

Overview WG DYN ‘dynamics and numerics’

COSMO General meeting, Rome
14-17 September 2026

Michael Baldauf (DWD)



Status of the BRIDGE project

Michael Baldauf, Sebastian Borchert (DWD)

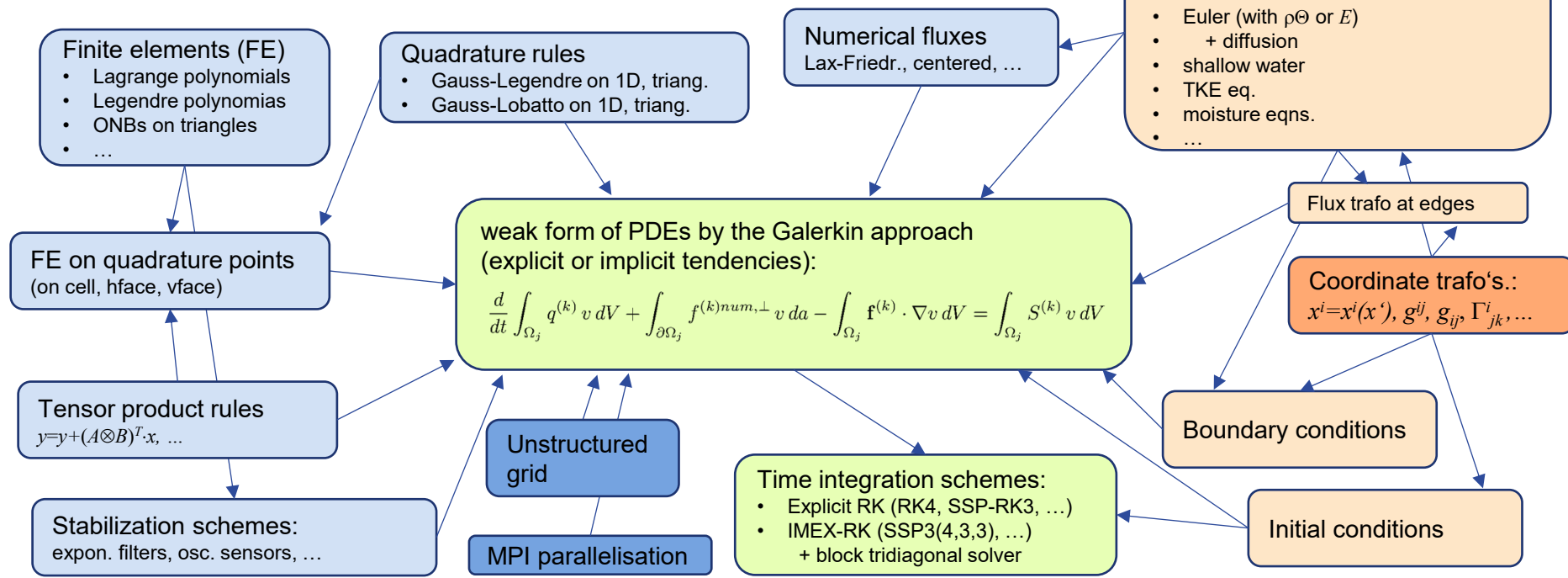
- Code optimizations and restructuring
- Comparison of 2 flavours of Euler equations
- Figure out the optimal HEVI / IMEX Runge-Kutta scheme
- Further steps towards moisture (Kessler scheme)

Why are we interested in an alternative dynamical core (esp. for ICON) and in particular in the Discontinuous Galerkin (DG) method?

- Our old global model GME and the former regional model COSMO didn't have any conservation properties at all. ICON (*Zängl et al. (2015) QJRMS*) locally conserves total mass and (almost!) tracer masses. **Local conservation** (or better say: no local conservation violation by the **flux divergence** terms) of **energy** and **momentum** might have positive effects, too.
- E.g. the WRF model (*Skamarock, Klemp (2008) JCP*) uses a 5th order scheme for horizontal advection that improves the simulation of explicitly resolved convection. Grid imprints vanish for higher order schemes, too. ICON uses 2nd order discretizations. It might be beneficial to treat every process in **higher order**.
- We would like to **get rid of grid staggering** (ICON uses Arakawa-C / Lorenz grid)
- We want to keep our **horizontally explicit-vertically implicit (HEVI)** approach: it allows efficient (horizontal) MPI parallelization and allows the use of direct (only vertically acting) solvers (we would like to avoid any iterative solver). **Use established time-integrators** (e.g. IMEX-RK schemes).
- Keep our (horizontally) **unstructured triangular grid** of ICON; allow both global and limited area simulations.
- Of course, the numerical scheme should run efficiently on **modern (massively parallel,) hardware architectures**
→ **BRIDGE – project (Basic Research for ICON with DG Extension).**

Basic elements of the BRIDGE dynamical core

mostly implemented as classes



BRIDGE code optimisations

- Make several subroutines **PURE** → no efficiency gain (tedious: LAPACK routines are not **PURE**; **WRITE** forbidden, ...)
- Define all array pointers as **CONTIGUOUS** → no efficiency gain
- Use **index-constants** for metric fields (metric tensor is symmetric, `g_unit_covar` contains 0's, ...) `g_covar_..(IDX_G_13, ..)` instead of `g_covar_..(1,3,...)` → **small efficiency gain**
- In `tensor_matrix_..` Routines:
 - Use LAPACK routines (→ **is much more expensive!**)
 - Replace **DOT_PRODUCT** by explicit matrix-vector mult. → **small efficiency gain**
- Try to enhance **cache efficiency** → complete rewrite of the weak form (=time loop) part (see next slide)
 - **efficiency gain for the explicit solver part until now: only ~10 %**
- **Combine subroutines** `tendency_explicit()` and `tendency_implicit()` into `tendency()`
 - **additional efficiency gain for all HEVI simulations: ~20%**

Code optimization by better usage of the cache

Time loop until now:

```
loop over all grid cells:
    interpolate amplitudes to quadrature points
loop over all grid cells:
    calculate diagnostic fields on quadr. points
loop over all grid cells:
    calculate fluxes on quadr. points
    Gauss quadrature (over quadr. points)
...
loop over all edges
    calculate numerical fluxes
...
```

Example: my DWD workstation has
L3 cache: 9 MB (~1 Mio DP numbers)
L1 cache: 64 kB (~ 8000 DP numbers)

New BRIDGE code version

```
loop over all grid cells:
    interpolate amplitudes to quadrature points
    calculate diagnostic fields on quadr. points
    calculate fluxes on quadr. points
    Gauss quadrature (over quadr. points)
...
loop over all edges
    calculate numerical fluxes
...

(e.g. Kronbichler, Kormann (2019) )
```

Unfortunately, the efficiency gain is quite marginal
until now. More investigations are needed here...

BRIDGE code optimisations

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First BRIDGE publication:

Geosci. Model Dev., 19, 7013–7040, 2026
<https://doi.org/10.5194/gmd-19-7013-2026>
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Geoscientific
Model Development



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Development and technical paper

Comparison of two Euler equation sets in a Discontinuous Galerkin solver for atmospheric modelling (BRIDGE v0.9)

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Received: 23 December 2025 – Discussion started: 13 January 2026

Revised: 19 June 2026 – Accepted: 28 June 2026 – Published: 31 July 2026

Abstract. The implementation of a “classical” Discontinuous Galerkin (DG) solver for atmospheric flows is presented that is designed for efficient use in numerical weather prediction, climate simulations, and meteorological research both on the whole sphere and for limited area modeling. To this purpose the horizontally explicit, vertically implicit (HEVI) approach is used together with implicit-explicit (IMEX)-Runge-Kutta (RK) time integration schemes and a moderate spatial approximation order (order 4 or 5). Two Euler equa-

1 Introduction

Among the numerous different methods to numerically solve partial differential equations, the Discontinuous Galerkin (DG) method has attracted a certain attention in many disciplines (fluid mechanics, elastomechanics, acoustics, electrodynamics, ...) during the last decades since its first invention at the beginning of the 1970's (for a historical overview see Hesthaven and Warburton, 2008). The DG method allows

One of the reviewers:
Francis X. Giraldo
(Naval Postgraduate School)

Euler equations (in covariant form)

Continuity eq.: $\frac{\partial \rho}{\partial t} + \nabla_k M^k = 0$

mass flux (= momentum density): $M^k = \rho v^k$

Momentum eq.: $\frac{\partial M^i}{\partial t} + \nabla_k T^{ik} = S_{(M)}^i$

momentum flux: $T^{ik} = \frac{1}{\rho} M^i M^k + p g^{ik}$

momentum source: $S_{(M)}^i = -g \rho e^i - 2g^{il} \epsilon_{ljk} \Omega^j M^k$

Energy budget eq.:

Variant 1: use density weighted potential temperature $\theta = \rho \Theta$

set , $\rho \Theta$ '

$$\frac{\partial \theta}{\partial t} + \nabla_k v^k \theta = 0$$

$$p = p(\theta)$$

Variant 2: use total energy density $E = E_{kin} + E_{pot} + E_{int}$

set , E '

$$\frac{\partial E}{\partial t} + \nabla_k v^k (E + p) = 0$$

$$p = p(E_{int})$$

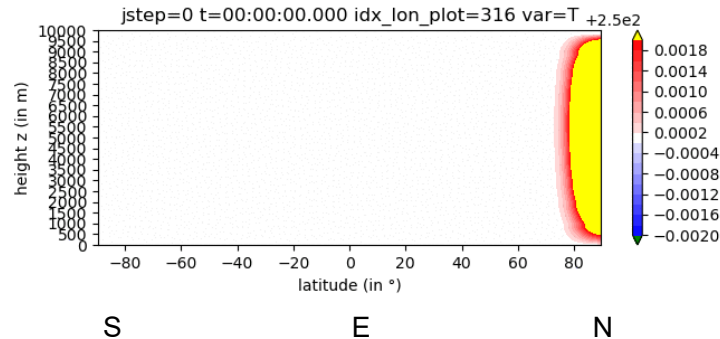
In case of **diffusion**: $T^{lk} \rightarrow T^{lk} + T_{diffus}^{lk}, \dots$

3D Euler equations: quasi-linear expansion of gravity and sound waves in a spherical shell

Baldauf, Reinert, Zängl (2014) QJRMS derive a linearized analytic solution for

- test scenario (A): $f = 0$
- test scenario (B): $f = 10 * f_{\text{geo}}(45^\circ) \rightarrow f/N \sim 0.05$

DG 4th order scheme with **explicit** time integration (4th order Runge-Kutta)



„small planet“:
 $R = R_{\text{earth}} / 50$

Linear gravity-/sound wave expansion in a spherical shell, Convergence against the analytic solution of *Baldauf, Reinert, Zängl (2014) QJRMS*

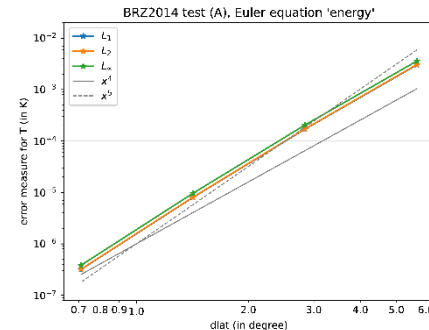
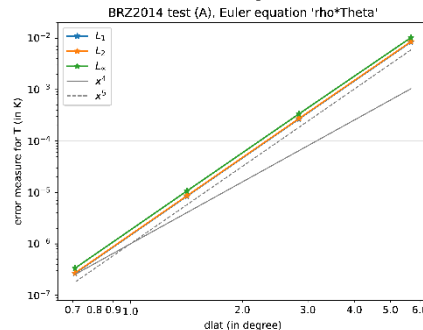
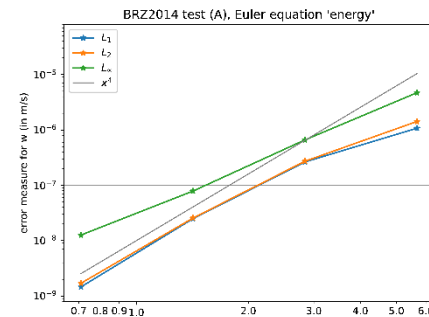
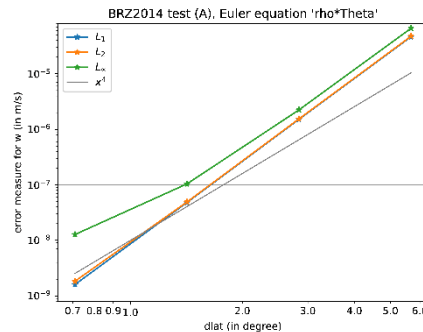
BRIDGE setup:
Horizontally 4th order
Vertically 5th order
SSP3(4,3,3) i.e. 3rd order

