Poster 211

An Update on the Convective Diagnosis Oceanic Algorithm

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Introduction

Detection and inflight display of oceanic convective storms is needed to ensure safe and efficient routing of transoceanic aircraft across vast reaches of oceanic air space. The Convective Diagnosis Oceanic (CDO) algorithm was first devised within the Federal Aviation Administration Aviation Weather Research Program (FAA AWRP) as part of the Oceanic Weather Product Development Team (OW PDT; Herzegh et al. 2000) in the early 2000's. At that time, the CDO only used satellite-based inputs to make a determination of the location of convective hazards (Kessinger et al. 2008; Kessinger et al. 2010). This early version of the CDO algorithm was validated using the NASA Tropical Rainfall Measuring Mission (TRMM) low earth orbit satellite and found to have good performance at detecting hazardous convection over both oceanic and continental regions (Donovan et al. 2008; Donovan et al. 2009). Since these early years, the CDO algorithm has undergone modifications that have enhanced the detection of convective hazards.

The CDO is currently being run in realtime over a global domain and results uplinked to an Electronic Flight Bag (EFB) display for selected Lufthansa Airlines flights (Kessinger et al. 2017). In addition, the CDO results are being used to validate numerical weather prediction results of a global, ensemble model system that provides strategic, probabilistic aviation guidance products (Stone et al. 2017).

The eFlightOps Atlantic Weather Hazard Trial

In June 2014, a real time demonstration to uplink one satellite-based convective weather product into the flight deck of transoceanic aircraft was begun with the National Center for Atmospheric Research (NCAR), Lufthansa Airlines, and Basic Commerce & Industries, Inc. (BCI) as partners (Kessinger et al., 2015). The initial display of the Cloud Top Height (CTH) product was in the Lufthansa Mission Support facility where the product was monitored for performance prior to uplink into the flight deck. Next, the CTH product was loaded onto a tablet during pre-flight briefings and carried into the aircraft as a static display of weather conditions near take-off time. Uplink into the flight deck of a Lufthansa Airbus 380 was accomplished in July 2014 and the product shown on an installed display for a test flight.

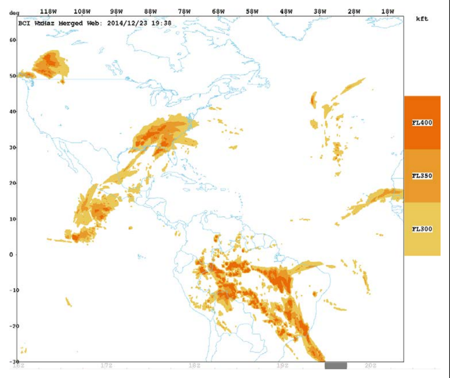
The images below show examples of the CTH product as displayed in Mission Support, on a tablet and on the EFB. An example of the CTH product over the GOES-East domain is shown below at the far right.

The eFlightOps Atlantic Weather Hazard Trial was deemed very successful with the CTH product showing good skill and accuracy. The next phase began with the Global Weather Hazards project, described in the following section.

