UNIVERSIDADE DE SÃO PAULO
Instituto Oceanográfico

Laboratório de Oceanografia por Satélites

A geometrical approach for Level 3 (super) collated and Level 4 SST analysis

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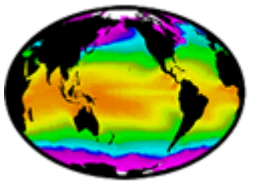
Universidade de São Paulo



GHRSST
GROUP FOR HIGH RESOLUTION SEA SURFACE TEMPERATURE

FAPESP
SÃO PAULO RESEARCH FOUNDATION

21th GHRSST International Science Team Meeting
Online, 1-4 June 2020

Motivation

- SST gradients/fronts play an important role in several fields (fisheries, ocean-atmosphere interaction, submarine acoustic communication...)

- Climatology of SST gradients can be used to improve cloud masking at Level 2

- So far, focus of satellite-based SST validation is conducted purely from a statistical perspective, i.e., bias/std against *in situ* measurements, **however**

- Statistical validation ≠ validation of gradients (see presentation from Jorge Vazquez)

GHRSST SST products terminology

- L2P: SST in swath projection (from one satellite sensor)
- L3U: “Uncollated” SST in lat/lon grid (from one satellite sensor)
- L3C: “Collated” SST in lat/lon grid using multiple observations from one sensor over a time window (1 hour, 1 day, 1 week...)
- L3S: “Super-Collated” SST in lat/lon grid using multiple observations from multiple sensors over a time window (1 hour, 1 day, 1 week...)
- L4: Gap-free SST in lat/lon grid using satellite (+ *in situ*) within an SST analysis (Optimal Interpolation, weighted average, multiscale analysis)

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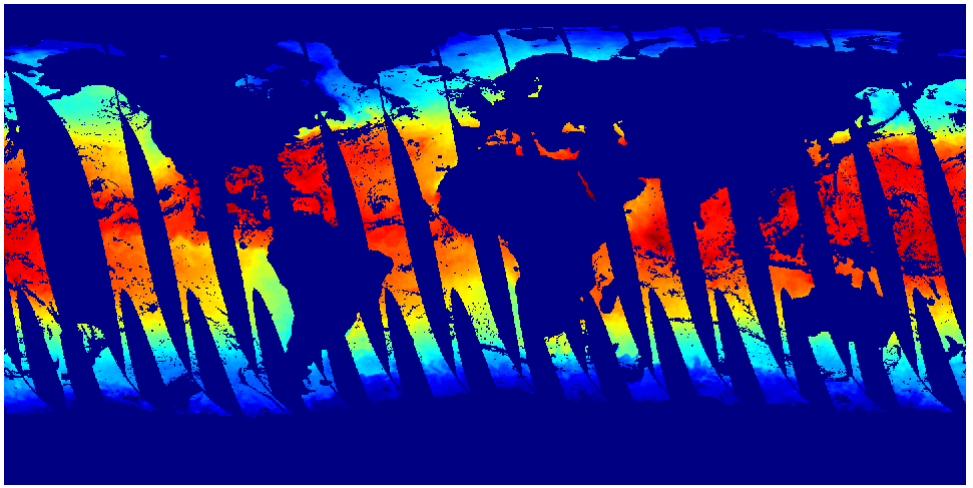
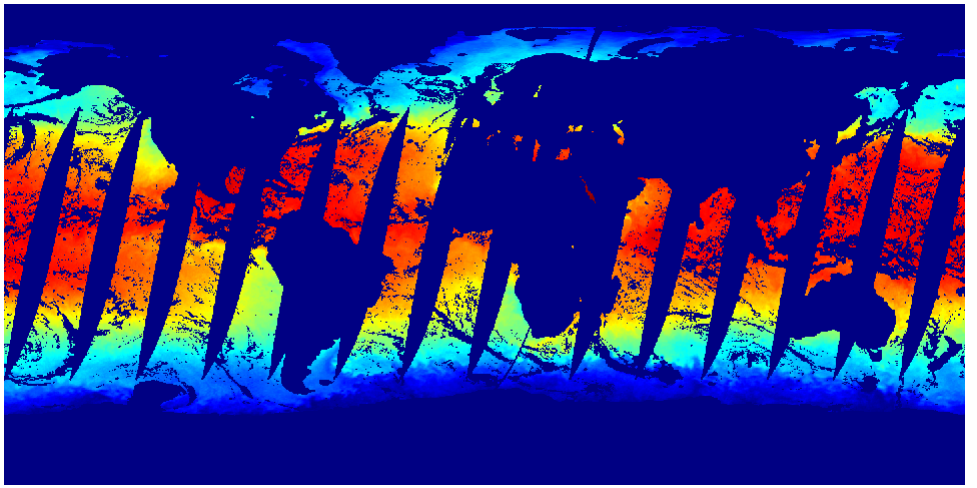
Limitations of standard compositing
Case study: L3C from AMSR2 L3U SST

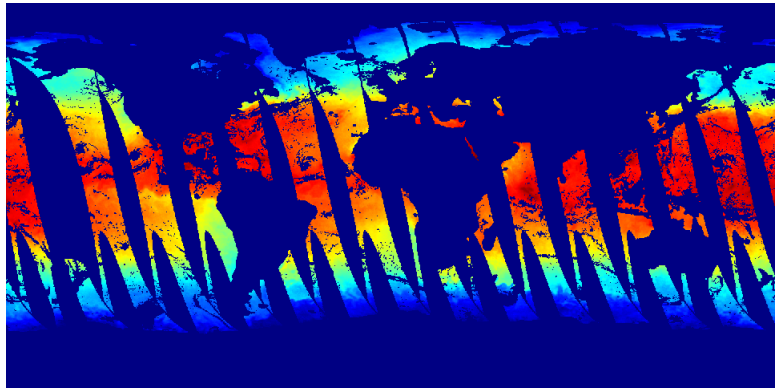


L3U SST from ascending node
September 09, 2018

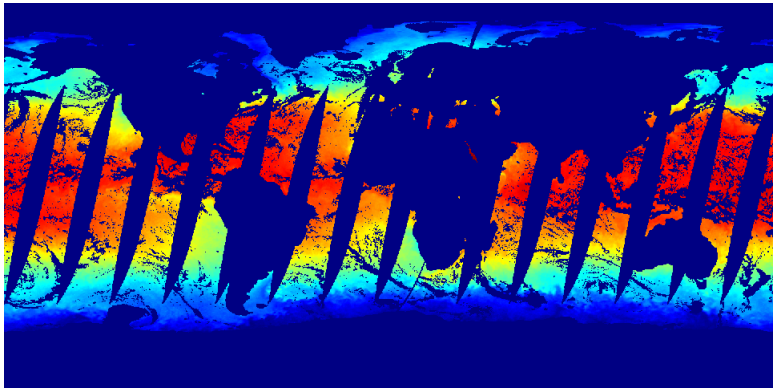


L3U SST from descending node
September 09, 2018

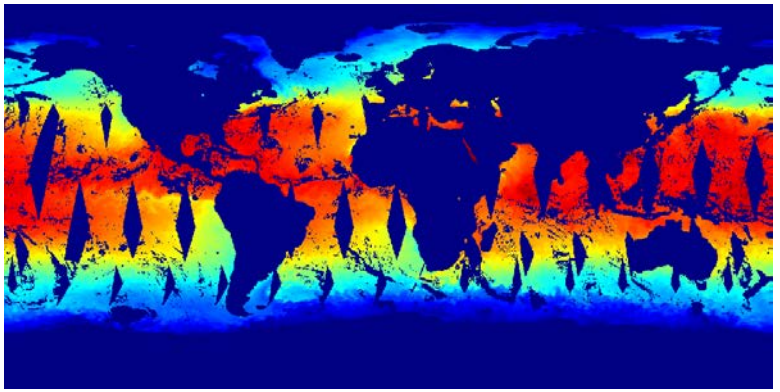
Limitations of standard compositing
Case study: L3C from AMSR2 L3U SST



L3U SST from ascending node
September 09, 2018



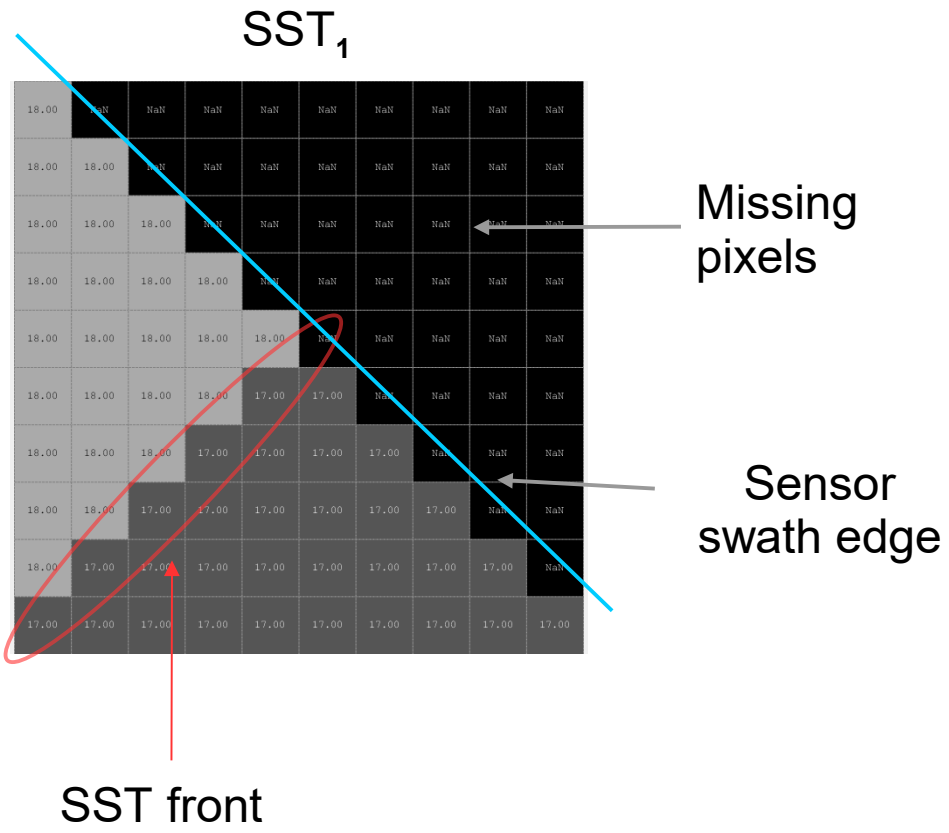
L3U SST from descending node
September 09, 2018



L3C SST (daily)
September 09, 2018

Standard merging/compositing

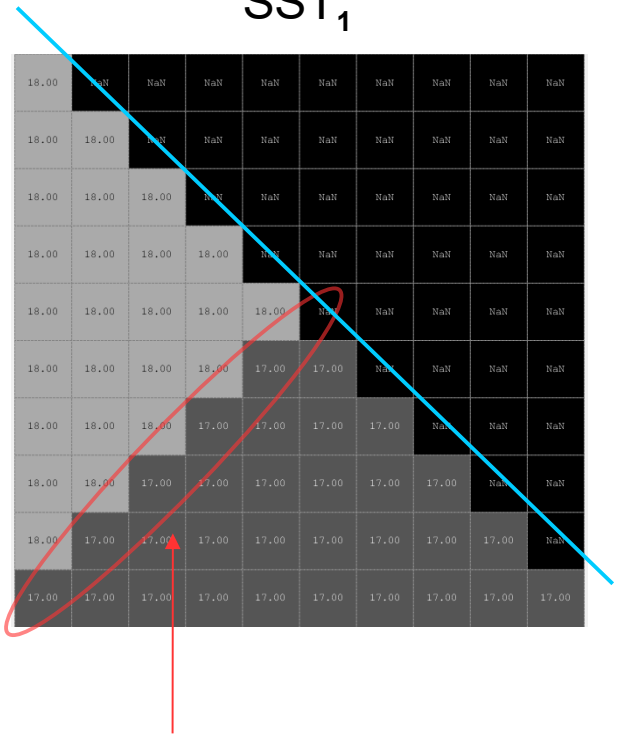
Time t



Standard merging/compositing

Time t

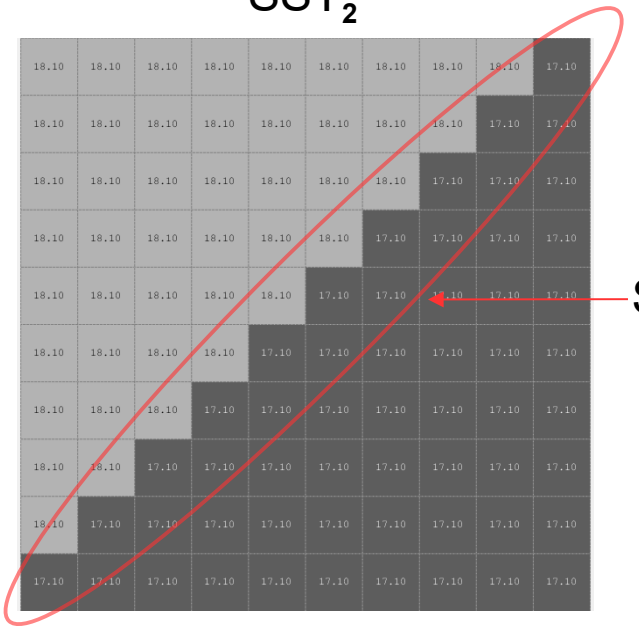
SST_1



SST front

Time t+1

SST_2



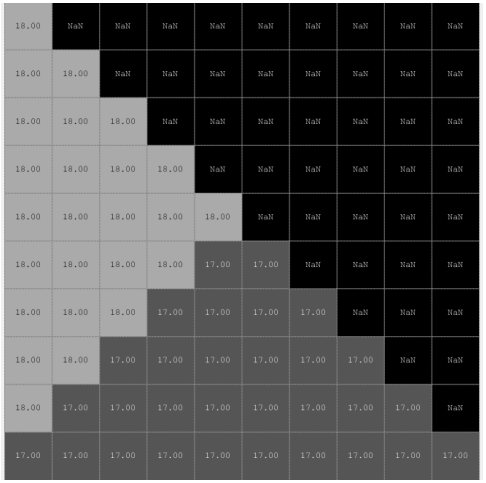
SST front

Overpass observation
bias = 0.1°C
(diurnal cycle, angular bias...)

