Land atmosphere coupling

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Reiner Schnur, Stefan Kollet+ discussions with many more

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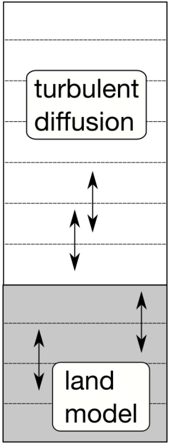
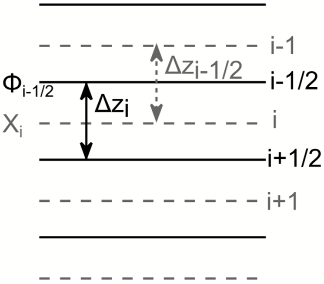


Diffusion Equation

$$\frac{\partial X}{\partial t} = -\frac{\partial}{\partial z}\Phi(z,t) = \frac{\partial}{\partial z}K(z,t)\frac{\partial}{\partial z}X \tag{1}$$

X: quantity
Φ: flux of X
K: exchange coefficient (eddy diffusivity)



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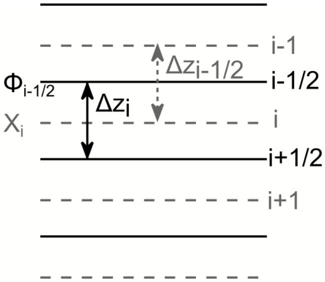

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space-discretized PDE (mesh z_i, interfaces $z_{i\pm 1/2}$):

$$\frac{\partial X_i(t)}{\partial t} \approx -\frac{\Phi_{i-1/2}(t)-\Phi_{i+1/2}(t)}{\Delta z_i} = \frac{K(z_{i-1/2},t)\frac{X_{i-1}(t)-X_i(t)}{\Delta z_{i-1/2}} - K(z_{i+1/2},t)\frac{X_i(t)-X_{i+1}(t)}{\Delta z_{i+1/2}}}{\Delta z_i} \qquad (2)$$

Diffusion Equation

time discretization, implicit Crank-Nicolson scheme, implicitness α:

$$\frac{X_i^{t+1} - X_i^t}{\Delta t} = \alpha \frac{K_{i-1/2}^{t+1} \frac{X_{i-1}^{t+1} - X_i^{t+1}}{\Delta z_{i-1/2}} - K_{i+1/2}^{t+1} \frac{X_i^{t+1} - X_{i+1}^{t+1}}{\Delta z_{i+1/2}}}{\Delta z_i} + (1-\alpha) \frac{K_{i-1/2}^{t} \frac{X_{i-1}^{t} - X_i^{t}}{\Delta z_{i-1/2}} - K_{i+1/2}^{t} \frac{X_i^{t} - X_{i+1}^{t}}{\Delta z_{i+1/2}}}{\Delta z_i} \tag{3}$$

Tridiagonal Matrix

$$A_i X_{i-1}^{t+1} + B_i X_i^{t+1} + C_i X_{i+1}^{t+1} = D_i; \qquad \mathcal{A} \cdot X^{t+1} = D; \tag{4}$$

sub-diagonal (A_i), diagonal (B_i) and super-diagonal (C_i); $\mathcal{A} = \begin{pmatrix} B_1 & C_1 & 0 & 0 & \dots \\ A_2 & B_2 & C_2 & 0 & \dots \\ 0 & A_3 & B_3 & C_3 & \dots \\ 0 & 0 & A_4 & B_4 & \dots \\ \dots & \dots & \dots & \dots & B_{n_i} \end{pmatrix}$

begin solution at the top, boundary condition $\Phi_1 = 0 \rightarrow K_{1/2} = 0 \rightarrow A_1 = 0$, downward sweep

bottom boundary condition: $\Phi_{n_i+1/2} = H$ or LE, upward sweep

usually set $K_{i\pm1/2}^{t+1} = K_{i\pm1/2}^{t}$

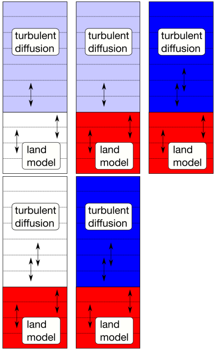
Coupling to the land-surface scheme – Explicit - Implicit - semi-implicit

at which time level are the surface fluxes H and LE taken ?

