Overview of Atmospheric Radiation Measurement Satellite Cloud and Radiation Products from Langley Research Center

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Introduction

The Atmospheric Radiation Measurement (ARM) Program has a wealth of ground-based instrumentation concentrated in three climatically important regions: the Southern Great Plains (SGP), the Tropical Western Pacific (TWP), and the North Slope of Alaska (NSA). These instruments provide important atmospheric monitoring but cover very little of the Earth's surface. Satellite imager data can be used to retrieve a number of cloud and radiative parameters over large-scale regions. With validation from ground-based instrumentation, satellite-derived datasets can be a valuable asset in climatic studies and complement the surface-based measurements.

National Aeronautics and Space Administration (NASA) Langley Research Center (LaRC) historically provided Geostationary Operational Environmental Satellite (GOES) satellite-derived cloud and radiation datasets to the ARM Archive, covering various intensive operational period (IOPs), and spanning a period of several years. The original dataset, based on the visible (VIS; 0.65 µm) and infrared (IR; 11 µm), was derived using the Layered Bispectral Threshold Method (LBTM; Minnis and Smith 1998). Later advances in the retrieval methodology have led to the development of an improved algorithm that combines the Visible Infrared Solar-Infrared Split-Window Technique (VISST; Minnis et al. 1995, 1998), Solar-Infrared Infrared Split-Window Technique, and Solar-Infrared Infrared Near-

Infrared Technique. For ease of use, we refer to the three new algorithms here as VISST. In addition to the VIS and IR channels, VISST employs as many as three additional channels; 1.6, 3.9, and 12 or 13.3 µm, depending on application and availability, resulting in improved retrieval accuracy.

Data and Domain

Cloud and radiation products are derived using VISST from GOES, National Oceanic and Atmospheric (NOAA) Advanced Very High Resolution Radiometer (AVHRR), and Terra and Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) covering the SGP, TWP, NSA ARM sites along with the ARM mobile facility deployments at Pt. Reyes, California and at Niamey, Niger. The domain definition, the temporal coverage and types of product datasets available for each domain are listed in Table 1.

Table 1. ARM domain and available products from NASA LaRC.

DOMAIN	COVERAGE	PRODUCTS		
		VISST	LBTM	GIF IMAGERY
SGP: (Half Hourly) GOES EAST & WEST (4km):	42N-32N, 105W – 91W	Jan, 1998 – Present	Jan, 1996 – Aug, 2003	Jan, 1996 – Present
NSA: (available overpasses) AVHRR, MODIS (1km)	74N-64N, 165W-140W	Sep, Oct 2004, MPACE IOP		Jan, 1996 – Present
TWP: (Hourly) GOES-9 (8 km)	10N – 20S, 120E- 180E	May, 2003 – Present	Jun, 1999 – Apr, 2003	Jan, 1998 – Present
MANUS: (Hourly) GOES-9 (4 km)	3N-12S, 135E-160E	May, 2003 – Present		Jan, 2005 – Present
NAURU: (Hourly) GOES-9 (4 km)	3N-17S, 155E-180E	May, 2003 – Present		Jan, 2005 – Present
DARWIN: (Hourly) GOES-9 (4 km)	5S-17S, 125E-136E	May, 2003 – Present		Jan, 2005 – Present
Pt. REYES: (Half Hourly) GOES-10 (4 km)	50N-25N, 135W-115W	Mar, 2005 – Present		Mar, 2005 – Present
NIAMEY: (Hourly) METEOSAT (3 km)	25N-0N, 20W-15E	Feb, 2005 – Present		Feb, 2005 – Present

Products

Three types of cloud products are available.

Pixel Level

VISST-derived pixel-level products, retrieved on the same resolution as the instrument pixels, offer a variety of new parameters for ARM. Each cloudy pixel is assigned a phase (water, super-cooled water, or ice) and cloud microphysical and radiation properties are derived from the pixel radiances. The VISST pixel-level products are summarized in Table 2. In contrast to the VISST, which explicitly determines phase, particle size, and optical depth, the LBTM assumes a particle size and estimates phase based on the temperature alone. The products, while sufficient for many applications, are averaged into

Table 2. VISST pixel-level cloud products.