Vertical velocity w :

Temperature T :

Euler, $\rho\Theta'$:

Euler, E' :



Baroclinic instability test on the sphere

Jablonowski, Williamson (2006) QJRMS

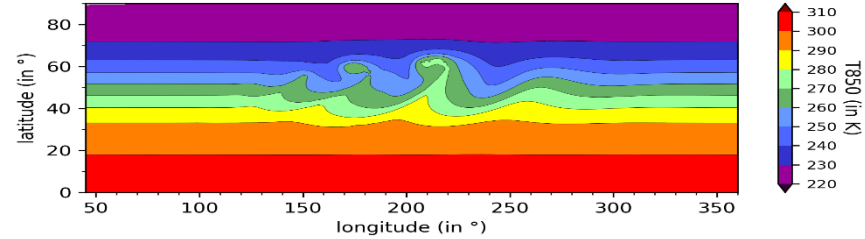
BRIDGE DG 4th order

R2B3 $\rightarrow \Delta x \sim 315$ km, $\Delta t = 80$ s

T in 850 hPa

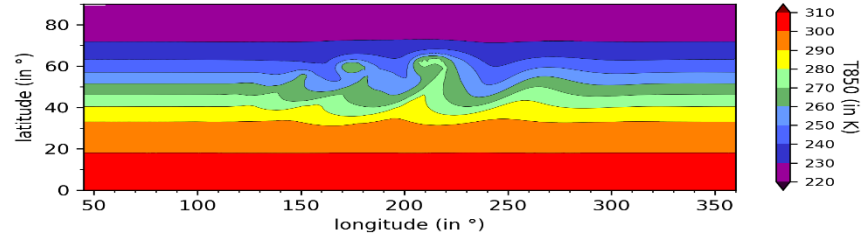
JW06_R2B3L10_HEVI_e3_251118_ad
jstep=9720 t=9d00:00:00.000

Euler, $\rho\Theta'$:

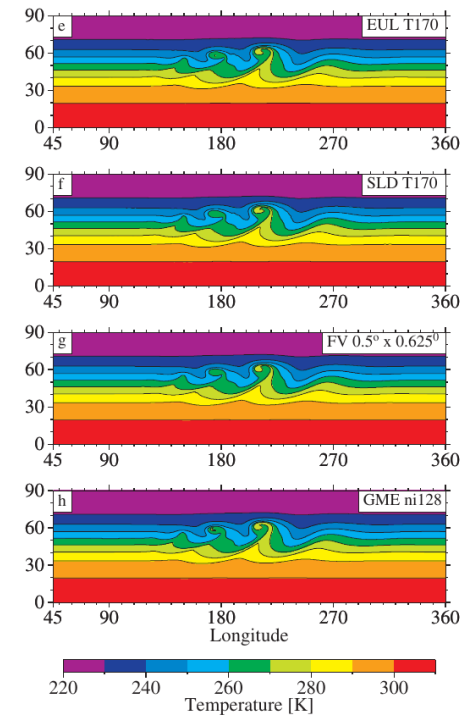


JW06_R2B3L10_HEVI_e5_251117_ad
jstep=9720 t=9d00:00:00.000

Euler, E' :



Stabilization by an exponential filter (1.0/0.5, 1, 10) + (0.5/0.4, 1, 4)



$\Delta x \sim 60$ km

T in 850 hPa at $t=9$ d (Fig. 7 from JW06)



Baroclinic instability test on the sphere

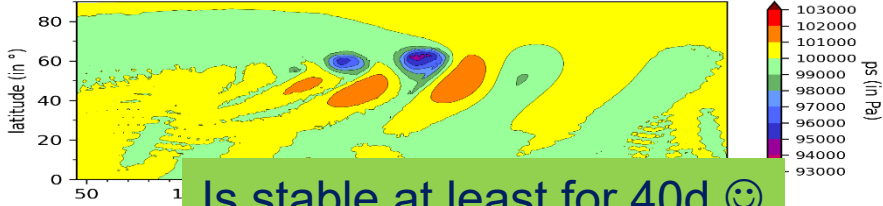
Jablonowski, Williamson (2006) QJRMS

BRIDGE DG 4th order

R2B3 → $\Delta x \sim 315$ km, $\Delta t = 80$ s

p_{surf}

JW06_R2B3L10_HEVI_e3_251118_ad
jstep=9720 t=9d00:00:00.000

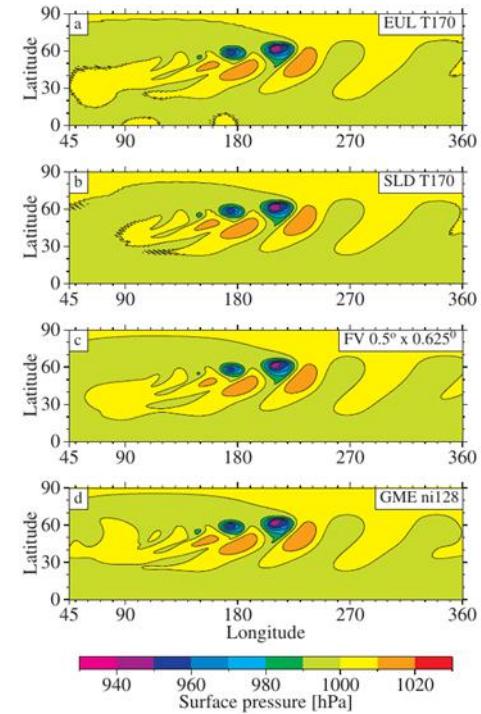


Is stable at least for 40d 😊

JW06_R2B3L10_HEVI_e5_251117_ad
jstep=9720 t=9d00:00:00.000



Crash after ~18d 😞



$\Delta x \sim 60$ km

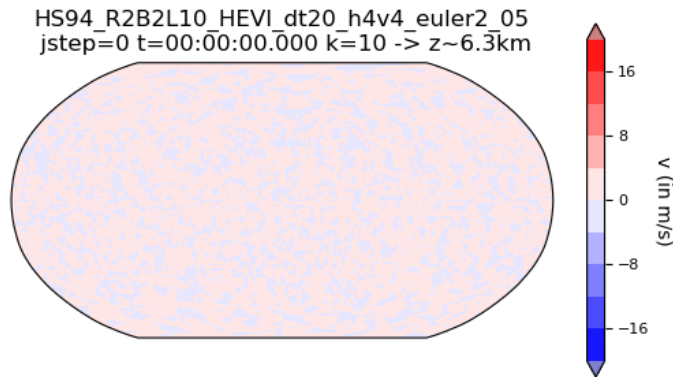
p_{surf} at $t=9$ d (Fig. 7 from JW06)

Stabilization by an exponential filter (1.0/0.5, 1, 10) + (0.5/0.4, 1, 4)



Held, Suarez (1994) test = ‚poor mans climate run‘

Only solve the **pure Euler equations** (no diffusion, no microphysics, ...), but add height and latitude dependent relaxation terms on the rhs of the momentum and energy equations.



Stabilization by standard exponential filtering necessary.

Feld 1: Min=-2.851375288326061e-14, Max=2.3936474813344577e-14

/home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/HS94_R2B2L10_HEVI_dt20_h4v4_euler2_05

Held, Suarez (1994) test = ,poor mans climate run‘

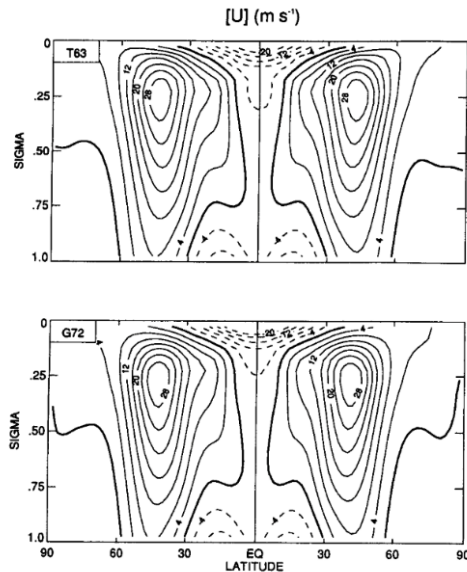
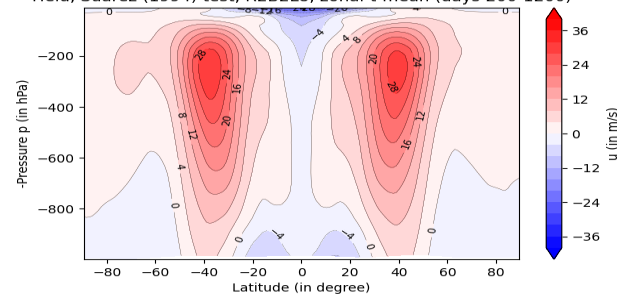


FIG. 2. The zonal-mean zonal wind produced by the T63 spectral model and G72 gridpoint model. Both are 1000-day means. Since the forcing is symmetric about the equator, differences between the hemispheres are indicative of sampling errors.

From Held, Suarez (1994)

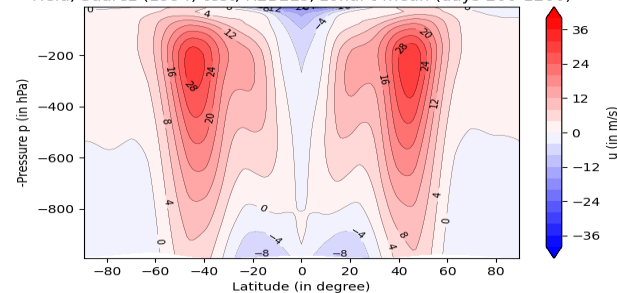
Held, Suarez (1994) test, R2B2L8, zonal-t-mean (days 200-1200)



u: Min=-30.982982360166705, Max=31.626698140553508

Euler set , $\rho\Theta$ '

Held, Suarez (1994) test, R2B2L8, zonal-t-mean (days 200-1200)



u: Min=-25.802281841935955, Max=31.749859798399104

Euler set ,E'

Summary of the comparison of 2 Euler equations sets $\rho\Theta'$ and E' :

- Set E' has better well-balancing properties than set $\rho\Theta'$
- Additionally, set $\rho\Theta'$ needs further (slightly accuracy reducing) hydrostatic stabilization by source term filtering (*Blaise et al. (2016)*, *Orgis et al. (2017)*)
- However, set E' suffers from nonlinear instabilities that cannot always be cured by filtering (at least in the pure Euler case without turbulence).
Larger sensitivity against instabilities due to its inherent non-dissipativeness (*Reddy et al., 2023*)
- Nevertheless, work on set E' is preferred due the basically superior property 'energy conserving'.
This optimistic view is justified by the fact that
 - in real applications, turbulent diffusion is applied and helps in stabilizing
 - entropy stable schemes should be helpful! (future work)

Baldauf, Prill (2026): *Comparison of two Euler equation sets in a Discontinuous Galerkin solver for atmospheric modeling (BRIDGE v0.9)*, Geosci. Model Devel.

