

Artificial Intelligence (AI) meets Numerical Weather Prediction (NWP)

ICamCloudOps Webinar, March 2, 2022

Roland Potthast, Frederik Kurzrock, Maria Reinhardt, Walter Acevedo,
Leonhard Scheck

1. **NWP** – Purpose, Processes, Components
2. **AI** – Functions, State-of-the-Art, Promise
3. **AI in NWP** – Concepts and Project World
4. **ICamCloudOps:**
 1. **Webcams, AI for Cloud Identification and Characterization**
 2. **Infrared-Cameras, Radiative Transfer and AI**
 3. **Wind-Retrievals based on Flow-Filtering and AI**
5. **Assimilation and Forecasts based on AI+Cloud Operators**

1 NWP – Purpose

Predict Weather Renewable Energy



Wind and Photovoltaics



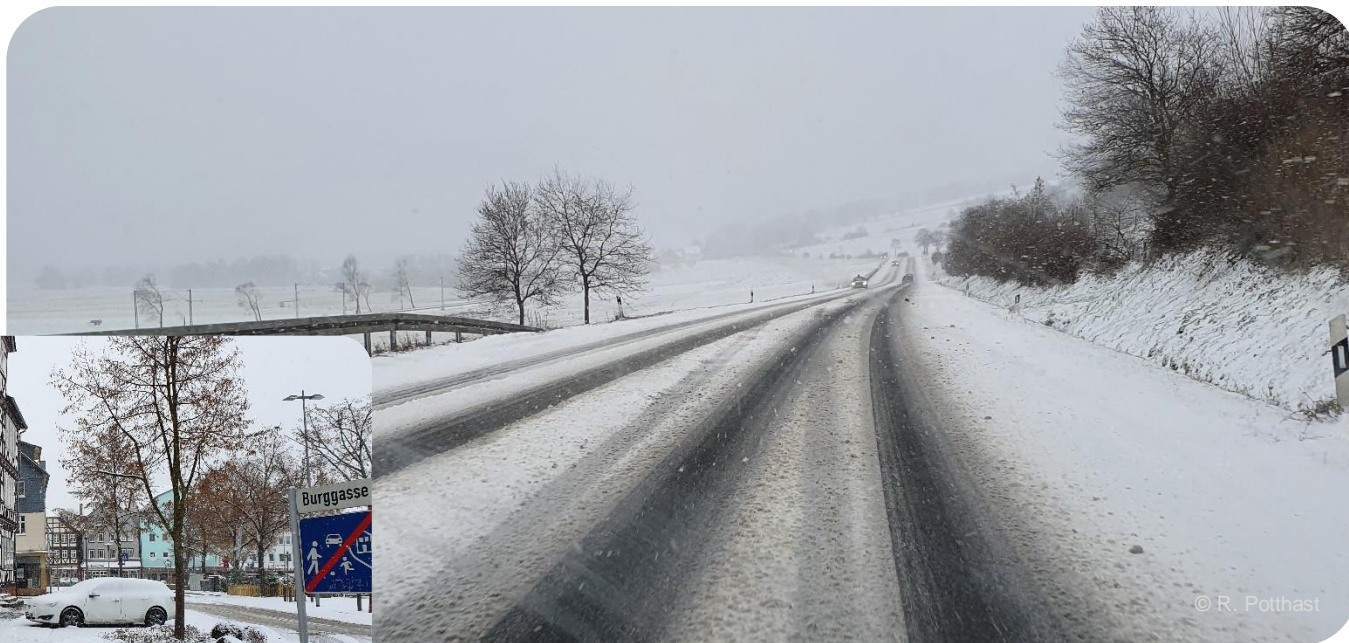
1 NWP – Purpose

Predict Weather Extremes and Flooding



1 NWP – Purpose

Predict Weather
