The POES-GOES Blended Sea Surface Temperature Analysis

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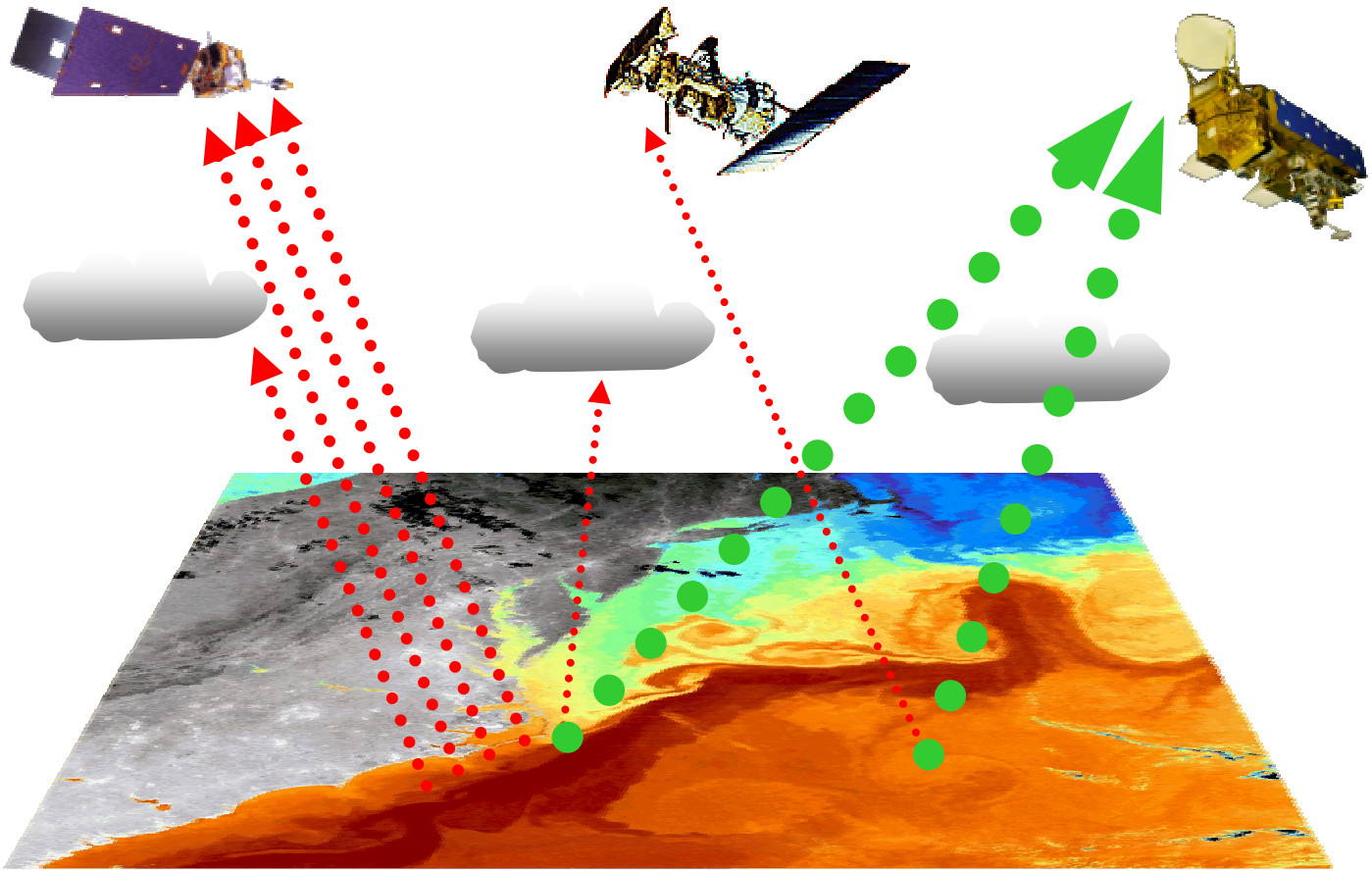
The Need

- Many users of high-resolution SST data
  - *E.g.* CoastWatch user base is >20,000
- Analysis products are also popular
  - Gridded, gap-free
  - Effectively a “best estimate” of SST from available sources
  - Opportunity to treat errors in the individual products – a “2nd bite at the cherry”

Maximize strengths – minimize weaknesses



POES IR has **high spatial resolution**

GOES IR has **high temporal resolution**

Microwave has **all-weather capability**

Combine to obtain the **optimal SST analysis**

NESDIS Requirements

- A blend of the “traditional” NESDIS AVHRR SST product and the newer GOES SST
  - Maximize return on investment
- Include SST data from other instruments as opportunity arises
  - Other geostationary (Meteosat-9, MT-SAT)
  - Microwave sensors
- Meet needs of user community
  - Ocean Forecasting
  - Mesoscale Oceanography (fronts, eddies)
  - Coral Reef Watch
  - CoastWatch/OceanWatch

The Specifications

- Daily global SST analysis
  - Day and night data are treated separately
  - Uses one day of data per day…
- 0.1°×0.1° resolution
  - Sufficient to resolve fronts, eddies, *etc.*
  - Rossby radius is ~20 km at mid-latitudes
- Uncertainty estimates
  - For each observation type
  - Dynamic bias correction
  - For each grid-point

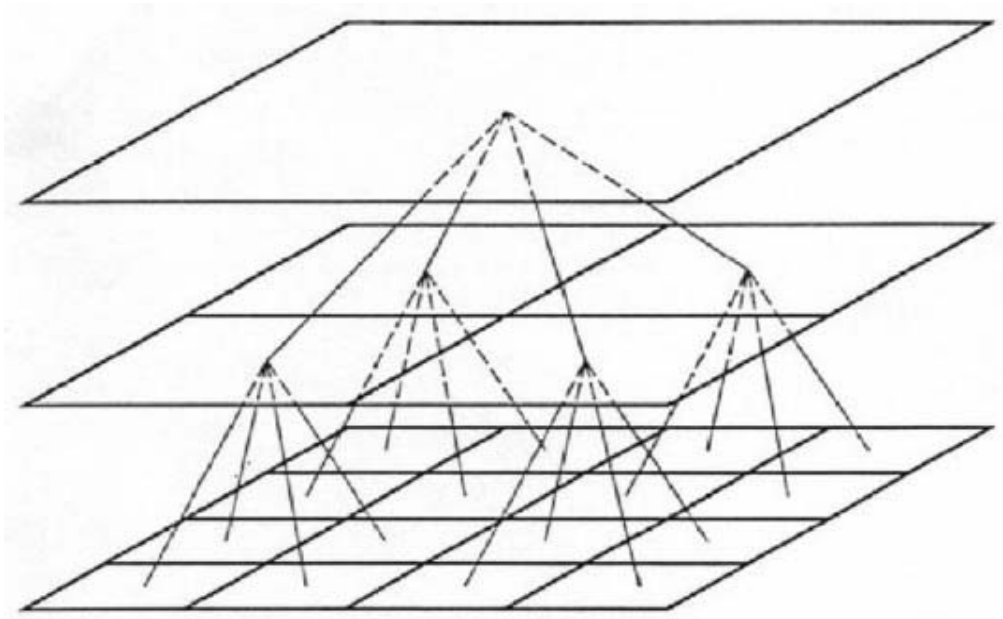
Overview of Methodology

- Dynamic estimation of SST field using a recursive estimation algorithm which emulates the Kalman filter
  - See Khellah *et al.* (2005) [I have a .pdf]
- Preserves fine-scale structure
  - Need to avoid excessive noise
- Error estimates
  - Inflate over time if observations are absent

- A quad-tree is used as the basis for multi-scale modelling
- Need to conditionally decorrelate the subtrees branching from each node so that each can be processed independently
- To do this requires knowledge of the prior model underlying the observations (for example, simple inverse correlation with distance)
- In physical terms this corresponds to assuming that for each subtree, the influence of the external SST field can be completely represented by knowledge of SST along subtree boundary
- But useful approximation can be achieved by sub-sampling boundary

Quad-tree hierarchical structure…

…divide and conquer

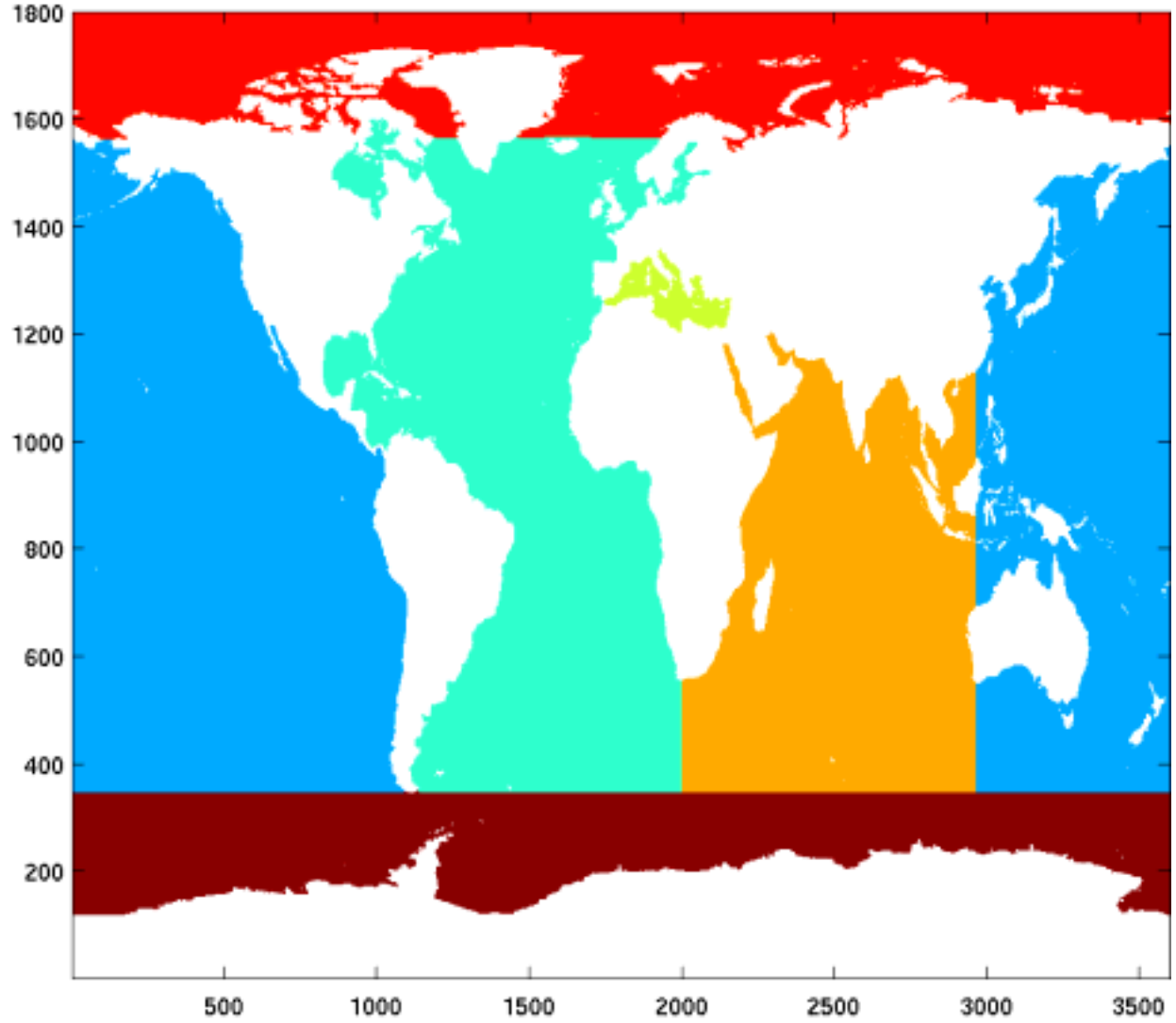


(Figure taken from Fieguth *et al.*, 1995)

Method requires:

- Initial estimate of background field
- Prior model of SST variability
- Observations with well-characterized errors
- Definition of relationship between observational datasets (*i.e.* assume one or more bias terms which are spatially correlated)

Separate basins



Relationship between SST datasets

- RTG_HR (thinned) – No bias correction
- ACSPO SST (N-18 + METOP)
  - Day & night treated separately
- GOES-SST (GOES-11 & GOES-12)
  - Again, separate day & night)
- Each dataset is super-ob'd to analysis grid
  - Bias corrected (previous day's bias)
  - Outlier removal (based on recent estimated variability of dataset and SST analysis)
  - Error of super-ob calculated for remaining data
  - Default error assigned if <3 data points in grid cell

The Analysis Step

- A simple prediction is used:

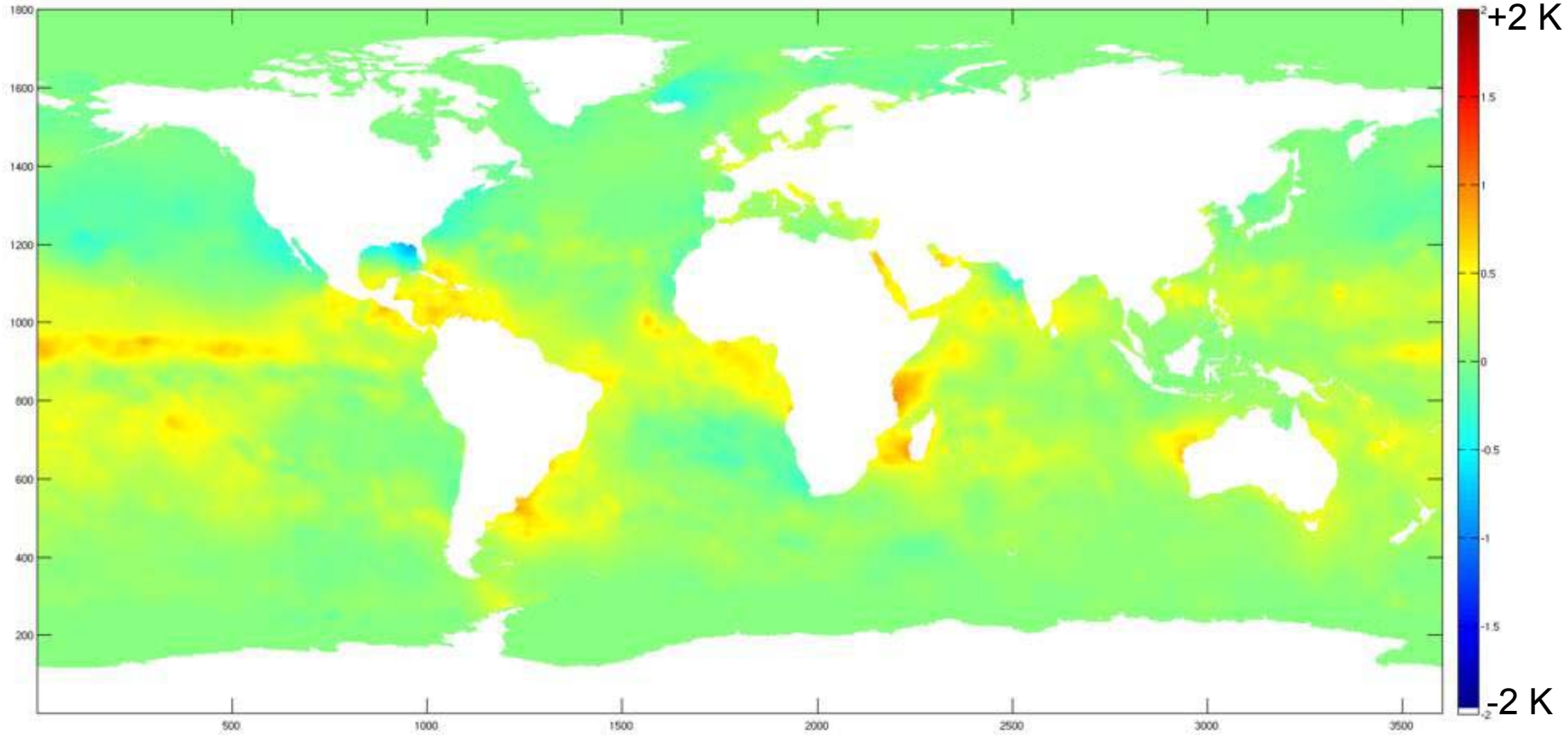
$$\boldsymbol{x}(t|t\text{-}1) = \boldsymbol{x}(t\text{-}1|t\text{-}1)$$

- We want to use a correlation function
  - which reflects innate variability of SST field
  - BUT, correlation function also affected by spatial distribution of measurements
  - Avoid negative definite or very close to singular (use parameterization which is known to be +ve definite)
- Multi-pass approach with range of correlation lengths
  - Estimates and errors obtained by interpolation
  - In effect, we use a mixture of stationary models to accurately mimic the effect of a non-stationary
- Method scales as $N\log_e(N)$