Baldauf (2021): *A horizontally explicit, vertically implicit (HEVI) discontinuous Galerkin scheme for the 2-dimensional Euler and Navier-Stokes equations using terrain-following coordinates*, JCP

Baldauf (2020): *Discontinuous Galerkin solver for the shallow-water equations in covariant form on the sphere and the ellipsoid*, JCP



Project: **ICON-DG: Gearing up the ICON Model with Smarter Discretizations**
in the call ‚**WarmWorld Module 4 Smarter**‘ by German Ministry of Research and Educ. (BMBF)
Duration: 01.07.2024 - 30.06.2027

Project partners:

- *DLR Köln, Inst. for software technology*, project leader: Benedict Geihe
- *Univ. Köln, Division of Mathematics*, group Prof. Gregor Gassner, PhD: Philipp Baasch
- *DWD*, M. Baldauf, BRIDGE group



Actual state:

- Montoya, Rueda-Ramirez, Gassner (2026): *Entropy stable discontinuous spectral element methods for the spherical shallow water equations in covariant form*, JCP
- Philipp Baasch: recently, entropy stable flux found for the covariant Euler equations!
- Andres Rueda-Ramirez, Oswald Knoth: steps for efficiency increase of HEVI schemes by twice application of Schur complement technique

Figure out the optimal HEVI / IMEX Runge-Kutta scheme

Horizontally explicit - vertically implicit (HEVI)-scheme with DG

Motivation: get rid of the **strong time step restriction** by vertical sound wave expansion in **flat grid cells** (in particular near the ground)

$$\underbrace{\frac{\partial q^{(s)}}{\partial t}}_{\text{explicit}} + \underbrace{\nabla \cdot \mathbf{f}_{slow}^{(s)}}_{\text{explicit}} + \underbrace{\nabla \cdot \mathbf{f}_{fast}^{(s)}}_{\text{implicit}} = \underbrace{S_{slow}^{(s)}}_{\text{explicit}} + \underbrace{S_{fast}^{(s)}}_{\text{implicit}} \quad \mathbf{f}_{fast}^{(s)} = f_{z,fast}^{(s)} \mathbf{e}_z \quad f_{z,fast}^{(s)} = \sum_{s'} H^{ss'} q^{(s')}$$

- The linear **implicit** part leads to several **block-tridiagonal** $N_{\sigma} N_h N_v \times N_{\sigma} N_h N_v$ matrices
- **Collocation** decouples equations in the horizontal base functions
→ more (N_h), but smaller ($N_{\sigma} N_v \times N_{\sigma} N_v$) block-tridiag. matrices → large efficiency increase
- **direct solvers** are useable (block-tridiag. Thomas algorithm); no need for iterative solvers!
- Use of **IMEX-Runge-Kutta** (SDIRK) schemes: SSP3(3,3,2), SSP3(4,3,3) (*Pareschi, Russo (2005) JSC*)

Baldauf, Prill (2026): *Comparison of two Euler equation sets in a Discontinuous Galerkin solver for atmospheric modeling (BRIDGE v0.9)*, accepted by Geosci. Model Devel.

Baldauf (2021): *A horizontally explicit, vertically implicit (HEVI) discontinuous Galerkin scheme for the 2-dim. Euler and Navier-Stokes equations using terrain-following coordinates*, J. Comp. Phys.

Rueda-Ramírez et al. (2021): *A statically condensed discontinuous Galerkin spectral element method ...*, J. Comp. Phys.

Remarks about the linearisation

Linearise vertical flux and source term:

with the linearisation coeff.s

$$f_{im}^{(\sigma)3} = \sum_{\sigma'=1}^{2N_\sigma} \frac{\delta f^{(\sigma)3}}{\delta q^{(\sigma')}} q^{(\sigma')}, \quad S_{im}^{(\sigma)} = \sum_{\sigma'=1}^{2N_\sigma} \frac{\delta S^{(\sigma)}}{\delta q^{(\sigma')}} q^{(\sigma')}$$

- for equation set , $\rho\Theta'$: relatively straightforward, see *Baldauf (2021) JCP*

- for equation set , E' : $\frac{\delta f_\rho^3}{\delta M^{i'}} = \underbrace{\frac{\partial x^3}{\partial x^{i'}}}_{\text{factor 1/2}}$ $\frac{\delta S_{(M)}^{3'}}{\delta \rho} = -g^{3'3'} \nabla_{3'} \Phi$

$$\frac{\delta T^{i'3}}{\delta \rho} = -\frac{1}{\rho^2} M^{i'} M^3 + \frac{R}{c_v} \left(\frac{1}{\rho} E_{kin} - \underbrace{\Phi} \right) g^{i'3},$$

$$\frac{\delta T^{i'3}}{\delta M^{k'}} = \frac{1}{\rho} \delta_{k'}^{i'} \frac{\partial x^3}{\partial x^{l'}} M^{l'} + \frac{1}{\rho} M^{i'} \frac{\partial x^3}{\partial x^{k'}} - \underbrace{\frac{R}{c_v} \frac{1}{\rho} M_{k'} g^{i'3}}_{\text{factor 1/2}}, \quad \frac{\delta T^{i'3}}{\delta E} = \underbrace{\frac{R}{c_v} g^{i'3}}_{\text{factor 1/2}},$$

$$\frac{\delta f_E^3}{\delta \rho} = -\frac{1}{\rho^2} M^3 (E + p) + \frac{M^3 R}{\rho c_v} \left(+\frac{1}{\rho} E_{kin} - \Phi \right),$$

$$\frac{\delta f_E^3}{\delta M^{k'}} = \underbrace{\frac{E + p}{\rho} \frac{\partial x^3}{\partial x^{k'}}}_{\text{factor 1/2}} - \frac{M^3 R}{\rho c_v} \frac{1}{\rho} M_{k'}, \quad \frac{\delta f_E^3}{\delta E} = \frac{M^3}{\rho} \left(1 + \frac{R}{c_v} \right)$$

Only take the underbraced terms

→ $T^{3'}_{im} = p g^{i'3}$

→ the vertically implicit flux is just the pressure

→ this is what we need for (vertical) sound expansion

→ Additionally: the implicit part fulfills hydrostatic balance!

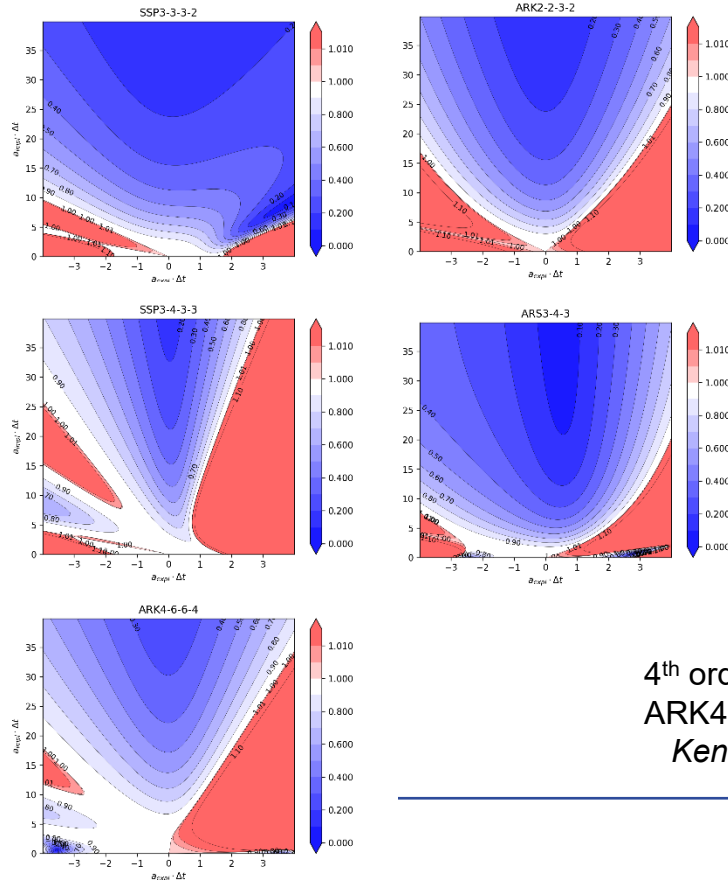
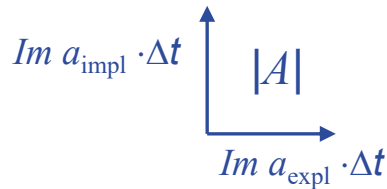
IMEX-RK schemes: simplified Dahlquist-problem

Dahlquist problem:
 $dq/dt = a_{\text{expl}} \cdot q + a_{\text{impl}} \cdot q$

Simplification: only consider a spatially exact hyperbolic part:

$$\begin{aligned} a_{\text{expl}} &= i k_x u \\ a_{\text{impl}} &= i k_x c \quad \text{with } u \ll c \end{aligned}$$

(analysis after
Giraldo et al (2024) JCP)



2nd order schemes:

SSP3(3,3,2):

Pareschi, Russo (2005) JSC

ARK2(2,3,2)b:

Giraldo et al (2024) JCP

3rd order schemes:

SSP3(4,3,3):

Pareschi, Russo (2005) JSC

ARS3(4,3):

Ascher, Ruuth, Spiteri (1997)

Appl. Num. Math.

4th order schemes:

ARK4(6,6,4):

Kennedy, Carpenter (2003), Appl. Num Math.

Efficiency of different IMEX-RK-schemes in 2D flow over mountain simulations

	flat, $\Delta x=1$ km max Δt	flat t_{Wall}	steep, $\Delta x=4$ km max Δt	steep t_{Wall}
SSP3(3,3,2)	0.26 s	33.5 h	0.5 s	20.4 h
ARK2(2,3,2)	0.45 s	24.2 h	0.28 s	31.3 h
SSP3(4,3,3)	0.2s	76.4 h		
ARS3(4,3)	0.25 s	60.3 h		

Summary about work on time integration:

- From all inspected IMEX-RK schemes, the **SSP3(3,3,2)** scheme proves to be superior with respect to efficiency.
- Generally: only use IMEX-RK schemes with the 'final stage condition' $b^{(\text{impl})} = b^{(\text{expl})} \rightarrow$ **BCs work!** (only those schemes have been inspected).
- Further justification for the **linearisation** of the set E' has been found.

Extension for multi-equation (Euler + Turbulence + ...) time integration:

- Type **'multieq'** = solve multiple equations (e.g. Euler, TKE, Tracer, ...) together in one Runge-Kutta scheme (2025: purely explicit, new: IMEX-RK)
→ intermediate step to develop moisture equations in BRIDGE
- Currently: further extension to true **time split schemes** (i.e. $dt_{\text{phys}} / dt_{\text{dyn}} > 1$) based on 2nd order Strang splitting

Further steps towards moisture in BRIDGE

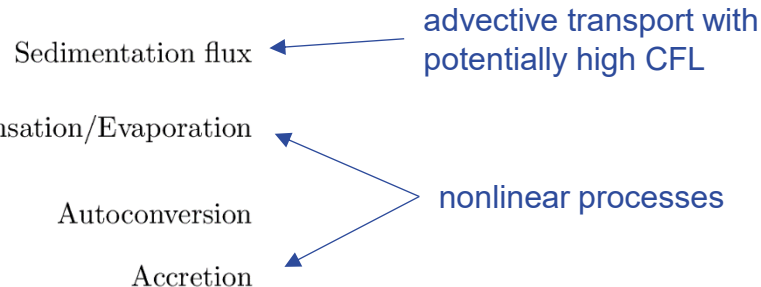
- Implementation of the **Kessler scheme** (transfer from the ICON code) by *Sebastian Borchert* (DWD)
- **Sedimentation** now can be treated implicitly
- Tracer **diffusion** can be treated vertically implicit (HEVI)
- Non-negativity treatment of all ρ_x (and TKE) by linear rescaling (Zhang, Shu, 2010)

The Kessler scheme = warm rain scheme

Kessler (1969), COSMO scientific documentation, part II (2018)

