A diurnally corrected high-resolution SST analysis

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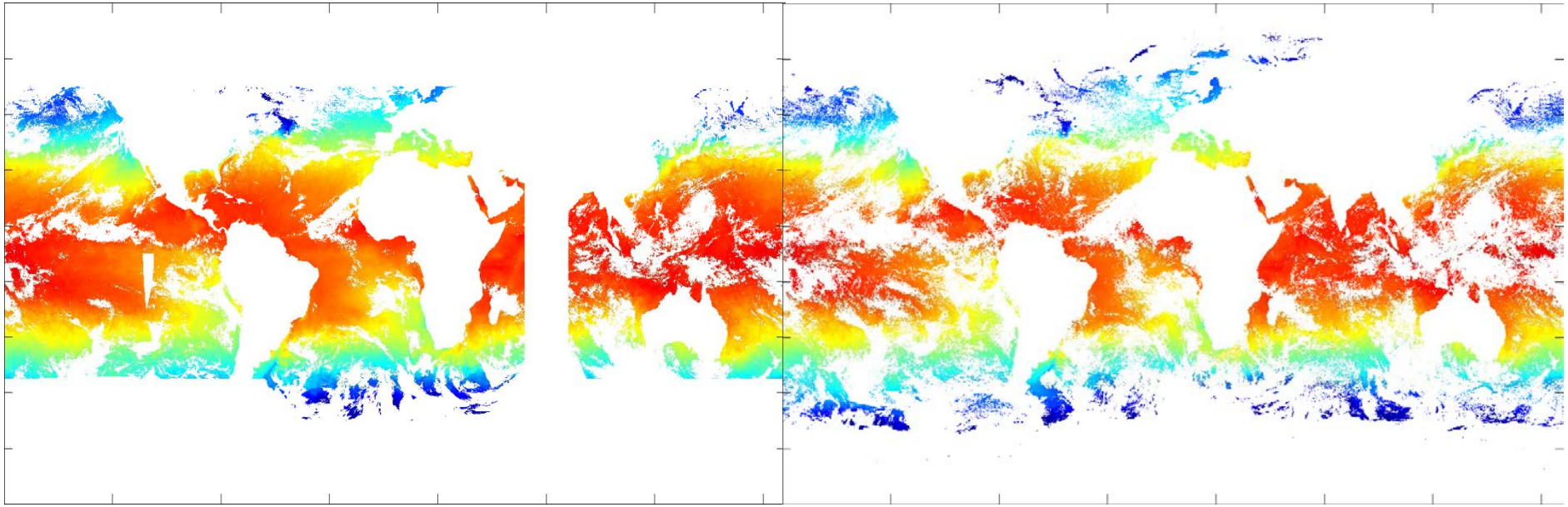
5-km Blended SST Analysis

- **Produced daily from 24 hours of AVHRR & Geo-SST**
  - NOAA-19, MetOp-B
  - GOES-E/W Imager
  - MTSAT-2 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>**

Data Coverage

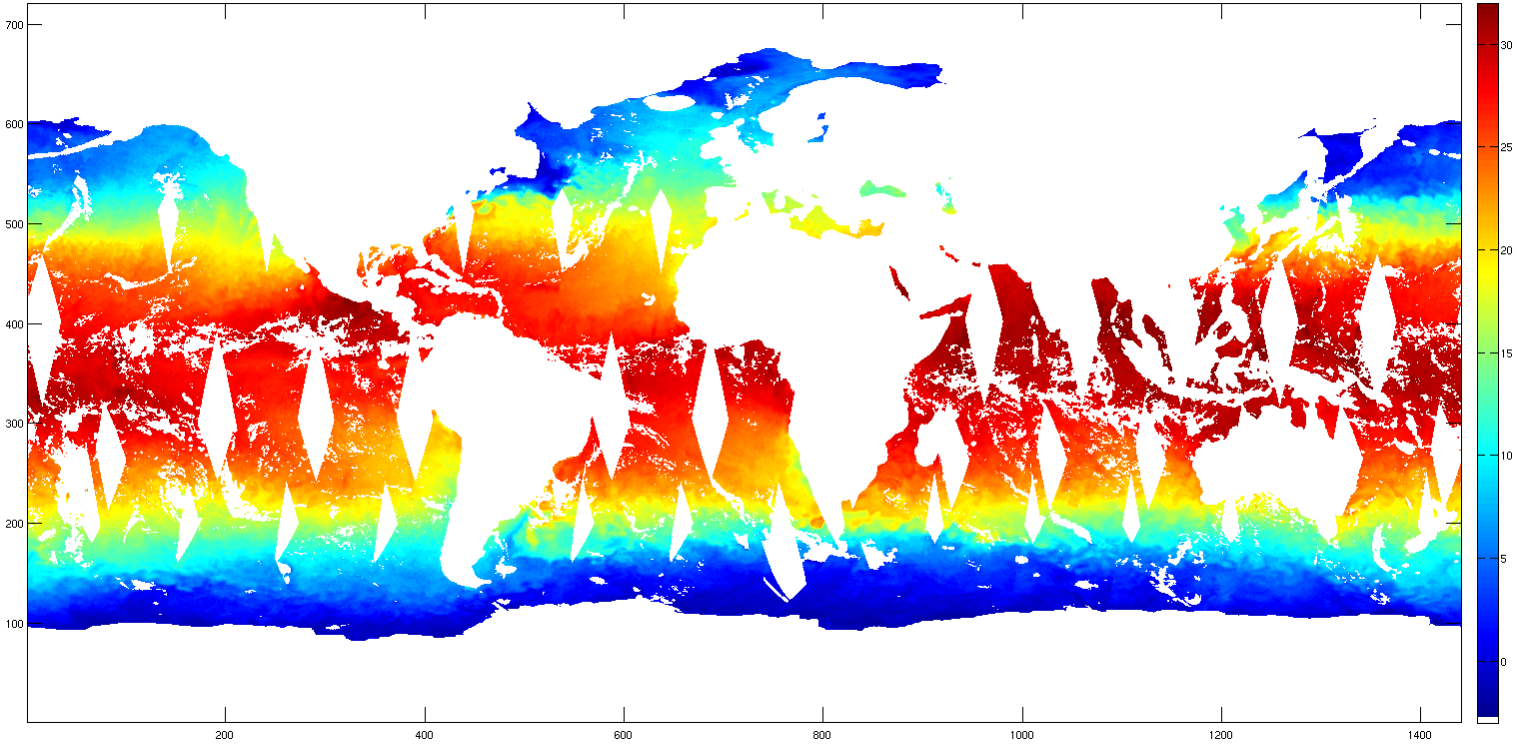
Geostationary SST

Polar-Orbiter SST



- **Geostationary data in particular provide lots of observations**
  - N.B. gap in coverage in Indian Ocean
- **Data-driven analysis**
  - Need to treat the input data “carefully”

