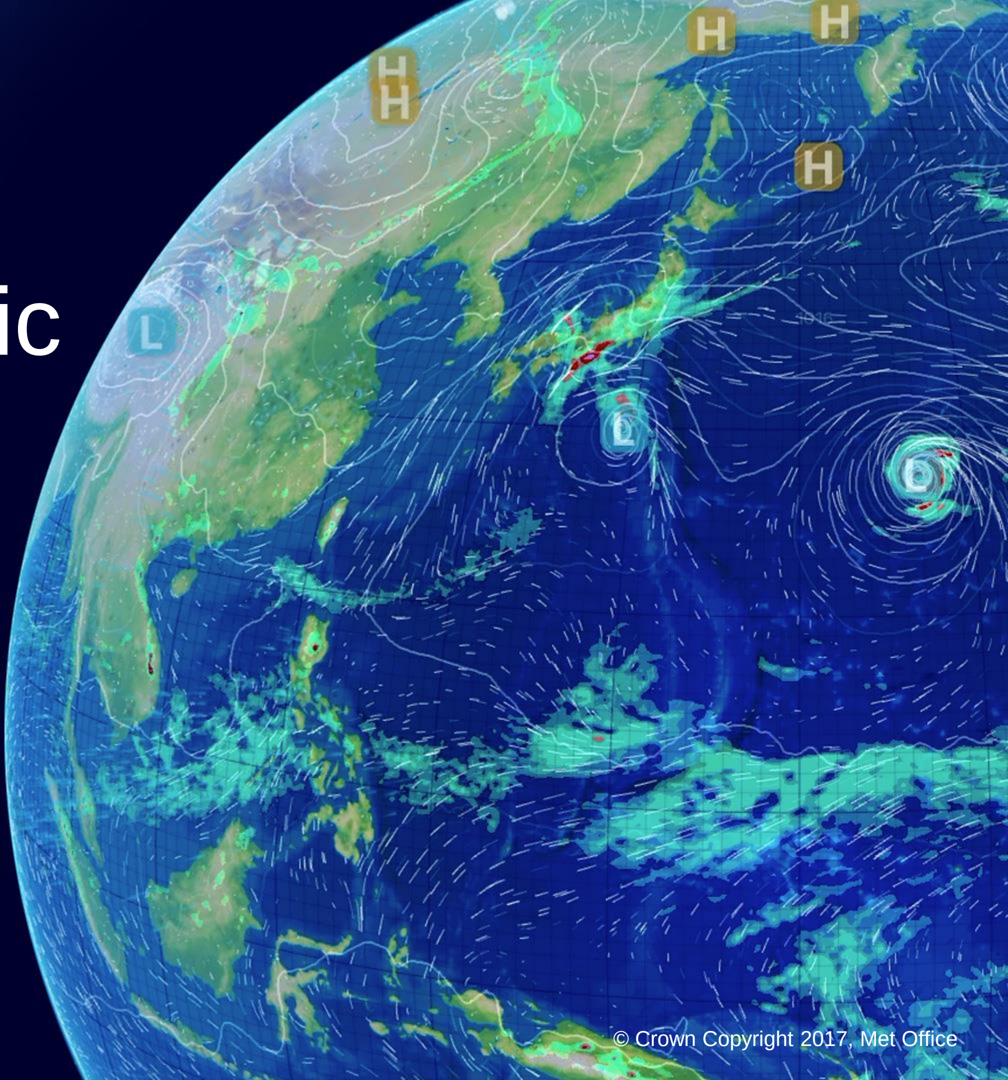
Met Office

The impact of parametrized diabatic processes on weather forecasts

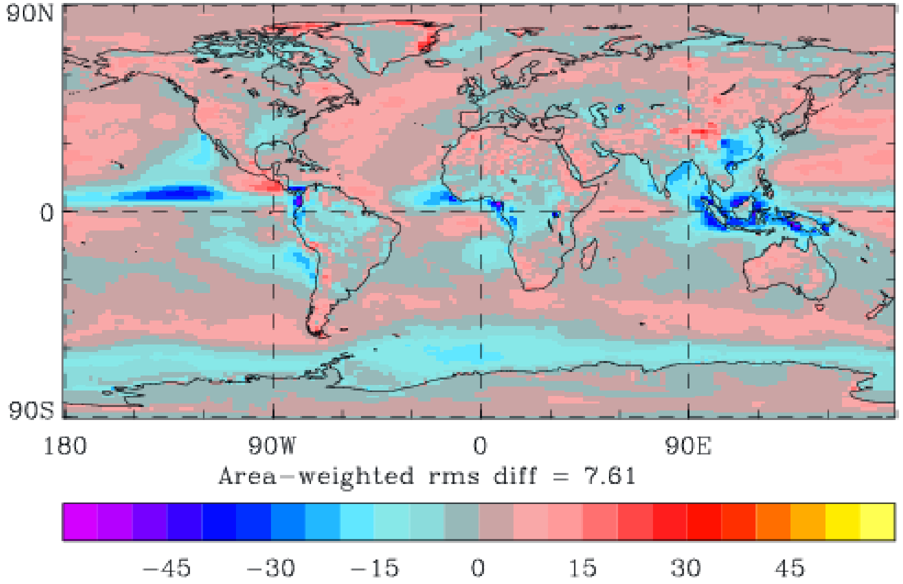
Keith Williams

Open IFS workshop, June 2019

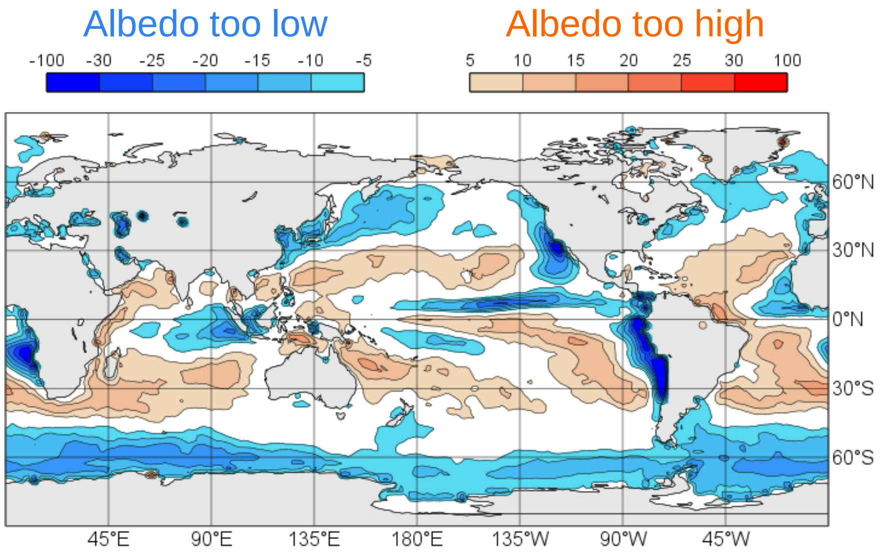


Annual mean bias in TOA reflected SW (vs CERES-EBAF)

UM (GA7.1)



IFS (cycle 43r1)

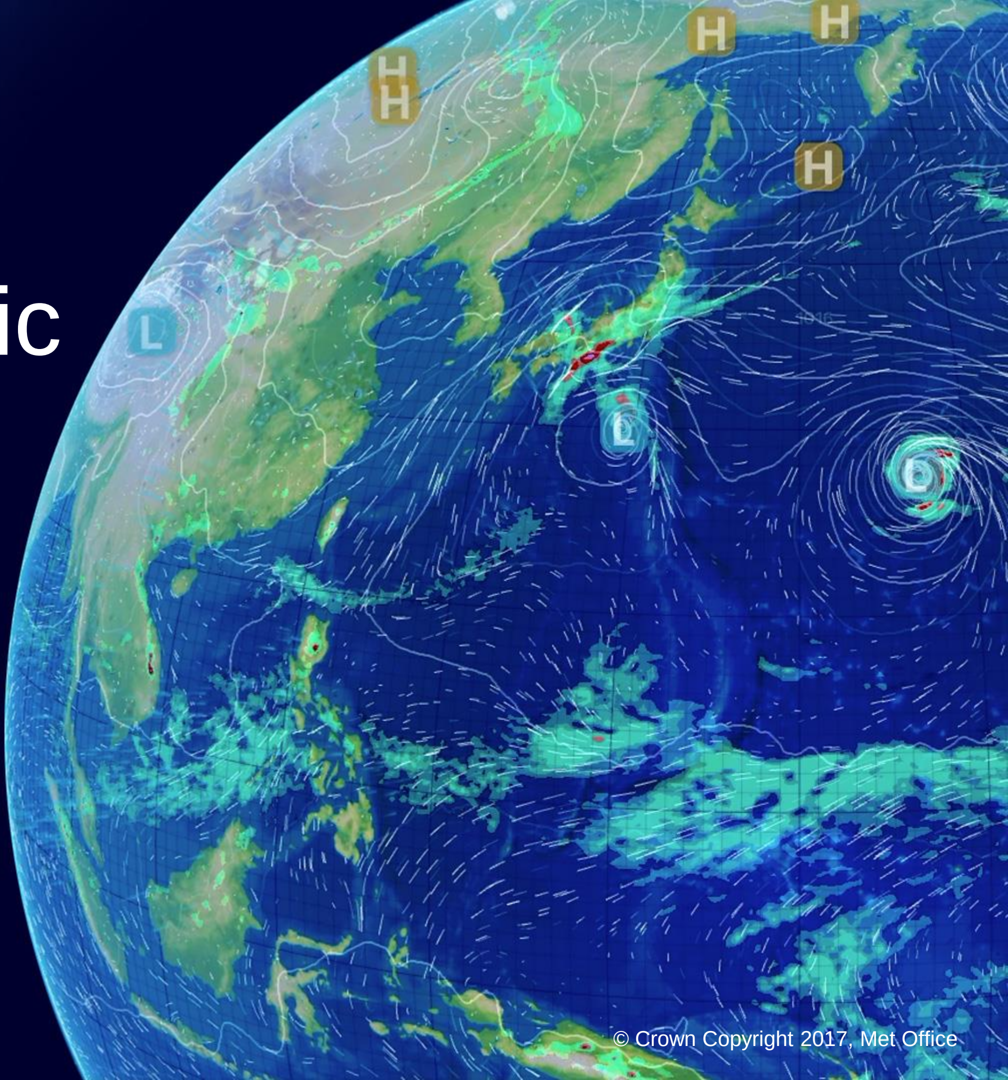


Richard Forbes (ECMWF)

The impact of parametrized diabatic processes on weather forecasts:

- By impacting the dynamical evolution
- Directly on the surface weather

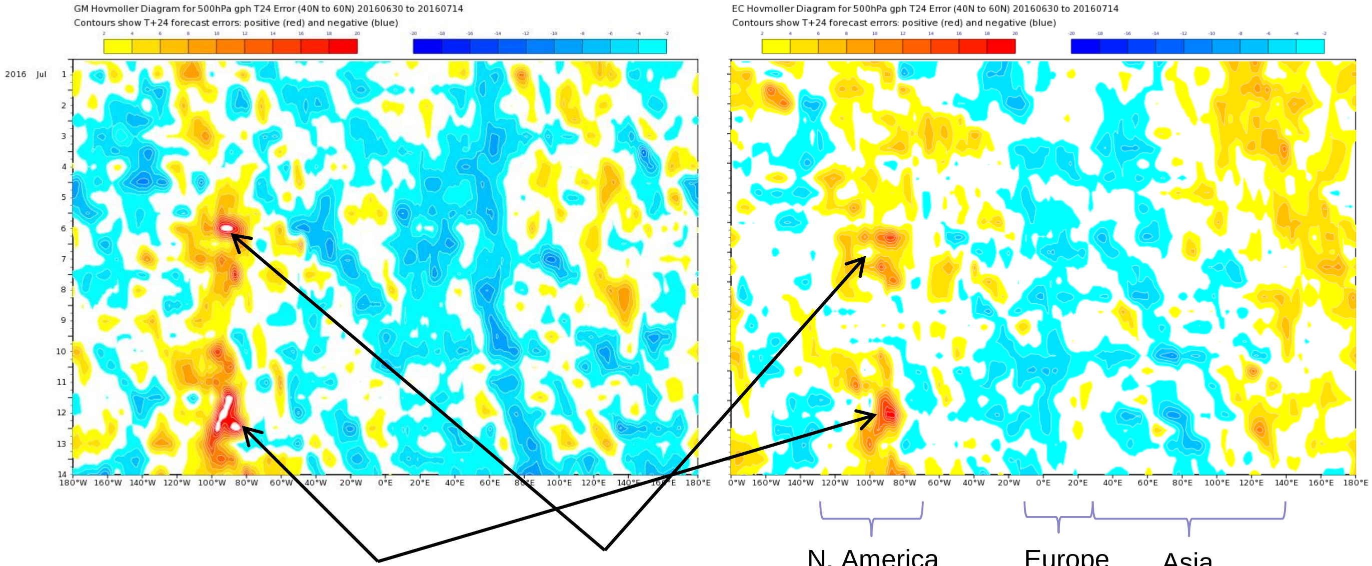
The impact of parametrized diabatic processes on dynamical evolution



Z500 Hovmoller Error Diagrams (July 2016)

UM

ECMWF



N. America

Europe

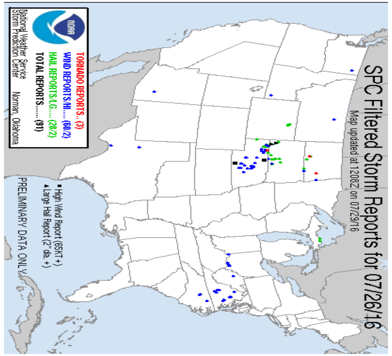
Asia

10th-14th July

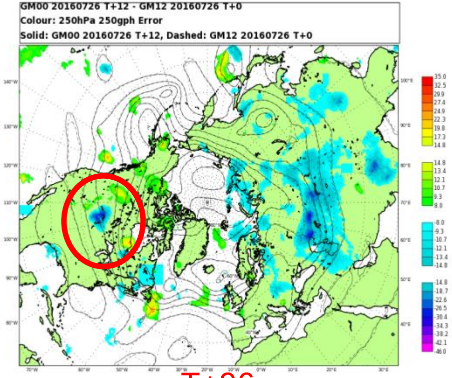
6th-8th July

Adrian Semple

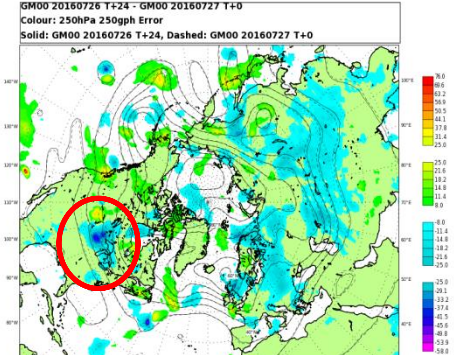
Downstream impact of convection induced on Europe (Z250)



