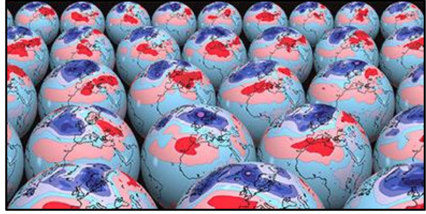
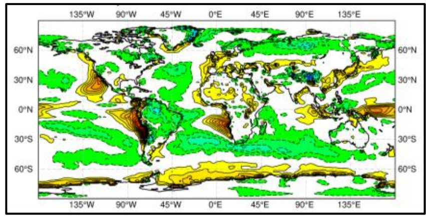
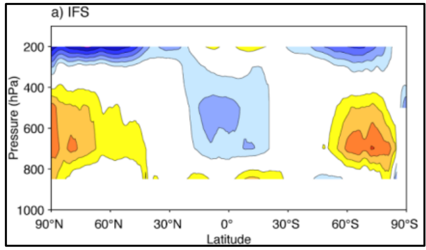


Improving global weather prediction: the role of spaceborne radar and lidar

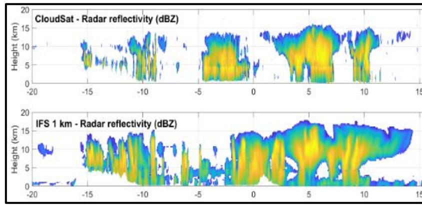


EarthCARE Modeling Workshop, 16-18 Feb 2022



Richard Forbes

European Centre for Medium-range Weather Forecasts

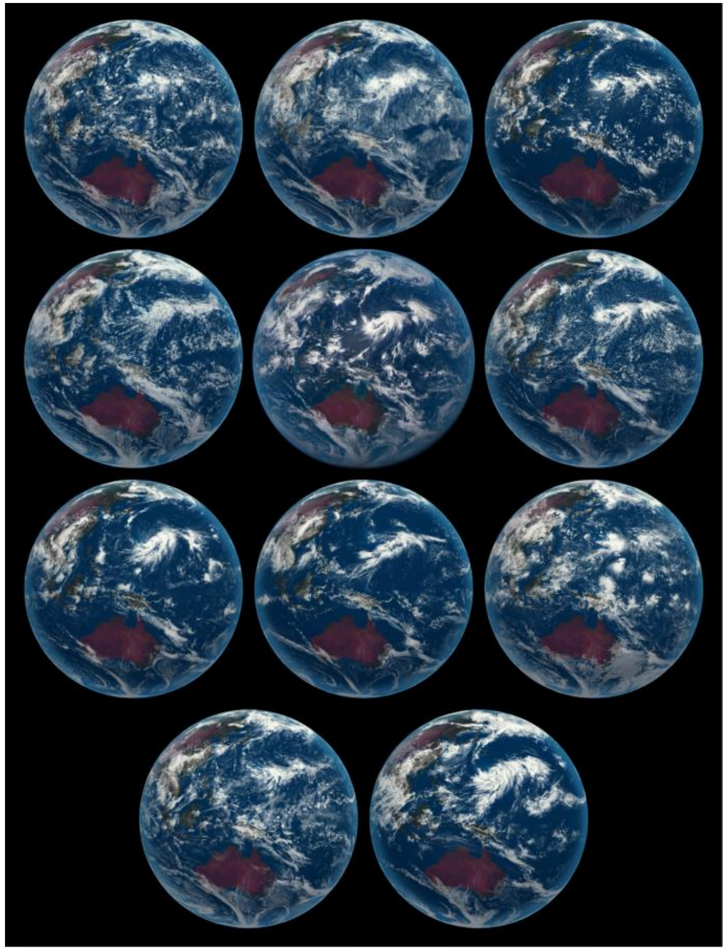


Thanks to Tobias Becker, Mark Fielding, Alan Geer,
Marta Janiskova, Linus Magnusson, Shannon Mason

