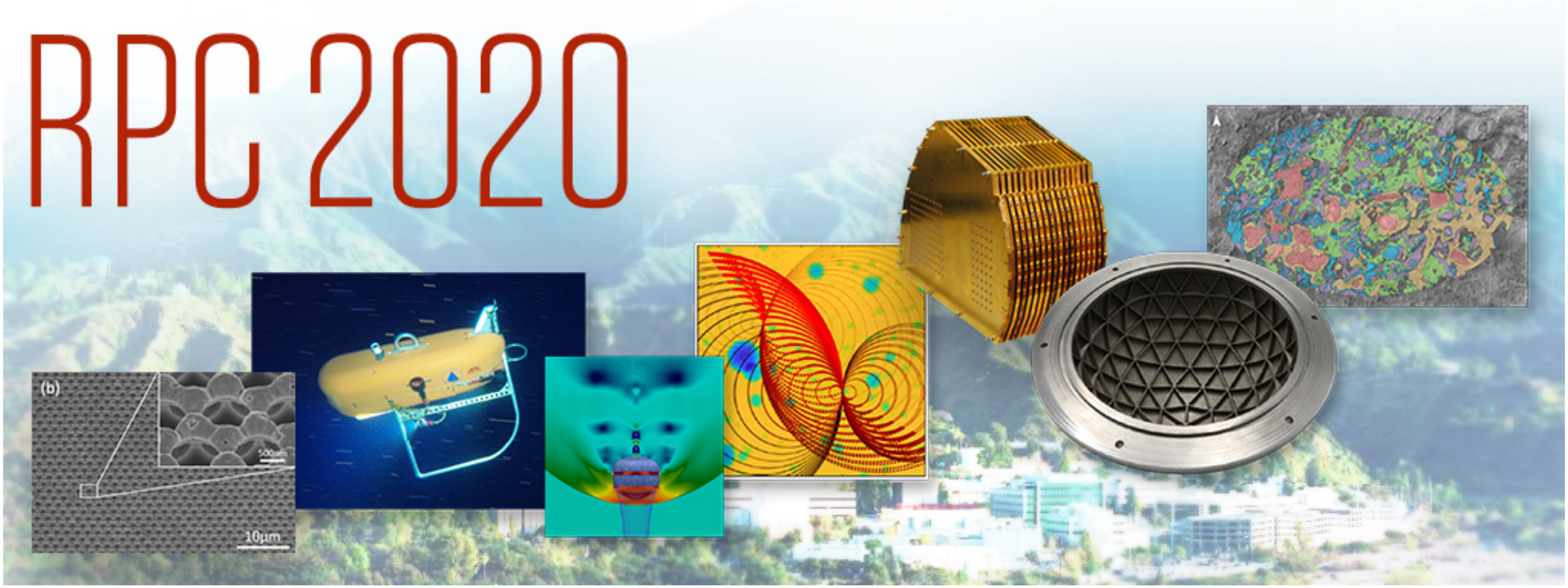

Virtual Research Presentation Conference

3D Tomography of Convective Environments with a Locally Dense Constellation of CubeSats

