

Synergistically using observations and models for the analysis of stratospheric aerosol events

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P. Sellitto, G. Berthet, B. Legras, F. Ploeger, D. Smale, M. v. Hobe, L. Thomason, G. Taha, F. Jégou, S. Bucci, A. Bossolasco, G. Kryzstofiak, C. Xue, C. Qiu, M. Ratnam, B. Barret, E. Le Flochmoen, B. Kumar, B. Madhavan, N. Bègue, J.P. Vernier, S. Khaykin

Short Introduction of myself + background



Masters in England
University of East Anglia
In: Atmospheric Sciences



PhD in Germany

Forschungszentrum Jülich
Thesis: OCS in the stratosphere



Scholarship: HITEC



Germany, New Zealand, USA, Nepal, Greece, Sweden

Postdoc in France

LPC2E, CNRS Orléans
Topic: Aerosols in the stratosphere



Fellowship: German Research Foundation (DFG)

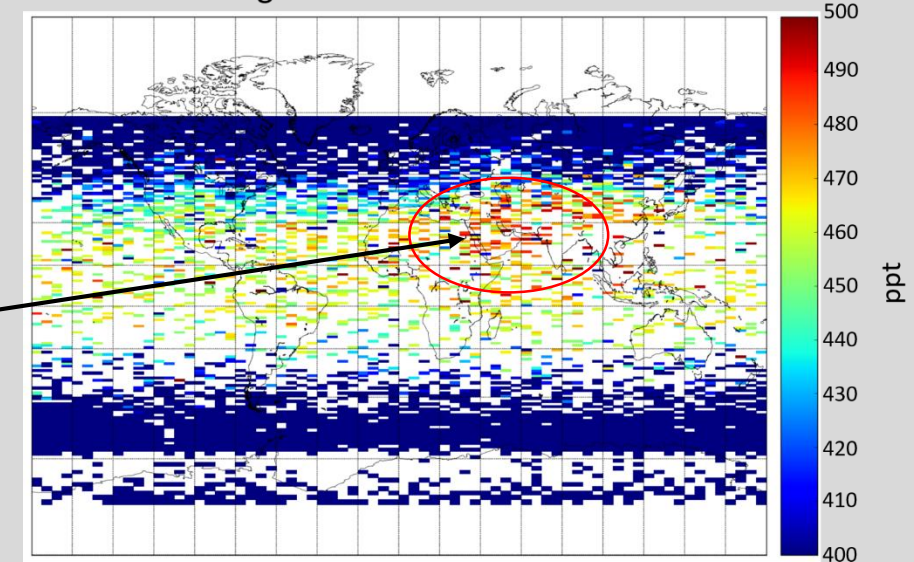
Key points

- **Instrumental development** of AMICA for airborne measurements
- **Satellite data analysis** of aerosol precursors in the Asian monsoon



ACE-FTS

OCS mixing ratio 15.5 – 16.5 km altitude



Tools I use



Satellite data:

For aerosol observations:

- SAGE, SAGE II, SAGE III/ISS
- OMPS

For trace gas observations:

- ACE-FTS
- MIPAS
- MLS

In situ data:

Aircraft:

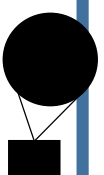
AMICA (OCS, CO observations)

Balloon:

LOAC, POPS (optical particle counters)

Lidar Network (NDACC)

Aerosol + trace gases



models:

Trajectory models:

FLEXPART, TRACZILLA, CLaMS

Whole atmospheric model:

WACCM

Radiative transfer model :

UVSPEC

Analysis of aerosol plumes in the stratosphere from volcanic eruptions and extreme fire events

and

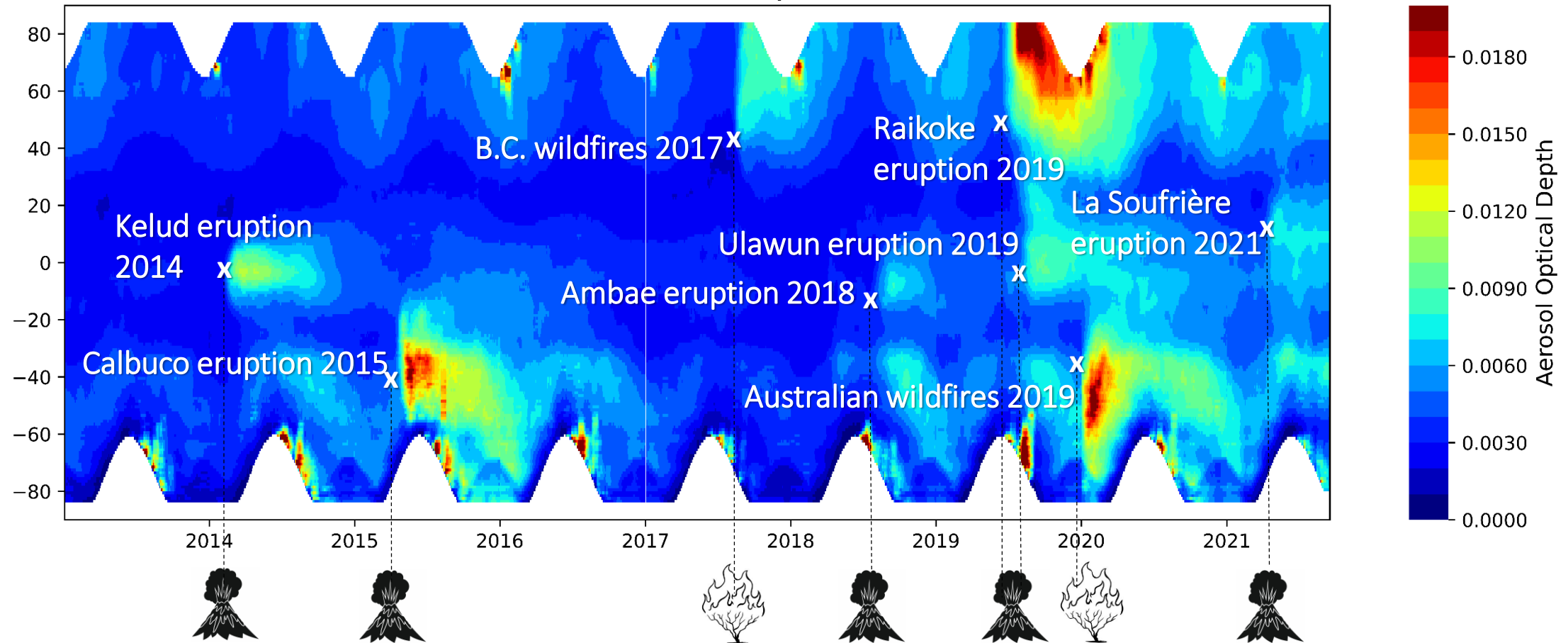
Analysis of the Asian Tropopause Aerosol Layer (ATAL)

Structure talk

- **Introduction/
Motivation**
- **Part 1** **Analysis of aerosol plumes in the stratosphere from volcanic eruptions and extreme fire events**
- **Part 2** **Analysis of the Asian Tropopause Aerosol Layer (ATAL)**

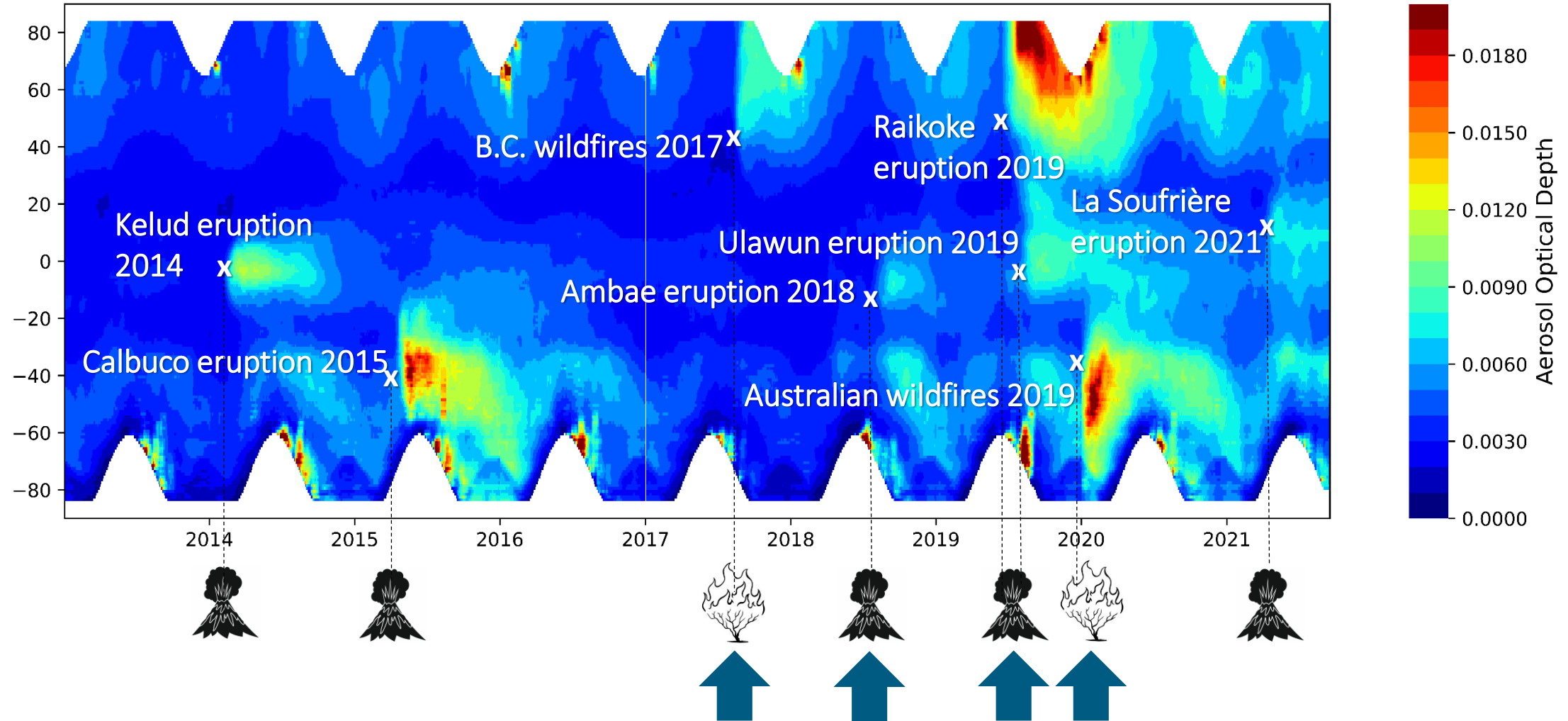
Introduction

OMPS 675nm stratospheric AOD



Introduction

OMPS 675nm stratospheric AOD



Kloss et al., 2019 (ACP) *Kloss et al., 2020 (JGR)* *Kloss et al., 2021 (ACP)* *Kloss et al., 2021 (Frontiers)*

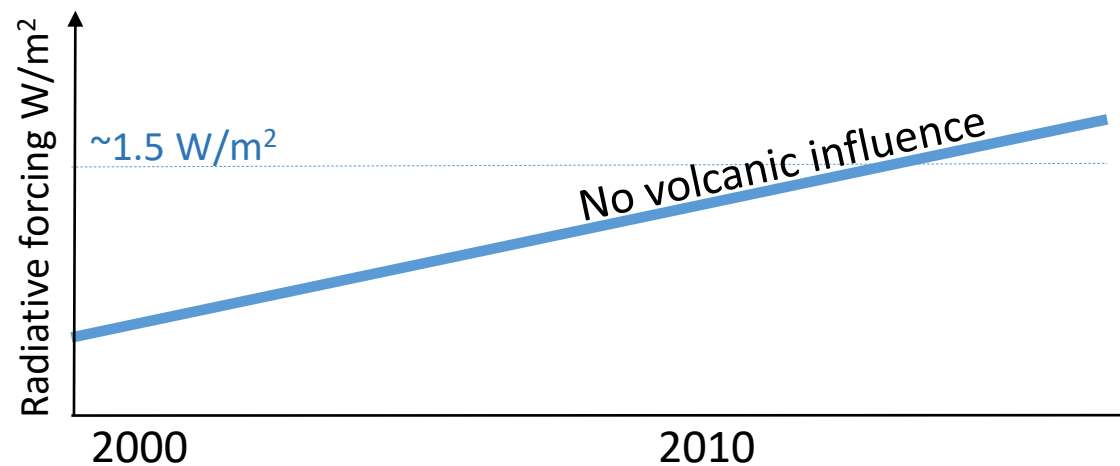
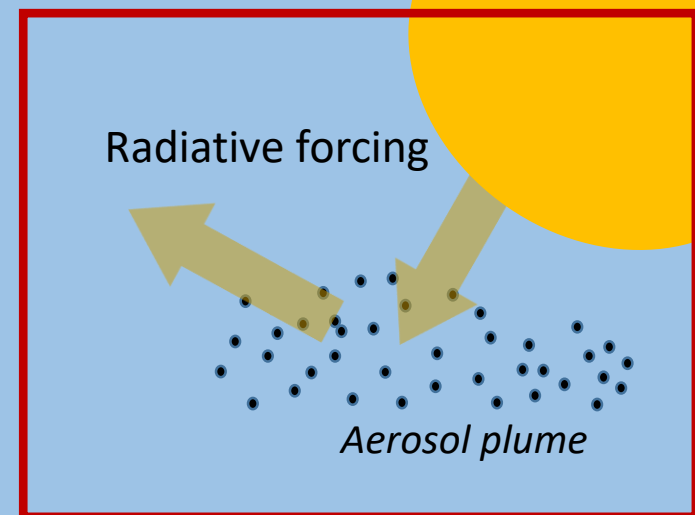
Introduction

