Two big controls on atmospheric oxidative capacity: Soil NO_x emissions and deforestation

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UNIVERSITY of WASHINGTON

Motivation:
Identify observable trends resulting from deforestation

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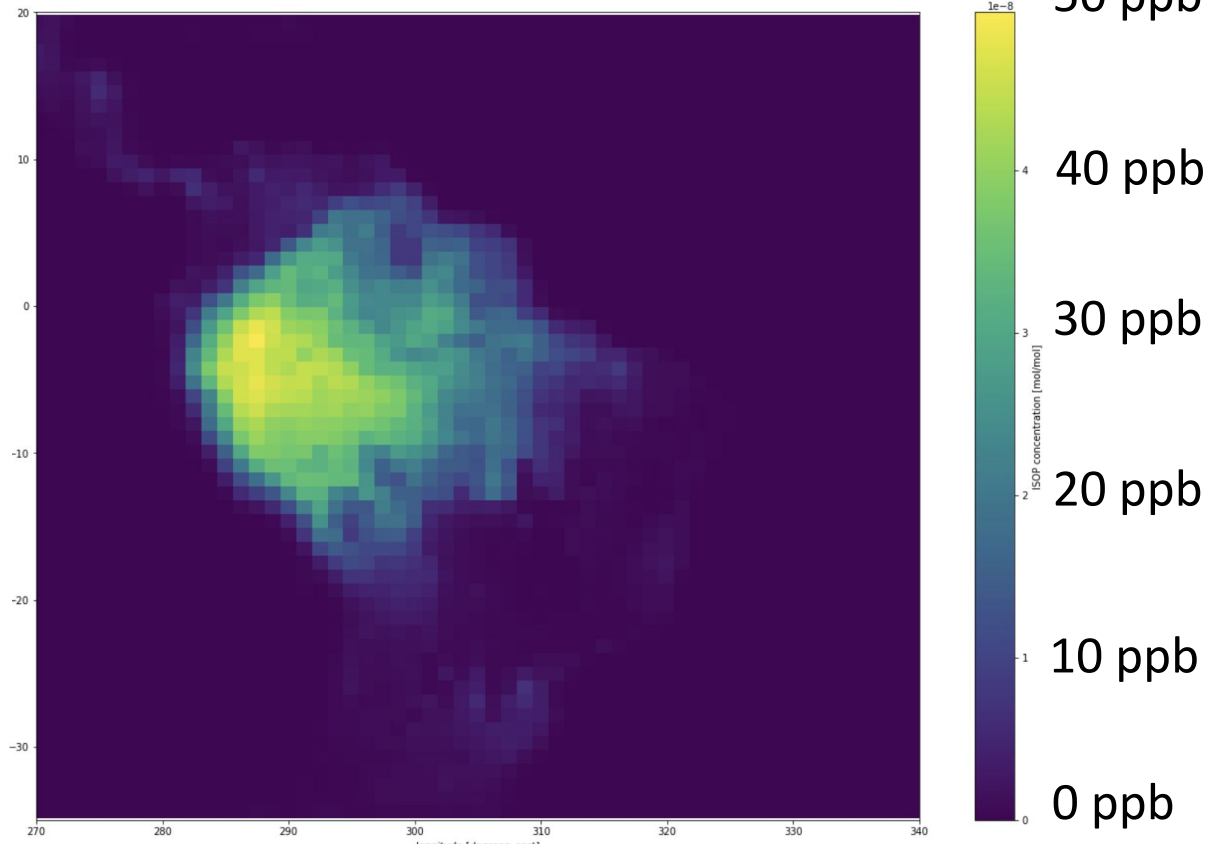
Can regional perturbations affect global atmospheric chemistry?

Model configuration:

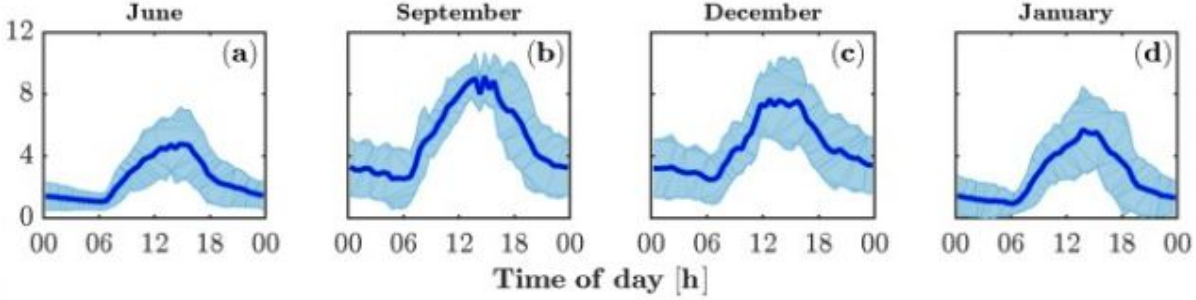
- CAM6-CHEM
- Land in BGC mode with fires
- Prescribed SST
- Historical transient simulation from 1970 to 2015
- Compset: FCfireHIST

