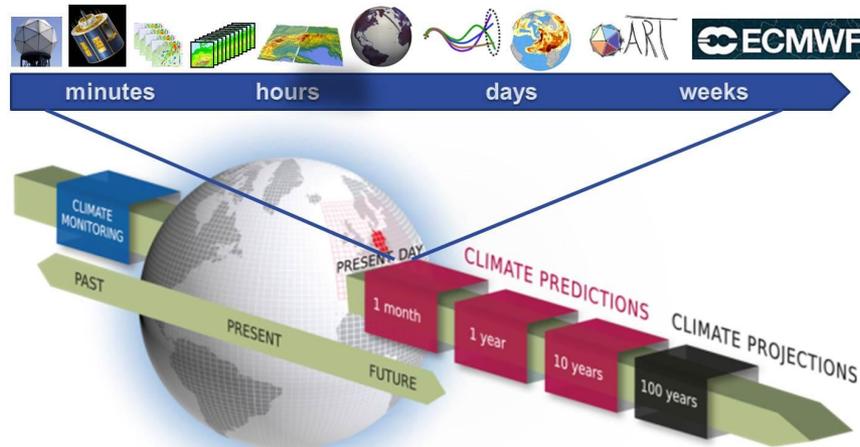


# Seamless Prediction @ DWD

Sarah Jones

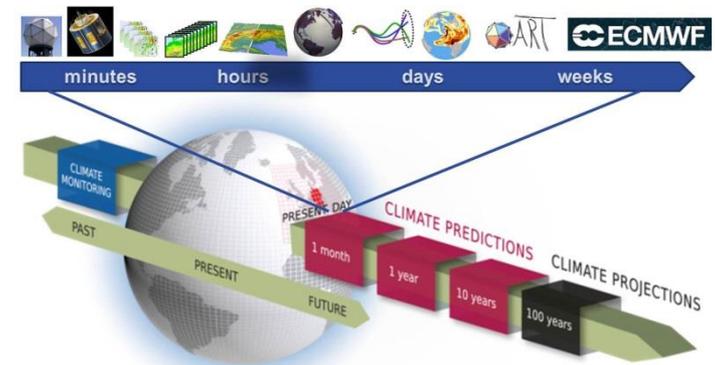
Detlev Majewski, Barbara Früh, Christina Köpken-Watts  
Tobias Fuchs, Roland Potthast, Günther Zängl and many others

