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Turning Satellite Data into Global Precipitation Maps

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Science and Technology

Intermission: Notes on What It Takes to Do Meteorology, Precipitation, and Satellites

Results

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1. The big picture – the water cycle

Water exists in all three phases across the globe.

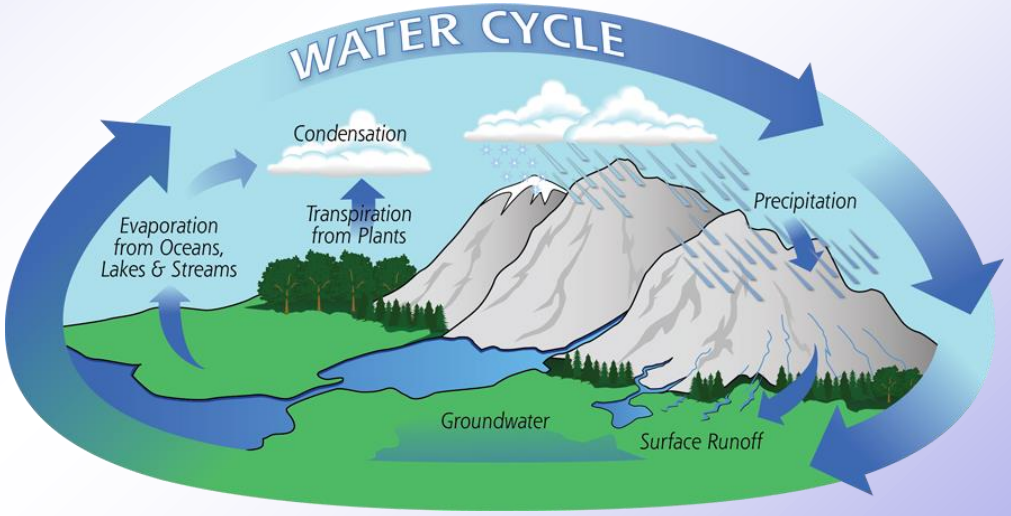
The “cycle” is “multi-scaled”

- a complicated combination of fast local effects, right up to global climate scales

The global water cycle is coupled with the global energy cycle

- 3-dimensional condensation, evaporation, and vapor transport enter both the water and energy balance equations

Precipitation is the ultimate source of all the natural fresh water on which terrestrial life depends



2. The small picture – precip is easy to measure, hard to analyze

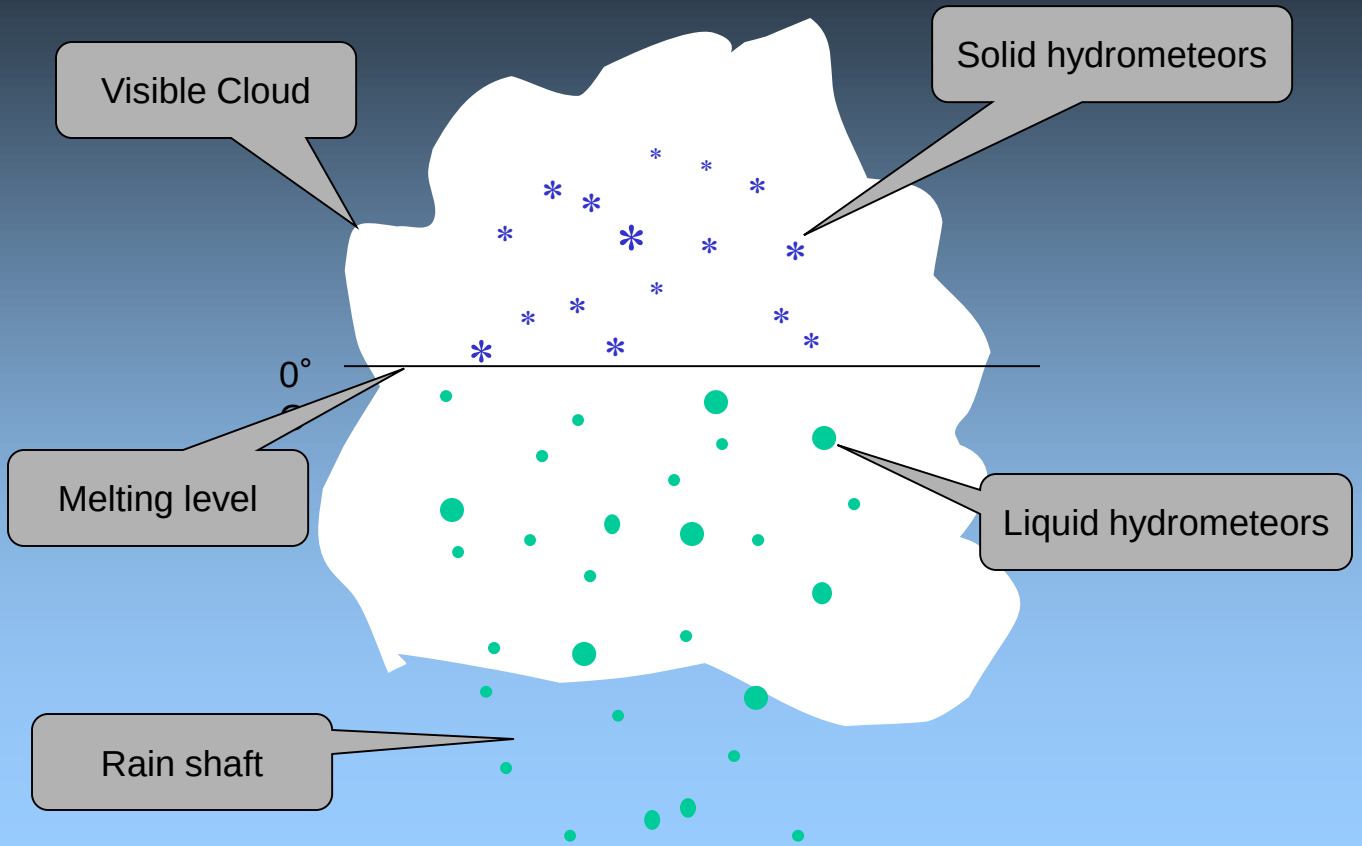
The physical process is hard to represent:

- the driving forces vary across a range of space/ time scales
- precip is generated on the microscale
- the decorrelation distance/time is short
- point values only represent a small area & snapshots only represent a short time

Intermittent sampling in space or time causes problems

Image courtesy of the University Corporation for Atmospheric Research

3. Remote sensing – what does the remote sensor view?



3. Remote sensing – how do remote sensors “see”?

Only a few bands in the electromagnetic spectrum are used for precipitation retrieval from satellite

visible - possible, but not used operationally for precipitation

passive infrared (IR)

