NAGOYA UNIVERSITY

ISEE Institute for Space-Earth Environmental Research

Roles of Convection in the Maintenance of Tropical Margins

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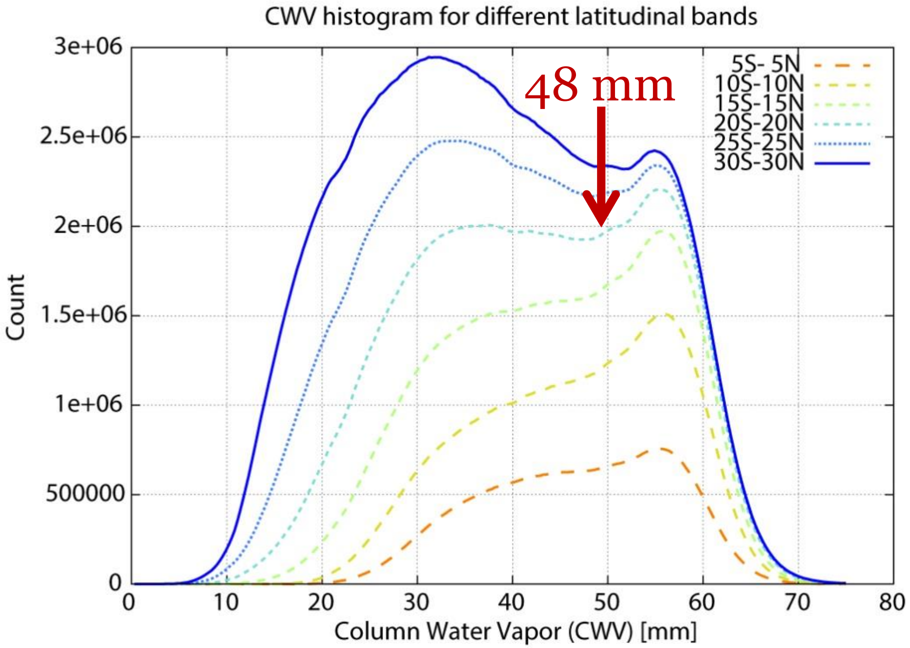
in collaboration with Brian Mapes (University of Miami)

Bimodality of tropical water vapor

The tropical water vapor histogram has double peaks on each side of a 48-mm minimum.

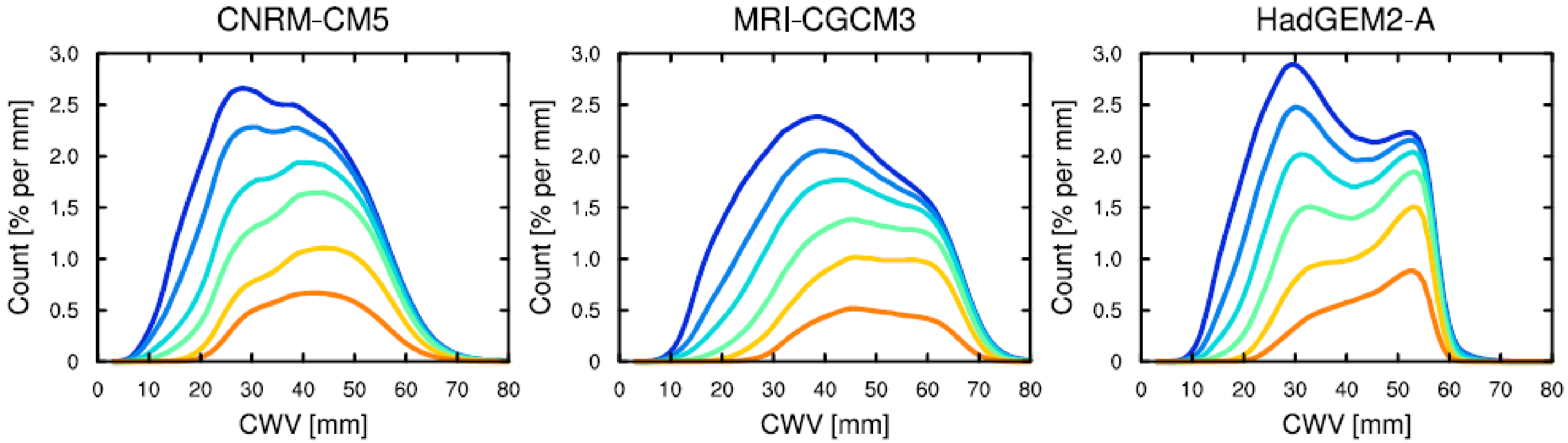


Mapes et al., GRL, 2018

Bimodality of tropical water vapor

The tropical water vapor histogram has double peaks on each side of a 48-mm minimum.

But climate models do not always reproduce it.

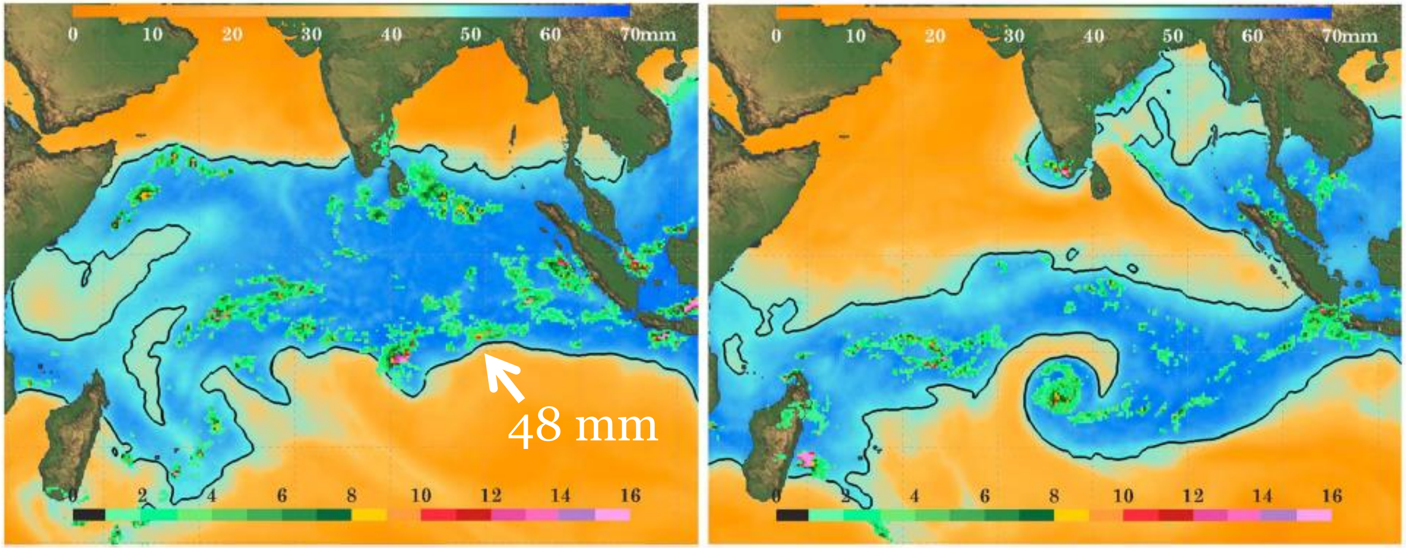


Mapes et al., GRL, 2018

Bimodality of tropical water vapor

The tropical water vapor histogram has double peaks on each side of a 48-mm minimum.

