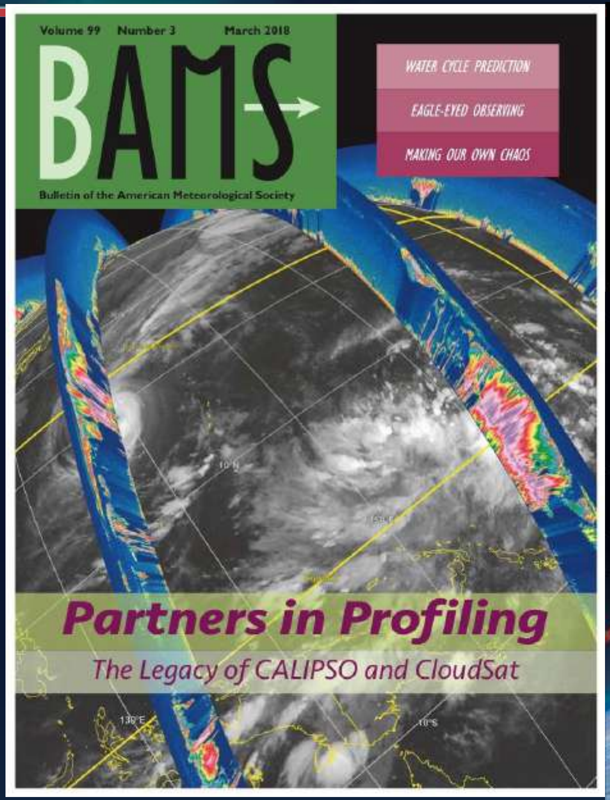
A-Train highlights: Scientific whole > sum of the parts



Launch – June 2011

Return to A-Train May 2012 until Feb 2018

C-Train Sept 2018 – Summer 2023

The 'golden age 'in EO

Graeme Stephens

Director of Center for Climate Sciences, Jet Propulsion Laboratory, California Institute of Tech., Pasadena CA

Distinguished Emeritus Professor, Colorado State University

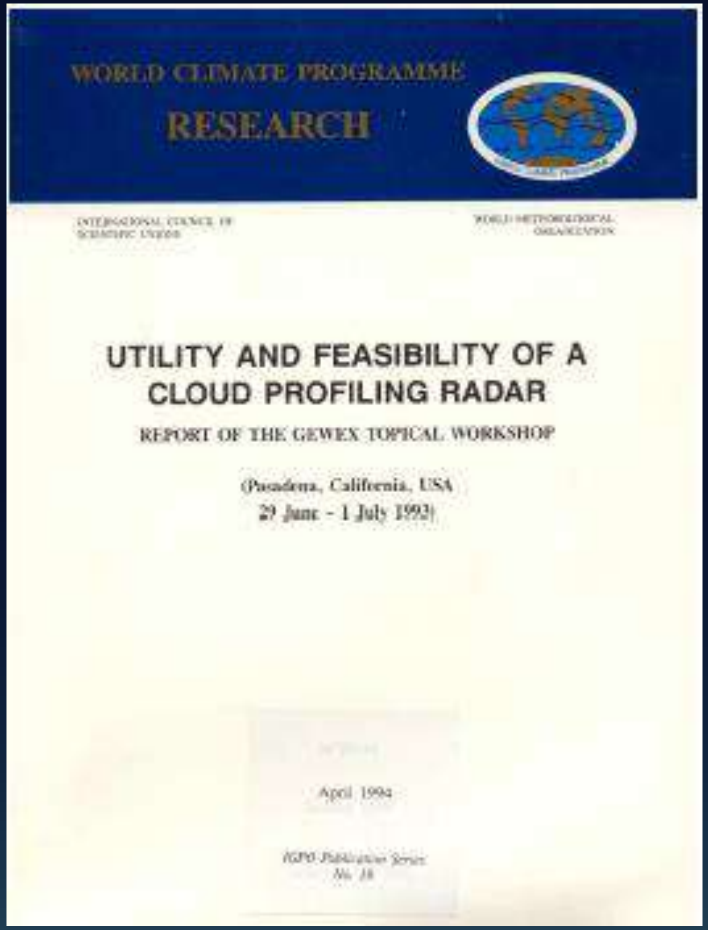
Visiting Professor, Oceanic & Planetary Physics, Uni of Oxford

A-Train highlights with emphasis on CloudSat and CALIPSO – Stephens et al., BAMS 2018

The arrival of CloudSat and CALIPSO, motivated to a large degree by a desire to better understand clouds & aerosols and their impact on the radiation budget and hydrological cycle, provided the true integration of A-Train

The CloudSat-CALIPSO-EarthCARE journey

It really began in 1993 at a WCRP supported workshop (held at JPL) that also included both the ESA and TRMM (not yet launched) communities.


WORLD CLIMATE PROGRAMME
RESEARCH

UTILITY AND FEASIBILITY OF A CLOUD PROFILING RADAR

REPORT OF THE GEWEX TOPICAL WORKSHOP

(Pasadena, California, USA
29 June - 1 July 1993)

April 1994

IGPO Publication Series
No. 18

Out of it grew CloudSat and CALIPSO , ERM →EarthCARE, and a wider vision at that time that is now reflected in AOS, 40 years later

What science achievements were enabled by the A-Train?

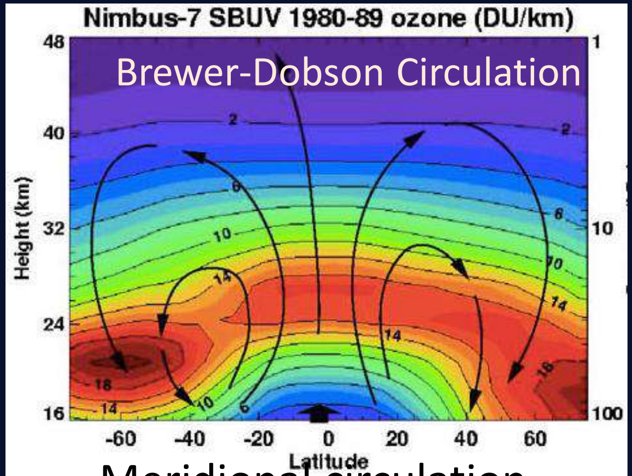
Integration across different observations platforms & sensors (synergy)

(i) Richer validation of key products & improvements of products
(ii) Remove guess work, with important applications
(iii) Develop new information from combinations of different matched observations,
(iv) Combine information to yield new insights on processes
(v) Offer a more integrated view of Earth far beyond that which had been possible.

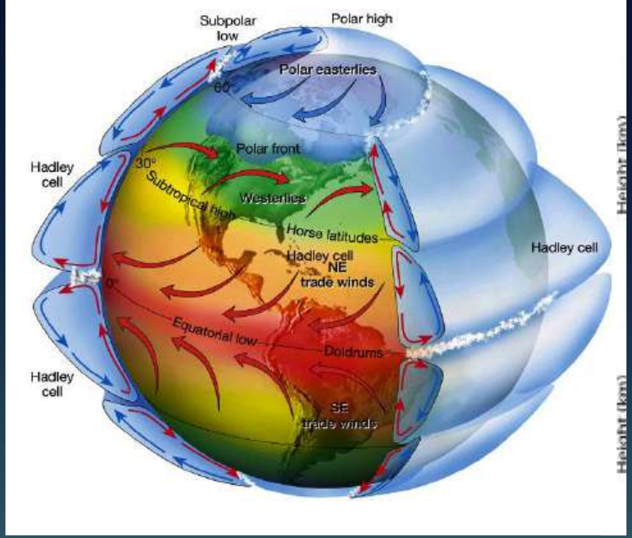
But there are other perhaps even more profound achievements @ the observing system level

