# MODIS SST retrievals - algorithm derivation, error budget and plans for validation


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and

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# *Introduction*

- Radiative transfer simulations for pre-launch SST algorithm derivation
- Instrumental uncertainties and SST error budget
- M-AERI measurements for SST retrieval validation

# ***Radiative transfer simulations***

Uses an accurate RTE model with representative sets of atmospheric conditions to predict MODIS band radiances (or $T_b$s).  These are used to derive the SST retrieval algorithm.

## **Pros:**

•Available pre-launch

•Permits numerical experimentation

•Provides better understanding of physics involved

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# *Radiative transfer simulations (Con't.)*

## Cons:

- Requires excellent RTE model
- Requires excellent instrument characterization
- Requires representative environmental conditions

# ***Track record of RTE model***

- Line-by-line radiative transfer model developed at RAL (UK) for ATSR Pre-Launch algorithm
- Includes the latest water vapor continuum model (Clough *et al.)*
- Permits realistic aerosol distributions and properties
- Used in many refereed publications in the last decade.

# *MODIS simulations:*

- 1200 quality-controlled radiosondes
- 5 zenith angles
- 5 atmosphere-surface temperature differences
- generates a database of 30000 brightness temperatures in each of MODIS bands 31,32 and 20,22,23.
- robust regression to provide coefficients for retrieval algorithm

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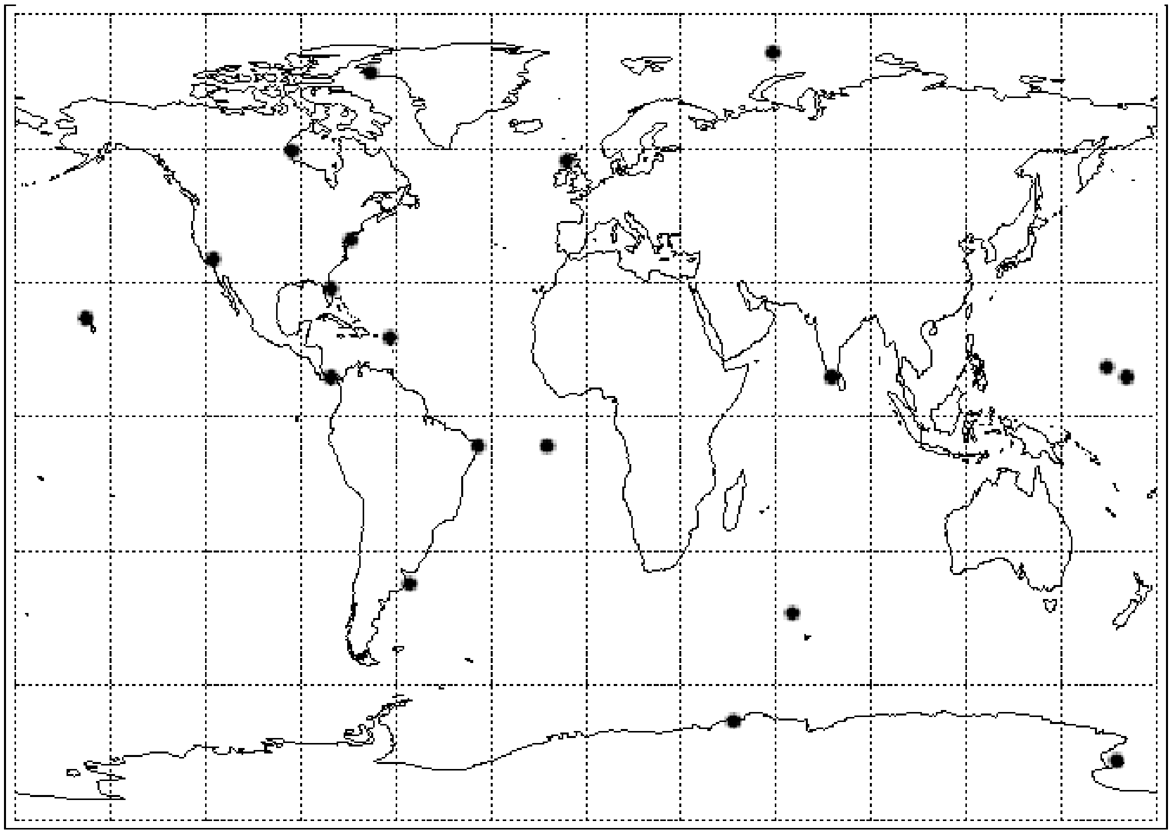
# Radiosondes

## MODIS Simulations (n=761 sondes)



# ATBD-reviewed SST retrieval algorithm:

Based on Miami Pathfinder AVHRR SST algorithm
(11,12$\mu$ m bands: 31,32)

$$modis\_sst = c_1 + (c_2 {*} T_{31}) + (c_3 {*} T_{3132} {*} T_{sfc}) + (c_4 {*}\ \mathrm{secterm})$$

$$\mathrm{secterm} = (\mathrm{secant}\ (\theta) - 1) * T_{3132}$$

$T_{31}$ is the band 31 brightness temperature (BT).
$T_{3132}$ is (Band31 – Band32) BT difference.
$T_{sfc}$ is an estimate of the surface temperature.
$\theta$ is satellite zenith angle.

