NOAA's Geo-Polar Blended SST Analysis

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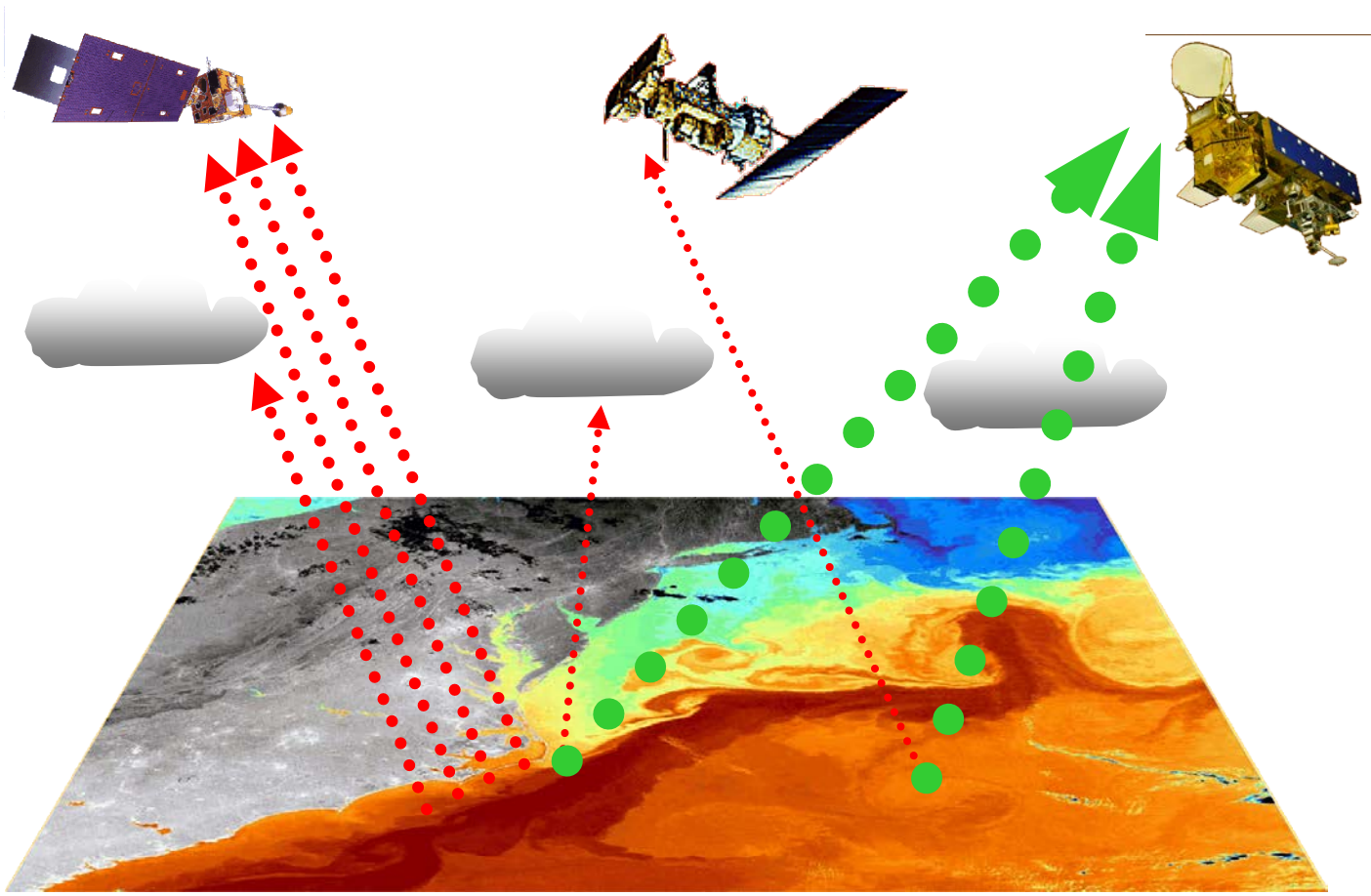
[2]NOAA/NESDIS/STAR

[3]NOAA/OAR/ESRL

[4]University of Reading, UK

[5]NOAA/NESDIS/OSPO

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**

5-km Blended SST Analysis

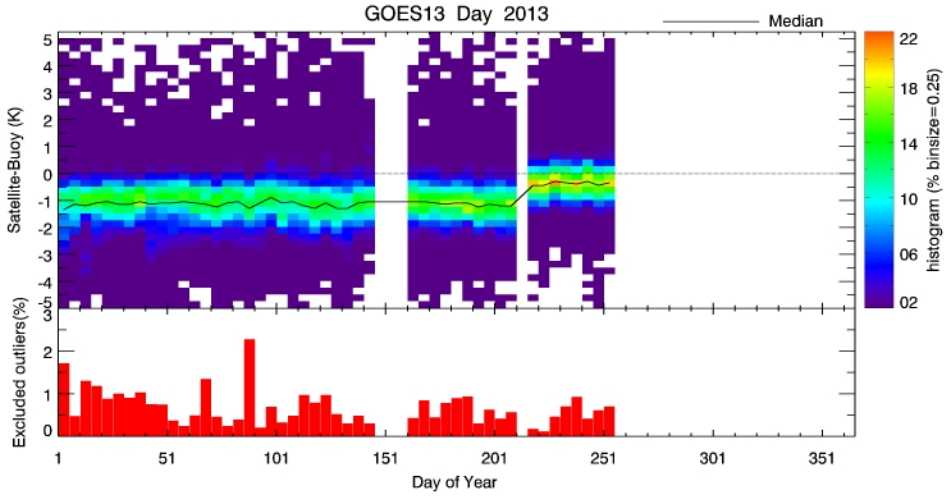
- **Produced daily from 24 hours of Polar- & Geo-SST**
  - MetOp-B
  - GOES-E/W Imager
  - MTSAT-2 Imager [Himawari-8 Imager]
  - Meteosat-10 SEVIRI
  - VIIRS
  - [AMSR-2]
  - **Does <u>not</u> use buoy data**
- **Multi-scale OI**
  - Mimics Kalman Filter **(***Khellah et. al., 2005***)**
- **3 stationary priors**
  - Short, intermediate and long correlation lengths
  - Mimic non-stationary prior while preserving rigor
  - Interpolation of resultant analyses based data density
    - ➢ **<u>Allows fine resolution where possible without introducing noise</u>**

Recent update to Geo-SST

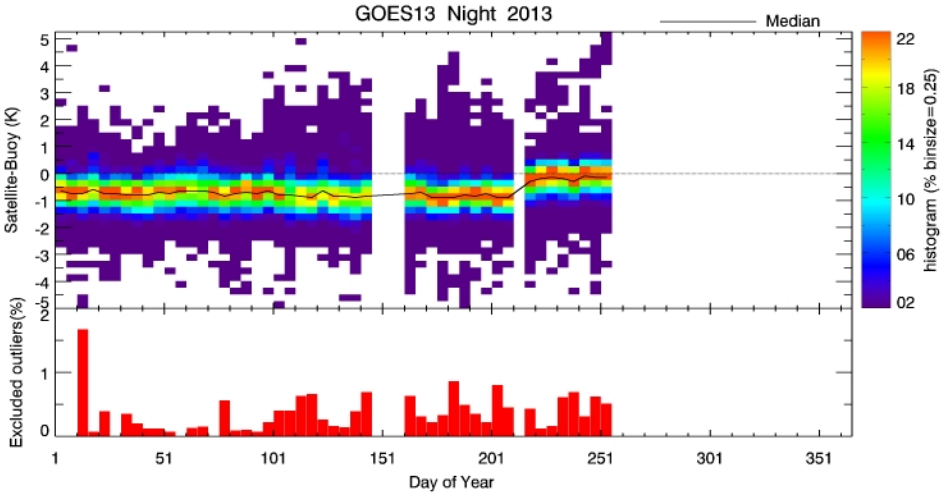
- **Physical retrieval based on Modified Total Least Squares**
- **Improved bias and scatter *cf.* previous regression-based SST retrieval**

GOES-13

Daytime



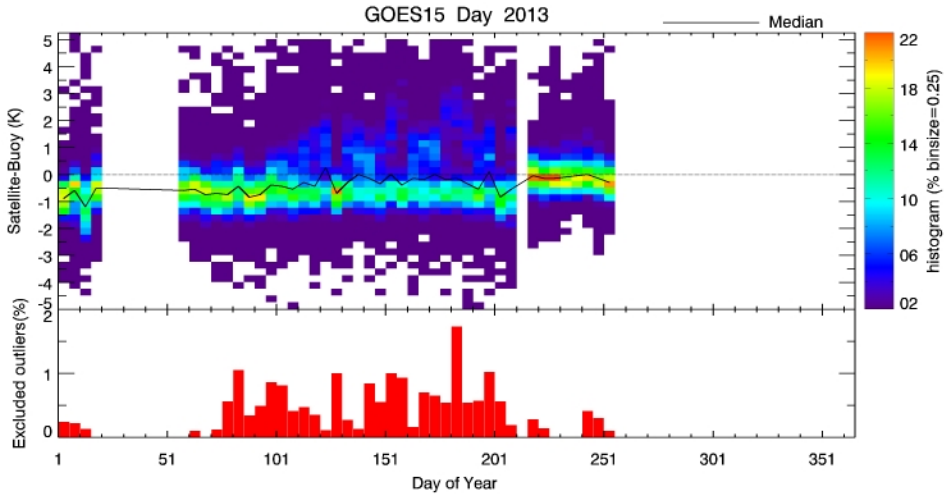
Nighttime

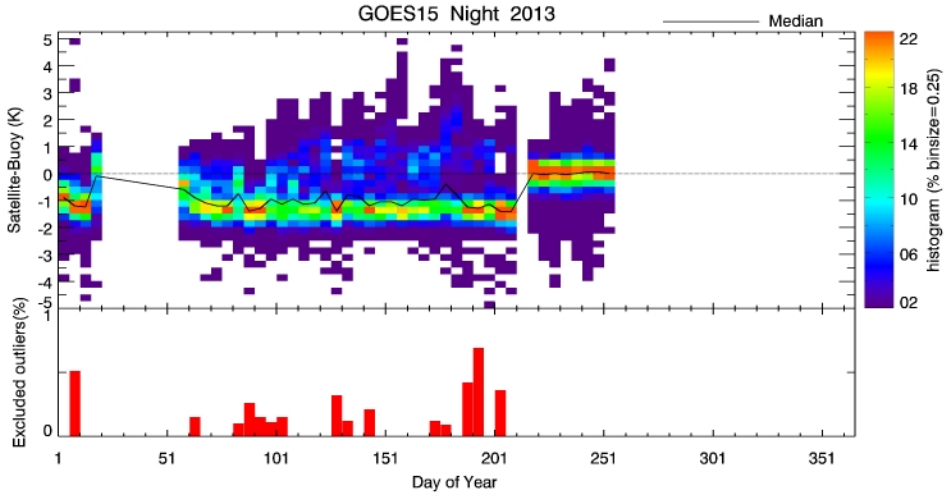


Recent update to Geo-SST

- **Physical retrieval based on Modified Total Least Squares**
- **Improved bias and scatter *cf.* previous regression-based SST retrieval**

GOES-15

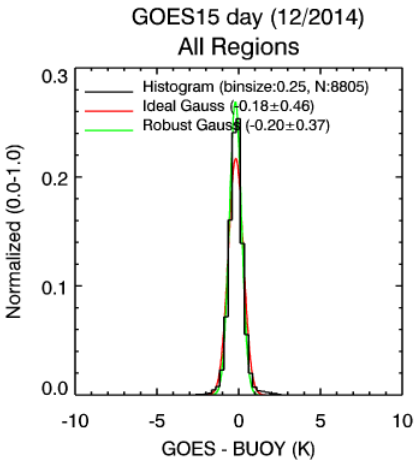




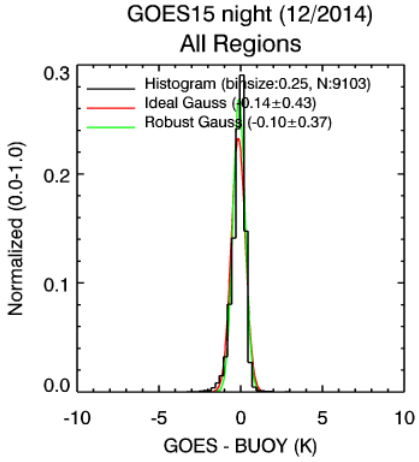
Daytime **Nighttime**

Product Accuracy: Geo-SST

GOES-15

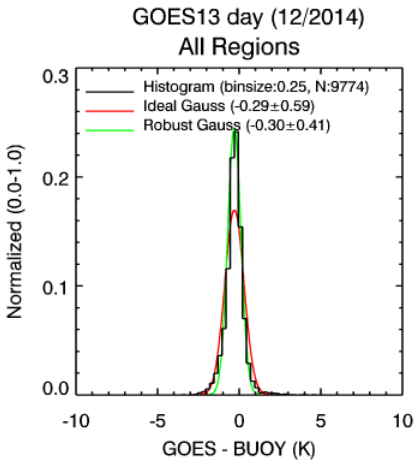


-0.18±0.46 (0.37)

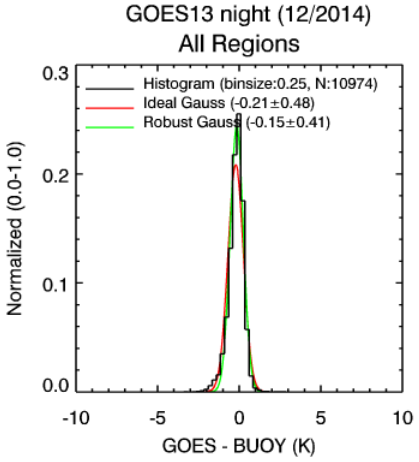


-0.14±0.43 (0.37)

GOES-13

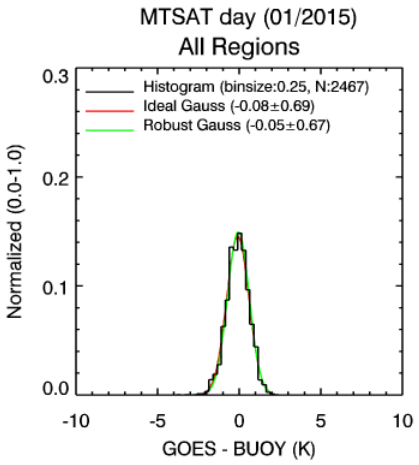


-0.29±0.59 (0.41)

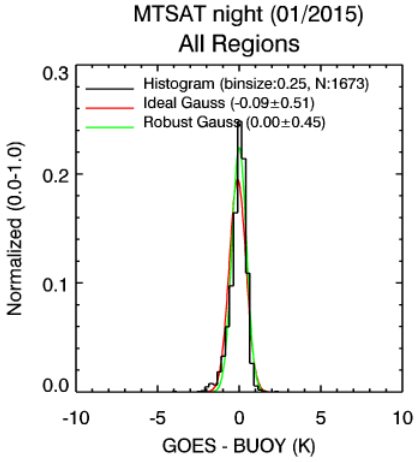


-0.21±0.48 (0.41)

MTSAT-2

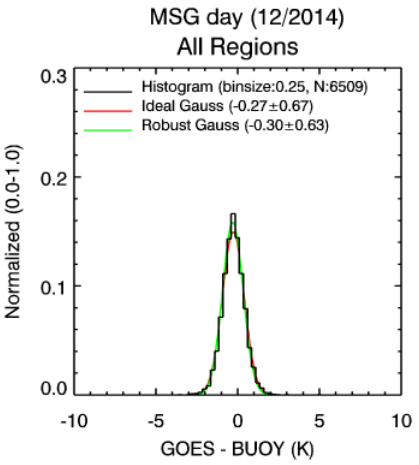


-0.08±0.69 (0.67)

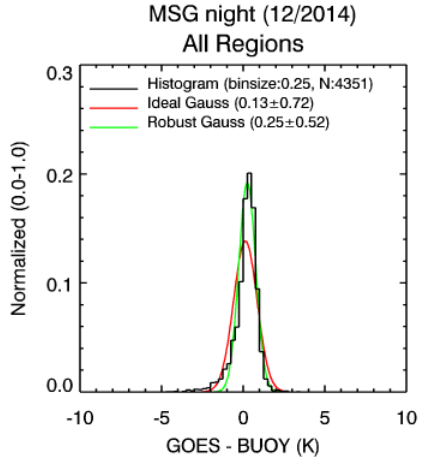


-0.09±0.51 (0.45)

Meteosat-10

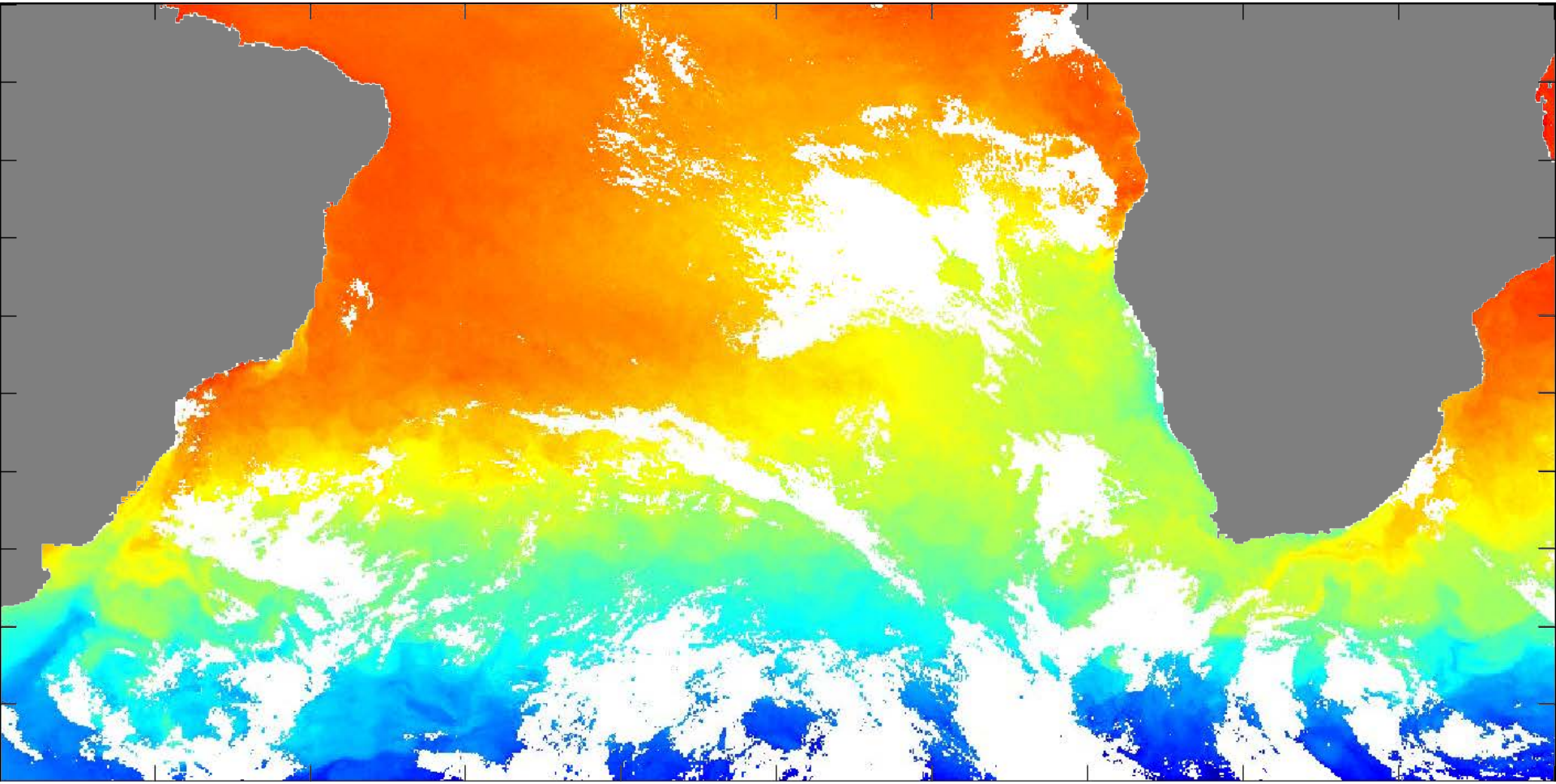


-0.27±0.67 (0.63)



