

EVOLUTION OF THE TROPICAL CYCLONE INTEGRATED DATA EXCHANGE AND ANALYSIS SYSTEM (TC-IDEAS)

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1. Introduction.

The Tropical Cyclone Integrated Data Exchange and Analysis System (TC-IDEAS) is being jointly developed by the Jet Propulsion Laboratory (JPL) and the Marshall Space Flight Center (MSFC) as part of NASA's Hurricane Science Research Program. The long-term goal is to create a comprehensive tropical cyclone database of satellite and airborne observations, in-situ measurements and model simulations containing parameters that pertain to the thermodynamic and microphysical structure of the storms; the air-sea interaction processes; and the large-scale environment. One aspect of TC-IDEAS is centered about JPL's TC portal (<http://tropicalcyclone.jpl.nasa.gov>), a global online historical database that enables assessment of these parameters both at the large-scale (e.g., sea surface temperature produced from a daily composite of satellite overpasses), and also on the storm scale (Hristova-Veleva et al., 2007; Li et al., 2007; Knosp et al., 2008). The storm scale database (i.e, satellite data subsetted within the vicinity of the storm, and associated imagery) currently includes per-overpass observations from the Tropical Rainfall Measuring Mission (TRMM) (TRMM Microwave Imager, TMI; and Precipitation Radar, PR), CloudSat (profiles from CloudSat Profiling Radar, CPR), Aqua (Advanced Microwave Scanning Radiometer, AMSR-E; Atmospheric Infrared Sounder, AIRS; Advanced Microwave Sounding Unit, AMSU-A; Humidity Sounder Brazil, HSB), DMSP (Special Sensor Microwave Imager, SSM/I), QuikSCAT (SeaWinds vectors), NOAA (AMSU-A; AMSU-B; Microwave Humidity Sounder, MHS), Aura (Microwave Limb Sounder, MLS; Ozone Monitoring Instrument, OMI) and radio occultation (GPS-RO) temperature and humidity profiles. While initial configuration of this historical record focused on the 2005-2006 period, the portal will eventually include all data collected during the lifetime of each sensor. The portal will utilize the NASA Real Time Mission

Monitor (RTMM) (<http://rtmm.nsstc.nasa.gov>) and other visualization tools to provide visual overlays of storm tracks, satellite and aircraft flight tracks, and various science products, as relevant for a given storm. Further improvements will include selected mesoscale model simulations and simulated radar and radiometric products.

During August-September 2010, the joint NASA/NOAA Genesis and Rapid Intensification Processes (GRIP) (<http://grip.nsstc.nasa.gov>) field experiment will be conducted to better understand how tropical storms form and develop into major hurricanes. In preparation for the field phase, the JPL TC portal was re-configured to work in a near realtime setting, utilizing collections of satellite and model products pertaining to the atmospheric and surface conditions over the Atlantic Ocean basin (Hristova-Veleva et al., 2010a). To maximize coverage over this large area (0N-45N, 100W-0E), six-hour composites (updated hourly) are produced for a number of different products derived from several low Earth orbiting satellites. Examples include scatterometer ocean surface wind vectors, a rain intensity indicator, total precipitable water vapor, 85 GHz brightness temperature composites, hourly geostationary composites, CAPE and lifted index stability indices and the capability to plot the skew-T diagram associated with these indices. The delivery of these data is driven by the use of the Google Earth API to time select, plot, overlay and animate selected products. We present a demonstration of the latest updates to the TC-IDEAS site, as well as to the GRIP interface. The GRIP portal site is located at <http://tropicalcyclone.jpl.nasa.gov/grip>.

Since both of these efforts are currently works in progress, in this manuscript we present several examples from the most recent stable builds of these two portals. Additionally, we demonstrate upcoming capabilities (new satellite products and model data) that are under development.