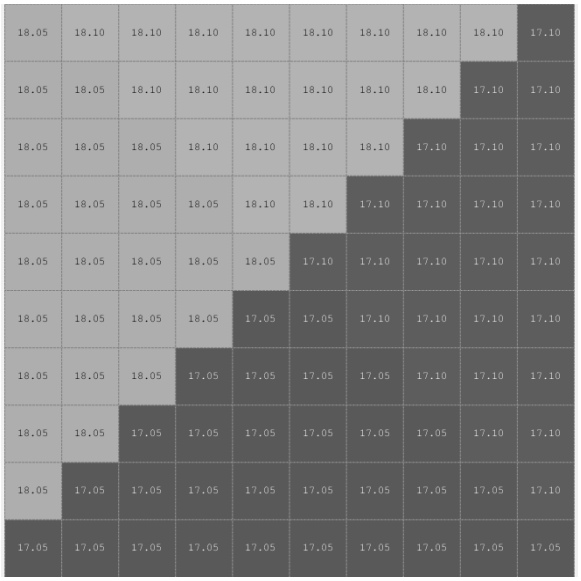
Standard merging/compositing

Time t

SST_1

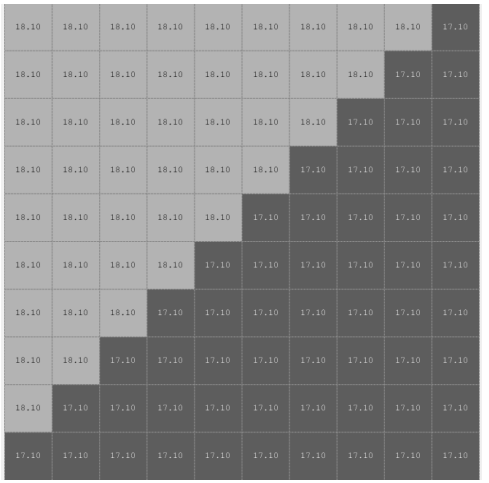


(SST_1, SST_2)



Time t+1

SST_2

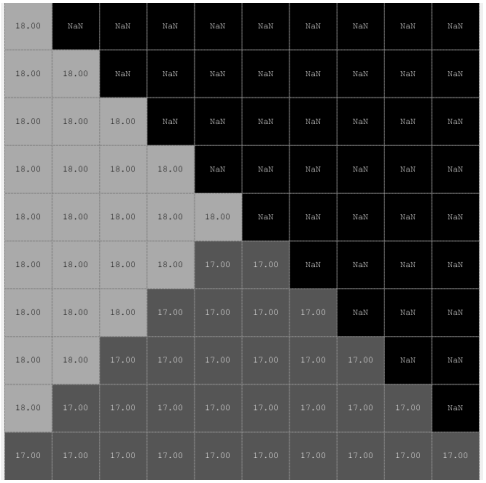


Overpass observation
bias = 0.1°C
(diurnal cycle, angular bias...)

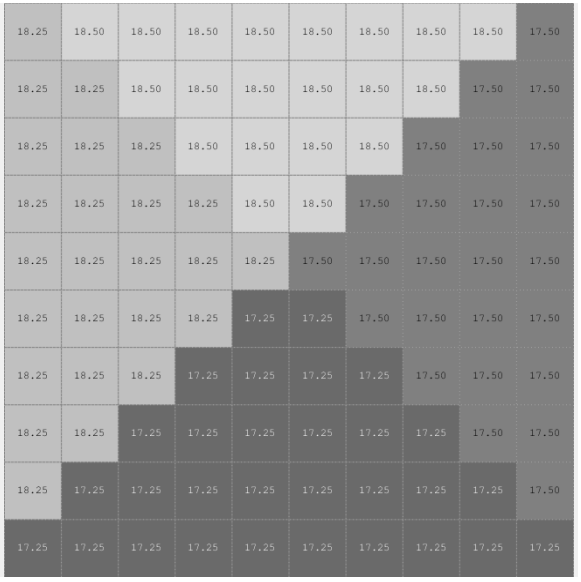
Standard merging/compositing

Time t

SST_1

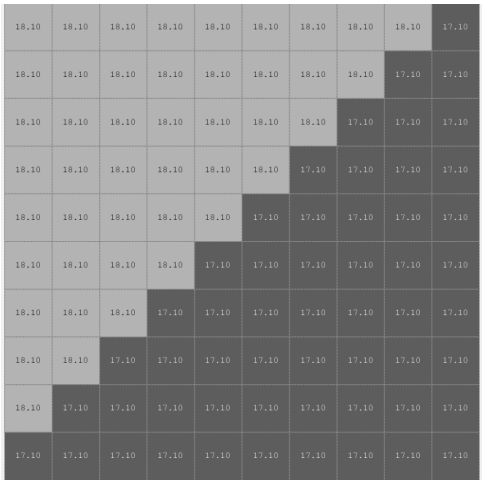


$\overline{(SST_1, SST_2)}$



Time t+1

SST_2

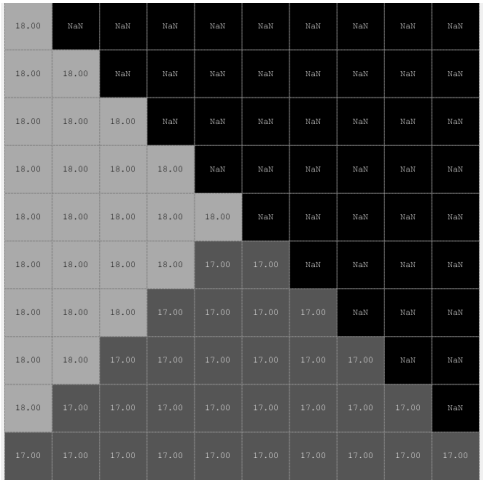


Overpass observation
bias = 0.5°C
(diurnal cycle, angular bias...)

Standard merging/compositing

Time t

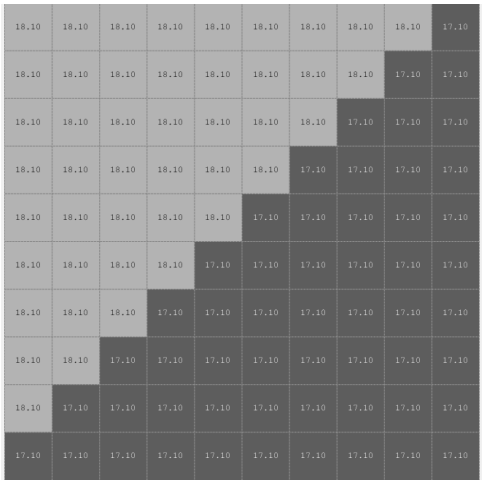
SST_1



$\overline{(SST_1, SST_2)}$

Time t+1

SST_2



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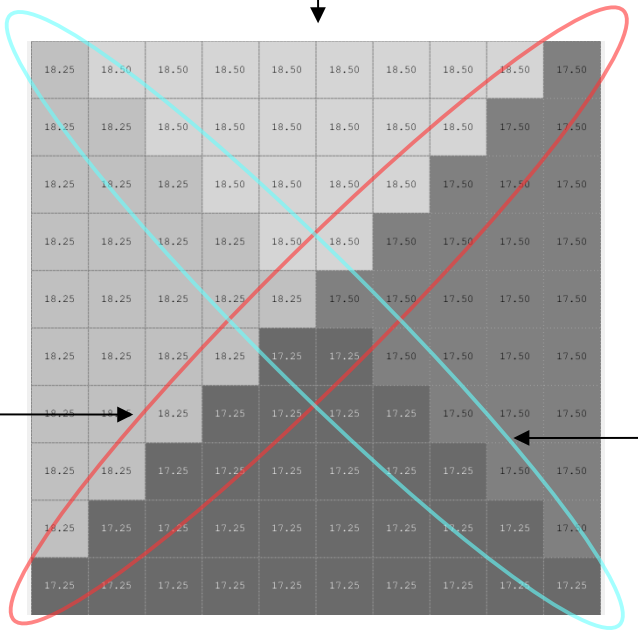
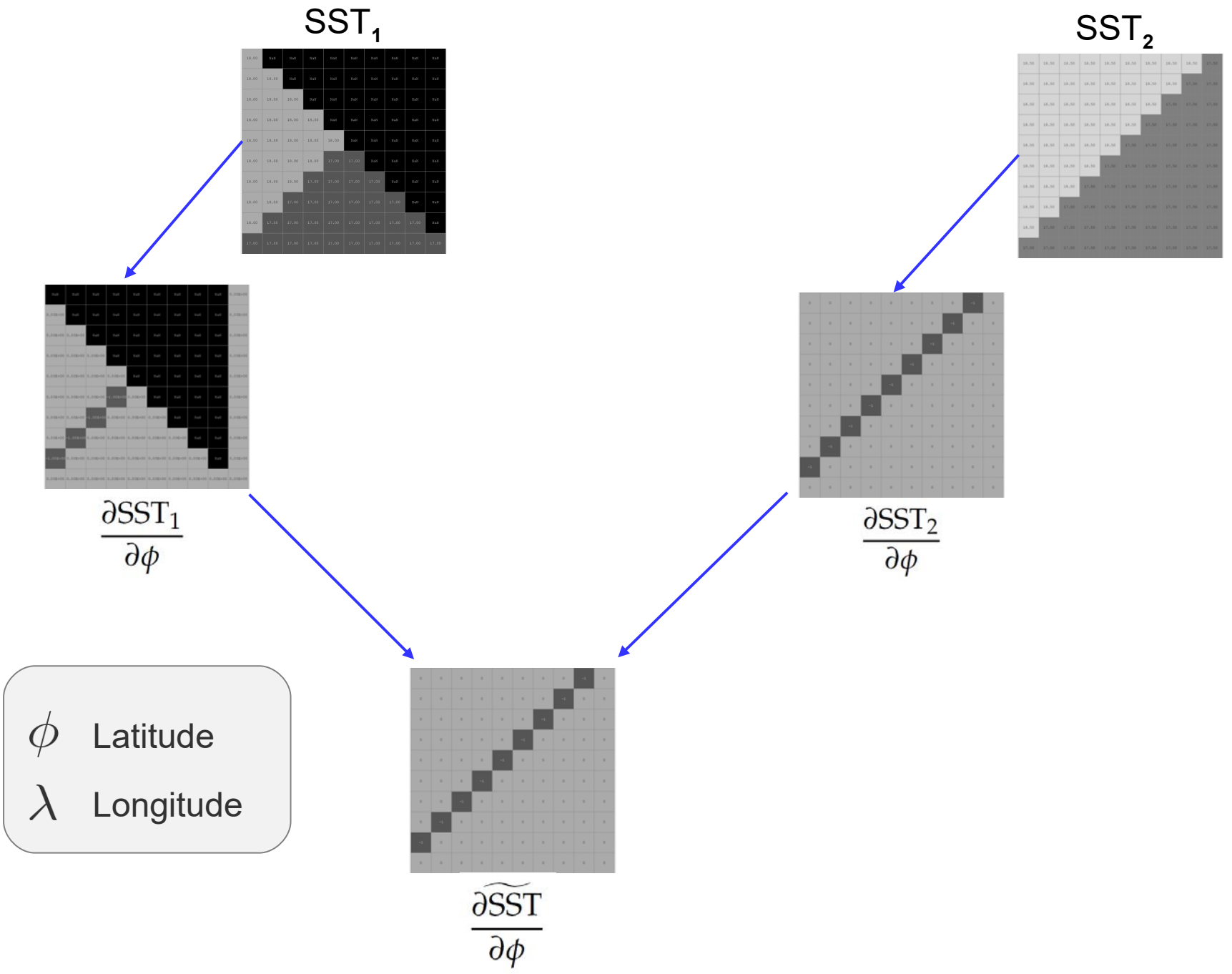


