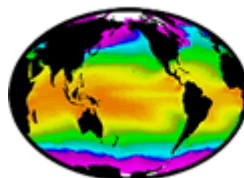




# A comparative study of ocean thermal gradients from GHRSSST Level 4 SST products

Marouan Bouali, Jorge Vazquez-Cuervo, Paulo Polito and Olga Sato

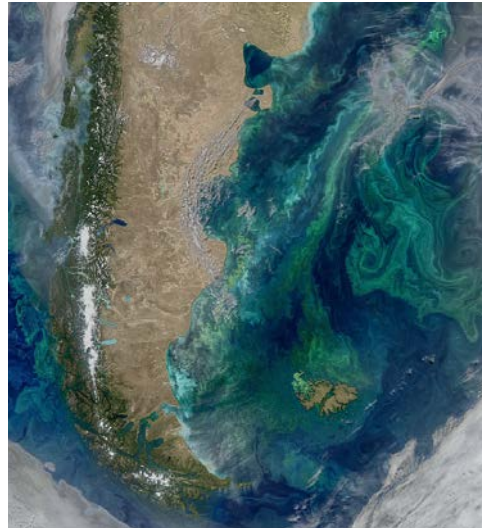


# Outline

- Importance of fronts
- Statistics vs Geometry
- SST gradients from Level 4 products
  - Feature resolution
  - Temporal variability
- Conclusion

# Fronts in oceanography

Marine ecosystem boundaries



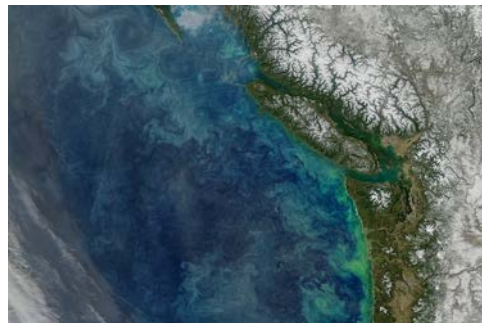
*Aqua MODIS, February 4, 2019*

Ocean 2D / 3D dynamics



*Landsat 8, OLI, June 3, 2018*

Fisheries



*Aqua MODIS, March 18, 2019*

Ocean-Atmosphere interaction



*Aqua MODIS, July 5, 2018*

# Product selection for SST gradients

The screenshot shows the PO.DAAC Dataset Discovery interface. At the top, a red banner reads: "PO.DAAC FTP services will be retired on 3 June 2019. For more information and alternate instructions (5)". The main header includes the "podaac" logo and navigation tabs: Home, Dataset Discovery, Data Access, Measurements, Missions, Multimedia, and Community. Below this are sub-tabs: Parameter, Latency, Collections, Platform, Sensor, and Spatial Coverage.

The "Select Filter" section on the left has two main categories:

- Processing Levels:** "Any processing level" and "Level-4 (Blended) (25)". The "Level-4 (Blended) (25)" option is circled in red, with an arrow pointing to the search results.
- Grid Spatial Resolution:** "Any grid spatial resolution" with sub-options: "≤ 0.05 deg (7)", "0.05-0.25 deg (6)", and "≥ 0.25 deg (12)".

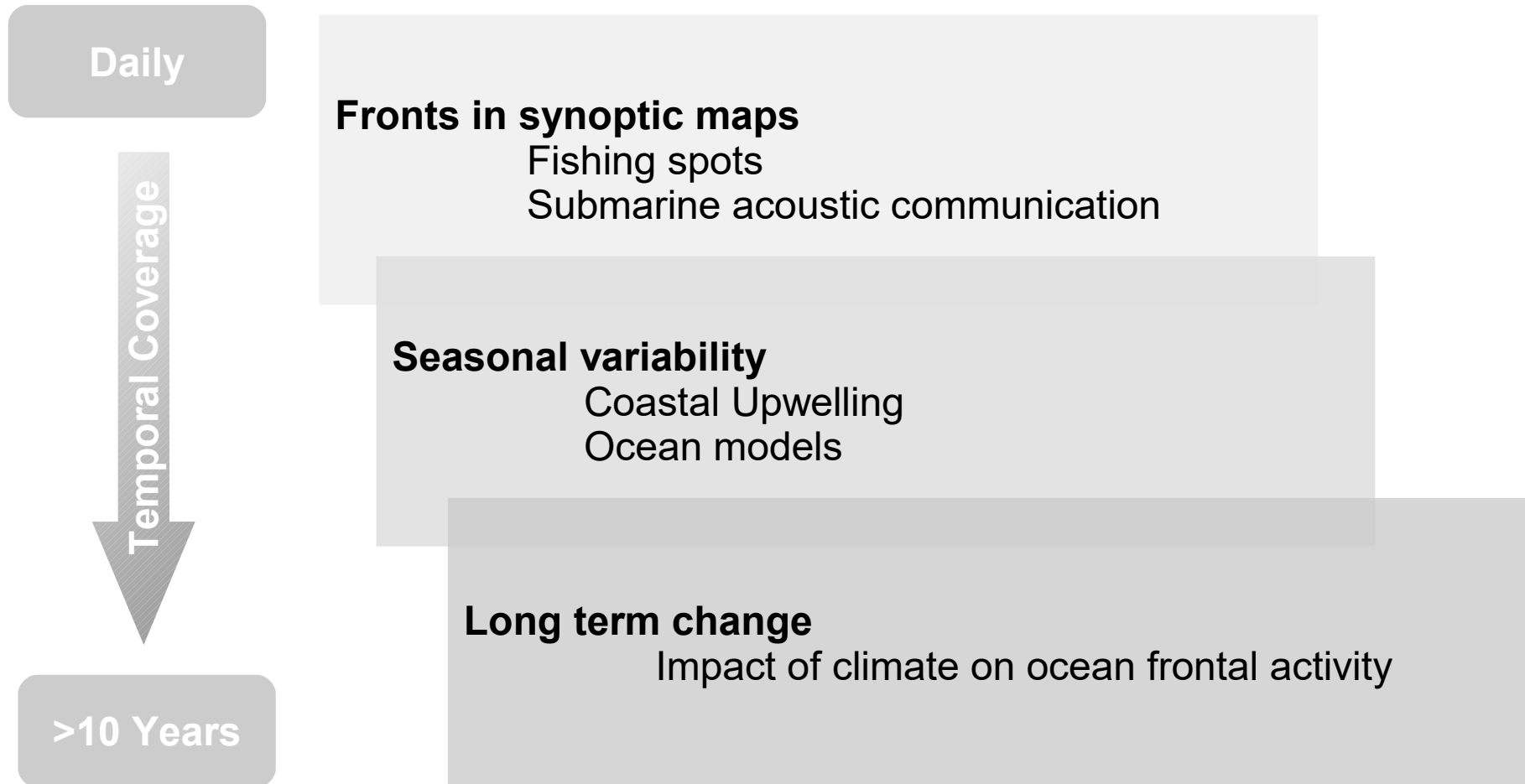
The "Dataset Discovery" section shows "All Products > Level-4 (Blended): 4" and "Found 25 matching dataset(s)". A link for "Advanced search" is visible below.

On the right, three search results are displayed, each with a world map thumbnail and a numbered circle (1, 2, 3):

- 1** GHR SST Level 4 K10\_SST Global 1 meter Sea Surface Temperature Analysis (NAVO-L4HR1m-GLOB-K10\_SST)  
Ocean Temperature  
Platform/Sensor: AQUA/AMSR-E, GOES-11/GOES-11 Imager, MetOp-A/AVHRR-3 ... more  
Processing Level: 4  
Longitude/Latitude Resolution: 0.1 degrees x 0.1 degrees  
Start/End Date: 2008-Apr-1 to Present  
Description: A Group for High Resolution Sea Surface Temperature (GHR SST) Level 4 sea surface temperature analysis produced daily on an operational basis at the Naval Oceanographic Office (NAVOCEANO) ... more
- 2** GHR SST Level 4 AVHRR\_AMSR\_OI Global Blended Sea Surface Temperature Analysis (NCDC-L4LRblend-GLOB-AVHRR\_AMSR\_OI)  
Ocean Temperature  
Platform/Sensor: AQUA/AMSR-E, InSitu/InSitu, NOAA-16/AVHRR-3 ... more  
Processing Level: 4  
Longitude/Latitude Resolution: 0.25 degrees x 0.25 degrees  
Start/End Date: 2002-Jun-1 to 2011-Oct-5  
Description: A Group for High Resolution Sea Surface Temperature (GHR SST) global Level 4 sea surface temperature analysis produced daily on a 0.25 degree grid at the NOAA National Climatic Data ... more
- 3** GHR SST Level 4 GAMSSA Global Foundation Sea Surface Temperature Analysis (ABOM-L4LRfnd-GLOB-GAMSSA\_28km)  
Ocean Temperature  
Platform/Sensor: InSitu/InSitu, MetOp-A/AVHRR-3, NOAA-19/AVHRR-3 ... more  
Processing Level: 4  
Longitude/Latitude Resolution: 0.25 degrees x 0.25 degrees  
Start/End Date: 2008-Aug-24 to Present  
Description: A Group for High Resolution Sea Surface Temperature (GHR SST) Level 4 sea surface temperature analysis produced daily on an operational basis at the Australia Bureau of Meteorology ... more



# “What's the “best” Level 4 product for SST gradients?”



# “What's the “best” Level 4 product for SST gradients?”

Daily

**Fronts in synoptic maps**

Fishing spots

Submarine acoustic communication

Can we use *in situ* measurements to evaluate the quality of a dataset with respect to SST gradients?