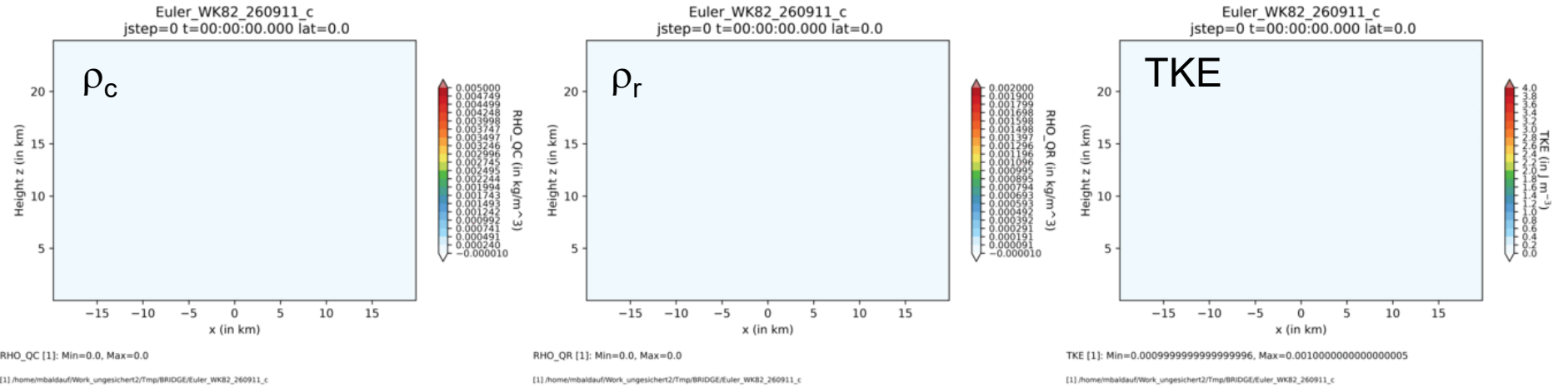
$$\begin{aligned}
 \frac{\partial \rho_v}{\partial t} + \nabla_k v^k \rho_v + \nabla_k f_{v,diffus}^k &= + S_{cond/evap}, \\
 \frac{\partial \rho_c}{\partial t} + \nabla_k v^k \rho_c + \nabla_k f_{c,diffus}^k &= - S_{cond/evap} - S_{au} - S_{ac}, \\
 \frac{\partial \rho_r}{\partial t} + \nabla_k v^k \rho_r + \nabla_k f_{r,diffus}^k + \nabla_k P_{(r)}^k &= + S_{au} + S_{ac}, \\
 \frac{\partial E}{\partial t} + \nabla_k v^k (E + p) + \nabla_k f_{E,diffus}^k &= - L_v S_{cond/evap}.
 \end{aligned}$$

$$\begin{aligned}
 P_{(r)}^{3''} &= -v_{r, sed} \rho_r, \quad v_{r, sed} = c_{r, sed} \rho_r^{1/8}, \\
 S_{cond/evap} &= \begin{cases} -\frac{\rho_v - \rho_{sat}(T)}{\tau}, & \rho_v > \rho_{sat}(T), \\ \frac{\min(\rho_c, \rho_{sat}(T) - \rho_v)}{\tau}, & \rho_v < \rho_{sat}(T), \end{cases} \\
 S_{au} &= \frac{1}{\tau_{au}} \max(\rho_c - \rho_{c, au}, 0), \\
 S_{ac} &= c_{ac} \rho_c \rho_r^{7/8},
 \end{aligned}$$



Moist setup by Weisman, Klemp (1982) MWR

200 x 16 grid cells, 40*40*25 km³, dt=0.5s, SSP3(3,3,2), Kessler microphysics + TKE scheme

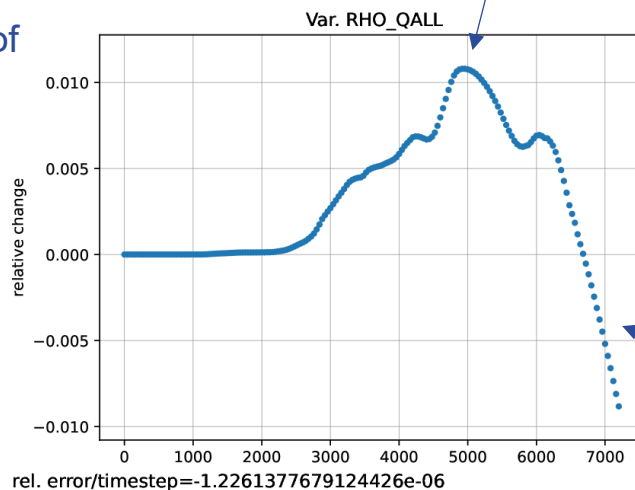


Moist setup by Weisman, Klemp (1982) MWR

200 x 16 grid cells, 40*40*25 km³, dt=0.5s, SSP3(3,3,2), Kessler microphysics + TKE scheme

Currently, an unphysical mass production of all moist variables occurs

Relative change of
 $\int (\rho_v + \rho_c + \rho_r) dV$



Conservative non-negativity treatment by linear rescaling of Zhang, Shu (2010) works correctly, but cannot prevent total emptying of grid cells. Probably flux limitation will help in the future...

Sedimentation (✓)

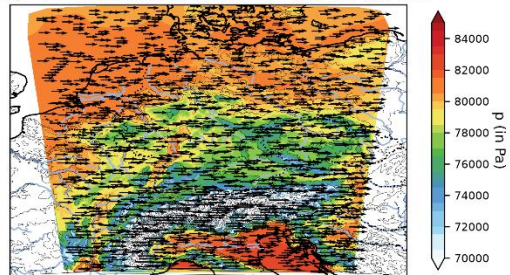
Further steps for moisture treatment

- Further inspection of the **Kessler scheme**
 - **Conservation** of non-negative moisture variables (implement flux limitation)
 - is **mass consistency** still important in a higher order discretization scheme?
 - Increase time step in the HEVI scheme
- Improve efficiency for **HEVI solver** of moisture variables.
This is straightforward, because the implicit systems for the N_q moisture variables are decoupled
→ solve factor N_q more equations that are smaller by factor N_q .
- Further inspection of time splitting schemes (i.e. $dt_{\text{phys}}/dt_{\text{dyn}} > 1$)

A slightly more realistic simulation with BRIDGE ...

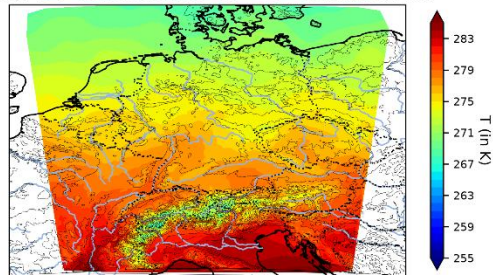
- ‚Limited area‘ simulation with initial/boundary values taken from the geostrophic/hydrostatic balancing scheme
- Nearly ICON-D2 area, R2B8 grid ($dx \sim 10\text{km}$)
- Orography on R2B10 ($\sim 2.5\text{km}$), generated from R2B13 ($\sim 300\text{m}$) ASTER data
- DG 4th order SSP3(3,3,2) IMEX-RK-HEVI time integration
- With TKE turbulence scheme
- With Kessler scheme (artificial init. of q_v and a cloud layer around $z \sim 5\text{km}$)

jstep=0 t=00:00:00.000 k=11 -> z~1.573...4.877km



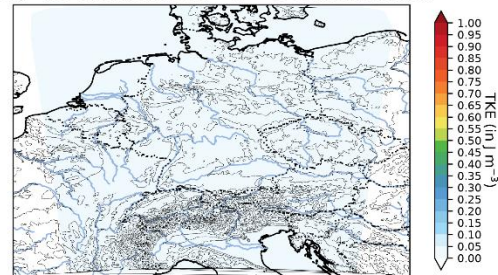
p [1]: Min=52676.496675634226, Mean=78064.1204406917, Max=82283.44400402816
 uv [2]: Min=10.70217912169287, Mean=13.050203951823601, Max=21.21407007579909
 [1] :home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d
 [2] :home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=0 t=00:00:00.000 k=11 -> z~1.573...4.877km



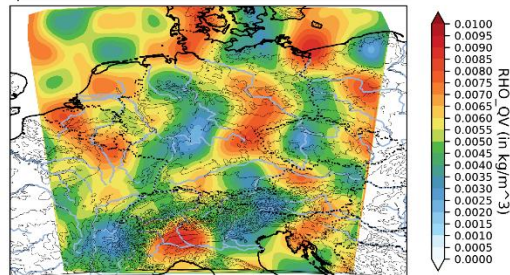
T [1]: Min=264.4948211306424, Mean=275.7755881793721, Max=285.35515864532493
 [1] :home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=0 t=00:00:00.000 k=11 -> z~1.573...4.877km



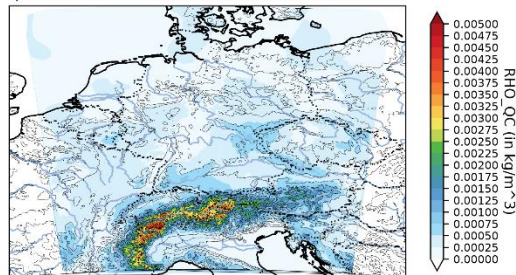
TKE [1]: Min=0.0009999999999999999, Mean=0.0010000000000000000, Max=0.0010000000000000000
 [1] :home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=0 t=00:00:00.000 k=11 -> z~1.573...4.877km



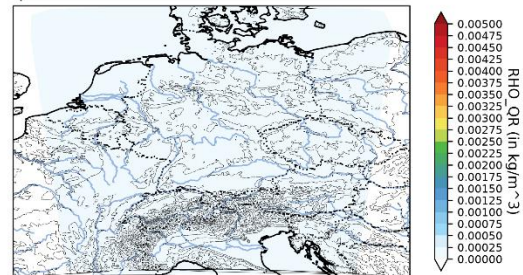
RHO_QV [1]: Min=0.0021169668253766516, Mean=0.005460167684222998, Max=0.00899043872595108
 [1] :home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=0 t=00:00:00.000 k=11 -> z~1.573...4.877km



RHO_QC [1]: Min=0.00010713761918338248, Mean=0.0004332779098795914, Max=0.004972964766394955
 [1] :home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

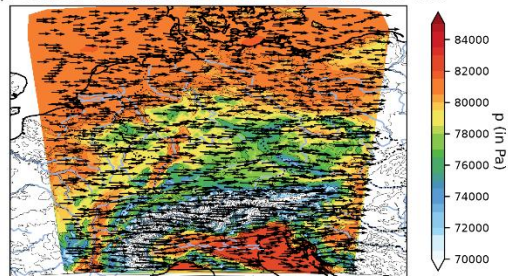
jstep=0 t=00:00:00.000 k=11 -> z~1.573...4.877km



RHO_OR [1]: Min=0.0, Mean=0.0, Max=0.0
 [1] :home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

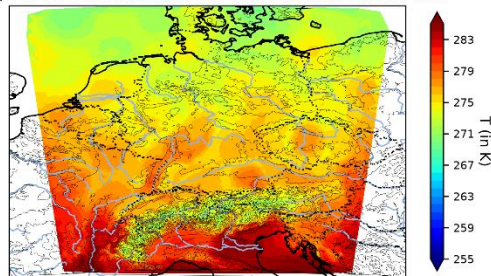


jstep=1200 t=00:10:00.000 k=11 -> z~1.573...4.877km



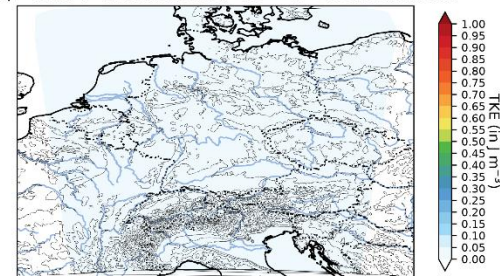
p [1]: Min=54780.4957296688, Mean=78566.5662523959, Max=82851.30187488592
 uv [2]: Min=6.504827373808669, Mean=12.988682816685012, Max=29.138413171720998
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d
 [2] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=1200 t=00:10:00.000 k=11 -> z~1.573...4.877km



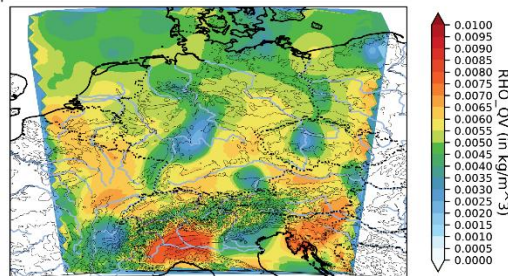
T [1]: Min=268.1196876291397, Mean=276.1485805166968, Max=286.4198031388219
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=1200 t=00:10:00.000 k=11 -> z~1.573...4.877km