ECMWF

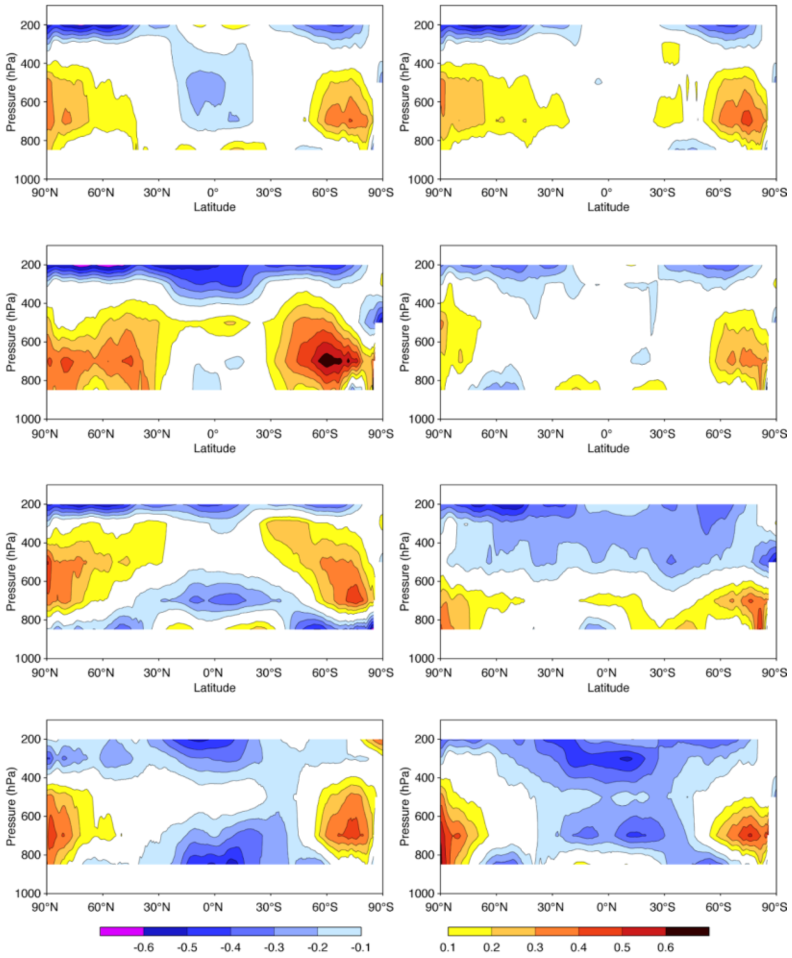
There is still much uncertainty in the global characteristics of forecast models

Snapshot of pseudo-satellite cloud images from 10 DYAMOND storm-resolving simulations on day 3 (and the observations)



Stevens et al. (2019)

Zonal mean x-section of **day 3 forecast temperature bias** for various operational global forecast models started from the same analysis (DIMOSIC)



Magnusson et al. (submitted)

Global NWP models – where are we heading?

- Increasing **resolution**

  Operational ECMWF global IFS 9km high res, 18km 50-member ensemble → 9km in 2022
  Future upgrades to ~4 km. Exploring 1-4 km now (DYAMOND, INCITE, NextGEMS, DestinationEarth)

- Embracing **uncertainty**

  Upgrade of global ensemble to 9km, same as the high-res "deterministic" - a milestone!

- Increased **use of observations** (all-sky (cloudy) and all-surface)

  E.g. successful assimilation of all-sky microwave, EarthCARE assim preparation (see Mark Fielding's talk)

