

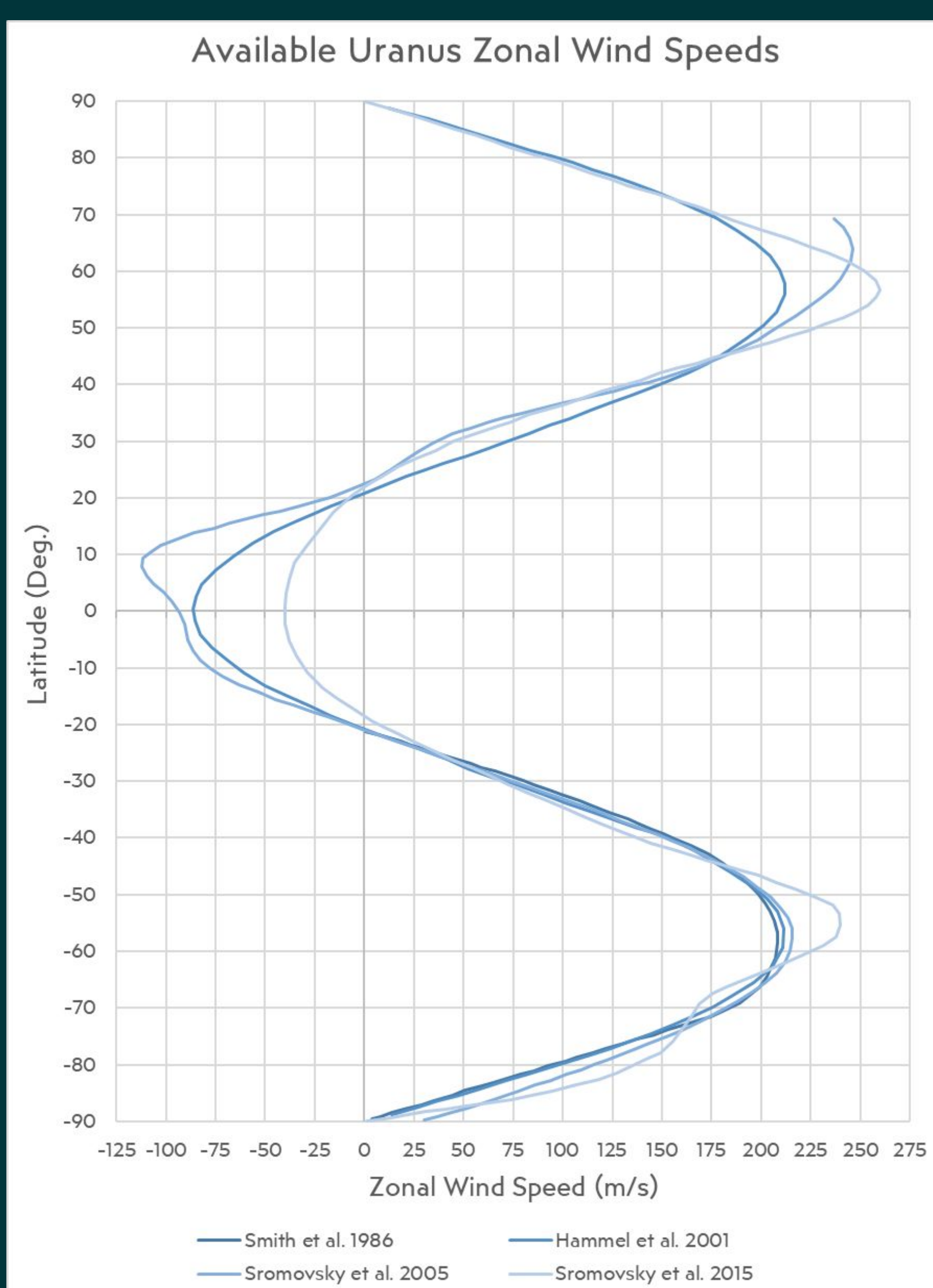
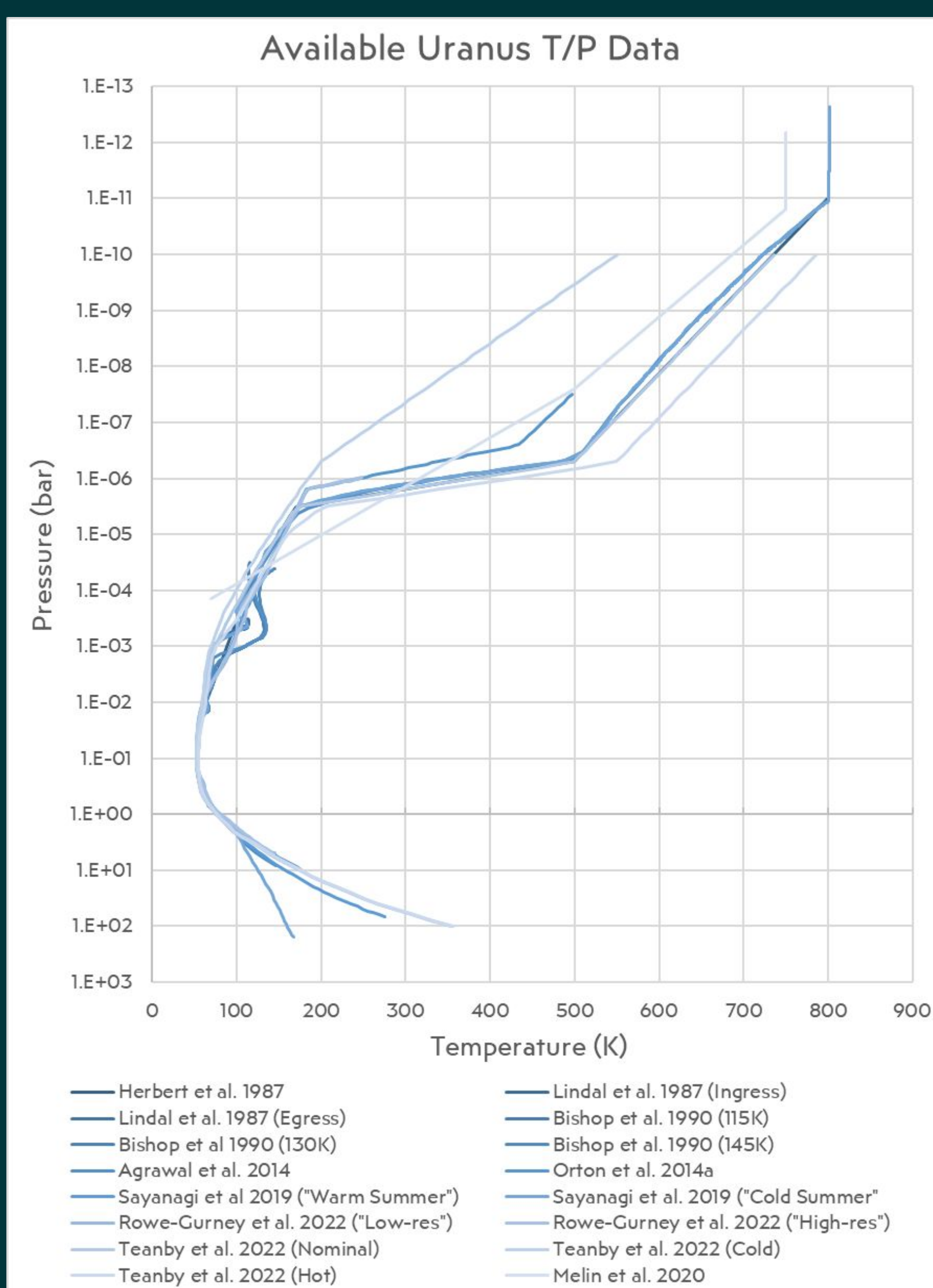
The Improved Uranus Global Reference Atmospheric Model (UranusGRAM)

