Toward improved VIIRS SST imagery, pattern recognition based clear-sky mask and ocean fronts product in ACSPO

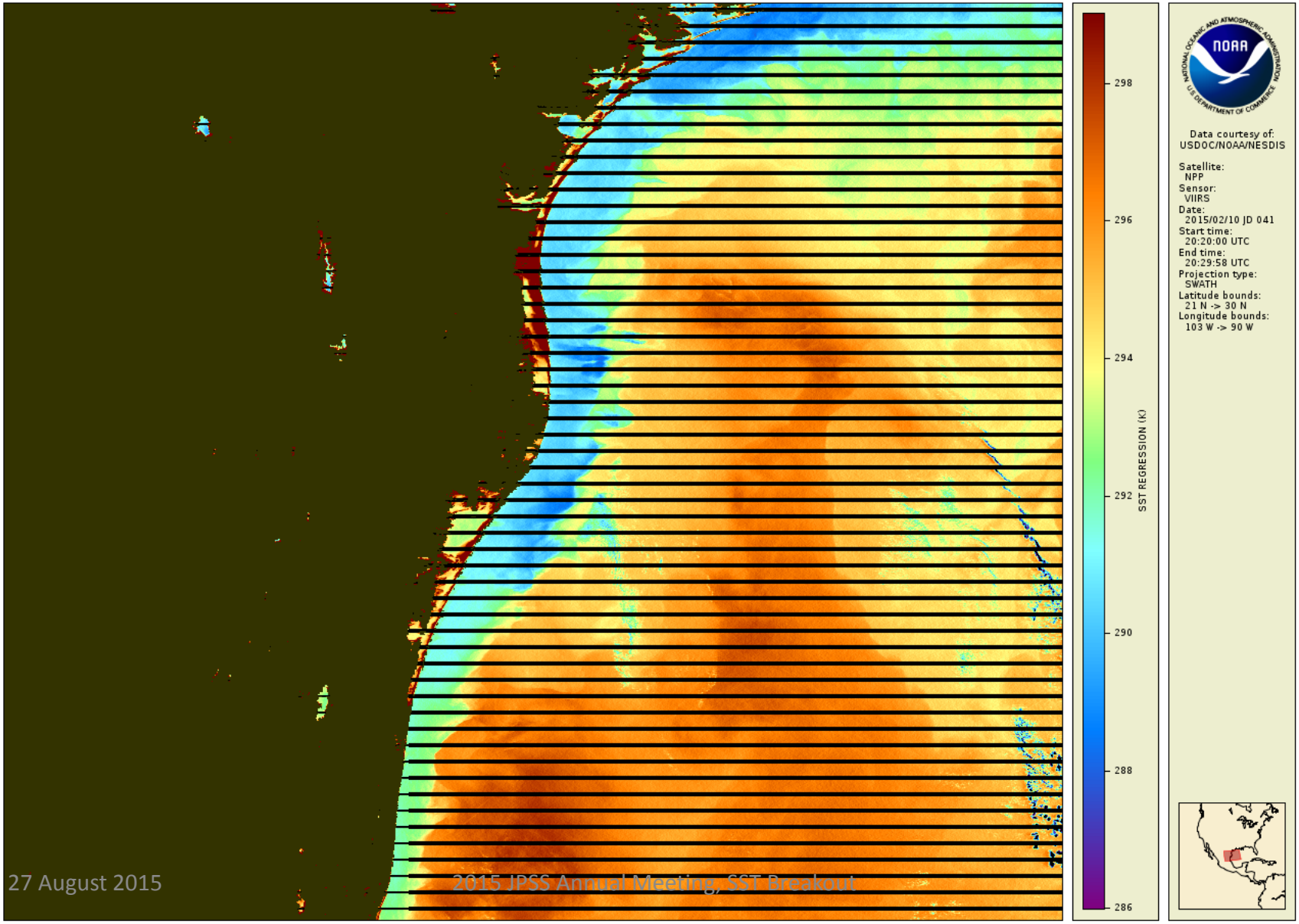
Irina Gladkova[1,2,3], Alexander Ignatov[1], Yury Kihai[1,3], Boris Petrenko[1,3]

[1]NOAA STAR,
[2]City College of New York, NOAA/CREST
[3]GST, Inc.

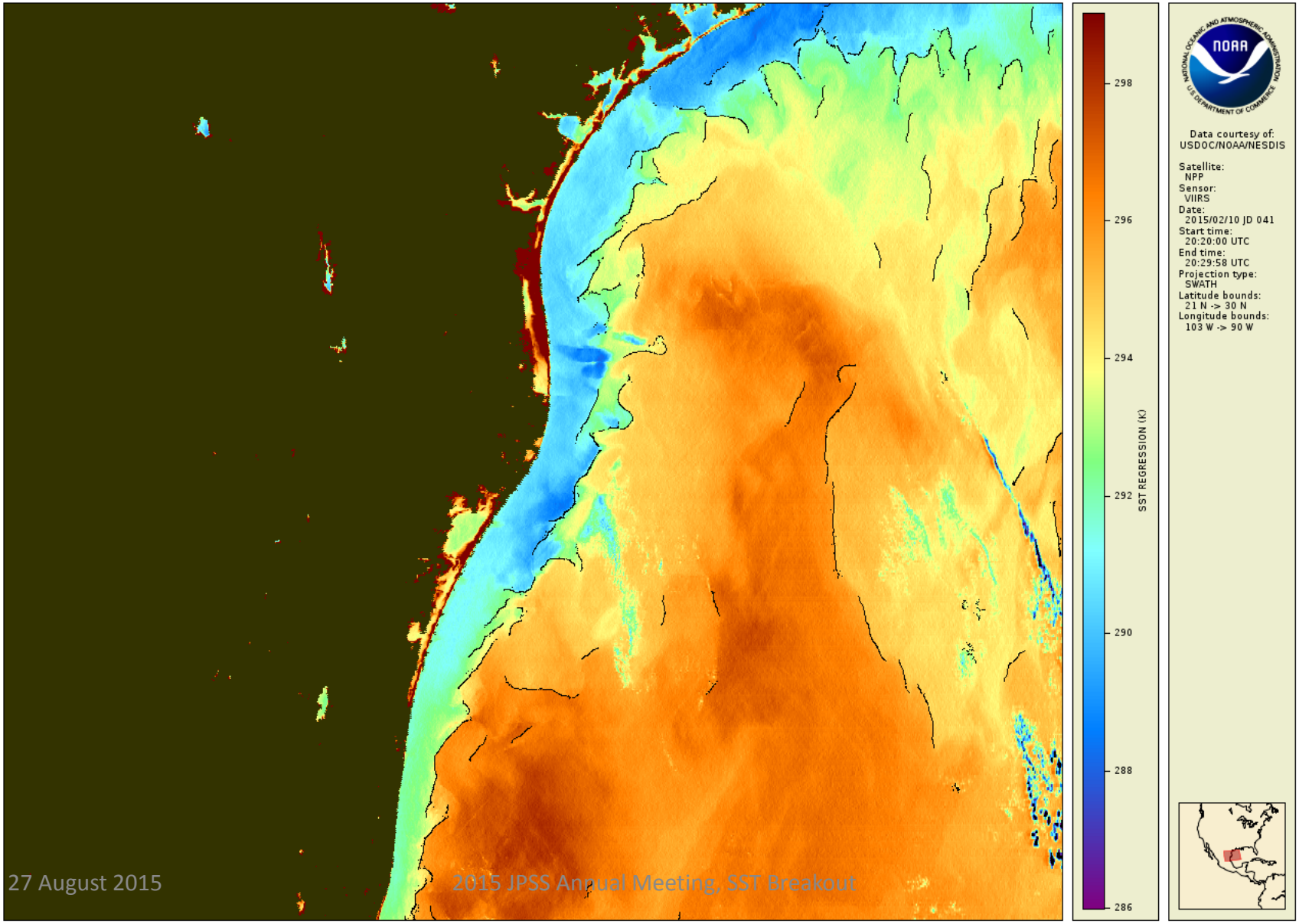
ACSPO Priorities in FY16

1. **(Prerequisite for tasks 2-3) Improve BT and SST Imagery: resample ("de-bowtize") and restore pixels in bow-tie areas deleted onboard**
2. **(Main Objective) Improve clear sky mask based on pattern recognition approach: Focus on dynamic, coastal, and high-latitude areas**
3. **(By-product of pattern recognition) Produce Ocean Thermal Fronts**

Original VIIRS SST Imagery



Improved VIIRS SST Imagery



27 August 2015

Task 2: Motivation

- Customarily, clear-sky mask is produced first
- Ocean dynamics (thermal fronts, currents, eddies and cold upwellings) are analyzed over clear sky pixels only
- However, clear sky mask is often overly conservative over dynamic ocean, and masks it out as cloud
- As a result, most interesting ocean areas with strong dynamics may be under-populated (or not populated at all), for long periods of time

Quality of Clear-Sky Mask

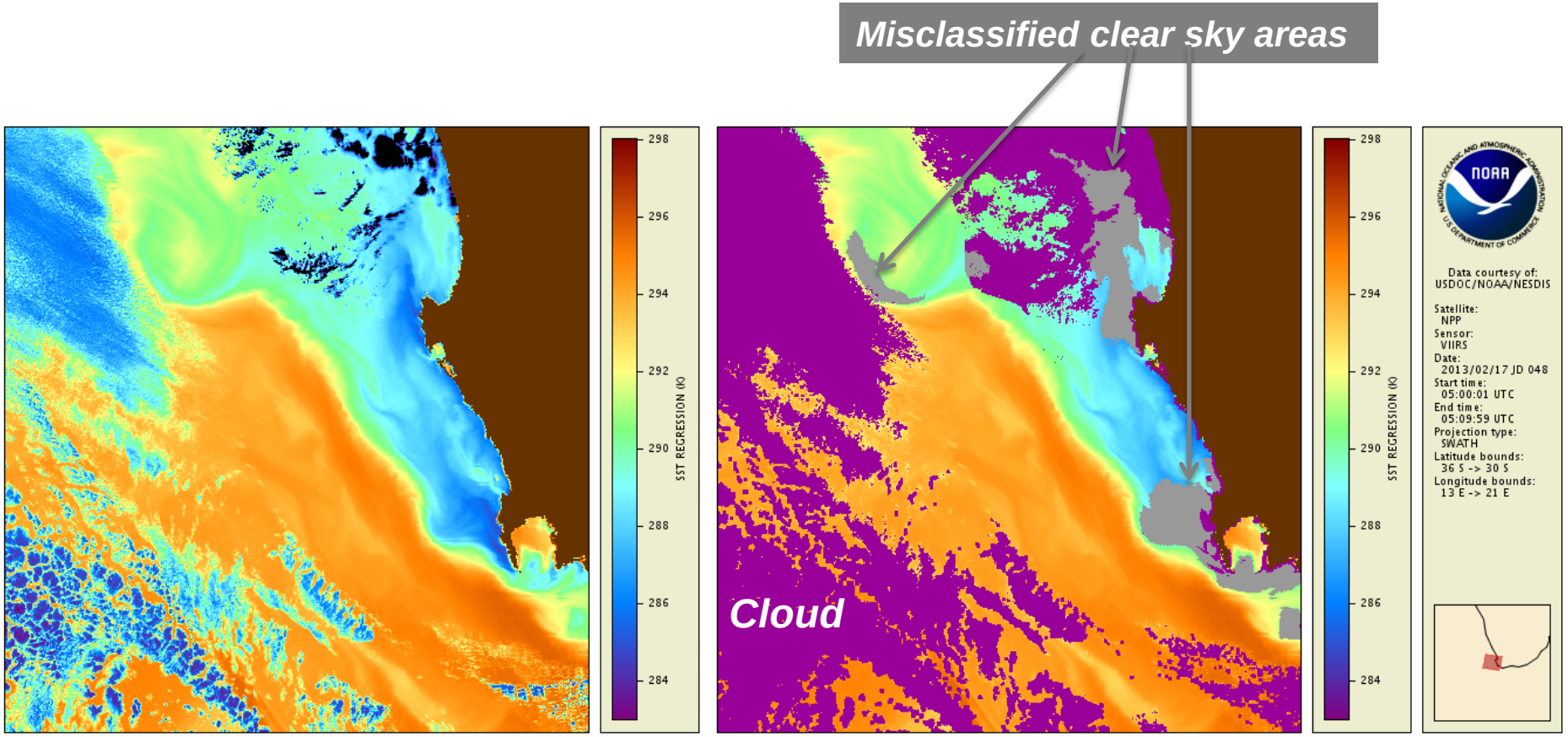
- Following majority of current masking algorithms, ACSPO uses “in-pixel thresholds”
- Liberal thresholds may result in “cloud leakages”, whereas conservative settings lead to “false alarms”
- Often, conservative SST mask is considered preferable, to minimize cloud leakages
- However, this is achieved at the expense of losing a (presumably small) fraction of clear pixels, globally

Standard Criteria of clear-sky mask performance:

- Minimal cloud leakages,
- While still preserving good global coverage

Typical False Alarms in ACSPO

S. Africa (S-NPP day pass)



VIIRS ACSPO SST (no cloud mask)

SST with ACSPO cloud mask overlaid

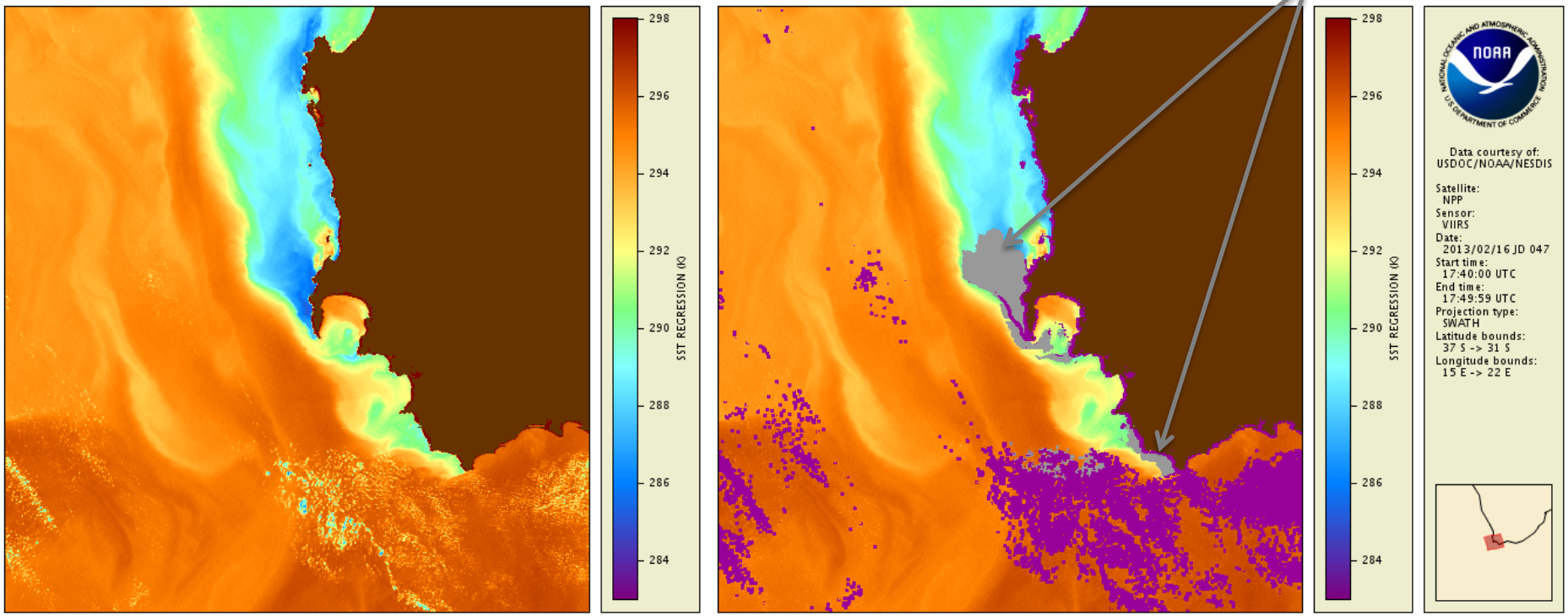
What is the price?

- The geographic distribution of “false alarms” is highly non-uniform, both in space and in time
- “False alarms” often persist from pass to pass
- Misclassifications most often occur in ocean areas where SST is
  - variable, and/or
  - significantly colder than surrounding waters, and/or
  - significantly colder than the first guess field

