Cloud-radiation interactions in the real atmosphere: A-Train, EarthCARE, and beyond

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Cloud-radiation interactions

A-Train (CloudSat, CALIPSO etc.) and EarthCARE

- Each carry a superb collection of satellite instruments to measure clouds and radiation.
- Only intermittently sample snapshots, disconnected from the context of temporal evolution.

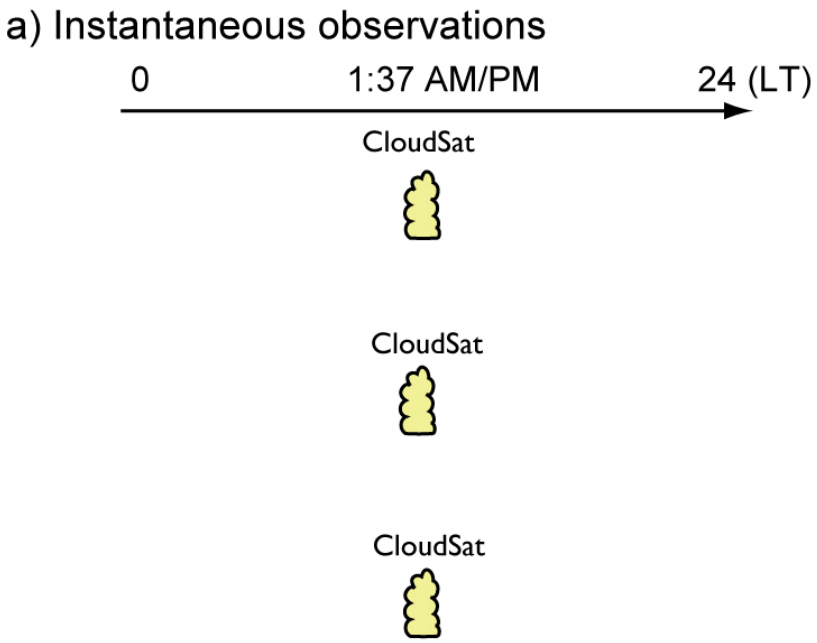
Composite analysis against a sun-async. satellite

- Allows to accumulate sporadic polar-orbiting satellite measurements into a “continuous” time series.

Masunaga (2012, 2013, …)

