Sea Surface Temperature.
MOD 28 Status

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MODIS Science Team Meeting
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The need for validation

The **infrared bands** of MODIS form **self-calibrating radiometers.** The retrieved SST fields are validated to confirm the procedures used to generate them from the radiometer data are performing as believed, *i.e.* it is the **atmospheric correction algorithm that is being validated**.

This requires **instrumental imperfections** to be **known** and the data **corrected**.

The validation exercise provides a determination of the **accuracy characteristics of the derived fields.**

ESE Relevance: Decadal SST trends

Based on conventional measurements over ~5 decades.

Signals are such that if satellite SST's are accurate to ~0.2K, signals should be detectable over a couple of decades.

From: Casey, K. S. and P. Cornillon (2001). "Global and Regional Sea Surface Temperature Trends." *Journal of Climate* **14**: 3801–3818.

MODIS TERRA NIGHTTIME 11_m SST

-2 5 10 15 20 25 30 35

°C

MAY 2001

V 3.3.1

MODIS/OCEAN GROUP
GSFC, RSMAS

SST Animation

- Seasonal migration
- Tropical Instability Waves
- Monsoon effects in Arabian Sea
- Warm water entering Arctic by Norway
- Gulf Stream…..

MODIS SST

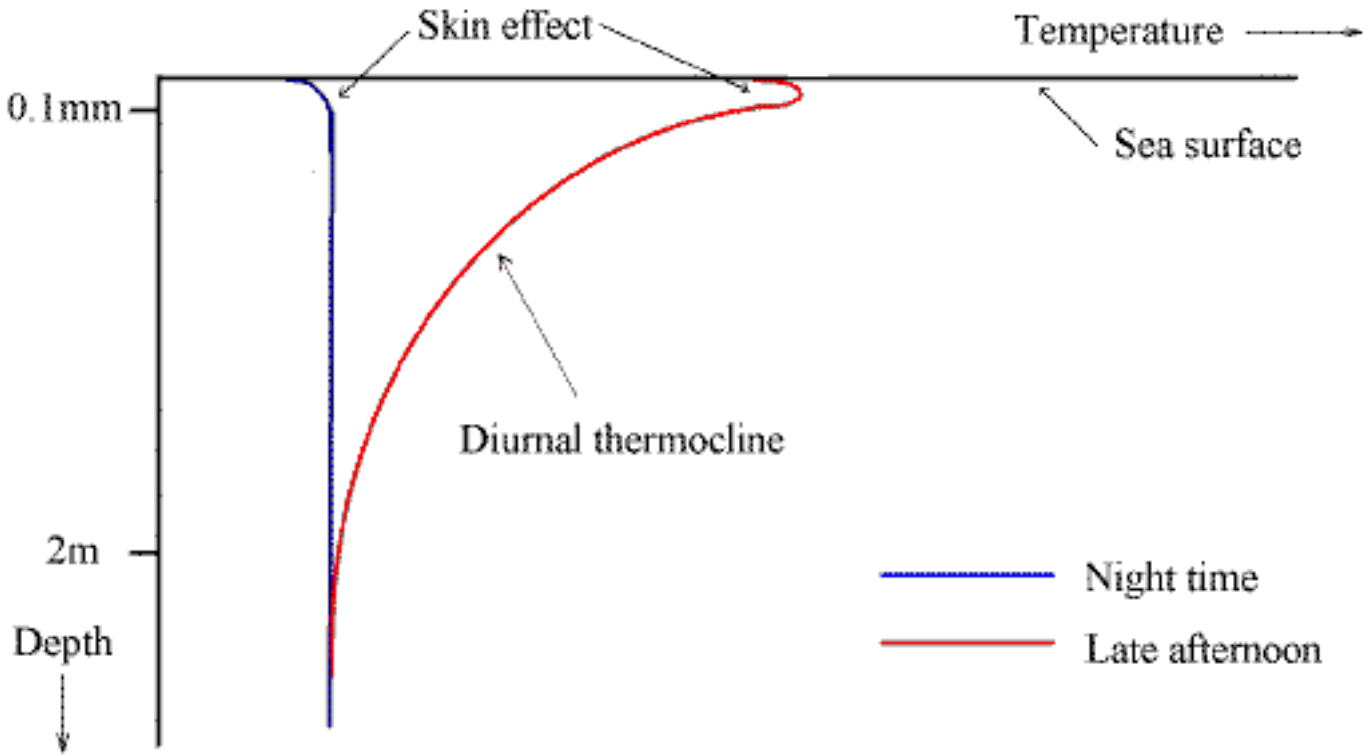
What is SST? – the skin *vs.* bulk debate

The optical depth of sea water at infrared wavelengths is < 1mm. The **source of the MODIS signal** in the atmospheric windows is the **skin layer** of the ocean, which is generally cooler than the subsurface layer because of heat flow from the ocean to the atmosphere.

The **conventional** meaning of **SST** is the temperature measured at a **depth of a meter** or more by a contact thermometer; the so-called bulk temperature.

At the levels of accuracy at which SST needs to be measured for MODIS, skin and bulk temperatures are not the same.

Near surface temperature gradients – ideal, conceptual situation



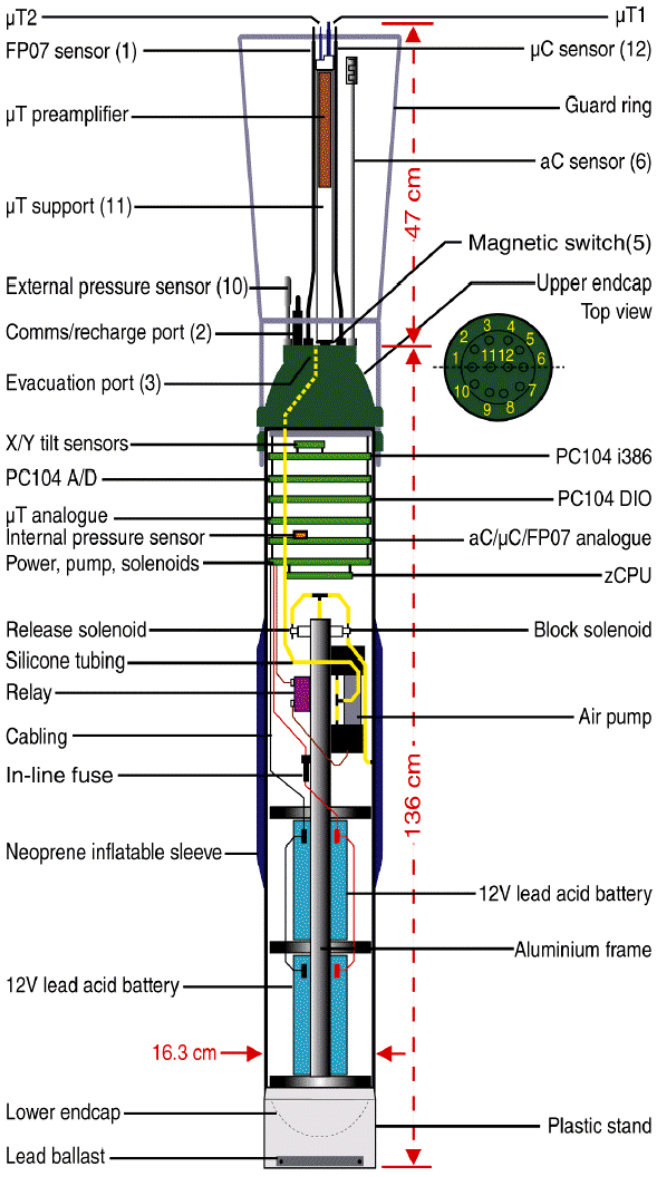
Combined effect of skin and diurnal thermocline effects

- Skin effect responds quickly to changing surface fluxes on time scales of seconds; vertical scale <1mm.

