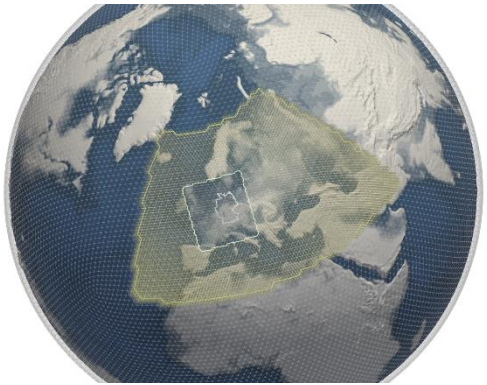
Innovation for Model Development in Numerical Weather Prediction



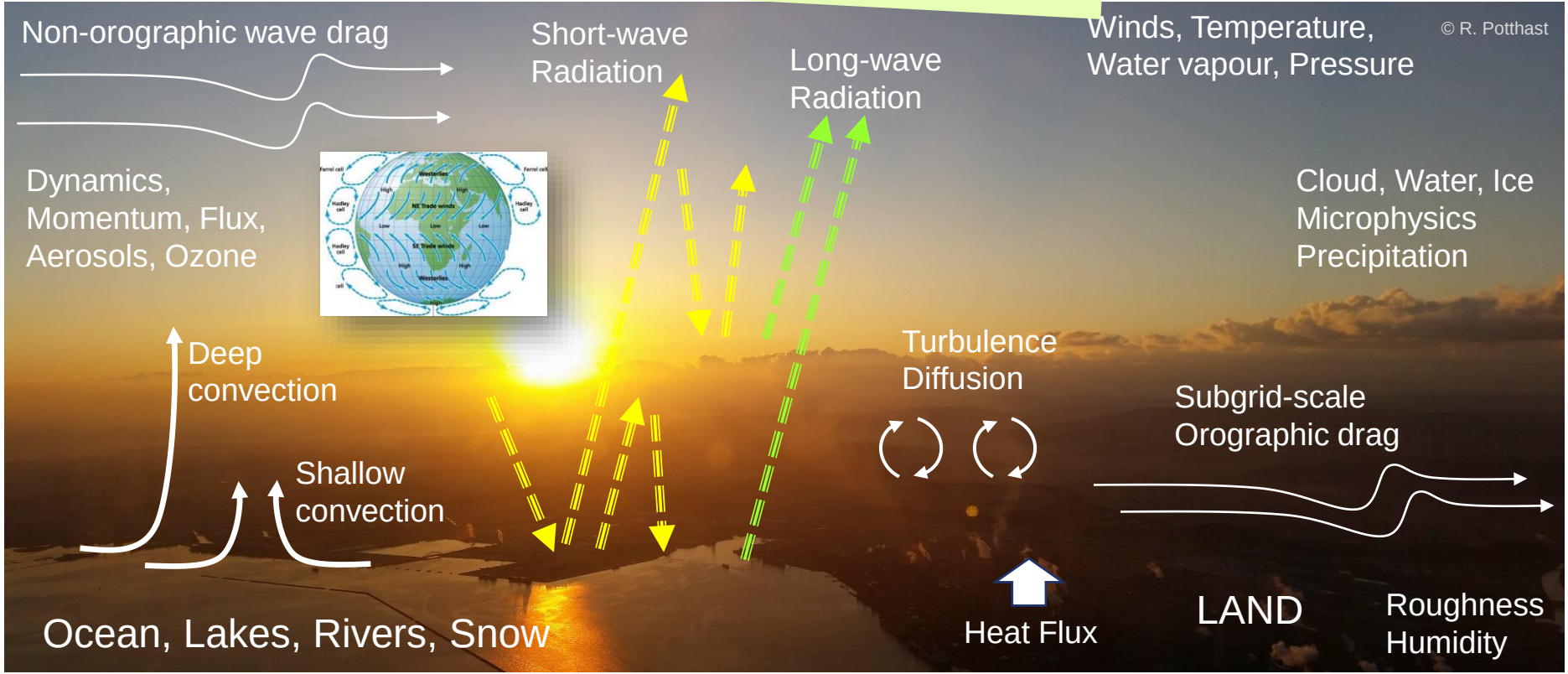
Roland Potthast

9/2022

NWP – Processes

