Validation of MODTRAN® 5.3 sea surface radiance computations

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**** With DRDC Valcartier**

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  - Aerosols, MBL thermodynamic modeling, etc.
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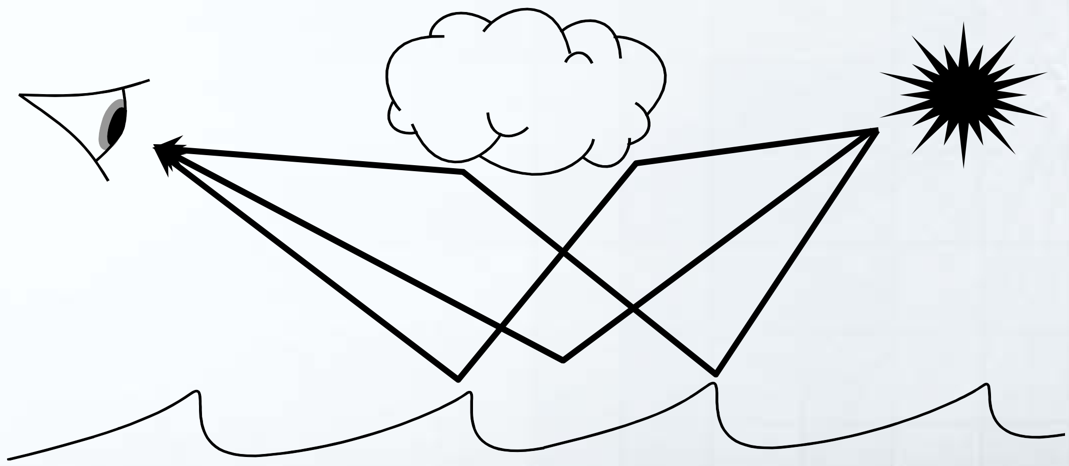
Introduction

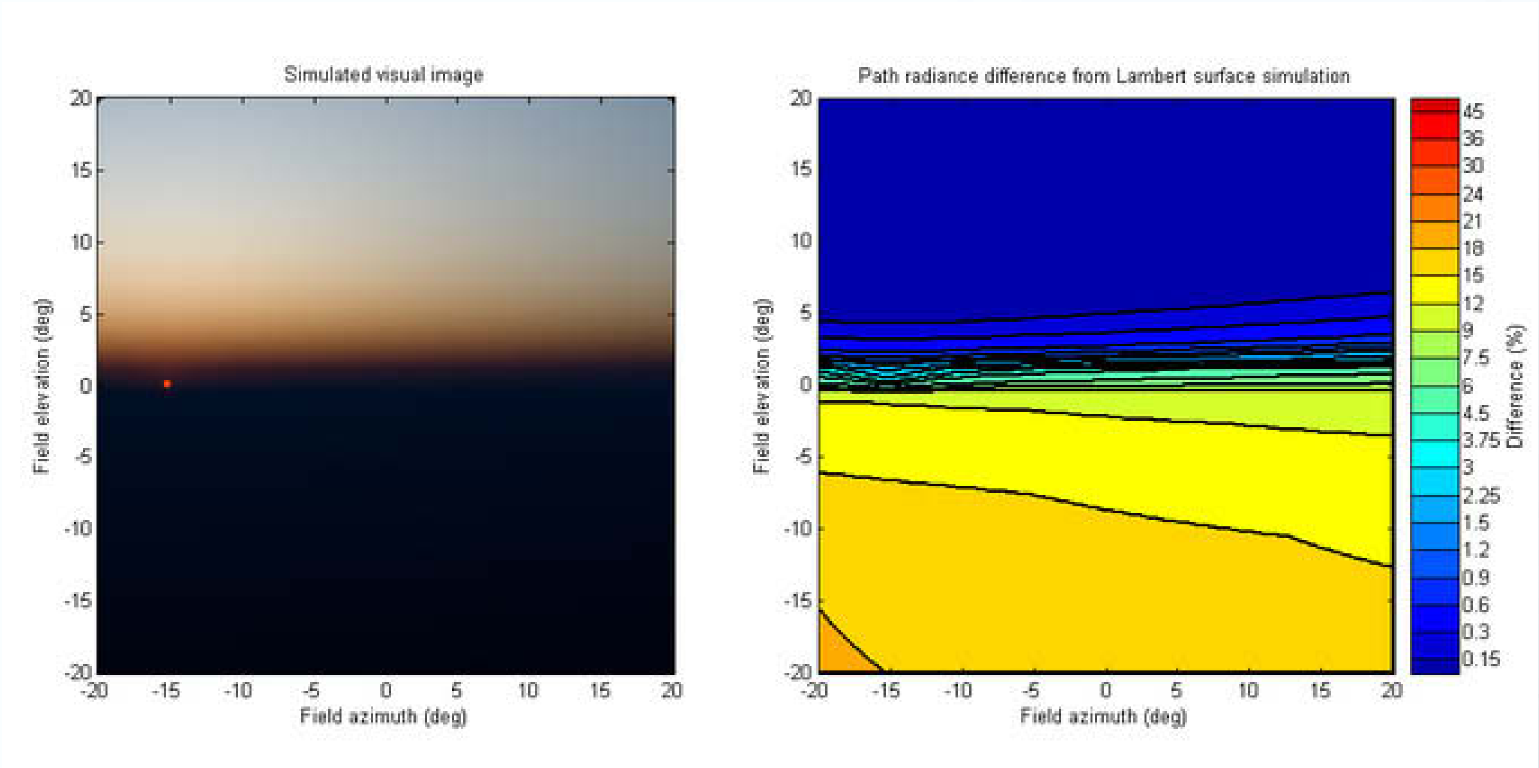
- Why is the sea surface reflectance important?
  - Background
    - Thermal emissions
    - Direct solar reflections
    - Indirect solar reflections
  - Foreground
    - Contributes to atmospheric radiance

