Observations and Processes (OP) Team

Overview

Fig. 1: Shapiro et al.'s (1999, their Fig. 1) conceptual diagram for scientific inquiry. Conceptual models and physical understanding are achieved through the union of observations, theory, and diagnosis.

The overarching goal of the OP team is to advance scientific understanding and conceptual and numerical models of convective weather phenomena in the spirit of Shapiro et al.'s (1999) conceptual diagram for scientific inquiry (Fig. 1). Utilizing theory, diagnosis, and observations, we aim to advance understanding and storm-scale and mesoscale modeling of convective weather hazards such as flash floods, large hail, damaging straight-line winds, and tornadoes through phenomenological and process studies.

Addressing the OP team's overarching goal requires obtaining detailed atmospheric observations collected during field programs, such as VORTEX-SE and TORUS. Unique observations are collected using platforms such as uncrewed aerial systems (UASs) and the Collaborative Lower Atmospheric Mobile Profiling System (CLAMPS). In addition to revealing the structure and evolution of convective storms and the turbulent boundary layer, these observations are compared against idealized and real-time numerical simulations. Idealized large eddy simulations and real-time convection-allowing forecasts from the Warn-on-Forecast System (WoFS) are used to advance theory and explore hypotheses uncovered by analysis of field program observations. Field program observations are also used to inform and validate the WoFS and its components, as well as to demonstrate potential benefits of new observation networks for the WoFS and broader numerical weather prediction (NWP) applications. Examples of key research areas are briefly discussed below.

Planetary Boundary Layer Studies

Research focused on the planetary boundary layer is multifold. A key area of interest is increasing the number and quality of observations in the atmospheric boundary layer through improving existing and developing new innovative sensing techniques for probing the lower atmosphere. This work includes characterizing and improving the physics-based thermodynamic retrievals from microwave radiometers (MWR) and the Atmospheric Emitted Radiance Interferometer (AERI), which are part of the CLAMPS, and developing a weather-sensing UAS (WxUAS) for probing the boundary layer in collaboration with the OU Center for Autonomous Sensing and Sampling.

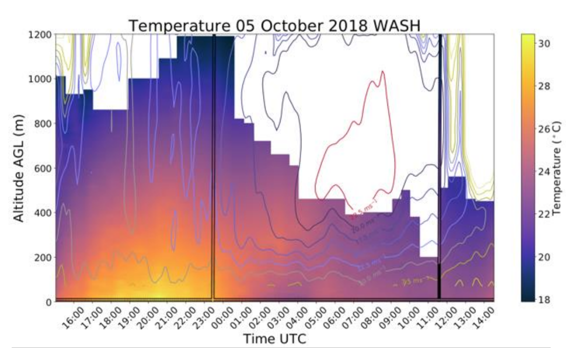

Fig. 2: Time-height profiles from data collected using a profiling WxUAS, the CLAMPS facility, and radiosondes. The background shaded contour corresponds to temperature data from WxUAS. The labeled line contours represent wind speed derived from the Doppler lidar. The two color-shaded vertical columns and the single color-shaded horizontal line at 10 m represent temperature measurements from radiosondes and from the Washington, Oklahoma Mesonet site (located at the Kessler Atmospheric and Ecological Field Station), respectively. Figure provided by Tyler Bell.

The OP team is also leading computational and theoretical studies of atmospheric boundary-layer flows and turbulence in collaboration with boundary layer scientists at NSSL FRDD. These types of studies aim to 1) improve numerical weather prediction models, such as the WoFS, in the areas of heterogeneous surface layers, scale-aware boundary-layer physics, and other storm-scale phenomena, and 2) develop analytical and numerical techniques to improve our understanding of boundary-layer structure and evolution.

Multiscale Studies on Severe Convective Storms

The significant socioeconomic impacts of convectively driven hazardous weather motivates the need to have accurate predictions of these events at all timescales. The OP team is focused on short-term prediction of supercell thunderstorms and organized mesoscale convective systems, including quasi-linear convective systems (QLCSs), and their attendant hazards through increasing physical understanding of their structure and evolution using obserations and high-resolution convection-allowing NWP models. On the observational side, current efforts include development and deployment of a mobile Doppler lidar system to measure the near-surface winds in supercells as part of the TORUS field campaign. The ultimate vision at CIMMS is to configure and deploy a network of these types of systems nationally to advance our understanding and conceptual models of convective storms, contributing to improve weather forecasts. Efforts also include developing syntheses of airborne pseudo dual-Doppler observations with ground-based in-situ and mobile dual-polarization Doppler radar observations, as part of the VORTEX-SE field campaign, to better understand the four-dimensional structure and dynamics of QLCSs.

The OP team is using UAS technologies to better characterize wind damage to vegetation. UAS-based damage surveys provide a more complete damage assessment by accessing impassable or remote locations and identifying damage not observable by ground or resolvable in satellite imagery. UAS-based damage surveys are especially important in the southeast U.S. as many areas are inaccessible for conventional damage survey work owing to dense forestation and lack of roads. This approach will be used as part of the VORTEX-SE and Propagation Evolution and Rotation in Linear Storms (PERiLS) field campaigns. A value of conducting UAS-based damage surveys is the ability to collect multispectral imagery that is better able to detect damage signatures in vegetation because of the high spatial information and spectral response of vegetation in the red, RedEdge, and near-infrared bands. A comparison of the visible and multispectral imagery is shown in Fig. 3 for the EF-2 tornado in Carpenter, Wyoming, on 12 June 2017. Ongoing funded work includes detailed analysis of data collected in the wake of the Iowa derecho in August 2020 (NSF RAPID grant awarded to Dr. Wagner) and upcoming severe events in the southeast U.S. in February–April 2021 (NOAA UxS grant). This UAS-based approach to damage surveys will provide additional information to augment the National Weather Service damage surveys and will contribute to the development of improved damage descriptors