**Long term change**

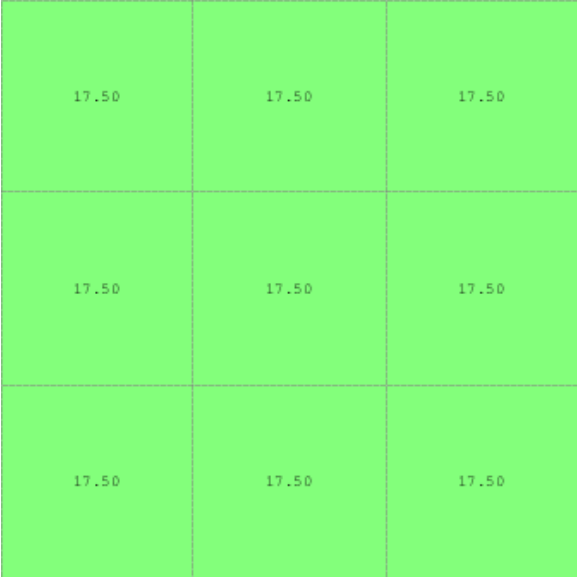
Impact of climate on ocean frontal activity

>10 Years

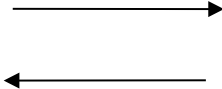
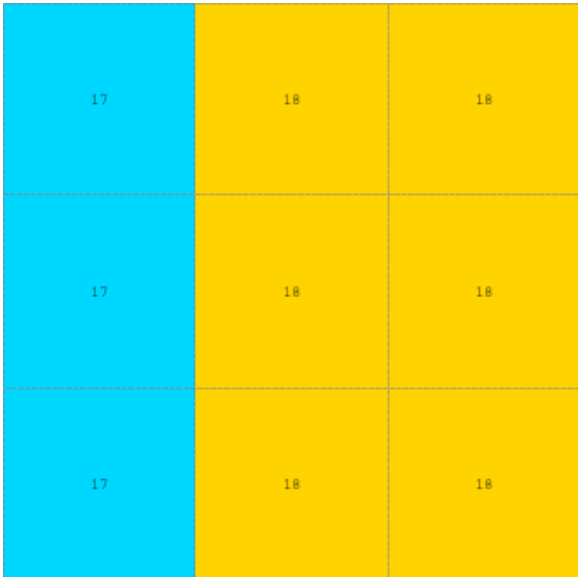
# Statistics vs Geometry

Matchup

*In situ*



Satellite



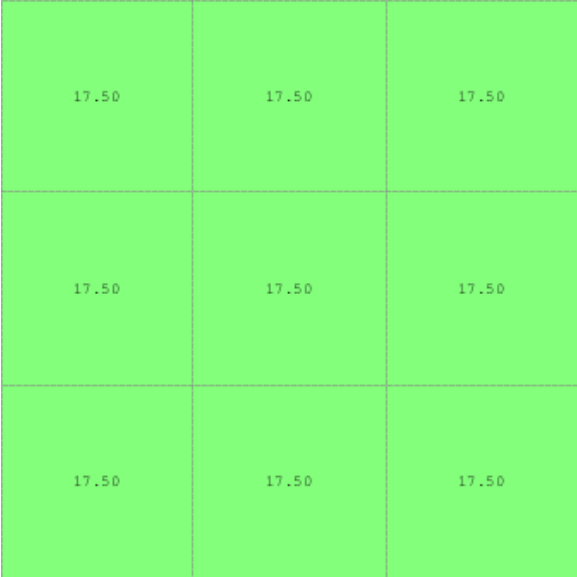
1km

**Bias = 0.16°C**  
**Stdev = 0.5°C**

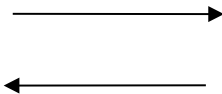
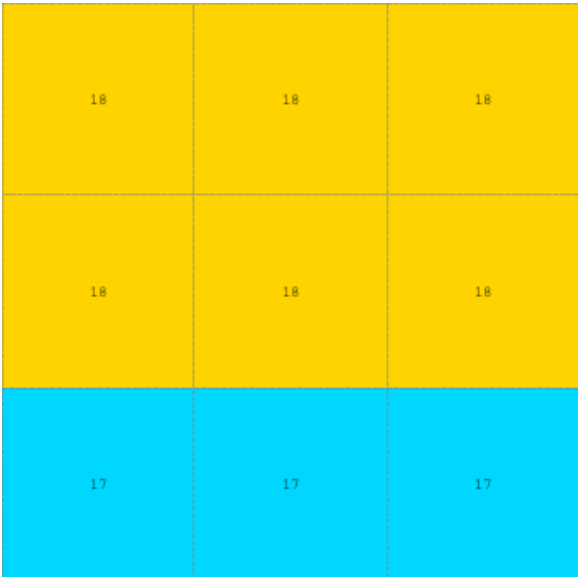
# Statistics vs Geometry

Matchup

*In situ*



Satellite



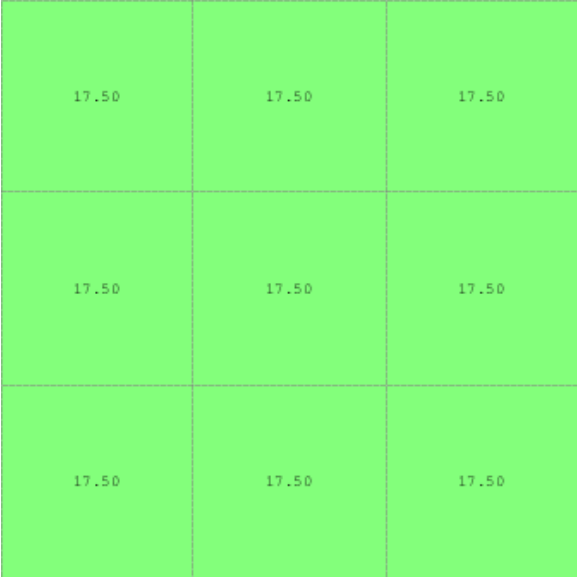
**Bias = 0.16°C**  
**Stdev = 0.5°C**



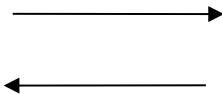
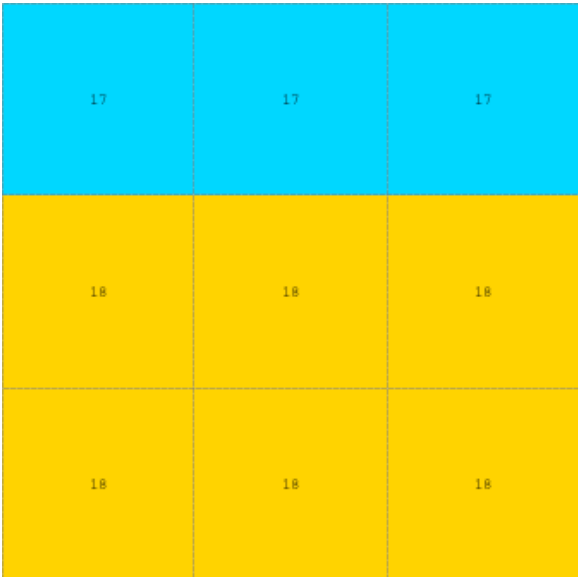
# Statistics vs Geometry

Matchup

*In situ*



Satellite



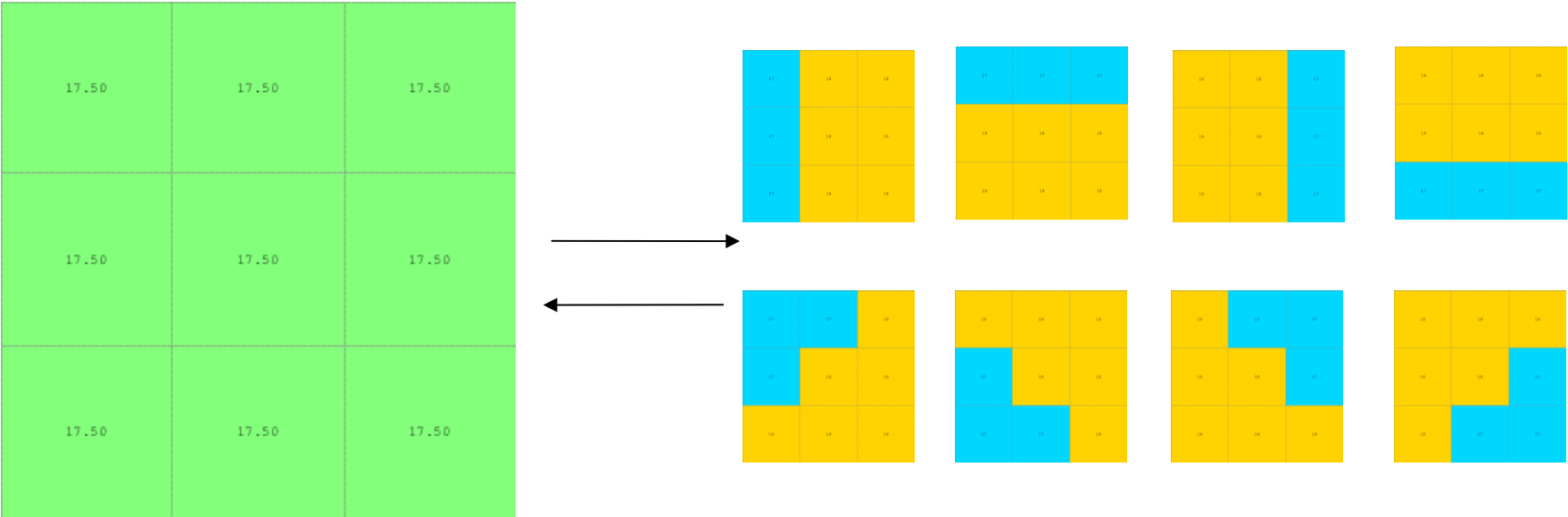
**Bias = 0.16°C**  
**Stdev = 0.5°C**

# Statistics vs Geometry

Matchup

*In situ*

Satellite



**Same statistics  
Different geometries...**

**How consistent are SST gradients from GHRSSST Level 4 datasets?**

# Datasets

## 6 GHR SST Level 4 SST (2016-2018)

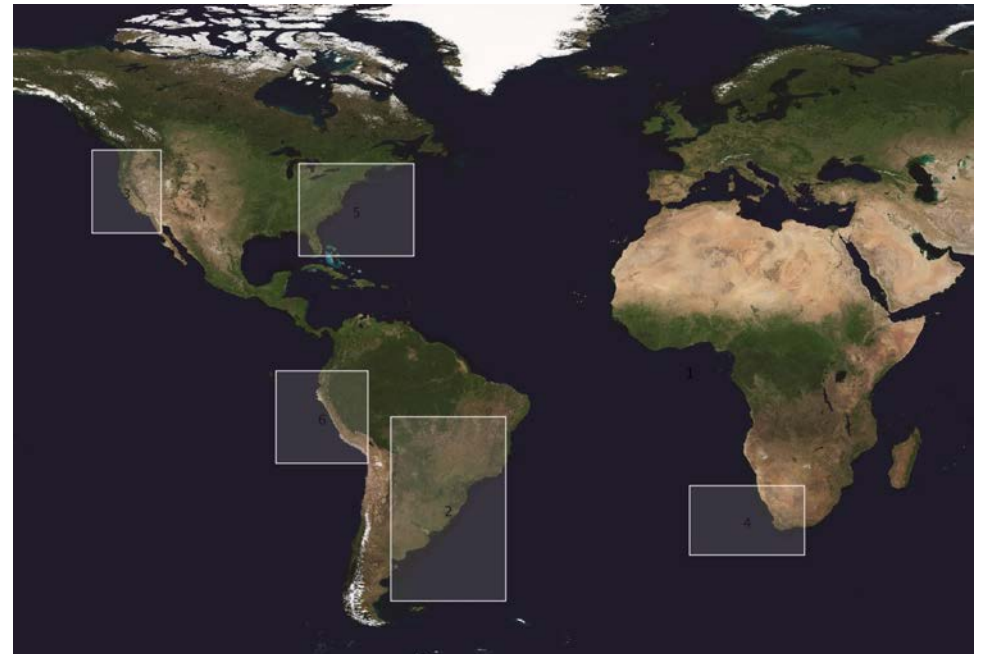
- Canadian Meteorological Center **CMC**
- Naval Oceanographic Office **K10**
- Remote Sensing Systems **REMSS\_MW\_IR**
- UK MetOffice **OSTIA**
- Danish Meteorological Institute **DMI**
- NASA/JPL Multiscale Ultrahigh Resolution **MUR**