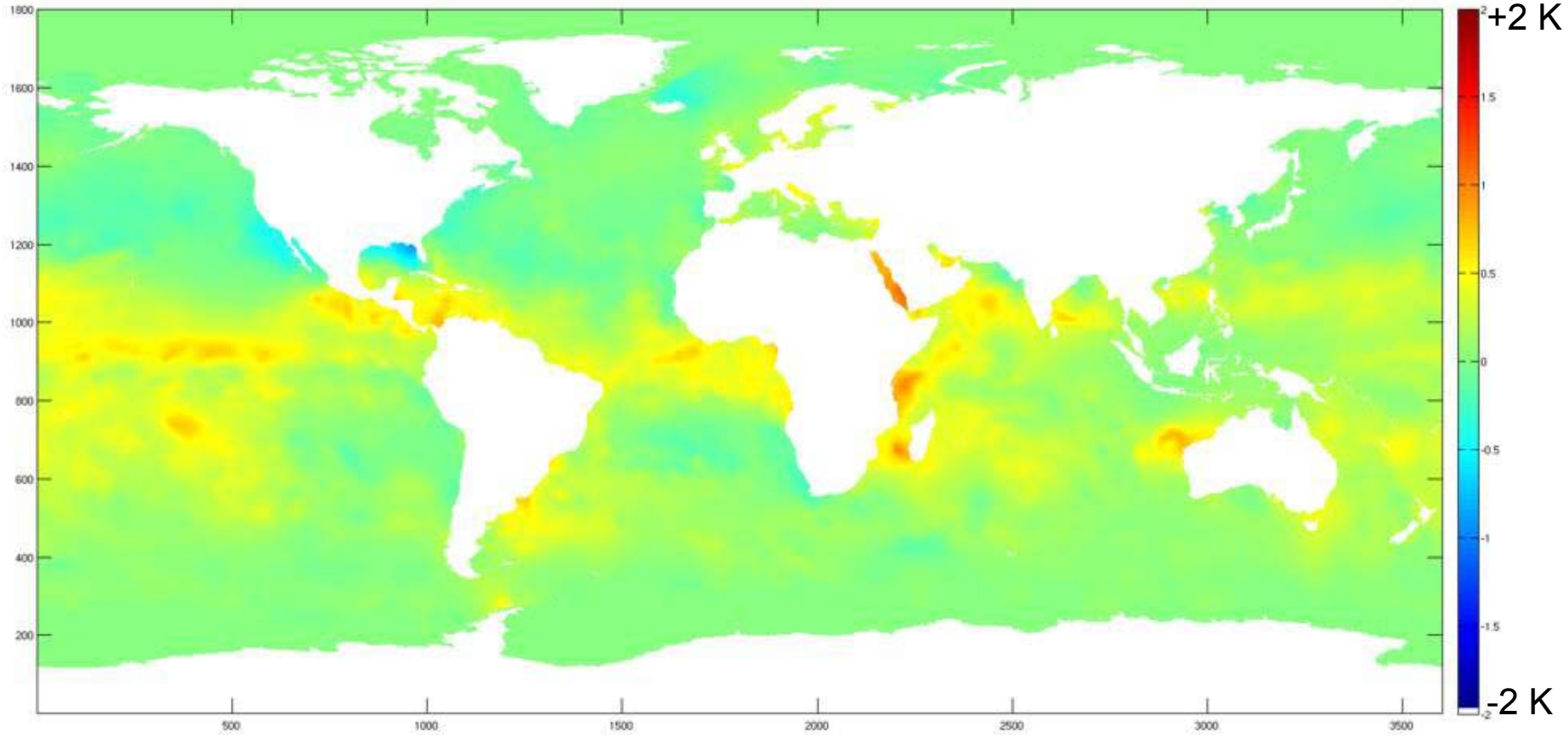
Bias Update

- GOES SST data in particular have significant (>1 K) regional biases which vary faster than we would like
- All biases are updated on a daily basis
  - Derived from (*O* – *A*)
  - Damped, but not much (weights are [0.6, 0.4])
  - No dependence on view angle, *etc.* for AVHRR
  - For GOES, geographic location defines view angle…
- In future, will use
  - GHRSST L2P Single Sensor Error Statistic (which we generate…)
  - Physical (MAP) retrieval (should be ~unbiased) for GOES, at least…
  - Diurnal bias estimates (NWP winds + SSI → turbulence model)

Bias: N-17 ACSPO (Daytime) December 16, 2007



Bias: N-17 ACSPO (Daytime) December 21, 2007



- Very similar bias pattern 5 days later

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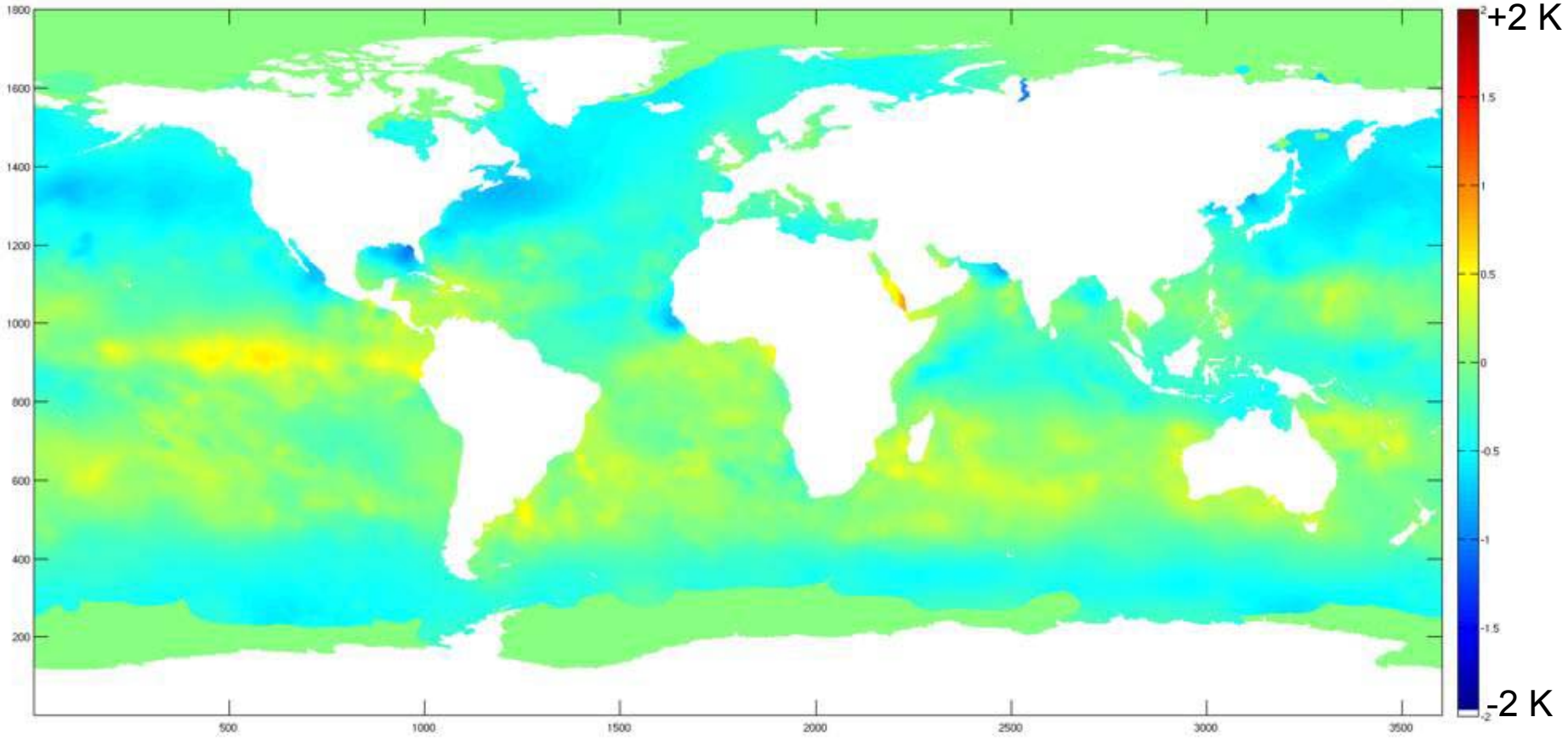

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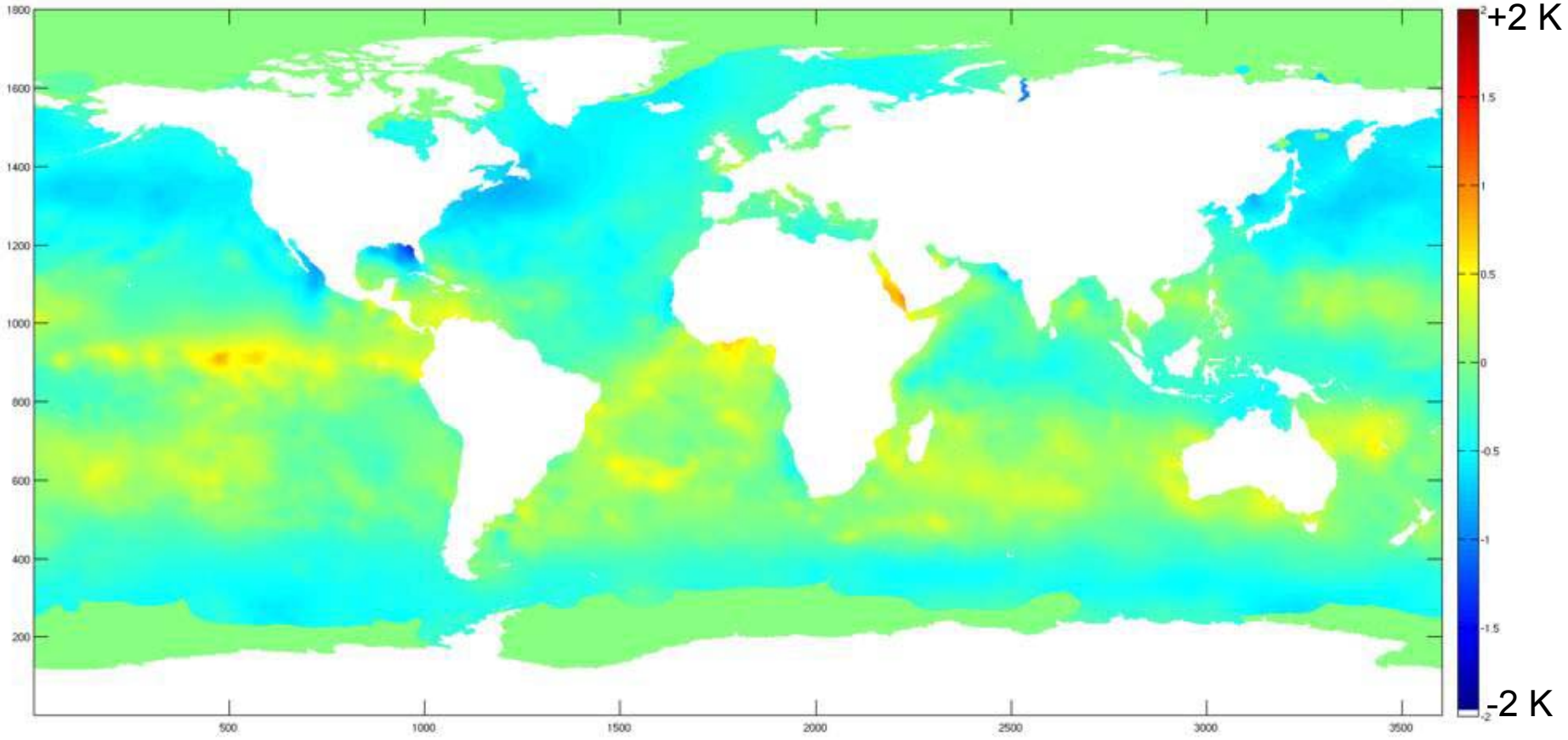
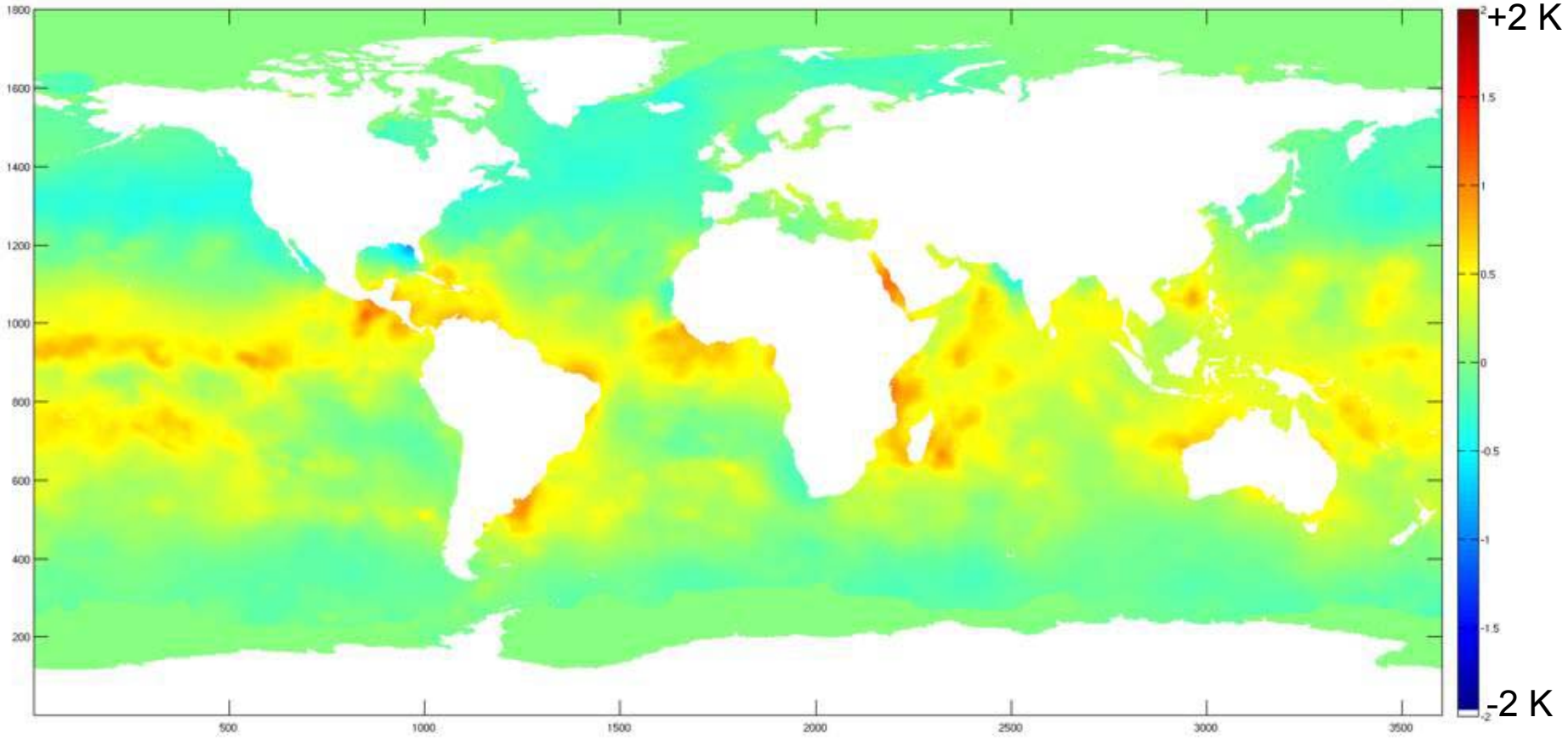


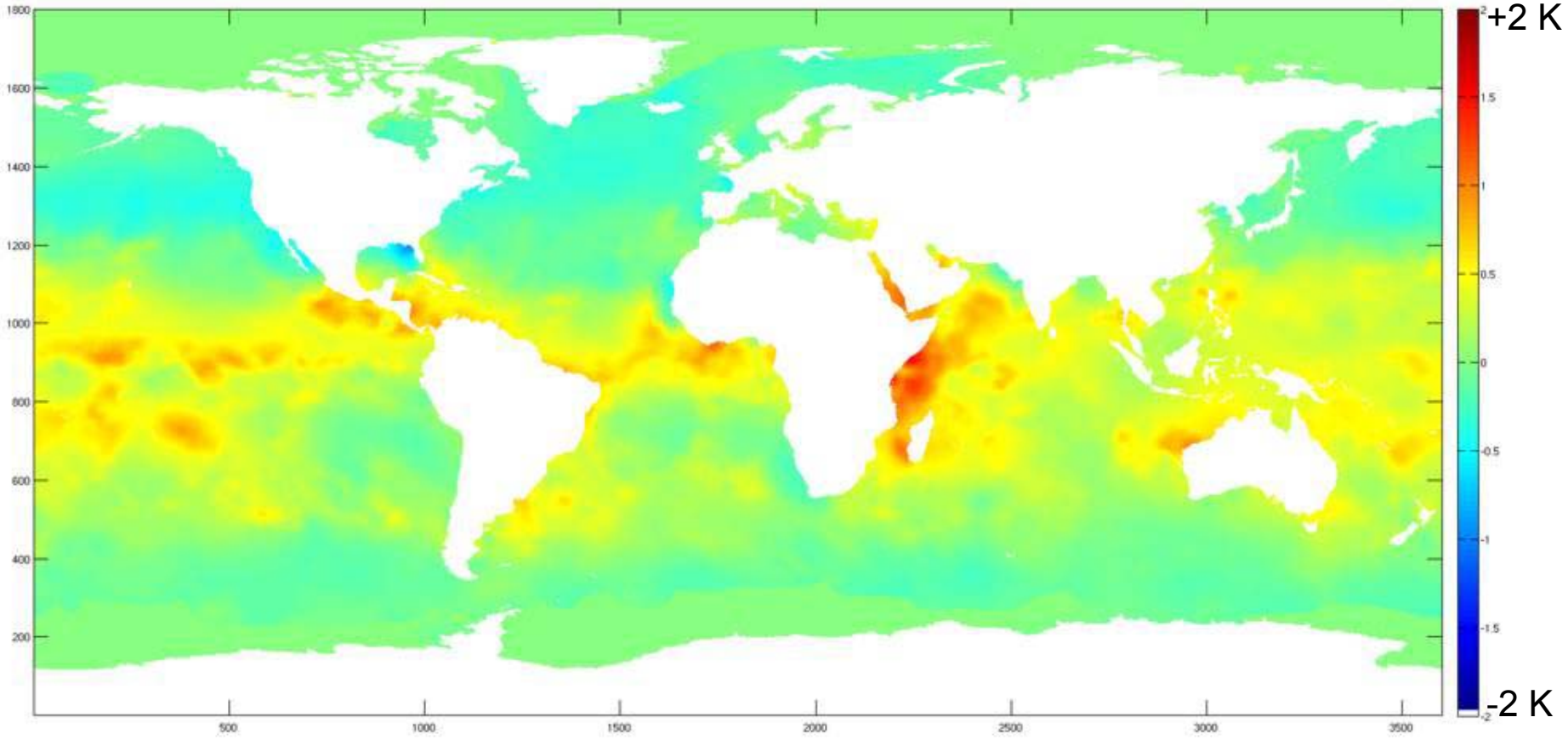
- As before, similar bias pattern 5 days later