Radiative coupling



Introduction

- Why is the sea surface reflectance important?



Current situation with MODTRAN®

- No full BRDF coupling up to MODTRAN® 4
- No sea surface BRDF up to MODTRAN® 5 v2
- Only basic aerosol models, limited user input
- Inadequate for accurate horizontal path refraction

- MODTRAN® 5 v?
  - Fully coupled analytical sea surface BRDF
  - SAP (Spectral Aerosol Profile) input
  - Refracted path input
  - Currently in beta testing stage, soon to be released.

} DRDC-Valcartier participation

The sea surface BRDF

Wave facet angle weighing

Probability of specular reflection

Wave facet hiding

Fresnel reflectance

$$f\left(\psi_s,\psi_r\right)=\frac{\pi r\left(\psi_s,\psi_r\right)p(\zeta)W(\zeta,\Psi_r)H_\zeta(\zeta,\Psi_r)}{4z_n^{\ 3}(\mathbf{U}_n\cdot\mathbf{U}_r)\left[1+\Lambda(v_r)+\Lambda(v_s)\right]\cos\theta_r\cos\theta_s}$$

Bistatic wave shadowing

Ross, V., D. Dion, and G. Potvin, "Detailed analytical approach to the Gaussian surface bidirectional reflectance distribution function specular component applied to the sea surface," J. Opt. Soc. Am. A Opt. Image Sci., 22, 2442– 2453 (2005).

Coupling to MODTRAN®

- BRDF is coded in FORTRAN in MODTRAN® 5
- Fourier moments are computed
  - Input in DISORT
- DISORT multiple scattering uses BRDF as a lower boundary condition