Persistent Misclassifications

S. Africa, 02/16/2013 (day pass)

Misclassified clear sky areas

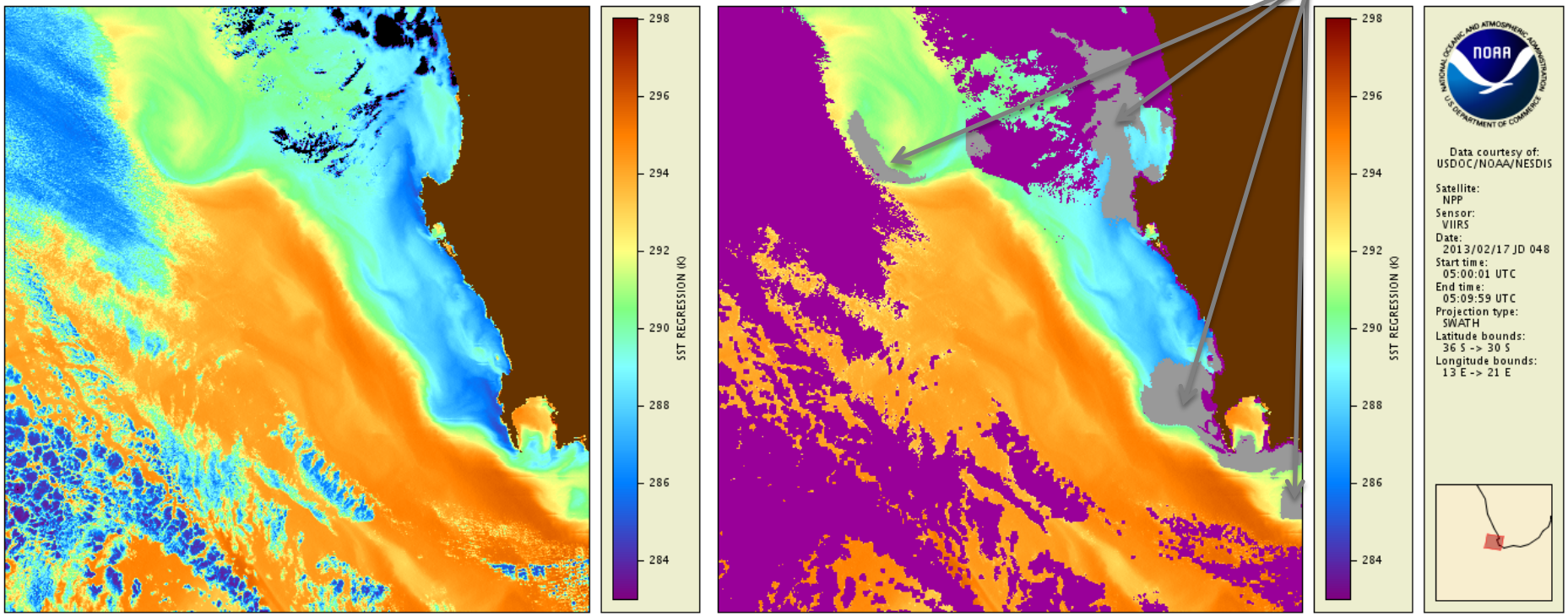


Cold upwelling (gray) is misclassified by ACSPO as cloud

Persistent Misclassifications

S. Africa, 02/17/2013 (day pass)

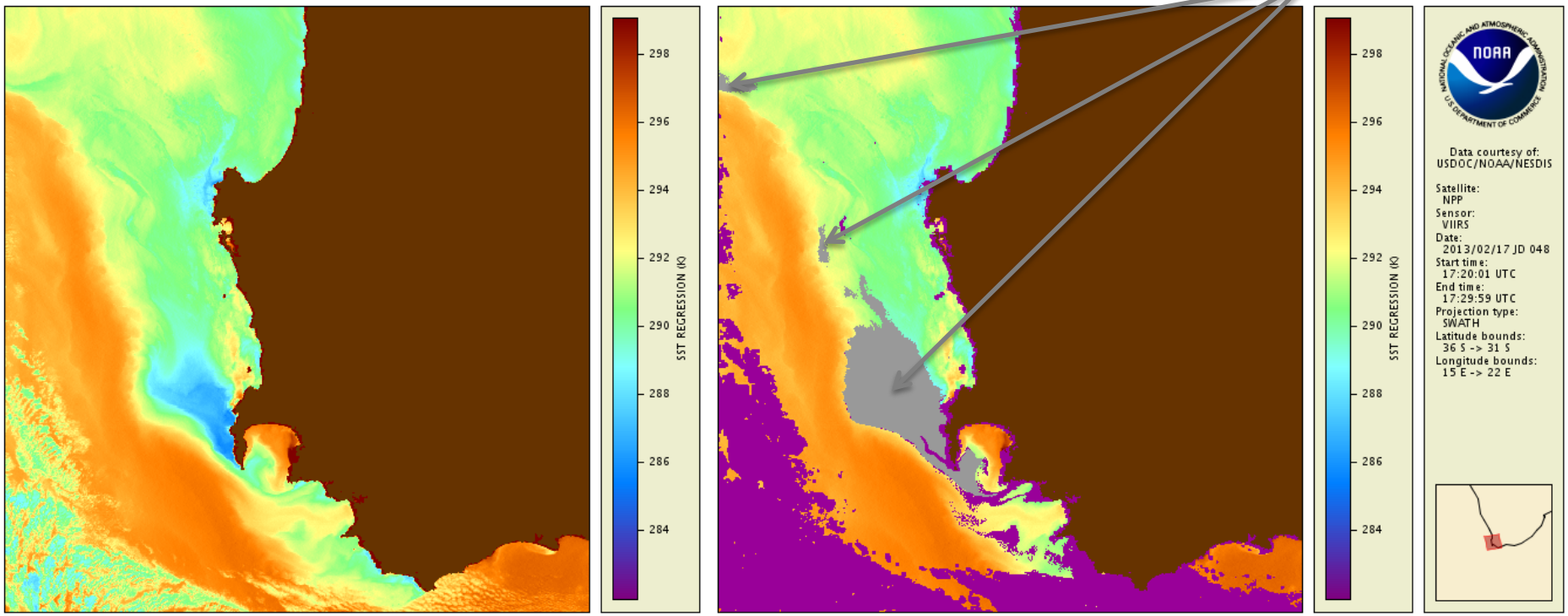
Misclassified clear sky areas



Misclassified by ACSPO as cloud on the next day as well

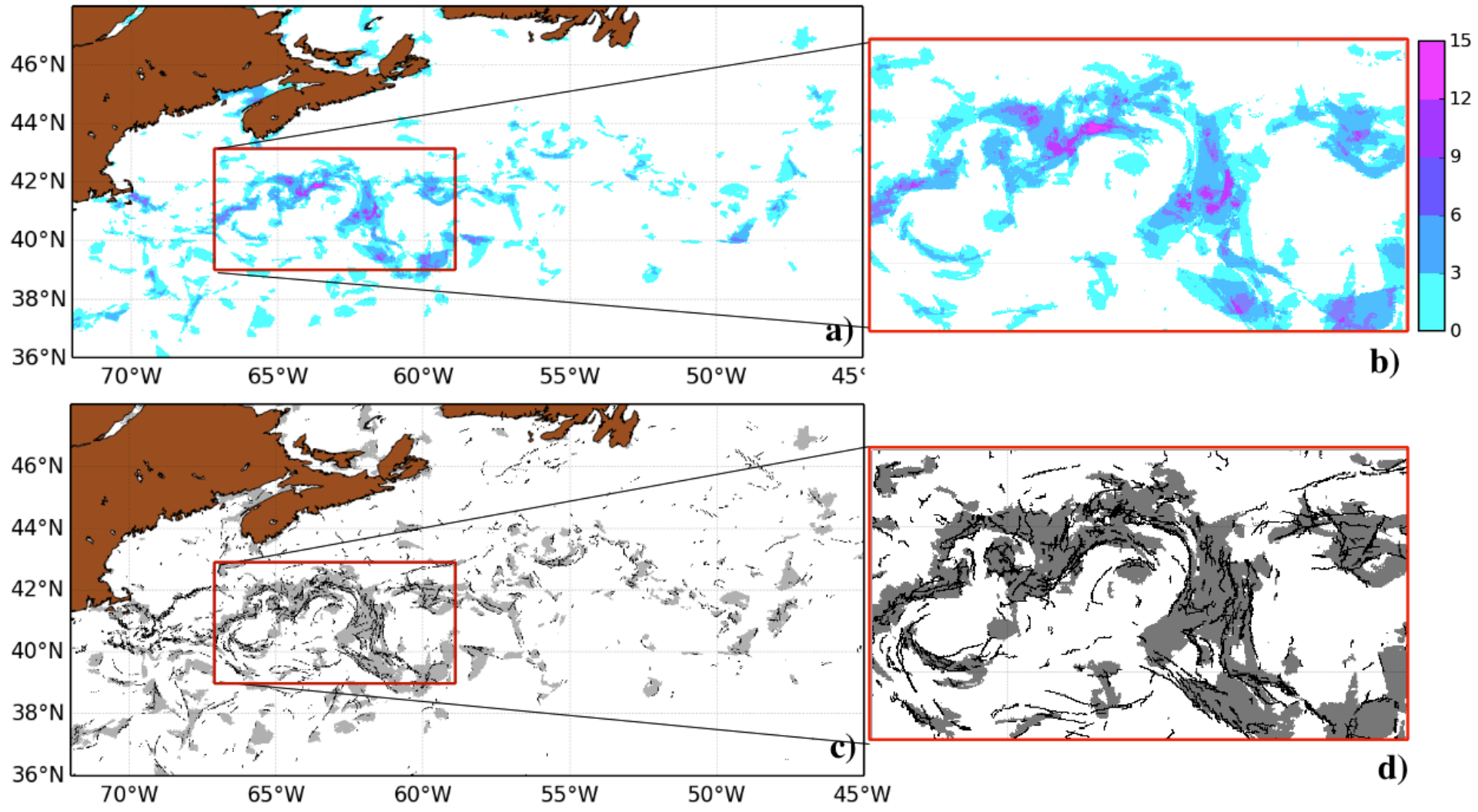
Persistent Misclassifications

S. Africa, 02/17/2013 (night pass)



Same cold upwelling misclassified at the night pass

Misclassifications near fronts



Impact

It is dynamical, coastal and hi-latitude waters that are of most interest to SST users, for

- accurate reproduction of ocean dynamics in L4 products
- modeling of ocean dynamics
- coastal management
- fishing
- ship navigation
- generating unbiased climatologies
- marine biology studies
- .. and more

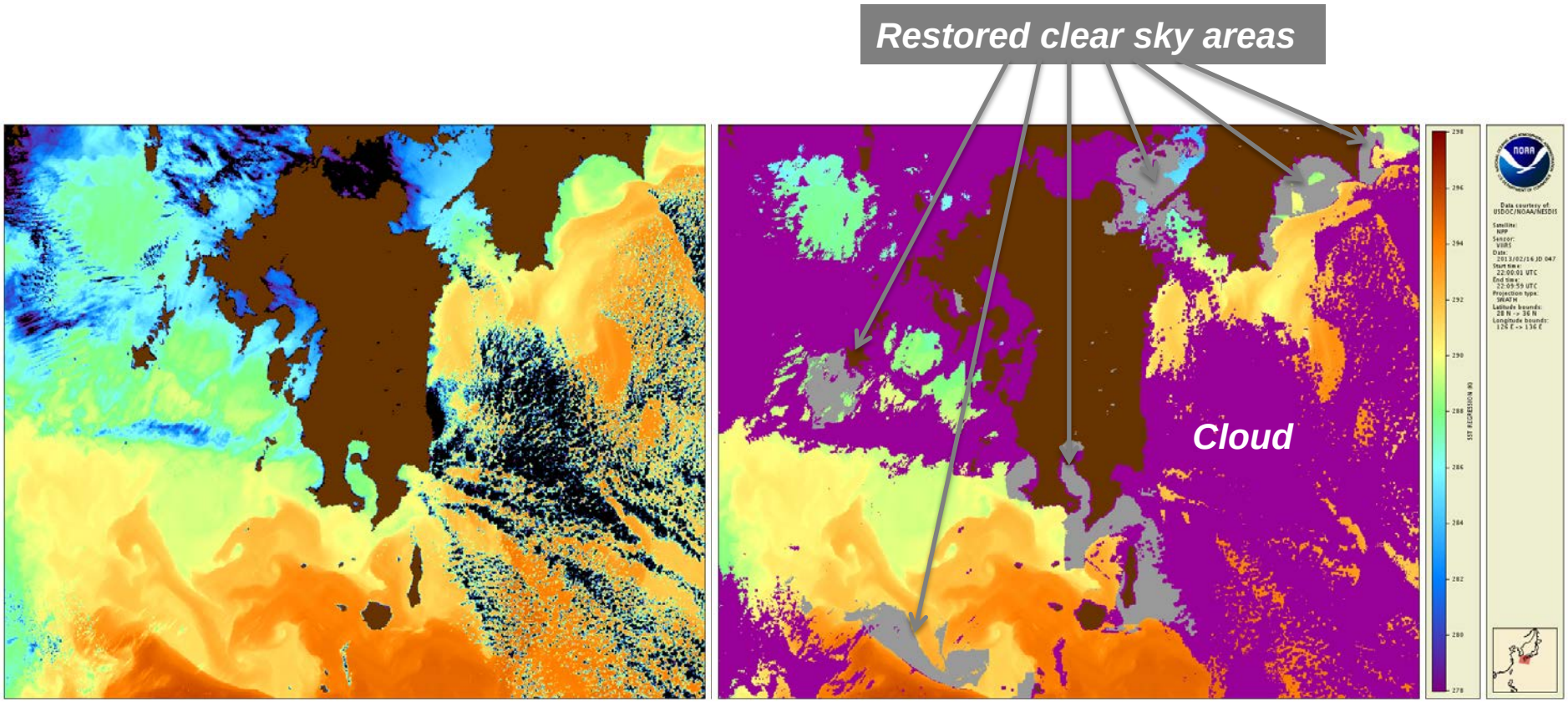
Approach

Automated SST Pattern Test

Identifies ocean thermal fronts and adjacent contiguous areas with uniform SSTs; and

Then makes ocean vs. cloud decision based on the statistics of the whole regions (vs. in-pixel)

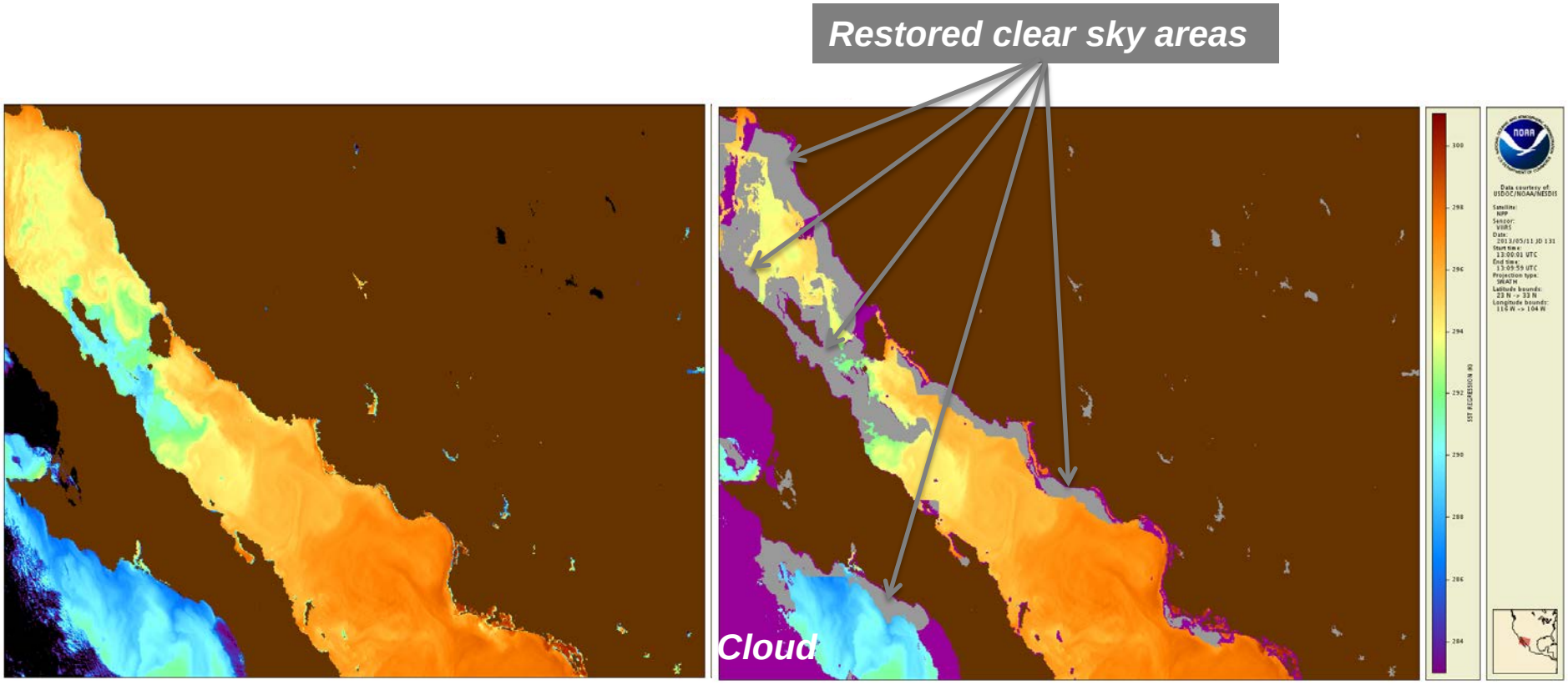
N. Pacific Kuroshio (near Japan)



VIIRS ACSPO SST (no cloud mask)

SST with ACSPO cloud mask overlaid

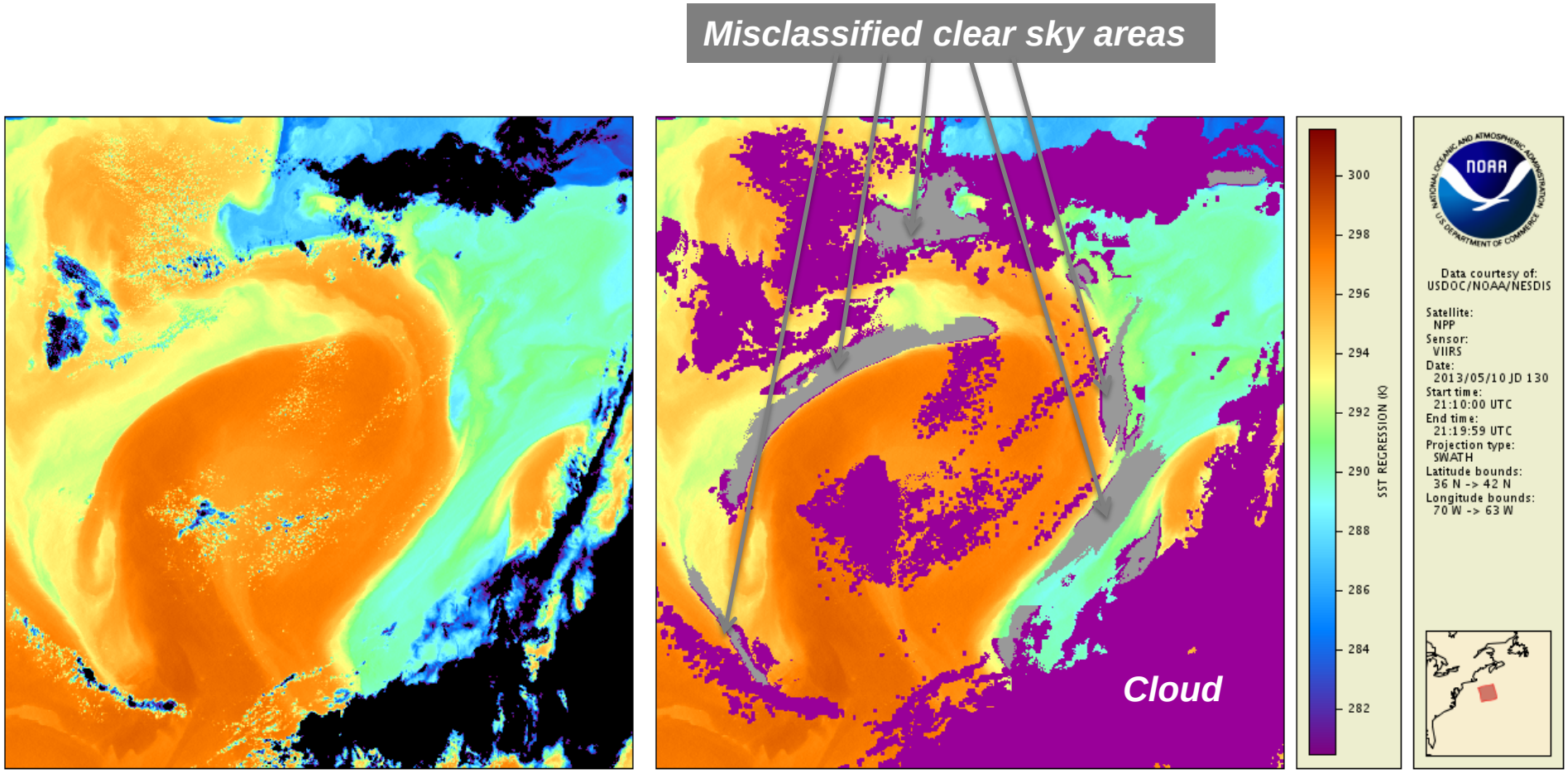
Bay of California



VIIRS ACSPO SST (no cloud mask)

SST with ACSPO cloud mask overlaid

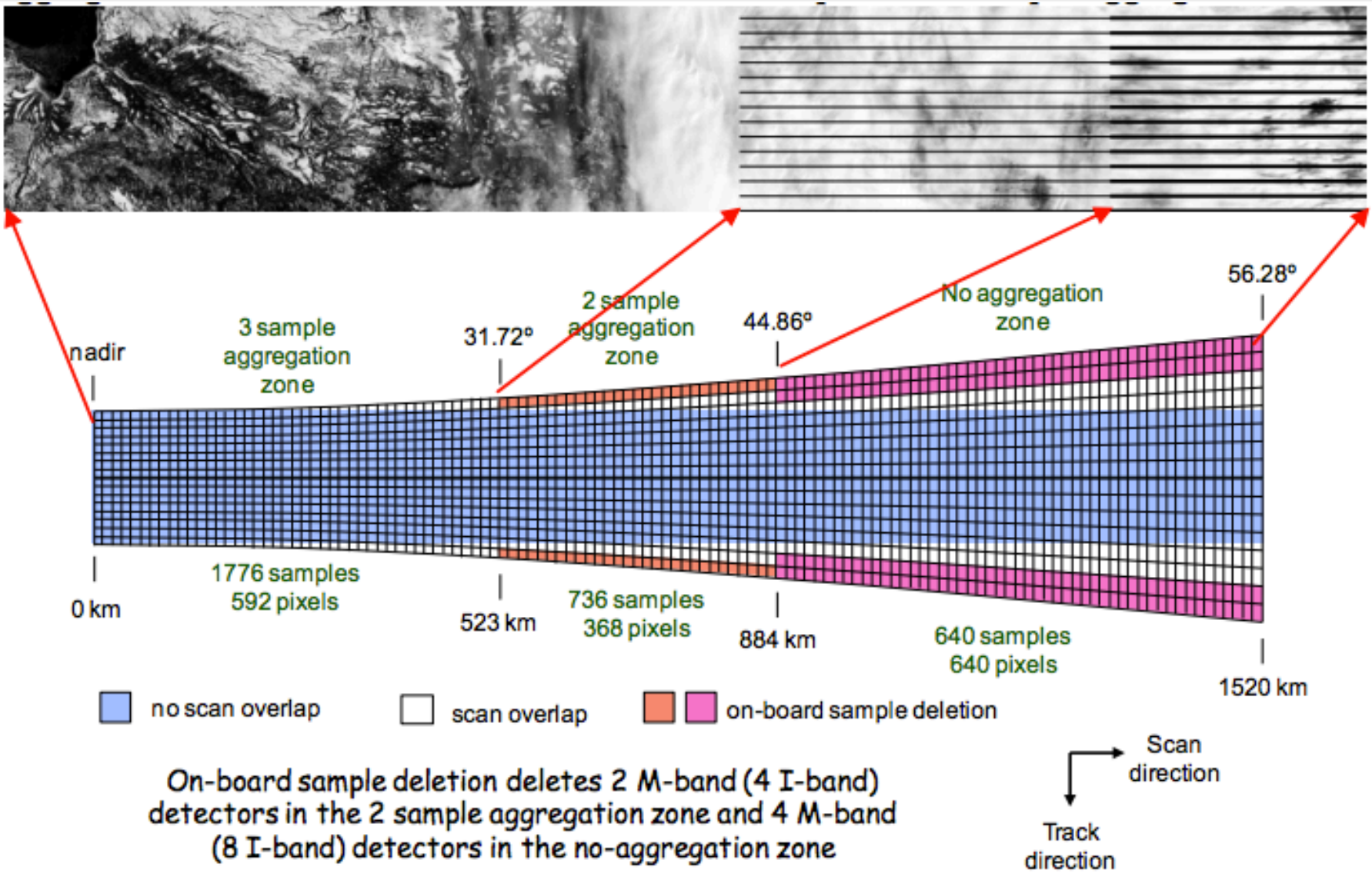
Gulf Stream



VIIRS ACSPO SST (no cloud mask)