# ATBD-reviewed SST retrieval algorithm:

| At-Launch Coefficients | | |
|---|---|---|
| | $T_{30} - T_{31} <= 0.7$ | $T_{30} - T_{31} > 0.7$ |
| $c_1$ | 1.228552 | 1.692521 |
| $c_2$ | 0.9576555 | 0.9558419 |
| $c_3$ | 0.1182196 | 0.0873754 |
| $c_4$ | 1.774631 | 1.199584 |

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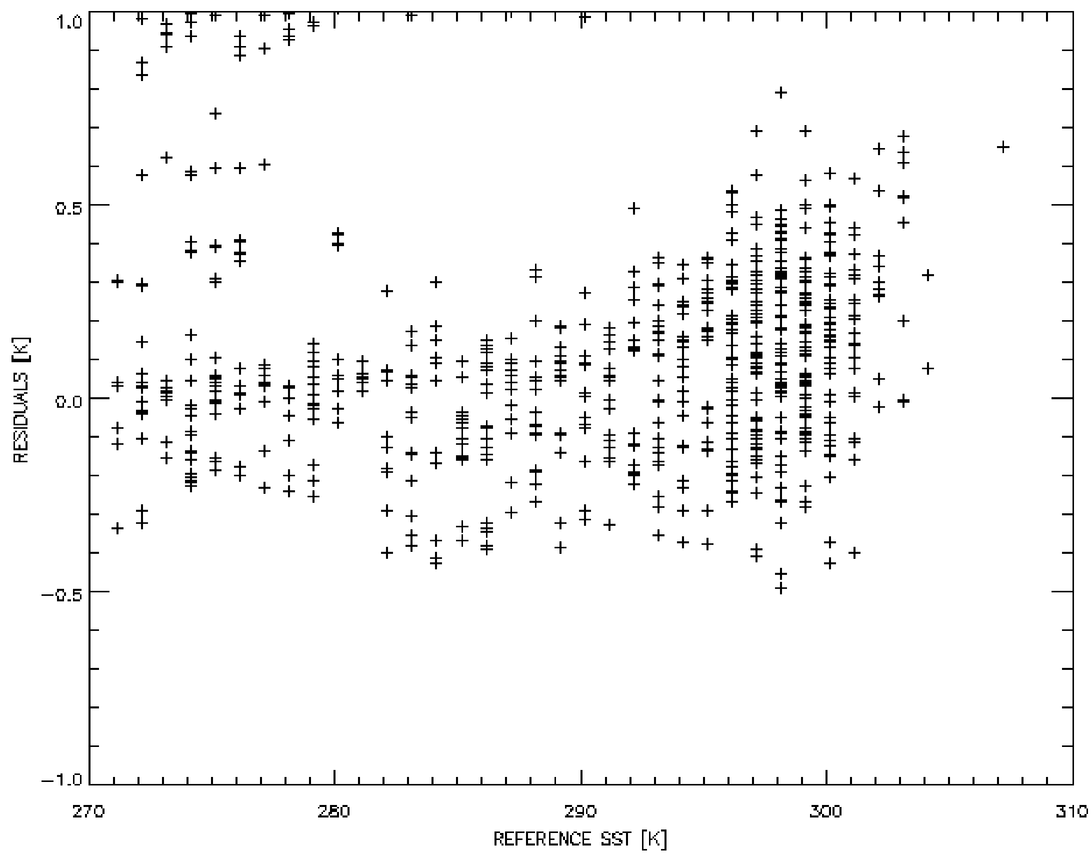
# *MODIS simulations:*

- for ATBD algorithm, residual SST uncertainty, caused by clear-sky atmospheric variability = **0.337K** at nadir; increases with increasing atmospheric path length.
- For MWIR algorithm, clear-sky atmospheric variability = **0.247K** at nadir, but has the potential for some reduction.

# *SST Retrieval Errors–Atmospheric*

**$SST = -4.43 + 1.83 \times Ch\ 22 - 0.804 \times Ch23 + Season$**

**$Season = -.222 \times \cos(2 \times 3.14 \times Julian/365) - 0.0643$**




**RMS = .247**

# SST Retrieval Errors–Atmospheric

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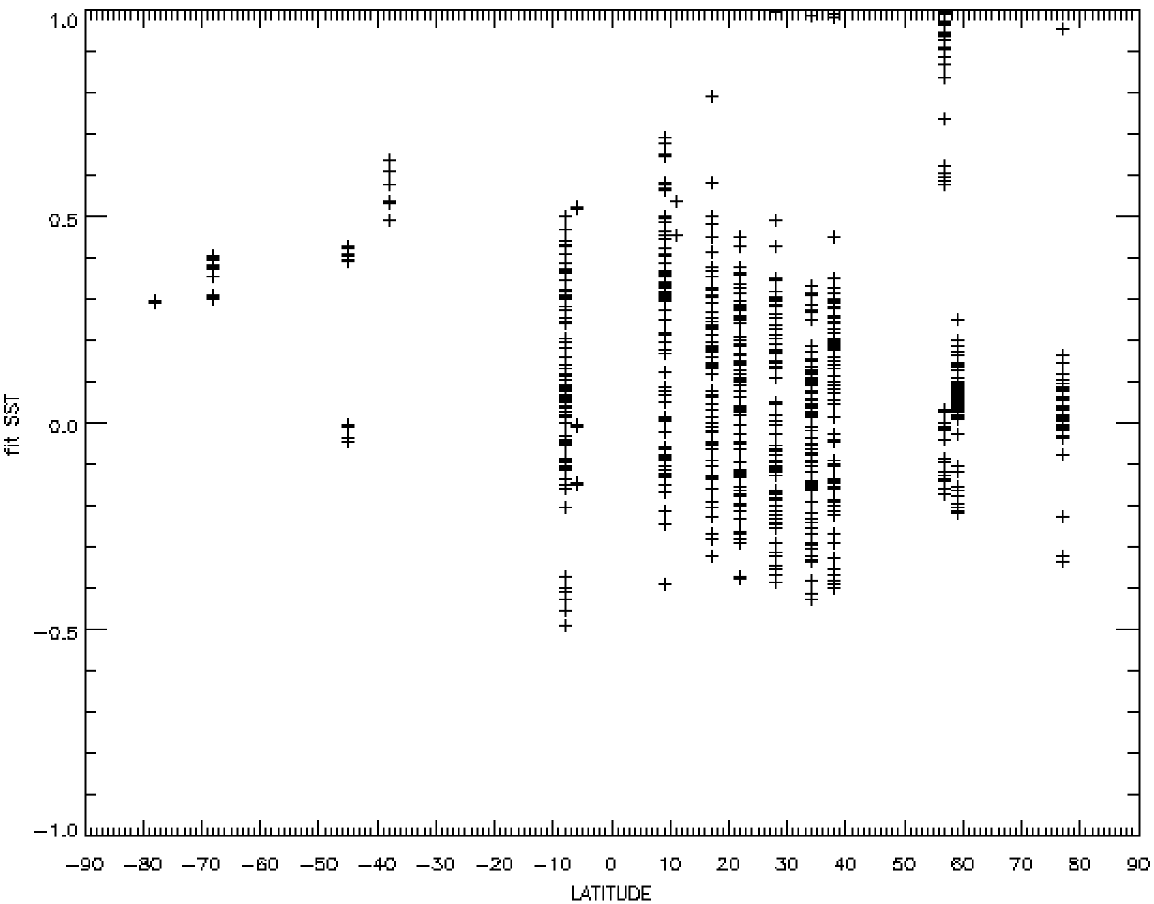


