New column boundary layer model integrations for the Viking landers

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- The Viking landers made good temperature and <u>wind</u> observations at 1.6 m, and also observations of visible optical depth τ, but not humidity directly.

- Viking orbiters provided surface temperatures and column water contents (PWC from the Mars Atmospheric Water Detectors, MAWD).

- Fog, frost and adsorption have been suggested to occur at both VL's.

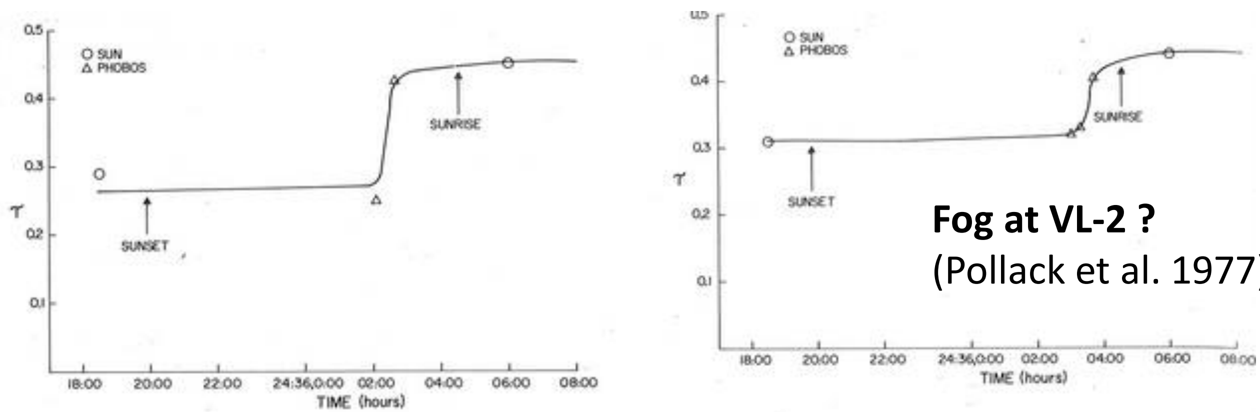
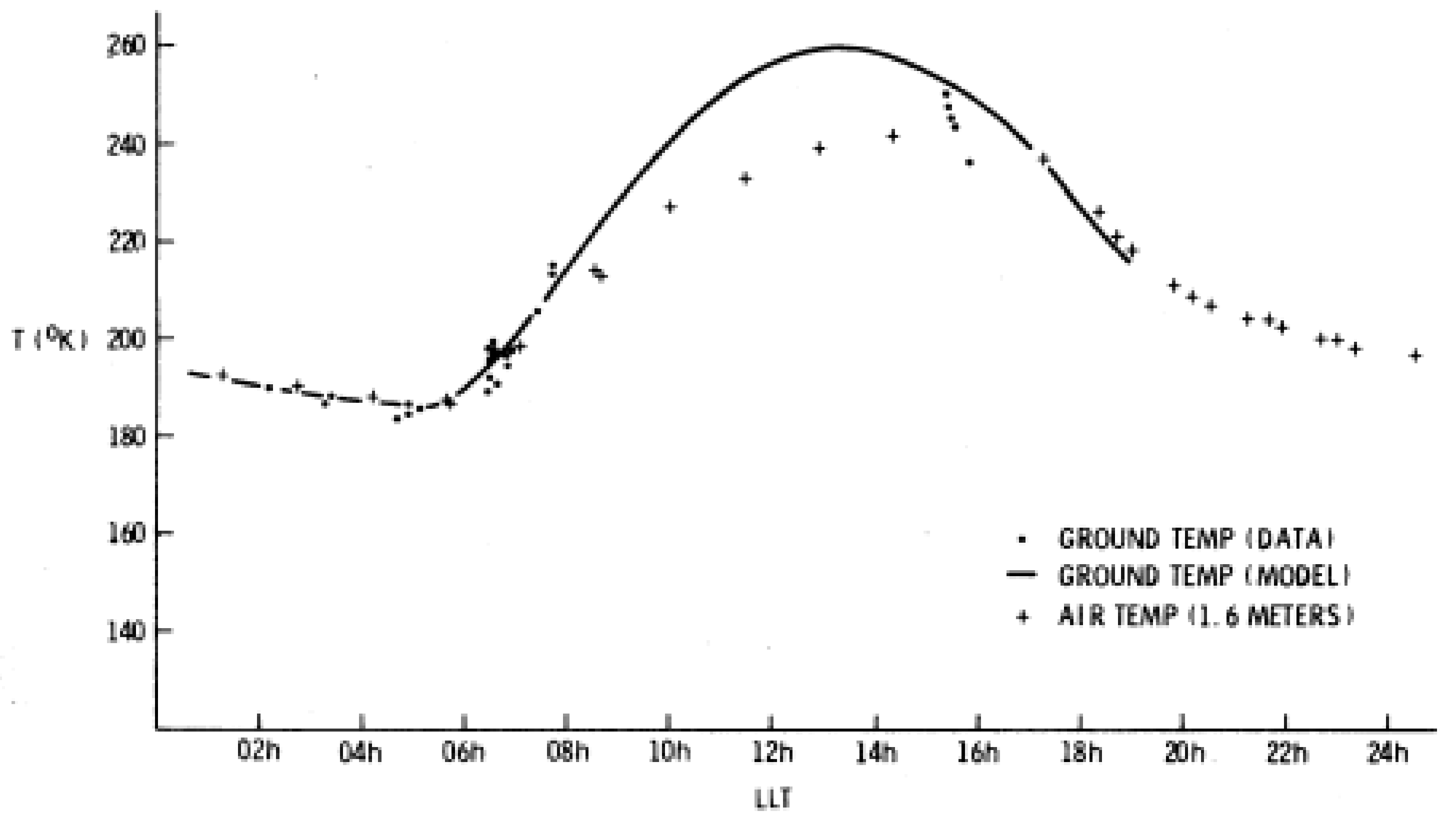


Fig. 3. (*a*) Variation of optical depth from the late afternoon of sol 24 to the early morning of sol 25 at the VL-2 site, as inferred from photographs of Phobos (triangles) and the sun (circles). The time coordinate gives hours in terrestrial units. (*b*) Similar data obtained on sols 28 and 29 at the VL-2 site.