Atmospheric isoprene



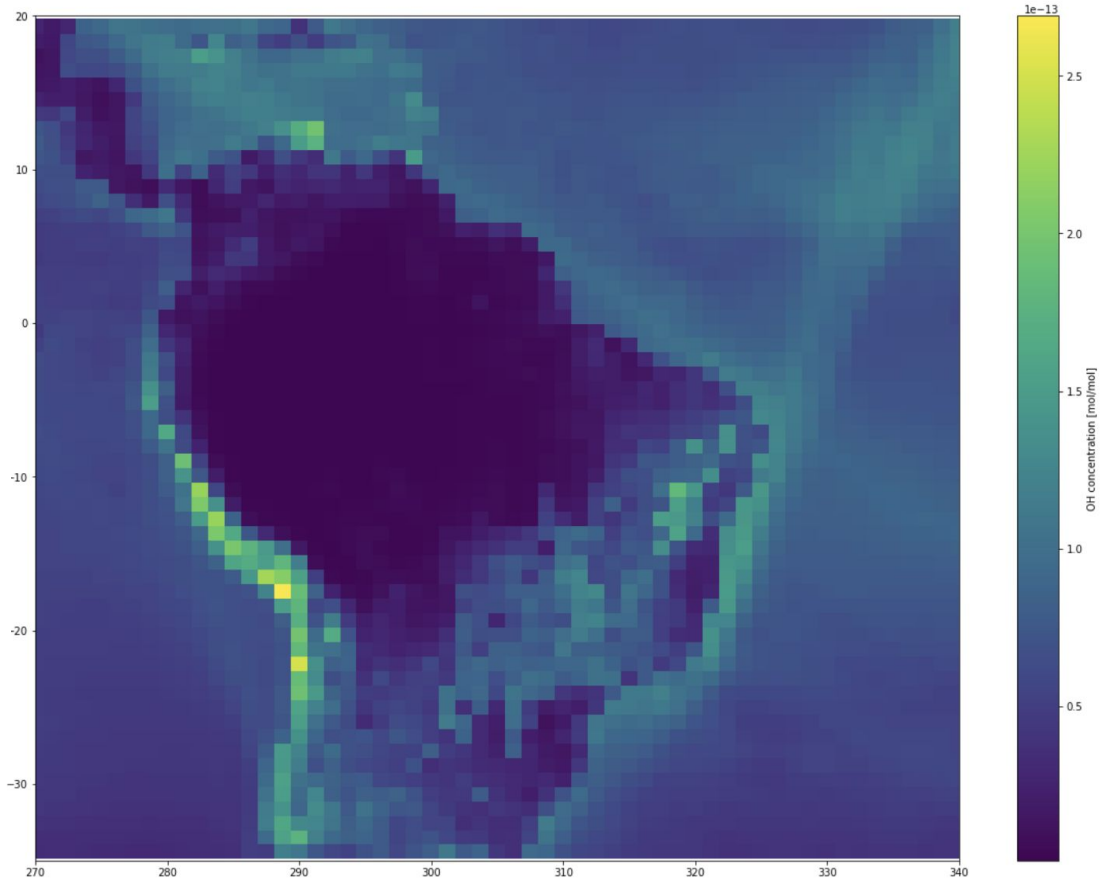
- Surface isoprene too high

GOAmazon 2014/15: **isoprene** (ppb)



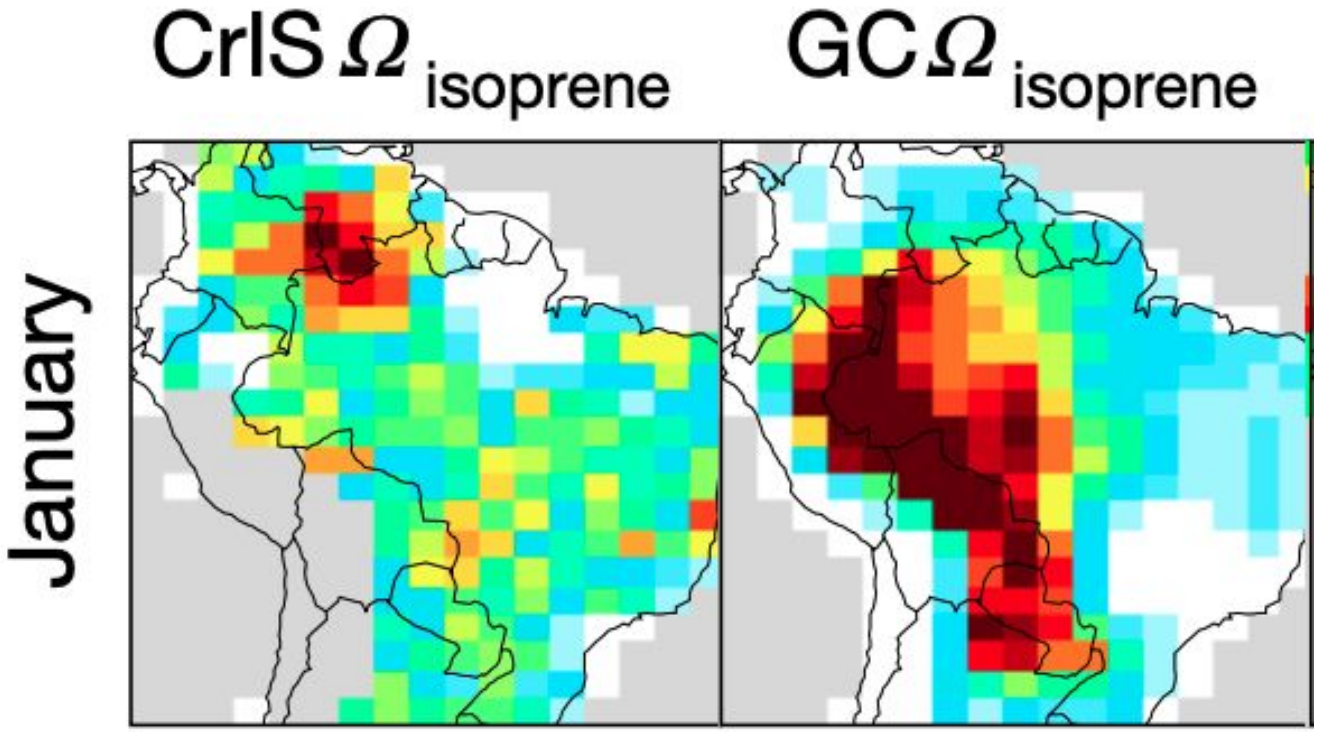
Wei et al., 2018

Atmospheric OH



- Surface isoprene too high
- Surface OH (and O_3 as well) too low, 1.5 to 3.5 × 10^4 molec cm^{-3}

Atmospheric OH



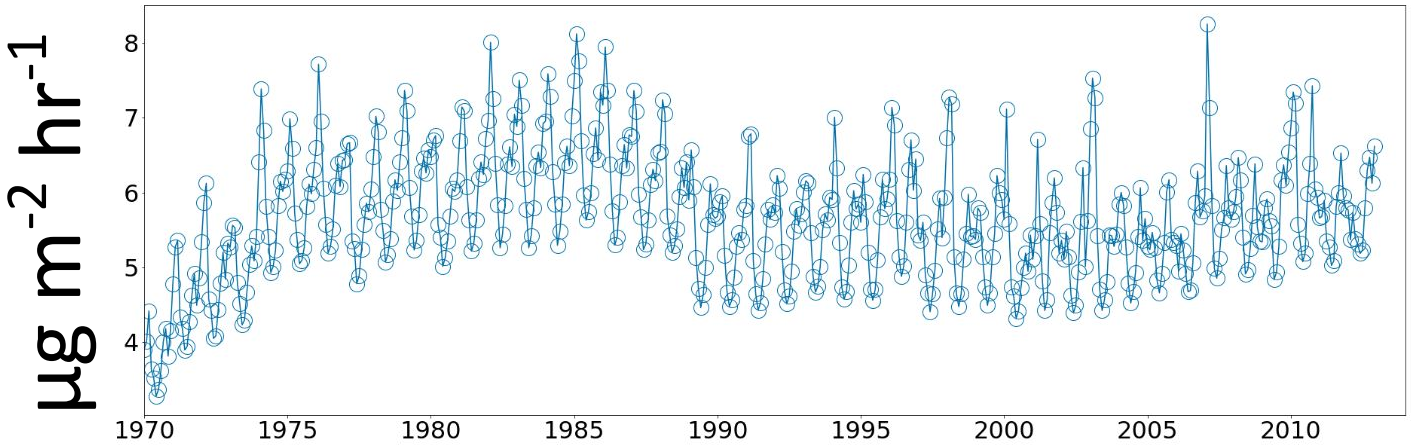
- Surface isoprene too high
- Surface OH (and O_3 as well) too low, 1.5 to 3.5 × 10^4 molec cm^{-3}
- GEOS-Chem also sees similar issue, attribute cause to underestimated OH, due to underestimated soil NO emissions

