Met Office

Observational campaigns
Informing weather and climate model development for aerosols

Clouds Aerosol Radiation Interaction and Forcing – Year 2017 (CLARIFY)

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The CLARIFY team

International Cooperative for Aerosol Prediction (ICAP) 10th Workshop

Met Office, Exeter, 8th June 2018

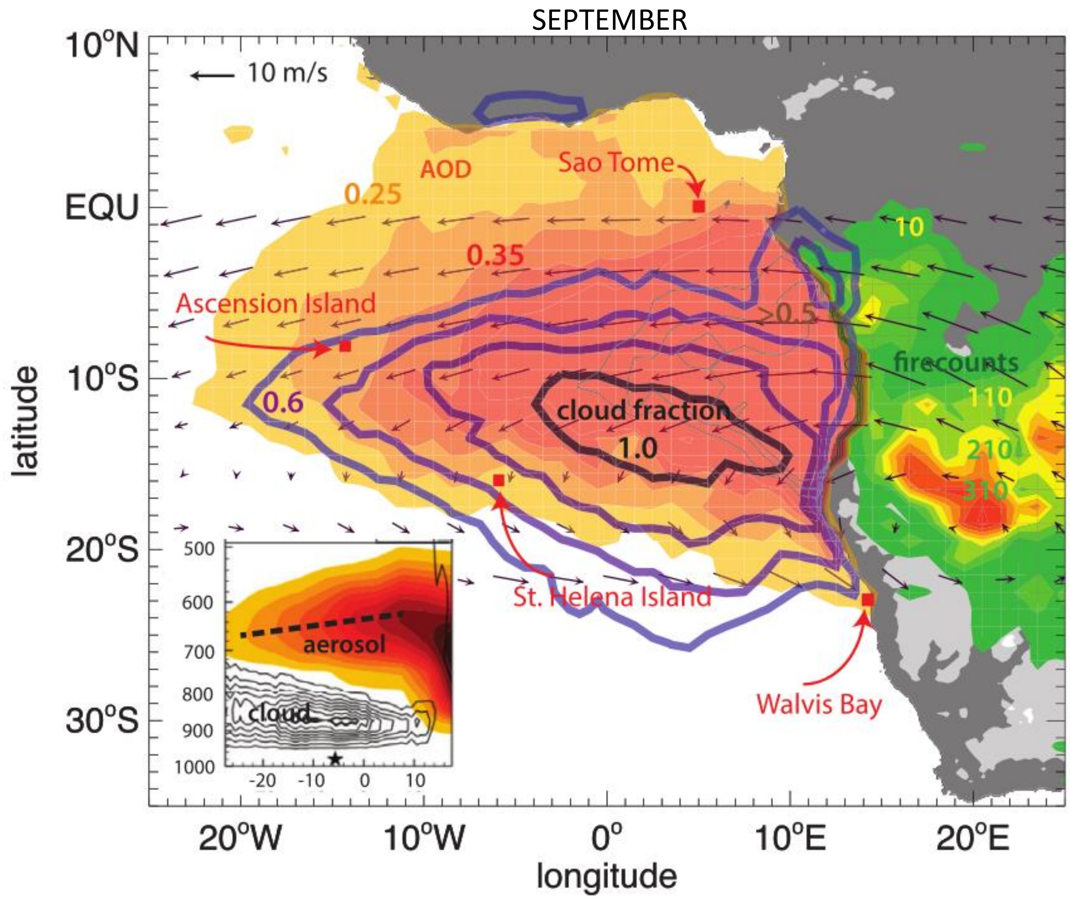
Talk outline

- Clouds Aerosol Radiation Interaction and Forcing – Year 2017 (CLARIFY)
    - Aerosol-cloud-radiation interactions in the SE Atlantic during the biomass burning season
    - Overview of the field experiment including broader international activities
    - Initial results: aerosol vertical profiles, composition and optical properties
    - How did the Unified Model NWP aerosol forecast perform during CLARIFY?
    - Modelling aerosol-cloud-radiation interactions in the region
    - Utilisation of CLARIFY observations to develop a new SEVIRI combined aerosol-above-cloud and cloud property retrieval
- Summary

Aerosol-cloud-climate interactions over the SE Atlantic

Aerosol-radiation-interactions (ARI): The geographic distribution, absorption properties of aerosol, vertical profile of aerosol, cloud fraction, cloud optical depth and liquid water content are crucial.

Aerosol-cloud-interactions (ACI): The degree of interaction of cloud and aerosols and the process level understanding are crucial.



Zuidema et al. (2016) https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-15-00082.1

Why the SE Atlantic?

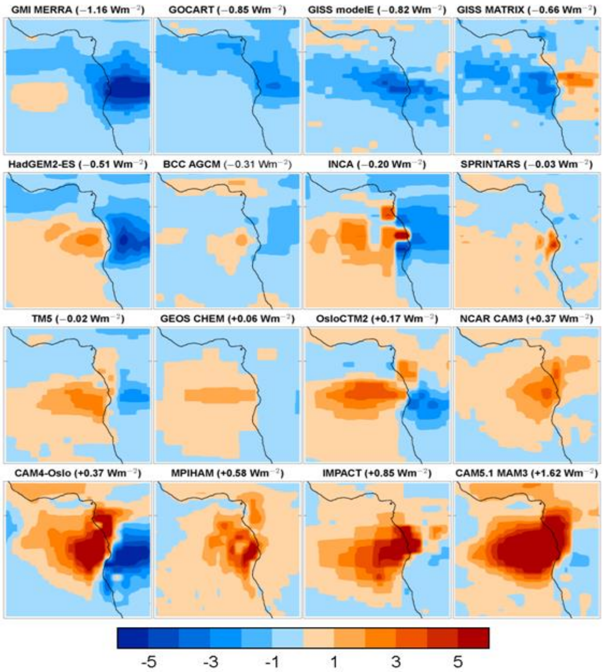


Figure 2. Aug-Sept SE Atlantic aerosol direct effect.

ARI: 16 AeroCOM models. Which is right? Why?

Regional hot-spot for aerosol direct radiative forcing, but a large uncertainty in the sign and magnitude in leading climate models.

Potentially large but very uncertain aerosol indirect effect from smoke

Lack of in-situ observations to evaluate and develop models

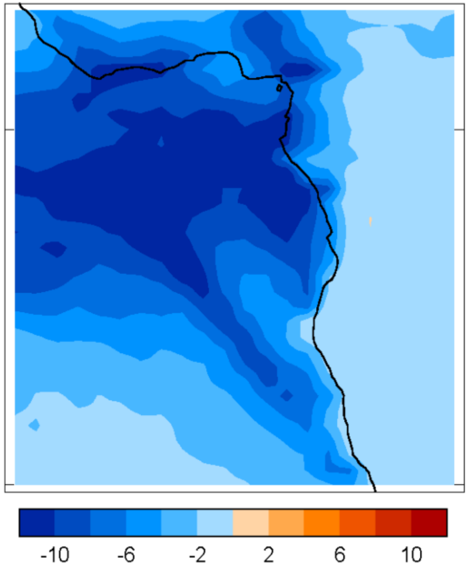


Figure 3. The 1st aerosol indirect effect in HadGEM2-ES (CLASSIC).

ACI: The degree of interaction of cloud and aerosols and the process level understanding are crucial.

The CLouds-Aerosol-Radiation Interaction and Forcing: Year 2017 (CLARIFY-2017) programme

Institutes and PIs

Haywood

Blyth

Coe

Stier

Bellouin

Abel

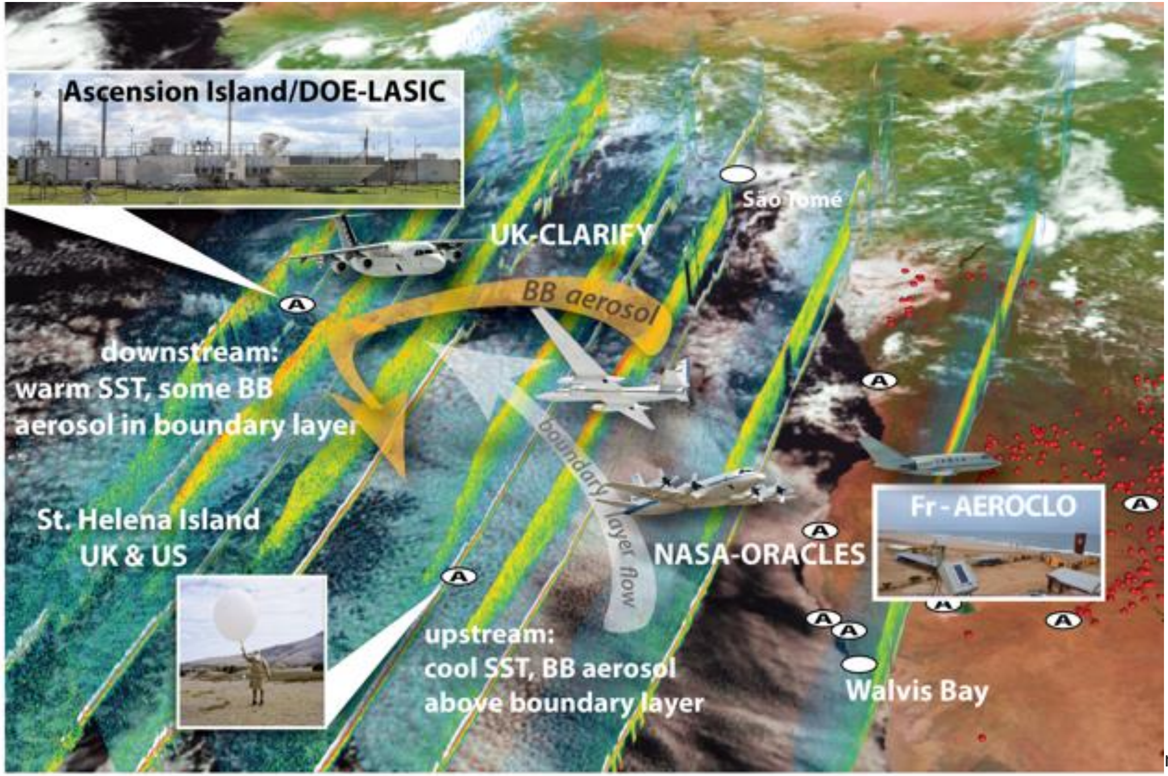
Key objectives

K01: Measure and understand the physical, chemical and optical properties of biomass burning aerosol over the SE Atlantic

K02: Measure and understand the physical properties of boundary layer clouds and their environment. Improve the representation of these clouds in a range of models

KO3: Evaluate and improve the representation of ARI and ACI over the SE Atlantic at a range of model scales and resolutions

CLoud-Aerosol-Radiation Interactions and Forcing: Year 2017 (CLARIFY-2017)



right

A large international effort.....

