New Mathematical Technique for Satellite Data Interpolation with Applications to L4 Generation

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The Numericus Group, LLC

Outline

- Motivation and Methodology
- Interpolation of SEVIRI L3 SST
- Interpolation of MODIS L2 SST
- Application to SST foundation from SEVIRI and corresponding diurnal warming

New Interpolation Method

- The method is proprietary technology of The Numericus Group, LLC
- It is based on Fourier Analysis and produces a smooth function (the INTERPOLATOR) that is fitted to the satellite data
- It is a global technique which, by estimating the frequency content of the input, avoids over-fitting or under-fitting
- The interpolator can be efficiently evaluated anywhere within the input domain, including buoy locations, the input grid or any other regular/irregular grid

Methodology

- We build interpolation functions from L3 SEVIRI and L2 MODIS SSTs inputs, and
- Generate corresponding L4 products by evaluating the interpolation functions at the native resolution grids
  - First Stage: single-sensor L4 SST products (shown here)
  - Second Stage: multi-sensor L4 SST products (preliminary results) in which observations from other platforms are used as inputs in their original resolutions

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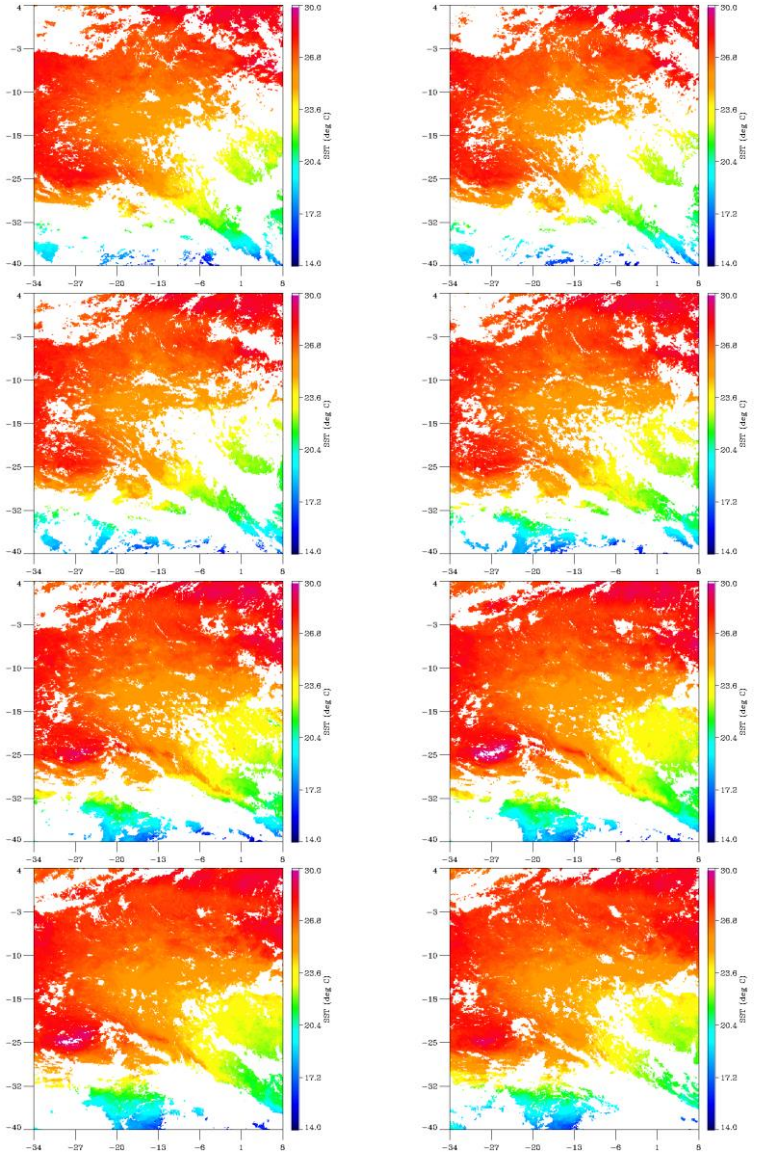
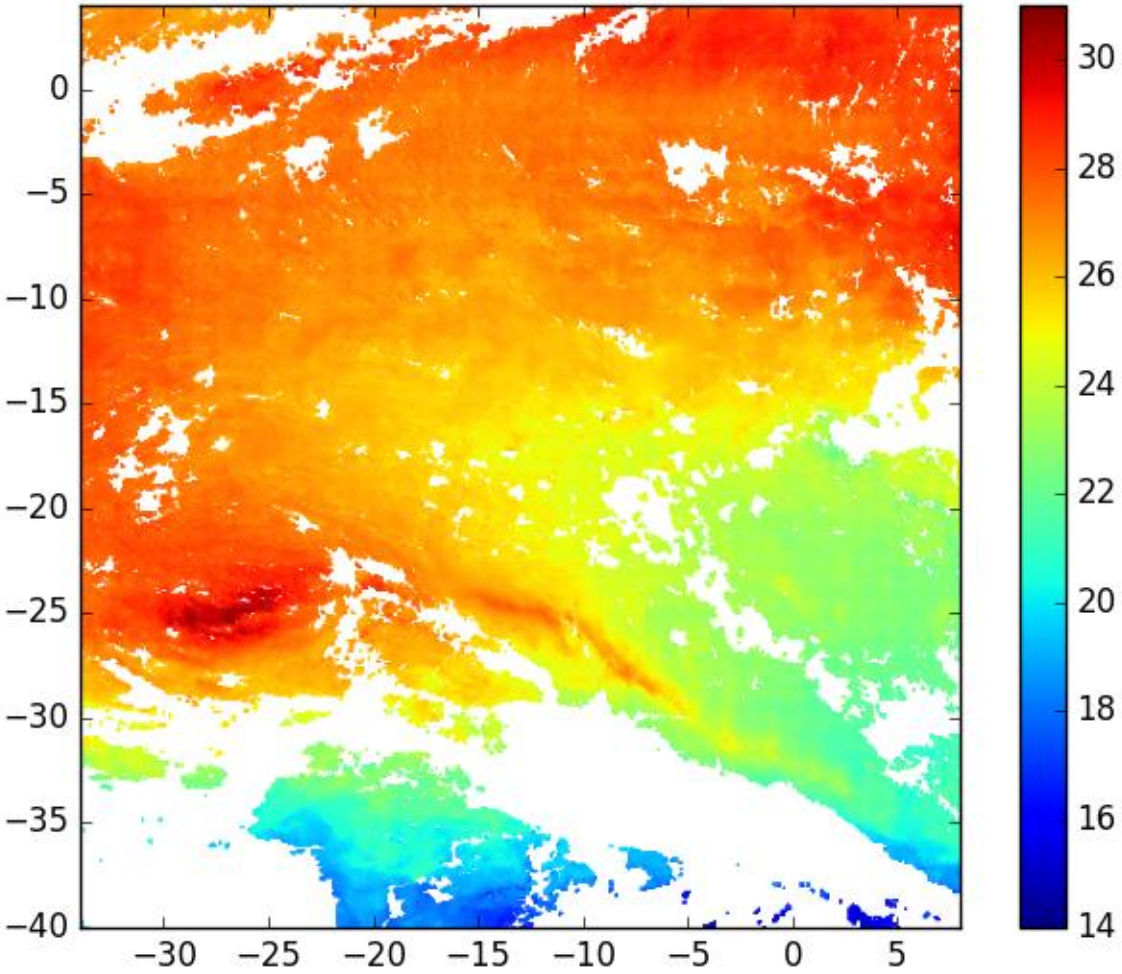
SEVIRI L3 SST Input Data

- L3 SST from OSI-SAF
- 3-hourly product
- Spatial Resolution:
  0.1 deg
- Proximity Confidence:
  Flags: 2-3-4-5
- Input Domain:
  4N-40S & 34W-8E

