Will EarthCARE lead to better weather forecasts?

2nd EarthCARE Modeling Workshop

for improving cloud and radiation of climate models

Shuzenji, Japan, 27-29 Mar 2023

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European Centre for Medium-range Weather Forecasts (ECMWF)

Additional thanks to Alan Geer, Andrew Gettelman, Mark Rodwell

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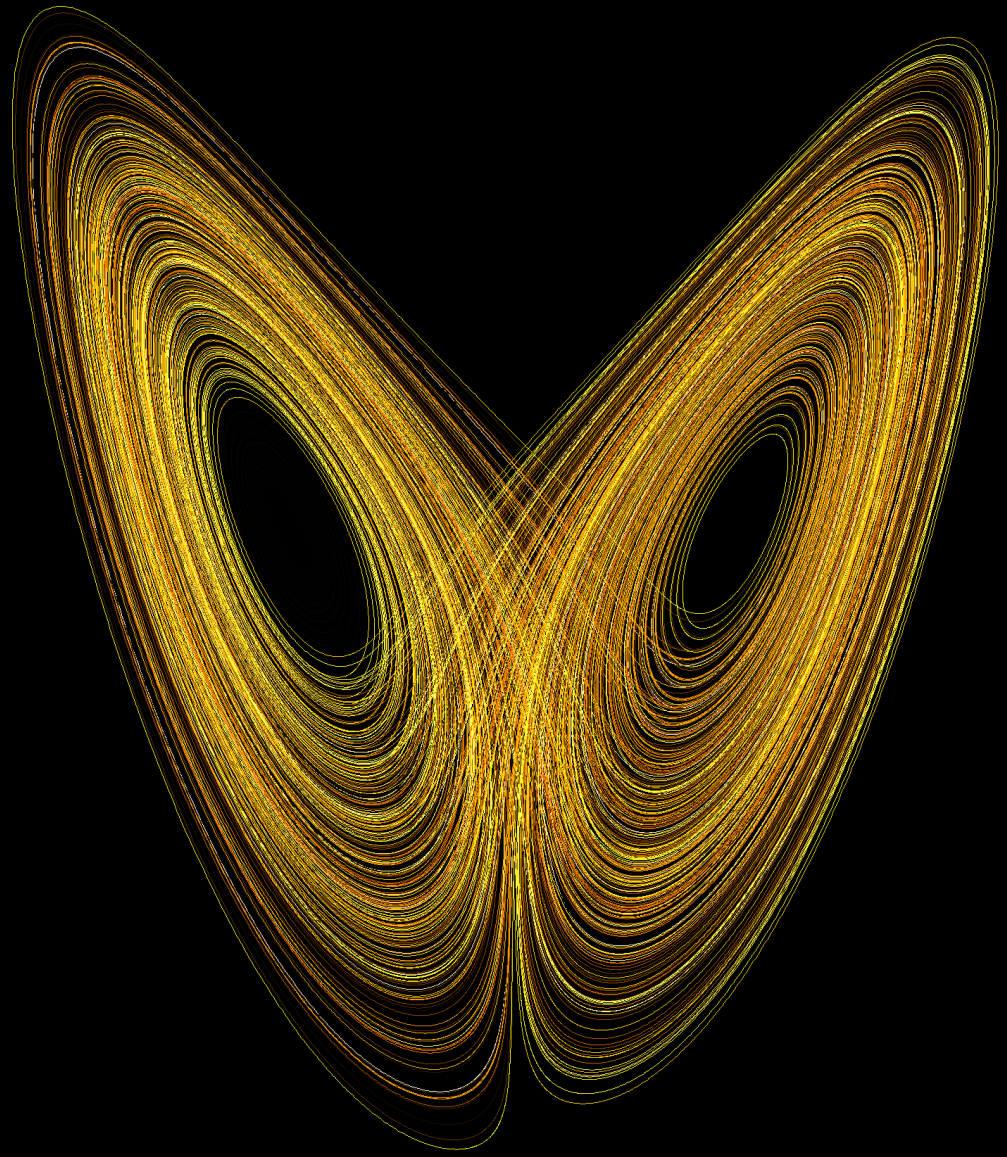
EUROPEAN CENTRE FOR MEDIUM RANGE WEATHER FORECASTS

