MODIS Sea-surface temperature

Otis B. Brown, Peter J. Minnett,
Robert H. Evans, Edward J. Kearns,
Richard J. Sikorski

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Rosenstiel School of Marine and Atmospheric Science

University of Miami

Overview

- Objectives
- Atmospheric correction algorithms
- Consequences of instrumental uncertainties
- Validation strategies

MODIS SST Objective

To produce SST fields of accuracy no worse than the heritage instrument (AVHRR)

Note:

- **Cloud screening requires data of high radiometric integrity on a pixel-by-pixel basis**
- **Atmospheric correction algorithm is applied on a pixel-by-pixel basis**

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Key Issue

- **Q - What is the target accuracy ?**
- ***i.e.*** **How well does AVHRR measure SST?**

- **A - Demonstrated AVHRR SST uncertainties are ±0.3 K (Kearns *et al*,** BAMS, **July 2000)**

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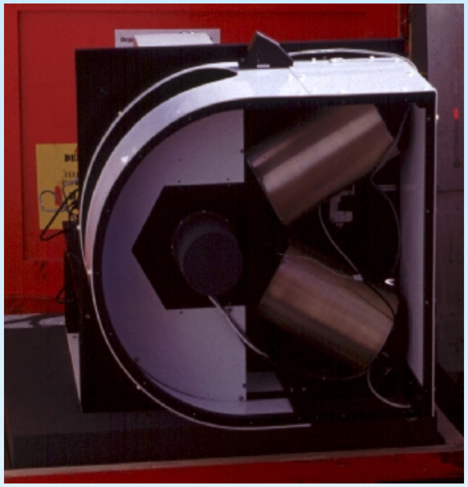
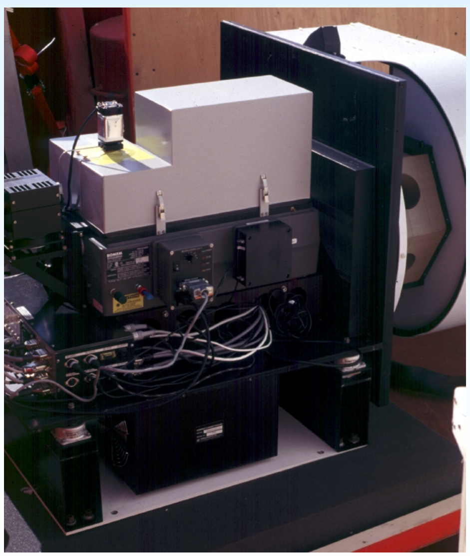
Marine-Atmosphere Emitted Radiance Interferometer



Laboratory tests of M-AERI accuracy

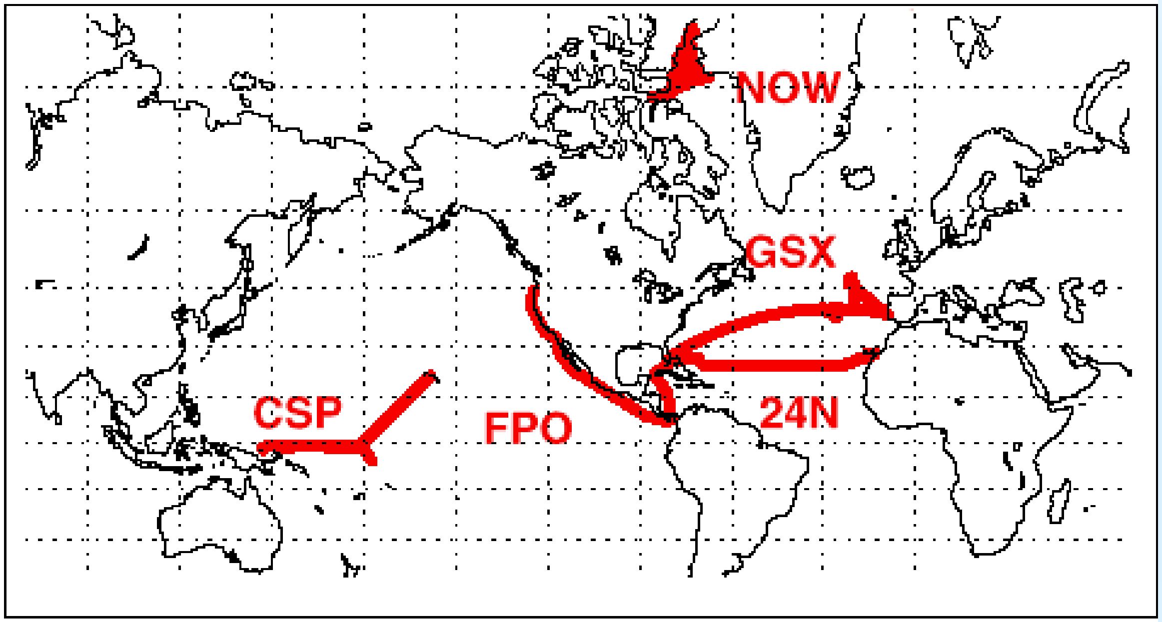
Target Temp.	LW (980-985 cm^{-1})	SW (2510-2515 cm^{-1})
20^oC	+0.013K	+0.010K
30^oC	-0.024K	-0.030K
60^oC	-0.122K	-0.086K

The mean discrepancies in the M-AERI 02 measurements of the NIST water bath blackbody calibration target in two spectral intervals where the atmosphere absorption and emission are low. Discrepancies are M-AERI minus NIST temperatures.



Specifications	
Spectral interval	~3 to ~18µm
Spectral resolution	0.5 cm^{-1}
Interferogram rate	1Hz
Aperture	2.5 cm
Detectors	InSb, HgCdTe
Detector temperature	78^0K
Calibration	Two black-body cavities
SST retrieval uncertainty	<<0.1K (absolute)

Pathfinder Validation Cruises



The areas of the cruises used in the radiometric validation of the Miami Pathfinder SST retrievals.