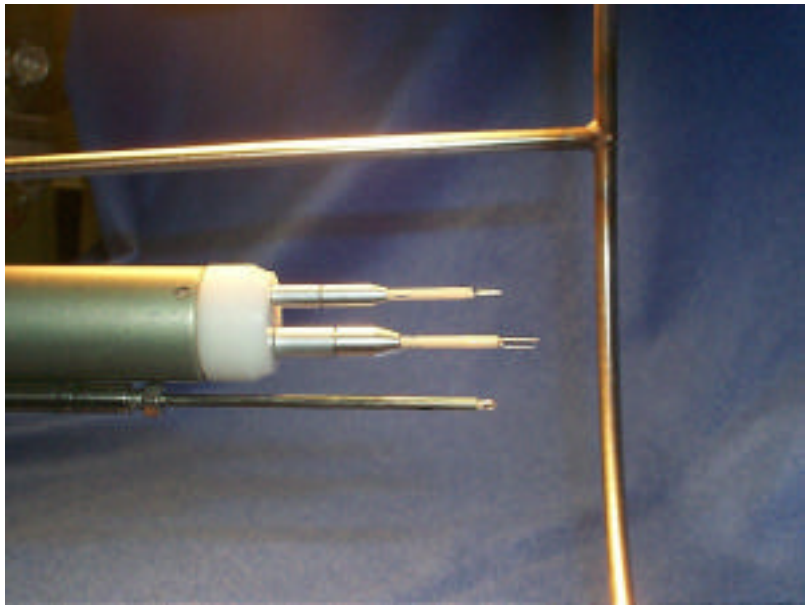
- Diurnal thermocline integrates fluxes, and responds to changing surface fluxes on time scales of minutes to hours; vertical scale of several m.

- Signs of effects are usually opposite.

SkinDeEP

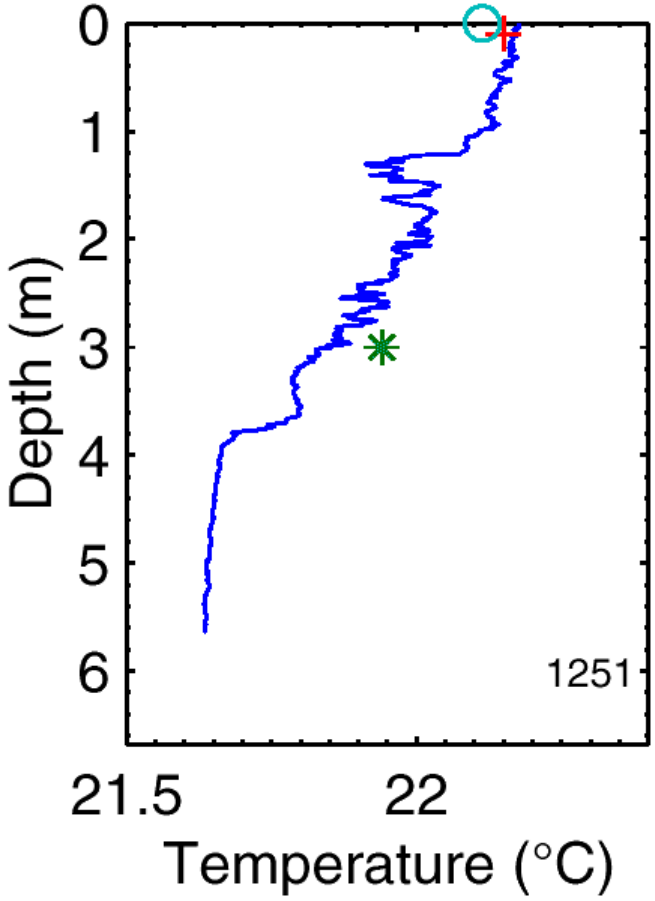


Skin Depth Experimental Profiler



Microstructure probes

Near surface temperature gradients – reality



Profile measured at 12:51 local time on 4 October 1999. Off Baja California, R/V *Melville* MOCE-5 cruise.

Blue line = SkinDeEP* profile

Blue circle = M-AERI skin temp.

Red cross = Float bulk SST at ~0.05m

Green star = Ship thermosalinograph at ~3m

From Ward, B. and P. J. Minnett, 2001. An autonomous profiler for near surface temperature measurements. *Gas Transfer at Water Surfaces.* M. A. Donelan, W.M. Drennan, E.S. Saltzmann and R. Wanninkhof (Eds.) *American Geophysical Union Monograph 127.* 167 - 172.

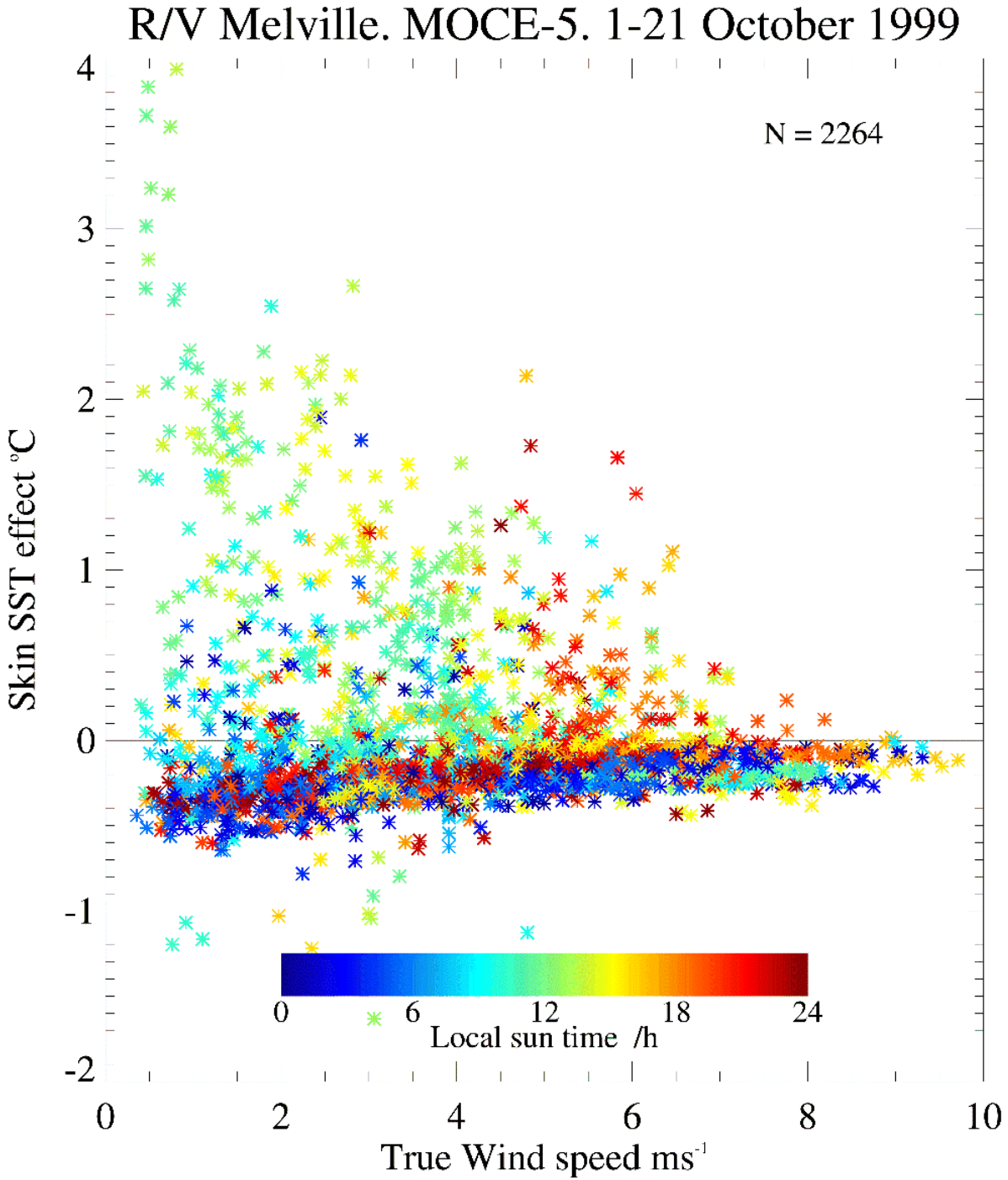
Time evolution of near-surface thermal gradients

SkinDeEP profiles on 12 October 1999. Off Baja California, R/V *Melville*.

