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Scientific contributions from GPS radio occultation sounding of the atmosphere: decadal-scale variability and vertical profiles of water vapor

Anthony J. Mannucci[1], Chi O. Ao[1], Panagiotis Vergados[1], Olga Verkhoglyadova[1], Byron A. Iijima[1], E. Rob Kursinski[2]

1. *Jet Propulsion Laboratory, California Institute of Technology*
2. *Space Science and Engineering, LLC*

Session 4 Observing Systems I

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Outline

1. Radio occultation as a measurement
2. RO and the “big picture”
3. Tropical belt widening: trend?
4. Water vapor: science
5. Water vapor: instruments
6. COSMIC-2
7. Conclusions

Earth Science Challenges

- **The challenge of satellite observations: spatial and temporal resolution and revisit time**
- **The challenge of geophysical models: multiple scales and undetermined boundary conditions**
- **The lack of controlled experiments in geophysics poses unique challenges in scientific inference**
  - **Mannucci, A. J., Tsurutani, B. T., Verkhoglyadova, O. P. & Meng, X. On scientific inference in geophysics and the use of numerical simulations for scientific investigations. Earth and Space Science 2, 359–367 (2015).**
- **Robust scientific inference requires multiple independent sources of data that provide unique information**

Radio Occultation: Deriving Atmospheric Parameters Based on Timing

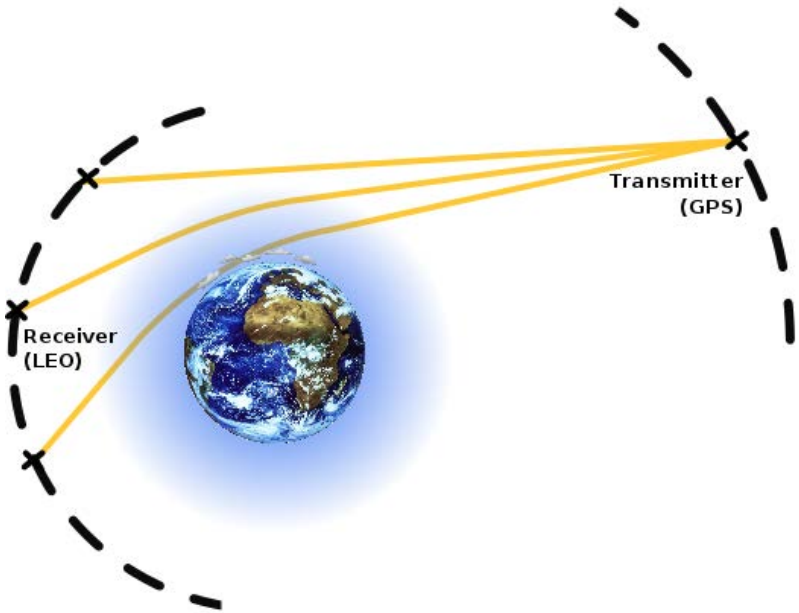
- **Global coverage – equal performance over land or ocean**
- **All weather capability – long L-band wavelength**
- **Water vapor accuracy:**

0.4 g kg^{-1} at 725 hPa

0.14 g kg^{-1} near 350 hPa

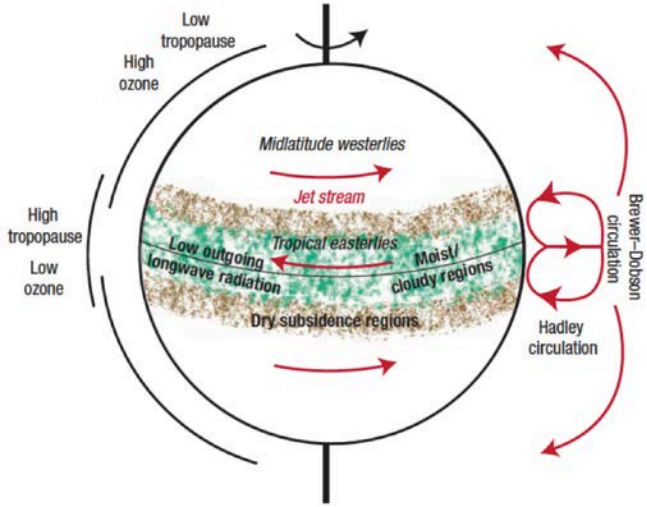
Kursinski, E. R., and T. Gebhardt (2014), A Method to Deconvolve Errors in GPS RO-Derived Water Vapor Histograms, J. Atmos. Oceanic Technol., 31(12), 2606–2628, doi:10.1175/JTECH-D-13-00233.1.