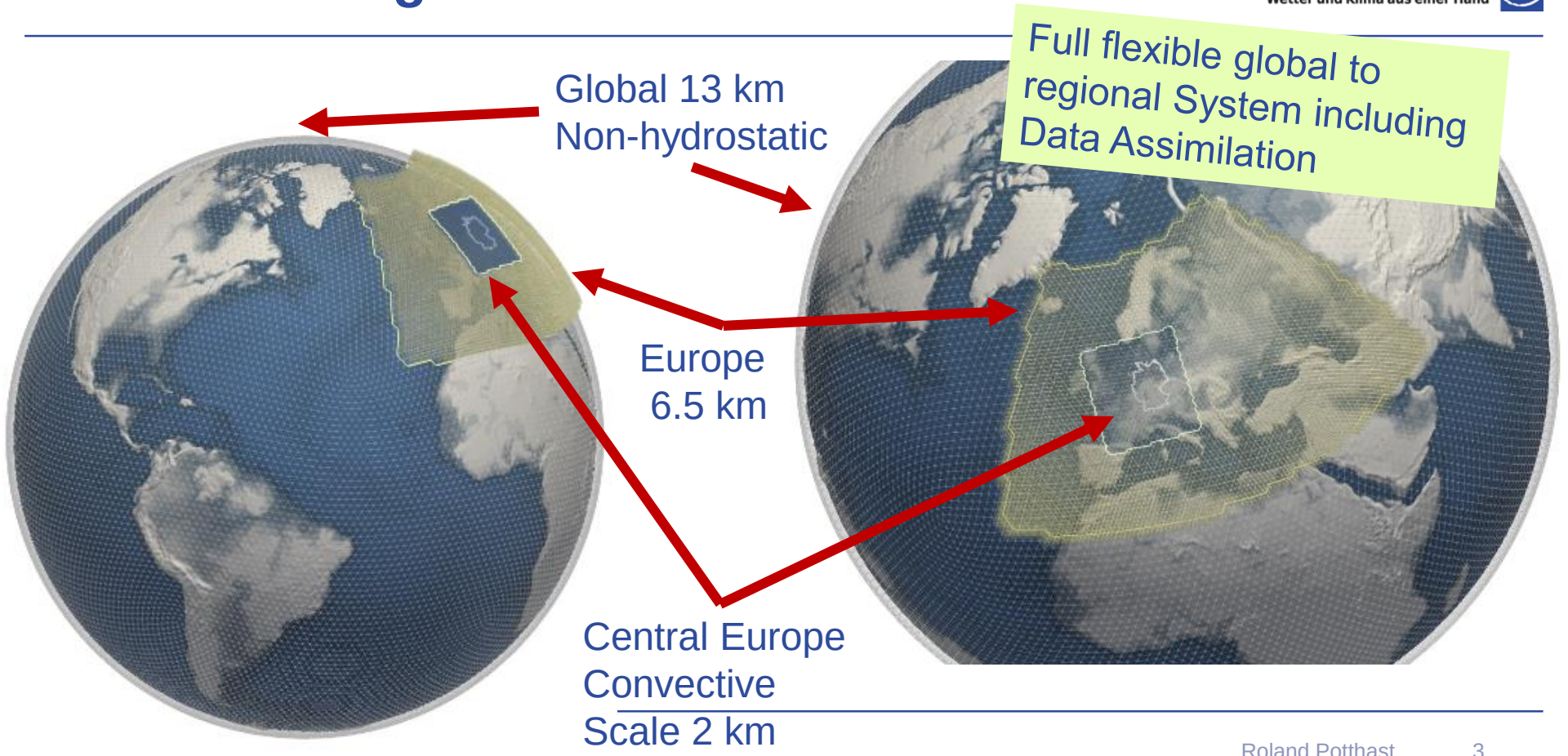
Resolved and parametrized processes – grey zone

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



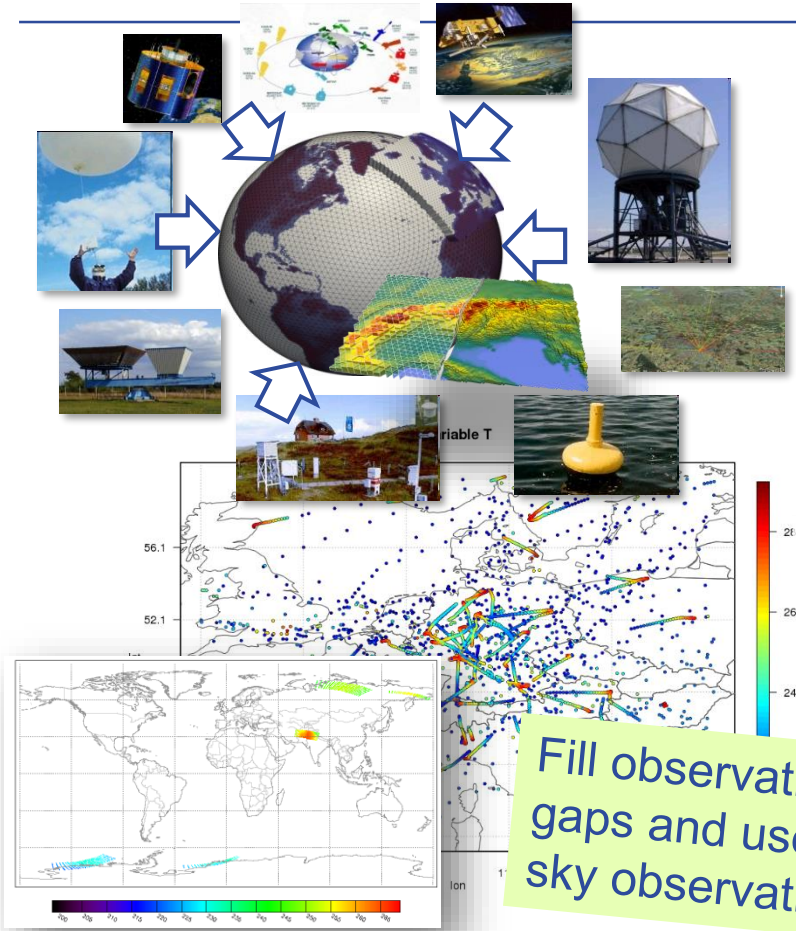
Global-to-Regional ICON with Ensemble DA