All data downloaded from PODAAC and reprojected to a 0.1°Lat/Lon  
grid

# Datasets

## Comparison over 5 regions

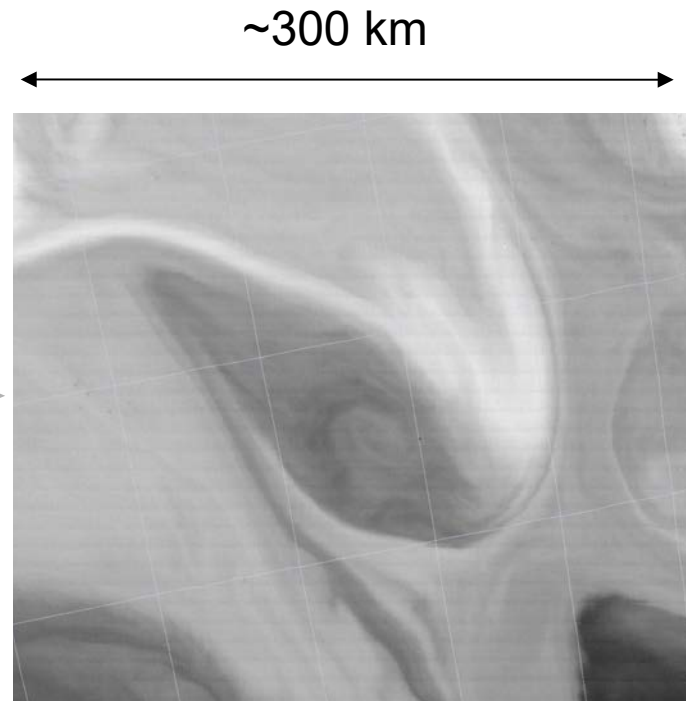
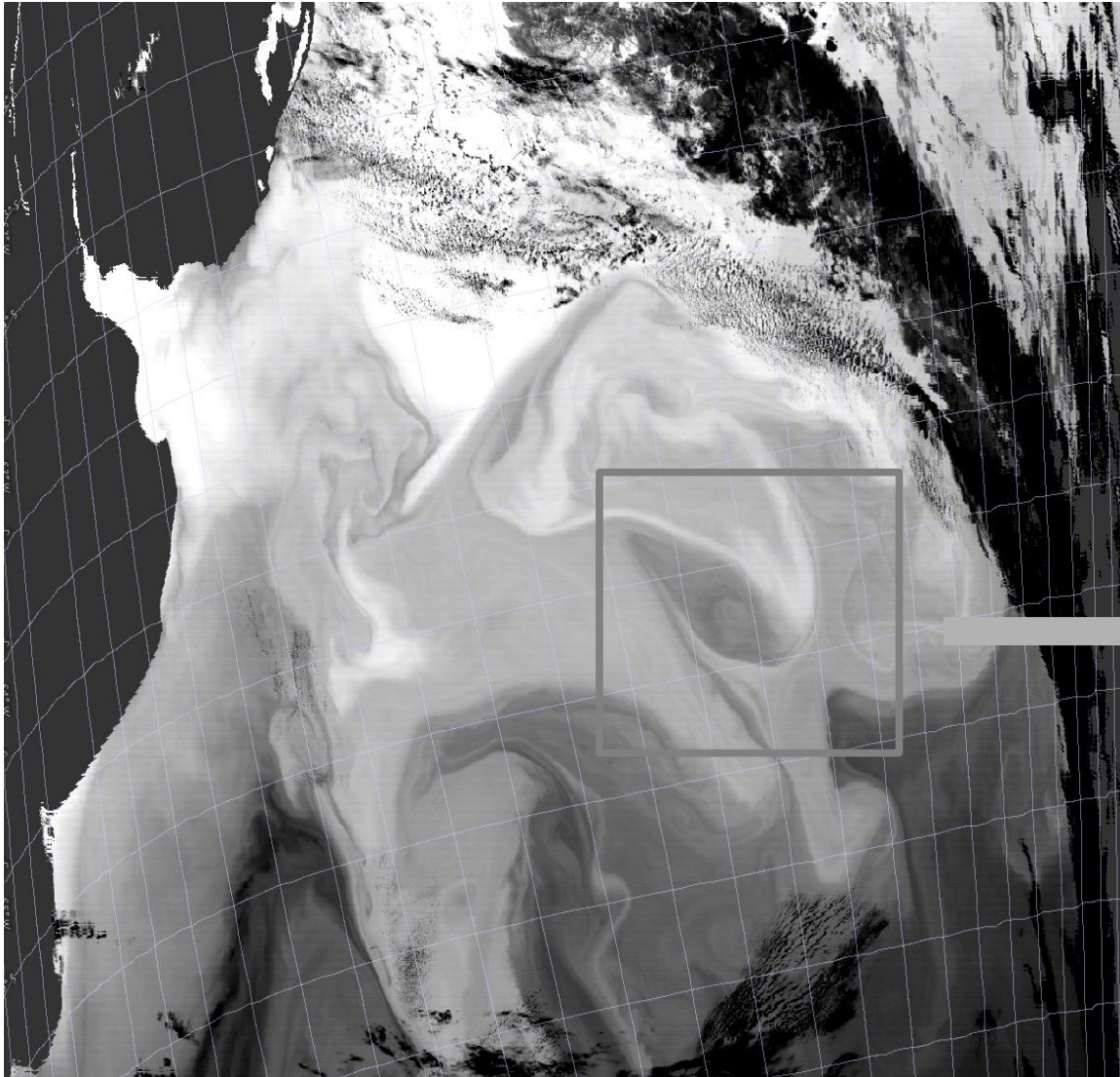
- Brazil-Malvinas confluence region
- California Current System
- Agulhas current and retroflexion zone
- Gulf Stream
- Peruvian Upwelling System



# Datasets

		INFRARED						MICROWAVE				
	<i>In situ</i>	MODIS	AVHRR	VIIRS	ABI	GOES	SEVIRI	AMSR-E	AMSRE-2	TMI	GMI	WINDSAT
CMC	✓		✓	✓					✓			
K10			✓			✓		✓				
REMSS		✓		✓				✓	✓	✓	✓	✓
OSTIA	✓		✓		✓		✓			✓		
DMI		✓	✓	✓			✓		✓			
MUR		✓	✓					✓				✓

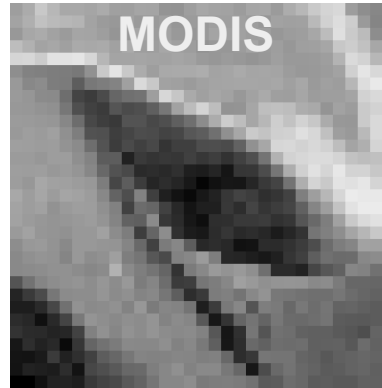
# Feature resolution



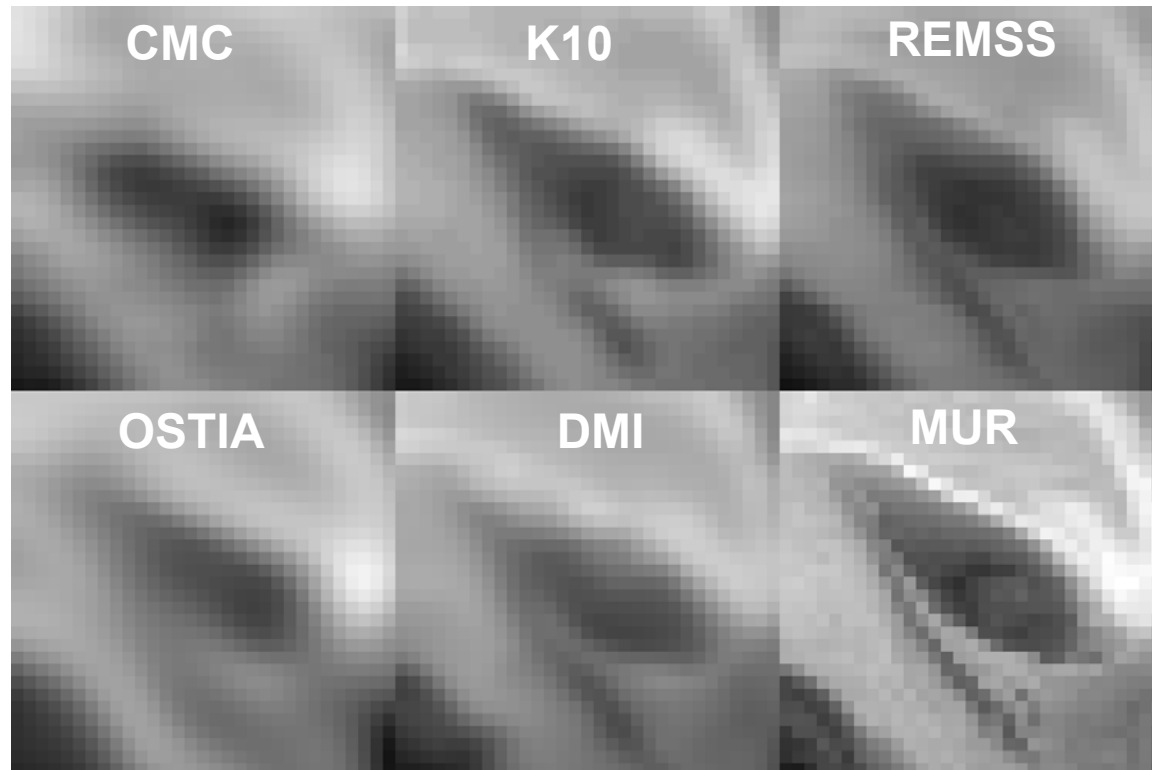
Aqua MODIS  
Dec 31 2018, Brazil-Malvinas (Level 2P, 1 km)

# Feature resolution

Level 3U  
(0.1° grid)