Part 1: Aerosol plumes,
extreme events

~25km altitude

**Aerosols in the stratosphere
have a cooling effect on the
climate**

8-16 km



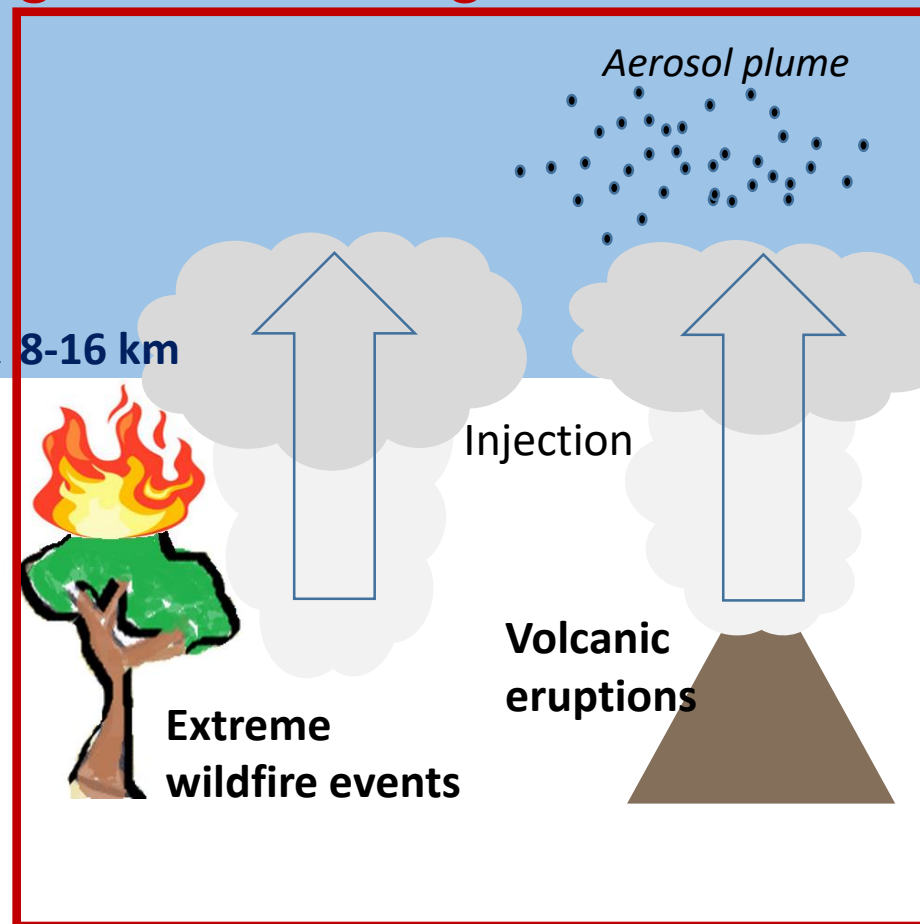
Adapted from Solomon et al., 2011

Introduction

Part 1: Aerosol plumes,
extreme events

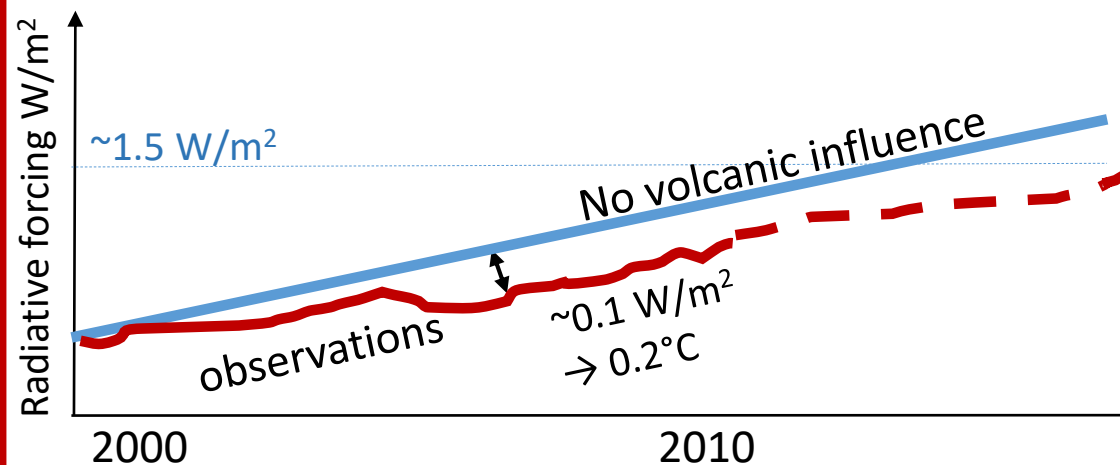
~25km altitude

Each stratospheric aerosol event is relevant in terms of global warming



Radiative forcing

Aerosol plume

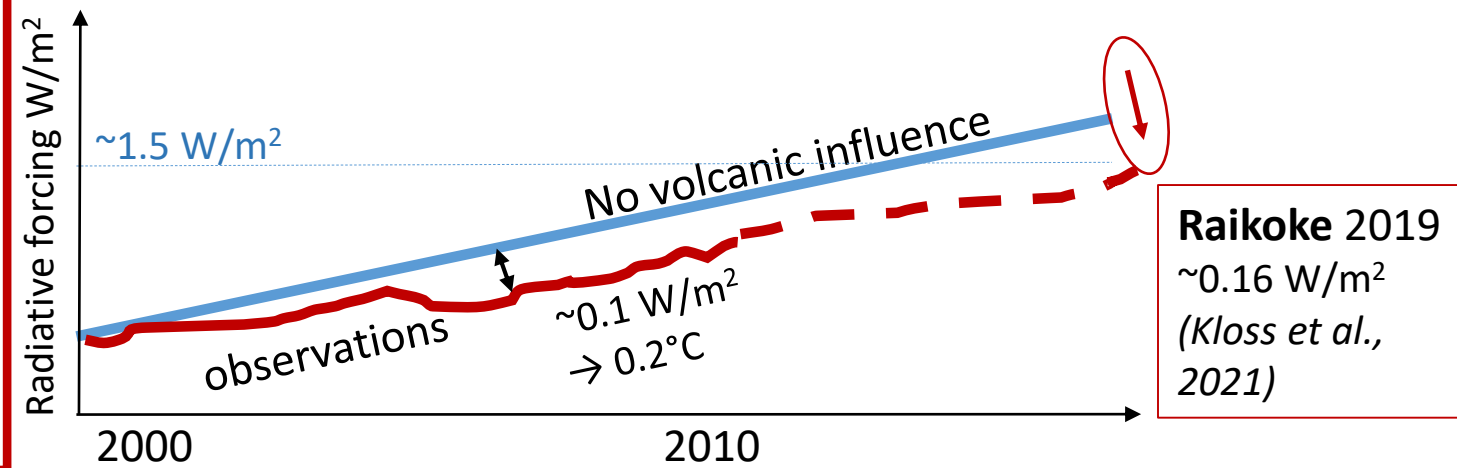
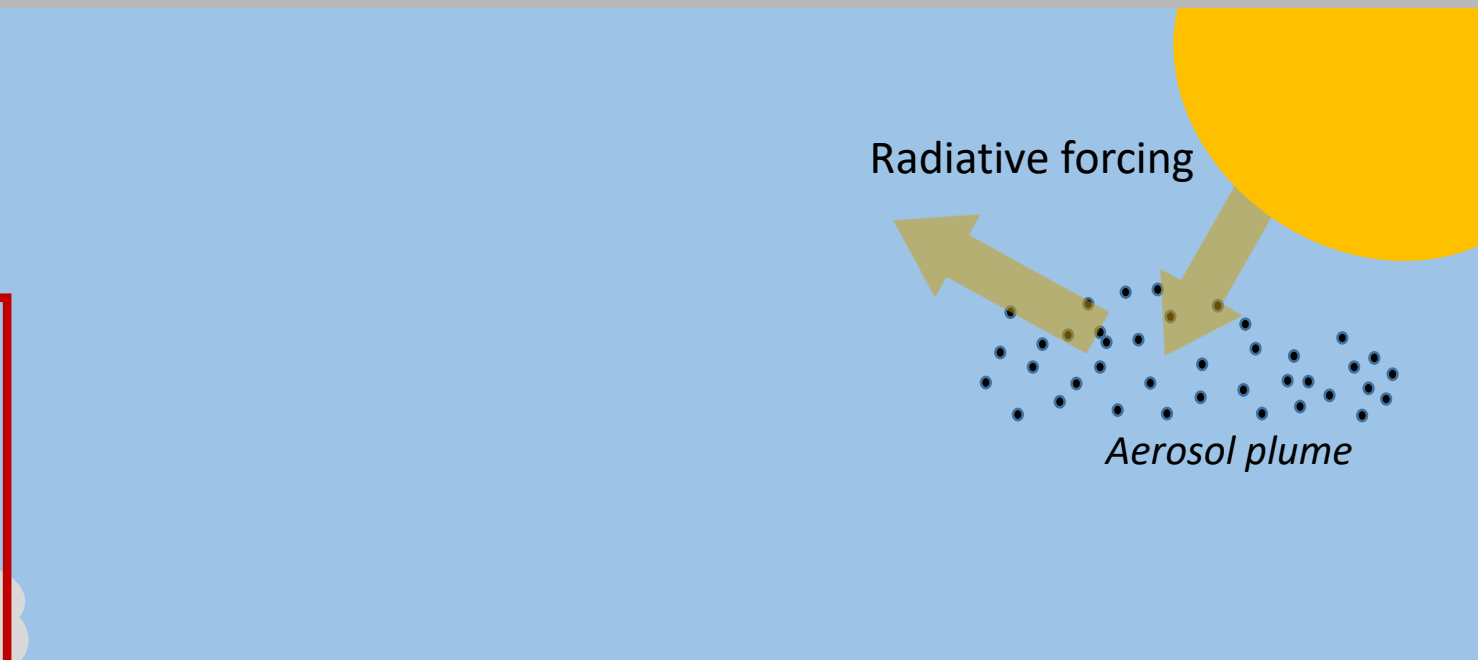
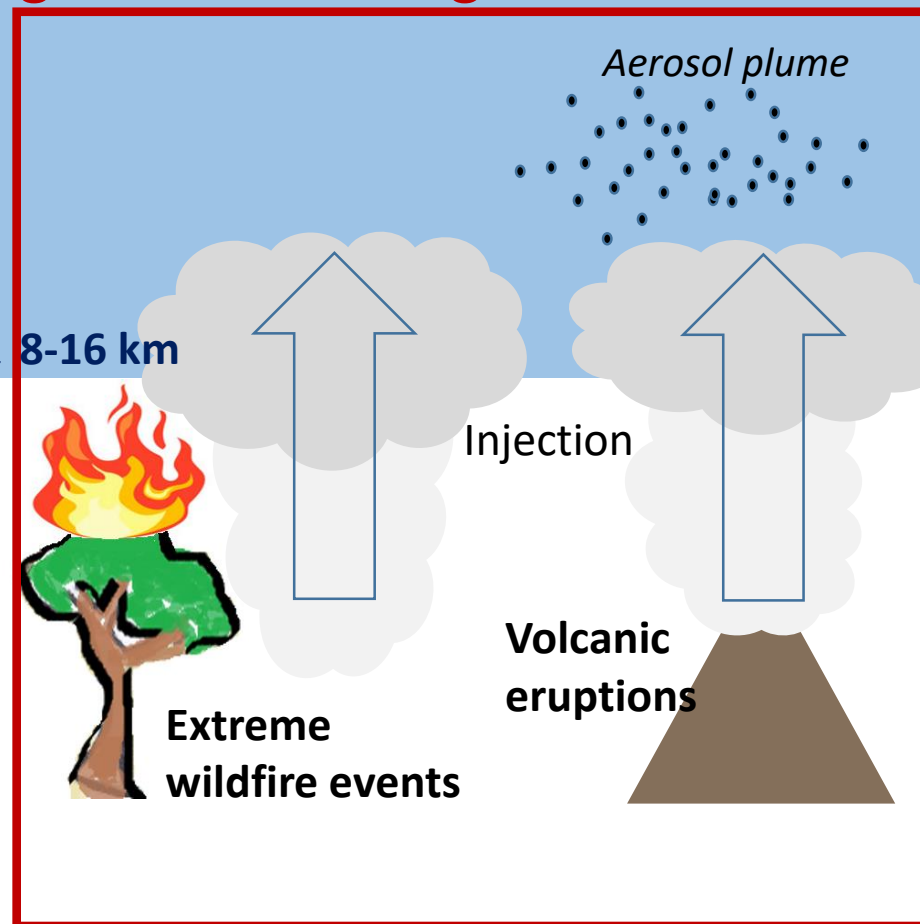


