# $SF_6$ Lifetime Adjustment Based on Measured Loss in the Stratospheric Polar Vortex

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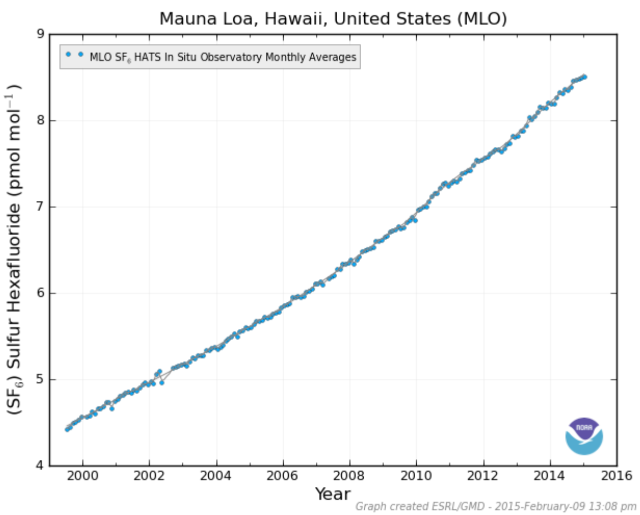
# Motivation and Objectives

- Sulfur hexafluoride ($SF_6$) is a potent greenhouse gas and important tracer of stratospheric transport but has somewhat uncertain loss.

- We use *in situ* measurements in the stratospheric polar vortex and mesospheric transport characteristics to derive annual $SF_6$ loss and estimate a revised $SF_6$ lifetime.

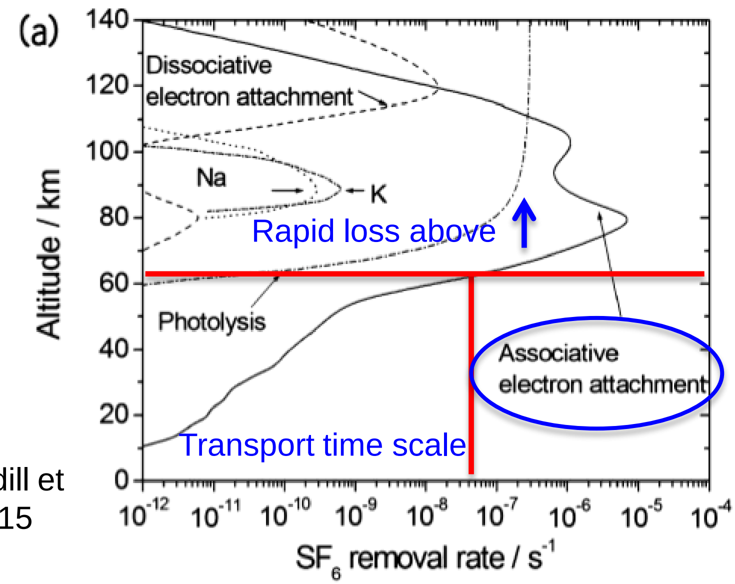
# $SF_6$ Characteristics

- Used primarily in the electrical industry as a dielectric medium, makes electricity grid more efficient therefore saves $CO_2$ emissions.
- Potent greenhouse gas with one of the highest known radiative efficiencies (0.57 $W/m^2$/ppbv) and the highest GWP for 100 year time horizon (23,500 based on 3200 year lifetime).

