Modeling geophysical flows with the use of EULAG

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What is EULAG?

EULAG is a numerical solver for all-scale geophysical flows. The underlying anelastic equations are either solved in an **EU**Lerian (flux form), or a **LAG**rangian (advective form) framework.

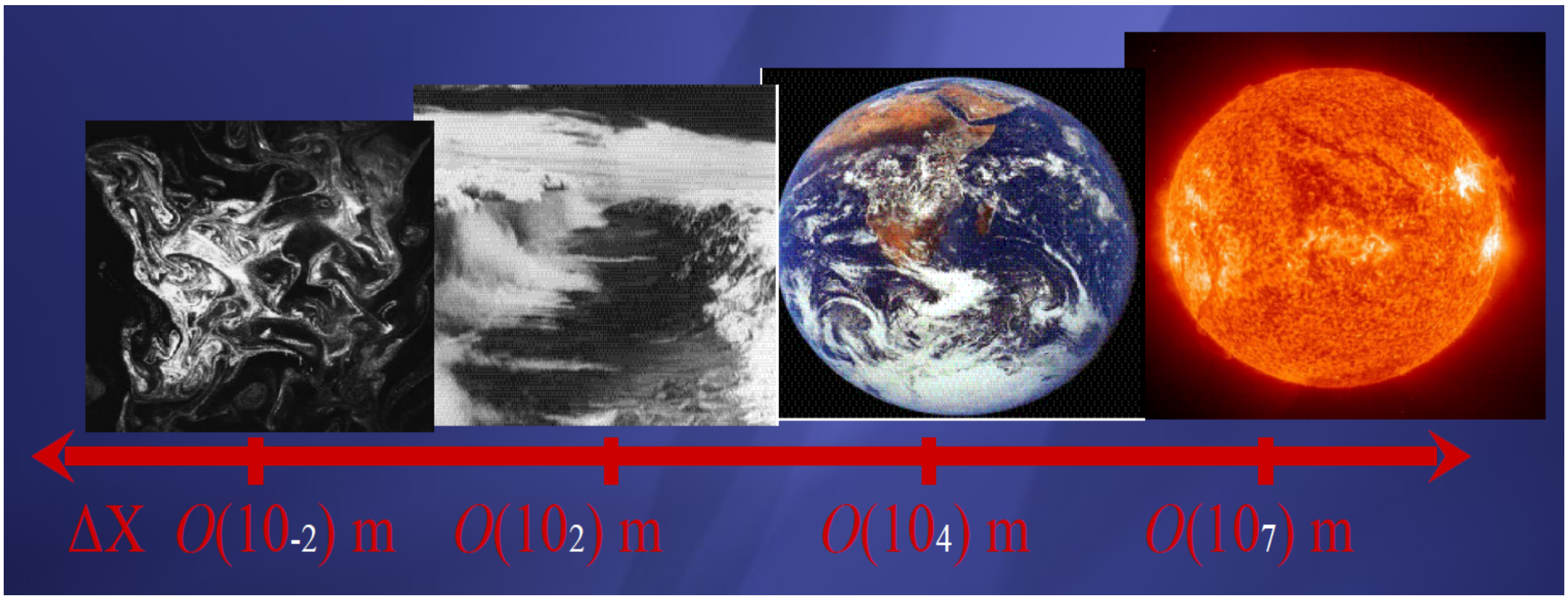
Model homepage: http://www.mmm.ucar.edu/eulag/

Model description: Prusa J., P. Smolarkiewicz and A. Wyszogrodzki. (2008), JCP, and extensive list of publications therein (development, applications, performance, etc.)