Tablet Display of the CTH

Mission Support display of CTH

Lufthansa Airlines A380 EFB



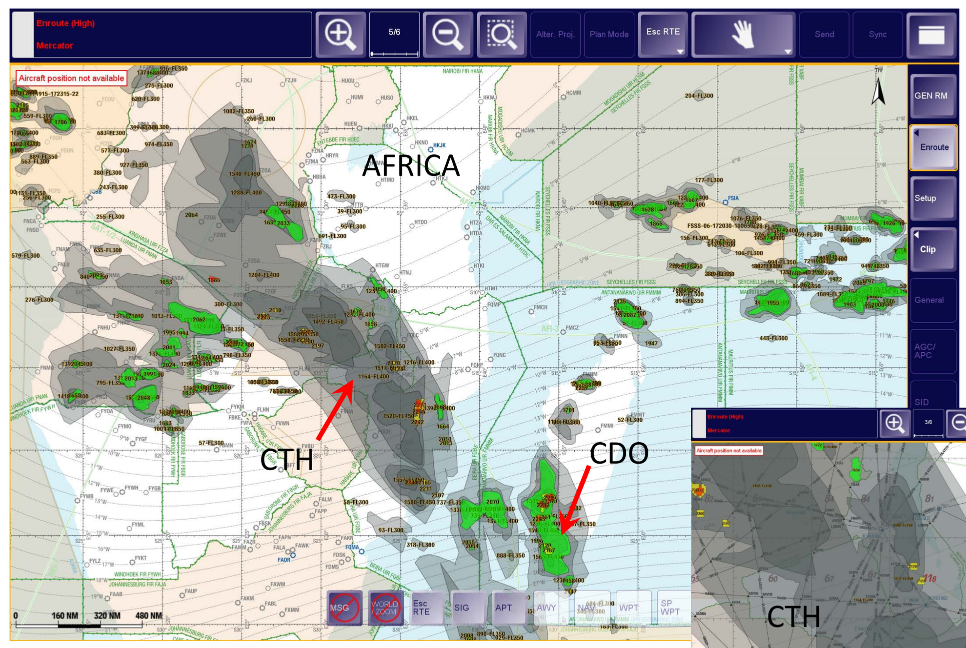
Cloud Top Height (CTH) Polygons

eFlightOps Atlantic Domain

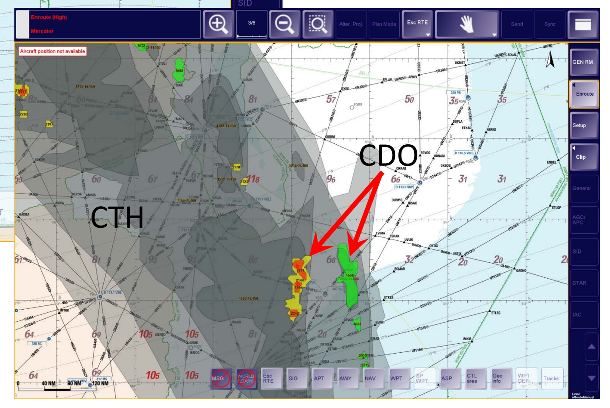
Global Weather Hazards Project

In 2015 and following the successful eFlightOps Atlantic Weather Hazard Trial, a real time operational demonstration to uplink two convective weather products into the flight deck of transoceanic aircraft began with Lufthansa Airlines, BCI, NCAR and MeteoStar collaborating as partners (Kessinger et al. 2017). The Global Hazards Weather project began with expansion to a global domain over latitude limits of 50S to 75N using data from six geostationary satellites (see far upper right panel). A second product, the Convective Diagnosis Oceanic (CDO), was added because of its skillful detection of convective hazards, giving additional information to the CTH. Used together, the CTH and the CDO give pilots a more complete picture of the convective storm structure and hazard locations.

The CDO and CTH products are displayed on an EFB in Lufthansa Airlines B747-8 aircraft, comprised of a Microsoft Surface Pro 3, using the Lido EnRoute Flight Manual (eRM), shown below.

