The Mars Thermospheric Circulation : Recent Constraints from Aerobraking and Mars Express (SPICAM) Measurements

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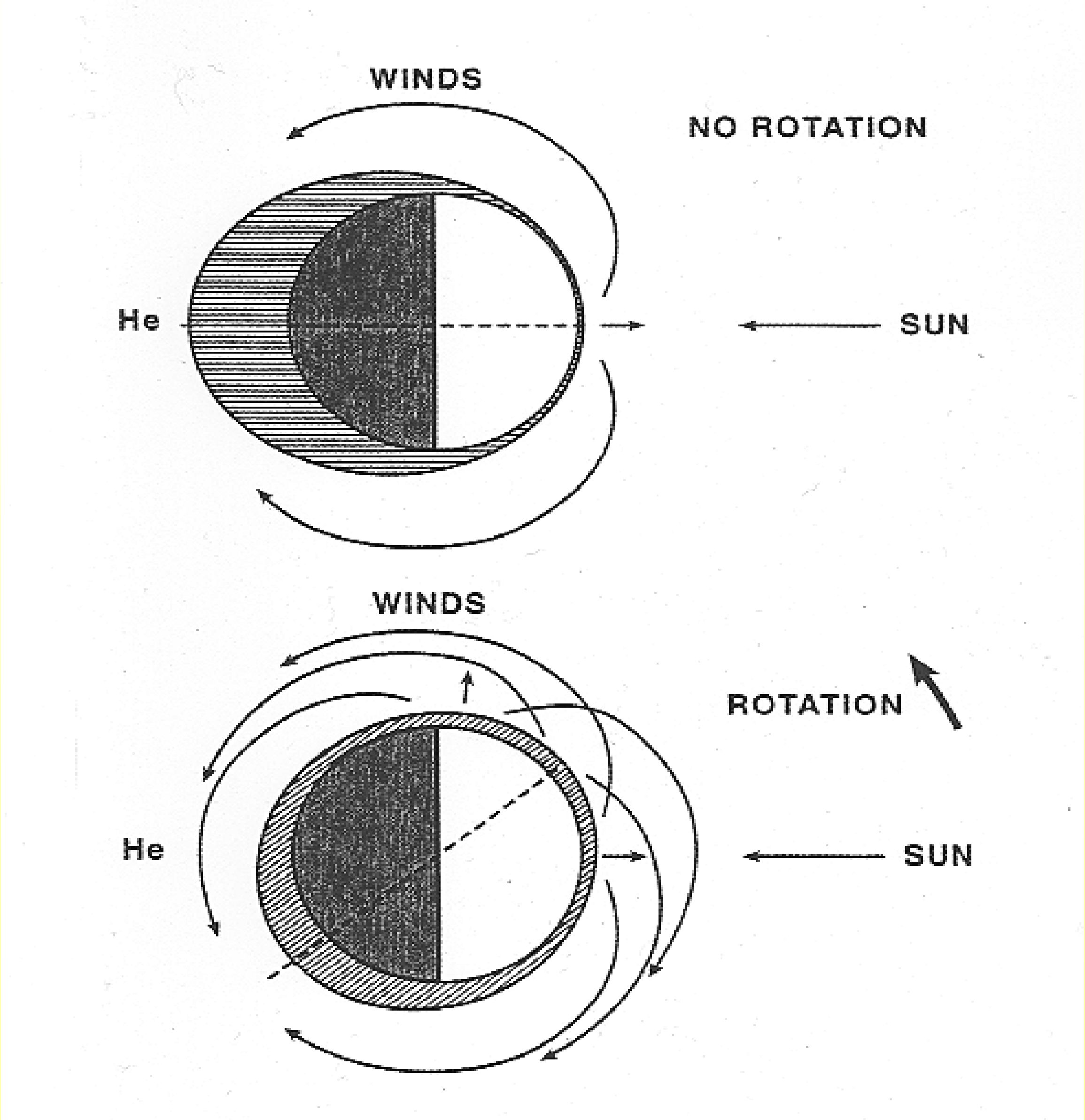
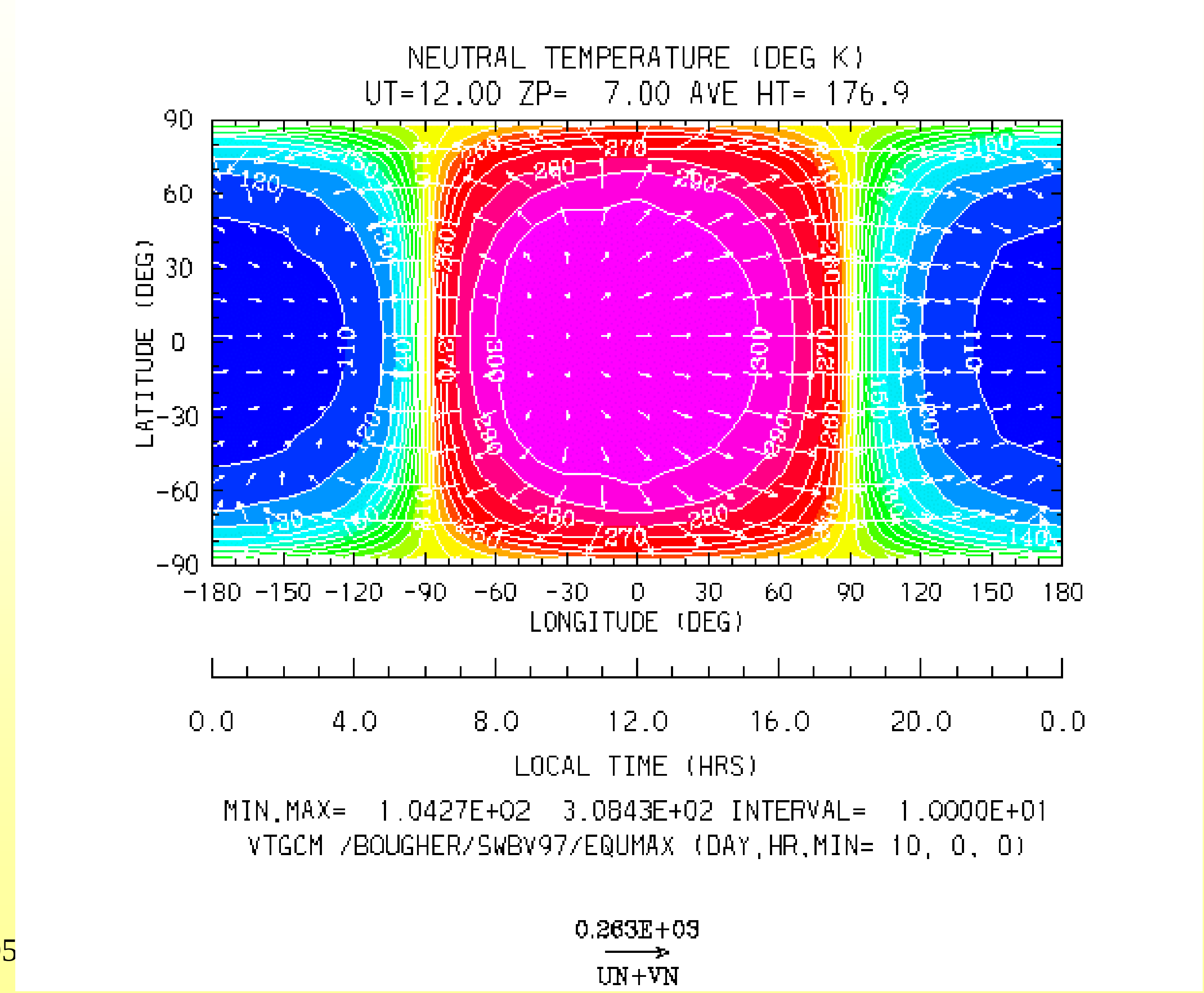
Why Investigate the Mars Thermospheric Circulation?

- ❑ Mars is a coupled atmospheric system (0-300 km):
  - ❖ Role of upward propagating tides, planetary and gravity waves coupling atmospheric regions.
  - ❖ Circulation ties together airglow and structure datasets into a coordinated whole (e.g. MGS, Odyssey, MEX).
  - ❖ Limited datasets (sampling diurnal, seasonal, solar cycle responses) can be understood in a global context.
- ❑ Aerobraking implications:
  - ❖ Density and temperatures structure in the thermosphere (~100-160 km) must be consistent with wind patterns.
  - ❖ Wave-mean flow interactions. Tidal oscillations of density.
- ❑ Comparative planetology (e.g. Venus)

Inferred Venus Thermospheric Circulation : ONMS Density Structure



Simulated Venus Thermospheric Circulation : VTGCM (Solar Maximum)



Martian Upper Atmosphere Datasets from MGS and Odyssey Accelerometers

•MGS Accelerometer data over Phase 1 (7-months) and Phase 2 (4.5 months) aerobraking. Measured densities (inferred scale heights and temperatures) over 110-160 km. Nearly ~1200 vertical structures.