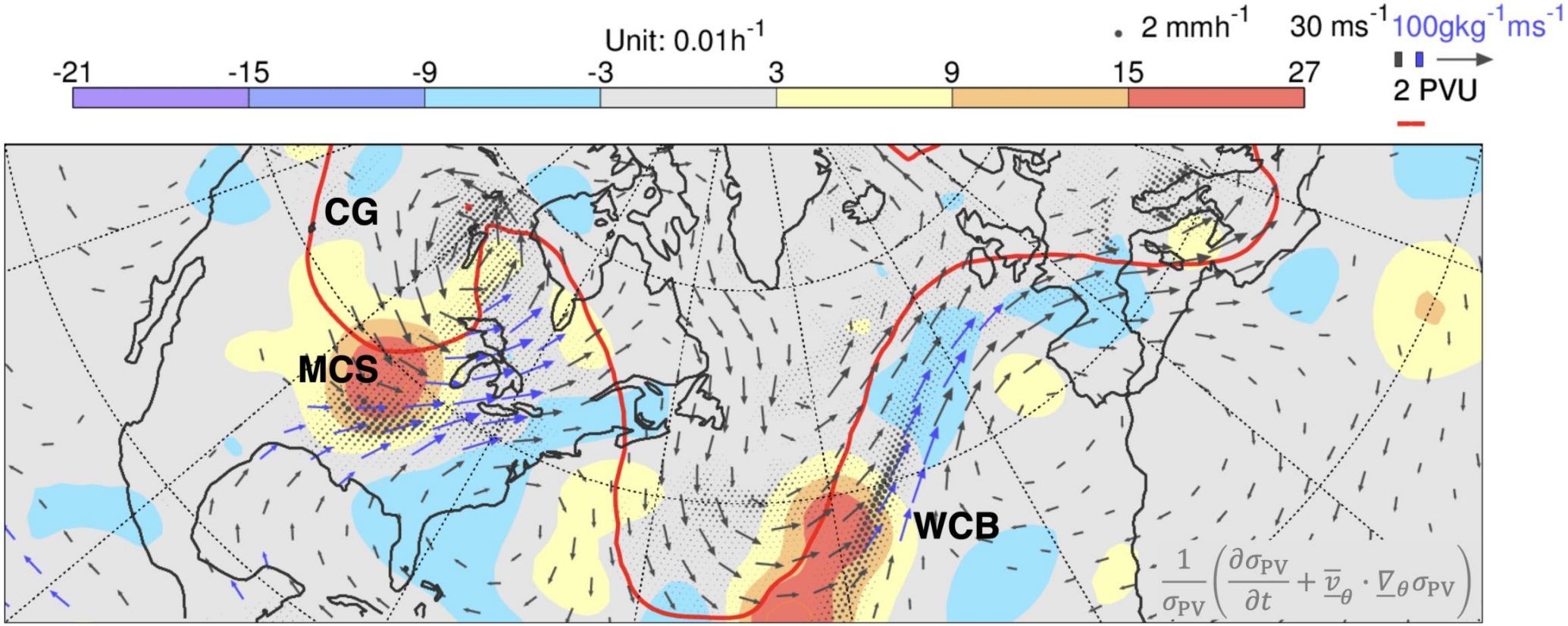
esa



Regions of sensitive dependence to initial state are associated with cloud/precip

e.g. Warm Conveyor Belts (WCB), Mesoscale Convective Systems (MCS), tropical cyclones…

