Impact of the refinement of the vertical resolution of the LMD's Martian GCM on the simulation of the water cycle

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UPWARDS
UNDERSTANDING PLANET MARS

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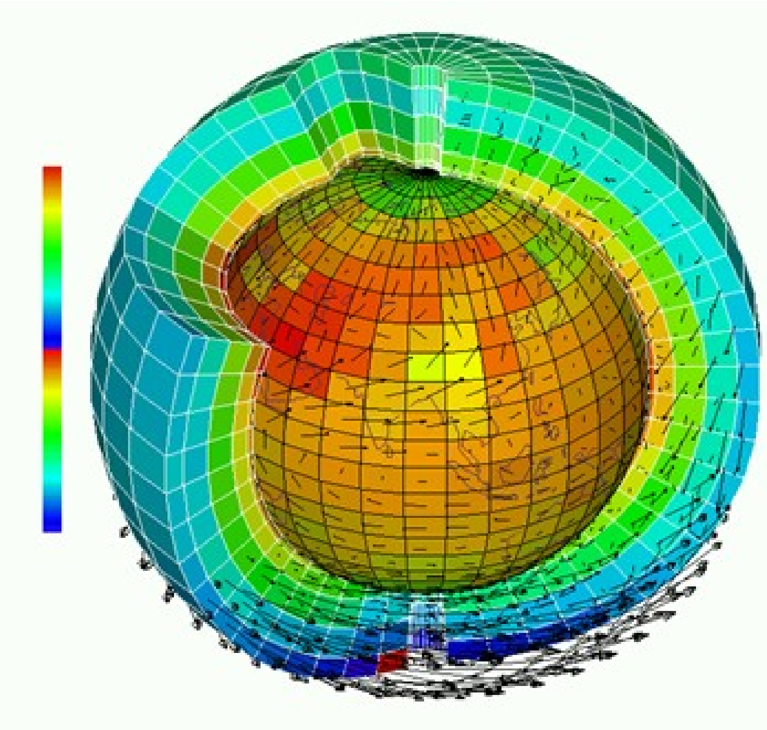
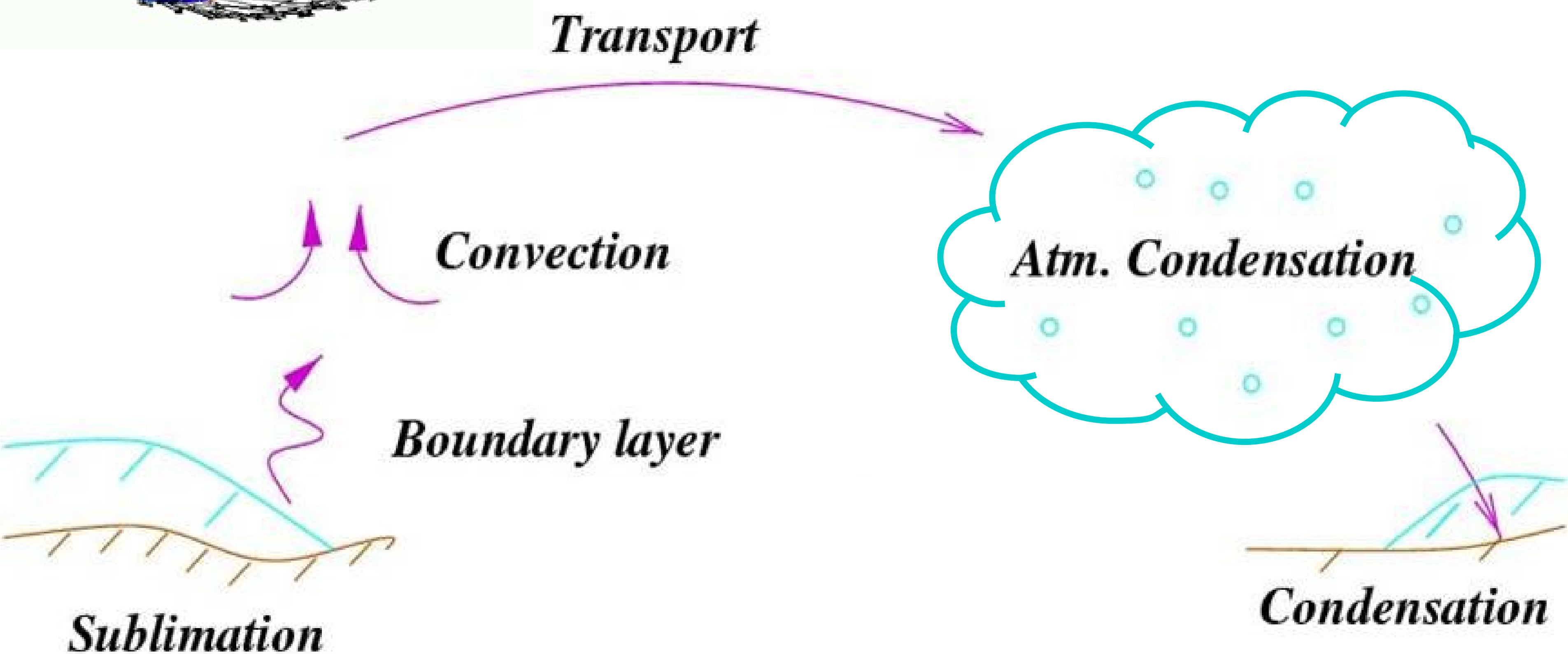
LMD



Modelling Mars water cycle with the LMD Global Climate Model

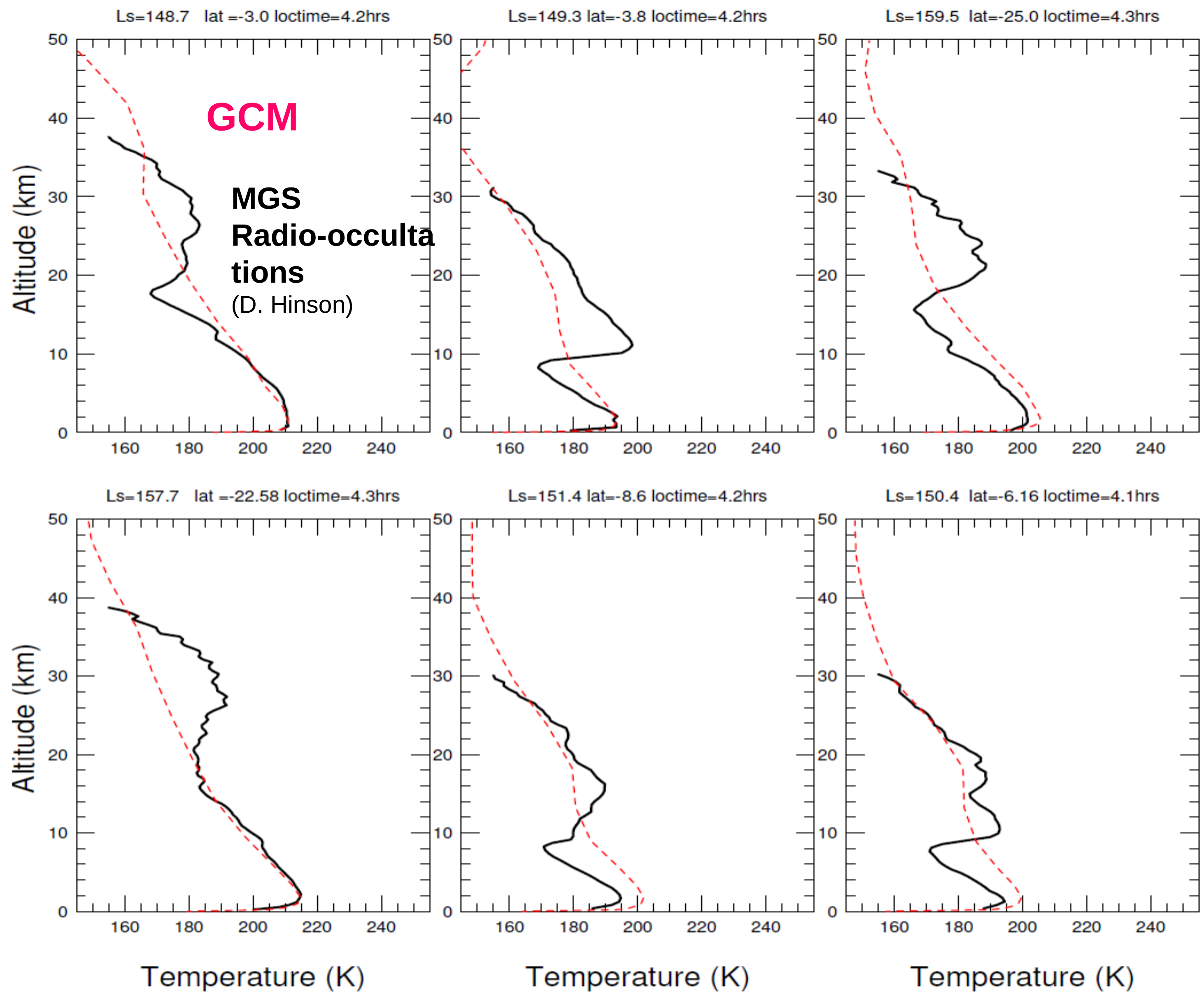


Main recent improvements

- **Radiatively active clouds** (*Madeleine et al. 2012, Navarro et al. 2014*)
- **Improved microphysics** *(Navarro et al. 2014*)
  - nucleation on dust particles
  - ice particle growth
  - scavenging of dust particles
  - supersaturation

