Impact of Thin Cirrus Clouds on Humidity in the UT/LS

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Stratospheric water vapor

- stratospheric ozone chemistry; climate (particularly sensitive to water vapor in the TTL *Solomon et al. 2010*)
- methane oxidation; transport from troposphere
- Lagrangian models give (inter)annual variabilities but dry-biased (30 %).

Factors determining dehydration

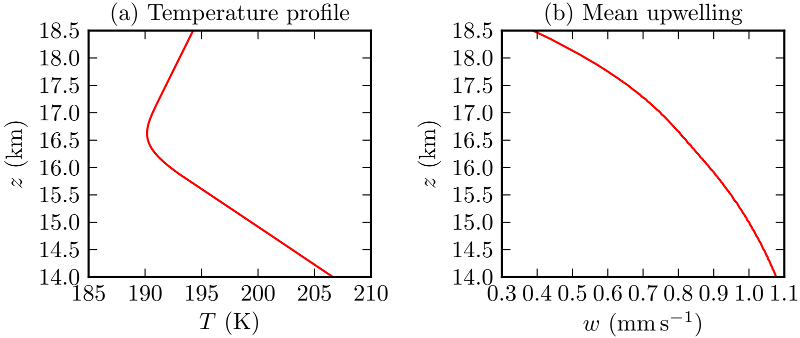
- Temperature: Mean upwelling through tropopause
- Spatial and temporal variations from waves:
  Joan and Ji-Eun's talks
  Dinh et al. 2012 and 2014 ACP

What about cloud processes?

- Ice absorption of radiation $\rightarrow$ heating $\rightarrow$ increases temperature
- Cloud heating $\rightarrow$ circulation $\rightarrow$ increases ice mass (*Dinh et al., 2010, 2012*)
- How much do cloud radiation and dynamics change temperature?
- Is relative humidity $\neq$ 100 %?
- $q_{\mathrm{v}} = \mathrm{RH} \times q_{\mathrm{s}}(T)$

Model 2D setup

- $\triangle x = 5$ km; $\triangle z = 30$ m; TTL domain 3200 km, 90 days (large cloud ensemble)
- Mean upwelling constent with mass flux in atmosphere
- Waves $\rightarrow$ Inhomogeneous cloud fields
- Equilibirum state: cloud heating balanced by Newtonian cooling



Three experiments

- **Rad-None**: No radiation
- **Rad-Mean**: Cloud radiative heating applies to entire horizontal domain. Domain warms but no cloud-scale dynamics.
- **Rad-Dynamics**: Warming and cloud-scale circulation are resolved.

Rad-None

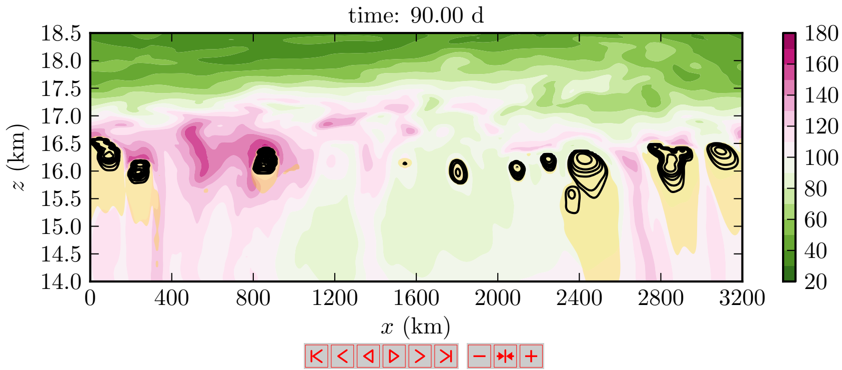


Figure : Relative humidity and clouds in Rad-None.

To get 1:1 scale (compare with observations): stretch figure horizontally 300 time.

