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COSMO Soil & Surface: Activity Review



Physical Process in COSMO			Method		Name	Authors
Local		Radiation Transport	δ two-stream; revised optical cloud properties		Ritter and Geleyn (1992) Blahak (->)	
Parameterizations of atmospheric source terms		Microphysics	1-moment; 3 prognostic ice phases; prognostic rain and snow		Doms (2004) Seiffert (2010)	
	А		optionally 2-moment version		CONCELECTO)	
Grid-scale Parameterizations of sub-grid scale atmospheric processes (dependent on horizontal resolution)		any other not yet (completely) considered process (e.g. SSO driven thermal circulations or horizontally propagating GW)				
		deep Convection shallow	deep onvection2-class (updraft-downdraft) mass-flux equations with moisture convergence closure and simplified microphysicsub-grid Scale Orography SO) effectsorographic blocking and breaking of vertically propagating Gravity Waves (GW)		Tiedke (1989), update by Bechthold et al. (2008) optionally	
	>	Sub-grid Scale Orography (SSO) effects			Lott and Miller (1997)	
		Quasi-Isotropic Turbulence	2-nd order closure; progn. TKE with addit, scale- interaction terms (STIC); horizont. BL-approx. with opt. 3D-extensions; turb. sat adjustm.		TURBDIFF	
		Surface-to-Atmosphere Transfer and Roughness Layer effects	transfer resistances based on vertically constant turbulent/laminar near-surface fluxes normal to roughness-covering surfaces; Separate heat budget of	tiled only	TURBTRAN	Raschendorfer (2001,->)
Modelling the non-	↓ -	Vertical Heat and Water Transport of the Soil including Vegetation and a Snow-cover	roughness elements (shading) 1- layer snow; m layer soil; freezing of soil water; resistances for vapor from stomata of leaves and soil pores; moisture and root mass dep. conduct.; coupled with roughness-layer concept	I C O N	TERRA (CLM and Veg3D can be coupled via OASIS- coupler)	Heise and Schrodin (2002), Schulz (2016, ->), Helmert (->), Raschendorfer (->)
atmospheric part below the surface			optional mlayer snow		Maschulskaya (->)	
		Heat Transport and Phase Change of Lakes	1-layer with an assumed shape function o	on of	FLAKE	Mironov (2008)
		Heat Transport and Amount of Sea Ice	water and a possible snow-cover			
CONSORTIUM FOR SMALL SCALE MODELING						

Deutscher Wetterdienst





Matthias Raschendorfer

EWGLAM/SRNPW, Reading, 2017

Main topics:

- ✓ Improved formulation of surface-to-atmosphere coupling:
 - $\circ~$ reformulation and implicit coupling of near surface heat-budget equations

for the snow-free skin (or roughness layer), snow-cover and rigid soil below

- \circ testing the shading effect of a (so far) mass-less roughness cover (skin-layer)
- o consistent integration of an improved multi-layer snow-model
- o an effective adaptation to urban surfaces
- ✓ More advanced soil-physics and relevant plant-physiology
 - testing different plant-phenology models
 - build-up of groundwater table; slop-dependent runoff
 - usage of harmonized Word Soil Database
 (improved soil-texture information including vertical structure)
- ✓ Objective Calibration of Model-Parameters (CALMO)
 - the problem of poorly confined model parameters

Current state of the TERRA-development in ICON:

Result of a history of "migration"

 COSMO (original version) -> ICON : further development (partly merged from parallel COSMO-development)

-> COSMO : adaptations (interfaces, parameter-generation, etc.)