**RMS = .247**

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# MODIS Error budget

Contains major component specific to MODIS design:

| Source of uncertainty | MODIS (Bands 31 and 32; Ltyp) | AVHRR 11,12 $\mu$m channels | ATSR 11,12 $\mu$m channels |
|---|---|---|---|
| Scan mirror emissivity | >0.25K, occurs both in earth view and space view for in-flight calibration | N/A - constant angle of incidence | |
| Temperature of BB | <0.1K | ? | <0.03K |
| Emissivity of BB | >0.995 | ? | >0.999 |
| NE$\Delta$T | 0.03 - 0.06K | 0.05K (?) | 0.02-0.04K |

MODIS Prelaunch calibration means we know more about the instrumental characteristics than for the AVHRR.

# *SST retrieval errors*

Has components from instrument, atmosphere and sea-surface (0.05K).

| | Uncorrelated | | Correlated | |
|---|---|---|---|---|
| | Nadir | $45^{o}$ zenith angle | Nadir | $45^{o}$ zenith angle |
| | | | | |
| Current instrumental uncertainties | 1.777 | 2.133 | 0.509 | 0.605 |
| If rvs uncertainties reduced to 50% | 1.038 | 1.256 | 0.397 | 0.526 |
| If rvs uncertainties reduced to 10% | 0.641 | 0.802 | 0.359 | 0.493 |

Does not include:

- Band 31-32 cross-talk
- Residual cloud effects
- Aerosol effects

# *SST uncertainties - MODIS, AVHRR, ATSR*

**MODIS**

| | **Uncorrelated** | | **Correlated** | |
|---|---|---|---|---|
| | **Nadir** | **45$^o$ zenith angle** | **Nadir** | **45$^o$ zenith angle** |
| | | | | |
| **Current instrumental uncertainties** | **1.777** | **2.133** | **0.509** | **0.605** |
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**AVHRR**: **0.2-0.5K** - algorithms derived from buoy matchups

**ATSR**: **<0.3K** - algorithms derived from RTE modeling
(improvement expect with reprocessing using an aerosol-robust algorithm)

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# *SST Validation*

**This is not in any form or fashion a 'vicarious calibration' of the MODIS infrared channels.**

- To provide confidence in the MODIS SST product
- To confirm the atmospheric correction algorithm is functioning properly, identify situations where breakdown occurs, and learn how to improve the algorithm.
- Compare like-with-like - *i.e.* infrared emission at the sea-surface
- Marine-Atmosphere Emitted Radiance Interferometer

