Assimilated volcanic SO_2 as a source of stratospheric sulfate aerosol

Atmosphere Monitoring

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The CAMS service chain

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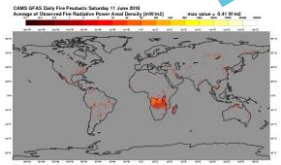
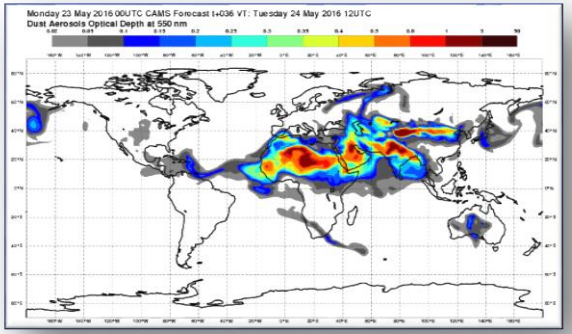
Observations

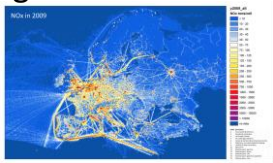


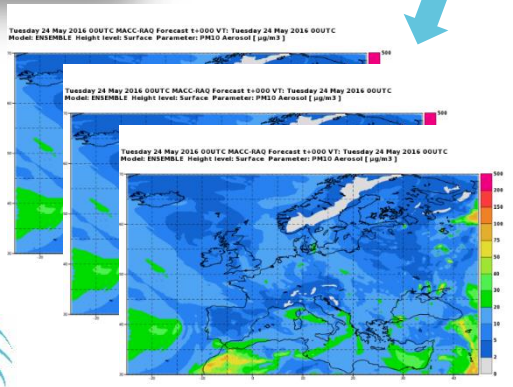
Fire emissions (GFAS)



Global (ECMWF IFS)

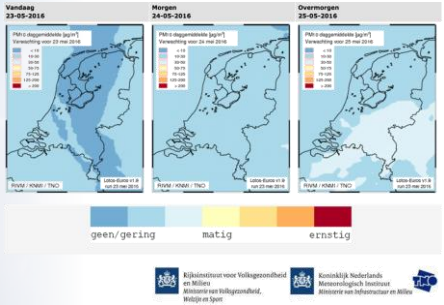
Anthropogenic emissions





Regional (multi-model ensemble)

National scale



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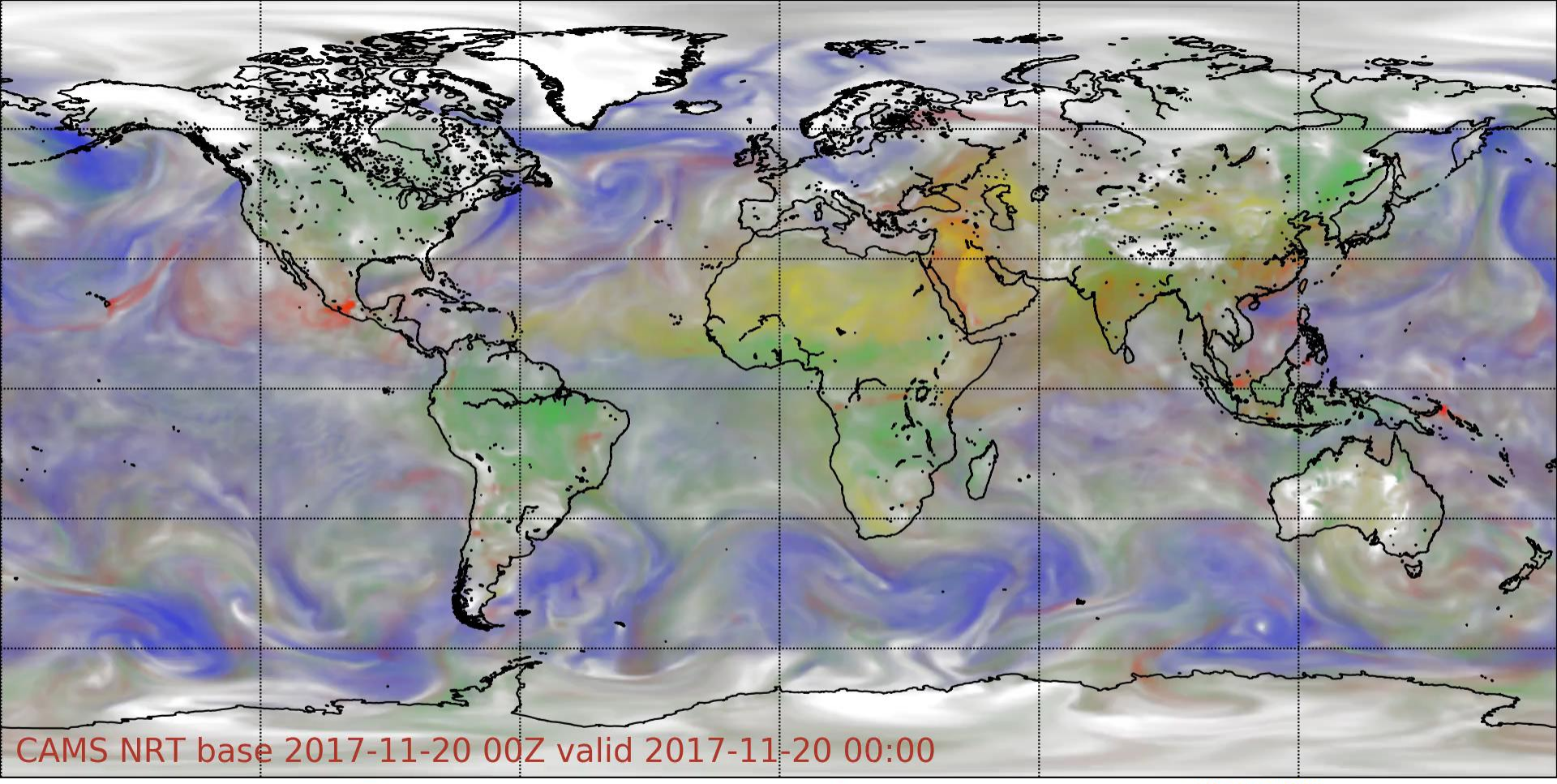

