Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Towards Rapid Update Cycling of Cloud and Precipitation Observations at DWD

Lisa Neef[1]
with input from: Lilo Bach[1,2], Kobra Khosravian[1], Christian Welzbacher[1], Uli Blahak[1]

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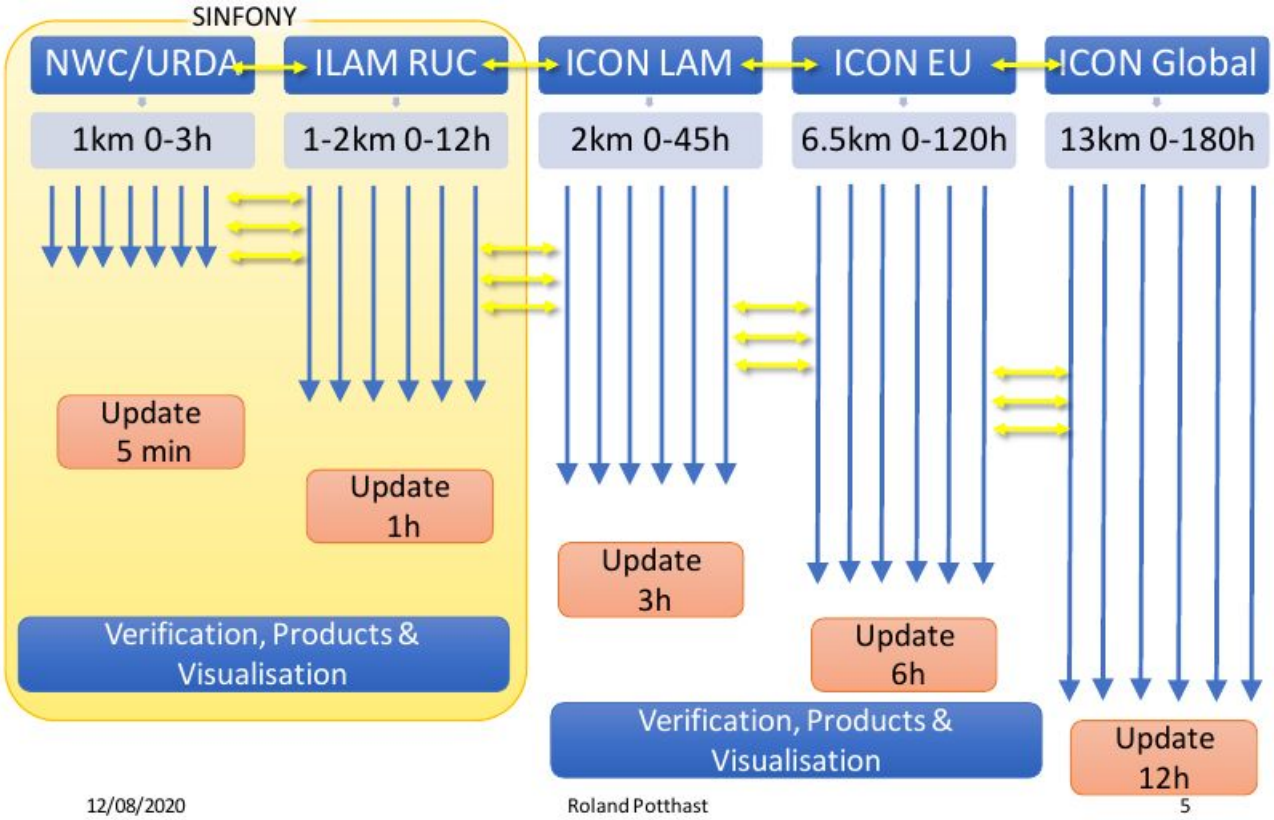
Rapid Update Cycling in SINFONY



SINFONY-RUC: New Observations

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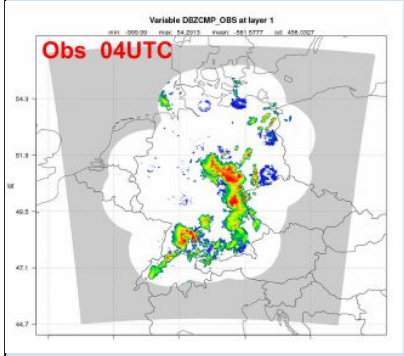
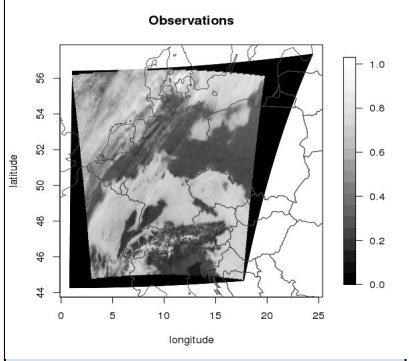
Radar