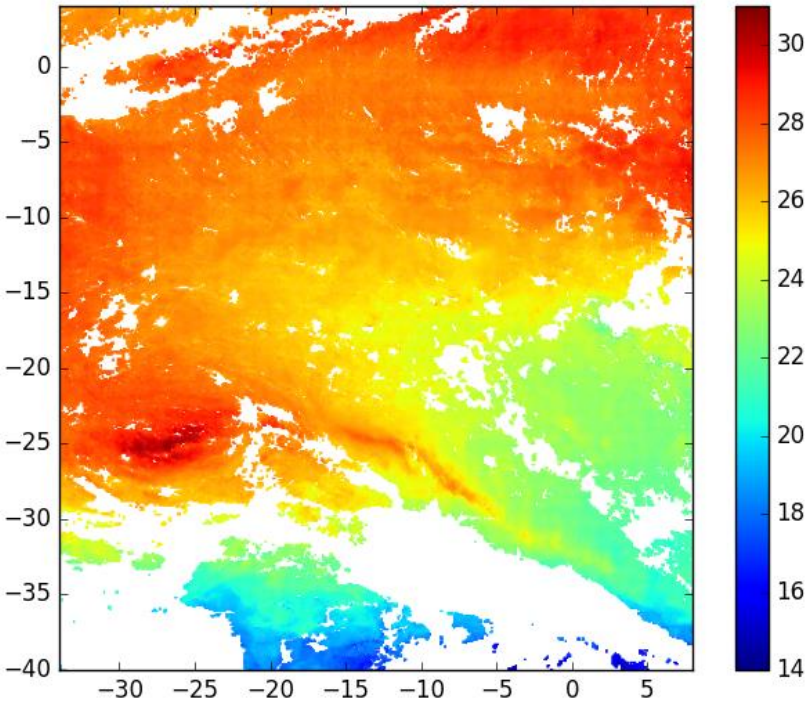


February 8 2009, 16:00 UTC

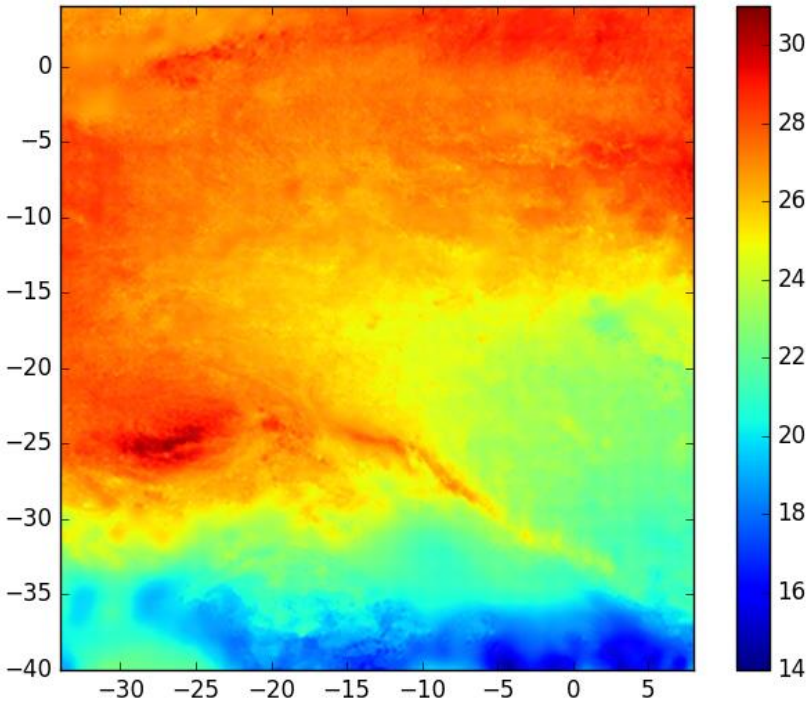


L4 SST from One L3 SEVIRI Scene

L3 SST: INPUT DATA



L4 SST: INTERPOLATOR EVALUATED AT 0.1 DEG GRID



Misfit in SEVIRI L3 SST

MISFIT= DIFFERENCE BETWEEN THE INPUT AND THE INTERPOLATOR, EVALUATED AT THE INPUT GRID

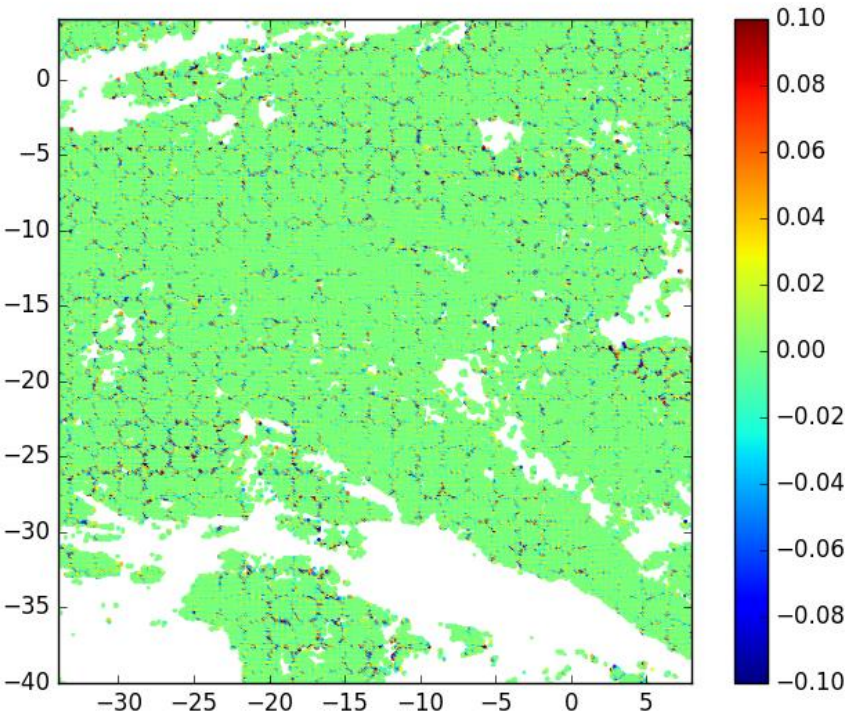
Misfit Statistics:

- RMSE = 0.018
- Max absolute error = 0.23 K
- Max relative error (K) = 0.087%
- 91% of the input data is within 0.01% of the fitted value (good quality of the SEVIRI input)

The function captures a circular structure in the SEVIRI input!

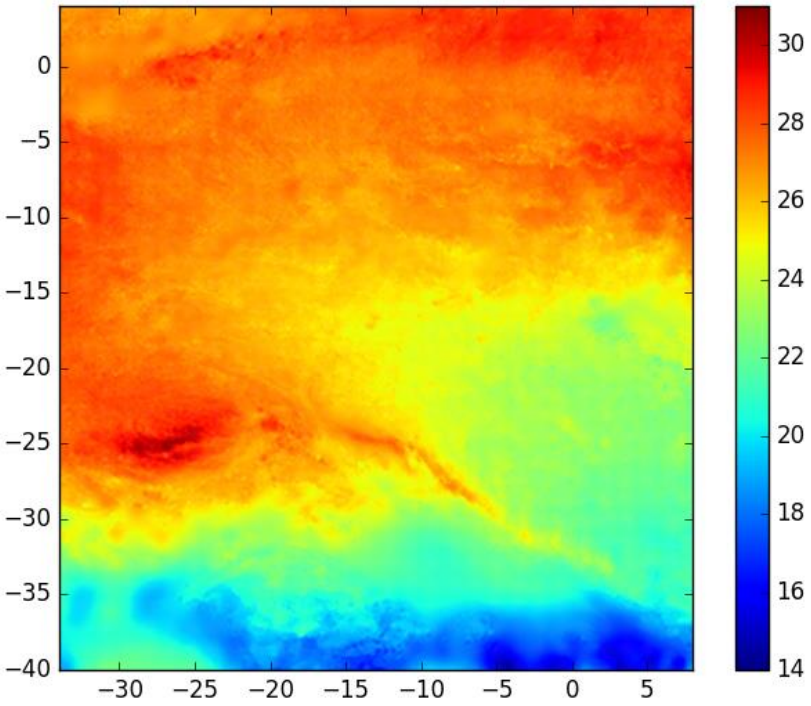
- Averaging effect in 3h-product?

