金星大気放射伝達モデルの開発: Influence of CO_2 line profiles on the equilibrium temperatures

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Objectives

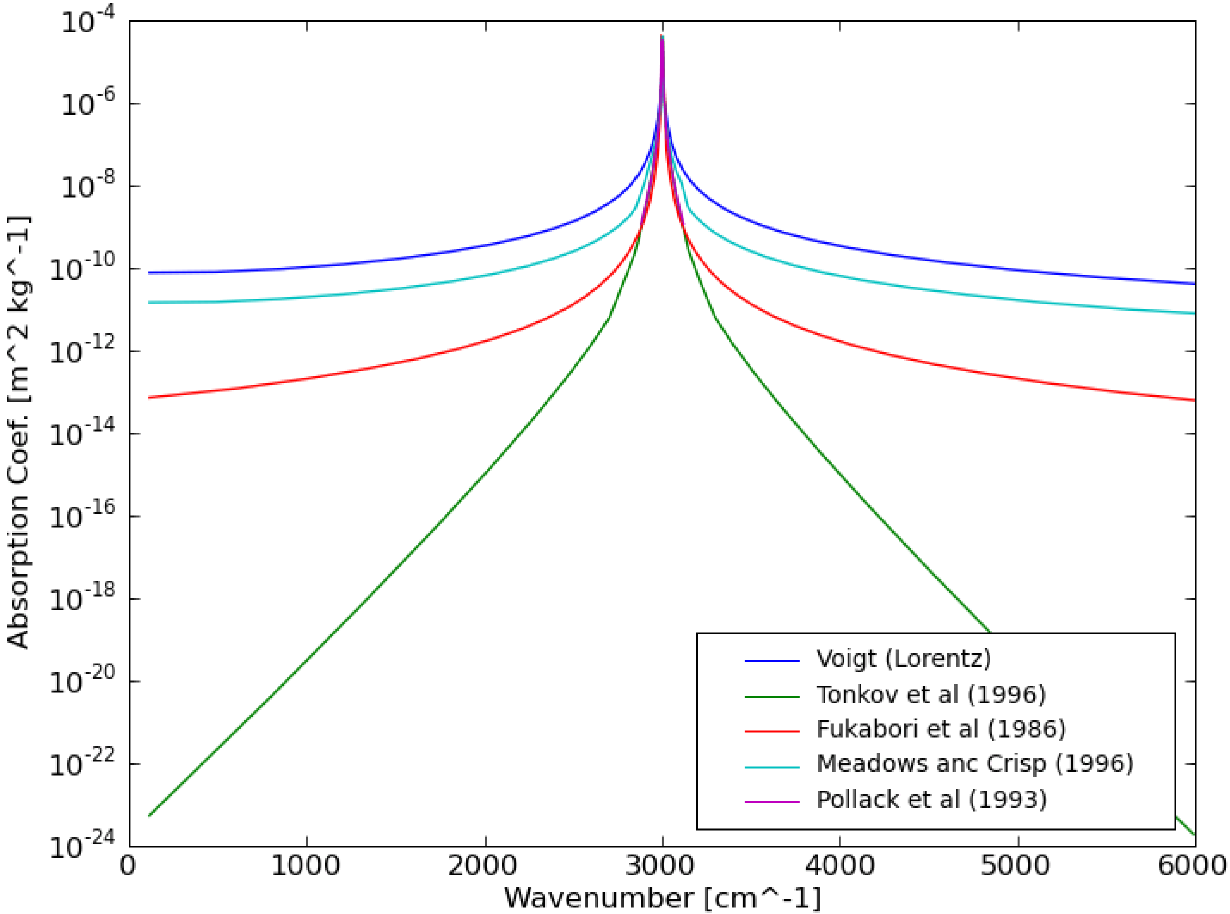
- Improvement of the dynamical model of the Venus atmosphere requires a an infrared radiative transfer model applicable to the Venus lower atmosphere.
  - The radiative process is extremely simplified by the Newtonian cooling in the present Venus GCMs.
  - However, this simplification cannot be justfied since the Venus atmosphere is optically quite thick (92 atm CO_2).
- In order to determine a reasonable CO_2 line profile, temperature distributions in the radiative and radiative-convective equilibrium are calculated for the following CO_2 line profiles:
  - Voigt (Lorentz) profile
  - Pollack et al. (1993)
  - Tonkov et al. (1996)
  - Fukabori et al. (1986)
  - Meadows and Crisp (1996)