Adapted from Solomon et al., 2011

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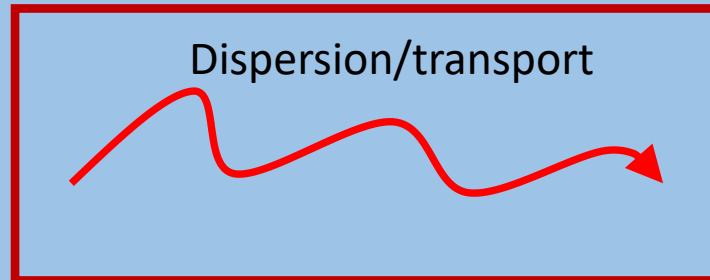
Adapted from Solomon et al., 2011

Introduction

Part 1: Aerosol plumes,
extreme events

~25km altitude

**The climate impact
depends on the plume's
evolution**



Radiative forcing

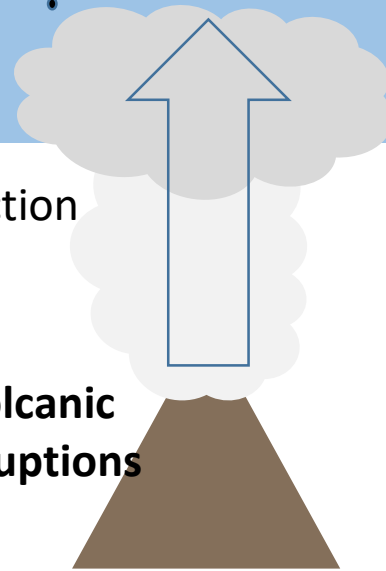
Aerosol plume

8-16 km

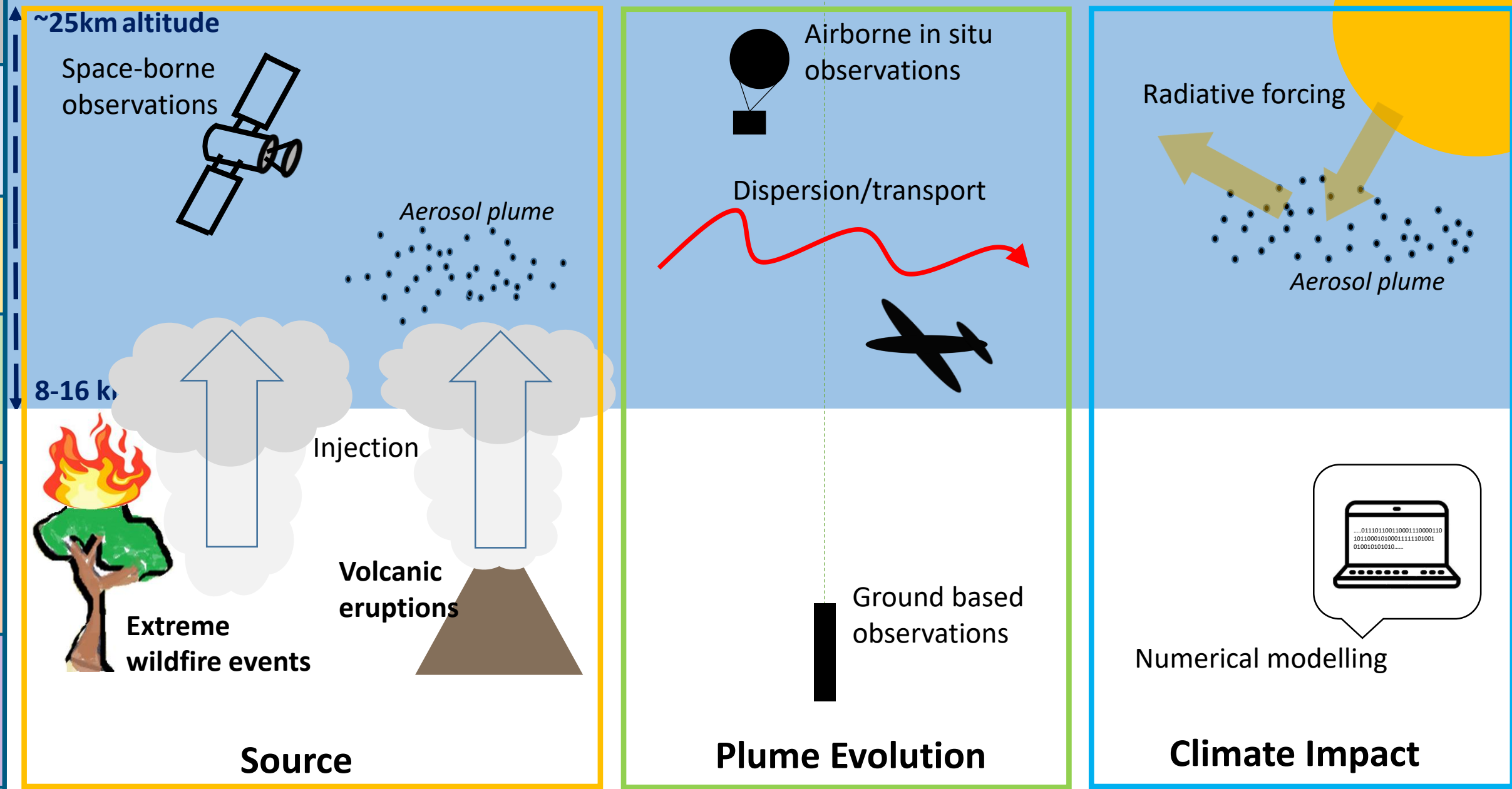
Injection

Volcanic
eruptions

Extreme
wildfire events



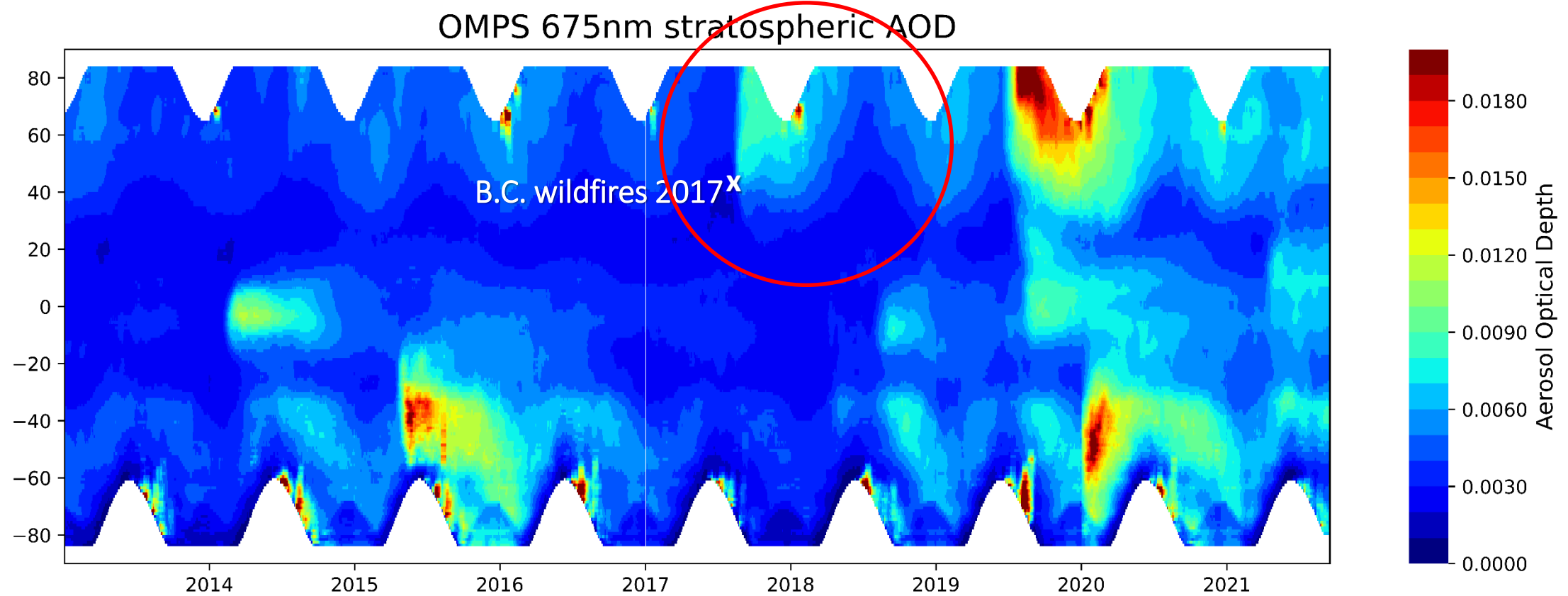
Introduction



B.C. wildfires (July/August 2017)

Part 1: Aerosol plumes, extreme events

19-13547



Introduction

B.C.
wildfires

Ambae

Raikoke &
Ulawun

Australian
wildfires

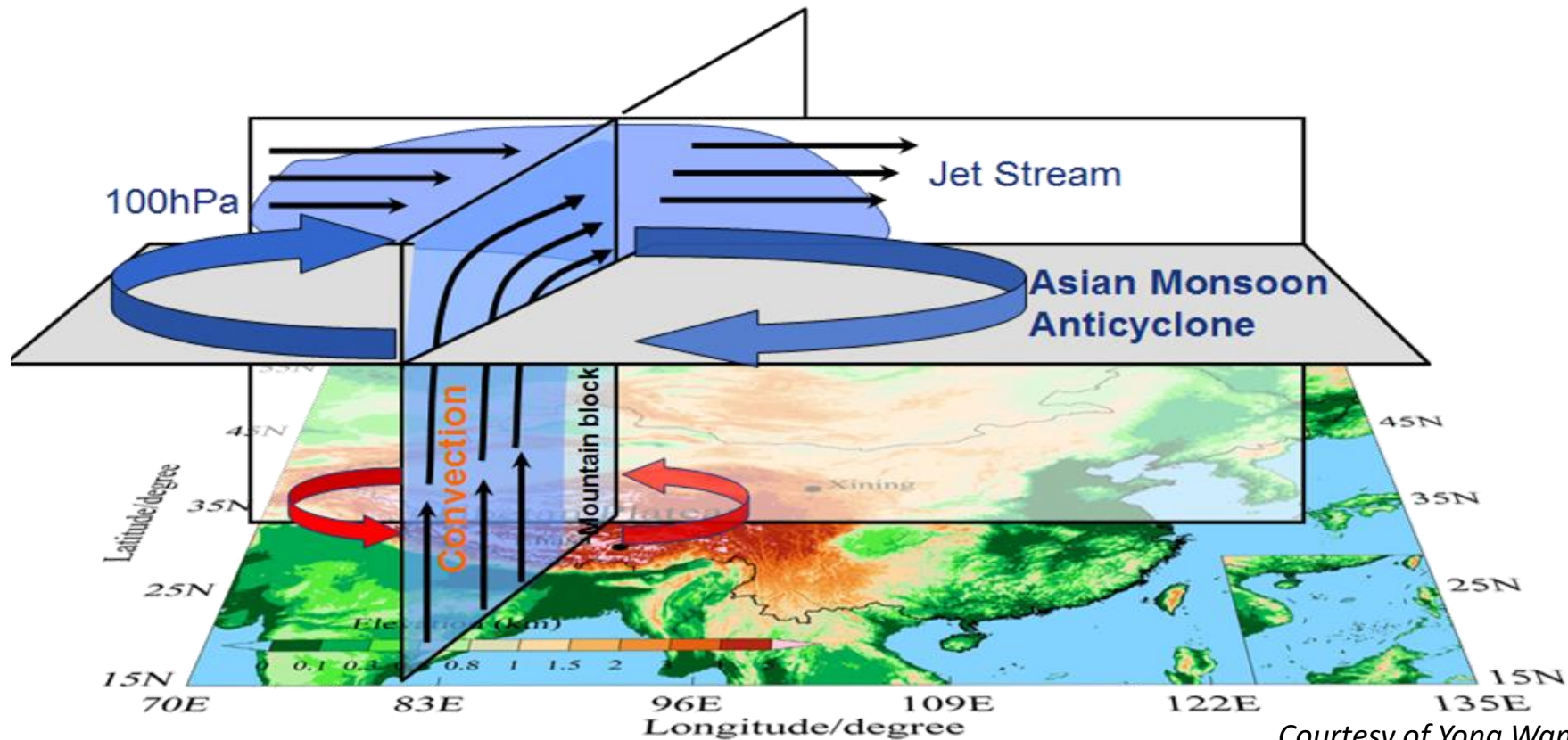
AOD

Asian Tropopause Aerosol Layer

→ Asian Monsoon Anticyclone (AMA)

Part 1: Aerosol plumes,
extreme events

- Effective upward transport of tropospheric tracers and aerosols to high altitudes
- Strongly isolated anticyclone up to 18 km, with elevated concentrations of tropospheric tracers and aerosols
- Asian monsoon season: June to August