2016

LASIC (Ascension)

ORACLES (Namibia)

2017

CLARIFY (Ascension)

LASIC (Ascension)

ORACLES (Sao Tome)

AEROCLO-SA (Namibia)

2018

ORACLES (Sao Tome)

Aerosol measurements from Ascension Island

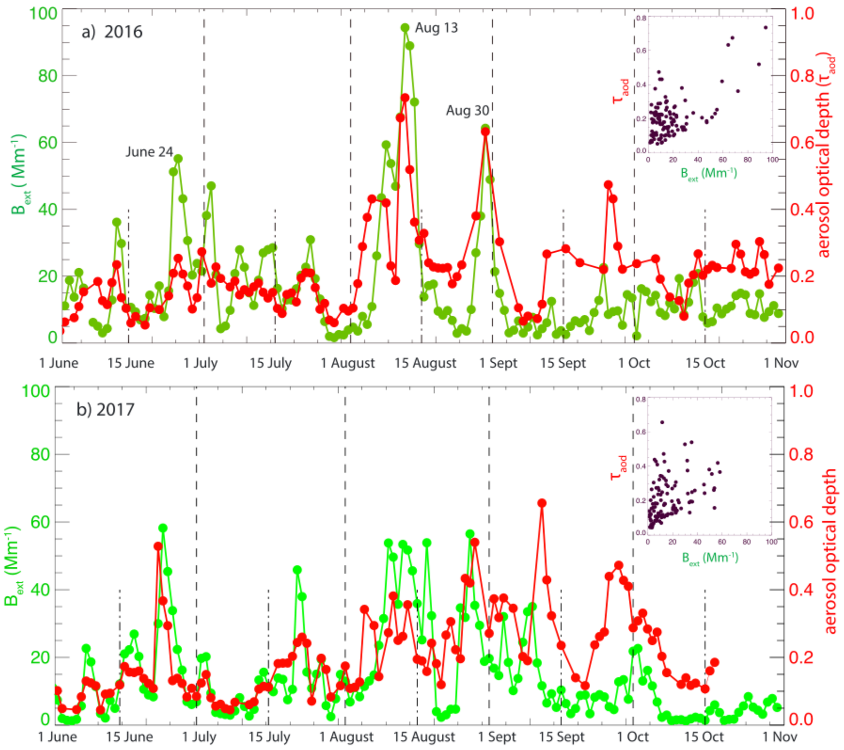


Figure 3. (a) The 1 June to 31 October 2016 light extinction time series (daily averaged, 529 nm; as the sum of nephelometer-derived scattering and Particle soot absorption photometer-derived absorption) and 500 nm AERONET Sun photometer aerosol optical depths (Version 3, Level 1.5, airport site). Inset is a scatterplot of the same data subsampled for coincidence. (b) same as (a) but for 1 June to 31 October, 2017.

LASIC ARM data provide multi-year measurements at Ascension Island

Surface aerosol extinction data correlate with AERONET AOD indicates BBA in MBL

Periods where they do not correlate are indicative of BBA in the free-troposphere

CLARIFY measurements will complement LASIC by providing detailed vertical information

Zuidema et al. (2018) https://doi.org/10.1002/2017GL076926

Central to CLARIFY-2017 was the deployment of the FAAM BAE146

Wide range of kit in 5 categories:-

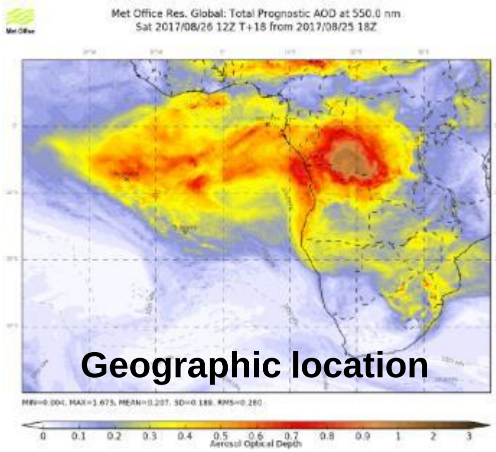
1) **Meteorological**
2) **Cloud microphysics**
3) **Aerosol microphysics, chemistry and optical properties**
4) **Trace-gases**
5) **Radiation measurements (mainly SW)**

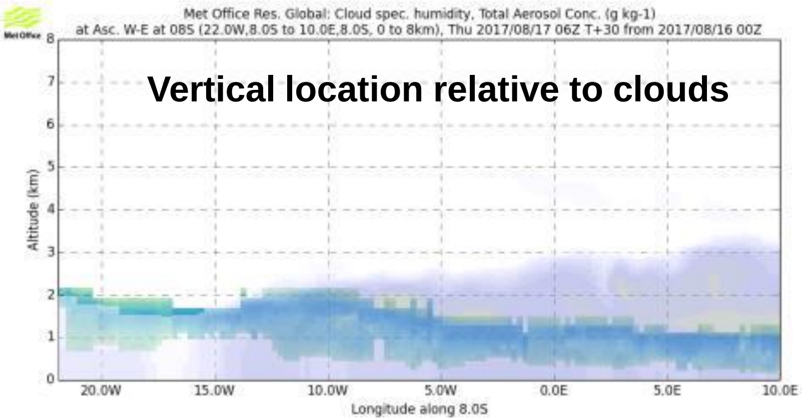
Unified Model forecast support: to get the aircraft in the right place at the right time

Model forecasts and satellite products were key for positioning the aircraft. Need to know information on clouds, aerosols and where regions of ACI may occur.

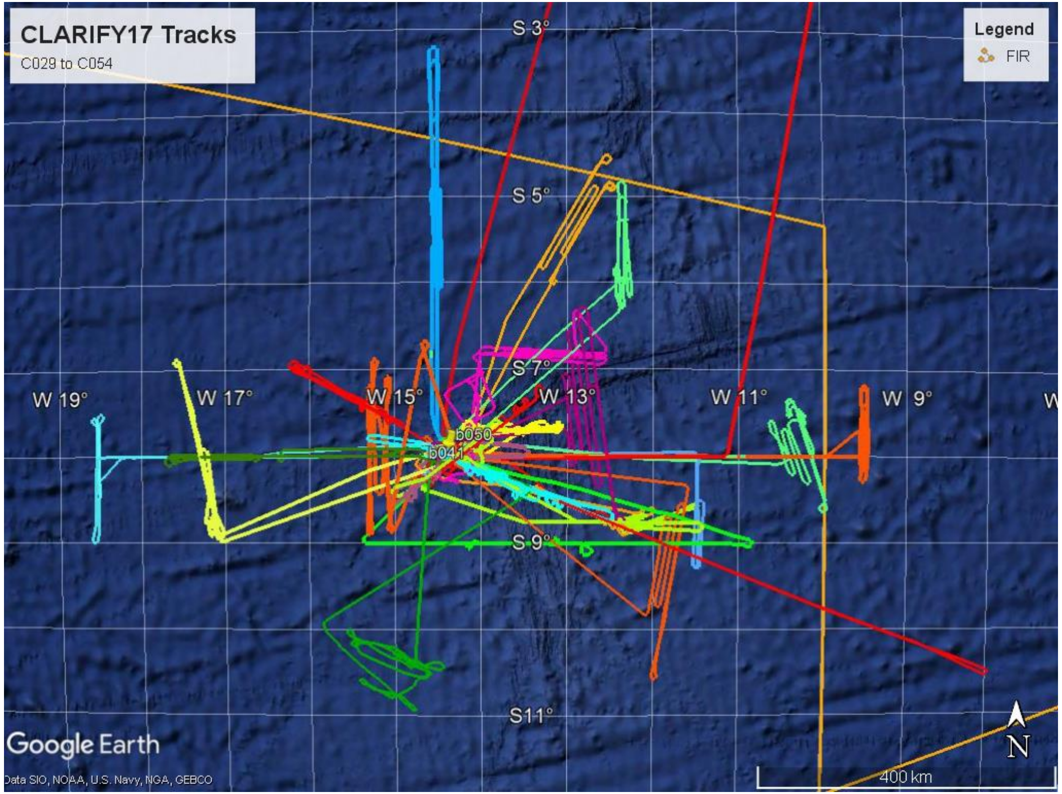
Global model forecasts (17 km) of clouds and aerosols. Include prognostic biomass burning (GFAS real-time emissions, CLASSIC), dust aerosols, and industrial aerosols. Biomass burning aerosol does not interact with radiation scheme or cloud microphysics.

Satellite imagery key for cloud details.