Snow, Ice, Storm



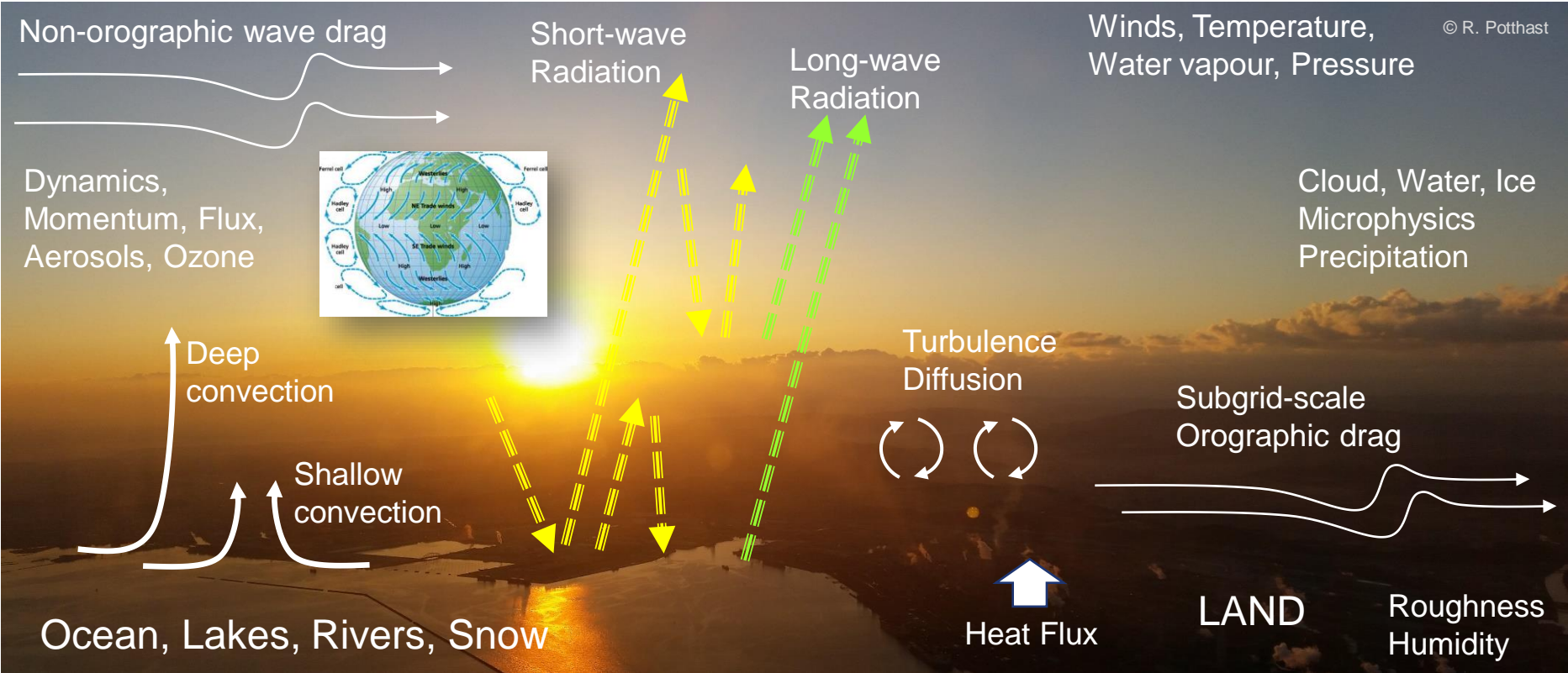
1 NWP – Purpose

Predict Weather
Air Traffic, Turbulence,
Clouds, Storms



1 NWP – Processes

© R. Potthast



1 NWP – Components

Model

Parametrizations

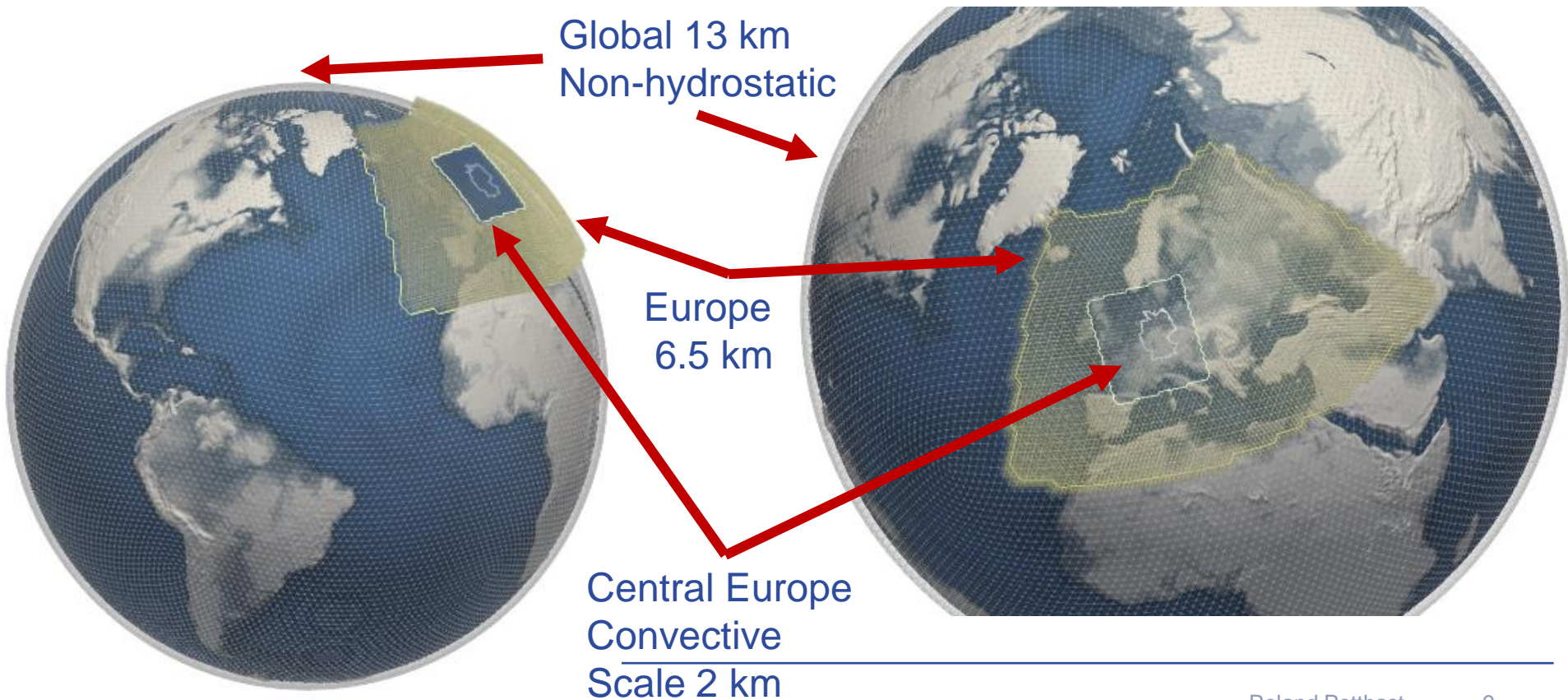
**Forecast
Variability**

**Observations &
Obs-Operators**

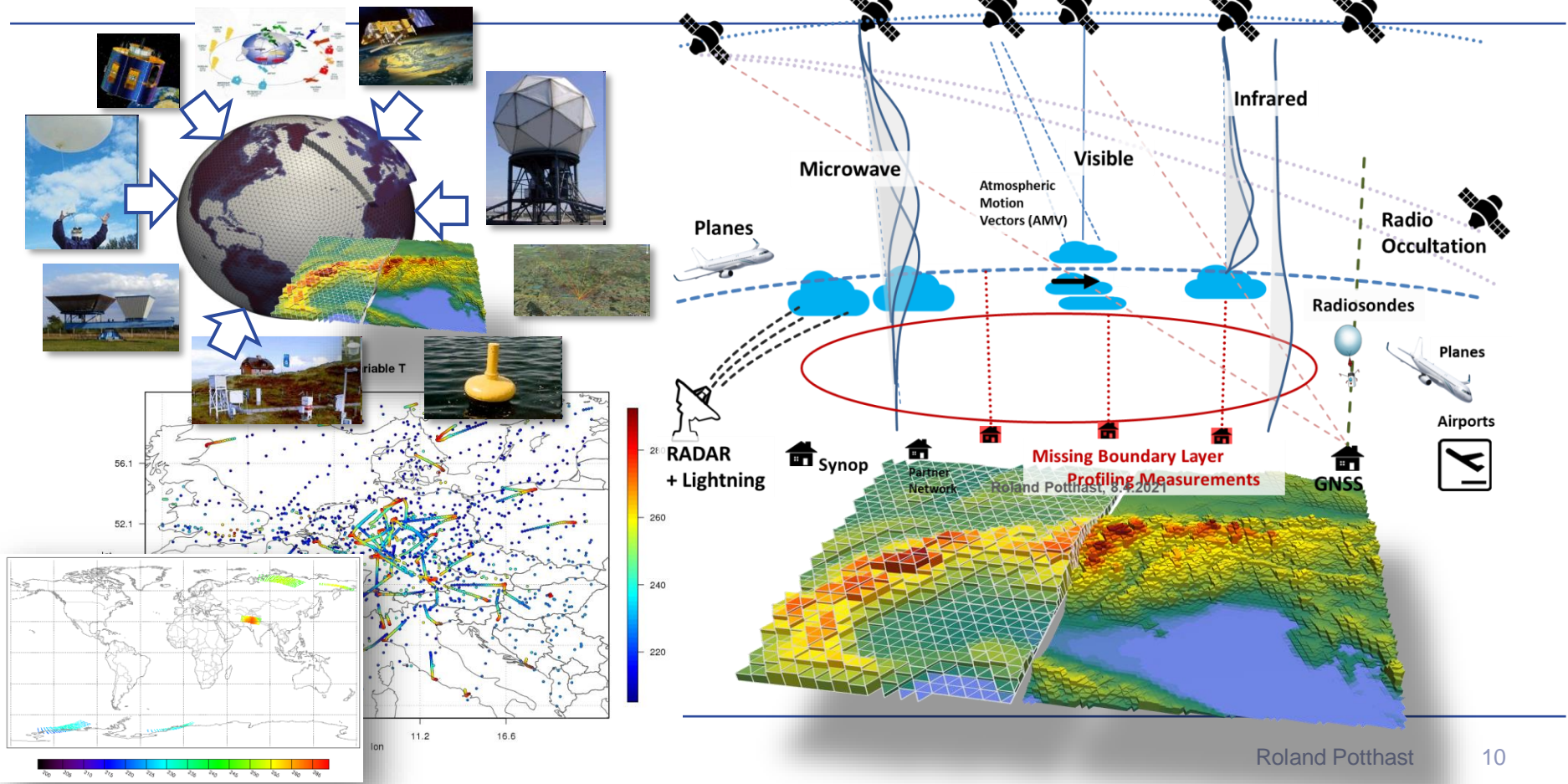
**Assimilation
Algorithms**

Verification

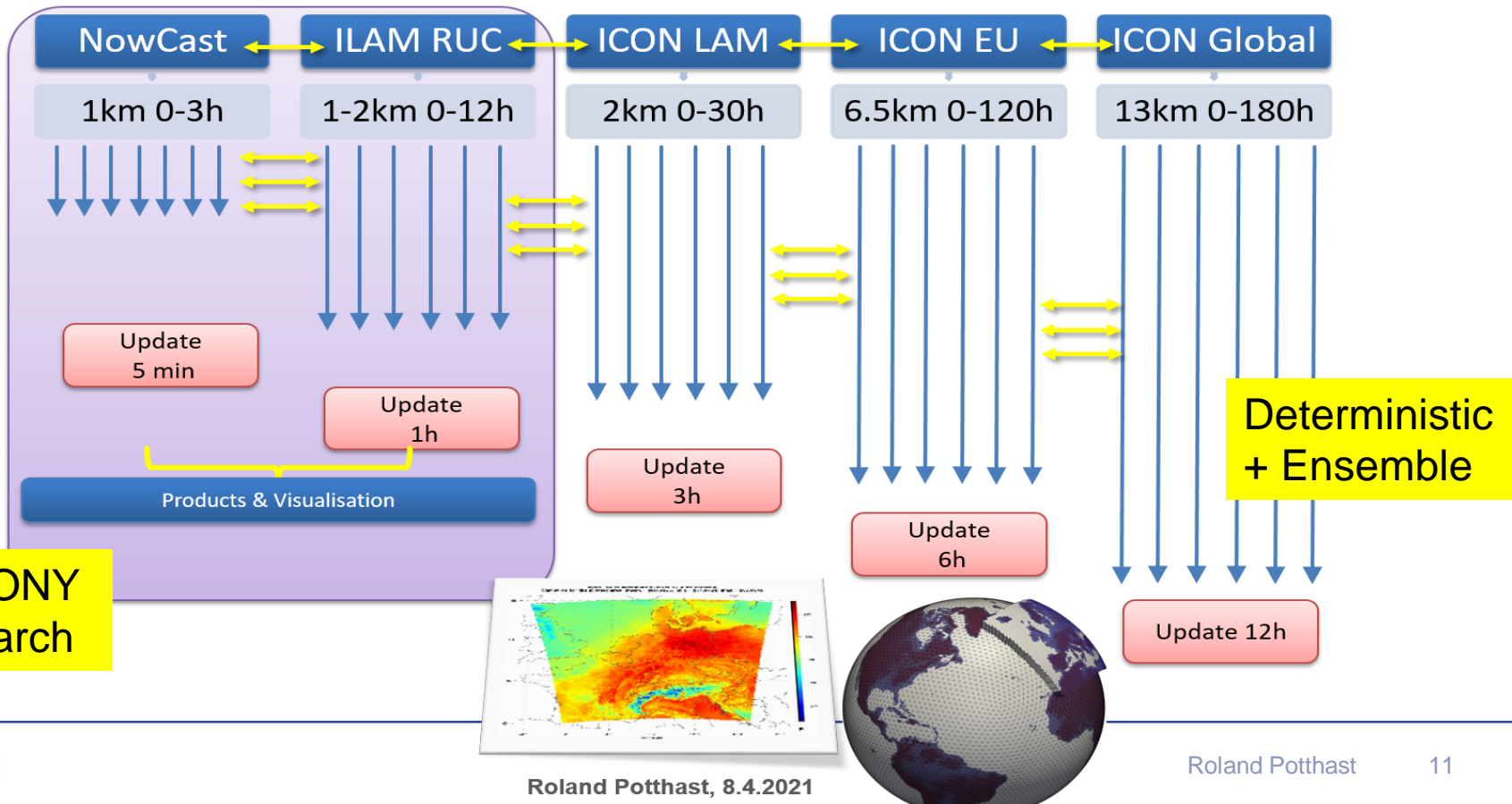
Global Model: ICON with Ensemble DA



Data Assimilation in High-Dimensional System



Operational System Setup



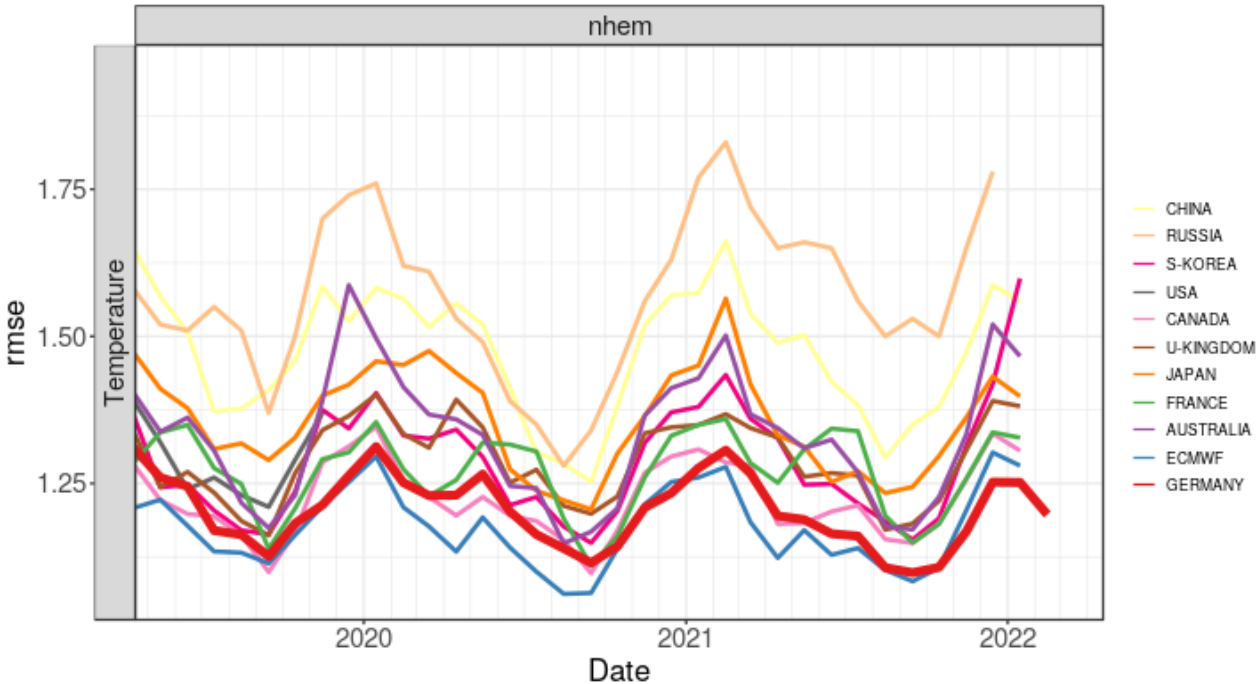
SINFONY
Research

Deterministic
+ Ensemble



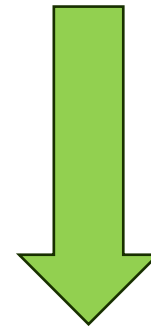
ICON Status – International Comparison

WMO verification against observations
lead-time: 24h
valid-time: 12UTC
level: 850hPa