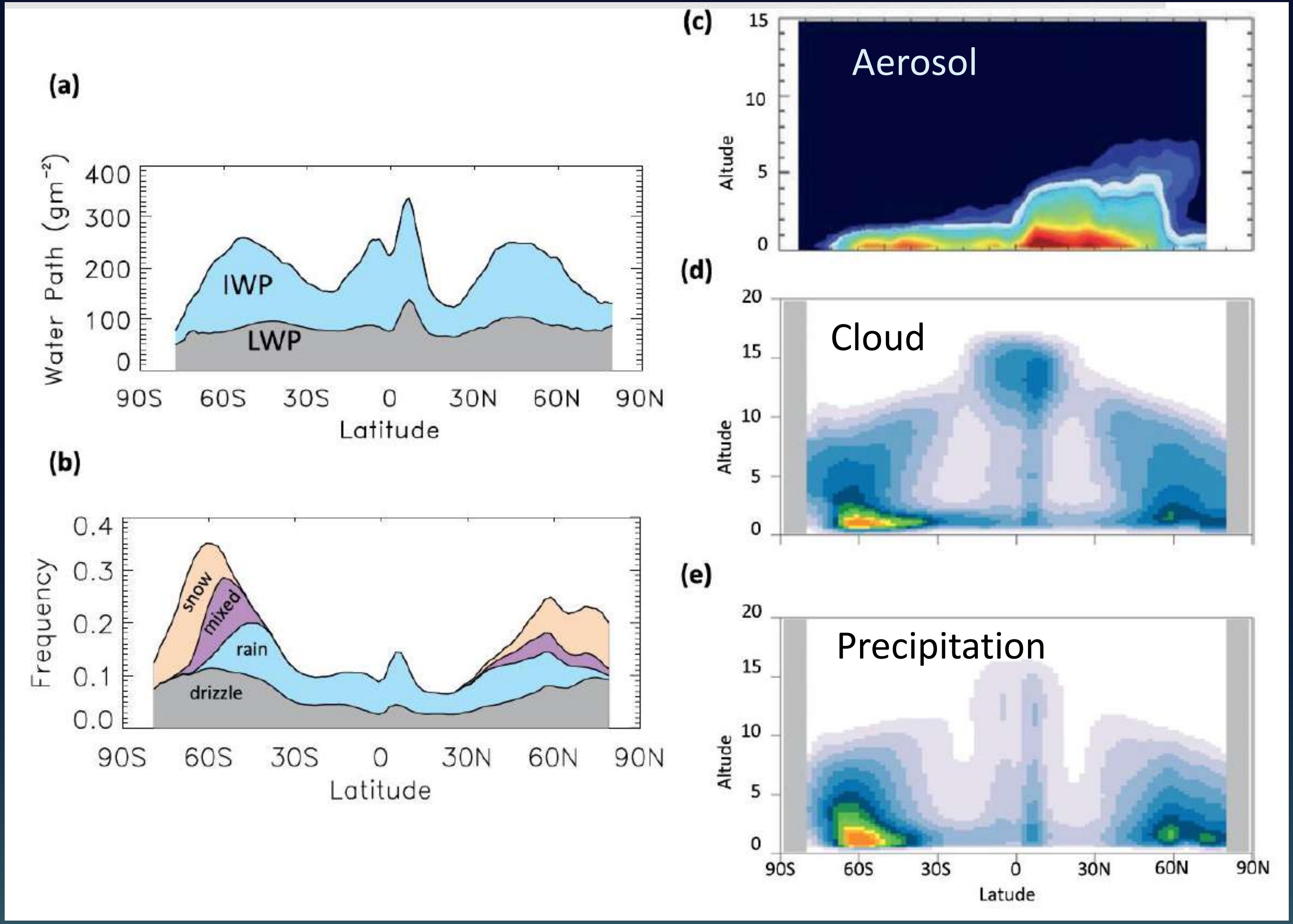
(i) Viability of disaggregated approaches for building observing systems
(ii) Viability of active RS systems for sustained EO’s