CLARIFY-2017: Deployment



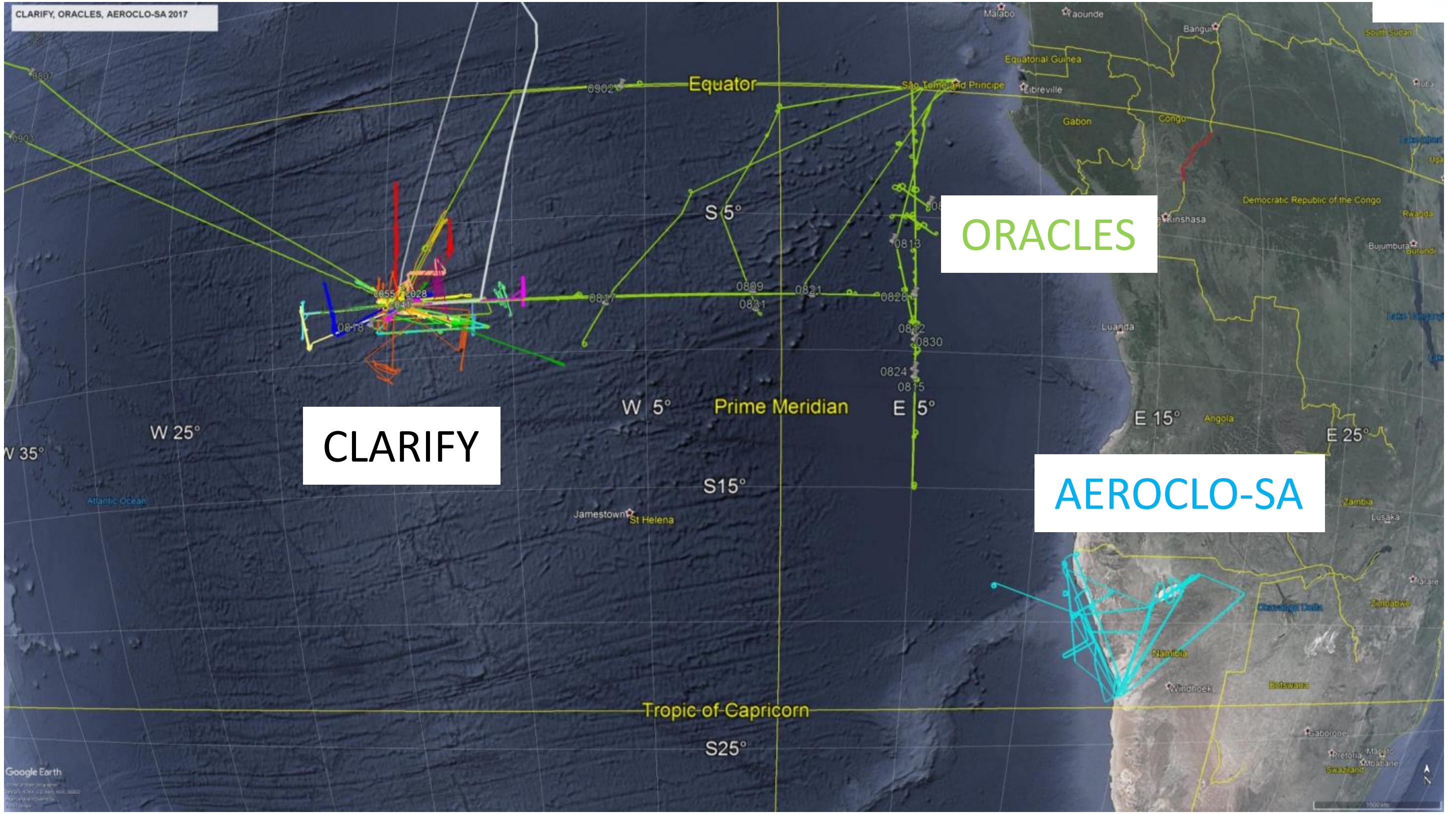
Period of Operations:
August 16th 2017 – September 7th 2017

Total Sorties:
28 Science flights in 23 operational days

Total Flight Time:
98 hours and 43 minutes.

45 dropsondes

2017 flight tracks



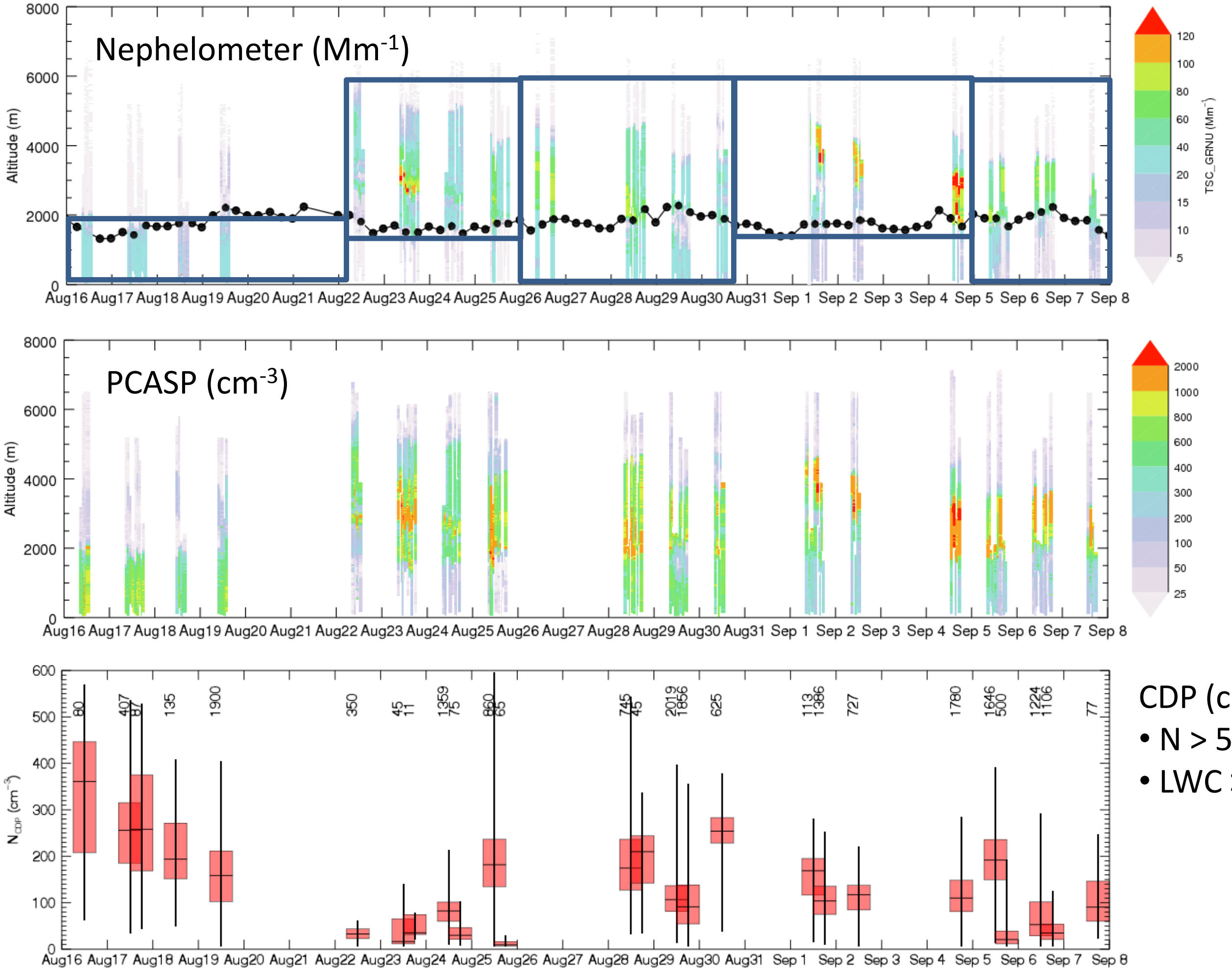
Intercomparisons

Wing-tip intercomparison flight to characterise any systematic biases in key aerosol/cloud/radiation measurements

Sorties upwind of ARM mobile facility. Including flight legs at the altitude of the ground site and in range of the scanning radars

Initial Analysis of Vertical Profiles and Aerosol Properties

Overview of aerosol vertical structure and cloud drop concentrations

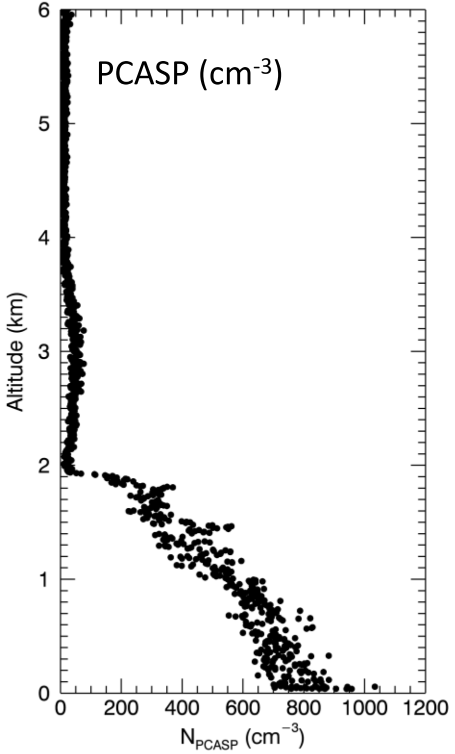


CDP (cm^{-3})