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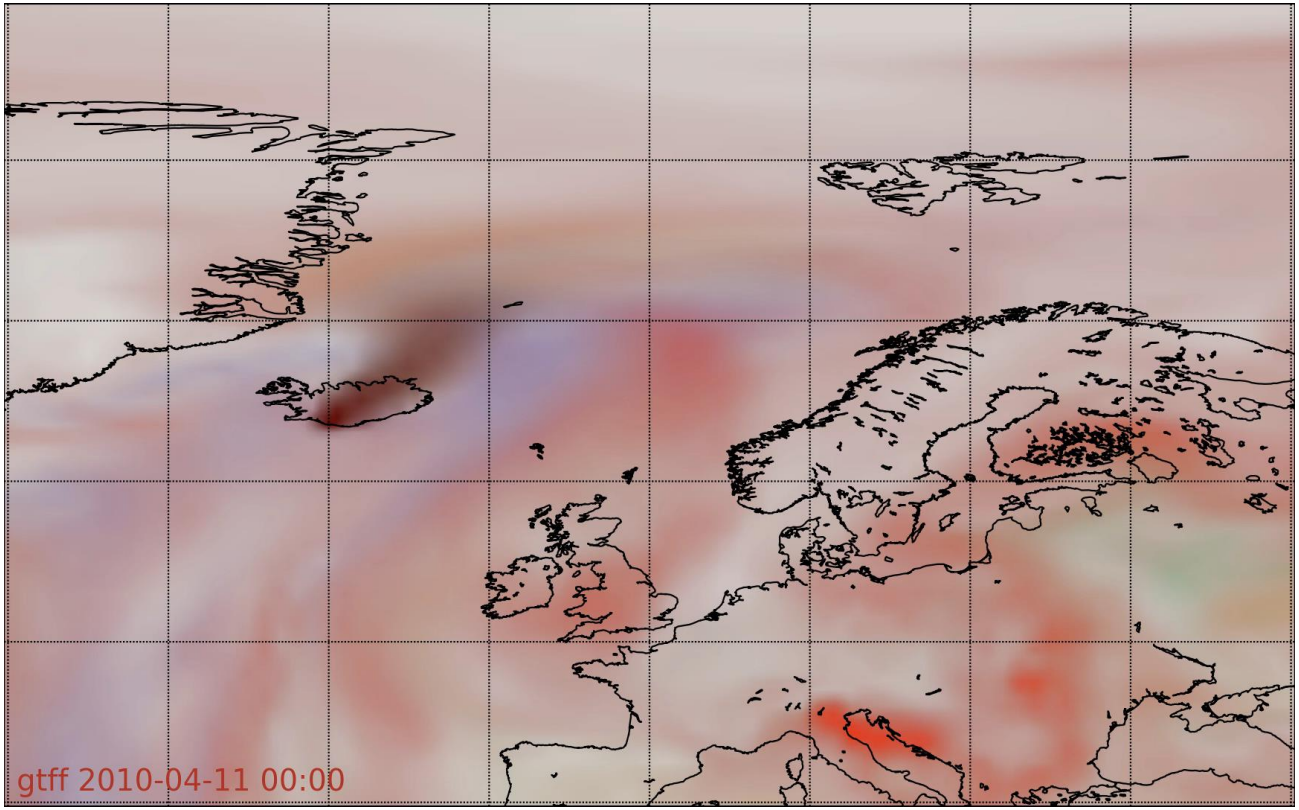
Custom forecast with emissions for Eyjafjallajökull (2010)



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Approaches to including volcanic aerosol

- Custom forecasts require timely knowledge of emissions (magnitude and injection height)
- AOD assimilation cannot distinguish species: if model misses a plume, increments go into those already present (e.g. sea-salt).
- AOD observations also give no vertical information.
- Other observations (e.g. thermal IR, lidar, polarimetry) could improve vertical resolution and/or speciation but require significant development effort before they can be assimilated.

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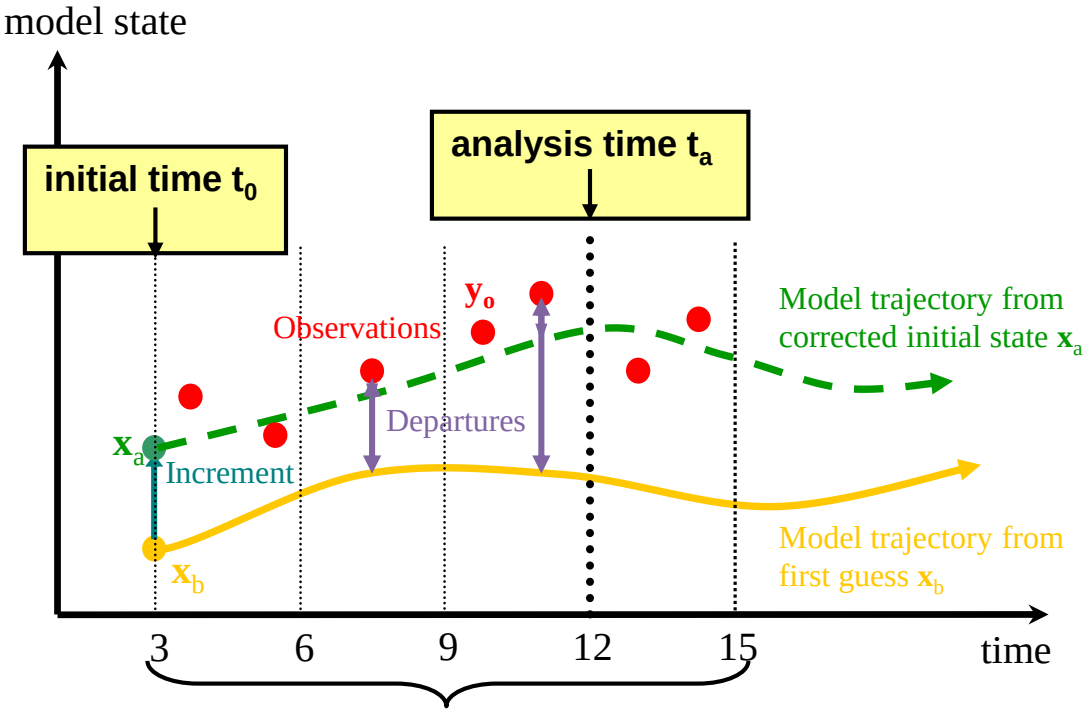
The chemistry route

- We do already assimilate the GOME-2 volcanic SO_2 product into our chemistry scheme.
- If this is coupled to the aerosol scheme, we gain an observation-driven source of volcanic sulfate aerosol via oxidation of this SO_2.
- This product is still not vertically resolved.

