# APPLICATION OF MERGED MICROWAVE GEOPHYSICAL OCEAN PRODUCTS TO CLIMATE RESEARCH AND NEAR-REAL-TIME ANALYSIS

Frank J. Wentz, Seung-Bum Kim, Deborah K. Smith, and Chelle Gentemann

Remote Sensing Systems, USA, kim@remss.com

ABSTRACT: The DISCOVER Project (Distributed Information Services for Climate and Ocean products and Visualizations for Earth Research) is a NASA funded Earth Science REASoN project that strives to provide highly accurate, carefully calibrated, long-term climate data records and near-real-time ocean products suitable for the most demanding Earth research applications via easy-to-use display and data access tools. A key element of DISCOVER is the merging of data from the multiple sensors on multiple platforms into geophysical data sets consistent in both time and space. The project is a follow-on to the SSM/I Pathfinder and Passive Microwave ESIP projects which pioneered the simultaneous retrieval of sea surface temperature, surface wind speed, columnar water vapor, cloud liquid water content, and rain rate from SSM/I and TMI observations. The ocean products available through DISCOVER are derived from multi-sensor observations combined into daily products and a consistent multi-decadal climate time series. The DISCOVER team has a strong track record in identifying and removing unexpected sources of systematic error in radiometric measurements, including misspecification of SSM/I pointing geometry, the slightly emissive TMI antenna, and problems with the hot calibration source on AMSR-E. This in-depth experience with inter-calibration is absolutely essential for achieving our objective of merging multi-sensor observations into consistent data sets. Extreme care in satellite inter-calibration and commonality of geophysical algorithms is applied to all sensors. This presentation will introduce the DISCOVER products currently available from the web site, http://www.discover-earth.org and provide examples of the scientific application of both the diurnally corrected optimally interpolated global sea surface temperature product and the 4x-daily global microwave water vapor product.

**KEY WORDS:** multi-sensor, microwave, sea surface temperature, water vapor.

## 1. INTRODUCTION

DISCOVER (Distributed Information Services for Climate and Ocean Products and Visualizations for Earth Research) is a NASA Earth Science REASoN project. The primary objective of the DISCOVER Project is to provide highly accurate, long-term ocean and climate products suitable for the most demanding Earth research applications via easy-to-use display and data access tools. A key element of DISCOVER is the merging of data from multiple sensors on multiple platforms into geophysical data sets consistent in both time and space. The resulting products include daily sea-surface temperature and rain rates as well as 4x-daily ocean surface wind, atmospheric water vapor, and cloud water. The information technology focus of DISCOVER is on providing online services for data access, ordering and visualization of the project's data products and information. DISCOVER is a collaboration of Remote Sensing Systems (RSS), the Global Hydrology & Climate Center (GHCC) and the University of Alabama in Huntsville (UAH). The GHCC and UAH are developing the information technology aspects of the project.

In order to provide highly accurate, long-term satellite retrievals useful in climate studies, extreme care in satellite inter-calibration and a common geophysical algorithm applicable to all sensors is required. RSS has a strong track record of identifying and removing unexpected sources of systematic error in radiometric measurements and has just completed an extensive inter-calibration of all sensors and update of retrieval algorithms as described in Section 2. All satellite data (SSM/I, TMI, AMSR-E) have been reprocessed, validated and are accessible, along with the merged DISCOVER products through the DISCOVER web site. The data products are distributed via easy-to-use display and data access tools and most of the products are released in near real-time (3-12 hours) on a 24×7 basis.

## 2. RECENT UPDATES THAT PRODUCE QUALITY CLIMATE DATA RECORDS

We have just completed a significant update to our algorithms and processing procedures. We consider this update to be a very important milestone in our production of Climate Data Records (CDR). Investigators can now confidently use these new satellite datasets for detailed interannual and decadal trend studies. The current satellite data are SSM/I Version 6 (V06), TMI Version 4 (V04) and AMSR-E Version 5 (V05a). The satellite datasets have been completely reprocessed and the new versions, in their entirety, are now available for downloading. Any users doing climate work with our wind speeds or rain rates should definitely replace their earlier versions with SSM/I V06 and TMI V04. We also suggest that the AMSR-E V05a datasets be downloaded to ensure complete consistency among the various datasets. A more extensive description of changes is available on the RSS web site, http://www.remss.com, and two scientific papers (wind and rain) are in preparation that describe in greater detail the new wind and rain products.

The major objectives of the updates were to:

*Remove spurious trends found in the wind speed retrievals.* The intersatellite calibration of the 6 SSMIs at the antenna-temperature ($T_A$) level has been completely

redone. The new SSM/I, TMI and AMSR-E wind retrievals are now consistent with buoys and scatterometers over the past 19-year period (1987-2006).

*Implement a much-improved cloud and rain rate retrieval algorithm.* More realistic freezing level heights and beam-filling corrections have been used in the updated algorithms. As a result, the cloud water and rain rates retrievals are very consistent across all 8 satellite platforms (i.e, 6 SSM/I, TMI, and AMSR-E;). This consistency is also a result of using the same method of $T_A$ resampling for all satellites.