0.65 µm Reflectance	Skin Temperature
1.6 µm Reflectance	Optical Depth
3.7 µm Temperature	Effective Radius/Diameter
6.7 µm Temperature	Liquid/Ice Water Path
10.8 µm Temperature	Cloud Effective Temperature
12 or 13.3 µm Temperature	Cloud Top Pressure
Broadband Albedo	Cloud Effective Pressure
Broadband Infrared	Cloud Bottom Pressure
Infrared Emittance	Cloud Top Height
Cloud Mask	Cloud Effective Height
Cloud Phase	Cloud Bottom Height
Pixel Latitude	Pixel Longitude

four categories: clear, or low, middle or high clouds, over a specified grid box. No pixel-level LBTM data are available and nighttime cloud amounts and heights are not very reliable (Khaiyer et al. 2002) because only the IR channel is used. The VISST uses several infrared cannels to detect clouds at night (e.g., Trepte et al. 2005). For researchers interested in matching satellite data to any surface-measured quantity or aircraft flight path, the high spatial resolution VISST results would be the product of choice.

Gridded Products

In order to provide continuity for past users of the cloud products, including the ARM CPM working group, the new data stream includes gridded averages of VISST products that will mimic the 0.5º x 0.5º LBTM products currently in the External Data Center for the SGP domain. These gridded files include the LBTM-like products, that have proven quite useful to the ARM community, as well as the additional cloud and radiation products that are obtainable from VISST. Gridded cloud products are calculated either by cloud height (low, mid, high, total) or by phase (water, ice, super-cooled). LBTM datasets currently in the External Data Center should remain, but users are encouraged to use VISST datasets whenever they are available. Retrieval of cloud properties at the pixel level provides for more accurate comparison with ground site instruments and with in-flight instrumentation during IOP's. The gridded VISST products will soon include surface radiation data (Nordeen et al. 2005).

Surface-Site and Intensive Operational Period Product

The surface site and aircraft products consist of the means of pixel-derived quantities whose center locations fall within a 10 or 20-km radius circle of a particular surface site (e.g. SGP Central Facility, Barrow, Nauru, Manus, or Darwin) or aircraft flight track. These data are useful for quick comparisons of satellite-derived quantities with surface or aircraft-measured quantities. Retrieval of cloud properties at the pixel level provide for more accurate comparison with ground site instruments and with in-flight instrumentation during IOP's. During the IOP's, cloud products are available at higher temporal resolution (every 15 minutes depending on availability) from the geostationary satellites (e.g. GOES, geostationary meteorological satellite, Meteosat) and all available overpasses from the sun synchronous satellite (e.g. AVHRR, MODIS). VISST products are calculated from the individual aircraft navigation files, where the cloud retrieval parameter is based on the weighted average of the 4 closest satellite pixels to the aircraft coordinates. The (spatial) standard deviation is based on a weighted distribution of the closest pixel and the 8 surrounding pixels. Data are available for many ARM IOPs including Mixed-Phase Arctic Cloud Experiment 2004 and ARM Enhanced Shortwave Experiment (ARESE)-II and IOPs sponsored by other programs such as MIDCIX 2004 and ATREC 2003.

Data Access and Web Tools

LaRC maintains an online database and website (http://www-pm.larc.nasa.gov) to access the VISST results over these regions in near real-time. The database includes a multi-year time series of site-specific averages including more than 100 cloud and radiative parameters, pixel-level gif images of retrieved properties, and binary pixel-level retrievals for selected regions. This site has web-based satellite data browsers and tools to access satellite imagery and products. The user has options to select the domain, single or multi-panel images, and time series to view an animation of the products (Figure 1.). These images are in GIF format and can be downloaded to the local systems. Another tool helps retrieve data or plot cloud products over the ARM surface sites or along flight tracks during the IOP's (Figure 2). The user can choose up to four cloud products at a time along with the cloud phase and radius (10 or 20 km). The plots are generated in both GIF and postscript format. A link to access the ASCII data is also provided. The user can download the ASCII data and integrate them into their application. Anther browser tool displays the flight track overlaid on the coincident satellite and VISST product imagery (Figure 2 top and bottom right) and also shows the elevation of the plane. Dedicated web pages for each IOP have links to these additional datasets and tools.