-- Phase 1 : Ls = 180-300; F10.7-cm = 70-90

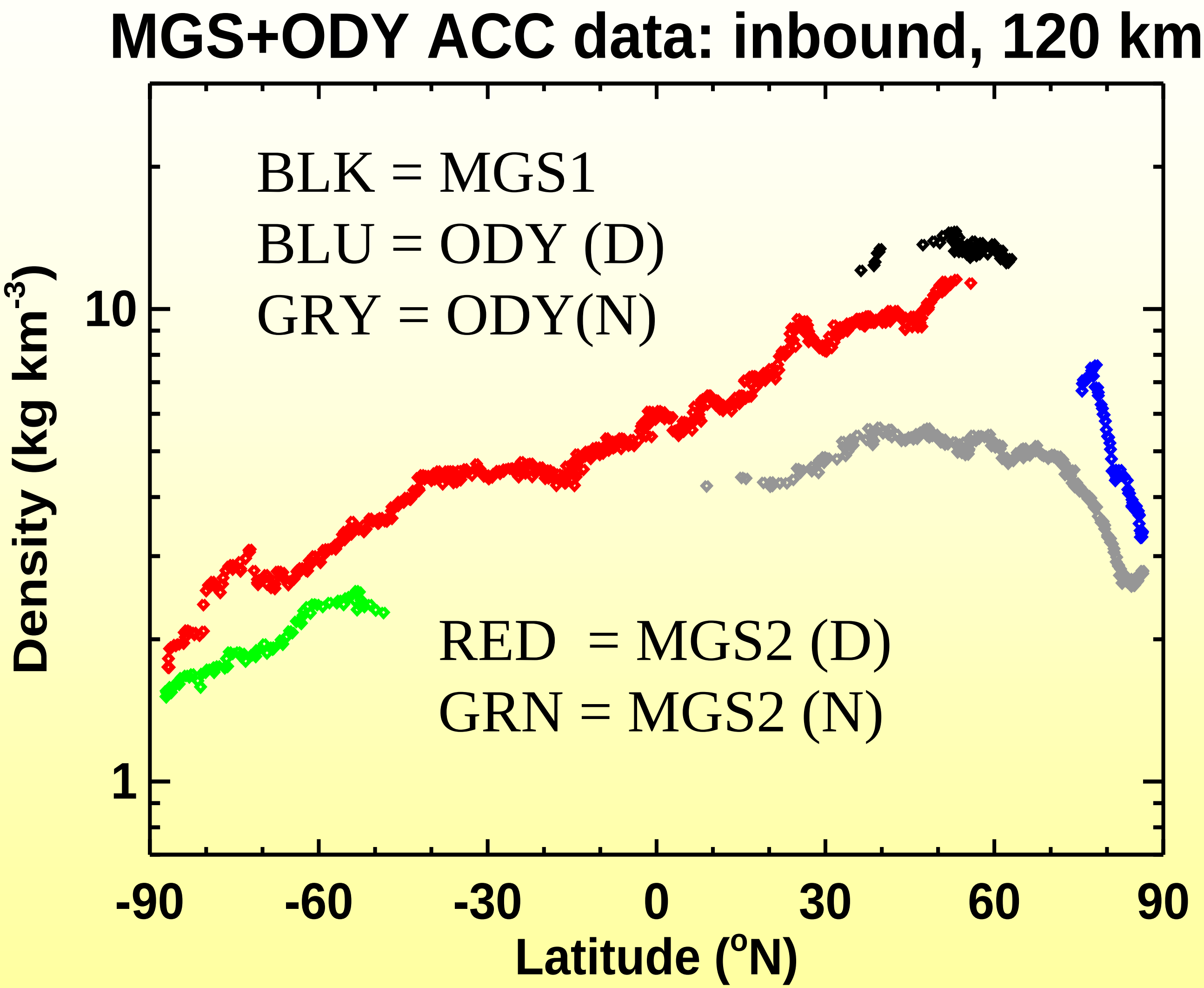
-- Phase 2: Ls = 30-95; F10.7-cm = 130-150

•Odyssey Accelerometer data over 5-months of aerobraking. Measured densities (inferred scale heights and temperatures) over 95-170 km. Nearly ~600 vertical structures .

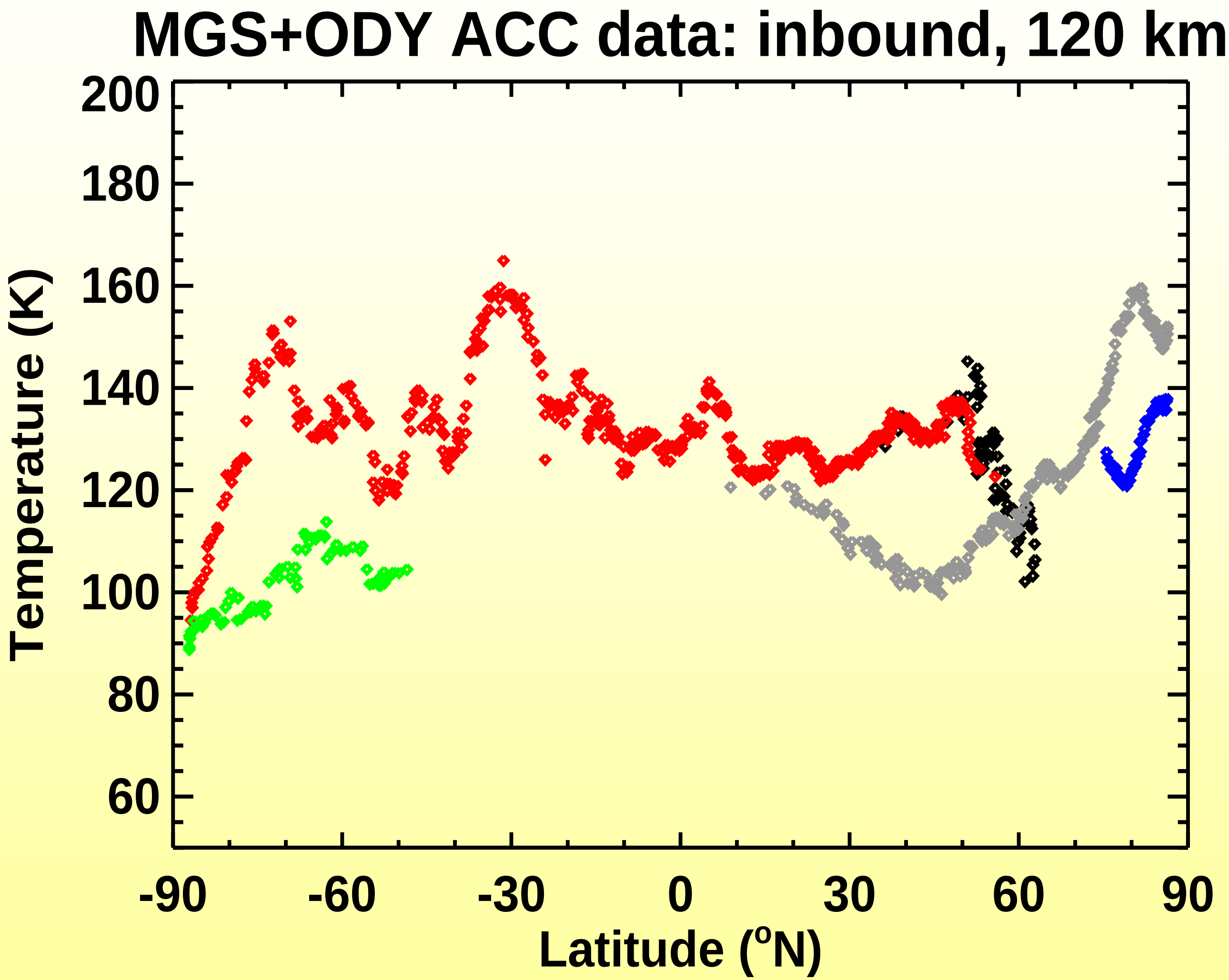
-- Total : Ls = 265-310; F10.7-cm = 175

-- Following summer 2001 dust storm season

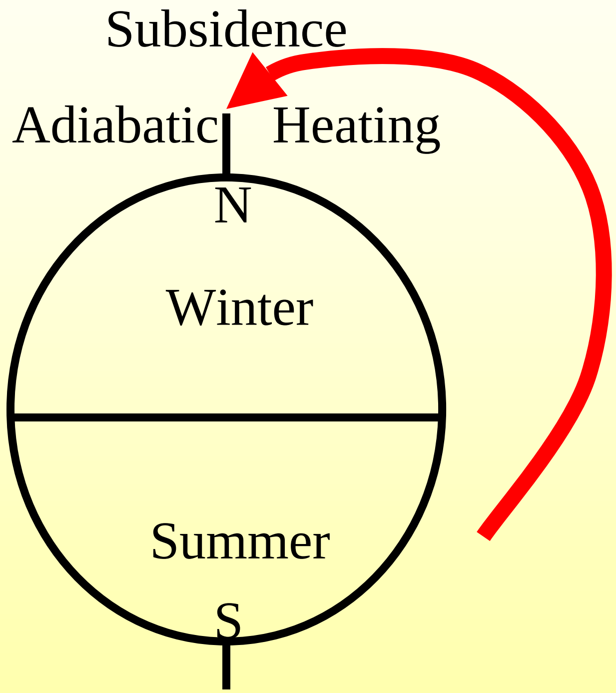
Accelerometer Densities :



Accelerometer Temperatures :



Schematic Of Possible Mars Winter Polar Warming Process



— Meridional Flow From Summer H. To Winter H.

MGCM-MTGCM Simulations: Formulation, Parameters and Inputs:

- Separate but coupled NASA Ames MGCM (0-90 km) and NCAR/Michigan MTGCM (70-300 km) codes, linked across an interface at 1.32-microbars on 5x5º grid.

- Fields passed upward at interface (T, U, V, Z) on 2-min time-step intervals. No downward coupling enabled.