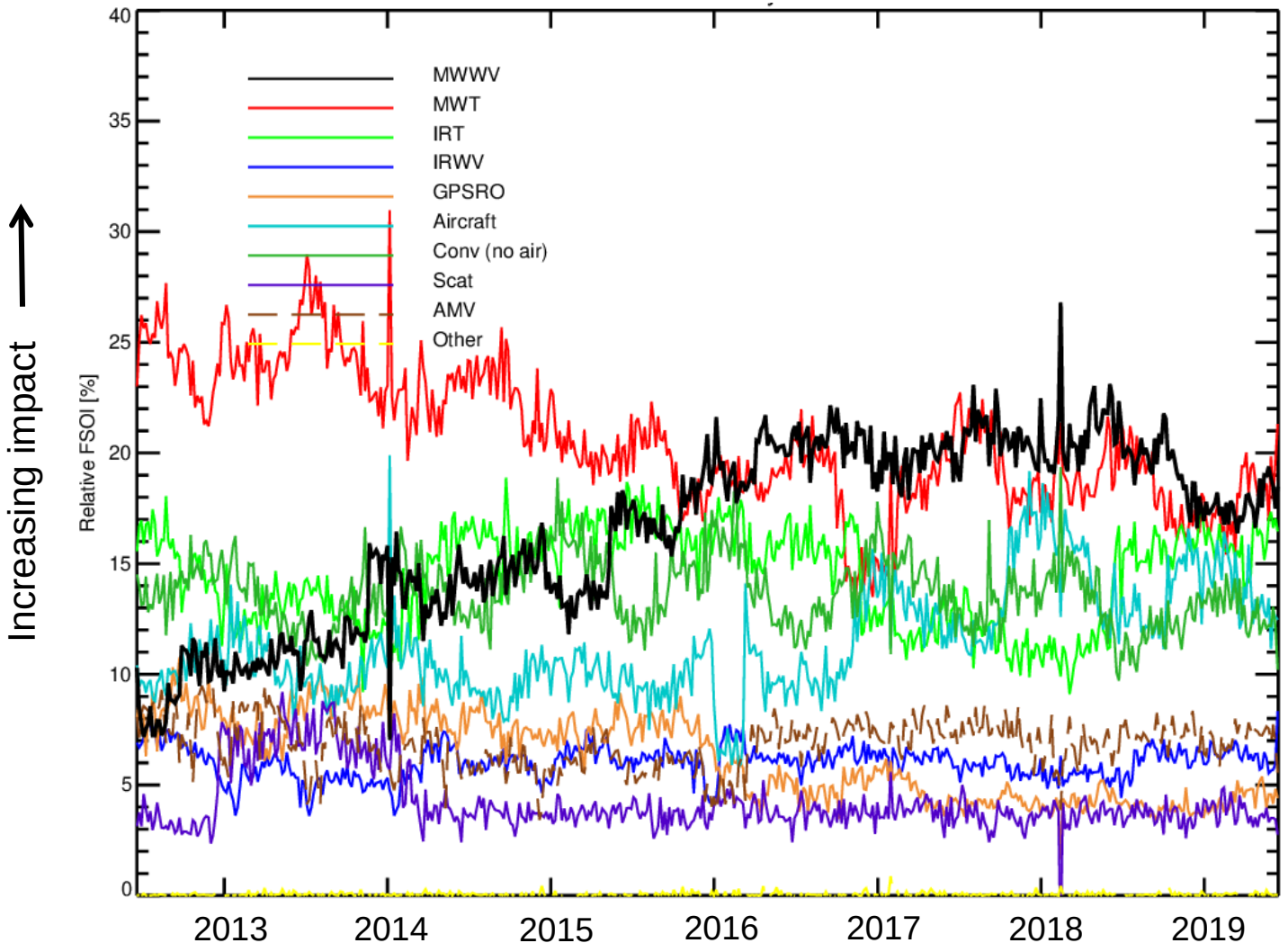
Example of 12 hour forecast growth rate of PV uncertainty for 2017-03-17



Control forecast PV_{315}=2, $\underline{v}_{850}$ and $q|\underline{v}|_{850}$, Ensemble-mean precipitation. 1d running-mean gives 12h-integrated growth rate with any diurnal cycle removed. T21 smoothed

Rodwell et al. (2018)

The rising importance of cloud-affected (all-sky) satellite observations in the global IFS assimilation system



A measure of observation impact on 24h forecast error reduction (FSOI) at ECMWF 2012-2019

Satellite microwave radiances
"All-sky" - sensitive to water vapour, cloud and precipitation

Satellite infrared radiances
sensitive to water vapour, currently assimilated in clear-sky and overcast situations only

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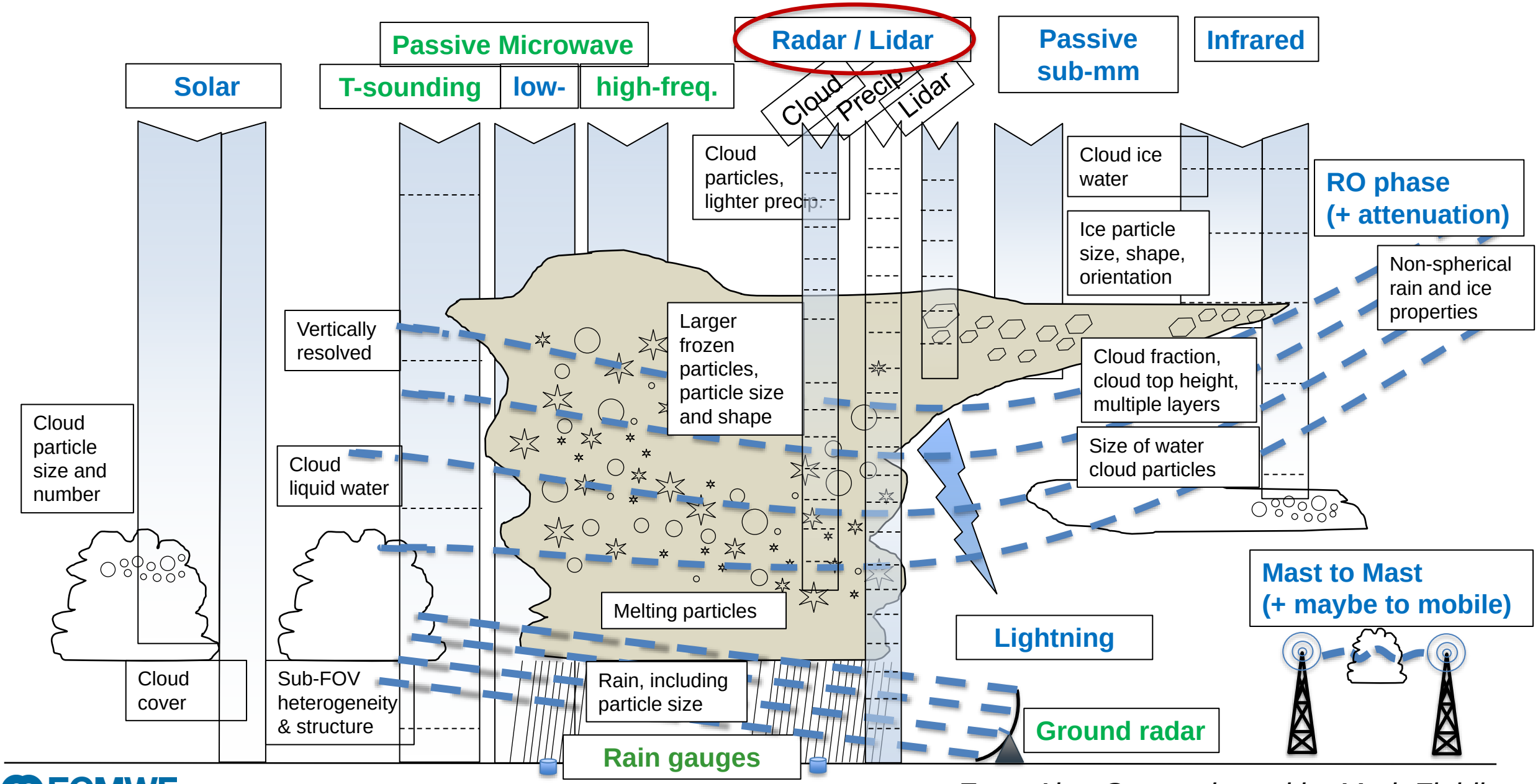
Geer et al. (QJRMS, 2017; ECMWF TechMemo; ECMWF Newsletter 161, 2019)

