

# State and Development Perspectives



# ICON Model and Data Assimilation



Roland Potthast

3/2022

## Status Reflection

Very Strong Weather and Climate Model  
Status NWP: ICON and Data Assimilation  
Systems, Scales, high Quality, good scores  
New Observation Systems  
Status ICON-ART in Operations  
RSMC Nuclear, Non-Nuclear, Pollen,  
Volcanic Ash, Mineral Dust/Sea Salt/Fires

## Consortium

Very Strong Partners, Process, Risks  
Governance evolving  
ICON-Board, ICON-C5, Leaders, Experts  
ICON Licences  
Research, NMHS, Support, Open-Source

## Partner

Consortia (COSMO, C2SM, ...)  
Computing Centres,  
Research Groups, Hans-Ertel Centre  
CLM Community  
National and international Institutions

## Working Mode

ICON and COSMO Working Groups  
ICON and DACE Support

## ICON-Seamless Theme

ICON-Seamless ESM Climate  
ICON-Seamless ESM Weather  
ICON-Land: Terra+JSBach+Vegetation  
ICON Reanalysis  
national ESM Initiative

## ICON-Consolidated, ICON-X

Modularization, Infrastructure, Mind-Set  
ICON-C Project World  
heterogeneous HPC and Exascale  
ICONIC ICON-in-the-Cloud  
Destination Earth EU Initiative  
Global-to-Regional ICON (GLORI) Alpine Twin

## Processes

ICON High-Resolution High-Quality Weather and Climate  
Parametrizations and Circulation  
Clouds  
Modelling, AI, Data Assimilation  
Radiation  
ecRAD, ART, Data Assimilation, PV  
Precipitation  
Codesign with Hydrology and ICON-Land  
Uncertainty Estimation Minutes-to-Days-to-Decades  
SINFONY, Extremes, Reliability, Communication

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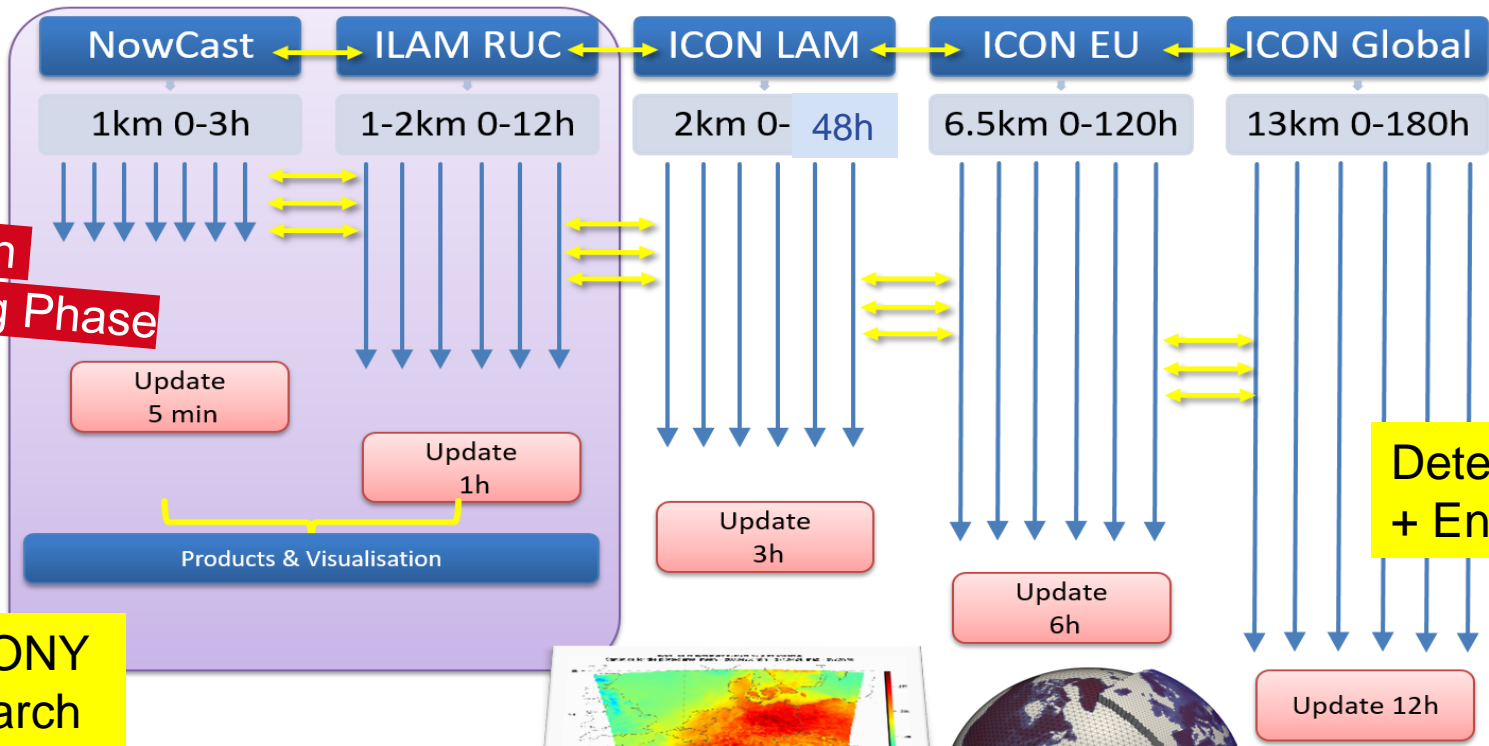
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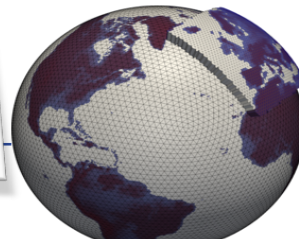
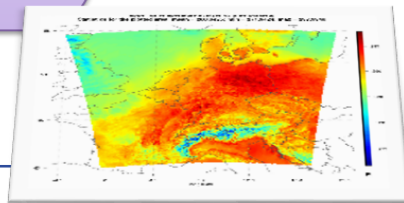
# NWP Operational System Setup



