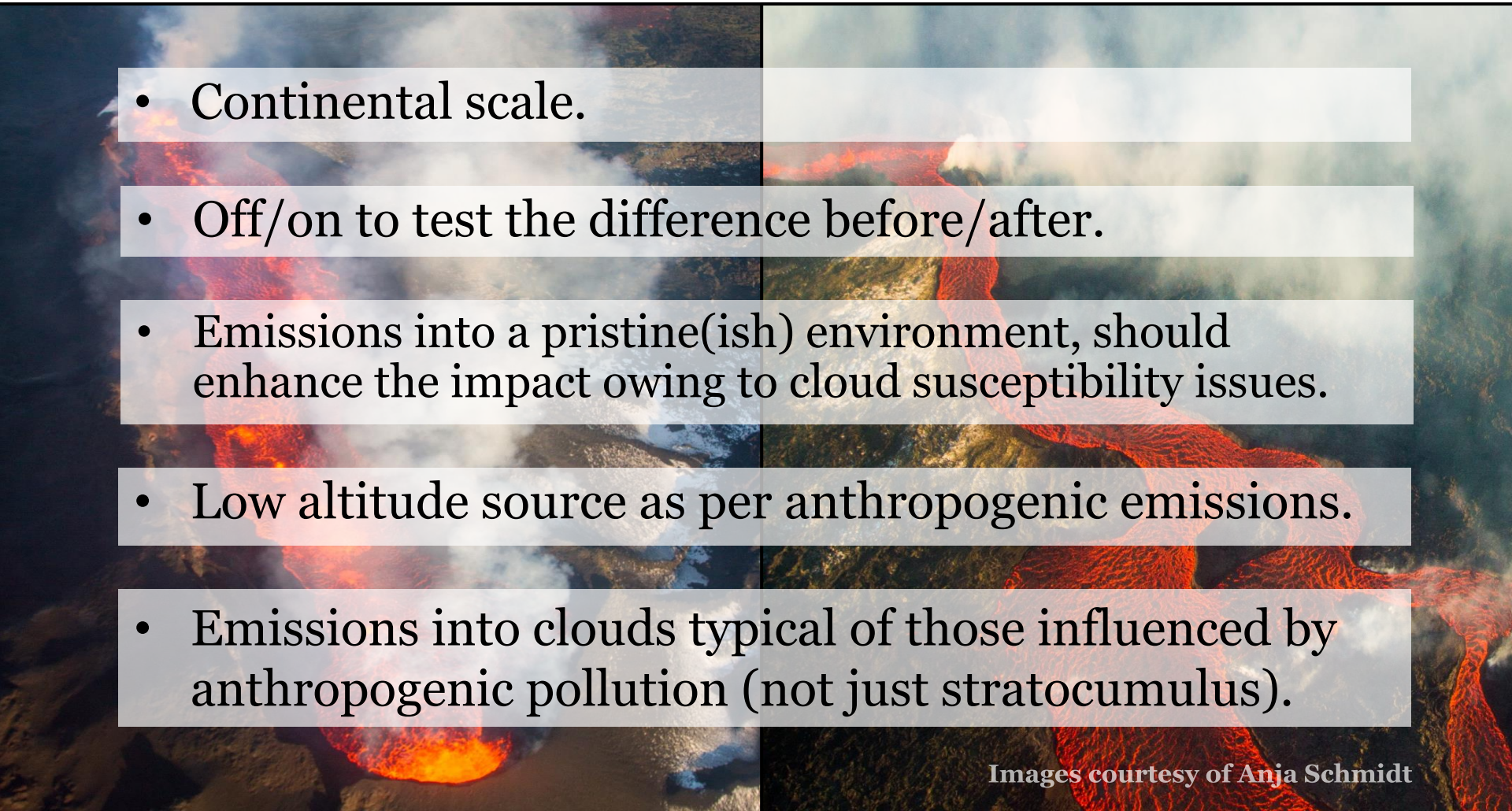
Update on the ‘Holuhraun ACI Experiment’

Florent Malavelle and all groups participating, by deputy ***Toshihiko Takemura***.

17th AeroCom workshop – 16th Oct 2018 – NOAA, College Park, MD, USA

We know that GCMs provides a wide range of ACI forcing ...

The 2014-15 fissure eruption at Holuhraun:
is a great test for challenging the representation of ACI in GCMs.



- Continental scale.
- Off/on to test the difference before/after.
- Emissions into a pristine(ish) environment, should enhance the impact owing to cloud susceptibility issues.
- Low altitude source as per anthropogenic emissions.
- Emissions into clouds typical of those influenced by anthropogenic pollution (not just stratocumulus).