A more integrated view of Earth



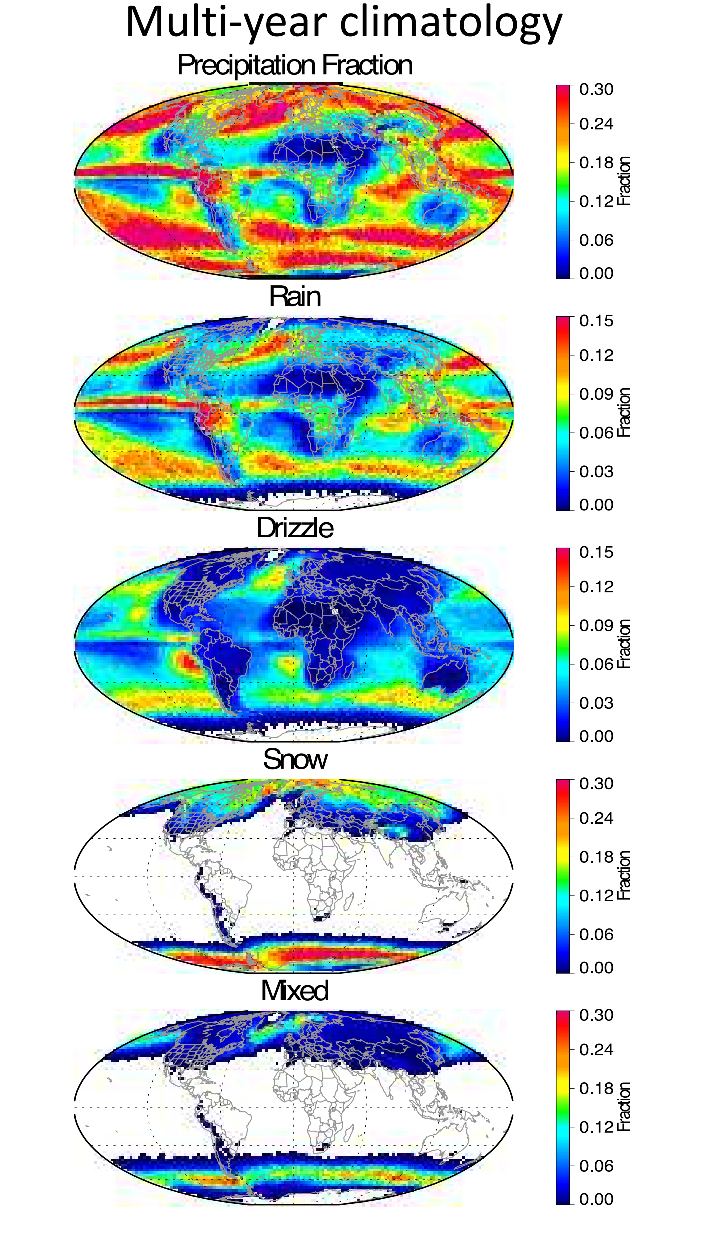
Meridional circulation





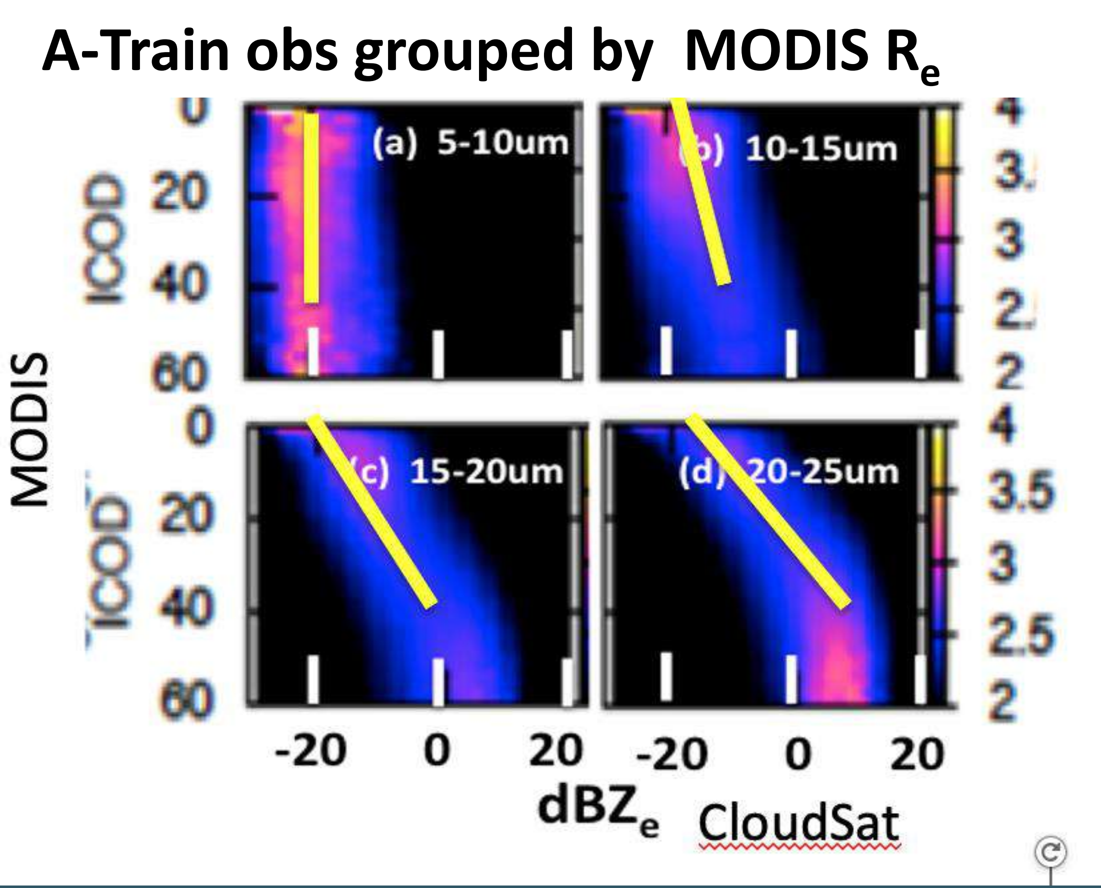
To the memory of Tobias *BAMS, 2018*

How often does it rain? Multi-sensor synergy reveals process.



Insight on the rain process made possible with multi-sensor views

We now have a good grasp of the occurrences of different modes of precipitation

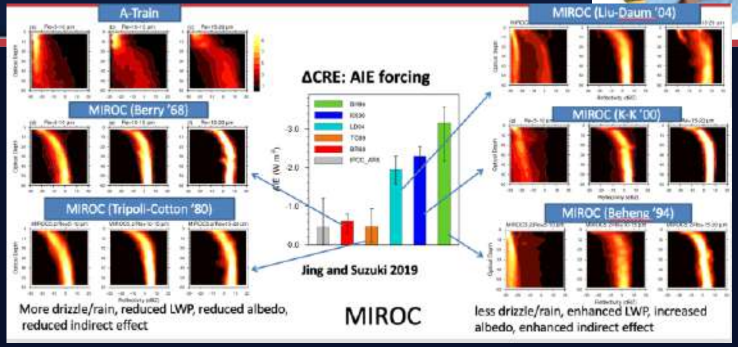


To the memory of Tobias

Series of paper by Suzuki, et al

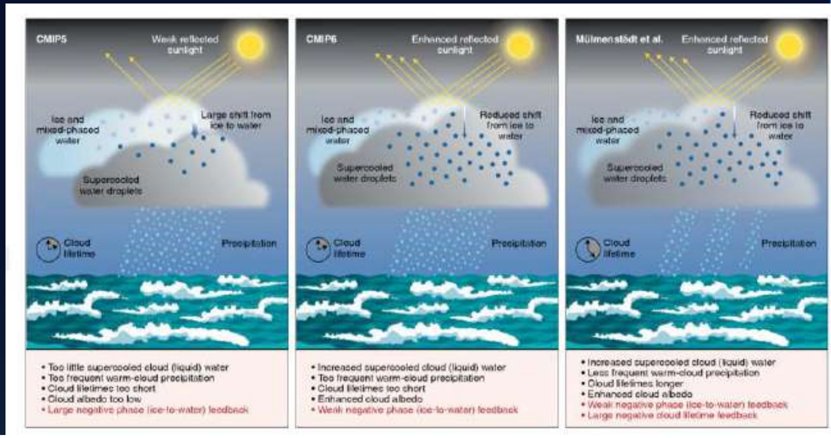
How often does it rain? So what?

- Jing and Suzuki (2019) illustrate a seven-fold range of AIE purely from the way warm rain is ‘made’ in models

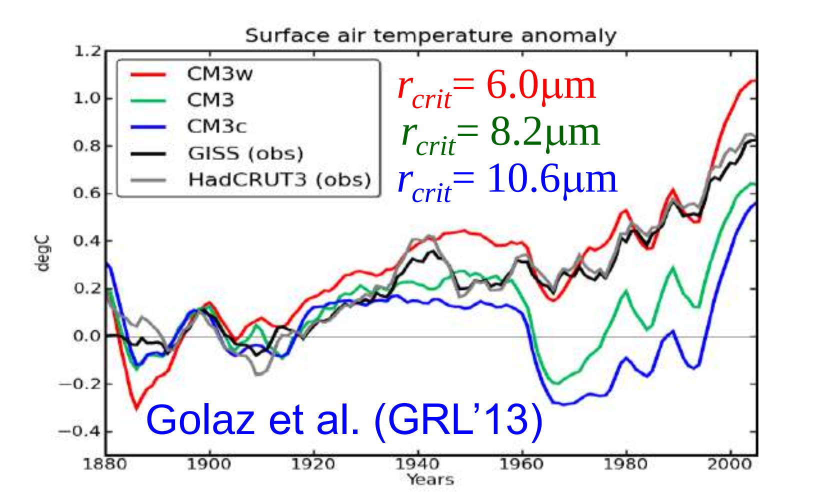


- Mulmenstat et al (2022) find “errors in the representation of cloud and precipitation processes bias cloud feedback estimates in models by as much as the feedback change of the opposite sign between CMIP5 and CMIP6.”

“The cooling of light rains in a warming world”; Nat Clim Change, to appear May 2021