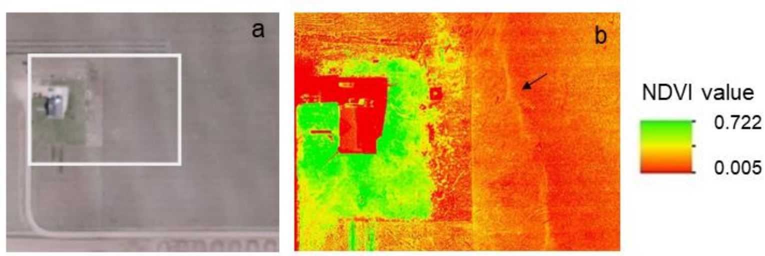

Fig. 3: UAS-based (a) visible and (b) multispectral imagery for the 12 June 2017 Carpenter, Wyoming, tornado. The outer edge scour of the tornado (black arrow) and damage to freshly laid sod (yellow hues) are shown in (b). These damage indicators are not detectable in visible imagery in (a). Figure provided by Dr. Melissa Wagner.

for vegetation (particularly in rural areas). Additionally, relating damage information in UAS-based surveys to severe storm structures and signatures on radar imagery will contribute to improved understanding of identifiable storm attributed on radar that produce damage.

The OP team also has a concentrated effort to analyze and diagnose short-range (0-12 h) convection-allowing forecasts of hazards associated with supercells and severe QLCSs from the NSSL WoFS ensemble, operational High-Resolution Ensemble Forecast version 2 (HREFv2), and the high-resolution rapid refresh (HRRR). In addition to significant events throughout the central Plains and upper Mississippi and Ohio valleys, analysis of cases in the southeast United States as part of the VORTEX-SE field campaign are of particular interest in order to assess the ability of these prediction systems to anticipate tornado outbreaks associated with QLCSs in low buoyancy/high vertical wind shear environments. One such event occurred in 30 April 2017, resulting in 56 tornadoes in Mississippi and surrounding regions during the morning hours. While the convection-allowing numerical guidance indicated that organized convection would occur, the models consistently indicated a linear convective mode rather than a robust tornado threat (Fig. 4). Work on this and other cases (such as the Nashville tornado case from 3 March 2020 and severe weather outbreak in Oklahoma on 20 May 2019) aim to highlight the ability of numerical guidance to represent the pre-storm environment and convective mode more generally, and focus on identifying and modifying the model physical processes that contribute to these errors.

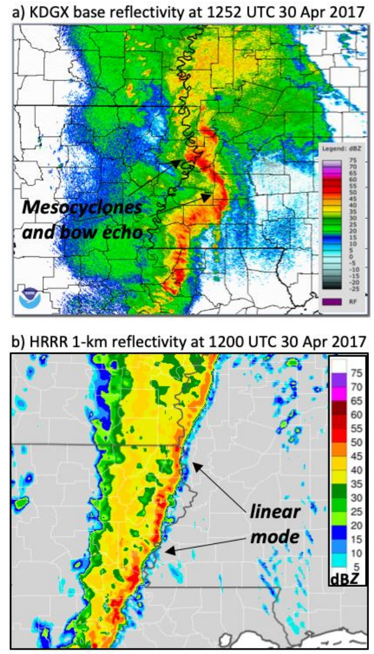

Fig. 4: (a) Base reflectivity (shaded in dBZ) from KDGX radar at 1252 UTC 30 April 2017. (b) 12-h HRRR forecast 1-km reflectivity (shaded in dBZ) verifying at 1200 UTC 30 April 2017. Figure provided by Dr. Thomas Galarneau.

Influence of Teleconnections on Midlatitude Jet Stream and High-Impact Weather

The OP team was recently funded by the National Science Foundation (PI Dr. Galarneau) to examine the influence of the stratospheric quasi-biennial oscillation (QBO) on the Madden-Julian Oscillation (MJO) and its attendant interaction and impacts on the midlatitude jet stream and high-impact weather in North America. For example, Fig. 5 illustrates how the midlatitude Rossby wave train response to the MJO is enhanced during the easterly phase of the QBO. This work will explore relationships such as this further and aim to determine the physical processes driving these relationships. This

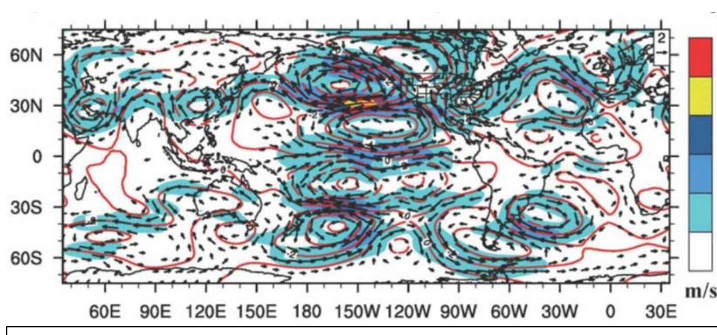

Fig. 5: Difference (QBOE–QBOW) between composites of 250–150 hPa layer-mean streamfunction (contours) and total wind (arrows with magnitude shaded in m s^{-1}) averaged over all MJO phases for all days when OMI>1.5 for DJF 1979–2018. Note the strong easterly wind anomaly in the North Pacific jet exit region. Calculation based on ERA-Interim dataset. Figure provided by Dr. Thomas Galarneau.

3-year funded project is a collaborative effort with Dr. Lon Hood from the Lunar and Planetary Laboratory at The University of Arizona.

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TEAM MEMBERS

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