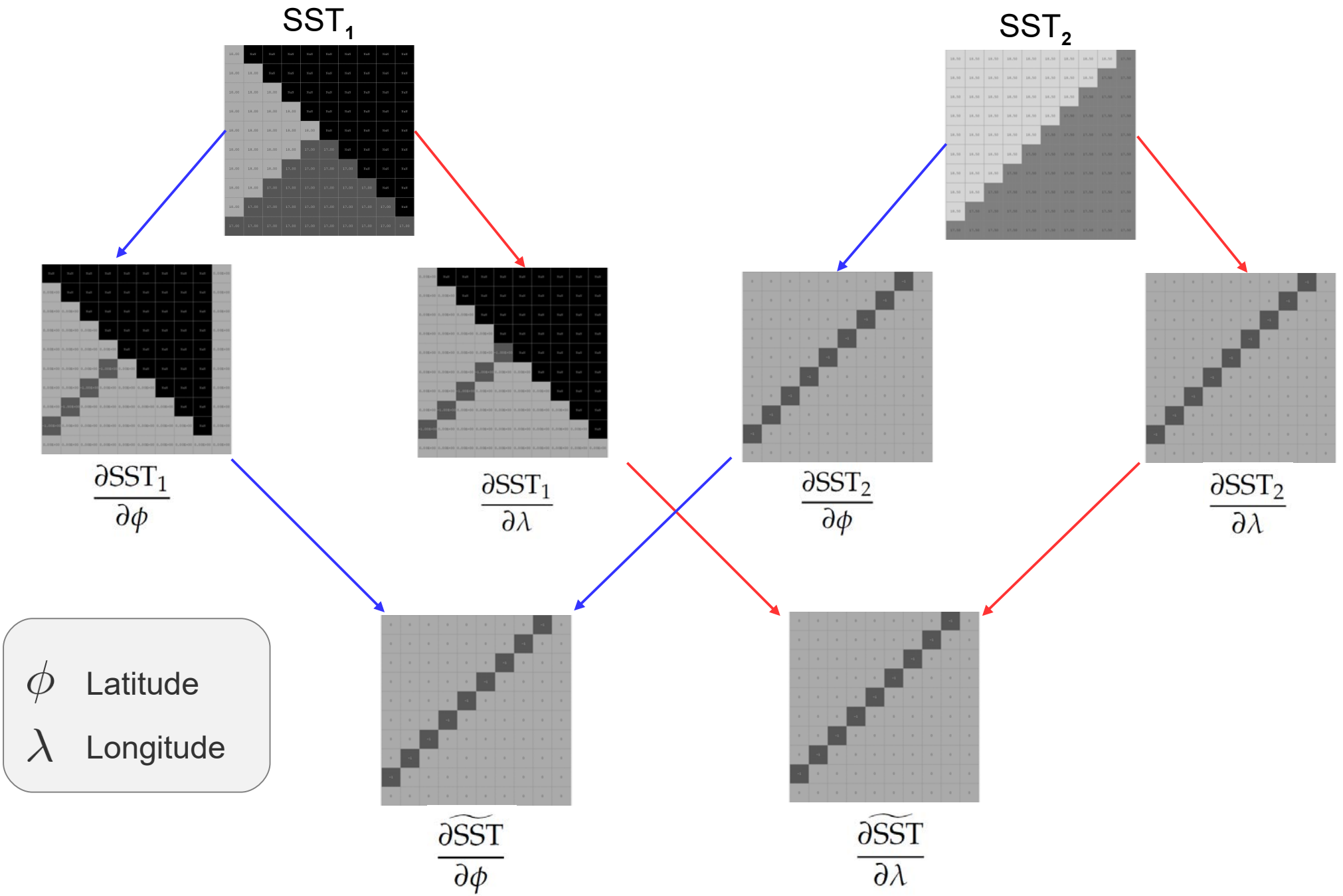
SST front

Artifact aligned
with swath edge

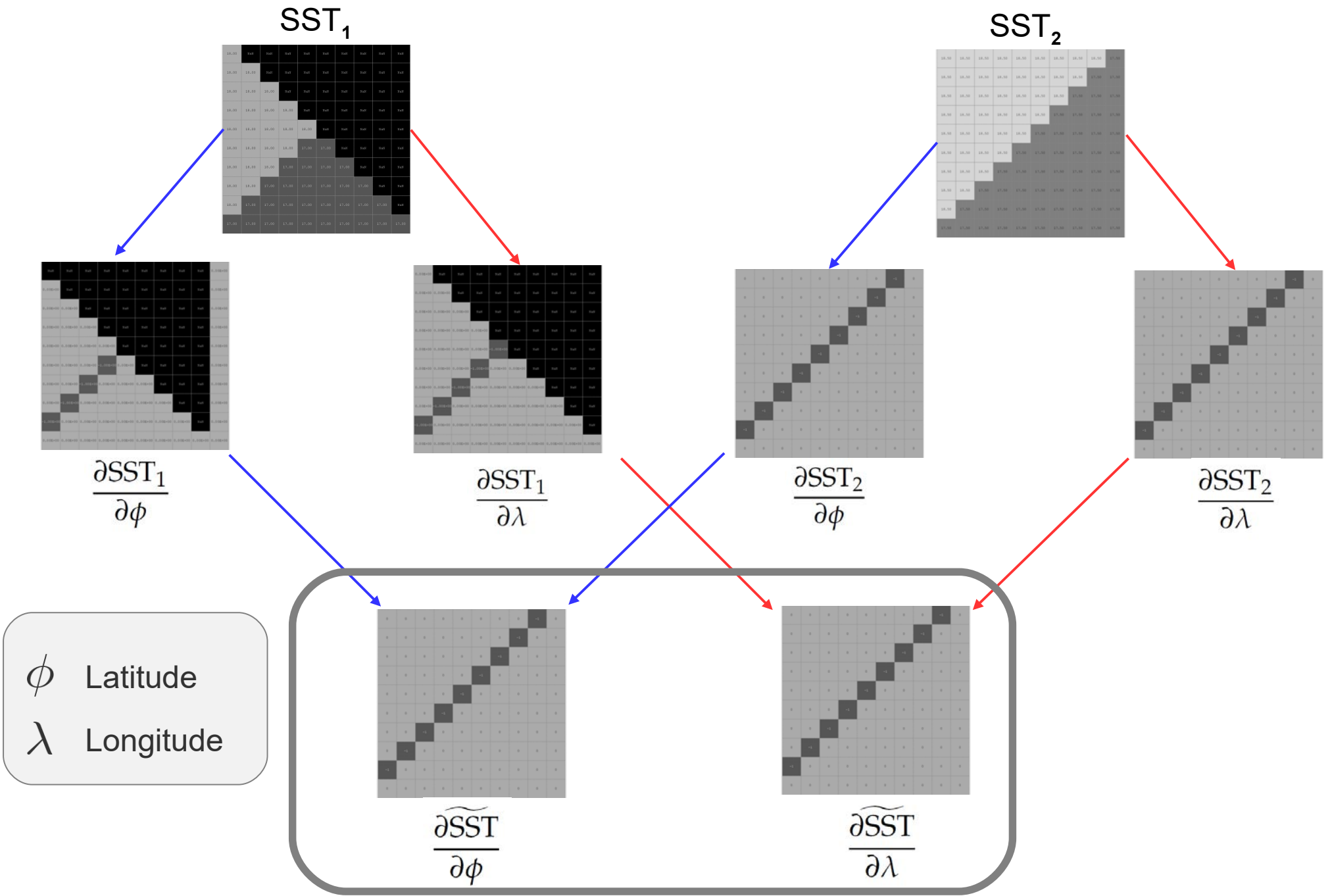
Gradient-domain merging



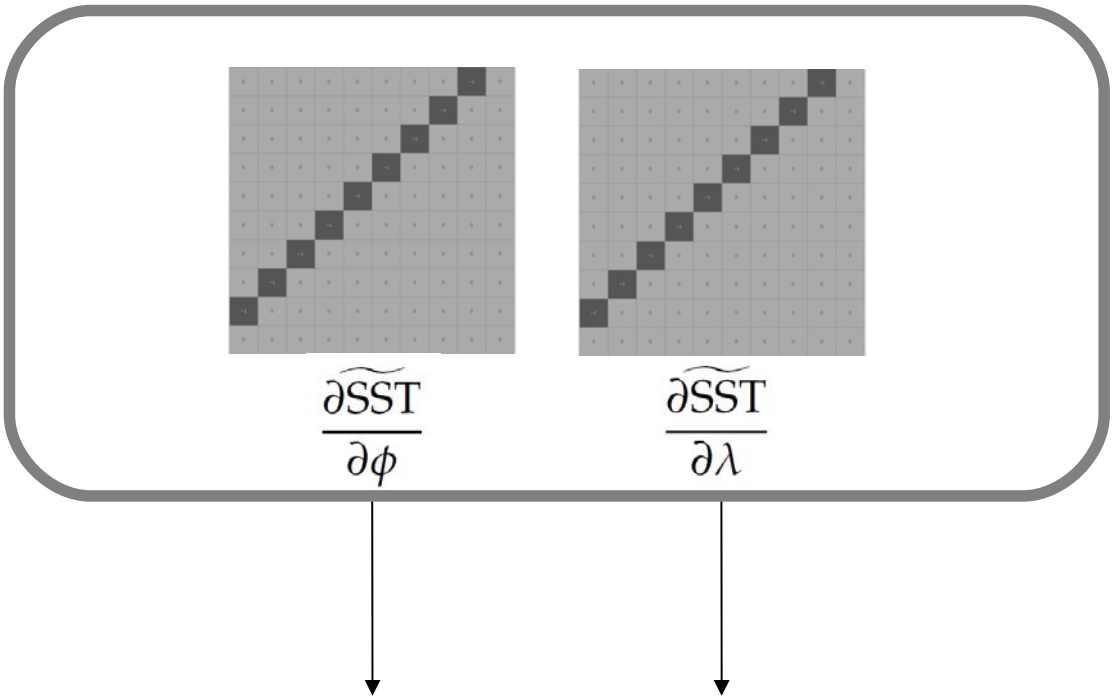
Gradient-domain merging



Gradient-domain merging



Gradient-domain merging

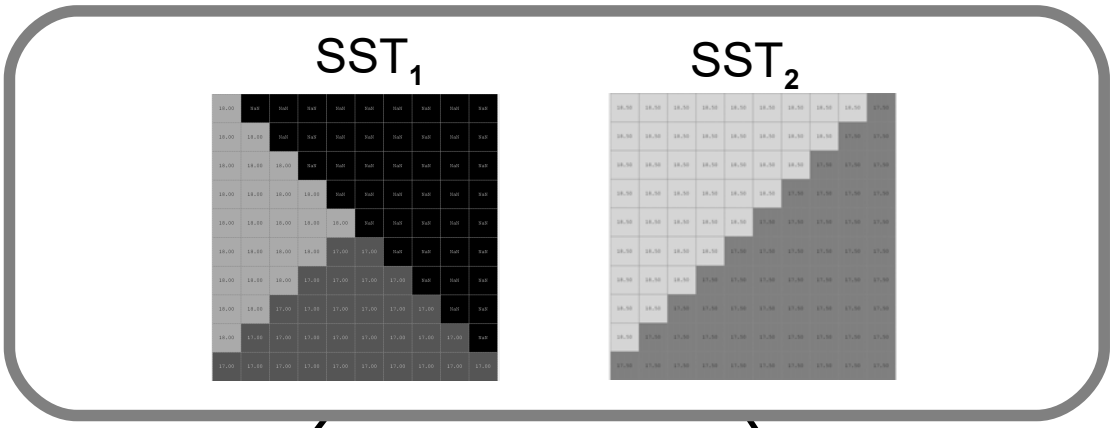


$$\int_{\phi}\int_{\lambda}\left(\widetilde{\frac{\partial sst}{\partial \phi}}\,,\ \widetilde{\frac{\partial sst}{\partial \lambda}}\right)d\phi\,d\lambda$$

ϕ Latitude

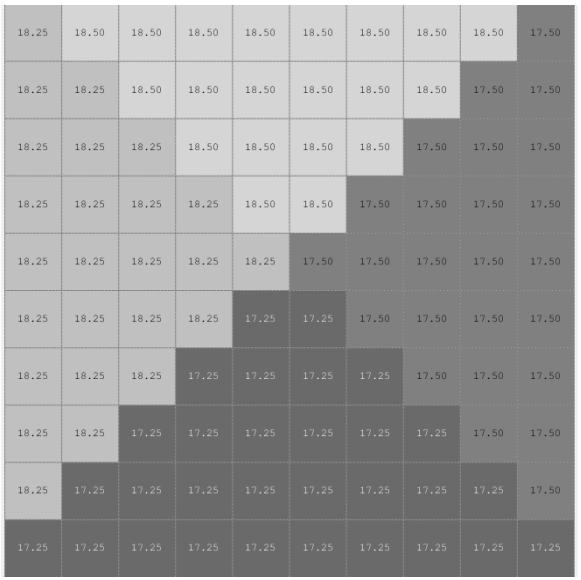
λ Longitude

Standard vs gradient-based merging



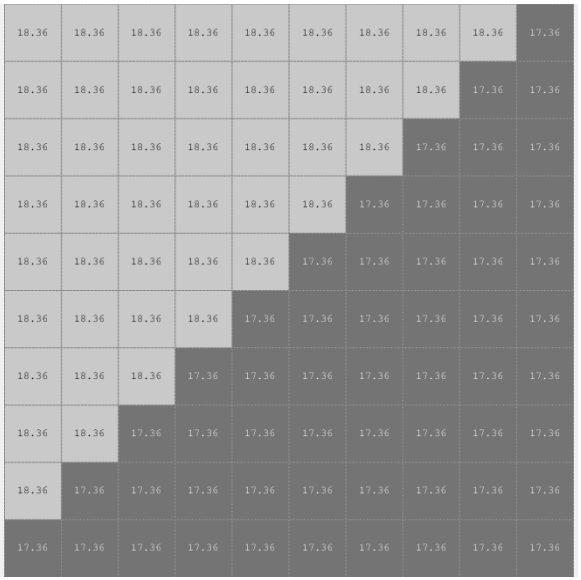
Standard merging

Gradient-based merging



Statistics ✓

Gradients ✗



Statistics ✓

Gradients ✓

L3C from AMSR2

Study area: Gulf Stream
(intense frontal activity in the mesoscale and submesoscale)

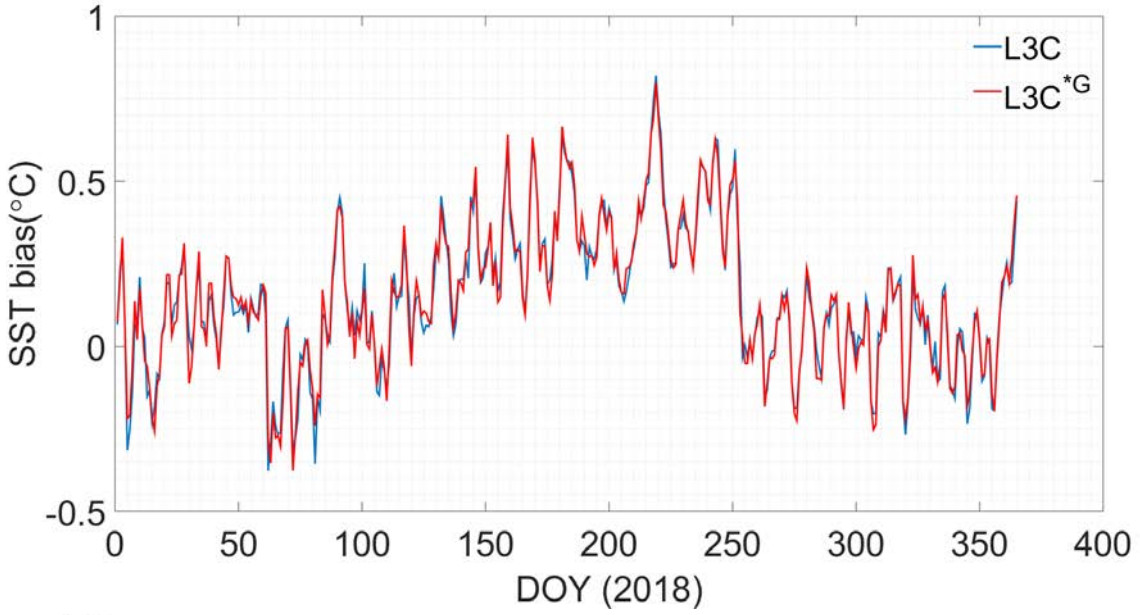
Input:
One year of daily data for 2018.
L3U AMSR2 REMSS (v8a) (PODAAC)
All data reprojected to a 0.05° grid

