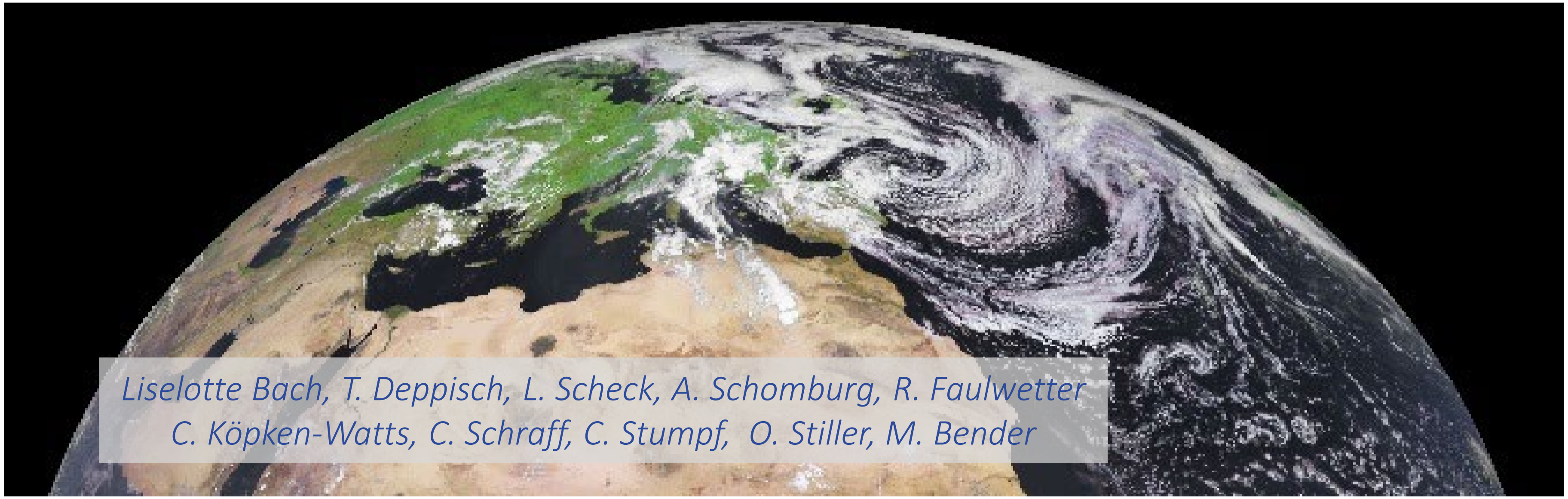
Assimilation of visible reflectances and water vapour channels from SEVIRI at DWD



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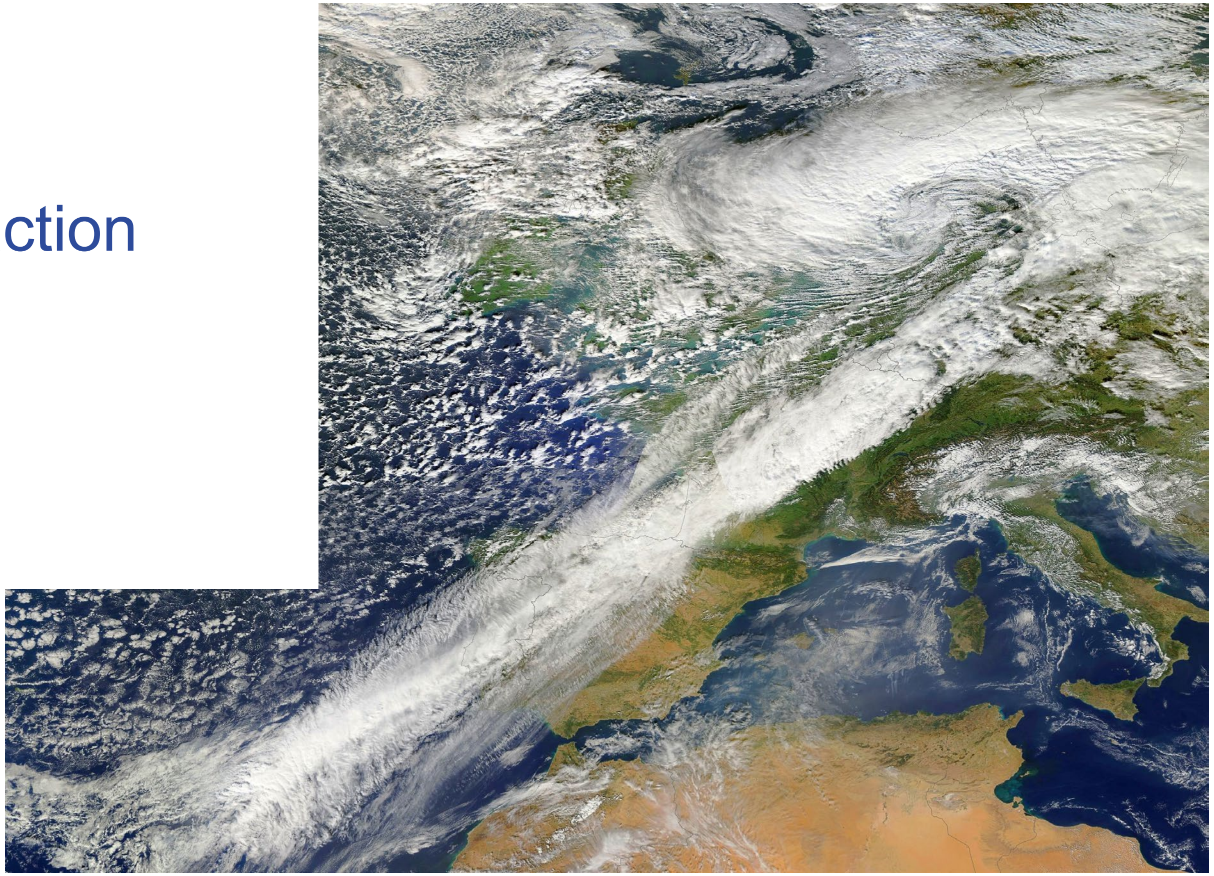
Outline

- Visible observations & short-range NWP system
- Visible assimilation setup & tuning
- Challenges: DA – model physics interaction
- Forecast impact
- Summary & outlook