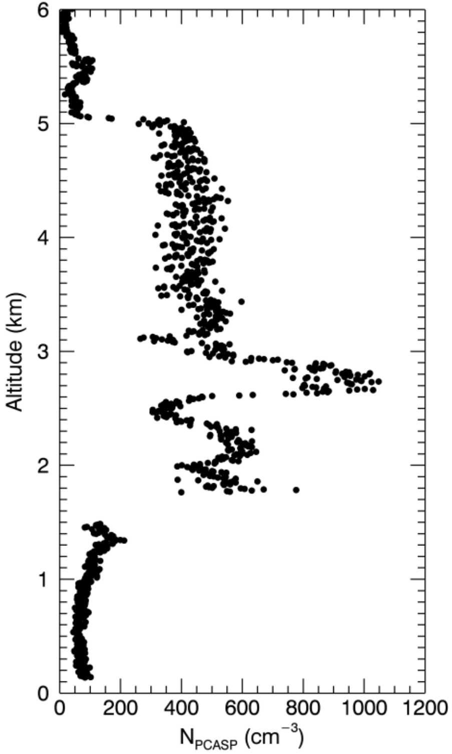
- N > 5 cm^{-3}
- LWC > 0.05 g m^{-3}

More details on the vertical profile

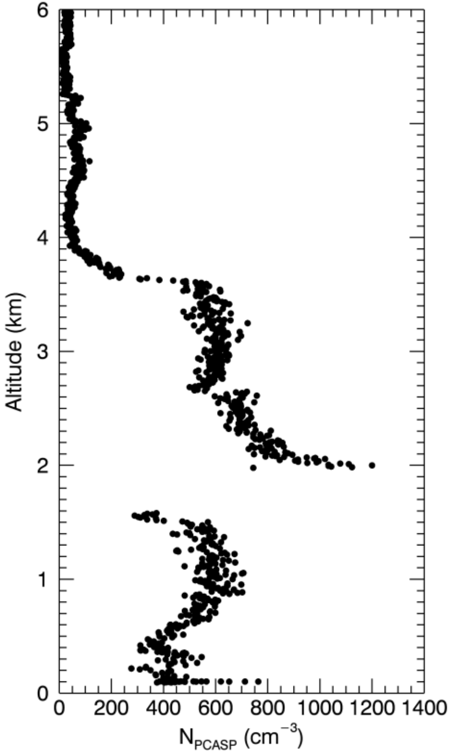
Regime 1
Aerosol only in MBL
16th August



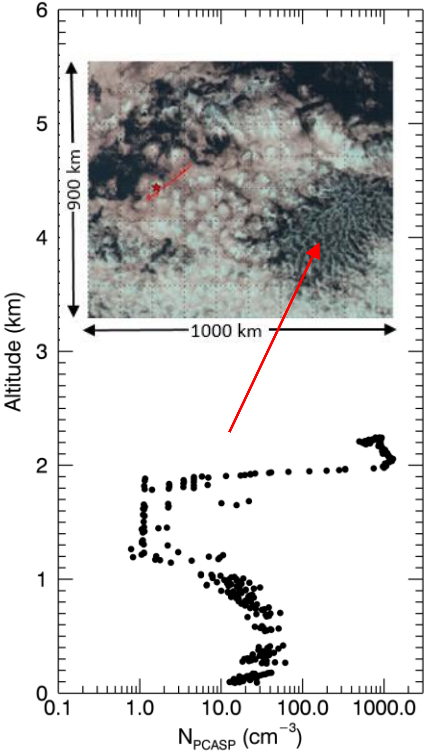
Regime 2
Aerosol only above MBL
24th August



Regime 3
Aerosol in both
29th August

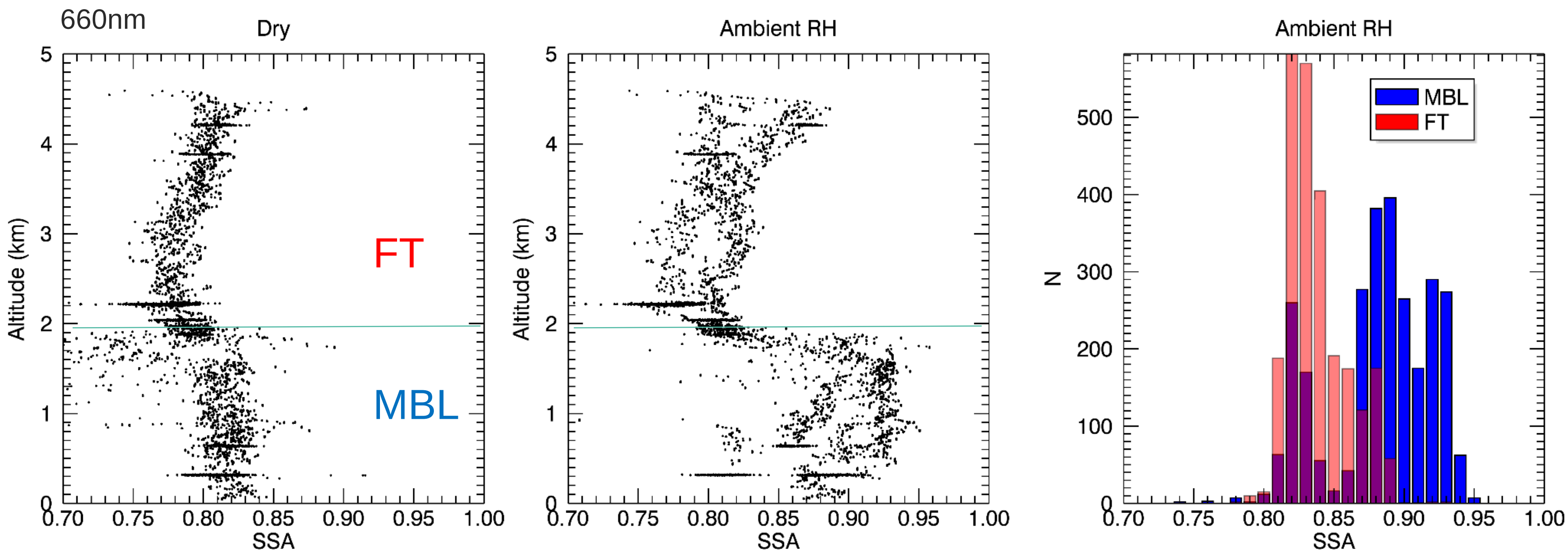


Regime 4
Ultra-clean MBL in POC
5th September



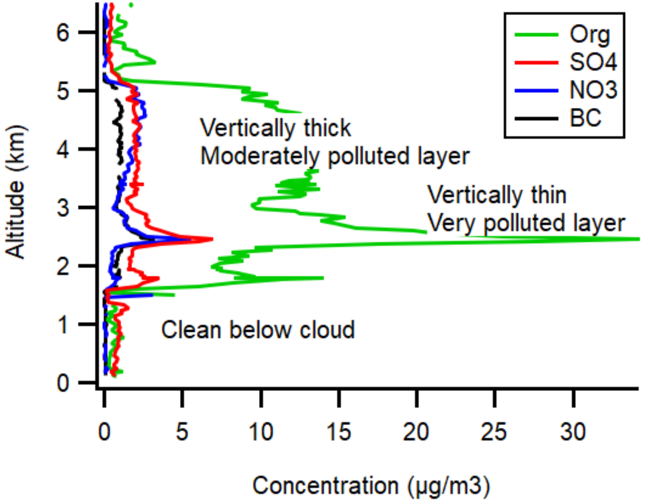
Single scattering albedo

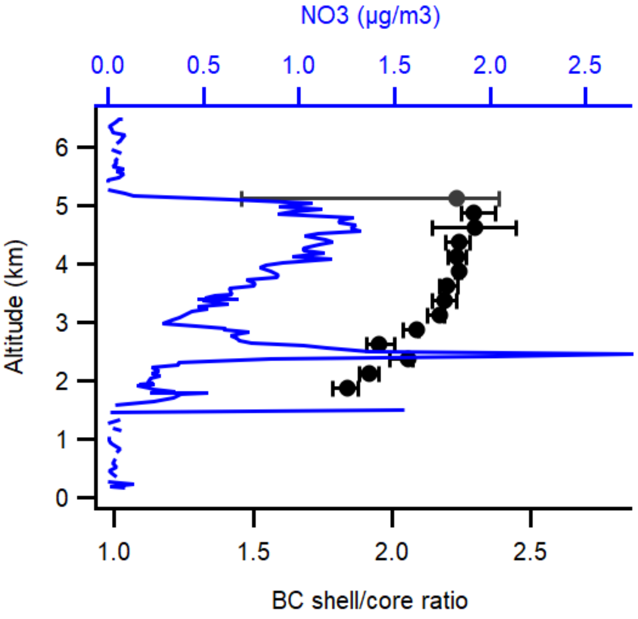
C042 – Biomass burning aerosol in the boundary layer and free-troposphere

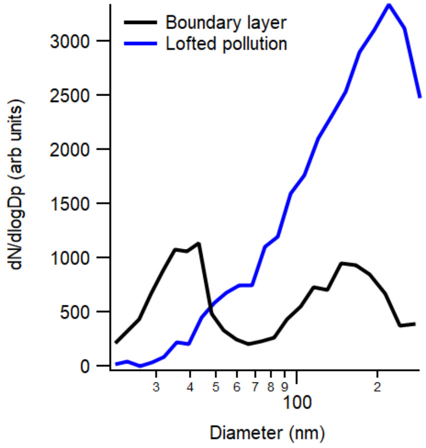


Relative humidity plays an important role in biomass burning aerosol optical properties