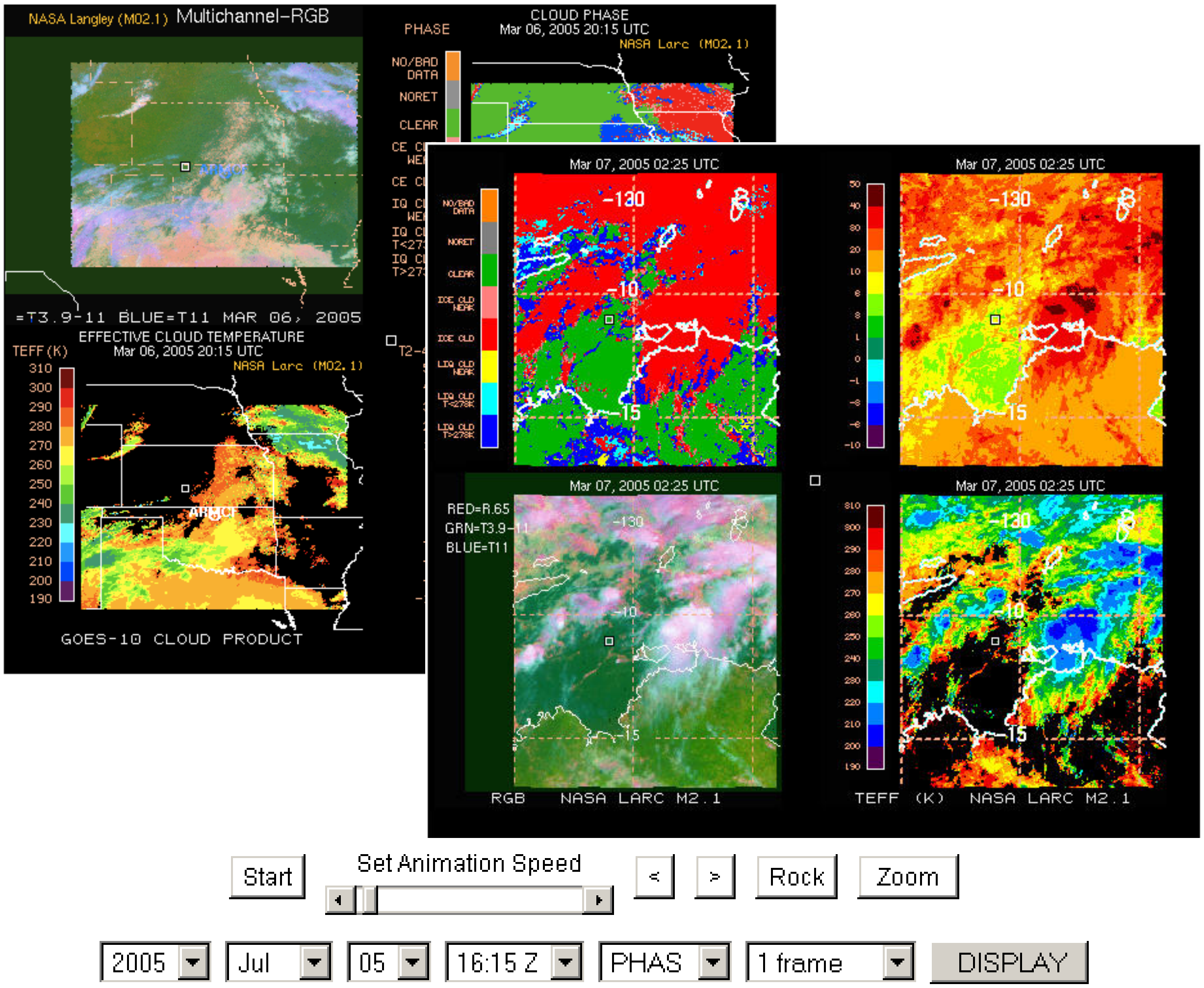

Figure 1. Web-based tool to view satellite & VISST product imagery.