*Achieve better consistency for all retrievals over the 8 satellite platforms.* The geophysical retrieval algorithms and data processing systems have been modified and restructured to bring a higher degree of commonality to the SSM/I, TMI, and AMSR-E. Essentially the same set of algorithms is now used to process all three types of satellite microwave radiometers.

*Make minor improvements in other retrievals, namely SST and vapor.* The geophysical retrieval algorithms required that the $T_A$ measurements from different frequencies all be resampled to a common spatial resolution. In the new algorithms, a precise $T_A$ resampling method is used to optimally interpolate the $T_A$ observations to a common footprint. The technique is now the same for SSM/I, TMI and AMSR-E. Use of the new technique increased the SSM/I cloud water and rain rates making them more consistent with AMSR-E and TMI.

The generation of a CDR for TMI was particularly challenging due to the following problems:

a. The vapor-deposited aluminum (VDA) on the TMI antenna either oxidized and/or cracked. As a result the antenna has an emissivity of graphite, which is 3 to 4%.

b. The solar environment for TMI is constantly changing due to its near-equatorial orbit drifting through the diurnal cycle. Furthermore, the solar environment changes radically every month or so when a 180° yaw manoeuvre is completed.

c. In September 2001, the TMI orbit was boosted from an altitude of 350 km to 400 km.

d. There are small errors in the knowledge of the satellite roll and pitch, particularly right after the 2001 orbit boost.

Our new calibration algorithms attempt to correct for all these effects.

## 3. DISCOVER MERGED PRODUCTS

RSS radiometer data are carefully inter-calibrated at the brightness temperature level. This process yields geophysical products from the SSM/I (F08, F10, F11, F13, F14, F15), TMI, and AMSR-E instruments that are consistent across instrument platforms. Data from these radiometers are available for July 1987 through the present, spanning a period of over 18 years. We therefore are in process of producing gridded maps on various time scales (e.g., 4x-daily, daily, weekly, monthly) for a number of the microwave parameters.

### 3.1 Optimal-interpolated sea surface temperature (OISST)

Our Optimal Interpolation daily sea-surface temperature product is currently available on the DISCOVER web site, http:\\www.discover-earth.org (Figure 1). We have developed a simple model that allows us to estimate and remove diurnal fluctuations (Gentemann et al. 2003), which is completed before assimilating SST measurements made by different instruments. The SST product is referenced to a constant early morning local time, at the minimum of the diurnal cycle. This multi-satellite product is a considerable improvement over IR-based coarser resolution (weekly, 100 km) SSTs most often used in applications, and is an improvement over the satellite-based SSTs offered on the RSS web site (see Figure 2).

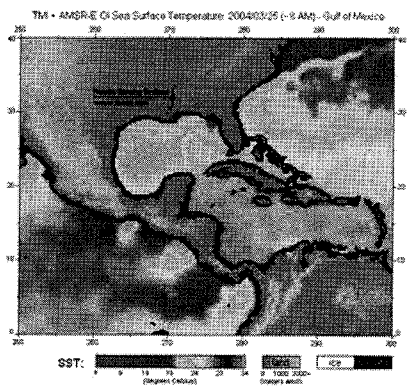


Figure 1. Features Highlighted by Daily Microwave OI SST: Atlantic Gulf Stream, Gulf of Mexico Loop Current, Gap flow causing wind-induced upwelling of cold sea water.

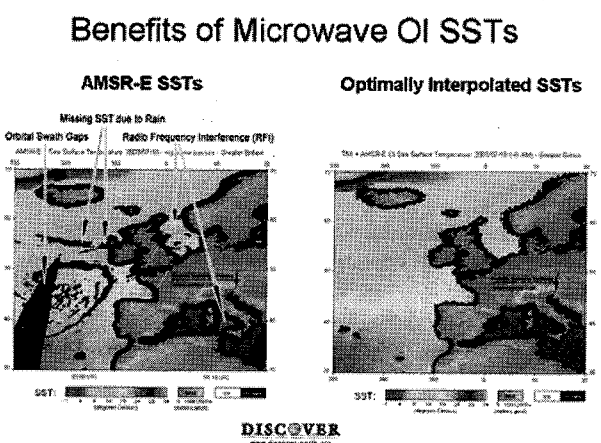


Figure 2. The DISCOVER OISST merged SST product removes data gaps and radio frequency interference.

### 3.2 Water Vapor

A vital part of DISCOVER is the production of merged climate data records of atmospheric water vapor.

Radiometer water vapor values are very well calibrated (Figure 3). The merged product is a 0.25-degree 4x/day global ocean water vapor map without data gaps. The 4x-daily water vapor product will be released now that the newly reprocessed microwave data are available.