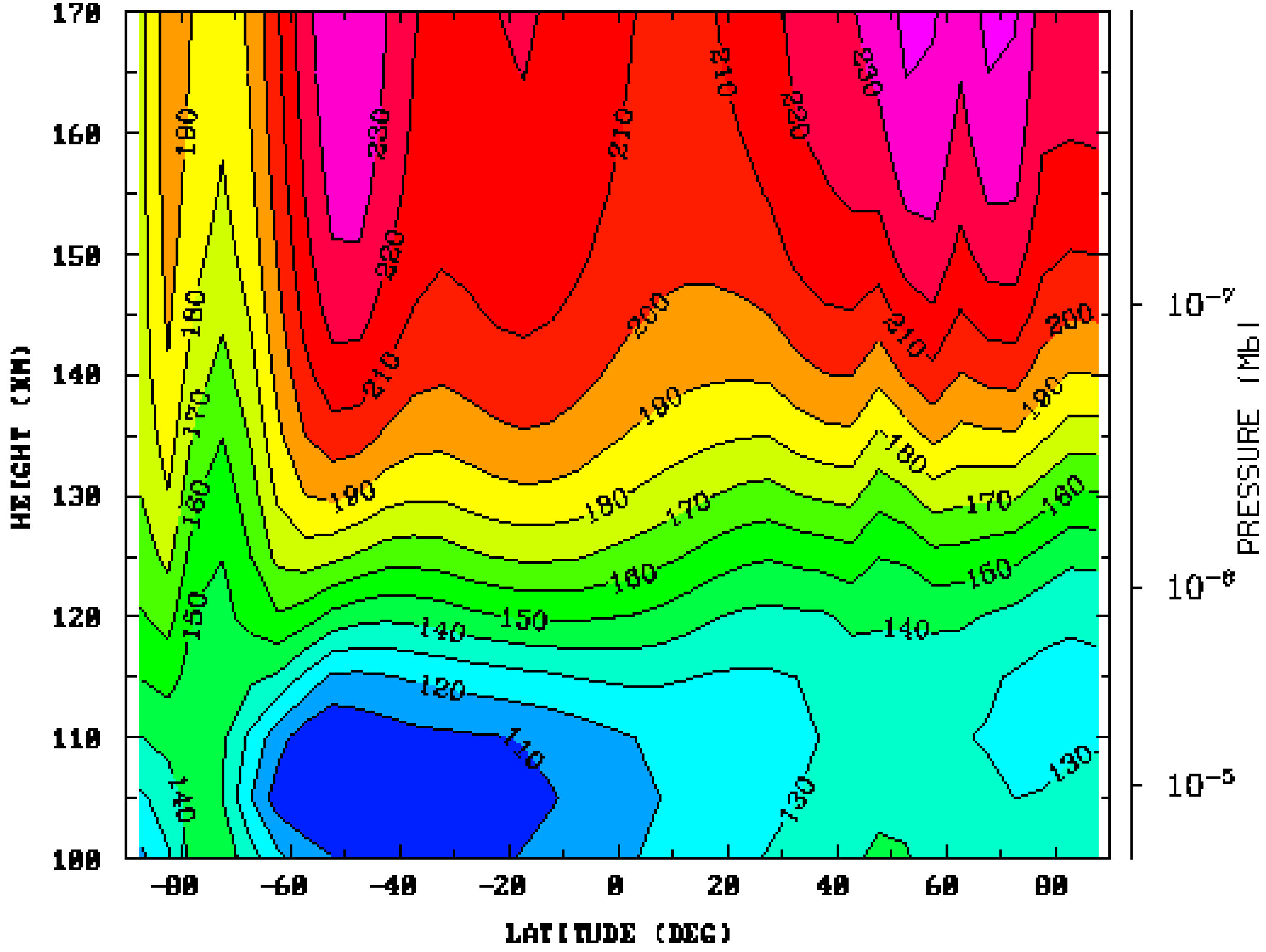
- MGCM-MTGCM captures upward propagating migrating & non-migrating tidal oscillations, as well as in-situ solar EUV/UV/IR heating (migrating tides).

- Ls = 90 (aphelion) and Ls = 270 cases (see next slide)

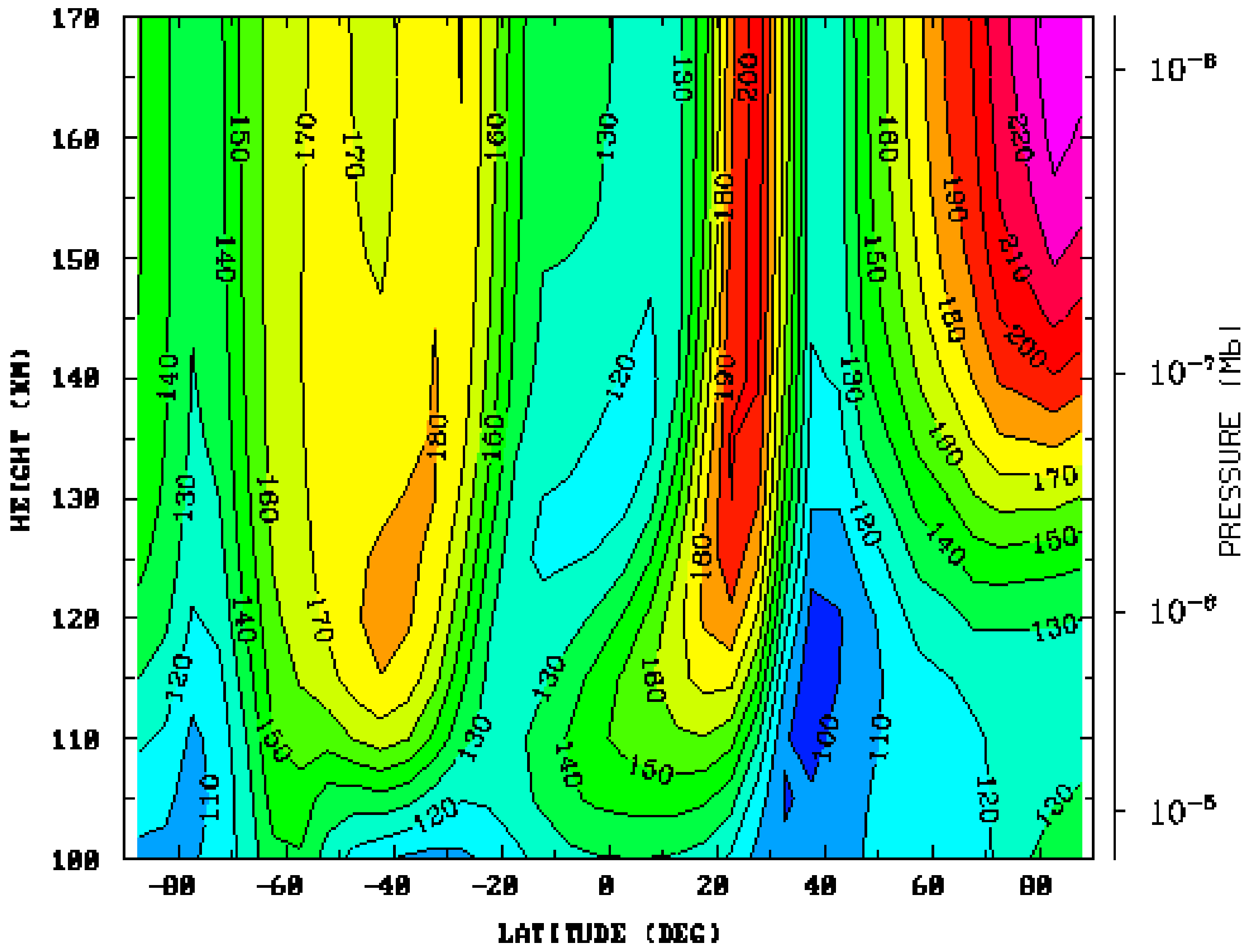
MGCM-MTGCM Parameters Being Adjusted

- TES archive for 1999-2000 (MGS2) and 2001-2002 (Odyssey). Empirical horizontal dust maps of integrated vertical opacity.
- Vertical dust distributions (Ls = 90 & 270) consistent with TES dust maps. Conrath parameter ~ 0.03 (mixed to ~40-50 km).
- Solar EUV/UV fluxes (F10.7 ~ 130 and 200) appropriate to MGS2 and Odyssey aerobraking periods.