Wells et al., 2020

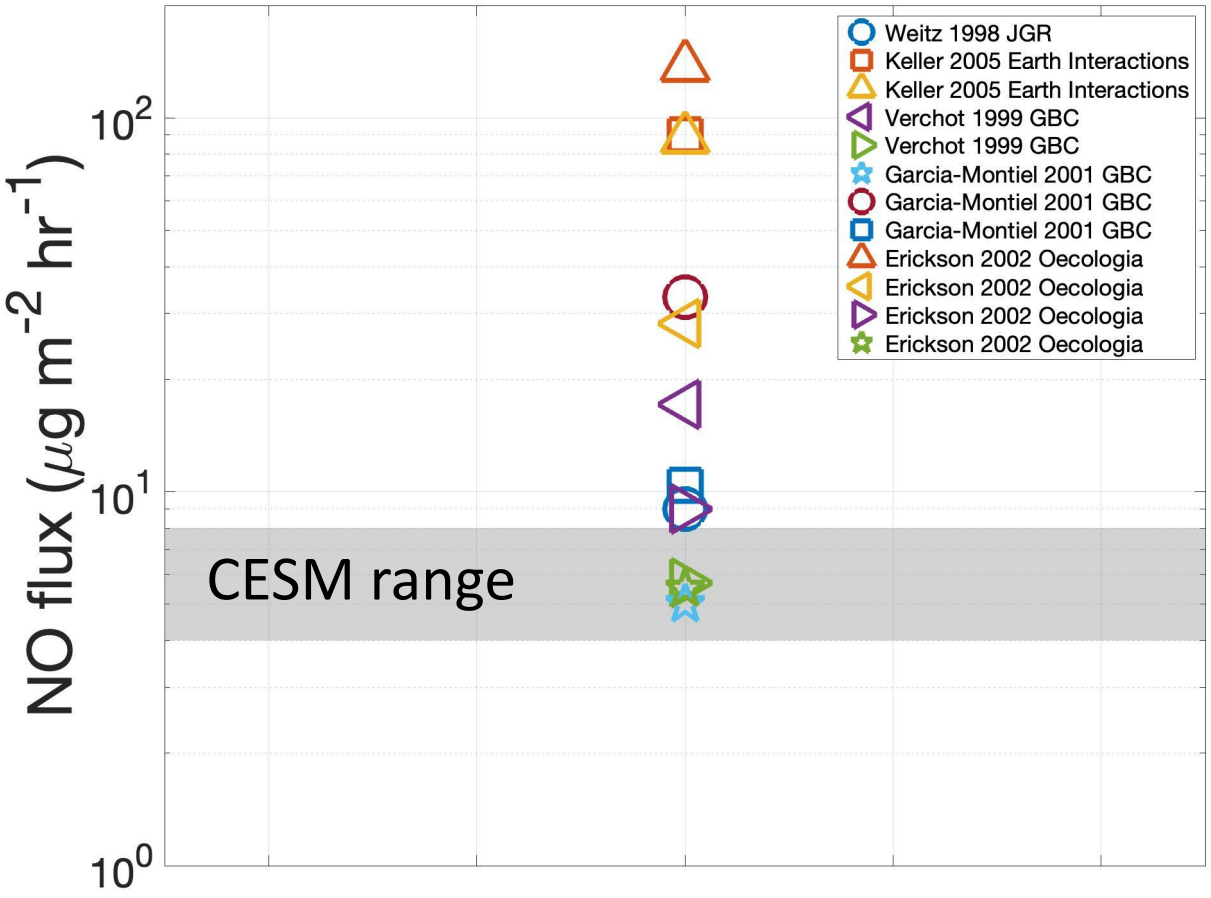
Soils: NO emissions

- Seasonal variability in soil NO emissions in CESM-Chem
- Range 4-8 µg m^{-2} hr^{-1}

CESM soil NO fluxes over the Amazon



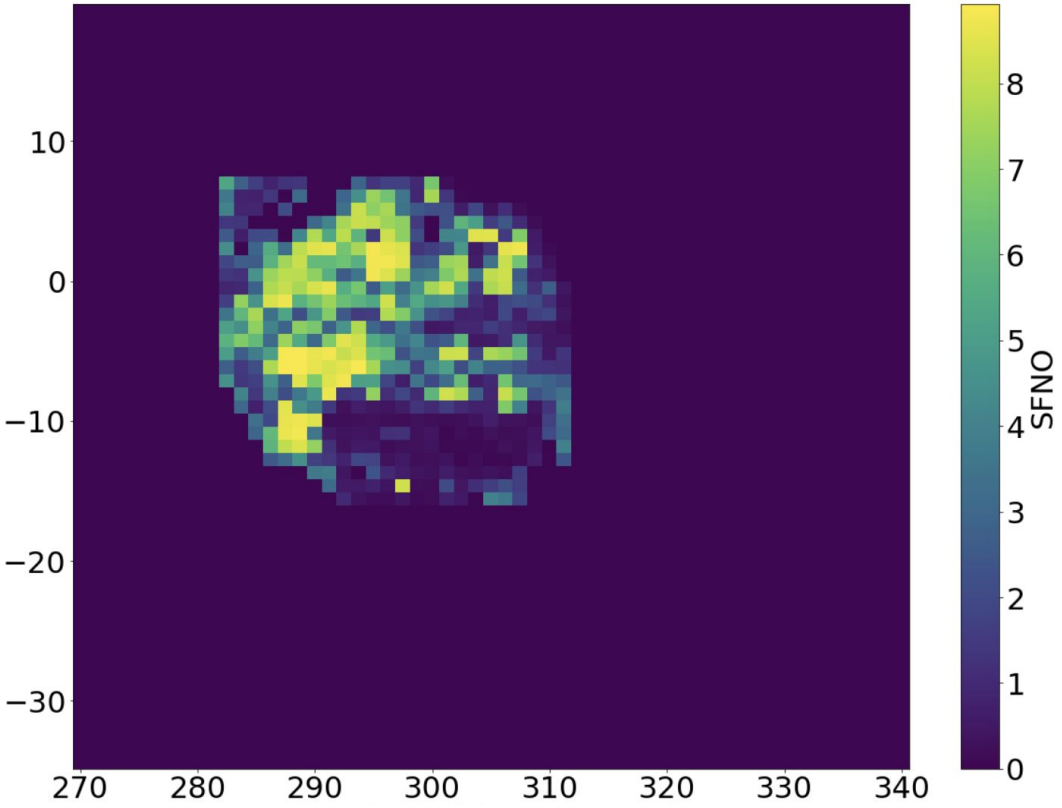
Soils: NO emissions



- Seasonal variability in soil NO emissions in CESM-Chem
- Range 4-8 μg m^{-2} hr^{-1}
- Soil chamber measurements at unique sites/periods, annual means, unperturbed Amazon forest

