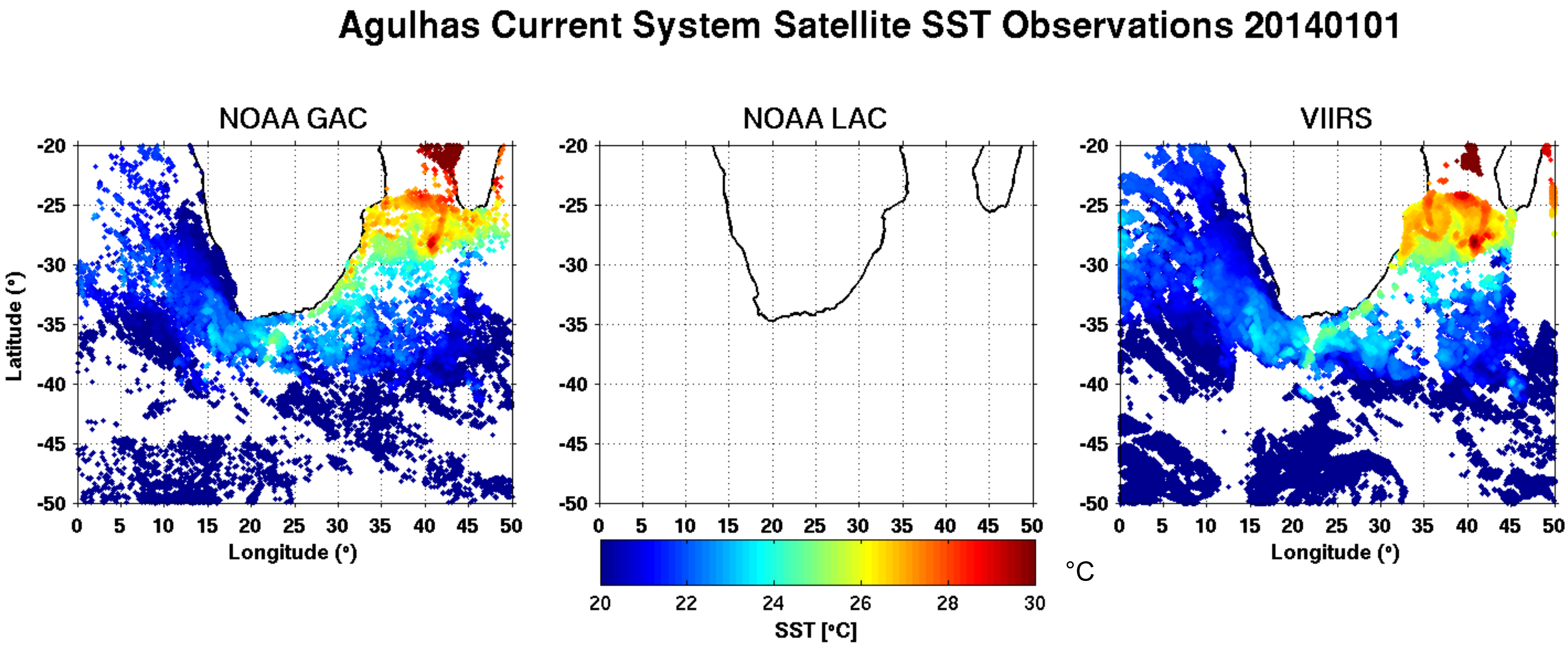
- AVHRR/3
- Advanced Very High Resolution Radiometer/3
- NOAA 18, NOAA 19
- Sun-synchronous polar orbiting mid-afternoon
- ECT: 15:23 NOAA 18
  13:39 NOAA 19
- 1.1 km pixels Local Area Coverage (LAC); global (GAC) processed to ~4 km at NAVOCEANO
- 2 per day per satellite
- IR is obscured by clouds



- VIIRS
- Visible/Infrared Imager Radiometer Suite
- Suomi-NPP Operational Environmental Satellite
- Sun-synchronous polar orbiting mid-afternoon
- ECT: 13:25
- NPP 28 Oct 2011+
- 750 m pixels as processed at NAVOCEANO
- 2 per day
- IR is obscured by clouds

Analyses and forecasts from models assimilating these satellite observations are compared with independent SST measurements from drifting buoys

Distributions of NOAA AVHRR3 (GAC and LAC) and Suomi-NPP VIIRS SST retrievals



Data as processed and provided by NAVOCEANO.
VIIRS and NOAA GAC give similar coverage.
LAC is daytime NOAA 19 in areas closer to land.