Pathfinder Validation Cruises

Cruise Name	Ship	Year	Days
Combined Sensor Program (CSP)	NOAAS Discoverer	1996	78-103
24^{o}N Section (24N)	NOAAS Ronald H. Brown	1998	8-55
GASEX '98 (GSX)	NOAAS Ronald H. Brown	1998	127-188
Florida-Panama-Oregon transit (FPO)	NOAAS Ronald H. Brown	1998	196-210
North Water Polynya '98 (NOW)	CCGS Pierre Radisson	1998	150-203

Cruises used in the radiometric validation of the Miami Pathfinder SST fields (Kearns, 2000).

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Pathfinder Analysis Results

Cruise	N	Mean K	St. Dev. K
CSP 1996	23	0.16	0.20
HNZ 1997	6	-0.03	0.25
24N 1998	16	0.03	0.18
GASEX 1998	168	-0.01	0.25
FPO 1998	47	0.27	0.40
NOW 1998 (Arctic)	176	0.24	0.44
Total, all data	436	0.13	0.37
Total, excluding NOW data	260	0.06	0.29

Results of the radiometric validation of the Miami Pathfinder SST fields.

The means errors are expressed as Pathfinder SST – M-AERI SST.

MODIS Atmospheric correction algorithm

Thermal infrared "split-window" algorithm is based on the successful *Pathfinder* formulation:

$$SST_{ij} = b_o + b_1 T_i + b_2 (T_i - T_j) SST_r + b_3 (T_i - T_j)(\sec\theta - 1)$$

- **where *i,j* refer to Bands 31 and 32 (11.03µm, 12.02 µm), SST_r is a reference SST (or first-guess temperature), and θ is the zenith angle to the satellite radiometer measured at the sea surface.**
- **coefficients b_n are derived from radiative transfer modeling.**

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MODIS Atmospheric correction algorithm

- **Terms in T_{31}-T_{32} contain the information about the effect of the atmosphere on the propagation of the infrared radiation. This is the basis of the atmospheric correction.**
- **It renders the SST retrieval very sensitive to the accuracy and noise levels in the brightness temperature measurements. The effect of the algorithm is to magnify uncertainties in the individual brightness temperatures by a factor of ~2 to ~6.**

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Features of the algorithm

$$SST_{ij} = b_o + b_1 T_i + b_2 (T_i - T_j) SST_r + b_3 (T_i - T_j)(\sec\theta - 1)$$

Sensitive to absolute calibration, rvs, mirror side effects, *etc.*

Sensitive to digitizer and differential rvs effects, *etc.*

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Coefficients for MODIS Band 31 and 32 SST Algorithm

Coefficients for the MODIS Band 31 and 32 SST retrieval algorithm, derived using ECMWF assimilation model marine atmospheres to define atmospheric properties and variability.

Coefficients		
	$T_{31} - T_{32} <= 0.7$	$T_{31} - T_{32} > 0.7$
b_0	1.11071	1.196099
b_1	0.9586865	0.9888366
b_2	0.1741229	0.1300626
b_3	1.876752	1.627125

The predicted rms uncertainty in the SST retrievals is 0.345K. This is caused by atmospheric variability and does not include instrumental contributions.

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MODIS algorithm for multiple bands in 3.5 to 4.2µm bands

SST = $a * T_i + b * T_j + c + m * \cos(2p(t + n)/365) + p$

where:

***i,j* are two of bands 20, 22, 23**

***m*, *n*, and *p* are coefficients, derived by radiative transfer modeling**

t(northern hemisphere)=days after day 173 (summer solstice)
t(southern hemisphere)=days after day 357 (winter solstice)

Because of day-time sun-glint contamination this algorithm can be used only at night-time.

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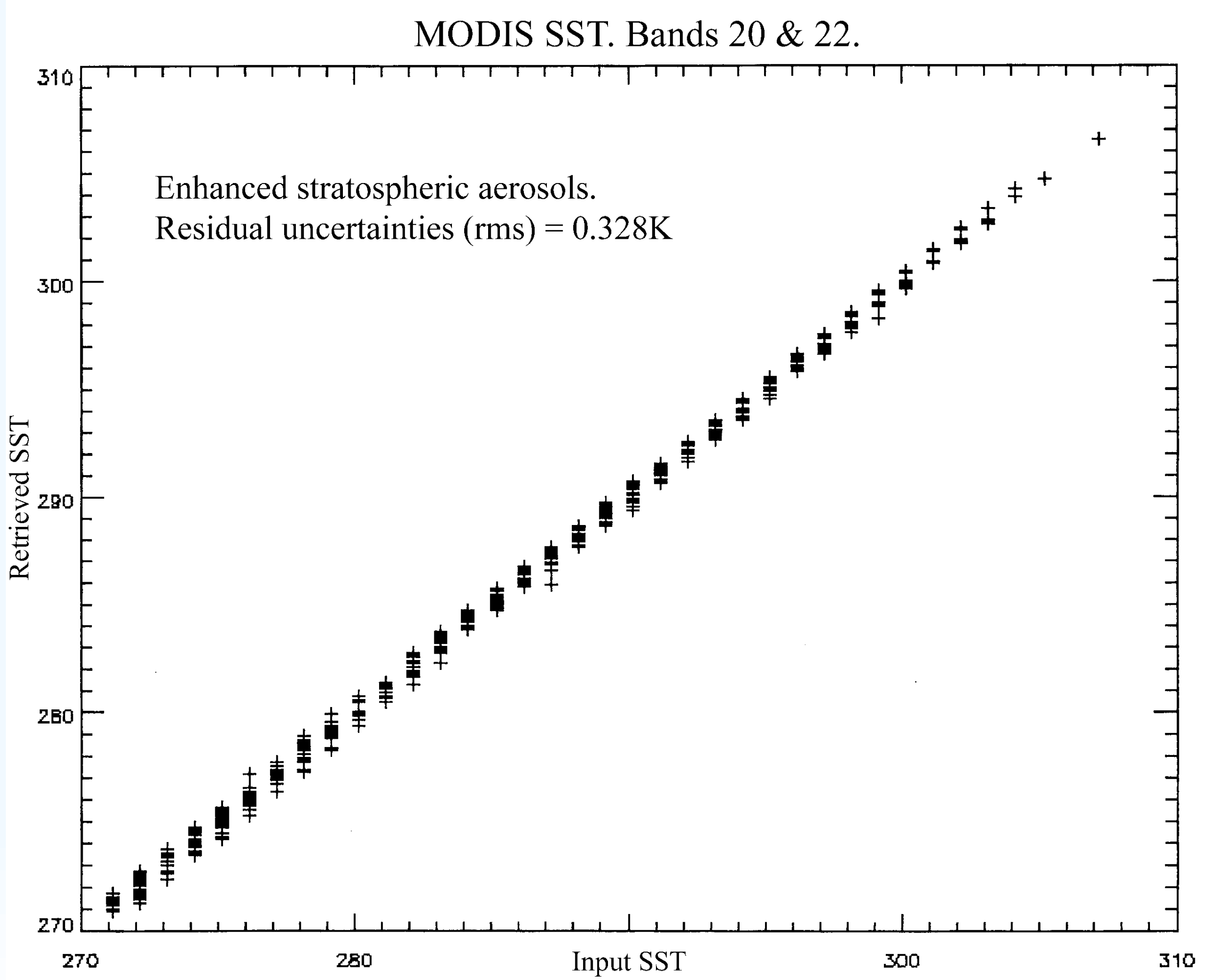
MODIS Midwave SST Simulation Results



