

GOESR3 Periodic Reporting

Reporting Period: July 2017 – December 2017 (1st half of FY17 funding cycle)

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Project Title: GOES-R High Impact Weather Research Theme

Project Number: 308

Executive Summary

The CIMSS GOES-R High Impact Weather Research Theme focuses on two major high impact weather events: fires and severe storms. The objective of the fires component of the research is to improve NWS WFO and IMET situational awareness during wildfire events. The fires component will have three sub-topics focusing on fire detection and characterization, smoke forecasting and data assimilation, and development of probabilistic estimates of lightning wildfire ignition sources. The severe storm component of this proposal will aim to improve severe storms and hurricane analysis/prediction by building on mature research activities and applying novel GOES-R observing capabilities to leading-edge product and data assimilation methodologies. FY17 funding to CIMSS was reduced by \$300K over what was originally proposed, which has adversely impacted progress especially on the severe storms component of the GOES-R High Impact Weather Research Theme.

Progress toward FY17 Milestones

Fires component:

In FY17, the fires component of the GOES-R High Impact Weather theme focused on 1) using GOES-16 Fire Radiative Power (FRP) retrievals to characterize the diurnal profile of wildfire emissions associated with large wildfires in the western US and 2) conducting Observation System Simulation Experiments (OSSE) to develop capabilities to assimilate GOES-16 Aerosol Optical Depth (AOD) within the High Resolution Rapid Refresh smoke forecasts (HRRR-Smoke).

1) Improved NWS IMET and WFO situational awareness during wildfire events

One of the largest concerns of NWS IMET and USFS Air Program Managers is the diurnal behavior of large wildfires. This information is critical for incident planning since the fire managers need to know when the fire will intensify and whether wild fire smoke will hinder fire suppression activities. Polar orbiters such as MODIS and VIIRS provide nighttime and daytime estimates of fire counts and FRP which provide only limited constraints on diurnal wildfire behavior. As a result, wildfire managers rely on idealized diurnal profiles of wildfire emissions. The BlueSky Framework (Larkin et al, 2009) which is used by the USFS for smoke dispersion modeling and by the NWS for wildfire emissions within the National Air Quality Forecasting Capability (NAQFC) assumes a wildfire profile with 68% of the emissions during the afternoon active fire period (1300–1700 hours local time) and a smoldering component that continues throughout the night.

Geostationary measurements from GOES-16 provide continuous measurements and provide better constraints on diurnal fire behavior. Discussions with USFS Air Program managers in the Pacific Northwest have guided our selection of the 2017 Rice Ridge Fire in Montana (<https://inciweb.nwcg.gov/incident/5414/>) as our first case study to determine what information GOES-16 fire detection can provide on diurnal fire behavior. This wildfire was started by lightning on July 24, 2017 and burned 160,187 acres before being contained on October 20, 2017. Daily USFS incident reports have been collected for this fire and provide information on the fire activity which can be used to validate the diurnal fire behavior obtained from GOES-16.

Figure 1 shows the mean FRP from GOES-16 binned by hour for the Rice Ridge Fire during its entire duration from 24 July 2017 to 20 October 2017. The FRP observations in the mean are the sum of all pixels in the complex, averaged for every hour of the entire period. Only valid FRP estimates were considered, which excludes the saturated, cloudy, medium possibility, and low possibility fire classes (but includes processed and high possibility). That decreases the reported FRP, sometimes quite substantially. The error bars represent one standard deviation of the data, which is quite large due to the variation of FRP values day to day. GOES-16 also experienced several product anomalies during this period which resulted in dropped data that peaked around the hottest part of the day in the region, causing an artificial depression in the means around 0 UTC. Despite the anomalies, large range in FRP values, and variables like cloud cover, the diurnal trend in fire intensity is consistent. GOES-16 mean FRP peaks between 03-04 UTC (9-10pm MDT) and then shows a gradual decline during the evening with lowest mean FRP between 14-17Z (8-11am MDT). GOES-16 mean FRP shows a secondary peak between 21-23 UTC (3-5pm MDT). Variability in GOES-16 FRP is 3-4 times larger during the evening (8-11pm MDT) than during the afternoon (1-5pm) for this fire complex. This diurnal profile is quite different than assumed within the NAQFC but is generally consistent with USFS incident reports for the Rice Ridge fire which included active fire behavior characterized as “Single tree torching, group torching and uphill runs with spotting occurred during mid and late afternoon” and reports of “Extreme fire behavior with crowning was observed in the evening hours”. We will continue to analyze the GOES-16 FRP for this fire complex by comparing daily USFS incident reports with the GOES-16 FRP timeseries.