RUC in Testing Phase

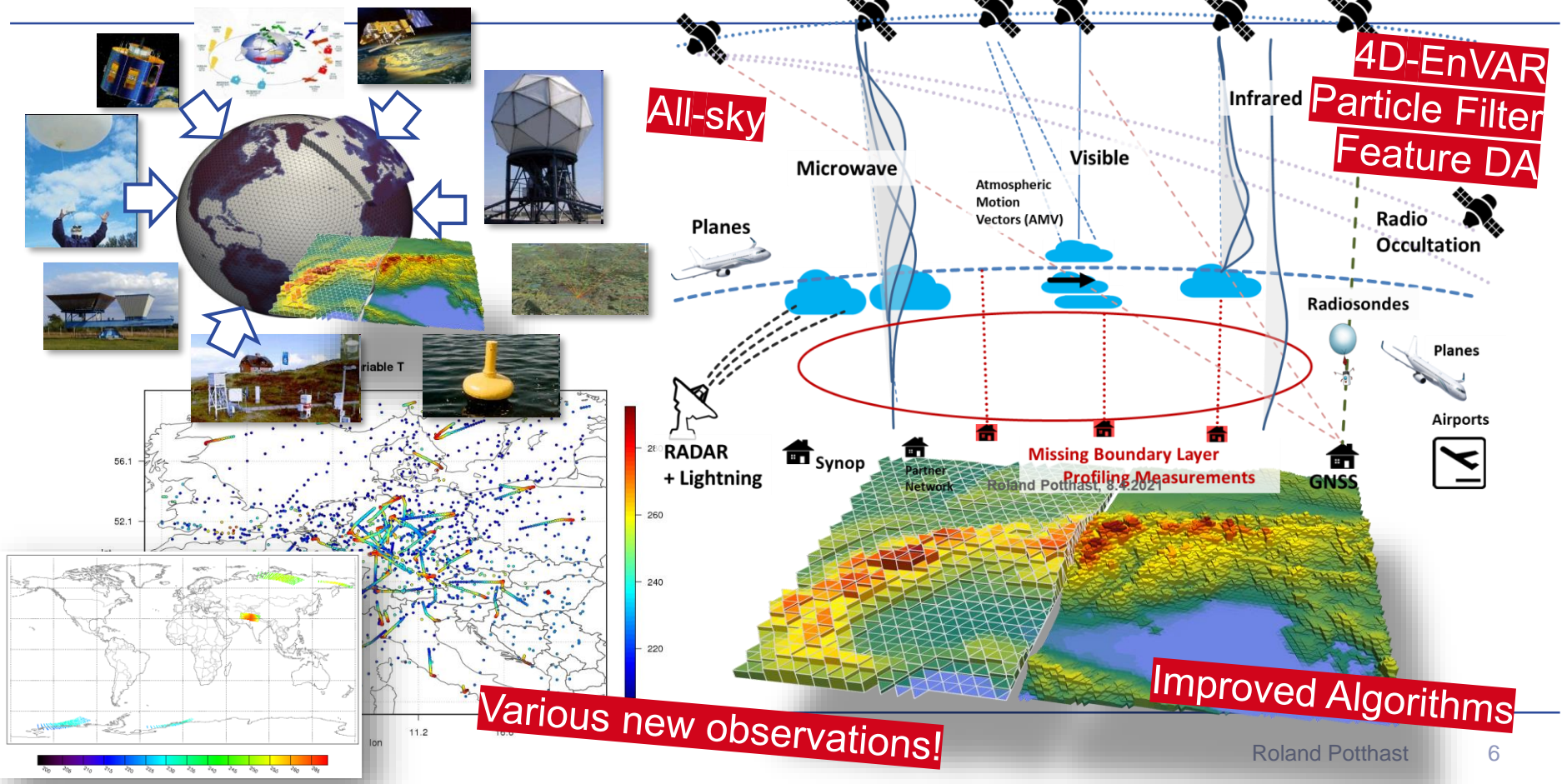
SINFONY Research

Deterministic + Ensemble





# Data Assimilation in High-Dimensional System

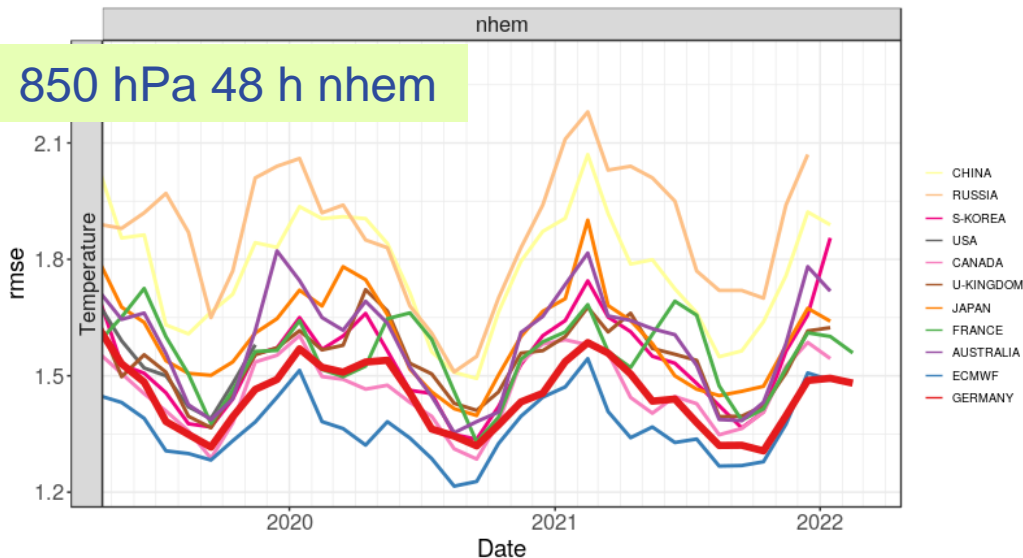


# ICON Status NWP



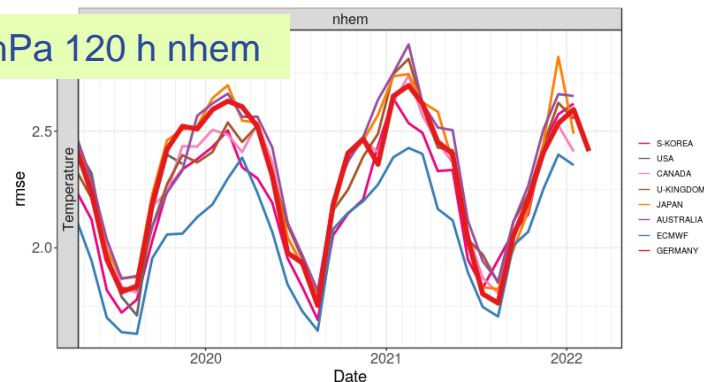
WMO verification against observations  
 lead-time: 48h  
 valid-time: 12UTC  
 level: 850hPa

850 hPa 48 h nhem



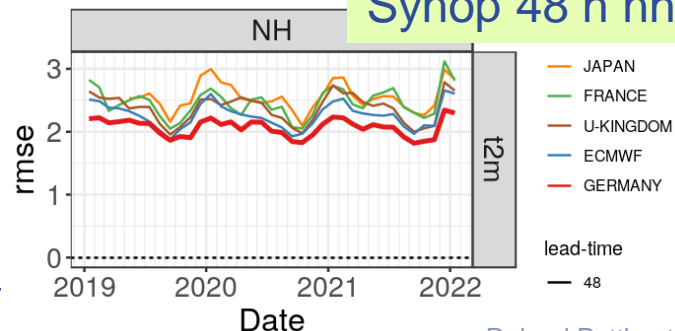
WMO verification against observations  
 lead-time: 120h  
 valid-time: 12UTC  
 level: 500hPa

500 hPa 120 h nhem



WMO verification against SYNOP  
 lead-time: 48h  
 valid-time: 12UTC

Synop 48 h nhem



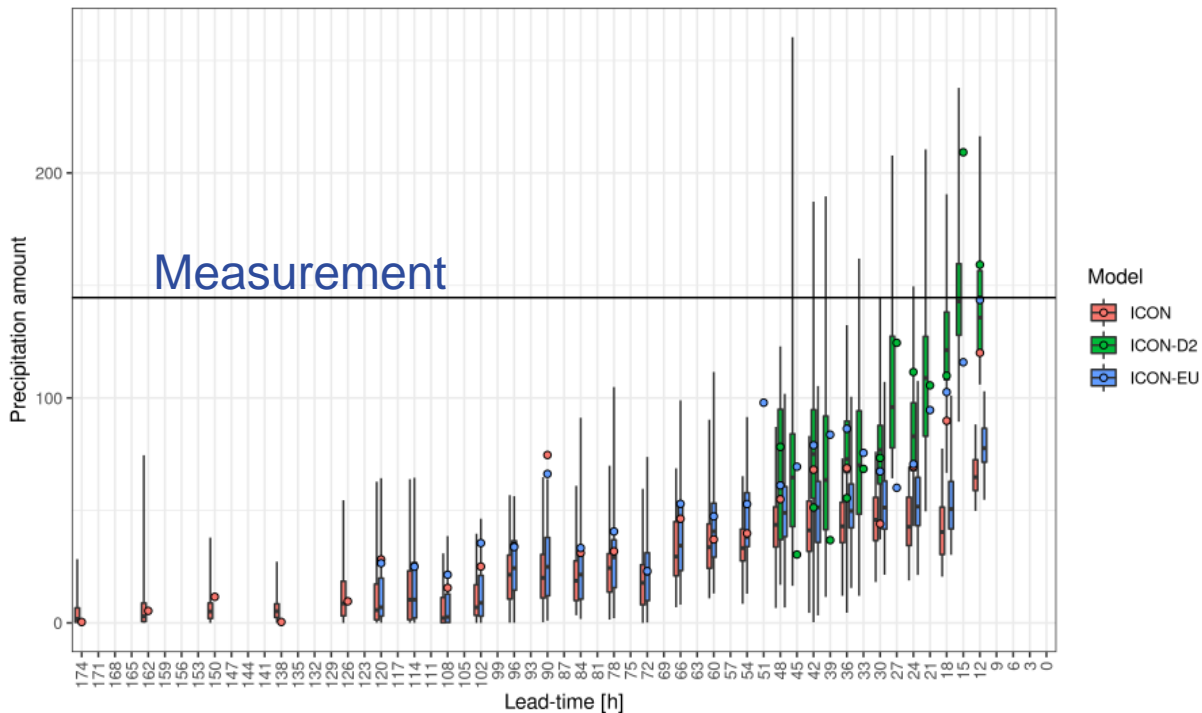
## ICON + Ensemble Data Assimilation

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



# Scales and Flood Prediction!

Predictability Diagram for 2021-07-14 18 UTC  
Station: NRW Max.  
Variable: RR\_12h (144.6)



