Max-Planck-Institut
für Meteorologie

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

ICON: The new non-hydrostatic Modelling Framework of DWD and MPI-M

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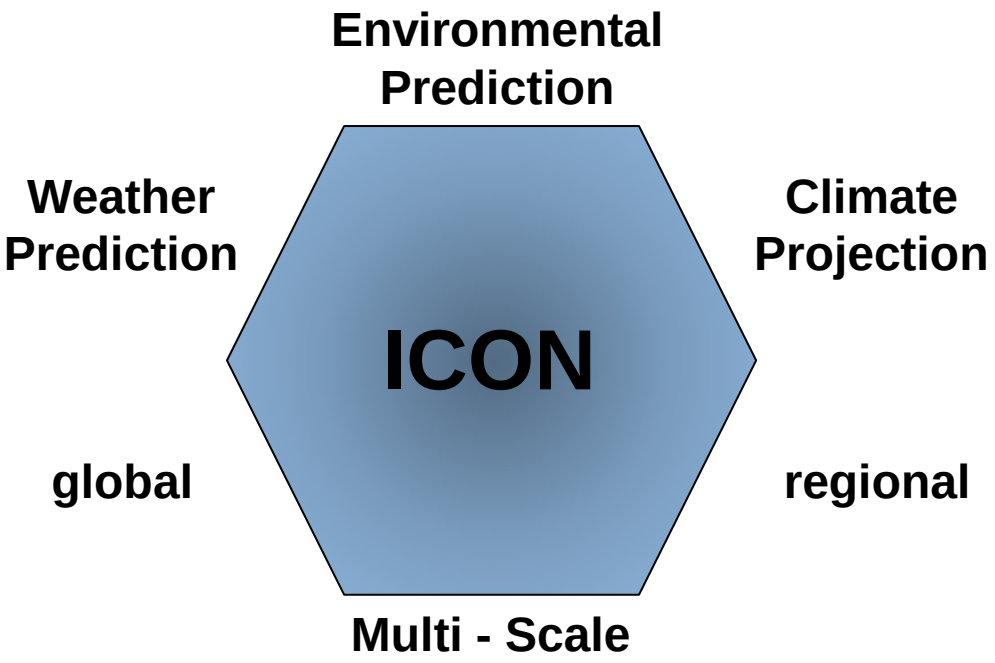
Outline

- Motivation
- ICON Modelling Framework
- Grid generation
- Local mesh refinement
- Atmosphere component
- Ocean component
- Technical aspects
- Cooperation and outlook

Motivation

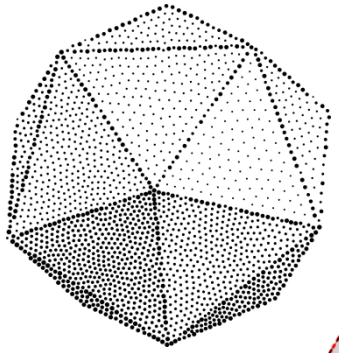
- Prepare for Seamless Prediction
- Benefit from the synergy in modelling "weather" and "climate"
- Combine modelling-Know-how of DWD and MPI-M
- Develop a new universal modelling framework
- Prepare flexible software design for modern supercomputers

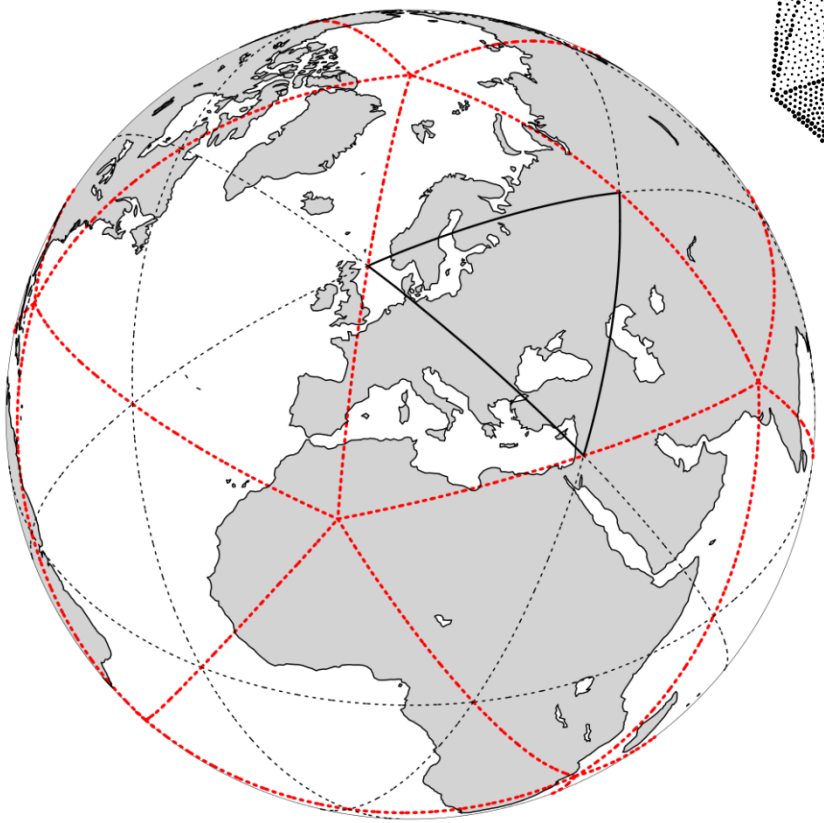
Modelling Framework ICON (ICOsahedral Non-hydrostatic)



