LaMETTA: The Lagrangian MESSy Tool for Trajectory Analysis in ICON

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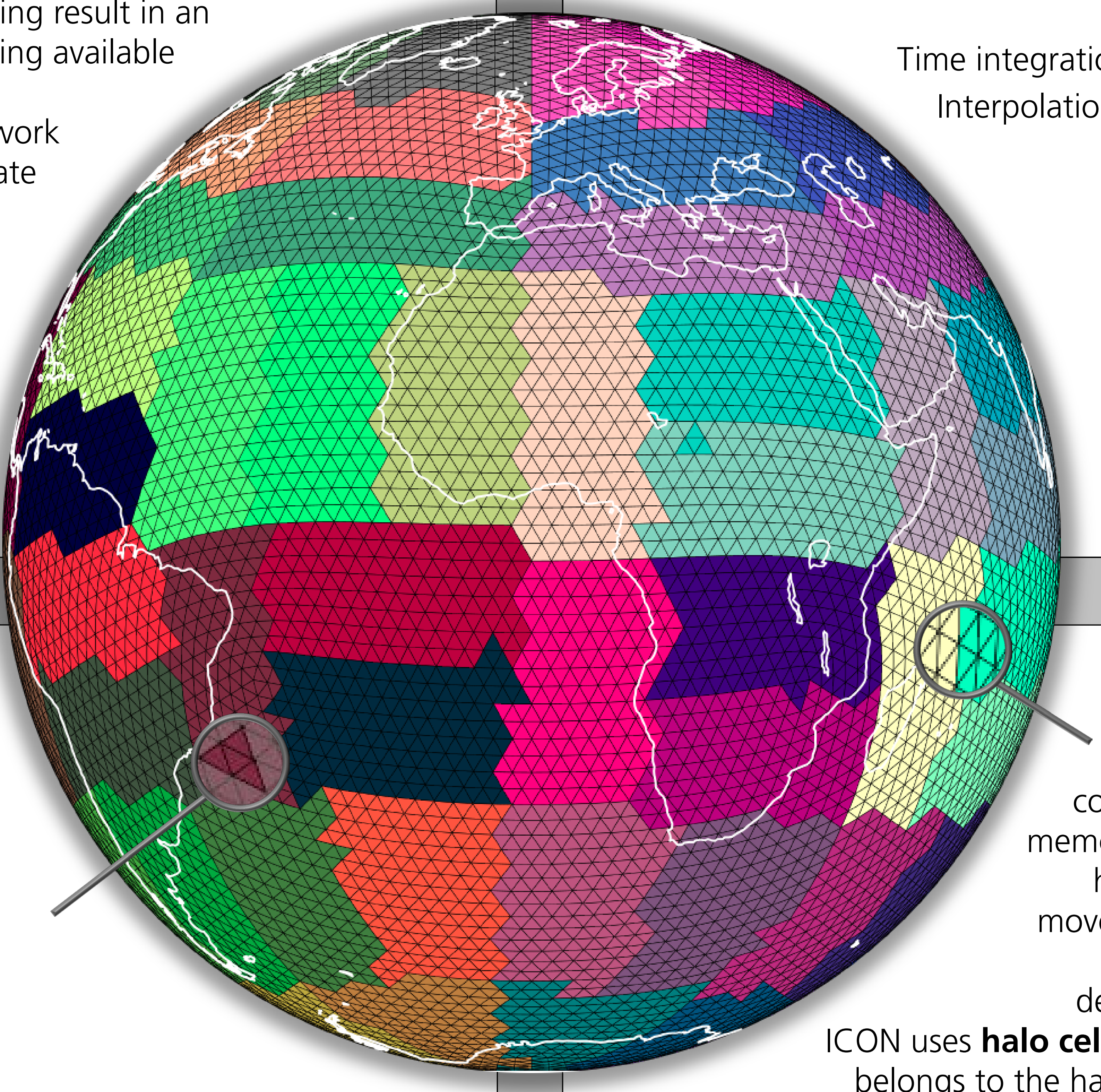
Introduction

Current developments in high performance computing result in an increasing number of processor cores and a decreasing available memory per core.