Images courtesy of Anja Schmidt

Some GCMs response to Holuhraun eruption:

Key findings: *i) Models have good skill in representing the strength of Twomey effect, but ii) strong LWP response however is not supported by observations*

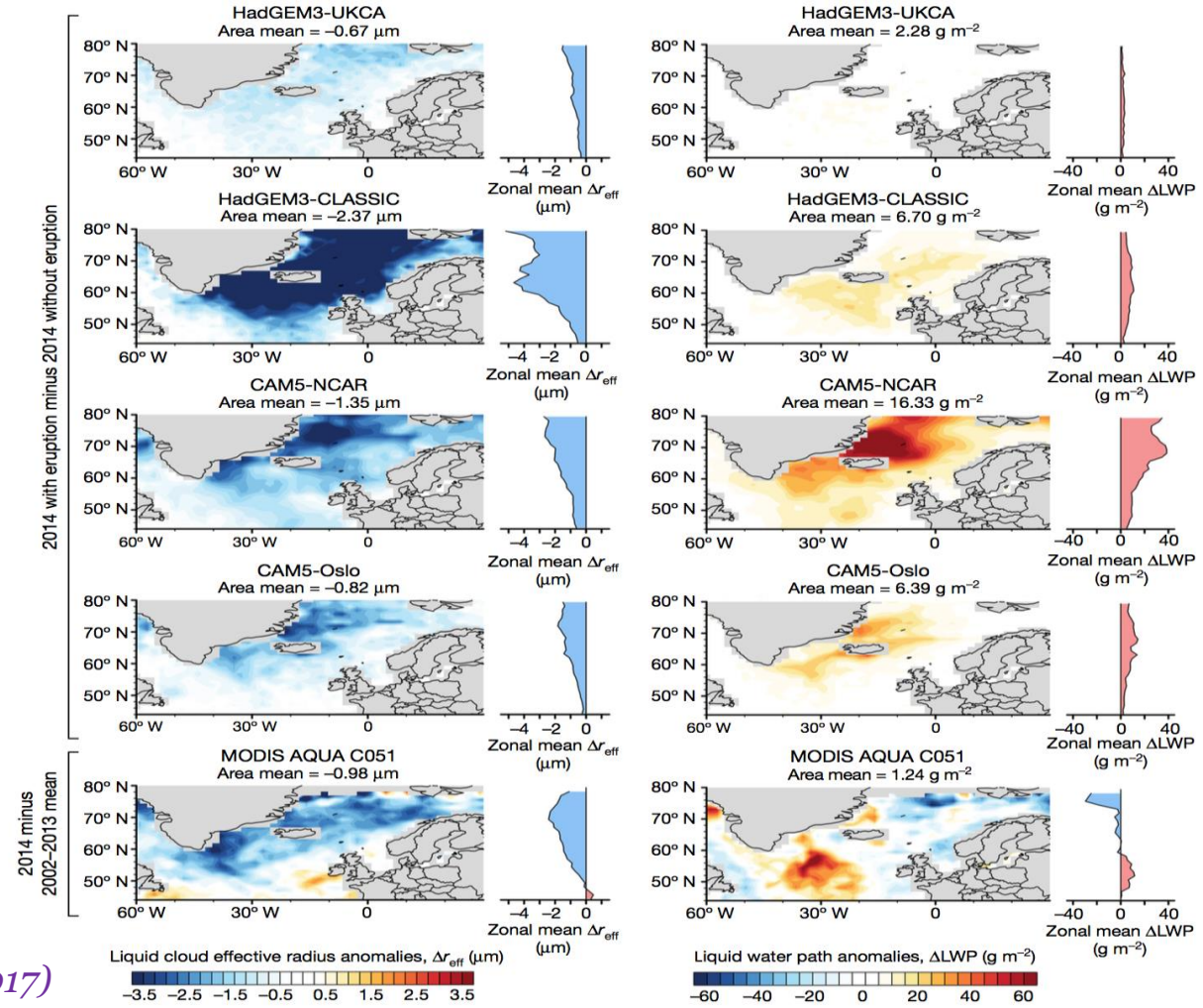
HadGEM3-UKCA

HadGEM3-CLASSIC

NCAR-CAM5.3

CAM5.3-Oslo

MODIS



from Malavelle et al. (2017)

Expected outcomes for the Holuhraun experiment

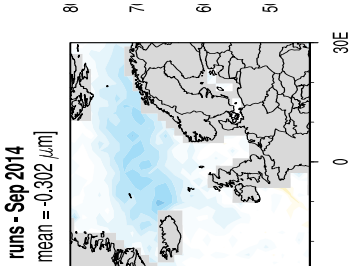
- *How state of the art GCMs capture aerosol indirect effects on this particular event ?*
- *Test models using configuration as close as possible to CMIP6.*
- *Provide guidance on estimate of ERF_ACI and climate sensitivity.*

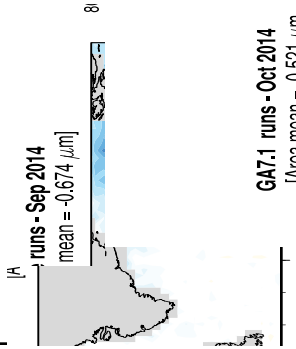
Could we expect surprises?

e.g. current version of HadGEM3
(i.e. 'quasi CMIP6')

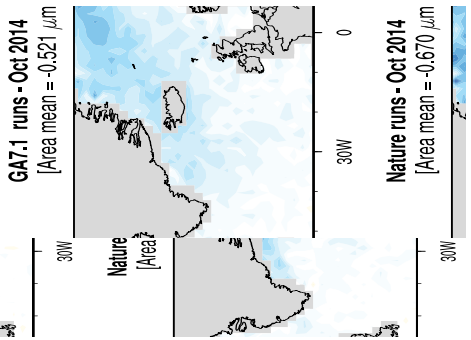
The Twomey effect is now much lower compared to MODIS.

