

Detection of aerosol growth rate using a mass balance model constrained by water isotope measurements at Mauna Loa

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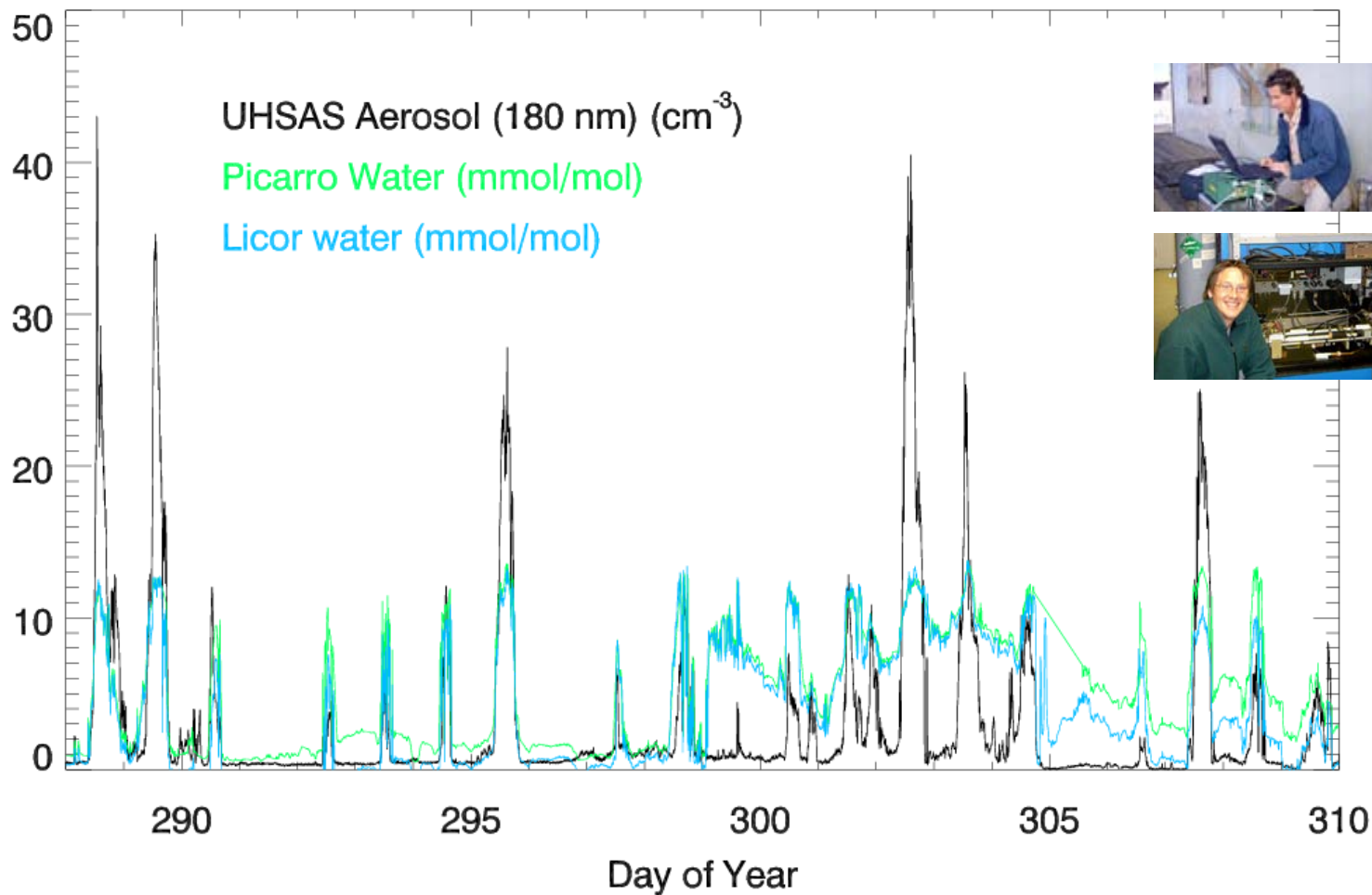
¹Atmospheric and Oceanic Sciences, University of Colorado at Boulder

²Cooperative Institute for Research in Environmental Sciences

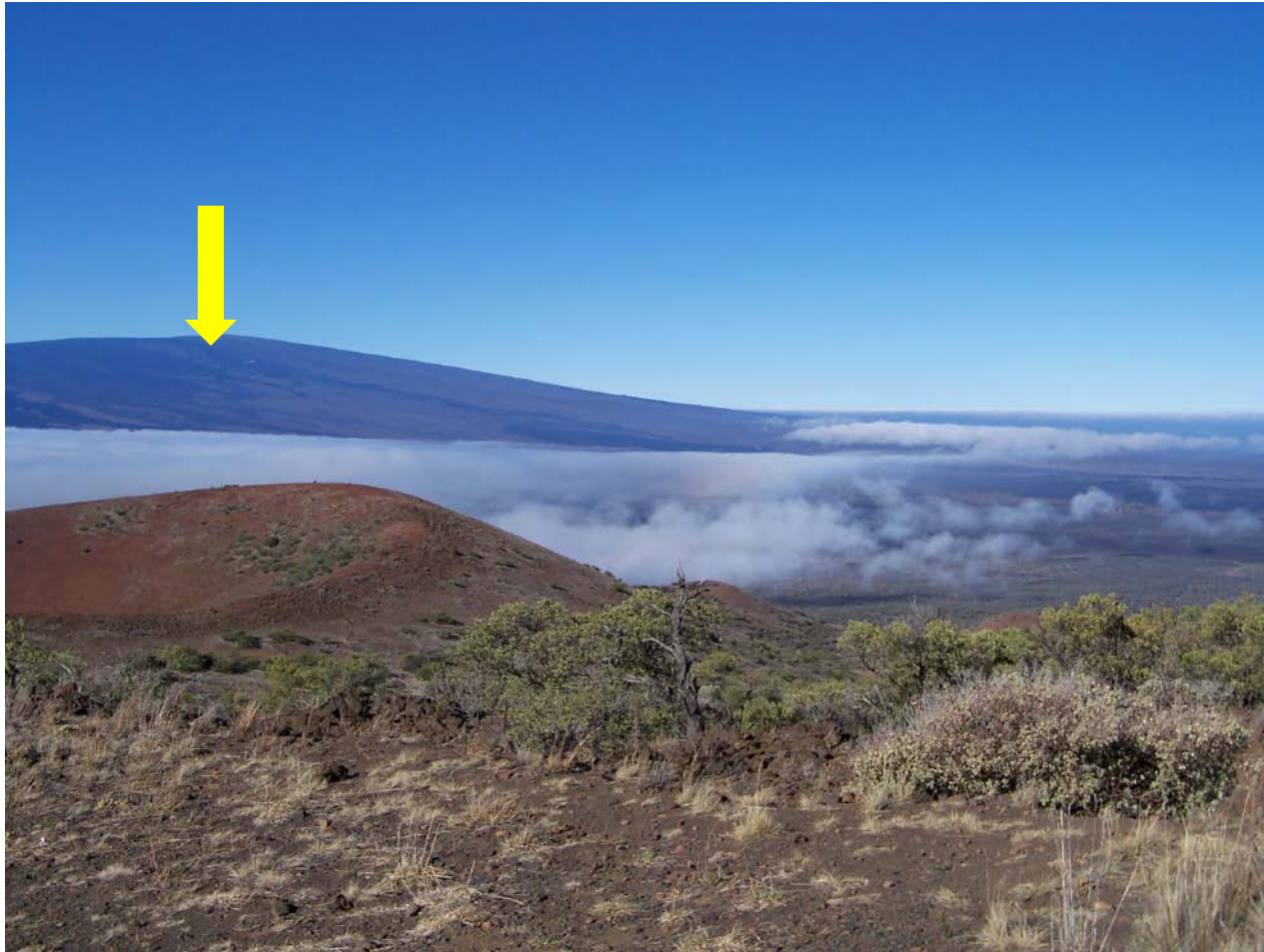


How well does water predict aerosols?

Observations: Mauna Loa 14 Oct-9 Nov 2008



The marine boundary layer rises during the day



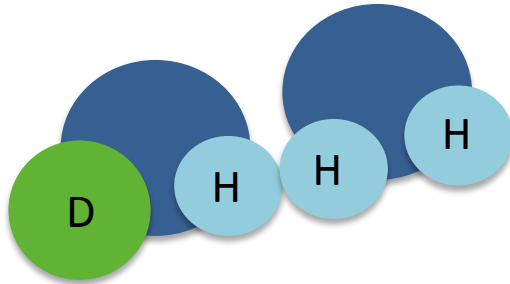
Yes, the cloud is massive



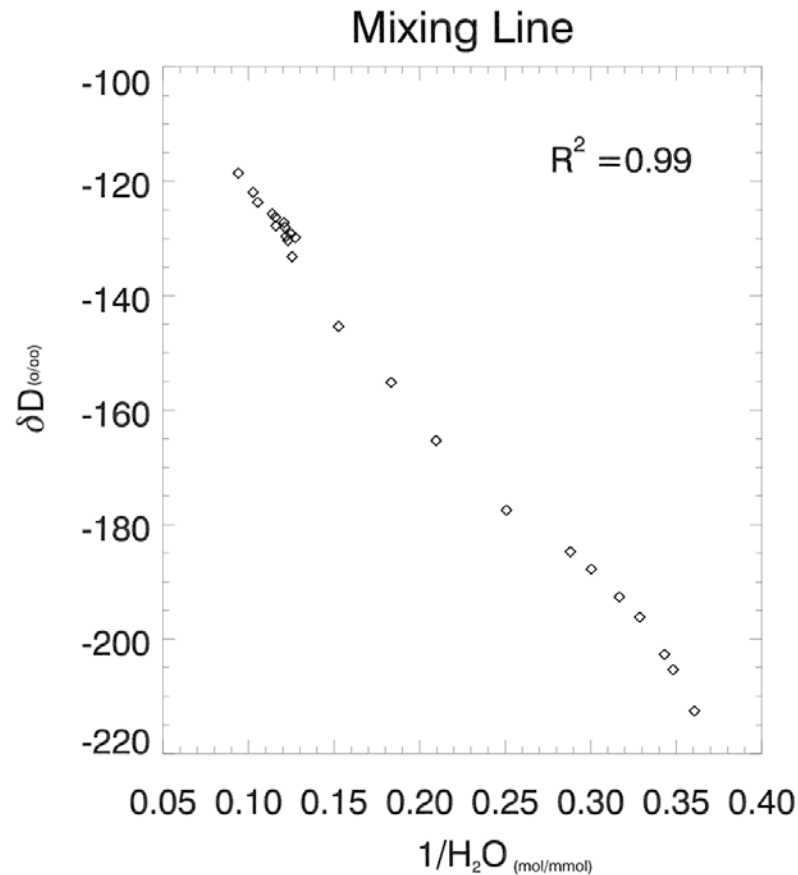
Transport also occurs within the free troposphere



A built-in tracer: stable isotopes



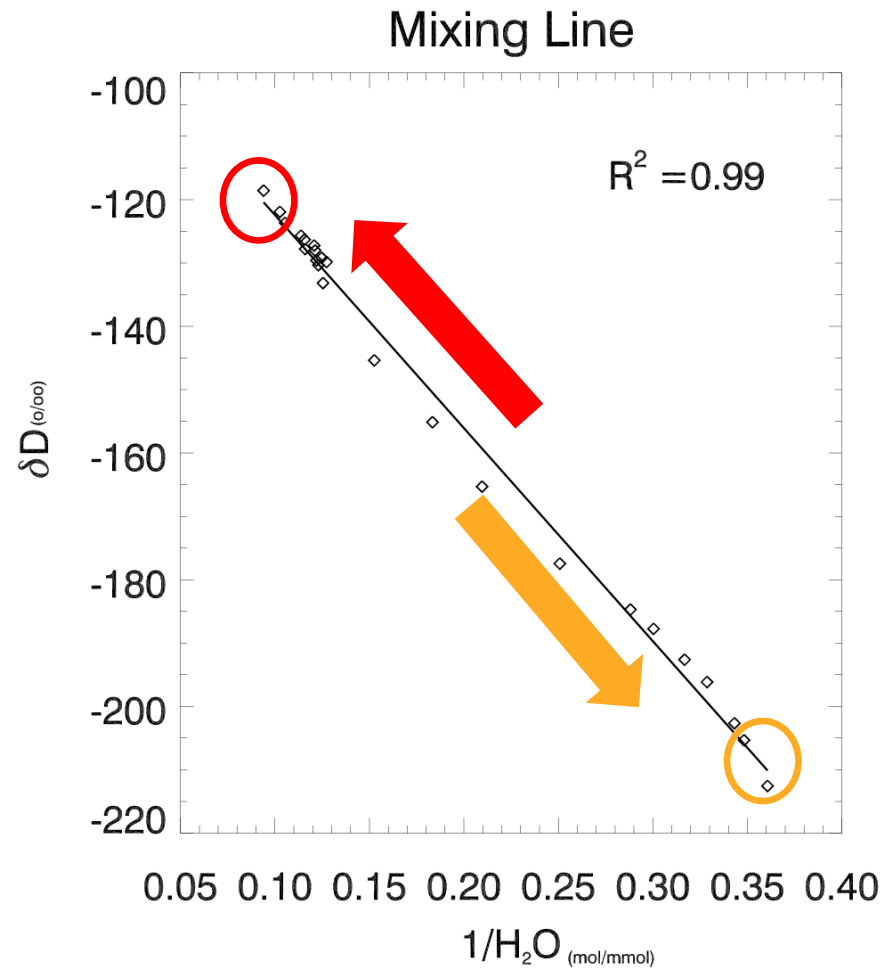
$$\delta_D = 1000 \times \left(\frac{q_{HDO} / q_{H_2O}}{R_{SMOW}} - 1 \right)$$