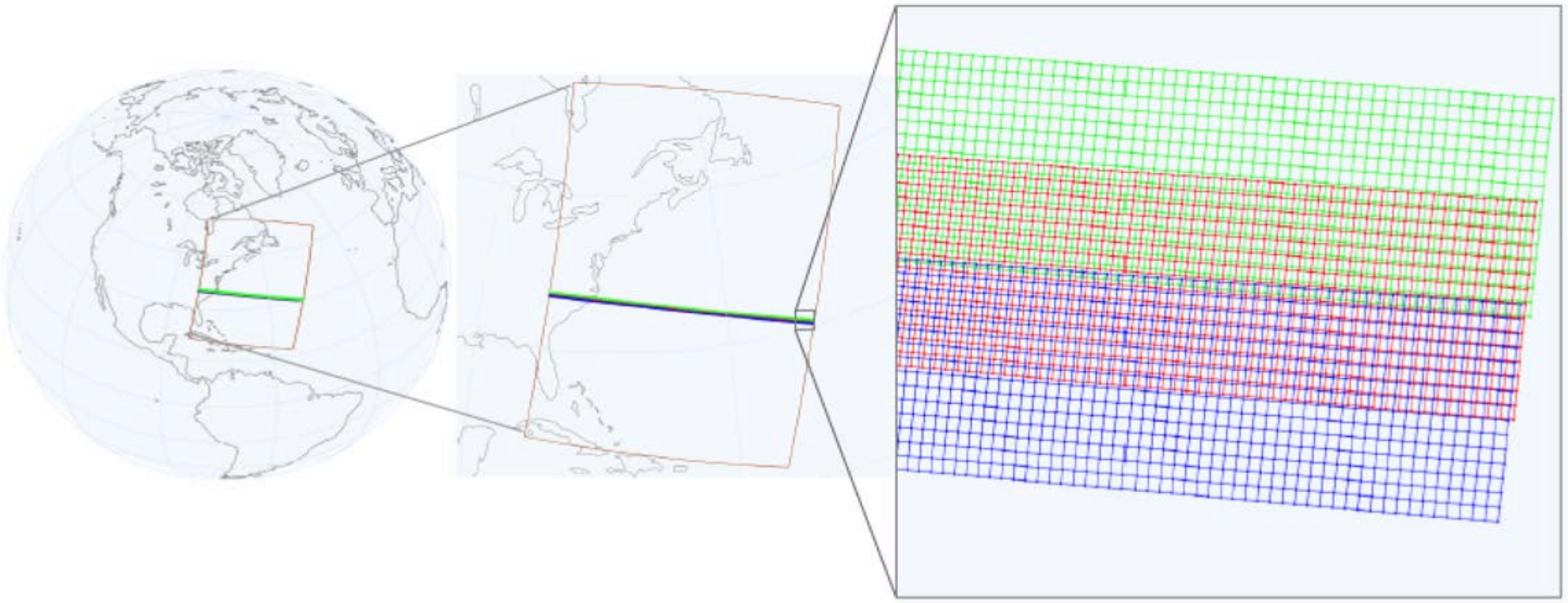
SST with ACSPO cloud mask overlaid

Task 1: Imagery Improvement



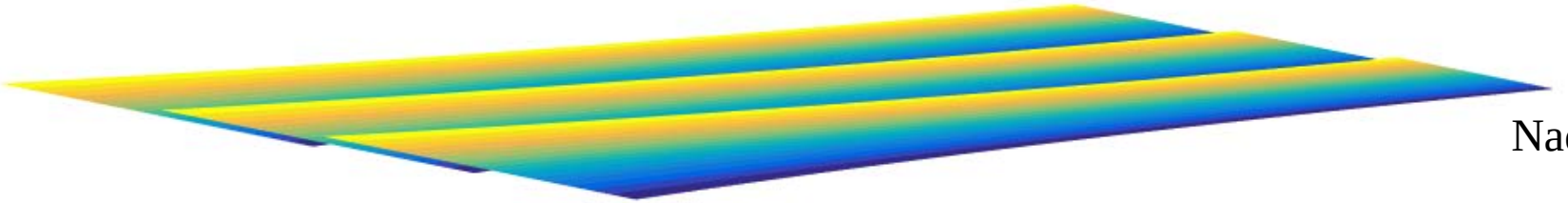
On-board sample deletion deletes 2 M-band (4 I-band) detectors in the 2 sample aggregation zone and 4 M-band (8 I-band) detectors in the no-aggregation zone

VIIRS Swath Projection

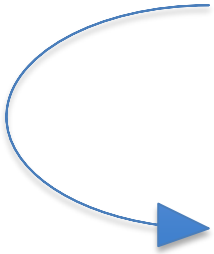


Three consecutive VIIRS scans (shown in green, red, blue), each including 16 detectors.
Overlaps create discontinuities in the VIIRS BT and SST imagery.

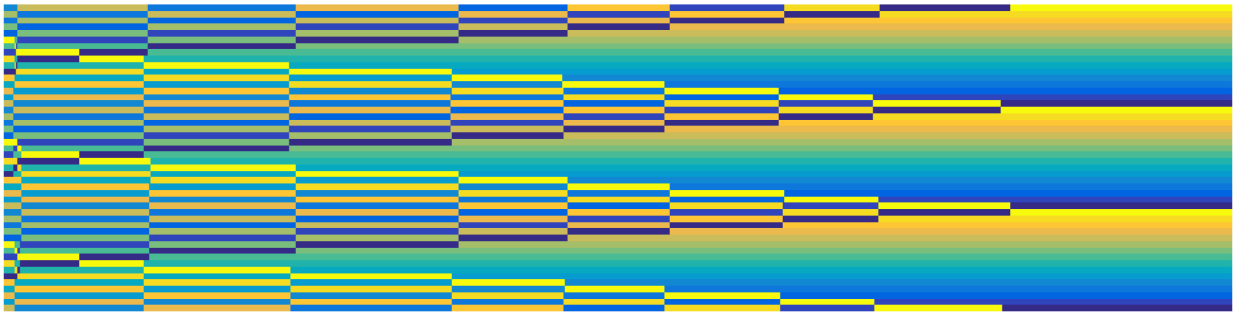
Re-ordering



Nadir

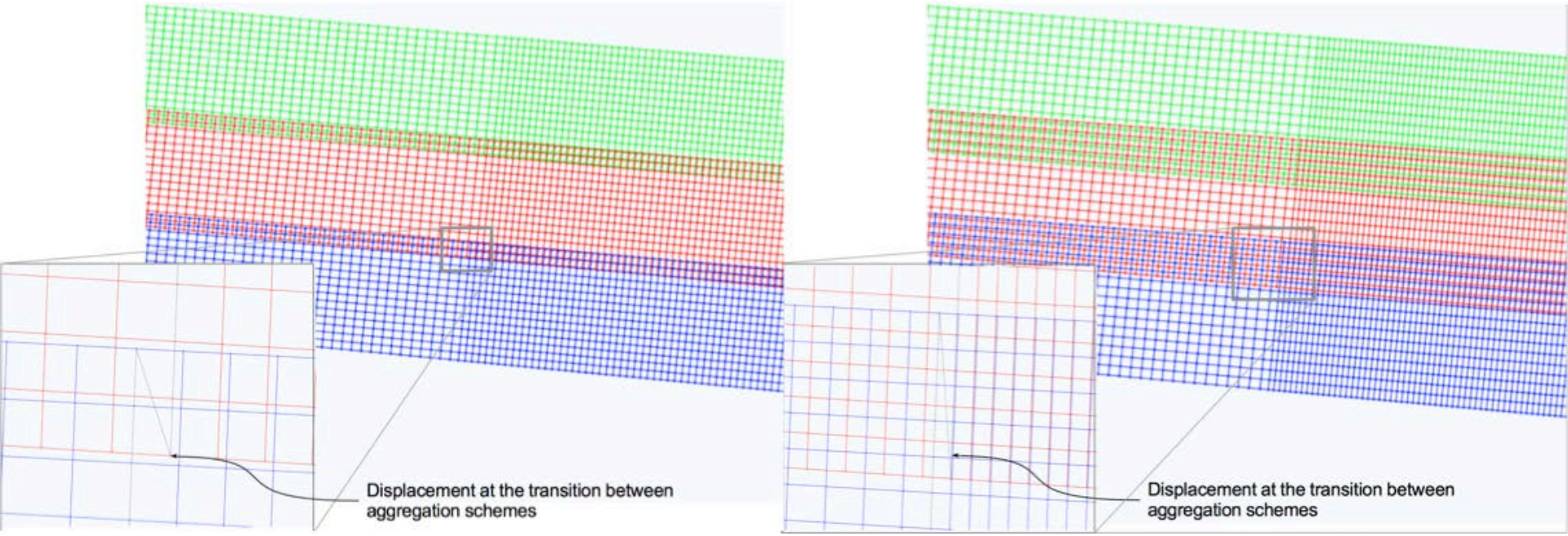


Nadir



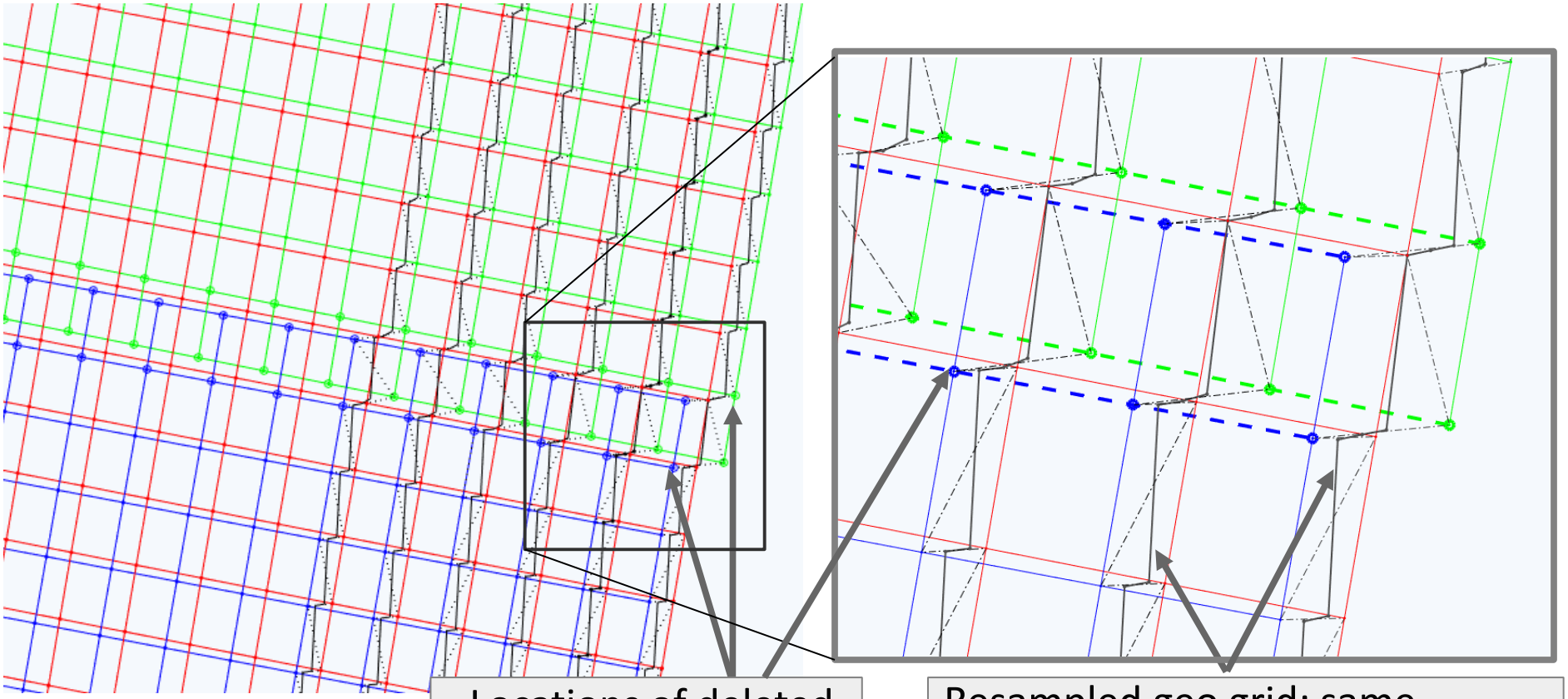
3 consecutive half-scans: original and re-ordered to satisfy Latitude monotonicity

Displacements



Significant shifts, especially in the areas where the aggregation scheme changes

L2 Geo resampling

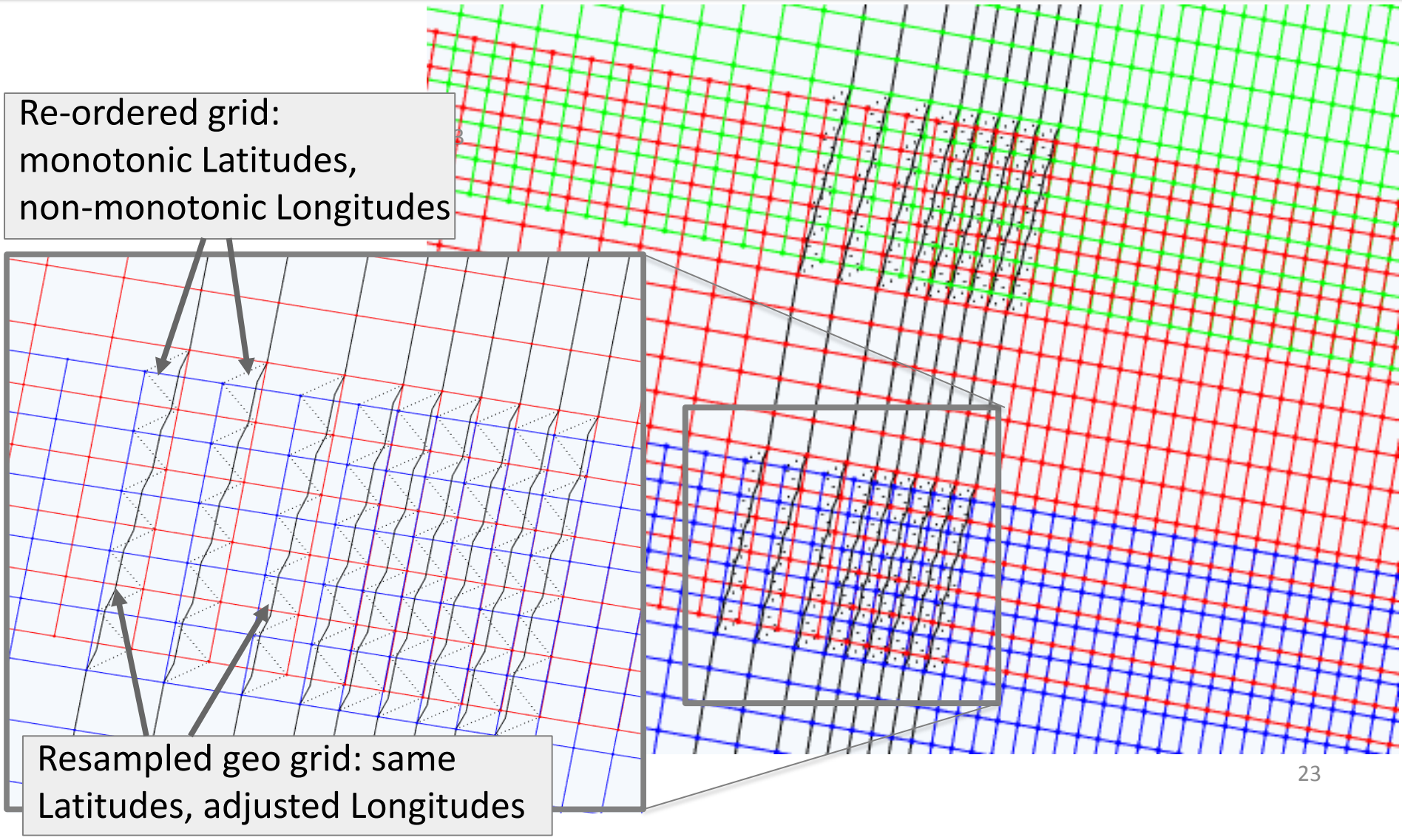


Locations of deleted onboard values

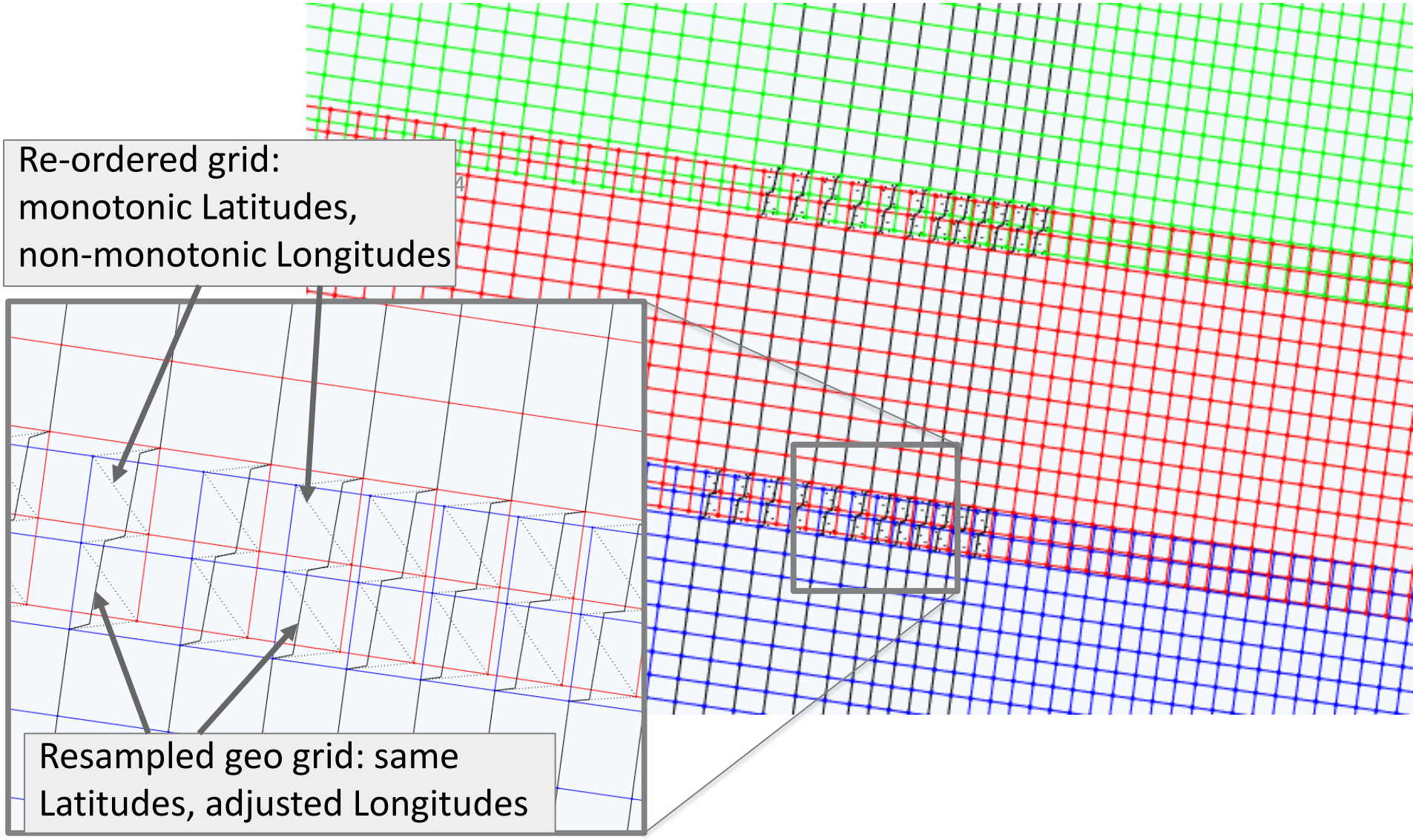
Resampled geo grid: same Latitudes, adjusted Longitudes

Black dash-dotted lines correspond to grid obtained by geo location re-ordering according latitude monotonicity. “Zig-zagging” at the scan overlaps are caused by satellite to Earth rotation. Solid black lines correspond to adjusted geo grid that minimize these displacements.