L3 SEVIRI – SEVIRI INTERPOLATOR EVALUATED AT L3 INPUT GRID

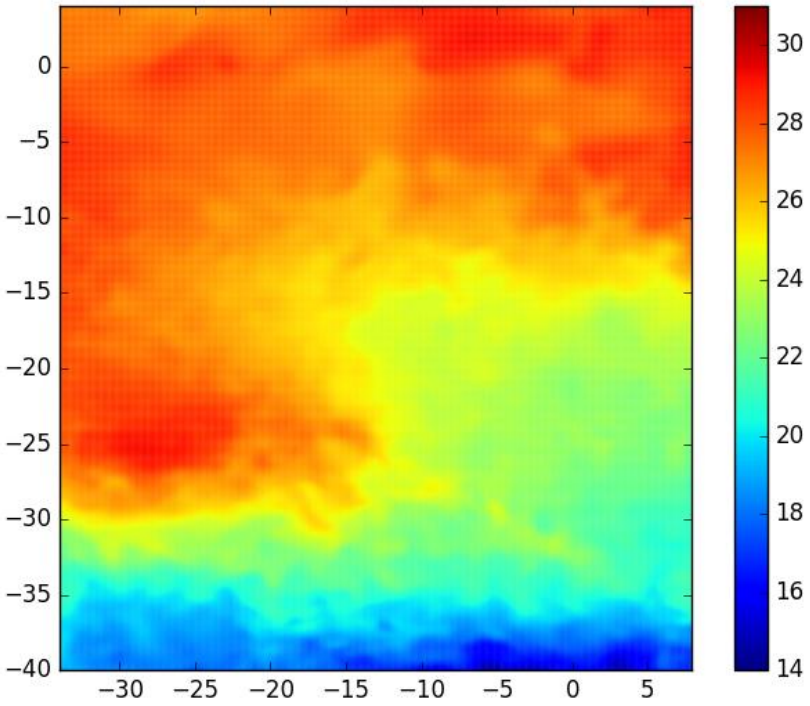


L4 Skin SST Comparison

SEVIRI 10 KM SST AT 16:00

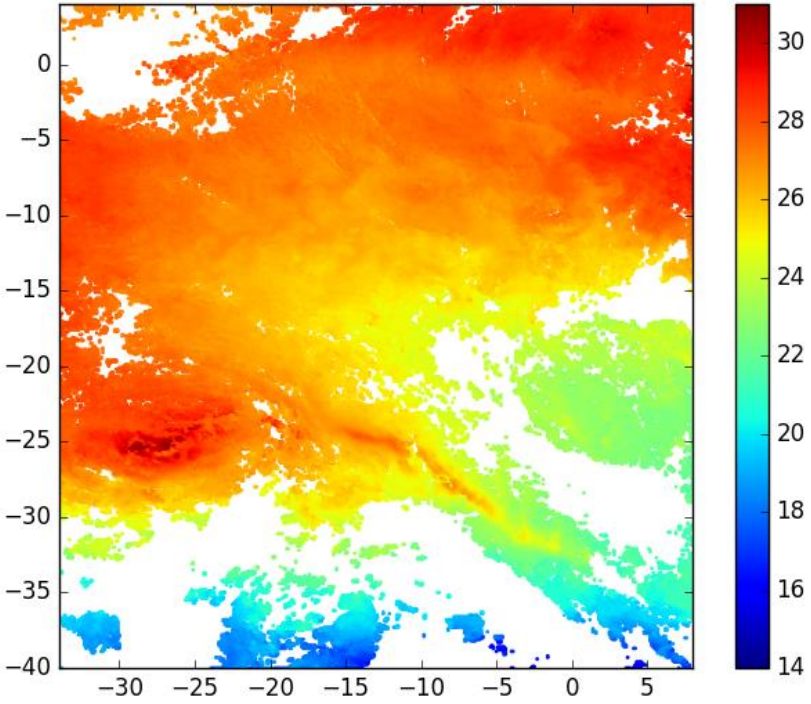


FNMOC 9 KM SST AT 18:00

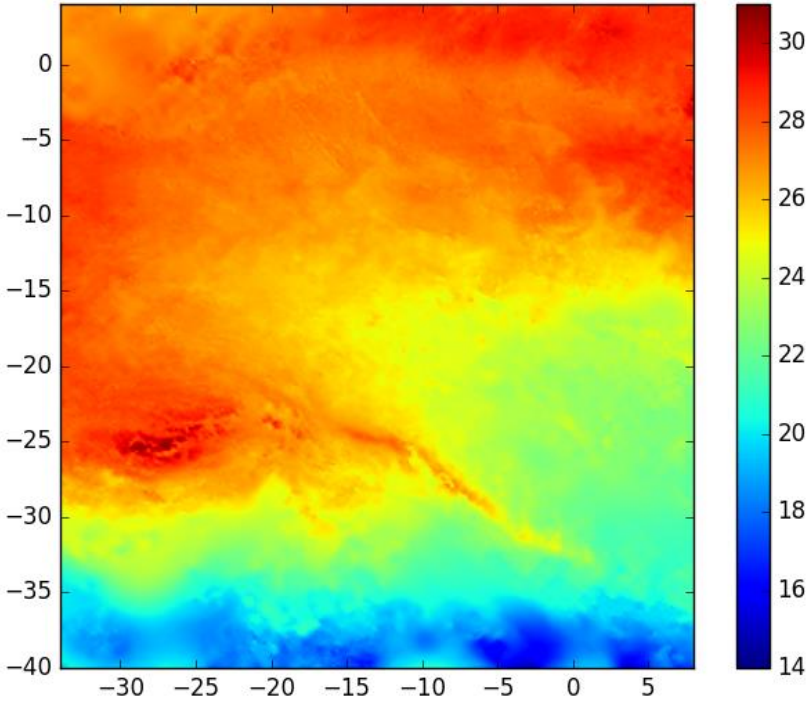


L4 SST Using Multiple L3 SEVIRI Scenes

DAILY MAXIMUM COMPOSITE USING ALL 3H SCENES AND QF=5



L4 PEAK SST: INTERPOLATOR EVALUATED AT 0.1 DEG GRID



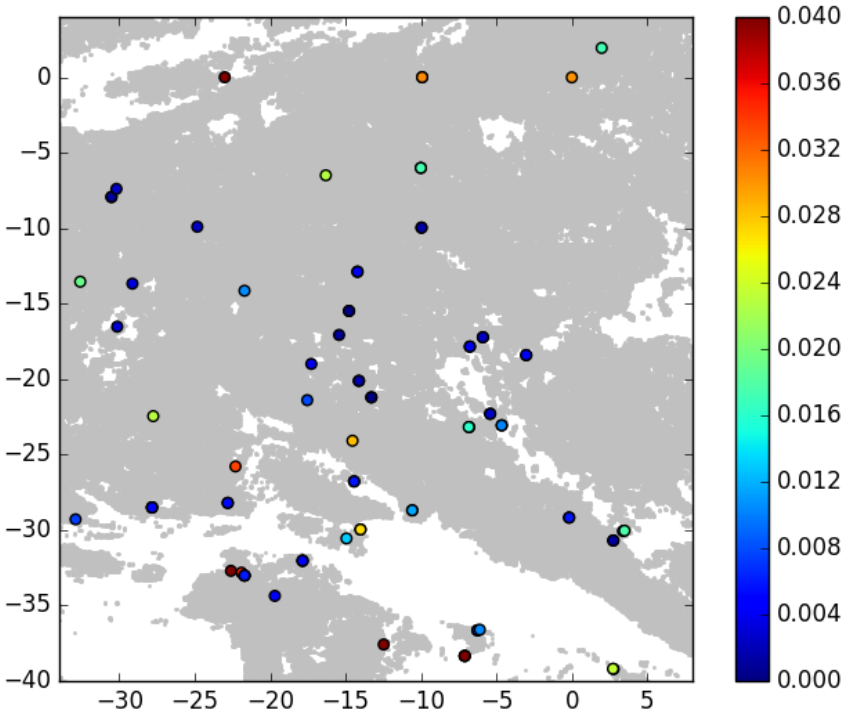
Validation of SEVIRI L4 with Buoys

Single-Scene	Buoys with SEVIRI Matchups			Buoys with no Matchups	
	No. Buoys	Matchup	Interpolator	No. Buoys	Interpolator
RMSE	81	**0.46**	**0.43**	24	**0.60**
Bias	81	-0.04	-0.05	24	-0.17
Max Rel Err (C, K)	81	0.073, 0.005	0.072, 0.005	24	0.052, 0.004

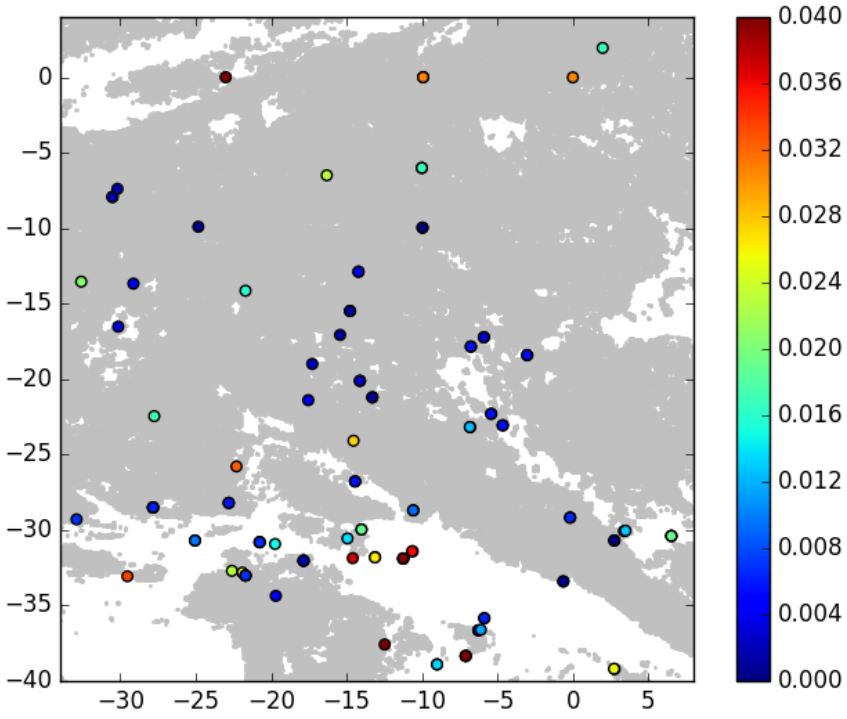
Multi-Scene	Buoys with SEVIRI Matchups			Buoys with no Matchups	
	No. Buoys	Matchup	Interpolator	No. Buoys	Interpolator
RMSE	47	**0.48**	**0.48**	26	**0.70**
Bias	47	-0.06	-0.08	26	0.23
Max Rel Err (C, K)	47	0.050, 0.004	0.053, 0.005	26	0.098, 0.006

Spatial Map of Buoy Differences

STANDARD MATCHUPS: SEVIRI SST PIXEL AT MINIMUM DISTANCE FROM BUOY LOCATION. WINDOW: 20-KM RADIUS AND 1HOUR



DIRECT SEVIRI INTERPOLATOR EVALUATED AT BUOY LOCATION



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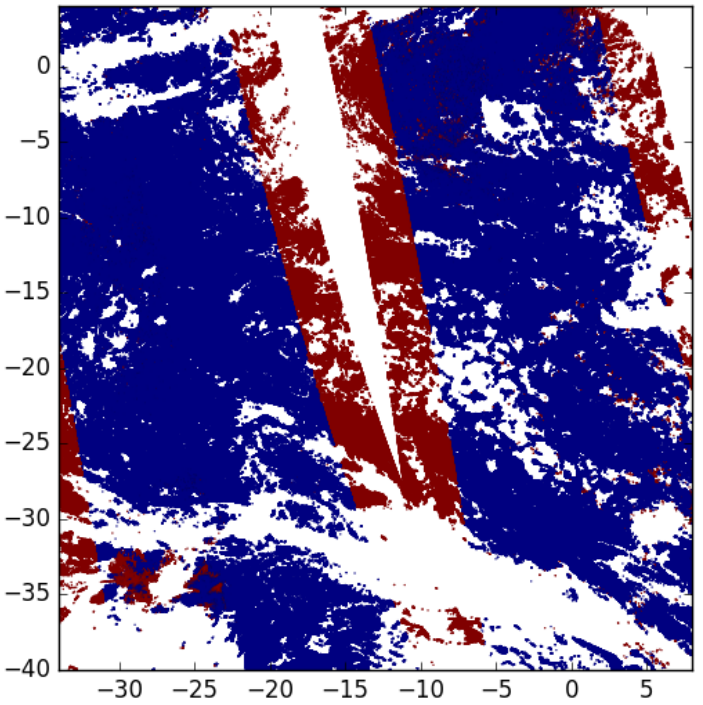
MODIS L2 SST INPUT

AQUA/MODIS L2 SST

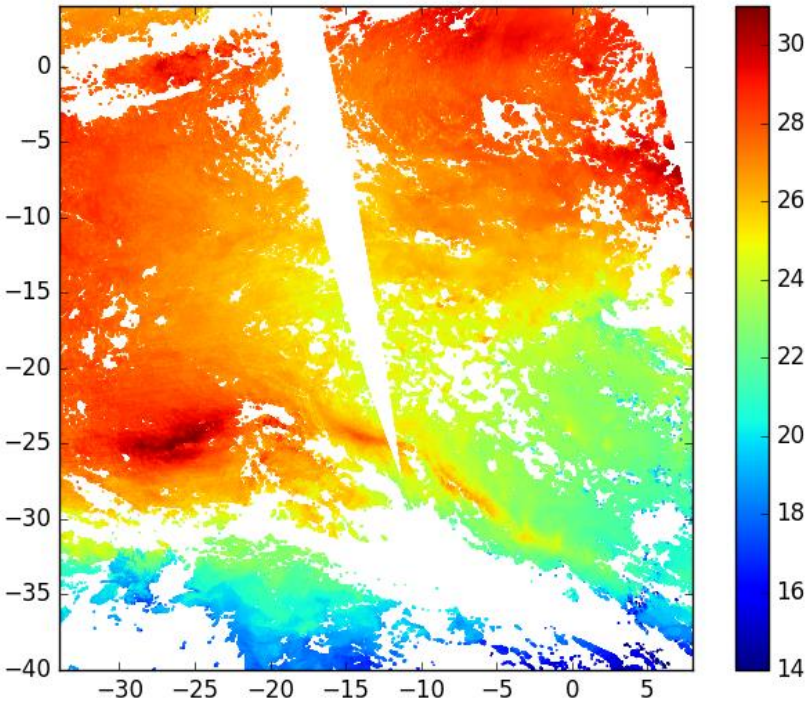
- L2 HDF files from NASA Goddard/OBPG
- Granules for Feb 8 2009 between 13:45 and 15:40 UTC
- Spatial Resolution: 1 km
- Proximity Confidence Flags: 0 and 1 (Best and 2nd Best)

MODIS PC MAP FOR 0 (BLUE) AND 1 (RED)