2) Support NWS smoke forecasting and assimilation

Observing System Simulation Experiments (OSSE) using synthetic observations derived from independent WRF-Chem simulations and formatted as BUFR to mimic future input files with GOES-R ABI retrievals were conducted using the Gridpoint Statistical Interpolation (GSI). GSI uses the Community Radiative Transfer Model (CRTM) with Goddard Chemistry Aerosol Radiation and Transport (GOCART) aerosol speciation to compute AOD at the ABI spectral bands. To accommodate the GOCART aerosols the smoke tracer used within the High Resolution Rapid Refresh smoke forecasts (HRRR-Smoke) was projected onto the GOCART smoke aerosol species (hydrophilic and hydrophobic black and organic carbon). Also, since the ABI Baseline AOD retrievals which are only provided at 550 nm and CRTM does not predict AOD at 550nm, the GSI was extended to provide a first guess AOD at 550nm. HRRR-Smoke only forecasts smoke and does not include sulfate, nitrate, secondary organic aerosols, dust, or seasalt. To constrain occurrence of analysis increments at locations where the actual smoke was detected, smoke masks derived from multispectral VIIRS retrievals were incorporated to the GSI and used in the assimilation. The synthetic AOD and smoke masks will be updated to ABI retrievals once these products are declared provisional, which should occur in March, 2018.

Figure 2 shows observed VIIRS AOD and smoke mask (upper panels) and 00Z forecasted smoke AOD for control and synthetic AOD assimilation experiments (lower panels) on August 31, 2016. The

synthetic ABI AOD retrievals were assimilated on an hourly basis as they would be with a geostationary satellite. Negative bias, associated with underestimates in wild fire emissions derived from MODIS and VIIRS fire detections are reduced when synthetic ABI AOD is assimilated. The ABI AOD OSSE shows that high frequency AOD assimilation has a potential to address the deficiencies of the forecasts. They also demonstrate that fire emissions based on satellite fire radiative power (FRP) algorithms require further tuning and improvement.

Severe Storms component

In FY17, the two research foci under this component are 1) explore the application and assimilation of GOES-16 Atmospheric Motion Vectors (AMVs) on fine time and space scales to better characterize the evolving mesoscale flows into and around severe storm development and hurricanes, and 2) improve tropical cyclone characterization using GOES-16 multispectral imagery and derived products. [Funding curtailments did not allow any R&D work on the other severe storm application foci originally proposed (these will be fully funded in FY18)]. The progress so far on these two tasks is summarized below.

1) Application and assimilation of high-resolution AMVs

One of the principle benefits expected from GOES-16 is the improved temporal sampling of images from the ABI. In addition to qualitative uses by forecasters, the rapid refresh (1-5 min.) will allow for quantitative improvements in derived products normally associated with geostationary satellite imagery. One of those products is AMVs. The reasons we are optimistic that GOES-16 AMVs can be an important contributor to mesoscale analyses derive from recent and ongoing proxy studies (Velden et al. 2017). Our plan in this project is to build on these efforts as we also take advantage of GOES-16 capabilities and new AMV derivation methods towards the production of mesoscale AMV datasets with the goal of extracting wind information that benefits short-term forecasts and operational NWP.

For this project, we utilize the new (and novel) approaches of the GOES-16 AMV tracking algorithm developed under the GOES-R Algorithm Working Group (AWG) program (Bresky et al. 2012) , and focus on the smaller (meso) scales for AMV derivation, quality control, and applications, taking advantage of what the improved ABI temporal and spatial sampling will provide. The first goal is to optimize the algorithm settings, tuning, and AMV derivation methodologies to increase the data density and improve the ultimate quality to better capture smaller-scale flow fields. This process involves empirical testing and statistical validation of the AMVs vs. existing GOES AMV datasets, rawinsonde observations, and other tropospheric wind datasets of opportunity.

Tropical Cyclone applications

During the 2017 hurricane season, AMV datasets were processed during selected events. The focus was on employing the GOES-16 1-min. meso scans when they were centered on a target tropical cyclone. An example of AMVs extracted for one time period during Hurricanes Harvey, Irma and Maria are shown in Figs. 2-4. The plotted vectors are thinned for viewing purposes, and shown in two colors representing upper (cyan) and lower (yellow) tropospheric coverage. The AMVs are derived from a combination of VIS, SWIR (3.9m), LWIR, and WV image triplets at nominal time resolutions (1-10mins) for each band. Datasets at hourly intervals were created for the entire lifecycles of Hurricanes Harvey, Irma and Maria.

In the 2nd half of FY17, we plan to start collaborations with experts in regional data assimilation and NWP (NCEP-EMC, AOML/HRD) to conduct AMV data impact experiments from the above cases. Locally, SDAT and HWRF will be the primary NWP tools for evaluation.