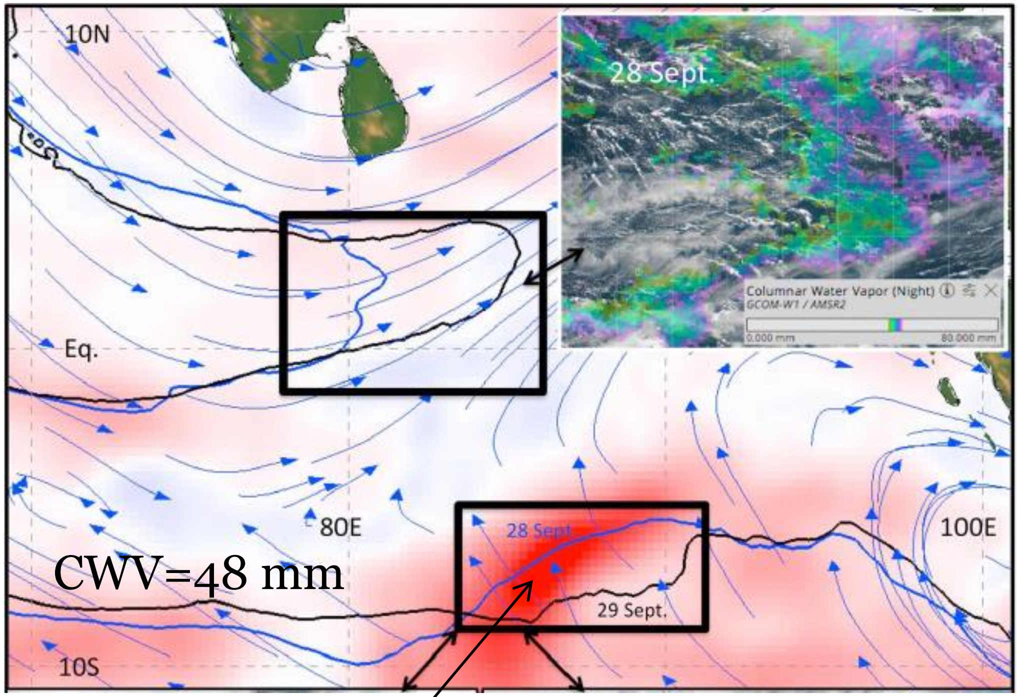
- Separating the *moist deep tropics* and *dry subtropics*.



Mapes et al., GRL, 2018

Sharp tropical margins

A lower-tropospheric air mass often moistens rapidly as it crosses the 48-mm contour (or “tropical margins”).



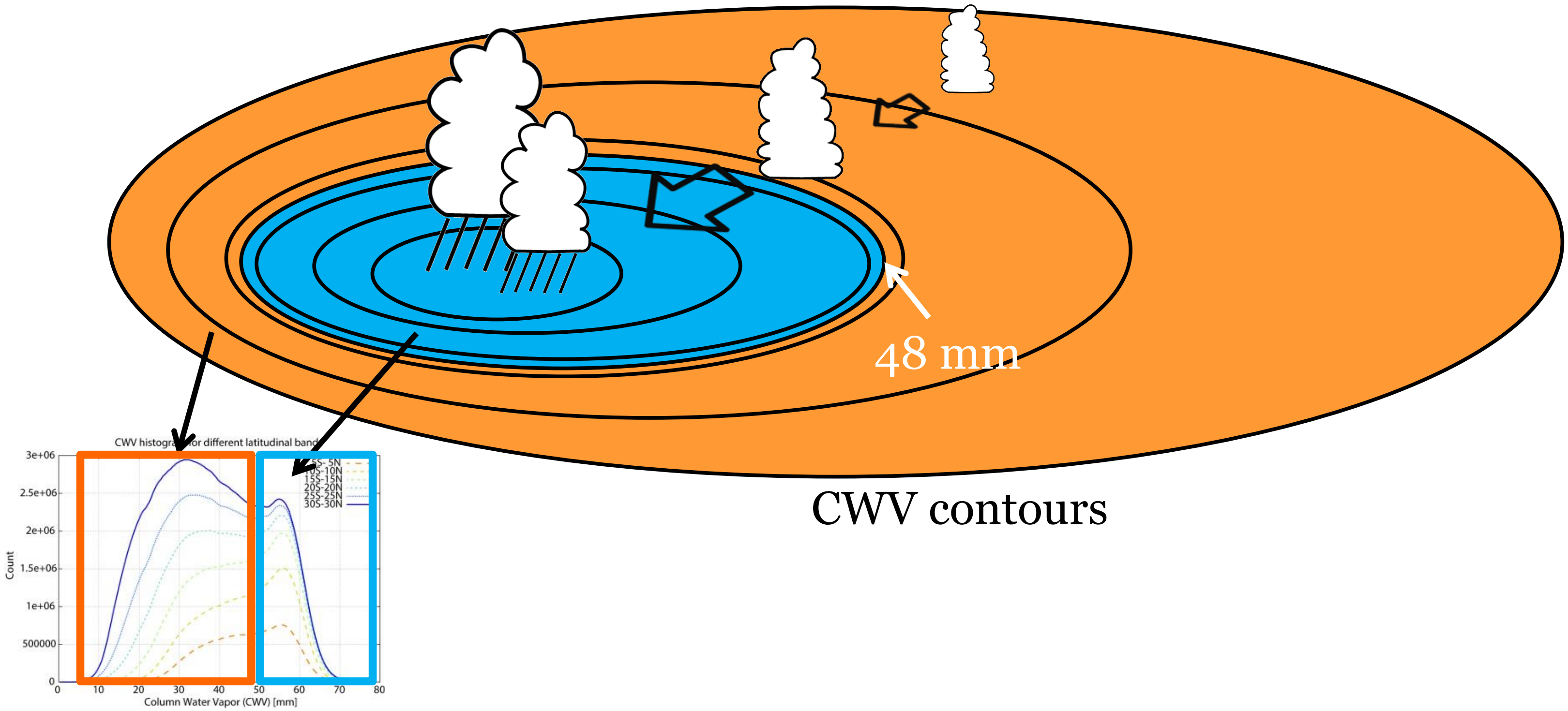
CWV=48 mm

Red shade:
Lagrangian *q* tendency

Mapes et al., GRL, 2018

Sharp tropical margins

A lower-tropospheric air mass often moistens rapidly as it crosses the 48-mm contour (or tropical margins).



