Observations of the hurricane boundary layer (ocean surface to ~ 1 km height) are important for vulnerable coastal communities and making predictions of storm intensity. These observations are difficult to obtain and have relied on point measurements taken from “dropsondes”. New analysis of IWRAP radar data provides a first look at coherent turbulence in the boundary layer of Hurricane Rita (2005). Intense turbulent eddies with new circulation signatures are connected to the evolution of the “eyewall replacement cycle” where an outer eyewall contracts and merges with the inner eyewall.
References:

Data Sources: Imaging Wind and Rain Airborne Profiler (IWRAP) airborne Doppler radar, WP-3D Tail and Lower Fuselage radars, Stepped Frequency Microwave Radiometer (SFMR) passive microwave radiometer, WP-3D flight level data.

Technical Description of Figures:
**Graphic 1 (left):** Vertical cross sections of IWRAP data at nadir between 1910 – 1920 UTC 22 September 2005 in Hurricane Rita during the concentric eyewall stage. The panels show Ku-band reflectivity (dBZ) and horizontal wind speed (m/s). These figures show the structure of turbulent filaments with the most intense eddies located at the inner edge of the outer eyewall. The filaments are vertically coherent with horizontal winds in-phase with vertical winds indicating a convectively coupled wave feature. These eddies transport high momentum upward and radially outward, likely playing a role in the intensity evolution of the storm.

**Graphic 2 (right):** The same as in Graphic 1 only between 2050 – 2100 UTC 23 September 2005 during the merging eyewall stage. The most intense turbulent eddies are now located at the inner edge of the inner eyewall after the coalescence of the concentric eyewalls. The system was slowly weakening during this time period but remained a powerful category 4 storm.

**Scientific significance, societal relevance, and relationships to future missions:** The destructive power of hurricanes is unlike anything else on Earth with the proven capability to significantly damage the US economy, destroy entire regions and kill thousands of people even in the modern era. The boundary layer of a hurricane (ocean surface to ~ 1 km height) is of prime importance for vulnerable coastal communities and for making accurate forecasts of storm intensity that can help mitigate the loss to life and property. Measurements of this intense and dangerous layer are difficult to make and have relied heavily on instruments dropped from aircraft, which are not optimal for capturing the full structure. New processing and analysis of data from the Imaging Wind and Rain Airborne Profiler (IWRAP) in intense Hurricane Rita (2005) is able to provide the nearly full structure of the turbulent boundary layer at very high resolution, filling a crucial measurement gap. The IWRAP measurements and calculations showed that Rita contained thin turbulent features that transported air with high momentum upward and outward away from the storm core, potentially playing a role in the eyewall replacement cycle of the storm. The structure of these coherent turbulent features is different than the prevailing understanding of boundary layer rolls, which transport high momentum air downwards towards the ocean surface. Overall, the results of this work demonstrate the potentially significant role played by the turbulent scales of motion in the hurricane vortex dynamics. The recent 2018 Earth science decadal survey mentions the important role of the boundary layer in the Earth system, but these measurements are even more difficult to make from space. The decadal survey makes recommendations for the community to set requirements, develop technologies and plan for future boundary layer missions. Studying the boundary layer of hurricanes from IWRAP can help set important science priorities and understand how to make measurements from space.
Traditionally, regional-level air quality in populated areas is assessed through chemical transport model (CTM) simulations, loosely constrained by observations from surface monitoring stations which typically provide limited coverage downwind of major pollution sources, or none at all. Using a physical approach, we demonstrate that CTM estimates of fine particulate matter (PM$_{2.5}$), and its major chemical component species, can be improved in space and time by adding broad regional context information from satellite retrievals of aerosol type. The images above show that the optimized concentration maps are spatially consistent with topography, typifying localized hotspots over known urban areas, and exhibiting realistic dispersion patterns. The optimized air quality estimation accuracy identifies and quantifies specific drivers of adverse, multi-pollutant health effects.
Reference:

Data Sources:
NASA MISR Research Aerosol Retrieval products; NASA MAIAC products; NASA DISCOVER-AQ products; AERONET and DRAGON products; EPA WRF–CMAQ simulations; EPA AQS in situ products.

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Technical Description of Figures:

*Graphic 1:* We examine the optimal application of this physical technique in the San Joaquin Valley, RGB image shown in (a). Surface PM$_{2.5}$ concentration maps of the regional CTM output are illustrated in (b). The combined satellite-based output of aerosol airmass-type maps from the MISR RA and total-column aerosol optical depth from the MISR RA and MAIAC are displayed in (c). The final image (d) shows the physically optimized (i.e., surface observations + satellite-based observations + model output) maps. The resolution of the concentration maps is 275 m, whereas the circular surface-observation-concentration-marker size is 11.1 km.

Scientific significance, societal relevance, and relationships to future missions:
Improved satellite retrievals of aerosol type can provide broad regional context and can decrease measurement uncertainties and errors, increasing the accuracy of near-surface air quality characterization. The frequent, spatially extensive and radiometrically consistent instantaneous constraints from satellites are especially useful in areas away from ground monitors and progressively downwind of emission sources.

