Profiling the Skin Sea Surface Temperature with Infrared Hyperspectral Measurements of the Marine-Atmosphere Emitted Radiance Interferometer

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Background

The skin sea surface temperature (skin SST) is one of the most important variables in driving air-sea interaction and is measured by infrared radiometry by emission from a depth of 10-20µm. There are 2 distinct processes happening in this layer: (1) The electromagnetic (EM) skin layer due to EM properties of water; (2) The thermal skin layer due to molecular diffusion processes of heat transfer from the ocean to the atmosphere.

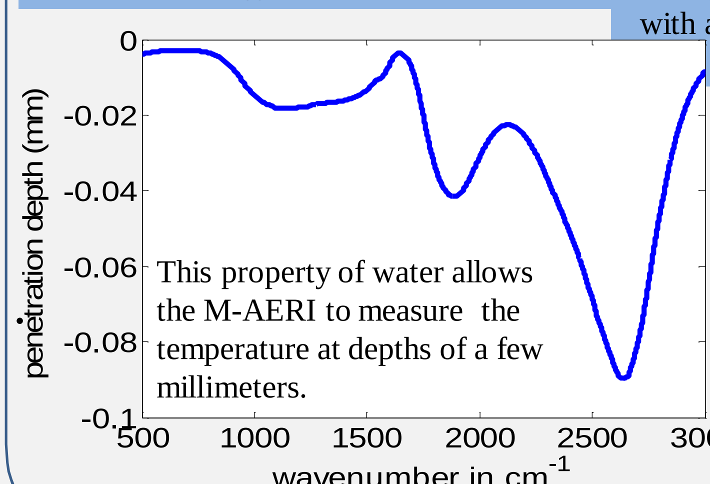
Here we present an iterative algorithm to retrieve the skin SST profile using spectral measurements made by the Marine-Atmosphere Emitted Radiance Interferometer (M-AERI). The objective is to understand the gradient of the SST profile as it is key to climate studies – driving primary variables, eg. Net heat flux, which are vital when obtaining knowledge of the climate system.

Instrumentation

The M-AERI measures emission from the water and atmosphere in the wavenumber range, ν=500-3000cm^{-1}. From this, the skin SST can be retrieved. The measured radiance is:

$$I_m(\nu) = \int_{-\infty}^{0} kB(\nu, T(z))e^{-kz}dz$$

where, ν = wavenumber in cm^{-1}, k = absorption coefficient in cm, B(ν,T(z)) = Planck's function with a temperature depth profile of T(z).



From Beer's Law: $I=I_0e^{(-\alpha z)}$, where α=absorption coefficient.

$D_p = \frac{1}{\alpha} = \frac{1}{4\pi\nu R_{img}}$,

R_{img} = imaginary part of the refractive index of water. (*Bertie and Lan*., 1996).

Figure 1. Penetration depth, D_p *vs* wavenumber.

Data Analysis

Field data measured from the RV Mirai during the Nauru99 cruise are used for analysis. Cloud-free, night-time data from 24th June – 4th July 1999 are processed as follows:

1) Spectral emissivity values are derived by minimizing the variance of the brightness temperature (BT) in narrow wavenumber, ν, intervals (Hanafin, 2005).
2) Emissivity values and measured radiances were averaged over all good data collected. (Fig 2)
3) Atmospheric correction was performed on the averaged data to obtain R_{sea} using the formula:

$$R_{measured} = \varepsilon R_{sea} + (1-\varepsilon)R_{sky}$$

where, R=radiance, Ɛ=emissivity

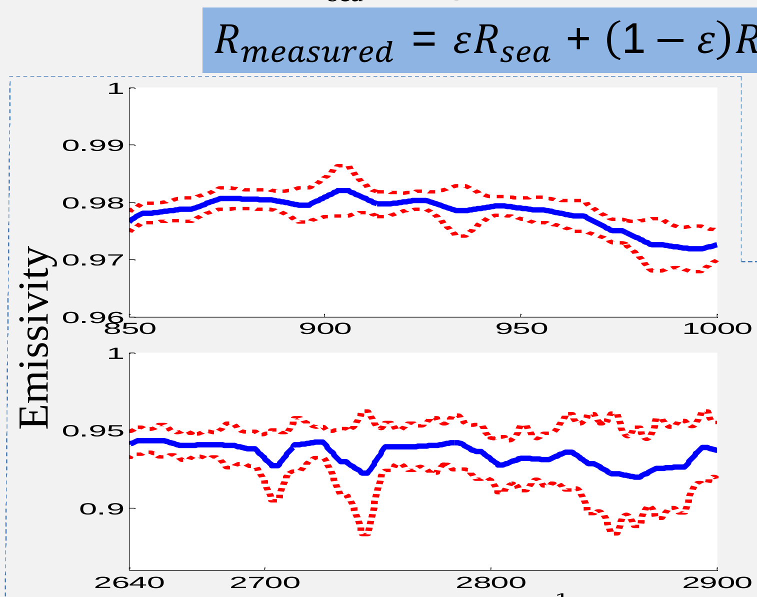
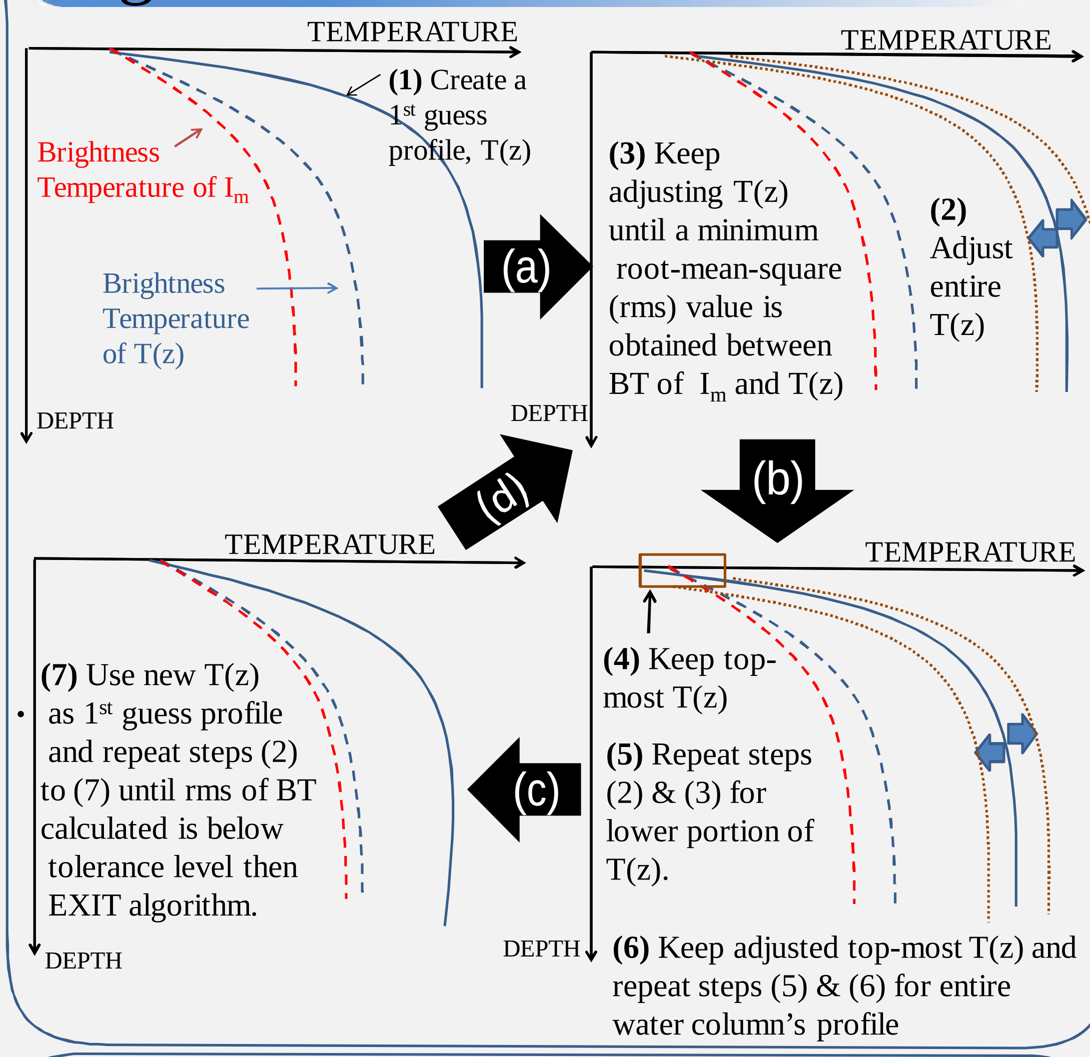


Figure 2. Blue Solid line: Mean Ɛ values obtained from using minimum variance technique. Red Dotted line: ±1 standard deviation.

ν =850-1000cm^{-1} and 2640-2900cm^{-1} are shown and used in the algorithm as they produce the most consistent Ɛ and gives a wide D_p range. (Fig 1)

Algorithm



Results

A first guess was produced using knowledge that the skin SST profile is approximated by a complementary error function (Liu and Businger, 1975). Results are shown in Fig 3(a) & (b).

