VolcACI Experiment Update

F. Malavelle, T. Yuan,
A. Laakso, T. Takemura, D. Neubauer,
I.-H. Karset, D. Watson-Parris
and many more!

Aerocom 2019 annual meeting, Barcelona

UNIVERSITY OF EXETER

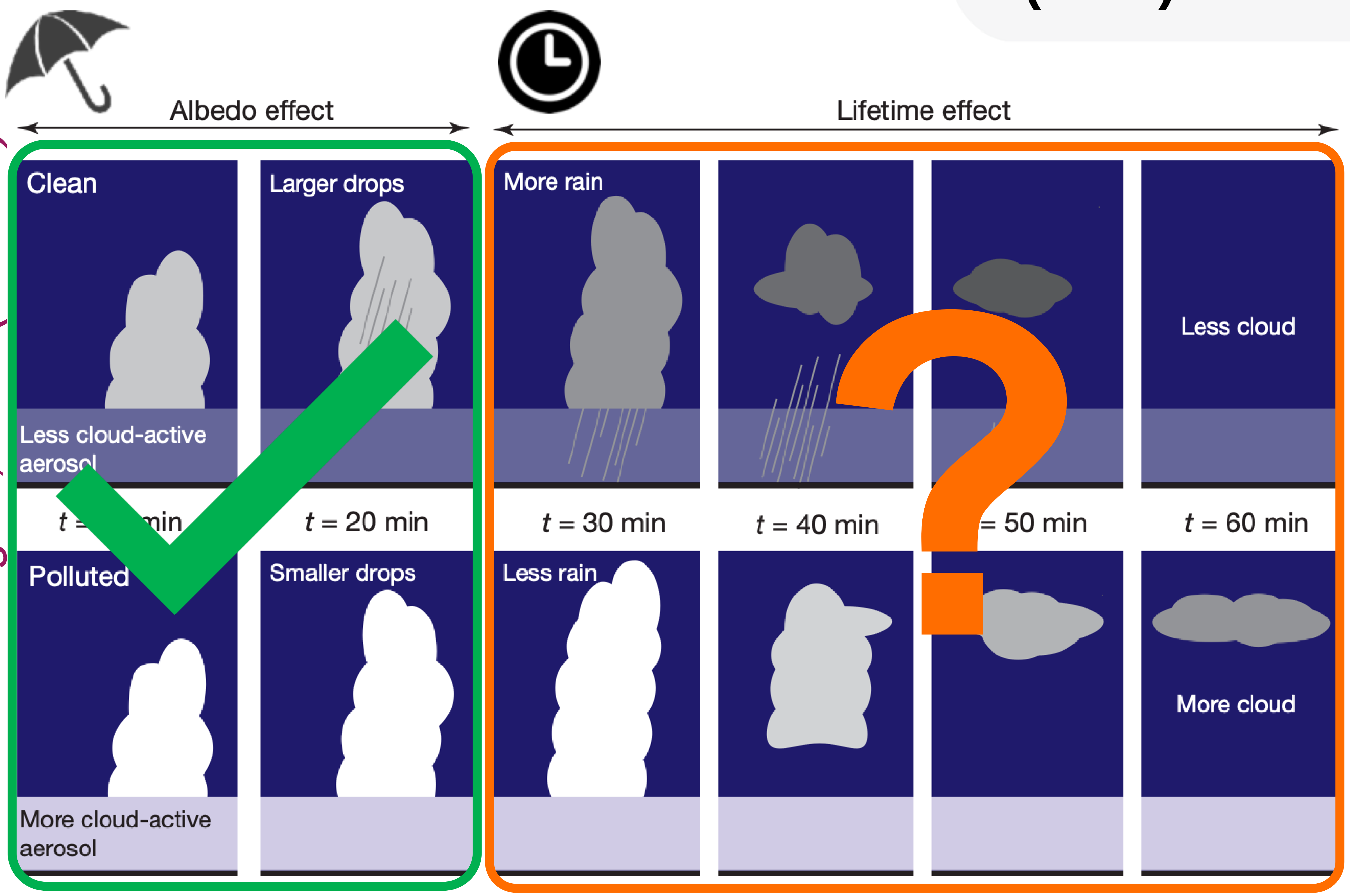
Met Office Hadley Centre

NASA

VolcACI: Rationale

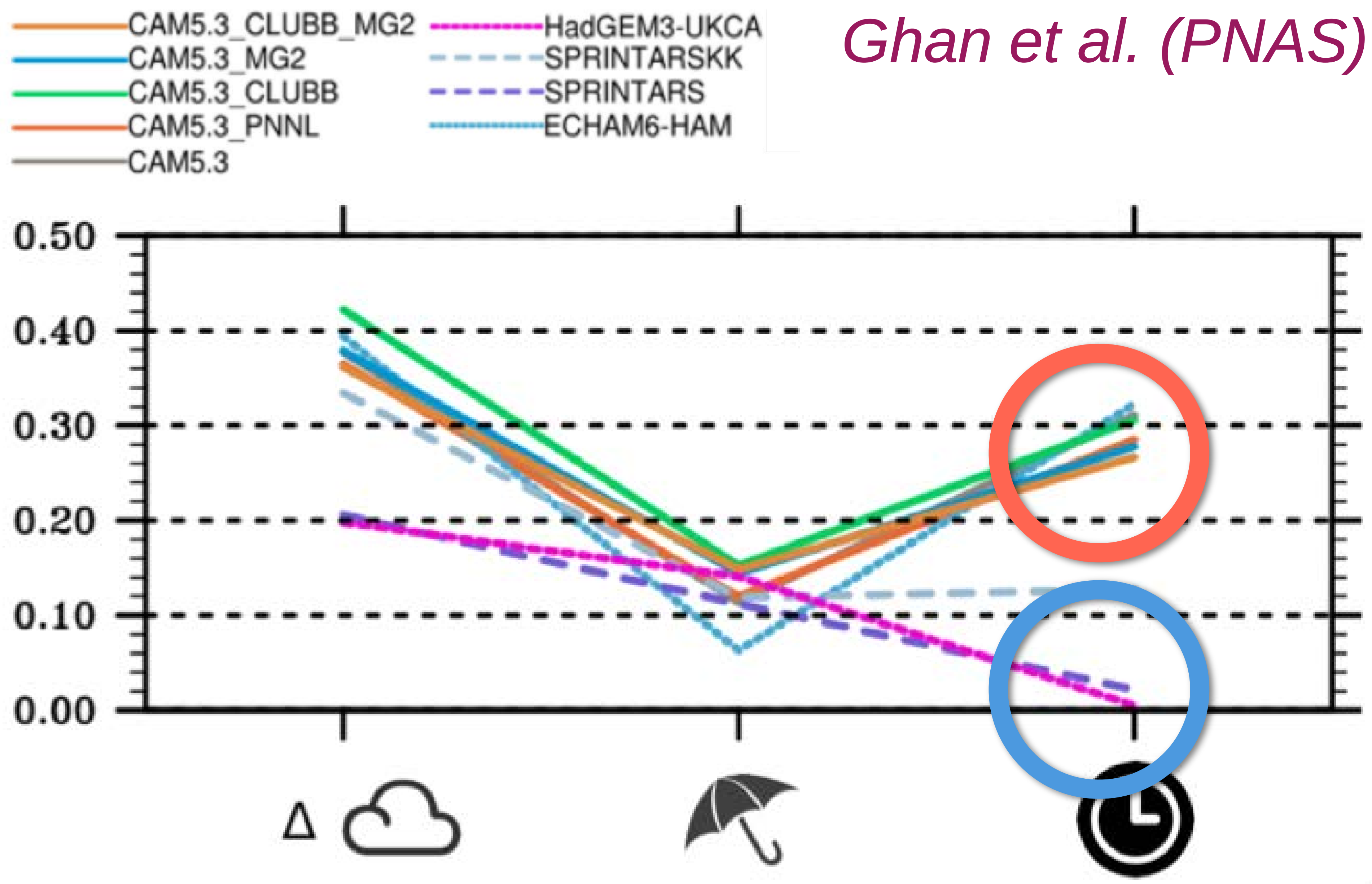
Aerosol (CCN) → **Cloud Droplet (CDNC)** → **Cloud properties** → **Radiation (forcing)**

Stevens & Feingold, 2009 (Science)



Aerocom Indirect Experiment

Ghan et al. (PNAS)



Natural experiments

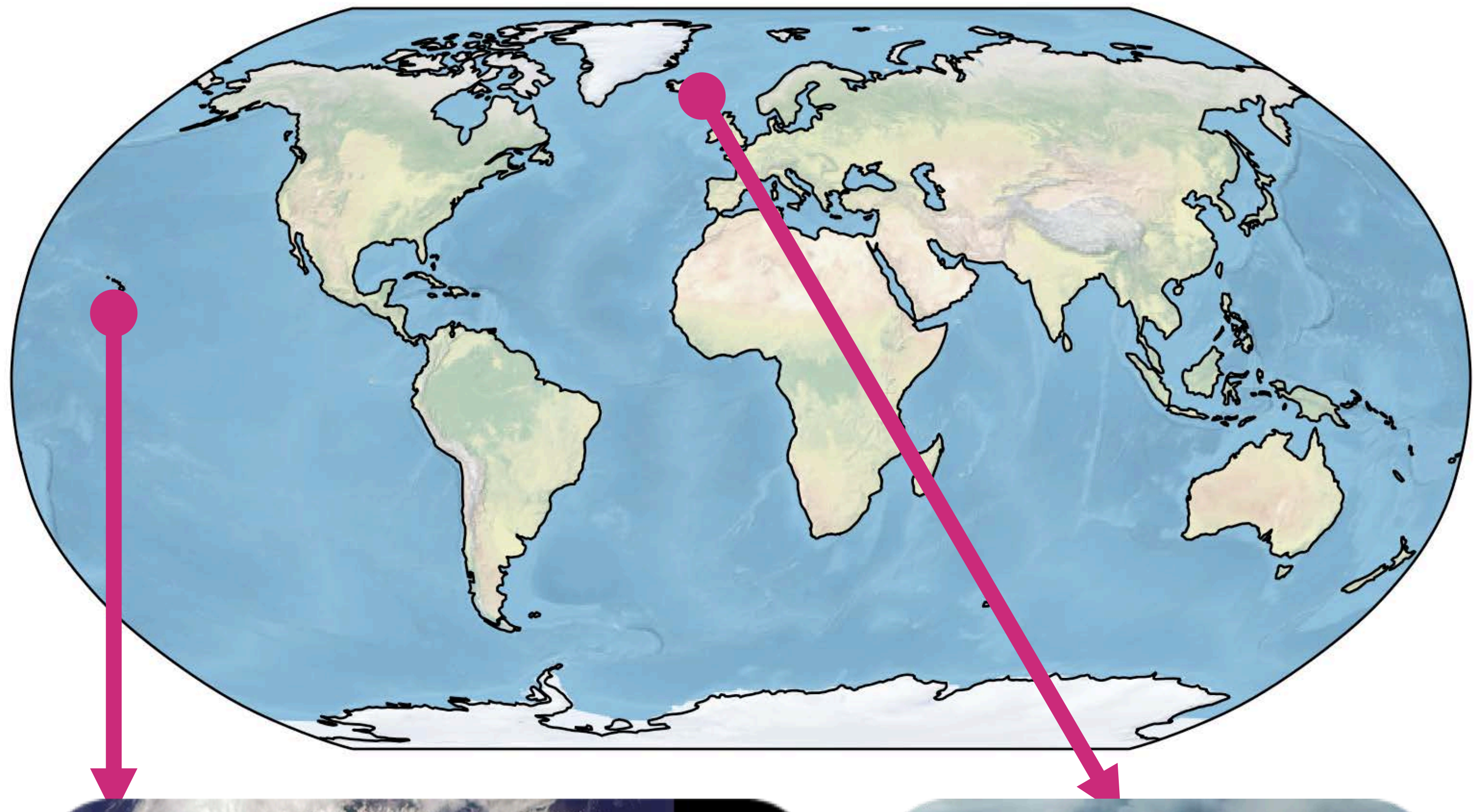
(volcanoes, ship-tracks, industrial tracks)

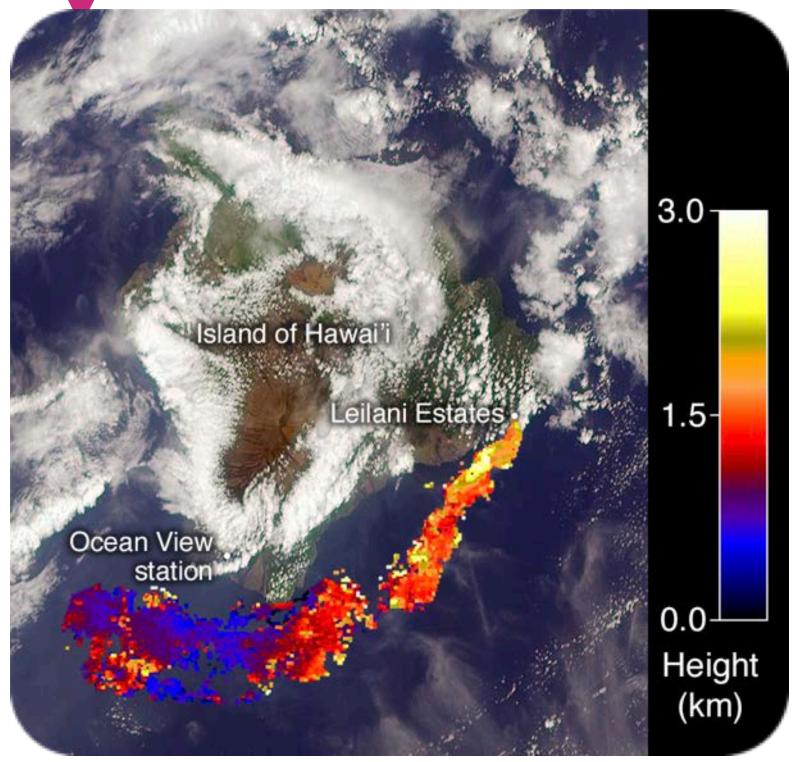
suggest a lesser impact of aerosols on liquid clouds than what is traditionally simulated by GCMs.

e.g. Toll et al., (2017,2019); Malavelle et al. (2017); Sato et al. (2018); Stephens et al. (2019)

VolcACI overview

- Evaluate Aerosol-Cloud Interactions (ACI) in CMIP6 class models using the **Holuhraun** & **Kilauea** eruptions framework.
- Provide constraint on ACI estimates for this new generation of models.





Kilauea (2008 & 2018)

Holuhraun (2014-15)

VolcACI Timetable

'Holuhraun' Aerocom Experiment proposed

Oct 2017

Kilauea erupted!

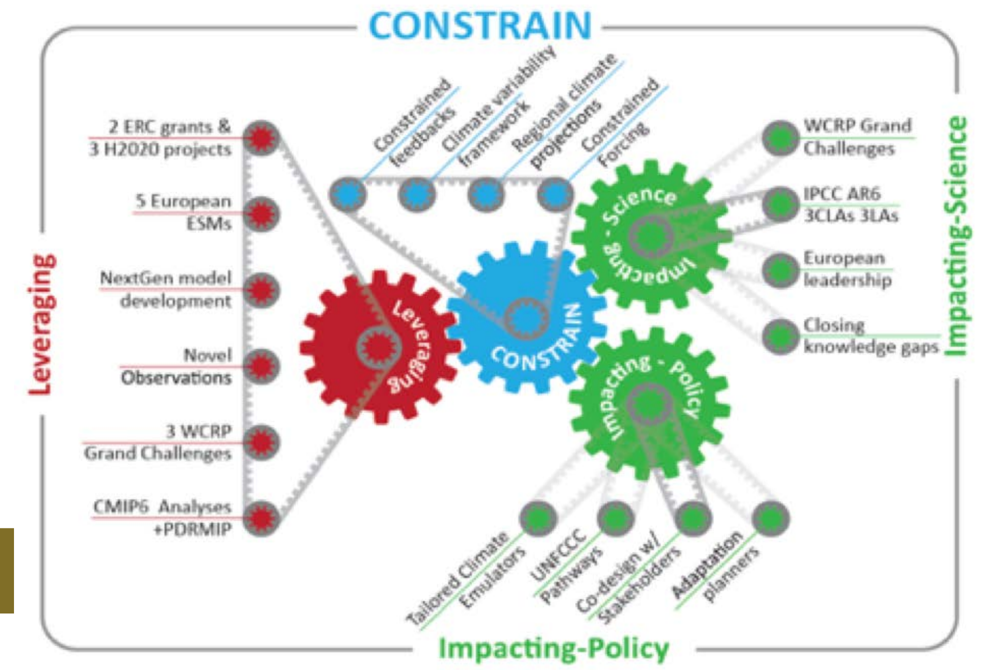
May 2018

'Kilauea' Aerocom Experiment proposed

Oct 2018

- Merging protocols
*- Homogenising data from first submissions (**6 MODELS**)*
- Starting analysis of Holuhraun runs

Sep 2019



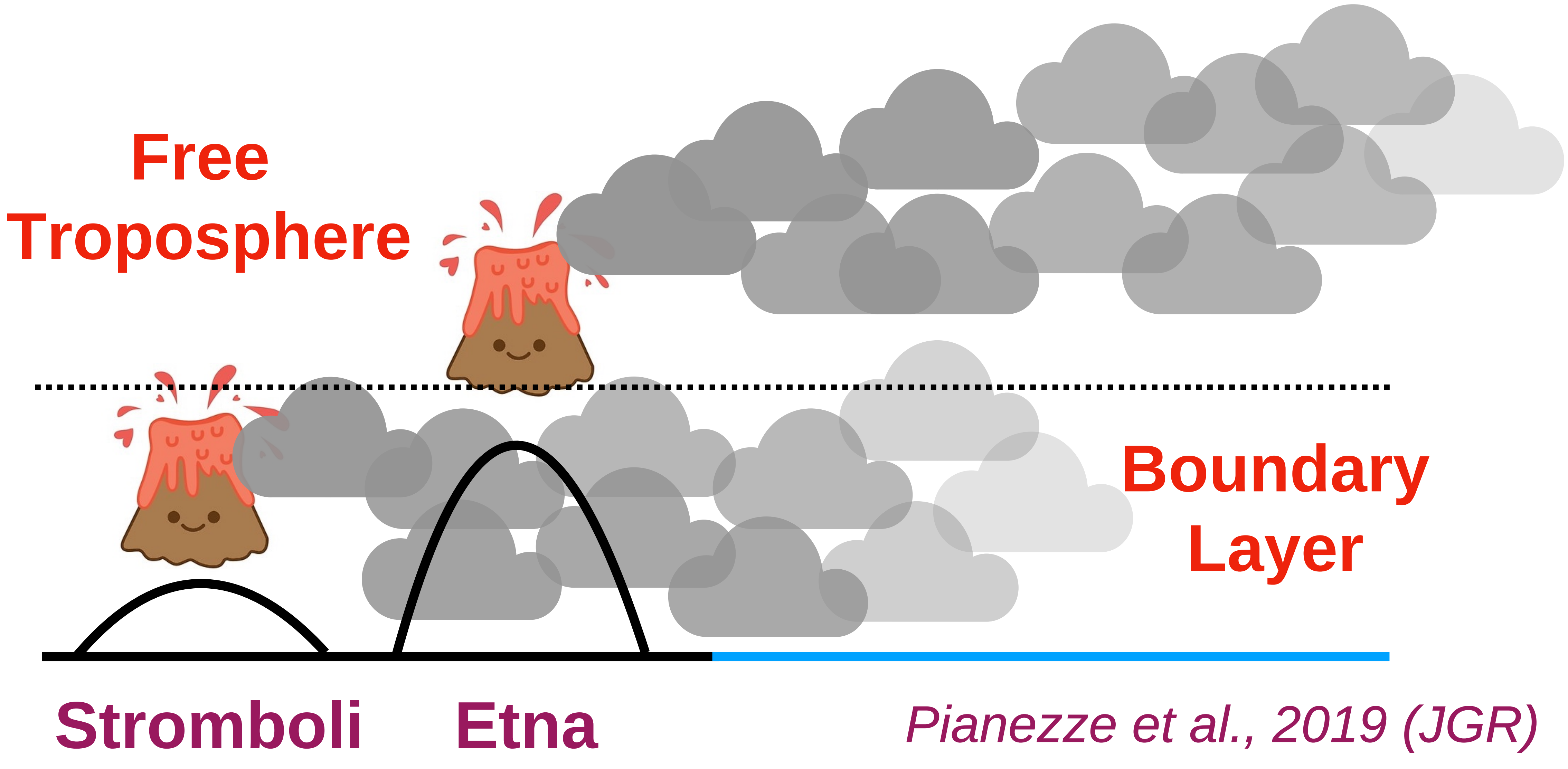
CONSTRAIN
(Horizon 2020) just kicked off

2021

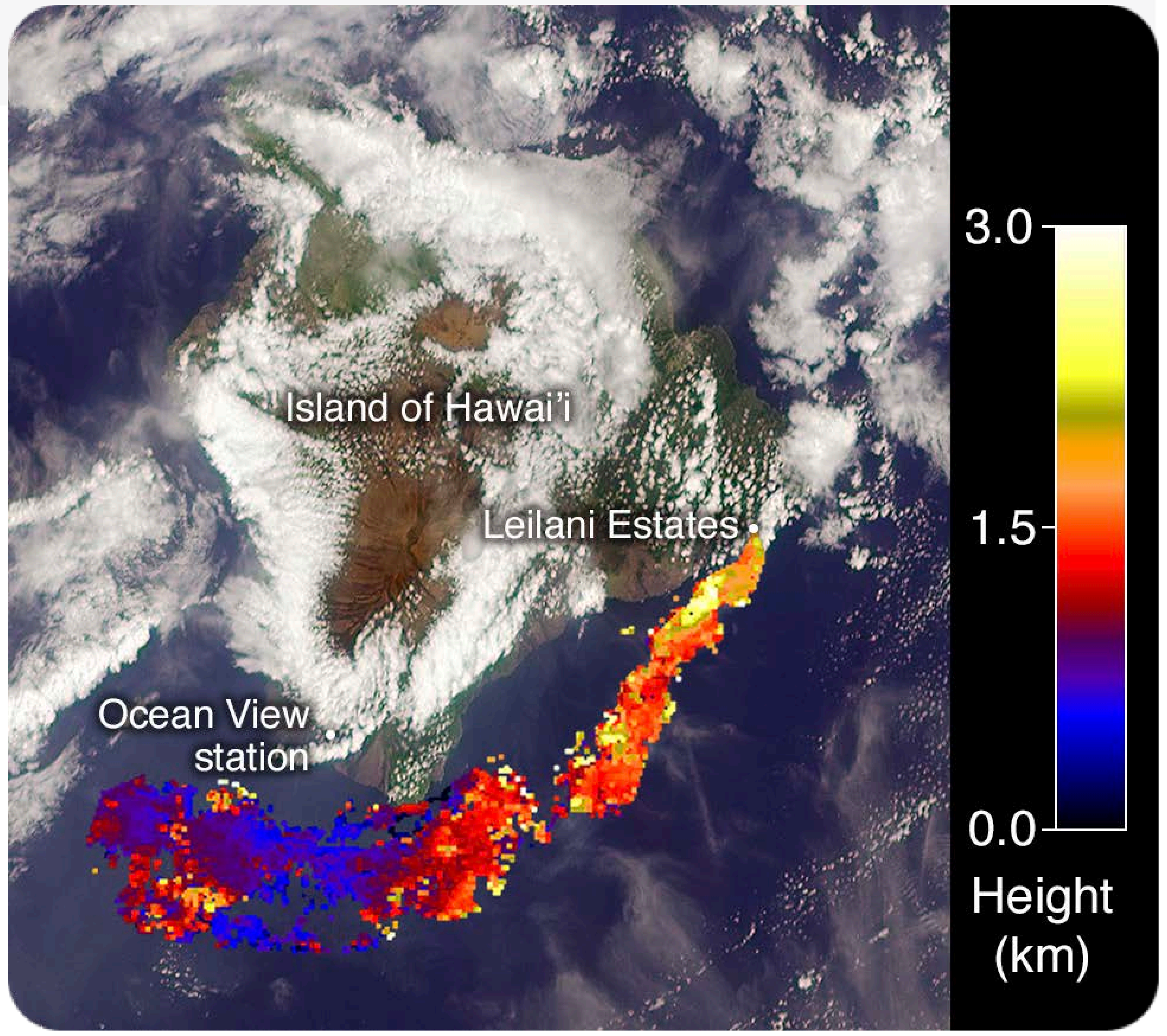
Kilauea: 2008 vs 2018

- Emissions: **2018 >> 2008**.
  Confirmed by initial tests already carried with the NASA GISS model.

- Kilauea **2008** mostly disturbed the liquid phase.
- Kilauea **2018** disturbed <u>both</u> liquid and ice phases.



Pianezze et al., 2019 (JGR)



MINX retrieved plume height (the MISR team)

- Injection Height will affect conversion pathway of SO_2 (oxidation vs aqueous).

- Strong competition between condensation and nucleation due to high concentration.

Holuhraun: earlier work

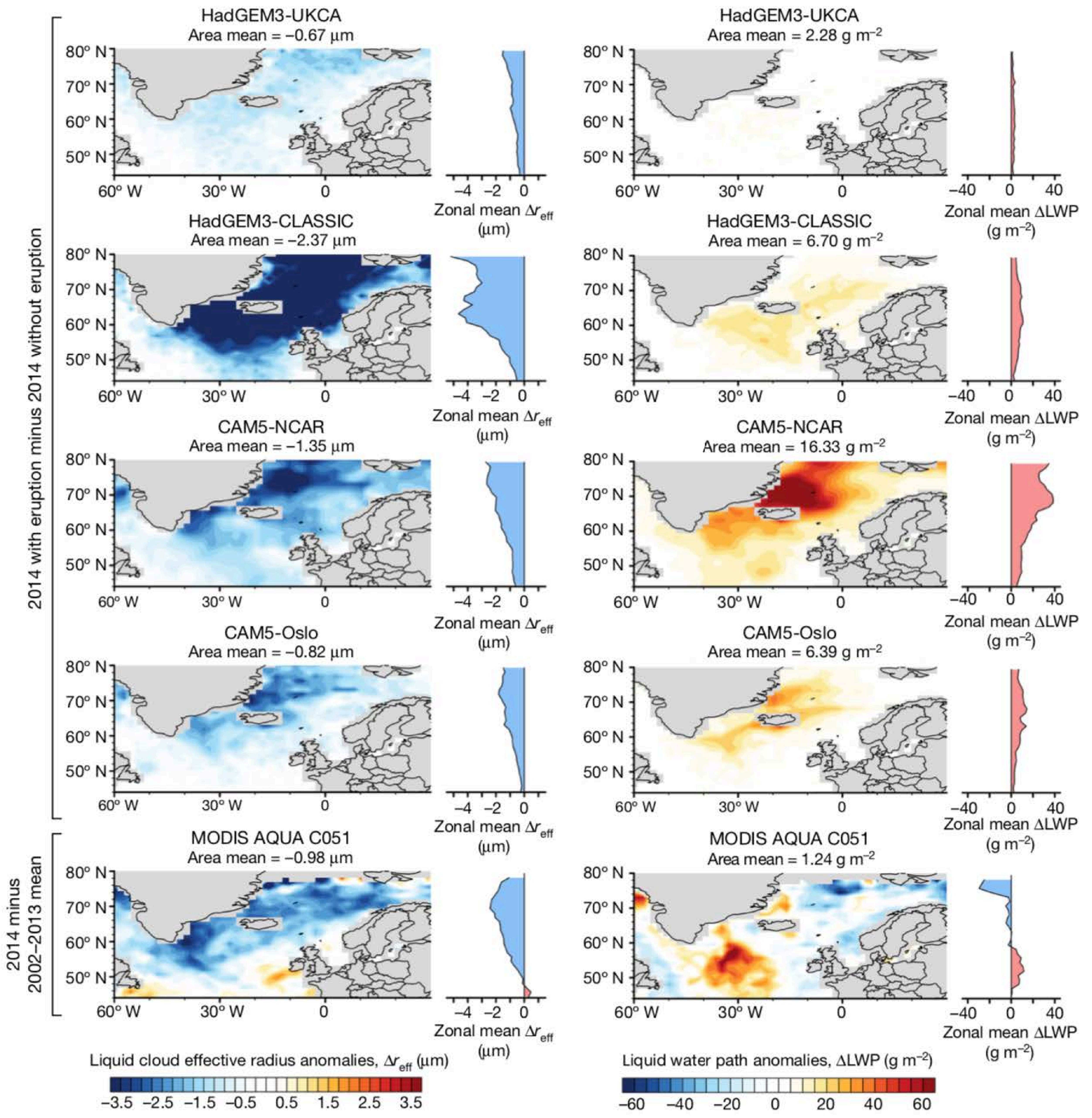
1 - Models tends to agree on the Twomey effect

2 - Models with a significant large aerosol 2nd indirect effect are likely in error.

But - We still have no understanding why !

Identification of error essential for accurate future climate estimates.