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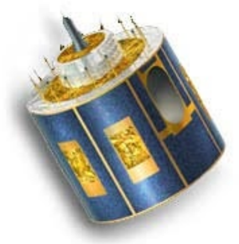
VIS assimilation: Observations & Motivation

Used measurements:

- 0.6 µm of SEVIRI Imager on MSG (0°/0°)
- Daytime observations
- **Reflectance = proportion of incoming solar radiance reflected to satellite**

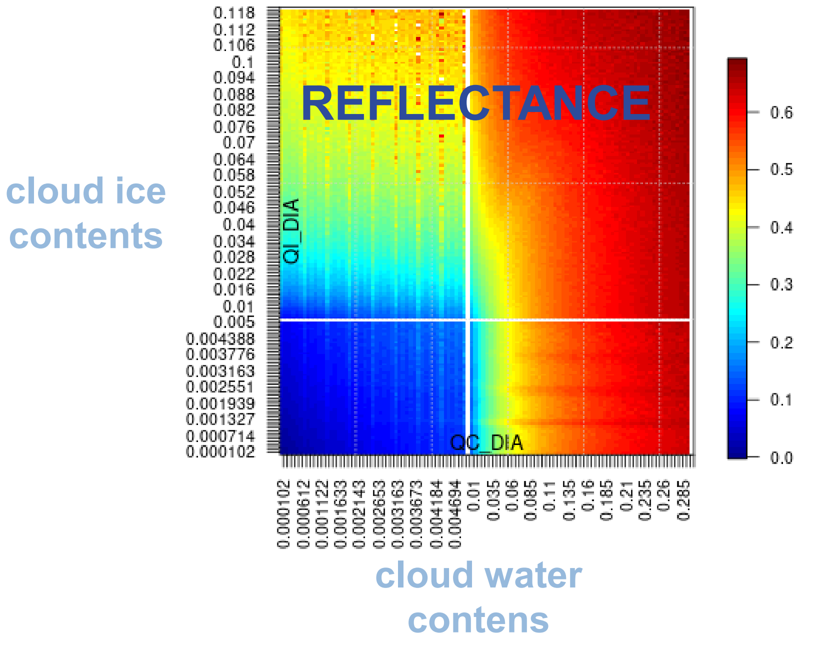


Information content of visible radiances

➔ Cloud water, cloud ice content

➔ Particle sizes of ice crystals, water droplets

Cloud Impact on reflectance



Aim:

➔ Better initialization of clouds

➔ Low stratus, fog, convective initiation (VIS complementary to IR)

➔ Improvements for radiation, surface parameters, precipitation

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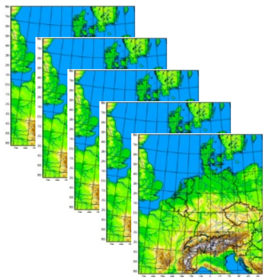
Convection-resolving NWP setups

Model: ICON-D2
DA-system: 4D - LETKF

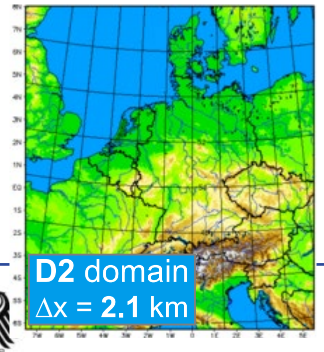
- Update of T, P, U/V, Qv, Qc (+ Qi)
- Analysis ensemble mean:
  linear combination of 40 first guess members
- 4D – LETKF: run H(x) at actual time of OBS

ICON – D2	SINFONY: ICON - RUC setup
2.1 km	2.1 km (currently)
3h assimilation cycle	1h assimilation cycle
48h forecasts (00 UTC, 12 UTC)	14h forecasts (hourly)
1-moment microphysics	2-moment microphysics

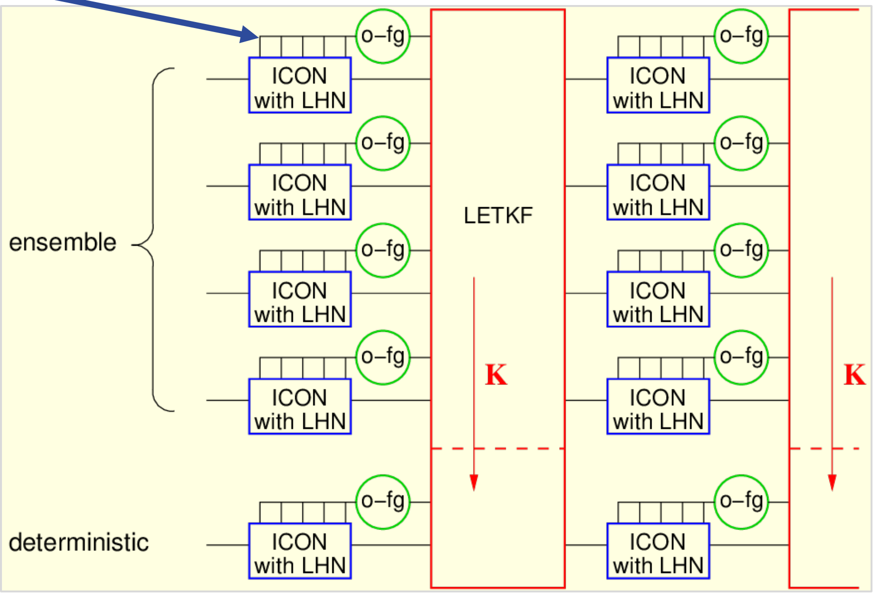
Prognostic variables:
- Hyrometeor mixig ratios
- Number concentration of particles



ensemble (40 members)



deterministic (unperturbed)



Data usage:
- RS, SYNOPS
- AIREP, MODE-S (u/v, T)
- Wind profiler
- 3D radar reflectivities, radial winds