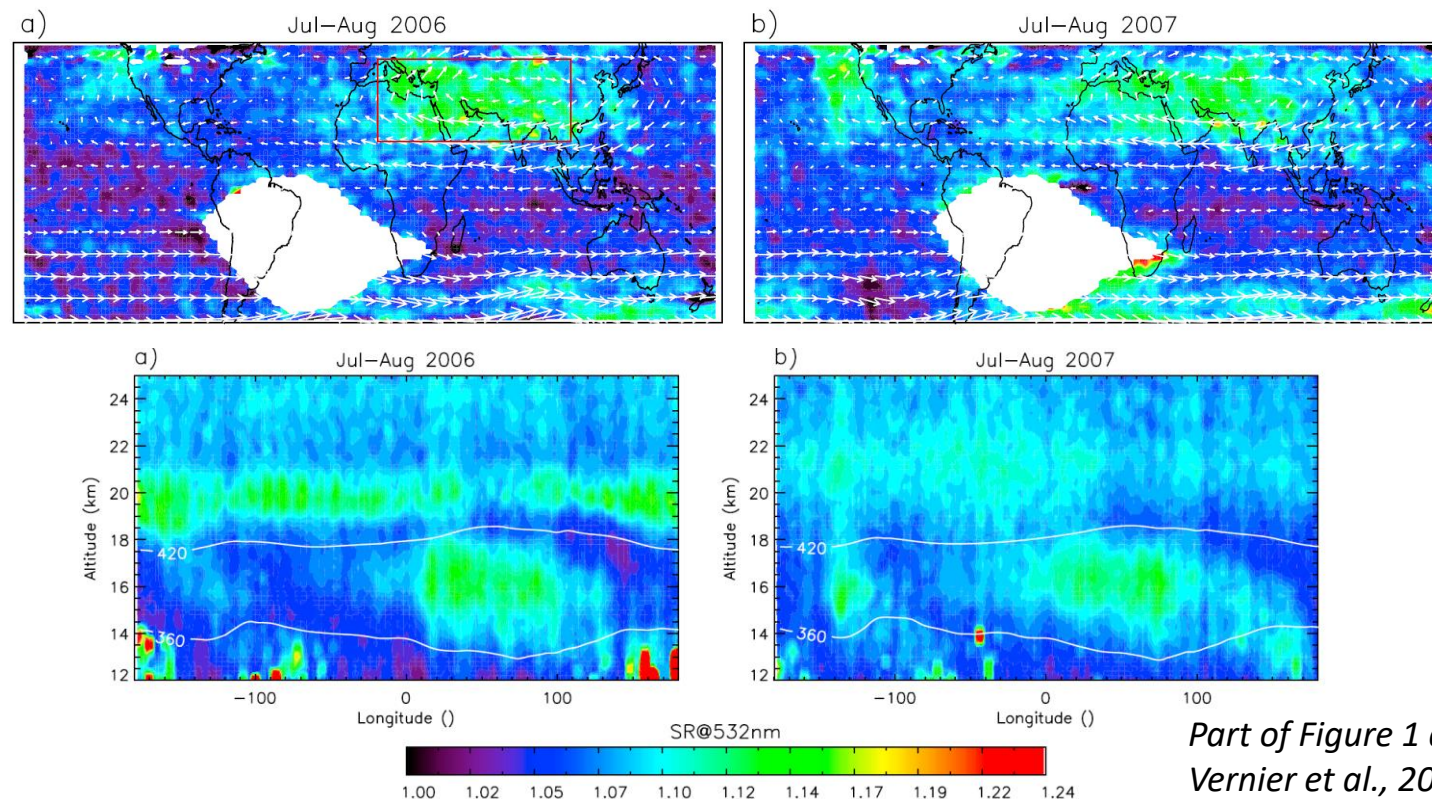


Asian Tropopause Aerosol Layer

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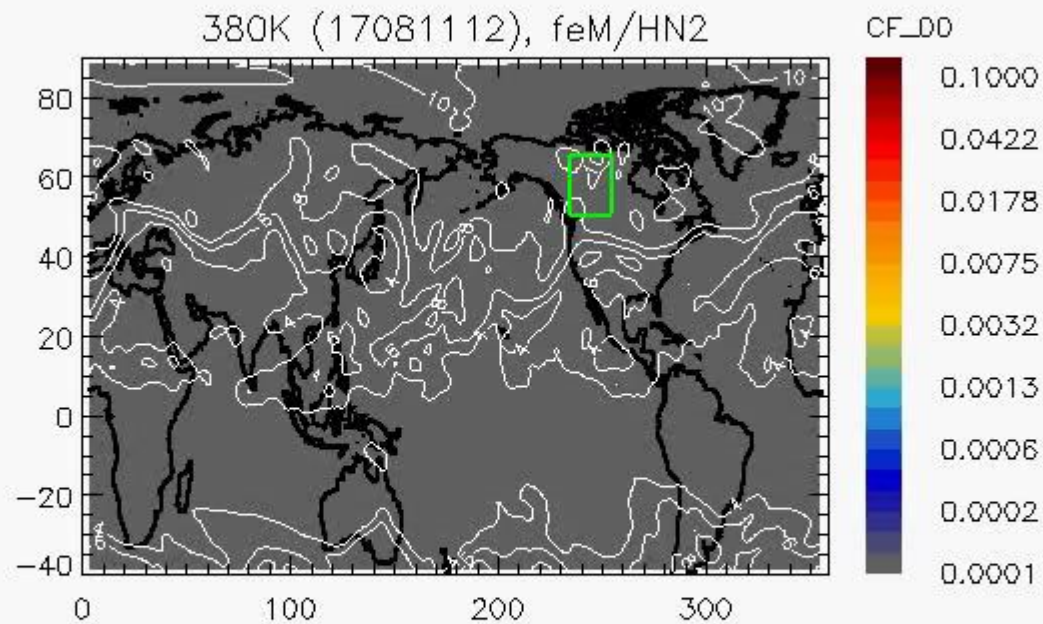
First description of the ATAL: CALIOP Scattering Ratio



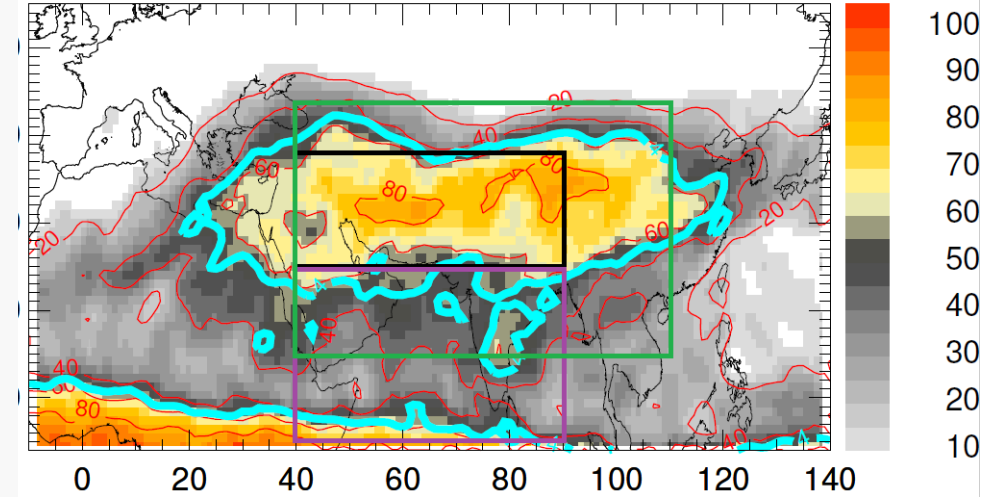
Part of Figure 1 and 3 from
Vernier et al., 2011 (GRL)

B.C. wildfires (July/August 2017)

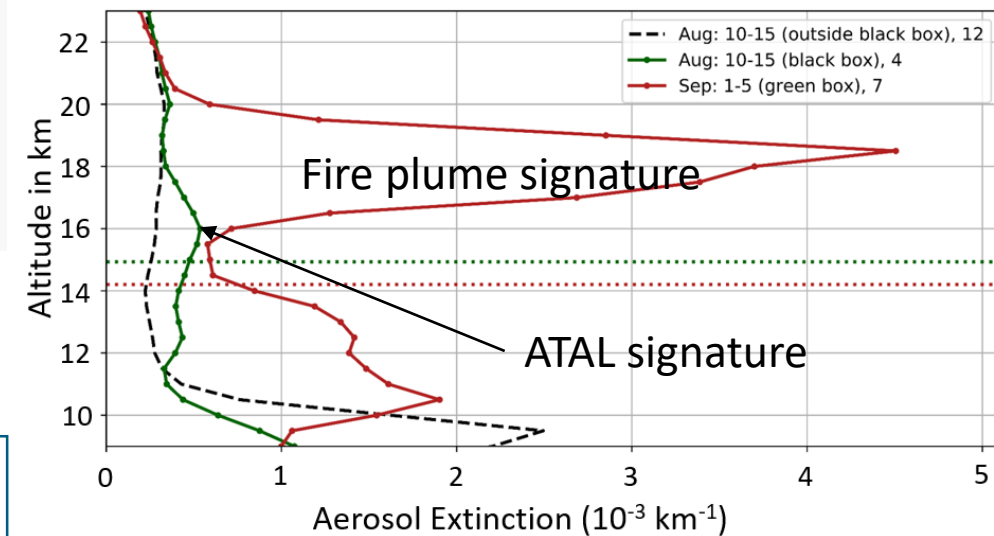
Part 1: Aerosol plumes, extreme events



Kloss et al., 2019 ACP: 19-13547
PV < 4.0 PVU occurrence (380K) Aug/Sep 2017 %/days



SAGE III mean profiles in 2017 (521 nm)



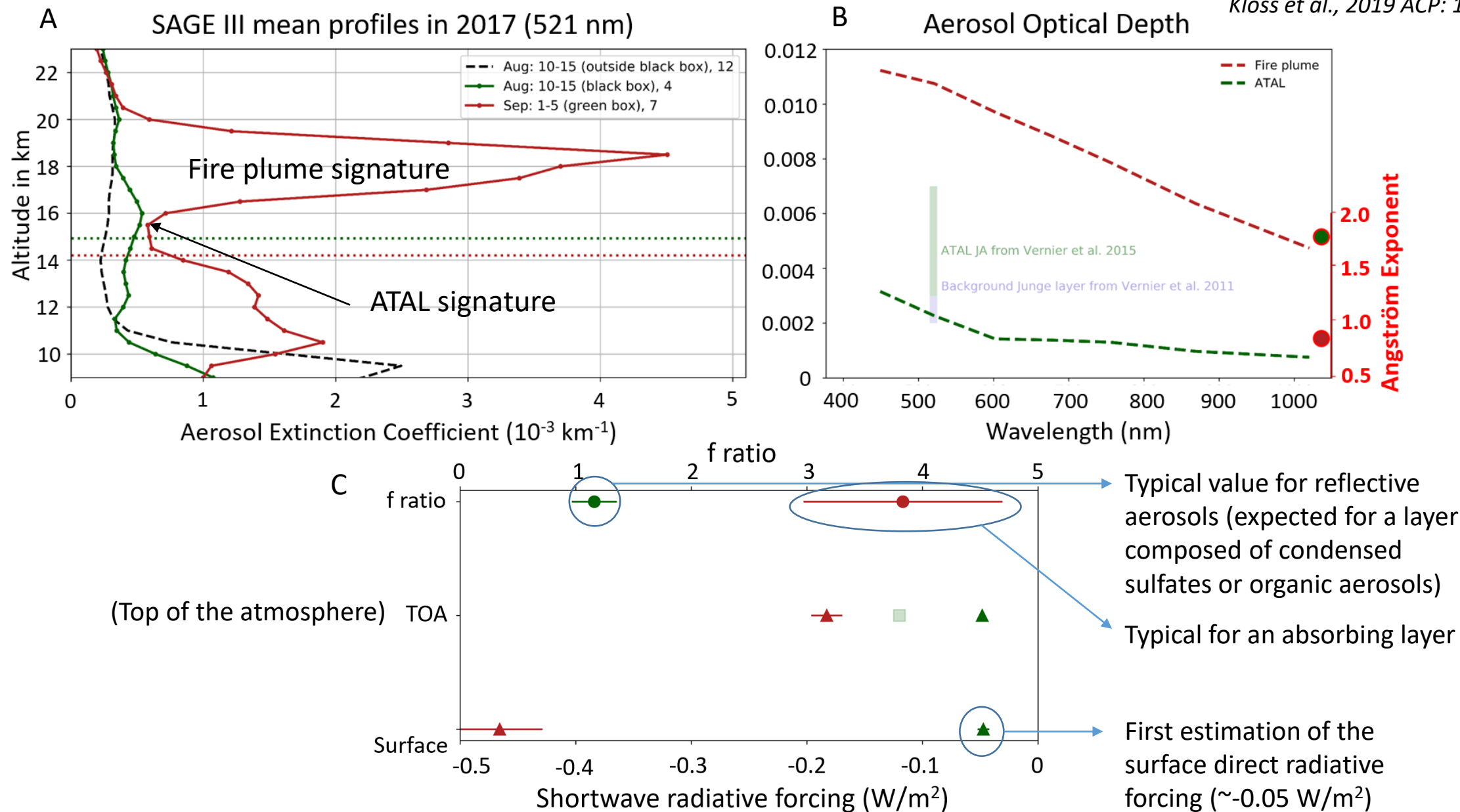
The circulation around the Asian monsoon anticyclone as a transport mechanism for fire plumes towards the tropics