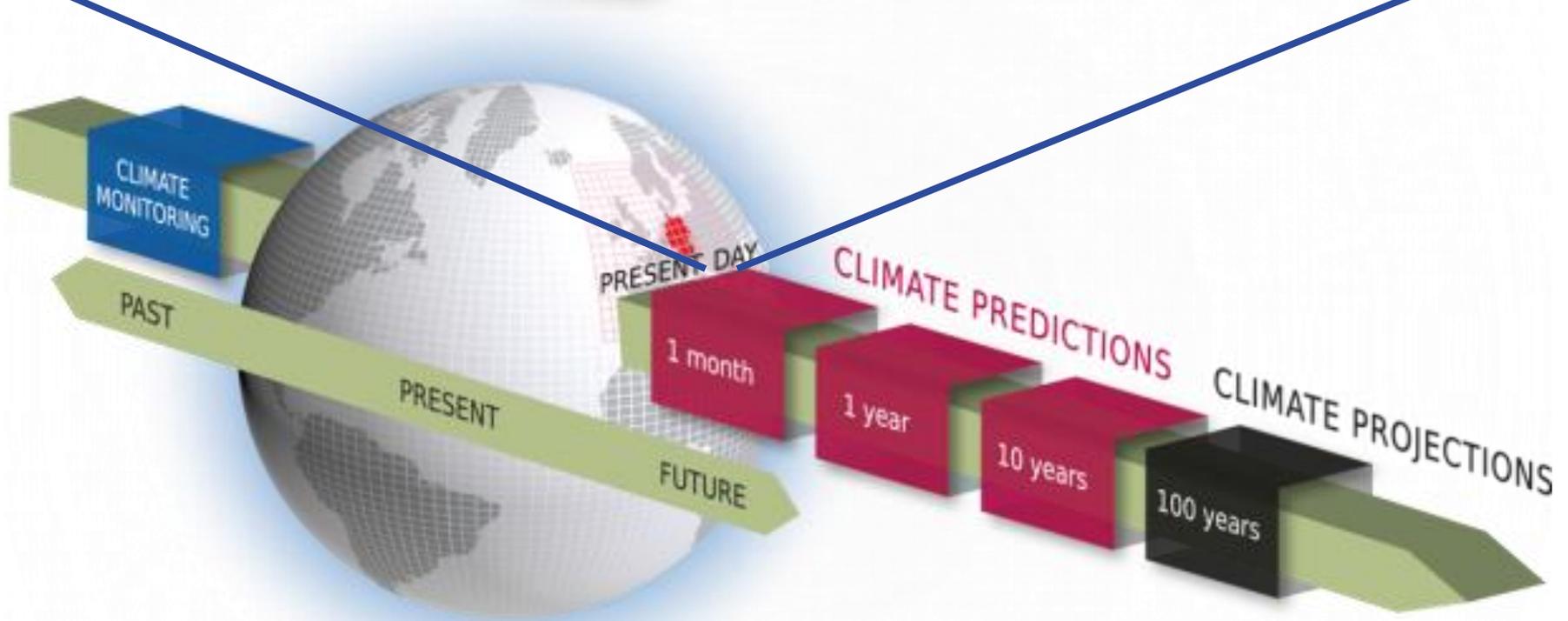


$$\begin{aligned}
 \partial_t v_n + (\zeta + f) v_t + \partial_n K + w \partial_z v_n &= -c_{pd} \theta_v \partial_n \pi \\
 \partial_t w + \vec{v}_h \cdot \nabla w + w \partial_z w &= -c_{pd} \theta_v \partial_z \pi - g \\
 \partial_t \rho + \nabla \cdot (\vec{v} \rho) &= 0 \\
 \partial_t (\rho \theta_v) + \nabla \cdot (\vec{v} \rho \theta_v) &= 0
 \end{aligned}$$



- for probabilistic seamless warnings and forecasts at very short time and space scales (SINFONY)
- for reliable and affordable renewable energy
- as a leading meteorological provider for aviation in Europe
- for an Integrated Greenhouse Gas Monitoring System in support of UNFCCC reporting
- for reliable assessment of seasonal, decadal and long-term climate trends
- for climate services in DAS & GFCS

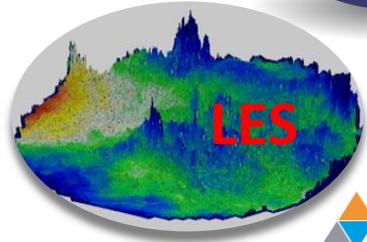
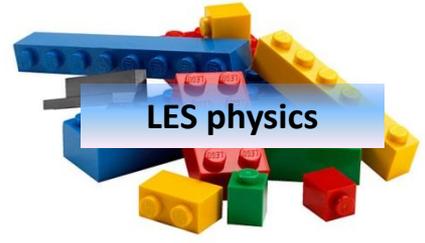
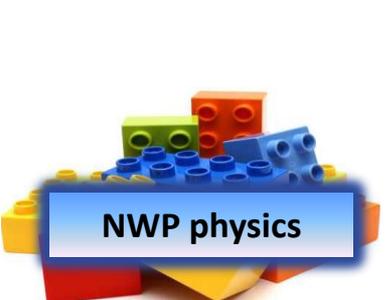






# The ICON Modelling Framework – an exciting opportunity for research and operations

- grid generation
- one- & two-way nesting
- nh dyn. core
- tracer module
- hybrid parallelization
- GRIB & NetCDF IO
- ocean & sea ice module