4-D Variational Data Assimilation ("4D-Var")



(based on figure from P. Lopez)

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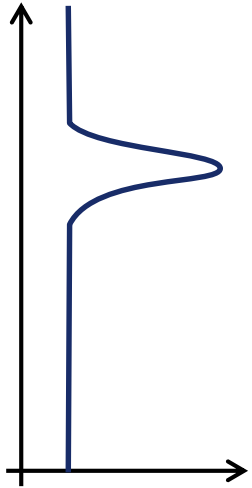
Specifying the model error covariance

- Error model based on differences between 24h and 48h forecasts (NMC method) of ***background*** SO_2 using horizontal wavelets

- Imposed vertical profile: increments go where the model error is artificially large to represent likely volcanic plume height



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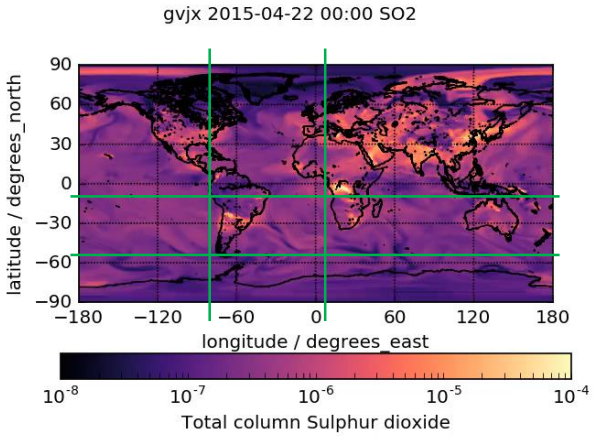
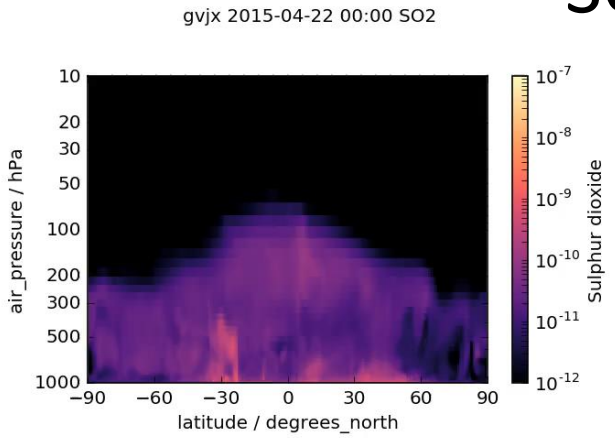
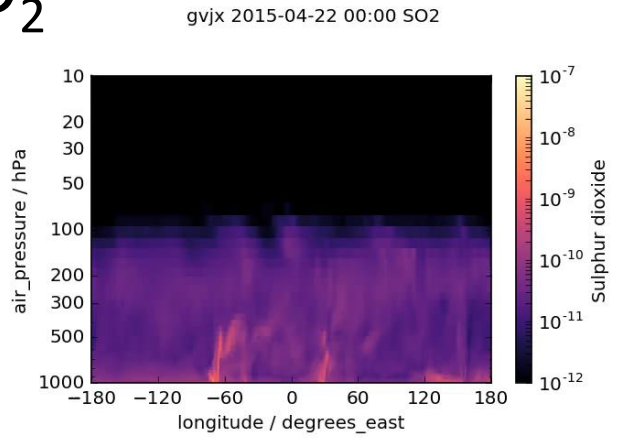
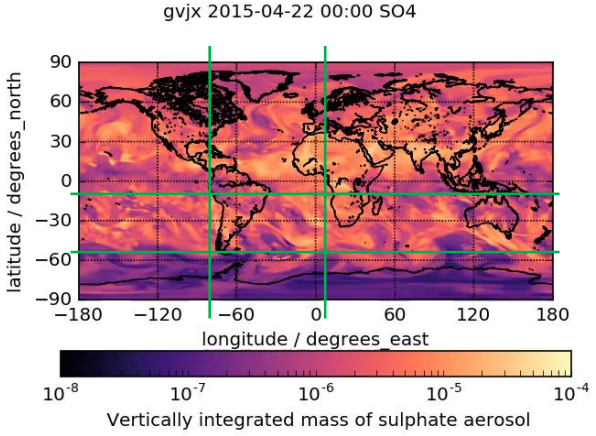
L60, peak ~100hPa (16.5km)