Soils: NO emissions

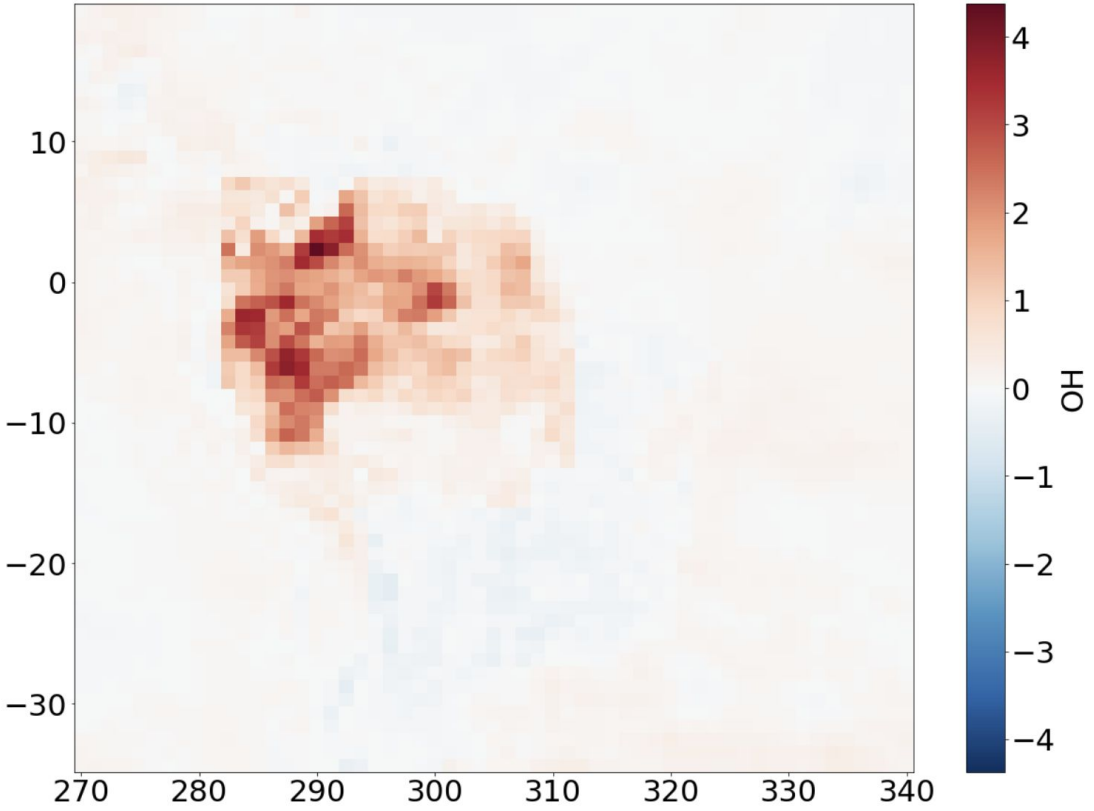
Fractional change surface NO flux



- Seasonal variability in soil NO emissions in CESM-Chem
- Range 4-8 μg m^{-2} hr^{-1}
- Soil chamber measurements at unique sites/periods, annual means, unperturbed Amazon forest
- Multiply soil NO flux (not anthropogenic, lightning, or fire) by 10

Impact of “correcting” soil NO fluxes

Fractional change surface [OH]



- OH increases by **<u>factor of ~4</u>**

$NO_2 + hv + O_2 \rightarrow O_3$

$O_3 + hv + H_2O \rightarrow 2OH$

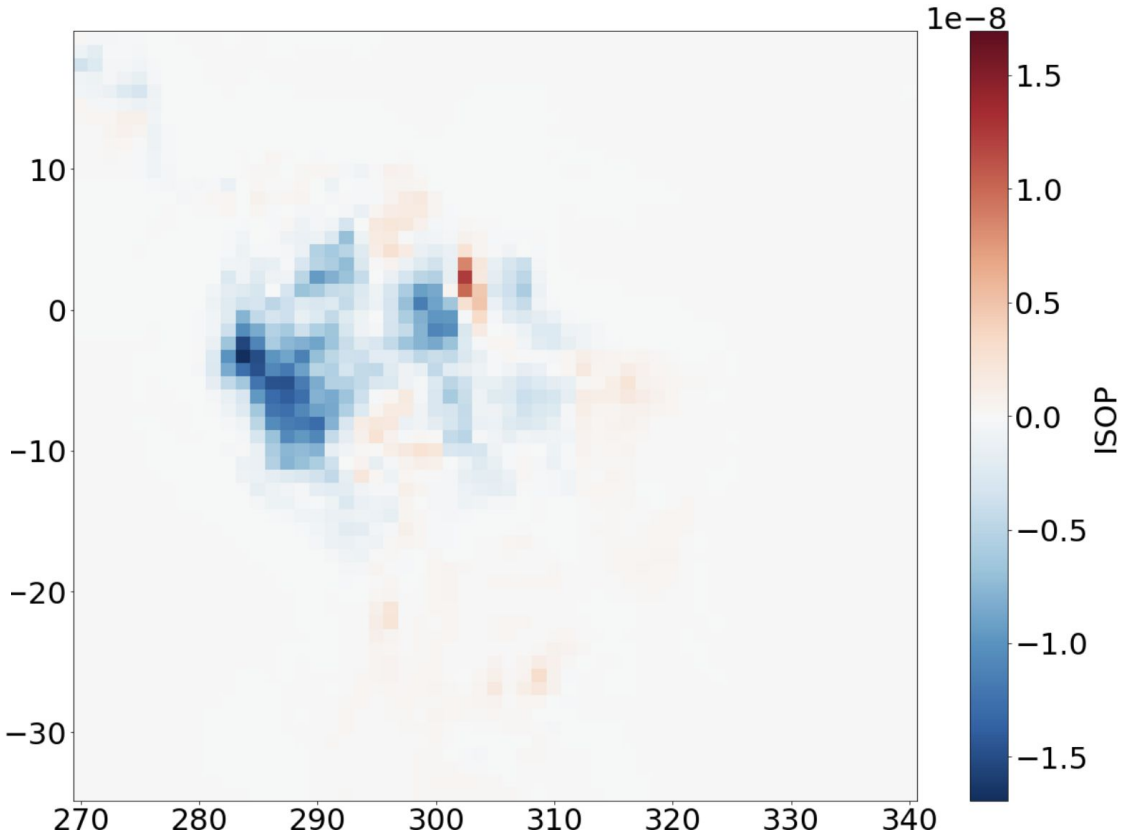
$RO_2 + NO \rightarrow NO_2 + C{=}O + HO_2$