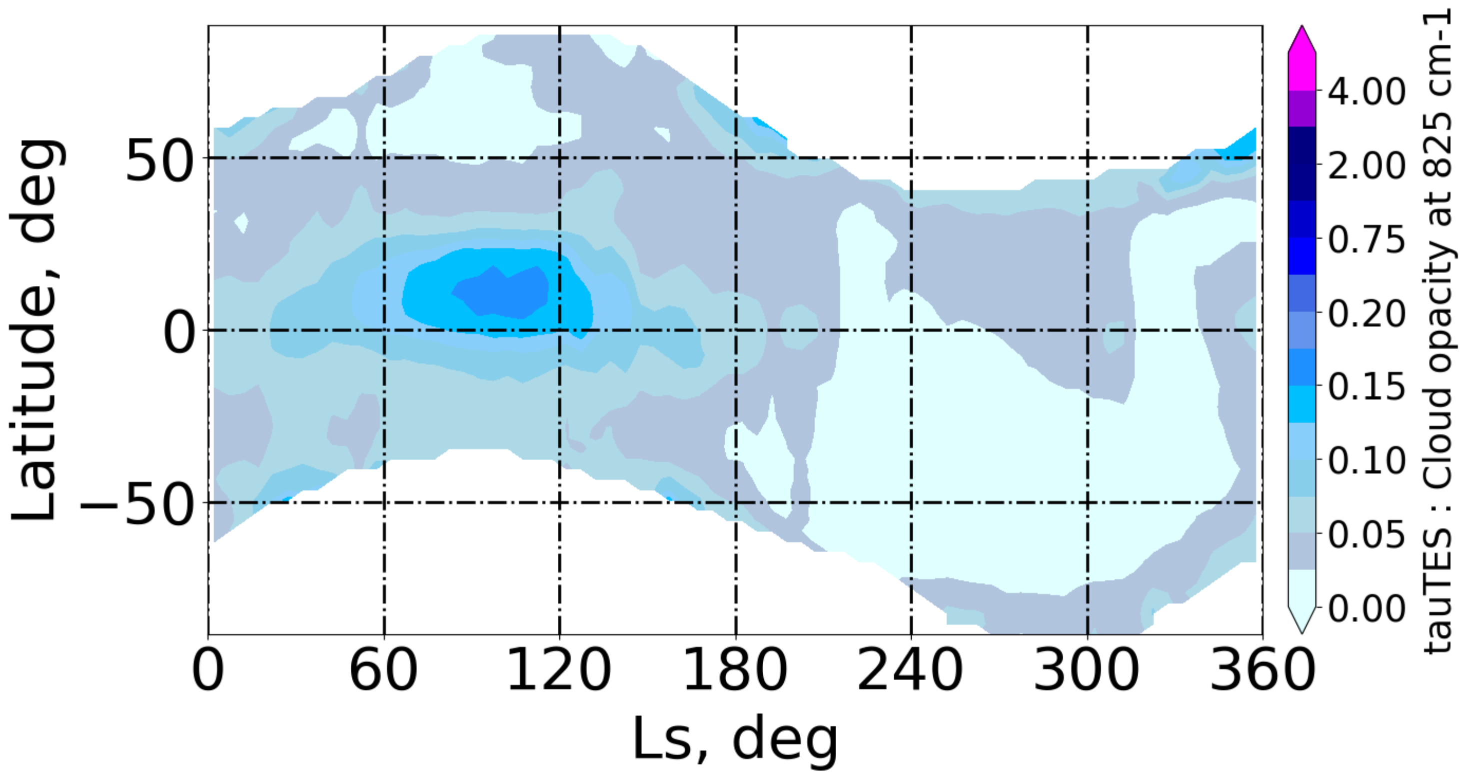
Main remaining issues

- **Systematic temperature inversion within nighttime clouds**

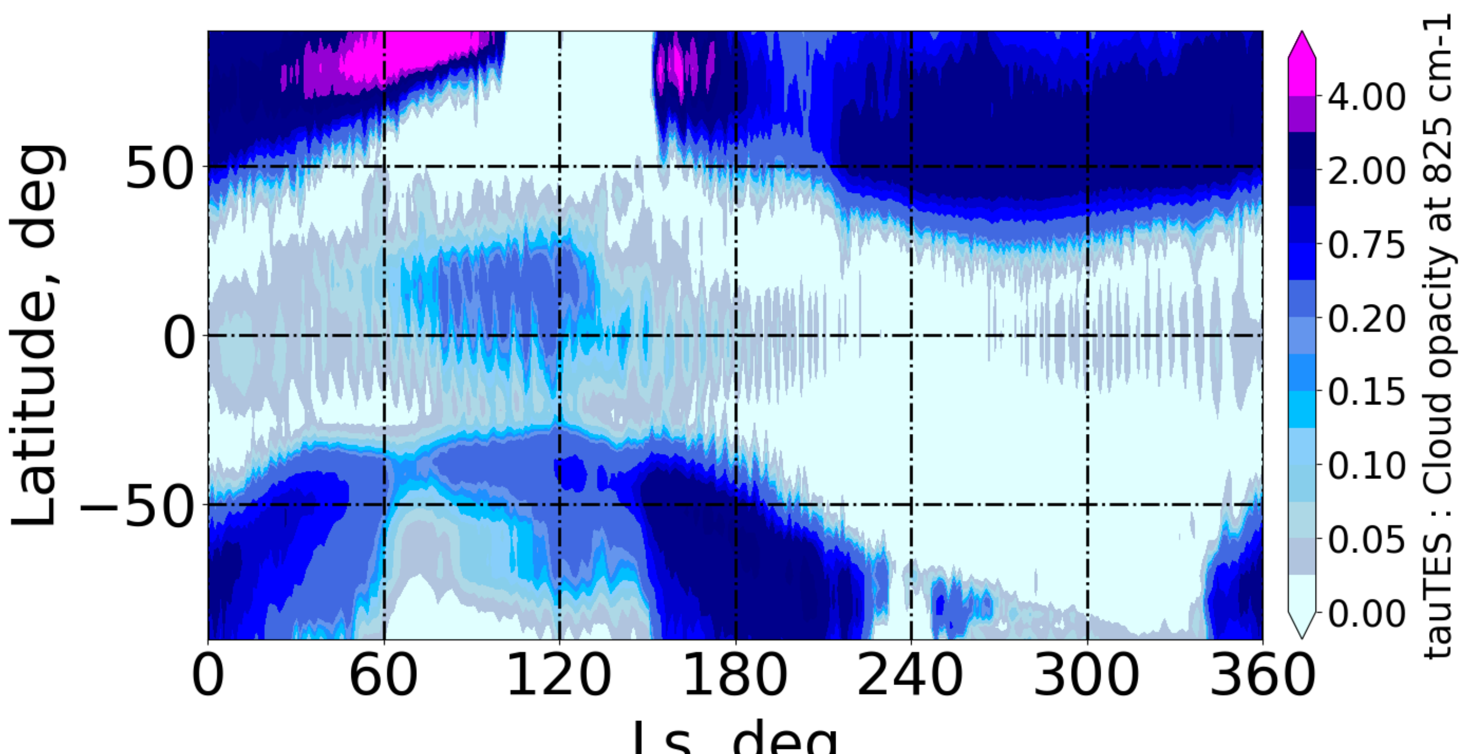


- **Polar hood too thick**

TES



GCM



ARTICLES
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Snow precipitation on Mars driven by cloud-induced night-time convection

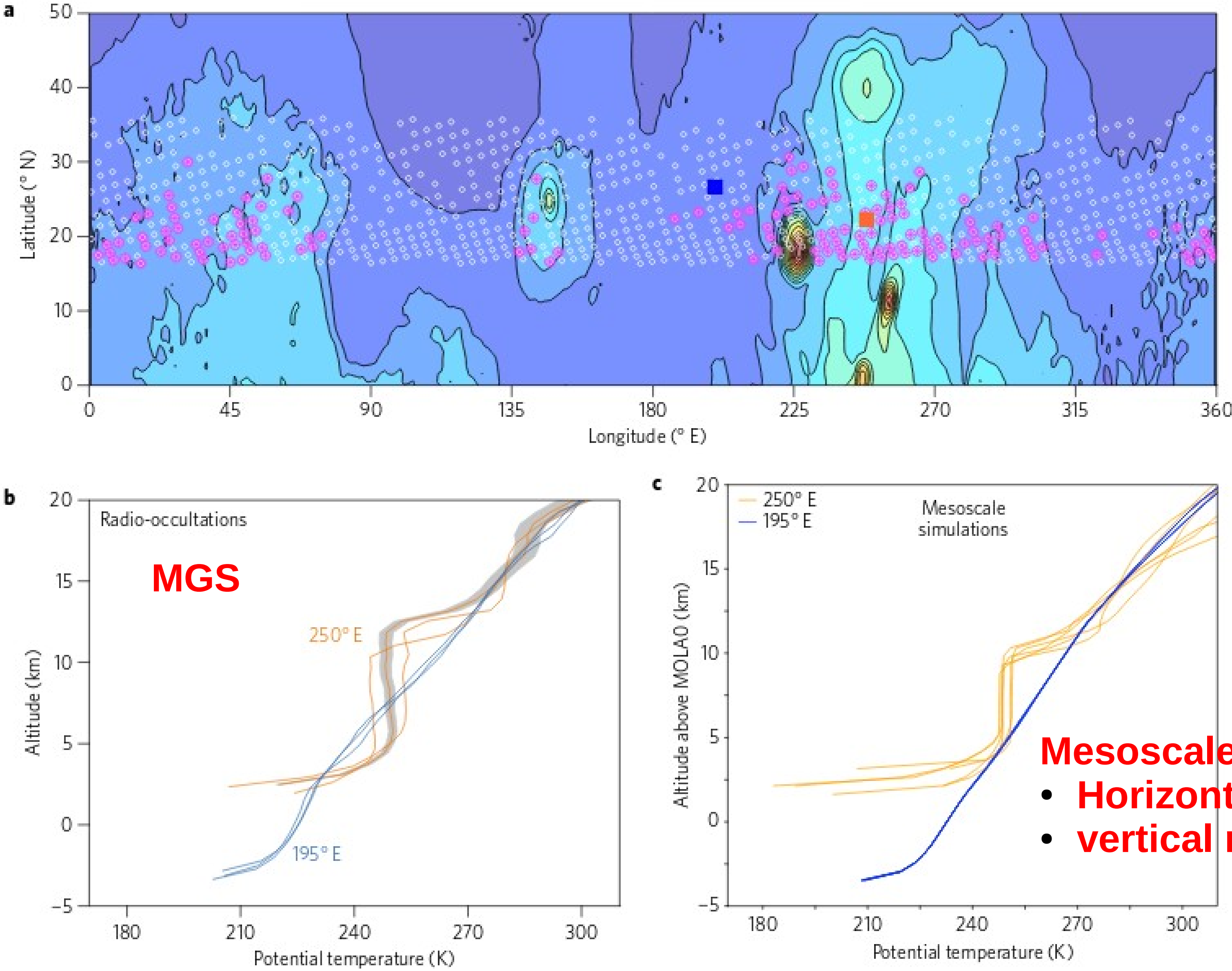
Aymeric Spiga[1*], David P. Hinson[2,3], Jean-Baptiste Madeleine[1], Thomas Navarro[1], Ehouarn Millour[1], François Forget[1] and Franck Montmessin[4]

Although it contains less water vapour than Earth's atmosphere, the Martian atmosphere hosts clouds. These clouds, composed of water-ice particles, influence the global transport of water vapour and the seasonal variations of ice deposits. However, the influence of water-ice clouds on local weather is unclear: it is thought that Martian clouds are devoid of moist convective motions, and snow precipitation occurs only by the slow sedimentation of individual particles. Here we present numerical simulations of the meteorology in Martian cloudy regions that demonstrate that localized convective snowstorms can occur on Mars. We show that such snowstorms—or ice microbursts—can explain deep night-time mixing layers detected from orbit and precipitation signatures detected below water-ice clouds by the Phoenix lander. In our simulations, convective snowstorms occur only during the Martian night, and result from atmospheric instability due to radiative cooling of water-ice cloud particles. This triggers strong convective plumes within and below clouds, with fast snow precipitation resulting from the vigorous descending currents. Night-time convection in Martian water-ice clouds and the associated snow precipitation lead to transport of water both above and below the mixing layers, and thus would affect Mars' water cycle past and present, especially under the high-obliquity conditions associated with a more intense water cycle.

Martian water-ice clouds were one of the first atmospheric phenomena to be observed on Mars[1–3]. The absolute quantity of water vapour is much smaller on Mars than it is on the Earth (a few precipitable micrometers, 1 pr-μm = 1 g m^{-2}); yet the low pressure and temperature of the Martian atmosphere cause the relative humidity to often reach saturation conditions, leading to the formation of water-ice clouds[4]. Water-ice clouds on Mars exhibit seasonal[5,6] and diurnal[7] variability, with the formation of a tropical cloud belt during the aphelion seasons and 'polar hood' clouds at high latitudes in fall/spring[8,9]. Their infrared absorption and emission dominate scattering and absorption in the visible[10] thereby warming the ...

water-ice cloud formation is regularly observed[12,16,17]; the daytime convective boundary layer is particularly deep[18,19]; atmospheric tides impact the thermal structure[14,20]; and the gravity wave activity is significant[21]. Night-time mixing layers cannot be the remainder of the mixing layers from the daytime convective boundary layer, which disappear a few hours after sunset[15]; and they are both too deep and too low in the Martian troposphere to be caused by the breaking of atmospheric tides and/or gravity waves, according to existing modelling and observations[22]. Thus, the only plausible origin of the deep night-time mixing layers is aphelion water-ice clouds ...

Night-time mixing layers under water ice clouds



MGS radio-occultation measurements

- **Mixing layer**
- **250°E**
- **195°E**

Potential temperature profiles

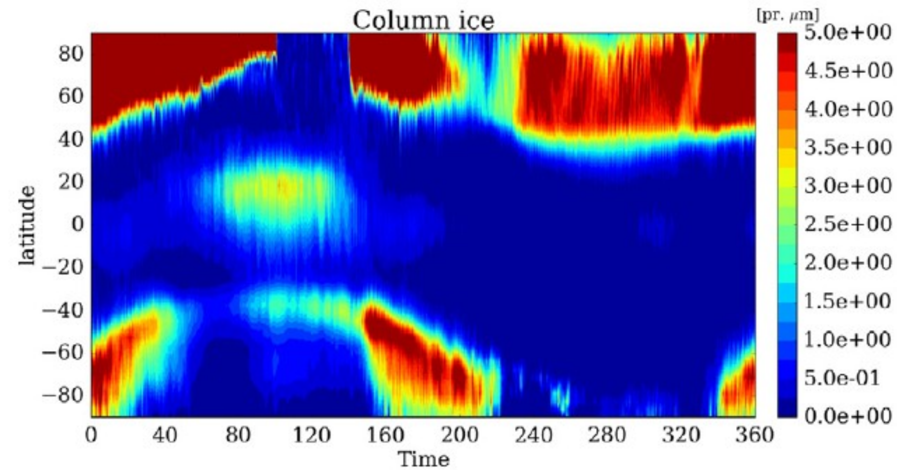
Mesoscale model :

- **Horizontal res~30km**
- **vertical res~750m**

Spiga et al. 2017

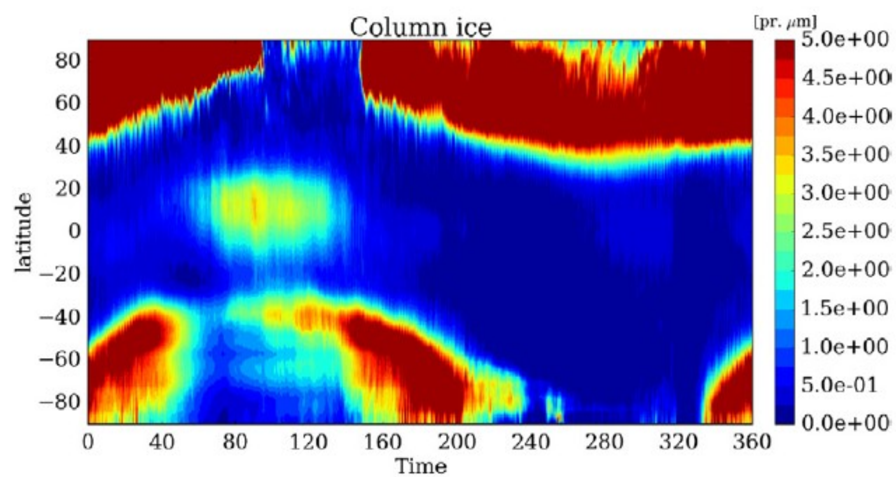
High horizontal resolution

GCM
Usual
res~3,75x5,625°
(~220x330km)



a Low resolution, active clouds

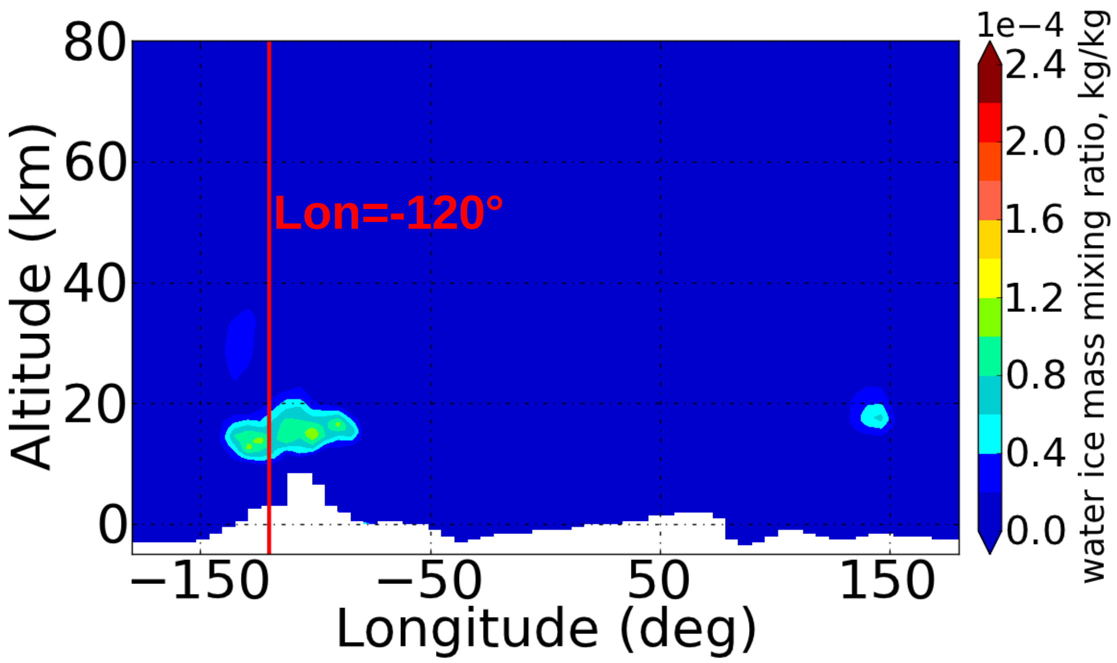
GCM
High
res~1x1°
(~60x60km)