Other modeling considerations

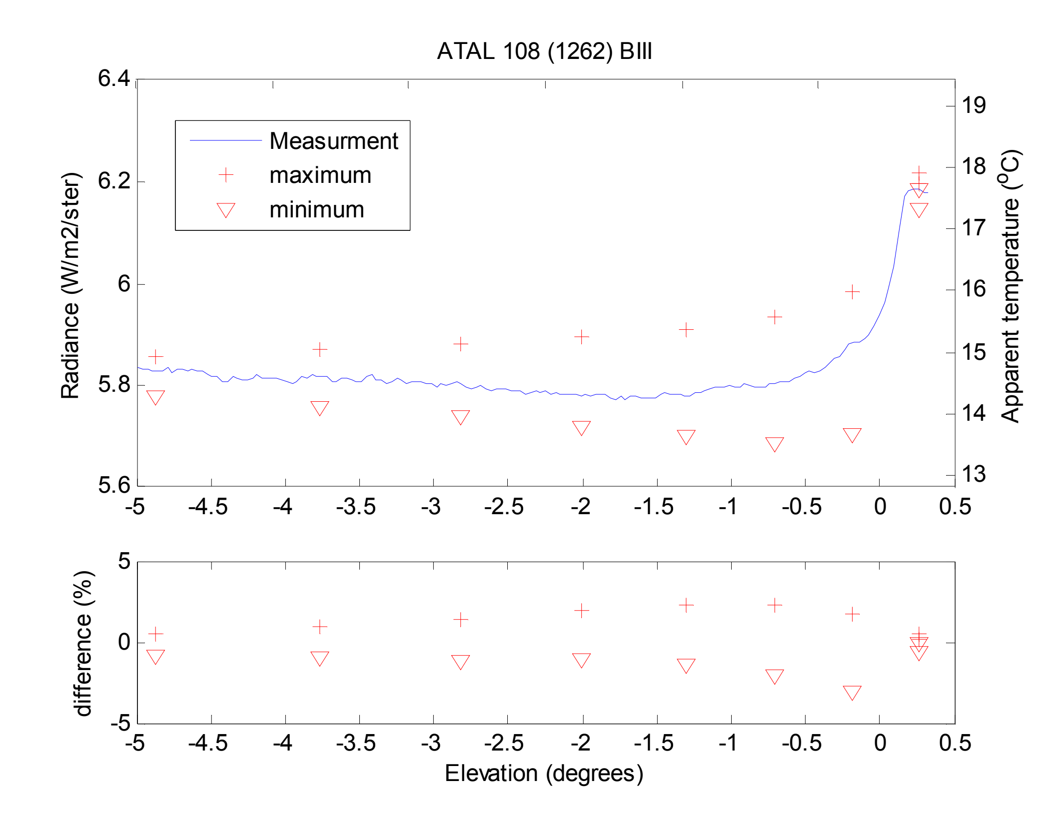
- Marine aerosols are computed using MEDEX
  - Well suited for the Mediterranean
  - Input in MODTRAN® using the SAP input
- MBL (marine boundary layer) thermodynamic profiles are computed using the DRDC "AP" module
  - Monin-Obukhov similarity theory
- Refracted optical path are input
- Sea surface statistical properties: Elfouhaily et al.
  - Fetch, atmospheric stability

The MIRAMER campaign

- From May 13th to May 18th
- In the Mediterranean sea near Toulon, France
- 2 Cedip Jade (Flir ATS) cameras on board the Atalante ship
  - 3.4 – 5.5 μm (3.93 – 4.14 μm filter for glint)
  - 8.19 – 8.96 μm
- Good environmental characterization
  - Radiosondes (2-3 day)
  - Local meteorological measurements
    - Air and sea temperature
    - Wind speed/direction
    - Relative humidity
  - Visibility meter (aerosols)
  - Aeronet station nearby (Toulon)
  - Solar pyranometer (solar irradiance)

