

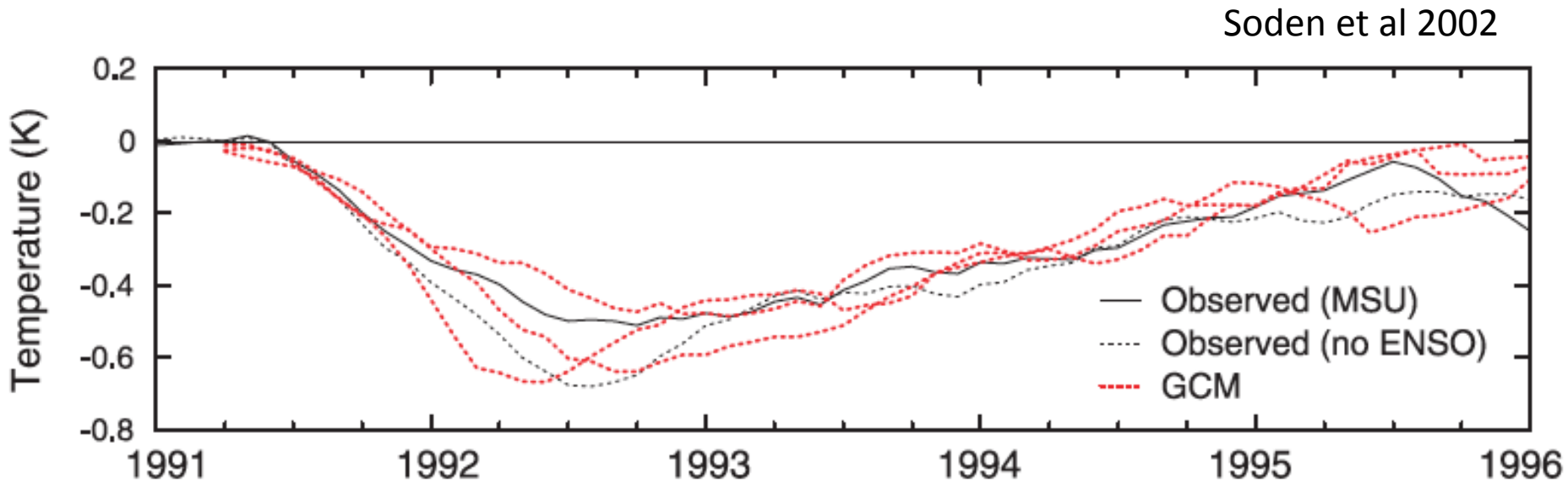


Tropospheric Volcanic Emissions and Climate

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J. E. Kristjánsson (U Oslo), J. Haywood, B.
Johnson (MetOffice), Jeff Stith (NCAR)

