First Remote Sensing Observations of Convective Bursts in a Rapidly Intensifying Hurricane from the Global Hawk Platform

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During the NASA GRIP field experiment, GSFC’s HIWRAP radar flying on the unmanned Global Hawk aircraft with additional measurements from the JPL HAMSR radiometer and NOAA radars provided an unprecedented view of the rapid intensification of Hurricane Karl (2010) for a ~14 hour period. Convective bursts formed in Karl through: (1) convergence generated from counter-rotating mesovortex circulations and the larger scale vortex flow and (2) the turbulent transport of warm, buoyant air from the eye to the eyewall at low-to-mid levels.
Reference:

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Data Sources: NASA/GSFC HIWRAP airborne Doppler radar, NASA/JPL HAMSR airborne radiometer, NOAA radars, GOES IR channel.

Technical Description of Figures:
*Figure 1:* Panel (i) shows the eye and eyewall of Hurricane Karl (2010) at 2 km height at ~ 1910 UTC 16 September from HAMSR 54 GHz Tbs (shading) along with HIWRAP wind vectors revealing cyclonic mixing of the warm core (high Tbs) into the eyewall, which helps to fuel the convective burst observed through ice scattering (low Tbs). Panel (ii) shows a vertical cross section of HIWRAP data through the storm center shown in panel (i) by the gray line. The data shown in panel (ii) is (a) Ku band reflectivity, (b) storm-relative meridional (radial) wind speeds and (c) vertical wind speeds, which reveal the detailed interaction between the eye and convective tower in the southern eyewall. Finally, panel (iii) shows a conceptual diagram summarizing the measurements and analysis from the rapid intensification of Karl. Red arrows denote the flow of air having anomalously warm characteristics. Green patches denote regions of convergence that form due to the interaction between the mesovortex circulations and the larger scale vortex inflow.

Scientific significance: Understanding and predicting the rapid intensification of hurricanes is among the most challenging problems in atmospheric science due to the stochastic, turbulent nature of the primary forcing (convective clouds). Comprehensive observations from a variety of instruments in many cases are required to determine if there is some level of order in the chaotic evolution of convection. The observations presented in this paper from new NASA technologies indicate that deep convective clouds can be organized by mesoscale circulations at the eye/eyewall interface that may provide some level of determinism for the predictive problem.

Relevance for future science and relationship to Decadal Survey: The recognition of the importance of small-scale processes in the evolution of the larger scale hurricane vortex motivates the need to develop sensors with very high spatial and temporal resolution to fully resolve the turbulent nature of convection. Other atmospheric phenomena with similar scale interactions such as severe storms and the Madden-Julian Oscillation (MJO) would benefit from this research and the sampling approach described above. A Doppler radar in space that can accurately measure the three-dimensional winds at reasonably high resolution would be a tremendous asset to address these problems.
The Deep Space Climate Observatory (DSCOVR), as all satellites, samples Earth at a finite temporal resolution. DSCOVR sampling of global radiation and cloud cover is simulated using high spatial resolution output from NASA’s GEOS-5 model. We find that the less frequent the sampling, the worse the correlation between the subsample and the original time series, as expected. On the other hand, more frequent sampling is not as beneficial as expected for errors in the global monthly, seasonal and annual means. For example, the uncertainty above right is larger for 6 hour sampling than for 7, 9, 10 and 11 hours. This is due to the Earth’s 24-hour rotation cycle. Using sampling frequencies that are a factor of 24 results in repeatedly capturing specific parts of the cycle, introducing a bias.
References:


Technical Description of Figures:
The figures show simulations of DSCOVR-like observations with GEOS-5 Nature Run at both original temporal resolution (30 min) and subsampled coarser temporal resolution in order to study the ensuing effects.
Upper Left Panel: Mean of the correlation coefficients between the original and subsampled global total outgoing radiation time series as a function of temporal sampling frequency. The different curves represent different time scales. For example, the “Monthly” curve is generated by calculating the correlation coefficients between the subsamples and the original time series for each month and then averaging over the entire Nature Run time period (2 years).
Upper Right Panel: The error in the global mean total outgoing radiation derived from the subsampled time series as a function of temporal sampling frequency.
Lower Left Panel: Same as the upper left panel, but for global mean cloud fraction.
Lower Right Panel: Same as the upper right panel, but for the global mean cloud fraction.