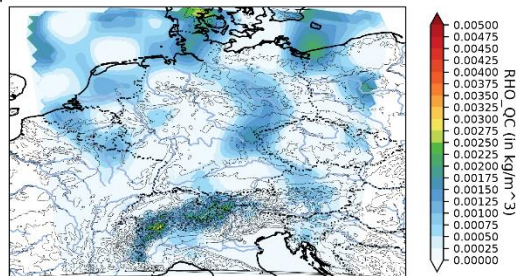
TKE [1]: Min=0.0, Mean=0.005976603033162789, Max=0.04728579671181912
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=1200 t=00:10:00.000 k=11 -> z~1.573...4.877km



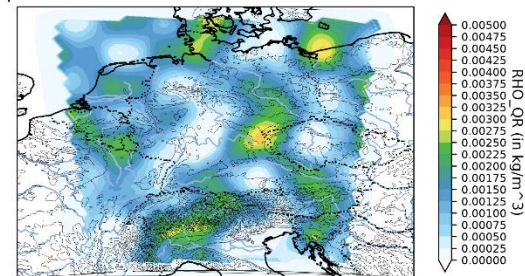
rho_QV [1]: Min=0.001157551675206676, Mean=0.00521984434768239, Max=0.008317461708060804
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=1200 t=00:10:00.000 k=11 -> z~1.573...4.877km



rho_QC [1]: Min=-2.117582368135751e-22, Mean=0.0004355964133235225, Max=0.0029272935693866746
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

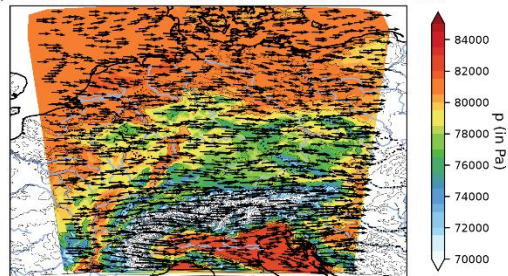
jstep=1200 t=00:10:00.000 k=11 -> z~1.573...4.877km



rho_OR [1]: Min=-1.2924697071141057e-26, Mean=0.001001363774925477, Max=0.003582675766781957
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

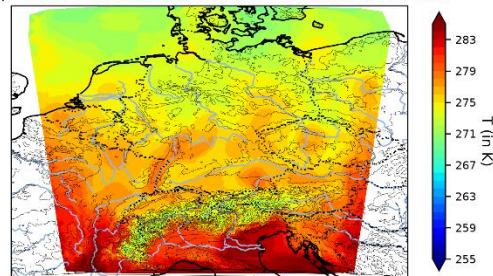


jstep=2400 t=00:20:00.000 k=11 -> z~1.573...4.877km



p [1]: Min=54838.92793767331, Mean=78627.4376081658, Max=82878.77114813111
 uv [2]: Min=5.988480863505749, Mean=12.951321219326923, Max=32.6517313950641
 [1] /home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d
 [2] /home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

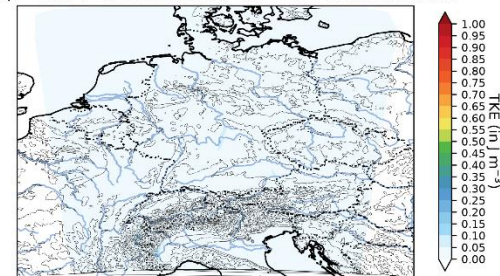
jstep=2400 t=00:20:00.000 k=11 -> z~1.573...4.877km



T [1]: Min=267.97997689769517, Mean=276.0917123400134, Max=286.09436666972385

[1] /home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

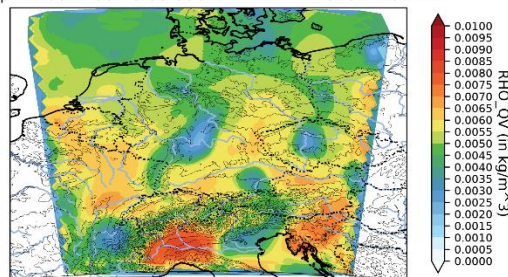
jstep=2400 t=00:20:00.000 k=11 -> z~1.573...4.877km



TKE [1]: Min=-1.3552527156068805e-20, Mean=0.01706112388549827, Max=0.34078269635169617

[1] /home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

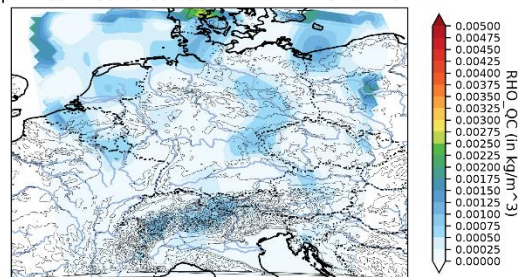
jstep=2400 t=00:20:00.000 k=11 -> z~1.573...4.877km



rho_QV [1]: Min=0.0011615876678901277, Mean=0.005220921567829265, Max=0.008209862034798754

[1] /home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

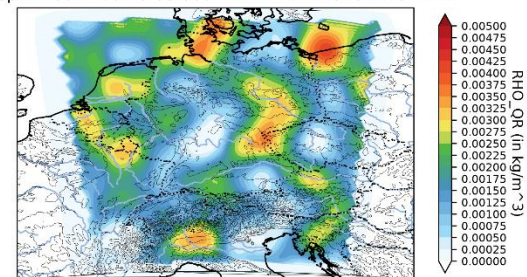
jstep=2400 t=00:20:00.000 k=11 -> z~1.573...4.877km



rho_QC [1]: Min=-2.6469779601696886e-23, Mean=0.00026221465297947706, Max=0.002899307421833139

[1] /home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=2400 t=00:20:00.000 k=11 -> z~1.573...4.877km

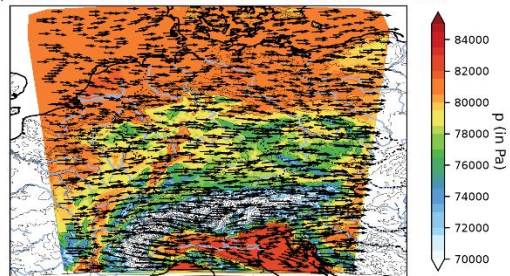


rho_OR [1]: Min=-4.1359030627651384e-25, Mean=0.0014022601463524963, Max=0.0041846878886770056

[1] /home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

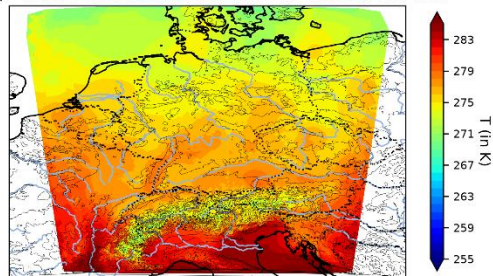


jstep=3600 t=00:30:00.000 k=11 -> z~1.573...4.877km



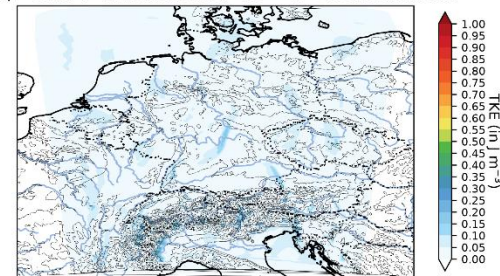
p [1]: Min=55039.0618068276, Mean=78686.61048763075, Max=82672.4993086945
 uv [2]: Min=5.760550072811986, Mean=12.902704779457396, Max=32.96218452617985
 [1] :home/mbaldauf/Work_ungeichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d
 [2] :home/mbaldauf/Work_ungeichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=3600 t=00:30:00.000 k=11 -> z~1.573...4.877km



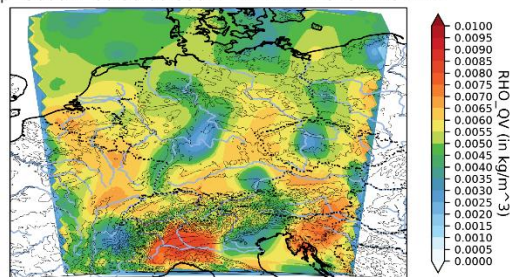
T [1]: Min=268.3315777540272, Mean=276.5441510703656, Max=286.103645250952
 [1] :home/mbaldauf/Work_ungeichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=3600 t=00:30:00.000 k=11 -> z~1.573...4.877km



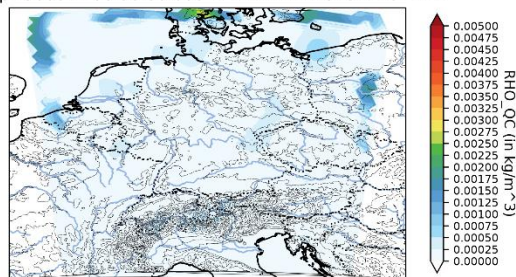
TKE [1]: Min=0.0, Mean=0.0309850634033368, Max=0.6324057877198063
 [1] :home/mbaldauf/Work_ungeichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=3600 t=00:30:00.000 k=11 -> z~1.573...4.877km



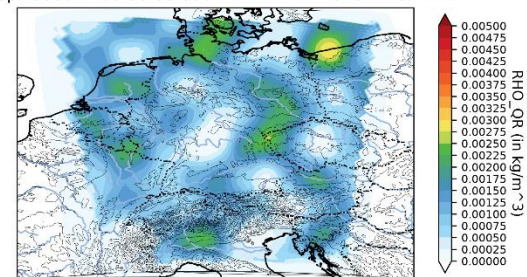
RHO_QV [1]: Min=0.0011657593737437807, Mean=0.005289011123550479, Max=0.008442383808800769
 [1] :home/mbaldauf/Work_ungeichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=3600 t=00:30:00.000 k=11 -> z~1.573...4.877km



RHO_QC [1]: Min=-2.117582368135751e-22, Mean=0.0001243124318624285, Max=0.002901597510945783
 [1] :home/mbaldauf/Work_ungeichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

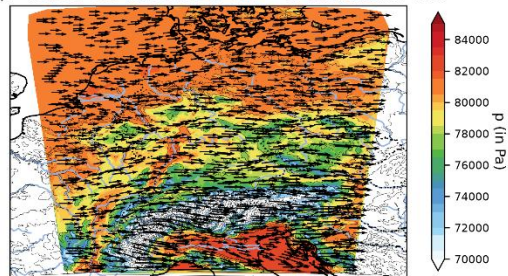
jstep=3600 t=00:30:00.000 k=11 -> z~1.573...4.877km



RHO_OR [1]: Min=-1.3234889800848443e-23, Mean=0.0008561549430913917, Max=0.00296312529108296
 [1] :home/mbaldauf/Work_ungeichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

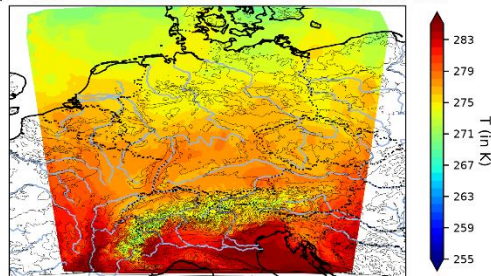


jstep=4800 t=00:40:00.000 k=11 -> z~1.573...4.877km



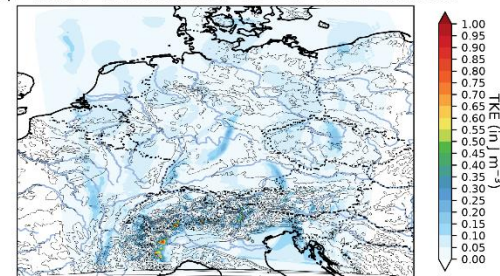
p [1]: Min=55027.029452519986, Mean=78726.2763945413, Max=82691.6533846744
 uv [2]: Min=5.3170296567716475, Mean=12.885921614683173, Max=33.29093483952704
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d
 [2] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=4800 t=00:40:00.000 k=11 -> z~1.573...4.877km