$HO_2 + NO \rightarrow NO_2 + OH$

$C{=}O + hv \rightarrow HO_2$

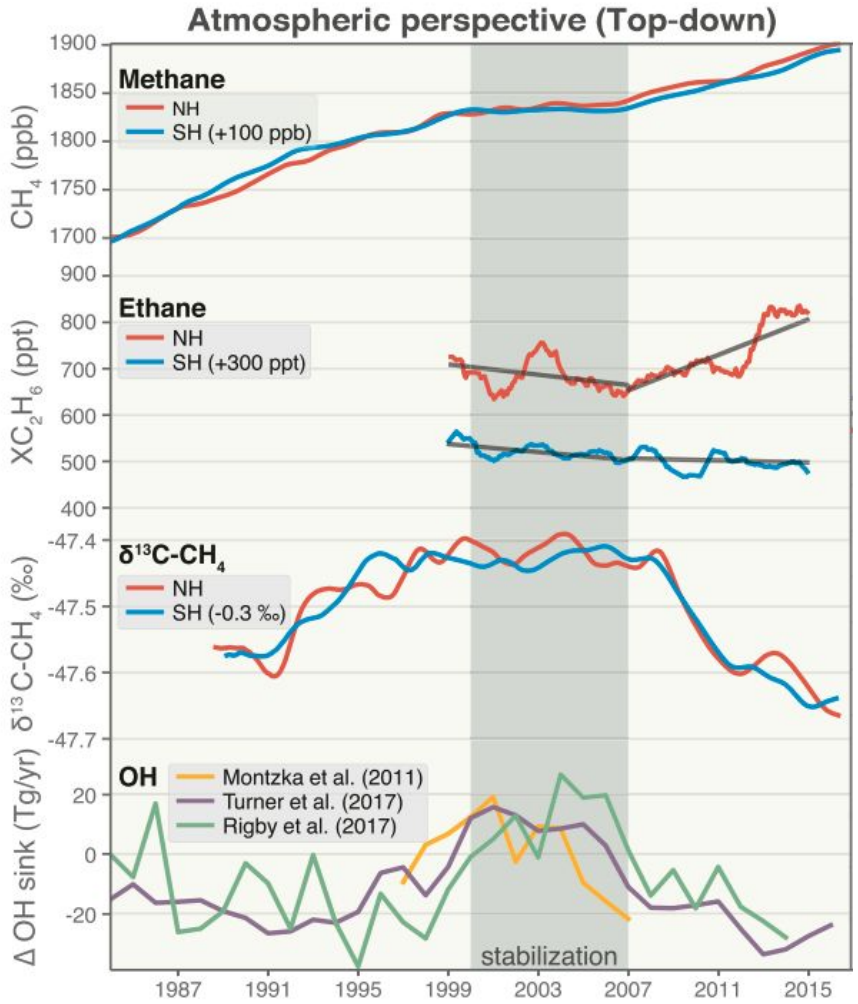
Impact of “correcting” soil NO fluxes

Change in surface [isoprene]



- OH increases by **<u>factor of ~4</u>**
- Isoprene towards closer to field-observed values
- Implications on lifetime of reactive species (CH_4, isoprene…) and distribution of precursors and oxidation products (SOA, O_3, HNO_3…)

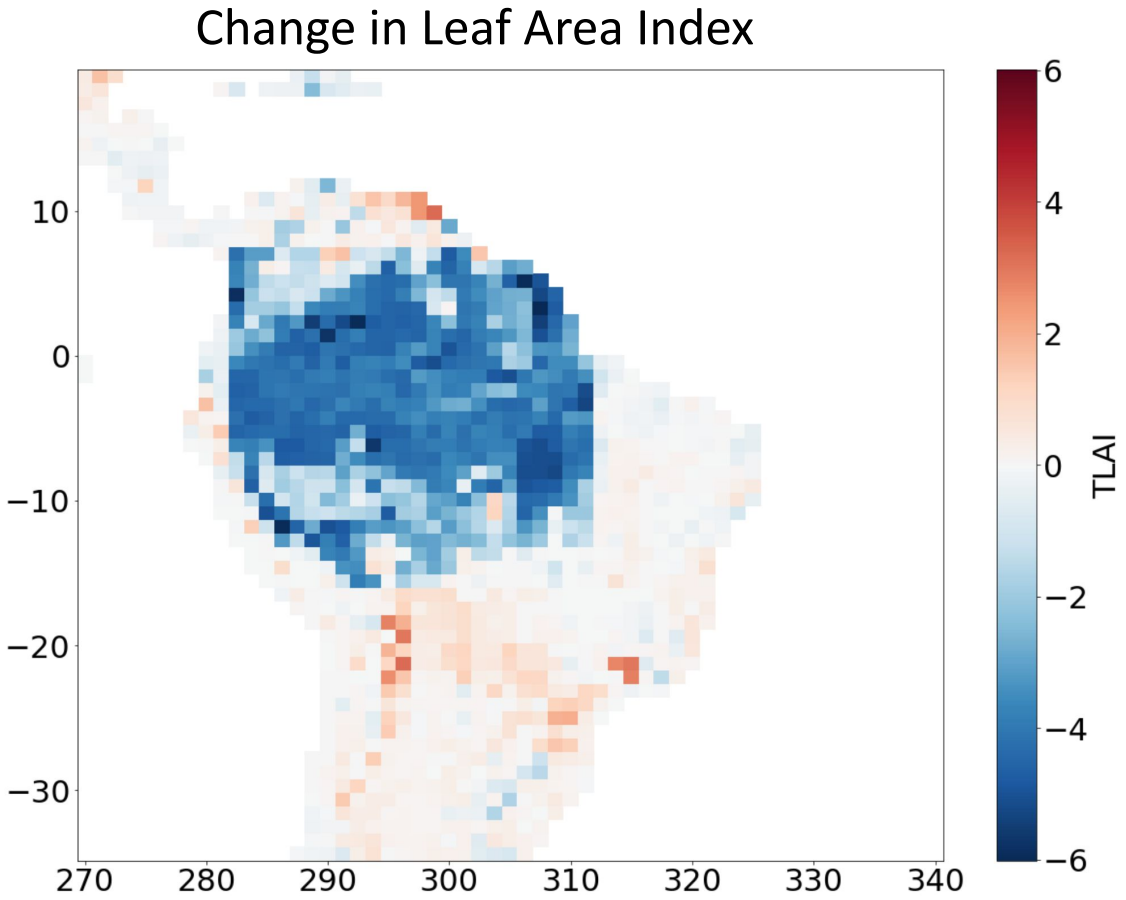
Impact of “correcting” soil NO fluxes



- OH increases by **<u>factor of ~4</u>**
- Isoprene towards closer to field-observed values
- Implications on lifetime of reactive species (CH_4, isoprene…) and distribution of precursors and oxidation products (SOA, O_3, HNO_3…)
- A ~4% increase in global OH explains methane stabilization of 2000-2008 [*<u>Turner et al</u>*., 2017; *<u>Rigby et al</u>*., 2017]