Severe Local Storm applications

The improved spatiotemporal sampling from the GOES-16 ABI will allow critical mesoscale flow features associated with severe local storms diagnostics and kinematics to be better observed. We are exploring both heritage and novel new AMV derivation methodologies that can identify key convective cloud-top variables associated with severe storm events. This work is being done in collaboration with John Mecikalski and Jason Apke at the University of Alabama-Huntsville, Jaime Daniels at NESDIS/STAR, and Bob Rabin at NOAA/NSSL. Preliminary attempts on case studies are encouraging. An example is shown in Fig. 5, comparing two methodologies to derive AMVs over a severe convective complex. Further tuning experiments and analysis will be needed to verify the optimal processing strategies. Once the AMV processing is optimized for this application, we also plan to partner with data assimilation experts and conduct AMV data impact studies.

2) Improve tropical cyclone characterization using multispectral imagery and derived products

The 16 channels on the GOES-16 ABI allow for multispectral combination products such as the pseudo-natural color and Saharan Air Layer (SAL) that are currently derived from MSG SEVIRI data. For this project, a focus of these derived-imagery products is on hurricane environment analyses in the Atlantic. Our longer-term plan is to expand and merge these products using the ABI imagery to cover the entire Atlantic, and explore hurricane-environment interaction cases.

An example of an experimental SAL product derived from GOES-16 ABI data is shown in Fig. 6. For comparison, a companion SAL image is shown from the MSG SEVIRI. This work is being done in collaboration with Jason Dunion (UM/CIMAS), and he will visit CIMSS for a week or two in May to fine-tune the derived products. Once the products are fully developed from ABI, we plan to showcase them as part of the GOES-16 NHC Proving Ground in 2018.

Plans for Next Reporting Period

Fires component

Once ABI FRP and AOD retrievals from GOES-R ABI are fully validated, they will be compared with similar products from VIIRS and used in simulations parallel to the current ones. After developmental work with WRF-Chem-Smoke at 20 km grid resolution is completed the simulations will be transferred to HRRR-Smoke domain to prepare for the eventual real-time deployment of the assimilation and forecasting of smoke at 4-km grid resolution. The real-time deployment will be demonstrated during the NOAA FIREX field experiment, which will occur during the summer of 2019. To match and exceed statistical verification metrics of the current simulations tuning of model background error statistics used in the assimilation will be required. Because of the dependency of model errors on source emissions further changes to the GSI that make model error variances proportional to smoke species concentrations, rather than being zonal as in the default configuration, will be investigated.

Severe Storms component

The emphasis in the next reporting period will be on analysing the impacts of the reprocessed GOES-16 AMVs in HWRF hurricane track and intensity forecasts, and refining the GOES-16 SAL product augmented by a visit to CIMSS from Jason Dunion for collaborative purposes. Also, first results will be presented at the upcoming AMS Tropical Conference in April.

Additional Information

1. Interaction with operational partners – Forecasters at NHC were shown the experimental GOES-16 AMVs during hurricane events last season. This peaked their interest, and they are keen to request higher-res-AMV-enabling GOES-16 meso sectors for future events this upcoming season. The improved SAL product is also high on their request list to get into AWIPS-2.

The fires project team participates in monthly JPSS Fire and Smoke Initiative conference calls and provides updates to Western Region NWS offices and IMETs on the status of HRRR-Smoke development and inclusion of ABI AOD and FRP products into the HRRR-Smoke forecasting system. This involves close collaboration with Ravan Ahmadov (OAR/ESRL, HRRR-Smoke Lead Developer). As part of the JPSS F&S Initiative we have formed a smoke modelling sub group with participants from the US Forest Service Washington DC Office, (Pete Lahm, Smoke Manager), Pacific Northwest Region (Rick Graw, Regional Air Program Manager) and Pacific Northwest Research Station (Susan O'Neill, Research Air Quality Engineer). This smoke modelling sub group will continue to provide guidance on evaluation of the GOES-16 FRP.

2. Conference/workshop participation – None in this reporting period

3. Outside project publicity – Given the high-interest hurricane events in 2017, GOES-R experimental AMV products were sent to Steve Goodman (GOES-R Chief Scientist) in near-real time for PR use by the Program Office.

