Atmospheric Scale-Height and Density of O2 via Solar Occultations Measured by SORCE

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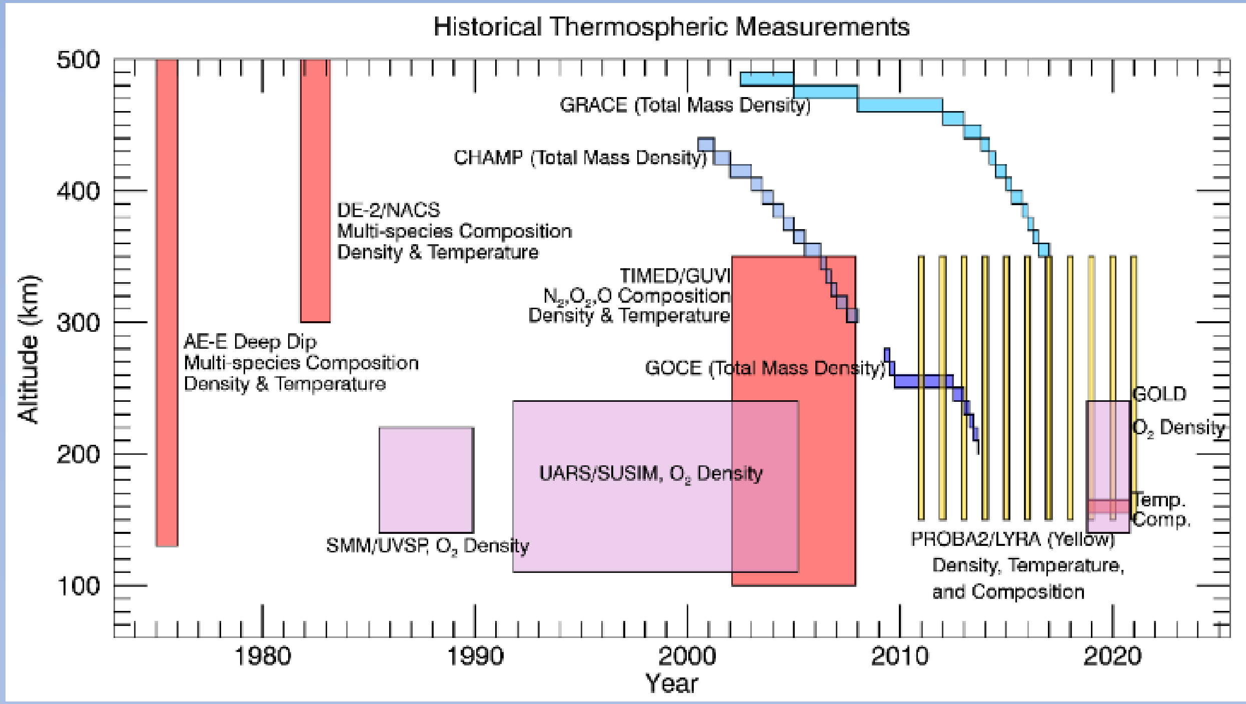
For the past 50 years, we have been using solar occultations to learn more about elements (atmospheric species) in our thermosphere

However, we still have some gaps in information as seen in this chart

In this project we hoped to fill in some of those gaps

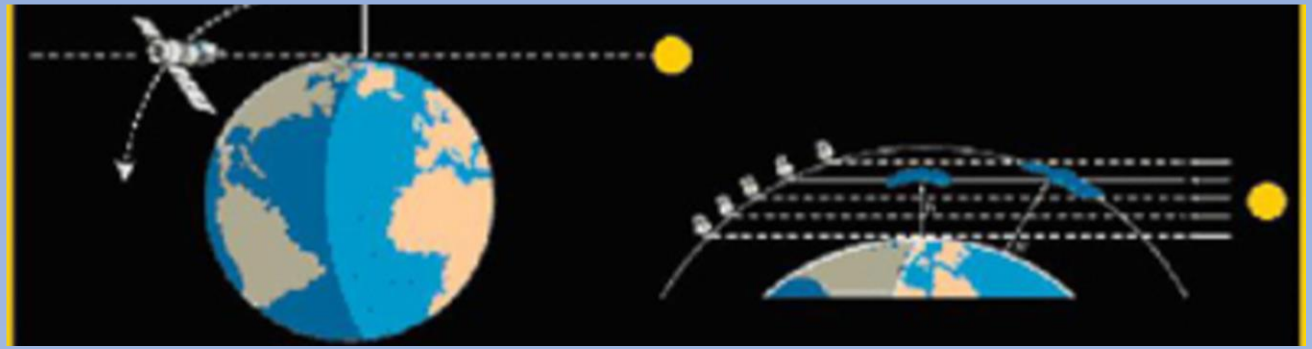


Measurements of atmospheric species obtained over time and altitude

Image credit: Thiemann & Dominique. JGR:Space, In-Press

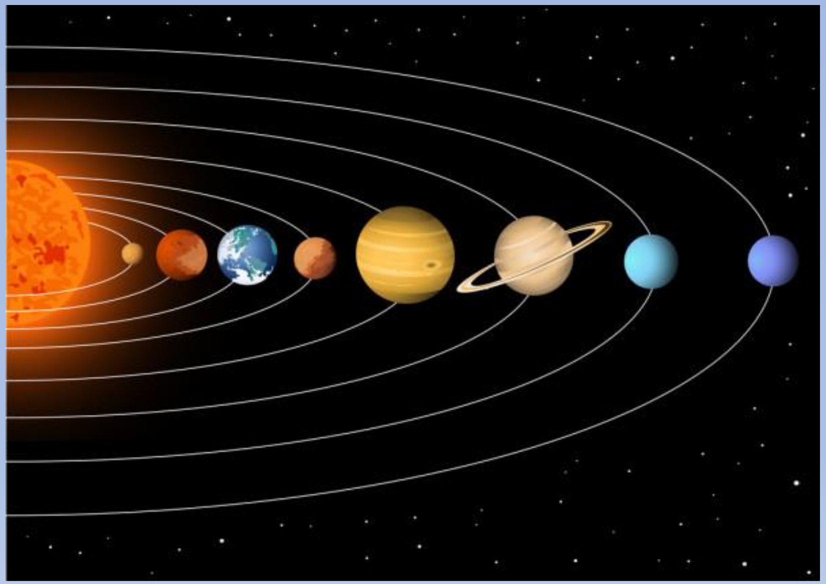
What is solar occultation?