passive microwave - emission channels

passive microwave - scattering channels

active microwave - radar

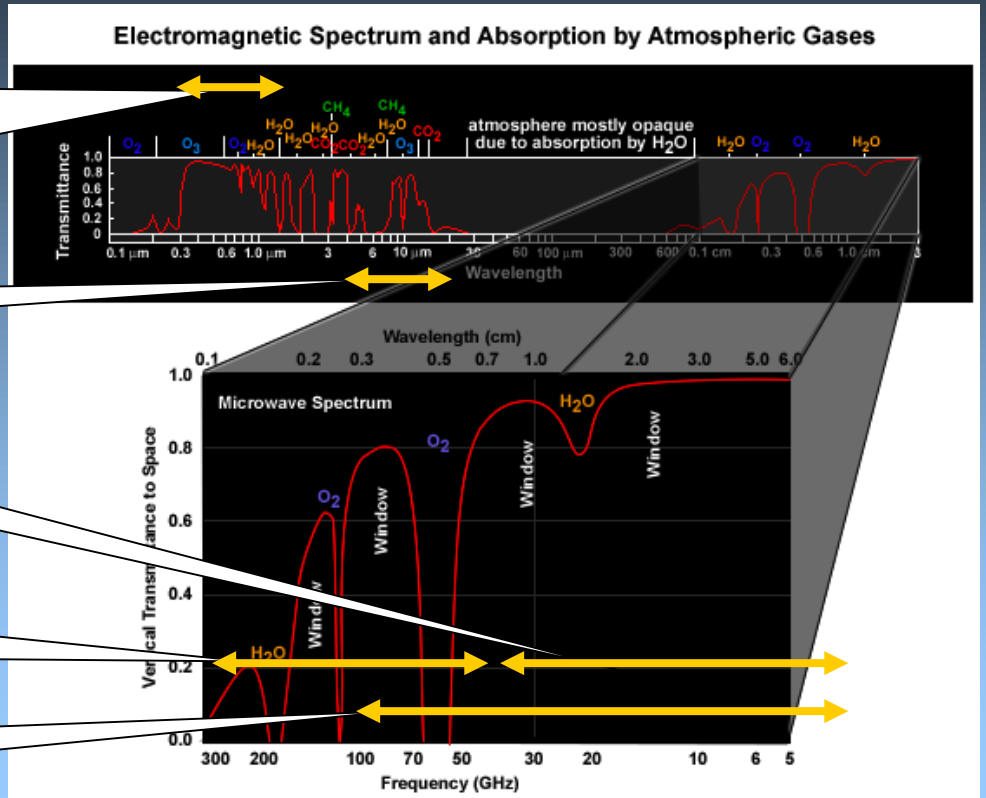
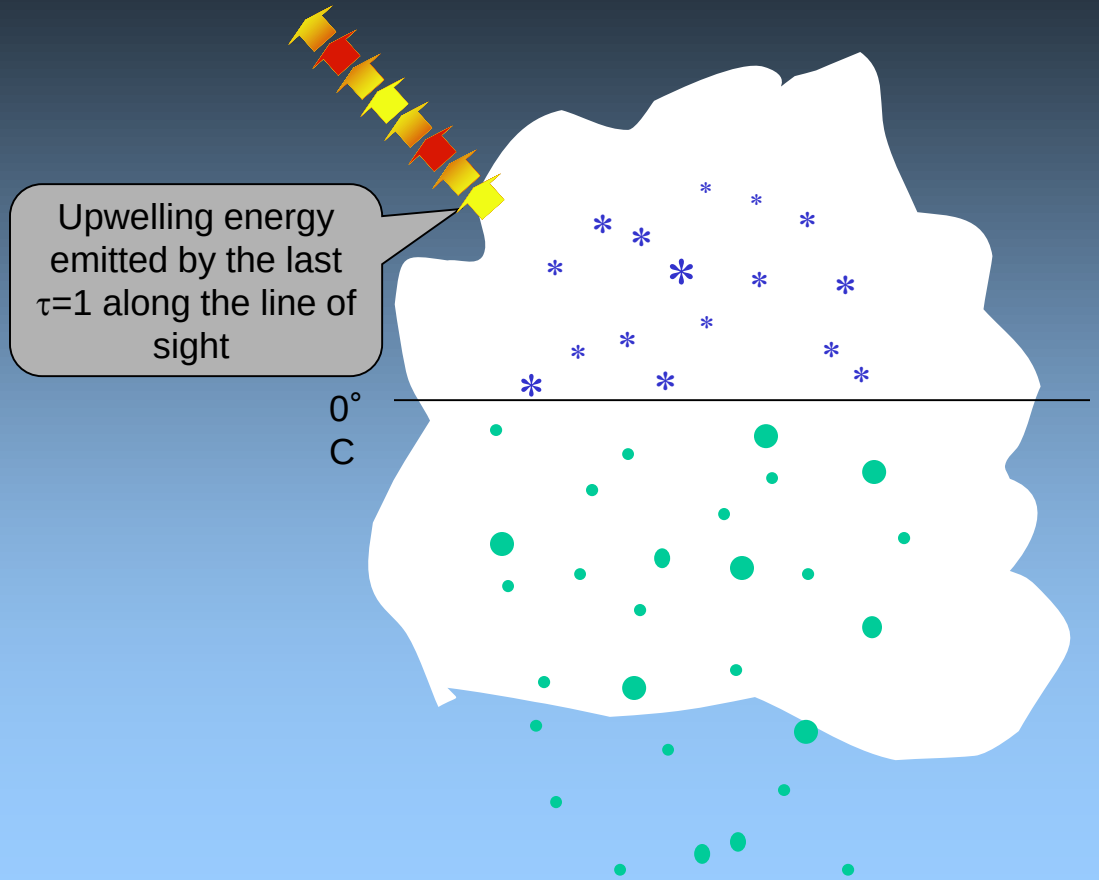
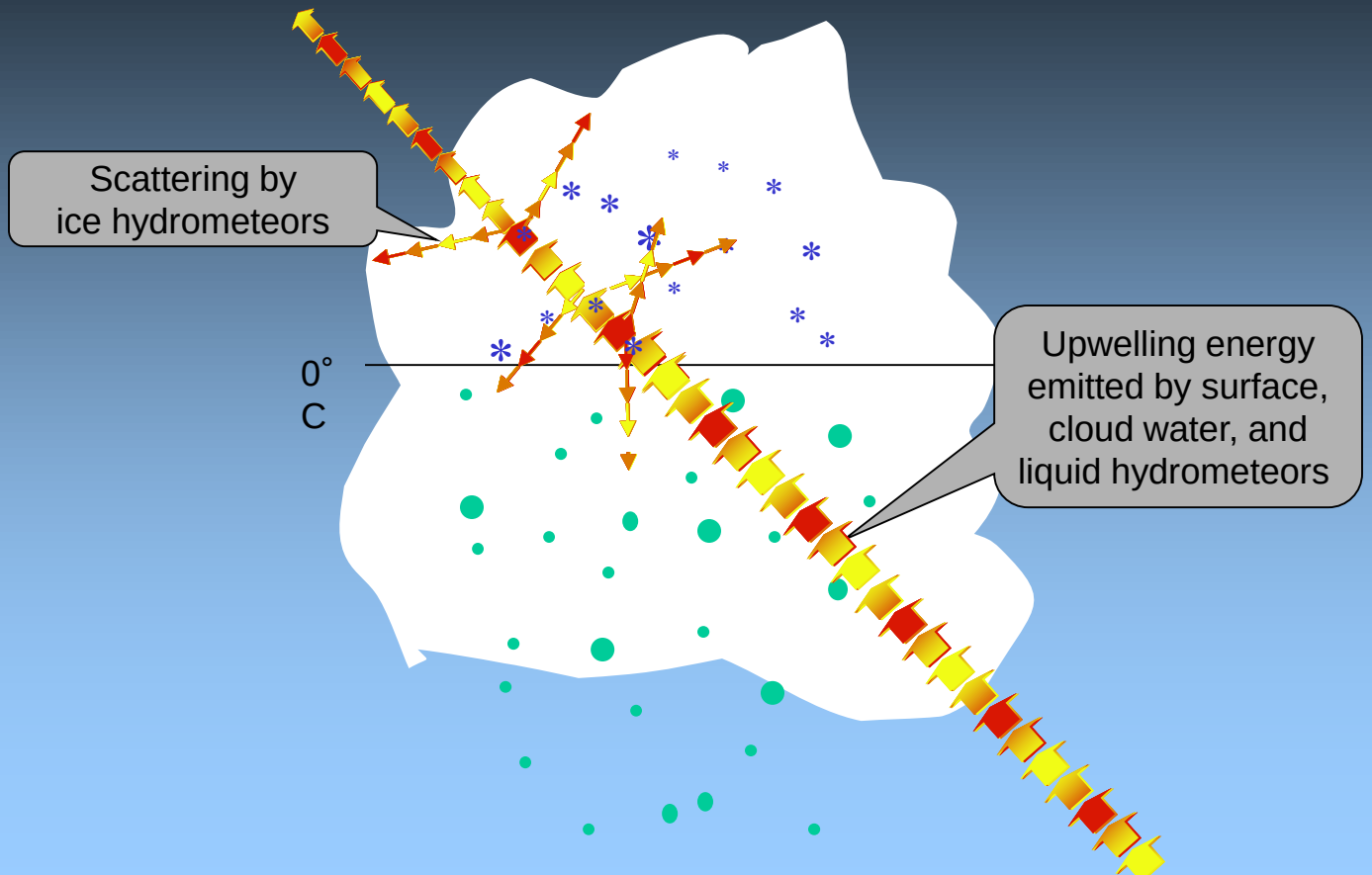


Image courtesy of the University Corporation for Atmospheric Research

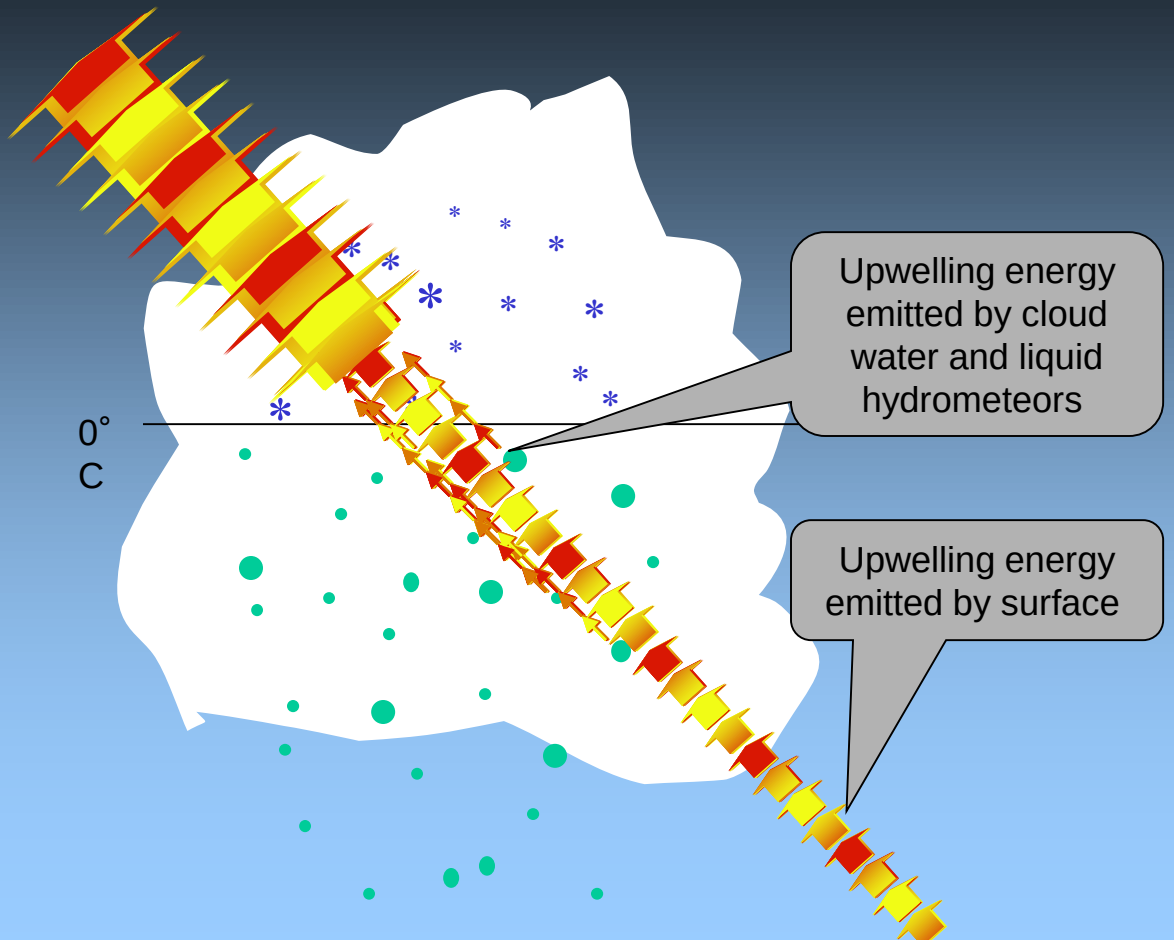
3. Remote sensing – passive infrared senses the cloud top