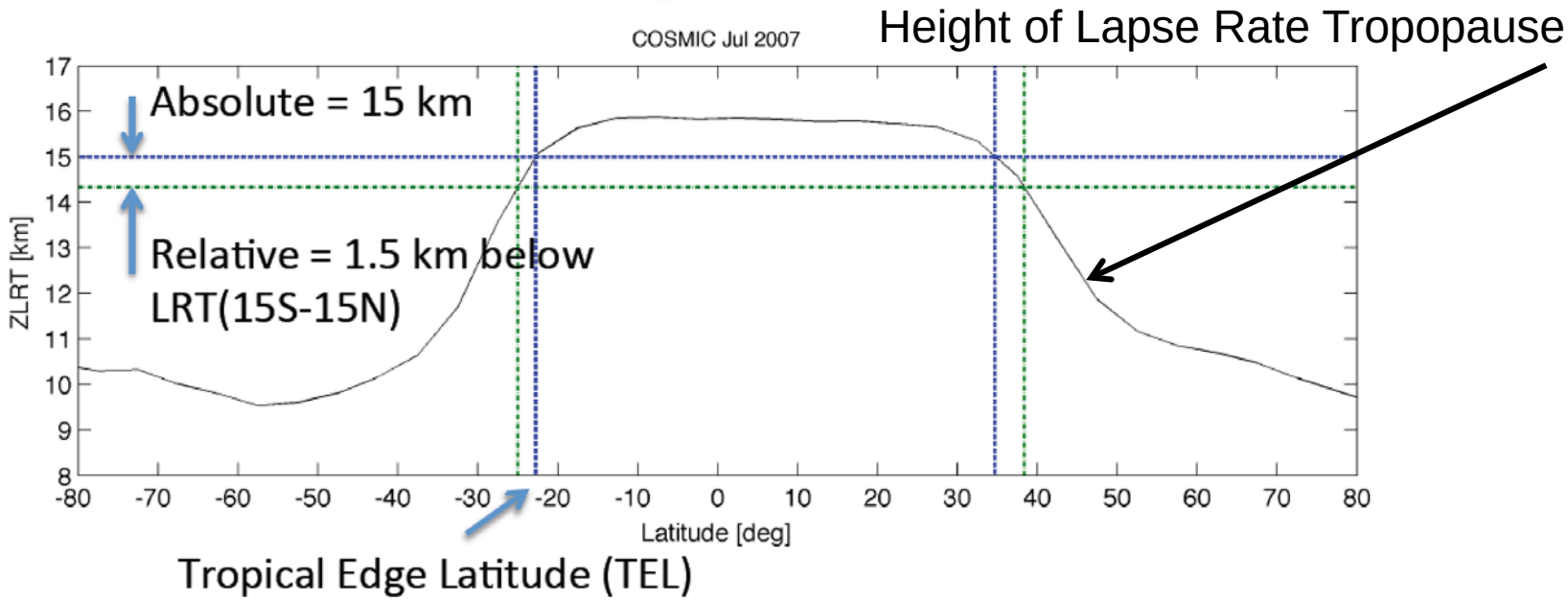
- **Vertical resolution**
  ~0.2 km in LT to ~1.5 km in the UTLS
- **Horizontal resolution**
  ~75 km in LT to 100-200 km in UTLS