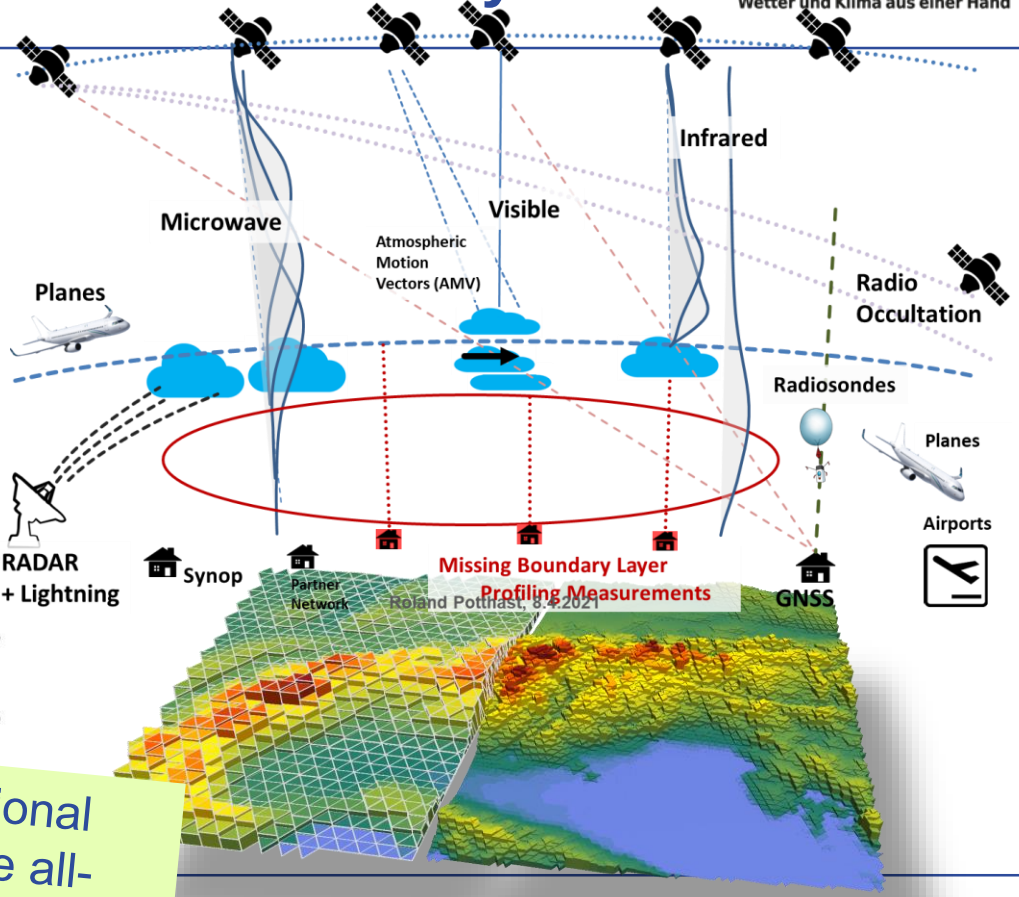
Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Data Assimilation in High-Dimensional System

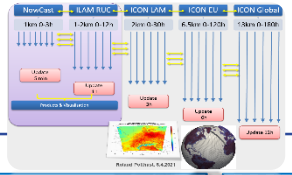
Deutscher Wetterdienst
Wetter und Klima aus einer Hand