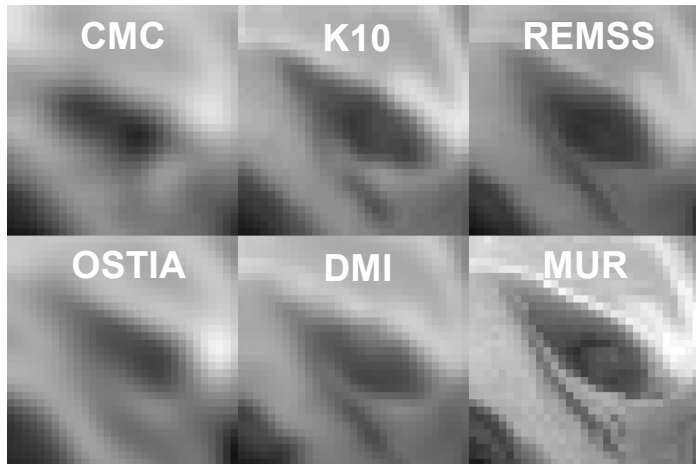
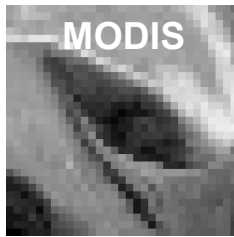


Level 4  
(0.1° grid)

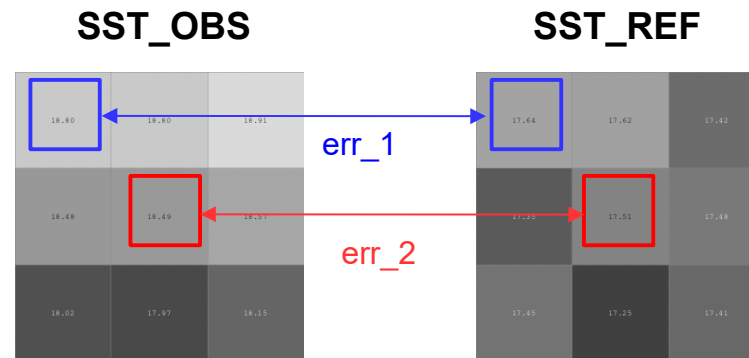




# Feature resolution



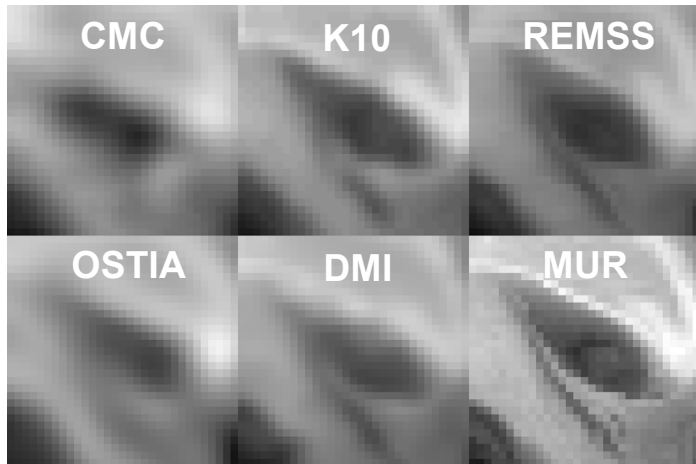
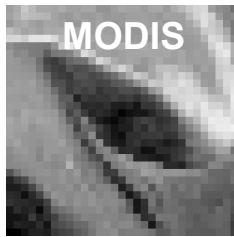
	Bias	Stdv	MSE
CMC	0.32°	0.59°	<b>0.46</b>
K10	0.28°	0.37°	0.22
REMSS	0.00°	0.41°	0.17
OSTIA	0.34°	0.48°	0.35
DMI	0.29°	0.55°	0.39
MUR	0.65°	0.23°	<b>0.47</b>



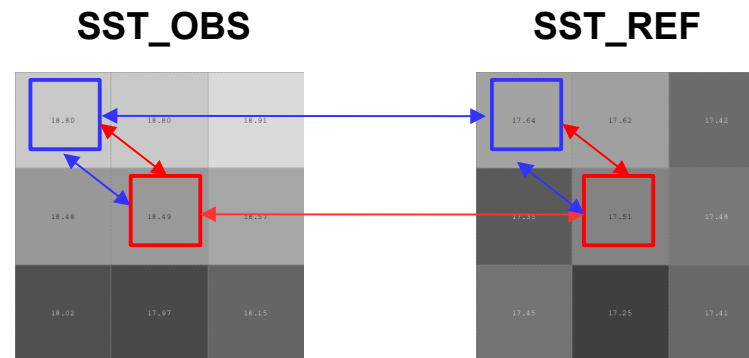
**Mean Squared Error**  

$$\text{MSE} = (\text{err}_1^2 + \text{err}_2^2 + \dots) / N$$

# Feature resolution



	Bias	Stdv	MSE	SSIM*
CMC	0.32°	0.59°	0.46	0.59
K10	0.28°	0.37°	0.22	0.79
REMSS	0.00°	0.41°	0.17	0.76
OSTIA	0.34°	0.48°	0.35	0.66
DMI	0.29°	0.55°	0.39	0.72
MUR	0.65°	0.23°	0.47	<b>0.91</b>

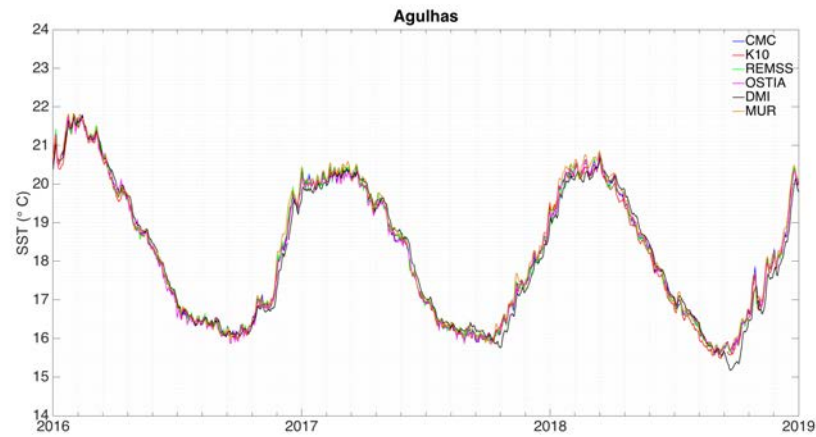
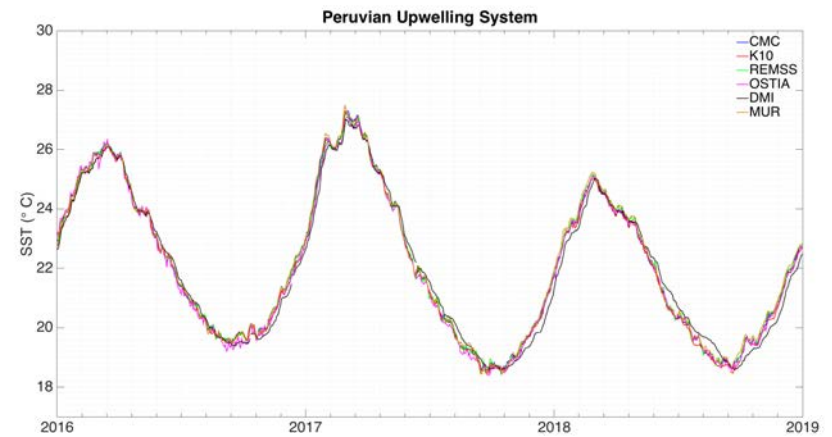
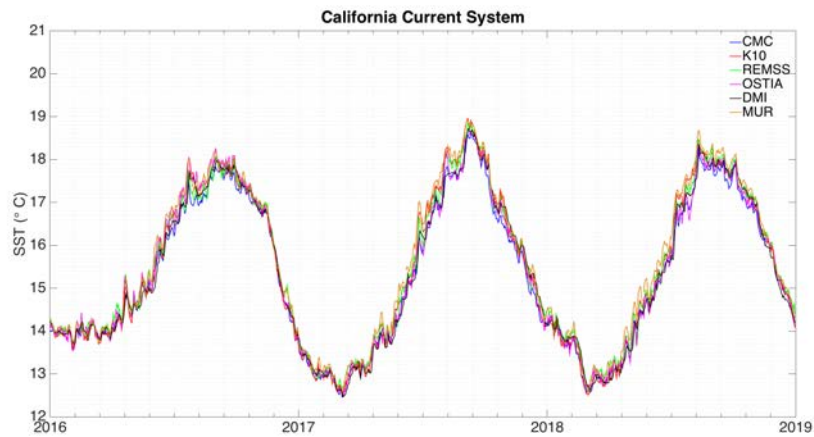
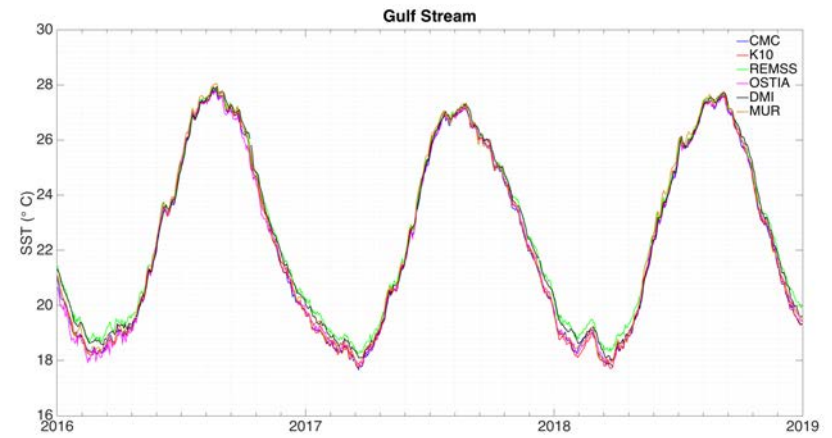
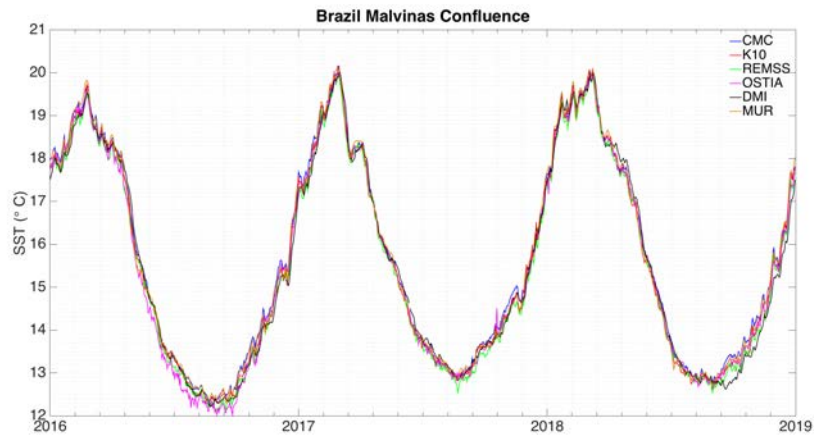