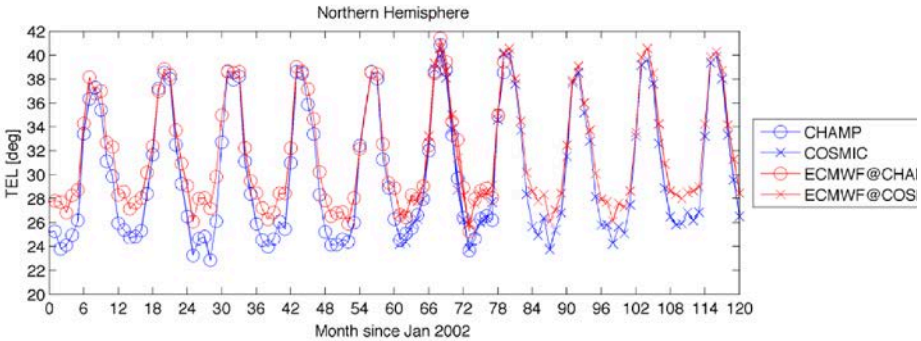
Tropical Belt Widening?

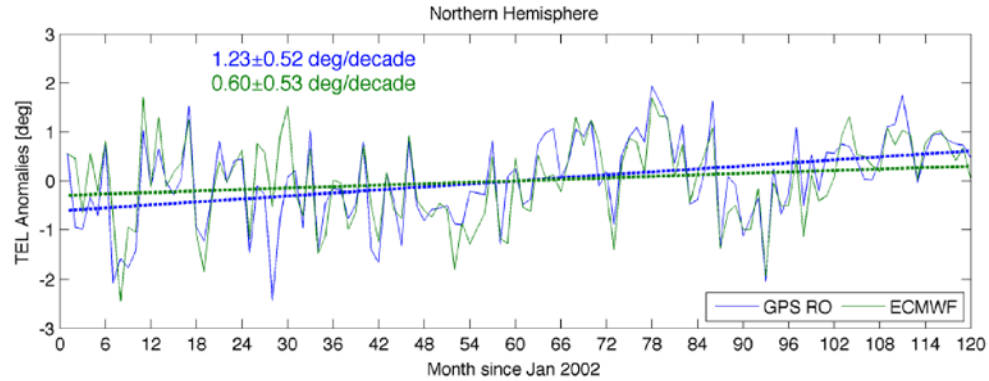
Ao, C. O., and A. J. Hajj (2013), Monitoring the width of the tropical belt with GPS radio occultation measurements, Geophysical Research Letters, 40(23), 6236–6241, doi:10.1002/2013GL058203.