Fill observational gaps and use all-sky observations

NWP Model-Chain 09/2022



Deutscher Wetterdienst
Wetter und Klima aus einer Hand

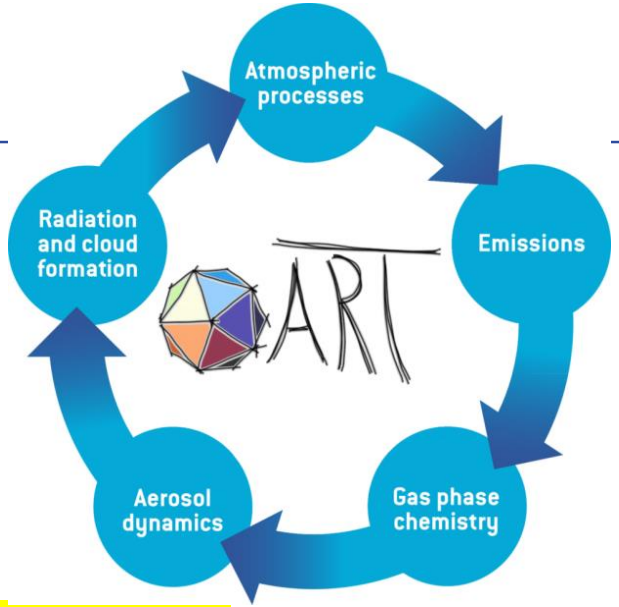
ICON Global Non-Hydrostatic	ICON-EU 2-way-nest	ICON D2 LAM Convective Scale	ICON-D2 RUC Convective Scale
Det **13 km** Resolution EPS 40 km Resolution 90 level	Det **6.5 km** Resolution EPS 20 km Resolution 60 level	Det **2 km** Resolution EPS **2 km** Resolution 65 level	Det **2 km** Resolution EPS 2 km Resolution 65 level
40 member	40 member	40 member	40 member
Analysis every 3h	Analysis every 3h	**Analysis every 1h**	**Analysis every 1h**
EnVAR + LETKF	EnVAR + LETKF	KENDA: 4D-LETKF	KENDA: 4D-LETKF
Forecasts **180h: 00,12 UTC** **120h: 06, 18 UTC** **51h: 03, 09, 15, 21UTC**	**Forecasts** **120 h: 00, 06, 12, 18 UTC** **51 h: 03, 09, 15, 21 UTC**	**Forecasts** **48h: 00, 03, 06, 09, 12, 15, 21 UTC**	**Forecasts** **8h: 06, 07, 08, … 17, 18 UTC**

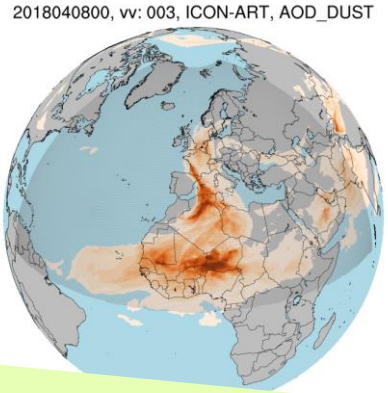
Move to more frequent forecasting

ICON ART in Operations

WORLD METEOROLOGICAL ORGANIZATION

Emergency Response Activities (ERA)





- ✓ **RSMC Nuclear** Emergency Setup Operational
- ✓ **RSMC Non-Nuclear** Emergency Setup Operational
- ✓ ICON-ART **Operational Pollen Forecast** Operational
- ✓ ICON-ART **Volcanic Ash** Emergency Setup Pre-Operational
- ✓ ICON-ART **Mineral Dust** *Near-Realtime* *Test System*

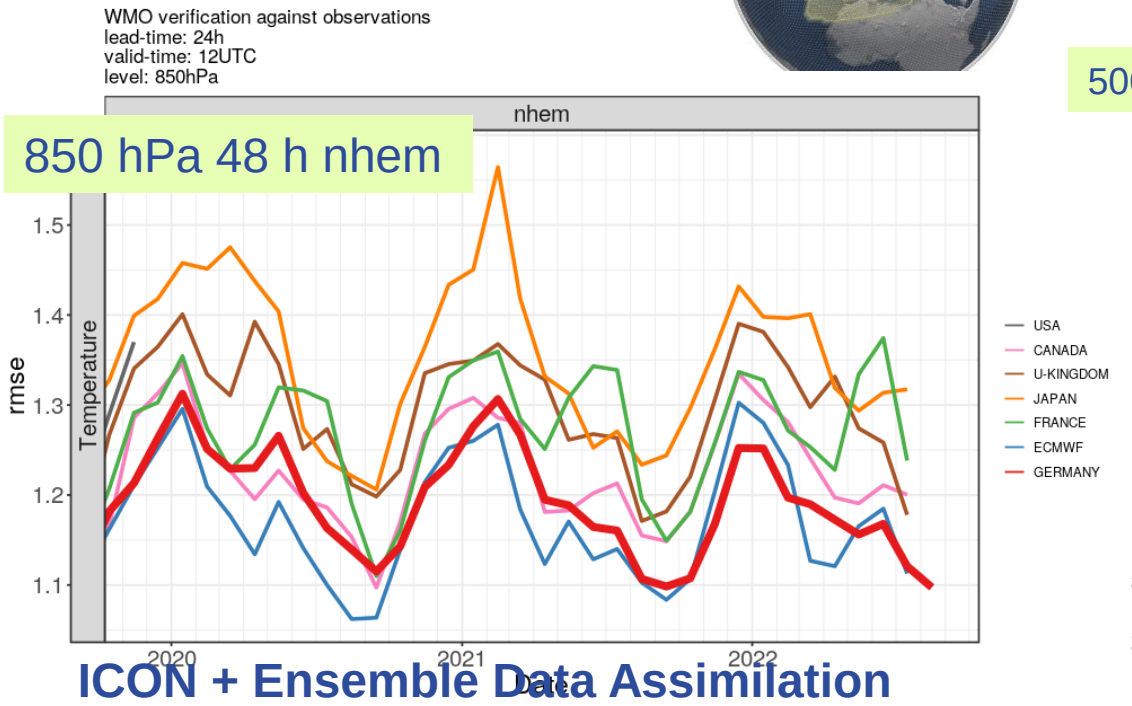
More complexity: ART and Coupled Systems

