

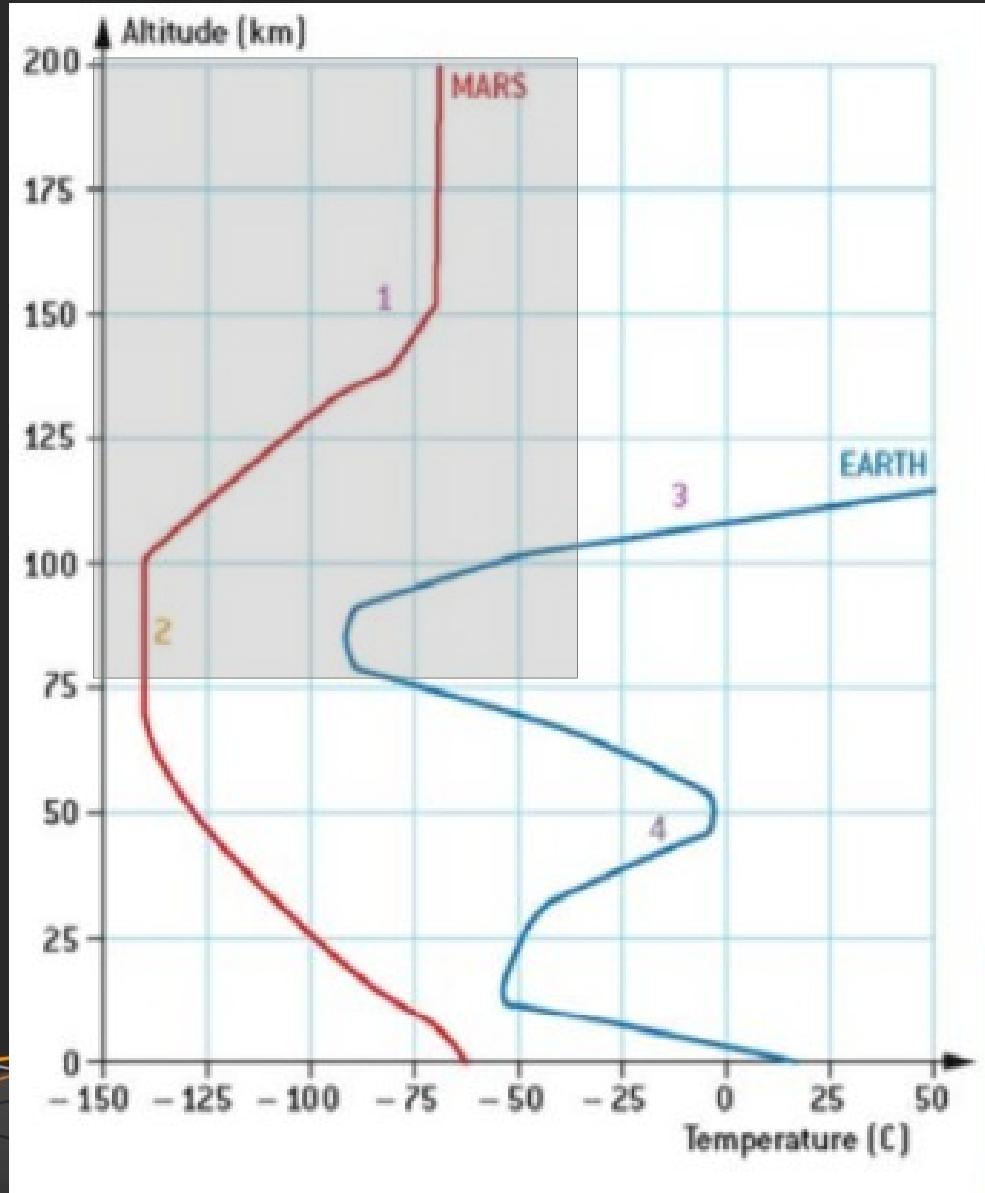
Variability of the Martian upper atmosphere

F. González Galindo + IAA GAPT group +
LMD (CNRS) + LATMOS (CNRS)

ggalindo@iaa.es

Reunión Ciencias Planetarias y
Exploración Sistema Solar
ESAC, 8 Junio 2017

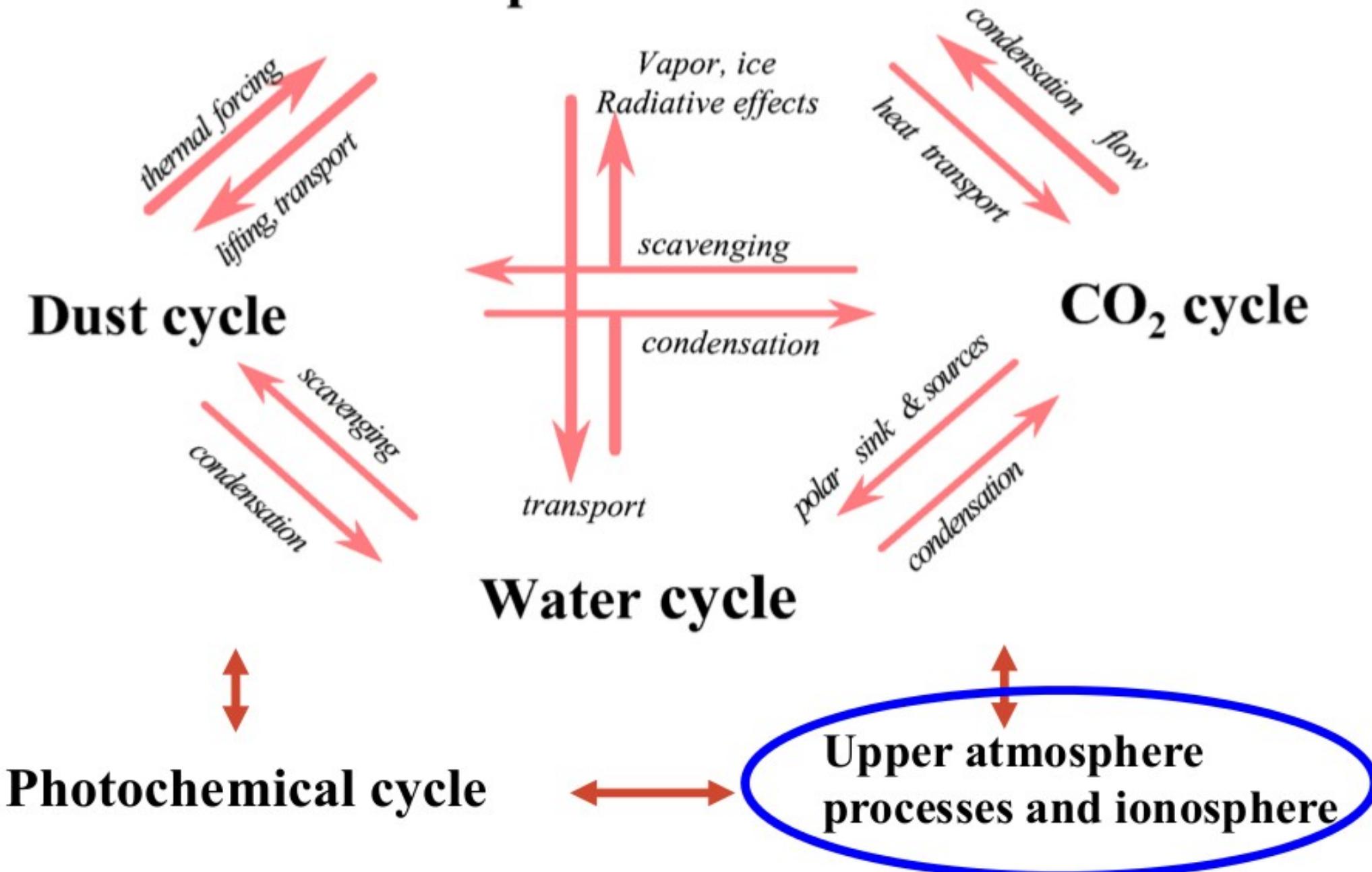
Upper atmosphere (UA)



- UA: mesosphere + mesopause + thermosphere + ionosphere
- Interface with UV solar activity + solar wind
- Transition between gravitationally bound atmosphere and escaping exosphere

Mars climate : a complex system

Atmospheric circulation

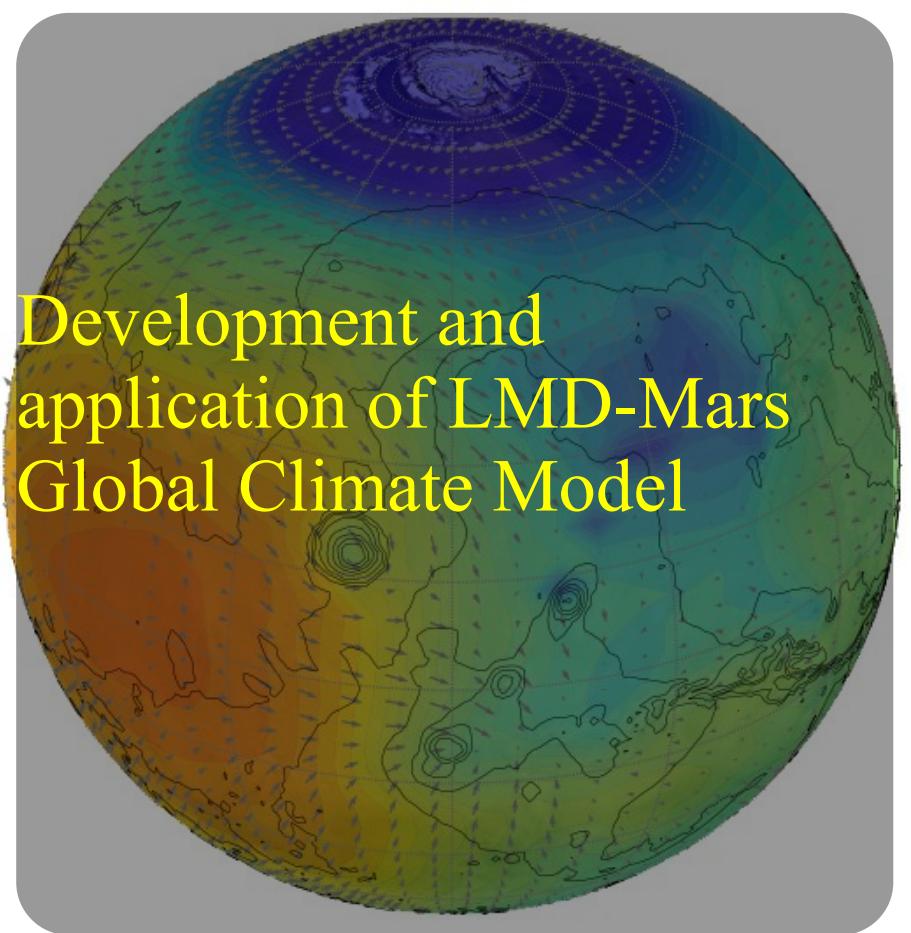


Tools

Observations

- Mars Express
Interdisciplinary Scientist
- Collaborator of
MAVEN/IUVS
- NOMAD/ExoMars TGO
science team