Absorption line profile

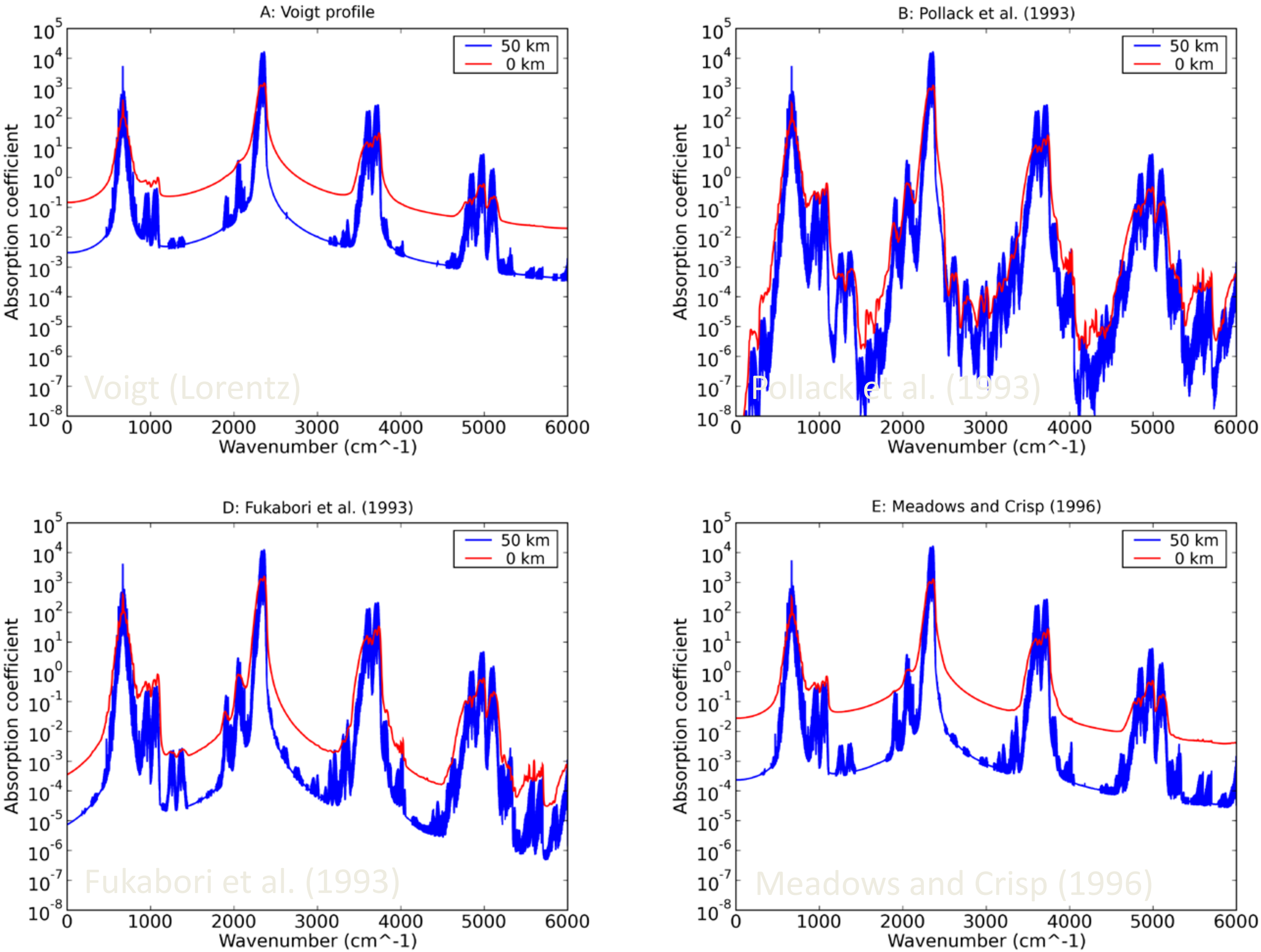
- CO_2
  - Voigt (Lorentz) profile near line center (Goody and Yung, 1989)
  - Sub-Lorentz profile in wing regions (Burch et al., 1969)
    - Depends on temperature and absorption bands.
    - Not uniquely determined.
  - Continuum absorption due to CO_2-CO_2 collisions cannot be neglected in the Venus lower atmosphere (Moskalenko et al., 1979)
- H_2O
  - Super-Lorentz profile (Goody and Yung, 1989)
  - However, the profile of H_2O is assumed to be Lorentzian in the present study in order to focus on the influence of the CO_2 line profiles on the equilibrium temperature distributions.

CO_2 line profiles

(92 atm, 730 K)