Model characteristics

• Anelastic, nonhydrostatic set of equations (also available: compress./incompress. Boussinesq, incompress. Euler/Navier-Stokes', fully compressible Euler eqns for high-speed flows)
• Generalized time-dependent curvilinear coordinates for grid adaptivity
• Nonoscillatory Forward-in-Time (NFT) algorithm for the governing PDEs
• Finite volume discretization
• Semi-implicit time integration scheme

Multiscale fluid solver



DNS

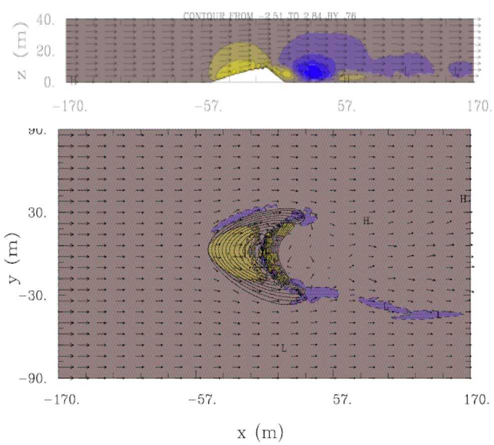
LES,
Mesoscale flows

Planetary flows

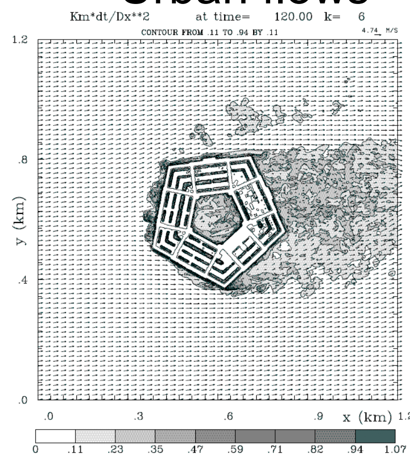
Solar convection

Multipurpose fluid solver

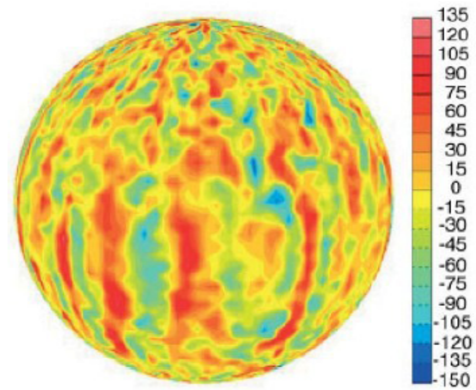
Aeolian flows



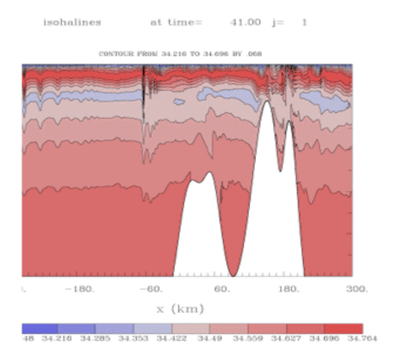
Urban flows



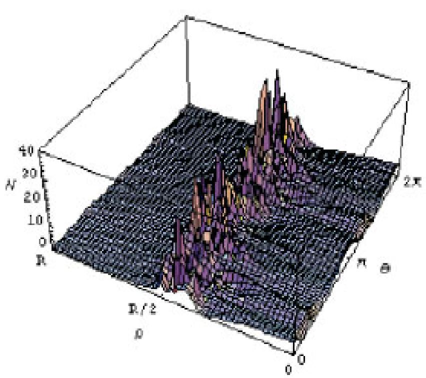
Solar convection(MHD)



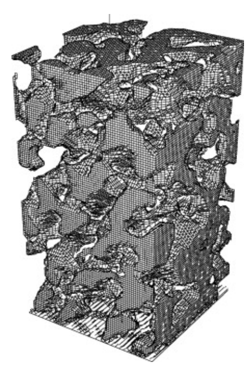
Oceanic flows



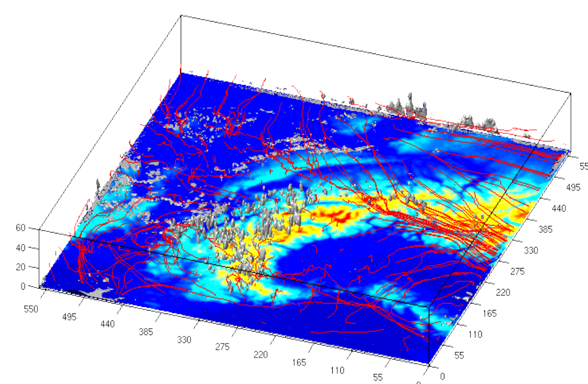
Brain injuries



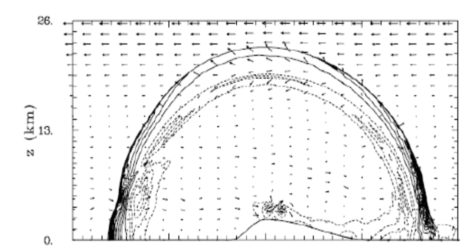
Porous media



Numerical Weather Prediction



Shock waves



etc.