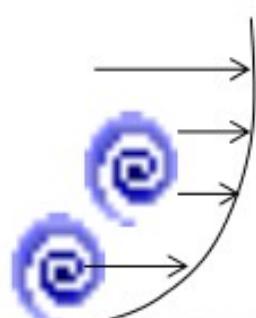
Modeling



Basic characteristics of the LMD Mars Global Climate Model :



1) LMDZ final Dynamical Core (Grid point Model)



3) Subgrid scale dynamics

- Turbulence: Mellor and Yamada 2.5 Scheme
- Convection :
- Gravity waves (orographic) + low level drag: Parametrisation of impact on the main flow

4) Surface and subsurface thermal balance

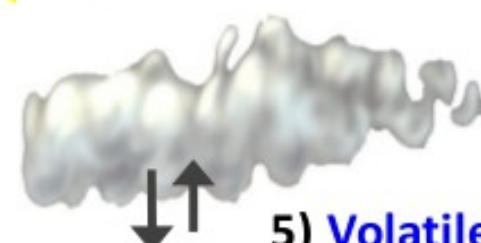


2) Radiative transfer:

- TIR CO₂ wide band model (Hourdin 1991) + NLTE model (Lopez-Valverde 2011)
- NIR CO₂ (NLTE)
- EUV absorption
- Aerosols: Toon et al. 1989



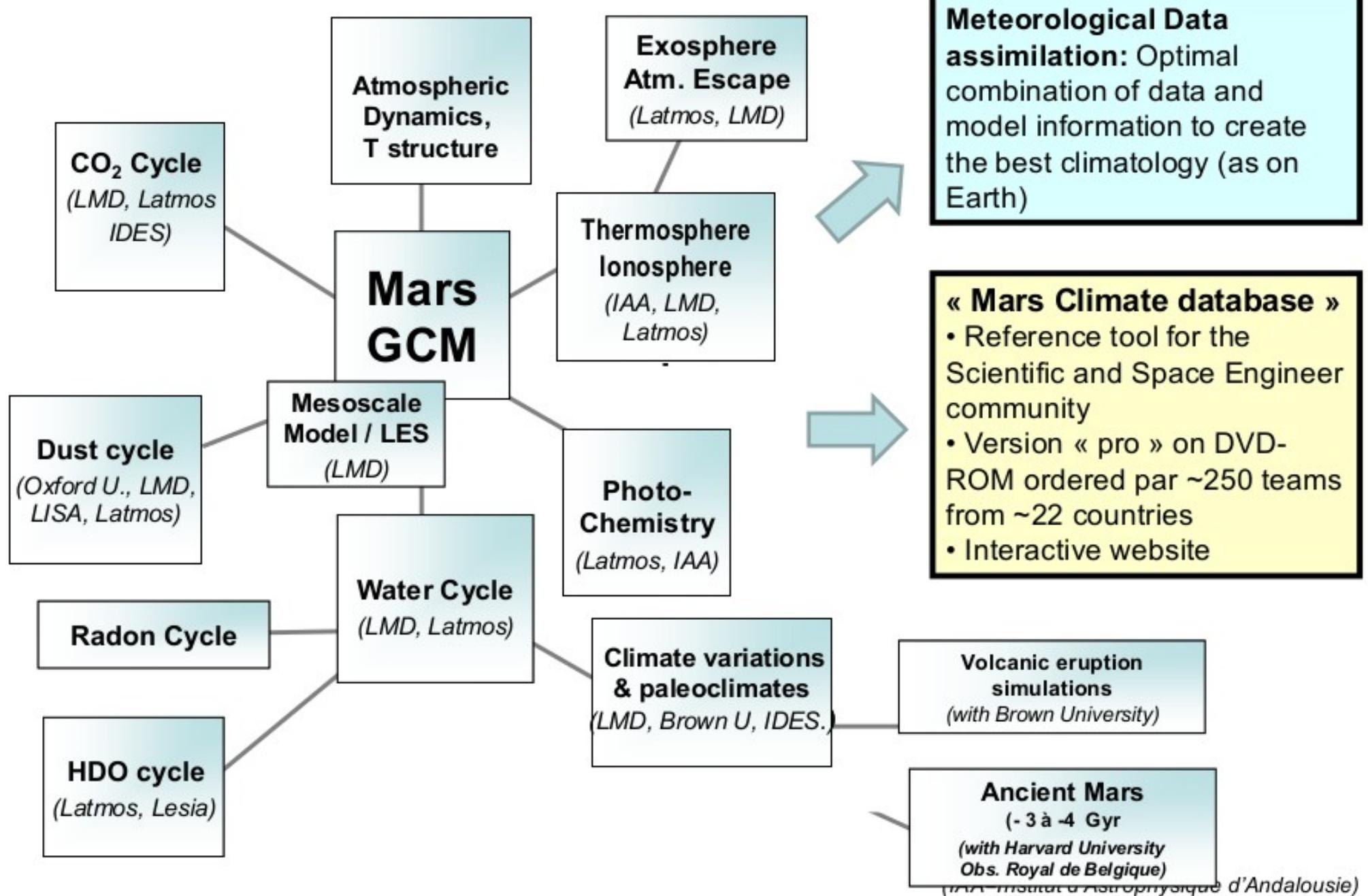
6) Dust transport and distribution : *see below*



5) Volatile:

- CO₂ cycle: *see below*
- H₂O cycle: *see below*

The LMD/IPSL « Mars system simulator »