Cloud and precipitation sensitive satellite observations assimilated now, and future(?)



From Alan Geer, adapted by Mark Fielding

Towards operational assimilation of radar/lidar from EarthCARE

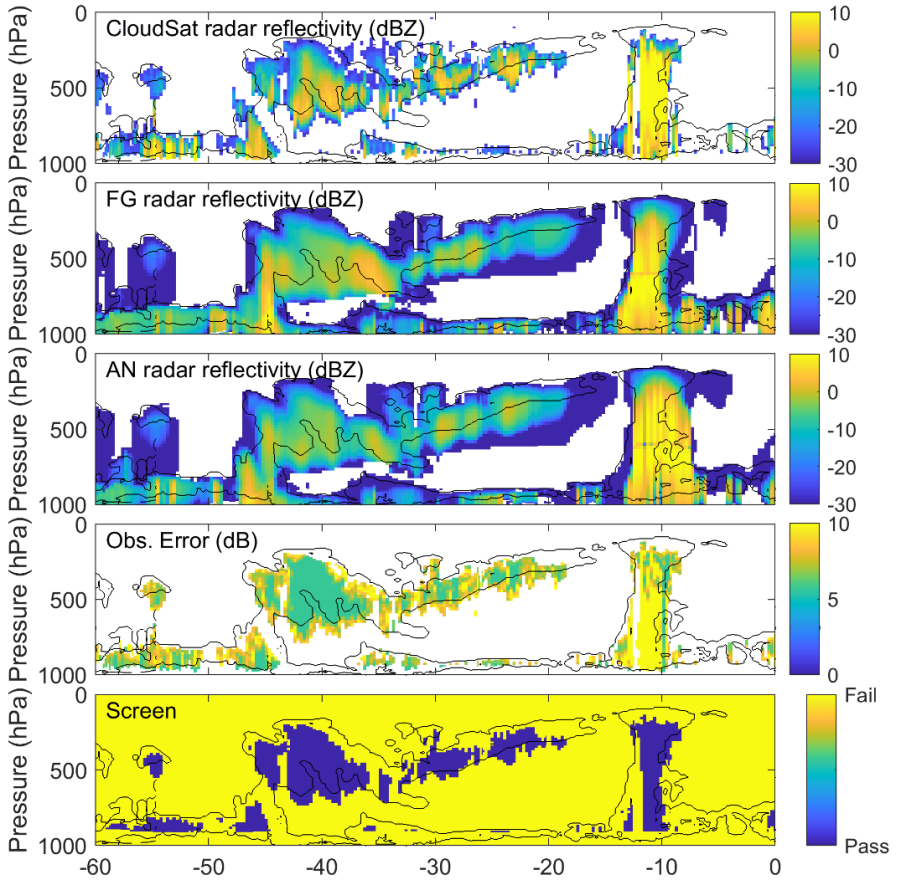
Assimilation of CloudSat radar reflectivity and CALIPSO lidar backscatter in the ECMWF IFS