**Flood** Prediction  
by

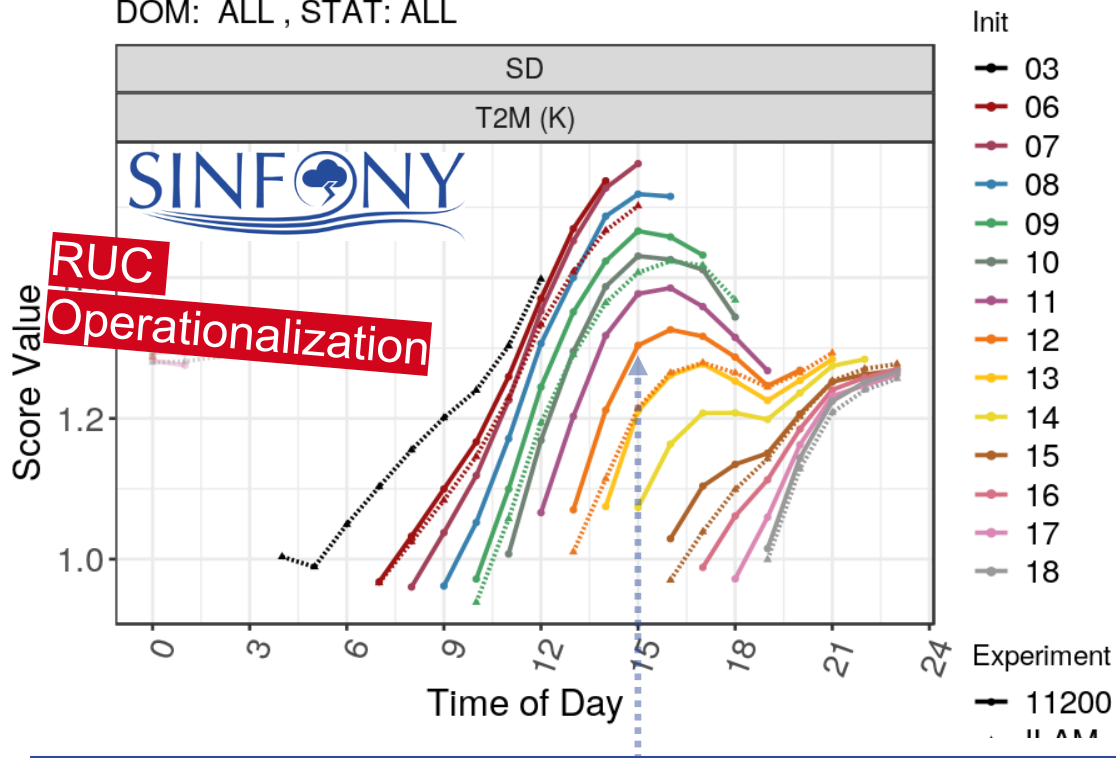
ICON-global,  
ICON-EU,  
ICON-D2

Important  
Applications and  
Partners



# 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

**Best forecast: lower error curve**



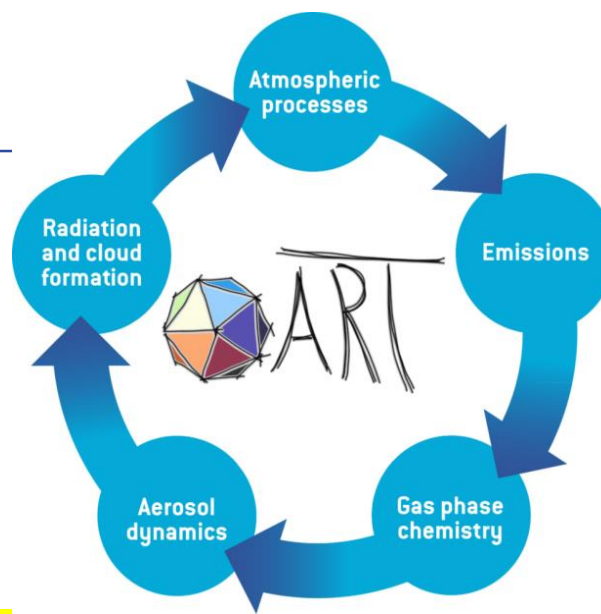
# ICON ART in Operations



WORLD  
METEOROLOGICAL  
ORGANIZATION

## Emergency Response Activities (ERA)

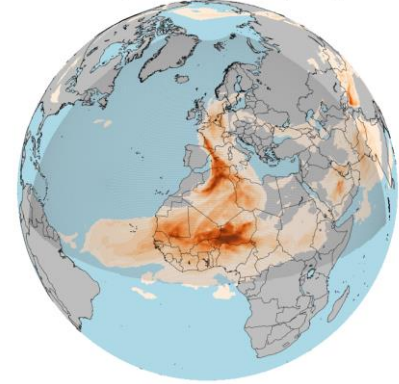
- ✓ **RSMC Nuclear** Emergency Setup **Operational**
- ✓ **RSMC Non-Nuclear** Emergency Setup **Operational**
- ✓ **ICON-ART Operational Pollen Forecast Operational**
- ✓ **ICON-ART Volcanic Ash** Emergency Setup **Pre-Operational**
- ✓ **ICON-ART Mineral Dust** *Near-Realtime Test System*



Deutscher Wetterdienst  
Wetter und Klima aus einer Hand



2018040800, vv: 003, ICON-ART, AOD\_DUST



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## Diversity and Partnership

**MPI:** Advance Climate Science, Atmosphere, Ocean, Land, understanding of global processes driving the planet

**DWD:** Forecasting for Weather (NWP/ESM) and Climate (Seasonal, Decadal, Projection), Climate Monitoring (Reanalysis), ART and GHG Monitoring and Forecasting

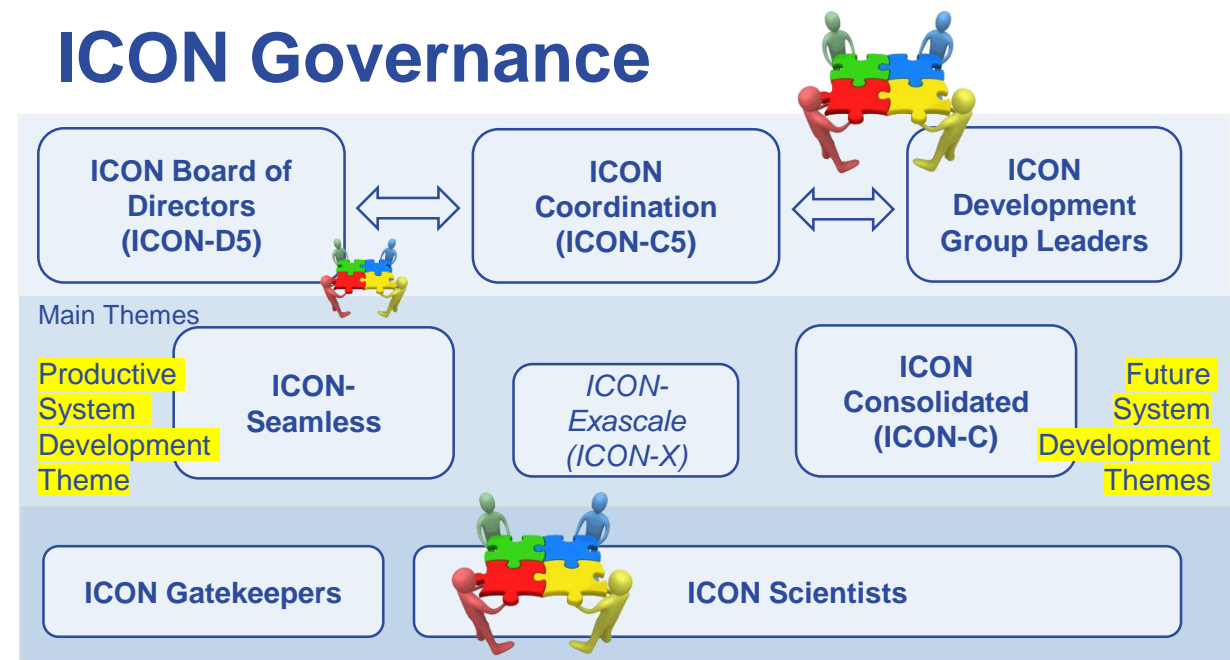
**DKRZ:** Infrastructure for Climate Science, Tools and Techniques, HPC Leadership