The Mars Climate Database

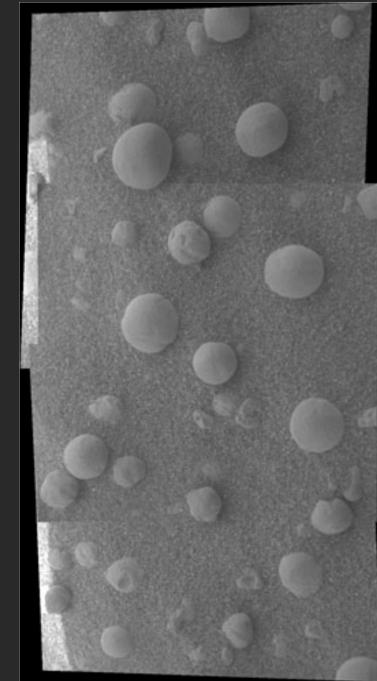
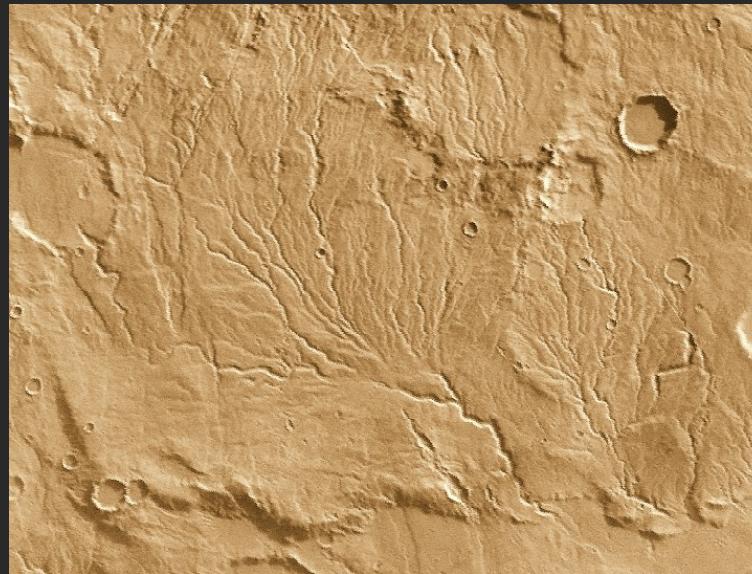
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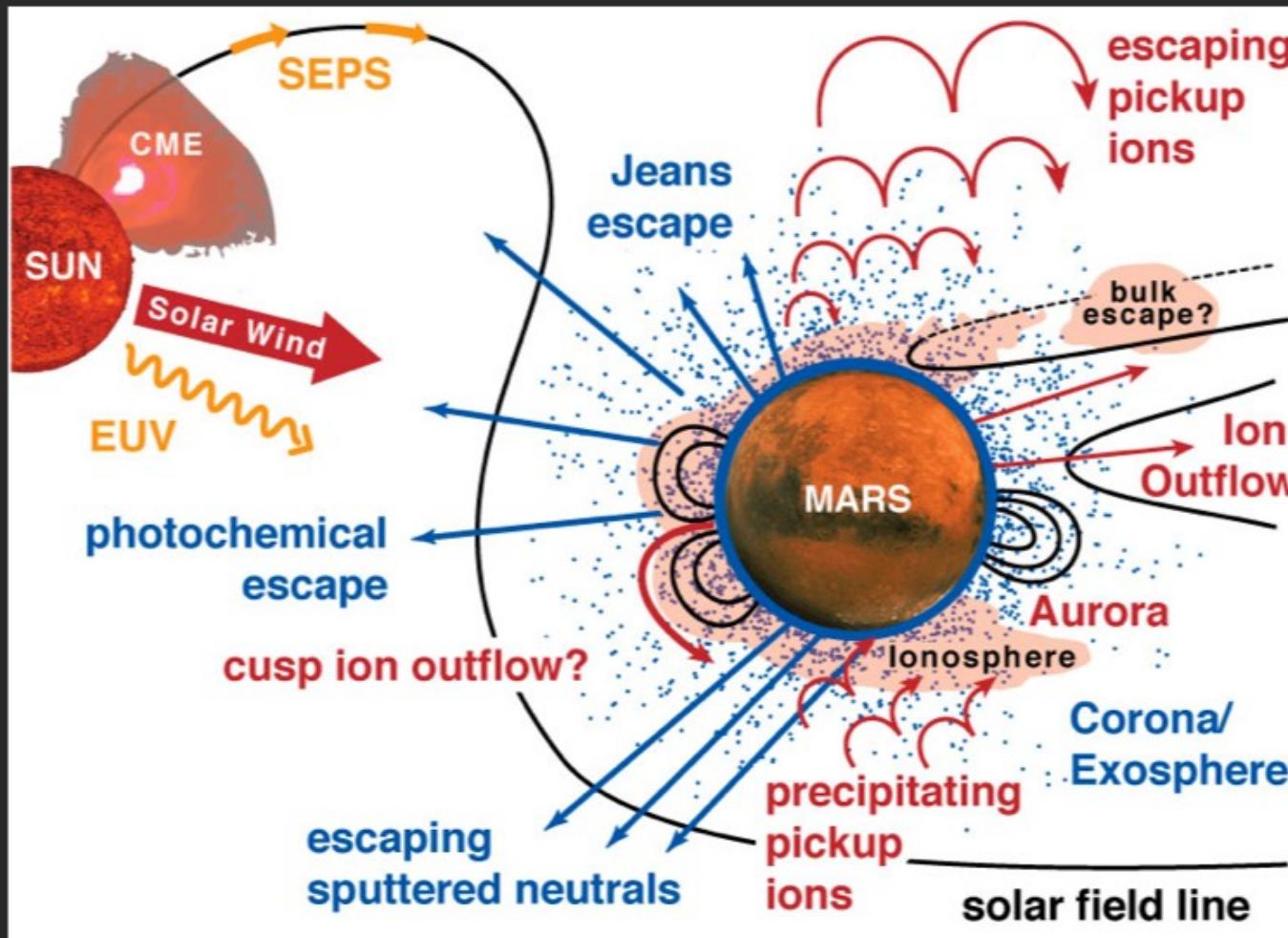
<i>Beginners' column (1-click presets)</i>	<i>Regular users' column</i>	<i>Advanced settings and information</i>
1) LANDING DATE <input checked="" type="radio"/> Land now! <ul style="list-style-type: none"> <input type="radio"/> Curiosity <input checked="" type="radio"/> Phoenix <input type="radio"/> Opportunity <input checked="" type="radio"/> Spirit <input type="radio"/> Pathfinder <input type="radio"/> Viking 2 <input checked="" type="radio"/> Viking 1 	<input checked="" type="radio"/> MARS date Solar longitude <input type="text" value="41.2"/> degrees Local Time <input type="text" value="12"/> Martian hour write a value (or) a range 'val1 val2' (or) 'all' <input type="radio"/> EARTH date YY / MM / DD @ hh:mm:ss UTC <input type="text" value="2015"/> / <input type="text" value="9"/> / <input type="text" value="14"/> @ <input type="text" value="7"/> : <input type="text" value="15"/> : <input type="text" value="10"/>	If longitude is a free dimension, local time value is <input checked="" type="radio"/> at longitude 0 <input type="radio"/> fixed for the whole planet Earth Julian Date <input type="text" value="2457279.80219"/> Mars MY <input type="text" value="33"/> - MM <input type="text" value="2"/> / 12 - sol <input type="text" value="86"/> / 669 EARTH DATE >>> MARS DATE
2) TIME <input checked="" type="radio"/> Morning <input type="radio"/> Afternoon <input type="radio"/> Evening <input type="radio"/> Night 3) ALTITUDE <input checked="" type="radio"/> Near-surface <input type="radio"/> Boundary layer <input checked="" type="radio"/> Troposphere <input type="radio"/> Mesosphere <input checked="" type="radio"/> Thermosphere	CUSTOMIZE COORDINATES ON MARS write a value (or) a range 'val1 val2' (or) 'all' <ul style="list-style-type: none"> • Latitude <input type="text" value="all"/> degree North • Longitude <input type="text" value="all"/> degree East • Altitude <input type="text" value="200000"/> m above surface 	<ul style="list-style-type: none"> • MCD version <input checked="" type="radio"/> 5.2 • <u>Dust/EUV scenario</u> <input type="text" value="Martian Year 25"/> • Interpolate using MOLA topography <input checked="" type="checkbox"/> • Zonal averaging (only lat/alt plot) <input checked="" type="radio"/> off <input type="radio"/> on • Picture resolution <input checked="" type="radio"/> medium <input type="radio"/> high <input type="radio"/> eps
4) INTEREST <input checked="" type="radio"/> Atmosphere <input type="radio"/> Winds <input type="radio"/> Weather <input type="radio"/> Water cycle <input checked="" type="radio"/> Chemistry <input type="radio"/> Landing engineering <input type="radio"/> Glaciology <input type="radio"/> Radiative balance	CUSTOMIZE VARIABLE(S) TO BE DISPLAYED Variable 1 <input type="text" value="Temperature (K)"/> Variable 2 <input type="text" value="O vol. mixing ratio (mol/mol)"/> Variable 3 <input type="text" value="Horizontal wind (m/s)"/> Variable 4 <input type="text" value="Ar vol. mixing ratio (mol/mol)"/>	<ul style="list-style-type: none"> • [1D] Log(values) <input checked="" type="radio"/> off <input type="radio"/> on • [2D] Colormap <input type="text" value="blue green yellow red"/> • [2D] Bounds <input type="text" value="min"/> min <input type="text" value="max"/> max • [2D map] <input type="text" value="flat"/> lat <input type="text" value="lon"/> • [2D map] Transparency (%) <input type="text" value=""/> • [2D map] Wind vectors <input checked="" type="radio"/> off <input type="radio"/> on
Values Daily cycle Vertical profile Global map	SUBMIT RESET	Mars Climate Database (c) LMD/OU/IAA/ESA /CNES. Open source python interface by A. Spiga (LMD). Javascript time conversion by E. Millour (link).

Motivation



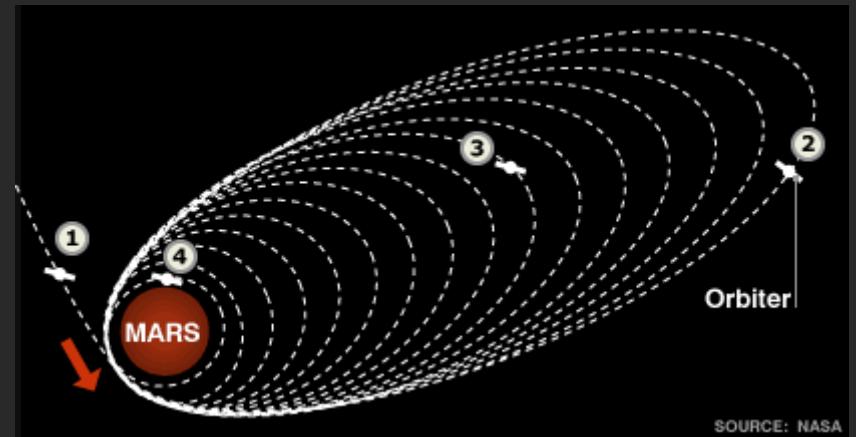
- Geological records on Mars show evidence of wetter, denser atmosphere in the past
- Where did that atmosphere go?
- Atmospheric escape is a key process to understand Mars atmospheric evolution