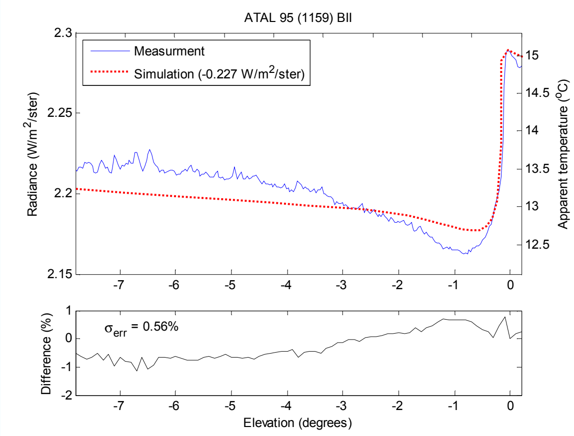
Experimental and modeling uncertainties

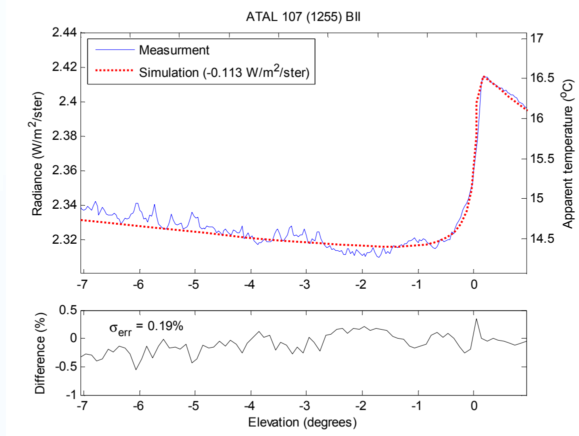
- Experimental
  - Image calibration and limited dynamic range
    - Can reach 20% but probably lower (4-5%)
  - Horizontal variations (temperature, etc.) not measured
    - Temperature +/- 1°
  - Wind gusts
  - Bulk vs. skin temperature
    - +/- 1°
- Modeling
  - Slope statistics values
    - 80% between models
  - Aerosol modeling
  - Multiple reflections
  - Cirrus clouds