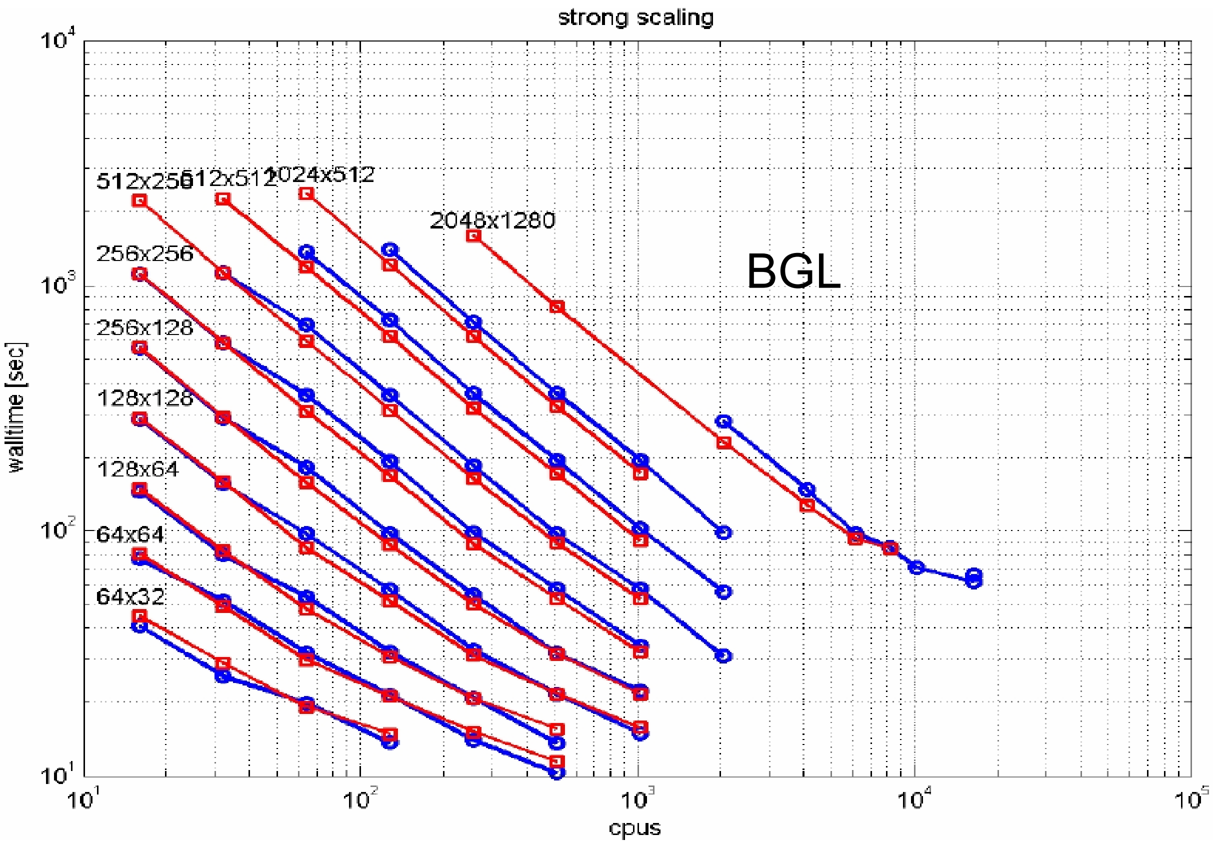
Atmosphere-related issues

- Cloud convection
- Orographic flows
- Vorticity generation
- Turbulence
- QBO
- Global circulation
- Cloud microphysics
- Subtropical convection (BOMEX, RICO)
- Stratocumulus (DYCOMS-II)
- ...