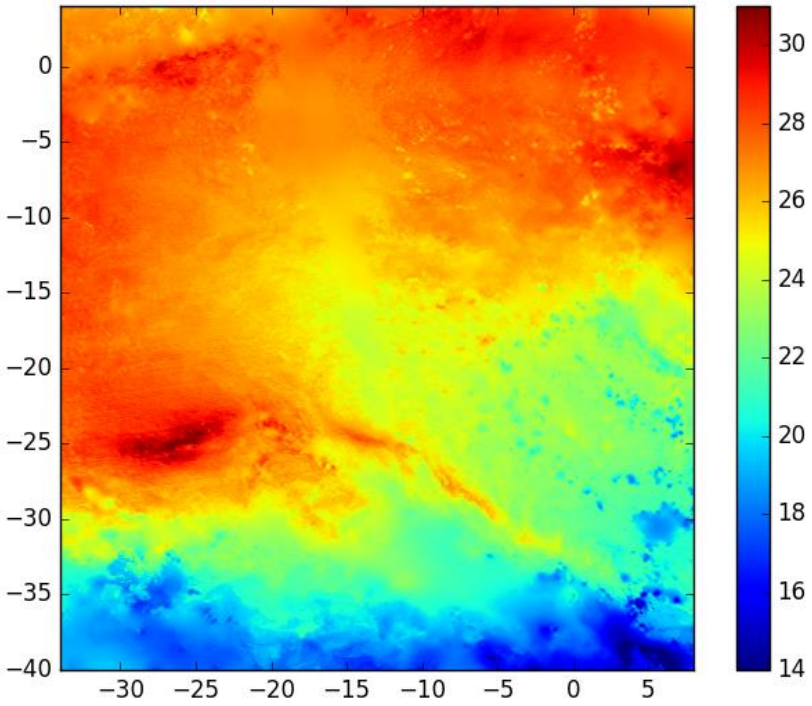


Preliminary MODIS Interpolation

ORIGINAL L2 INPUT DATA WITHOUT QUALITY CONTROL



L4 SST: MODIS INTERPOLATOR EVALUATED AT L2 INPUT GRID

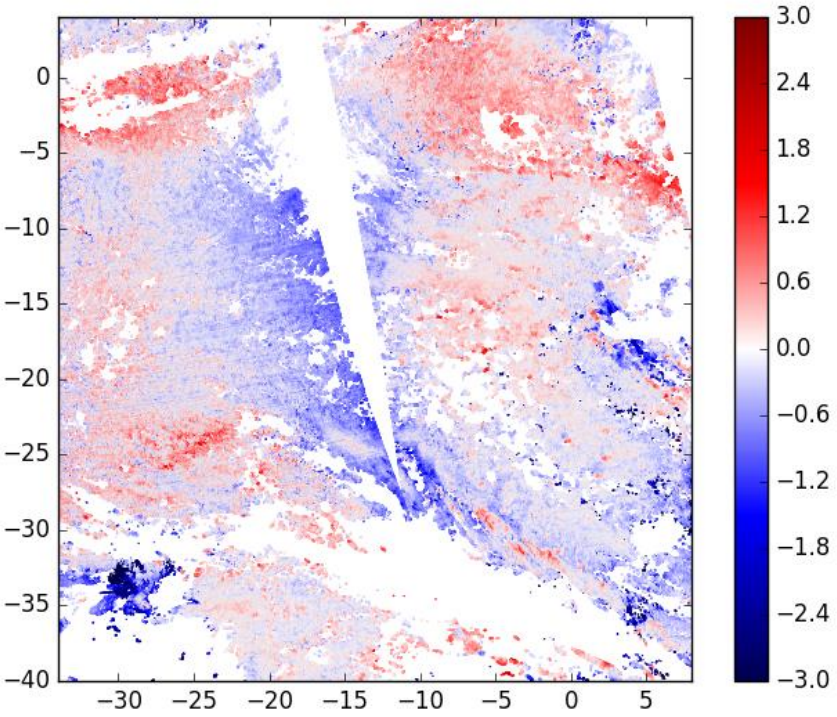


Using the SEVIRI Interpolator to Quality-Control MODIS L2 SST

REMOVAL OF RESIDUAL CLOUD CONTAMINATION IN MODIS

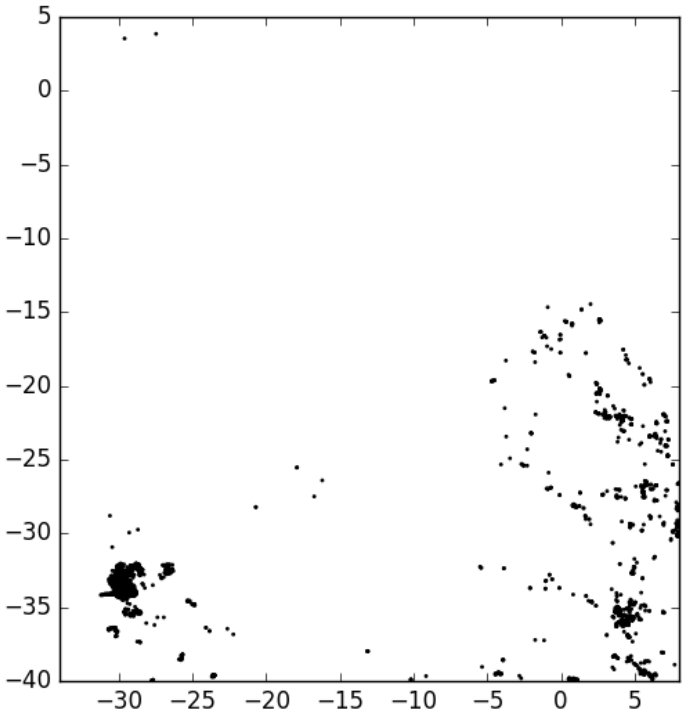
- Used the SEVIRI interpolator evaluated at the MODIS L2 input grid
- Normalized the differences relative to the MODIS observations
- Removed 4223 MODIS pixels where the relative difference > 11%
- Removed less than 0.08% of input data