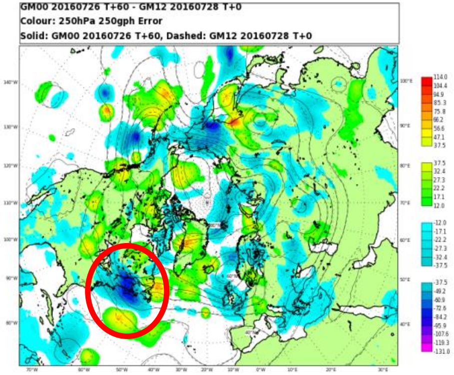
T+12



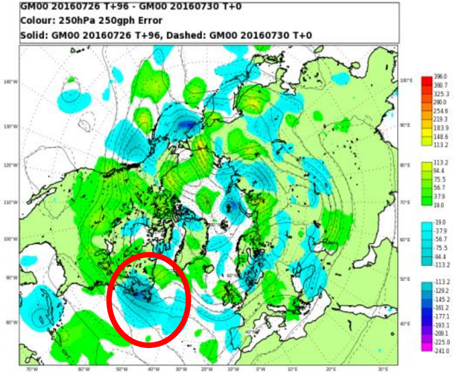
T+24



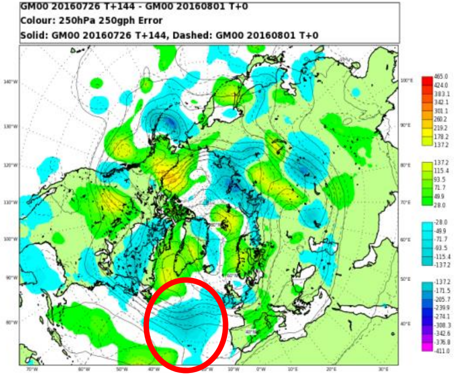
T+60



T+96

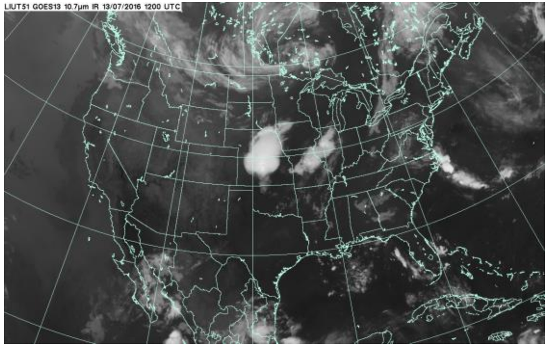


T+144

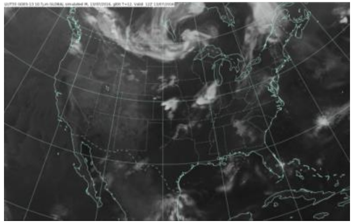


Model or DA?

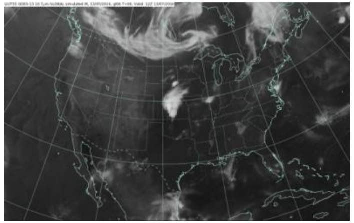
IR Image



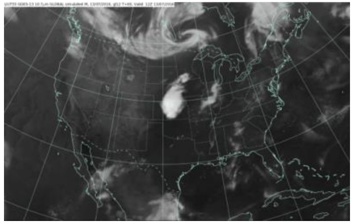
DA appears perfectly capable of representing the system. But model clearly resists developing it.



QG00 13th July T+12



QG06 13th July T+6

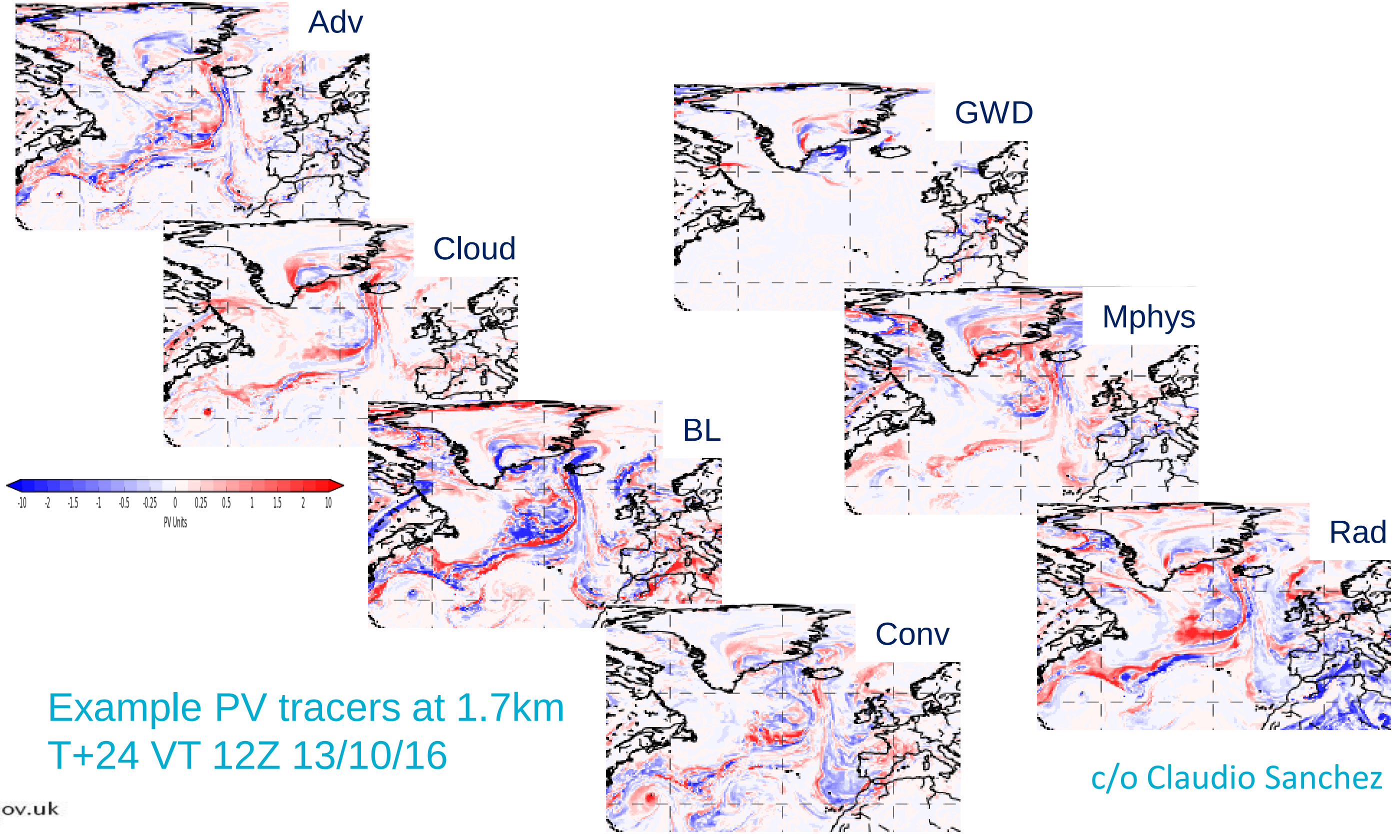


QG12 13th July T+0

Sim IR Images from separate Fcsts approaching the event

Adrian Semple

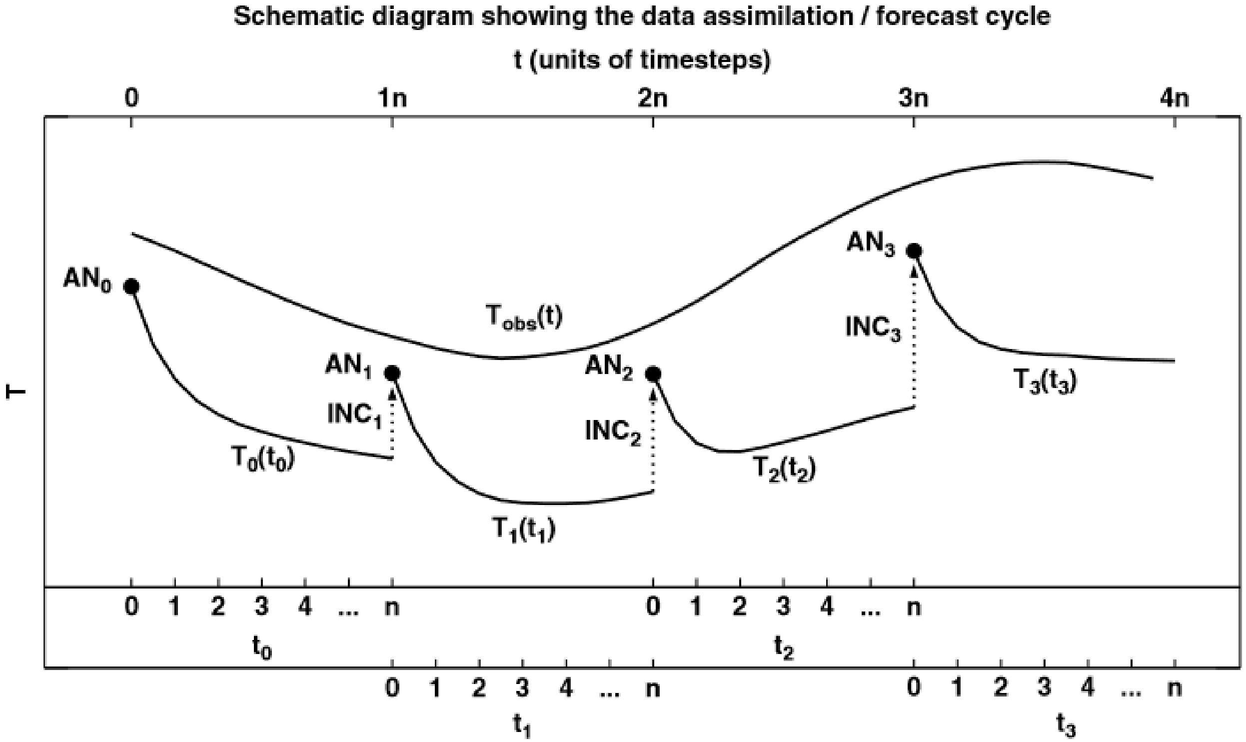
NAWDEX (North Atlantic Waveguide and Downstream impact EXperiment)
PV tracer diagnostics



Example PV tracers at 1.7km
T+24 VT 12Z 13/10/16

c/o Claudio Sanchez

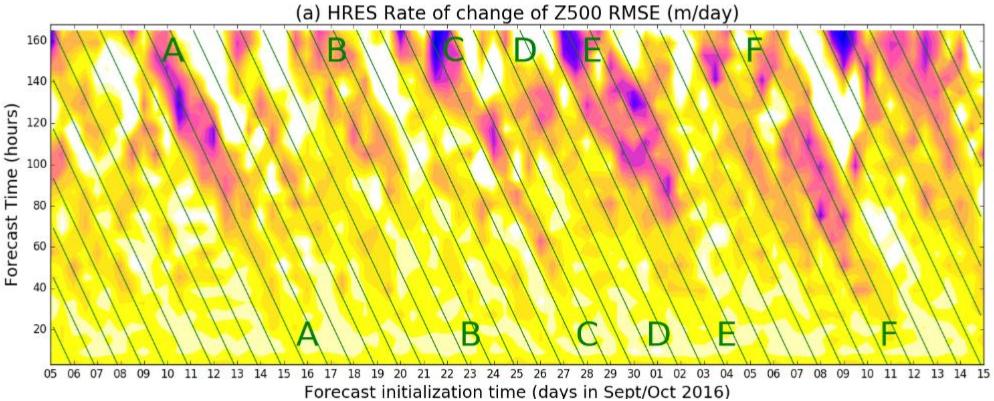
Assessing forecast tendencies



Rodwell and Palmer (2007)

Predictability barriers

Claudio Sanchez



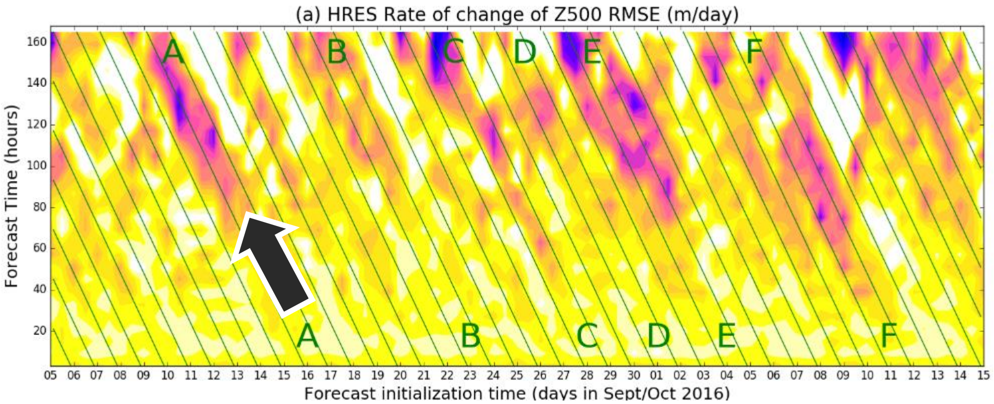
(a) HRES Rate of change of Z500 RMSE (m/day)

Z500 RMSE rate of change (∂ ‘error’ / ∂ ‘T+’):
Across NAWDEX Period (15/9 to 15/10).

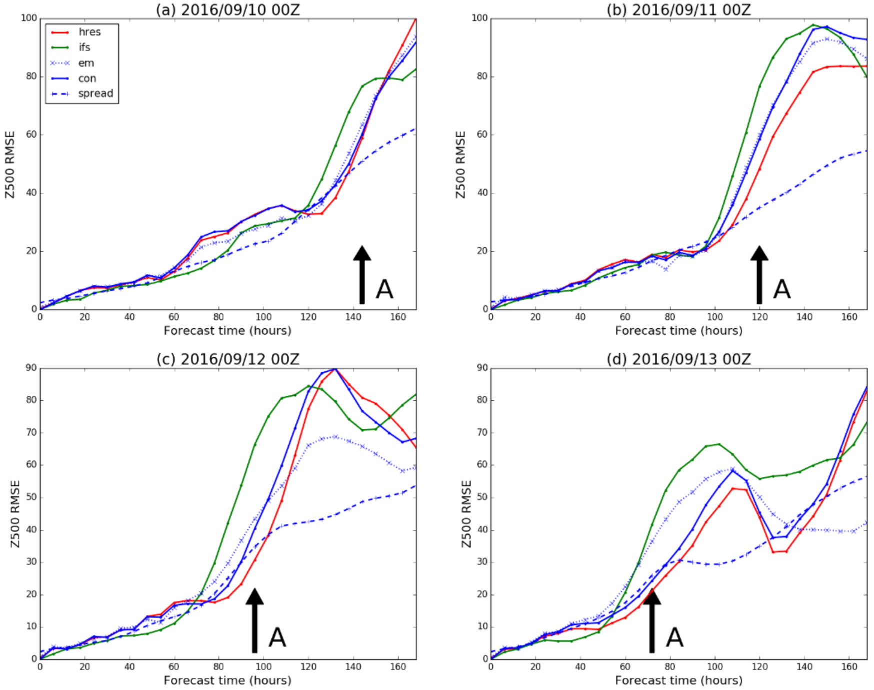
Predictability barriers

Claudio Sanchez

There are events where error grows rapidly, occurring at the same validation time (00Z 16th for event A).