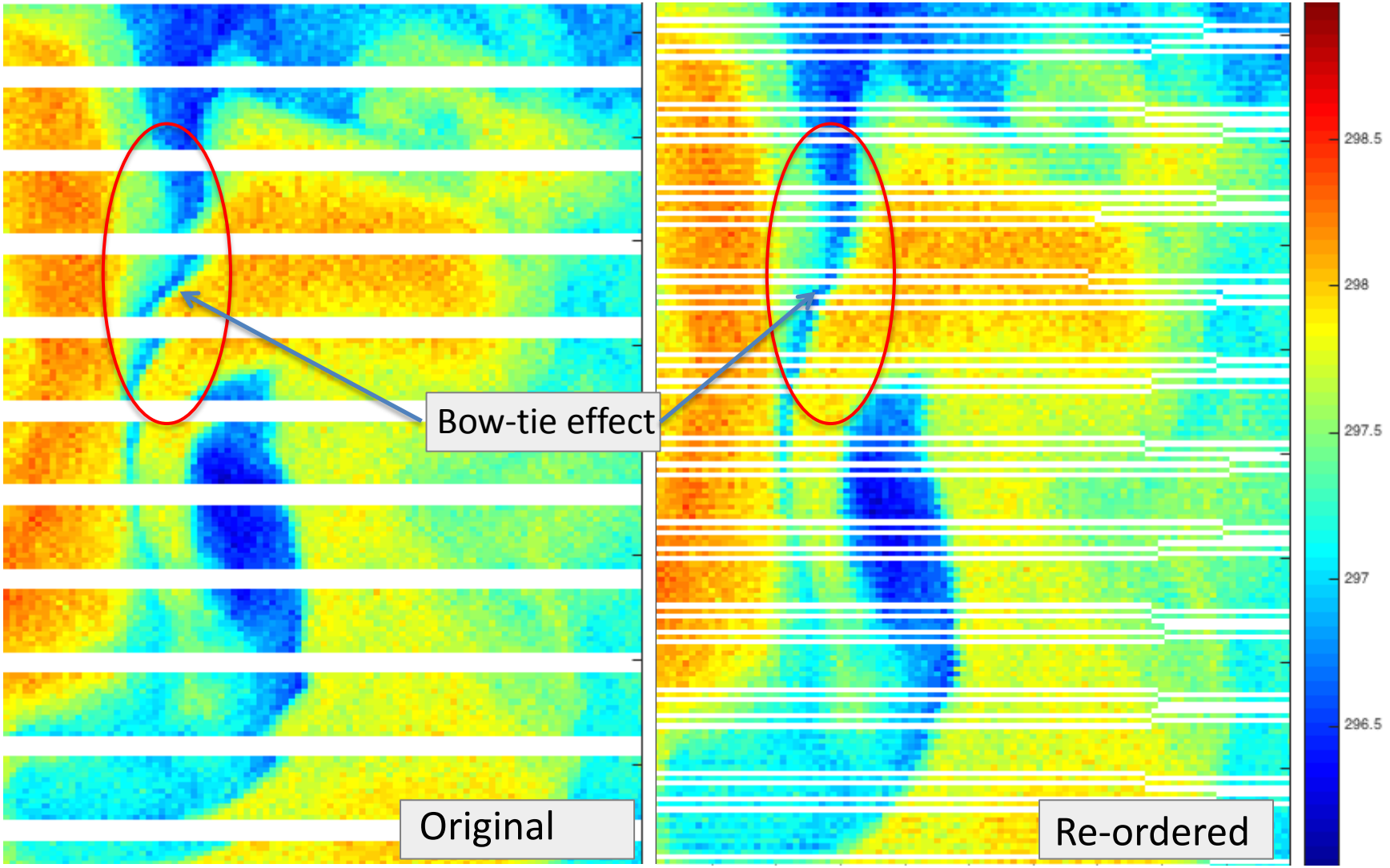
Aggregation switch 2 to 1



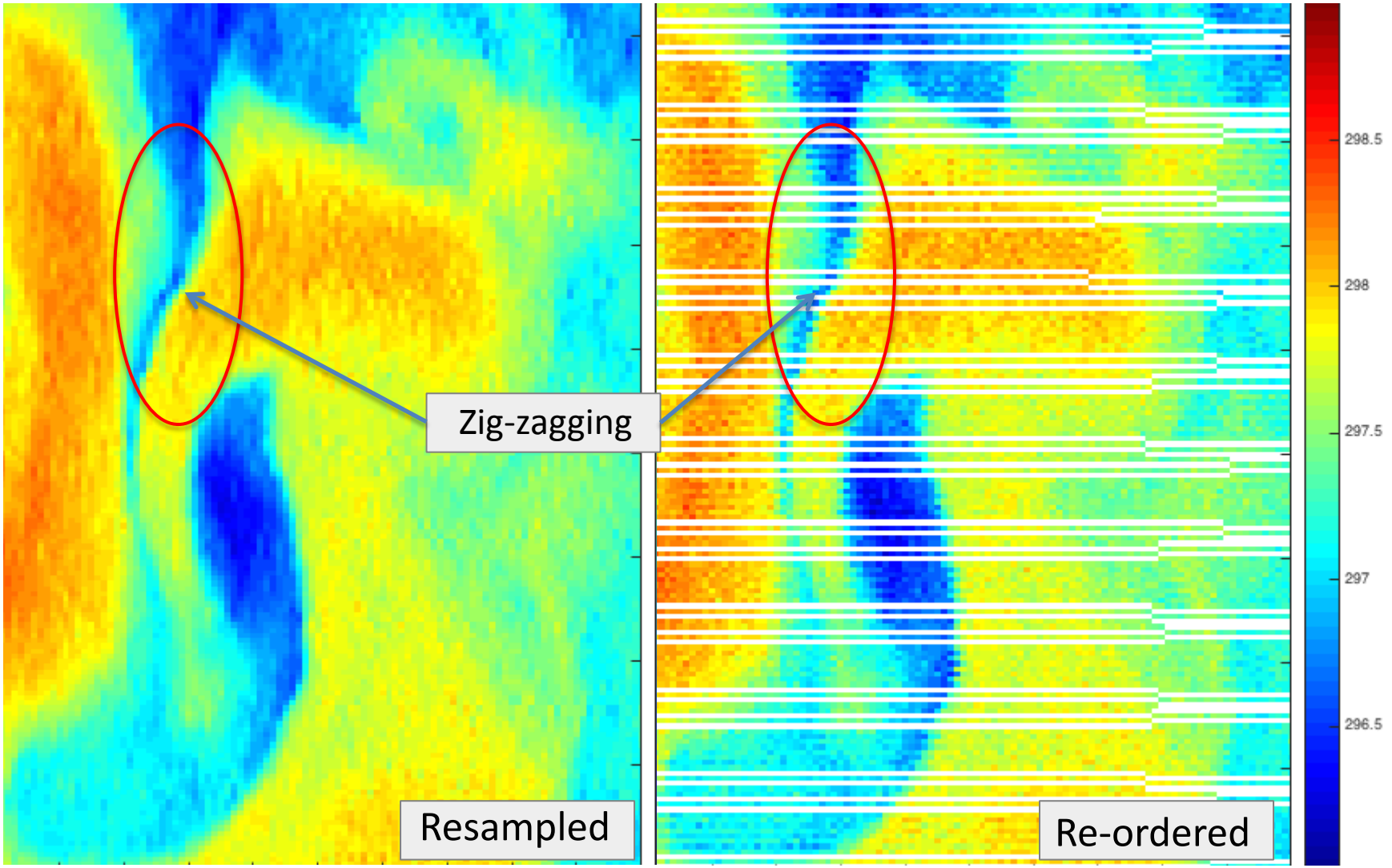
Aggregation switch 3 to 2



L2 row-wise re-ordering



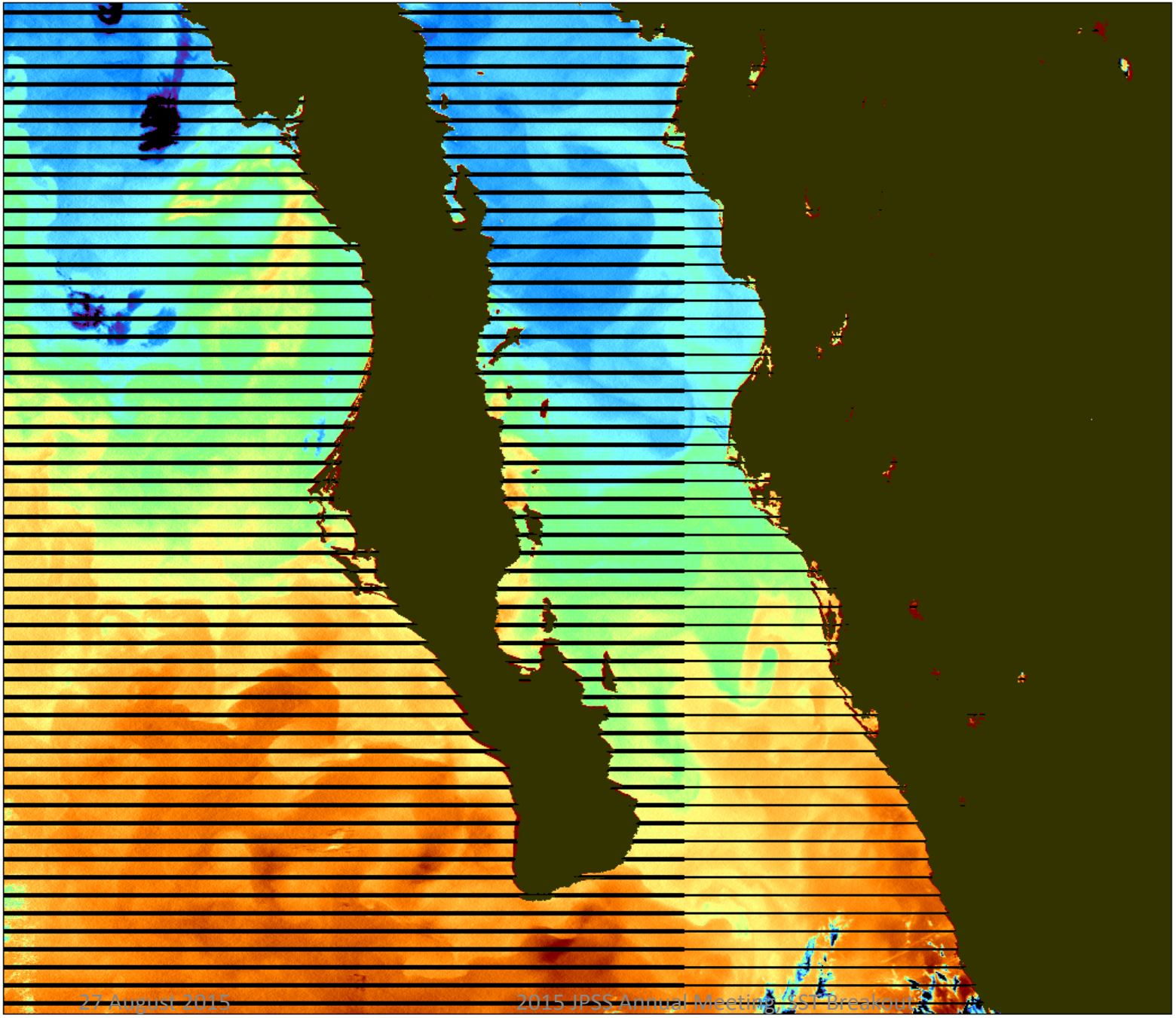
Improved SST imagery



Resampling examples

California Bay
(original swath projection):

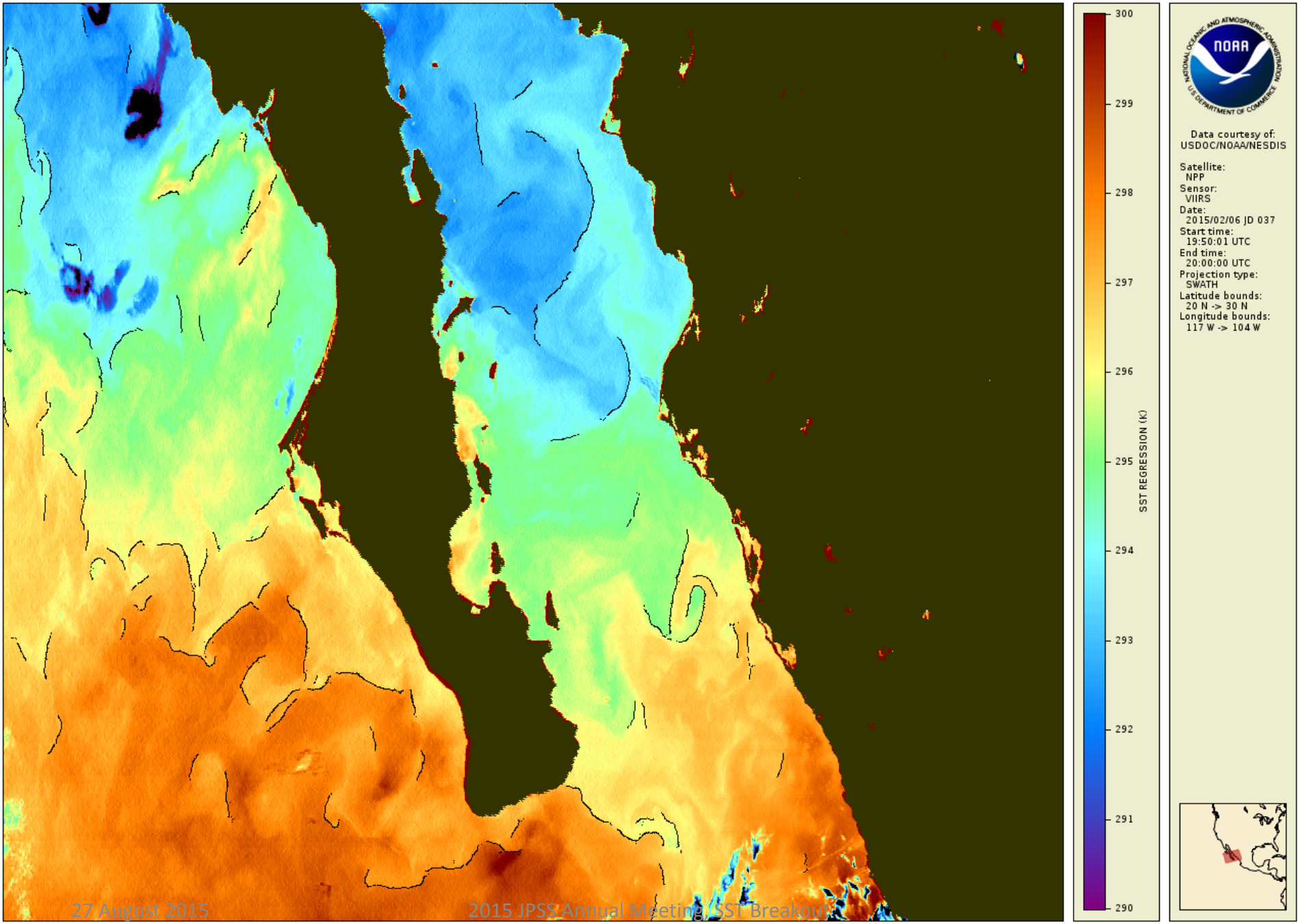
Improved imagery
&
Oceanic Thermal Front Mask

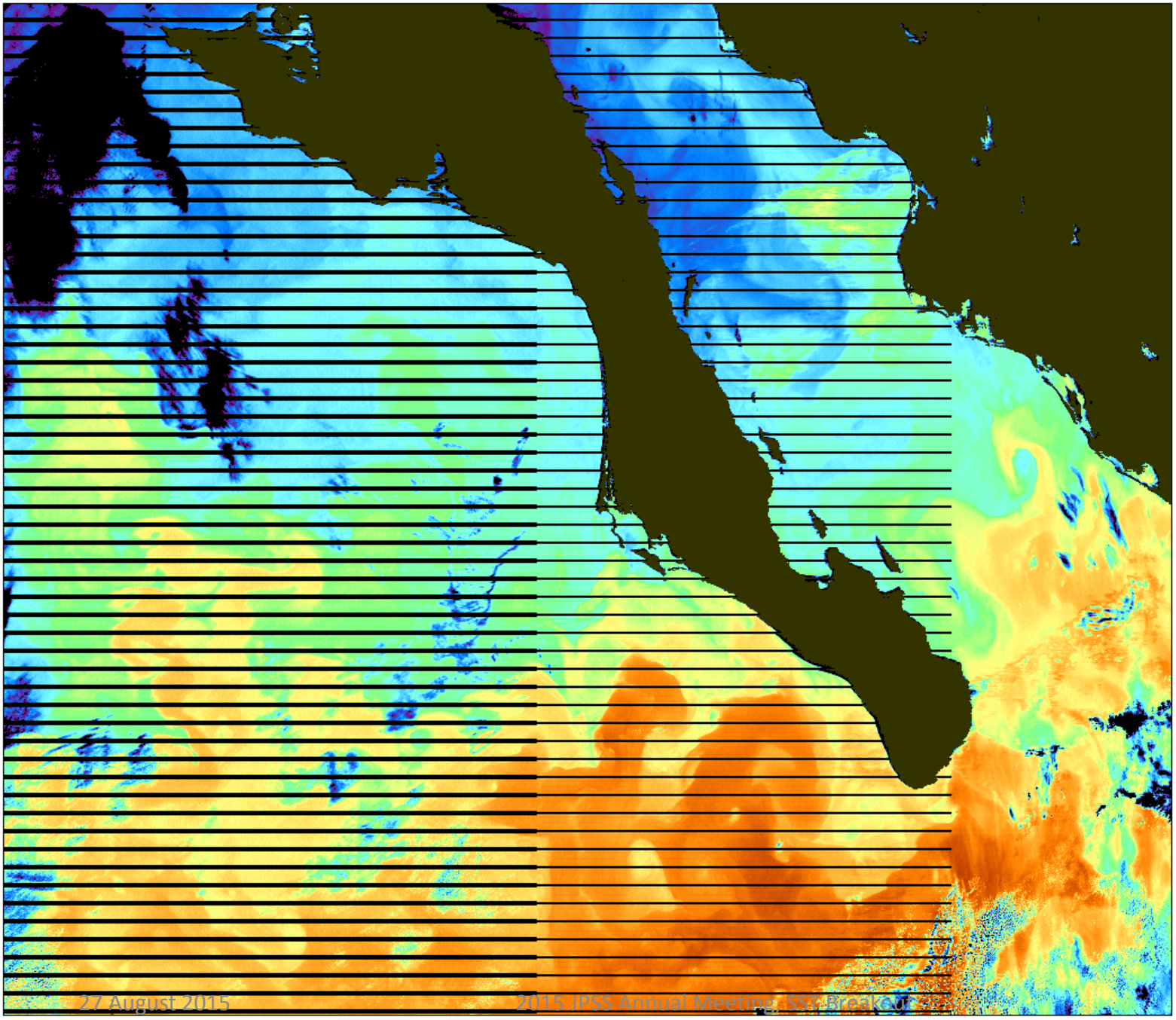


Data courtesy of:
USDOC/NOAA/NESDIS

Satellite:
NPP
Sensor:
VIIRS
Date:
2015/02/06 JD 037
Start time:
19:50:01 UTC
End time:
20:00:00 UTC
Projection type:
SWATH
Latitude bounds:
20 N -> 30 N
Longitude bounds:
117 W -> 104 W