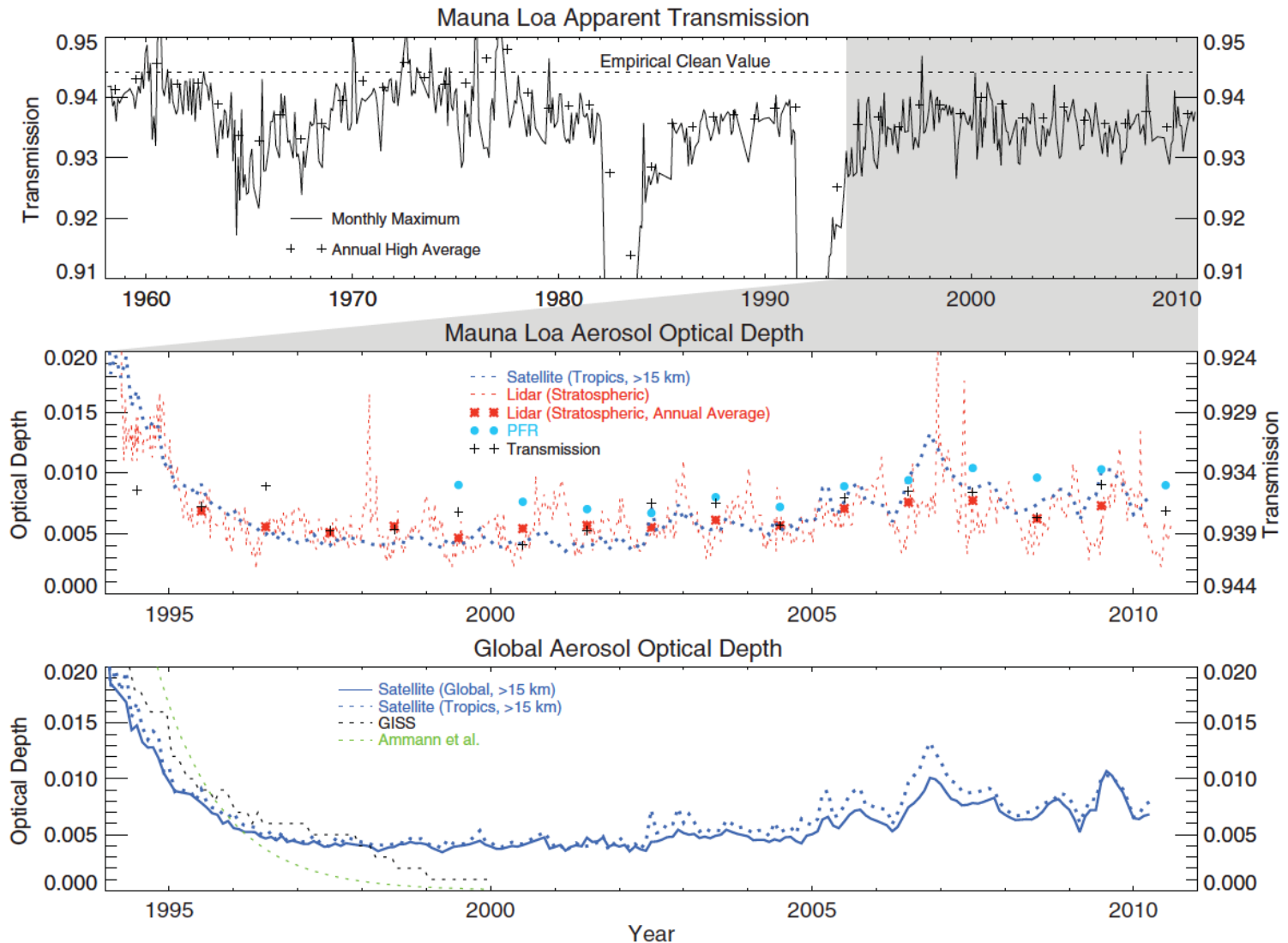
Tropospheric Volcanic Emissions

- SO_2 in the stratosphere= aerosols & cooling
E.g.: Mt. Pinatubo



- What about in the troposphere?
 - Direct effects small: rapid scavenging

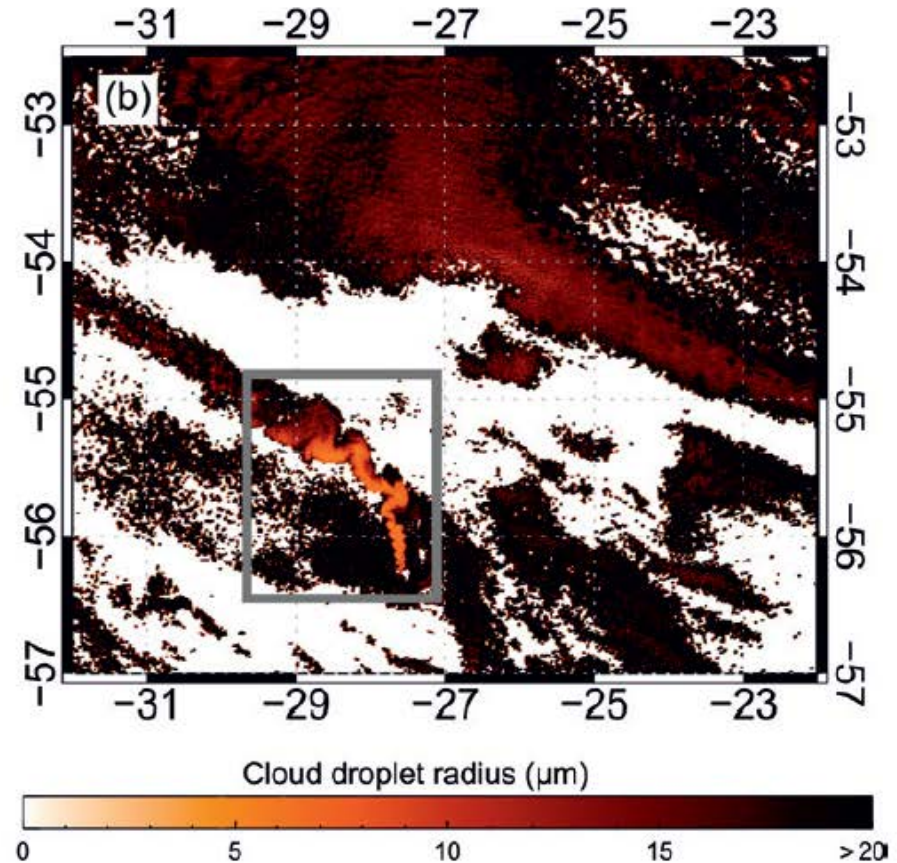
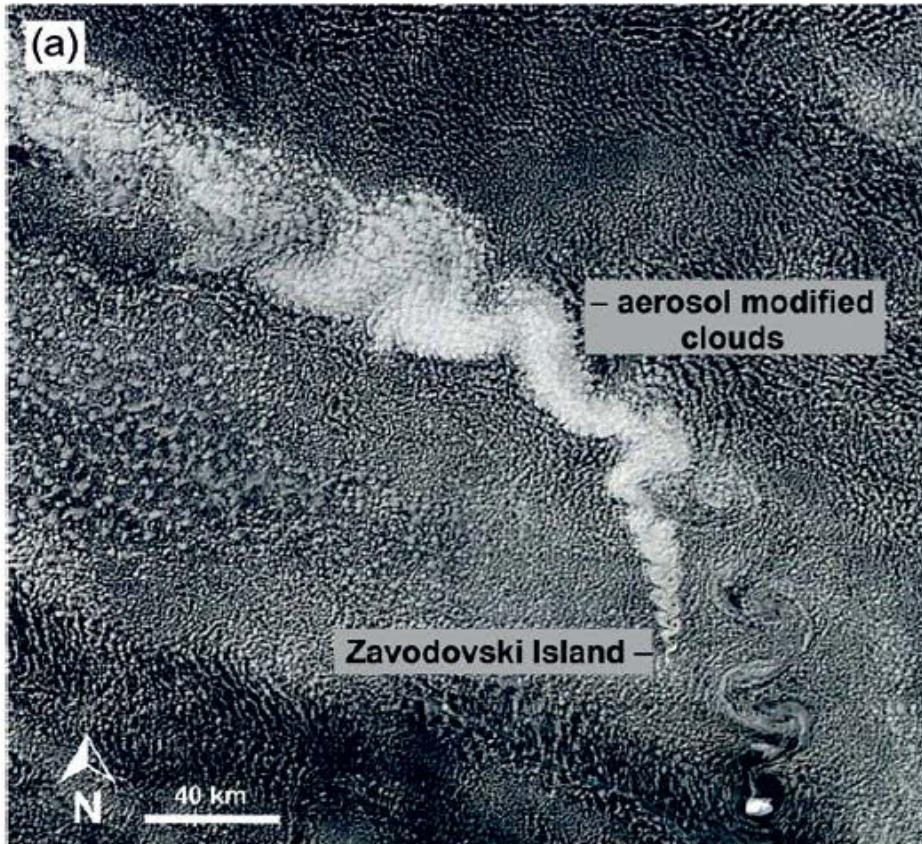
Recent Effects of Small Volcanoes



Solomon et al 2011, Science: Not just large magnitude volcanoes.
But still focused on the stratosphere.