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- Motivation -

- UranusGRAM is an engineering oriented atmospheric model that estimates mean values and statistical variations of atmospheric properties
- The new UranusGRAM release updates the old, Voyager-based reference data with modern reanalyses and observations
- Aerocapture and probe mission designs depend on reliable temperature, wind, and density estimates



- Temperature -

- Tropospheric model adopts the best-fit profile of Orton et al. 2014
 - ◆ Spitzer Space Telescope / Voyager 2
- Thermospheric model "family" connects profiles over the observed temperature range at the base and top of Uranus' thermosphere
 - ◆ Profiles follow the hydrostatic equation with a constant lapse rate:

$$p(z) = p_o \left(\frac{T(z)}{T_o} \right)^{\frac{\gamma}{R\Gamma}}$$

- Deep model adopts the temperature range of Sayanagi et al. 2019 by assuming constant Brunt-Väisälä (BV) frequencies
 - ◆ Warmest follows the dry adiabatic lapse rate; coolest assumes a constant BV frequency of 0.004 s^{-1}
- Densities are calculated for each profile using the ideal gas law and an altitude-dependent mean molecular mass
- Permutations of the 3 segments form the full model ensemble: see top right figure
 - ◆ "Mean", default profile is that closest to the mean Voyager profile of Teanby et al. 2022
 - ◆ "Cool" profile includes the thermospheric cooling trend of Melin et al. 2019
 - ◆ "Hot" profile connects the highest observed Voyager temperatures

- Altitude -

- We calculate altitudes for each TP profile via the barometric equation:

$$P = P_o \exp \left[- \int_0^z \frac{dz}{H} \right] = P_o \exp \left[- \int_0^z \frac{g(z)}{R(z)T(z)} dz \right]$$

- Local gravity is calculated at each grid level, using the first zonal harmonic coefficient.

$$g_r(r, \phi) = \frac{GM}{r^2} \left(1 - \frac{9}{2} \left(\frac{R}{r} \right)^2 J_2 \sin^2 \phi + \frac{3}{2} \left(\frac{R}{r} \right)^2 J_2 \right) - \omega^2 r \cos^2 \phi$$