MODIS Midwave SST Simulation Results

Algorithm characteristics for the Bands 20 and 22 simulations.

Latitude (λ) range	Coefficients						rms K
	a	*b*	*c*	*m*	*n*	*p*	
All λ	-4.66101	0.00179459	1.02132	0.0	0.0	0.0	0.171
Include seasonal effects:							
All λ	-4.66101	0.00179459	1.02132	-0.020878	0.0	-0.020470	0.165
Include seasonal and latitudinal effects:							
|λ| < 23.45	-4.66101	0.00179459	1.02132	-0.020447	-66.15	+0.008356	0.154
23.45 ≥ |λ| ≥ 46.9	-4.66101	0.00179459	1.02132	+0.023525	-57.07	-0.092053	
|λ| > 46.9	-4.66101	0.00179459	1.02132	-0.073570	-28.30	-0.008209	

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MODIS vs. *AVHRR*

Instrumental error sources		
	AVHRR Bands 4,5	MODIS Bands 31,32
NE? T	~0.05K	~0.03K
Digitizer		~0.05K
Mirror rvs	Not applicable	Distinct
Mirror sidedness	Not applicable	Distinct
Multiple detector striping	Not applicable	Distinct
Spatial cross-talk	Not evident	Likely*
Spectral cross-talk	Not evident	Likely*

* Evident in Moon scans.

MODIS has some significant sources of uncertainty that contribute to the SST errors that are absent in AVHRR

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MODIS vs. AVHRR (Continued)

The MODIS and AVHRR measurements are governed by the same physics, so to achieve the objective of comparable accuracy with AVHRR SST retrievals, it is necessary to have better MODIS instrumental performance in aspects that contribute common errors to compensate for the additional error sources in MODIS.