From Ward, B. and P. J. Minnett, 2001. An autonomous profiler for near surface temperature measurements. *Gas Transfer at Water Surfaces.* M. A. Donelan, W.M. Drennan, E.S. Saltzmann and R. Wanninkhof (Eds.) *American Geophysical Union Monograph 127.* 167 - 172.

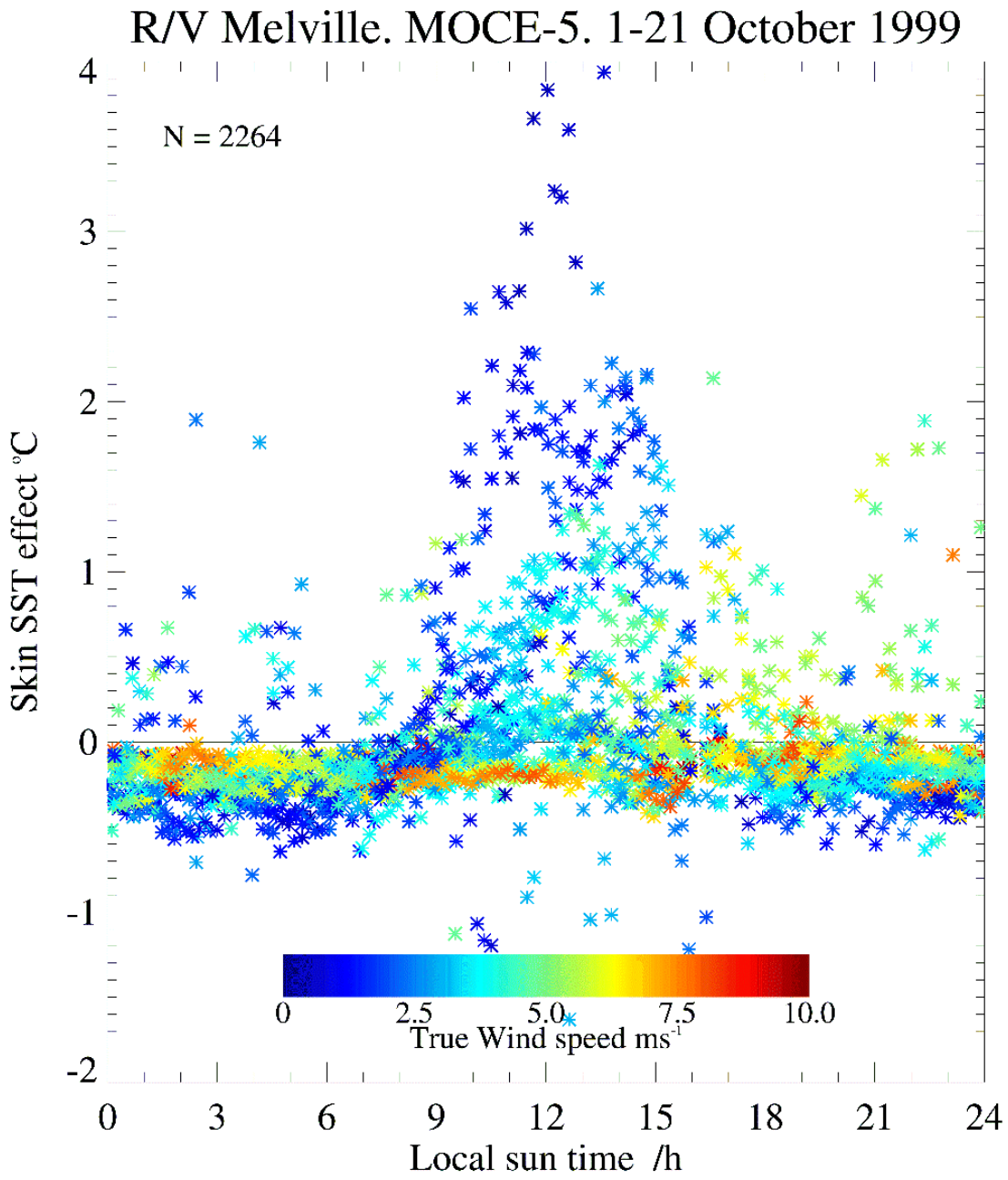
Wind speed dependence of the skin effect

Note collapse of envelope at moderate to high wind speeds.



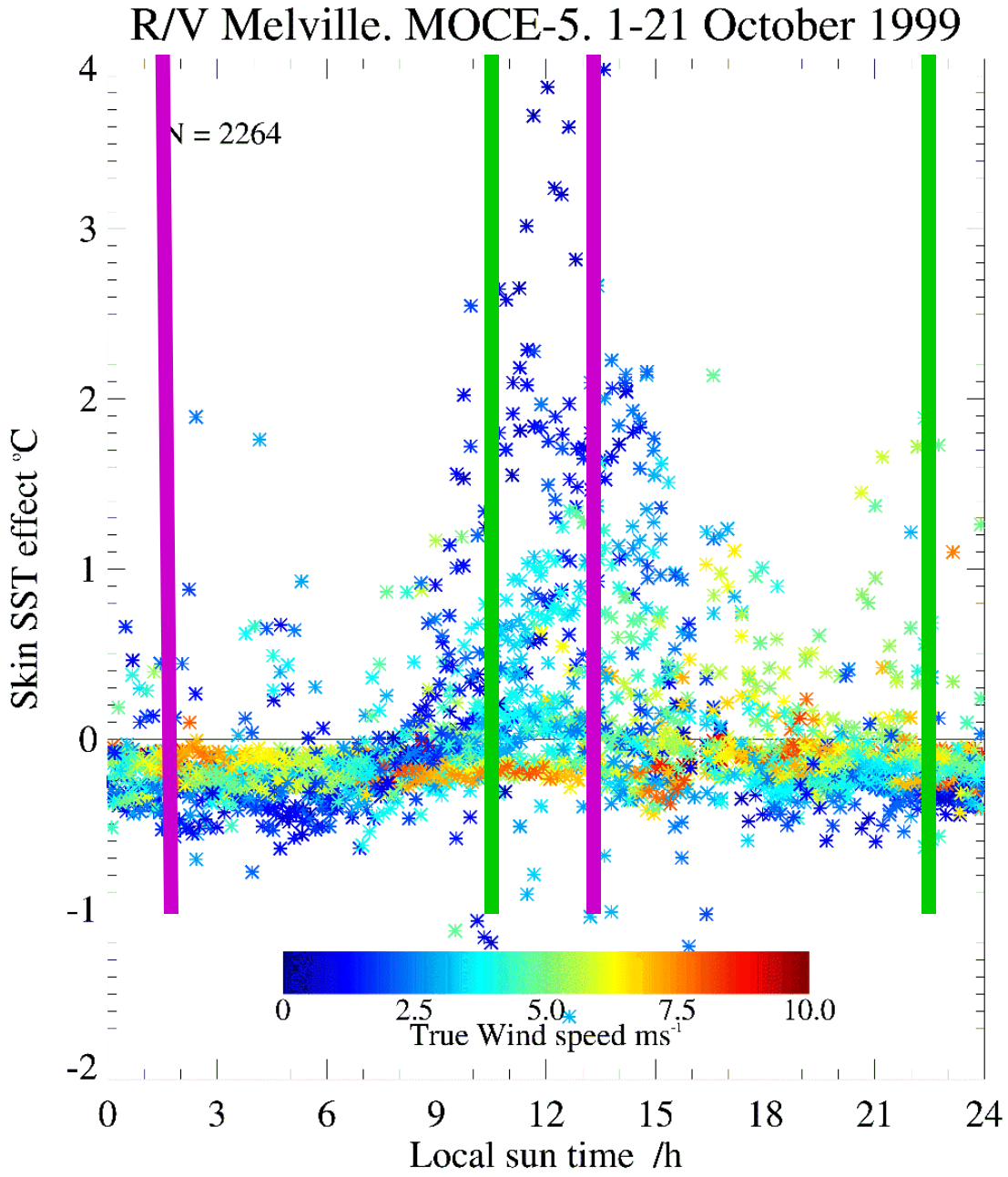
Wind speed dependence of diurnal & skin effects

Note: effects of diurnal thermocline effects at low winds



Wind speed dependence of diurnal & skin effects

Terra and Aqua overpass times.