- A technique that measures the change in solar irradiance after it has passed through atmosphere



We are not limited to Earth

- Venus
- Mars
- Saturn
    - Titan
- Anything with an atmosphere

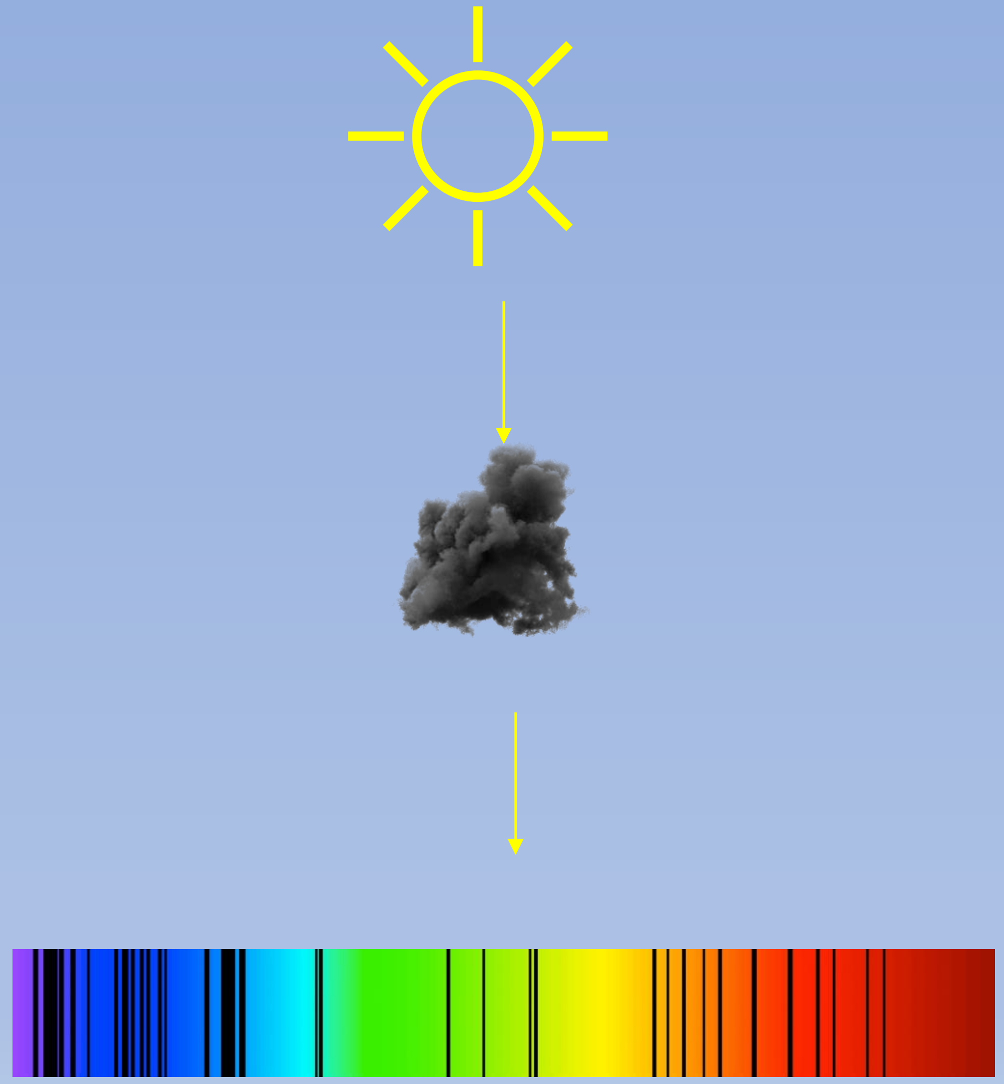


Gassy absorption

- Whenever light passes through gas (or any material) some of that light is absorbed

- Each species absorbs light in a different way, we can see this by looking at its absorption spectra

- By looking at the absorption spectra of light that has passed through a type of material we can learn what that material is made of



absorption spectra of oxygen

Where our data came from

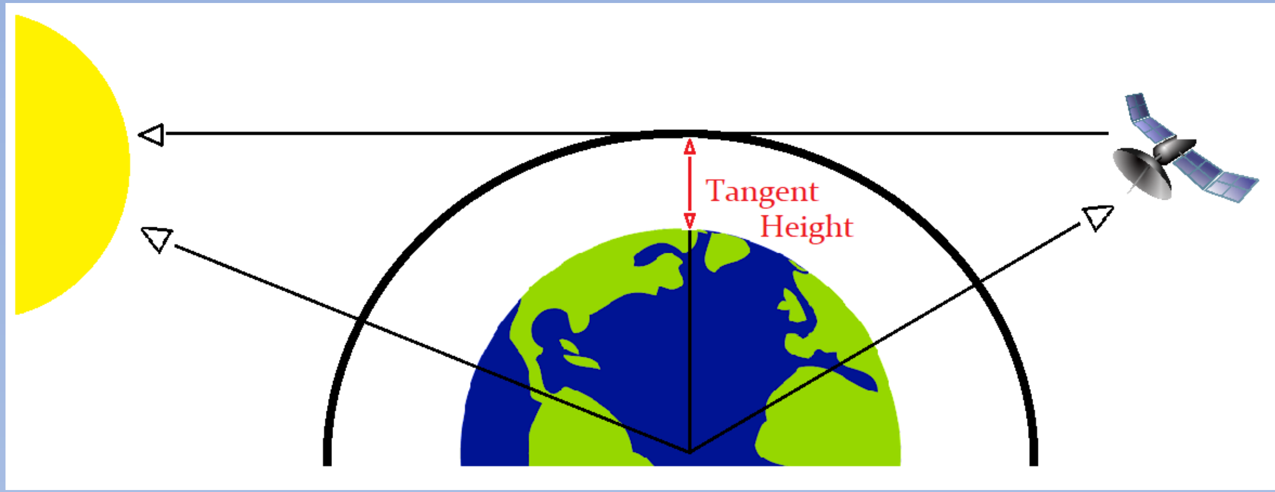
Information collected by the SOlar Stellar Irradiance Comparison Experiment (SOLSTICE) instrument, which flew aboard the Solar Radiation and Climate Experiment (SORCE) satellite