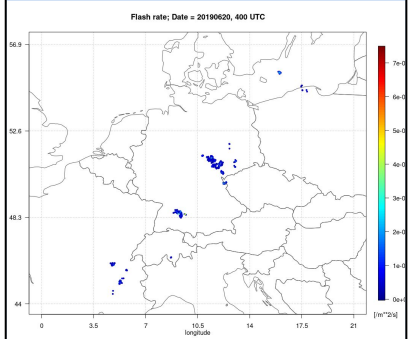
Precipitation

SEVIRI VIS Refl



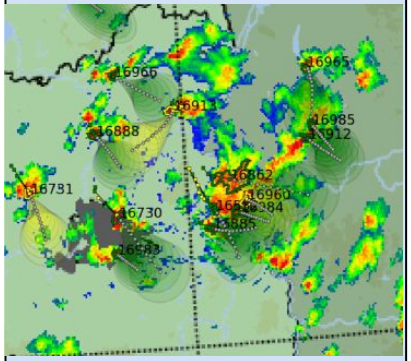
Clouds & Cloud Cover

Lightning



Cloud discharge

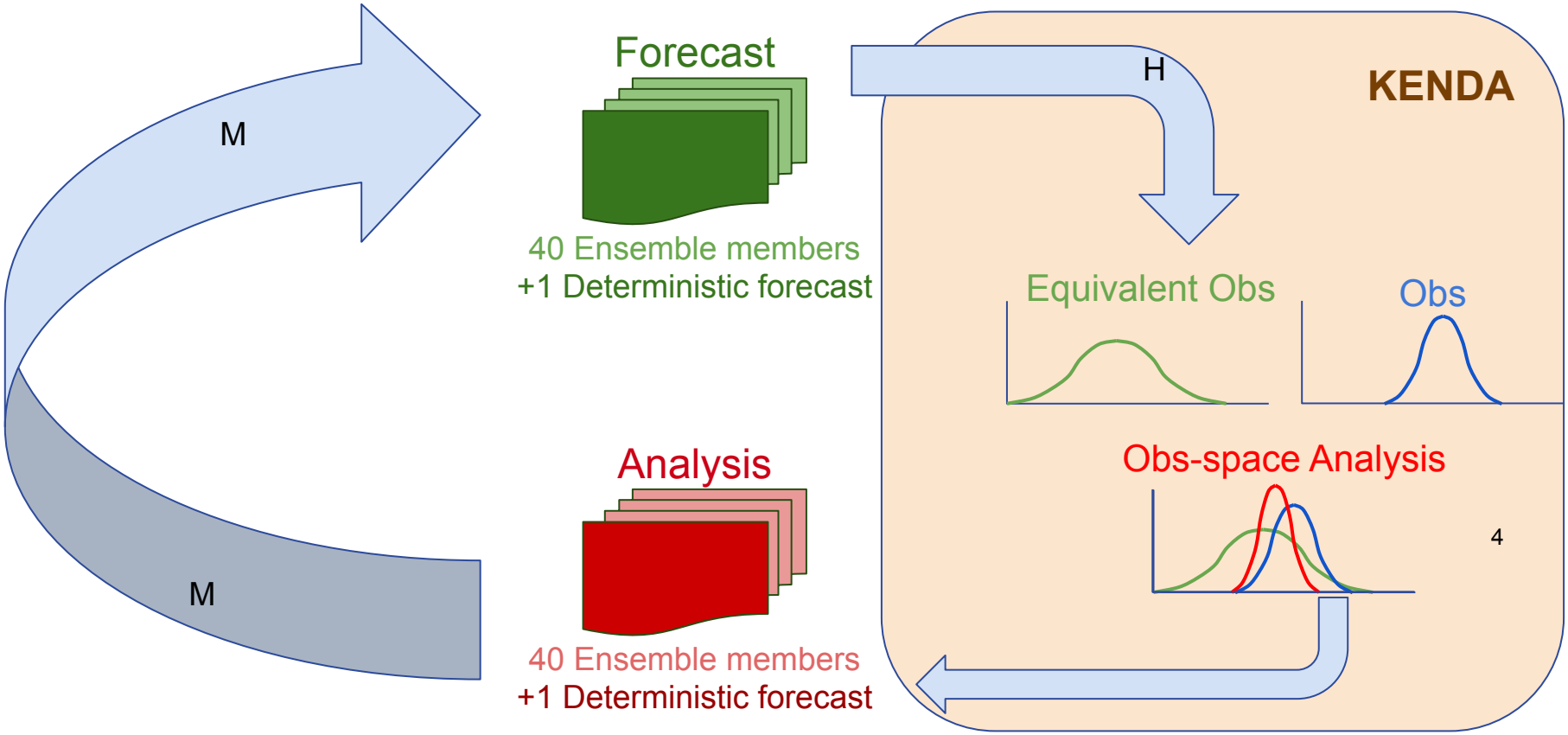
NWC Objects



Precipitation + Nowcasting Knowledge

Data assimilation can use these observations to constrain precip and clouds, and also the variables related to it. But how well does this actually work?

Data Assimilation in ICON-LAM



The LETKF spreads observed information across the model state using ensemble statistics.

Assimilation of Cloud and Precip ...but how?

double-penalty problem: convection in (slightly) wrong place

1h DA intervals (fast!) still **long rel. to cloud microphysics**.

Imbalance (leading to spurious gravity waves)

zero spread problem: often not enough ensemble members have convection

non-linear / non-Gaussian forecast and obs errors

Hydrometeor updates with react to their surrounding environment -- what happens?

Updating a cell with(out) convection with an obs that shows the opposite is **an agressive state adjustment**

Representativity error: there's a limit to how much truth a model can represent.

Seasonality? - Diffs between winter and summertime precip

Localization? -- Decorrelation lengths for hydrometeors much shorter than traditional control variables.

Cloud and Precip Observations

SEVIRI-VIS		
background	forward operator	examples

Radar		
background	forward operator	examples

Lightning		
background	forward operator	examples

Nowcast Objects		
background	forward operator	examples

- SEVIRI measures **reflectance in the visible band**, the percentage of incoming solar radation reflected back from the earth's surface or clouds
- the visible channel is around 0.6 microm and is sensitive to the following cloud properties:
  - optical thickness
  - number of particles
  - effective radii

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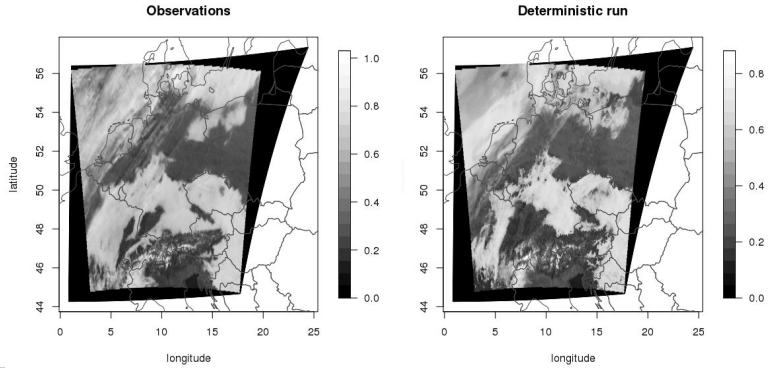
MFASIS Cloud Forward Operator