## \* Structural similarity (SSIM) index

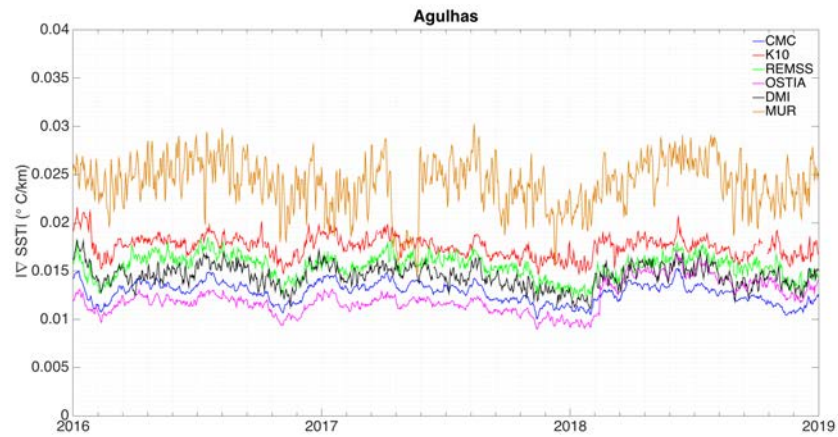
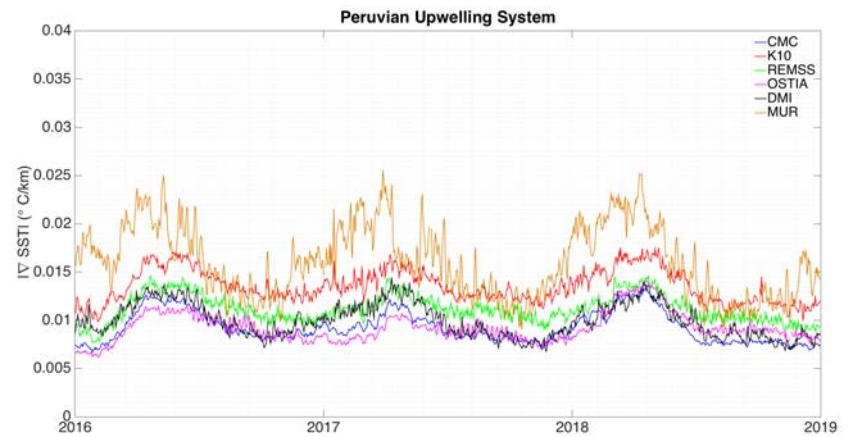
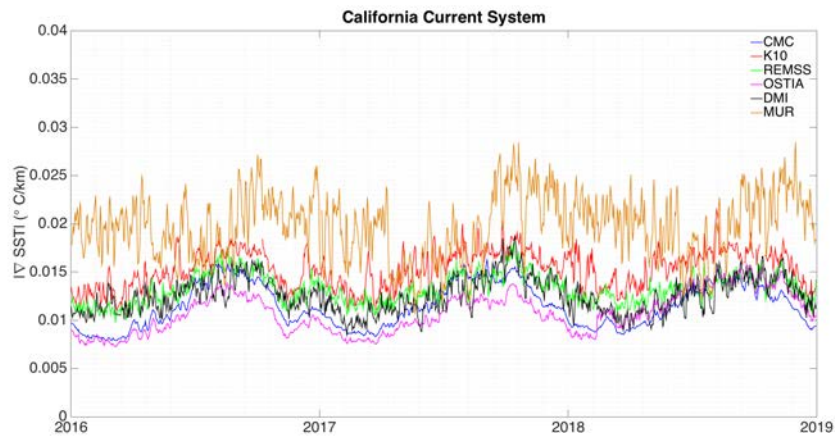
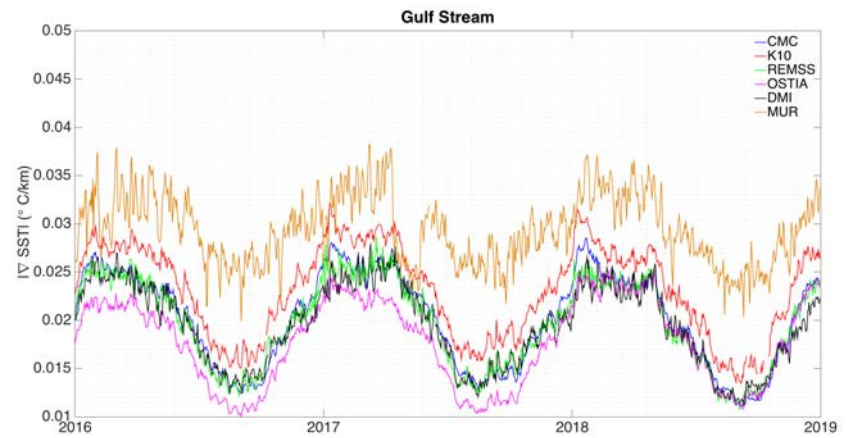
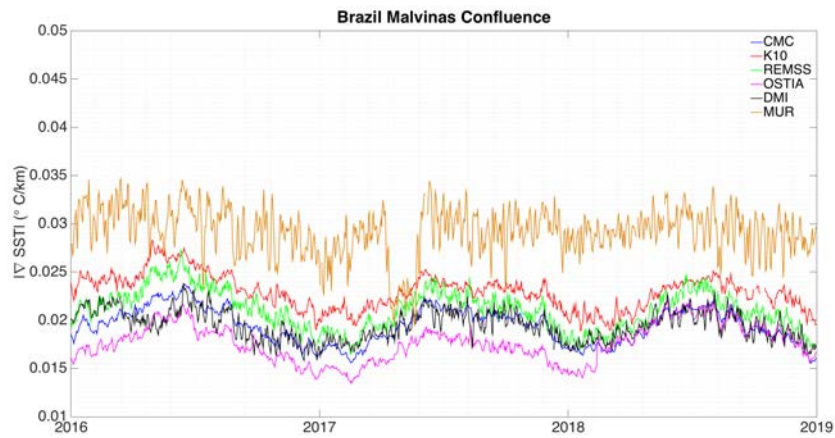
Wang, Zhou; Bovik, A.C.; Sheikh, H.R.; Simoncelli, E.P. (2004). "Image quality assessment: from error visibility to structural similarity". IEEE Transactions on Image Processing. 13 (4): 600–612

Citations May 2019 > 21400

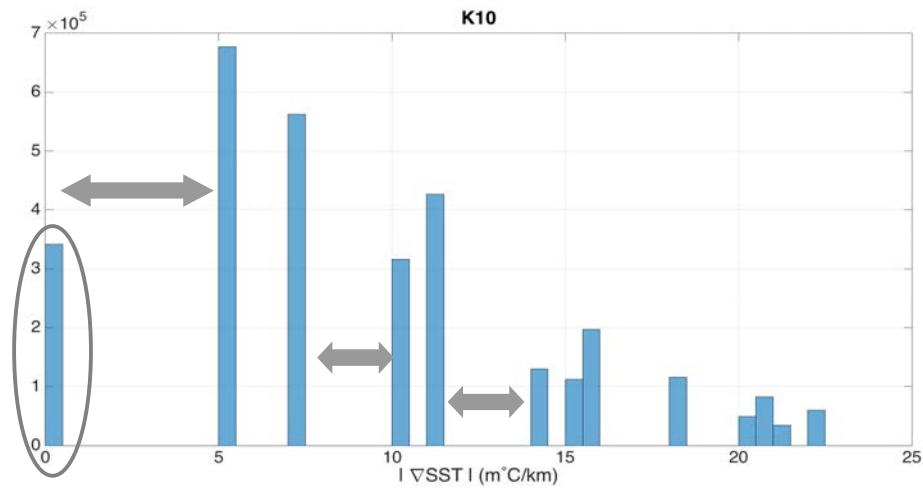
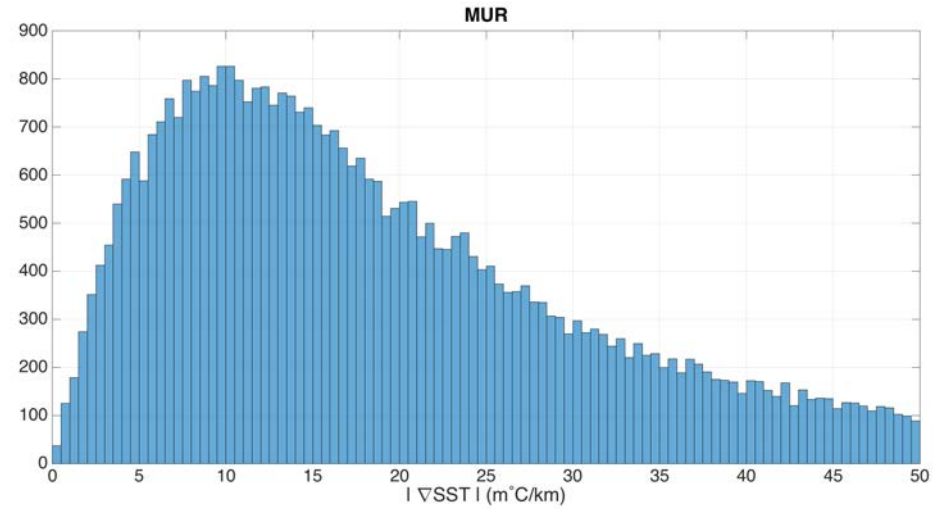
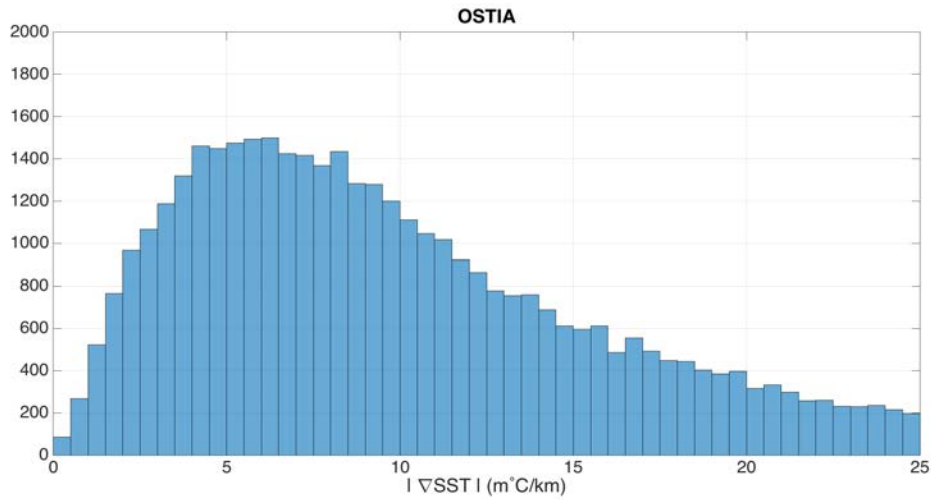
# Interannual variability: SST