S. Ocean Clouds: 'Volcano Tracks'

Cloud brightening due to volcanic aerosols ($\text{SO}_2 \rightarrow \text{H}_2\text{SO}_4$) in the troposphere



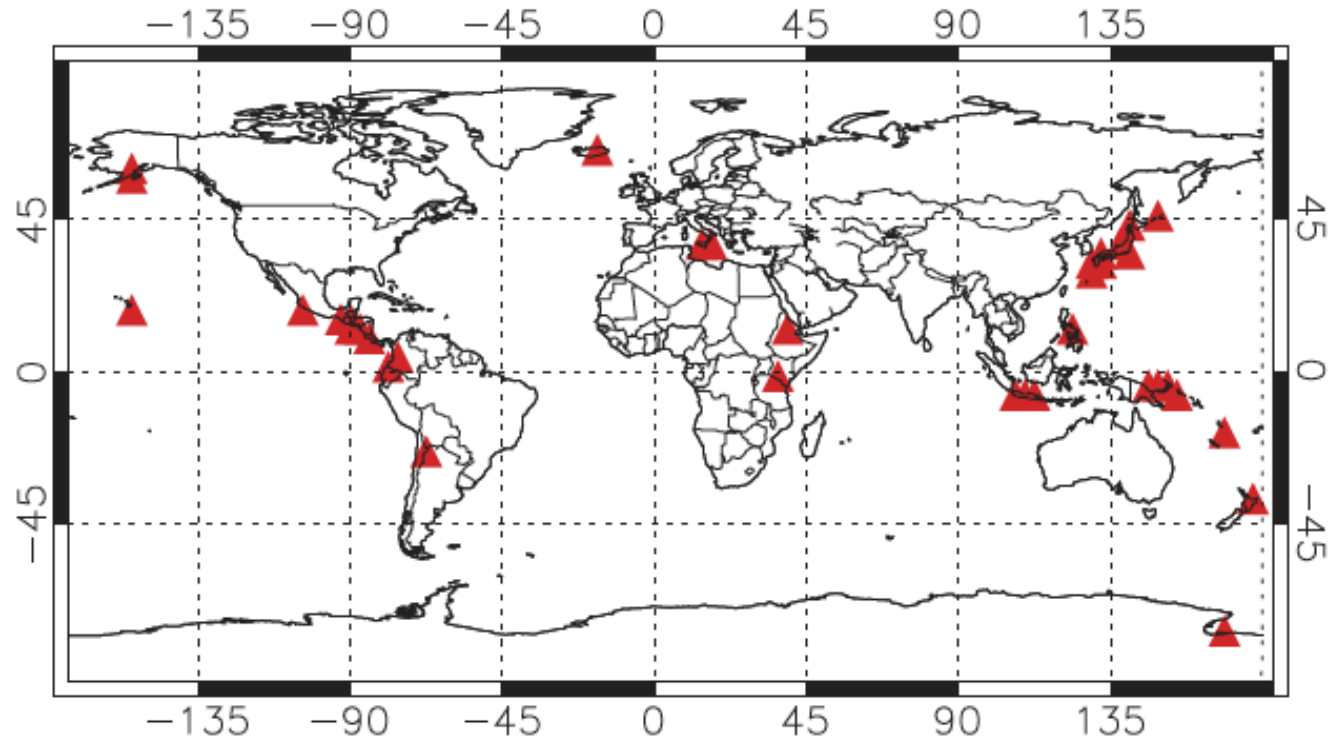
S. Sandwich Islands (Between S. America & Antarctica)

Schmidt et al 2012

Global Impacts

b)

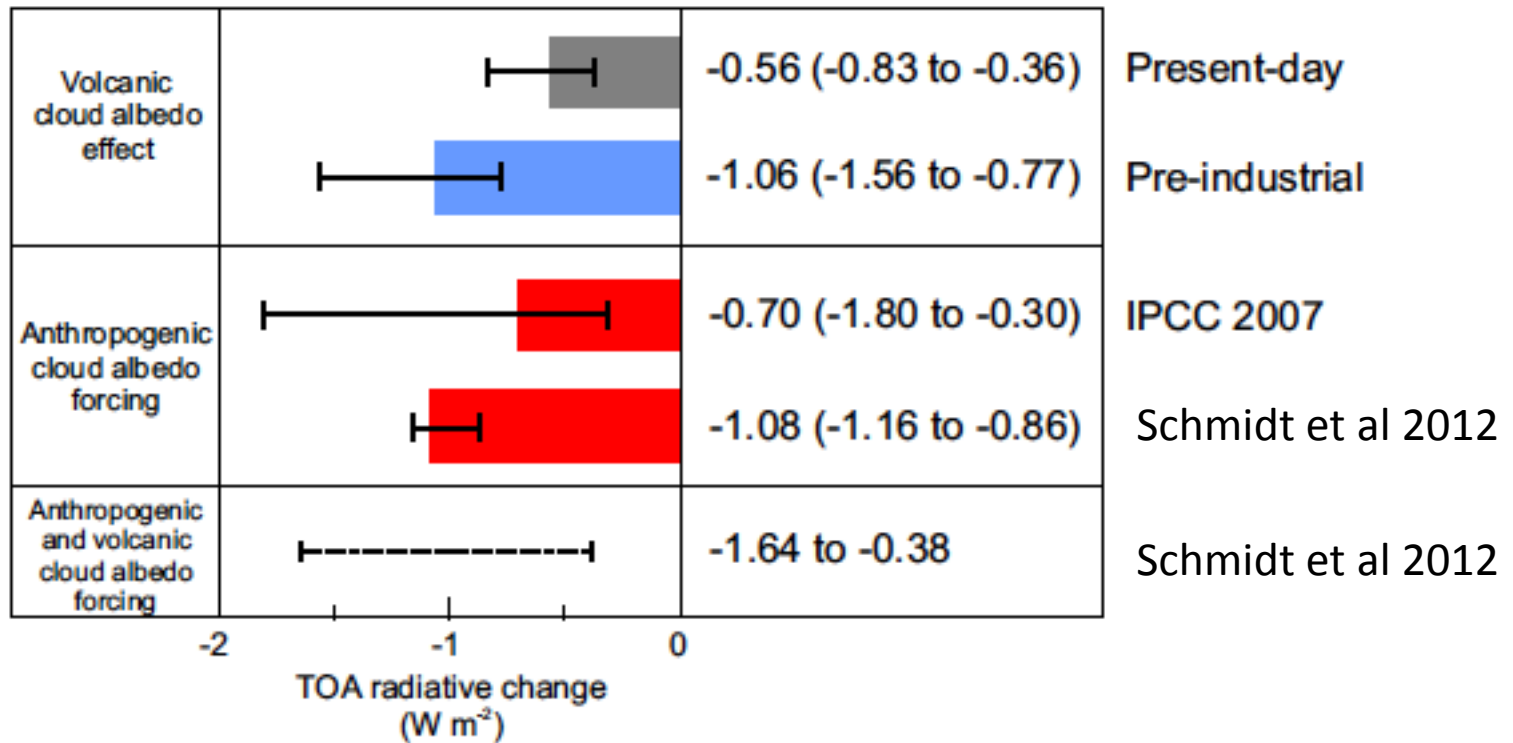
location of volcanoes



Volcanic $S = 13 \text{ Tg yr}^{-1}$ (35 kTd^{-1})