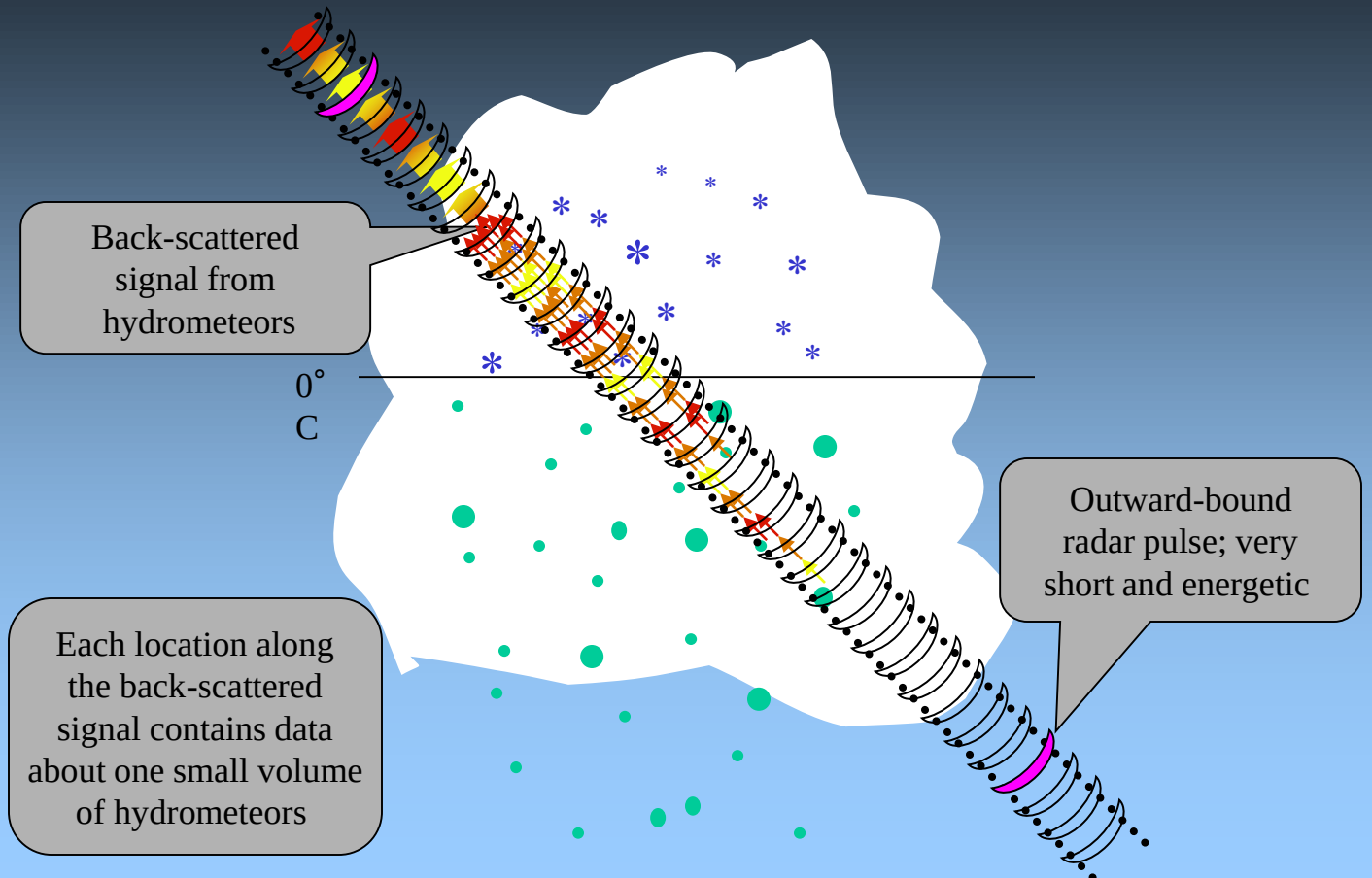
3. Remote sensing – Passive microwave at “high” frequencies senses scattering by ice hydrometeors



3. Remote sensing – passive microwave at “low” frequencies senses emission by liquid hydrometeors



3. Remote sensing – radar – active microwave – provides range-resolved information about all hydrometeors



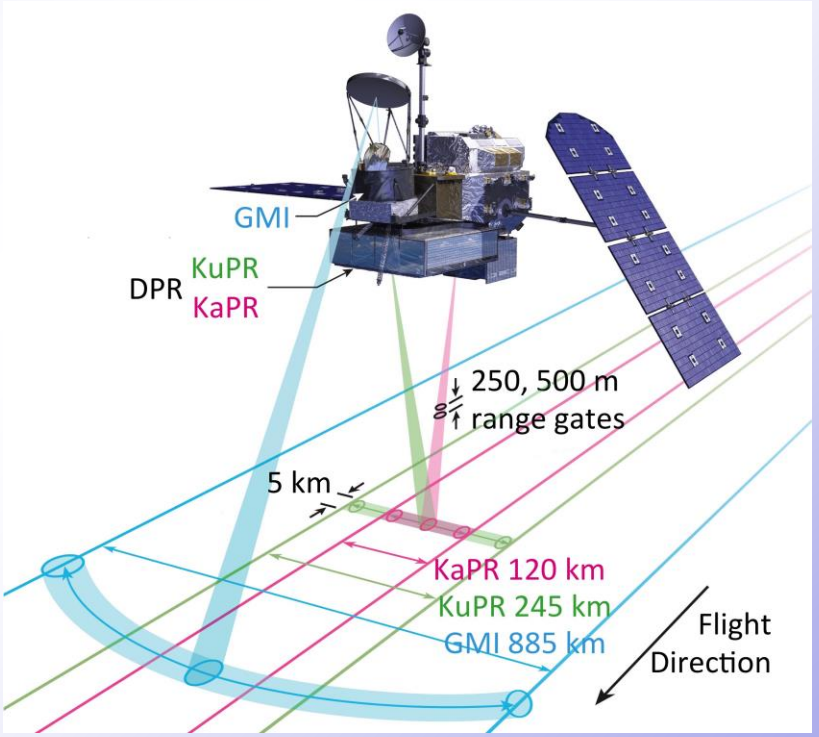
4. GPM Core Observatory – provides passive and active microwave observations