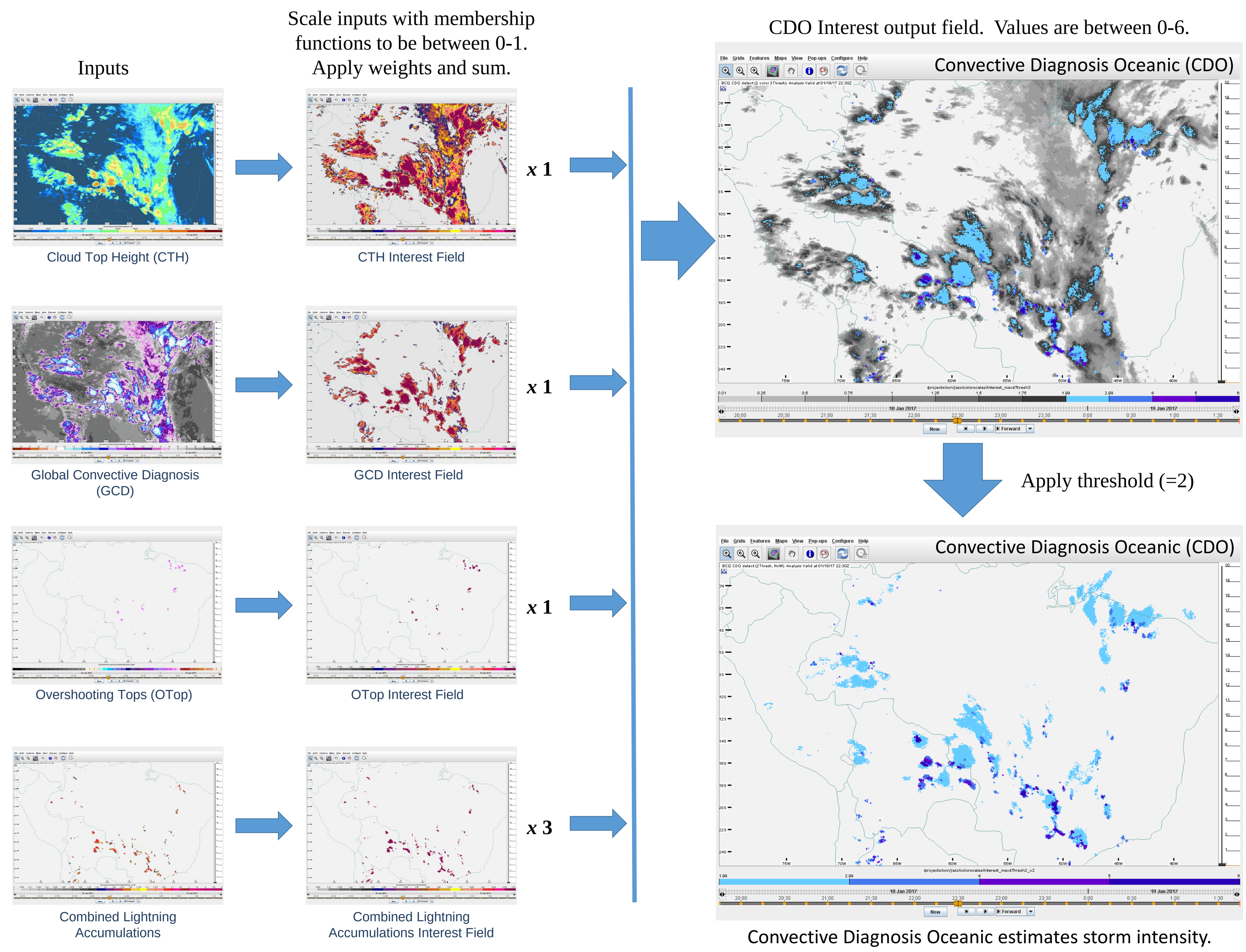


eRM display showing CTH (gray polygons) and CDO (green, yellow, red shapes)



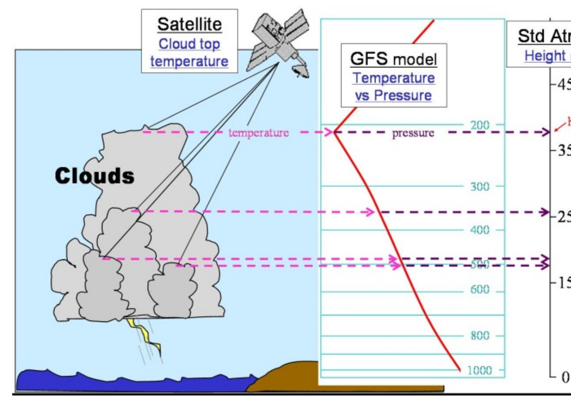
Magnified view of large storm.