850 hPa, 24-48 h Upper Air

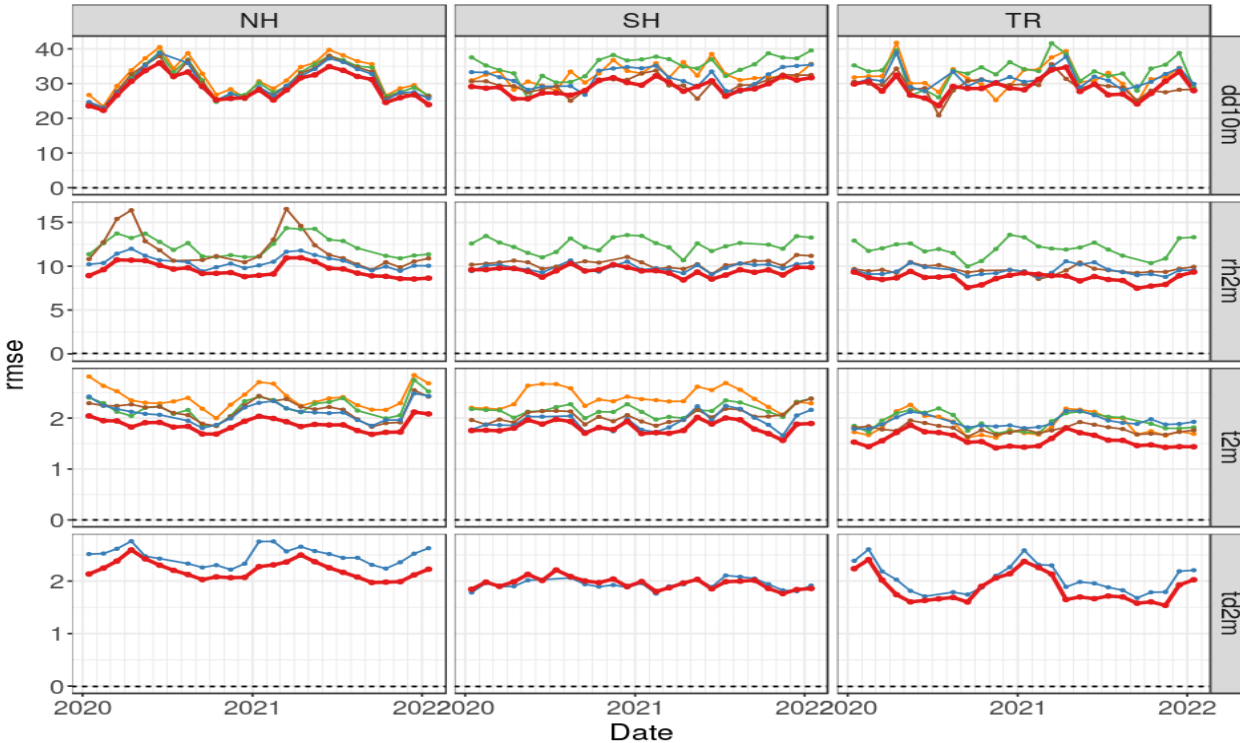
ICON similar to EMCWF



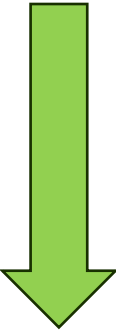
Better

ICON Status – Surface Scores

WMO verification against SYNOP
lead-time: 24h
valid-time: 12UTC



Better



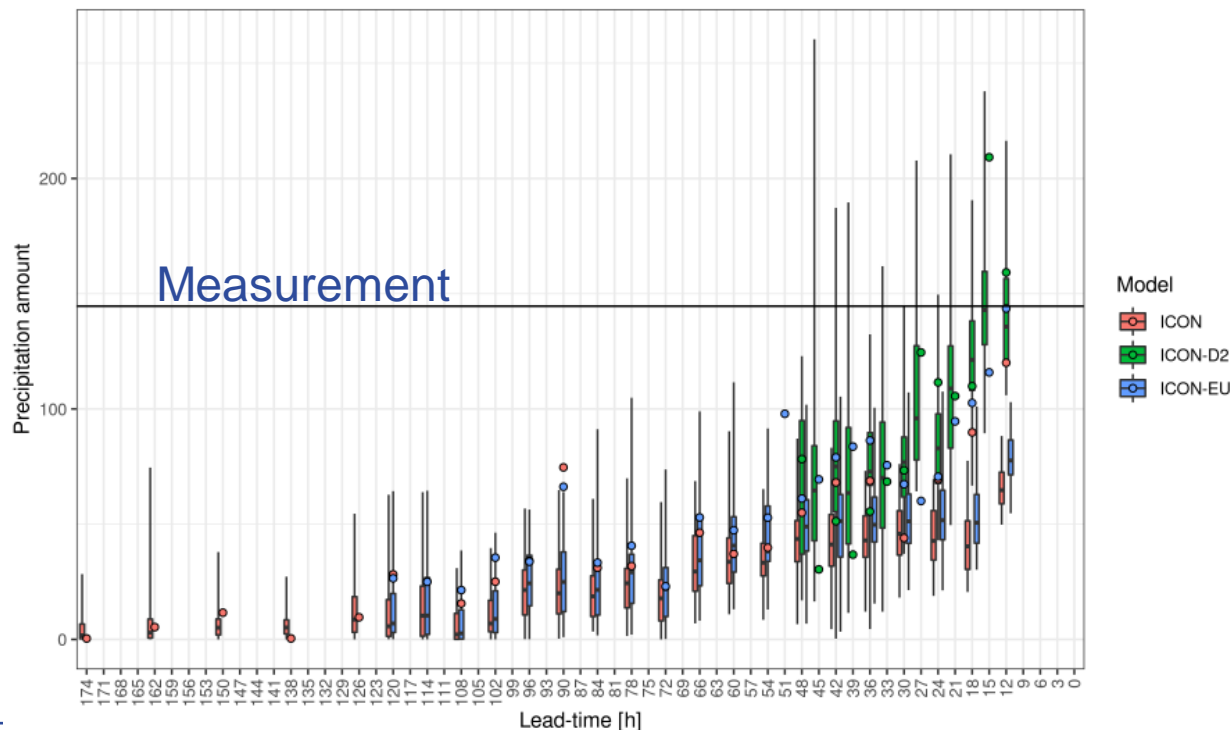
SYNOP, 24-72 h

ICON best



Scales and Flood Prediction!

Predictability Diagram for 2021-07-14 18 UTC
Station: NRW Max.
Variable: RR_12h (144.6)

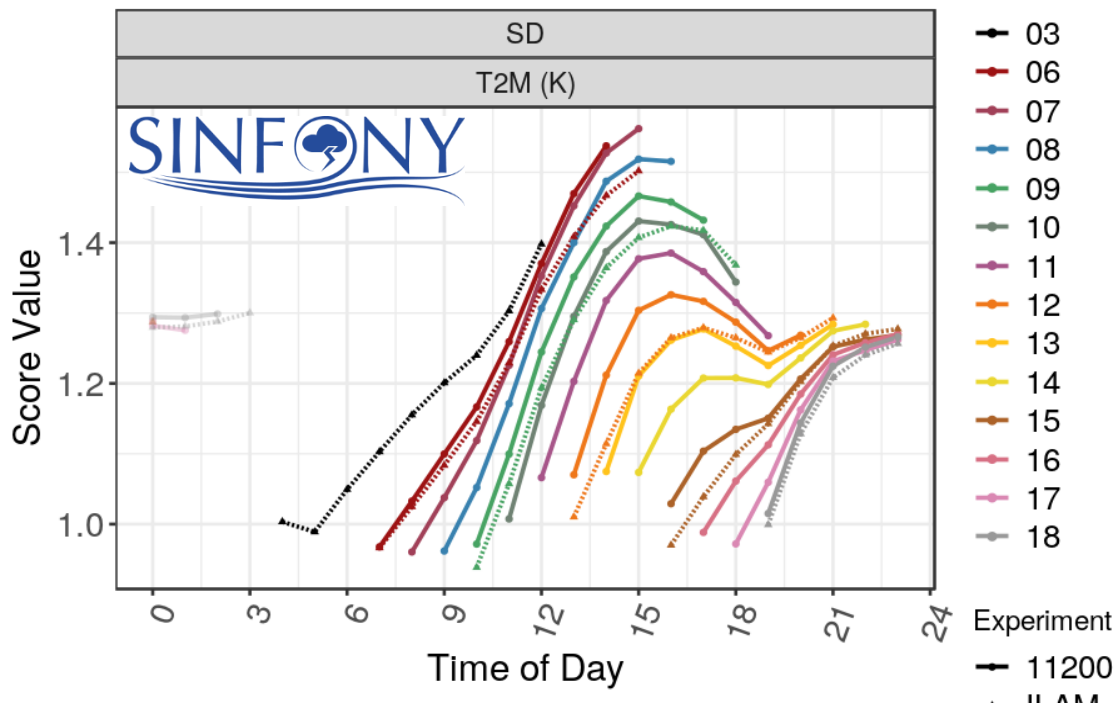


Flood Prediction
by

**ICON-global,
ICON-EU,
ICON-D2**

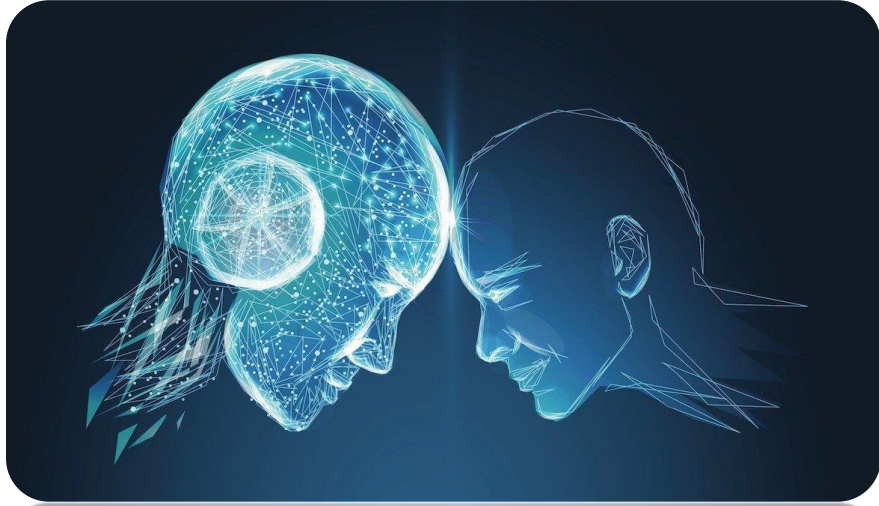
RUC: Advantage of timely EPS Initialization