Fog at VL-2 ?
(Pollack et al. 1977)

- **What would a modern column model predict for the diurnal cycles of temperature, wind and moisture at the Vikings?**

VL-1: Comparison of the first directly measured air temperatures with ground temperatures (by infrared from orbit). All observations on sols 0 to 3. (Hess et al., Science 27 Aug 1976)



VL-1: T-inflection at 02LT: if fog → $q_{sat}(T,p)$ at 1.6m, const. → PWC,lander < MAWD,
(Jakosky et al. 1997) → **depletion of near-surface moisture at night?**
by frost or adsorption, or both?

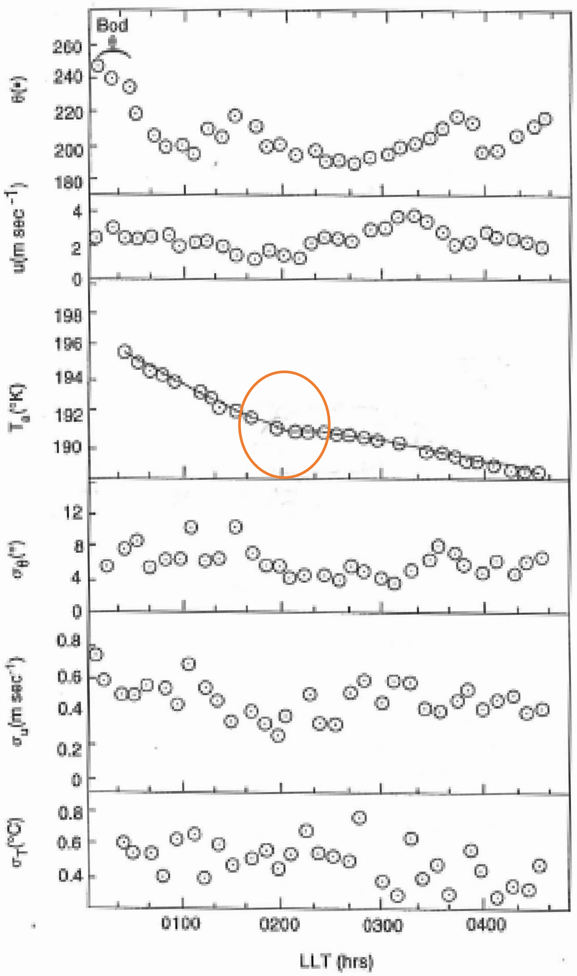


FIG. 3. Example of inflection in the nighttime atmospheric temperatures as measured at the VL-1 site. Additional meteorology parameters also are shown; from top, they are wind direction, wind speed, atmospheric temperature, and the standard deviations of the three parameters. Each is shown as a function of local time of day, referenced to local midnight, for VL-1 sol 21. (From Ryan *et al.* 1982.)

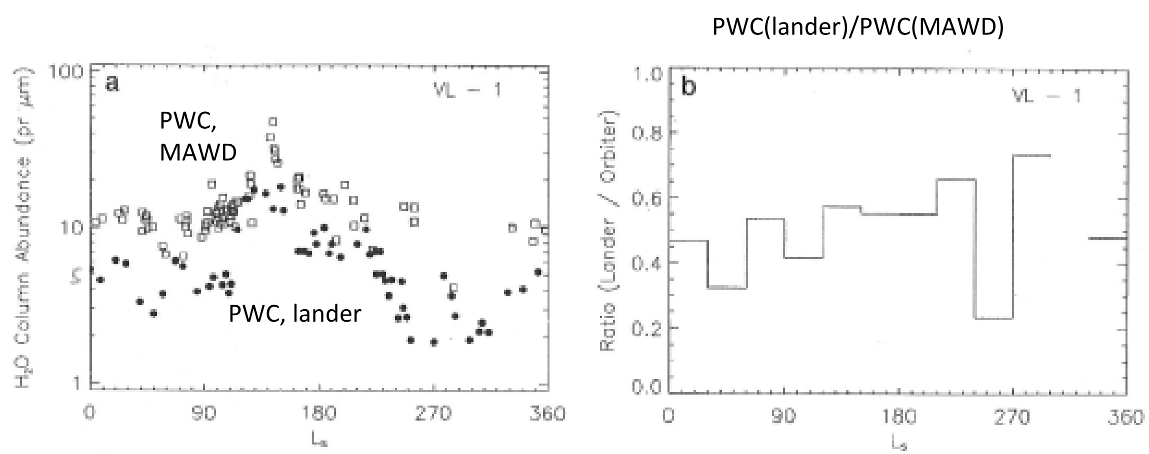


FIG. 1. (a) Measurements of the atmospheric water vapor abundance at the VL-1 site. Open boxes are orbiter MAWD measurements of the column abundance, shown as daily averages of values with a 5° box centered on the landing site. Closed circles are the surface number density inferred from the atmospheric temperature nighttime inflections, multiplied by the nominal atmospheric scale height of 10 km for comparison with orbiter measurements. (b) Ratio of the orbiter-derived abundance to the lander-derived abundance, averaged over 30° of L_s.

