Simulation of Remote Sensing of Clouds and Humidity from Space

using a combined platform of radar and multi-frequency microwave radiometers

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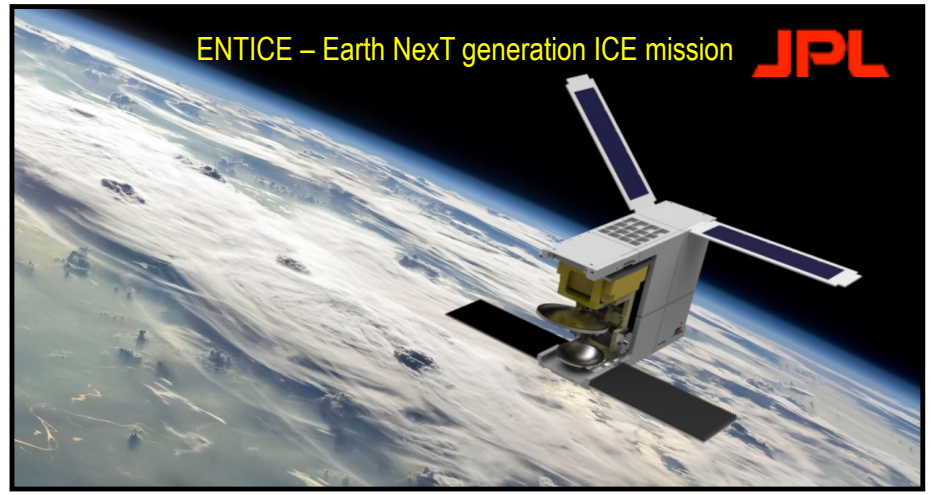