Sharp tropical margins

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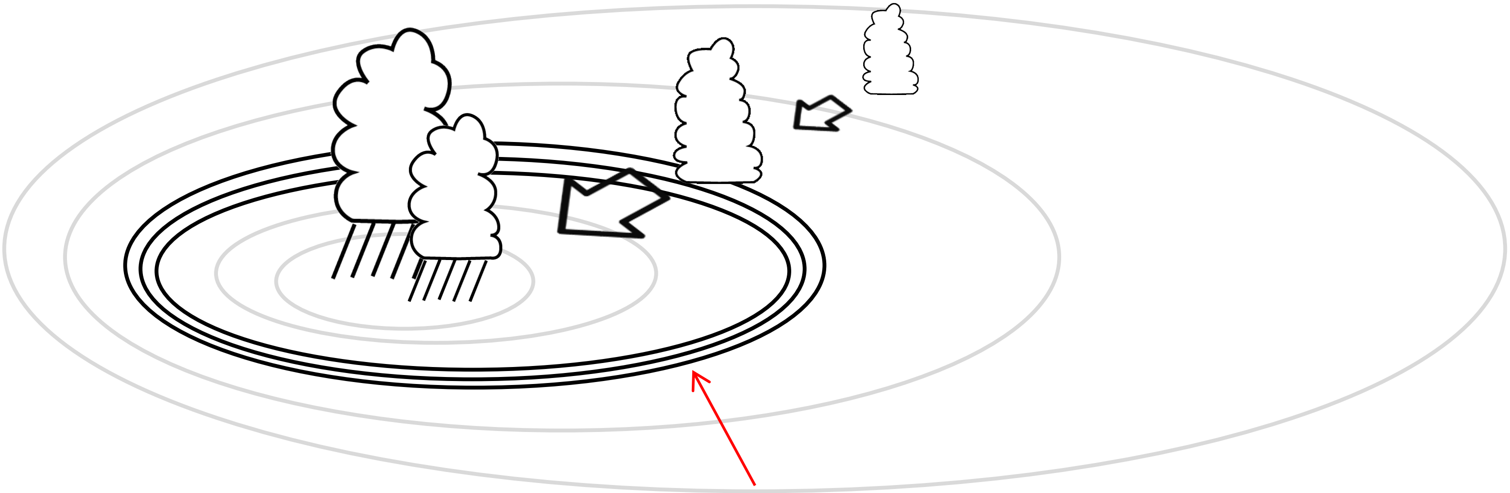


Q. What brings about the sharp tropical margins?

Data

A-Train satellite measurements (except for horizontal wind) are analyzed for cloud and atmospheric parameters.

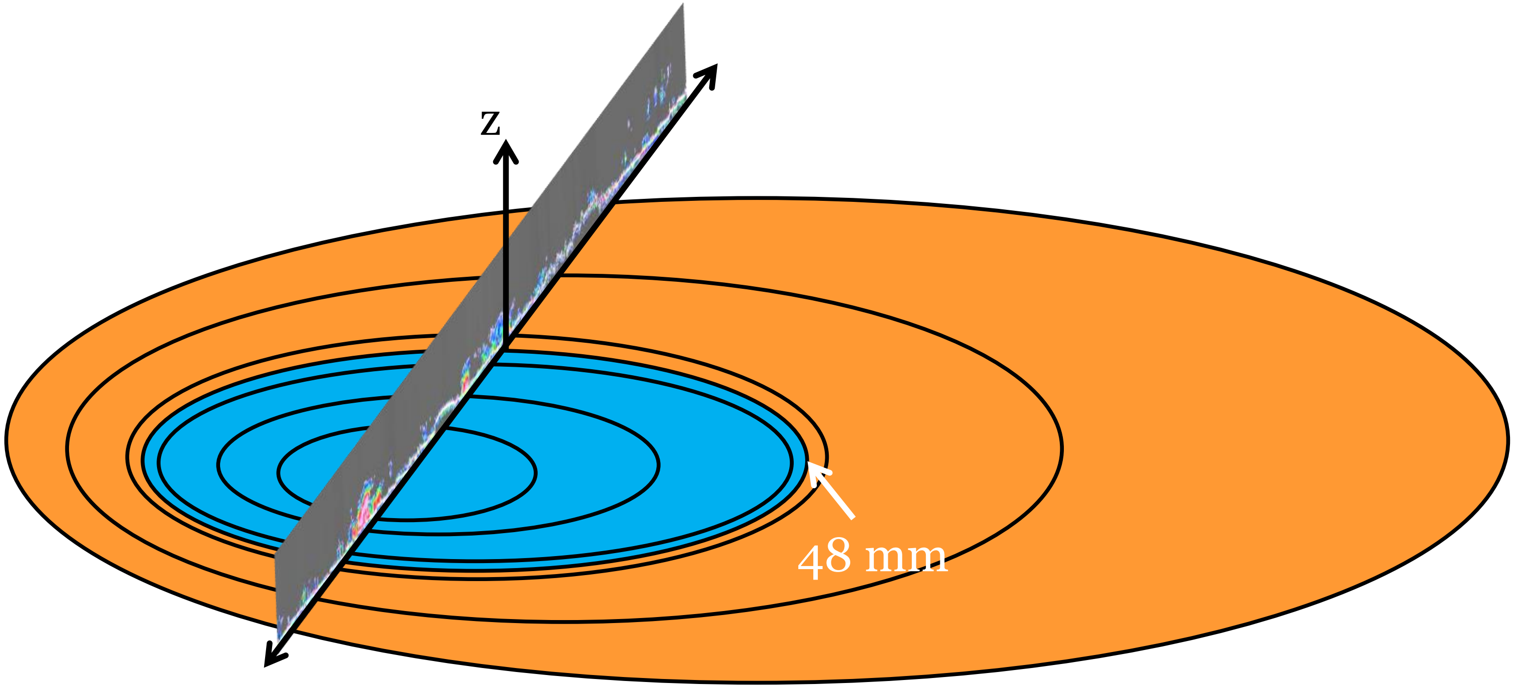
- Global tropical oceans (25°S-25°N) for July 2006 – December 2009.