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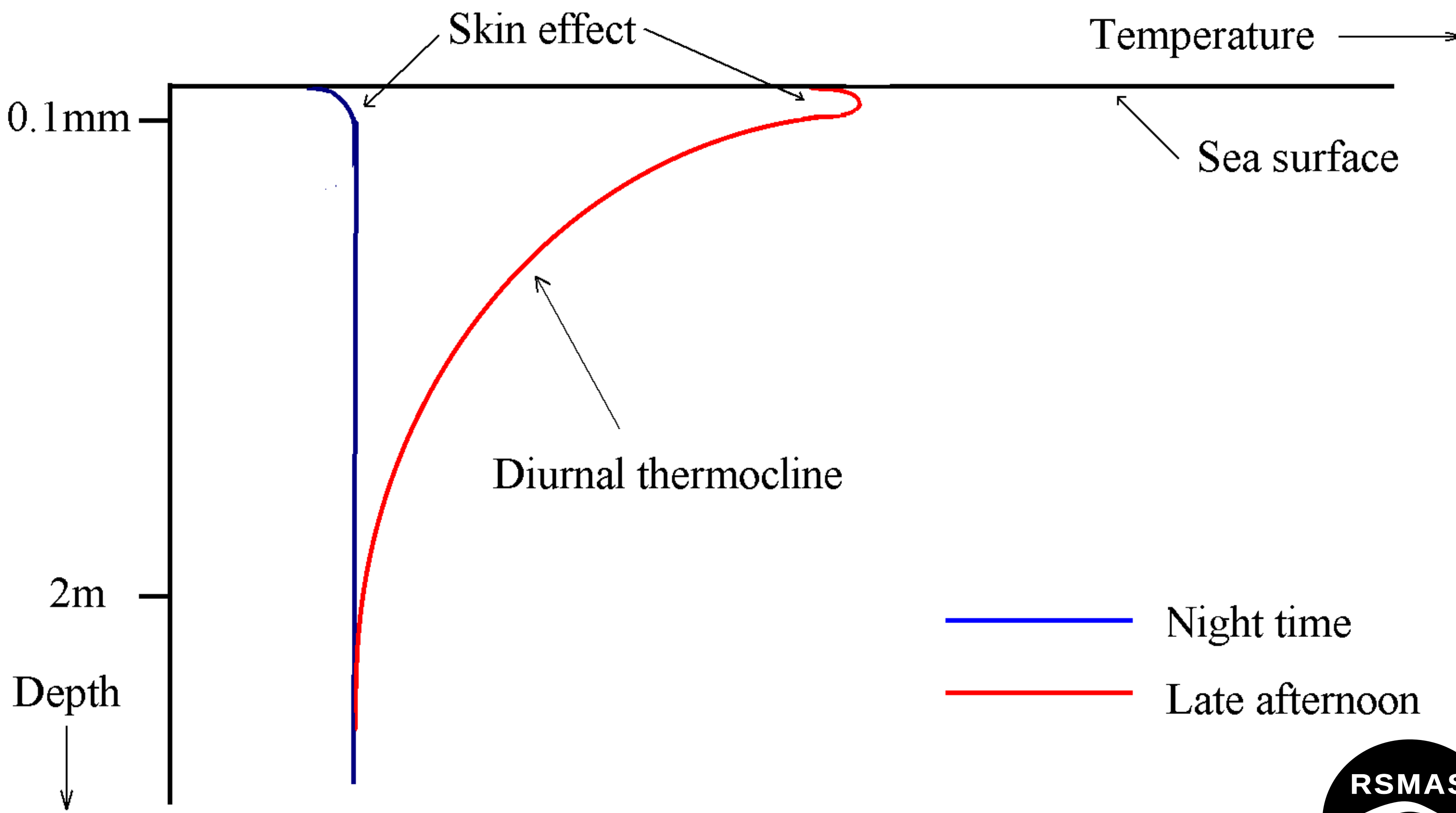
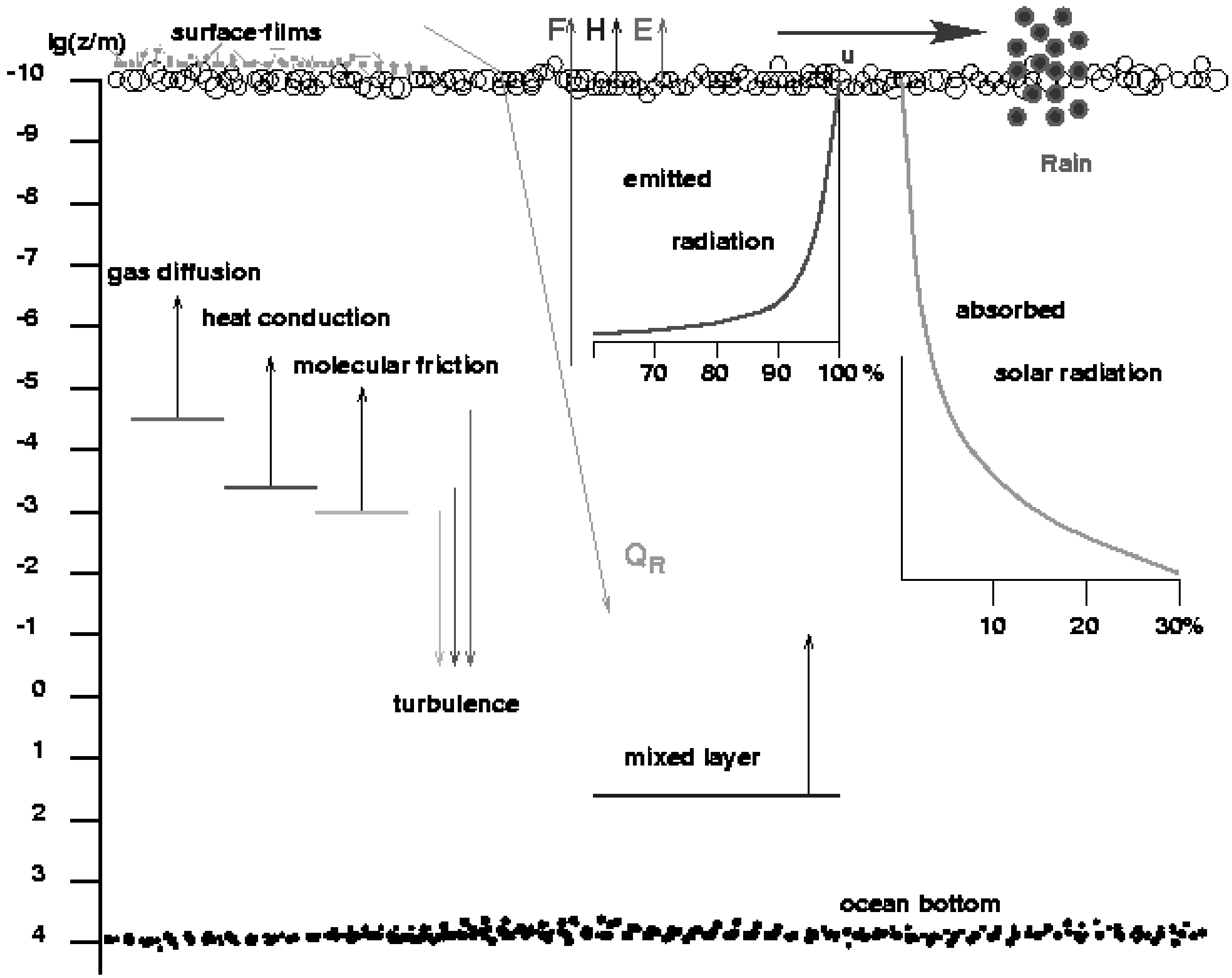
# *Temperature Gradients at the Air-Sea Interface*