C036&7- 24/08/2017
Clean boundary layer, lofted smoke





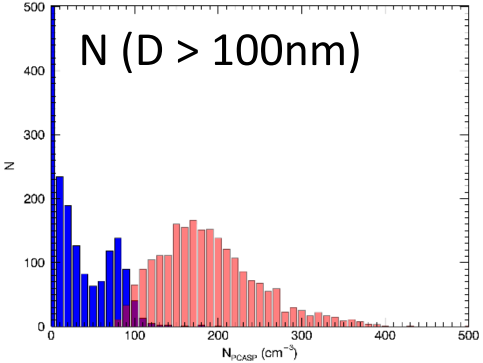


Biomass burning aerosol composition broadly similar throughout CLARIFY

Thick coatings observed on BC

Pocket of Open Cells (POC) studies

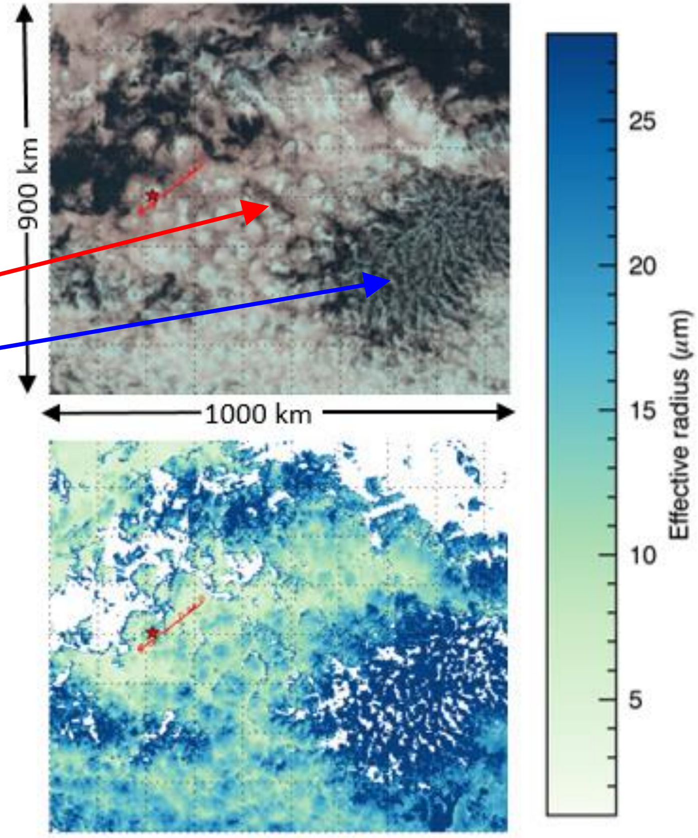
- Clean MBL result of collision-coalescence processes
- Although elevated smoke plume pervades across both cloud regimes, lower CO in POC also suggests lower entrainment rates

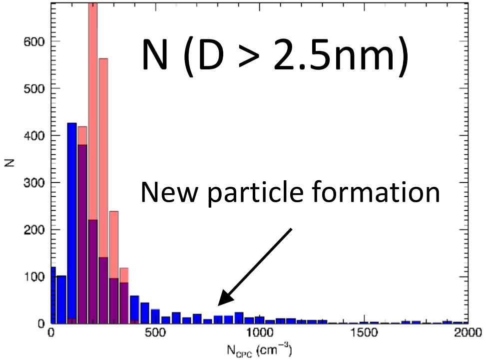


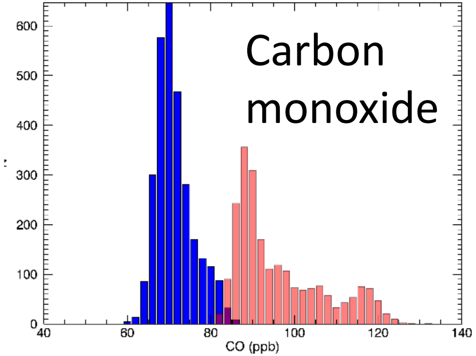
Data in MBL

Upwind of POC

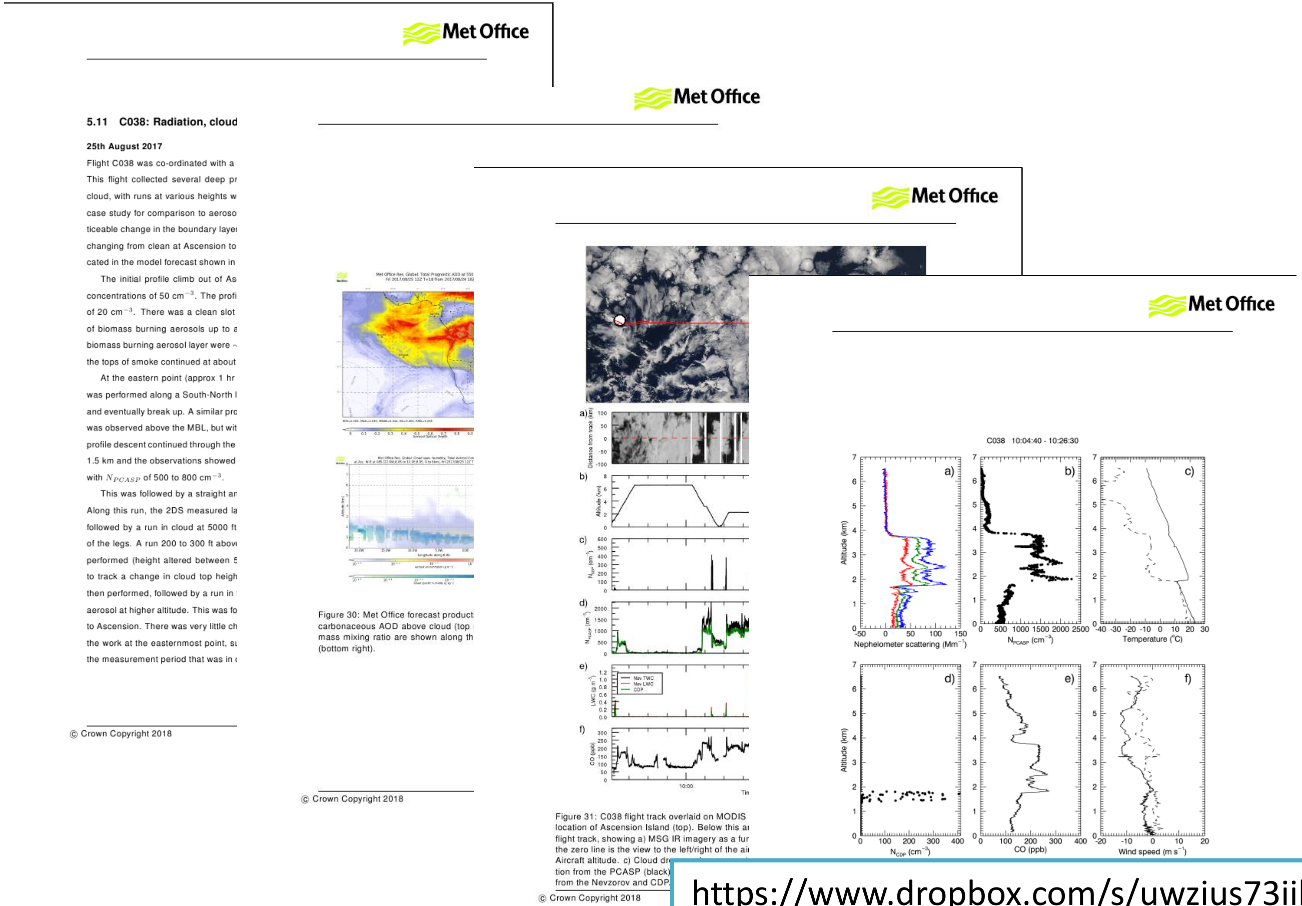
POC







Campaign summary document



- Campaign overview
- Individual flight summaries
  - flight aims
  - description of flight
  - model forecasts
  - flight track
  - satellite imagery
  - selected aircraft data

https://www.dropbox.com/s/uwzius73iiha2wj/clarify_summary_v2.pdf?dl=0

CLARIFY data archive

http://data.ceda.ac.uk/badc/faam/

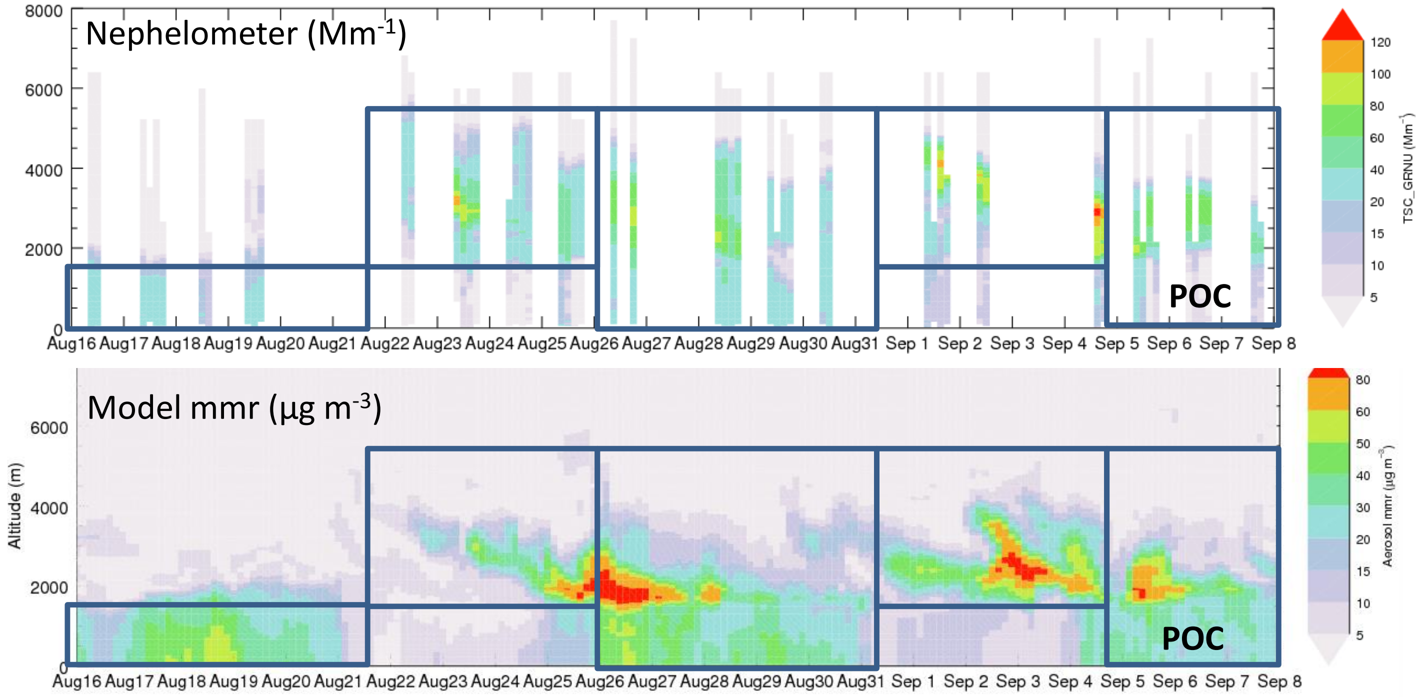
Current status

- Flight logs
- FAAM core data
- FAAM core / 2DS / CIP cloud physics
- Dropsondes
- CCN