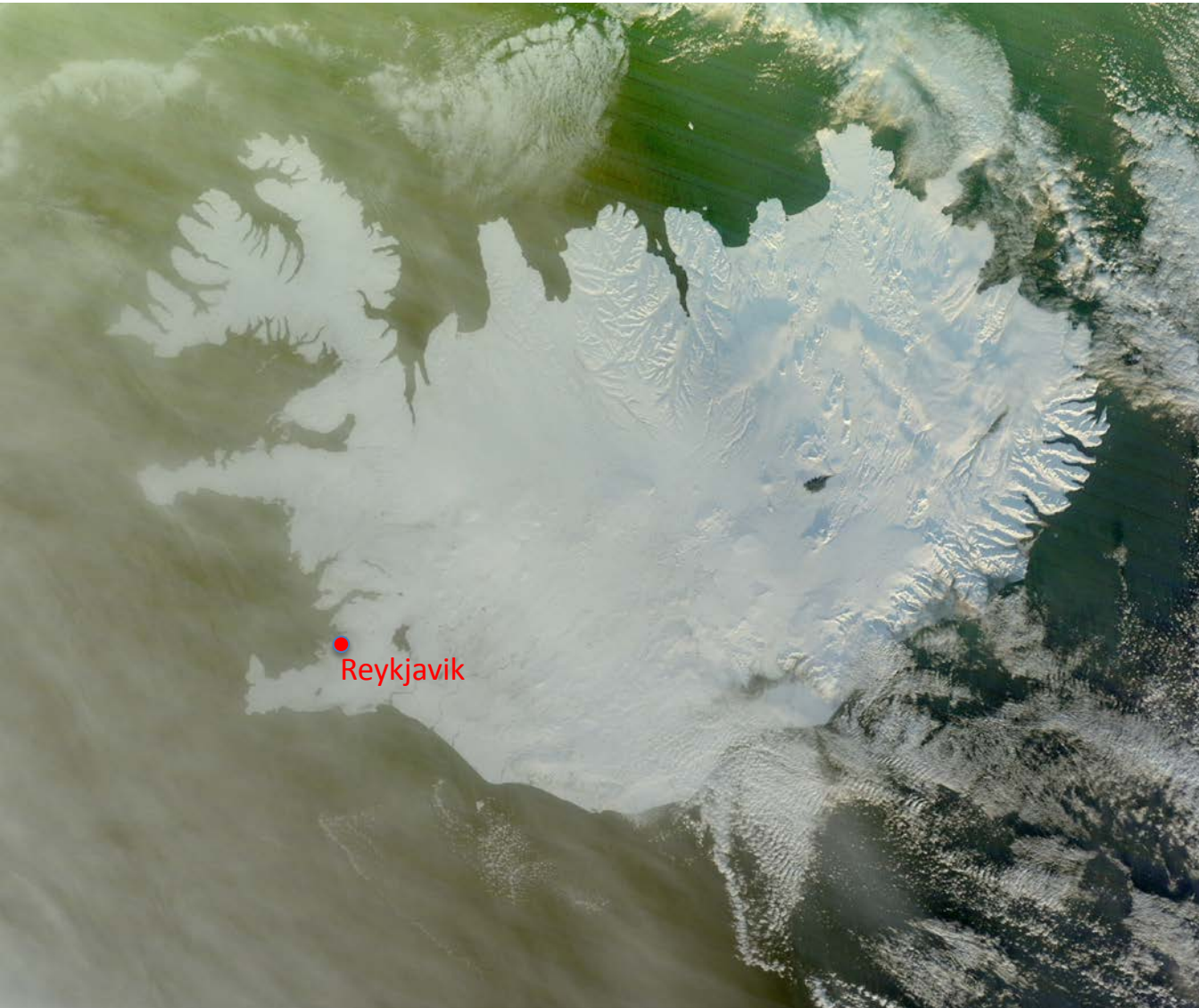
Total Anthropogenic $S = 60 \text{ Tg yr}^{-1}$

Radiative Effect



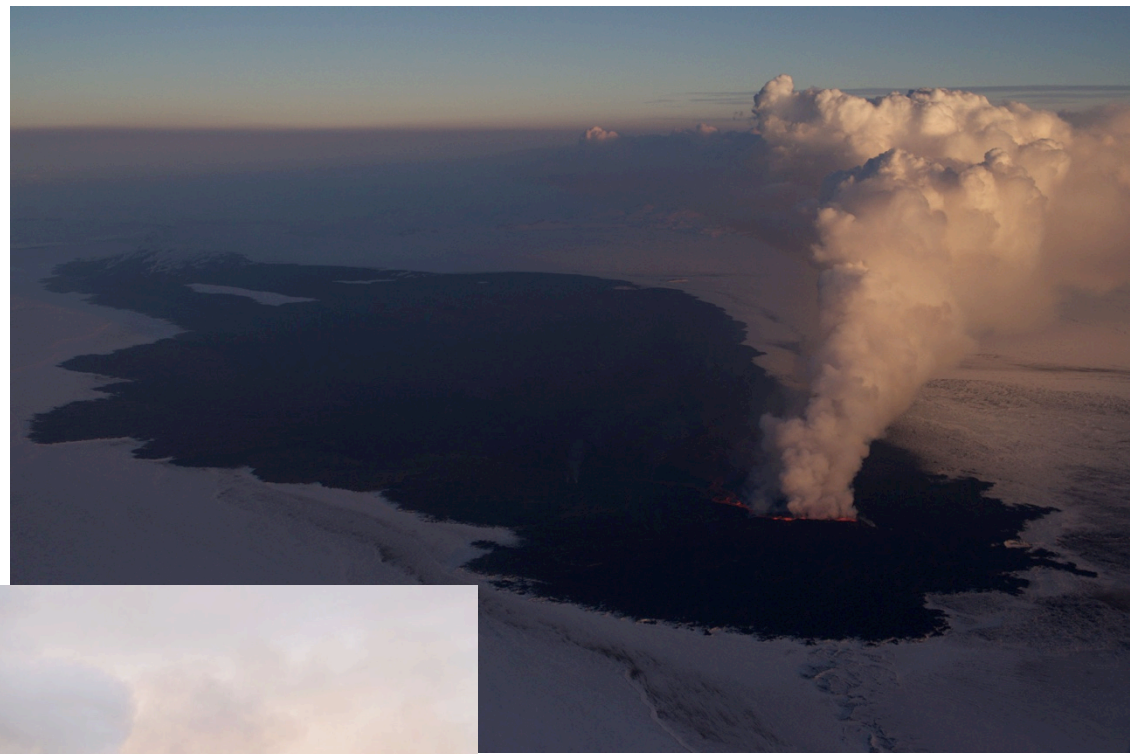
- Detailed Aerosol Model (GLOMAP)
- No cloud microphysics
 - assumed CCN, CDNC, Albedo
- Volcanic impact is half of anthropogenic S impact