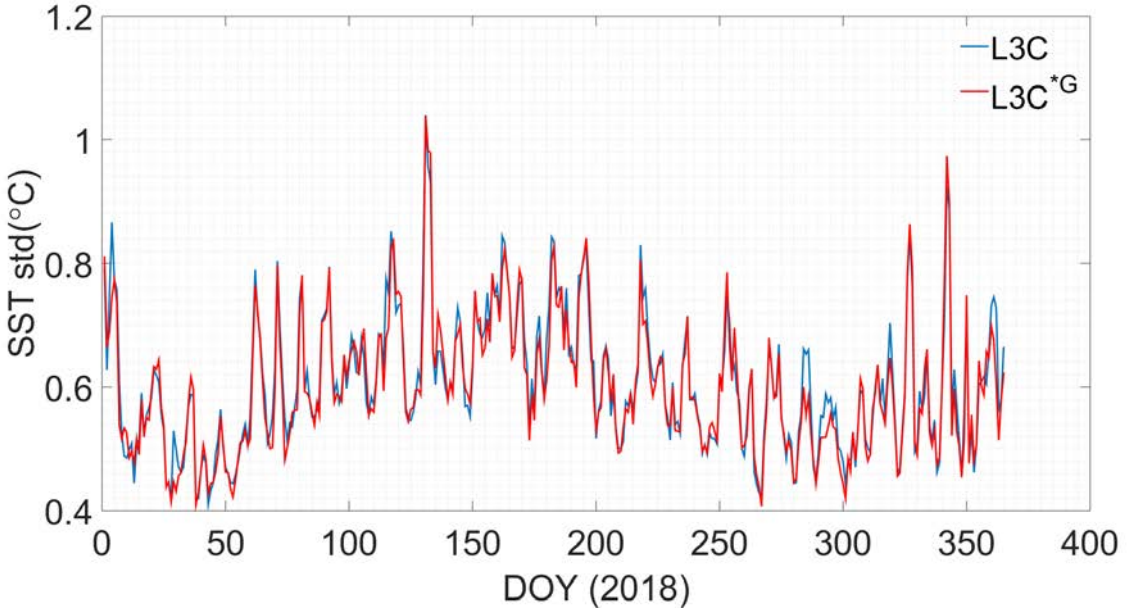
Output:
Two collated SST products
- L3C: Standard composite
- L3C*G: Gradient-domain merging

Validation:
NOAA/NESDIS iquam v2.1
- Quality flag 5 (best quality)
- Drifting buoys + Coastal moored buoys

L3C from AMSR2 (±1 day)

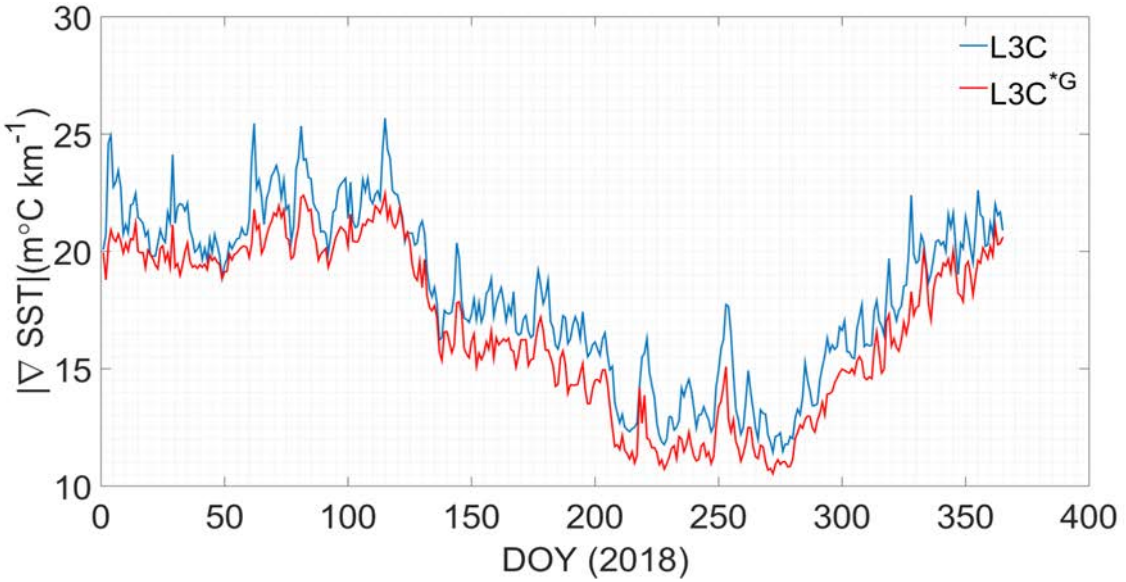
Validation statistics L3C vs L3C^{*G}

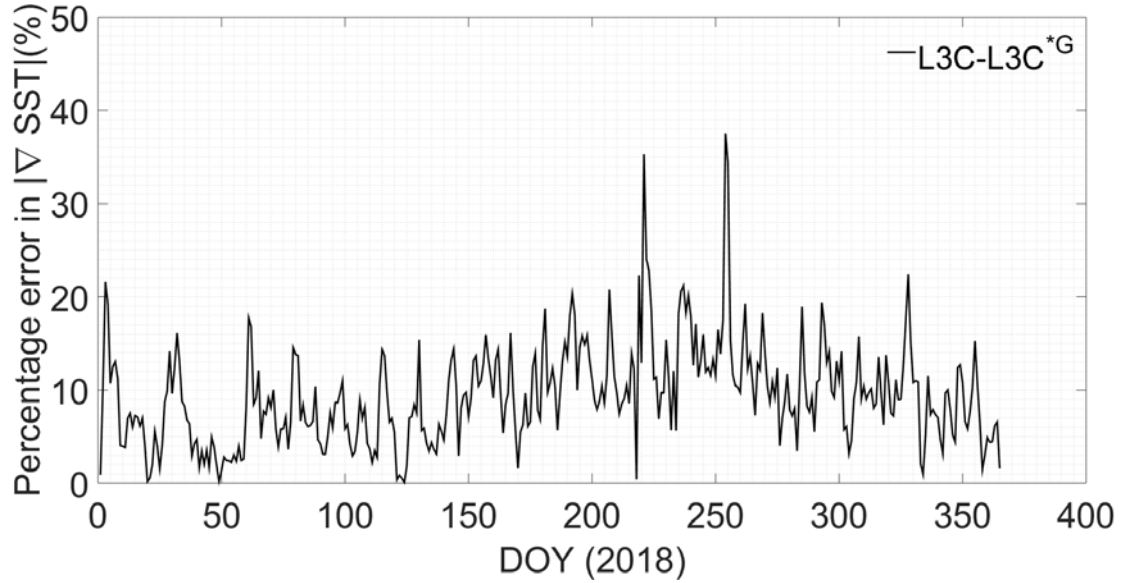




L3C from AMSR2 (±1 day)

SST gradients L3C vs L3C^{*G}

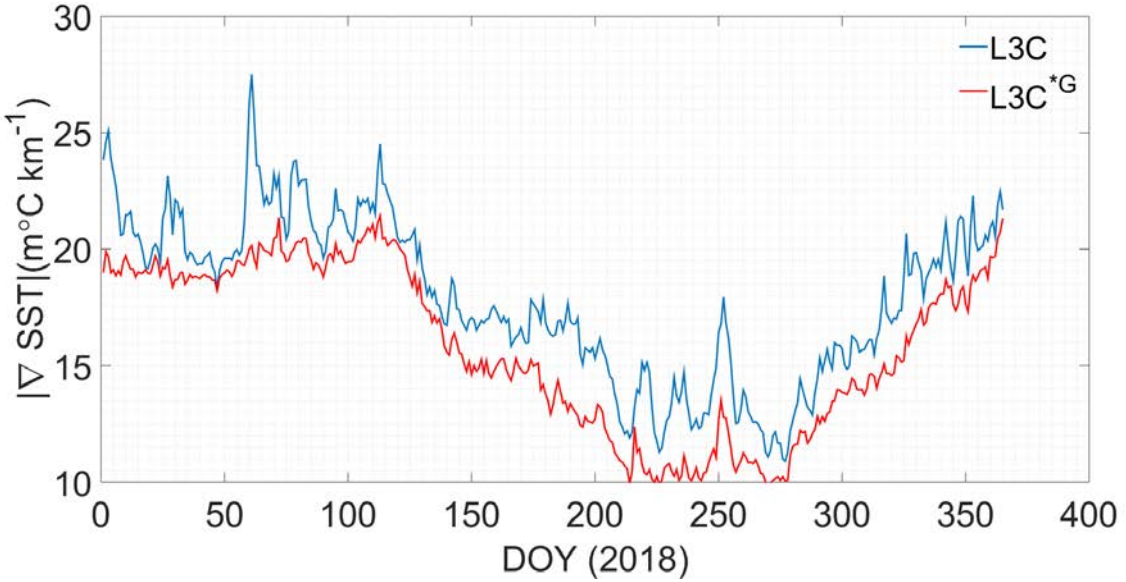


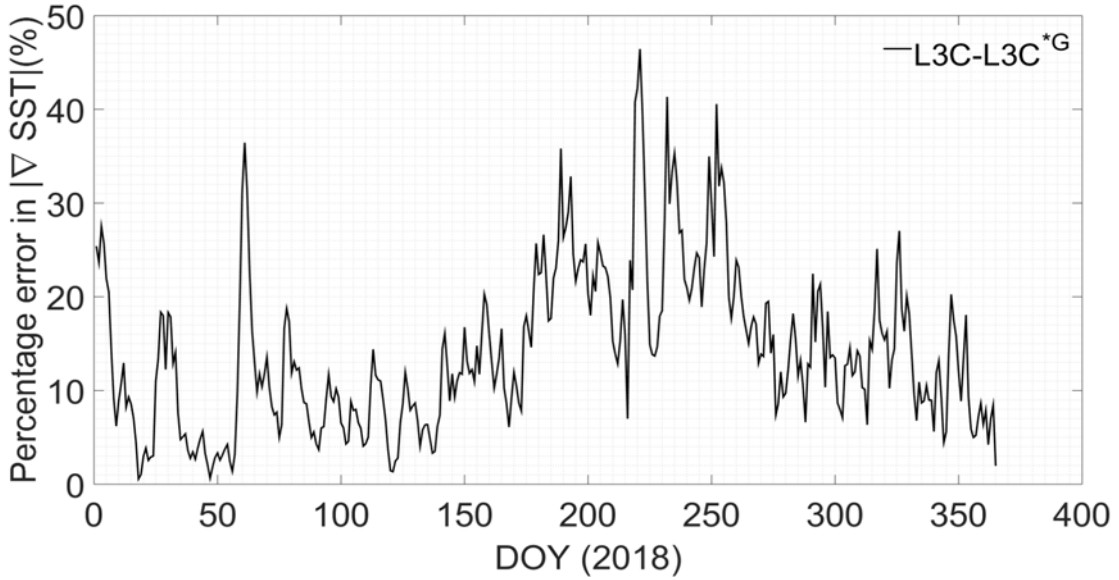


~10% error for 2018

L3C from AMSR2 (±3 days)