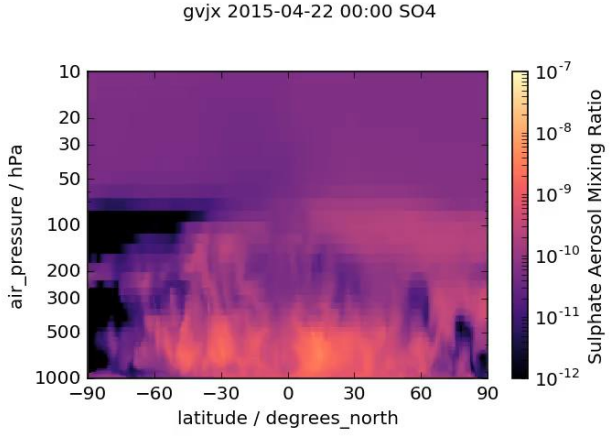
SO_2

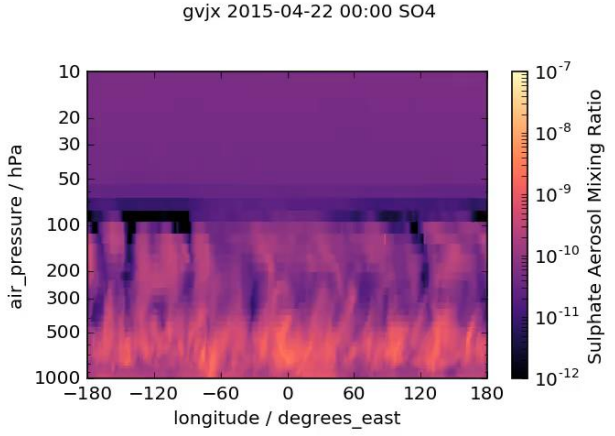












Sulfate

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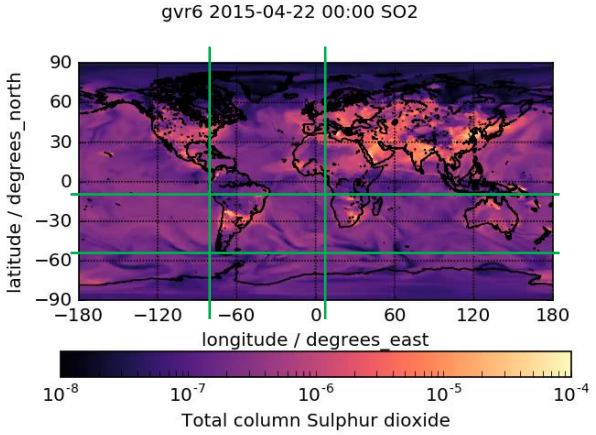
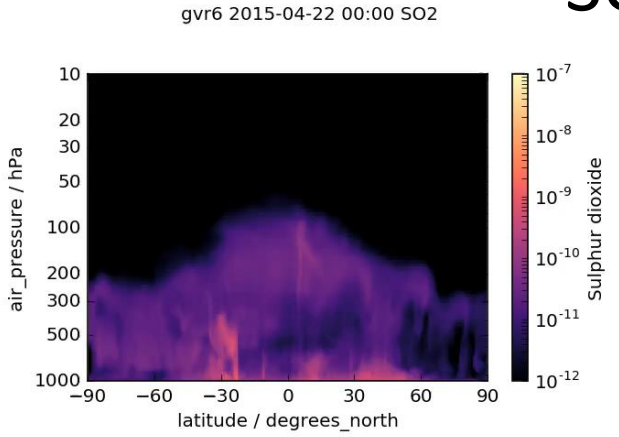
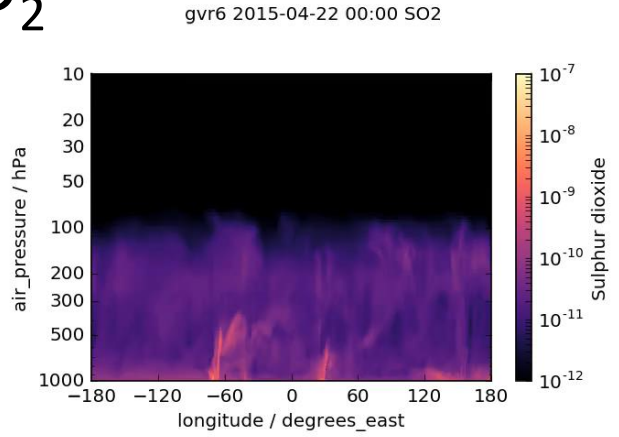
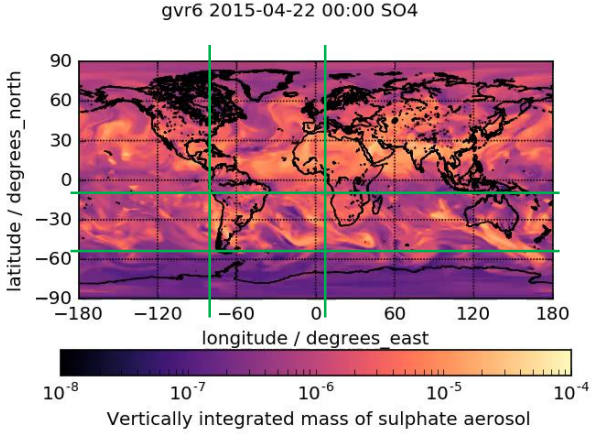
L137, peak ~100hPa (16.5km)

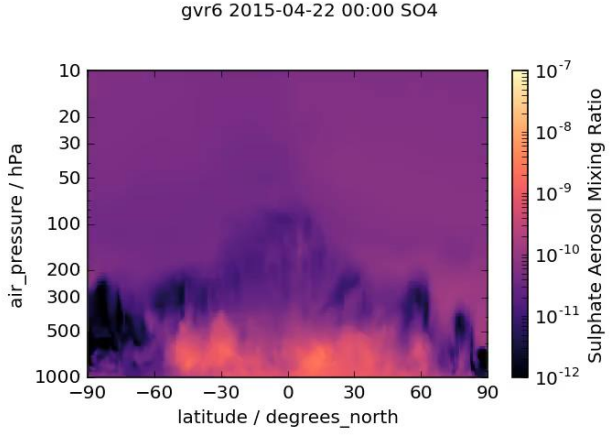
SO_2

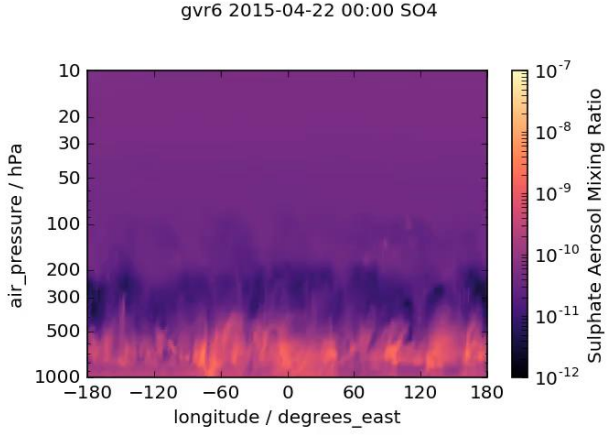












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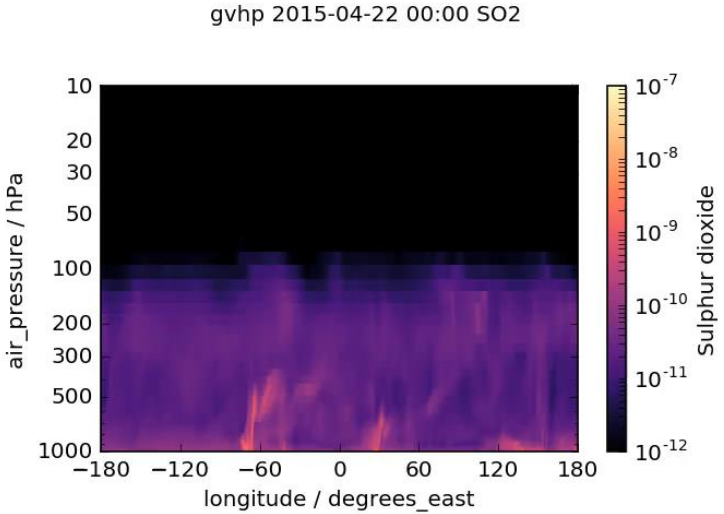
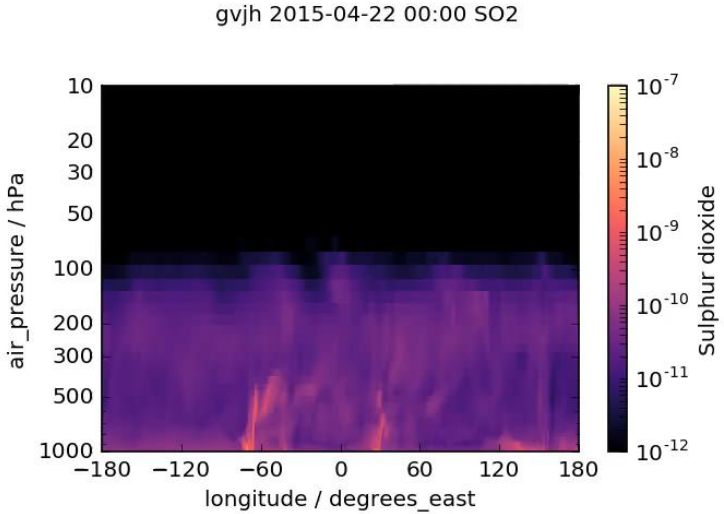
L60 SO_2