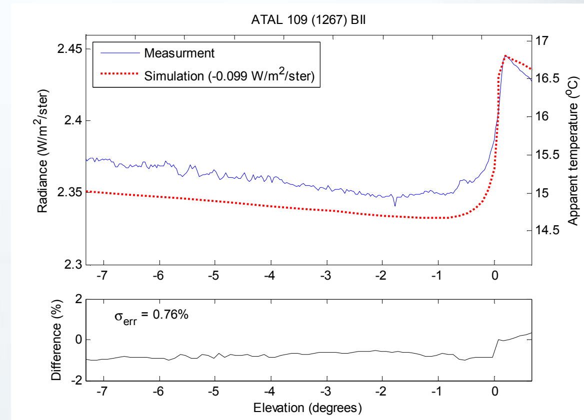


Results

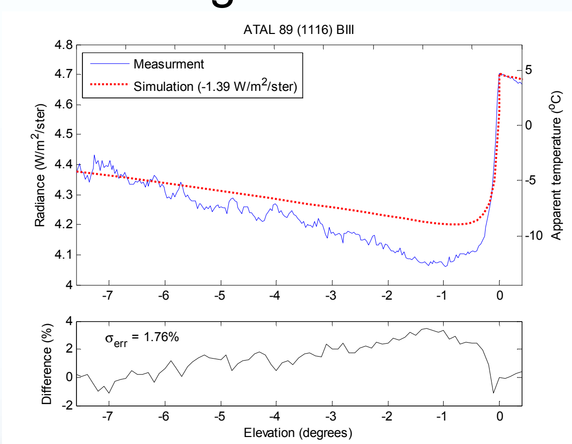
- Non glint
  - Midwave

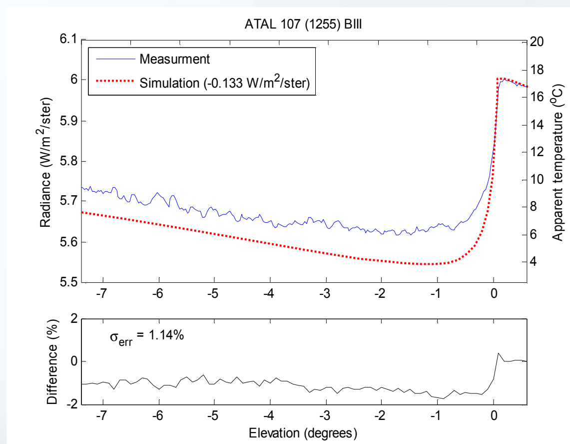


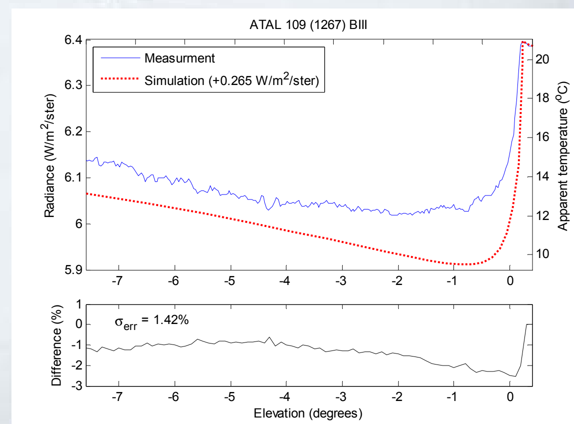




  - Longwave

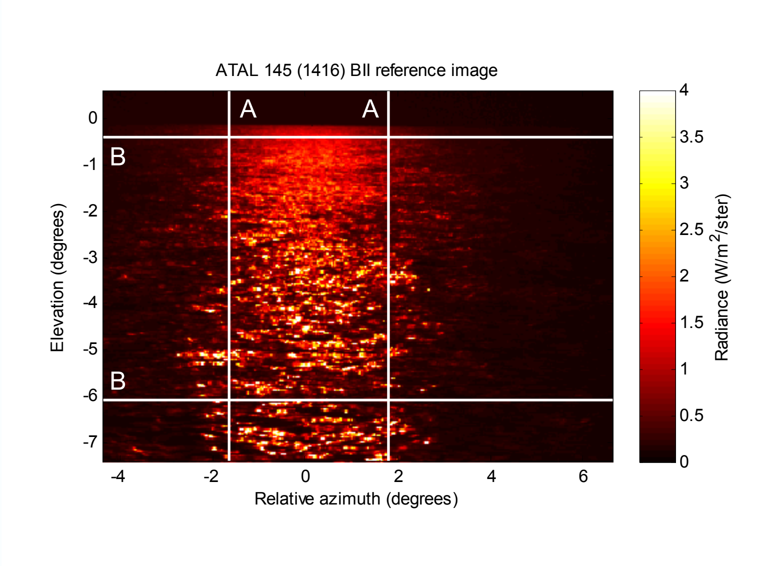


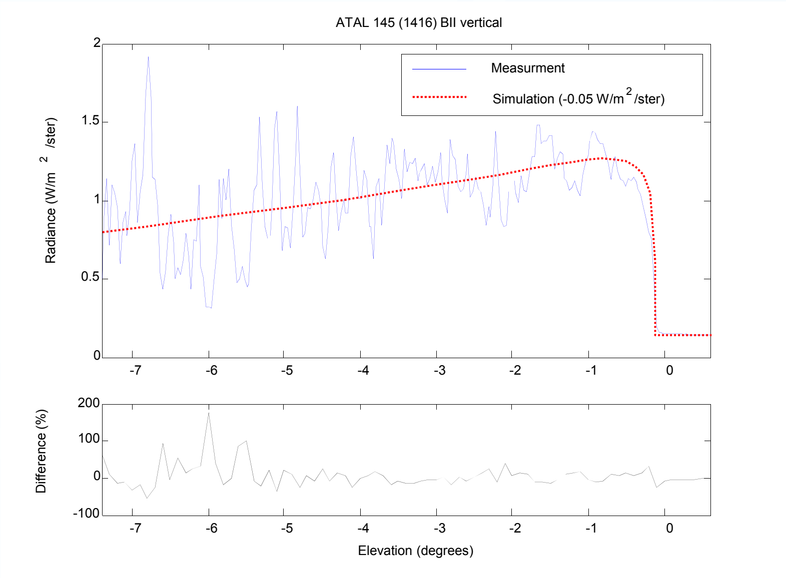


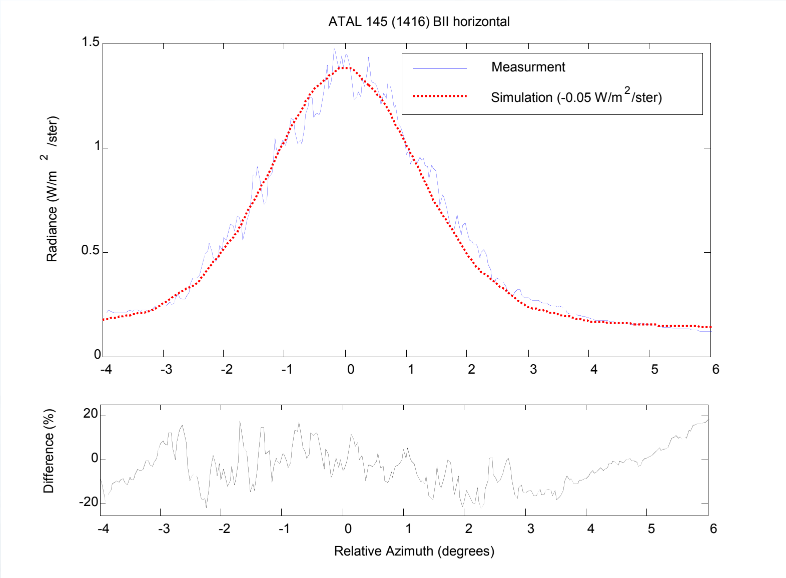


Results

- Glint







(Note: Cirrus cloud modeled using Aeronet AOD data)