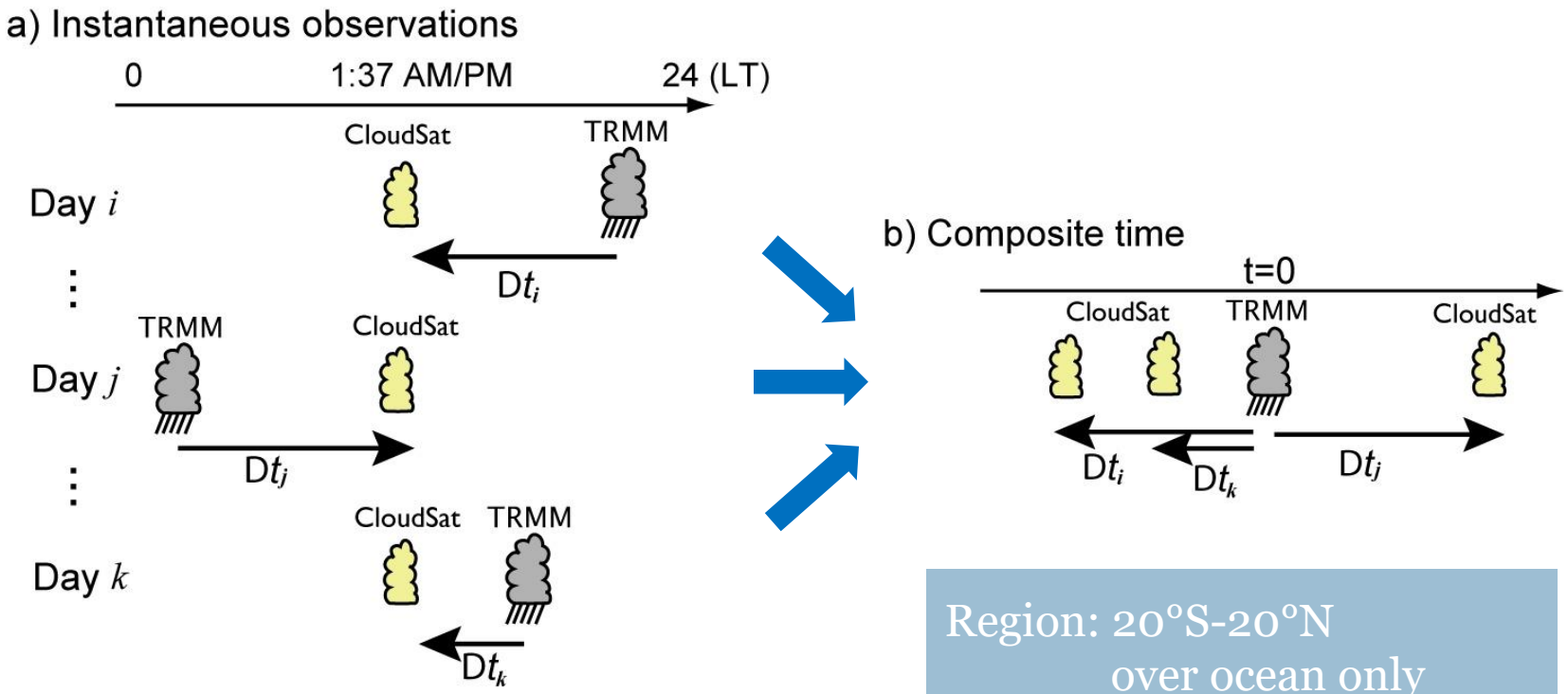
Making a composite time series

CloudSat



Making a composite time series

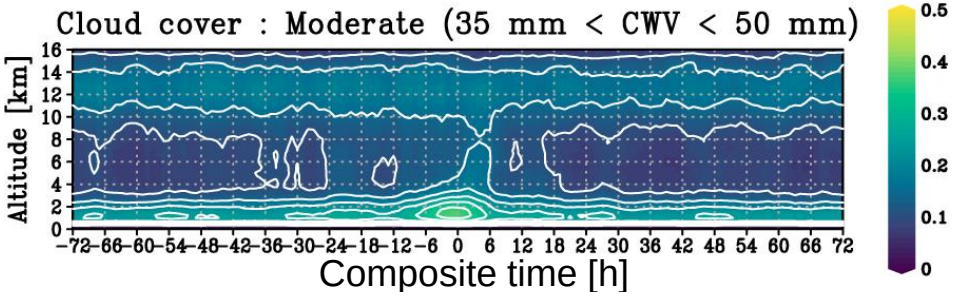
CloudSat is sorted in time against TRMM PR.



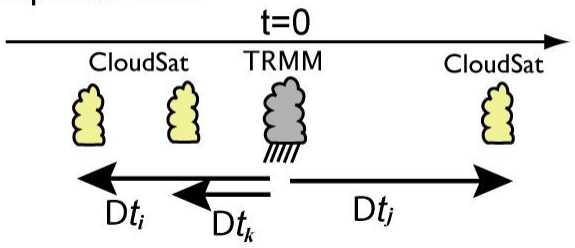
Region: 20°S-20°N
over ocean only
Period: Jul 2006 – Dec 2009