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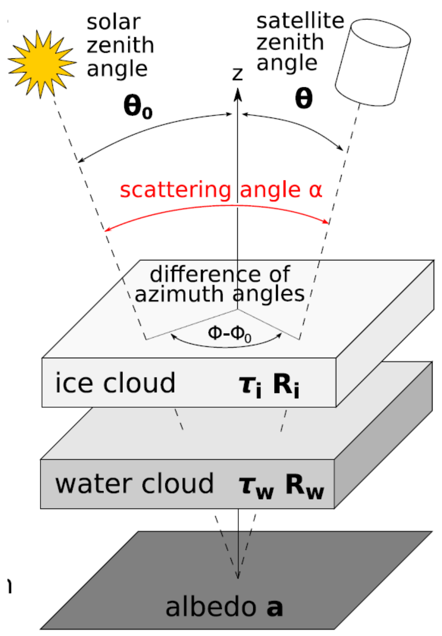
Forward operator: MFASIS

➔ MFASIS in RTTOV v13.1: Fast and accurate Look-Up Table method

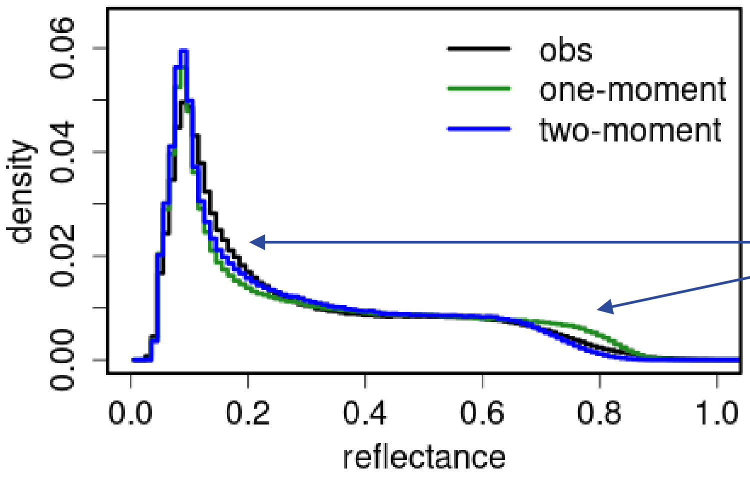


➔ Clouds simplified as two layers: ice and water cloud

- Total optical thickness, effective particle radii for water, ice cloud
- Surface albedo
- Viewing geometry: sate

➔ **See also talk by Leonhard Scheck**

Comparison of observed and modelled reflectances



Observation
ICON-1Mom
ICON-2Mom

Better agreement of OBS and simulation for 2-moment microphysics scheme

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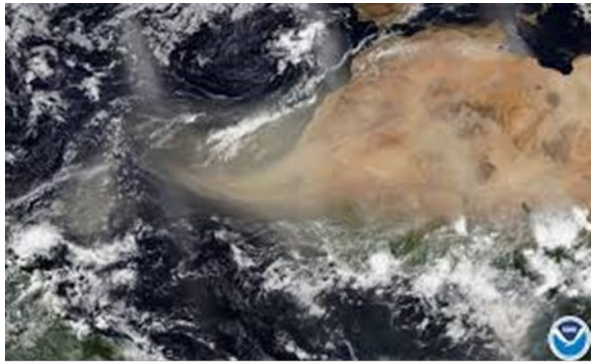
Data assimilation setup: Quality control

- QC at stage of forward operator call

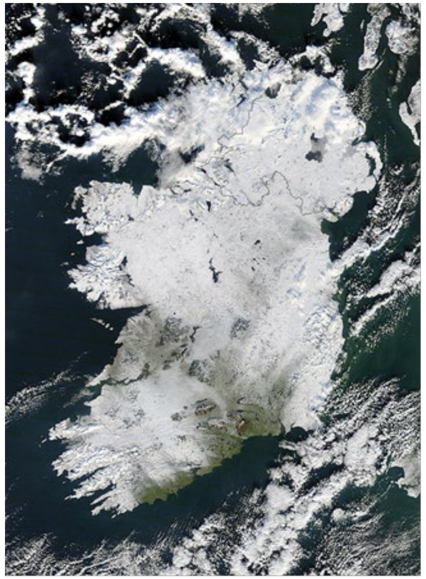
QC check	Reason for rejection
Sun zenith angle (> 75°)	Missing 3D-effects in MFASIS Nighttime conditions
Obs > 1.5	Missing 3D-effects in MFASIS
Model orography > 1100 m Cloud mask = „SNOW“	Misinterpretation of snow as clouds
Cloud mask = „DUST“	Misinterpretation of dust/volcanic ash as clouds
BRDF snow flag	Snow in BRDF climatology

NWC-SAF cloud mask

- Flags for snow, aerosol, volcanic ash
- Part of satellite preprocessing QC



Saharan dust outbreak



Mixture of snow and clouds

- QC within LETKF step
  - General checks: relation of spread and OBS error
- Bias correction:
  - Histogram bias correction has been developed → tested and works well, but neutral forecast impact
  - Currently not used (paper T. Deppisch et al. in preparation)

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Data assimilation setup: Configuration