- About Me -

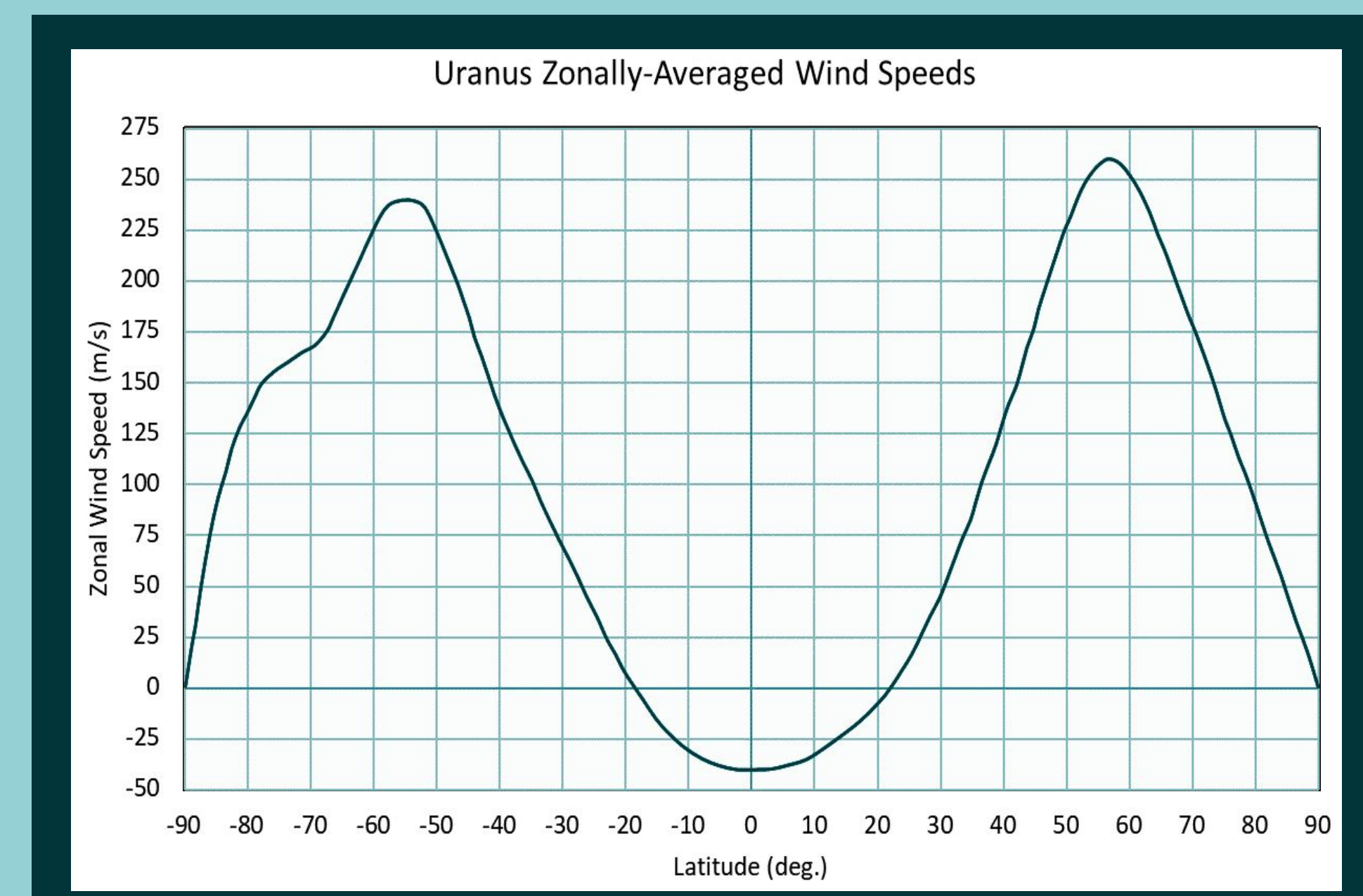
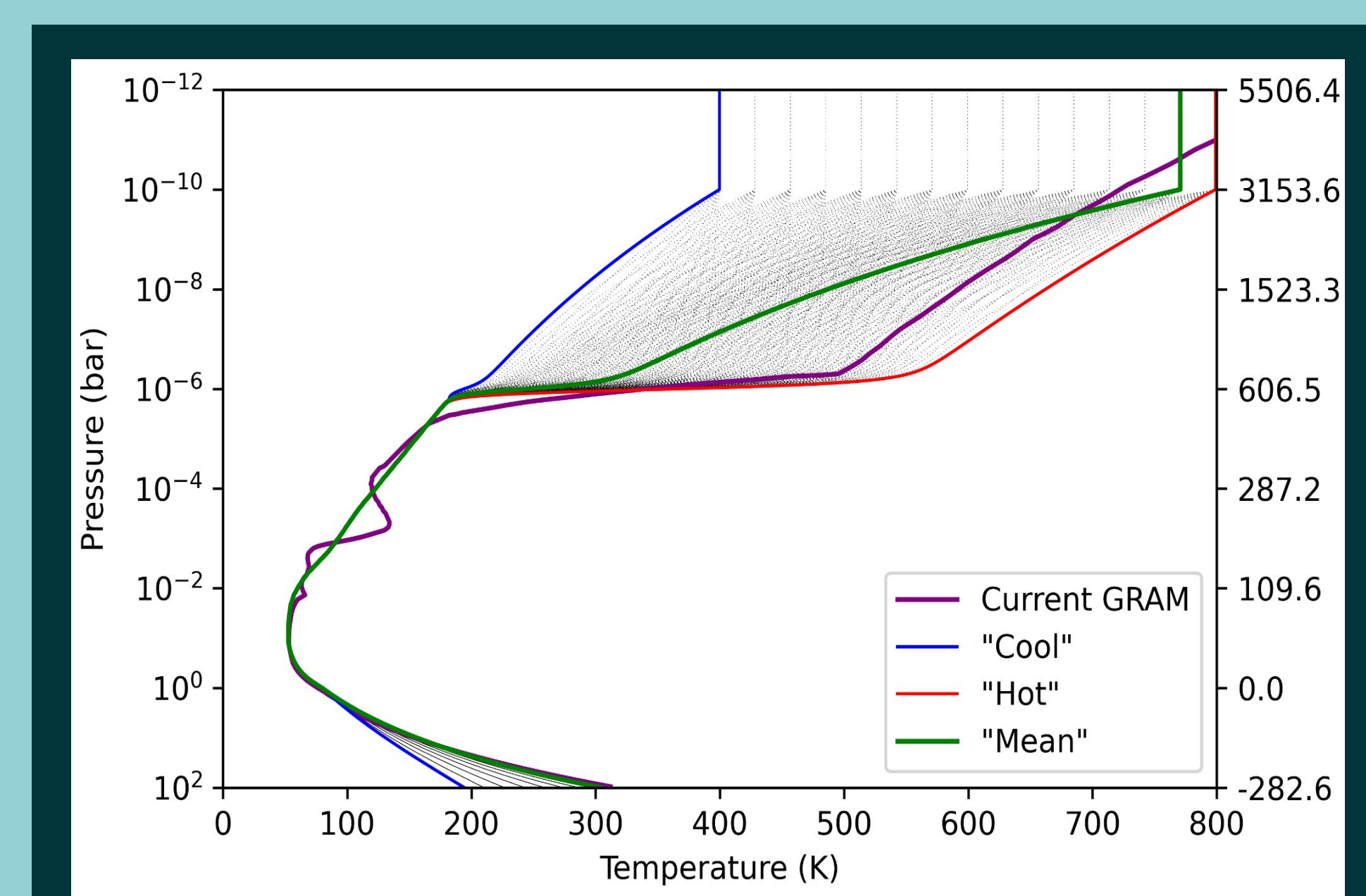