Two-member mixing model

$$q_{next} = q_{end} - (q_{end} - q_{now})e^{-k\Delta t}$$

$$k = -\frac{1}{\Delta t} \left(\frac{q_{end} - q_{next}}{q_{end} - q_{now}} \right)$$



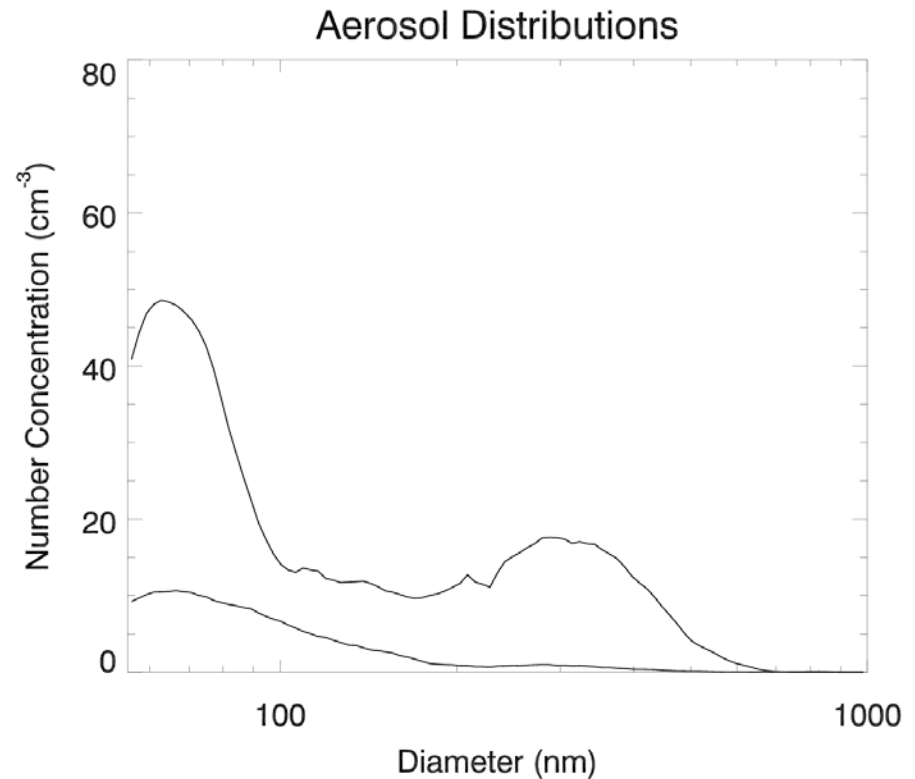
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No aerosol source/sink:

$$a_{next} = a_{end} - (a_{end} - a_{now})e^{-k\Delta t}$$



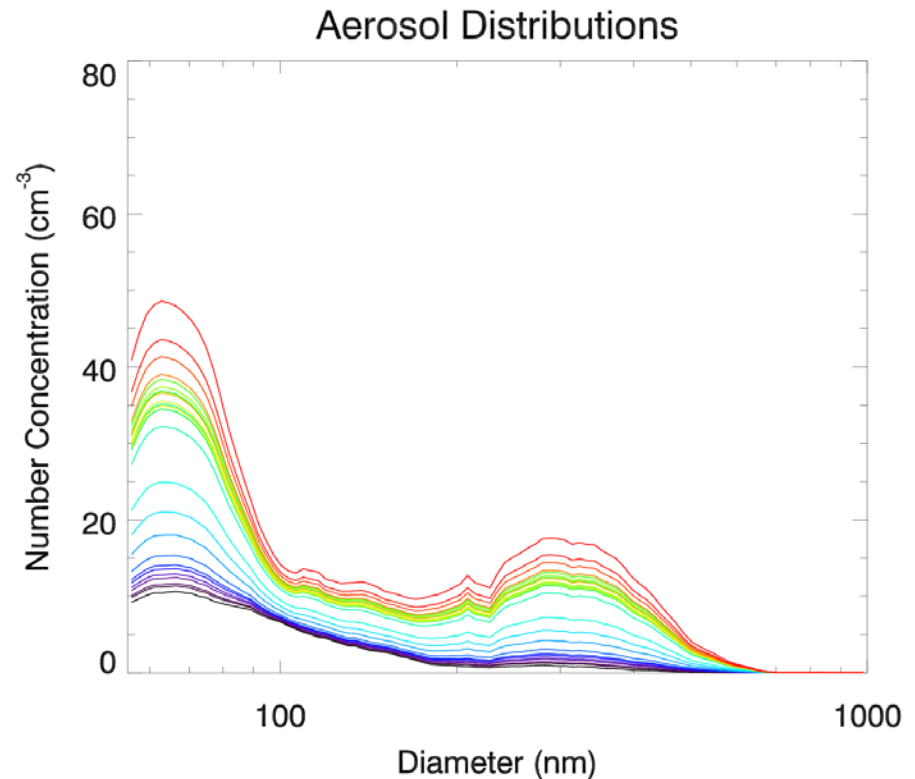
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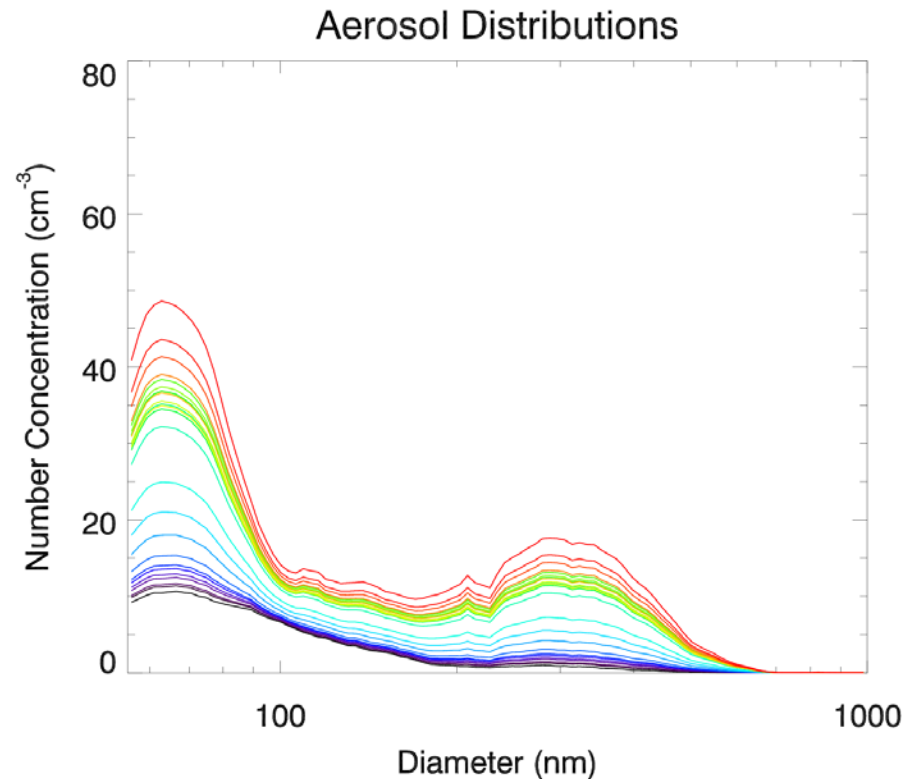
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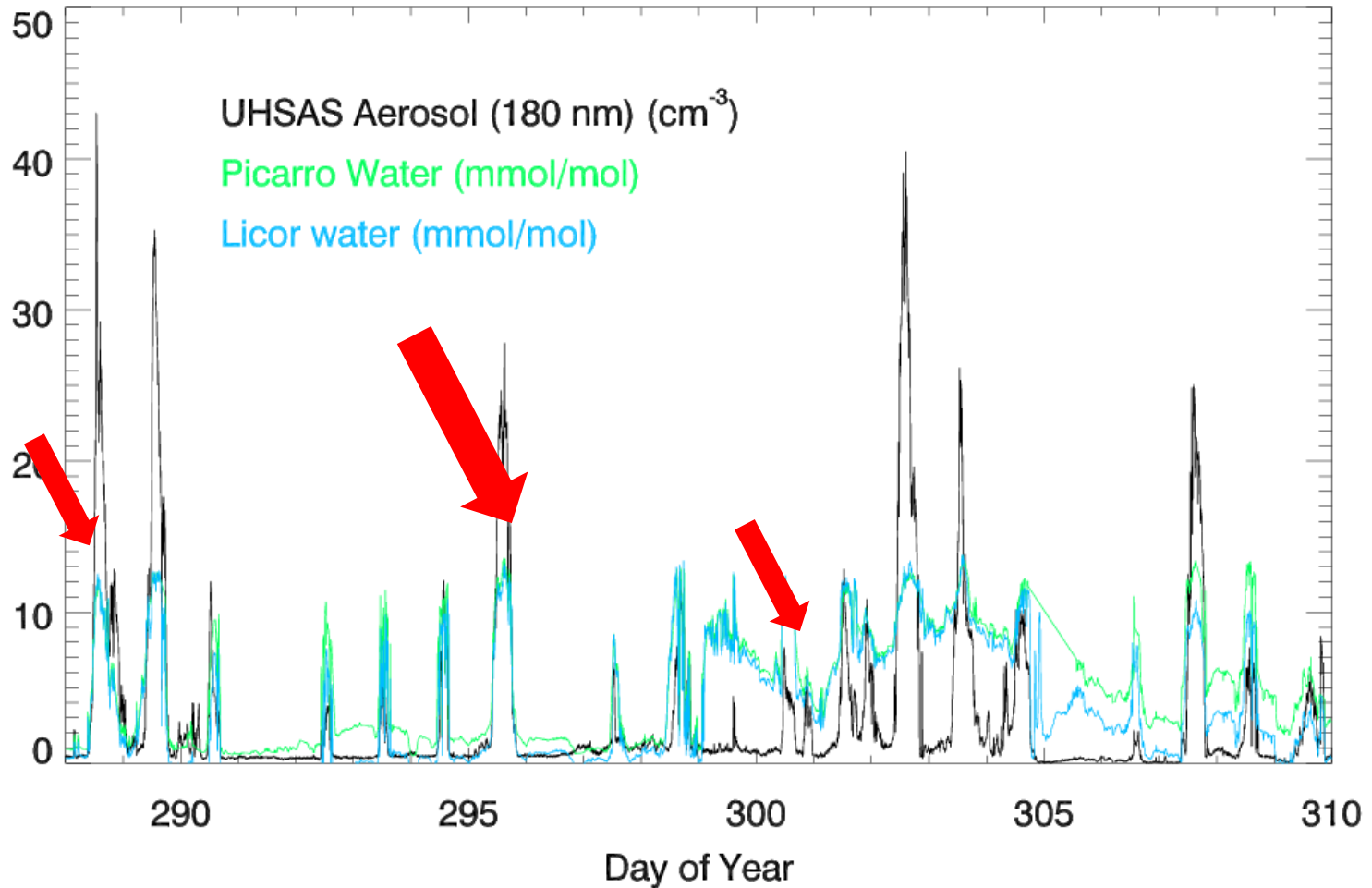
Explicit source term:

$$\frac{da}{dt} = k(a_{end} - a) + source$$

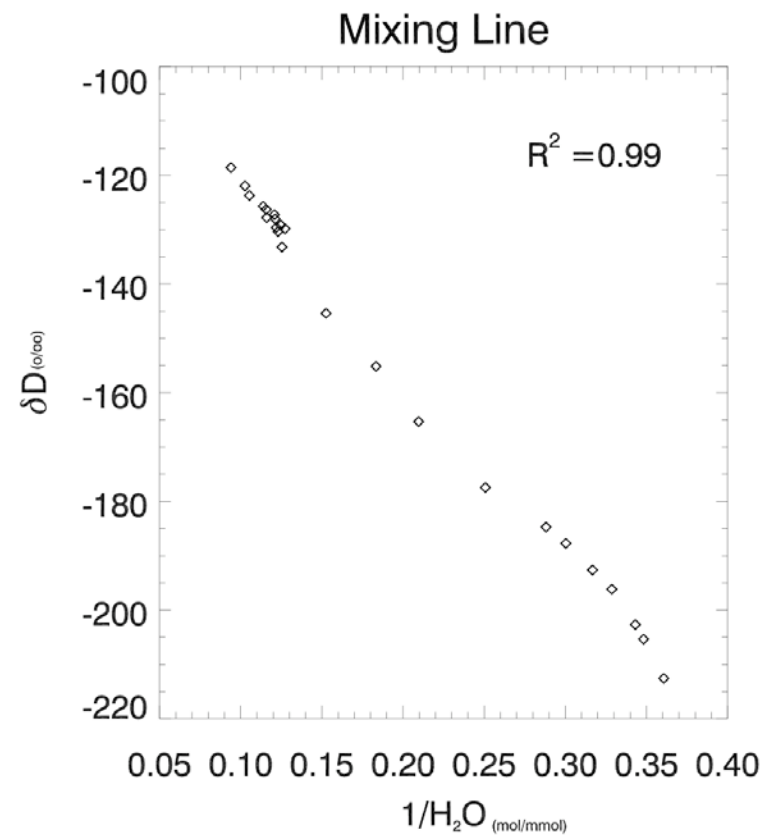
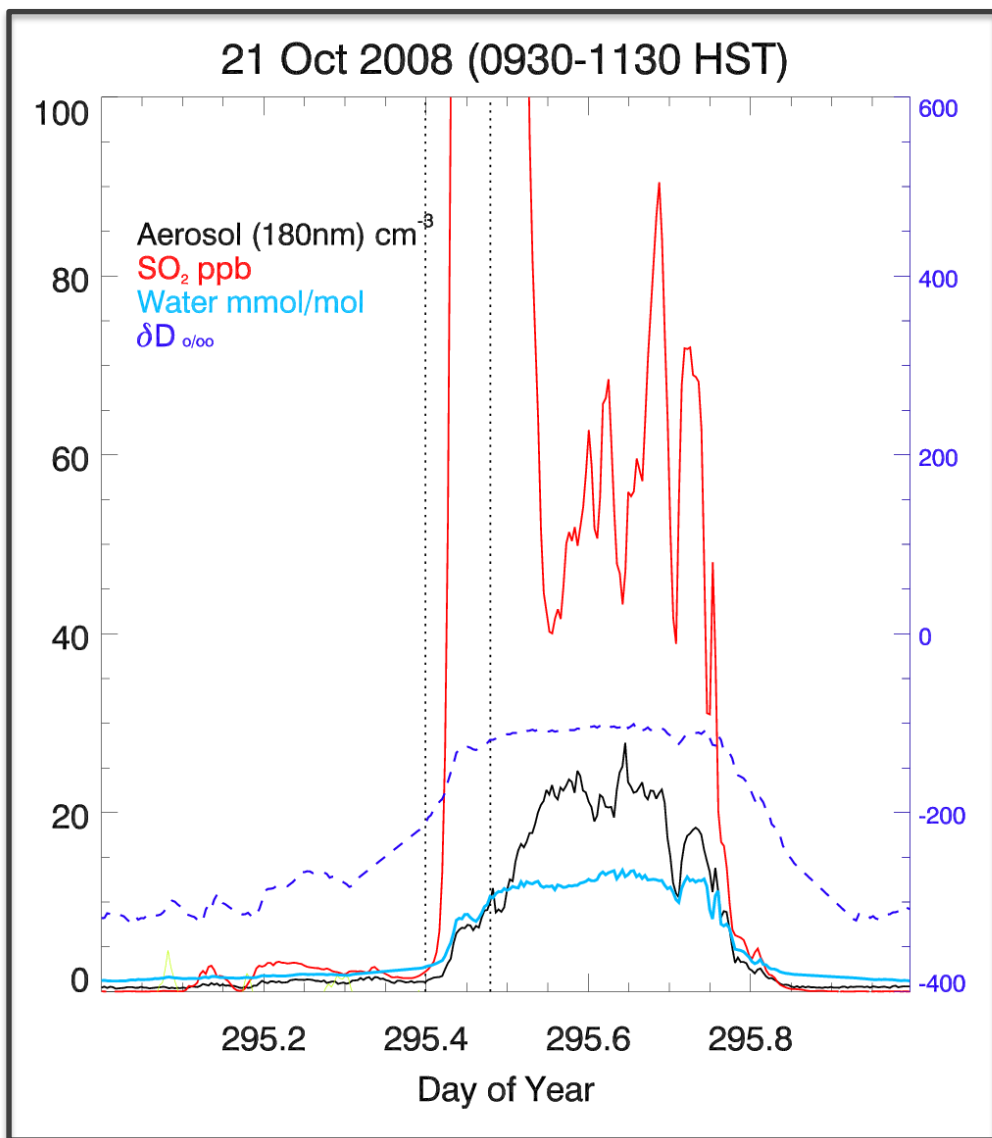


Putting the model to work...

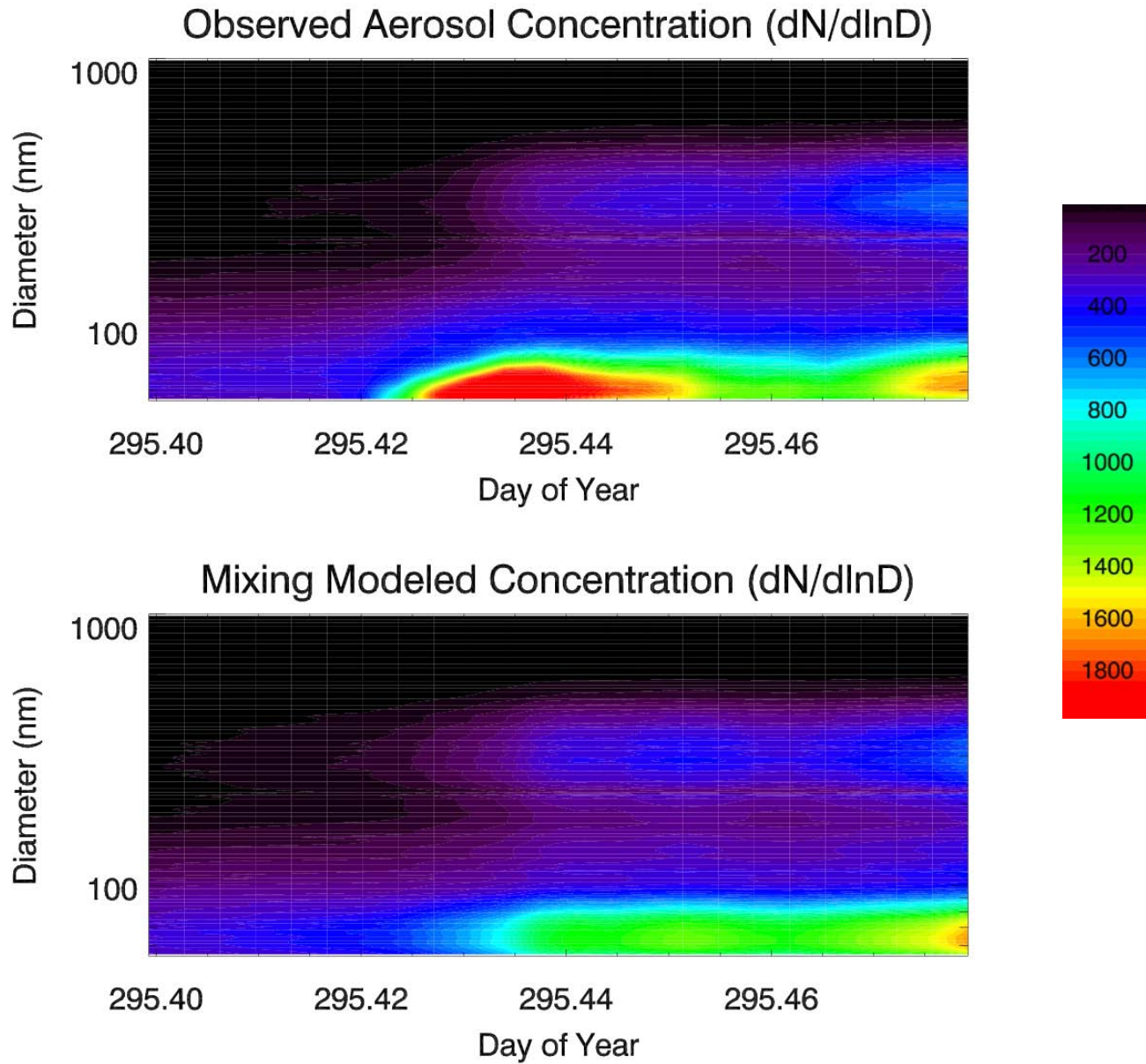
Observations: Mauna Loa 14 Oct-9 Nov 2008