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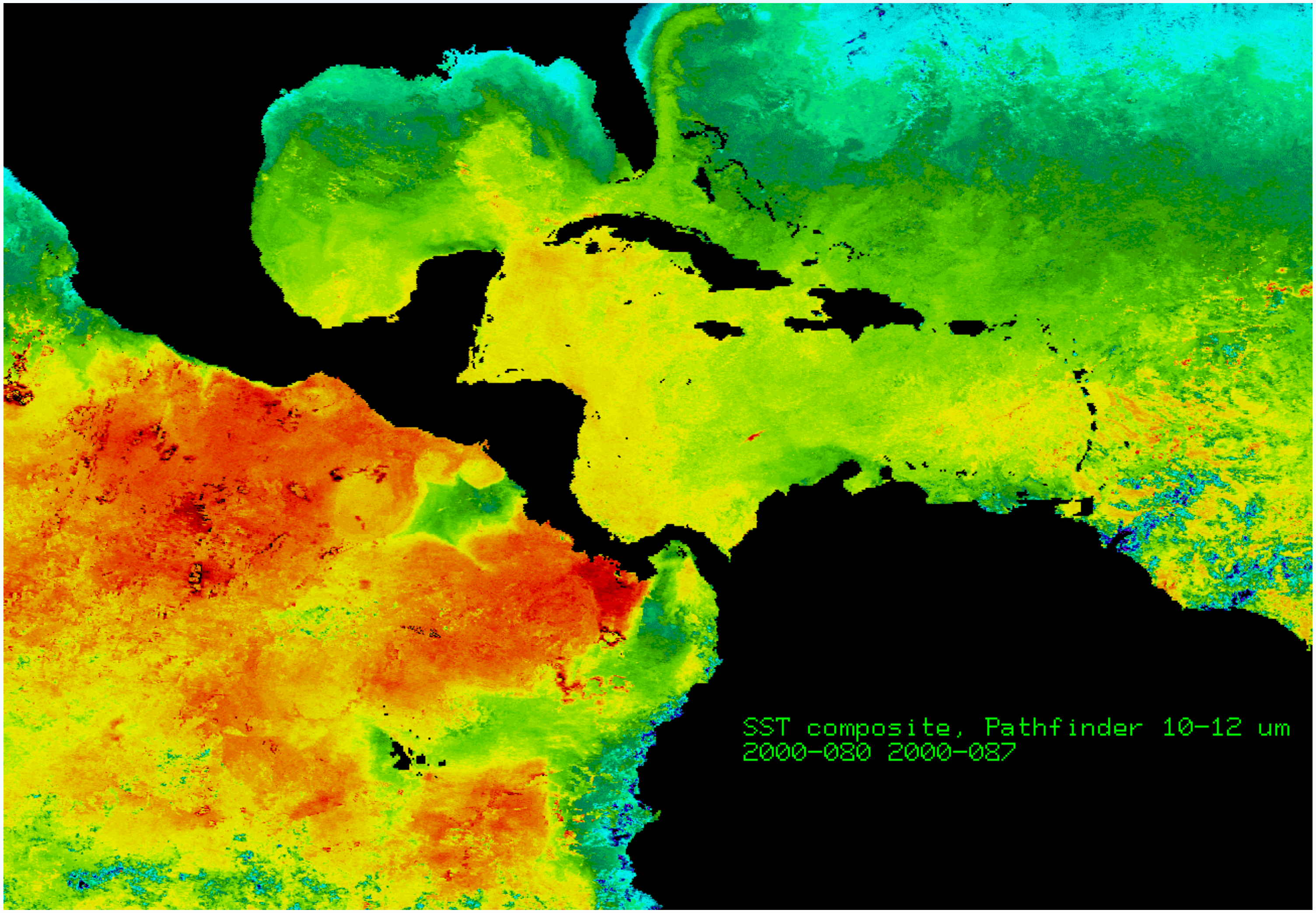
