Viewing Comparisons of Radar and Lidar on Particle scatterers

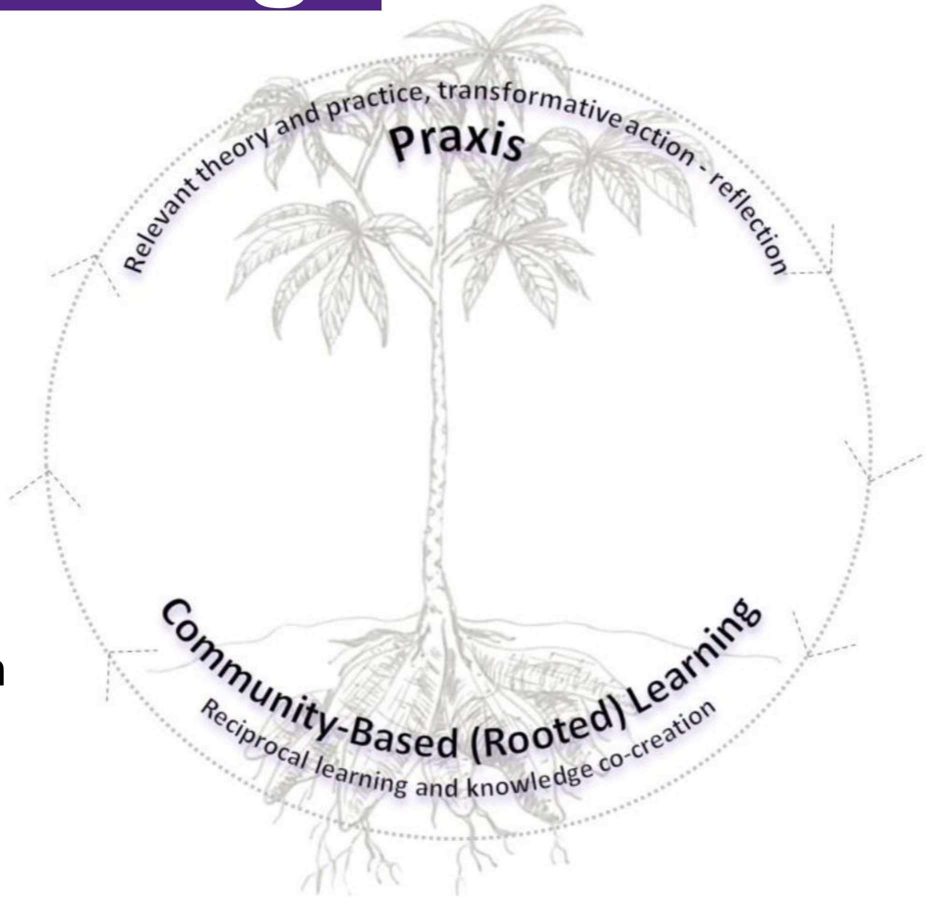
Victoria Pinnegar, Callum Dewsnap

Indigenous Forecasting

- Chugachmiut Traditional Weather Forecasting:
  - Weatherman- time observation for speed, direction, shape of clouds
  - (Traditional Ecological Knowledge (TEK)) Low atmosphere winds-> Current days weather, High atmosphere winds -> Large storm systems
  - Cloud halo around sun and moon indicate weather is going to turn for the worse
  - “Cloud streaks high in the sky means it is going to be windy.” - Mary Malchoff, Port Graham
  - “Dark clouds means there will be rain, snow, or wind.” - Tom Yeaton Sr., Port Graham
- Plains People:
  - Damp, foggy weather precedes cold and storms
  - Omaha People - Curlew Call in the morning foretells cloudless day

Decolonizing Research and use of Indigenous Knowledge

- Utilizing and publishing indigenous knowledge follows a trend of disrespect, lack of documentation, lack of care, and follow up on research for communities
- Proposed Research system from : Yuca-Cassava growth System:
  - Built around Yuca growth system from Caribbean Indigenous population the
  - Community based, reciprocal learning, and knowledge co-creation
  - Nurture growth for Praxis -> Transformative Action-Reflection
  - Community members are considered Participant researchers, and are allowed to participate as co-authors
  - Inclusion of Storywork