4. Journal articles – None in this reporting period.

Key Graphics

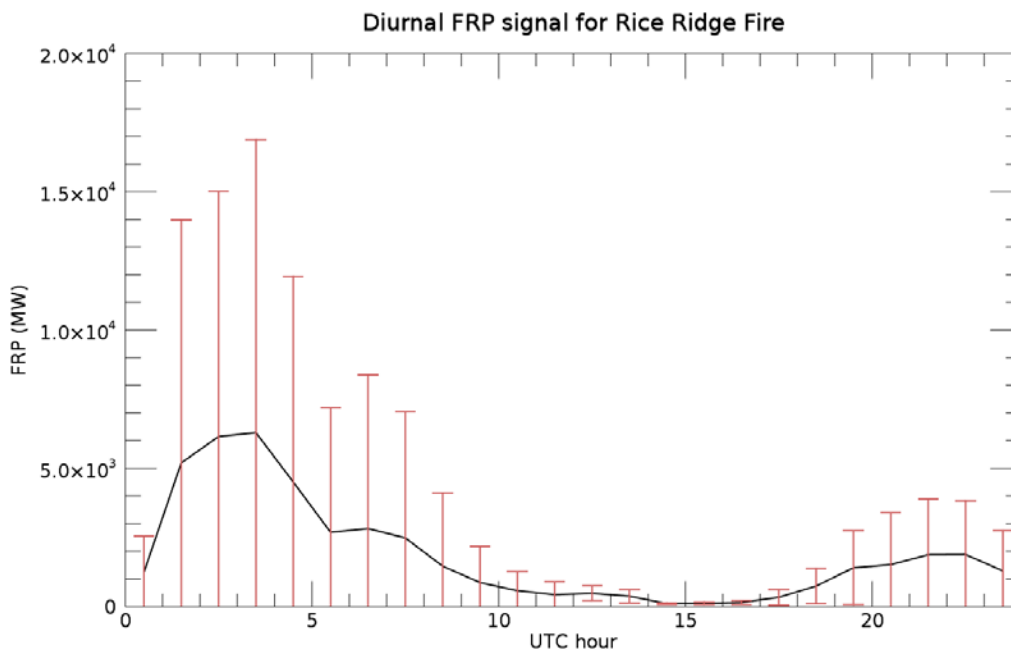


Figure 1: Diurnal variation of Fire Radiative Power (FRP, mw) for the Rice Ridge Fire in Montana during July-October, 2017. The black line shows the median FRP and the red lines show the standard deviation of FRP as a function of time in UTC hours.

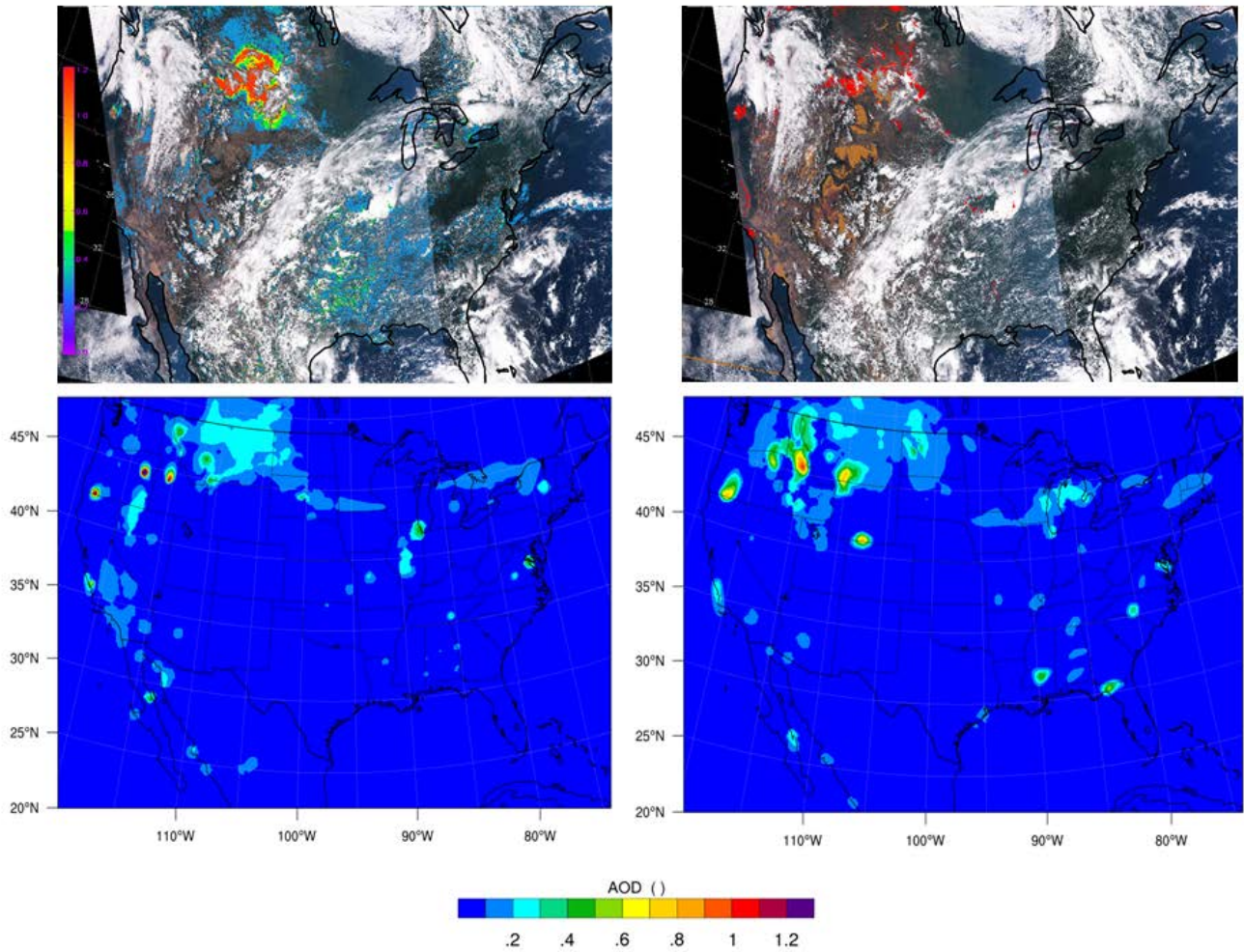


Figure 2: VIIRS AOD (upper left) and smoke mask (upper right) and 00Z forecasted smoke AOD for control (lower left) and synthetic AOD assimilation experiments (lower right) on August 31, 2016.