# Interannual variability: $|\nabla SST|$

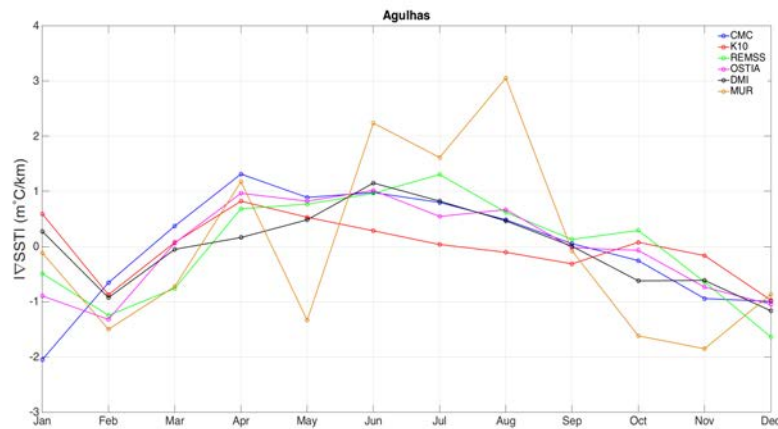
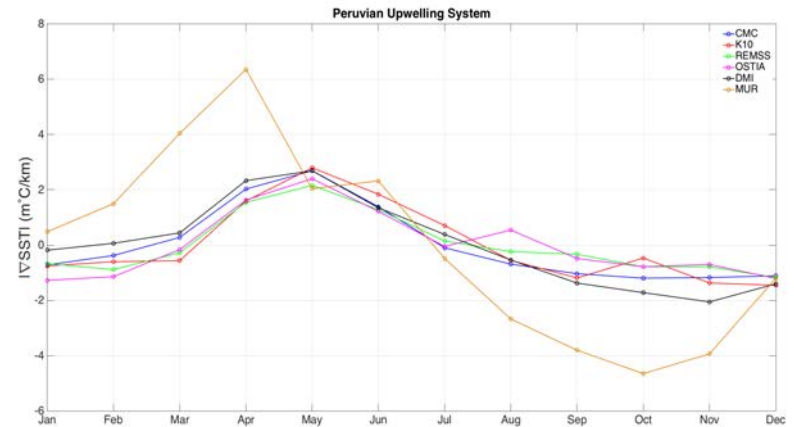
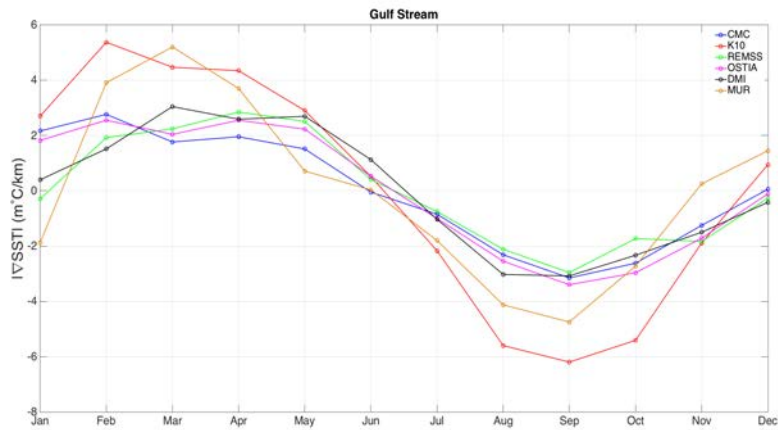
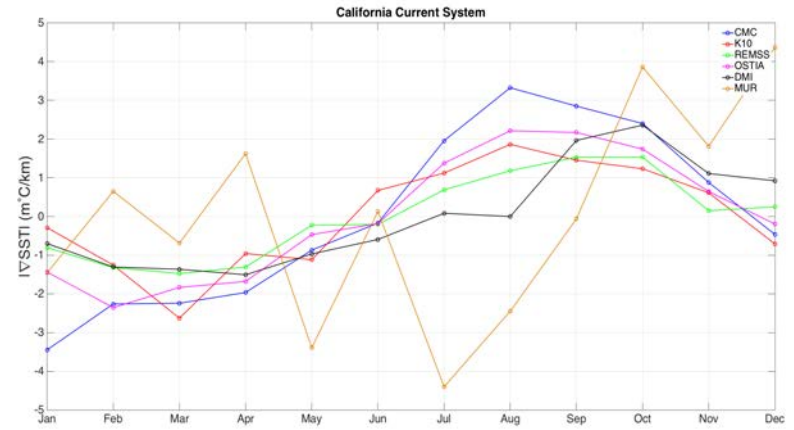
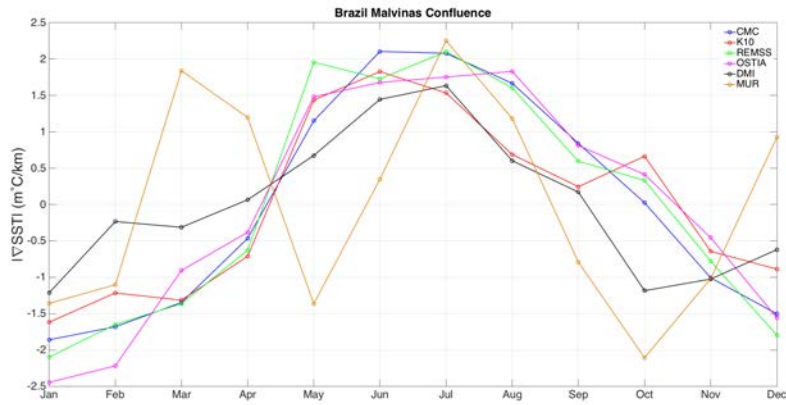


# Histogram of $|\nabla SST|$



Histogram of SST gradient magnitudes from Level 4 (Daily, Global)