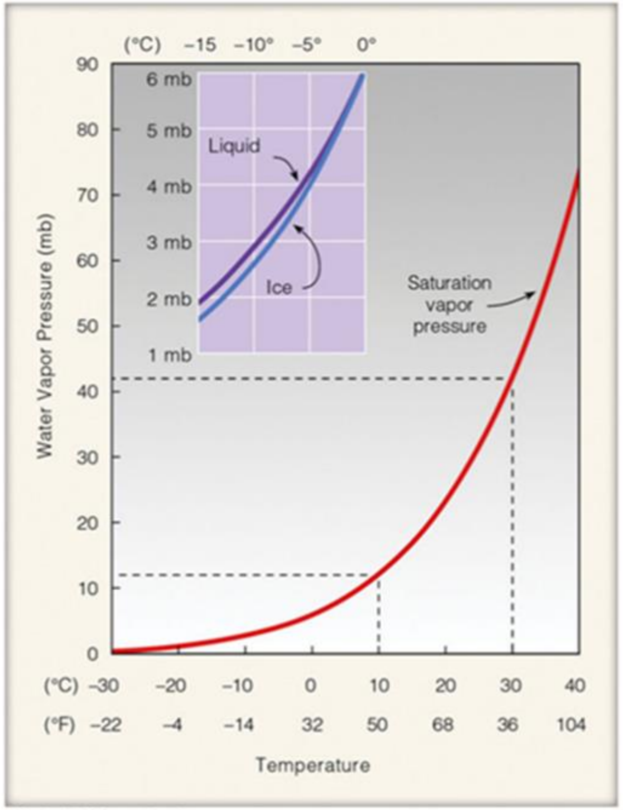


Cloud Formation Parameters -Forecasting

- Relative Humidity
  - More easily formed in lower temperatures due to Saturation Vapour Pressure
  - Water acts as an Ideal gas, so if the cloud formation occurs more efficiently at lower temperature, what change in parameters allows better cloud formation?

$$T = \frac{P}{nk}$$

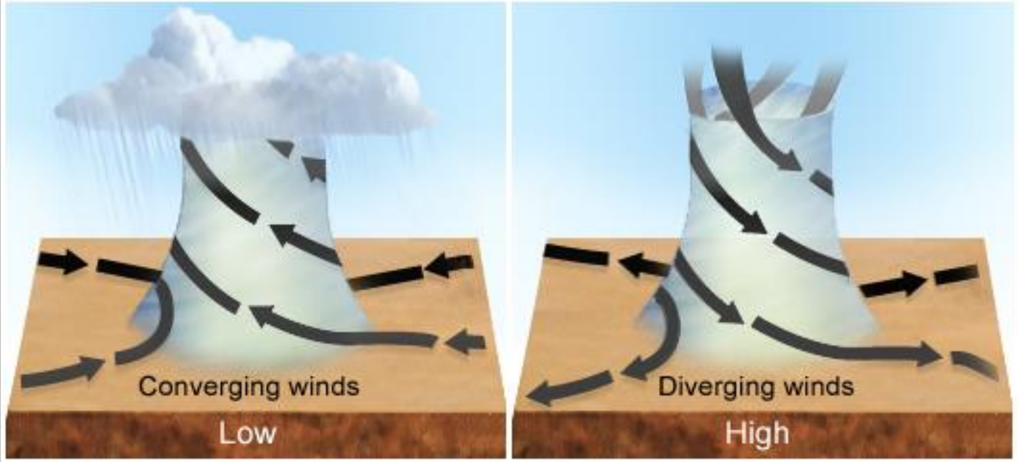
- If $nk \sim 100$:
  - T increases, harder to condense into clouds
- If $nk \sim 10$:
  - T decreases, easier condensation
- If P decreases:
  - T decreases, easier condensation



Cloud Formation Parameters -Forecasting

- Tracking of High- Low pressure zones through the atmosphere
- Clouds form more easily in lower pressure zones alongside upward circulation and convergence of ai

- Low-pressure and High-pressure systems follow large scale atmospheric circulation:
  - Hadley Cells- Closed Circulation loop near the Equator, low pressure zone near equator → rises up → travels to 30th parallel to a high- pressure zone → sinks → circulates back to equator
  - Polar Cell- Air rises → moves towards pole and eastward → descends → moves towards equator and west
  - Ferrell Cell- Transition between 60˚to poles, Eddy created by Polar and Hadley