Absorption coefficients due to CO_2



Model

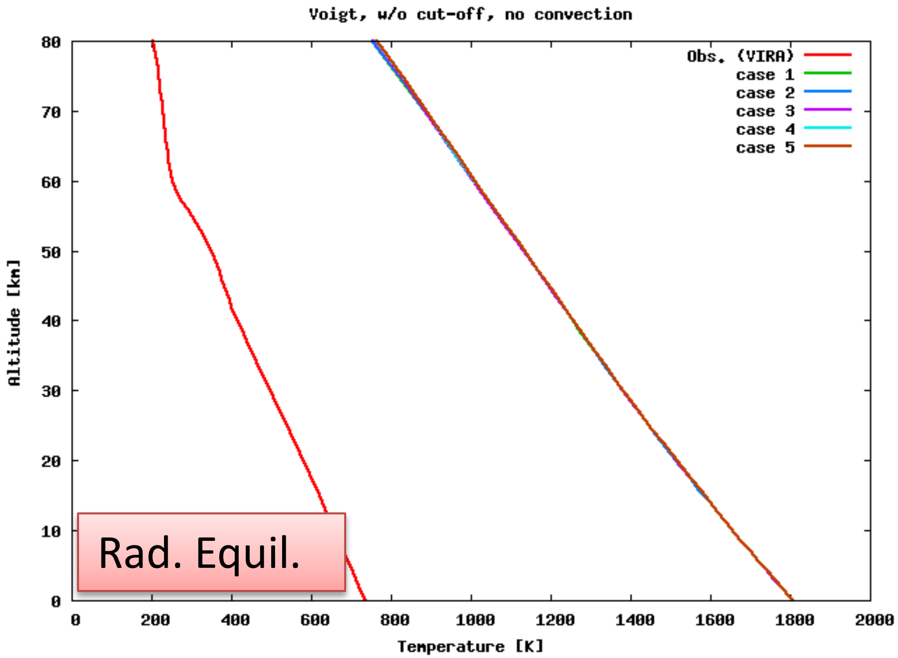
- Based on the correlated *k*-distribution method.
  - Wavenumber region: 0-6000 cm^{-1} (30 channels)
  - CO_2, H_2O, and H_2SO_4 cloud are taken into account.
  - Absorption coefficient is calcluated by the line-by-line method with data provided by HITEMP and HITRAN 2004.
- Vertical region
  - 0–80 km, divided into 50 layers.
- Solar heating
  - The solar heating profile is fixed to the distribution of the absorbed solar energy averaged over the sphere (Tomasko et al., 1980).
- Convection
  - The heat transport by free convection is represented by the vertical eddy diffusion which is based on the mixing length theory.
- Time integration
  - From a constant temperature profile (300 K).

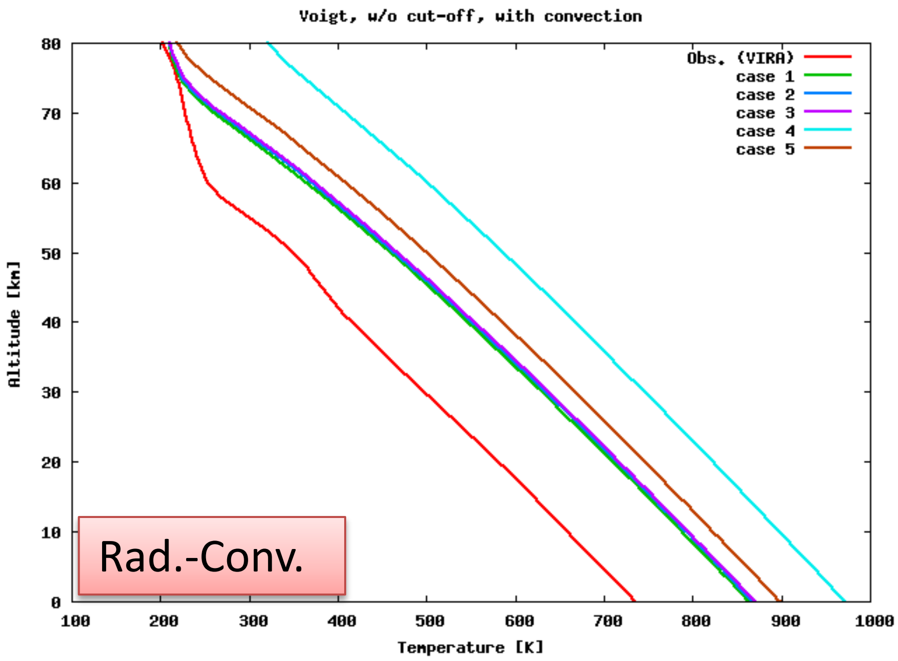
Conditions

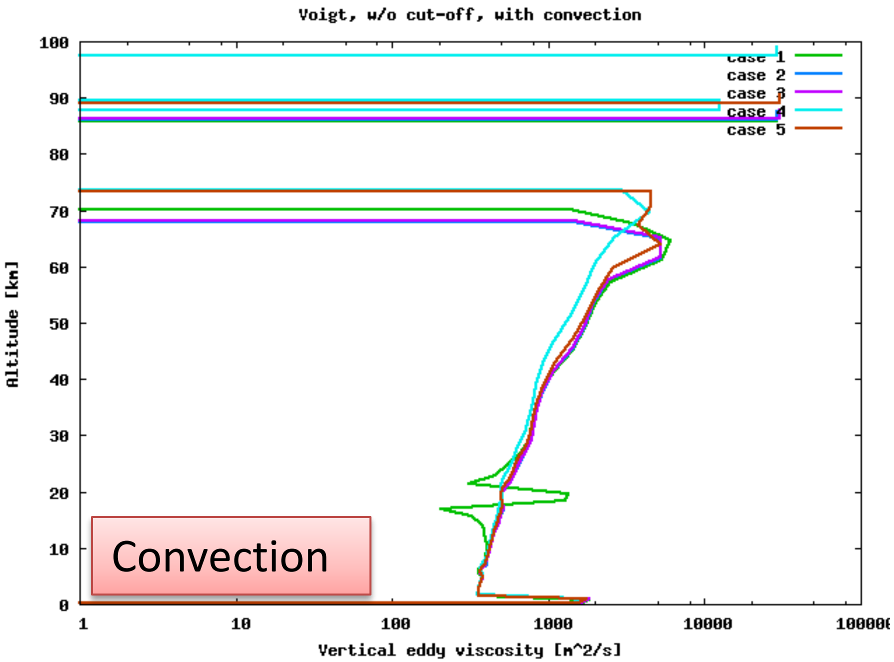
- Case 1: Absorption due to CO_2 only.
- Case 2: Case 1 + pressure induced absorption caused by CO_2 pairs.
- Case 3: Case 2 + absorption due to H_2O
- Case 4: Case 3 + cloud ($k*\rho$ const.)
  - Samuelson et al. (1975)
  - Matsuda and Matsuno (1978)
- Case 5: Case 3 + cloud (k const.)