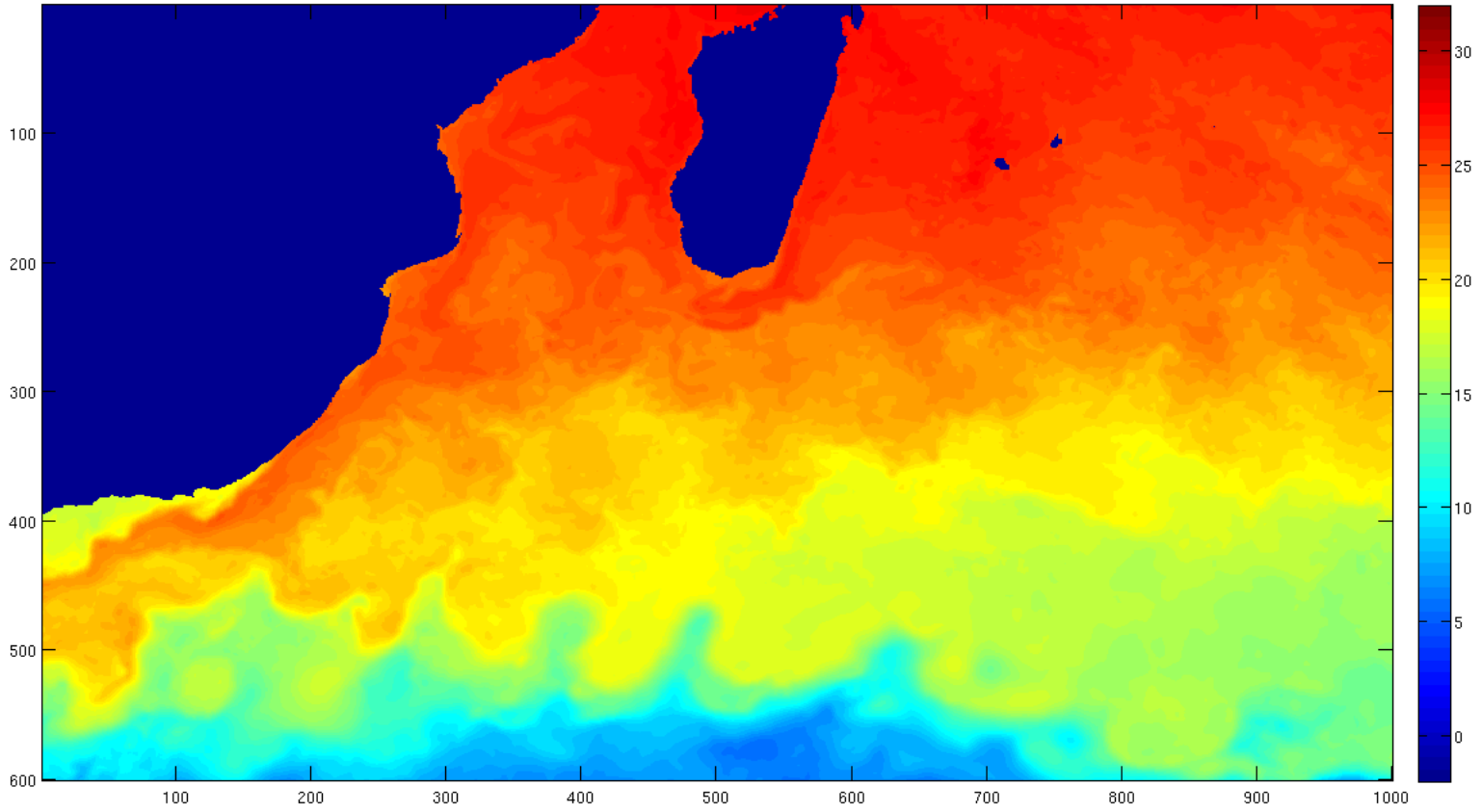
Data Coverage – AMSR-2



- 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**

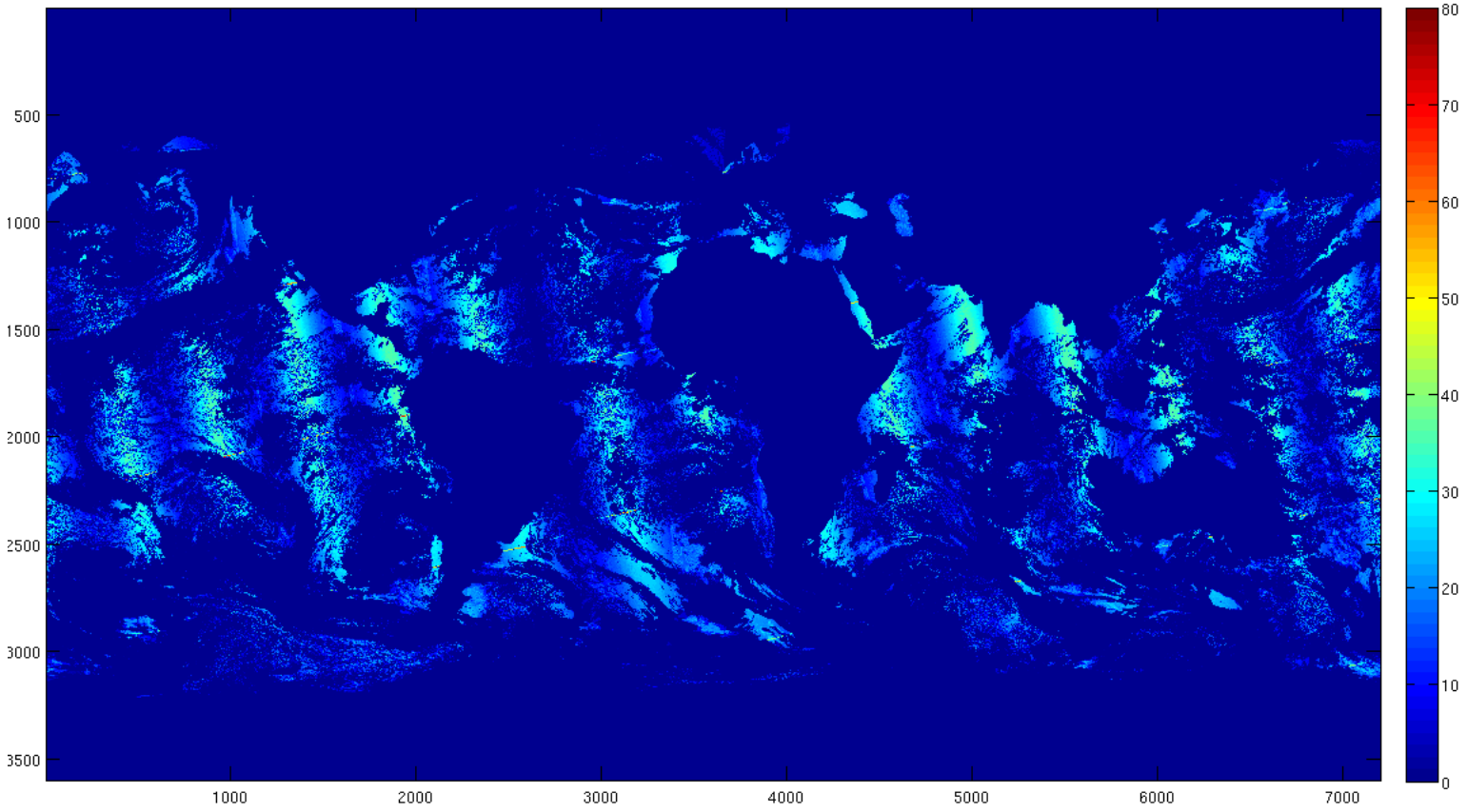


Super-obbed VIIRS SST

Final SST analysis

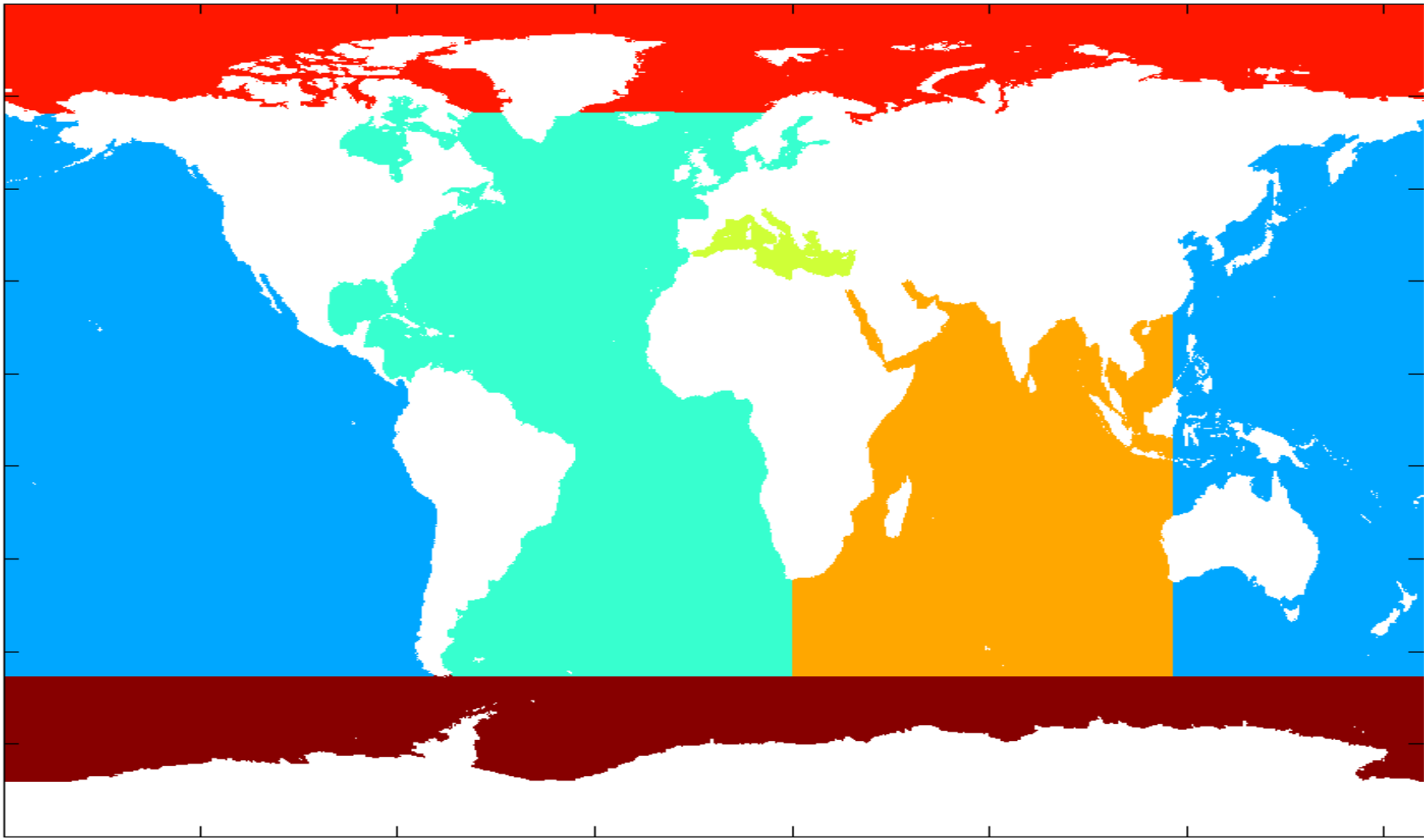
VIIRS coverage

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

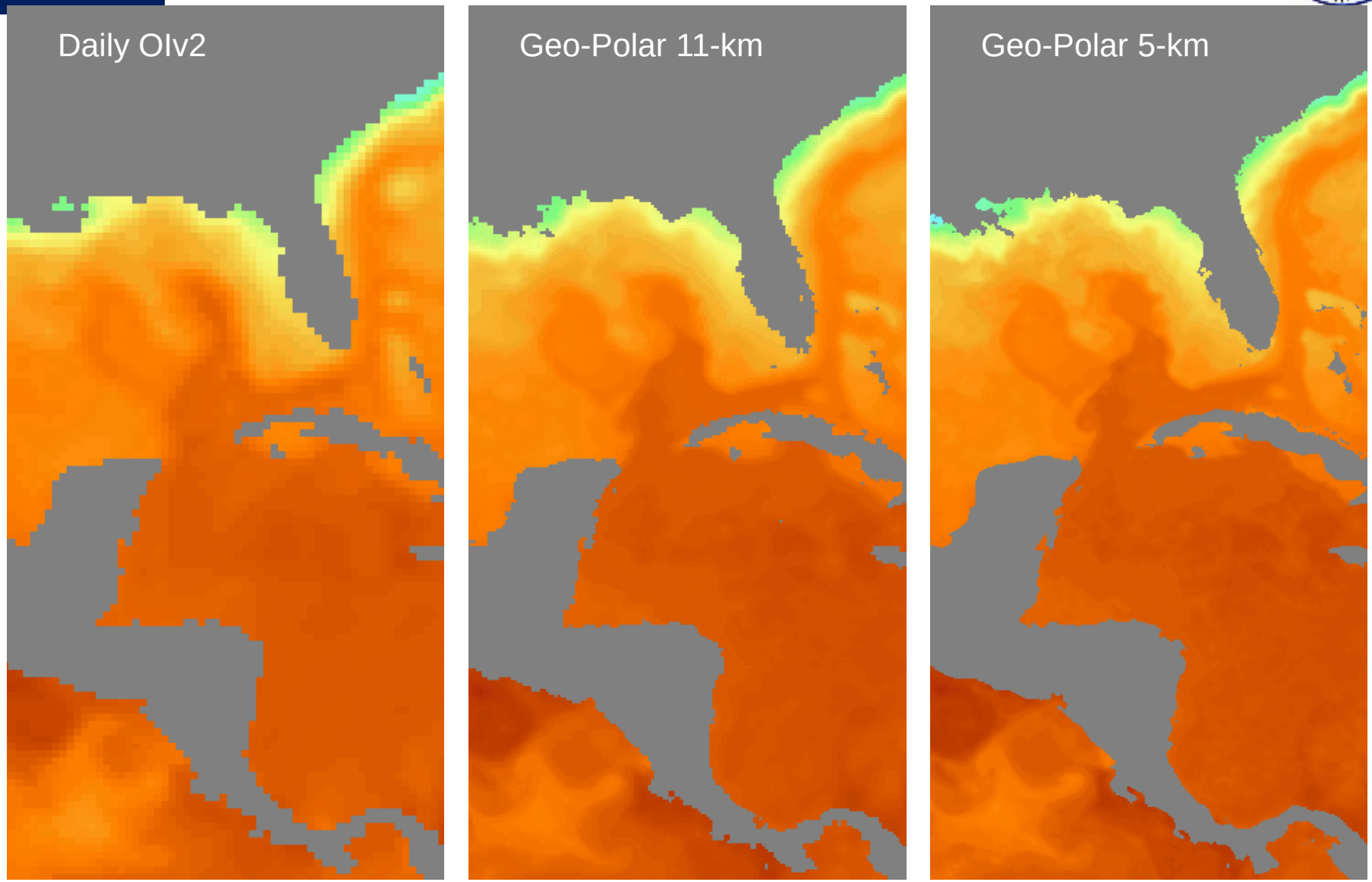


ACSPO AVHRR coverage

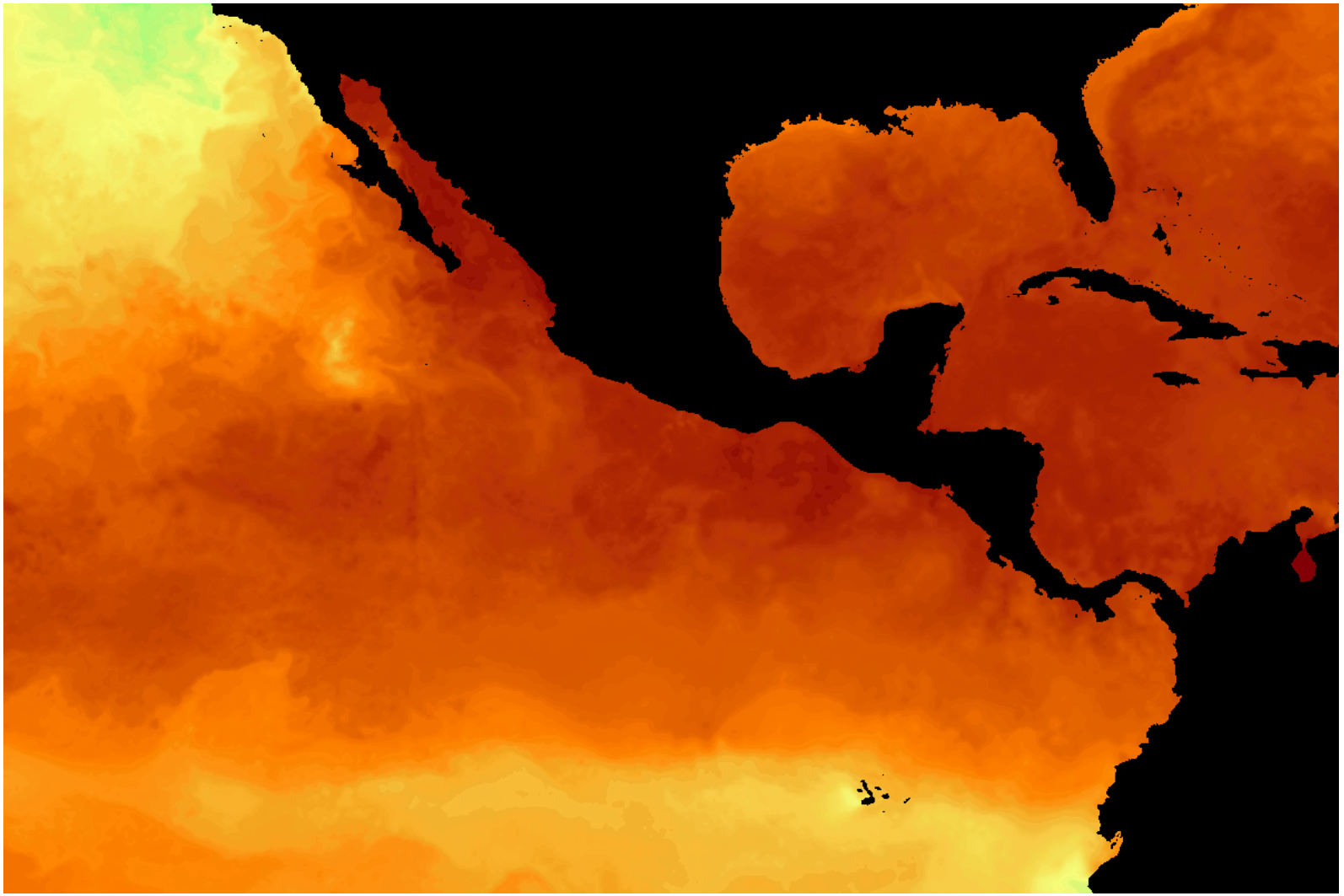