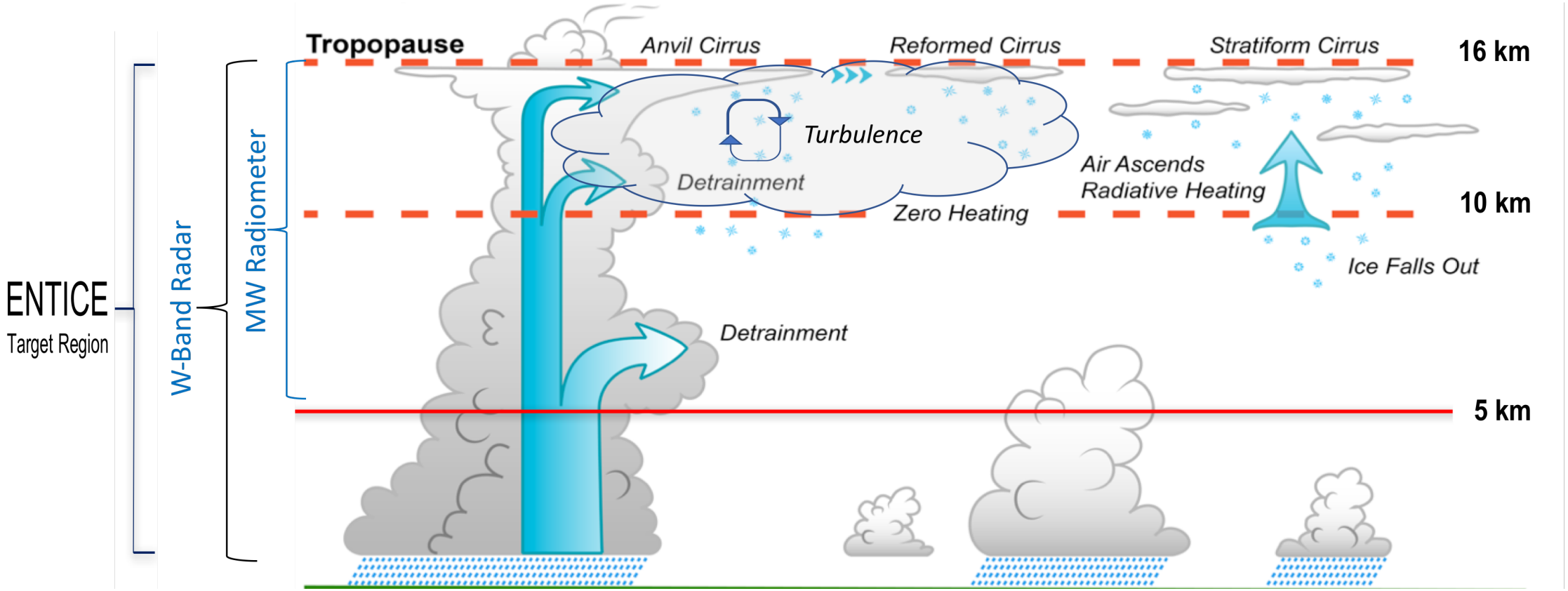

ENTICE Instrument Package

Passive radiometers suite

Channel	Center frequency	Offset frequency	Bandwidth
1	118.75	1.1	0.4
2	118.75	1.5	0.4
3	118.75	2.1	0.8
4	118.75	5.0	2.0
5	183.31	1.0	0.5
6	183.31	3.0	1.0
7	183.31	6.6	1.5
8	243.20	2.5	3.0
9	310.00	2.5	3.0
10	380.20	0.75	0.7
11	380.20	1.80	1.0
12	380.20	3.35	1.7
13	380.20	6.20	3.6
14	664.00	4.20	4.0
15	850.00	4.50	4.0