- Total opacity of the cloud is fixed to 10.

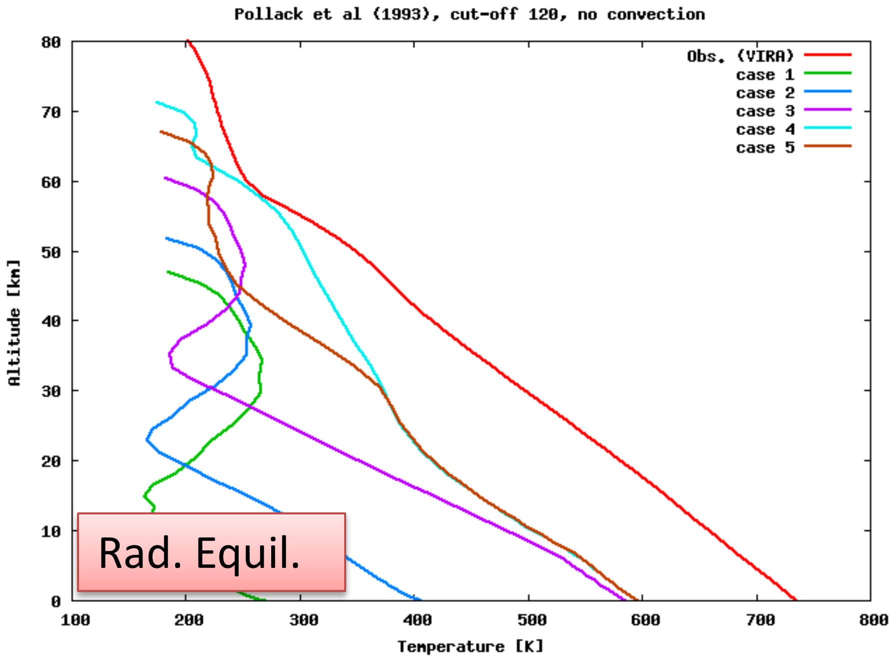
Equil. temperatures
Voigt (Lorentz)
w/o line cut-off

