Uranus Atmospheric Upgrade for Orbiter 2010

By DR_AERONAUTICS

Description

This atmospheric upgrade is designed for Orbonauts like myself who enjoy aerobraking, de-orbiting, or flights in the upper atmosphere of Uranus. As there is such a huge fuel price to pay for so little gain, there's likely not many of you. However if you tried this stunt you likely noticed the Surface MFD's thermal readout reading a constant 288K. Thus the vanilla orbiter config file defines the following for Uranus's atmosphere:

T=288K

P=454e3*e^(-z/h) in kPa, where z is a constant

Rho= 0.5293*e^-(g0/(R*T)*z) kg/m^3, where g0 and T are constant

The result is an atmosphere that is generic in orbiter. It takes only a few minutes to define, but is totally lacking distinct layers. This makes it much more difficult to recreate any future Uranus missions (such as the proposed atmospheric probe) or demonstrate concepts of said missions with any reasonable accuracy. Such examples might include (but are not limited to) attempting aerocapture at 400 kilometers per a NASA design document only to find thyself incinerated, and attempting to re-enter with a delta glider and seeing higher than realistic heating due to a stratosphere at +15C. This is precisely what encouraged me to spend the hours involved in coding up a proper atmosphere.

Using the data remotely sampled, I was able to identify 9 unique layers, meaning this module does the work of 9 config files, each one also defining temperature.

Process

Unlike Jupiter, Uranus did not have a probe directly sample the atmosphere (as of 2023). Instead data was collected based on Voyager 2 occupation experiments and large ground and space based telescopes that helped to create a standard model of the atmosphere.

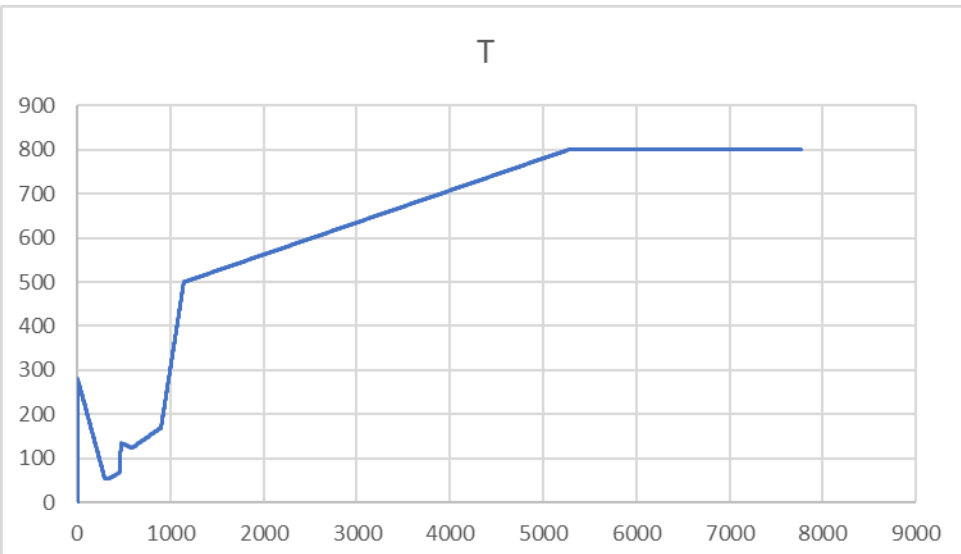
The data was tabulated from graphs onto an excel spreadsheet using transfer functions and converted to an excel table. The data was compiled onto a single table where the abbreviated header is shown below.

R0	3730.1					
1 bar true	Cutoff tru	g	T	P	rho	Layer

At this point to keep things harder to make careless mistakes I translated the 0 altitude datum from the 1-bar level (1 bar true column) to the zero altitude (Cutoff true column) in Orbiter.

This allowed me to work in Orbiter compliant altitudes, as altitudes below 0 km are not simulated. The translation was exactly +265000m, which is the exact distance from the explicitly defined Uranus altitude-0 and the 7 Celsius isotherm which just about corresponds with the lowest condensing water clouds.

Next I needed to determine some data trends. This module runs fundamentally from specific gas constant, R, acceleration due to gravity, g, and measured temperature, T. All other parameters are calculated using these 3 base values. As there was no probe, we don't know precisely the R values of Uranus versus altitude. Therefore I had to assume a constant value based on the molecular distribution of the known mixture of gases up to the methane vaporization point (around 56km above 1 bar), and then above that R is set to model a mixture of hydrogen and helium only. Gravity calculates using the simple formula $g = Gm/(r+h)^2$, where m is the mass of Uranus, r the radius at 1 bar, and h the altitude relative to 1-bar (the "surface"). That just leaves T to be filled in by remote sensing observations. Shown below is the plot of T based on collected scientific papers. All x axis values are in km.



The following equations represent R, G, and T:

$$For\ base\ through\ stratosphere, R0(z) = 3730.1$$

$$For\ stratopause\ through\ top, R1(z) = 3813.04$$

g is the simple 1/r^2 law. For all altitudes:

$$g(z) = \frac{6.67E-11 * 8.6811E+25}{25362000 + z^2}$$

For temperature, out comes 9 equations for the 9 layers I found:

$$For\ troposphere, T0(z) = 280 - z * 1/g(z)/143.6$$

$$For\ troposphere\ top, T1(z) = -9.375E - 5 * z + 83.1$$

$$For\ tropopause, T2(z) = 1.145E - 4 * z + 16.3$$

$$For\ stratosphere, T3(z) = 5.154E - 3 * z - 2261.6$$

$$For\ lower\ stratopause, T4(z) = -9.1667E - 5 * z + 177.6$$

$$For\ upper\ stratopause, T5(z) = 1.4791E - 4 * z + 37.5$$

$$For\ thermosphere, T6(z) = 1.35426E - 3 * z - 1041.9$$

$$For\ transition, T7(z) = 7.2727E - 5 * z + 417$$

$$For\ exosphere, T8(z) = 800$$

And when graphed together, these produce the graph found above.