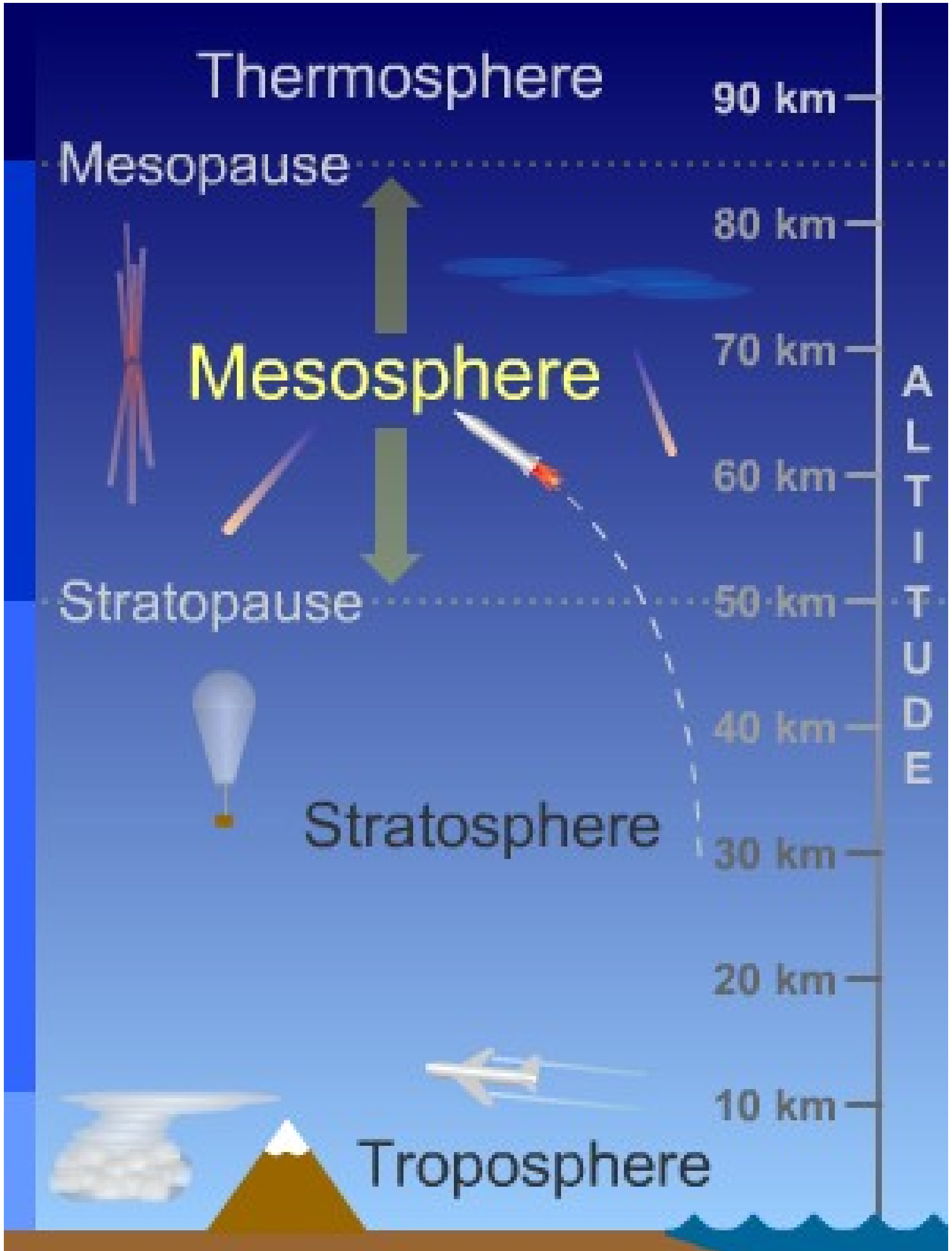



- Mixing ratio is < 10 ppt and current growth rate is 4-5%/year.
- Useful as a diagnostic of mean age of air in the stratosphere due to rapid growth and long lifetime.

- Dominant loss mechanisms are Lyman-α photolysis and electron attachment at altitudes > 50-60 km (details are somewhat uncertain).




Totterdill et al., 2015

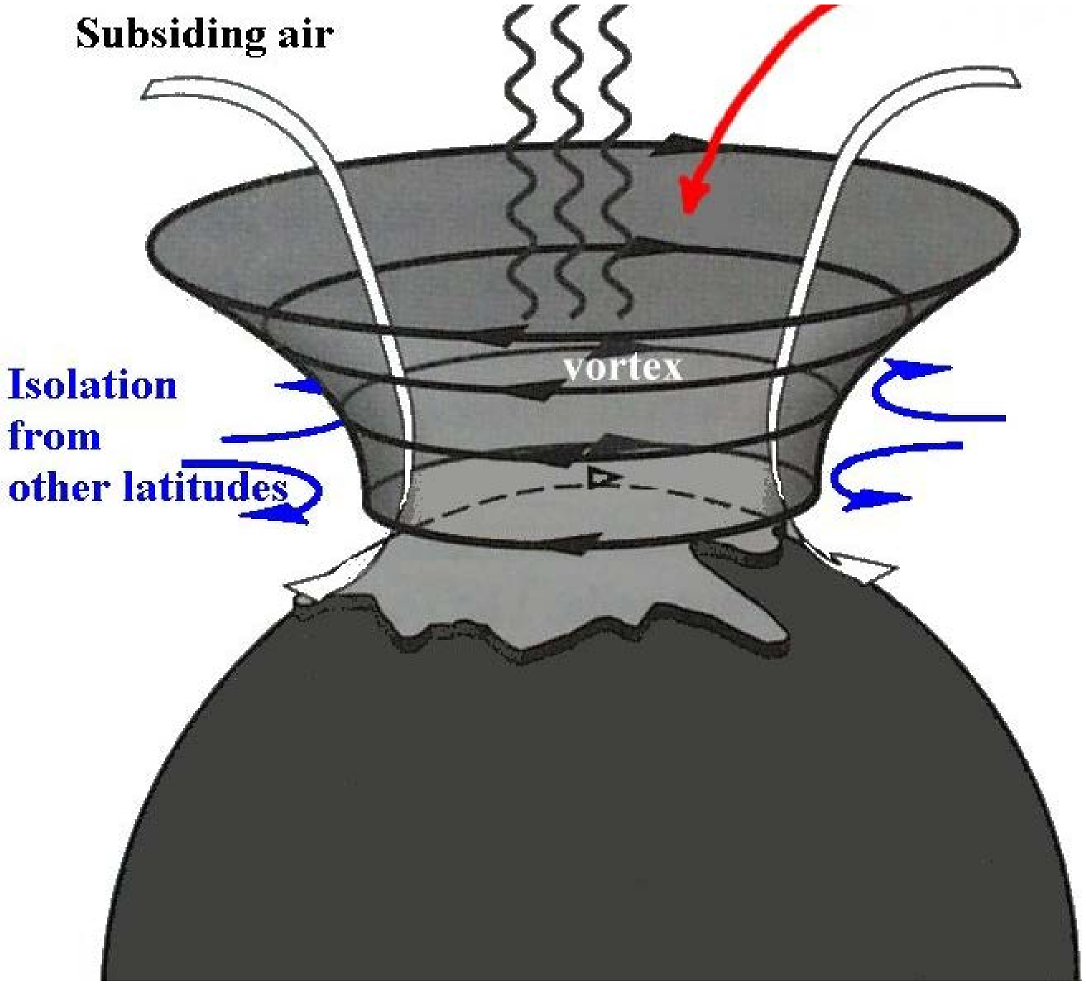



# Upper Atmosphere

Trace gases with lifetimes > ~300 years are likely to be destroyed in the mesosphere and above.