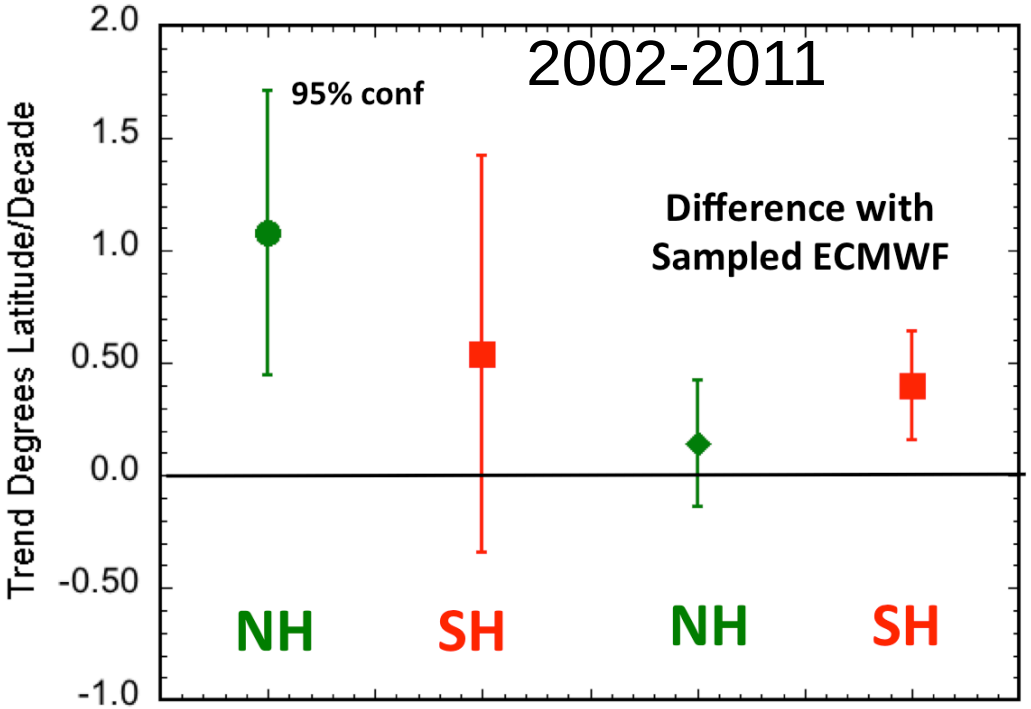




Tropical Edge Latitude Trends







Trends, Deseasonalized Anomalies

Water Vapor Representation In Models

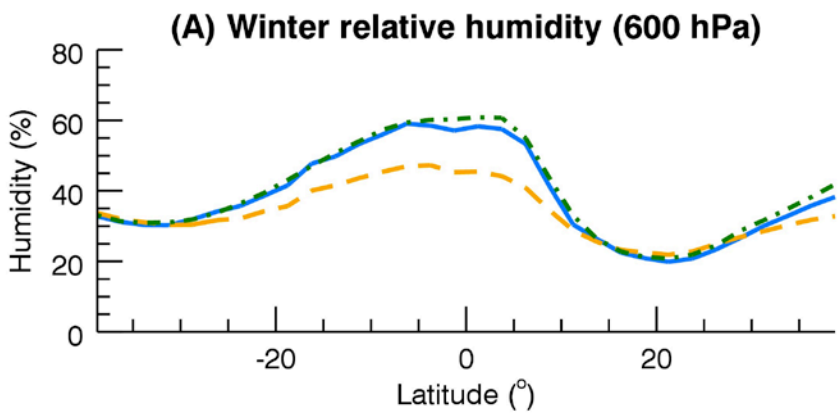
- **Jiang et al. (2012): "We find more than half of the models show improvements from CMIP3 to CMIP5 in simulating column-integrated cloud amount, while changes in water vapor simulation are insignificant."**
- **Representing deep convection properly remains a challenge (Stratton and Stirling, 2012)**
- **GNSS RO provides unique observations of lower-to-mid troposphere water vapor**
- **Studying seasonal differences can identify key process shortfalls**

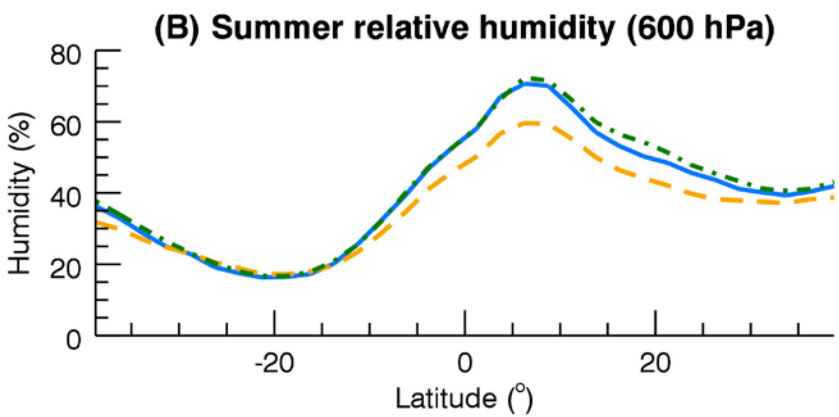
Zonal Mean Relative Humidity: Tropics 2007-2009

