P4.18 NASA-Langley web-based operational real-time cloud retrieval products from geostationary satellites

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1. INTRODUCTION

Ground-based instruments measuring cloud and radiative parameters can 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. NASA Langley Research Center (LaRC) historically provided Geostationary Operational Environmental Satellite (GOES) satellite-derived cloud and radiation datasets, spanning a period of several years, covering the central United States. More recently, GOES retrievals from the entire continental United States (CONUS) have been initiated, as well as retrievals over Europe (Meteosat Second Generation; MSG or Meteosat-8), Asia (Feng-Yun-2; FY2C), the Pacific Ocean and Australia (Multi-functional Transport Satellite; MTSAT-1R). This paper presents an overview of the multiple products available, summarizes the content of the online database, and details web-based satellite browsers and tools to access satellite imagery and products. These near-real time datasets should be valuable for numerical weather prediction, validation and assimilation and a variety of nowcasting applications.

2. DATA & DOMAIN

The availability of additional satellite spectral channel and advances in our understanding of clouds and interaction with the atmosphere led to the development of a improved algorithm that combines the Visible Infrared Solar-Infrared Split-Window Technique (VISST; Minnis et al. 1995, 1998), Solar-Infrared Infrared Split-Window Technique (SIST), and Solar- Infrared Infrared Near-Infrared Technique (SINT). In addition to the VIS (0.65 µm) and IR (10.8 µm) 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. The SIST provides a more accurate assessment of cloud cover and height than possible using only IR data. For ease of use we refer to the three algorithms as VISST.

LaRC has provided satellite-derived cloud and radiation datasets in support of ARM program (Khaiyer et al., 2002) and various field experiments for several years. In addition to the ARM domains (Palikonda et. al. 2005) and special field program domains, cloud and radiation products are derived in near-real time using VISST from GOES, National Oceanic and Atmospheric (NOAA) Advanced Very High Resolution Radiometer (AVHRR), *Terra* and *Aqua* Moderate Resolution Imaging Spectroradiometer (MODIS), MSG, MTSAT-1R and FY2C covering CONUS (Minnis et al., 2005), Alaska, Europe and the tropical western Pacific Ocean. The domain definitions and the temporal resolution for each domain are listed in Table 1. The FY-2C analysis began in January 2006 to provide higher temporal coverage over the TWP.

3. PRODUCTS

Near Real Time Products:

Each half-hourly GOES-WEST and GOES-EAST satellite data is analyzed to generate a set of VISST products. The individual product image from each satellite is stitched together to give a real-time product over CONUS (Fig 1). The data are merged at 100ºW longitude. As described in Palikonda et al. (2005), three type of cloud products are available.

Pixel Level

VISST-derived pixel-level products are retrieved at the instrument pixel resolution. When lower resolutions are given, the processing skips the requisite number of lines and pixels to achieve the specified resolution. Each pixel is classified as clear or cloudy. Clear pixels are denoted as clear or snow (a recent addiiton to the output). Each cloudy pixel is assigned a phase (water, super-cooled water, or ice) and cloud microphysical and radiative properties are derived from the pixel radiances following the procedurres outlined by Minnis et al. (2005). The VISST pixel-level products are summarized in Table 2. Researchers, who are interested in matching satellite data to any surface-measured quantity or aircraft flight path or averaging over a non-uniform grid, should use the high spatial resolution VISST results.

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Table 1: Domains and available products from NASA LaRC

DOMAIN	COVERAGE	PRODUCTS	
		VISST	**GIF IMAGERY**
EAST CONUS: (Half Hourly) GOES EAST (8km):	55N-18N, 105W – 60W	Oct. 2003 – Present	Oct. 2003 – Present
WEST CONUS: (Half Hourly) GOES WEST (8km):	55N-18N, 130W – 90W	Oct. 2003 – Present	Oct. 2003 – Present
MERGED CONUS: (Half Hourly) GOES EAST& WEST (8km):	55N-18N, 130W – 60W	Oct. 2003 – Present	Oct 2003 – Present
WESTERN EUROPE: (Hourly) MSG (3km):	54N-39N, 4 W – 17 E	April 2005 – Present	April 2005 – Present
EUROPE: (Hourly) MSG (6km):	55N-30N, 12W – 30E	May 2004 – Present	May 2004 – Present
NSA: (Half Hourly & available overpasses) GEOS-WEST, AVHRR	74N-64N, 165W-140W	Oct. 2005-Present Sep, Oct 2004, MPACE IOP	Oct. 2005-Present
SGP: (Half Hourly) GOES EAST & WEST (4km):	42N-32N, 105W – 91W	Jan. 1998 – Present	Jan. 1996 – Aug. 2003
TWP: (Hourly) GOES-9 (8 km) MTSAT-1R (4 km)	10N – 20S, 120E- 180E	May 2003 - Present	Jan. 1998 – Present
Manus: (Hourly) GOES-9 (4 km) MTSAT-1R (4 km)	3N-12S, 135E-160E	May 2003 - Present	Jan. 2005 - Present
Nauru: (Hourly) GOES-9 (4 km) MTSAT-1R (4 km)	3N-17S, 155E-180E	May 2003 - Present	Jan. 2005 - Present
Darwin: (Hourly) GOES-9 (4 km) MTSAT-1R (4 km) FY-2C (4 km, 0.5 hour))	5S-17S, 125E-136E	May 2003 - Present	Jan. 2005 - Present Jan. 2006-