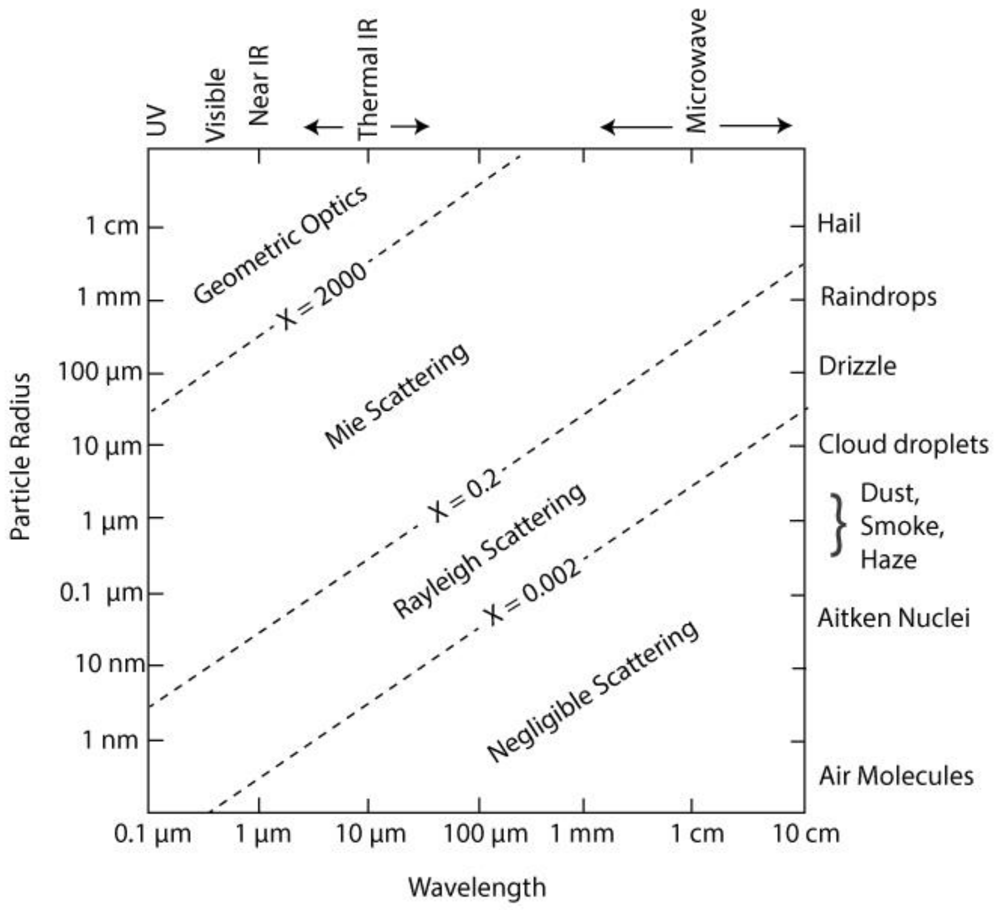


In a low pressure system, air is dragged in and forced upwards where it cools and forms clouds. In a high pressure system, dense air is forced downwards and spreads out over the surface of the Earth.

Backscatter in Remote Observation

- Scattering of radiation through the atmosphere
- Radiation interacts (Absorbs or Scatters) with a particle
  - Absorption removes photon and converts to Energy
  - Scattering shoots radiation into a new direction
    - Depends on Wavelength, Size, Shape and Composition

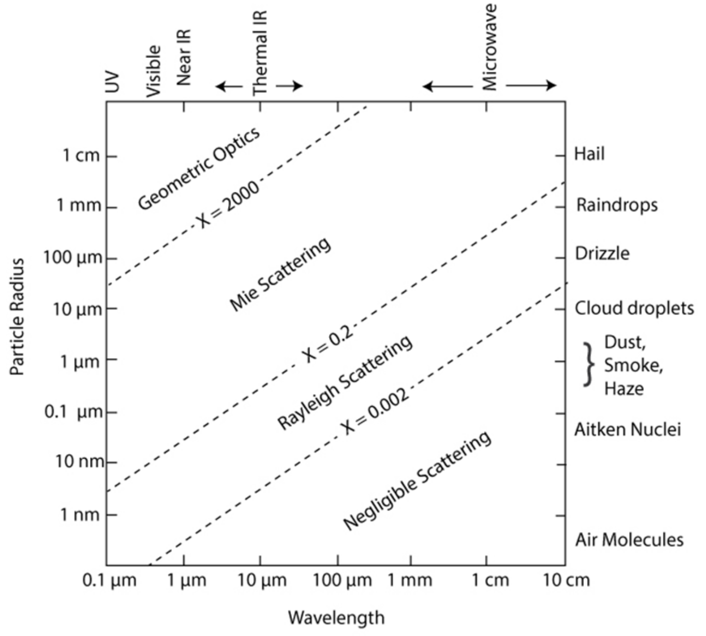
The Size Parameter: $x = \frac{2\pi r}{\lambda}$