2. The Near Realtime GRIP Portal

The near realtime GRIP portal is designed to tap near realtime data sources for environmental satellite data and numerical forecast model fields. Unlike the historical hurricane portal, the GRIP portal emphasizes maximum flexibility and capabilities for the user to overlay and compare a number of different datasets in an operational field experiment setting (rather than viewing previously exported imagery). Previous Keyhole Markup Language (KML)-based tropical cyclone portals (Turk et. al, 2010; Naval Research Laboratory-Monterey TC-Web <http://www.nrlmry.navy.mil/TC.html>) work within the Google Earth application directly, which opens separately, outside of the browser. Additionally, the Google Earth Places panel can quickly become cluttered after several objects or expandable folders are opened. For this reason, the Google Earth API was adopted for all graphical interaction, using a simple calendar and selection-box interface. The Google Earth API (<http://code.google.com/apis/earth>) is a Javascript library that allows developers to add Google Earth objects and runs within the browser, eliminating the need to open up the external Google Earth application. All image data are exported in PNG with transparent (or semi-transparent, when necessary to discern areas of no satellite coverage from areas of zero-valued data) alpha layers, embedded inside of KML wrappers. With the exception of the geostationary data and daily products such as the sea surface temperature (SST) analysis, the GRIP portal presents 6-hour composites of various low Earth-orbiting satellite channels and derived products, updated every hour with approximately 2-3 hour latency. The GRIP portal is visualization-based only, but the research-quality satellite data will be added as part of the TCIS for the 2010 season.

The interface is shown in Figure 1 below. The left panel presents the user with a selection of all datasets to view, and after the selections which the portal automatically overlays the time-coincident layers. A calendar is used to select data from a desired date and time. Initially, the user is directed to the most recent overlay combination of the six-hourly 85H GHz composite overlaid on top of the GOES-East (currently GOES-13) IR data at the center time of the composite. In addition to the 85 GHz, current 6-hourly layers include AMSU total precipitable water (TPW), QuikSCAT wind vectors from the Physical Oceanography Distributed Active Archive Center (PO.DAAC) (<http://podaac.jpl.nasa.gov>), CAPE and Lifted Index computed from the AIRS retrievals and a combined TMI+AMSU-E "rain indicator" (RI) (Hristova-Veleva et al., 2010b). Daily SST (Chao et. al, 2009; <http://sst.jpl.nasa.gov/SST>)

data are available as a background layer. The animation panel is shown at the bottom of Figure 1. After the user has selected the products and time span of the objects to be animated, the individual objects are wrapped inside of a new KML embedded with the appropriate KML time tags.

As an example of the flexibility afforded by this selectable layering concept, Figure 2a displays the RI from a composite of AMSU-E data in the vicinity of Hurricane Fred on 10 September 2010 in the eastern Atlantic Ocean. The storm track up to this time is shown via intensity-coded markers every 6-hours, and the thin transparency indicates the area of satellite swath coverage. The color coded lines indicate the CloudSat tracks (as a companion A-Train satellite, CloudSat flies nearly along center of the Aqua/AMSU-E swath). When the Earth navigation controls are adjusted to view along the atmospheric limb, the associated CloudSat reflectivity profile is revealed, as shown in Figure 2b.

During the GRIP field phase, mission staff and scientists will often be in remote locations, away from computers with high speed Internet connectivity. We have implemented a simplified mobile device version of the GRIP portal (GRIP-Lite) which can run on any mobile browser that supports Javascript. Currently, GRIP-Lite presents a selection of two reduced-size composites (AMSU TPW, 85 GHz) and also GOES-IR and visible. An example is shown in Figure 3.

3. Improvements to the Historical Database

The TC-IDEAS database has been significantly updated with the addition of radiance-level datasets from the swath-level TRMM Microwave Imager (TMI) 1B11 product, the AMSU-E Level-2A (L2A), and both HURSAT-B1 and HURSAT-MW datasets from the HURSAT project (<http://www.ncdc.noaa.gov/oa/rsad/hursat/index.php>) at the National Climate Data Center (NCDC) (Knapp and Kossin, 2007).