Scientific significance, societal relevance, and relationships to future missions:
Orbiting around the Earth’s L1 Lagrange point, the DSCOVR satellite always stays near the Sun-Earth line. At this location, which lies around 1.5 million km away from the Earth, DSCOVR can view the entire daytime hemisphere continuously. Observations from the two Earth-observing instruments onboard, the National Institute of Standards and Technology Advanced Radiometer (NISTAR) and the Earth Polychromatic Imaging Camera (EPIC), are being used to derive information about the Earth’s radiation budget, cloud, aerosol, ozone, and vegetation. DSCOVR, like any other satellite, can only provide observations with a finite temporal resolution. As a result, the information derived from these observations does not represent the true system. We investigate how subsampling affects the mean and how close the sampled time series is to the truth using GEOS-5 Nature Run data. Our analysis shows that the errors in the global monthly, seasonal and annual means, be it radiation budget or cloud coverage, are not a monotonic function of sampling frequency. Error peaks appear at four, six, eight and twelve hour sampling rate because of the 24 hour cycle associated with the Earth's rotation. DSCOVR should therefore avoid sampling at these time intervals. Analysis of correlations between subsamples and the original time series show that while obtaining a mean close to the truth is possible even at large sampling intervals, in general the subsampled time series moves farther away from the truth, the coarser the temporal resolution. Even though this study is about the DSCOVR mission, the results are helpful in understanding the uncertainties in products from other satellites (past, current or future) as well. As shown by DSCOVR, satellites located at the L1 point has the unique advantage in observing the climate system. In the future, should a DSCOVR follow up be planned, this study could provide general guidance in the sampling strategy.
A new “top-down” emission-source detection algorithm was applied to the measurements of sulfur dioxide (SO$_2$) from the Ozone Monitoring Instrument (OMI) on-board the NASA Aura satellite. It was used to compile the first global, satellite-based emissions inventory, and is completely independent of conventional information sources. Nearly 40 of the sources identified by this new method were found to be missing from leading emissions inventories (black symbols and country color code), representing about 12% of the global total. Regionally, emissions can be off by factors of 2 or 3. This method has potential applications to detecting emissions for other pollutants (NOx, particulate matter).
Satellite Finds Unreported Sources of Toxic Air Pollution

NASA's Earth Monitoring Instrument (OMI) SO2 and NO2 NASA standard products. The Dutch-Finnish built OMI instrument is part of the NASA's EOS Aura satellite payload. The OMI project is managed by KNMI (PI Pieternel Levelt) and the Netherlands Space Agency (NSO). The Planetary Boundary Layer SO2 product (PBL OMSO2 v1.2.0) is publicly available from the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC) (http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI/omso2_v003.shtml). The NASA standard SP tropospheric NO2 product (OMNO2 version 2.1) is publicly available from NASA GES DISC at http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI/omno2_v003.shtml.

Technical Description of Figure:
The map shows global distribution of location and magnitude of missing anthropogenic (circles) and volcanic (triangles) SO2 emission sources detected by OMI. The downwind-upwind difference, determined by merging OMI SO2 measurements with wind information, is an indicator used to determine the presence of a source of SO2. Many of the missing SO2 sources were located in the Middle East and related to the oil & gas sector. Also, each nation is color-coded according to the fraction of emissions that were found to be missing from their national totals.

Scientific significance, societal relevance, and relationships to future missions:
These results represent the first global satellite-derived emissions inventory. It is independent of previous, conventional knowledge sources and hence can be used to both verify emissions and locate new or unaccounted for emissions sources. Further, it provides a consistent method for deriving emissions, independent of source type and geopolitical borders. We find that of the 500 or so large sources in our inventory, nearly 40 are not captured in leading conventional inventories. These missing sources are scattered throughout the developing world (e.g., over a third are clustered around the Persian Gulf) and add up to roughly 6–12% of the global anthropogenic total. This method can be used for other short-lived pollutants such as nitrogen oxides, particulate matter, and ammonia.

The next generation of instruments will enable more accurate emissions and improved detection limits. This includes the TROPOspheric Monitoring Instrument (TROPOMI) mission, planned for launch on ESA's Sentinel 5 Precursor (S5P) satellite in 2016, and later on the geostationary constellation of satellites: NASA's first EV-I Tropospheric emissions: monitoring of pollution (TEMPO) over North America, http://tempo.si.edu, over Europe (ESA's and Copernicus Sentinel 4 UVN) and East Asia (Geostationary Environment Monitoring Spectrometer (GEMS) on board the GeoKOMPSAT satellite).