Backscatter in Remote Observation

- Geometric optics
  - $x > 2000$
  - Traditional optical principles
- Rayleigh
  - $x = 0.002\text{-}0.2$
  - $\beta = N\sigma = N\left(\frac{2\pi}{\lambda}\right)^4 \frac{1}{|K|^2}\langle r^6\rangle$
- Mie
  - $x = 0.2 - 2000$
  - $\beta = N\sigma = N\pi r^2 Q_{back}$

$$\beta \ - Backscatter$$
$$N \ - Number\ Density$$
$$\lambda - Wavelength$$
$$K = \frac{n^2 - 1}{n^2 + 2}$$
$$n \ - Refractive\ index$$
$$r - Particle\ radius$$
$$Q_{back} = \frac{1}{x^2}\sum_{n=1}^{\infty}|(2n+1)(-1)^{-n}(a_n + b_n)|^2$$



Victoria Pinnegar, Callum Dewsnap

Lidar Observation

- Lidar- Light Detection and Ranging

$$P(R,\lambda) = P_0 \frac{c\tau}{2} A\eta \frac{O(R)}{R^2} \beta(R,\lambda) \exp\left(-2\int_0^R \alpha(r,\lambda)dr\right)$$

$$\beta(R,\lambda) - Backscatter$$
$$P_0 - Average\ power\ of\ a\ single\ laser\ pulse$$
$$A - Area\ of\ Primary\ Reciever$$
$$\frac{c\tau}{2} - Effective\ spacial\ pulse\ length$$
$$\eta\ - Efficiency$$
$$O(R) - Overlap\ function\text{: } geometric\ arrangment\ of\ the\ transmitting\ and\ recieving\ optics$$

- Rayleigh scattering for small particles (Molecular Scattering)
- Mie scattering for large particles (Particulate Scattering)

Radar Observation

- Radar- Radio Detection and Ranging

$$P(R,\lambda) = \frac{P_t G^2 \lambda^2}{(4\pi)^3 R^4 l}\sigma = \frac{P_t G^2 \lambda^2}{(4\pi)^3 R^4 l}\frac{\pi^5 |K|^2}{\lambda^4} Z$$

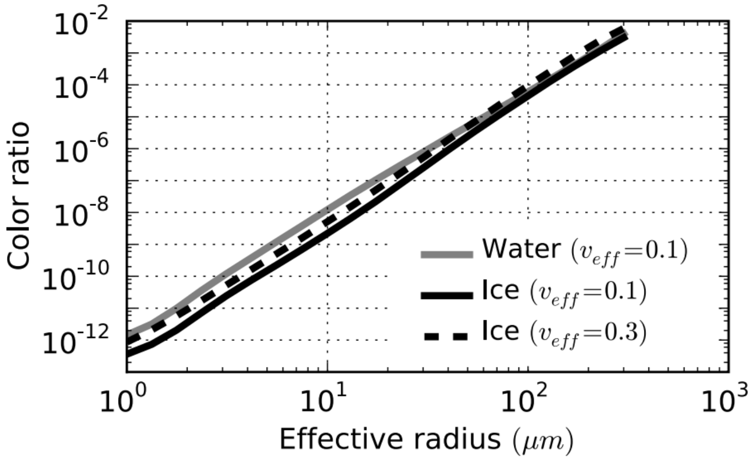
$$Z(R,\lambda) - Reflectivity$$
$$P_t - Average\ power\ of\ a\ single\ laser\ pulse$$
$$G - Gain$$
$$l - loss$$
$$\beta = Z_e \frac{(m^2-1)}{m^2+2}\frac{\pi^4}{4\lambda^4}$$

- Radar wavelengths are so long, the particles are all small by comparison
- All particulates used are in Rayleigh range (Cloud, Aerosol)
- Molecular backscatter is negligible