Bias: N-18 ACSPO (Daytime) December 16, 2007



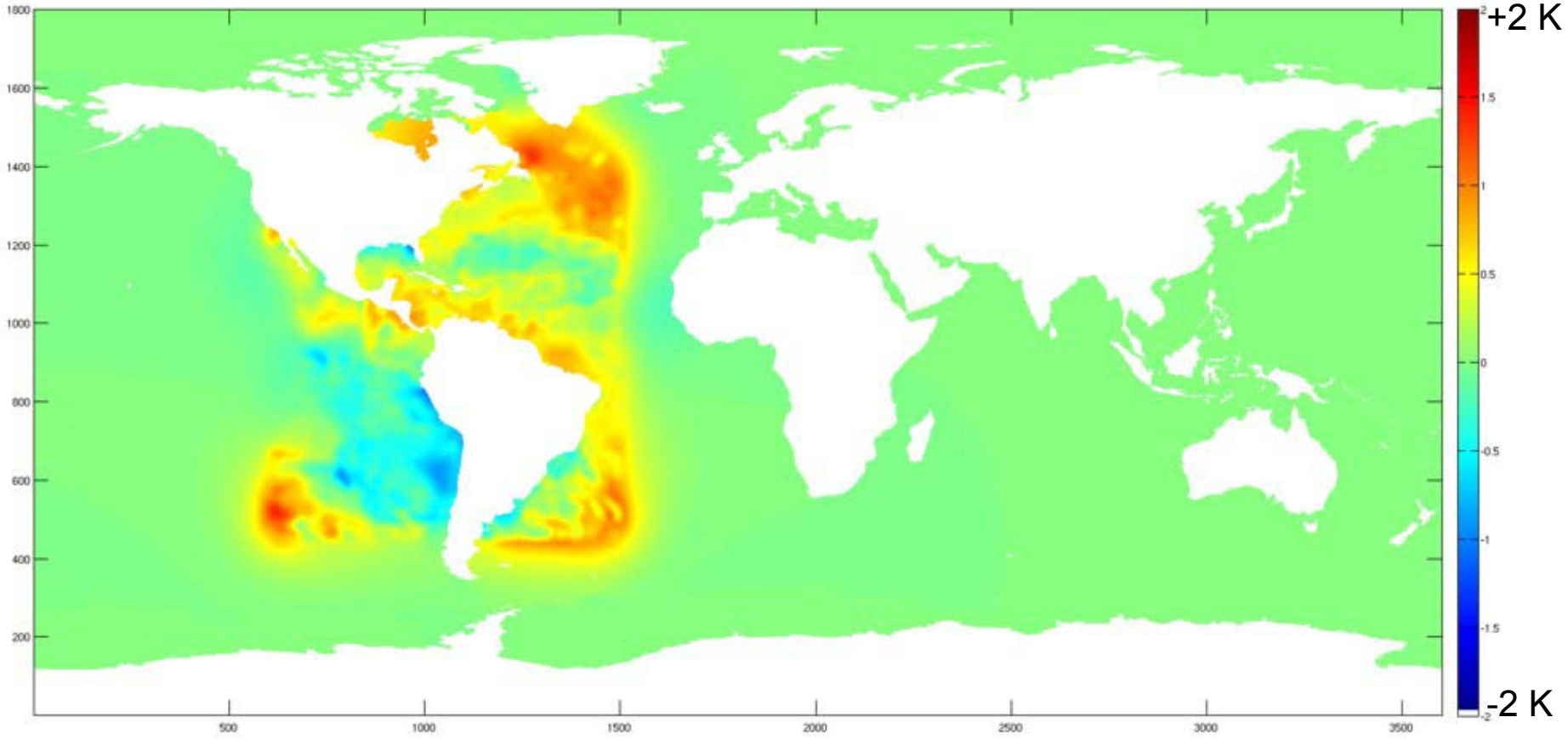
- Note more regions of warm bias in SH…

Bias: N-18 ACSPO (Daytime) December 21, 2007



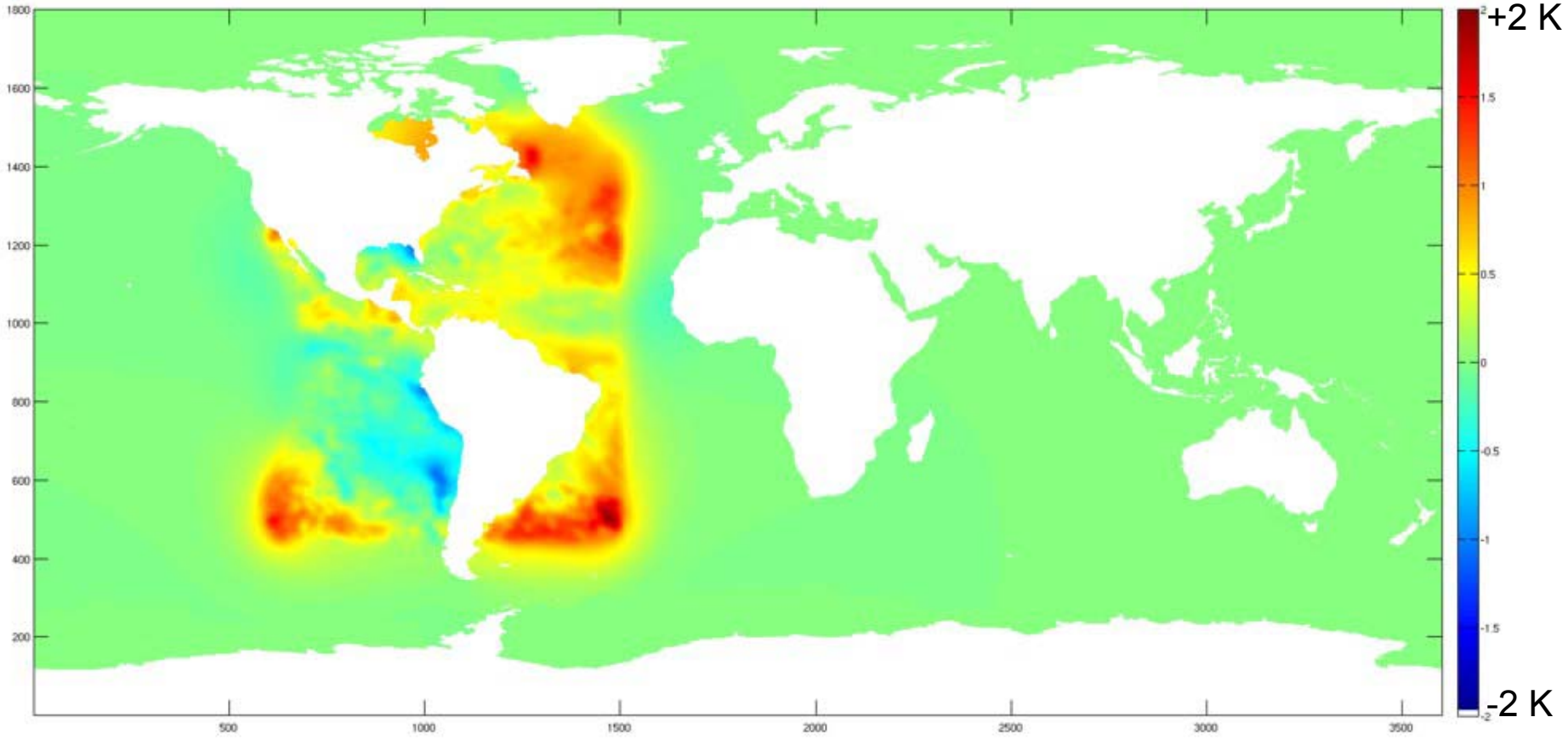
- Regions of warm bias move

Bias: GOES-12 (Daytime) December 16, 2007



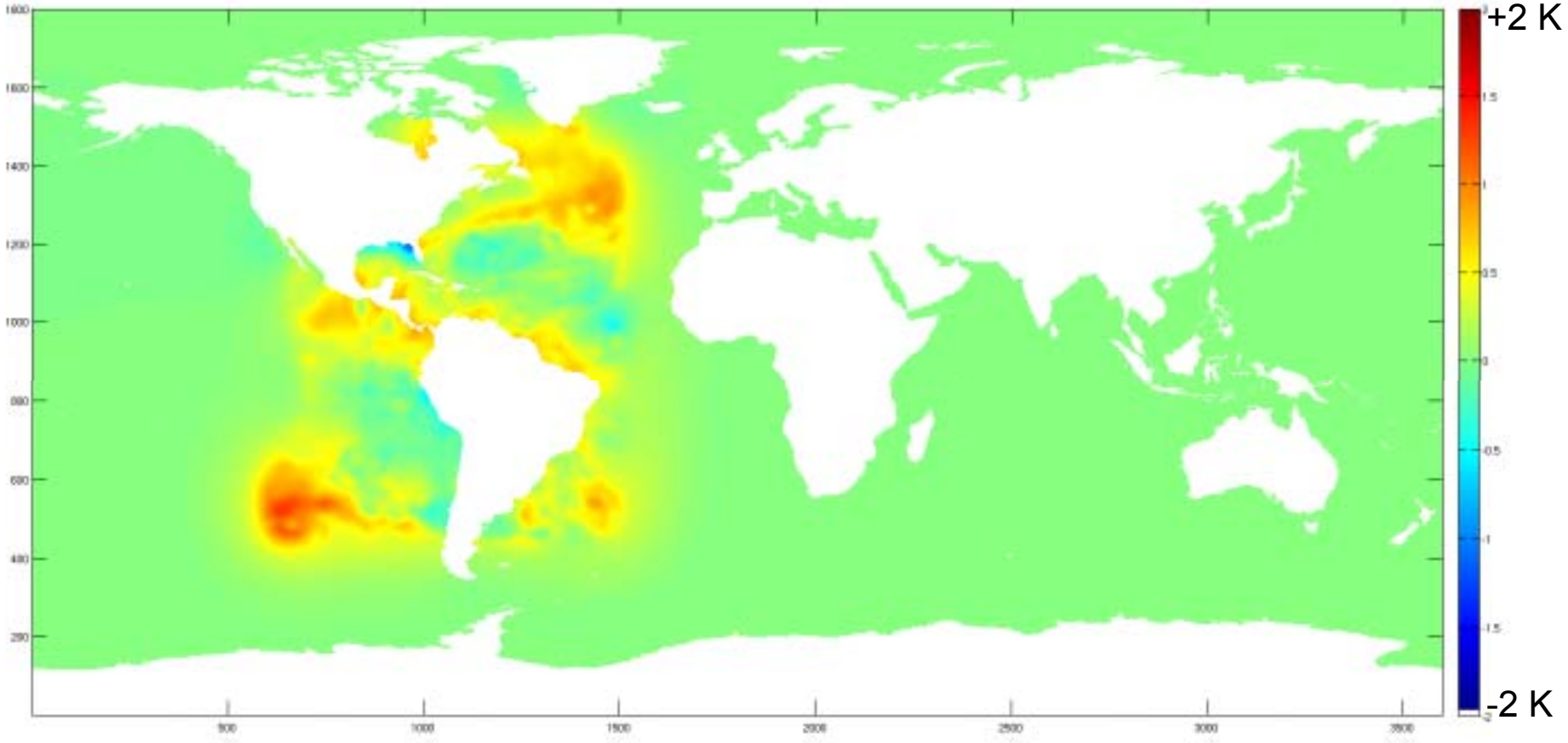
- Significant bias at edges of scan area

Bias: GOES-12 (Daytime) December 21, 2007



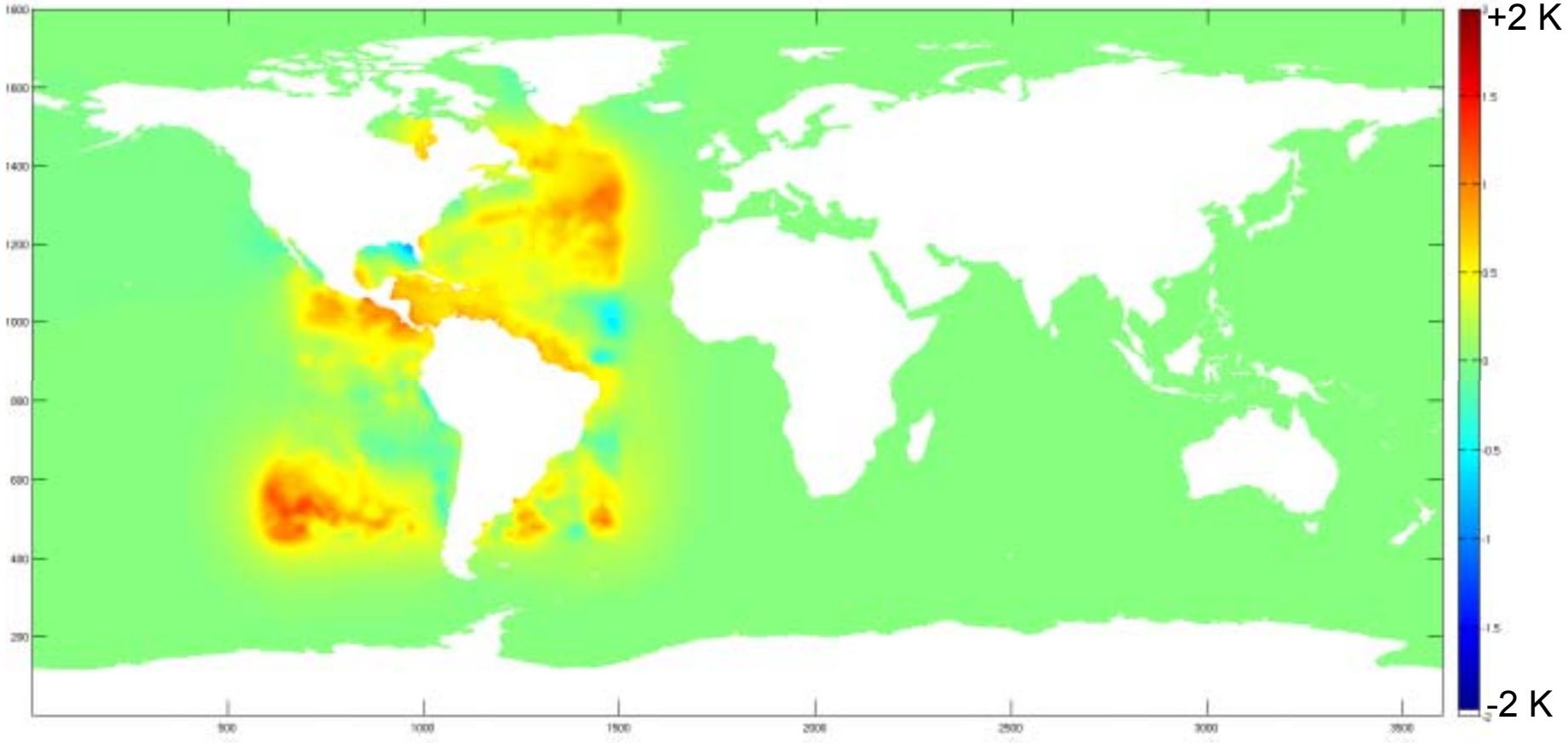
- Even stronger bias pattern evident 5 days later

Bias: GOES-12 (Nighttime) December 16, 2007



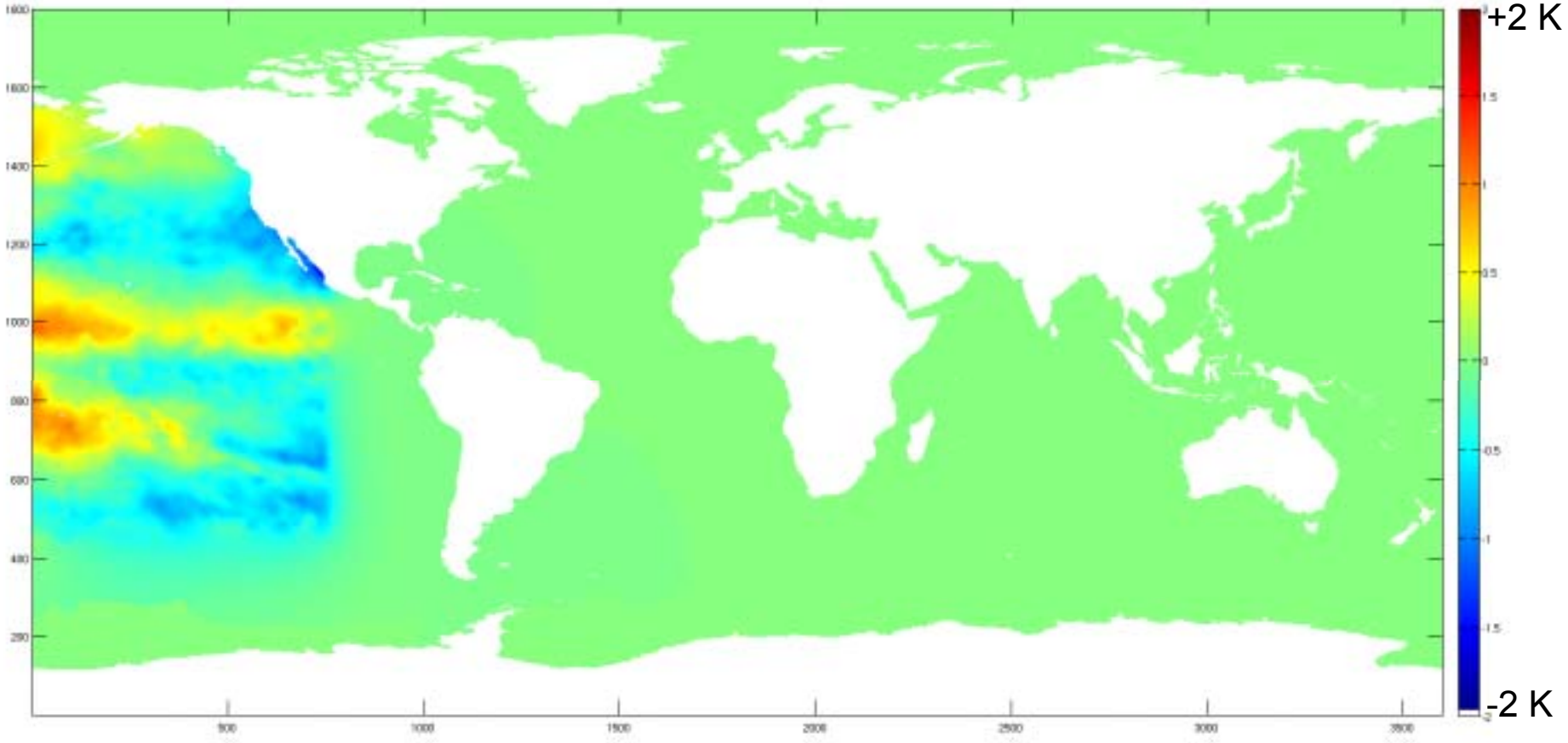
- Less prominent bias pattern at night but still significant