Parameters	**Instrument**	**Data Product**
Cloud cover	CloudSat-CALIPSO	2B-GEOPROF-LIDAR R04
Q_R	CloudSat-CALIPSO	2B-FLXHR-LIDAR R04
CWV, P, u_{10}, and SST	AMSR-E	RSS daily v7
E	AMSR-E	RSS + bulk equation (1)
$q_v(p)$ and $T(p)$	AIRS	AIRX2RET v6
$v^*(p)$ (2)	-	ERA Interim (3)

(1) Surface q_v is derived from CWV and SST (Masunaga and L'Ecuyer, JC, 2010)
(2) v^* is the horizontal wind projected onto the CloudSat-CALIPSO track.
(3) Interpolated in time to A-Train overpasses (1:30 am/pm)

Composite method for the tropical margins

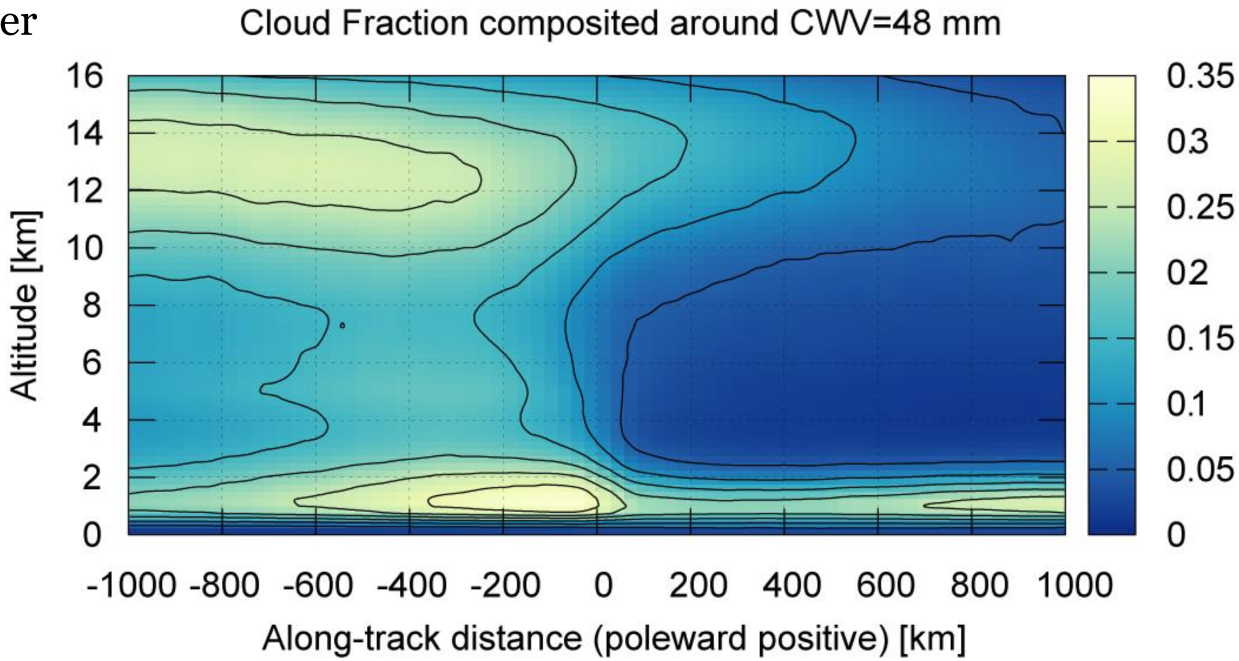
All CloudSat-CALIPSO tracks are composited in such a way as they are centered on the most poleward 48-mm value.



Composite cloud cover around CWV=48 mm

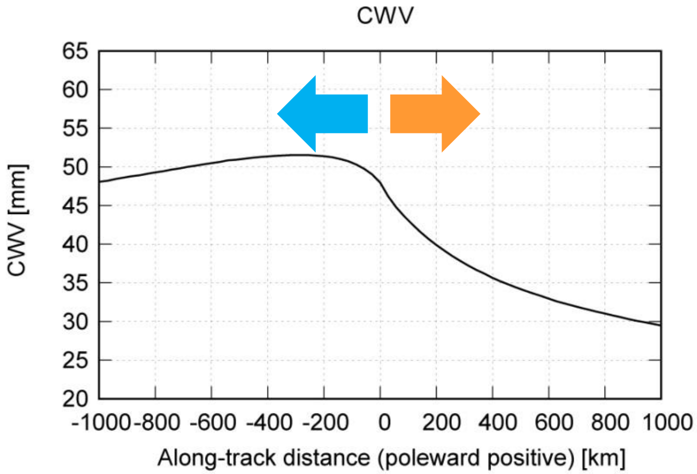
All CloudSat-CALIPSO tracks are composited in such a way as they are centered on the most poleward 48-mm value.