Inputs	Look-up Tables	Output
Temp Pressure Specific Humidity Cloud ice, water, snow Cloud cover	Sun zenith angle Particle radius Albedo Sat. zenith angle Scattering angle Optical thickness	Fourier coefficients of reflectance



plots by Lilo Bach

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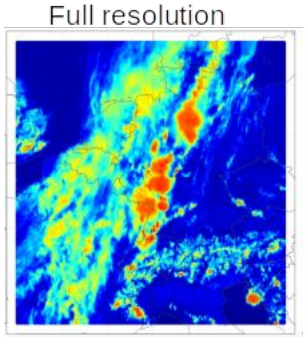
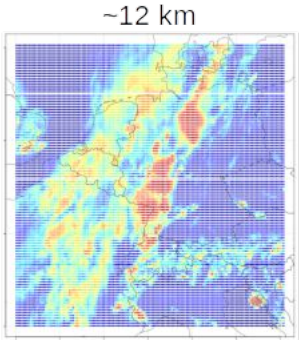
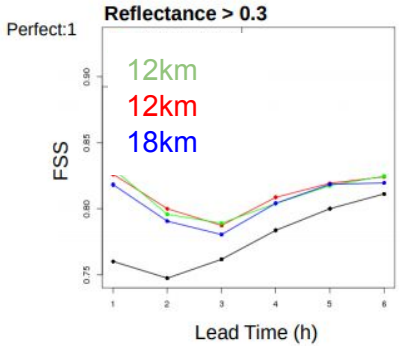
Superobbing avoids representativity errors, overwhelming the system.







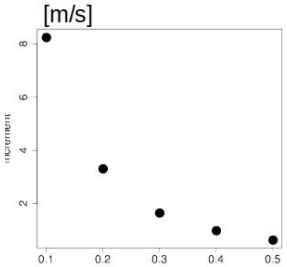
FSS

Adaptive Obs Error avoids shocks to the system

manually adjust assumed obs error relative to first guess departure:

$$\sigma_o^2 = \max(e_c^2, (o-b)^2)$$

wind increment



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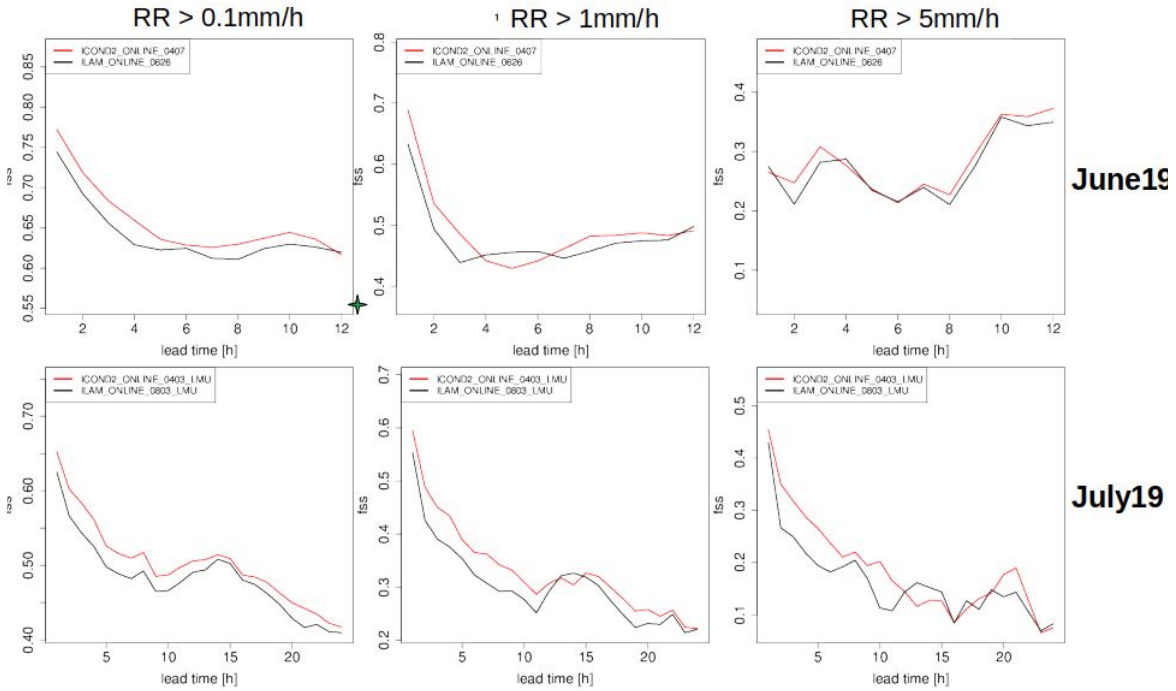

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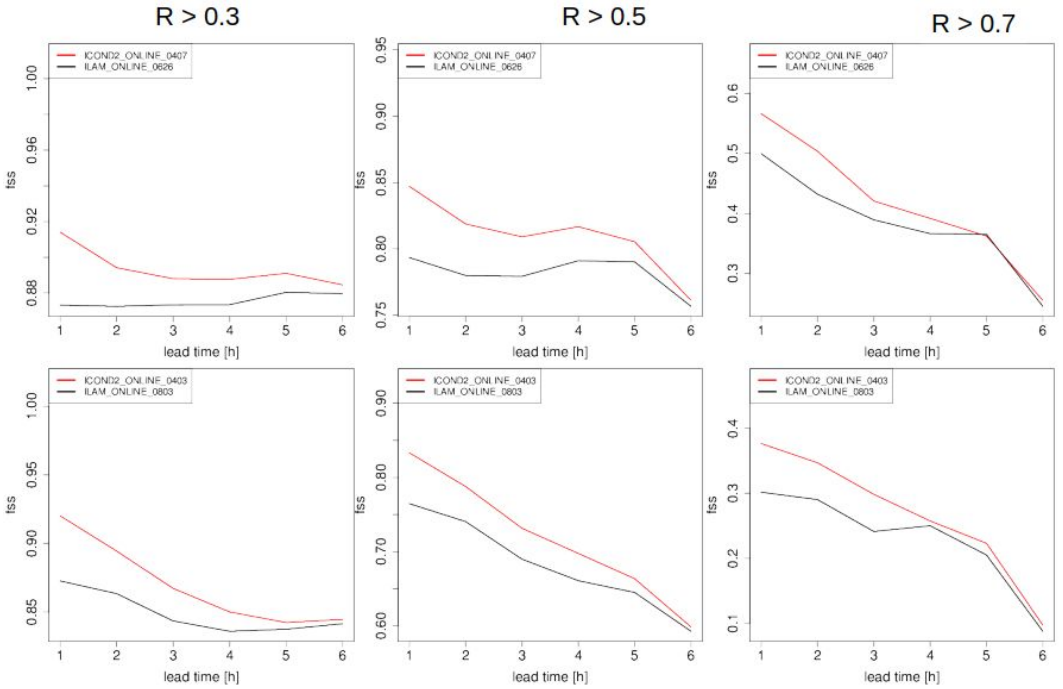