Colour Ratio

- The Colour Ratio- larger wavelength over smaller wavelength

$$\frac{\beta_{rad}}{\beta_{lid}} = \frac{\sigma_{radar}}{\sigma_{lidar}}$$



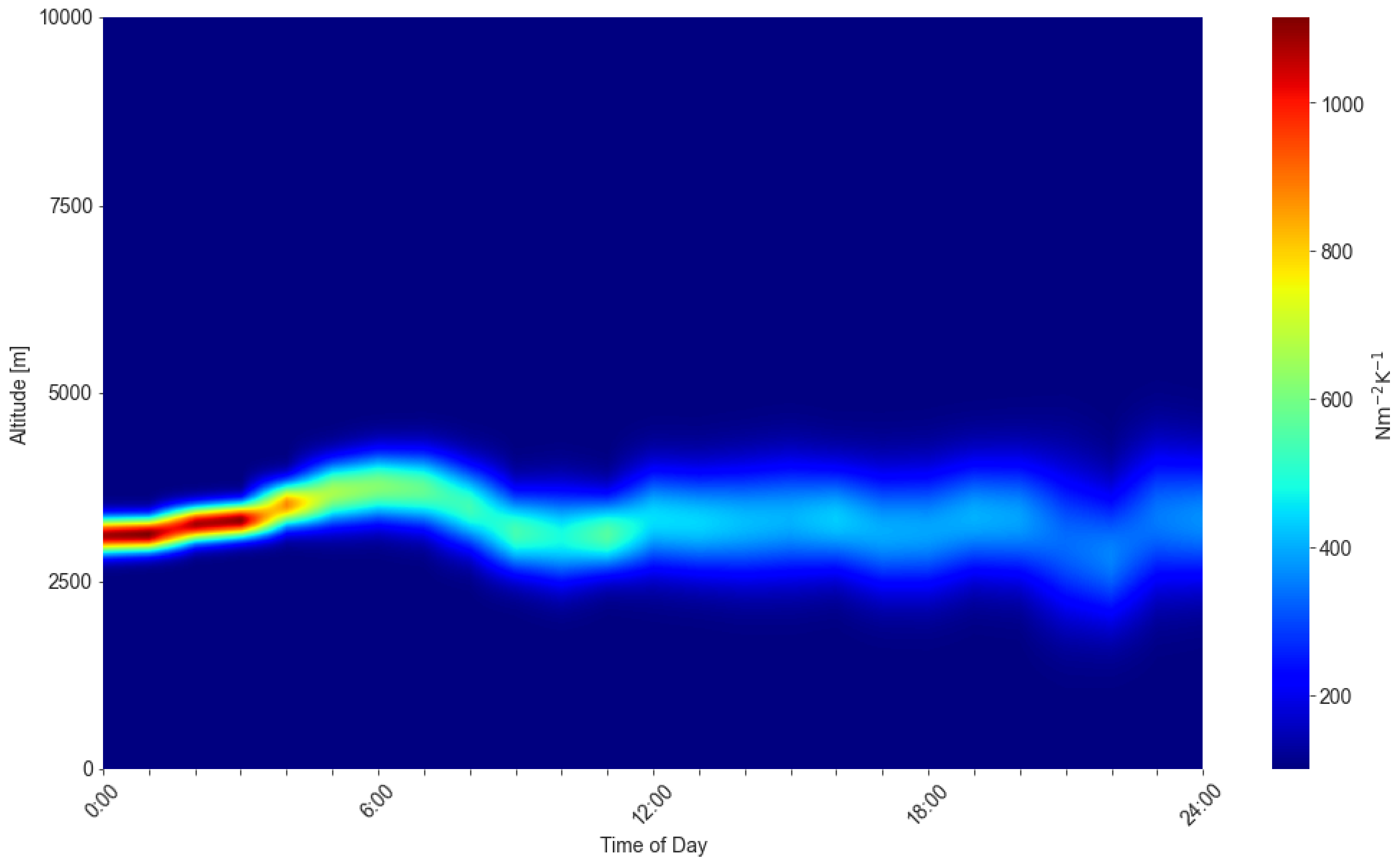
- Effective radius – ratio of radar to lidar of the time averaged radius

$$R'_{eff} = \left(\frac{\langle r^6 \rangle}{\langle r^2 \rangle}\right)^{\frac{1}{4}}$$