Gridded Products

Gridded cloud products are calculated on a user defined grid resolution (e.g. 0.5° x 0.5° or 1.0° x 1.0°). Each of the cloud properties listed in Table 1 can be further separated based either by cloud height (low, mid, high, total) or by phase (water, ice, super-cooled) to provide an average value for each grid. Future gridded output will include to isurface radiative flux and skin temperature estimates (Nordeen et al., 2005).

Surface-site & Field Experiment Products

The surface site and aircraft products consist of averages of pixel-derived quantities within a 10 or 20-km radius circle of a particular surface site (ARM sites: SGP CF, Barrow, Nauru, Manus and Darwin, Europe sites: SIRTA, Chilbolton, Cabauw, Lindenberg & Potenza) or aircraft flight track. These data are useful for quick comparisons of satellite-derived quantities with surface or aircraft-measured quantities. During the field experiments, cloud products are available at higher temporal resolution (every 5 - 30 minutes depending on availability) from the geostationary satellites (e.g. GOES, GMS, Meteosat-8) 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 four closest satellite pixels nearest to the aircraft coordinates. The (spatial) standard deviation is based on a weighted distribution of the closest pixel and the eight surrounding pixels.

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 SW Albedo	Cloud Effective Pressure
Broadband LW Flux	Cloud Bottom Pressure
Infrared Emittance	Cloud Top Height
Cloud Mask	Cloud Effective Height
Cloud Phase	Cloud Bottom Height
Pixel Latitude	Pixel Longitude

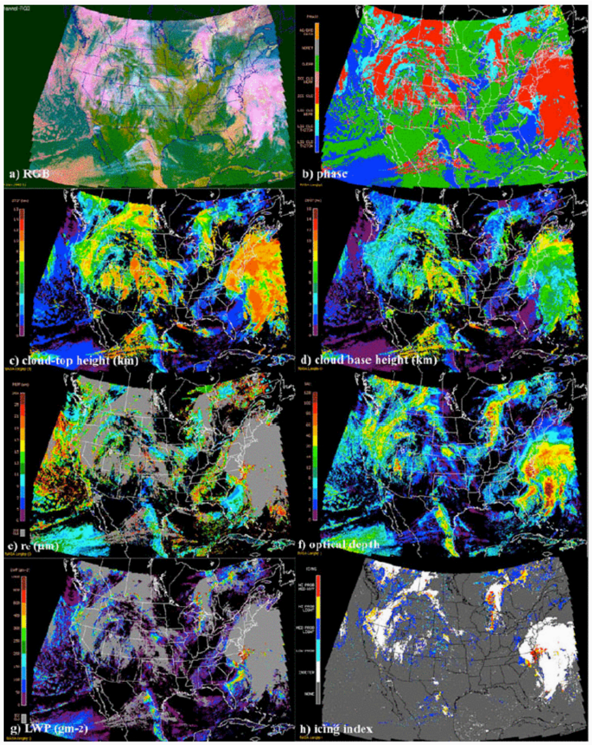

Figure 1. Stitched VISST cloud products from GOES-10 and 12, 1645 UTC, 6 May 2005.

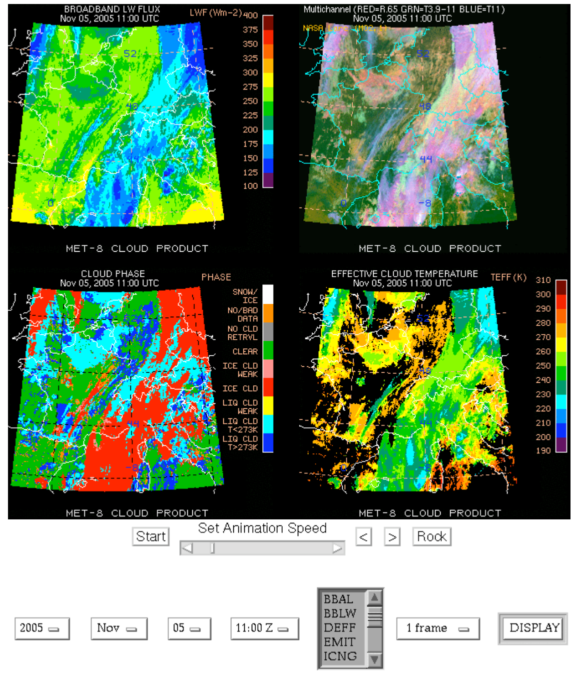

Figure 2. Web based 4-panel display of satellite image and VISST cloud products from MSG 11 UTC, 5 Nov 2005 over Western Europe.