- Increasingly **coupled** across Earth system components

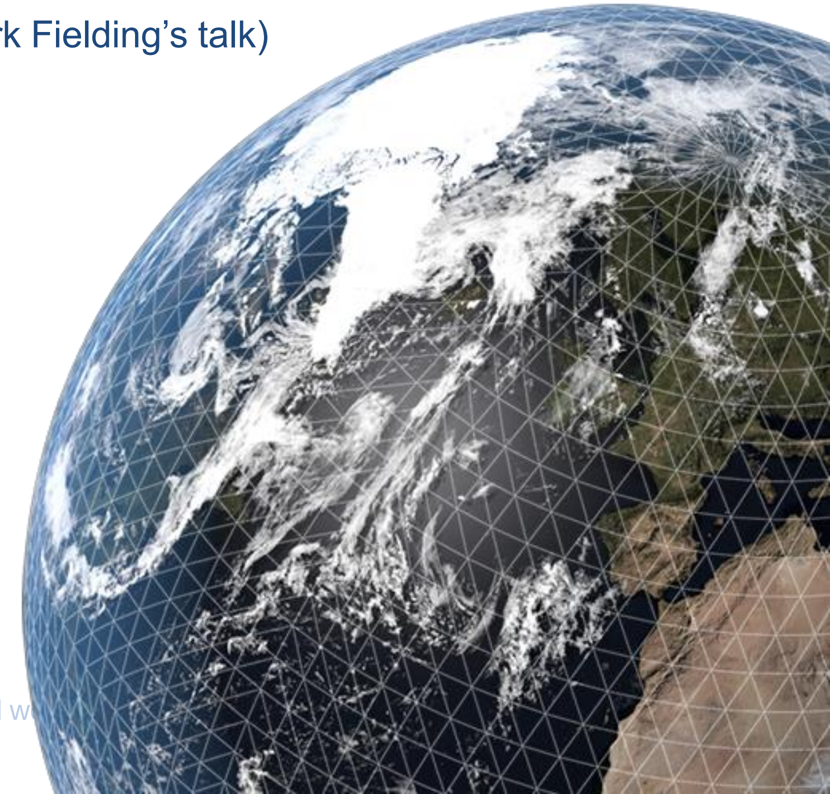
  Atmosphere, land, waves, ocean, sea-ice, atmos. composition, hydrology

- Improving the **physics**, **dynamics** and **DA algorithms**

- Extending the **forecast range** of predictive skill

  Beyond 10 days, monthly, seasonal

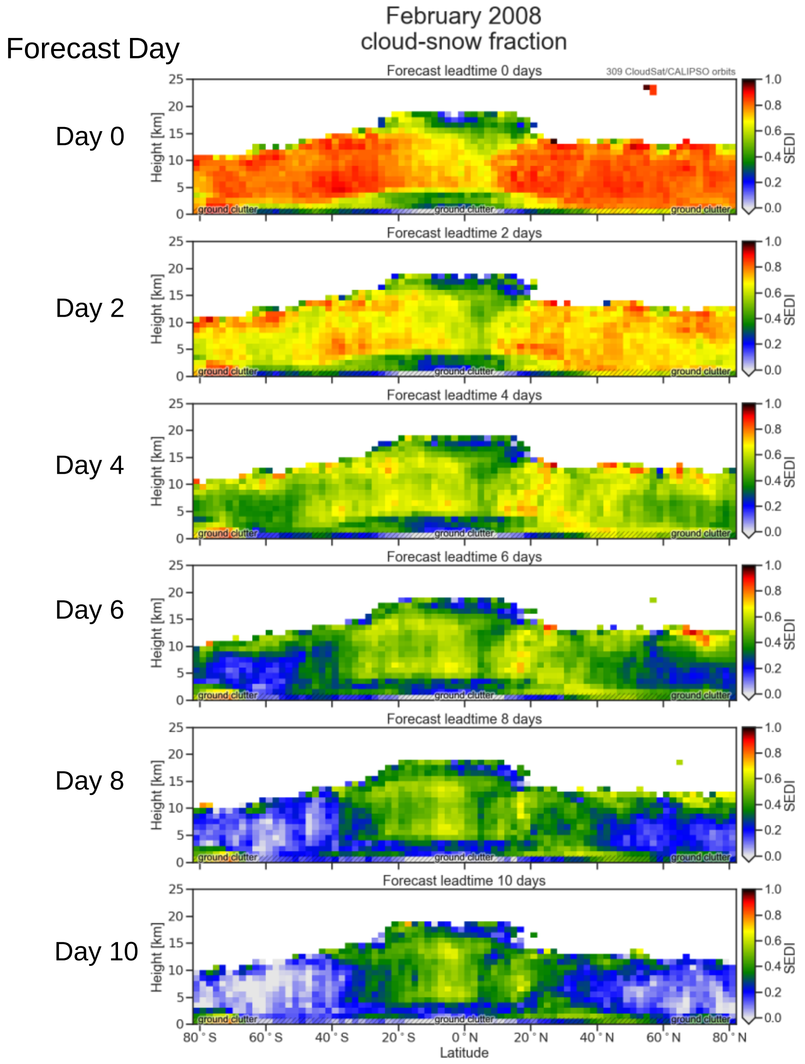
- Use of enabling technologies (**GPUs**, **ML**, …)