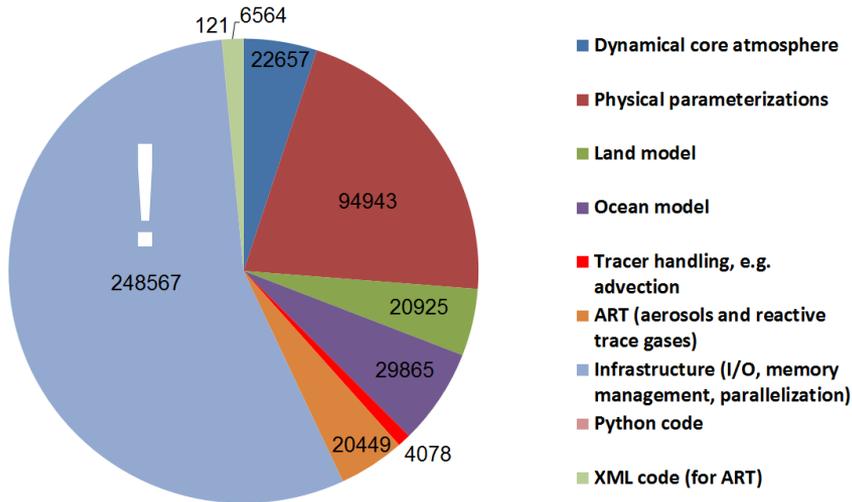
## Important ICON-A (atmosphere) design features

- Unified modelling system for NWP and climate prediction / projection in order to bundle knowledge and to maximize synergy
- Nonhydrostatic dynamical core to enable seamless prediction
- Mass conservation, mass consistent tracer advection
- Up-to-date physics packages, e.g. RRTM, tile approach
- Global and limited area mode; one-way and two nesting options
- Shallow and deep atmosphere options
- Scalability and efficiency on  $O(10^4+)$  cores; hybrid MPI / OpenMP parallelization

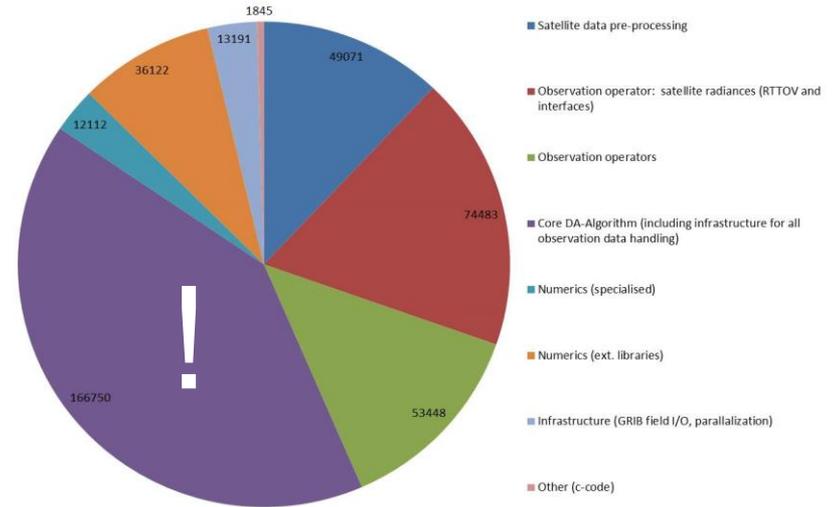




# ICON ~ 445.000



# DACE ~ 425.000



## Global / regional seamless ICON-Modelling Framework and DACE: EnVar & LETKF assimilation code Logical lines (code statements) as of August 2018

Estimated cost of code development for ICON (2004-2018: 2500 PM)

Based on the Constructive Cost Model (COCOMO)