MODIS L2 - SEVIRI INTERPOLATOR EVALUATED AT MODIS INPUT GRID

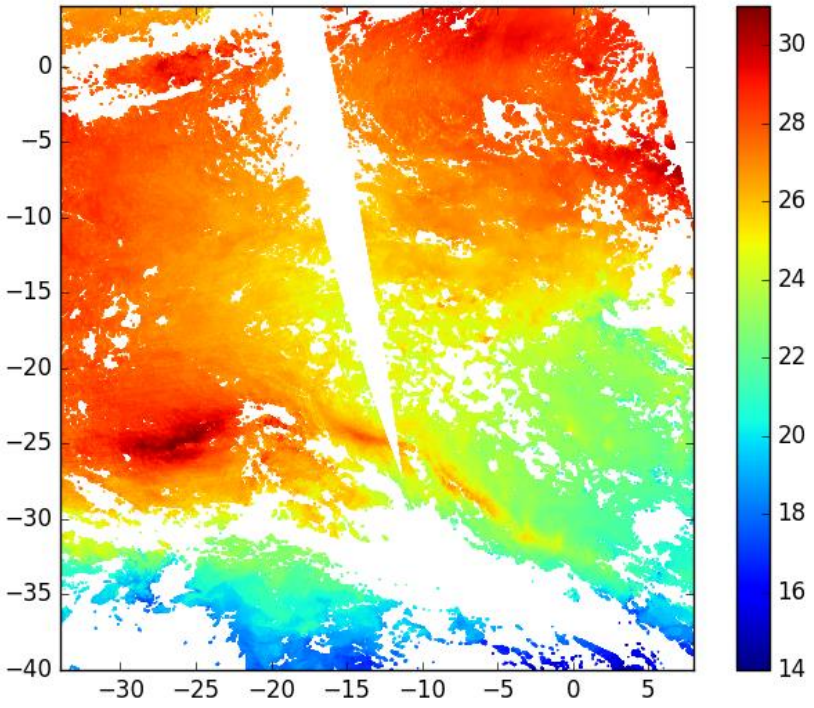


MODIS Quality Control

LOCATION OF OUTLIERS DETECTED USING THE SEVIRI INTERPOLATOR

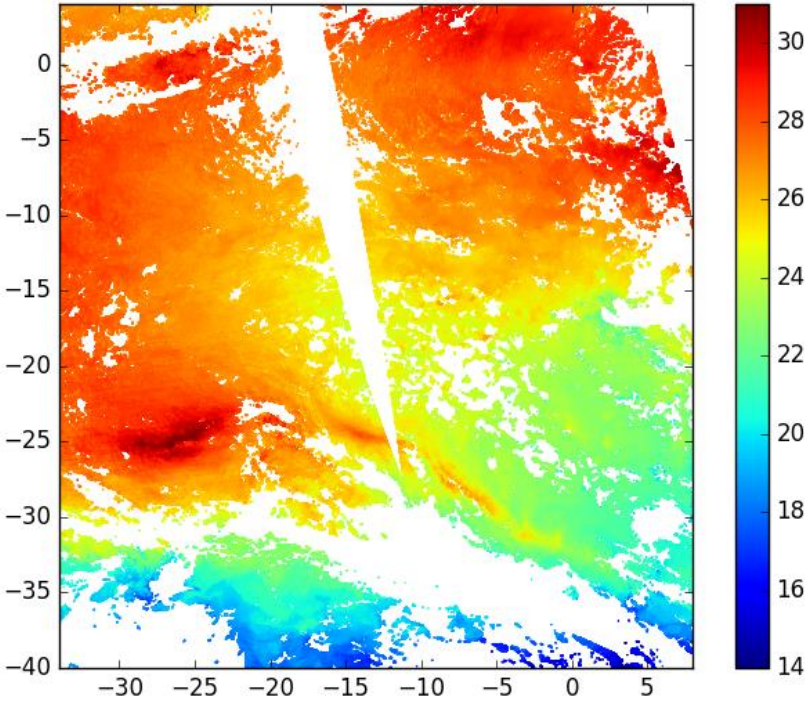


QUALITY-CONTROLLED MODIS L2 SST

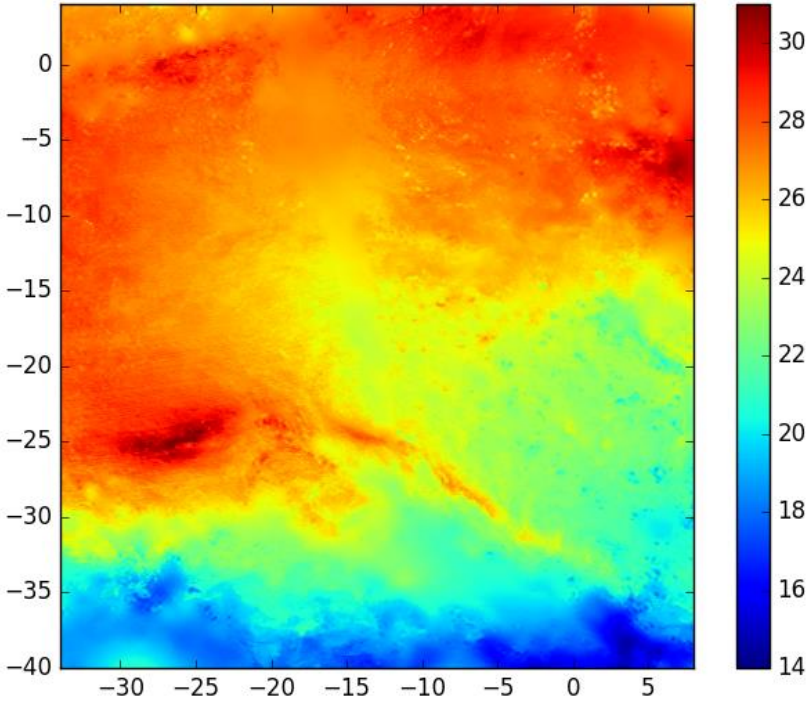


NEW MODIS L4 SST

L2 QC MODIS INPUT



MODIS L4: INTERPOLATOR FOR QC MODIS, EVALUATED AT L2 INPUT GRID

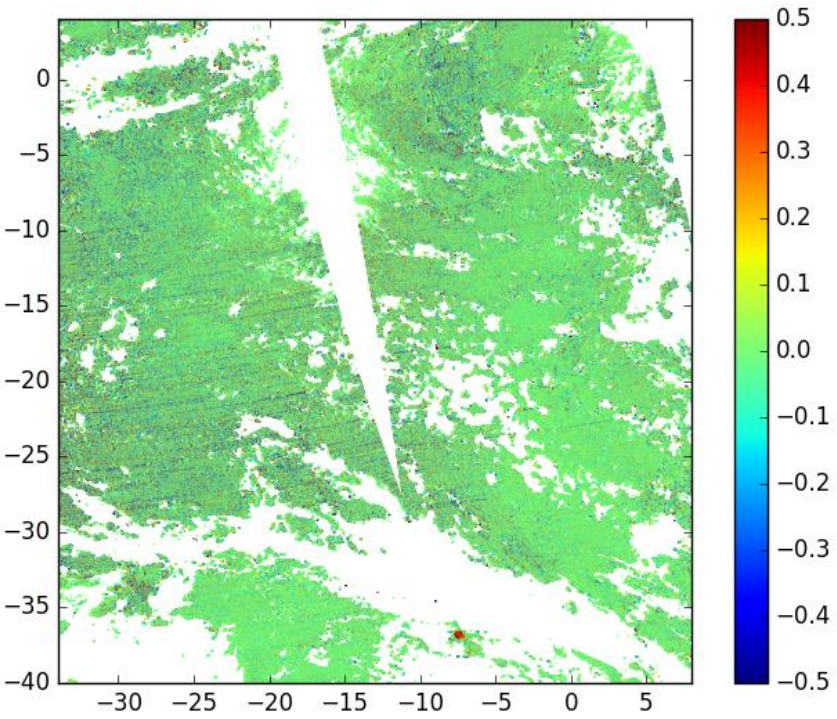


Misfit in MODIS L2 SST

MISFIT = DIFFERENCE BETWEEN INPUT AND THE INTERPOLATOR, EVALUATED AT THE INPUT GRID

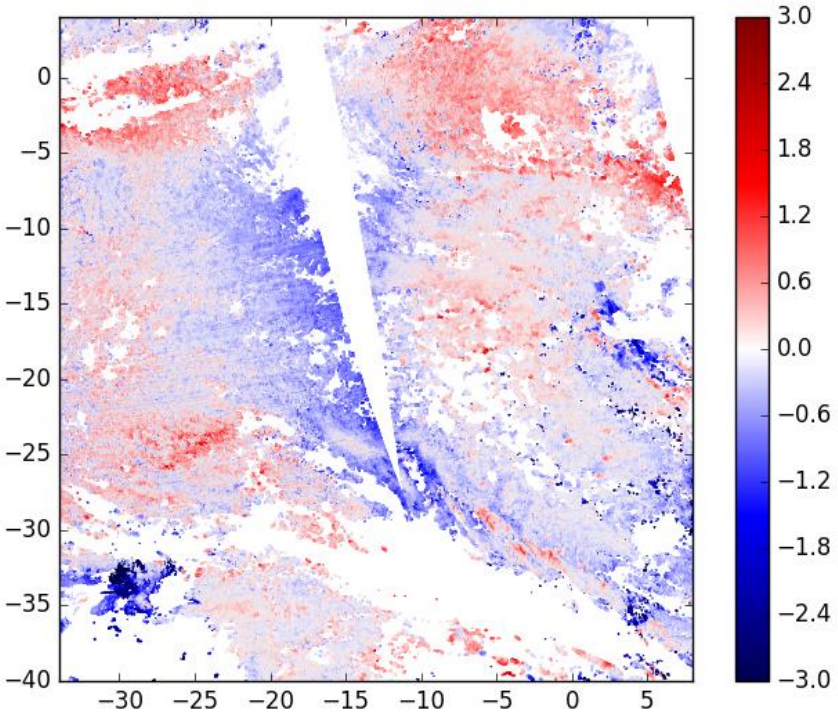
- The interpolator "adjusts" original values that are a bit off of a more appropriate value given the frequency content in the input
- In doing so, the interpolation function picked up residual scan stripping in the MODIS L2!

MODIS L2 – MODIS INTERPOLATOR AT INPUT GRID

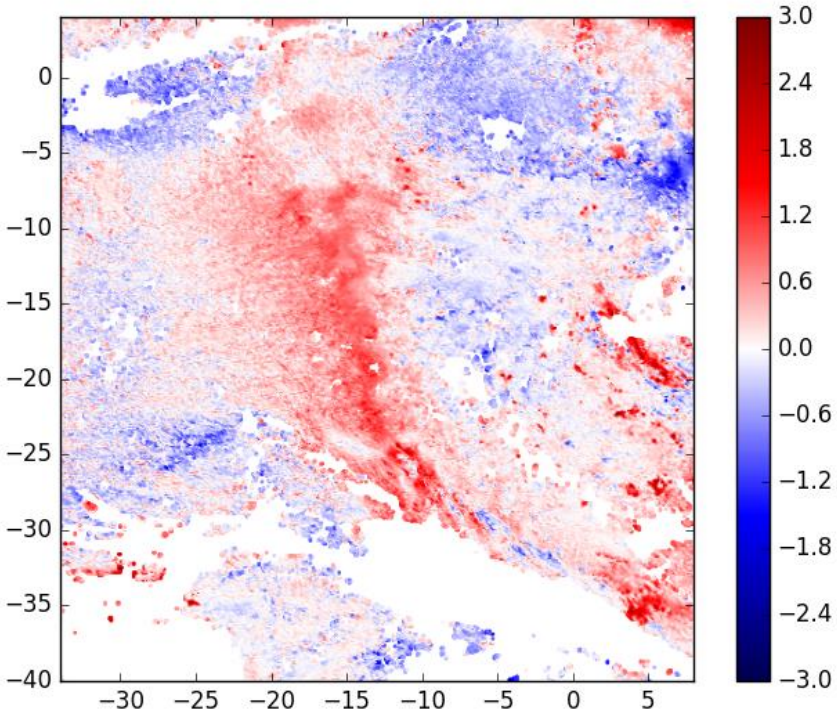


Interpolator Errors

MODIS L2 – 1 KM SEVIRI L4

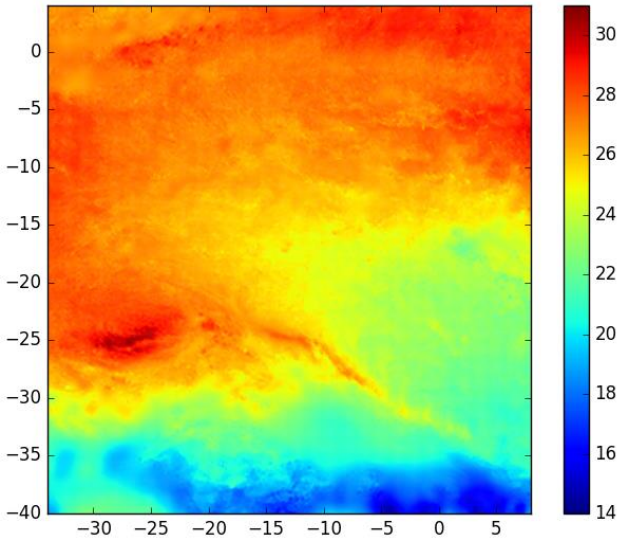


SEVIRI L3 – 10 KM MODIS L4

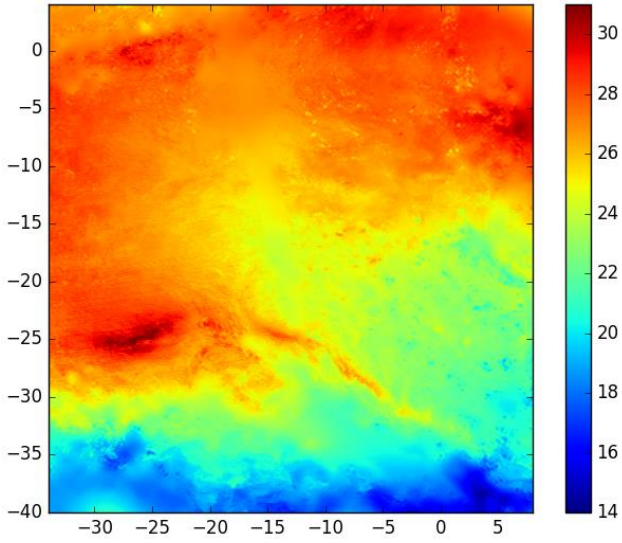


New L4 SST Analyses

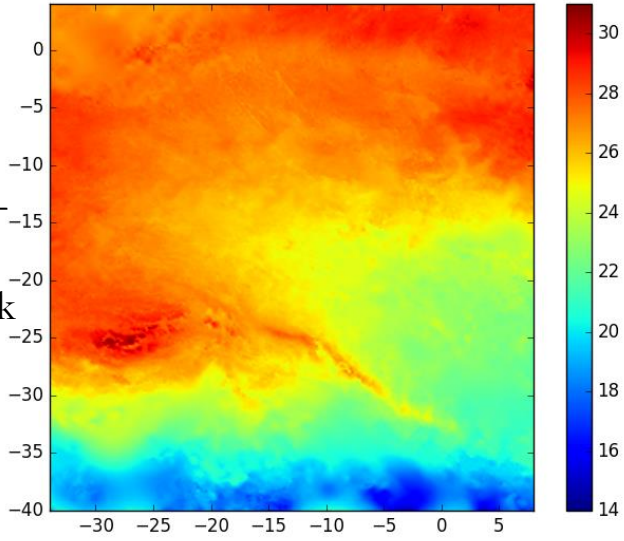
10 km Single-scene L4 SEVIRI Skin SST at 16:00



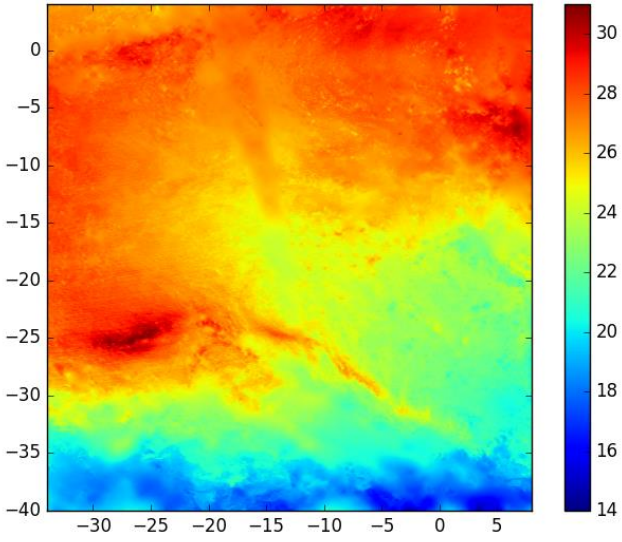
1 km Single-sensor L4 MODIS Skin SST



10 km Multi-scene L4 SEVIRI Peak SST



1 km Multi-sensor L4 MODIS Skin SST



The frequency content in SSTs is limited, as indicated by the fine detail present in the coarse resolution product (SEVIRI)

The gain of new information from the ultra high resolution (MODIS) was minimal

It may be preferable to have coarser resolution with smaller gaps than finer resolution with larger gaps