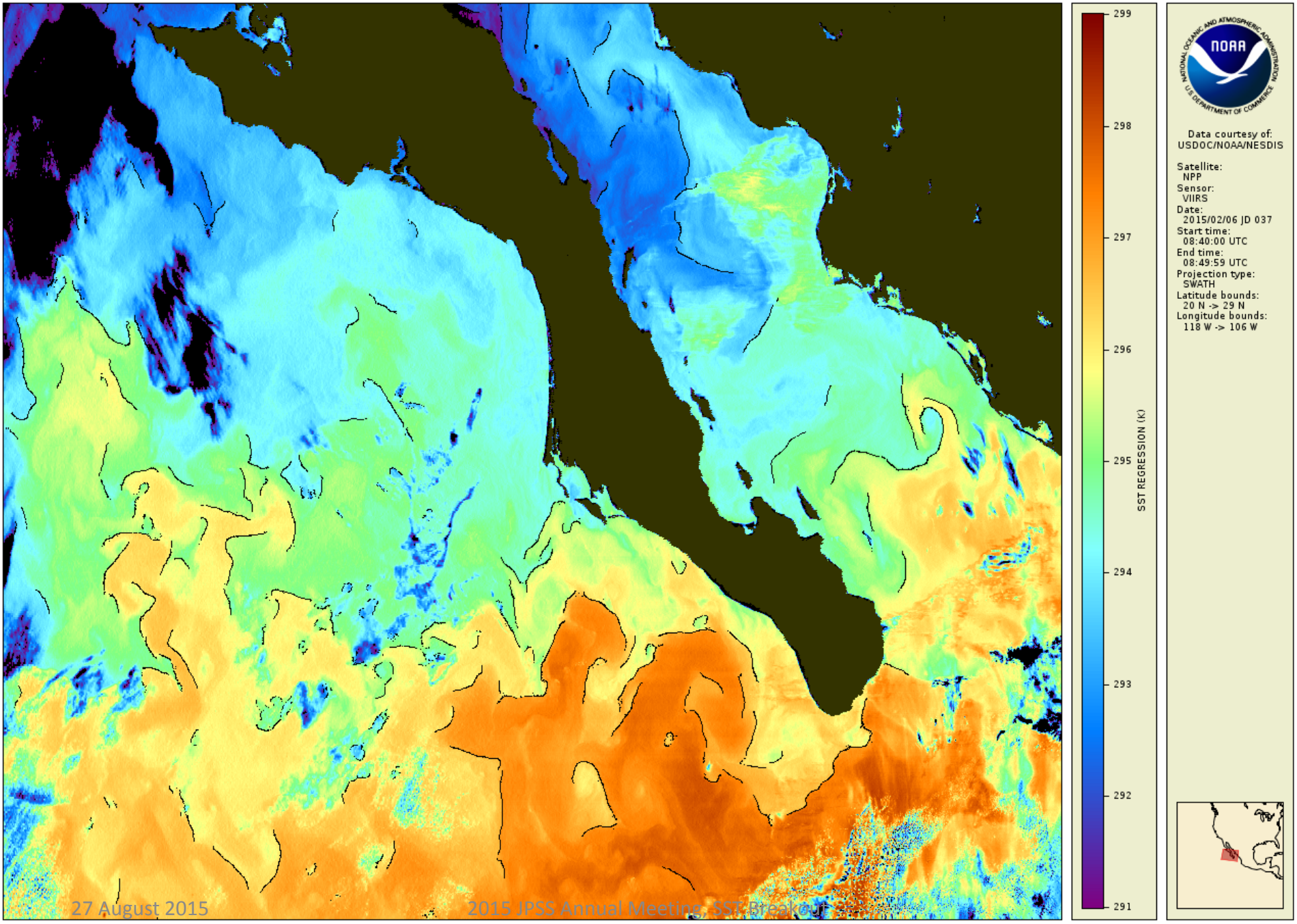

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SST REGRESSION (K)
Data courtesy of:
USDOC/NOAA/NESDIS
Satellite:
NPP
Sensor:
VIIRS
Date:
2015/02/06 JD 037
Start time:
19:50:01 UTC
End time:
20:00:00 UTC
Projection type:
SWATH
Latitude bounds:
20 N -> 30 N
Longitude bounds:
117 W -> 104 W
27 August 2015
2015 JPSS Annual Meeting SST Breakout

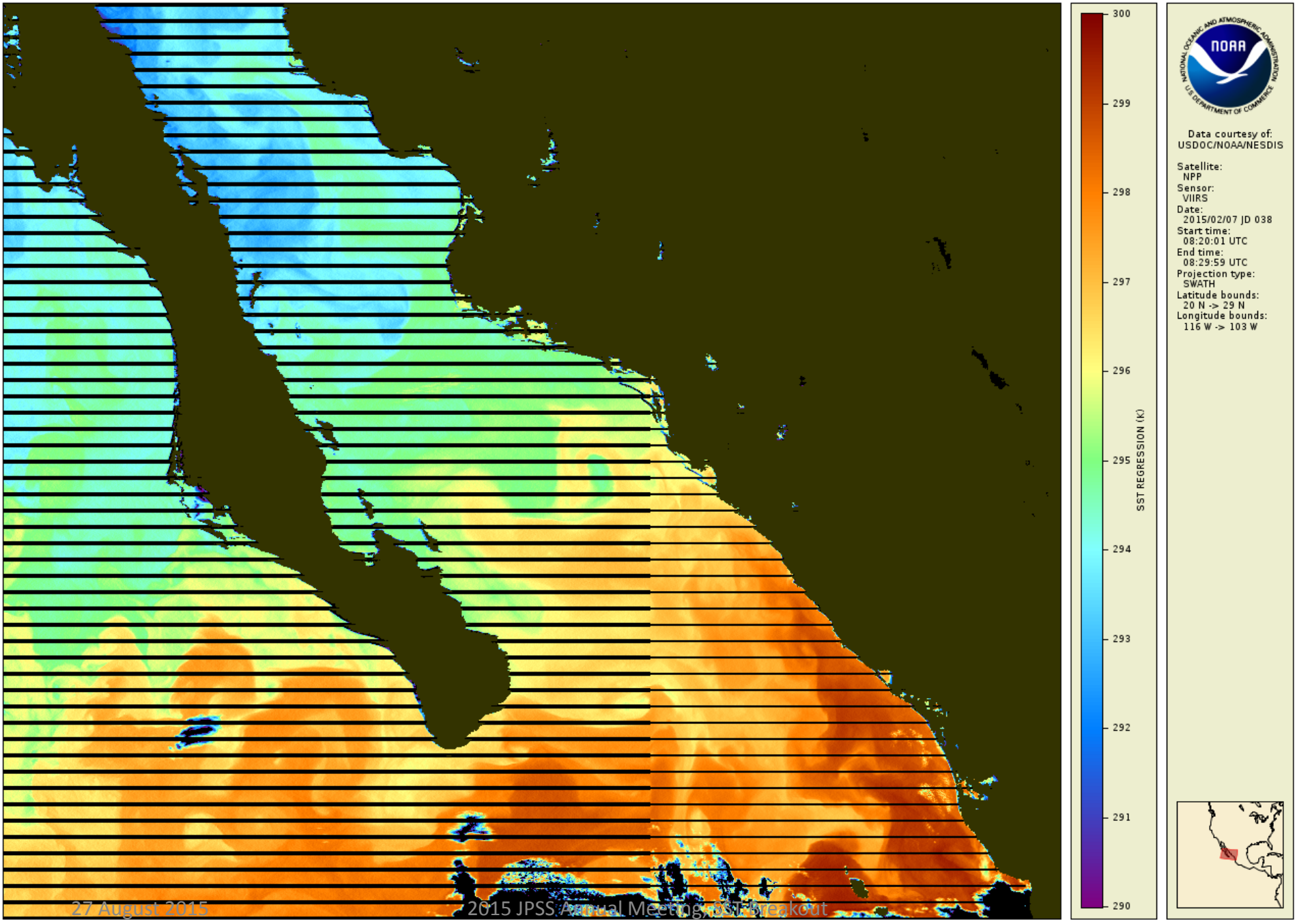


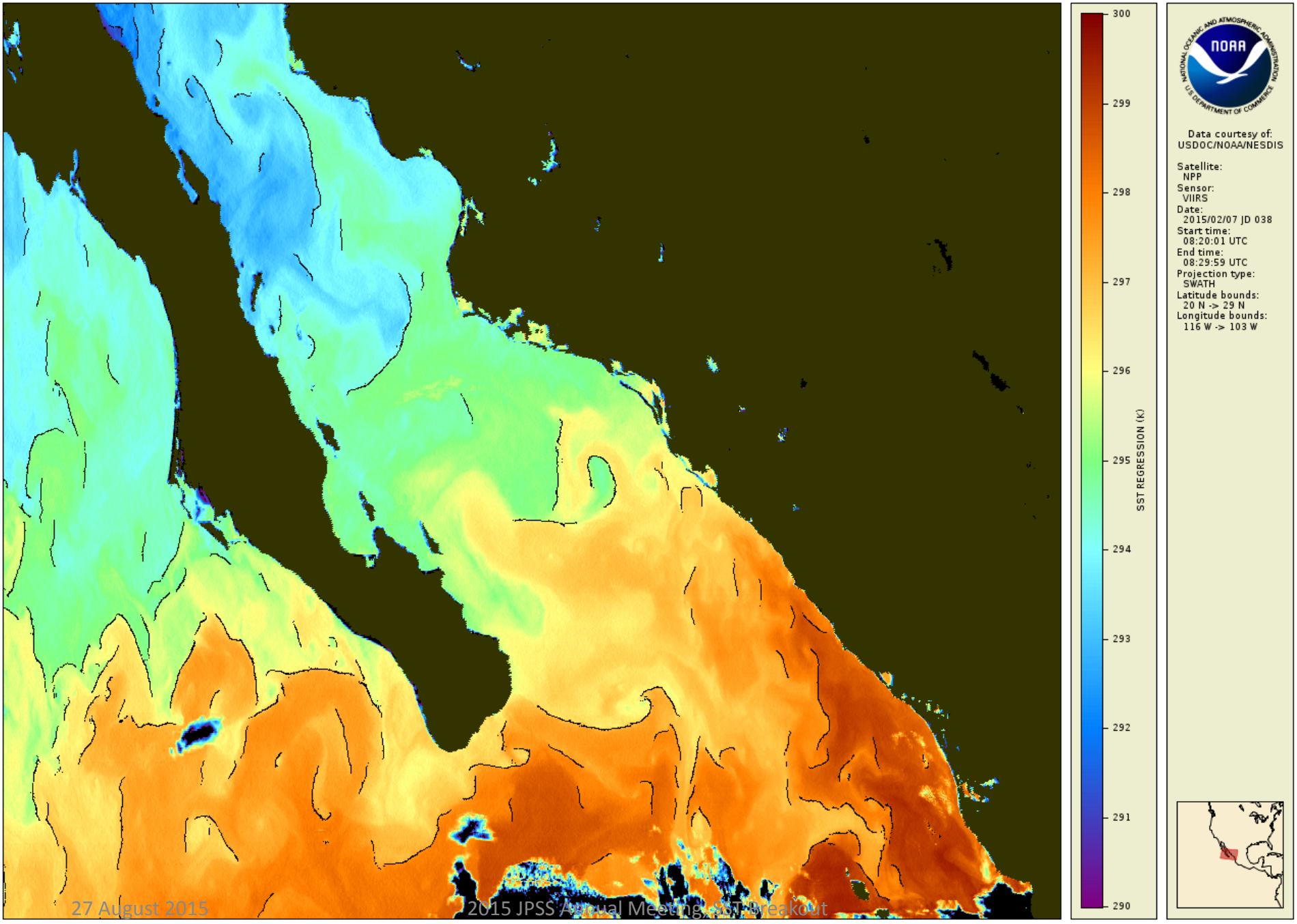
Data courtesy of:
USDOC/NOAA/NESDIS

Satellite:
NPP
Sensor:
VIIRS
Date:
2015/02/06 JD 037
Start time:
08:40:00 UTC
End time:
08:49:59 UTC
Projection type:
SWATH
Latitude bounds:
20 N -> 29 N
Longitude bounds:
118 W -> 106 W




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SST REGRESSION (K)
Data courtesy of:
USDOC/NOAA/NESDIS
Satellite:
NPP
Sensor:
VIIRS
Date:
2015/02/06 JD 037
Start time:
08:40:00 UTC
End time:
08:49:59 UTC
Projection type:
SWATH
Latitude bounds:
20 N -> 29 N
Longitude bounds:
118 W -> 106 W
27 August 2015
2015 JPSS Annual Meeting, SST Breakout


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SST REGRESSION (K)
Data courtesy of:
USDOC/NOAA/NESDIS
Satellite:
NPP
Sensor:
VIIRS
Date:
2015/02/07 JD 038
Start time:
08:20:01 UTC
End time:
08:29:59 UTC
Projection type:
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Latitude bounds:
20 N -> 29 N
Longitude bounds:
116 W -> 103 W

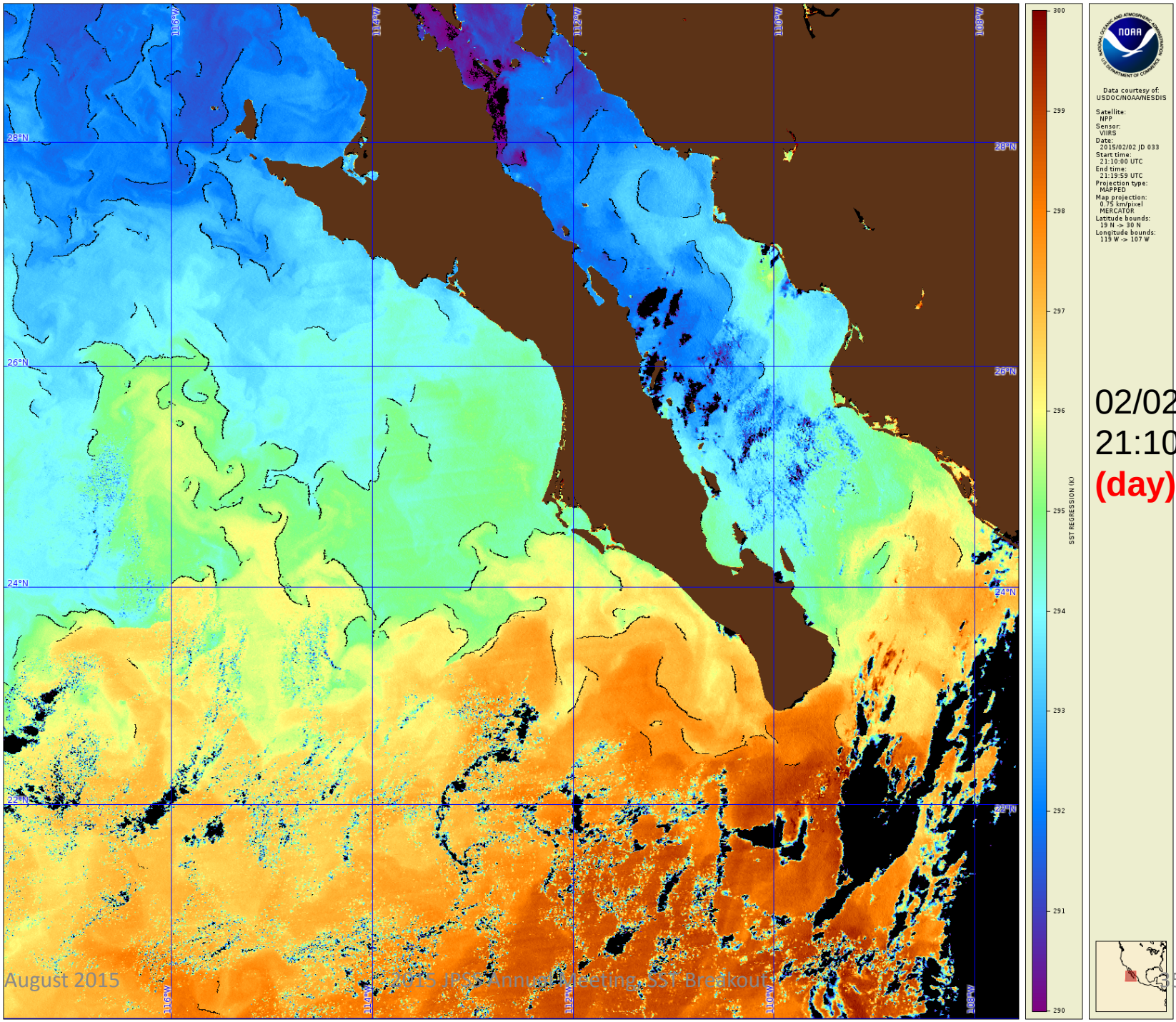

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SST REGRESSION (K)
Data courtesy of:
USDOC/NOAA/NESDIS
Satellite:
NPP
Sensor:
VIIRS
Date:
2015/02/07 JD 038
Start time:
08:20:01 UTC
End time:
08:29:59 UTC
Projection type:
SWATH
Latitude bounds:
20 N -> 29 N
Longitude bounds:
116 W -> 103 W
27 August 2015
2015 JPSS Annual Meeting - SST Breakout

Remapped Fronts

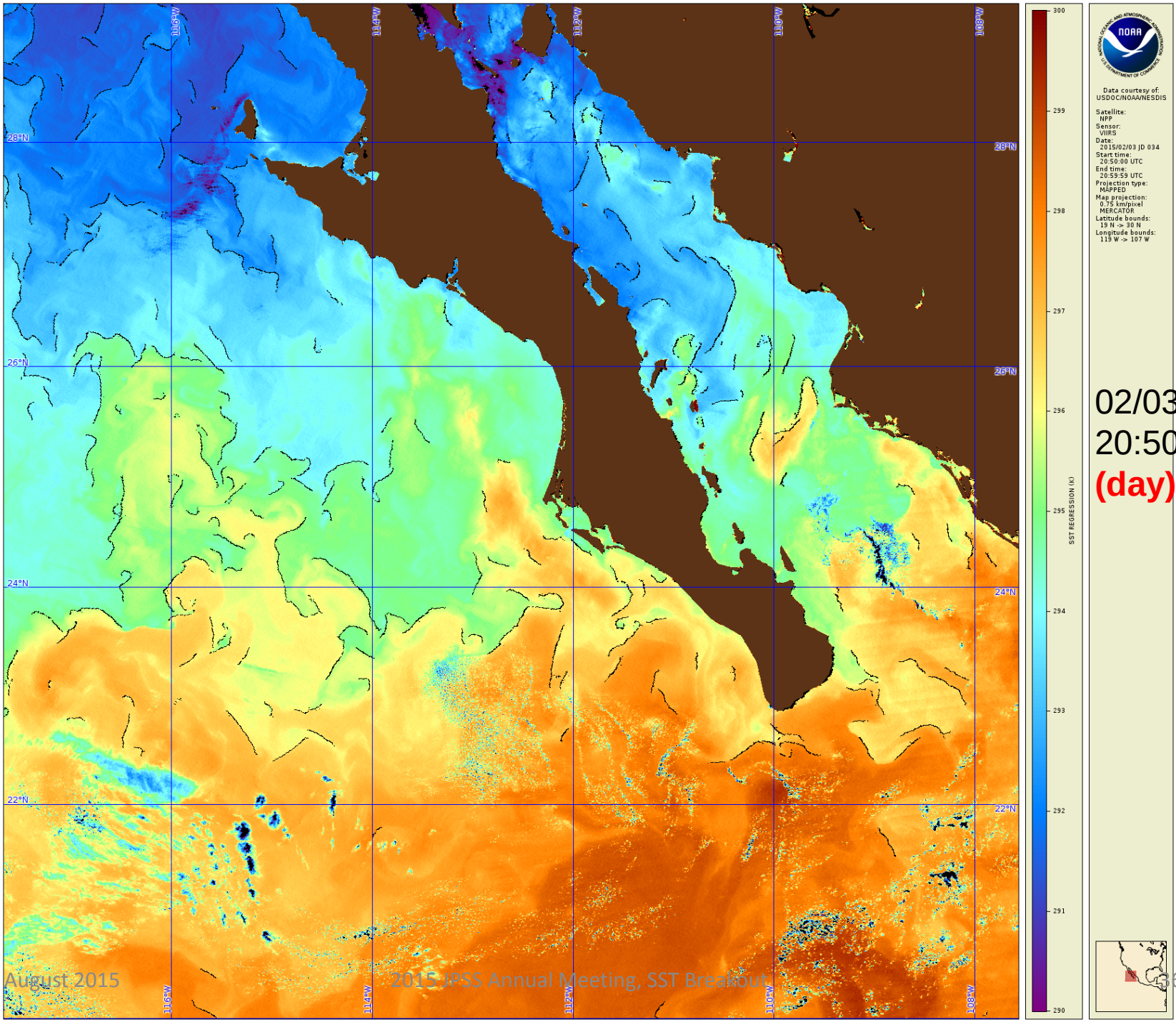
California Bay (remapped)