**KIT:** Modelling and Forecasting of Aerosols and Greenhouse Gases, ART and Cloud Process Interaction





## ICON Governance



*ICON with its partners is in a phase of significant development on several layers of the partnership.*





*There has been a long process of evaluation including DWD legal department, DWD finances department, external licence lawyers and advice by experts.*

ICON Research Licence

active

ICON NMHS Usage Licence

approved

ICON NMHS Support Licence

approved

ICON Open-Source Licence

target approved

**Usage Licence** ~11 k€ p.a.

Use of ICON by NMHS  
Official Duty

**Support Licence** ~4 k€ p.a.

1st-Level-Support, 2nd-Level-Support, 3rd-Level-Support  
Initial and Boundary Data  
Data Assimilation DACE

vs.  
Evaluation, Verification, Measurements by NMHS

vs.  
20 T€ p.a. „Licence Money“  
(Decision by COSMO STC)



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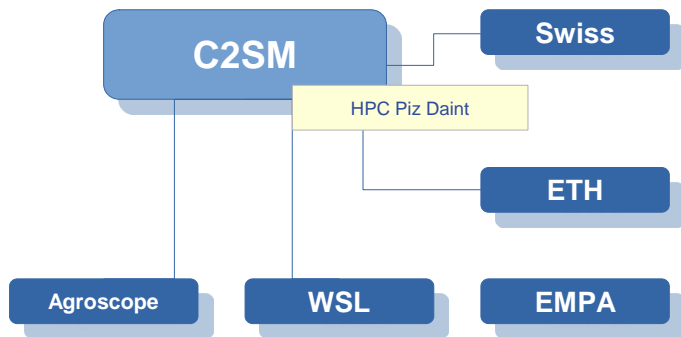
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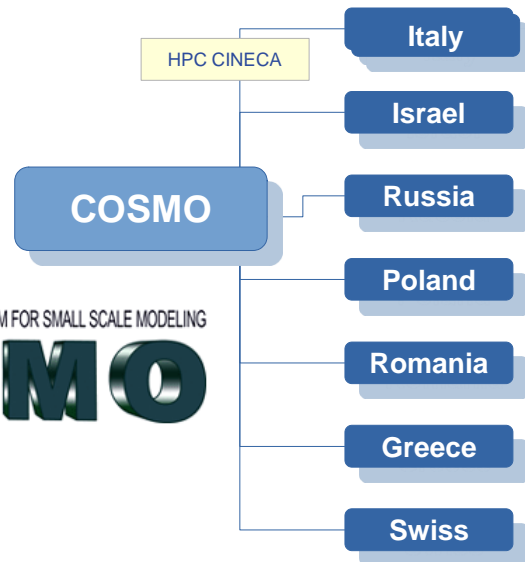
## Key Development Partners



**C2SM:** Heterogeneous Computing Architectures, Forecasting Weather and Climate



**C2SM in D5 + C5**



Supercomputers

- HPC HoreKa
- HPC Mistral
- HPC NEC Aurora

**COSMO:** Regional Weather Forecasting in different weather regimes

## CLM-Community WORLD

## CLM-Community EUROPE



## ICON Research

Partnerships with

**many Universities  
and Research Institutions**

by partnerships of our  
consortium members



**Moving to ICON**



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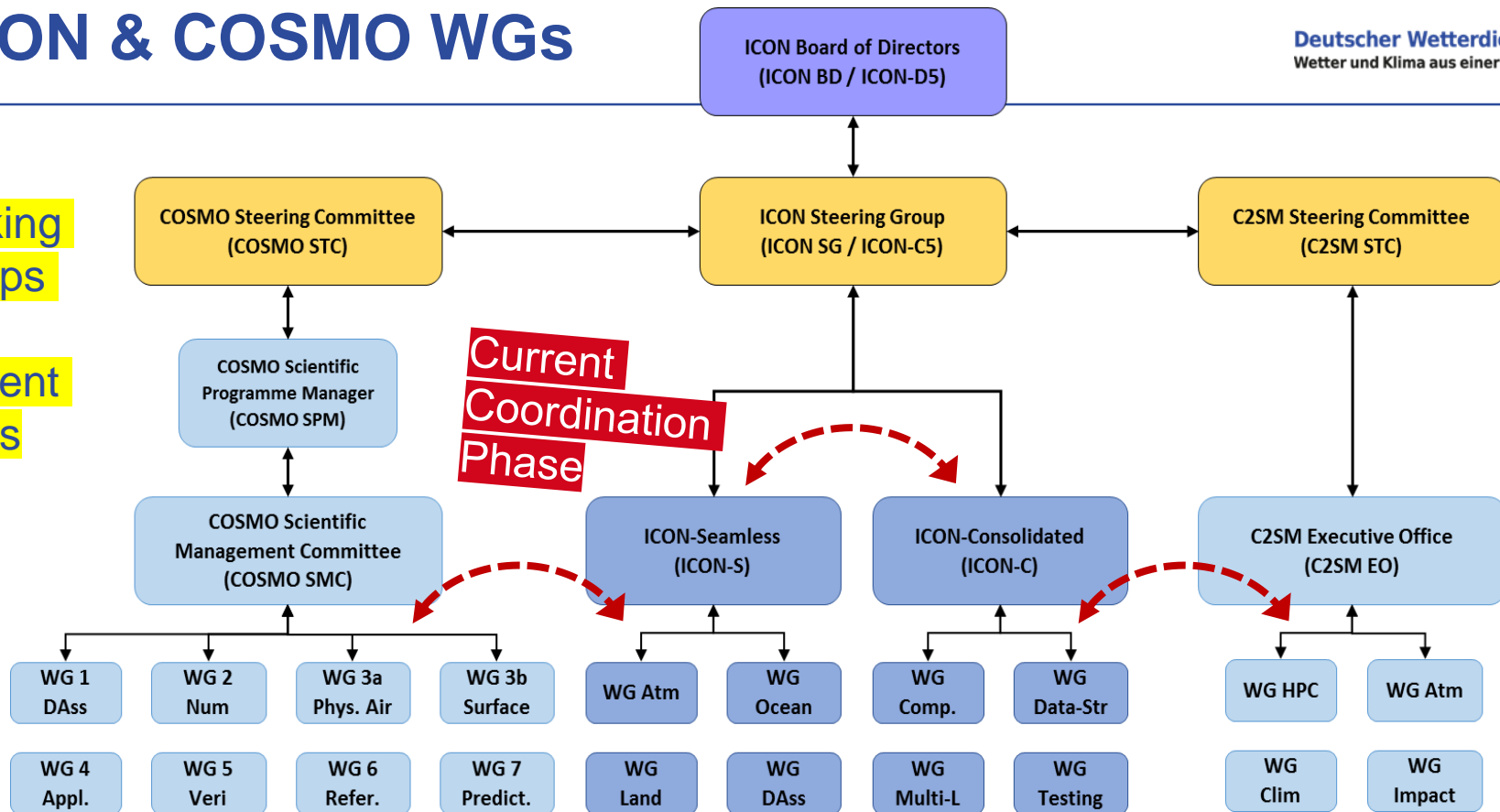
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# ICON & COSMO WGs