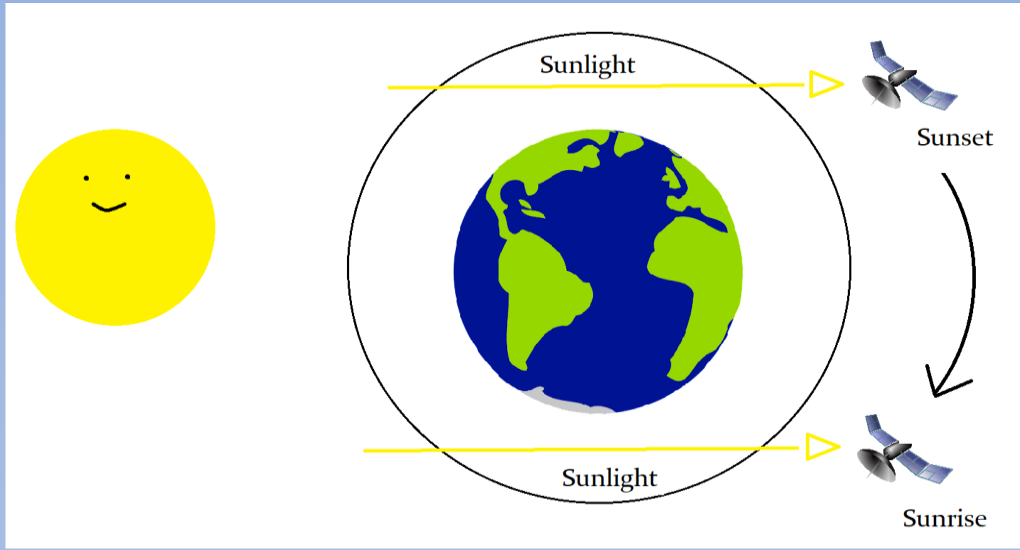
Collected during the months of June and July of 2004

Latitudes ranging from 20° to 33°

Because molecular oxygen (O_2) is the only major species absorber of the lyman-alpha line, centered at 121.6nm. We used the irradiance values taken at wavelengths in the range 120.5-122.0nm

A bit of geometry





- Altitudes ranging from ~100-200 km (tangent height)

- Observations taken during sunset and sunrise

So much information!

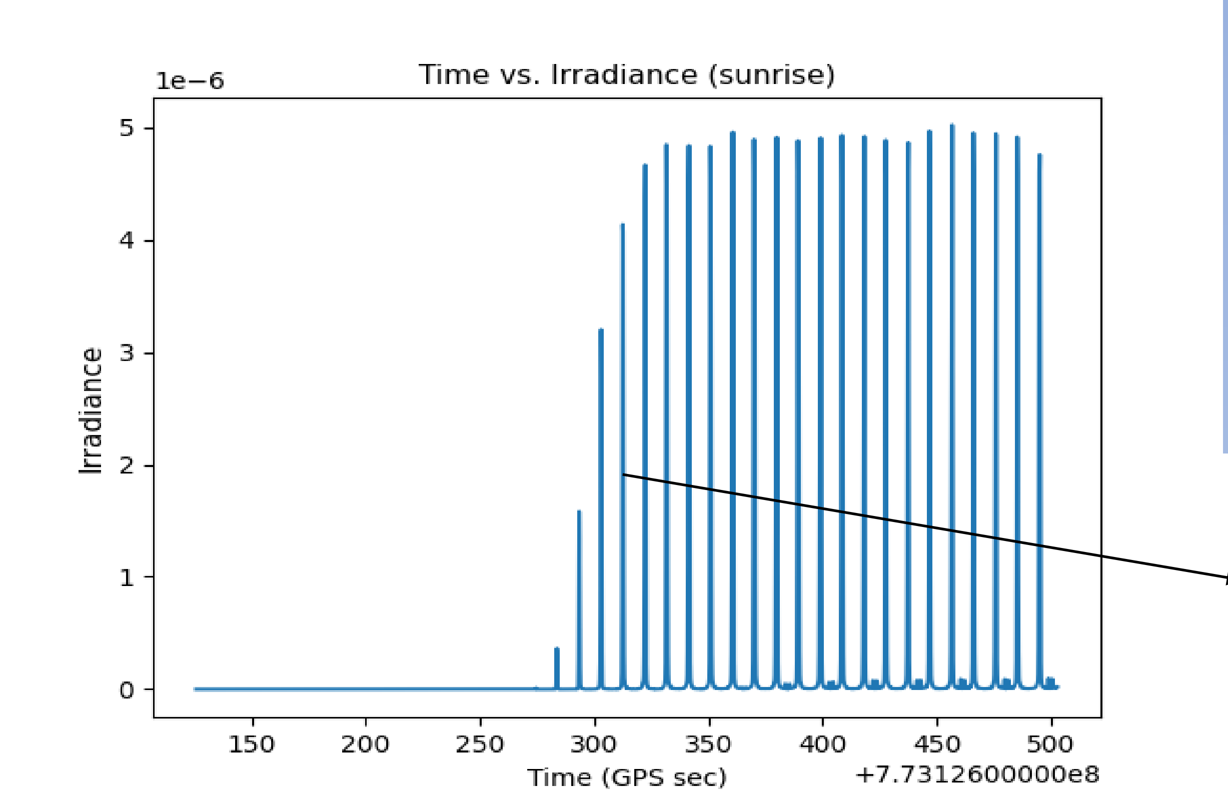
From this:

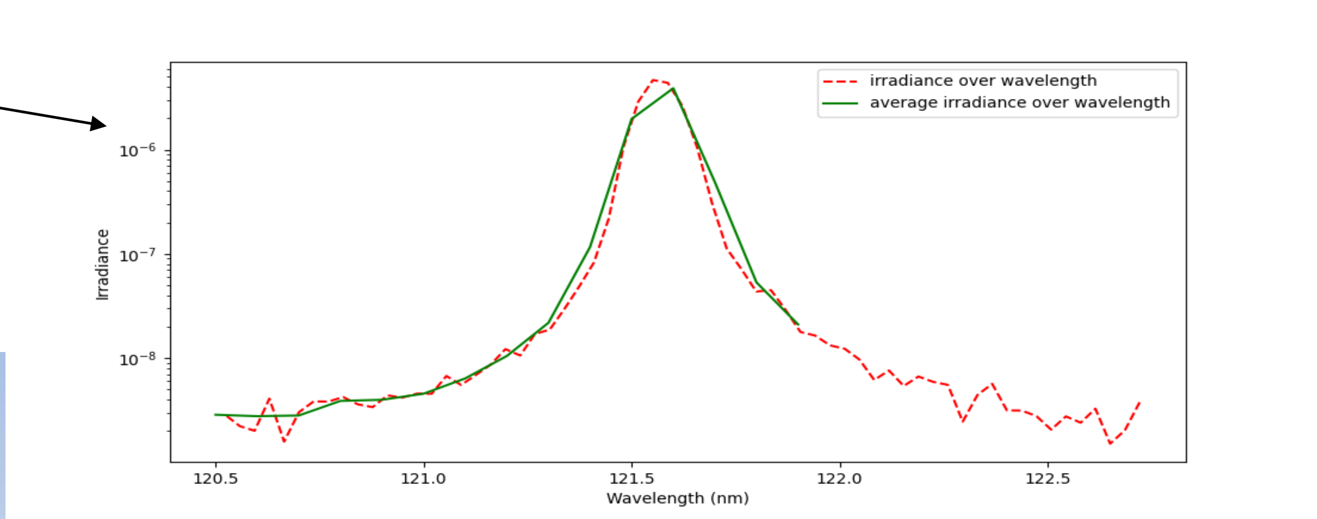
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	WAVELENGTH	BANDPASSUNC	INSTRUMENTMC	TANHT	COMBINEDSTAI	IRRADIANCE	LAT	LON	MICROSECONDSSINCEGPSEPOCH	WAVELENGTHU	VERSION_1	BANDPASS	SZA	VERSION	REPEATABILITY	ALT
2	122.6852438	4.42E-08	11	-28.90671665	65602750	1.06E-10	36.09650403	-48.06783888	773126125563590.00	0.001025433	1820	0.085830306	114.9953517	1820	65573028.71	625.9285573
3	122.6498048	4.42E-08	11	-28.80110019	0	0	36.09349366	-48.05763075	773126125713590.00	0.001025448	1820	0.085831833	114.9932754	1820	0	625.9308553
4	122.6143653	4.42E-08	11	-28.69548372	162669147.7	4.56E-10	36.0904833	-48.04742262	773126125863590.00	0.001025463	1820	0.08583336	114.9911992	1820	162448479.2	625.9331532
5	122.5789253	4.42E-08	11	-28.58986725	66085224.31	1.07E-10	36.08747293	-48.03721449	773126126013590.00	0.001025478	1820	0.085834886	114.9891229	1820	66055310.25	625.9354512
6	122.5434847	4.41E-08	11	-28.48425079	0	0	36.08446256	-48.02700636	773126126163590.00	0.001025494	1820	0.085836412	114.9870467	1820	0	625.9377491
7	122.5080436	4.41E-08	11	-28.37863432	0	0	36.08145219	-48.01679823	773126126313590.00	0.001025509	1820	0.085837938	114.9849705	1820	0	625.9400471
8	122.4726019	4.41E-08	11	-28.27301786	124116423.1	2.84E-10	36.07844182	-48.0065901	773126126463590.00	0.001025524	1820	0.085839463	114.9828942	1820	124004220.5	625.9423451
9	122.4371598	4.41E-08	11	-28.16740139	0	0	36.07543145	-47.99638197	773126126613590.00	0.001025539	1820	0.085840988	114.980818	1820	0	625.944643
10	122.4017171	4.41E-08	11	-28.06178493	0	0	36.07242109	-47.98617384	773126126763590.00	0.001025554	1820	0.085842512	114.9787418	1820	0	625.946941
11	122.3662739	4.41E-08	11	-27.95616846	0	0	36.06941072	-47.97596571	773126126913590.00	0.001025569	1820	0.085844036	114.9766655	1820	0	625.9492389
12	122.3308301	4.41E-08	11	-27.85055199	0	0	36.06639768	-47.96575976	773126127063590.00	0.001025585	1820	0.08584556	114.9745893	1820	0	625.9515365
13	122.2953859	4.41E-08	11	-27.74493553	0	0	36.06338102	-47.95555678	773126127213590.00	0.0010256	1820	0.085847083	114.972513	1820	0	625.9538337
14	122.2599411	4.41E-08	11	-27.63931906	0	0	36.06036436	-47.9453538	773126127363590.00	0.001025615	1820	0.085848606	114.9704368	1820	0	625.9561308
15	122.2244958	4.41E-08	11	-27.5337026	67798089.26	1.10E-10	36.05734769	-47.93515082	773126127513590.00	0.00102563	1820	0.085850129	114.9683606	1820	67767488.61	625.958428
16	122.18905	4.40E-08	11	-27.42808613	0	0	36.05433103	-47.92494784	773126127663590.00	0.001025645	1820	0.085851651	114.9662843	1820	0	625.9607251

To this:

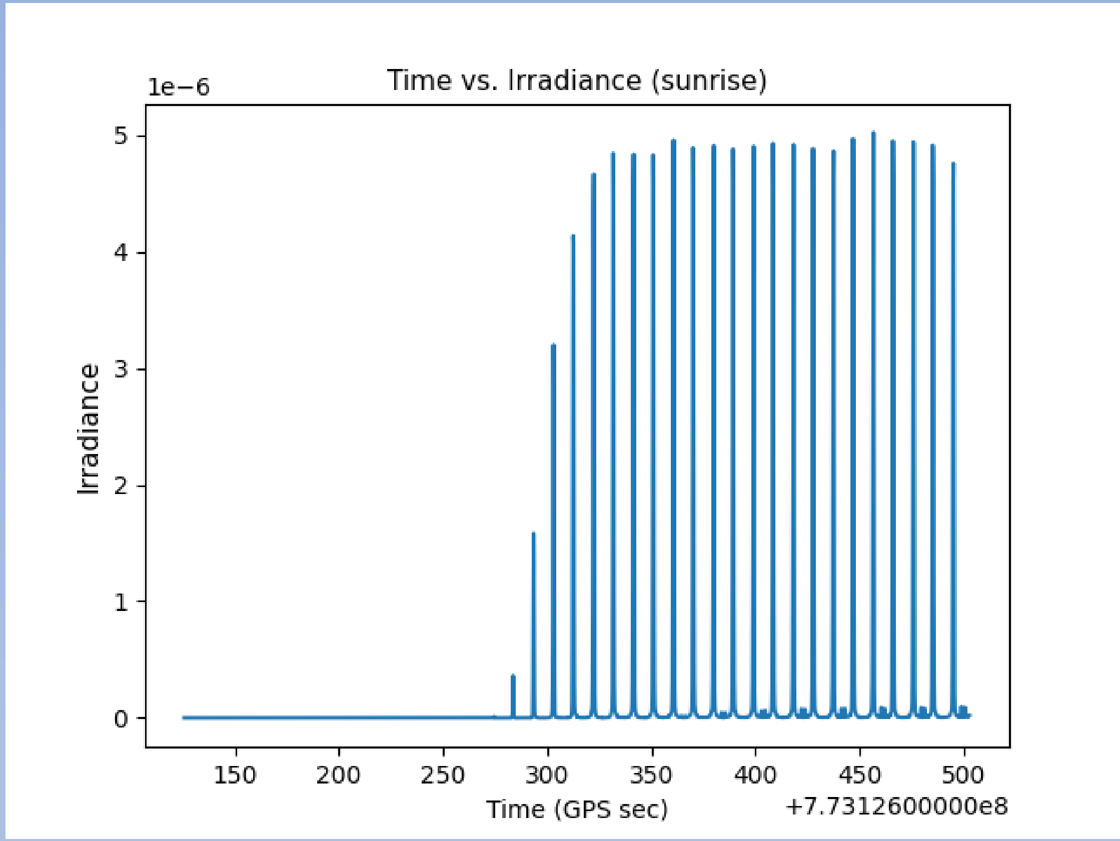
1	WAVELENGTH	TANHT	IRRADIANCE	MICROSECONDSSINCEGPSEPOCH
2	122.6852438	-28.90671665	1.06E-10	773126125563590.00
3	122.6498048	-28.80110019	0	773126125713590.00
4	122.6143653	-28.69548372	4.56E-10	773126125863590.00
5	122.5789253	-28.58986725	1.07E-10	773126126013590.00
6	122.5434847	-28.48425079	0	773126126163590.00
7	122.5080436	-28.37863432	0	773126126313590.00
8	122.4726019	-28.27301786	2.84E-10	773126126463590.00
9	122.4371598	-28.16740139	0	773126126613590.00
10	122.4017171	-28.06178493	0	773126126763590.00
11	122.3662739	-27.95616846	0	773126126913590.00
12	122.3308301	-27.85055199	0	773126127063590.00
13	122.2953859	-27.74493553	0	773126127213590.00
14	122.2599411	-27.63931906	0	773126127363590.00
15	122.2244958	-27.5337026	1.10E-10	773126127513590.00
16	122.18905	-27.42808613	0	773126127663590.00