Motivation



- Escape variability strongly affected by temperature/density variability in UA

Motivation

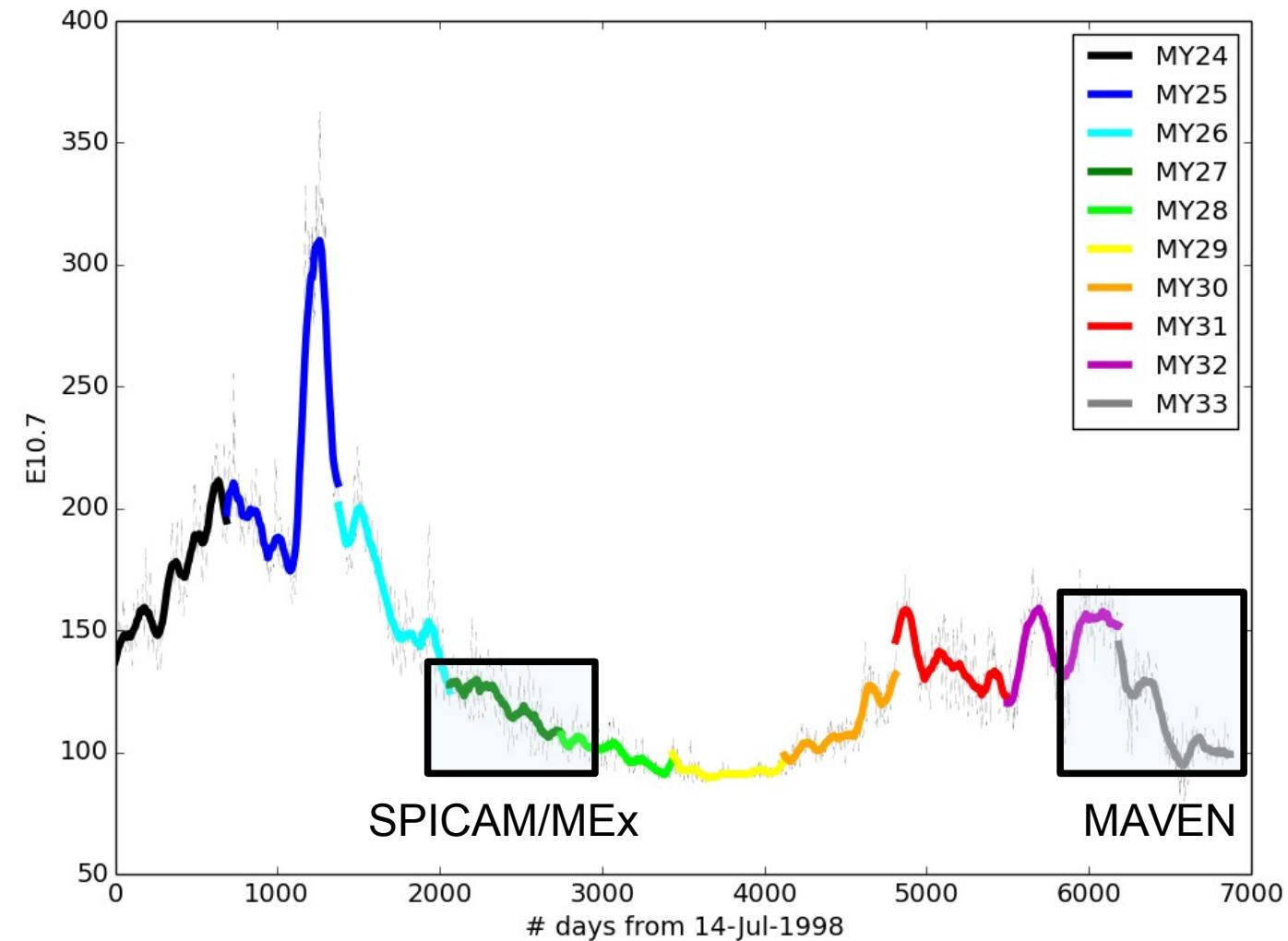


- Good knowledge of UA structure and variability essential for aerobraking manoeuvres

Sources of variability in UA

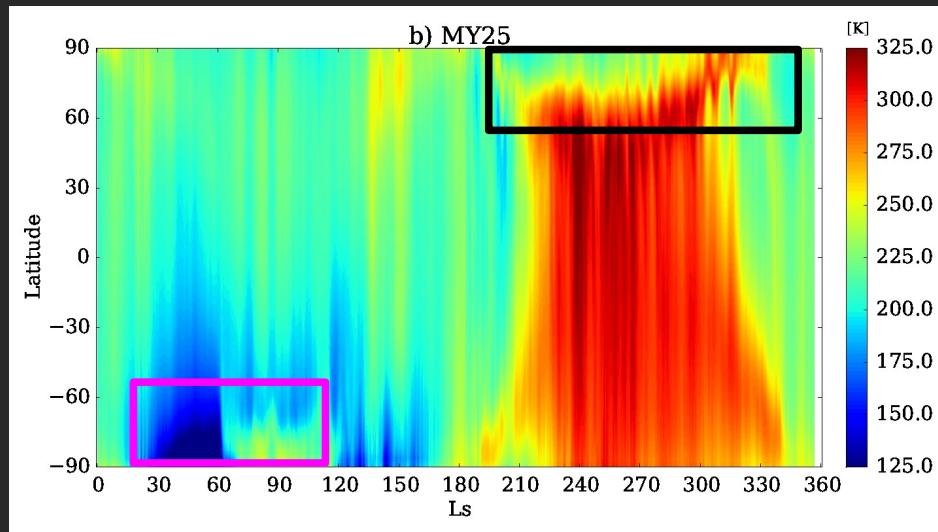
- Solar UV variability
 - 11-year cycle
 - 27-sols
 - Flares
 - Orbital eccentricity
 - Latitudinal/LT due to insolation variations
- Atmospheric waves
 - Tides (migrating/non migrating)
 - Transient waves
 - Gravity waves
- Dust load in the lower atmosphere