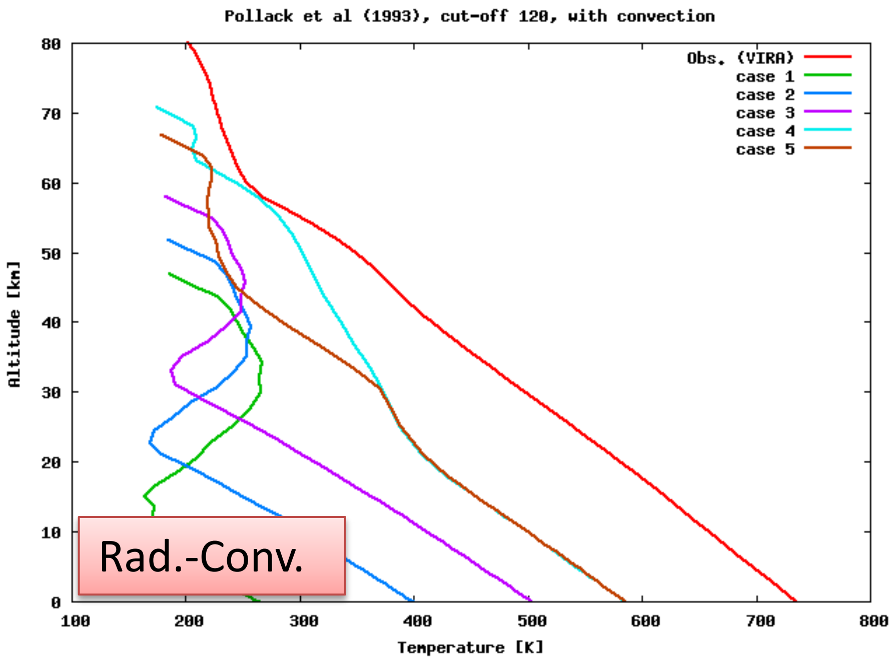


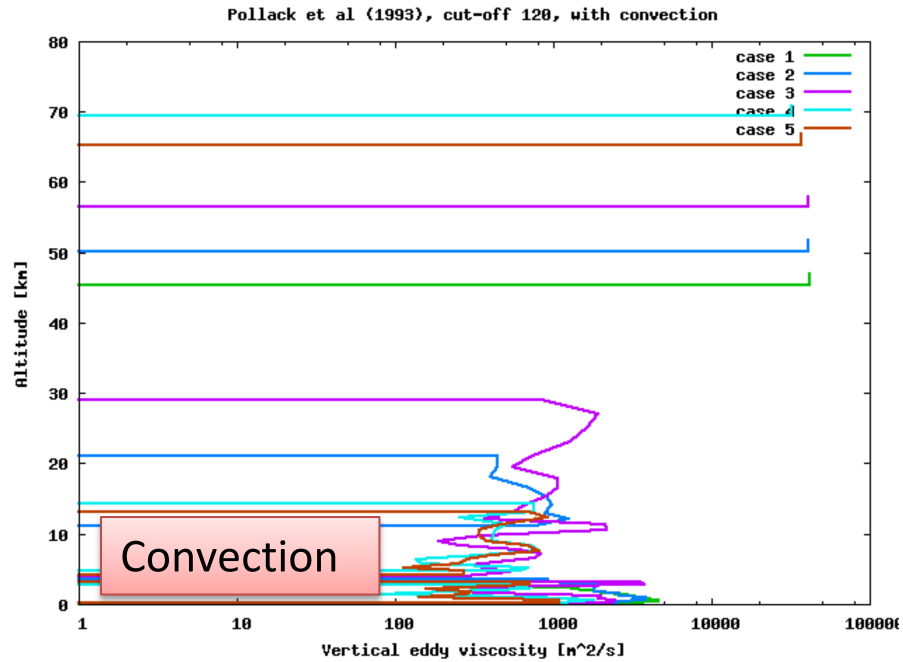




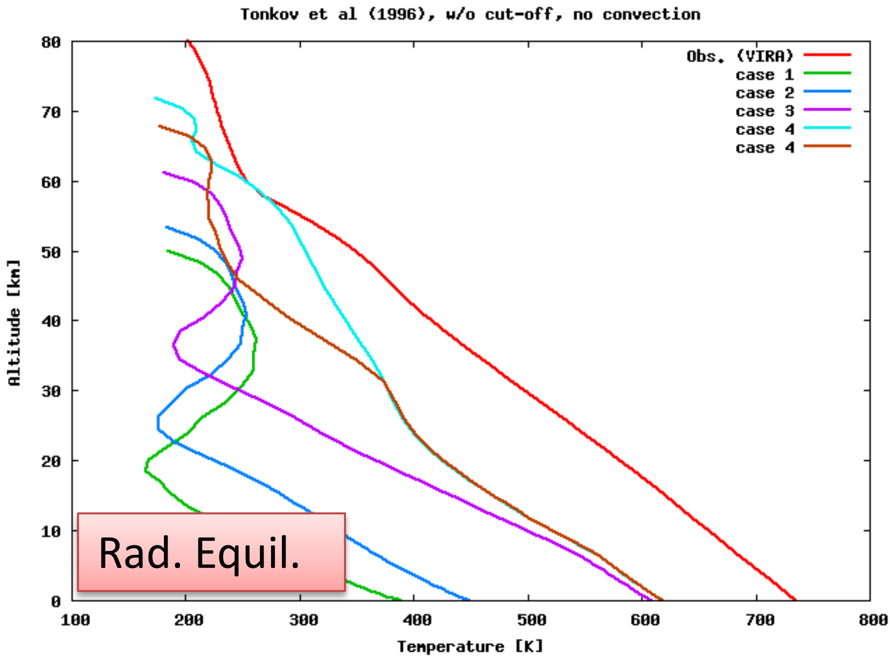
Equil. temperatures Pollack et al. (1993) 120 cm^{-1} cut-off