ICON Quality NWP

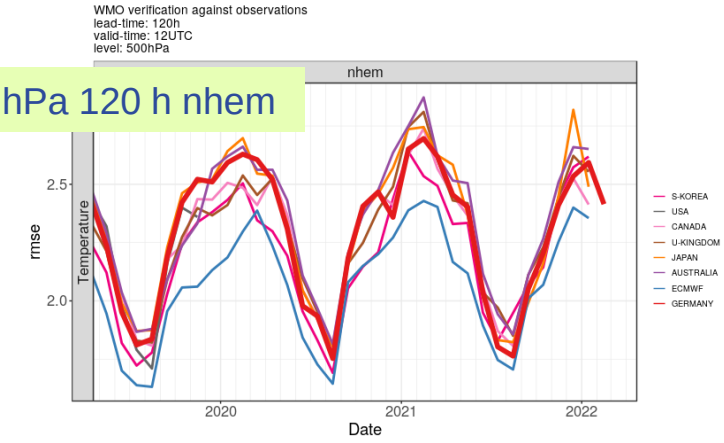
Better Predictions

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

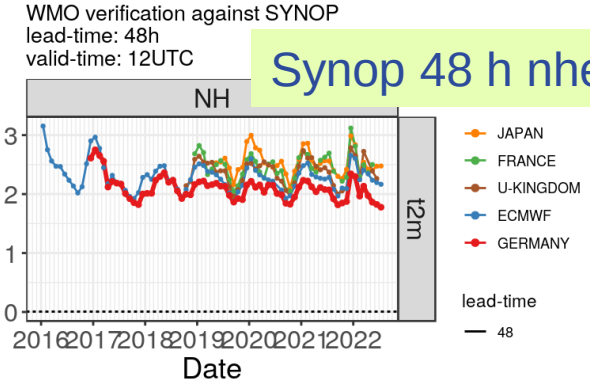
850 hPa 48 h nhem



500 hPa 120 h nhem



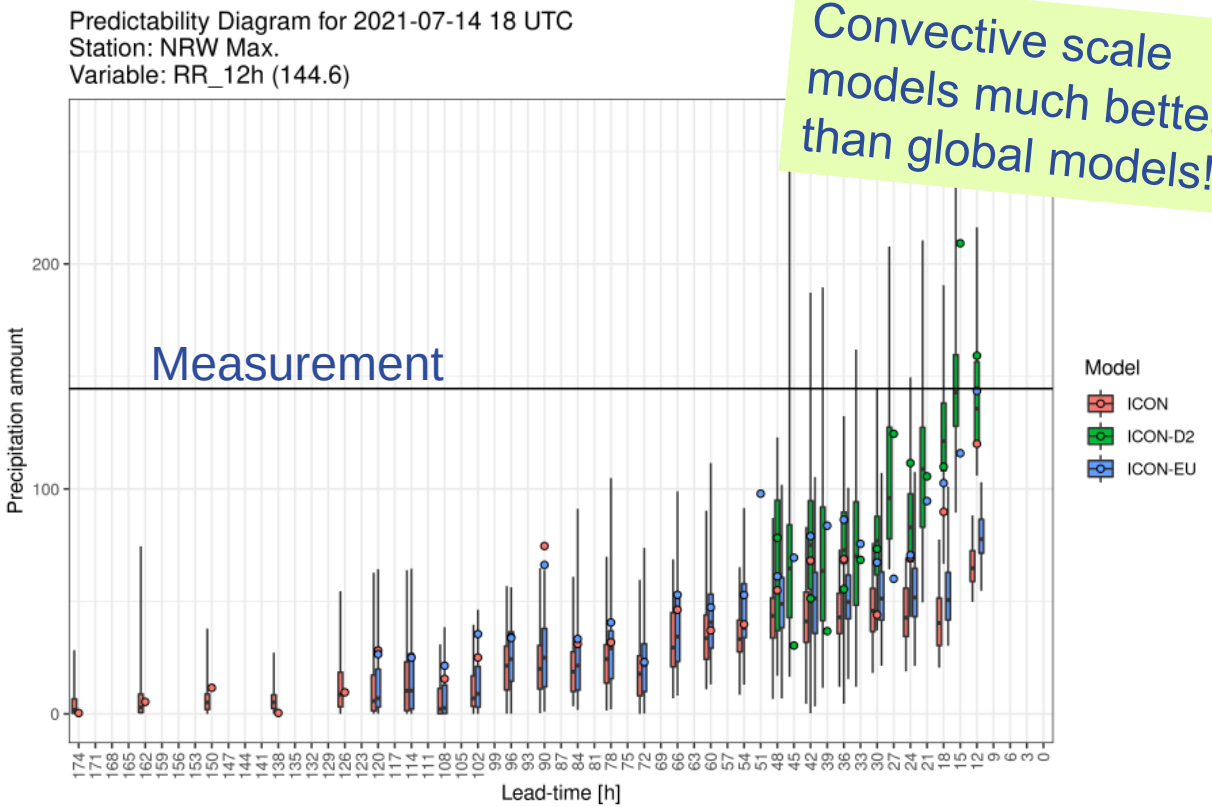
Synop 48 h nhem



ICON + Ensemble Data Assimilation

14 NWP Centres with global Forecasts,
ICON well positioned in in Top Group

Scales and Precipitation Prediction!



Convective scale models much better than global models!

Precipitation
Prediction by

ICON-global,
ICON-EU,
ICON-D2

Important Applications and Partners

SINFONY R&D Topics

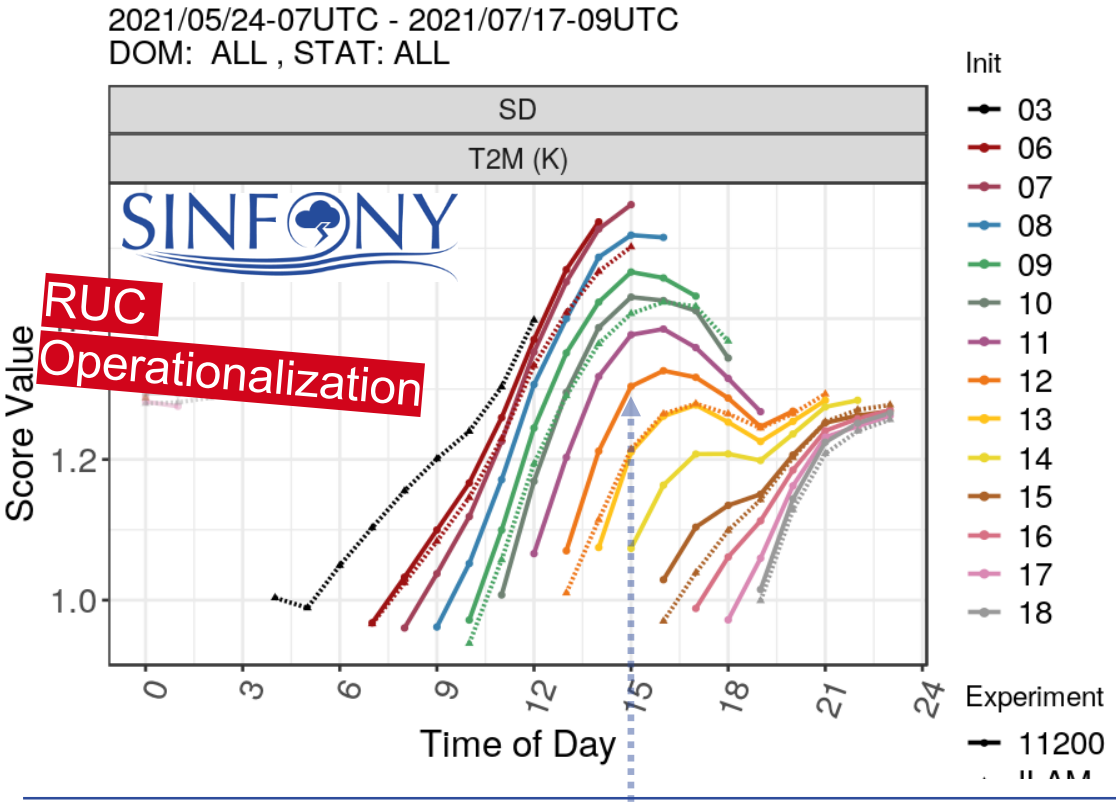
Seamless Integrated Forecasting

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

- **NWC-NWP Integration** by
  - NWP Rapid Update Cycle **RUC** with hourly forecasts
  - using the same **observations** (3D-RADAR, SEVIRI VIS, Lightning, …)
  - **uncertainty estimation** by ensembles **EPS** on all components NWC+NWP
  - using NWC Information in NWP
    - **RADAR object assimilation**,
    - assimilation of nowcasted objects **NWC-DA**
  - using NWP information in NWC
    - life cycle estimates, initialization using DA techniques and AI/ML

- **Seamless Products in observation space (RADAR, clouds)**
  - STEPS **multiscale nowcasting** for precipitation fields
  - ensemble selection and composition methods in **object space**
  - **guiding nowcasting EPS** through NWP using an EnKF

