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INFRARED ALGORITHM DEVELOPMENT FOR OCEAN OBSERVATIONS WITH EOS/MODIS

Abstract

Efforts continue under this contract to develop algorithms for the computation of sea surface temperature (SST) from MODIS infrared retrievals. This effort includes radiative transfer modeling, comparison of *in situ* and satellite observations, development and evaluation of processing and networking methodologies for algorithm computation and data accession, evaluation of surface validation approaches for IR radiances, and participation in MODIS (project) related activities. Efforts in this contract period have focused on radiative transfer modeling, evaluation of atmospheric correction methodologies, involvement in field studies, production and evaluation of new computer networking strategies, and objective analysis approaches.

MODIS INFRARED ALGORITHM DEVELOPMENT

A. Near Term Objectives

A.1. Continue algorithmic development efforts based on experimental match-up databases and radiative transfer models.

A.2. Continue interaction with the MODIS Instrument Team through meetings and electronic communications.

A.3 Continue evaluation of different approaches for global SST data assimilation and work on statistically based objective analysis approaches.

A.4 Continue evaluation of high-speed network interconnection technologies.

A.5 Continue evaluation of various *in situ* validation approaches for the MODIS IR bands.

A.6 Provide investigator and staff support for the preceding items.

B. Overview of Current Progress

B.1 July-December 1995

Activities during the past six months have continued on the previously initiated tasks. There have been specific continuing efforts in the areas of (a) radiative transfer modeling, (b) generation of model based retrieval algorithms, (c) continued work on IR calibration/validation as part of the MODIS Ocean Science Team cruise effort, and (e) work on test and evaluation of an experimental wide area network based on ATM technology. Previously initiated activities such as team related activities are ongoing.

Special foci during this six month period have been:

1) completion of the first draft of the MODIS Oceans Infrared Validation Plan,
2) laying the foundations for a DOE/NOAA/NASA ARM joint cruise in the Tropical Western Pacific in the spring of 1996,
3) exploring the potential sources of radiosondes to compile a global marine data set that correctly represents the distributions of conditions in the atmosphere,
4) initiating a study of the probability distribution of near-surface diurnal gradients in the global ocean, and,
5) writing the SST sections of the EOS Science Plan (and have been submitted to Dr. Rothrock for inclusion in the draft document).

In early November Dr. R. Sikorski joined the team in a post doctoral position. He is currently working on the compilation of a marine radiosonde database and will do some of the radiative transfer simulations.

B.1.1 Radiative Transfer Modeling

Initial work is underway to examine correction approaches based on fast-forward codes and those based on EOF decompositions of atmospheric profiles with exact forward calculated coefficients. It is currently unclear whether computer capability will permit implementation of the fast, forward RTE-based correction approach for routine atmospheric correction of MODIS retrievals.

The RAL radiation transfer code is being rewritten to extend its spectral coverage to include the MODIS infrared channels, to improve its performance on Digital ÒAlphaÓ machines, and to permit it to provide profiles of channel radiance through the atmosphere. Discussions have continued between P. Minnett and A. Z‡vody concerning enhancements to the RTE radiative transfer simulation code. Z‡vody has agreed to furnish up-to-date spectral data to permit the simulationÕs use over the complete MODIS-IR band set, but as yet this has not been completed.

B.1.2 Algorithm Development Efforts Based on Experimental Match-up Data bases

The main objective of our recent work is to explore the associations between atmospheric water vapor content and various AVHRR-derived quantities. Insight gained on the nature of these associations will allow us to better understand the performance of existing SST algorithms, as well as to improve the parameterization of various terms in such algorithms. The difference in brightness temperatures in AVHRR channels 4 and 5 is the quantity most often used as a proxy for atmospheric effects. Therefore, during this period we have dedicated considerable attention to exploring the association between this quantity and water vapor, including the effects of AVHRR viewing geometry, geographic location, and season

Simultaneously, studies were conducted to improve ÒclearingÓ of potentially contaminated retrievals from imagery and the comparison database. It was found that the database was contaminated by a number of Ò0CÓ values from the NOAA TAO buoys (they use Ò0CÓ to denote a missing observation).

The distribution of buoy positions in the satellite-buoy comparison data base is strongly biased away from high latitudes, having hardly any values north of 50^{o} N. Polar and sub-polar regions represent an extreme in the atmospheric conditions, and it is known that atmospheric correction algorithms optimized for global conditions perform less well here than at mid-latitudes. This is suspected to be because, even though the low water-vapor burden of the high-latitude atmospheres makes them more transmissive, the spectral gradient in the 10-12 {symbol 109 \f "Symbol" \s 12}m window becomes increasingly the result of that of the surface emissivity and less of that of the atmospheric water vapor effects. To study this using the AVHRR retrieval and drifting-buoy temperature data base, it is necessary to increase the population of high-latitude samples. The NATO SACLANT Undersea Research Centre in La Spezia, Italy, has conducted research in the Nordic (Greenland, Icelandic and Norwegian Seas) for many years and has deployed more than one hundred drifting buoys in that area. Data from this drifting buoy program were made available by Dr. P.M. Poulain, and the trajectories of the buoys are shown in Figure 1. After quality control, nearly 150,000 records of buoy position and surface temperature are now awaiting to be merged with the corresponding AVHRR data and be incorporated into the database of AVHRR-buoy comparisons. These buoy data are also being incorporated into the WOCE Surface Velocity Program (SVP) database by the NOAA Atlantic Oceanographic and Meteorological Laboratory.

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Figure 1. Trajectories of the buoys deployed by the NATO SCALANT Undersea Research Centre in the Nordic Seas. The period covered is mid-1991 to 1994.