Constraining global characteristics of cloud and precipitation

- CloudSat/CALIPSO was a game-changer for 3D cloud and precipitation model evaluation. Continue to be new results…
- EarthCARE will continue, and expand on, that legacy
- Synergy of observations (e.g. in retrievals) can be powerful – many examples
- NWP data assimilation system is a powerful (and under-utilised!) framework for evaluating models (although historically restricted to NWP centres)
- **Challenge**: to utilise synergy (including in DA) to improve processes and reduce systematic regime-dependent errors related to clouds/precipitation/radiation across scales

Skill score (SEDI, 0-1) for cloud+snow location

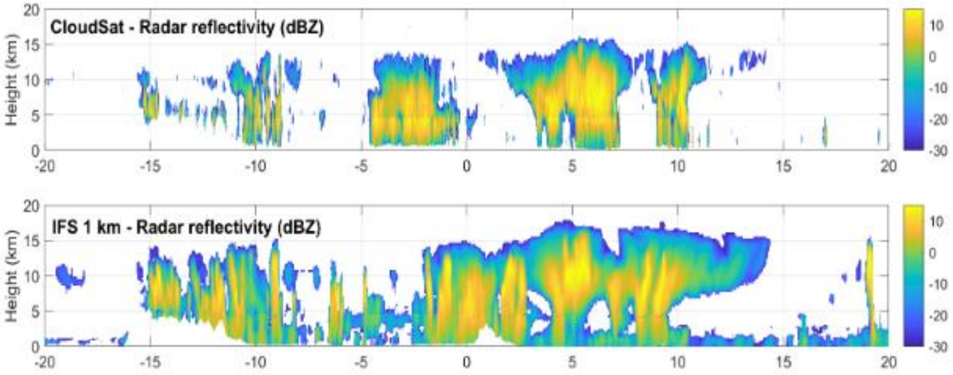


Shannon Mason

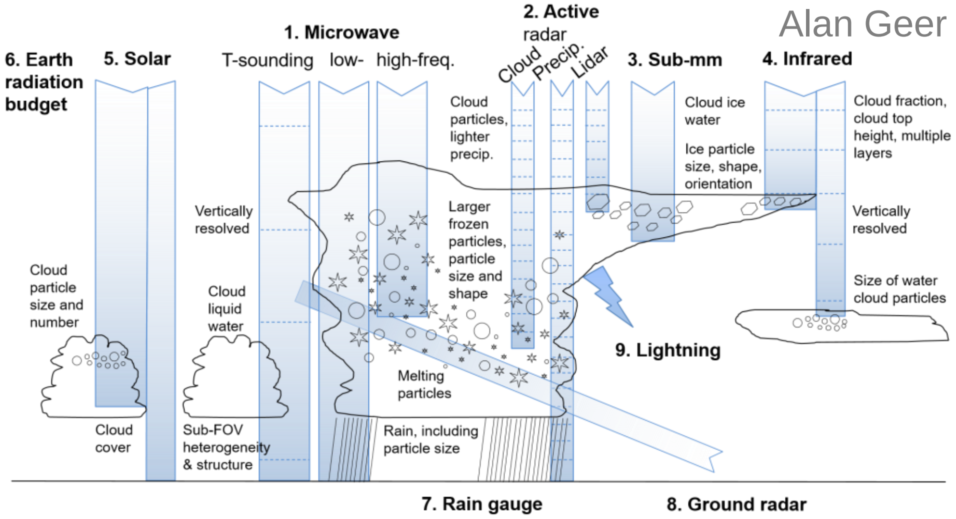
Constraining microphysics?