Malavelle et al., 2017 (Nature)



VolcACI Objectives

1 - Could GCMs capture the magnitude of ACI during the eruptions ? **1**

2 - Quantify model responses to the volcanic perturbation and assess where models (dis)agree → **ACI metrics** **2**

3 - Identify biases in models and parameterisation contributing to spread in ACI estimates → **Process Based Metrics** **2**

Aerocom wiki

AeroCom

- AeroCom WIKI home

Common AeroCom phase III Diagnostics Request 2019

The diagnostics for most of the experiments mentioned on this wiki page are put together here:

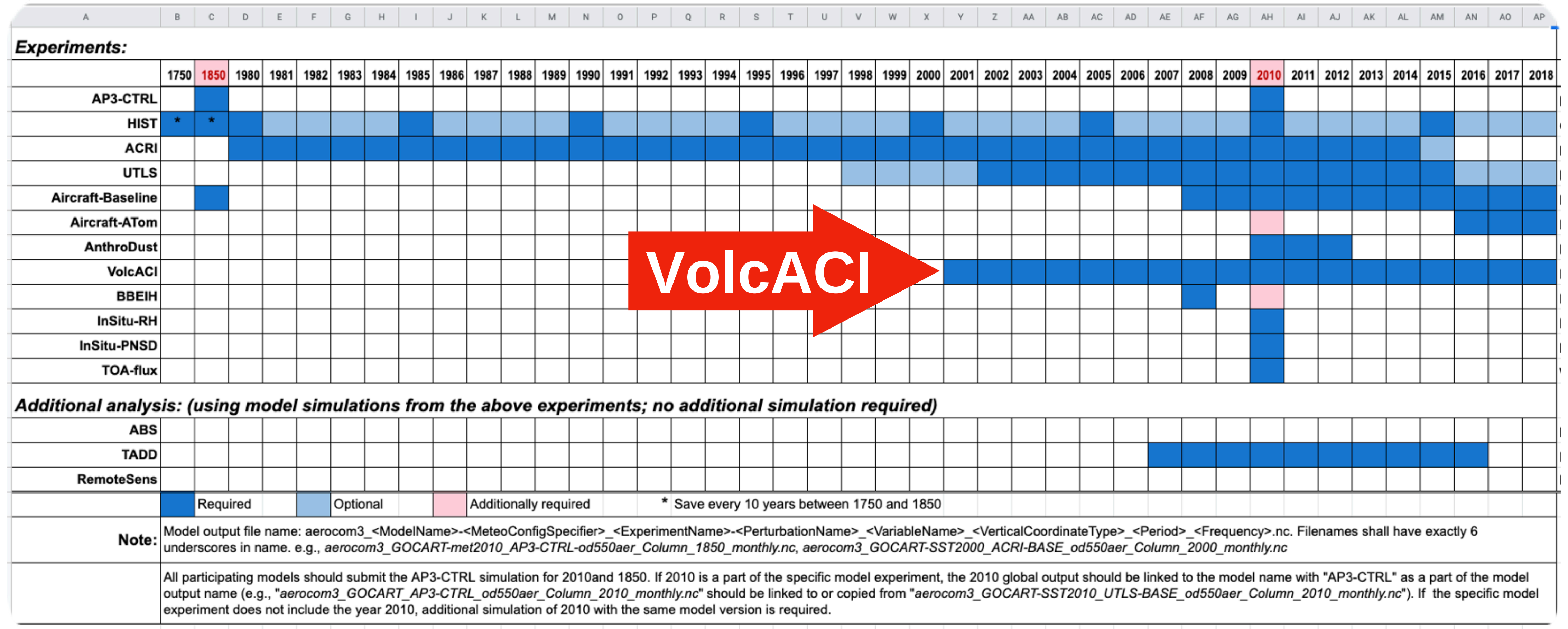
AeroCom experiments diagnostics sheets 28.2.2019

aer2dmon
aer3dmon

1 MANDATORY

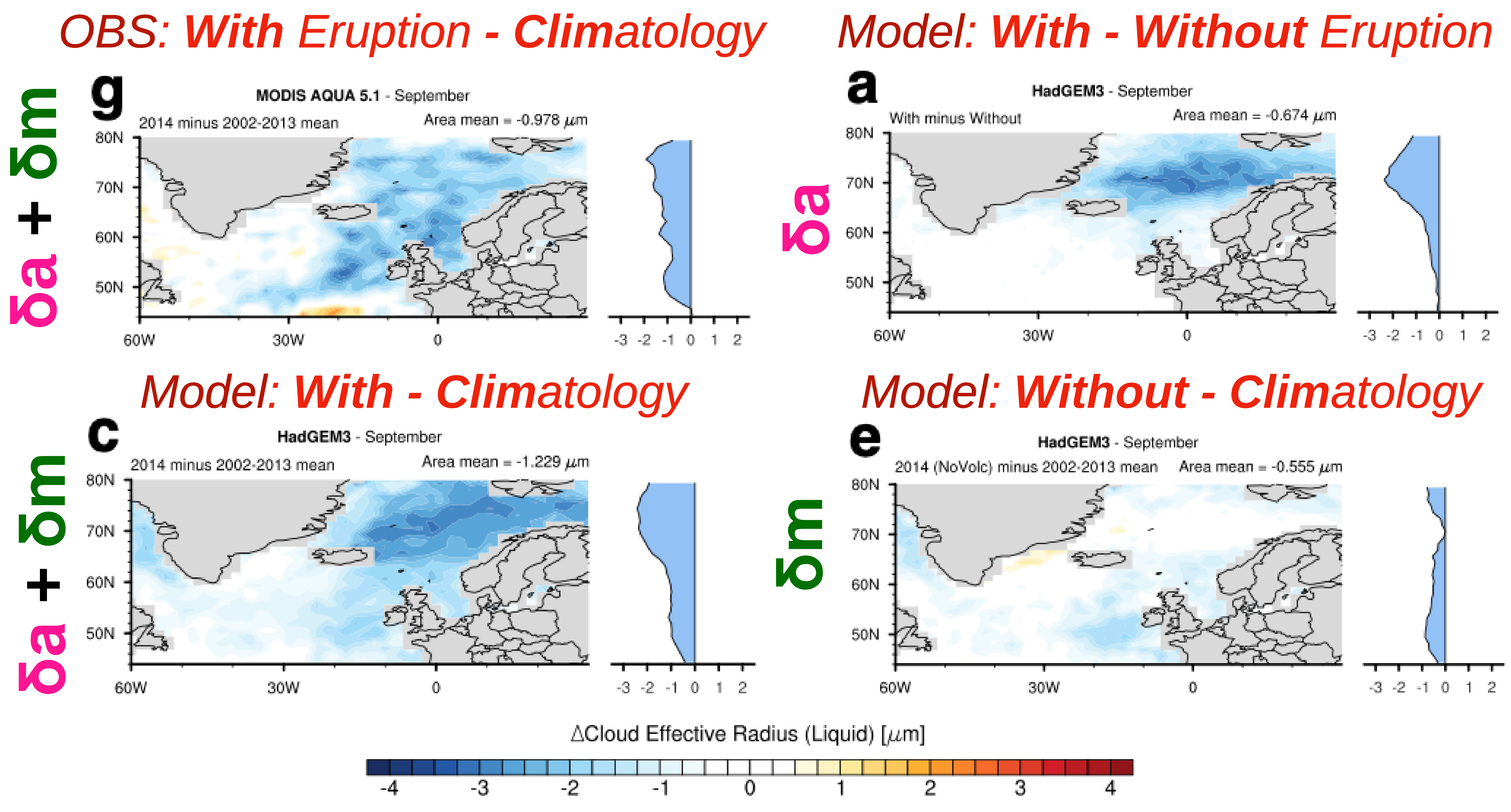
aer2d3hr
aer3dhr
aerxd6hr

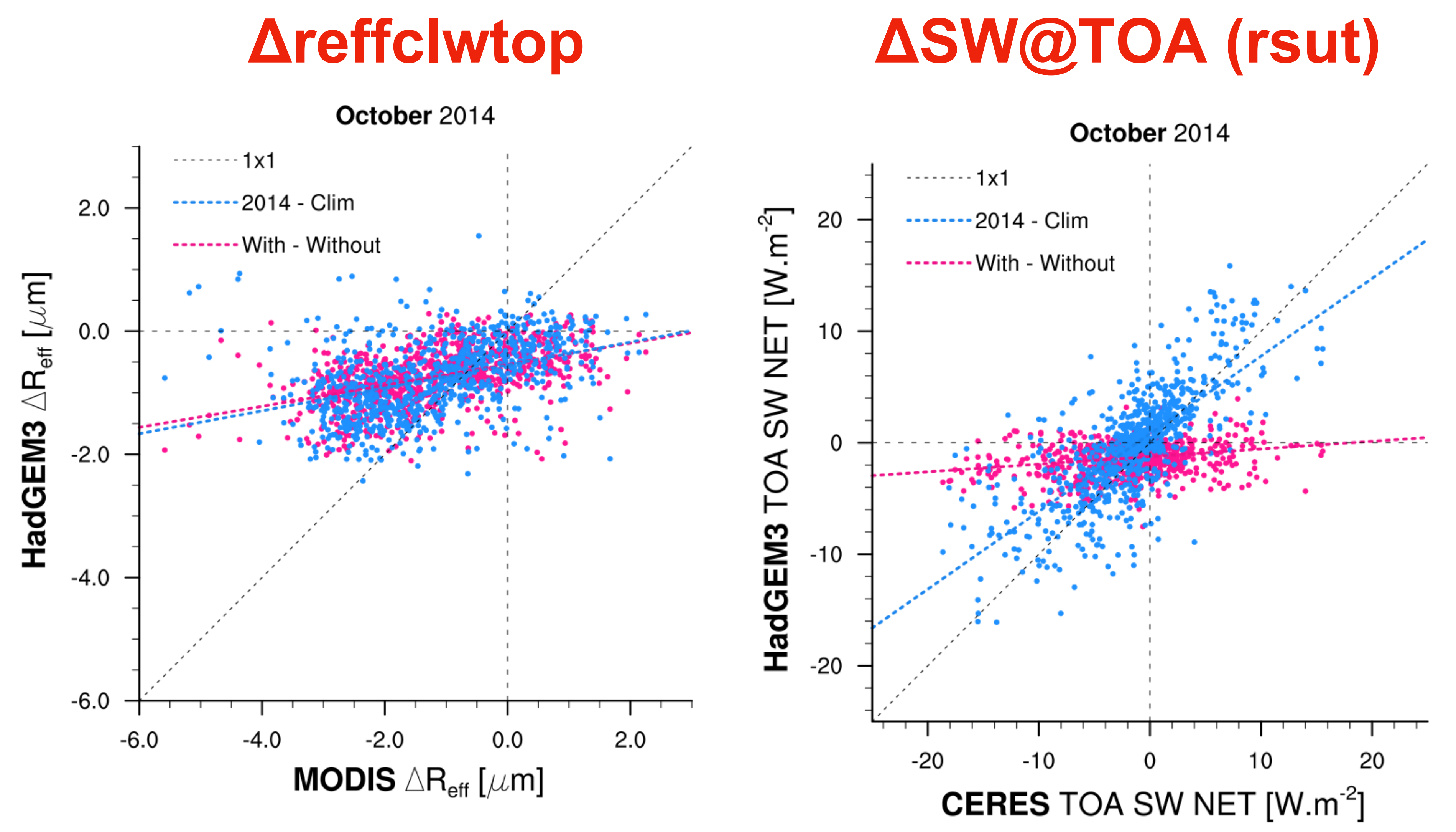
2 DESIRED

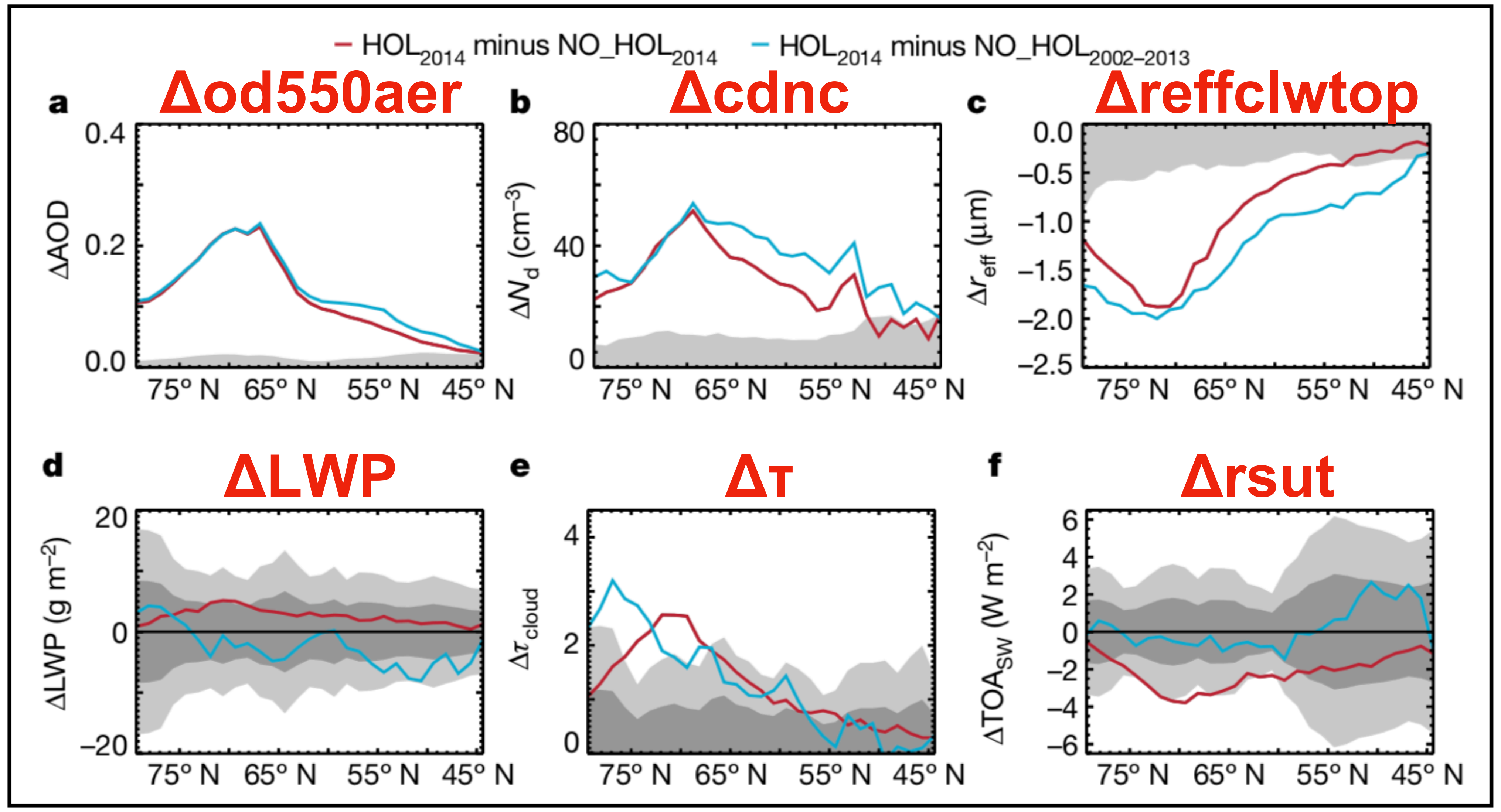


Methods: Disentangling the aerosol effect

'Long-term' nudged CTRL required to separate the influence of meteorology from the aerosol perturbation: **Δreff ~ ∂reff.δm + ∂reff.δa**





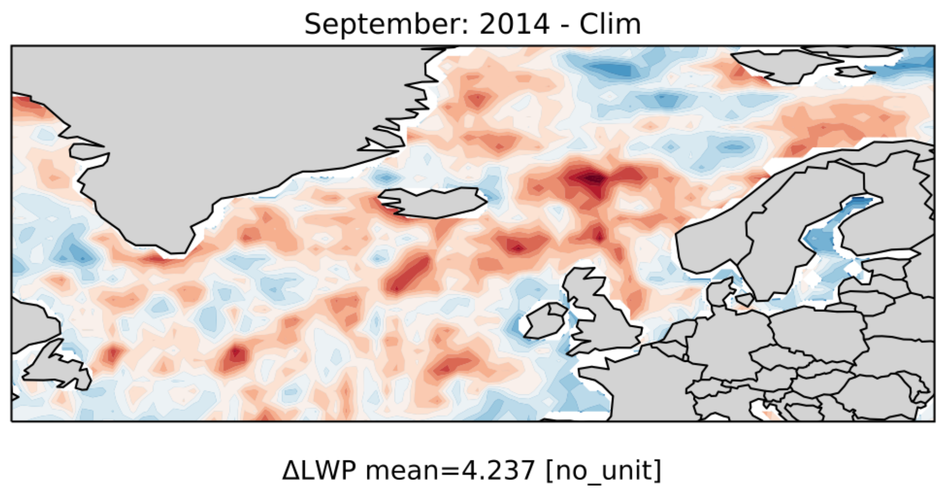


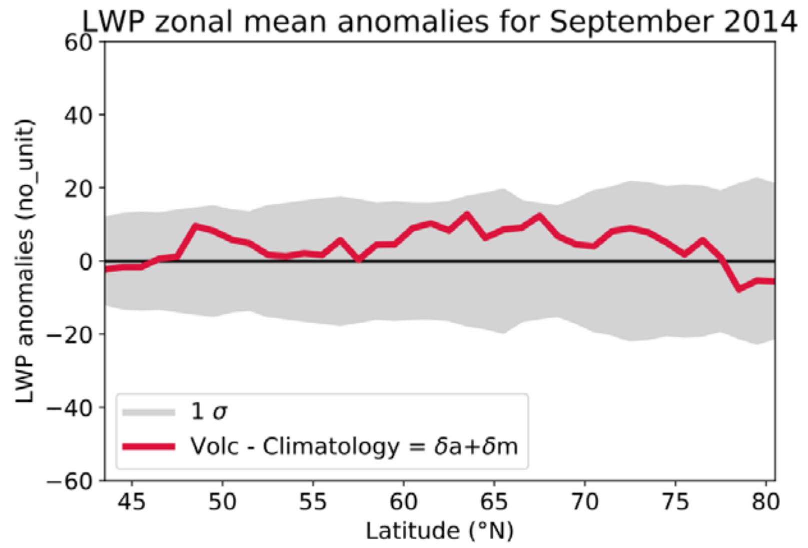
Aerosol (CCN) → **Cloud Droplet (CDNC)** → **Cloud properties** → **Radiation (forcing)**

Cloud properties - LWP

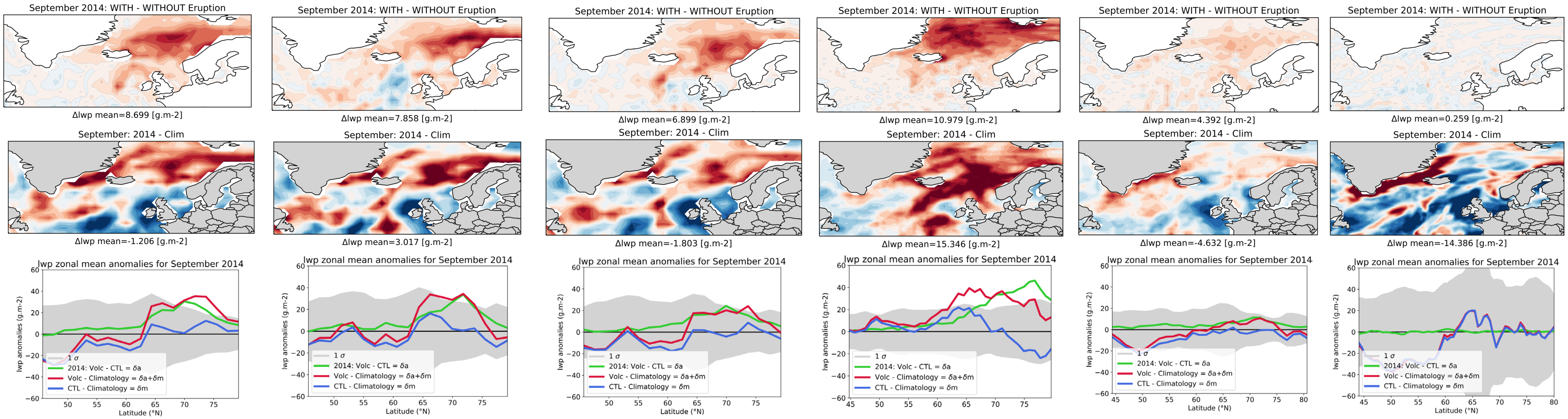
September 2014

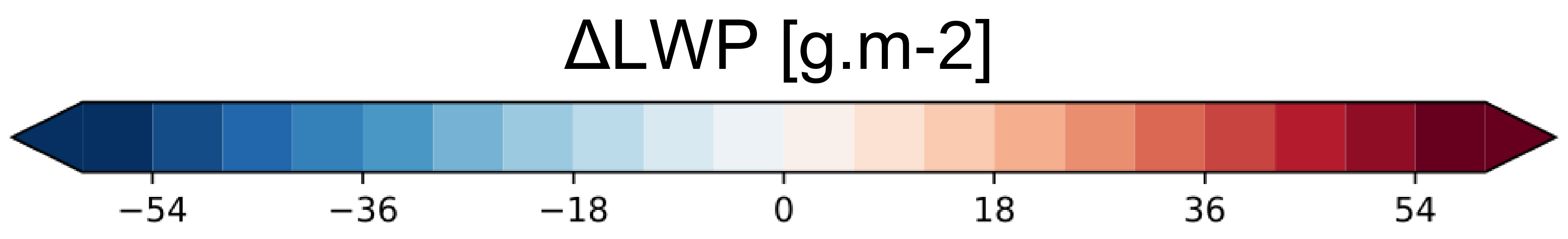
AQUA C6.1





ECHAM-P3 | ECHAM-SALSA | ECHAM-HAM | OLSO-CAM | UKESM1 | MIROC-SPRINTARS





Cloud properties - LWP

September 2014

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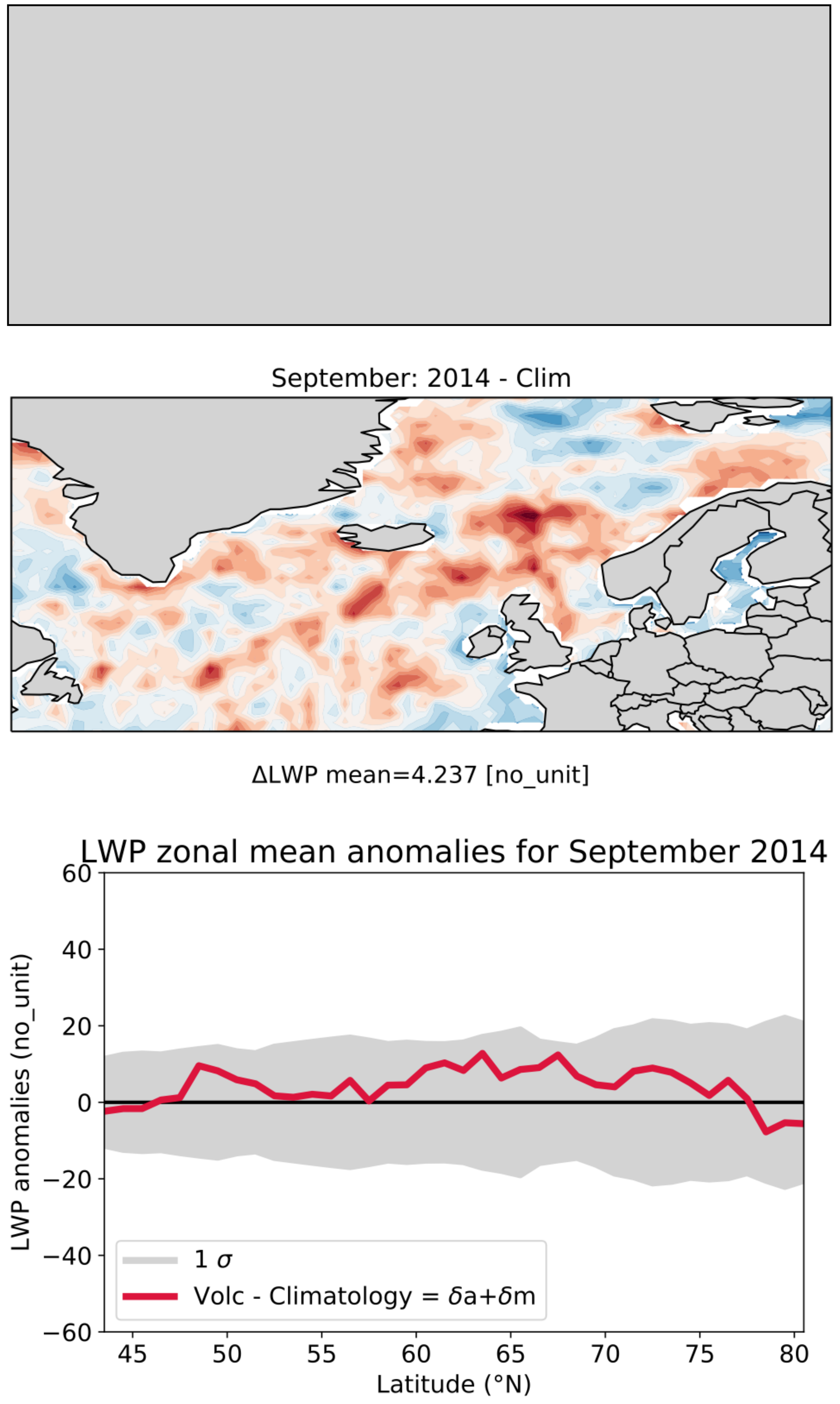
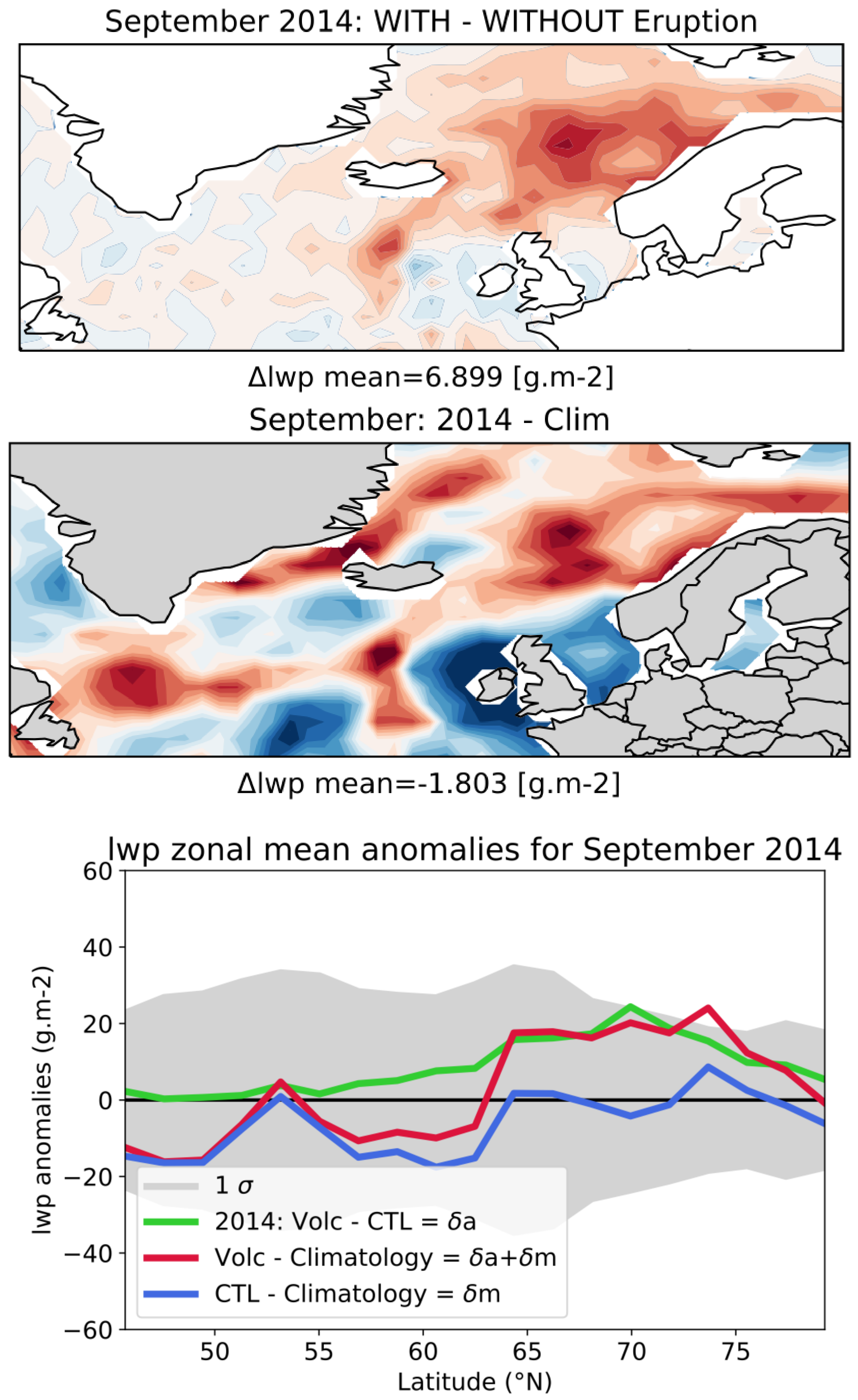
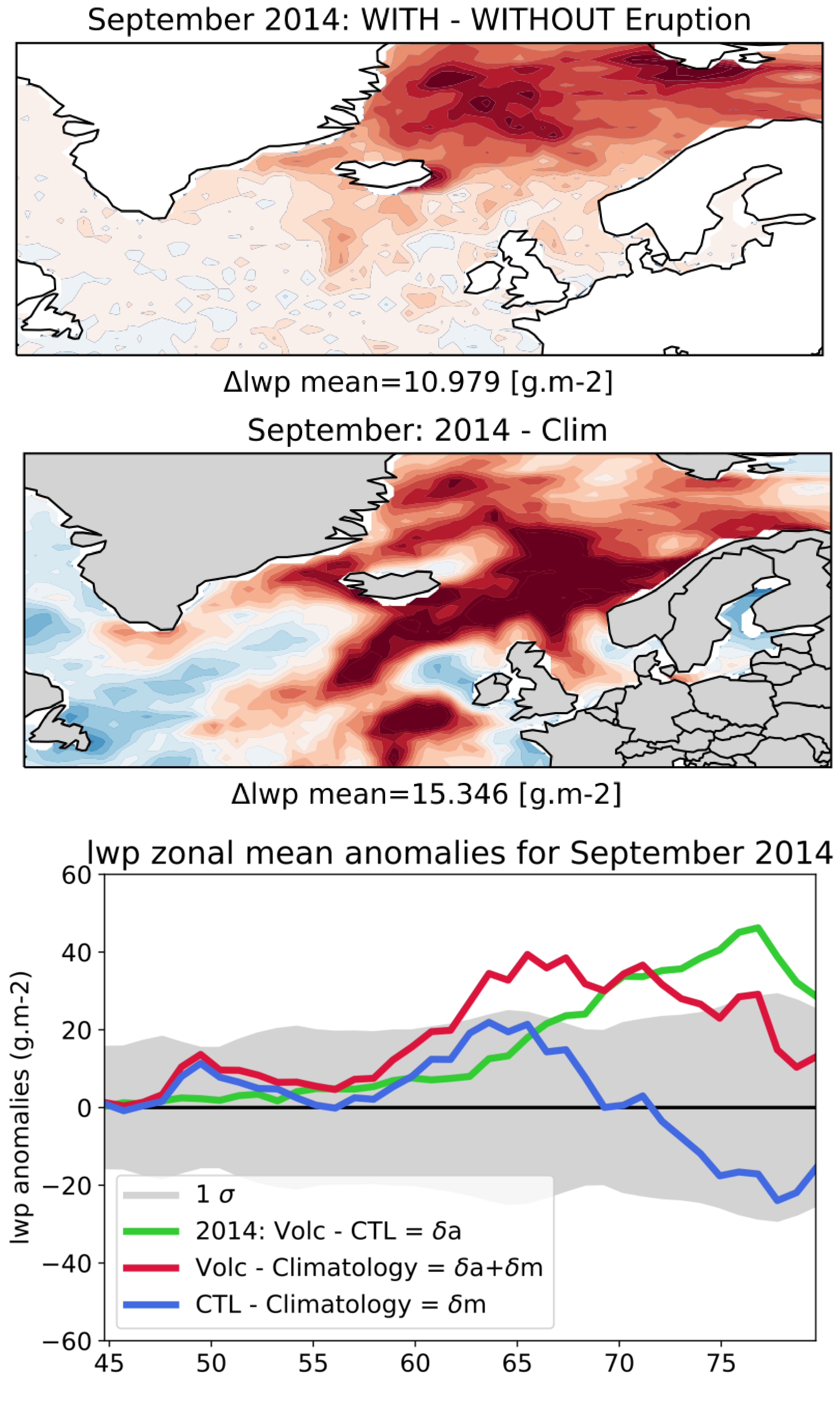