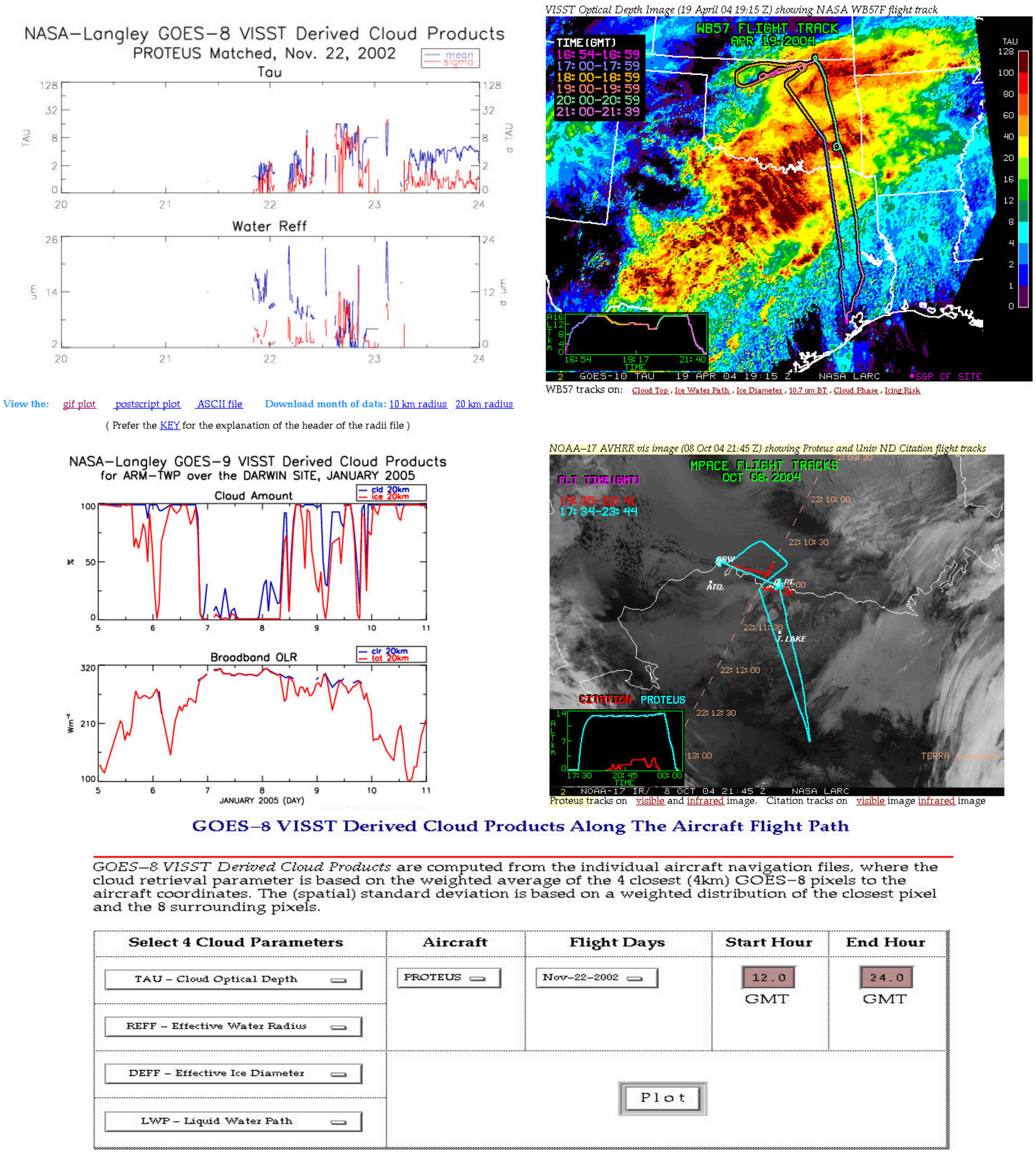

Figure 2. Examples of surface-site & IOP browser tools and results.

Summary

A large array of cloud and radiation products has been developed for ARM from a variety of satellite imager radiances. The products are available online and at the ARM data center. As improvements in algorithms, such as multilayered cloud detection (Minnis et al. 2005) and calibrations, become available, they will implemented and used to update the older versions. Several tools have been developed to provide easy access to the data. New tools for enhanced accessibility are under development and will be placed online when they become available. These products are being derived for use by the ARM community and any comments, suggestions, or other feedback are welcomed.

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