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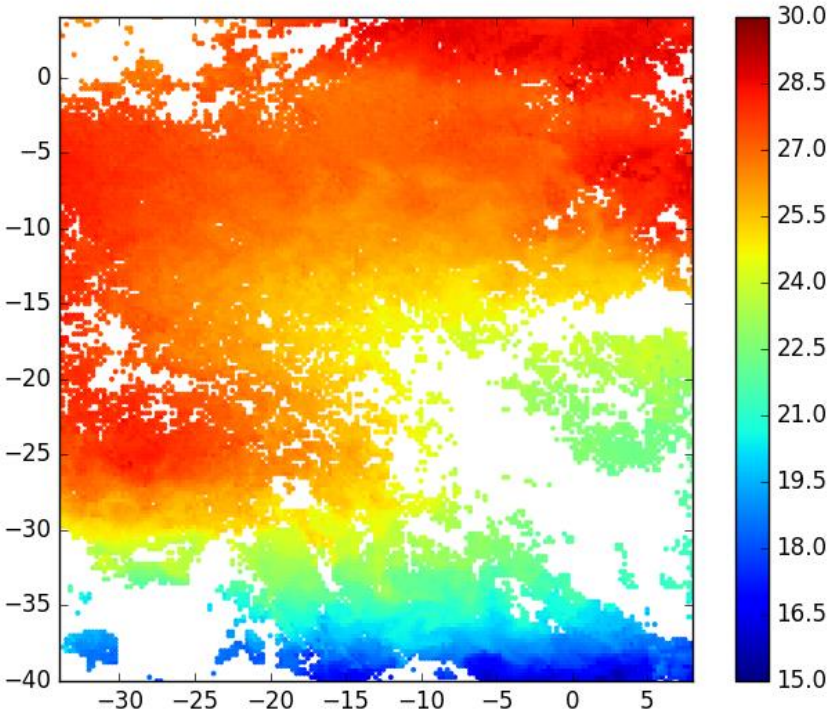
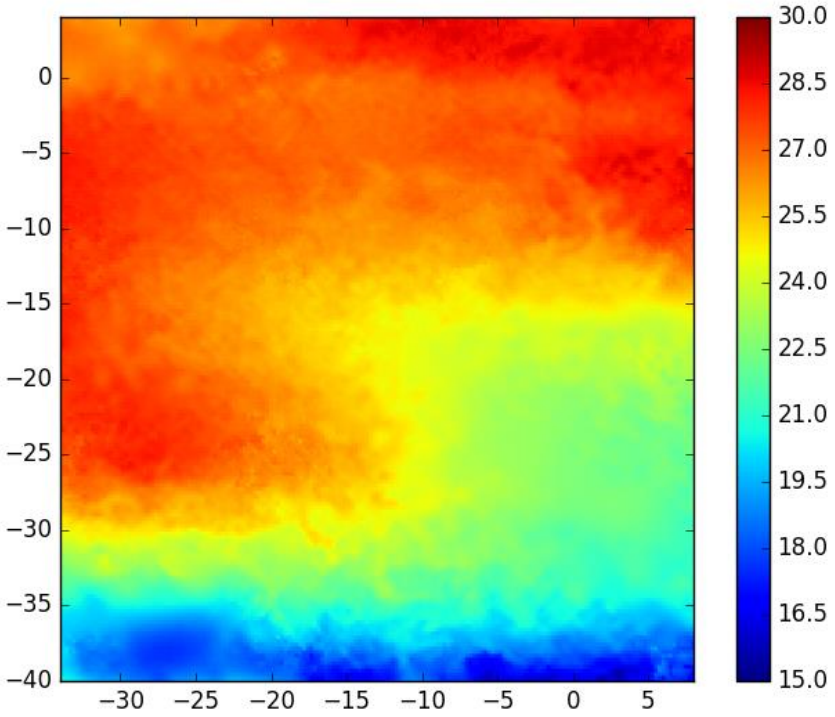
L4 SEVIRI SST Foundation