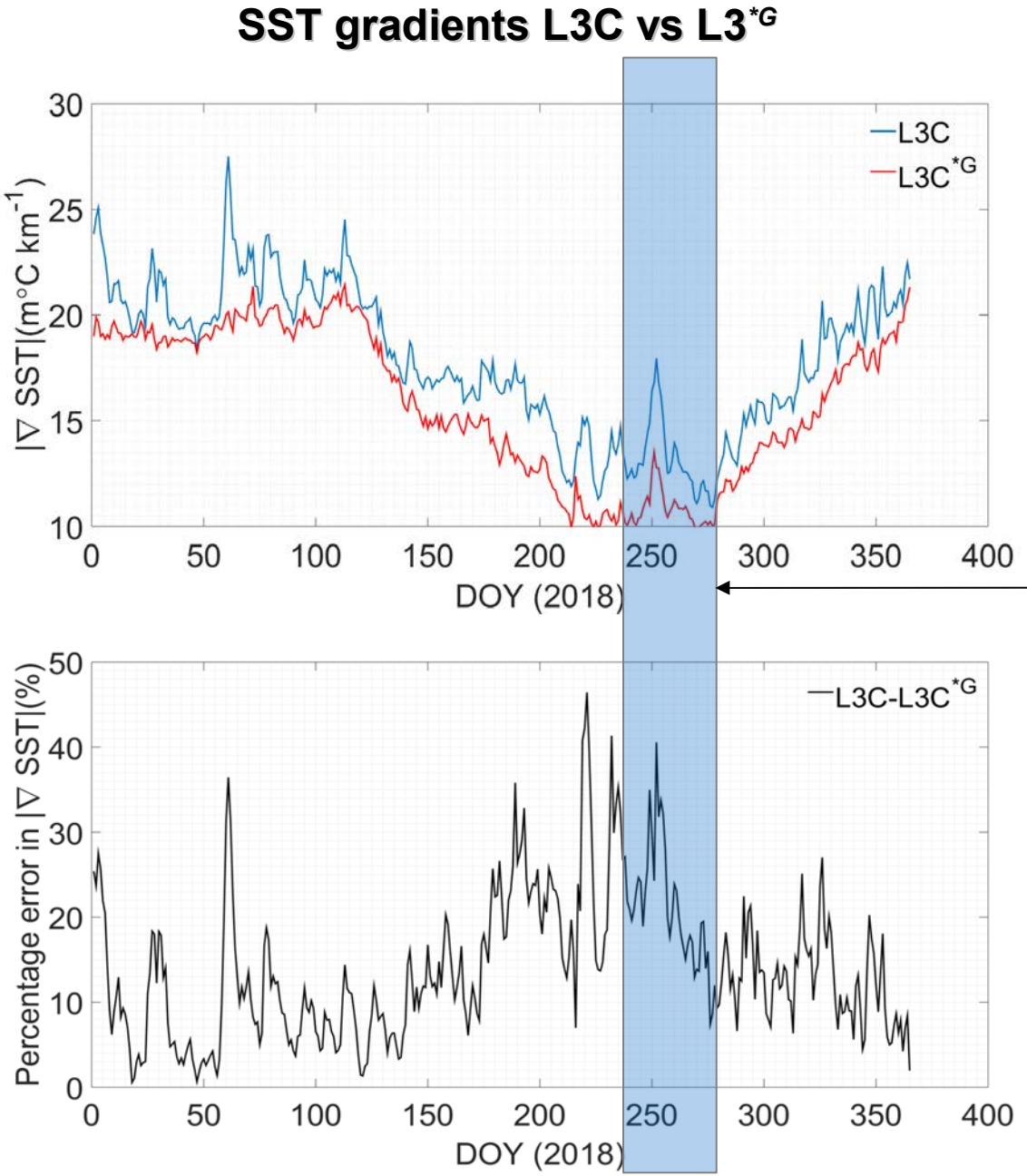
SST gradients L3C vs L3C^{*G}





~15% error for 2018

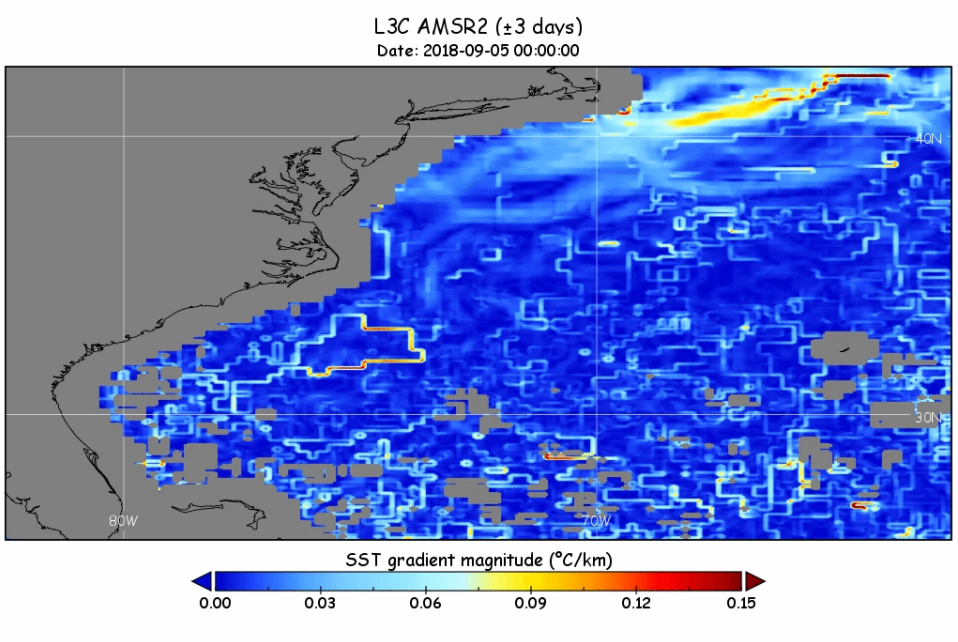
L3C from AMSR2 (±3 days)



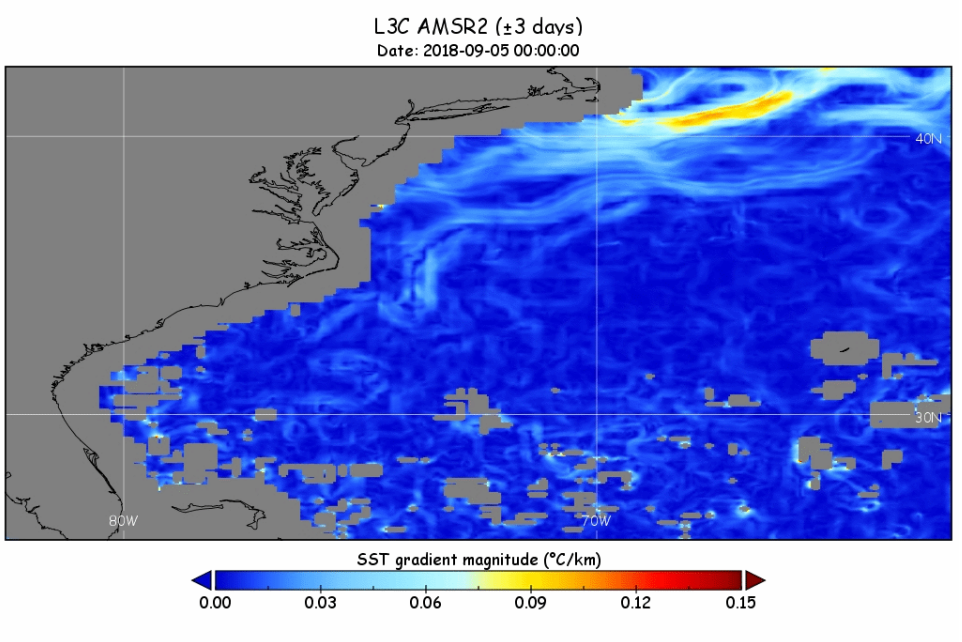
September 5-20, 2018

L3C from AMSR2

SST gradient magnitudes: September 5–20, 2018



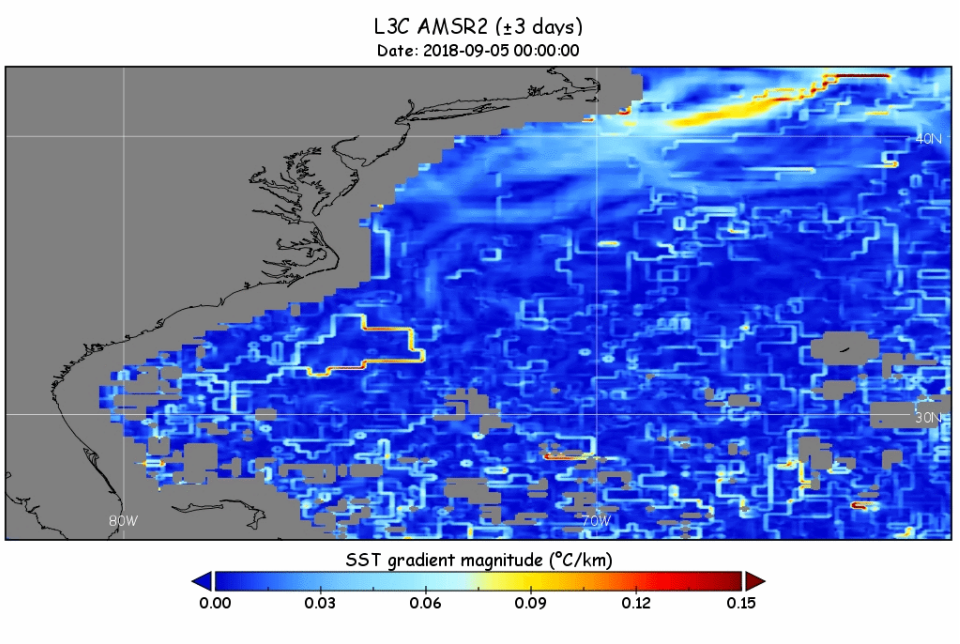
L3C



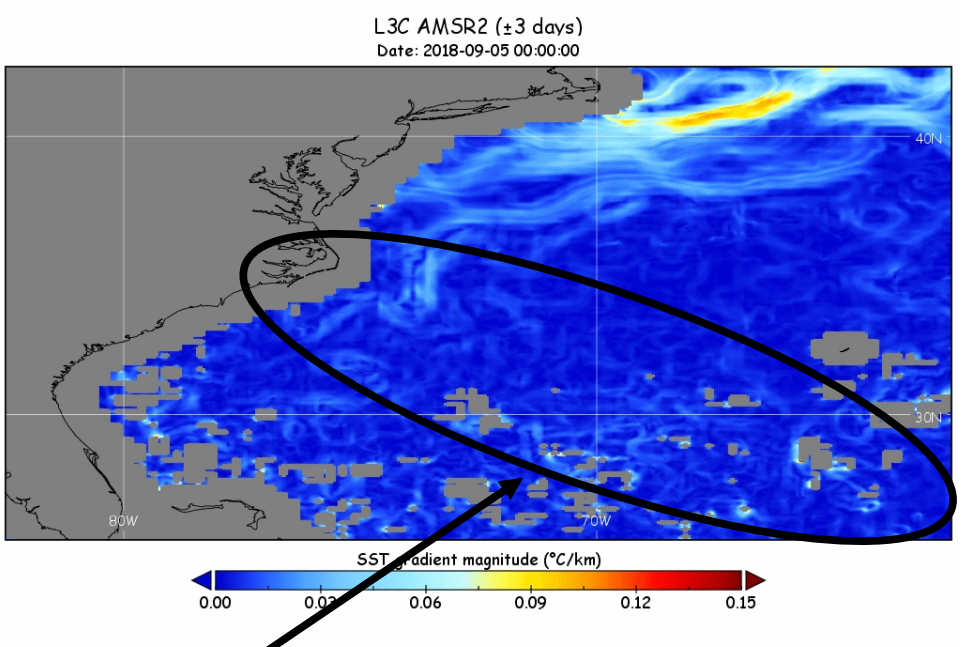
L3C*G

L3C from AMSR2

SST gradient magnitudes: September 5–20, 2018



L3C



L3C*G

Hurricane Florence path
(August 31-September 18, 2018)

L3S from VIIRS/MODIS

Input:
NASA/JPL L2P v2.0 (https://podaac.jpl.nasa.gov/)
- SNPP VIIRS
- Aqua MODIS
- Terra MODIS

Processed with alternative cloud mask to reduce over-flagging of fronts*
All data reprojected to a 0.05° grid

Output:
Two super-collated SST products
- L3S: Standard compositing
- L3S*G: Gradient-based merging

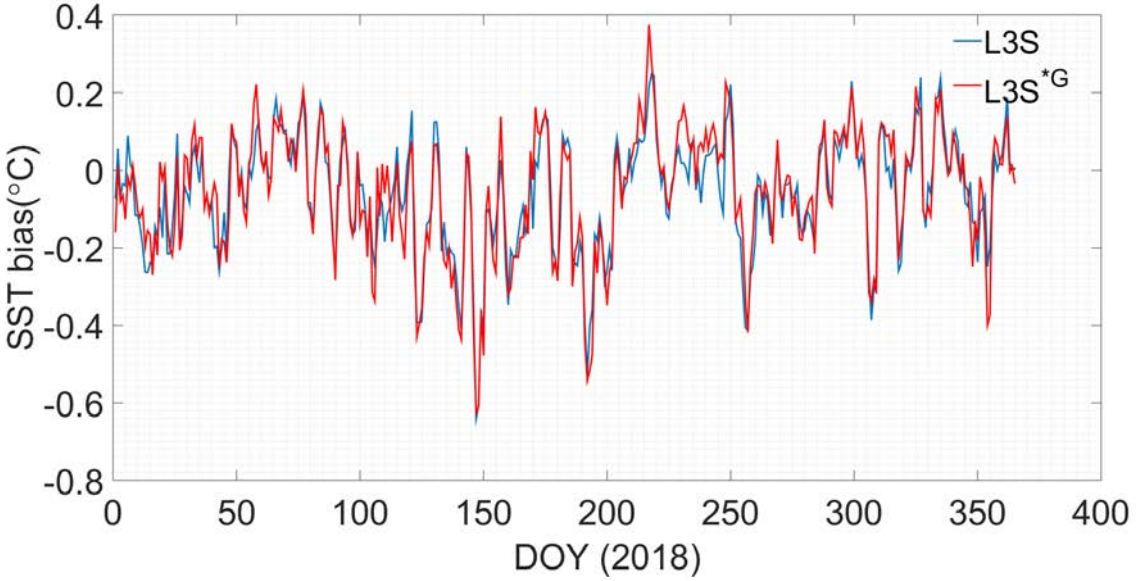
Validation:
NOAA/NESDIS iquam v2.1
- Quality flag 5 (best quality)
- Drifting buoys + Coastal moored buoys