Bias: GOES-12 (Nighttime) December 21, 2007



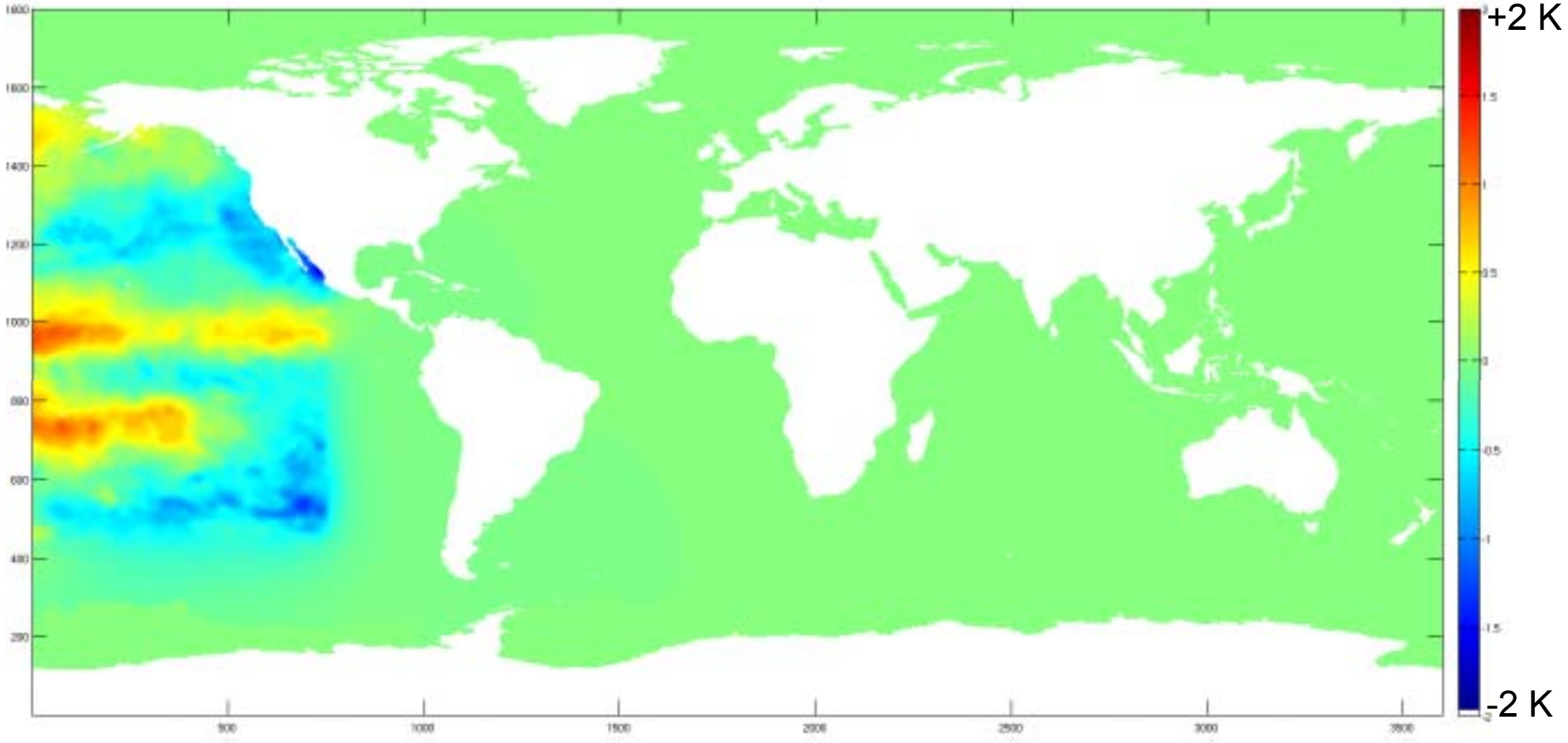
- Not as much temporal variability as daytime case

Bias: GOES-11 (Daytime) December 16, 2007



- Some E-W (scan angle & water vapor) trend evident

Bias: GOES-11 (Daytime) December 21, 2007



- May also be some diurnal warming variation

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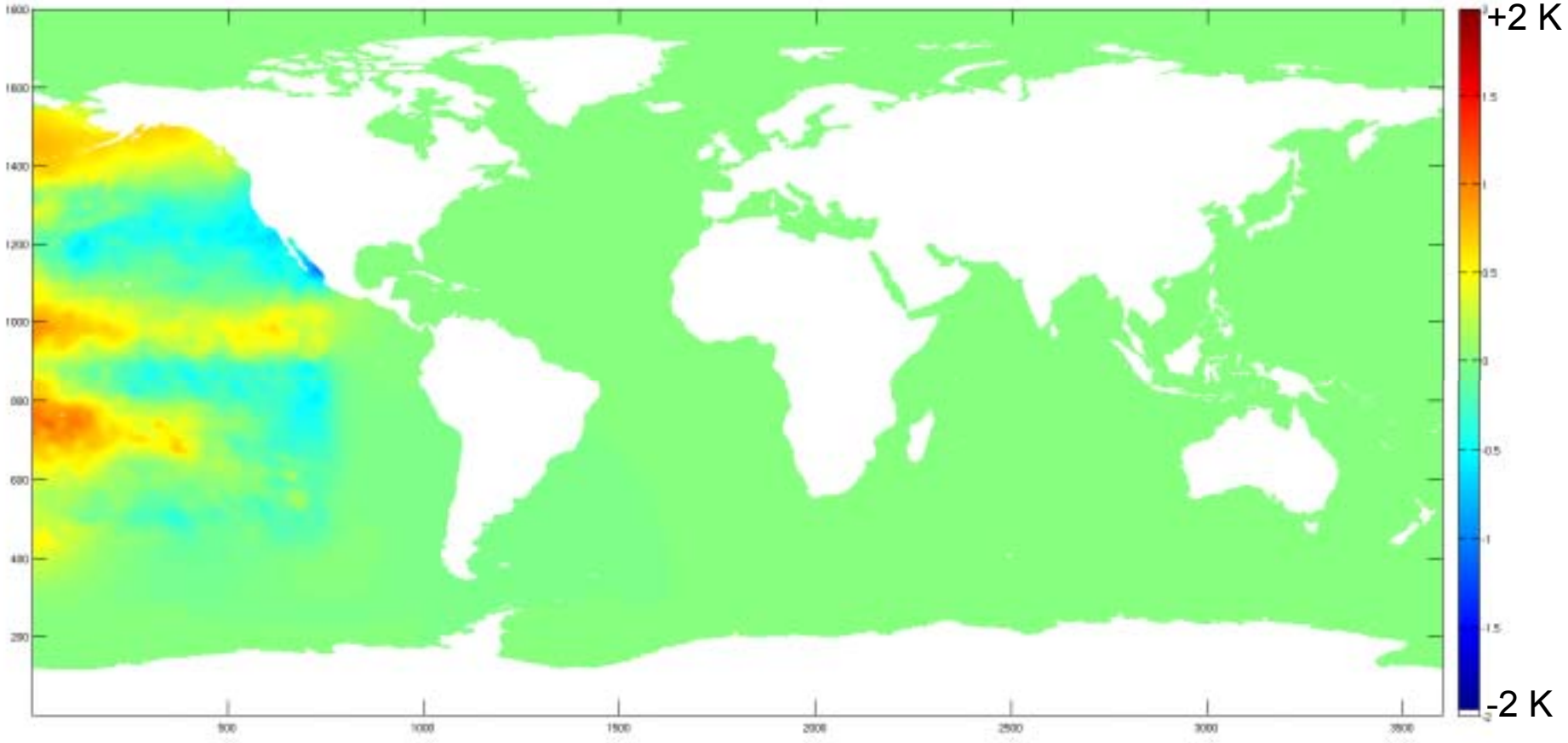
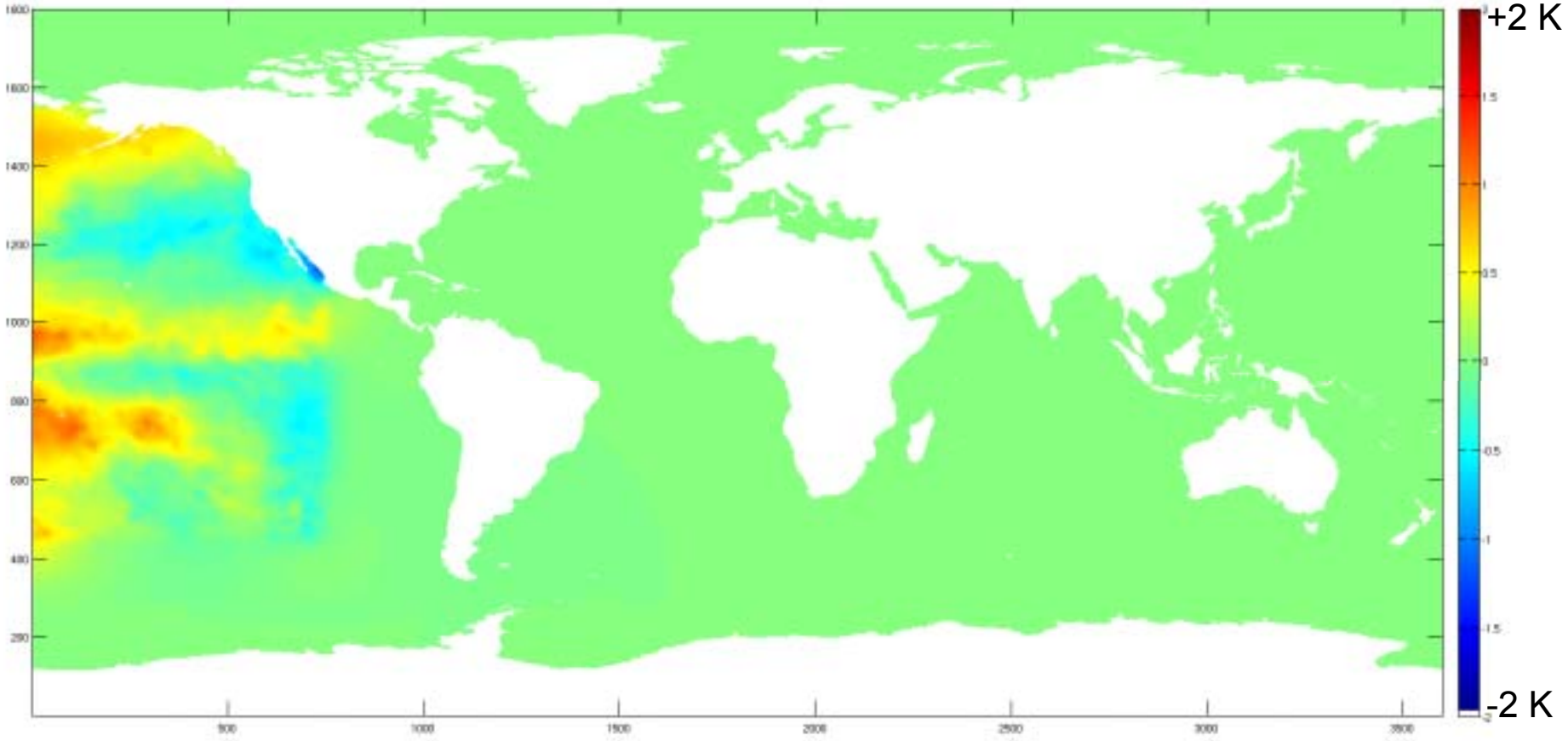
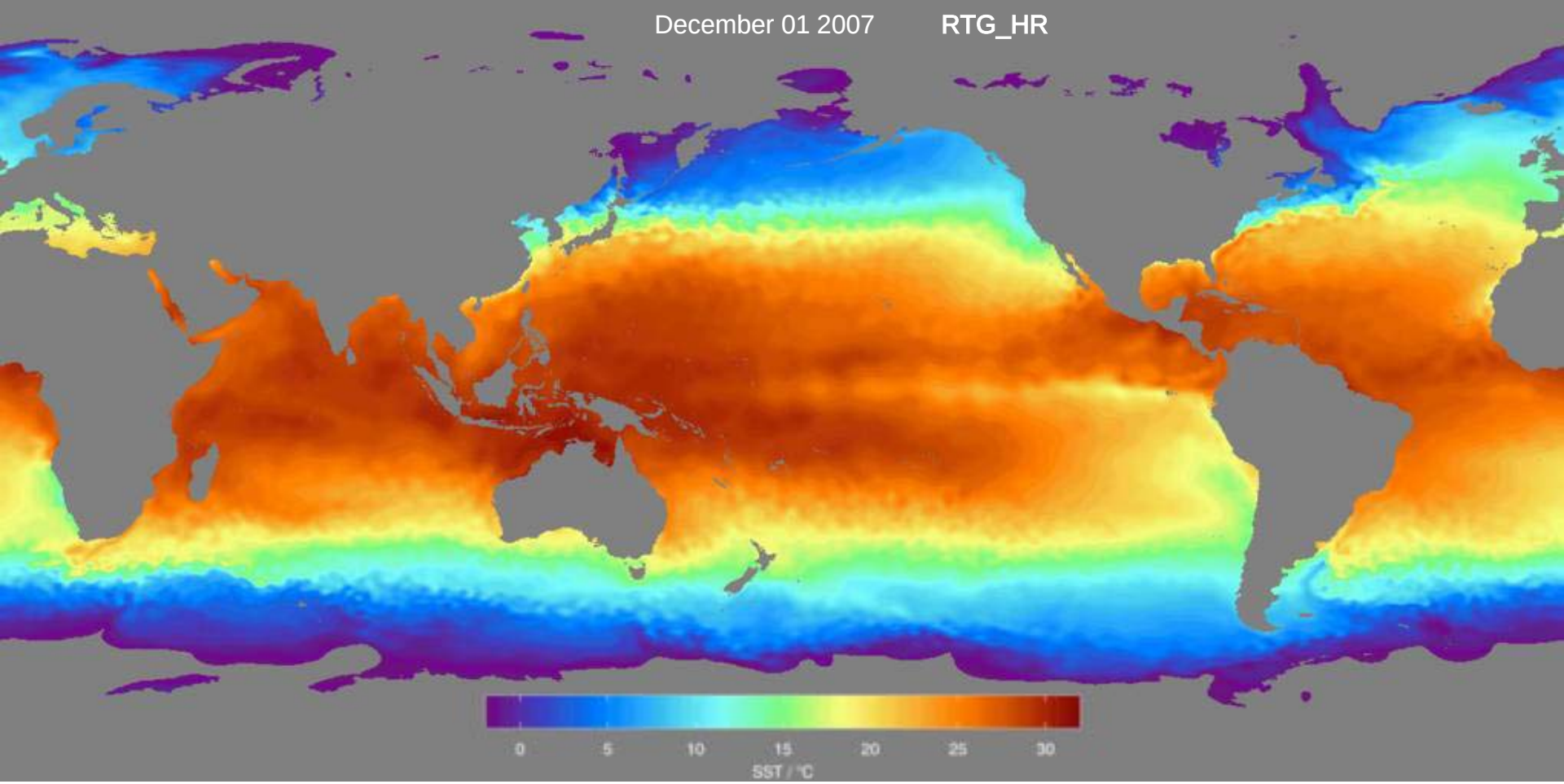