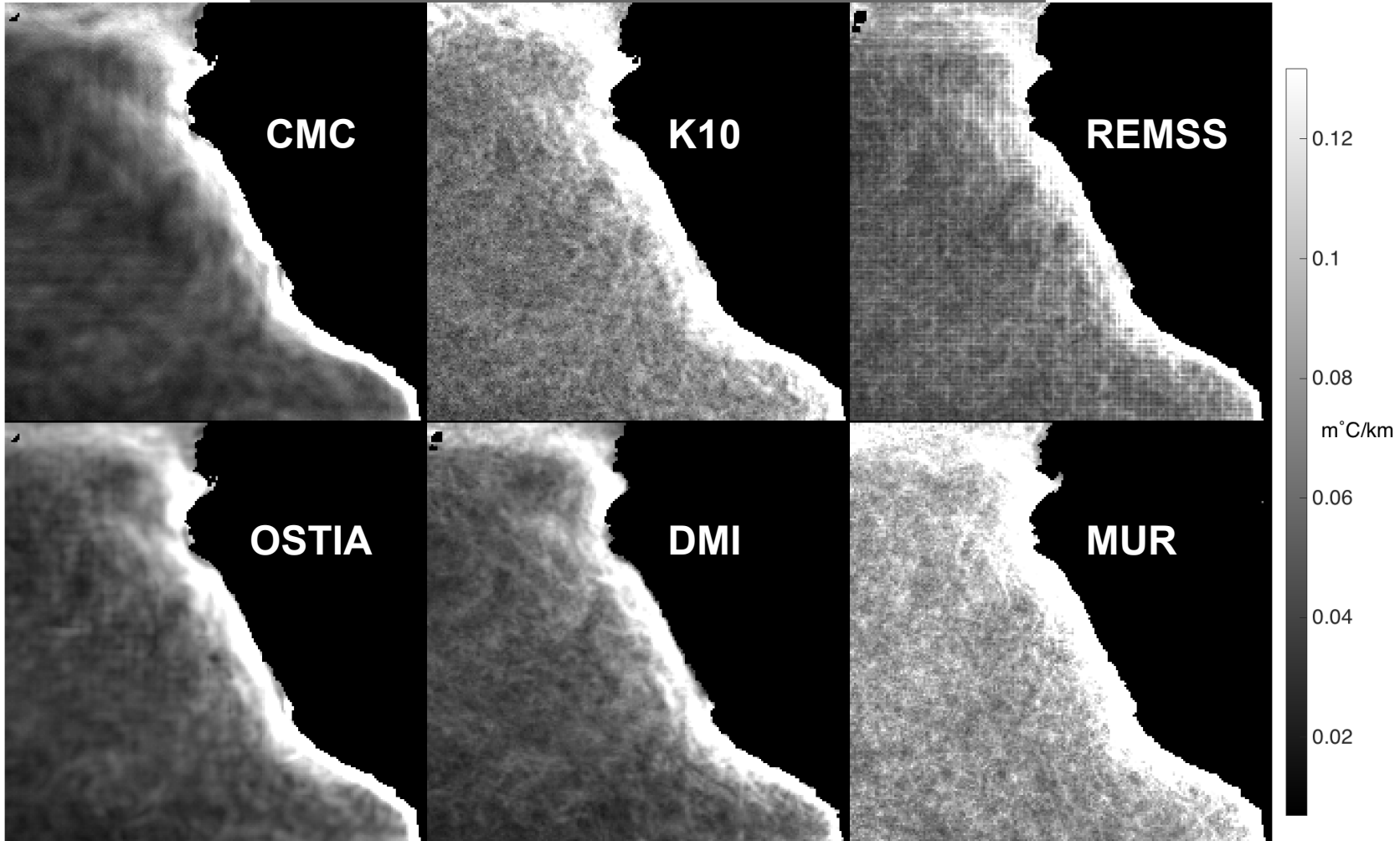
# Annual Cycle: $|\nabla SST|$





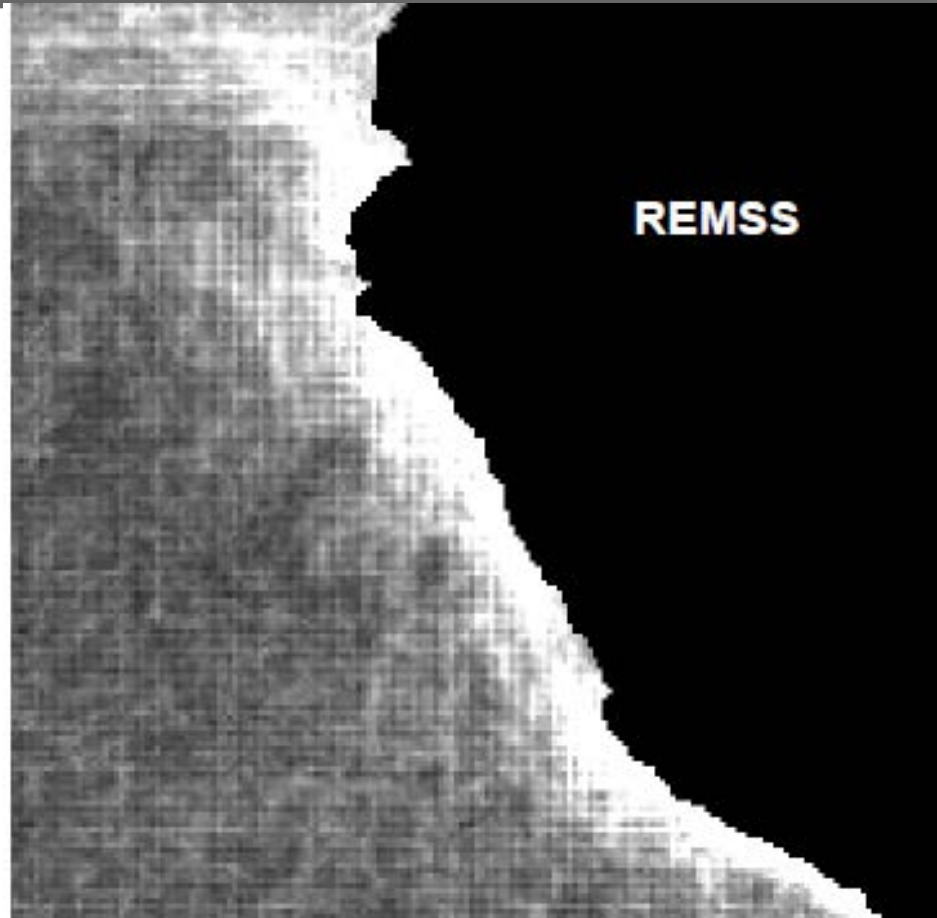
# Annual Maps: $|\nabla SST|$

Peruvian Upwelling System (2018)



# Annual Maps: $|\nabla SST|$

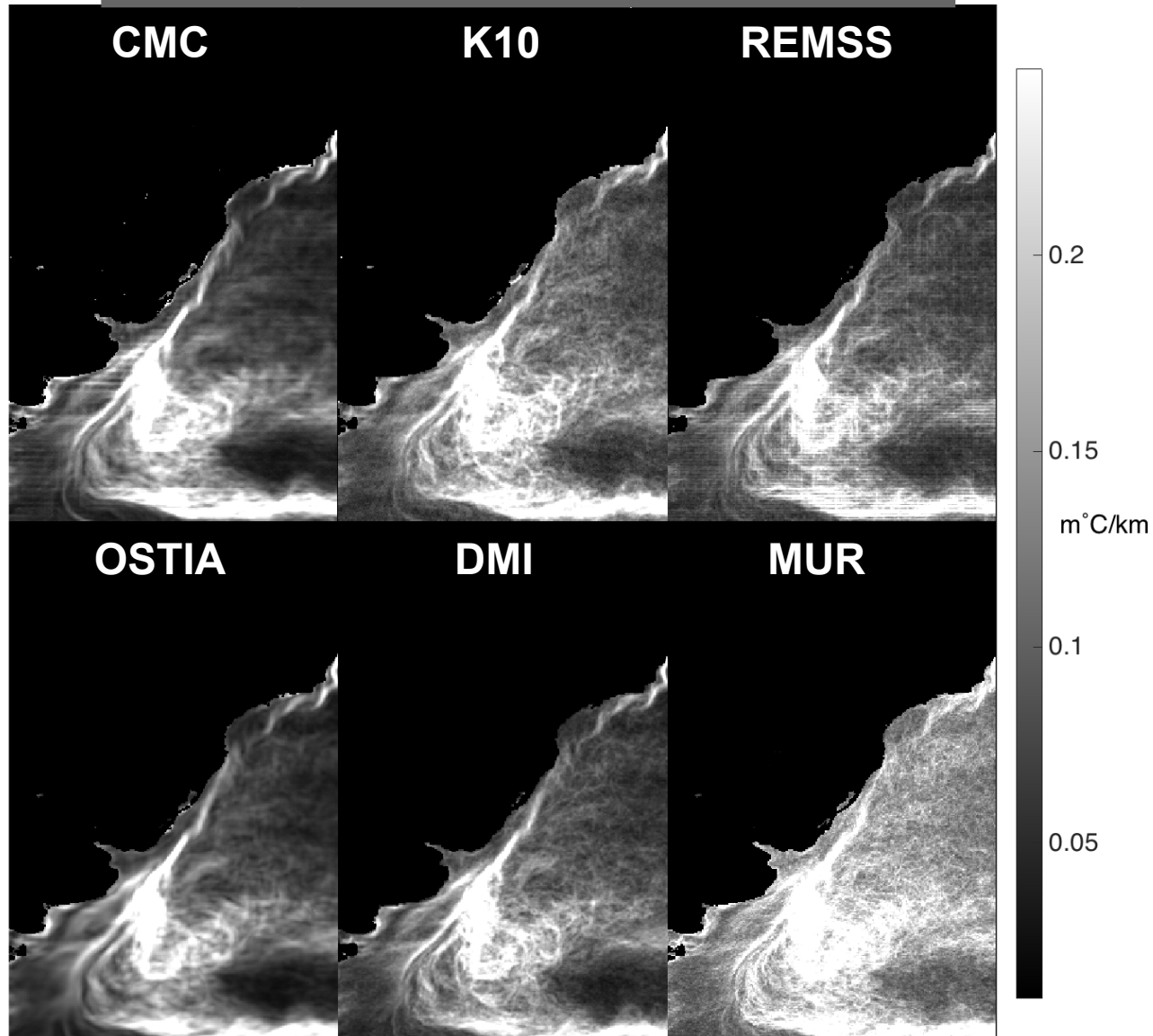
Peruvian Upwelling System (2018)





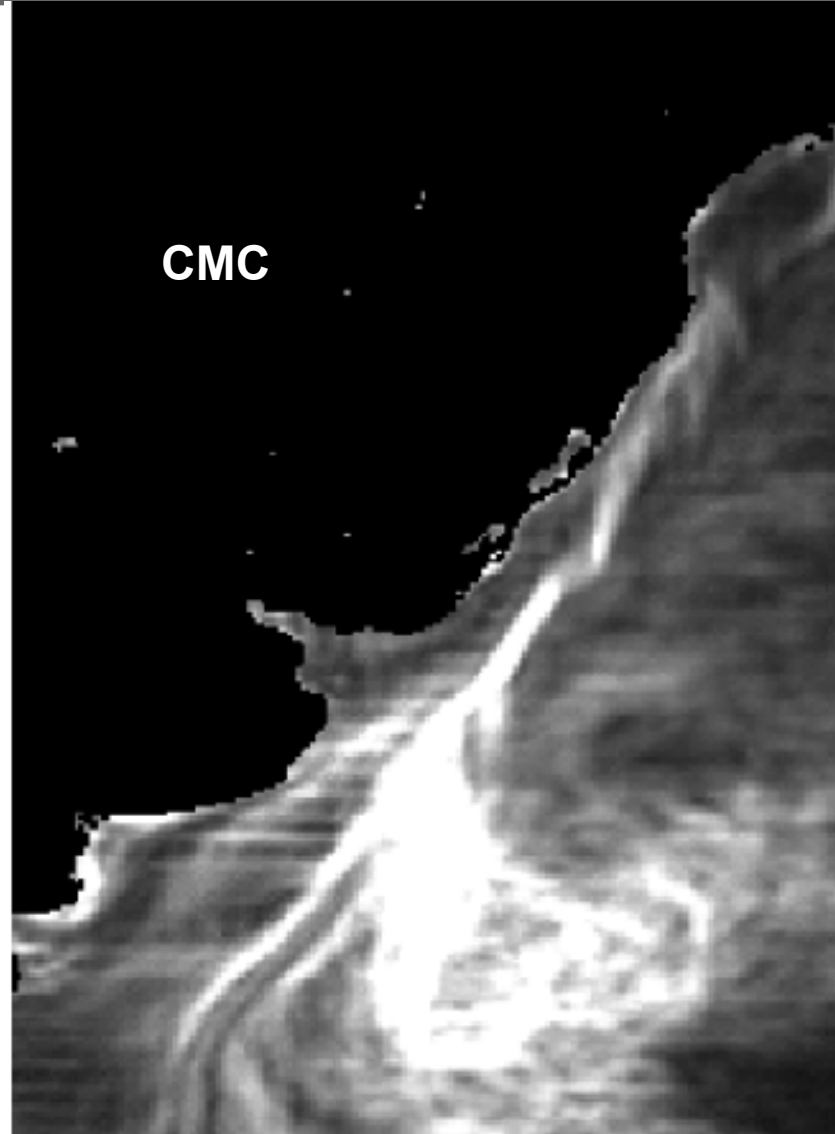
# Annual Maps: $|\nabla SST|$

Brazil-Malvinas (2018)



# Annual Maps: $|\nabla SST|$

Brazil-Malvinas (2018)