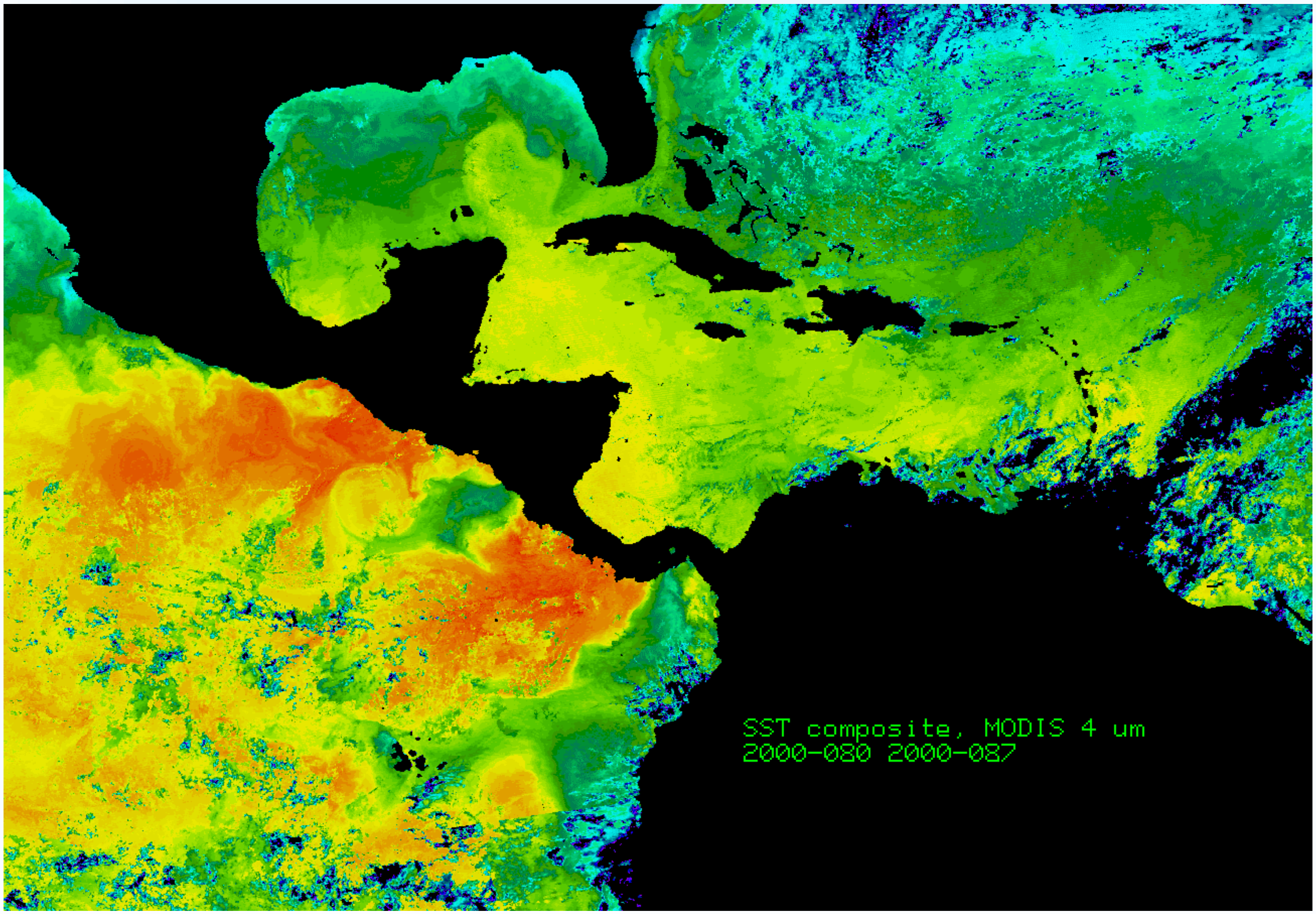
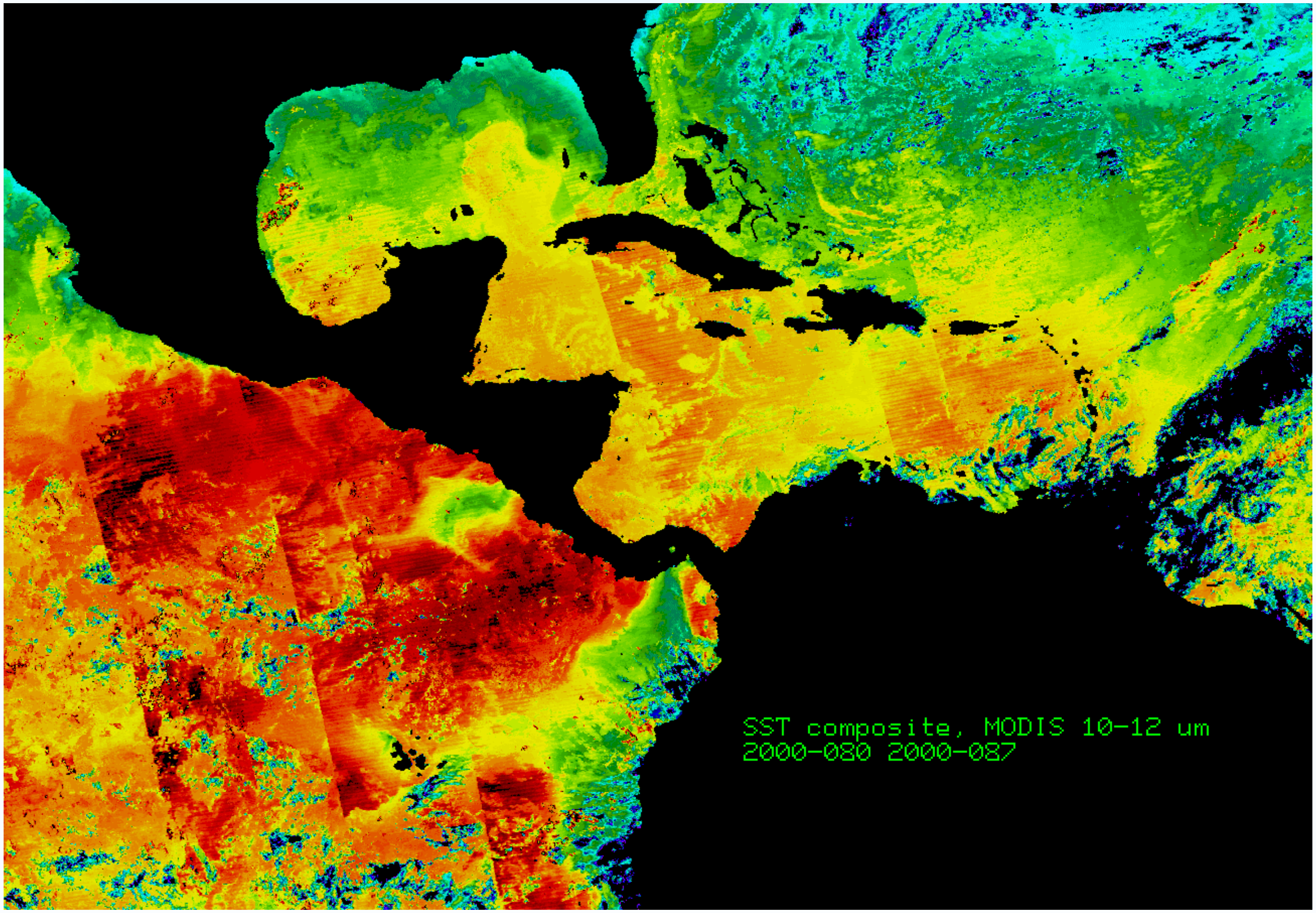
Pathfinder SST Composite