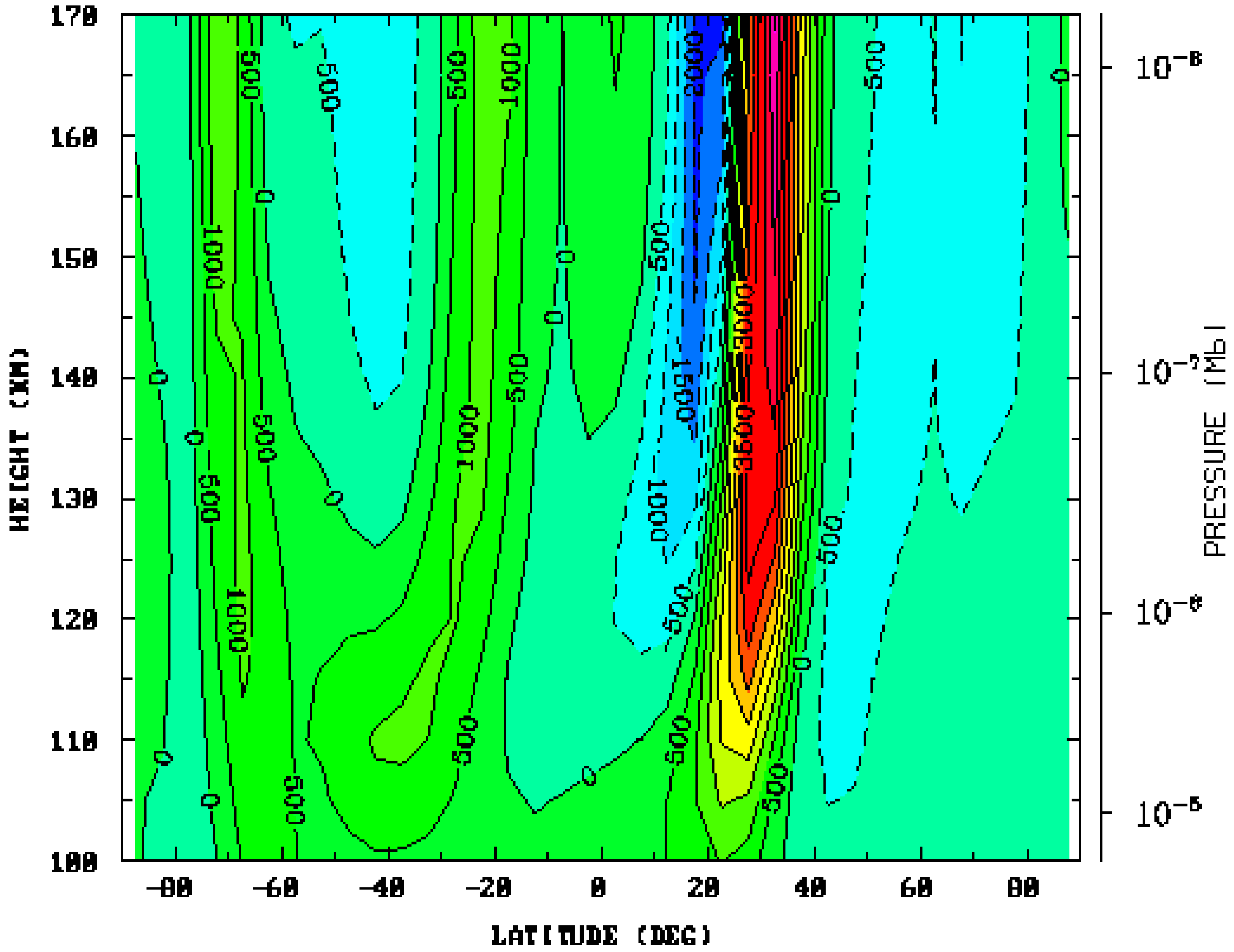
MTGCM Aphelion Case (Ls = 90): Temperatures (K) at SLT=15 (TES yr #1)



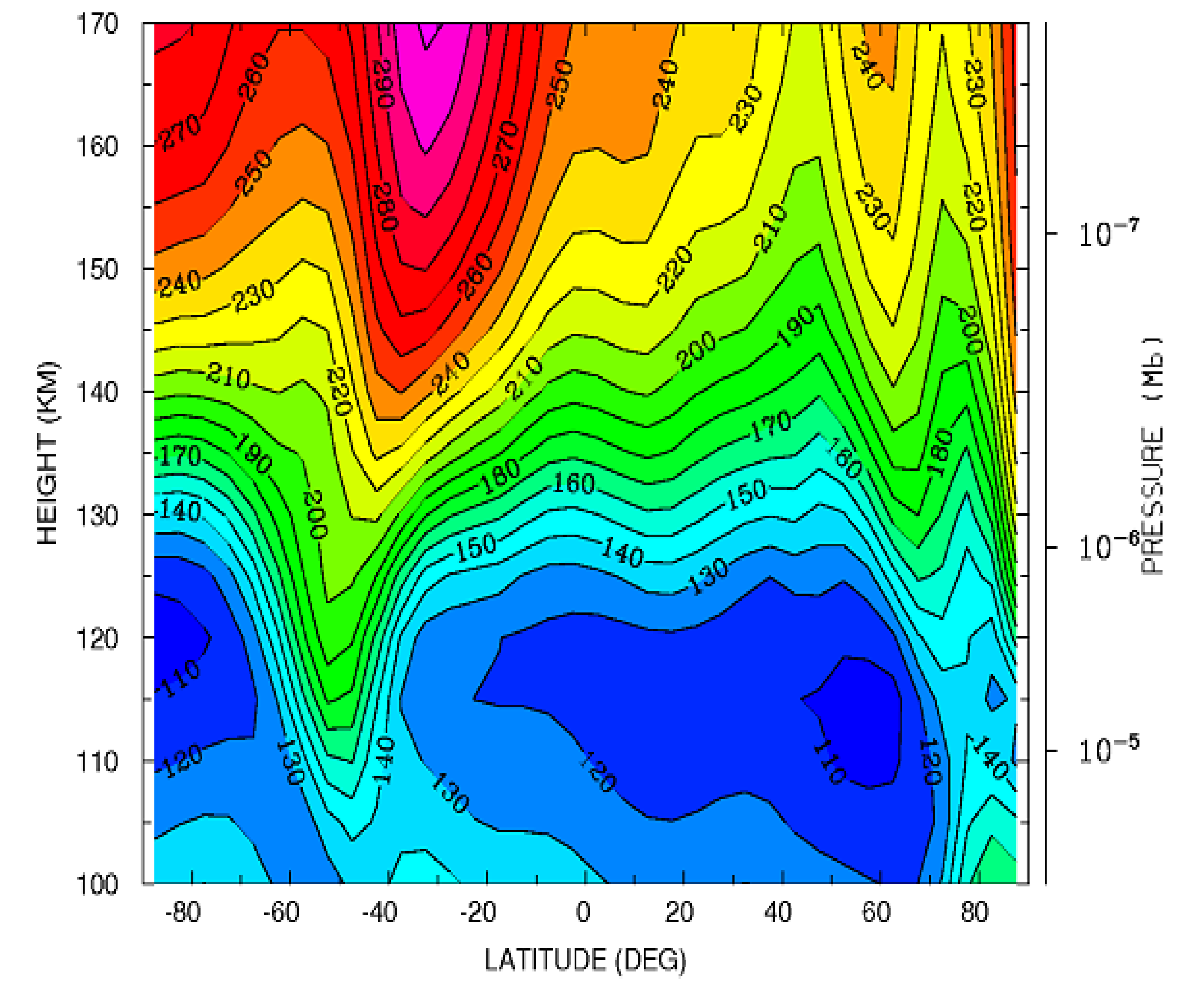
MTGCM Aphelion Case (Ls = 90): Temperatures (K) at SLT=3 (TES yr #1)



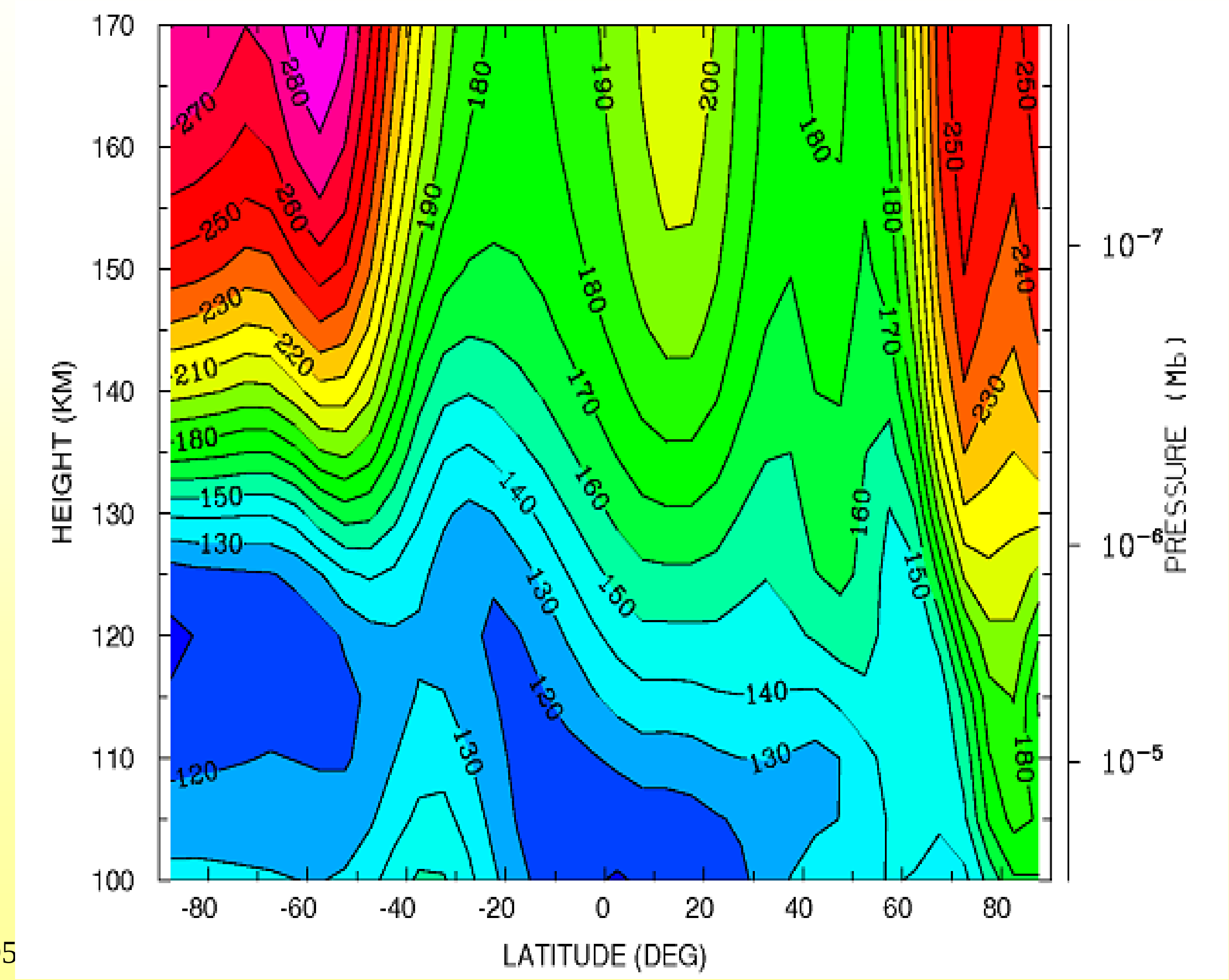
MTGCM Aphelion Case (Ls = 90):
Dynamical Heating (K/day) : SLT = 3