Example cross-section:
Analysis bring first guess Z closer to observations

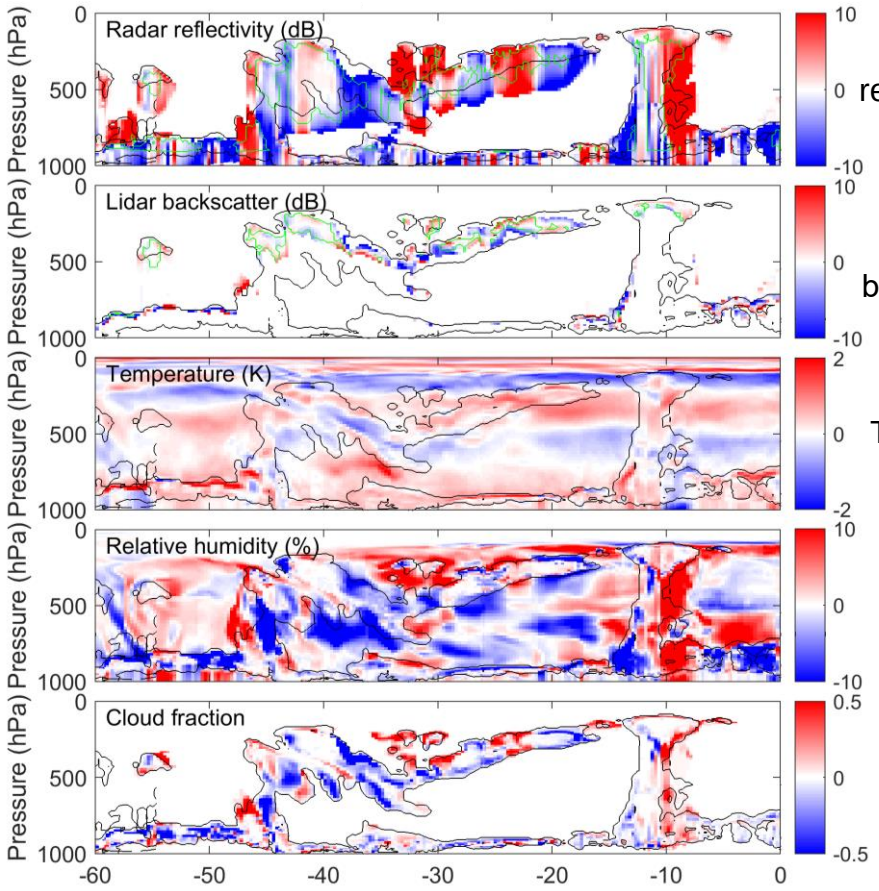
Observations

First guess from model

Analysis



Example cross-section:
Assimilating Z/β impact on T, RH, Cloud frac



Radar reflectivity, Z (dB)

Lidar backscatter, β (dB)