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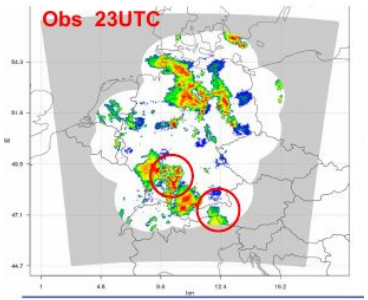
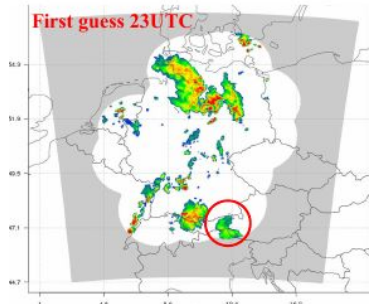
EMVORADO Forward Operator

Inputs	EMVORADO	Output
hydrometeors (qx) hydrometeor number densities	scattering attenuation partial melting beam broadening	Simulated Z, Vr





plots by Kobra Khorsravian

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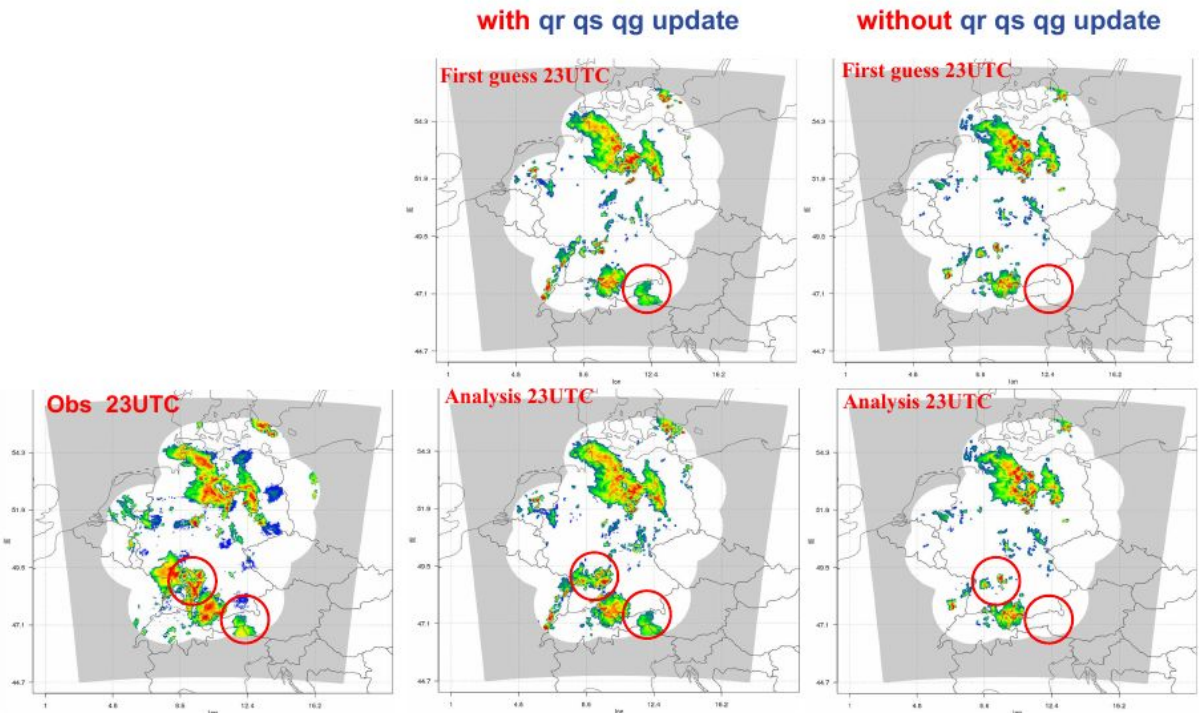
Updating Hydrometeors?



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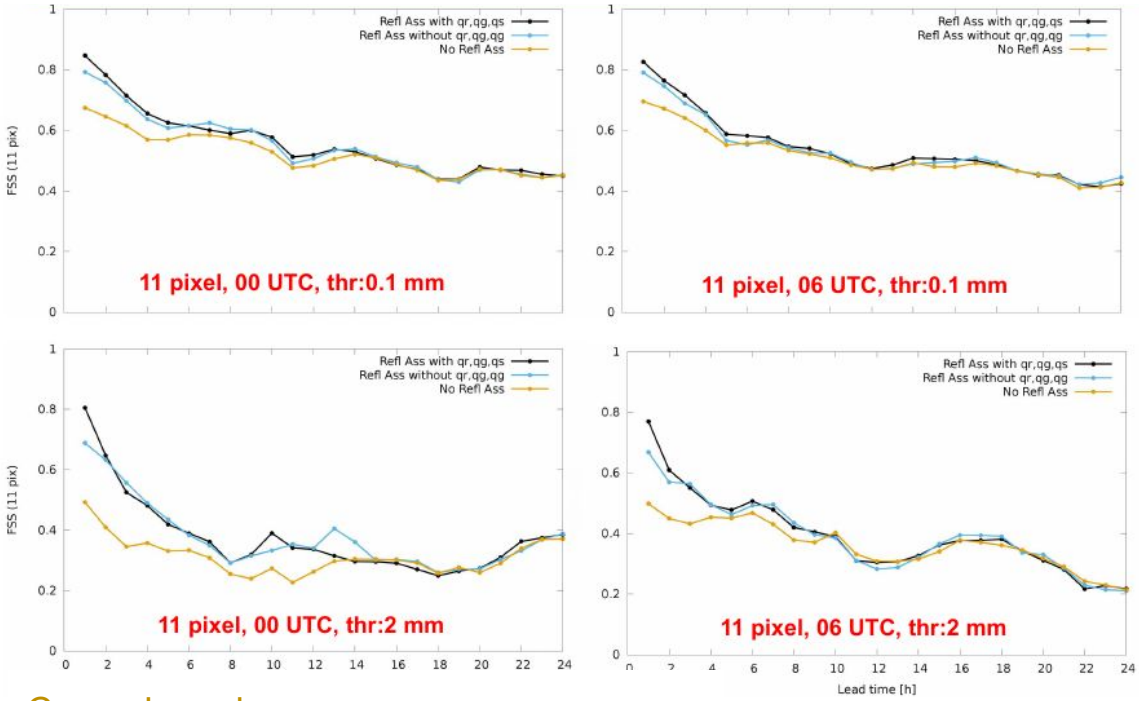
Precip Verification