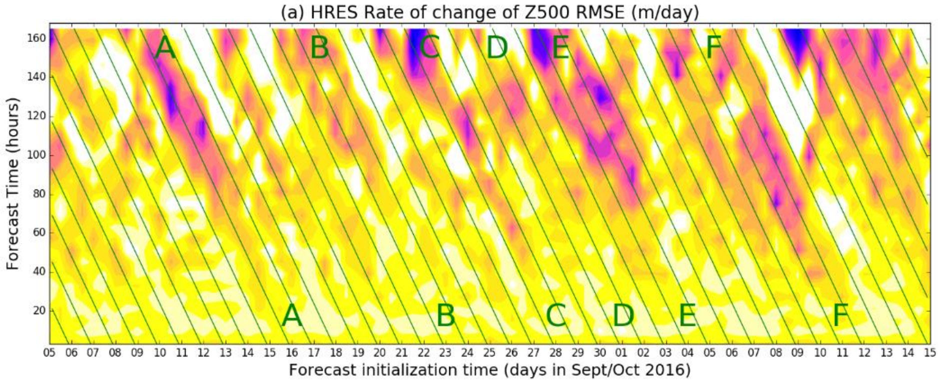


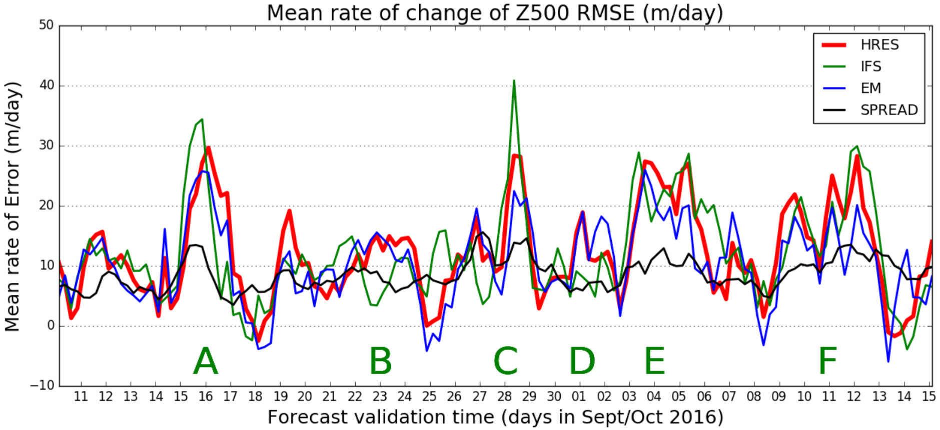
Z500 RMSE rate of change (∂ ‘error’ / ∂ ‘T+’): Across NAWDEX Period (15/9 to 15/10).



Predictability barriers (2)

Claudio Sanchez


(a) HRES Rate of change of Z500 RMSE (m/day)


Mean rate of change of Z500 RMSE (m/day)

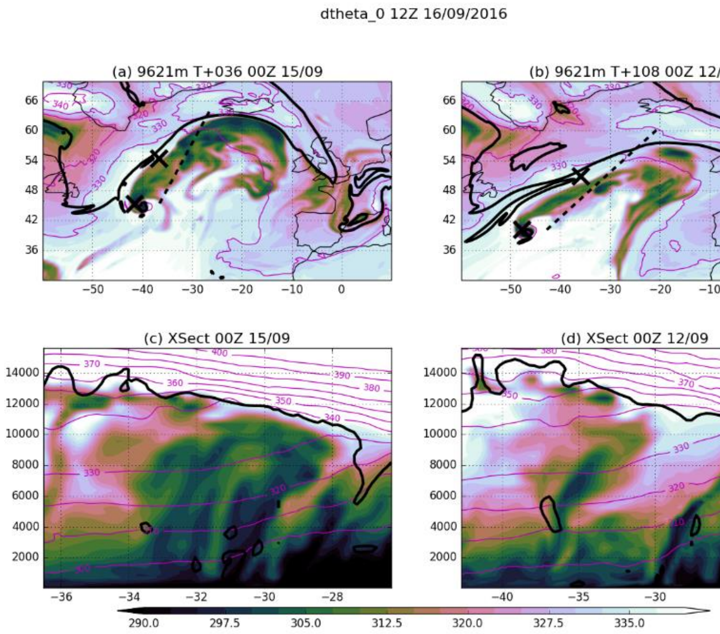
Events with large increase of error at a similar validation time are defined as ***predictability barriers***

- Similar for IFS and UM.
- Low ensemble spread and ensemble mean not too different from deterministic.

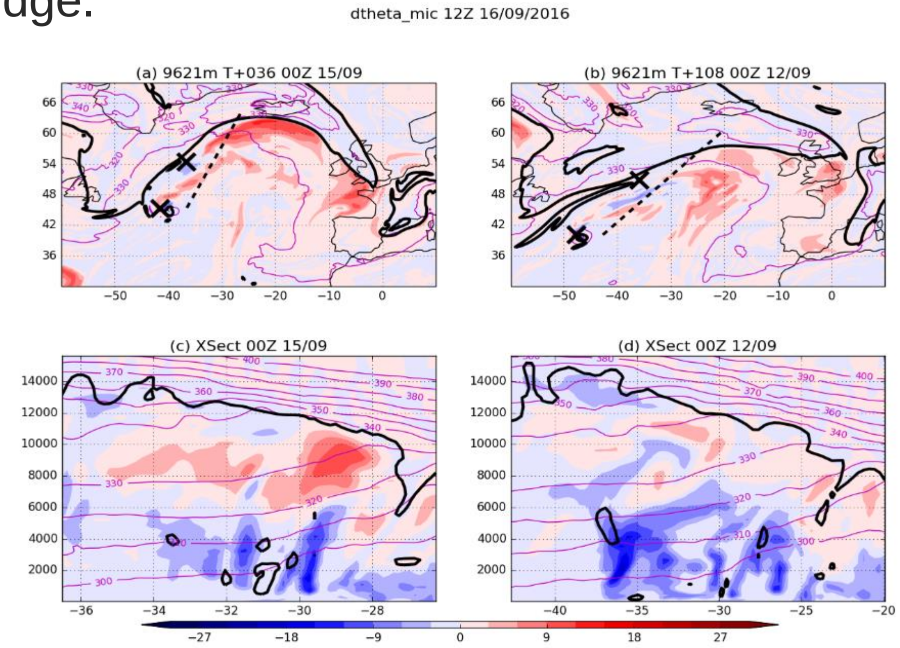
A:Ex-TC Ian (IOP1)

Claudio Sanchez

Longer forecast fail to merge, important ascent and heating from LS-rain over ridge.



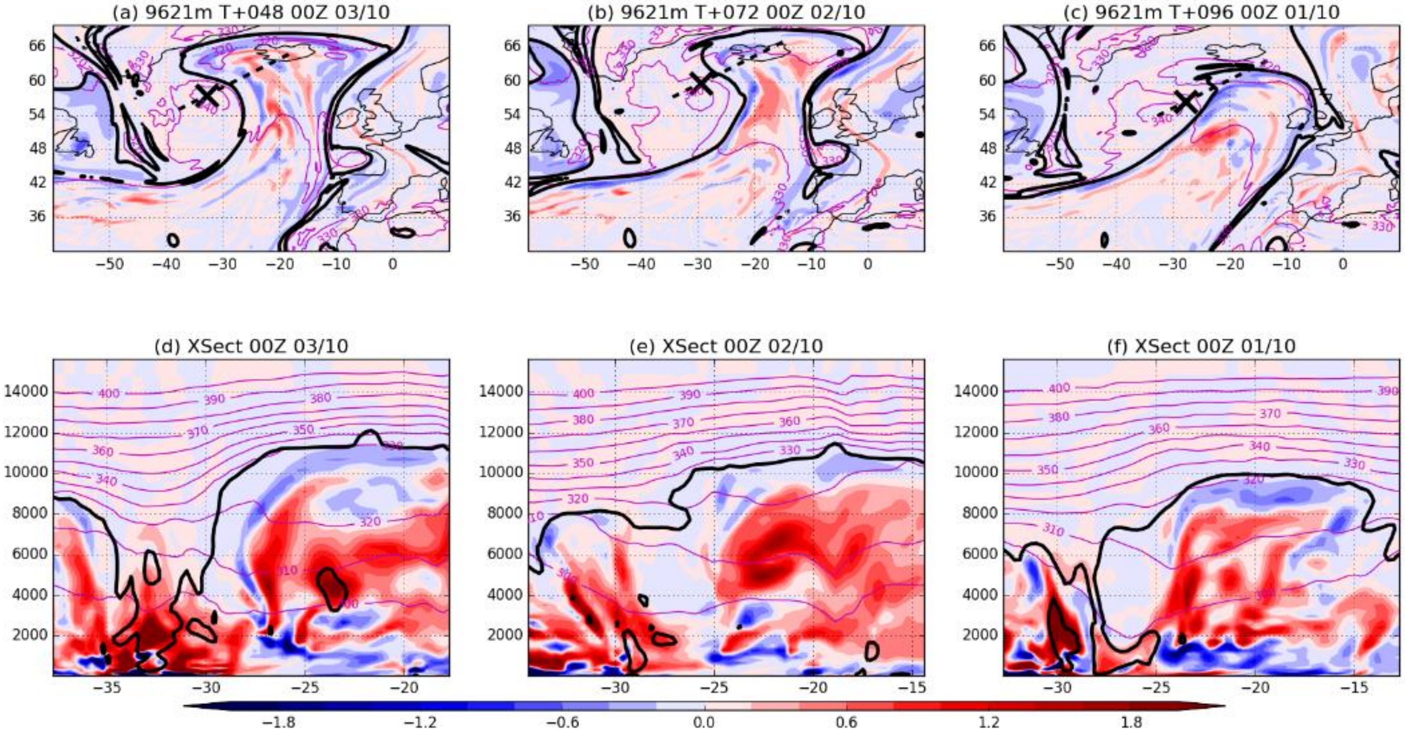
‘advection only dθ’ tracer on 12Z 16th for (a,c) 00Z 15th (b,d) 00Z 12th forecast. (c,d) Cross section on dashed line in (a,b). X: Pos of Ian and merged cyclone. Tracer initialized at 00Z 15th



Same as left, but for $d\theta_{LS}$.

E: After stalactite (IOP7)

Claudio Sanchez



dPV_{LS} tracer in different forecasts (initialized at 00Z 3rd, 2nd and 1st).

Delay in ridge building, strong negative PV filament associated to LS rain process

SG and predictability barriers

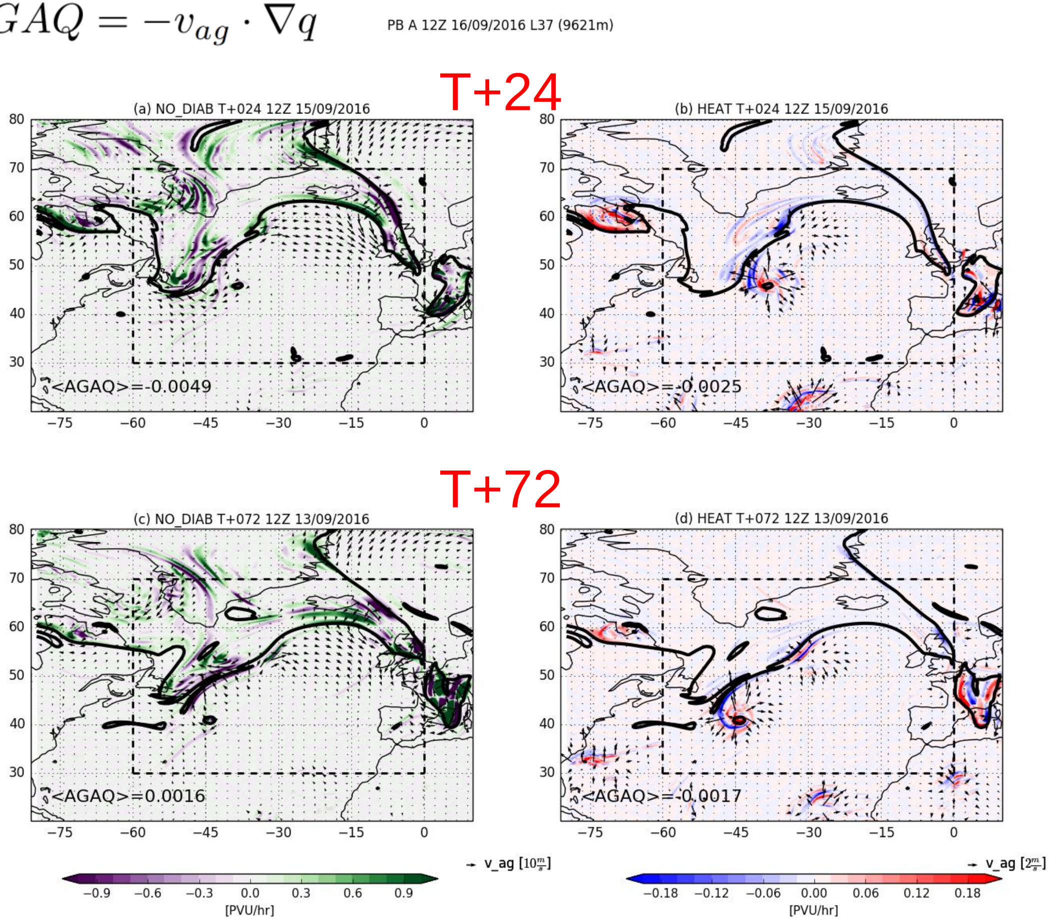
Claudio Sanchez

SG model integrated for one hour from Met-UM (N768) 6 hourly output

AGeostrophic Advection of PV (AGAQ) shows areas where:

- Deposition of diabatic heating on the Warm Conveyor Belt (WCB) outflow region
- There are cross-tropopause and ridge building action