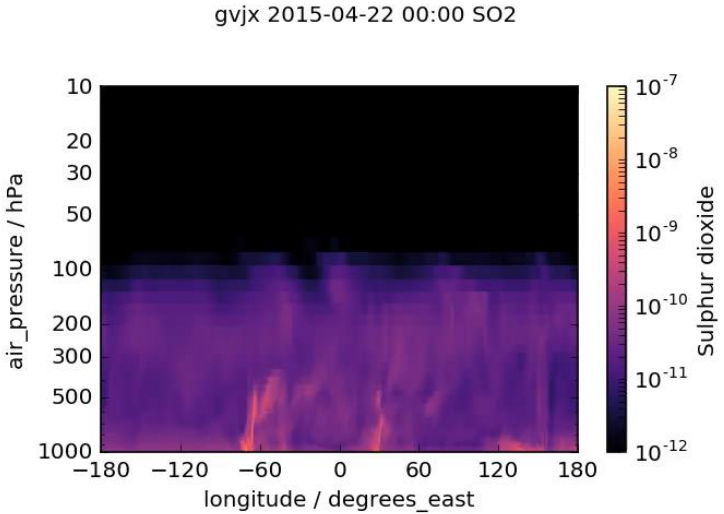
no SO_2 assimilated

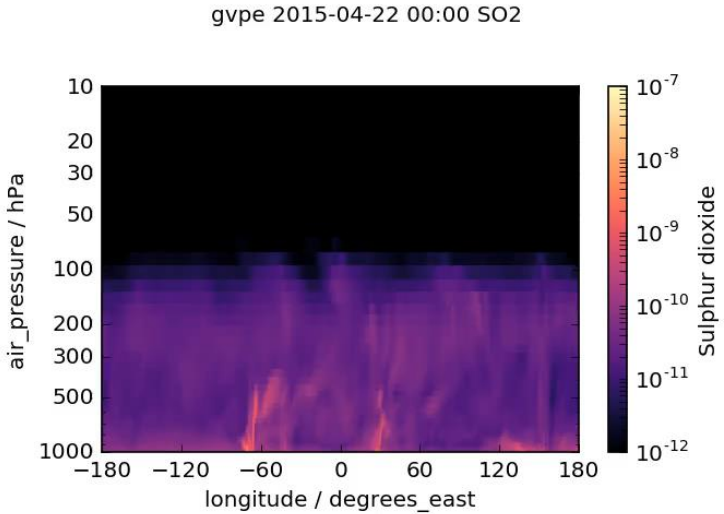




peak ~250hPa (10km)

peak ~100hPa (16.5km)

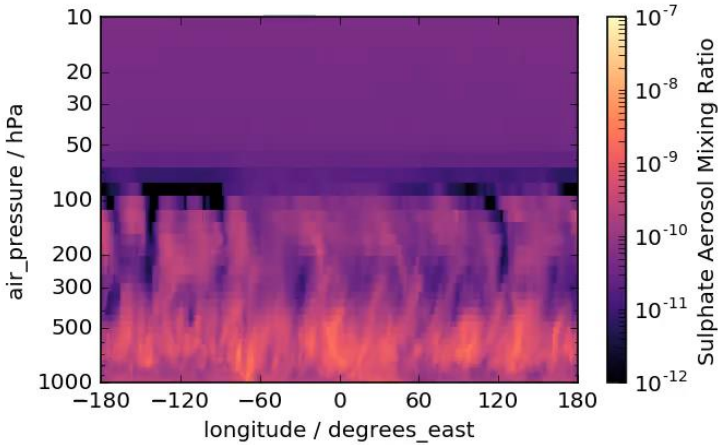


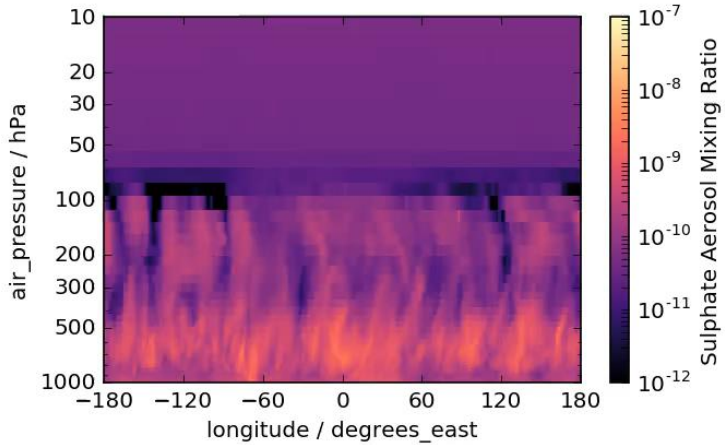


peak ~50hPa (20km)

L60 sulfate

no SO_2 assimilated





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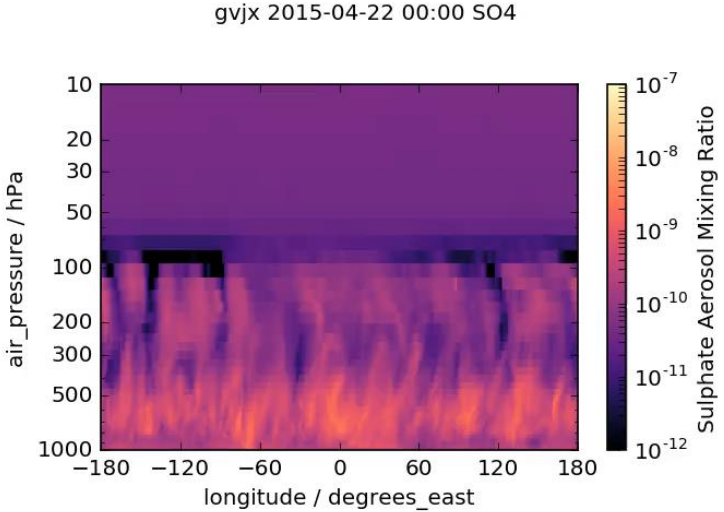

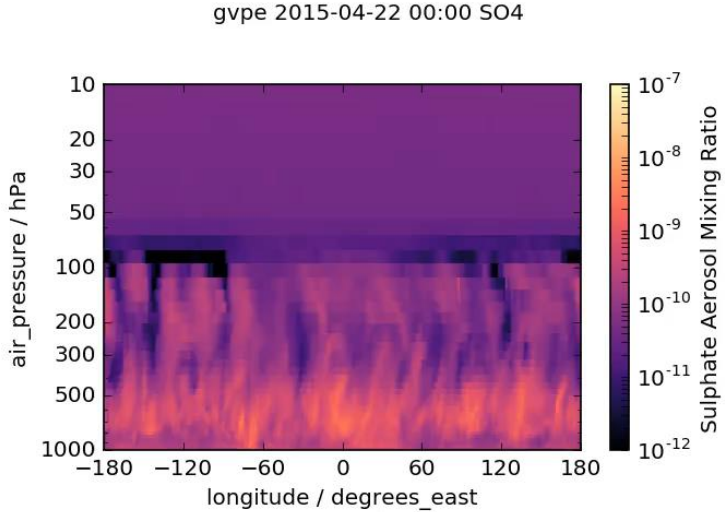

peak ~50hPa (20km)

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Outstanding issues

- This only provides volcanic sulfate, not ash.
- Can we get information on the SO2 plume height from the assimilated observations?
- Is there a better way to produce an appropriate error covariance?
- How much do the “ripples” due to the wavelet formulation matter, and can we filter them out somehow?
- What is the best way to combine this with other observations (visible AOD, IR ash retrievals, lidar etc.) to extract maximum information?