Estimated cost of ICON code development: 12 Mill. Euro

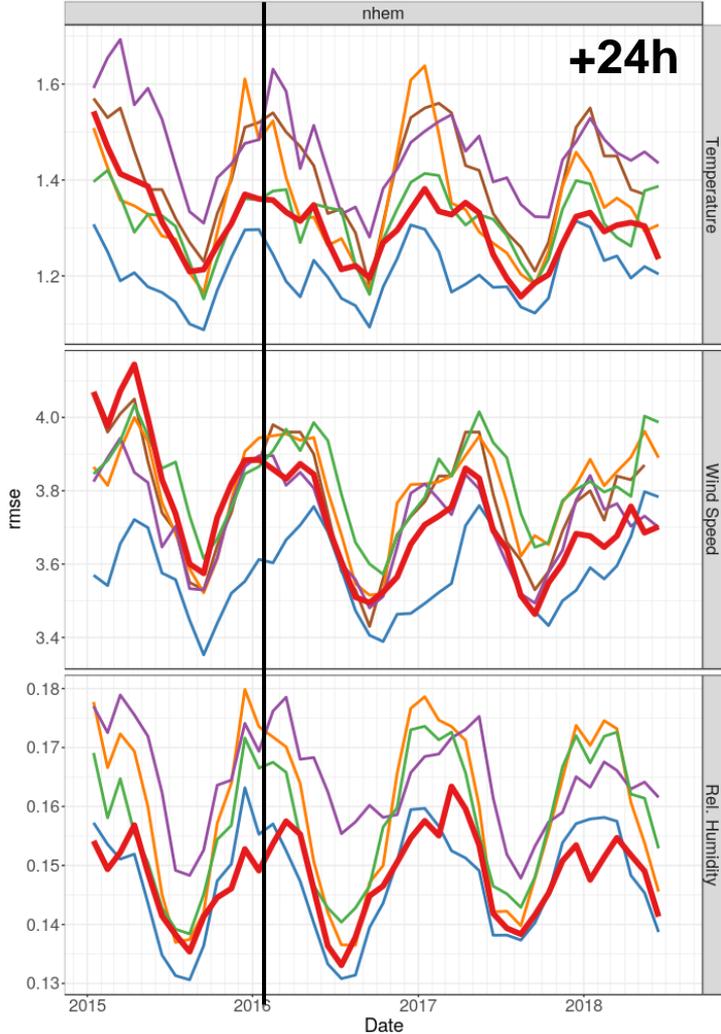


# Verification of global forecasting systems against radiosonde observations for the northern hemisphere 2015 to 2018



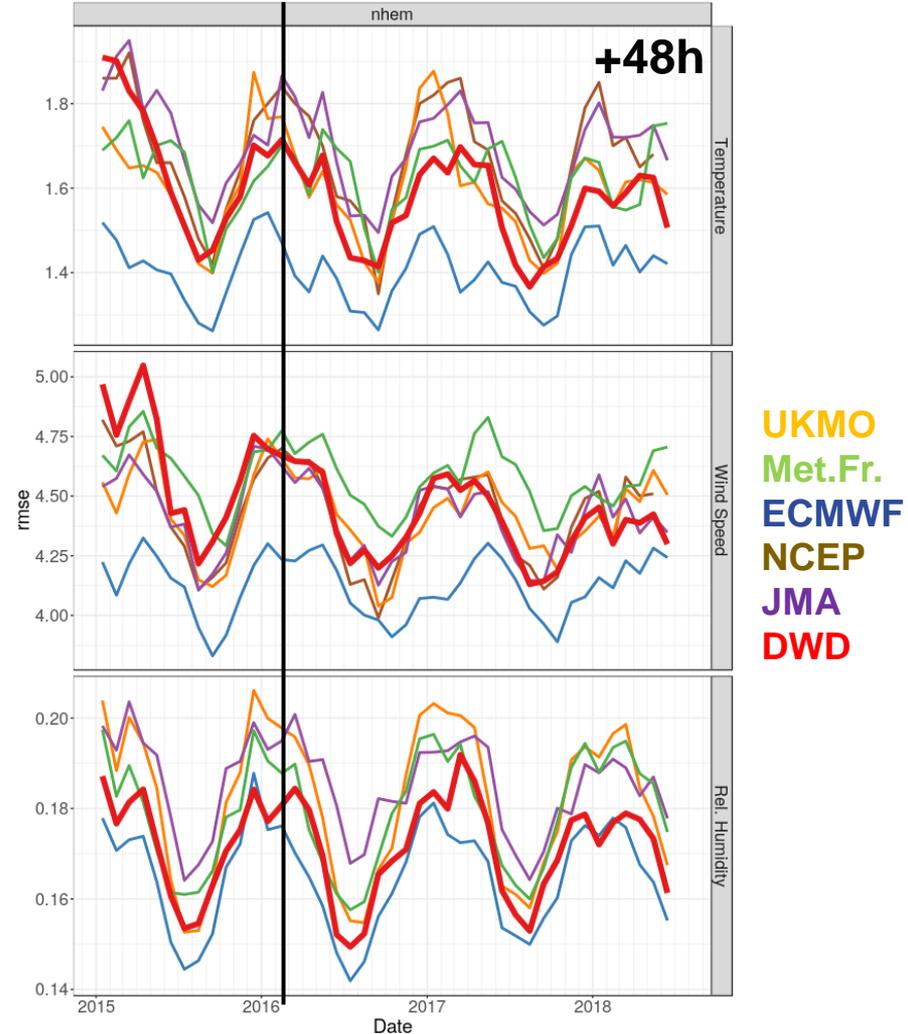
WMO verification against observations  
lead-time: 24h  
valid-time: 12UTC  
level: 850hPa