Measurements of skin temperature

Because of the effects of diurnal thermoclines and the skin layer, **primary validation** of MODIS SST should be by reference to surface-level measurements of **skin temperature**. This can be measured by filter radiometers or spectroradiometers on ships, aircraft or fixed platforms.

The instruments must be well calibrated to reach the level of <0.1K absolute uncertainties. There are few such instruments available. One of which is the M-AERI……

Marine-Atmosphere Emitted Radiance Interferometer

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°K
Calibration	Two black-body cavities
SST retrieval uncertainty	<< 0.1K (absolute)

Laboratory tests of M-AERI accuracy

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

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.

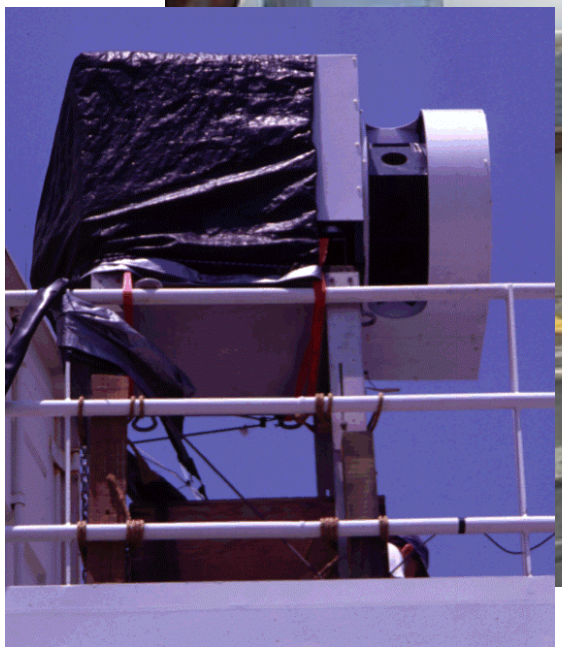
Temperatures are traced to NIST

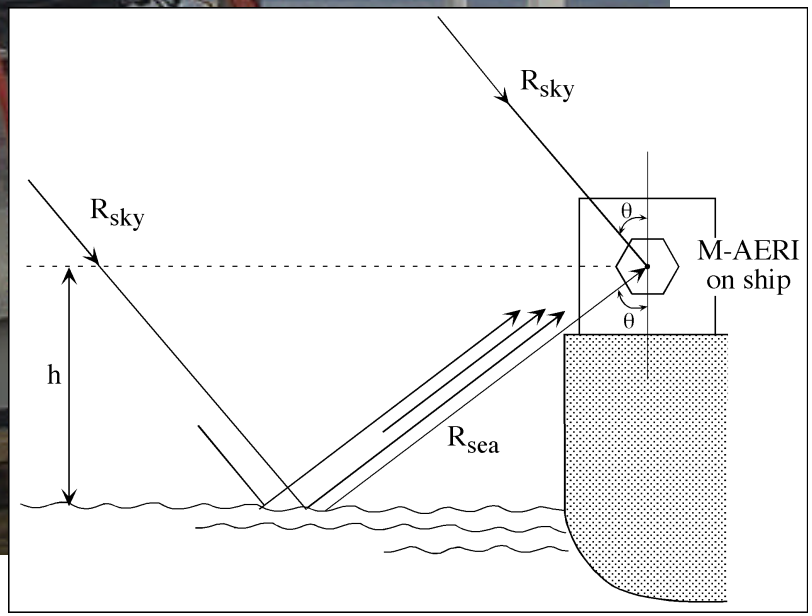
1. On-board black-body cavities have thermometers calibrated to NIST-traceable thermometers (SSEC)
2. Periodic calibration using a 3rd black body in M-AERI zenith view.
3. Periodic calibration of M-AERI system with a NIST-designed Water-Bath Black-Body target at RSMAS, using NIST-traceable reference thermometers.
4. RSMAS Water-Bath Black-Body target characterized with NIST EOS TXR