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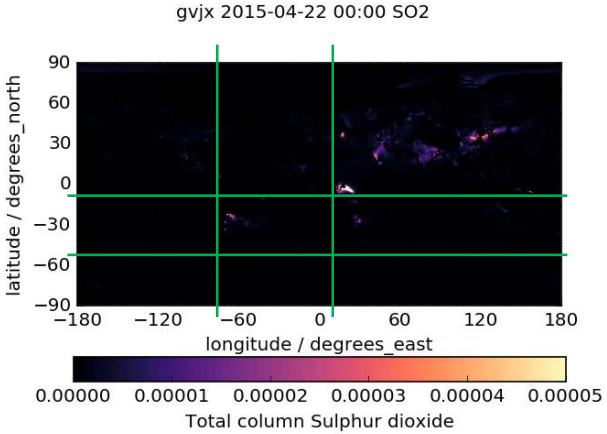
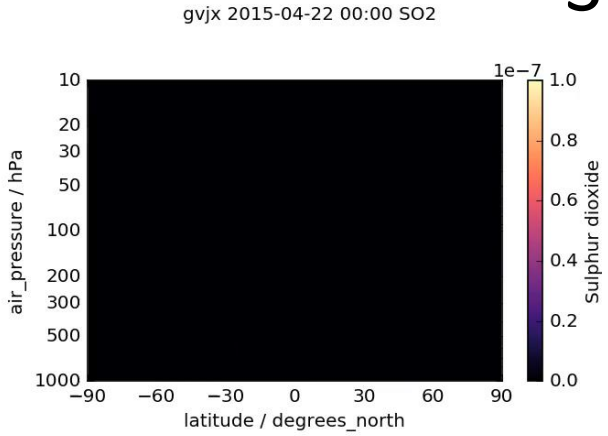
Conclusions

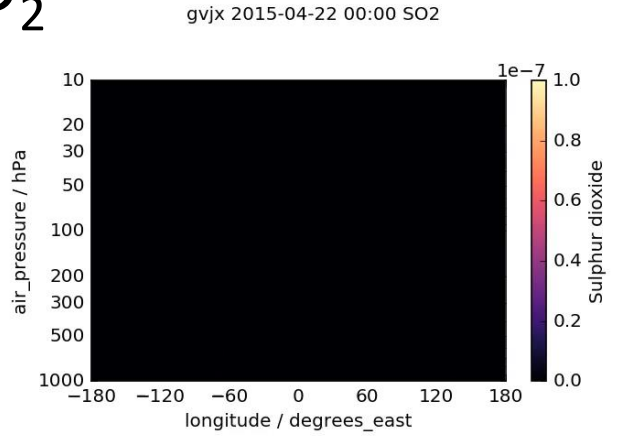
- AOD assimilation can’t properly identify volcanic sulfate plumes.
- SO2 assimilation can drive sulfate production in the right place without prescribed emissions.
- Lack of vertical information requires a priori choice of likely plume height.
- Despite limitations, this approach can successfully produce volcanic sulfate layers in the troposphere and stratosphere.
- Further evaluation against observations and tuning of assimilation and oxidation parameters likely to be beneficial.

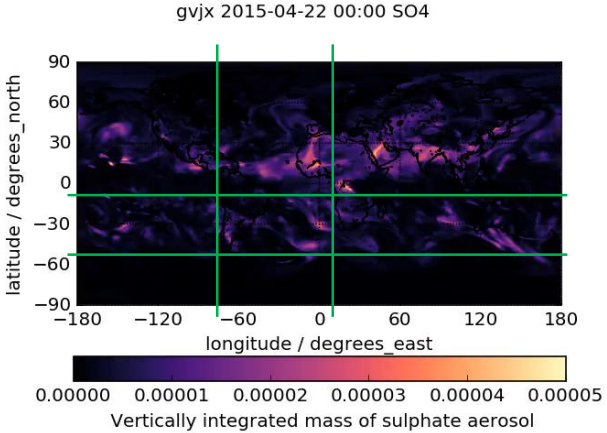
L60, peak ~100hPa (16.5km)

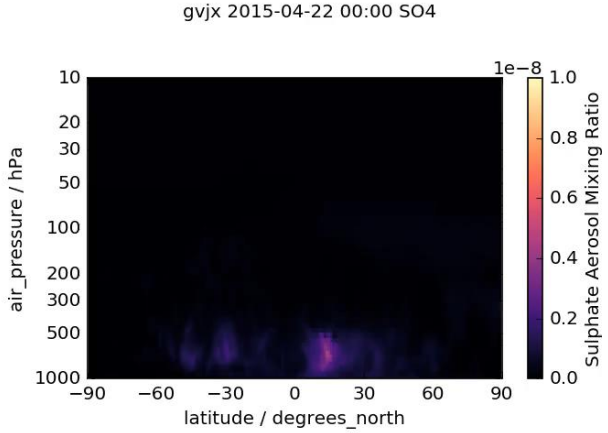
SO_2

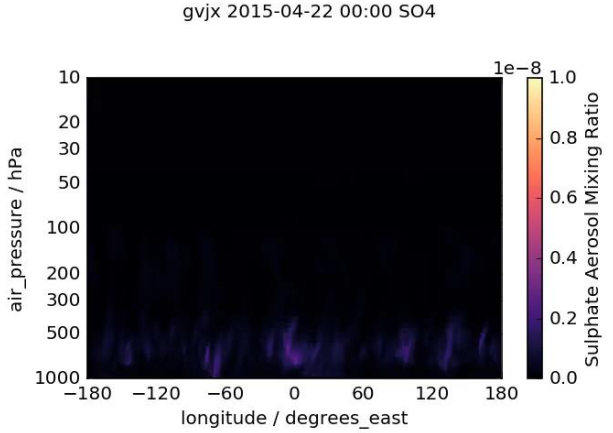












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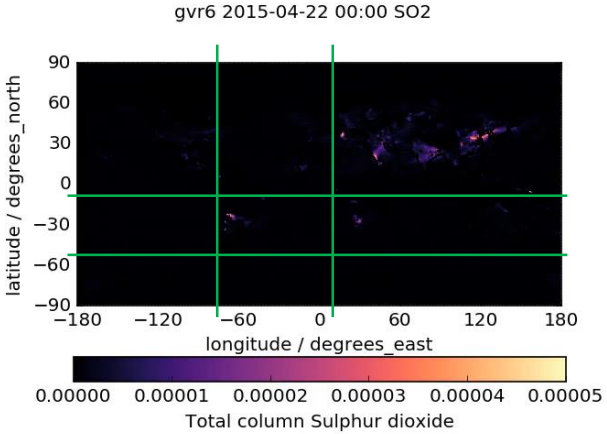