The on-line trajectory tool LaMETTA is designed to work on highly parallelised systems, optimised for moderate inter-process communication and memory consumption. This poster presents details on the implementation and optimisation of the novel tool and first results of application within the ICON (ICOsahedral Non-hydrostatic model system; Zängl et al., 2015) utilising the MESSy (Modular Earth Submodel System; Jöckel et al., 2010) interface (Kern and Jöckel, 2016).



Implementation Details

current status:

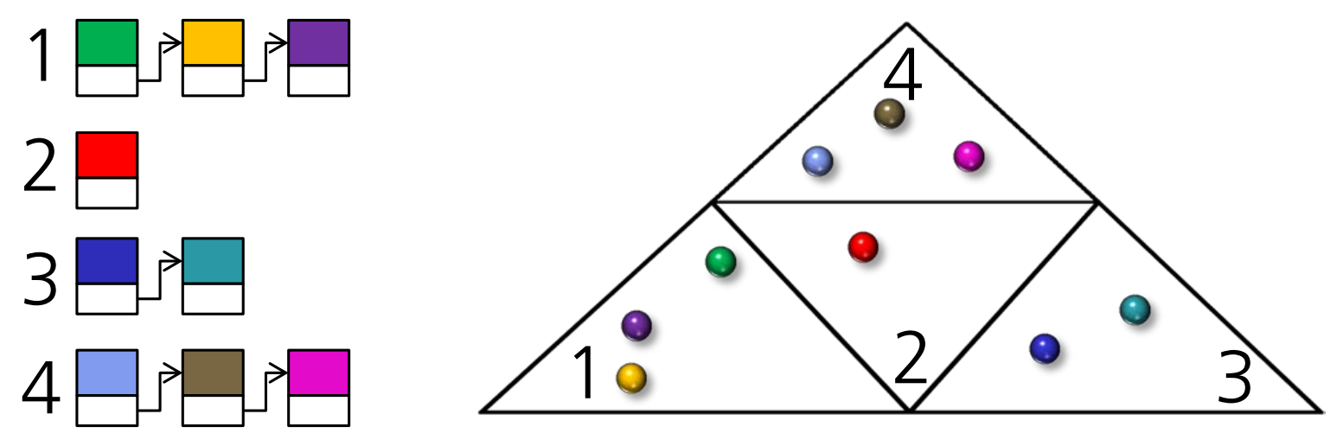
Time integration scheme: Euler Forward, Runge-Kutta 4th order
Interpolation of horizontal wind: Inverse distance weighting,
4 stencil (direct neighbours) or
13 stencil (direct + indirect neighbours)
Interpolation of vertical wind: linear

under development:

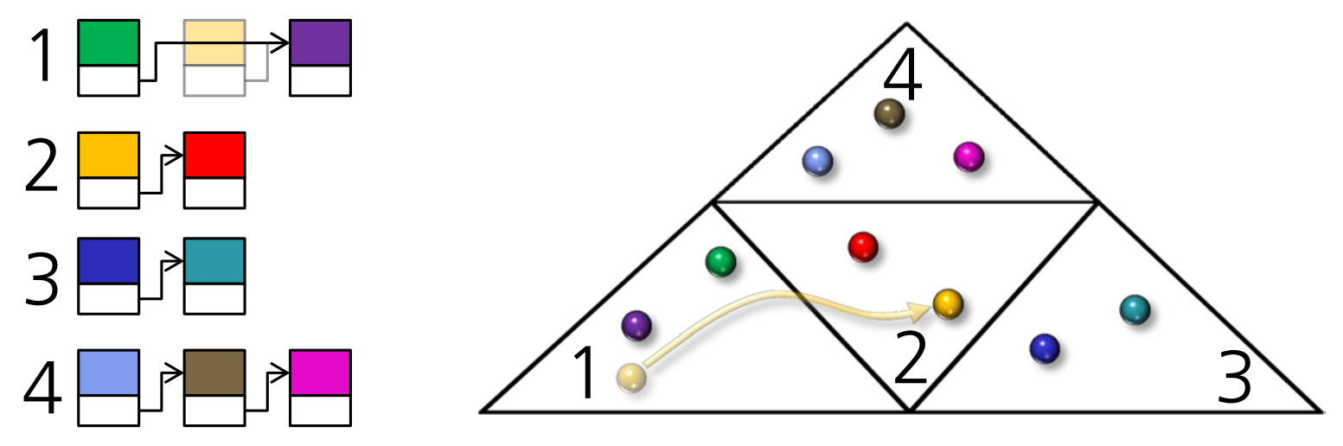
Interpolation schemes
User-defined / "automatic" starting positions
User-defined trajectory properties
Nested domains
Efficient I/O

Memory Management

The Lagrangian submodel is optimised for a **low memory footprint**. Instead of using global fields for storing the trajectory particles' properties, **linked lists for each model box** are used.