94 GHz Radar:

Reflectivity simulated at 0.5km resolution from surface to 16 km

- More frequencies can be simulated: e.g. GPM DPR

References: Jiang et al. 2019; 2017

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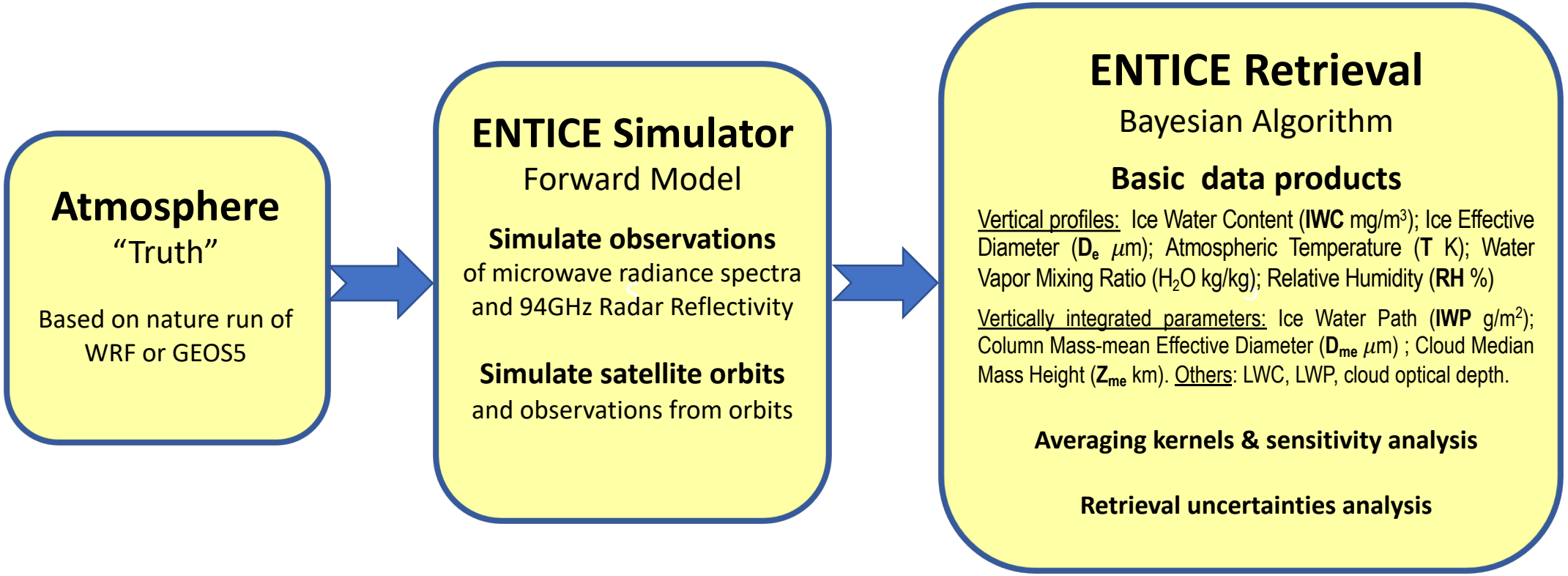
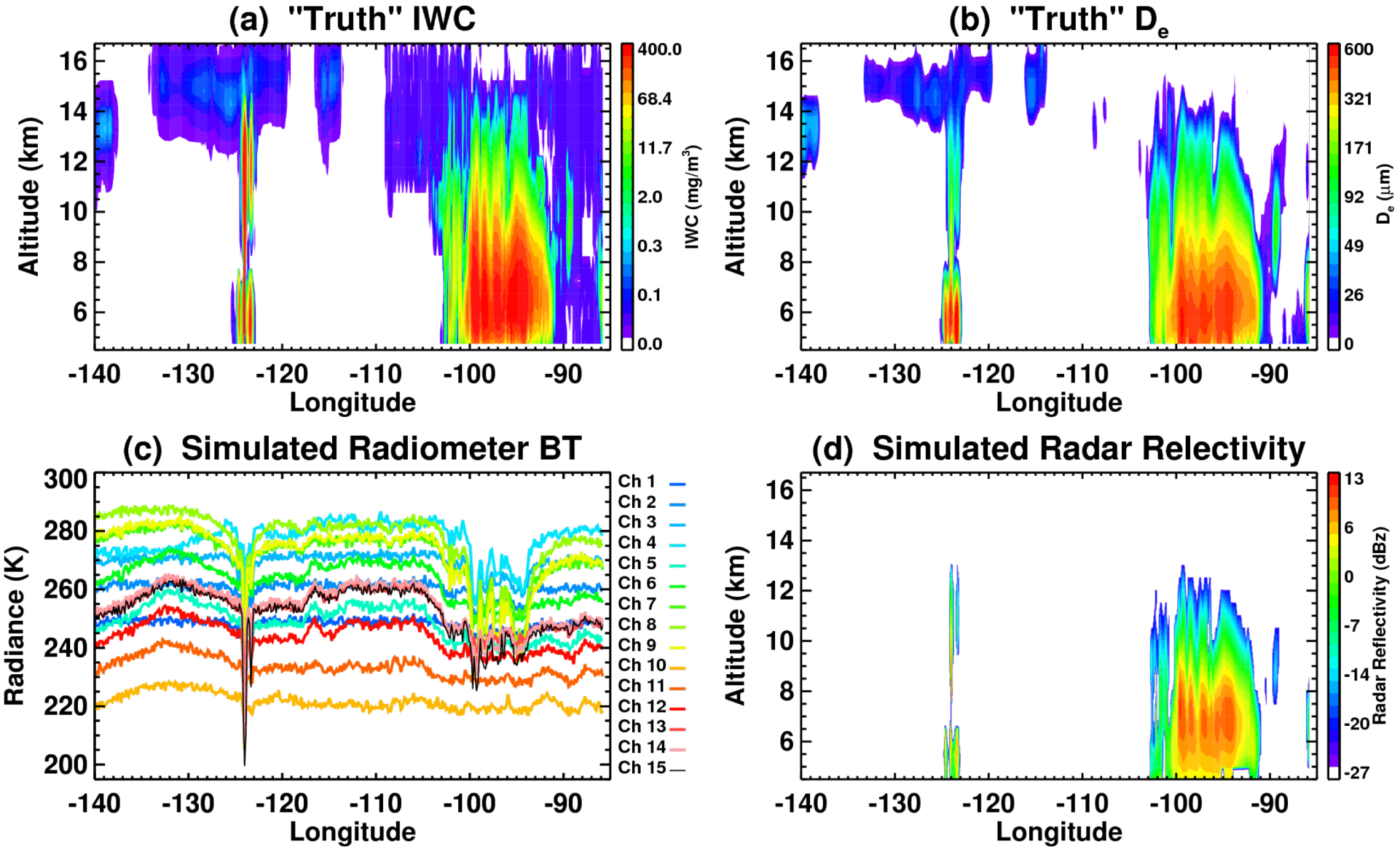
https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1002/2017EA000296