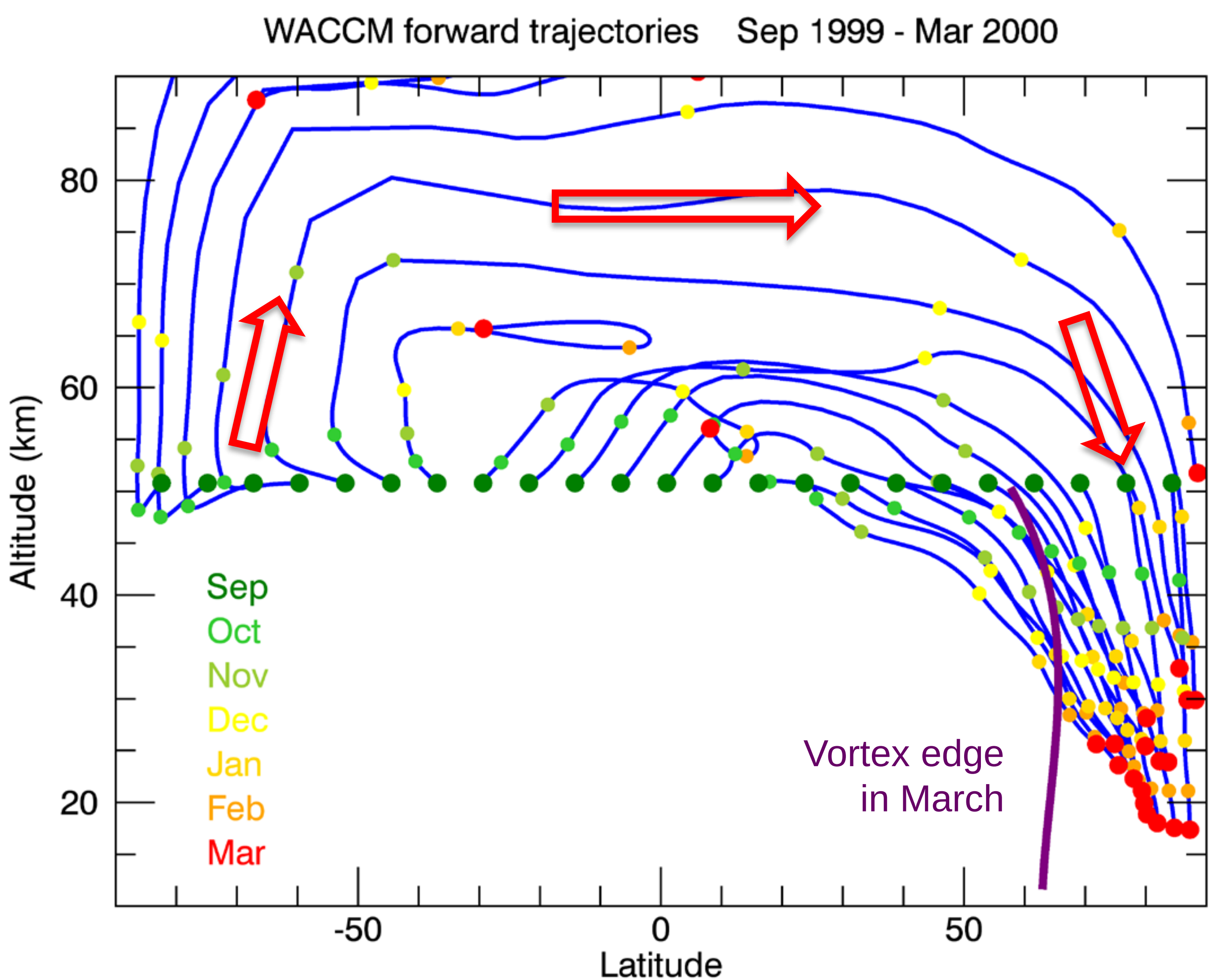
Tough to make trace gas measurements above 35 km (except from satellites).

# Mesospheric Descent Into Stratospheric Polar Vortex




The entire mass of the mesosphere (several times over) descends into each of the stratospheric polar vortices every year!