If a trajectory particle is transported out of a model box (which is determined by geometrical constraints), pointers of the linked lists are modified such, that the particle ends up in the linked list of the model box, which contains the particle's new position.



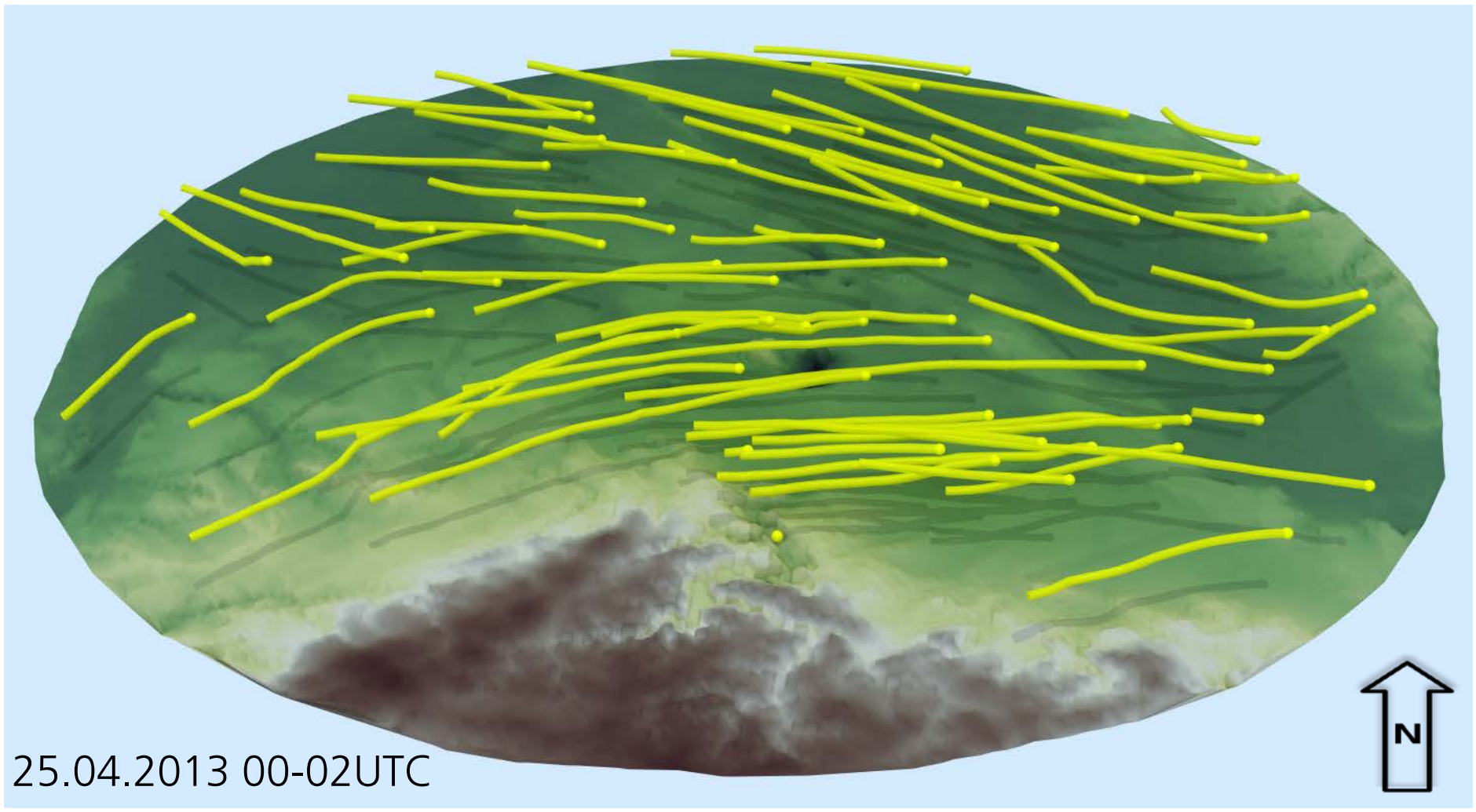
Transfer and MPI Communication

LaMETTA uses no global storage for the trajectory particles and avoids global (all-to-all) communication via MPI. Because of the distributed memory, a transfer to a new owner process entity (PE) has to be performed, when a trajectory particle is moved outside of its model box and ends up in a box belonging to a neighbouring PE in the domain decomposition (different colours in the left figure).

ICON uses **halo cells** in its **domain decomposition**. If the new box belongs to the halo cells, the trajectory particle.is transferred to its new PE. This