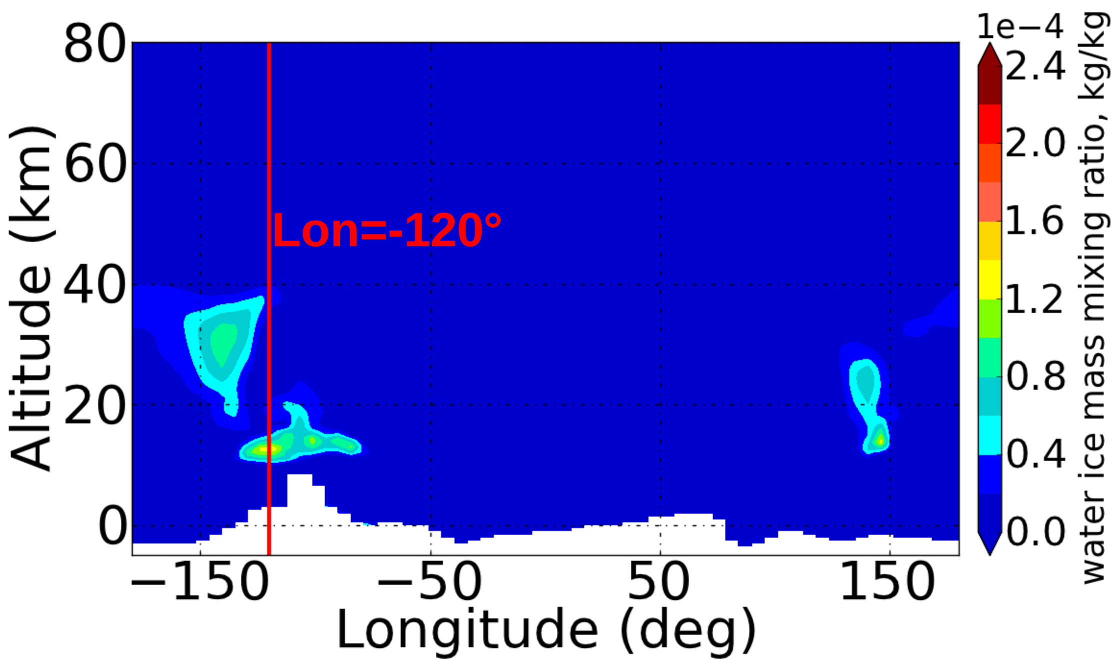
b High resolution, active clouds

Pottier et al. 2017

Ls=150° ; Lat=10° ; LT=2am



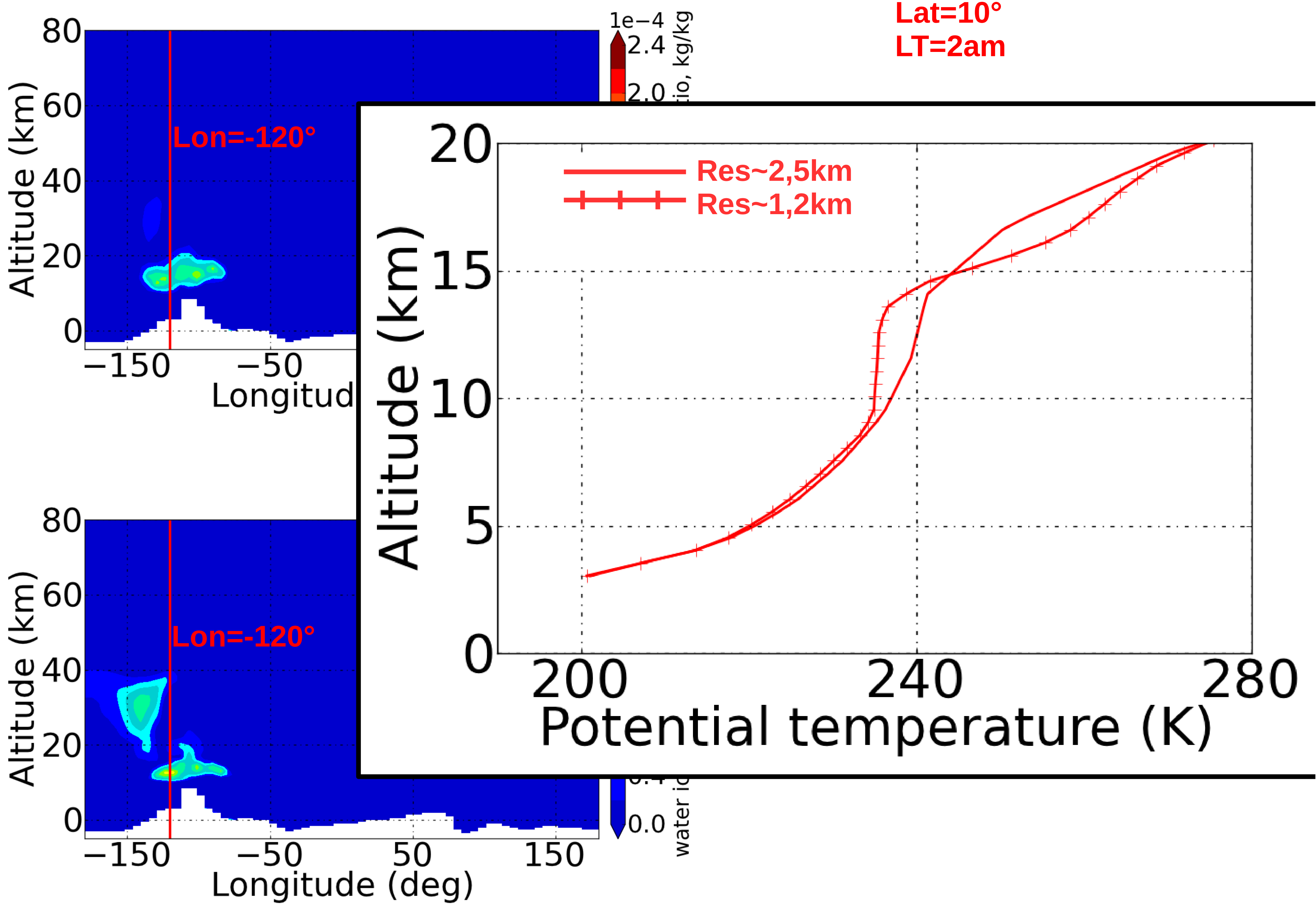
Usual vertical resolution~2,5km



High vertical resolution~1,2km

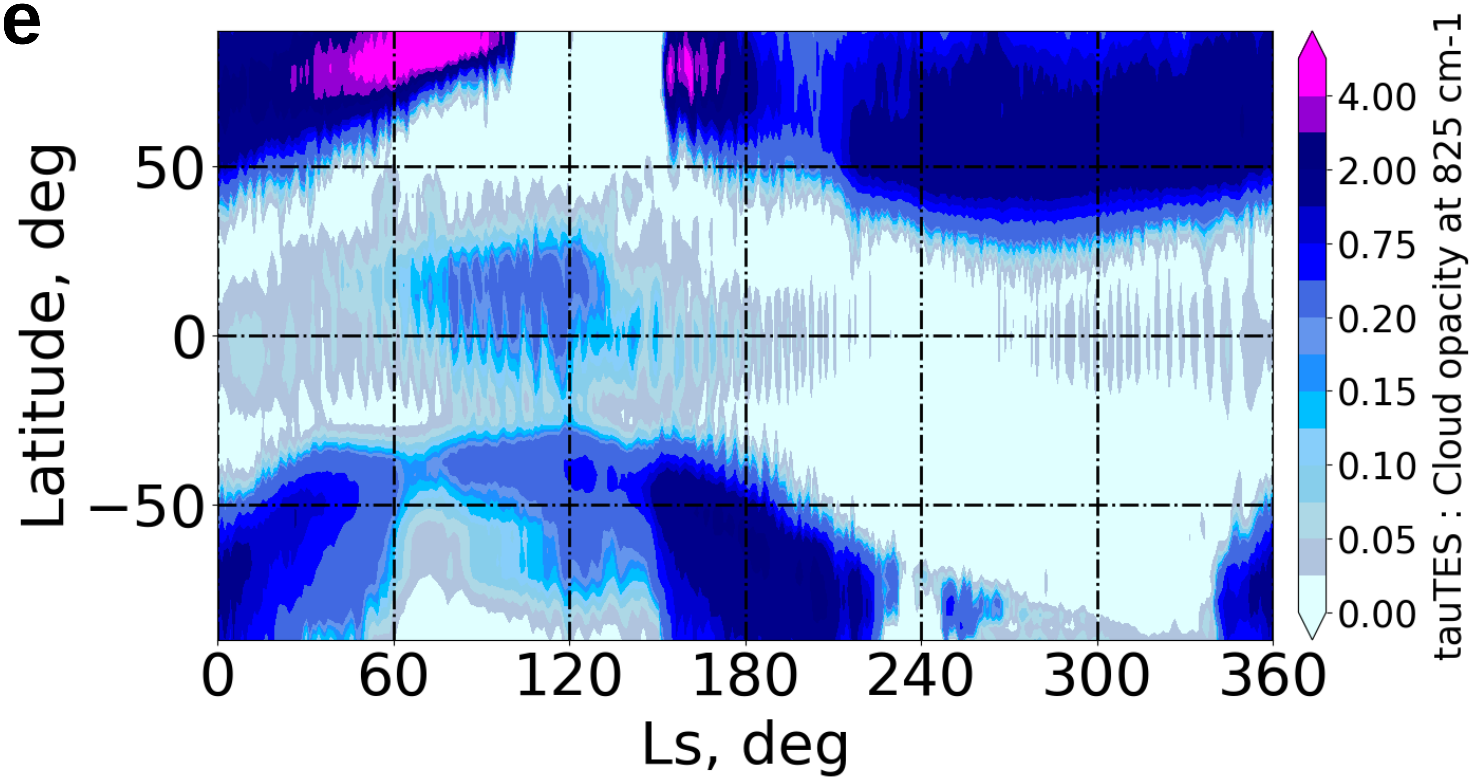
Ls=150° ; Lat=10° ; LT=2am