Bardarbunga Volcano: Holuhraun Eruption 29 Aug 2014– 28 Feb 2015



Lava Field
January 2015

Photos



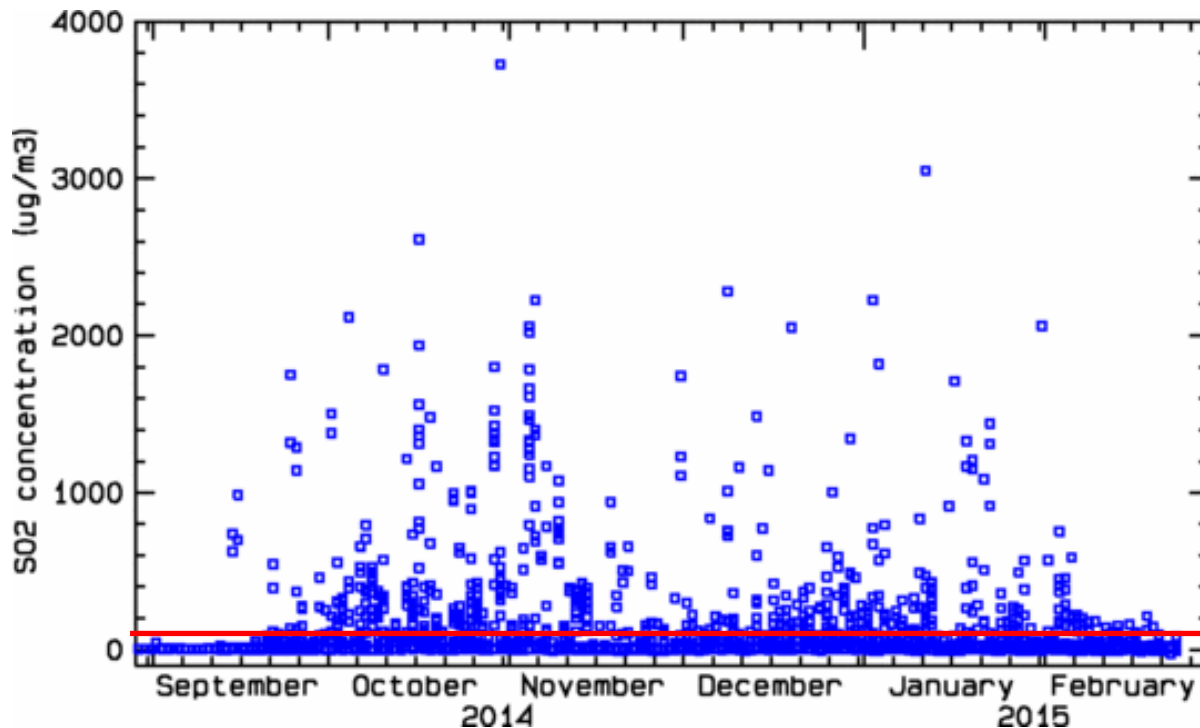
24 Oct



5 Sep

Impact

- Unpopulated Region of Iceland
- No Flooding
- No Emissions/Ash into Stratosphere
- But: LOTS of SO₂



SO₂ measurements near
(several km from) the
eruption

US EPA 1-hr SO₂ standard
= 75 μg m⁻³

How much SO₂?

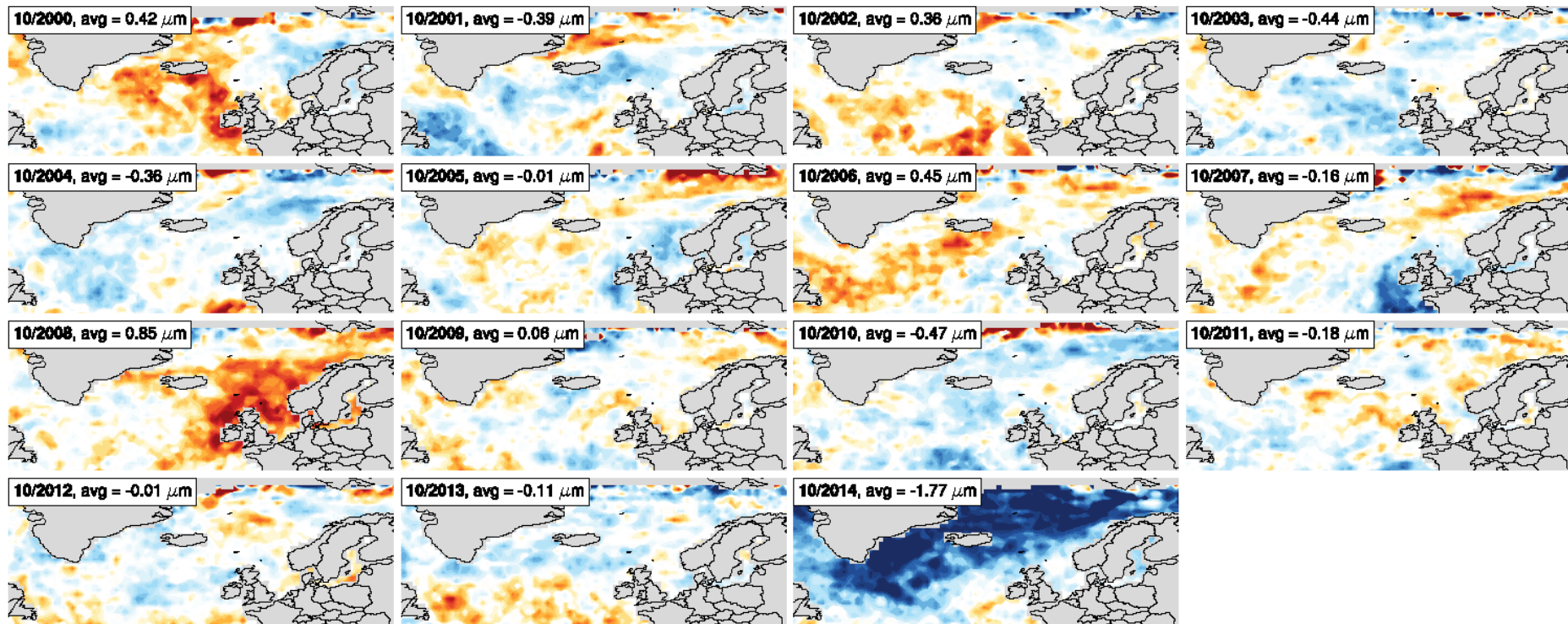
- Estimate over 10 Tg in 6 months
- Total Annual Anthropogenic = 60-80 Tg yr⁻¹
 - Peak emissions 120KT day⁻¹ (35KT d⁻¹ average over 3 months)
 - Estimated daily EU emissions of SO₂=10KT d⁻¹
- Sufficient to create local adverse health impacts