Conv obs only
Conv+Radar
Conv+Radar+Hydrometeor Updates

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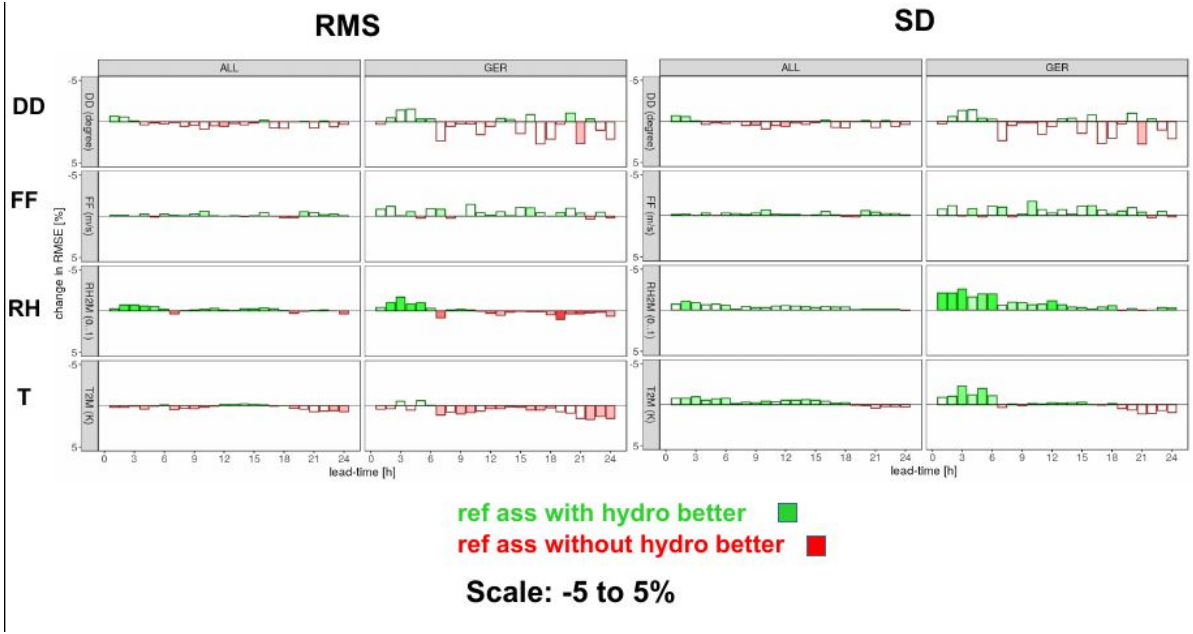
Verification against SYNOP Data



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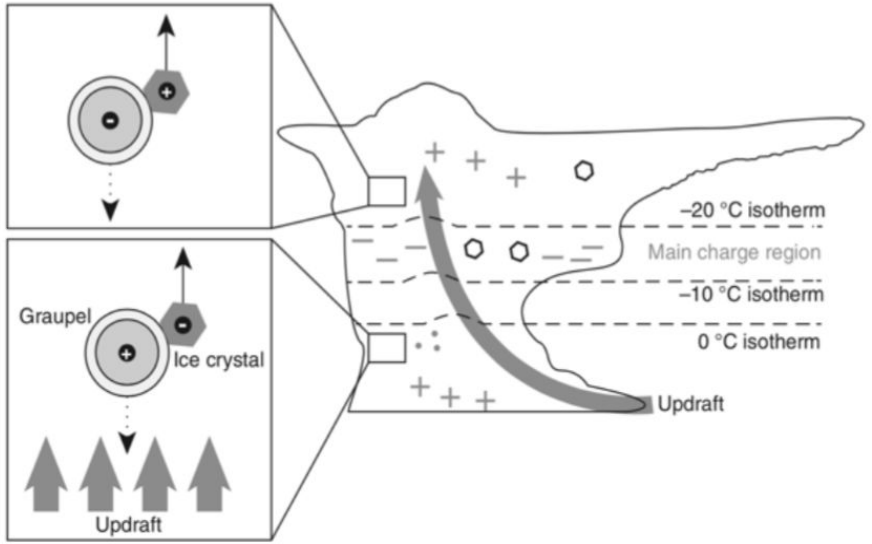
How does lightning happen?



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Lightning Potential Index

Inputs	LPI module	Output
Temp Updraft Hydrometeor conc.	Integrate Apply filters Count lightning on model grid -- flashrate	Flashrate for every model gridbox

$$\mathrm{LPI} = f_1 \frac{1}{\Delta z} \int_{z_{0^\circ C}}^{z_{-20^\circ C}} w^2 \epsilon g_w(w)\, g_g(q_g)\, dz$$