Ls=150°
Lat=10°
LT=2am

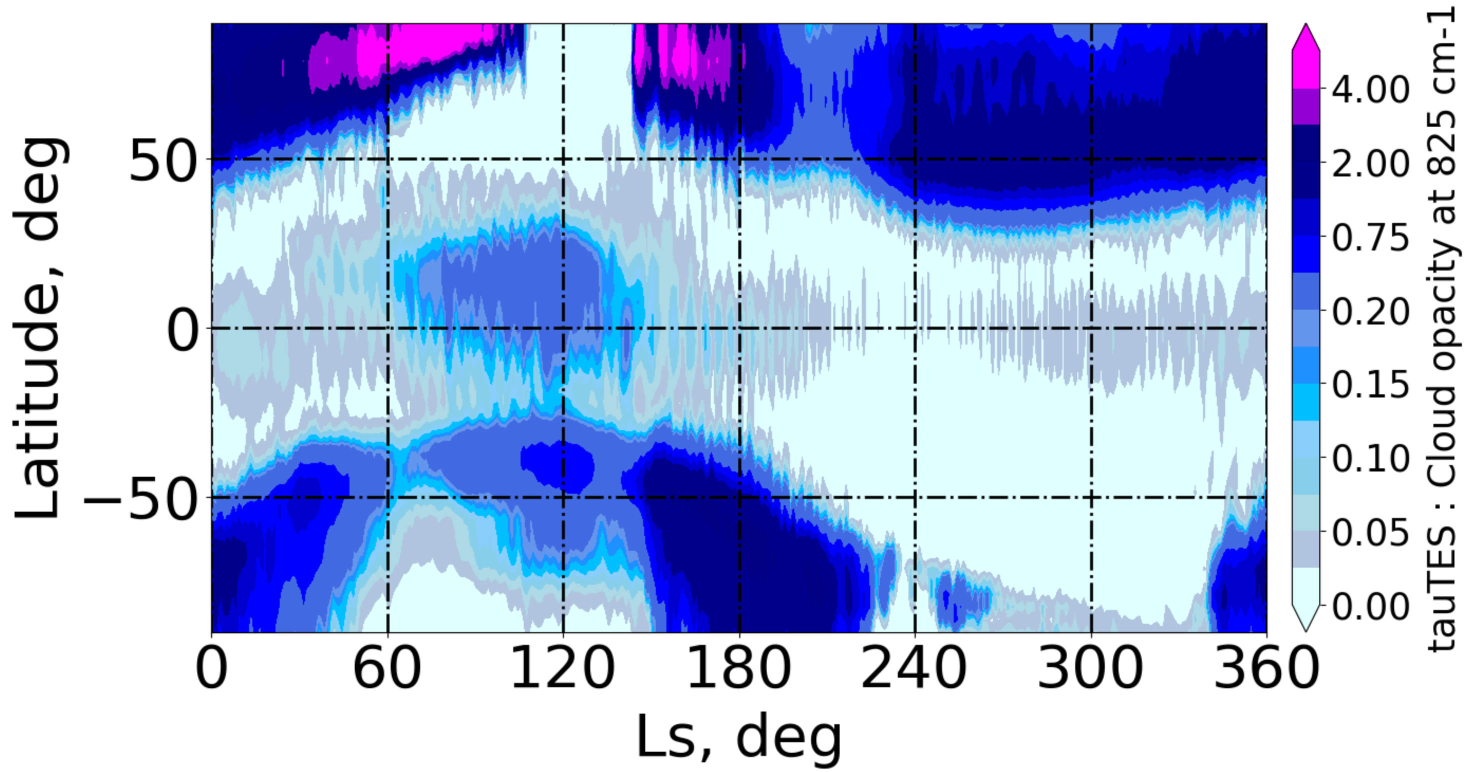


Water cloud cycle

GCM Vertical Res~2.5km

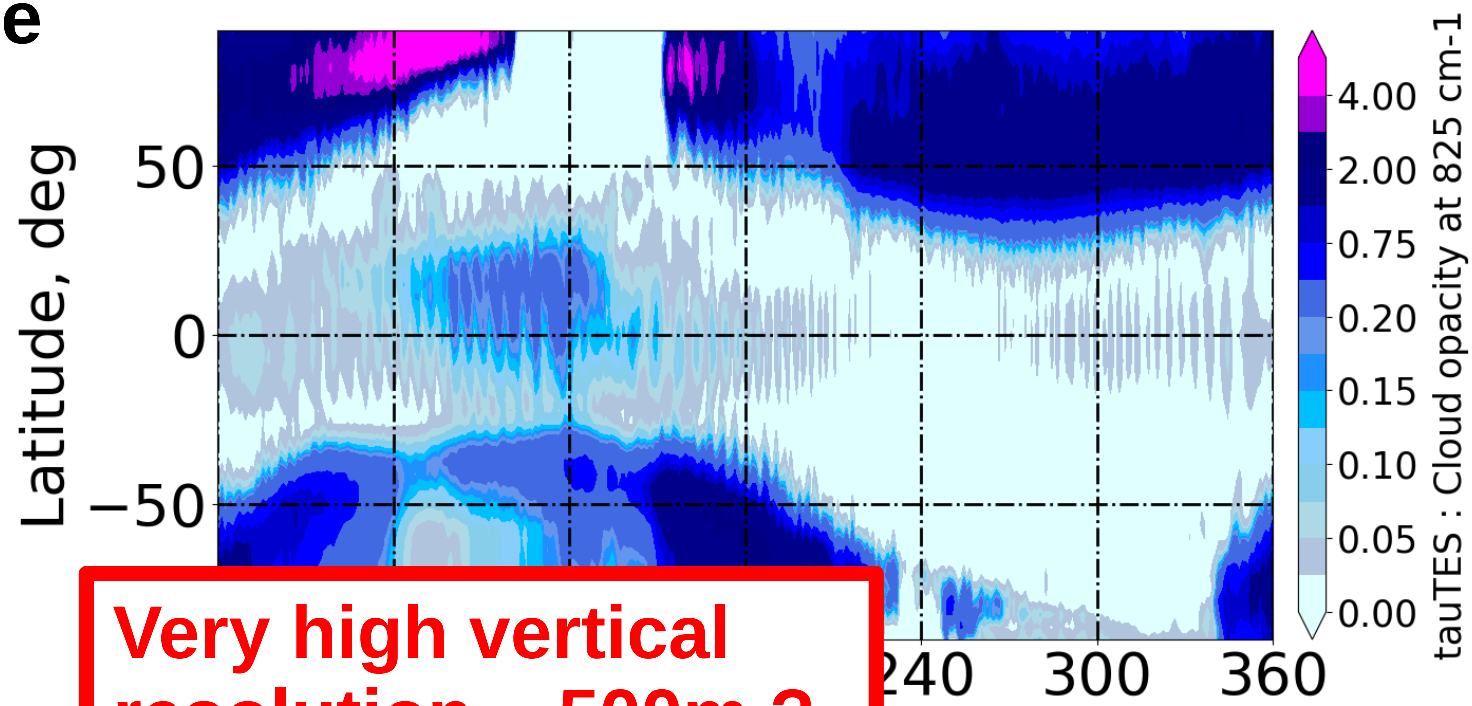


GCM Vertical Res~1.2km



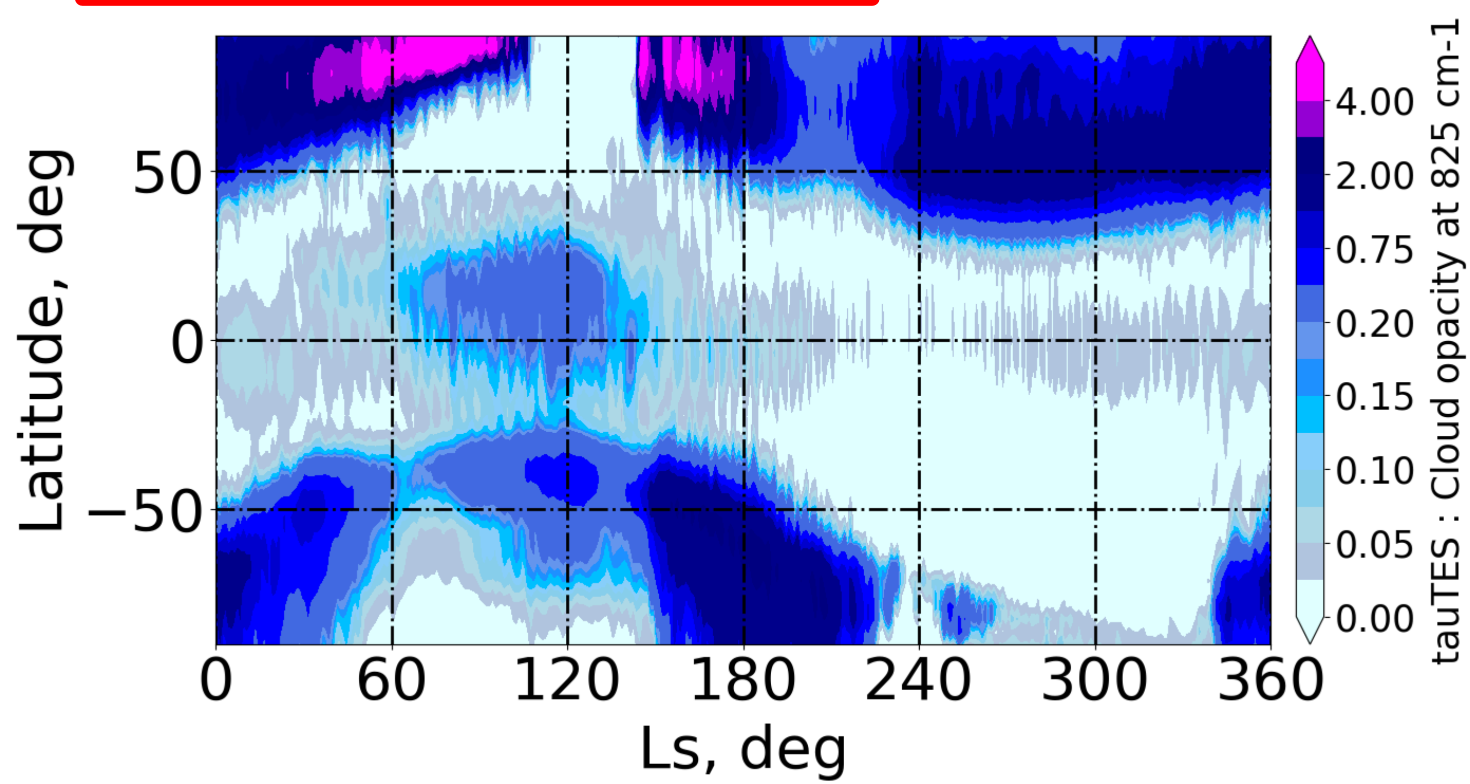
Water cloud cycle

GCM Vertical Res~2.5km



Very high vertical resolution ~ 500m ?