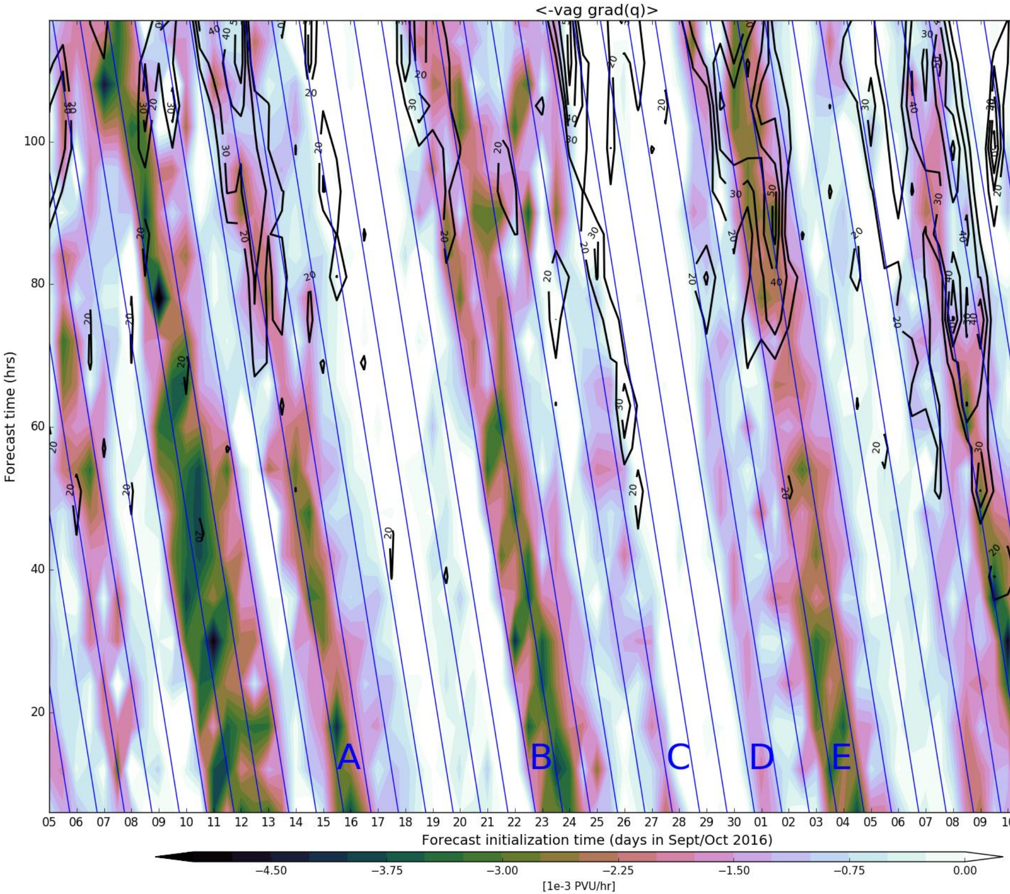
$$AGAQ = -v_{ag} \cdot \nabla q$$



[Right]: AGAQ (coloured) and ageostrophic wind (vectors) for Case A (12Z 16/9/2016). (a) No diabatic sources T+24. (b) Diabatic heating only for T+24. (c) No diabatic sources T+72. (d) Diabatic heating only for T+72. Box: area of average for AGAQ and RMSE

SG and predictability barriers

Claudio Sanchez



Most of PB cases (A,B,C,D,E,F) coincide with <AGAQ>↑

Several of the PB (A,B,F) got lower <AGAQ> values on T+↑ than T+↓

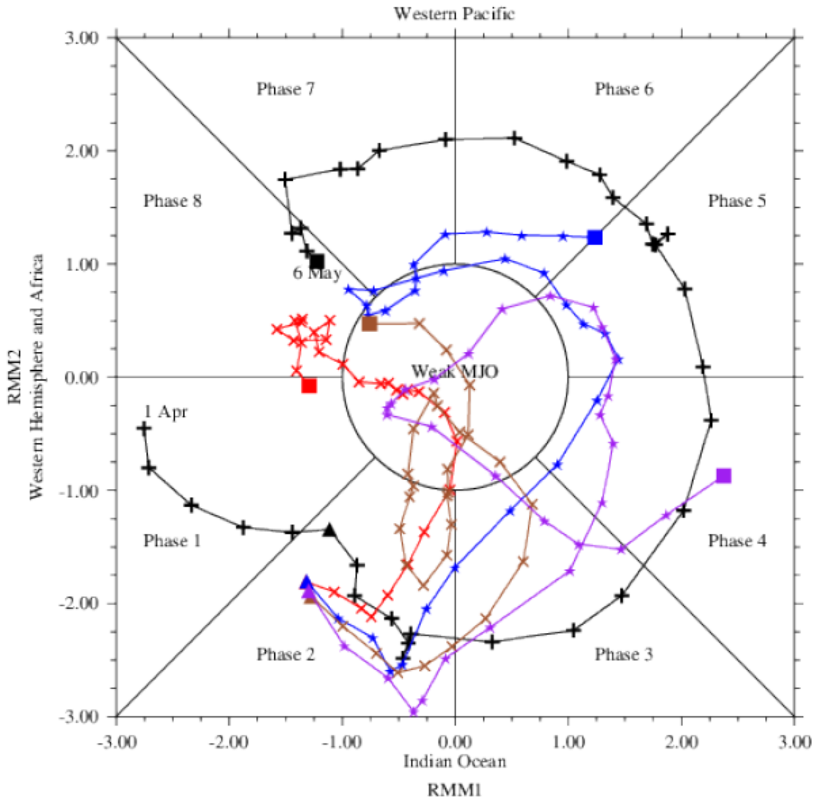
Strong influence of diabatic processes over outflow region on model error

[Left] <AGAQ(DIAB)> (coloured) and PB (contoured)

April 2009 case study results

National Centre for
Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

Effect of convective entrainment on MJO



Increasing the entrainment (blue) and switching off the convective momentum transport (brown) improve the strength and propagation of the active event.

The 1.5x entrainment simulation shows the lowest RMSE against the observations (black).

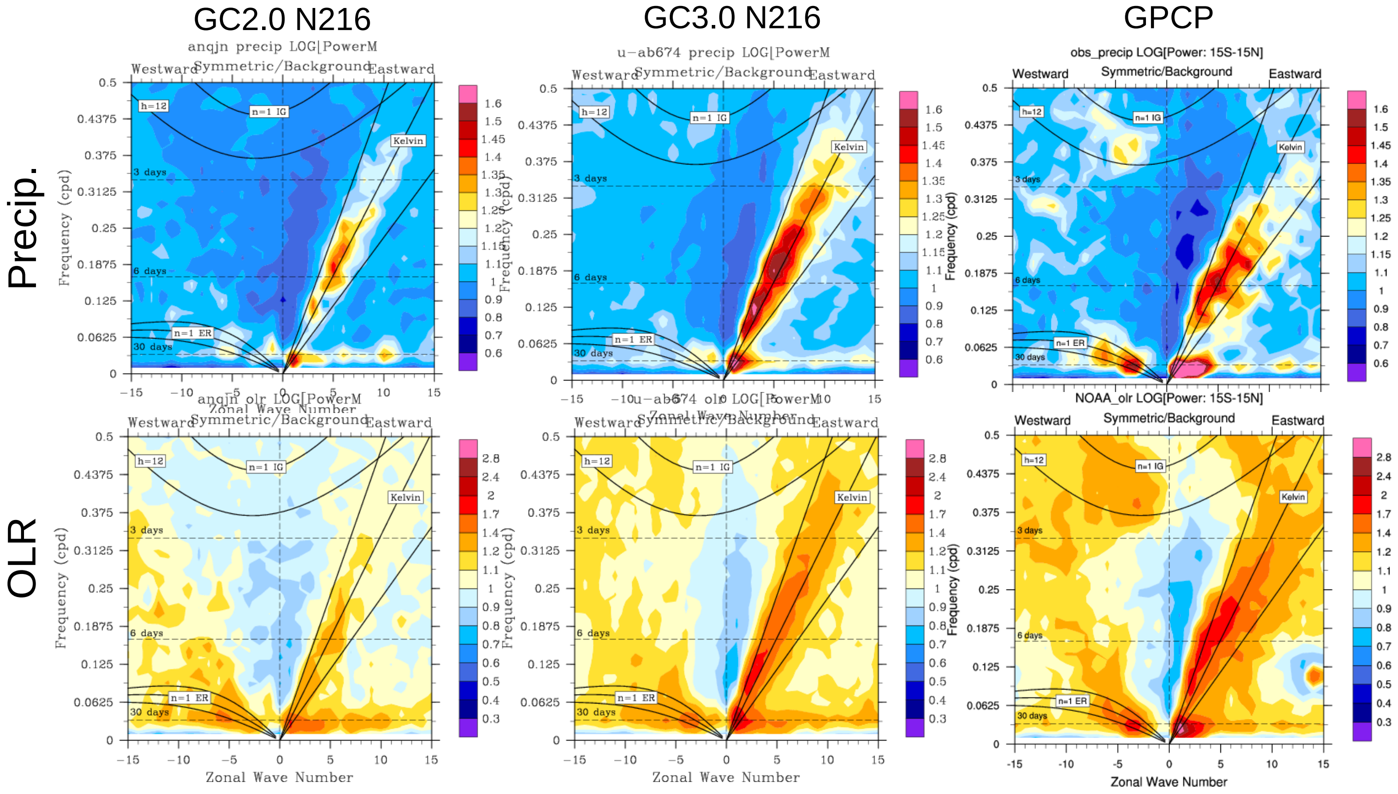
Model	RMSE (forecast)	RMSE (days 1-10)	Speed (forecast)	Speed (days 1-10)
Observations			8.974	9.758
xfadh	2.797	1.576	6.152	10.41
xfadk	2.143	1.082	11.77	11.54
xfadl	3.324	1.116	13.26	8.210
xfadm	3.110	1.128	14.59	10.65

Nick Klingaman
(U. Reading)

Tropical wave spectra

(effect of cloud and convection package)

Prince Xavier

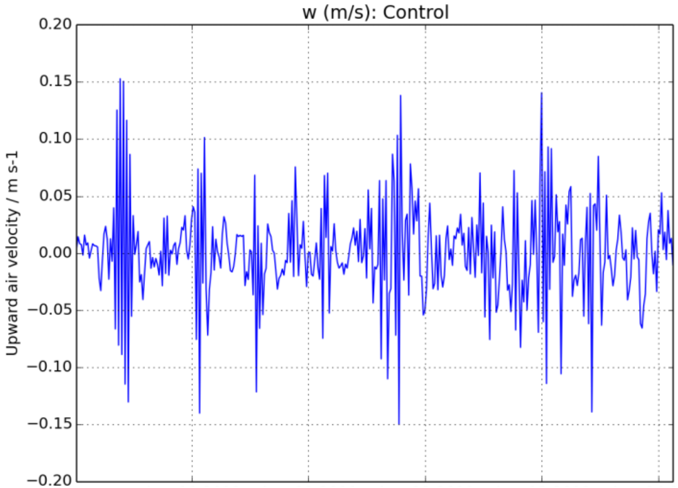


Dynamical impact of tropical convection

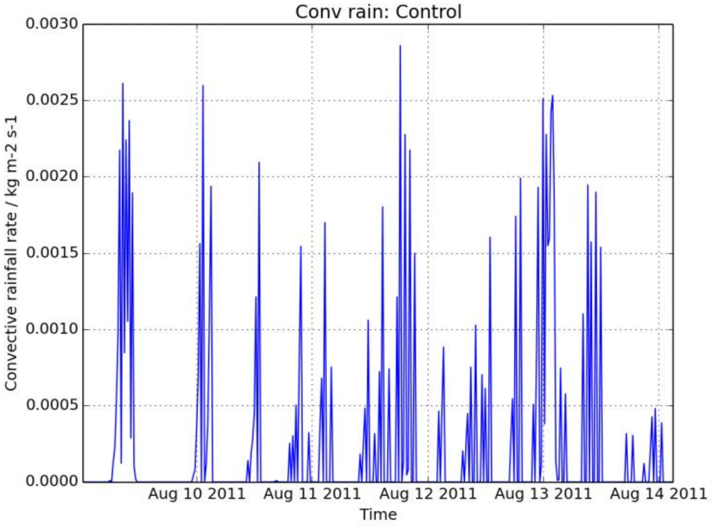
High frequency noise in vertical winds above convection

Martin Willett

w at ML 55(23km)