$$\epsilon = 2\frac{\sqrt{Q_i Q_l}}{Q_i + Q_l},$$

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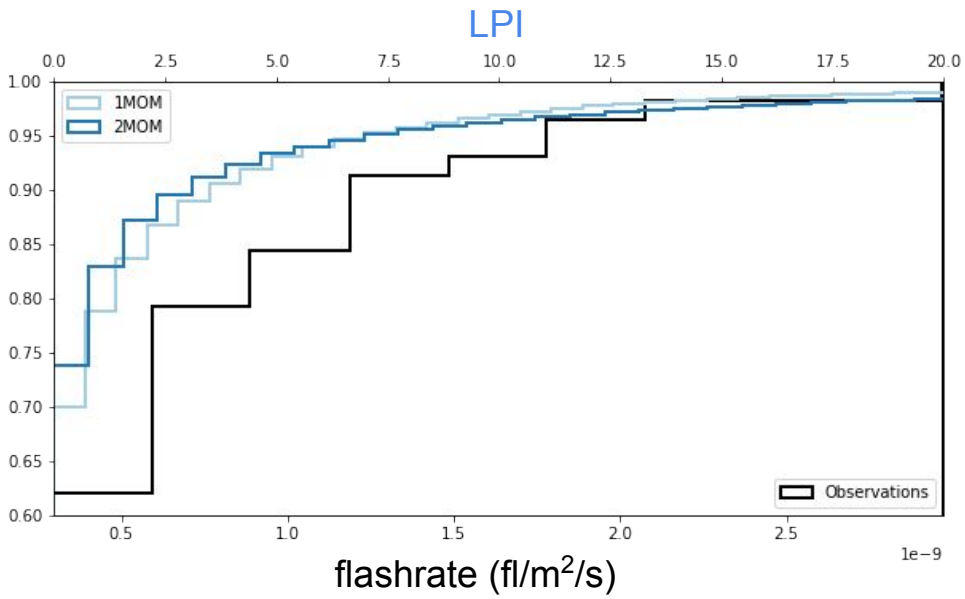
Scaling **Lightning Potential Index** to **Flashrate**



FLR = (1.56E-10) * LPI

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How does a patch of lightning get assimilatd?

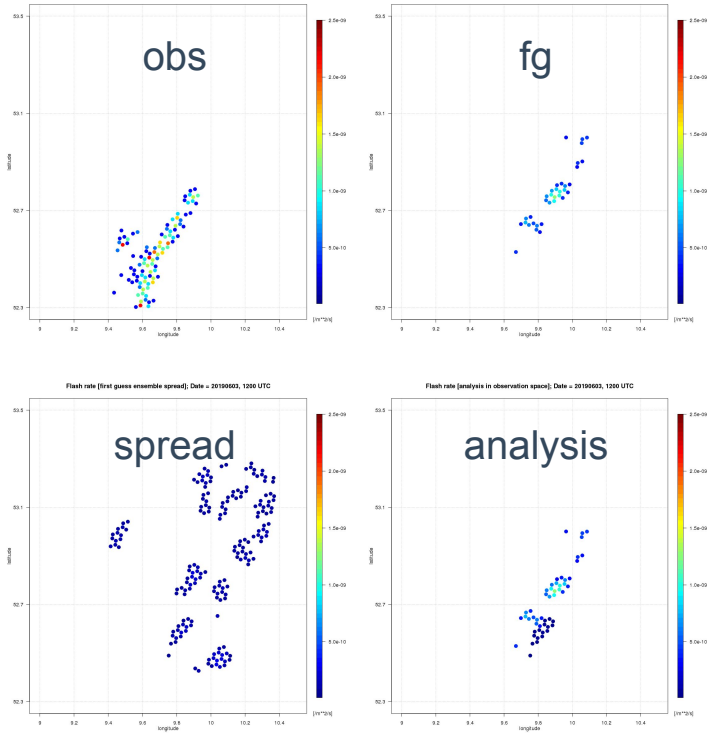
"Brute force" DA:

flashrate at every model gridbox

e^{obs} = 2 flashes/box

assign height = 500 hPa

Obs assimilated:
181/3030 = 6%



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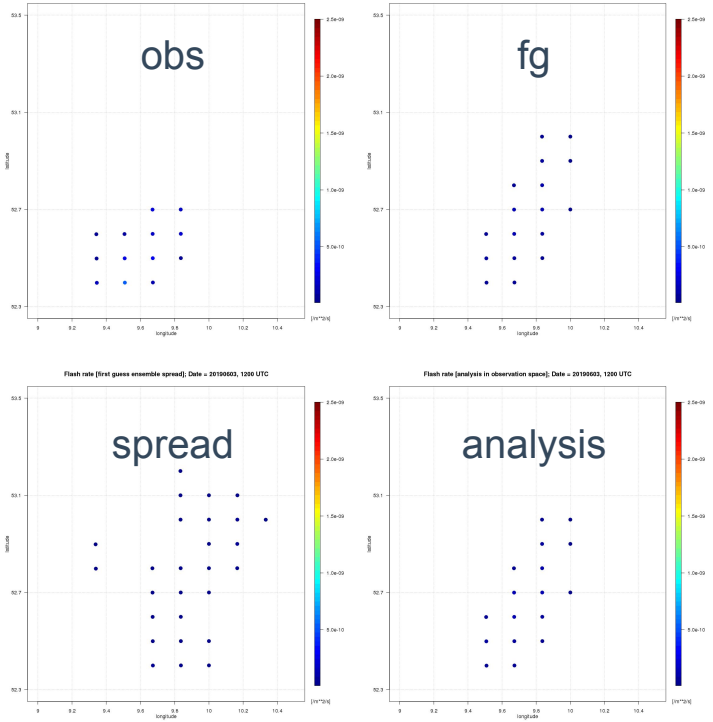
How does a patch of lightning get assimilatd?

Superobbed DA:

flashrate at every 4th COSMO box (ca 12km)

Obs assimilated:
74/114 = 65%



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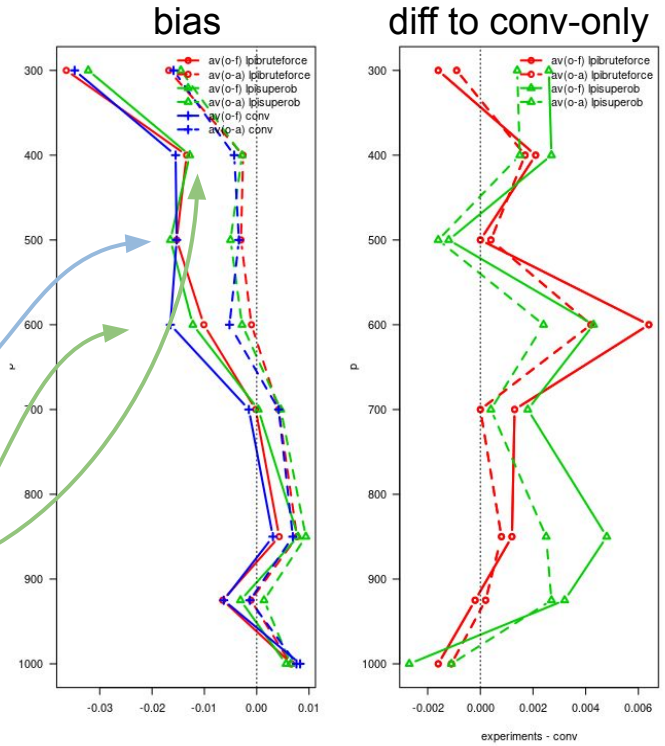
Verification against AIREP & TEMP humidity obs