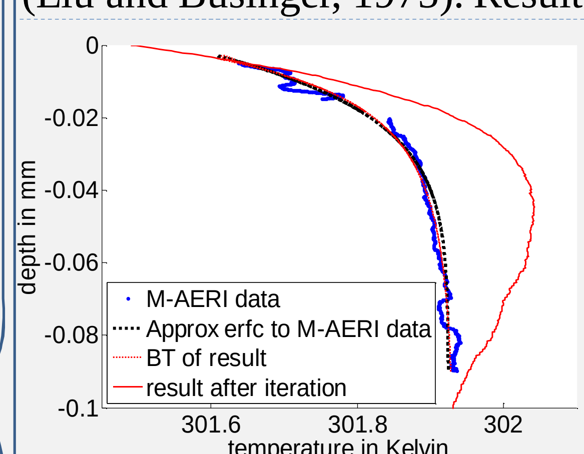


Figure 3(a). Result of iterating cruise data.

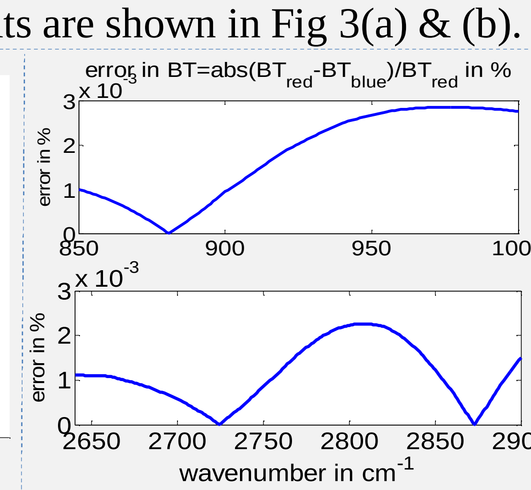


Figure 3(b). BT error of Fig 3(a).

Previous runs on synthetic data (Fig 4(a)), shows that there is a tendency for an overshoot at the curvature of the skin SST profile. This overshoot is <0.01% when the BT error is <0.003% (fig 4(b)), which is the case on the cruise data run.

Ts=300, Q=200. Solid line=original T(z), dotted line=T(z) after iteration

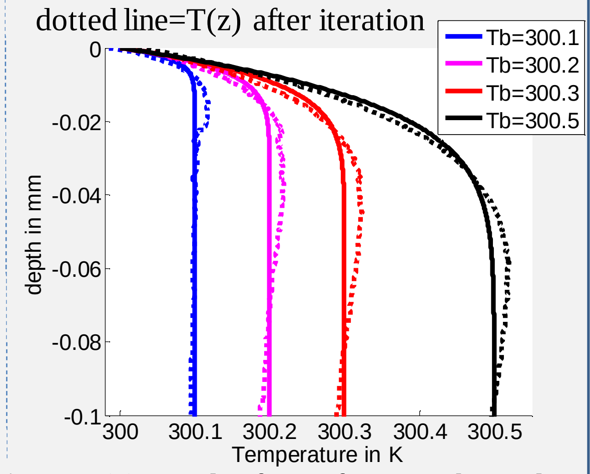


Figure 4(a) Result of runs from synthetic data.

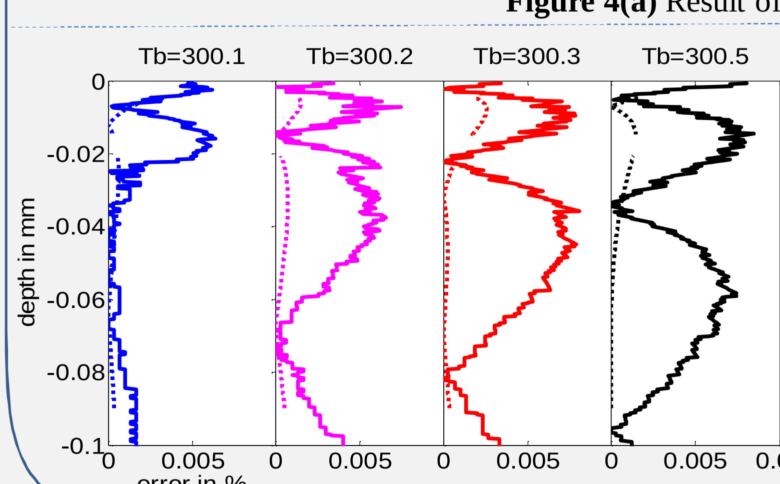


Figure 4(b). BT error (dotted) & T(z) error (solid) of Fig 4(a) in %. Graphs plotted with respect to D_p.

Future Work

1) Algorithm needs to be tested on more datasets from other cruises.

2) Quantification of algorithm's accuracy and errors.

References:

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