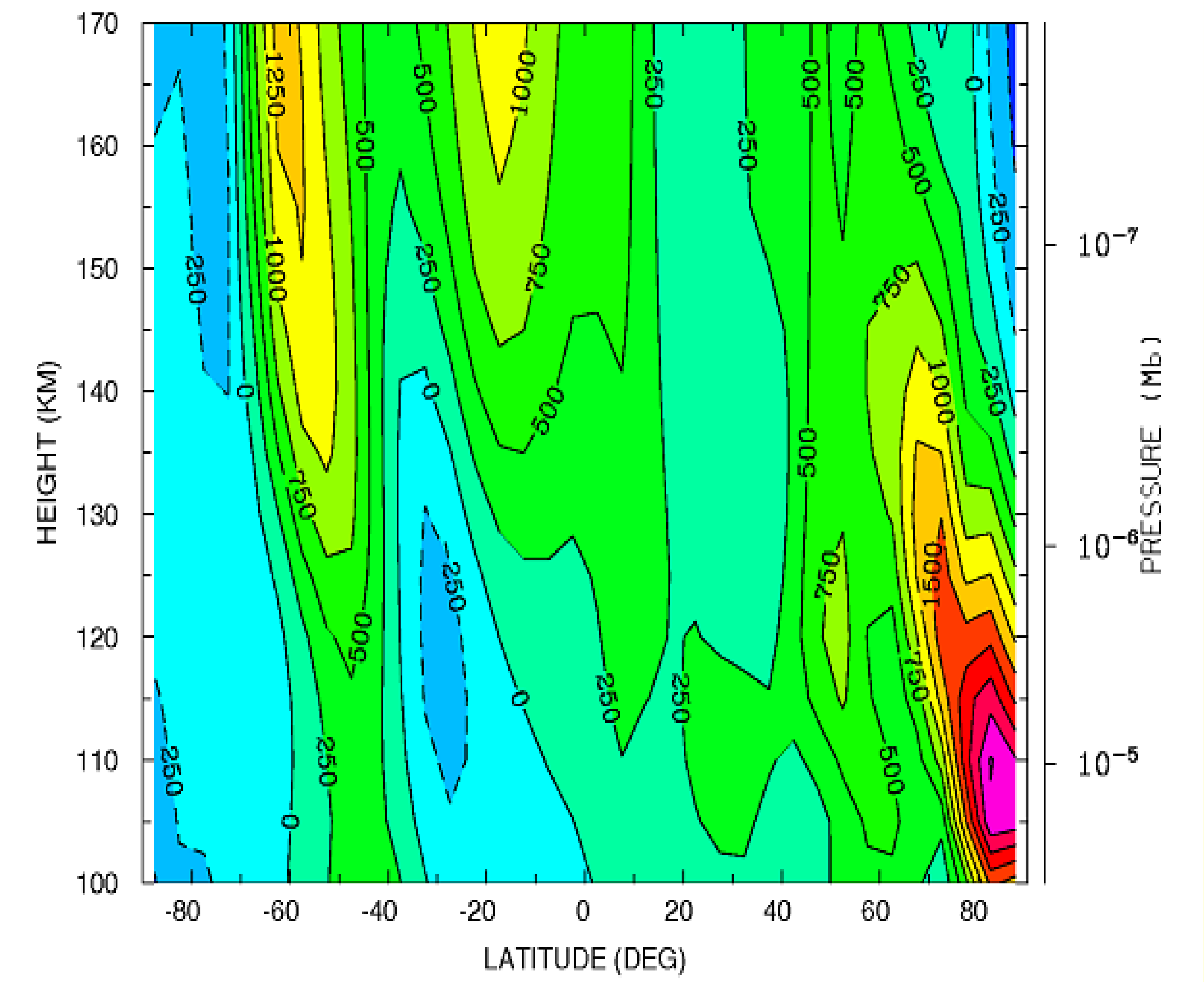
MTGCM Odyssey Case (Ls = 270): SLT=17 Temperatures versus Latitude



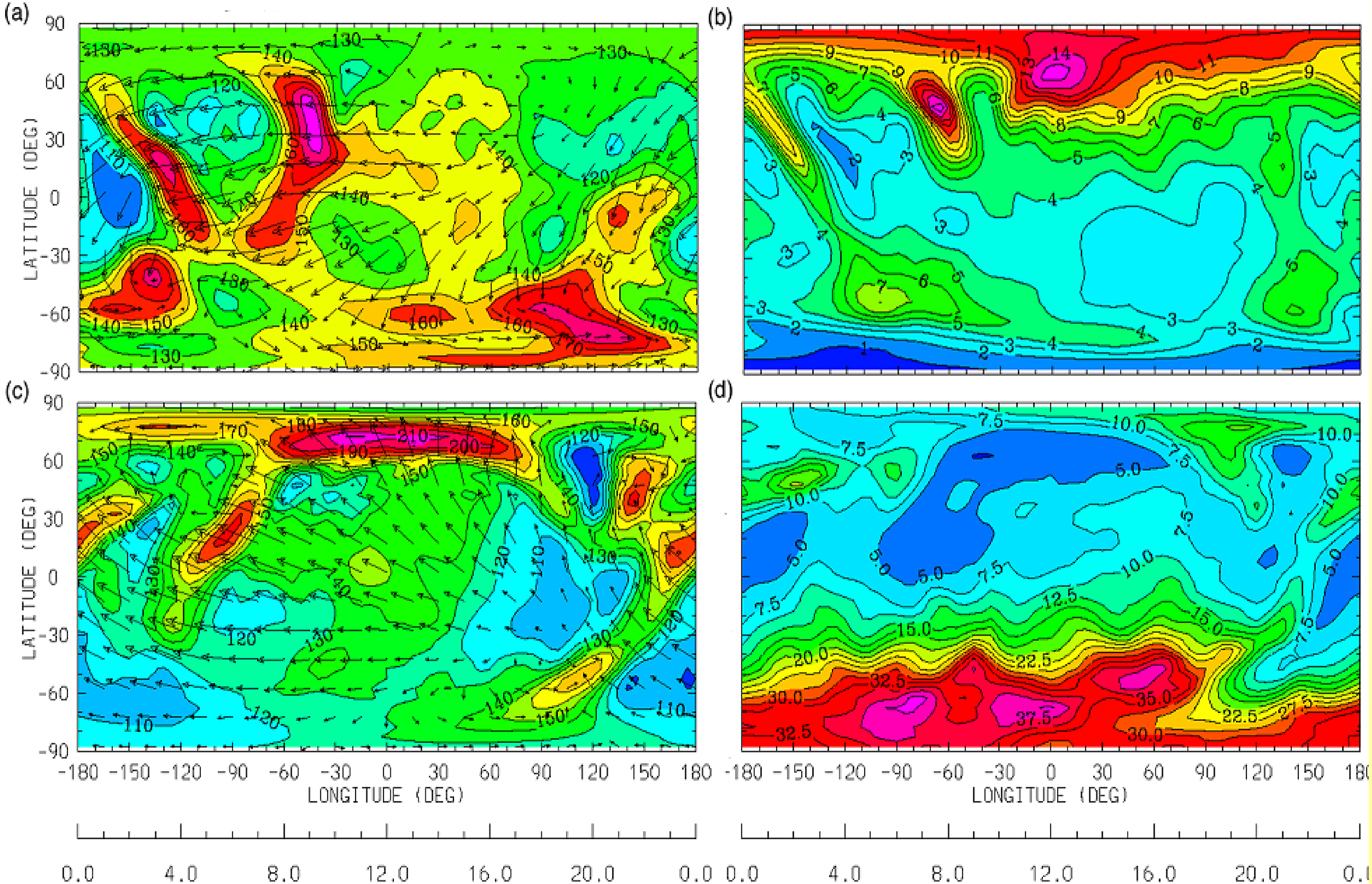
MTGCM Odyssey Case (Ls = 270): SLT=3 Temperatures versus Latitude



MTGCM Odyssey Case (Ls = 270): Dynamical Heating (K/day) : SLT = 3



Ls = 90 (top) and 270 (bottom) Density (kg/km^3) and Temperature (K) maps at 120 km



