Sunglint contamination of sea surface temperatures measured at infrared wavelengths

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Introduction

- Interim report of study by A. Zavody of the effects of sun-glint on the 11 and 12 micron channels of ATSR-2.
- Although effect of reflected solar radiation at 11 and 12 micron is small, doubts have sometimes been expressed as to the validity of radiometer retrievals in sun-glint conditions
- Objectives
  - Quantify sun-glint effect at 11 and 12 microns
  - Look for evidence of it in the data
  - Propose a correction scheme if appropriate

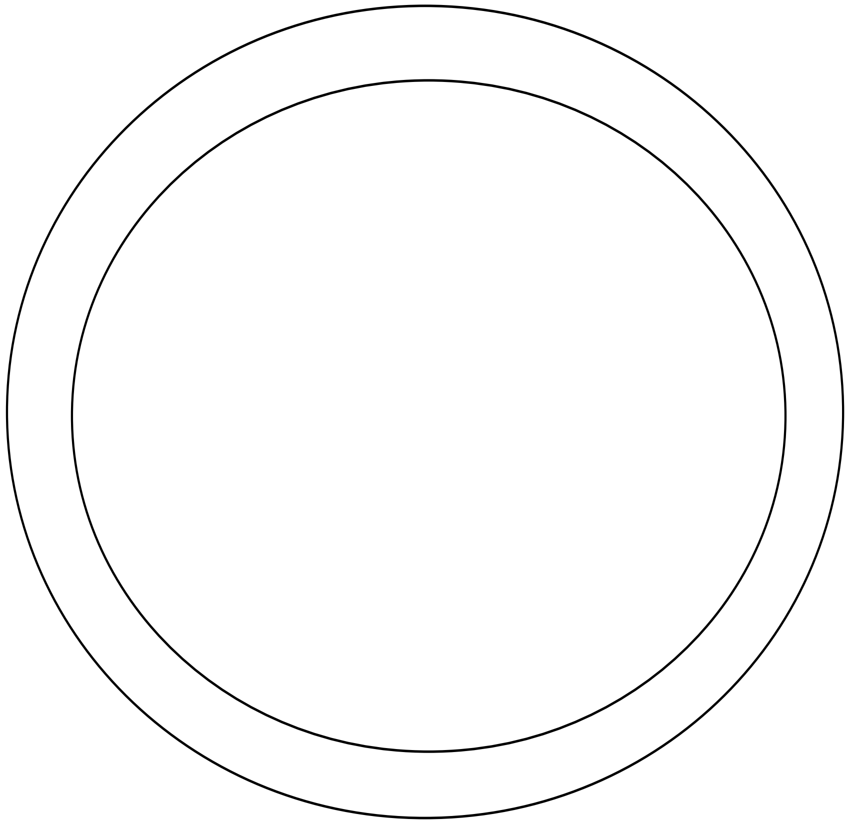
Previous Studies

- Sun-glint is known to affect the 3.7 micron channel. Previous work by Zavody et al (1998) showed that sun-glint effect at 3.7 micron can be used to predict that at 1.6 micron
  - Zavody, A. M., Watts, P. D., Smith, D. L. and Mutlow, C. T., 1998, A novel method for calibrating the ATSR-2 1.6-um channel using simultaneous measurements made in the 3.7-um channel in sun glint, J. Atmos. Oceanic Technology, 15, 1243-1252
- Conversely, it is therefore possible to deduce the effect at infra-red wavelengths from the measured 1.6 micron reflectivity
- Established the techniques for the present work

Geometrical Effect

- Sun-glint: solar energy reflected from the ocean surface when an image of the sun falls in the field of view
- Predominant scattering mechanism is specular reflection
- Angular distribution of reflected power depends on probability distribution of surface slopes, and is independent of wavelength
- We can deduce the spatial distribution of reflected solar energy in the infra-red channels from the calibrated reflectance in the 1.6 micron (or visible) channels

Sunglint on ATSR-1/2 images



Method

- Select cloud-free ATSR-2 images from sun-glint regions and identify those having cloud-free pixels with 1.6 μm reflectance > 50%
- 15 of (more than) 145 images examined were found to be suitable for further analysis
- If sun-glint effects are present in the long wavelength channels, the (glint - non-glint) view difference at 11 or 12 microns will be dominated by the reflected solar signal. Pixel differences will correlate with the 1.6 micron reflectivity
- Two secondary effects had first to be corrected:
  - 1.6 micron channel saturation
  - Path length effect