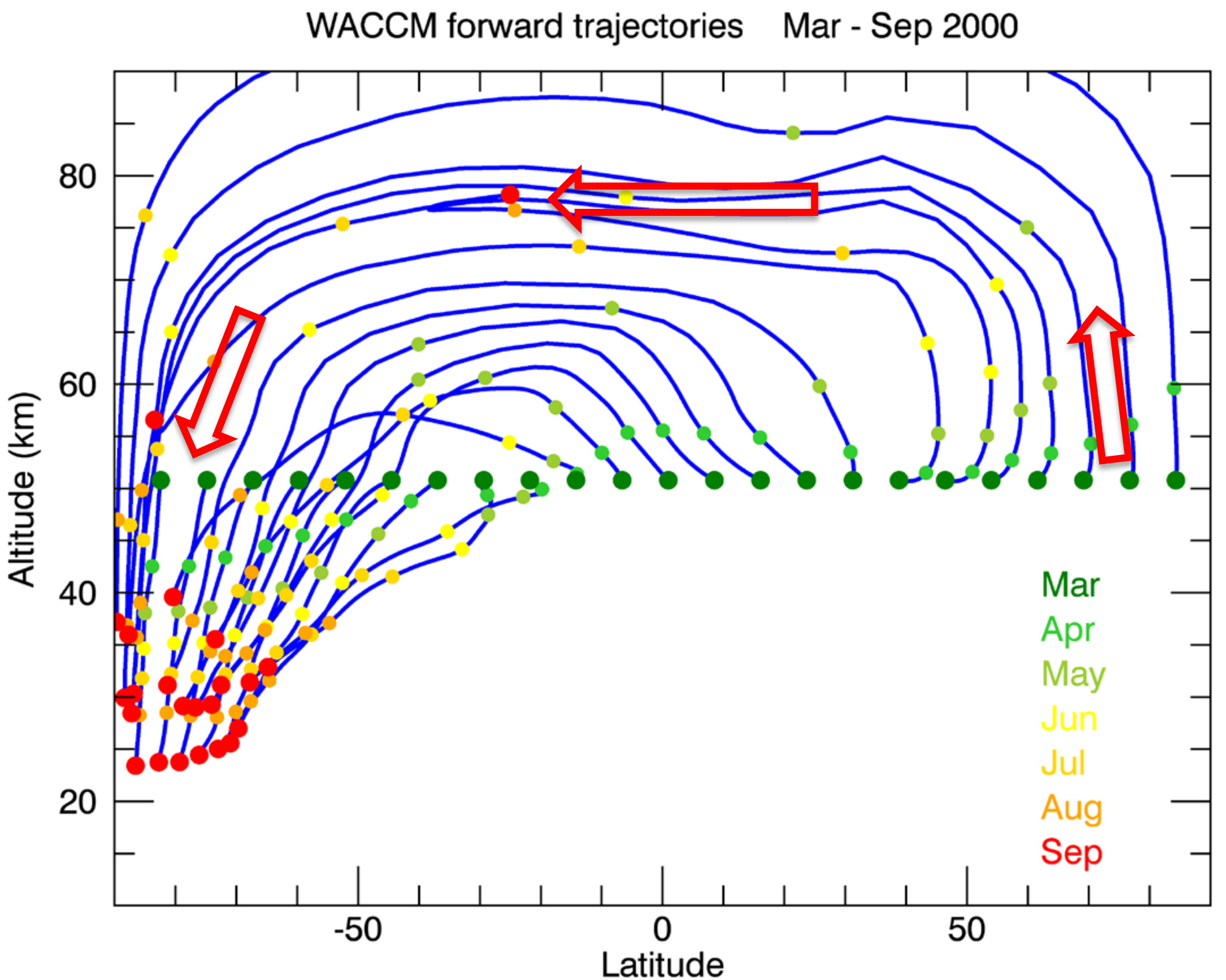
# Mesospheric Descent Into Stratospheric Polar Vortex




Model trajectories show that air in the mesosphere can move from pole to pole in months.

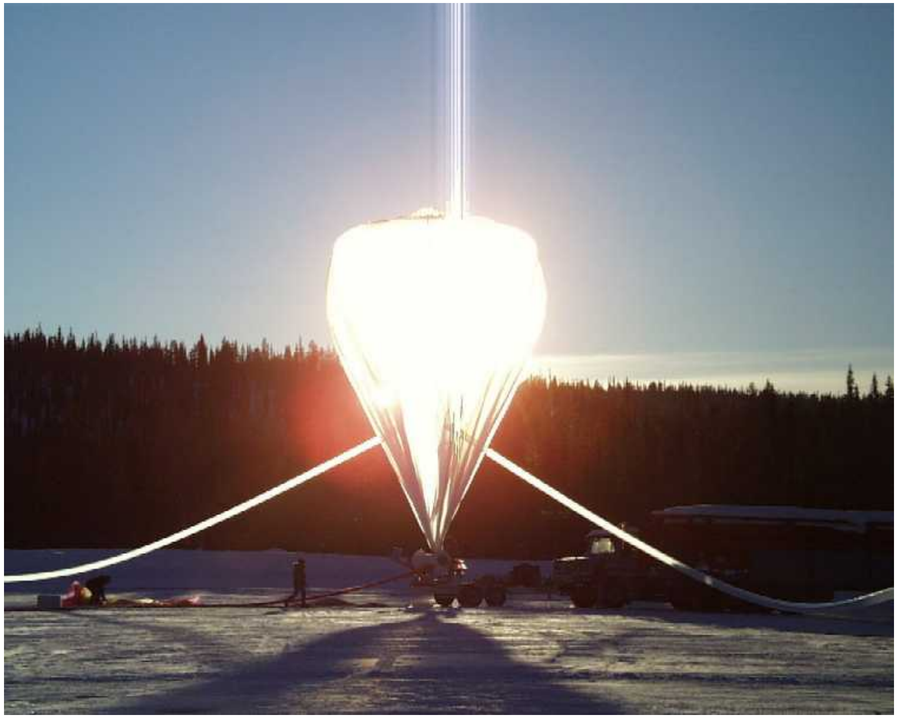
Air parcels descend and remain isolated in the vortex through March.