2009 February 8

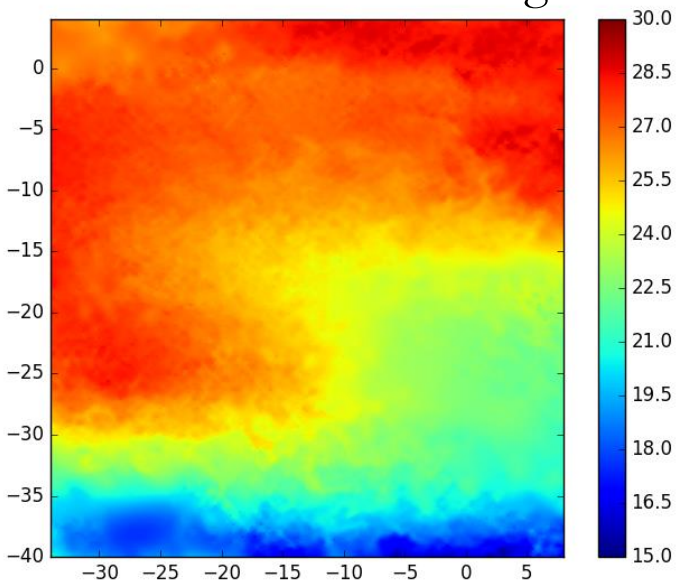
WICK L3, 25 KM SEVIRI FOUNDATION



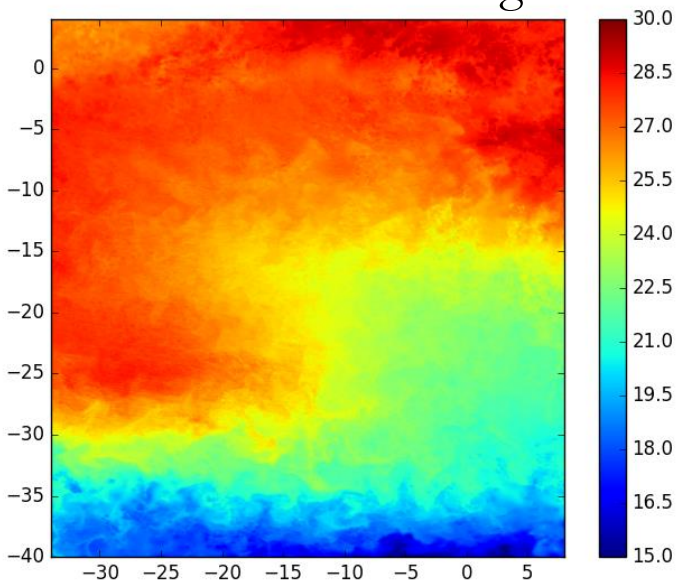
WICK L4 FOUNDATION: INTERPOLATOR EVALUATED AT INPUT FOUNDATION GRID



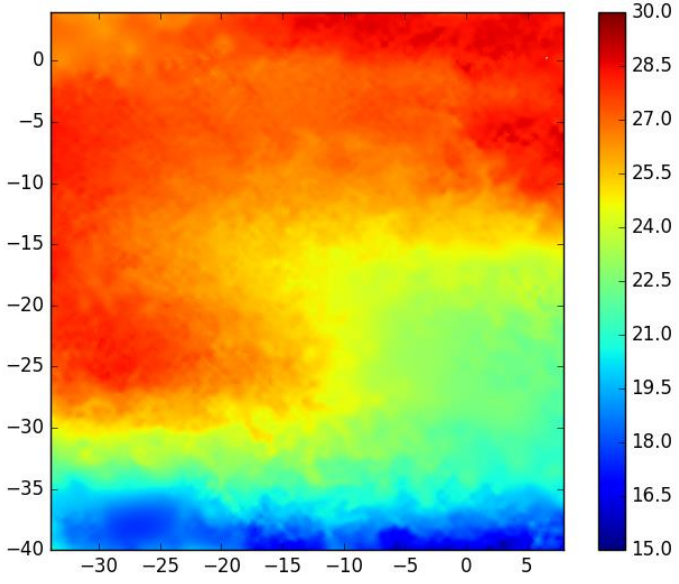
Wick Fnd at 0.01 deg



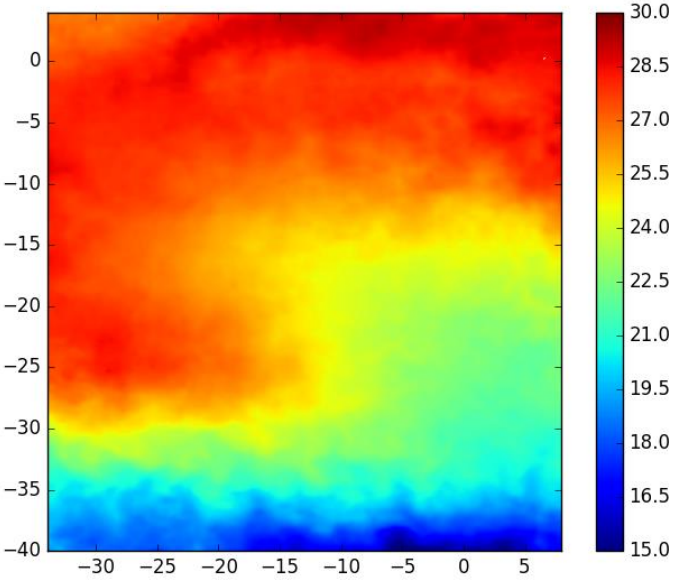
MUR Fnd 0.01 deg



Wick Fnd at 0.06 deg

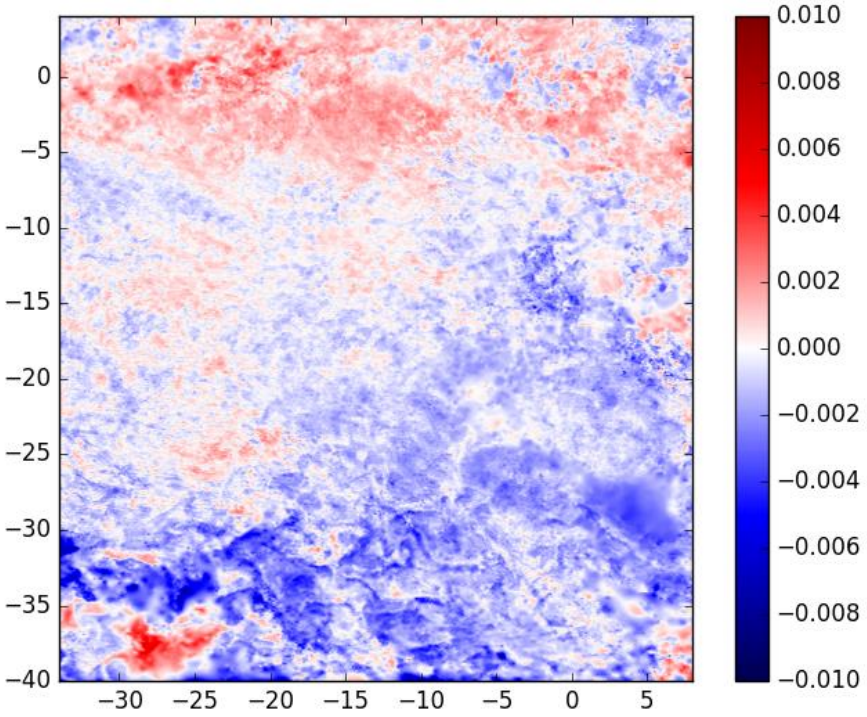


OSTIA Fnd 0.06 deg

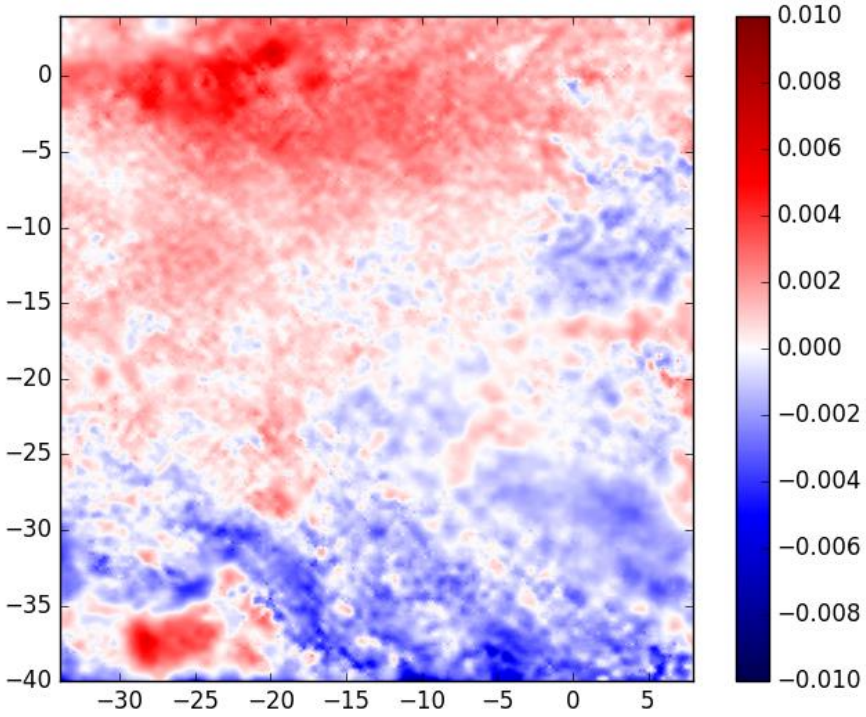


Relative Errors (K) in L4 SEVIRI Foundation vs MUR and OSTIA

MUR FND – 1 KM SEVIRI FND

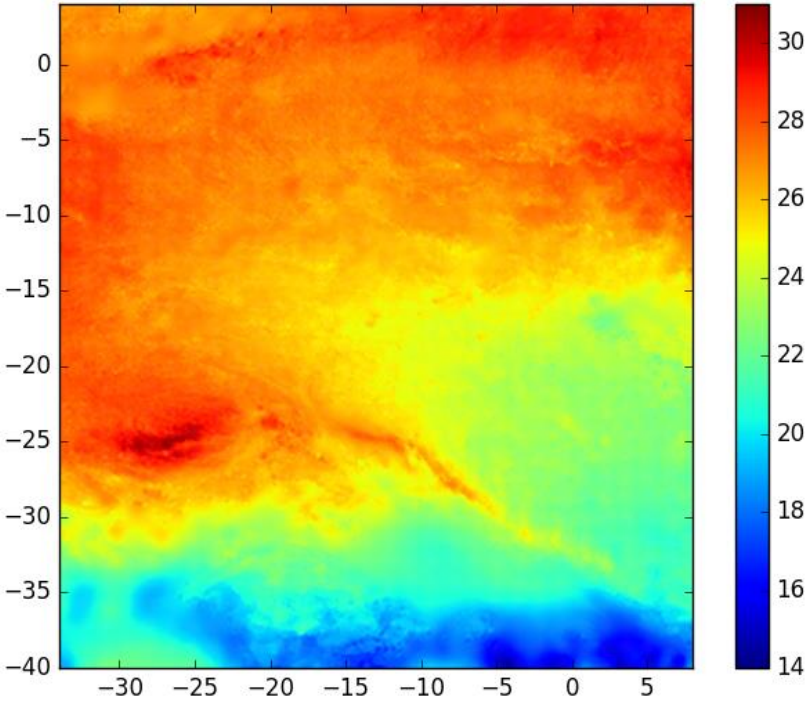


OSTIA FND – 6 KM SEVIRI FND

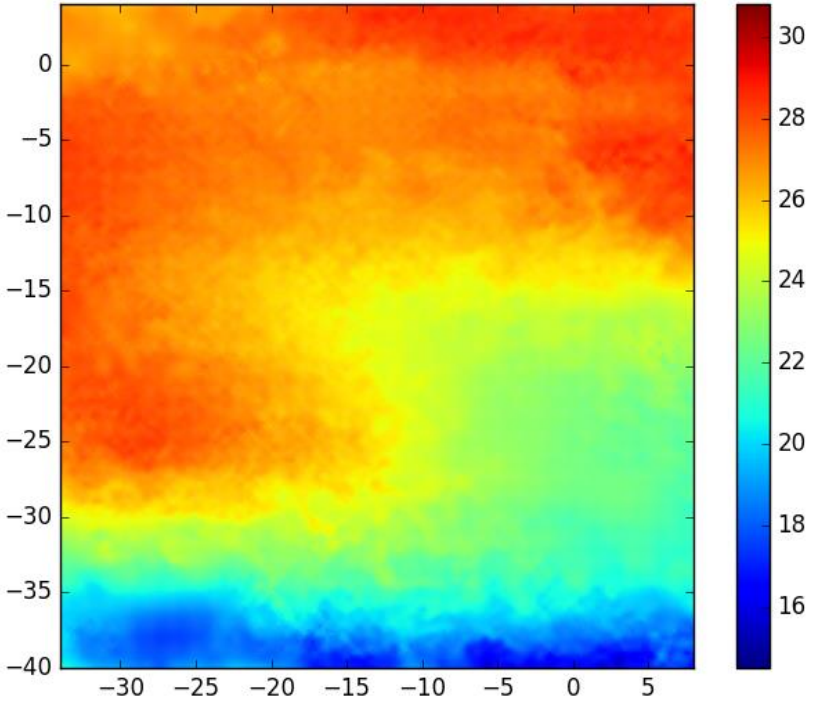


Application to Diurnal Warming

L4 SEVIRI SST FOR 16:00 AT 0.1 DEG RESOLUTION



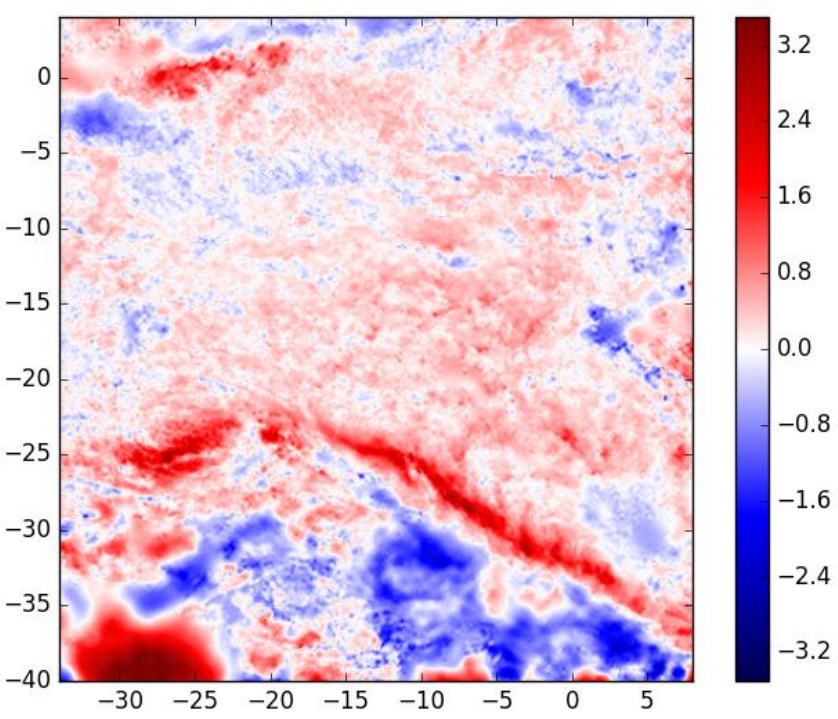
L4 SEVIRI FOUNDATION AT 0.1 DEG RESOLUTION