RO

MERRA

ECMWF



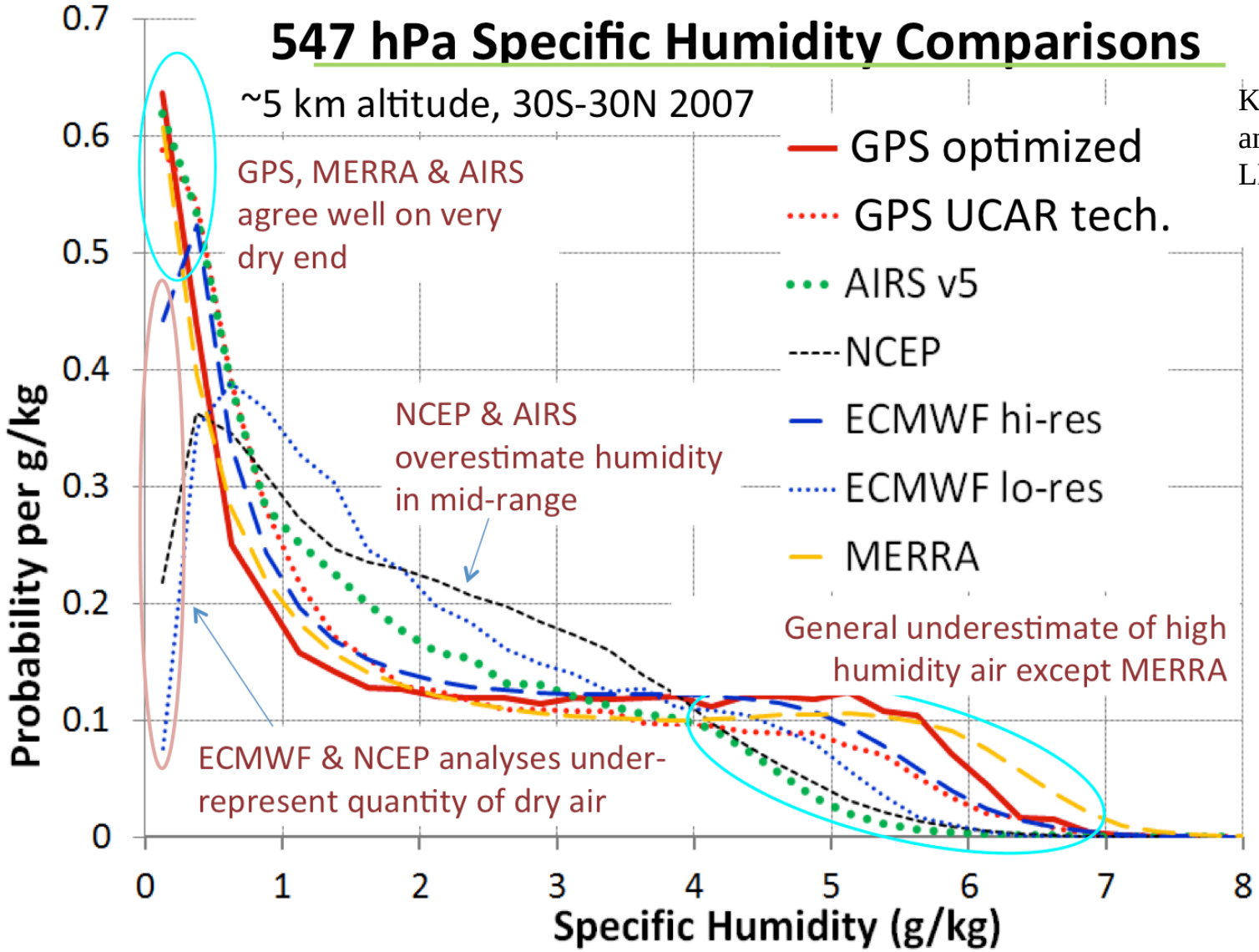


Vergados, P., A. J. Mannucci, C. O. Ao, J. H. Jiang, H. Su (2015), On the comparisons of tropical relative humidity in the lower and middle troposphere among COSMIC radio occultations and MERRA and ECMWF data sets, *Atmos. Meas. Tech.*, *8*(4), 1789–1797, doi:10.5194/amt-8-1789-2015.

