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Observation strategy of the INCUS mission: retrieving vertical mass flux in convective storms from low-earth-orbit convoys of miniaturized microwave instruments

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Microwave radiometers and radars in low Earth orbit (LEO) are sensitive to the amount of condensed water in clouds. However, their temporal sampling is quite limited – a single LEO instrument will very rarely observe a weather system more than once during the lifetime of the system. Recent technological advances have enabled the design of miniaturized microwave instruments that are quite capable and, at the same time, inexpensive enough to consider the formation of a convoy of identical radars or radiometers in low-Earth orbit, separated in time by a very short interval, on the order of a minute, the temporal scale required to observe the highly nonlinear cloud dynamics. The time sequences of observations are conceptually similar to the loops that are currently obtained from ground weather radar, as well as geostationary imagery, which readily show the evolution of precipitation (in the radar case) or cloud tops (in the imagery case) over minutes. The satellite convoys overcome the limitations of geostationary images (which are sensitive only to the very top of the clouds), and those of ground radar (with its very limited spatial coverage and its insufficiently short interval between consecutive scans). Because each satellite instrument is sensitive to the 3-dimensional distribution of condensed water within its field of view, the convoy is sensitive to the change in this condensed water over the minute(s) separating the convoy members. NASA's recently selected INCUS mission will be the first project to demonstrate this new concept, with a convoy of three identical Ka-band reflectivity profiling radars, along with a five-channel microwave radiometer.

We have conducted analyses based on simulations – as well as observations from ground-based zenith-pointing profilers – to quantify the ability of a convoy made up of a pair of small Ka-band radars that measures reflectivity only, or a pair of mm-wave radiometers that measures microwave radiances in several mm-wavelength channels, to detect convective updrafts above the freezing level and to quantify their intensity. In the case of a pair of radars, one can retrieve the vertical profile of the vertical transport in the portion of the column where the condensed water concentration is above a minimum threshold (of about 0.05 g/m^3 in our analyses) and the vertical

velocity exceeds a minimum threshold (of about 2 m/s) with quite low uncertainty (whose characteristics depend on the coarse shape of the vertical velocity as a function of height). These new observation strategies are not only useful to evaluate and improve the model representation of vertical transport in convective storms, they are also uniquely useful to quantify a currently “missing link” in the Hadley circulation, in establishing the potential-energy contribution by an individual convective system to the Upper Troposphere / Lower Stratosphere bubble of high-entropy air mass.

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