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Program: Topic

Assigned Presentation # RPC-274

Jet Propulsion Laboratory
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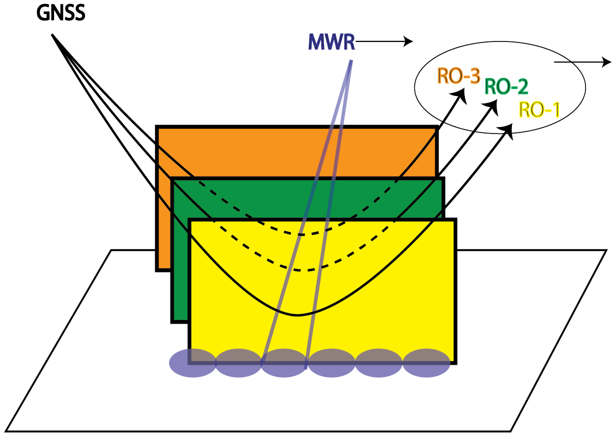
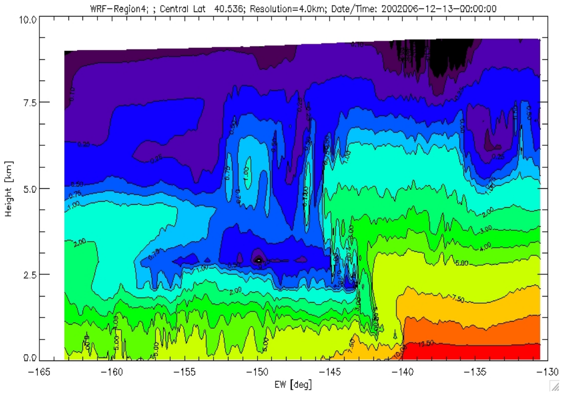
Tutorial Introduction

The goal of this project is to explore a new mission concept that can yield highly detailed structures of tropospheric water vapor under all-sky conditions, with vertical resolution of ~200 m and horizontal resolution of ~20 km.

The mission concept is centered upon the novel idea of a “dense” constellation of CubeSats that are equipped with GNSS radio occultation (RO) receivers. Each of these receivers can track radio signals from a GNSS transmitter (such as a GPS satellite) and turn them into a vertical profile of water vapor in the troposphere. Normally, we want to spread out the receivers so we can more uniform coverage over the globe. However, if the receivers are flying in close formation with each other, they can provide simultaneous water vapor profiles that are close to each other, thus enhancing the spatial resolution.

GNSS-RO has high vertical resolution (200 m) but poor horizontal resolution (100 km). On the other hand, nadir passive microwave (MW) radiometer has relatively high horizontal resolution (20 km) but poor vertical resolution (4 km). By combining these measurements we could retrieve high resolution 3D water vapor structure from space. Such observations are important for understanding processes involving clouds, convection, and precipitation.





Problem Description

- Water vapor is a fundamental parameter critical to understand convective processes and global hydrological cycle. However, observing it at high resolution from space is challenging. GNSS-RO and MW are two established techniques that can measure water vapor under cloudy conditions. But either alone can provide the full picture.
- While the important role of water vapor is acknowledged, it is often neglected when Aerosol, Clouds, Convective, and Precipitation (ACCP) type missions are being formulated.
- At the same time, GNSS-RO and MW technologies are being implemented on low-cost CubeSats, making the idea of ”large” constellation of these sensors appealing.

Relevance to NASA and JPL

- JPL has long been a technology leader in both GNSS-RO and MW radiometer instrument developments.
- Results from this study can lead to new Earth Science mission concepts that are responsive to 2017 Earth Science Decadal Survey (ESAS 2017), capitalizing on JPL’s past and current instrument developments.

Methodology

Our study was carried out using end-to-end simulations. The following elements were addressed:

- Explore constellation configurations to enhance collection of collocated GNSS-RO and MW observations.
- Develop retrieval algorithms to combine complementary information from collocated GNSS-RO and MW observations, with the goal of retrieving high-resolution 3D water vapor in the troposphere.
- Investigate the role of water vapor in addressing ESAS 2017 science questions.

Innovation

- The dense GNSS-RO constellation is a novel idea that has recently been advocated by this team.
- Complementarity between limb-sounding GNSS-RO and nadir sounders has been recognized but not been fully exploited. This work can open a new area of research.