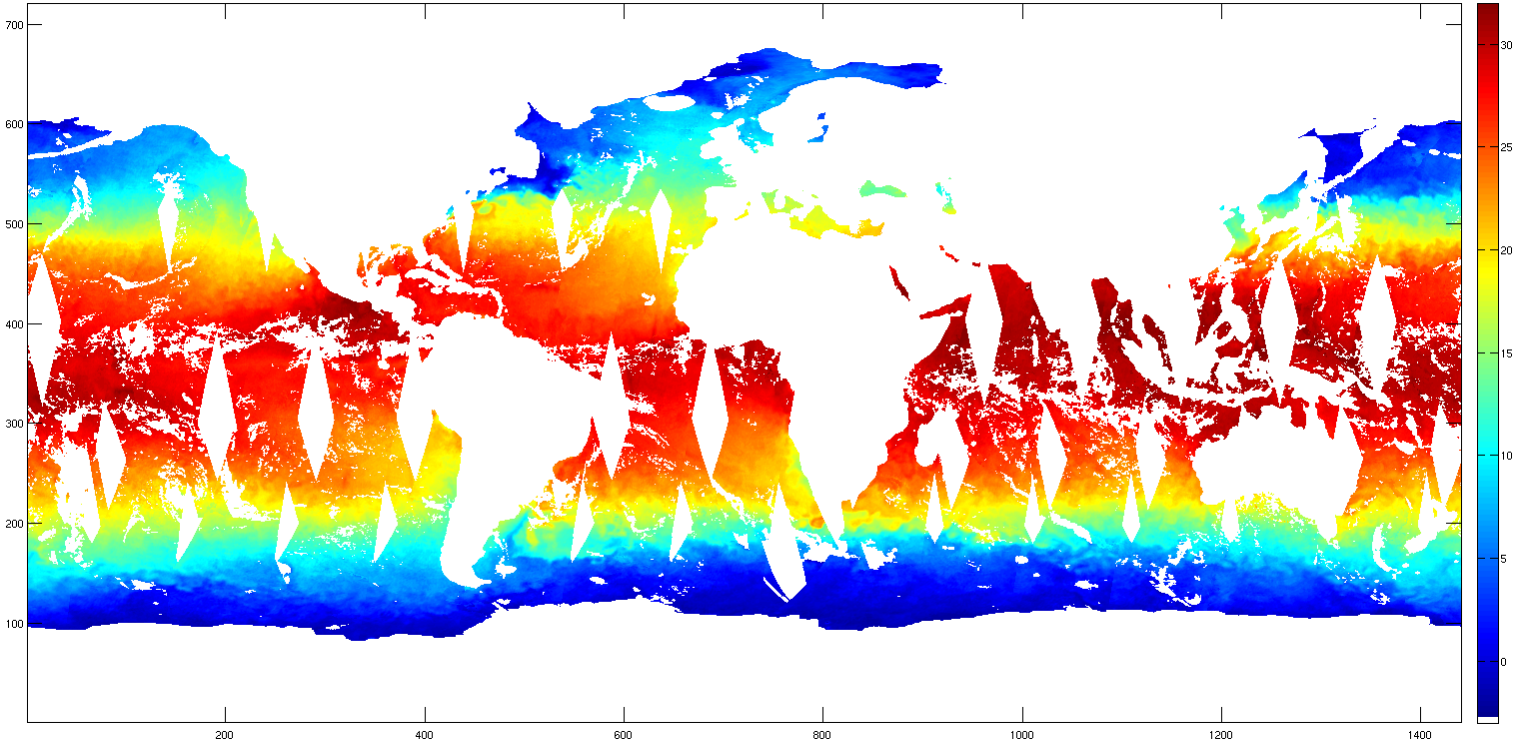
0.13±0.72 (0.52)

Combined coverage



Geo-SST dominates low-to-mid latitudes

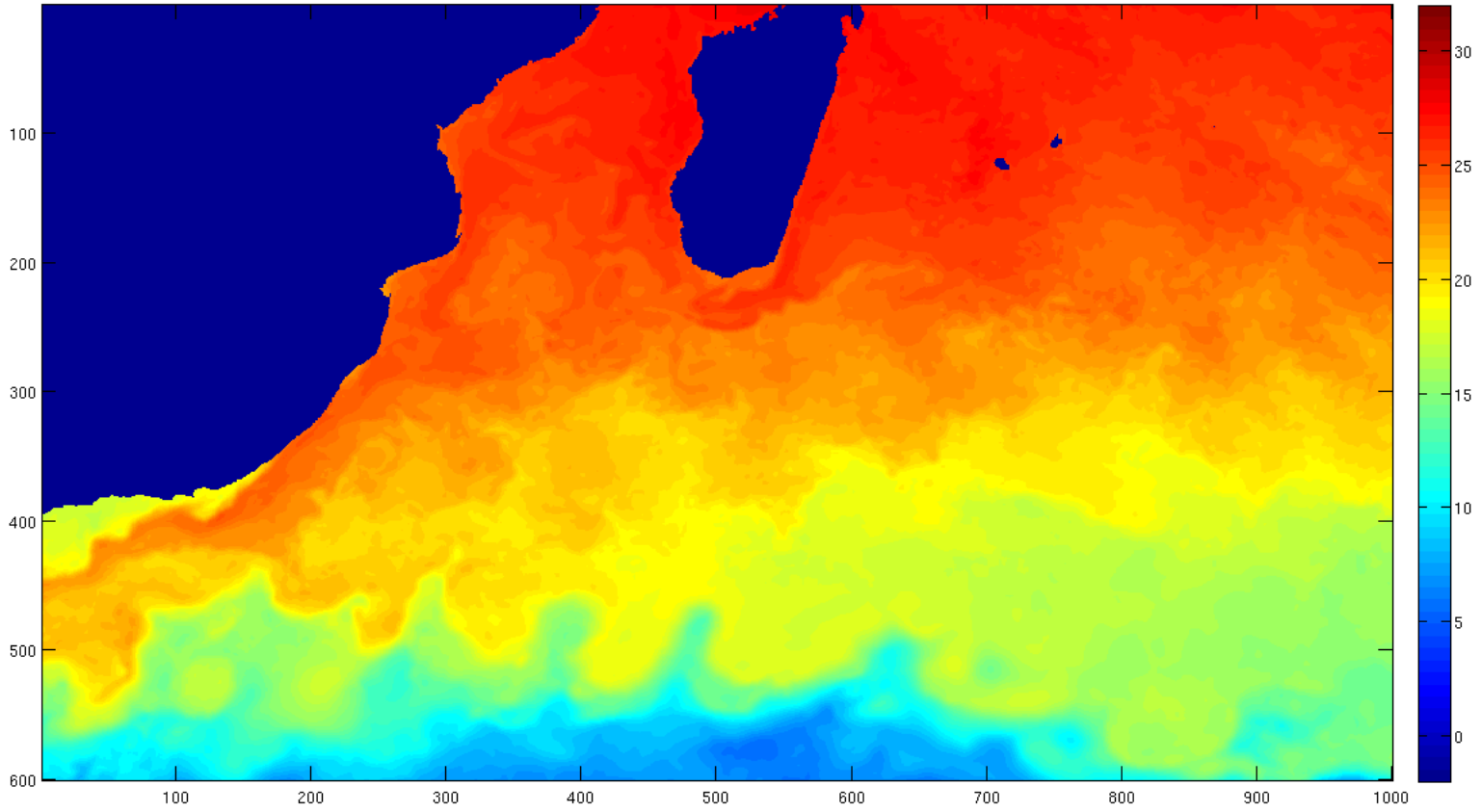
Data Coverage – AMSR-2



- Valid SST data coverage from AMSR-2 for 2014-05-01
  - » Improved coverage in both Tropics and High Latitudes
  - » 3 days gives almost complete coverage away from land & ice

VIIRS data

- **VIIRS successfully incorporated into Geo-Polar Blended 5-km global SST analysis**