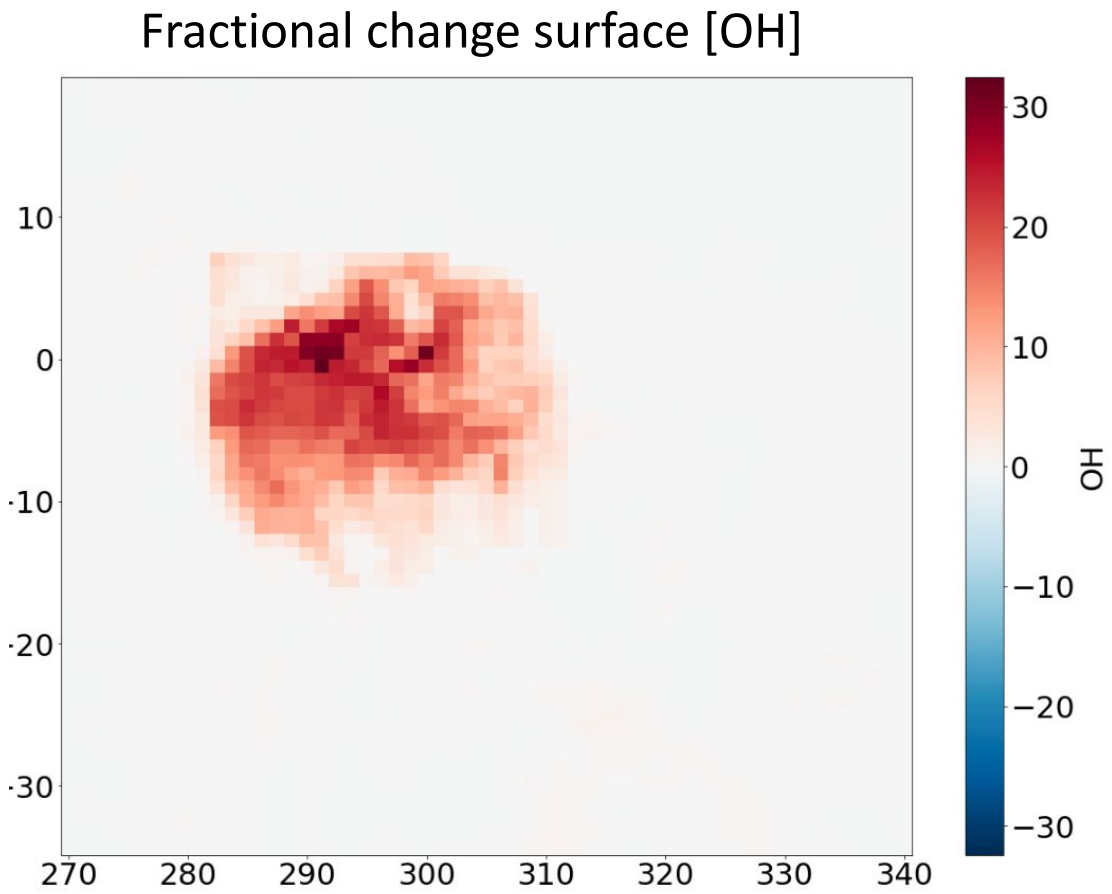
<u>Turner et al</u>., 2019

Forests: VOC emissions



- Simulate deforestation by altering land cover, which changes Leaf Area Index (LAI)

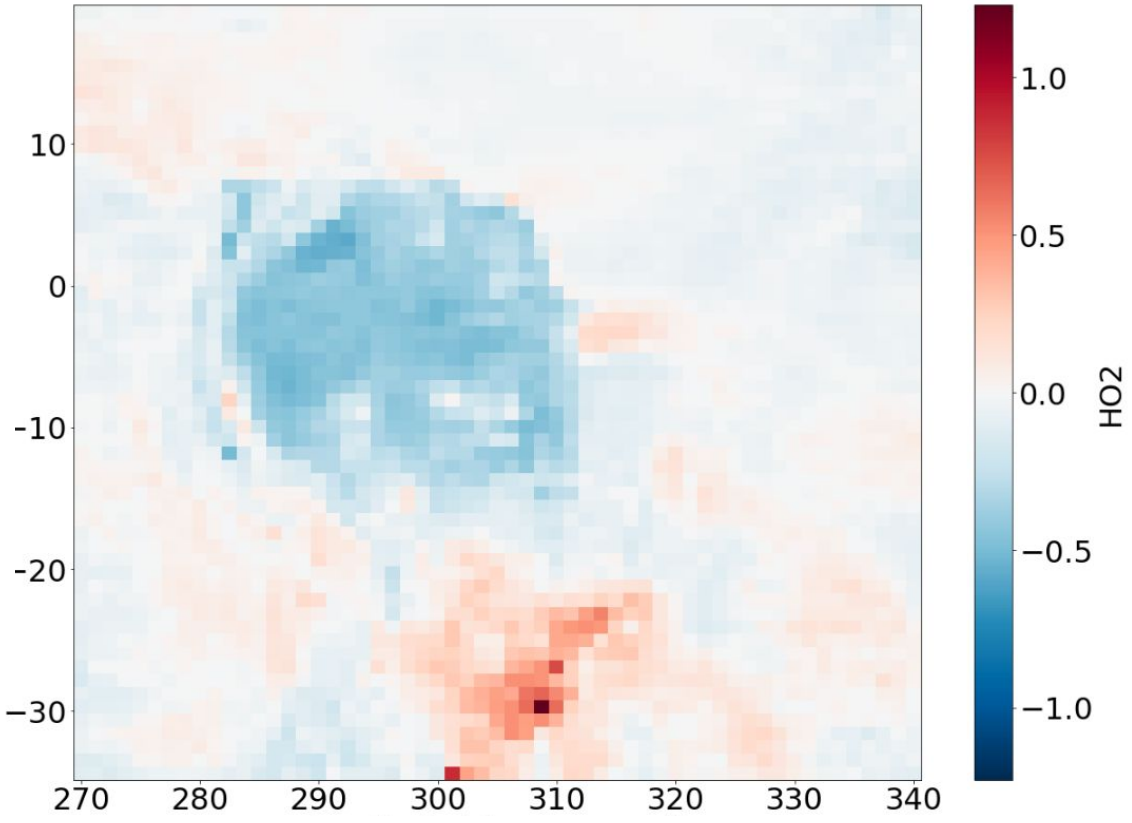
Impact of deforestation



- Simulate deforestation by altering land cover, which changes Leaf Area Index (LAI)
- 1970 forest vs fully deforested (both with “correct” soil NO)
- OH increases by **factor ~30** due to deforestation