HadGEM3-UKCA (circa 2016) i.e. version used in Malavelle et al., 2017.



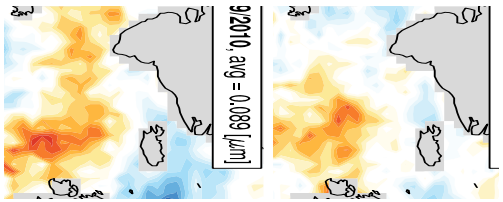


Current HadGEM3-UKCA (2018) i.e. close to the version to be used for CMIP6.



MODIS AQUA

(note Δr_E= {*2014* – Clim} here)



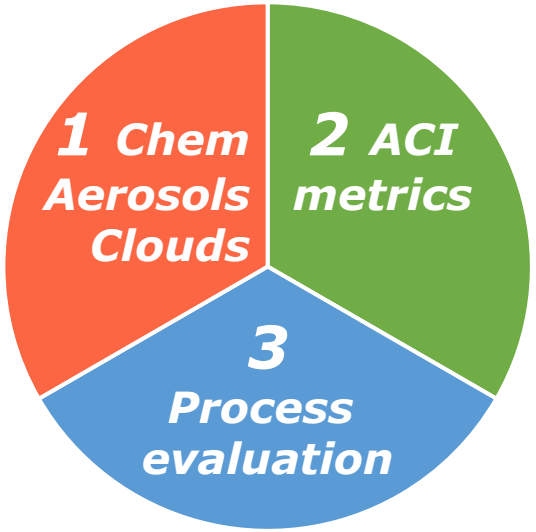
What will we be looking at:

Required Diagnostics organised in 3 packages:

1 - MON_DIAG_PKG – *180+2 months (disentangle natural variability)* (Mandatory)
2 - ACI_DIAG_PKG – *2 months with eruption + 2 months from control.* (optional)
3 - PROCESS_DIAG_PKG –*2 months with eruption + 2 months from control.* (optional)

1 Chemistry, Aerosols & Clouds – (2D & 3D monthly means)

- Evaluation of chemistry-aerosols models (e.g. sulfate formation, removal), volcanic plume transport, to be linked with the Trajectory Experiment (D. Partridge) and cloud mean changes



2 ACI metrics – (2D, 3hourly)

- Cloud susceptibilities following the Indirect Experiment *(Ghan et al., 2016, PNAS)*. Are susceptibilities during Holuhraun comparable to global susceptibilities?

3 Process evaluation – (2D, 6hourly)

- Are the differences between climate model simulated LWP response related to differences in the onset of precipitation formation? *(e.g. Michibata et al., 2016 ACP; Jing et al., 2017, JGR)*.

What's next for the 'Holuhraun ACI Experiment'

- ***Approximately 15 models (not all independents) expected to engage -*** *Simulations completed or ongoing:*
  - *Hadgem3-UKCA (Exeter)*
  - *ECHAM6.3-HAM2.3 (Oxford)*
  - *ECHAM6.3-HAM-P3 (ETH)*
  - *CAM5.3-Oslo (Oslo)*
  - *CAM6-NCAR (NCAR)*
  - *MIROC-SPRINTARS (RIAM)*

Timetable

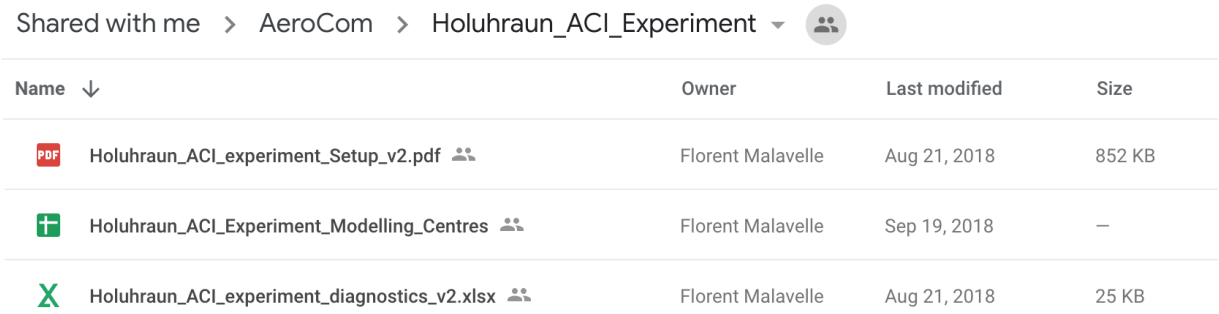
- ***Expected submission of model outputs by end of 2018:*** *There is obviously flexibility with dates and new participants are welcome to join.*
- ***Analysis of the model outputs to start beginning of 2019***
- ***First summary of the results to be presented at the next AeroCom meeting (October 2019).***

Resources for the experiment

Exp. protocol and list of diagnostics finalised *- Resources accessible online:*

Drive

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



Data server created @Exeter to provide long term storage of model outputs.