Solar UV variability

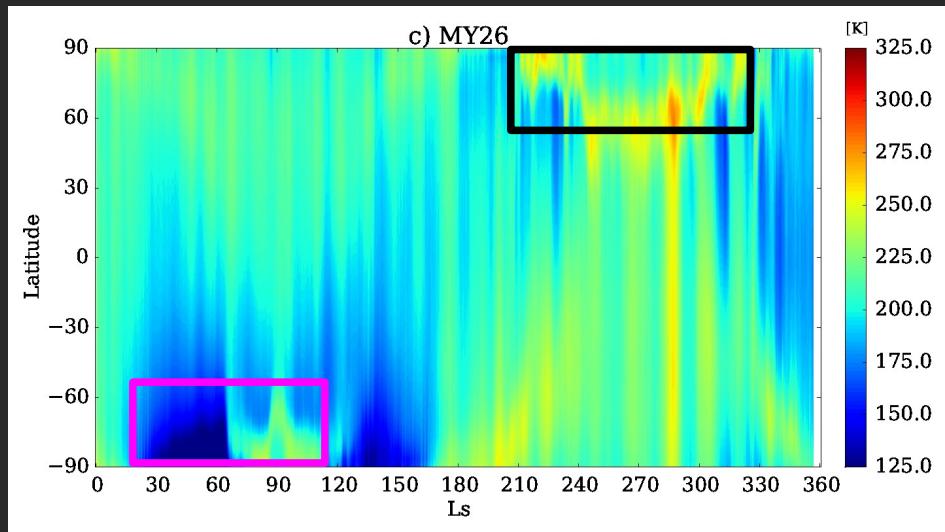


Results: temperature variability

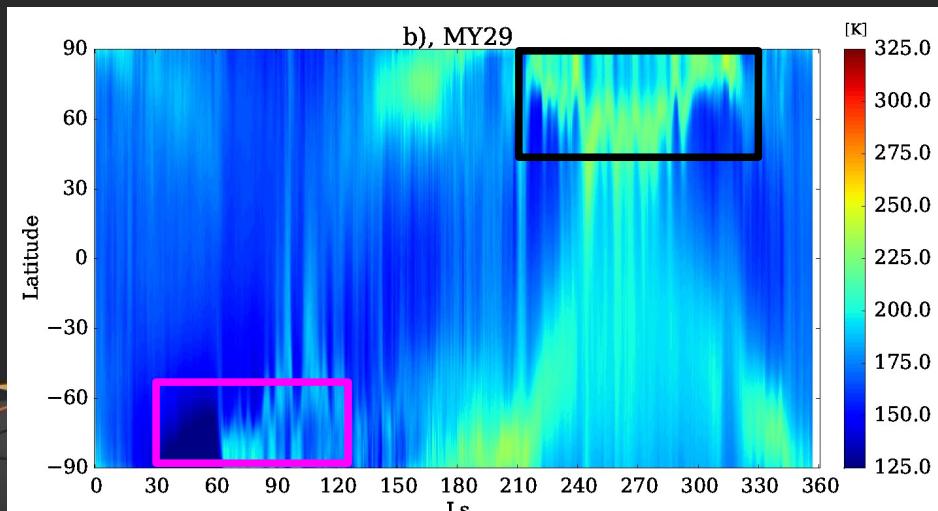
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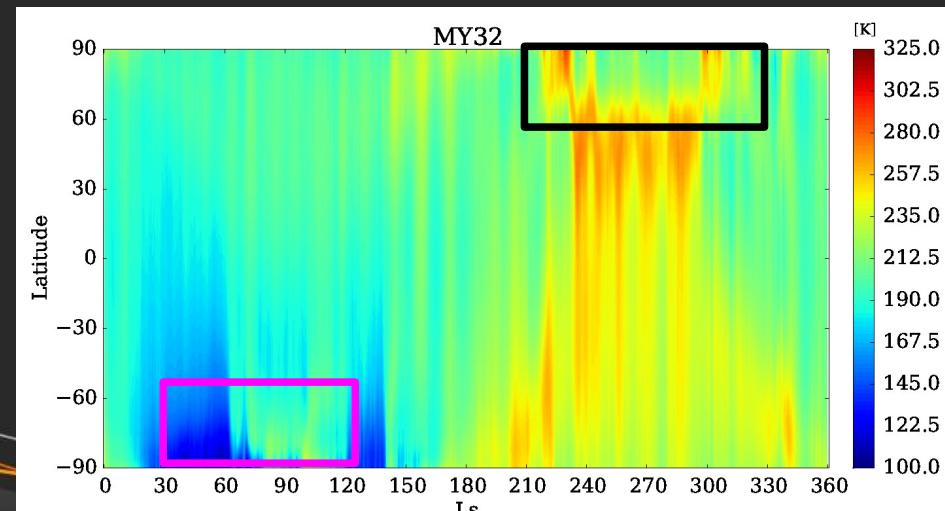
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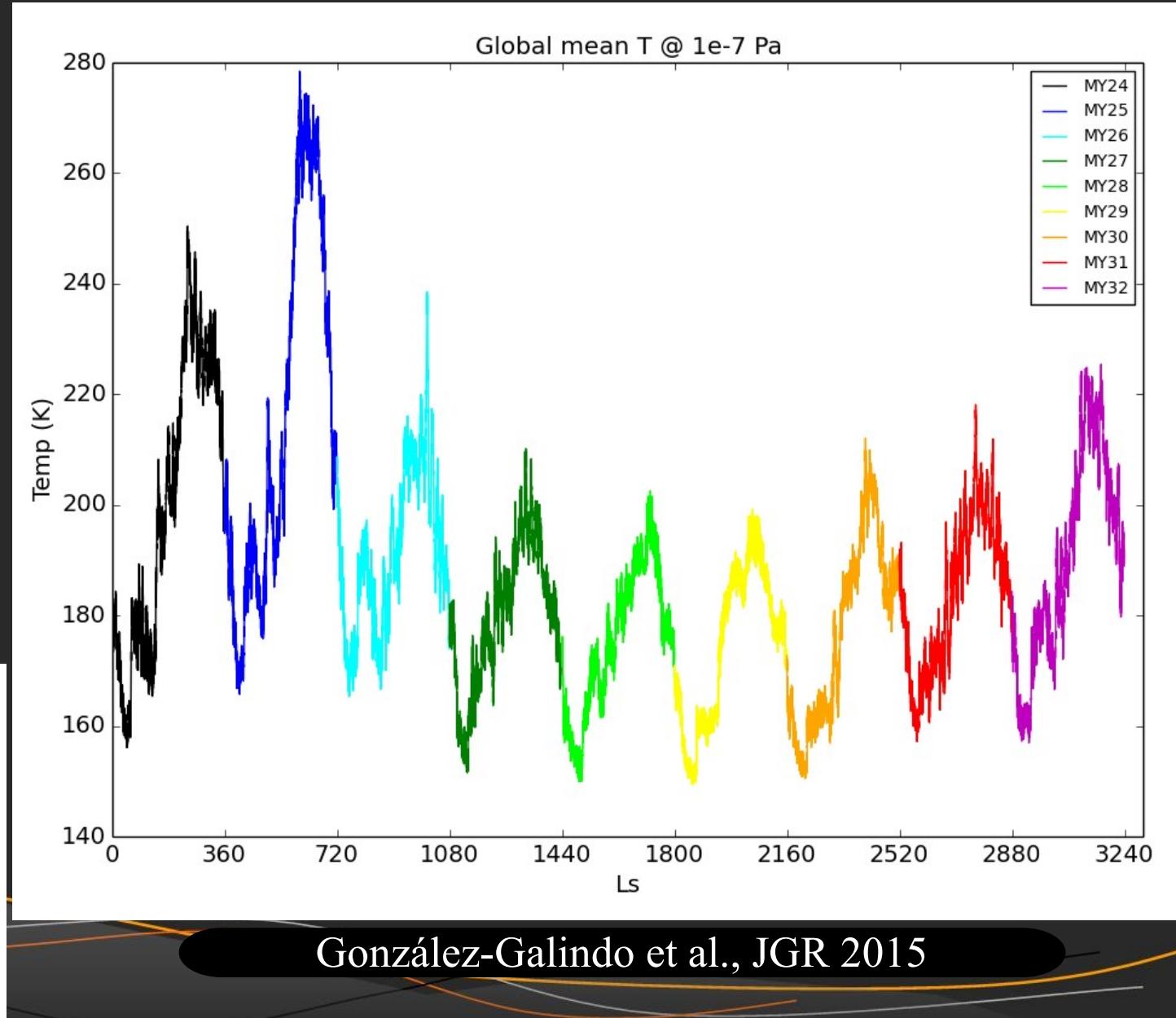
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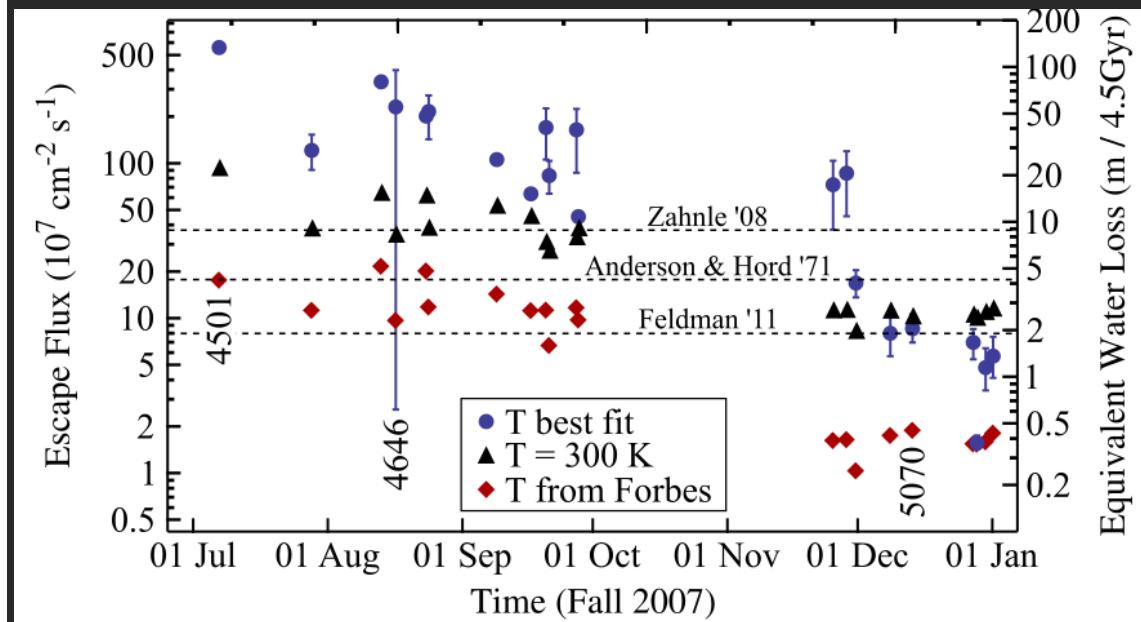
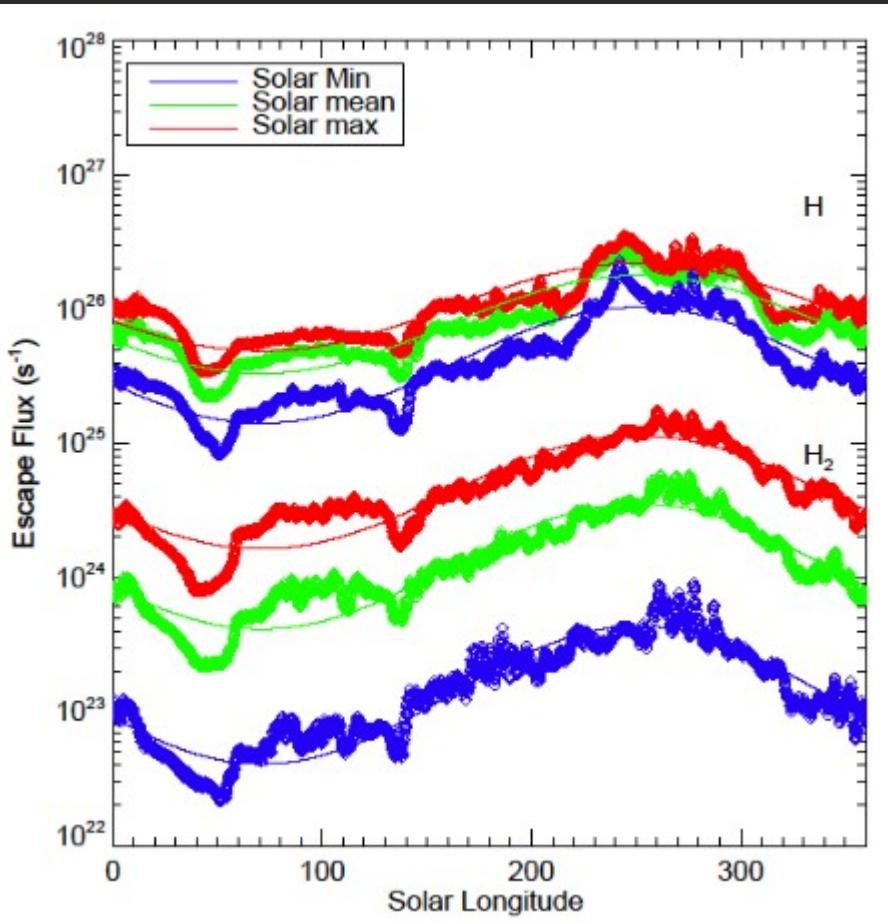
MY32