- More resolved dynamics, less subgrid assumptions
- The details of the microphysics are increasingly important for accurate cloud/precipitation and impacts (rather than dominated by the uncertainty of subgrid assumptions)
- Forward modelling/observation operator increasingly important for data assimilation and model evaluation
- Increasing amounts of data from passive and active satellite instruments. EarthCARE a part of this.
- Microphysics params increasing in complexity (ECMWF global IFS moving towards a flexible framework for multi-moment microphysics)
- **Challenge**: to globally constrain particle mass, phase, density, size, shape in multi-moment microphysics parametrizations

Comparison of a cross-section (20°S to 20°N) of radar reflectivity from (a) CloudSat, (b) IFS 1.4km simulation, (c) IFS 9 km simulation



Mark Fielding, Marta Janiskova



Alan Geer

Constraining/quantifying uncertainty at the process level?

- Uncertainty is inherent in the forecast system. How to best represent the uncertainty in ensembles?
- ECMWF IFS changing from stochastic perturbations of total tendencies (**SPPT**) to perturbations closer to the source of uncertainty in parametrizations (**SPP**)
- Improved consistency in representation of uncertainty and closer link to processes
- How can we use observations to best constrain/quantify the different uncertainties (e.g. microphysics)?
- Current SPP, perturb e.g. rain evaporation rate, snow sublimation rate, ice aggregation rate
- Future SPP? perturb particle size distributions, ice habit, densities?
- **Challenge**: to use EarthCARE with other obs to quantify uncertainties in microphysics globally

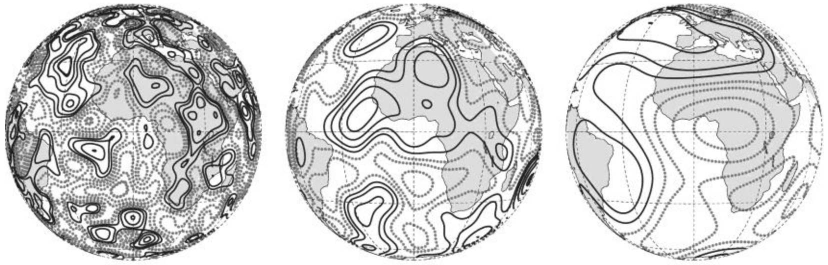
SPPT (current operational in the IFS)
Stochastically **P**erturbed **P**arametrisation **T**endency
Buizza et al. (1999), Leutbecher et al. (2017), Lock et al. (2019)

Perturbs total temperature, humidity, wind tendencies from parametrizations with spatial and temporal correlation

SPP (planned for IFS operations in 2023)
Stochastically **P**erturbed **P**arameterisations
Ollinaho et al. (2017, QJRMS), Lang et al. (2021, QJRMS)

Process level representation of model uncertainties closer to source - perturb parameters/coefficients within the parametrizations with spatial and temporal correlation