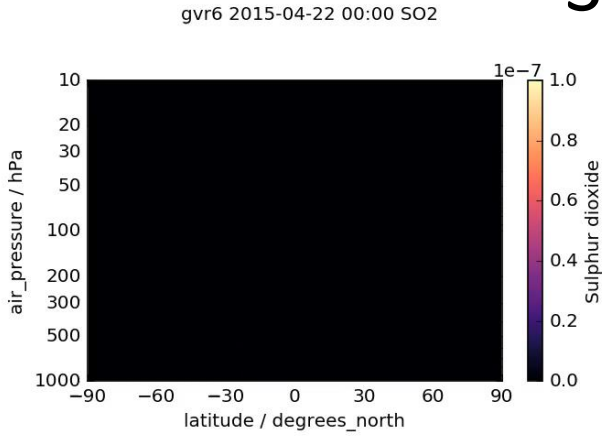

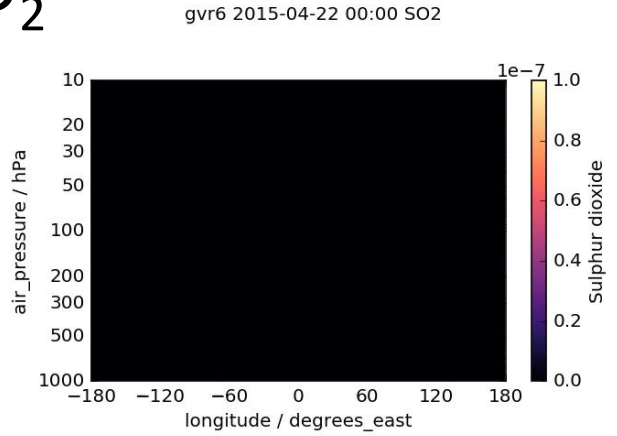

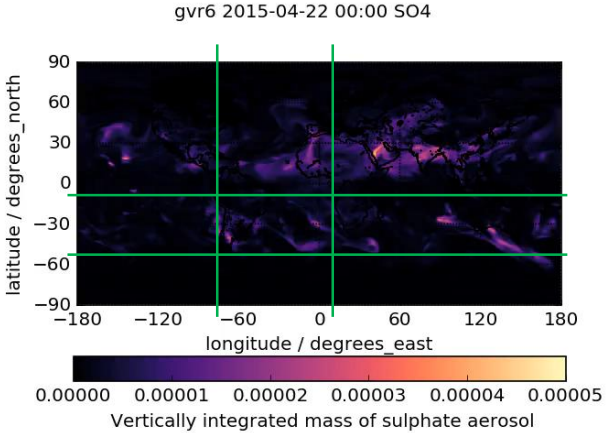

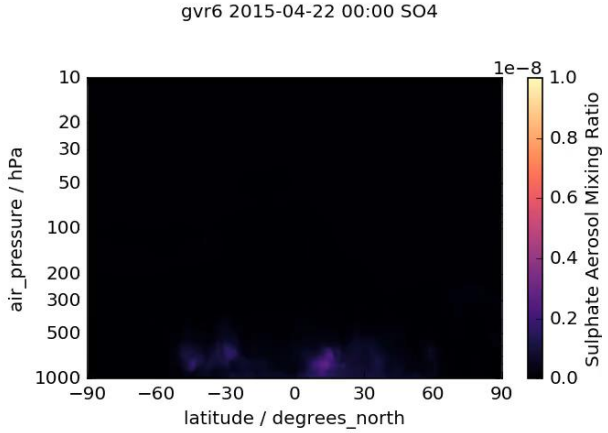

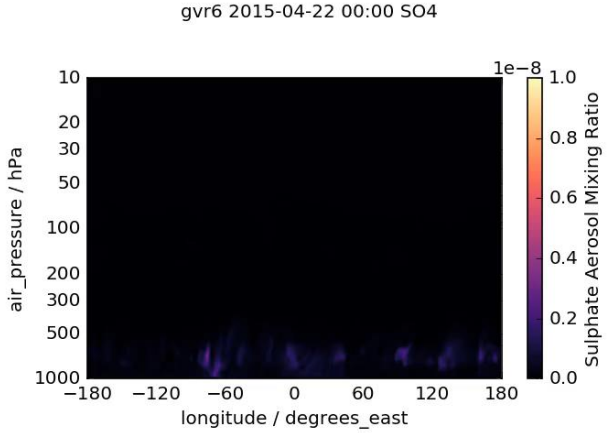

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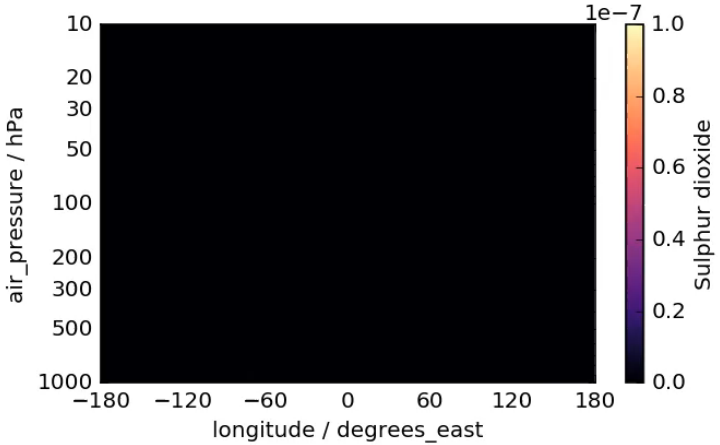
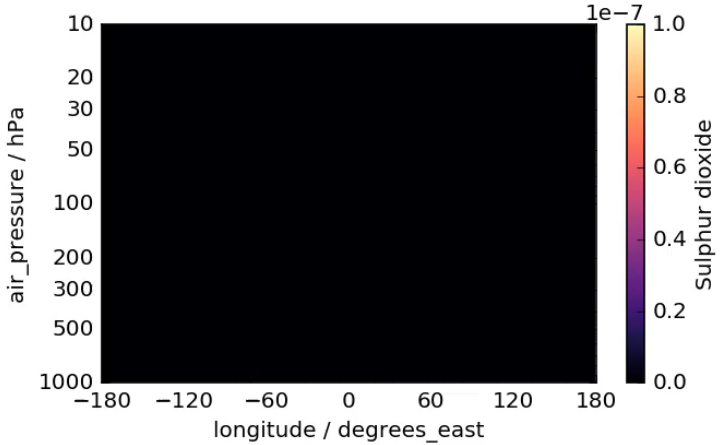
L60 SO_2

no SO_2 assimilated





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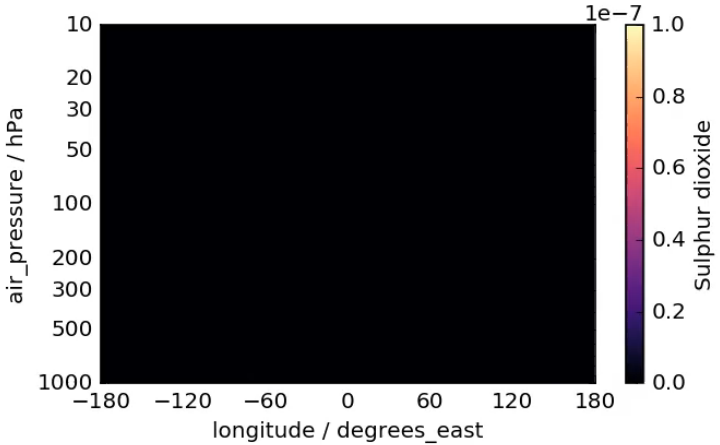