# *Processes at the Air-Sea Interface*




Courtesy Peter Schluessel, University of Munich

# *M–AERI on NOAA S Ronald H. Brown*

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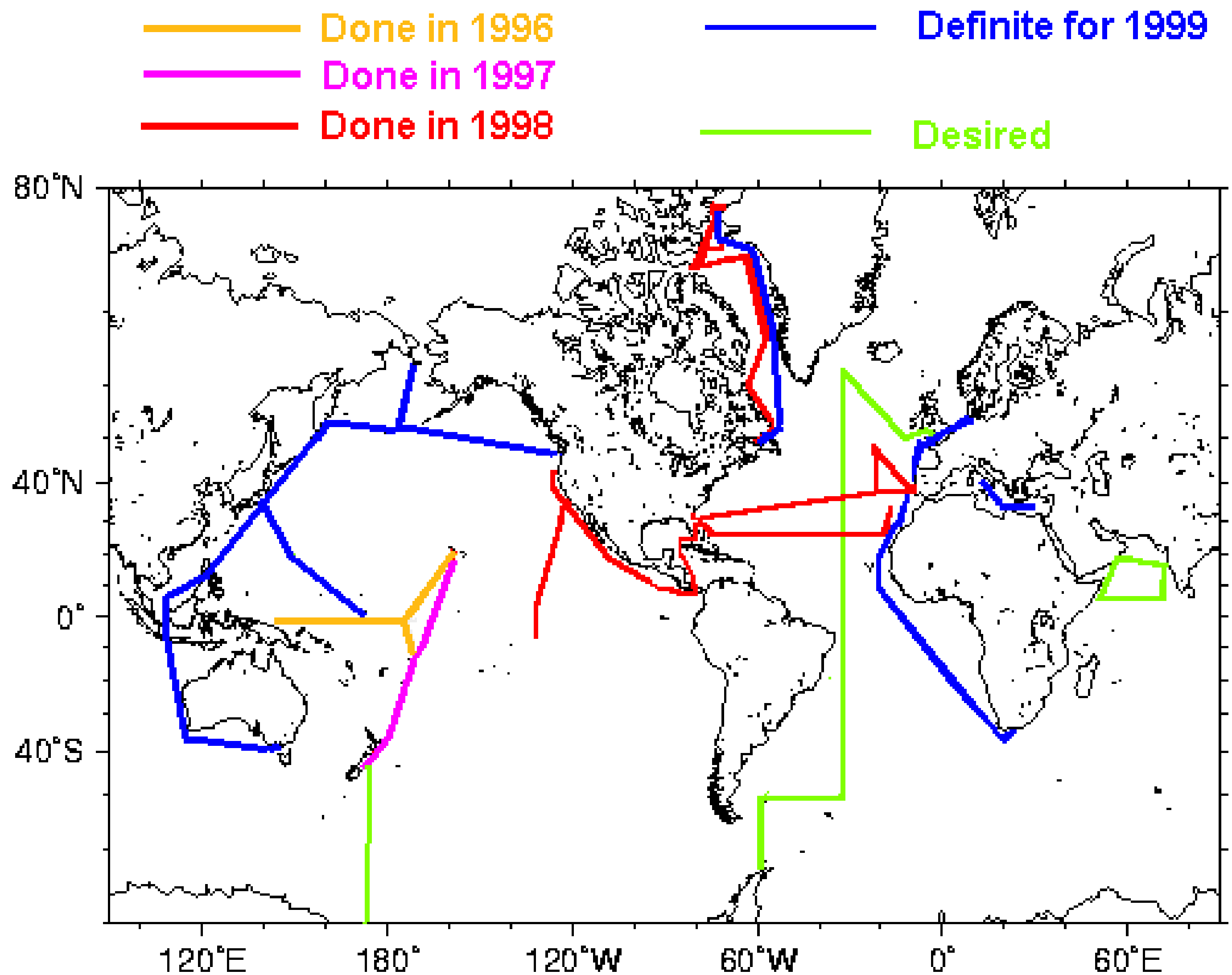
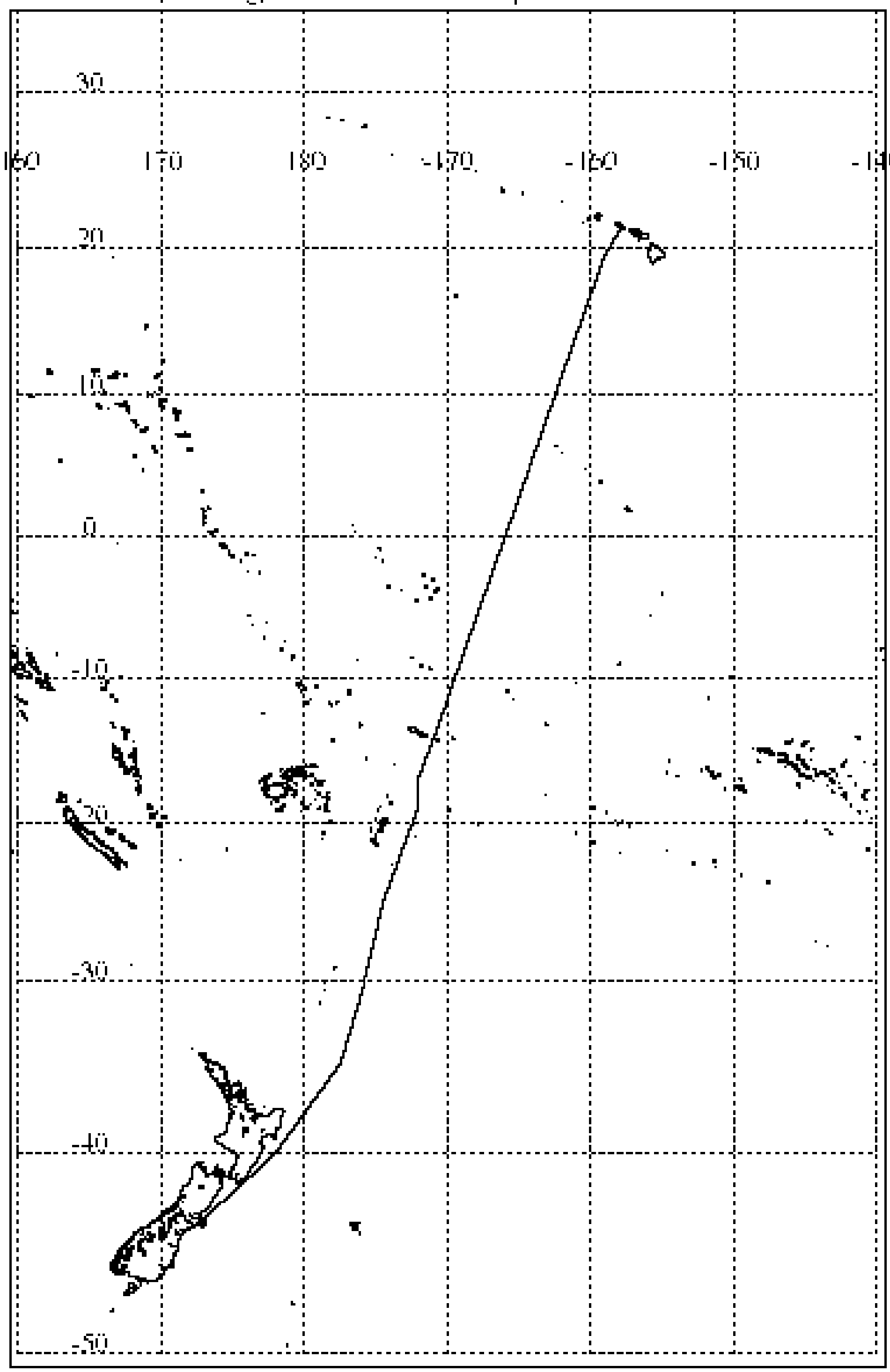
# *M–AERI Cruises*