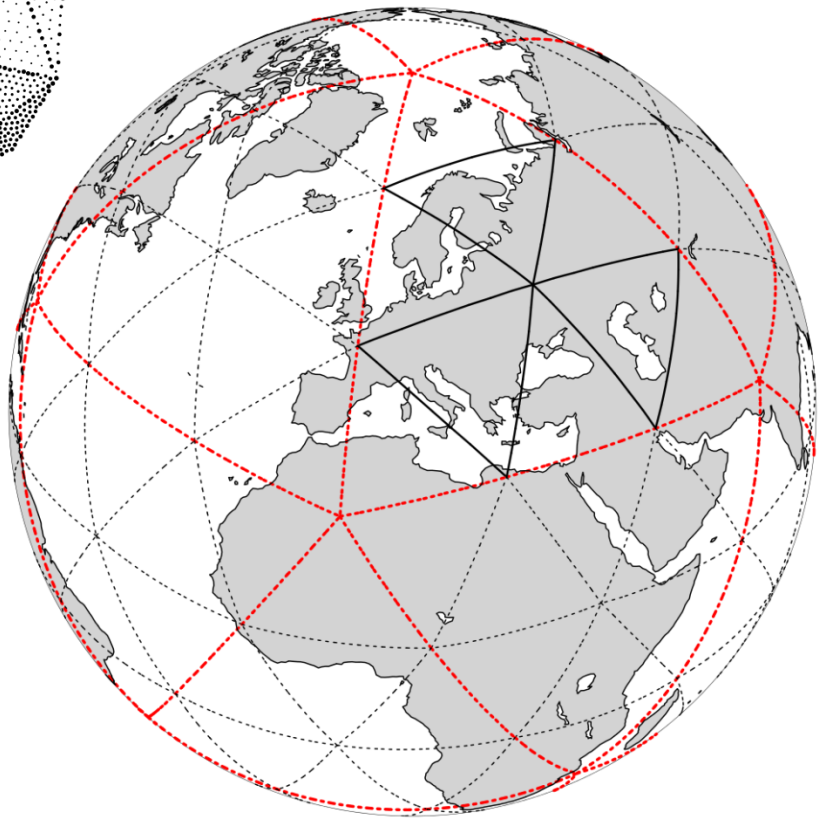
Grid generation is based on the icosahedron

R2B00





R3B00



Static local mesh refinement

Effective grid spacing (distance between points):

$\Delta x \approx 5050 / (n\ 2^k)$ [km]

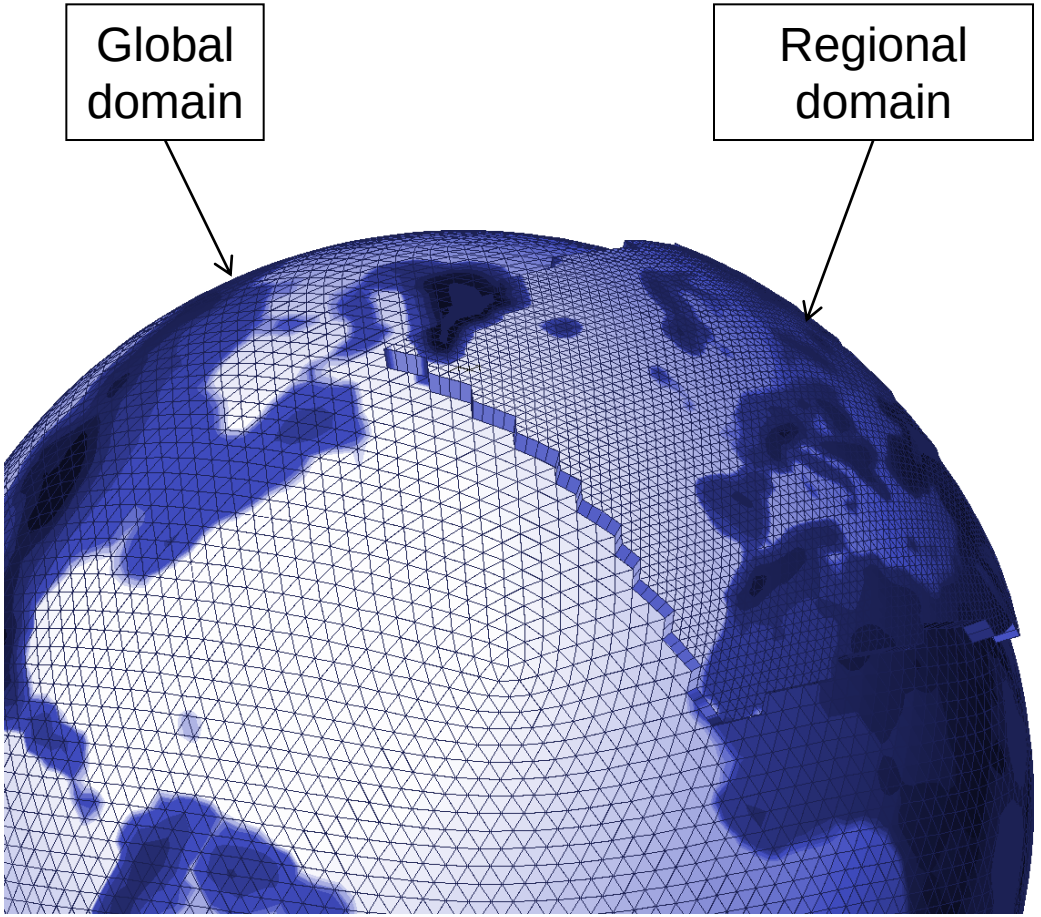
Example:

R2B7: n = 2, k = 7

Grid spacing: 20 km

Global grid consists of 1.3 million spherical triangles.

Regional domain with higher horizontal resolution.