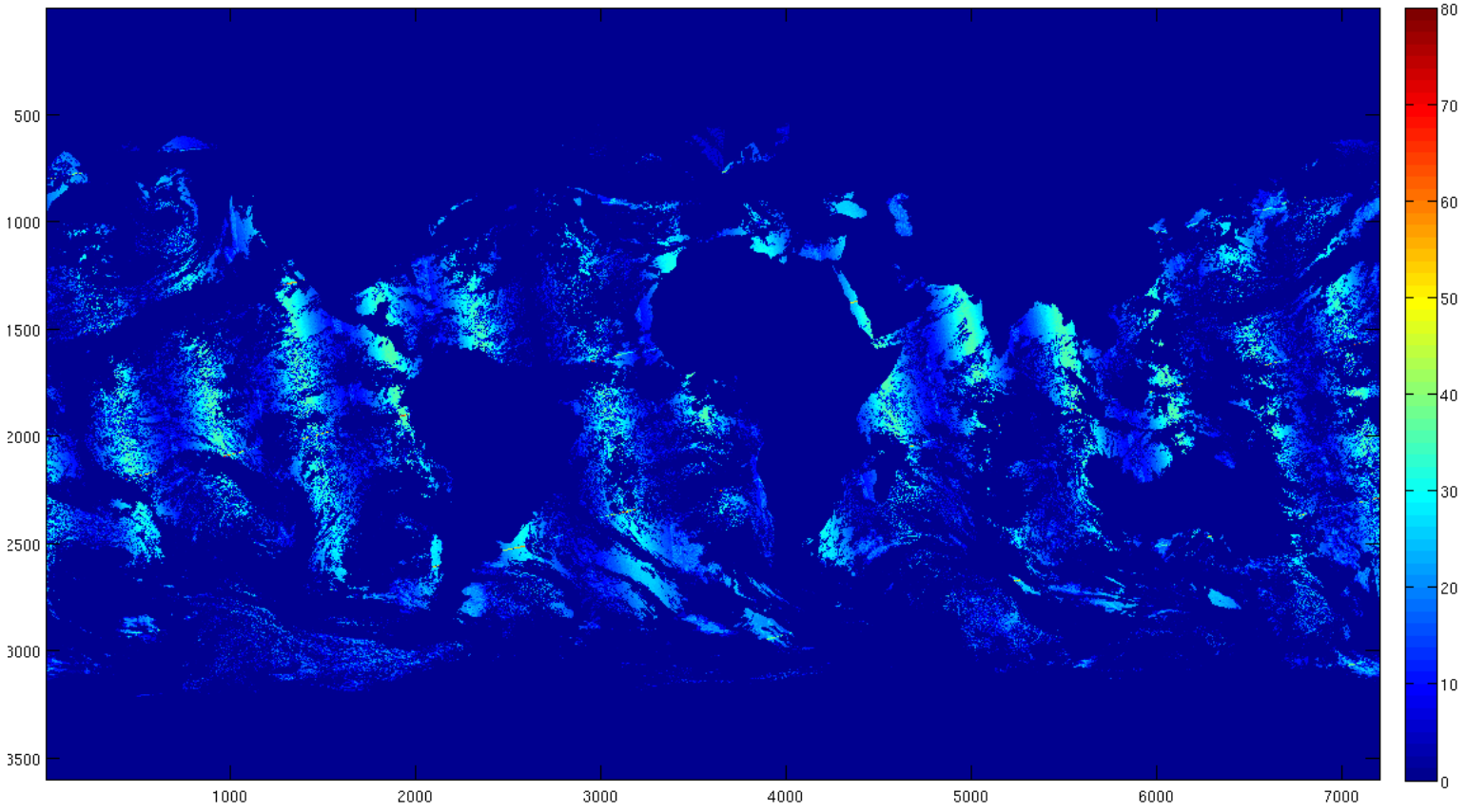


Super-obbed VIIRS SST data

Final SST analysis

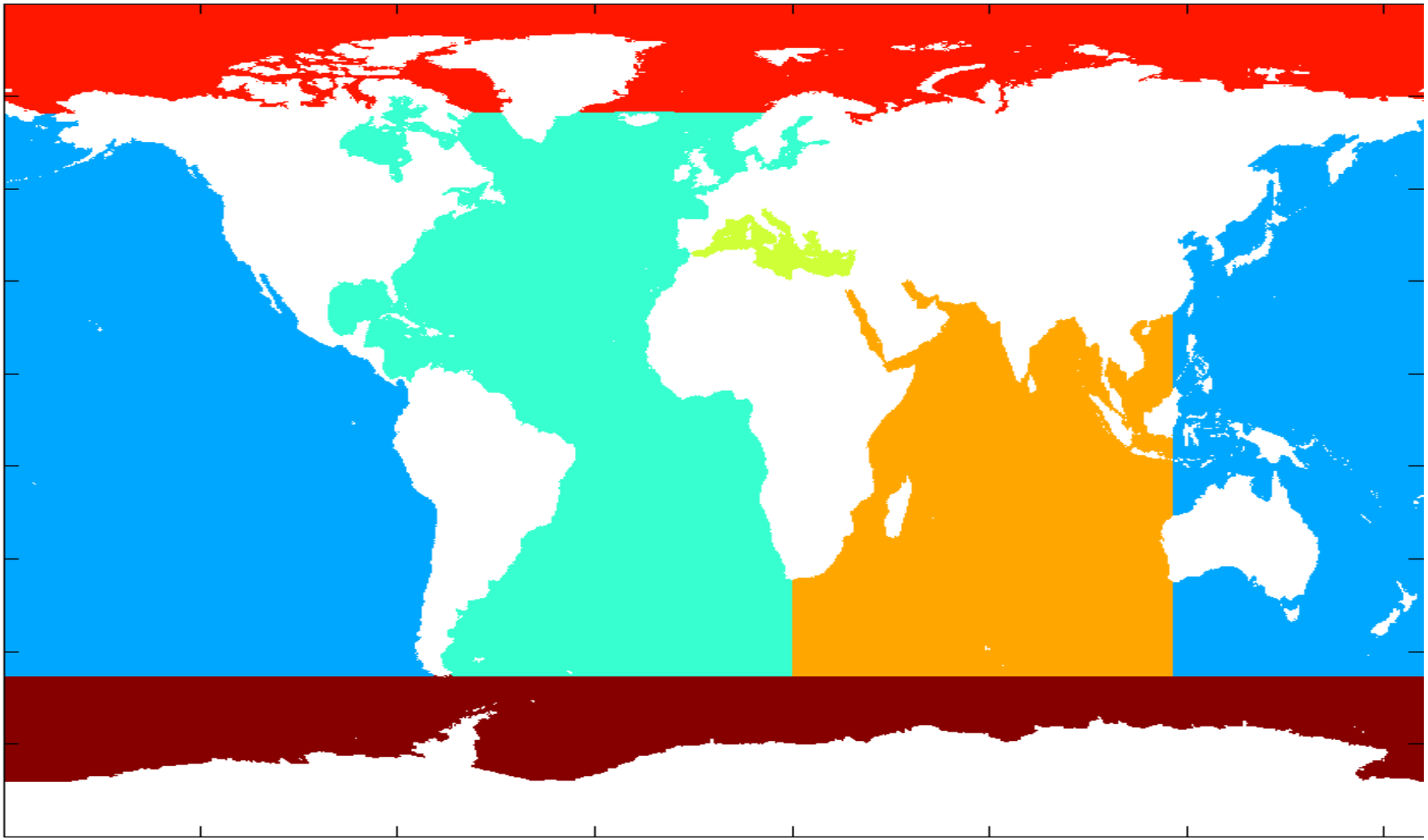
VIIRS coverage

- **Coverage is improved w.r.t. MetOp AVHRR**

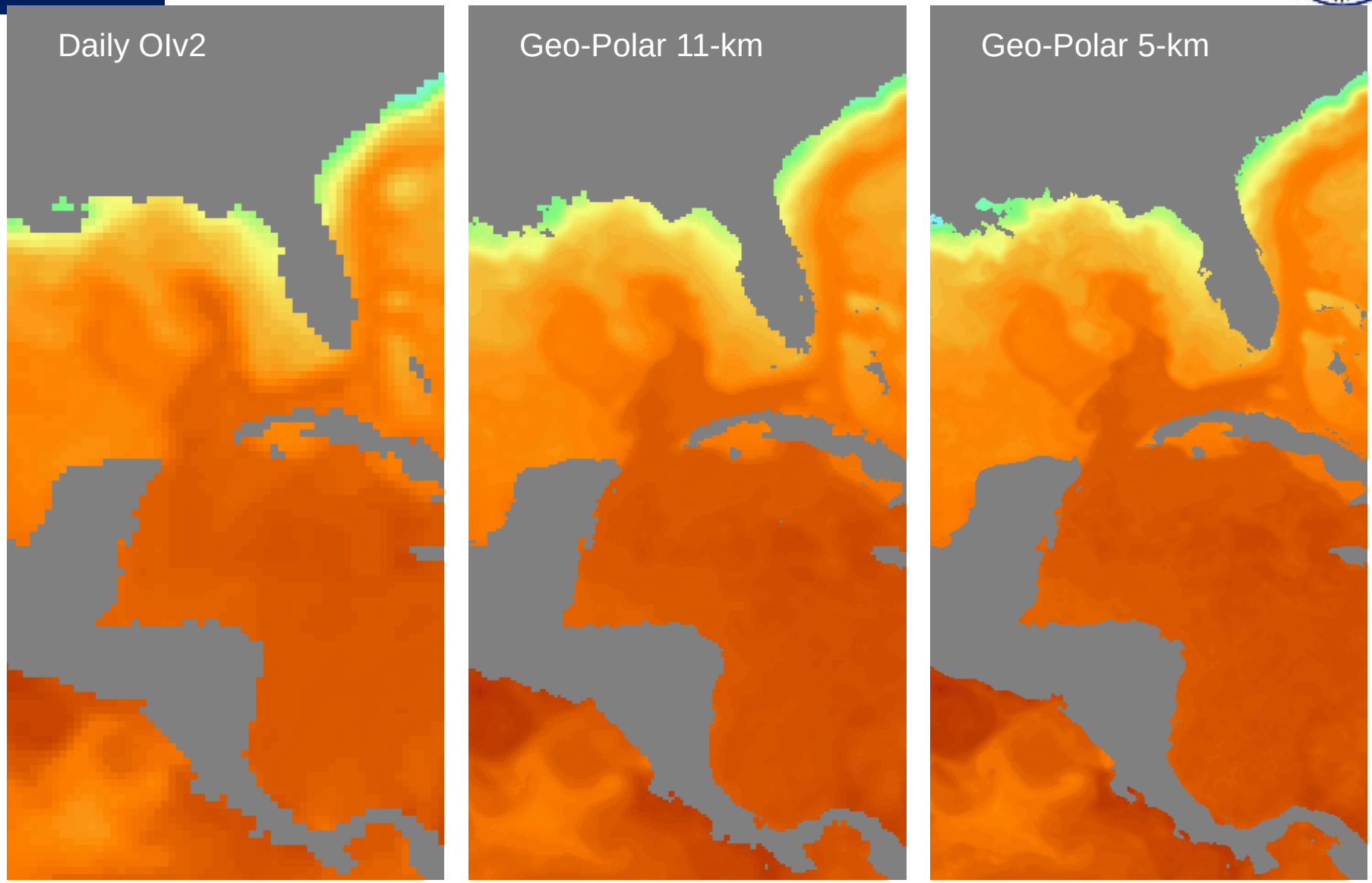


ACSPO AVHRR coverage

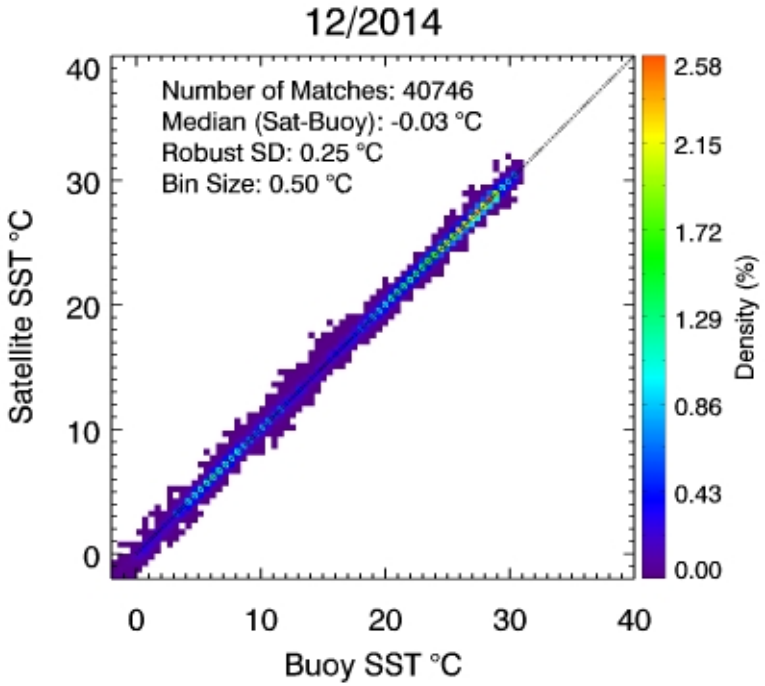
Separate Ocean Basins

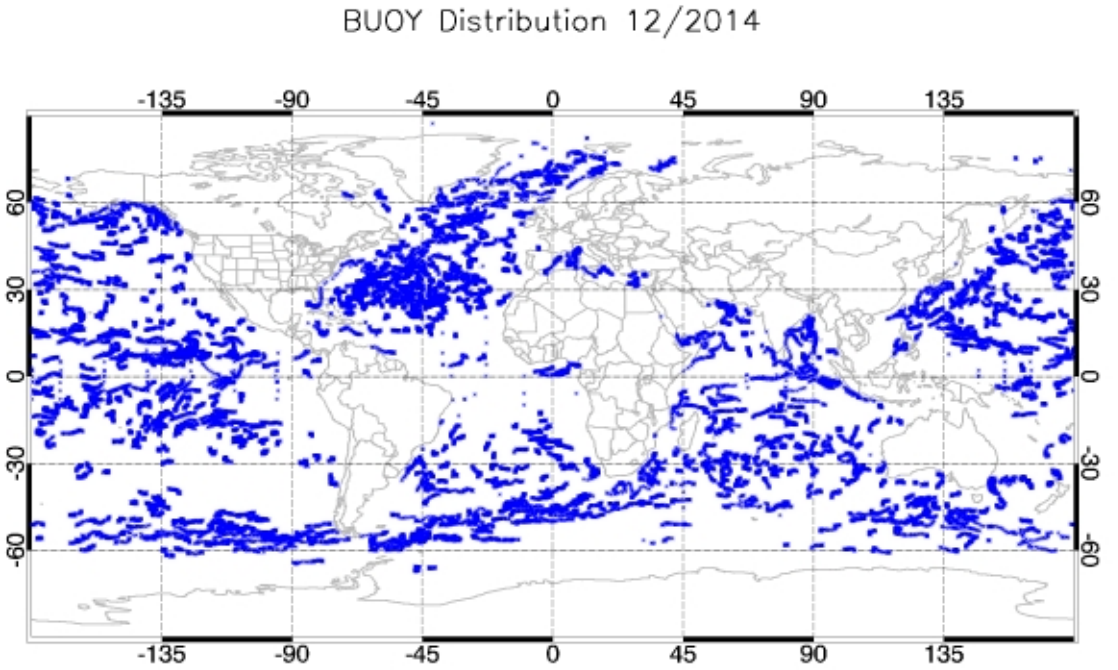


Resolution difference



Product Accuracy: Blended SST



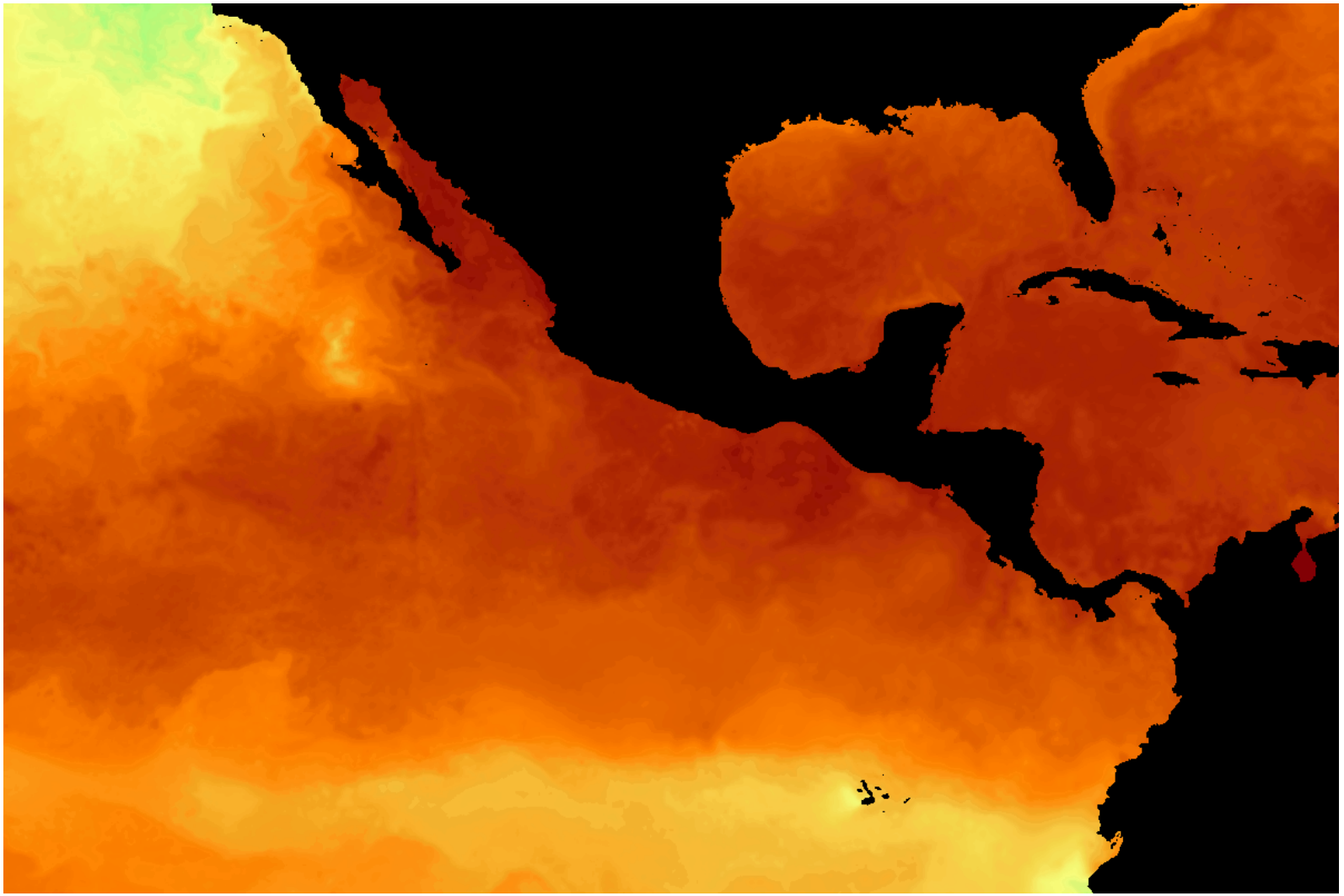


Median bias (analysis – buoy) -0.03 K

Robust Standard Deviation 0.25 K

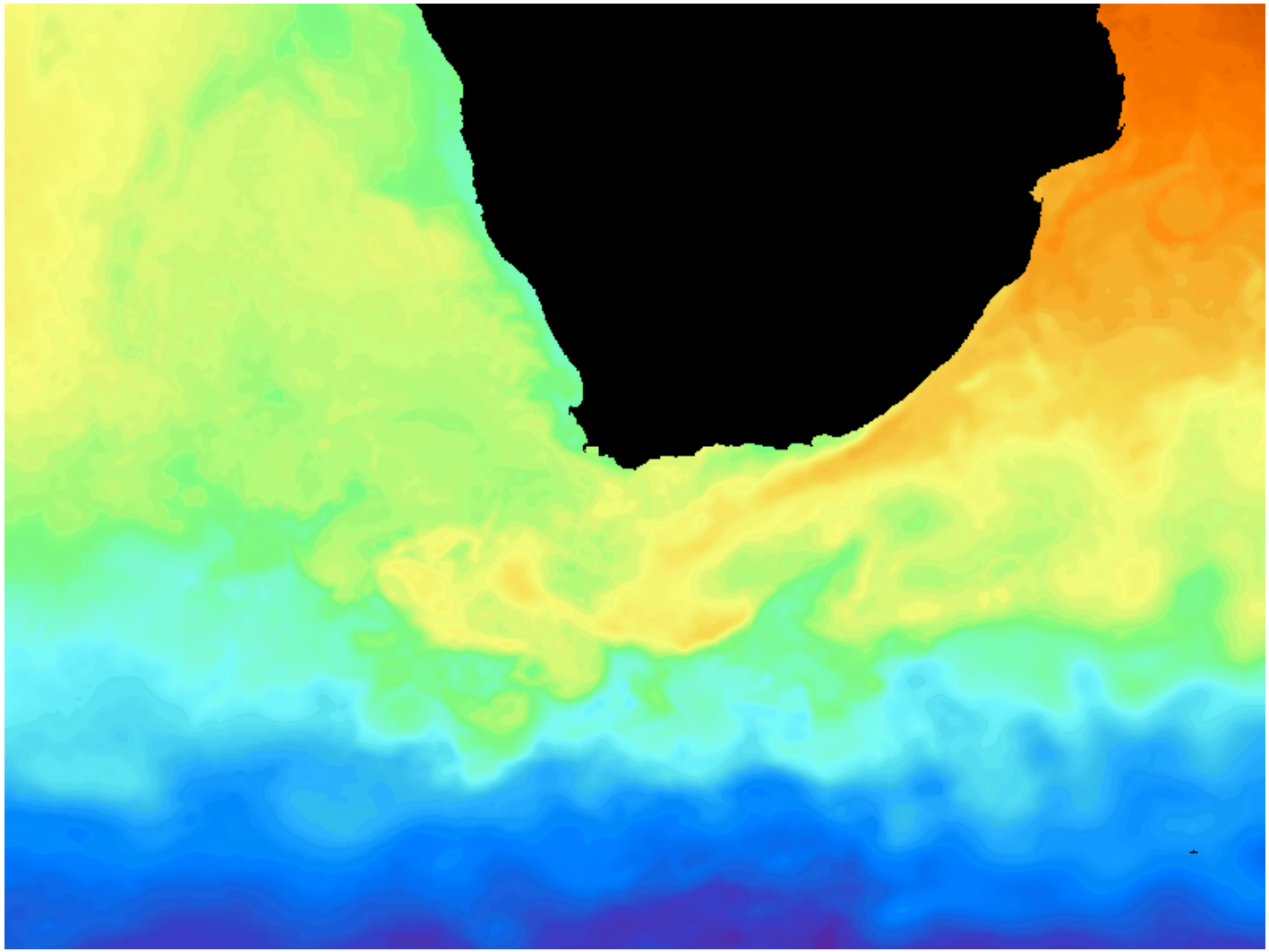
Robust Standard Deviation = (75% - 25%)/1.349

5-km Examples



Day+night 5-km, Nov 1 – Dec 31, 2012

5-km Examples



Day+night 5-km, Nov 1 – Dec 31, 2012

NOAA Coral Reef Watch

NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)

DOC > NOAA > NESDIS > STAR > CRW

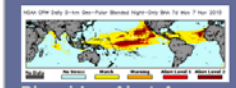
Coral Reef Watch

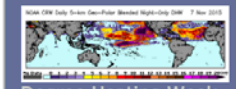
CRTF | CRCP | CREIOS | CoRIS

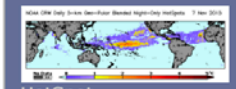
CRW Home

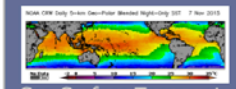
Products Overview

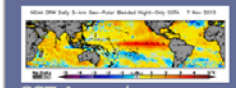
Near-Real-Time Data
(5-km Resolution)

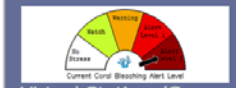

Bleaching Alert Area


Degree Heating Week


HotSpot


Sea Surface Temperature


SST Anomaly


Virtual Stations/Gauges

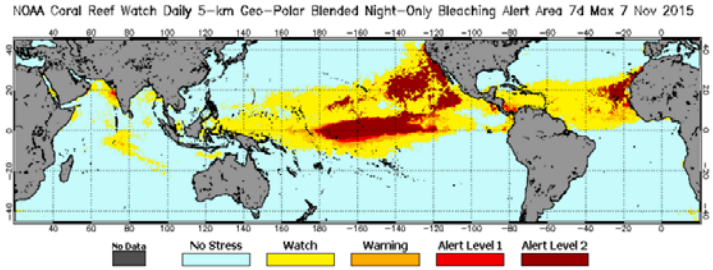
Near-Real-Time Data
(50-km Resolution)

Coral Reef Watch Satellite Monitoring

NOAA Coral Reef Watch is pleased to announce the release of its new Daily 5-km Satellite Coral Bleaching Thermal Stress Monitoring Product Suite. The 5-km products are accessible directly below, in the left navigation bar, and throughout this website. Access to our heritage suite of operational 50-km satellite monitoring products will still be possible for the next several months. We encourage all of our users to look over the new 5-km products and provide feedback to us at coralreefwatch@noaa.gov.

Click on buttons below image to change parameter; click on image to navigate to parameter's web page.

Switch to 50-km products ►



Alerts | HotSpot | DHW | SST | Anomaly | SST Trend | Outlook | Doldrums | Virtual Stations

El Niño bleaching patterns web page

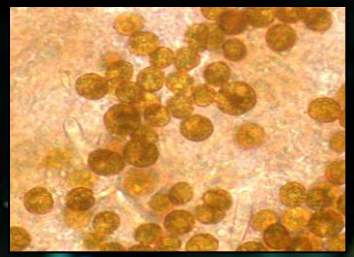
The NOAA Coral Reef Watch program's satellite data provide current reef environmental conditions to quickly identify areas at risk for coral bleaching, where corals lose the symbiotic algae that give them their distinctive colors. If a coral is severely bleached, disease and partial mortality become likely, and the entire colony may die.

Continuous monitoring of sea surface temperature at global scales provides researchers and stakeholders with tools to understand and better manage the complex interactions leading to coral bleaching. When bleaching conditions occur, these tools can be used to trigger bleaching response plans and support appropriate management decisions.

Announcements

October 8, 2015: NOAA announces third ever global coral bleaching event on record! Read the NOAA press release here.

Corals live in symbiosis with algae



Stress

Corals release their algae

With thanks to Scott Heron

Thermal Stress Causes Mass Coral Bleaching

With thanks to Scott Heron

Thermal Stress Causes Mass Coral Bleaching…

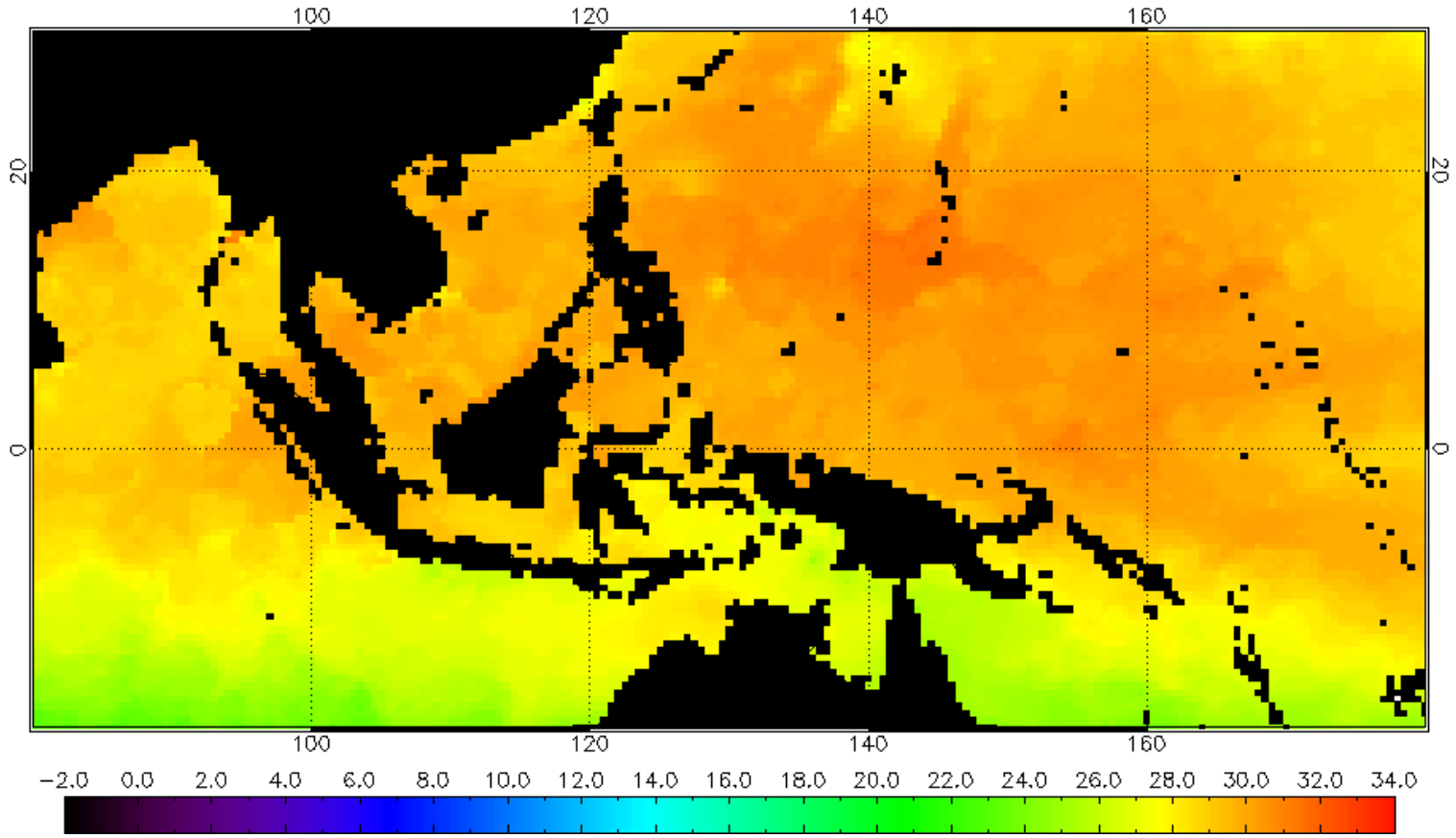
With thanks to Scott Heron

Thermal Stress Causes Mass Coral Bleaching…
…and Mortality

With thanks to Scott Heron

Coral Reef Watch Products

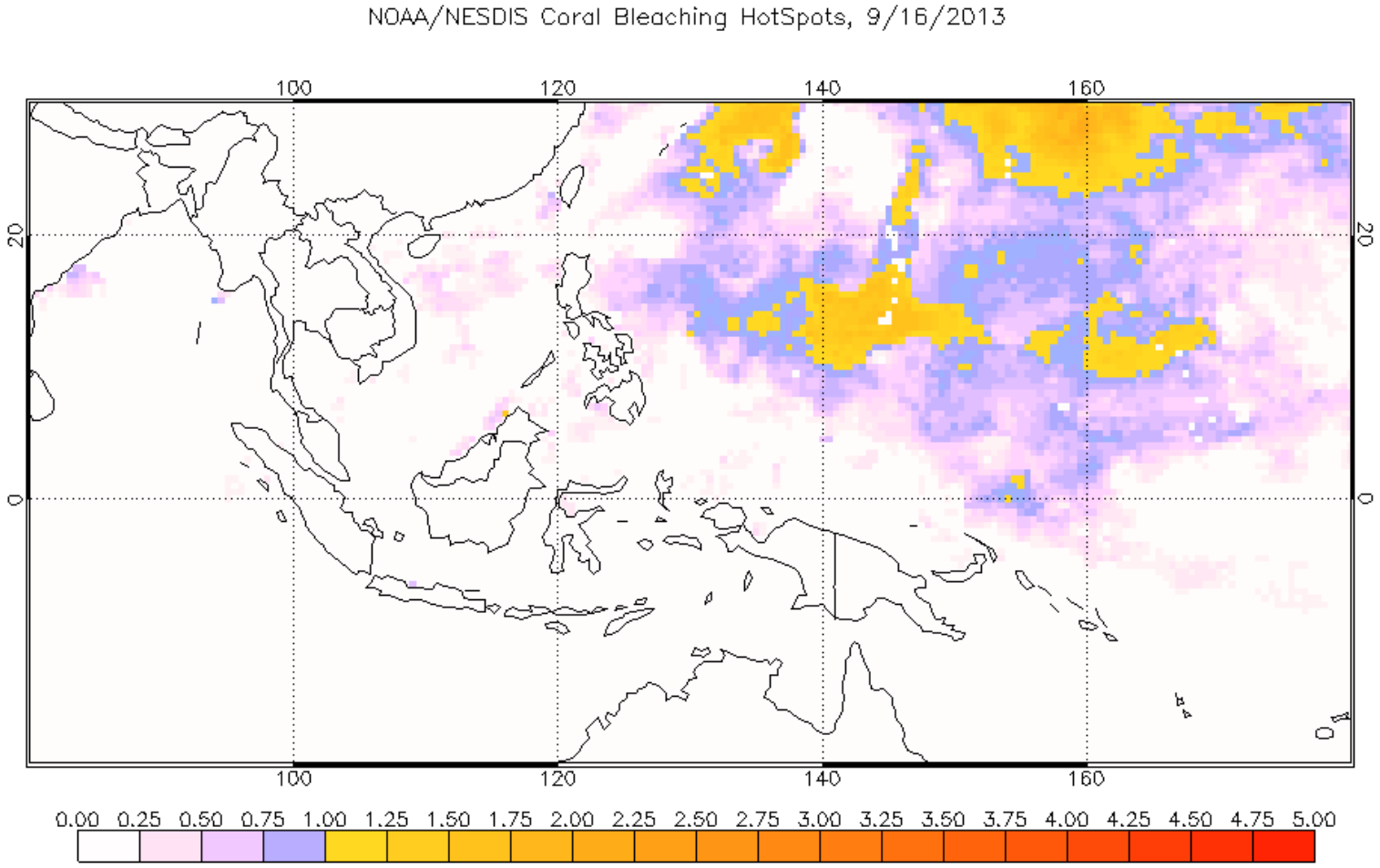
"Coral Triangle"