B.C. wildfires (July/August 2017)

→ Radiative forcing: based on SAGE III/ISS observations

Part 1: Aerosol plumes, extreme events

Kloss et al., 2019 ACP: 19-13547

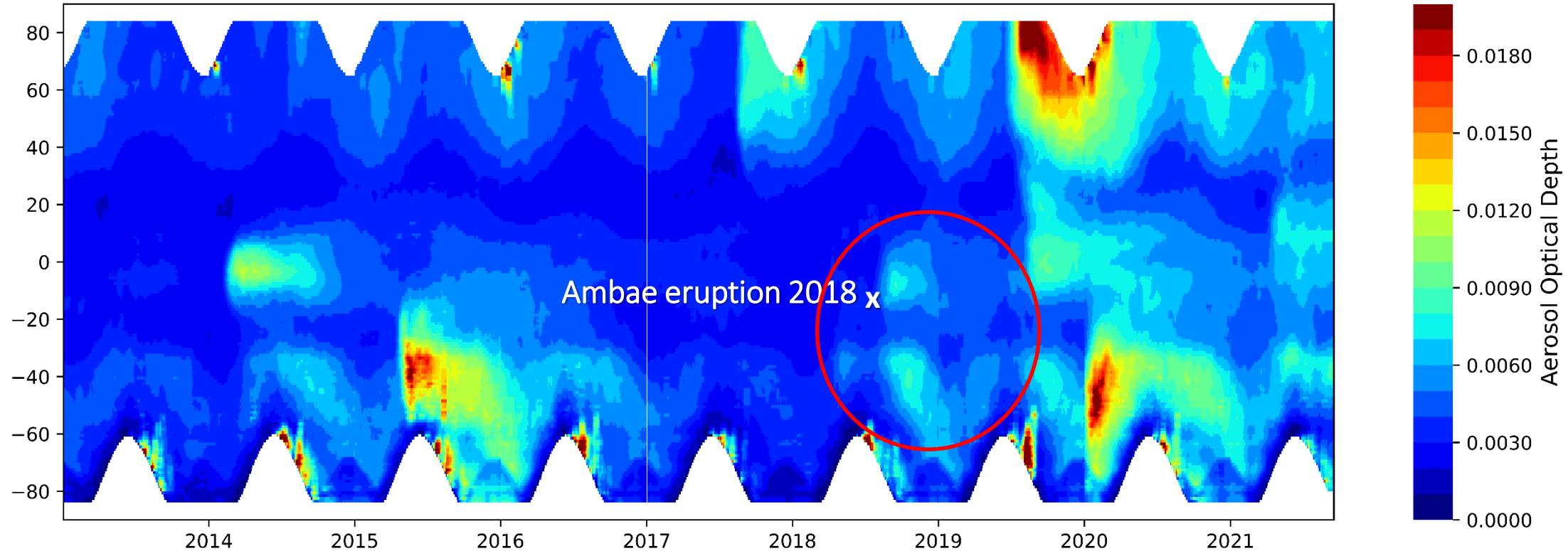


Ambae eruption (April/July 2018)

→ 2 stratospheric eruptions at Ambae 2018

Part 1: Aerosol plumes,
extreme events

OMPS 675nm stratospheric AOD



releans.fr

Ambae eruption (April/July 2018)

→ 2 stratospheric eruptions at Ambae 2018

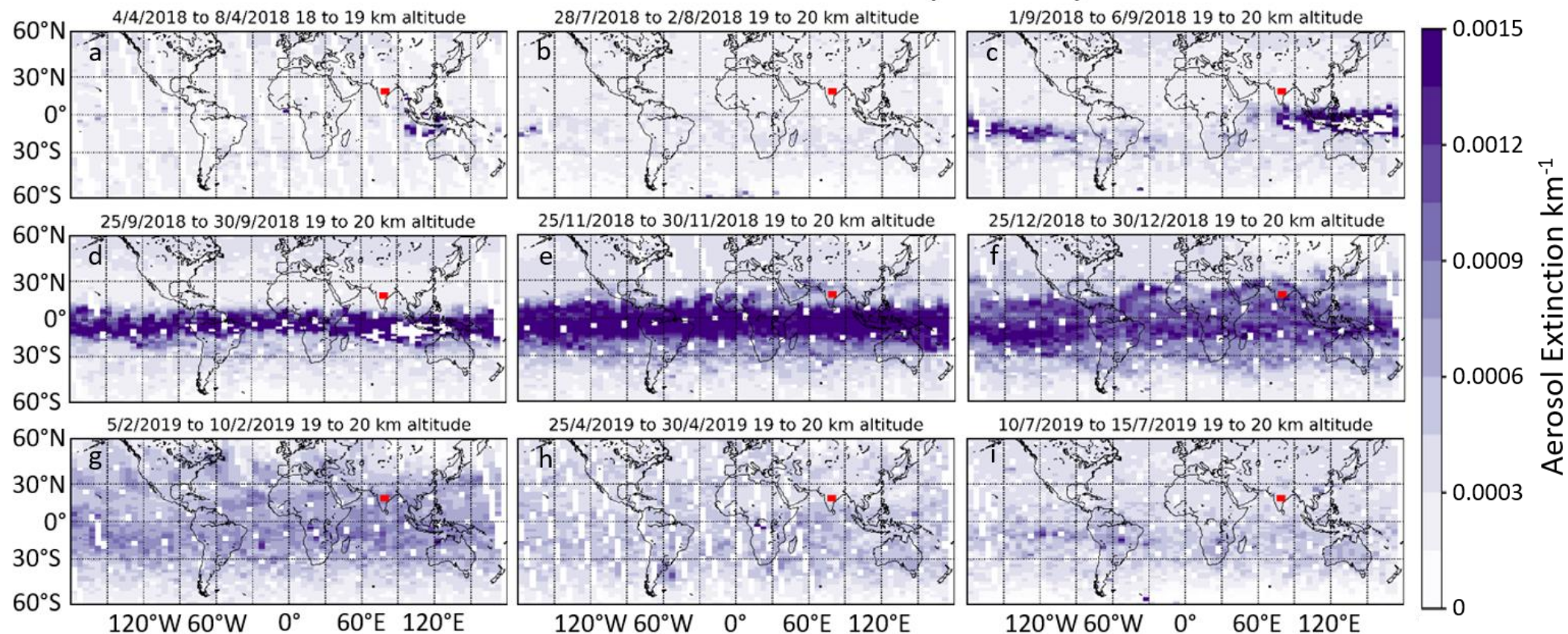
Part 1: Aerosol plumes,
extreme events



- Tropical
- Stratospheric
- Widely overlooked
- Impacting both hemispheres

Kloss *et al.*, 2020 JGR
→ corinna.kloss@cnr-orleans.fr

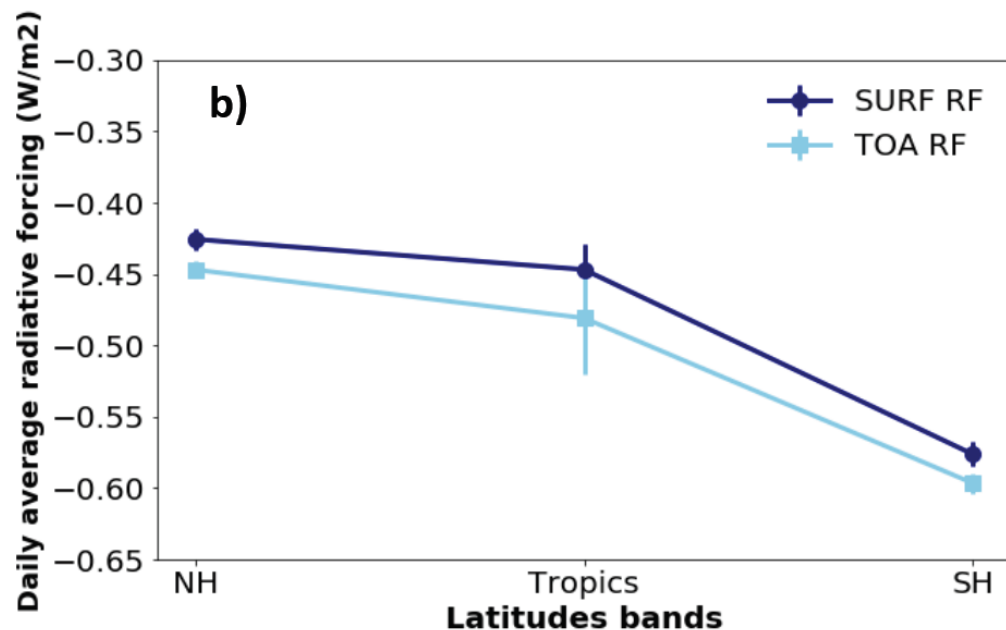
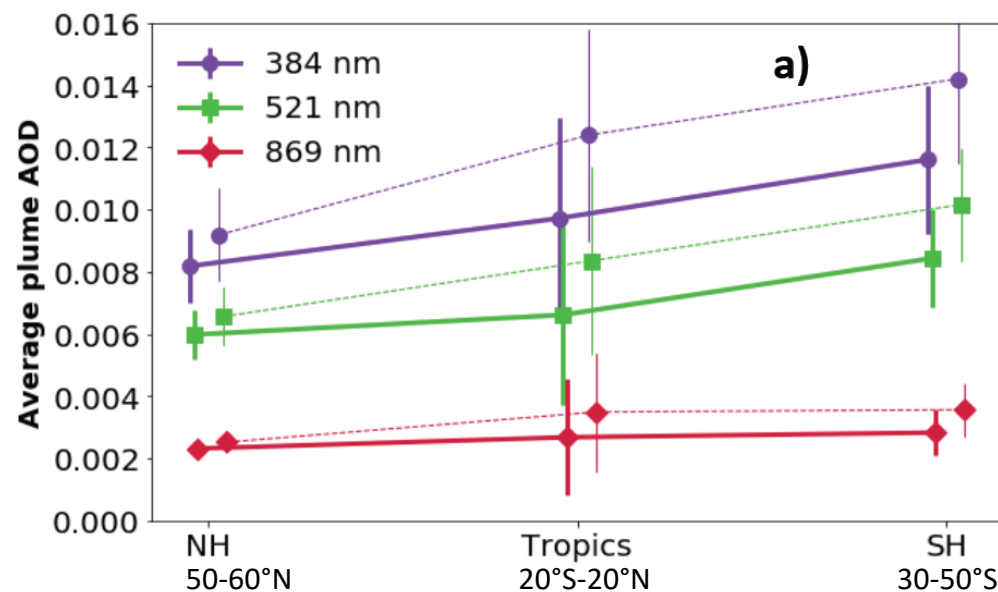
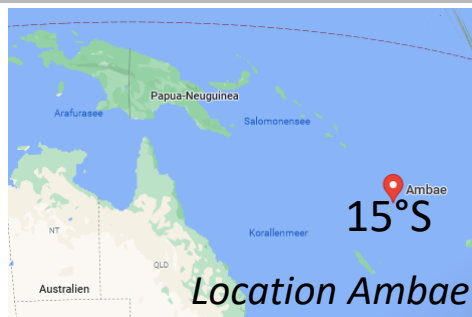
OMPS Aerosol Extinction (675 nm)



Ambae eruption (April/July 2018)

→ Radiative forcing: based on SAGE III/ISS observations

Part 1: Aerosol plumes,
extreme events



Kloss et al., 2020 JGR

→ corinna.kloss@cnr-orleans.fr

Dashed: total stratospheric AOD

Solid: plume AOD

AOD: slightly smaller, but comparable to previous, well studied volcanic eruptions (Kasatochi, Sarychev etc.)