(for references see i.e. EULAG homepage)

Massively parallel solver

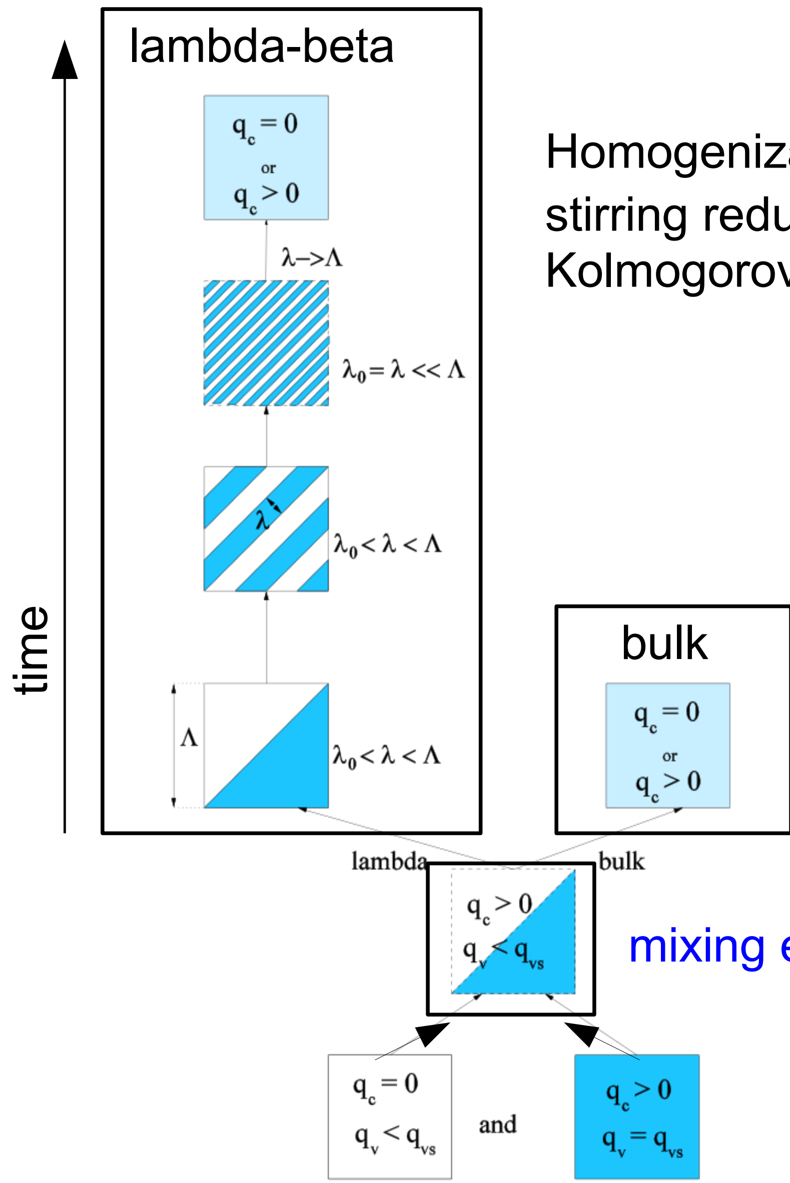
- 2D domain decomposition (no decomposition in z-direction)
- MPI protocol
- Scaling tests up to 16000 processors
- Tested on IBM BGL, Linux clusters, vector machines



Moist processes in EULAG

- Moist fields (prognostic variables): qv, qc, qr (optionally ice, qi)
- Condensation/evaporation based on saturation adjustment
- Kessler scheme for warm rain
- Lambda-beta scheme for stirring in LES
- 2-moment microphysics

Lambda-beta vs *bulk* parametrization

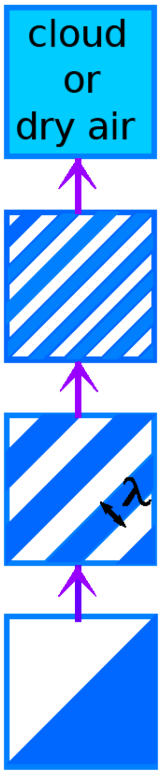


Homogenization is postponed until turbulent stirring reduces the filament size (λ) down to Kolmogorov microscale (~1cm)