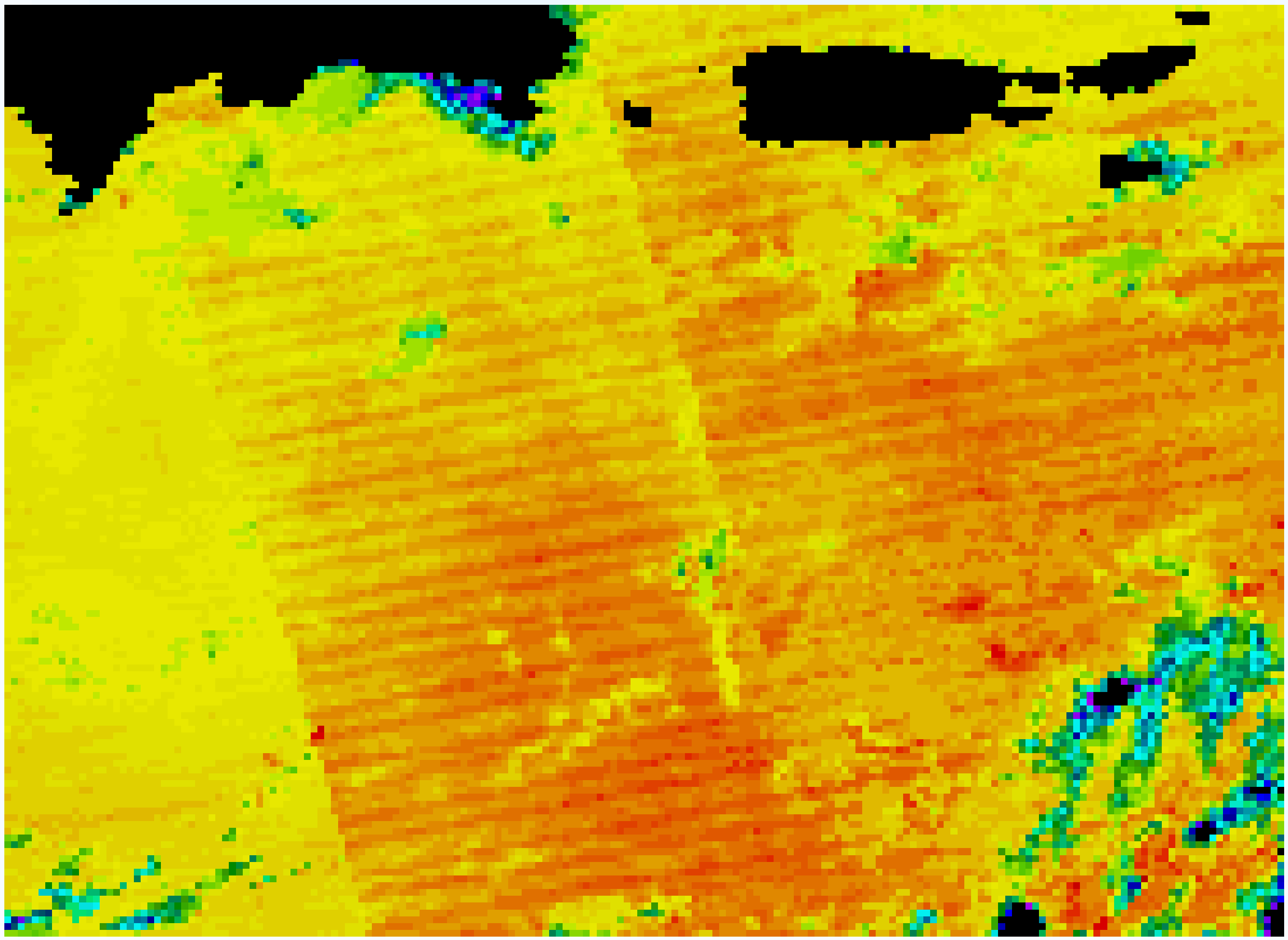
MODIS Midwave SST Composite



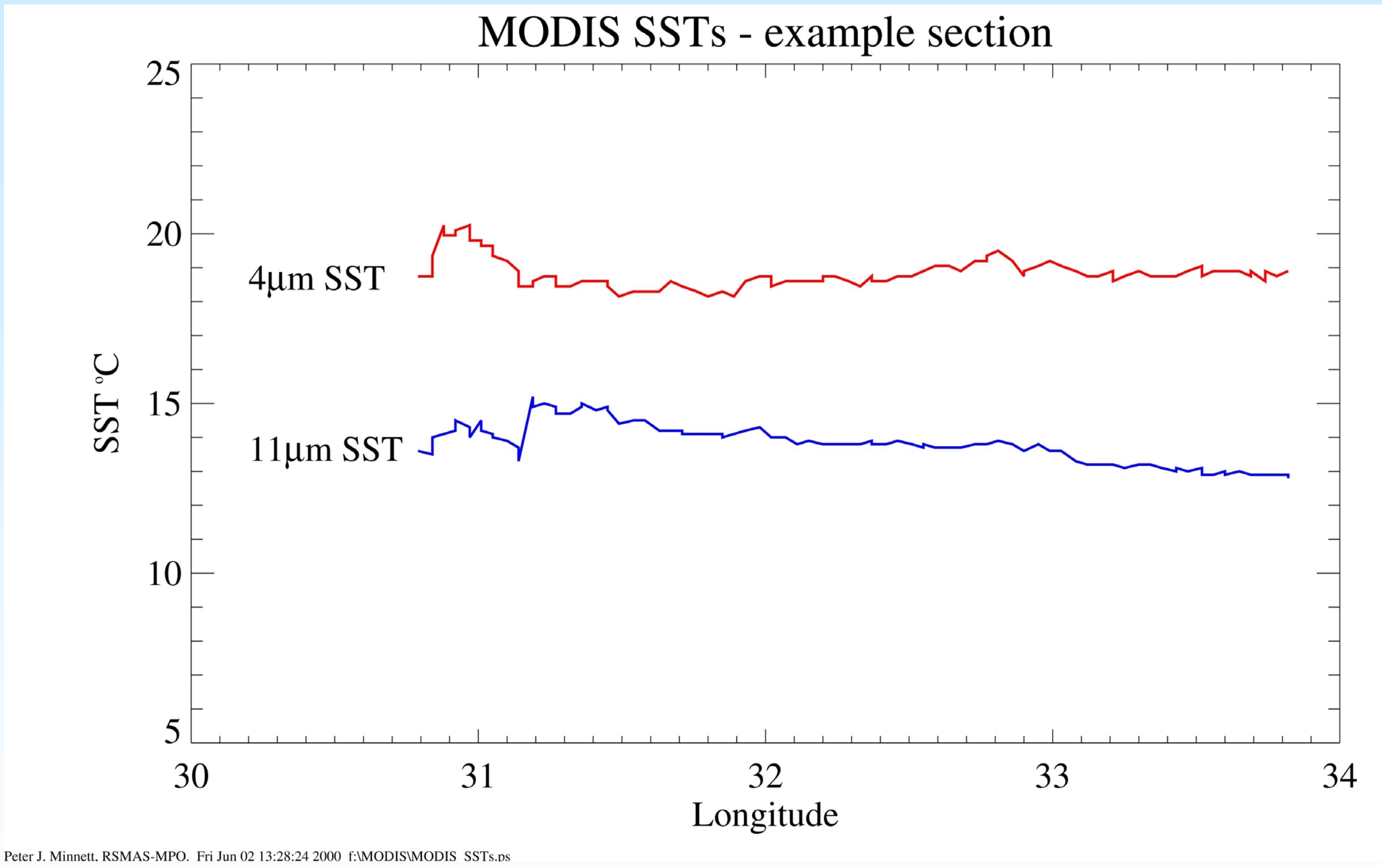
MODIS Far-wave SST Composite



MODIS Far-wave SST: Magnified



MODIS SST Track



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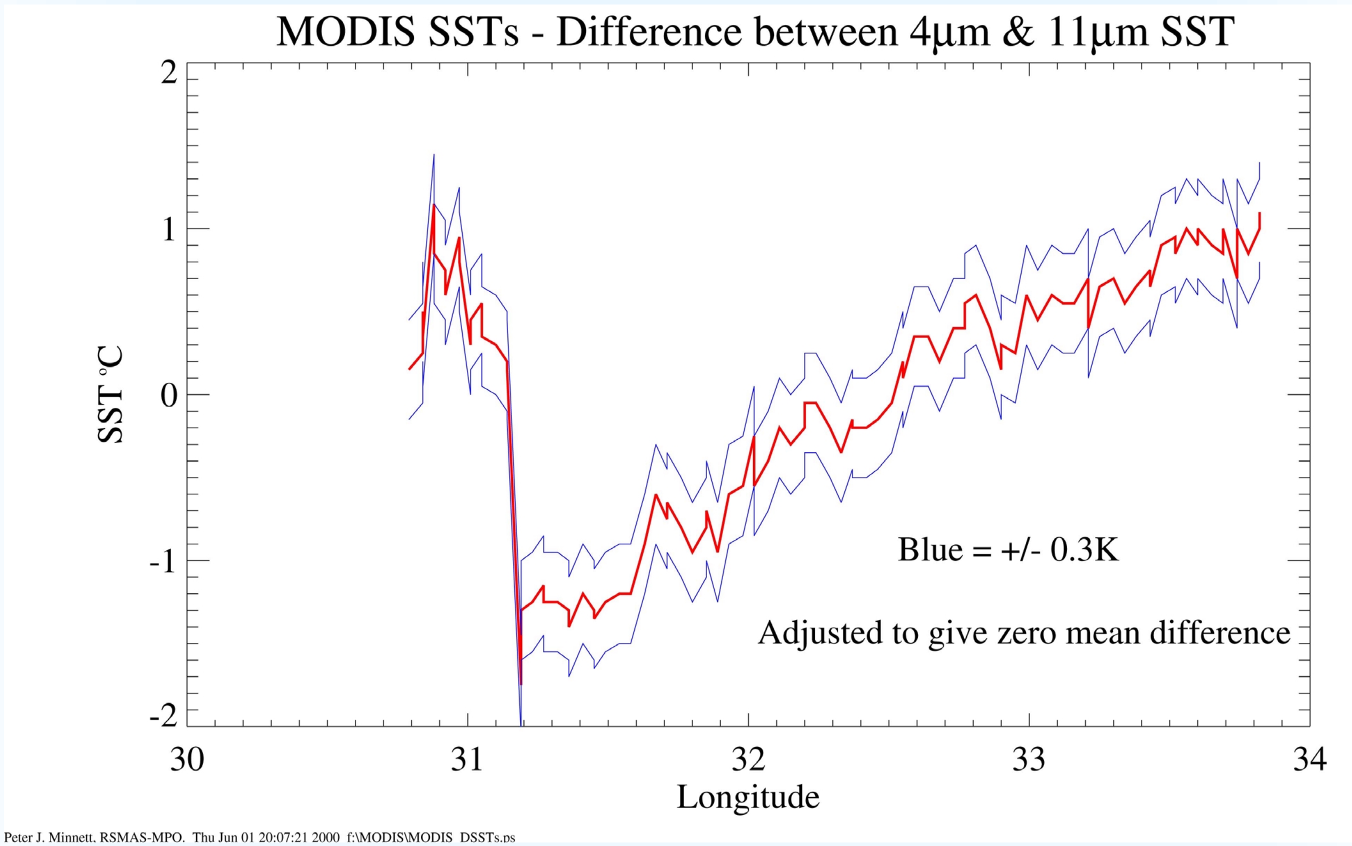
MODIS SST Track Differences



Validation strategy

Data contain influences from both instrumental and environmental effects. These are intimately combined so identifying particular signatures is very difficult, and requires a large data set and/or cases with particular characteristics (*e.g*. quasi-uniform atmospheric and oceanic properties).

Until instrumental effects can be sufficiently well corrected, attempts at validating the atmospheric correction and derived SST are futile.

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Analyses will include:

- Comparison with AVHRR, ATSR, ASTER brightness temperatures, and derived SSTs
- Comparison with shipboard M-AERI radiometric SSTs
- Comparison with buoy SSTs