ENTICE Instrument Simulation and Retrieval Package

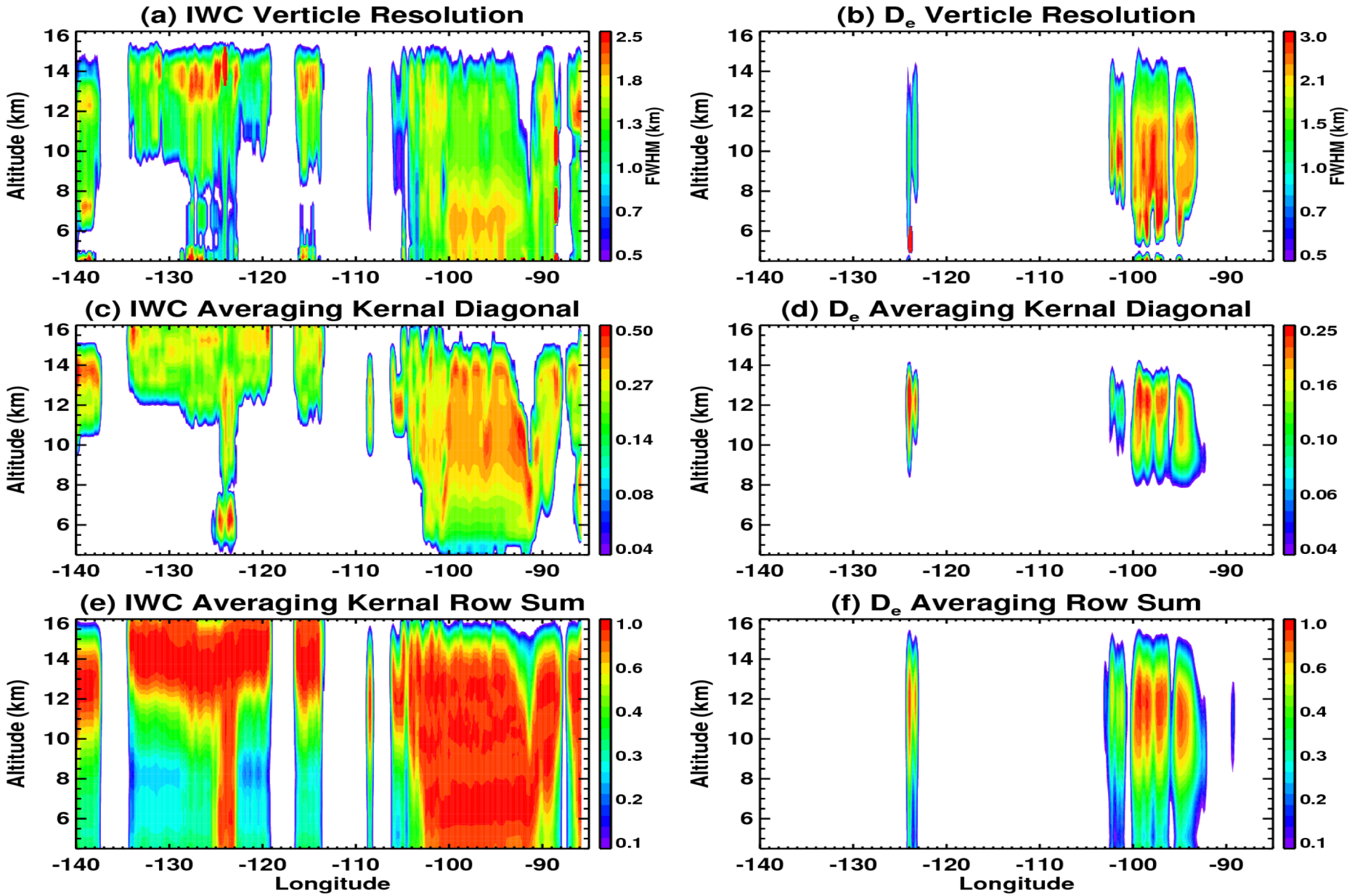


Forward Model Simulated ENTICE Observations

Using Atmosphere and Clouds from WRF



Averaging Kernels Analysis (Radiometers suite only)