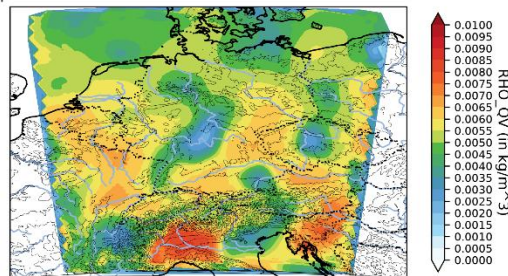
T [1]: Min=267.9484132301469, Mean=276.83993855690187, Max=286.2133901798111
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=4800 t=00:40:00.000 k=11 -> z~1.573...4.877km



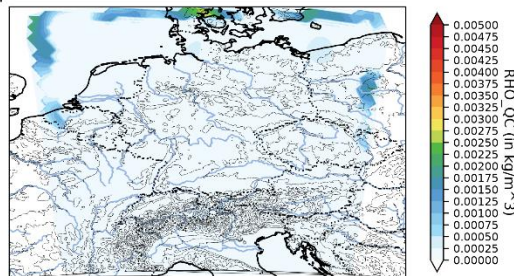
TKE [1]: Min=-1.6940658945086007e-21, Mean=0.04658748425100941, Max=1.3310561675434105
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=4800 t=00:40:00.000 k=11 -> z~1.573...4.877km



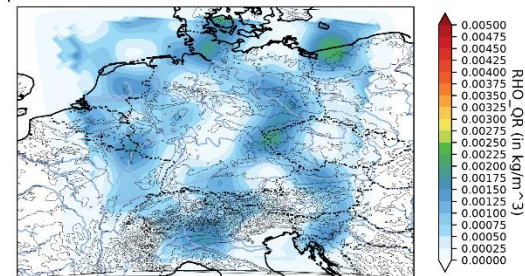
rho_QV [1]: Min=0.0011700279595322246, Mean=0.0052916919165332385, Max=0.008524951638440591
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=4800 t=00:40:00.000 k=11 -> z~1.573...4.877km



rho_QC [1]: Min=-4.235164736271502e-22, Mean=8.972890842940698e-05, Max=0.0029222526045932272
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

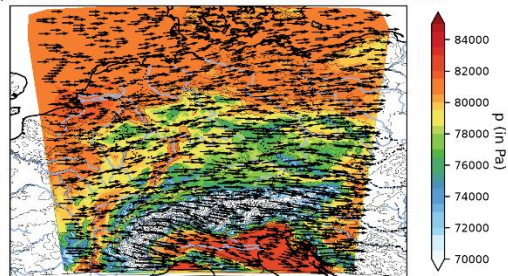
jstep=4800 t=00:40:00.000 k=11 -> z~1.573...4.877km



rho_OR [1]: Min=-1.0339757656912846e-25, Mean=0.0005625235763069321, Max=0.0023840247157662885
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

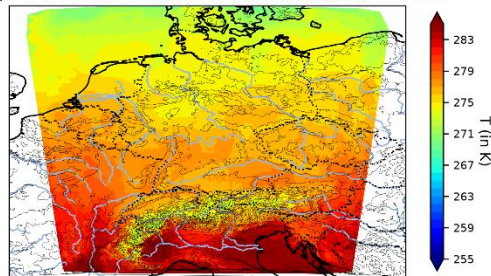


jstep=7200 t=01:00:00.000 k=11 -> z~1.573...4.877km



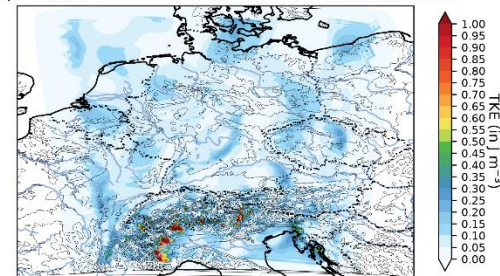
p [1]: Min=55124.37611879169, Mean=78646.64454843804, Max=82652.59705803094
 uv [2]: Min=0.5460256557712405, Mean=12.802668577338638, Max=33.38615844944423
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d
 [2] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=7200 t=01:00:00.000 k=11 -> z~1.573...4.877km



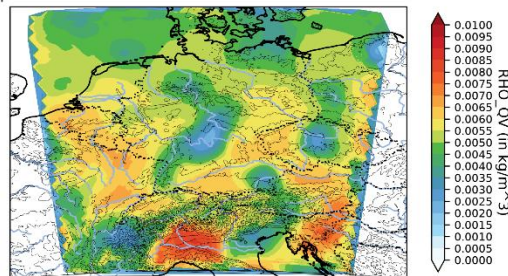
T [1]: Min=269.4681095143872, Mean=277.02211073901583, Max=287.6374994141171
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=7200 t=01:00:00.000 k=11 -> z~1.573...4.877km



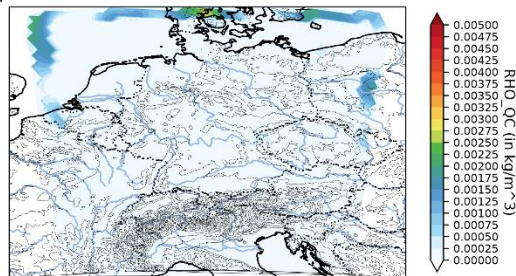
TKE [1]: Min=0.0, Mean=0.07850303801334994, Max=2.3400677888533012
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=7200 t=01:00:00.000 k=11 -> z~1.573...4.877km



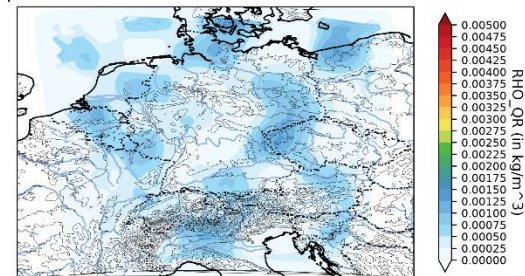
RHO_QV [1]: Min=0.0011786332584915076, Mean=0.005251878948429934, Max=0.008551239021499823
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=7200 t=01:00:00.000 k=11 -> z~1.573...4.877km



RHO_QC [1]: Min=-2.117582368135751e-22, Mean=8.179215872841432e-05, Max=0.0029323843206208087
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

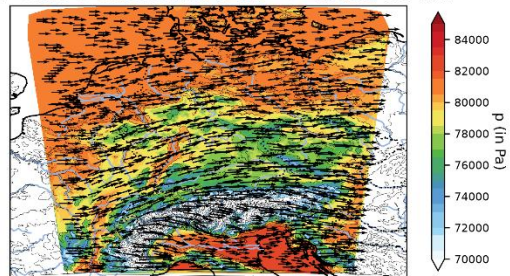
jstep=7200 t=01:00:00.000 k=11 -> z~1.573...4.877km



RHO_OR [1]: Min=-2.0679515313825692e-25, Mean=0.0003466345348814519, Max=0.0015935444684182926
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

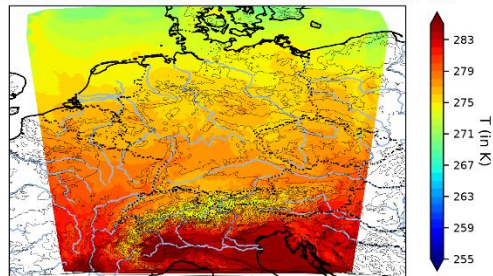


jstep=14400 t=02:00:00.000 k=11 -> z~1.573...4.877km



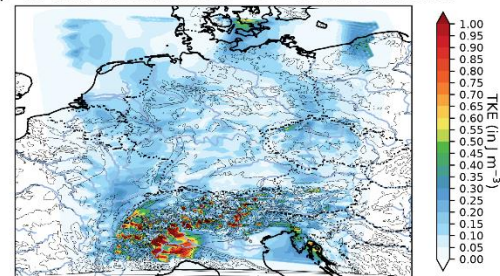
p [1]: Min=55065.18824078616, Mean=78511.96366600154, Max=82444.3600387664
 uv [2]: Min=-5.200508857498691, Mean=13.025827576632896, Max=33.18502936222781
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d
 [2] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=14400 t=02:00:00.000 k=11 -> z~1.573...4.877km



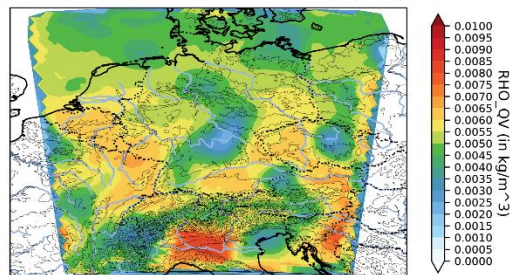
T [1]: Min=269.6330772311145, Mean=277.25668992726025, Max=287.2047788946807
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=14400 t=02:00:00.000 k=11 -> z~1.573...4.877km



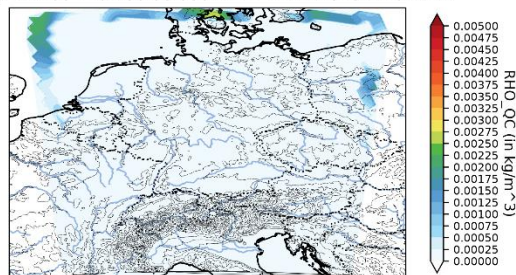
TKE [1]: Min=-3.3881317890172014e-21, Mean=0.12256985162024901, Max=4.34778237378079
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=14400 t=02:00:00.000 k=11 -> z~1.573...4.877km



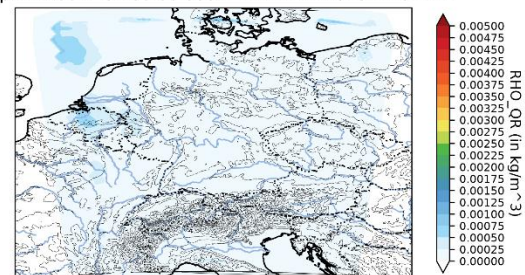
rho_QV [1]: Min=0.0011994045906366876, Mean=0.005181014572963064, Max=0.00836102485486503
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=14400 t=02:00:00.000 k=11 -> z~1.573...4.877km



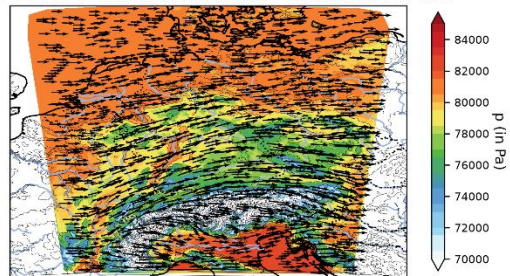
rho_QC [1]: Min=-5.293955920339377e-23, Mean=7.17506628470973e-05, Max=0.00295489963845196
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=14400 t=02:00:00.000 k=11 -> z~1.573...4.877km



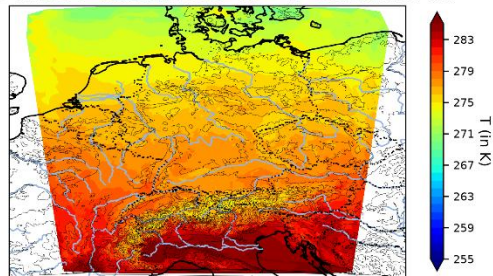
rho_OR [1]: Min=-1.6543612251060553e-24, Mean=8.572388111408834e-05, Max=0.0008855055960455255
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=21600 t=03:00:00.000 k=11 -> z~1.573...4.877km



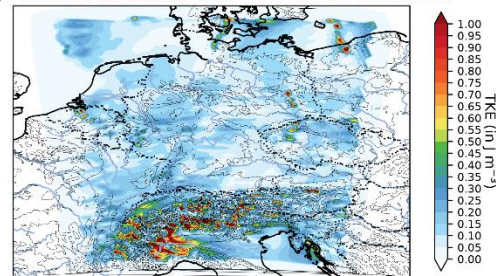
p [1]: Min=55094.92684501234, Mean=78523.50281196593, Max=82441.67437733043
 uv [2]: Min=-3.1147579137842483, Mean=13.200871758169251, Max=31.413732306251504
 [1] /home/mbaldauf/Work_ungeichert2/TmpBRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d
 [2] /home/mbaldauf/Work_ungeichert2/TmpBRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=21600 t=03:00:00.000 k=11 -> z~1.573...4.877km