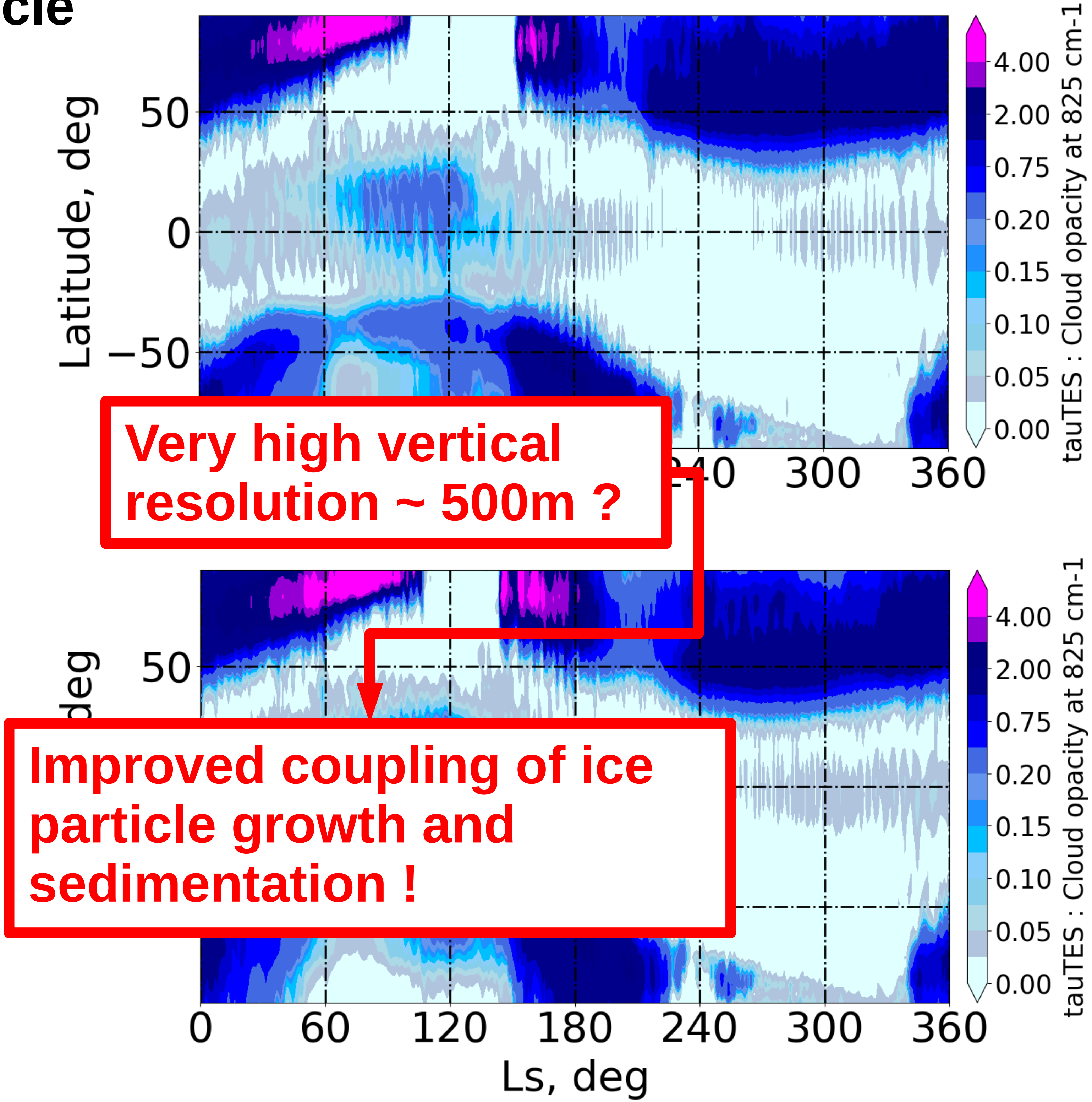
GCM Vertical Res~1.2km



Water cloud cycle

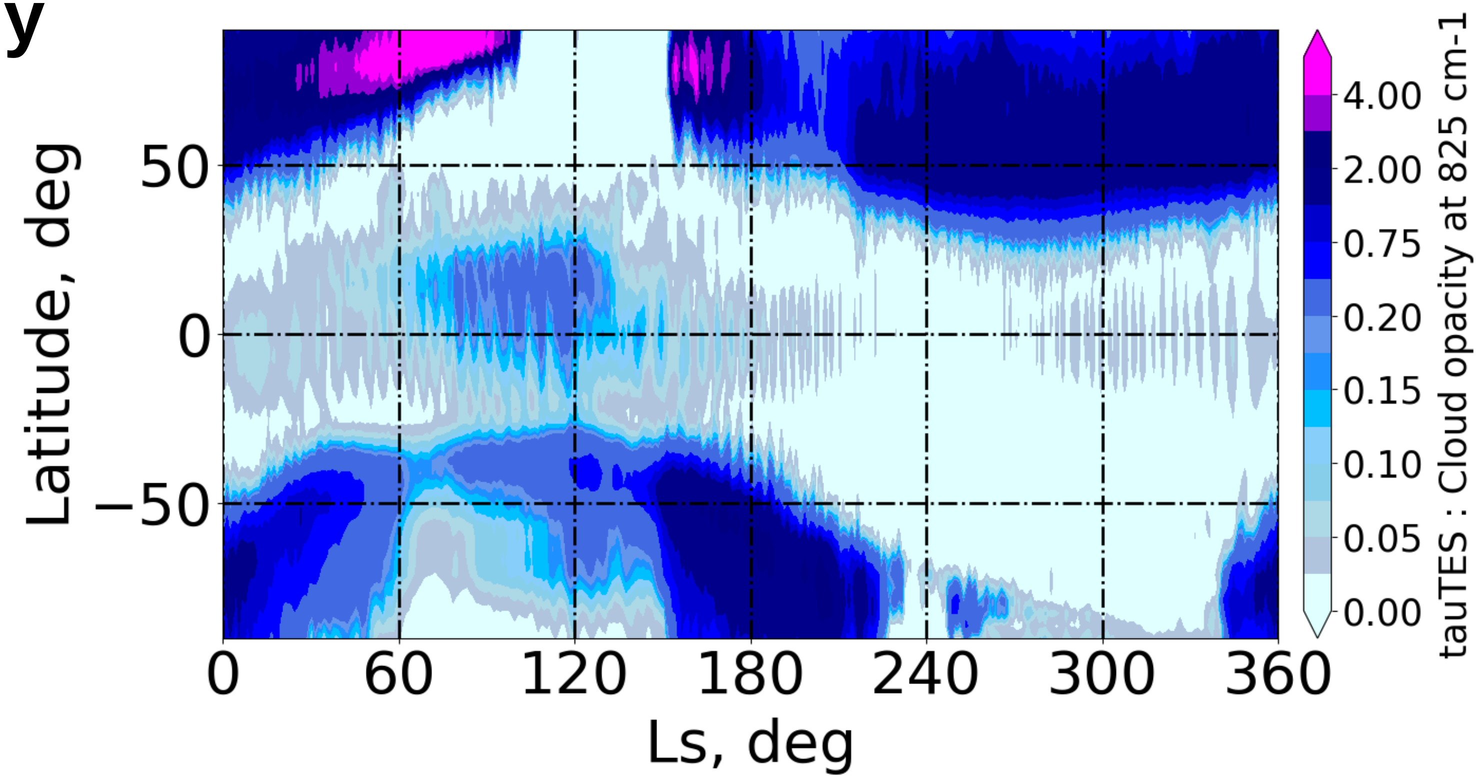
GCM Vertical Res~2.5km

GCM Vertical Res~1.2km

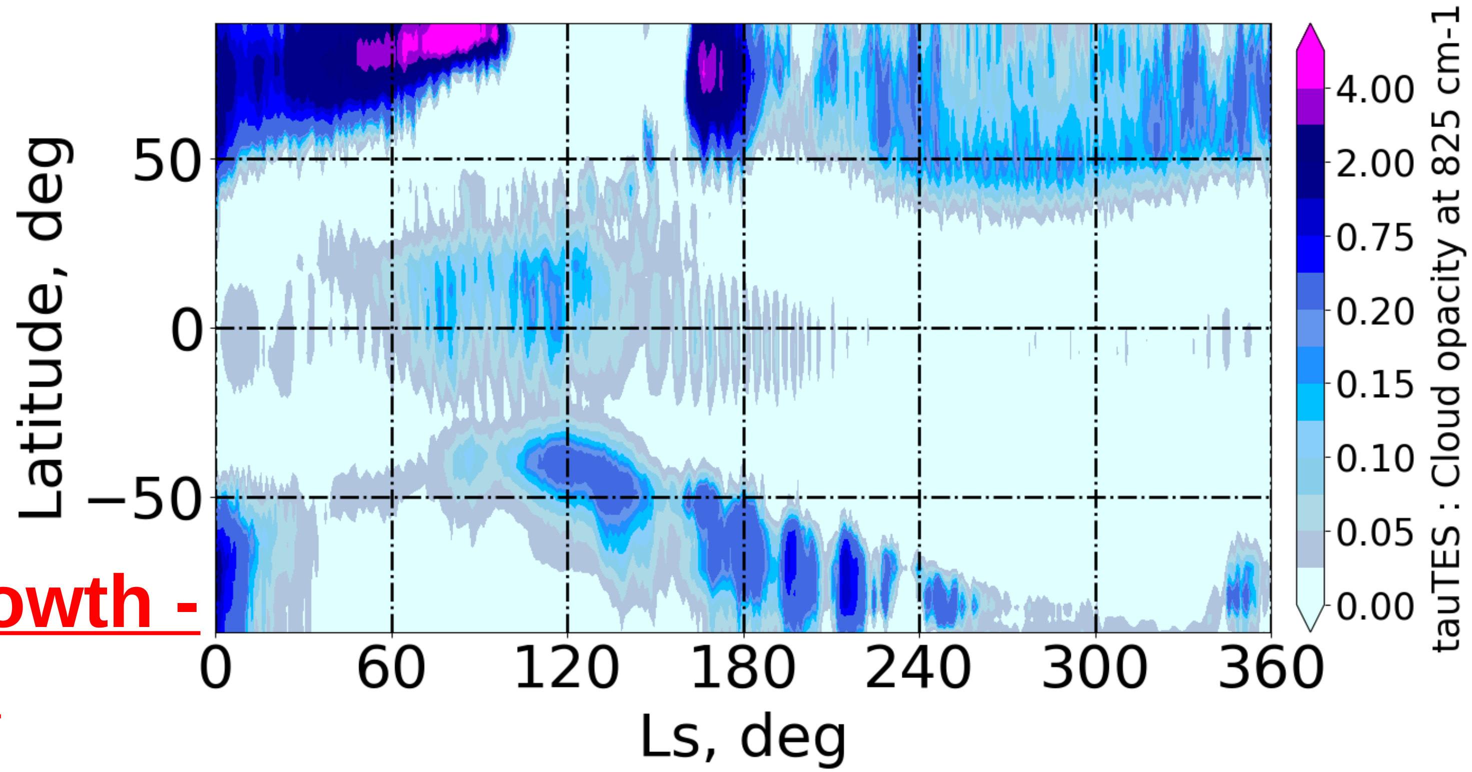


Preliminary study

GCM
Vertical
Res~2.5km

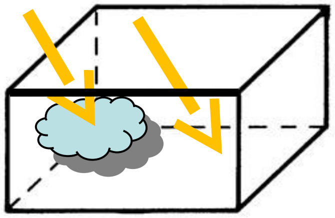


GCM
Vertical
Res~1.2km
Improved
Coupling
Ice particle growth -
sedimentation



Conclusion & perspectives

- Investigate on significant improvements of the high vertical resolution
- Microphysics resolution : coupling of ice particle growth and sedimentation, retuning parameters ?
- Implement improvements :
  - Choice of a good vertical resolution
  - Sub-grid scale clouds implementation ? (A. Pottier)
  - Dust cycle : parametrization of detached dust layers (PhD Chao Wang)

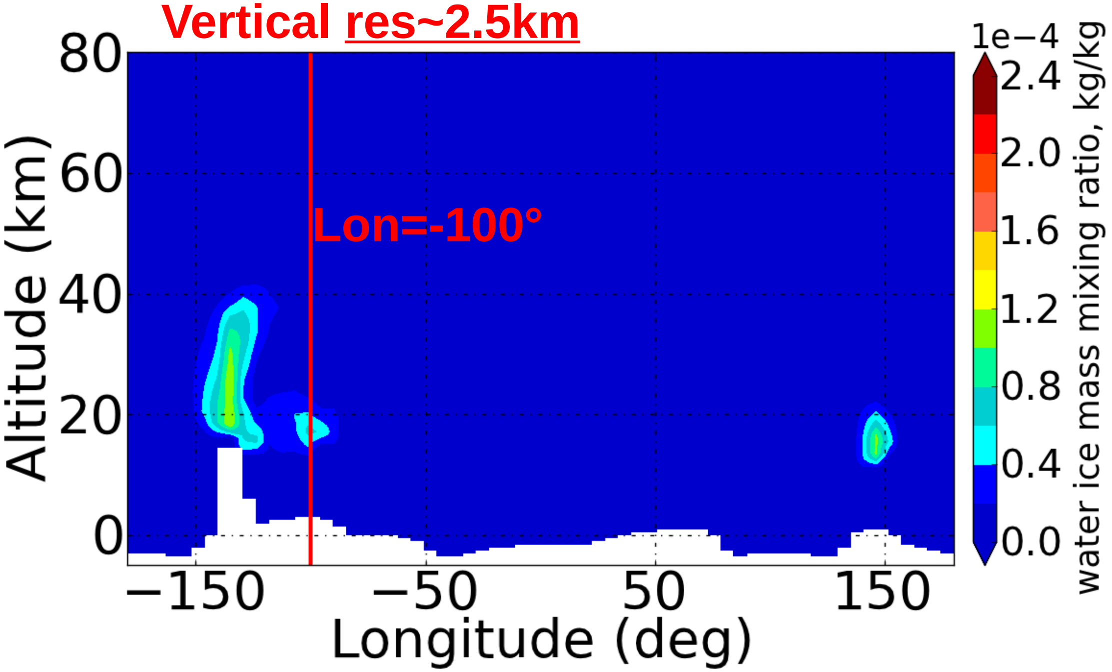


- Future comparisons with brandnew observations (TGO)

- **Question : are we missing a physical process to correctly simulate the water cycle on Mars ?**