1.6 micron channel saturation

- 1.6 micron channel may saturate in low wind speed conditions
- 0.56 micron channel saturates much later, and if present may be used to correct the data
- A quadratic function is fitted to the 1.6 micron vs 0.56 micron data where both are valid
- This relationship is used to correct the 1.6 micron channel where it is saturated
- The 0.56 micron channel saturates later than the 1.6 micron channel primarily owing to higher extinction by scattering

Path Effect

- Correlation between the 11 or 12 micron view difference and 1.6 micron reflectivity may occur in the absence of sun-glint
- This is because the view difference and the 1.6 micron reflectivity are separately correlated with the pixel across-track distance
  - The reflected solar energy is displaced towards the east side of the image. The reflectivity thus increases towards the eastern edge of the swath
  - As one moves from the centre of the swath to the edge, the nadir view path lengthens while that in the forward view shortens. The differential path, and hence the view difference, is thus correlated with across-track position

Correction for path effect

- The path length effect was corrected as follows:
- A precomputed look-up table, based on US standard atmospheres gave the following brightness temperature differences in terms of water vapour loading and sea - air temperature difference:
  - nadir_11 - nadir_12
  - nadir_11 - frwrd_11
  - nadir_11 - frwrd_12
- This table was used to estimate the water vapour loading and sea - air temperature difference characteristic of the image
- The RTM nRADGEN was run with the standard atmosphere and parameters thus found to derive model brightness temperatures as a function of air mass. The channel and view differences found from this model were used to correct the pixel data in the scatter plots

Data Processing

- Plots of view and channel difference vs 1.6 micron reflectivity were prepared
- Plots were generated both with and without the path length correction
- The slopes of the best fitting lines were determined using only pixels having reflectivity greater than some threshold
- Correlations are observed in the non-glint view channel difference. The origin of these is uncertain at present

Modelling

- The theoretical 11 and 12 micron effect was calculated from the 1.6 micron effect using

$$\Delta r(\lambda) = I_0(\lambda)\left(\frac{R_\lambda}{R_{1.6}} \cdot \frac{\hat{R}_{1.6}}{\tau_{1.6}}\right)\tau_\lambda / \pi$$

- where

$I_0(\lambda)$ is the solar irradiance at wavelength λ

R_λ is the surface reflectivity at wavelength λ

τ_λ is the path attenuation in the atmosphere at wavelength λ

$\hat{R}_{16}$ is the measured (TOA) reflectance at 1.6 μm wavelength

Results (11 μm forward view)

H2O	Computed slope (mK/%)	Observed slope (mK/%)	Anomalous slope (mK/%)	Observed corrected
17.4	-1.12	-2.61	-1.24	-1.60
8.7	-1.63	-5.01	-1.71	-3.62
13.9	-1.35	-0.82	4.76	-2.88
13.0	-1.24	0.18	4.33	-3.33
10.4	-1.22	-1.96	1.09	-2.84

Inclusion in retrieval scheme

- For each channel and view, empirical expressions for glint slope as a function of precipitable water *ppw* have been derived: eg

$$\delta T_{11}^{N} = (1.8 - 0.0338 \times ppw)\hat{R}_{1.6}$$

- for the 11 micron channel, nadir view
- These equations may form the basis of a correction if *ppw* is estimated from the brightness temperatures, and if the 1.6 micron channel is unsaturated
- Alternatively, it may suffice to flag affected data: retrieved temperatures may be flagged as affected by glint if
  - sun-glint flag is set, and
  - 1.6 micron channel is saturated

Conclusions

- Observations show correlations in high glint conditions that are consistent with sunglint effects on the 11 and 12 micron channels
- These correlations are consistent in order of magnitude with theoretical expectation
- The effect is of the order of 0.2 K in extreme cases. This is small, but may be worth flagging or correcting
- The correction proposed can be used routinely only if the 1.6 μm channel is not saturated. Otherwise SST retrieval should be flagged
- For AATSR, the 0.56 μm channel is available everywhere so may be used. (Note that the 0.56 μm channel can saturate in very strong glint)
- Correlations are seen in the non-glint view. These cannot be due to sun-glint, but are presently unexplained