Composite time series

Evolution of CloudSat/CALIPSO cloud fraction



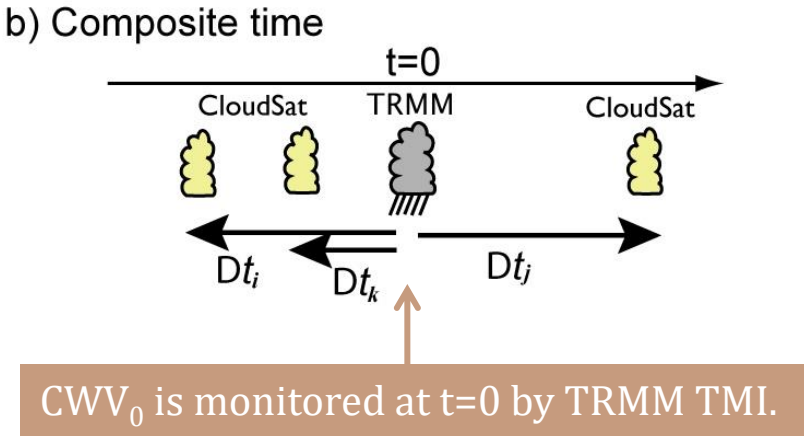
b) Composite time



Cloud cover defined over R=100 km domain

Separation by background moisture

Breakdown by column water vapor (CWV) at t=0

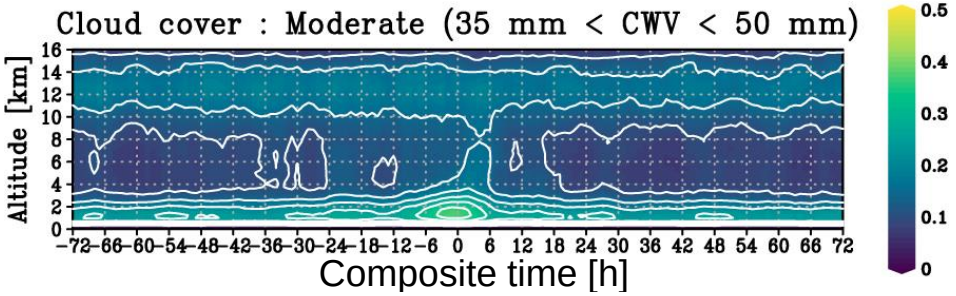


Three composite classes

1) Dry: $CWV_0 < 35$ mm
2) Moderate: $35 < CWV_0 < 50$ mm
3) Moist: $CWV_0 > 50$ mm

Composite time series

Evolution of CloudSat/CALIPSO cloud fraction



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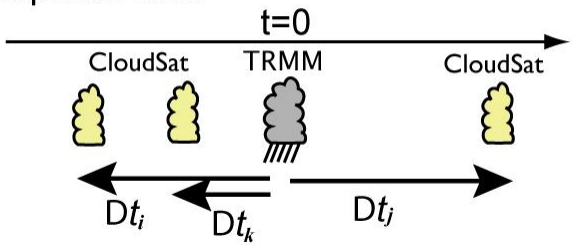
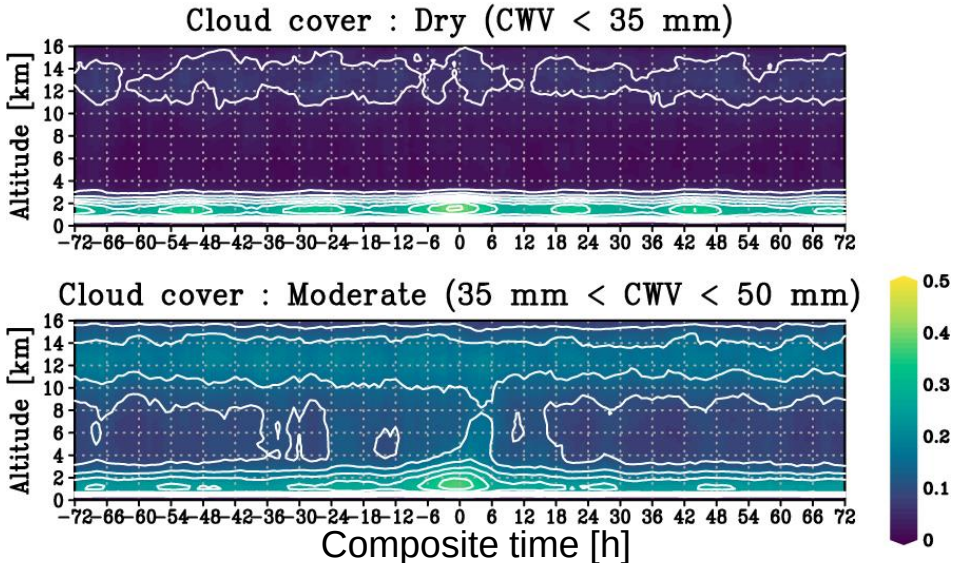