3.1 TMI and AMSU-E

At present, the best track database for the 2005 and 2006 seasons has been searched for all TRMM and Aqua overpasses whose subtrack lies within 500 and 800 km of the storm best track, respectively. These data are subsetted by extracting imager scanlines whose center beam position lies within 1200-km of the storm position. A unique feature of TC-IDEAS is that both quick-look imagery from each of the radiometer channels is produced with the best-track overlaid, and the associated subset of the dataset is archived, maintained in the native format of the original dataset (HDF for AMSU-E

and TMI, netCDF for HURSAT). The subsetted data contains all necessary geolocation to remap these data, as well as ancillary information such as storm intensity and position necessary to develop analysis tools (some of which are being developed online for TCIS (Knosp et. al, 2008). All graphics are in a common format to ease interpretation of each sensor, with common color tables and ranges for similar channels on similar sensors. The nearest-time HURSAT-B1 IR data (described next) are used for the background areas outside of the sensor swath. An example of AMSR-E is shown in Figure 4.

3.2 HURSAT B1 and HURSAT-MW

HURSAT-B1 is derived from the International Satellite Cloud Climatology Project (ISCCP) B1 dataset. The HURSAT-B1 data spans 1978-2006 and provides coverage of global tropical cyclones at 8-km and 3-hourly temporal resolution, collected from Japanese (GMS, MTSAT), European (Meteosat, MSG), Chinese (FY) and US (GOES) geostationary satellites. At a minimum, the infrared window (IR) channel data area provided for all satellites, which are particularly relevant for TC analyses, and which have been recalibrated to reduce inter-satellite differences. When available, the water vapor channel near 6.7 μm and (during daytime) the broadband visible (VIS) channel calibrated to albedo units are also provided. These observations are provided on a $0.07^\circ \times 0.07^\circ$ (~8km) 301x301 Lagrangian grid that follows the TC center at 3-hourly intervals. An example of the HURSAT-B1 data is shown in Figure 5.

The HURSAT-MW data are collected from all operating Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager (SSM/I) radiometer systems since their inception in 1987 (F-8, 10, 11, 13, 14, and 15). Six of the seven channels (22V is not shown) are mapped to the identical 301x301 grid as HURSAT-B1, and the nearest-time HURSAT-B1 IR data are used for the background areas outside of the sensor swath (not shown). At the time of this conference, TCIS has been augmented with the B1 and MW data from the 2005 and 2006 seasons.

4. Future Plans

At the time of this conference (May 2010), both the GRIP portal and the TC-IDEAS database are undergoing significant updates. We provide a brief description of ongoing efforts.

4.1 GRIP Portal

The GRIP portal is undergoing significant updates in preparation for the GRIP field phase in August-September 2010. The most important

addition for the field campaign is support for a number of numerical weather prediction (NWP) forecast models (NOGAPS, GFS, HWRF and several others). The ability to overlay model forecasts (winds at various pressure levels, wind shear, with various satellite datasets (matched in time to each forecast time step) provides powerful capability to analyze the model skill in predicting hurricane track and intensity and furthering understanding of hurricane genesis (Wang et. al, 2009). As an example, Figure 6a displays the 925 mbar streamlines from the forecast of the Navy Operational Global Atmospheric Prediction System (NOGAPS) global forecast model, initialized at 00Z on 6 September 2009. Figure 6b shows the 700 mbar streamlines at the same time overlaid on the GOES-IR data.

For satellite data, daily composited MODIS aerosol optical thickness (AOT) and fraction fine mode from Terra and Aqua will be available for the background layer.

The architecture and software tools developed for the GRIP portal have been designed to allow flexibility in their use for future projects. While the GRIP portal is currently configured for the tropical Atlantic Ocean domain, it can easily be relocated to other domains (e.g., East Pacific, West Pacific, etc.). Since KML objects are self-describing (i.e., the projection is contained within), only the data processing scripts would have to be reconfigured with a different geographical domain.