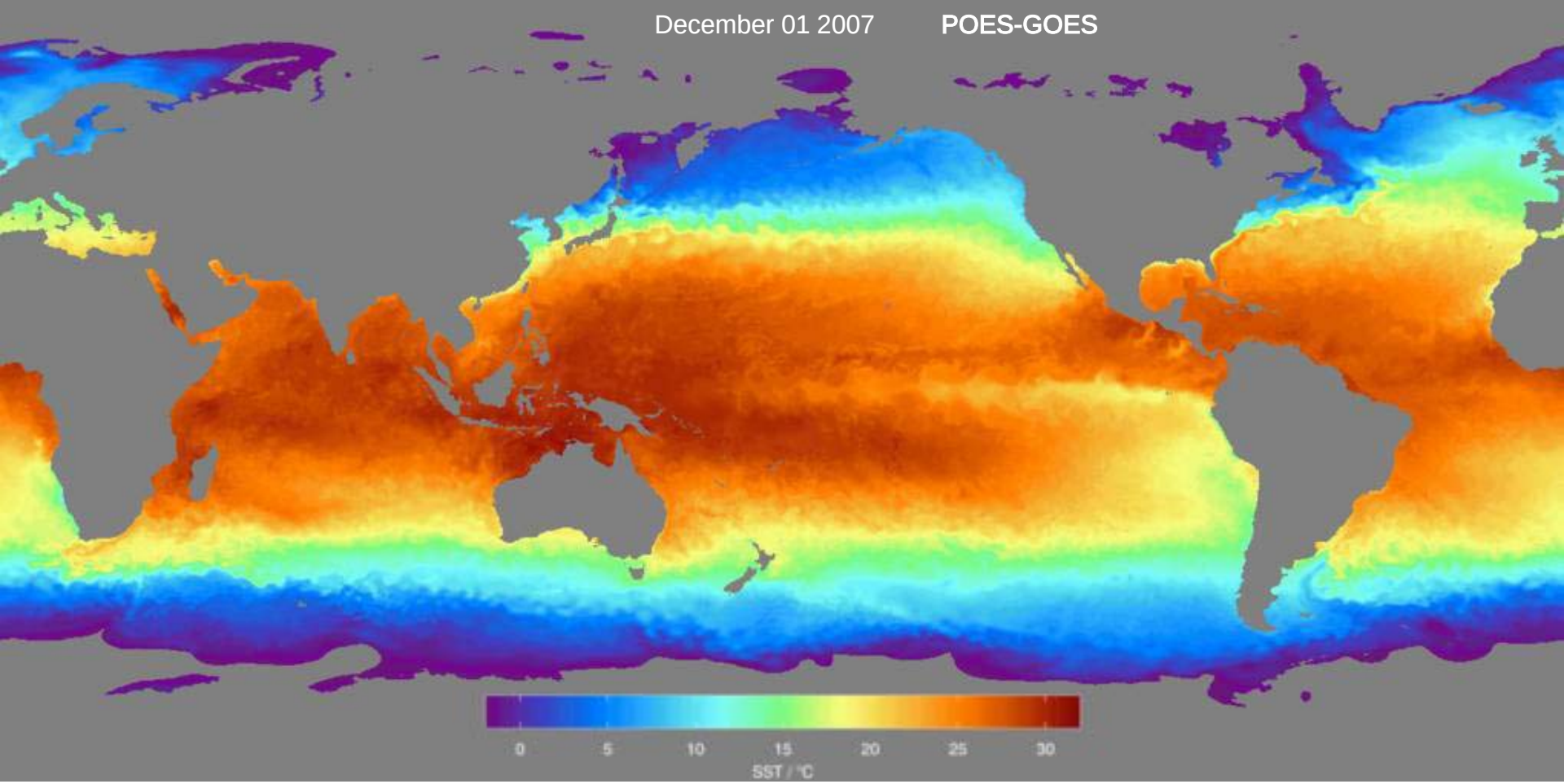
- Not much cold bias but warm in E

Bias: GOES-11 (Nighttime) December 21, 2007

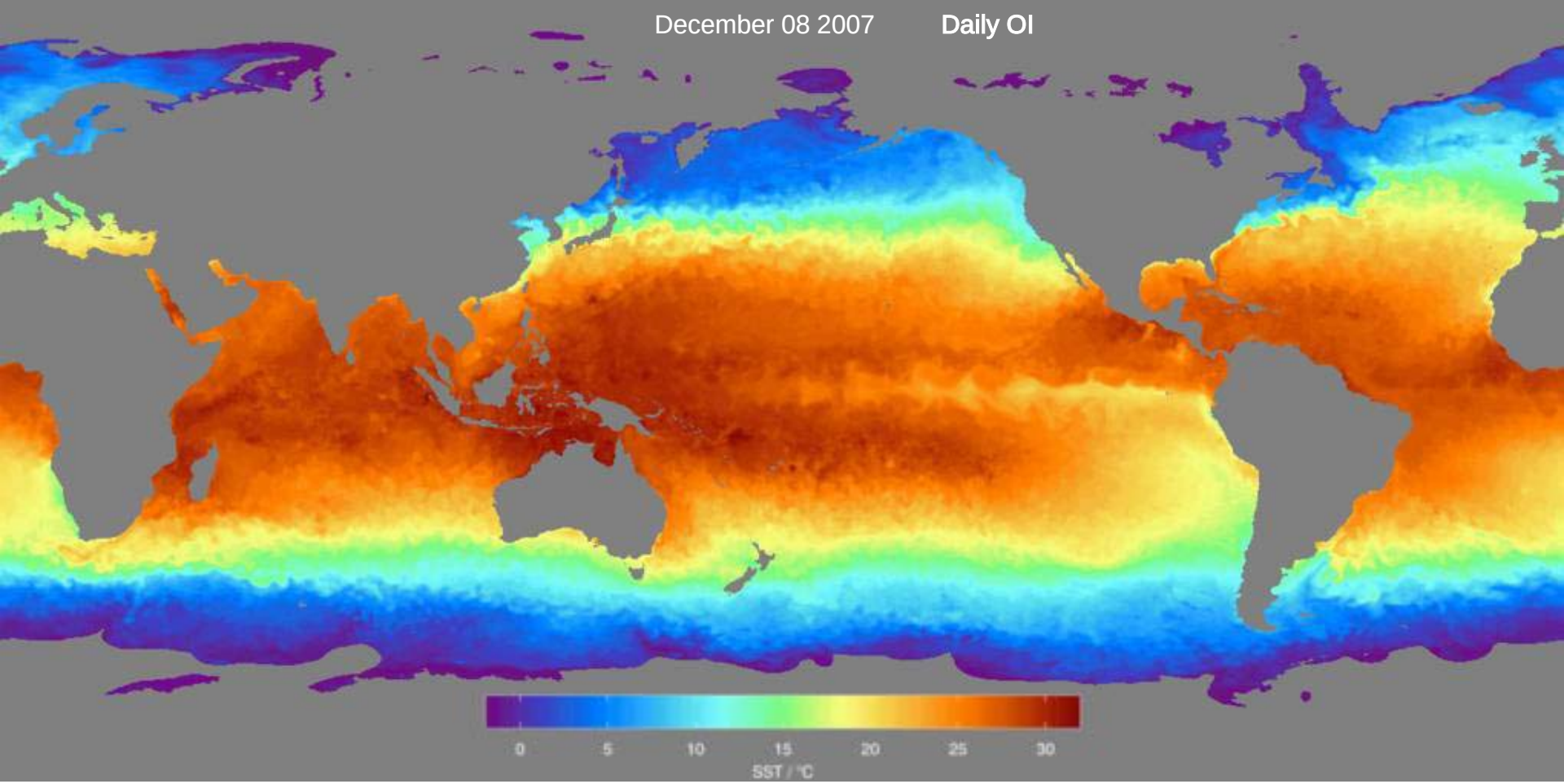


- Not so much temporal variation


December 01 2007
RTG_HR
0
5
10
15
20
25
30
SST / °C



- Improvement over RTG_HR 1/12° analysis is immediate where data are available



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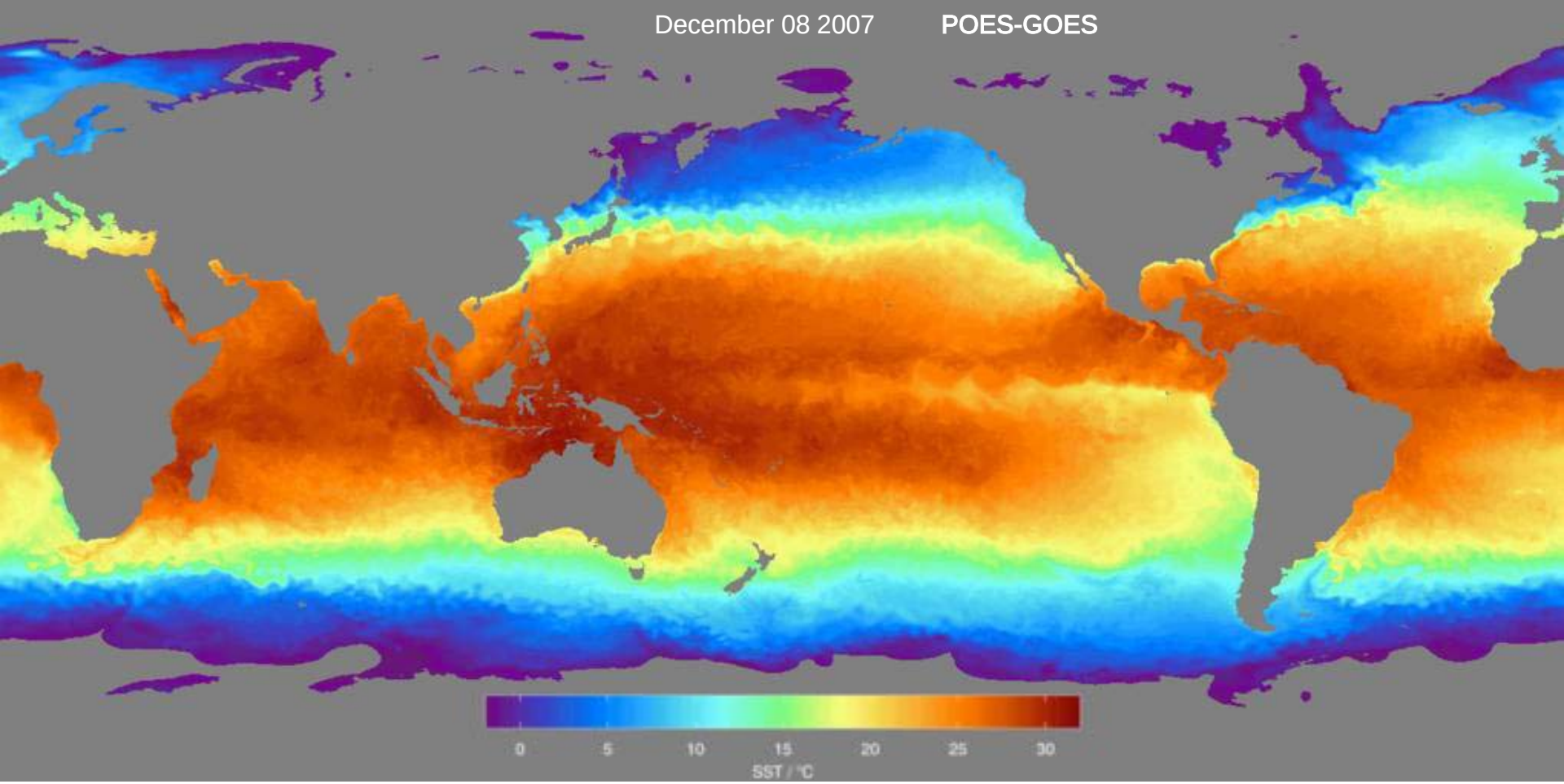
- Reynolds “Daily” OI ¼° MW+IR analysis has advantage where cloud is persistent



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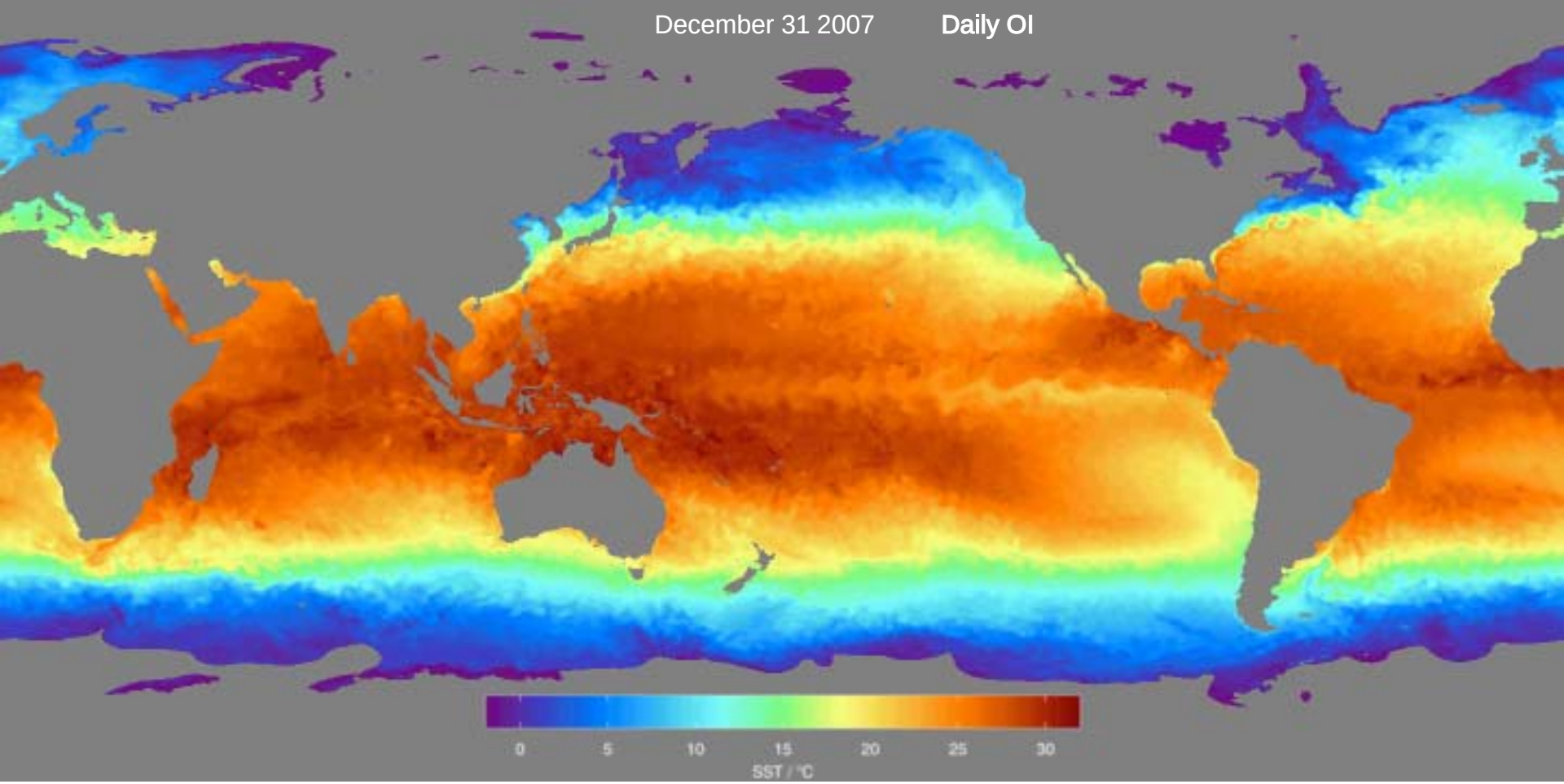
- RTG is reference field, but may drift when data are infrequent/absent, so inclusion of MW data in POES-GOES must be done with care (or also included in RTG)



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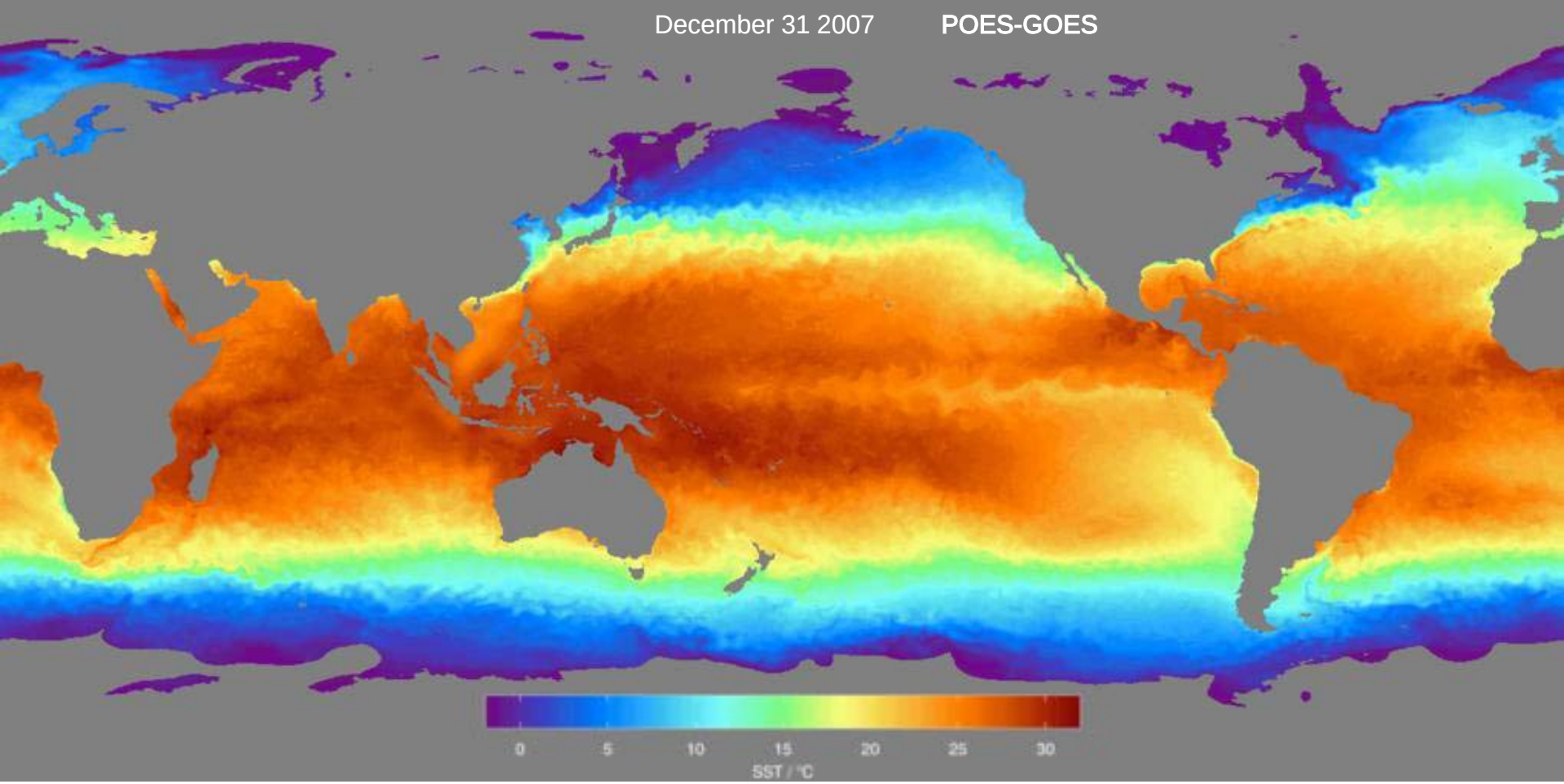
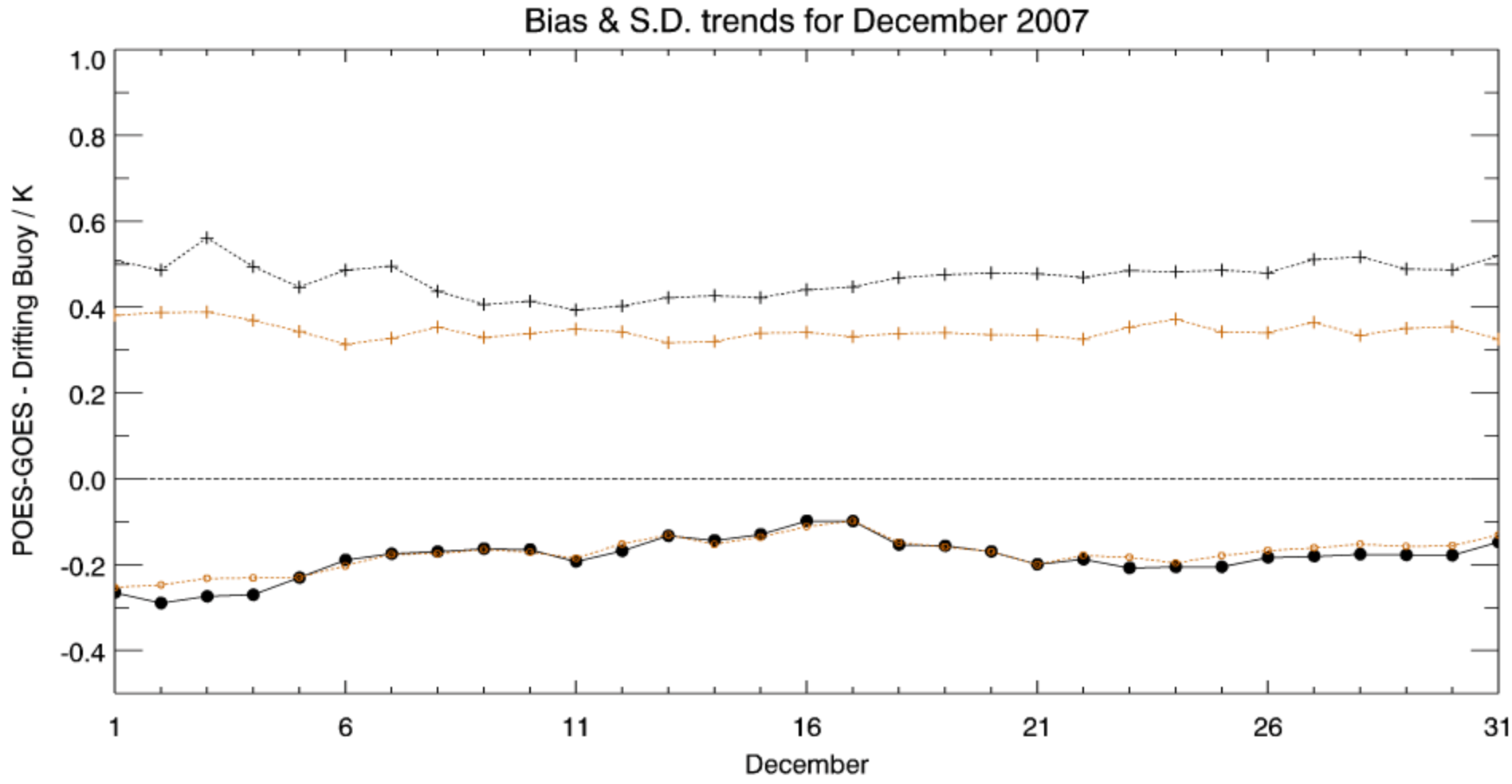