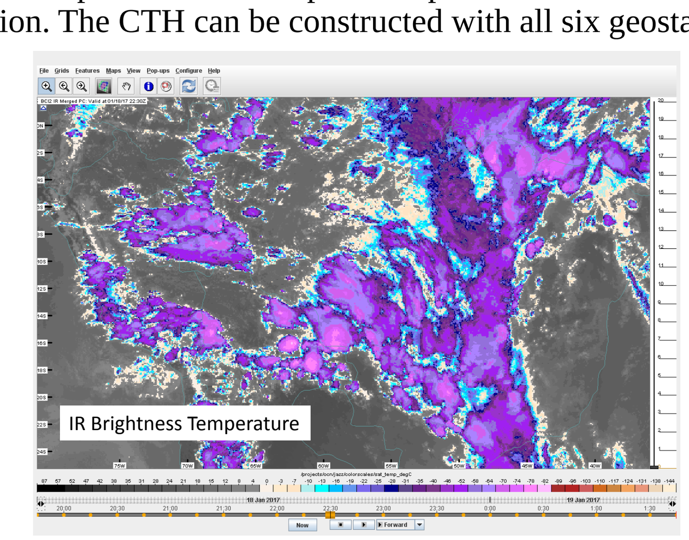
Convection Diagnosis Oceanic (CDO) Fuzzy Logic, Data Fusion Methodology

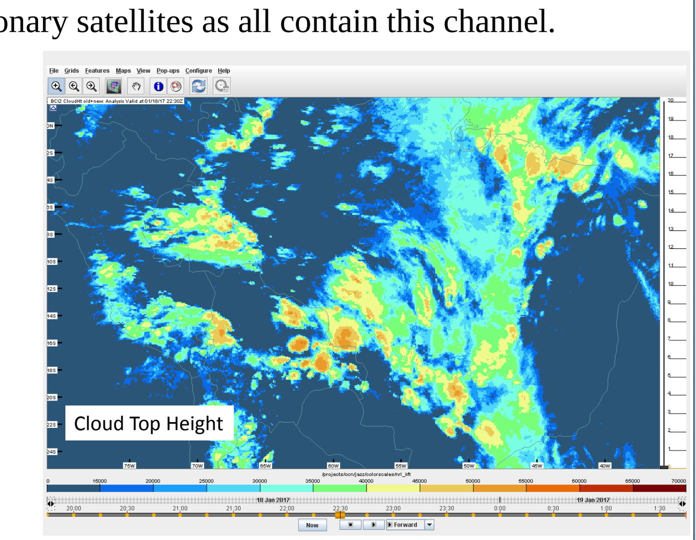


Cloud Top Height (CTH) is computed by: 1) converting the satellite 10.8 micron infrared (IR) brightness temperature to pressure by comparison to the NCEP Global Forecast System (GFS) model sounding and then 2) converting the pressure to a flight level through the standard atmosphere equation (Miller et al. 2005). This process is illustrated in the figure, below left.

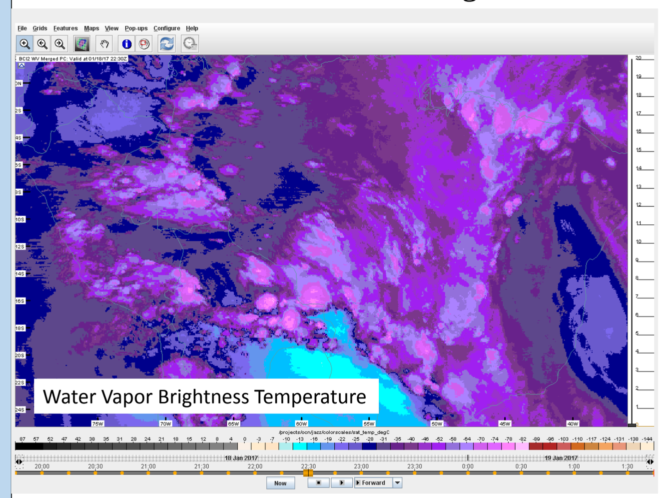
The IR brightness temperature only measures the temperature of the tops of deep convection and cannot resolve internal structures. The anvil clouds can have a much larger area than the convective region. The CTH can be constructed with all six geostationary satellites as all contain this channel.