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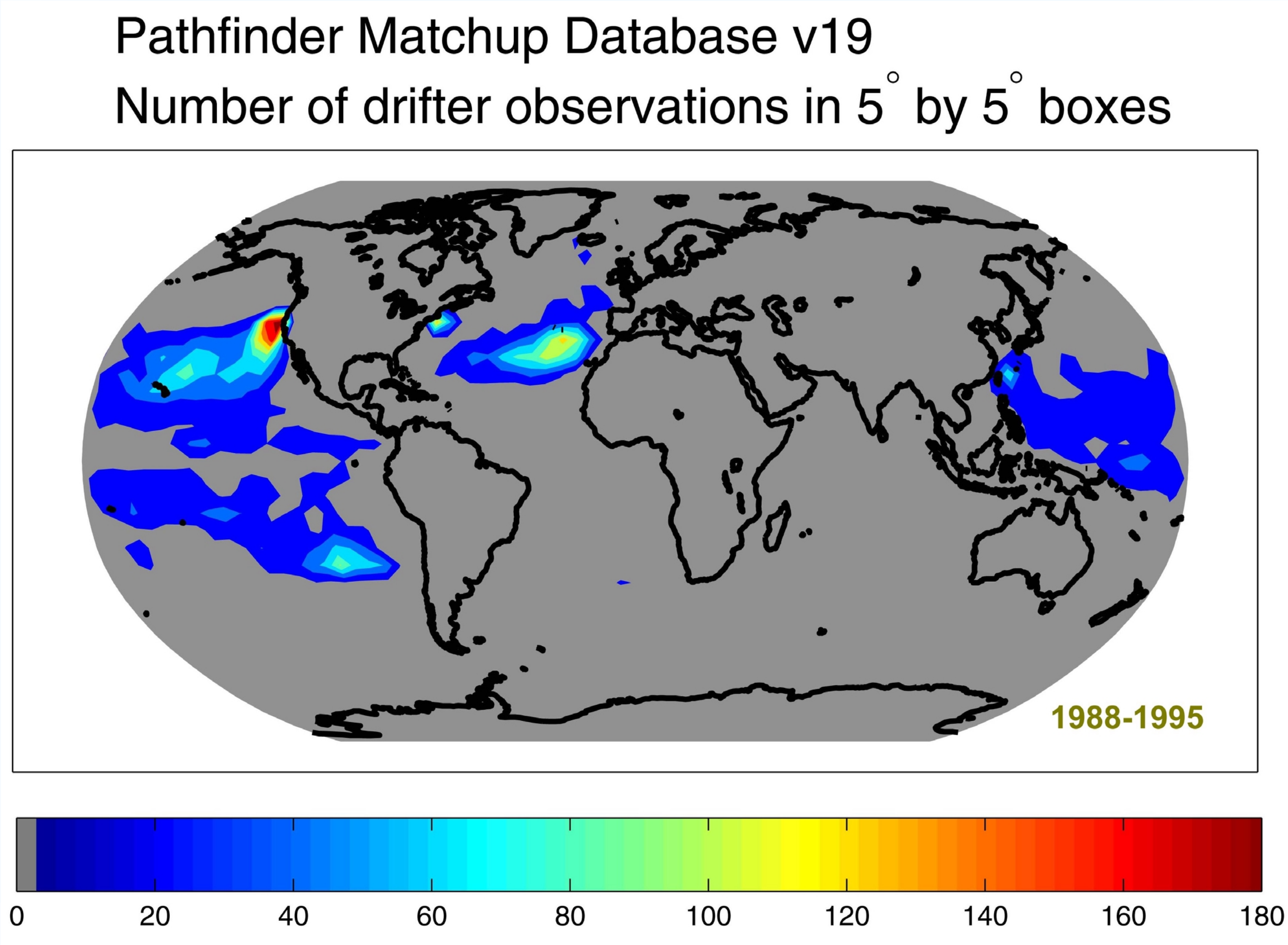
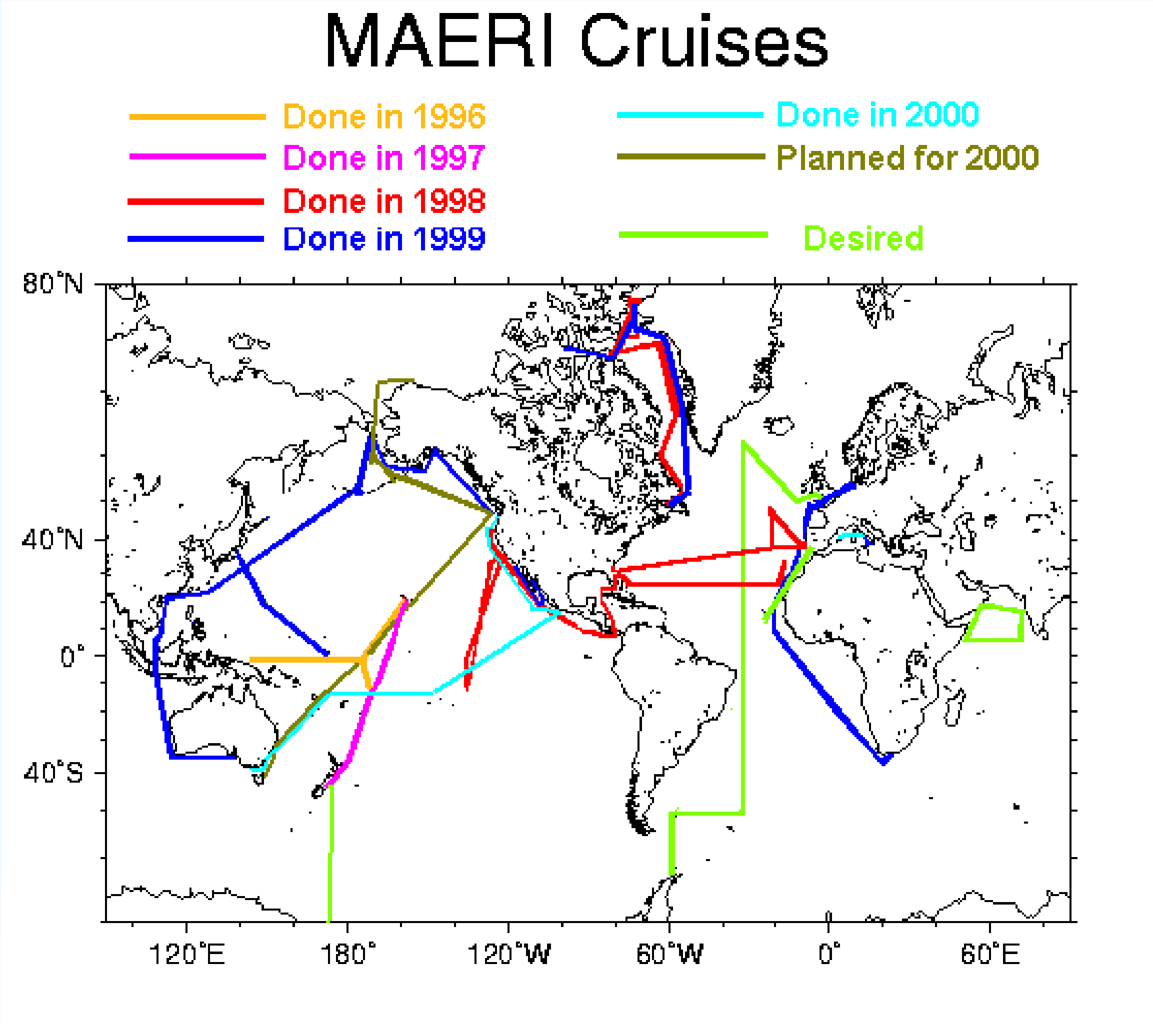
Surface Drifter Density



M-AERI Cruise Tracks



Conclusions

- There are many problems that need to be resolved before MODIS can produce SSTs comparable to AVHRR, for the "climate record".
- A lot of effort will need to be invested in analysis and validation.
- Resources should be directed to avoid a repeat performance with AQUA.
- The SSTs from Bands 20 and 23 show a lot of promise and are very exciting.