- *We expect 150-200 Go of outputs per model if all diagnostics are provided.*
- *Data will be available to the AeroCom community.*

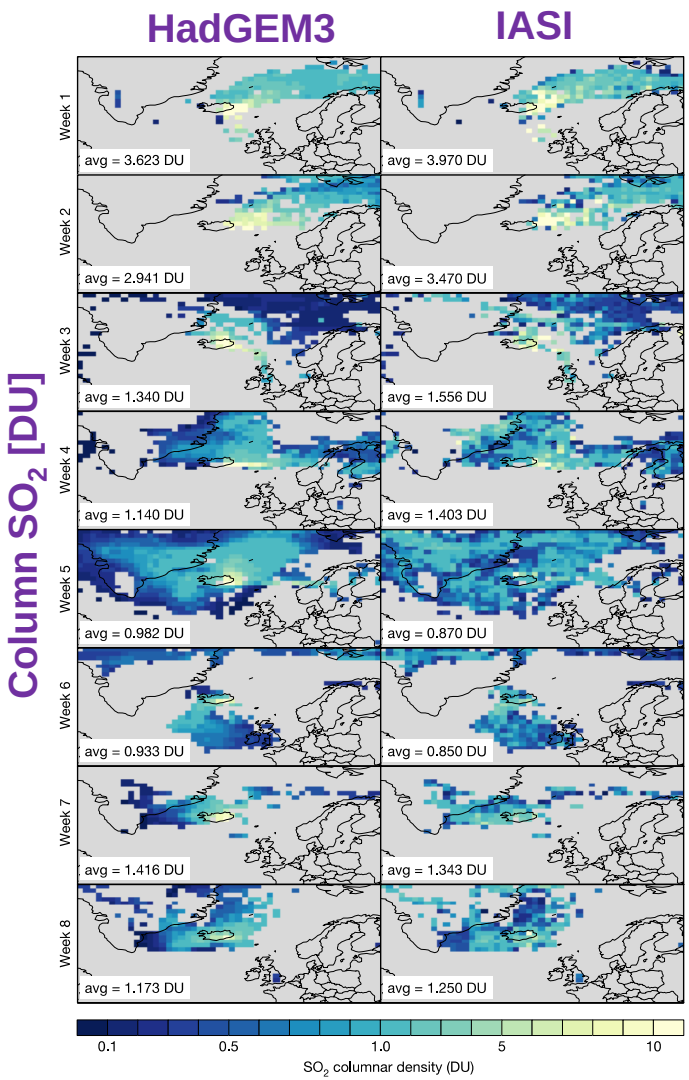
Questions and help can be addressed to Florent Malavelle: f.malavelle@exeter.ac.uk

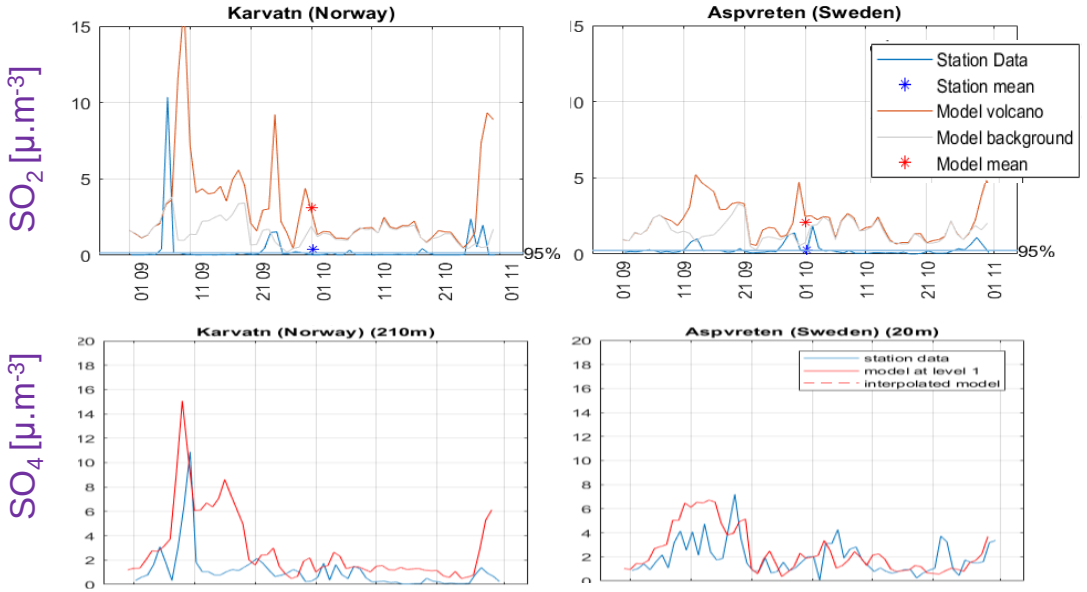
Thanks!

Removed slides

1 – Chemistry & Aerosol evaluation

The plume of SO_2 is well-represented in coarse model (here HadGEM3) despite the resolution and crude emissions estimates.