# Track of R/V Roger Revelle

R/V Roger Revelle. 28 Sept. - 14 Oct. 1997



# M-AERI Skin SST comparisons

R/V *Roger Revelle* section, Hawaii to New Zealand

55$^o$ incidence angle, $\lambda$ = 7.7 $\mu$m

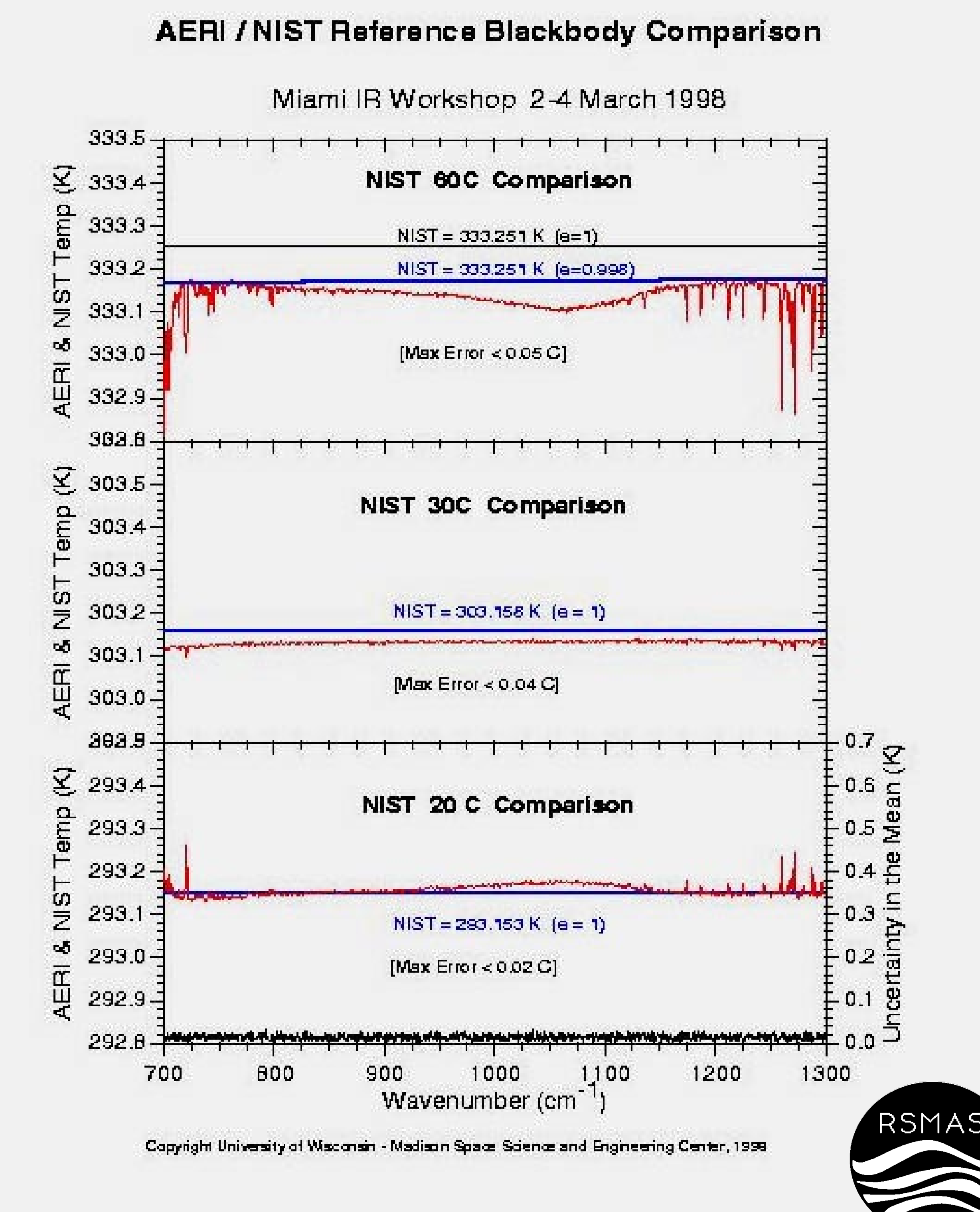
M-AERI 01 data interpolated to times of M-AERI 02 measurements

24 h data segments

$\Delta_m T$ = Skin SST ( M-AERI 02 – M-AERI 01)

| Dates - UTC | N | Mean $\Delta_m T$ /K | St.dev.$\Delta_m T$ /K |
|---|---|---|---|
| October 1-10 | 890 | 0.005 | 0.077 |