RUC: Advantage of timely EPS Initialization



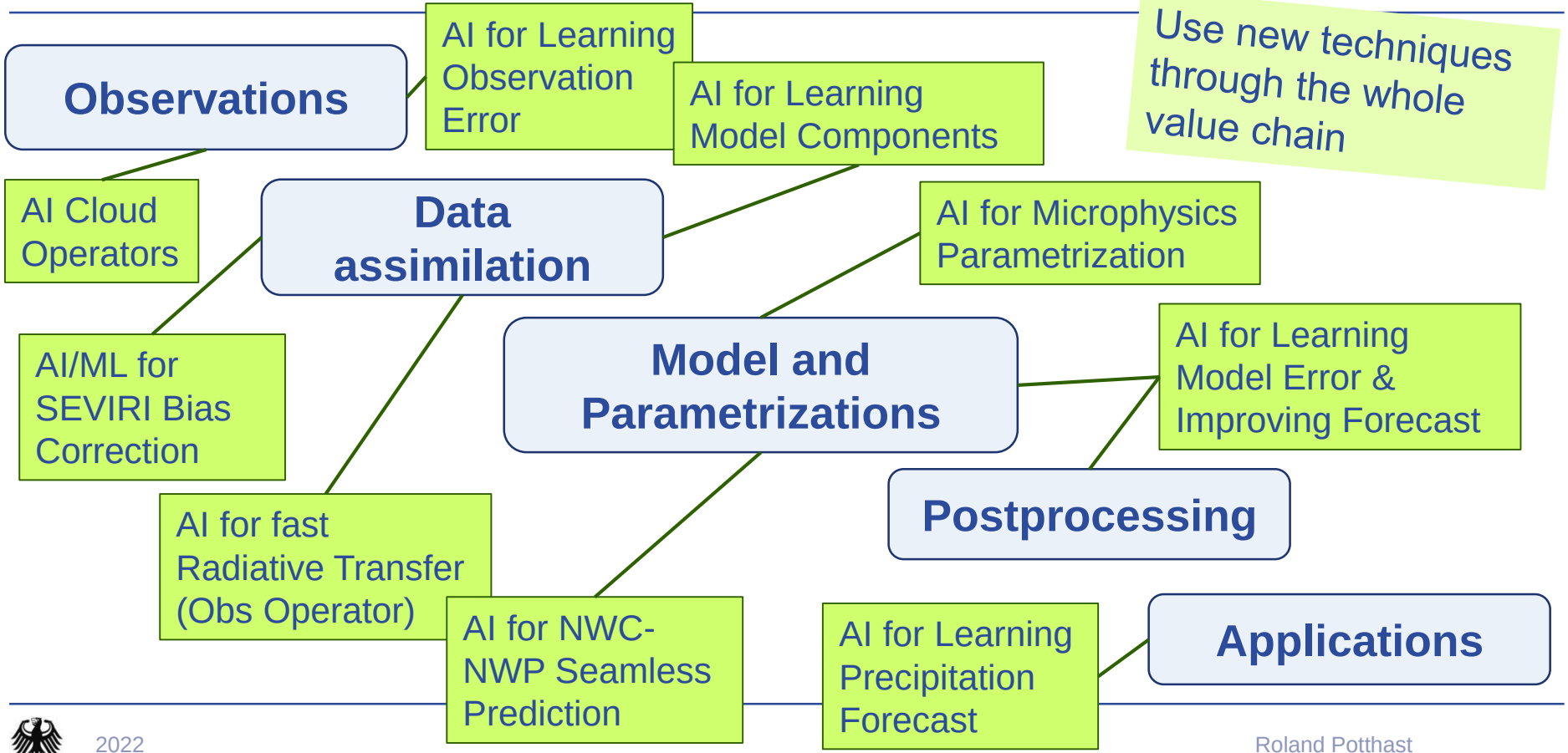
Best forecast: lower error curve

Experimental KENDA RUC System 2022

- Hourly Initialization by EDA
- Hourly Forecast Runs, 8h
- Spin-off from classical cycle at 3 UTC
- **Younger Fast Initialization shows Best Scores** for several hours
- 3-hourly KENDA with **more observations** better after 5 hours