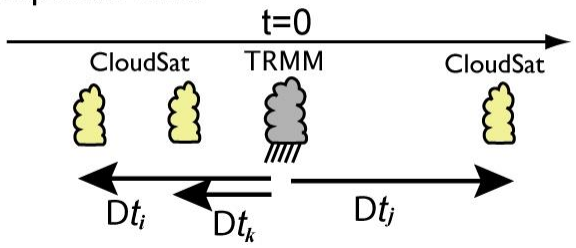
Cloud cover defined over R=100 km domain

Composite time series

Evolution of CloudSat/CALIPSO cloud fraction



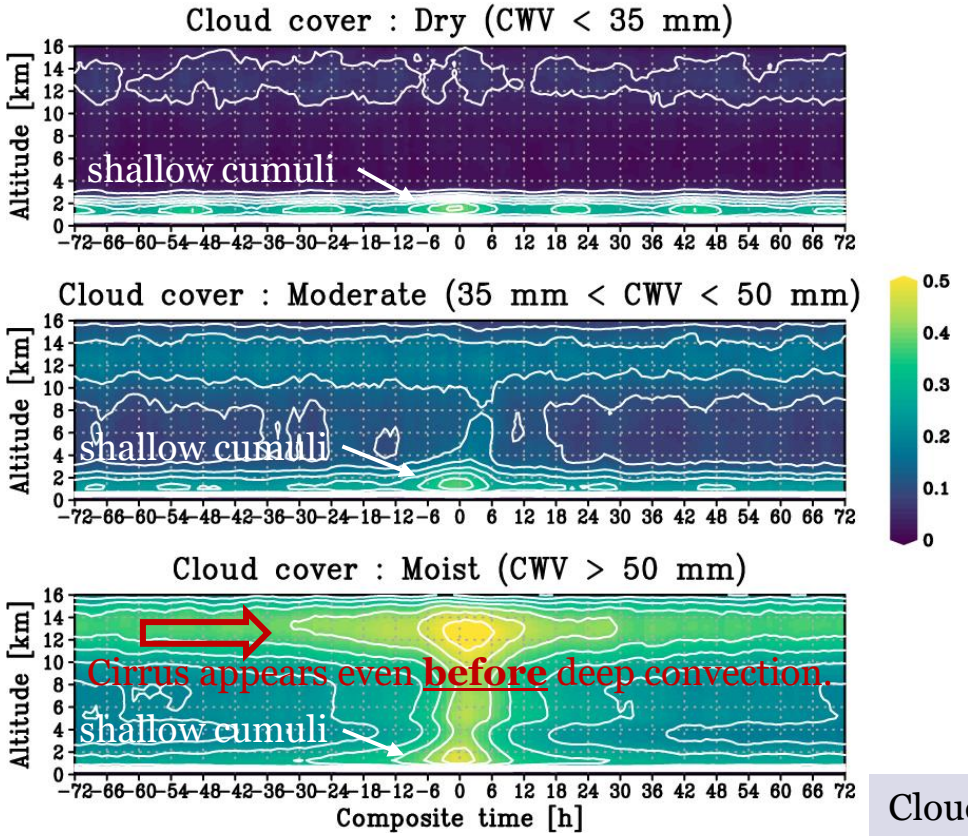
b) Composite time



Cloud cover defined over R=100 km domain

Composite time series

Evolution of CloudSat/CALIPSO cloud fraction



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Cloud cover defined over R=100 km domain

An enhanced Q_R could promote convection.