02/02/2015 – 02/10/2015

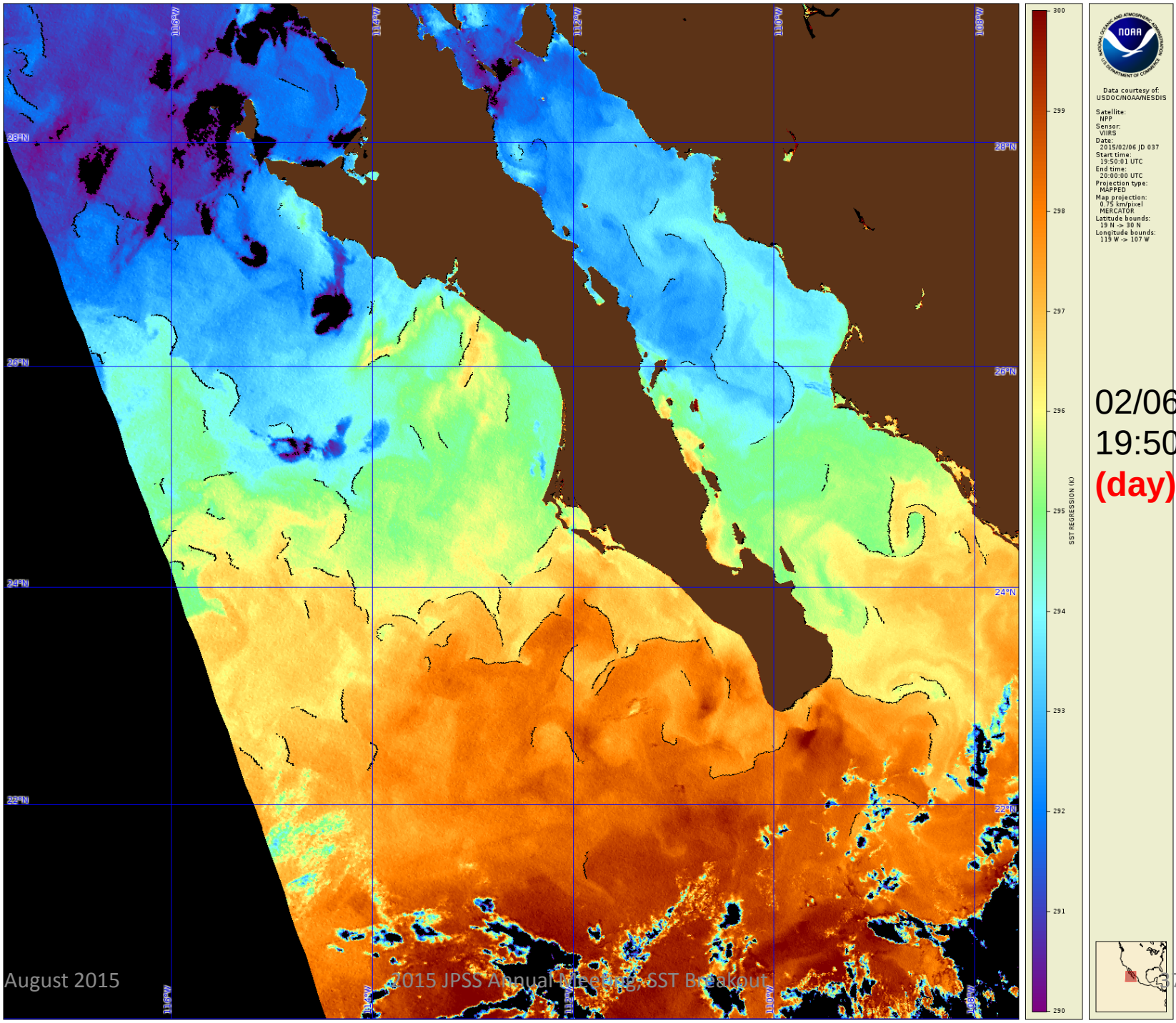
Improved imagery
&
Oceanic Thermal Front Mask

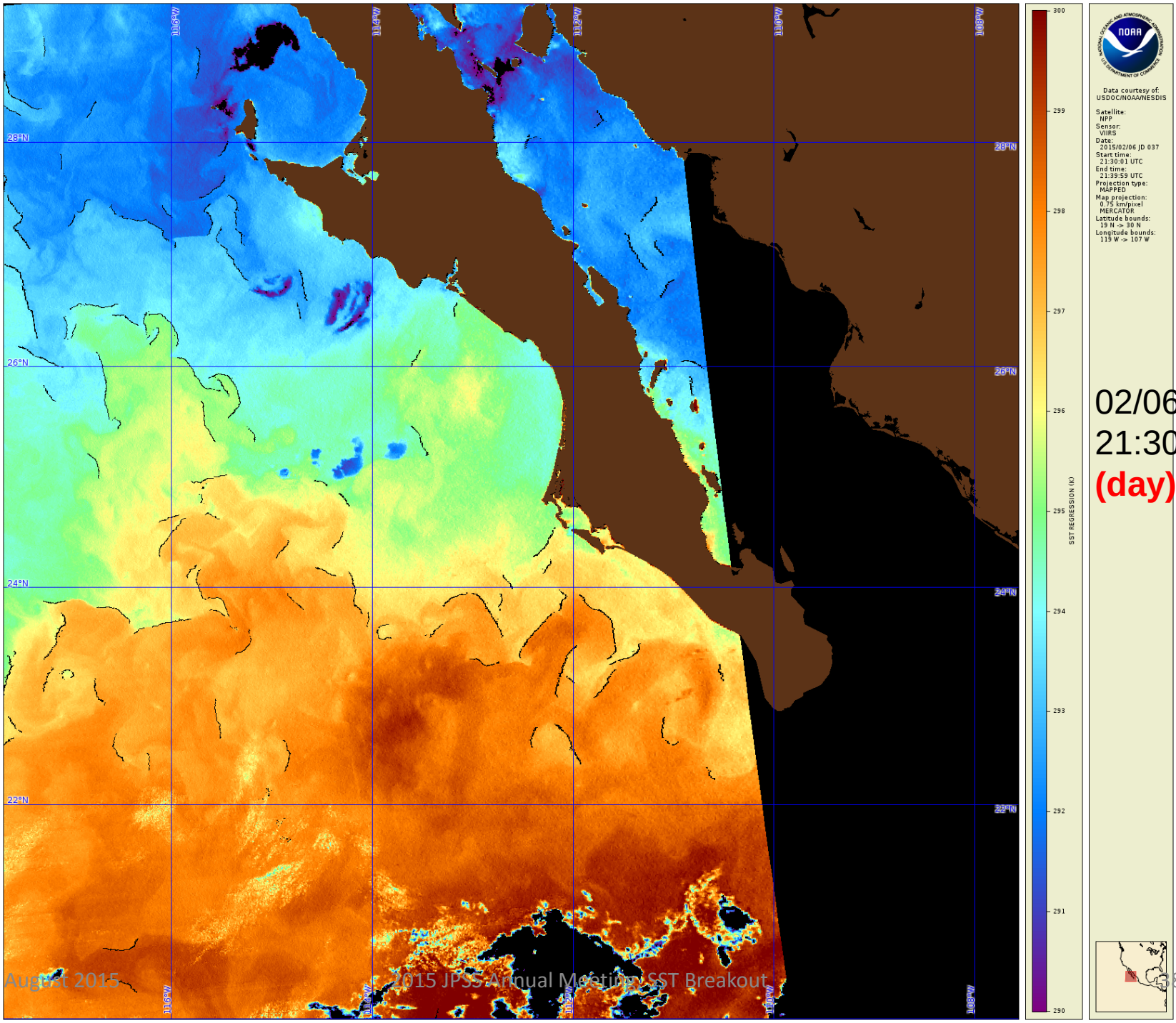


02/02/2015
21:10 UTC
(day)

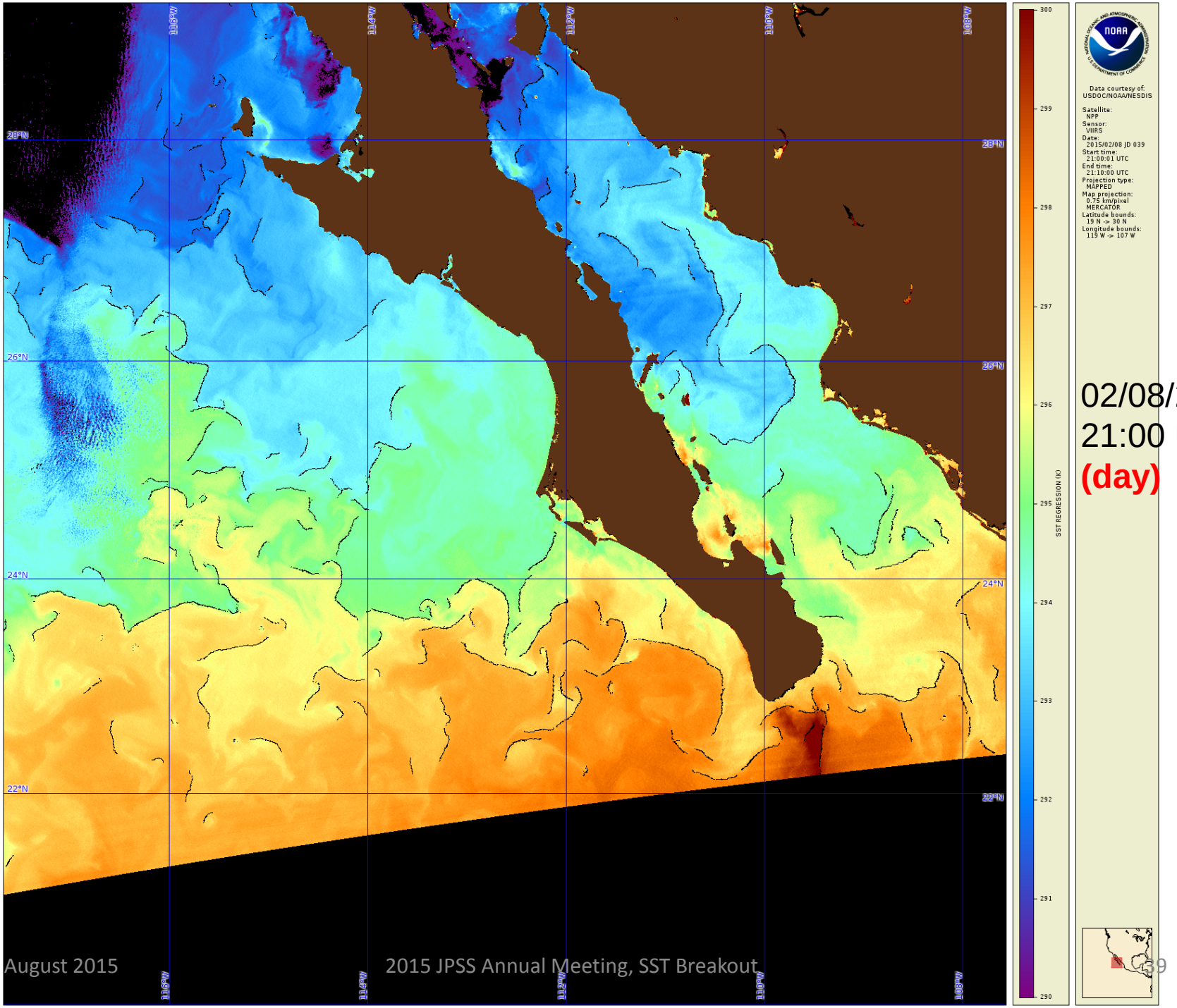


02/03/2015
20:50 UTC
(day)

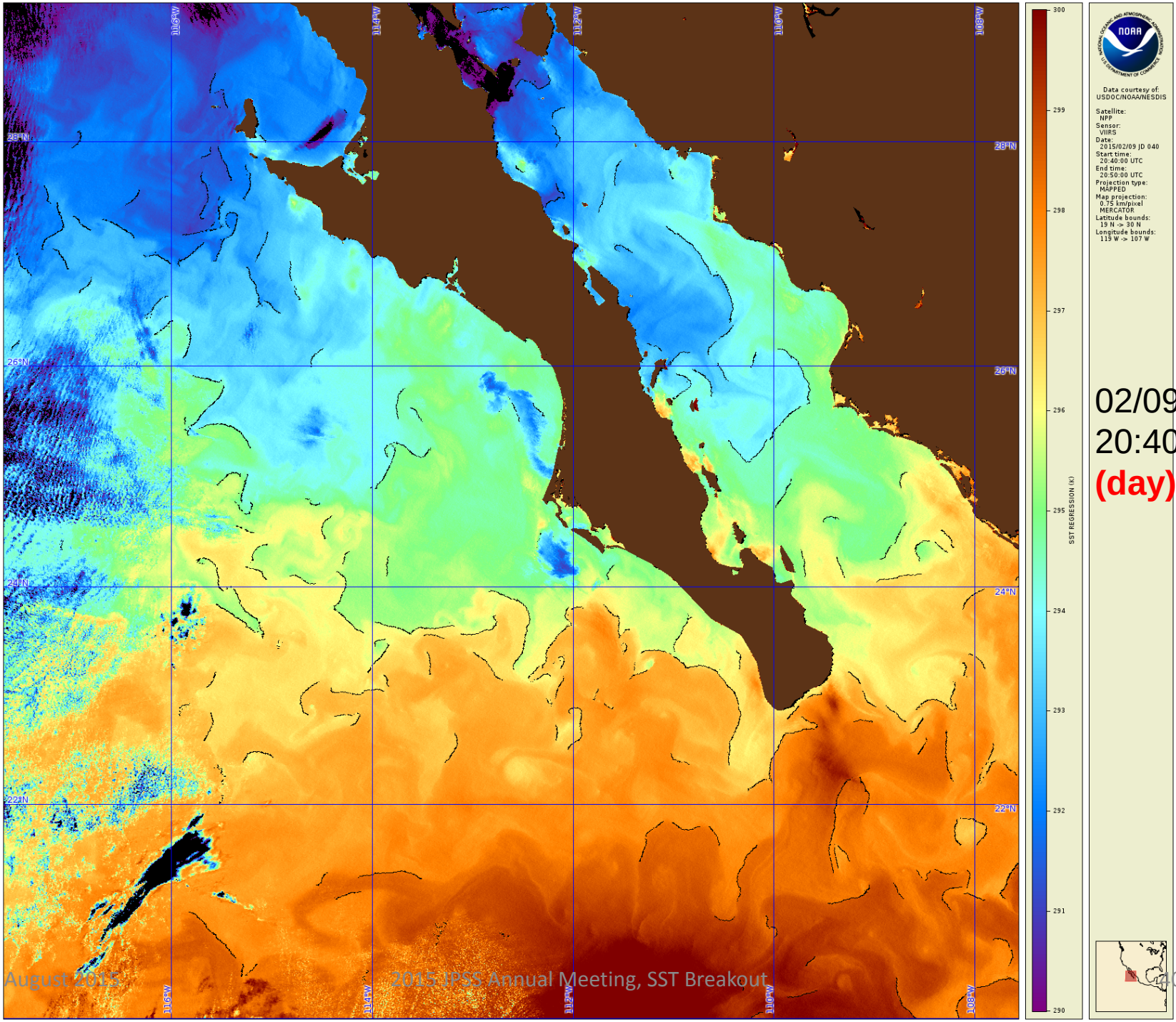

02/06/2015
19:50 UTC
(day)
SST REGRESSION (K)
Data courtesy of:
USDOC/NOAA/NESDIS
Satellite:
NPP
Sensor:
VIIRS
Date:
2015/02/06 JD 037
Start time:
19:50:01 UTC
End time:
20:00:00 UTC
Projection type:
MAPPED
Map projection:
0.75 km/pixel
MERCATOR
Latitude bounds:
19 N -> 30 N
Longitude bounds:
119 W -> 107 W



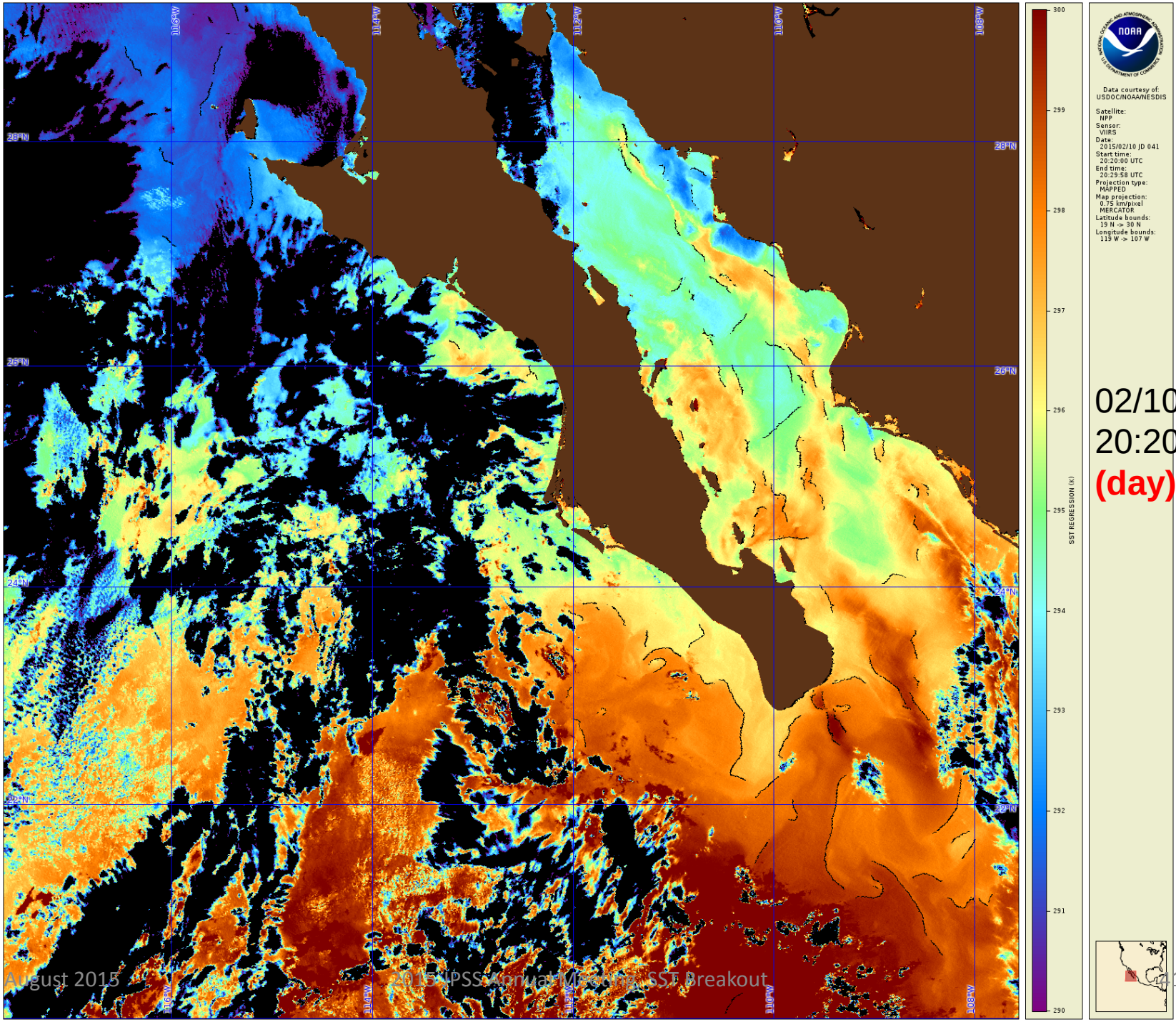
02/06/2015
21:30 UTC
(day)