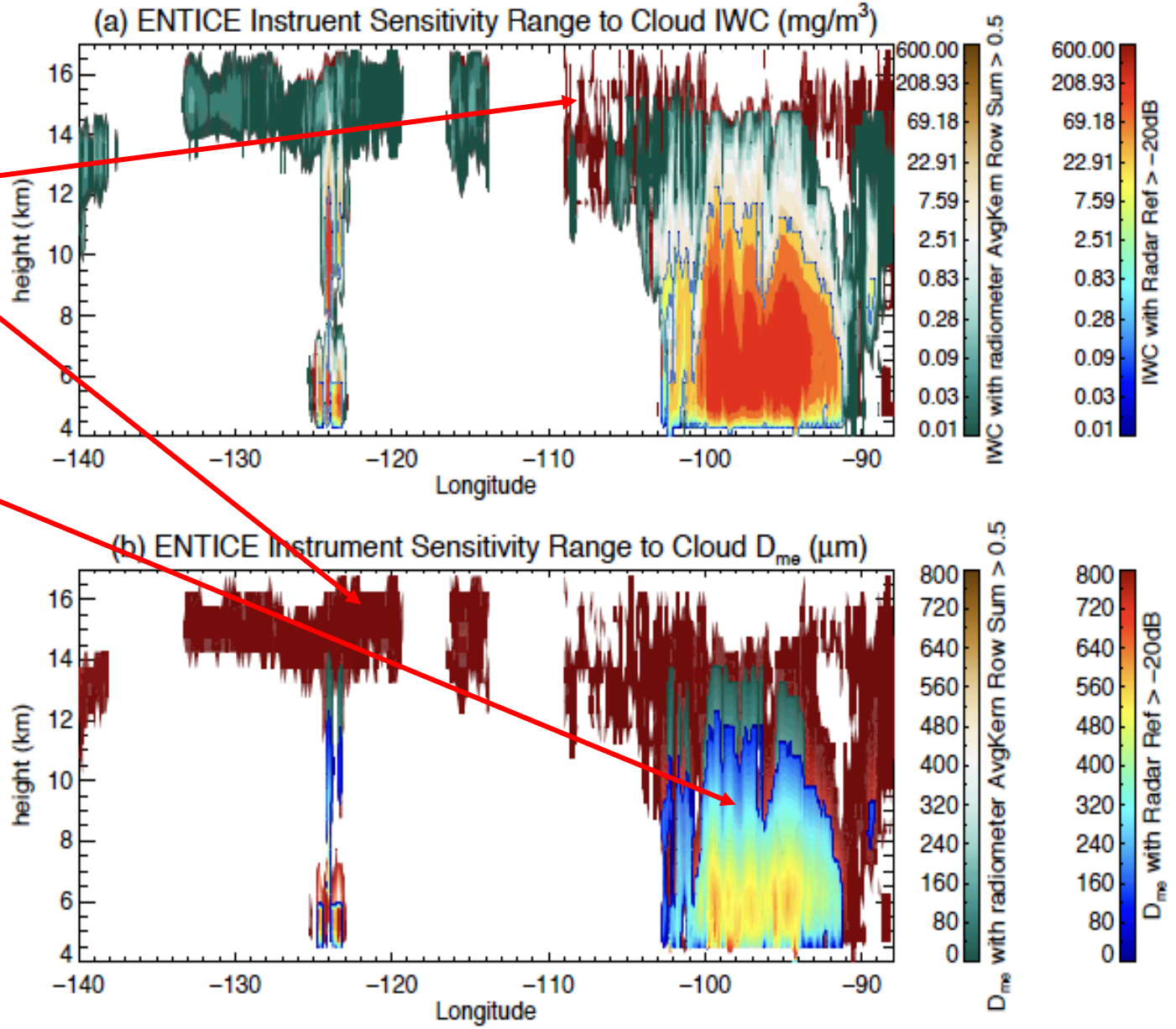


Sensitivity Analysis (Radiometers + Cloud Radar)

Radar missing the thin cirrus and the very top of the deep convective cloud, especially for particle size retrieval.