4.2 TC-IDEAS Historical Database

As part of the AIRS data processing system at JPL, all AMSU data since inception (beginning with NOAA-15 in 1995, and extending to NOAA-19 and MetOp-A currently) have been archived. We plan to pass these data through the best-track satellite overpass time extraction to add all possible AMSU data to TC-IDEAS. AMSU-A is onboard Aqua, MetOp and all NOAA satellites, whereas the associated humidity sounding instrument has three different names (AMSU-B on NOAA-15/16/17, HSB on Aqua, and MHS on NOAA-18/19 and MetOp), each with slight channel differences. With such a large volume of AMSU data, there will be many overpasses during the storm lifetime to enable thermodynamical lifecycle analysis tools, such as warm core evolution studies (Brueske and Velden, 2003).

The era of routine passive microwave data used in HURSAT-MW began in 1987 with the SSM/I, and the ISCCP B1 dataset used for HURSAT-B1 began in 1978. Using new best track information such as iBTrACS (Knapp et. al, 2010), we are investigating opportunities to extend the TC-IDEAS historical portal to these

early years, which would enable development of extended-time analysis tools related to hurricanes and climate.

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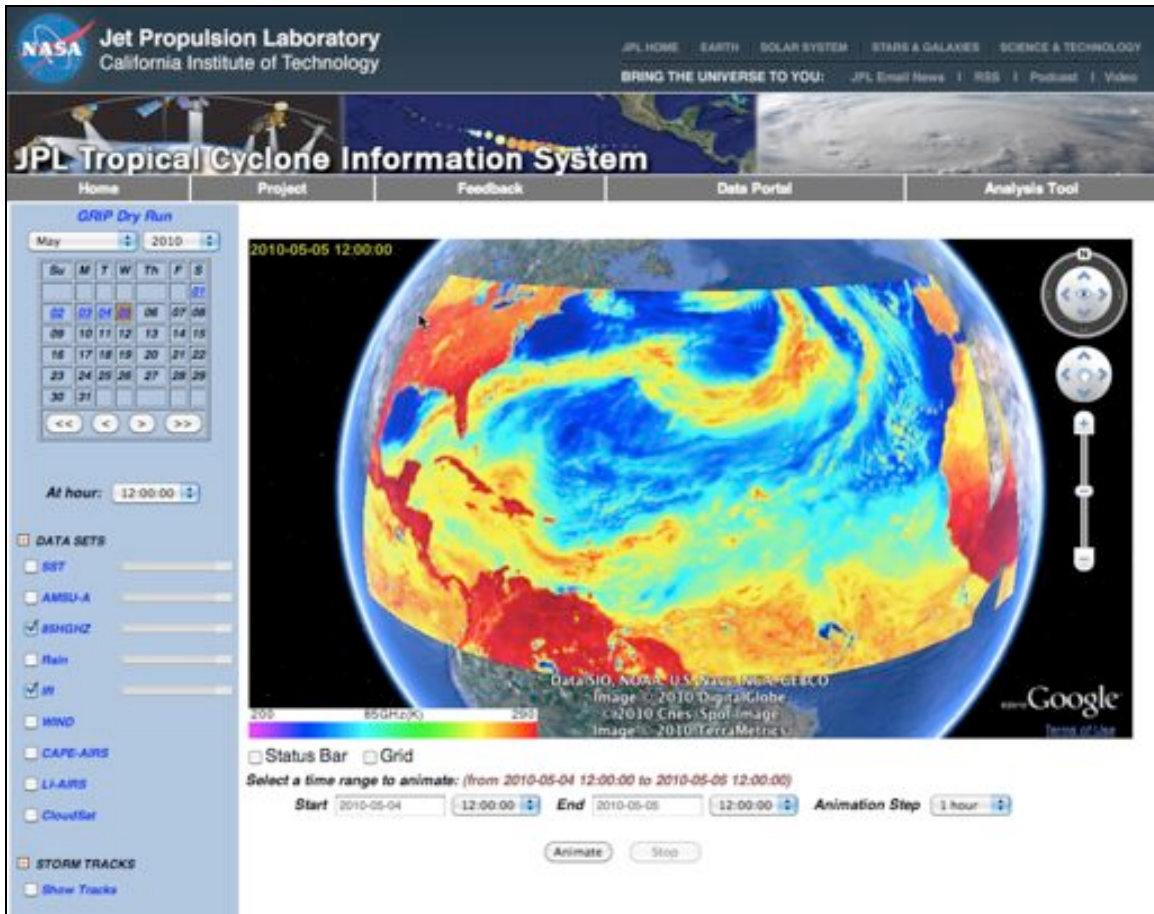