Atmosphere component, part I

$$\frac{\partial v_n}{\partial t} + (\zeta + f) v_t + \frac{\partial K}{\partial n} + w \frac{\partial v_n}{\partial z} = -c_{pd} \theta_v \frac{\partial \pi}{\partial n}$$

$$\frac{\partial w}{\partial t} + \nabla \cdot (\vec{v}_n w) - w \nabla \cdot \vec{v}_n + w \frac{\partial w}{\partial z} = -c_{pd} \theta_v \frac{\partial \pi}{\partial z} - g$$

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\vec{v} \rho) = 0$$

$$\frac{\partial \rho \theta_v}{\partial t} + \nabla \cdot (\vec{v} \rho \theta_v) = 0$$

v_n,w: normal / vertical wind components

ρ: density

θ_v: virtual potential temperature

K: horizontal kinetic energy

ζ: verticale corticity component

π: Exner Function

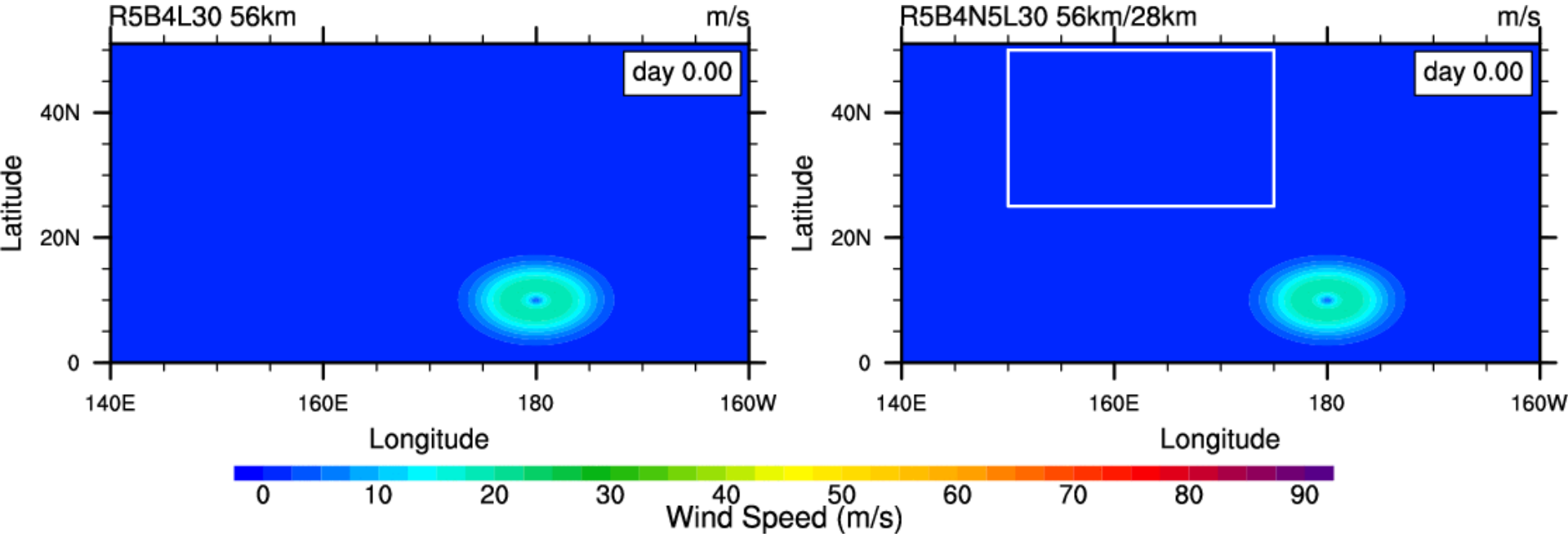
blue: independent prognostic variables

Atmosphere component, part II

Process	Authors	Scheme	Origin
Radiation	Mlawer et al. (1997) Barker et al. (2002)	RRTM (later with McICA McSI)	ECHAM6/IFS
	Ritter and Geleyn (1992)	δ two-stream	GME/COSMO
Non-orographic gravity wave drag	Scinocca (2003) Orr, Bechtold et al. (2010)	wave dissipation at critical level	IFS
Sub-grid scale orographic drag	Lott and Miller (1997)	blocking, GWD	IFS
Cloud cover	Doms and Schättler (2004)	sub-grid diagnostic	GME/COSMO
	Köhler et al. (new development)	diagnostic (later prognostic) PDF	ICON
Microphysics	Doms and Schättler (2004) Seifert (2010)	prognostic: water vapor, cloud water,cloud ice, rain and snow	GME/COSMO
Convection	Tiedtke (1989) Bechthold et al. (2008)	mass-flux shallow and deep	IFS
Turbulent transfer	Raschendorfer (2001)	prognostic TKE	COSMO
	Louis (1979)	1st order closure	GME
	Neggers, Köhler, Beljaars (2010)	EDMF-DUALM	IFS
Land	Heise and Schrodin (2002), Machulskaya, Helmert, Mironov (2008, lake)	tiled TERRA + FLAKE + multi-layer snow	GME/COSMO
	Raddatz, Knorr	JSBACH	ECHAM6

Atmosphere component, part III

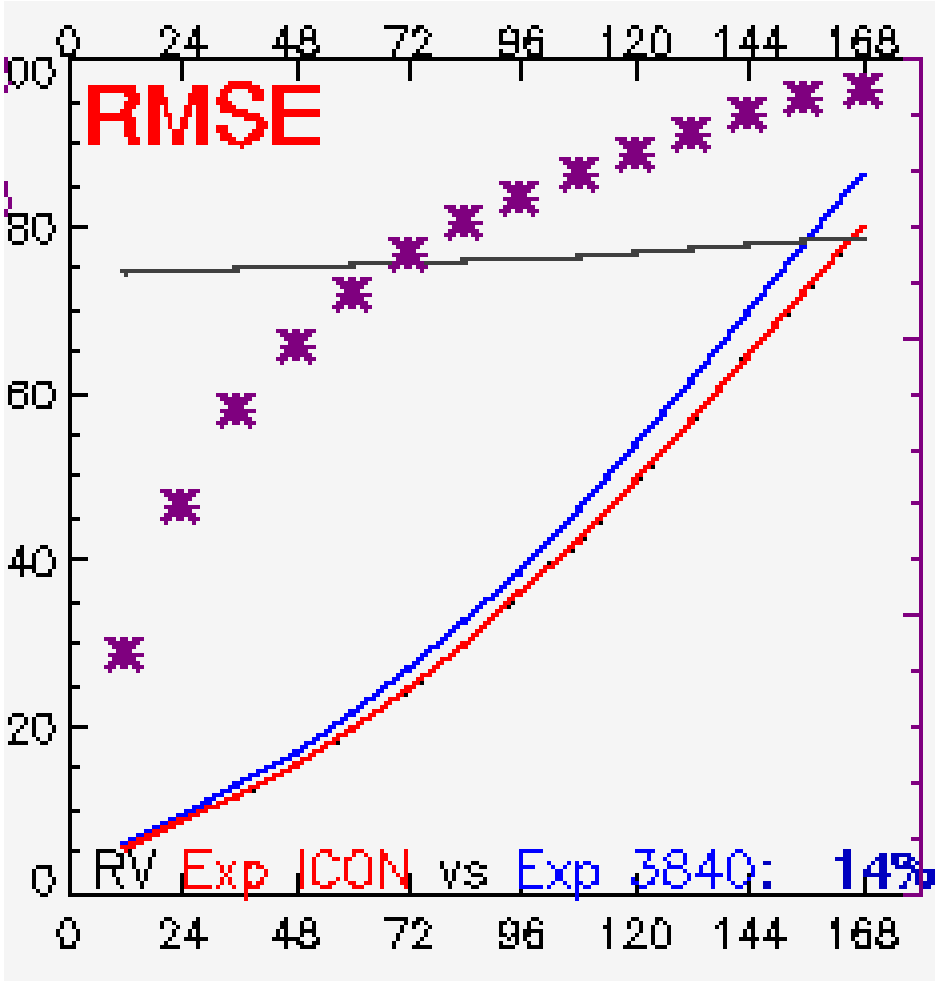
DCMIP-Test: Idealised tropical cyclone, 12-day-simulation