2021/05/24-07UTC - 2021/07/17-09UTC
DOM: ALL , STAT: ALL



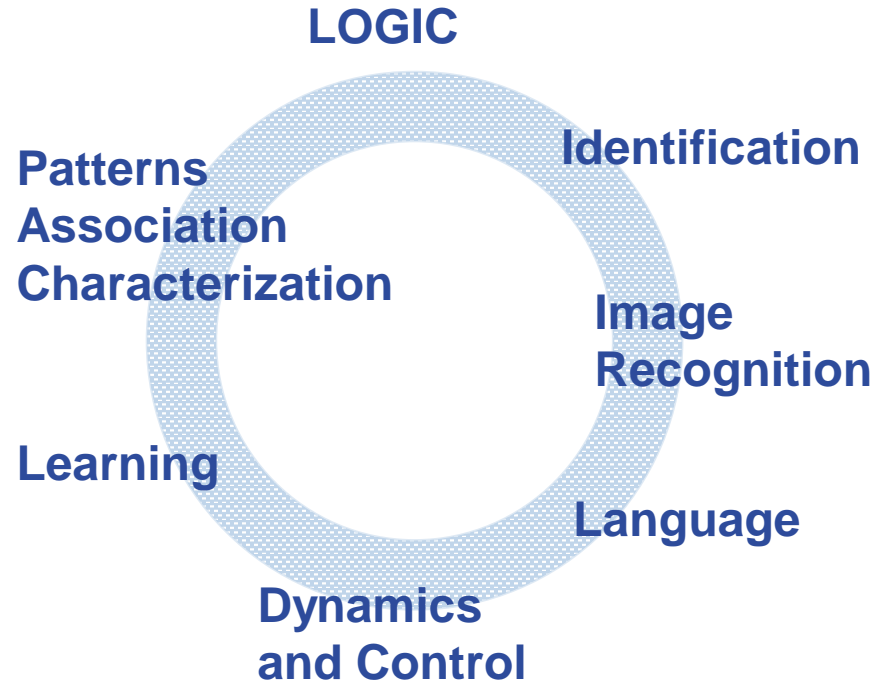
Experimental KENDA RUC System 2022

- 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

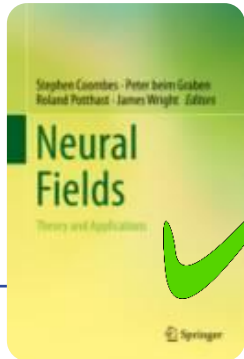
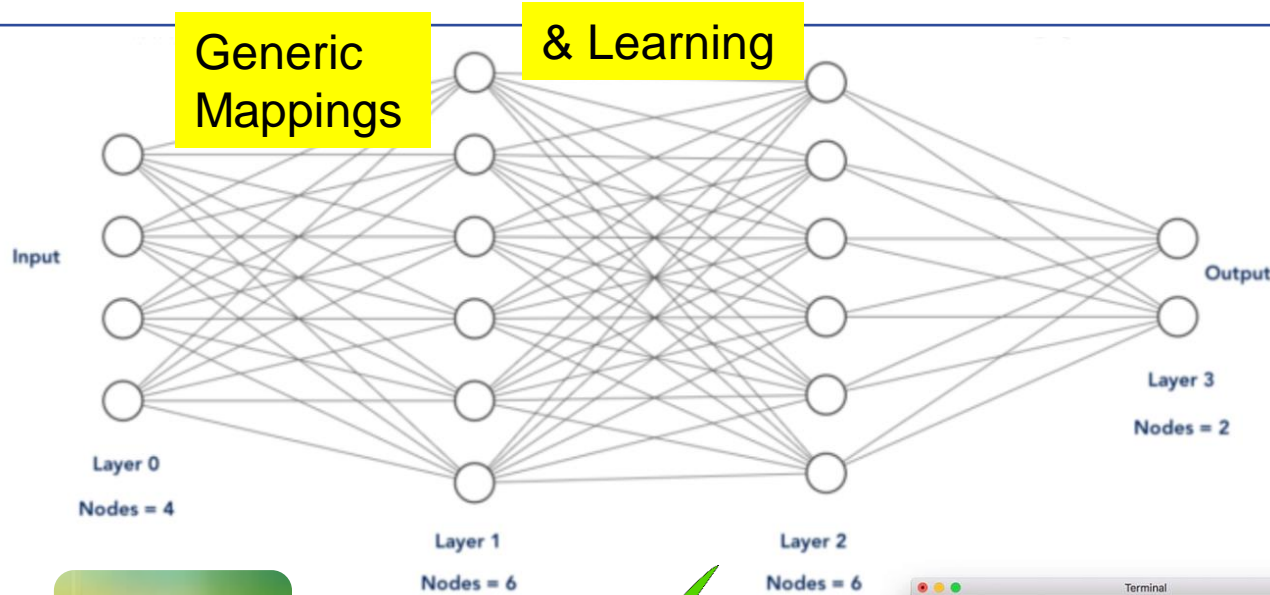


Techniques of AI:

- Programming in Logic
- Statistical Learning/Bayes
- Neural Networks and Neural Fields



2 AI – Functions, State-of-the-Art, Promise



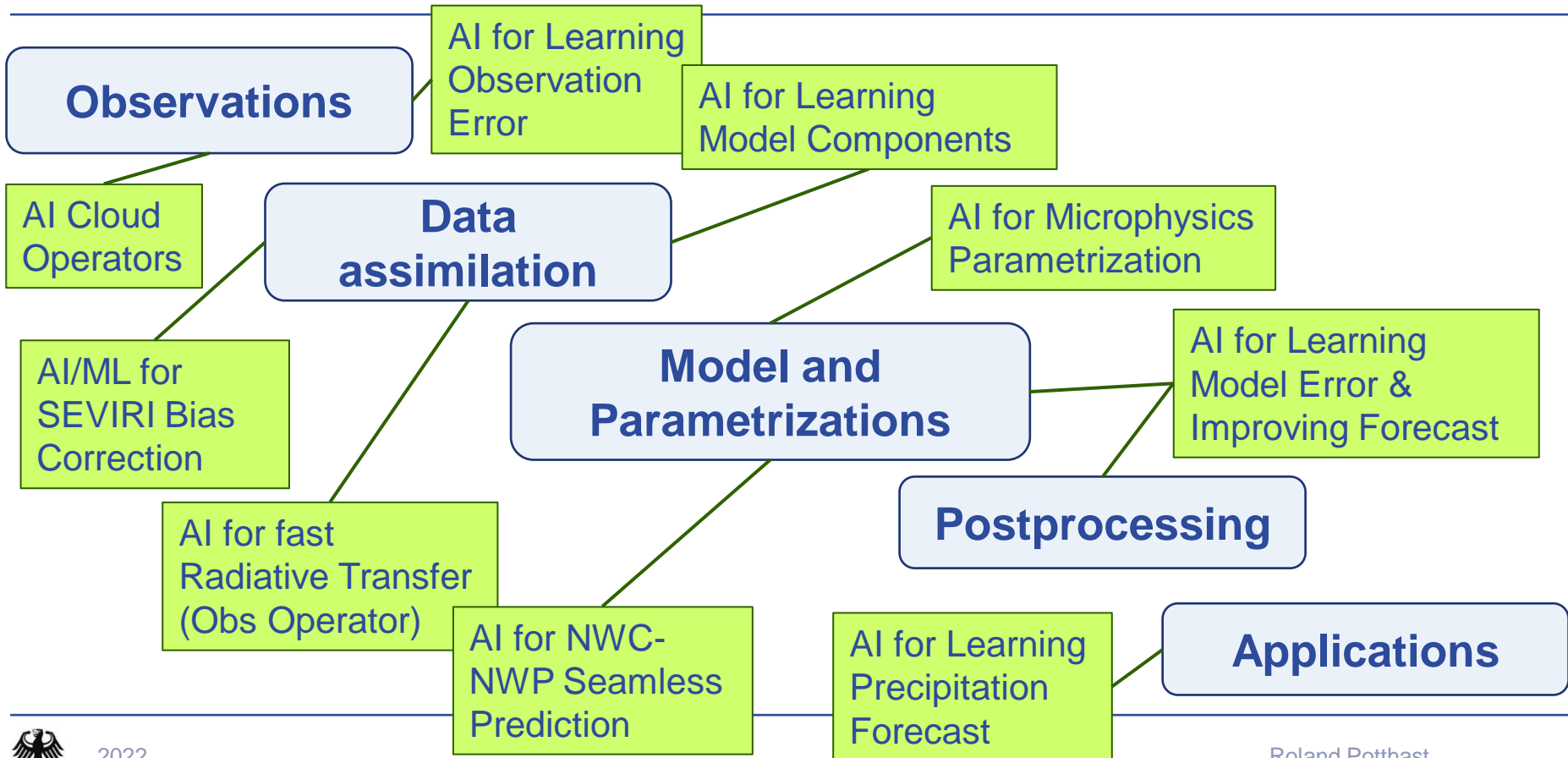
Python Framework

+ FORTRAN Implementation

```
Terminal  
$ workon keras.tf  
(keras.tf) ~ $ python  
Python 3.6.4 (default, Mar 27 2018, 15:31:37)  
[GCC 4.2.1 Compatible Apple LLVM 9.0.0 (clang-900.0.39.2)] on darwin  
Type "help", "copyright", "credits" or "license" for more information.  
>>> import keras  
>>>
```



3 AI in NWP – DWD Project World



How to progress – specific milestones

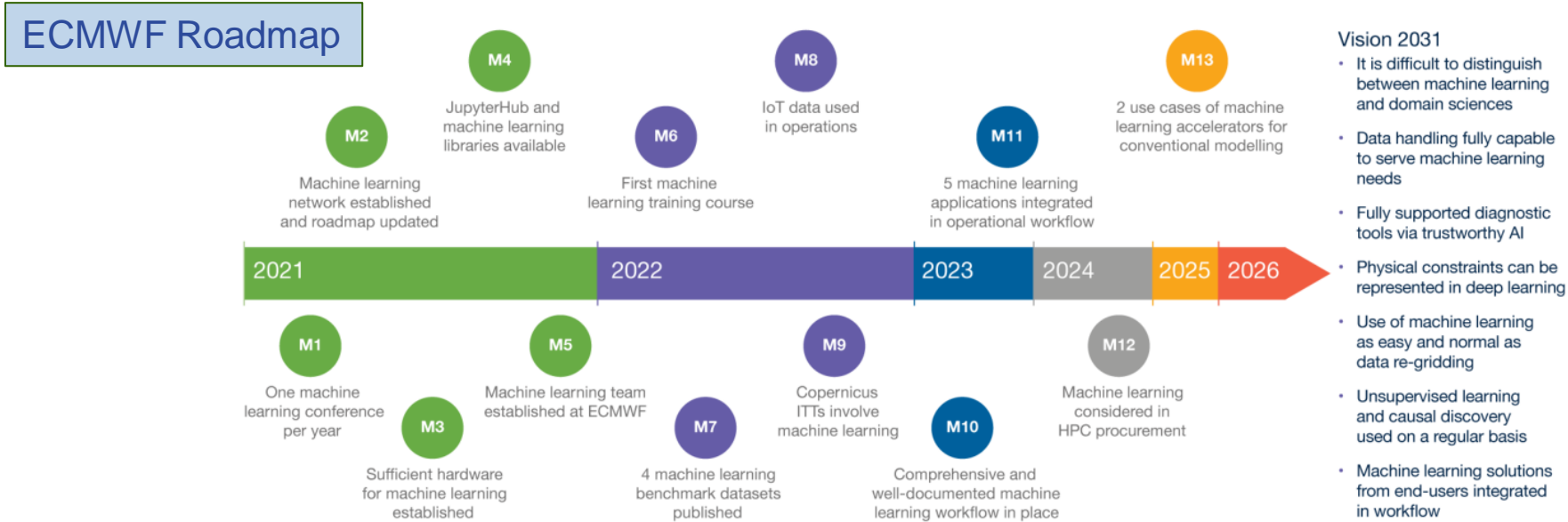


Figure 2: Timeline of machine learning developments at ECMWF with all milestones.