From here backup slides

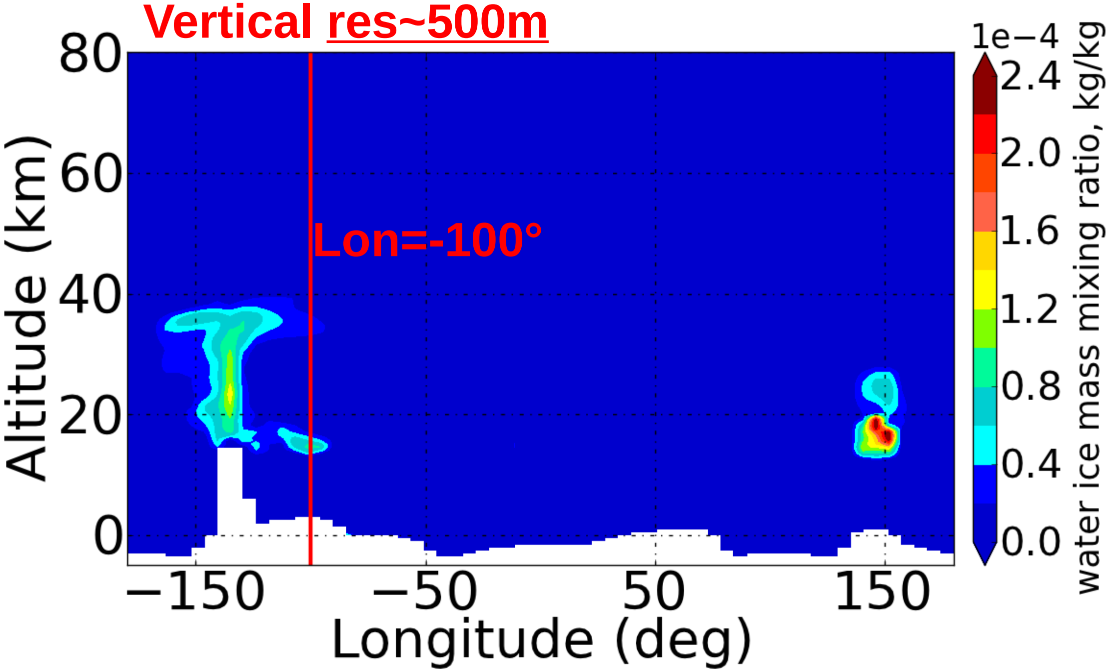
GCM :
Vertical <u>res~2.5km</u>

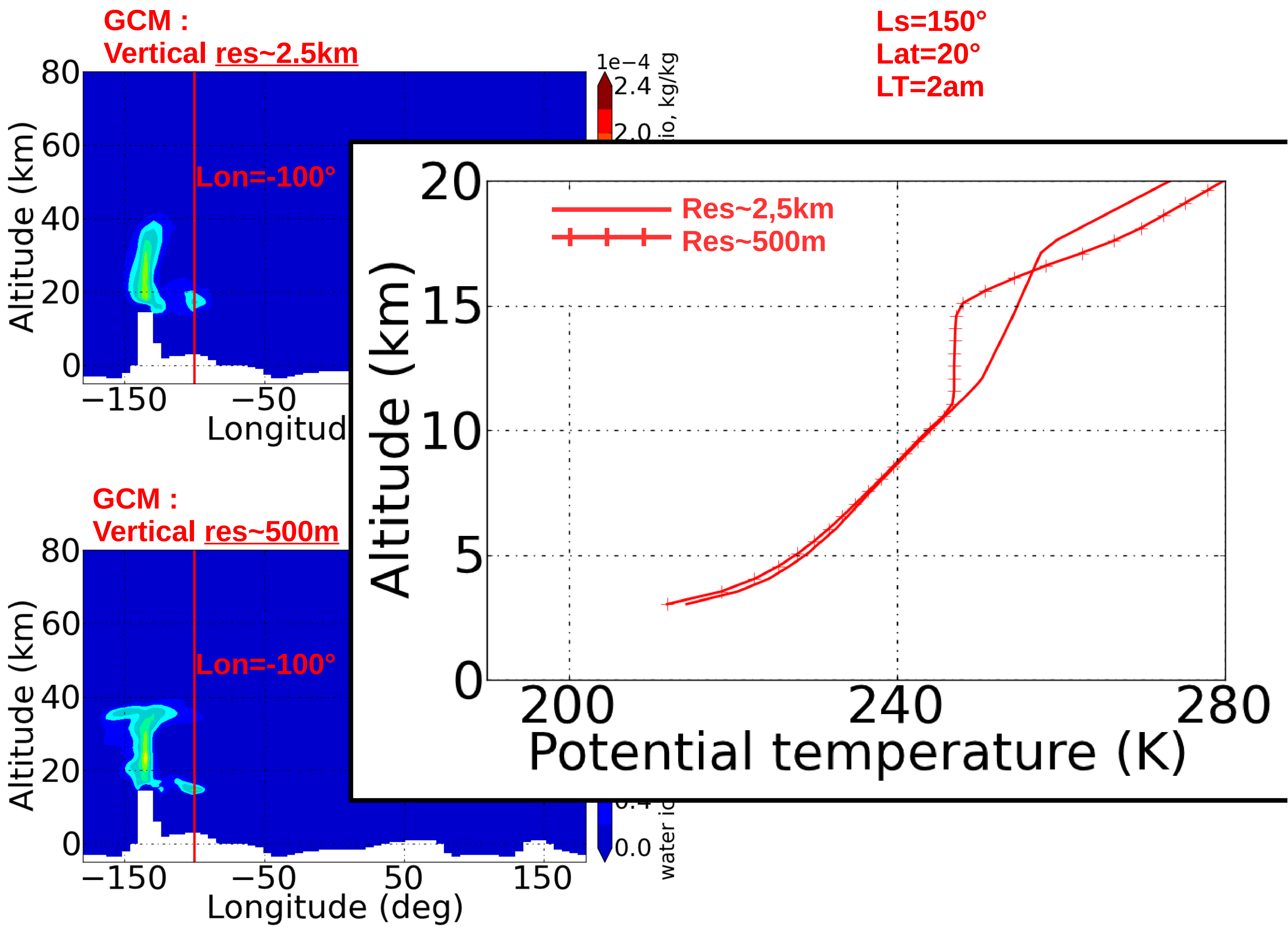


Ls=150°
Lat=20°
LT=2am

Very high resolution

GCM :
Vertical <u>res~500m</u>

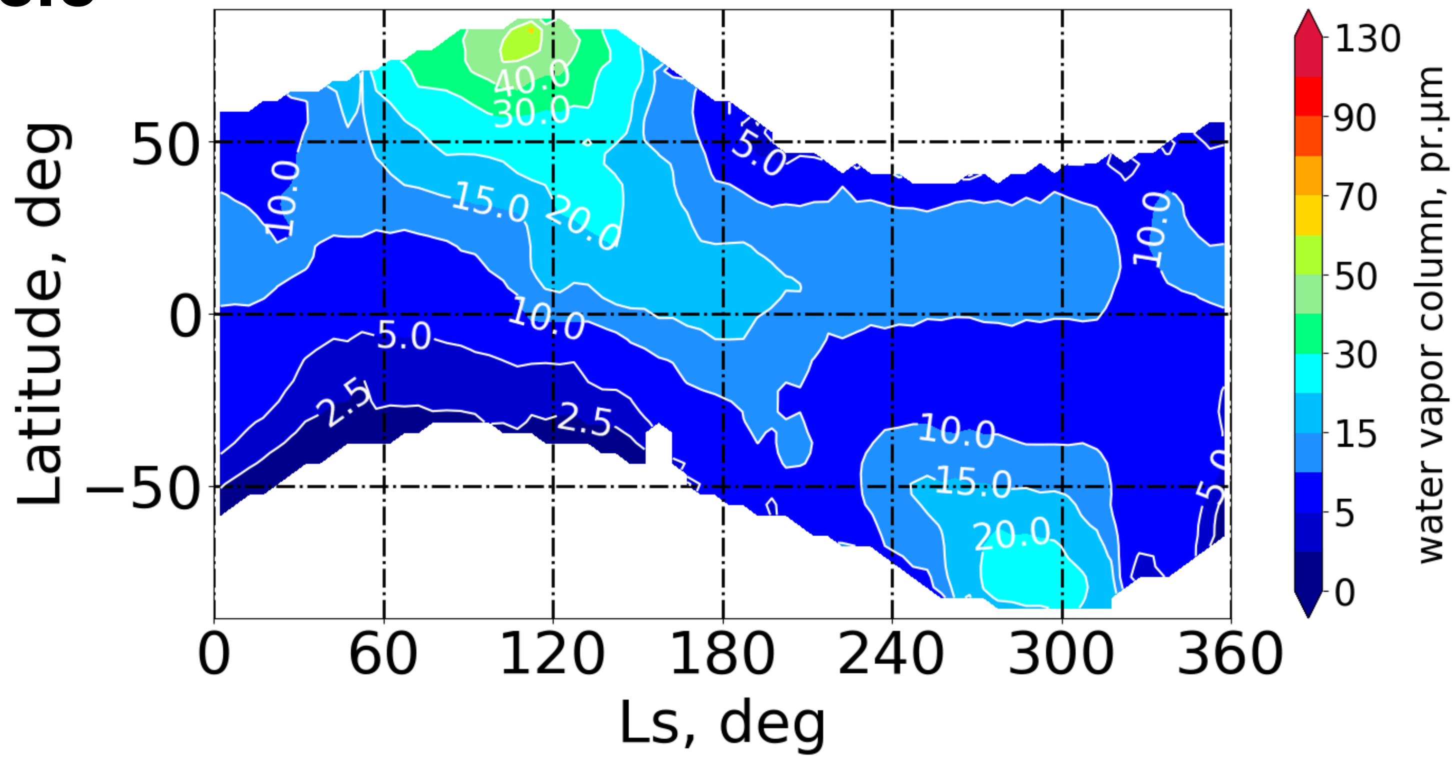




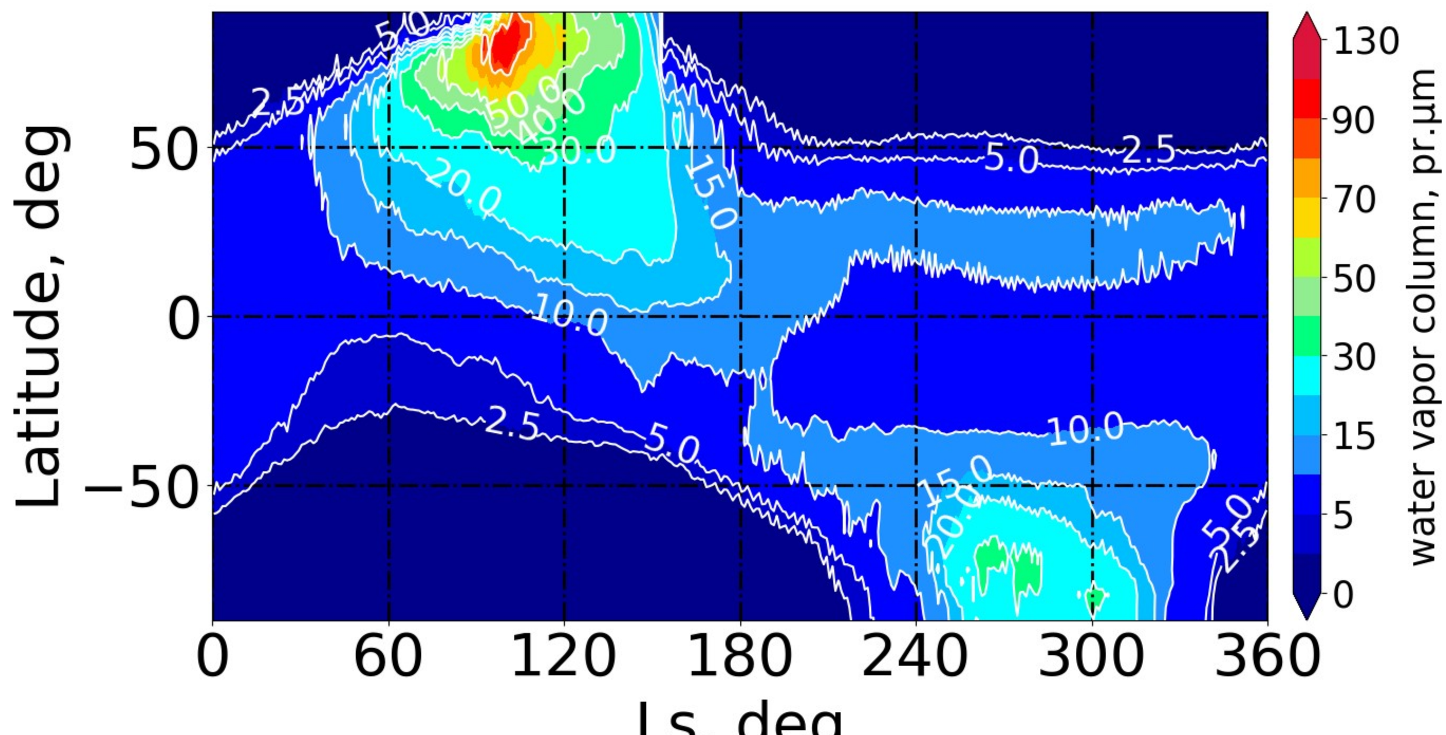
GCM :
Vertical res~2.5km
Ls=150°
Lat=20°
LT=2am
Lon=-100°
GCM :
Vertical res~500m
Lon=-100°
Altitude (km)
Longitude (deg)
1e−4
water ic
Res~2,5km
Res~500m
Altitude (km)
Potential temperature (K)