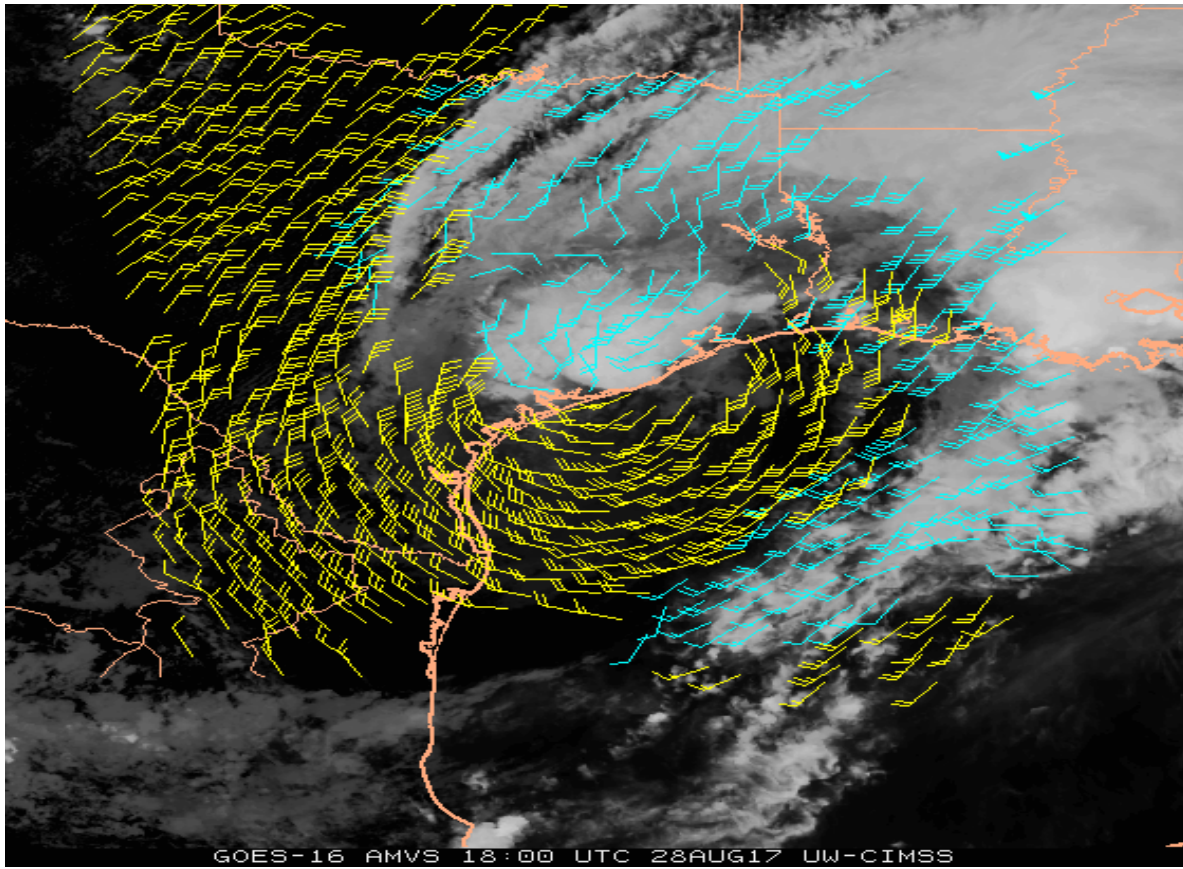


Figure 3: Plot of AMVs derived from a triplet of multispectral GOES-16 meso sector scan images during Hurricane Harvey (2017). Yellow (Cyan) vectors denote lower (upper) tropospheric flow.