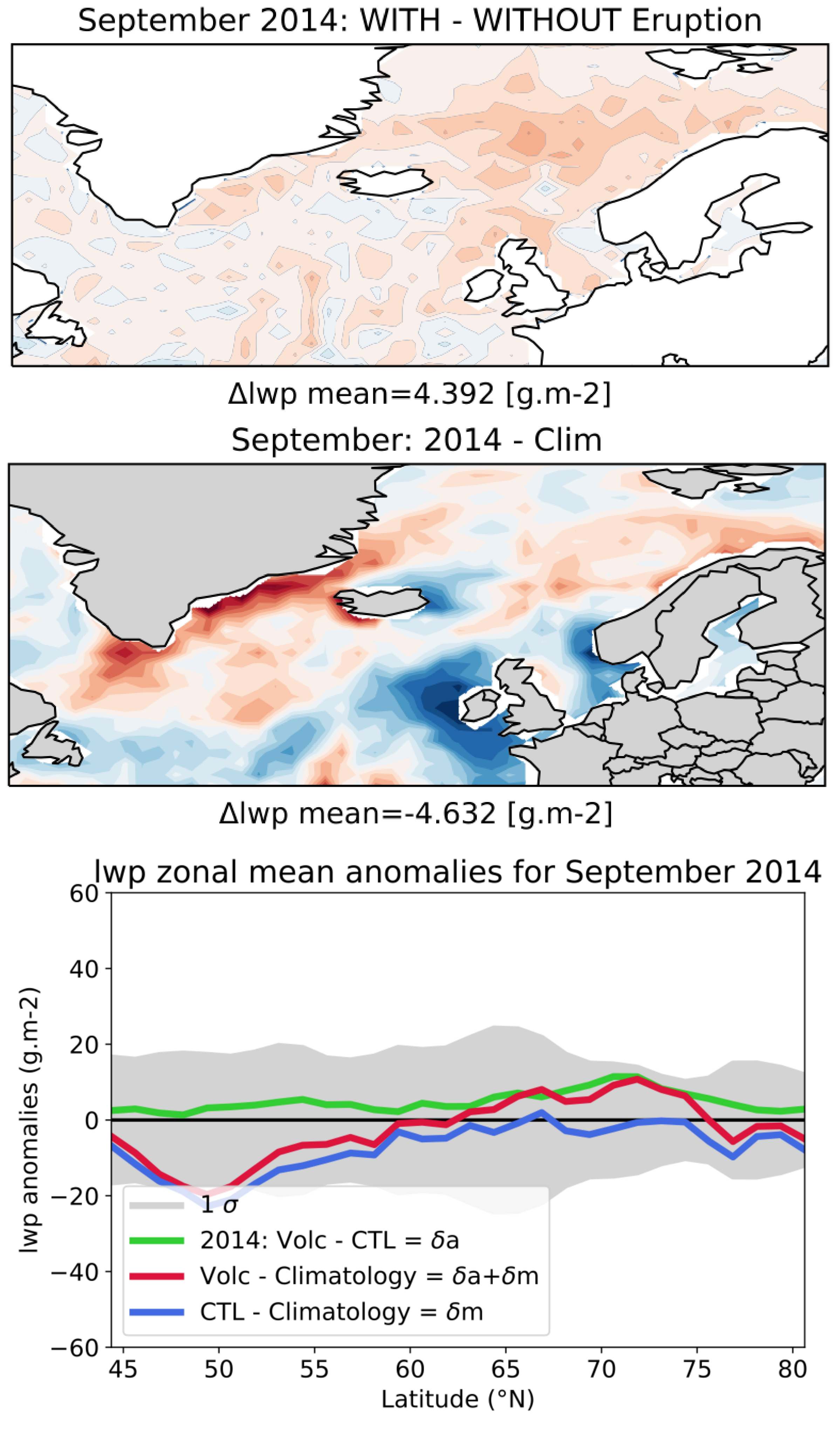
ECHAM-HAM

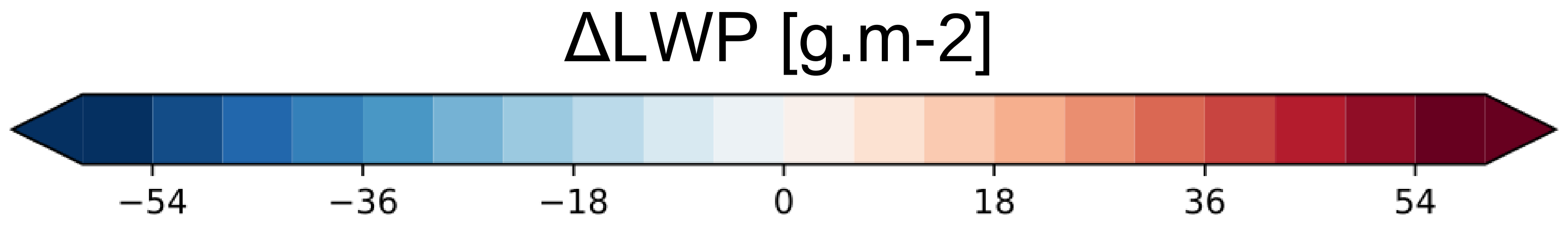


OLSO-CAM



UKESM1





Cloud properties - Reff

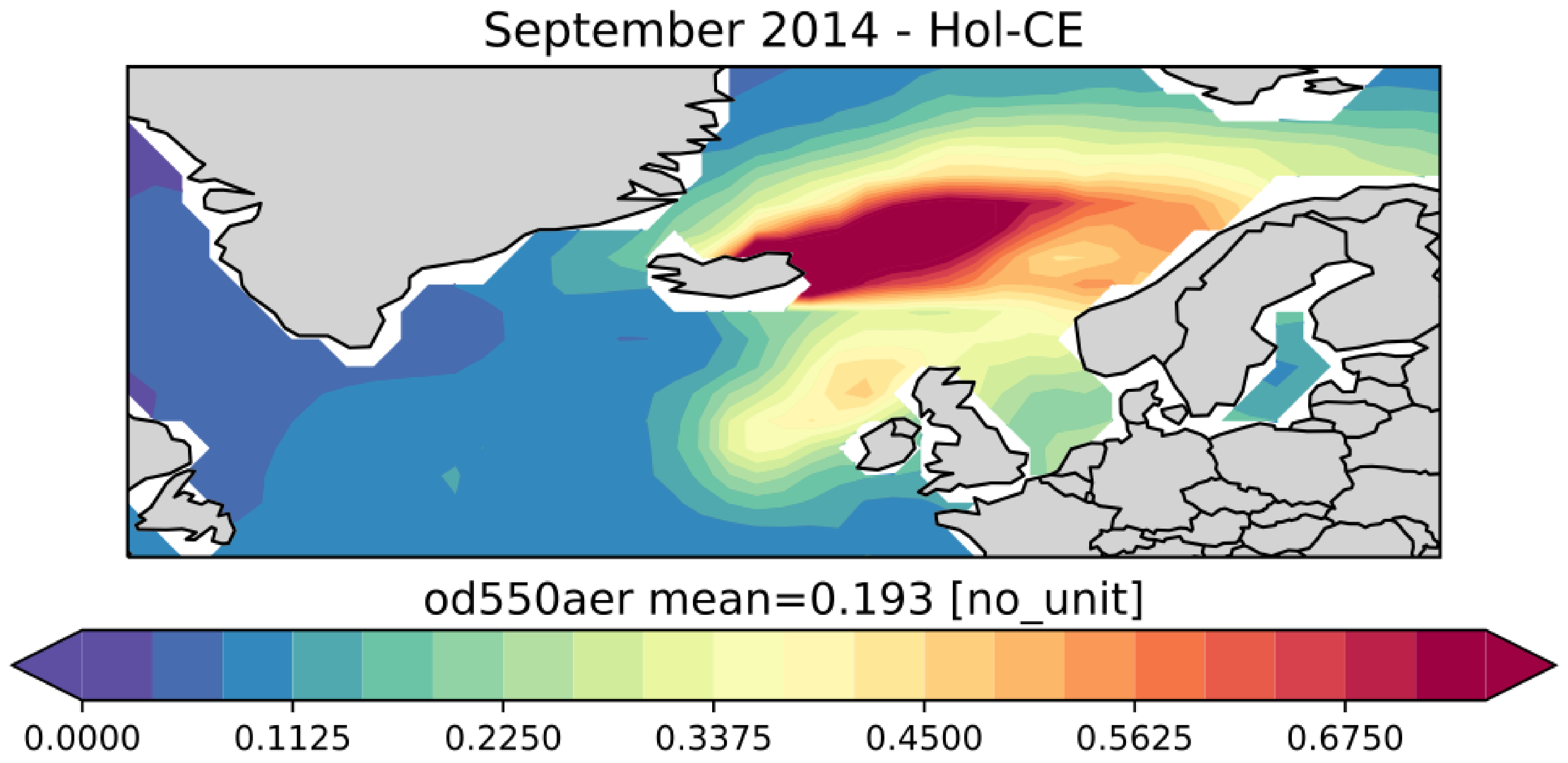
September 2014

AQUA C6.1 | ECHAM-HAM | OLSO-CAM | UKESM1

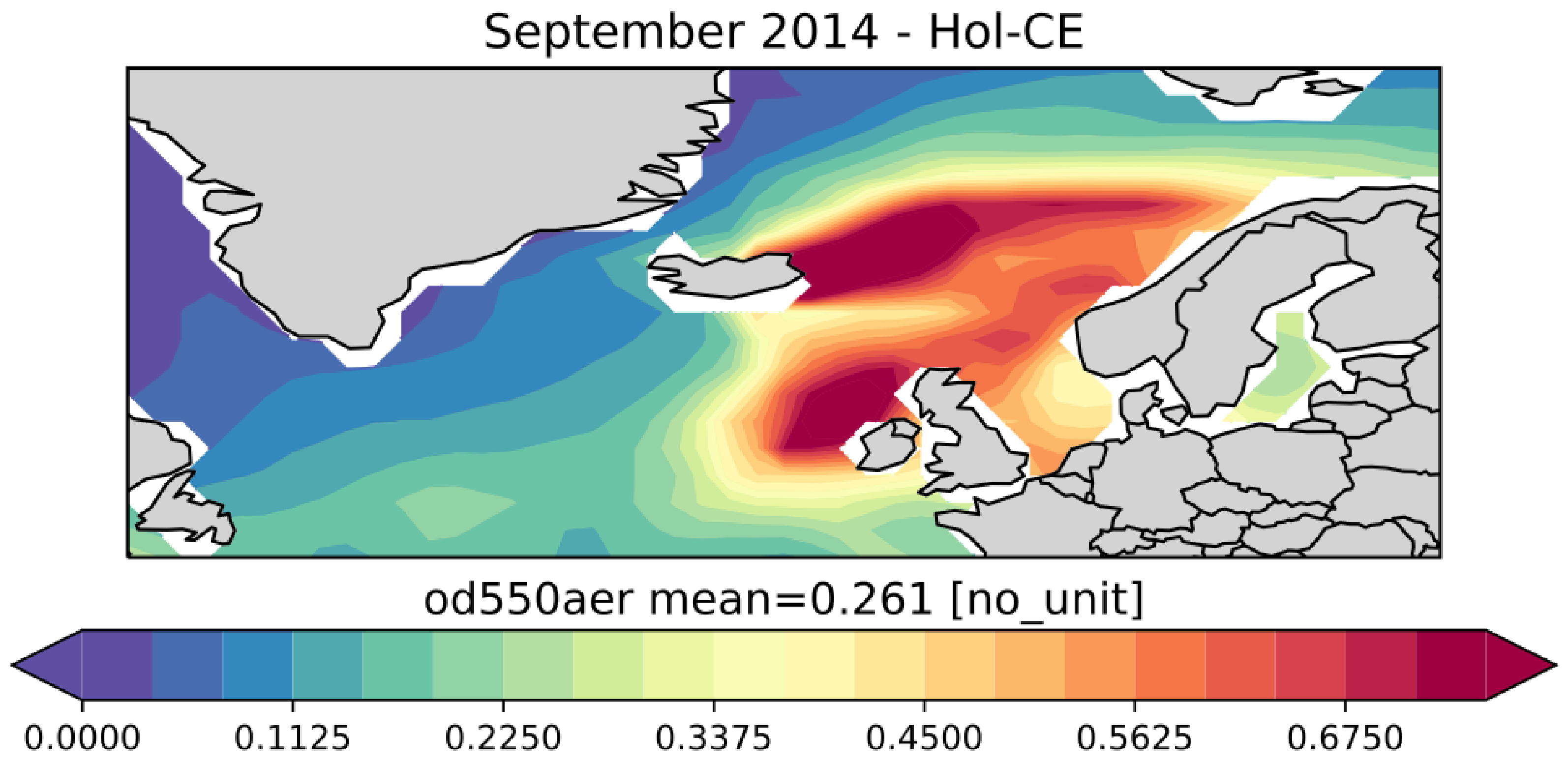
Aerosols - od550aer

September 2014

ECHAM-P3



ECHAM-SALSA



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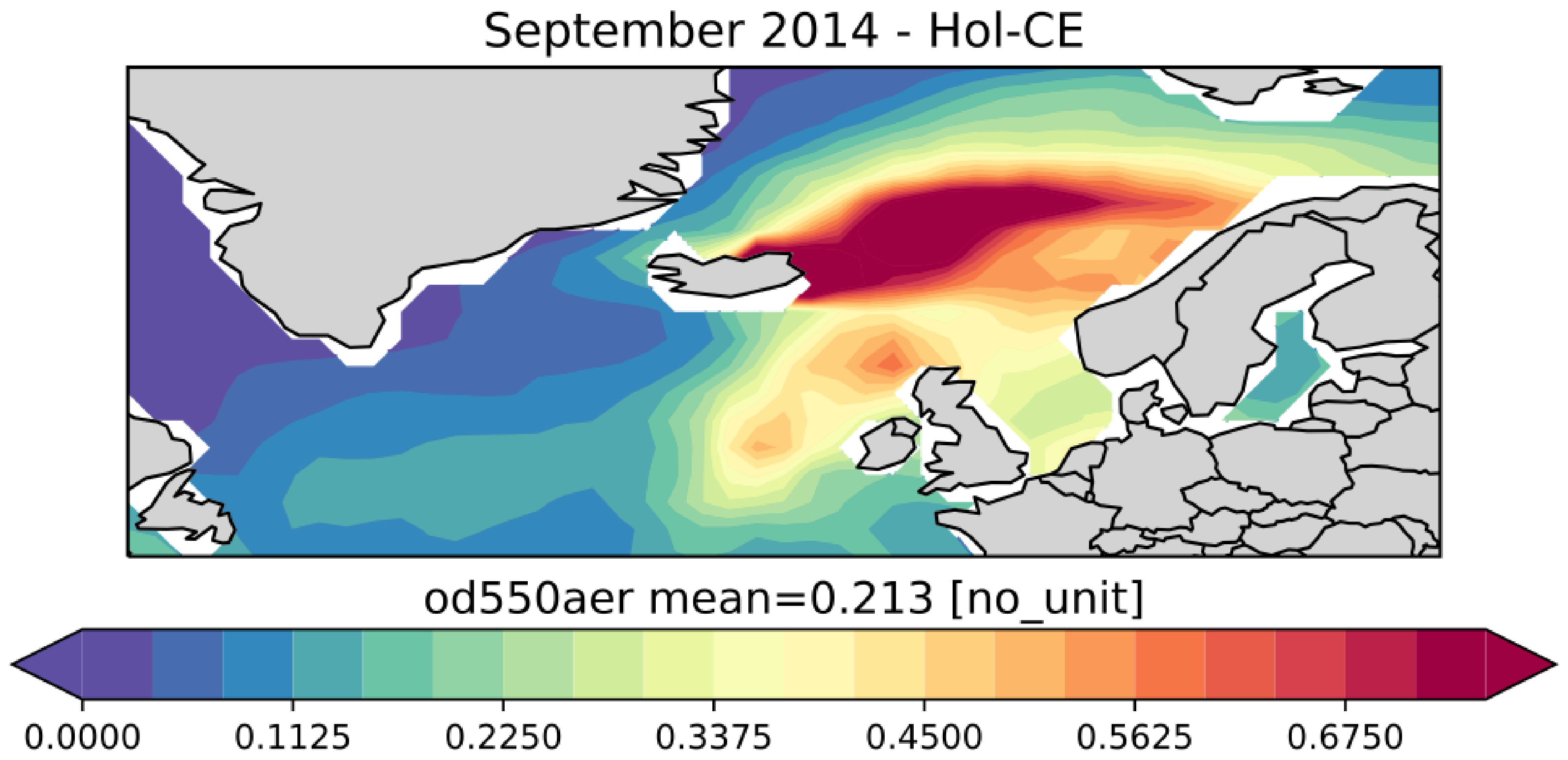

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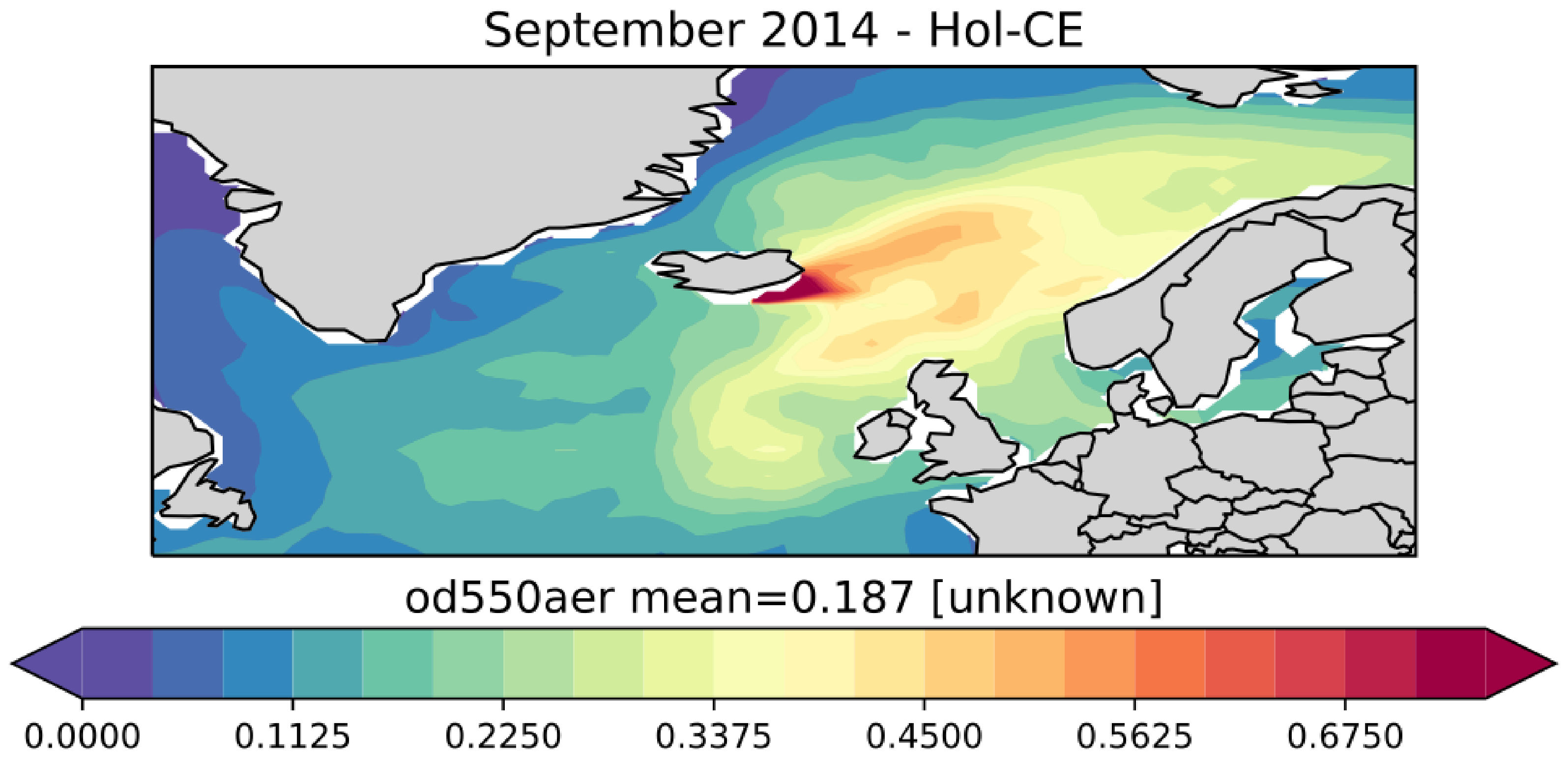
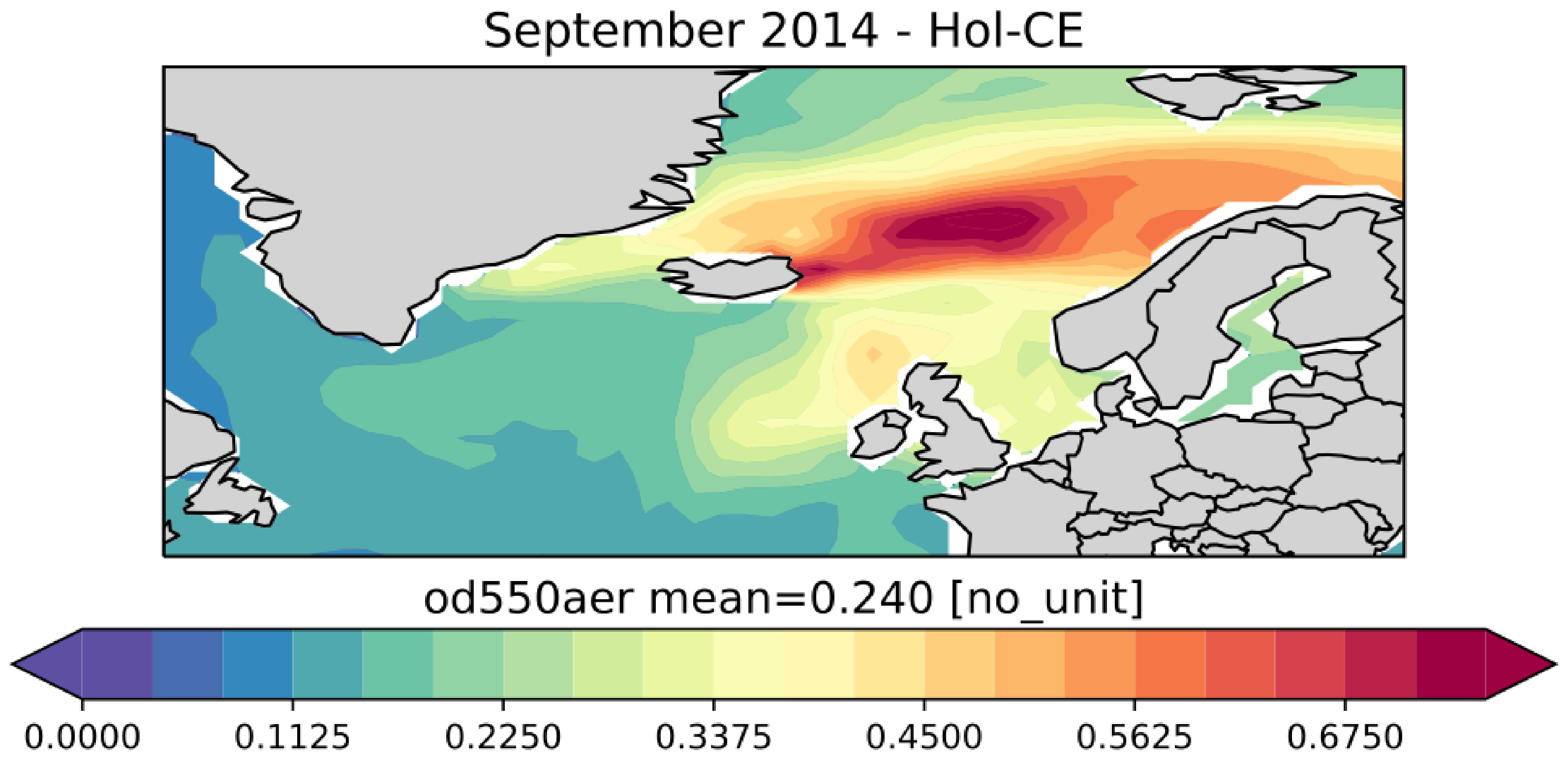
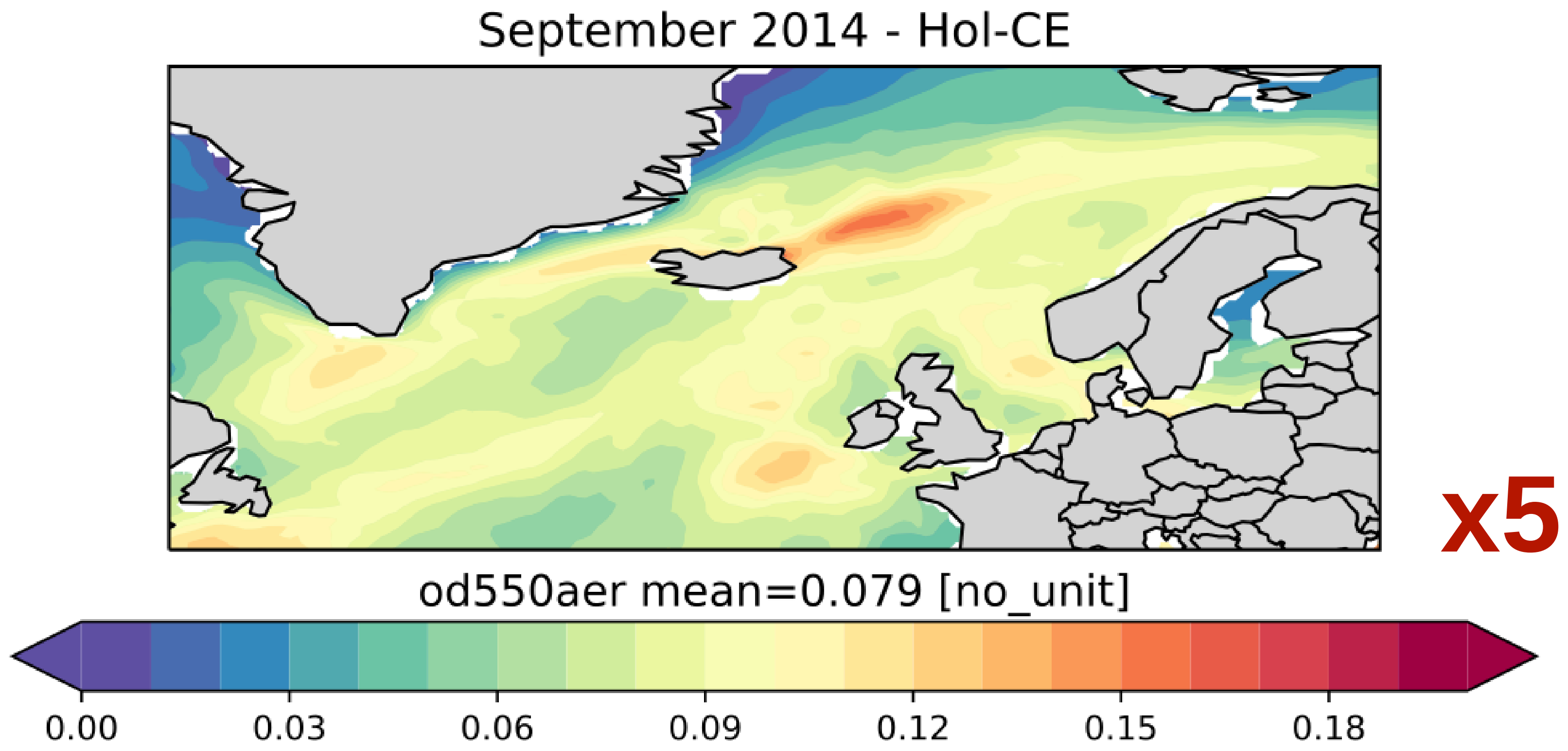