Global radiative forcing

~-0.45 to -0.6 W/m²

→ comparable to RF from Kasatochi, Sarychev and Nabro (between -0.4 and -0.5 W/m²)

Raikoke/Ulawun eruption (Jun/Aug 2019)

Part 1: Aerosol plumes,
extreme events

Kloss et al., 2021 ACP: 21-535

Introduction

B.C.
wildfires

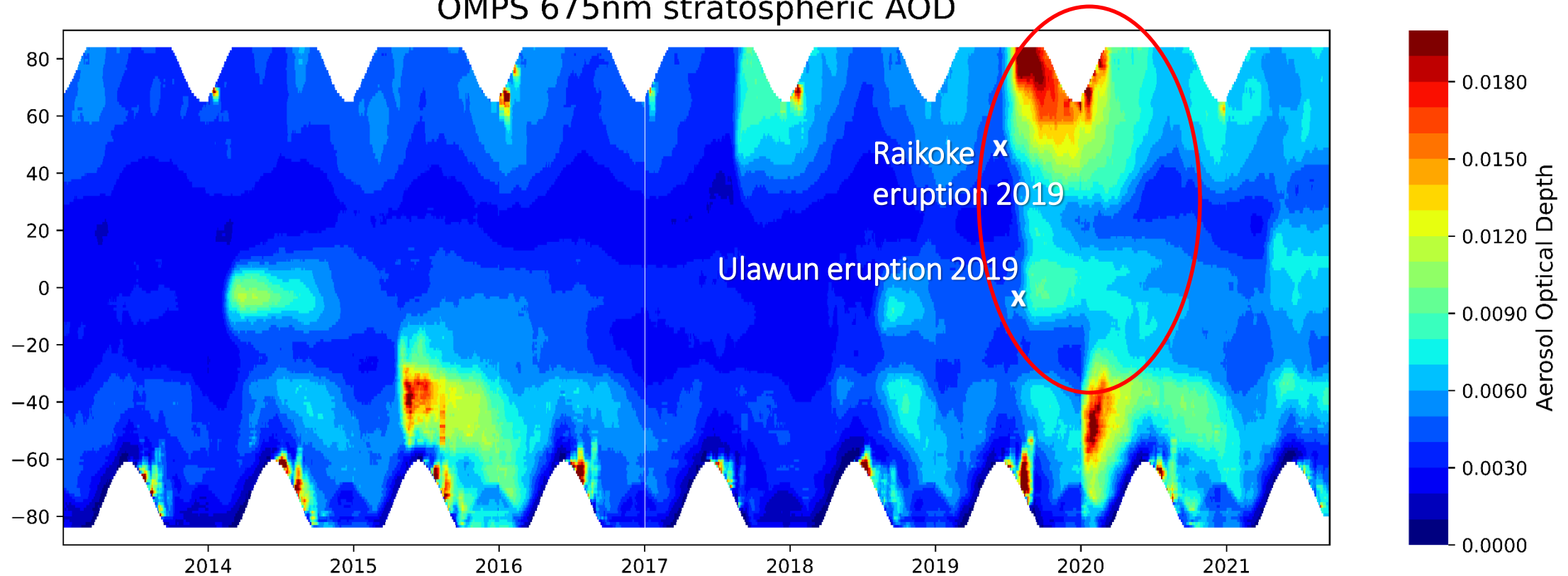
Ambae

**Raikoke &
Ulawun**

Australian
wildfires

AOD

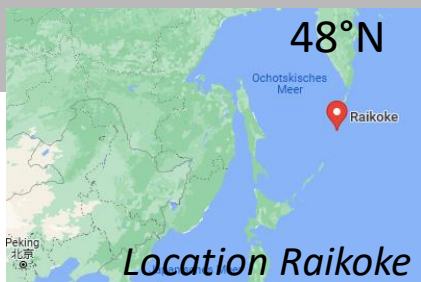
OMPS 675nm stratospheric AOD



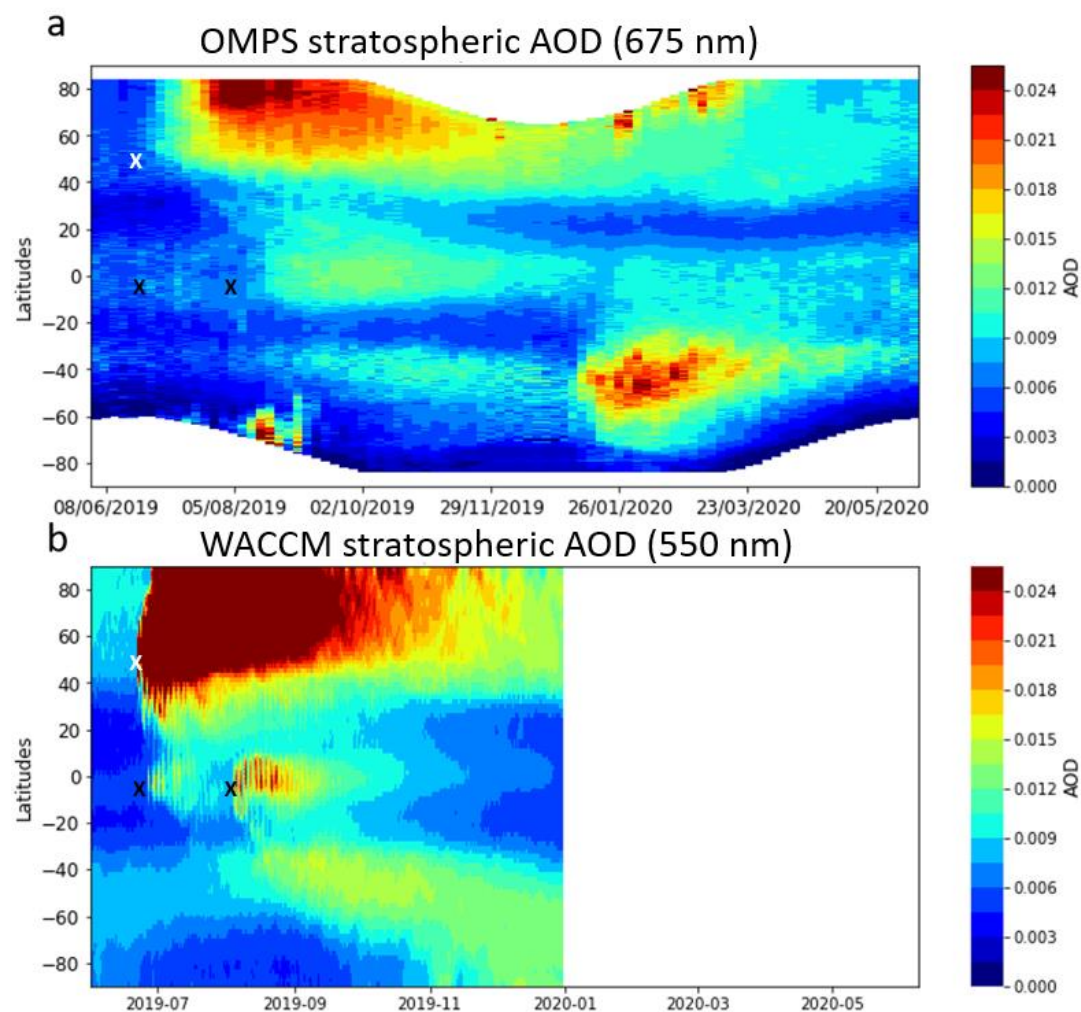
Raikoke/Ulawun eruption (Jun/Aug 2019)

Part 1: Aerosol plumes,
extreme events

Kloss et al., 2021 ACP: 21-535



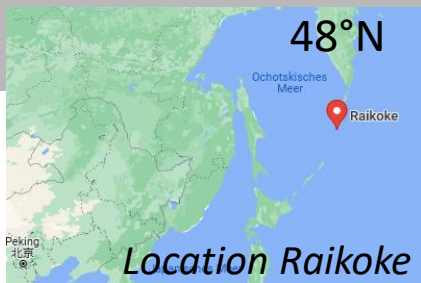
Model simulations do not match well with observations



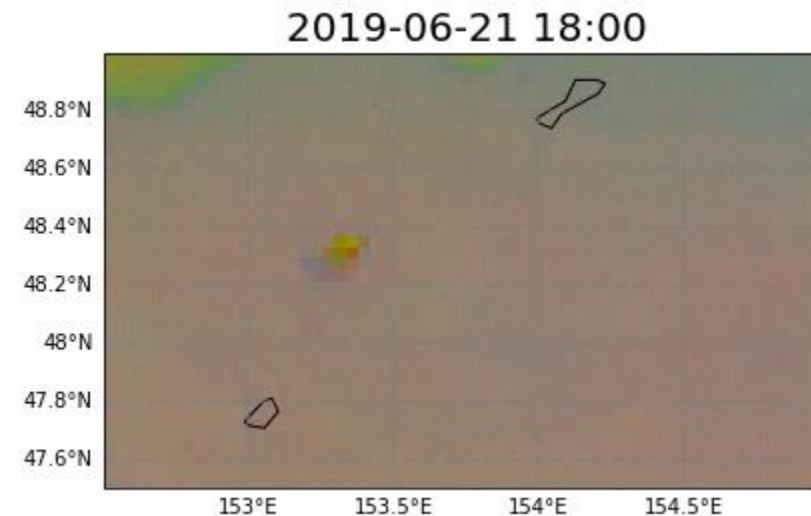
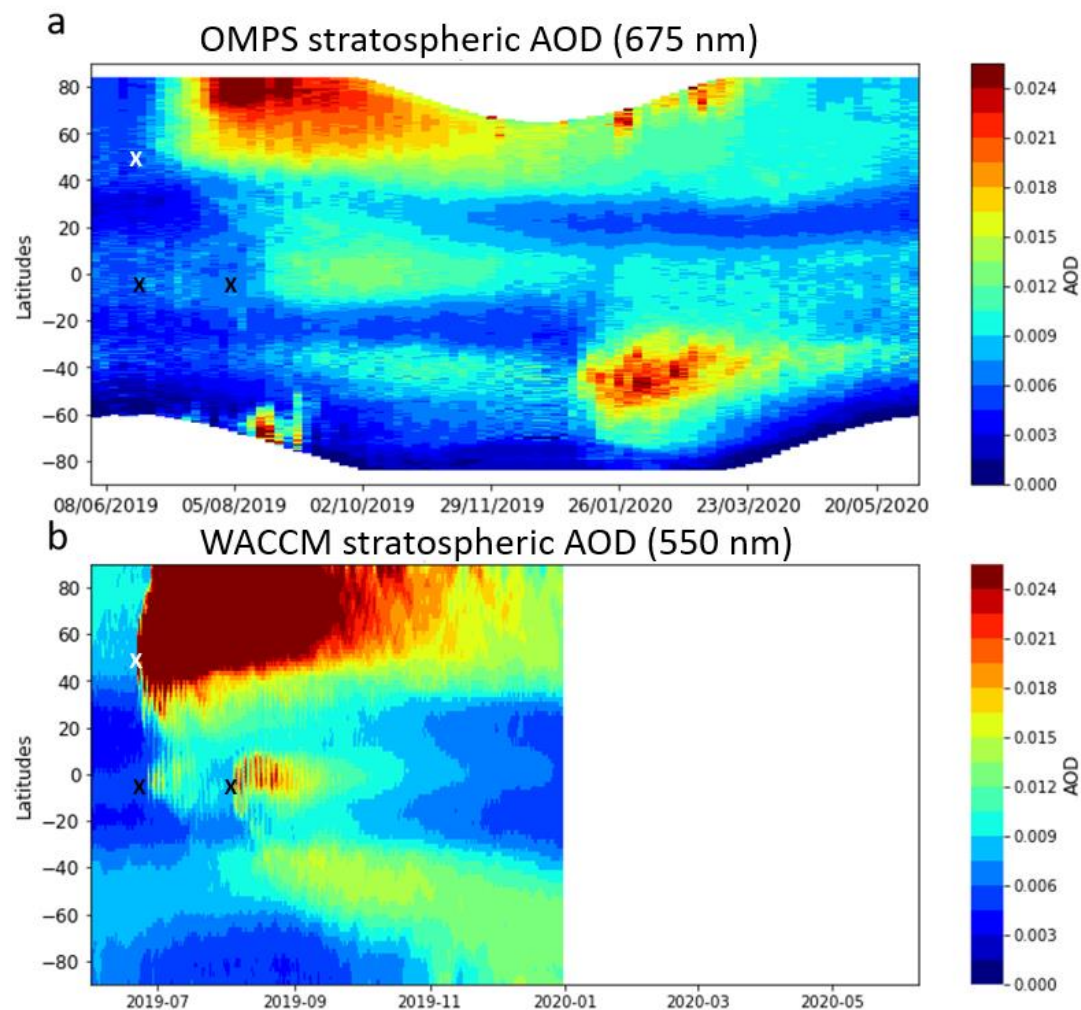
Raikoke/Ulawun eruption (Jun/Aug 2019)

Part 1: Aerosol plumes,
extreme events

Kloss et al., 2021 ACP: 21-535



Model simulations do not match well with observations, possible reasons:

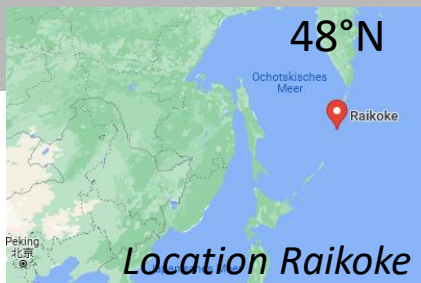


- Complex Raikoke injection sequence
- Model simulations do not contain ash
'the role of volcanic ash'

Raikoke/Ulawun eruption (Jun/Aug 2019)