Instantaneous homogenization

mixing event

Stirring within a grid box



$$\frac{d\lambda}{dt} = -\gamma \epsilon^{\frac{1}{3}} \lambda^{\frac{1}{3}}$$

Broadwell and Breidenthall, 1982, JFM

λ – spatial scale of cloudy filaments

$\Lambda > \lambda > \lambda_0$

Λ – model gridlength
λ_0 – Kolmogorov microscale
ε – dissipation rate of TKE

More details: *Grabowski 2007, JAS*

Microphysics – 2 moment scheme

Mixing event

$$N_f = N_i \left(\frac{q_f}{q_i} \right)^{\alpha}$$

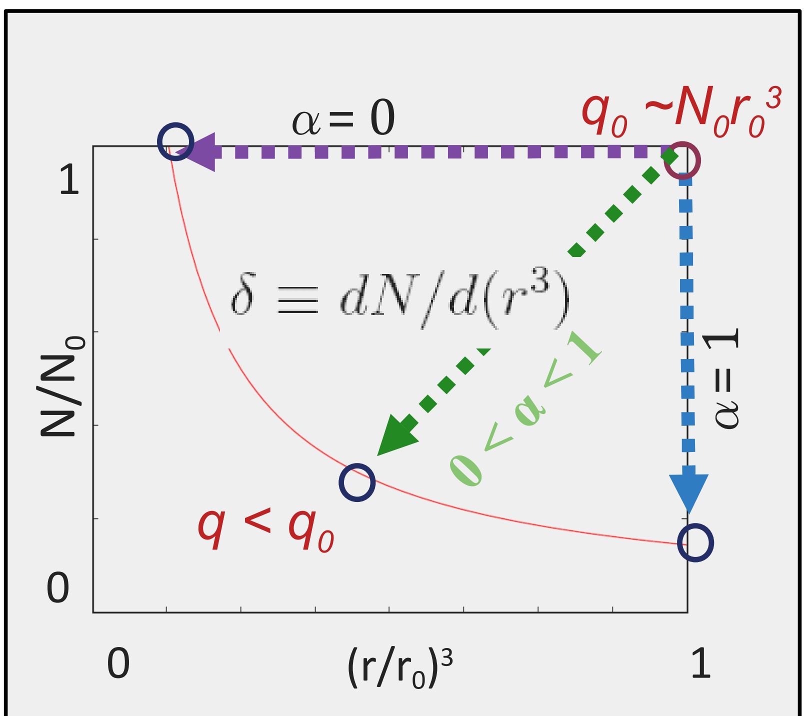
q_i, q_f – initial and final cloud water mixing ratios

N_i – droplet concentration after turbulent mixing; the initial value for microphysical adjustment

N_f – final value of droplet concentration (i. e. after turbulent mixing and microphysical adjustment)

α - determinant of the mixing scenario:

- α=1 extremely inhomogeneous
- α=0 homogeneous
- 1<α<0 inhomogeneous

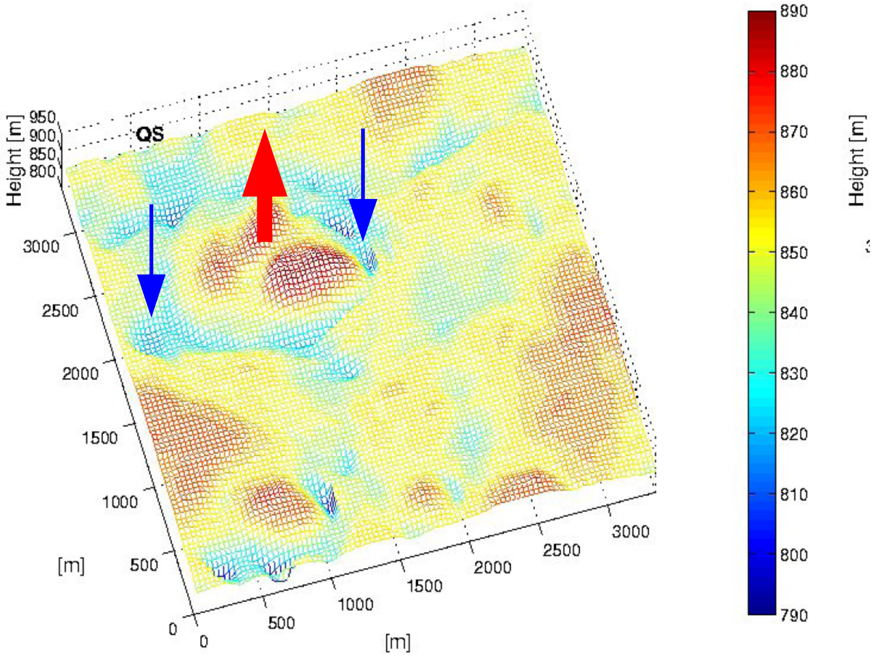


$$\alpha = \frac{\delta}{1+\delta}$$

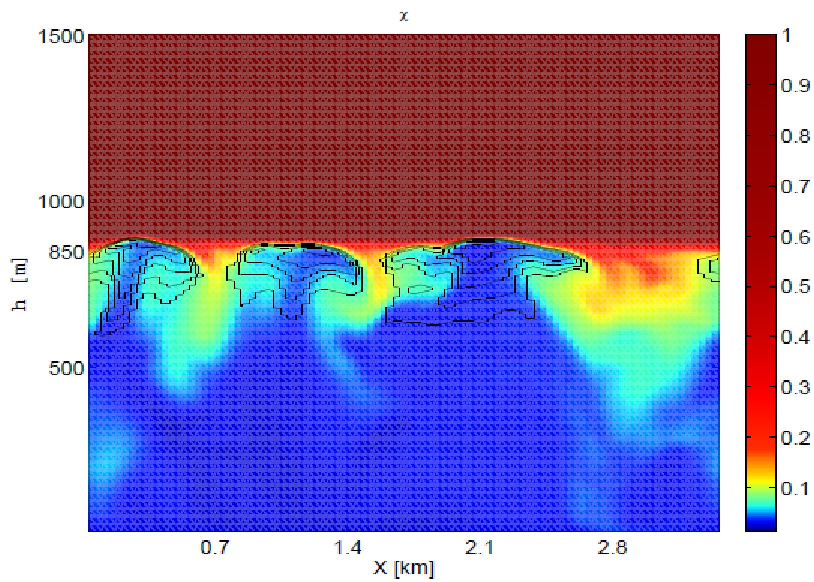
$$\delta = f\left(\tau_{mix} / \tau_{evp} \right) = f'(\lambda)$$

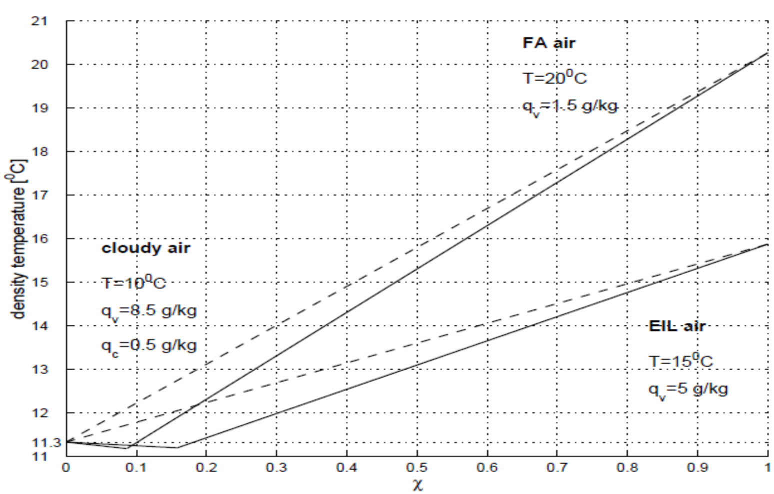
Morrison and Grabowski, 2008, JAS
Andrejczuk et al., 2008, JAS