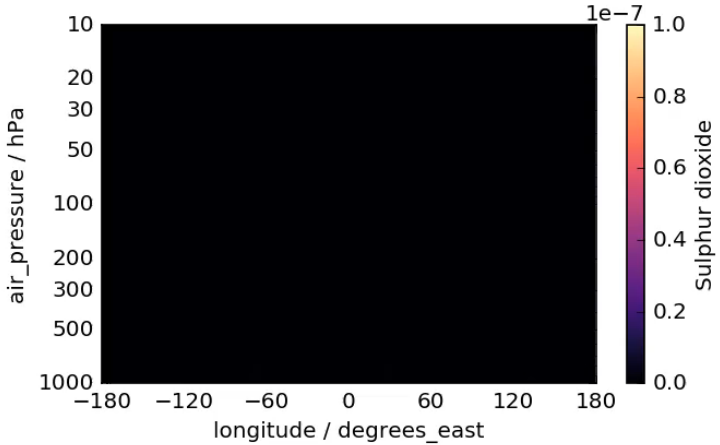

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L60 sulfate

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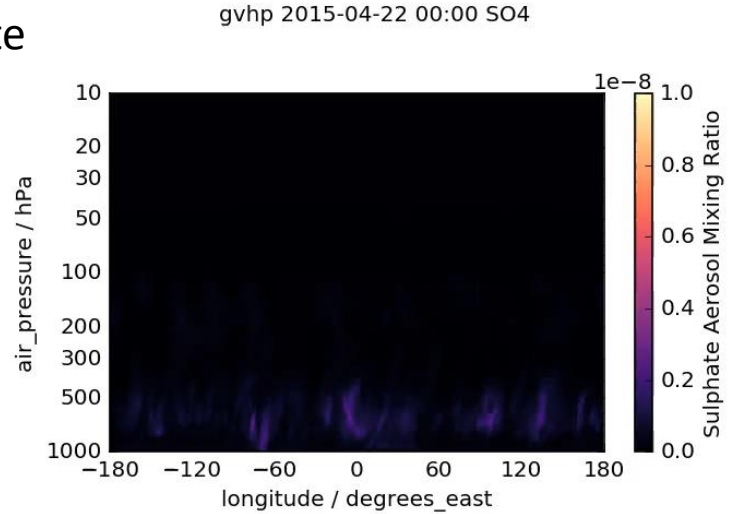

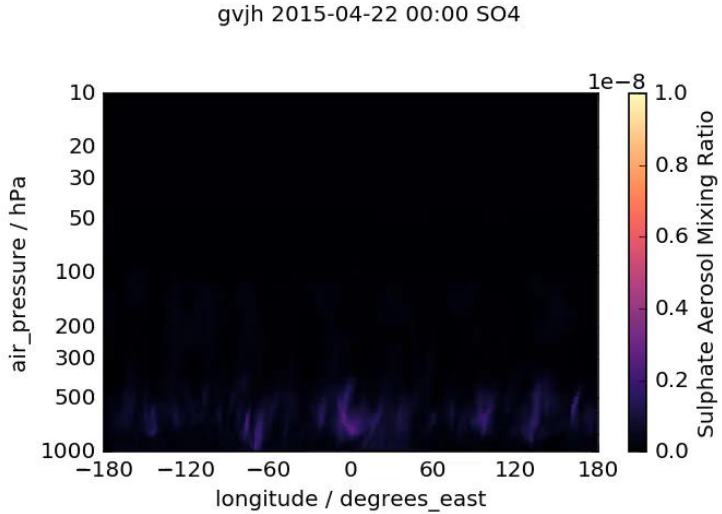

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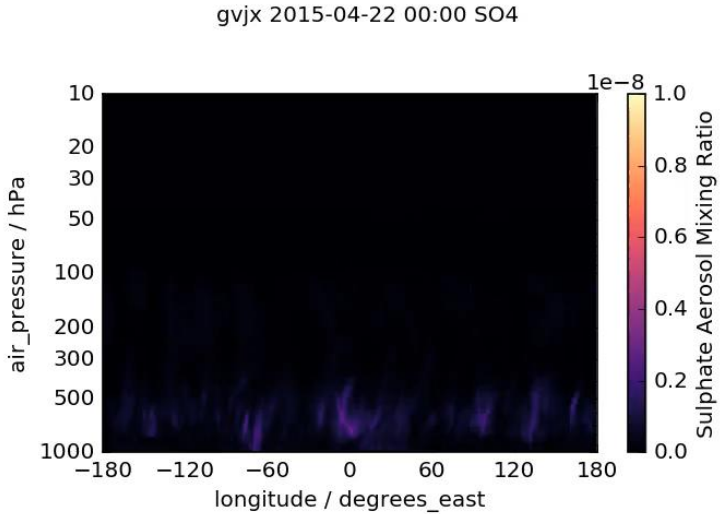

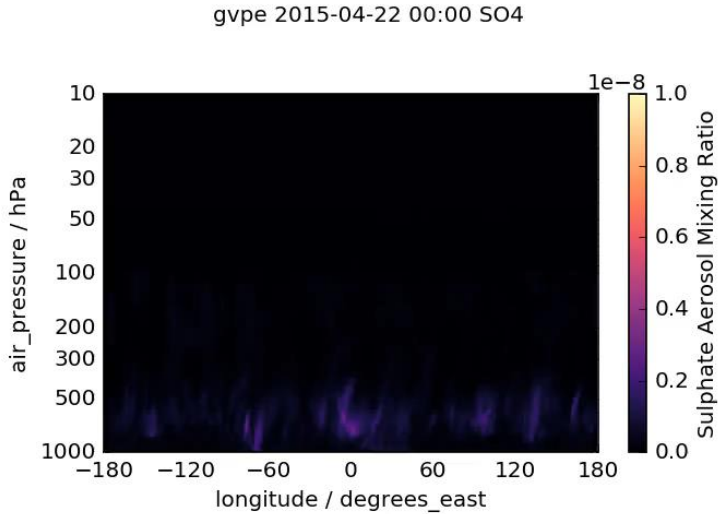

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