4. DATA ACCESS & WEB TOOLS

LaRC maintains online database and website at http://www-pm.larc.nasa.gov/satimage/products.html to access near real-time or archived VISST results and satellite imagery. 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 These images are in GIF format and can be downloaded to the local systems. The user has options to select the domain, single or multi-panel images, and time series to view an animation of the products (Fig 2.). Another tool helps retrieve data or plot cloud products over the surface sites or along flight tracks during the IOP's (Fig 3.). 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

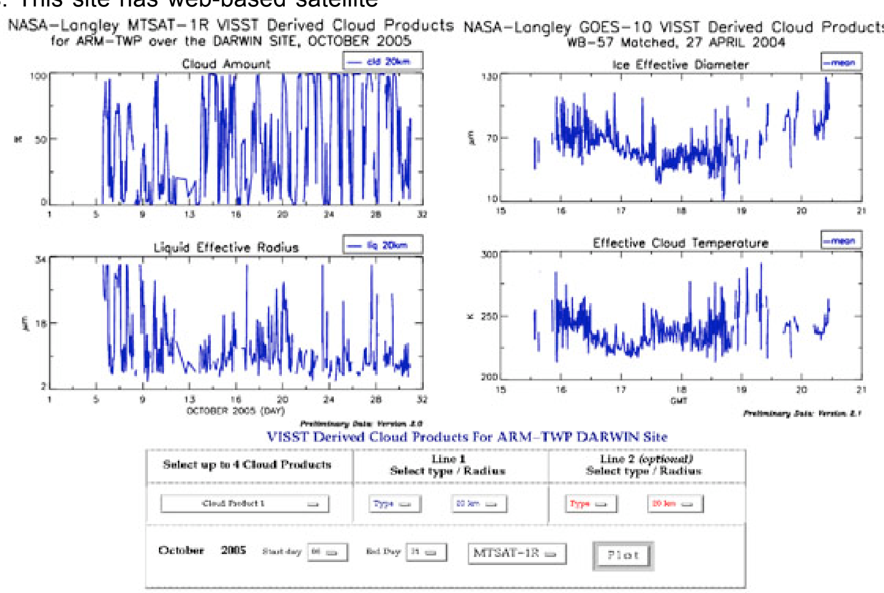

Figure 3: Web-based tools to plot VISST products. right: MTSAT-1R over Darwin. left: GOES-10 along WB-57 flight track.