- **Legacy product uses 50-km AVHRR-only SST**

Coral Reef Watch Products

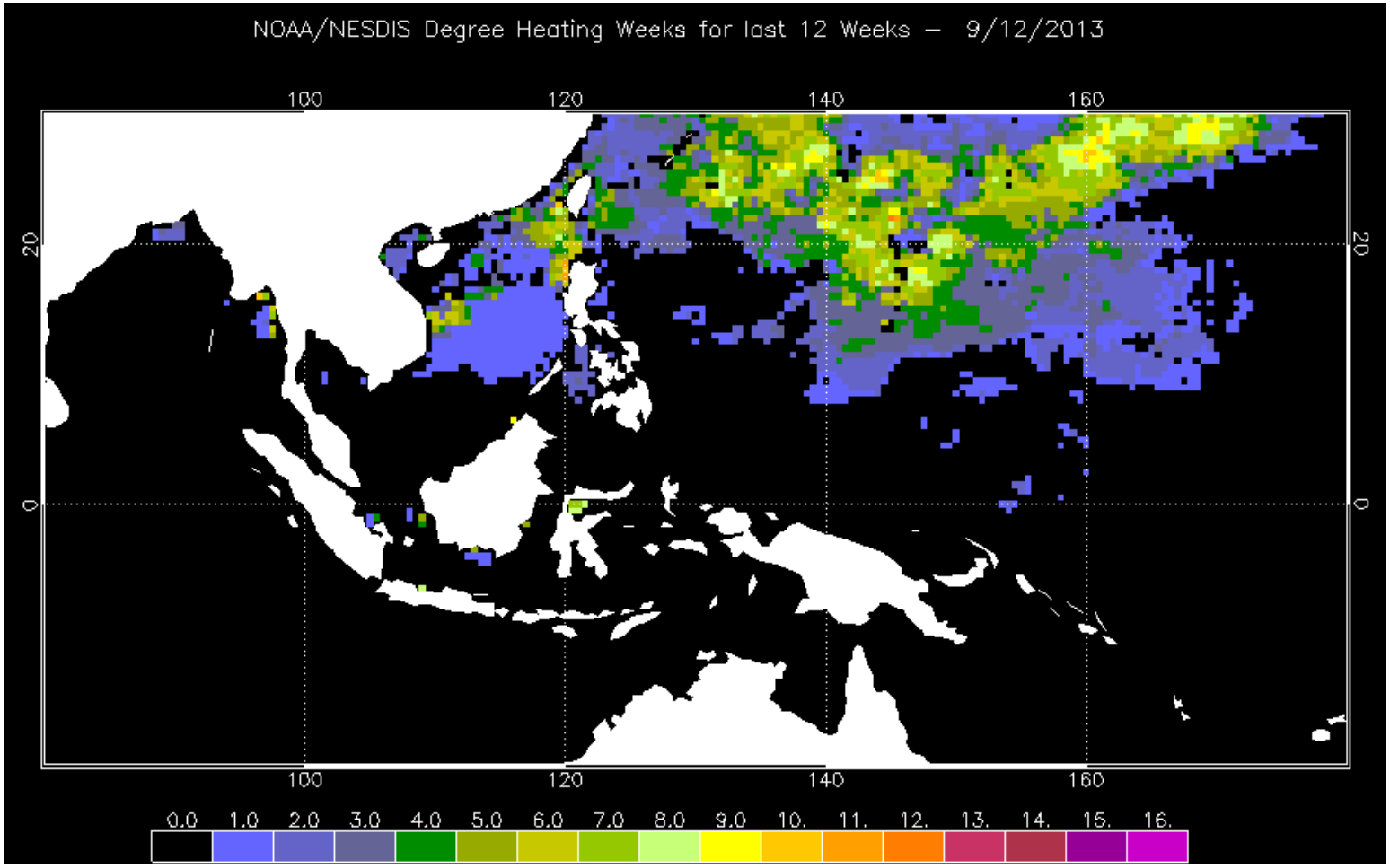
"Coral Triangle"



- **Hotspots are derived with respect to climatological threshold**

Coral Reef Watch Products

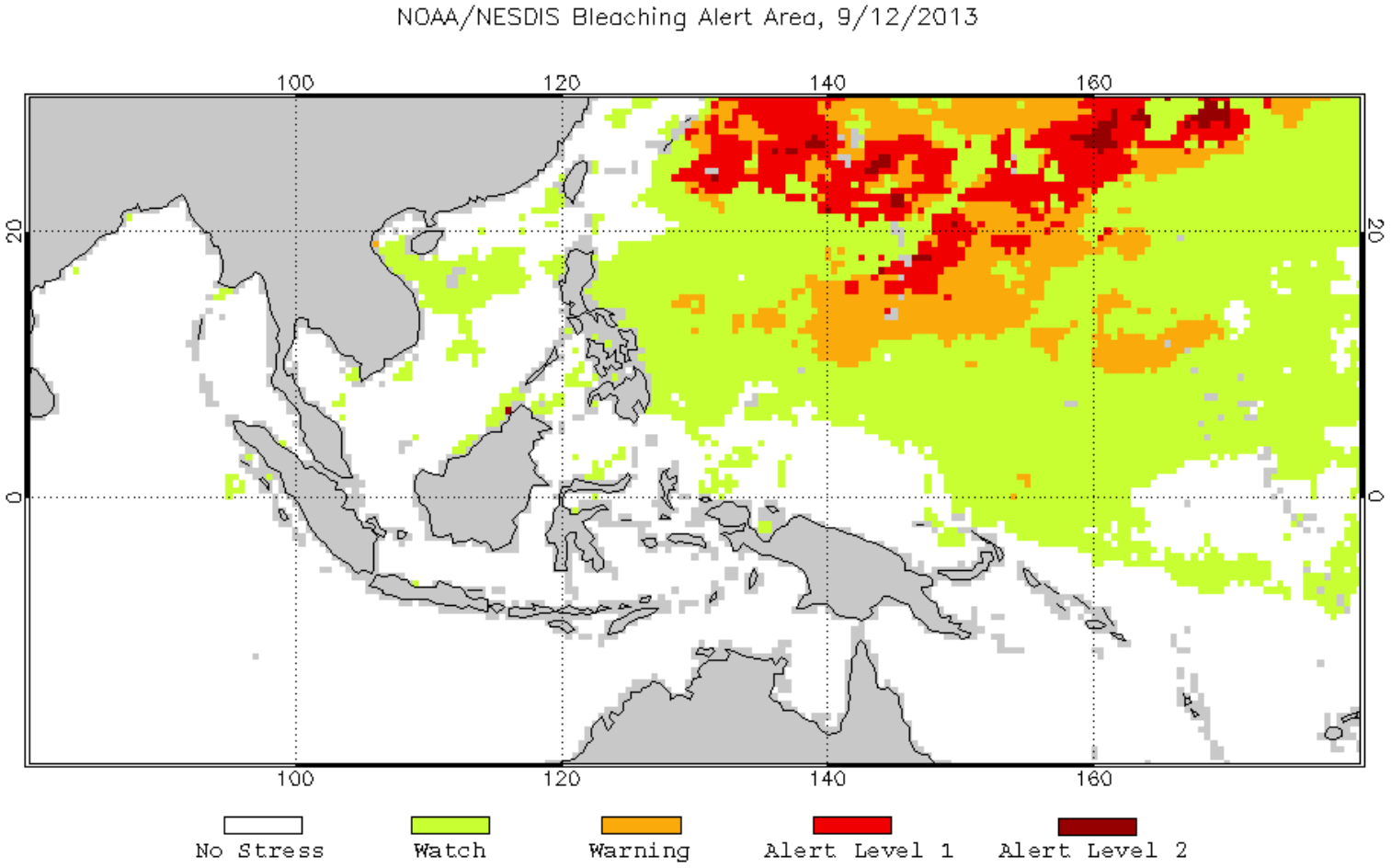
"Coral Triangle"



- **Accumulated thermal stress is predictor of bleaching risk**

Coral Reef Watch Products

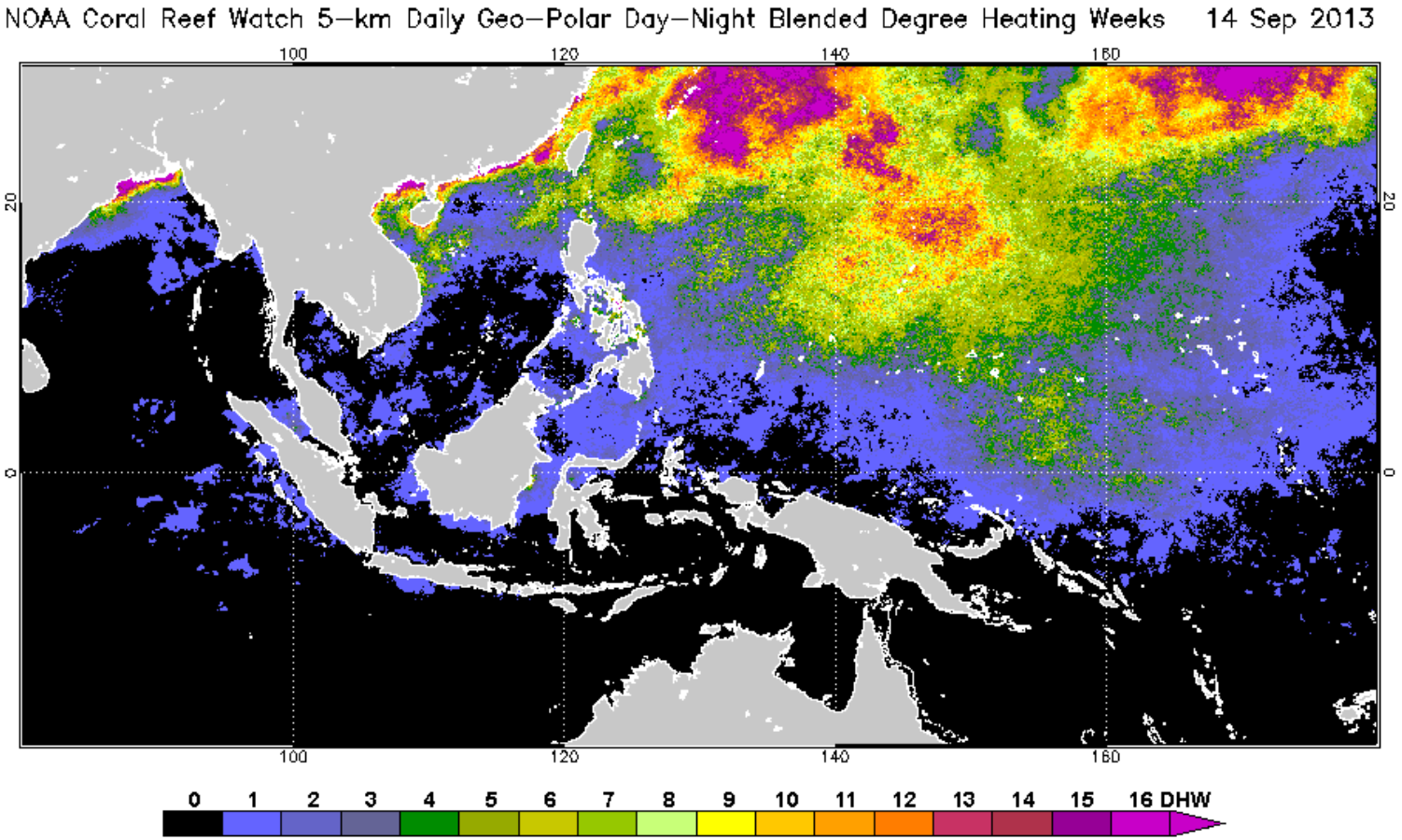
"Coral Triangle"



- **Bleaching risk alerts are issued**

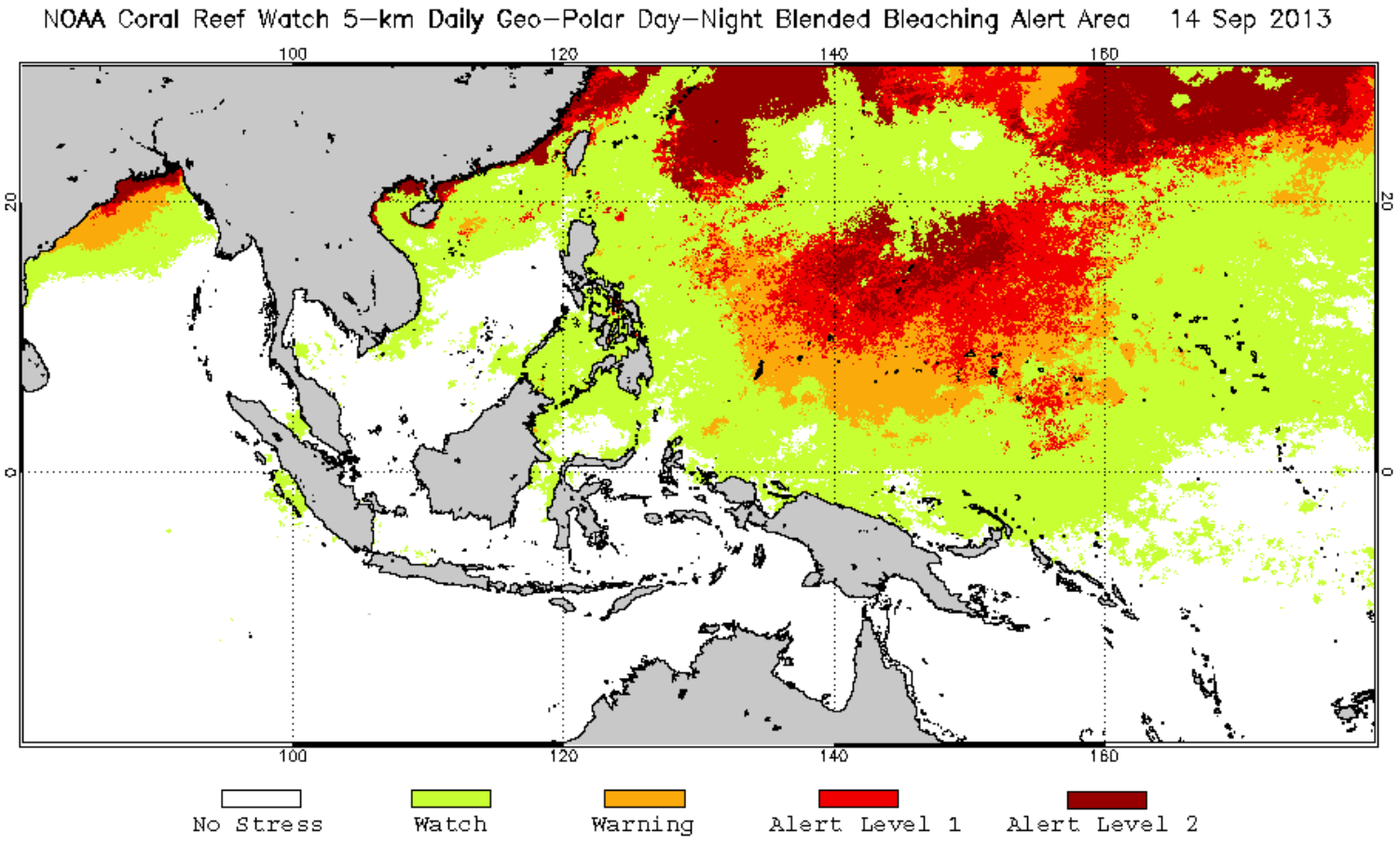
CRW Products based on 5-km SST

"Coral Triangle"