- *HadGEM3 captures the surface peak in SO_2 and SO_4 measured at these two Scandinavian sites around 10-Sep.*
- *Background SO_2 seems to be too high. Too much contribution from anthropogenic sources?*

Evaluation of the plume lifecycle will also be performed in a Lagrangian framework in coordination with the **Trajectory experiment (D. Partridge)**

2 – ACI metrics for each models

Second indirect (Albrecht) - aka cloud lifetime - effect

First indirect, (Twomey) - aka cloud albedo - effect

$$\frac{d\ln \overline{R}}{d\ln \overline{E}} = \left[\frac{d\ln \overline{C}}{d\ln \overline{N}_d} + \frac{d\ln \overline{R}_c}{d\ln \overline{\tau}}\left(\frac{d\ln \overline{L}}{d\ln \overline{N}_d} - \frac{d\ln \overline{r}_e}{d\ln \overline{N}_d}\right)\right] \frac{d\ln \overline{N}_d}{d\ln \overline{CCN}} \frac{d\ln \overline{CCN}}{d\ln \overline{E}}.$$

Cloud microphysical and macrophysical responses

Aerosol Activation / Droplet Nucleation

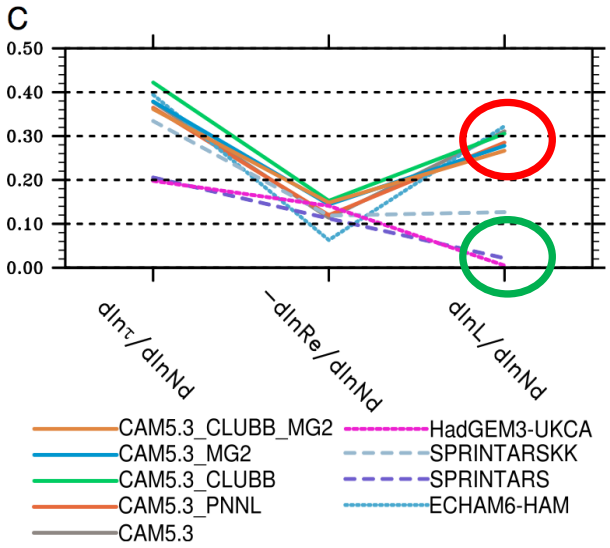
Aerosols & Chemistry processes

Ghan et al., PNAS (2016)

How much can we learn from Holuhraun ? Can it help constraining ACI overall ?

- *Are the susceptibilities during Holuhraun similar to global susceptibilities?*
- *Can we better characterize where the diversity in the causal chain from Emissions to ERF_ACI originates?*

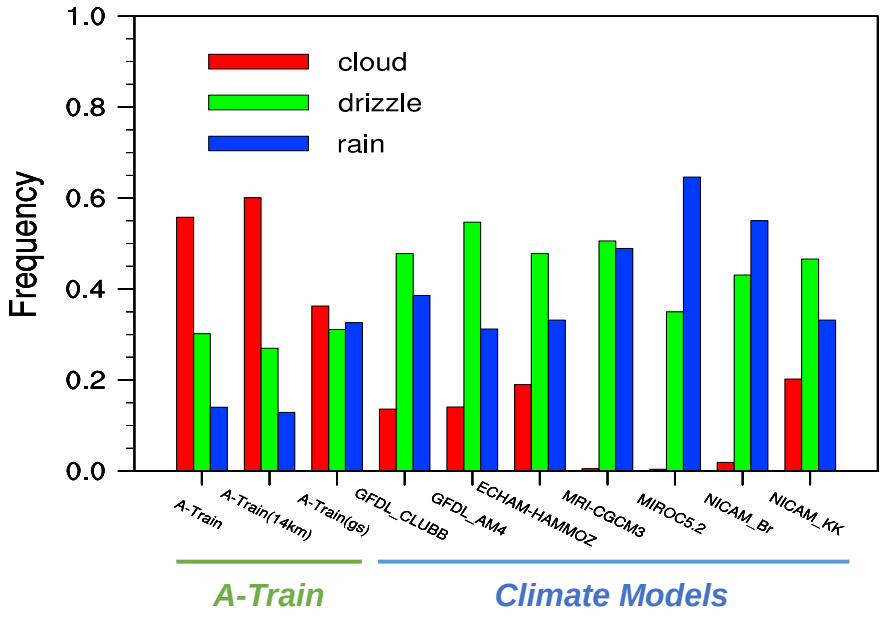
e.g. 'Canonical' 1st/2nd Indirect effects at the global scale:



- What most GCMs tend to do
- What is suggested from observations during Holuhraun.