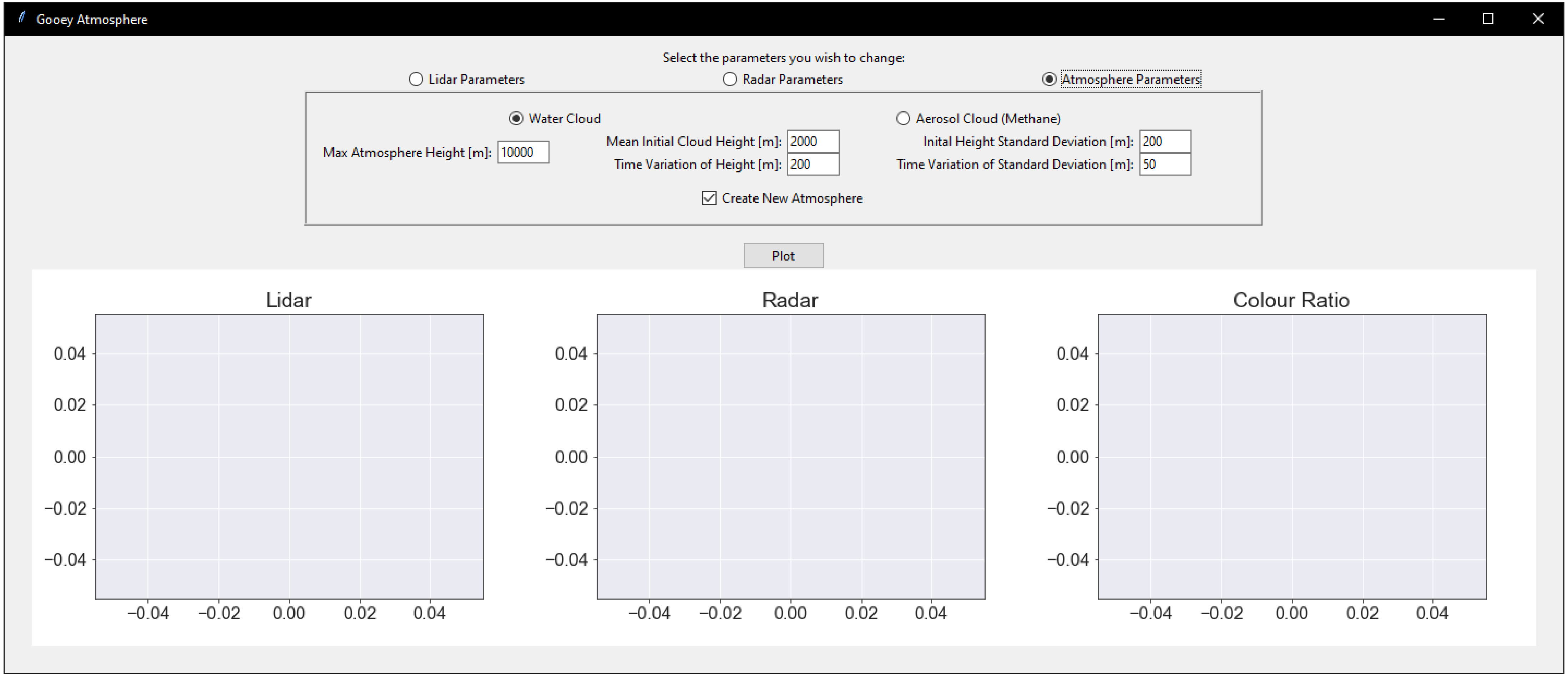
Particle	δ_{lin} (%)	colour ratio	r_{eff} (μm)	z (km)
Aerosols	<20			<3 km
M-P Cloud WD	<3	10^{-9}–10^{-6}	5–40	0.5–3.5
M-P Cloud IC	20–50	10^{-6}–10^{-3}	40–220	0–3
Ice Cloud IC	20–50	10^{-7}–10^{-4}	25–120	>3.5
		10^{-6}–10^{-3}	40–220	<3.5
B-L IC	>20	10^{-8}–10^{-5}	15–70	<0.7