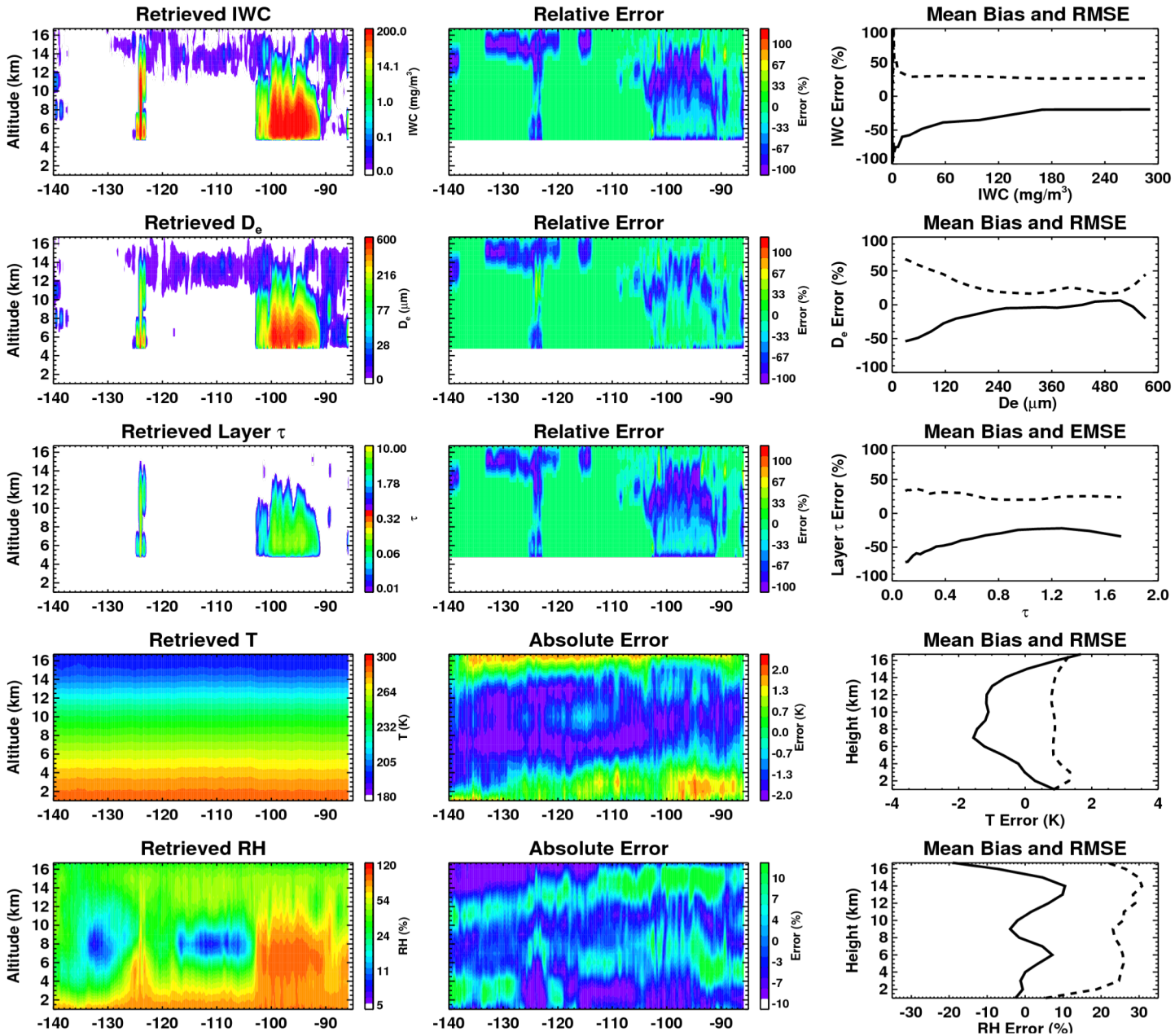
Radar provides additional information on particle size distribution below 8km in the deep convective cloud

The combined radar and passive radiometers provide more information than either of them alone, especially profiling throughout the deep convections.