NIST EOS TXR

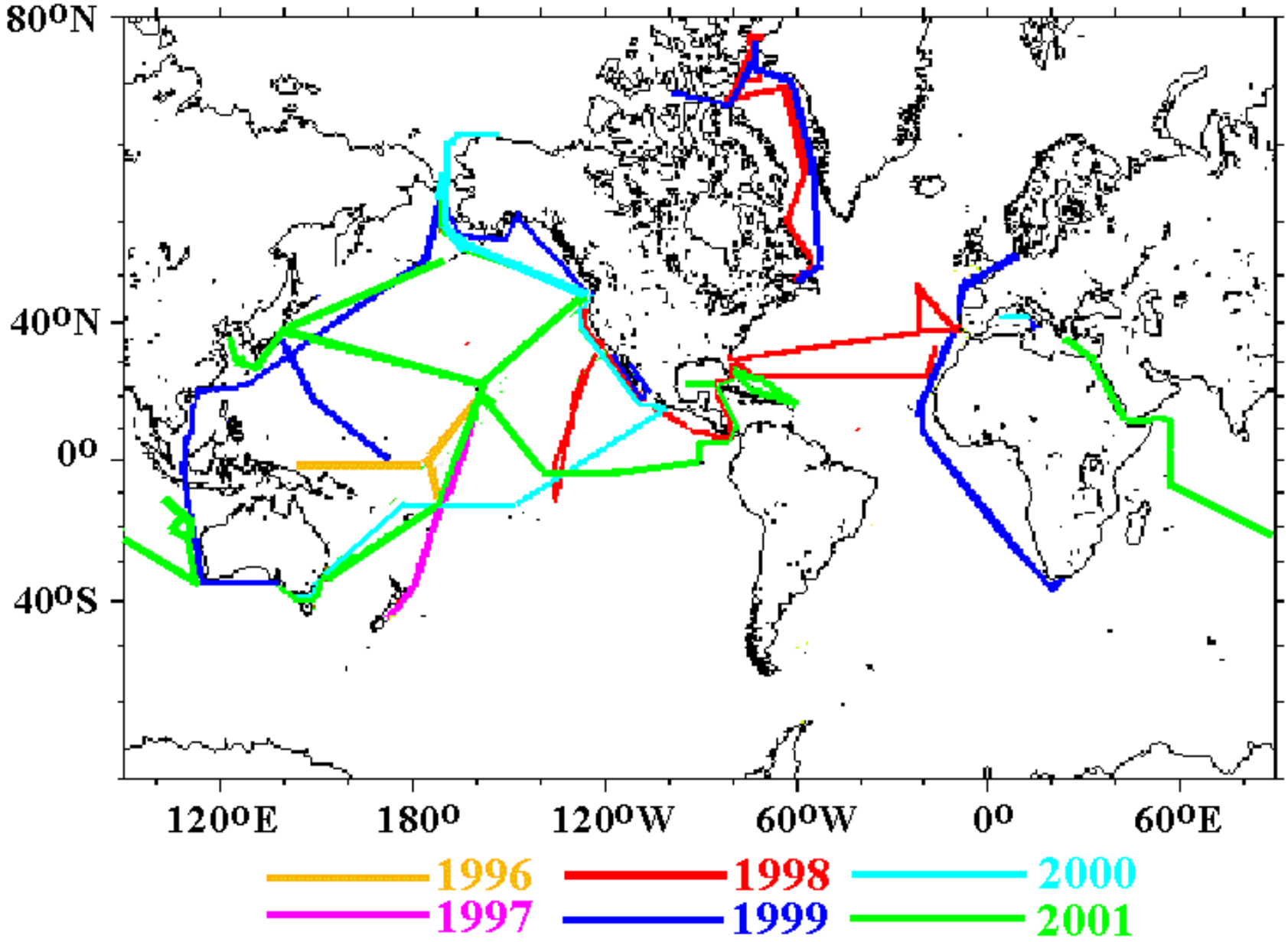
TXR characterizing the RSMAS WBBB

M-AERI on USCGC *Polar Star*, March 2000





M-AERI cruises



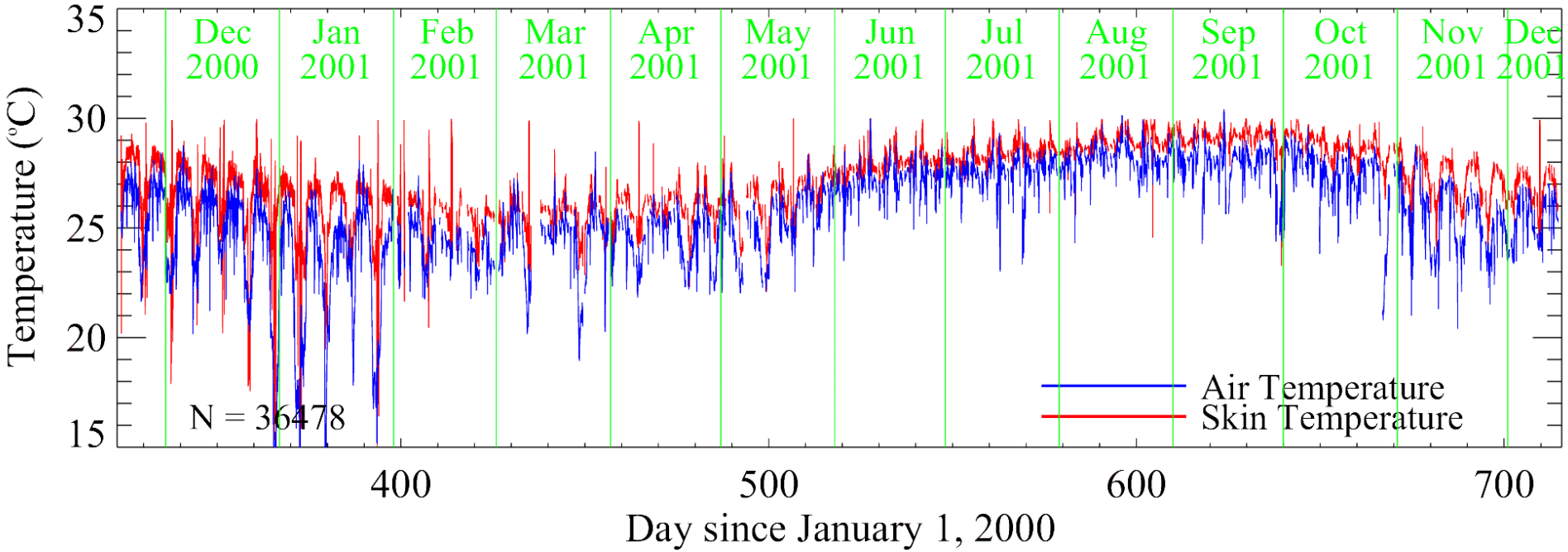
Time-series of M-AERI measurements on *Explorer of the Seas*

The *Explorer of the Seas* is a Royal Caribbean Cruise Liner, operating a weekly schedule out of Miami. It is outfitted as an oceanographic and atmospheric research vessel, very suitable for satellite validation. For more details see http://www.rsmas.miami.edu/rccl/.

M-AERI data from *Explorer of the Seas*

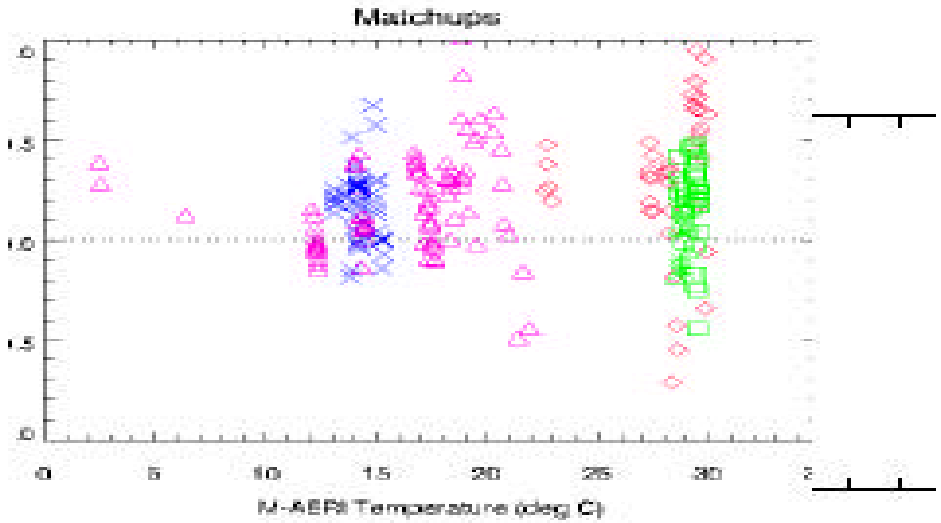
As at last Team Meeting…..

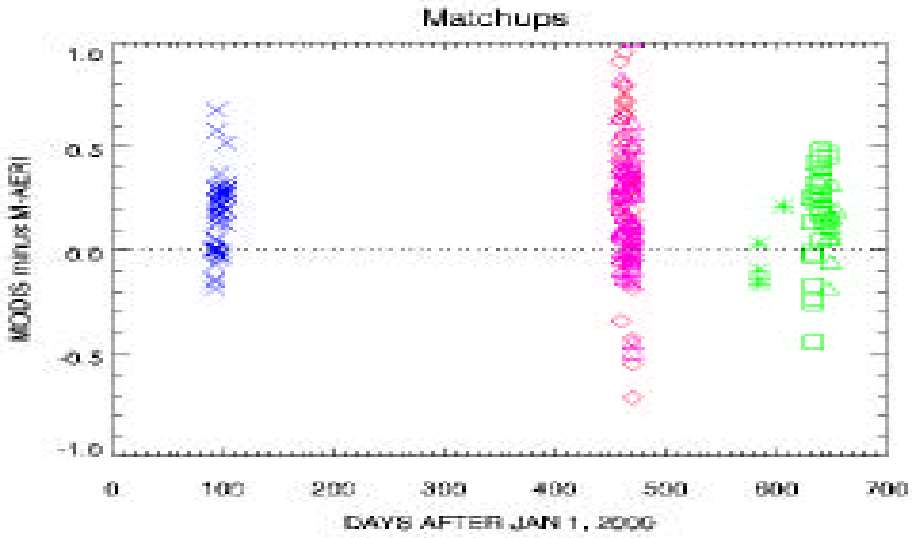
M-AERI data from *Explorer of the Seas*

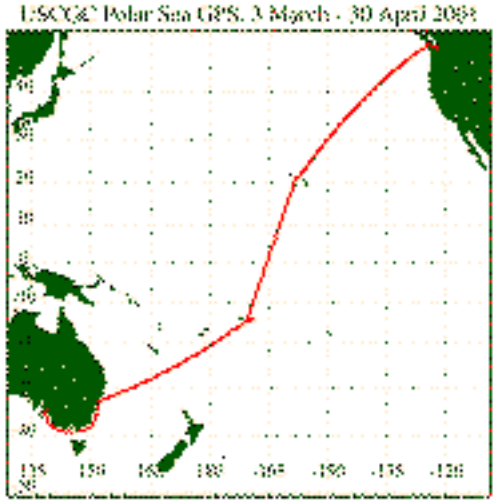


MODIS-M-AERI Matchups

Blue = Mediterranean – April 2000; Red =Pacific – March, April 2001;
Pink = Pacific – March, April 2001; Green = Atlantic - Explorer of the Seas.