# M–AERI Calibration with NIST Black Body Target

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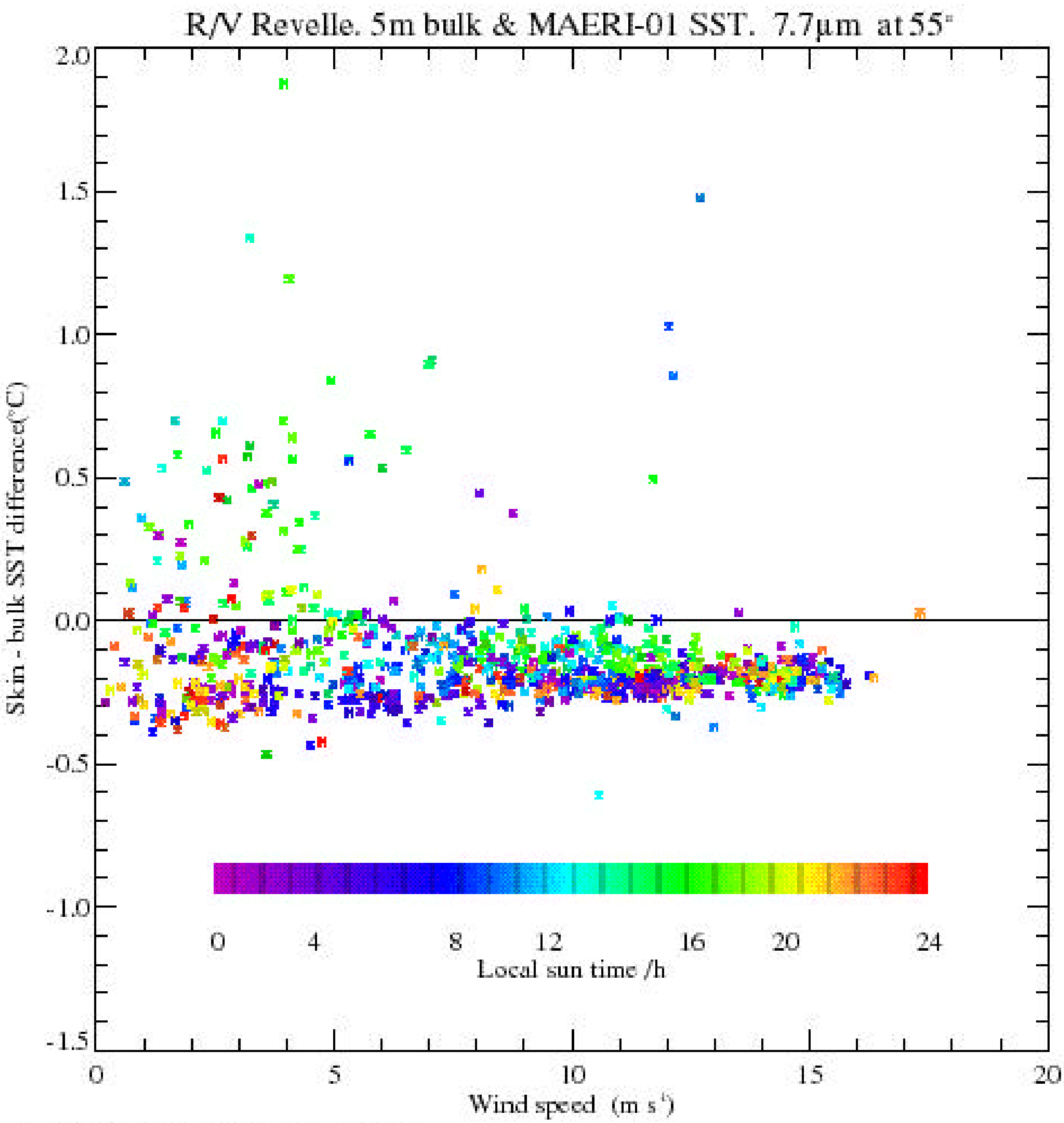
# Wind Speed Dependence of Skin Effect

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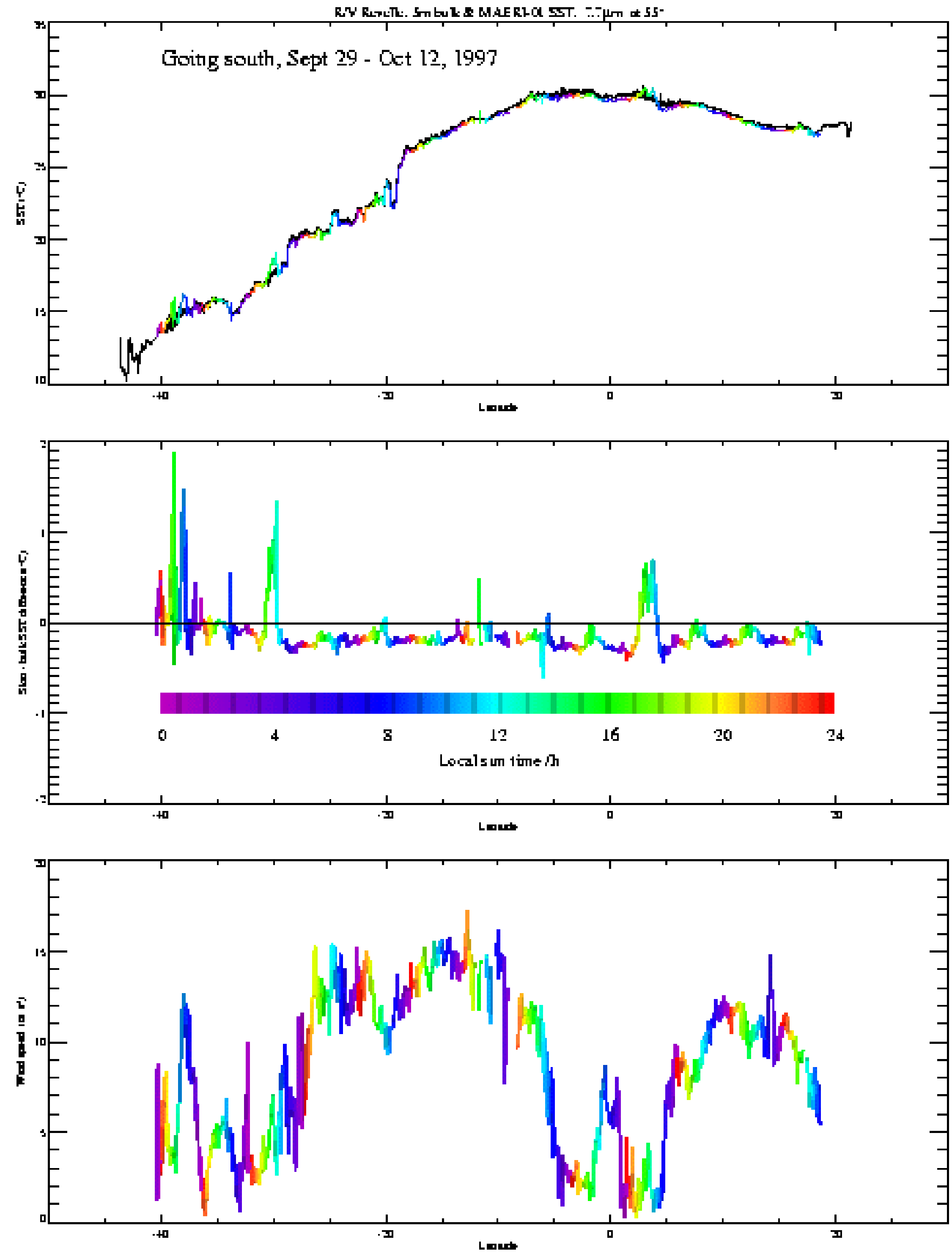
# Hawaii–New Zealand Section