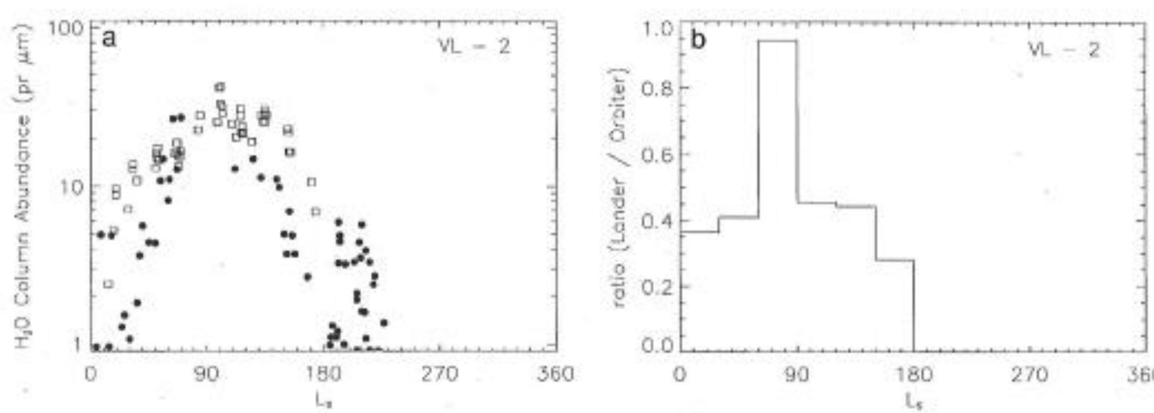


FIG. 2. (a) Measurements of the atmospheric water vapor abundance at the VL-2 site. Symbols are the same as in Fig. 1. (b) Ratio of the orbiter-derived abundance to the lander-derived abundance, averaged over 30° of L_s.

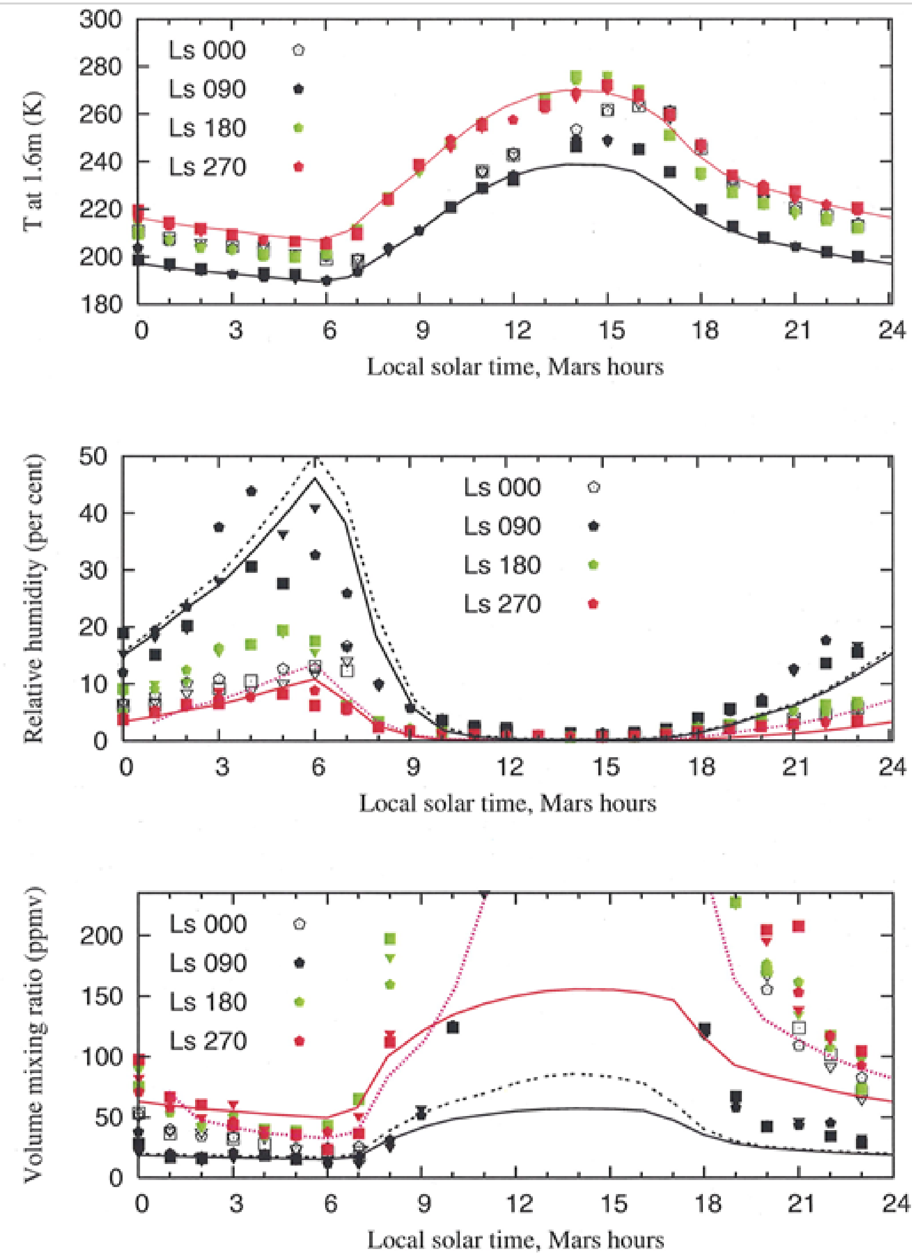
MSL REMS-H obs at 1.6 m: T, RH, VMR
3 sols at four seasons:

UH/FMI 1-D model, cold and warm season:
Ls 90°: black lines, Ls 270°: red lines
(two adsorption isotherms used:
Fanale and Cannon (1971): dashed, too active?
Jakosky et al. (1997, J97): solid)

Good match with nighttime REMS-H obs, when including adsorption to porous regolith.