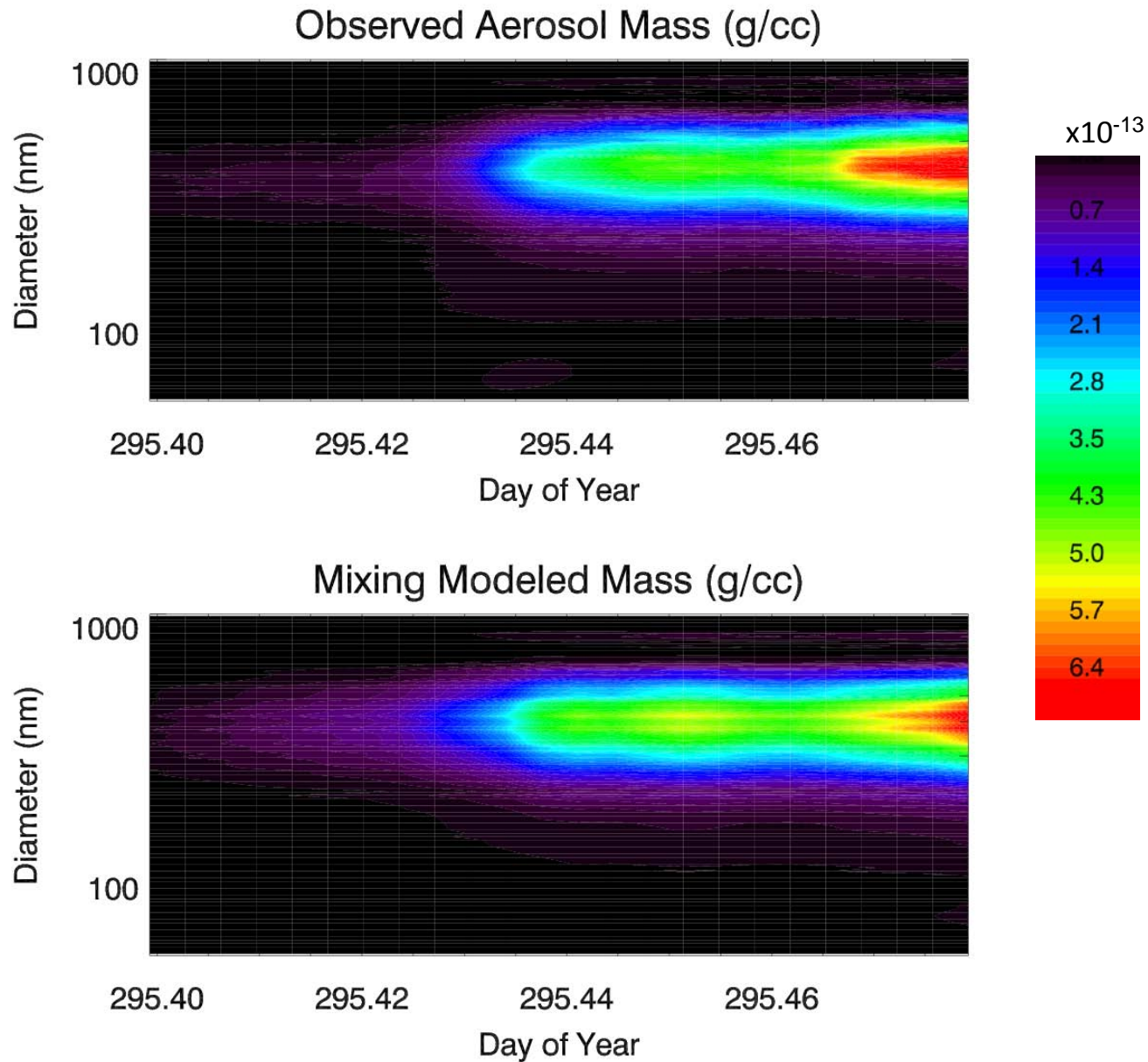
Snapshot: 21 Oct



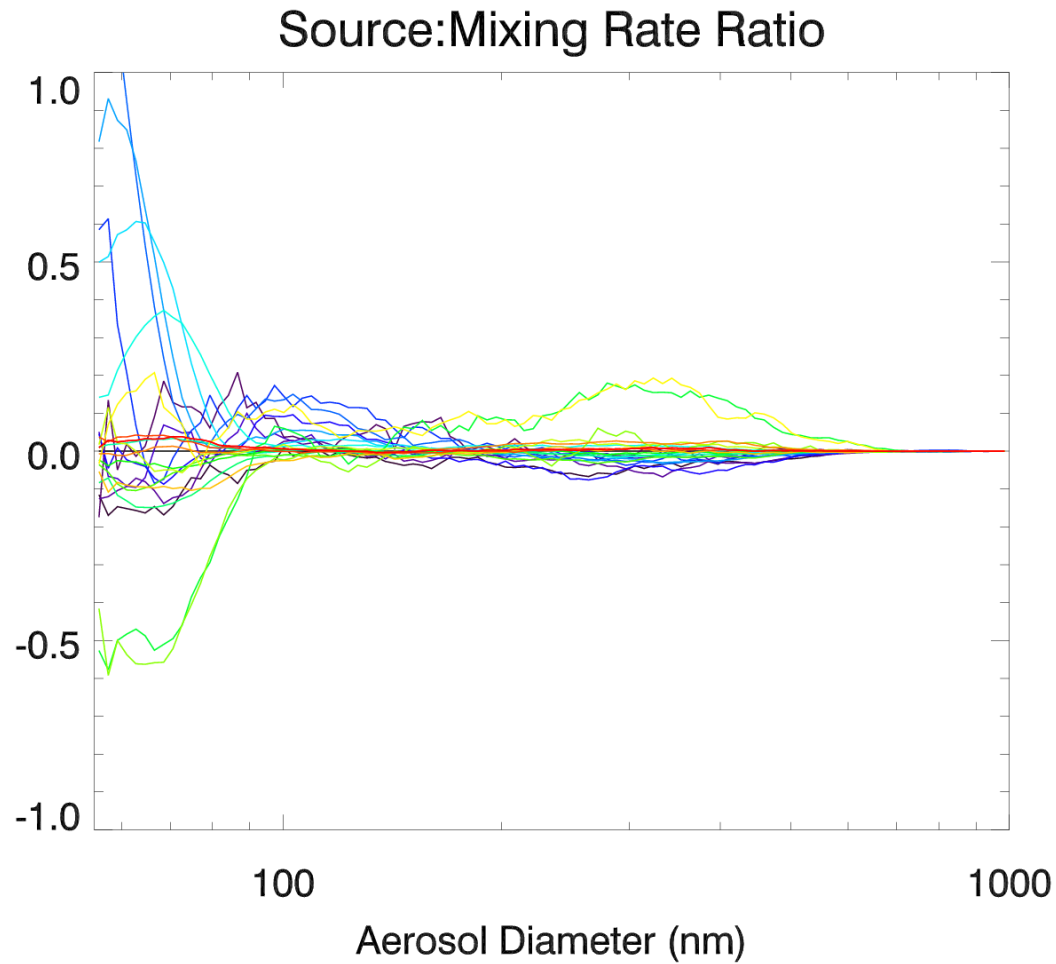
New particles form mid-morning



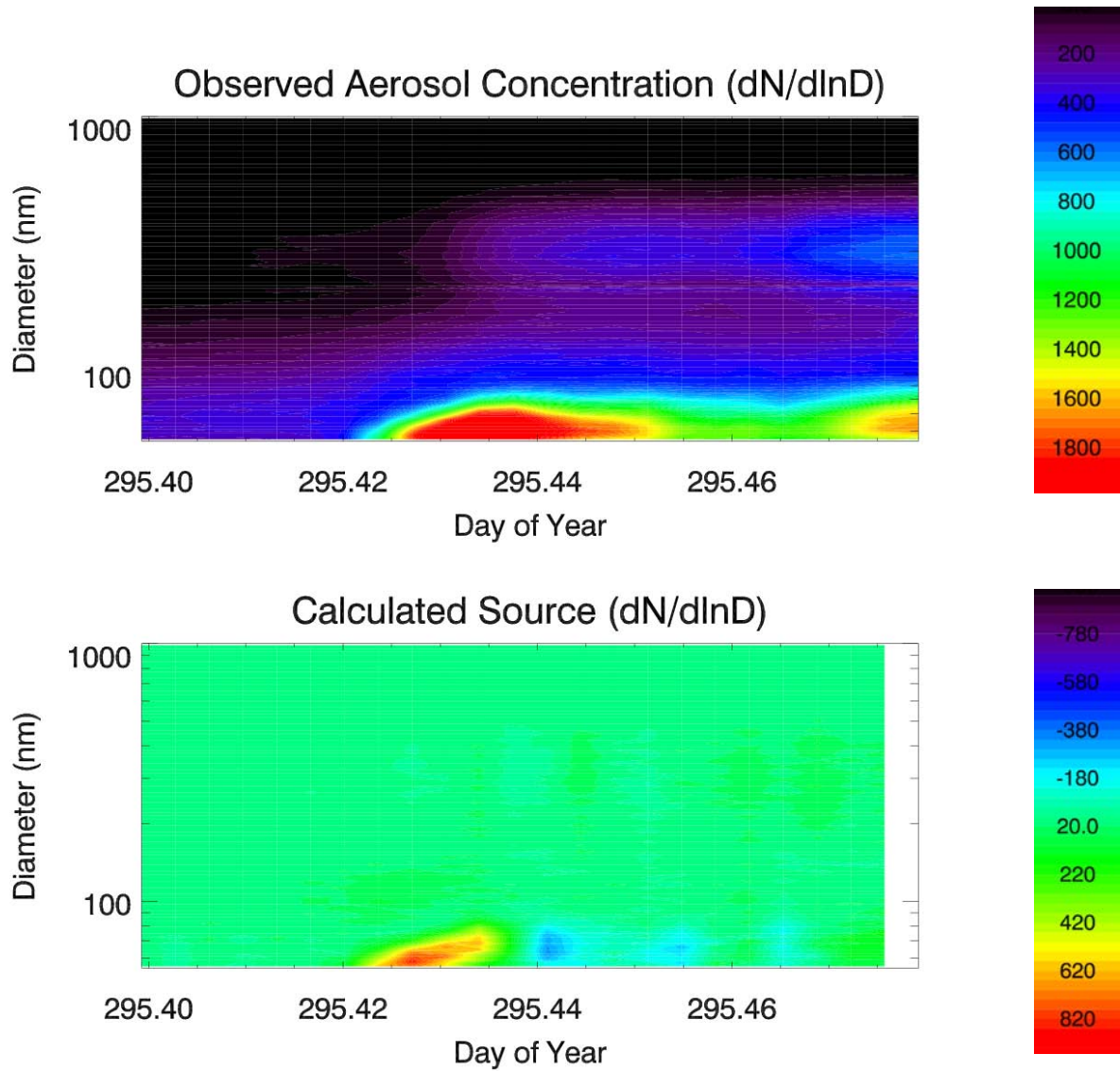
Growth occurs later in the morning



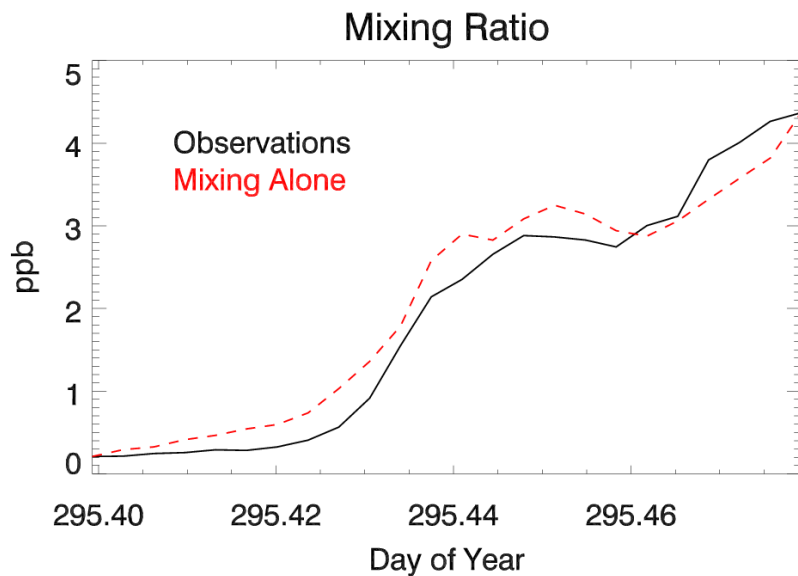
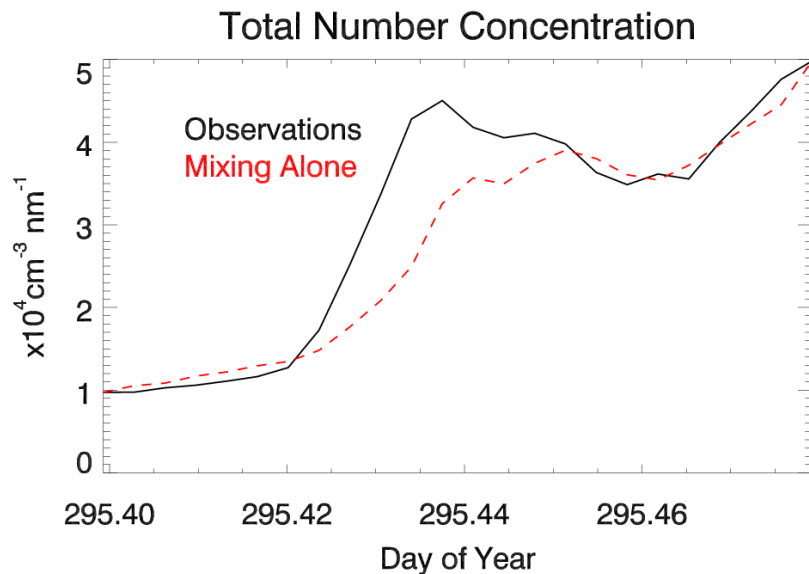
Source importance with time can be diagnosed with S/k



“Source” delineates a nucleation and growth event



Is the source of the calculated source obvious?



Back of the envelope:

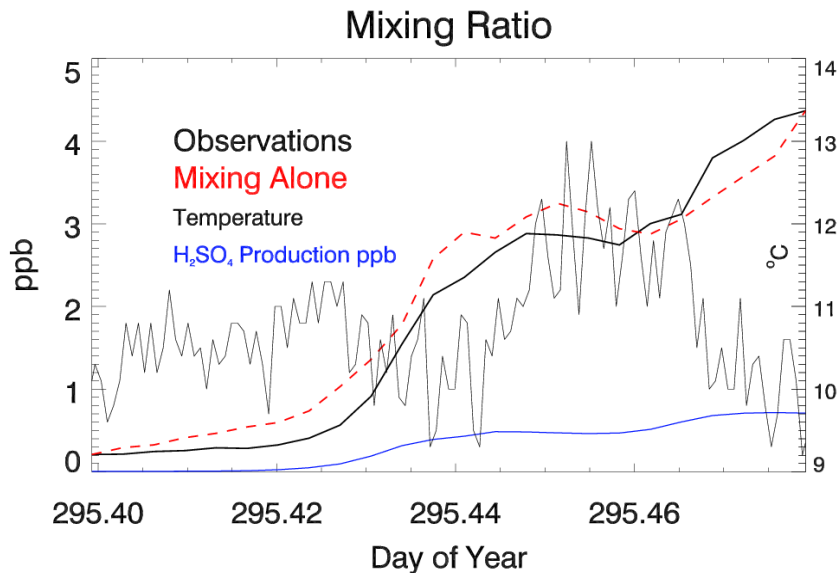
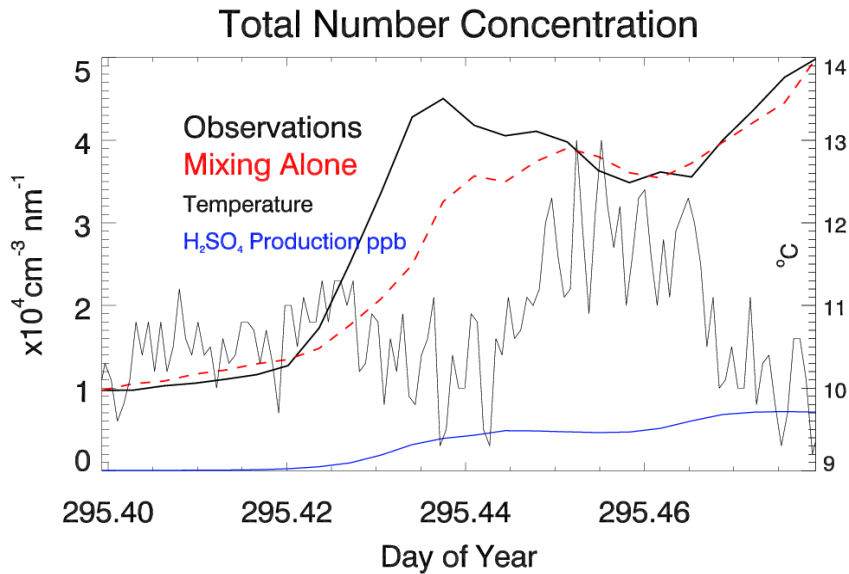
$$\frac{d[H_2SO_4]}{dt} = k_{eff} [OH][SO_2]$$

$$k_{eff} \approx \frac{k_o [M]}{1 + \frac{k_o [M]}{k_\infty}}$$

k_o = low pressure rate constant

k_∞ = high pressure rate constant

H₂SO₄ production from SO₂ seems plausible!