# Mesospheric Descent Into Stratospheric Polar Vortex



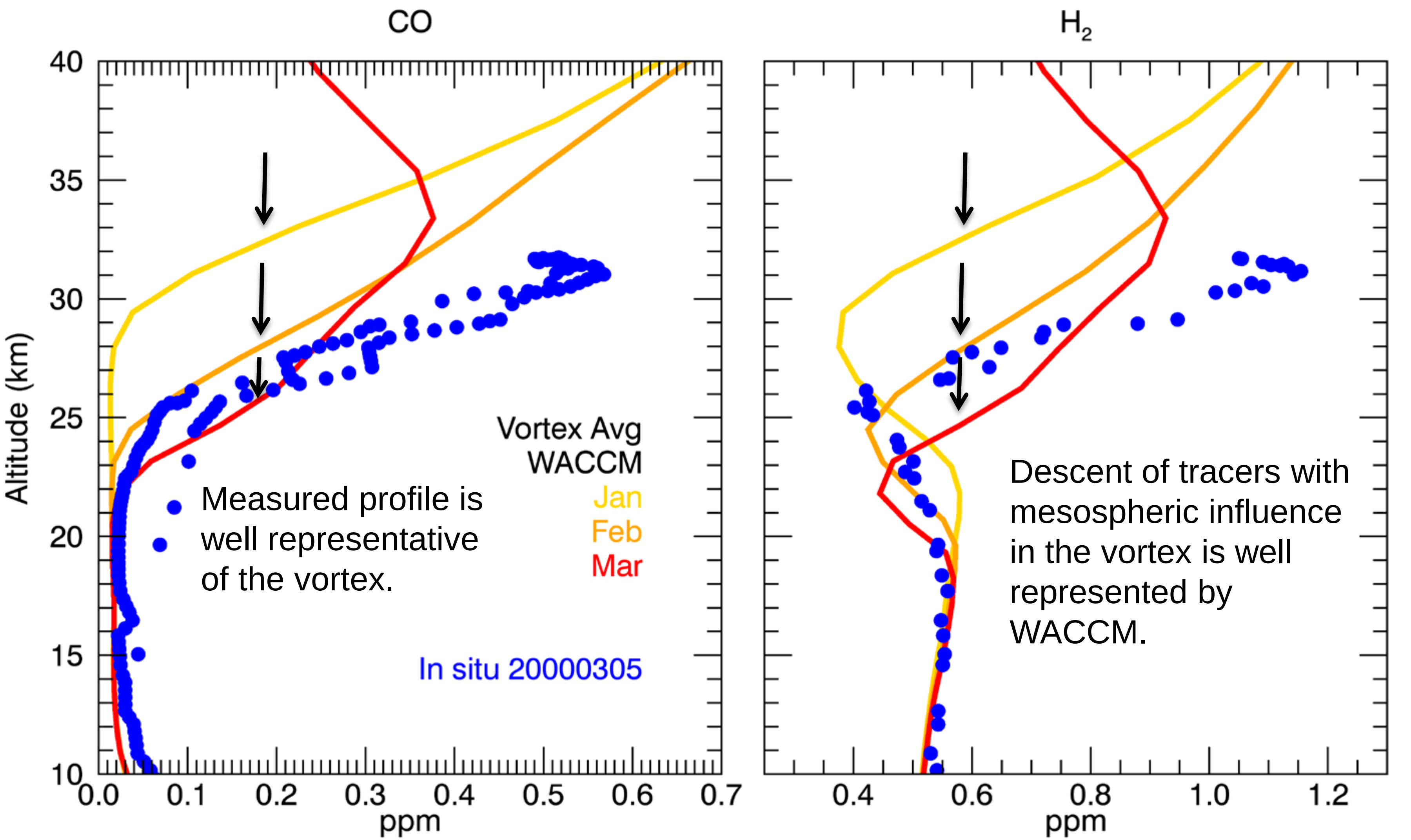

Circulation reverses in SH winter.