13-channel GPM Microwave Imager (GMI) provided by NASA

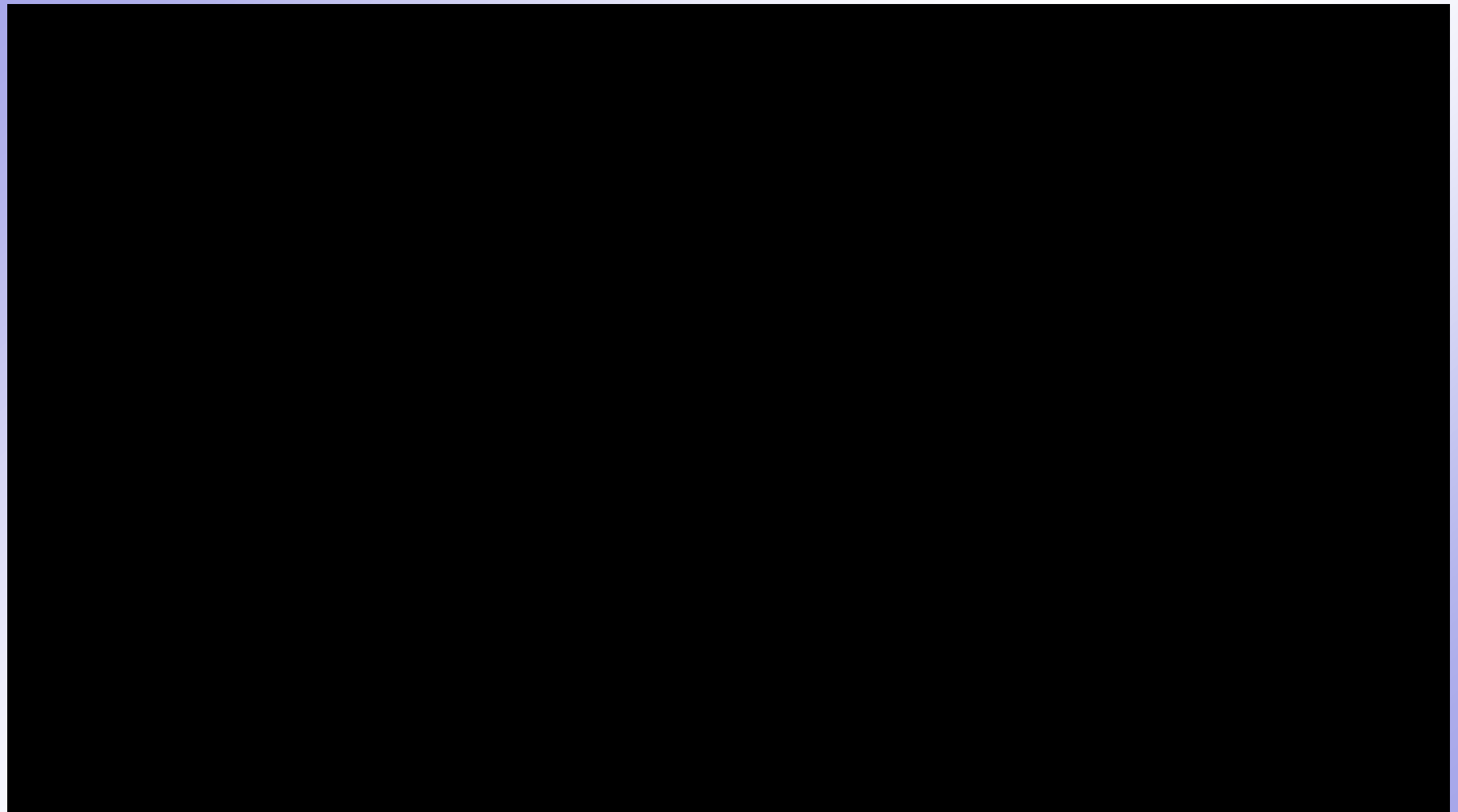
- passive radiometer with excellent calibration
- 10VH, 19VH, 23, 36VH, 89VH, 166VH, 183±3, ±7
- provides observations of precipitation (rain and snow) intensity and distribution over 885 km swath
- high spatial resolution (down to ~5 km footprints)

Dual-frequency Precipitation Radar (DPR) provided by JAXA

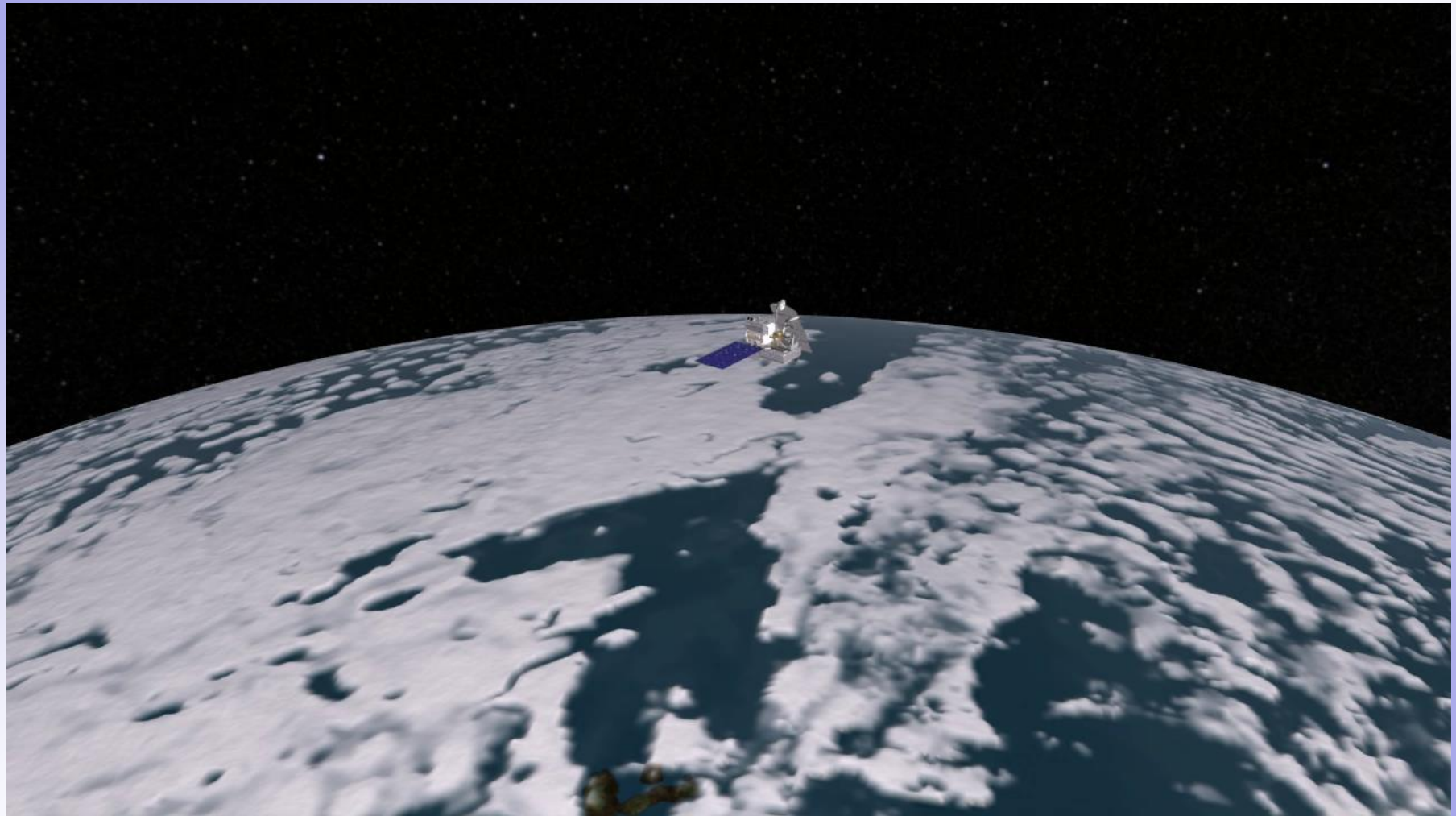
- KuPR similar to TRMM, KaPR added for GPM
- provides 3D observations of precipitation structure, precipitation particle size distribution
- high spatial resolution (5 km horiz.; 250 m vertical)



4. GPM Core Observatory – and this is what it takes to make it fly



4. GPM Core Observatory – data-gathering operations



5. The constellation – bringing in all the other precip-relevant satellites

5. The constellation – algorithms transform observations into estimates

Note … despite the mission name, we're not measuring precipitation – it's "observing" and "estimating"

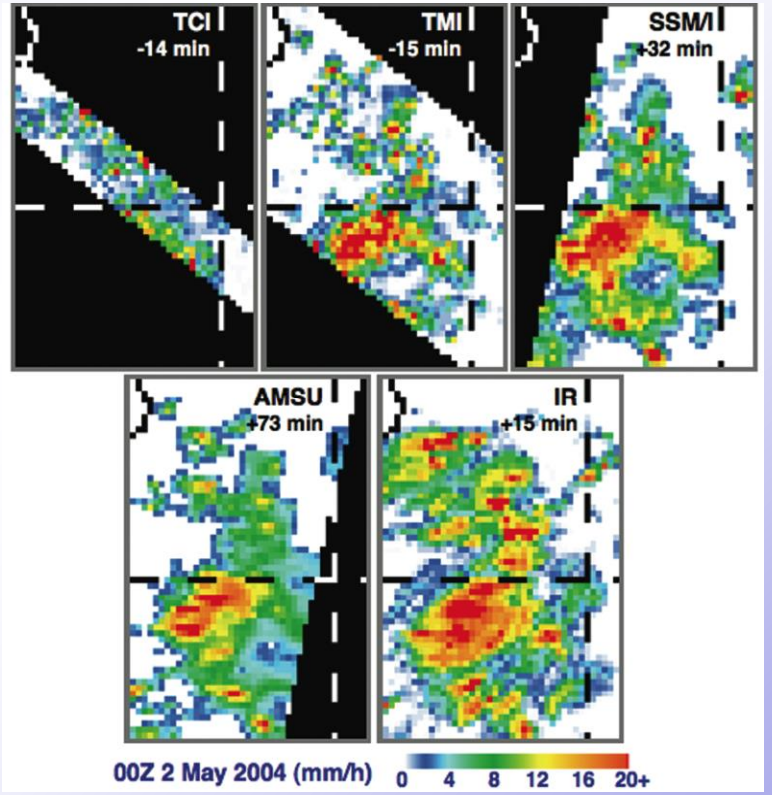
Nearly coincident views by 5 sensors southeast of Sri Lanka