Latitude-time diagrams of zonal averages of the differences between AVHRR and ReynoldsÕ composite SST fields for the years 1990-1993 have revealed some intriguing differences. Discrepancies fall in the range of ±1.5K with extreme positive values appearing at high latitudes in the summer season, with the northern hemisphere being more effected, and with a coherent seasonal migration between the hemispheres. A secondary band of extreme positive values is found in the tropics. It is hypothesized that these are caused by either diurnal gradients in the near-surface layers, or by residual atmospheric water vapor contamination.

B.1.3 Wide Area Networking

A network between heterogeneous machines, switches and adapters (FORE, SGI and DEC) has been implemented and is in use in a production environment. This configuration routinely carries 40-60 Gigabytes of traffic per day. Tasks include disk-to-disk, disk-to-tape and tape-to-disk transfers.

B.1.4 *In Situ* Calibration/Validation of MODIS IR Radiances

An offer for joint work with DOE and NOAA investigators has been accepted to make measurements using a prototype M-AERI (Marine-Atmospheric Emitted Radiance Interferometer; Revercombe *et al*., 1993; Smith *et al*., 1996) on a research cruise of the NOAA R/V Discoverer in the Tropical Western Pacific from mid-March to mid-April 1996. The cruise, called the *Combined Sensor Cruise,* brings together an unprecedented selection of sensors to characterize the marine atmosphere. This cruise is in a region of extreme sea and atmospheric conditions. In addition to providing measurements for the validation of the atmospheric corrections used with existing satellite infrared radiometers (AVHRR, ATSR, GMS), this cruise will enable us to test strategies and tactics for the validation of MODIS infrared measurements and SST retrievals. It also facilitates measurement of the sea-surface emissivity at the extreme of environmental conditions. The dependence of sea-surface emissivity on external parameters (especially wind speed; *e.g.* Masuda *et al*., 1988) will be measured, and the cruise will provide data with which to study the diurnal thermocline and the skin effect. It also provides us with the opportunity to test a prototype M-AERI at sea before the contractual delivery date, so that potential difficulties can be identified and corrected. Funding to participate in the cruise has been secured from the DOE ARM (Atmospheric Radiation Measurements) Program, and additional funding to enhance the instrument suite with an all-sky camera and broad-band infrared radiometric thermometer to characterize the cloud fields and to support extra data analysis has been requested from NASA. Equipment used during the Pelican cruise (please refer to previous reports; Smith *et al*., 1996) is currently being refurbished for this cruise.

B.1.5. Diurnal thermocline study

A study of the global probability distribution has begun using monthly-averaged U.S. Navy ÔclimatologyÕ of the surface parameters, and monthly ERBE surface insolation fields. The spatial resolution of the data used in this study is 1^o. The winds, given as means and standard deviations, have been recast into the shape and scale factors of the Weibull distribution, and this allows the calculation of probabilities of winds being above or below given values. The ERBE measurements have been interpolated to match the wind fields resolution. SST, air temperatures and surface humidities will be extracted from the Navy climatology, and other parameters that are necessary to drive a diurnal thermocline model (e.g. Price et al., 1986) will be calculated. Results from this study will assist in the interpretation of the discrepancies between in situ and satellite derived SSTs, and guide strategy formulation for the validation of MODIS SSTs.

B.1.6 MODIS IR Validation Plan

The first version of the MODIS-Infrared Sea Surface Temperature Algorithm, Science Data Validation Plan has been written and submitted. A copy can be obtained using the World Wide Web on URL http://www.rsmas.miami.edu:80/modis/ in both *ps* and *pdf* formats. The document discusses the need for, and requirements of, an extensive validation strategy to ensure confidence in the MODIS infrared measurements and derived sea-surface temperature fields. The approach recommended includes validation of top-of-the-atmosphere radiances, surface radiances and surface temperatures, using a variety of methods, instruments and platforms. These include radiometers or other satellites, high-flying and low-flying aircraft, ships and research platforms. Both highly-focused, intensive measurement campaigns to study the physical processes at the ocean surface and in the atmosphere that influence the MODIS measurements, and long-term global-scale monitoring of the MODIS data will be required. Synergism and collaboration will be sought with groups involved in the validation of MODIS ocean color and atmospheric properties derived from EOS instruments.

The Validation Plan will be revised when appropriate to take into account new and relevant findings, and to document new collaborative opportunities that are pertinent to the MODIS AM-1 infrared validation activities.

C. Investigator Support

July	J. Brown V. Halliwell A. Li	D. Li P. Minnett	**Oct.**	J. Brown G. Goni	A. Li D. Li
August	W. Baringer J. Brown P. Evans G. Goni	V. Halliwell A. Li D. Li P. Minnett	**Nov.**	W. Baringer O. Brown P. Evans	V. Halliwell A. Li
Sept.	W. Baringer J. Brown P. Evans	G. Goni A. Li D. Li	**Dec.**	W. Baringer P. Evans	V. Halliwell A. Li

D. Future Activities

D.1 Current:

D.1.1 Algorithms

a. Continue to develop and test algorithms on global retrievals
b. Evaluation of global data assimilation statistics for SST fields
c. Continue radiative transfer modeling using RAL code
d. Participate in Combined Sensor Cruise, and analyze data
e. Continue to study near-surface temperature gradients

f. ATBD updates (as needed)
g. Validation Plan updates (as needed)
h. EOS Science Plan updates (as needed)
i. Define and implement an extended ATM based network test bed
j. Evaluate and analyze results of calibration/validation experiment
k. Continued integration of new workstations into algorithm development environment

D.1.2 Investigator support

Continue current efforts

E. Problems

No new problems to report.

F. Publications

None to report.

G. References:

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