What does 35KT d⁻¹ SO₂ do to the N. Atlantic?

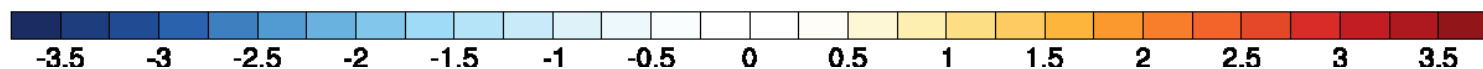
- Oxidizes to H₂SO₄: forms aerosols
- Results: Increased AOD
 - Indirect Aerosol Cooling on low clouds
- Demonstrate this in Models
 - Idealized: NCAR-CESM
 - Assimilated: MetOffice HadGEM3 v. Observations

Holuhraun Impact on Clouds

15 Octobers: N. Atlantic MODIS Cloud Effective Radius (r_{eff}) anomalies
Which of these is not like the others?



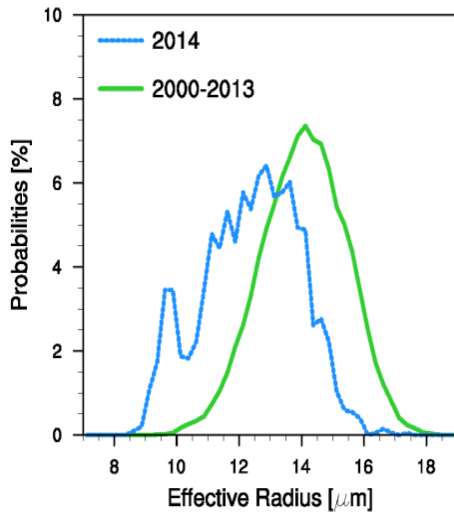
Liquid Cloud Effective Radius Anomalies, ΔR_{eff} [μm]



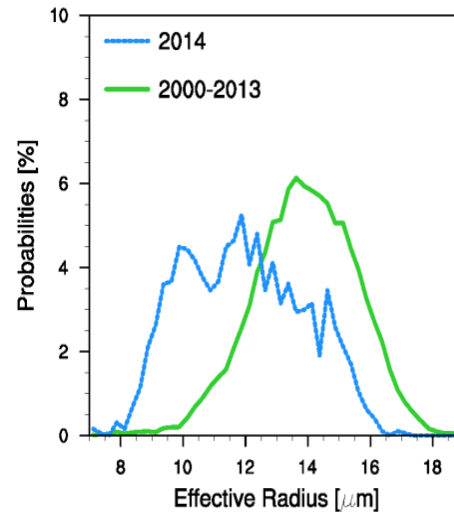
HadGEM3: Microphysics

MODIS

SEPTEMBER - MODIS TERRA (C051)

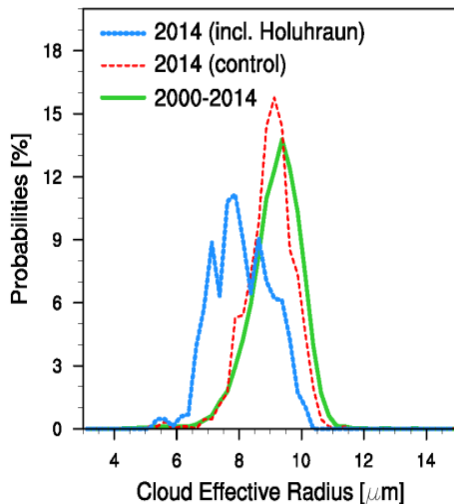


OCTOBER - MODIS TERRA (C051)

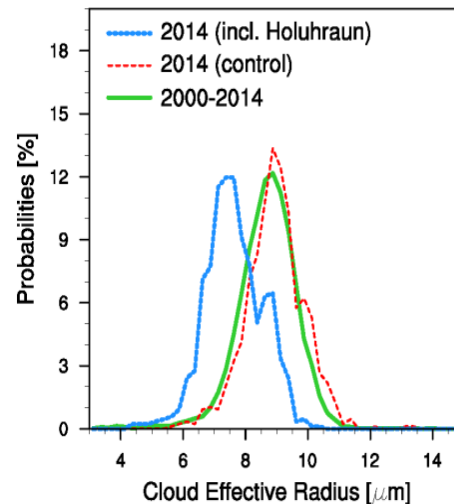


HadGEM3

SEPTEMBER - HadGEM3 (TH15)



OCTOBER - HadGEM3 (TH15)