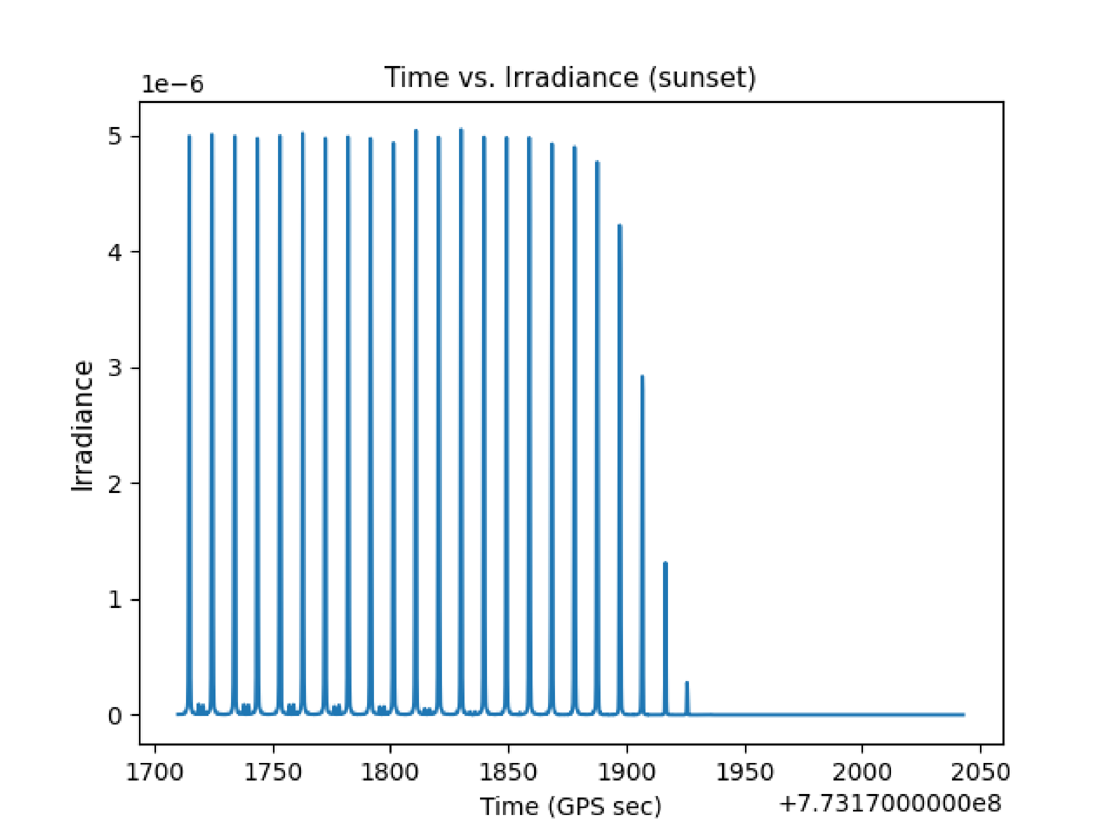
Plotting individual scans



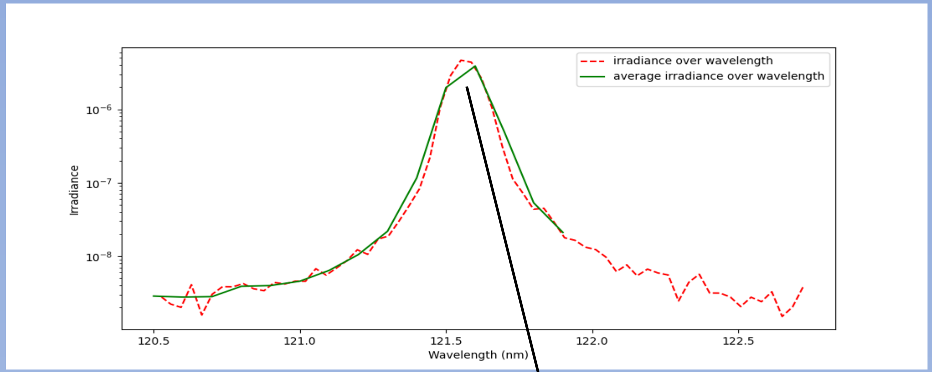


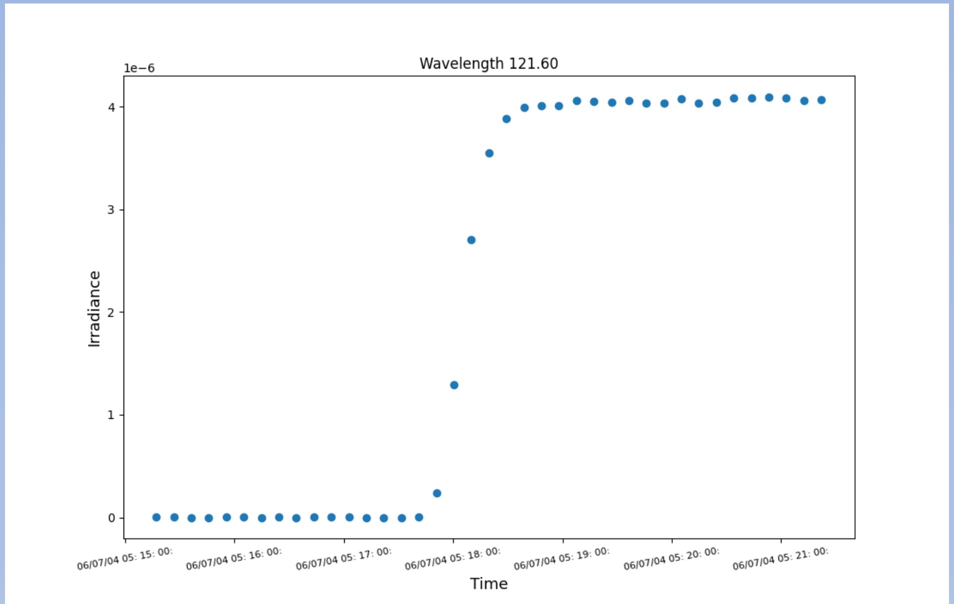
Plotting the observations

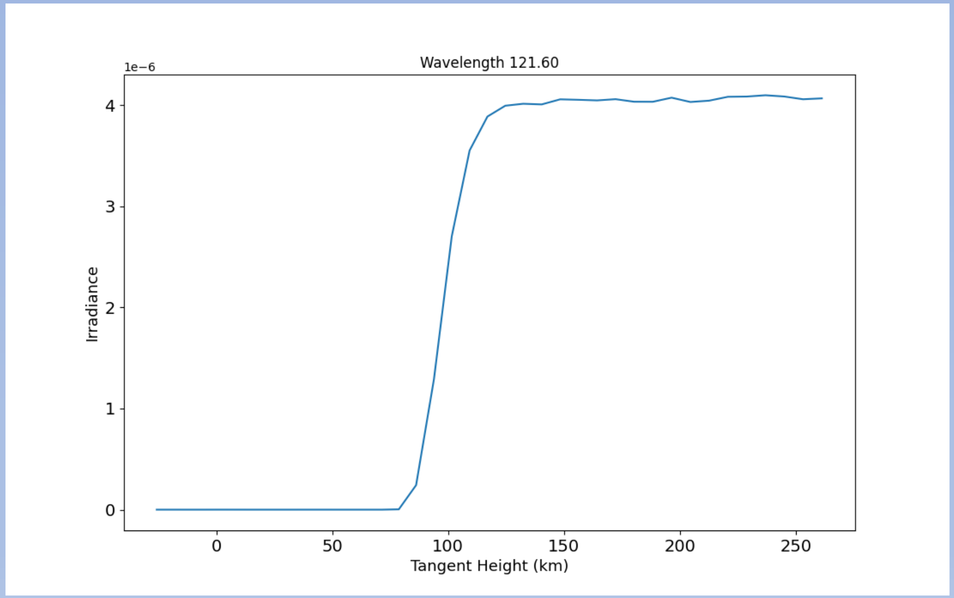