Figure 1. Main interface to the JPL Near Realtime GRIP portal. The selection panel is on the left and the animation panel is directly below the main Earth panel. The portal is built entirely around the Google Earth API.

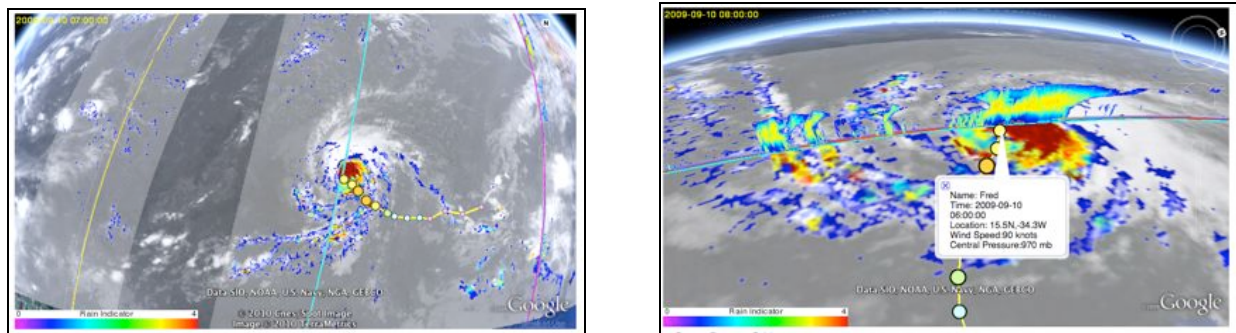


Figure 2. (a, left) Rain Indicator (RI) computed from the AMSR-E sensor, composited from a six-hour collection of overpasses of the Aqua satellite. The composite ends at 06Z on 10 September 2009. Areas of thin transparency indicates swath coverage area, to distinguish no coverage areas from areas where $RI < 0$. The satellite tracks of the CloudSat satellite are shown, colored coded by time latency. (b, right) When the navigation controls are such that Earth is rotated up to view along an oblique perspective, the vertical profile of CloudSat Profiling Radar (CR) radar reflectivity is revealed. In this case, the user has also selected the storm track icon nearest the storm center, which brings up a small popup box with storm intensity information.

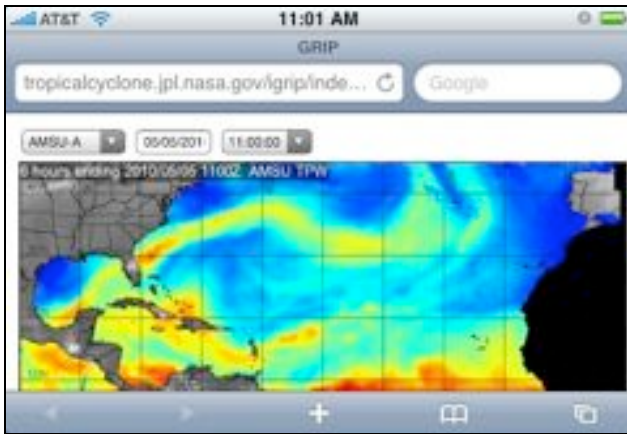


Figure 3. Example of the “GRIP Lite” version of the GRIP portal suitable for mobile device users during the GRIP field campaign. Currently, hourly-updated satellite products (AMSU TPW, 85 GHz, GOES IR and daytime VIS) are available from a user-selectable menu.