Water vapour cycle

TES

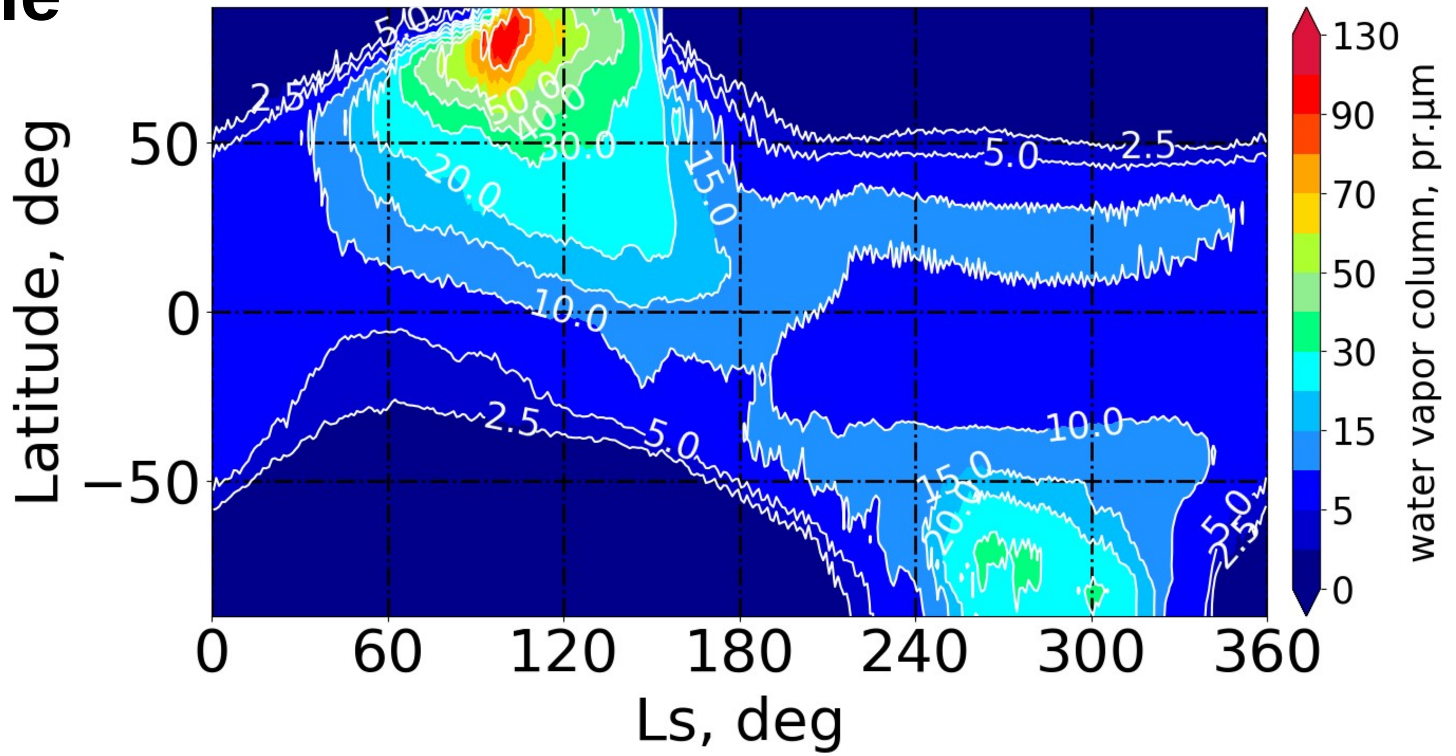


GCM

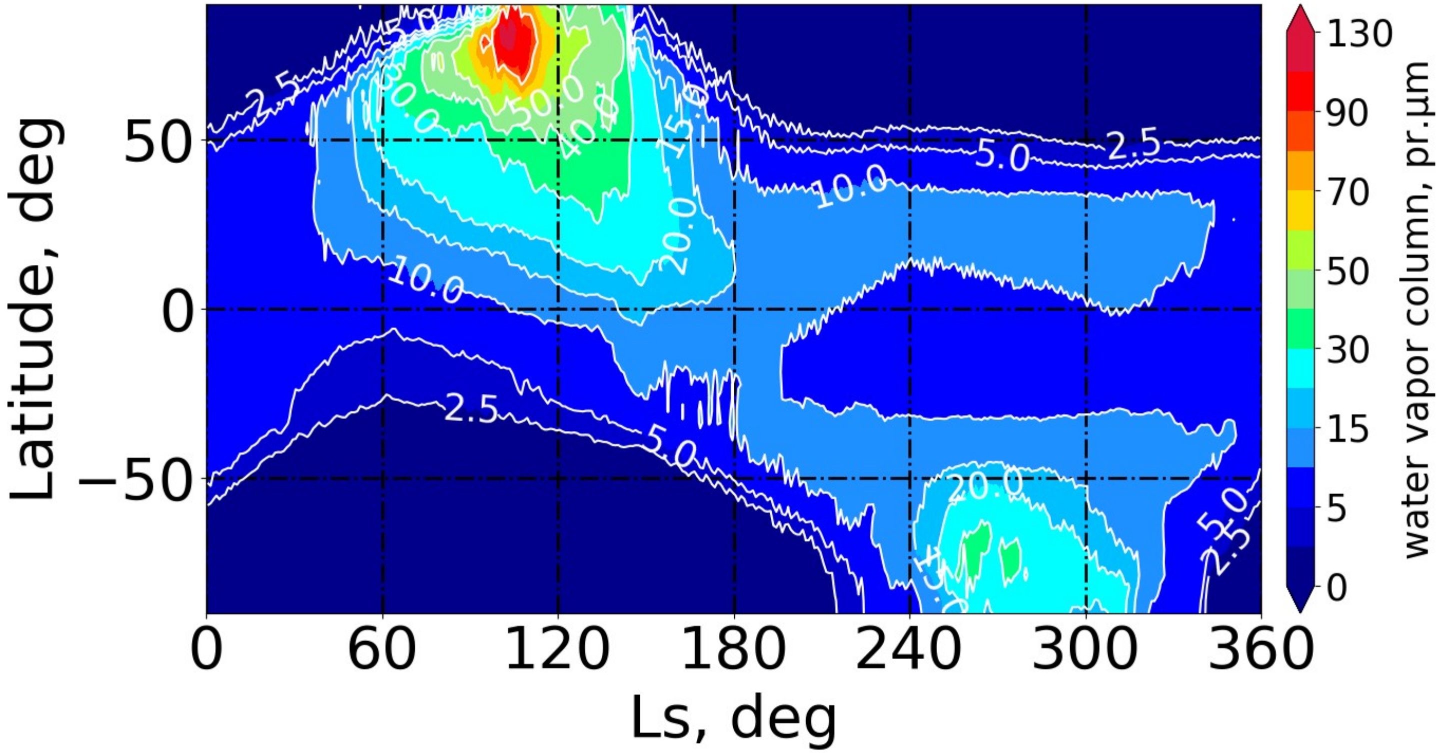


Water vapour cycle

GCM Vertical Res~2.5km

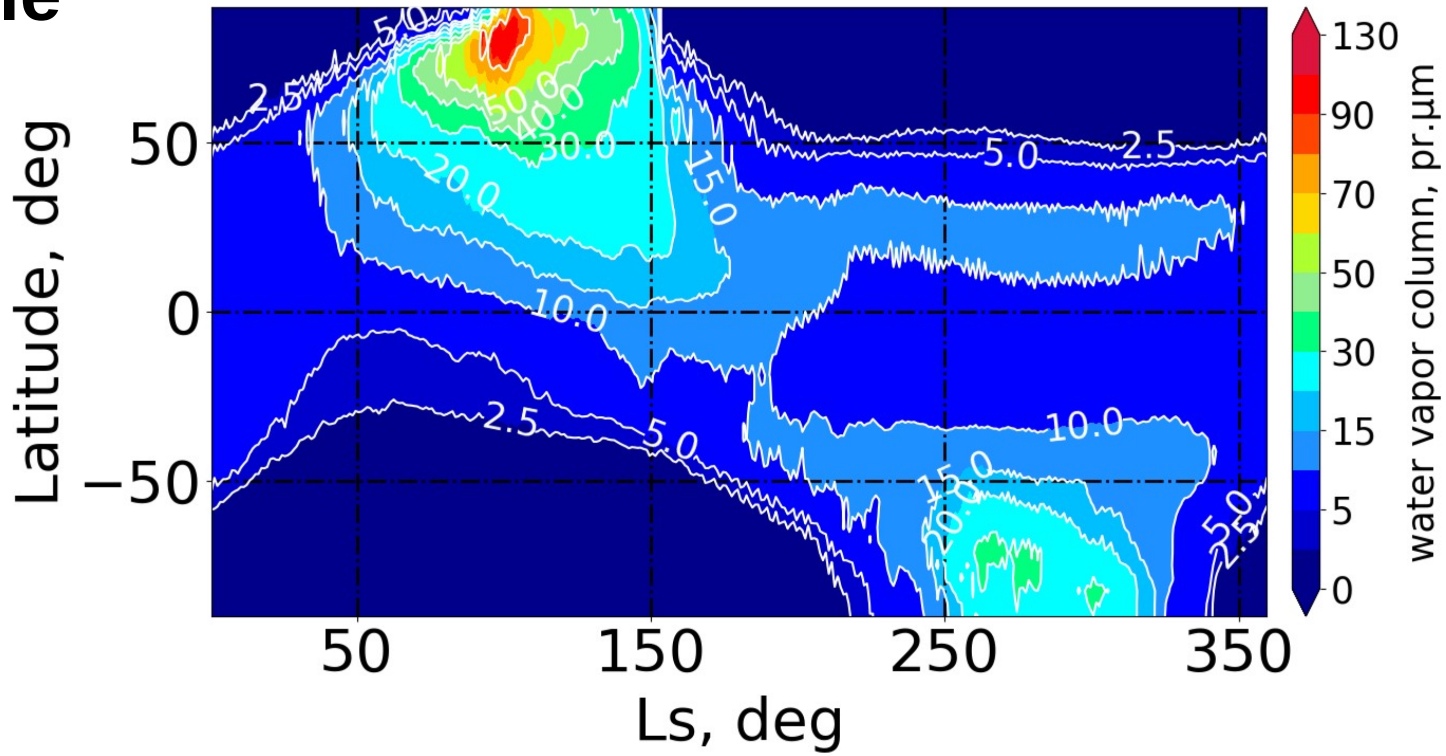


GCM Vertical Res~1.2km

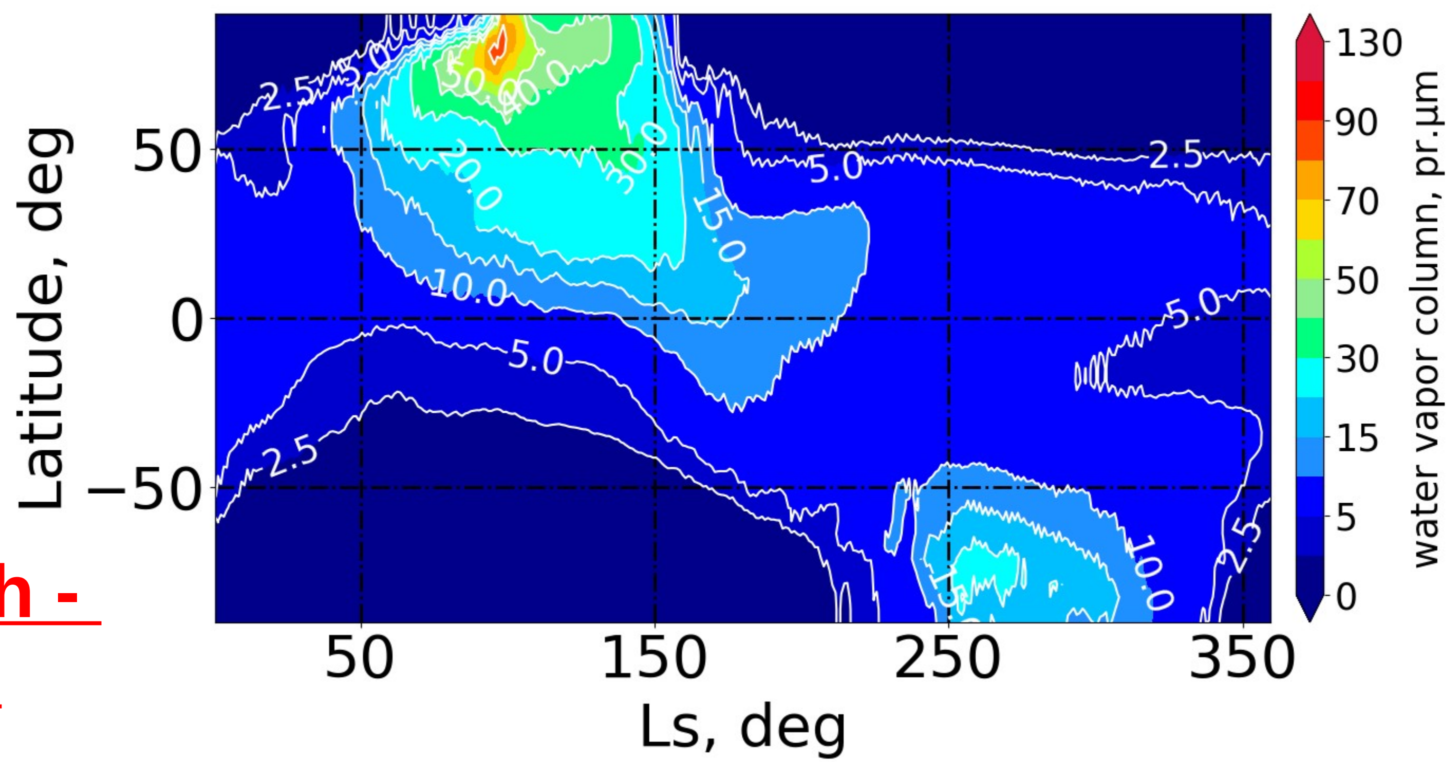


Water vapour cycle

GCM
Vertical
Res~2,5km

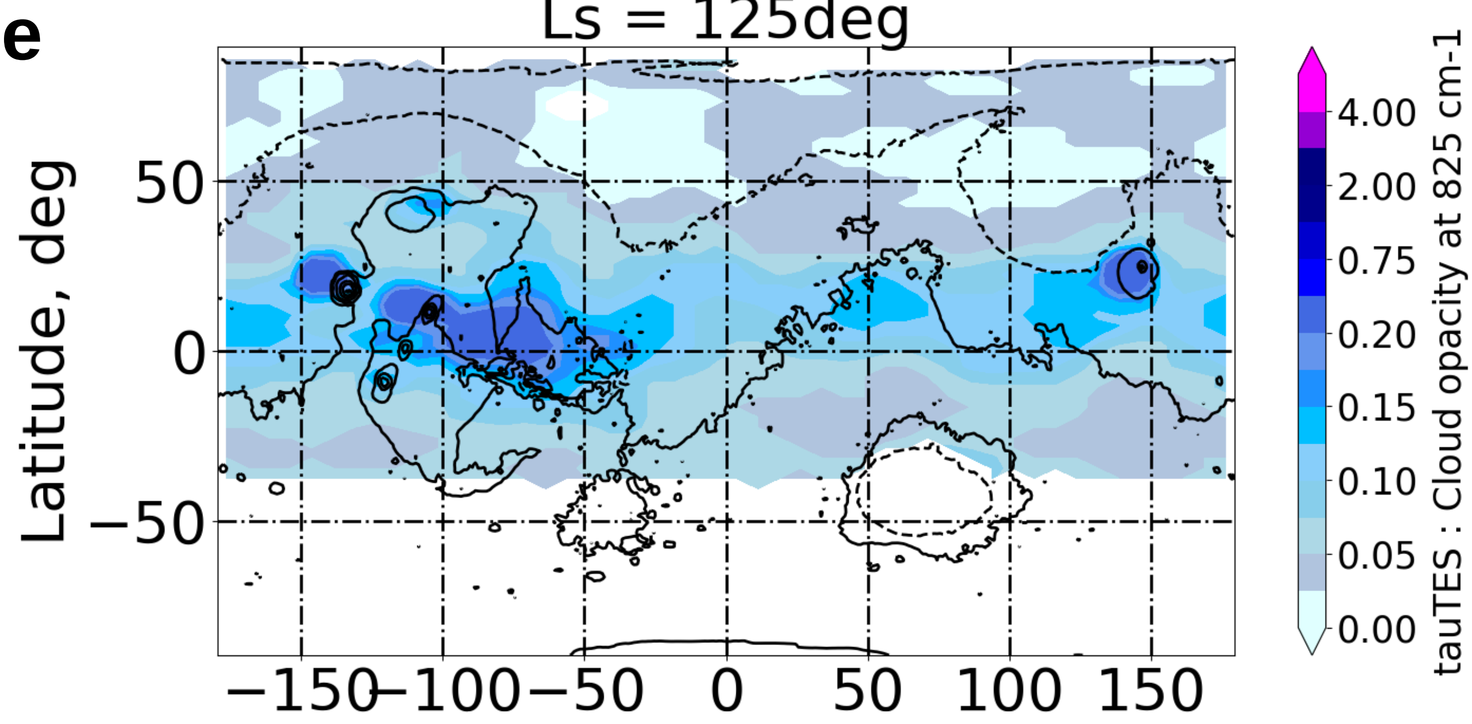


GCM
Vertical
Res~1,2km