Conclusions: Polar Warming and Mars Thermospheric Circulation

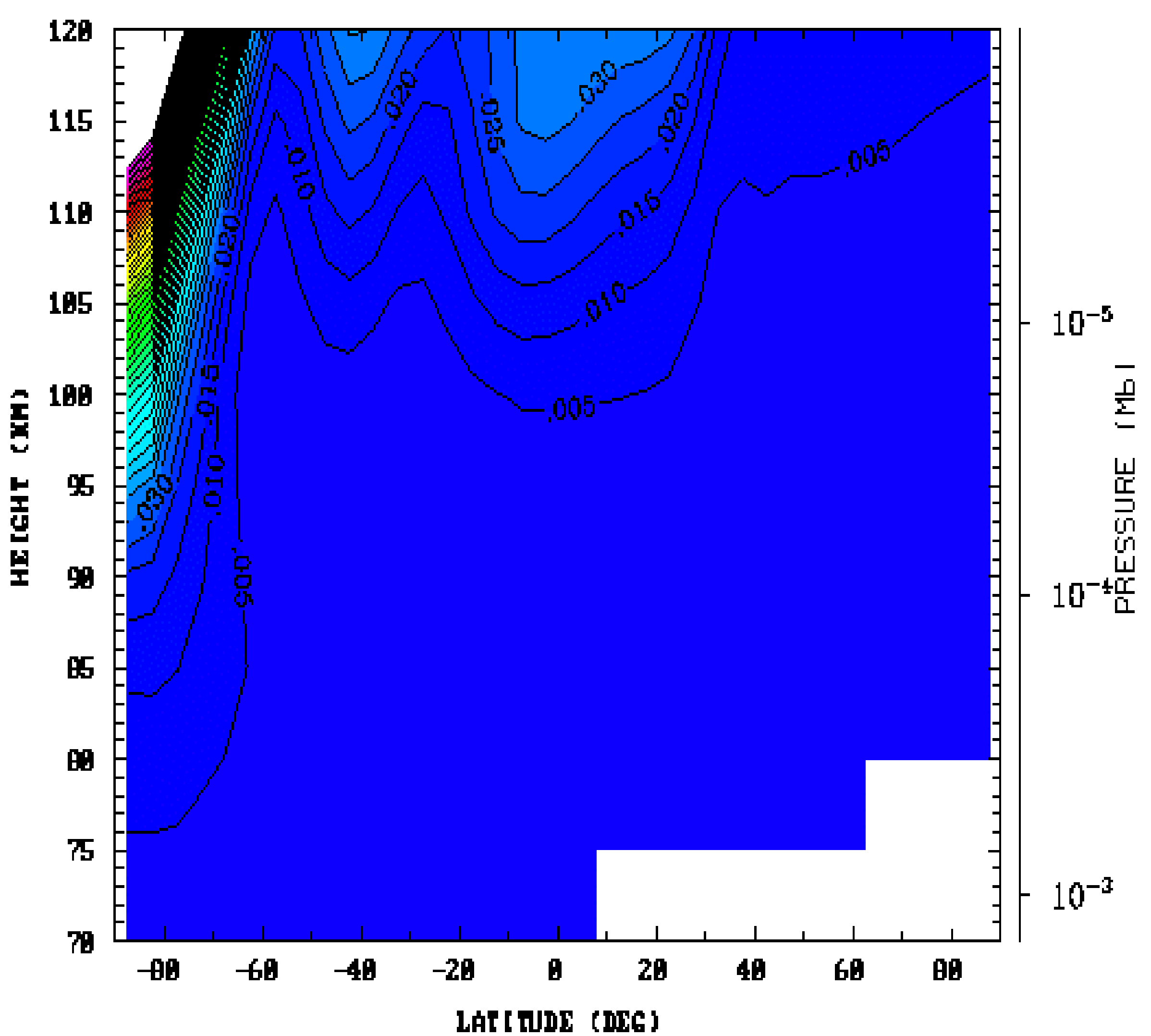
❑Coupled MGCM (0-90 km) and MTGCM (70-300 km) simulations capture the upward propagating migrating and non-migrating tides for Ls = 90 and 270 conditions appropriate to MGS2 and Odyssey period observations. Mars seasonal atmospheric expansion and contraction is also properly accommodated.

❑MTGCM winter polar temperatures near 100-130 km are markedly different between these seasons. Strong Northern polar warming features are reproduced, in accord with Odyssey observations. Weaker Southern polar warming features are simulated, similar to MGS2 data.

❑A stronger inter-hemispheric circulation pattern during Northern winter (Ls = 270) yields larger dynamical heating in the Northern polar region. Seasonally varying TES dust distributions (and local vertical mixing) are likely responsible for these changing winds and the resulting polar heat balances at thermospheric altitudes.

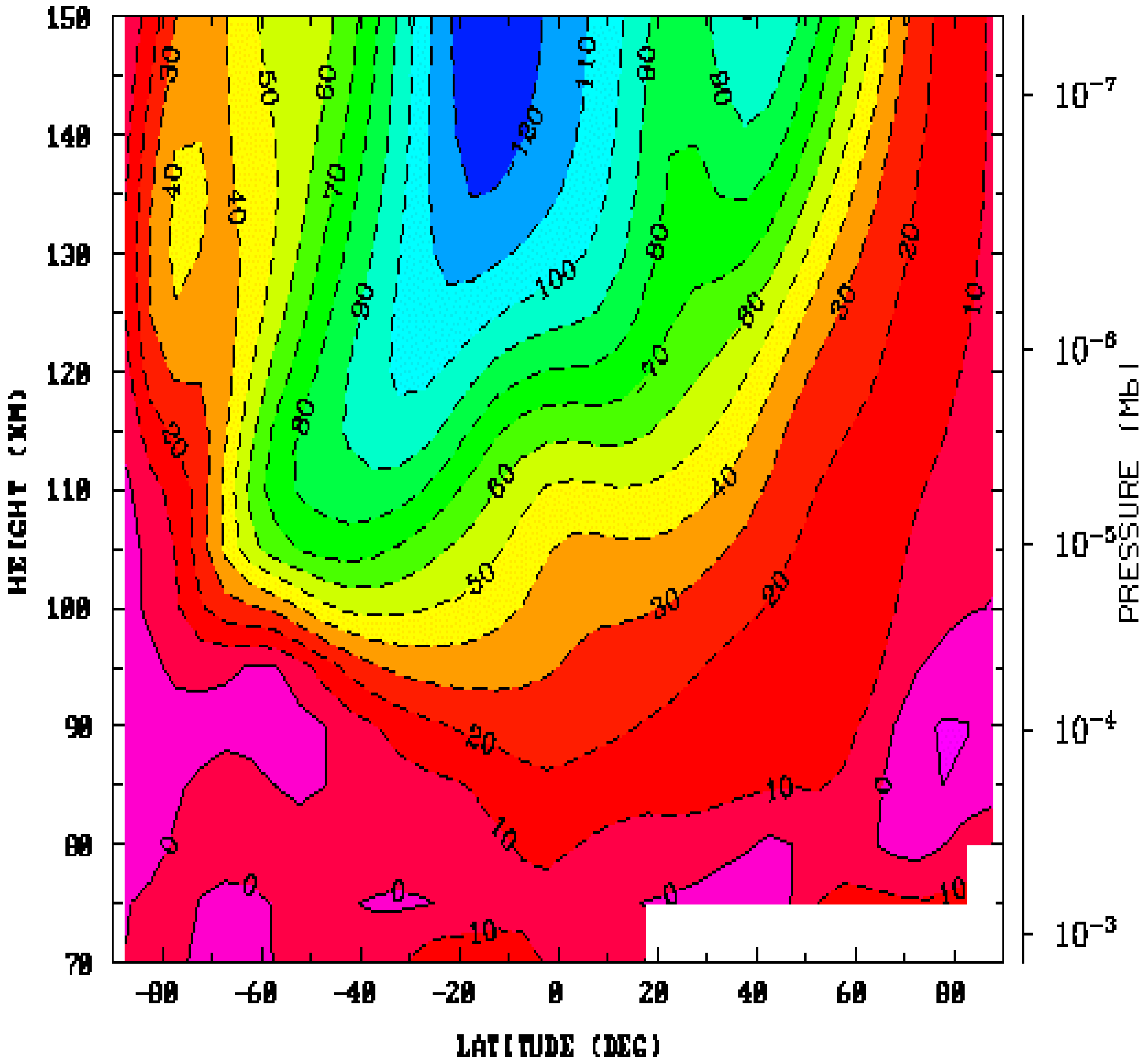
Mars Polar Night Structure : MTGCM (Ls = 90; F10.7 = 130; SLT = 3)