Water Vapor Histograms

- **Kursinski, E. R., & Gebhardt, T. (2014) "A Method to Deconvolve Errors in GPS RO-Derived Water Vapor Histograms," Journal of Atmospheric and Oceanic Technology, 31(12), 2606–2628.**
- **"Direct method" for retrieving water vapor: independent of water vapor estimates from analyses**
- **Developed deconvolution technique that removes negative water vapor values**
- **Provides error information**

RO-IR Synergy



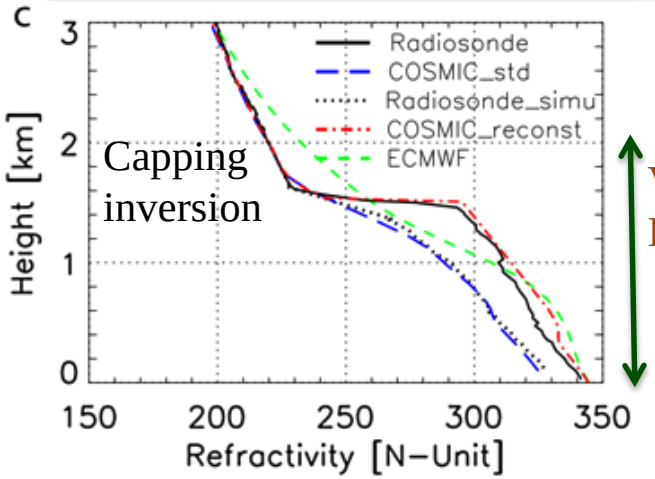
Kursinski, Earth and Space Science LLC

RO: Unique Boundary Layer Data

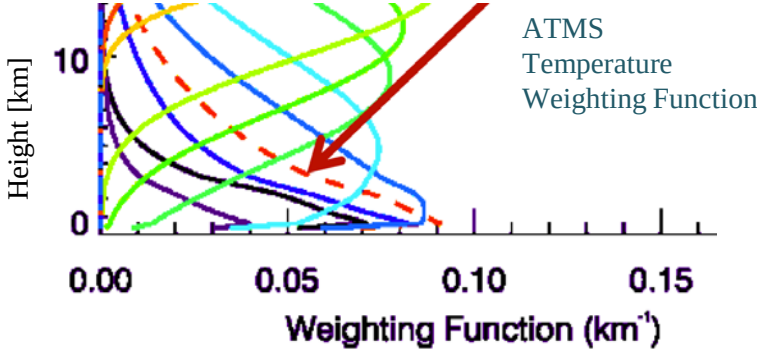
Radio Occultation:
- Cloud penetrating
- High vertical resolution

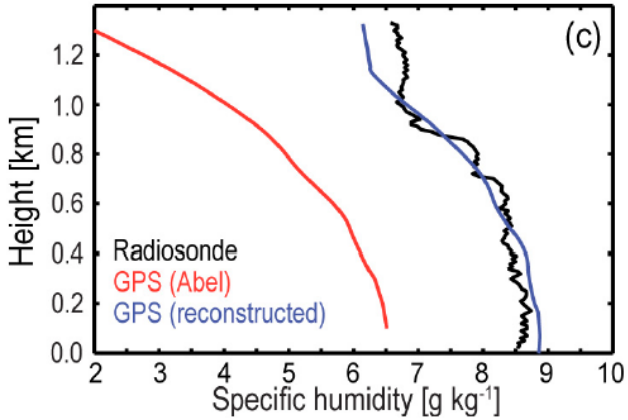
Infrared:
- Blocked by clouds
- Moderate vertical res