The offset times from 00Z are given below the "sensor" name

The estimates are related, but differ due to

- time of observation
- resolution
- sensor/algorithm limitations

Combined-sensor schemes work with all of these data to build a uniformly gridded product



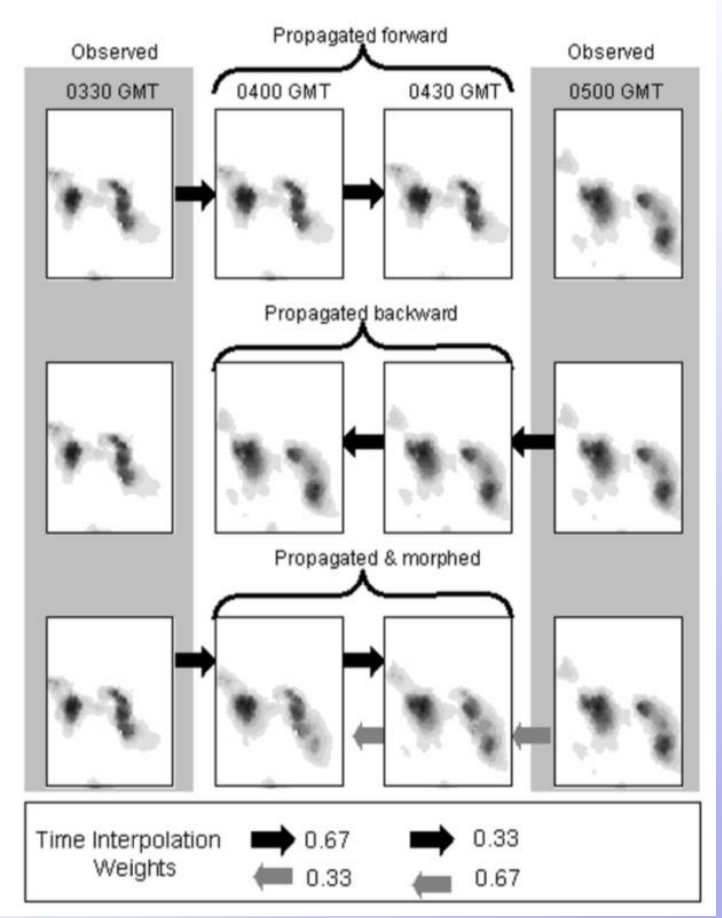
5. IMERG – using “morphing” to get estimates between the satellite overpasses

Try to estimate precip area motion

- propagation vectors originally derived from geostationary IR cloud motion, adjusted by ground radar-based scale factors
- now using motion of vertically integrated water vapor patterns as depicted in numerical analysis (MERRA2, GEOS5)

Simple quasi-Lagrangian shifts of microwave overpasses

- propagate previous (forward) and future (backward) half-hour snapshot precipitation until “overwritten” by current half-hour snapshot precipitation
- compute weighted average at each time lacking an overpass
- no guarantee that vector gives the best path between overpasses



from Joyce, et al (2004)

5. IMERG – upgrade “morphing” to include IR estimates with a Kalman smoother

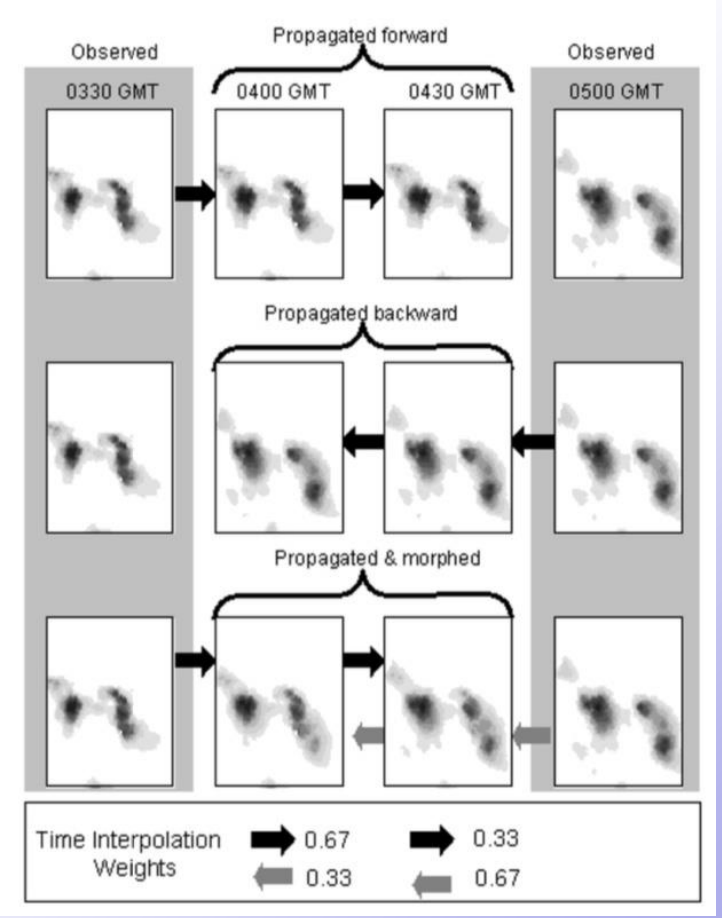
Weights were originally just timespan from adjacent overpasses

- but correlations are very low after ~90 min.
- IR has better (but still low) correlation

Kalman smoother introduced

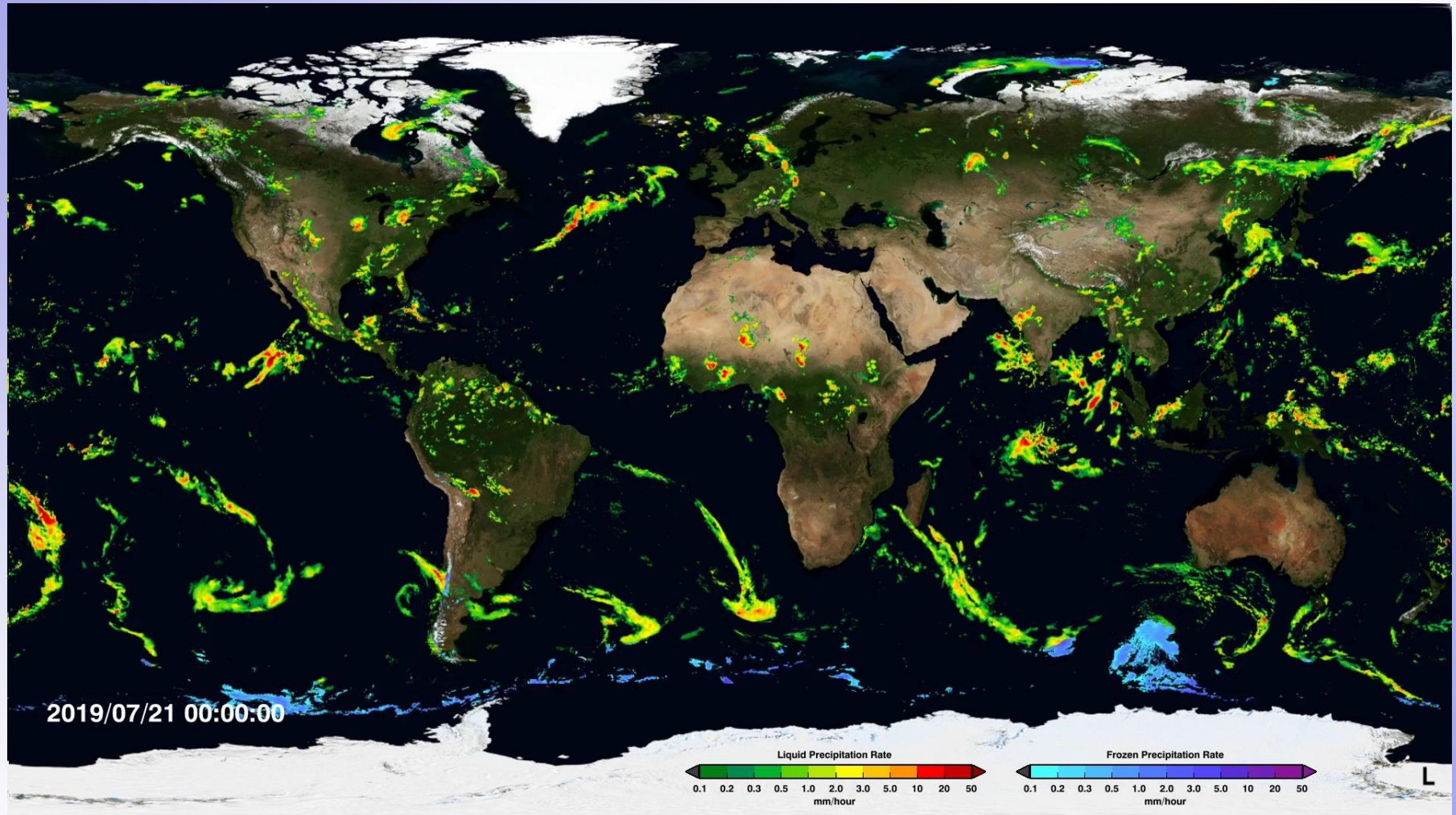
- propagated microwave is the “model”
- IR at the time is the “observation”
- weights are time-average correlation of at-time GMI (or TMI in TRMM) to propagated overpass

Always have a precipitation estimate everywhere even though some estimates may have been propagated a long time



from Joyce, et al (2004)

5. IMERG – a recent “last week” visualization



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6. What specialties are related to precip?