UKESM1



MIROC-SPRINTARS

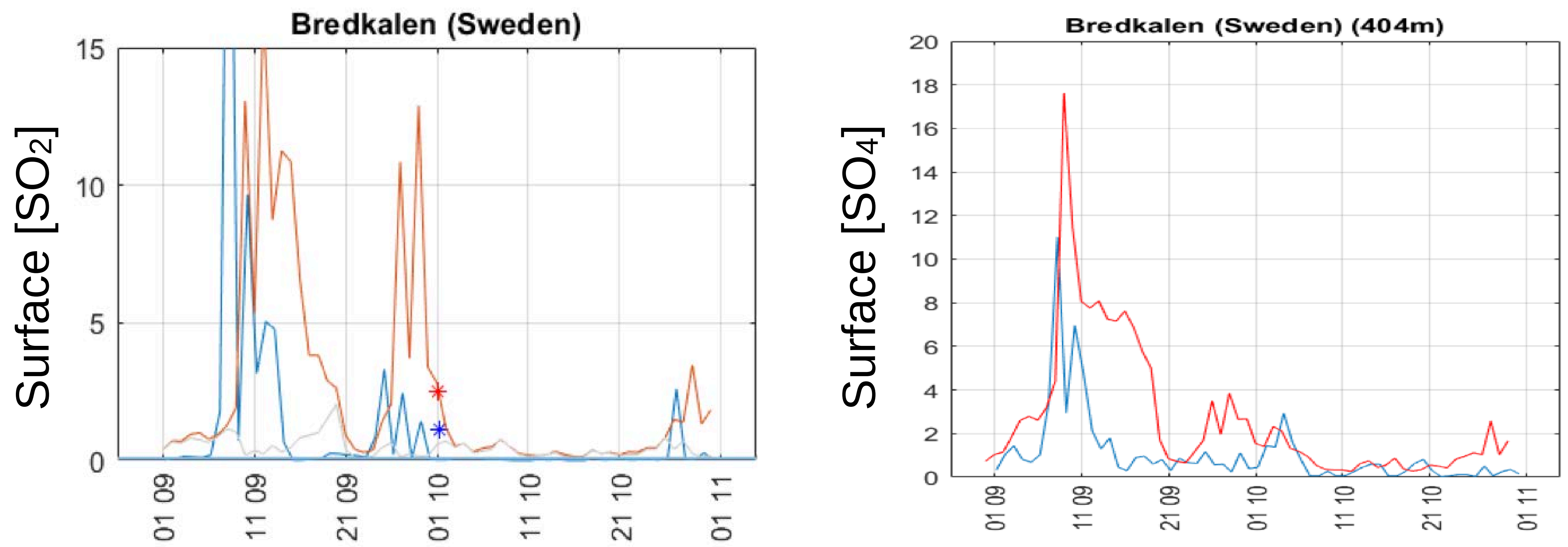


x5

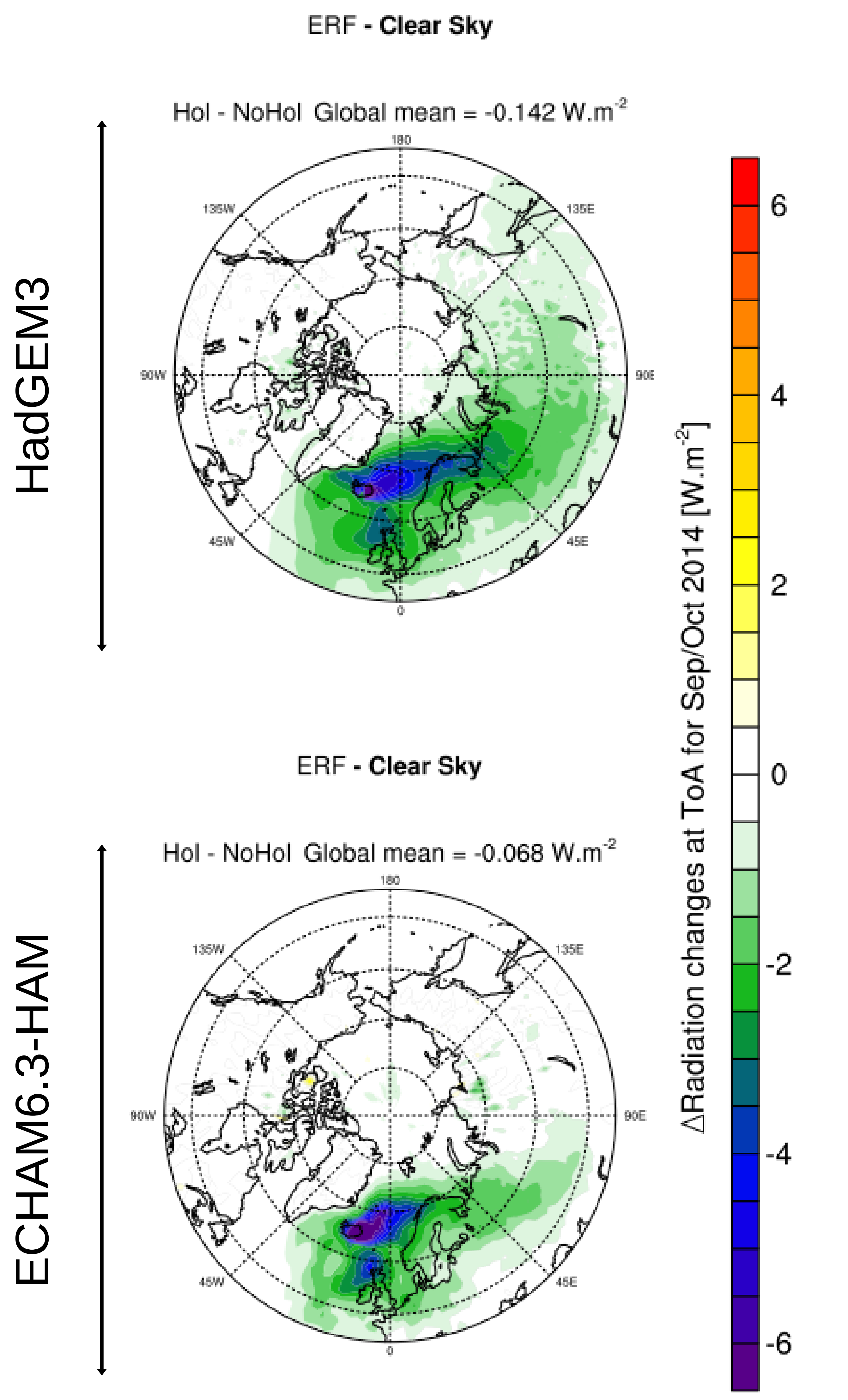
Some implication and future work direction

These case studies are also useful to test aerosol representation in models with extreme emissions

1 - Evaluate the volcanic plume lifecycle during transport: **VolcTraj** (*see P. Kim & D. Partridge presentation*)



2 - Identify mechanism responsible for the distribution of the plume - How does it affect forcing in the far field?

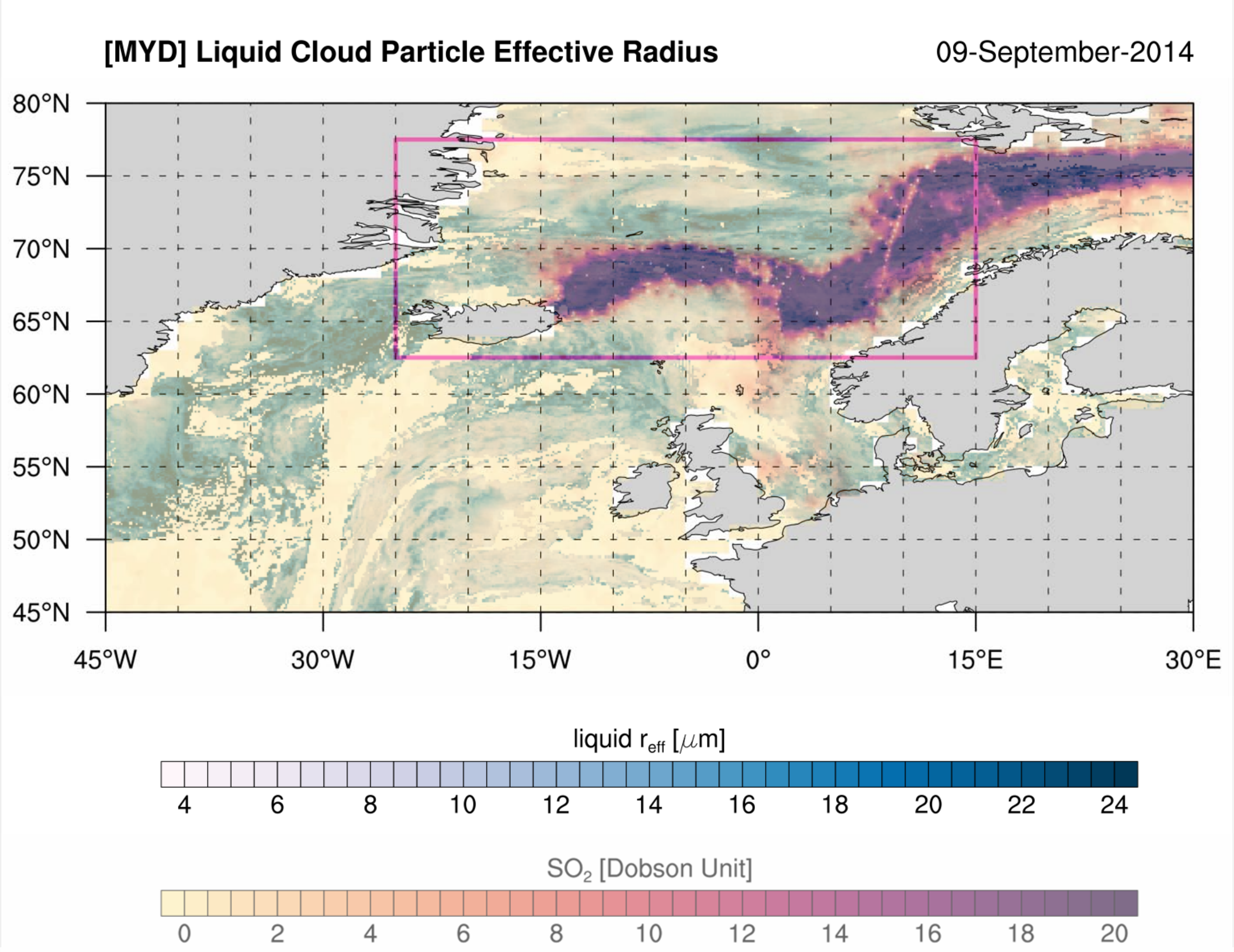


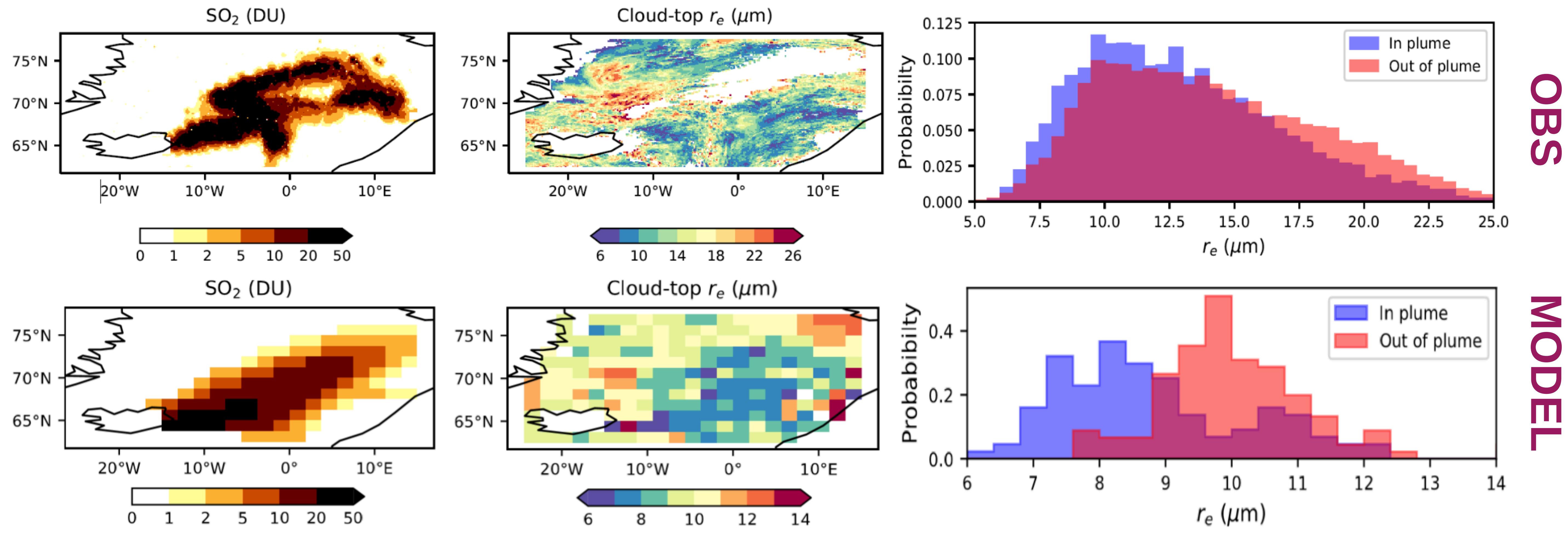
Volcanoes as Giant ShipTracks

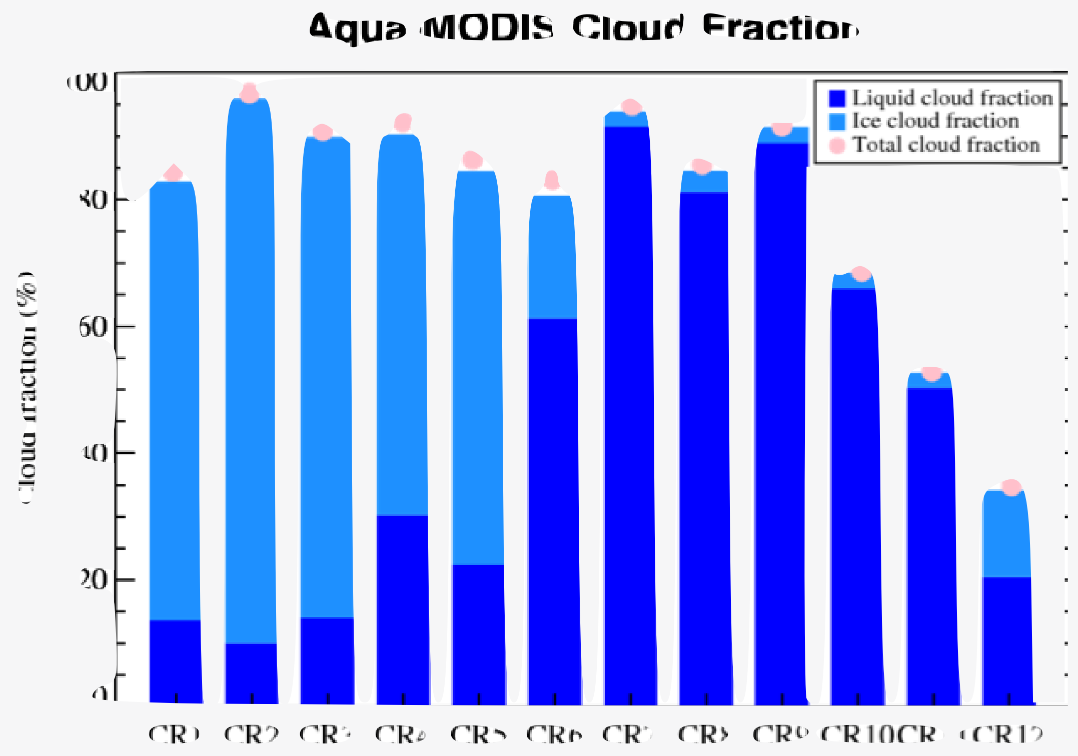
Both ‘easy’ to observed and to model

SO_2 → Aerosol (CCN) → Cloud Droplet (CDNC) → Cloud properties → Radiation (forcing)

SO_2 -> **OMPS** (SUOMI-NPP)
Cloud -> **MODIS** (AQUA)







Can we observe any systemic changes between in/out plume?
e.g. shift in ‘cloud regime’ ?

Summary

OBJECTIVES

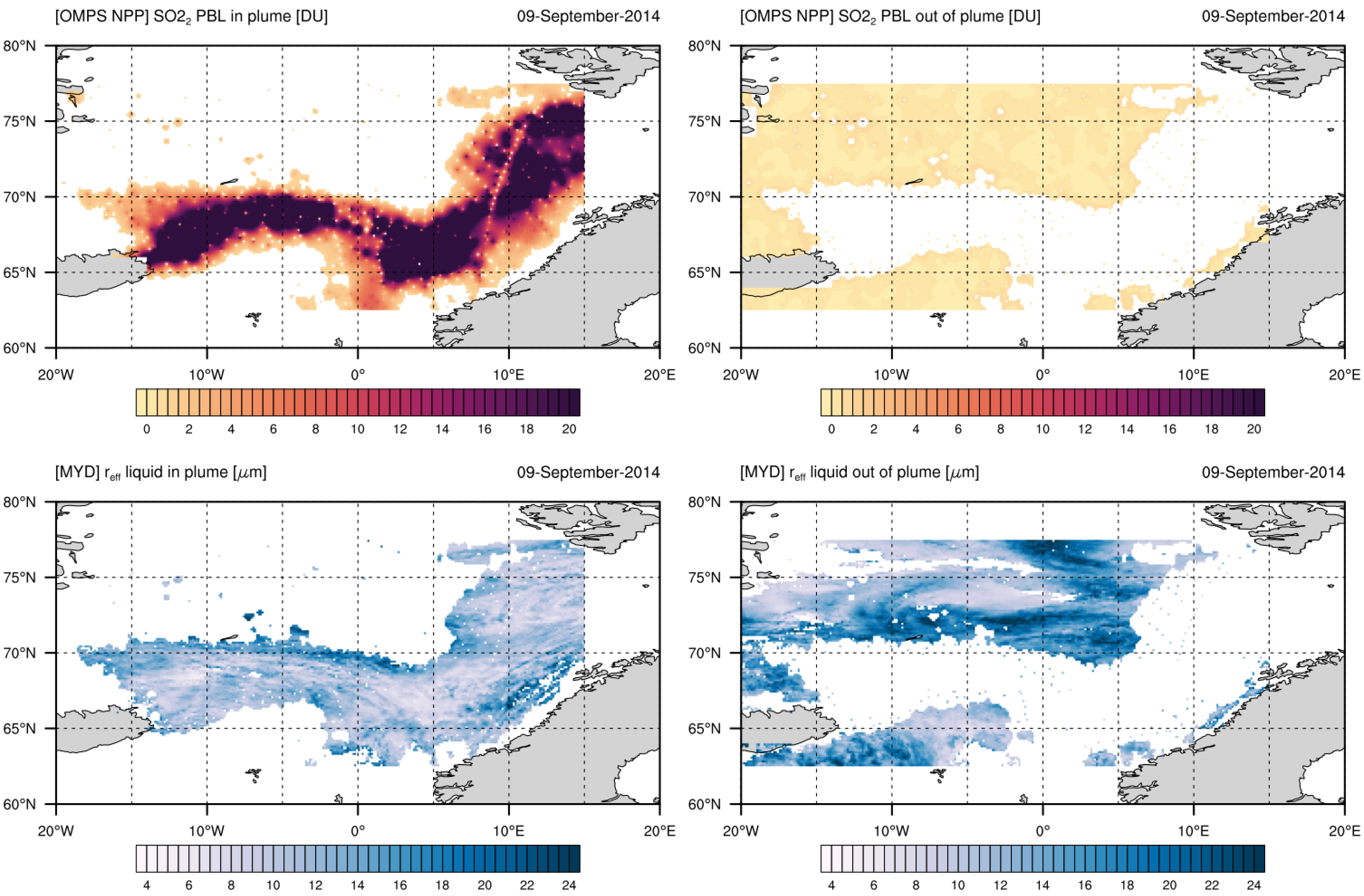
1 - Could GCMs capture the magnitude of ACI during the eruptions ?
2 - Quantify model responses to the volcanic perturbation and assess where models (dis)agree **- ACI metrics**
3 - Identify biases in models and parameterisation contributing to spread in ACI estimates **- Process based Metrics**

- **next 2/3 months** - Finish analysing current submissions (6): Identify remaining issues and find fixes.
- **By the end of 2019:**
  - Update all participants about potential alteration and provide details about (re)run (if applicable)
  - Request running 2018 Kilauea.
  - Request centre interested in participating to submit contributions.
- **2020 -** Full analysis (see above).
- **Mid 2020 -** Idealised runs with simplified plume model (Macv2SP & EASY Aerosols).
- **Early 2021 -** Early-draft summarising VolcACI results.

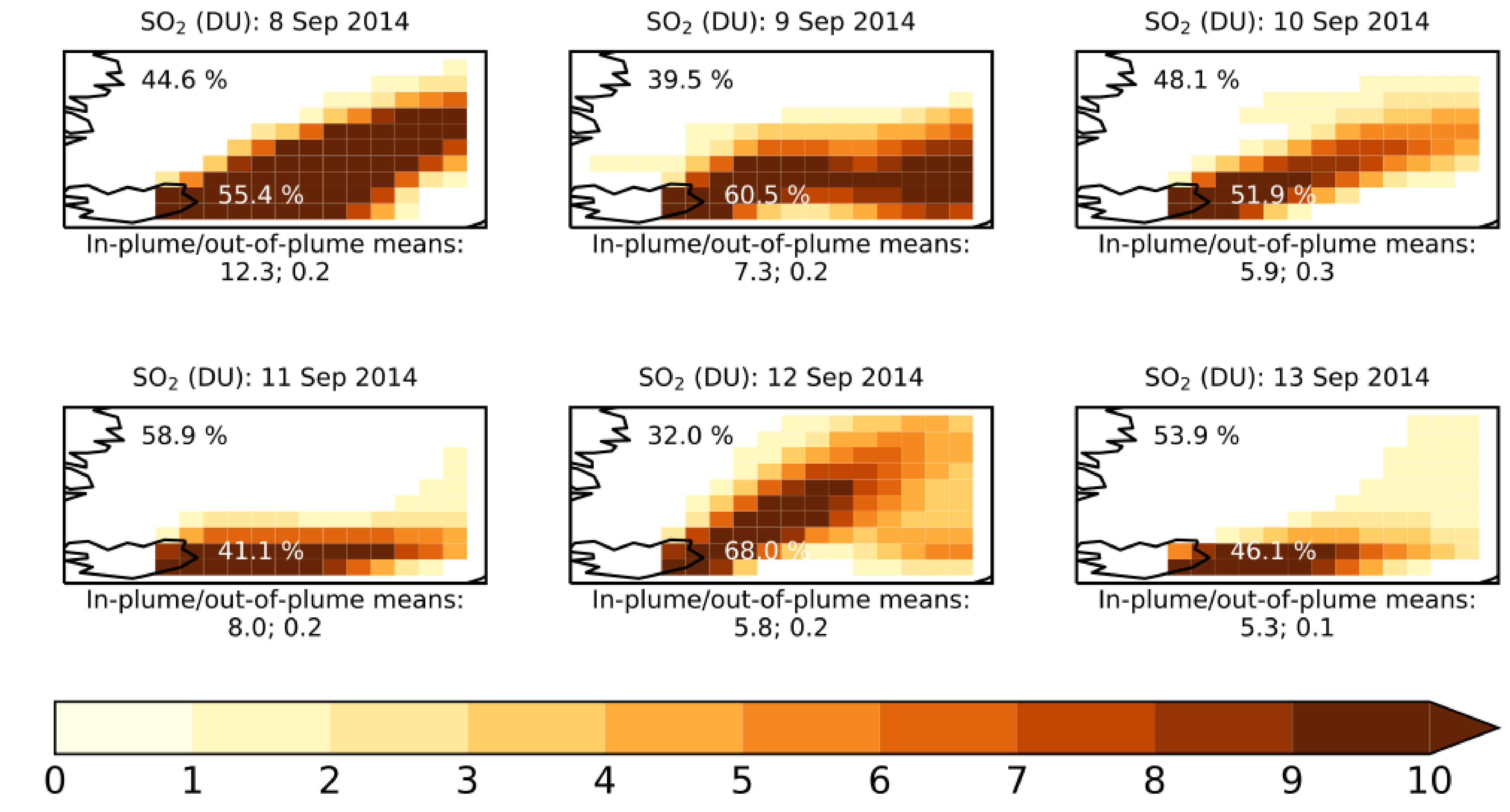
Thanks you for your Attention

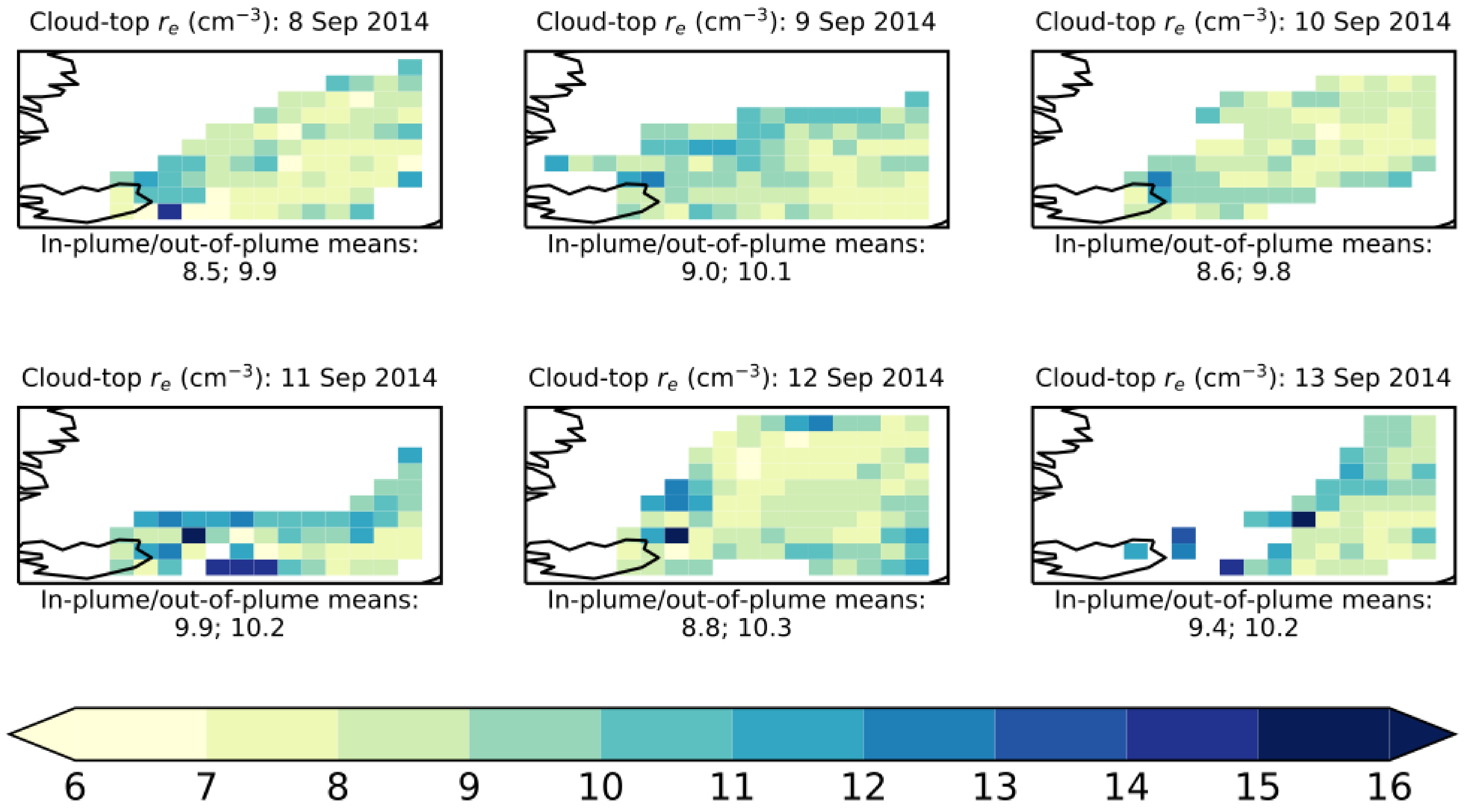
https://drive.google.com/drive/u/1/folders/1kDjywuf-5DND2kiiQw3hsPav9SQka2uO