Working Groups with different Focus



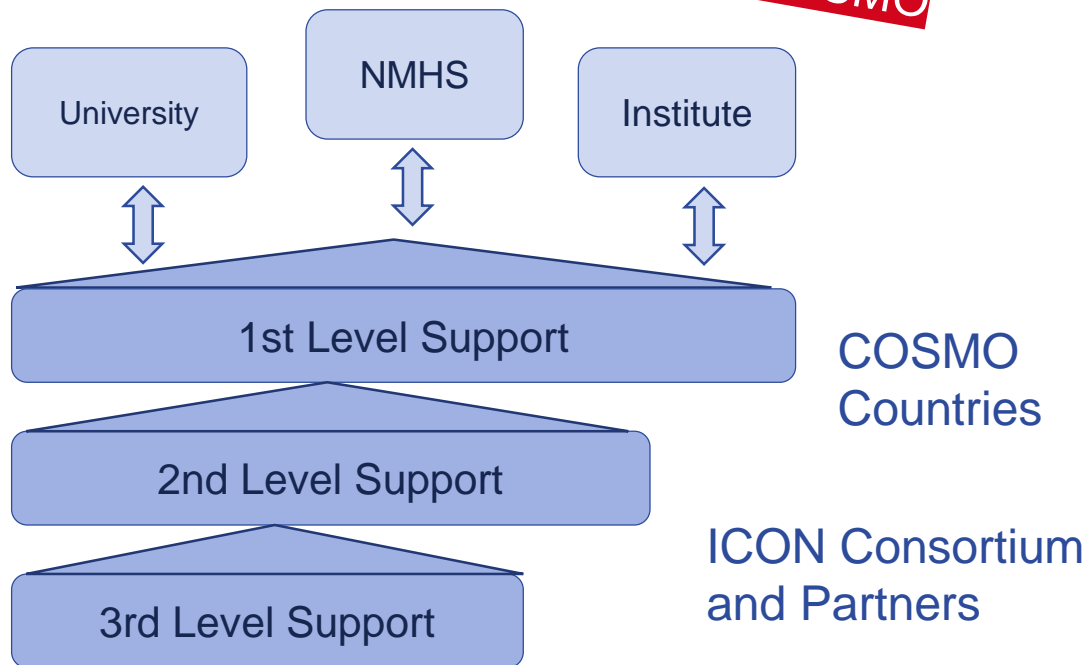
Regional NWP Focus

ESM Climate and Weather Focus

Infrastructure Focus



Currently we work out  
these elements jointly  
with COSMO



## Support Elements

- Availability of Tools
- Initial and Boundary Values
- Verification MEC and Rfdbk
- Data Assimilation DACE
- Installation Support
- Bug Support
- Evaluation Support
- Training
- List of Software and Support Level

## Support Licence

## Technical System (Tracker)

## Payment Options

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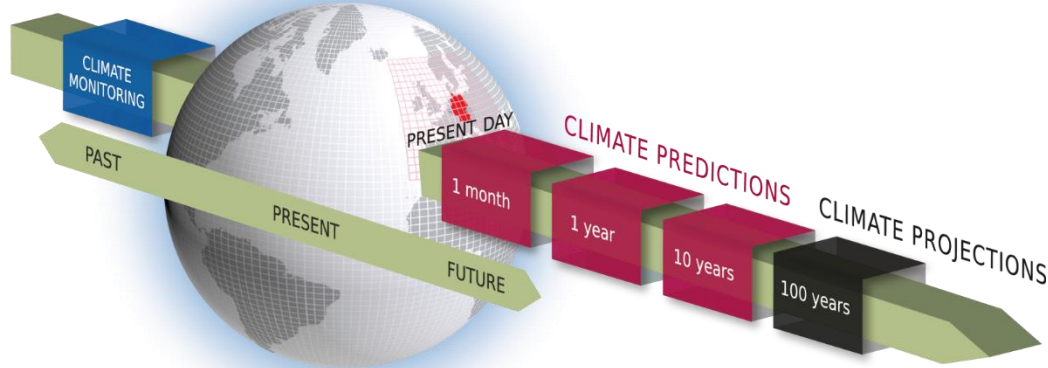
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# 4 ICON Seamless



- **Seasonal and decadal** climate simulations based on ICON-NWP and ICON-O
- **one integrated seamless system** for NWP, climate prediction and climate projections

- ✓ Technical **coupling** of ICON-NWP and ICON-O with YAC/YAC2,
- ✓ Extend model **IO and diagnostics**
- ✓ Create a joint technical environment (BACY)
- ✓ Varying **Aerosol, Solar Radiation, Ozone**
- ✓ Experimental investigation of the influence of NWP physics on processes in the coupled climate (TOA, SST, Means, AMOC, ...)
- ✓ **Weakly coupled data assimilation** for atmosphere, land and ocean

## Expert Groups

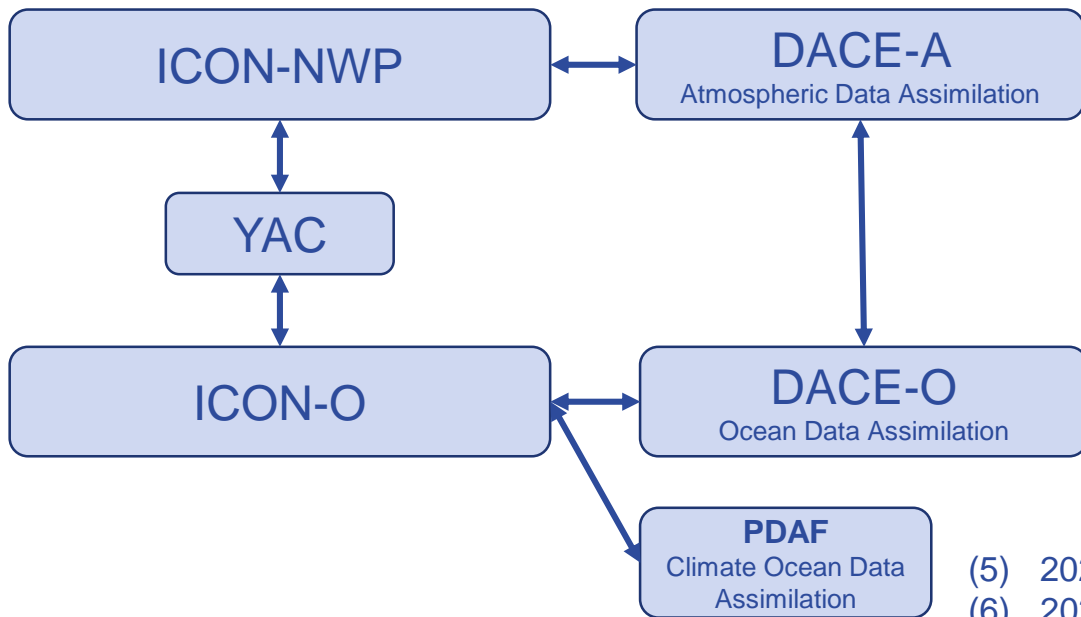


Fotos Pixabay

ICCARUS ICON-Seamless  
Keynote Talk + Session Thursday



# ICON Seamless ESM (0-7 Days)



- (1) 2023 **Coupling A+O YAC** on NEC  
*Experimental Data Assimilation, **ICON-O-LAM** technical*
- (2) 2024 Coupling A+O in BACY  
Verification available  
**Data Assimilation** in DACE technical  
ICON-O-ZOOM technical
- (3) 2025 **Near-Realtime Tests** with BACY,  
Data Bases, NUMEX Prep,  
**ICON-O-LAM Data Ass.** technical
- (4) 2026 Implementation in NUMEX  
**Deterministic Cycle with Data  
Assimilation** preoperational
- (5) 2027 **LETKF** implementation and testing
- (6) 2028 hybrid **EnVAR + LETKF** implementation and testing
- (7) 2029 **NUMEX** for hybrid system, Testing
- (8) 2030 **Ensemble-Variational ESM** ready for operational forecasting