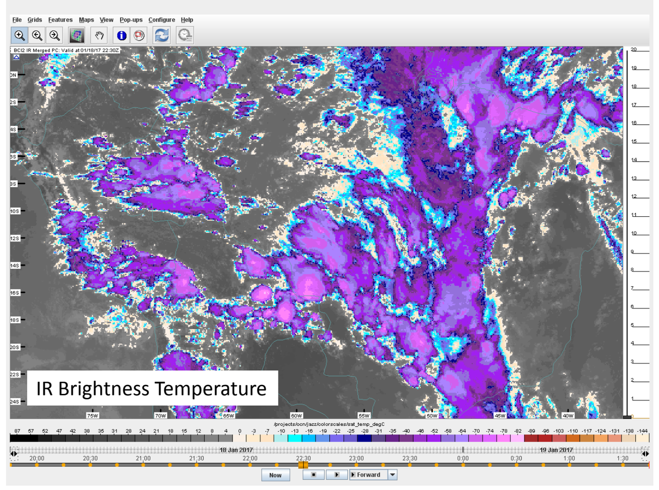


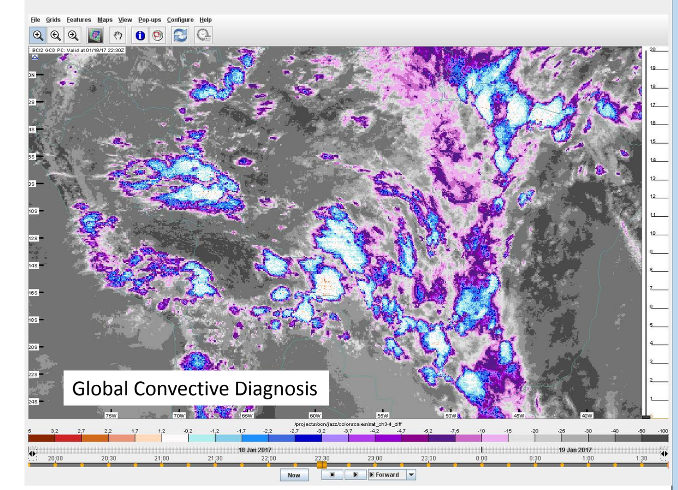


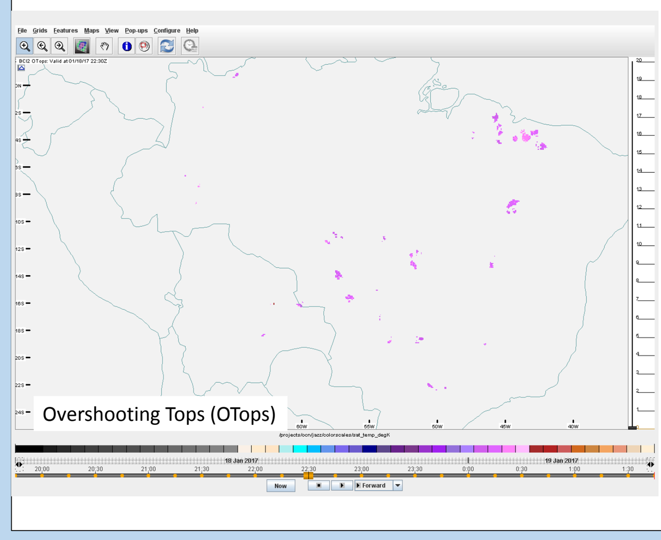


Global Convective Diagnosis (GCD) is computed by subtracting the brightness temperature of the IR channel from the brightness temperature of the water vapor channel (Mosher, 2002) . The GCD indicates the location of mature updrafts when the difference is near zero. All geostationary satellites have these two channels, allowing this field to be computed globally.