Separate Ocean Basins



Resolution difference

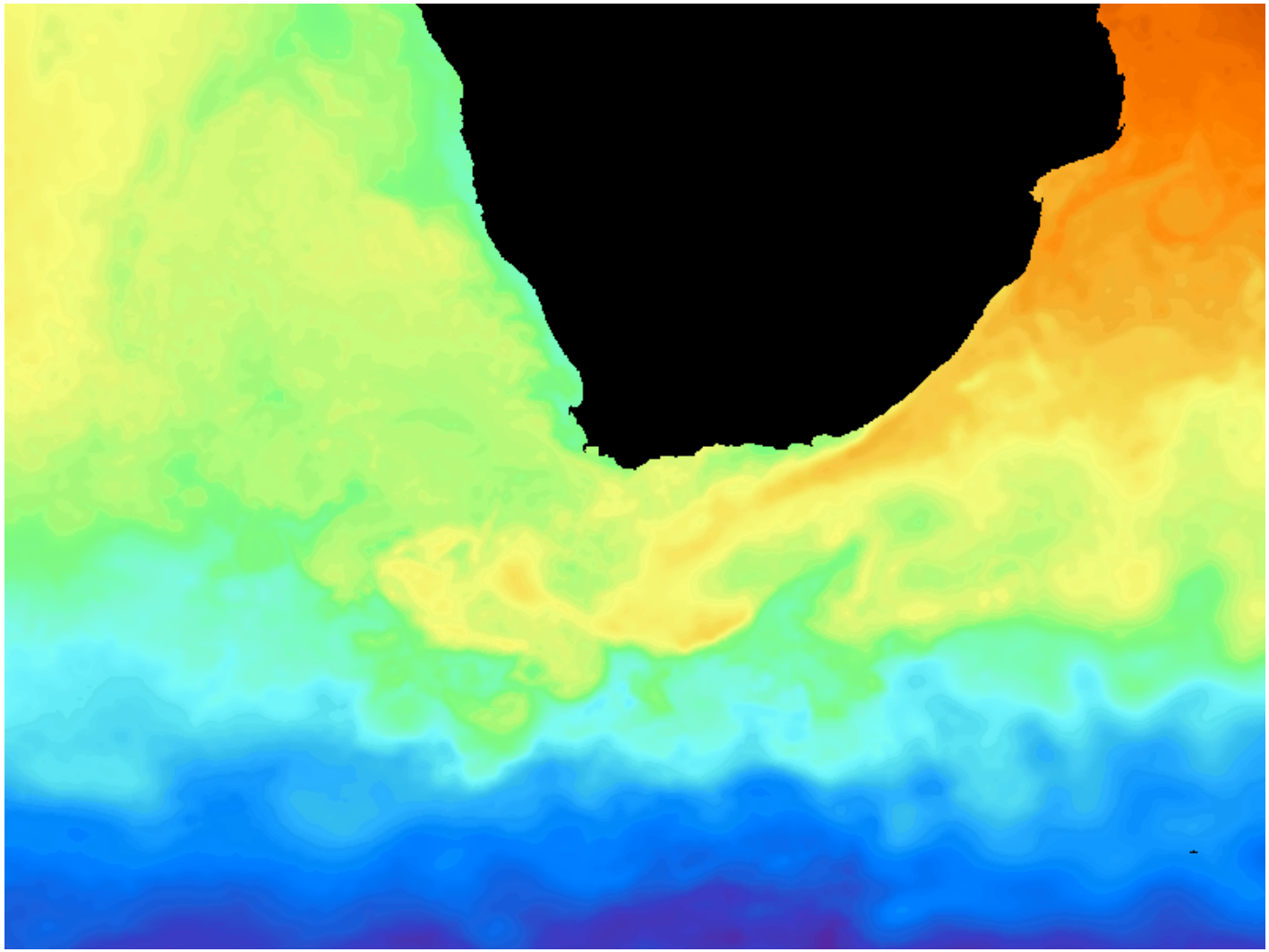


5-km Examples



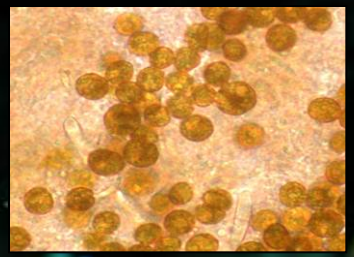
Day+night 5-km, Nov 1 – Dec 31, 2012

5-km Examples



Day+night 5-km, Nov 1 – Dec 31, 2012

Corals live in symbiosis with algae



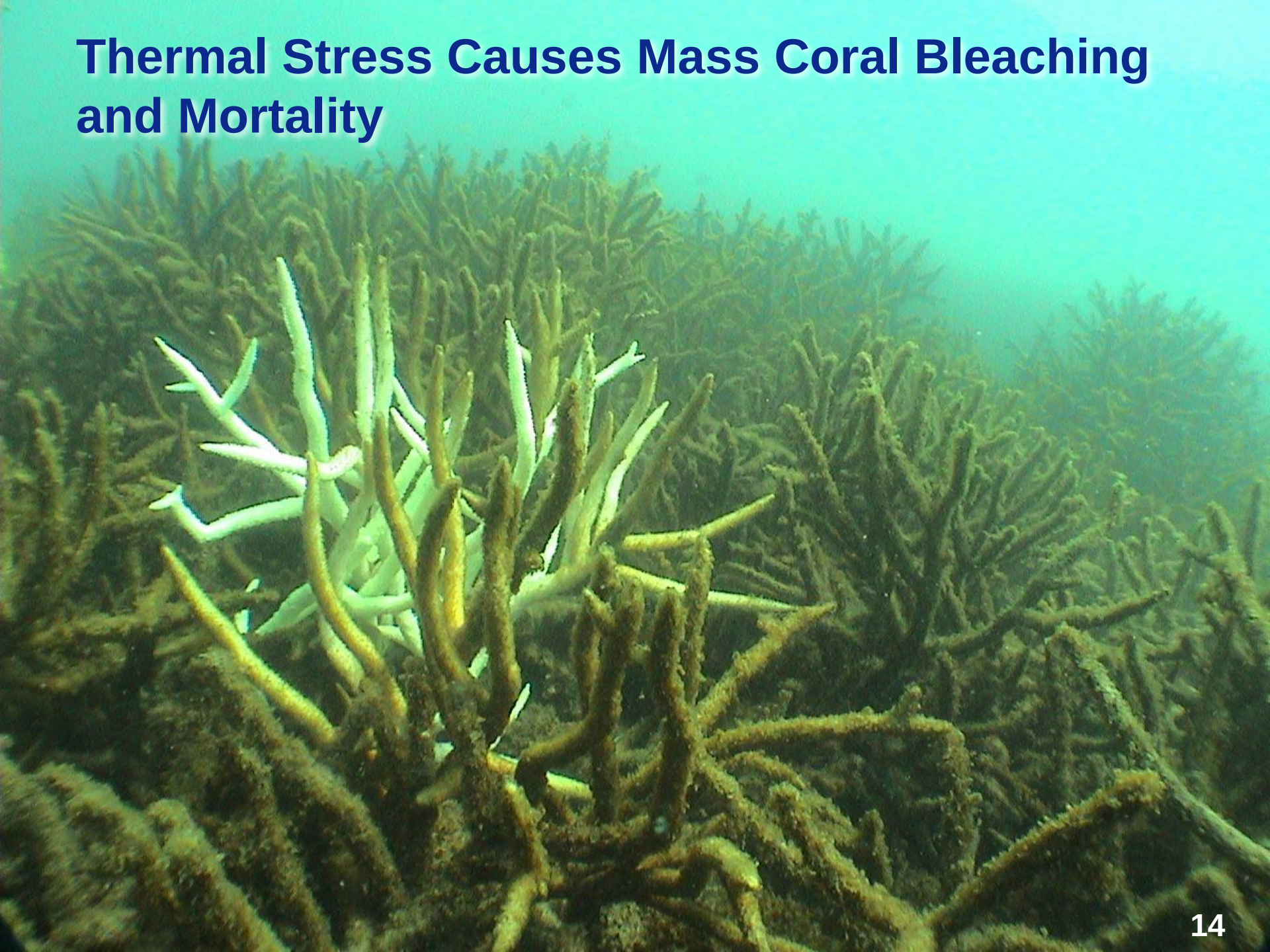
Stress

Corals release their algae

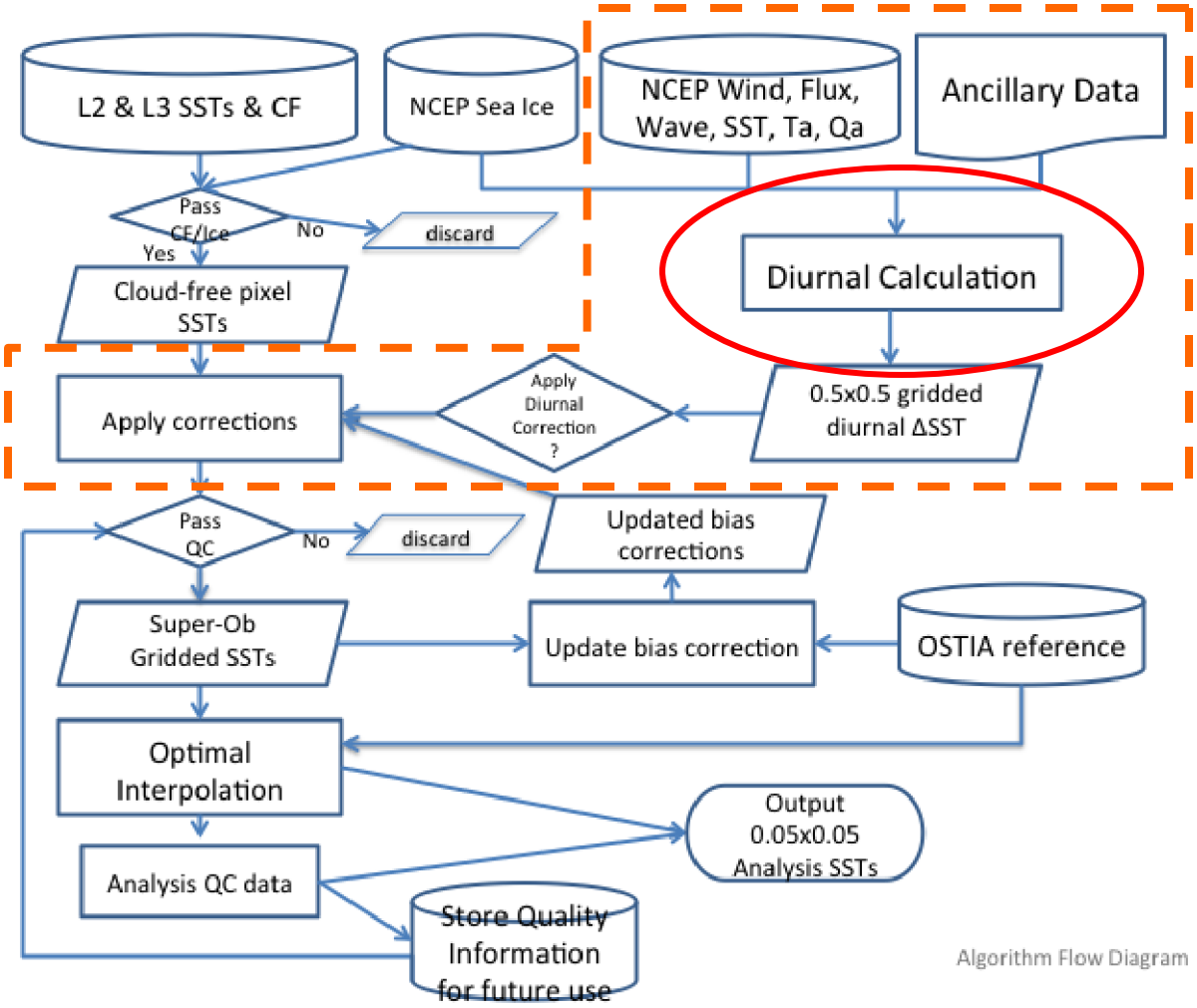
Thermal Stress Causes Mass Coral Bleaching