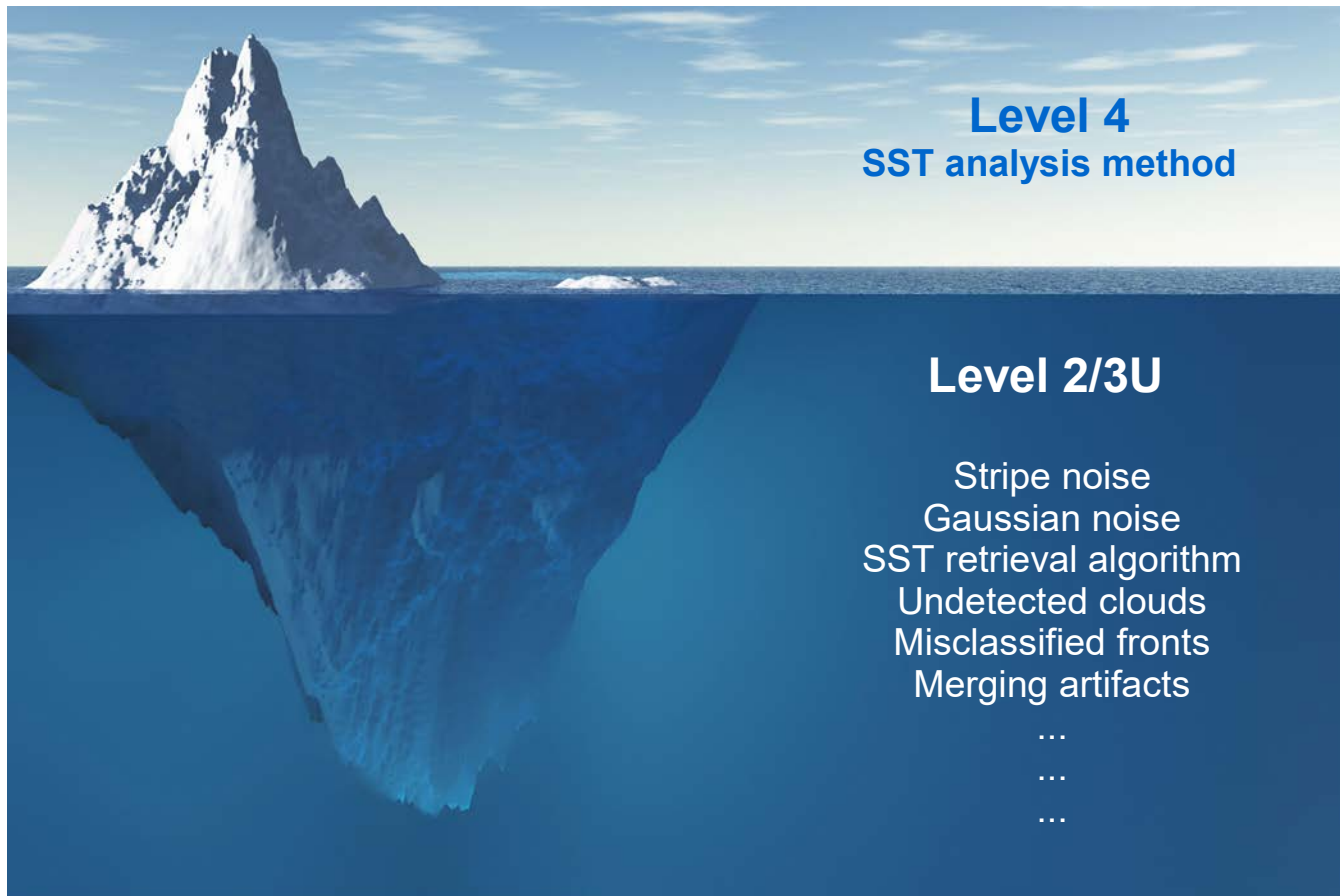


# Conclusion

- The magnitude of SST gradients from Level 4 products shows major differences in space and time despite consistency of SST
- Differences originate from the SST analysis **AND** the Level 2 data ingested
- Statistical metrics (Bias, Stdv, MSE) do not quantify the “geometrical quality” of SST fields (i.e., Statistical validation  $\neq$  Geometrical validation)
- Validation of SST gradients requires new methods and metrics

# Conclusion

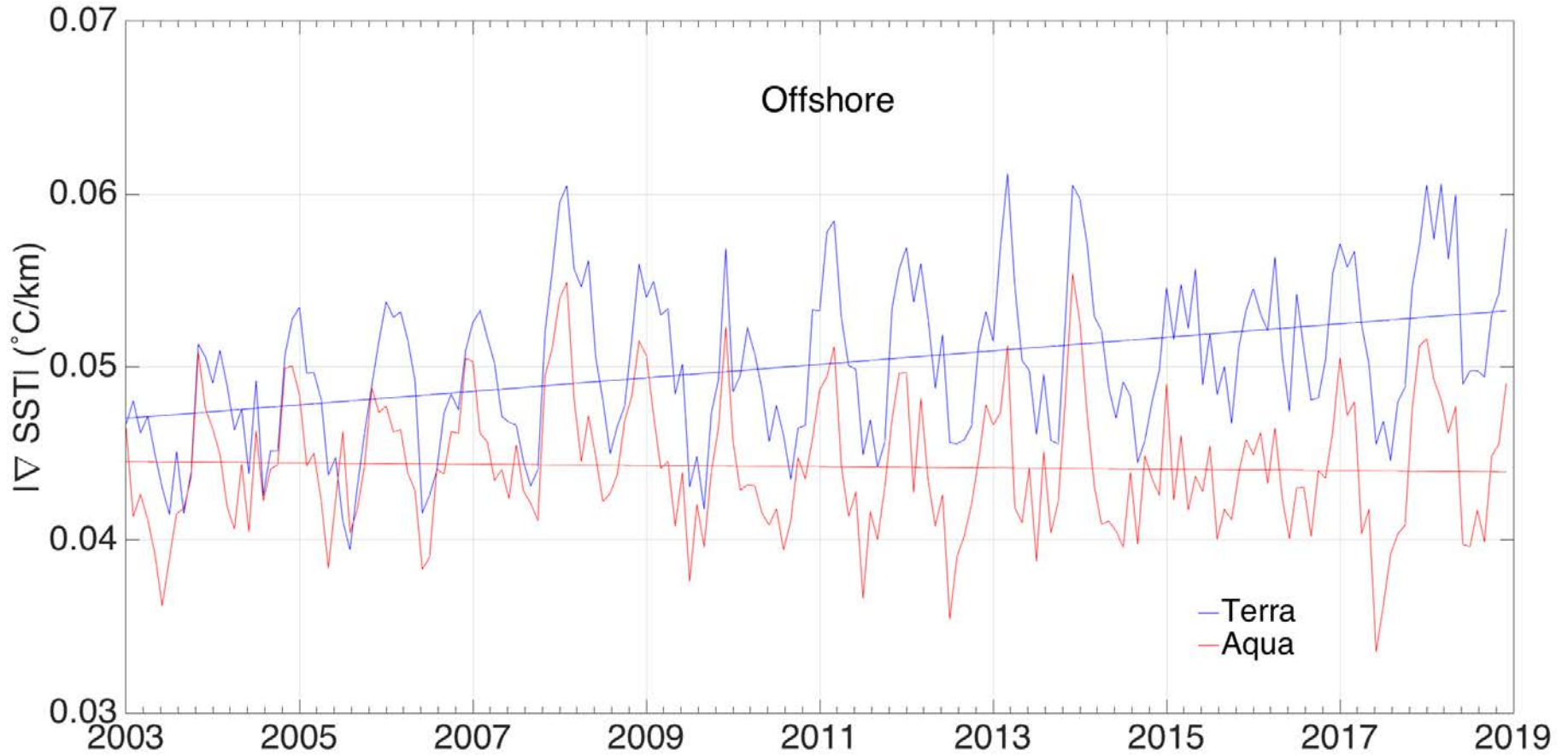
## Differences in SST gradients



# Case study

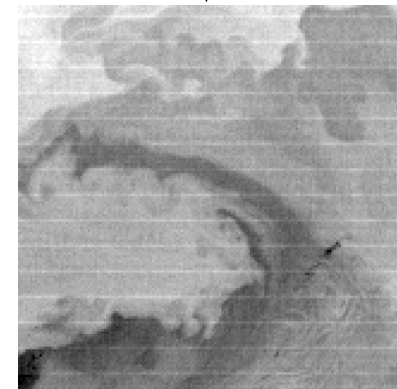
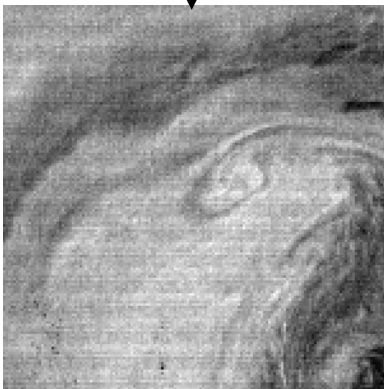
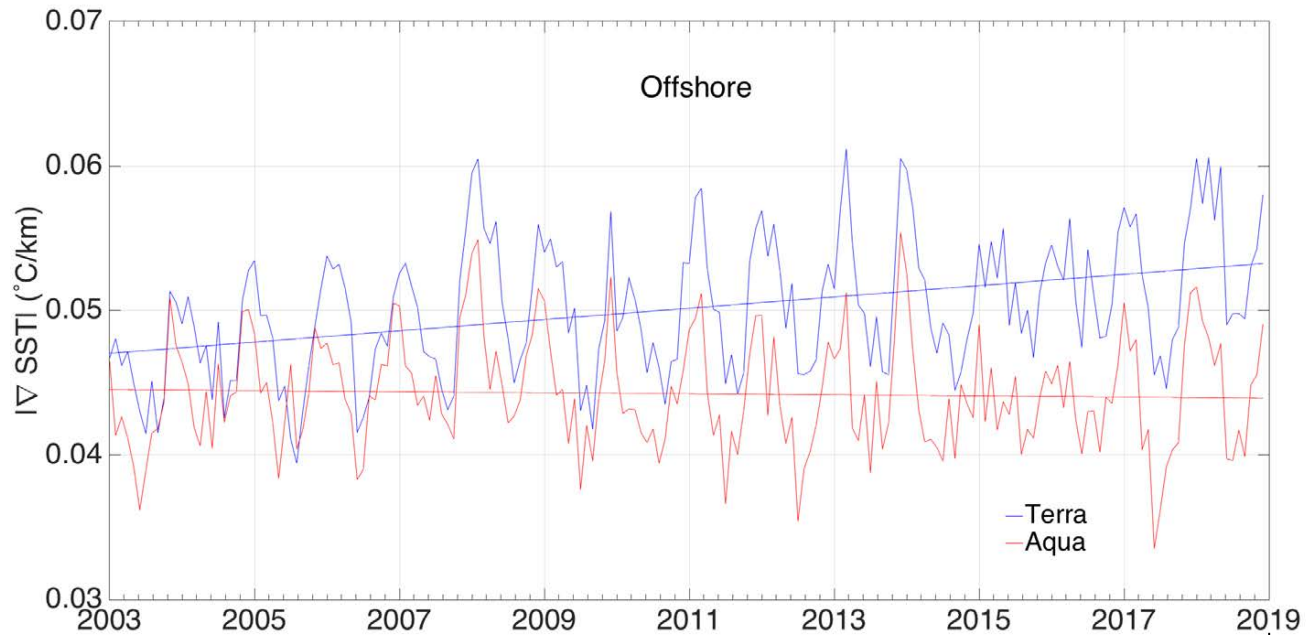
## SST gradients from Level 2 MODIS

### California Current System



# Case study

## SST gradients from Level 2 MODIS California Current System



**Increasing trend of SST gradients on Terra MODIS due to continuous degradation of detectors in channels used for SST**



An aerial satellite-style image of Earth, showing the Atlantic Ocean, Europe, and Africa. The colors are stylized, with deep blues for the ocean, greens and yellows for land, and greys for ice and snow. The text "Thank you! Questions?" is overlaid in white at the top.

**Thank you! Questions?**