AI in NWP – DWD Project World

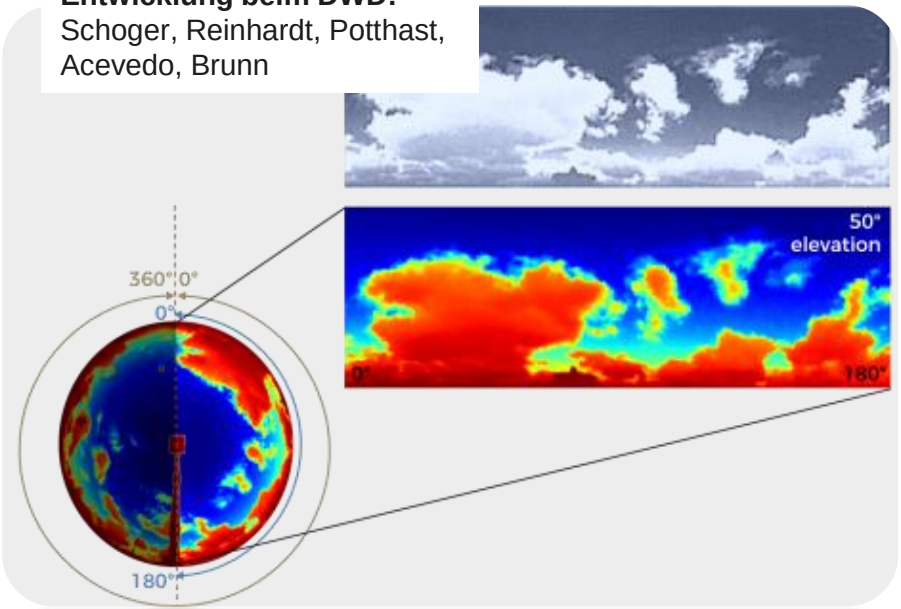
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

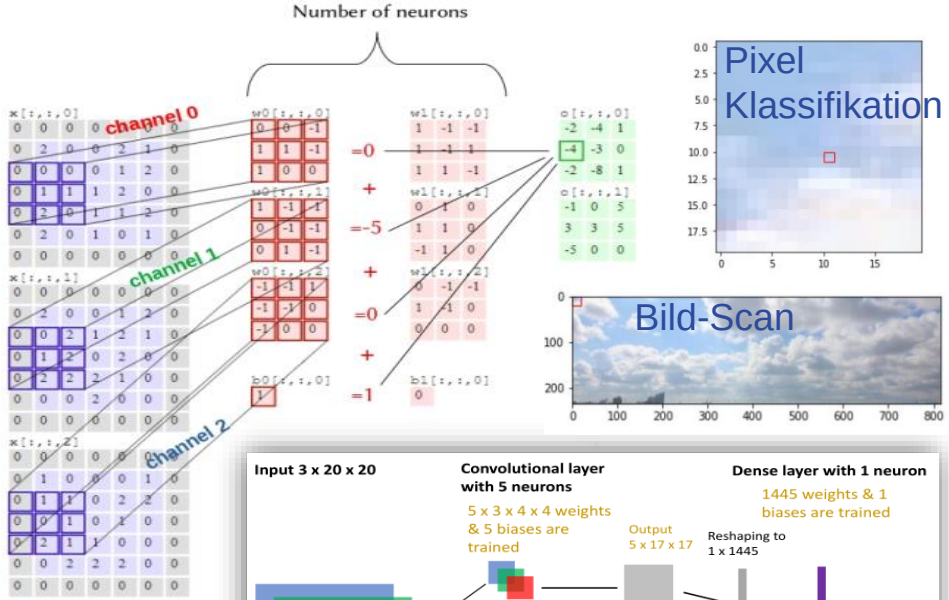


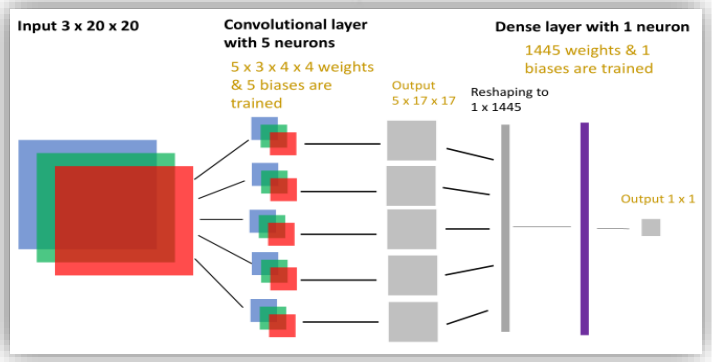
ICamCloudOps: Webcams + AI

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Entwicklung beim DWD:
Schoger, Reinhardt, Potthast, Acevedo, Brunn







Deep Neural Network for Cloud Identification and Classification

NWP Research Themes at DWD (selection)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand
DWD

- High-Resolution Forecasting global-to-regional
- GPU-CPU Computing Architectures for ICON
- ICONIC Icon in the Cloud

- Convection parametrization and resolved convection
- Turbulence TKE-SV
- Microphysics parametrizations, ART and AI

- Stochastic Perturbation Methods for EPS
- Singular Vectors SV

- Multi-Fidelity or heterogeneous (h-EPS) Ensemble Assimilation and Forecasting

- Discontinuous Galerkin Dynamical Kernel
- Wind-Park Roughness Parametrization

- Model-Data-Assimilation-Coupling (MDAC)

- 4D-EnVAR
- cEnVAR
- Particle Filters
- Feature Data Assimilation

Fully balanced innovative systems

- Ocean data assimilation
- Coupled data assimilation (Atm.-L)
- EnVAR (& LETKF) for surface data assimilation

- High-resolution observations assimilation
- All-Sky Data Assimilation Global-to-Regional
- Lightning Obs in DA

- Pilot Station Boundary Layer Obs Assimilation