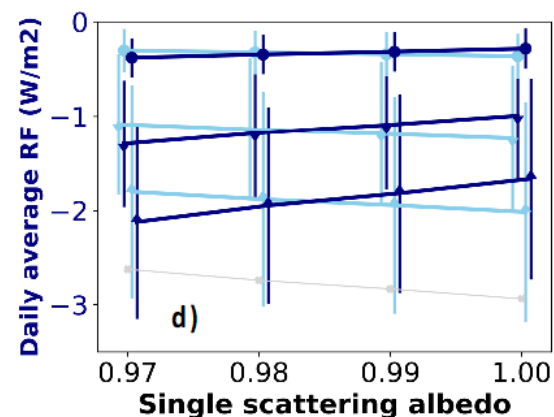
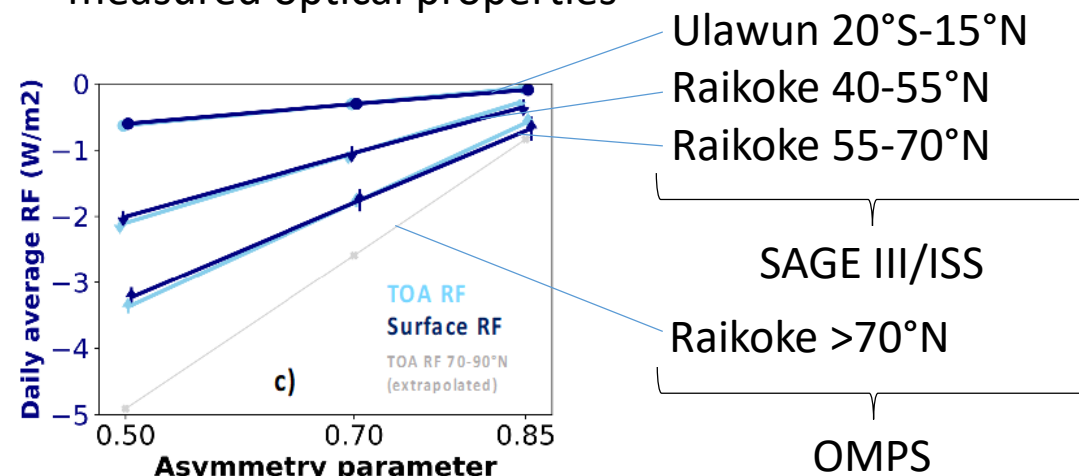
Part 1: Aerosol plumes, extreme events

Kloss et al., 2021 ACP: 21-535



Radiative forcing with UVSPEC: Pasquale Sellitto at LISA, Paris

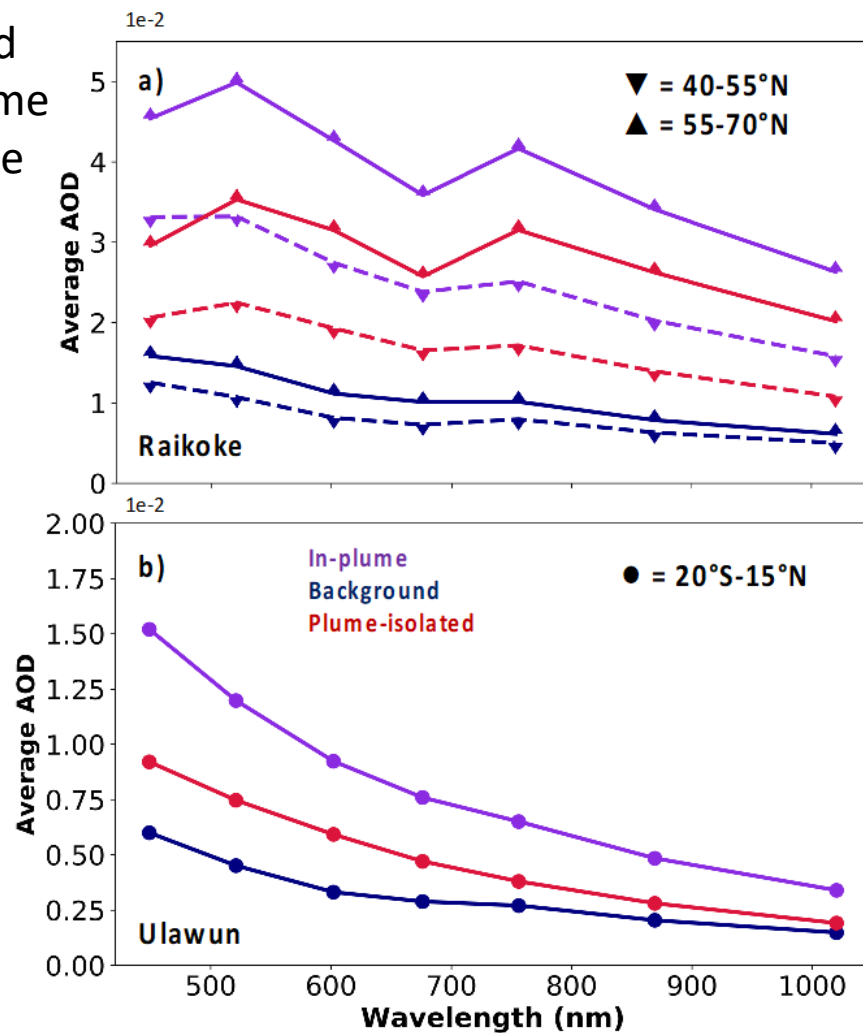
Assumptions on two non-measured optical properties



Clear sky RF Raikoke:
~**-0.38 W/m²**
All sky RF Raikoke:
~**-0.11 to -0.16 W/m²**

Comparable to
Sarychev

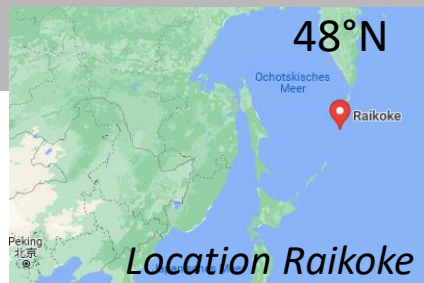
Blue: background
Purple: with plume
Red: purple - blue



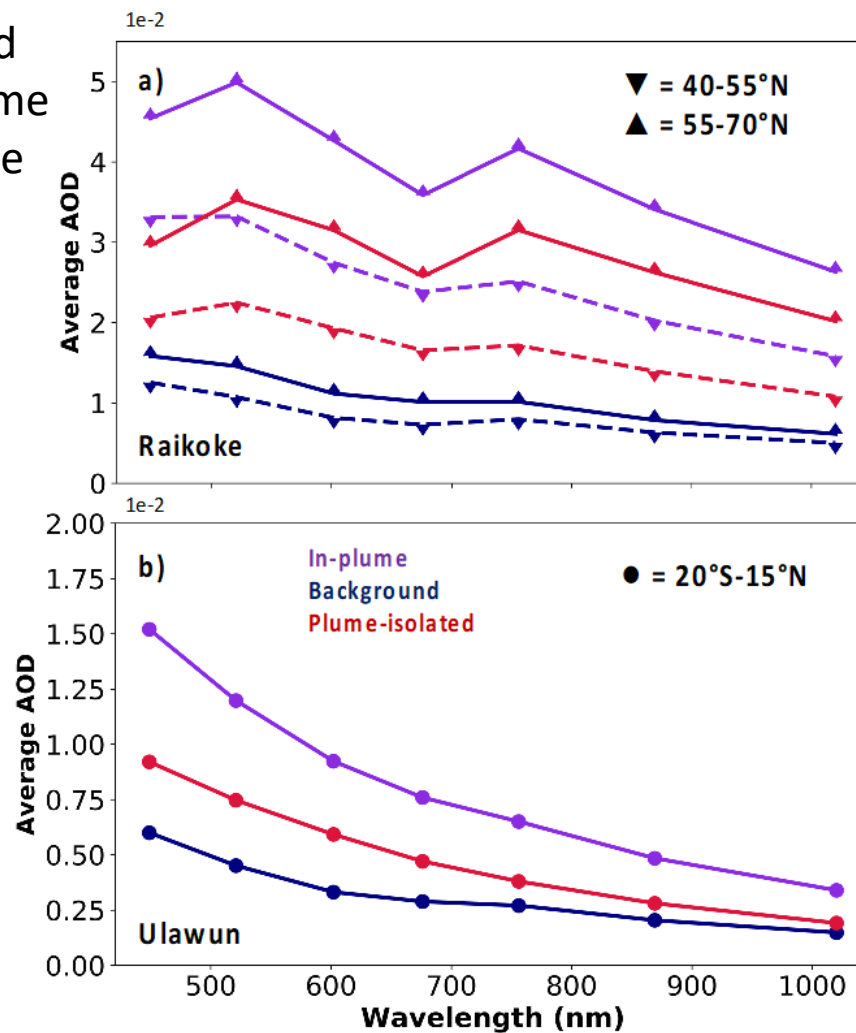
Raikoke/Ulawun eruption (Jun/Aug 2019)

Part 1: Aerosol plumes, extreme events

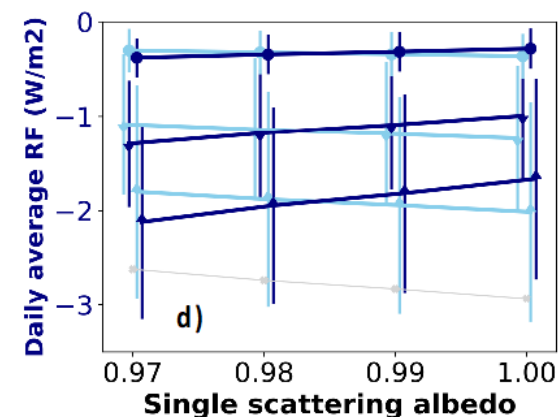
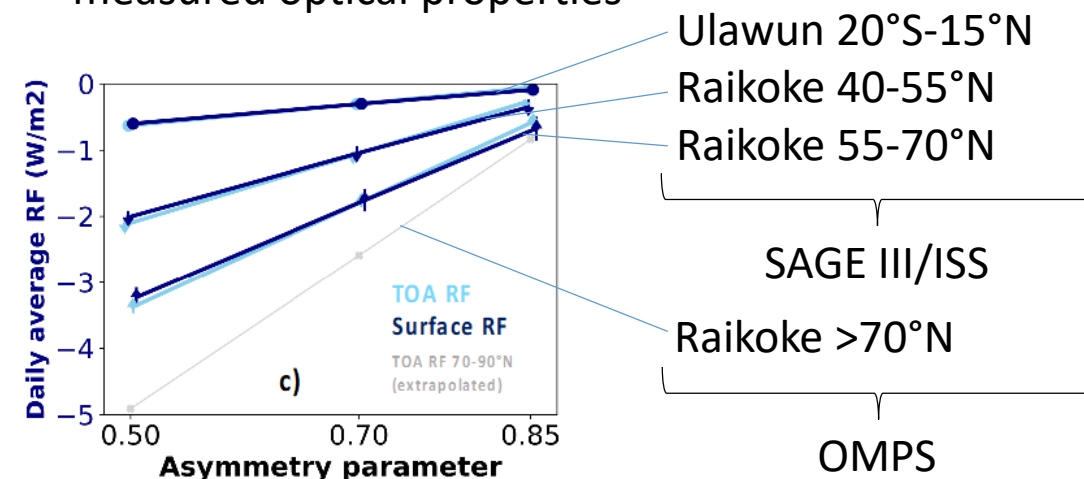
Kloss et al., 2021 ACP: 21-535



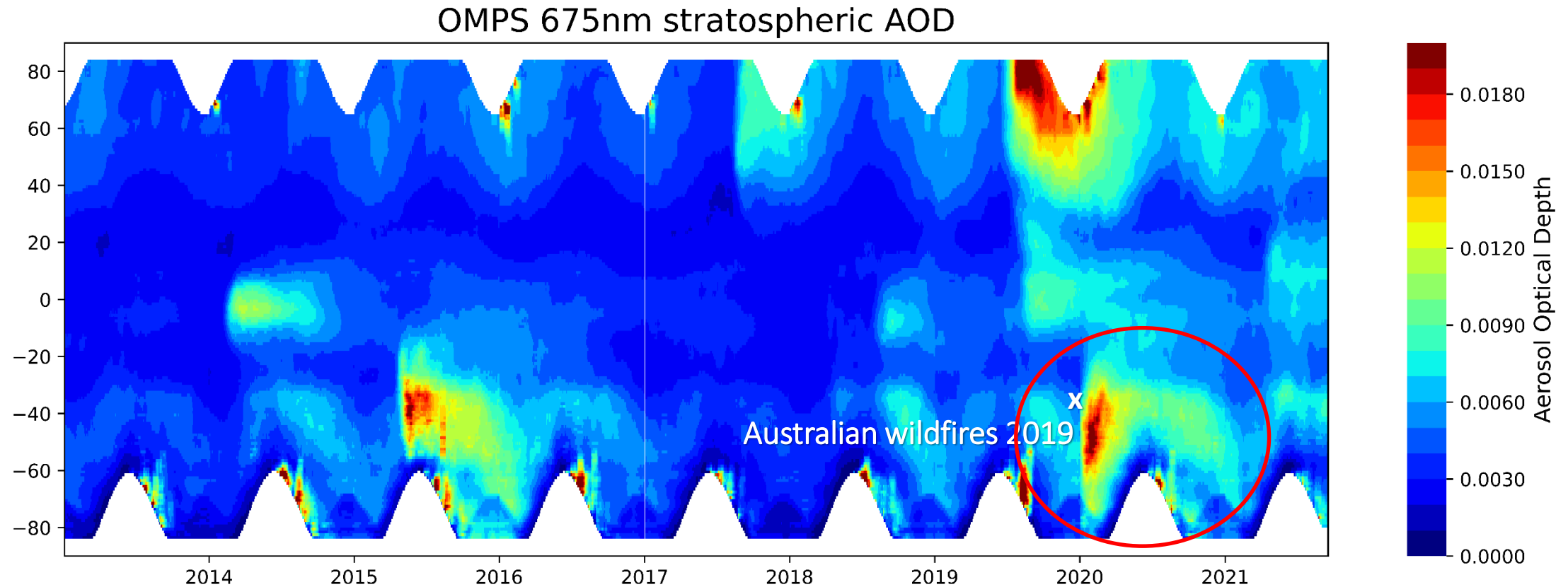
Blue: background
Purple: with plume
Red: purple - blue