Justin Garland is a planetary scientist with AMA at NASA Langley. Interests include gas giant atmospheres, exoplanets, image processing, and machine learning.

Questions?
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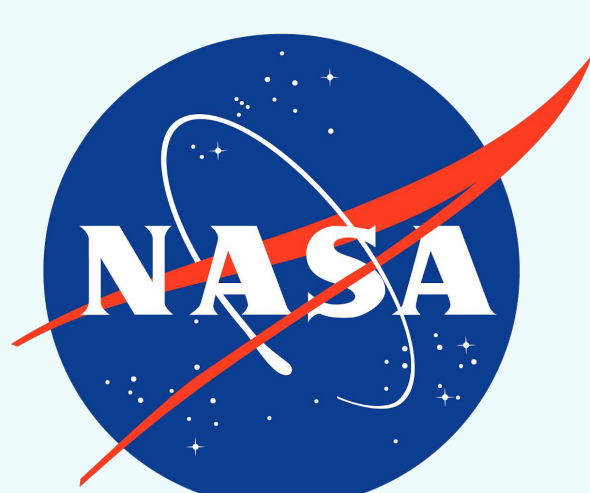
- Zonal Winds -

- We adopt Sromovsky et al. 2015's cloud-top zonal wind profile: see bottom right figure
 - ◆ Keck / Gemini AO observations combined with Karkoschka 2015's reanalysis of Voyager 2 images
- Vertical wind shear is roughly estimated from the only in-situ measurement on a giant planet: the Galileo Probe Doppler Wind Experiment at Jupiter
 - ◆ The vertical wind shear of Atkinson et al. 1998 is applied to decay winds above the clouds



- Future Work -

- The next UranusGRAM release will include these atmospheric upgrades
- Planned for Summer 2024
- Next steps for UranusGRAM include:
 - ◆ Updated estimates of constituent gas species, including variability
 - ◆ Tropospheric temperature variability
 - ◆ Thermospheric model stability testing
- A 2D, zonally-averaged Uranus atmospheric model is also in development
 - ◆ Will provide pole to equator variation of atmospheric properties



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