**Advanced infrared sounder in geostationary orbit: Monitoring water vapor evolution with high spatial and temporal resolution**

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Description:

Monitoring the horizontal and vertical distribution of atmospheric water vapor is necessary for understanding the details of the hydrological cycle, and characterizing convection. Given the need for relatively high temporal resolution, an advanced geostationary infrared sounder is proposed to meet this ongoing challenge of the weather community.

Body:

The quantification of tropospheric moisture through the appropriate absorption bands and water vapor retrievals would address a longstanding research need to study processes that characterize, and contribute to water vapor, in the boundary layer and lower troposphere. There are many unanswered questions, particularly related to atmospheric convection, such as:

- How does the vertical distribution of moisture in the troposphere modulate storm mode and updraft strength?
- How does evapotranspiration influence available potential energy for convection prior to storm development?
- How does the water vapor content of an air mass impact precipitation efficiency?
- What modulates the rate at which convective storms (of all types) intensify to produce severe weather, tornadic storms, lightning, and other hazards? (NASA Weather Workshop Report, 2015)

Space-based observations, especially from the geostationary perspective, are fundamental for monitoring the spatial and temporal scales of moisture. Vertical profiles of moisture evolve on short timeframes, hours or less, that few other observational platforms are able to capture, and none over a vast geographic area, such as the contiguous United States. An advanced infrared sounder with numerous water vapor bands in the geostationary orbit could contribute radiances for numerical weather prediction (NWP), derived product imagery of potential value to operational meteorologists, and supplement surface, aircraft, and radiosonde observations in better depicting concentrations of moisture that contribute to precipitation.

Beyond that, the ability to sense water vapor in the troposphere is critical for monitoring and predicting certain hazardous weather conditions. For example, differential water vapor advection is a typical ingredient that fuels severe thunderstorm outbreaks. Large variations in atmospheric water vapor occur over a scale of 10 km in the horizontal plane and hundreds of meters in the vertical plane. Severe thunderstorms, which form mostly over land, evolve on scales of one to ten minutes (Schmit et al., 2009). Individual storm characteristics are highly dependent on the extent of water vapor in the surrounding air mass.

*a. Whether existing and planned U.S. and international programs will provide the capabilities necessary to make substantial progress on the identified challenge and associated questions. If not, what additional investments are needed?*

Currently, there are no existing or planned U.S. weather satellite missions to provide vertical moisture profiles on both high time and space scales that make substantial progress on the identified questions. The investments needed are consistent with global attention to launch and operate high-spectral-resolution infrared-sensing instruments in the geostationary orbit, but those missions are focused on Europe and Asia.

Operational forecasters in the U.S. have already identified the utility of the three Geostationary Operational Environmental Satellite (GOES) Sounder channels in assessing the advection of the elevated mixed layer (Gitro, personal communication). But this is not sufficient. According to the National Weather Service Storm Prediction Center (SPC), "A major limitation in convective forecasting is the lack of high resolution [four-dimensional evolution of] water vapor [structures]." The SPC notes that "lack of necessary detail in mapping water vapor that has been identified by the [United States Weather Research Program (USWRP)] as major obstacle to improved [quantitative precipitation forecasts (QPF)] and severe weather forecasting" and that "new sources of accurate and reliable observational data are critical to improve assessment of environment and convective forecasting" (Weiss, personal communication).

*b. How to link space-based observations with other observations to increase the value of data for addressing key scientific questions and societal needs;*

To decrease the observational gaps in time and space between radiosondes and aircraft observations, temperature and moisture profiles derived from weather satellites need to be of commensurate quality and vertical resolution. Aircraft observations are currently the backbone of short range NWP forecasting over the U.S. (Benjamin et al., 2010). Nowcasting (focusing on the imminent evolution of the atmospheric state) and short-term forecasts (within six to nine hours) of severe thunderstorms could improve with additional vertical moisture information and rapid scan capabilities in clear skies and above low clouds from a high-spectral-resolution infrared sounder.

Furthermore, the highest-resolution NWP models are now convection-allowing. In order to properly initialize these models for operational forecasting, observations on the grid scale (less than 5 km) are required to improve state/base fields responsible for initiating convection within the model. Better moisture analyses also have the potential to improve numerical precipitation forecasts. Accurate moisture analyses can alter forecasted precipitation amounts in NWP models with parameterized convection as well.

*c. The anticipated scientific and societal benefits; and*

The socioeconomic impact of improved detection and warning ahead of impactful weather events is substantial, and evident through a decrease in loss of life to weather-related disasters over time. Given the precarious position of the central and eastern contiguous United States between cooler, drier air filtering southward from Canada, and warm, moist air flowing northward from the Gulf of Mexico that produces unsettled weather, a large segment of the nation’s population and farmland, and Gross Domestic Product (GDP), is weather-sensitive.

*d. The science communities that would be involved.*

With an advanced sounder in the geostationary orbit, there would be many subdisciplines and related communities within meteorology that would have an opportunity to improve their foundational understanding of the development of high-impact atmospheric phenomena, many related to convection, such as mesoscale convective systems, tropical cyclones, and tornadoes.

Beyond characterizing the severity of convection, monitoring the horizontal and vertical distribution of water vapor in the atmosphere is necessary for understanding the details of the hydrological cycle. Given the need for relatively high temporal resolution, an advanced infrared sounder in the geostationary orbit is proposed as the best fit to meet this ongoing challenge of the broad meteorological community.

References and notable works:


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