Thermal Stress Causes Mass Coral Bleaching

Thermal Stress Causes Mass Coral Bleaching and Mortality

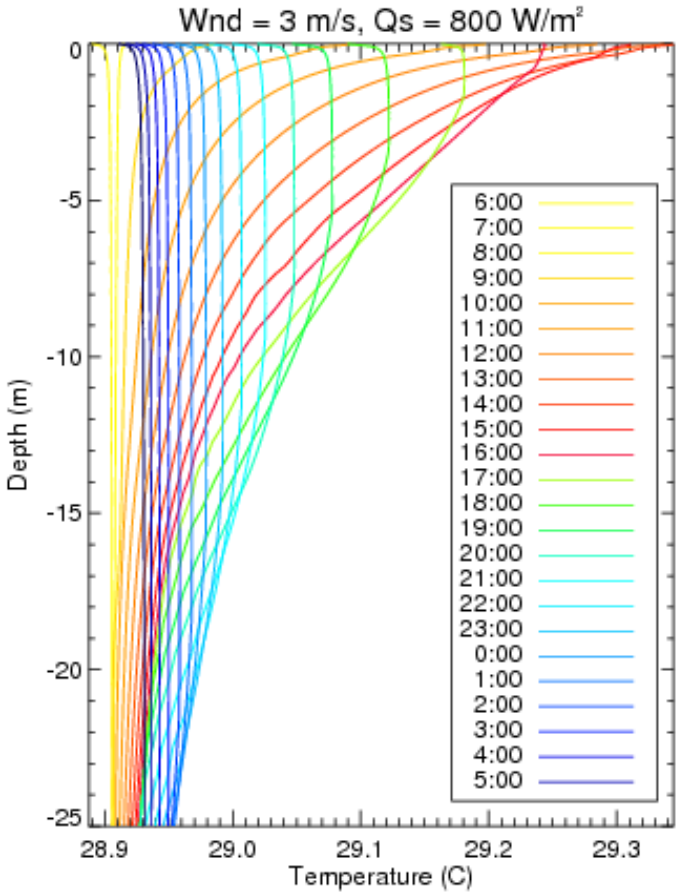


Including diurnal warming correction in SST analysis

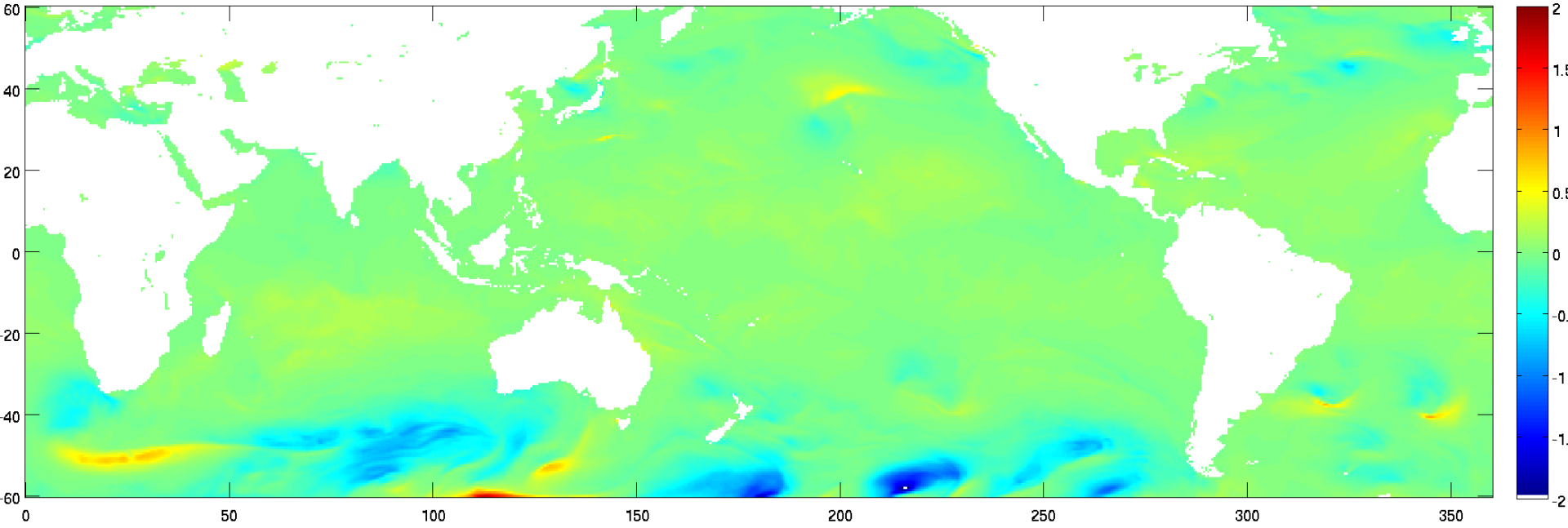


Diurnal Warming Correction – Sample Model Profile of Warming with Depth

- **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**

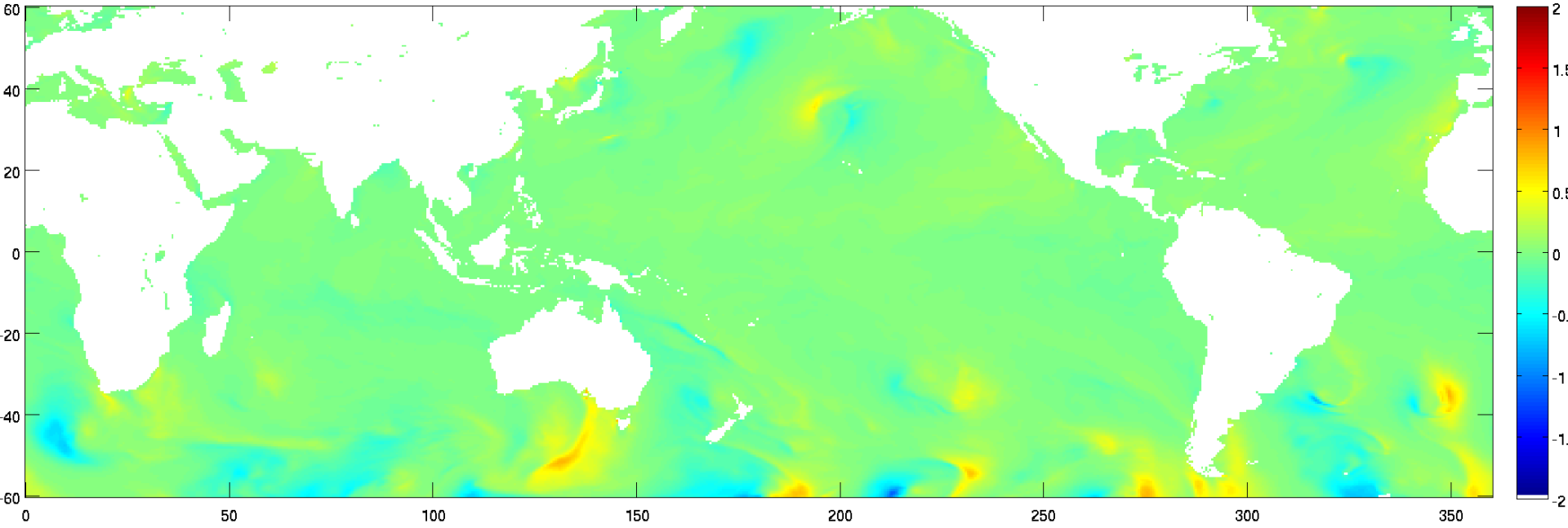


Diurnal Warming Correction - Sample Model Forcing Fields



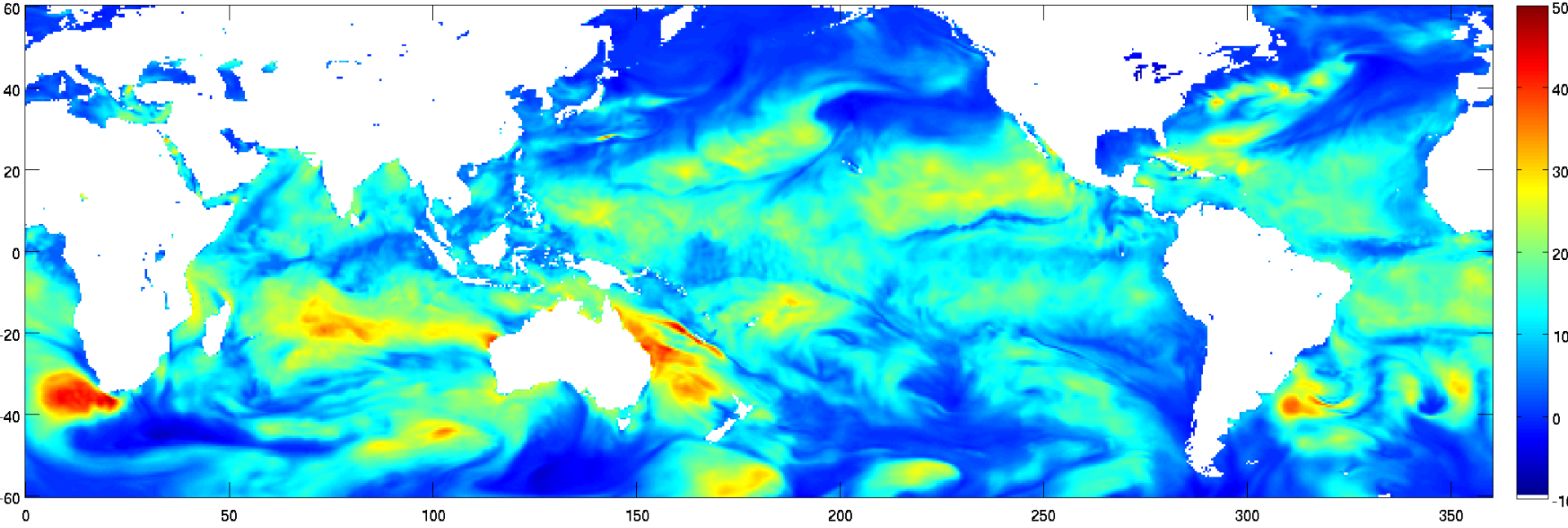
Zonal wind stress

Diurnal Warming Correction - Sample Model Forcing Fields



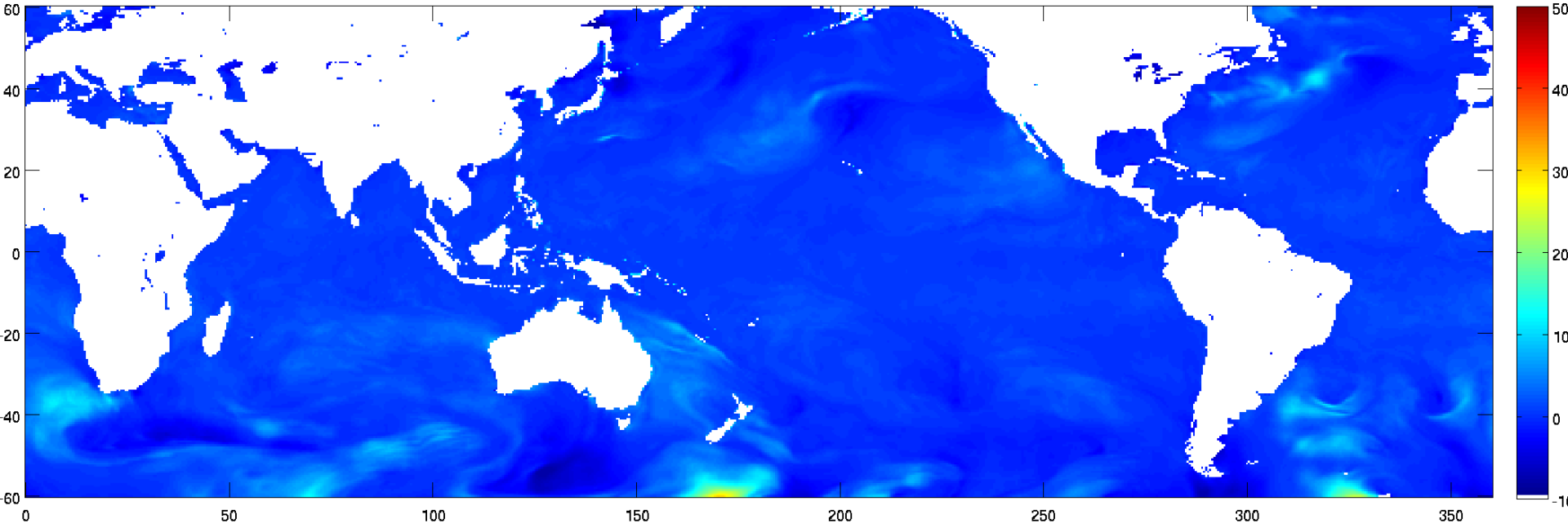
Meridional wind stress

Diurnal Warming Correction - Sample Model Forcing Fields



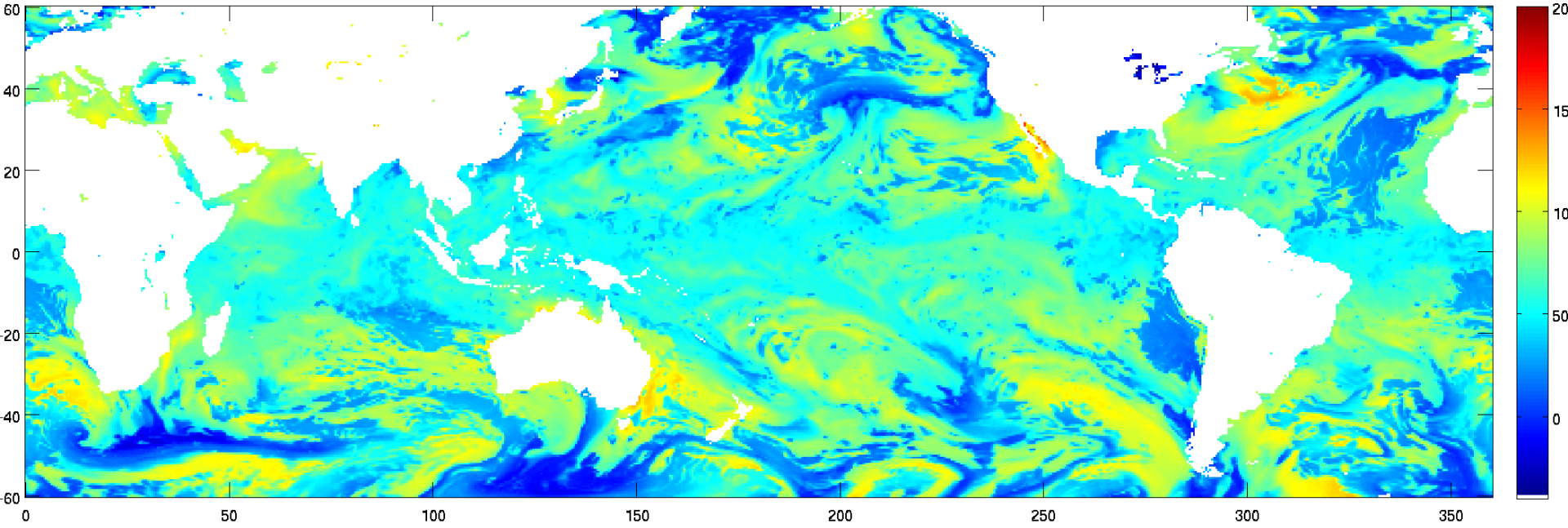
Latent heat flux

Diurnal Warming Correction - Sample Model Forcing Fields



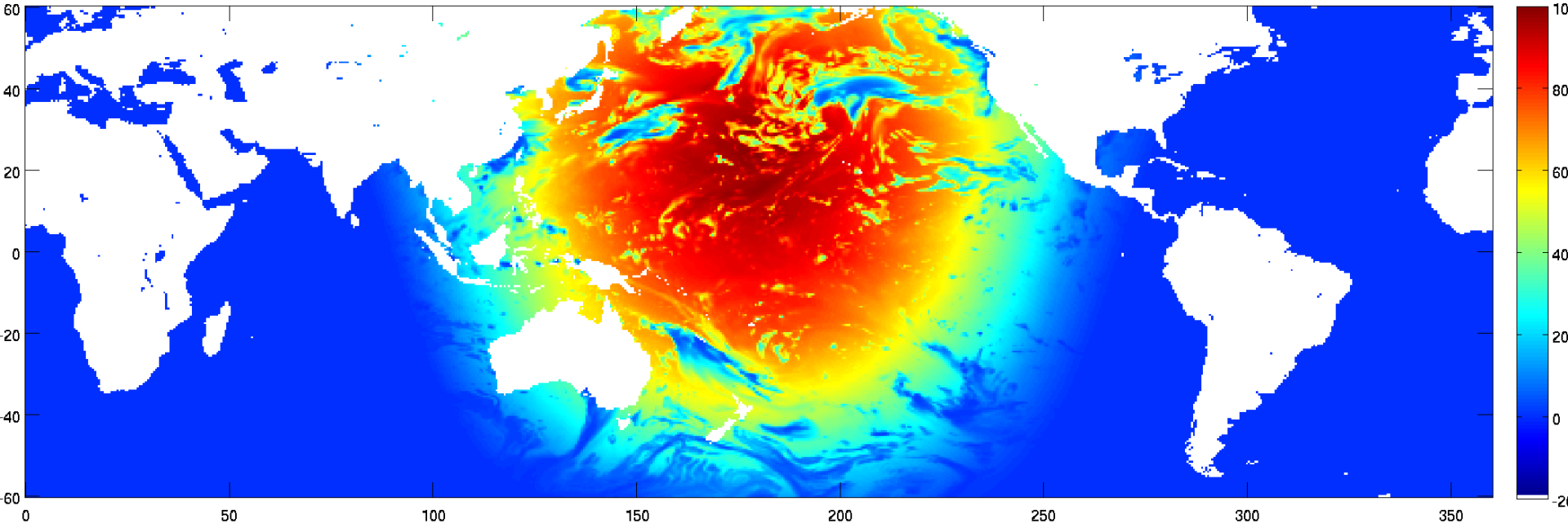
Sensible heat flux

