Saturn 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 Saturn. 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 Saturn's atmosphere:

T=288K

P=746e3*e^(-z/h) in kPa, where z is a constant

Rho= 0.7293*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 Saturn missions 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 remote sampled and a little bit in-situ that Cassini gave us, I was able to identify 8 unique layers, meaning this module does the work of 8 config files, each one also defining temperature.

Process

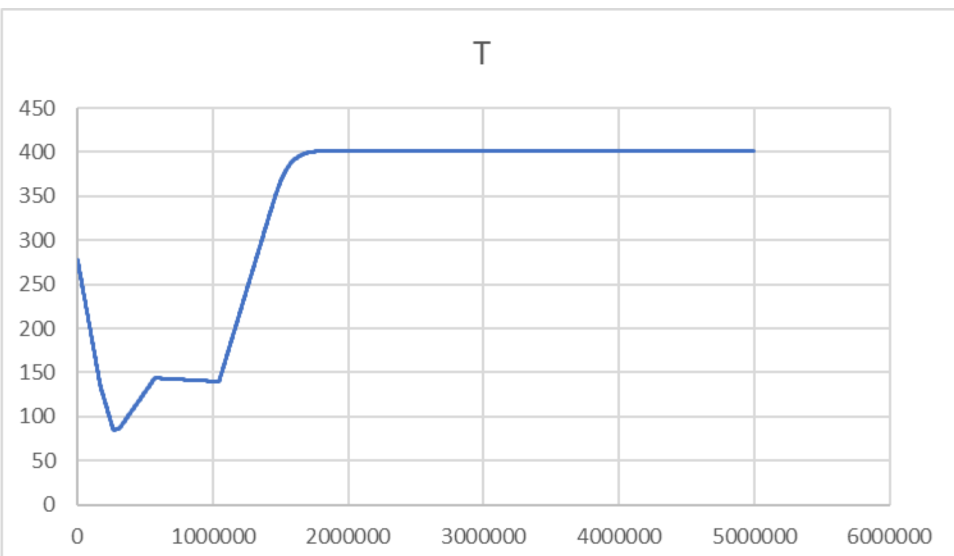
Unlike Jupiter, Saturn did not have a probe directly sample the atmosphere. The Cassini spacecraft did directly sample the thermosphere, but it obliterated long before it reached the stratosphere. What I did instead was research atmospheric remote sensing of Saturn and compile a list of modeled graphs, which I then discarded clear outliers from and took the average values of the rest to create my own model.

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.

R	3881.06					
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 +170000m, which is the exact distance from the explicitly defined Saturn altitude-0 and the 6 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 Saturn versus altitude. Therefore I had to assume a constant value based on the molecular distribution of the known mixture of gases up to the homopause, and then above that R is set to pure hydrogen as it fits the remotely sensed curve best. Gravity calculates using the simple formula $g = Gm/(r+h)^2$, where m is the mass of Saturn, 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 meters.



The following equations represent R, G, and T:

$$For\ base\ through\ stratosphere, R0(z) = 3881.6$$

$$For\ stratopause\ through\ top, R4(z) = 4124.2$$

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

$$g(z) = \frac{6.67E - 11 * 5.6834E + 26}{60098000 + z^2}$$

For temperature, out comes 8 equations for the 8 layers I found:

$$For\ deep\ troposphere, T0(z) = -8.5E - 4 * z + 278.4$$

$$For\ troposphere, T1(z) = -5.16E - 4 * z + 221.62$$

$$For\ tropopause, T2(z) = -4.444E - 5 * z + 73.1$$

$$For\ stratosphere, T3(z) = 2.19E - 4 * z + 18.99$$

$$For\ stratopause, T4(z) = -8.421E - 6 * z + 148.62$$

$$For\ thermosphere, T5(z) = 5.07E - 4 * z - 389.995$$

$$For\ transition, T6(z) = \frac{144}{1 + e^{1.4E-5*(z-1.42E+6)}} + 257.945$$

$$For\ exosphere, T7(z) = 401.941$$

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

Here is the table mapping each equation to altitude:

Temperature Layers			
Lower Troposphere	0	170000	0
Troposphere	170000	265000	1
Tropopause	265000	310000	2
Stratosphere	310000	570000	3
Stratopause	570000	1045000	4
Thermosphere	1045000	1420000	5
Transition	1420000	2170000	6
Exosphere	2170000	5000000	7
	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	3881.6
R4	4124.2
Z0	0
Z1	170000
Z2	265000
Z3	310000
Z4	570000
Z5	1045000
Z6	1420000

Z7	2170000
Z8	5000000
T0	278.4
T1	133.9
T2	84.8766
T3	86.88
T4	143.82
T5	139.82
T6	329.945
T7	401.941
P0	1026624
P1	101325
P2	9488.974
P3	2333.735
P4	5.193895
P5	0.00138
P6	2.258E-05
P7	1.17E-06
L0	-0.00085
L1	-0.00052
L2	4.444E-05
L3	0.000219
L4	-8.42E-06
L5	0.000507
rho0	0.950017

For every altitude except the transition and exosphere,

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

Where # represents 0-5 as shown in the table. Z may be taken by reading the altitudes in the 2nd column of the mapping table.

In the transition region, pressure is always $p(z) = P6 * e^{-\frac{g(z)}{R4*600}*(z-Z6)}$

In the exosphere, pressure is always $p(z) = P7 * e^{-\frac{(z-Z7)}{R4*T7/g(z)}}$

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 Saturn.cfg file:

AtmPressure0- adjusted to pressure at the 6C isotherm (water cloud deck base).

AtmDensity0- adjusted to rho0 constant.

AtmGasConstant- adjusted to R0 constant.

AtmAltLimit- raised to 5000 km to simulate the exosphere transition to space and enable atmospheric driftdown of low hanging orbits.

AtmHazeShift- adjusted to neatly overlie the ammonia cloud layer.

CloudAlt- adjusted to the base of the ammonia cloud deck at 1.7 bar.

CloudRotPeriod- adjusted so that it moves at 200 m/s relative to the rigid body of Saturn, simulating winds at that level. Note that because Saturn 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 Saturn.

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/