Conv obs
Conv obs + Lightn
Conv obs + Lightn Superob

slight decrease where obs inserted

larger increase surrounding



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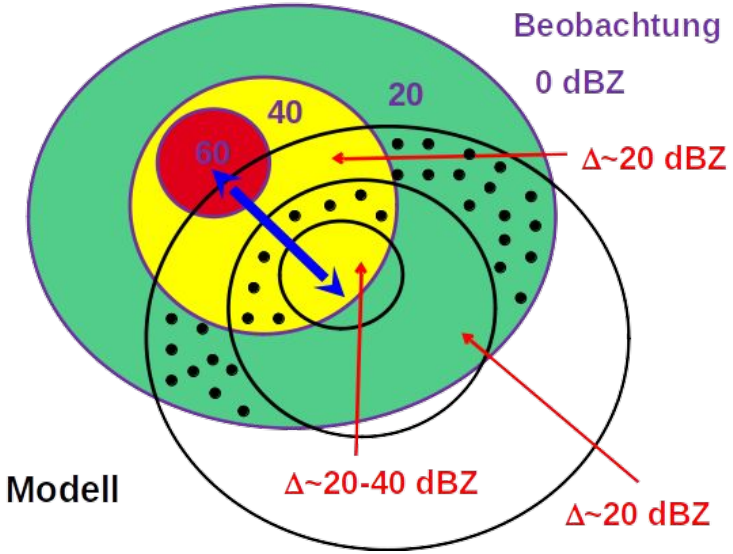
- = „gut“



schematic by Christian Welzbacher

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KONRAD3D Objects

KONRAD3D (**KON**vectionsentwicklung in **RAD**arprodukten) is a deterministic method for:

object recognition

object tracking

object forecasting

...developed by Manuel Werner at DWD

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KONRAD3D Objects

Inputs	KONRAD3D	Output
model-equivalend 3D radar data (EMVORADO output)	object detection tracking forecasting	cell polygons cell centroids cell tracks uncertainty ellipses cell intensity hail flag cell velocity cell volume cell area number of objects cell VIL & more...

→ “gridded features”

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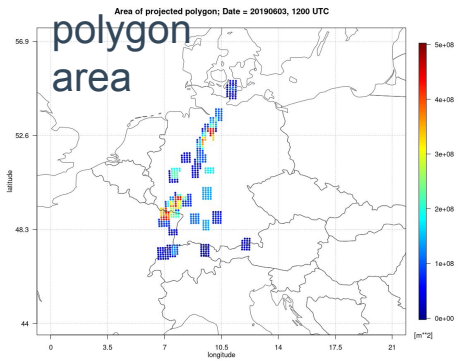
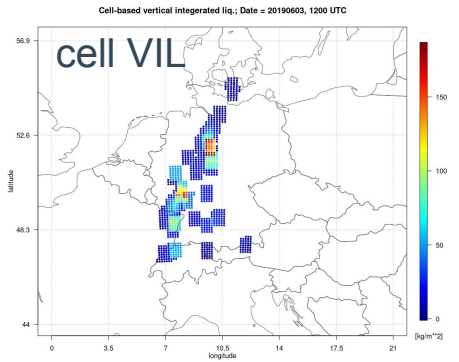
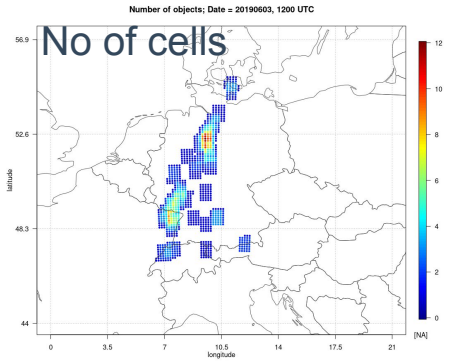
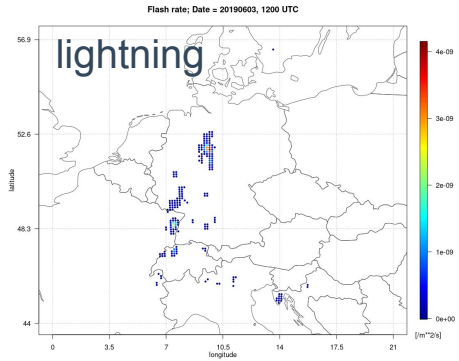
Gridded Features Examples









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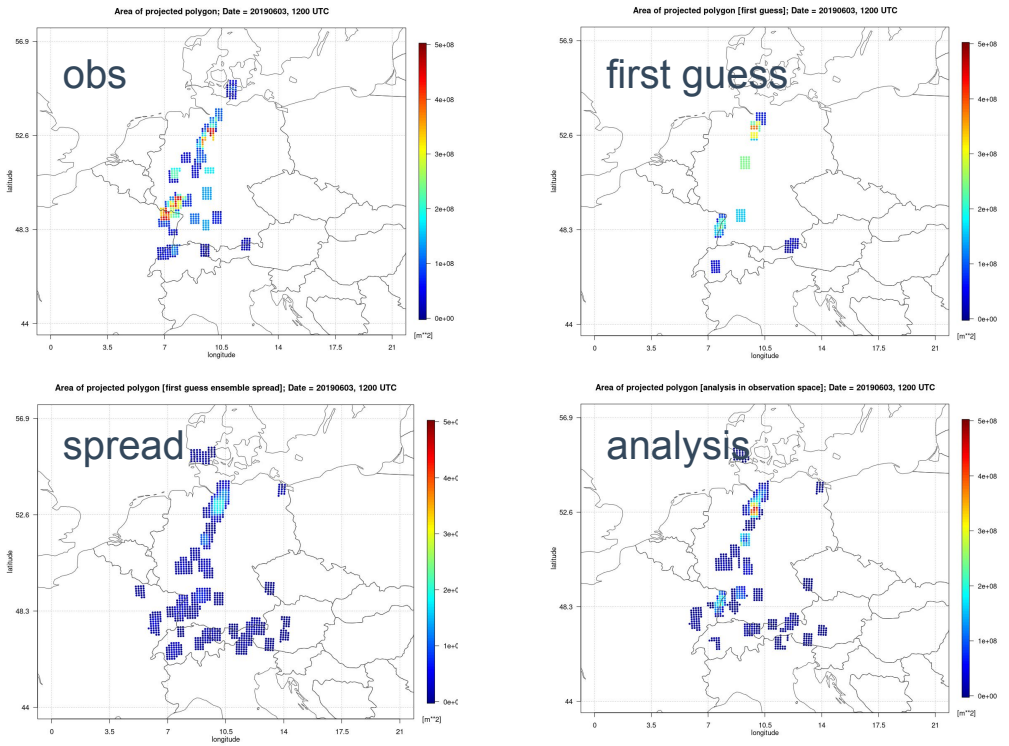
Sample DA: Area of Projected Polygon