DWD activities took very similar steps



3 AI in NWP – Concepts and Project World

ECMWF Roadmap

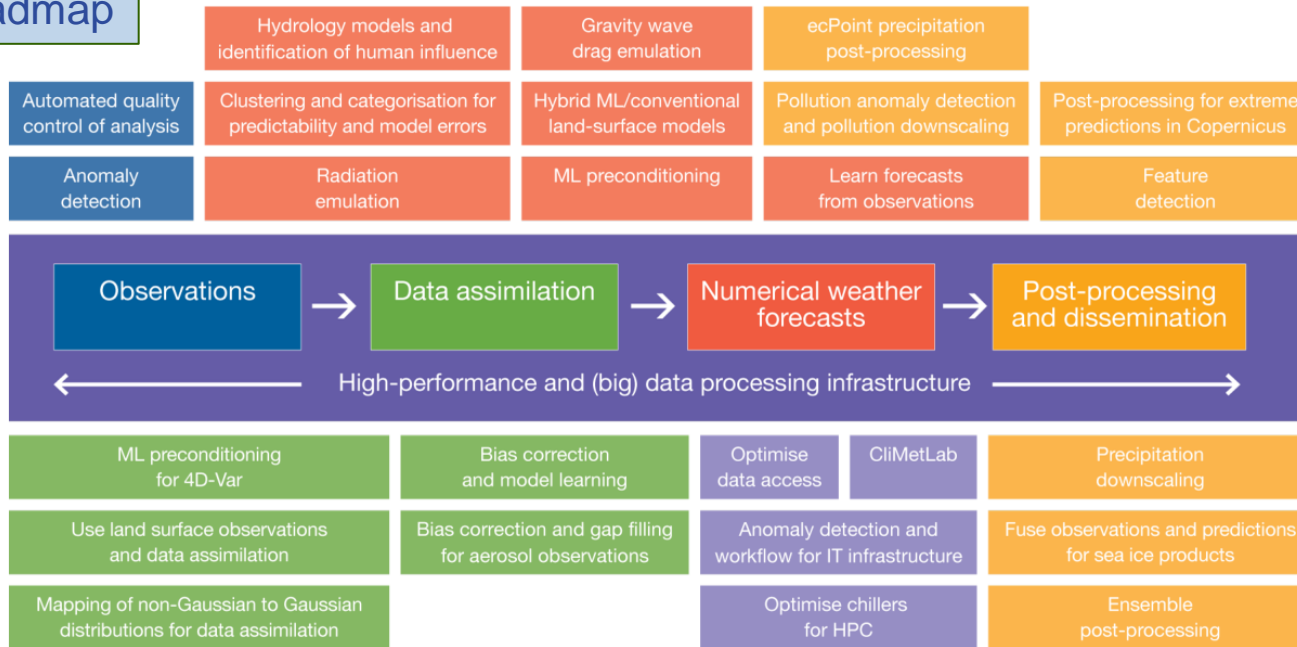
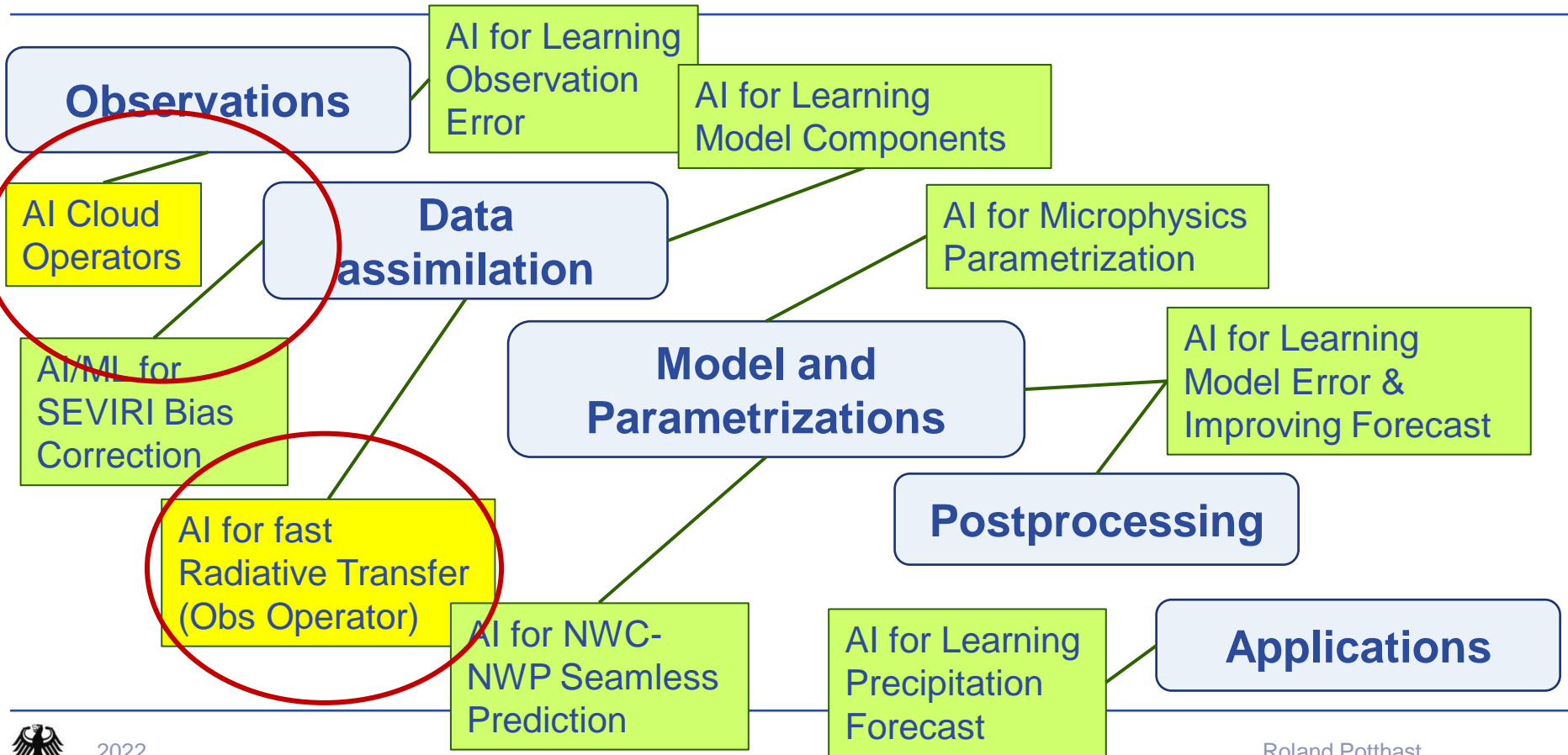


Figure 1: Machine learning applications at ECMWF that are already being explored or planned. The colour-coding of the boxes corresponds to the respective component of the workflow for NWP

3 AI in NWP – DWD Project World



4 ICamCloudOps: 4.1: Webcams + AI

Offenbach DWD - Ost - Blick nach Offenbach
31.05.20 11:10 UTC / 13:10 CEST (f/0.0 1/800s iso100)



Exploit Camera Images based on Artificial Intelligence (AI/ML)



Munich DWD - Blickrichtung Südost - elbaufwärts
20 08:10 UTC / 10:10 CEST (f/7.1 1/640s iso100)

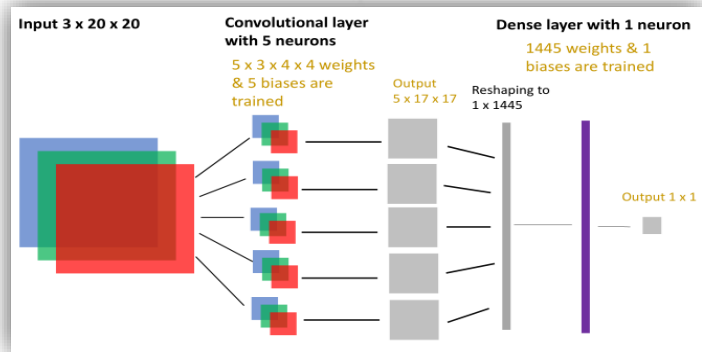
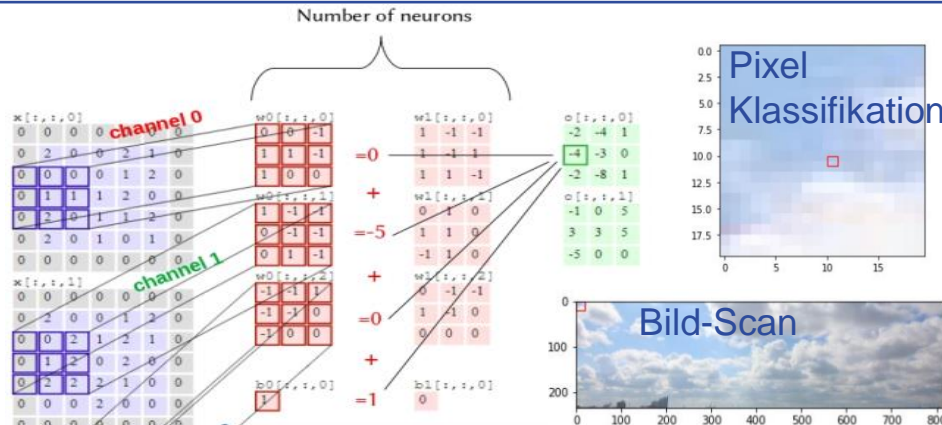
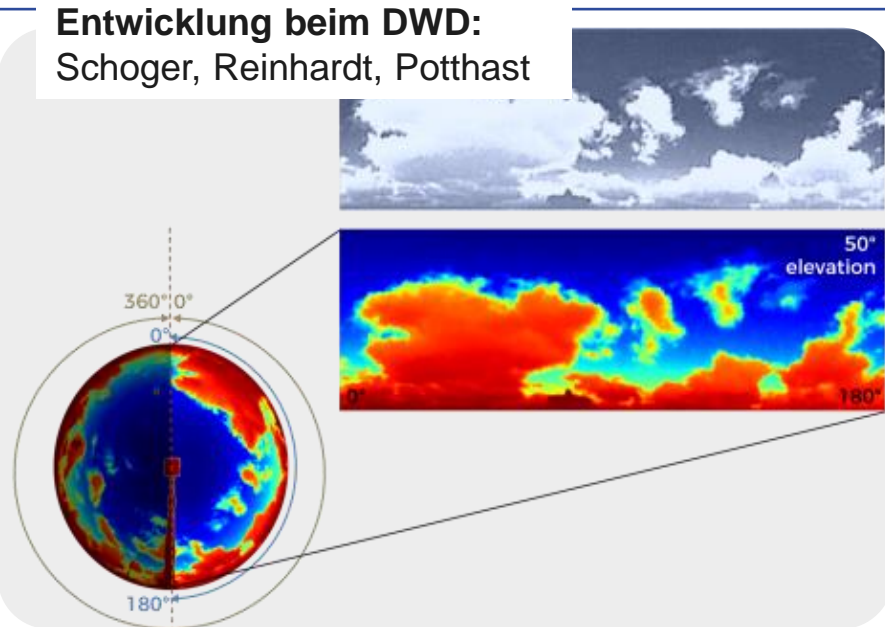


Maria Reinhardt, Sybille Schoger, Frederik Kurzrock



4 ICamCloudOps: 4.1: Webcams + AI

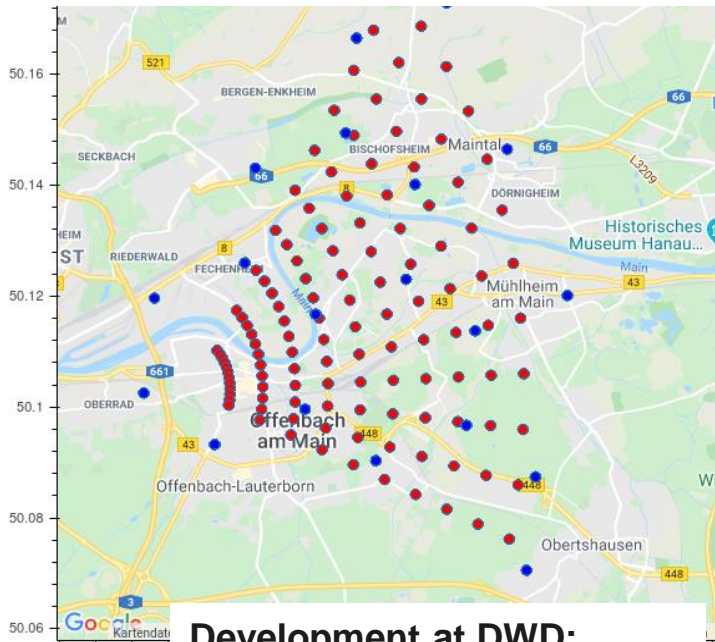
Entwicklung beim DWD:
Schoger, Reinhardt, Potthast