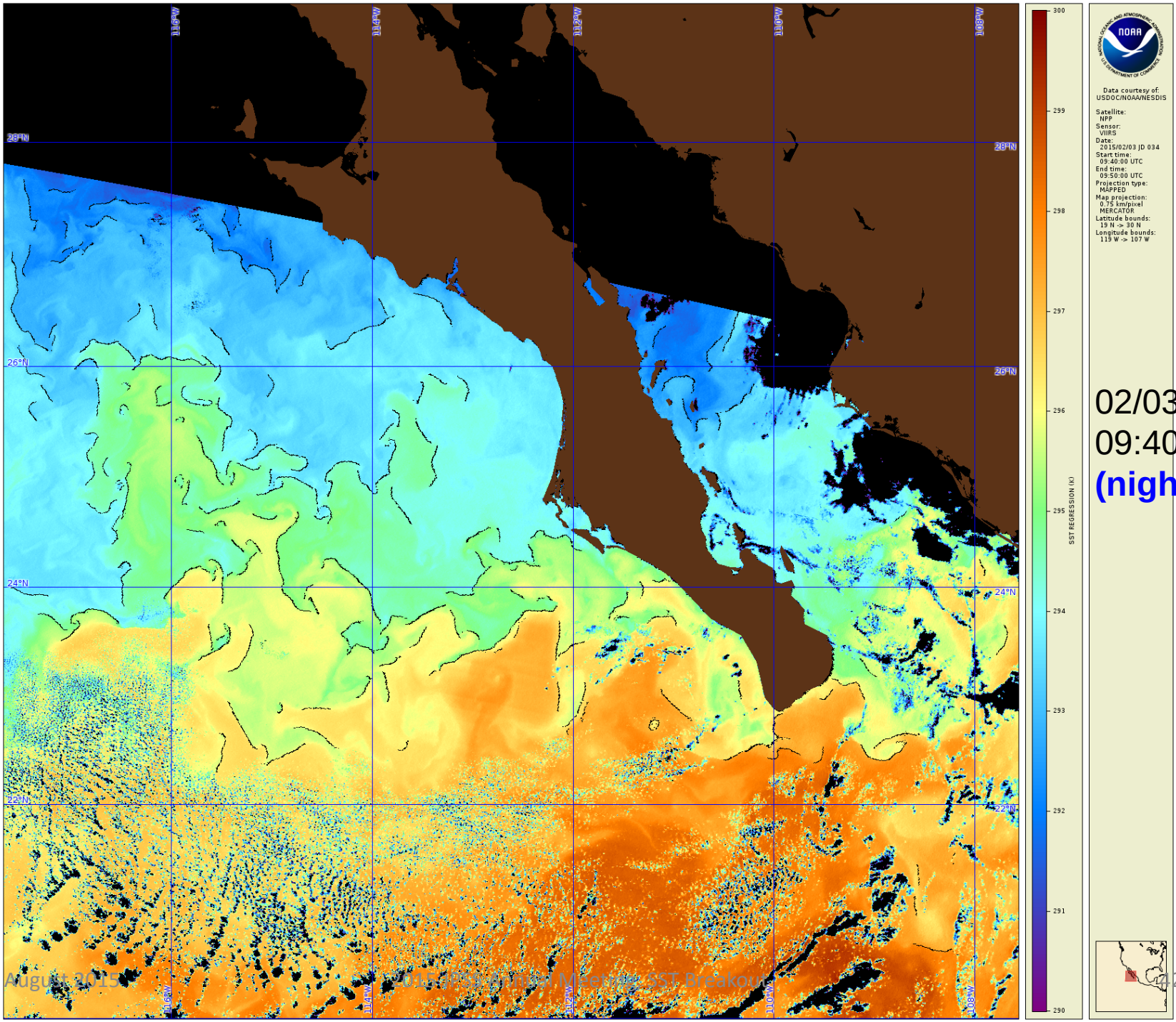
02/08/2015
21:00 UTC
(day)



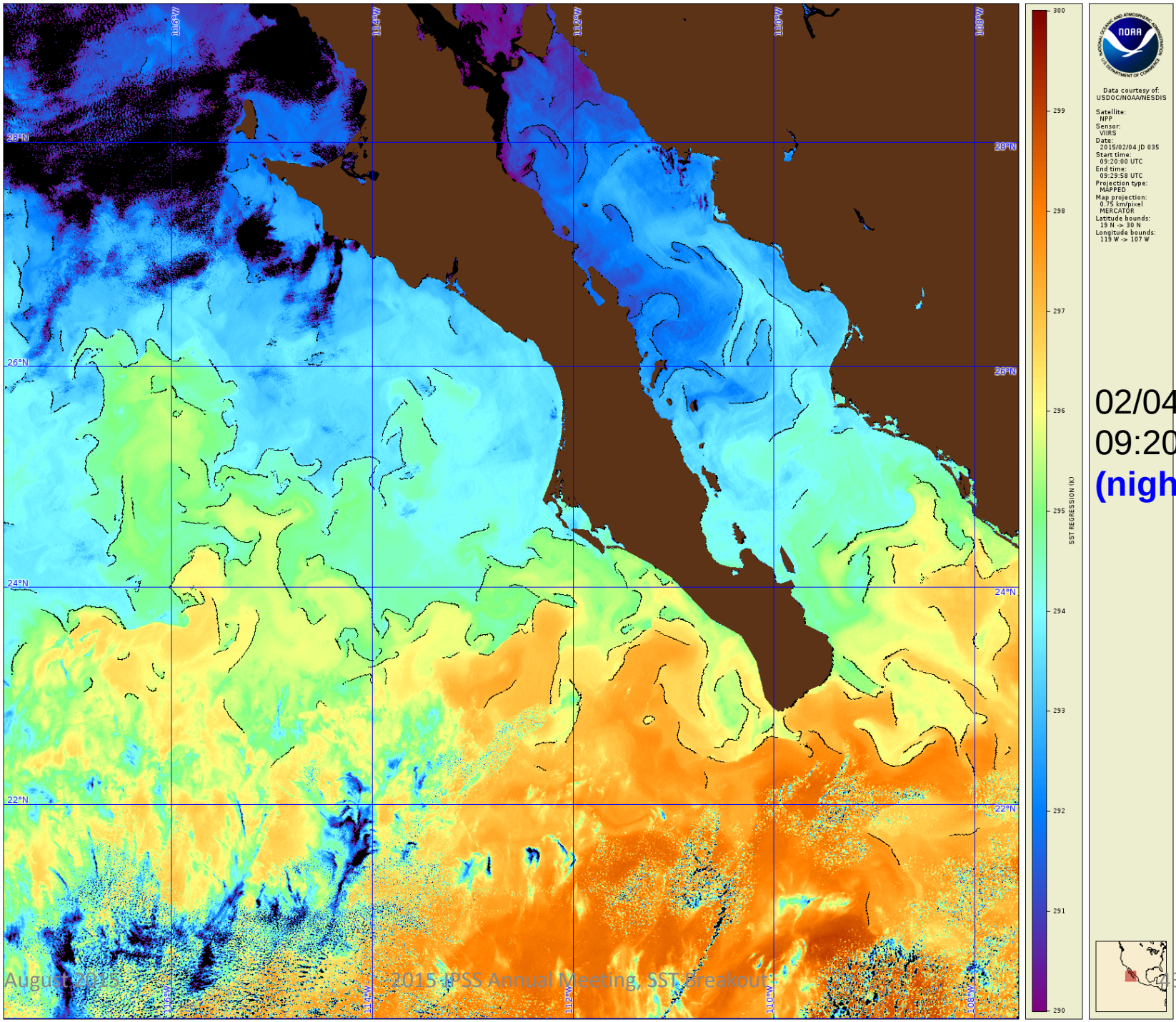
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(day)



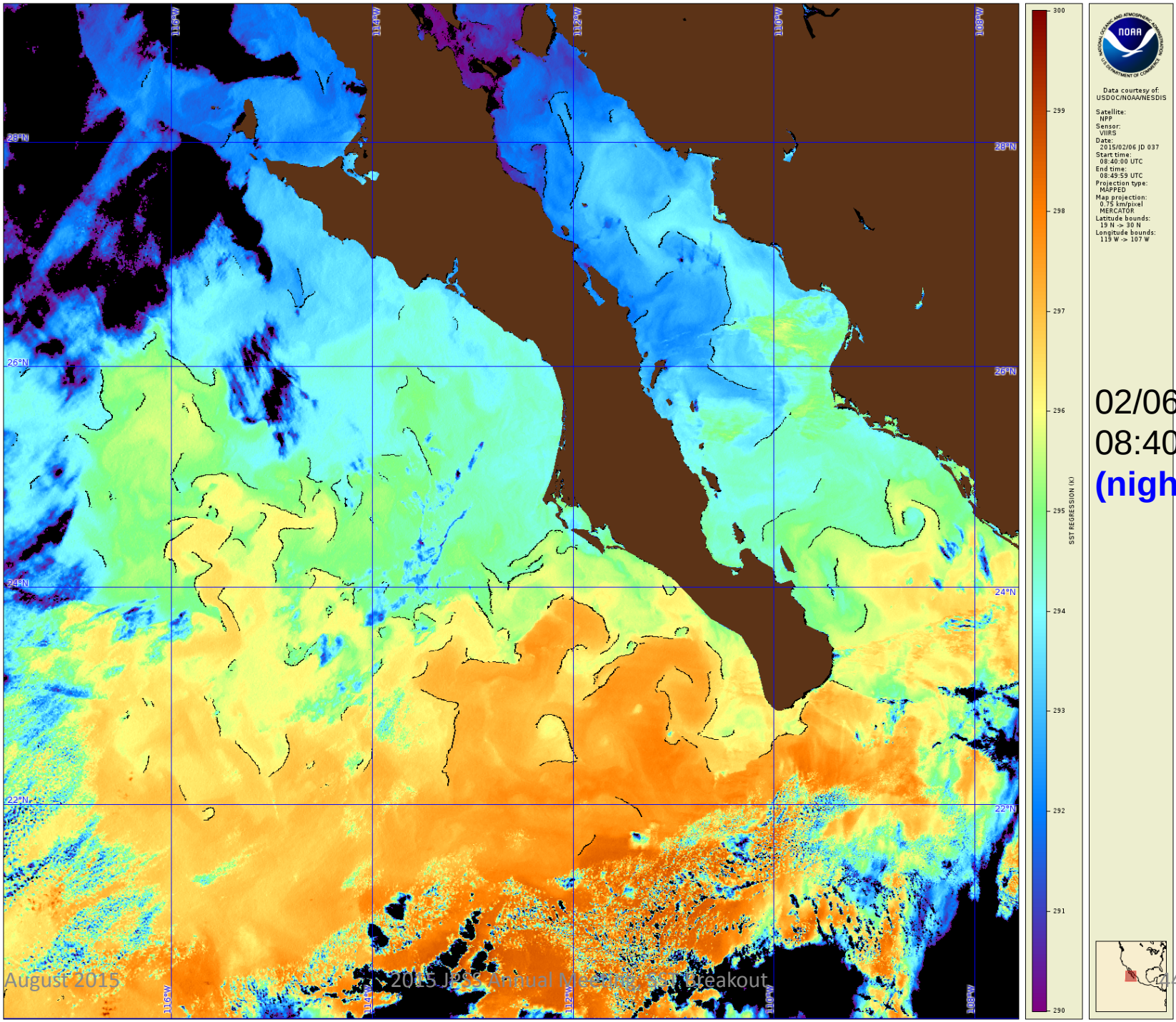
02/10/2015
20:20 UTC
(day)



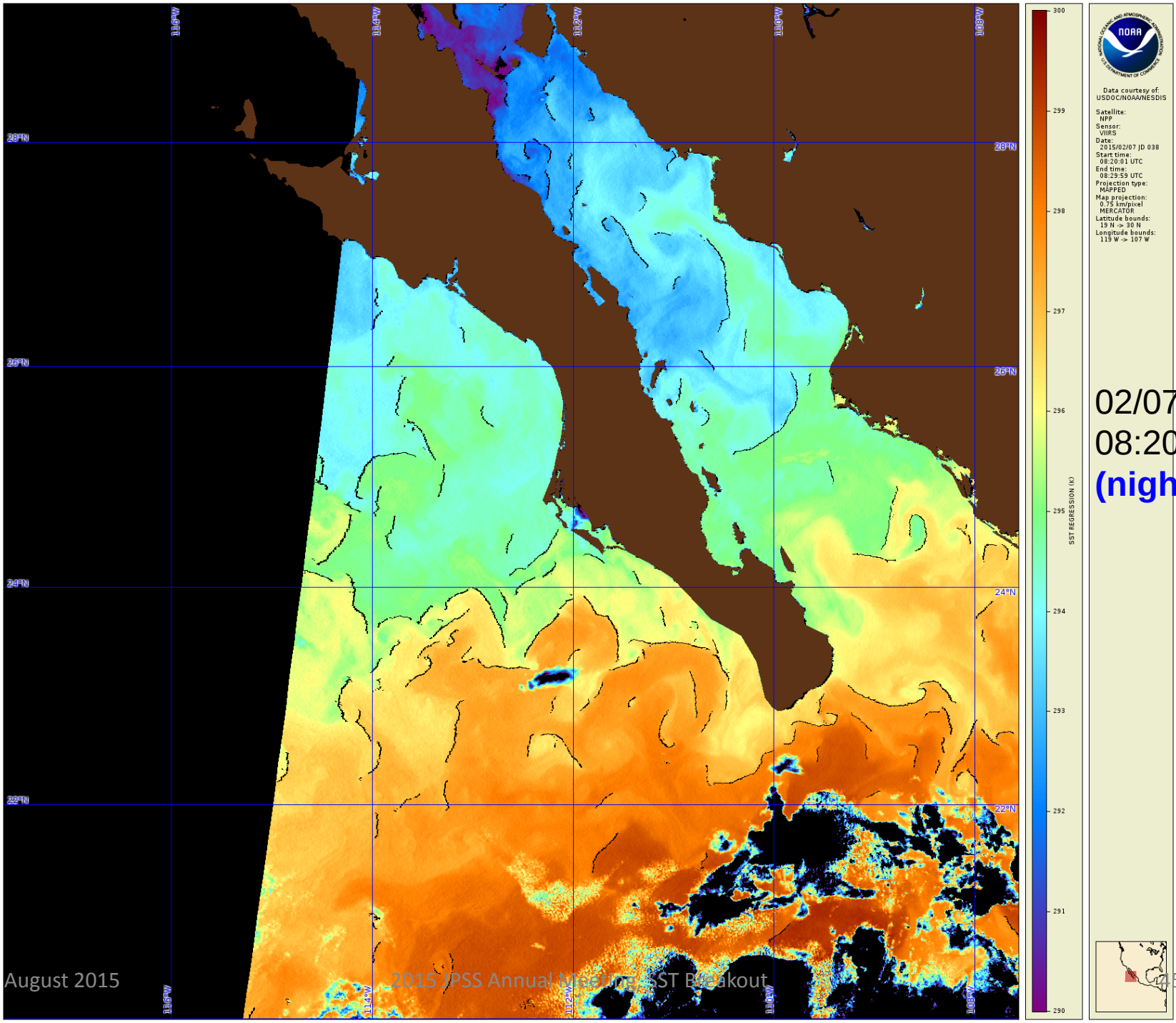
02/03/2015
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(night)



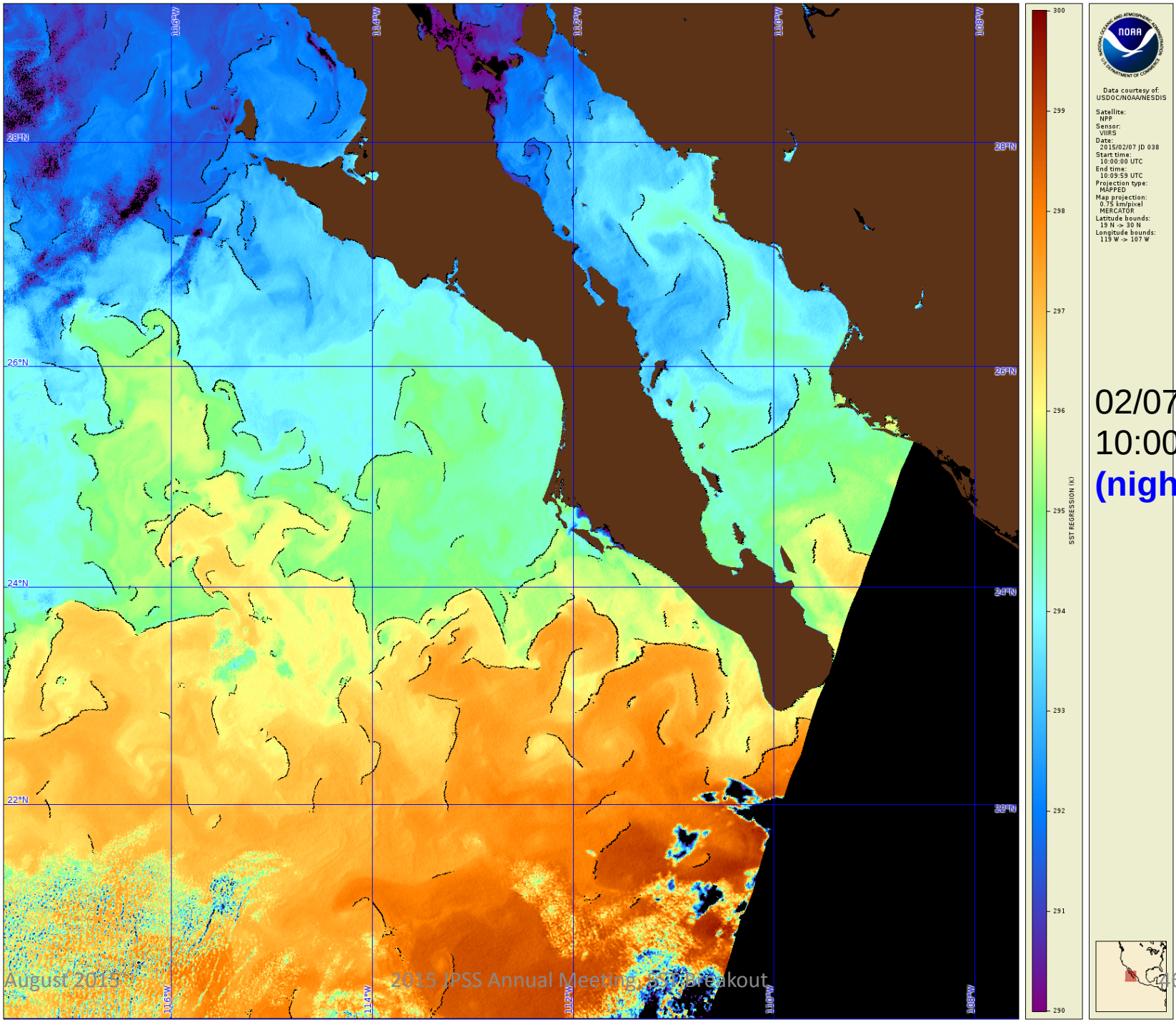
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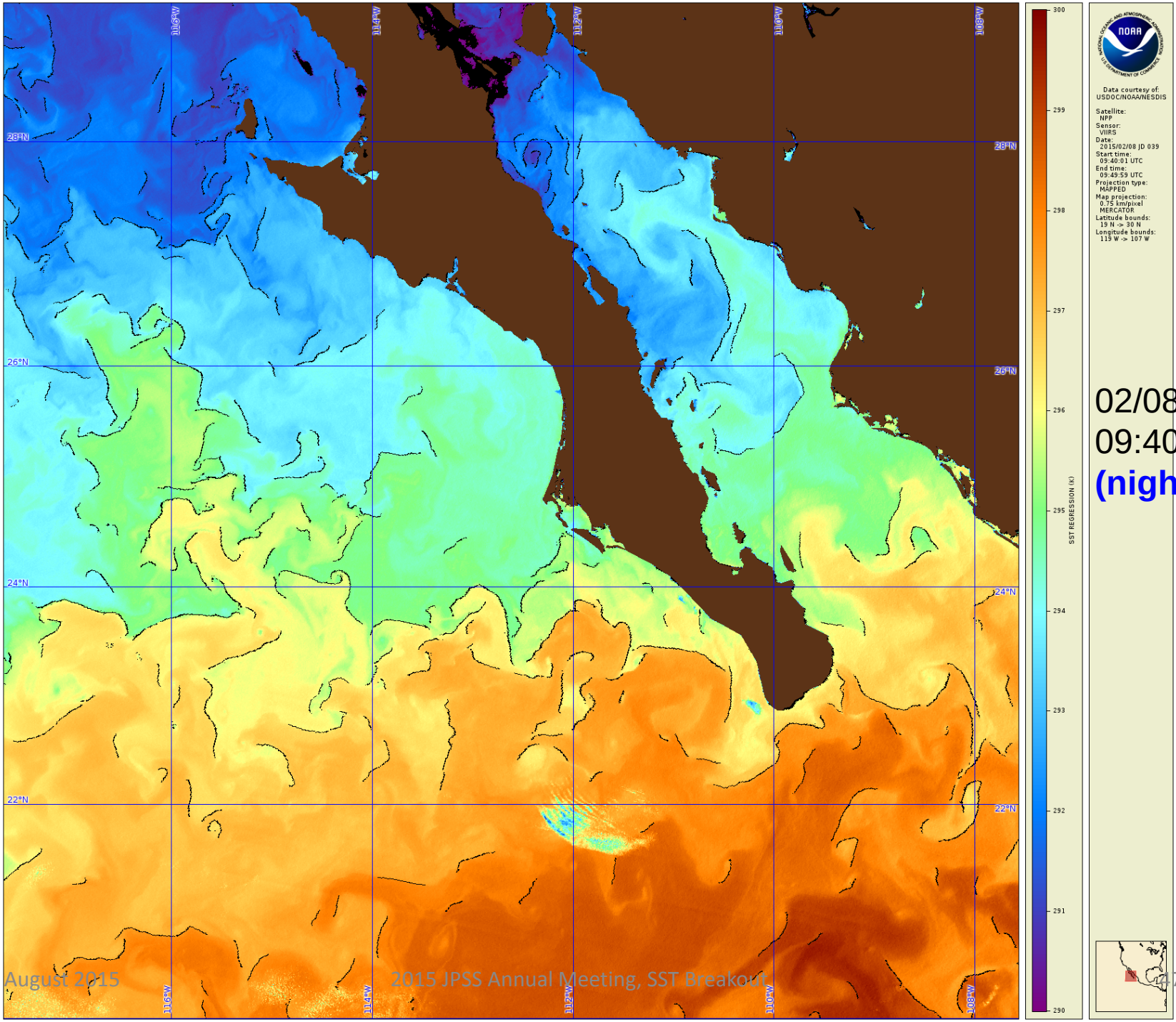
02/06/2015
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(night)