Back of the envelope:

$$\frac{d[H_2SO_4]}{dt} = k_{eff} [OH][SO_2]$$

$$k_{eff} \approx \frac{k_o [M]}{1 + \frac{k_o [M]}{k_\infty}}$$

k_o = low pressure rate constant

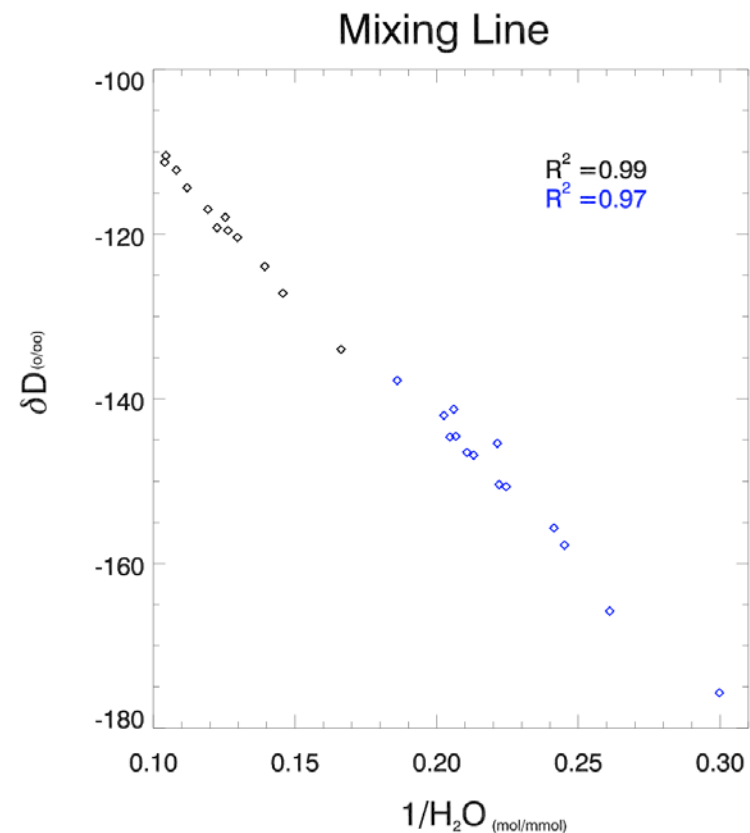
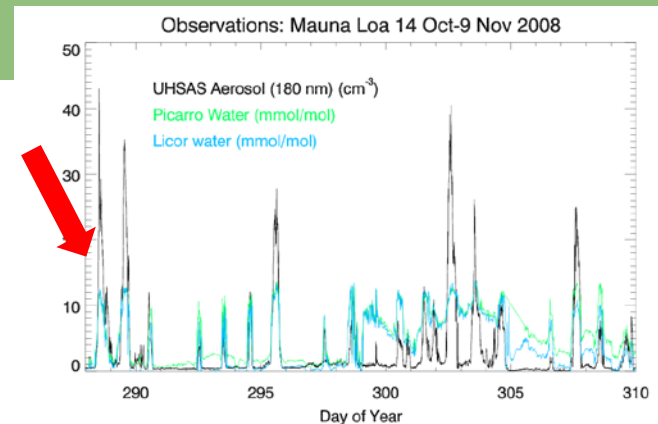
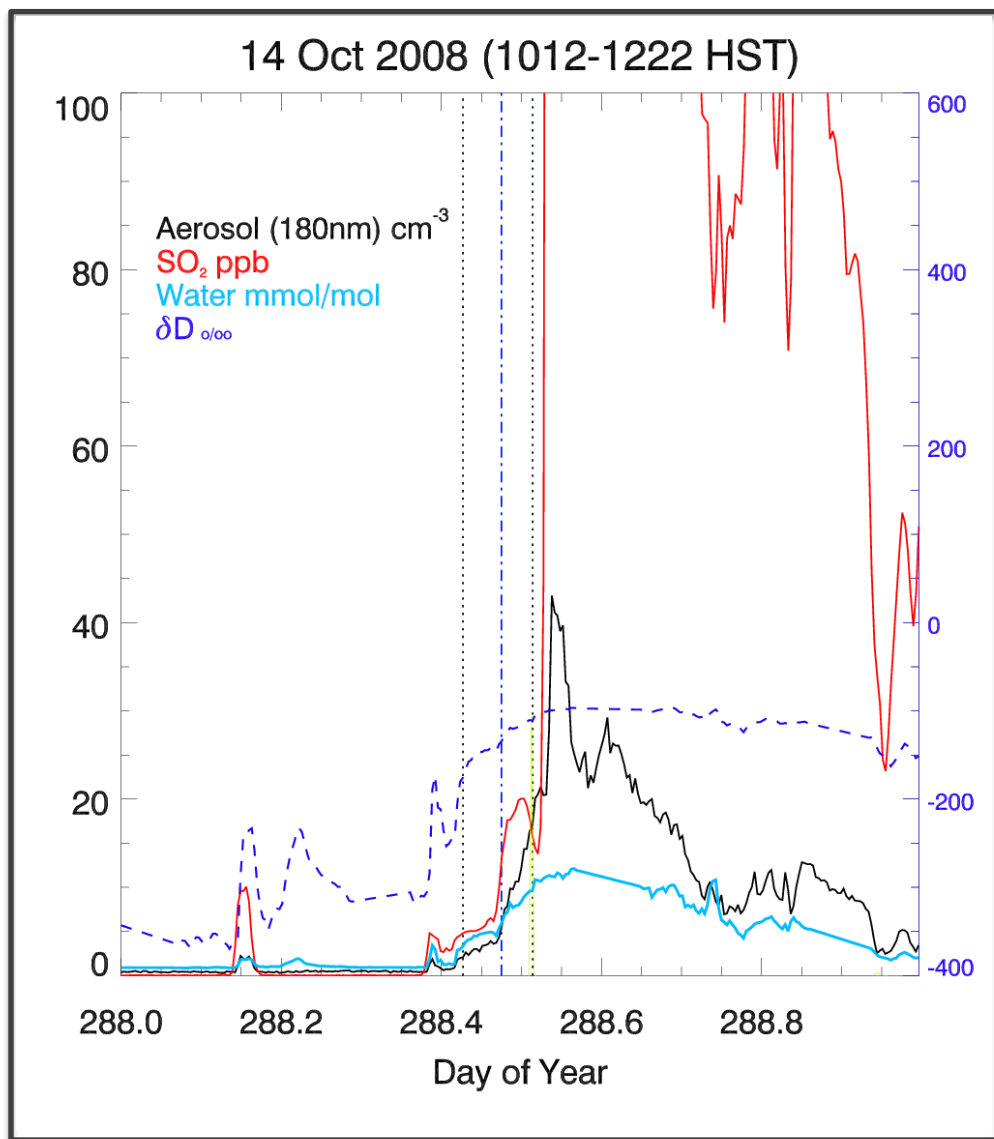
k_∞ = high pressure rate constant

Application/Future Work

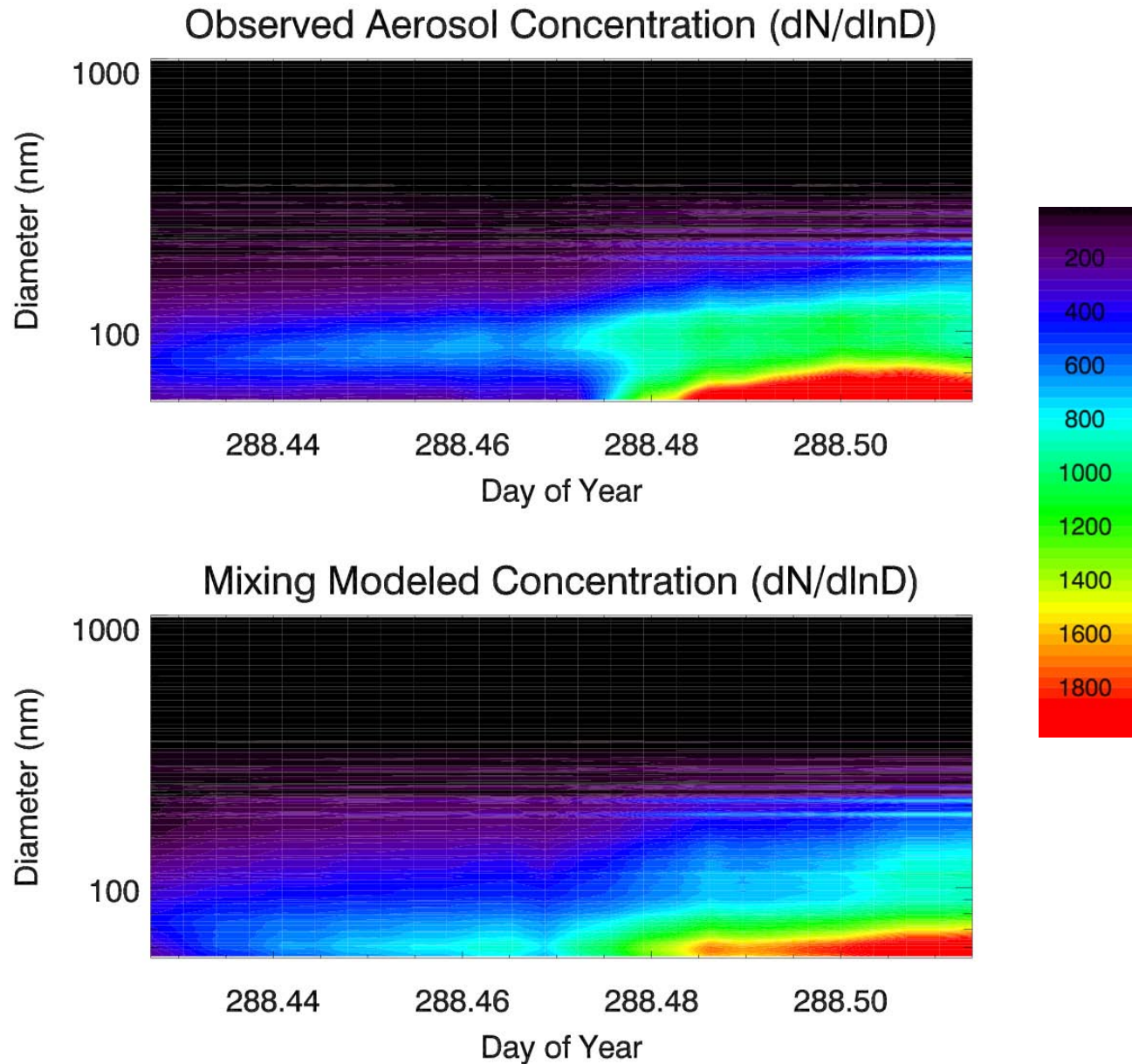
Water's isotopologues define mixing periods and can be combined with aerosol measurements to predict aerosol distribution changes due to air mass mixing and to back out the “true” particle source or sink (independent of mixing)

- Analyze additional mixing events + “stagnant” events
- Consider other aerosol sources such as upper troposphere