CRW Products based on 5-km SST

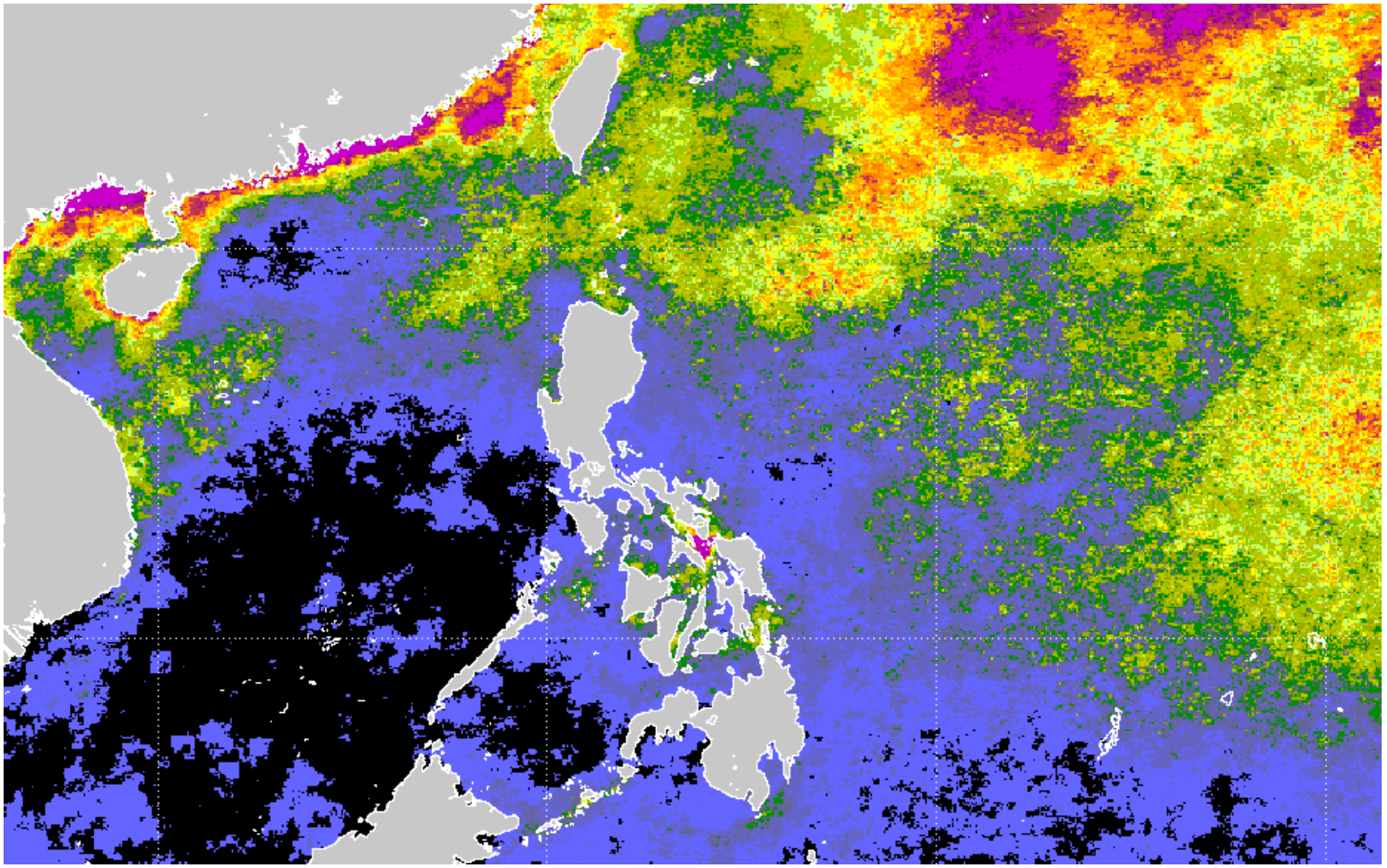
"Coral Triangle"



- **Strong bleaching alert for reefs in Guam & Mariana Islands – (coincided with bleaching in September 2013)**

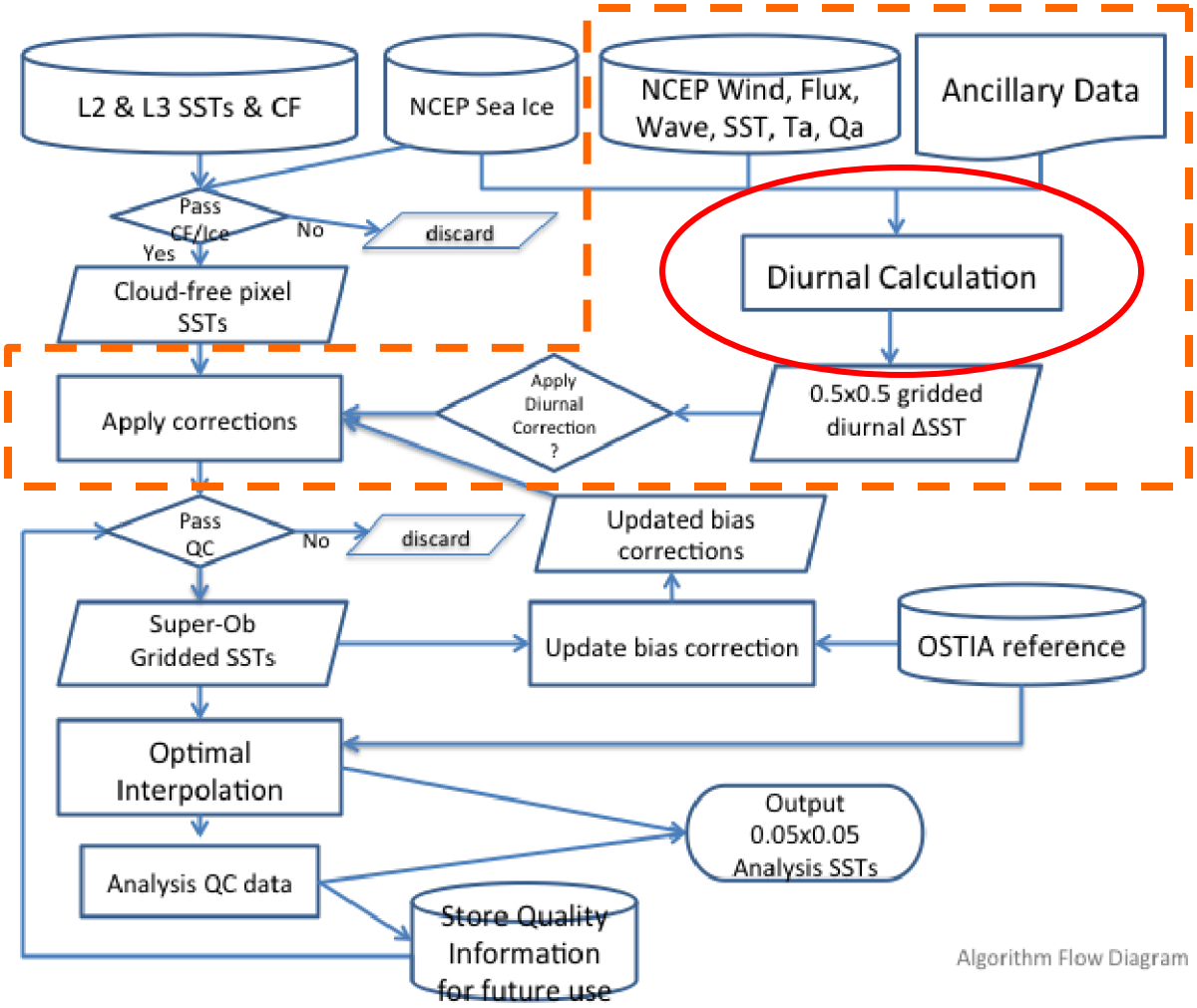
CRW Products – 5-km detail

"Coral Triangle"



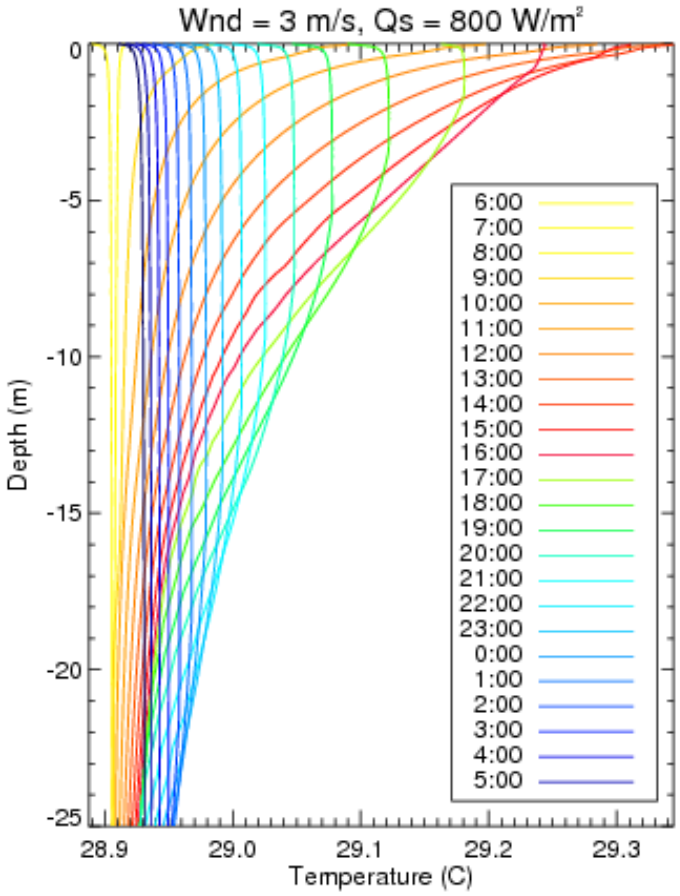
- **New analysis enables much greater precision, *e.g.* small fringing reefs**
- **However, <u>climatology is not derived from same dataset</u>**

Including diurnal warming correction in SST analysis

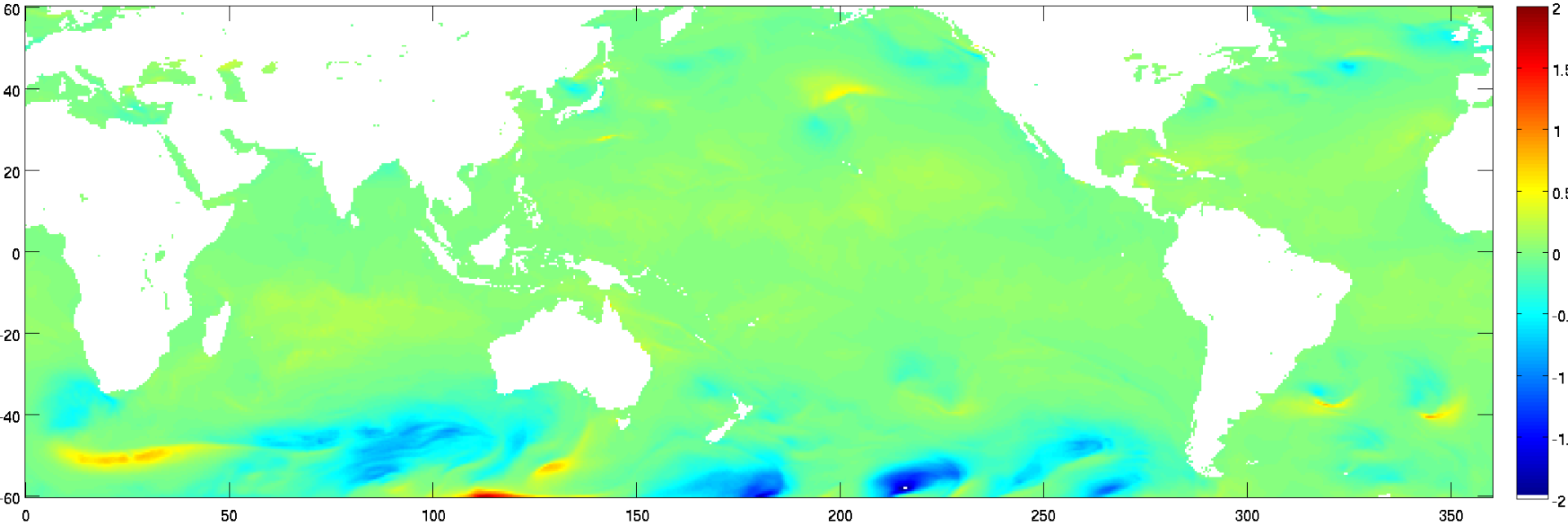


Diurnal Warming Correction – Sample Model Profile of Warming with Depth

- **Model simulates full vertical profile of warming**
  - Enables estimation of warming at arbitrary depth
  - Model presently run to a depth of 50 m
- **Time evolution of vertical temperature profile shown here for idealized forcing with a constant wind speed of 3 m/s and a peak insolation of 800 W/m²**