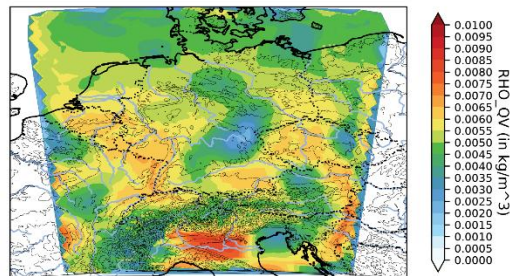
T [1]: Min=269.70589789330364, Mean=277.33223996367167, Max=287.97630297845757
 [1] /home/mbaldauf/Work_ungeichert2/TmpBRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=21600 t=03:00:00.000 k=11 -> z~1.573...4.877km



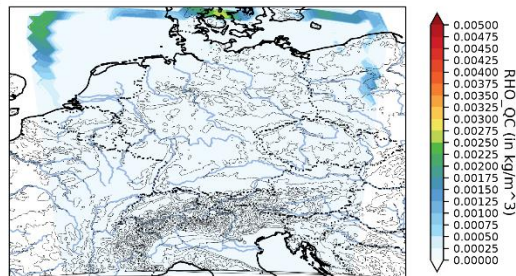
TKE [1]: Min=-3.3881317890172014e-21, Mean=0.12634556956298254, Max=3.1857643725531344
 [1] /home/mbaldauf/Work_ungeichert2/TmpBRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=21600 t=03:00:00.000 k=11 -> z~1.573...4.877km



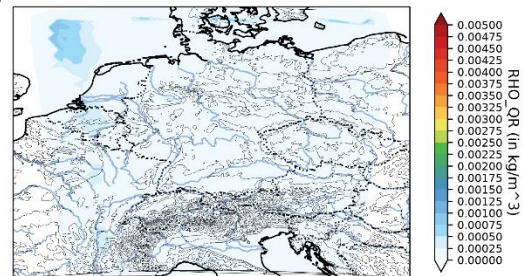
RHO_QV [1]: Min=0.0011199465206615106, Mean=0.005159728967913356, Max=0.008421756220594063
 [1] /home/mbaldauf/Work_ungeichert2/TmpBRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=21600 t=03:00:00.000 k=11 -> z~1.573...4.877km



RHO_QC [1]: Min=-1.0587911840678754e-22, Mean=6.840744602588482e-05, Max=0.002981844567453832
 [1] /home/mbaldauf/Work_ungeichert2/TmpBRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

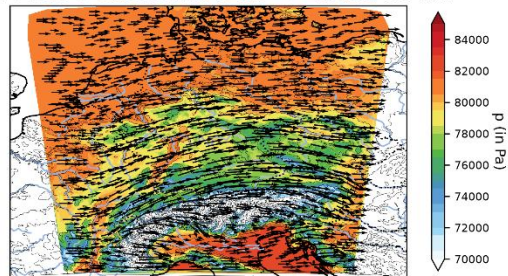
jstep=21600 t=03:00:00.000 k=11 -> z~1.573...4.877km



RHO_OR [1]: Min=-6.617444900424222e-24, Mean=5.87678455138336e-05, Max=0.0010298631368064696
 [1] /home/mbaldauf/Work_ungeichert2/TmpBRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

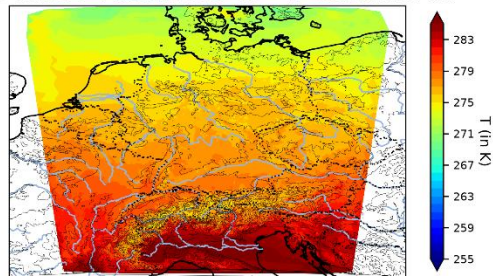


jstep=28800 t=04:00:00.000 k=11 -> z~1.573...4.877km



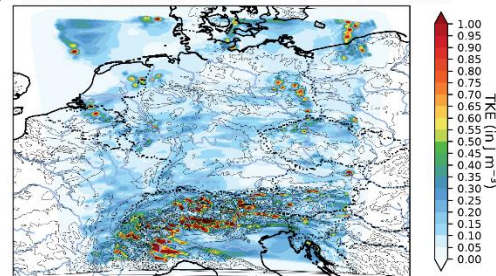
p [1]: Min=55136.598799401734, Mean=78537.09814572669, Max=82451.34324948
 uv [2]: Min=-3.592929173193007, Mean=13.28247985230643, Max=28.711921101113052
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d
 [2] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=28800 t=04:00:00.000 k=11 -> z~1.573...4.877km



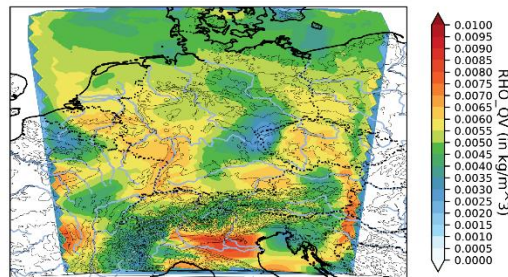
T [1]: Min=269.6232564369706, Mean=277.37288521189544, Max=287.7322903336108
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=28800 t=04:00:00.000 k=11 -> z~1.573...4.877km



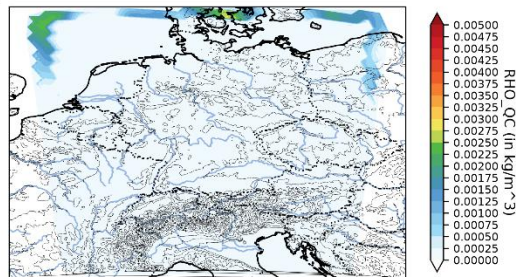
TKE [1]: Min=0.0, Mean=0.12926899742972436, Max=3.5723074788657905
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=28800 t=04:00:00.000 k=11 -> z~1.573...4.877km



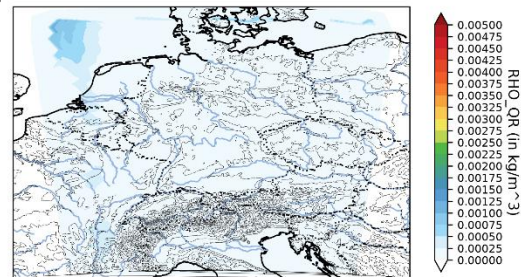
rho_QV [1]: Min=0.0009696554905786759, Mean=0.005154078555509727, Max=0.008534520811108666
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=28800 t=04:00:00.000 k=11 -> z~1.573...4.877km



rho_QC [1]: Min=-5.293955920339377e-23, Mean=6.711690926534207e-05, Max=0.002989020047915157
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

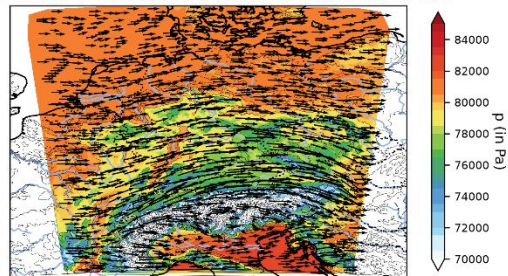
jstep=28800 t=04:00:00.000 k=11 -> z~1.573...4.877km



rho_OR [1]: Min=-2.0194839173657902e-28, Mean=5.316352057167987e-05, Max=0.0010903375972155574
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

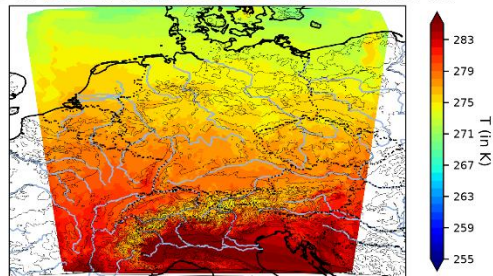


jstep=50400 t=07:00:00.000 k=11 -> z~1.573...4.877km



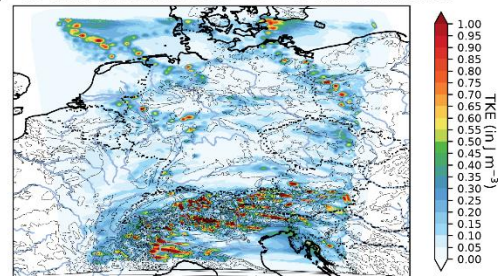
p [1]: Min=55161.310251968316, Mean=78545.35176273074, Max=82426.95744594852
 uv [2]: Min=-4.622742390609722, Mean=13.328701003232055, Max=28.326994793301232
 [1] :home/mbaldauf/Work_ungesichert2/TmpBRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d
 [2] :home/mbaldauf/Work_ungesichert2/TmpBRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=50400 t=07:00:00.000 k=11 -> z~1.573...4.877km



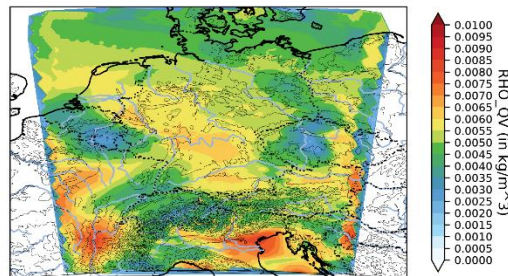
T [1]: Min=269.5063657752127, Mean=277.4026836271346, Max=287.82557162034306
 [1] :home/mbaldauf/Work_ungesichert2/TmpBRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=50400 t=07:00:00.000 k=11 -> z~1.573...4.877km



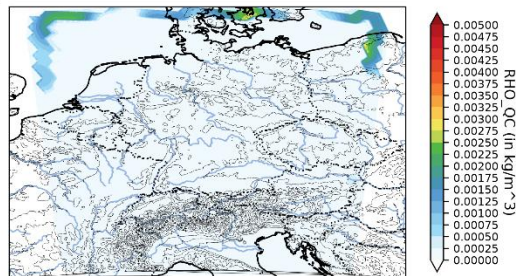
TKE [1]: Min=0.0, Mean=0.12415188515375758, Max=3.2476111445715654
 [1] :home/mbaldauf/Work_ungesichert2/TmpBRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=50400 t=07:00:00.000 k=11 -> z~1.573...4.877km



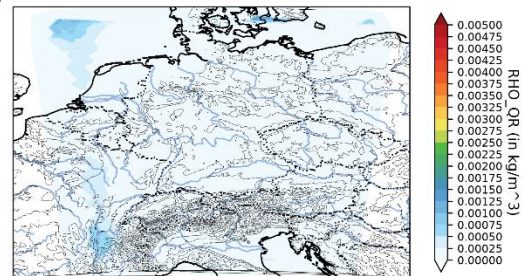
rho_QV [1]: Min=0.000750752053605843, Mean=0.005160406847842342, Max=0.008913097471903456
 [1] :home/mbaldauf/Work_ungesichert2/TmpBRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=50400 t=07:00:00.000 k=11 -> z~1.573...4.877km



rho_QC [1]: Min=-1.0587911840678754e-22, Mean=6.90364638505164e-05, Max=0.0029340197489072717
 [1] :home/mbaldauf/Work_ungesichert2/TmpBRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

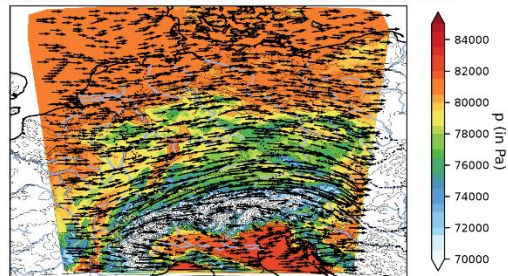
jstep=50400 t=07:00:00.000 k=11 -> z~1.573...4.877km



rho_OR [1]: Min=-1.0339757656912846e-25, Mean=4.547869774594941e-05, Max=0.0014005333796056664
 [1] :home/mbaldauf/Work_ungesichert2/TmpBRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