Diurnal Warming Correction - Sample Model Forcing Fields



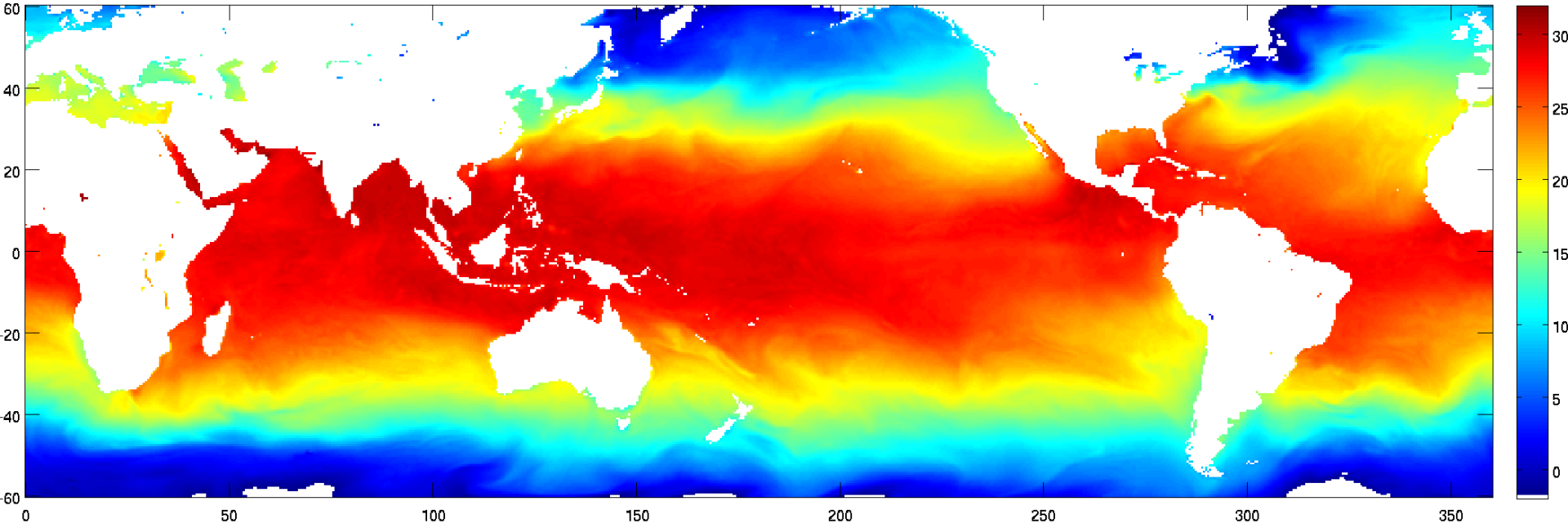
Net longwave heat flux

Diurnal Warming Correction - Sample Model Forcing Fields



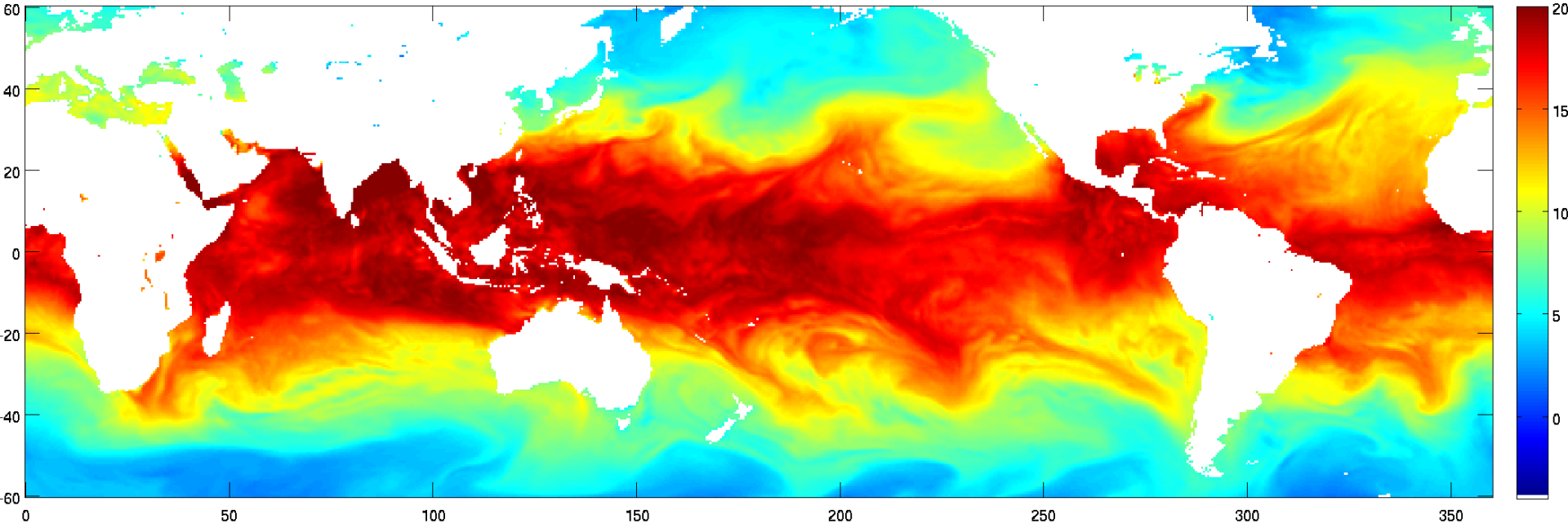
Net shortwave heat flux

Diurnal Warming Correction - Sample Model Forcing Fields



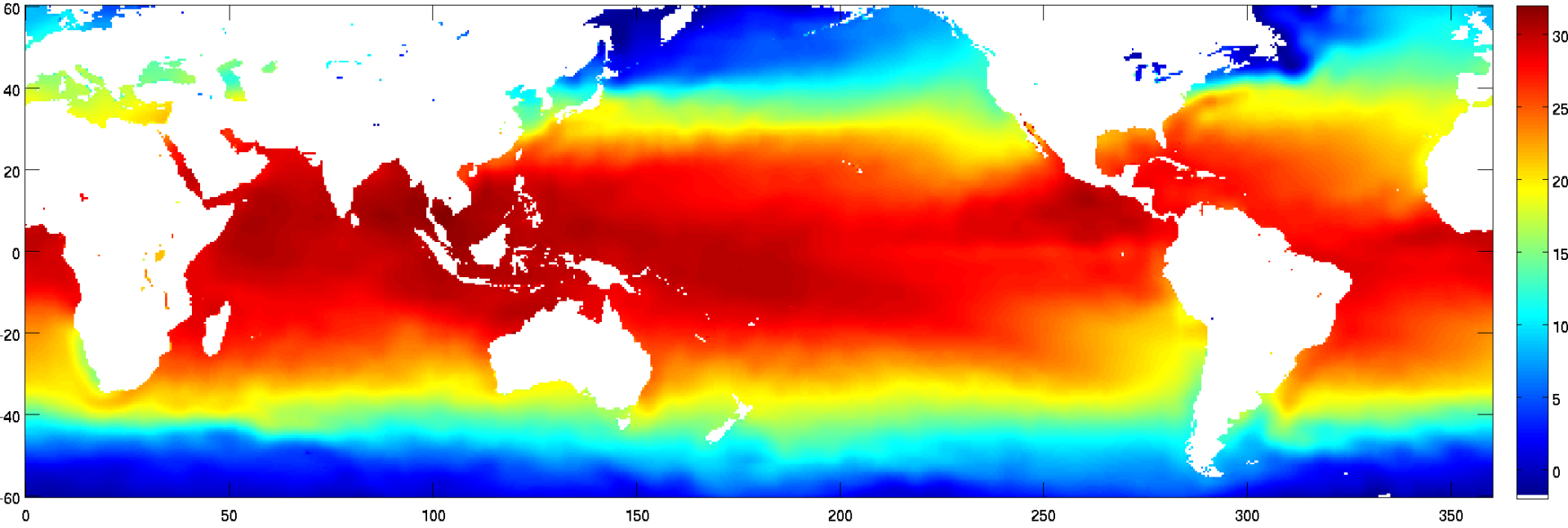
2m air temperature

Diurnal Warming Correction - Sample Model Forcing Fields



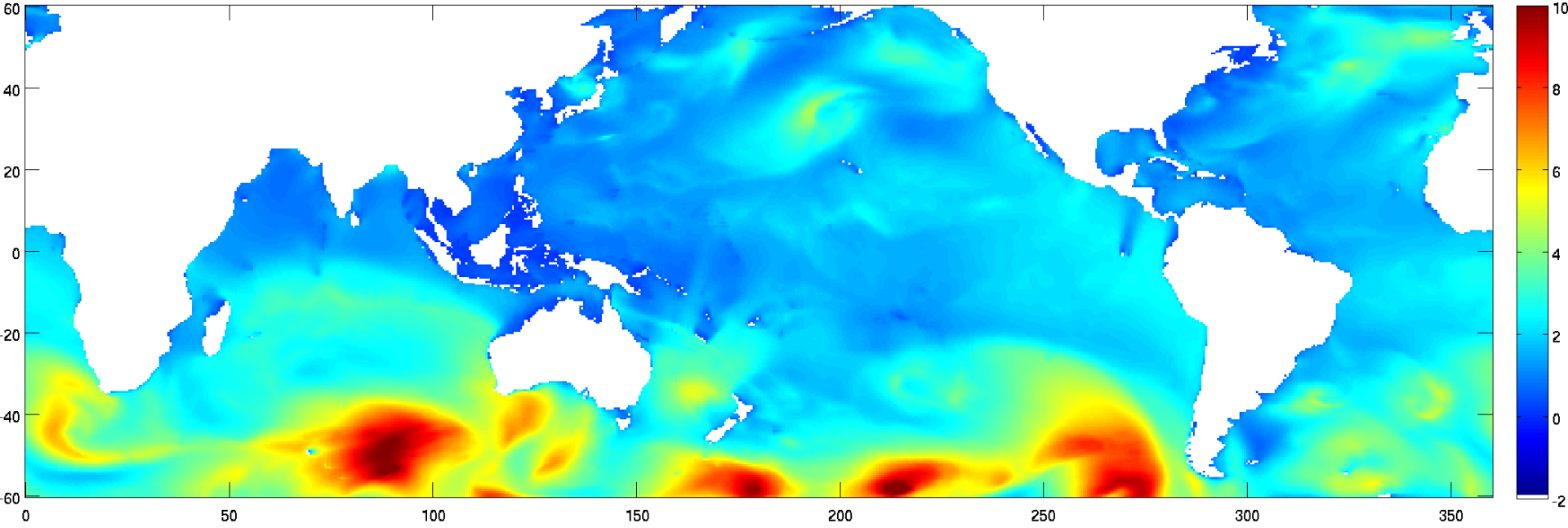
2m specific humidity

Diurnal Warming Correction - Sample Model Forcing Fields



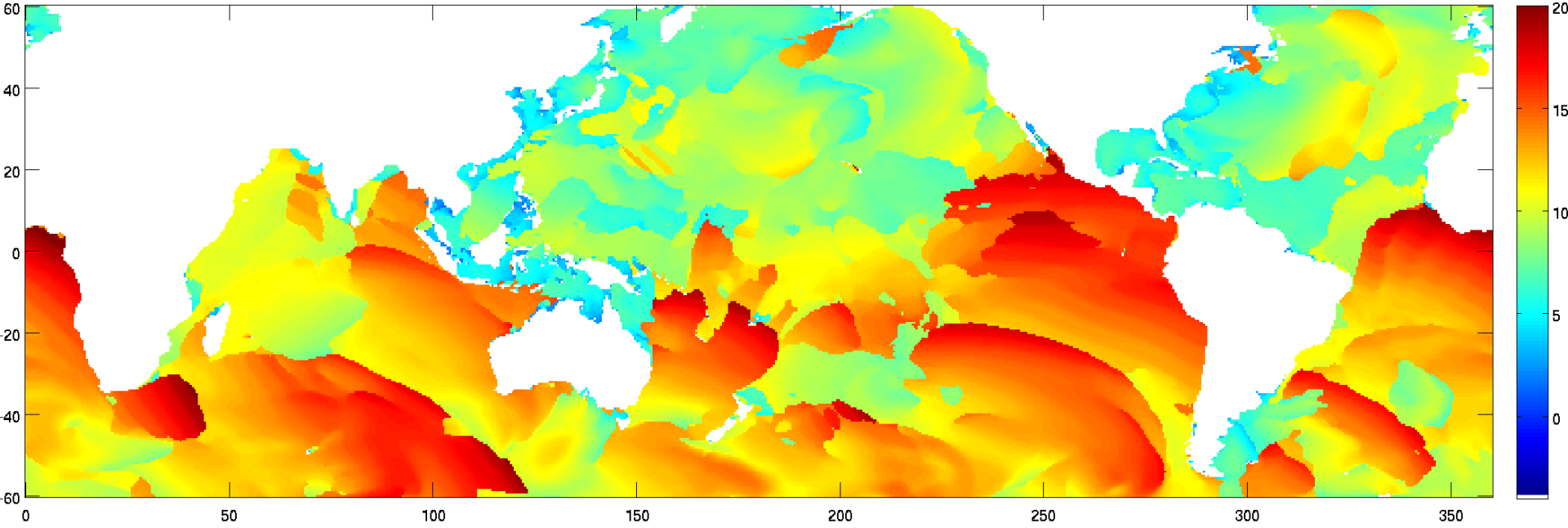
NWP SST

Diurnal Warming Correction - Sample Model Forcing Fields



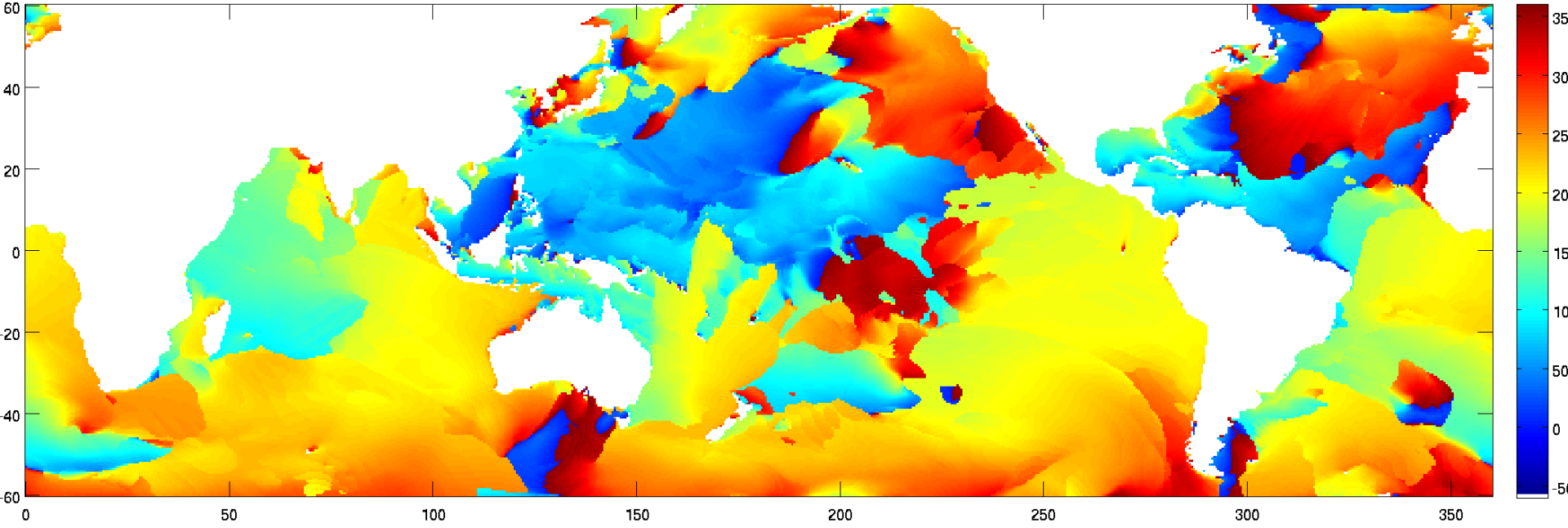
Significant wave height

Diurnal Warming Correction - Sample Model Forcing Fields



Primary wave period

Diurnal Warming Correction - Sample Model Forcing Fields



Primary wave direction

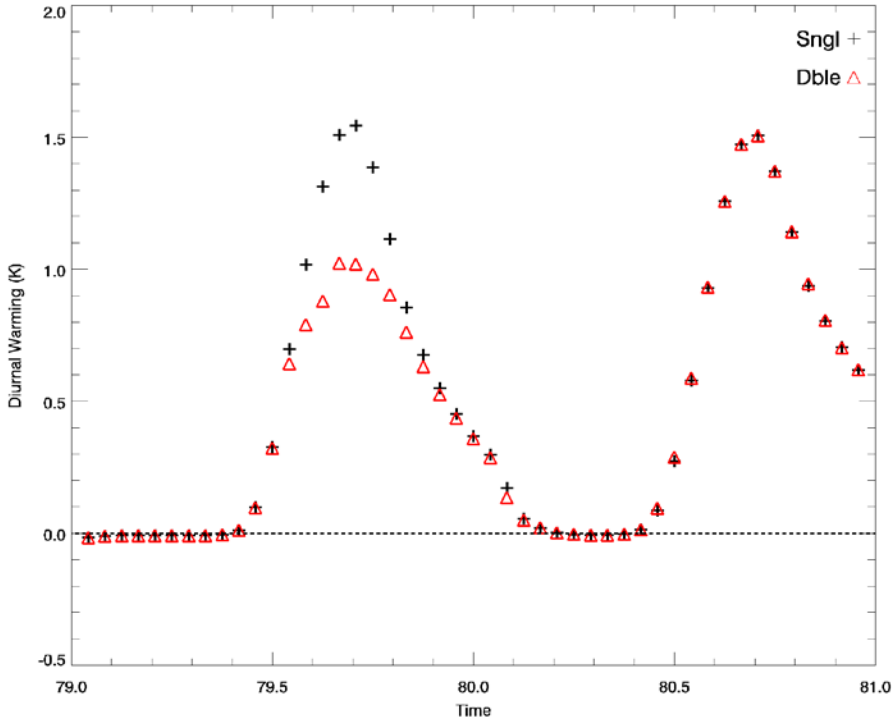