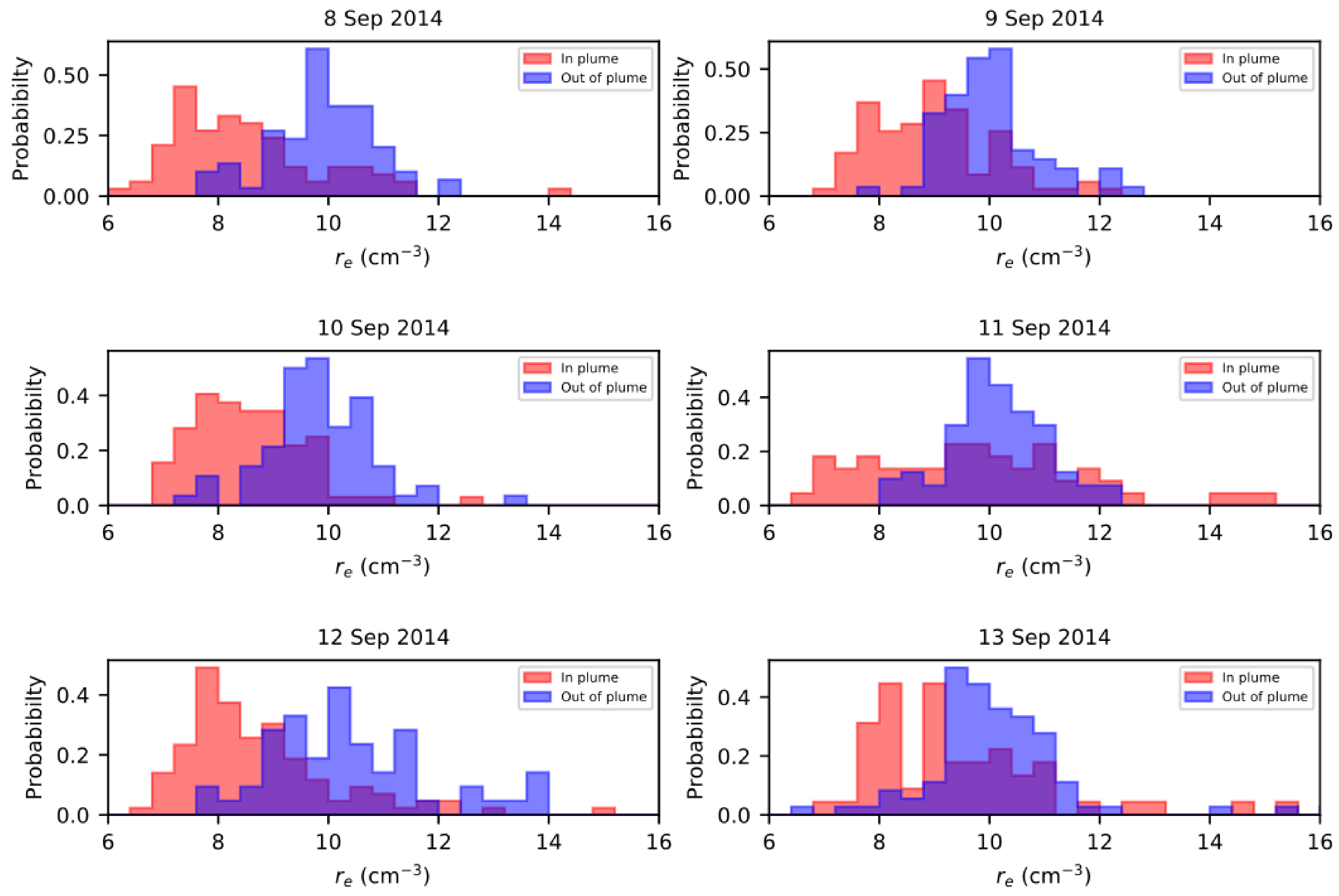
https://wiki.met.no/aerocom/phase3-experiments#volcanic_aci_experiment_volcaci

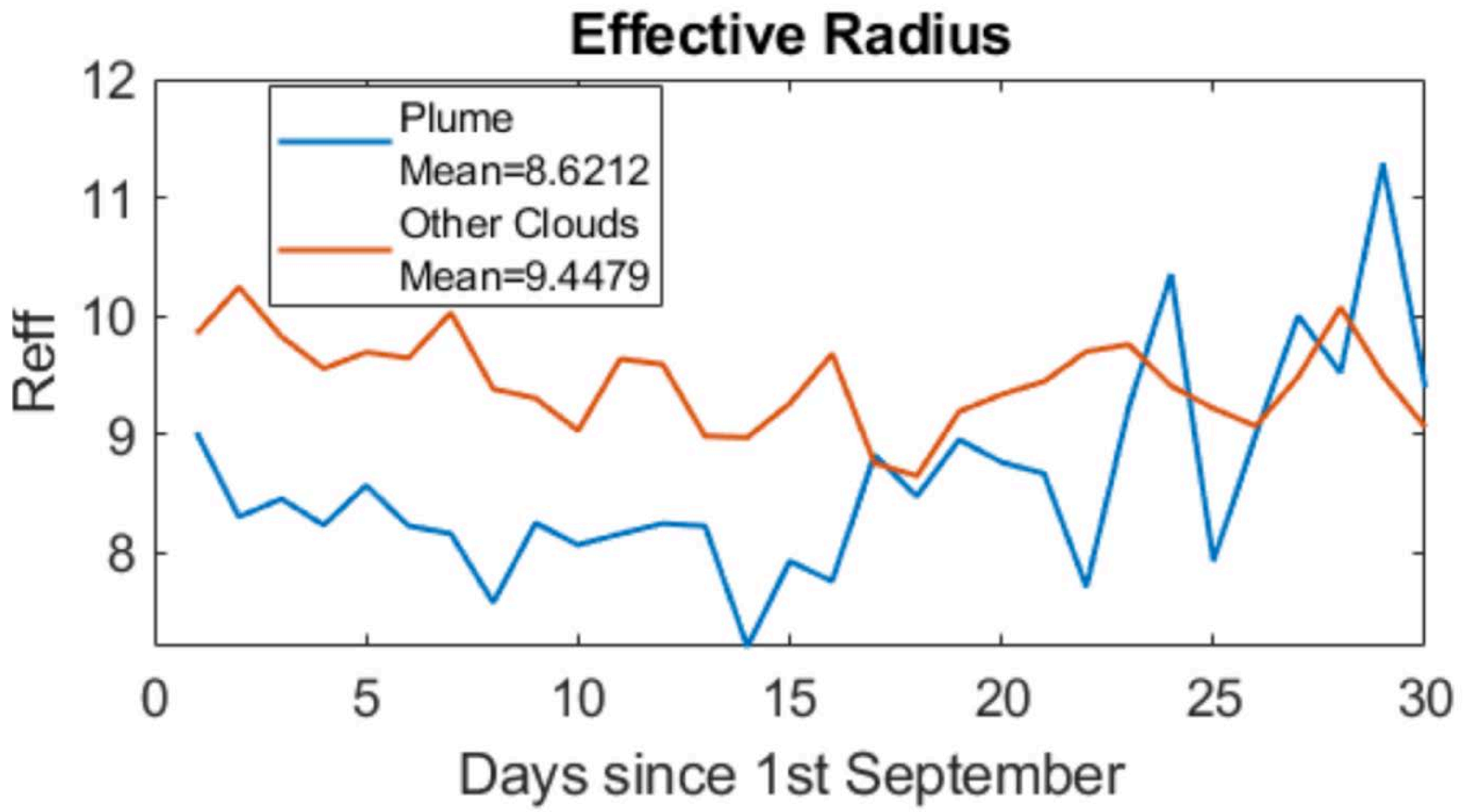

[OMPS NPP] SO2$_2$ PBL in plume [DU]
09-September-2014
[OMPS NPP] SO2$_2$ PBL out of plume [DU]
09-September-2014
80°N
75°N
70°N
65°N
60°N
20°W
10°W
0°
10°E
20°E
0 2 4 6 8 10 12 14 16 18 20
[MYD] r_{eff} liquid in plume [μm]
09-September-2014
[MYD] r_{eff} liquid out of plume [μm]
09-September-2014
4 6 8 10 12 14 16 18 20 22 24

Volcanoes as Giant ShipTracks





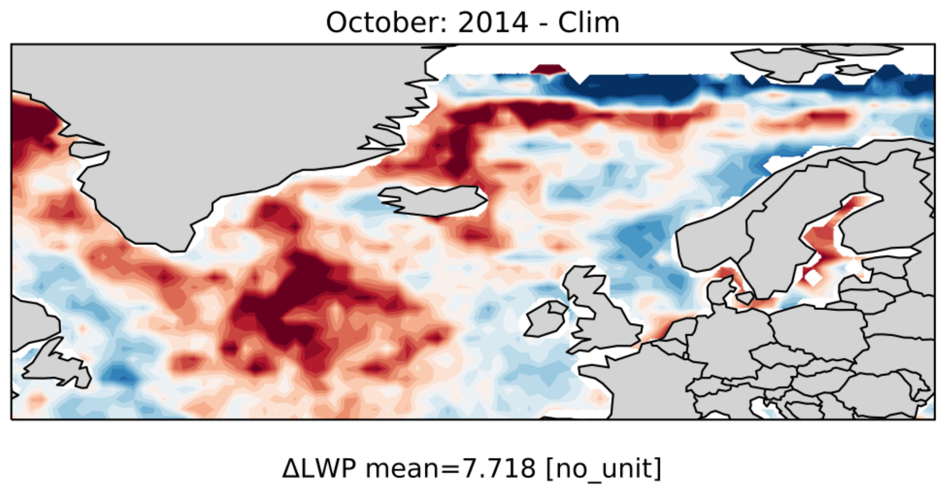


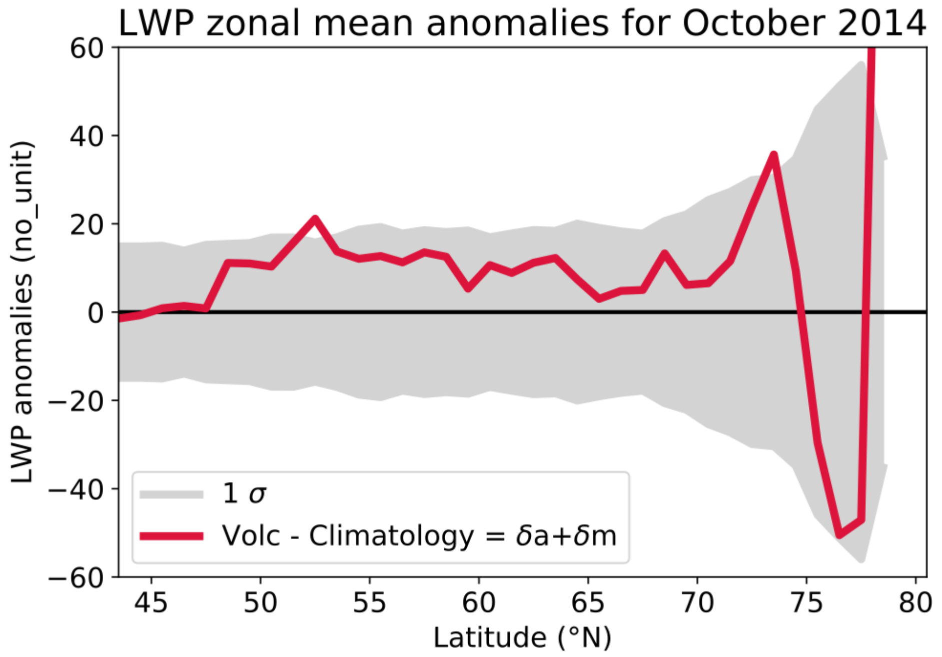


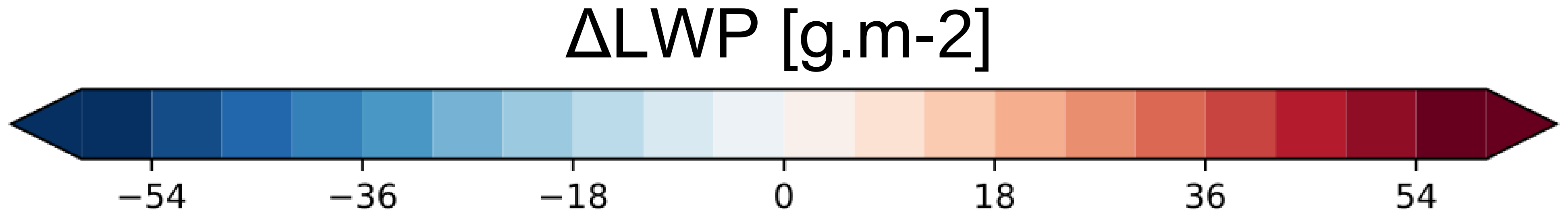
Cloud properties - LWP

October 2014

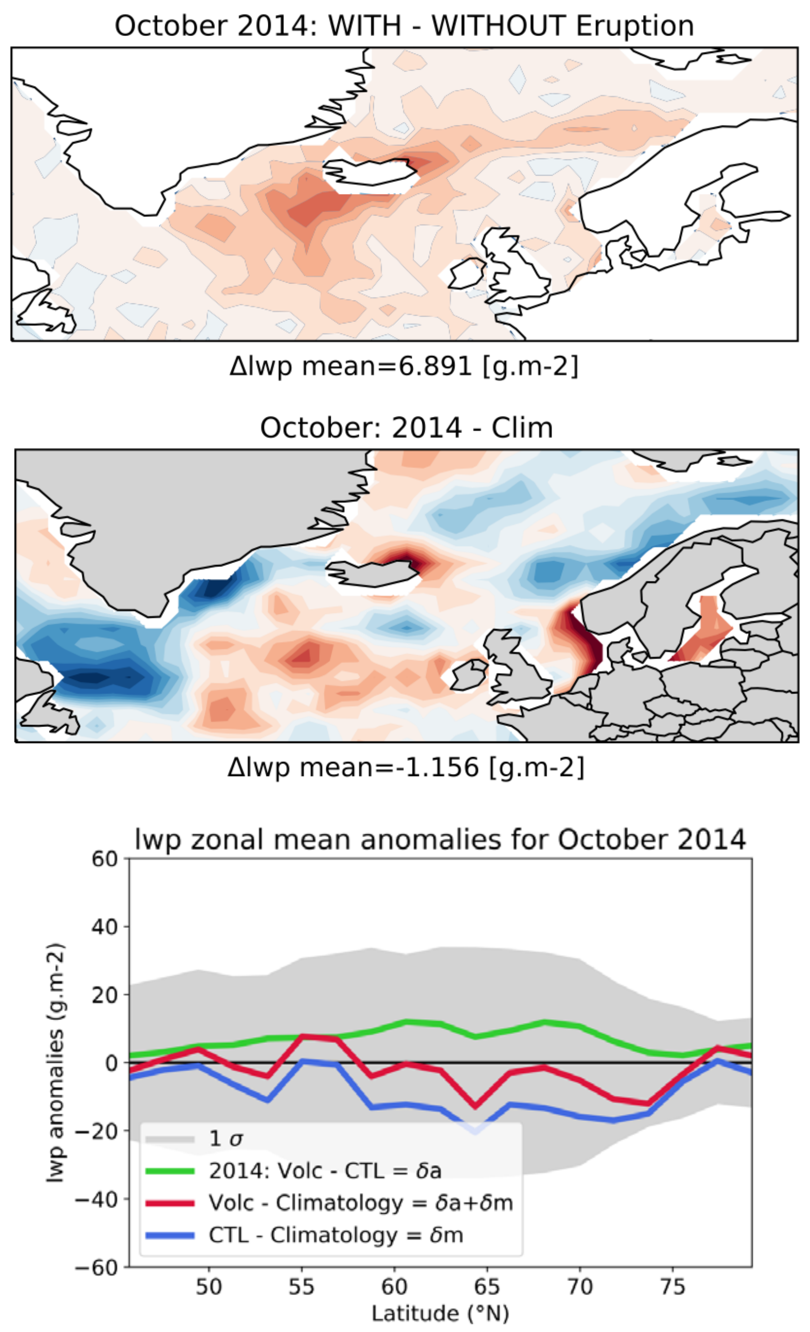
AQUA C6.1



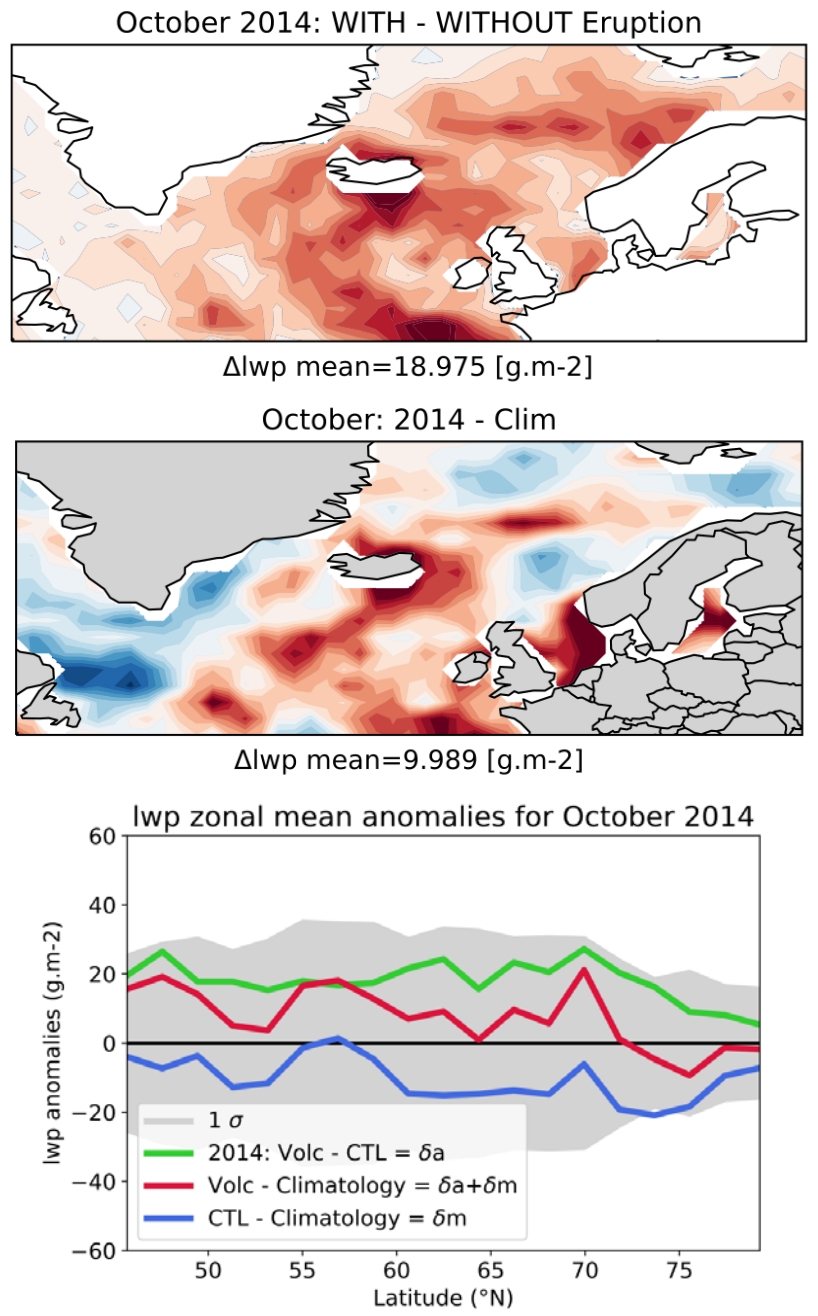




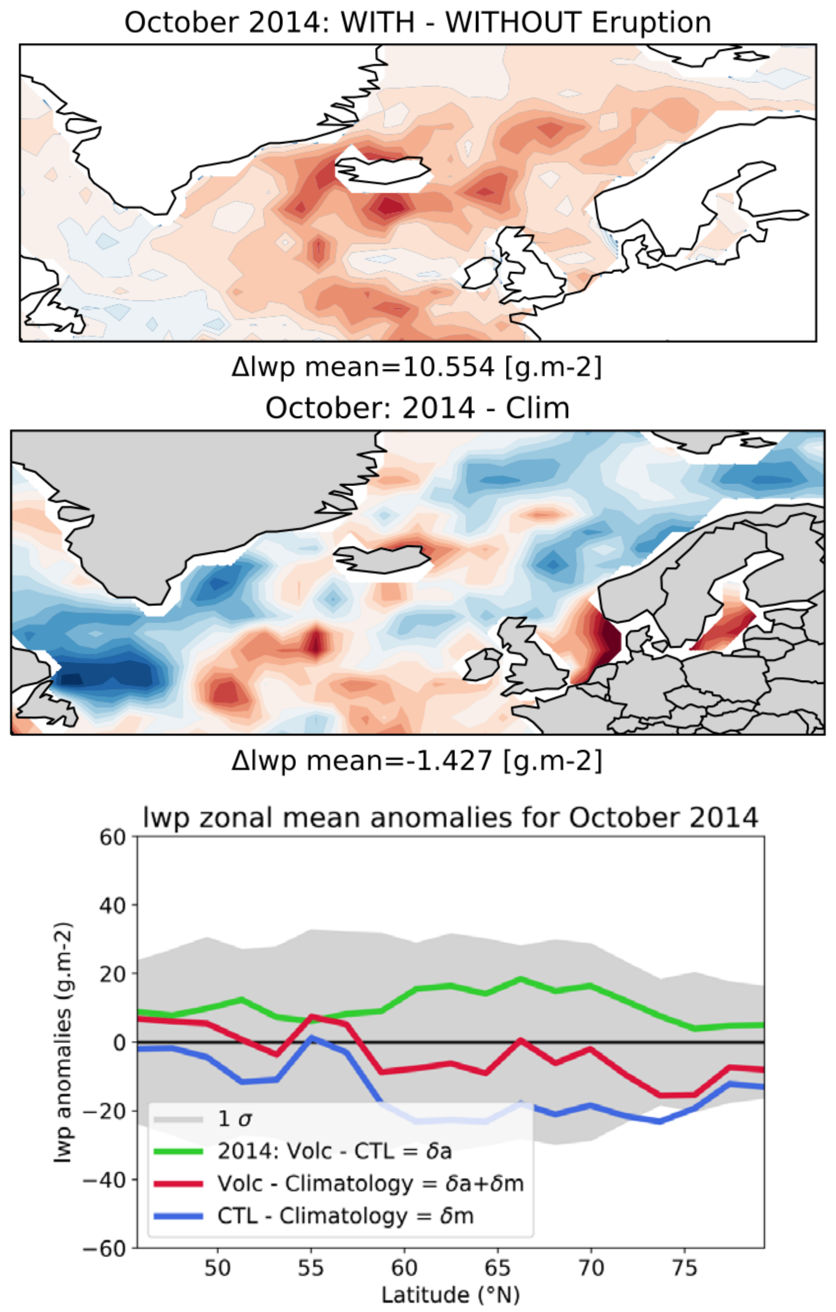
ECHAM-P3



ECHAM-SALSA



ECHAM-HAM



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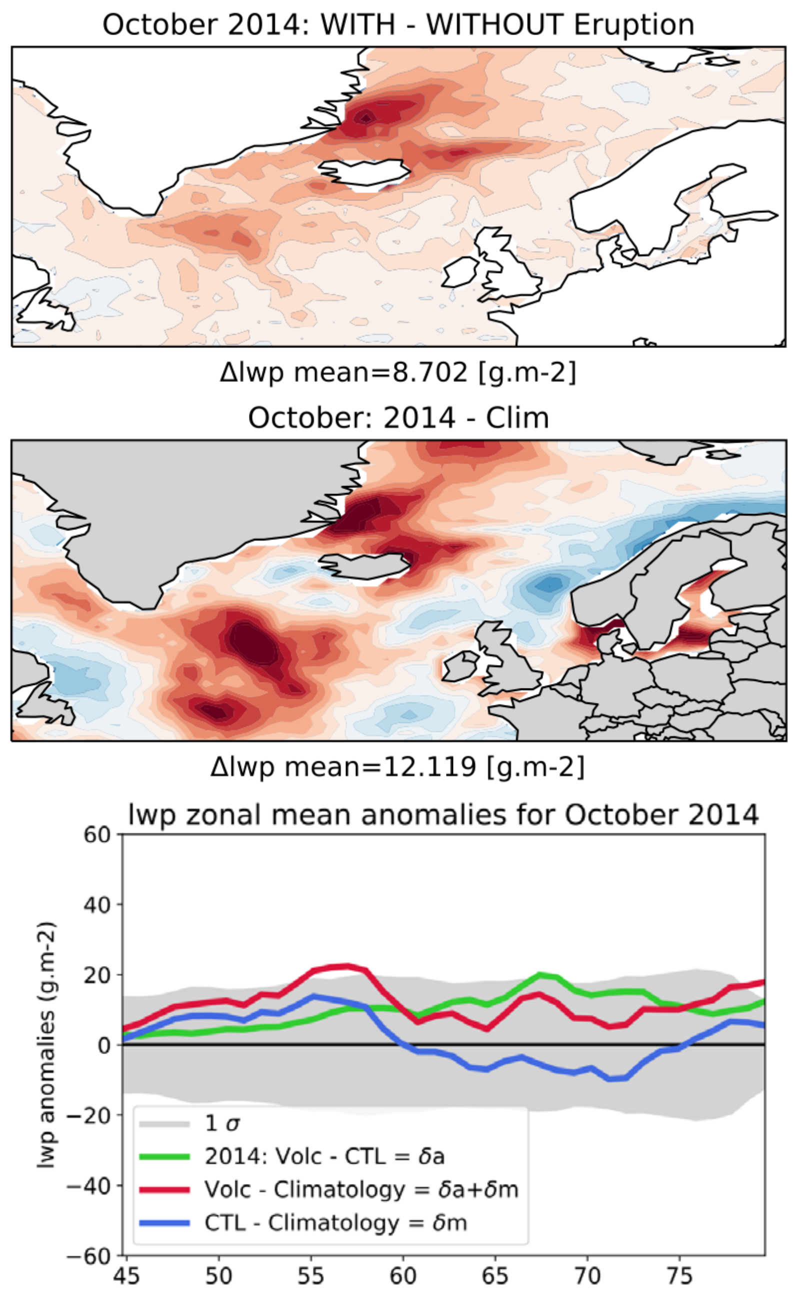
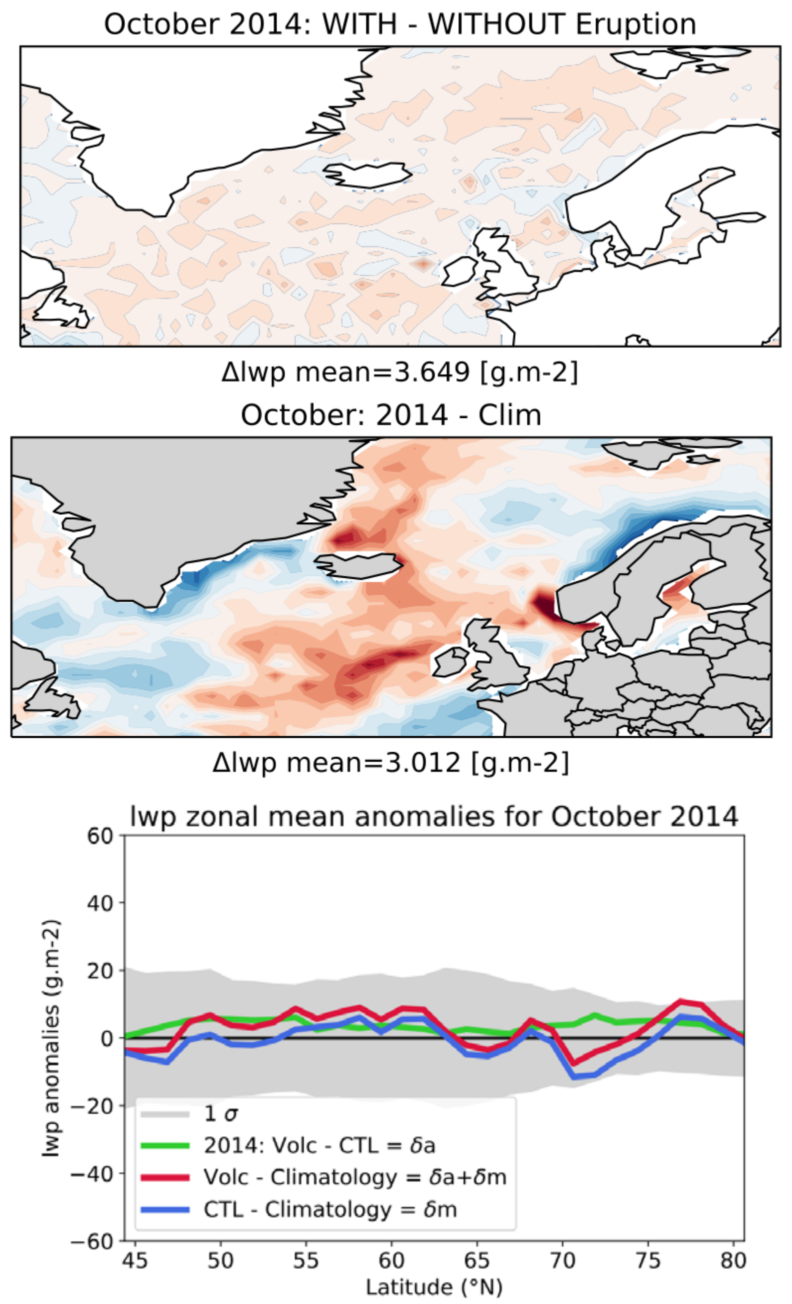