# Measurements in the Stratospheric Polar Vortex

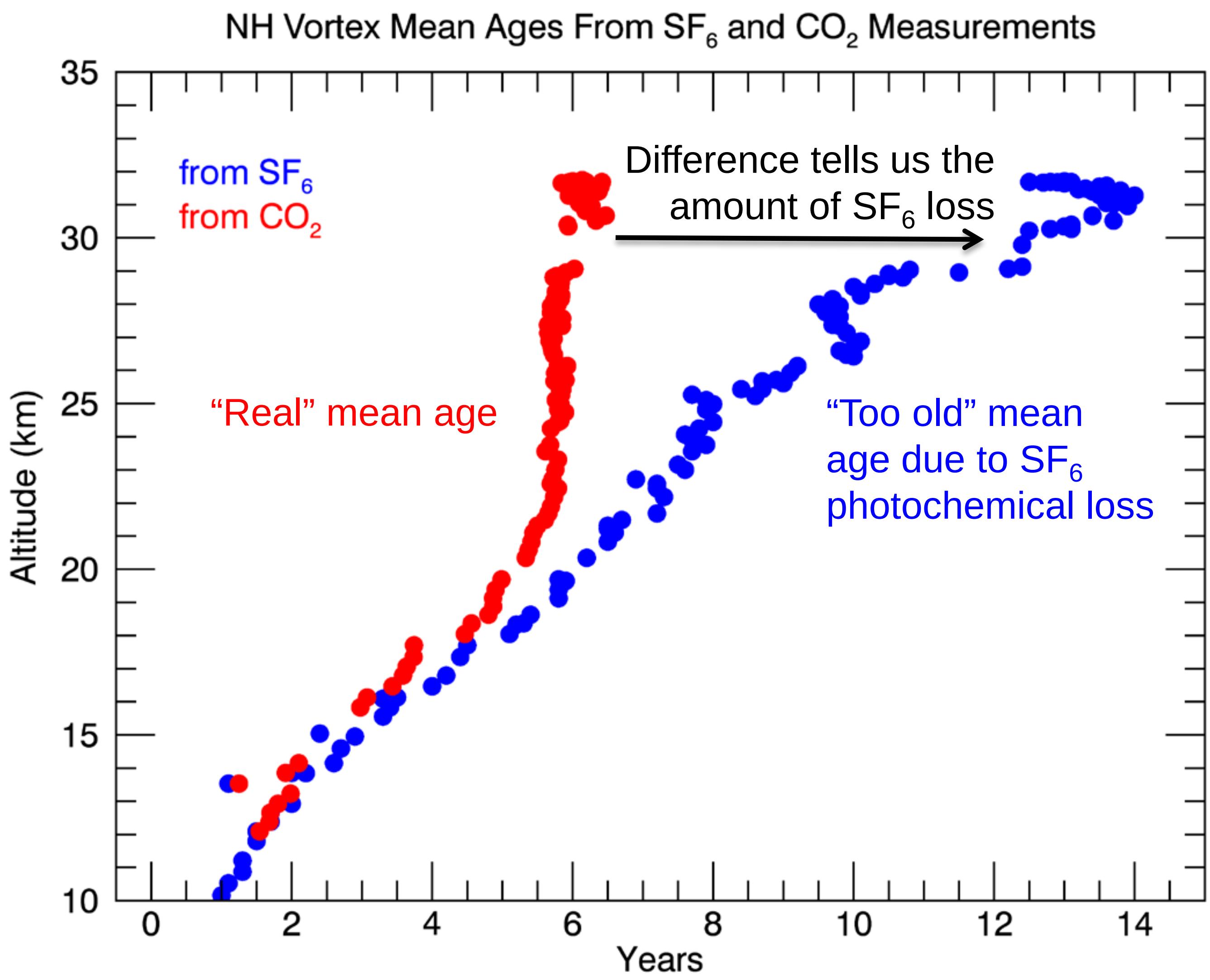


As part of SOLVE campaign, Lightweight Airborne Chromatograph Experiment (LACE) measurements from balloon launch at Kiruna, Sweden on March 5, 2000.

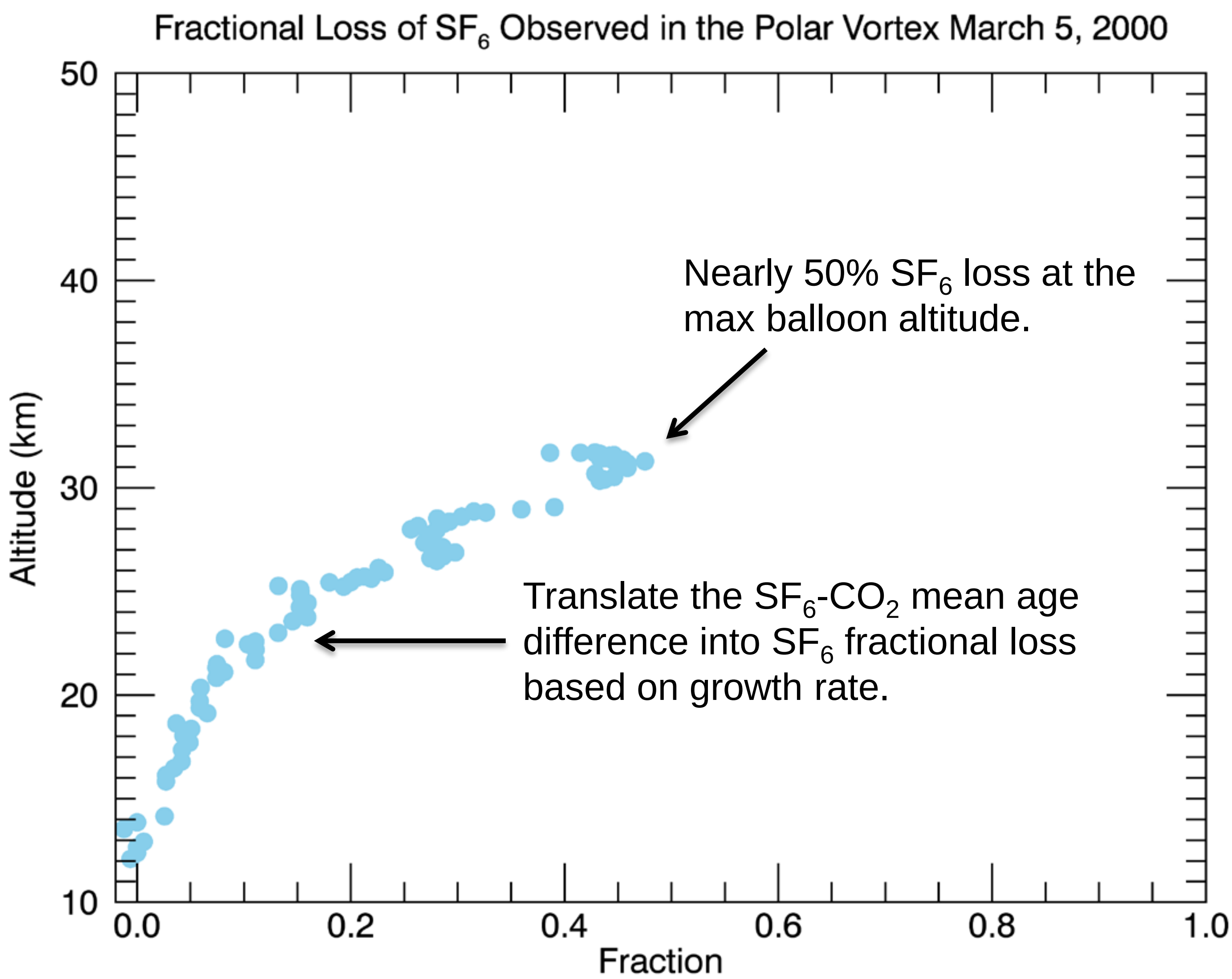
# Measured vs. Modeled Vortex Trace Gas Profiles