Cloud cover

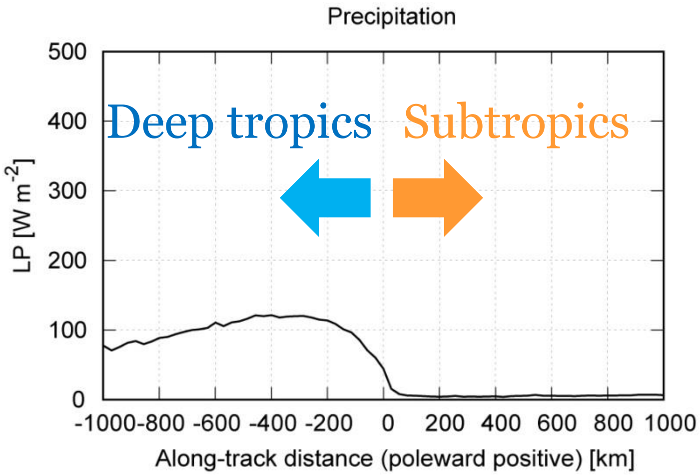


Composite CWV and Precipitation

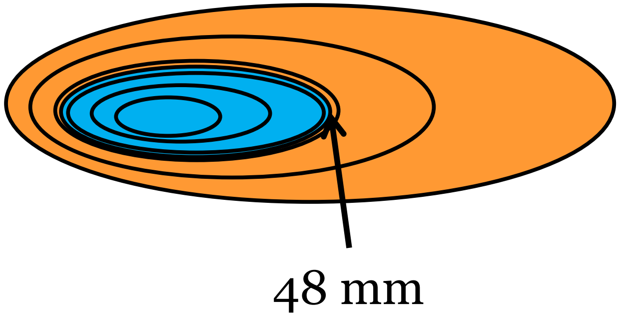
CWV



LP



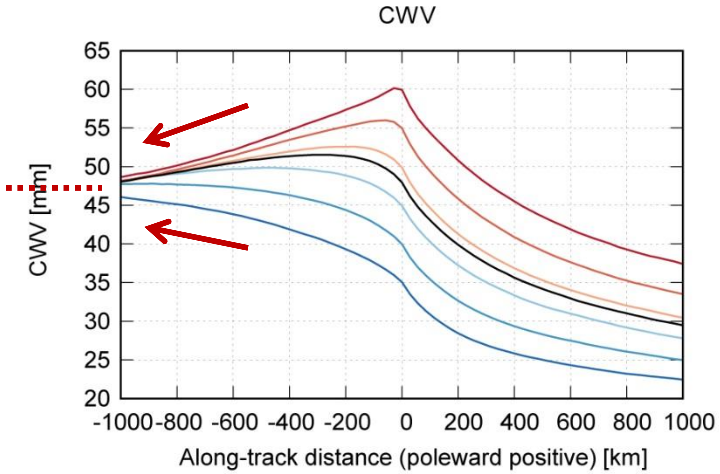
Deep tropics Subtropics



Composite CWV and Precipitation

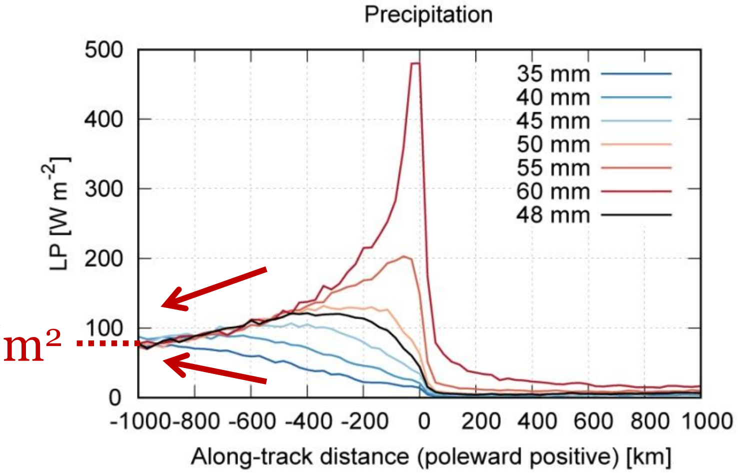
48 mm

CWV

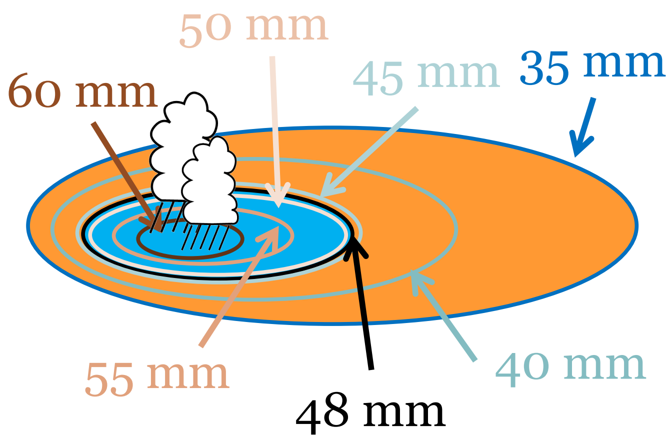


LP

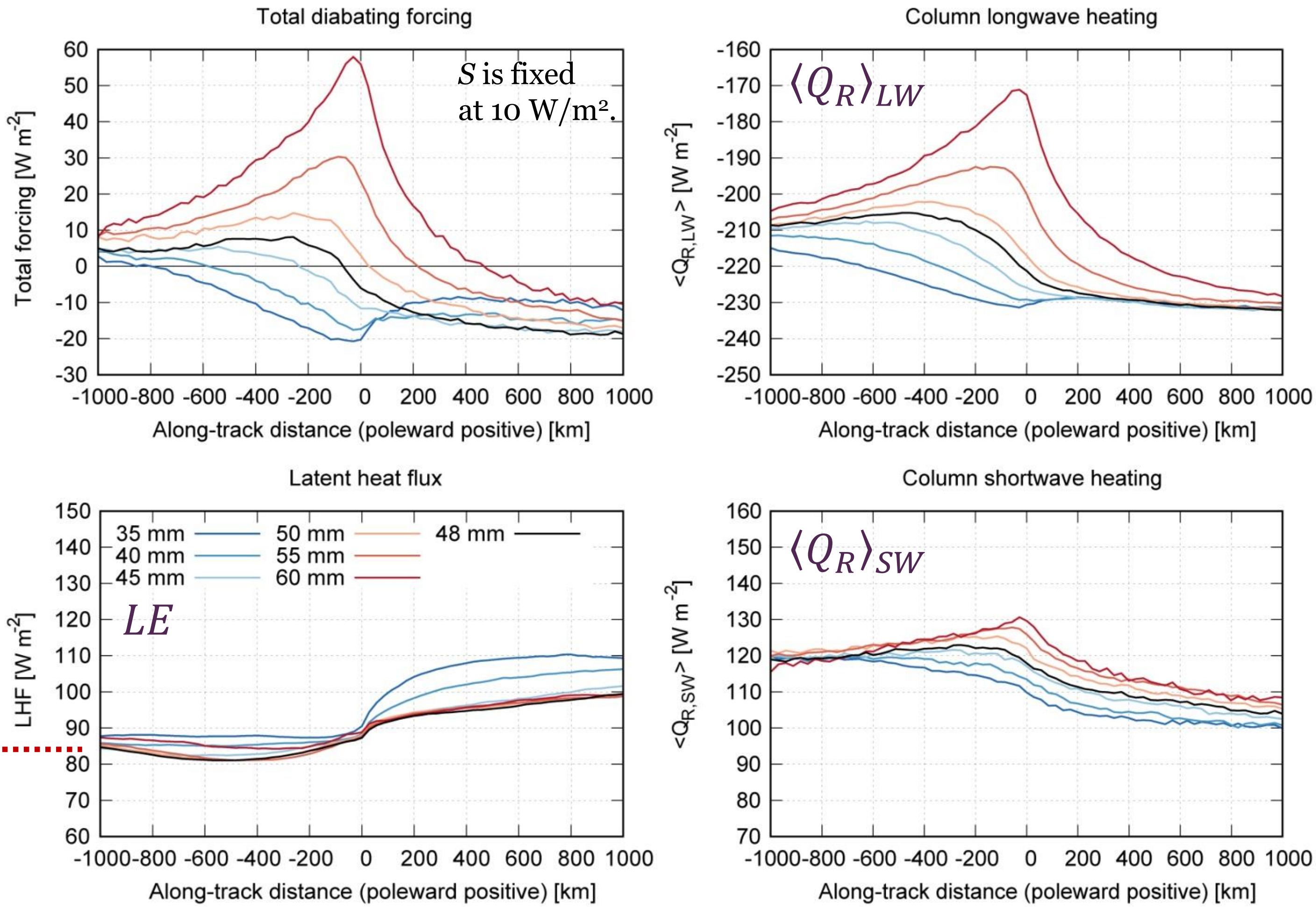
85 W/m²



For comparison, a set of other composites are tested with different threshold values.



Diabatic forcing breakdown



S is fixed at 10 W/m^2.