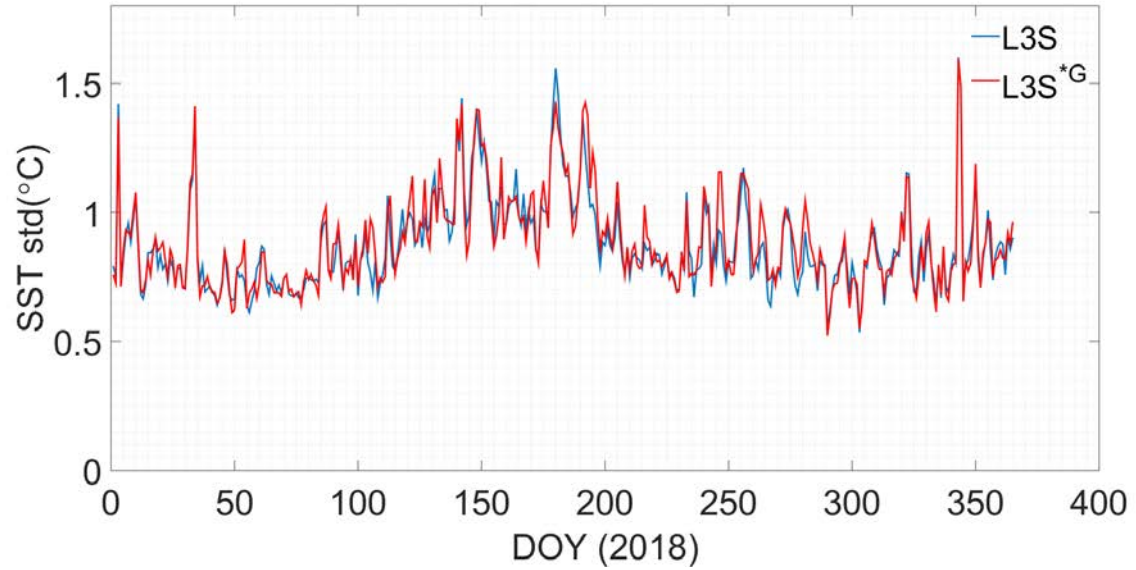
* Bouali M., Sato O., Polito P., 2017, Temporal trends in sea surface temperature gradients in the South Atlantic Ocean, *Remote Sensing of Environment*, Volume 194, 1 June 2017, Pages 100-114

* Bouali M., Sato O., Polito P., Bernardo P., 2020, Impact of cloud masking on the climatology of SST gradients, *Remote Sensing Letters*, (in review)

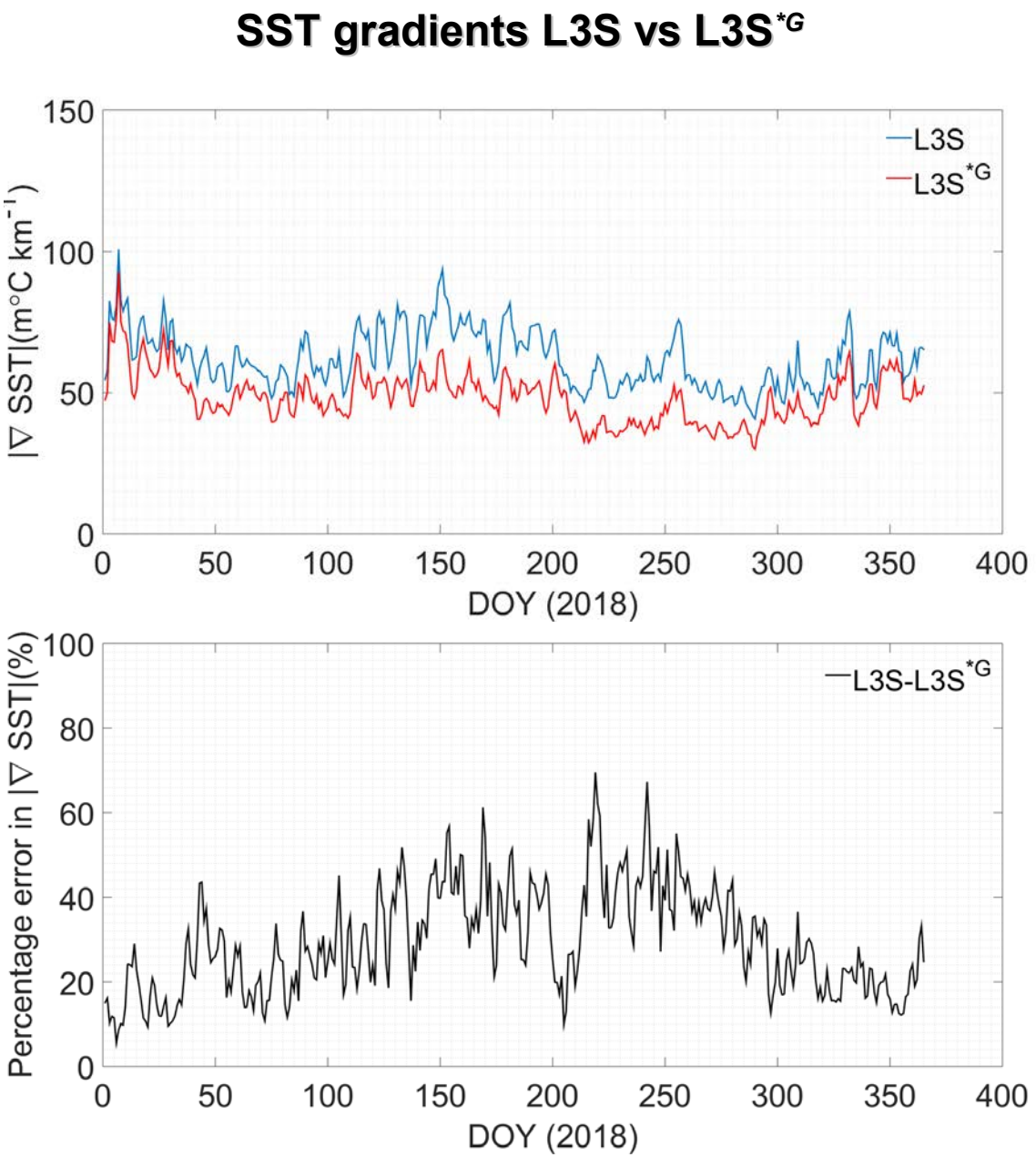
L3S from VIIRS/MODIS(±1 day)

Validation statistics L3S vs L3S^{*G}



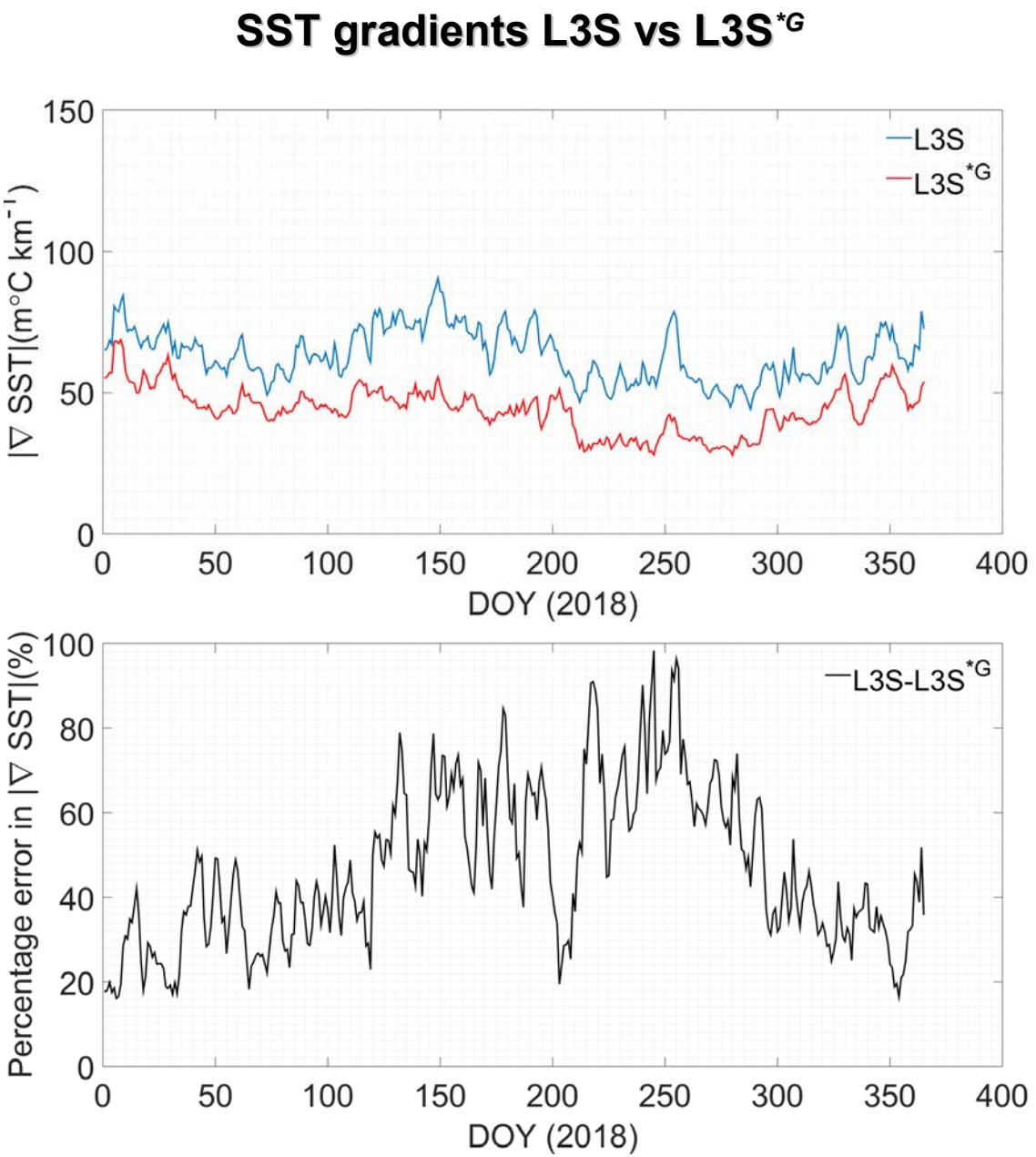


L3S from VIIRS/MODIS(±1 day)



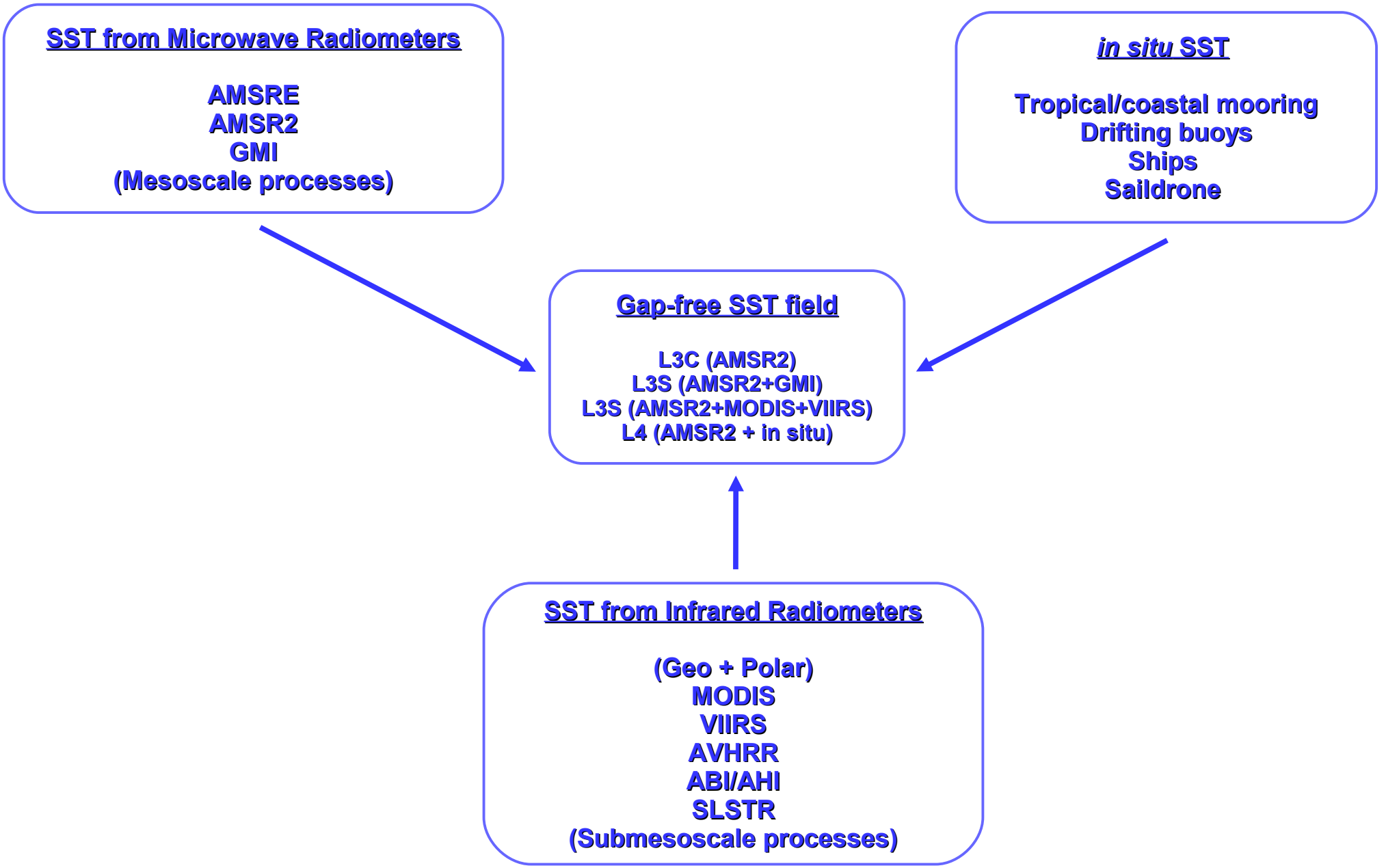
~25% error for 2018

L3S from VIIRS/MODIS(±3 day)