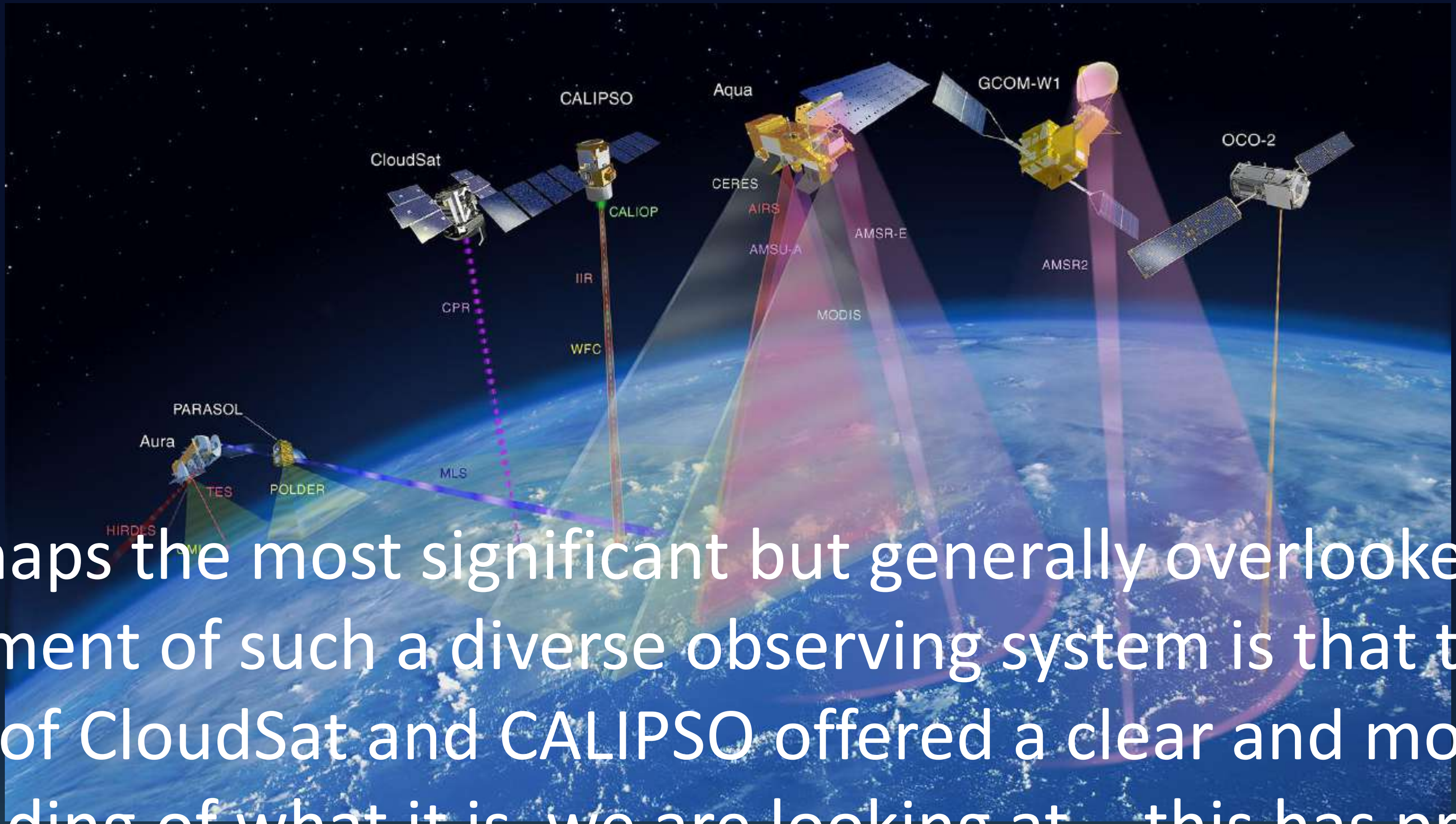


- Golaz et al. (2013) demonstrated a profound sensitivity in replication the the historical warming to how rain is made – this sensitivity is a manifestation of aerosol indirect life-time effects



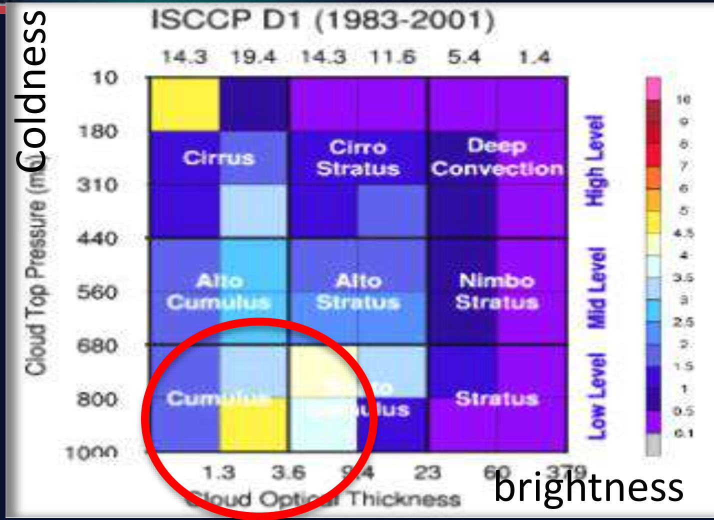
To the memory of Tobias

Removing much of the guess work

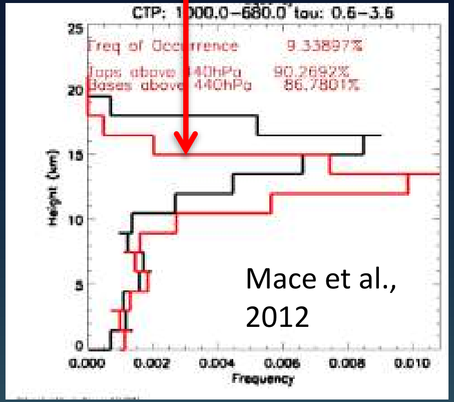


Perhaps the most significant but generally overlooked accomplishment of such a diverse observing system is that the active instruments of CloudSat and CALIPSO offered a clear and more precise understanding of what it is we are looking at - this has profound influences on information extracted from other sensors

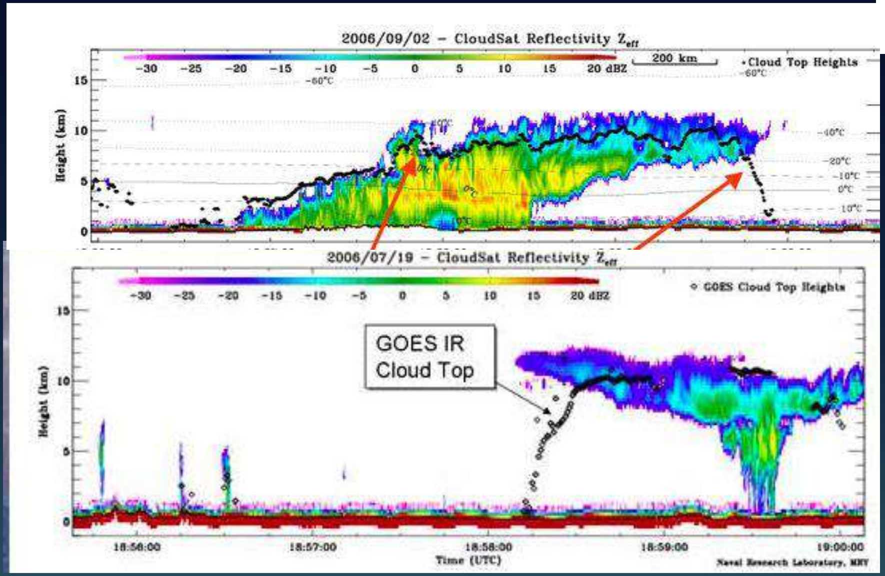
Knowing what we are looking at changes 'everything' and presents new opportunities