EnVar



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

EnVar

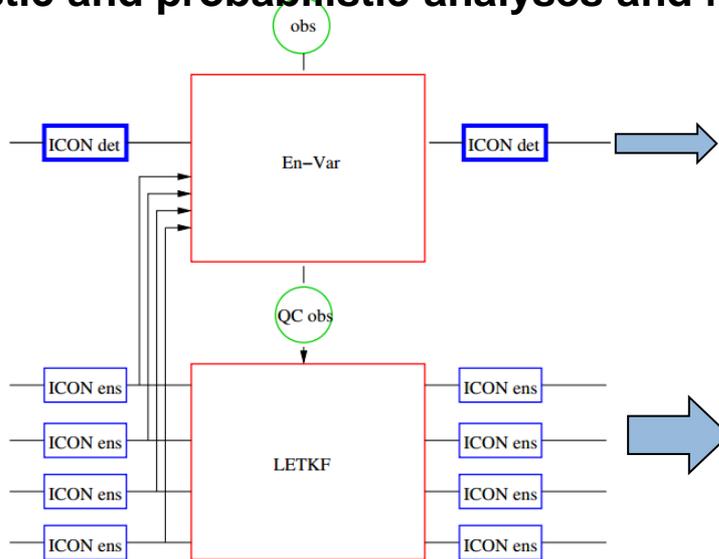


# The operational NWP system of DWD in 2018

Deterministic and probabilistic analyses and forecasts on *global* and *regional* scales

EnVAR Hybrid  
DA-System

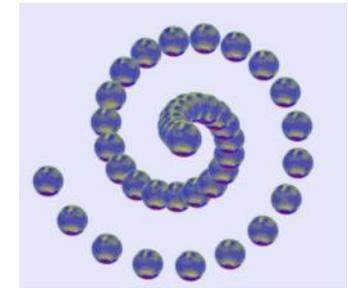
*Global*  
Ensemble  
Data  
Assimilation  
**ICON-EDA**  
40 members  
40/20 km