Retrieval Uncertainties Analysis (Radiometers + Cloud Radar)

1. Less than 40% bias (**25%**) for IWC>0.02 (**1**) g/m^3 and De> 50 (**100**) μm and optical depth >0.3 (**1**).
2. Less than 20% bias for RH and ~1 K for T.
3. Underestimate or completely miss thin ice cloud and cloud top.



ENTICE Orbits Simulations

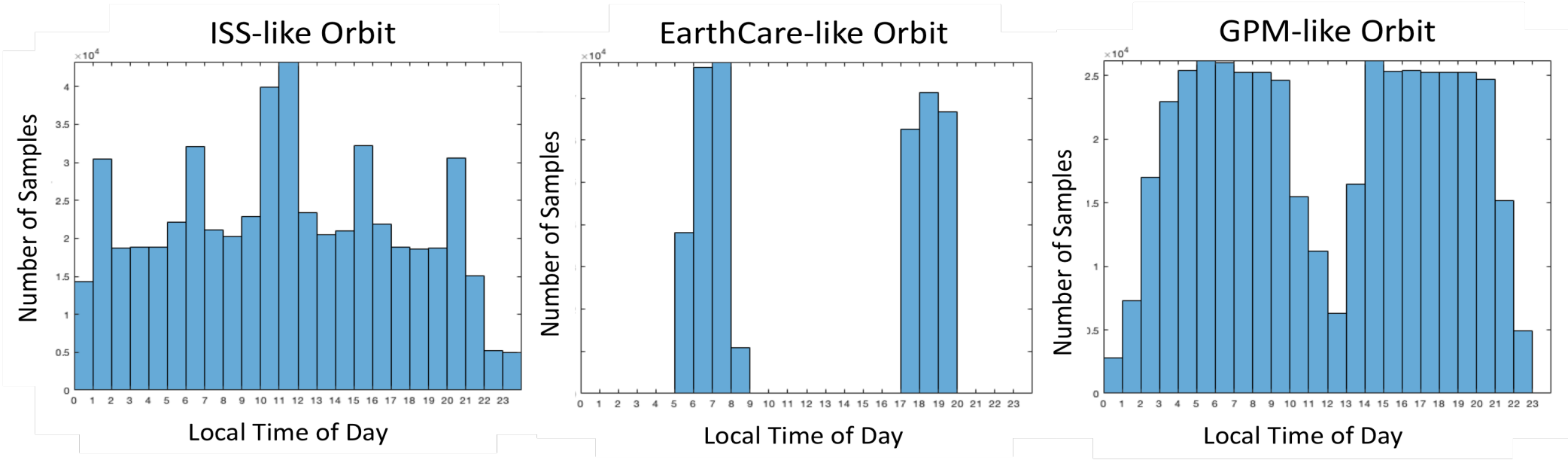
Scan Assumption: Forward looking conically scanning, viewing the Earth over an azimuth angle range of 100° side-by-side and a fixed Earth incidence angle of 45°.

FOV Assumption: For a 400 km altitude orbit, the FOV at the surface is 10 km × 15 km