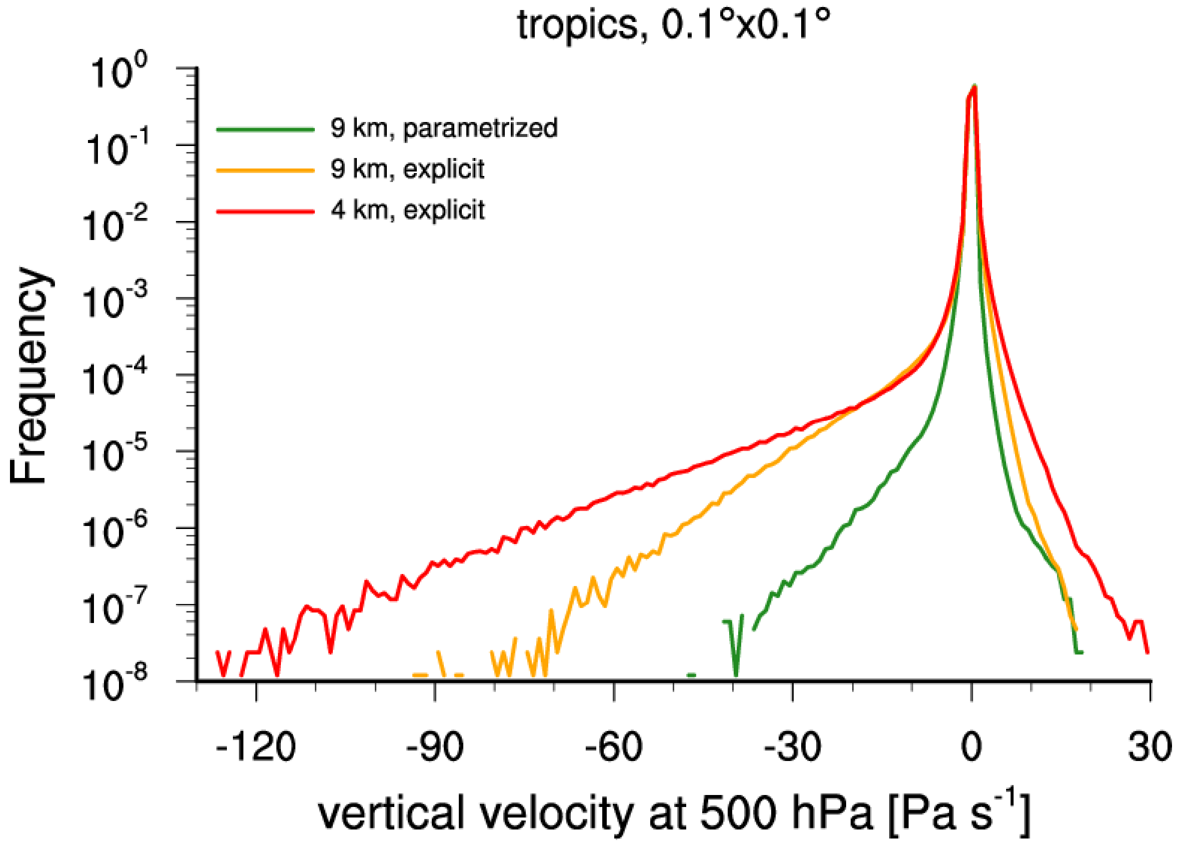
Examples of 2D random perturbation fields at different scales in SPPT/SPP



Constraining storm-scale models?

- "Storm-scale" resolutions with no deep convection parametrization are explicitly representing convective systems
- In the deep convective grey zone (e.g. 1-9km) models tend to have too strong vertical velocities
- Impacts the cloud, large-scale circulation
- EarthCARE can help to constrain the cloud, microphysics, radiation
- **Challenge**: to use Doppler to constrain vertical air velocity at storm-scales (separating the hydrometeor signal?)

PDF of vertical velocity (tropics) from the 4km IFS and 9km with and 9km without deep conv param



Tobias Becker

Improving global weather prediction: the role of spaceborne radar and lidar

Summary

- Cloud and precipitation and their impacts on radiation and latent heating remain a major challenge for NWP

- EarthCARE can continue and expand on the legacy of CloudSat/CALIPSO to play an important role in model development and improving forecasts through:

  – Constraining initial conditions – see Mark Fielding's talk assimilating spaceborne radar and lidar

  – Constraining global characteristics of cloud / precipitation / radiation – across regimes

  – Constraining microphysics – mass, number concentrations, particle shapes

  – Constraining / quantifying uncertainties

  – Constraining the next generation global storm-scale models