**ICON deterministic**  
13 / 6.5 km (Europe)

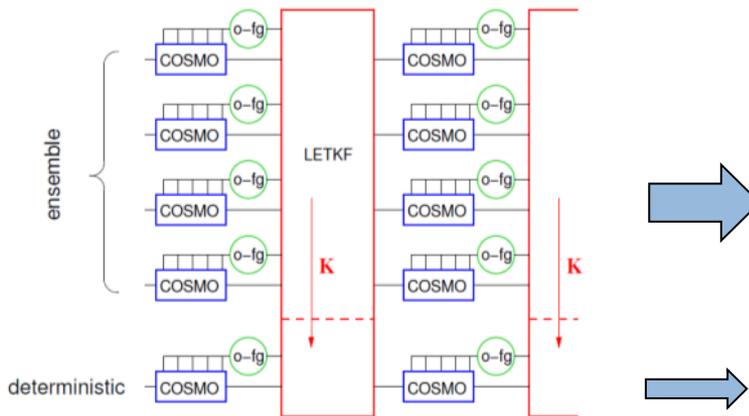


**Global Ensemble  
Prediction System**  
**ICON-EPS**  
40 members  
40 / 20 km (Europe)

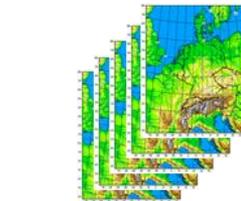


GLOBAL

*Regional*  
Ensemble  
Data  
Assimilation  
**KENDA**  
40 members  
2.2 km

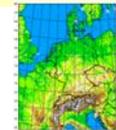


**Regional Ensemble  
Prediction System**  
**COSMO-D2-EPS**  
20 members  
2.2 km



Physics  
perturbations

**COSMO-D2 deterministic**  
2.2 km



REGIONAL

# Climate forecasts and projections

## Monthly Outlook

user tailored  
climate services  
based on monthly  
forecasts from  
**ECMWF**

## Seasonal forecasts

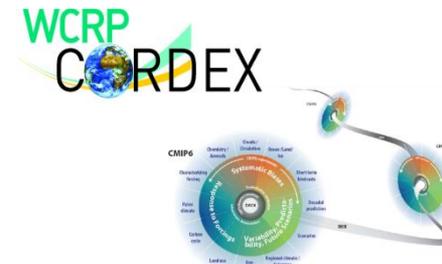
routine provision of  
seasonal forecasts  
with **German  
Climate Forecast  
System (GCFS)** in  
collaboration with  
Universität  
Hamburg, MPI-M,  
C3S

## Decadal forecasts

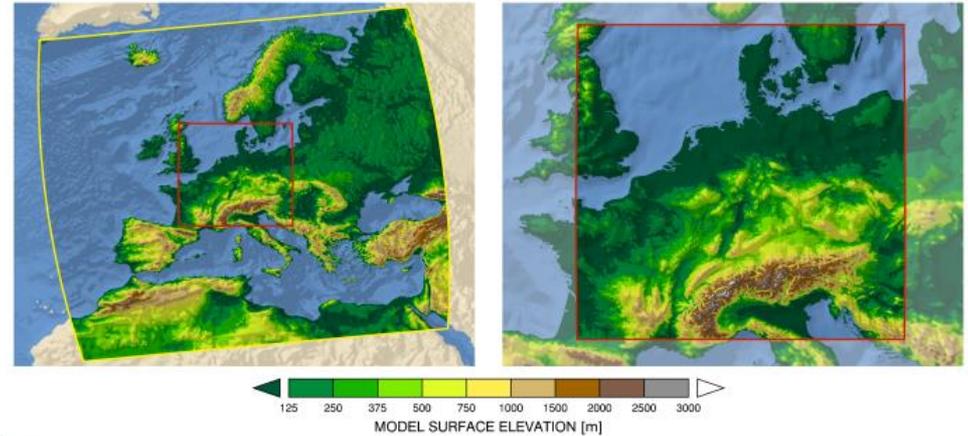
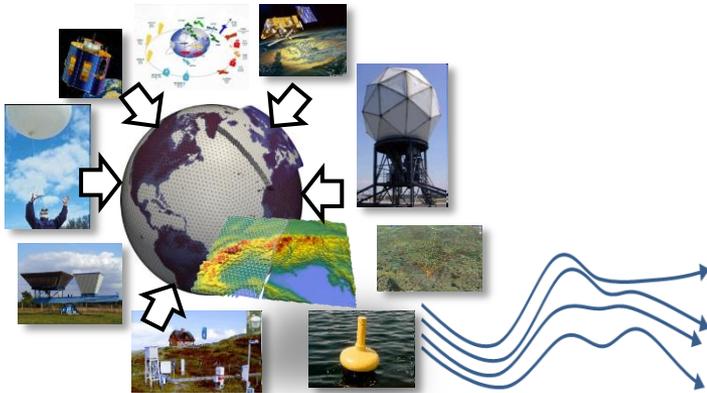
BMBF research  
project **MiKlip II**  
until Oct 2019,  
routine provision of  
global decadal  
climate forecasts  
from 2020