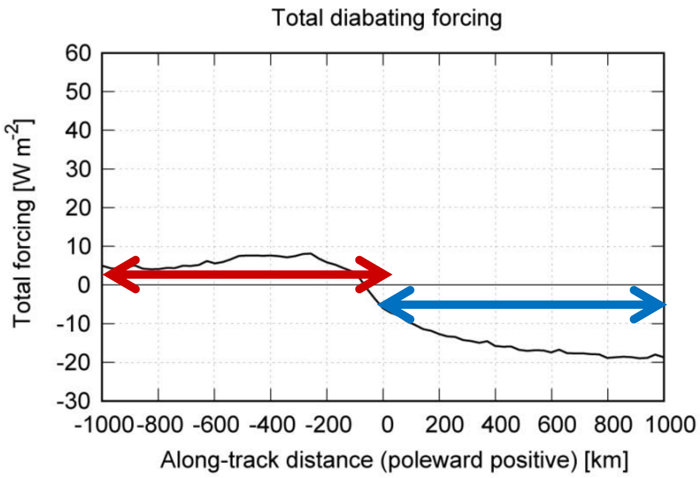
$\langle Q_R \rangle_{LW}$

LE

$\langle Q_R \rangle_{SW}$

85 W/m^2

Diabatic forcing breakdown



$\boldsymbol{LE + S + \langle Q_R \rangle > 0}$ on the tropical side of the 48-mm margin.

$\boldsymbol{LE + S + \langle Q_R \rangle < 0}$ on the subtropical side of the 48-mm margin.

Climatological energy balance, $\boldsymbol{LE + S + \langle Q_R \rangle \sim 0}$, is achieved when CWV ~ 48 mm (=CWV$_{eq}$) over tropical oceans.

Moisture/MSE budget analysis

$$\cancel{\partial_t\langle q\rangle} = -\langle v\partial_y q\rangle - \underline{\langle\omega\partial_p q\rangle} + E - P$$

$$\cancel{\partial_t\langle h\rangle} = -\langle v\partial_y h\rangle - \underline{\langle\omega\partial_p h\rangle} + LE + S + \langle Q_R\rangle$$

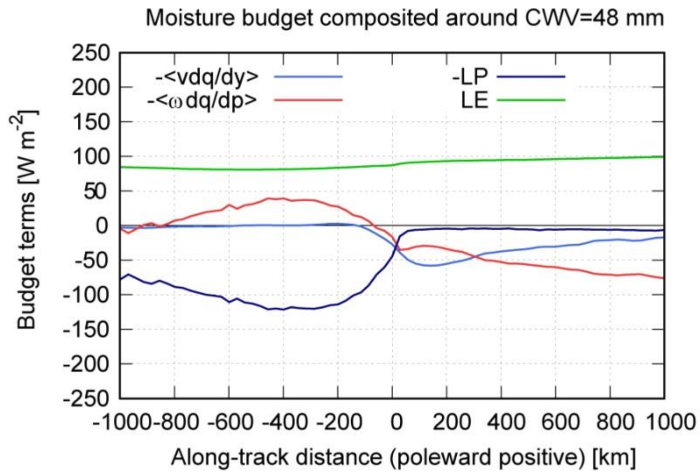
With the hypothesis that the composite plots represent a steady meridional flow ($\rightarrow D_t\langle q\rangle = \langle v\partial_y q\rangle$).

Vertical advection is estimated as the residual.

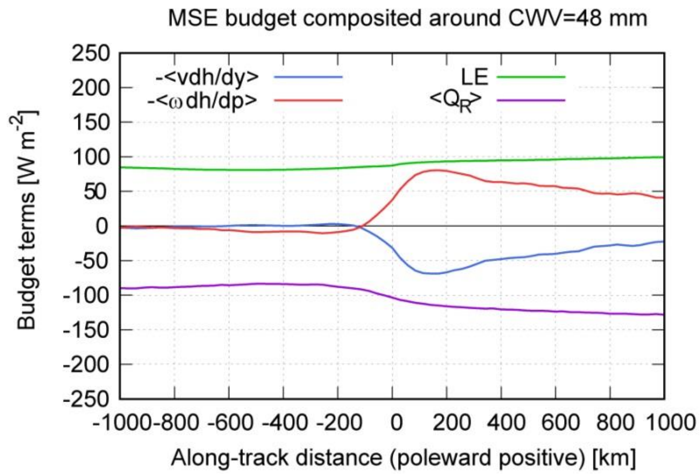
Since ω from reanalysis may not be reliable enough, the vertical advection is diagnosed as the residual (rather than directly from ω) so the budget closure is guaranteed.