Results: temperature variability



Results: Hydrogen escape



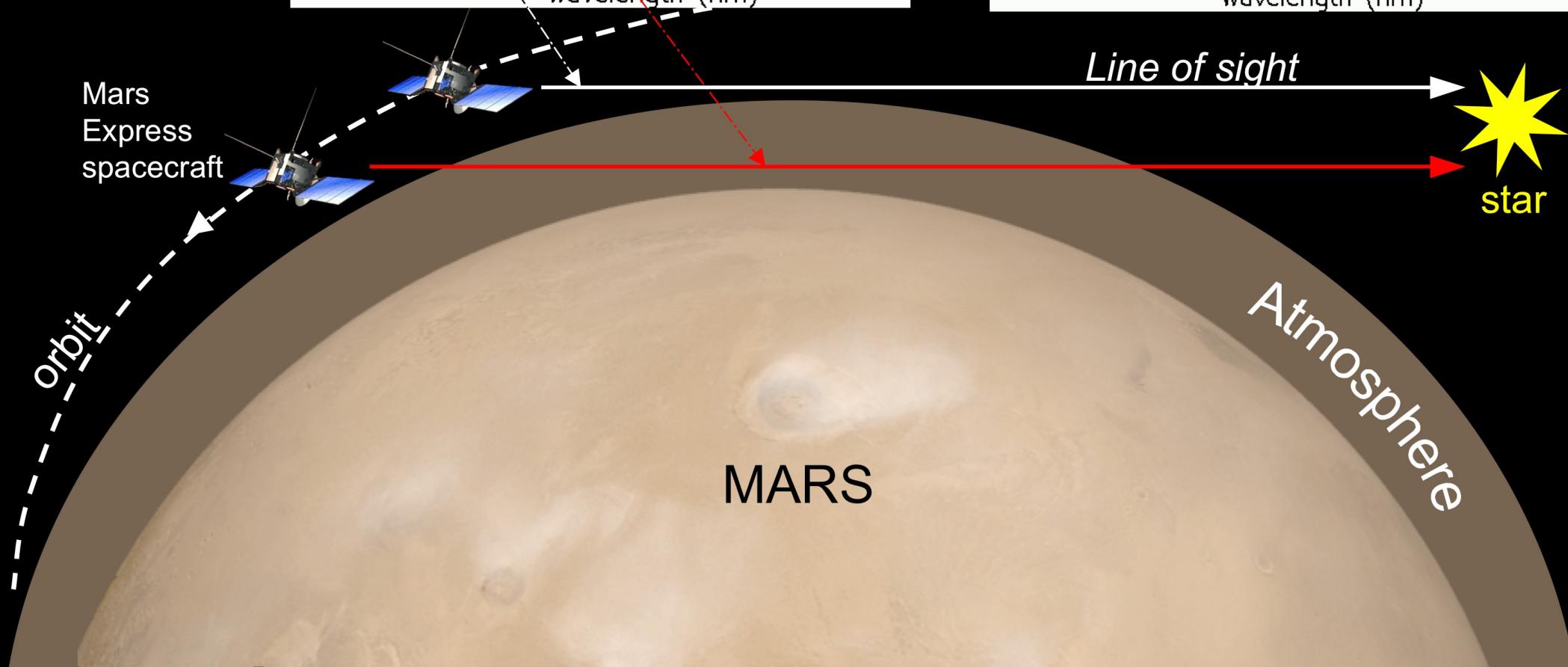
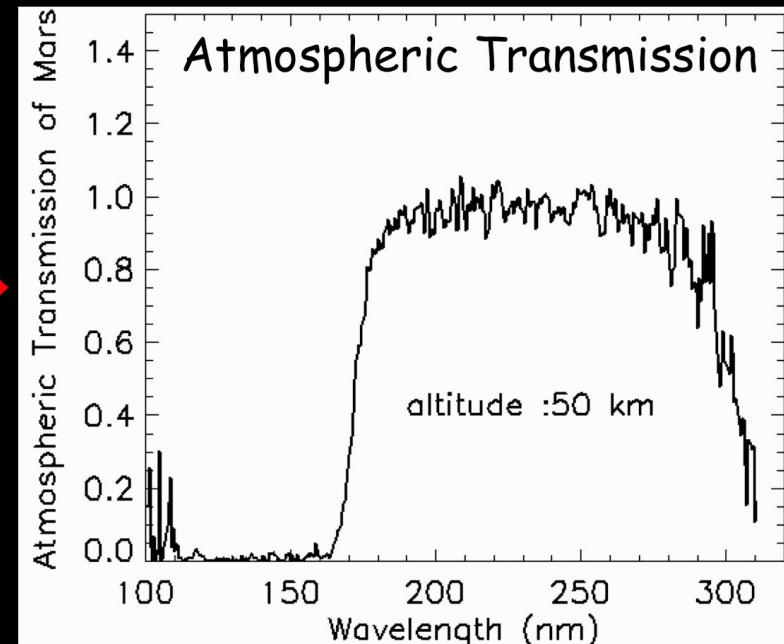
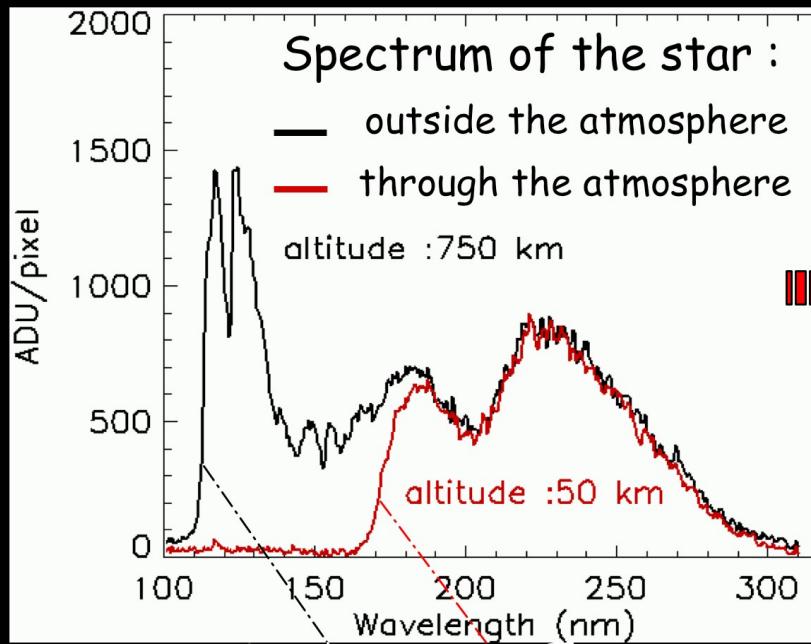
Chaffin et al., GRL 2014

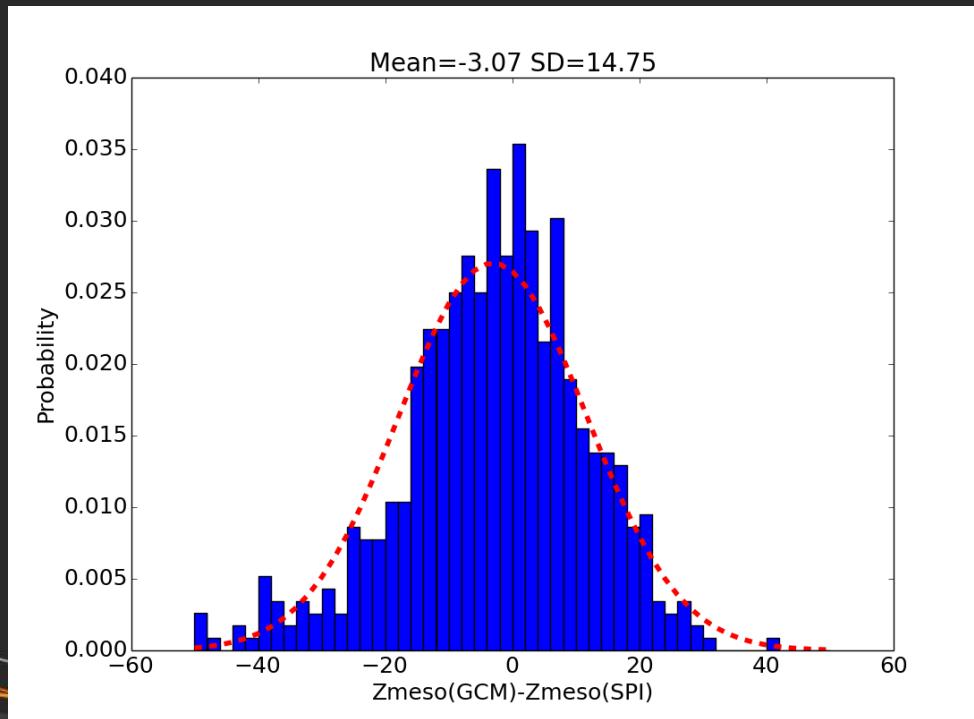
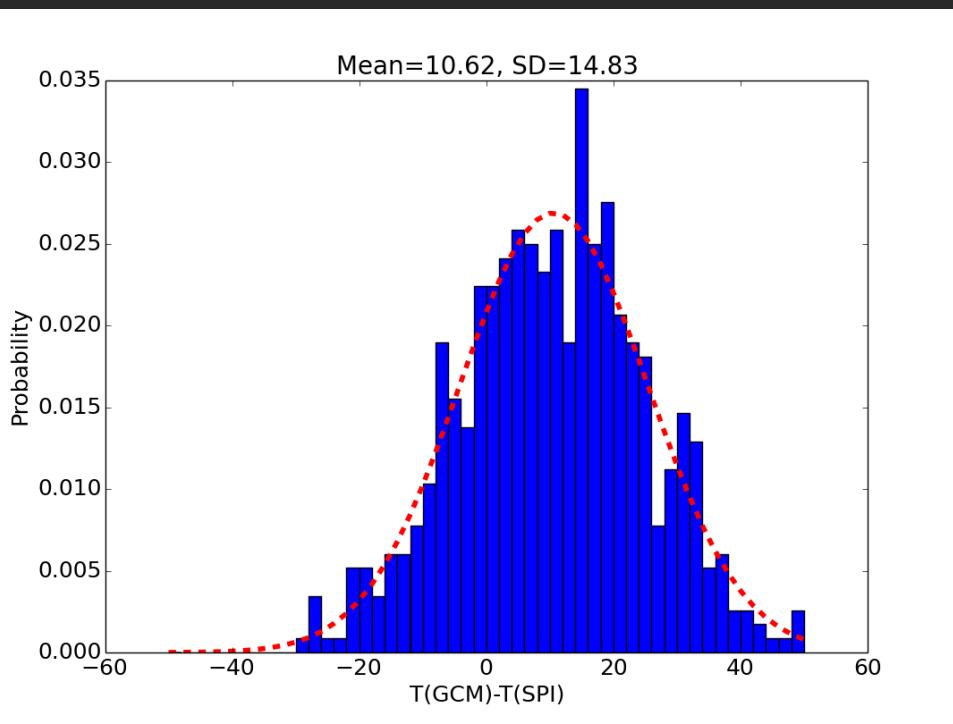
Chaufray, González-Galindo et al.,
submitted