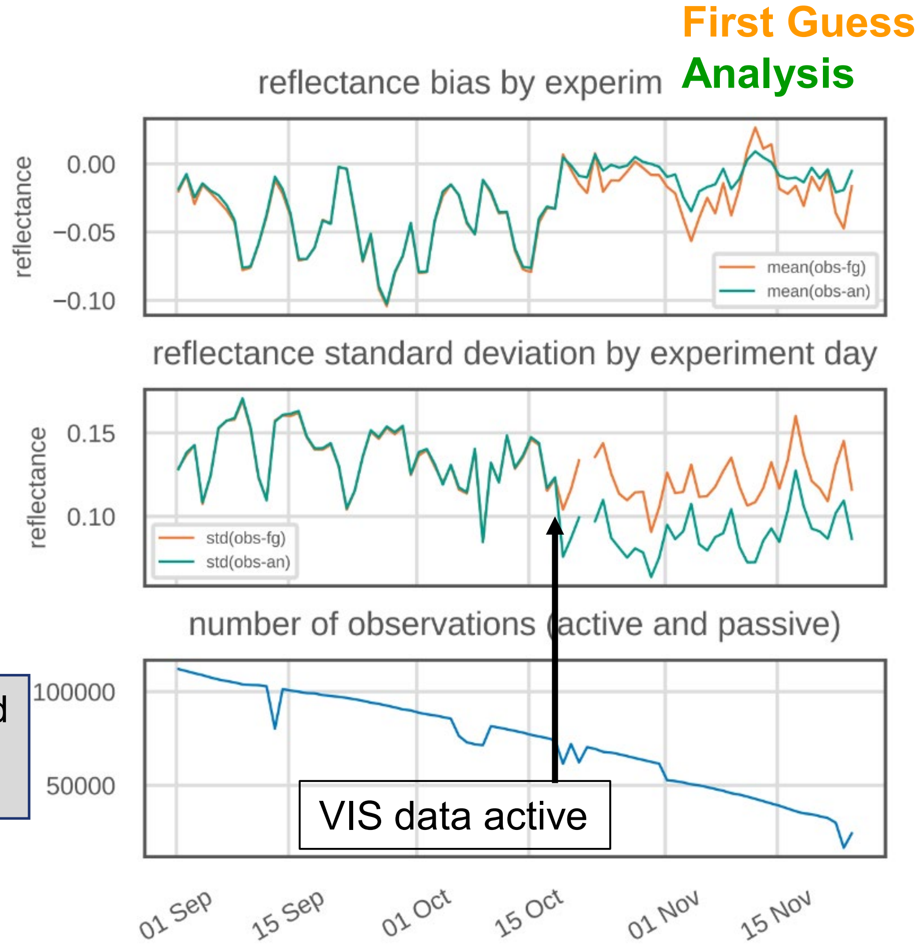
	ICON – D2	SINFONY: ICON-RUC
Forward operator	RTTOV-MFASIS v13.1	
SEVIRI & NWC-SAF mask	Scan @ 45 min (for full hour analysis)	
Calibration factor	1.08	
Data reduction	Superobbing: ~12 km	
OBS error & error model	σ_o = 0.2, Minamide + Zhang	
Localization	Horizontal: 35 km; Vertical: none	
Analysis variables	T, P, U/V, Qv, Qc	T, P, U/V, Qv, Qc + Qi, Qr, Qs, Qg, Qh
Effektive radii for water and ice particles	RTTOV/MFASIS (Martin et. al, 1994 McFarquar, 2003)	Predicted by 2-moment scheme

Hydrometeor Qx updates included
(important for 3D radar reflectivity assimilation)

Pre-operational suites with VIS 0.6 µm

- SINFONY RUC: since 19 Oct 2022
- ICON-D2: since 9 Dec 2022, operational 15 Mar 2023

Reflectance monitoring (RUC DA cycle) shows reflectance error reduction



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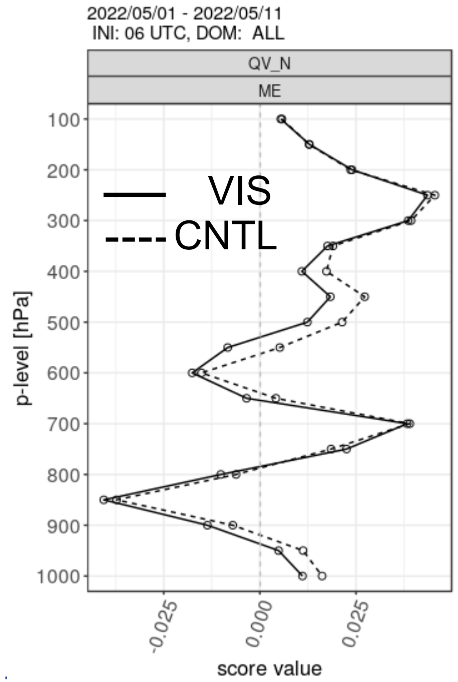
Challenges: DA – model physics interaction

70 Jahre
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

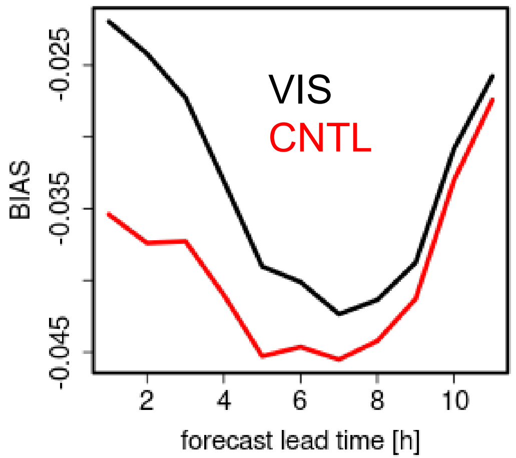
- Earlier experiments : VIS assimilation showed distinct improvement (surface parameters and precipitation)
- Later experiments : Changes in model physics and additional data (3D reflectivities, MODE-S data)
  → suddenly negative impact on precipitation despite improved clouds, humidity

Humidity profiles
(model – obs)

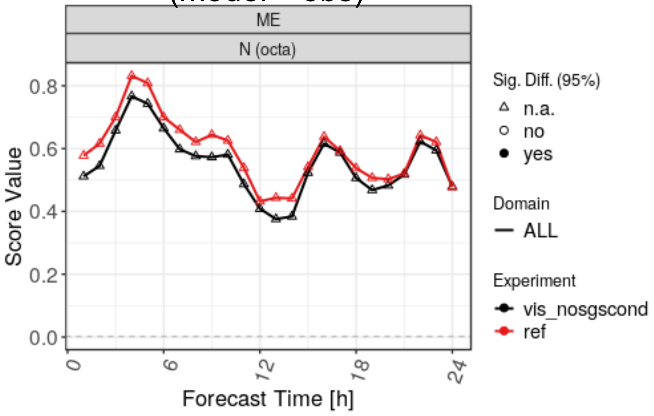


➢ Humidity & clouds improved

Reflectance

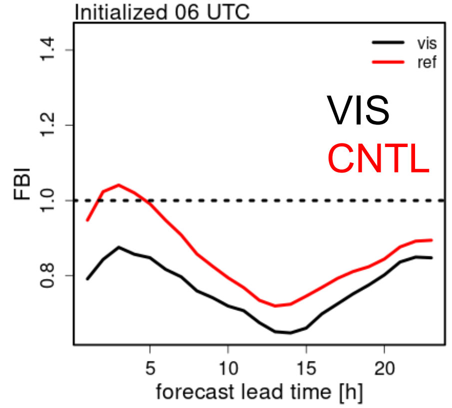


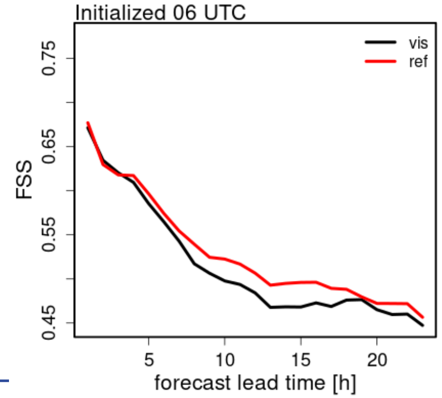
Cloud cover bias
(model – obs)



