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Analysis of along track scanning radiometer-2 (ATSR-2) data for clouds, glint and sea surface temperature using neural networks

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Abstract

Improved oceanic cloud climatologies and more accurate sea surface temperature (SST) from satellite data (e.g., the Along Track Scanning Radiometer-2 (ATSR-2)) depend upon the identification, and in the case of SST, masking of cloud from the data. Few cloud-screening algorithms for ATSR-2 data, however, have been published. This is unfortunate because, unlike the original ATSR (hereafter referred to as ATSR-1), ATSR-2 has three bands of visible data in addition to its traditional suite of near-to-far thermal infrared bands. A new neural network-based cloud detection algorithm, which accommodates both the nadir and forward views of the ATSR-2, is presented. It evaluates every pixel in the scene, is statistically reproducible, computationally efficient, and requires no knowledge of cloud type. Moreover, the algorithm accurately detects glint radiance, which is often seen in at least one of the 1.6 μm (and/or visible) views, subpixel cloud near cloud boundaries, low-lying marine stratiform cloud, and does not misinterpret actual ocean thermal gradients as cloud. These latter issues have interfered with many SST retrievals in the past. Dual view/dual channel SST retrievals were derived and validated against buoy data (1 m depth). RMS error between retrieved SST and the buoy data is typically about 0.3 K in regions of minimum SST gradient. Pre-processing of the data is done prior to analysis because some artifacts not seen in ATSR-1 data can seriously compromise both cloud detection and SST retrieval. Detailed comparison between the ATSR operational cloud detection scheme and that developed herein, based upon 1077 scenes, shows that the operational product consistently misinterprets regions of cold but cloud-free oceanic thermal gradient as cloud, leading to a sampling-related warm bias in many of the operational SST products. The basis for this misinterpretation has been identified and quantified. Thus, the operational cloud detection scheme may have to be revised if a fully representative global ocean SST dataset is to be obtained from ATSR data.

Keywords: ATSR-2; Sea surface temperature; Cloud detection; Climate; Oceanography

1. Introduction

Accurate, efficient and automatic detection of clouds in satellite data over the world's oceans is essential for many scientific applications. Small changes in cloud cover, for example, can have the same effects on planetary temperature as doubling/halving the atmospheric CO_2 concentration (IPCC, 1996). Clouds are also a key element in hydrometeorological cycles because they are the focal point in the conversion of water vapor to rain and snow. The importance of accurate cloud detection and retrieval of quality insolation estimates from satellite data at high temporal (hourly or less) and spatial (1 km or less) resolution for improving hydrologic streamflow model prediction has recently been demonstrated (Simpson et al., 2004).

Sea surface temperature (hereafter called SST) profoundly influences weather and climate. Indo-Pacific SST, for example, is related to the Madden–Julian Oscillation (MJO) which affects the Asian monsoon (Soman & Slingo, 1997). SST is also used to predict the genesis and intensity of tropical cyclones (Emanuel, 1999; Saunders & Harris, 1997). Unfortunately, undetected cloud (e.g., low-lying marine stratiform cloud (LMSC), subpixel cloud) in a

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satellite scene is often a significant source of residual error in SST, even from improved sensors such as the Along Track Scanning Radiometer, ATSR (Harris et al., 1995; Jones et al., 1996a,b; Simpson et al., 1998).

Better cloud detection will: 1) improve the reliability of satellite-based oceanic cloud climatologies where alternative cloud observing systems are impractical; 2) provide more accurate satellite-derived SST retrievals needed for both numerical weather prediction and climate studies; and 3) enhance understanding of the oceanic mixed layer and air–sea exchange processes.

A new neural network-based cloud detection procedure for ATSR-2 data is developed. It accommodates nadir and forwards views. Glint (enhanced Fresnel reflection off the sea surface) is treated as a separate class because if glint-contaminated (but cloud-free) pixels are incorrectly included in the cloud class, then cloud cover amount reported in satellite-based oceanic cloud climatologies will be over-estimated. Moreover, glint generally does not preclude a valid SST retrieval if only the far thermal infrared (11 and 12 μm) data are used. Excluding glint-contaminated but cloud-free pixels limits SST climatologies, especially in persistently cloud covered regions (e.g., Indonesian Seas, see Merchant et al., 2003).