Diurnal Warming – Flux Feedback Adjustment

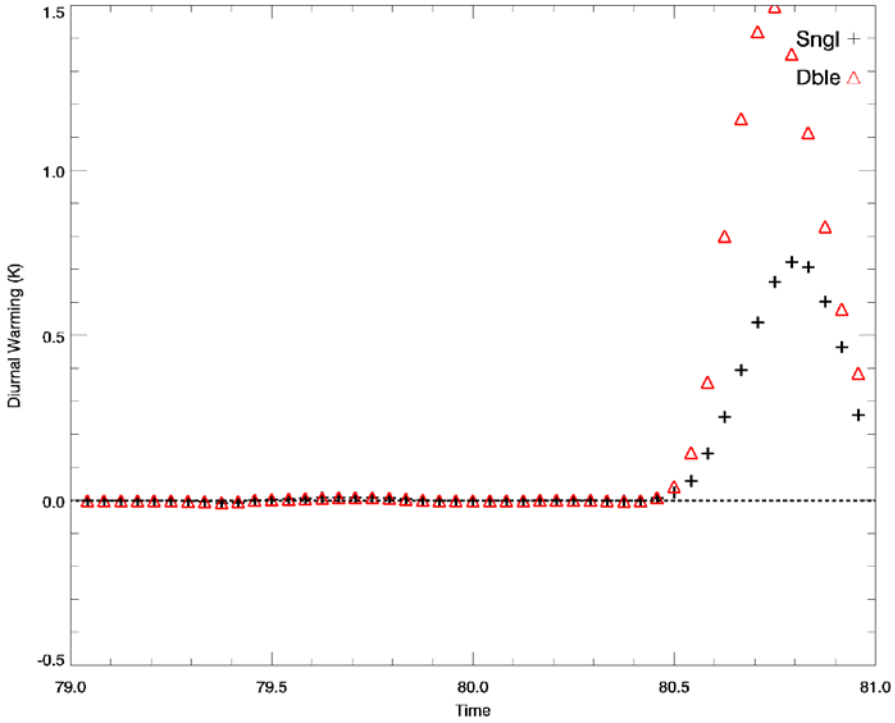
- NCEP heat fluxes assume fixed SST
- In the presence of diurnal warming, the heat fluxes will change
- Use a simple "scaled bulk formulae" approach, e.g.:
  - » $Q_L = K_L u^*(Q_s - Q_a)$
  - » Determine K_L from NCEP values of Q_L, u^*, Q_s & Q_a
  - » Adjust Q_L as Q_s changes (a function of SST)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

Status

- **All relevant routines from the research (Wick) DW code have been rewritten in F90 to NOAA/NESDIS coding standards**
- **New code runs ~ 2.5x faster than old code**
- **Code includes**
  - Wave breaking
  - Stokes drift (impact of waves)
  - Single parameter file to select modes/change behaviour
    - New code enables user to change some parameters without code modifications e.g. scaling for Langmuir/Stokes drift Q2 surface boundary condition (currently set to 1. – makes a big difference to DW)