- Data-adaptive correlation length scales give reasonable balance between noise reduction and detail preservation

Validation vs Drifting Buoys



- **~1150 buoy average SSTs per day**
  - **-0.18 ± 0.47 K (-0.17 ± 0.34 K)**

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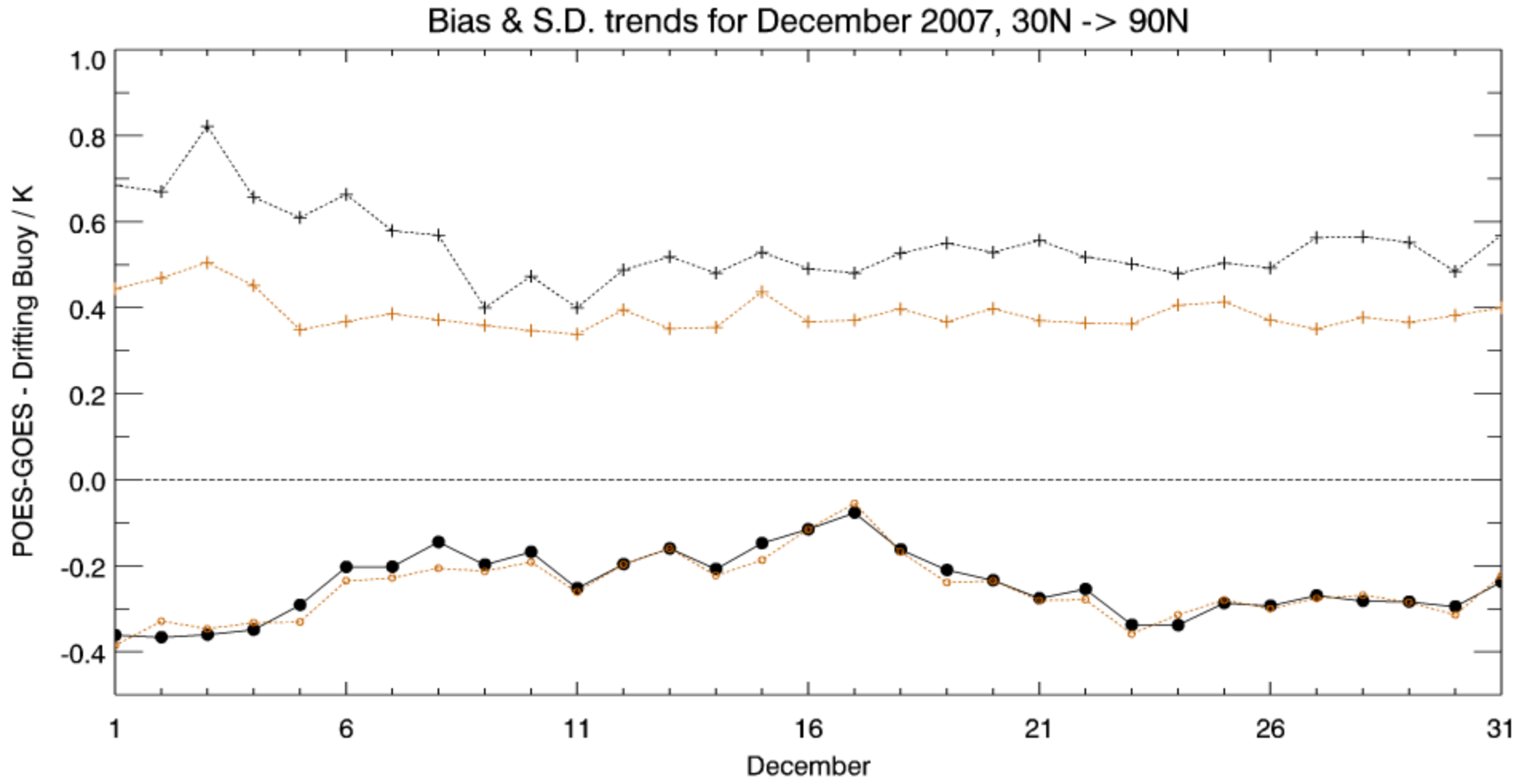

- **~1150 buoy average SSTs per day NH ~300/dy -0.24 ± 0.56 K (-0.25 ± 0.39 K)**
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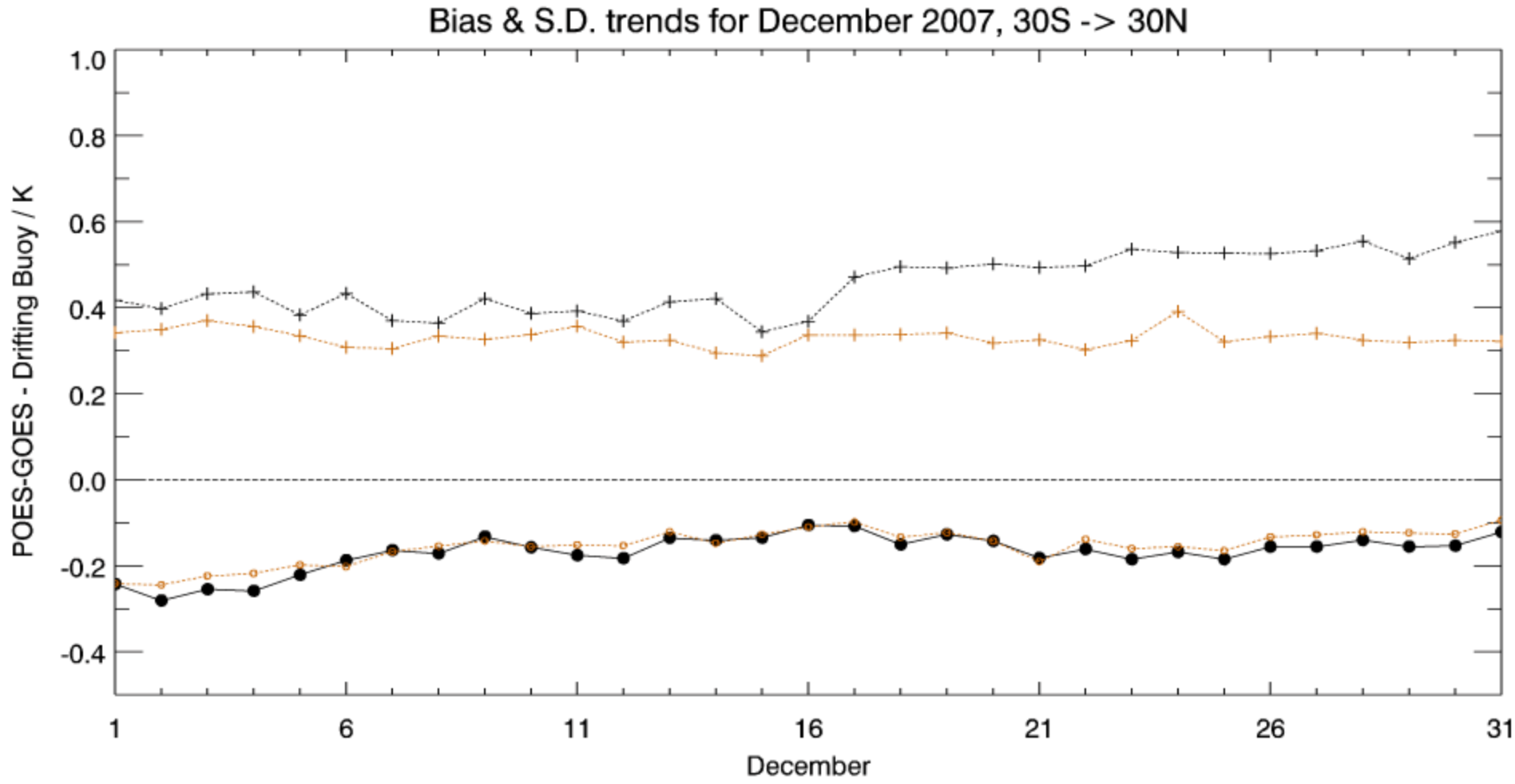

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NH ~300/dy -0.24 ± 0.56 K (-0.25 ± 0.39 K)

TR ~550/dy -0.17 ± 0.46 K (-0.15 ± 0.33 K)

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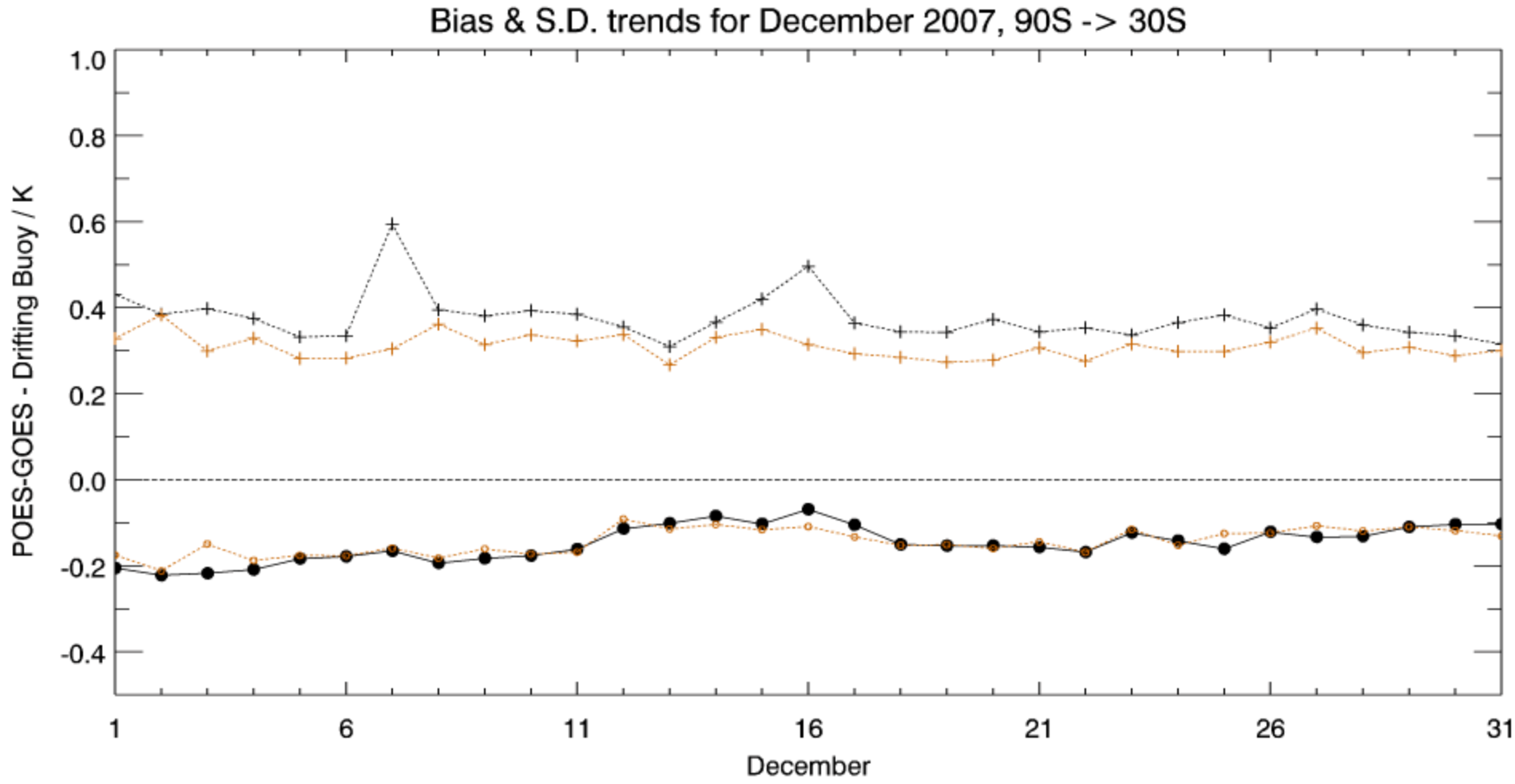

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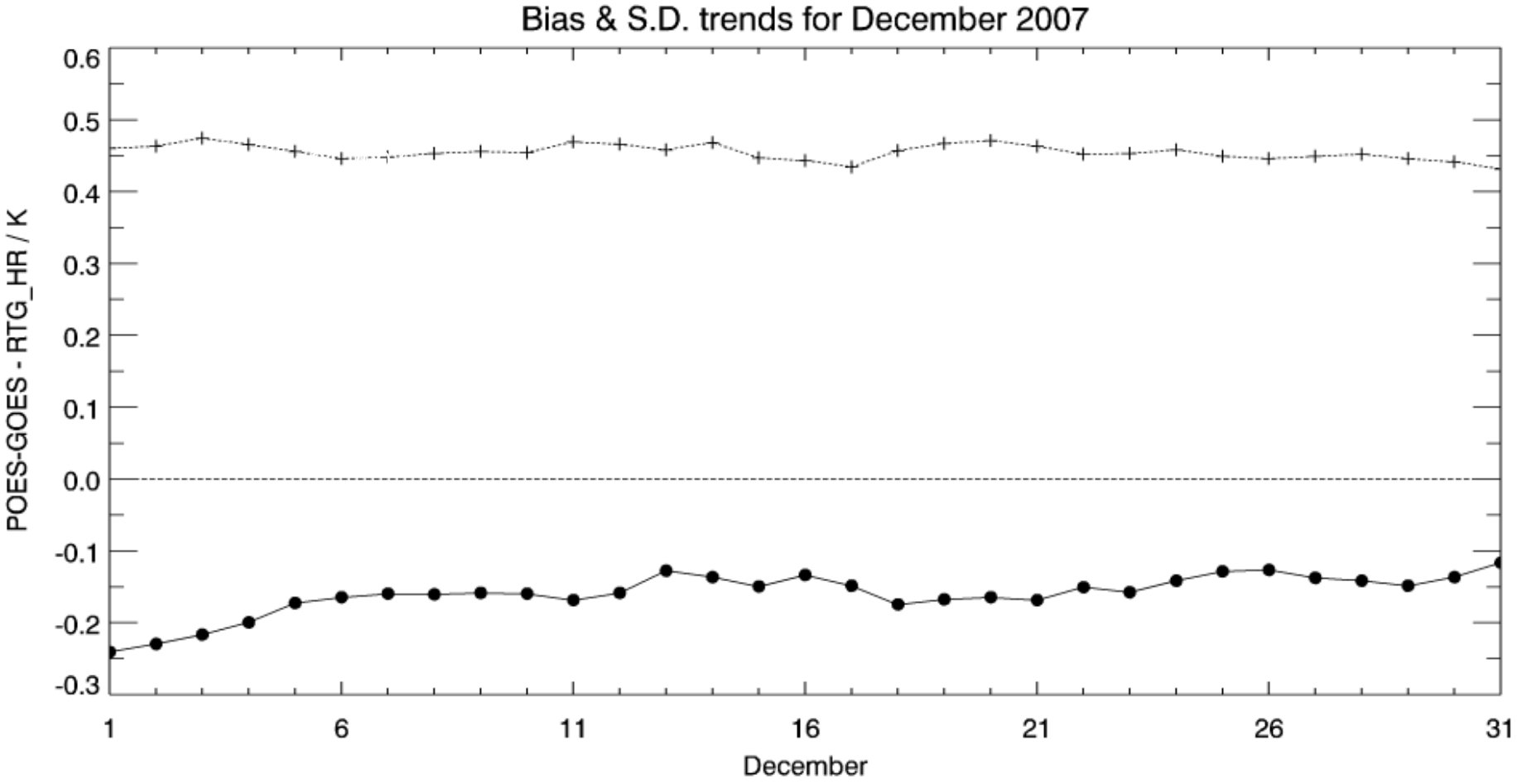
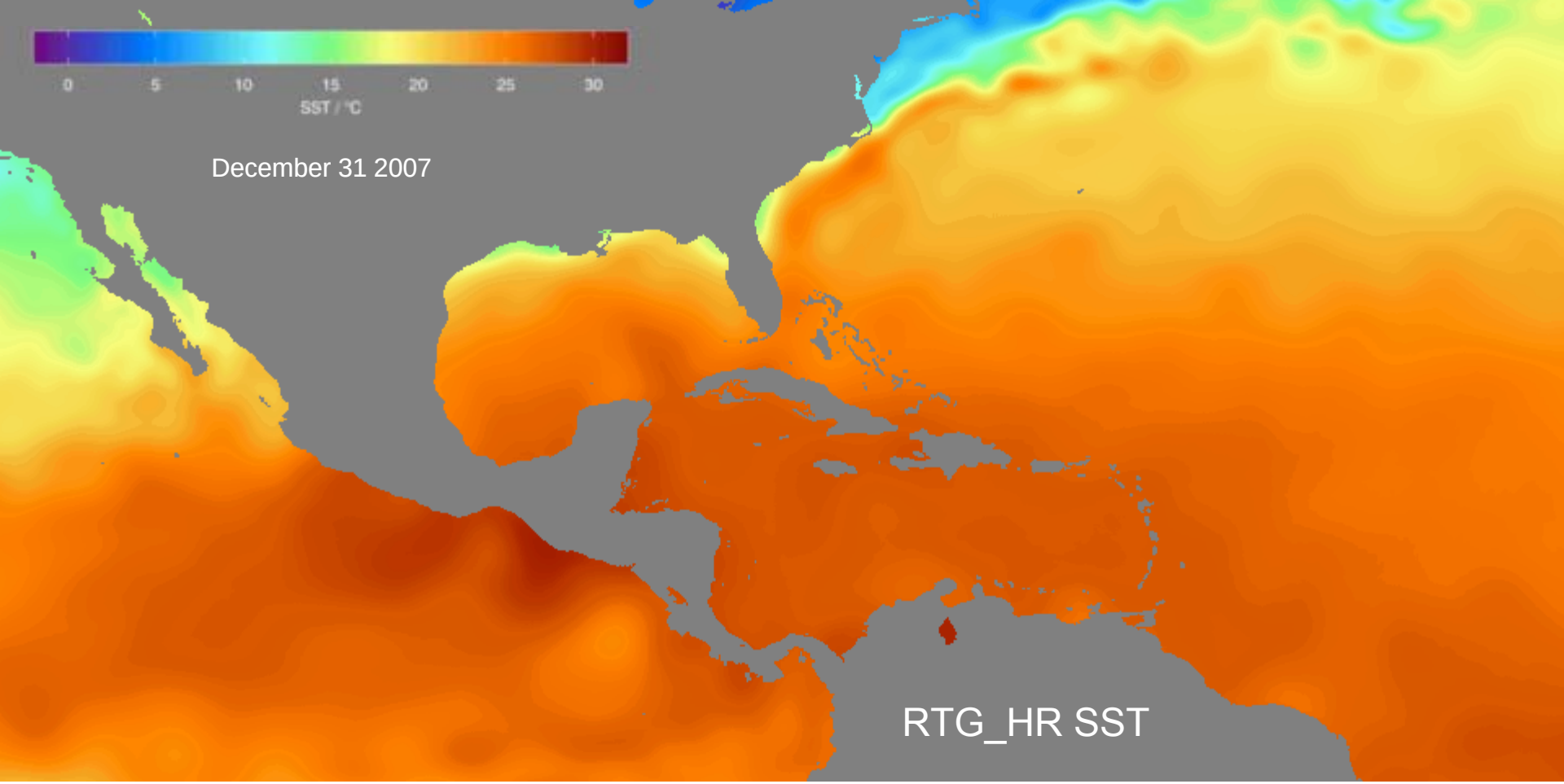
SH ~300/dy -0.14 ± 0.38 K (-0.14 ± 0.31 K)