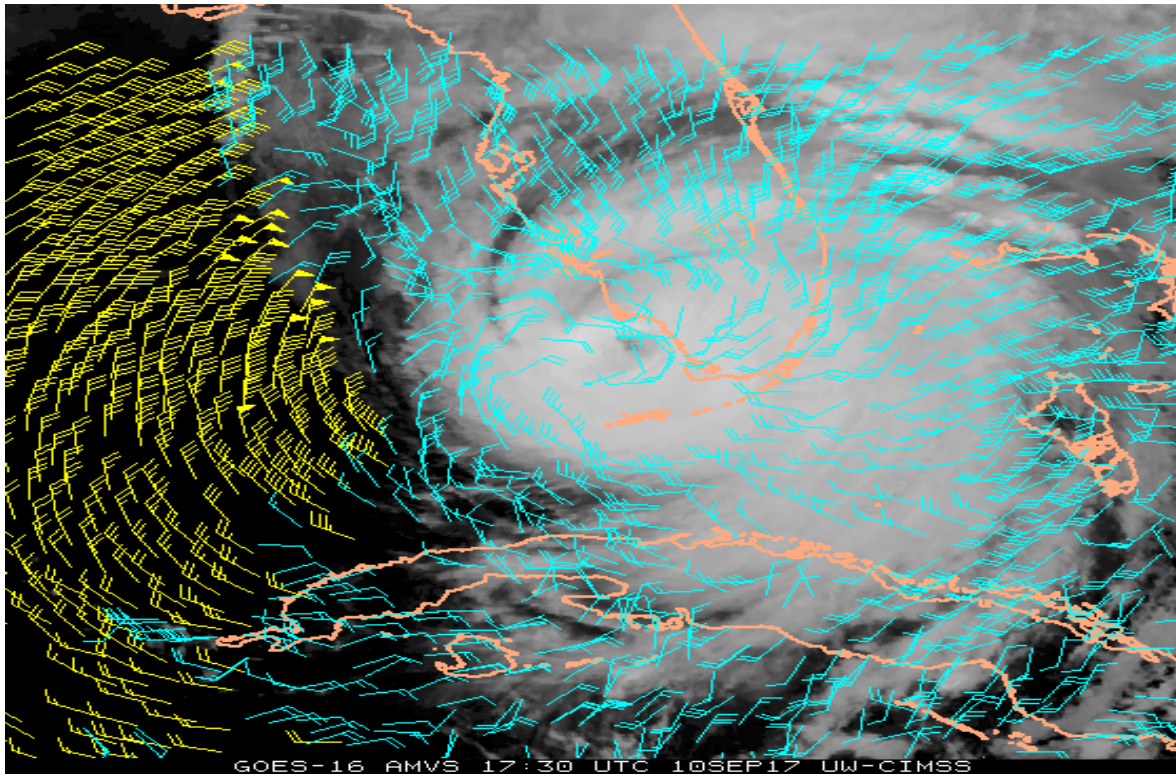


Figure 4: Plot of AMVs derived from a triplet of multispectral GOES-16 meso sector scan images during Hurricane Irma (2017). Yellow (Cyan) vectors denote lower (upper) tropospheric flow.