The effect of data precision

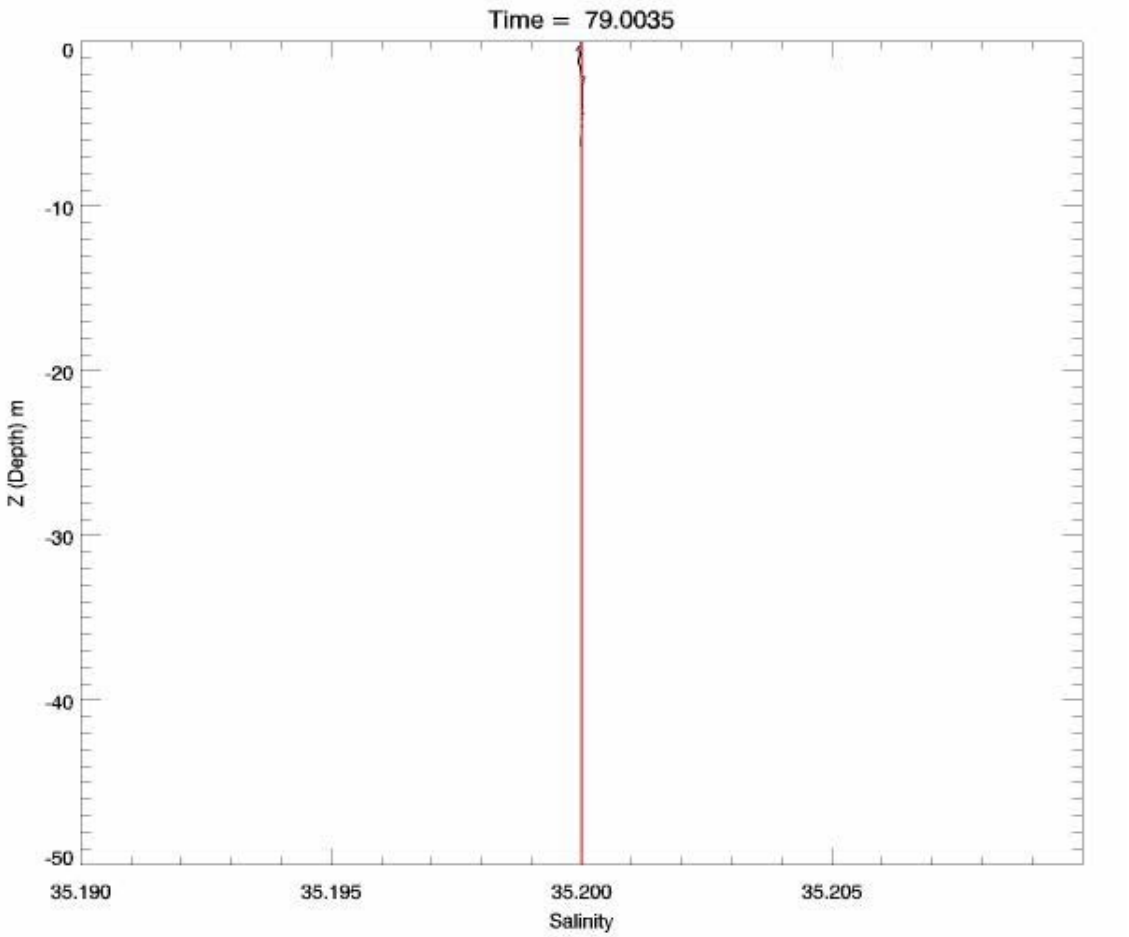




Change of precision has an impact on the result – sometimes quite large

- Change in precision a trivial exercise in new code
- Double precision version runs 28% slower
- Profile parameters are more stable in double precision

Salinity profile– single vs double precision

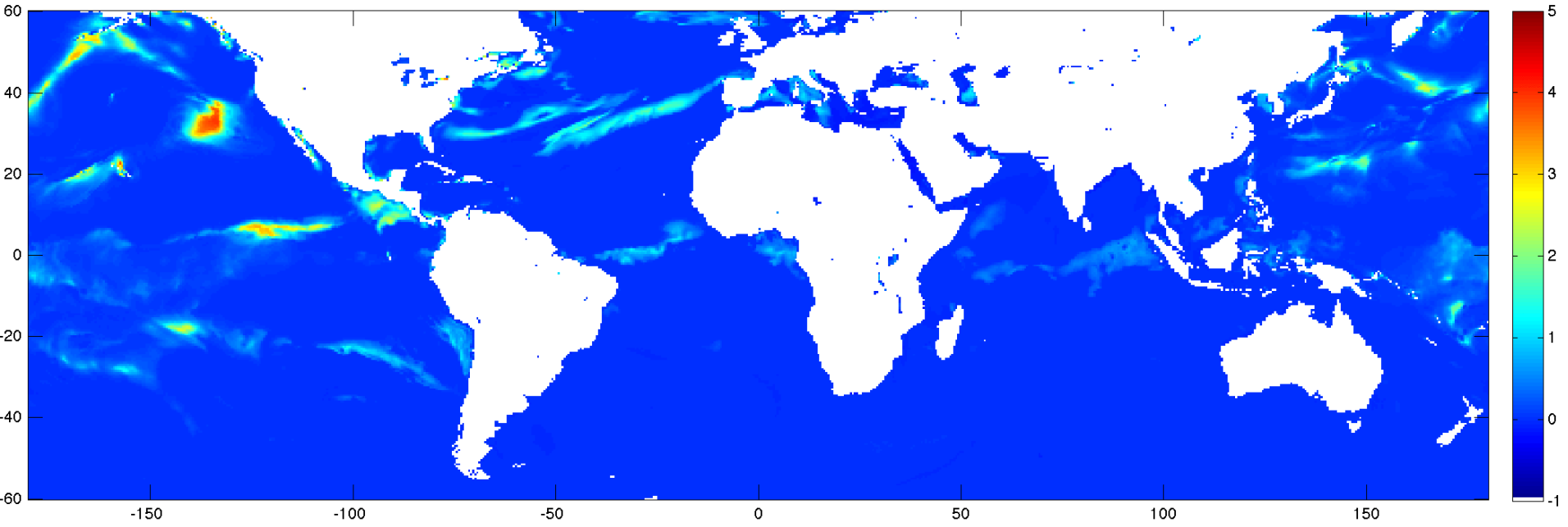


- **Double precision gives the correct answer – no salinity variations expected for this run**
- **No evaporation/rainfall included**

Summary

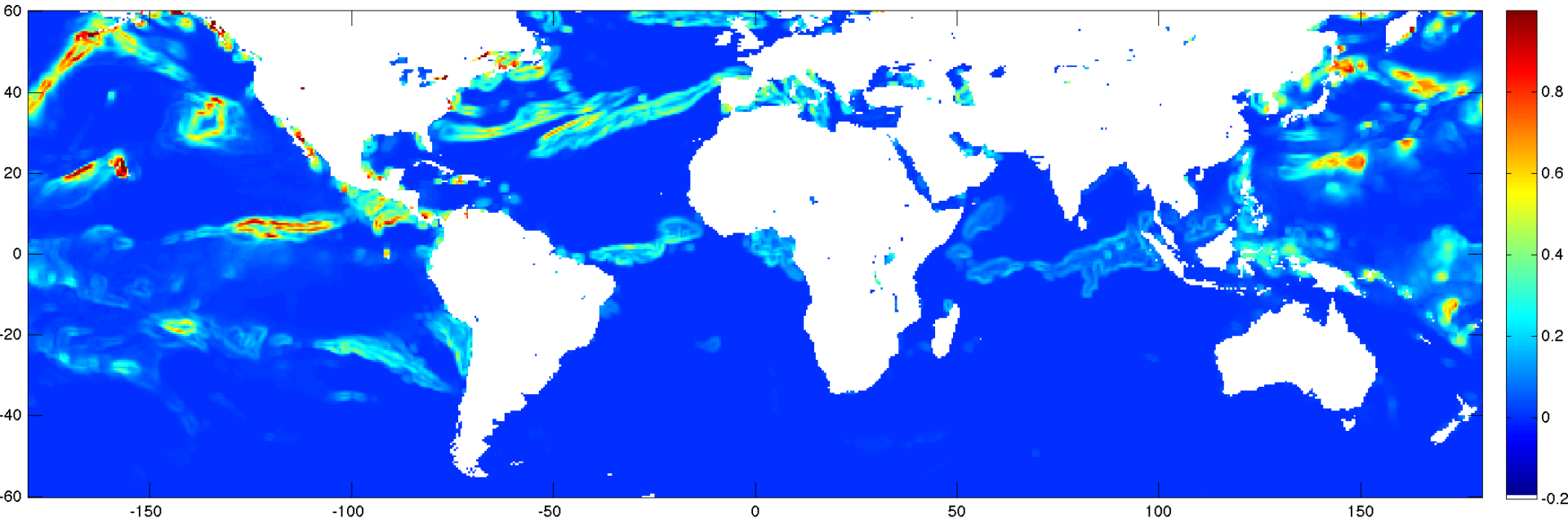
- **New code**
  - Cannot get exact agreement with original research code
  - Result can change if precision changed in new code
    - Double precision required for stability
  - Ability to ‘tune’ DW in parameter file if run against *in situ* cases
    - Modifications to parameter file – no recoding should be required
- **Code available from NOAA after made operational**
  - Current schedule pre-operational Oct 2014
    - Still under testing for NOAA operational systems
  - Will include involvement from Gary Wick (NOAA) via collaboration on any new developments

Sample output



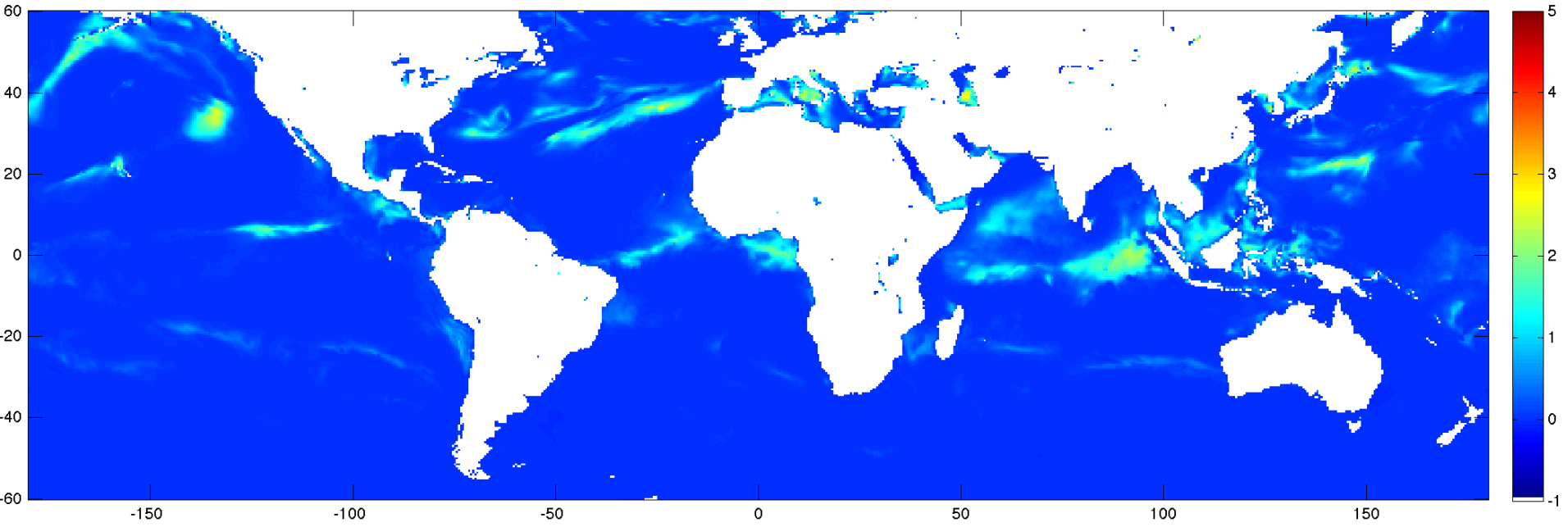
- **Regions of >5 K warming**
- **Note, warming events on edge of ±60° limit**

1st cut uncertainty estimate



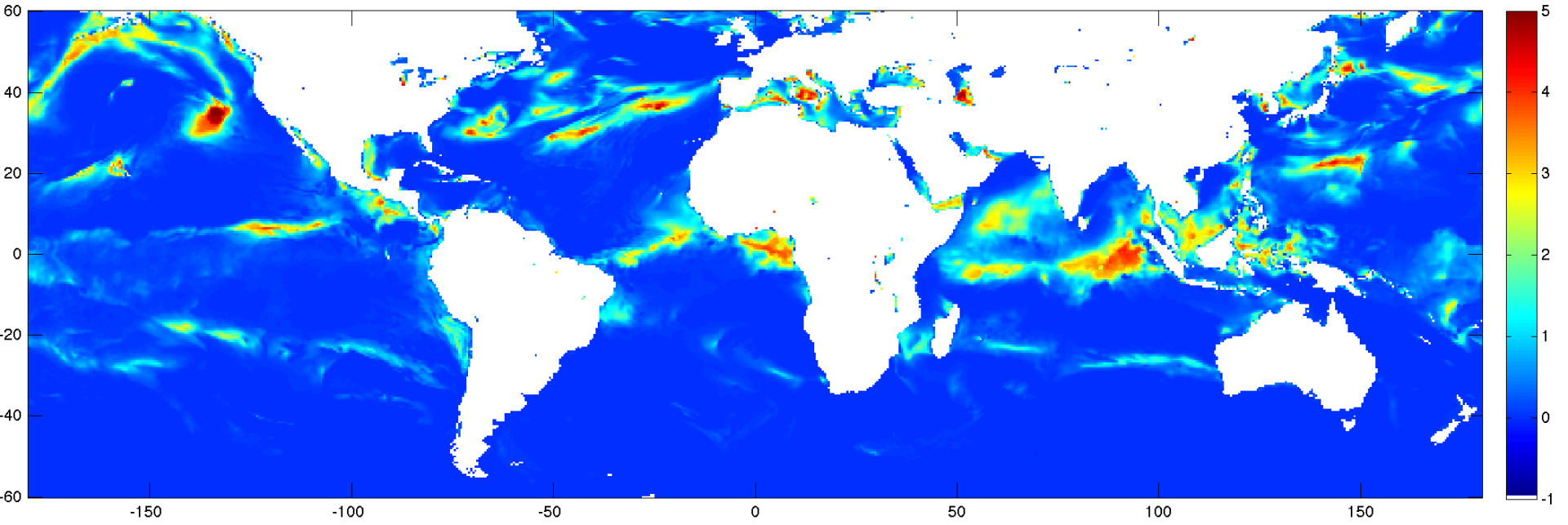
- **Calculate Std Dev of [x-1:x+1, y-1:y+1, t-1:t+1]**
- **Values in the "peaks" not as high as edges**