Rad-Mean

Intermediate simulation: Not shown

Rad-Dynamics

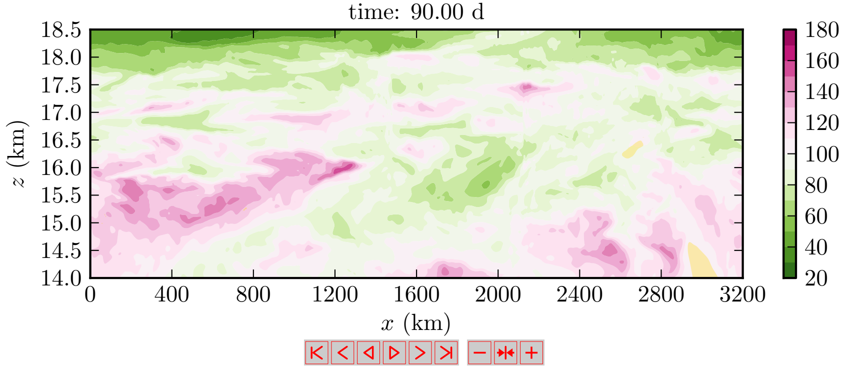
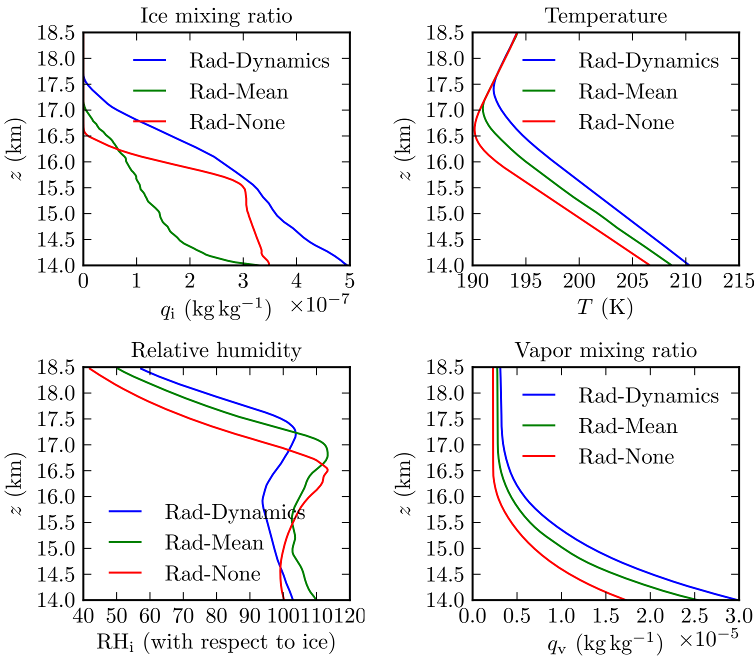
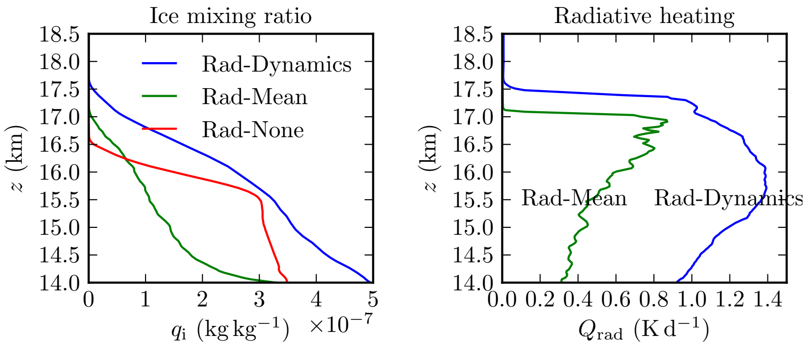


Figure : Relative humidity and clouds in Rad-Dynamics.

To get 1:1 scale (compare with observations): stretch figure horizontally 300 time.


Ice mixing ratio
Rad-Dynamics
Rad-Mean
Rad-None
z (km)
q_i (kg kg^{-1}) $\times 10^{-7}$
Temperature
T (K)
Relative humidity
RH_i (with respect to ice)
Vapor mixing ratio
q_v (kg kg^{-1}) $\times 10^{-5}$



Feedback mechanism:

$Q_{rad} \rightarrow$ Cloud dynamics $\rightarrow$ Ice mass $\rightarrow Q_{rad}$

Table : Cold point tropopause statistics

	Rad-None	Rad-Mean	Rad-Dynamics
RH_i (%)	112	111	103
T (K)	190	191	192
q_s (10^{-6} kg kg^{-1})	2.1	2.6	3.2
q_v (10^{-6} kg kg^{-1})	2.3	2.8	3.3

When cloud radiation and dynamics are considered:

- RH_i decreases by less than 15 %.
- q_s increases by 55 % because of temperature increase.
- q_v increases by 40 %.

Interactions between small-scales and large-scales

Cloud-scale processes affect large-scale (tropics-wide) temperature and water vapor

Dinh and Fueglistaler, 2014, Geophys. Res. Lett., Microphysical, radiative, and dynamical impacts of thin cirrus clouds on humidity in the tropical tropopause layer and lower stratosphere