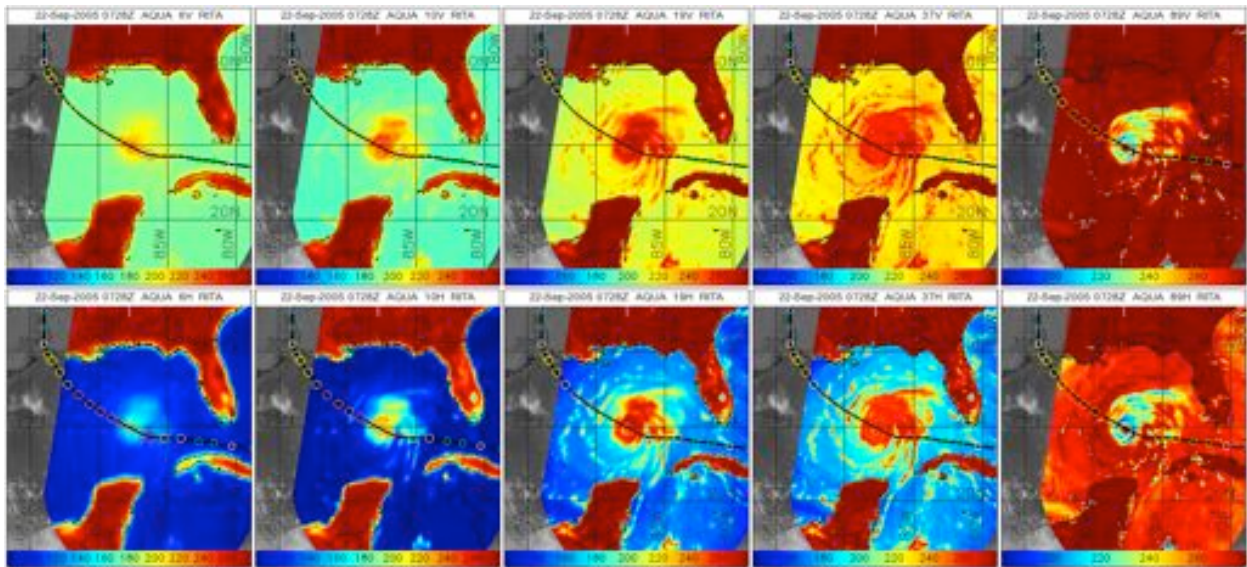


Figure 4. Multi-panel image of the AMSR-E 6, 10, 19, 37 and 89 GHz V and H channels from the 0728 UTC EOS-Aqua pass on 22 September 2005 over Hurricane Rita in the Gulf of Mexico. The best-track is shown via a series of connected color-coordinated intensity level circles. An identical panel is used for TMI (without the 6 GHz) and for the SSM/I (without the 6 and 10 GHz). Each image in the panel is a 301x301 image mapped onto a 0.07x0.07 (8-km) grid.