The physical approach we developed leverages the complete spatial and temporal coverage of CTMs along with their physical constraints, such as aerosol mass balance and meteorological consistency. The CTM also aids in identifying relationships between observed species concentrations and emission sources. The paper also discusses the impact on surface PM$_{2.5}$ fields progressively downwind of large single sources, and evaluates the results using concurrent ambient air quality observations. Assessing this physical technique in well-instrumented regions opens the possibility of applying it globally, especially to areas where surface air quality measurements are limited or entirely absent.

This physical optimization approach uses ground-based monitors where available, combined with aerosol optical depth from both the Multi-angle Imaging SpectroRadiometer (MISR) Research Aerosol retrieval algorithm (RA) and the Moderate Resolution Imaging Spectroradiometer Multi-Angle Implementation of Atmospheric Correction (MAIAC) advanced algorithm, plus MISR qualitative constraints on aerosol size, shape, and light-absorption properties.
First SO$_2$ Retrievals from JPSS-1/NOAA-20 OMPS Reveal Greater Details of Volcanic Plume
Can Li, Colin Seftor, Glen Jaross, Nickolay Krotkov
Code 614, NASA/GSFC, UMD/ESSIC, SSAI

• Maps show SO$_2$ column amounts in Dobson Units (1 DU = 2.69 × 10$^{16}$ molecules/cm$^2$) detected by JPSS-1/NOAA-20 (N20)/OMPS, Aura/OMI, and SNPP/OMPS, after the eruption of Feugo volcano on Feb. 1, 2018.
• Footprints of the instruments are overlaid on the maps, showing much higher resolution offered by N20/OMPS.
• Such high-resolution measurements reveal greater details and cover a larger portion of the volcanic plume, and yield a higher and likely more accurate (albeit preliminary) estimate of SO$_2$ injection from the eruption, a key input for climate models.

*Note: the N20/OMPS instrument is currently operating at high resolution (10×10 km$^2$) during the commissioning phase and all data are preliminary. After this phase, the instrument will take measurements at reduced resolution (~10×20 km$^2$) that is still higher than that of SNPP/OMPS.
References:

Data Sources:
Level 2 NASA Aura Ozone Monitoring Instrument (OMI) total column SO$_2$ data (OMSO2) produced from OMI level 1 radiance data, using the NASA GSFC principal component analysis (PCA) satellite trace gas retrieval algorithm. Data are publicly available at NASA GES-DISC.
Level 2 NASA Suomi-NPP Ozone Mapping and Profiler Suite (OMPS) total column SO$_2$ data (NMSO2-PCA-L2) produced from SNPP/OMPS level 1 radiance data, using the same PCA-based retrieval algorithm as OMI. Data are publicly available at NASA GES-DISC.
Preliminary level 2 JPSS-1/NOAA-20 OMPS total column SO$_2$ data produced from preliminary N20/OMPS level 1 radiance data, using the same PCA-based retrieval algorithm as OMI.

Technical Description of Figures:
Graphic 1: Total SO$_2$ column amounts in Dobson Units (1 DU = 2.69 $\times$ 10$^{16}$ molecules/cm$^2$) retrieved with N20/OMPS (upper left), Aura/OMI (upper right), and SNPP/OMPS (lower left), after the eruption of the Feugo volcano in Guatemala on Feb. 1, 2018. The total column amount reflects the estimated total number of SO$_2$ molecules in the entire atmospheric column above a unit area of the surface. The retrieved column amounts change with the assumed a priori vertical profiles of SO$_2$. In this plot, SO$_2$ is presumed to be centered at about 8 km altitude. According to the National Coordination for Disaster Reduction of Guatemala (CONRED), the plume from the eruption reached an altitude of ~6.5 km. For such relatively small eruptions, the detection of SO$_2$ depends on the spatial resolution of satellite sensors, as large footprint often dilutes the SO$_2$ signal to below the detection limit. As compared with OMI (13×24 km$^2$ at nadir) and SNPP/OMPS (50×50 km$^2$ at nadir), N20/OMPS operates at a much greater resolution (10×10 km$^2$ at nadir) in this case, allowing SO$_2$ over a larger area to be detected and quantified.

Scientific significance, societal relevance, and relationships to future missions:
SO$_2$ from anthropogenic (e.g., coal burning) and volcanic sources has important impacts on air quality and climate. NASA has been providing global observations of SO$_2$ from Aura/OMI and SNPP/OMPS since their launches in 2004 and 2011, respectively. The preliminary SO$_2$ results here demonstrate that the new N20/OMPS instrument is also capable of producing high-quality SO$_2$ data, enabling the continuation and extension of the space-based SO$_2$ data records. In addition, the high spatial resolution offered by N20/OMPS will significantly improve the detection limit for relatively weak SO$_2$ signals, allowing emissions from even smaller SO$_2$ sources to be quantified than currently possible with OMI or SNPP/OMPS. N20/OMPS will also provide more accurate estimates of SO$_2$ injection from small and modest volcanic eruptions, and help to better understand their climate impact. This preliminary test with N20/OMPS further demonstrates that the PCA-based trace gas retrieval algorithm can be quickly implemented with new satellite instruments such as NASA TEMPO and KSA GEMS, and the follow-up JPSS/OMPS instruments. The PCA-based OMI and OMPS SO$_2$ data are also being used to evaluate the SO$_2$ retrievals from the recently launched ESA S5P/TROPOMI.