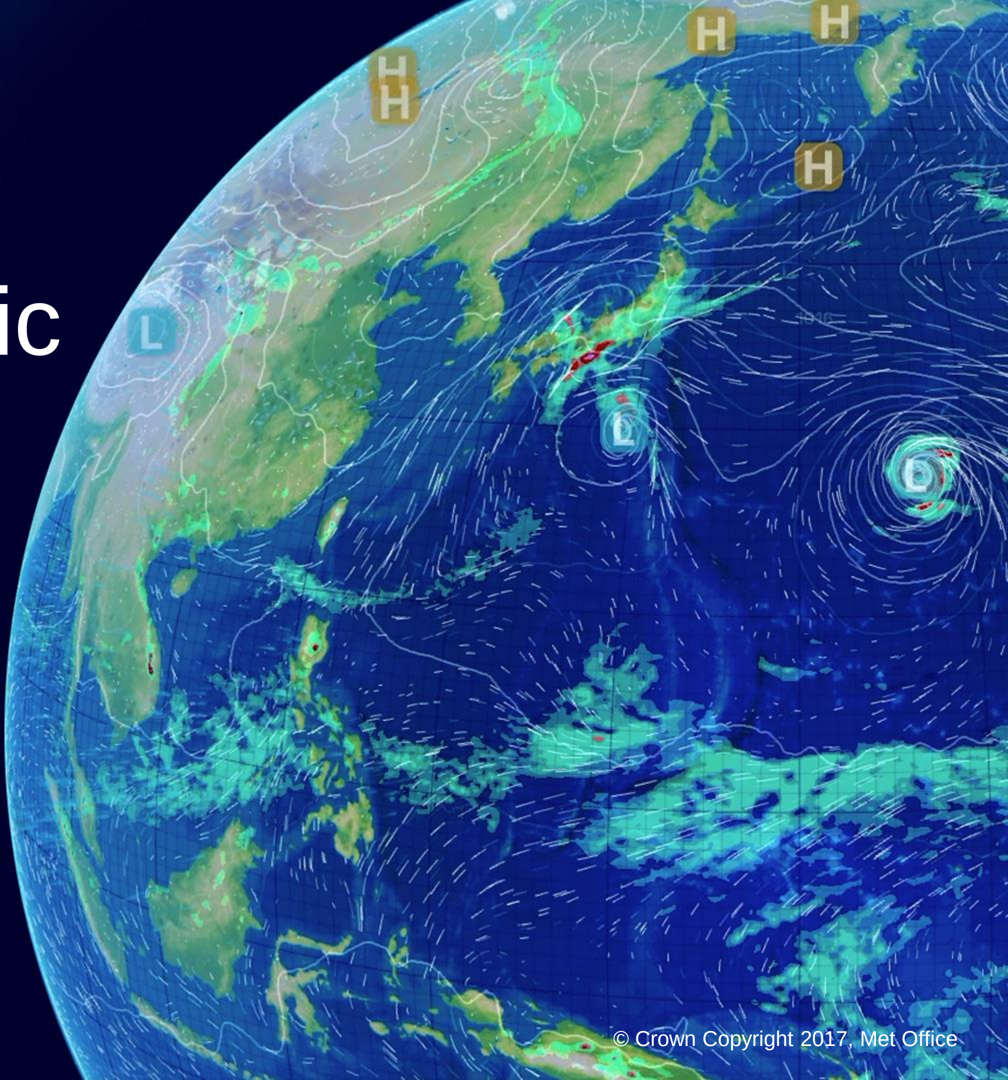


Convective rain rate



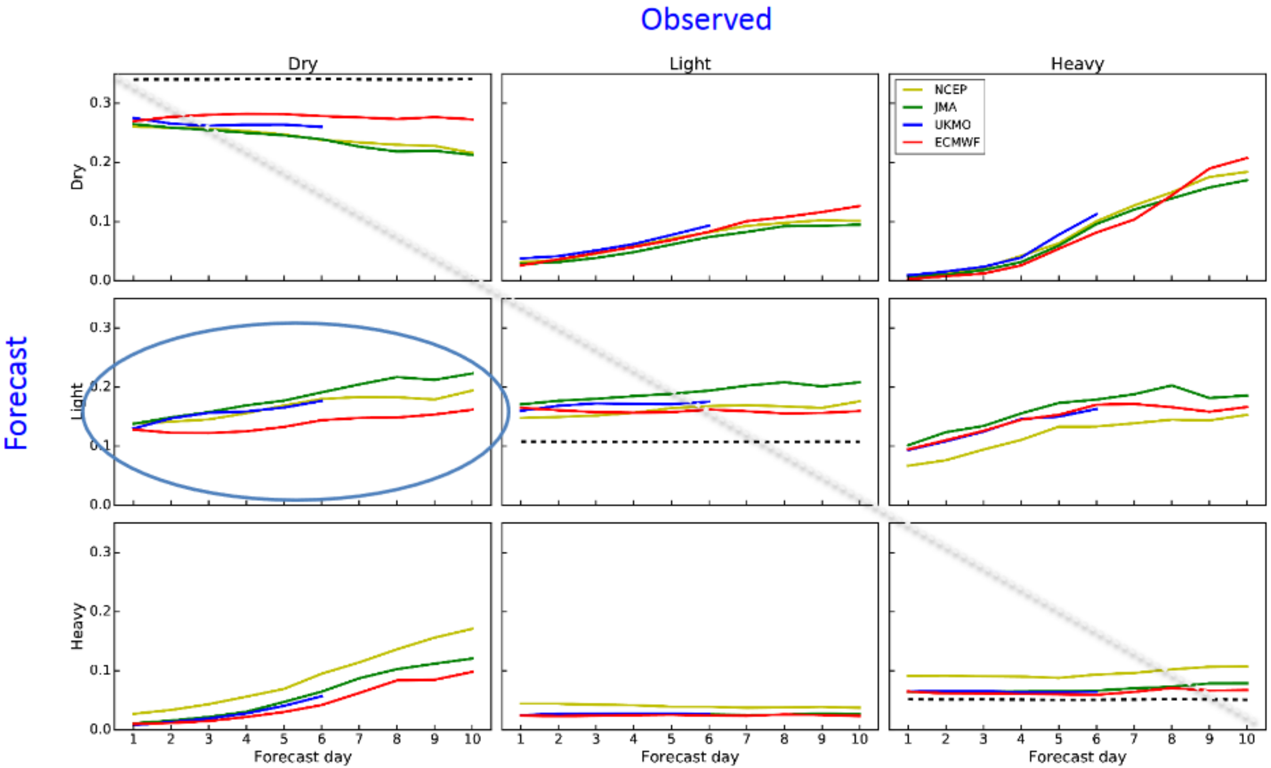
Met Office

The impact of parametrized diabatic processes on the weather



Europe

SEEPS decomposition - winter

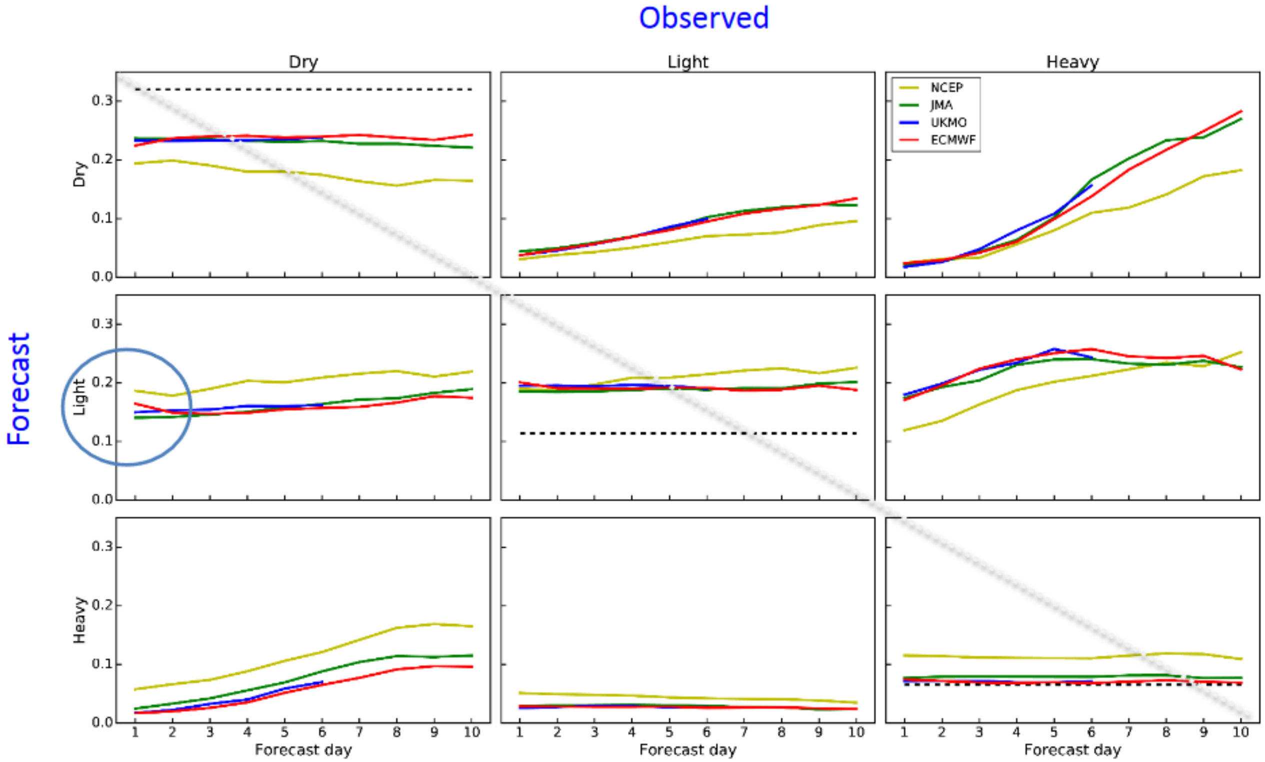


c/o Nils Wedi (ECMWF)

ECMWF

Europe

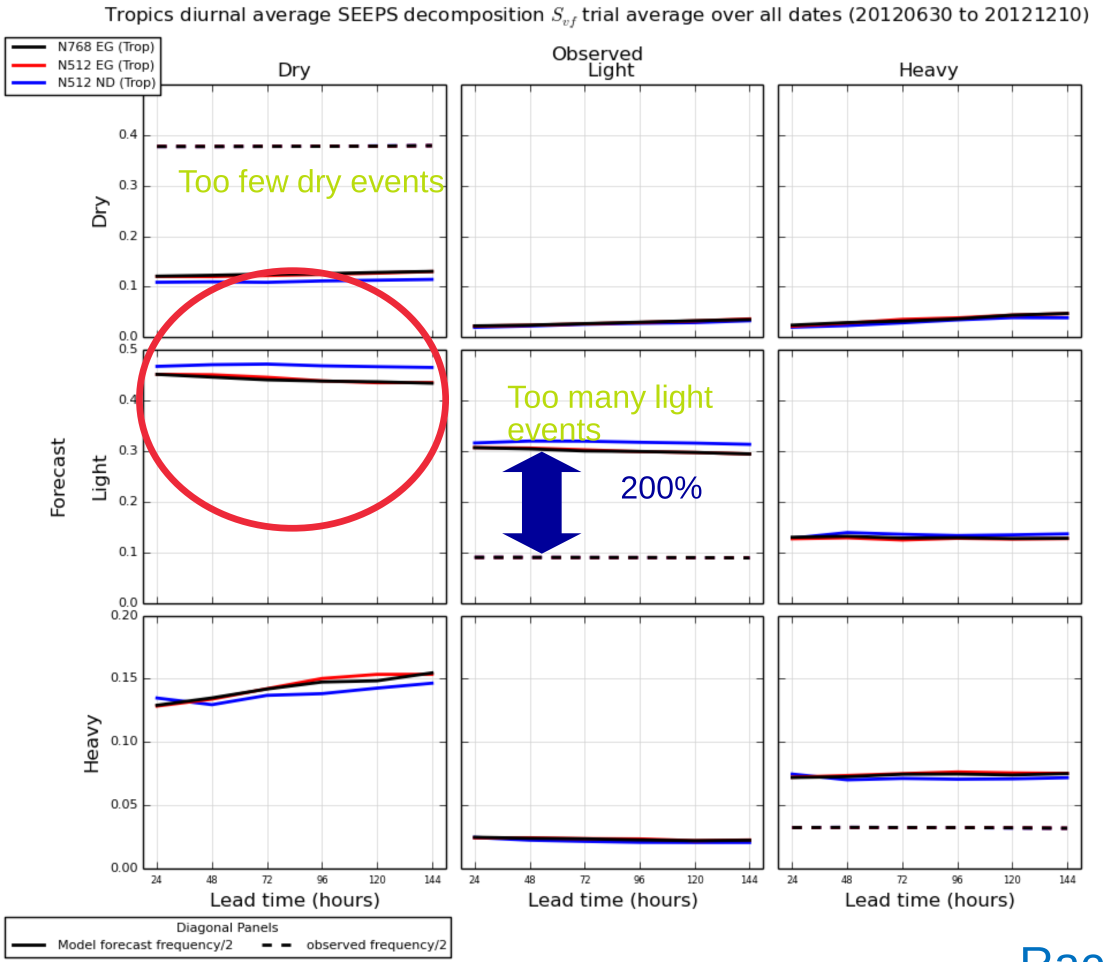
SEEPS decomposition - summer



c/o Nils Wedi (ECMWF)

ECMWF

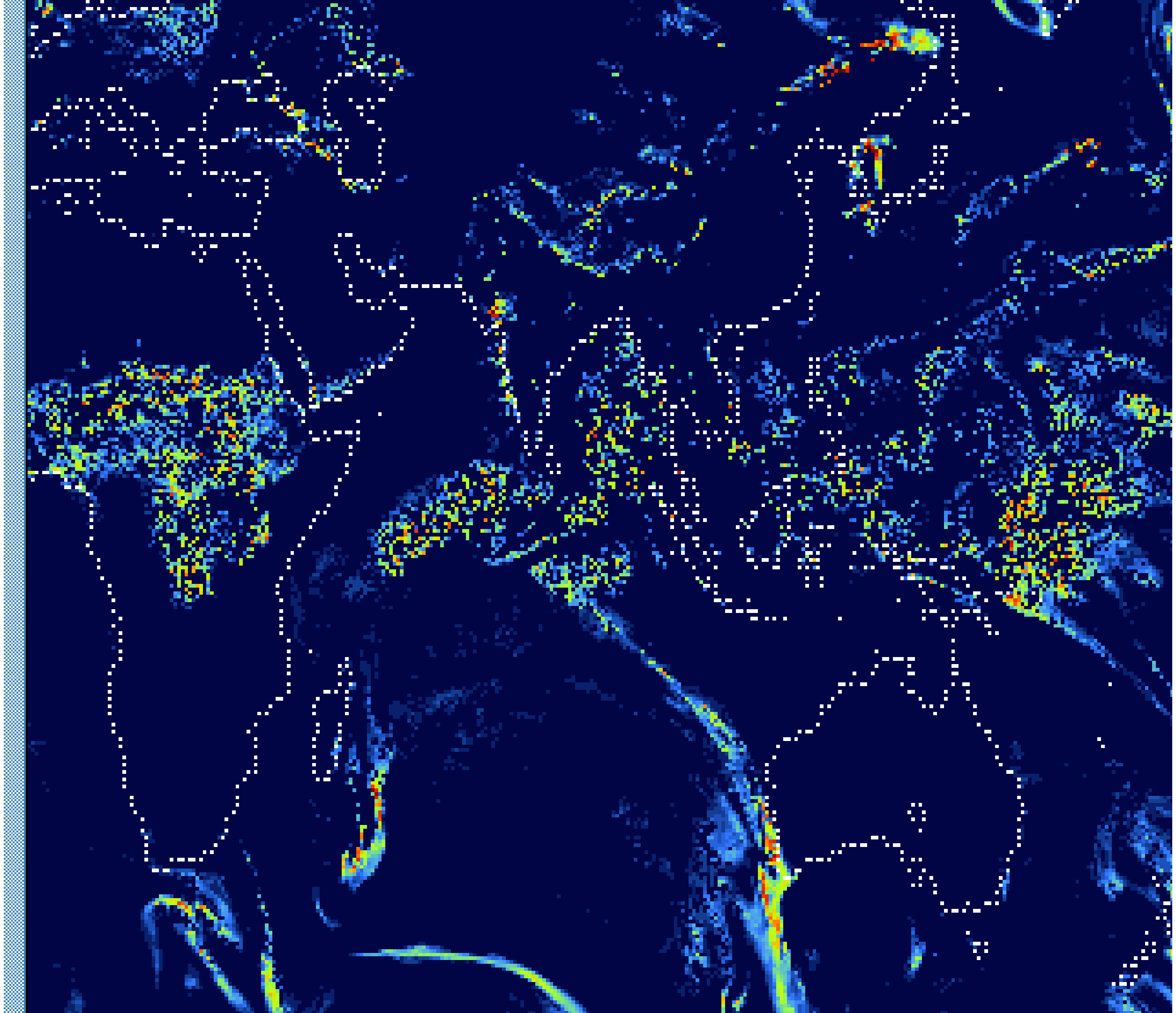
Tropics



Rachel North

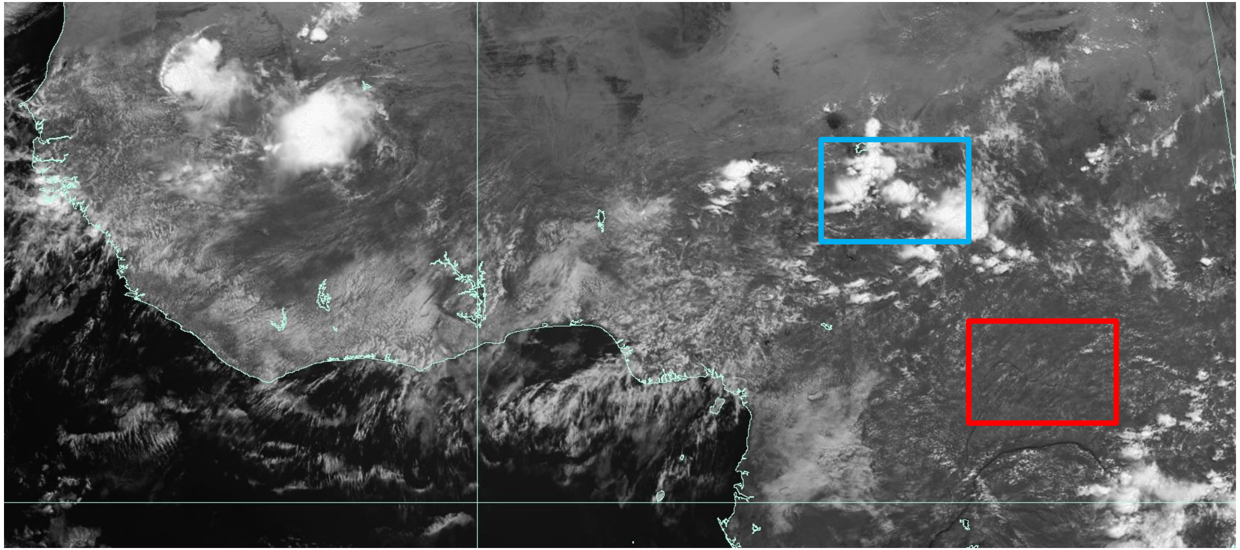
Convective intermittency

Instantaneous precip. rate (GA7 N320)