Additional instrument data will be made available on CEDA when quality controlled

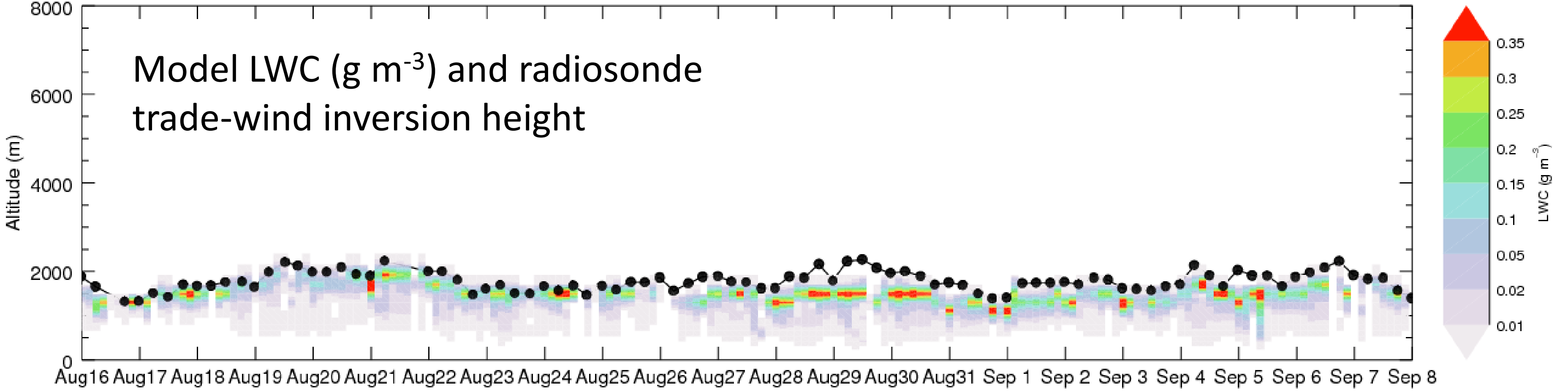
Data policy: *CLARIFY aircraft datasets will be made available to project partners and collaborators immediately after quality control has been performed. Data will be made publically available 2 years after the campaign.*

Met Office Unified Model forecast (17km): vertical profile of aerosol at Ascension Island



Model performs reasonably enough to address science questions except when a POC occurs – suggests missing physical processes under these conditions

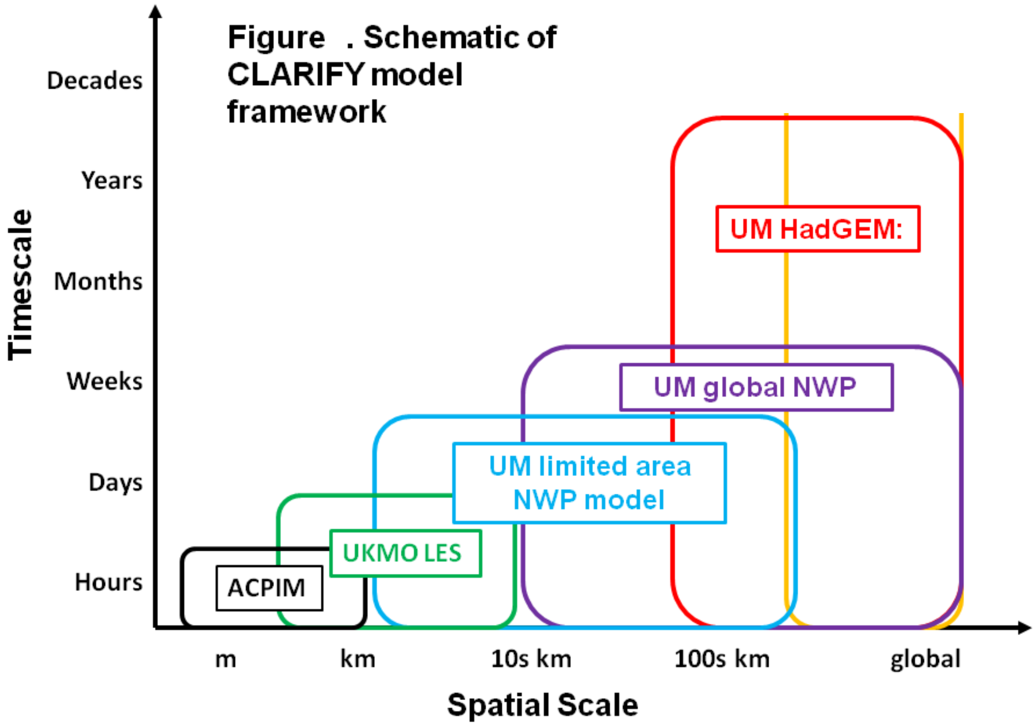
Met Office Unified Model forecast: the vertical position of cloud at the top of the MBL is represented reasonably well



- Model did a reasonable job at forecasting the arrival of smoke plumes at Ascension
- Captured the occurrence of elevated smoke plumes and/or the mixing of smoke into the boundary layer. Underestimates the top altitude of elevated smoke plumes though

- Good job at forecasting boundary layer depth → probably key to getting the mixing of smoke into the boundary layer correct and hence ACI correct

CLARIFY modelling activities

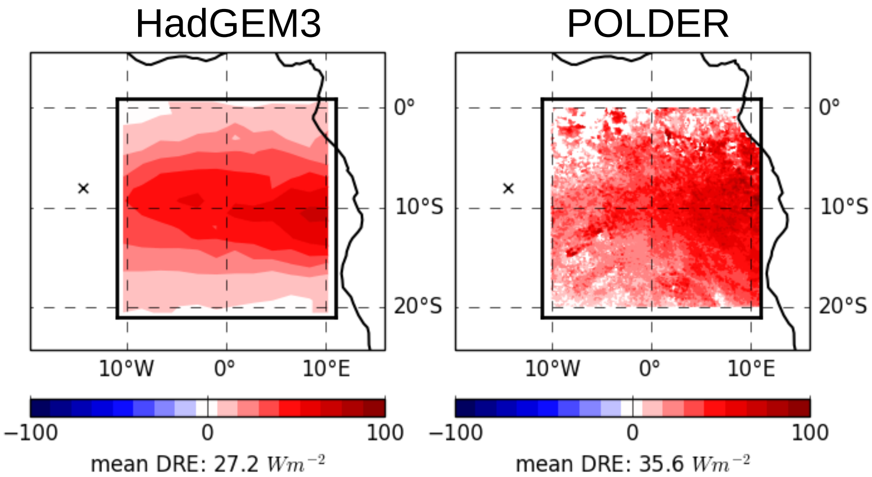


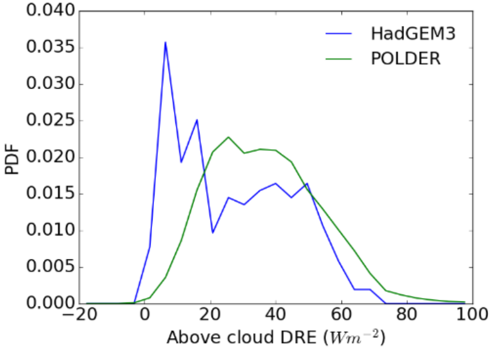
- Broad range of modelling activities to further explore ARI and ACI
- Parcel models → climate model
- Following slides will show some early examples from climate and limited area configurations of the UM

HadGEM3 climate model versus POLDER satellite retrievals of Aerosol Direct Radiative Effect (DRE)

- POLDER retrievals of absorbing aerosol properties above cloud and DRE [Peers et al., 2015] .
- HadGEM3 DRE sampled for cloudy portion of grid cells at POLDER overpass times.
- Preliminary results for Aug-Sept 2006 show positive DRE for the relatively absorbing aerosol layers (SSA_{550}~0.85) above stratocumulus $\tau_{cloud} > 3$.