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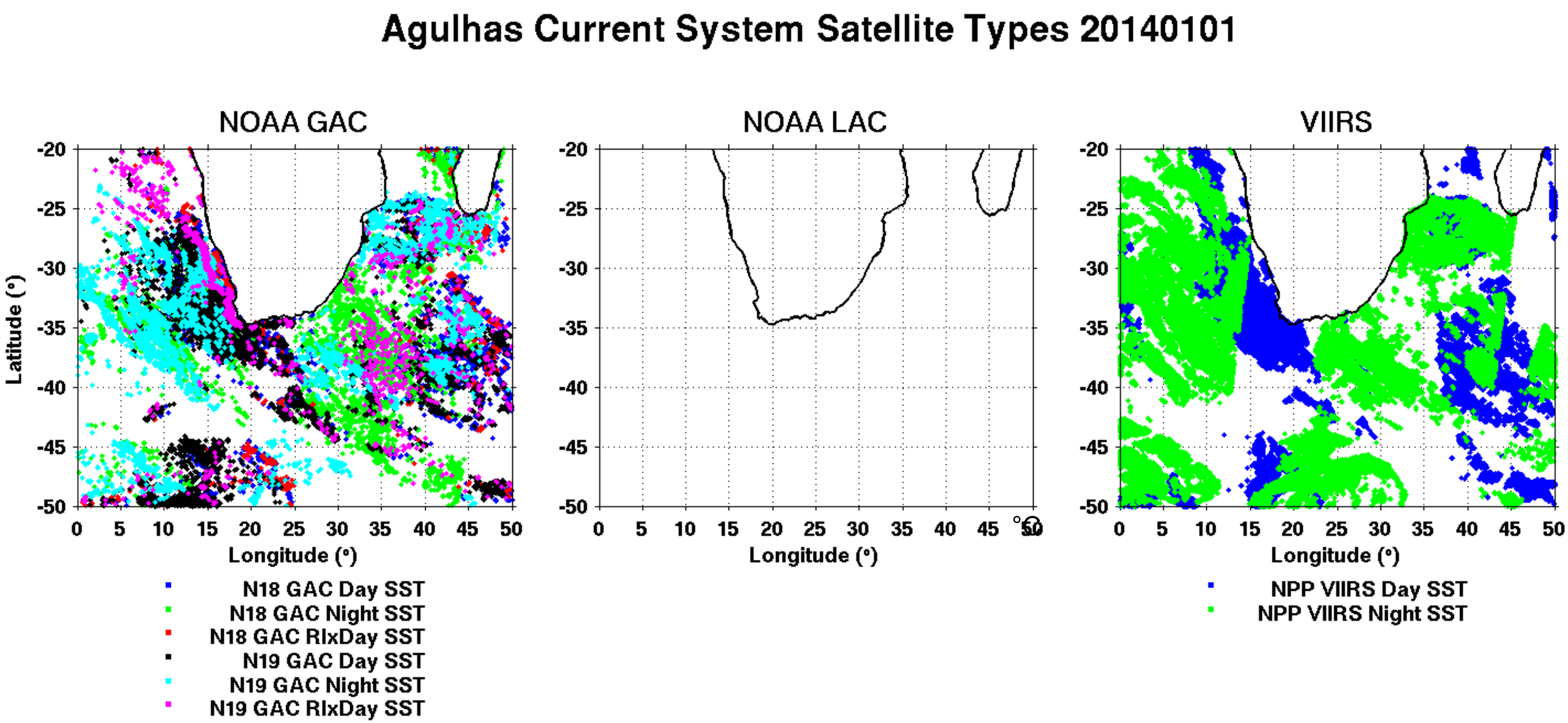