Horizontal wind speed (m/s)

Left: Global domain, $\Delta x \approx 56$ km; right: 2-Way-Nesting, $\Delta x \approx 56$ km / 28 km

Atmosphere component, part IV



ICON (red line) vs. GME (blue)

Both on a 40-km grid

Initial state: IFS analysis

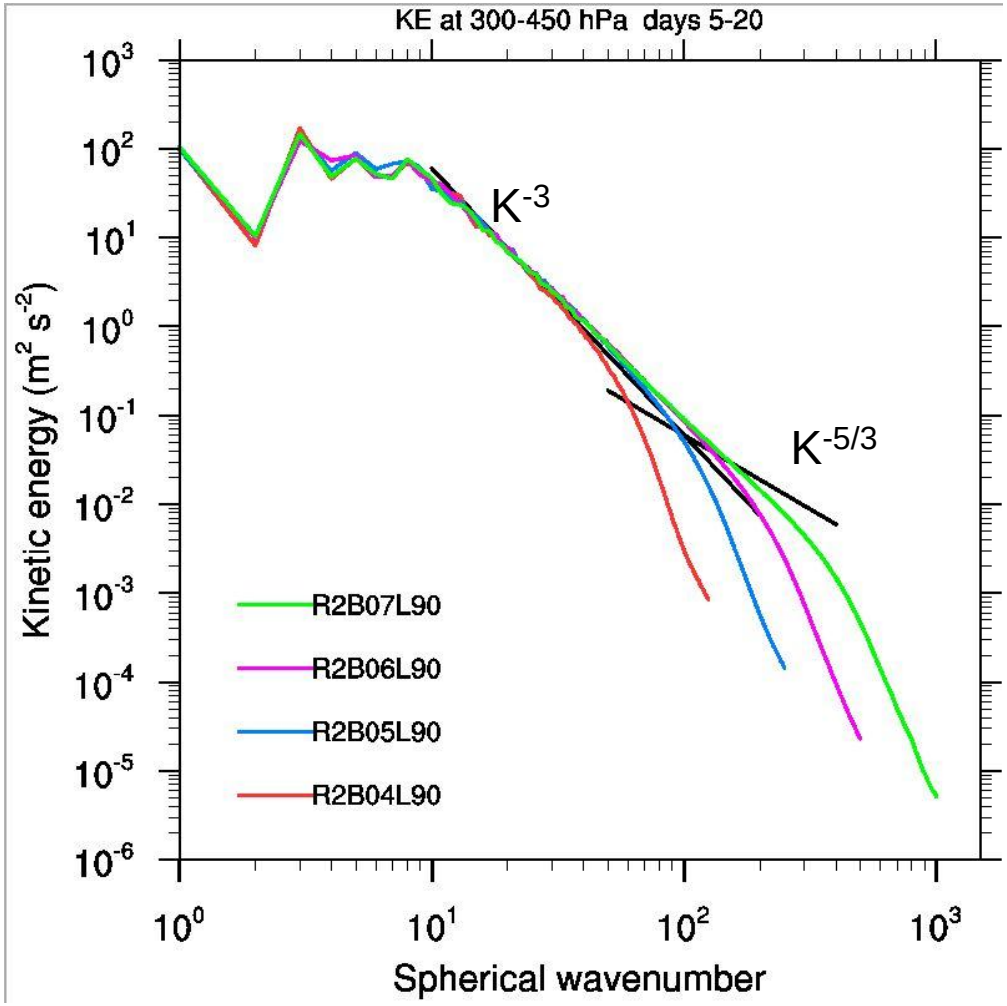
7-d forecasts

RMSE for geopotential 500 hPa vs. IFS analysis