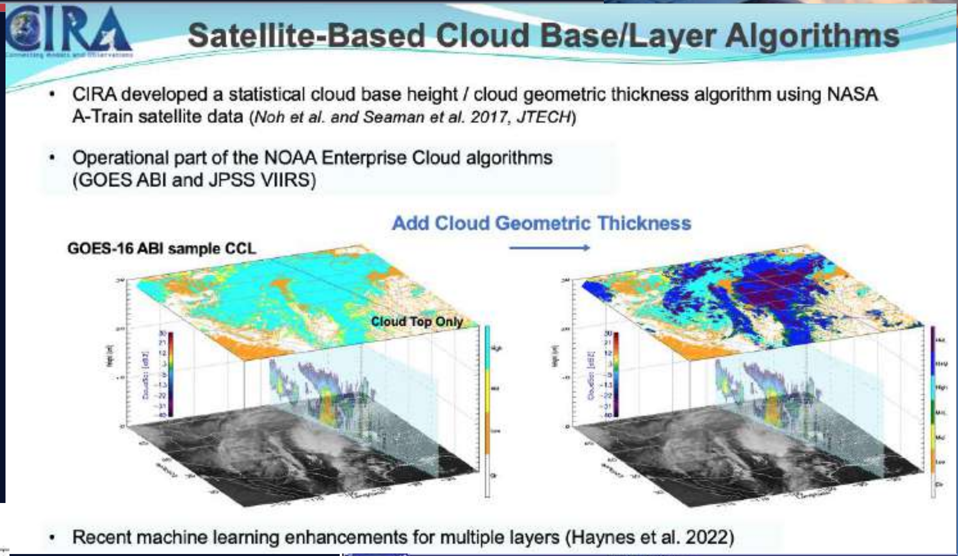


Example in the west pacific



Operational products

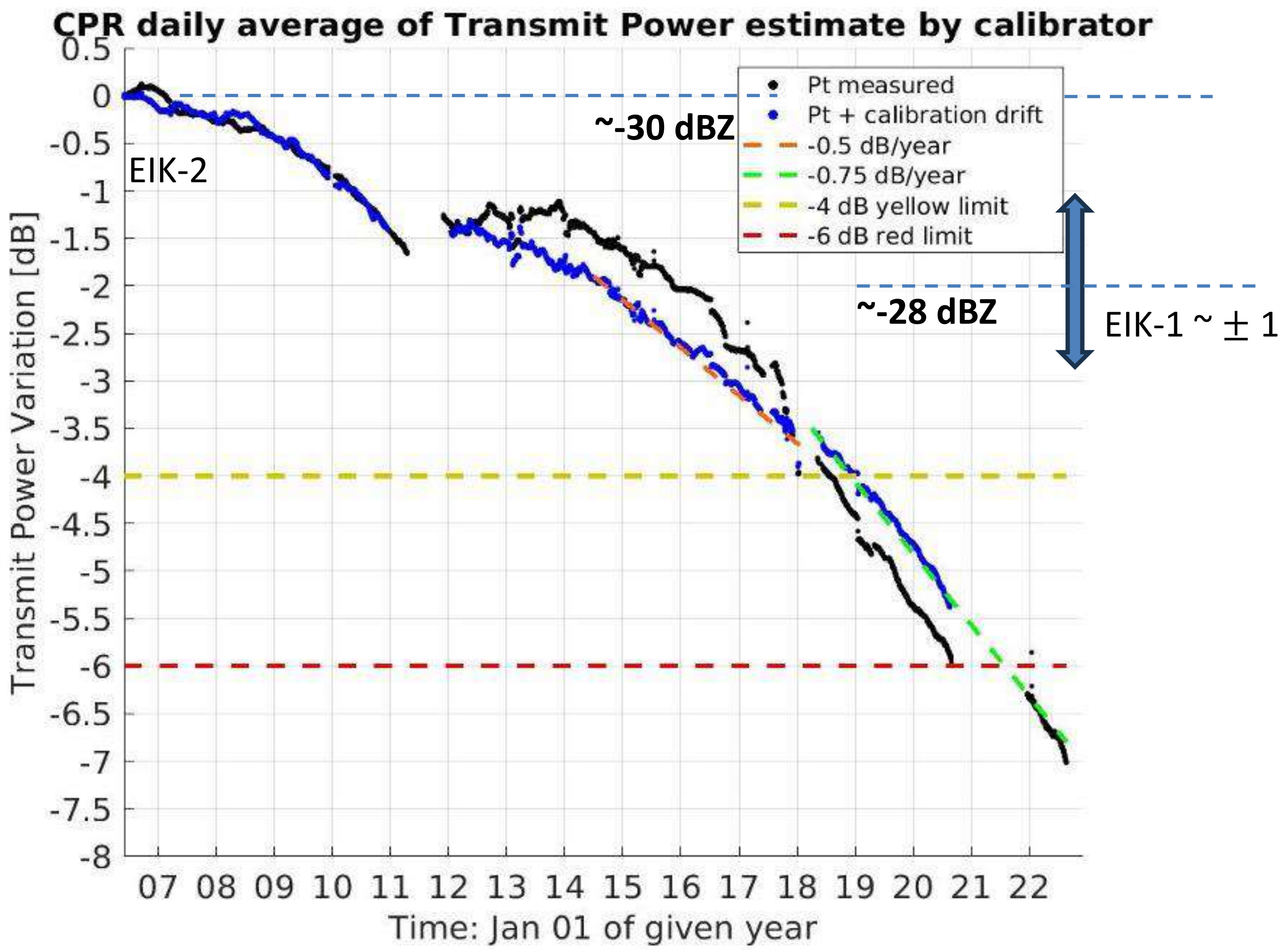




Haynes et al. 2022;2023

To the memory of Tobias

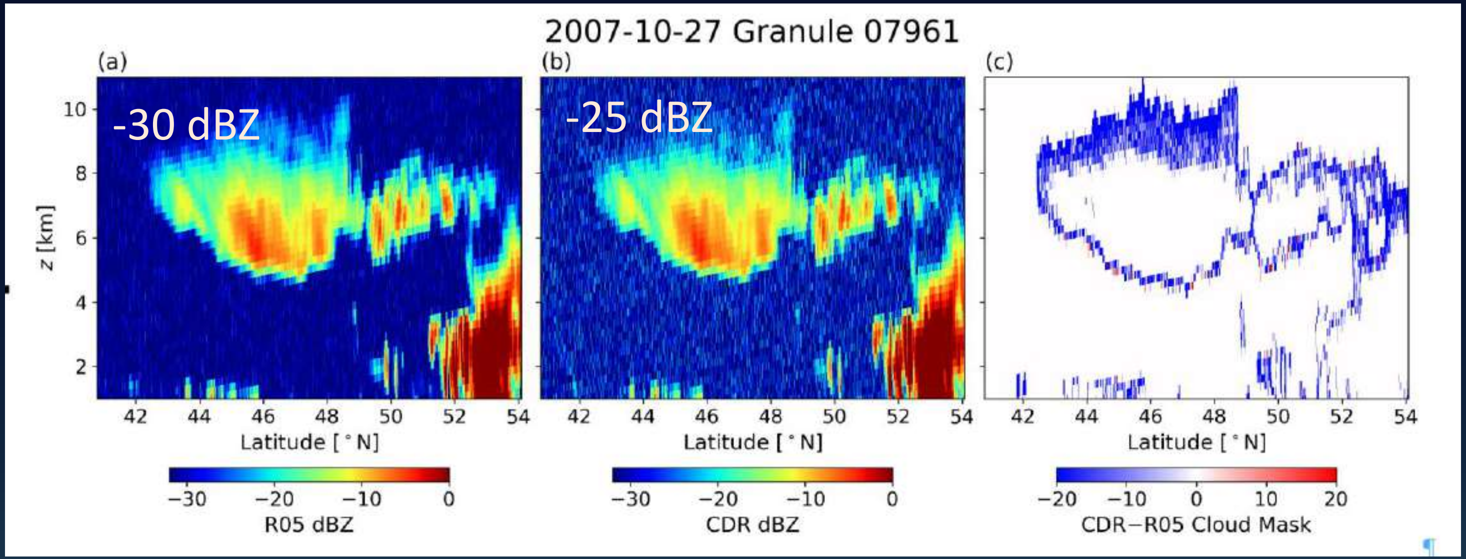
Viability

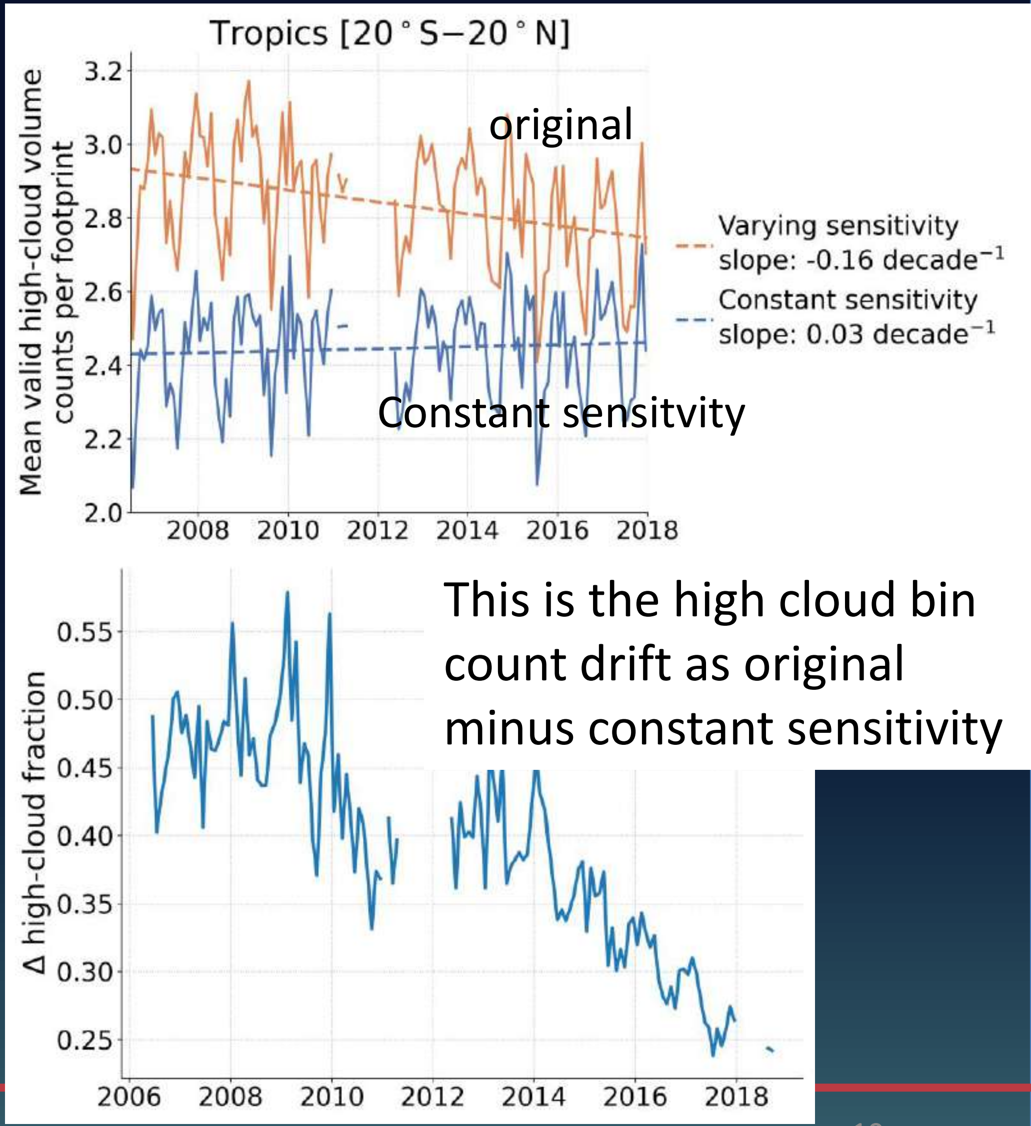


Instrument sensitivity changes over time and can be explicitly monitored

The instrument outlived the spacecraft!!!!

CloudSat constant sensitivity data product establishes a new climate data record and allows for new climate trend studies (see Mark Richardson's talk tomorrow)





EarthCARE now offers us an opportunity to continue the climate data record (CDR)