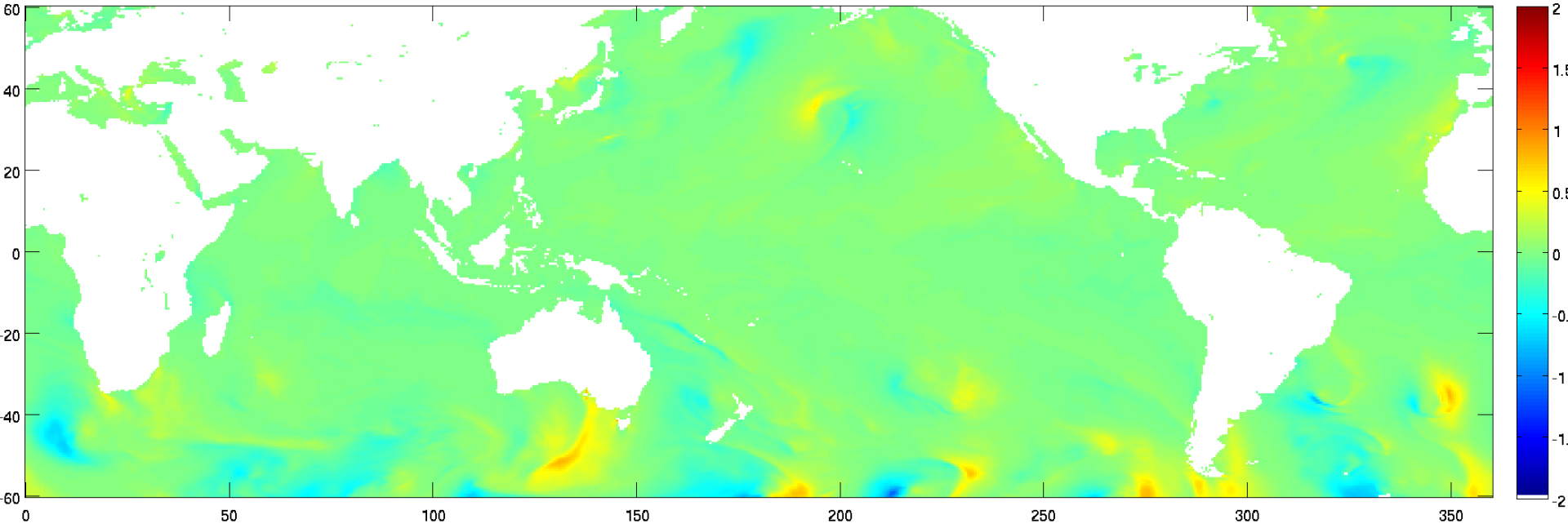


Diurnal Warming Correction - Sample Model Forcing Fields



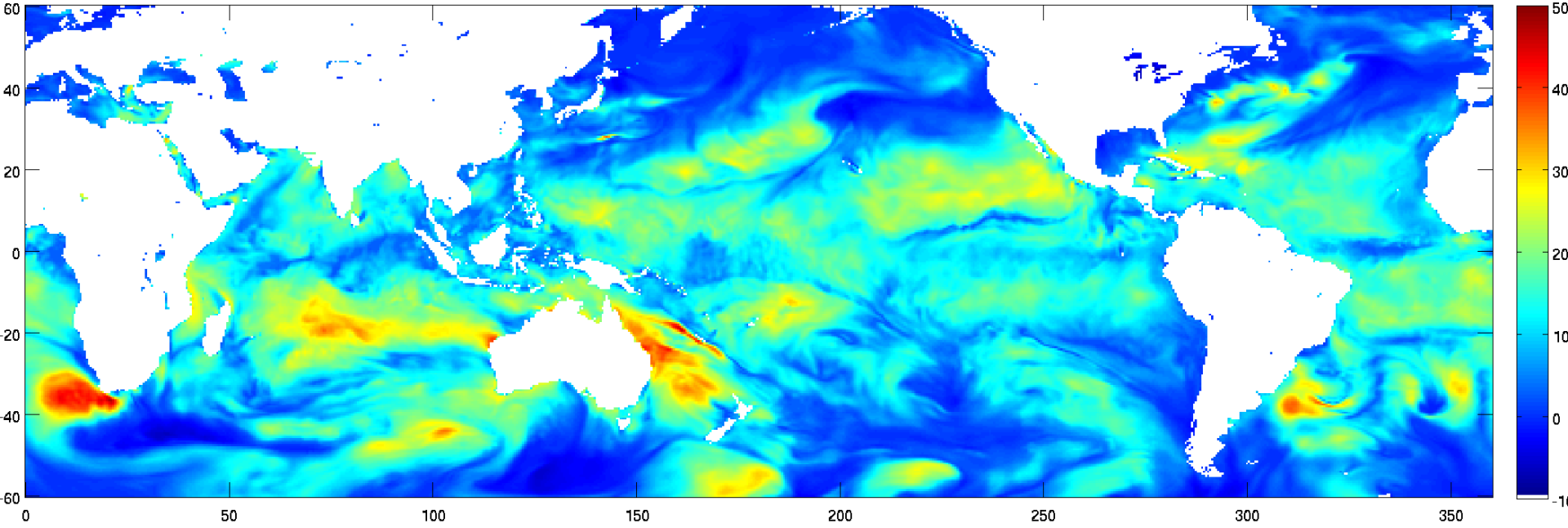
Zonal wind stress

Diurnal Warming Correction - Sample Model Forcing Fields



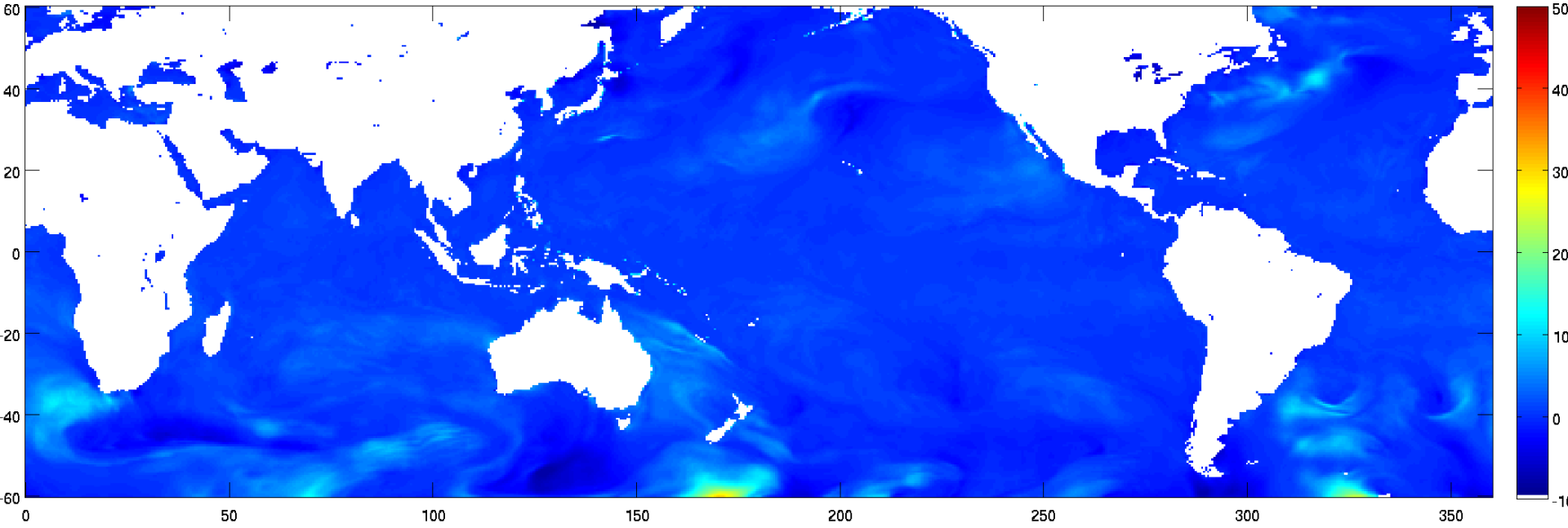
Meridional wind stress

Diurnal Warming Correction - Sample Model Forcing Fields



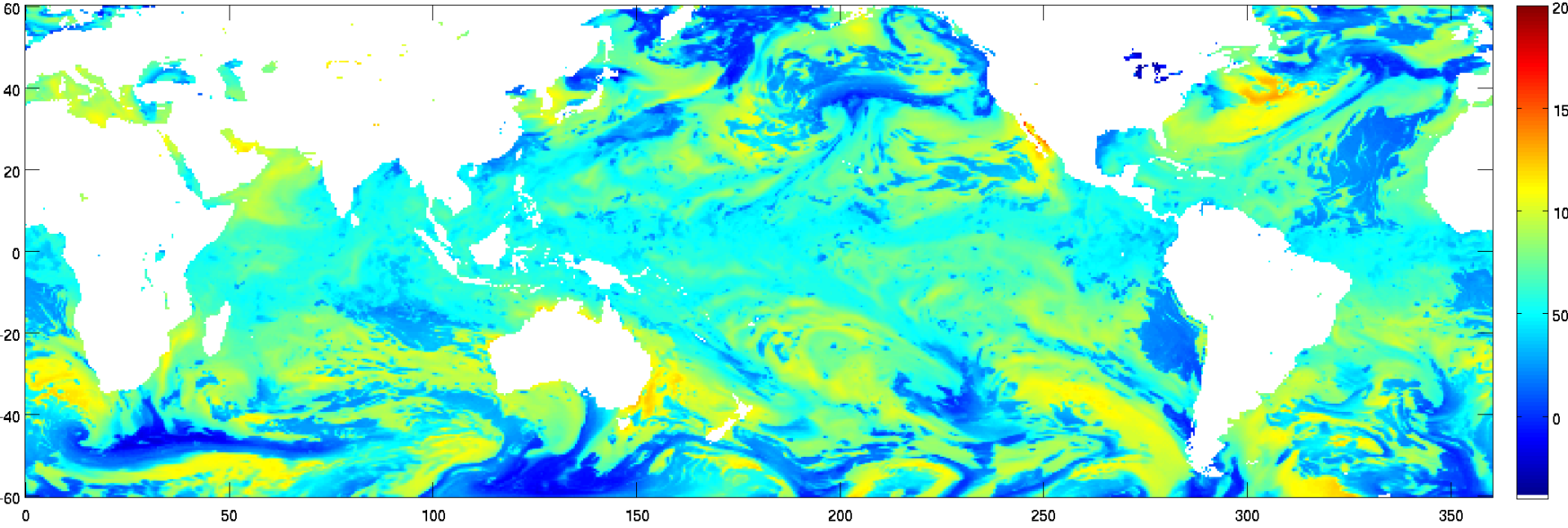
Latent heat flux

Diurnal Warming Correction - Sample Model Forcing Fields



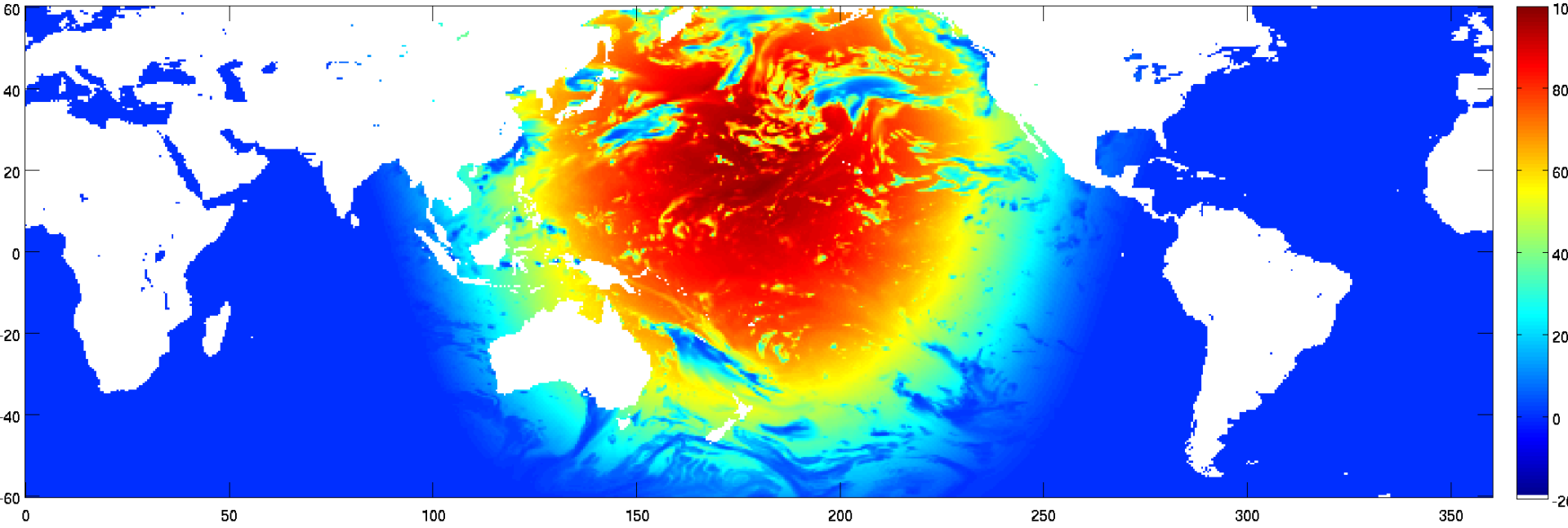
Sensible heat flux

Diurnal Warming Correction - Sample Model Forcing Fields



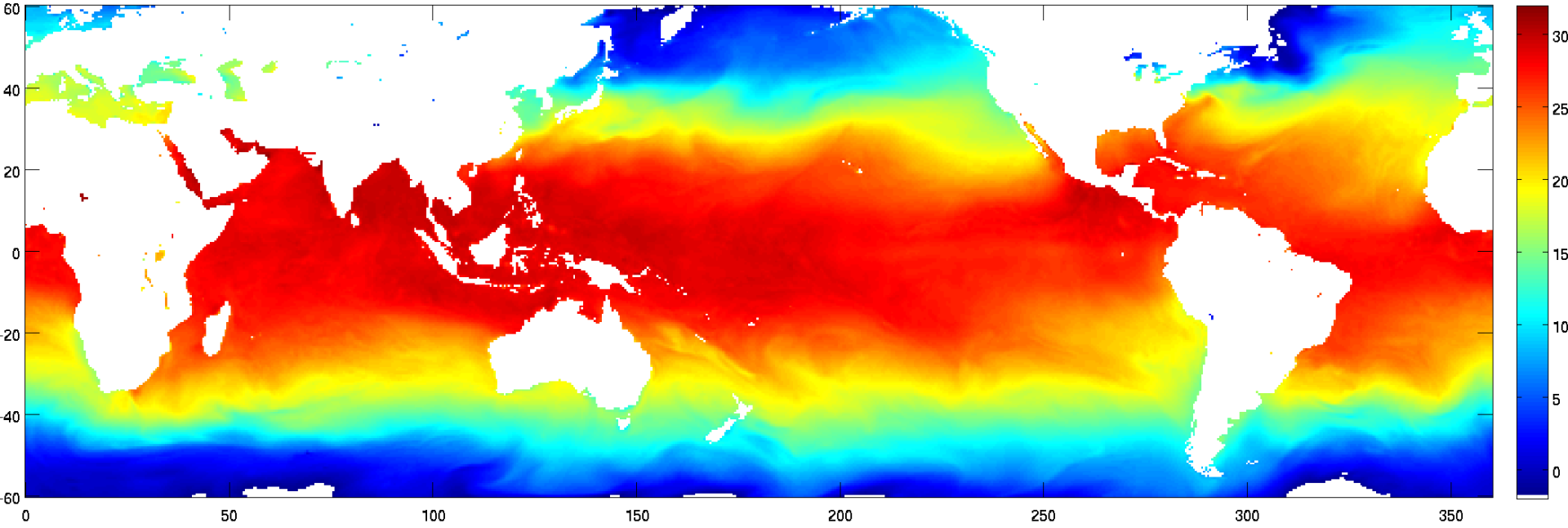
Net longwave heat flux

Diurnal Warming Correction - Sample Model Forcing Fields



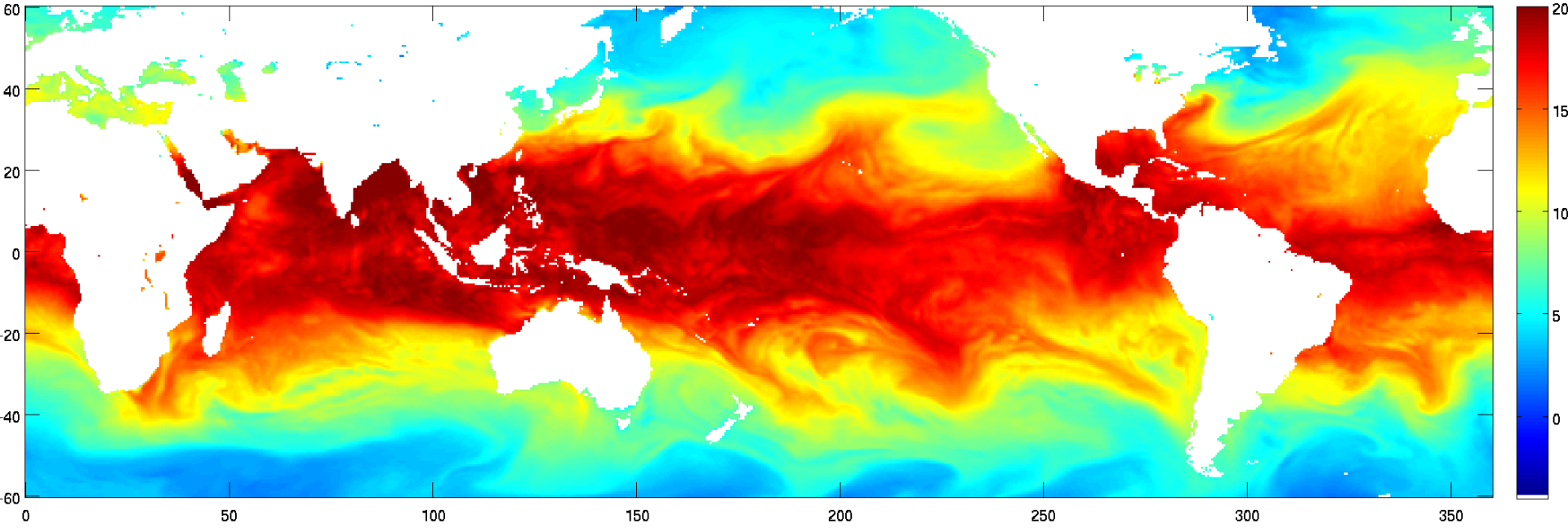
Net shortwave heat flux

Diurnal Warming Correction - Sample Model Forcing Fields



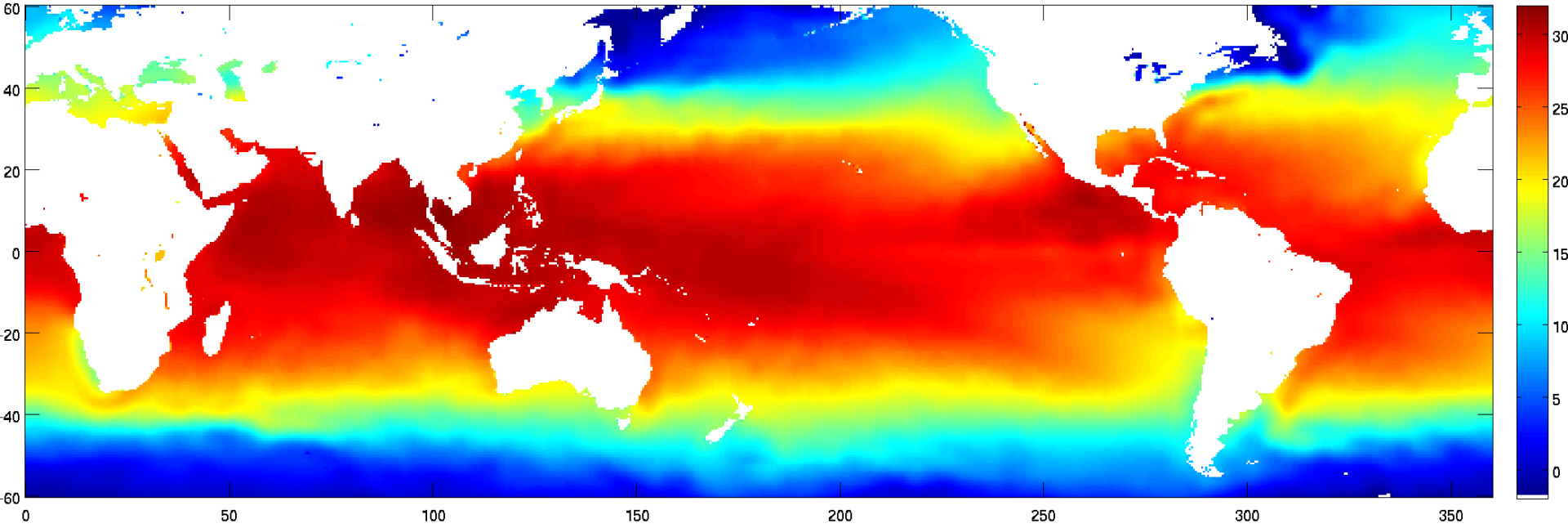
2m air temperature

Diurnal Warming Correction - Sample Model Forcing Fields



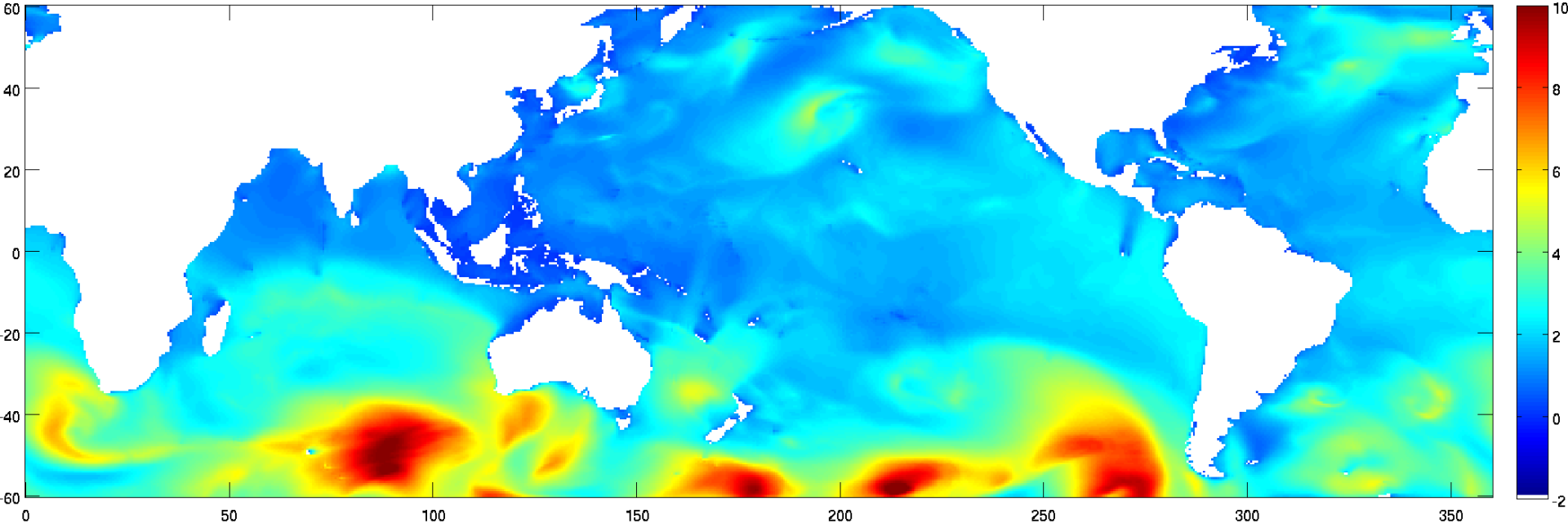
2m specific humidity

Diurnal Warming Correction - Sample Model Forcing Fields



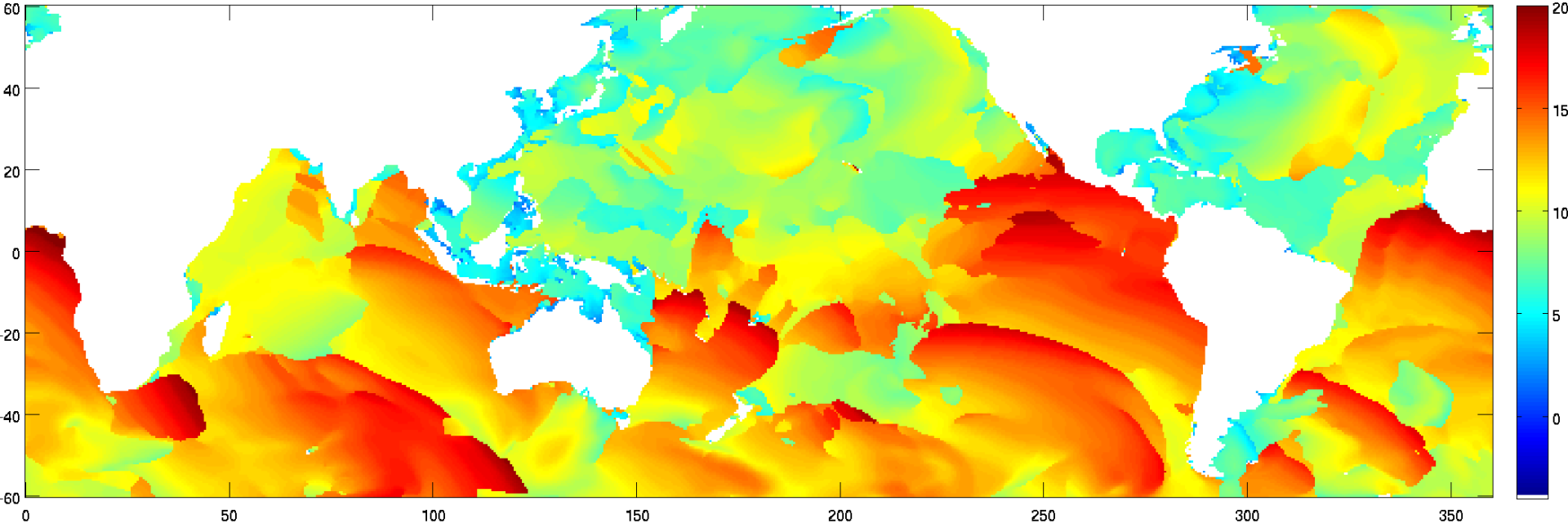
NWP SST

Diurnal Warming Correction - Sample Model Forcing Fields



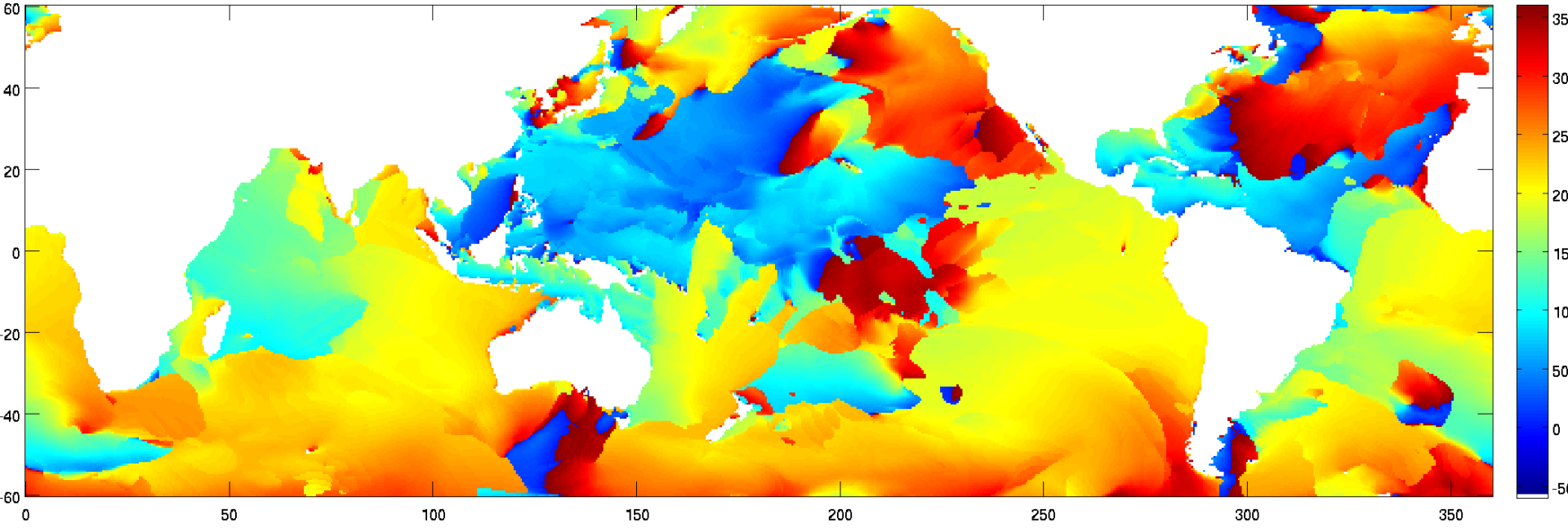
Significant wave height

Diurnal Warming Correction - Sample Model Forcing Fields



Primary wave period

Diurnal Warming Correction - Sample Model Forcing Fields

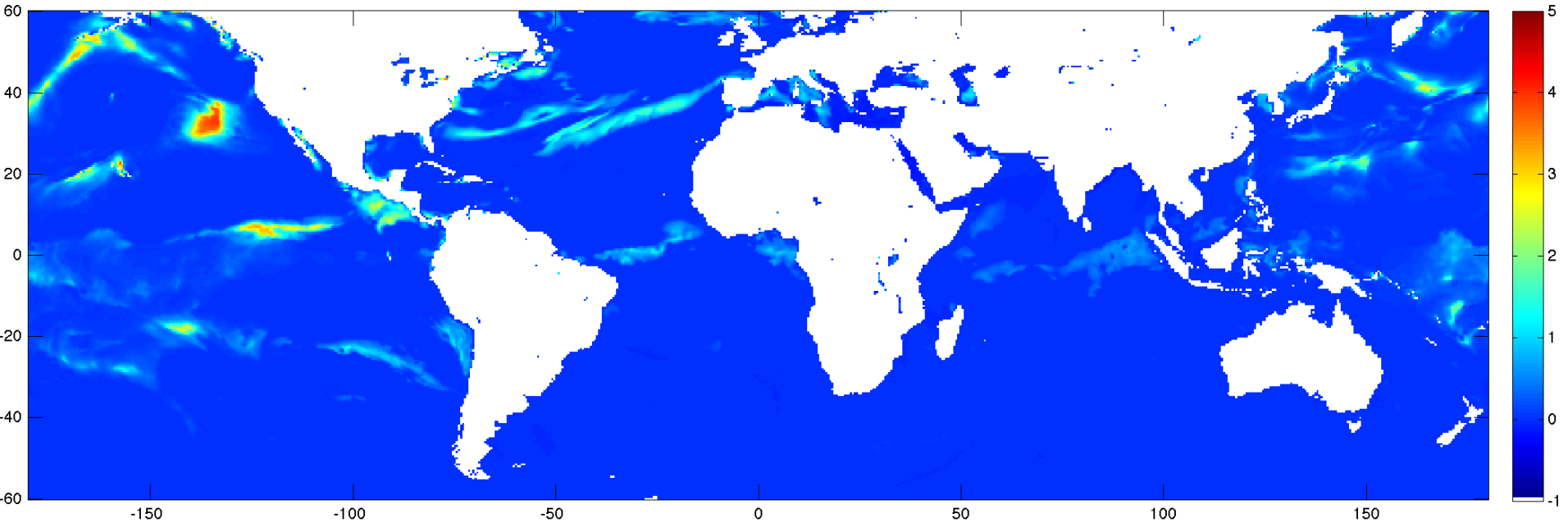


Primary wave direction

Diurnal Warming – Flux Feedback Adjustment

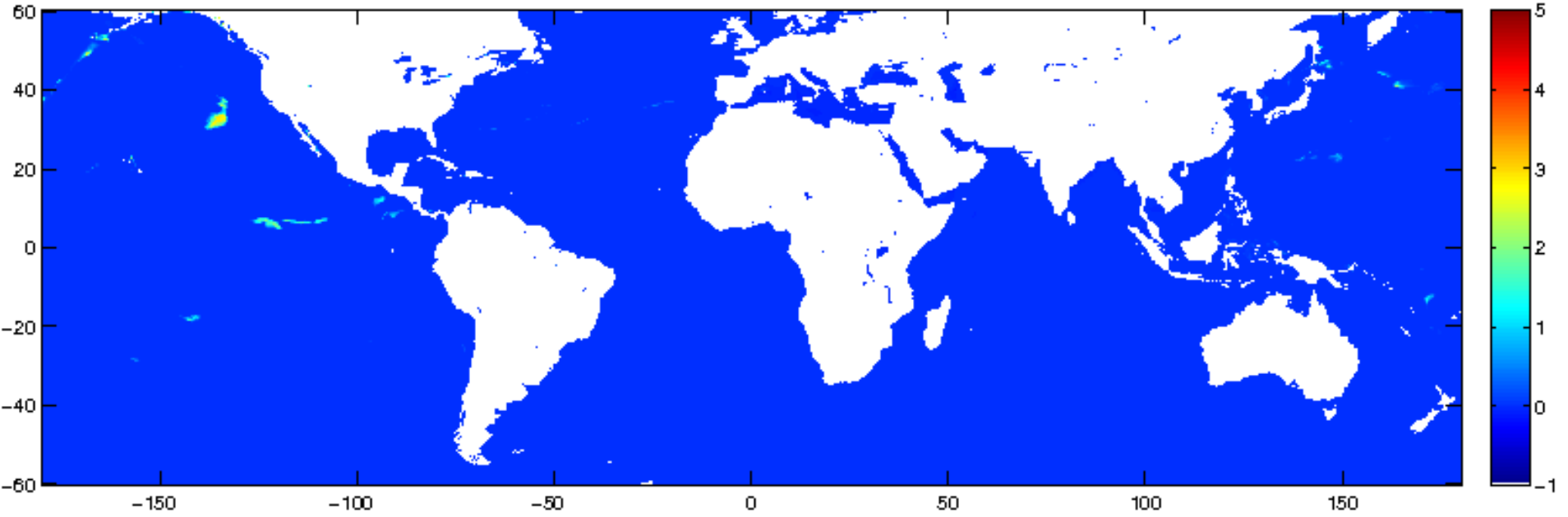
- NCEP heat fluxes assume fixed SST
- In the presence of diurnal warming, the heat fluxes will change
- Use a simple "scaled bulk formulae" approach, e.g.:
  - » $Q_L = K_L u^*(Q_s - Q_a)$
  - » Determine K_L from NCEP values of Q_L, u^*, Q_s & Q_a
  - » Adjust Q_L as Q_s changes (a function of SST)
- Longwave heat flux simply changes as $\varepsilon\sigma T^4$
- Option to toggle flux feedback on/off

Sample output



- **Regions of >5 K warming**
- **Note, warming events on edge of ±60° limit**

Sample output w.r.t. 1 m



- **Regions of >3 K warming**
- **Still some warming events on edge of ±60° limit**

Reprocessing

- **Some operational products depend on anomalies w.r.t. a baseline**
  - *E.g.* NOAA Coral Reef Watch
- **Geo-Polar SST analysis September 2004 – present**
  - Captures some major bleaching events
  - Sufficient to retune bleaching thresholds