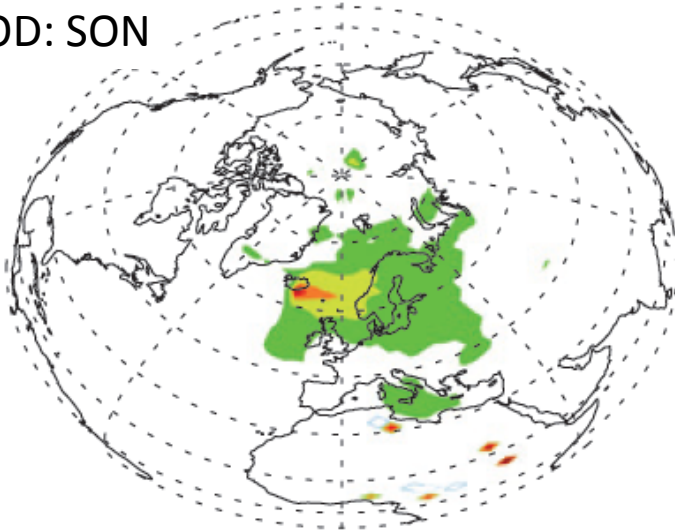
Probability density functions of monthly mean effective radius (r_{eff}) in the N. Atlantic region: Get smaller drops only with 2014 Holuhraun emissions. Control matches 2000-2013 average

Significant Change in Cloud Microphysics

CESM-Radiative Effects

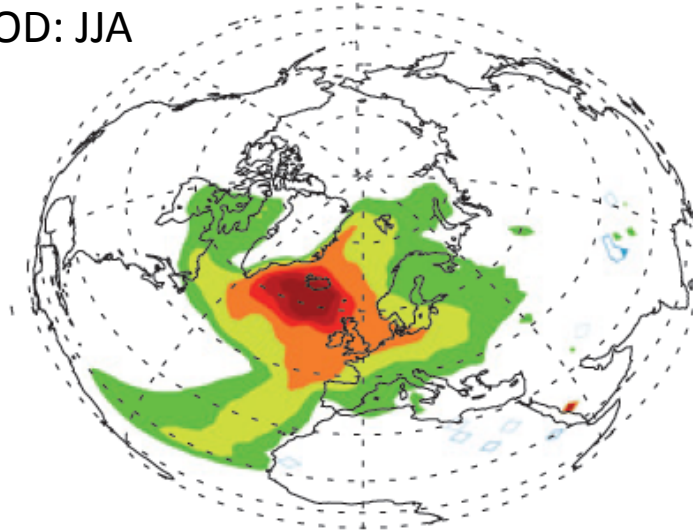
Gettelman et al 2015, Nat. Geosci.

$\Delta AOD: SON$

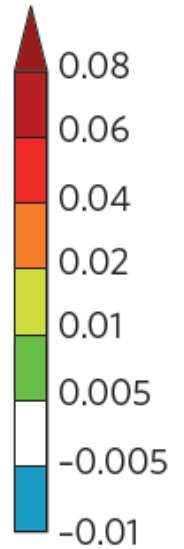


$\Delta AOD = 0.005 \quad \sigma = 0.001$

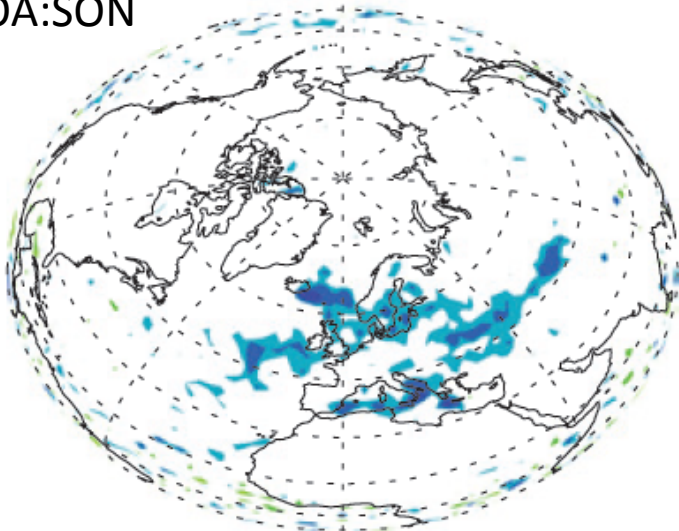
$\Delta AOD: JJA$



$\Delta AOD = 0.03 \quad \sigma = 0.006$

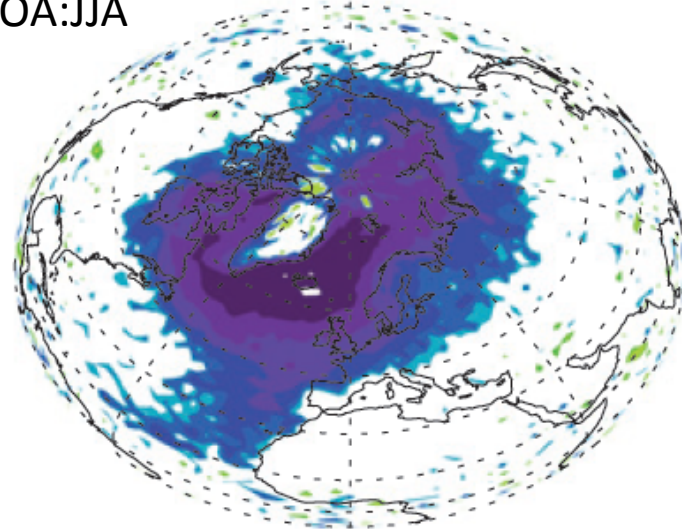


$\Delta TOA: SON$

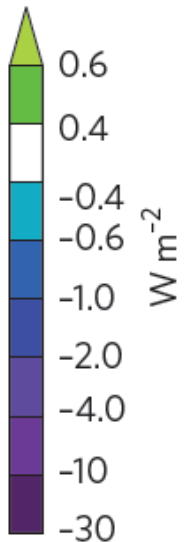


$-0.21 \text{ Wm}^{-2} \quad \sigma = 0.05 \quad (\text{Anthro} = -1.5 \text{ Wm}^{-2})$

$\Delta TOA: JJA$



$-7.4 \text{ Wm}^{-2} \quad \sigma = 1.0 \quad (\text{Anthro} = -5.8 \text{ Wm}^{-2})$



Summary

- Effusive volcanic eruptions (in the troposphere) may have significant climate effects
- Significant impact of large Effusive Eruptions
 - Regional, lasts weeks
 - ‘Moderate’ eruptions = -7 Wm^{-2} cooling
 - Stopped before summer, only fall
- Historical Impact: Laki 1783-1784
 - Bigger than this, may have created ‘acid fogs’ and heat waves in N. Europe (See poster on Laki)
- Laboratory for measuring Aerosol-Cloud Interactions...