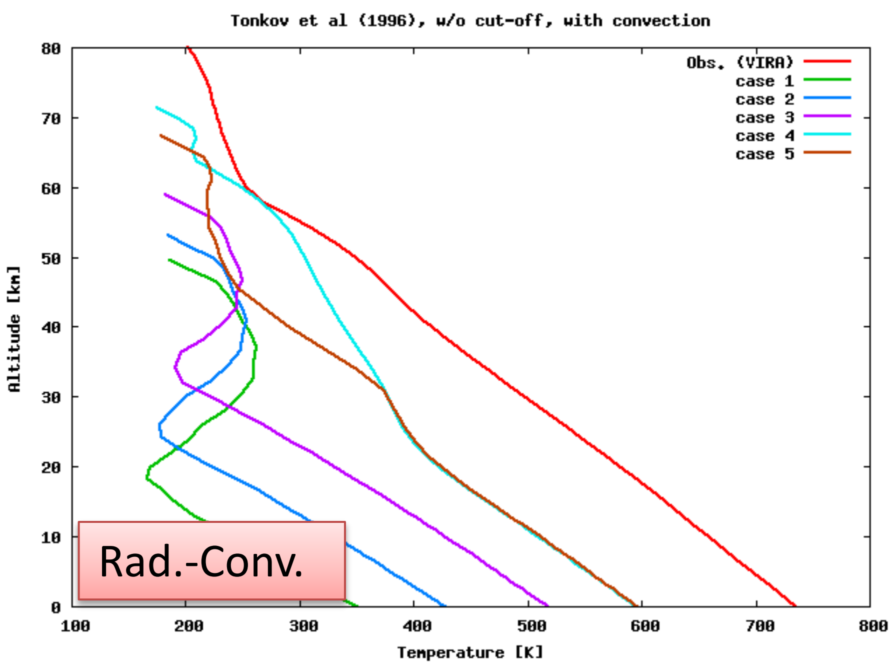


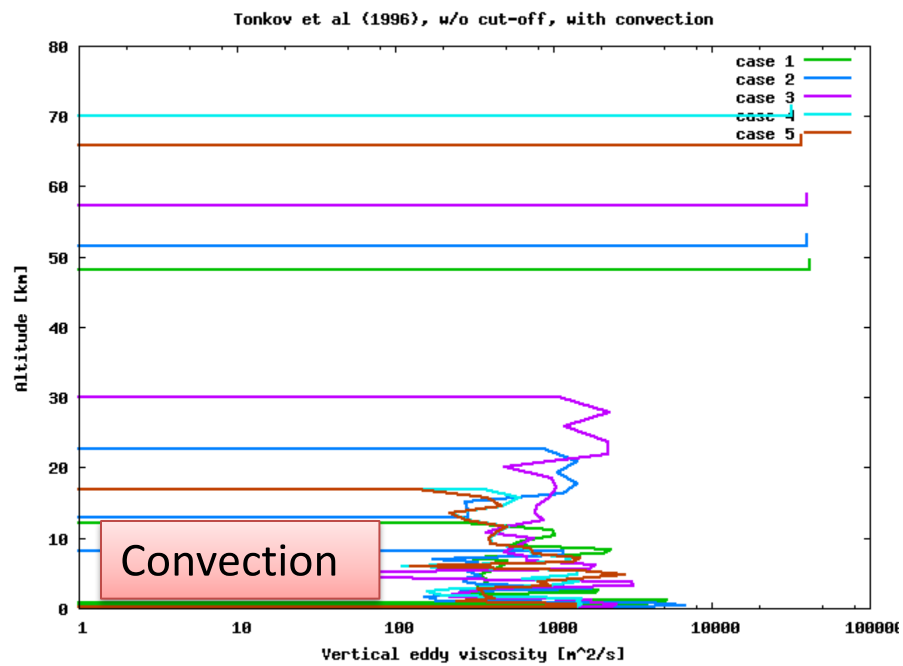




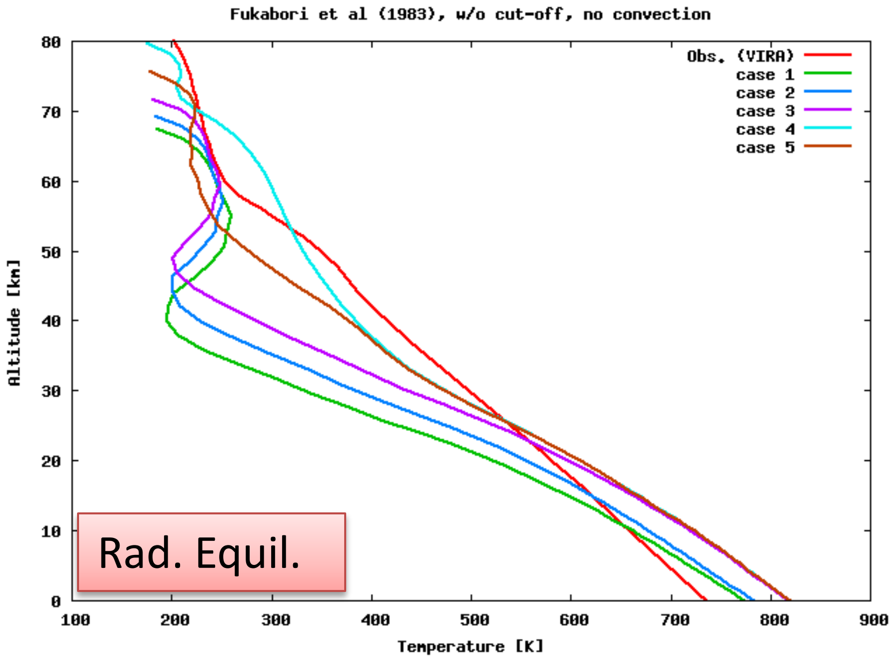
Equil. temperatures Tonkov et al. (1996) w/o line cut-off