Example: DYCOMS-II stratocumulus



Kurowski et al. QJRMS, 2009





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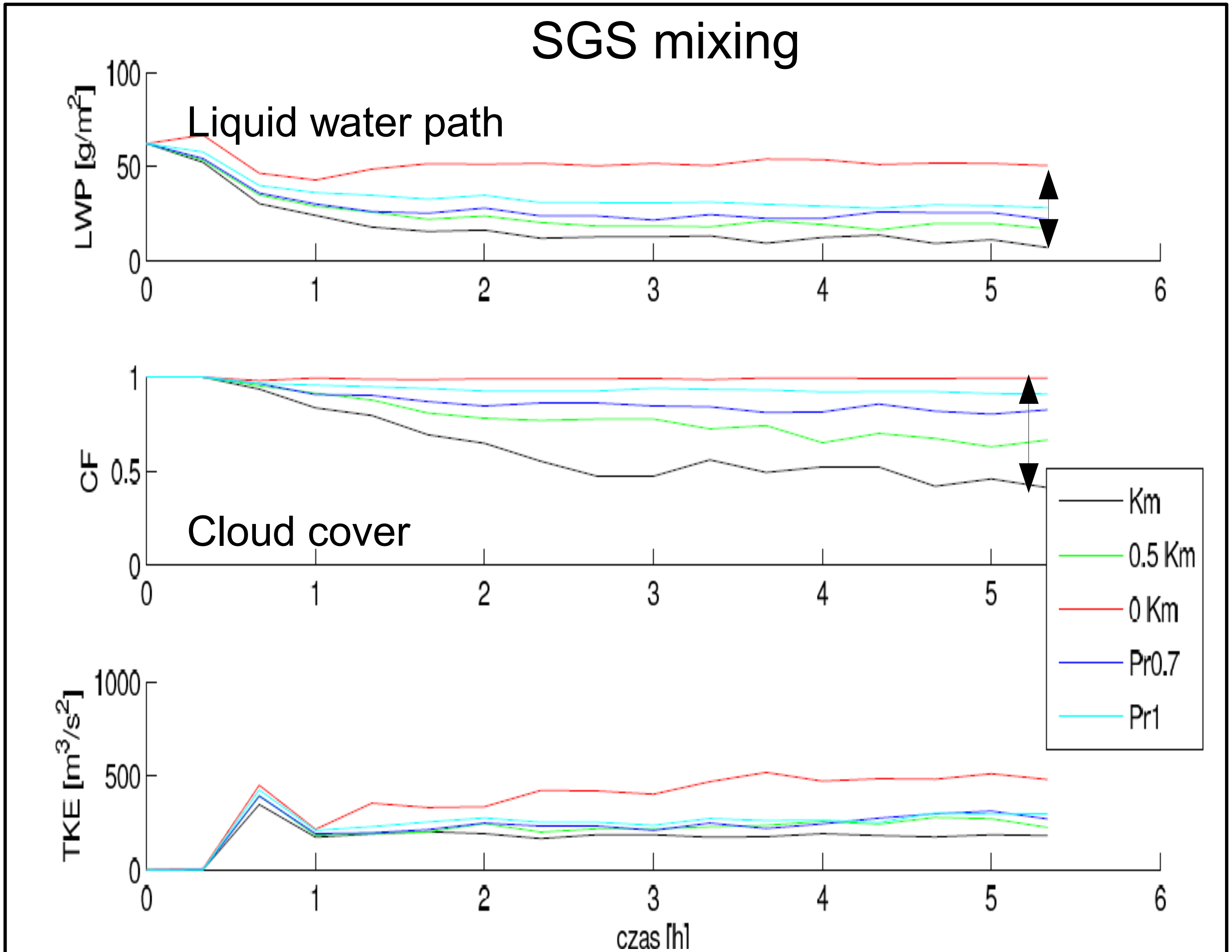

Kurowski et al., AMS Conference on Cloud Physics, Portland 2010

EUCLIPSE – things 'to do' in EULAG

- Adaptation of vertical stretching (SGS)
- Implementation of diurnal cycle, i.e. time-dependent surface fluxes (there is no soil model in EULAG)
- Implementation of new radiation scheme
- Verification and agreement of a basic set of physical parameters
- Adaptation of I/O (initial profiles and required data format)