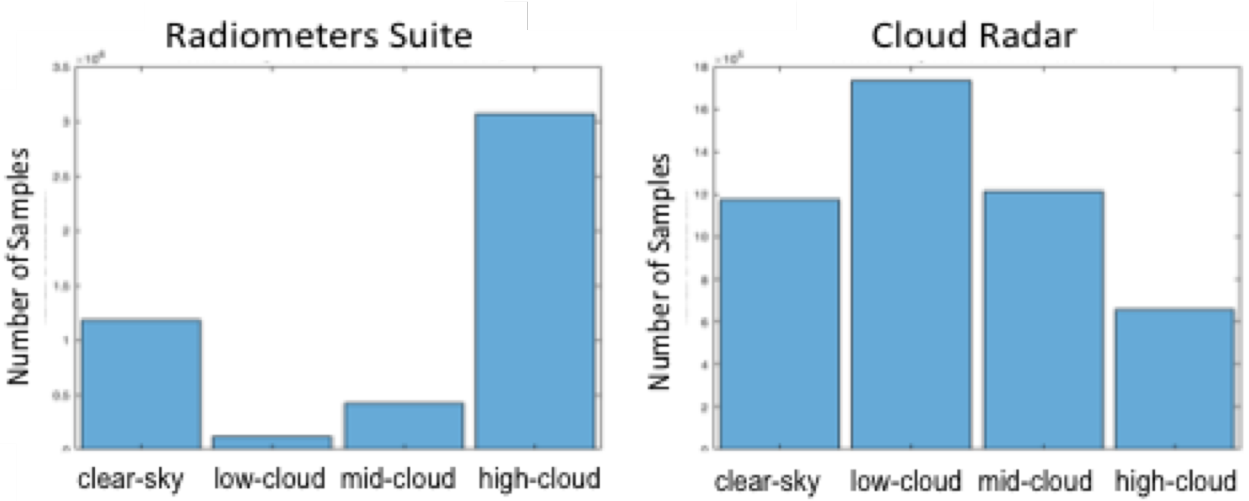
Sampling Assumption: One single measurement time is 0.1 second; One scanning from side to side is 1 second.

1. **In ISS orbit**
   1) Nadir view
   2) Forward looking conically scan side-by-side
2. **On ISS**
   1) 45° sideward looking conically scan back-to-front-to-back
3. **Single payload spacecraft Following EarthCare**
   1) Nadir view
   2) Forward looking conically scan side-by-side
4. **Single payload spacecraft Following GPM**
   1) Nadir view
   2) Forward looking conically scan side-by-side

ENTICE Diurnal Sampling Simulations



ENTICE Cloud Sampling Simulations



ENTICE SCIENCE OBJECTIVES

- **Mission Objective:** To fill the gap in satellite observations of ice cloud microphysical properties for accurate quantification of the effects of ice clouds on radiation and the hydrological cycle by providing the first-ever global measurements of seasonally and geographically varying vertical profiles of ice particle size. It will begin a new era in remote sensing and numerical modeling of cloud and precipitation processes.
  - ✓ ENTICE will provide direct global measurement of ***ice particle size*** along with associated atmospheric states, which would constitute a breakthrough in improving ice cloud microphysics parameterization, quantitative precipitation forecasting, more accurate quantification of cloud radiative effects, improved understanding of aerosol-cloud interactions and more accurate cloud ice and precipitation retrievals from remote sensing measurements.

ENTICE Standard ENTICE Data Products

Level 1b: Calibrated radiometer radiances (Tb) in the units of brightness temperatures and radar logarithmic reflectivity dBz. These Level 1b data require no a-priori information. They are valuable for interpretation of the radiometric signal relative to the sampled atmosphere (in the presence of cloud and precipitation), for assimilation into the global circulation models, and for cloud radiative transfer model evaluation. The ENTICE science team would provide a forward model for science application of these data (e.g. ENTICE simulator).

Level 2: These data, retrieved using radiances from instrument field-of-view are ‘close’ to the measurement in the sense that they require only weak a-priori information, in the form of assumptions on the statistics of structure and microphysics. These Level 2 data are the baseline (or core) measurements of the ENTICE mission.

Level 3: Gridded monthly mean. Whereas Level 2 data are relatively `close' to the measurement, Level 3 data are `close' to the atmospheric models - the data which could be easily used for direct model-measurement comparisons.

The projected ENTICE baseline instrument performance

Detection Limit: IWC > 0.01 g/m^3; D_e > 50 μm; optical depth > 0.3

Precision: D_e: 25%; IWC: 25%; IWP: 20%; H_2O: 20%; RH: 20%; T: < 1.5K;

Accuracy: D_e: 25%; IWC: 0.1 mg/m^3; IWP: 1 g/m^3; H_2O: 20%; RH: 20%; T: 1.0 K

Resolution: Vertical: 500 m (2km) for baseline (threshold) D_e and IWC; 2-3 km for T and H_2O;
Horizontal: 15 km x 7 km field of view for radiometers and 5 km for radar.

Coverage: Global