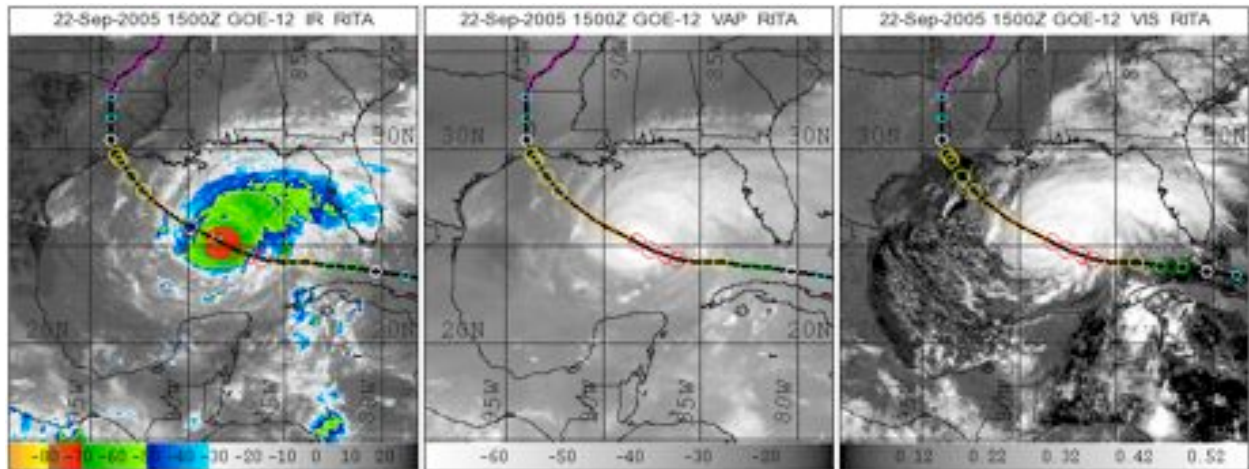


Figure 5. Example from the HURSAT-B1 dataset, corresponding to the AMSR-E data in Figure 4. Multi-panel image of the GOES-12 IR, water vapor and visible channels, from the 15Z image of Hurricane Rita on 22 September 2005. The best-track is shown via a series of connected color-coordinated intensity level circles. Each image in the panel is a 301x301 image mapped onto a 0.07x0.07 (8-km) grid, i.e. the identical map dimensions as shown in Figure 4.

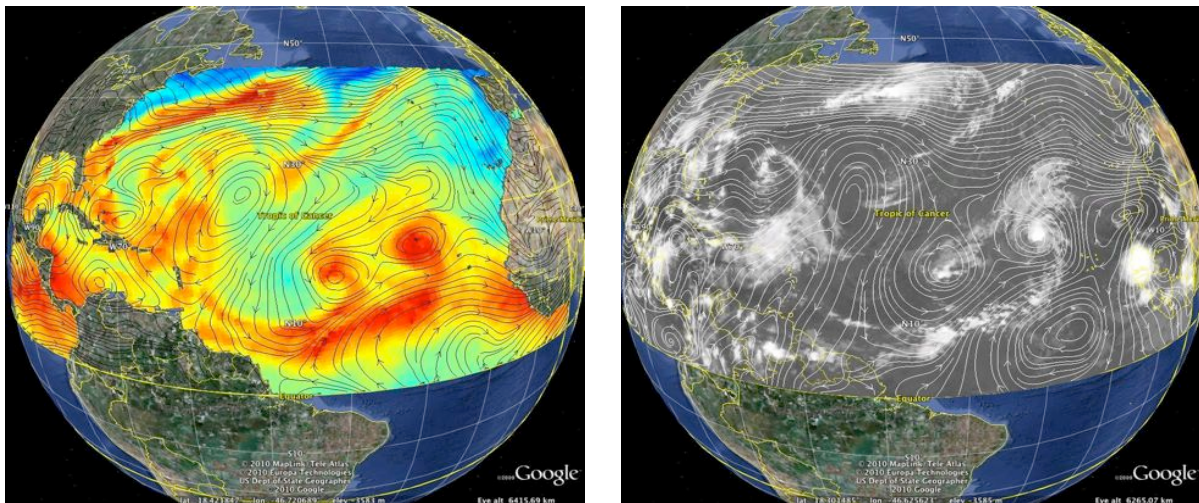


Figure 6. (a, left) 925 mbar streamlines from the NOGAPS model initialized at 00Z on 6 September 2009, overlaid on top of the time-coincident AMSU total precipitable water over the GRIP domain. (b, right) Same as left, except the 700 mbar streamlines are overlaid on top of time-coincident GOES IR data.