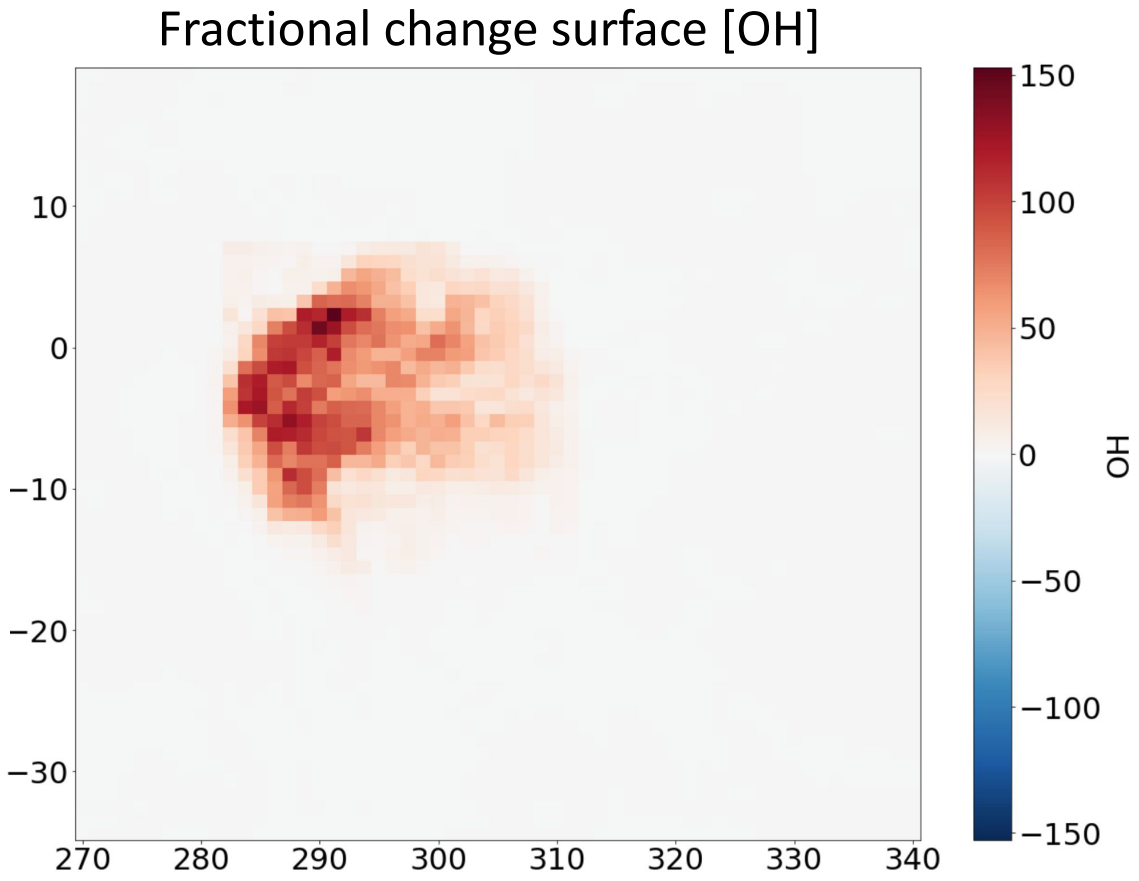
Impact of deforestation

Fractional change surface [HO_2]



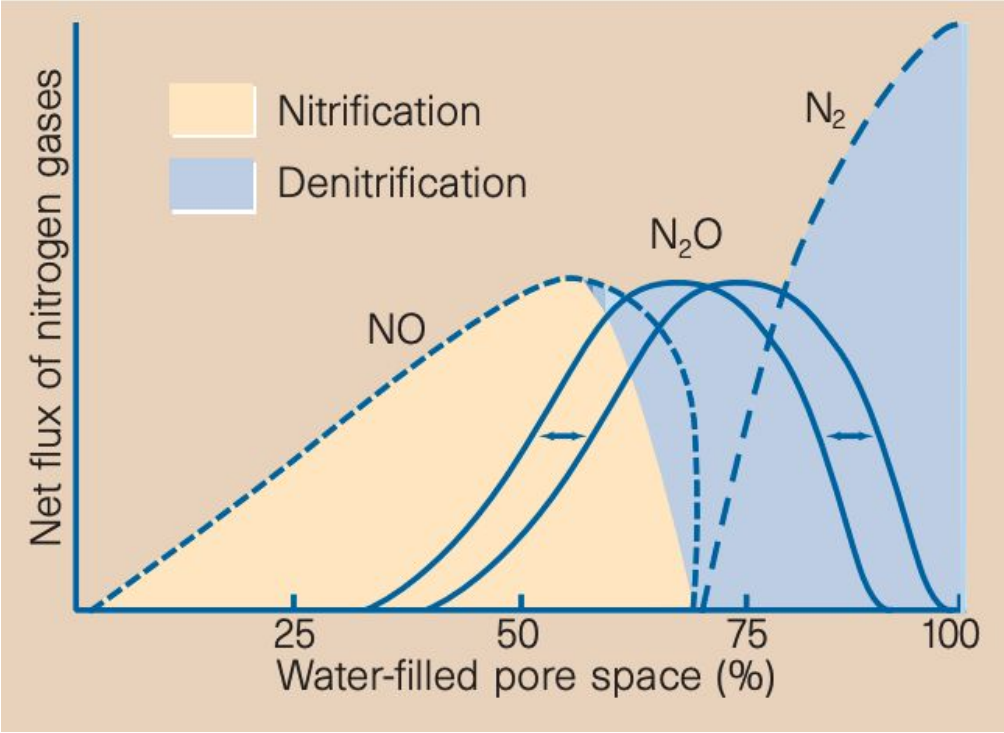
- Simulate deforestation by altering land cover, which changes Leaf Area Index (LAI)
- 1970 forest vs fully deforested (both with “correct” soil NO)
- OH increases by **<u>factor ~30</u>** due to deforestation
- HO_x decreases overall since HO_2 production from RO_2+NO ceases

Impact of deforestation AND “correcting” soil NO



- Low VOC/High NO_x vs High VOC/Low NO_x
- OH increases by a **factor of ~150**
- CESM-Chem excellent tool to study this coupled, non-linear NO_x-HO_x-VOC chemistry interfacing with ecosystems
- Changes to HO_x observed outside of the perturbation region; Evidence of teleconnection or model noise?