cf. Polcher et al., (1998):

$$LE^{t+1} = -\rho C_q^d |\vec{V}| \left(q_a^j - q_{sfc}^l \right) \qquad (5)$$

$$H^{t+1} = -\rho C_h^d |\vec{V}| \left(\theta_a^j - \theta_{sfc}^l \right) \qquad (6)$$



j, l: time indices

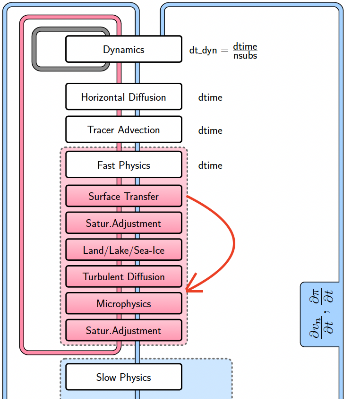
j=t+1;l=t+1 : implicit coupling, VDIFF+JSBACH

j=t+1;l=t : semi-implicit coupling

j=t ;l=t+1: explicit coupling, TERRA

j=t; l=t : open-explicit coupling

Process Order, ICON



Dynamics $dt\_dyn = \frac{dtime}{nsubs}$

Horizontal Diffusion dtime

Tracer Advection dtime

Fast Physics dtime

Surface Transfer

Satur.Adjustment

Land/Lake/Sea-Ice

Turbulent Diffusion

Microphysics

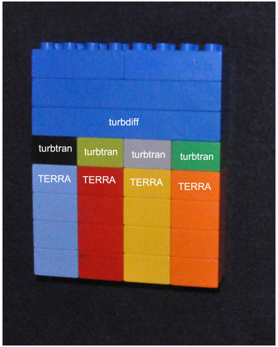
Satur.Adjustment

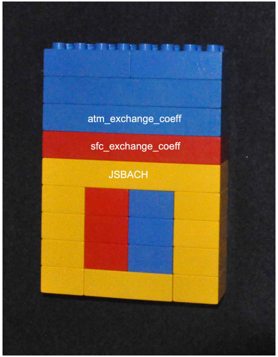
Slow Physics

$\frac{\partial v_n}{\partial t}, \frac{\partial \pi}{\partial t}$

Prill et al. (2020)

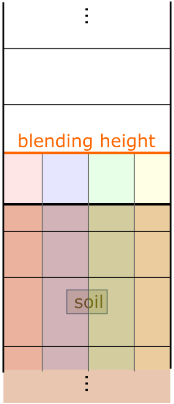
Tiles

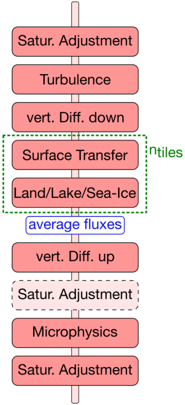




- Tiles determined by land-use class
- TERRA: Averaging of the *fluxes* after calling the land-surface scheme (TERRA) at 0 m height
- JSBACH: Only one drag coefficient C_q^d for the the grid box, different transfer coefficients for sea-ice, water, land, averaging at lowest atmospheric level

Tiles, blending height



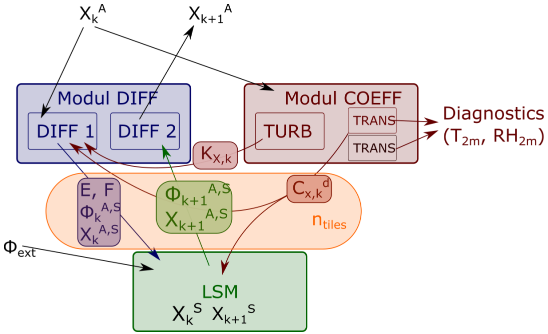


Tiles, questions

- space: land-use class (tile) vs. geometric subdivision (mosaic)
- blending height: averaging at the surface, some blending height in the BL (e.g. lowest atmospheric level), or extending the tiles throughout the entire atmosphere
- relevance for different resolutions, feedback on mean and ensemble spread

Unified turbulence scheme, unified land-surface scheme

in close collaboration with projects WarmWorld, ICON-C



Experiments

- “climate” runs
  - conservation properties
  - control run
  - global patterns, long-term behaviour
- “weather” runs
  - validation
  - interplay with data assimilation
  - ensemble spread