Modelling the Atmosphere

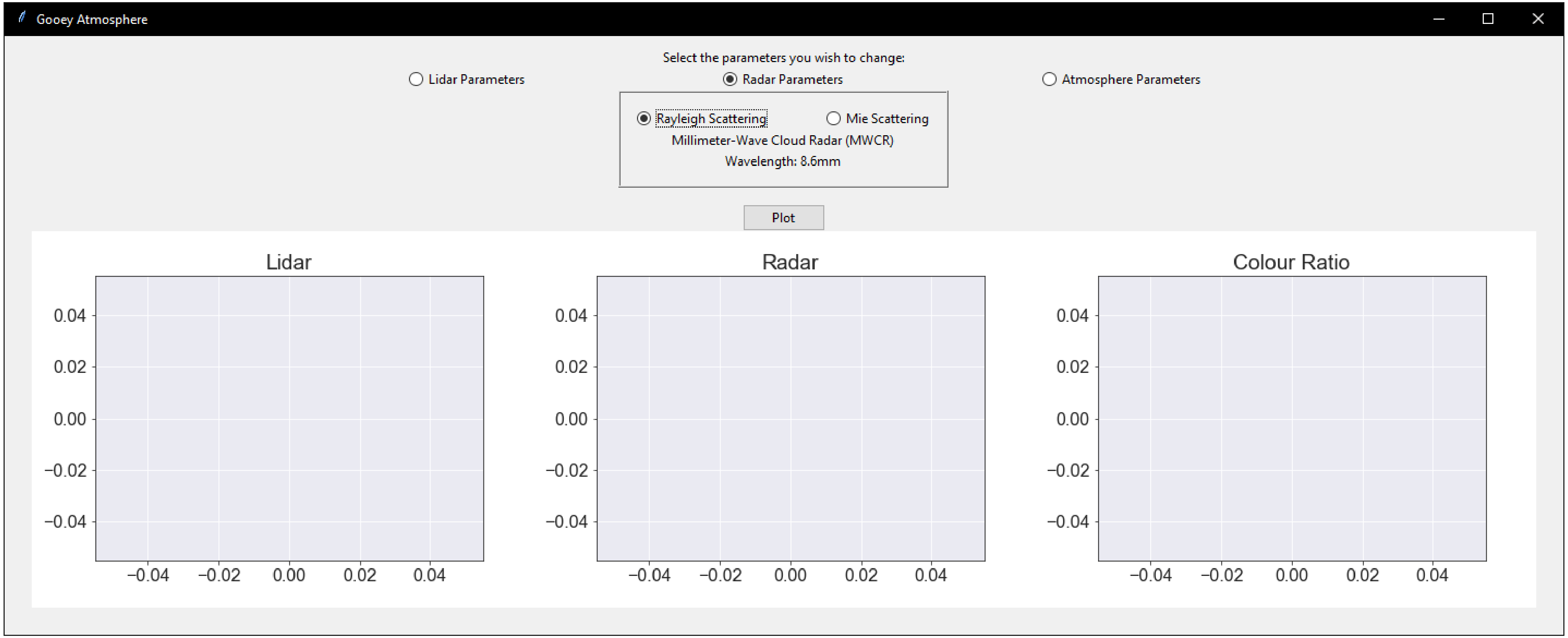
- Water acts as an ideal gas in the atmosphere and thus we can model the water clouds in the atmosphere by modelling $\frac{P}{T} = nk$
- Model $\frac{P}{T}$ with a Gaussian, shift the mean height, standard deviation, and scaling factor by a random (Gaussian) amount every hour
- Gaussian model based on observed values of cloud formation
- Linear interpolation between each hour segment to achieve a temporal resolution of 1 minute