“weather”

“climate”

air chemistry/air pollution

theoretical

forecasting

applications

instruments

computing

“outreach”

education

TV/video production

7. What training does it take to do this?

heavy math / physical science emphasis

balance of computing and physical insight

English – oral and written

leadership skills

almost always 4-year college degree, more and more an advanced degree

my job didn’t exist when I graduated

8. Who hires precip specialists?

academia

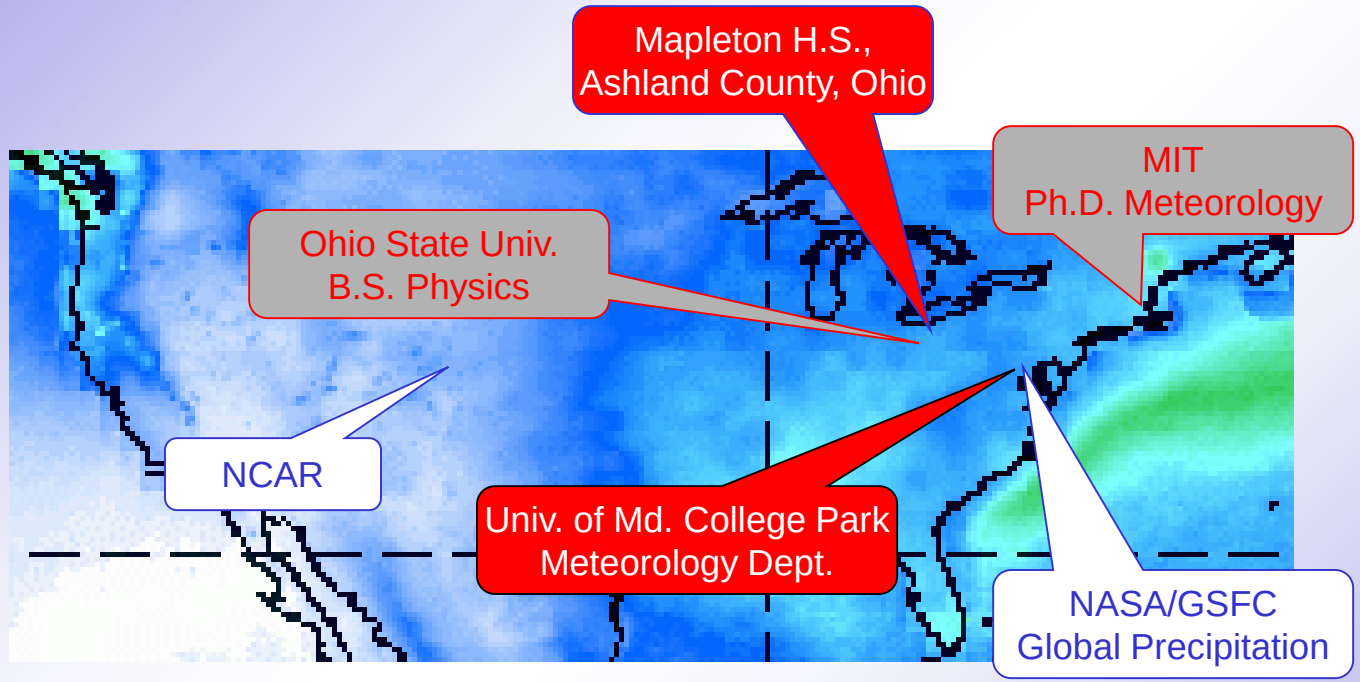
government agencies

non-governmental organizations

private companies

- consulting
- insurance
- in-house expert

9. My path to precip fame (??) and fortune (??)



Early on, I decided that weather is fascinating

Then I discovered that weather is relevant

Then I discovered that people will actually pay you to do more than TV weathercasts

And, I discovered (noted above) that it requires

- lots of math and science
- computer skills
- English skills

10. What is Goddard Space Flight Center like? (1/2)

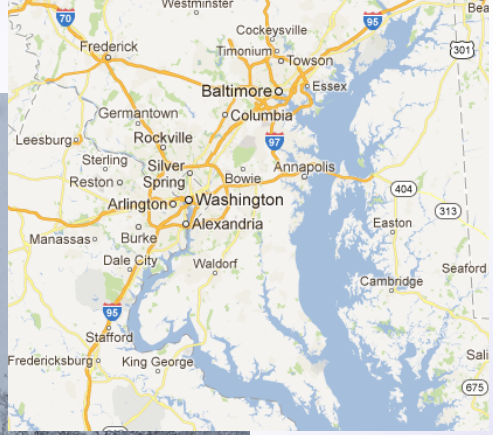
Suburban Maryland, and

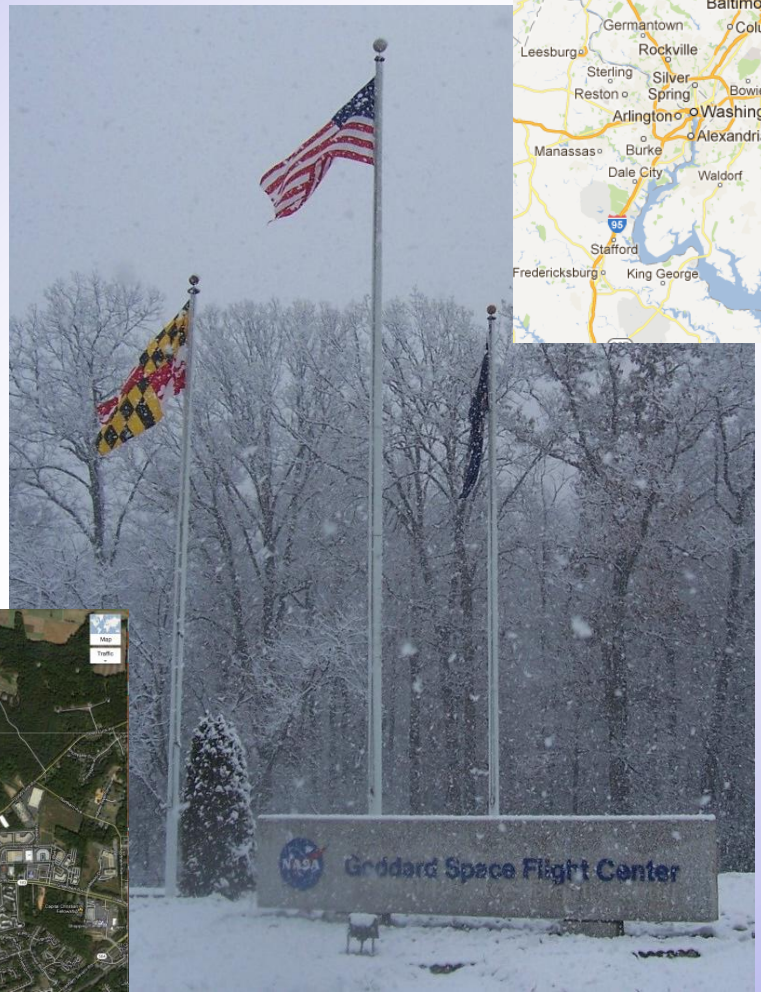
- Wallops Flight Facility (coastal Virginia)
- Goddard Institute for Space Studies (New York City)

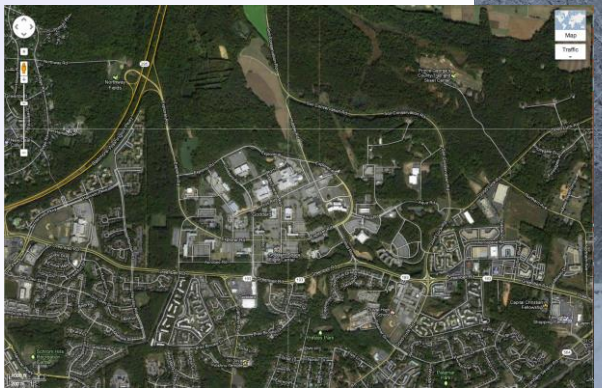
Security perimeter means you can't just stop by for a visit

Mostly the "other" NASA

- Earth Science
- Space Science
- 1 of 7 NASA Centers







10. What is Goddard Space Flight Center like? (2/2)

The science labs are like a research university minus classes and most students

Other areas are like small-scale industrial facilities

~11,000 personnel on-site

- ~50% civil servants
- university personnel
- private contractors
- actual funding for individual positions is proposal-driven
  - flight projects
  - science research funding