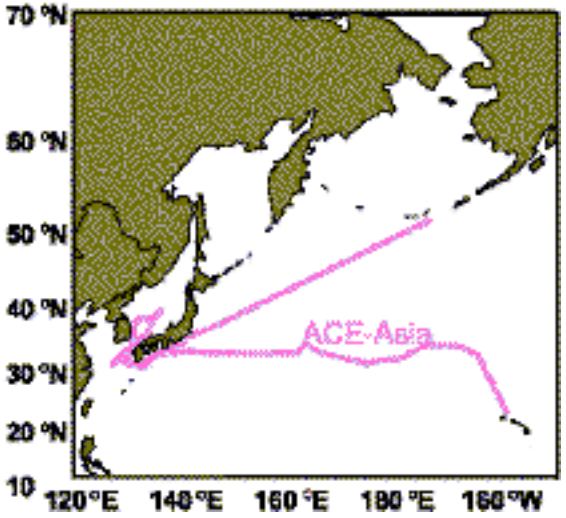


All data

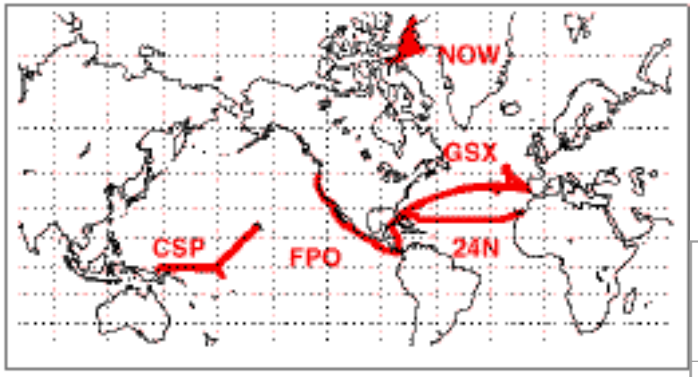
M = 0.20K
std= 0.26K
N = 242

Explorer of the Seas

M = 0.15K
std= 0.21K
N = 50



AVHRR-MAERI SST validation experience



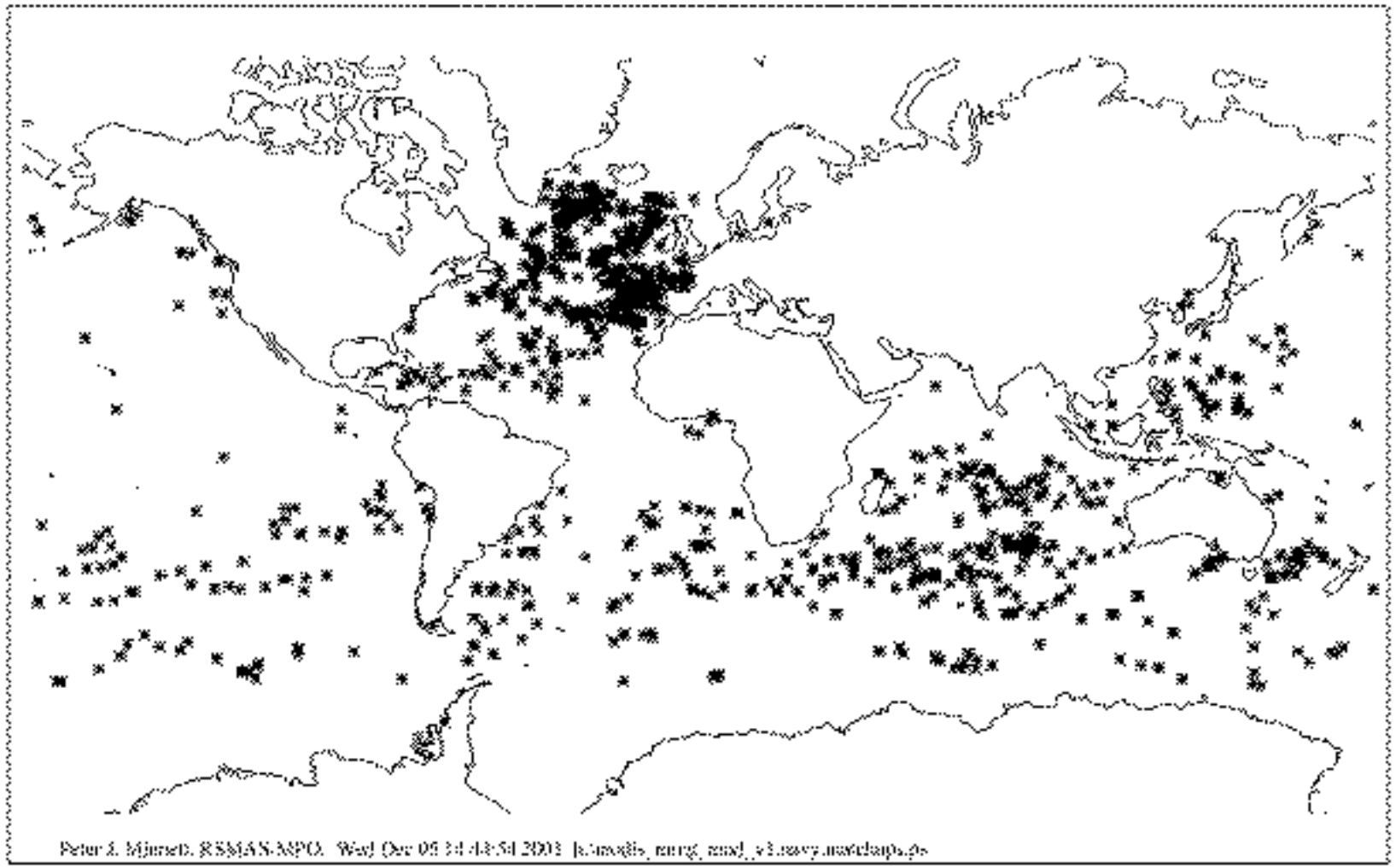
M-AERI validation of Pathfinder SSTs

Cruise Name	N	Mean K	St. Dev. K
CSP 1996	23	0.16	0.20
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	430	0.13	0.37
Total, excluding NOW data	254	0.06	0.29

Using skin temperatures reduces the uncertainties by about a factor of two.

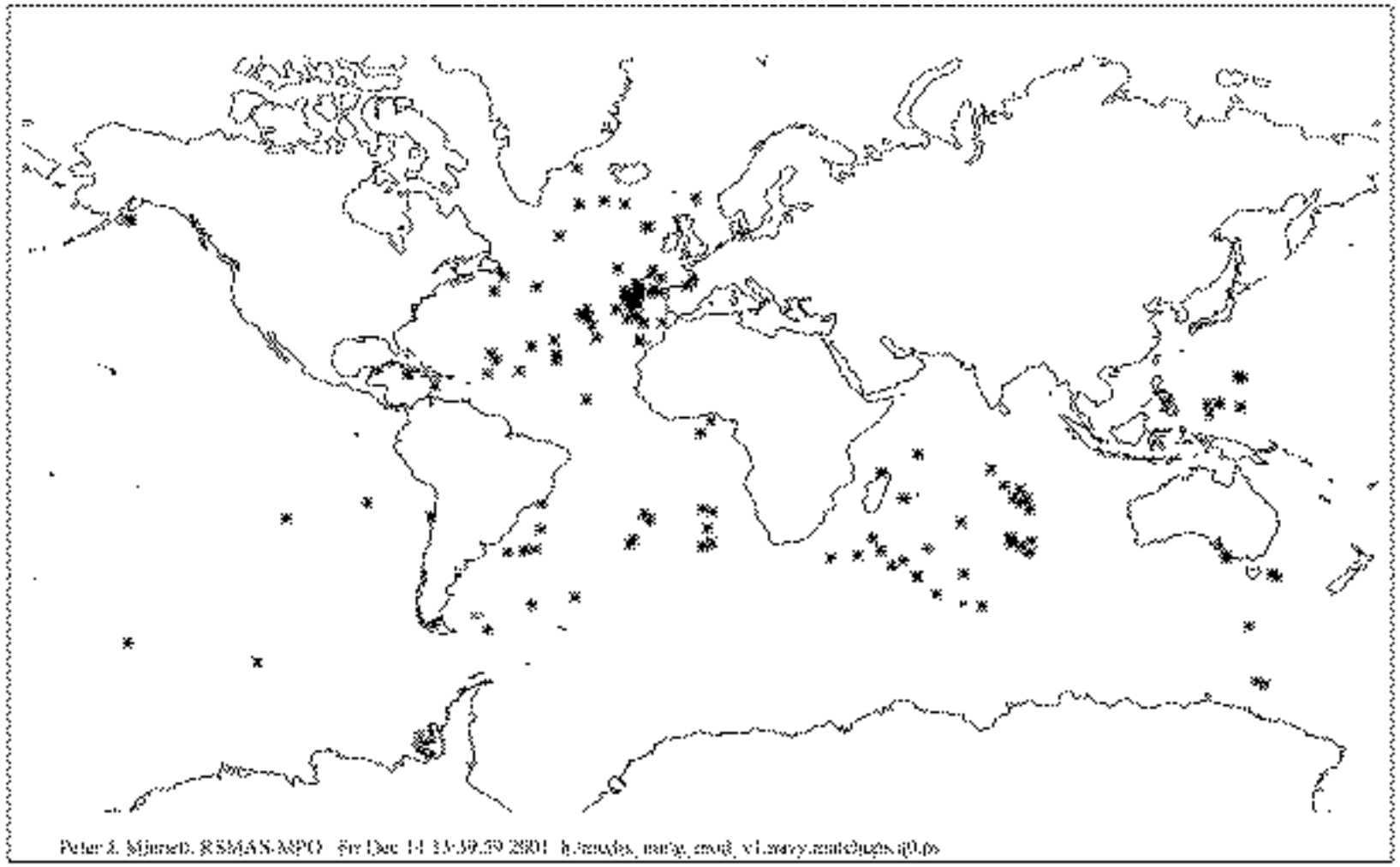
See Kearns *et al*, 2000, ***Bull. Am. Met. Soc.*, 81**, 1525-1536