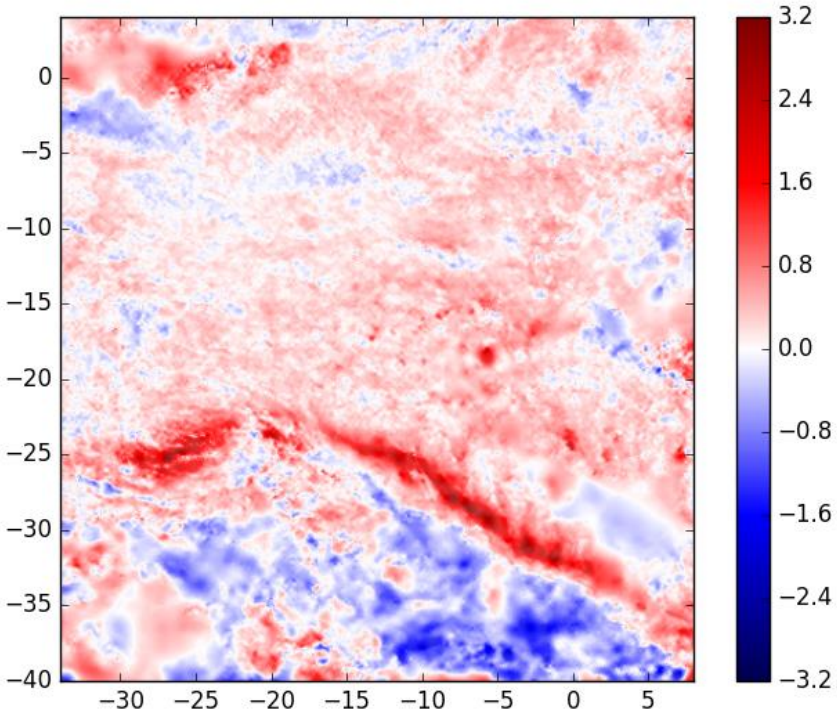
SEVIRI Diurnal Warming

2009 February 8

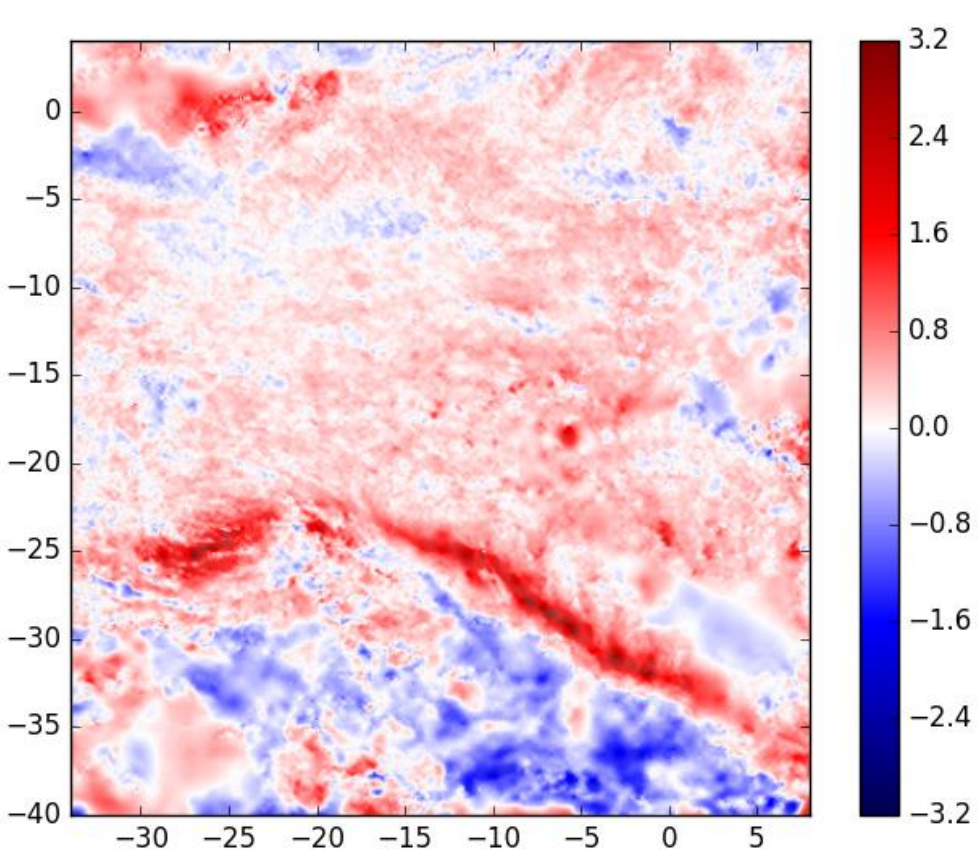
DIURNAL WARMING AT 16:00

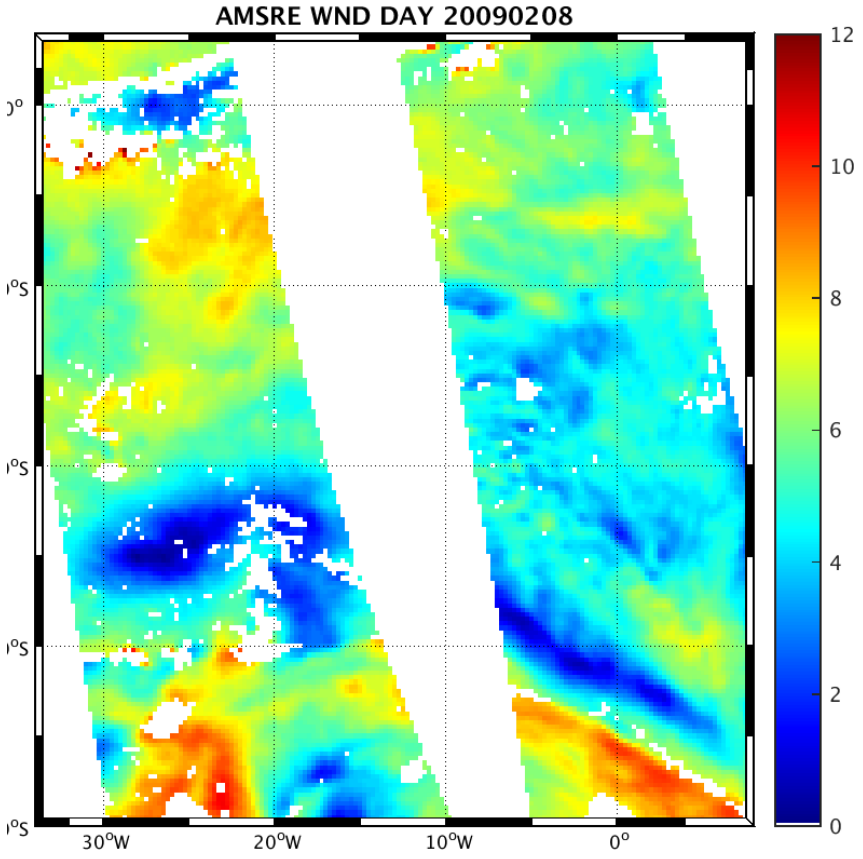


PEAK WARMING



SEVIRI Peak Warming vs. Wind



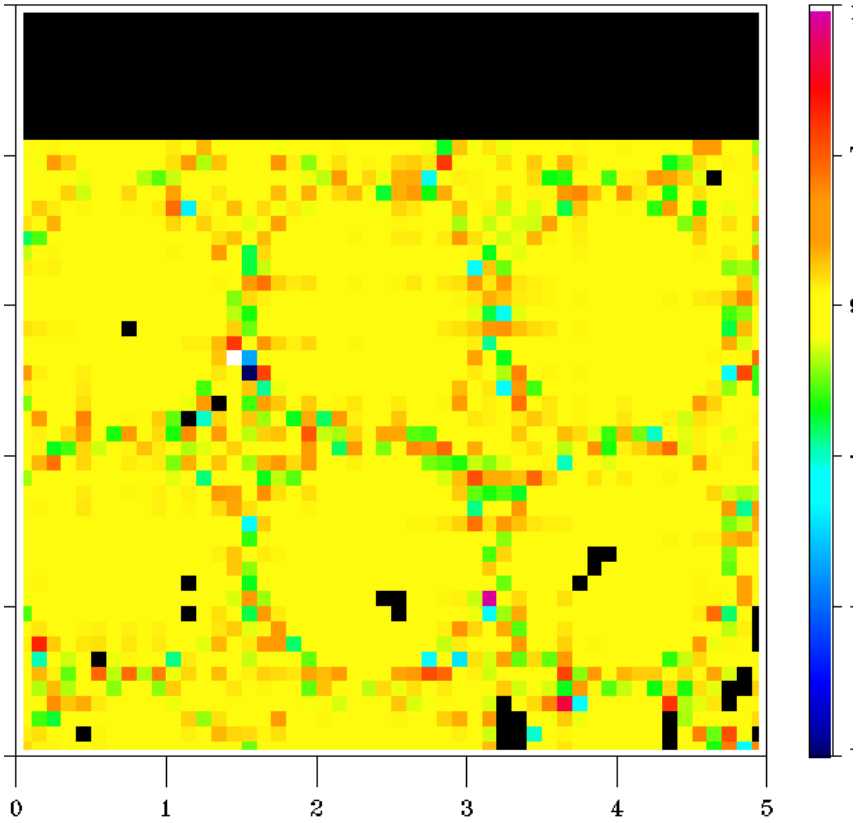


Conclusions

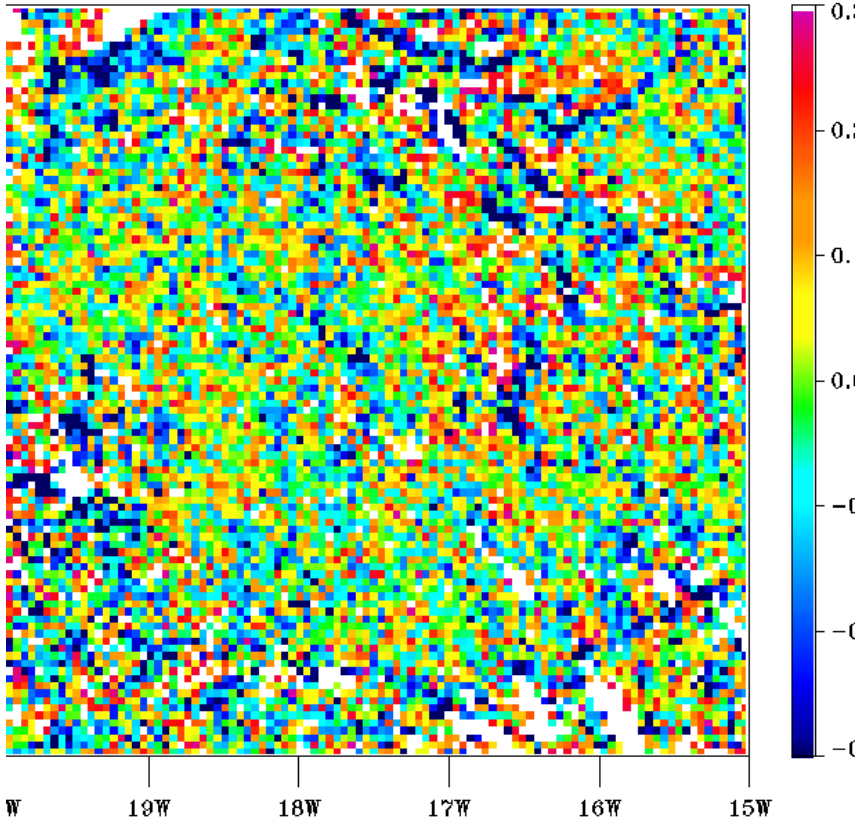
- The new method provides an efficient and robust interpolation. The accuracy of the fit is user-controlled and can be adjusted to match properties of the input data.
- The interpolator can be also used to detect noise, outliers, and artifacts present in the input data.
- Our next goal is to develop multi-sensor algorithms that carefully combine inputs collected at different resolutions and to incorporate additional information (quality flags, wind, etc.) so that the SSTs are adjusted and assigned different weights.

Artifacts in SEVIRI L3 SST

3-H L3 SEVIRI SST

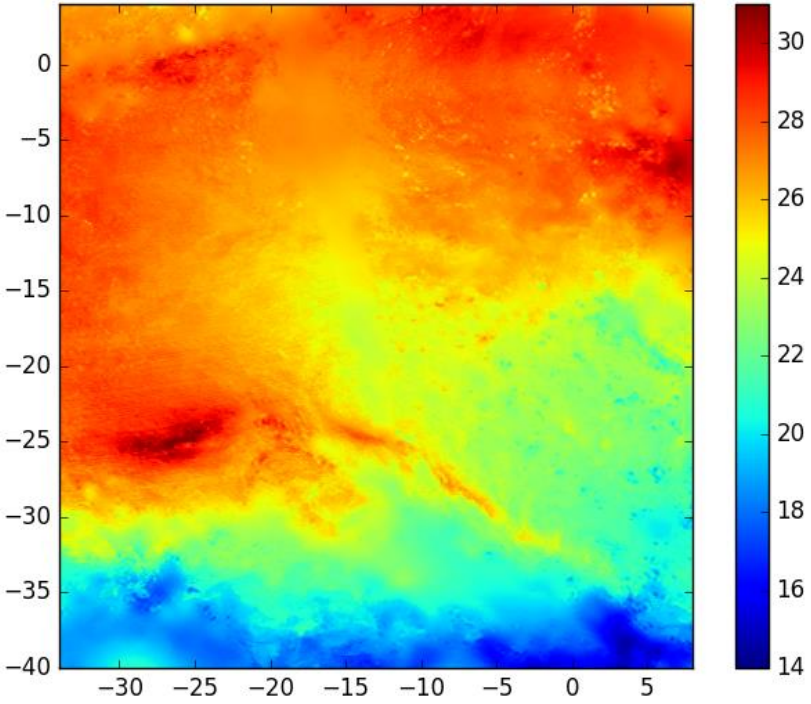


1-H L3 SEVIRI SST



MODIS vs. AMSR-E

L4 MODIS SST



L2 AMSR-E SST