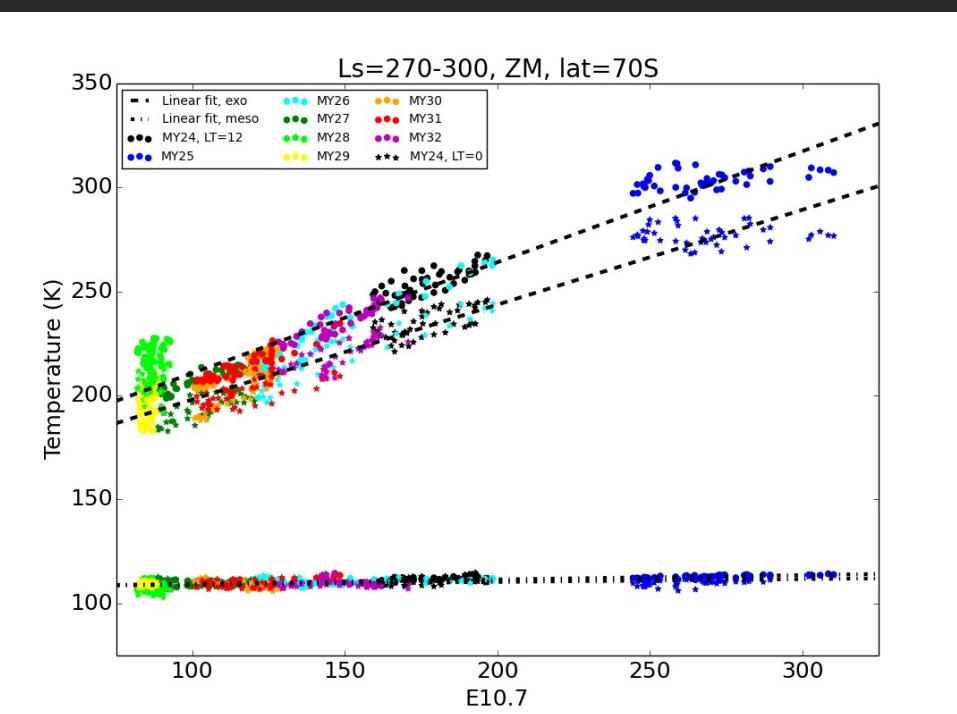
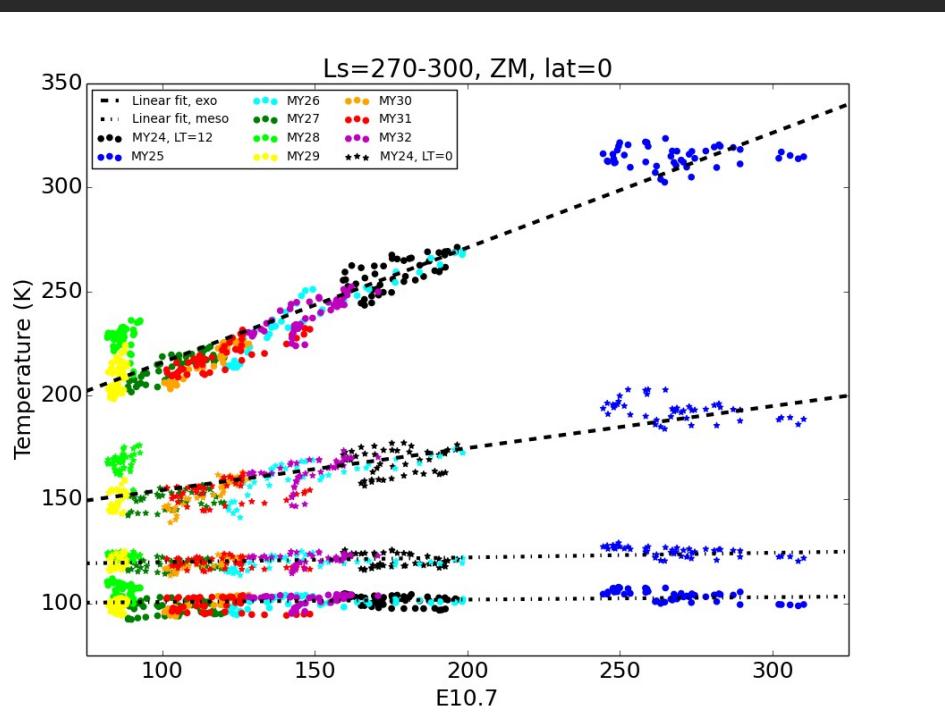
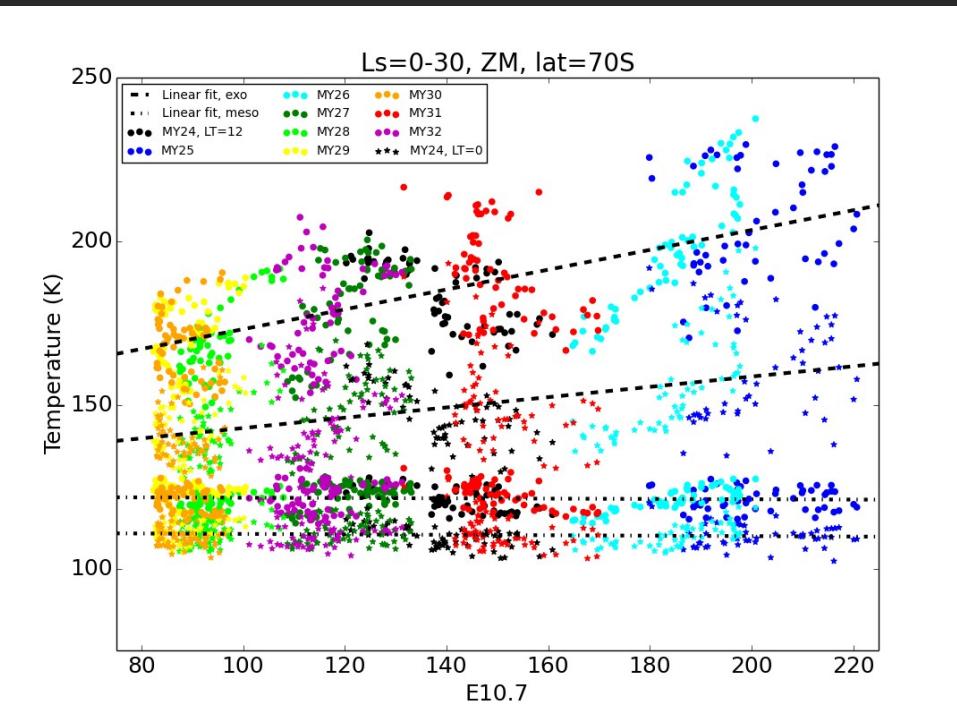
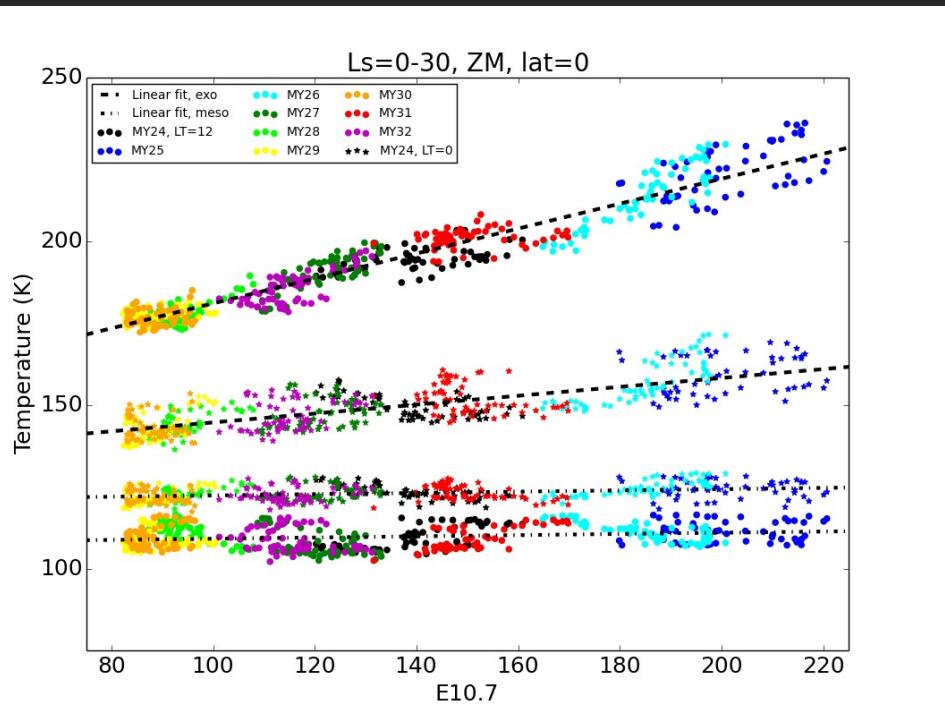
Summary and future work

- Mars upper atmosphere strongly affected by variability
- We have characterized the temperature variability in the UA during the last 10 MYs
 - Strong seasonal variability
 - Important solar cycle variability
- Strong H escape rate variability
 - x10 seasonal, good agreement with MEx and MAVEN
 - x2-5 solar cycle
- Future directions:
 - Study temperature/escape rate at past solar conditions, to provide estimates of accumulated H loss

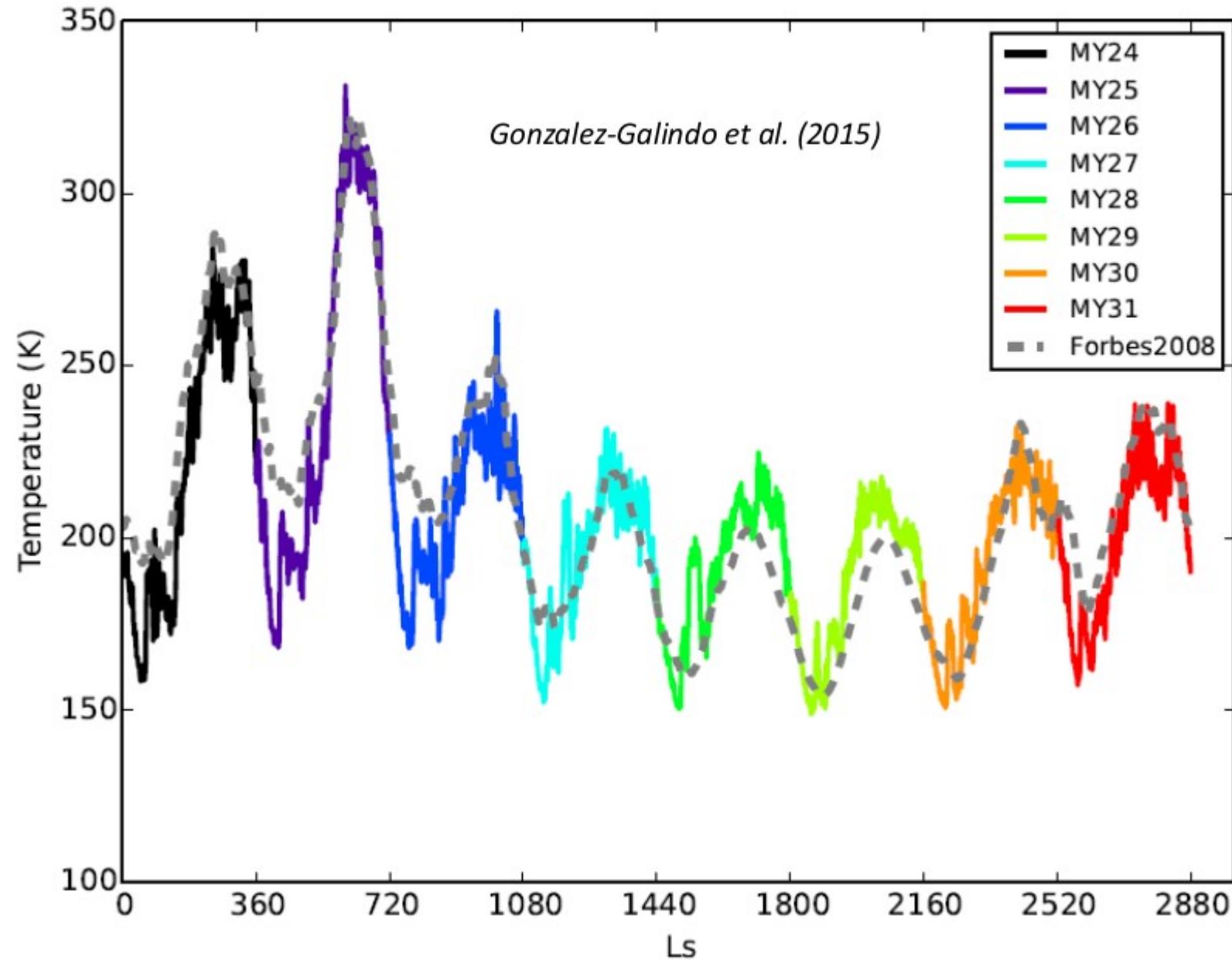
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Ultra-Violet
observations,
orbit #17
13 jan. 2004