Pre-processing is done because some artifacts (e.g., Fig. 1), not seen in ATSR-1 data, exist in ATSR-2 data. Most, but not all, of the artifacts are features of the data compression schemes applied to the visible channels. They can seriously compromise the intended applications. Such artifacts did not occur with ATSR-1 data because that instrument did not have visible channels. A dual view dual channel SST is computed and validated with in situ buoy data. Comparisons with Rutherford Appleton Laboratory (RAL) operational products (e.g., Bailey, 1993; Zavody et al., 2000) are given. Night-time cloud detection is not discussed herein because the night-time cloud detection method for ATSR-1 data (see Simpson et al., 1998) applies equally well to ATSR-2 data as the data from both instruments are nearly identical at night.

2. The along track scanning radiometer-2 (ATSR-2) instrument

ATSR-2 is a second generation radiometer designed to produce climate quality SST. Like ATSR-1, ATSR-2 has 1.6 μm (short wave infrared), 3.6–3.9 μm (mid-infrared), and two thermal infrared (10.3–11.3 and 11.5–12.5 μm) channels. ATSR-2 also has three relatively narrow-band (20 nm wide) visible channels centered at 0.55, 0.65 and 0.87 μm. They provide additional constraints for glint and LMSC detection. Pixel size is about 1 km at nadir. A small swath width (about 500 km) compared to that of larger swath width (>2000 km) instruments like the Advanced Very High Resolution Radiometer (AVHRR) also improves navigational accuracy because off-nadir pixel distortion is minimized (Bailey, 1993), but the conical scan pattern does render the geometric calculations more complex.

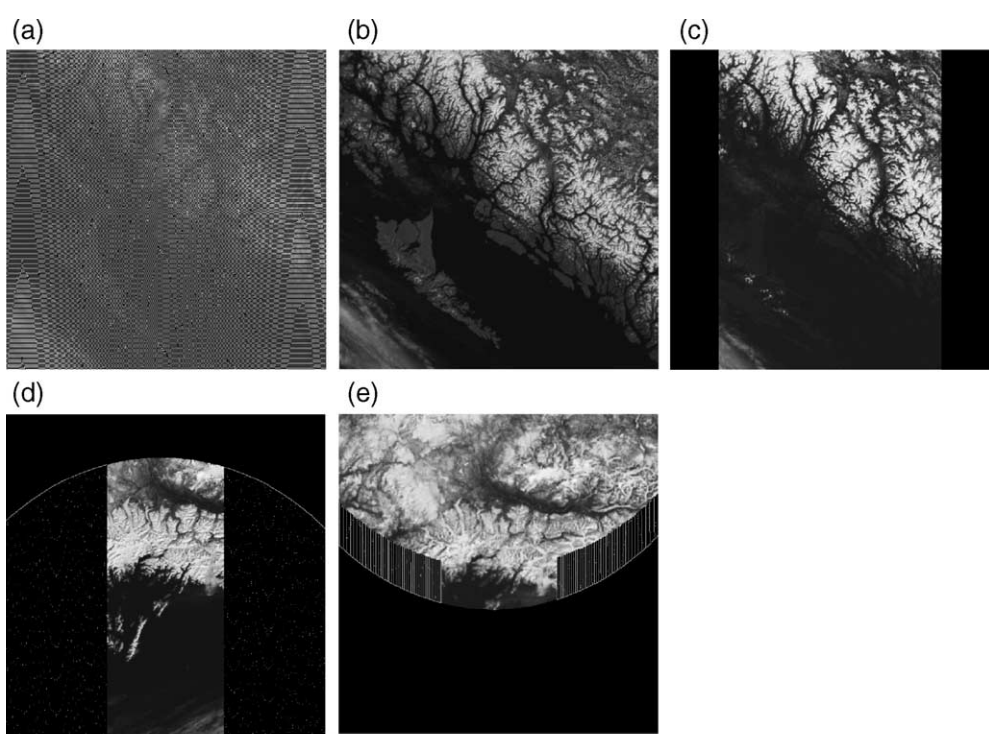

Fig. 1. (a) 0.87 μm forward view with invalid data. White/grey regions are valid data. (b) Analogous to panel a, except for nadir view. No invalid data occur. (c) 0.55 μm nadir view with a different pattern of invalid data (d) 0.65 μm nadir view with a large portion of invalid data in a “sweep” pattern. Invalid data also occur on the sides. (e) 0.65 μm forward view analogous to panel d.