Results

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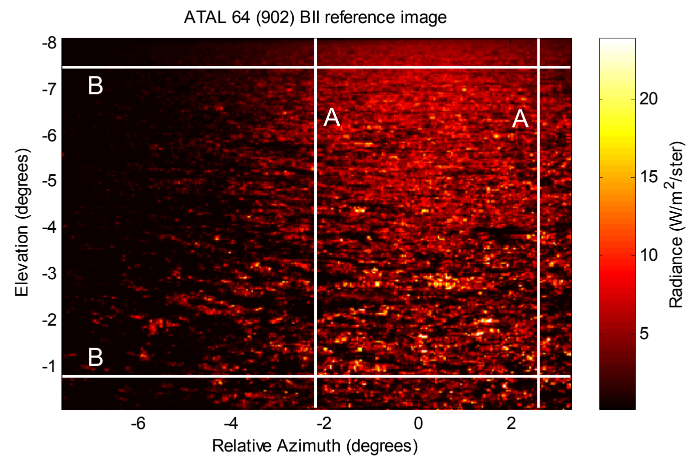
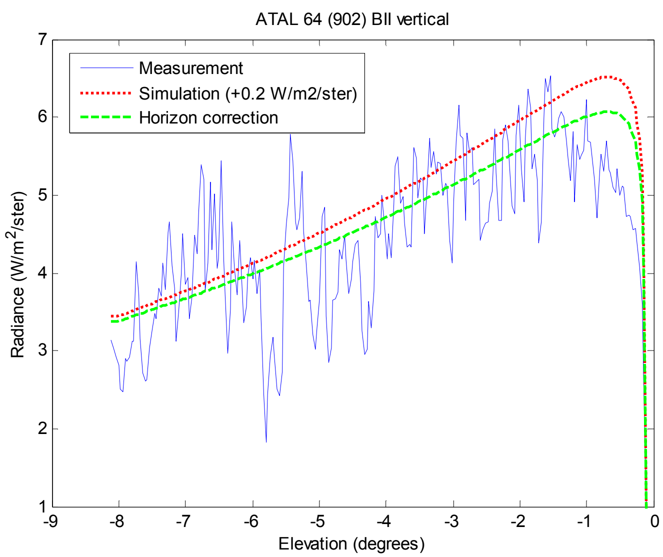
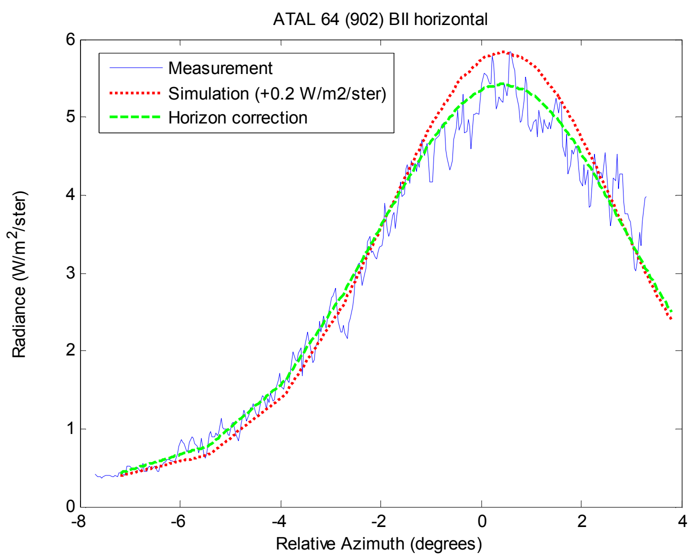
- Glint







Ross, V., Dion, D., "Sea surface slope statistics derived from Sun glint radiance measurements and their apparent dependence on sensor elevation, J. Geophys. Res., 112, C09015, (2007)

Conclusion

- A radiatively coupled sea surface BRDF is important in maritime environment radiative transfer
- MODTRAN® 5 v? will introduce a coupled sea surface BRDF
  - And many other useful features
  - Soon to be released
- Validation against MIRAMER radiometric images shows promise
  - Simulations and measurements agree well within experimental uncertainties
  - No systematic errors

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