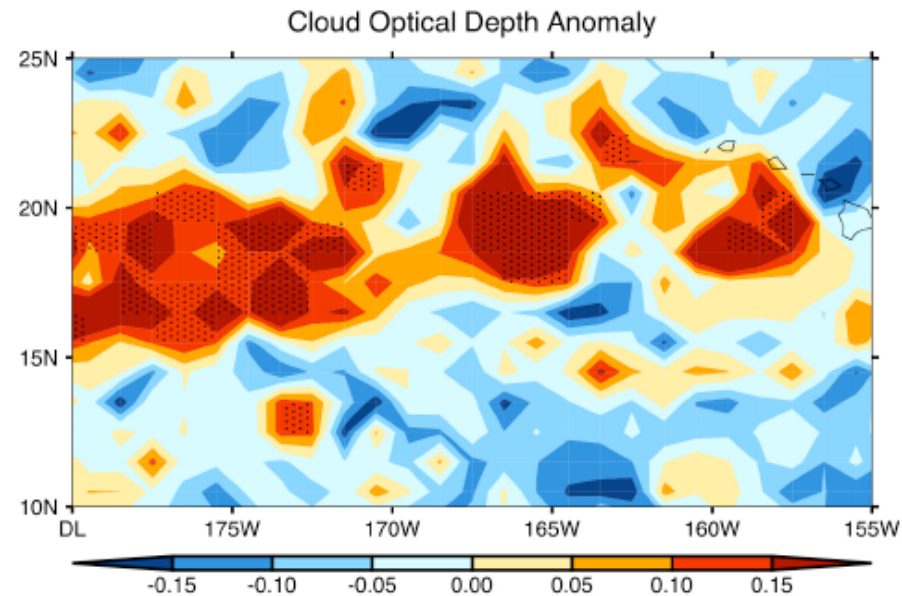
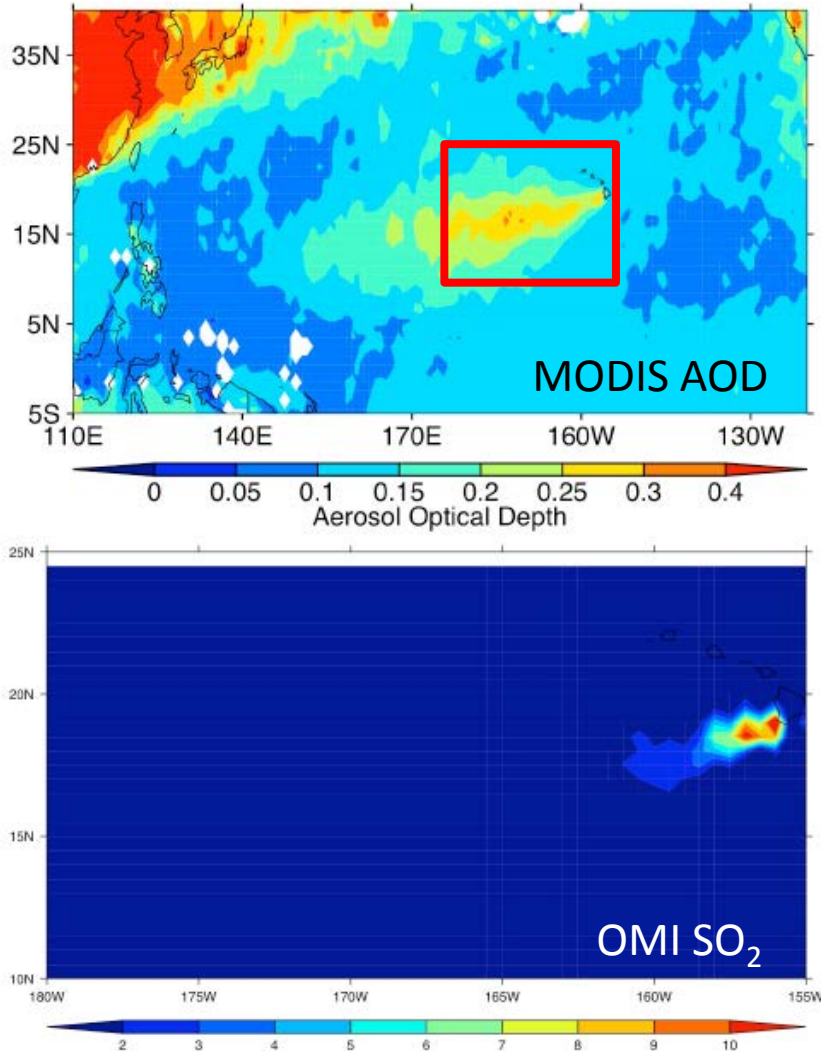
Ideas for Model Experiments

- Kilauea Sampling and Model inter-comparison
- Multi-Model Experiments with Holuhraun emissions

Effects of Mt. Kilauea (2008)

JJA 2008

- 2008 Kilauea Eruption increased Cloud OD in Pacific



Kilauea as an SO₂ Laboratory

- Background Kilauea SO₂ emissions ~2-7kT/day
=10-20% of European emissions, or =Illinois
 - Isolated emissions (no other major SO₂ source)
- Eruption continuous since 1983
 - Several groups working on MODIS observations
- Preliminary simulations indicate detectable effects in models
- Exploring In-situ & Satellite sampling for model inter-comparison
 - Working on a proposal now, experiment 2-3 years out
 - Determine microphysical sensitivities in-situ, model observations. Reduce uncertainty in indirect effects.
- Goal: provide a data set for models
 - Contact me if interested

Holurahun Model Comparison

- Specify model simulations
 - Weekly emissions from Thordarson & Hartley 2015
 - Assume a fixed emission height & SO₄ fraction
- What do models say for r_{eff} v. MODIS?
 - Good for an intercomparison
 - Met Office (Haywood) working on UM paper
 - Follow on with multiple models?

Conclusions

- Tropospheric volcanic emissions can have regional climate effects
- Large eruptions (e.g.: Iceland) can be significant for regional climate now and in the past
- Recent (Holurahun) and Ongoing (Kilauea) emissions are a natural laboratory for testing Aerosol and Cloud Microphysical effects in models.
 - Good opportunities for inter-comparisons