Summary Comments

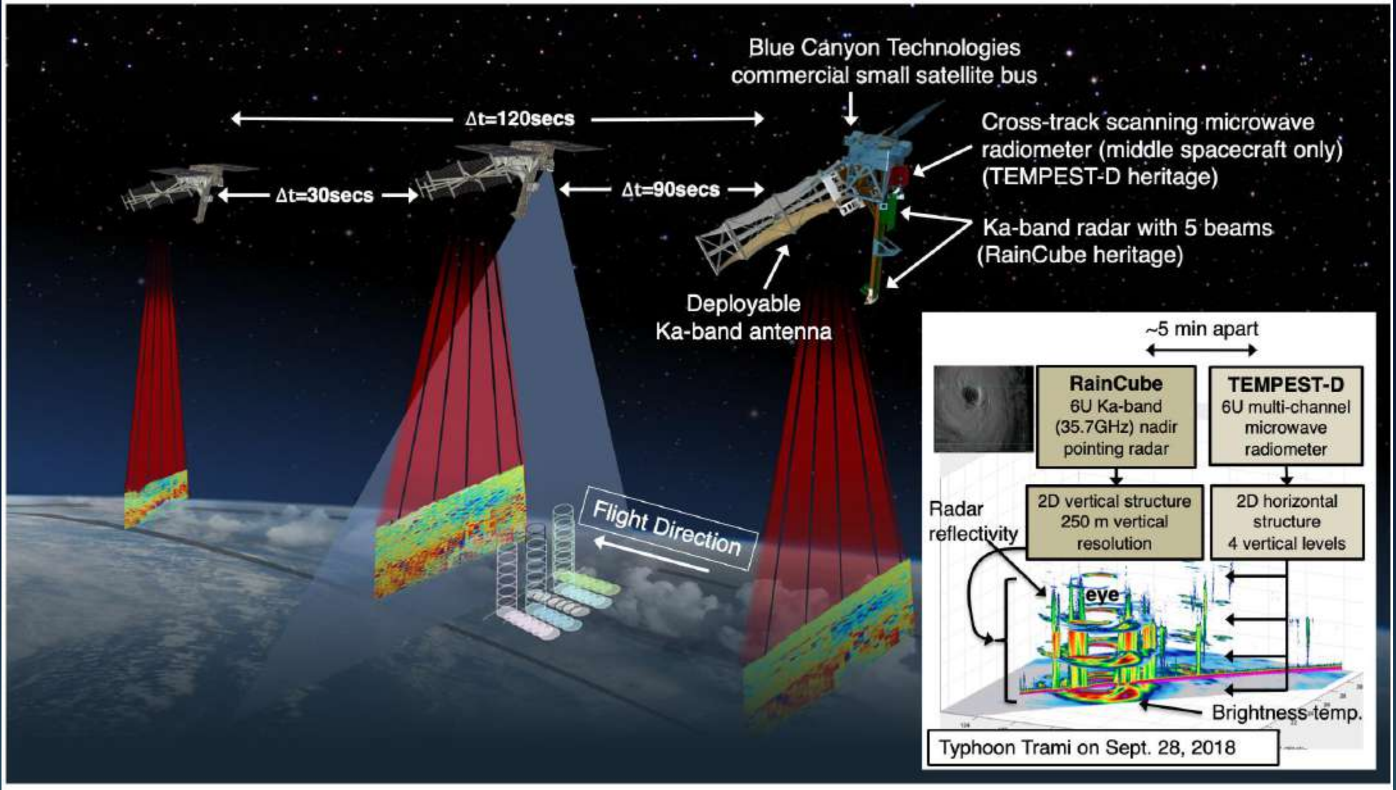
1) **TRMM, CloudSat, CALIPSO and now GPM:** What the last two decades revealed was the viability of active systems - just as ‘affordable’ and just as reliable as passive systems. We now have the beginning of a climate data record
2) **The A-Train -** offered a ‘new’ paradigm in EO & demonstrated the value of an ‘integrated’ observing approach

3) **CloudSat** in the A-Train demonstrated the viability of ‘formation flying’ as a way of creating a single virtual observatory from two separate spacecraft and payloads thus demonstrating the credibility of building something large from disaggregated parts.