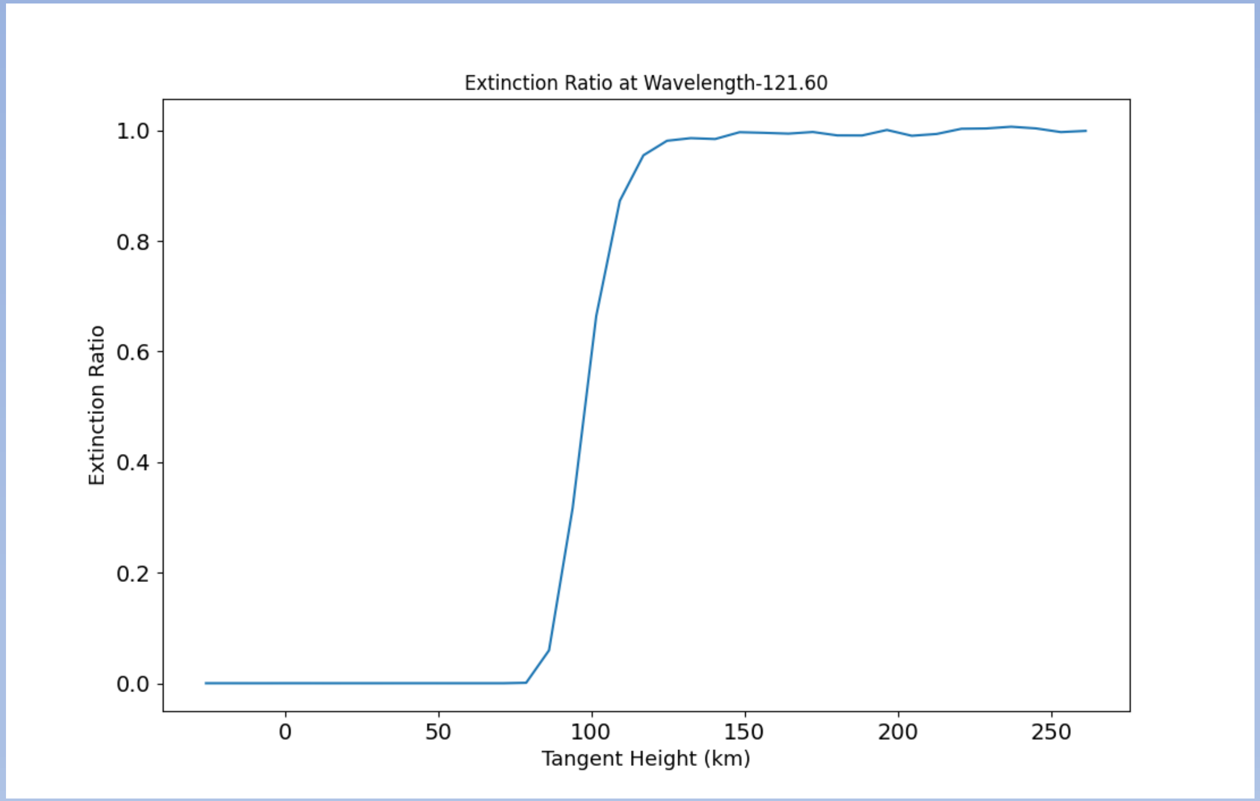
Plotting by wavelength







Finding the extinction ratio



$$ER = \frac{I_{(rh)}}{I_{\infty}}$$

$$Extinction\ Ratio = \frac{measured\ irradiance}{average\ irradiance\ at\ high\ tangent\ height}$$