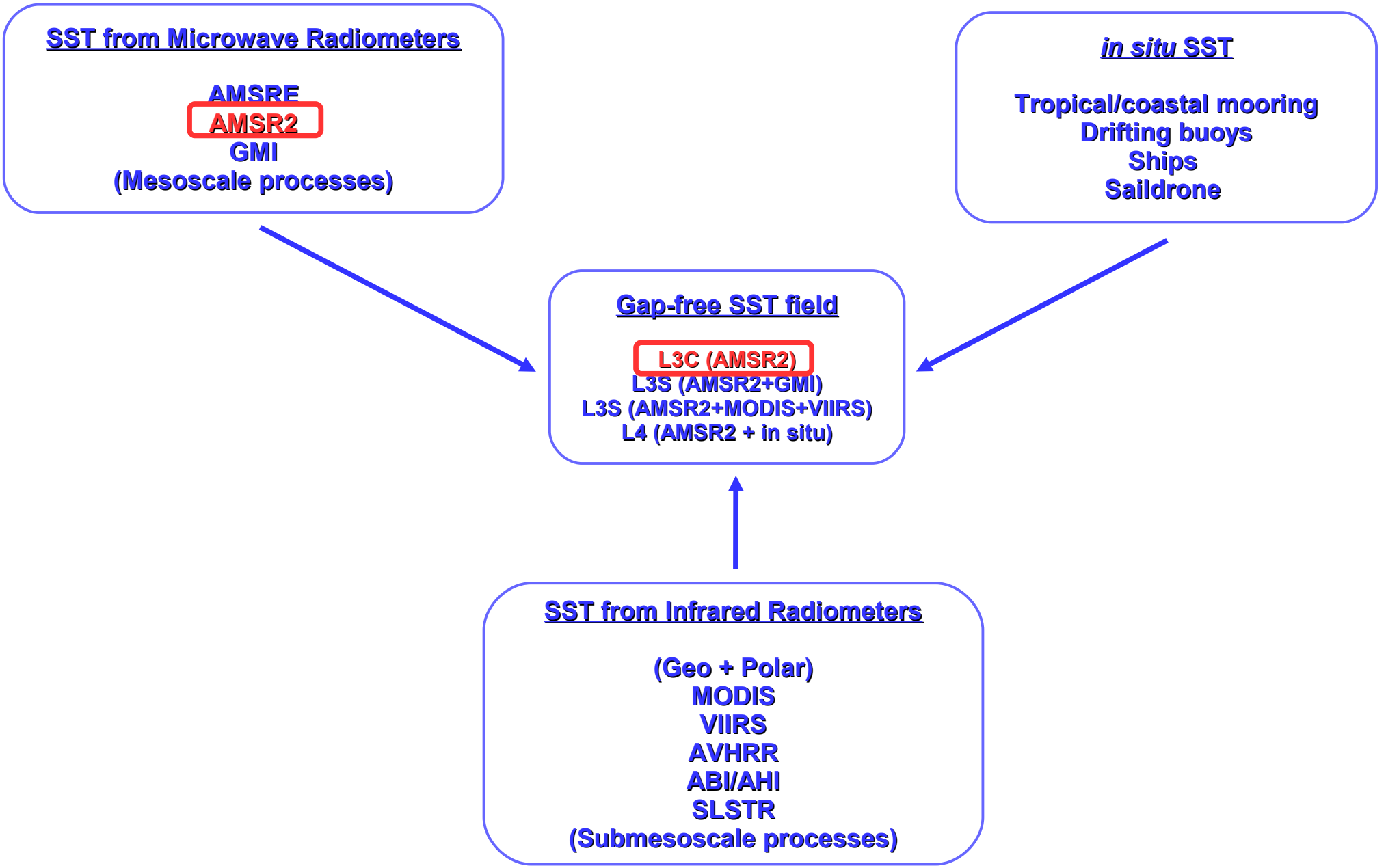


~40% error for 2018

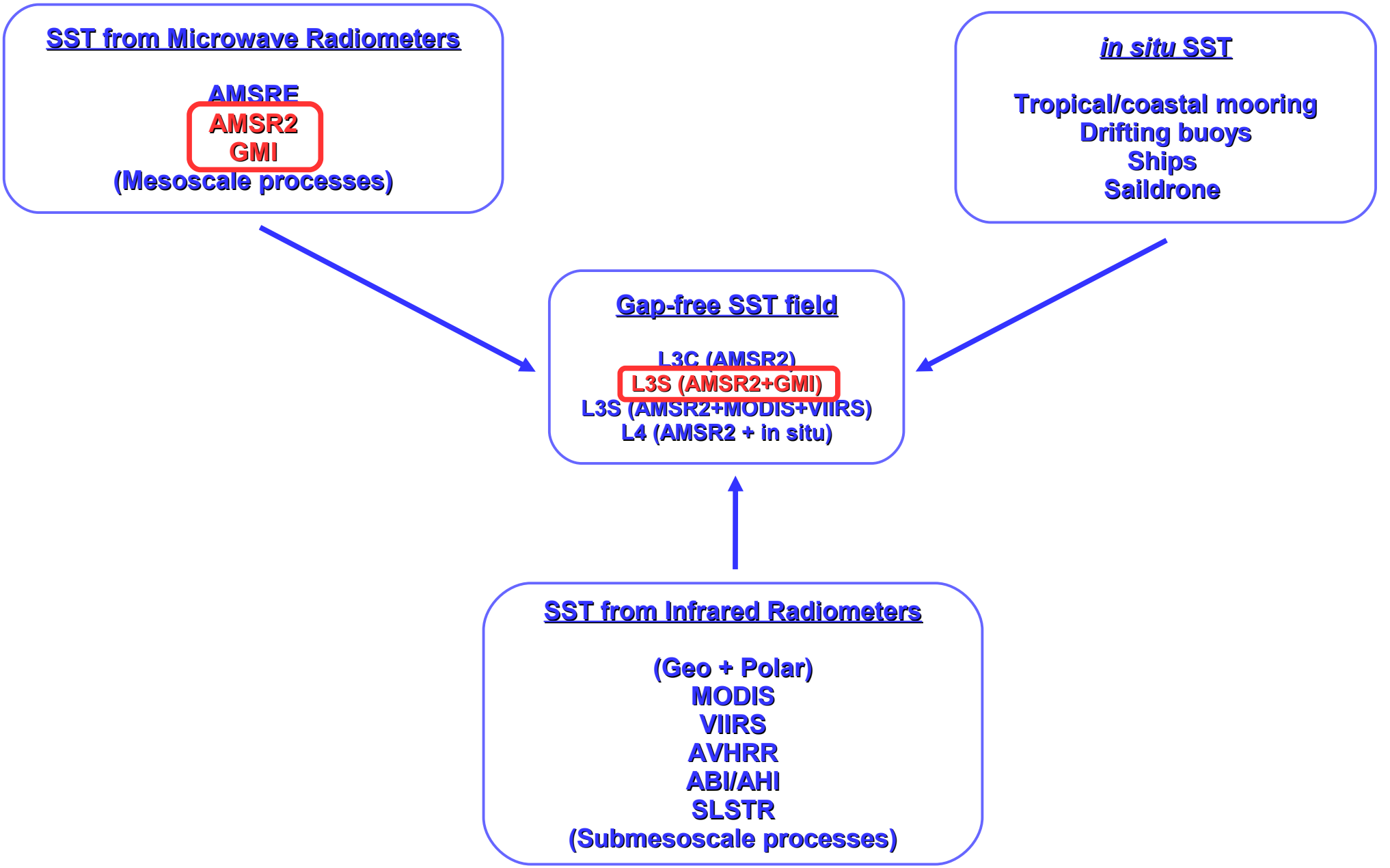
Fom Level 3 to Level 4



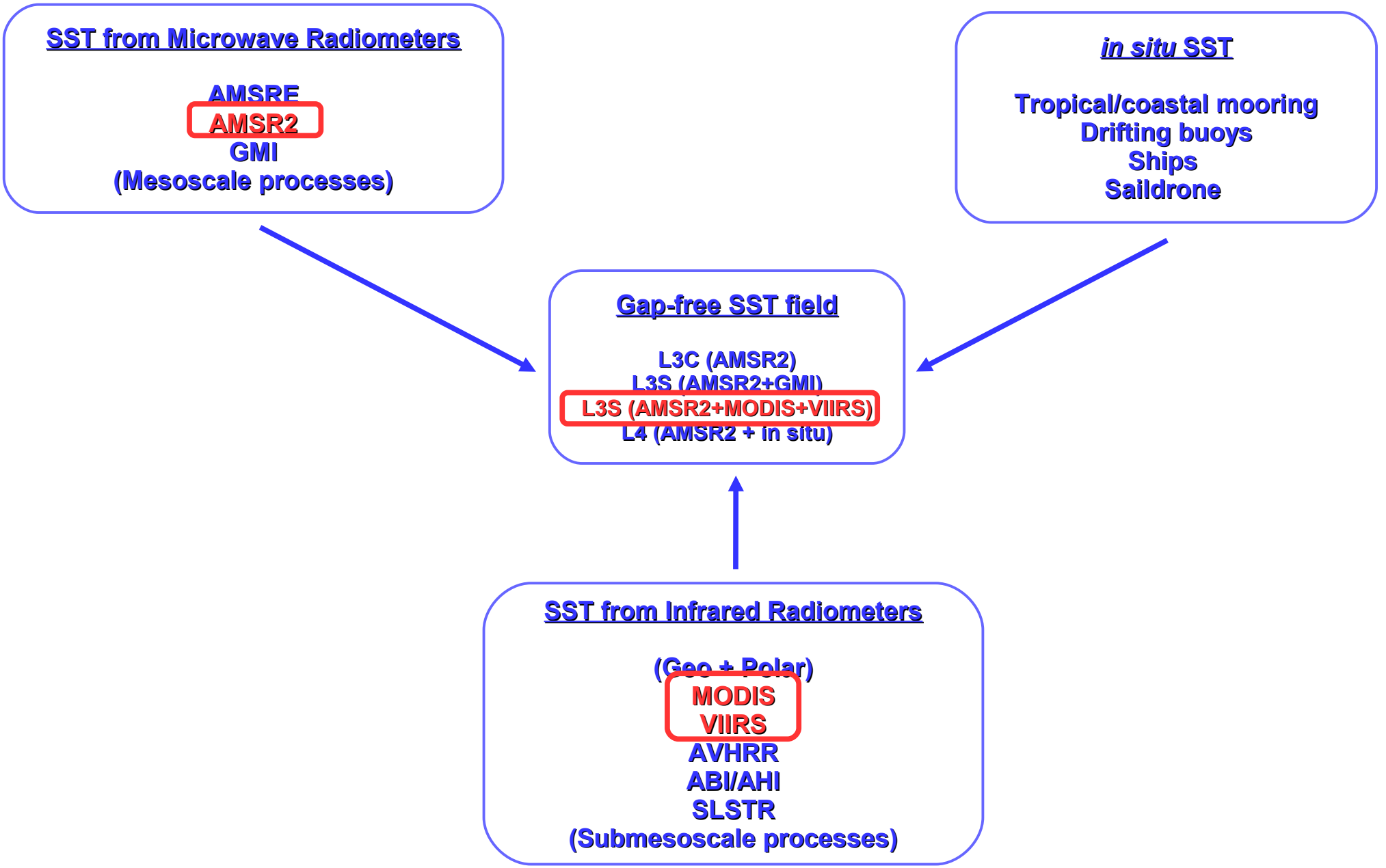
Fom Level 3 to Level 4



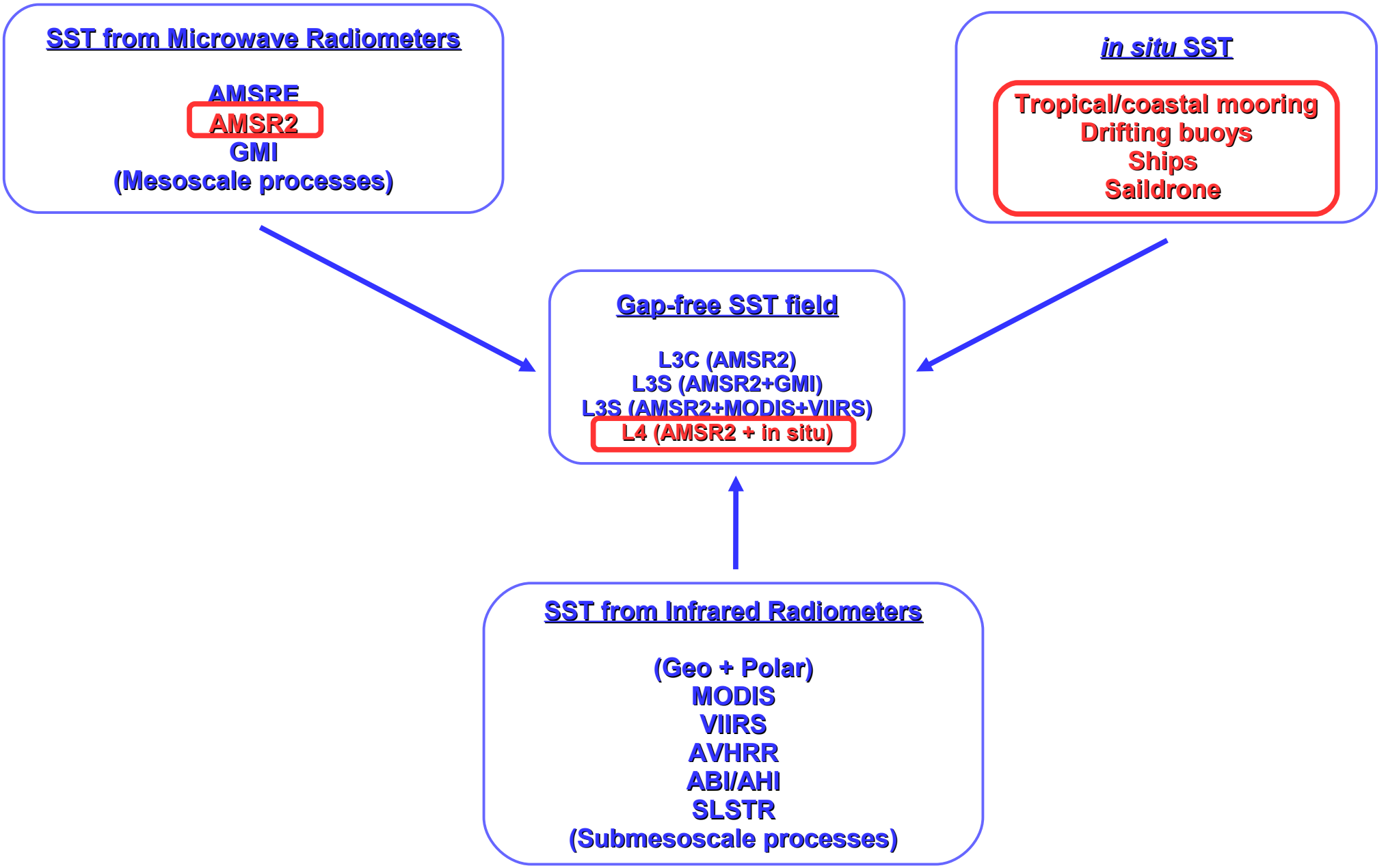
Fom Level 3 to Level 4



Fom Level 3 to Level 4



Fom Level 3 to Level 4



Fom Level 3 to Level 4

SST from Microwave Radiometers
~~AMSRE~~
AMSR2
~~GMI~~
(Mesoscale processes)