3 – Process evaluation

from Jing et al., JGR (2017)



- Cloud: $Z_e < -15$dBZ
- Drizzle: -15dBZ $< Z_e <$ 0dBZ
- Rain: $Z_e >$ 0dBZ

} "Satellite-oriented" definition of rain

- *Global Models are biased towards too much rain.*
- *Global Models tend too form rain too efficiently (e.g. Michibata et al., ACP 2016)*

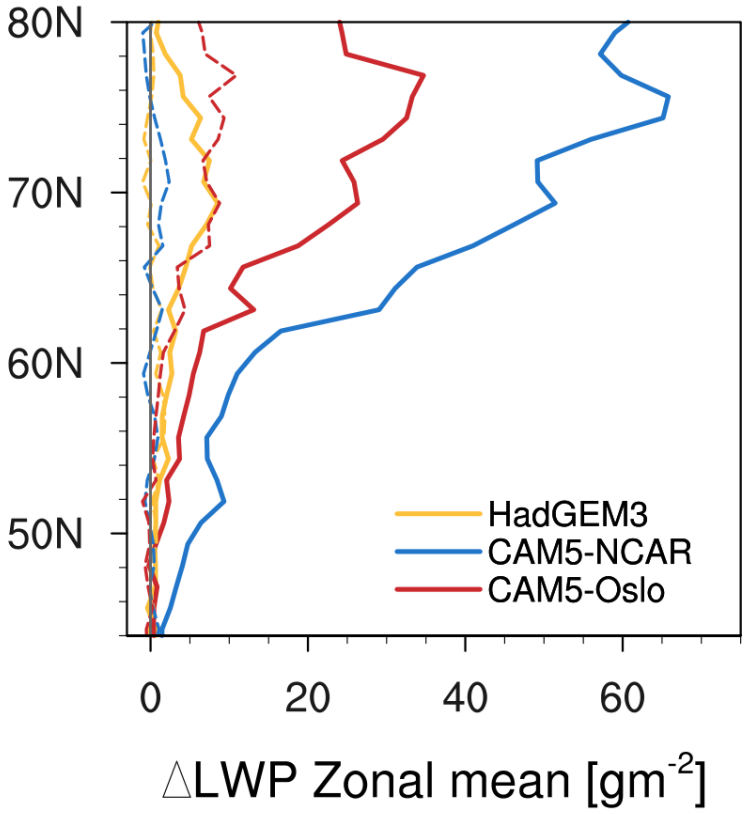
Systematic evaluation of models against observational constraints on precipitation efficiency needed:

- It is unclear why climate models strongly differ in their LWP response to aerosol perturbations.
- It is therefore essential to derive robust observational constraints on the processes driving this response.
- We hypothesise that differences in the climate model simulated LWP response might be attributable to differences in the onset of precipitation formation (as small-scale evaporation-entrainment feedbacks are not represented).

Additional slides

3 – Process evaluation

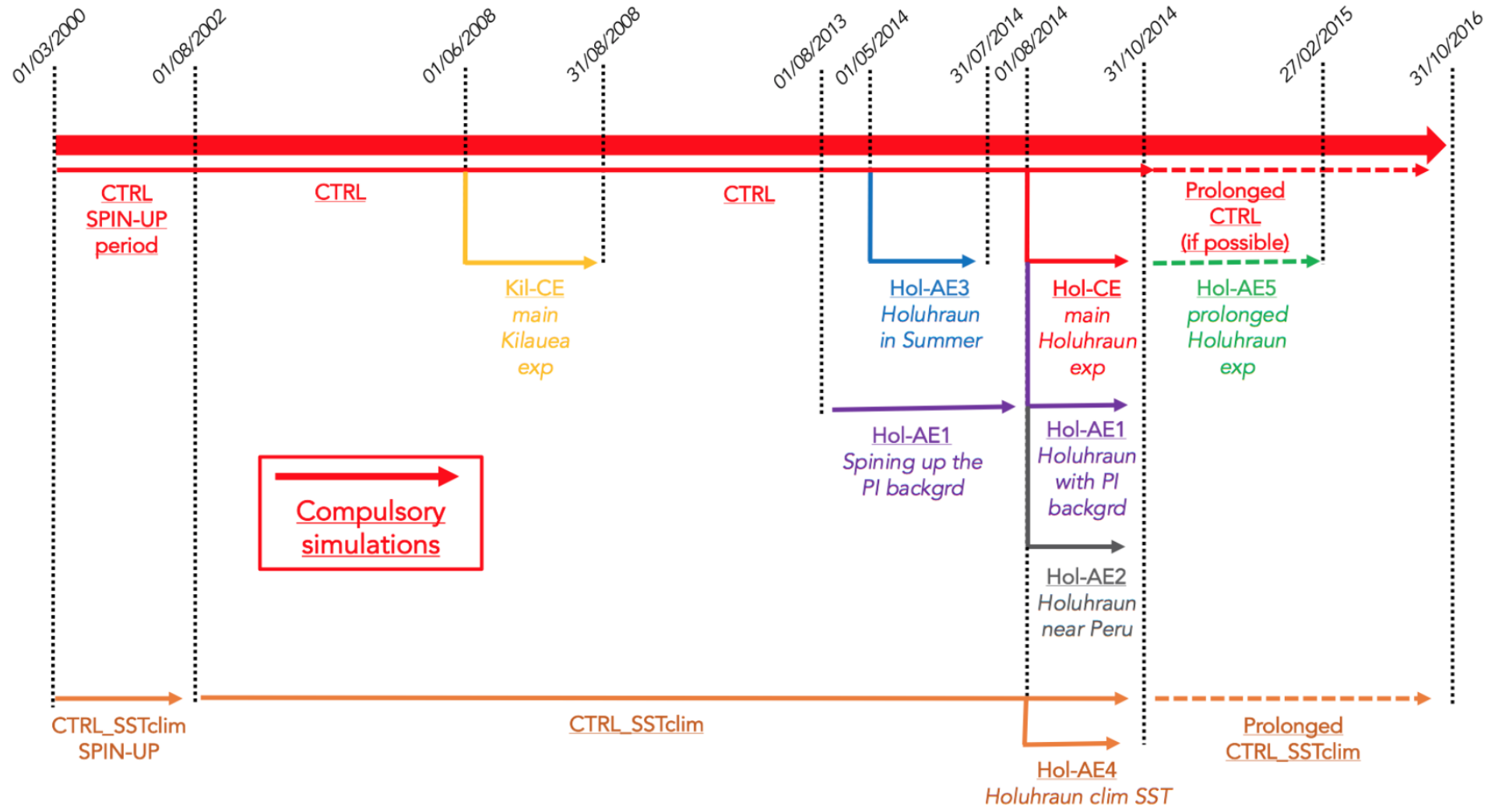
Turning off dependence on CDNC in Autoconversion …