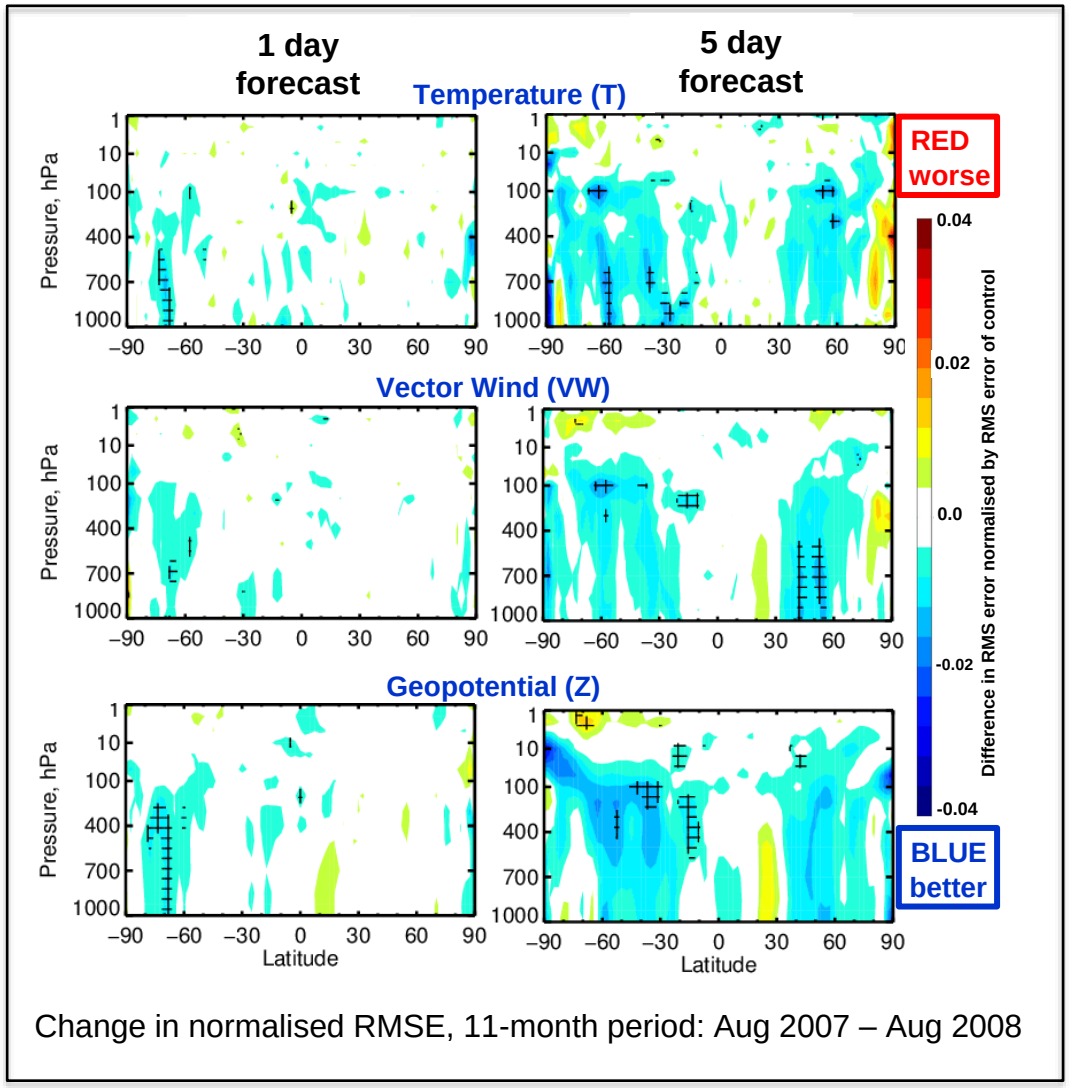
Temperature (K)

Relative Humidity (%)

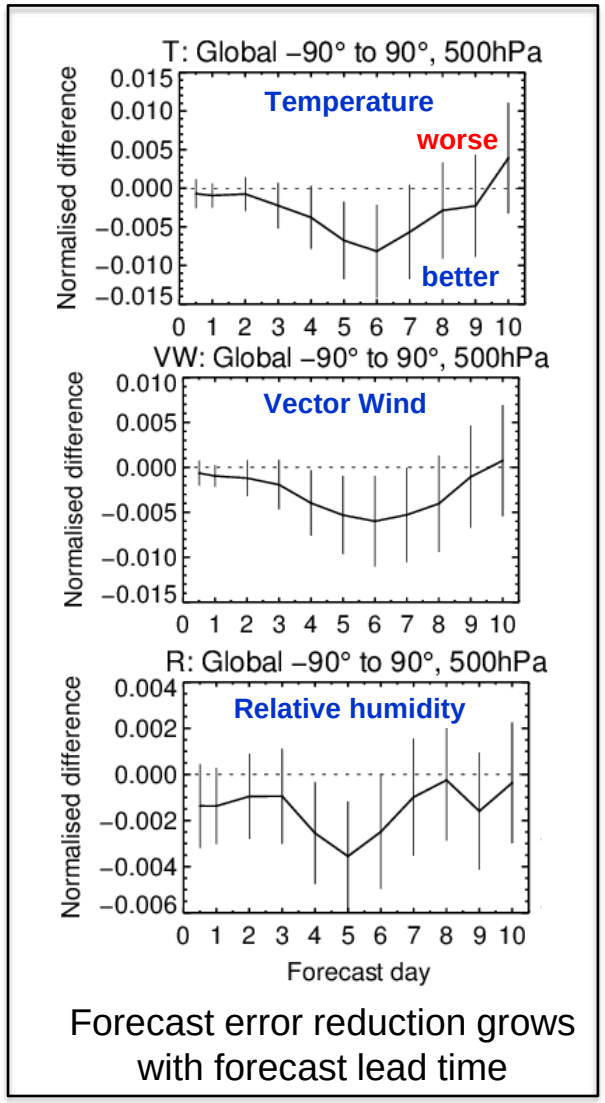
Cloud Fraction (0-1)

Towards operational assimilation of radar/lidar from EarthCARE

4D-Var experiments using CloudSat/CALIPSO show **improvements in medium-range forecast skill**!