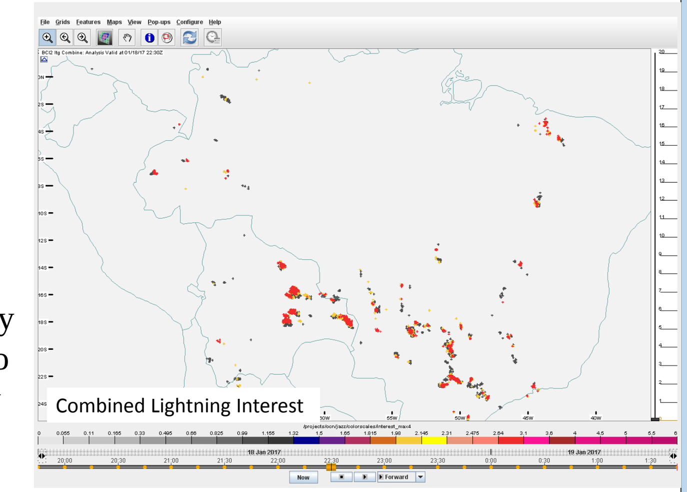






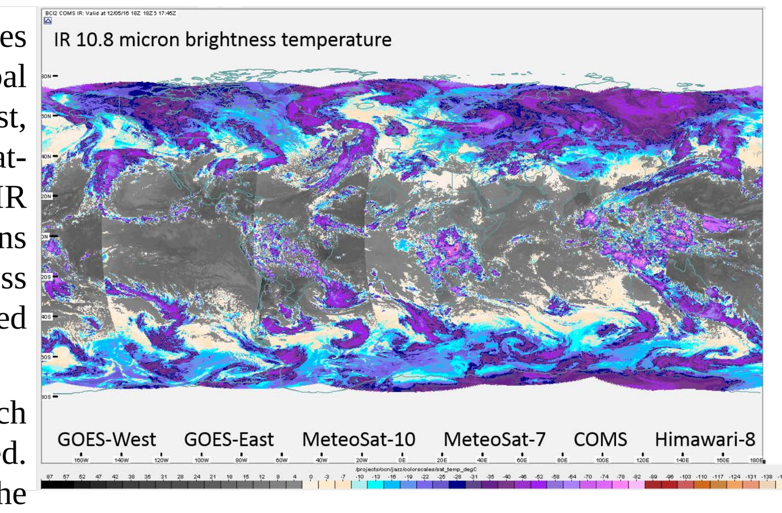
GOES-R Overshooting Tops Algorithm (OTops, left) is computed following Bedka et al. (2010) and shows the locations of overshooting tops.

Combined Lightning Interest (right) is computed by accumulating EarthNetworks lightning strike data into 15 min, 30 min and 60 min accumulation fields. They are combined in a fuzzy logic framework to produce an interest map.

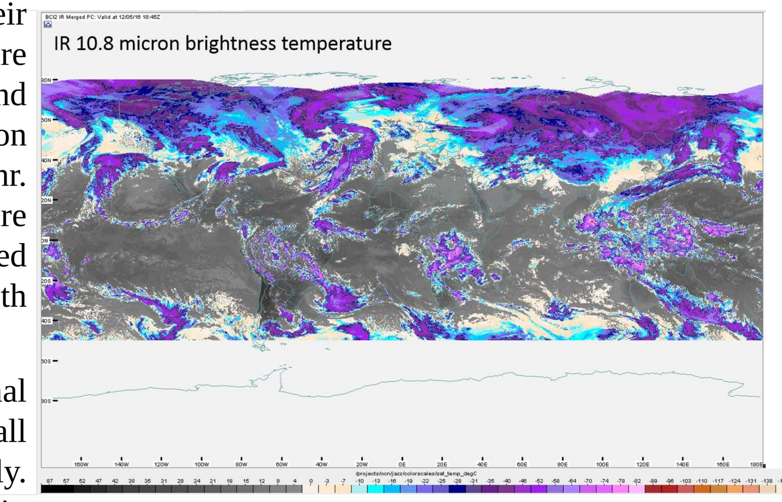


Geostationary Satellite Mosaic

Data from six geostationary satellites are utilized to construct a global mosaic and include: GOES-West, GOES-East, MeteoSat-10, MeteoSat-7, COMS and Himawari-8. The IR brightness temperature at 10.8 microns and the water vapor brightness temperature at ~6.7 microns are used from each satellite.



To create the mosaic, data from each satellite are first parallax-corrected. Due to their scanning strategies, the GOES satellite data from the various sub-domains are merged to cover their respective domains. In regions that are only covered by the full disk scan (and not by a partial scan), an extrapolation of the data is done to 1-hr and 2-hr. Data from adjoining satellites are mosaicked by using weighted combinations where the satellite zenith angle determines the weight applied.



The global mosaics have a nominal 15 min update interval, but not all satellites update that frequently. Horizontal grid spacing is 0.06 deg in latitude and longitude.