is done at the end of each timestep, when all trajectory particles have reached their new position. For the transfer, LaMETTA uses a **handshaking concept** and MPI communication:

- collect the information of all particles in halo cells
- determine the native owner (PE) of the halo cells
- signal the native owner how many particles will be transferred
- pack and send the information from the sender PEs
- receive and unpack the information on the receiver PEs
- transfer the received information into the linked lists on the receiver PEs

First Examples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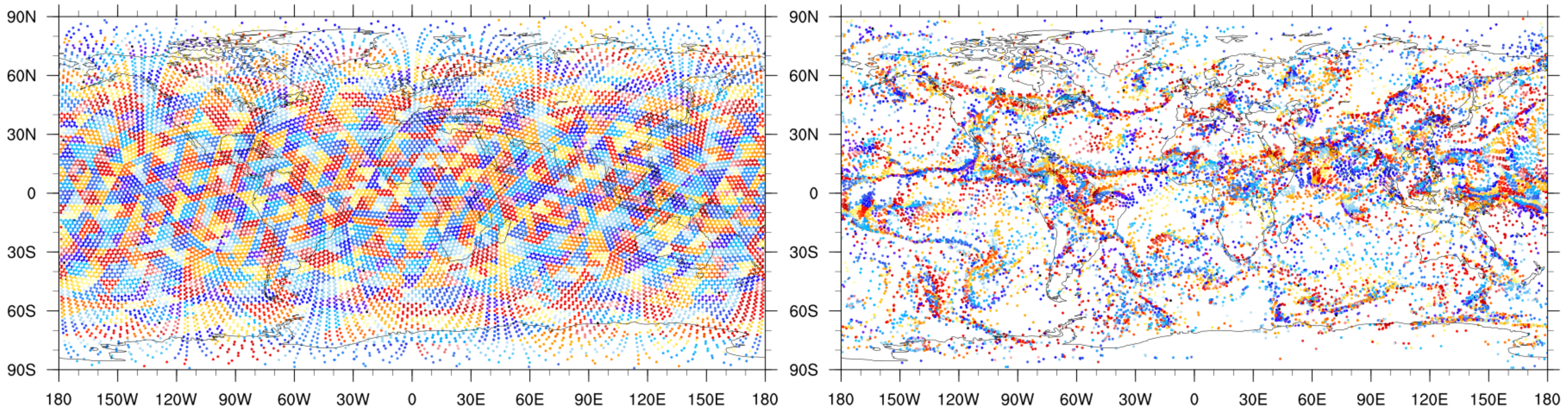
LaMETTA in ICON-LEM

model resolution 625m
model timestep 3 s
~100 km around Cologne
integration time 2h
3.72 M trajectories started at t_0
trajectory output every 5 min
trajectories shown:
height < 400m, every 1500th

LaMETTA in ICON-NWP (global)