Precipitation vs radar
FBI, > 0.1 mm/h 06UTC

➢ Precipitation FBI, FSS degraded





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Challenges: DA – model physics interaction

Treatment of subgrid-scale clouds

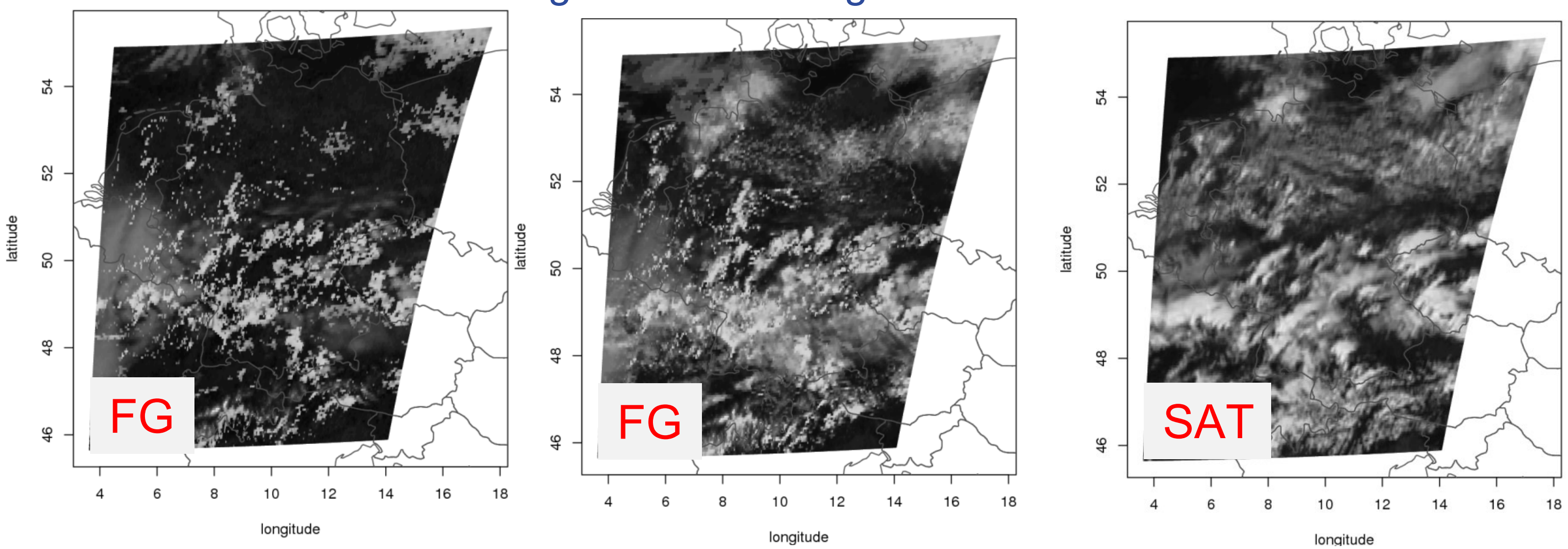
- Interaction with radiation → need to be part of MFASIS forward calculation to avoid reflectance bias
- Depend on cloud scheme, convection scheme, turbulence, grid-scale humidity, ...
- Create correlation of observed reflectances to grid-scale specific humidity

→ Assimilation of VIS influences many model processes, e.g.
- grid-scale humidity
- sub-grid and grid-scale clouds
- precipitation
- radiation
- …

→ Careful joint tuning of assimilation and physics needed

MFASIS results with

grid-scale clouds | grid-scale + subgrid-scale | observations



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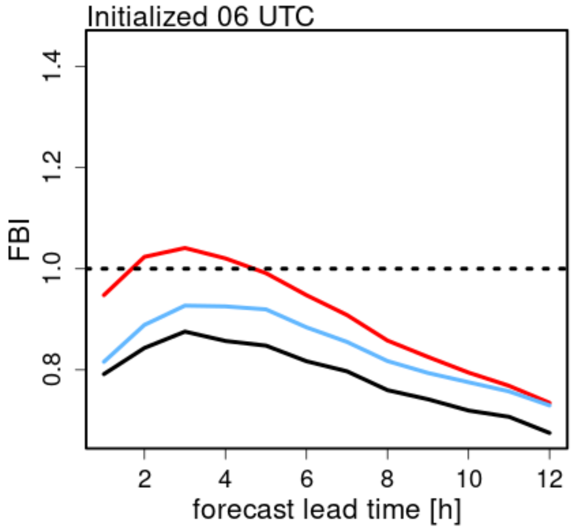
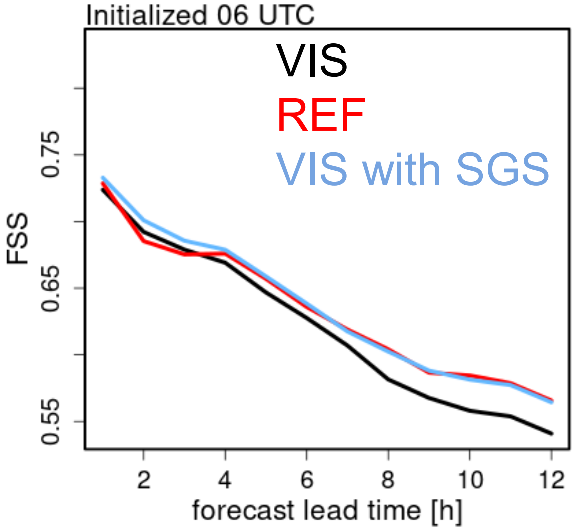
Challenges: DA – model physics interaction