Nick Davies[1], Ben Johnson[2], Fanny Peers[1]
[1]University of Exeter
[2]Met Office Hadley Centre





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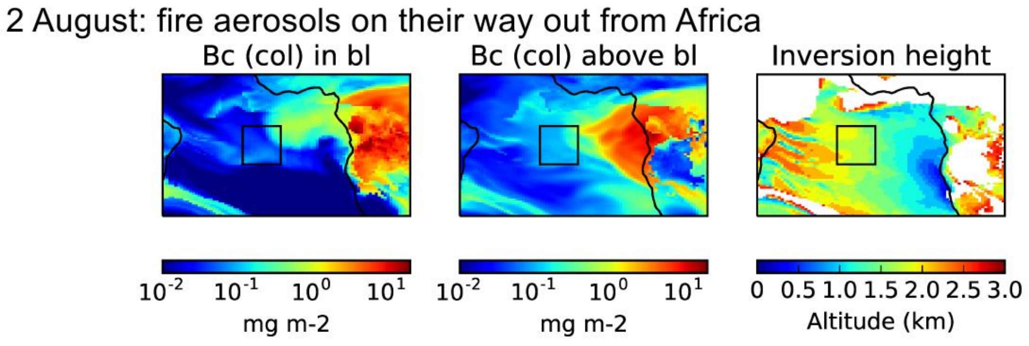
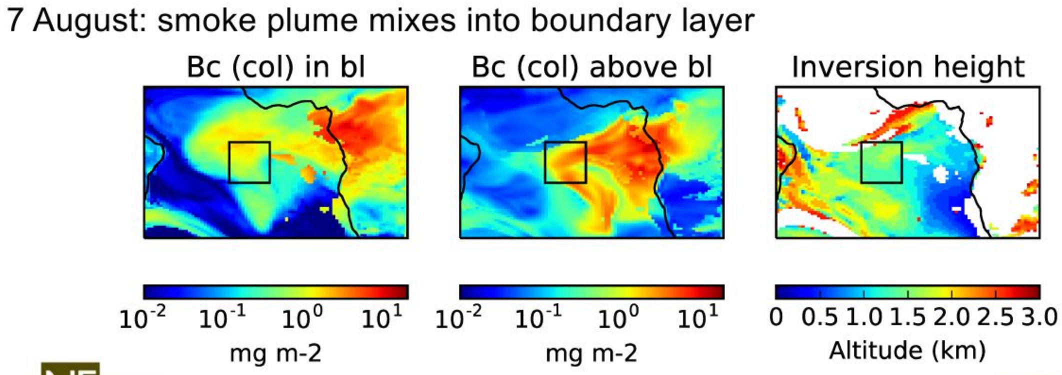
HadGEM3 global → 4 km convection-permitting

Examine direct, indirect and semi-direct radiative effect



FEER (MODIS) daily fire emissions
BC (col) =column-integrated black carbon



70 vertical levels: resolution ~ 200m at inversion

- 10-day case study of smoke transported to Ascension Island (pre-CLARIFY)
- HadGEM3 (65km) driving nested 4 km model
- Examine the interaction of smoke with clouds and radiation

Hamish Gordon (U. Leeds)

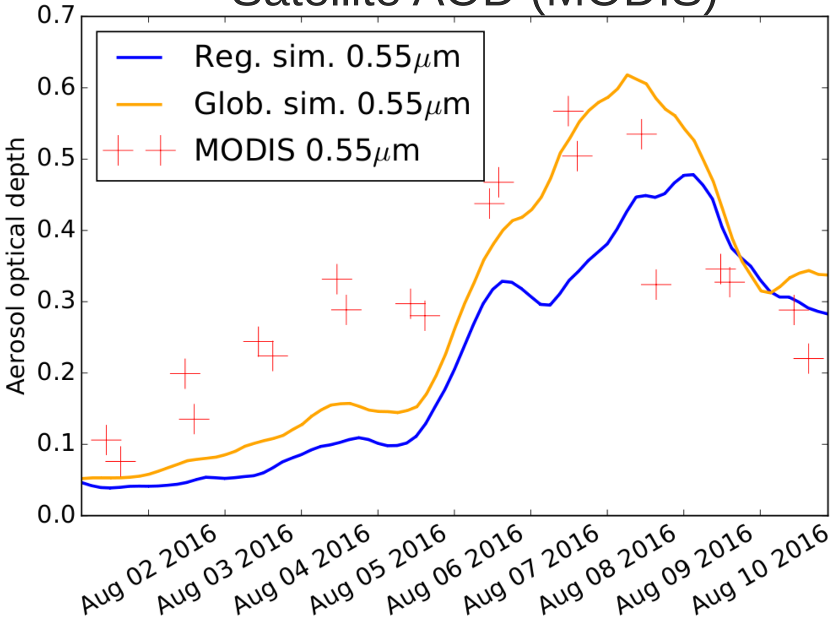
NERC SCIENCE OF THE ENVIRONMENT

Met Office

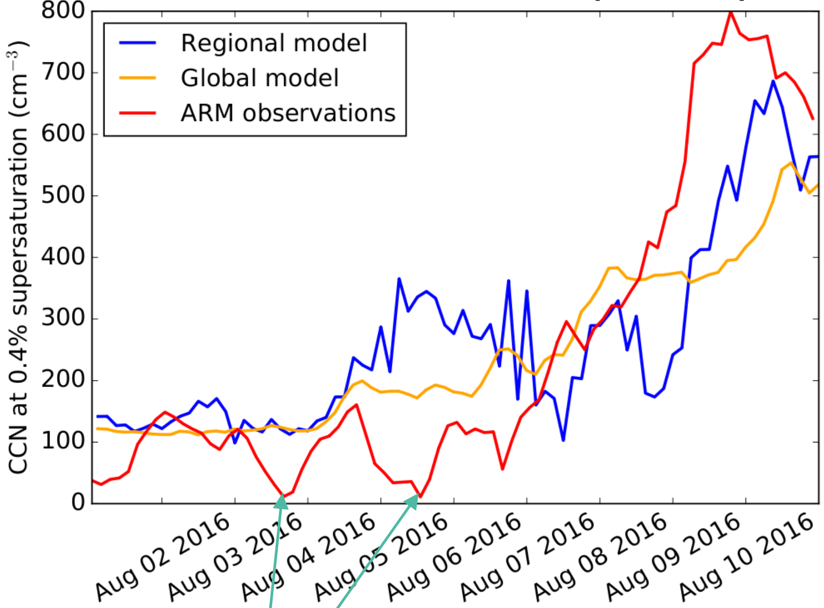
Gordon et al. (2018) https://doi.org/10.5194/acp-2018-305

AOD and CCN comparisons

Satellite AOD (MODIS)



Surface based CCN (LASIC)

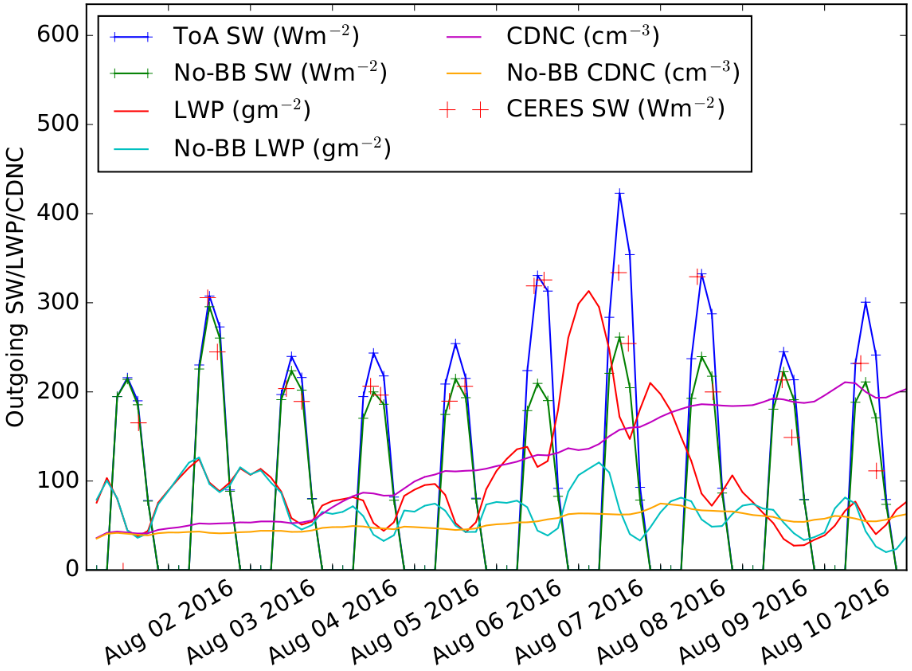


Aerosol wash-out not captured by the model c.f. POC

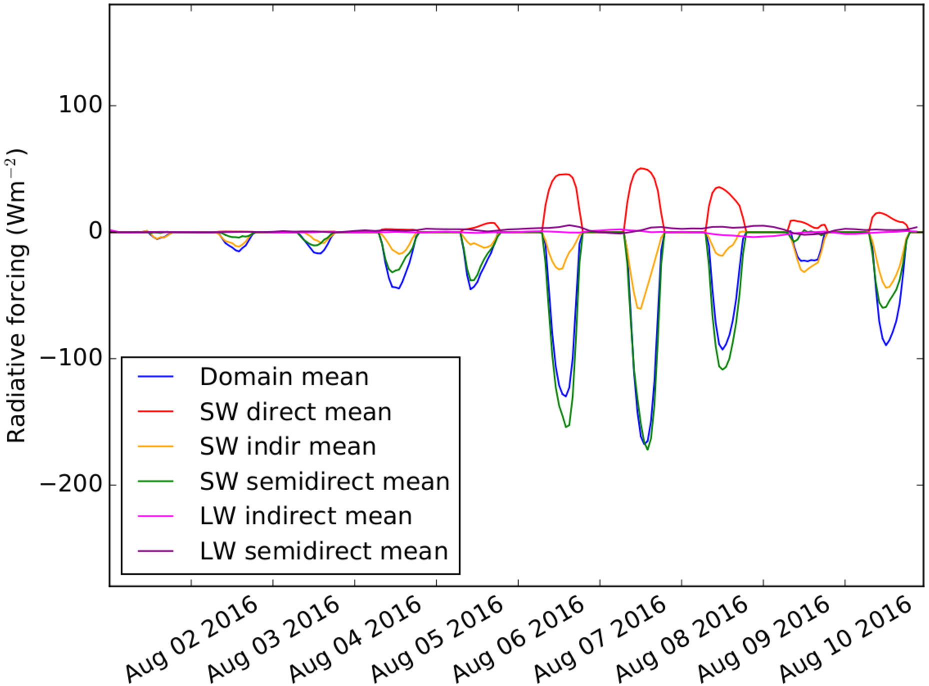
Gordon et al. (2018) https://doi.org/10.5194/acp-2018-305