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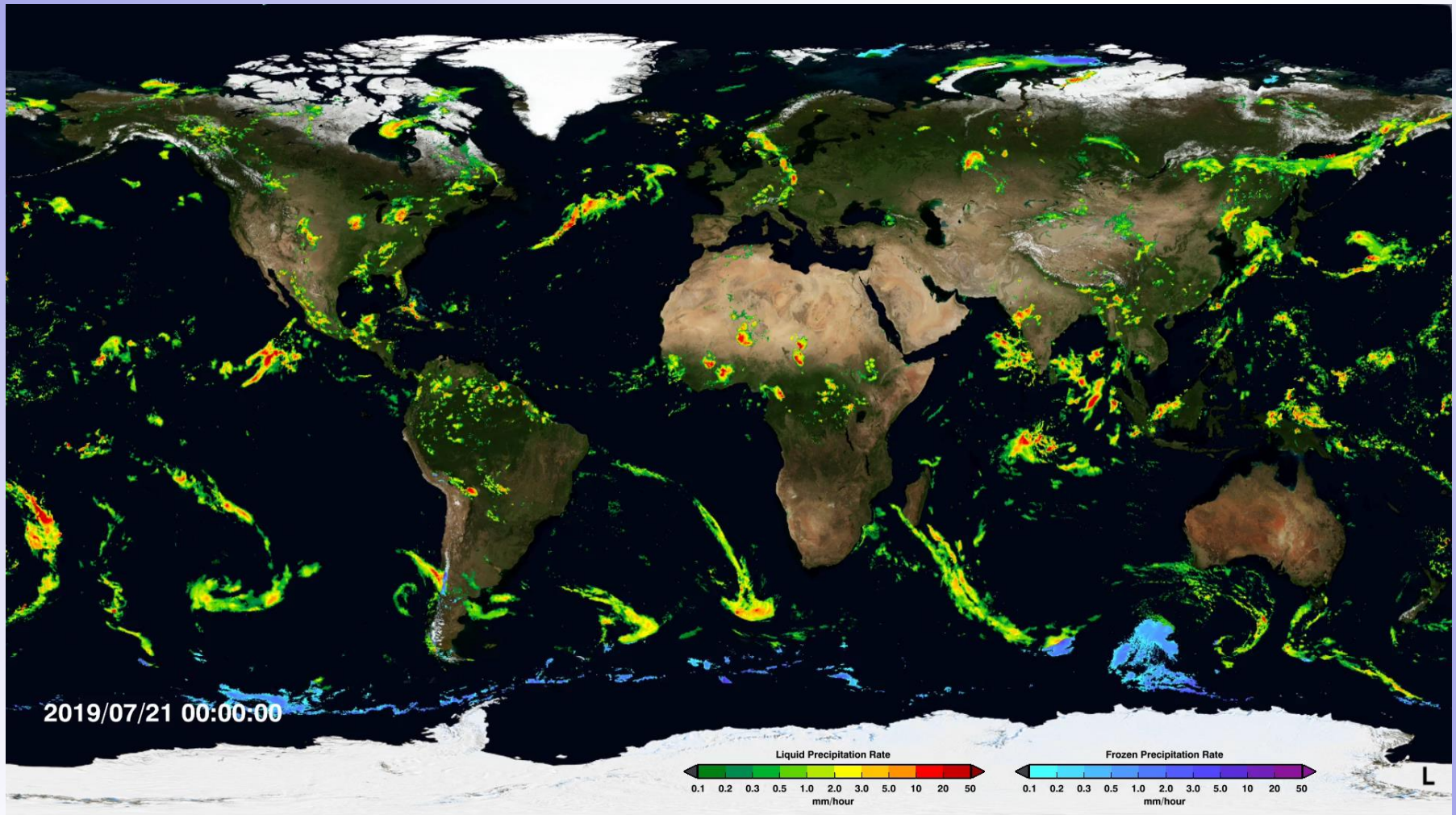
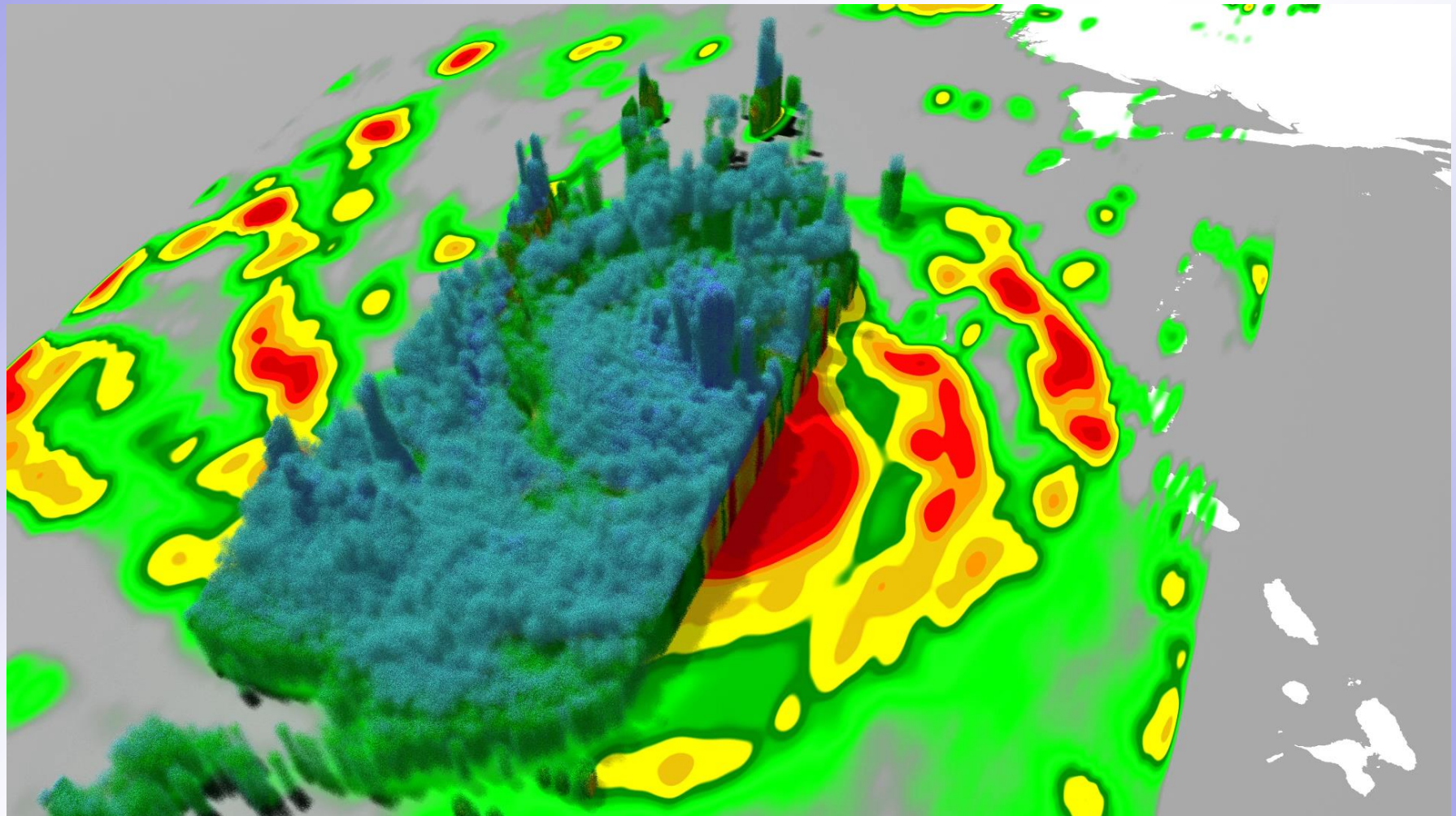
11. Back to the last week of IMERG



12. “Melting” through the levels of precipitation for a Core Observatory overpass of Hurricane Maria