O/CO_2 RATIO



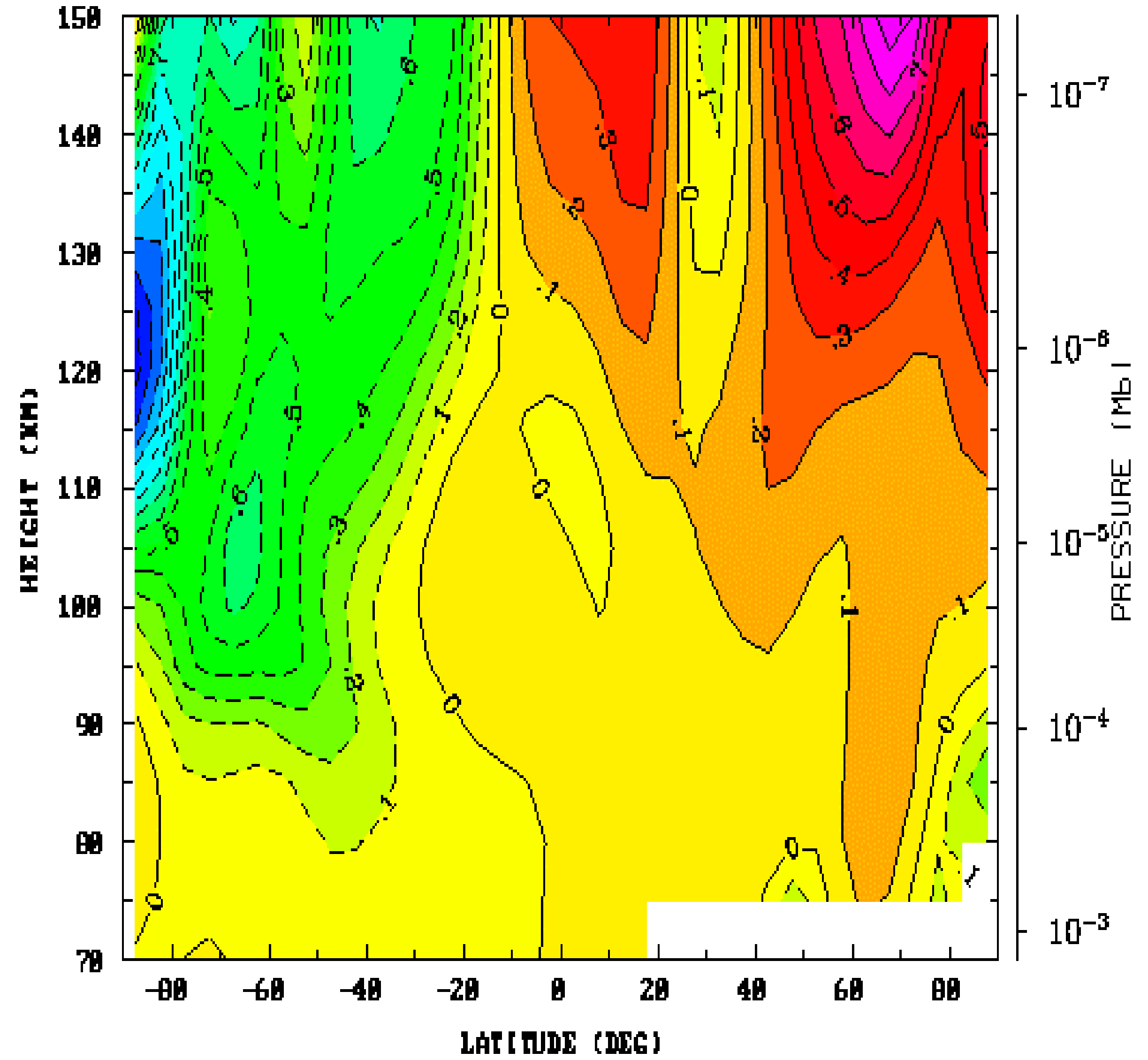
Z.A. MTGCM Meridional Winds (m/s)
(Ls = 90; F10.7 = 130)

Min = -128 m/s



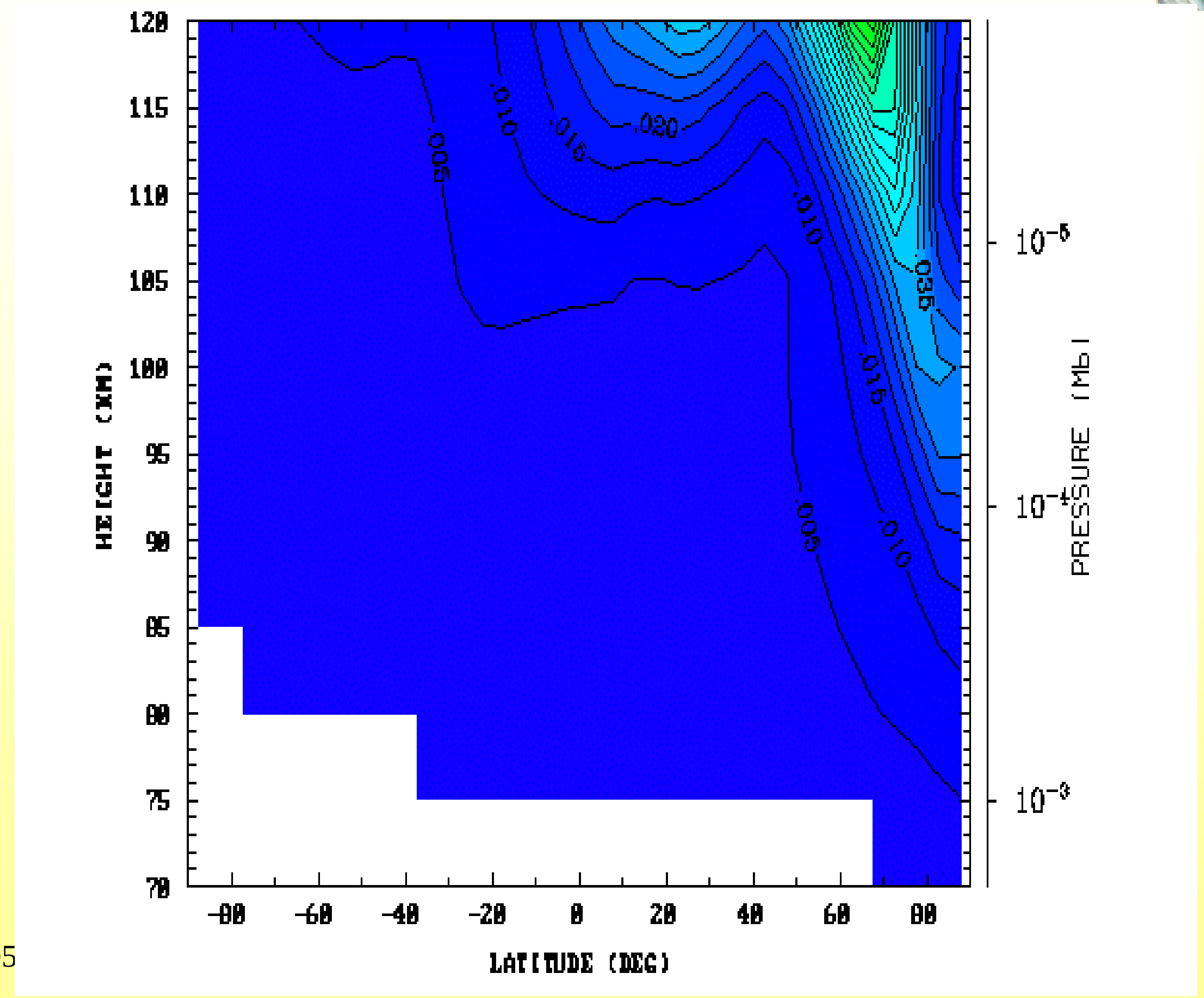
Z.A. MTGCM Vertical Winds (m/s)
(Ls = 90; F10.7 = 130)

Max = +1.0 m/s
Min = -1.3 m/s



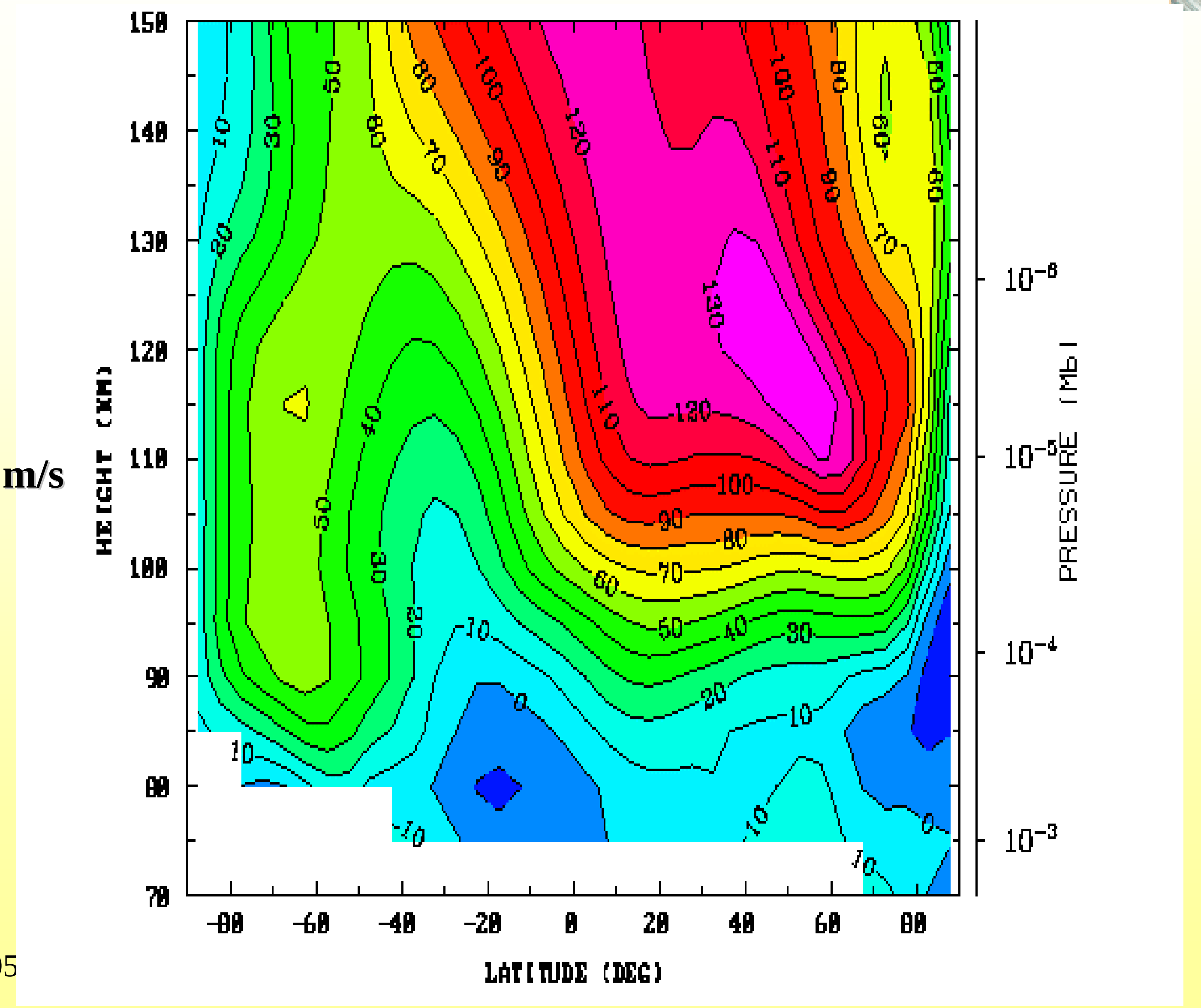
Mars Polar Night Structure : MTGCM
(Ls = 270; F10.7 = 175; SLT = 3)