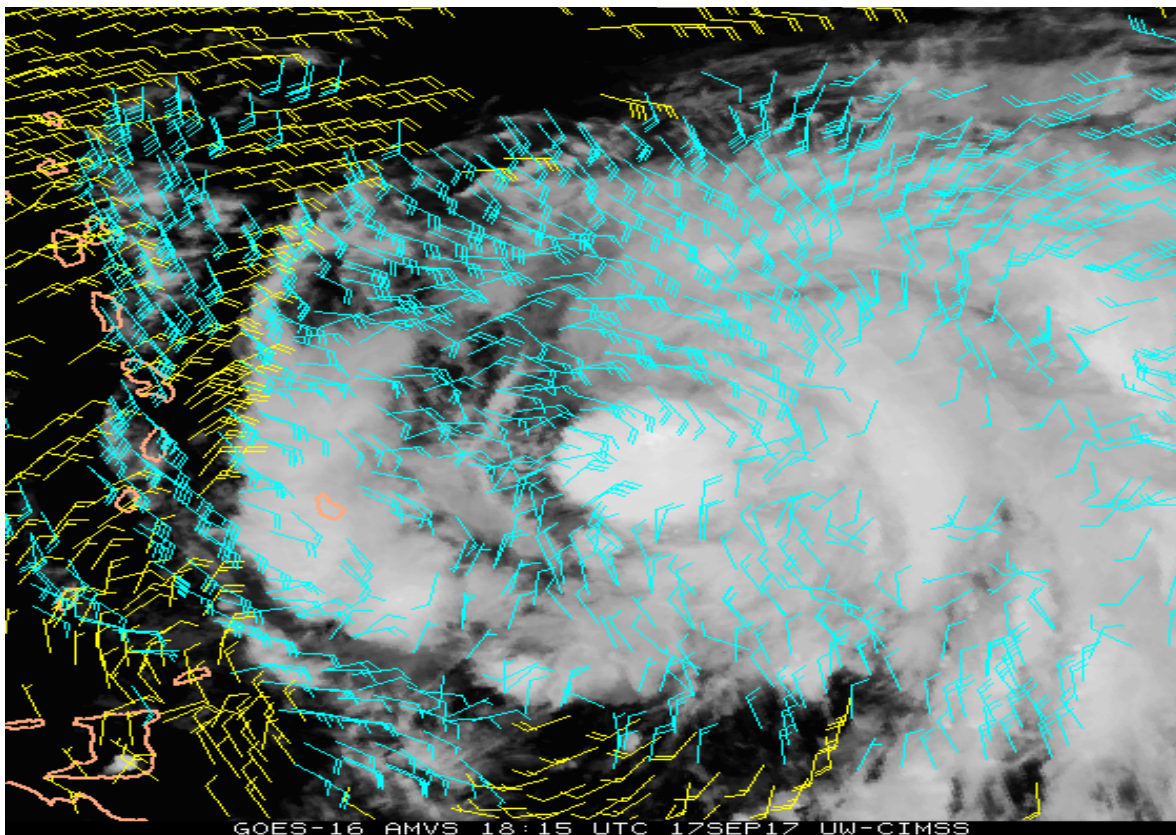


Figure 5: Plot of AMVs derived from a triplet of multispectral GOES-16 meso sector scan images during Hurricane Maria (2017). Yellow (Cyan) vectors denote lower (upper) tropospheric flow.

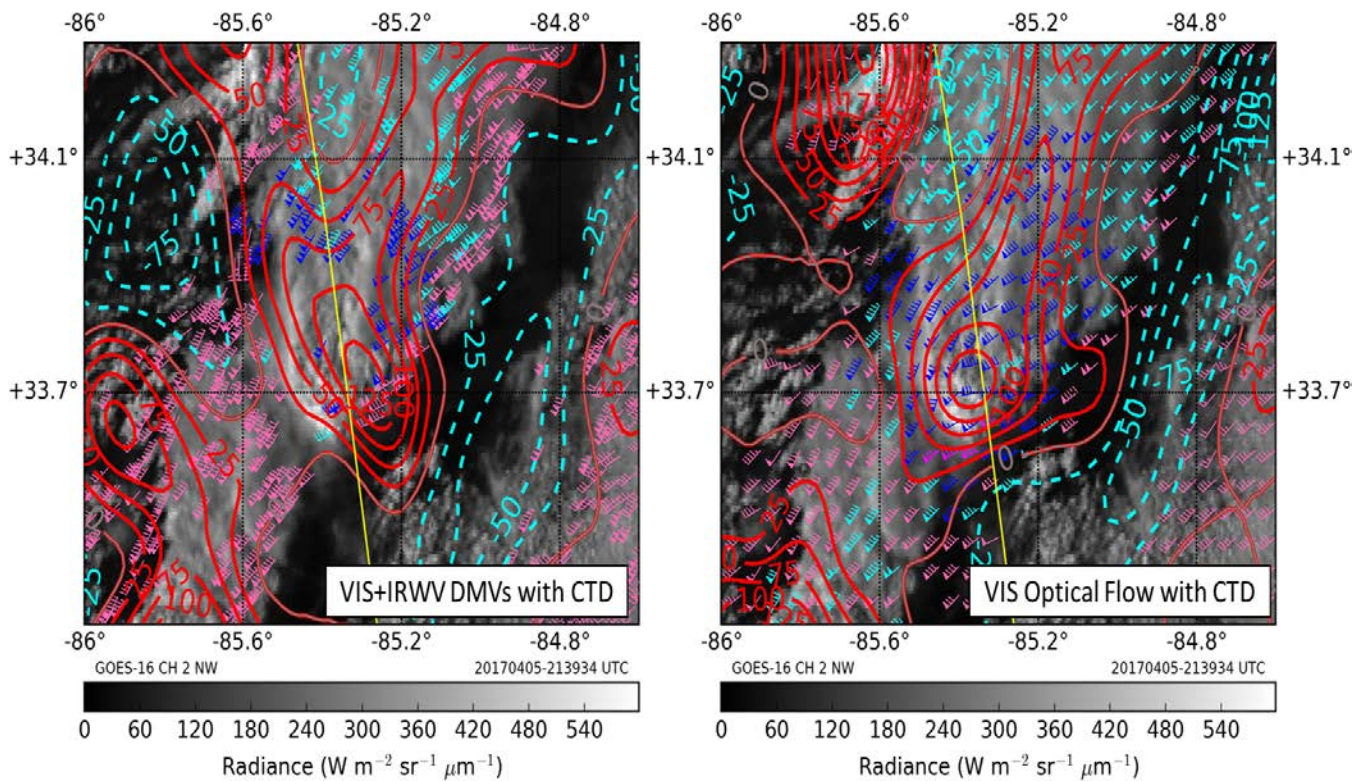


Figure 6: The GOES-16 channel 2 VIS imagery of a severe storm on 5 April 2017 over eastern Alabama with an overshooting top. Plotted are AMVs derived from GOES-16 VIS, IR and WV imagery from the NESDIS algorithm and subsequent cloud-top divergence (CTD) analysis (*Left*), and VIS vectors derived with a novel Optical Flow algorithm with CTD (*Right*). CTD is contoured with positive (negative) values in red (blue dash) every $25 \times 10^{-5} \text{ s}^{-1}$, and vectors are colored by pressure, with hot pink representing vectors at pressure (p) $500 \text{ hPa} > p \geq 200 \text{ hPa}$, cyan at $200 \text{ hPa} \geq p > 175 \text{ hPa}$, blue at $175 \text{ hPa} \geq p > 150 \text{ hPa}$.