Outlook- some what uncertain, perhaps bleak- after EarthCARE comes AOS but there is nothing in these comparable to the A-Train and really no coherent plans, despite AOS’s best efforts, to re-produce this golden age of EO.

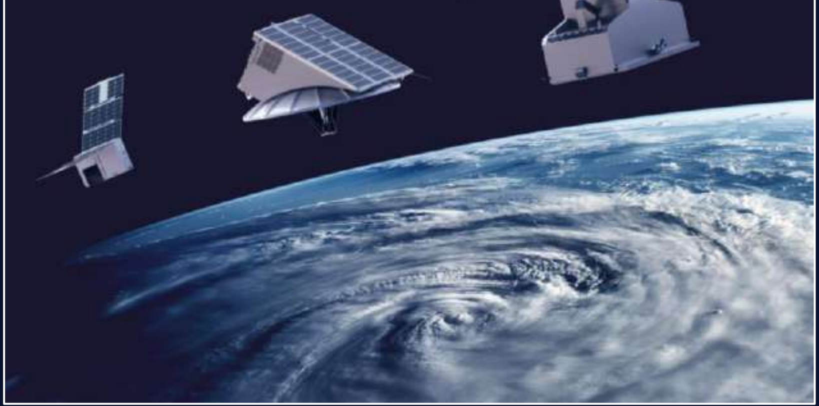
Constellations in the coming decade with active sensors (Ka rain radars)

INCUS Mission (3 small Ka radar sats),

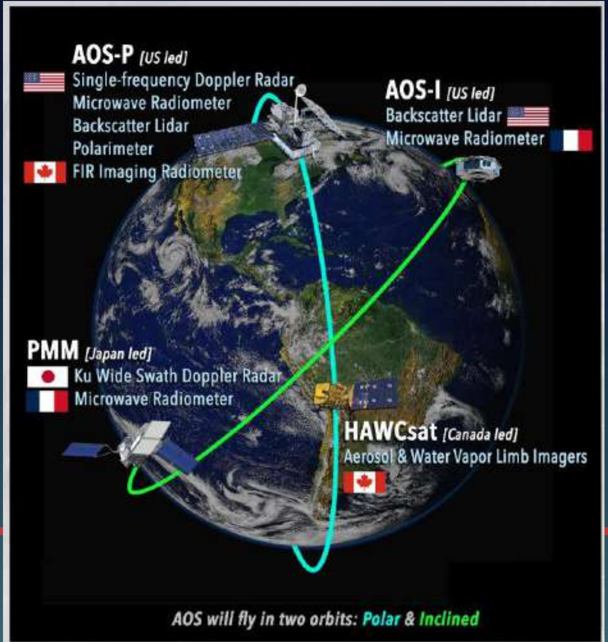


Tomorrow.io – commercial

Constellation of Ka-band radars



AOS (proposed)



EarthCARE in the decade of convection

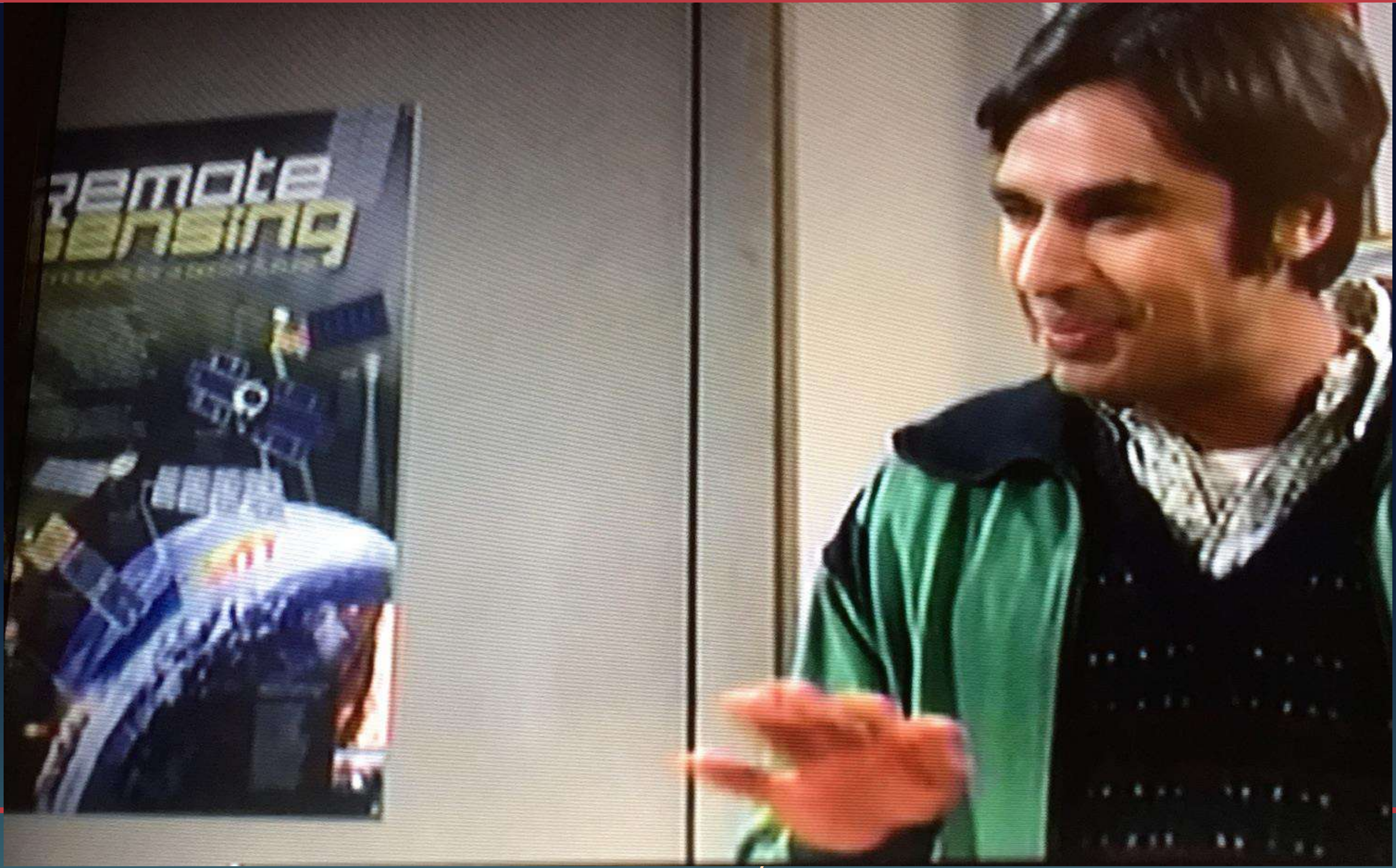
Graeme L Stephens

Prestented at EarthCARE meeting March, Shuzenuji

Why :