- Extensive tuning & testing with modified physics sub-grid scheme (SGS)
  - Tuning parameter: subgrid-scale clouds as a function of grid-scale humidity
  - Added subgrid-scale condensation heat release to grid-scale T

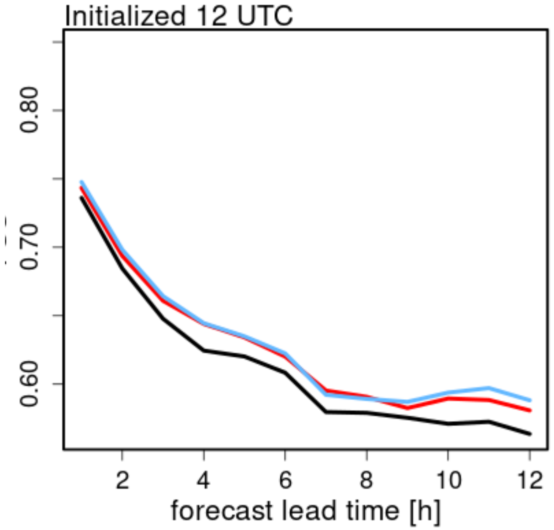
Tuning period:
1 May – 1 June 2022

➢ Retuning of physics achieved:
  - ➢ Remaining small degradation of FBI in this period (esp. removed false alarms)
  - ➢ Solves reduced accuracy in FSS

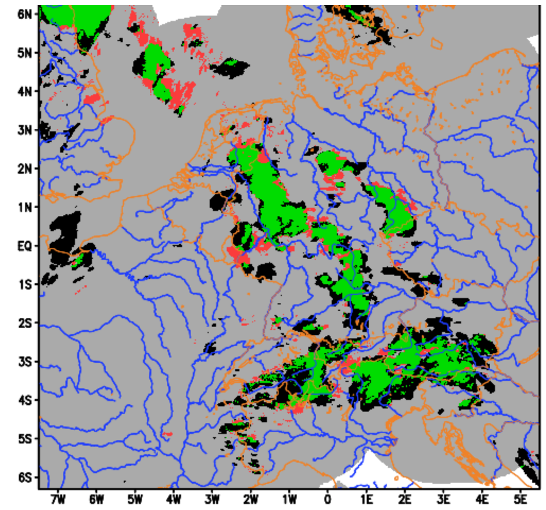




Radar: statistical verification
rr > 0.1 mm/h, 11 pixels



Evaluation of cases:
contingency
map for precipitation



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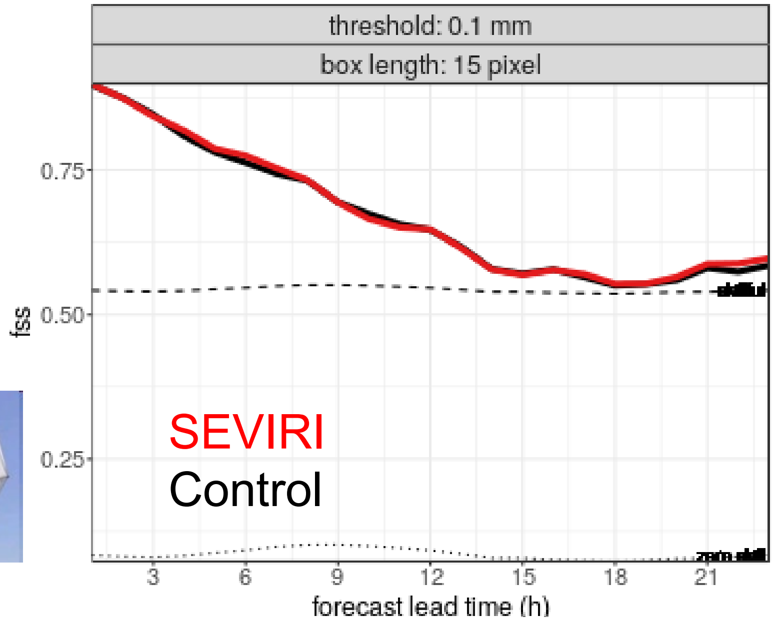
VIS impact: Deterministic forecast

Final tests with ICON-D2 in near-operational environment (period 12.05. – 11.06.2022)

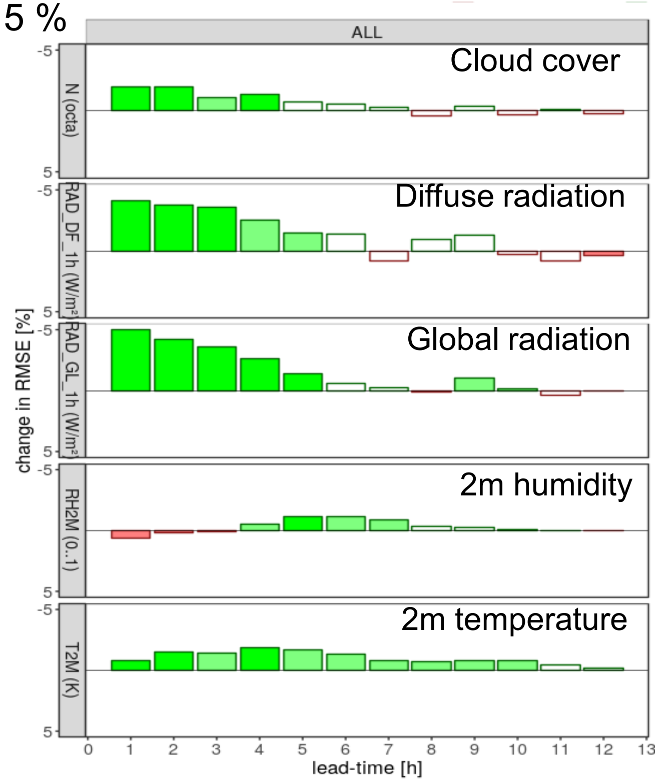
- Positive impact on cloud cover, diffuse & global radiation, T_{2m} & RH_{2m}
- Precipitation: neutral
- Upper air RS verification: neutral