No night frost nor fog observed at these sols

(because adsorption removes a lot of moisture from the air in the evening)



1-D model for VL-1, VL-2:

- Similar to the Phoenix version (Savijärvi and Määttänen 2010 QJRMS) but with the MSL model soil scheme of Savijärvi et al. (2016 Icarus).

- **28-layer atmosphere** (mixing length turbulence, Monin-Obukhov surface layer, radiation with CO_2, water vapor, ices and dust active).

- **Prandtl theory slope wind terms, constant basic geostrophic wind V_g**

- **Cloud condensation/sublimation** (latent heats included, clouds/fogs are radiatively active).

- **8-layer soil scheme** (diffusion and adsorption/desorption of water vapor in regolith pores. Surface exchange sensitive to stability and wind. No exchange if porosity is set to 0 (normally 22% for the VL sites).

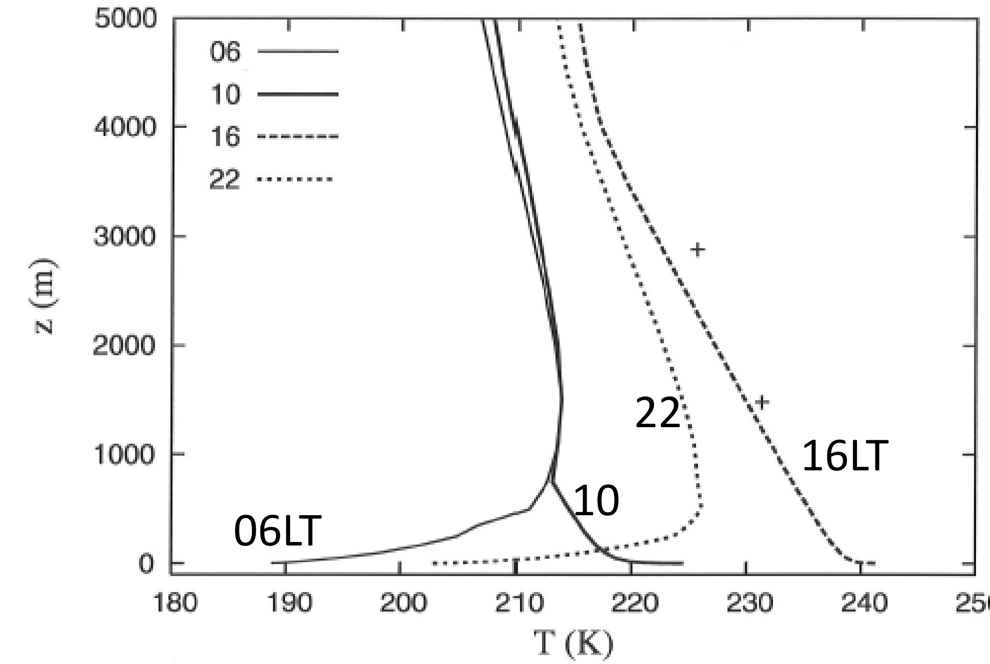
- **Ground ice formation and sublimation** (frost layer cuts off adsorption).

Results:

T(z) 1.6 m - 5 km from the VL-1 simulation at Ls 100°

Two obs points shown from the 1615LT parachute landing of VL-1 at Ls 97°.

T1.6m is within +- 2K of those observed during the first sols of VL-1.

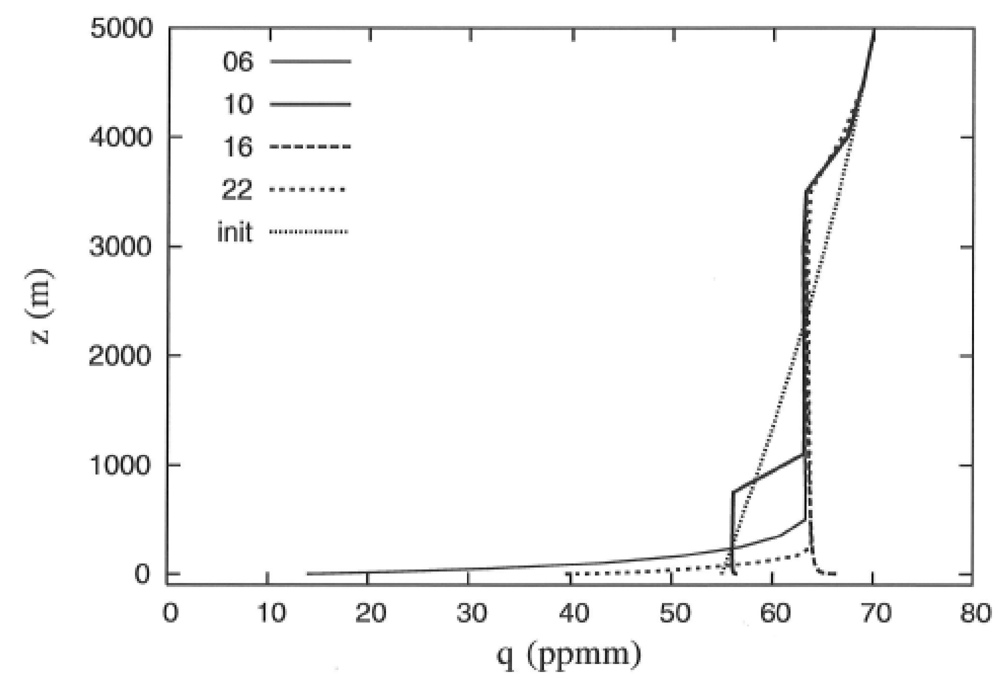


Water vapor mixing ratio q:

Initial q(z) from the Mars Climate Database (MCD) scaled to the local MAWD-observed PWC of 12.5 μm.