Daily mean warming



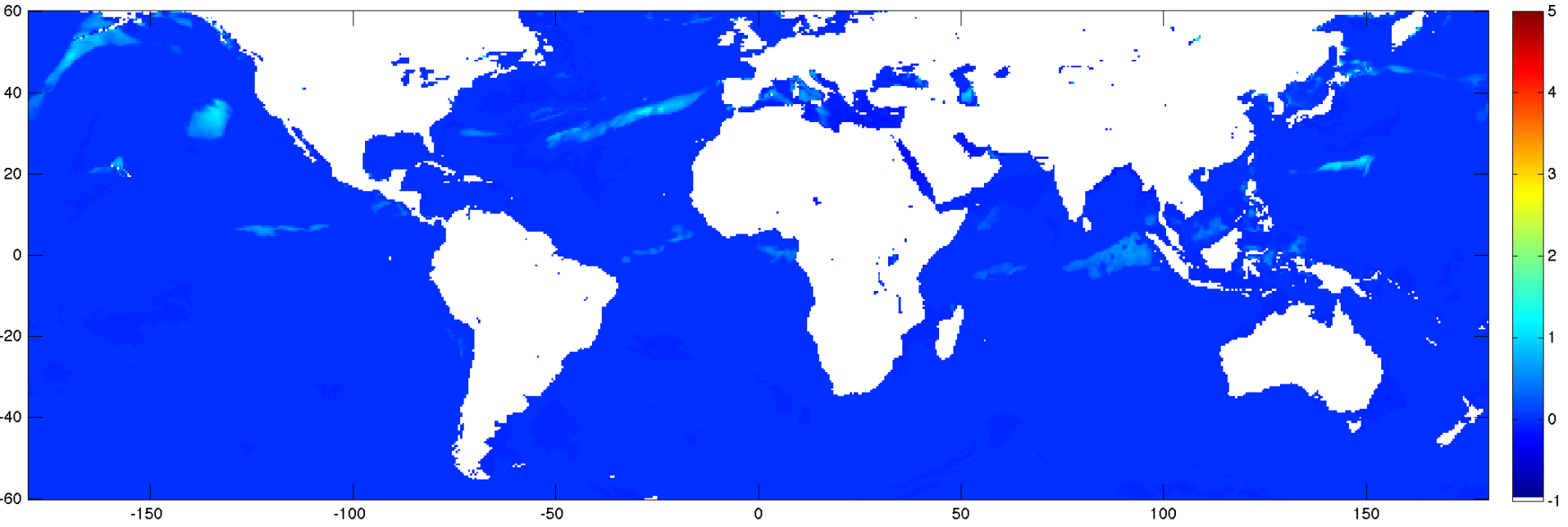
- **Reasonable fraction with ≥1 K**
- **Recall that warming doesn't always disappear**

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**

How sensitive is retrieved SST to true SST?

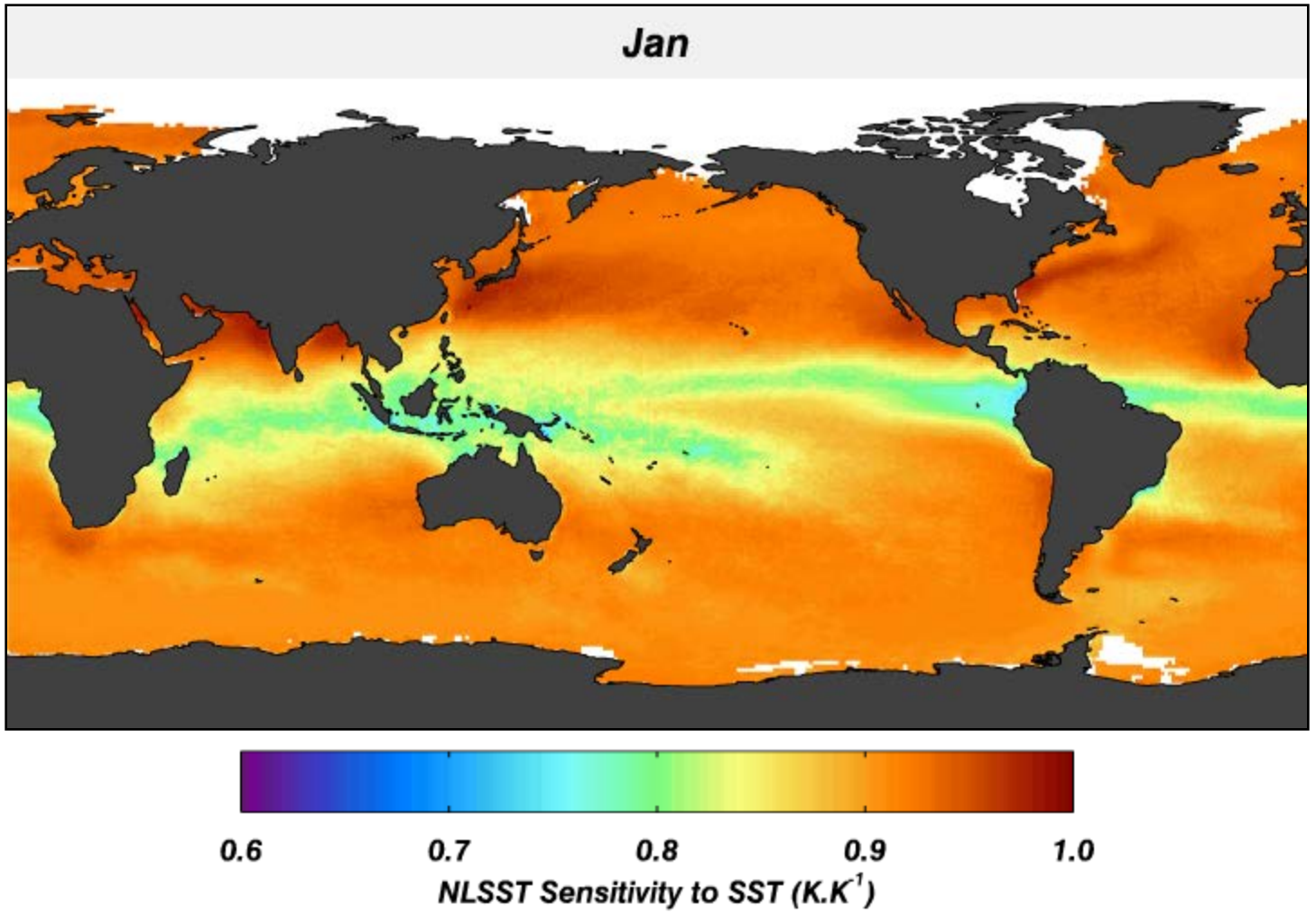
- If SST changes by 1 K, does retrieved SST change by 1 K?
- CRTM provides tangent-linear derivatives $\partial T_{11}/\partial SST_{\text{true}}$ $\partial T_{12}/\partial SST_{\text{true}}$

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

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

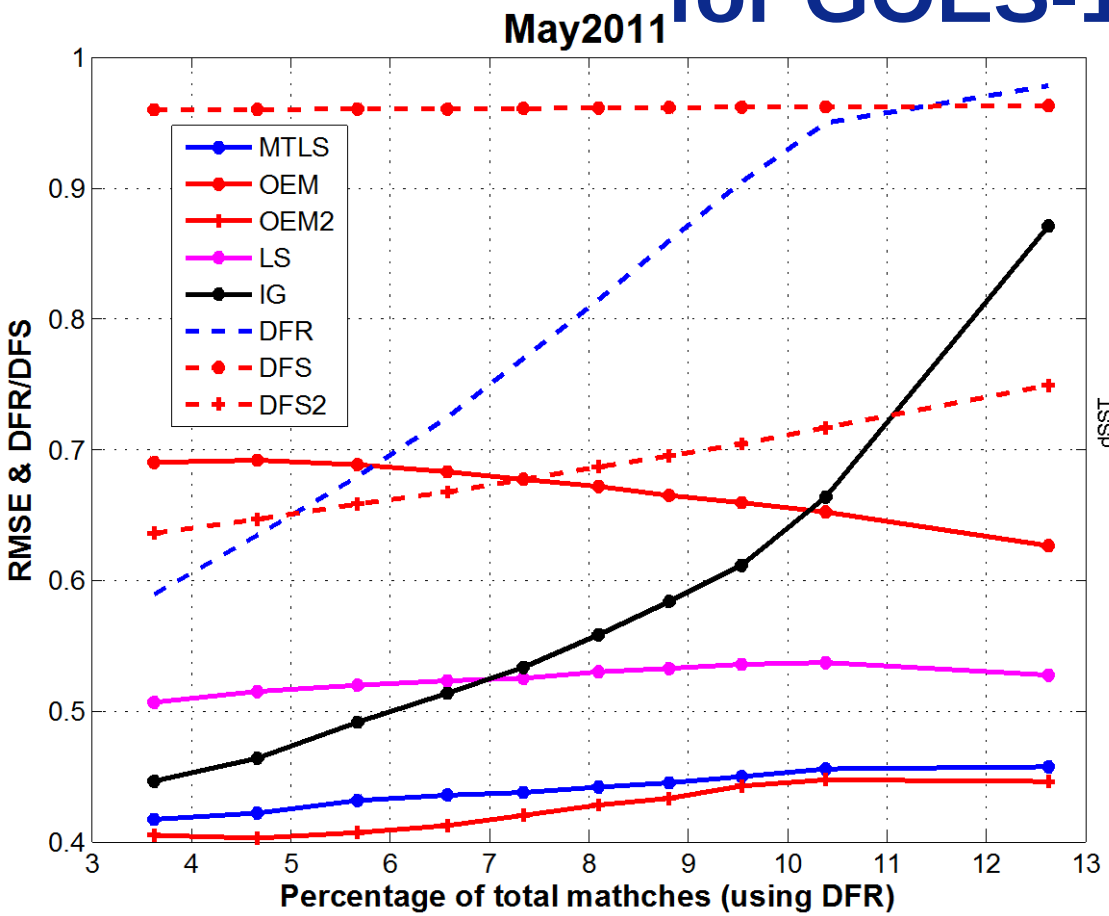
Merchant, C.J., A.R. Harris, H. Roquet and P. Le Borgne, Retrieval characteristics of non-linear sea surface temperature from the Advanced Very High Resolution Radiometer, Geophys. Res. Lett., **36**, L17604, 2009

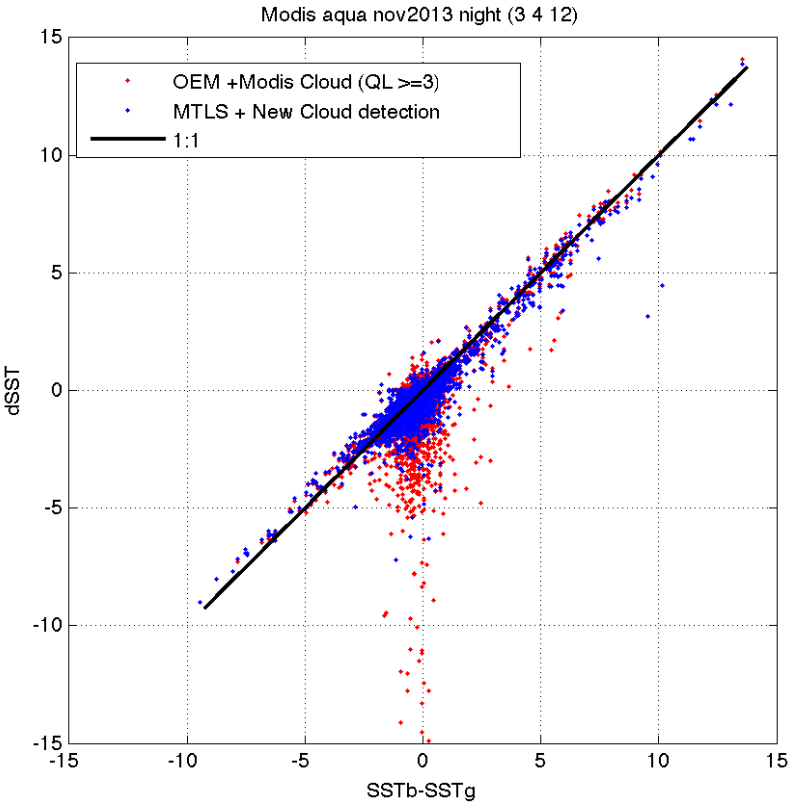
Sensitivity to true SST



Sensitivity often <1 and changes with season

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

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