Adding convective memory

Martin Willett



High recent convective activity

- Large convective clouds
- Low entrainment rates

Low recent convective activity

- Small convective clouds
- High entrainment rates

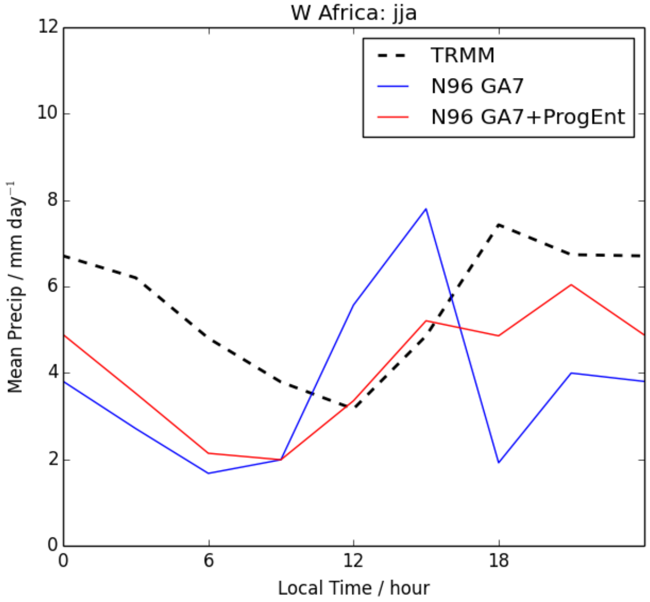
Martin Willett

West Africa

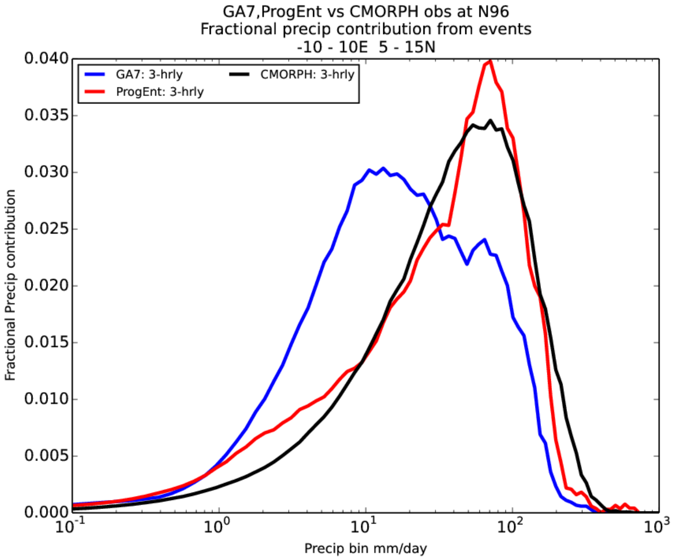
Observations

Control

Prog. Entrainment



Impact on diurnal cycle

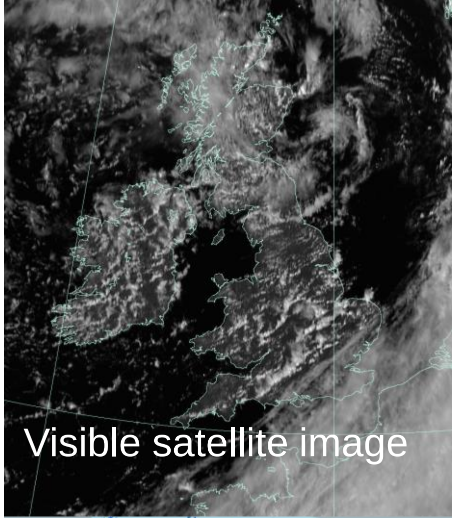


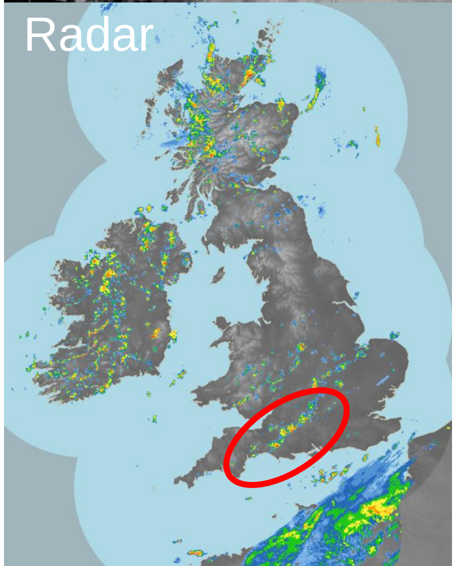
Impact on precip intensity distribution

Case study test of PS38 physics

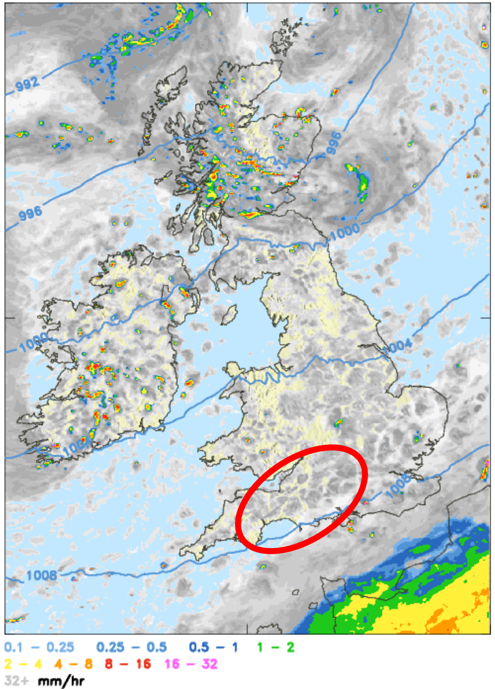
14UTC 27th Aug 2015, T+11

Stochastic BL perturbations in PS38 initiates showers more readily

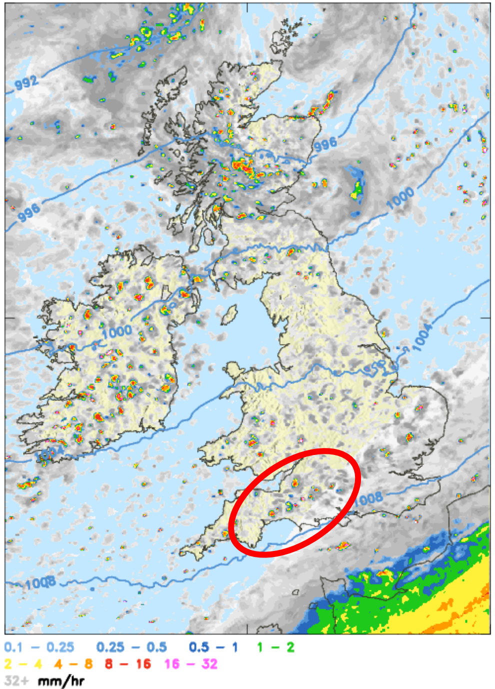

Visible satellite image


Radar

PS36



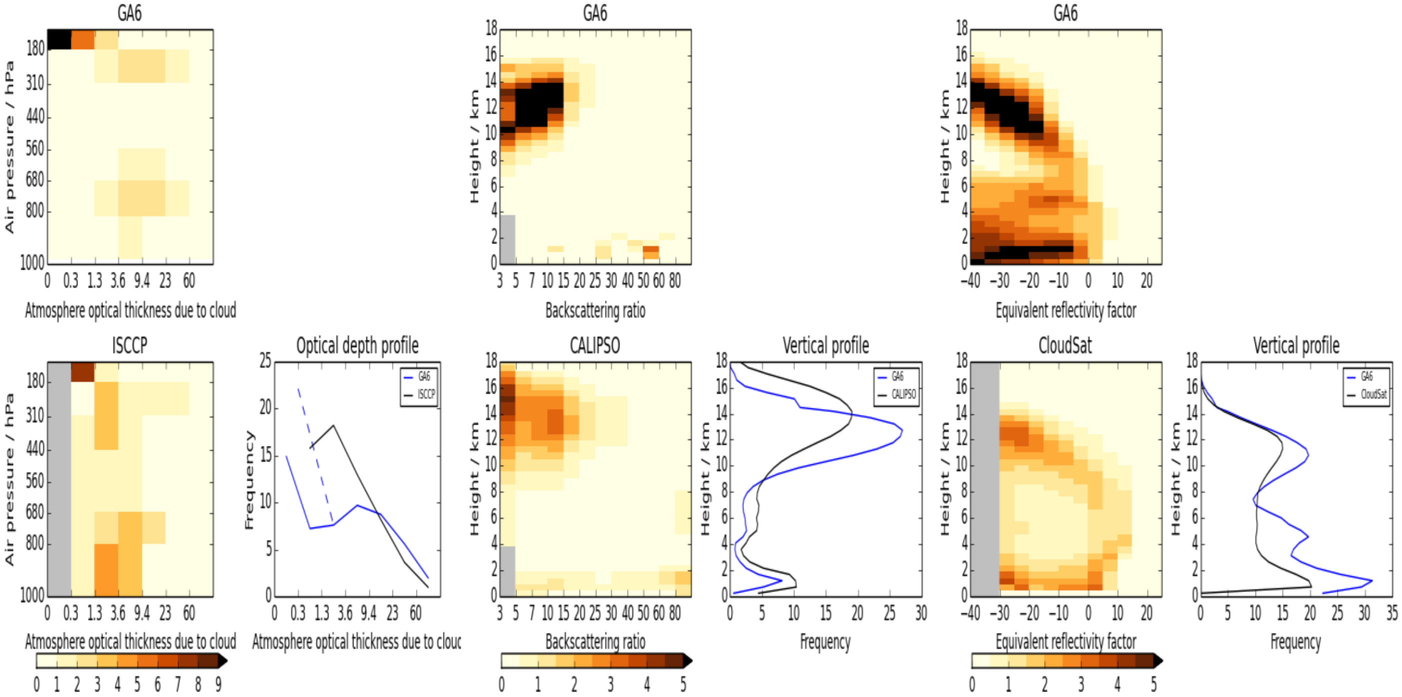
PS38



Adrian Lock

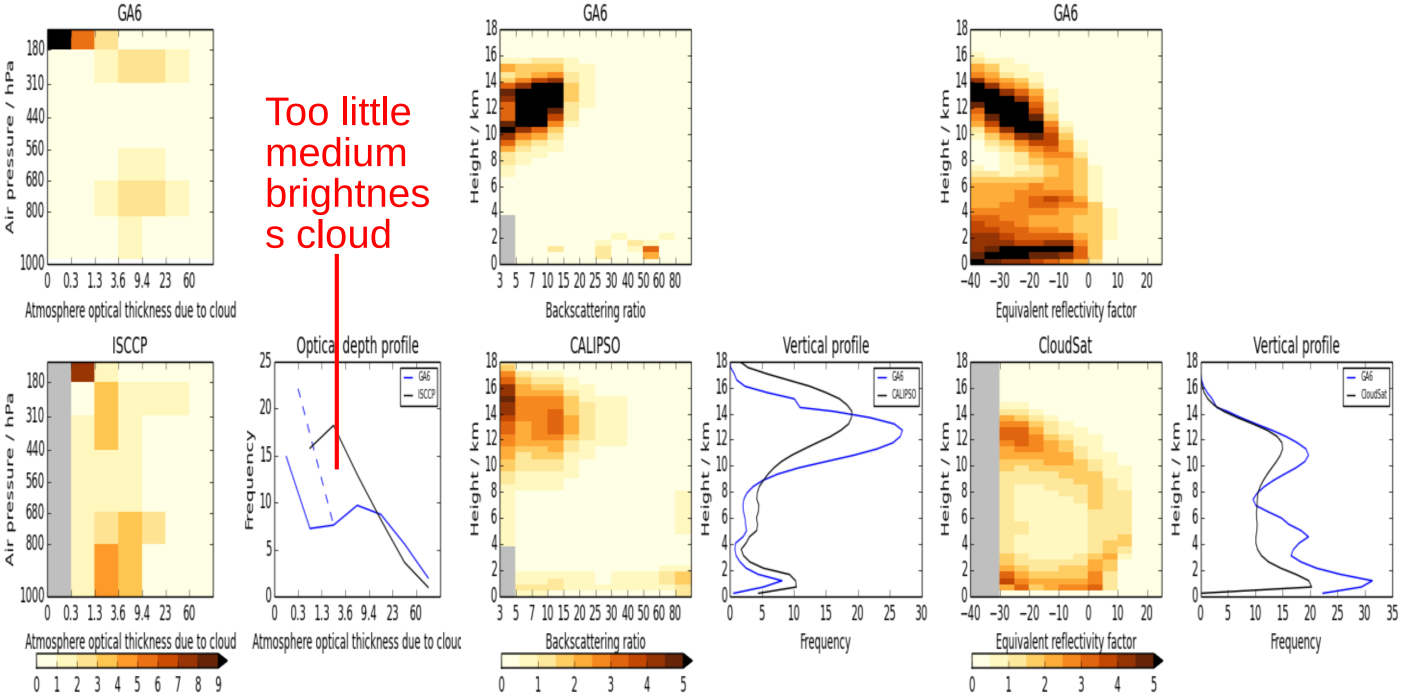
Comparison against satellite data over the tropics