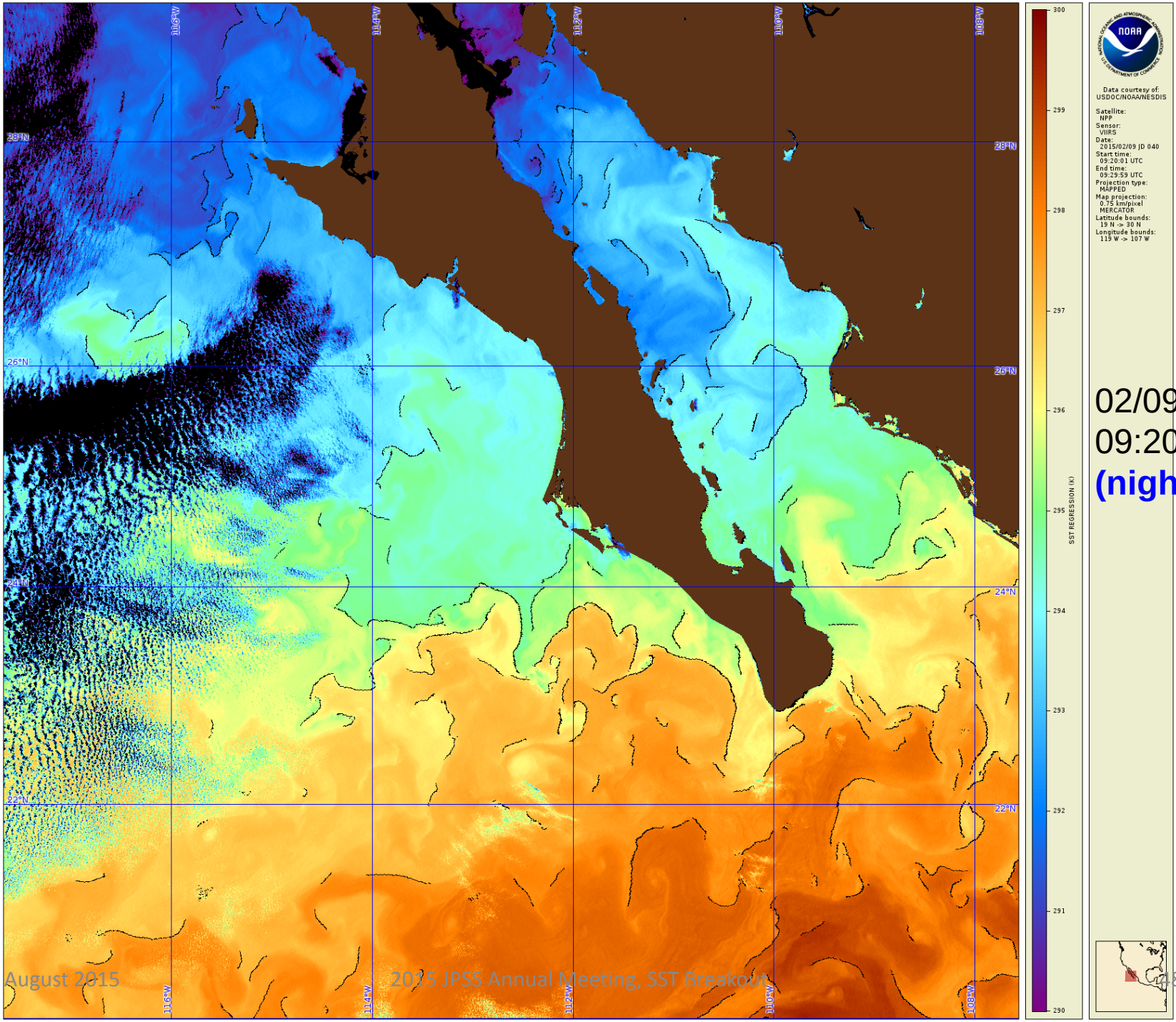
02/07/2015
08:20 UTC
(night)



02/07/2015
10:00 UTC
(night)



02/08/2015
09:40 UTC
(night)



02/09/2015
09:20 UTC
(night)

ACSPO Planned Milestones

Main objective: Improve clear sky mask (with focus on dynamic, coastal, and high-latitude areas)

ACSPO 2.50 (Mar 2016): Improve BT and SST Imagery: Resample (de-bowtize) & Restore pixels in bow-tie areas deleted onboard

ACSPO 2.60 (Dec 2016): Version 1 of (1) Pattern recognition improvements to ACSPO clear-sky mask; and (2) Oceanic Thermal Front Product (can save bit mask; reaching out to user community for additional requirements).

Plan

- **Implement resampling/reordering algorithms with ACSPO VIIRS and MODIS (ACSPO v2.50)**
- **The L2 VIIRS and MODIS swath product will contain**
  a) **Resampled BT and SST values**
  b) **bow-tie pixels filled in (but flagged as "filled", in case users don't want to use estimated values)**
- **Implement pattern recognition algorithms in ACSPO v2.60 Generate Ocean Fronts Product, improve Clear-Sky Mask**
- **Comprehensively test/evaluate the improved ACSPO clear-sky mask**
- **Work with L4 users to evaluate the effect on their analyses**

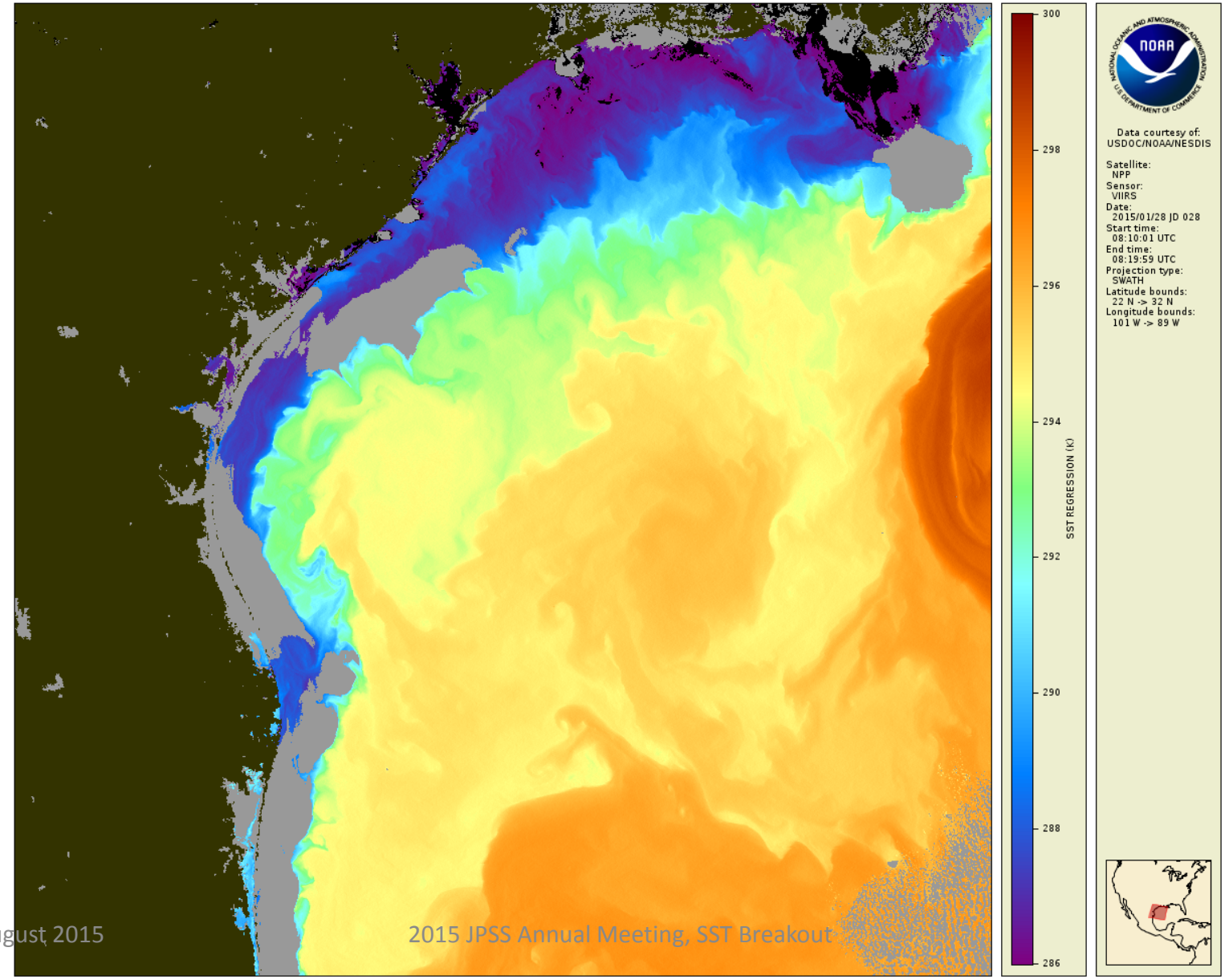
Backup Slides

Practical Considerations

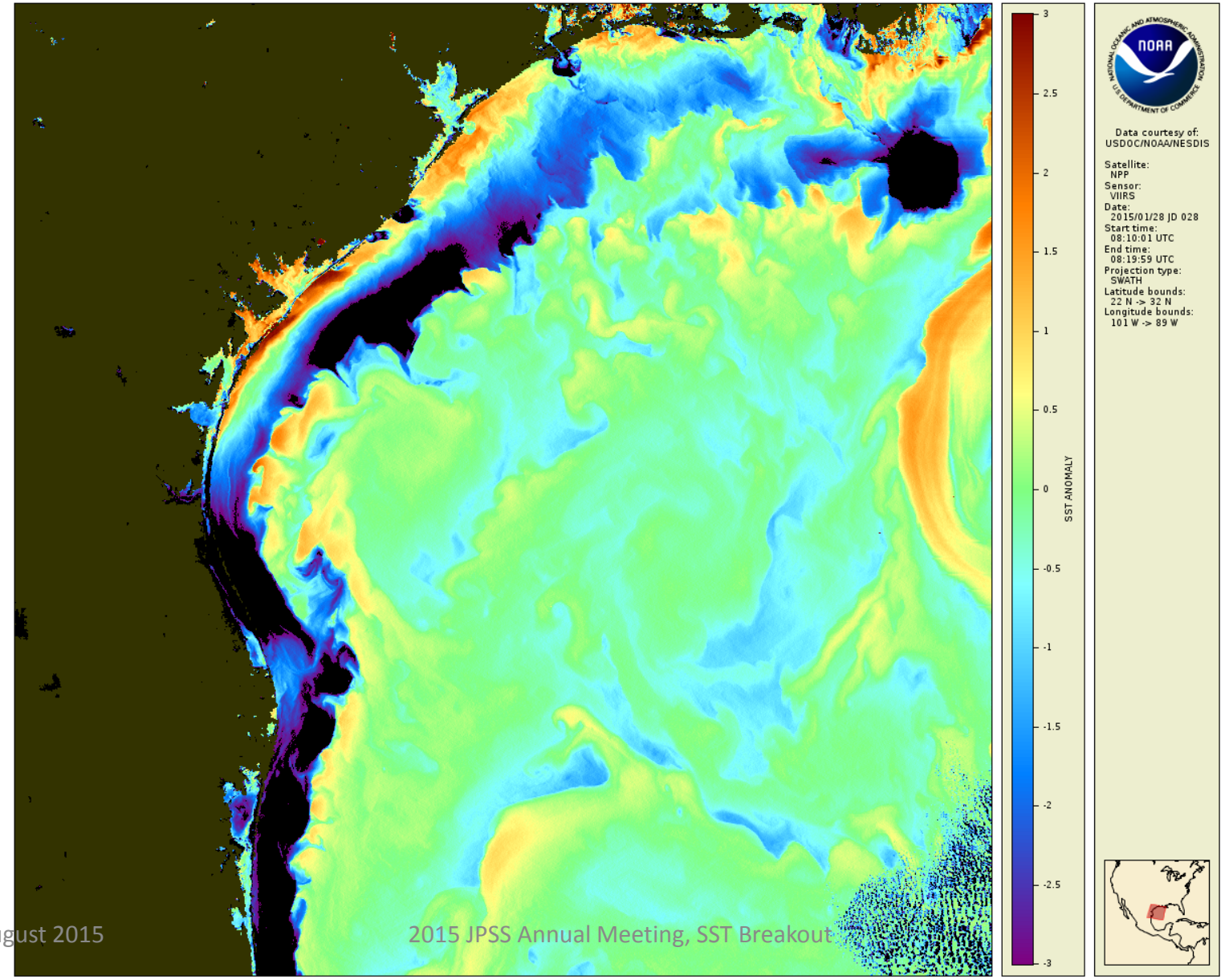
Algorithm is meant for real time processing at the Level 2 products. We use the following standard functions from optimized openCV library:

- **gradient filter**
- **range filter**
- **median filter**
- **standard deviation filter**
- **Gaussian filter**
- **Laplacian of Gaussian (LoG) filter**
- **bilateral filter**
- **zero crossing filter**
- **erosion/dilation morphological function**
- **connected components**

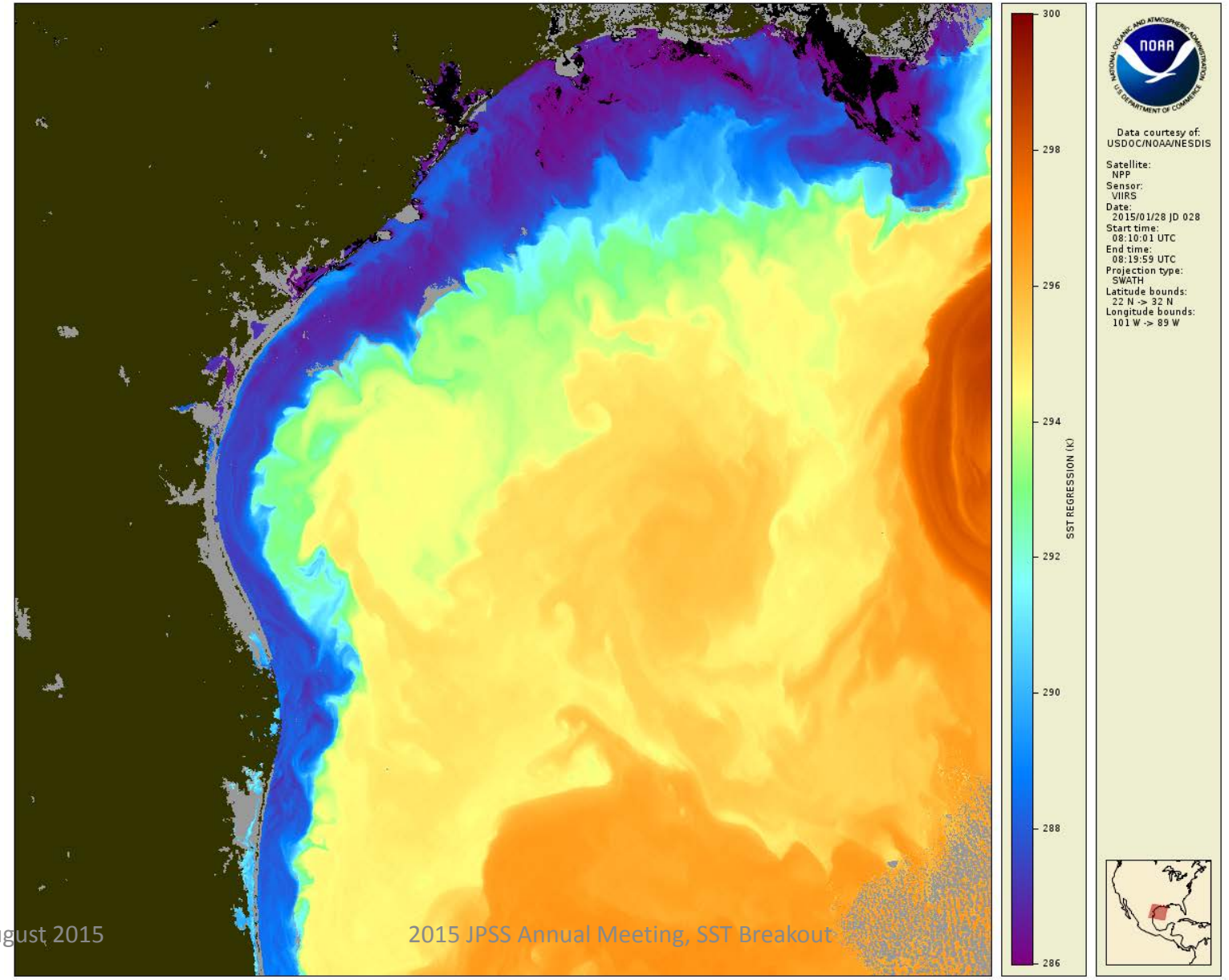
Current clear-sky mask



Delta SST


3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
SST ANOMALY
Data courtesy of:
USDOC/NOAA/NESDIS
Satellite:
NPP
Sensor:
VIIRS
Date:
2015/01/28 JD 028
Start time:
08:10:01 UTC
End time:
08:19:59 UTC
Projection type:
SWATH
Latitude bounds:
22 N -> 32 N
Longitude bounds:
101 W -> 89 W

Improved clear-sky mask



Thermal Fronts