# Measurement Based Mean Age in Polar Vortex



# Inferred $SF_6$ Loss in Polar Vortex



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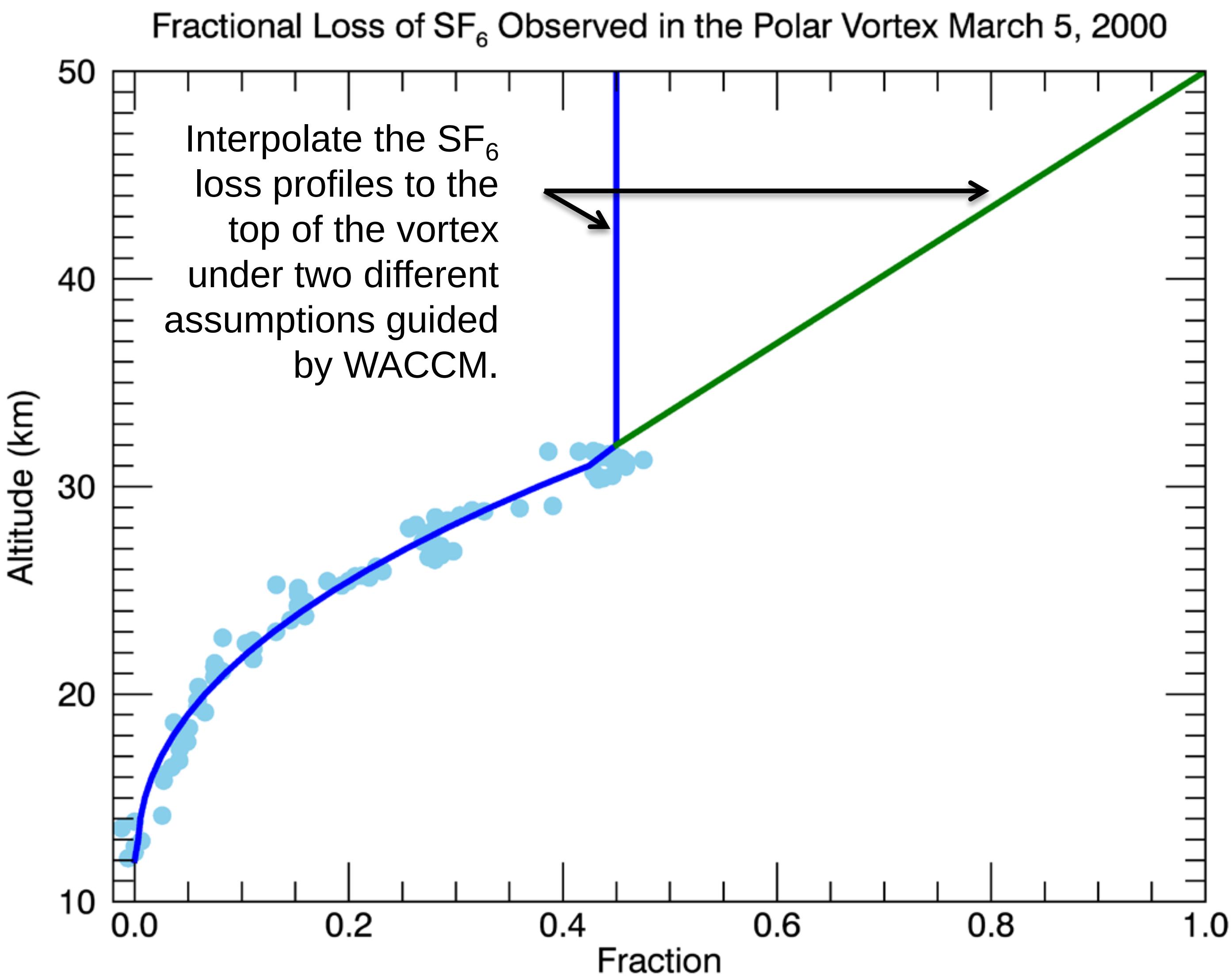
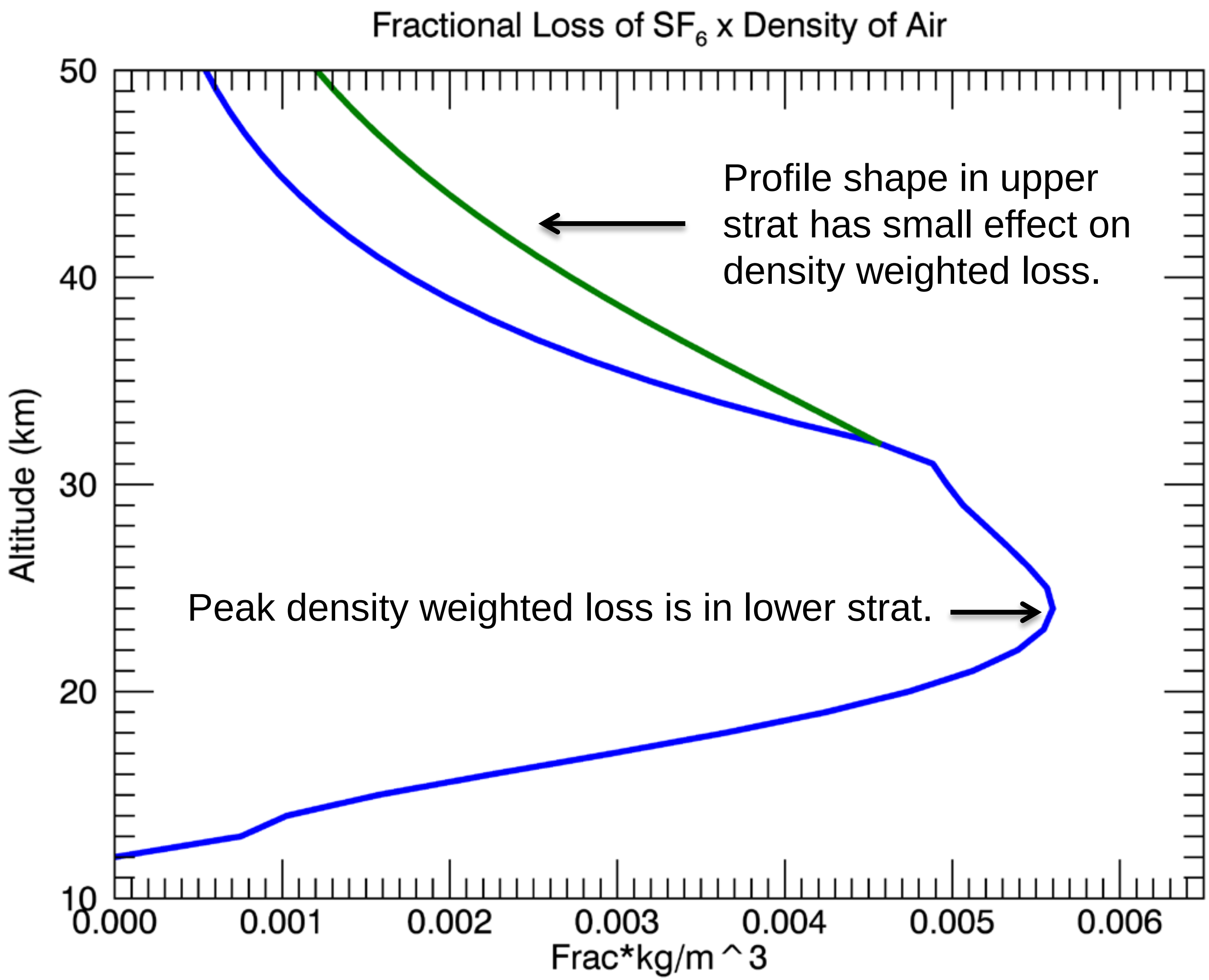