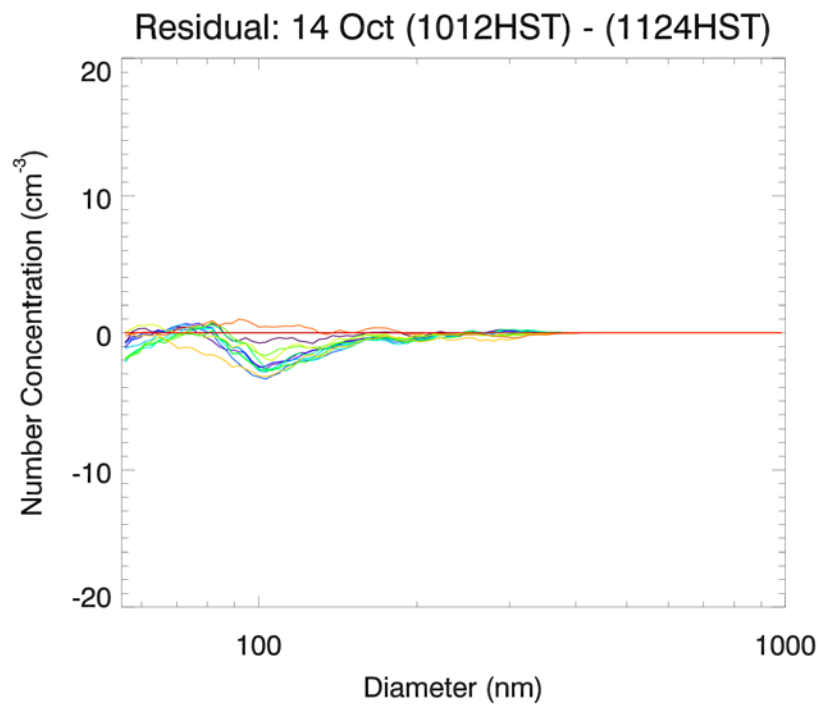
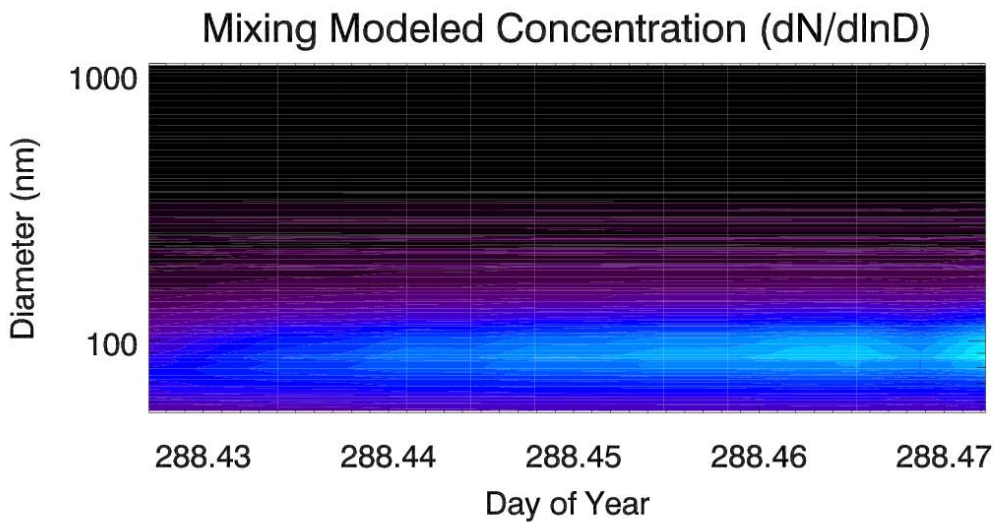
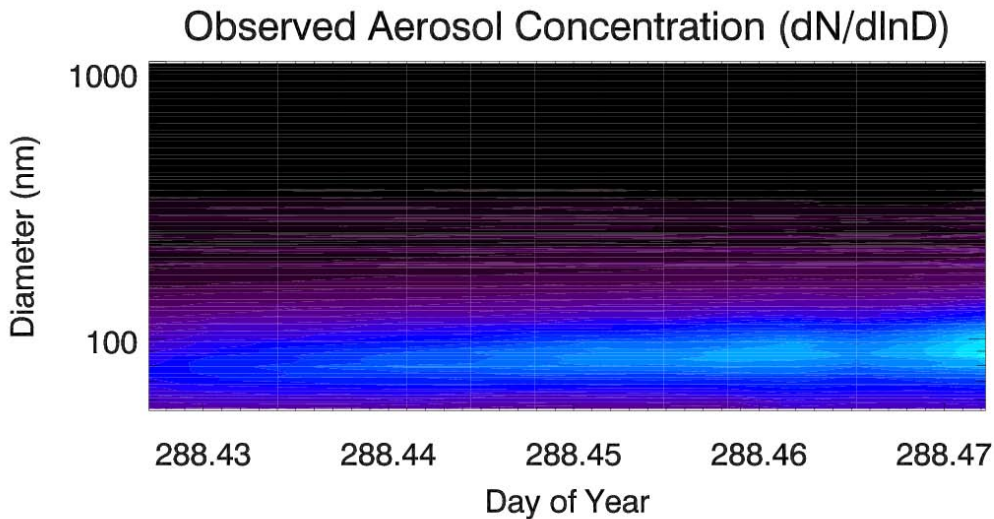
Snapshot: 14 Oct



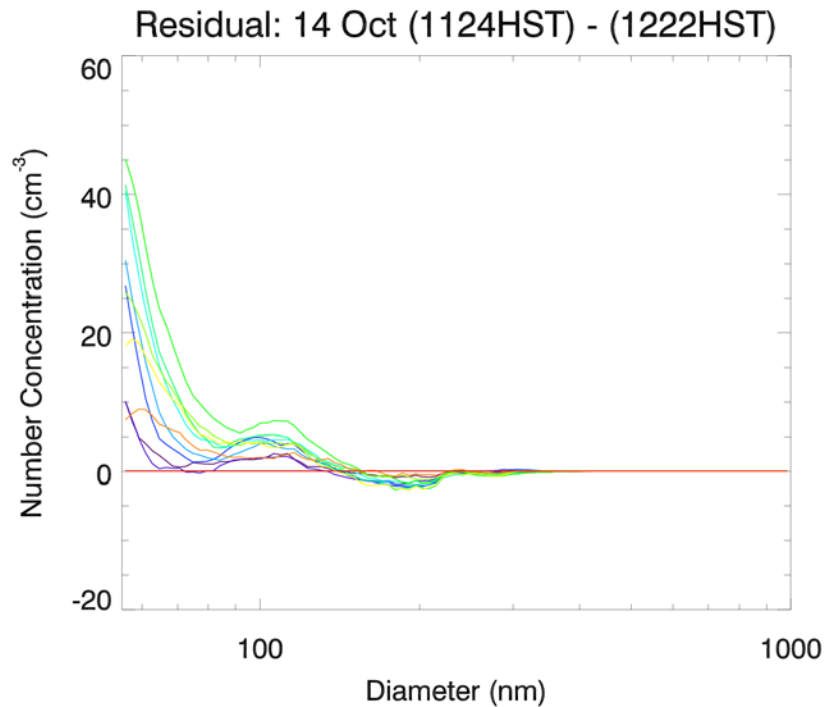
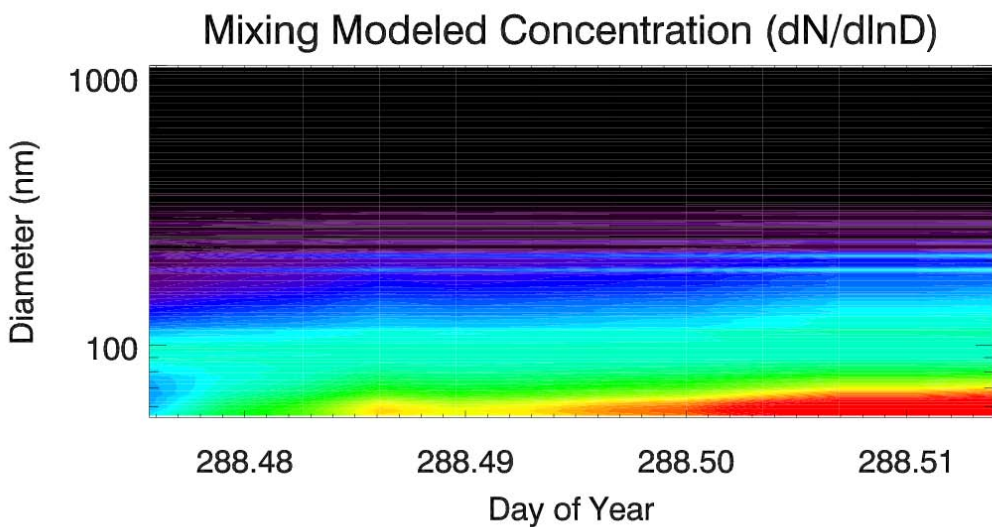
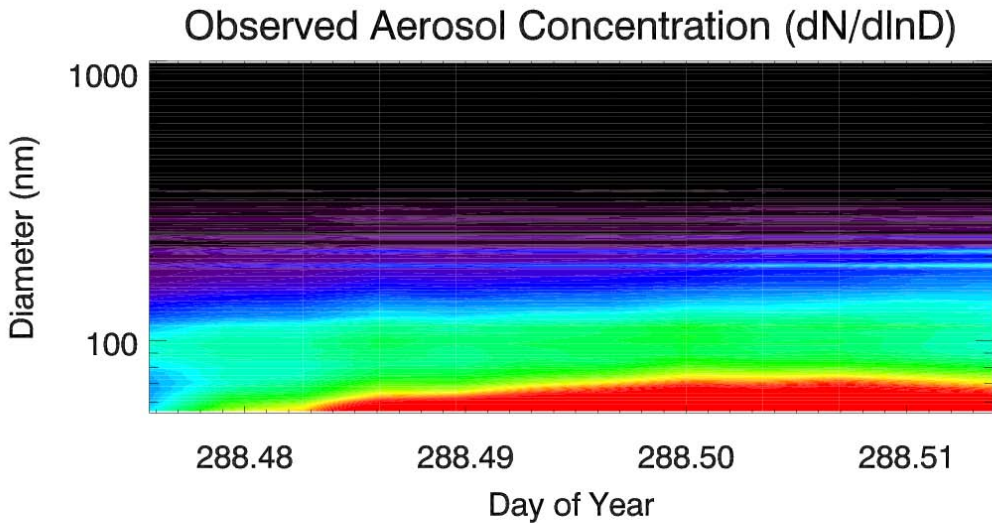
Is there chemistry occurring too?



