Aerosol-aware, convection-resolving climate modelling

Regional and global modelling approaches with WRF and MPAS

Towards convection-resolving, global atmospheric simulations

Convection-permitting global model applications are the next grand challenge in NWP and on the horizon of next-generation, massively parallel HPC systems.

Extreme scaling experiment with MPAS on FZJ JUQUEEN (IBM Bluegene Q): • Regular 3km mesh, 65 Mio grid cells • 41 vertical levels, double precision • 1hr model integ., no disk output • Initial conditions: 1.1TB netCDF3 • Min. 4096 nodes, 651TB memory • Max. 26872 nodes (458752 cores) • Fastest run: 6.3s real-time, 1.6Mio CPUh/24h integer

The dynamical solver of MPAS scales up 400000 MPI tasks (160 cells/task) as on smaller meshes. The bottlenecks are model initialisation and disk I/O.

Step 1. Addressing the disk I/O performance • SIGNAL I/O layer for massively parallel I/O, internal + external data (http://www.fz-juelich.de/de/signal) • Post-processor core to convert to netCDF and more

Step 2. Reducing model initialisation times • Hybrid MPI/OpenMP parallelisation to speed up bootstrapping and decrease MPI comm. • Focus on dynamical solver • Maintain scaling of MPAS

MPAS allows variable-resolution meshes with smooth transitions to address limitations of limited area models.

Putting it to the test: an NWP study over Europe • Three selected events, 72h and 84h forecasts • Variable-resolution meshes transitioning the grey zone, using the Grell & Freitas (2014) cu scheme • Regular 3km mesh as reference model • (to come) Validation against operational WRF forecasts at MeteoGroup (with Wageningen Univ.)

Dynamics vs. I/O: Time required to write 1.2TB restart file on LRZ SuperMUC (18384 tasks)

<table>
<thead>
<tr>
<th>I/O format</th>
<th>Write time</th>
</tr>
</thead>
<tbody>
<tr>
<td>phDF/netCDF4</td>
<td>607 s</td>
</tr>
<tr>
<td>netCDF (CDDS)</td>
<td>133 s</td>
</tr>
<tr>
<td>SIGNAL</td>
<td>12.5 s</td>
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</tbody>
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WA West Australia
BC West Coast
BC Back Country
HP Perth/Fremantle
P Perth
M Maja Power Plant

dm2 -3.1

WA-3.1

Maja Power Station, commissioned 1966, 974MW, 1°x1°CCNs

Airborne measurements of CCN emission rates of coal power plants in East Australia with similar size (Junkermann and Hacker, 2015).

Three different aerosol model runs • Pre-industrial CCN/IN levels, std. aerosol profile (wt-aero) • Post-1970s CCN/IN levels, 3x std. aerosol profile (wt-aerox3) • Pre-industrial CCN/IN levels + Maja Power Station (wt-muja) Maja Power Station emissions: • 4.6·10^5 particles/kg, added to surface emissions at location of Maja Power Station (M) within first 1500m above ground

Decline in precipitation for increasing aerosol concentrations, strongest effect on the back country. CCN are advected by near-afc wind, seasonal variation in wt-muja rainfall decline.

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1970-1974 means of CCN number concentration and surface wind (top) and rainfall Apr-Sep (left), wet season; Apr-Sep, dry season: Oct-Mar

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Anthropogenic aerosol emissions and rainfall decline in South-West Australia
D. Heinzeller, W. Junkermann, H. Kunstmann, 2016: Journal of Climate, http://dx.doi.org/10.1175/JCLI-D-16-0082.1

Significant decline in precipitation in SW Australia in the 20th century • Continuous decline by about 15% for entire region (WA) • Sudden drop by further 15% for Perth/Fremantle (PF) in the 70s Possible reasons are: • Continuous changes due to large scale circulation (slow) • Deforestation, irrigation (fast) • Anthropogenic aerosols from power plants/smelters (fast) Anthropogenic aerosol emissions and rainfall decline – coincidence or causality?


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