ISCCP CALIPSO CloudSat



Comparison against satellite data over the tropics

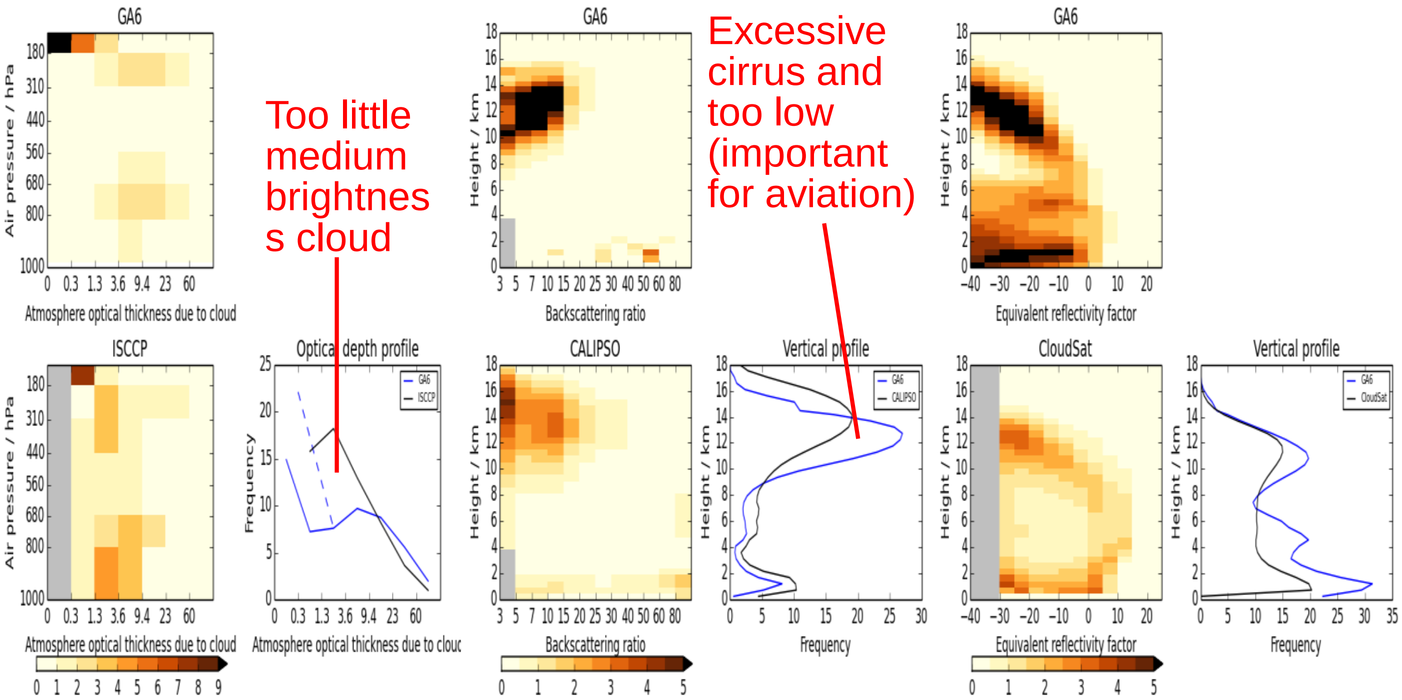
ISCCP   CALIPSO   CloudSat



Too little medium brightness cloud

Comparison against satellite data over the tropics

ISCCP CALIPSO CloudSat

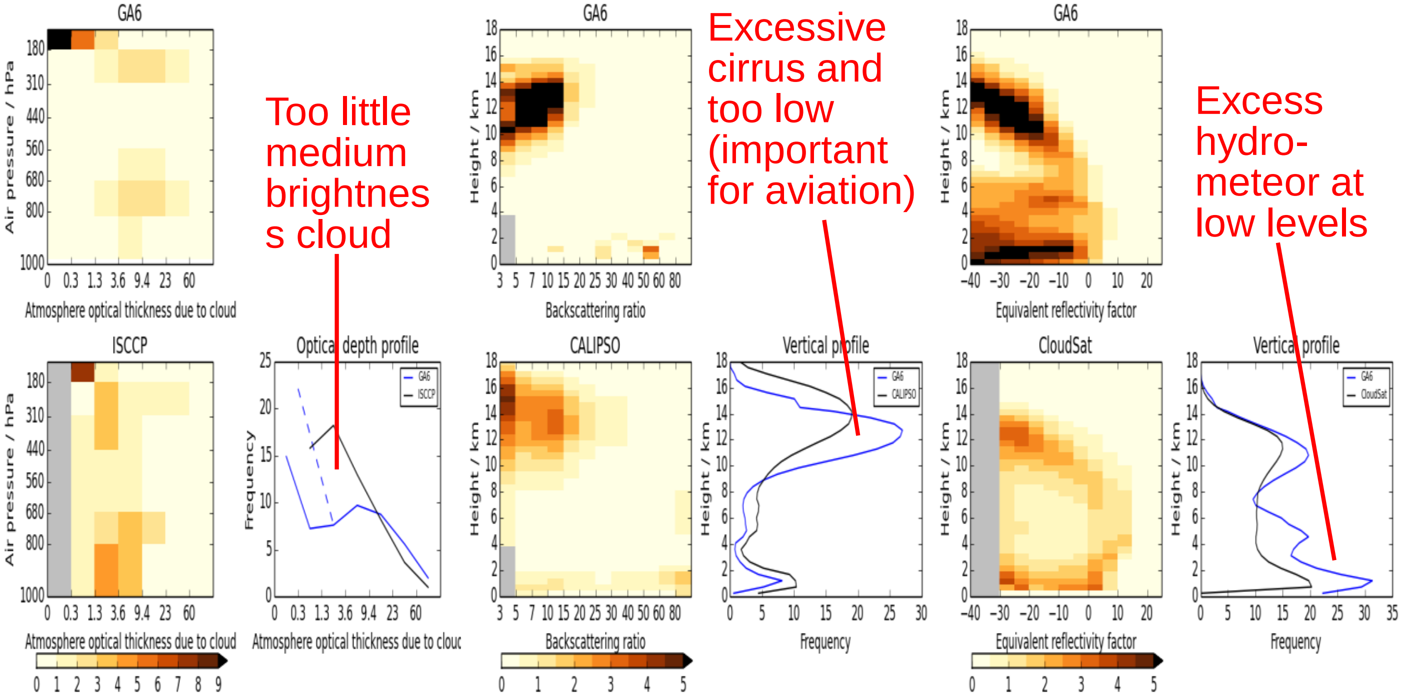


Too little medium brightness cloud

Excessive cirrus and too low (important for aviation)

Comparison against satellite data over the tropics

ISCCP CALIPSO CloudSat



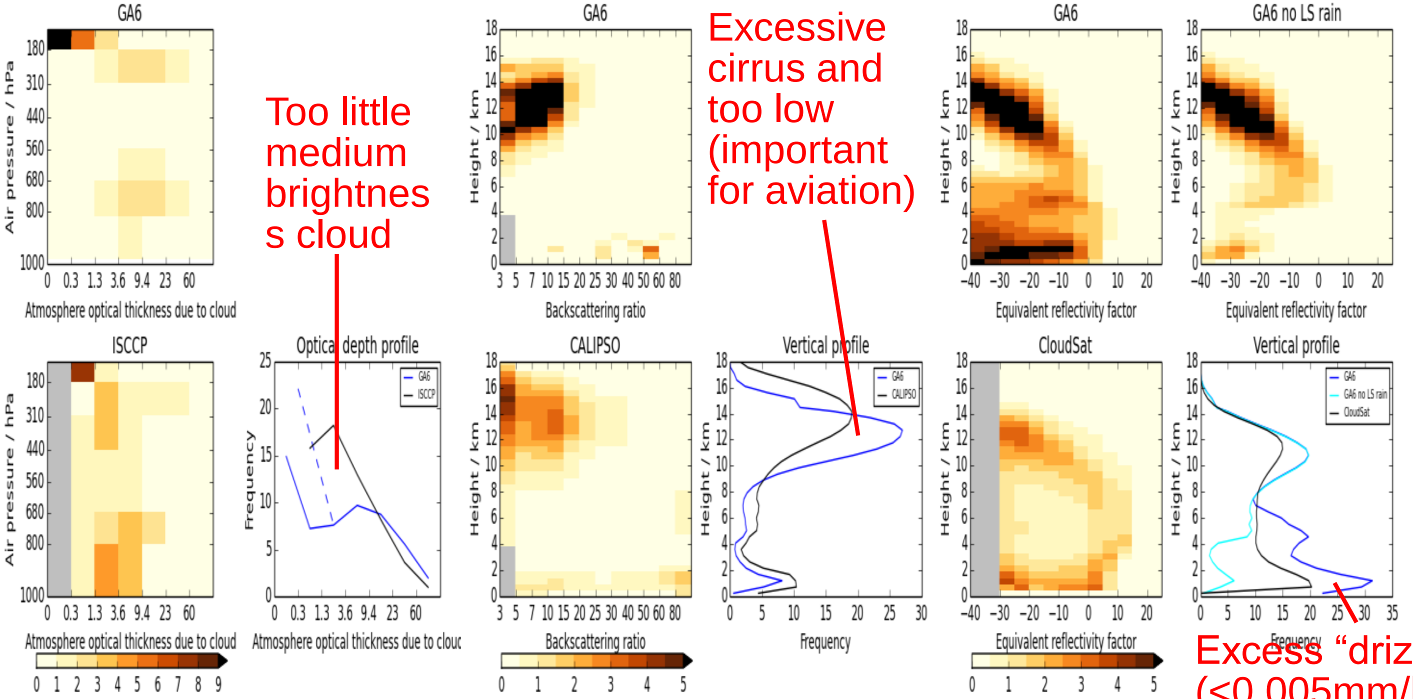
Too little medium brightness cloud

Excessive cirrus and too low (important for aviation)

Excess hydro-meteor at low levels

Comparison against satellite data over the tropics

ISCCP CALIPSO CloudSat



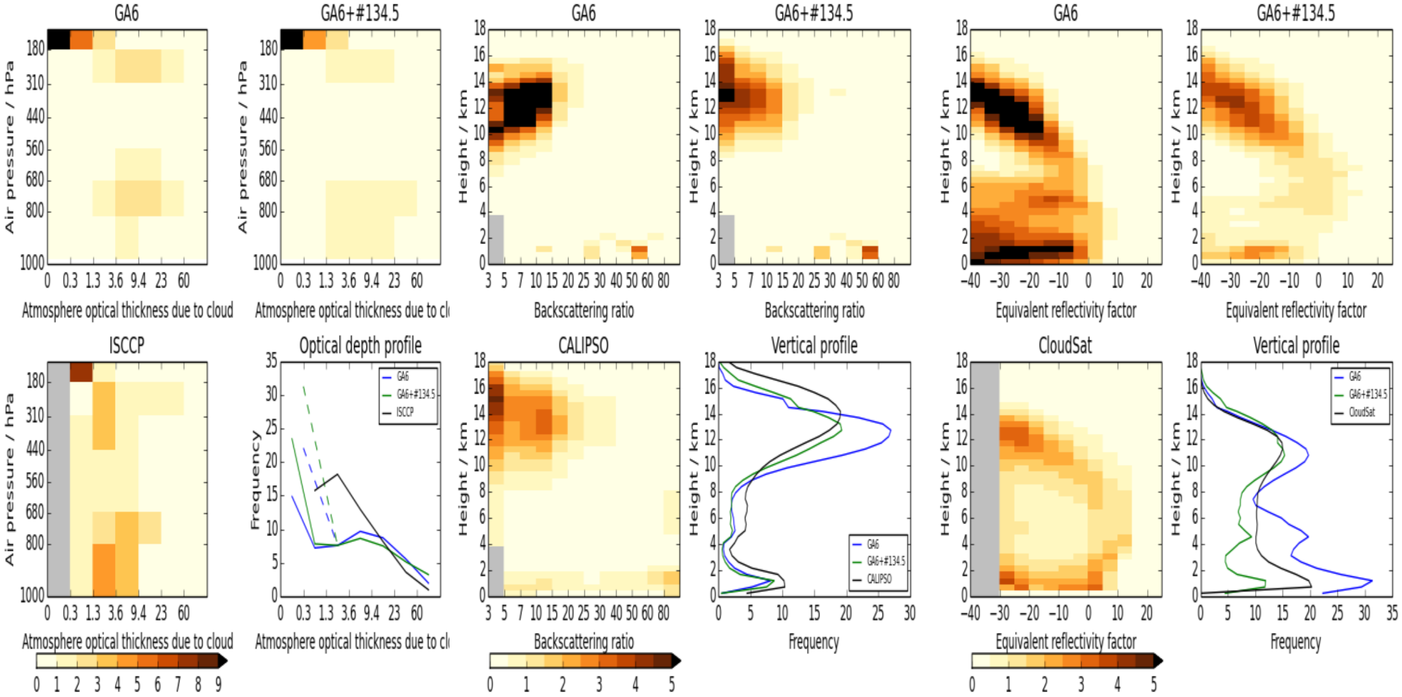
Too little medium brightness cloud

Excessive cirrus and too low (important for aviation)

Excess "drizzle" (<0.005mm/hr) (important for products)

Comparison against satellite data over the tropics

ISCCP CALIPSO CloudSat



Comparison against satellite data over the tropics

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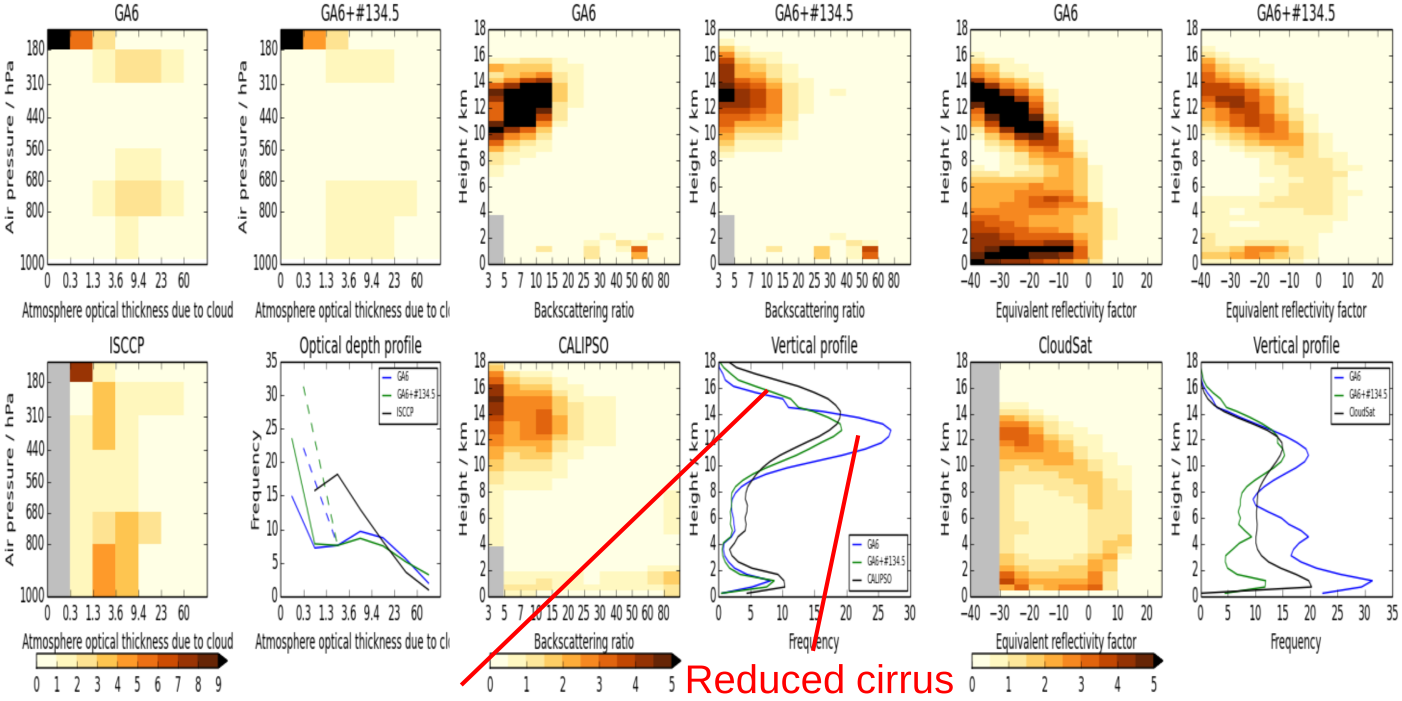
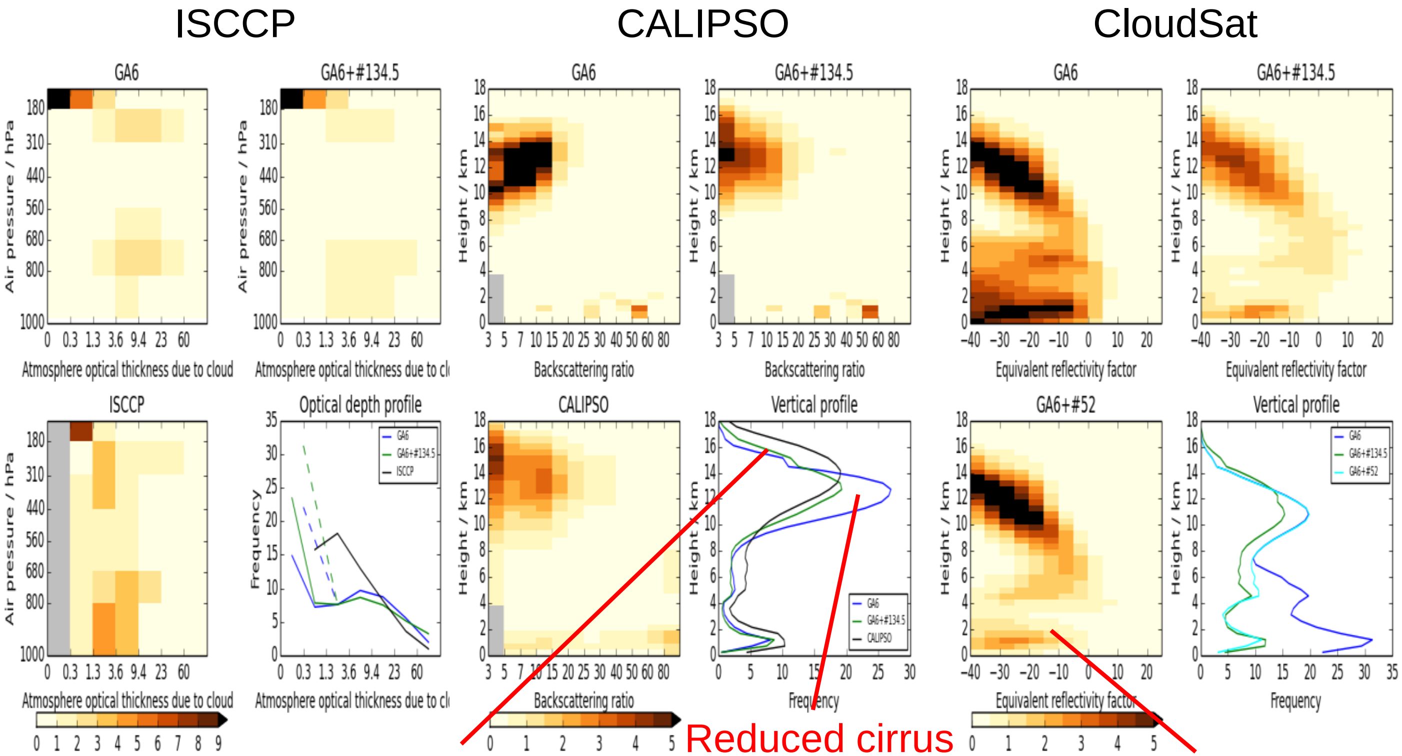