- Point-for-point comparison with RTG_HR shows S.D. of 0.45 K
  - Note: Bias gradually adjusting to zero
- Comparison with Reynolds ¼° daily OI has S.D. of 0.65 K



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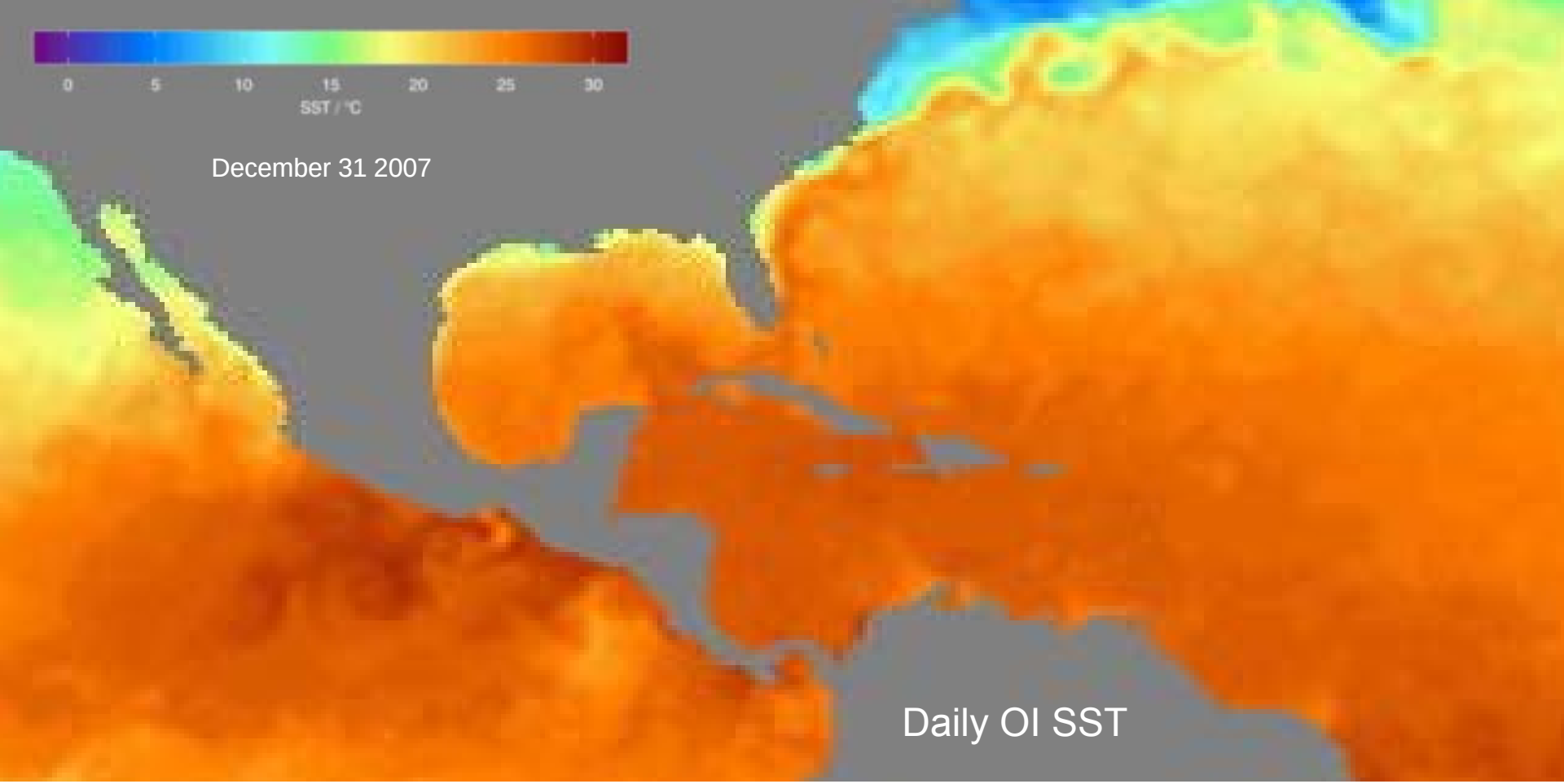

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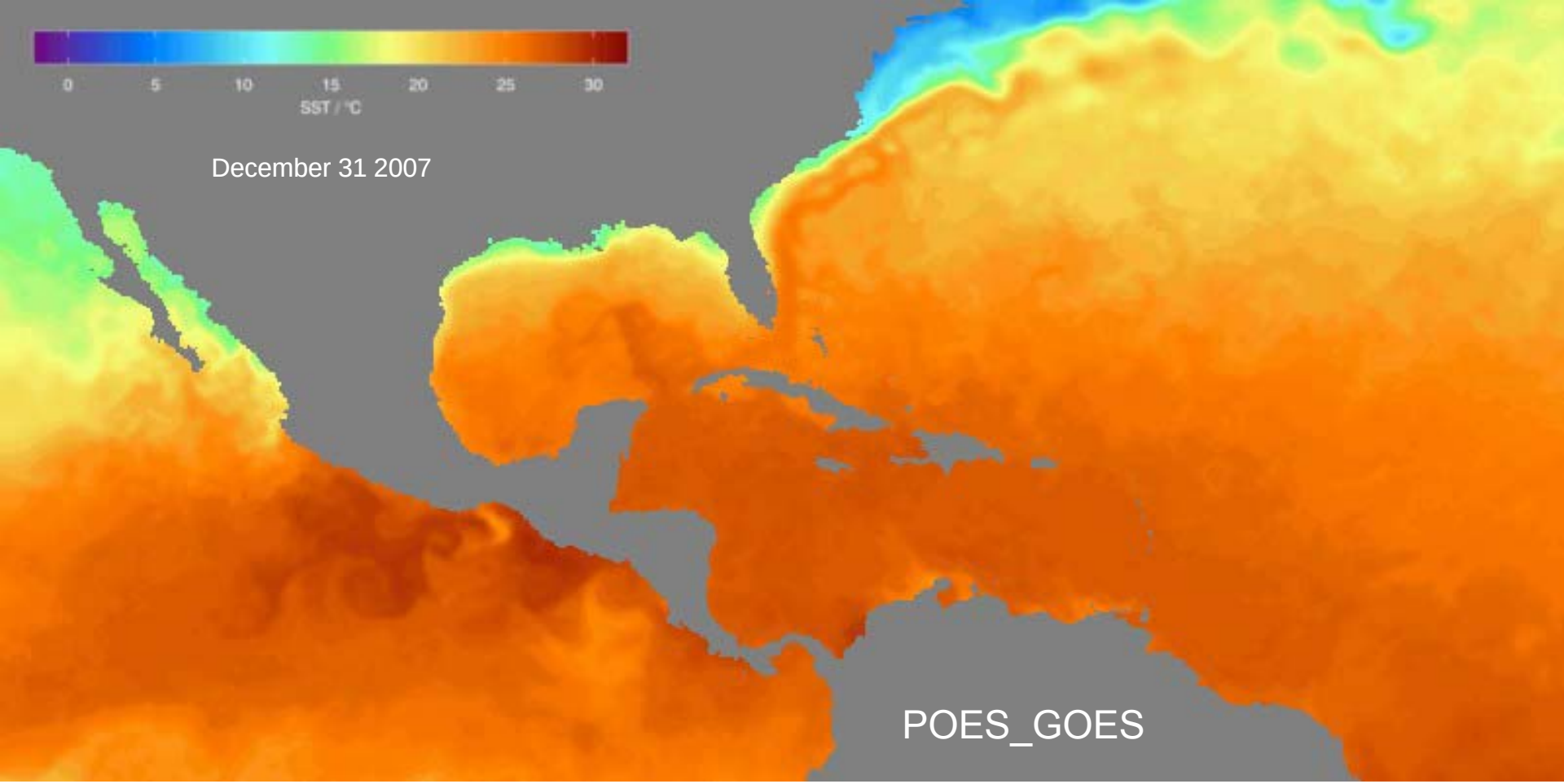

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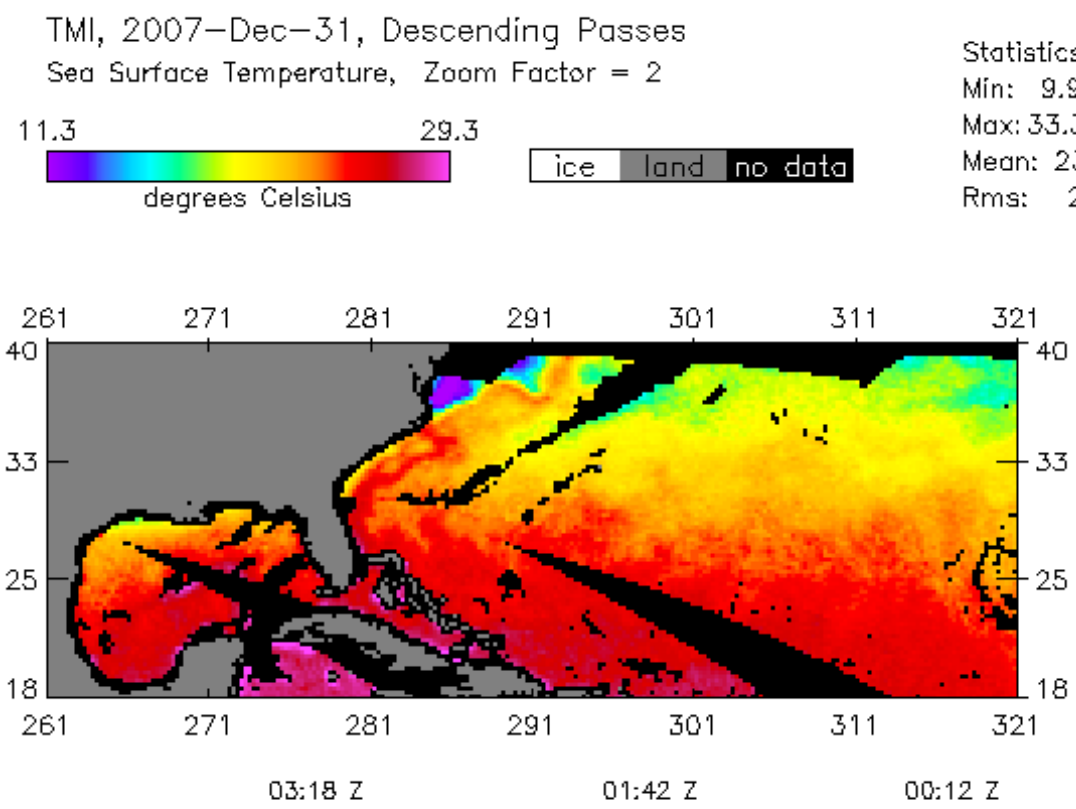
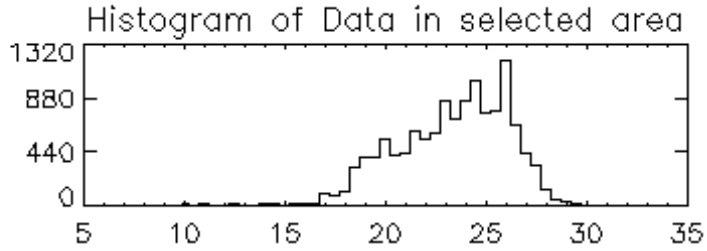
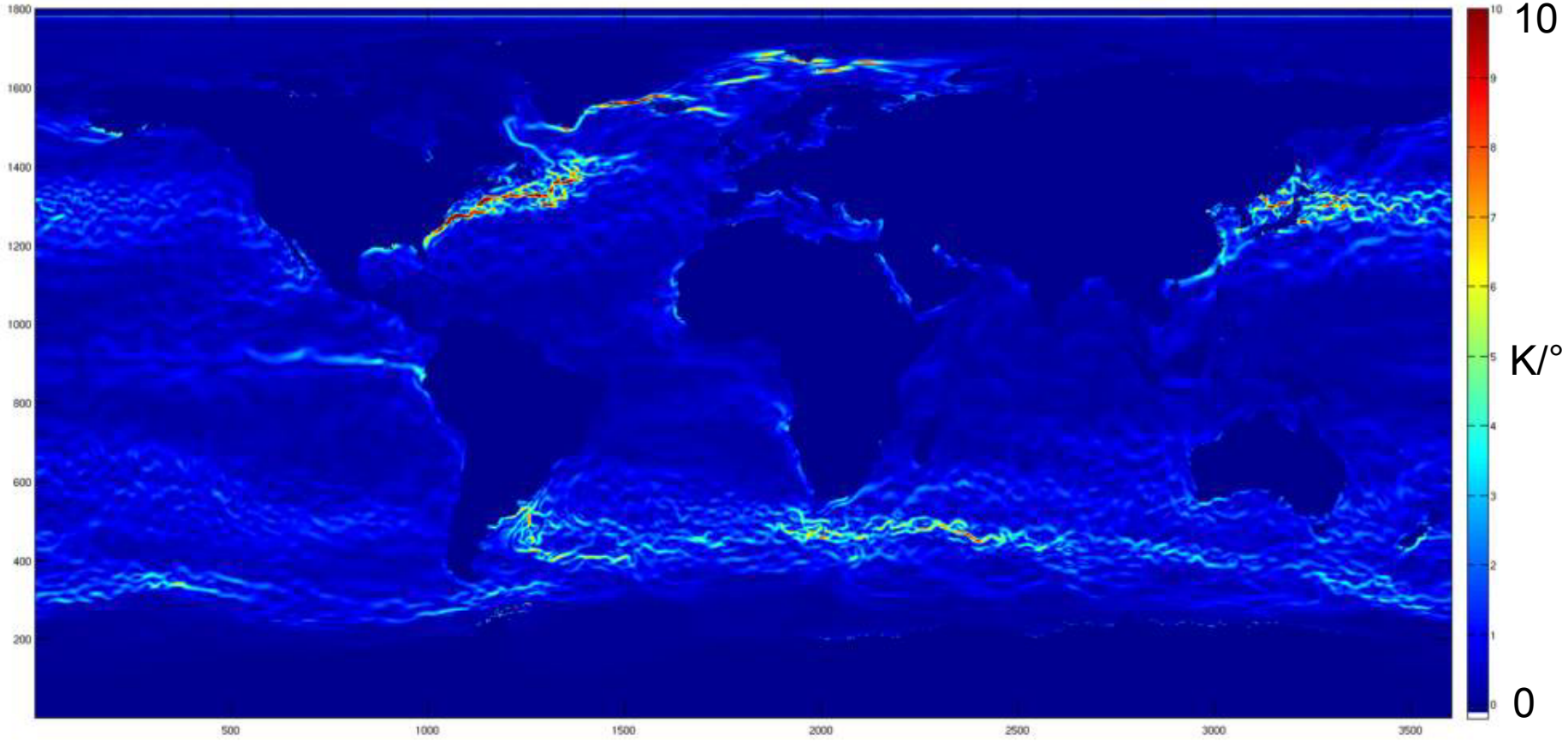
MW Data for December 31 2007