Change in normalised RMSE, 11-month period: Aug 2007 – Aug 2008



Forecast error reduction grows with forecast lead time

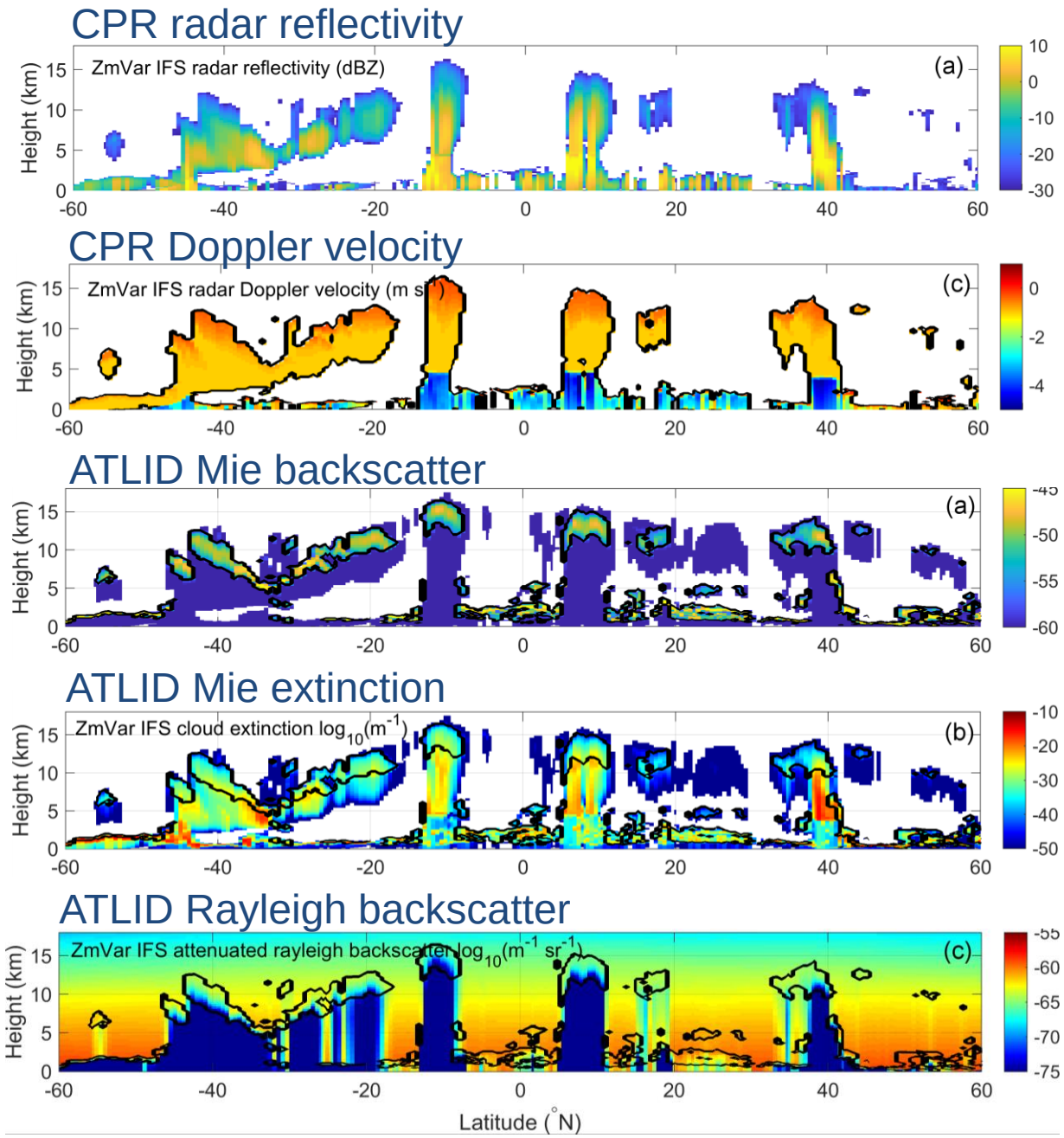
ECMWF

Mark Fielding and Marta Janisková

Going beyond radar reflectivity and lidar backscatter with EarthCARE…

- Observation operators are required for obs assimilation and model evaluation (model → obs)
- A suite of observation operators for simulating EarthCARE are now available within the IFS
- Doppler velocity and Rayleigh backscatter should complement radar reflectivity and Mie backscatter
- To make better use of the observations, need to improve the representation of cloud and precipitation microphysics, e.g. particle size, density, fall speeds