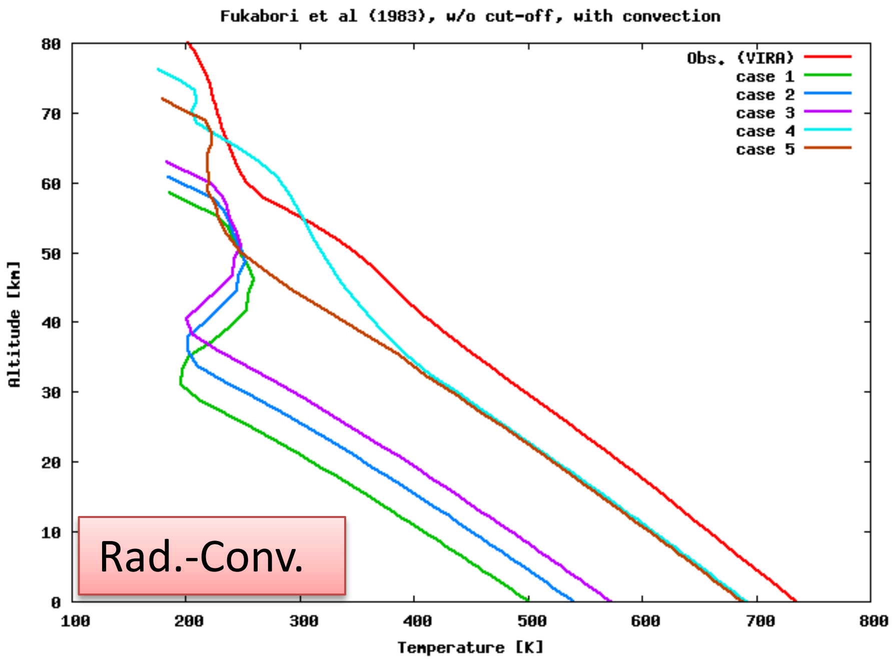


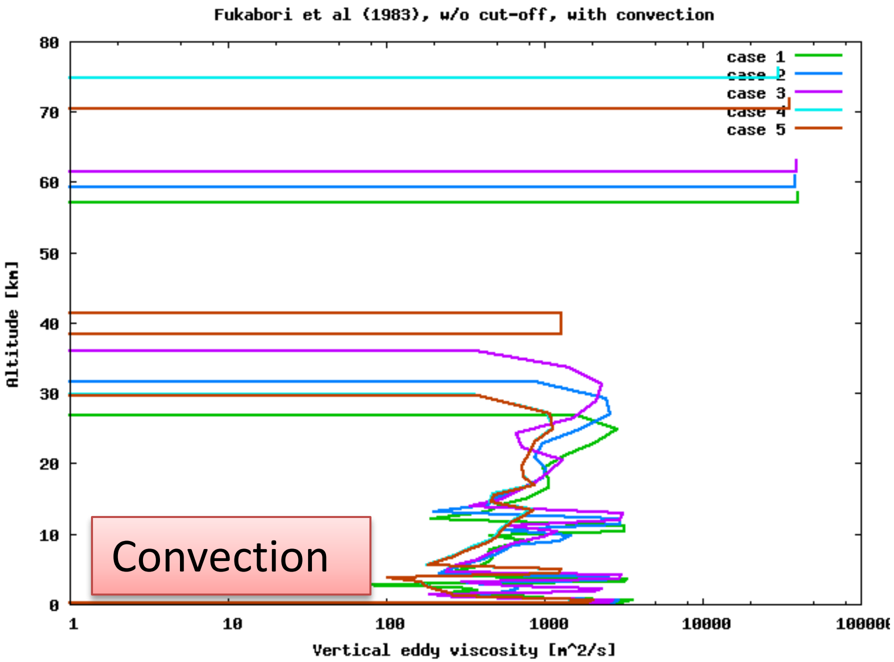




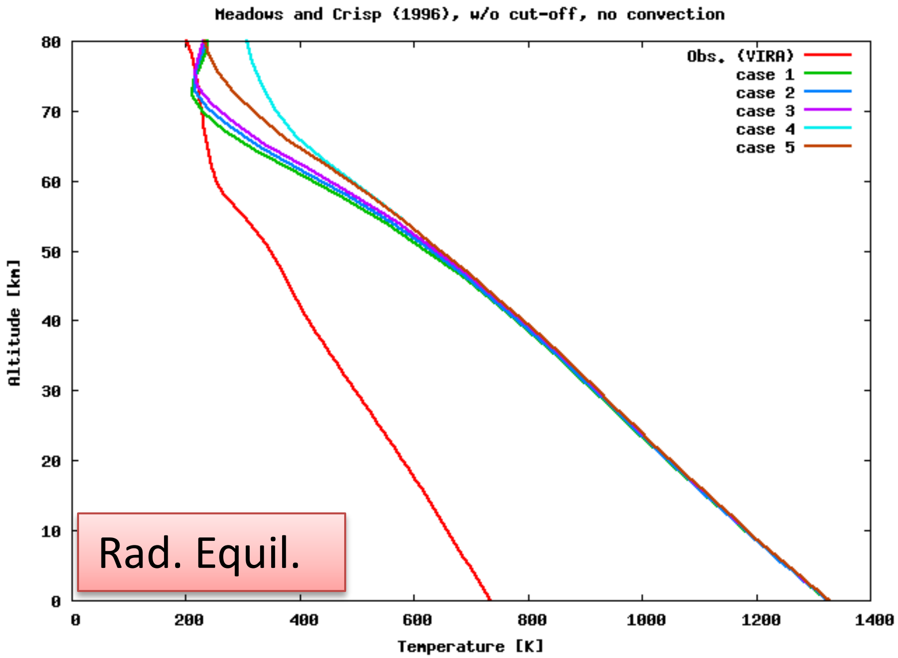
Equil. temperatures Fukabori et al. (1983) w/o line cut-off