GeInfoDienst Bw  
and DWD

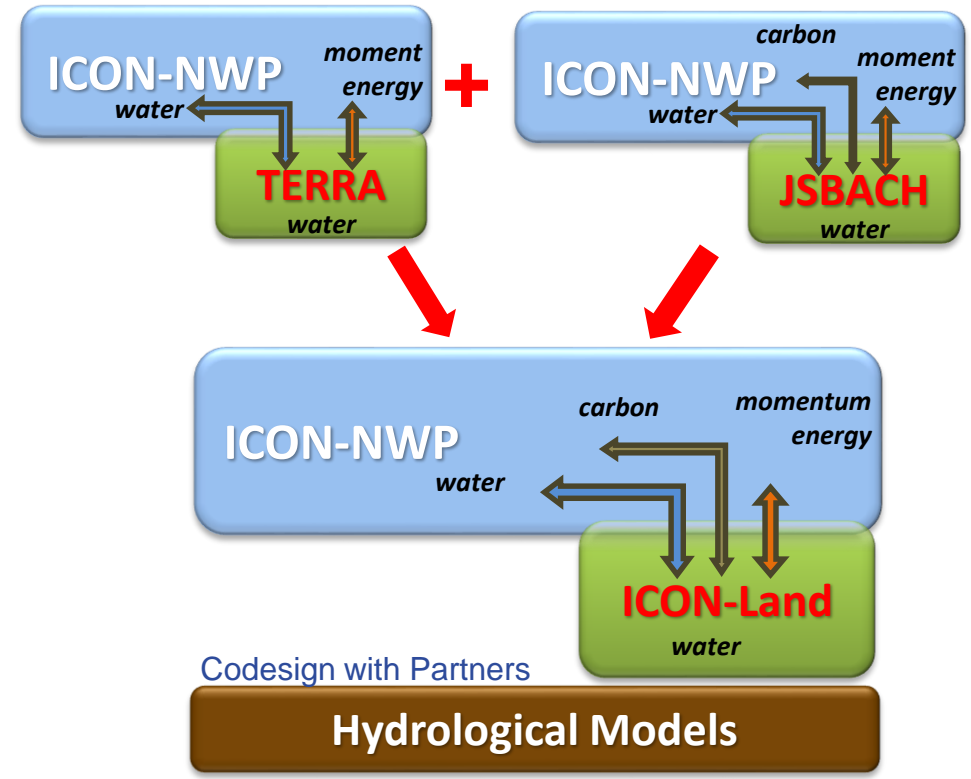
**Project starting  
Q3/2022**





Currently: design phase

- Based on the Land models **TERRA** and **JSBach**
- **ICON-Land** Software Framework
- Allowing *explicit, semi-implicit and implicit coupling* between A and L
- **Tiles** including transfer layer
- Include all necessary state-of-the-art surface processes and vegetation
- **Codesign** with Partners from Hydrology with their hydrological models



# ICON Reanalysis

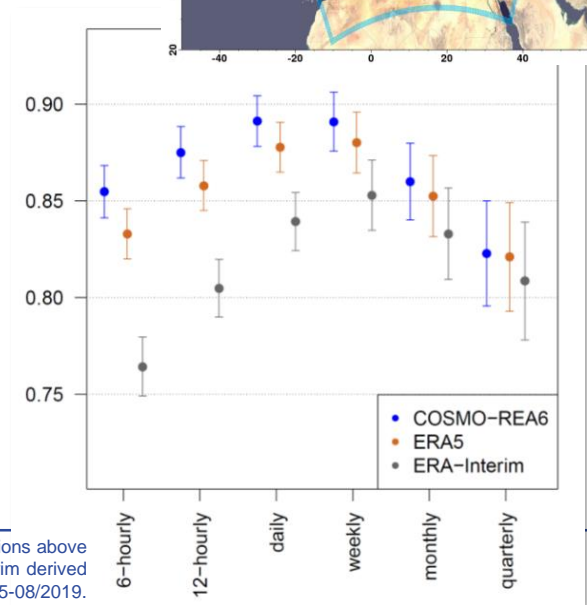
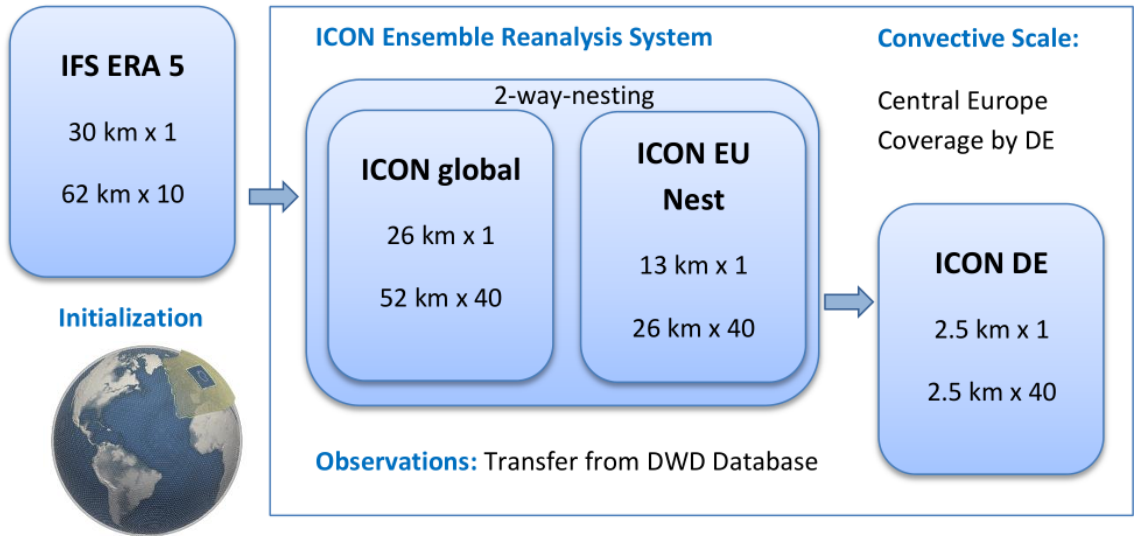
## Global-to-Regional ICON Reanalysis System

- Global-to-regional ICON Reanalysis
- Adaptation of **Observation Interface** for historical observations ongoing

Frank Kaspar, Deborah Niermann, Michael Borsche, Stephanie Fiedler, Jan Keller, Roland Potthast, Thomas Rösch, Thomas Spangehl, Birger Tinz



Bollmeyer 2015



Time dependence of the Pearson correlation coefficient averaged over 128 German locations above 100-m station height for COSMO-REA6 and the two global reanalyses ERA5 and ERA-Interim derived from the time period 01/1995-08/2019.



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# ICON Consolidated Target

Enable more modular development

## Modularization, Infrastructure, Mind-Set

Lines for Change Management

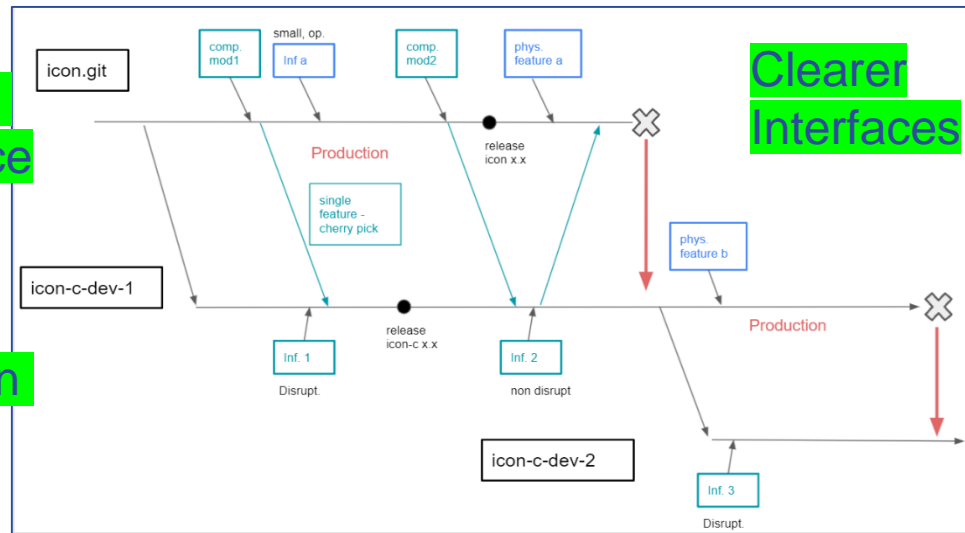
Our goal is to formulate and realize a process leading to a **common and modular structure** for the ICON development. This includes a process to manage a consolidated ICON version and how to interact between key branches for individual ICON development lines.