SEVIRI-VIS better
Control better

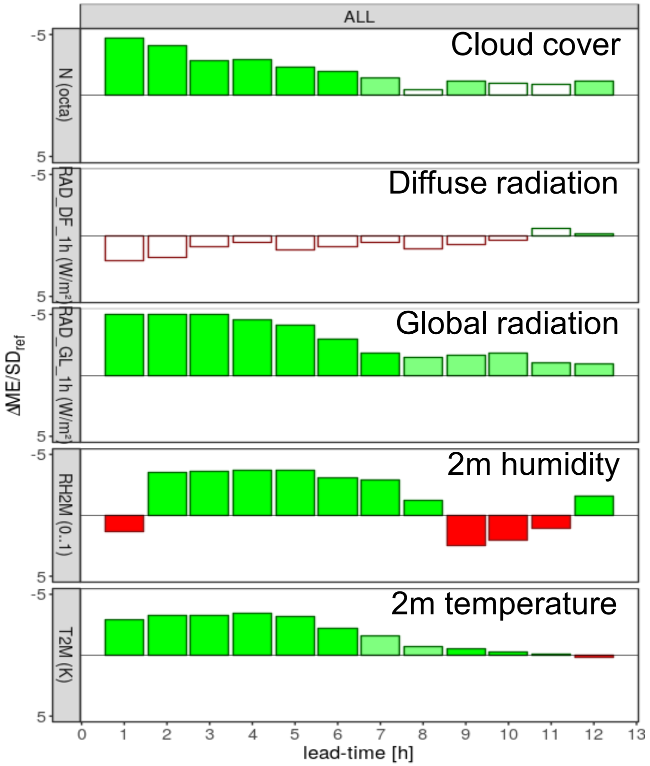
FSS vs. RADAR



RMSE vs. SYNOP



BIAS vs. SYNOP



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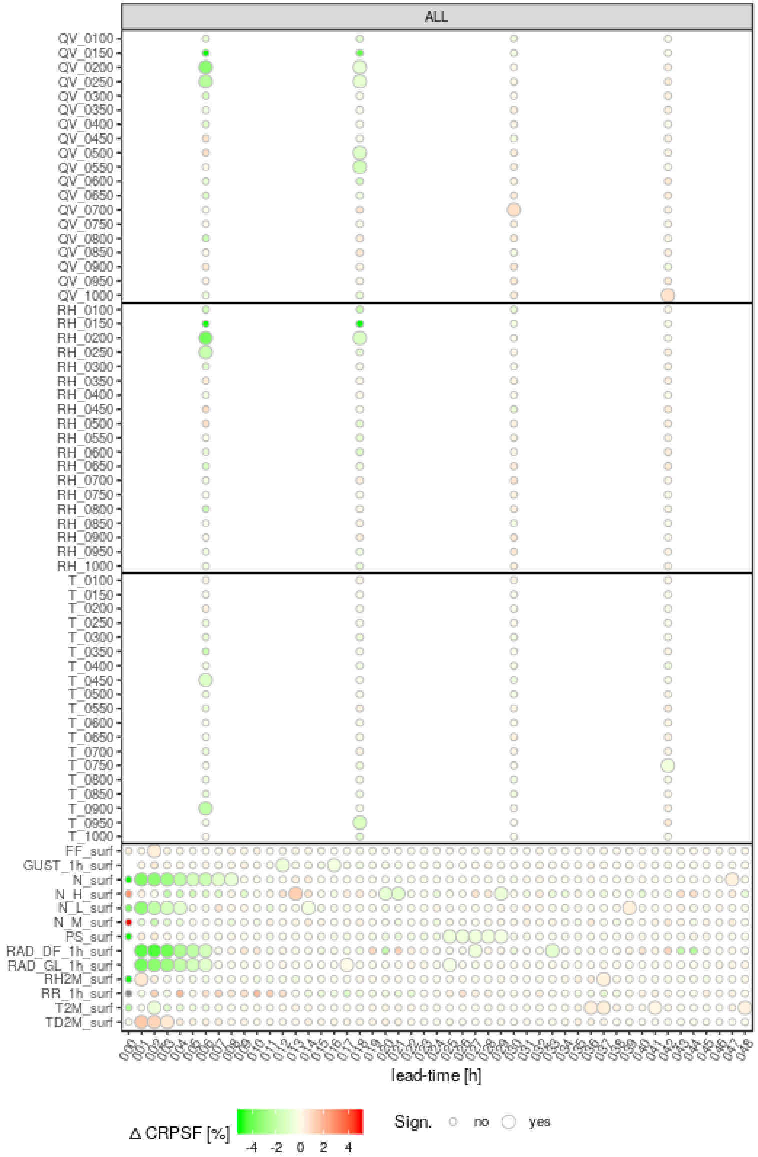
VIS impact: Ensemble

Improvement of CRPS

- Upper air RS verification
- Surface parameters:
  - Cloud cover
  - Global & diffuse radiation
  - T_{2m}

➢ VIS data assimilation has clear positive impact on the skill of the ICON-D2-EPS system



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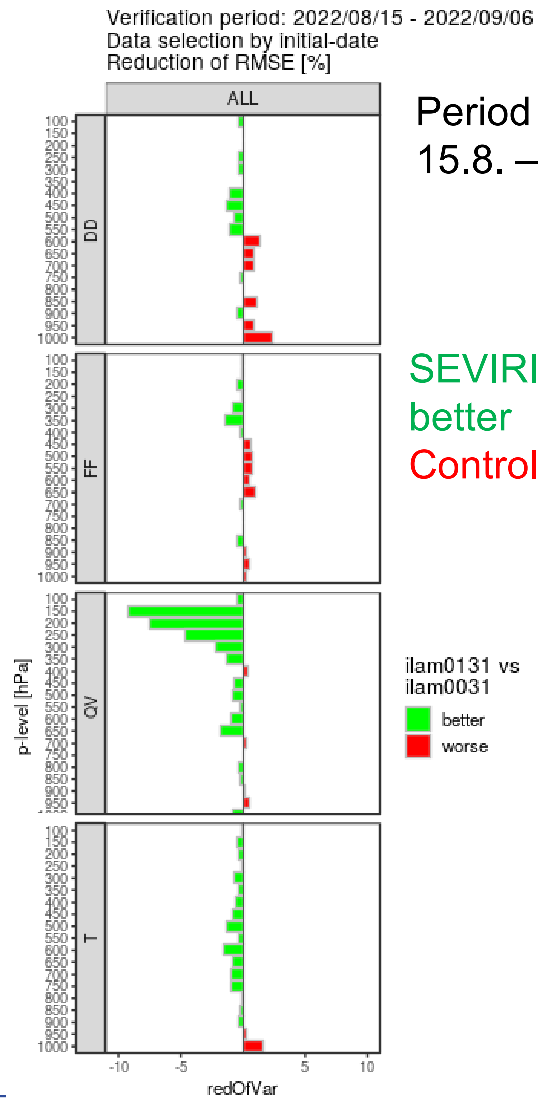
All-sky assimilation: Visible and WV radiances