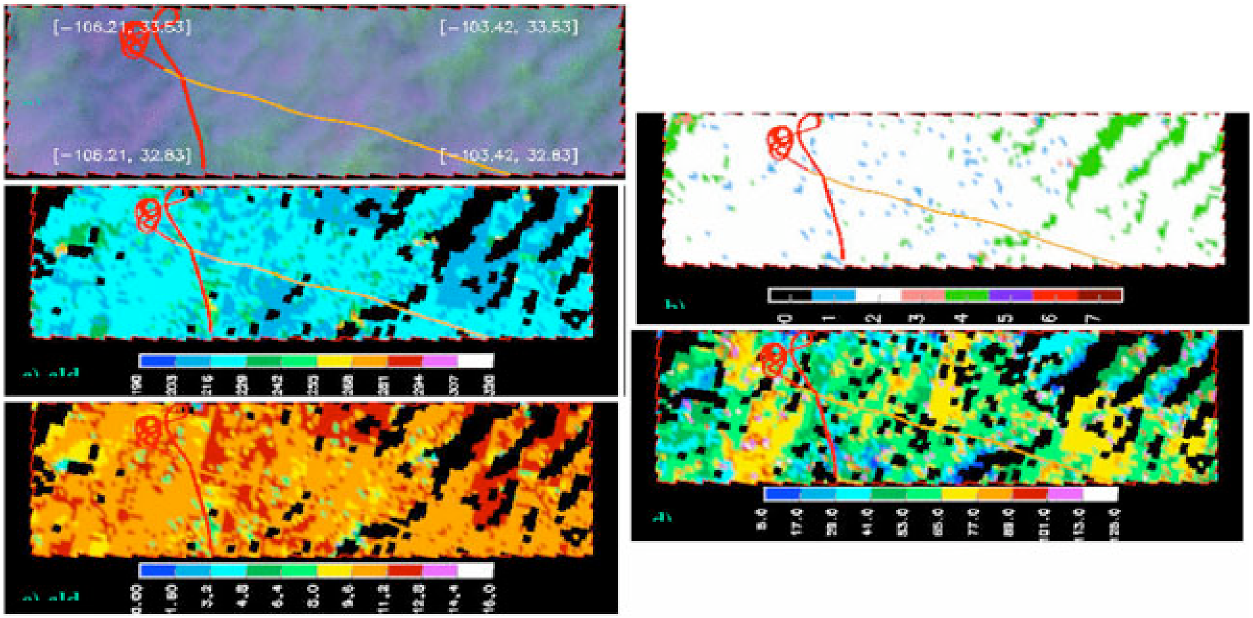

Figure 4: *Terra* MODIS retrieval 1745 UTC, 27 April 2004 during MIDCIX experiment with the matching WD57 flight track overly. a) 3-channel RGB image with latitude and longitude of the 4 corners in the image. b) shows the phase (white-clouds, green-clear). c) effective cloud temperature d) ice diameter e) cloud height

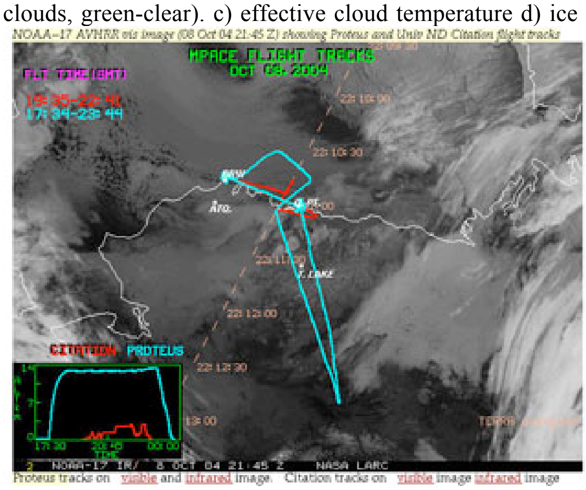

Figure 5: Proteus(cyan) and the Citation (red) flight track overlay on NOAA-17 2145 UTC, 8 Oct. 2004. At the bottom left corner is the elevation of each plane. The light brown dotted line is the *Terra* overpass.

provided. The user can download the ASCII data and integrate them into their application. Another browser tool displays the flight track overlaid on the coincident satellite and VISST product imagery (Fig 4) and shows the elevation of the plane (Fig 5). Dedicated web-sites for each IOP have links to these additional datasets and tools (Table 3).

Value Added Products

The increased retrieval accuracy has led to many value-added products, both in-house and through collaborative efforts with others such as icing potential (Fig. 6, Minnis et.al. 2005, Haggerty et al., 2005) and surface radiation budget (Nordeen et al., 2005)

SUMMARY

A large array of cloud and radiation products has been developed from a variety of satellite imager radiances. The products are available online. As improvements in algorithms, such as multilayered cloud detection (Minnis et al., 2005) and calibrations, become available, they will be 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 derived for use by the Atmospheric Science community and any comments, suggestions, or other feedback are welcomed.

Table 3. Recent field experiments supported.

FIELD EXPERIMENT	DEDICATED WEBSITE
CRYSTAL	http://angler.larc.nasa.gov/crystal
ATREC	http://angler.larc.nasa.gov/bangor
MIDCIX	http://angler.larc.nasa.gov/midcix
MPACE	http://angler.larc.nasa.gov/mpace
THORPEX	http://angler.larc.nasa.gov/thorpex
CLAMS	http://angler.larc.nasa.gov/clams

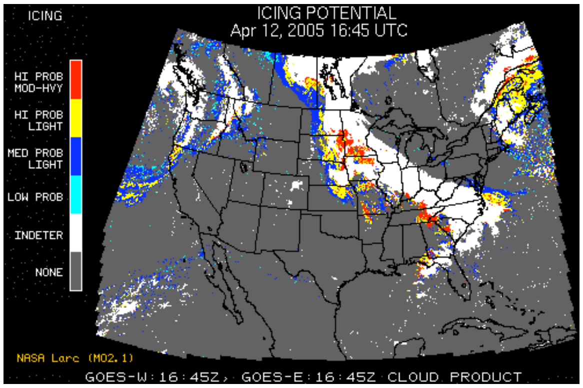

Figure 6. Icing probability in near real-time from GOES, derived from VISST products, 12 April 2005, 1645 UTC.

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