First steps taken

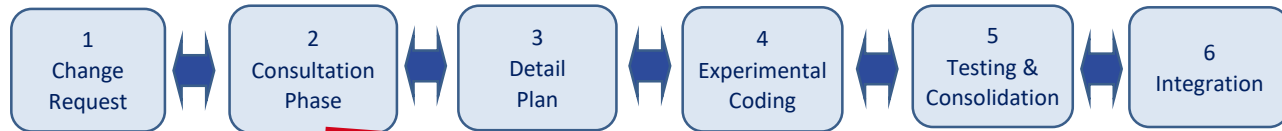
Easier Science

Clearer Interfaces

More Innovation by Partners



## Management process



Towards new HPC architectures

Now Conceptual concretization

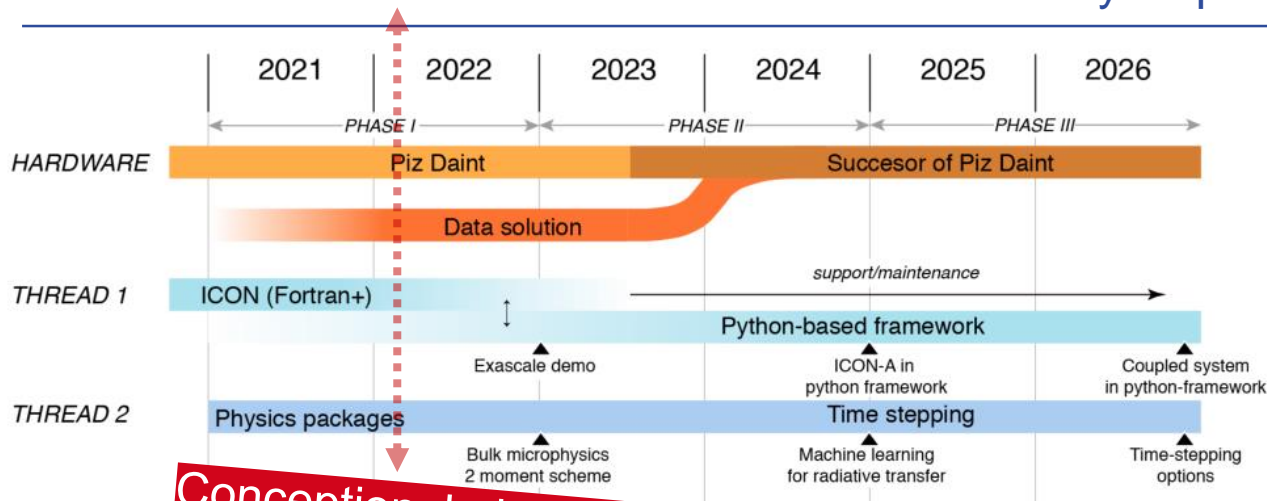


# ICON Consolidated Projects

Several projects  
by all partners!

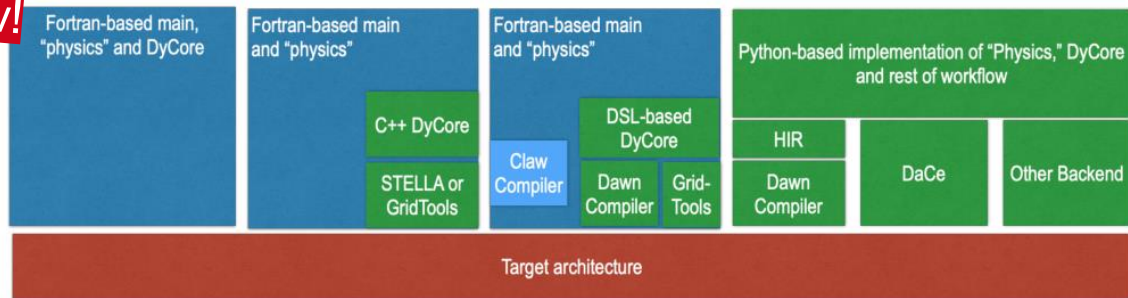
## EXCLAIM Project C2SM

Exascale Computing  
and Data Platform  
for Cloud Resolving  
Weather and  
Climate Modelling



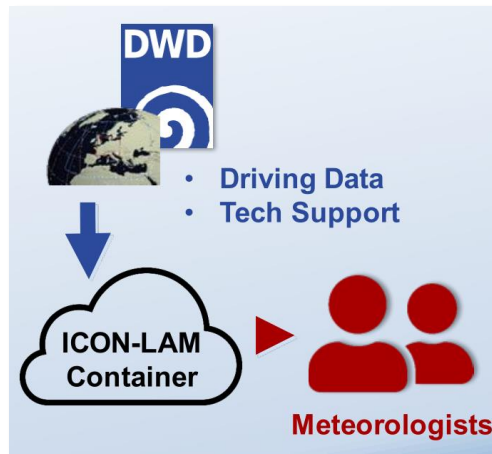
**Conceptual phase is now!**

Warmworld  
by MPI,  
DWD, KIT  
and many  
partners





# ICONIC = ICON-in-the-Cloud



## Principle:

- Design **Container with ICON**
- Upload the Container
- Control via Jupyter

ICON is running in the Cloud, in particular:

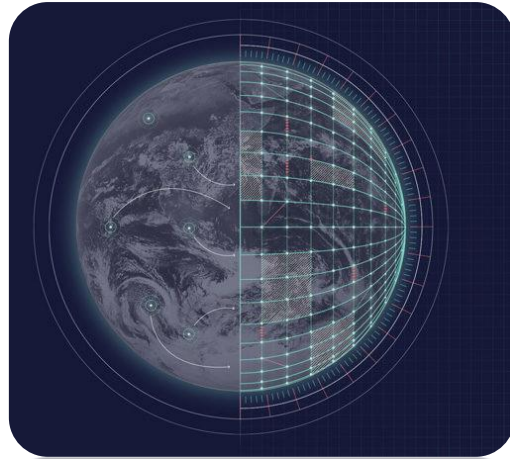
- ✓ Amazon Cloud
- ✓ Google Cloud
- ✓ Microsoft Azure Cloud

**Move towards a  
sustained cloud  
backbone**

# Destination Earth = DestinE

Currently  
Procurement is run

Deutscher Wetterdienst  
Wetter und Klima aus einer Hand



Destination Earth aims to develop a **high precision digital model of the Earth** to model, monitor and simulate natural phenomena and related human activities.

As part of European **Commission's Green Deal** and the Digital Strategy, Destination Earth (DestinE) will contribute to achieving the objectives of the twin transition, green and digital. DestinE will unlock the potential of **digital modelling of the Earth system**. It will focus on the effects of the **climate change**, water and marine environments, polar areas, cryosphere, biodiversity or **extreme weather** events, together with possible adaptation and mitigation strategies. It will help to predict major environmental degradation and disasters with unprecedented fidelity and reliability.

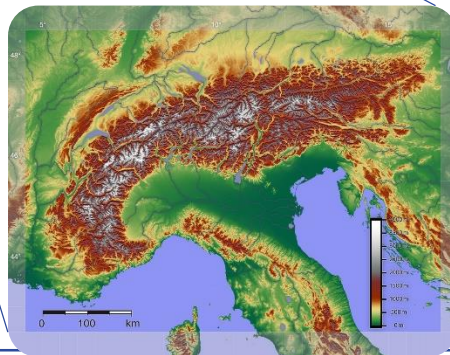


# Global-to-Regional-ICON Alpine Twin



Tri-lateral Cooperation  
Germany, Italy, Switzerland

DestinE  
2<sup>nd</sup> Phase Option



Work on the Glori-Alps Twin has started

The **GLORI (Global-to-Regional ICON) Alpine Digital Twin (DT)** is a **configurable on-demand** global-to-regional short-range high resolution Digital Twin based on the prediction capability of the **ICON** earth system model and the Data Assimilation Coding Environment **DACE** developed by the COSMO Consortium.

## Status Reflection

- Very Strong Weather and Climate Model
- Status NWP: ICON and Data Assimilation
  - Systems, Scales, high Quality, good scores
  - New Observation Systems
- Status ICON-ART in Operations
  - RSMC Nuclear, Non-Nuclear, Pollen,
  - Volcanic Ash, Mineral Dust/Sea Salt/Fires

## Consortium

- Very Strong Partners, Process, Risks
- Governance evolving
  - ICON-Board, ICON-C5, Leaders, Experts
- ICON Licences
  - Research, NMHS, Support, Open-Source

## Partner

- Consortia (COSMO, C2SM, ...)
- Computing Centres,
- Research Groups, Hans-Ertel Centre
- CLM Community
- National and international Institutions

## Working Mode

- ICON and COSMO Working Groups
- ICON and DACE Support

## ICON-Seamless Theme

- ICON-Seamless ESG Climate
- ICON-Seamless ESG Weather
- ICON-Land: Terra+JSBach+Vegetation
- ICON Reanalysis
  - national ESG Initiative

## ICON-Consolidated, ICON-X

- Modularization, Infrastructure, Mind-Set
- ICON-C Project World
- heterogeneous HPC and Exascale
- ICONIC ICON-in-the-Cloud
- Destination Earth EU Initiative
- Global-to-Regional ICON (GLORI) Alpine Twin

## Processes

- ICON High-Resolution High-Quality Weather and Climate
- Parametrizations and Circulation
- Clouds
- Modelling, AI, Data Assimilation
- Radiation
- ecRAD, ART, Data Assimilation, PV
- Precipitation
- Codesign with Hydrology and ICON-Land
- Uncertainty Estimation Minutes-to-Days-to-Decades
- SINFONY, Extremes, Reliability, Communication

# Clouds

and Precipitation, Radiation, Microphysics, ART, ...