We have used the 6-hour water vapor field product to test closure of the hydrological budget. The hydrological equation states that the storage of water vapor plus the divergence of water vapor equals the difference of evaporation minus precipitation. This allows us to use a feature tracking technique on sequential merged water vapor maps to derive water vapor transport from which we can calculate divergence. Our estimates using feature tracking matched evaporation minus precipitation very well.

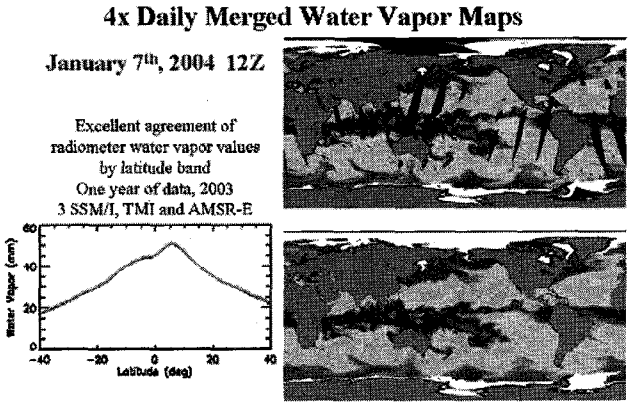


Figure 3. Radiometer water vapor values are very well calibrated. An example of merged water vapor plot is shown on the right for January 7th 2004 12Z.

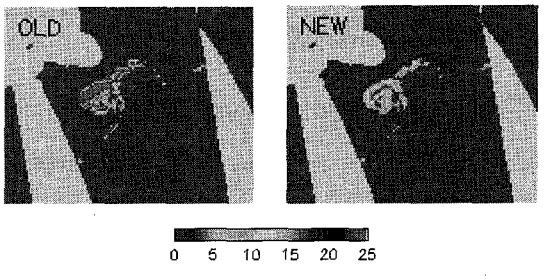


Figure 4. A storm in the North Atlantic viewed by AMSR-E. This shows rain rate from our old algorithm (left) and our new algorithm (right). The major changes are due to the explicit modeling of saturation in our beamfilling correction. These changes are event both in the center of the storm and in the small isolated rain cells.

### 3.3 Rain Rate

Prior to an extensive microwave rain rate analysis, SSM/I rain rates were in disagreement with those of TMI and AMSR-E. We rederived the relationship between rain column height and sea surface temperature (Reynold's SST) using NCEP freezing level heights in raining conditions. The new relationship produces freezing level heights that are more realistic and spatially representative. In addition, we have made two major changes to the beamfilling correction by better handling of the saturation cases and incorporating footprint sizes into the beamfilling correction (in order to bring SSM/I, AMSR-E and TMI rain rates into better agreement). Improved rain rates are shown in Figure 4.

## 4. USERS OF DISCOVER

Our statistics show we have developed a strong user base consisting of NASA and NOAA scientists, researchers and students from US and foreign universities, scientists at independent companies, and foreign government researchers. These users can be categorized into 4 major groups: those using the data for 1) climate research, 2) instrument validation, 3) analysis of regional atmospheric and oceanographic features, and 4) operational forecasting (Figure 5).

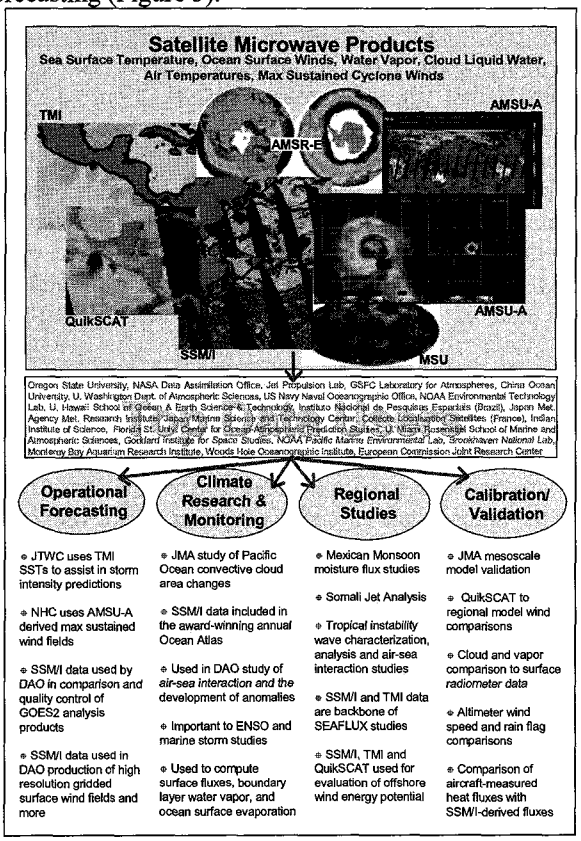


Figure 5. Summary of research and operation efforts served by DISCOVER Products.

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**Reference**:

Gentemann, C.L., C.J. Donlon, A. Stuart-Menteth, and F.J. Wentz, Diurnal signals in satellite sea surface temperature measurements, Geophysical Research Letters, 30 (3), 1140, 2003.