UKESM1



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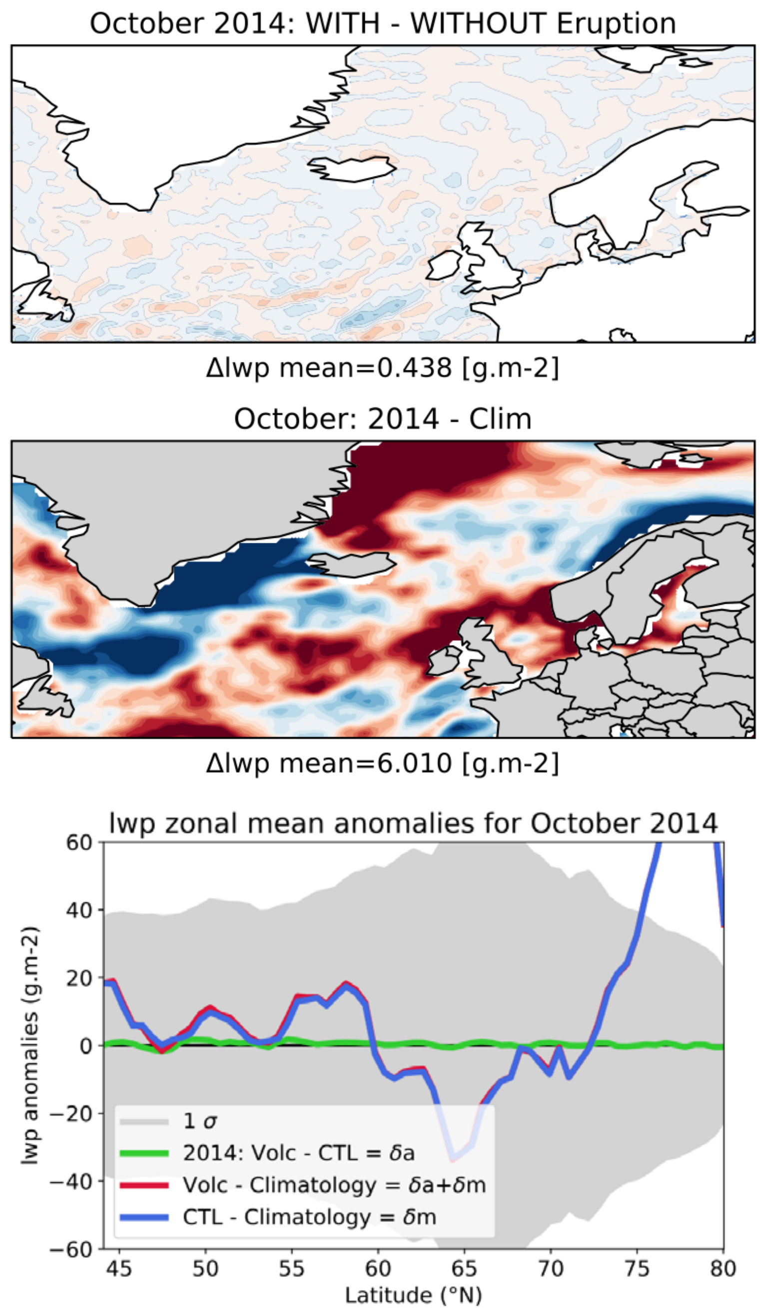
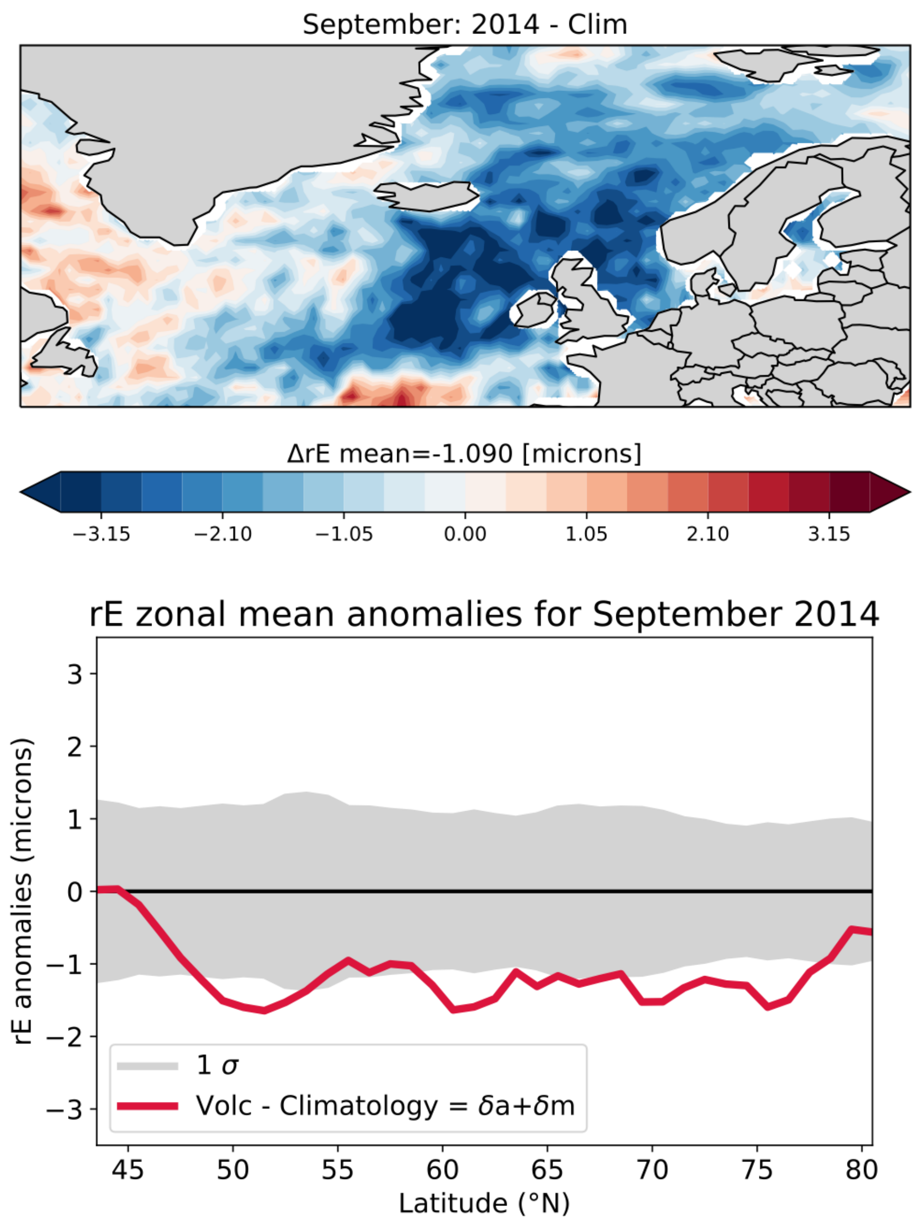