Finally! The formula to the complex word problem we've been trying to solve

$$ER = e^{-\sum N_i \sigma_i}$$

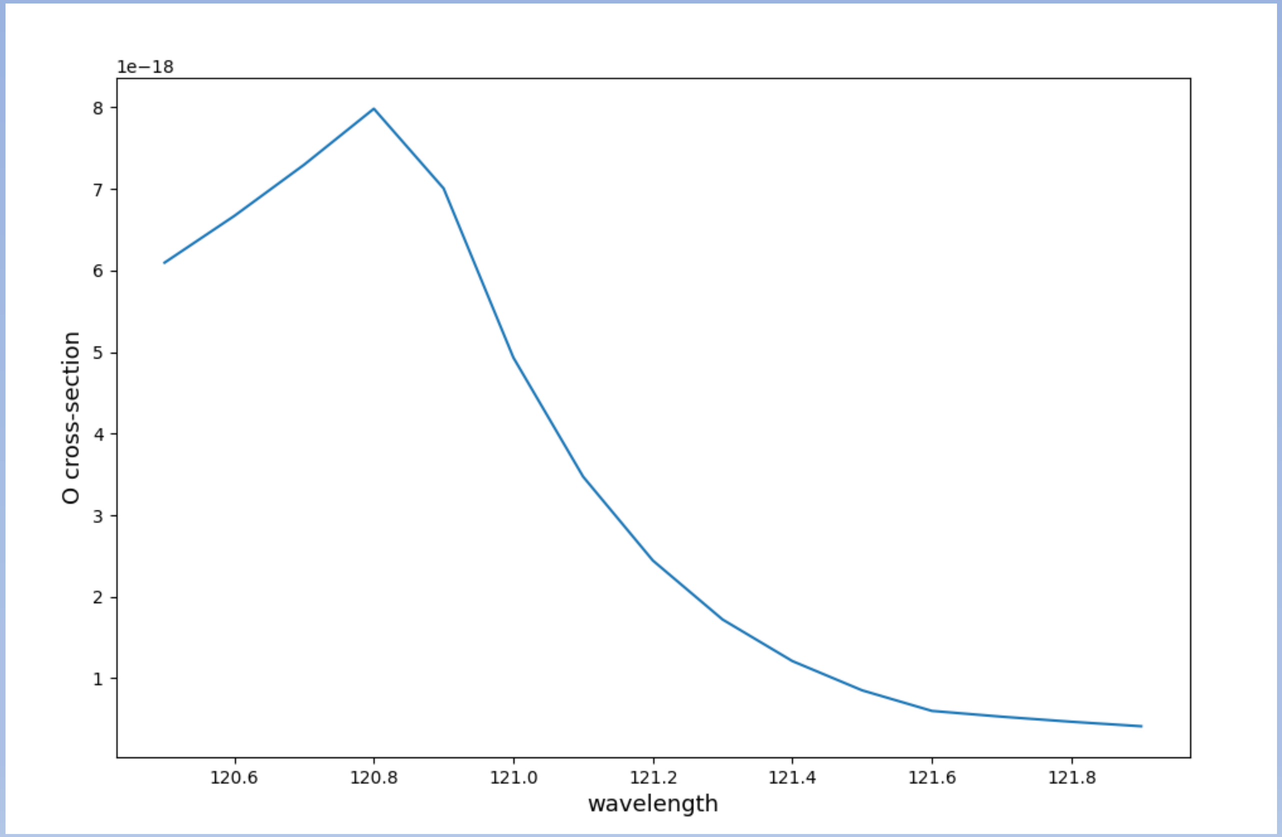
$$ER = e^{-N_i \sigma_i} \xrightarrow{\text{Solve for N}} N = \frac{-\ln(ER)}{\sigma}$$

Where:
$ER = extinction\ ratio$
$N = column\ density$
$\sigma = O2\ cross\ section$

O2 cross-sections - The final piece of the puzzle

What is an O2 cross-section?

- How the size of a molecule of O2 looks to an incoming beam of light

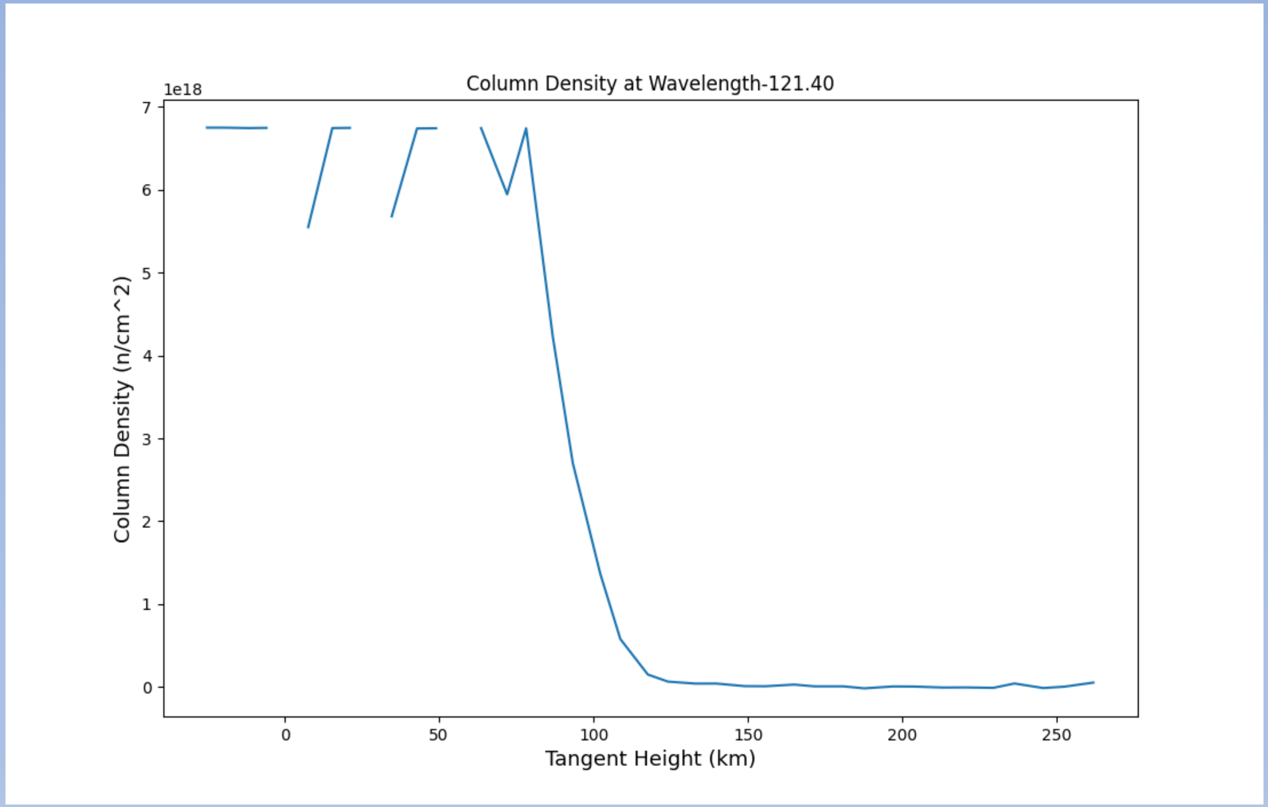


We have column densities!