<u>Improved Coupling Particle growth - sedimentation</u>

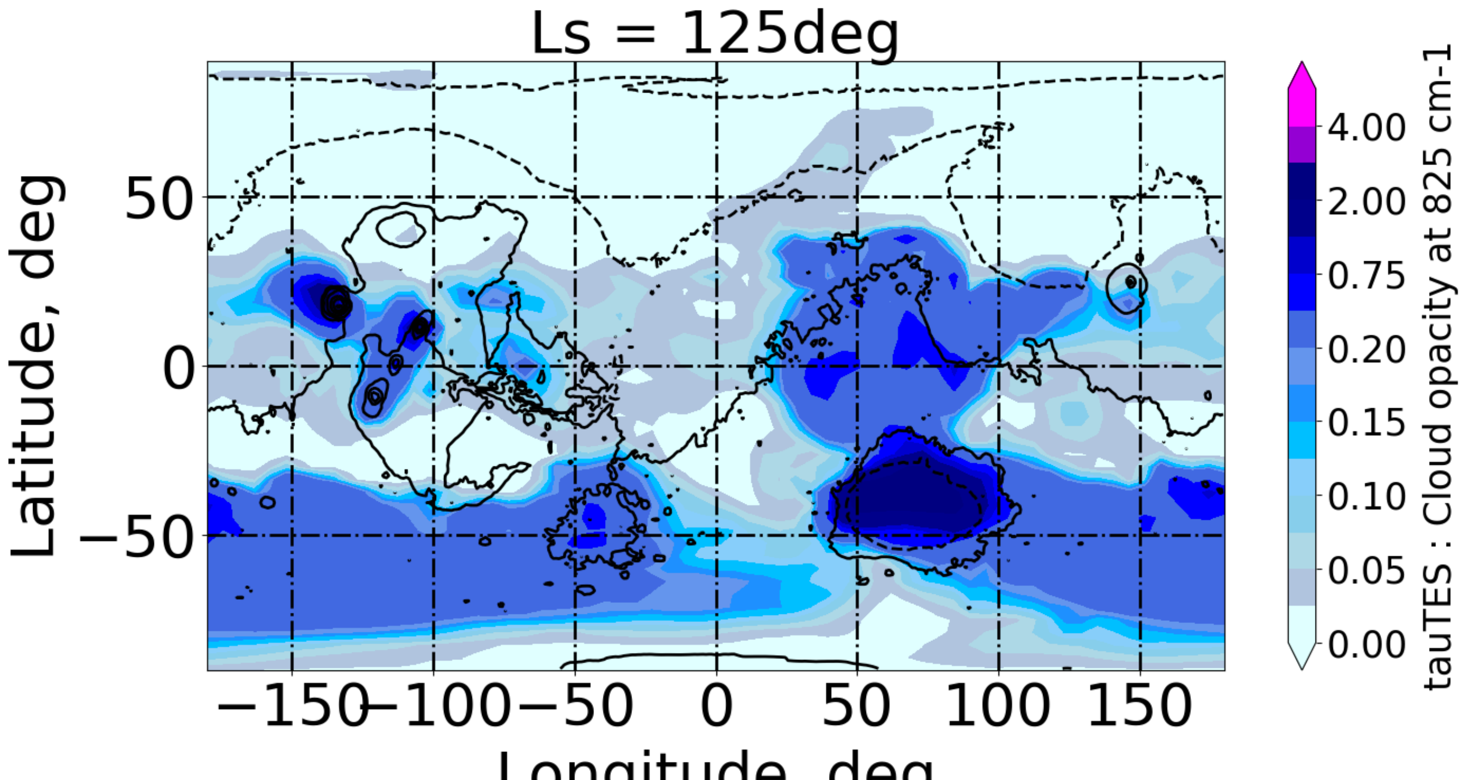


Water cloud cycle

TES



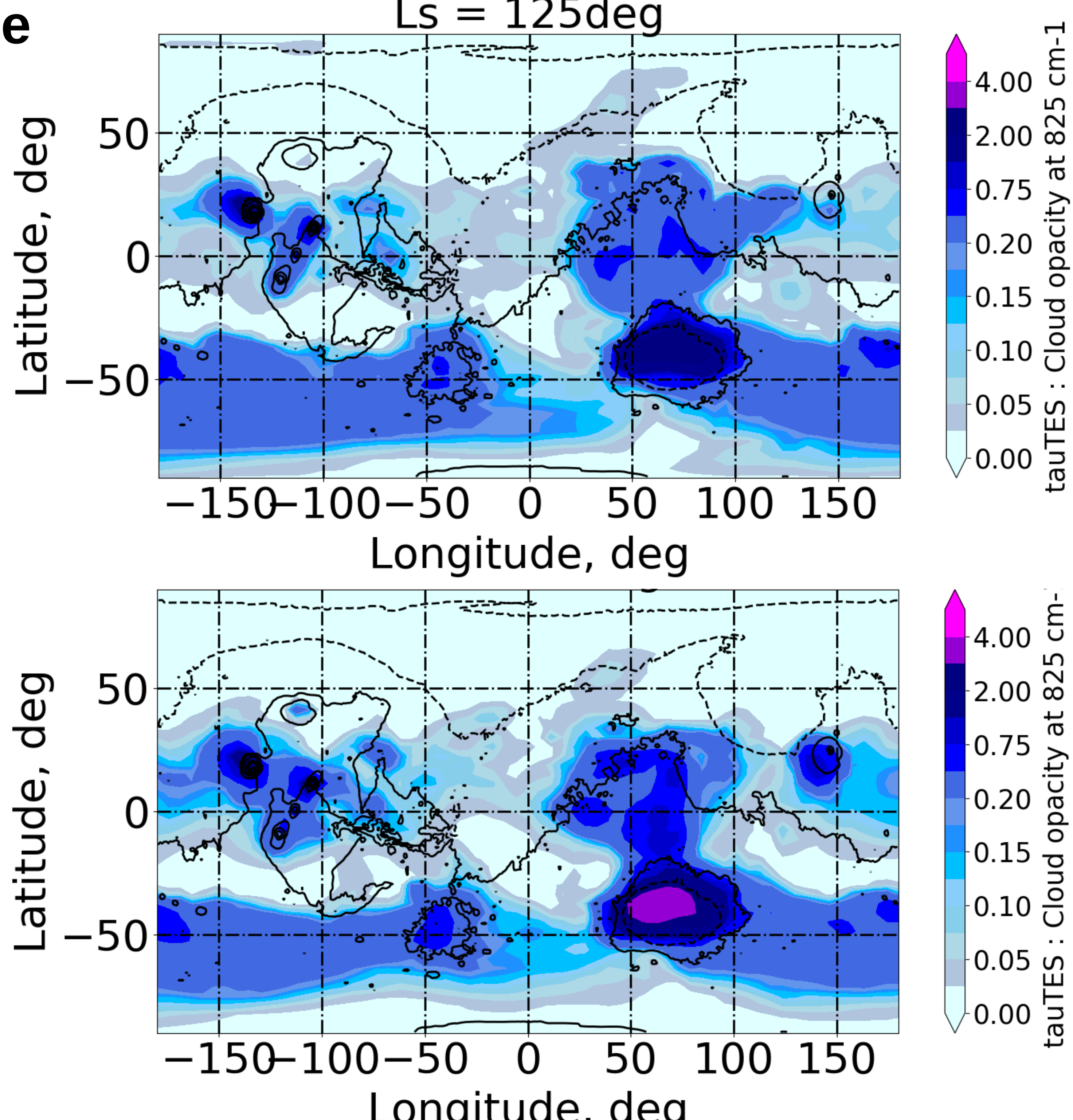
GCM Vertical Res~1.2km



Water cloud cycle

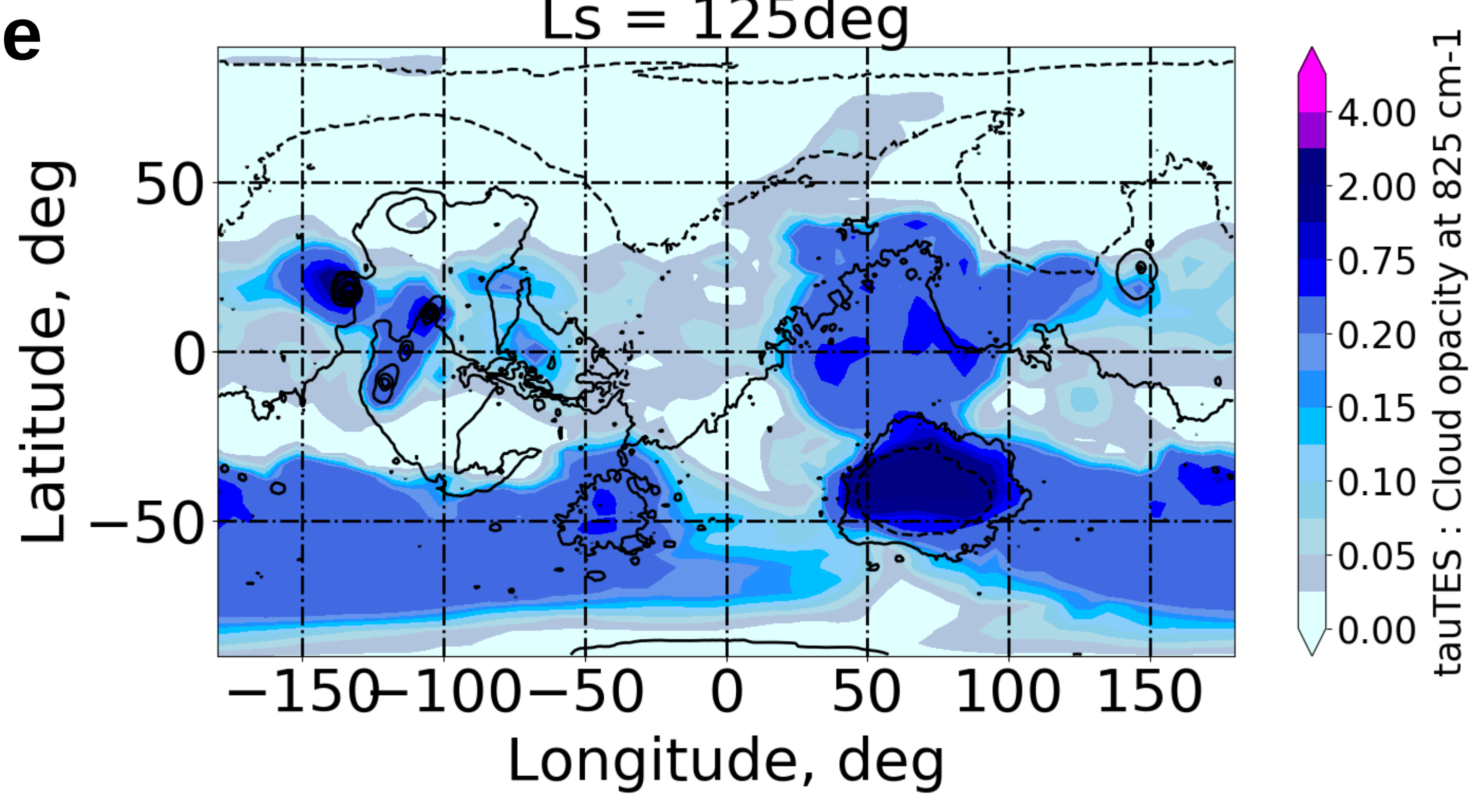
GCM Vertical Res~2.5km

GCM Vertical Res~1.2km



Water cloud cycle

GCM
Vertical
Res~2,5km



GCM
Vertical
Res~1,2km
Improved
Coupling
Particle growth -
sedimentation