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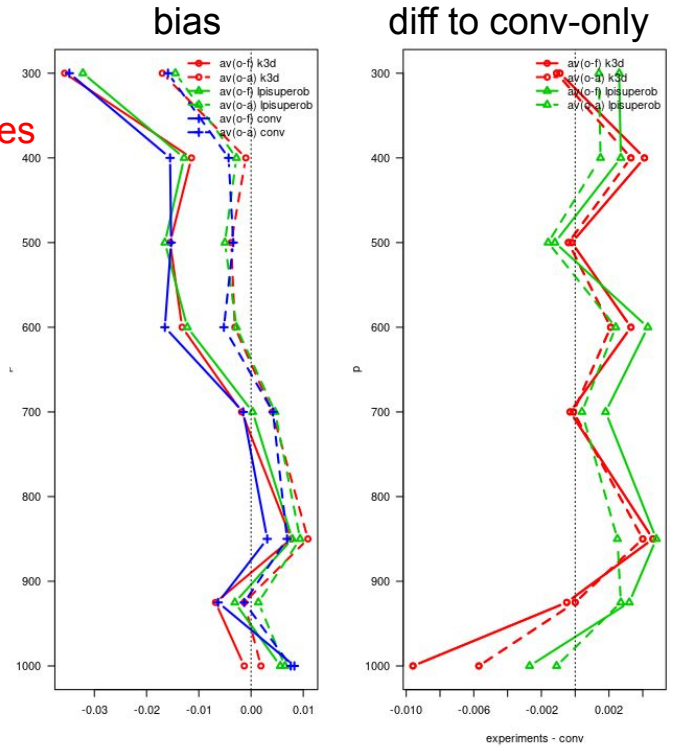

Summary

Successes

- Radar DA improves things pretty robustly
- Updating hydrometeors generally works well in radar DA
- SEVIRI-VIS obs improve precip & other variables, esp. if imbalance is avoided

Challenges

- Lightning most nonzero obs rejected due to zero spread
- Lightning & Features many unknowns remain
  - vertical position
  - obs error
  - localization

Outlook

Questions that need answering

- **Adaptive observation error** works well for cloud obs DA -- can we say the same for lightning?
- How do these results change for ICON with **2-moment microphysics**?
- How do we implement/tune new obs together while **moving towards operationality** at different speeds?
- Is making lightning DA “work” a worthwhile pursuit, or **should we treat lightning as a gridded feature**?
- How much still holds up after the **most recent ICON-LAM bug fix**?
- Do these obs have to be assimilated differently for **winter precip**?

Contact:

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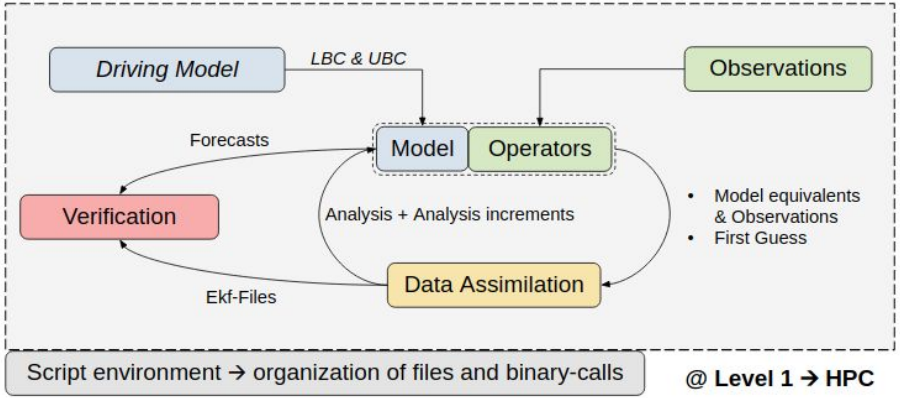

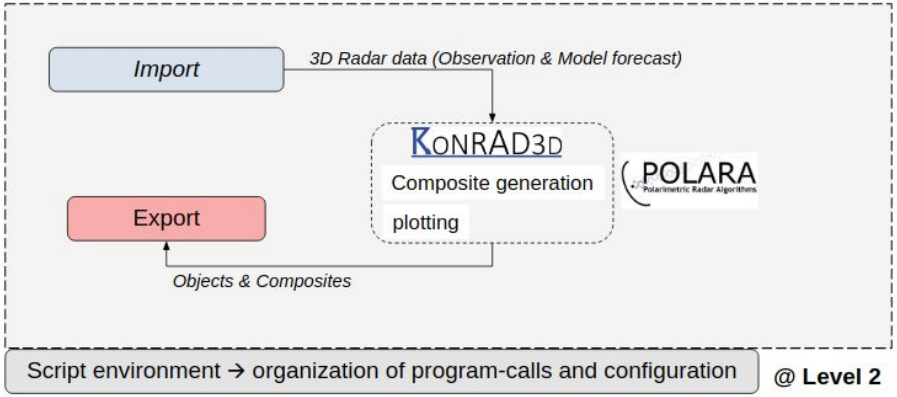

SEVIRI-VIS DA with Particle Filter

What we see:

- the ensemble is really not Gaussian
- the pull towards obs is strongest where the variance is highest
- this looks the way it should