Buoy Matchups

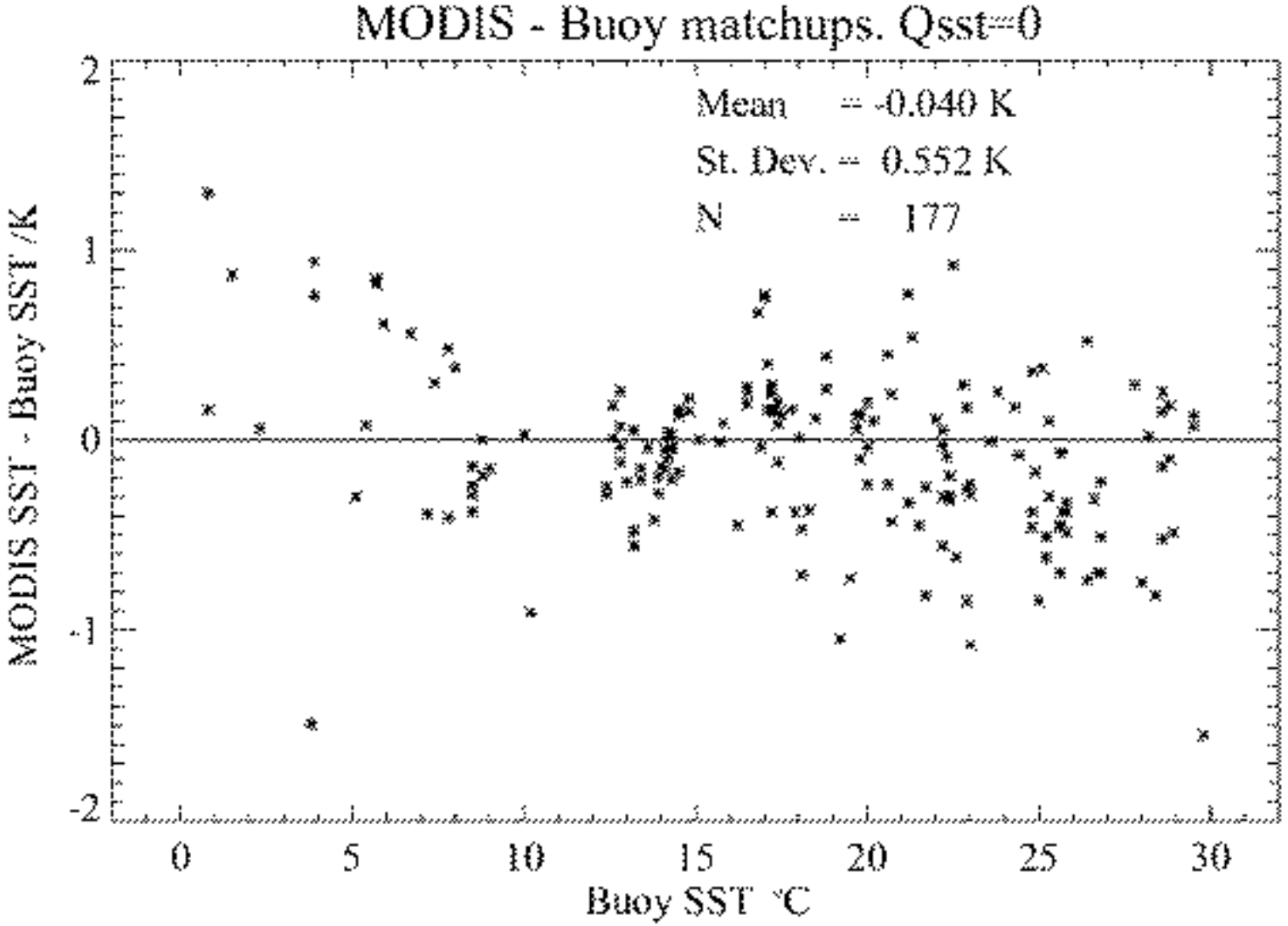


Buoy Matchups

SST Quality Flag = 0

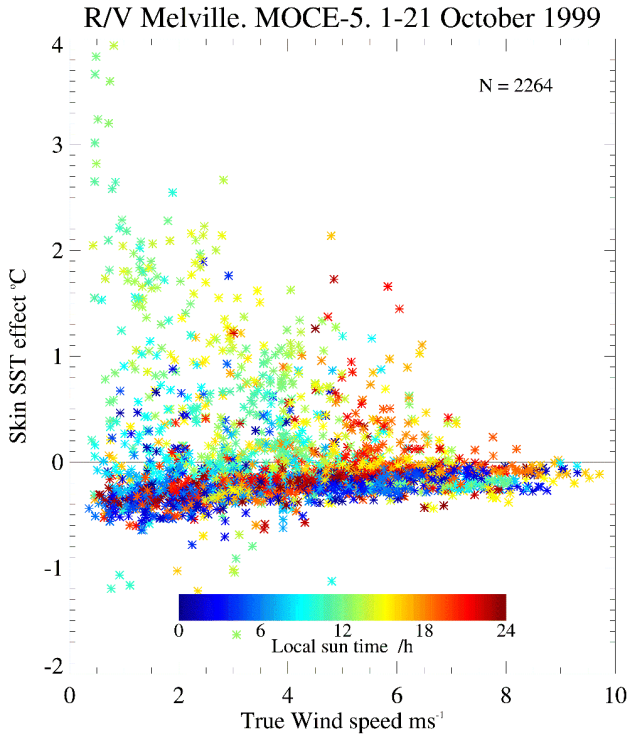


MODIS Buoy matchups



Wind speed criterion for SST validation

For winds > ~6ms^{-1}, relationship between skin and bulk SSTs becomes quite well behaved, at the level of ~0.1K. In these conditions bulk SST may be used to validate satellite-derived SSTs.



See Donlon, C. J., P. J. Minnett, C. Gentemann, T. J Nightingale, I. J. Barton, B. Ward and J. Murray, 2002. Towards improved validation of satellite sea surface skin temperature measurements for climate research. ***J. Climate***. In the press.

Distribution of wind speed <6ms^{-1}

Buoy data can be used, with caution, in blue areas

From Donlon, C. J., P. J. Minnett, C. Gentemann, T. J Nightingale, I. J. Barton, B. Ward and J. Murray, 2001. Towards improved validation of satellite sea surface skin temperature measurements for climate research. ***J. Climate***. In the press.