Moisture/MSE budget analysis

Moisture budget parameters

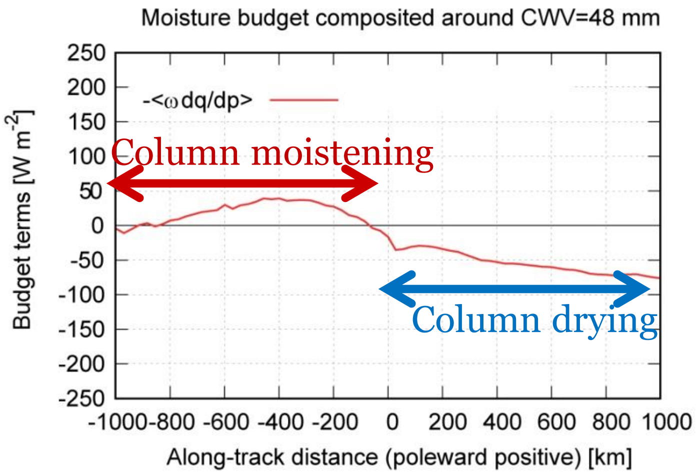

Moisture budget composited around CWV=48 mm

MSE budget parameters


MSE budget composited around CWV=48 mm

Moisture/MSE budget analysis

Vertical *q* advection

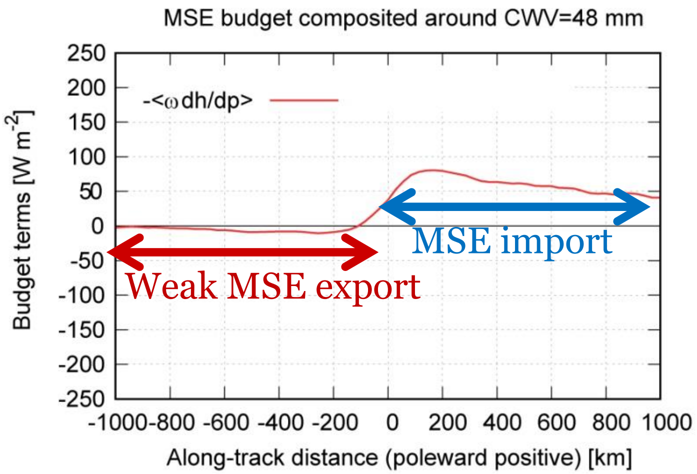


Moisture budget composited around CWV=48 mm

Column moistening

Column drying

Vertical *h* advection



MSE budget composited around CWV=48 mm

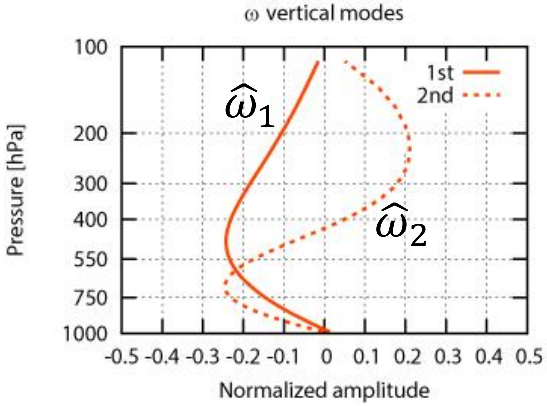
MSE import

Weak MSE export

Vertical mode decomposition: Method

Mode decomposition into 1st and 2nd modes

$$\omega = \Omega_1 \widehat{\omega}_1 + \Omega_2 \widehat{\omega}_2$$



The coefficients α_1 and α_2 are determined so they satisfy the vertical advection of q and $s(= h - Lq)$.

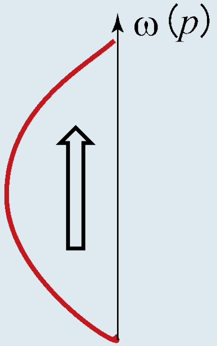
(a simplified version of Masunaga and L'Ecuyer, JAS, 2014)

$$\langle \omega \partial_p q \rangle = \Omega_1 \langle \widehat{\omega}_1 \partial_p q \rangle + \Omega_2 \langle \widehat{\omega}_2 \partial_p q \rangle$$
$$\langle \omega \partial_p s \rangle = \Omega_1 \langle \widehat{\omega}_1 \partial_p s \rangle + \Omega_2 \langle \widehat{\omega}_2 \partial_p s \rangle$$

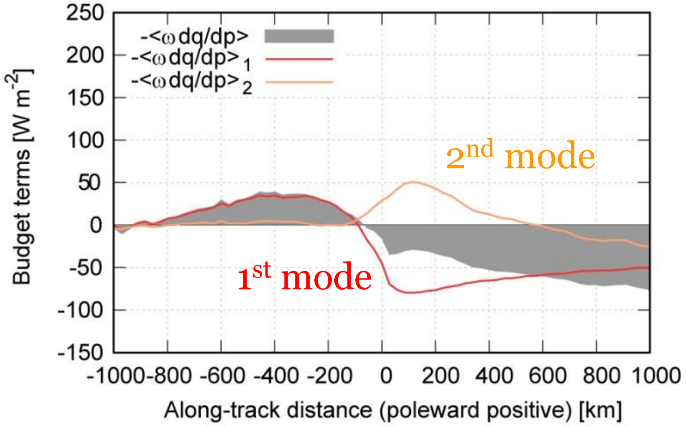
→ Ω_1 and Ω_2

Vertical mode decomposition: VADV

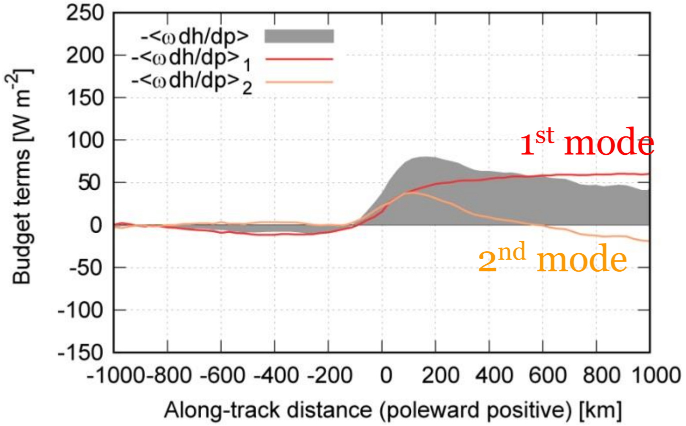
Deep tropics



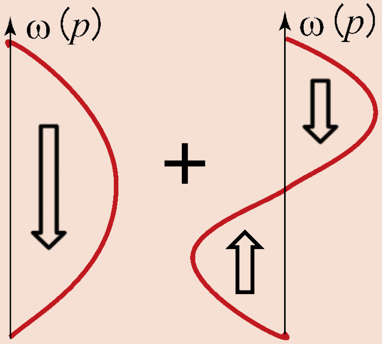
<ω dq/dp> decomposition composited around CWV=48 mm