## Climate projections

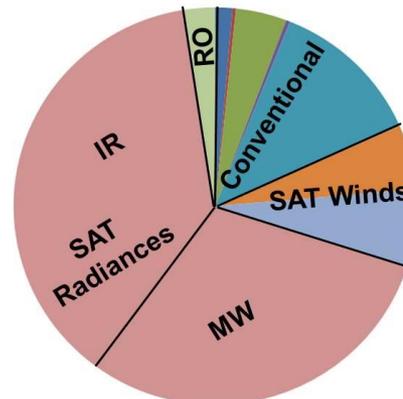
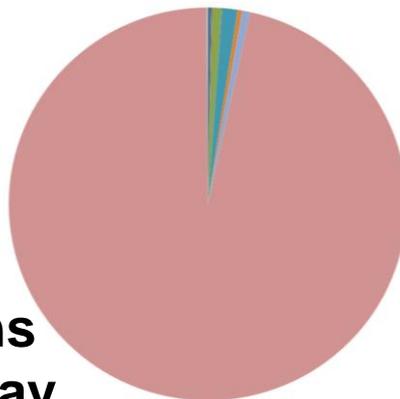
contribution to  
(global) **CMIP6** &  
(regional) **CORDEX**  
in collaboration  
with DKRZ and  
MPI-M & CLM-  
Community



# Data Assimilation / Regional Reanalysis



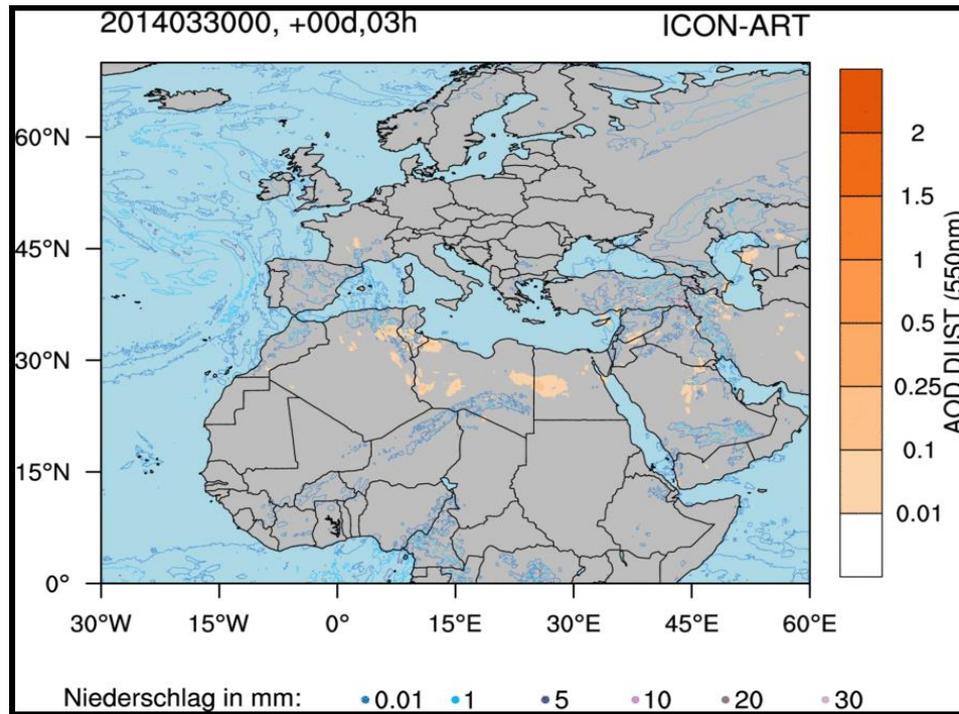
**135 million  
observations  
received / day**



**4,7 million used / day  
(after QC, thinning)**



ICON-ART for global and regional dispersion of **mineral dust**,  
**volcanic ash**, **radioactive particles** and **pollen**.