Northern hemisphere

June 2012

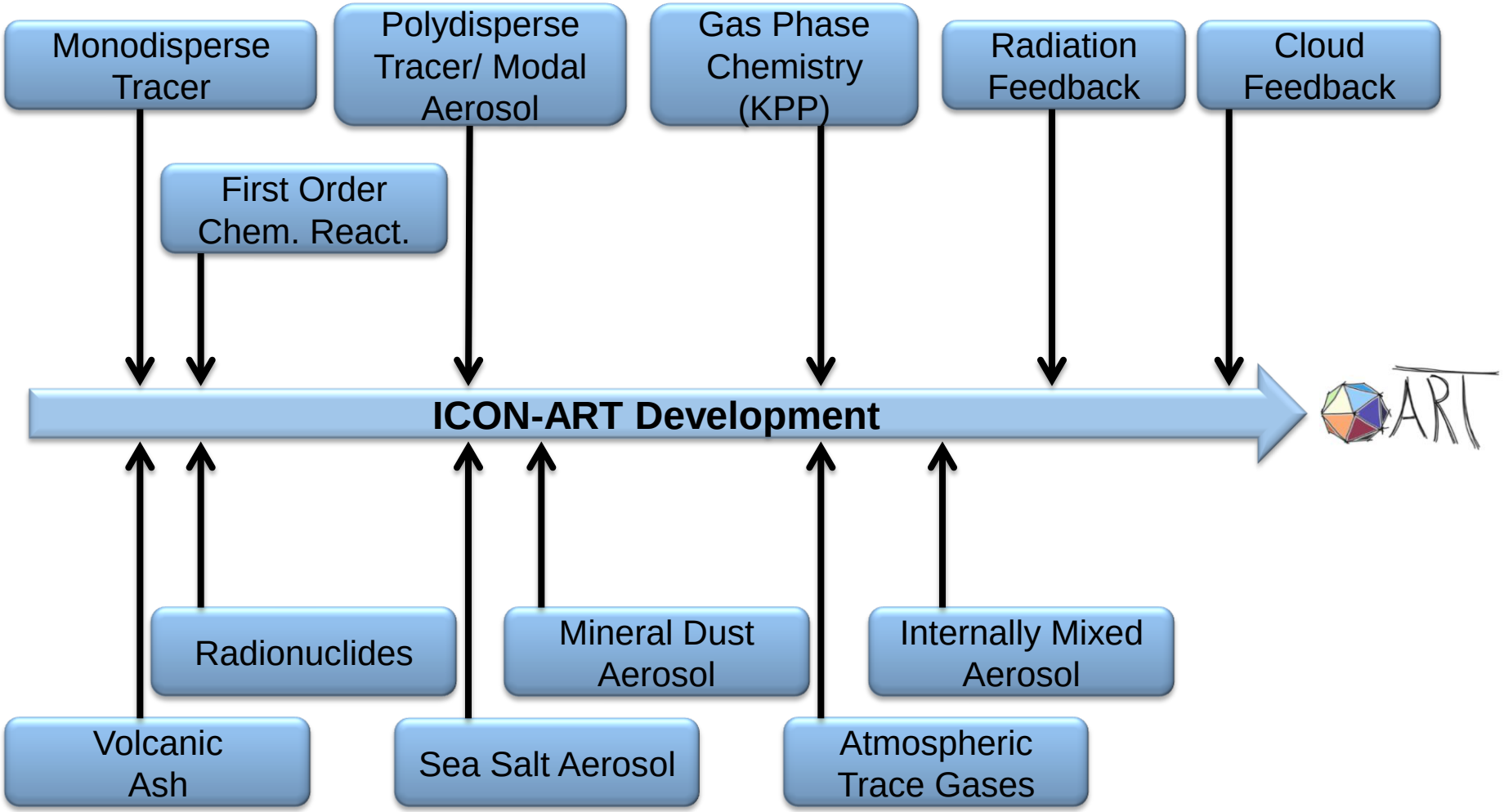
Atmosphere component, part V



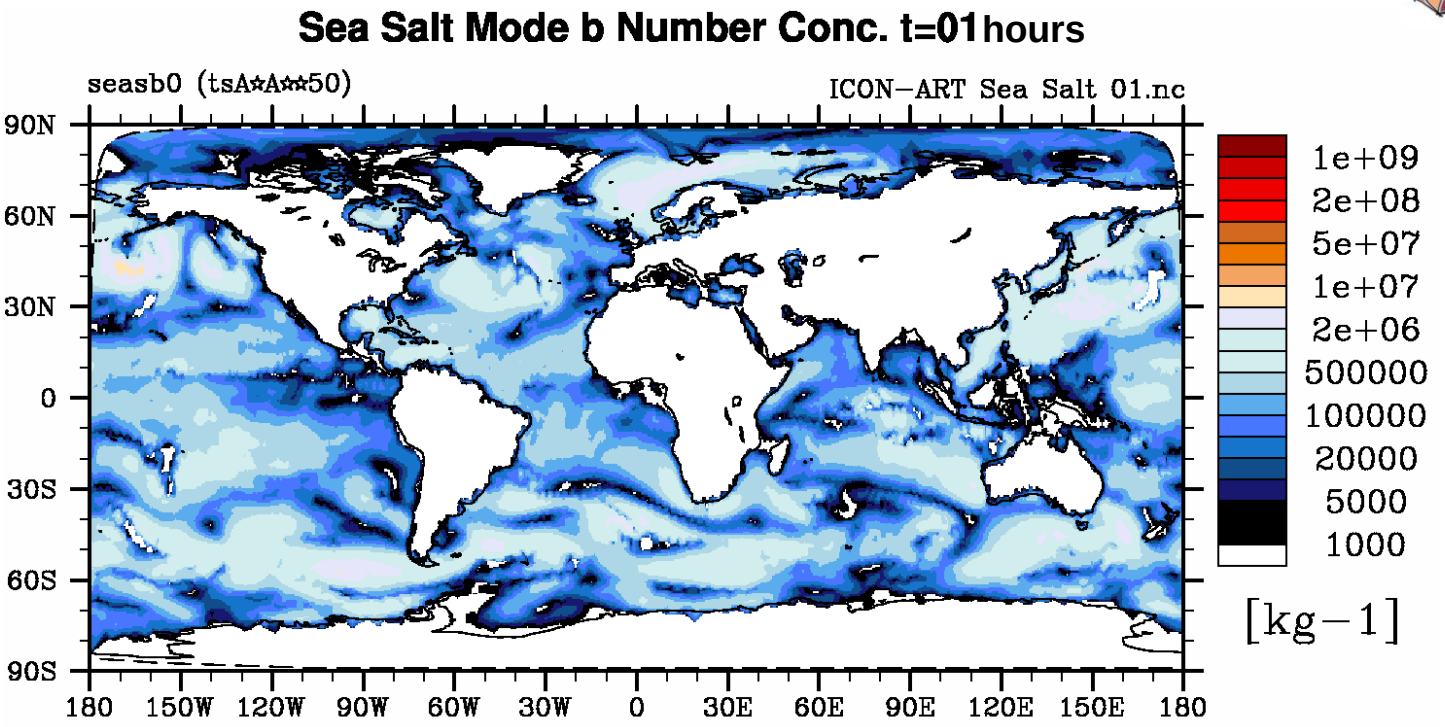
Kinetic energy spectra between 300 and 450 hPa for ICON at a grid spacing of
158 km (red)
79 km (blue)
40 km (magenta)
20 km (green)

True model resolution about 6 x grid spacing!