Saharan Air Layer Product: 19 Aug 2017 12 UTC

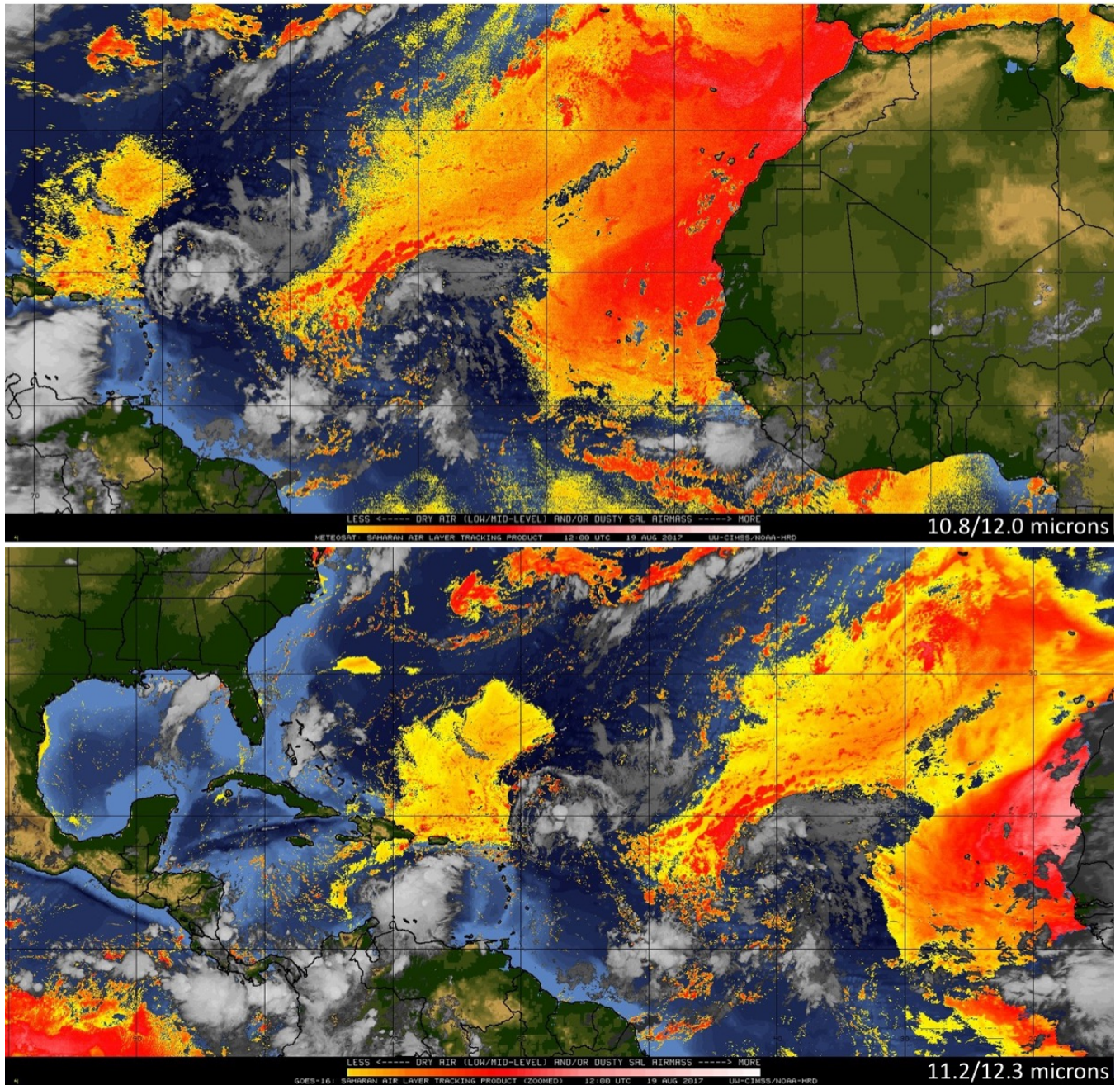


Figure 7: Example of experimental Saharan Air Layer (SAL) split-window derived imagery from concurrent MSG-SEVIRI (top) and GOES-16 ABI (bottom). The warm colors in the imagery depict dry air and especially dry/dusty air associated with air masses originating over the African Saharan desert.