O/CO_2
RATIO

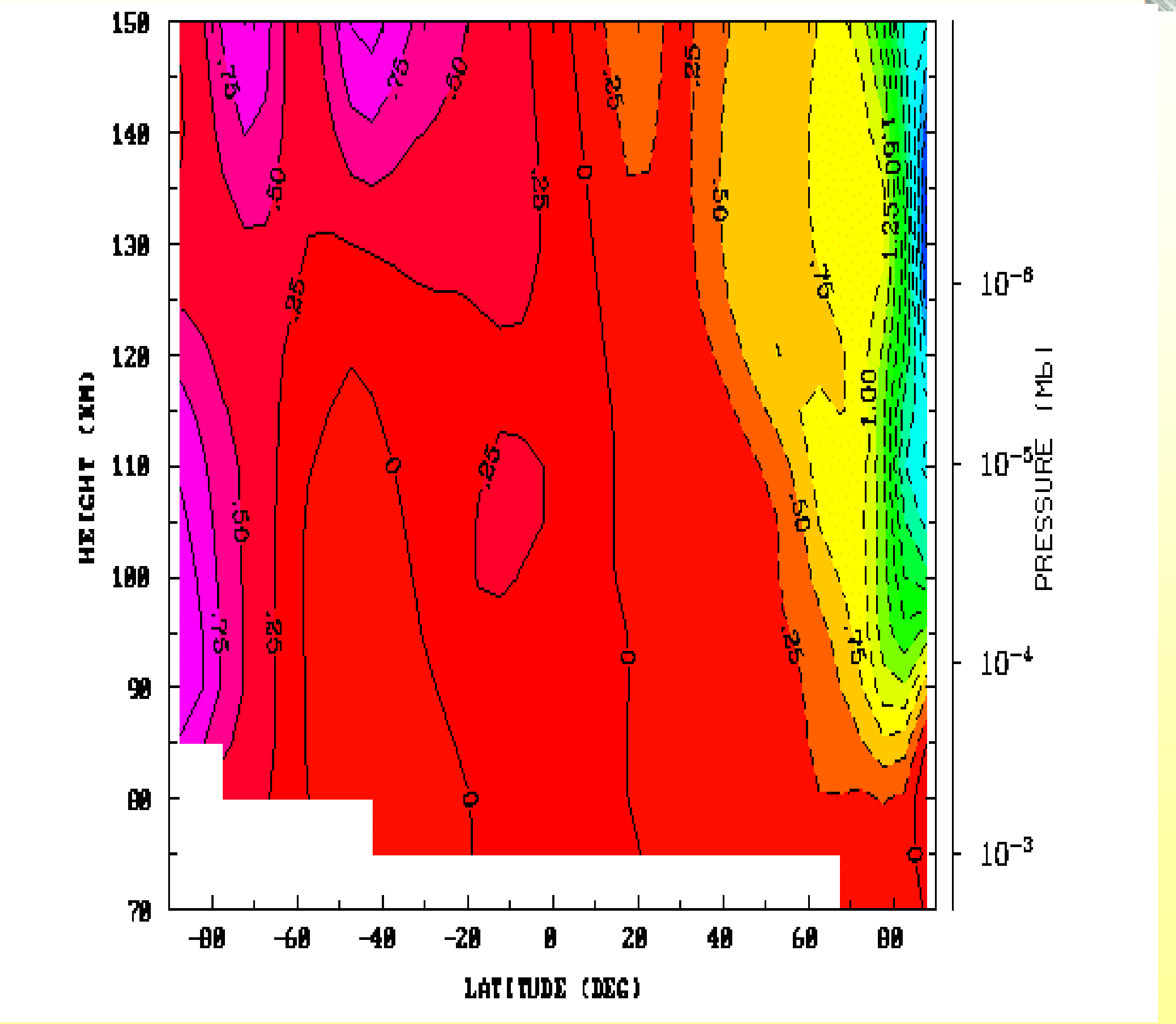


Z.A. MTGCM Meridional Winds (m/s)
(Ls = 270; F10.7 = 175)

Max = + 140 m/s

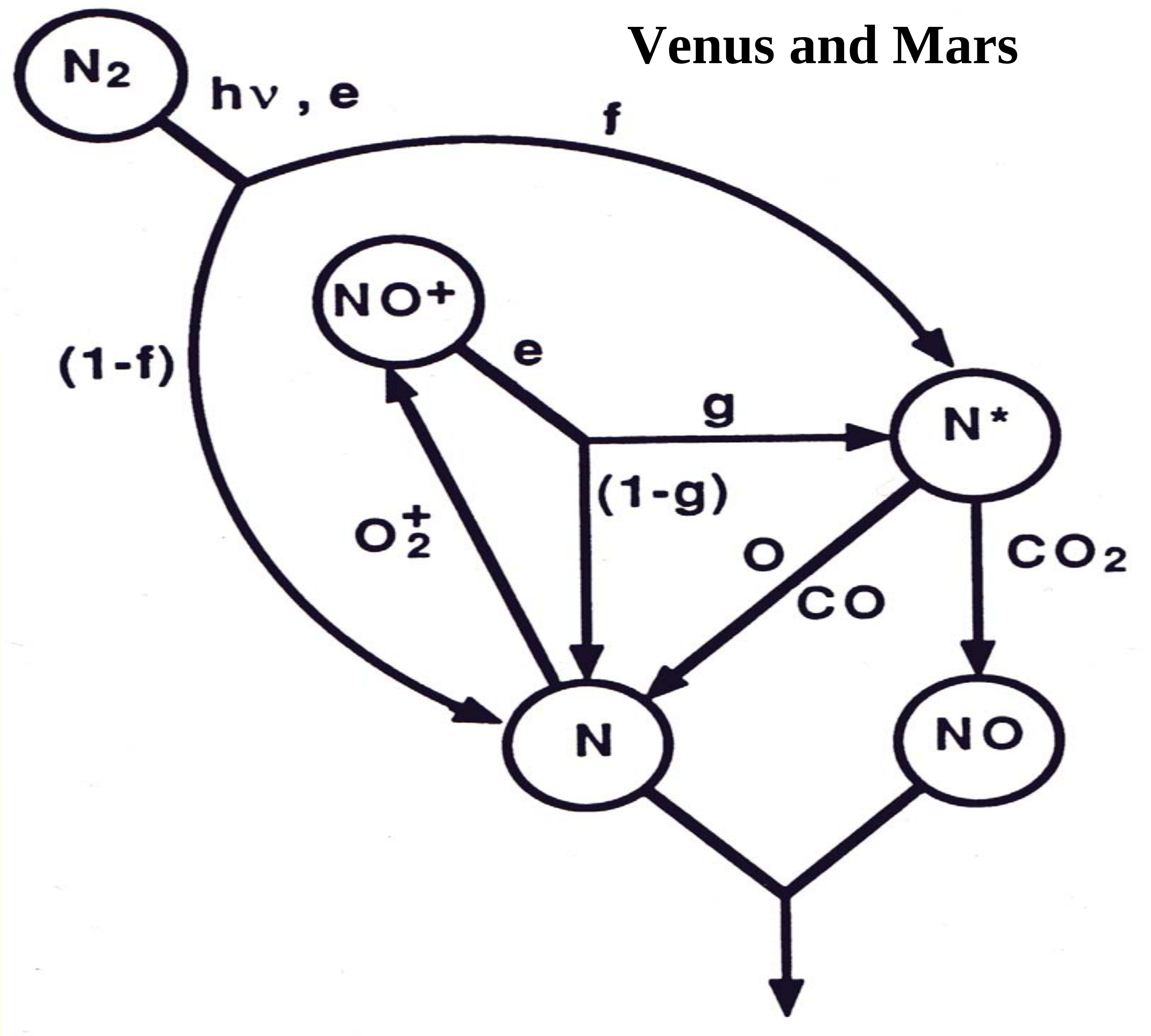


Z.A. MTGCM Vertical Winds (m/s)
(Ls = 270; F10.7 = 175)



Max = +1.2 m/s
Min = -3.5 m/s

Simplified Dayside Nitric Oxide Chemistry : Bougher et al. [1990].



Conclusions: NO* Nightglow and Mars Thermospheric Circulation

- ❑Mars thermospheric circulation, especially during solstice conditions, can be traced by NO* nightglow and latitudinal density and temperature variations :
  - ➢A stronger thermospheric circulation is expected during perihelion (Ls = 270) than for aphelion (Ls = 90) conditions;
  - ➢Hemispheric differences observed and simulated in aerobraking polar night temperatures (polar warming);
  - ➢Hemispheric differences expected in NO* nightglow (stronger emission during Ls = 270 polar night). Simulations.

- ❑Separate datasets (MGS, Odyssey, MEX) are better understood in a global context with consideration of the Mars thermospheric circulation.