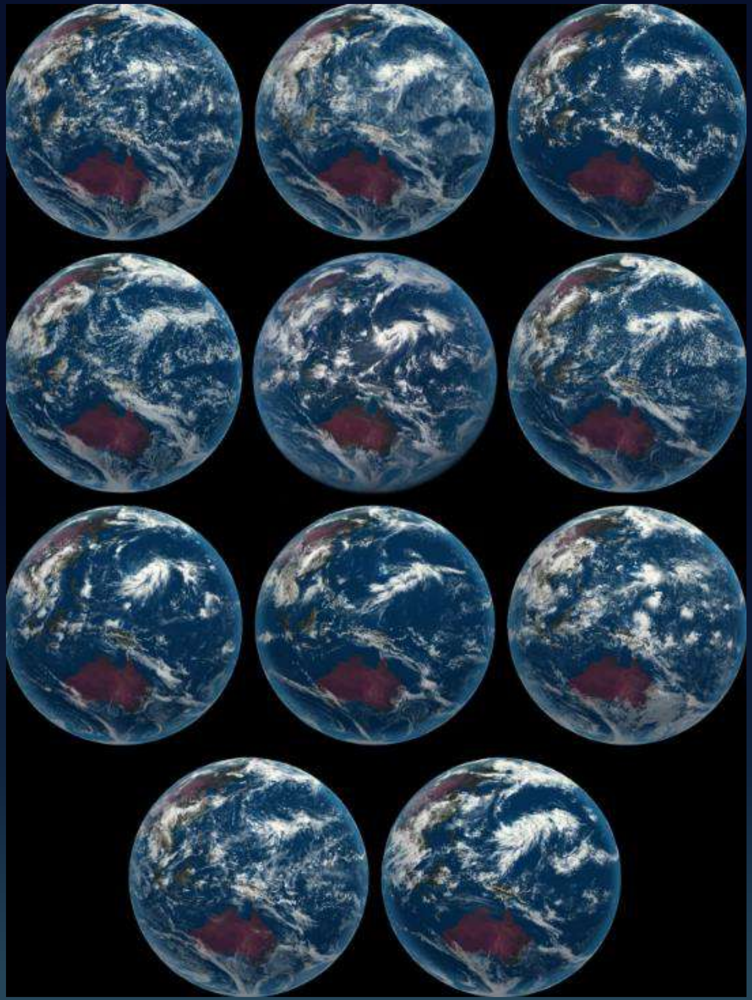
km scale models with ‘explicit’ convection is here (e.g Philip Stier’s talk)
There is much the W-band radar can tell us about convection including deep convection (series of papers by Luo, Takahashi etc)
The convergences of new emerging obs (EarthCARE, INCUS, AOS) with these model advances means we can contemplate now more apples to apples comparison that have not been possible in the CloudSat era.

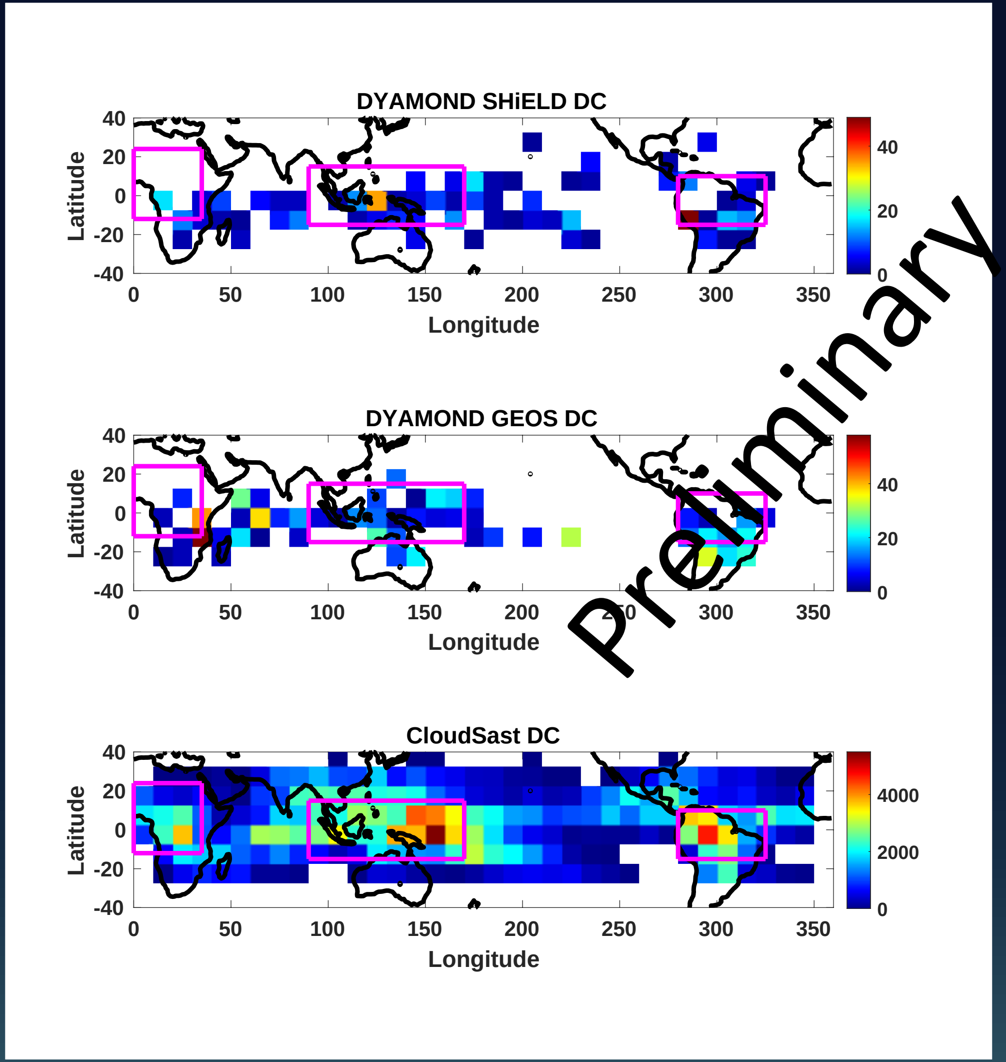
The A-Train arrived with a 'Big Bang (Theory)'

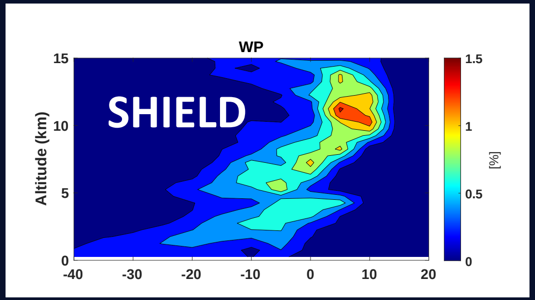


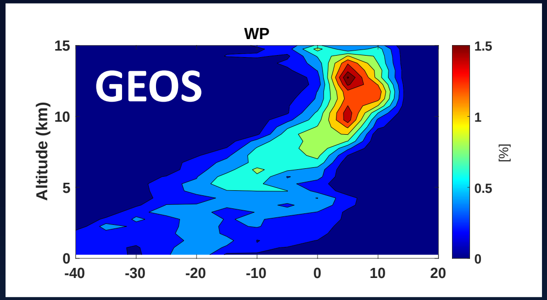
The era of km –scale model and assessment – deep convection

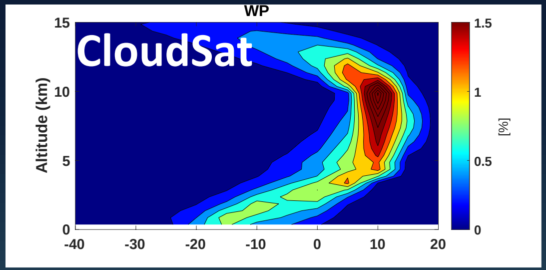
DYAMOND











A series of papers from Luo, Takahashi, Masunaga

To the memory of Tobias

Multi-year average
Cloud cover >50%
At 1X 1 degree

Multi-year average
Opaque Cloud cover
>20% at 1X 1 degree

Multi-year average
Precipitation
frequency >5%
At 1X 1 degree