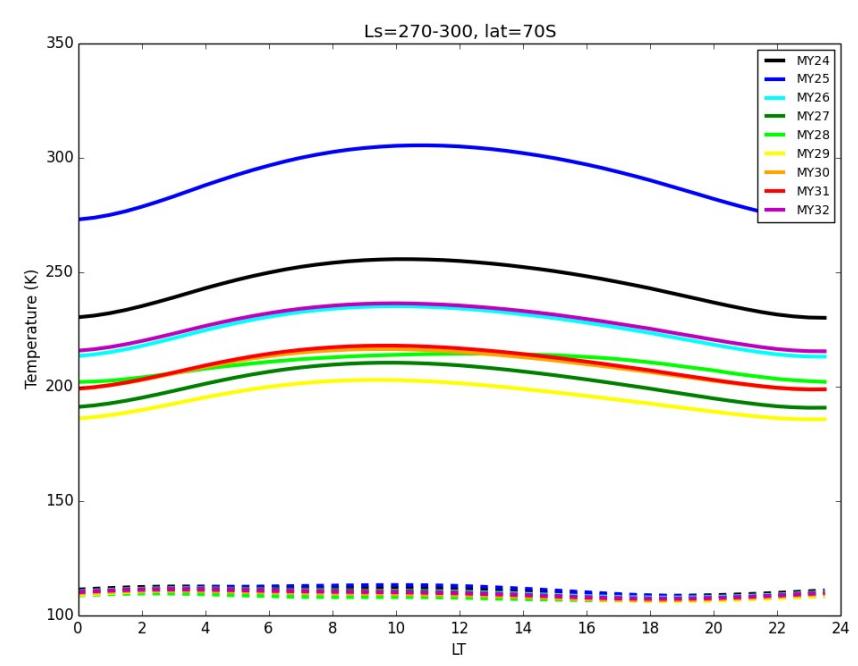
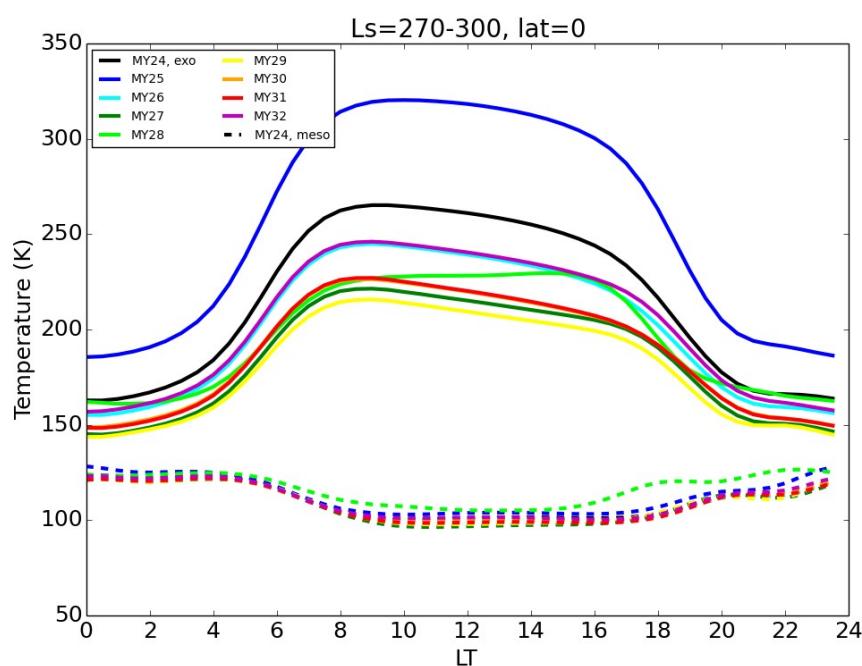
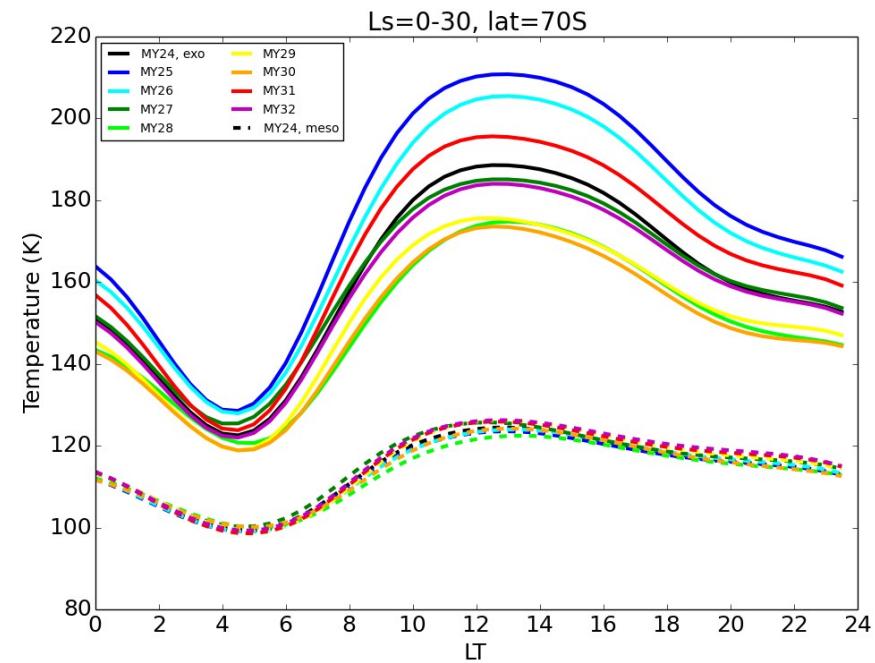
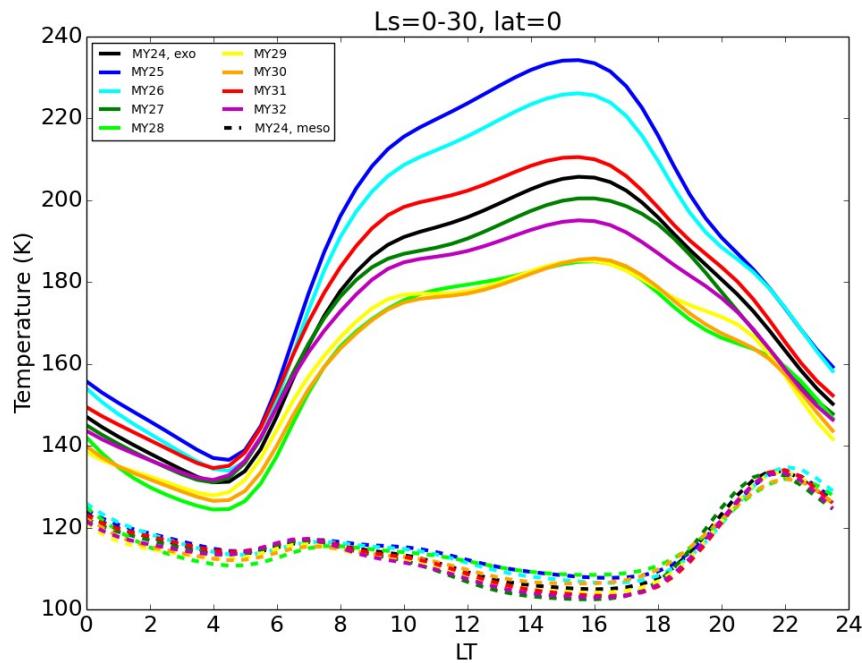


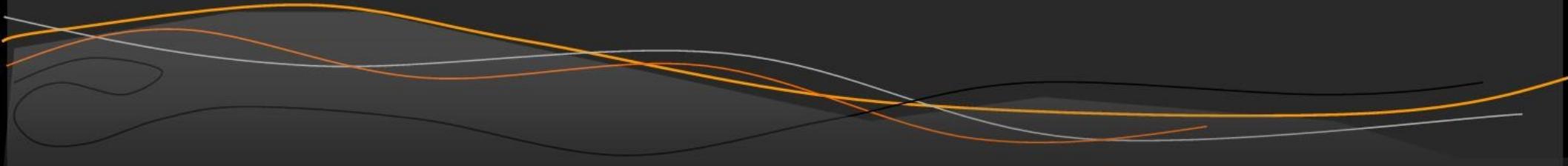




LMD GCM Zonal mean exobase temperatures at noon and lat=50S







The Mars Climate Database

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The Mars Climate Database