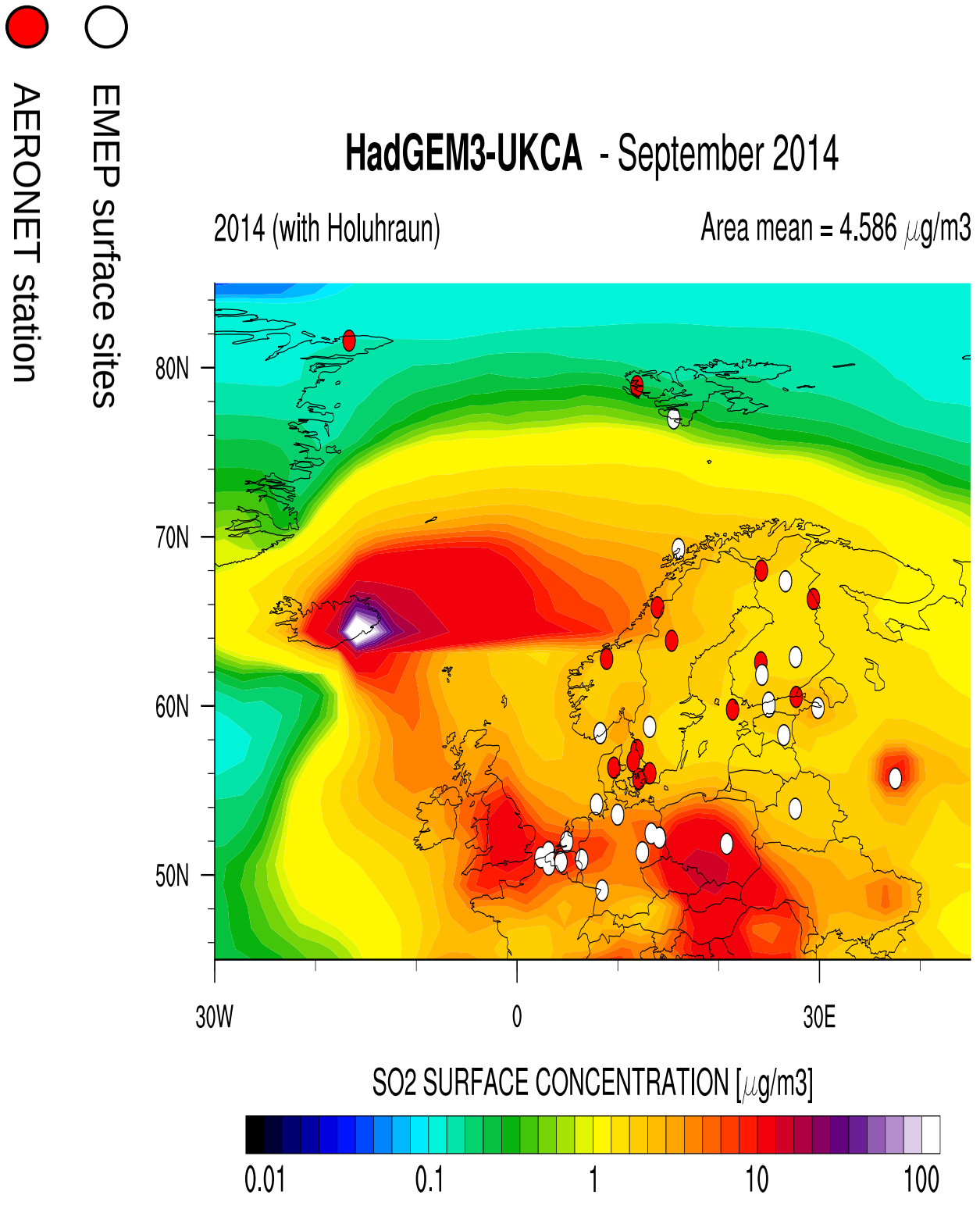


Three GCMs, all use KK200. Yet the LWP response differ but why:

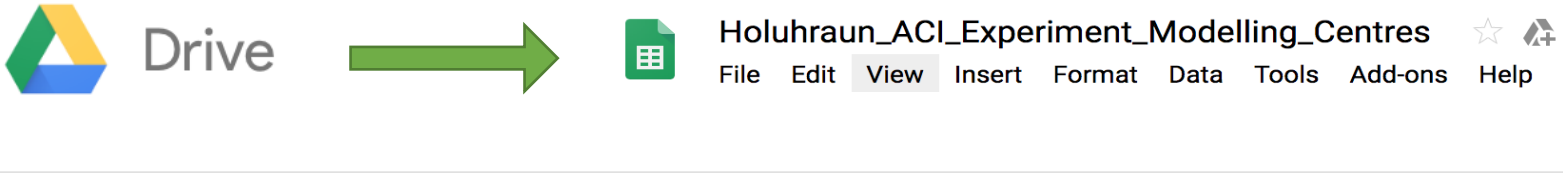
- Is just an autoconversion tuning exercise ? probably not …
- Are models missing crucial physical feedbacks? *(e.g. Sato et al., 2018; Nature Comm.)*
- Are models capturing warm rain process rates and cloud regimes correctly? *(e.g. Suzuki et al., 2011; JAS)*

Simulation design …




AERONET station
EMEP surface sites
HadGEM3-UKCA - September 2014
2014 (with Holuhraun)
Area mean = 4.586 μg/m3
80N
70N
60N
50N
30W
0
30E
SO2 SURFACE CONCENTRATION [μg/m3]
0.01
0.1
1
10
100

Note for Participants – Fill the spreadsheet



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fx Rsync module folder name i.e. centername (fixed and assigned by University of Exeter)

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Point of Contact	Modelling Centre	Rsync module folder name i.e. centername (fixed and assigned by University of Exeter)	Model Name (+ Version Number)	Model resolution (Lat x Lon x LvL)	Aerosol emission data-set used	Aerosol scheme	Aerosol nucleation parameterisation	Droplet activation scheme (e.g. ARG) & sub-grid scale updraft scheme (e.g. PDF, 20 bins)	Stratiform clouds	Rain scheme (diagnostic/ prognostic)	Autoconversion / Accretion (e.g. liq:KK)	Nudging reanalysis (e.g. ERA-interim) & relaxation time used (e.g. 6hr)
2	Anonymous Goose Florent Malavelle (f.malavelle@exeter.ac.uk)	University of Exeter	UEX	HadGEM3-UKCA & HadGM3-Easy Aerosol	(N96) 1.125x1.875x85	CMIP6 + GFED3.1	UKCA	UKCA	ARG & sub-grid scale updraft scheme (PDF, 20 bins, West et al., ACP 2014)	PC2 (Wilson et al. QJRMS, 2017)	Prog rain	liq: KK	ERA-Interim (U&V 6 hourly)
3	Florent Malavelle (f.malavelle@exeter.ac.uk)	UK Met Office	UKMO	HadGM3-Easy Aerosol	(N96) 1.125x1.875x85	CMIP6 + GFED3.1	UKCA	UKCA	ARG & sub-grid scale updraft scheme (PDF, 20 bins, West et al., ACP 2014)	PC2 (Wilson et al. QJRMS, 2017)	Prog rain	liq: KK	ERA-Interim (U&V 6 hourly)
4	Duncan Watson-Parris (duncan.watson-parris@physics.ox.ac.uk)	University of Oxford	UOX	ECHAM6.3-HAM2.3									
5	Inger Helene Karset (i.h.h.karset@geo.uio.no)	University of Oslo	UOS	CAM5.3-Oslo	0.95x1.25x30	CMIP6	OsloAero (Kirkevåg et al. 2018)	OsloAero	ARG	MG1.5 (Gettelman & Morrison 2015)	Diag rain	liq:KK	ERA-Interim (U&V 6 hourly)
6	Gunnar Myhre (gunnar.myhre@cicero.oslo.no) & Ragnhild Bieltvedt Skeie (r.b.skeie@cicero.oslo.no)	CICERO	CICERO	OsloCTM3 & WRF									
7	Andrew Gettelman (andrew@ucar.edu)	NCAR	NCAR	CAM6	1.9x2.5x32	CMIP6	MAM4	MAM4	ARG	MG2 (Gettelman & Morrison 2015)	Prog Rain	liq:KK modified so N exponent = -1.1	MERRA2, U&V, 2 hourly
8	Toshihiko Takemura (toshi@riam.kyushu-u.ac.jp)	Research Institute for Applied Mechanics, Kyushu University	RIAM	MIROC-SPRINTARS									
9	Kentaroh Suzuki (ksuzuki@aori.u-tokyo.ac.jp) & Junya Uchida (junya@aori.u-tokyo.ac.jp)	University of Tokyo	UTO	NICAM									
10	David Neubauer (david.neubauer@env.ethz.ch)	Institute for Atmospheric and Climate Science - ETH	ETH	ECHAM-HAM-P3	(T63) 1.875x1.875x47	CMIP6	M7	Kazil and Lovejoy (2007) as described in Kazil et al. (2010)	ARG; TKE based single updraft	HAM2.3 (Neubauer et al., 2018)	diagnostic rain (prognostic ice phase precipitation, Dietlicher et al., 2018)	liq: KK	ERA-Interim; 24hr surface pressure; 48hr divergence; 6hr vorticity

Sheet1