20480 trajectories, started in lowest model level, colour = trajectory ID



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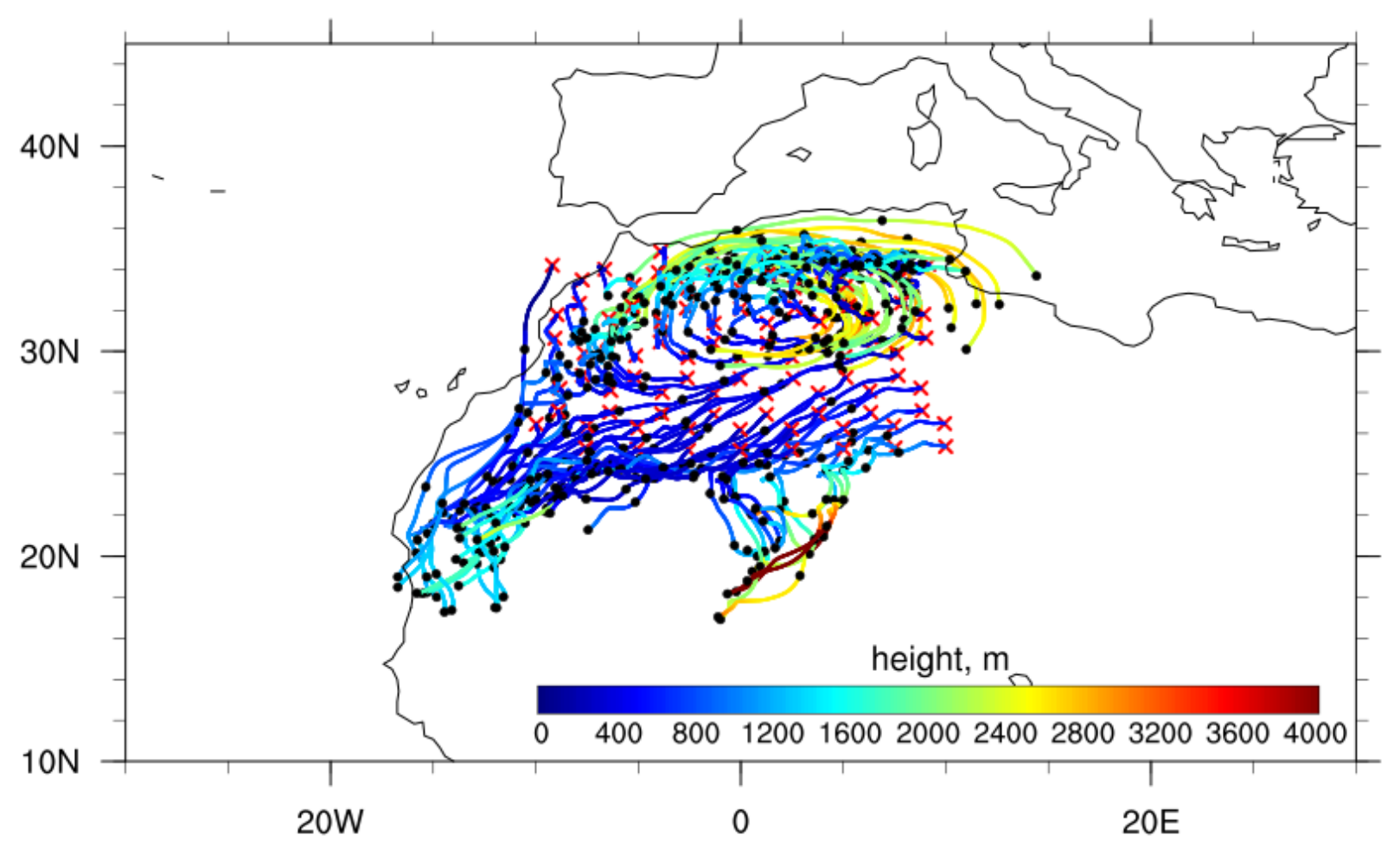
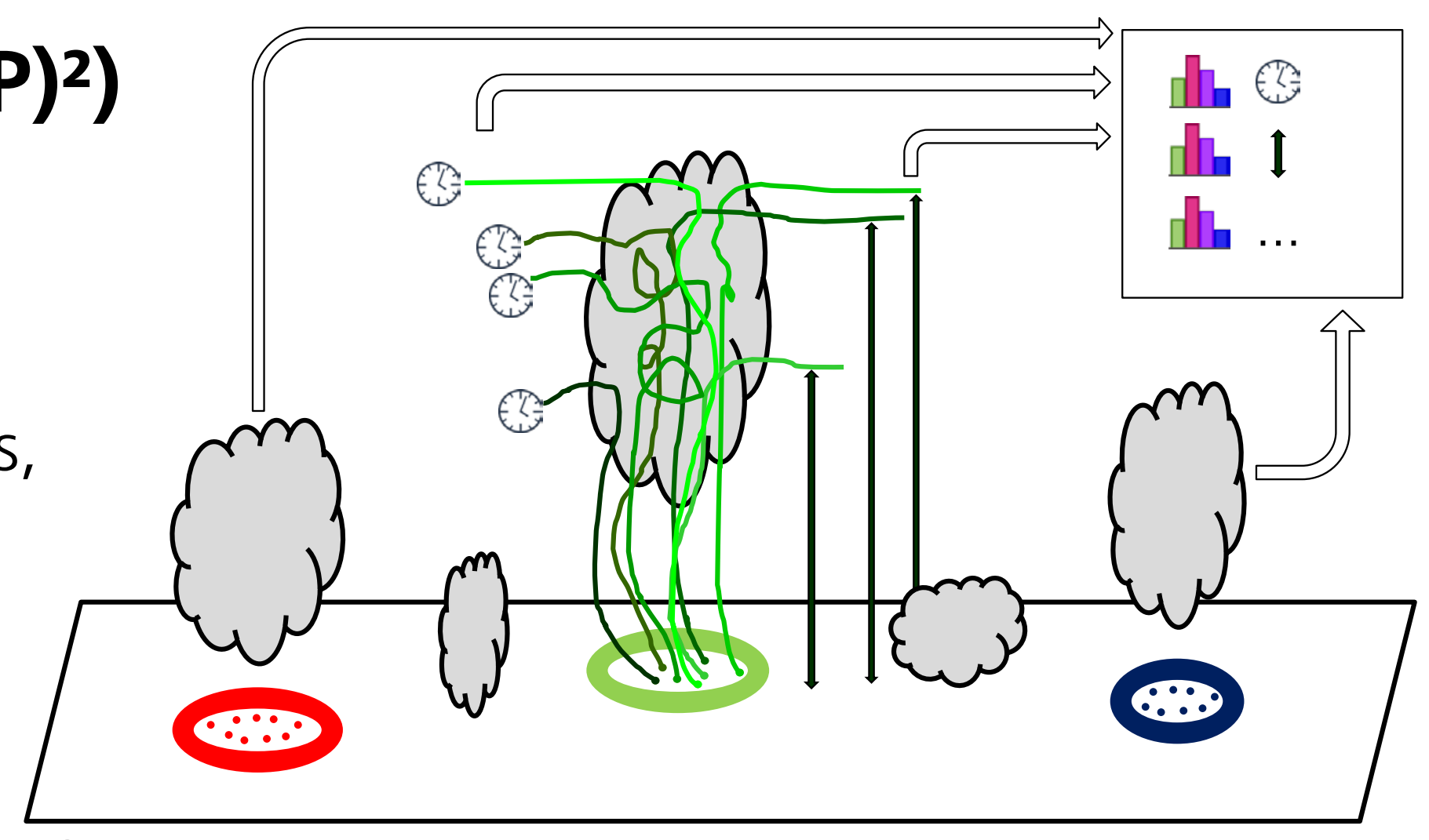
model resolution R2B04
model timestep 10 min
integration time 5 days



zoom over northern Africa, trajectories started 10W-10E, 25N-35N, in lowest level

Future Application (HD(CP)²)



Combined on-line feature tracking and trajectory tool

To study:
life cycle of convective systems,
characteristics of convection,
outflow of convective systems

Start trajectories during the simulation in convective regions → on-line feature identification

Extract distributions of mass fluxes, freezing levels, microphysical conversion rates, detrainment, anvil top heights, and temperature within the convective systems

Assess the accuracy of our expectations of anvil cirrus changes due to climate change from characteristics

Insight in the development of convective cells and a more process-oriented validation of the model system from Lagrangian viewpoint

Complement the analysis of the dynamics of large-scale structures (e.g., tracked motion of individual cloud objects) by computation of local quantities and their changes along trajectories (e.g., moisture transport inside convective cells)

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