Results

Constellation Simulations

Statistics of RO+MW collocations

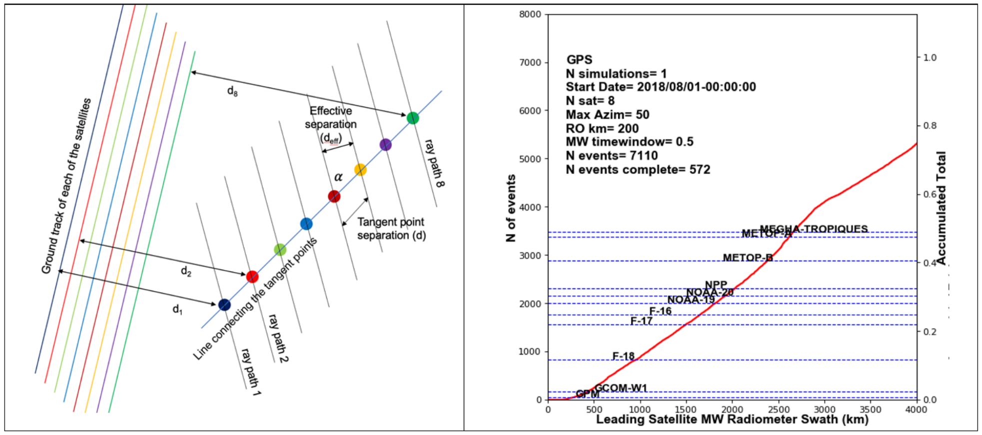


Figure 1. (left, a) Geometry of one RO "event". The tangent points (TP) are shown from each receiving satellite (each with a different color), and the corresponding satellite ground track in the same color. The TP locations are separated by a distance *d*, connected by a blue line. (right, b) Summary of the cumulative passive MW swath coverage obtained from a single across-tracking scanning passive MW radiometer on the first satellite (red line). The cumulative coverage obtained when considering only existing passive MW data is shown by the series of dashed blue lines.

2D Tomography Retrieval: Kalman Filtering

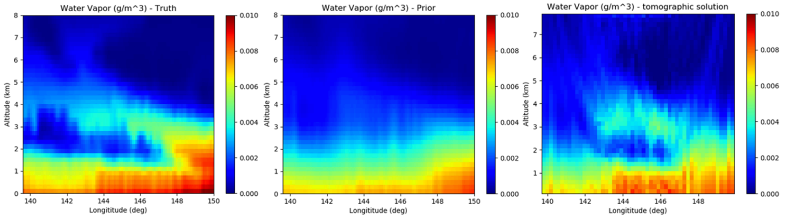


Figure 2. (left) Water vapor density from a WRF simulation showing strong spatial variability; (middle) Water vapor a priori obtained from MW retrievals; (right) 2D tomographic solution.

3D Tomography Retrieval: Generalized Abel Inversion

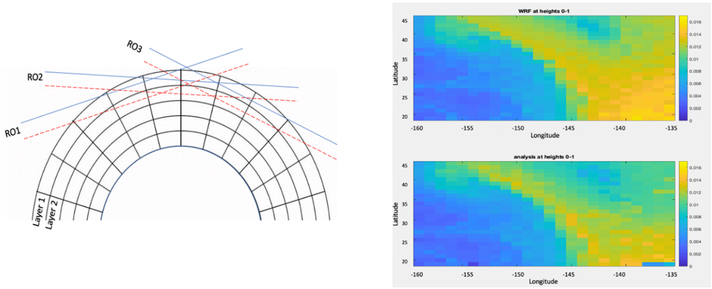


Figure 3. (Left, a) A pictorial representing the generalized Abel inversion concept. Starting with a prior solution of densities obtained by MW observations, measurements from different ROs are combined one set at a time starting from the top and going to the bottom. E.g., blue rays from three ORs (dubbed RO1, RO2 and RO3) are combined to resolve the structure in Layer 1. Next, red rays from RO1-3 are combined to resolve the structure of Layer 2 after removing the contribution to these rays from layer 1. The process continues all the way to the bottom. (Right, b) Simulated generalized Abel inversion of water vapor in the lowest 1km of the atmosphere by use of GNSS-RO. Top is simulated water vapor density (g/m^3) of a weather front based on the WRF model. Bottom is reconstructed by use of the generalized Abel method described above.

Publications and References

Publication

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