$$N = \frac{-\ln(ER)}{\sigma}$$

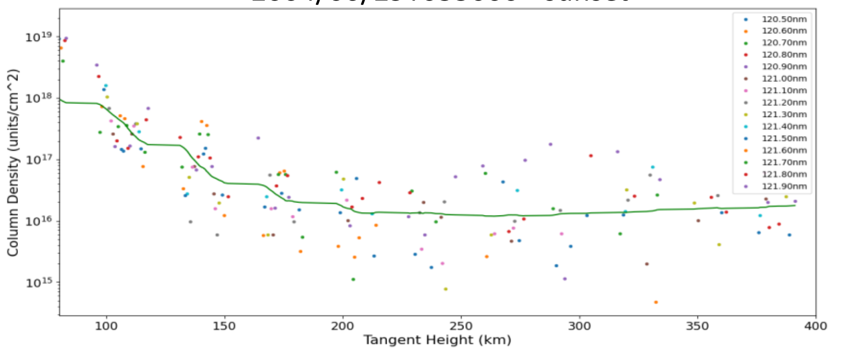
Now that we have our cross-section values, we finally have all the variables we need to solve for our column densities

Column densities are given in units/cm^2 or O2 atoms per cm^2

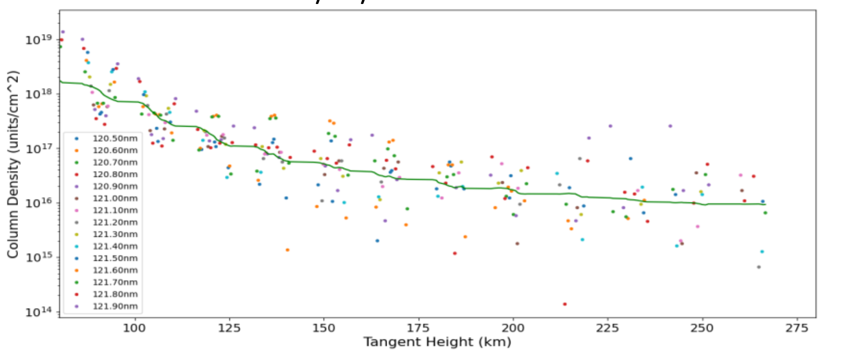


Results

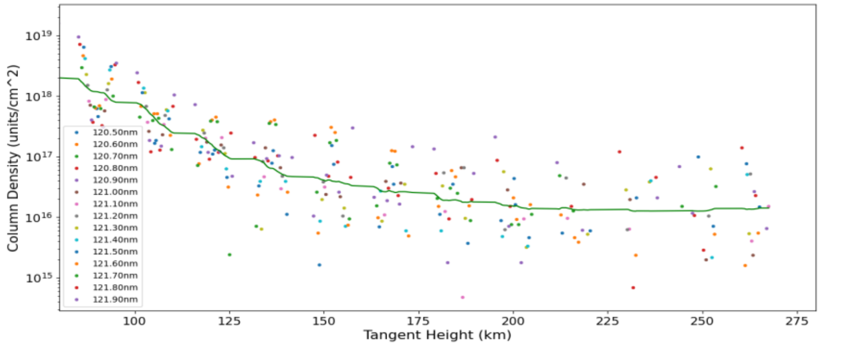
2004/06/29T055000 - sunset



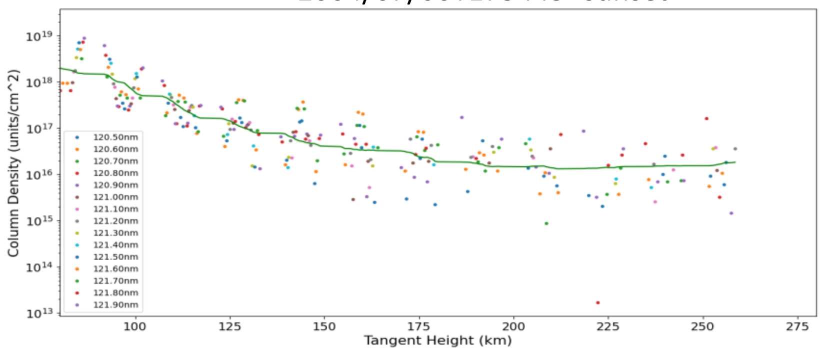
2004/07/06T045600 - sunset



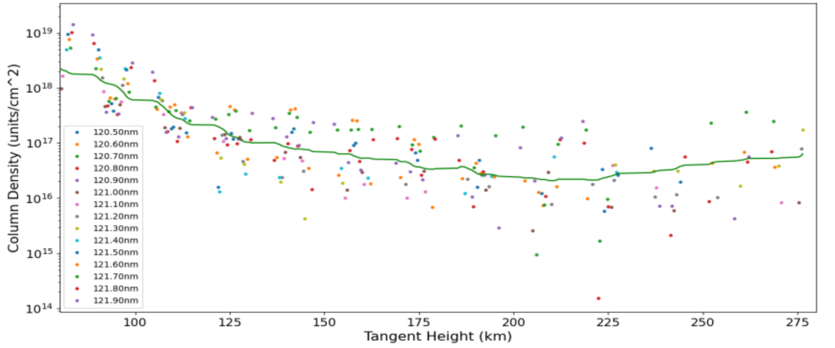
2004/07/06T051500 - sunrise



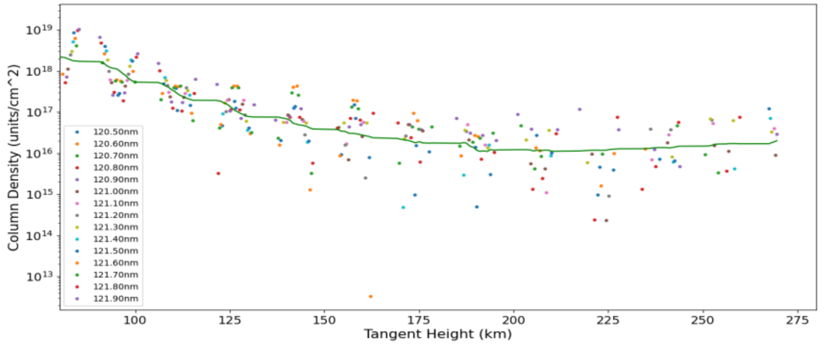
2004/07/06T175445- sunset



2004/07/06T181400 - sunrise



2004/07/05T193151 - sunrise



References

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