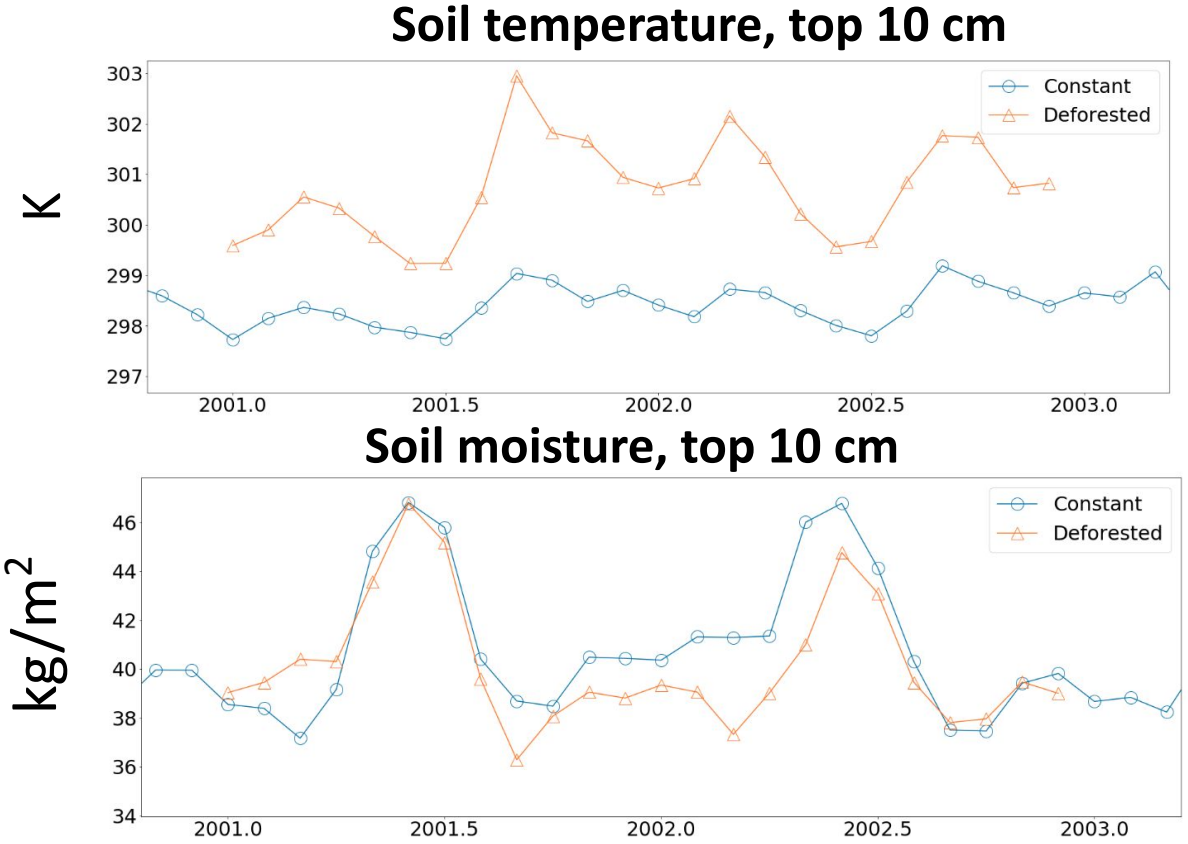
Going forward…



- Many factors affect nitrification & denitrification, such as soil type, T, H_2O, tree species…

Davidson, 1991

Going forward…



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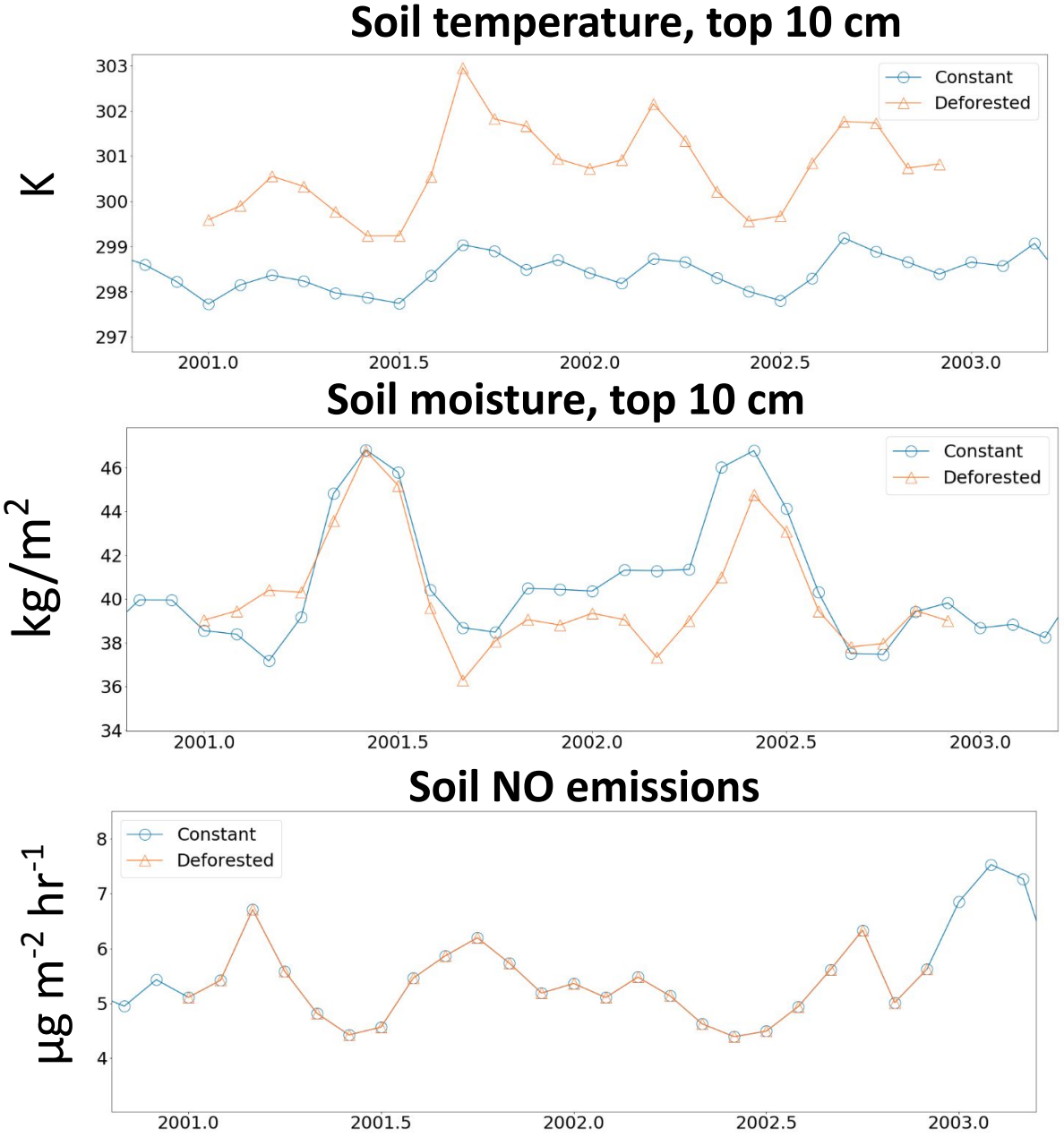
- Warming and deforestation should impact soil NO emissions, hence, OH

Going forward…



- Many factors affect nitrification & denitrification, such as soil type, T, H_2O, tree species…
- Warming and deforestation should impact soil NO emissions, hence, OH
- CESM soil NO emissions not affected by soil T and H_2O changes
- Pastures? Farmlands? Logging and soil compaction increased soil NO emissions 30 to 350% [*Keller et al.*, 2005]