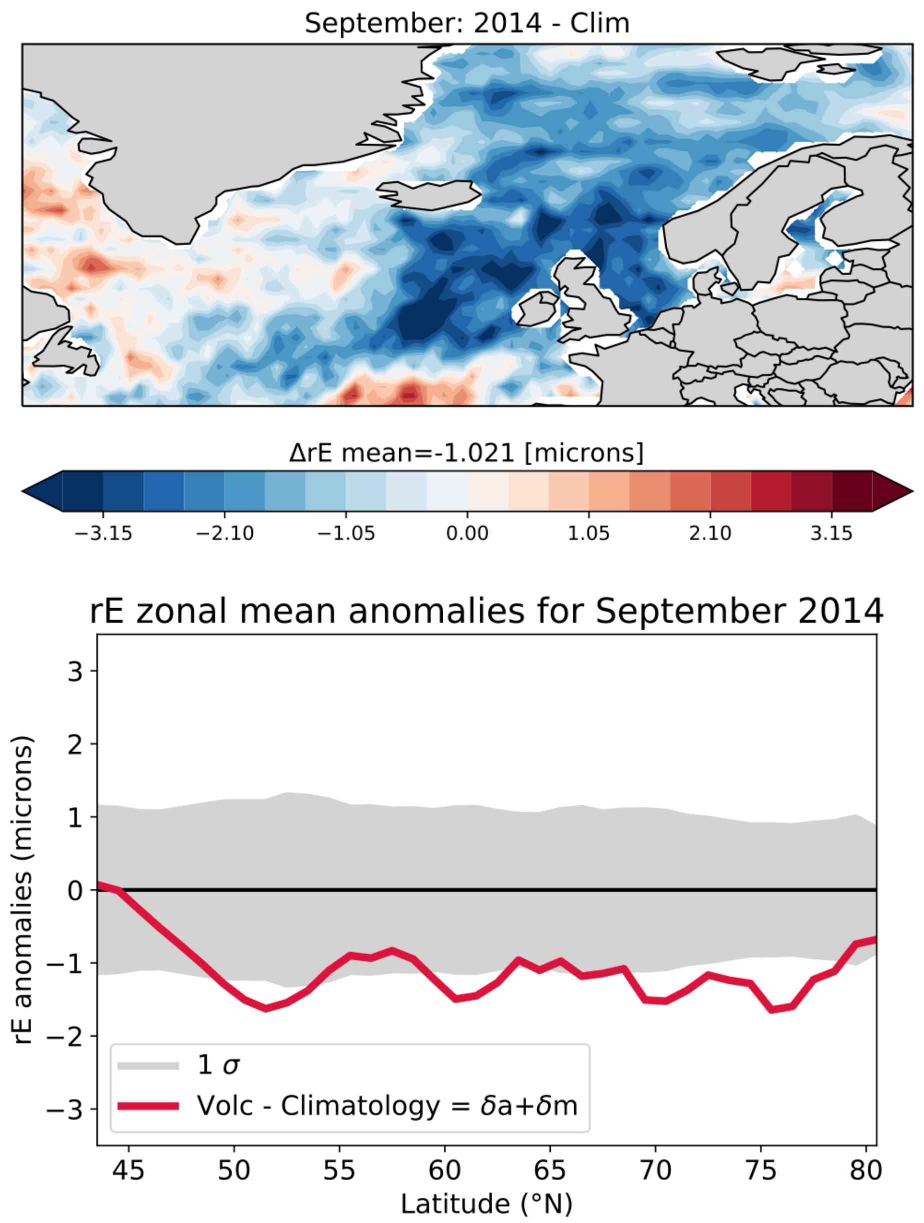
Hol. earlier work

September 2014

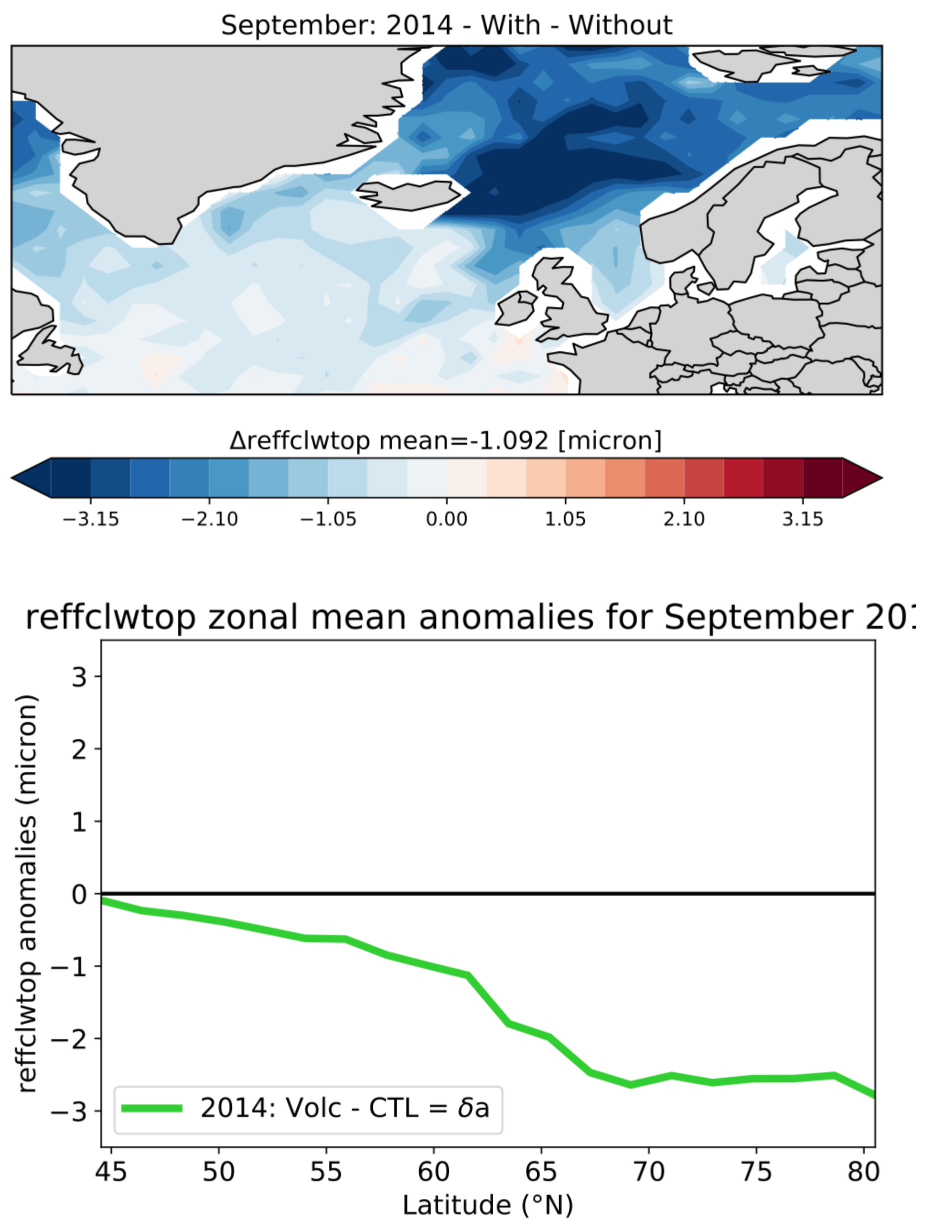
AQUA C6.1



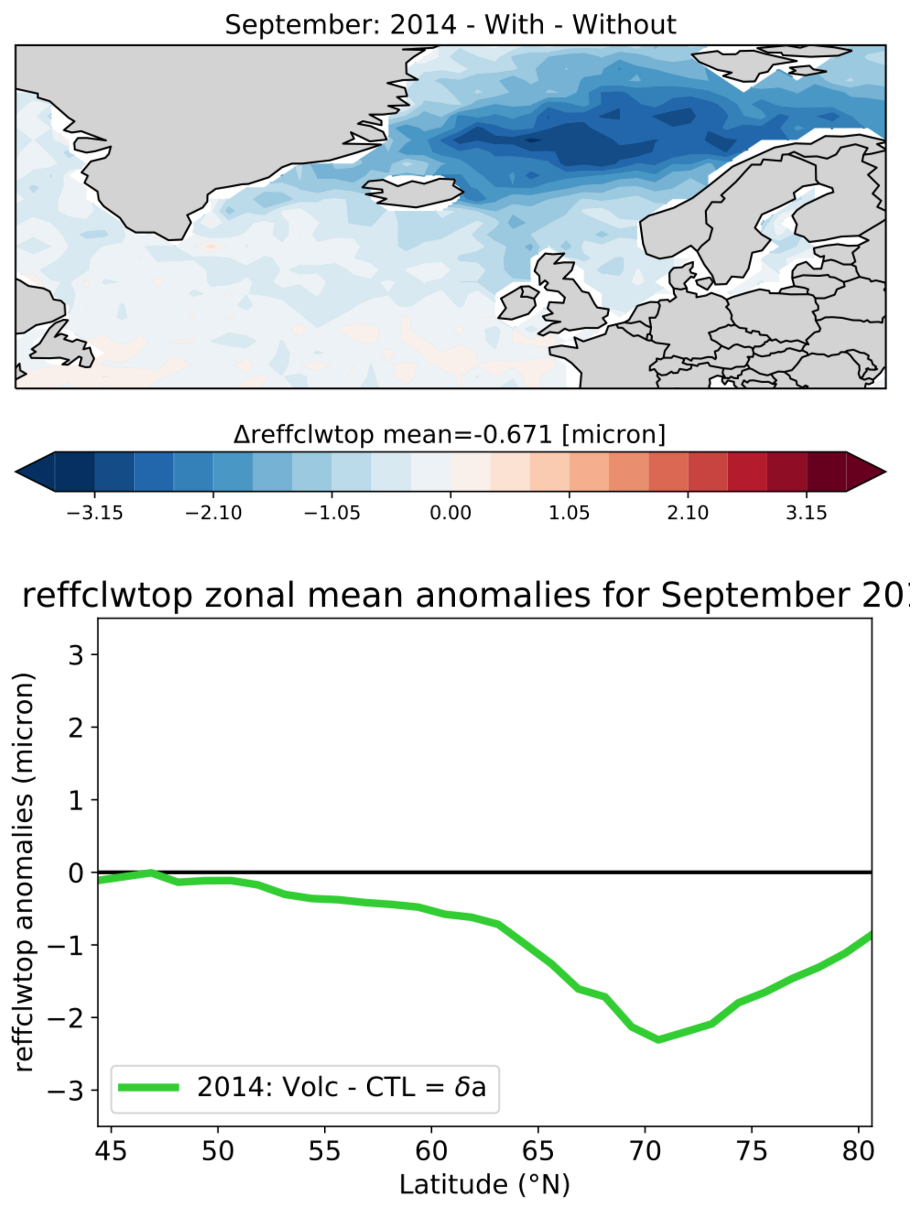
TERRA C6.1



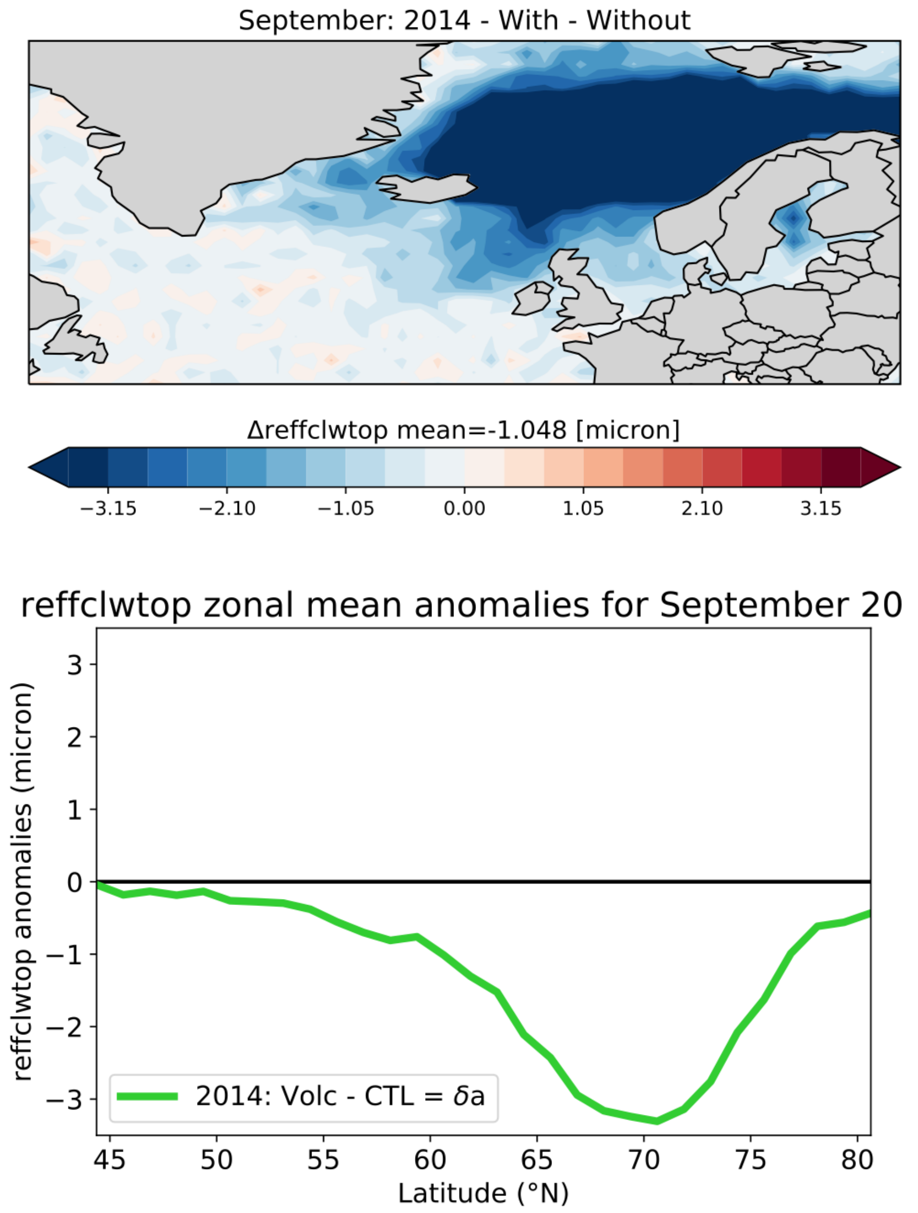
NCAR-CAM5.4



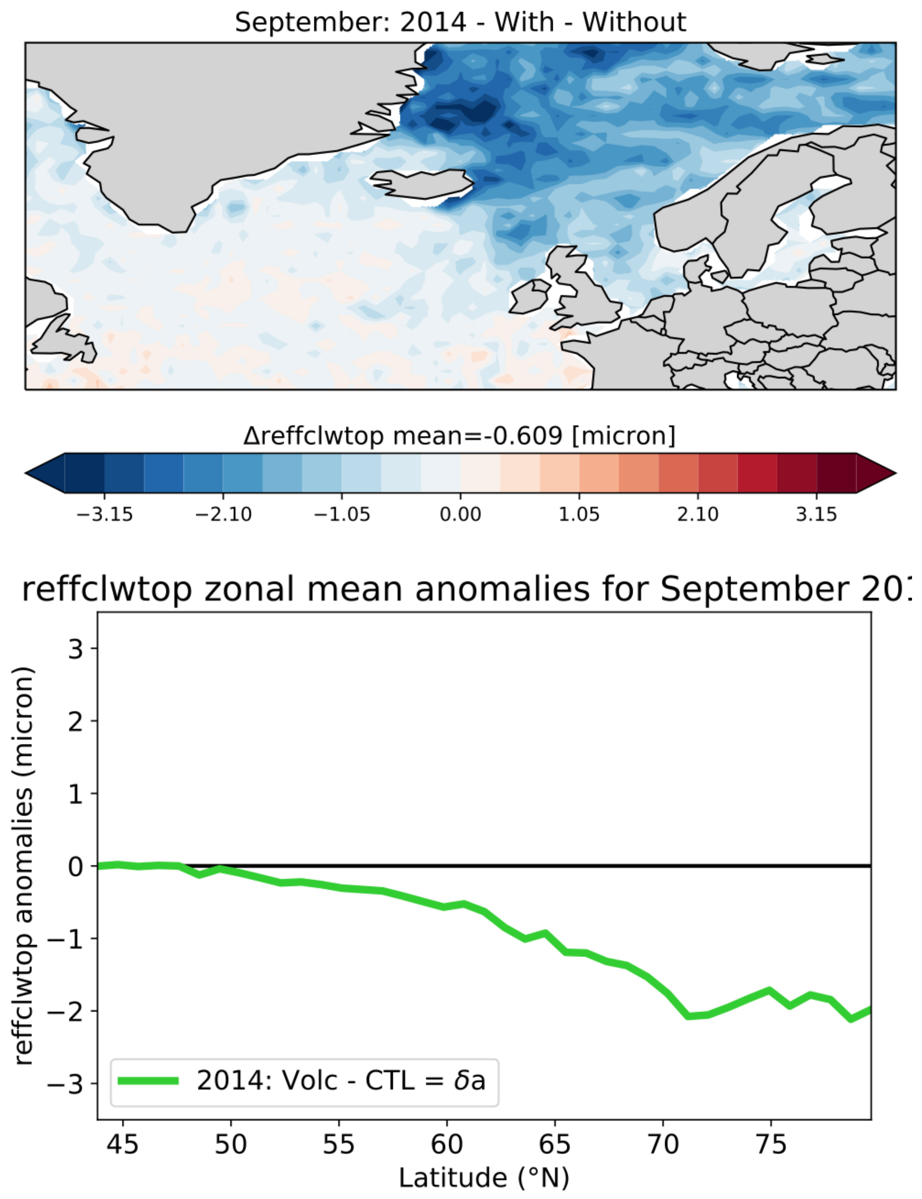
HadGEM3-UKCA



HadGEM3-CLASSIC



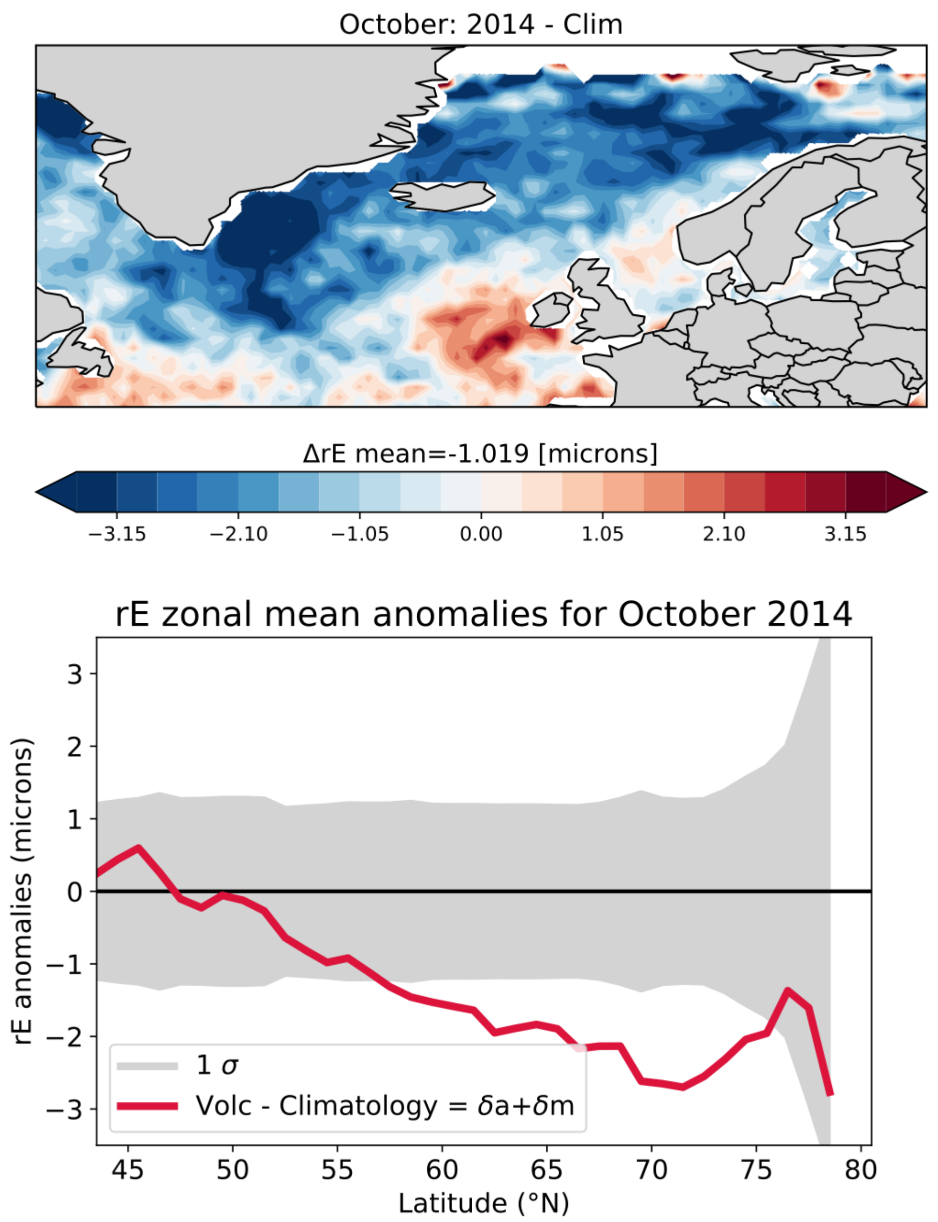
Oslo-CAM5.3



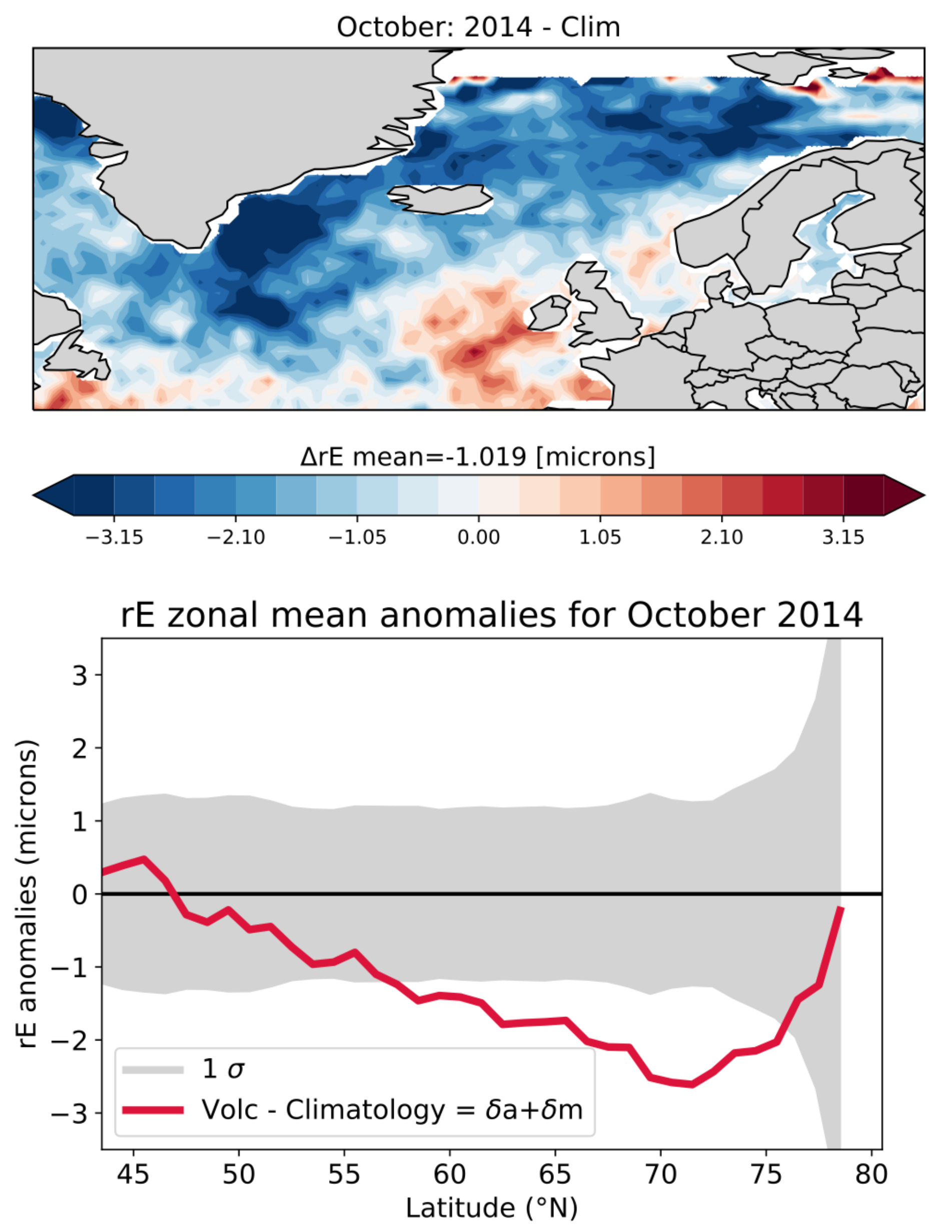
Hol. earlier work

October 2014

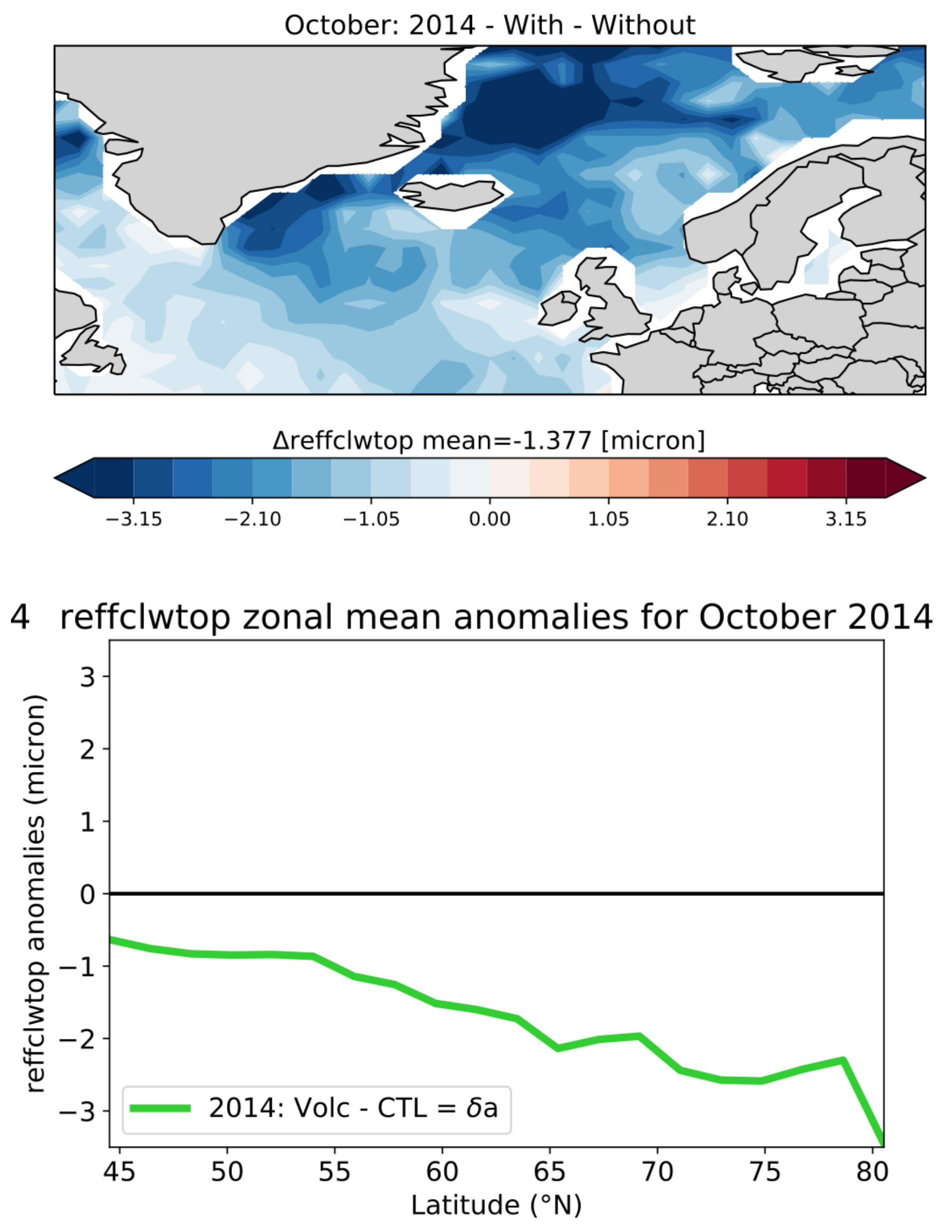
AQUA C6.1



TERRA C6.1



NCAR-CAM5.4



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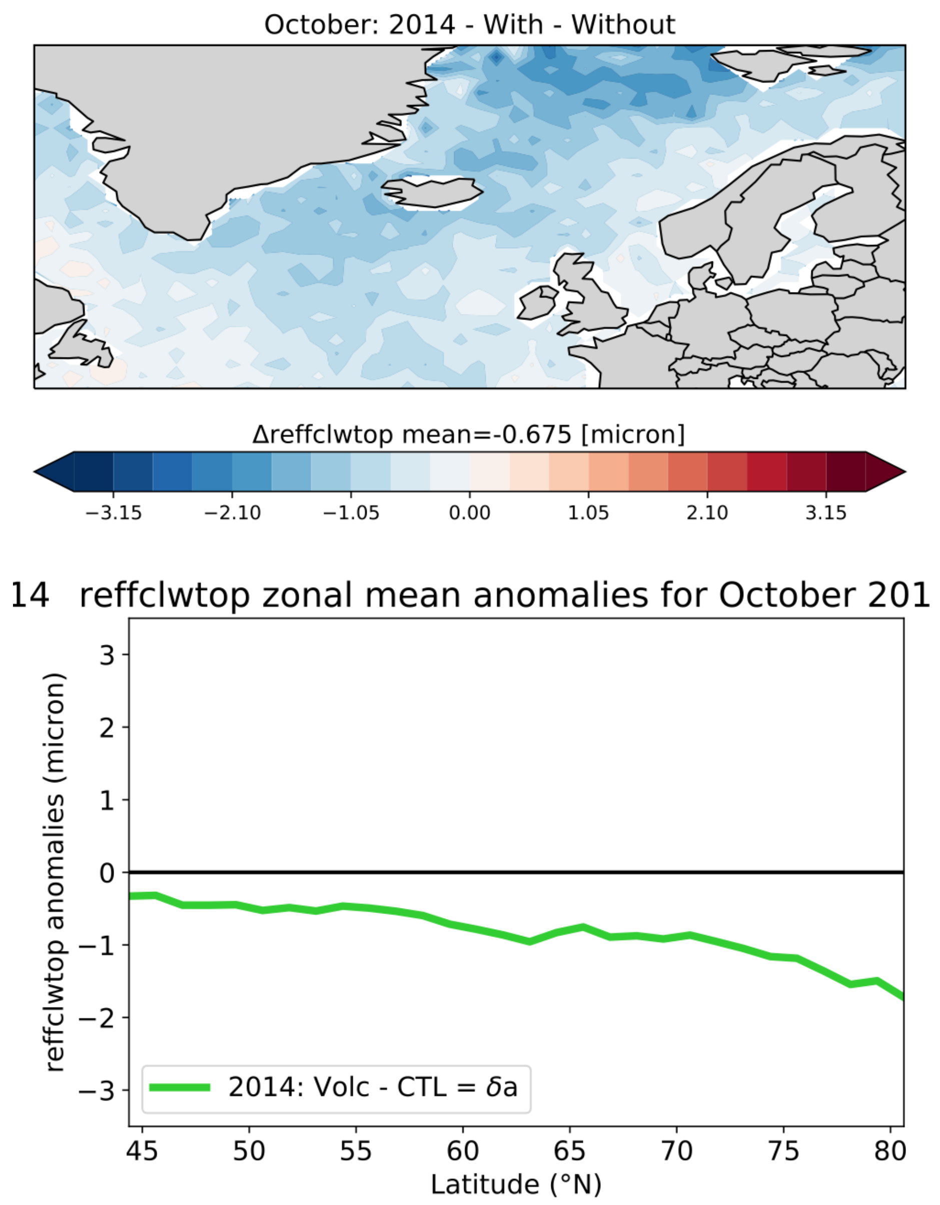

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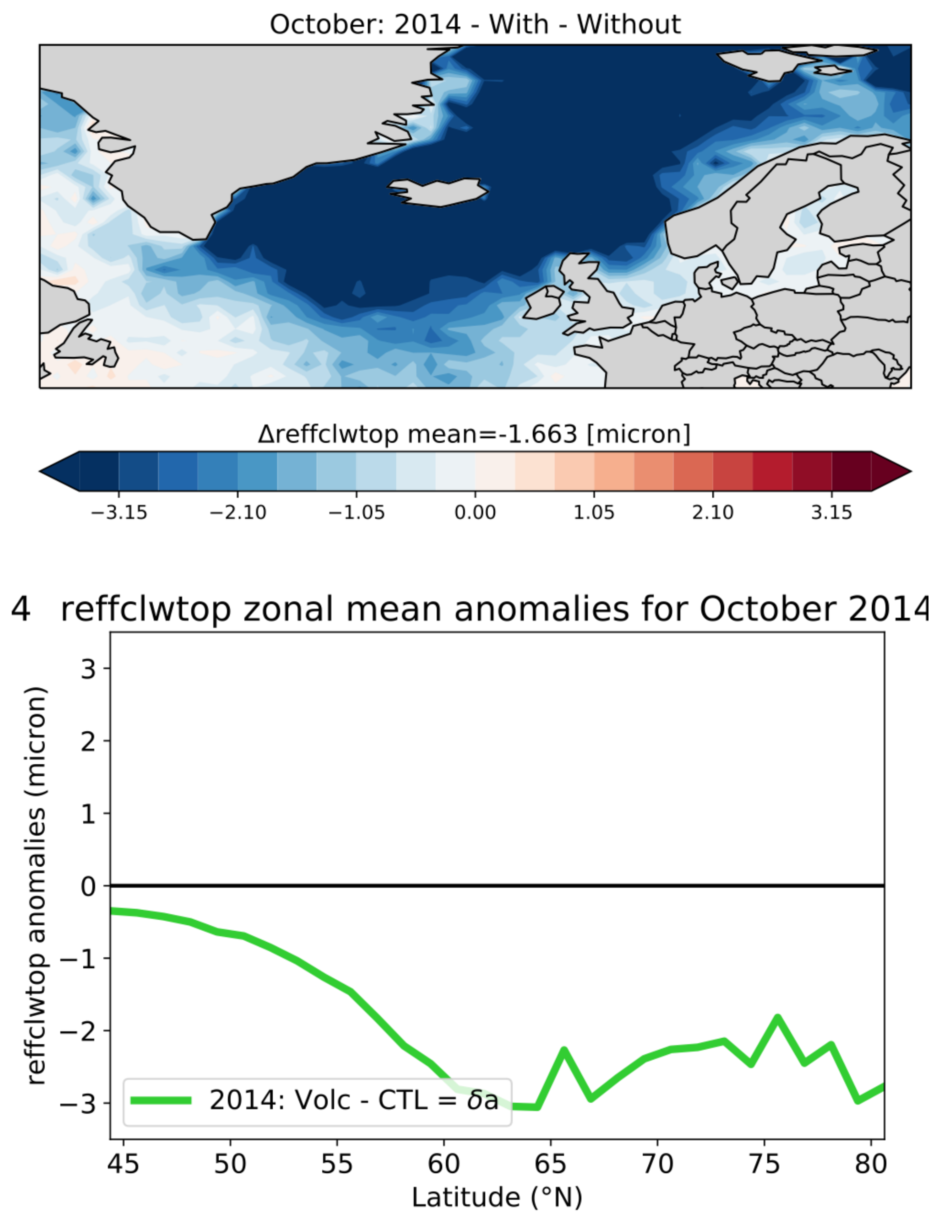
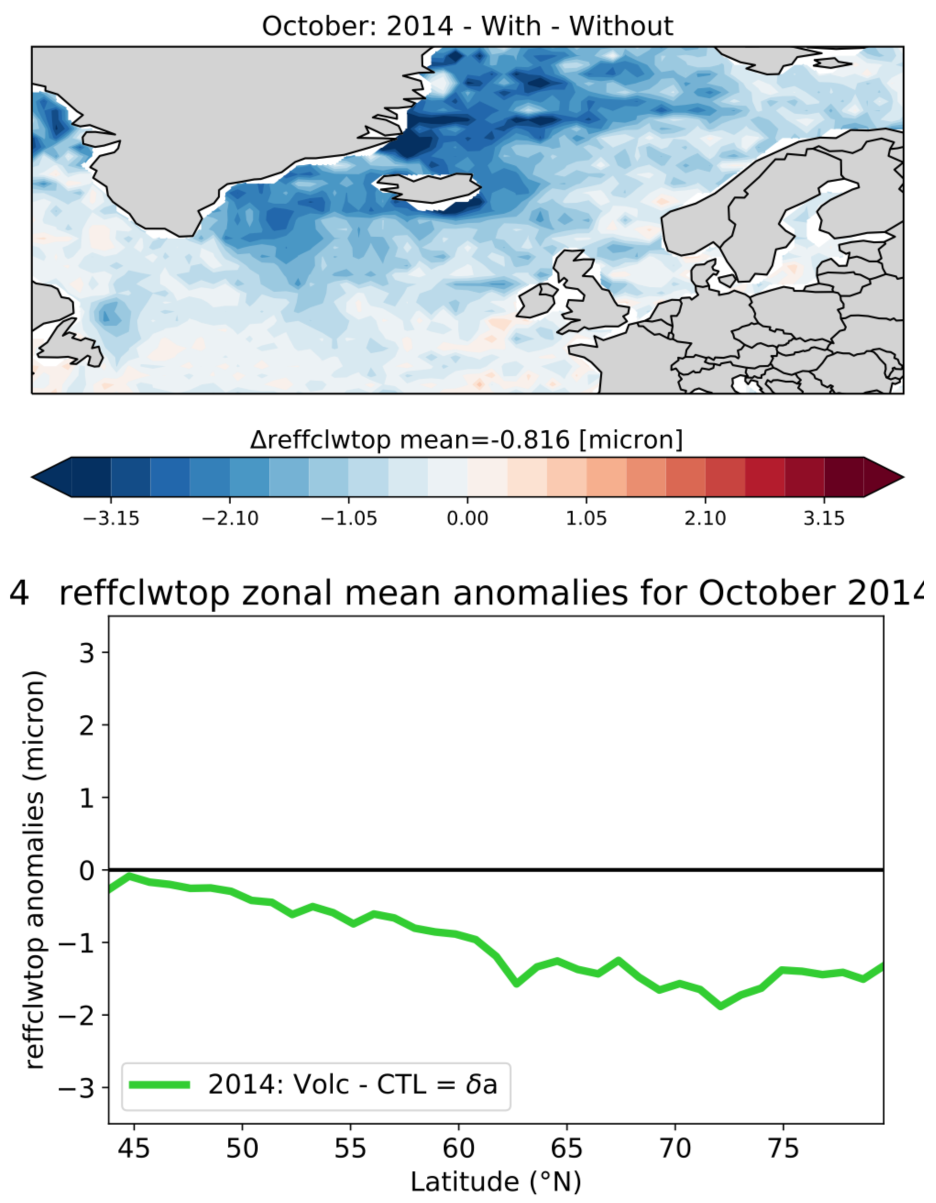
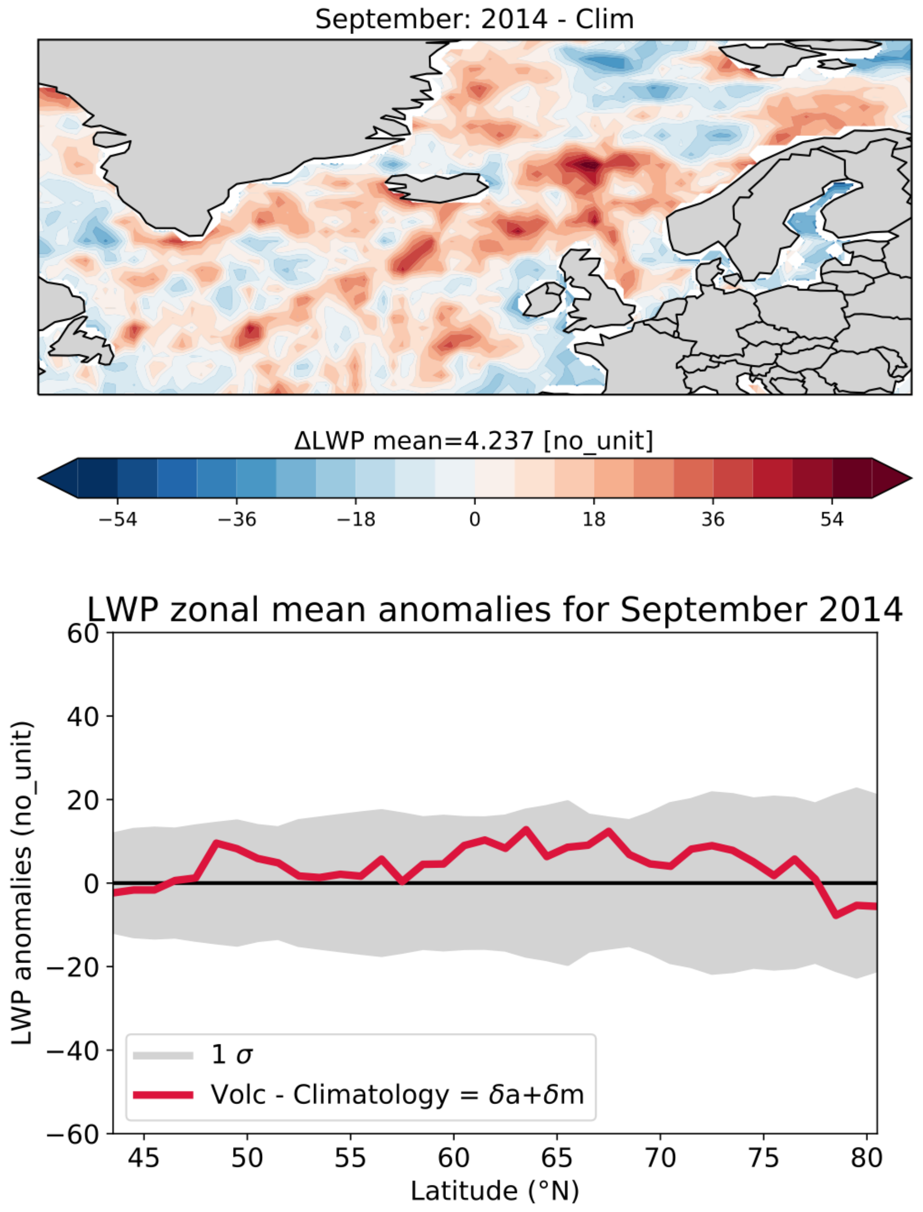


Oslo-CAM5.3

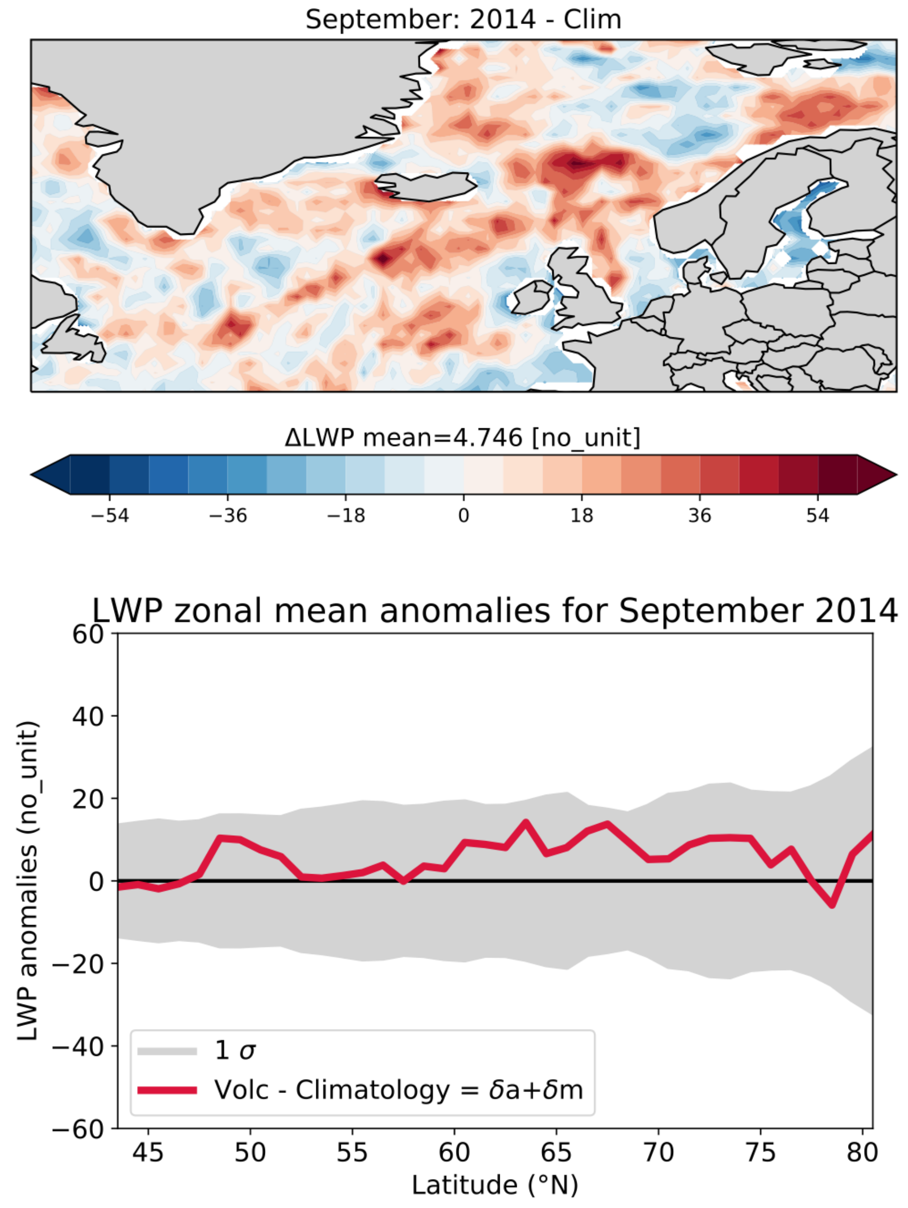


Hol. earlier work

AQUA C6.1



TERRA C6.1



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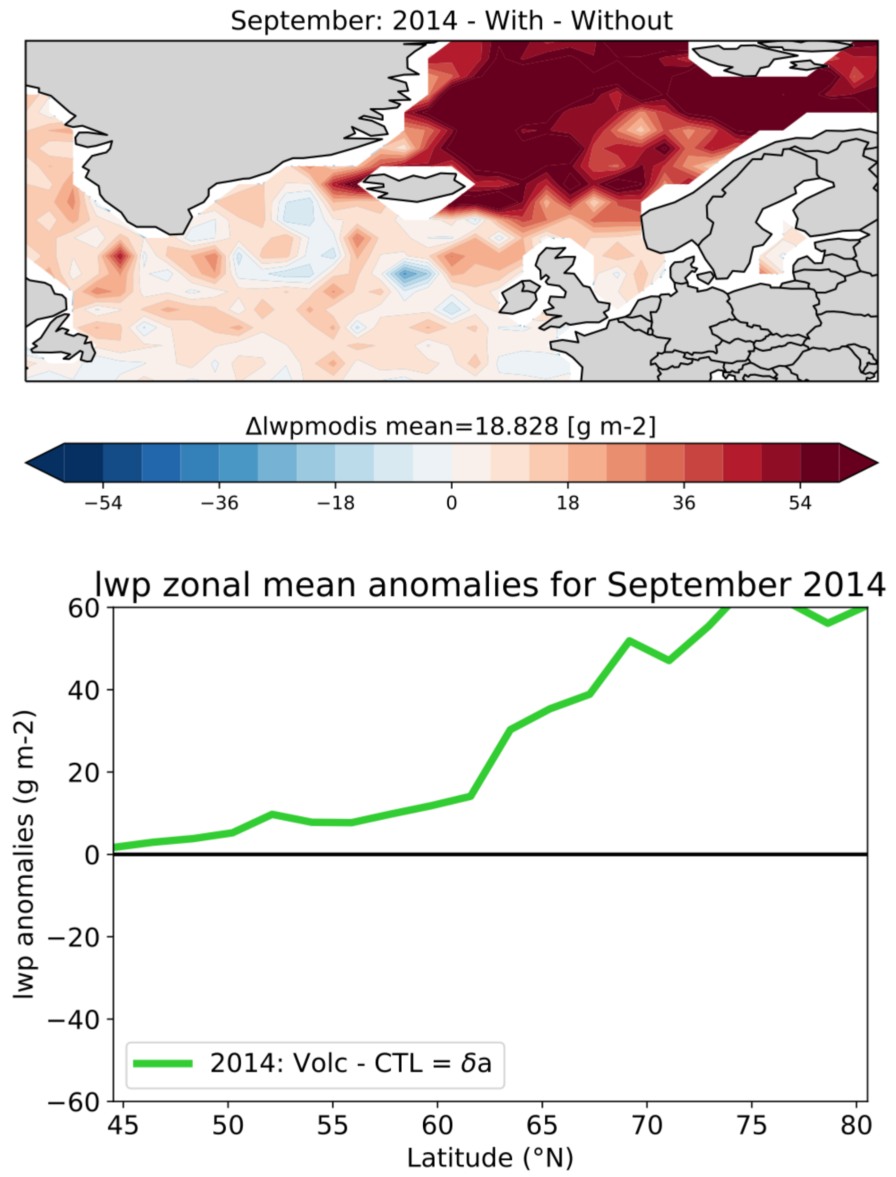