  - **Requires input data to be reprocessed as well**
- **Datasets**
  - NOAA AVHRR (METOP, NOAA)
  - GOES-E/W (8, 10, 11, 12, 13, 15)
  - MTSAT-1R, MTSAT-2, GOES-9 **~200 TB**
  - Meteosat-8/9/10
  - Ancillary NWP
- **Should be complete by March 2016**

Summary

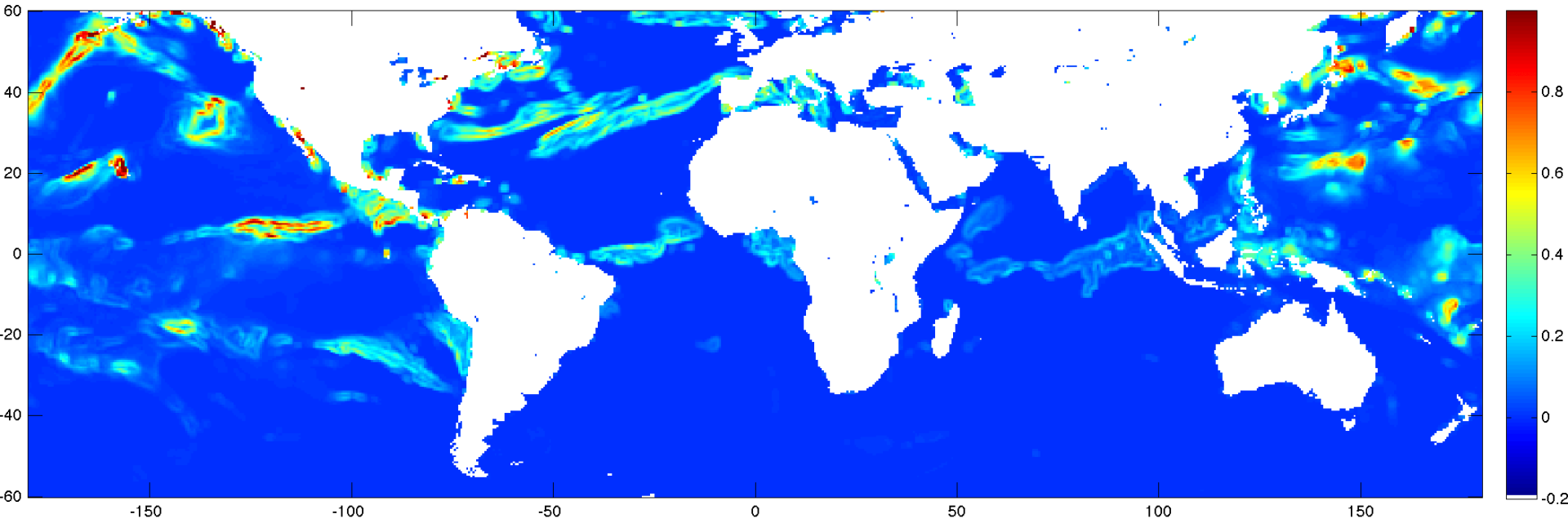
- **NOAA produces all the L2 data that go into the analysis**
  - Polar data – ACSPO regression SST
  - Geostationary – Bayesian cloud + MTLS Physical retrieval
  - *N.B.* Convergence on ACSPO means Himawari-8 will be ACSPO
  - AMSR-2 SST processed with NOAA GAASP algorithm
    - Improvements imminent
- **L4 SST analysis continues to be improved**
  - Data-adaptive correlation length **preserves features without introducing excessive noise**
  - 5-km noticeably better than 11-km (mesoscale oceanography)
  - Diurnal correction with turbulence model and Stokes' Drift
    - Beneficial for applications that depend on SST at depth (*e.g.* CRW)
  - Geo-Polar Blended SST analysis available in GHRSST L4 format
- **Reprocessing L4 analysis to provide stable climatology**
  - L2 Geo & Polar data are reprocessed with state-of-the-art
  - Improve quality of downstream anomaly-based products
  - 2004 – present by March 2016, 1994 – present by end-2016

Backup slides

Summary

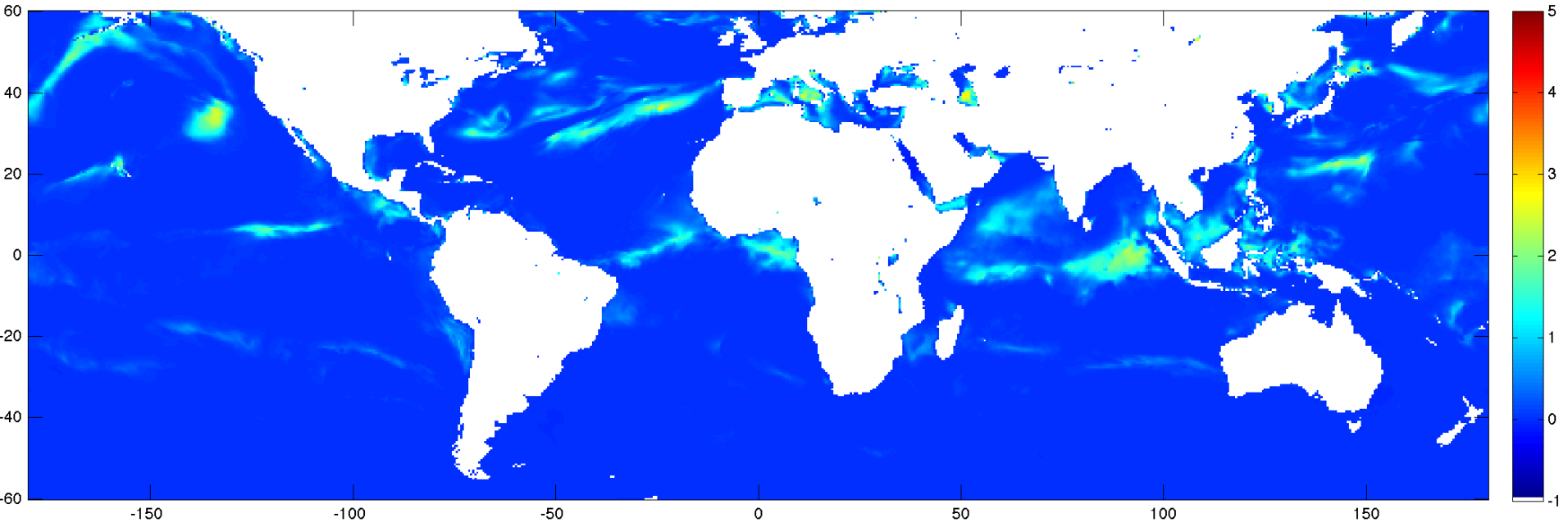
- **It is possible to run a full turbulence scheme in a timely manner for operations**
  - Wave parameterization for Stokes' Drift, Langmuir circulation
- **Uncertainty in forcing fluxes likely to be significant issue**
  - Revisions of DW uncertainty scheme are likely, *e.g.* $\langle \varepsilon \rangle \propto \Delta T$
- **May still be issues if model works well *cf.* geophysical warmings**
  - Is the satellite retrieval fully sensitive to large warming events
  - In daytime, split-window retrievals are used & may have sensitivity significantly <1
  - *N.B.* Empirical DW models derived from satellite observation would need rederivation if algorithm is improved
- **We're getting close**
  - Model can be made available after it goes operational at NOAA

1st cut uncertainty estimate



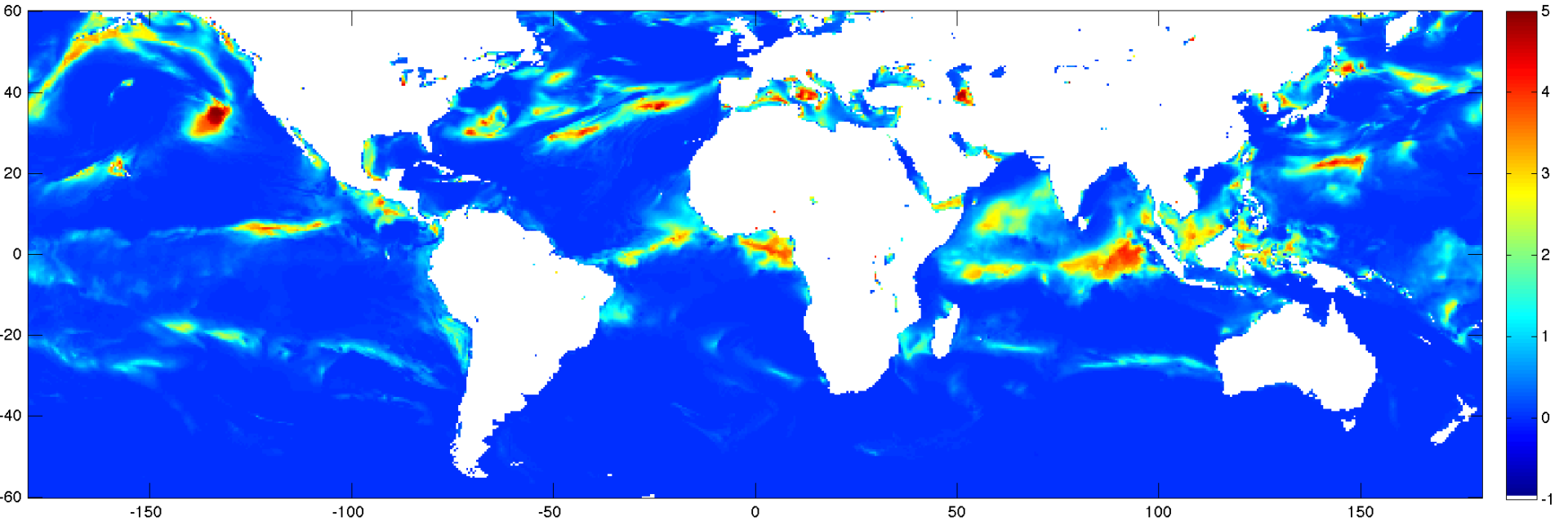
- **Calculate Std Dev of [x-1:x+1, y-1:y+1, t-1:t+1]**
- **Values in the “peaks” not as high as edges**

Daily mean warming



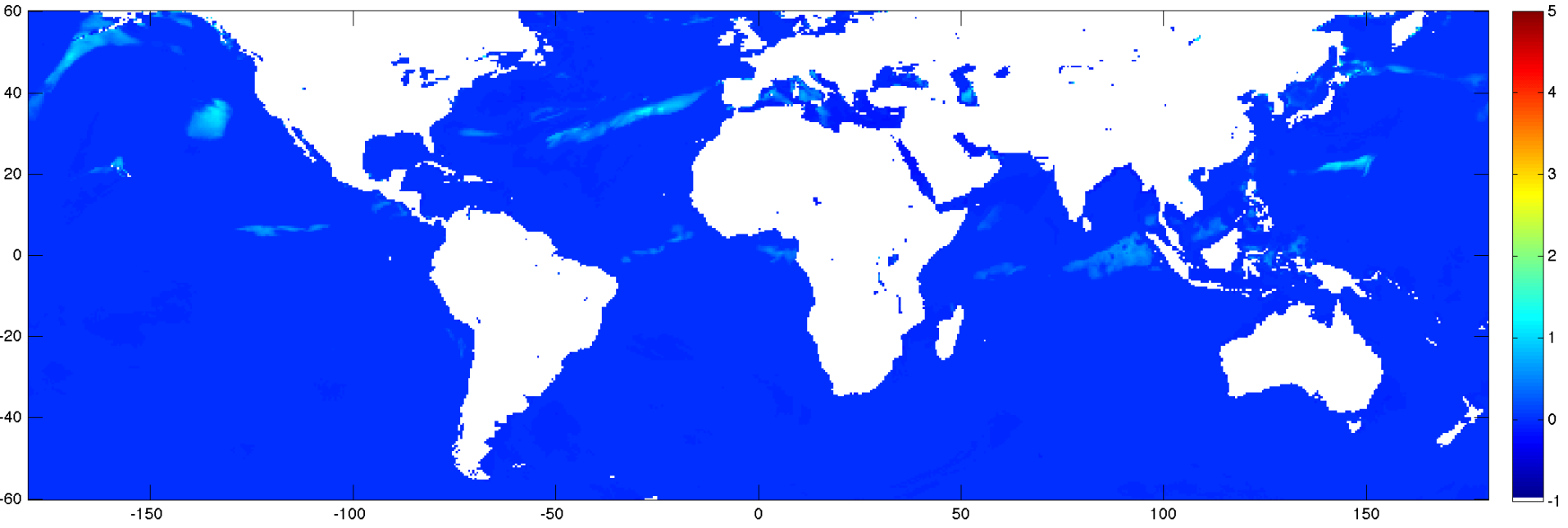
- **Reasonable fraction with ≥1 K**
- **Recall that warming doesn't always disappear**