Atmosphere component, part VI

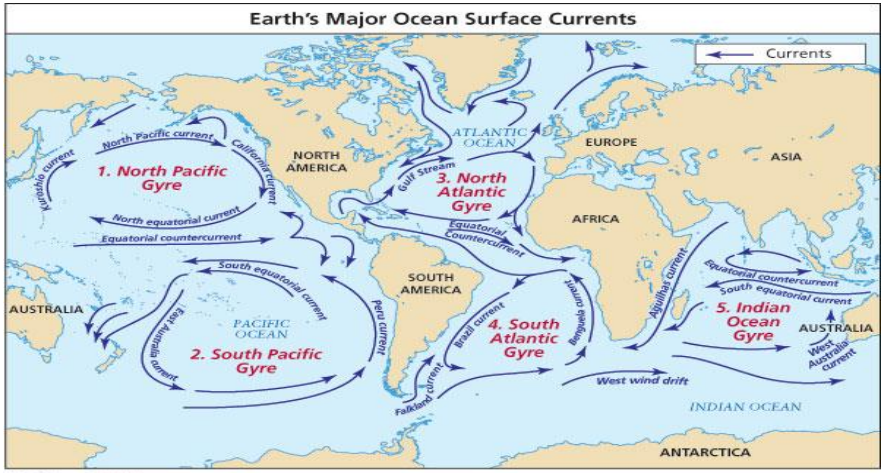


Atmosphere component, part VII

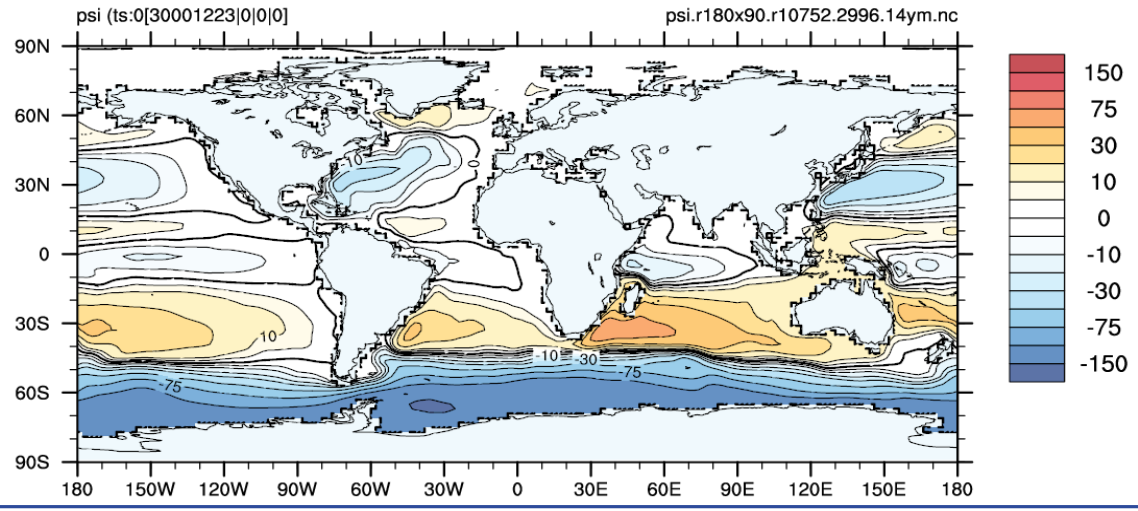


+ Modal parameters
+ Washout for modal aerosol
+ Emission as function of v_H and SST
+ 6 tracers for sea salt aerosol

Ocean component, part I



ICON



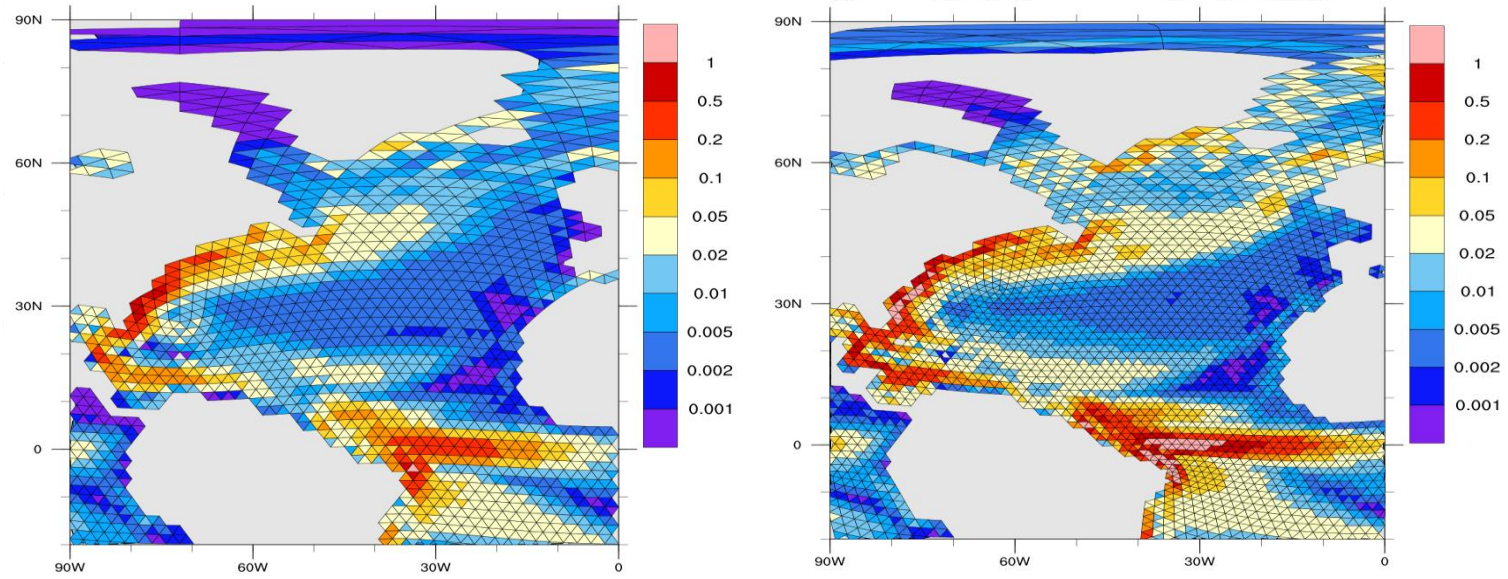
Barotropic Stream Function

Meridional & vertical integrated velocity

Major ocean gyres from theory (top)

can be recovered qualitatively from simulation over ~400 years (bottom)