Note strong near-surface depletion of q at 22LT (by adsorption, J97 isotherm).

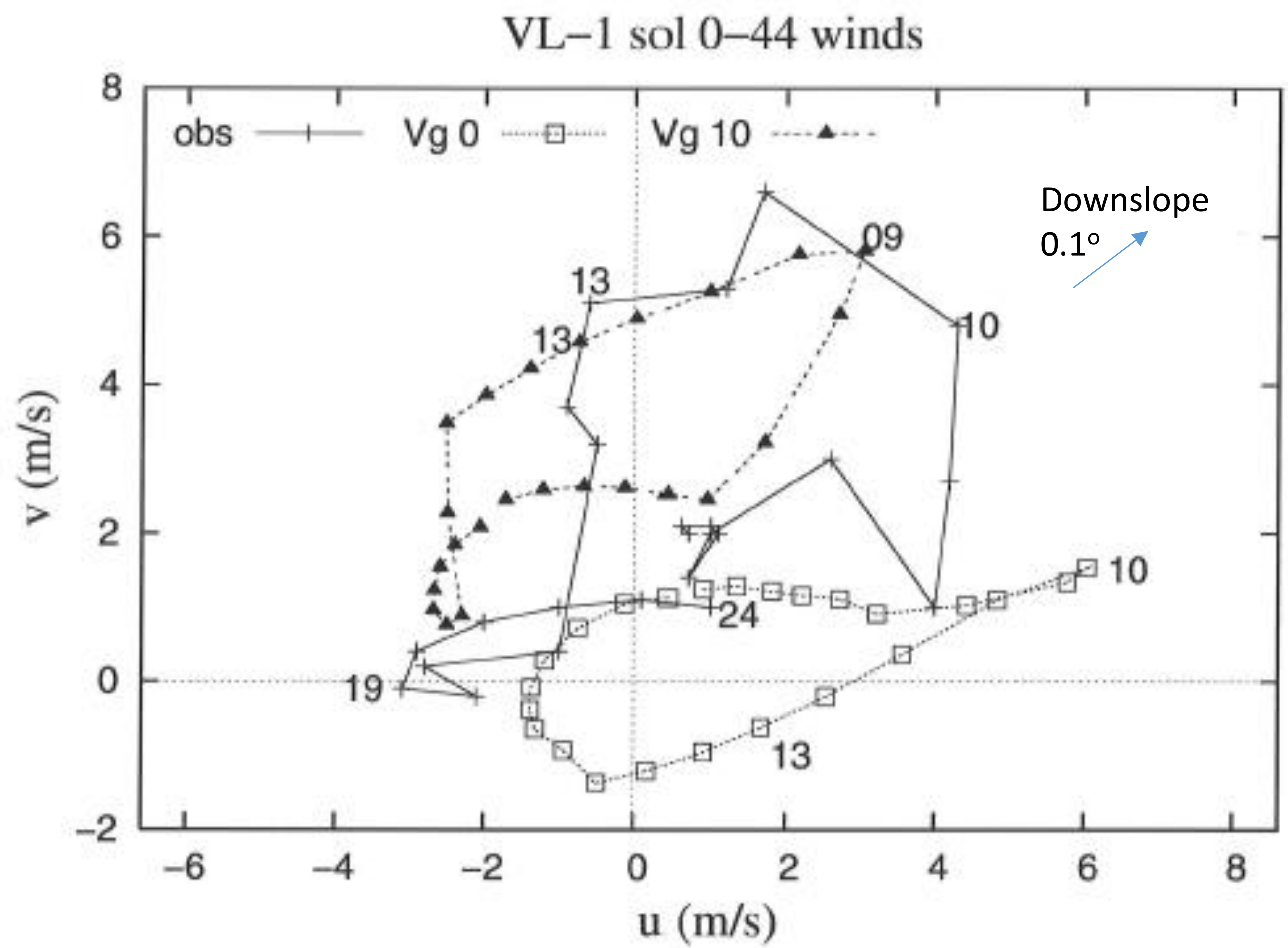
PWC stays at 12.5 μm from sol to sol.



VL-1 mean wind hodograph (Hess et al. 1977) and 1-D simulations

a) $\mathbf{V}_g = 0$ (no basic wind → Prandtl slope winds only, clockwise rotation)

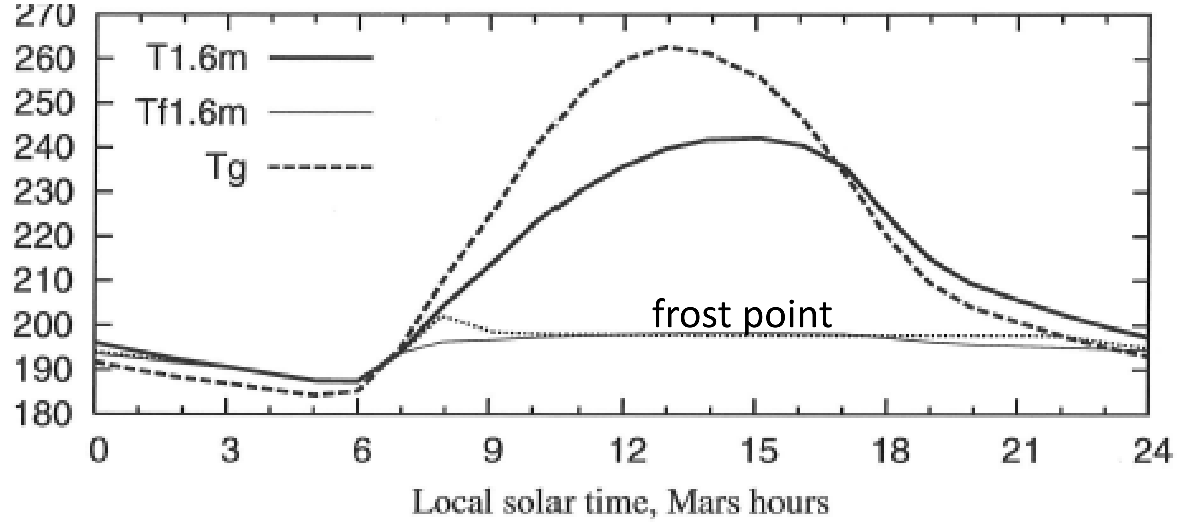
b) $\mathbf{V}_g$ = 10 m/s from SSE (→ daytime anticlockwise rotation, as observed)