Here is the table mapping each equation to altitude:

Temperature Layers			
Troposphere	0	289000	0
Troposphere Tops	289000	321000	1
Tropopause	321000	452000	2
Stratosphere	452000	465000	3
Lower Stratopause	465000	585000	4
Upper Stratopause	585000	896000	5
Thermosphere	896000	1140000	6
Transition	1140000	5265000	7
Exosphere	5265000	7765000	8
	From	To	ID

From that point, we have what we need to determine p and rho.

For every altitude, the pressure equation was run for the entire layer, and the outputs at the top of the layer defined the equation coefficients for the next layer. Here is a table of coefficients used in the calculations:

R0	3730.1
R1	3813.04
Z0	0
Z1	289000
Z2	321000
Z3	452000

Z4	465000
Z5	585000
Z6	896000
Z7	1140000
Z8	5265000
Z9	7765000
T0	280
T1	56
T2	53
T3	68
T4	135
T5	124
T6	170
T7	500
T8	800
P0	6586125
P1	34980
P2	8796.57
P3	55.63
P4	40.83
P5	4.83
P6	0.176145
P7	3.03E-02
P8	7.22E-07
L0	-7.98E-04
L1	-9.38E-05
L2	1.145E-04
L3	5.15E-03
L4	-9.17E-05
L5	6.68E-04
L6	1.35E-03
L7	7.27E-05
rho0	6.035956

For every altitude except the exosphere,

$$p(z) = P\# * (1 + (z - Z\#) * L\#/T\#)^{-g(z)/(R*L\#)}$$

Where # represents 0-7 as shown in the table. Z may be taken by reading the altitudes in the 2nd column of the mapping table (cutoff true altitude).

In the exosphere, pressure is always $p(z) = P8 * e^{-\frac{(z-Z8)}{R1*T8/g(z)}}$

Density is a simple relationship between everything so far. At all altitudes, $\rho = \frac{p}{R0*T(z)}$

Now some changes I made to the Uranus.cfg file:

Mean Radius- biggest change of all. In a gas or ice giant planet, which lacks a distinct surface, the "height of 0 altitude" is defined as the radius from the center of the planet to where the ambient pressure of the atmosphere is 1 Earth Standard Atmosphere (101325 kPa). Orbiter defines 0 altitude as the height at which the atmosphere ends and the solid surface of the planet is drawn. If we want to simulate the atmosphere down to 65 bar, then we need to decrease the radius from the center of the planet to the level the atmosphere reaches 65 bar. Otherwise, the planet will appear inflated (1 bar would be 265km too high, meaning the radius at 1 bar would be incorrectly represented as 25627km, making planet Uranus 265 km too thicc. I set the radius to 25,097km, which means the 1 bar altitude is 265 above that, at 25,362km which is the correct size.

RingMinRadius- If you adjust the mean radius, then you have to also adjust everything attached to that unit. In this case, that includes the rings. All I did was scale the original altitude by the fraction 25362/25097, which ensures the rings stay in place at the correct altitude above the planet.

RingMaxRadius- for the same reason above, adjusted by the fraction 25362/25097 to keep the ring located where it belongs.

AtmPressure0- adjusted to pressure at the 7C isotherm (water cloud deck base). Roughly 65 bar.

AtmDensity0- adjusted to rho0 constant.

AtmGasConstant- adjusted to R0 constant.

AtmAltLimit- raised to 7765 km to simulate the exosphere transition to space and enable atmospheric driftdown of low hanging orbits. Uranus has very low gravity and high exospheric temperature, and 5000 km (which I used for Jupiter and Saturn) doesn't cut it.

ATMColor0- Uranus appeared too green as compared with the Voyager 2 image, so I adjusted it to be more cyan. There's nothing stopping you from adjusting it back to the original color if you want that instead. You did back up the original config file like I told you to in the install instructions, right?

AtmHazeColor- again, adjusted to appear more like the Voyager 2 image. Can be easily changed back if desired.

AtmHorizonAlt- Adjusted to 487km to improve the optical thickness of the atmosphere.

AtmHazeExtent- Adjusted to 0.13 to better simulate Rayleigh scattering in the troposphere.

AtmHazeShift- Adjusted to neatly overly the H_2S cloud deck. This allows it to function as methane haze.

CloudAlt- adjusted to the base of the H2S cloud deck at 4 bar. This is the first optically thick cloud deck. The methane one is mostly transparent (except for the rare icebergs).

CloudRotPeriod- adjusted so that it moves at 150 m/s relative to the rigid body of Uranus, simulating winds at that level. Note that because Uranus is NOT a rigid body, its cloud deck appearance evolves over time. So you'll see a slightly different surface every day.

Well that about covers it. I hope you enjoy flying in your realistically upgraded Uranus.

If you have questions or want to learn more you can reach out on the forums.

Be sure to check out my Youtube Channel: https://www.youtube.com/user/4656nick/