Steady-state moist static energy (MSE) balance

vertical MSE advection — surface turbulent flux — column radiative heating

$$D_t\langle h\rangle = -\langle \omega \partial_p h\rangle + F_T + \langle Q_R\rangle \approx 0$$

Feedback?

(e.g., Raymond and Zeng, QJRMS, 2000)

MSE budget thinking revisited

Steady-state moist static energy (MSE) balance

vertical MSE advection; surface turbulent flux; column radiative heating

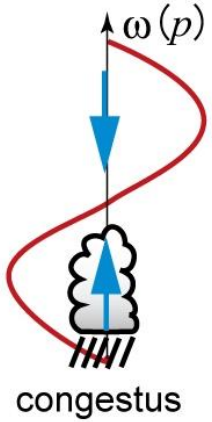
$$D_t\langle h\rangle = -\langle \omega \partial_p h\rangle + F_T + \langle Q_R\rangle \approx 0$$

> 0 in the Tropics.

$-\langle \omega \partial_p h\rangle > 0$

↓

Steady balance does not hold.



2nd baroclinic or "congestus" mode

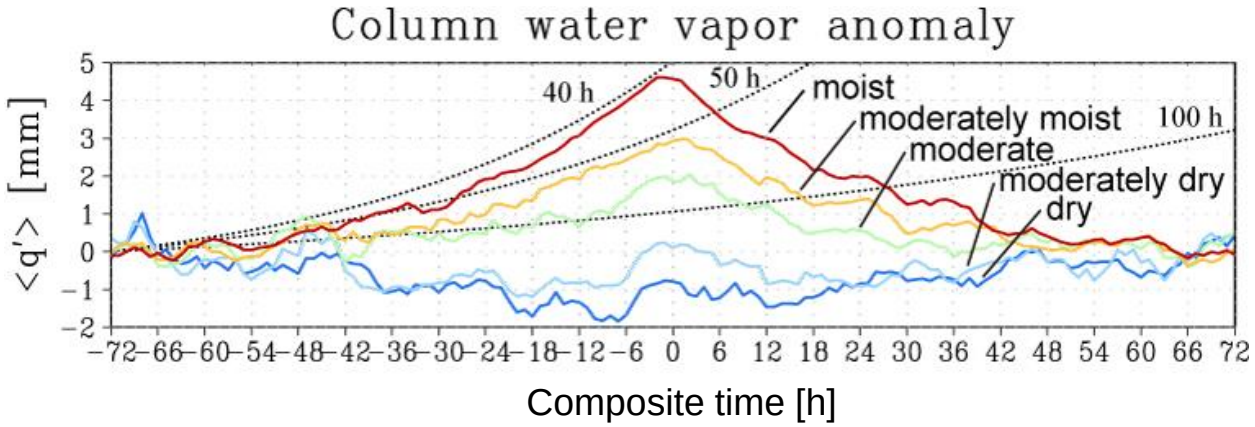
$-\langle \omega \partial_p h\rangle < 0$