Microwave:
- Penetrates clouds
- Low vertical res

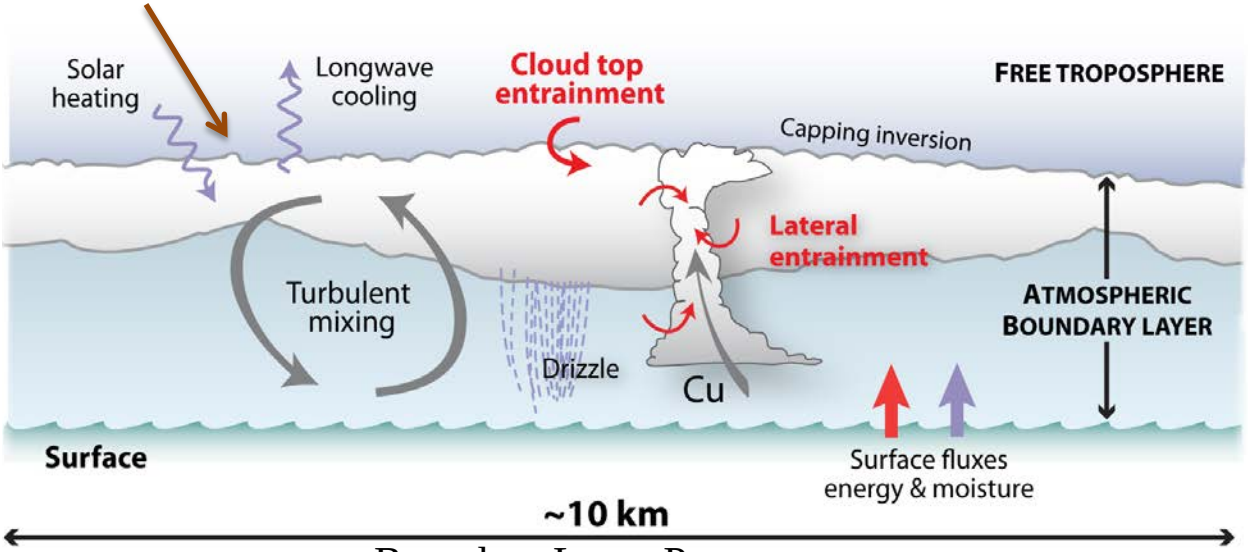


Vertical resolution
IR sounders (~2 km)





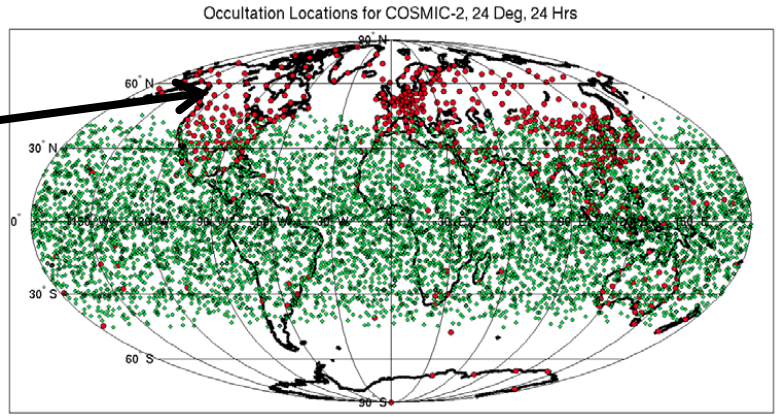
Opaque to IR



Boundary Layer Processes

COSMIC-2

No data above 40° latitude



- Data locations from COSMIC-2 A (Equatorial) constellation
- Launch 2016

- **COSMIC-2A planned for launch in 2016**
- **COSMIC-2B is currently on hold**
- **COSMIC-2 will provide 9X profile number between ±30° latitude**

Summary

- **Needed for Earth science: measurements with unique information content**
- **RO tropopause measurements suggest different tropical belt widening trends between northern and southern hemispheres**
- **Low latitude water vapor distributions represented differently in ECMWF and MERRA – RO agrees more closely with MERRA below 500 hPa**
- **Water vapor histograms: reveals different "perspectives" from reanalyses and instruments**
- **COSMIC-2: potential significant advances in boundary layer water vapor – but concerns regarding global coverage**