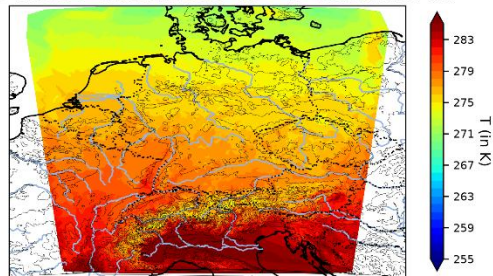


jstep=72000 t=10:00:00.000 k=11 -> z~1.573...4.877km



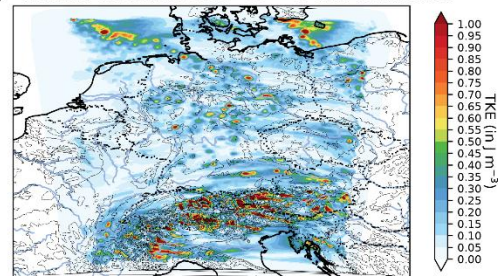
p [1]: Min=55156.06774952479, Mean=78535.74479607934, Max=82409.42183264115
 uv [2]: Min=-7.099760075652255, Mean=13.165074195010403, Max=28.795902441432112
 [1] /home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d
 [2] /home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=72000 t=10:00:00.000 k=11 -> z~1.573...4.877km



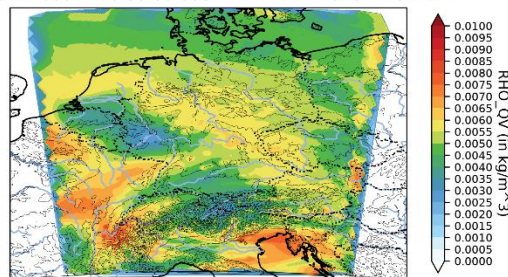
T [1]: Min=269.70957220035405, Mean=277.36984141236167, Max=288.2722101633348
 [1] /home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=72000 t=10:00:00.000 k=11 -> z~1.573...4.877km



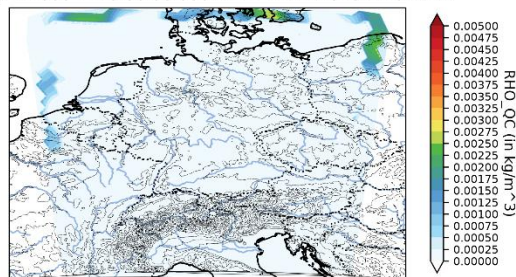
TKE [1]: Min=-1.6940658945086007e-21, Mean=0.14161682054728458, Max=3.0260580825741363
 [1] /home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=72000 t=10:00:00.000 k=11 -> z~1.573...4.877km



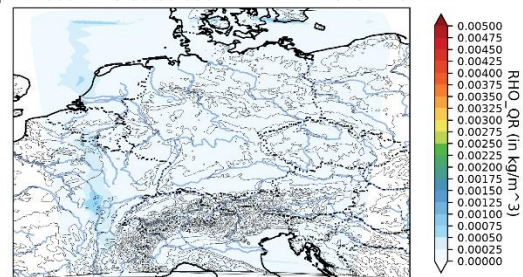
rho_QV [1]: Min=0.0009222764124149749, Mean=0.0051755648786621315, Max=0.00845552689117273
 [1] /home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=72000 t=10:00:00.000 k=11 -> z~1.573...4.877km



rho_QC [1]: Min=-5.293955920339377e-23, Mean=6.47891777782206e-05, Max=0.002971994294837114
 [1] /home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

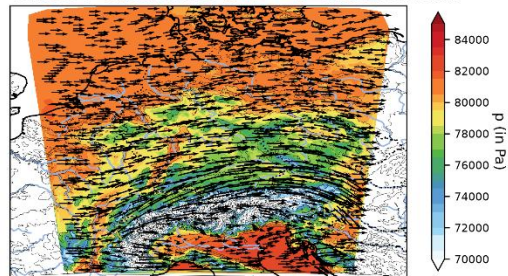
jstep=72000 t=10:00:00.000 k=11 -> z~1.573...4.877km



rho_OR [1]: Min=-3.308722450212111e-24, Mean=4.006338903375094e-05, Max=0.0009740711196671209
 [1] /home/mbaldauf/Work_ungesichert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

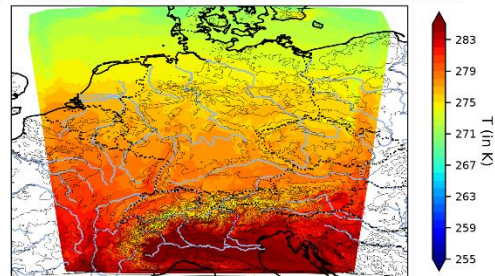


jstep=100800 t=14:00:00.000 k=11 -> z~-1.573...4.877km



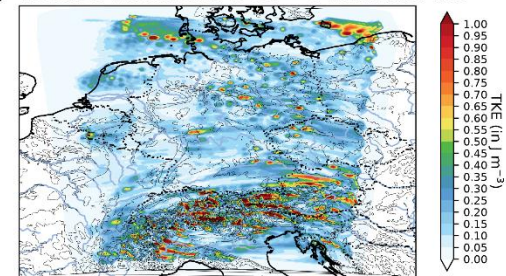
p [1]: Min=55153.434391746094, Mean=78530.6896874101, Max=82407.25310795395
 uv [2]: Min=-11.355677305803383, Mean=13.000337045299993, Max=29.711394655284572
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d
 [2] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=100800 t=14:00:00.000 k=11 -> z~-1.573...4.877km



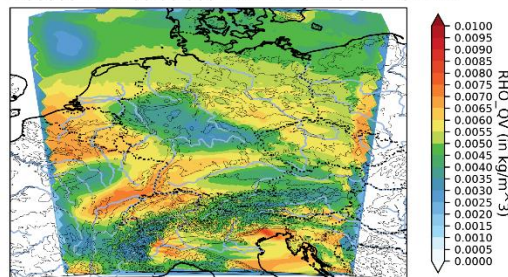
T [1]: Min=269.5720402644164, Mean=277.3849021828215, Max=288.3623693819521
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=100800 t=14:00:00.000 k=11 -> z~-1.573...4.877km



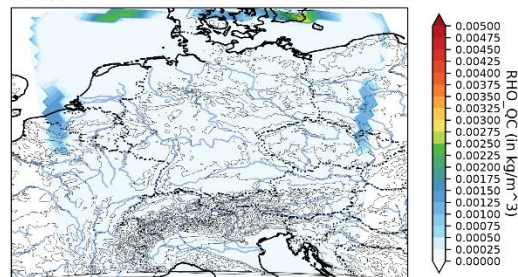
TKE [1]: Min=0.0, Mean=0.1629628619904708, Max=3.0372765452146293
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=100800 t=14:00:00.000 k=11 -> z~-1.573...4.877km



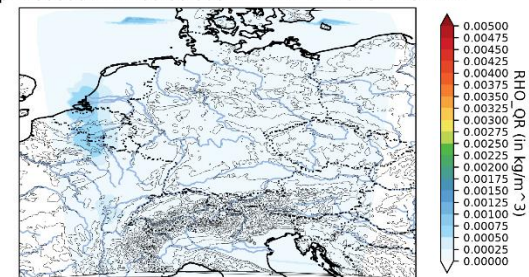
rho_QV [1]: Min=0.0013724722777367269, Mean=0.00506299507012574, Max=0.00854057540478542
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=100800 t=14:00:00.000 k=11 -> z~-1.573...4.877km



rho_QC [1]: Min=-1.0587911840678754e-22, Mean=6.426108339877752e-05, Max=0.0029302895895097036
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d

jstep=100800 t=14:00:00.000 k=11 -> z~-1.573...4.877km



rho_OR [1]: Min=-1.6543612251060553e-24, Mean=4.294528598656231e-05, Max=0.0011772175939585377
 [1] /home/mbaldauf/Work_ungeschert2/Tmp/BRIDGE/Euler_LAM_DE_TKE_Kessler_260903_d



Presentation of the BRIDGE project at the

SciCADE 2026 conference, 29 June – 03 July 2026, Edinburgh, UK

Minisymposium 73: High resolution numerical weather prediction

Org.: Philip Birken (Univ. Lund, Sweden), Stephane Gaudreault (ECCC, Canada)

Motivation of the organizers of this minisymposium:

Environment and Climate Change Canada (ECCC) actually is developing a Discontinuous Galerkin solver for their future forecasting system (in particular for their high resolution/limited area applications)

Gaudreault et al., (2022): High-order numerical solutions to the shallow water equations on the rotated cubed-sphere grid, JCP

- | | |
|--|---------------|
| 0. first version of a FE/DG framework available, MPI parallelized | Q2/2021 ✓ |
| 1. shallow water equations on the sphere, explicit time integration (RK) | Q3/2021 ✓ |
| 2. 3D Euler equations on the sphere, explicit time integration (RK) | Q1/2022 ✓ |
| 2.b with 3D diffusion (+ a simple turbulence scheme) BR1/BR2 | Q2/2022 ✓/✗ |
| 2.c grid refinement works | Q2/2022 ✓ |
| 3. Euler equations, HEVI time integration (IMEX-RK) | Q3/2022 ✓ |
| 3.b optimization of the vertically implicit solver (Schur compl.,...) | Q4/2022 ✓ |
| 3.c with 3D diffusion (+ a simple turbulence scheme), HEVI | Q1/2023 ✓ |
| 4. cloud microphysics (Kessler) + tracer advection (positive definit)
+ explicit sedimentation scheme | Q4/2022 ✗ |
| 4.b cloud microphysics (cloud ice, Graupel)
+ vertically implicit sedimentation scheme | Q1/2023 ! |
| 5. HEVI diffusion on dt(fast phys.); physics-dynamics coupl./time integr. | Q4/2023 ✓/✗ |
| 6. limited area (=use lateral BCs) version available | Q1/2023 ✓/... |
| 7.a vectorized version available | Q2/2023 ! |
| 7.b GPU version | Q1/2024 ! |
| 7.c general code optimization | Q4/2024 ✗ |
| 8. coupling of a one-equation turbulence + BL scheme | Q2/2023 ✓ |

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|--|-------------|
| 0. first version of a FE/DG framework available, MPI parallelized | Q2/2021 ✓ |
| 1. shallow water equations on the sphere, explicit time integration (RK) | Q3/2021 ✓ |
| 2. 3D Euler equations on the sphere, explicit time integration (RK) | Q1/2022 ✓ |
| 2.b with 3D diffusion (+ a simple turbulence scheme) BR1/BR2 | Q2/2022 ✓/✗ |
| 2.c grid refinement works | Q2/2022 ✓ |
| 3. Euler equations, HEVI time integration (IMEX-RK) | Q3/2022 ✓ |
| 3.b optimization of the vertically implicit solver (Schur compl.,...) | Q4/2022 ✓ |
| 3.c with 3D diffusion (+ a simple turbulence scheme), HEVI | Q1/2023 ✓ |
| 4. cloud microphysics (Kessler) + tracer advection (positive definit)
+ explicit sedimentation scheme | Q4/2022 ✓ |
| 4.b cloud microphysics (cloud ice, Graupel) (Kessler)
+ vertically implicit sedimentation scheme | Q1/2023 ✓/✗ |
| 5. HEVI diffusion on dt(fast phys.); physics-dynamics coupl./time integr. | Q4/2023 ✓/✗ |
| 6. limited area (=use lateral BCs) version available | Q1/2023 ✓ |
| 7.a vectorized version available | Q2/2023 (!) |
| 7.b GPU version | Q1/2024 (!) |
| 7.c general code optimization | Q4/2024 ✗ |
| 8. coupling of a one-equation turbulence + BL scheme | Q2/2023 ✓ |

Further steps in BRIDGE

the biggest working places:

- Continue work on **moist** atmosphere (Kessler scheme with IMEX-RK)
- Further inspection of **time split** schemes ($dt_{\text{phys}}/dt_{\text{dyn}} > 1$)
- Further improvement of **code efficiency** (cache efficiency, ...)
- Implementation of **entropy stable** schemes (also kinetic energy preserving schemes) ← Warmworld project
- C++/Kokkos **rewrite** ? ← depends on the ICON dycore C++/Kokkos rewrite

End of the BRIDGE project

→ Decision about implementation of the BRIDGE code into ICON