Daily maximum warming



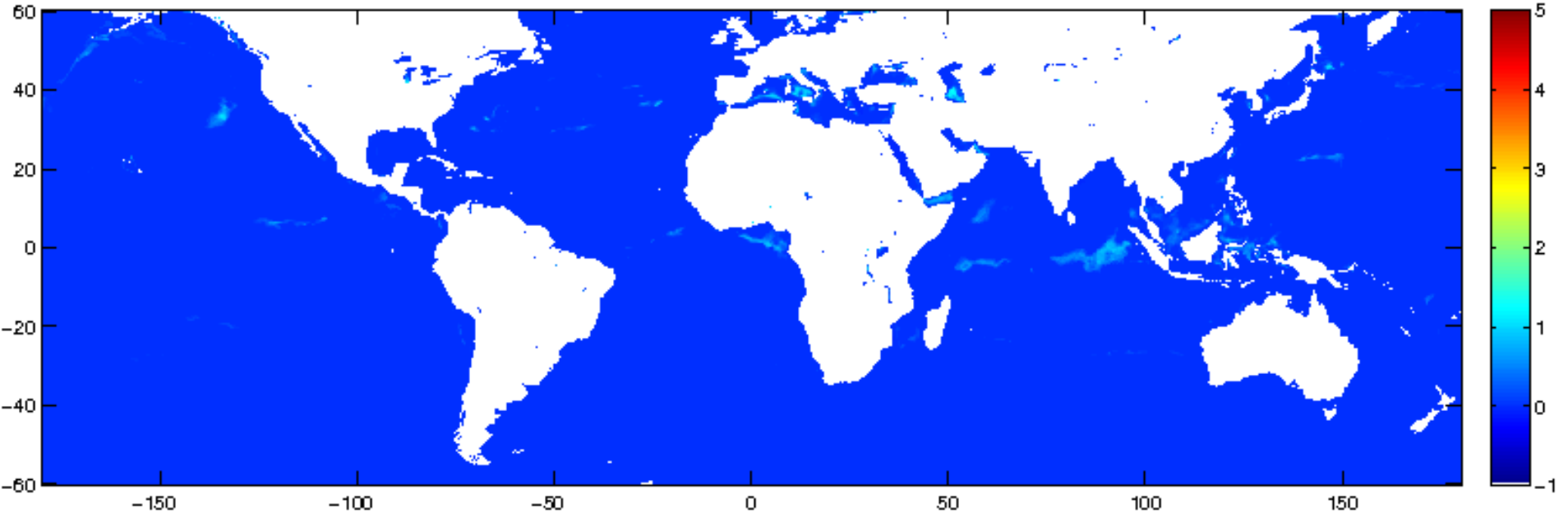
- **Regions with large warming may build on previous day**

Daily minimum warming



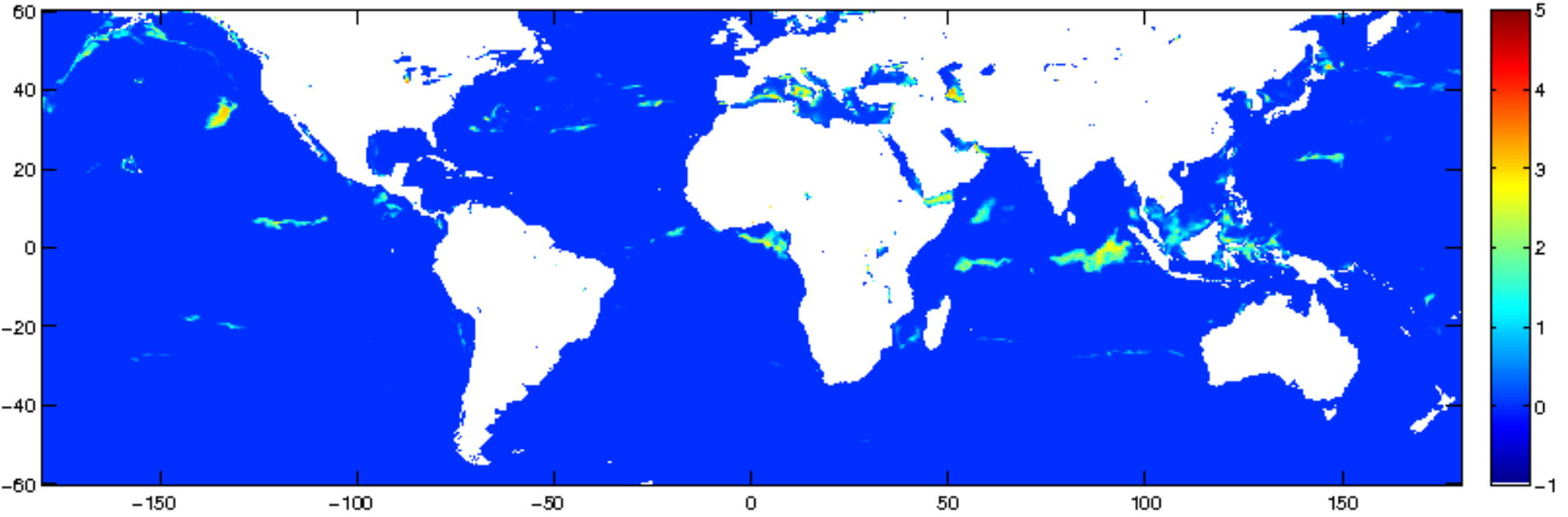
- **Some areas where minimum is still ~1 K**
- ***N.B.* Reference depth is set to 5 m**

Daily mean warming w.r.t. 1 m



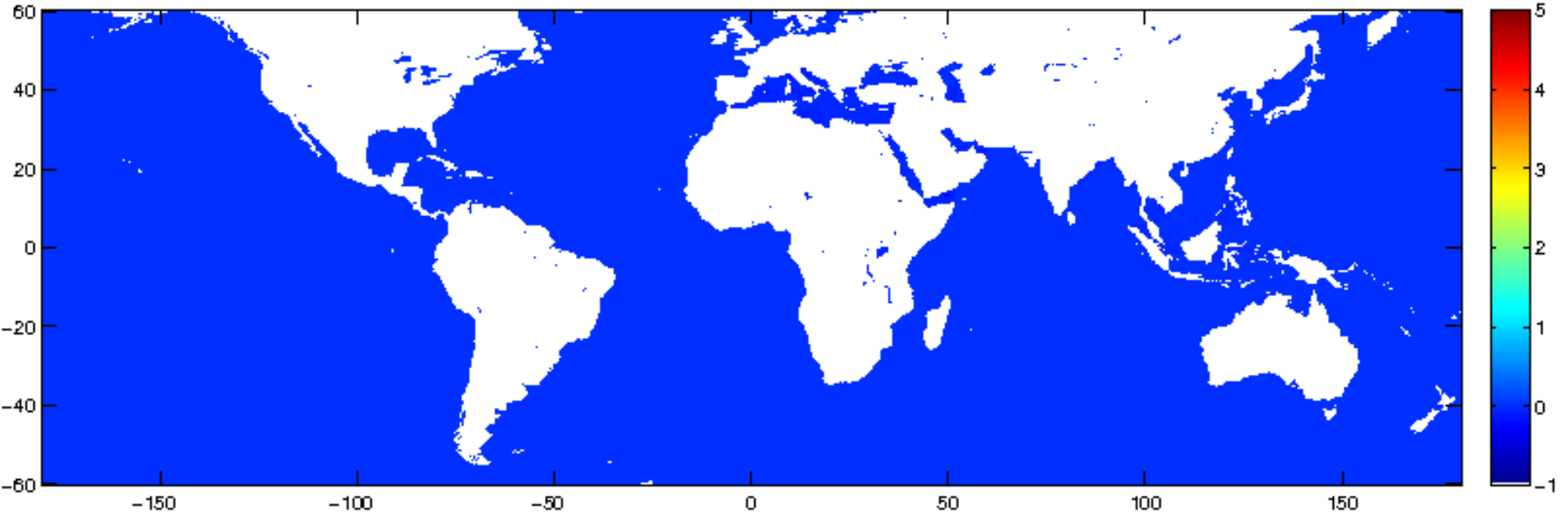
- **Relatively small fraction with ≥1 K**

Daily max warming w.r.t. 1 m



- **Not seeing warmings as large as 5 K**

Daily min warming w.r.t. 1 m



- **Essentially zero everywhere**

How sensitive is retrieved SST to true SST?

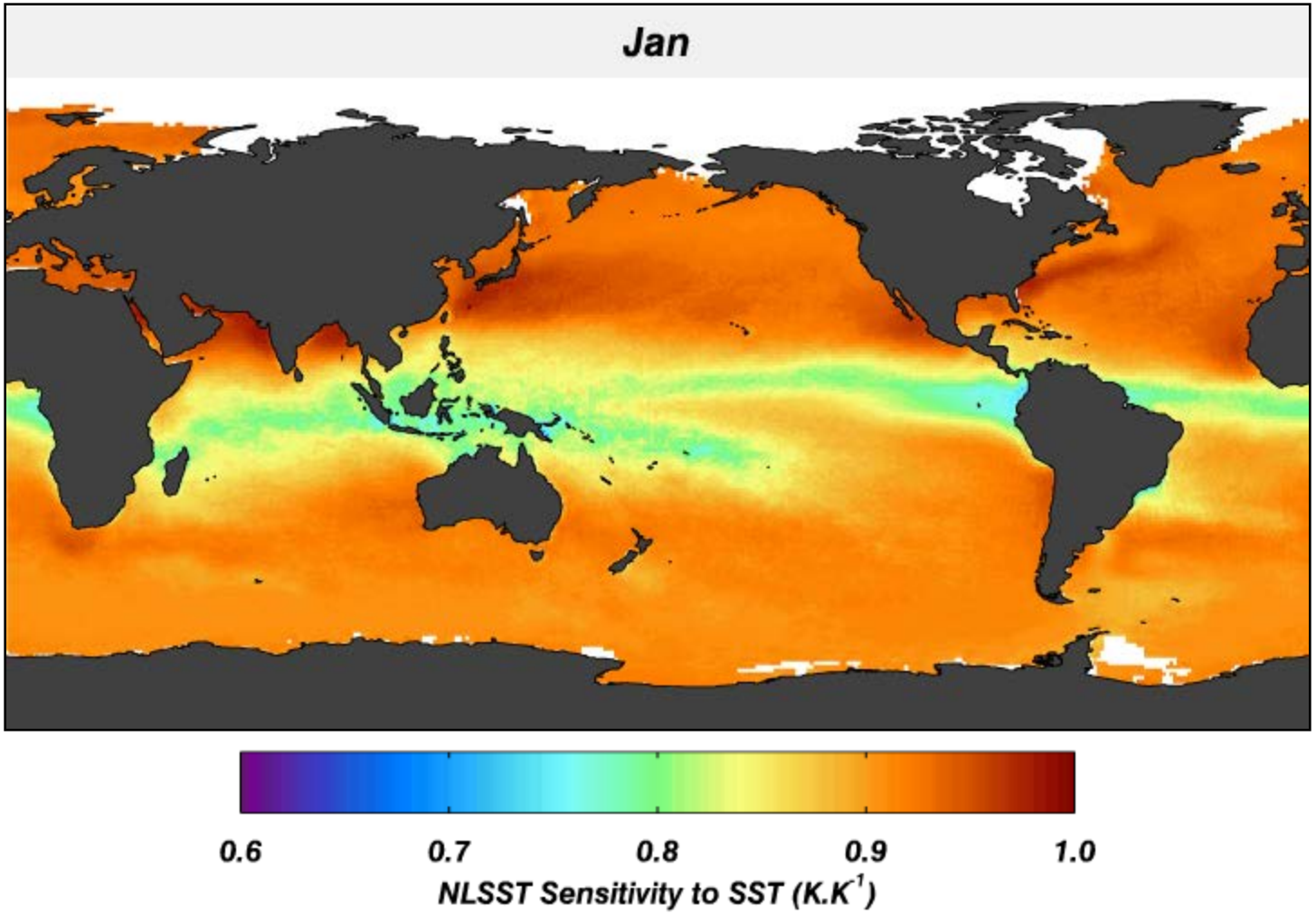
- If SST changes by 1 K, does retrieved SST change by 1 K?
- CRTM provides tangent-linear derivatives $\partial T_{11}/\partial SST_{\text{true}}$ $\partial T_{12}/\partial SST_{\text{true}}$

Response of **NLSST algorithm** to a change in **true SST** is…

$$\partial NLSST/\partial SST_{\text{true}} = \left(a_1 + a_2 \times SST_{bg} + a_3 \times \{\sec(ZA) - 1\}\right) \times \partial T_{11}/\partial SST_{\text{true}} - \left(a_2 \times SST_{bg} + a_3 \times \{\sec(ZA) - 1\}\right) \times \partial T_{12}/\partial SST_{\text{true}}$$

Merchant, C.J., A.R. Harris, H. Roquet and P. Le Borgne, Retrieval characteristics of non-linear sea surface temperature from the Advanced Very High Resolution Radiometer, Geophys. Res. Lett., **36**, L17604, 2009

Sensitivity to true SST



Sensitivity often <1 and changes with season

History of Inverse Model

- **Forward model:** $\mathbf{Y} = \mathbf{K}\mathbf{X}$
- **Inverse:** $\mathbf{X} = \mathbf{K}^{-1}\mathbf{Y}$ **(measurement error)**
- **Legendre (1805) Least Squares:**

$$\mathbf{X} = \mathbf{X}_{ig} + (\mathbf{K}^{\mathrm{T}}\mathbf{K})^{-1}\mathbf{K}^{\mathrm{T}}(\mathbf{Y}_{\delta} - \mathbf{Y}_{ig})$$

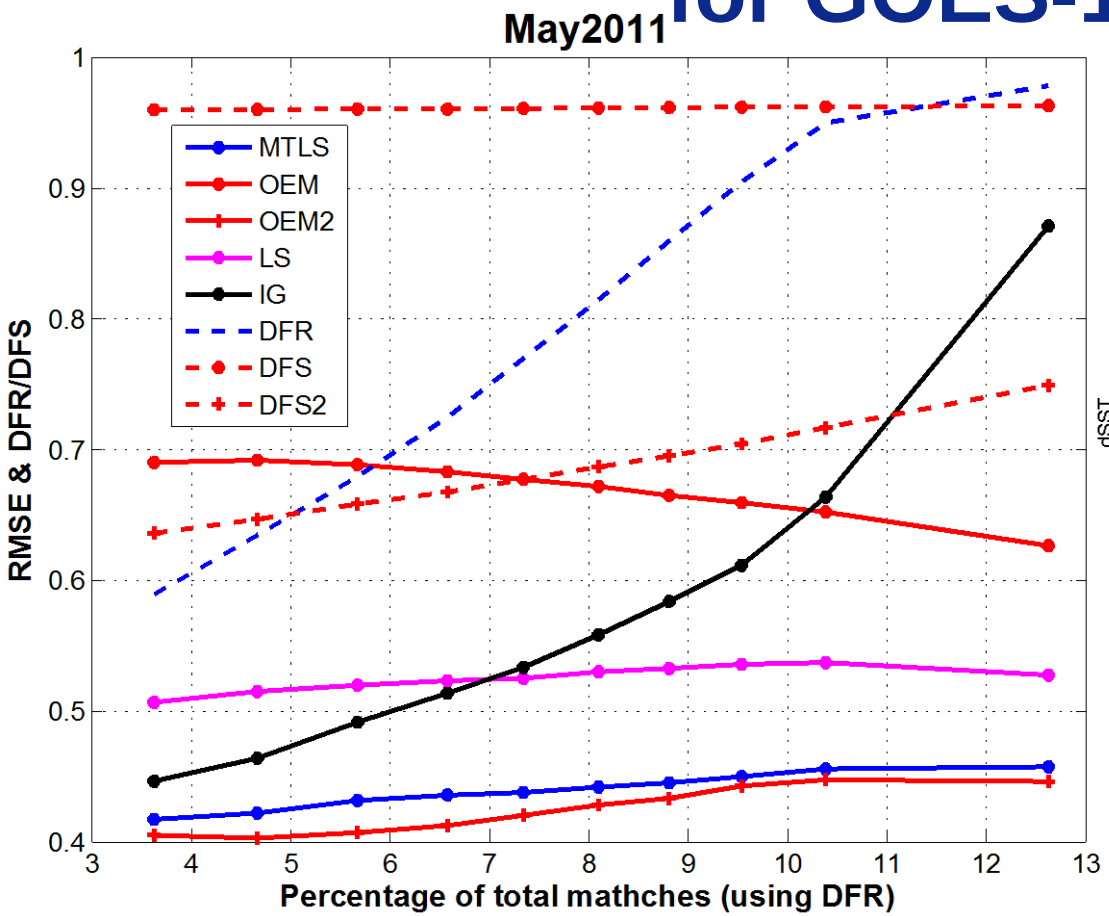
- **Last 30~40 years**

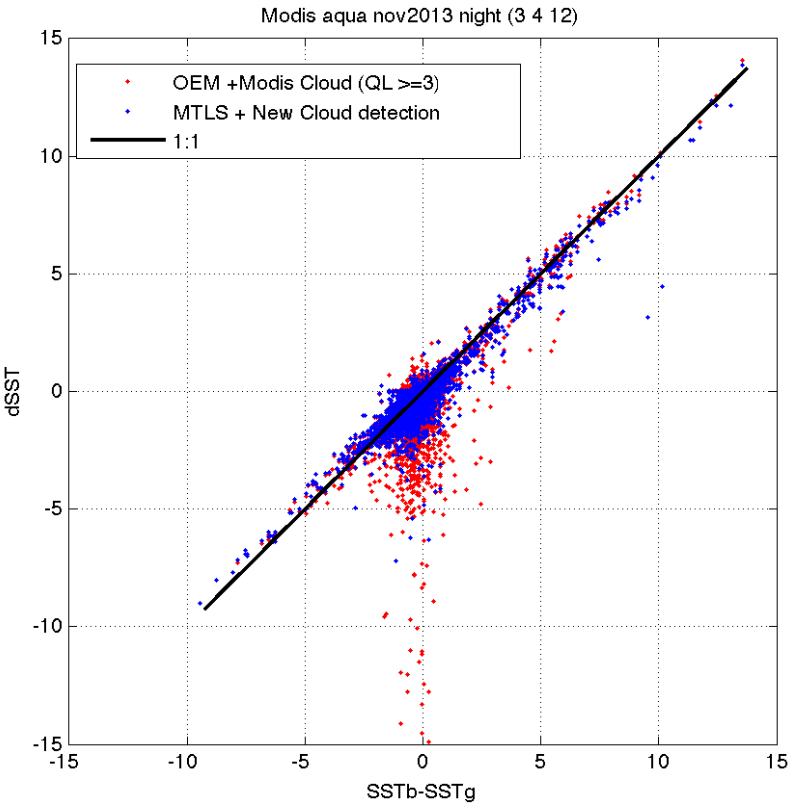
$$\delta X \leq \mathrm{cond}(\mathbf{K})\,\delta E$$

- **MTLS:** $\mathbf{X} = \mathbf{X}_{ig} + (\mathbf{K}^{\mathrm{T}}\mathbf{K} + \lambda\mathbf{R})^{-1}\mathbf{K}^{\mathrm{T}}(\mathbf{Y}_{\delta} - \mathbf{Y}_{ig})$

- **OEM:** $\mathbf{X} = \mathbf{X}_{\mathbf{a}} + (\mathbf{K}^{\mathrm{T}}\,\mathbf{S}_{\mathbf{e}}^{-1}\mathbf{K} + \mathbf{S}_{\mathbf{a}}^{-1})^{-1}\mathbf{K}^{\mathrm{T}}\mathbf{S}_{\mathbf{e}}^{-1}(\mathbf{Y}_{\delta} - \mathbf{Y}_{\mathbf{a}})$

DFS/DFR and Retrieval error for GOES-13





- Retrieval error of OEM higher than LS
- More than 75% OEM retrievals are degraded w.r.t. *a priori* error
- DFR of MTLS is high when *a priori* error is high
- The retrieval error of OEM is comparable when *a priori* perfectly known, but DFS of OEM is much lower than for MTLS