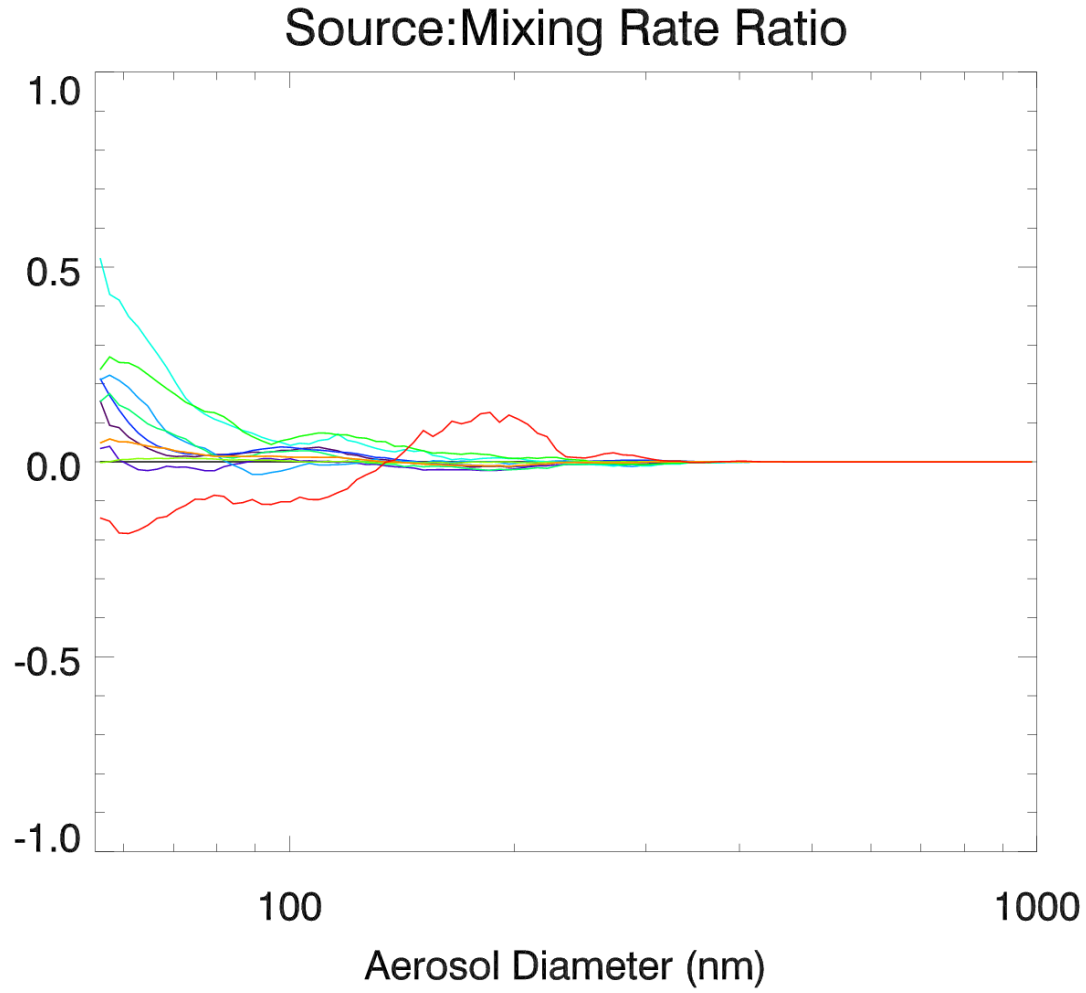
Mixing dominates earlier



Particle formation appears to occur later on

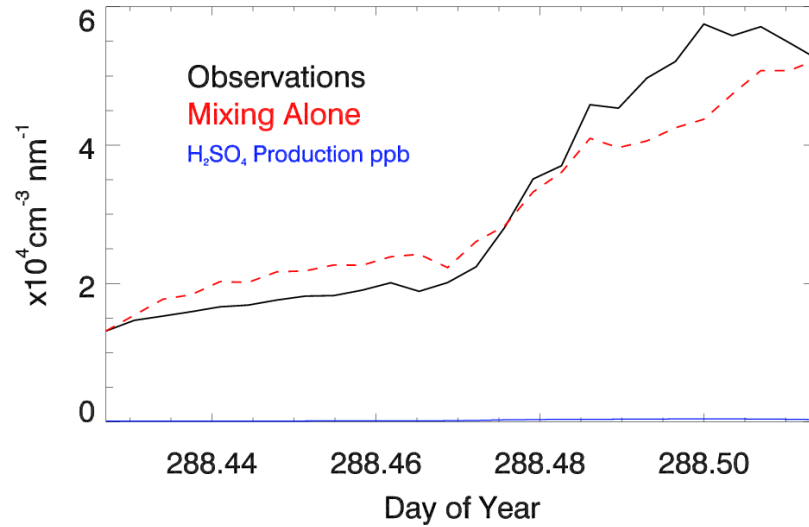


Calculated source important but smaller than expected?

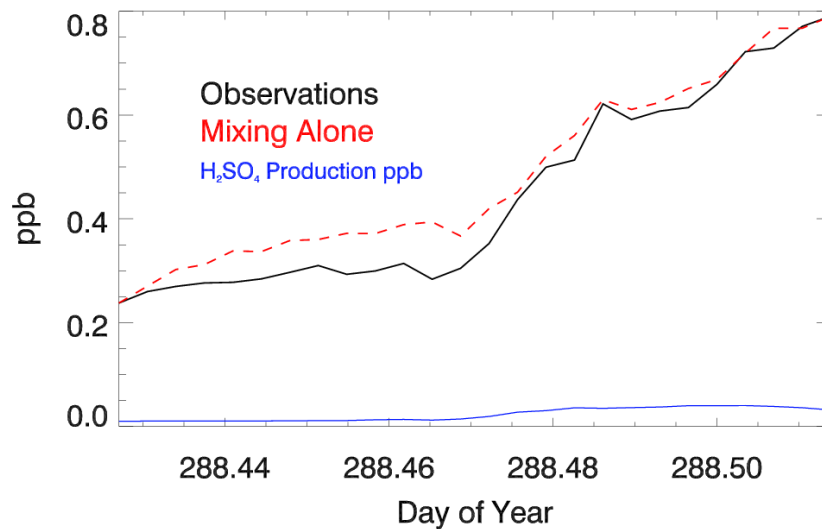


H₂SO₄ may be a plausible source

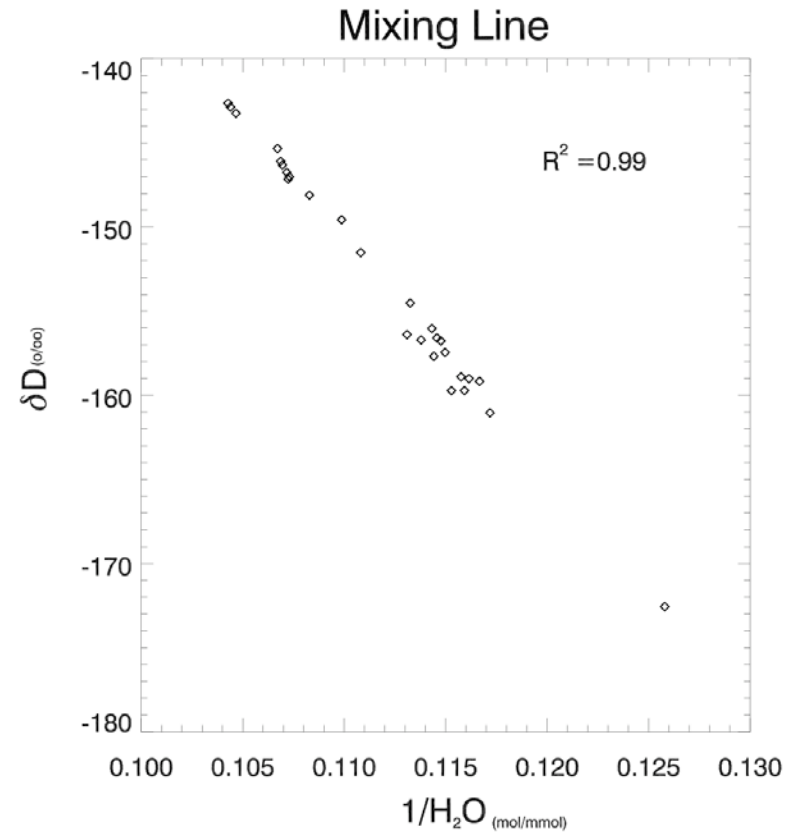
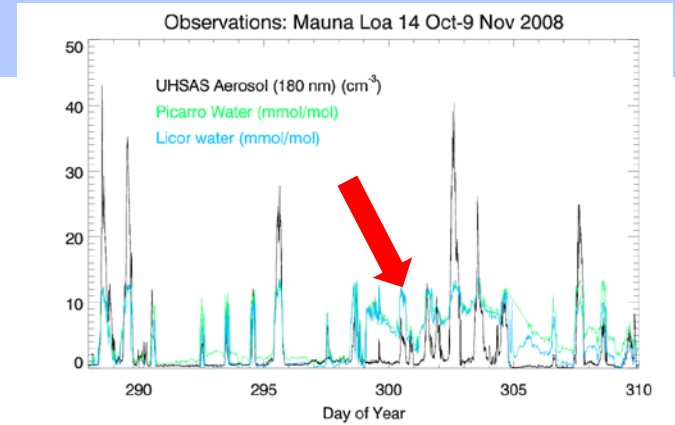
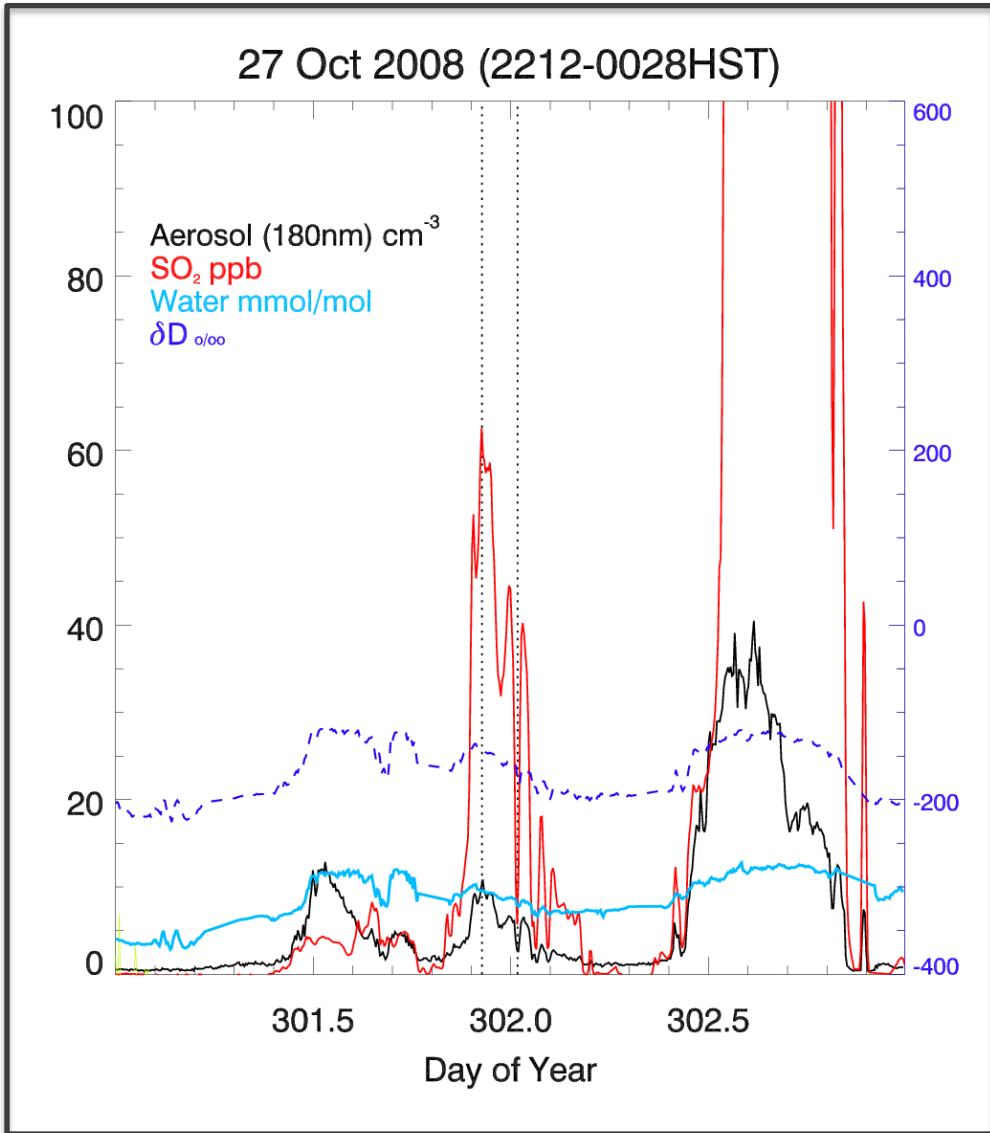
Total Number Concentration



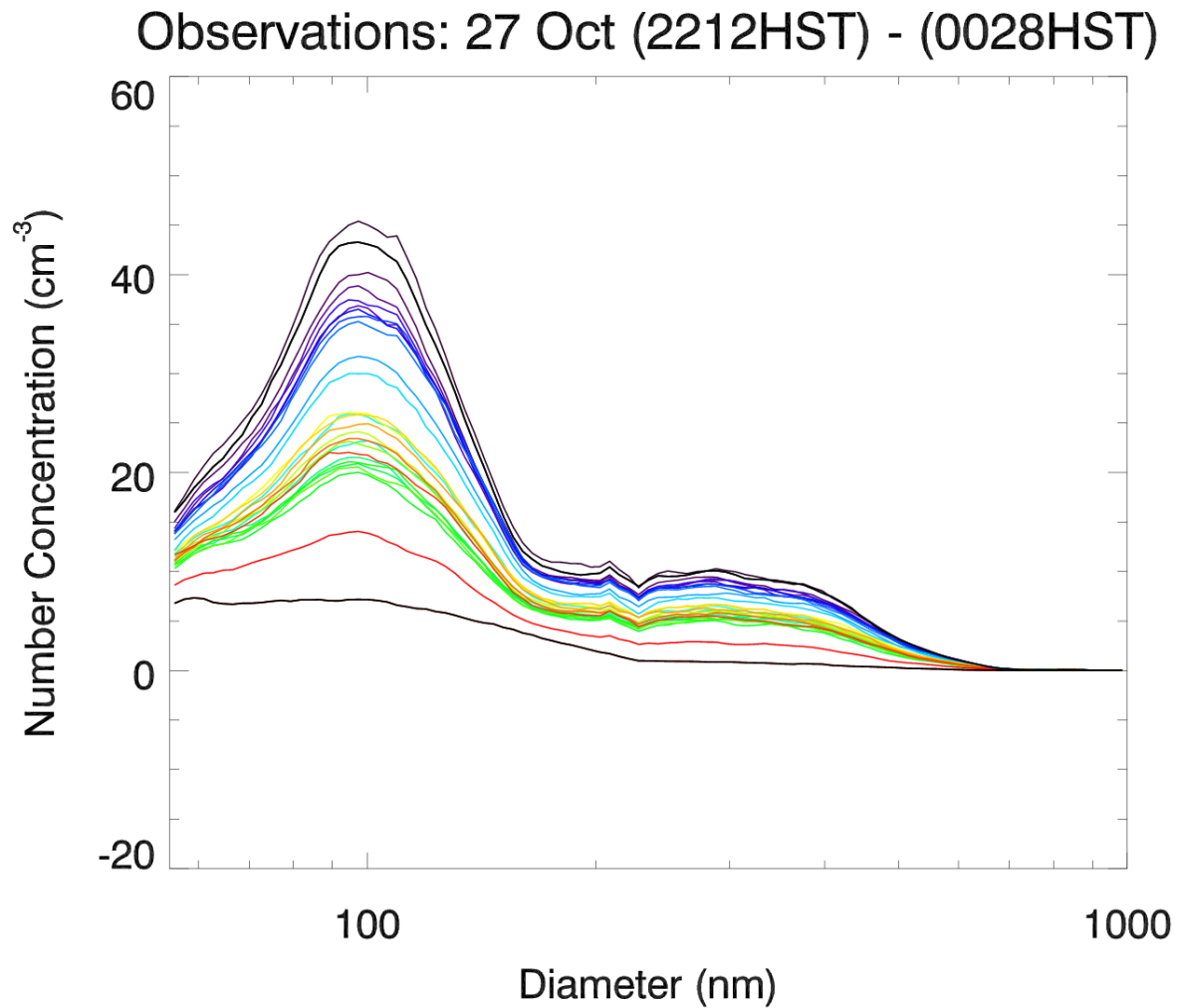
Mixing Ratio



Snapshot: 27 Oct (Night)