# Density Weighted $SF_6$ Loss in Polar Vortex

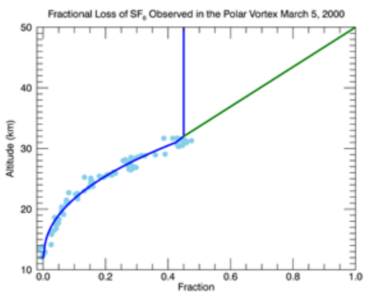


# $SF_6$ Lifetime Calculation

$SF_6$ loss per year is given by the integrated mass of the loss in both vortexes divided by the total mass of the atmosphere:

$$\frac{dL_{SF_6}}{dt} = 2 \times \int_{z_b}^{z_t} A_V(z) \times \rho(z) \times F_{SF_6}(z)\,dz \Big/ M_A$$

$SF_6$ lifetime given by the inverse of the above annual loss rate is 800 to 900 years depending on upper vortex loss assumption with additional uncertainty of ±100 years due to uncertainty of vortex size.




## Assumptions

1. Mesospheric air only descends into the stratospheric polar vortexes.
2. We sampled representative polar vortex air mass.

# Implications and Conclusions

- Reduction of $SF_6$ lifetime from 3200 to 900 years only reduces GWP by 5% for 100 year time horizon, but 50-75% reduction for time horizons > 2000 years.

- Hard to quantify overall radiative impact of $SF_6$ because it's main use results in lower $CO_2$ emissions.

- *In situ* measurements in the stratospheric polar vortex are useful for better understanding transport and photochemistry throughout the middle atmosphere.