Satellite VIS

Parametrizations

Satellite All-Sky

AI Model  
Components

AI Operators

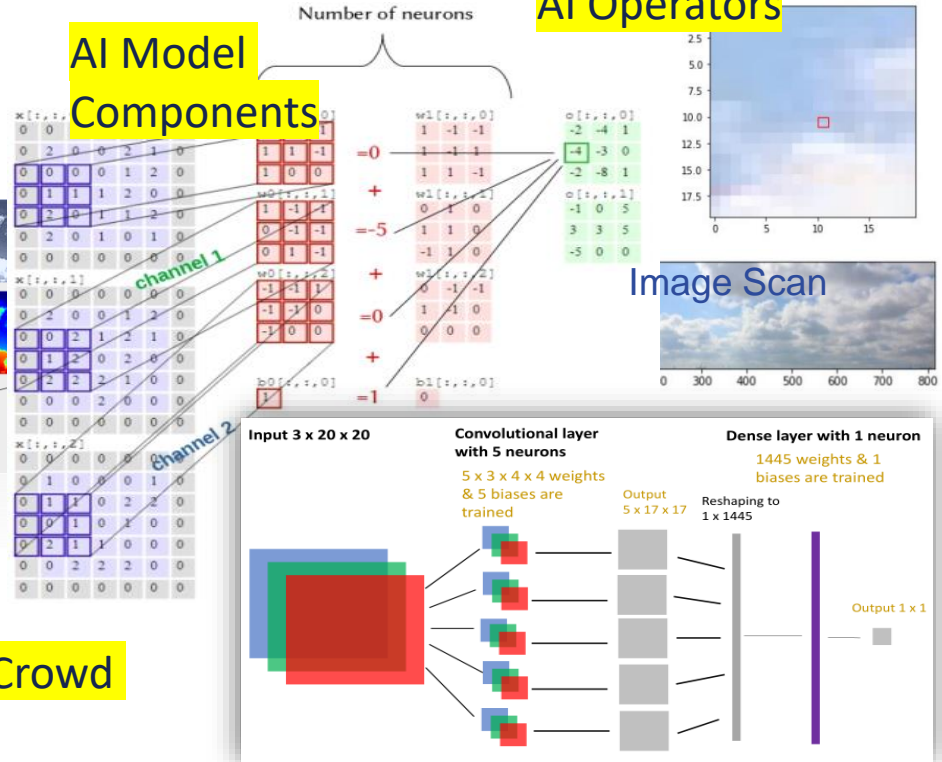
Image Scan

Clouds  
in the  
Climate  
System

ARTIFICIAL  
INTELLIGENCE

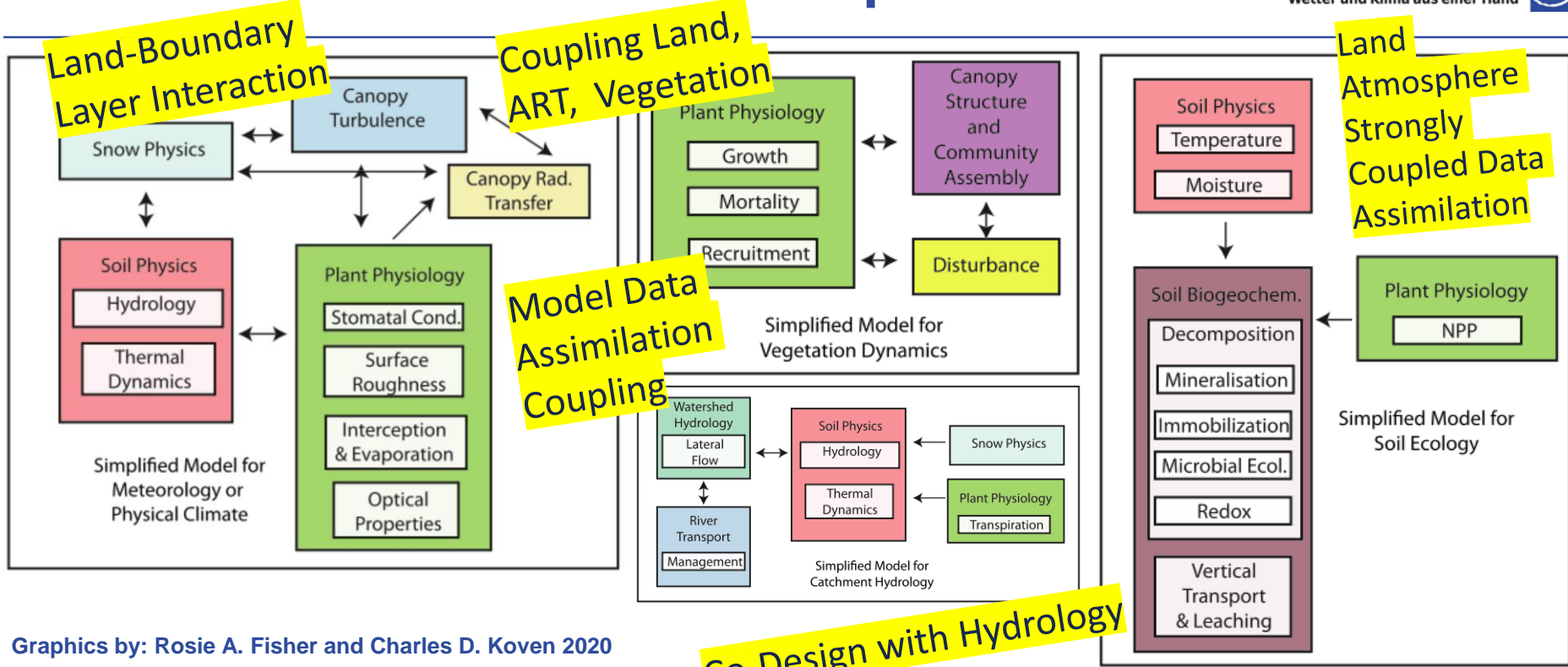
Camera and Crowd  
Observations

Global Circulation





# ICON-Land Processes in Complex Terrain



Graphics by: Rosie A. Fisher and Charles D. Koven 2020

Perspectives on the Future of Land Surface Models and the Challenges of Representing Complex Terrestrial Systems

Journal of Advances in Modeling Earth Systems, 12, e2018MS001453. <https://doi.org/10.1029/2018MS001453>





# Summary and Thank You

ICON/COSMO/  
CLM/ART Community

## Status Reflection

Very Strong Weather  
Status NWP: ICON and  
Systems, Scalability scores  
New Observations  
Status ICON-ART in Operational  
RSMC Nuclear, Non-Nuclear, Pollen,  
Volcanic Ash, Mineral Dust/Sea Salt/Fire

**We made significant progress**

## Consortium

Very Strong Partners, Proactive  
Governance evolving  
ICON-Board, ICON-C5, Leaders, Experts  
ICON Licences  
Research, NMHS

**ICON has high potential**

## Partner

Consortia (COSMO, C2SM, ...)  
Computing Centres,  
Research Groups, Hans-Ertel Centre  
CLM Community  
National and international In

**There are risks**

## Working Mode

ICON and COSMO Working Groups  
ICON and DACE Support

**Anyway:  
Let us do it!**

## N-Seamless Theme

ICON-Seamless ESMS Climate  
ICON-Seamless ESMS Weather  
ICON-Land: Terra+JSBach+Vegetation  
ICON Reanalysis  
national ESMS Initiative

## ICON-Consolidated, ICON-X

Standardization, Infrastructure, Mind-Set  
-C Project World  
heterogeneous HPC and Exascale  
ICONIC ICON-in-the-Cloud  
Destination Earth EU Initiative  
Global-to-Regional ICON (GLORI) Alpine Twin

## Processes

ICON High-Resolution High-Quality Weather and Climate  
Parametrizations and Circulation  
Clouds  
Modelling, AI, Data Assimilation  
Radiation  
ecRAD, ART, Data Assimilation, PV  
Precipitation  
Codesign with Hydrology and ICON-Land  
Uncertainty Estimation Minutes-to-Days-to-Decades  
SINFONY, Extremes, Reliability, Communication