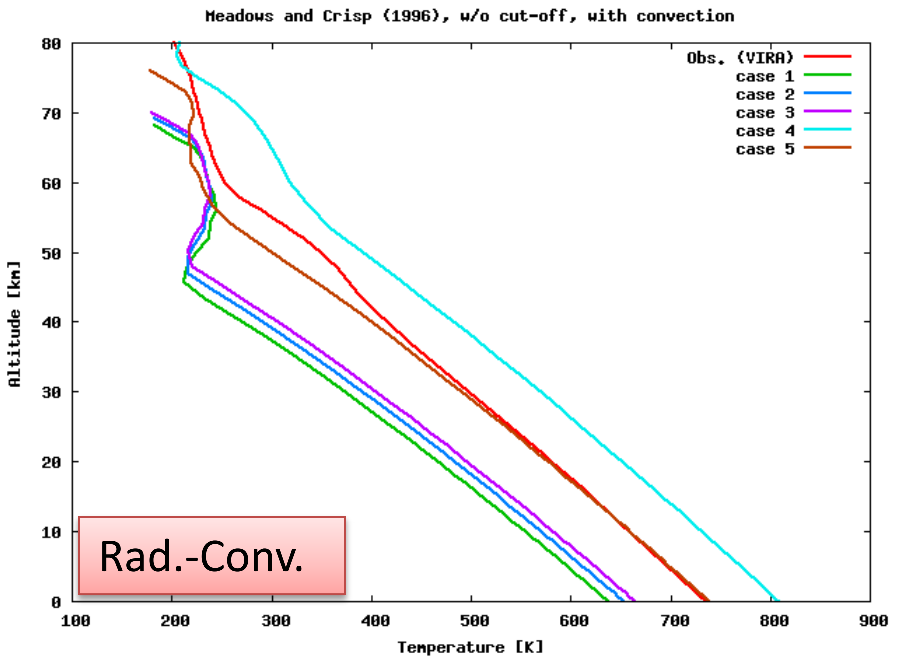


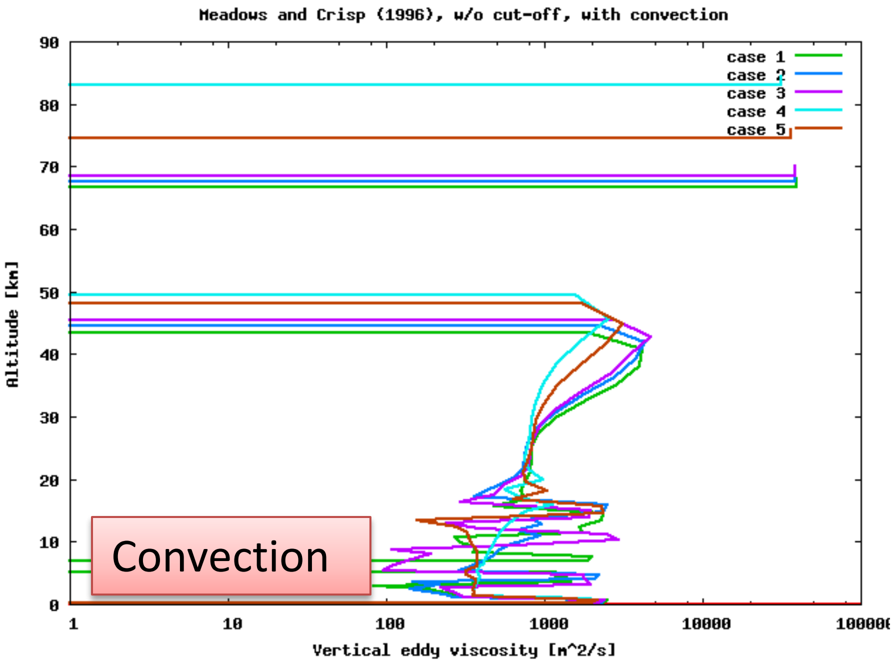




Equil. temperatures Meadows & Crisp (1996) w/o line cut-off







Summary

- Temperature distributions close to the observed one can be obtained by the CO_2 line profiles of Fukabori et al. (1983) and Meadows and Crisp (1996).
- A realistic radiative transfer model may be constructed by using an intermediate CO_2 line profile between Fukabori and Meadows profiles.
- Radiative equil. temperatures are:
  - Super-adiabatic from the surface to 10-80 km altitudes (depends on the assumed CO_2 line profiles).
  - Considerably higher than the observation (820-1300 K at the surface).
- Rad.-Conv. equil. temperatures are:
  - Convective from the surface to 30-50 km altitudes for the Fukabori and Meadows profiles.
  - Strongly affected by the temperature at the bottom of the cloud layer (in contrast to those in the rad. equil.).