70 Jahre
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

- Combination of visible (0.6 µm) and WV radiances (6.2 µm and 7.3 µm)
  - Details on all-sky WV channel assimilation: see poster 4p.10

- Requires new tuning also for VIS assimilation:
  - Use data at consistent positions: both with horizontal thinning every 4th/2nd pixel, horizontal localization 25 km
  - Vertical localization:
    - VIS: main influence in low troposphere (localized around 800 hPa)
    - WV: higher troposphere (localized around level of channel transmittance 0.5)
  - Control experiment includes SEVIRI VIS
    - Positive impact of WV all-sky, esp. on higher level humidity



Period
15.8. – 9.6.2022

SEVIRI WV exp better
Control better

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Summary & outlook

- VIS reflectance: have clear positive impact on forecasts up to 12 h
- Improvements especially for surface parameters, ensemble verification
- Impact depends on season (e.g. daylight conditions), weather regime, overall observation use
- Implementation status:
  - Operational introduction in ICON-D2 in March 2023
  - SINFONY - RUC runs continuously with visible assimilation (to be operational in 2024)
  - Implementation of SEVIRI water vapour radiances (all-sky) planned for 2023
- Next steps
  - Upgrade to RTTOV v13.2 (MFASIS-NN)
  - Preparation for FCI
- Global:
  - Preparation of all-sky capability ongoing
  - VIS used for model diagnostics (see poster 1p.05)

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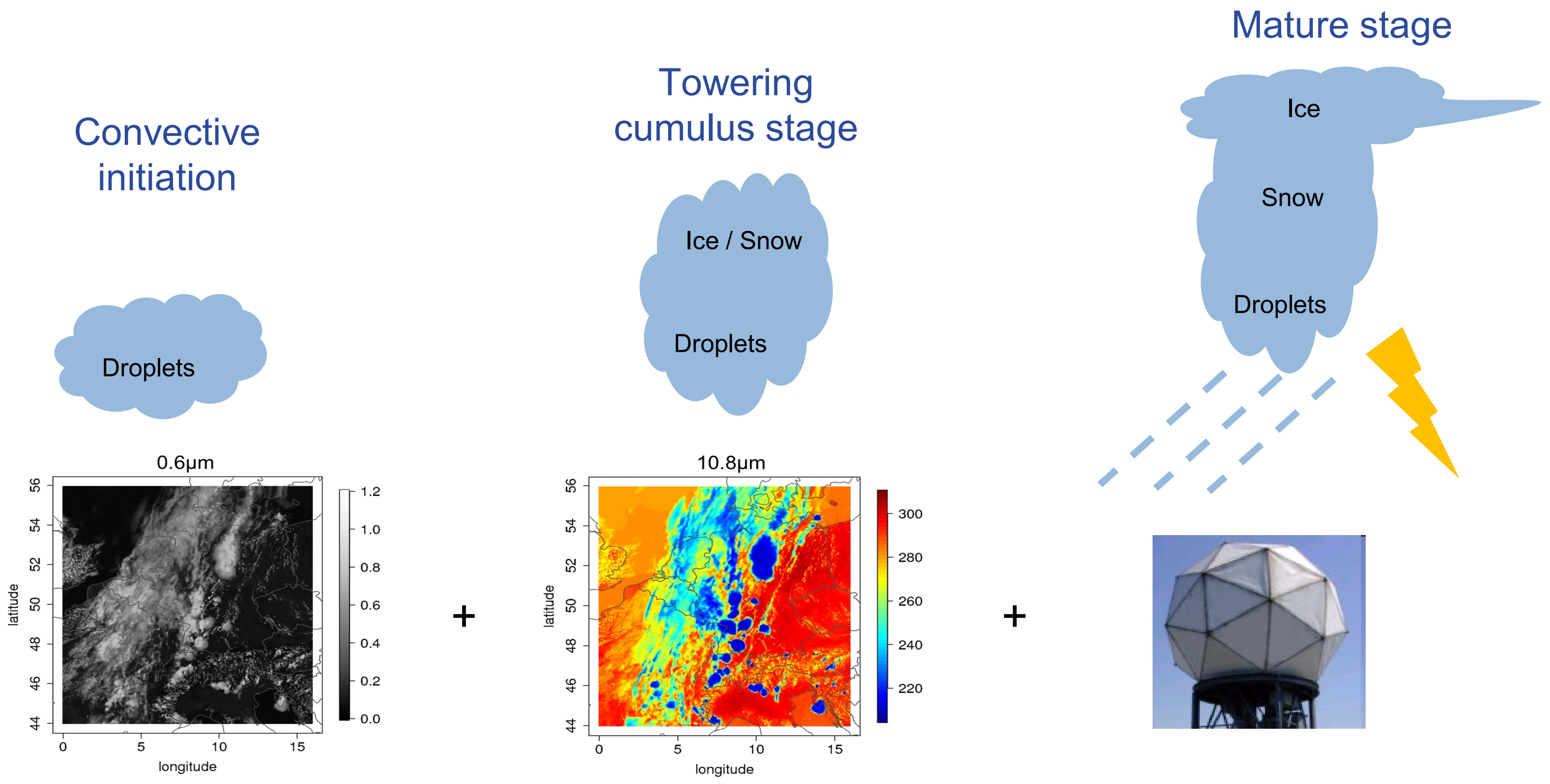
Visible data in the life cycle of convection



Aim: Constrain cloud mass and positions already at convective initiation!