Radiation balance

TOA outgoing SW (CERES)



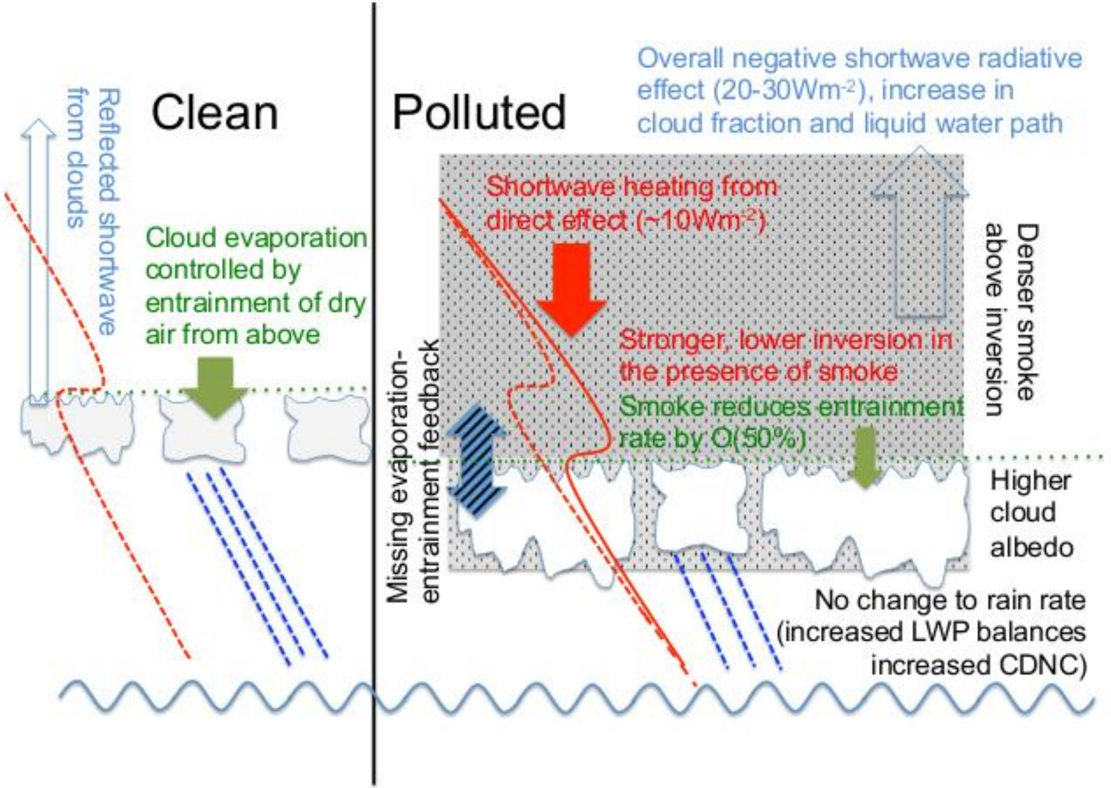
Decomposition of radiative effects



Strong –ve semi-direct effect dominates

Gordon et al. (2018) https://doi.org/10.5194/acp-2018-305

Radiation balance

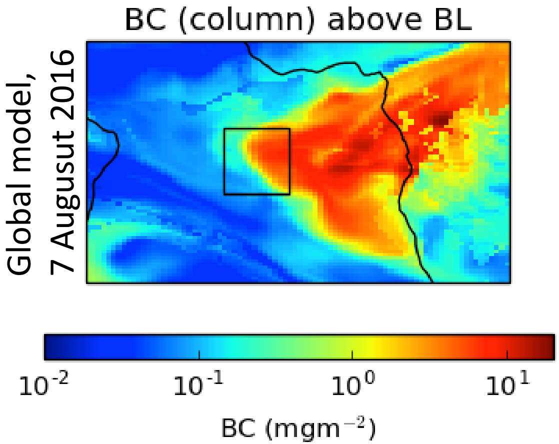


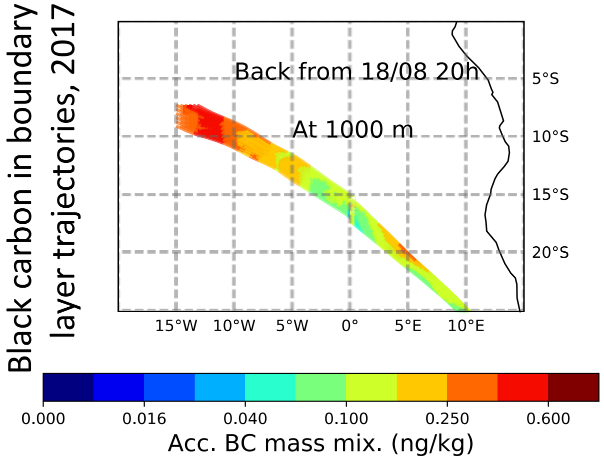
Radiative effect	Global K & K	Regional K & K	Regional Kogan
Direct SW	10.3	11.4	9.67
Indirect SW	-11.9	-10.1	-11.8
Semi-direct SW	-17.0	-30.5	-23.0
Indirect LW	0.5	-0.4	-0.3
Semi-direct LW	0.9	2.3	1.8
Total	-17.2	-27.6	-23.6

Semi-direct effect sensitive to model configuration

Gordon et al. (2018) https://doi.org/10.5194/acp-2018-305

Future regional modelling with UKCA





- Set up and evaluate mesoscale models (500m, 4km, 65km/global resolution) with prognostic aerosol number concentration
- CLARIFY campaign next – several possible case studies
- Aiming to study aerosol-cloud-radiation interactions and stratocumulus-to-cumulus transition
- Intention to provide driving fields for LES models

Hamish Gordon (U. Leeds)

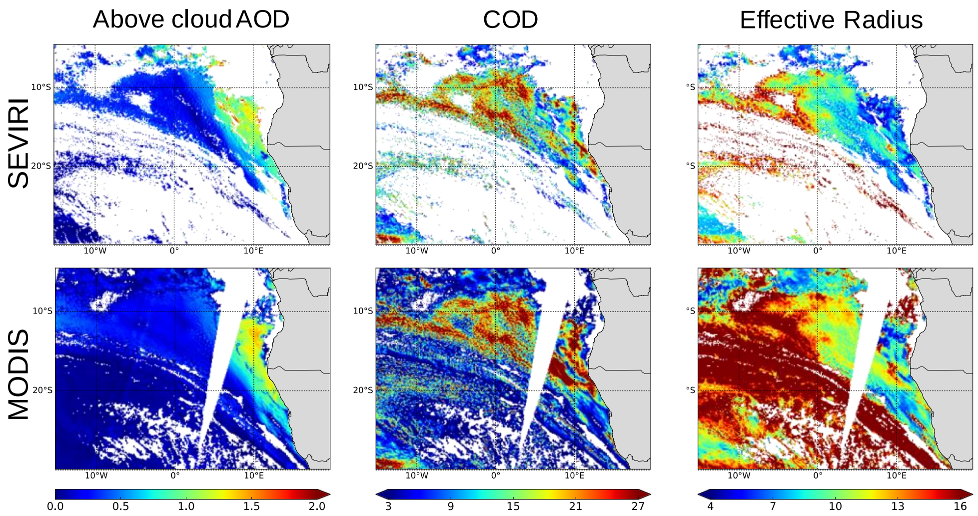
Development of high temporal resolution Satellite Retrievals

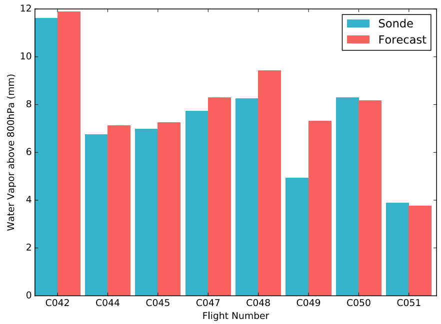
Simultaneous retrieval of (absorbing) above-cloud aerosol and underlying cloud properties from the geostationary instrument SEVIRI

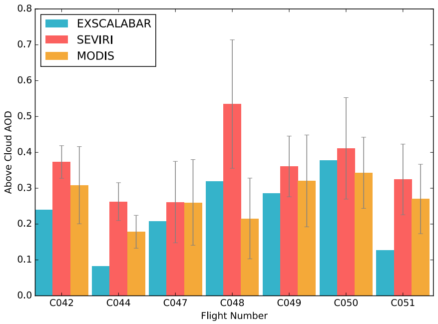
Inter-comparison with MODIS
(K Meyer, S Platnick)

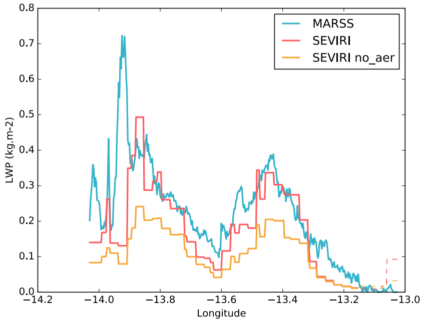
Evaluation against the CLARIFY measurements:

- water vapor profile (for the atmospheric correction scheme)
- in-situ Above Cloud AOD (EXSCALABAR)
- LWP from microwave remote sensing (MARSS)
- Better temporal resolution than MODIS









F Peers, P Francis, J Haywood

Summary

- Very successful campaign with strong links to co-ordinated international projects.
- Wide variety of aerosol and cloud conditions observed. The vertical profile is very variable and important for both ARI and ACI
- Unified Model represents the vertical profile of aerosol and cloud adequately but the radiative effects can be sensitive to the model configuration
- Range of models (LES→climate) are being used for further assessment

Thank you for listening

Any questions?