Stretched grid with focus on the North Atlantic



Standard

Refined

Resolution: ~160 km

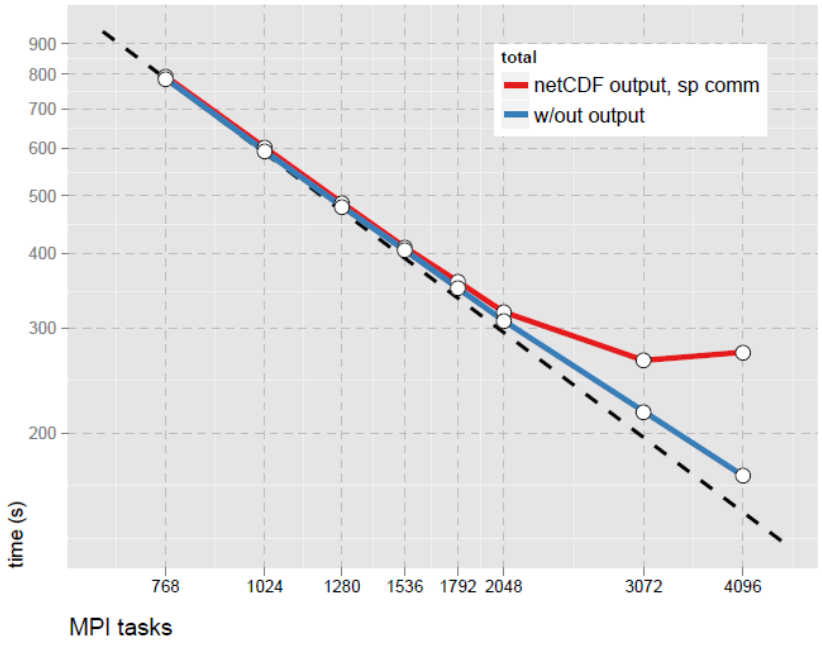
Kinetic energy, 10 years, scaled by max value

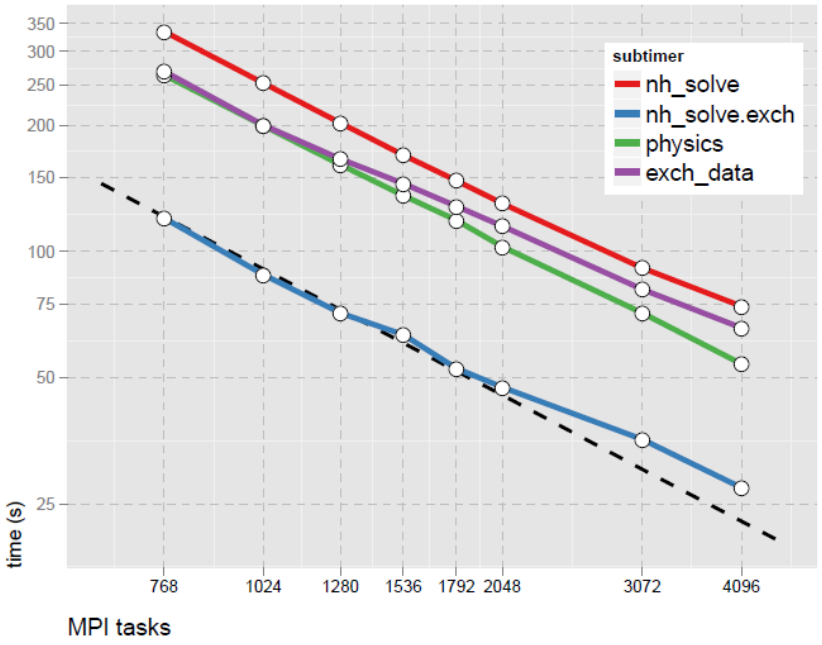
Resolution: ~80 km in North Atl.