Are MODIS SSTs Validated?

- VALIDATED PRODUCTS: science quality with well defined uncertainties; improvements ~~may still be~~ are ongoing.
- These are high quality products suitable for longer term or systematic scientific studies and publication. There ~~may~~ will be later improved versions.
- Within the limits of current analyses, (temporal and regional) ….. **YES**.

Are MODIS SSTs Validated?

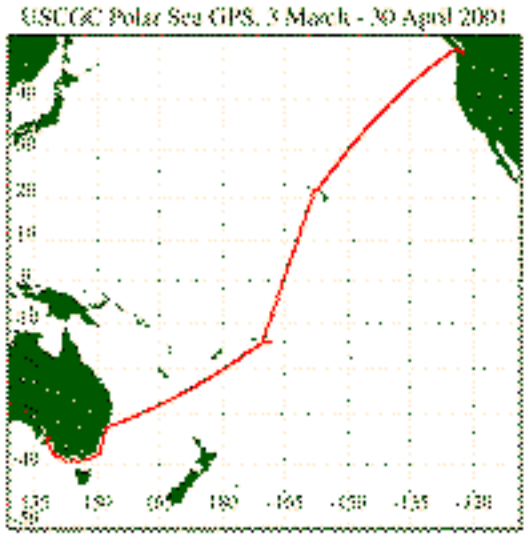
BUT……

- Sample size is still small
- Some regions under-represented
- Time-series not yet established
- Continued validation into the future to determine effects of instrumental re-configurations

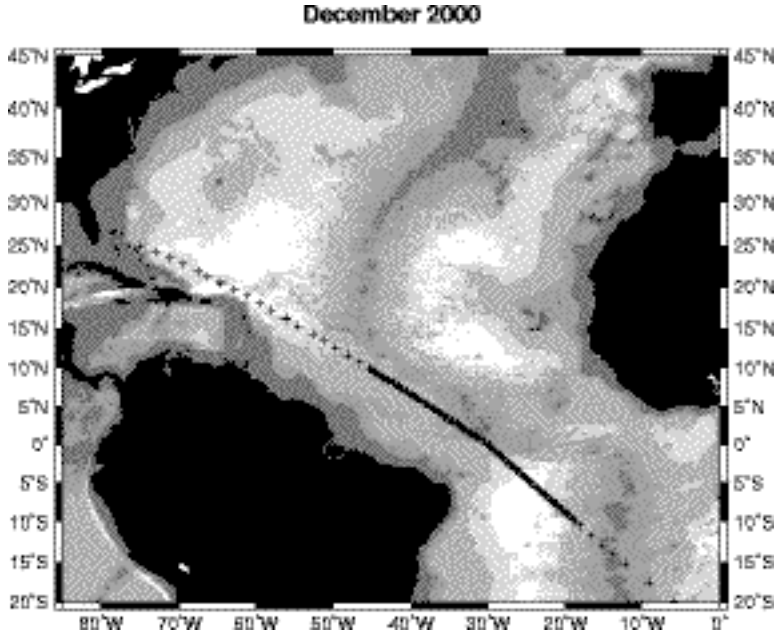
Future Plans

- Establish reasons for regional and seasonal trends, and correct for these effects
- Prepare for 2002 validation cruises (*Terra* and *Aqua*)
- Prepare *Aqua* SST retrieval algorithm
- Explore SST_4 (4 _m) retrievals
- Improve SST retrieval accuracies

Trans-oceanic sections



USCG Ice-breakers across the Pacific, twice each year



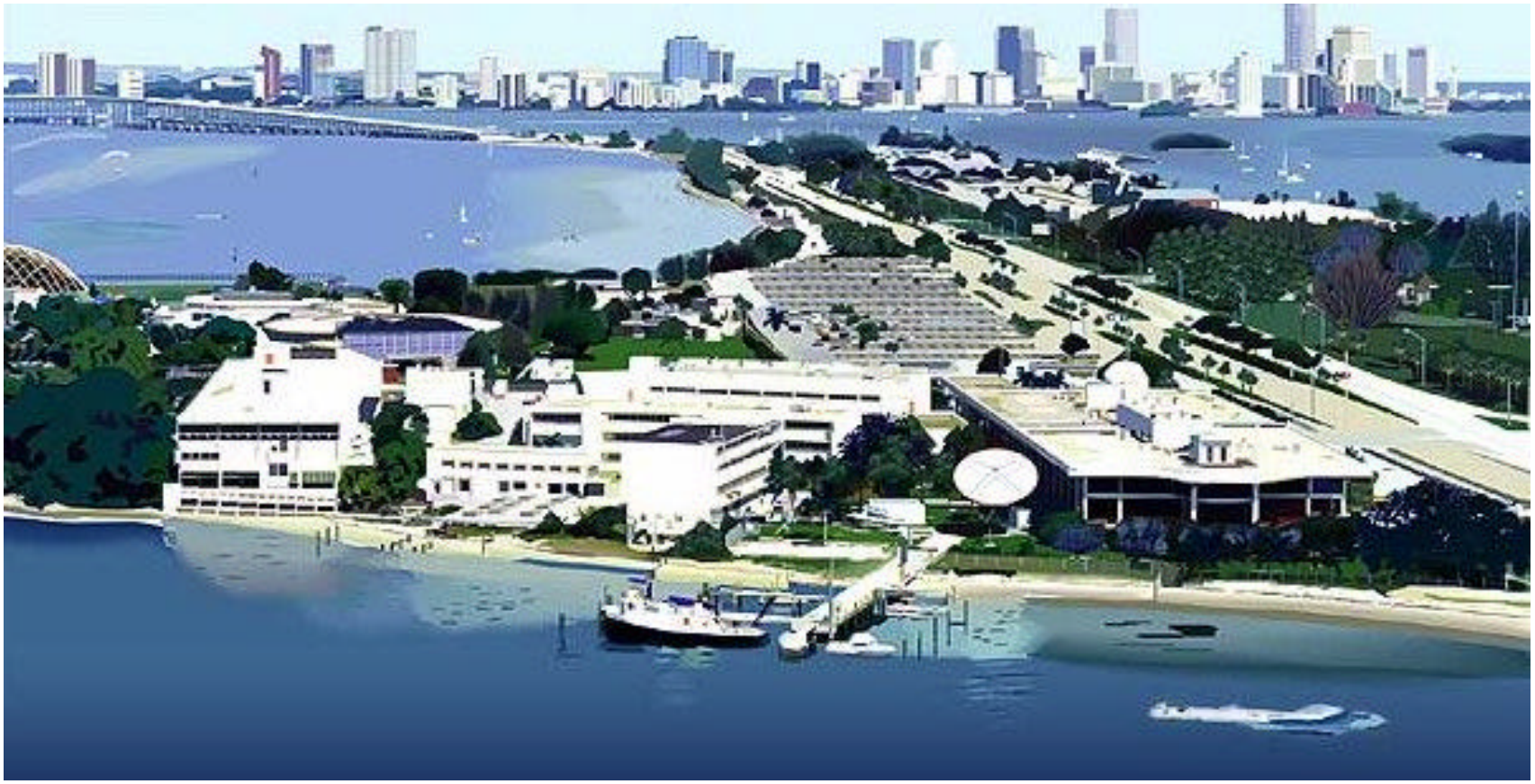
Research cruises, e.g. NOAA S *Ronald H. Brown*

Container vessels, e.g. SAFMARINE - USA to SA along WOCE AX8 in Atlantic, several times each year

Repeat Hydrographic Sections

Conclusions

- M-AERI provides a critical validation tool for MODIS SST
- Buoys provide a valuable secondary validation, numbers allow sampling a wider selection of environmental variability
- Initial, preliminary SST validation shows *Terra* MODIS comparable to best AVHRR
- Need to establish lack of seasonal and regional biases
- Need to validate experimental SST_4 fields
- Need to prepare for *Aqua* MODIS at launch SST algorithm.



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