Deep Neural Network for Cloud Identification and Classification

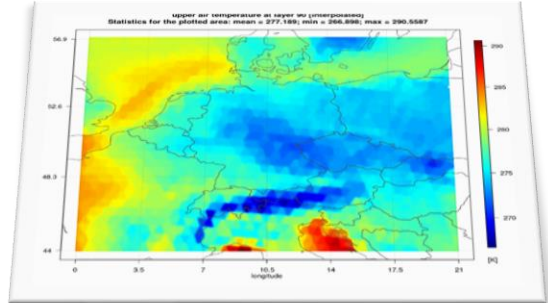
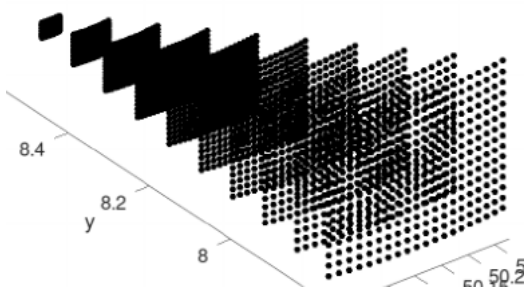
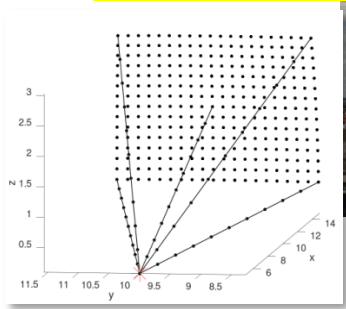
4 ICamCloudOps: 4.1: Webcams + AI

Covering by Camera (Offenbach Webcam, red)
and Model Grid Points (ICON-LAM, blue)



Development at DWD:
Schoger, Reinhardt, Potthast

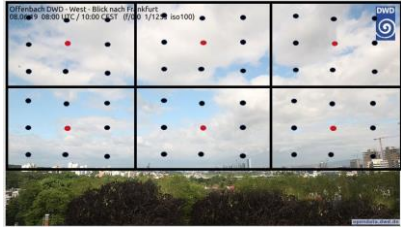
Working on Rays



ICON Model Field

Camera Observation Operator:
Model to Image

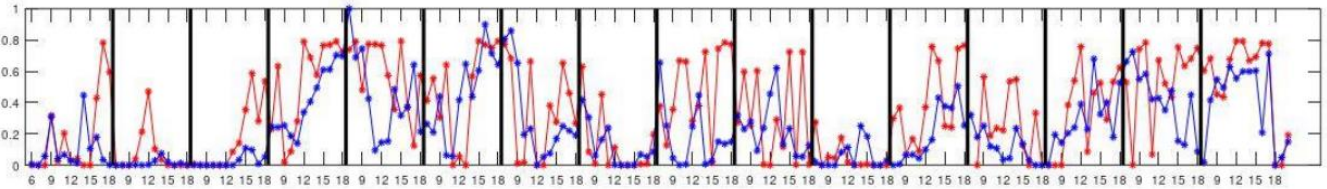
4 ICamCloudOps: 4.1: Webcams + AI



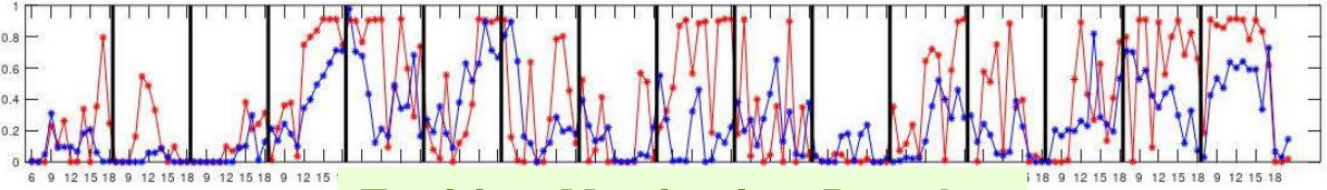
12.07.2020 – 26.07.2020, jeweils 06:00 Uhr – 18:00 Uhr

— Observation — Modell Äquivalent

Box (1,1)

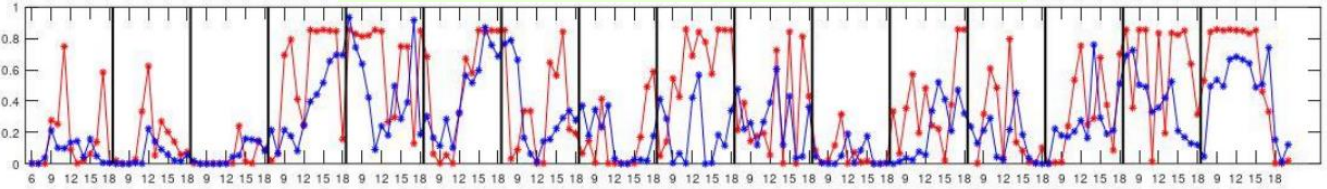


Box (1,2)



Exciting Monitoring Results

Box (1,3)



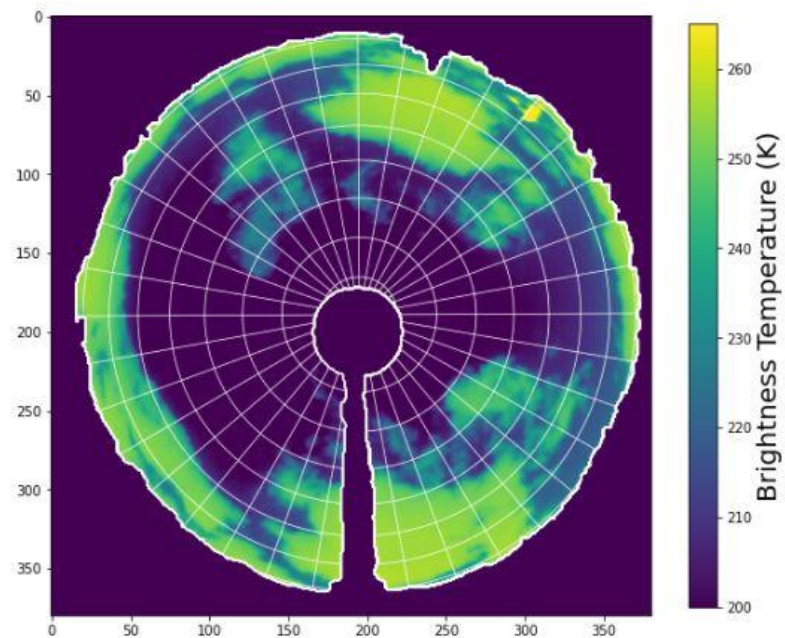
- Boxes
- Averages
- Modell CLC
Cloud-Variables
- Comparison
Time Series



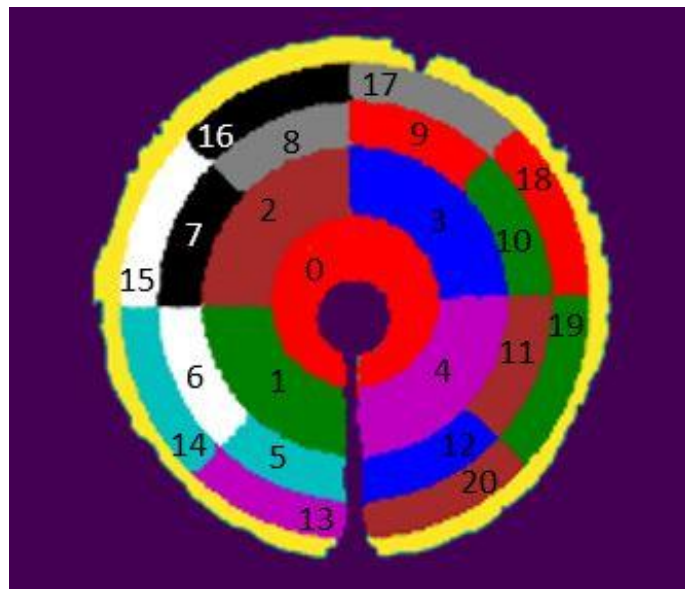
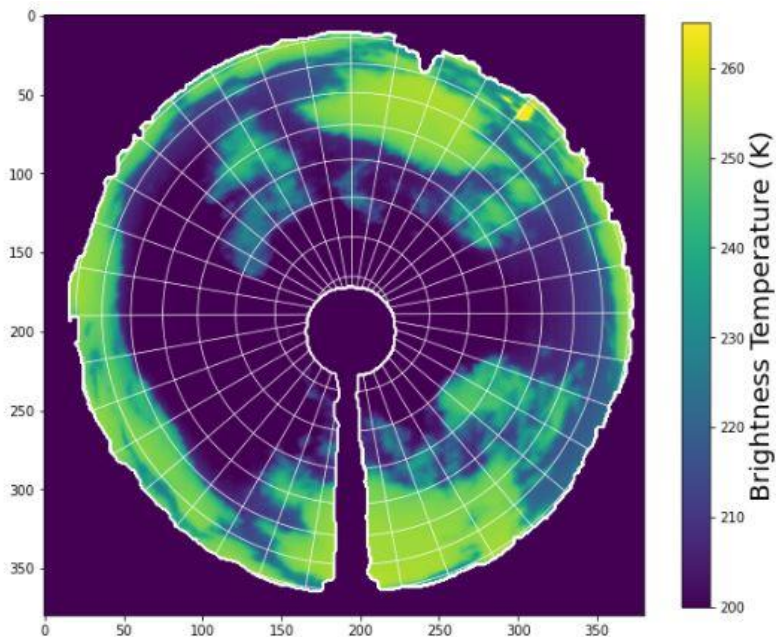
- Infrared Camera from Reuniwatt
- Located in Lindenberg



RAD = Radiative Transport



Maria Reinhardt, Frederick Kurzrock

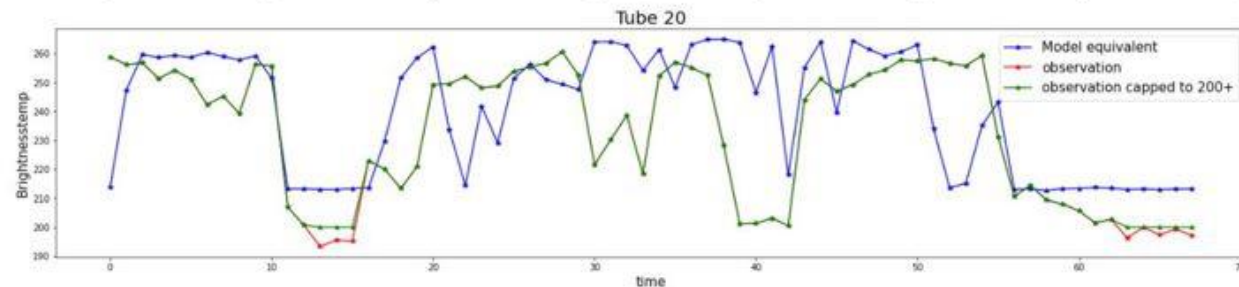
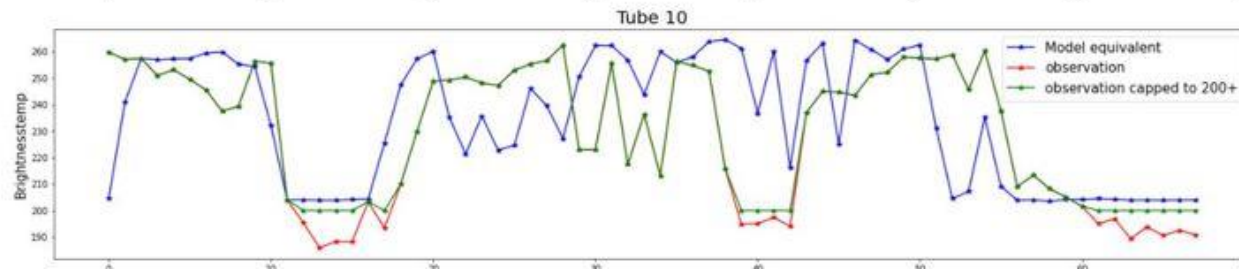
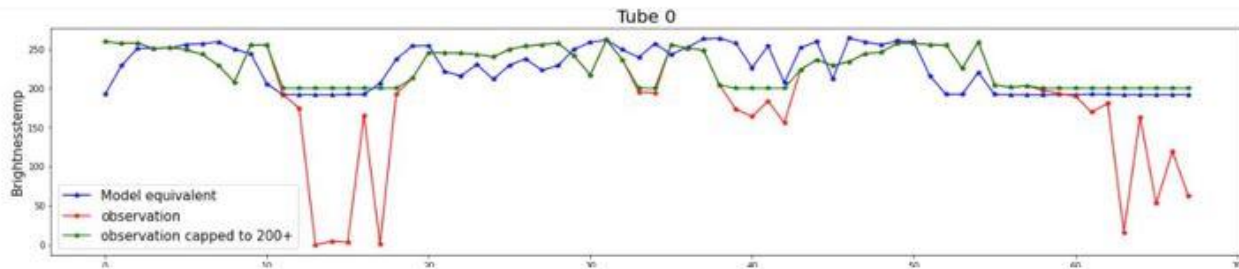