VL-1 model diurnal cycles at 1.6 m and surface:

T at 1.6 m and T_g (K):

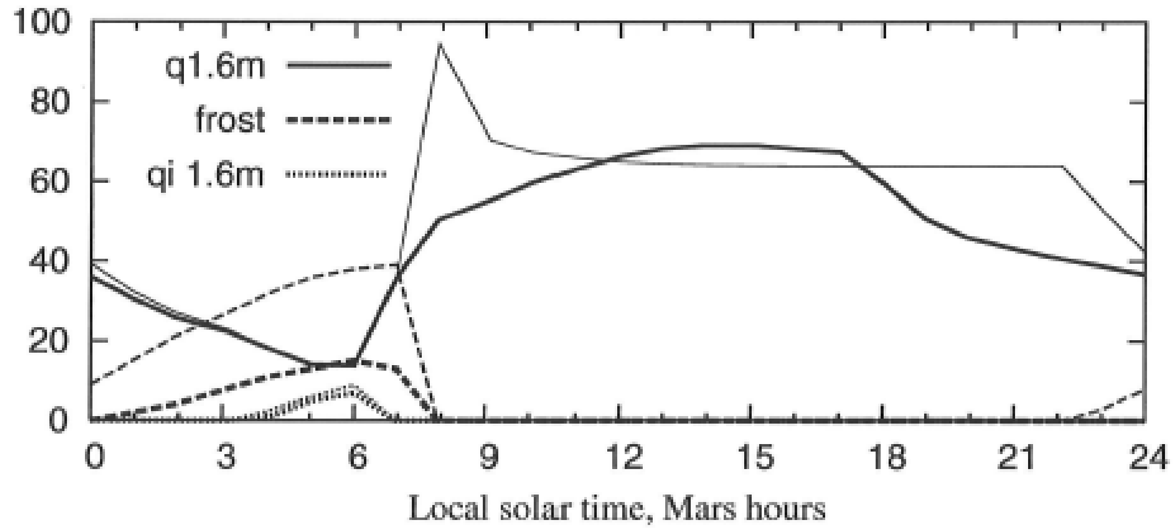
Within +-2 K of observed. **Inflection at 0200-0300LT** but weaker than obs.



q and q_{ice} at 1.6 m (ppmm), frost depth (0.01 μm):

Thick lines: full model:

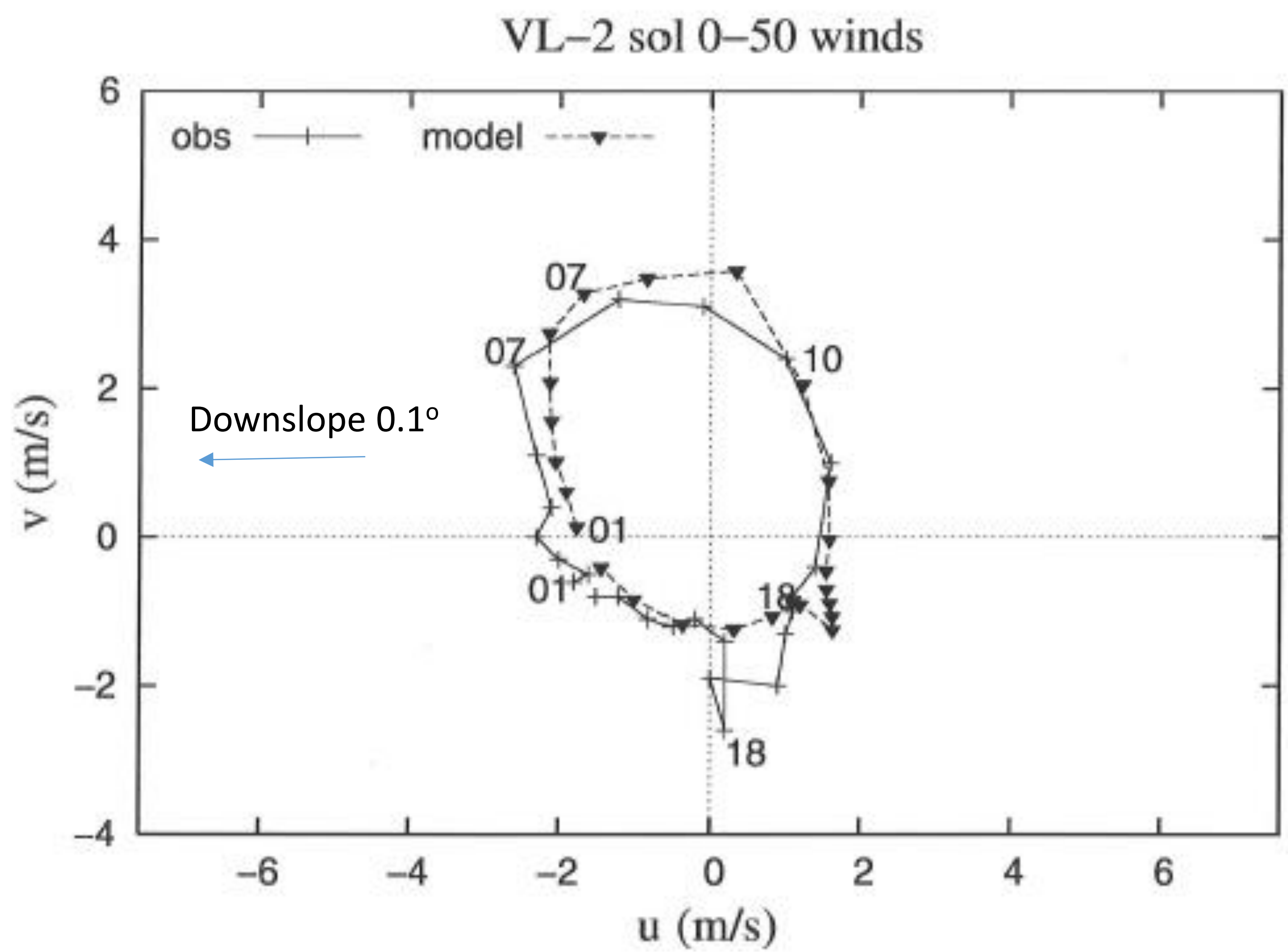
Thin lines: no adsorption:



Adsorption and desorption as at MSL, but also fog and frost. More frost and sublimation peak at 07-08LT if no adsorption. Fog in both simulations from 03 to 07LT.

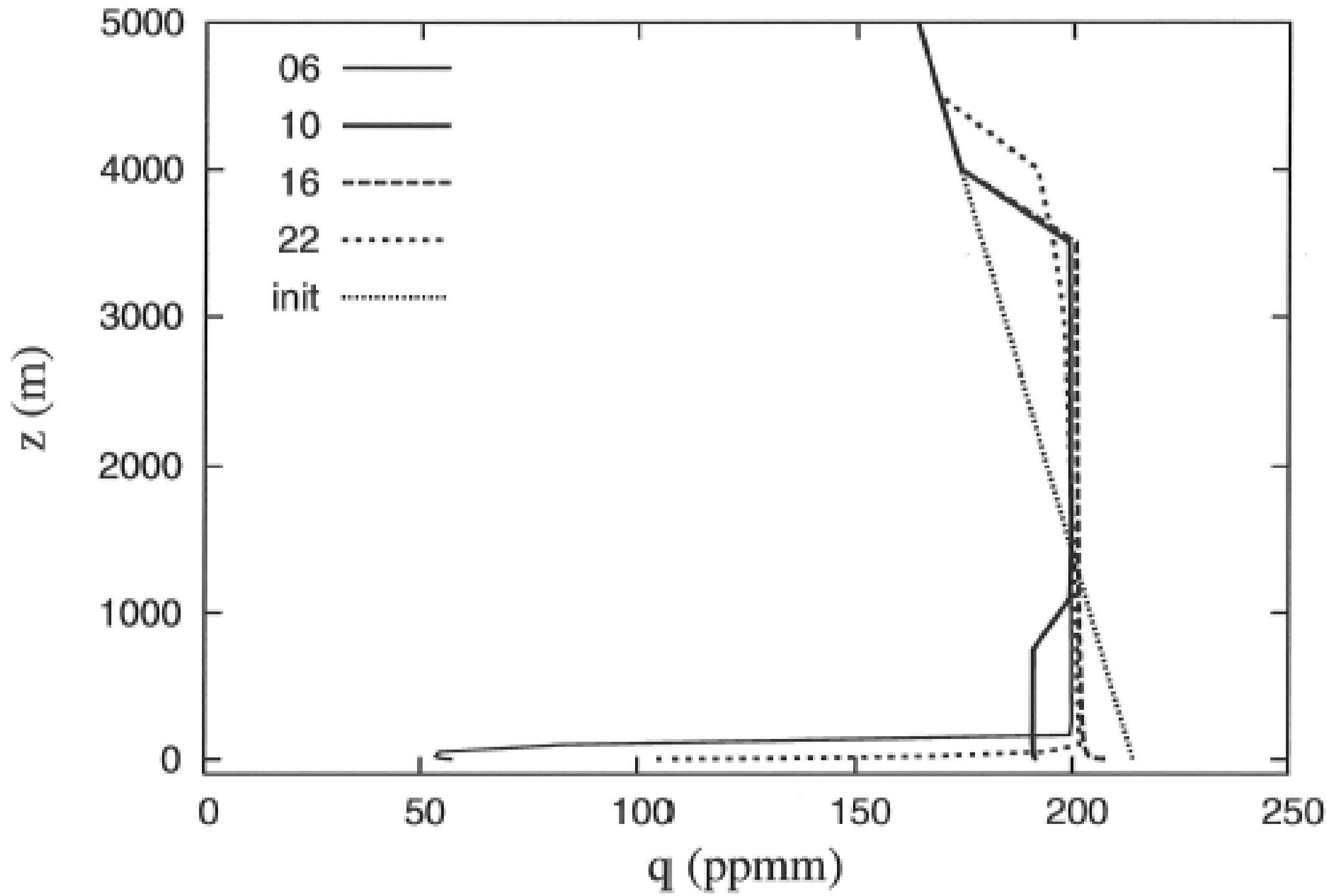
VL-2 model winds (Ls 120°) vs. observed mean winds (Hess et al. 1977)

Good simulation when no V_g
Weak slope winds dominate the diurnal cycle



VL-2 model q-profiles (Ls 120°) with adsorption:

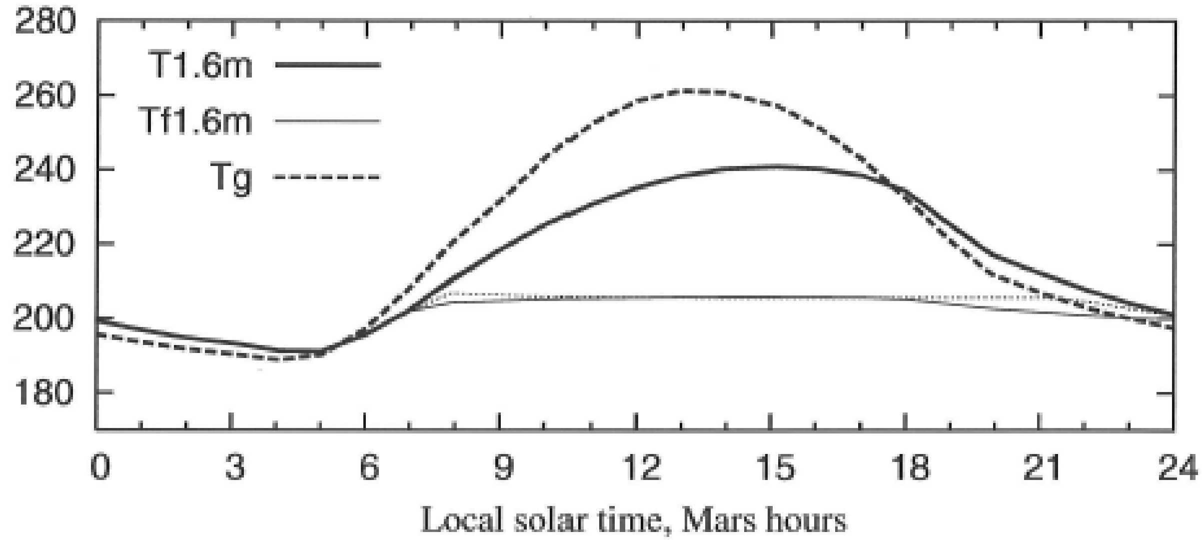
- Initial q(z) from MCD scaled to the MAWD-observed PWC of 25 μm.
- Twice as humid as at VL-1, as this is midsummer at 48°N.
- Note strong near-surface depletion at 2200LT (by adsorption).
- PWC stays at 25 μm from sol to sol during the integration.



VL-2 model diurnal cycles at 1.6 m and surface:

T at 1.6 m and T_g:

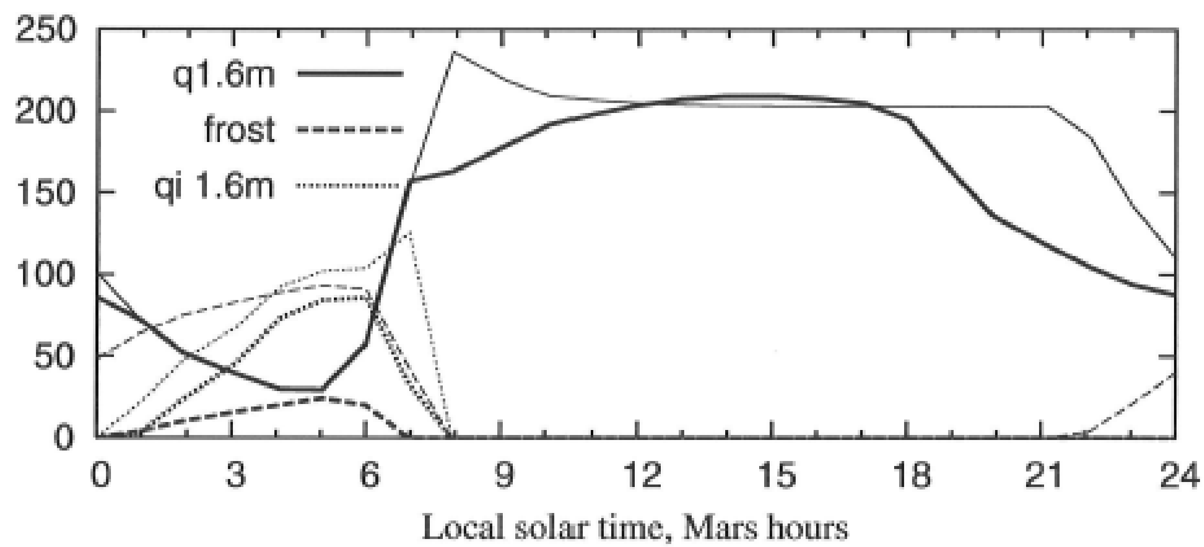
within +-2 K of observed.
Inflection at 01-02LT
(obs composite 0130LT
at199K, with fog suggested)



q and q_{ice} at 1.6 m (ppmm)
frost depth (0.01 μm):

Thick lines: full model
fog at 01-08LT

Thin lines: no adsorption.
fog at 00-08LT (too early).



More moisture than at VL-1 so more fog, frost and adsorption. Desorption from 08LT after the frost is gone.

Conclusions

- VL-1 and VL-2 first sols: temperatures and winds fairly well simulated, especially the weak slope winds at VL-2.

- Good simulation of temperature and wind is important for realistic moisture simulation: adsorption and moisture exchange is sensitive to temperature, wind and stability near the surface.

- The environments are very favorable both for this sort of model and for comparison with observations: Both sites are flat and homogeneous (safe and boring!!), and weather is benign during summer, especially at VL-2.

- **At both sites the full model predicts T-inflection and fog at 1.6 m with an increase in optical depth, when these have been indicated to occur.**

- If adsorption is not allowed, frost depletes near-surface q so effectively that fog occurs in the same way as in the full model (and as observed) at VL-1.

- However, in the moister VL-2 simulation, fog occurs too early in the no-adsorption case. Hence **adsorption is probable at the VL sites.**