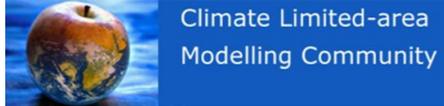


# Future additional ICON application modes at DWD

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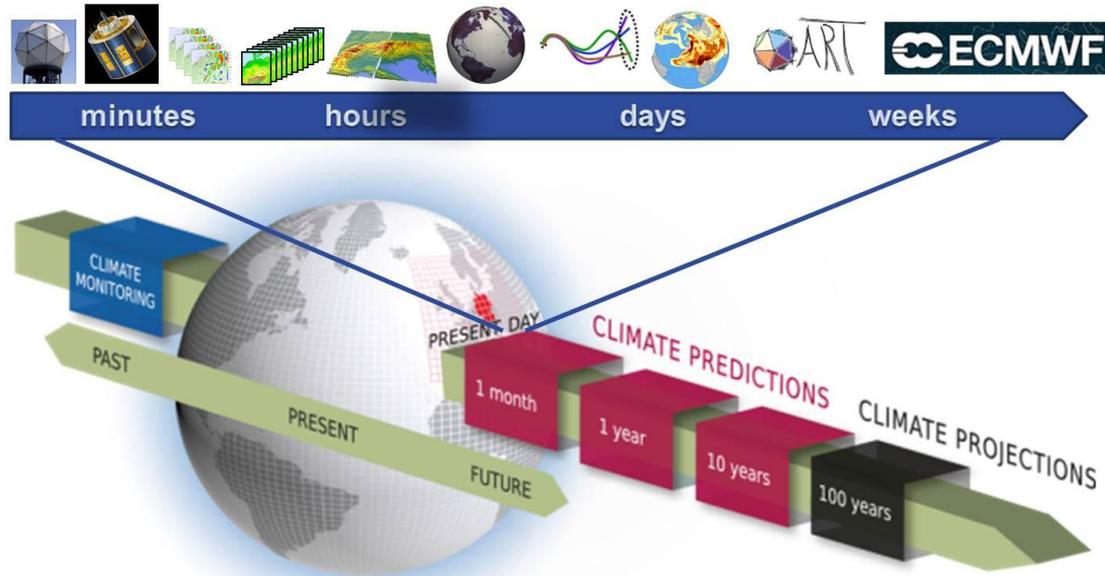
- ICON-LAM replacing COSMO-D2 as regional forecasting system
- Long range (one-month) forecasts
- Seasonal (up to three months) forecasts (currently based on ECHAM6 and MPI-OM)
- Decadal prediction (currently based on ECHAM6 and MPI-OM)
- Climate projections
- Integrated greenhouse gas monitoring system (ITMS for ICOS)
- Regional re-analyses (atmosphere only and coupled)

# Examples of research projects and partners

- Further development of the ICON Modelling Framework together with MPI-M, KIT and DKRZ
- Migration of  and  to ICON-LAM (Limited Area Mode of ICON)
- Adapt ICON to emerging and future hardware architectures while addressing the issue of performance portability 
- Hans Ertel Centre:   
Data Assimilation @ LMU; Reanalysis @ Uni Bonn / Köln; Model Development @ MPI-M/Uni Hamburg & Uni Frankfurt
- and many more .....



# Seamless Prediction @ DWD



$$\begin{aligned}
 \partial_t v_n + (\zeta + f) v_t + \partial_n K + w \partial_z v_n &= -c_{pd} \theta_v \partial_n \pi \\
 \partial_t w + \vec{v}_h \cdot \nabla w + w \partial_z w &= -c_{pd} \theta_v \partial_z \pi - g \\
 \partial_t \rho + \nabla \cdot (\vec{v} \rho) &= 0 \\
 \partial_t (\rho \theta_v) + \nabla \cdot (\vec{v} \rho \theta_v) &= 0
 \end{aligned}$$