<ω dh/dp> decomposition composited around CWV=48 mm

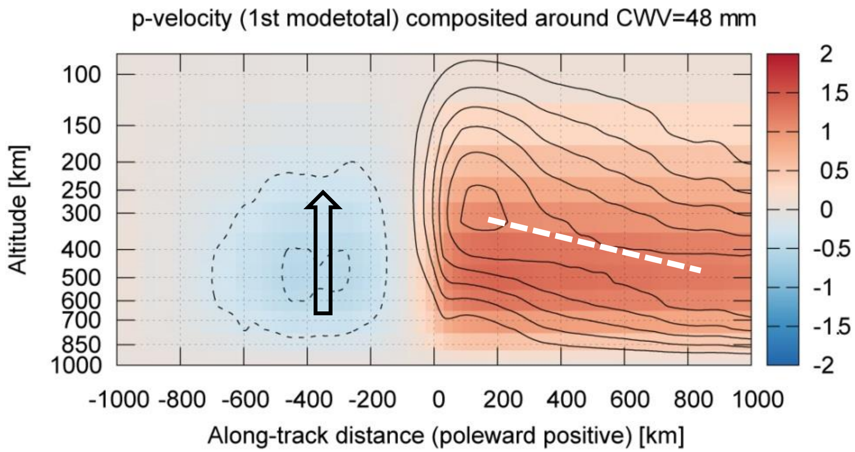


Subtropics

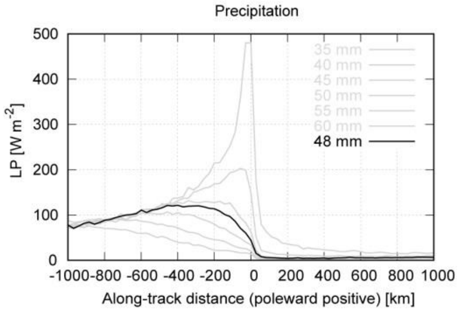


Vertical mode decomposition: ω

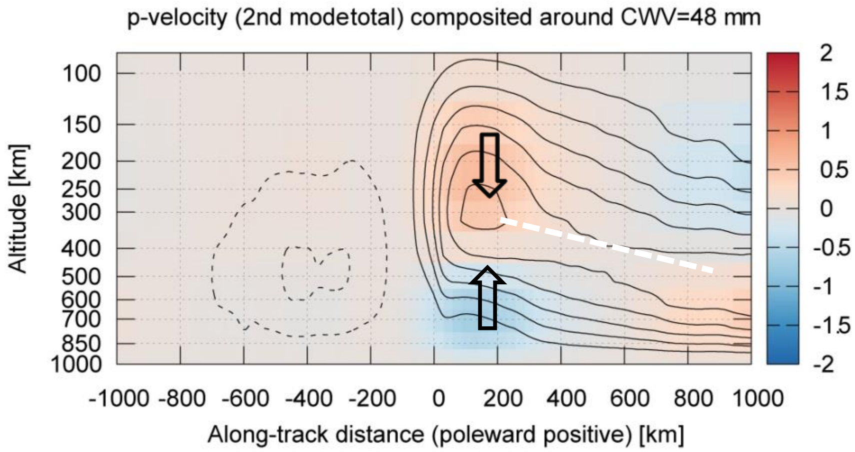
Contour: total ω
Shade: 1st mode



48-mm composite

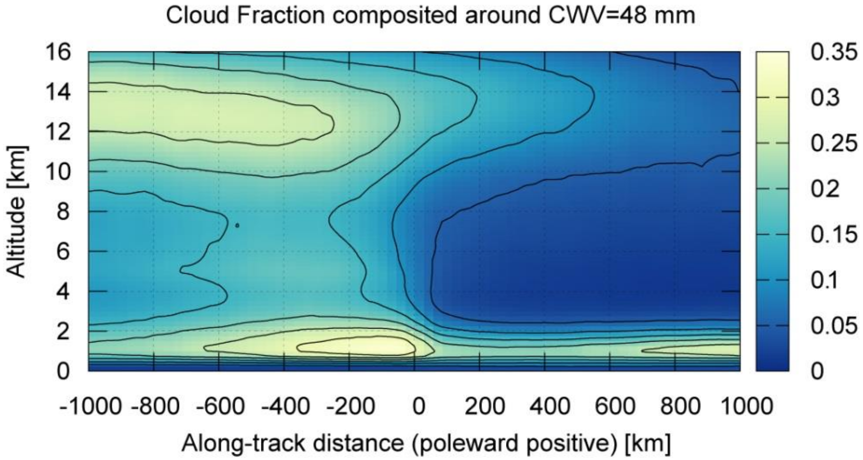


Contour: total ω
Shade: 2nd mode

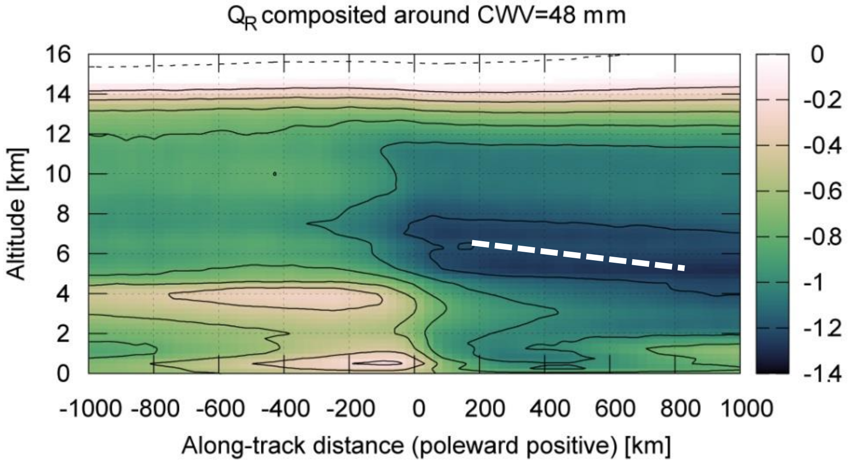


Relation to radiative heating profiles

Cloud cover

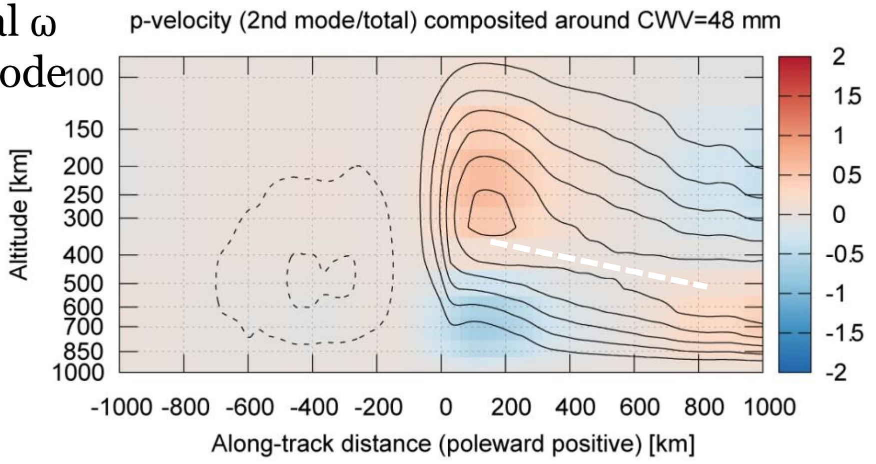


Q_R

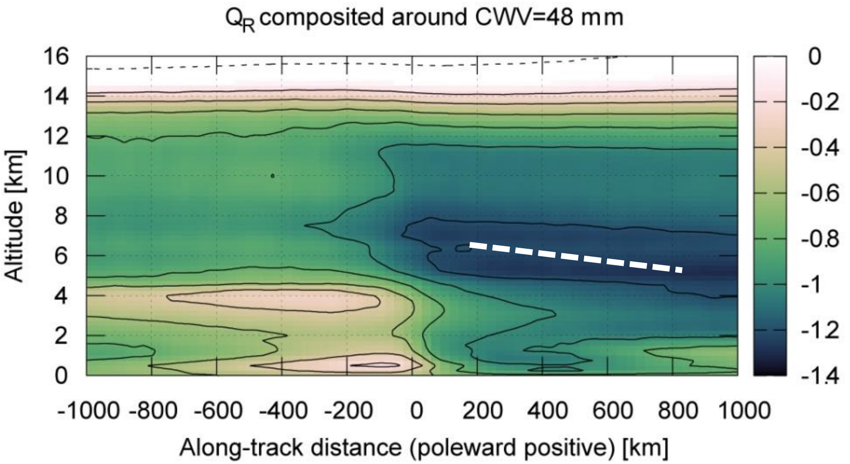


Relation to radiative heating profiles

Contour: total ω
Shade: 2^{nd} mode



Q_R



In the subtropics

$$\omega \partial_p s \sim Q_R$$

the Q_R minimum ascends as CWV increases to the equator, which (partly) accounts for the equatorward strengthening of the 2^{nd} mode in the ω profile.

Schematic summary