Statistics :
Min: 9.90
Max: 33.30
Mean: 23.19
Rms: 2.82



Comparison of gradients



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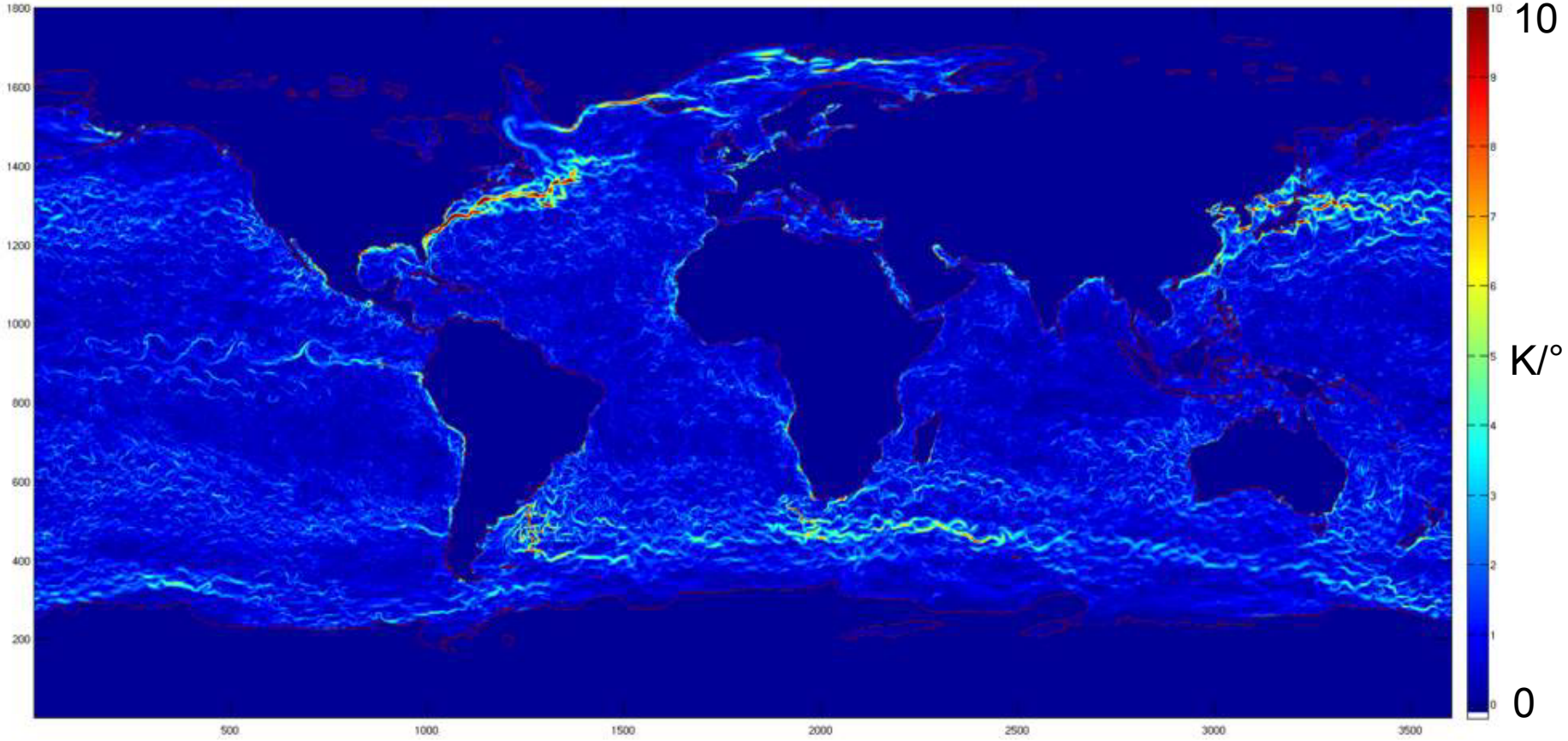
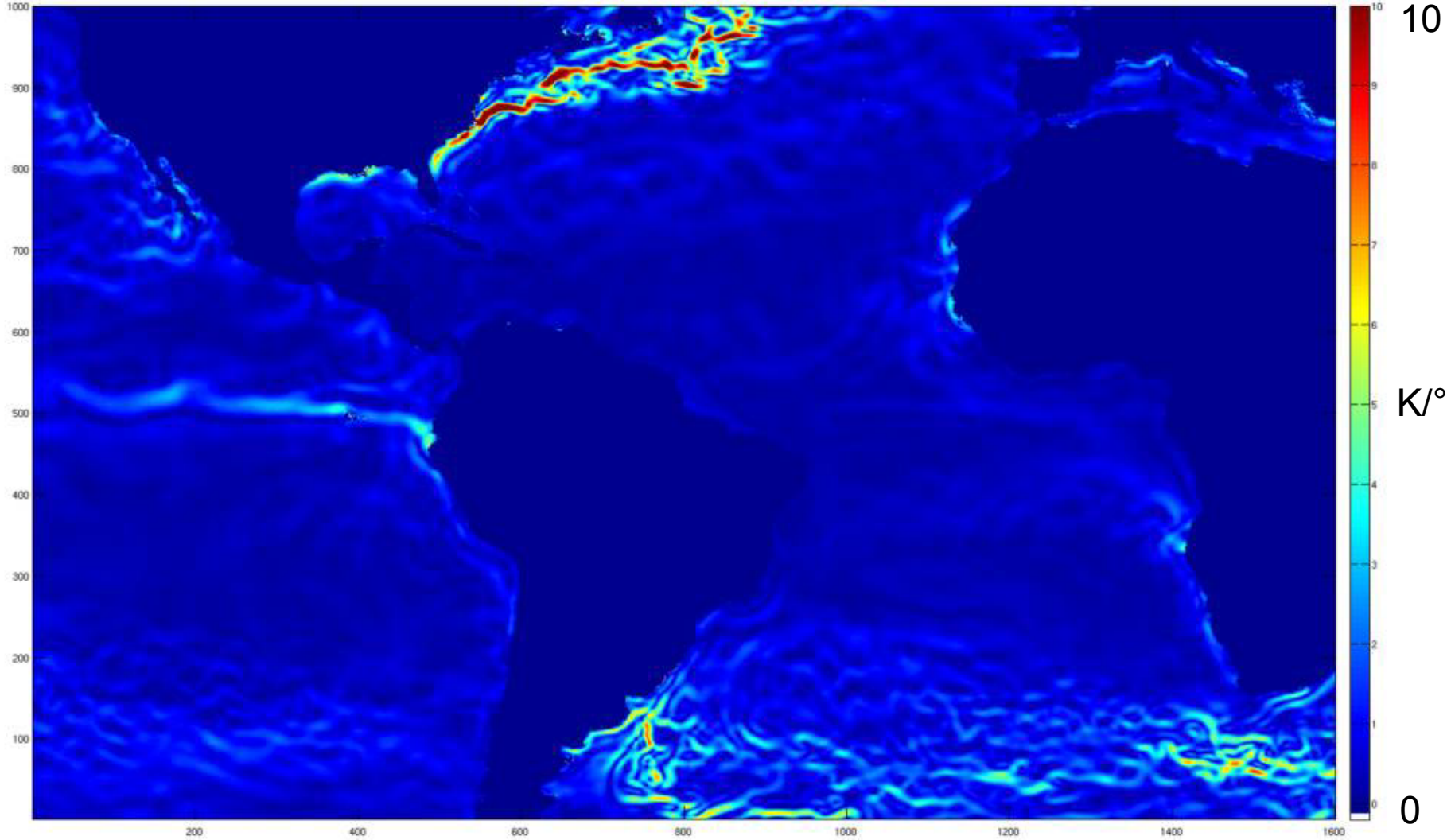


Regional Comparison



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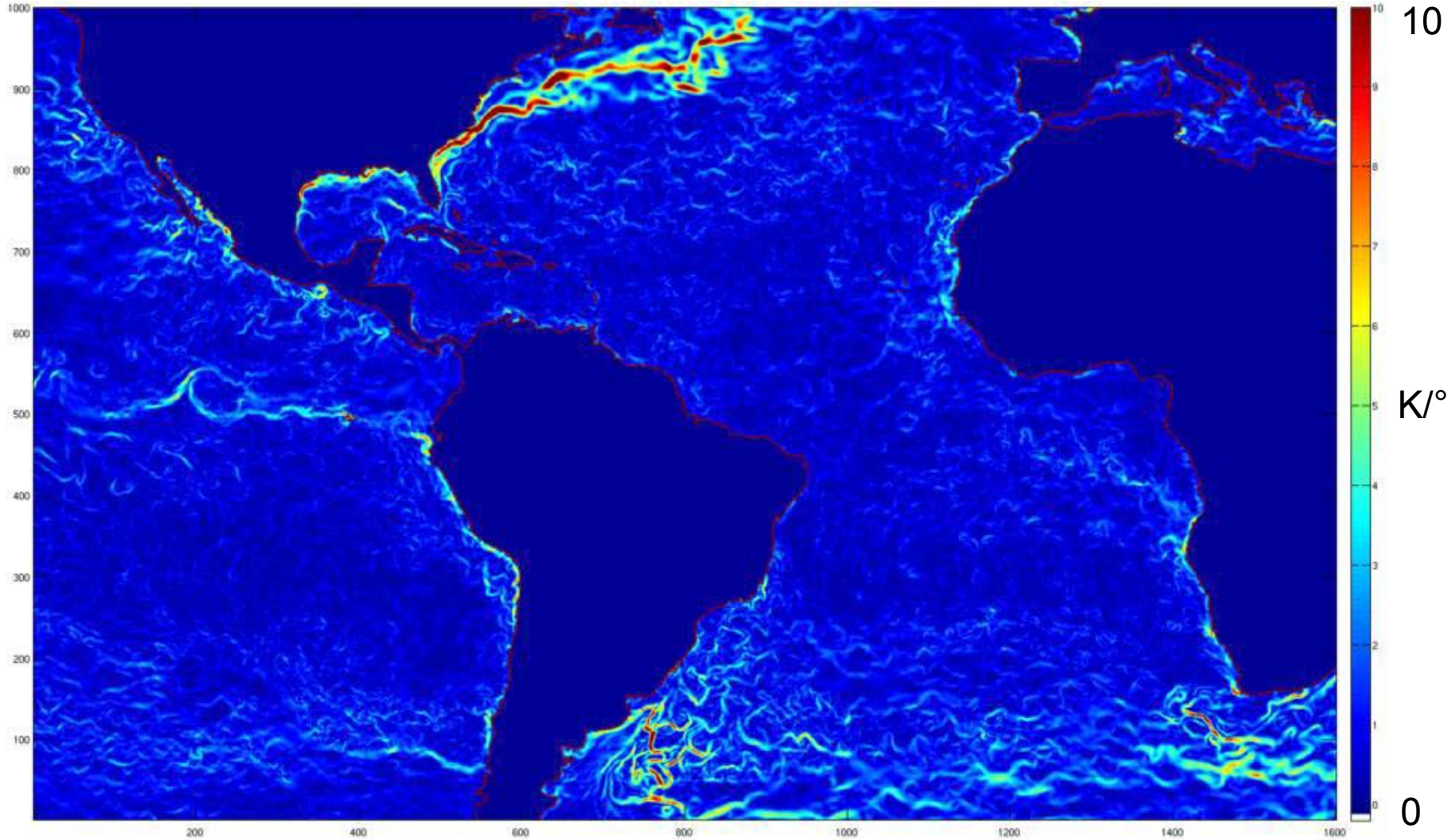
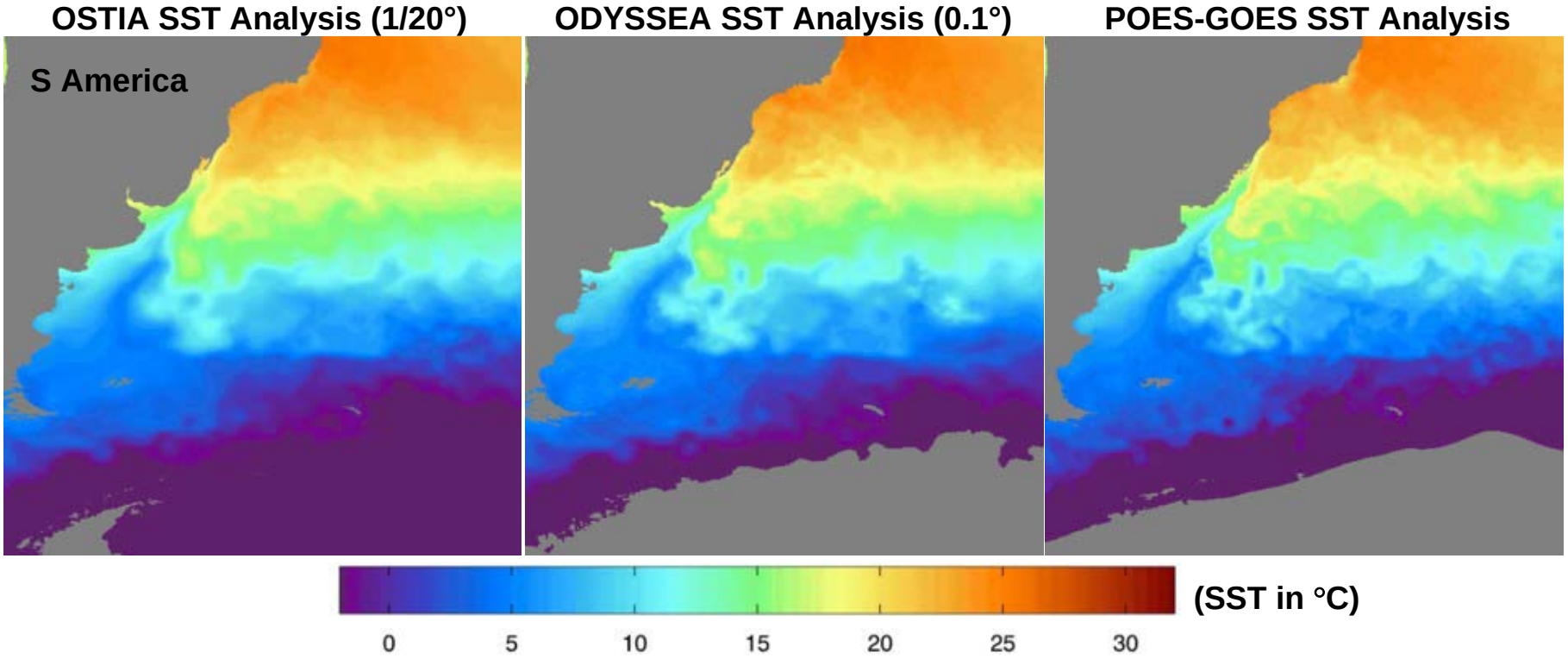
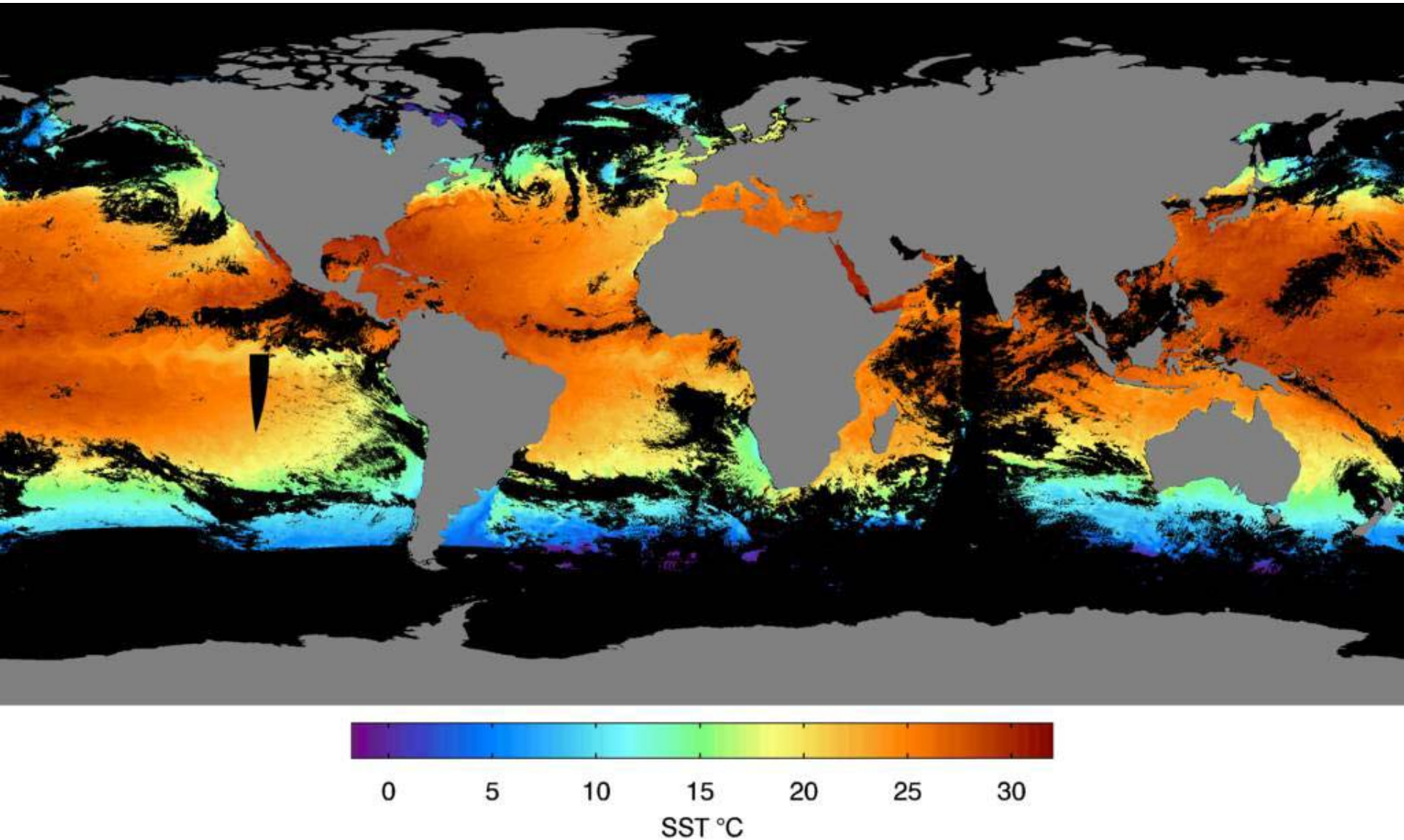


Quick look *c.f.* other “hi-res” global SST analyses



- It seems that the correlation length scales for the OSTIA analysis are not sufficient to permit mesoscale oceanic features to be well-resolved
- GOES data are not currently being ingested by the ODYSSEA system, which is also not computationally efficient enough to permit inclusion of full analysis of separate datasets

Geostationary coverage



Summary

- POES-GOES Analysis has following features
  - Rigorous multi-scale with Kalman Filter emulation is fast & efficient (27 mins/day)
  - Preprocessing currently takes much longer (~2 hours) but can be parallelized (and probably optimized)
  - Data-adaptive correlation length strikes reasonable balance between feature preservation and noise suppression
- Future plans include
  - Add MW data (with care)
  - Include other geostationary SST data (MT-SAT & Meteosat-9)
  - GHRSST L4 product
  - 1/20° global version (CoastWatch)
  - 1-km regional (nested multi-scale)
    - Coral Reef Watch
- Looking forward to reducing errors in input data
  - Especially calibration cycling in GOES & MT-SAT
  - Physical retrieval