Aggregation of Observations: Superobbing

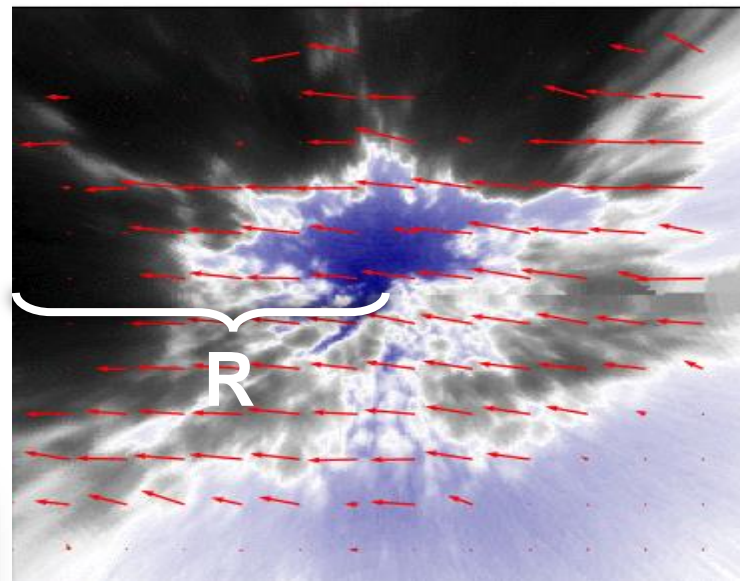
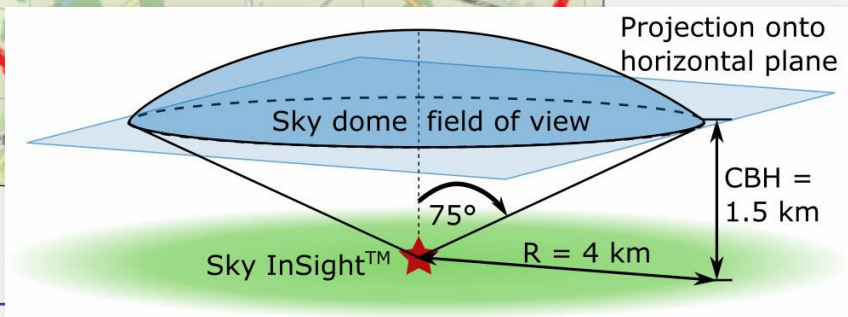
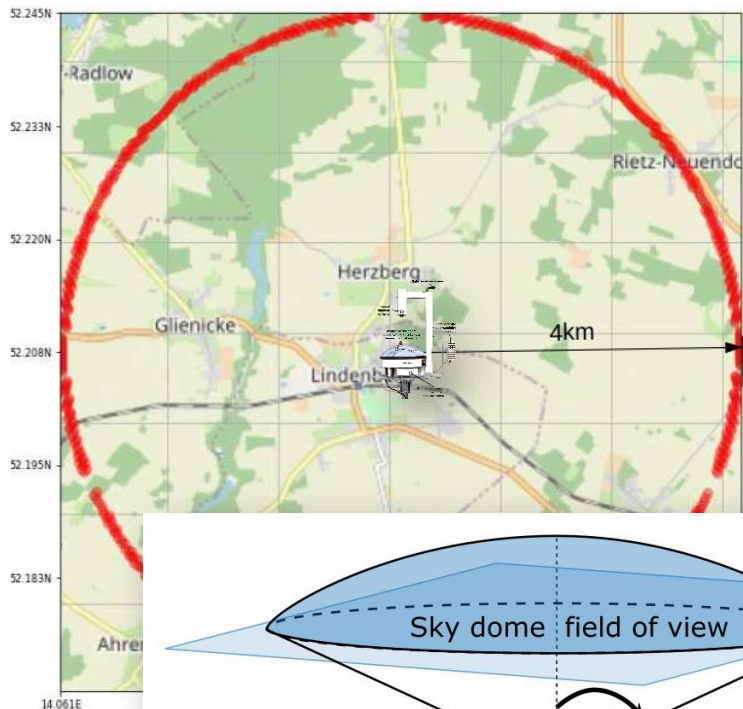
4 ICamCloudOps: 4.2: IR-Cams + RAD + AI

IR Camera
+
Radiative
Transport

Monitoring of
Observation
Equivalents

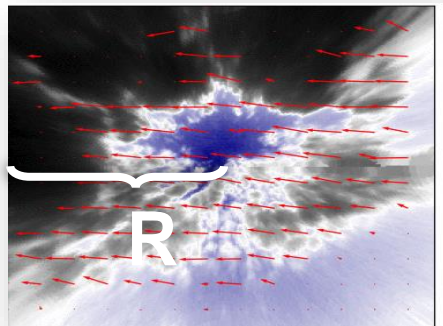


4 ICamCloudOps: 4.3: WIND through AI



Flow Estimation for Wind Derivation

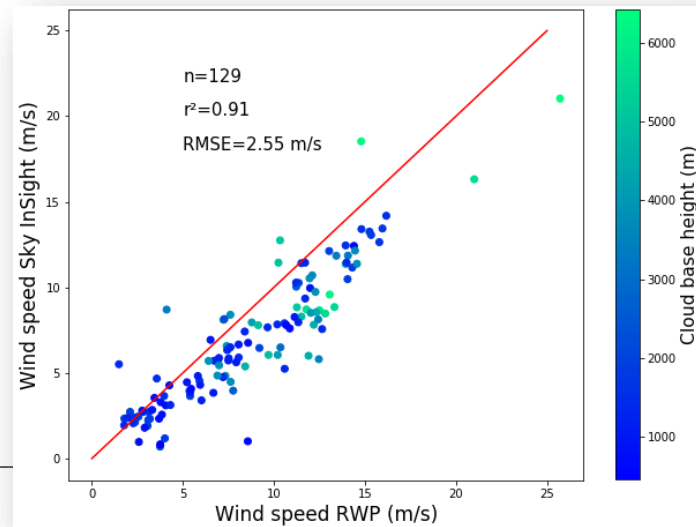
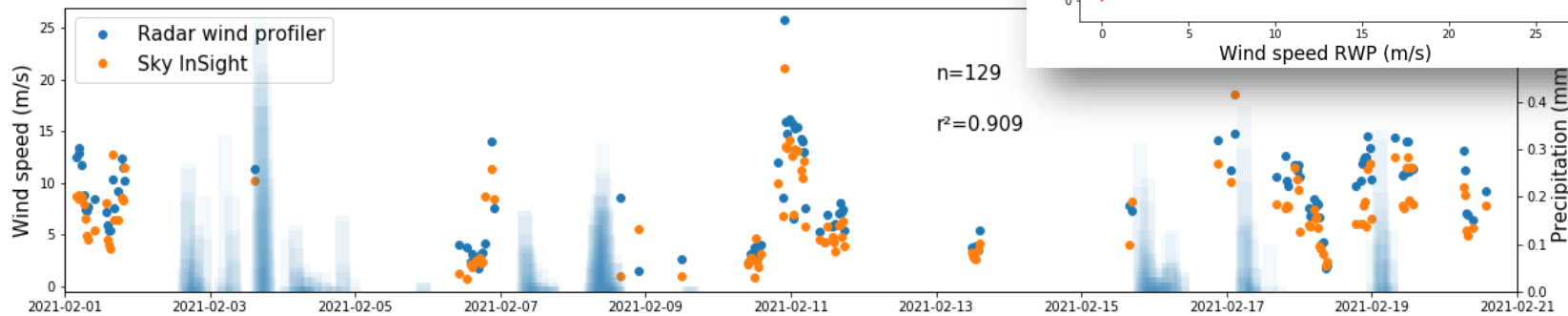
4 ICamCloudOps: 4.3: WIND through AI



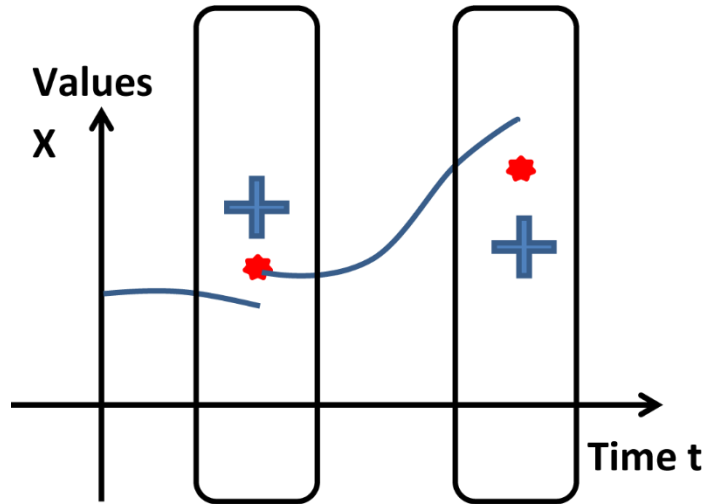
Flow Estimation for Wind Derivation

Monitoring

Walter Acevedo, Frederik Kurzrock



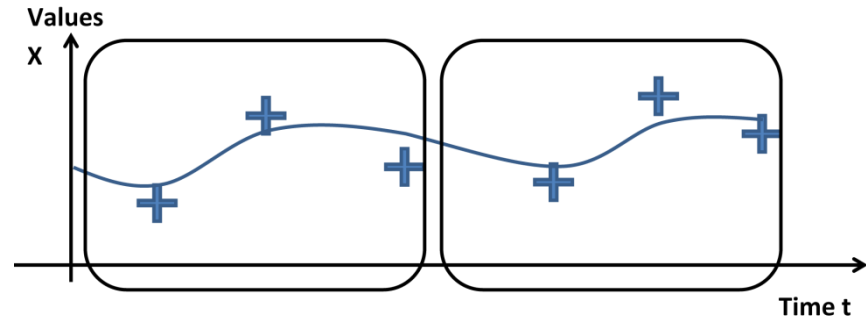
5 Assimilation and Forecasts: Basic Idea



3D-VAR =
Minimize distance to
Observation and first guess

First Guess -
Observations +
Analysis *

4D-VAR =
Minimize over
time window

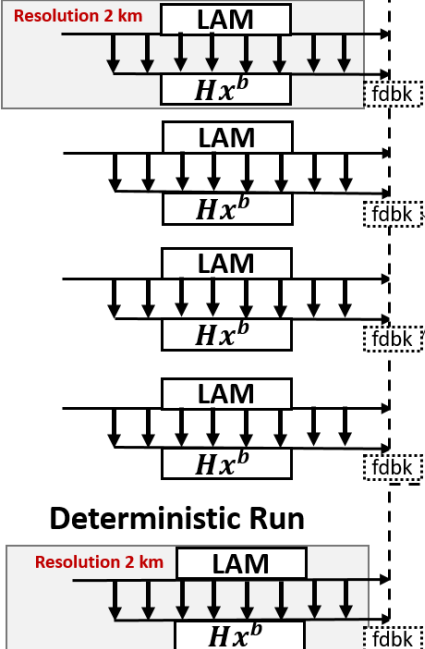


5 Assimilation and Forecasts

-59 : +0 Observations

IAU Incremental
Analysis Update
-5 to +5 min

Ensemble (Convective EPS)