Kinetic energy, 10 years, same scaling as left

Technical Aspects

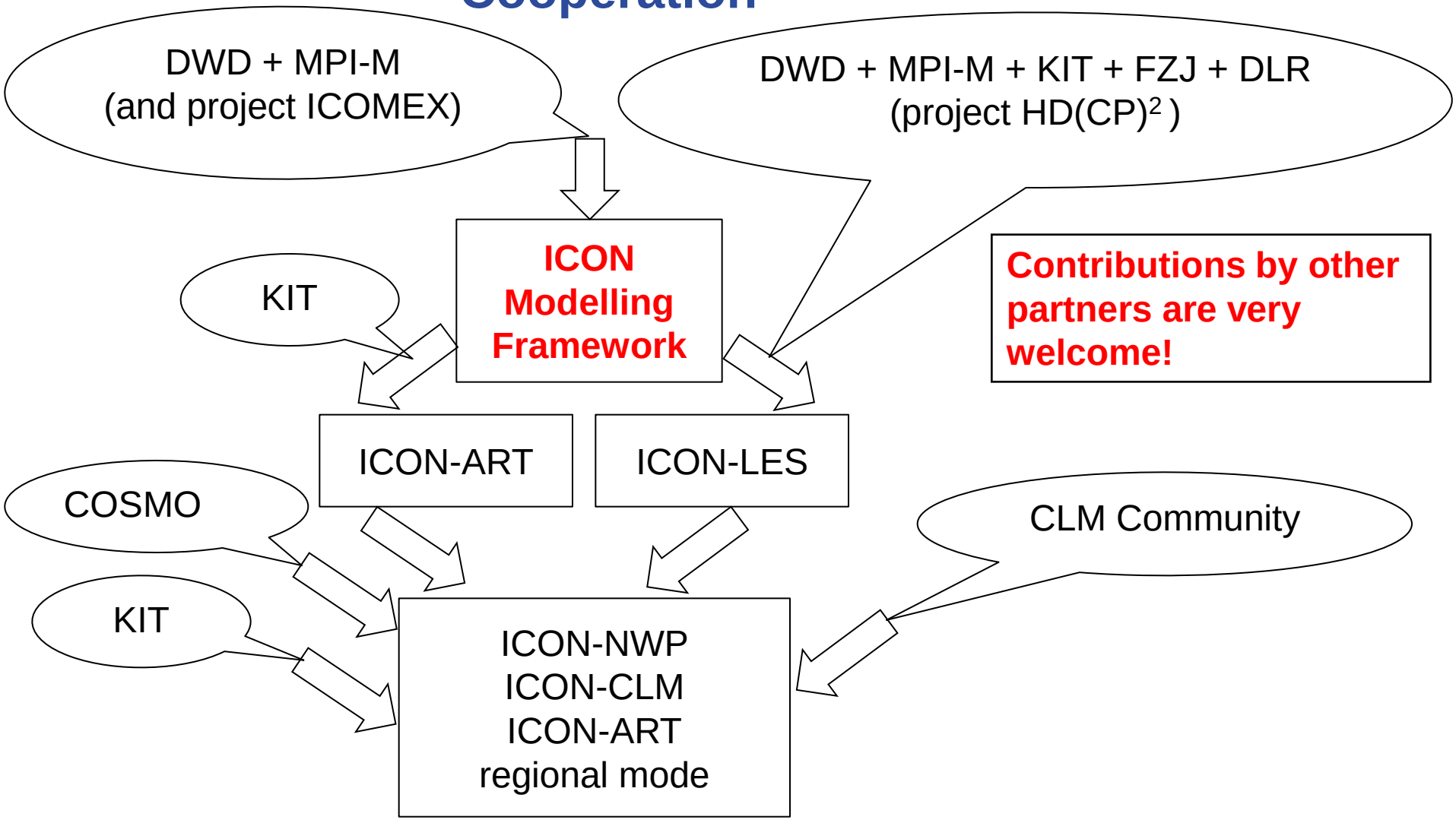
Flat-MPI Performance



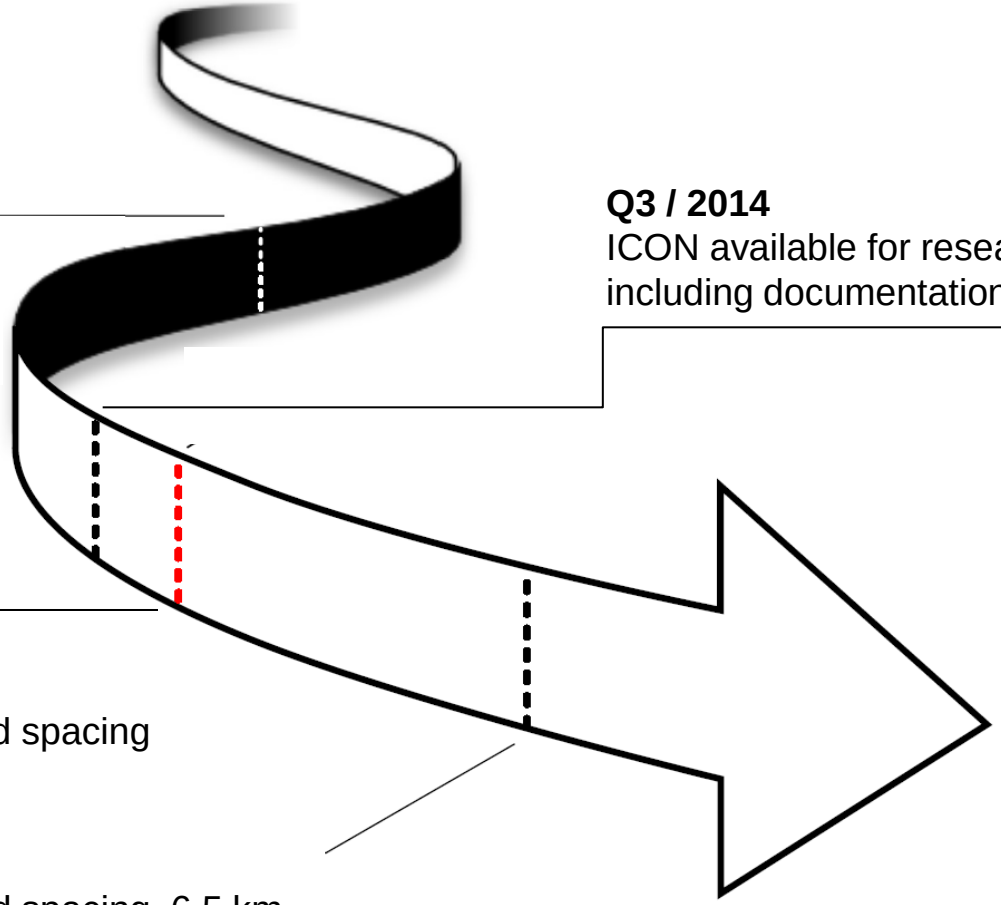


Test setup: **ICON RAPS 2.0**, **IBM Power7**
20/10/5 km, 8 h forecast, reduced radiation grid

Cooperation



Outlook



Q3 / 2013
Start of pre-operational phase with full data assimilation (only global)

Q3 / 2014
ICON available for research including documentation / training

Q4 / 2014
Start of operational phase with grid spacing 13 km L90; replacement of GME

Q2 / 2015
Start of operational phase with grid spacing 6.5 km over Europe; replacement of COSMO-EU


Thank you for your attention!
Any questions?