Assumptions on two non-measured optical properties



Clear sky RF Ulawun:
 $\sim -0.1 \text{ W/m}^2$
 All sky RF Ulawun:
 $\sim -0.04 \text{ W/m}^2$



Australian wildfires (Dec 2019/ Jan 2020)

Part 1: Aerosol plumes,
extreme events

Kloss et al., 2021 Frontiers

Introduction

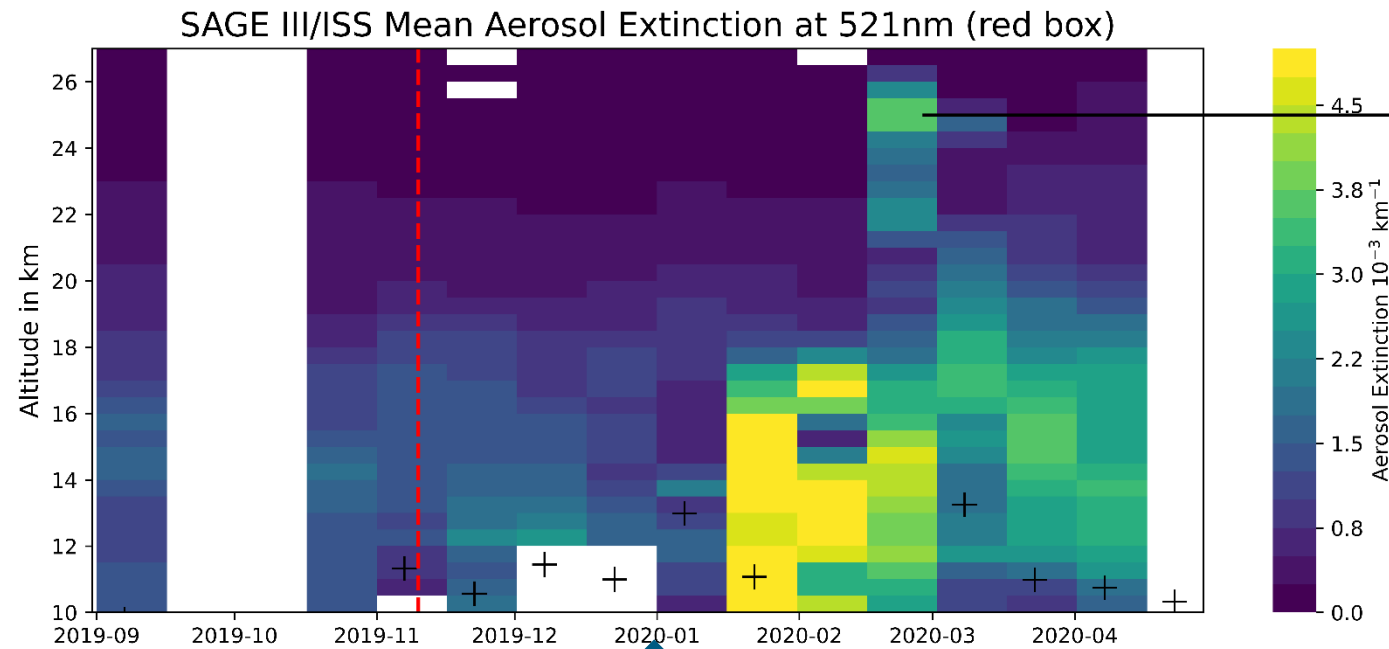
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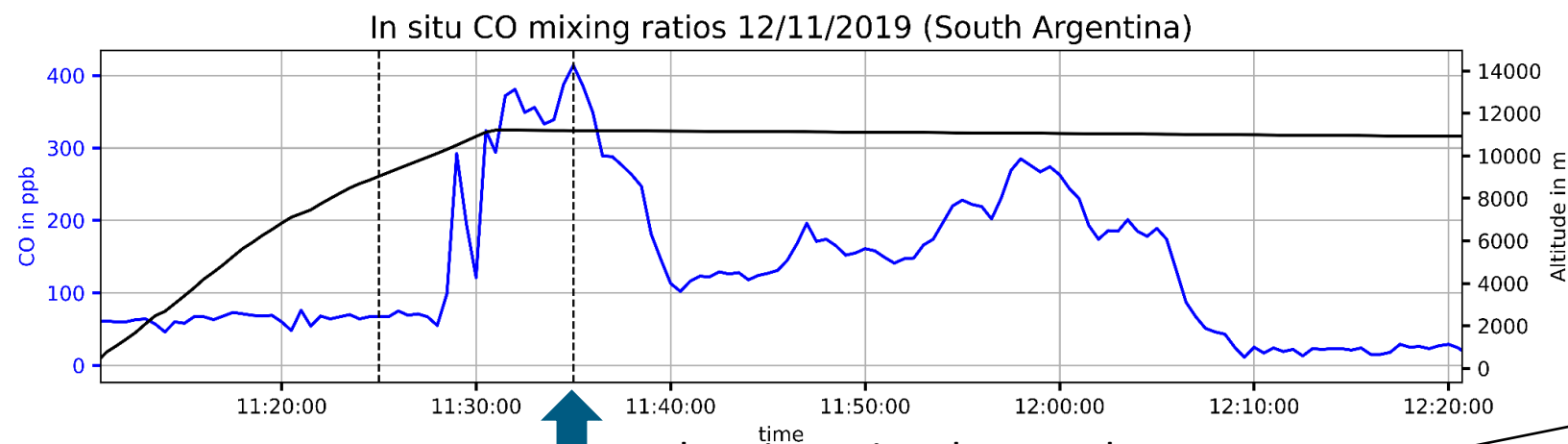


Self-maintaining, rising smoke vortex

Commun. Earth Environ.: Khaykin, 2020
Project ASTuS: Bernard Legras (LMD, Paris)

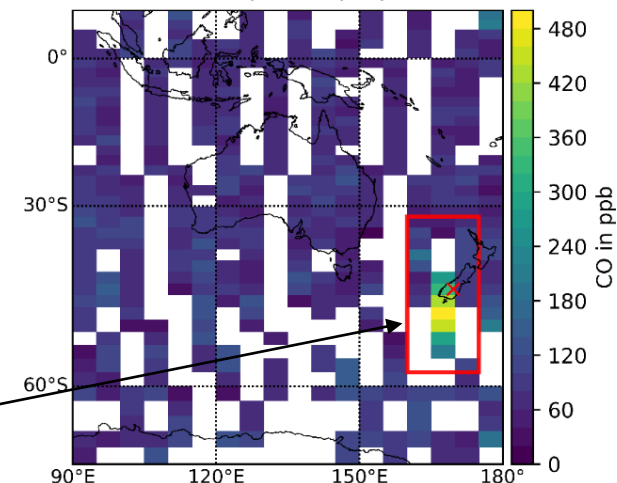
Presentation later today: Jean Paul Vernier

Pyro convection, followed by clear signal in the stratosphere



Back trajectories show path over New Zealand and south western Australia

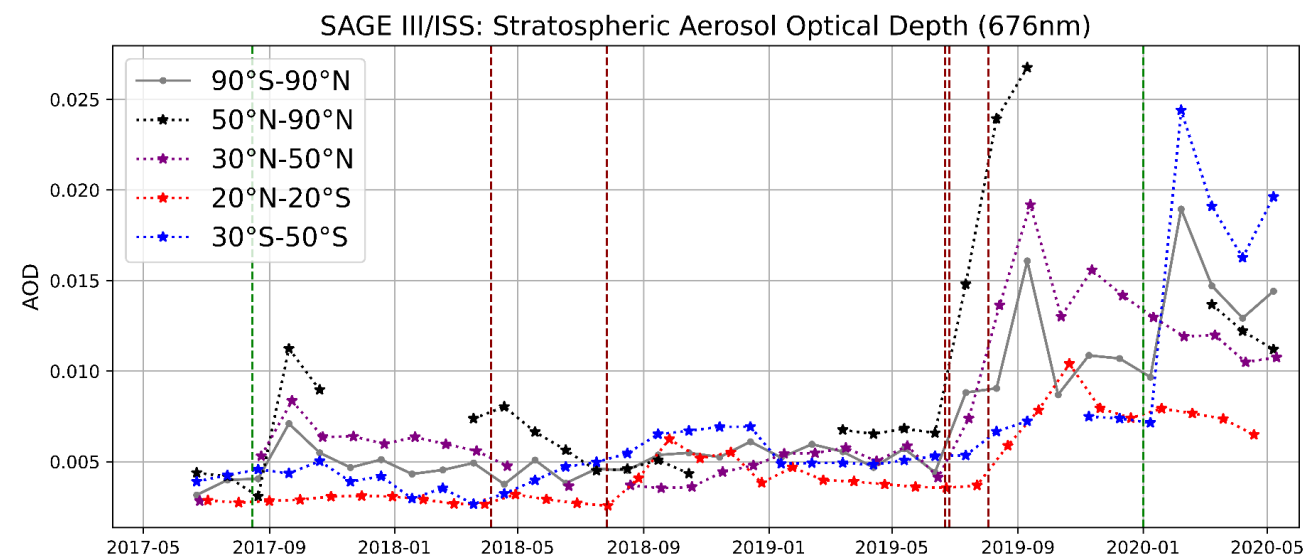
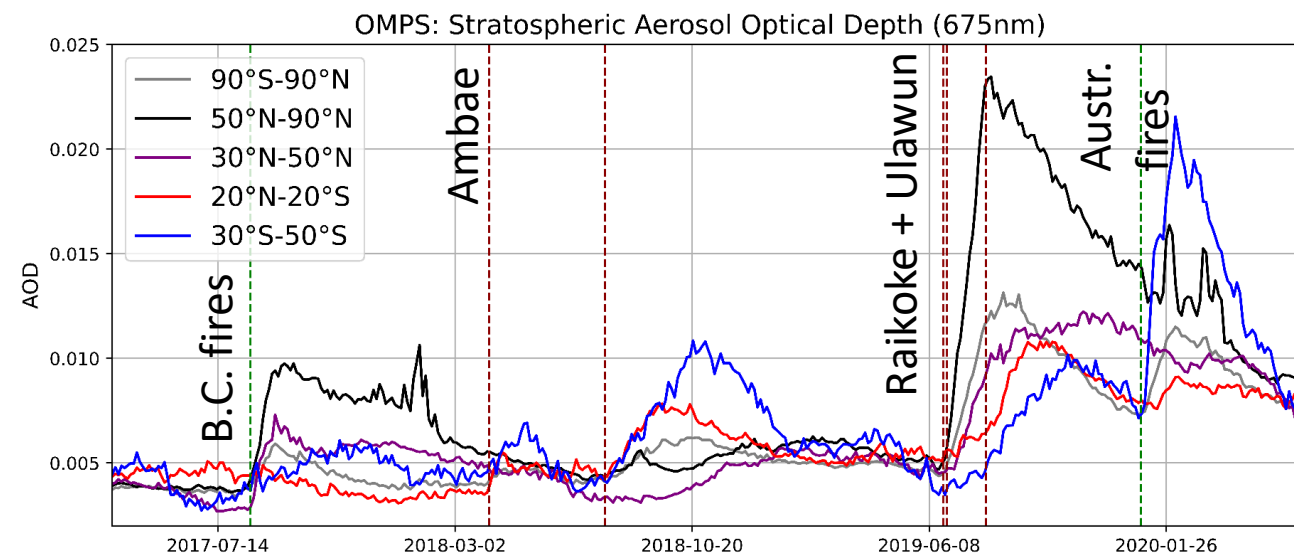
MLS CO: 8/11- 10/11/2019



Stratospheric Aerosol Optical Depth comparison

Part 1: Aerosol plumes, extreme events

- Good comparison between OMPS and SAGE III/ISS
- Slower decrease of enhanced sAOD values after fire events visible
- SAOD increase after the Australian fires increases slower than what OMPS plot shows.
- For the chosen latitude ranges:
biggest impact by Raikoke/Ulawun eruptions (SAGE III/ISS and OMPS)



Overall key points

Stratospheric aerosol plumes from extreme events

- During the past 5 years the global stratosphere was basically always influenced by stratospheric events (volcanic eruptions + extreme fire events)
- Canadian wild fires 2017, Ambae eruption 2018, Raikoke and Ulawun eruptions 2019, Australian fires 2019/2020 and Soufrière eruption 2021
- The Asian monsoon anticyclone as an efficient transport pathway for aerosol plumes from northern extreme fire events towards the tropics
- For the selected latitude bands the Raikoke eruptions had the strongest impact in terms of AOD and radiative forcing