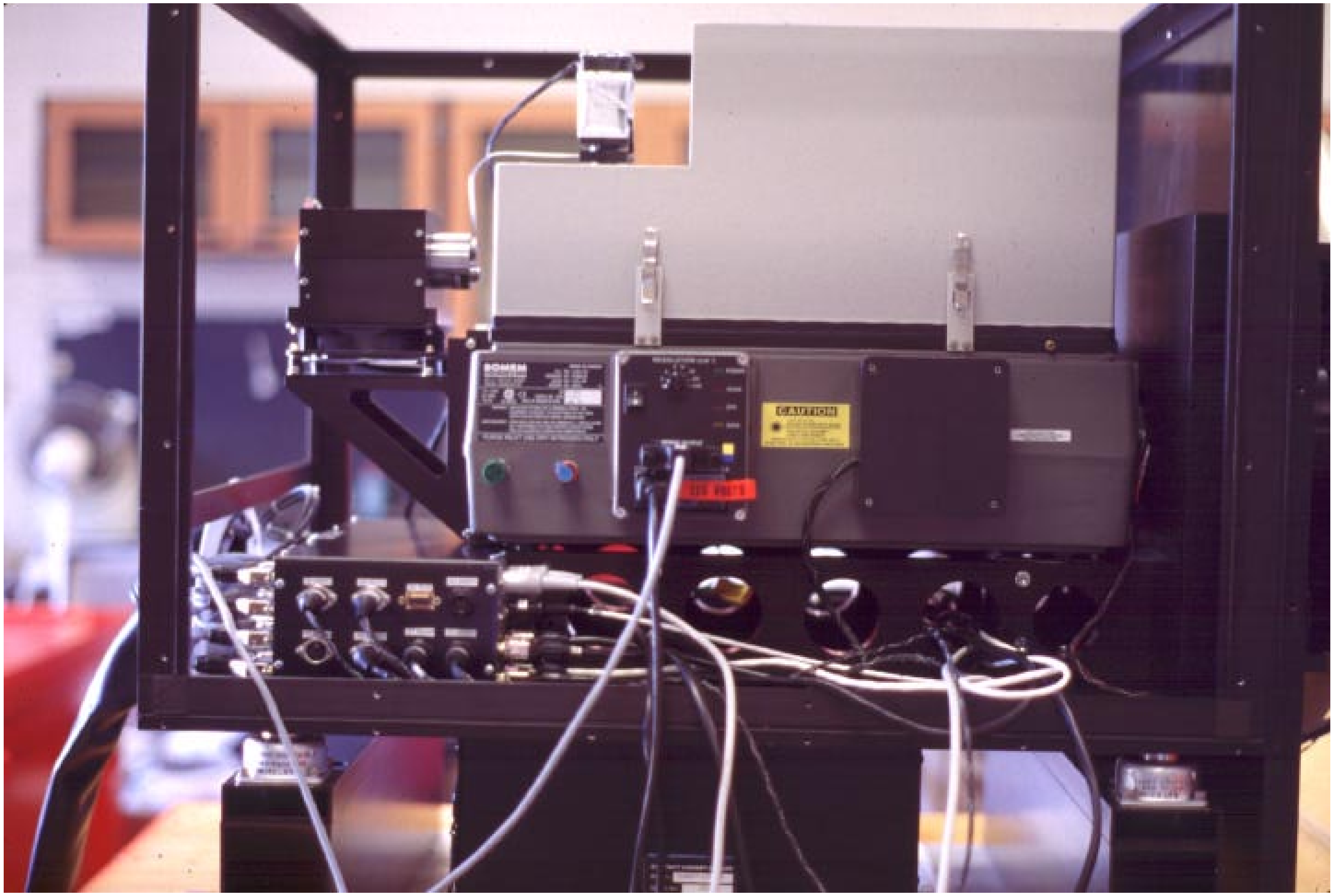
# Summary

- At launch algorithm in place. Expected uncertainty in SST caused by atmospheric variability ~0.33K.
- Bands 20,22,23 algorithms have smaller uncertainties, but are limited to night time use.
- Unless uncertainties in RVS for scan mirror can be significantly reduced, MODIS SST retrievals will not meet Level 1 Scientific Requirements and are unlikely to improve on AVHRR retrievals.

# Summary (Continued)

- Unknown uncertainties introduced into SST by absence of system-level determination of band 31 and 32 relative spectral responses, and cross talk.
- Contamination of SST fields by aerosols likely to be a concern, but with MODIS we have the potential for better diagnostics than AVHRR or ATSR.

# M–AERI Optical Bench



# M–AERI on Pierre Radisson

# M–AERI Front End

# Shipboard Assembly of M–AERI