4D-LETKF/PF

Localized Ensemble
Transform Kalman Filter

2 km, 1h
Analysis-Grid for LETKF

Feedback Files (fdbk) allow
experimental observations

Kalman Matrix to update
Unperturbed Deterministic
Control Run

LETKF
Deterministic
Analysis

2 km, 1h

Surface Analysis

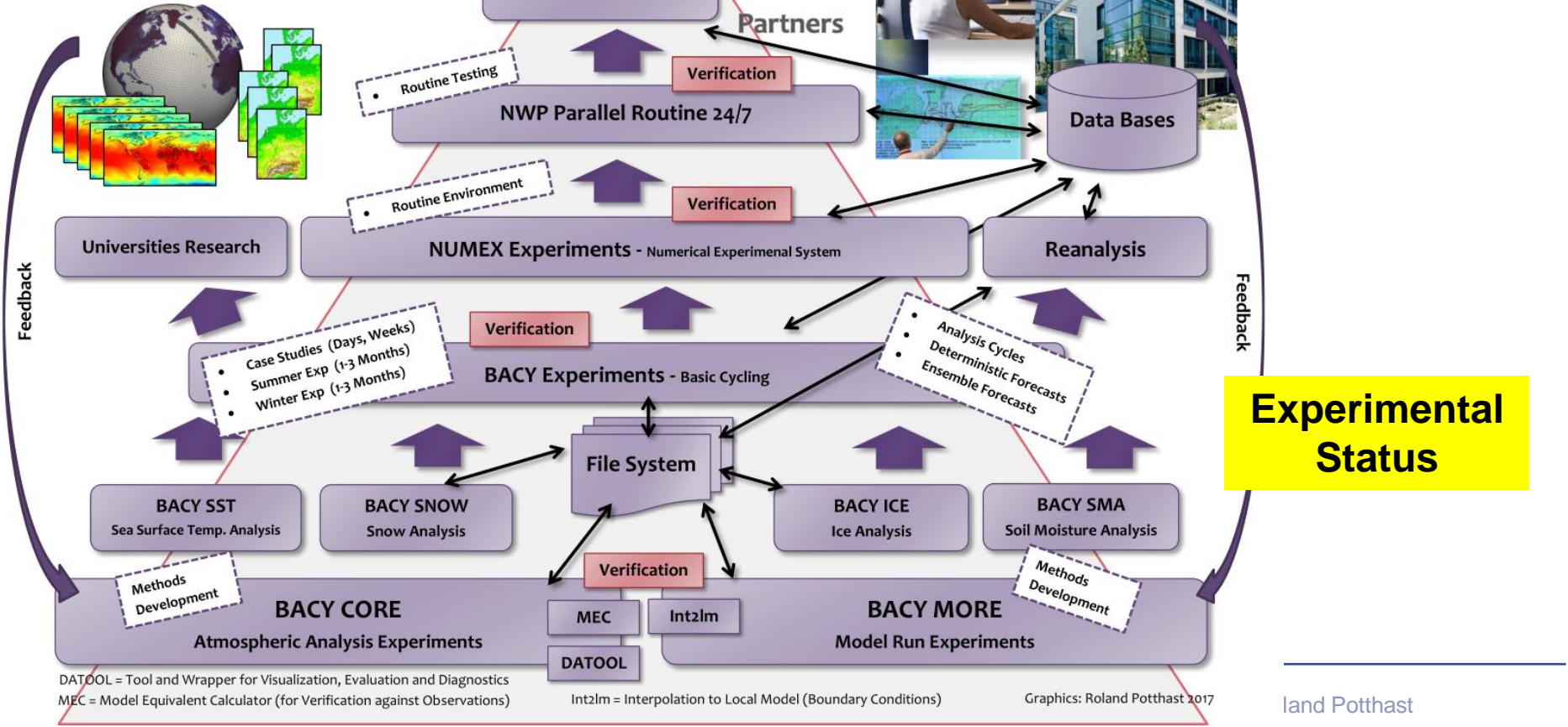
KENDA System 2021

- 1-hourly LAM Analysis Cycle, Forecasts Lead Time 48h every 3 hours
- Ensemble Resolution 2 km with 40 members
- Boundary Conditions from ICON global or ICON Nest, EPS + Det
- Ensemble Analysis by 4D-LETKF
- Particle Filter Capability
- Deterministic Run LETKF Analysis
- Incremental Analysis Update (IAU)
- Portable Script Environment (BACY)



NWP Experimental Hierarchy at Deutscher Wetterdienst DWD

ICON Model + COSMO Model
Global + Convective Scale



DATOOL = Tool and Wrapper for Visualization, Evaluation and Diagnostics
MEC = Model Equivalent Calculator (for Verification against Observations)

Int2lm = Interpolation to Local Model (Boundary Conditions)

Graphics: Roland Potthast 2017

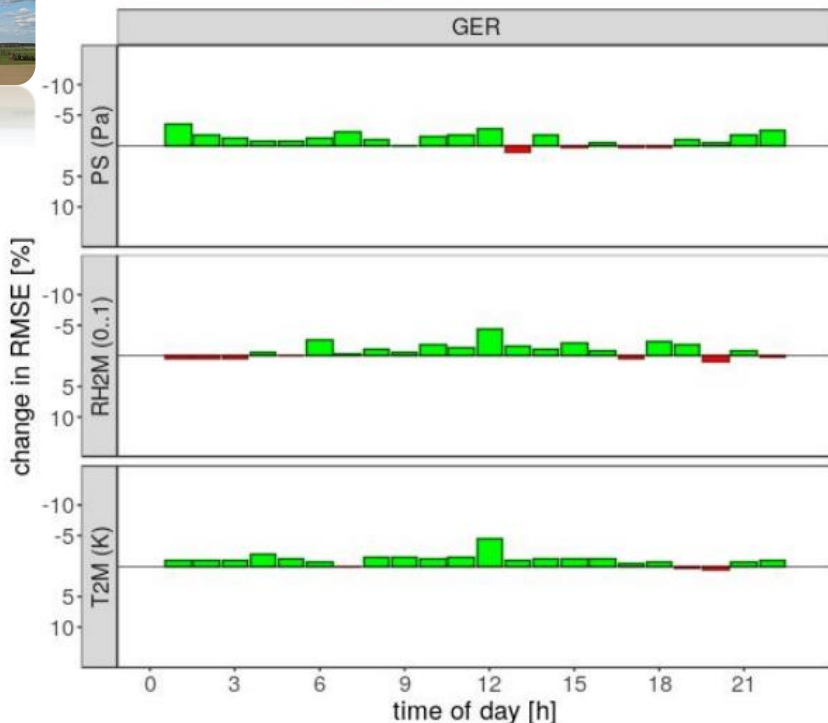
Experimental Status

5 Assimilation and Forecasts: AI + VIS

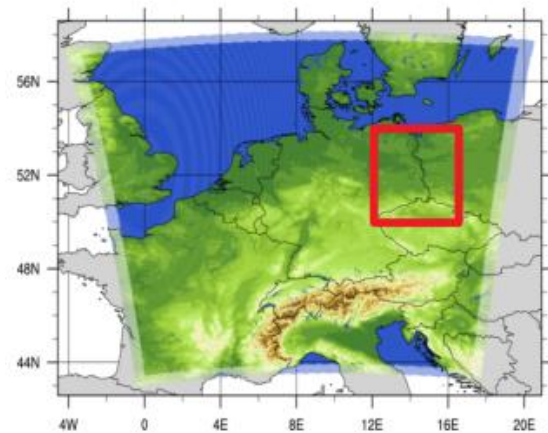


Forecasts initialized from 2020/08/20 to 2020/08/26
Reduction of RMSE [%], INI; 00, 06, 12, 18UTC

■ icam_aktiv better ■ icam_passiv better



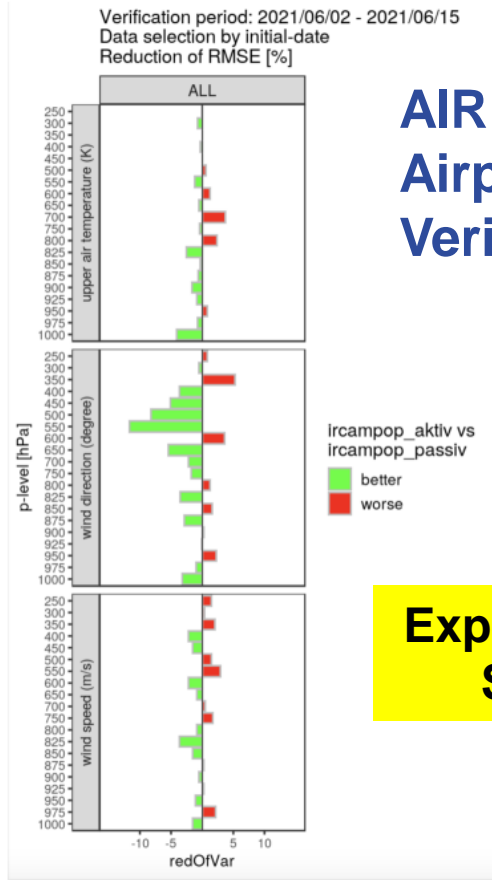
SYNOP Surface Stations Verification



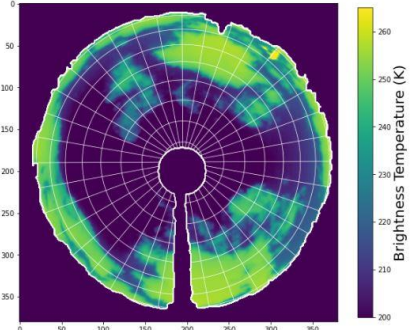
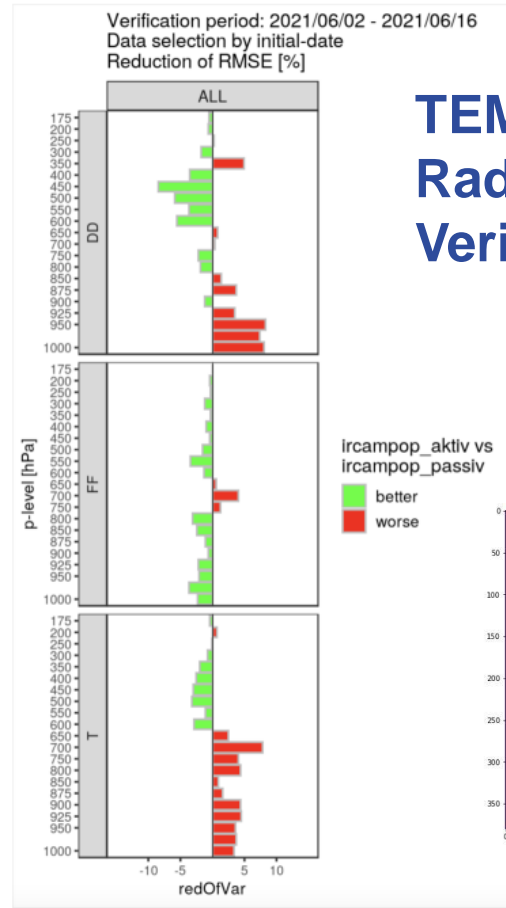
Courtesy of Daniel Reinert, DWD



5 Assimilation and Forecasts: : IR+RAD



**Experimental
Status**



Roland Potthast



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