***in situ* SST**
Tropical/coastal mooring
Drifting buoys
Ships
~~Saildrone~~

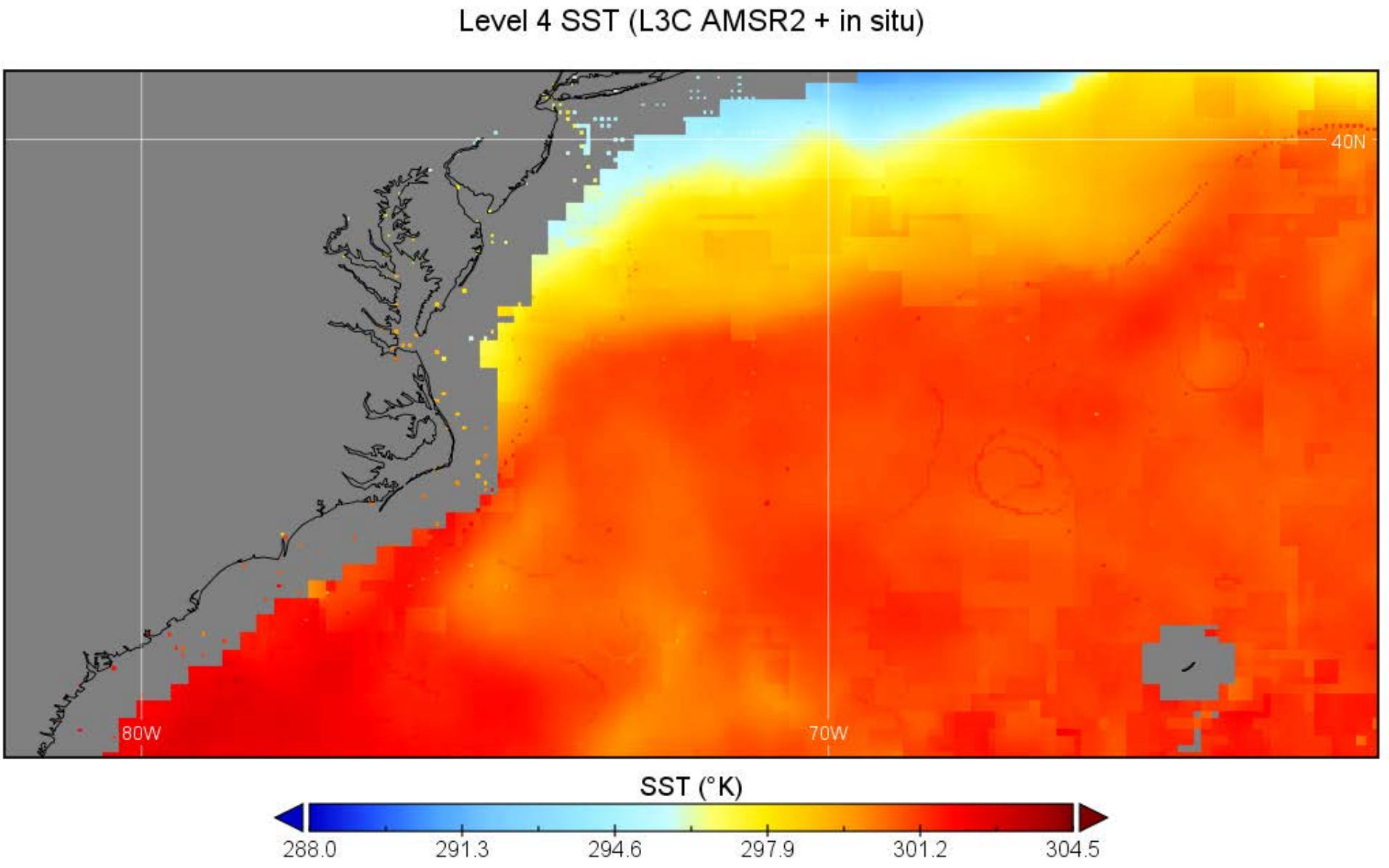
Gap-free SST field
L3C (AMSR2)
L3S (AMSR2+GMI)
L3S (AMSR2+MODIS+VIIRS)
…
…
L4 (AMSR2 + in situ)

±1 day AMSR2: coverage > 80%
±1 day AMSR2+GMI: coverage >90%
±2 day AMSR2+GMI: coverage >95%
±3 days AMSR2: coverage >95%

SST from Infrared Radiometers
(Geo + Polar)
MODIS
VIIRS
AVHRR
ABI/AHI
SLSTR
(Submesoscale processes)

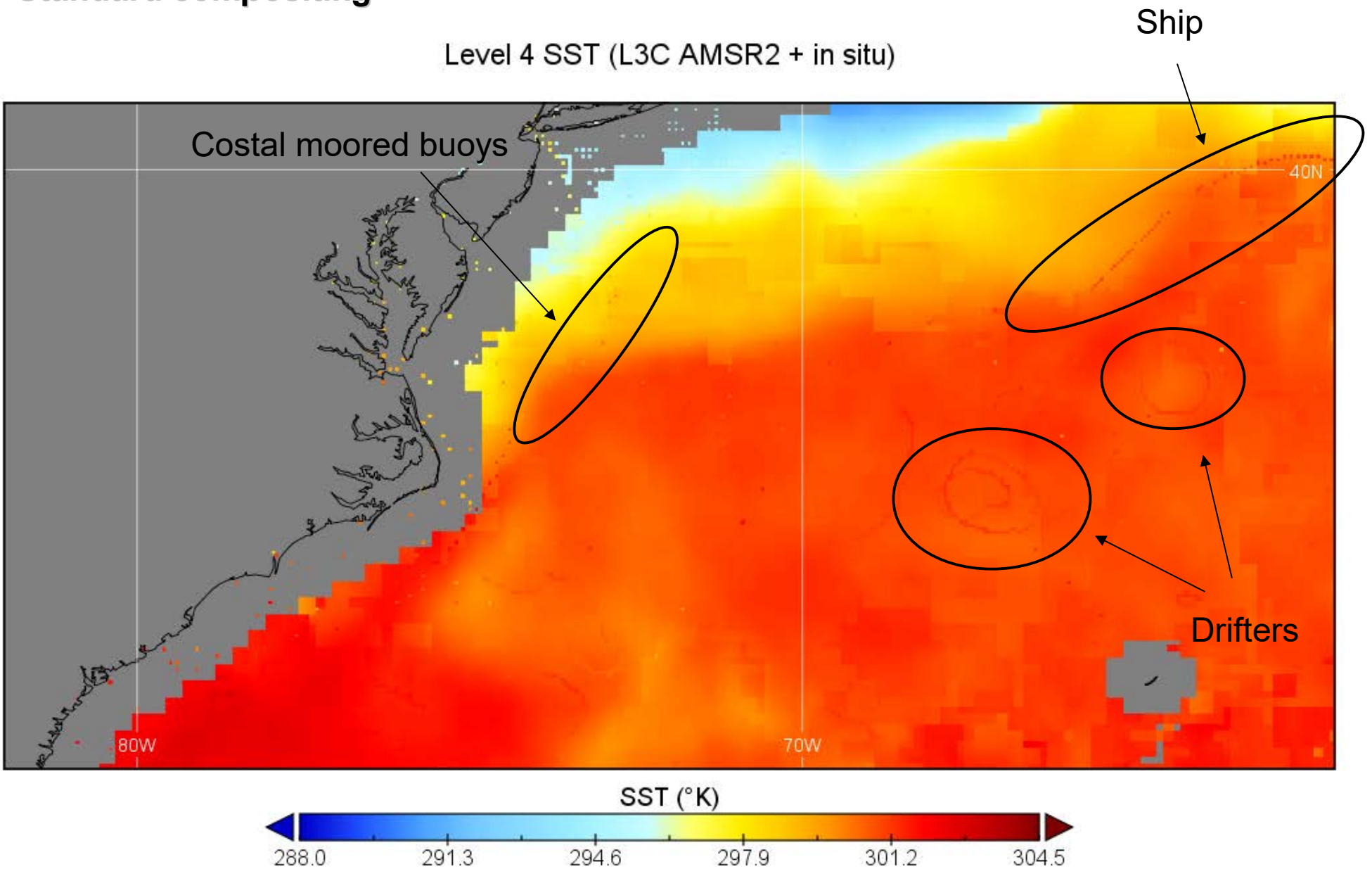
L4 (AMSR2 + *in situ*)

Standard compositing



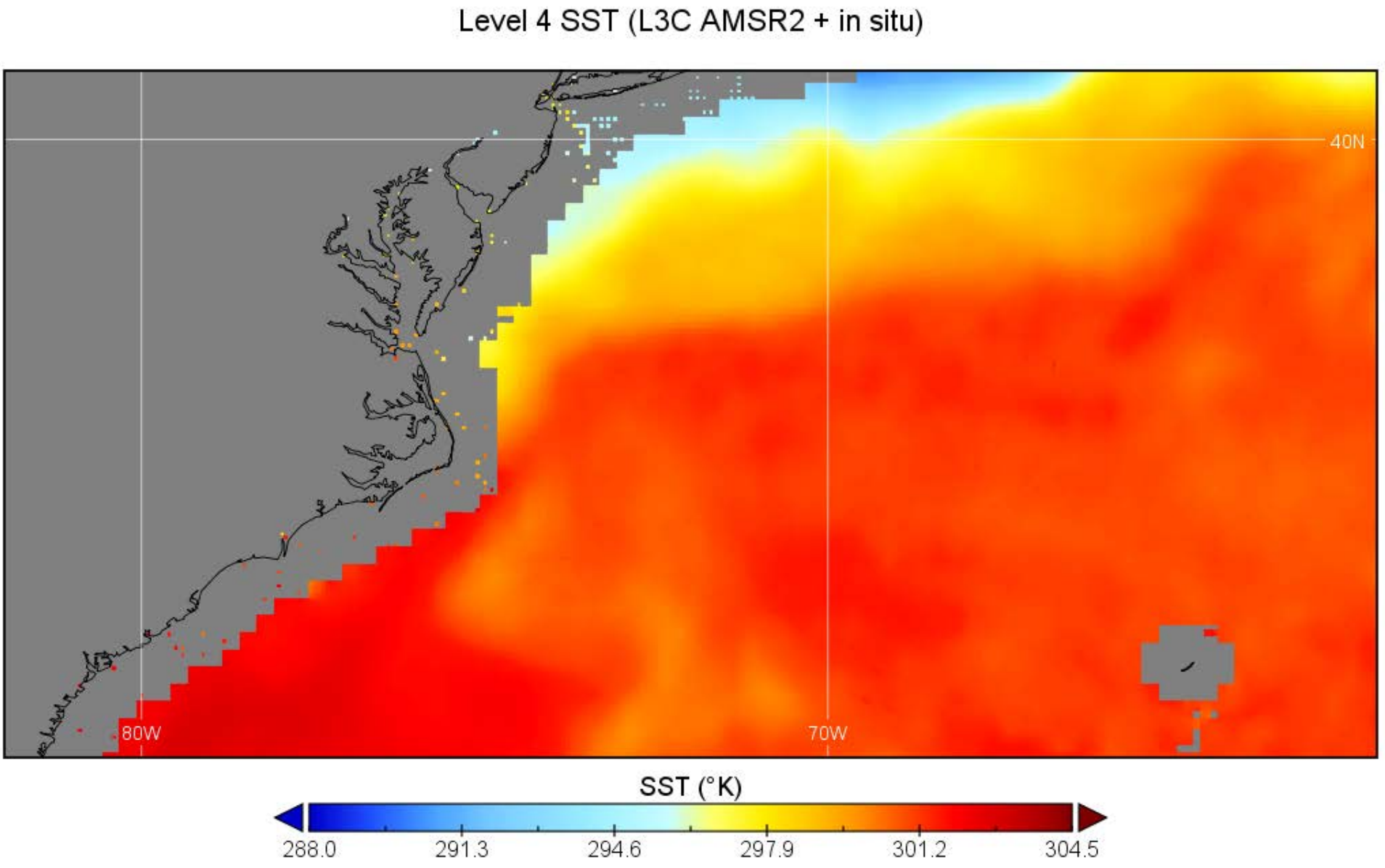
L4 (AMSR2 + *in situ*)

Standard compositing



L4 (AMSR2 + *in situ*)

Gradient-based merging



Summary

- Gradient-based (super) collation of SST allows to preserve both statistics and dynamics without introducing artifacts

- No need for single sensor bias correction

- Main computational cost fully independent of the number of input datasets

- Highly efficient approach: integration of the estimated SST gradient field requires 1-2 Fast Fourier Transforms

- Can ingest SST gradients captured by moving *in situ sensors (i.e.,* drifters, ships and Saildrone)

- Robust to instrument noise (Gaussian + striping) and undetected clouds (cirrus clouds do not introduce strong gradients)


Questions:
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