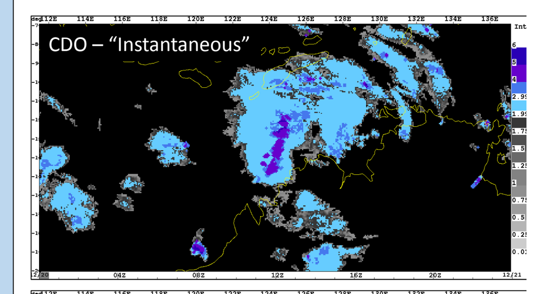
Validation of CDO with GPM IMERG

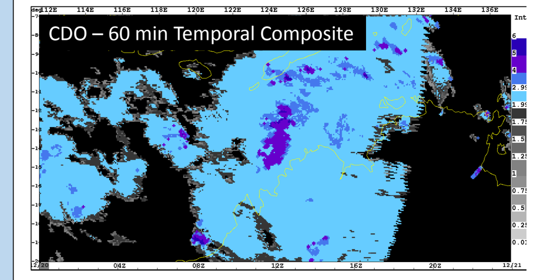
Data from the NASA Global Precipitation Measurement (GPM) Integrated Multi-satellitE Retrievals for GPM (IMERG; Huffman, et al. 2014; Huffman et al. 2015) algorithm output are used to validate the CDO performance. The IMERG algorithm is a multi-instrument, multi-data set effort to create global, high resolution estimates of precipitation accumulation. The algorithm combines precipitation estimates from all available low-earth-orbit (leo) satellite passive microwave (PMW) sensors after they have been inter-calibrated, merged and interpolated. In addition, precipitation estimates from microwave-calibrated satellite IR data and precipitation gauge analyses are included in the IMERG algorithm processing.

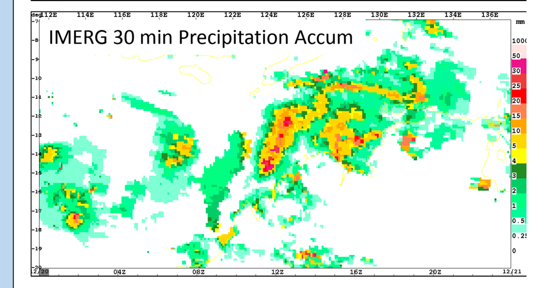
The IMERG is produced over a global domain at 0.1 horizontal resolution with a nominal 30 min precipitation accumulation and update rate. However, as explained in Huffman et al., (2014 and 2015), the 30 min estimates may include precipitation accumulation over time periods of an hour or more. Because the CDO is computed for a particular instance in time while IMERG is an accumulation over 30-60+ min, differences in coverage areas are expected. To offset this difference in coverage, a temporal composite of the CDO is computed. The temporal composite retains the maximum value of CDO at a particular grid point over the specified time interval, in this case 60 min. Preliminary statistics are calculated on a gridpoint-to-gridpoint basis from three recent cases. A more complete statistical study is planned to verify this methodology.

Summary and Future Work

An update on the Convective Diagnosis Oceanic (CDO) algorithm was given and input variables discussed. A preliminary statistical analysis shows that CDO compares well to the IMERG precipitation accumulation estimates, particularly at the 1.5 interest threshold and 0.5 mm accumulation. Higher thresholds are less robust; however additional processing techniques will be investigated and additional work with the NASA GPM satellite mission variables is planned.







The CDO and CTH products are being displayed on the eRM EFB in Lufthansa Airlines 747-8 aircraft over a global domain (see Kessinger et al. 2017).

Date	IMERG Threshold (mm)	CDO Threshold (interest)	CDO 60 min accumulation	
			CSI	Bias
13 Dec 2016 0-23 hrs	0.5	1.5	0.25	0.92
	3.0	2.0	0.17	1.17
	8.0	3.0	0.07	0.92
20 Dec 2016 0-23 hrs	0.5	1.5	0.24	0.94
	3.0	2.0	0.19	1.49
	8.0	3.0	0.09	0.87
1 Jan 2017 0-23 hrs	0.5	1.5	0.26	1.11
	3.0	2.0	0.19	1.50
	8.0	3.0	0.07	0.95

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