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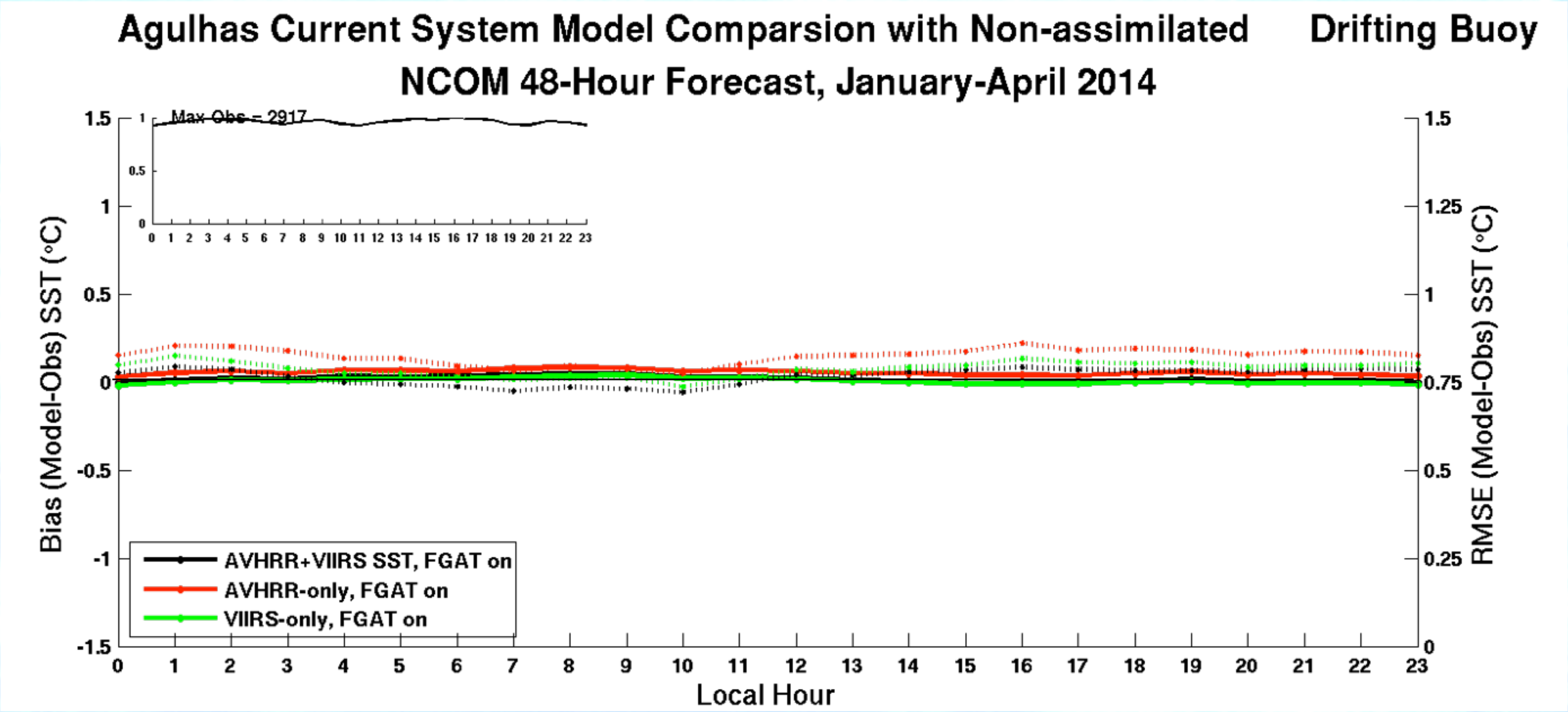

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