6A convection

Reduced cirrus spreading rate

Comparison against satellite data over the tropics



6A convection

Reduced cirrus spreading rate

Warm rain microphys

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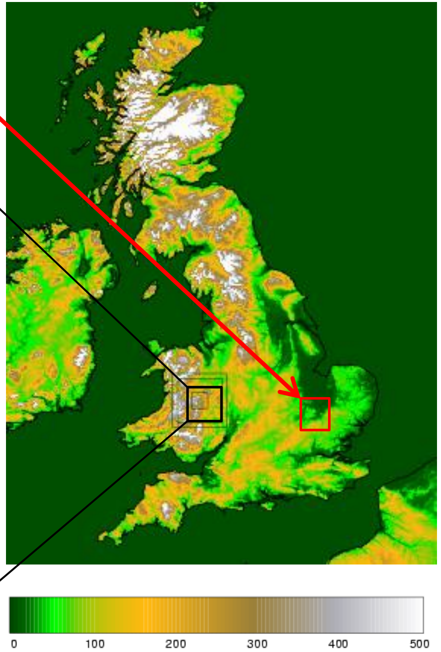
Fog

- Biggest gap between user expectation and forecast skill.
- Current skill is poor and uncertainty is large
  - Spatial distribution subject to both large scale and local influences
- Physically complicated
  - Result of feedbacks and imbalances between many small scale processes (turbulence, microphysics, radiation, land surface)

LANFEX

Local And Non-local Fog EXperiment

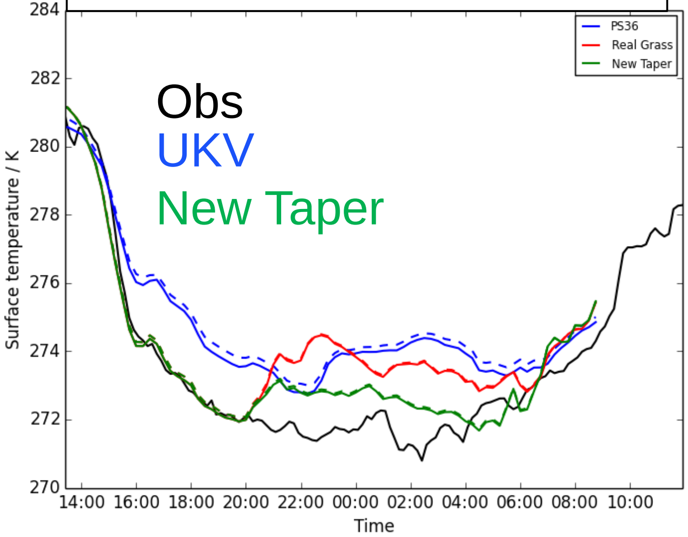
- 18 month campaign to examine development and evolution of (primarily) radiation fogs (Autumn 2014-Spring 2016).
  - Deploying long-term networks of instruments (flux towers, surface sites, dopler lidar, etc)
  - IOPs with sondes, tethered balloon
- High resolution modelling run in parallel
- Two sites: **Shropshire hills** and Met Office Cardington
  - Contrasting **hilly** and flat(-ish)



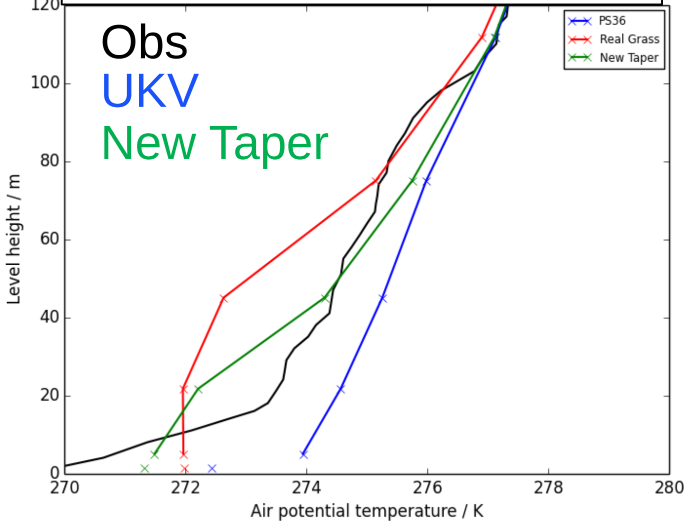
Fog onset much improved by more realistic fog microphysics

Ian Boutle

Surface Temperature



Potential temperature profile



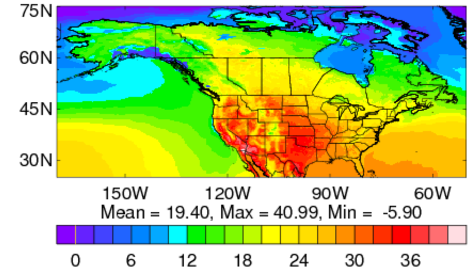
- “New taper” applies observed cloud droplet number (50 cm^{-3}) below 150m
  - Smaller drop number implies optically thinner for a given condensed water content
- Surface temperature and vertical profile now much improved, although still not perfect (higher vertical resolution?)

Impacts of cloud-aerosol interaction

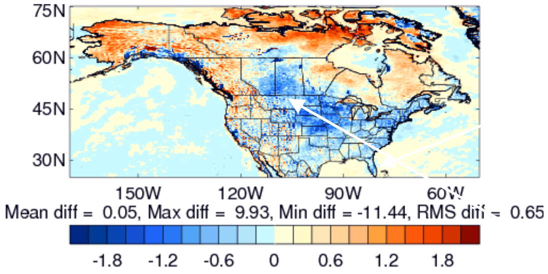
Improved continental temperature biases

(T+120 errors July/August 2012)

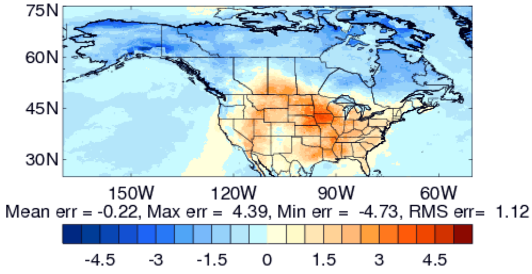
Mean N512
GA3.1 f/c



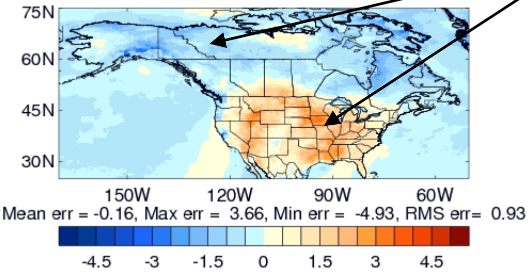
Mean f/c difference N768
GA6.1 – N512 GA3.1



Mean N512 GA3.1 error



Mean N512 GA3.1 error



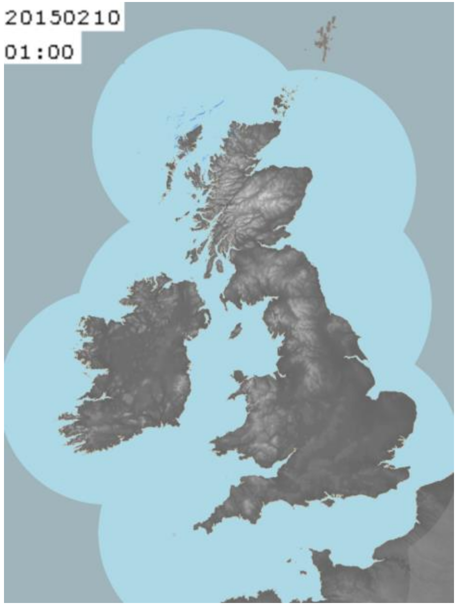
Aerosol indirect effect from HadGEM-based climatotolgies improves N. American low-cloud/T biases

Malcolm Brooks

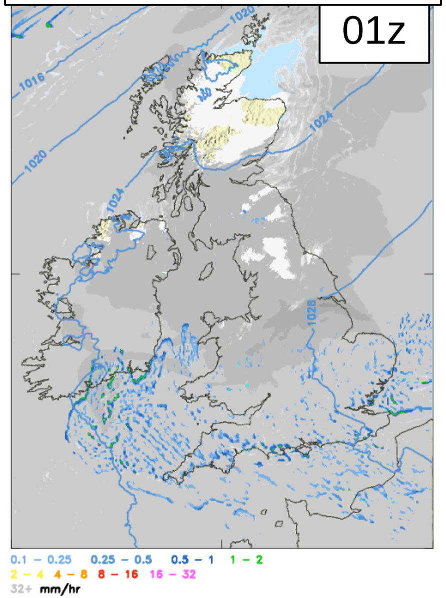
Excessive drizzle & microphysics

Paul Field

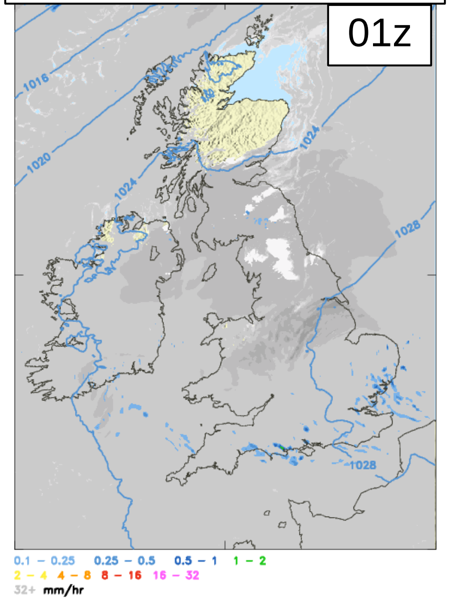
- Issues with mixed phase microphysics
  - Main culprit was too efficient riming of supercooled water onto ice
  - Including the crystal shape in the cross-sectional area, rather than assuming circular, reduces efficiency – now operational



Model operational
in Feb 2015



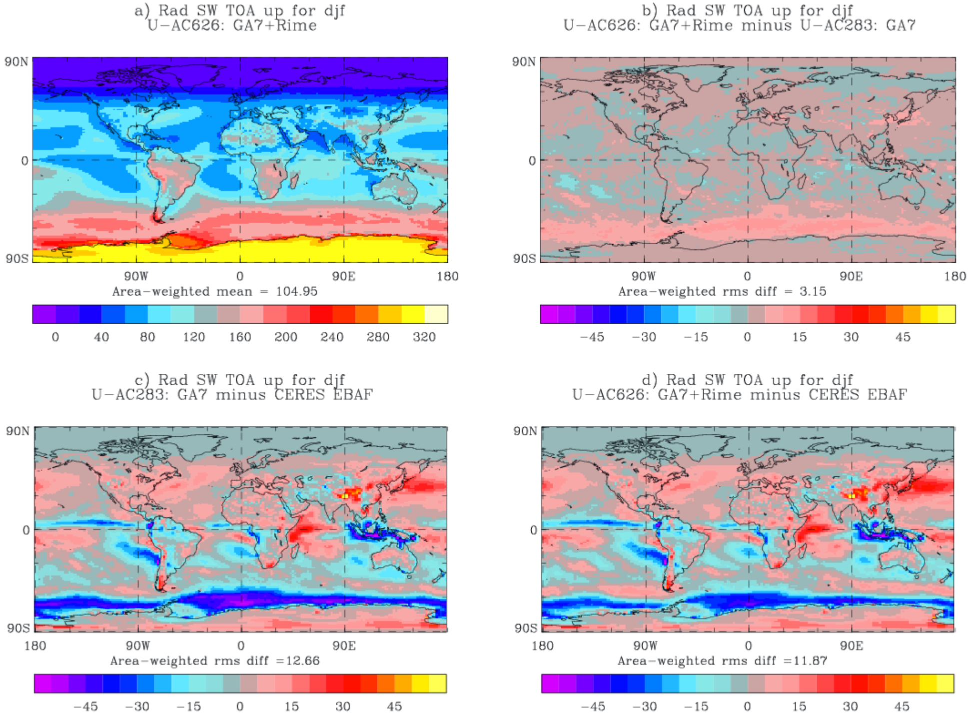
Including revised riming



Crystal shape-dependent riming in the climate model

Paul Field

- Despite significant effort over many years on the “Southern Ocean problem”, too efficient riming had not been thought of until it fortuitously ruined UKV!



Summary

- Parametrized diabatic processes affect weather forecasts:
  - By impacting the dynamical evolution
  - Directly on the surface weather
- Getting both aspects right is important.
- Detailed diagnostic techniques such as PV tracers and satellite simulators help with understanding which processes are contributing.
- Sometimes the solution to one error can help with something (seemingly) completely different.