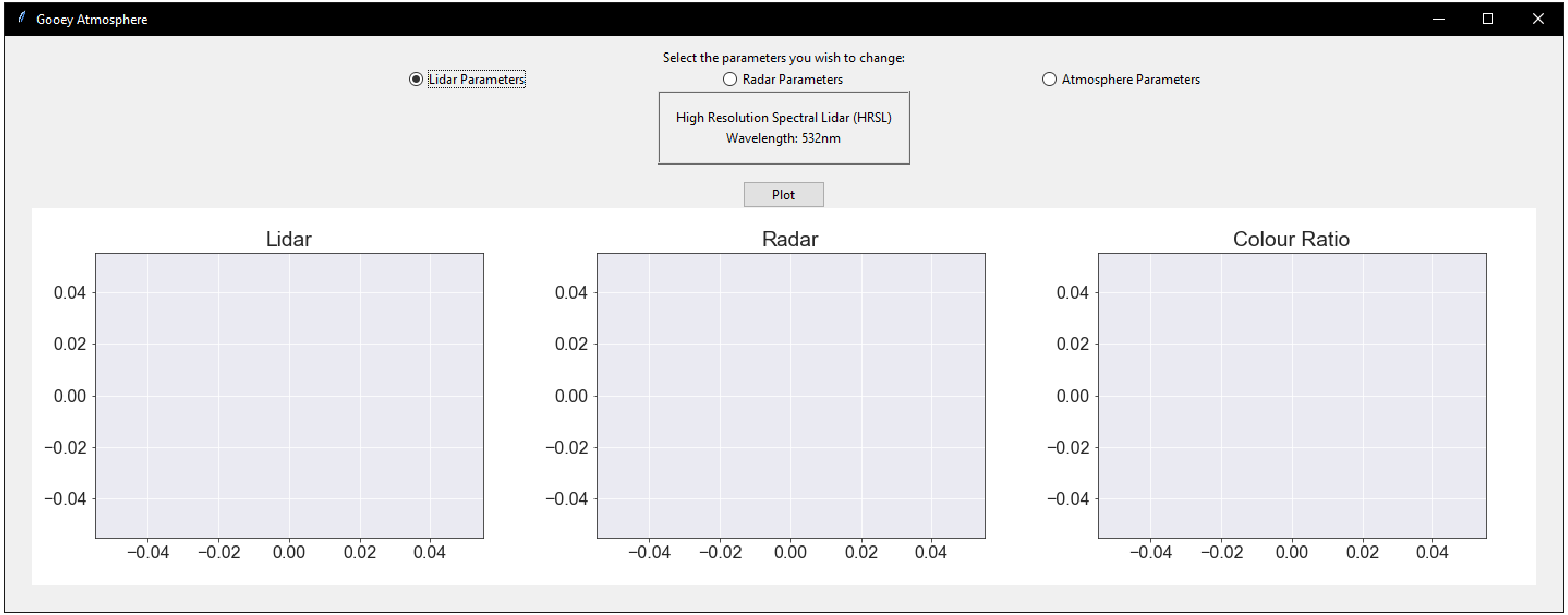
GooeyAtmosphere.py



GooeyAtmosphere.py

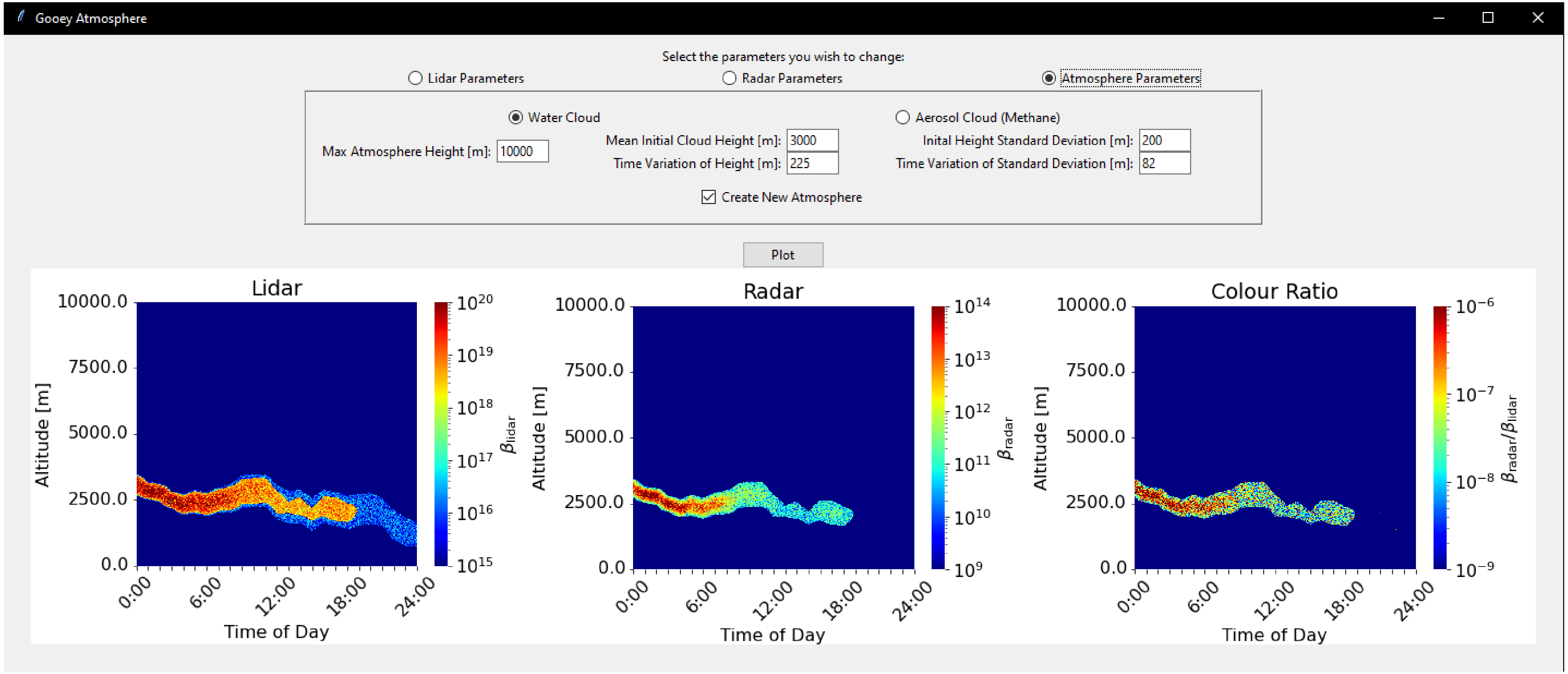


GooeyAtmosphere.py



Callum Dewsnap, Victoria Pinnegar

GooeyAtmosphere.py



Callum Dewsnap, Victoria Pinnegar