13. IR clouds, storm tracks, and IMERG for the 2017 Atlantic hurricane season

14. Time series for the ocean averaged each month over 50ºN-S

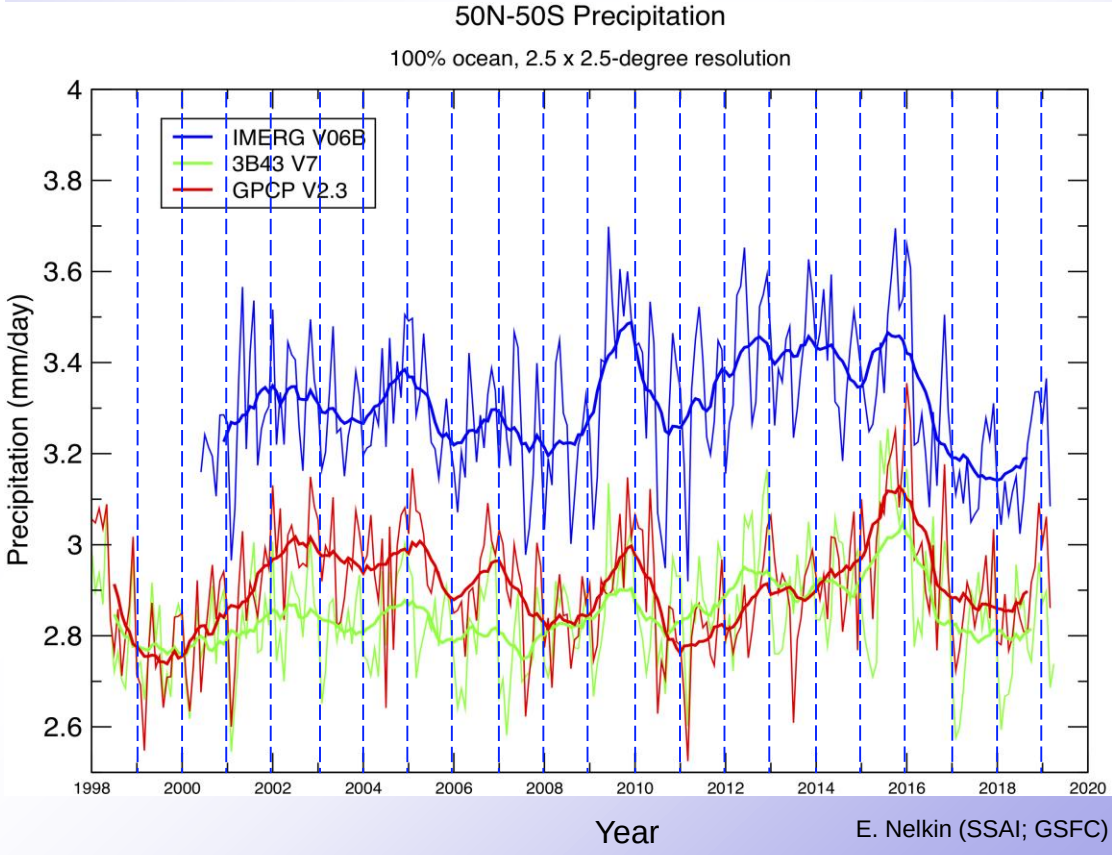
V06 Final Run starts June 2000

Different datasets have different biases, but very similar interannual variation

- but, systematic differences in timing depending on what we use as the calibration standard

Additional multi-year variations

- IMERG (and 3B43) are High Resolution Precipitation Products, not Climate Data Records



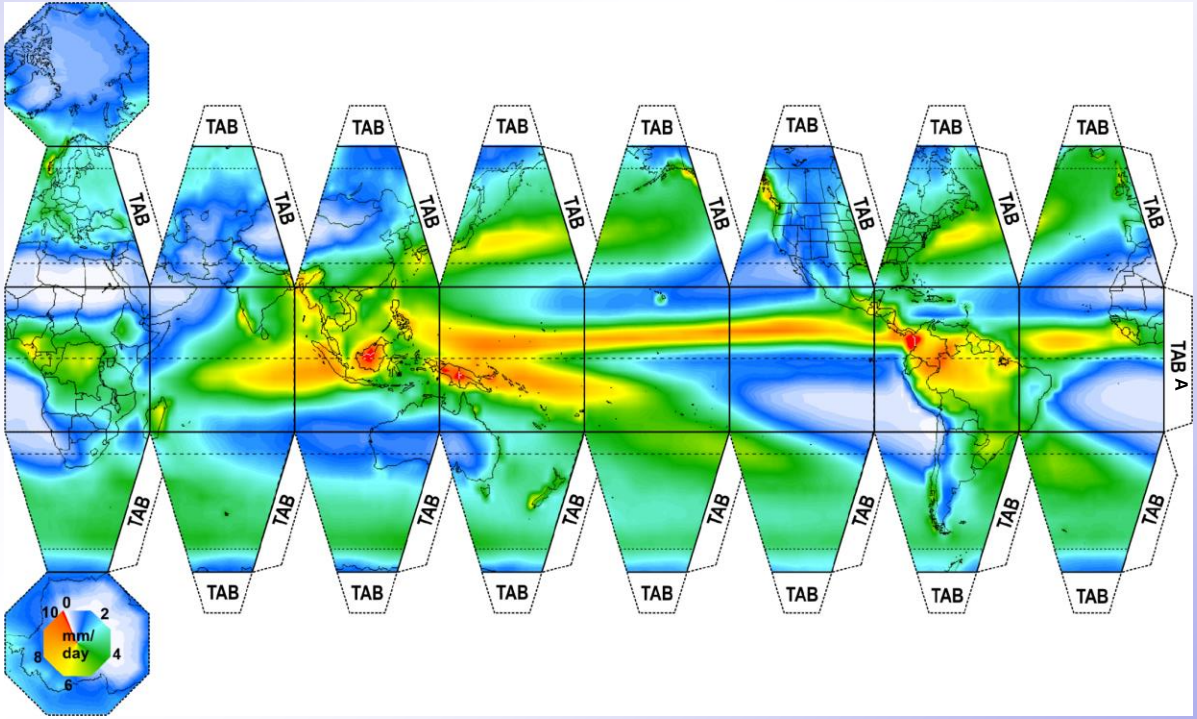
E. Nelkin (SSAI; GSFC)

15. The global climatology

The global climatology of precip from GPCP

This reminds you of the difficulty in mapping a sphere on a 2-D sheet of paper

The PDF can be downloaded from *https://pmm.nasa.gov/sites/default/files/document_files/educational/Global_Precipitation_Sphere_concept_FINAL.pdf*



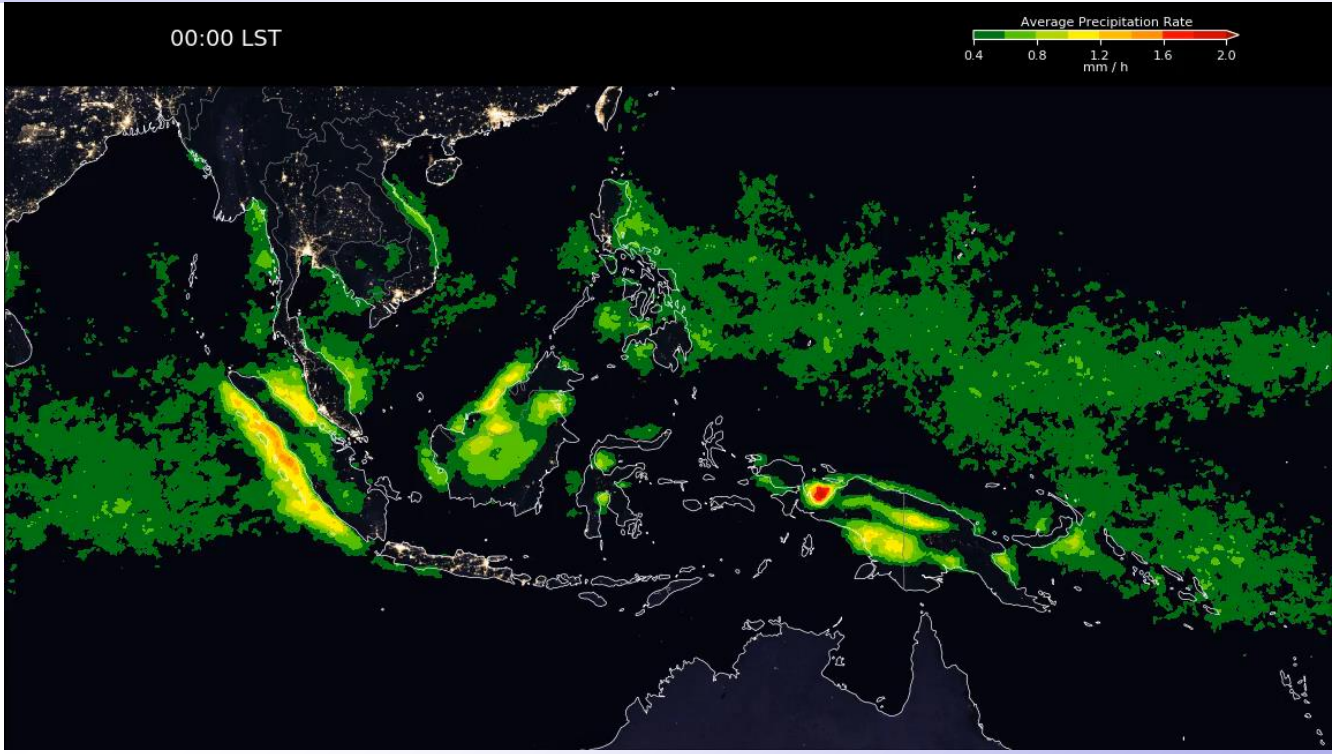
16. The September-October-November Diurnal Cycle for the Maritime Continent

Average September-November for 2001 to 2018

- data re-sorted to give the same LST over the globe
- surface cycles between Blue Marble and Night Lights

Reminiscent of the same computation with an older dataset (TMPA), but

- more detailed, broader spatial coverage
- no interpolations between the 3-hourly times in TMPA
- less IR-based precip used (which tends to have a phase lag)



J. Tan (USRA; GSFC)

17. Multiple Earth Science datasets tell us about the Monsoon