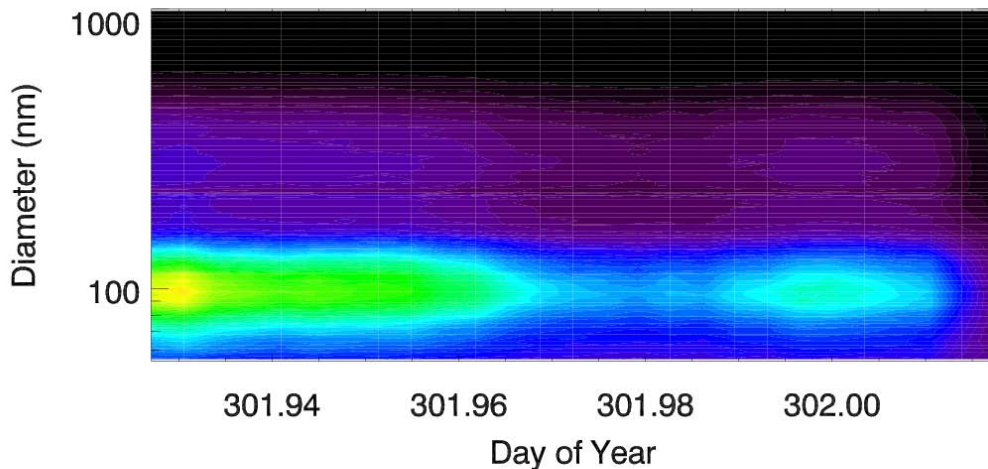


Aerosols do not monotonically decline

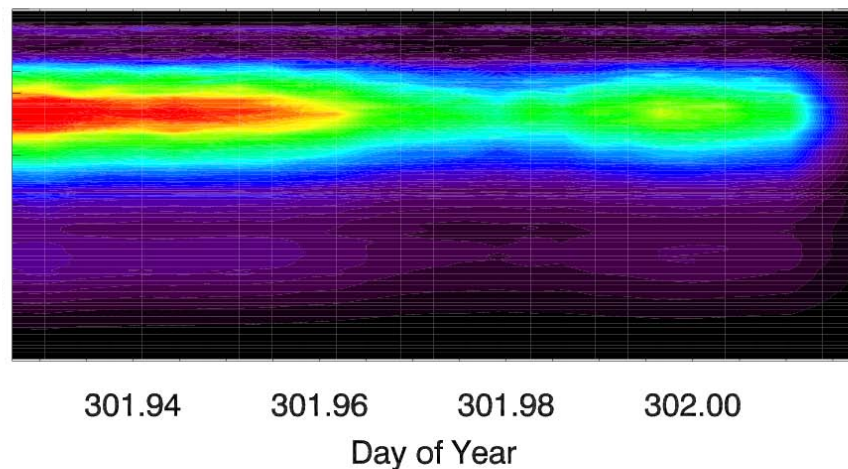


The mixing model still captures the aerosol change

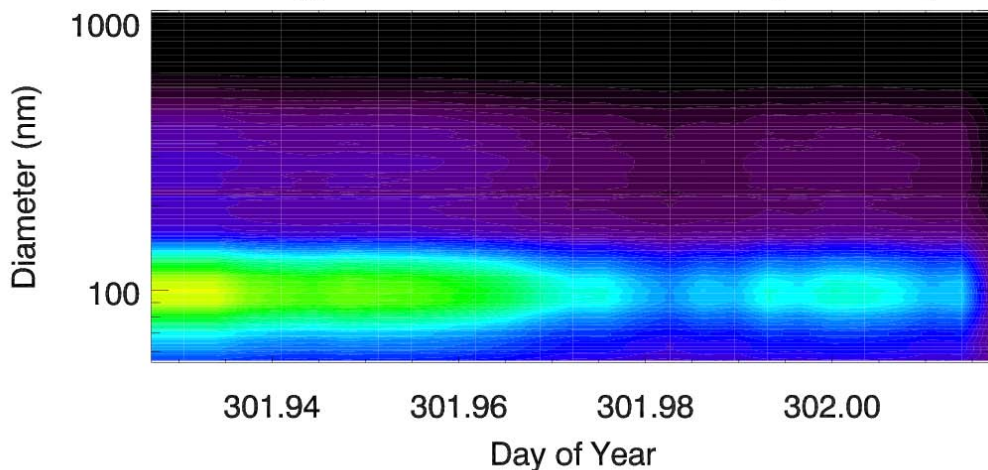
Observed Aerosol Concentration (dN/dlnD)



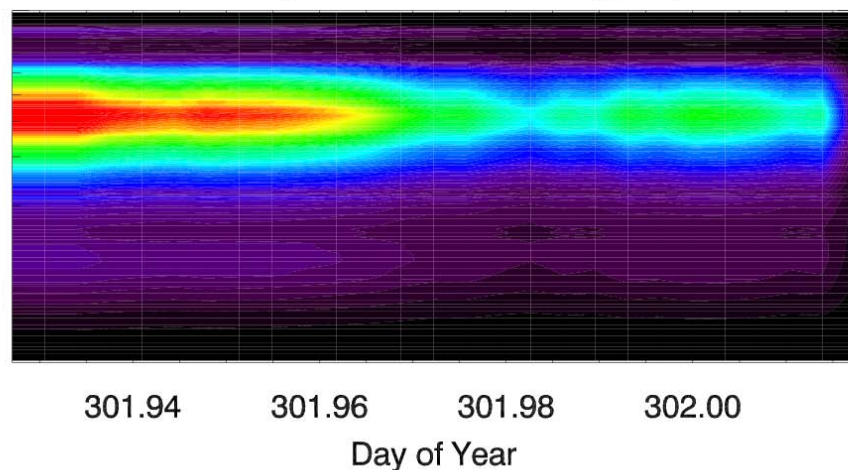
Observed Aerosol Mass (g/cc)



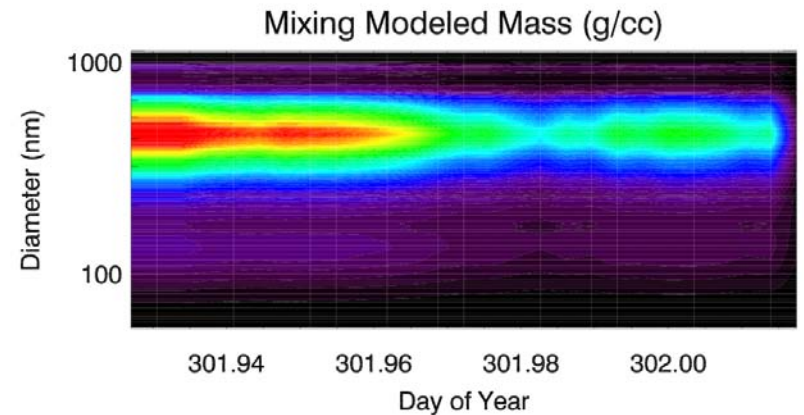
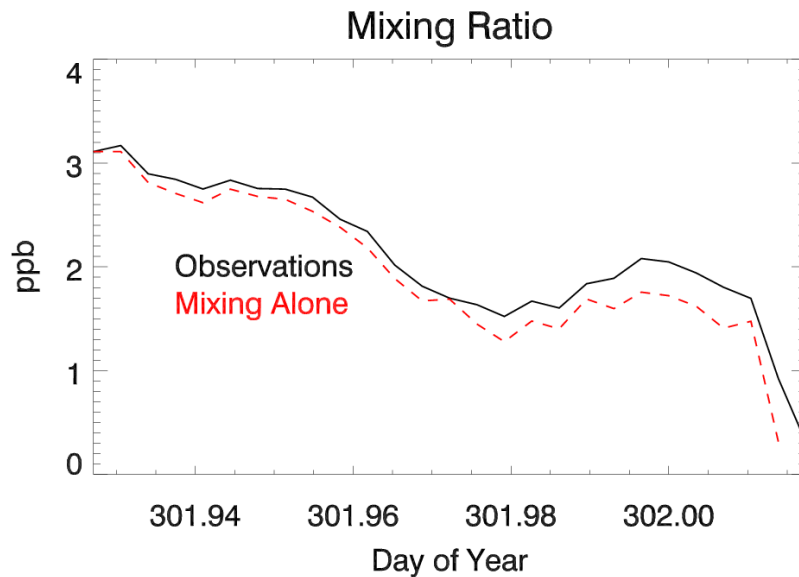
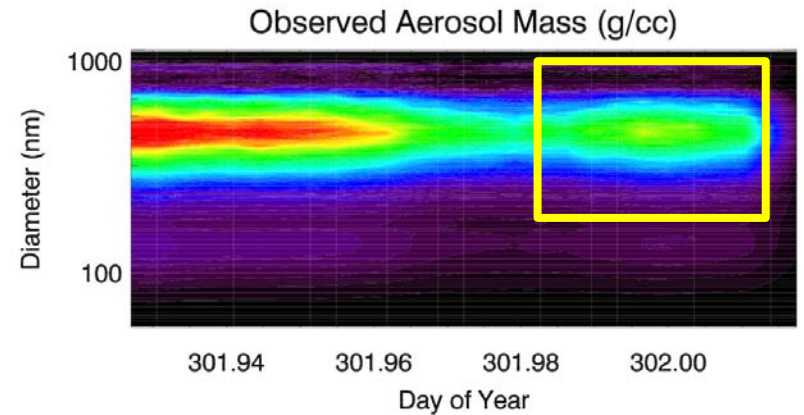
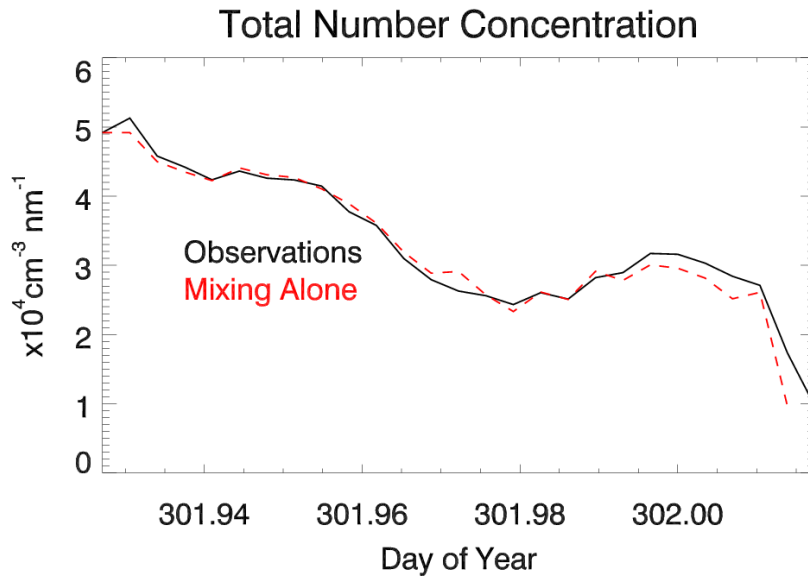
Mixing Modeled Concentration (dN/dlnD)



Mixing Modeled Mass (g/cc)



...and constrains the aerosol loss



Obs v. "mixing only" model