  → microphysics developments can be evaluated



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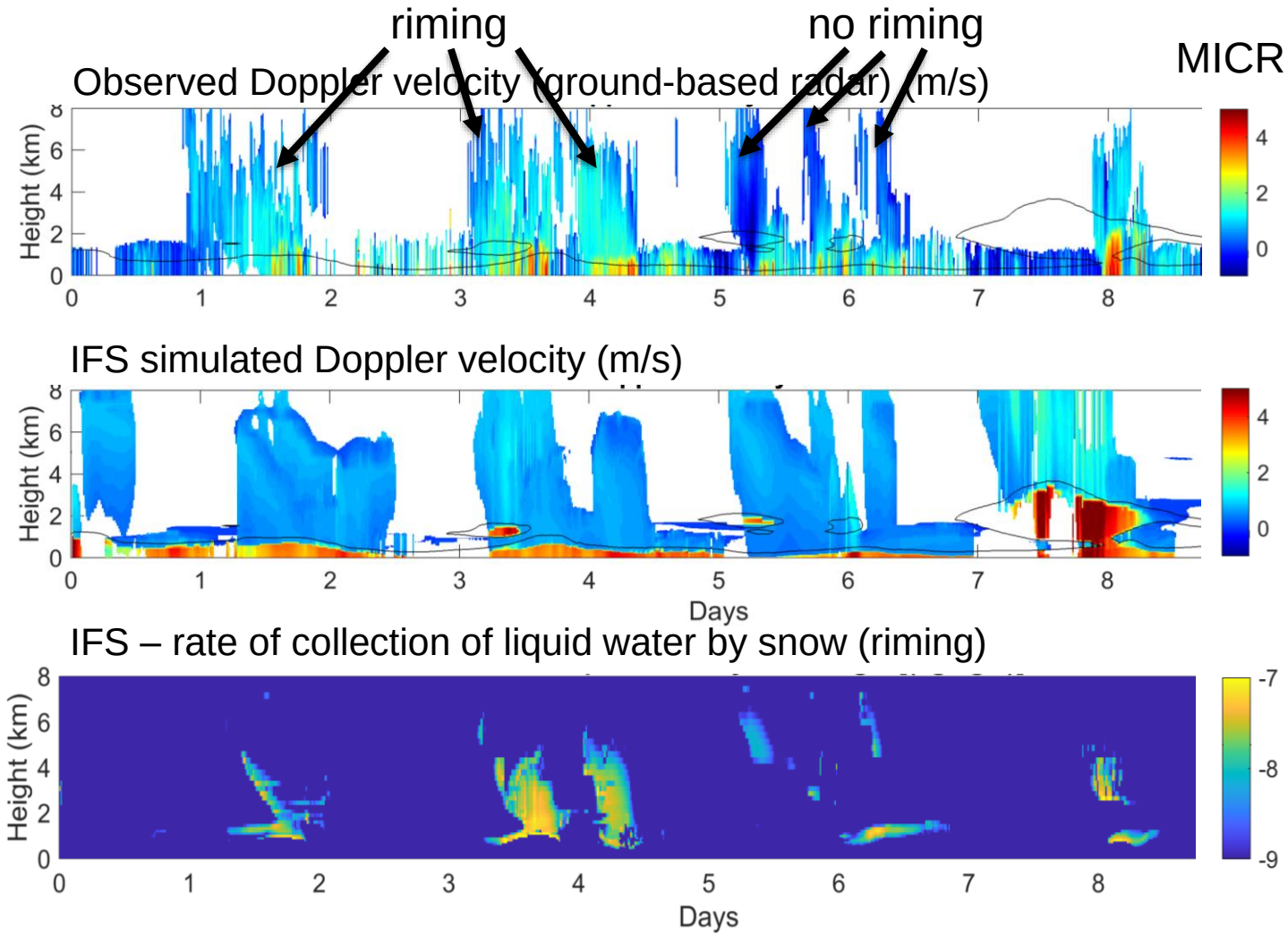
Need to improve the representation of microphysics

An example of not representing the increased fall-speed of rimed ice particles: Doppler velocity obs



MICRE obs campaign (Southern Ocean)
ground-based Doppler radar 9 day timeseries

- IFS has a single-moment scheme, prognostic cloud liquid, rain, ice, snow
- To simulate the Doppler velocity of ice-phase particles more effectively, more complexity is required
- e.g. additional hydrometeor species required for rimed snow/graupel, P3 scheme (Morrison and Milbrandt 2015) or diagnose ‘density factor’?

Will EarthCARE lead to better weather forecasts? Yes! はい！

Improvement of initial state

- Observations in cloudy/precipitating regions are vital to reduce error growth for future NWP improvement
- Assimilation of CloudSat/CALIPSO radar/lidar in the IFS shows the potential for future benefit of EarthCARE in global medium-range NWP forecasts (ESA-funded project at ECMWF)
- Additional instrumentation (e.g. HSRL/Doppler) provides synergy for further constraints on cloud/precip/aerosol

Improvement of the forecast model

- We have learnt so much from CloudSat/CALIPSO. There is so much more to learn from EarthCARE!
- Towards km-scale global NWP – more complexity of microphysics representation – need global constraints
- The forecast model is also part of the 4DVar assimilation system
  → better forecast model = extract more from the obs = better weather forecasts