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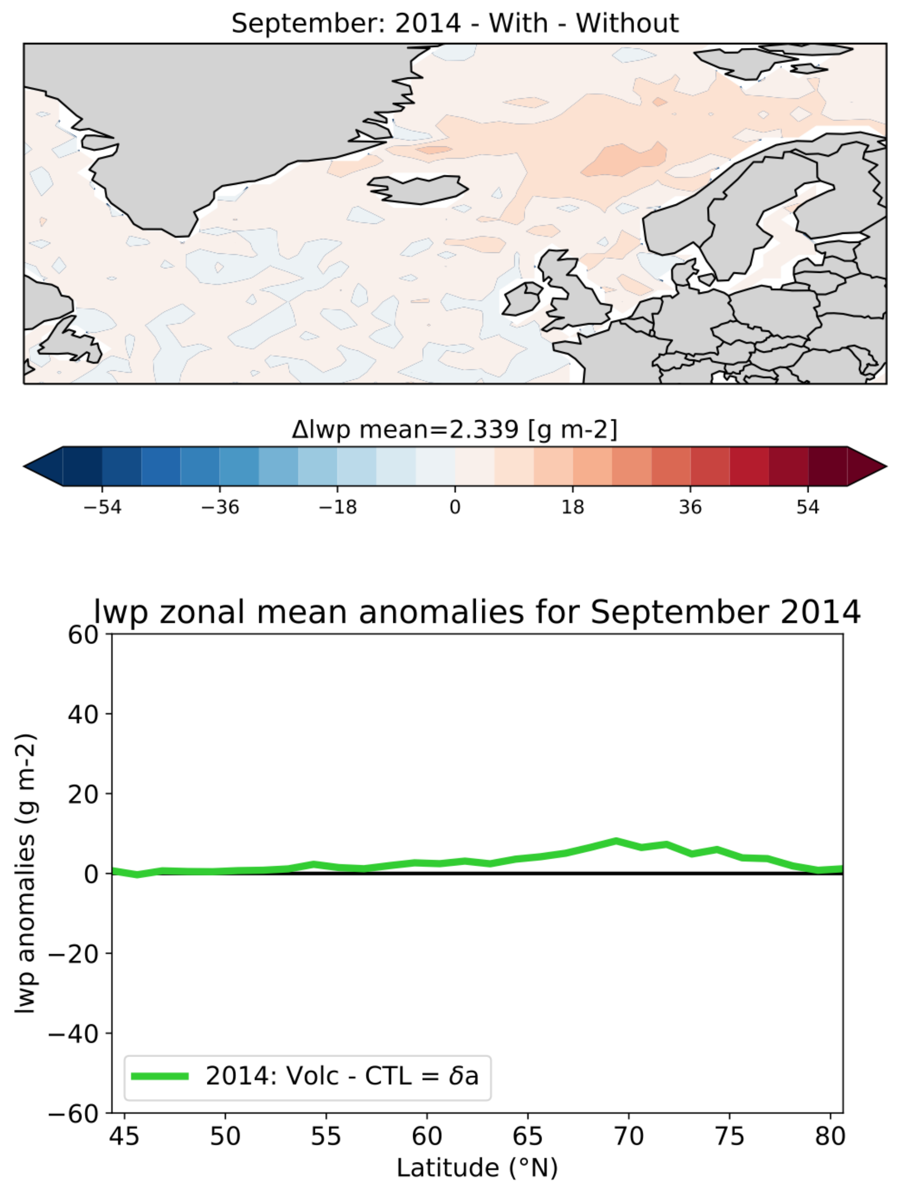

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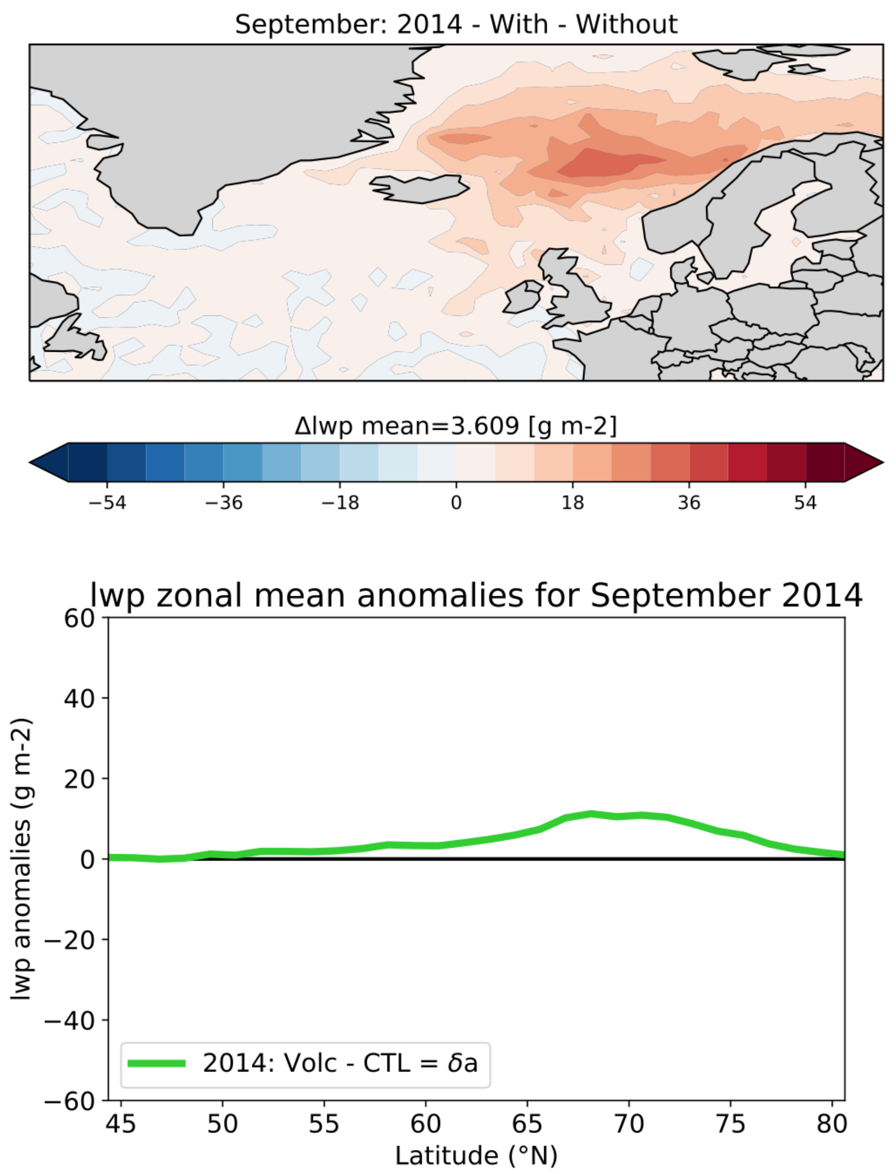
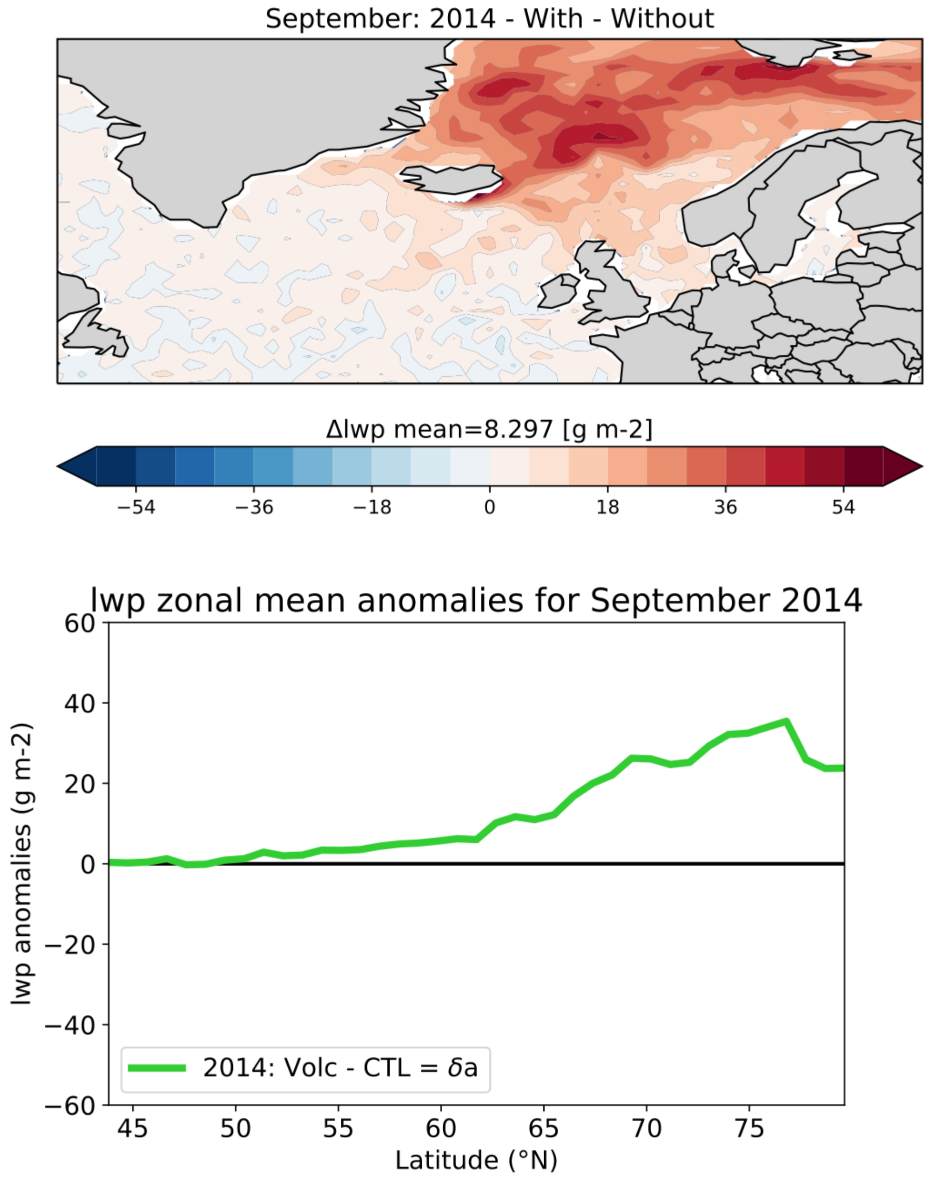
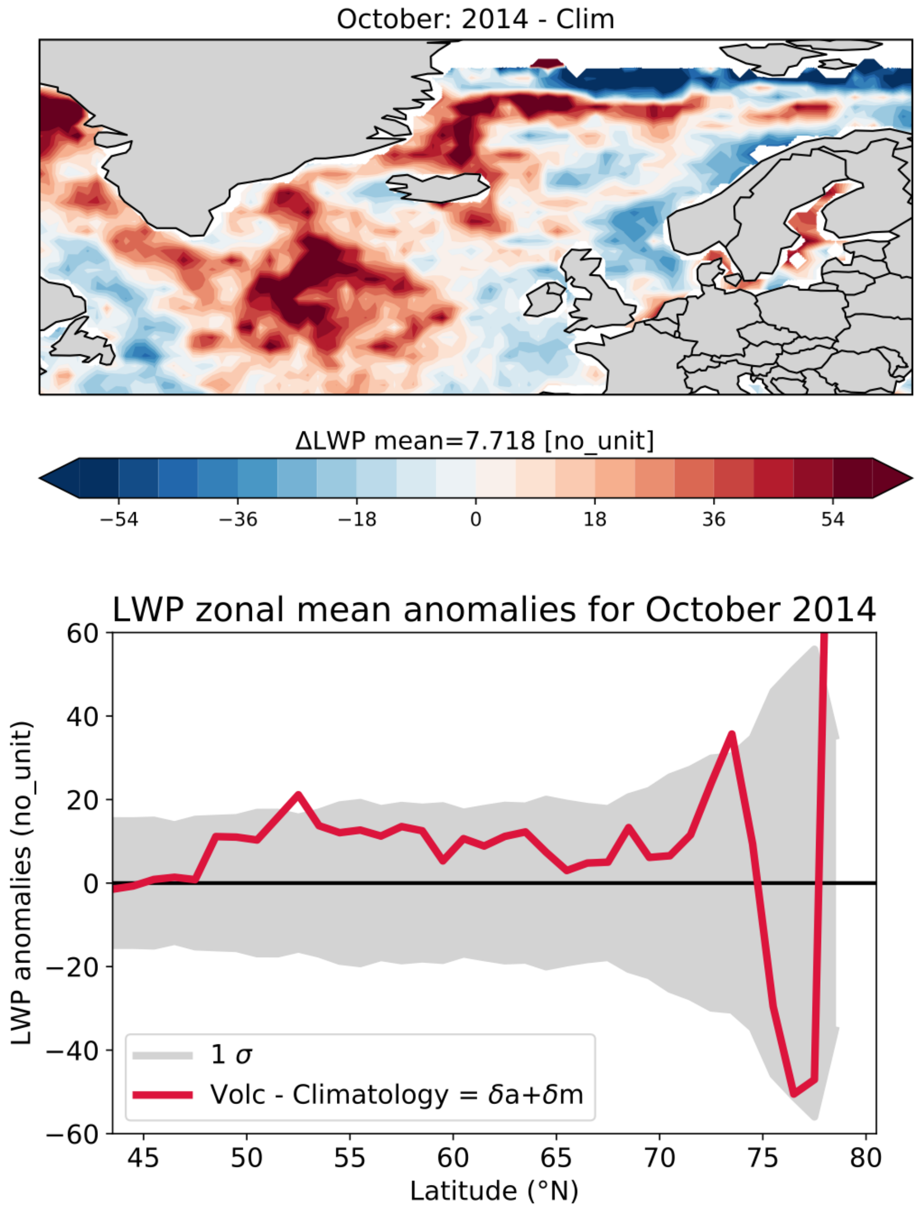


Oslo-CAM5.3



Hol. earlier work

AQUA C6.1



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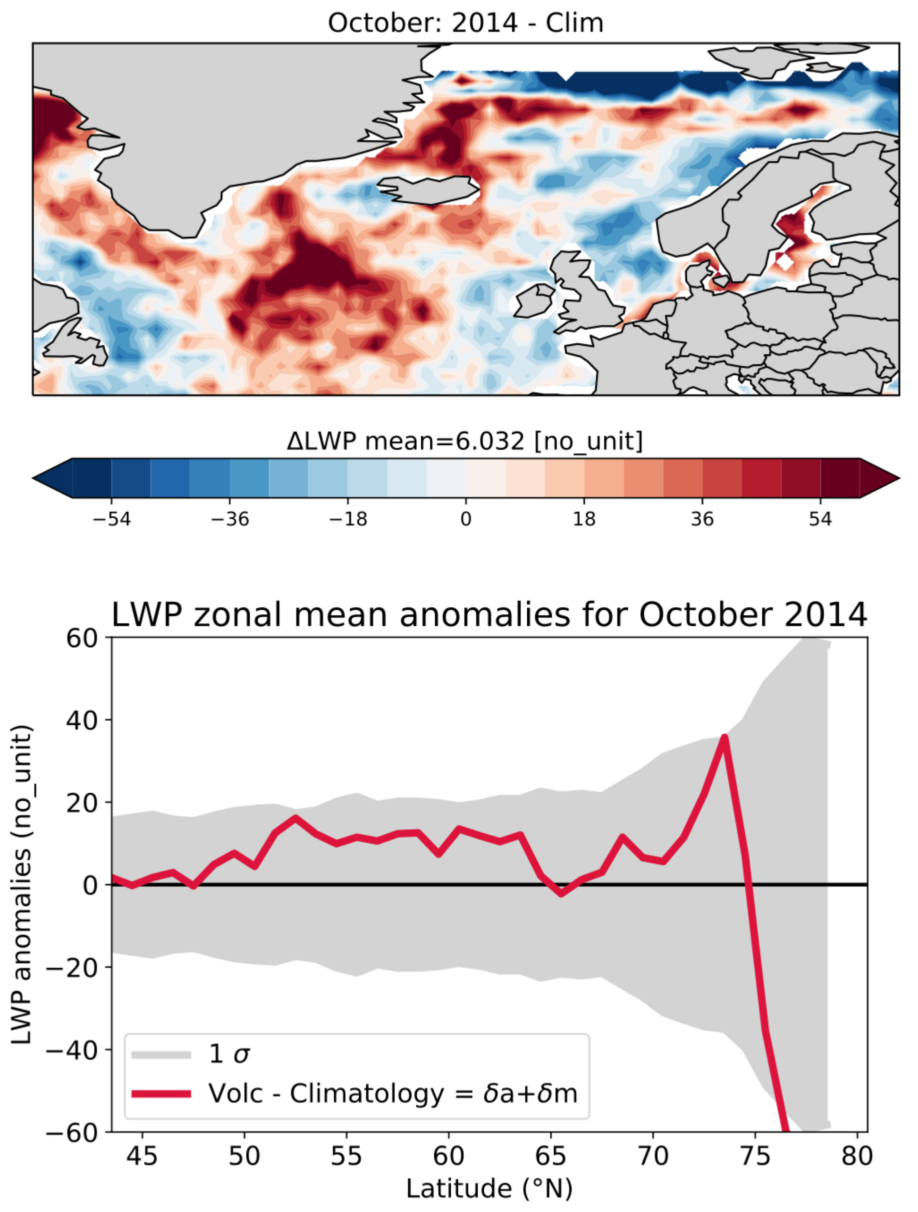

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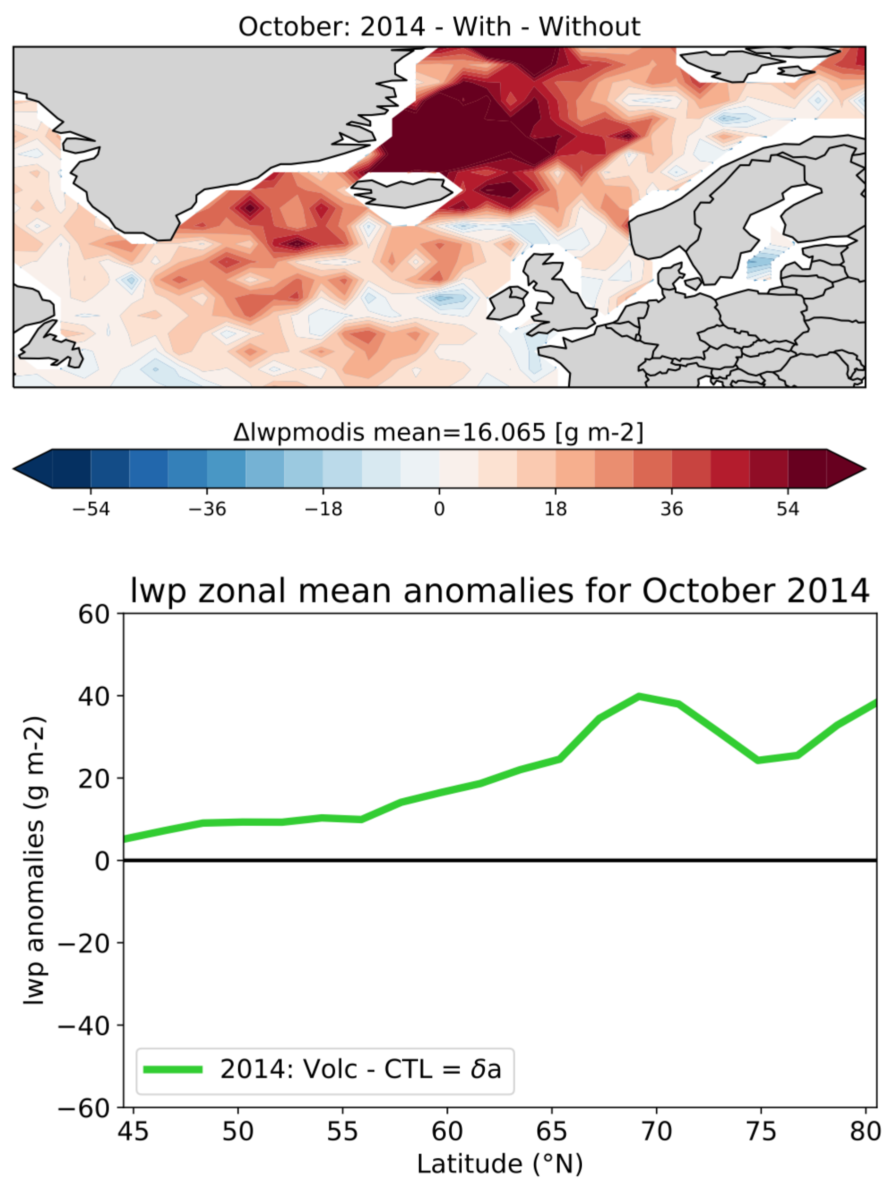

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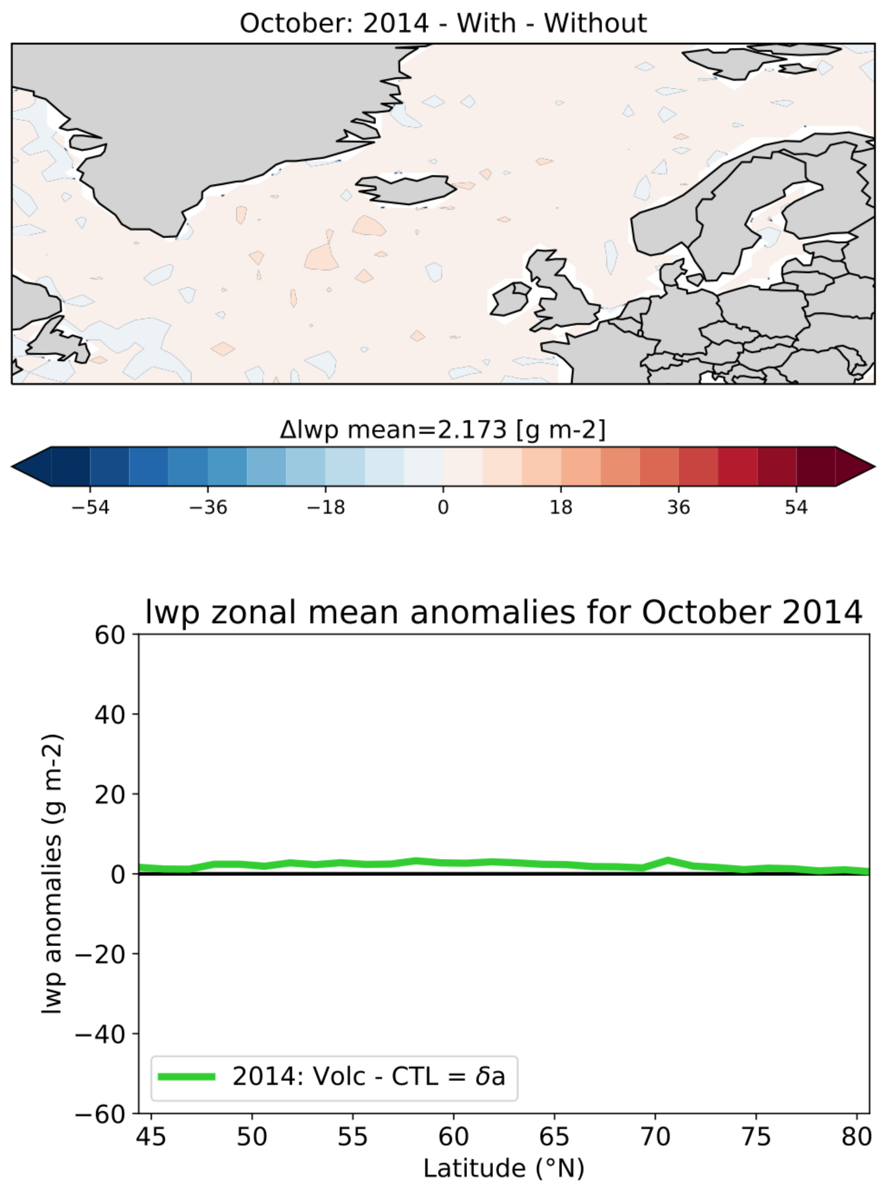

4

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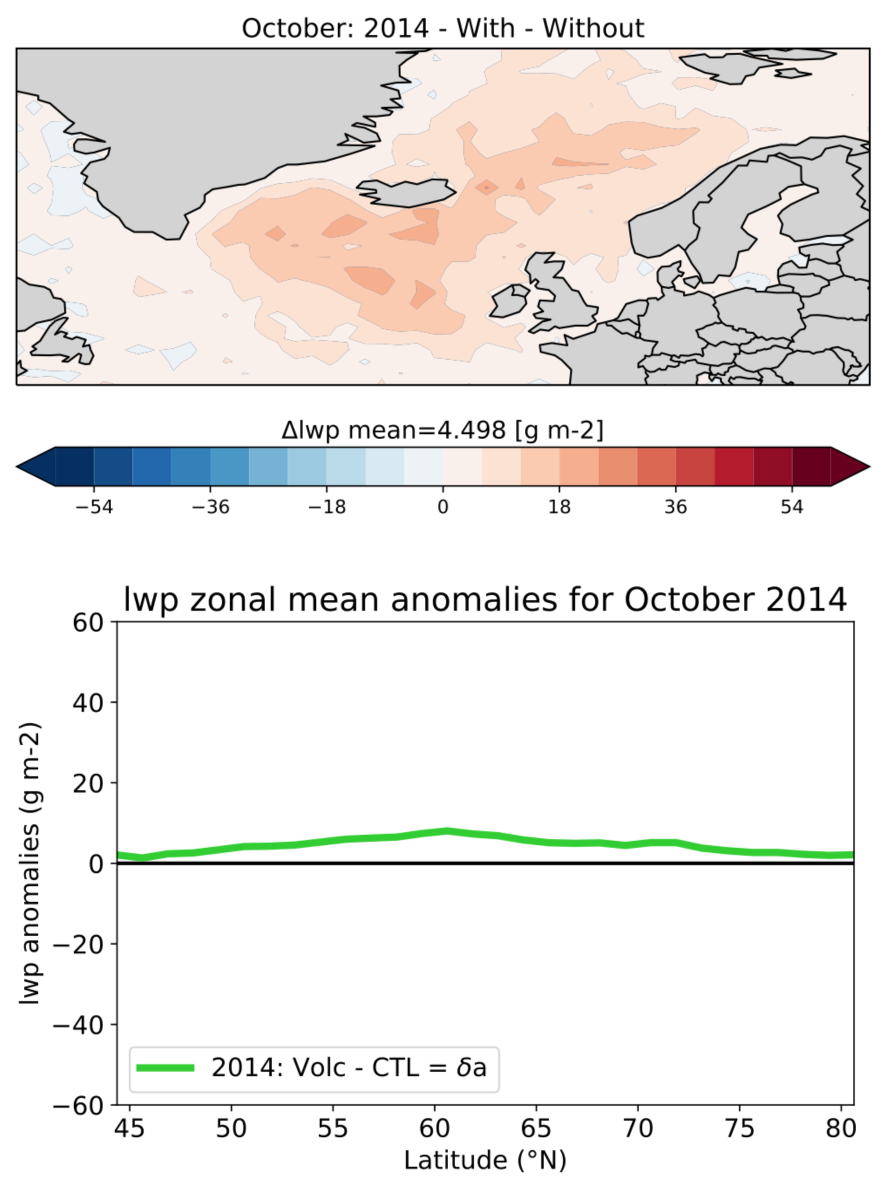

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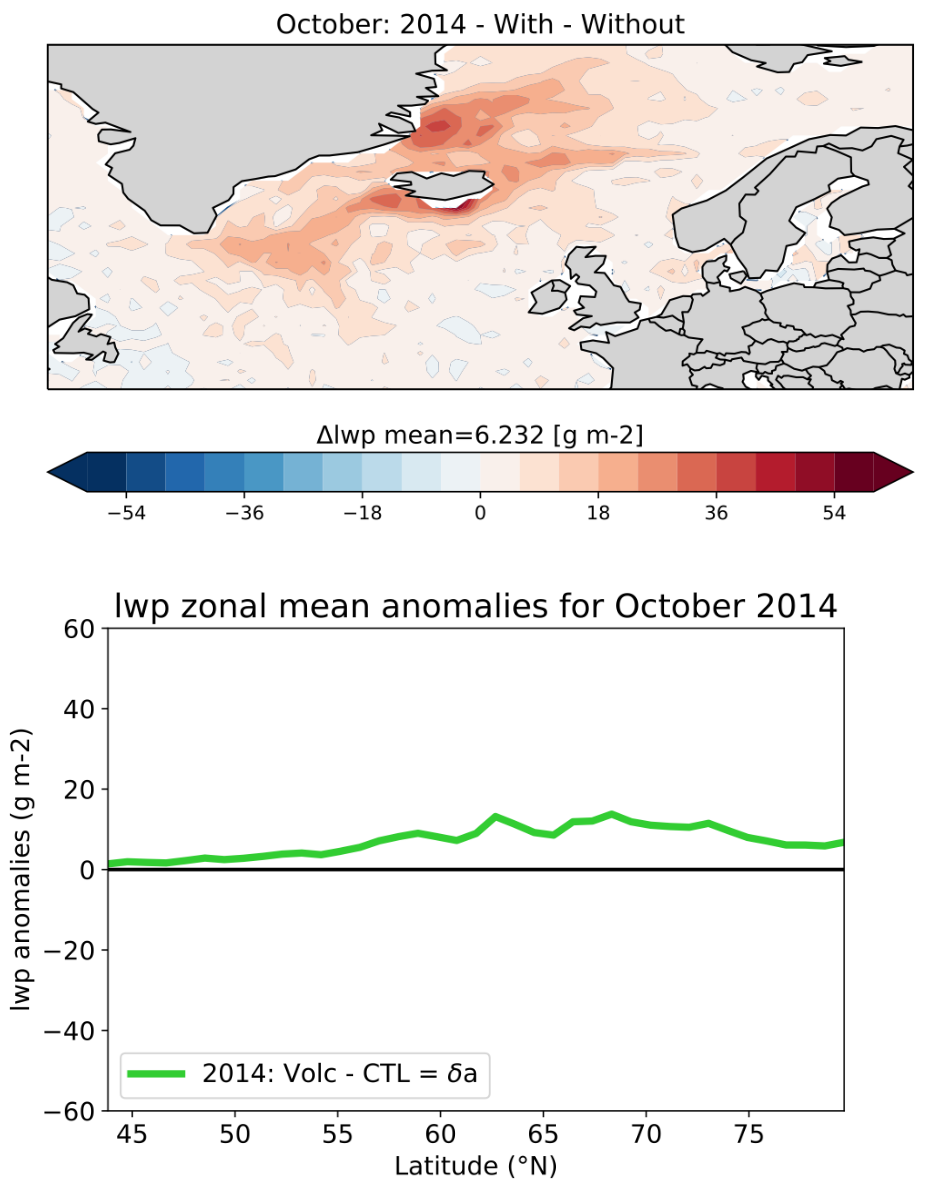

SWITCHING OFF 'LIFETIME' EFFECT (i.e. fixed Nd in AutoConversion)