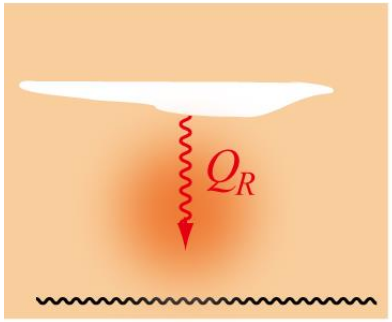
↓

Steady balance

1st baroclinic or "deep" mode

Cirrus radiatively triggers deep convection





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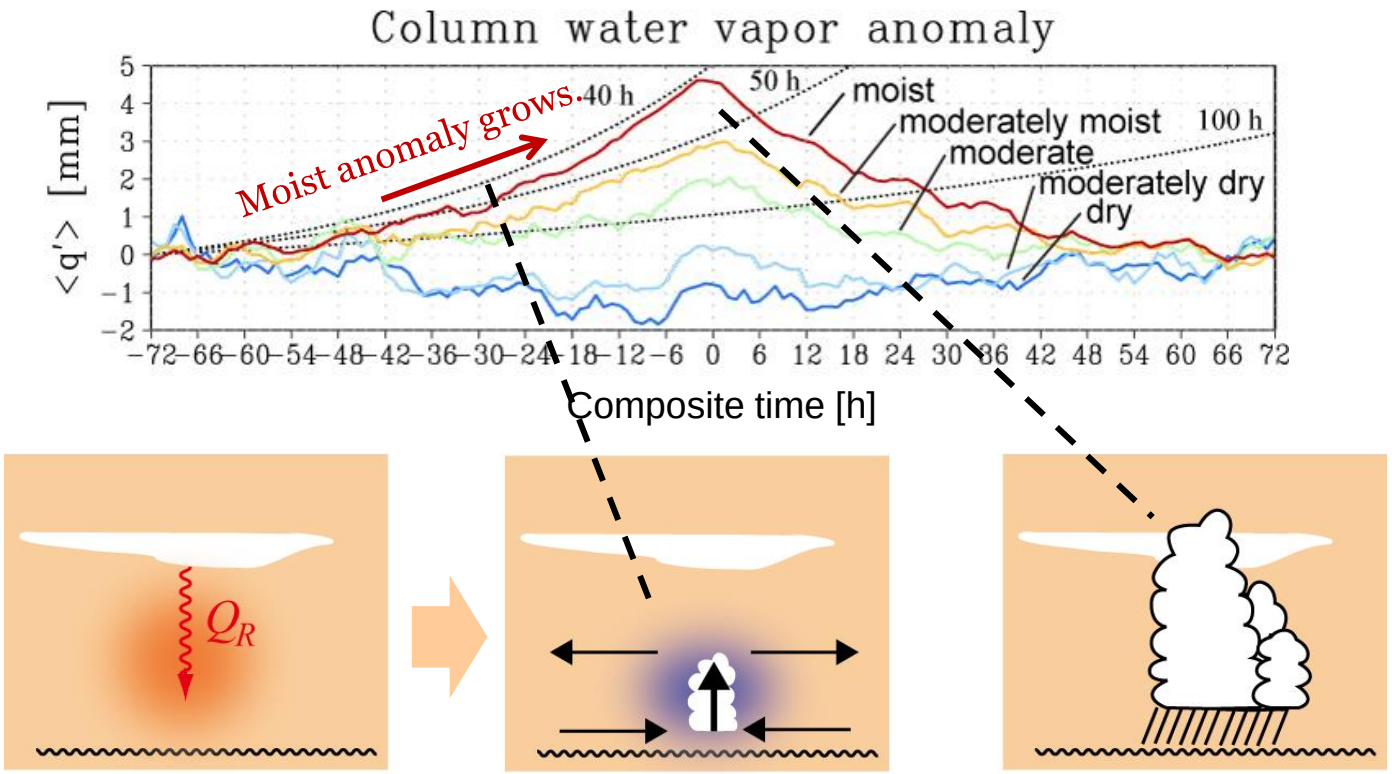
Cirrus radiatively triggers deep convection



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Key science questions

Hourly/daily evolution of convective clouds

- Shallow convection can grow on its own (GMS<0), while deep convection is destined to die out (GMS>0).
  - Models may or may not well reproduce this.
- Cirrus radiative effect may help shallow convection grow into deep convection.
- More work is needed to grasp a more complete picture of the cloud-radiation interactions governing tropical convection
  - Convective self-aggregation, iris effect, etc.

Satellite pairs for the composite time series

A-Train era

- CloudSat/CALIPSO/CERES versus TRMM

EarthCARE era (2023-)

- CPR/ATLID/BBR versus GPM

AOS era (2028/30-)

- W/Ka Doppler with HSRL etc. versus Ku Doppler