Additional TERRA-development in ICON:

- → surface tiles (is a matter of technical organization of the model, not foreseen for COSMO so far)
- → some special tuning (desert, Geenland-ice): G. Zängl
- → tuned GlobCover 2009 look-up table for land-use parameters: G. Zängl
- → exponential root density profile and impact of roots on thermal and hydraulic conductivity:
 - J. Helmert
- → reformulated resistance based bare soil evaporation: J.-P. Schulz
- more advanced treatment of snow-fraction (including effect of vegetation and SSO) and revision of interception store): G. Zängl
- Introduction a resistance based treatment of a vegetation canopy similar to the treatment in HIRLAM (not yet consistently integrated into surrounding physics): ICON-test-version by J. Helmert
- ➔ Introduction of a preliminary skin-layer extension for testing the shading-effect of plants (according to Viterbo and Beljaars 1995: ICON-version by J.-P. Schulz
- → Major reformulation of surface heat budgets (including 1-layer snow-cover), of snow-fraction calculation, as well as evaporation of snow and interception water in terms of implicitness (and associated removal of detrimental artificial limits) for numerical stabilization, already including the above skin-layer extension: recent development; ICON-version by M. Raschendorfer



This year

New Surface-to-atmosphere coupling in TERRA:

M. Raschendorfer, DWD



<u>Test-grid-point Kenia (+33.71_+7.89) :</u>

after-noon situation; tropical hot; strong radiation forcing Test-grid-point North-India (+58.51_+28.33) :

evening situation; tropical hot; frozen soil; snow-fall with thin snow-cover

 3 hour ICON-global test-runs (R2B6, dt = 6 min) with <u>OLD</u> surface-coupling in TERRA



!! Strong oscillations in T_sf or T_sn
(although artificial flux-limiter is activated) !!

New Surface-to-atmosphere coupling in TERRA:

M. Raschendorfer, DWD



- For n=8 soil layers, there are always n+2 linearly coupled heat-budget equations for the temperatures T_sn, T_sf, T_b1, ..., T_bn, which can easily be tri-diagonalized.
- For the time being, only the S-layer approximation is implemented into ICON

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3 hour ICON-global test-runs (R2B6, dt = 6 min) with <u>NEW</u> surface-coupling in TERRA



Physical advantages of the new coupling:

- Shading of a (semi-transparent) roughness cover with an rather loose thermal coupling to the rigid soil can be considered:
 - Smaller diurnal-cycle amplitudes of GHF and T_bx
 - Larger diurnal-cycle amplitudes of SHF, LHF and T_2m, Td_2m

 Experiment with a preliminary skin-layer-extension added to the <u>current</u> TERRA-equations (<u>before</u> the major reformulation; only a few lines of code) using a tuned fixed effective heat-conductivity between level b1 and the skin-surface-level sf (according to scheme in IFS, adapted by J.-P. Schulz):



a welcome behaviour for COSMO/ICON!

- A more advanced semi-transparent C-layer extension (by M. Raschendorfer) with parameterized heatconduction and heat storage of the full roughness cover (e.g. plant canopy) is being adapted from an existing test-version prepared last year within COSMO.
 - The final combination with the reformulated budgets will include all related partial development! 0
- Experiment with the existing test-version in COSMO: 2)
 - COSMO-DE with lateral boundaries from ICON-EU \cap
 - domain averaged daily cycles of near-surface variables 0
 - almost saturated soil due to long standing rain period before Ο
 - only for rather smooth surfaces: applied filter 0

2m-temperature [C] (over land with roughness length <= 0.3 m and cl cov <= 10%) Lon -5 5.5, Lat -5 6.5

T 2m

still some problems

amplitude

overestimated

slightly

32

30

28

26

22

almost no clouds due to high pressure situation + applied filter Ο

removed cold bias

in the afternoon!

already shown last year



conditional

diagnostic



EWGLAM/SRNPW, Reading, 2017

More advanced treatment of the snow-covered surface:

- Special treatment of a roughness C-layer only prepared for the <u>snow-free (sf) surface</u>.
 - **Snow-cover** is treated as a substitute of the roughness C-layer.
- A **sophisticated multi-layer snow-model** may describe its own roughness C-layer:

Diurnal cycle of Snow-Surface Temperature: COSMO standard versus advanced snow model (SCM)



Testing different plant-phenology models:

J.-P. Schulz et al., DWD

- Catch inter-annual variability of vegetation cycle
 - → currently LAI *climatology* is used in COSMO ('sine curve')
 - \rightarrow over Europe, inter-annual variability of vegetation cycle is important
 - \rightarrow trying different phenology models to capture this inter-annual variability
 - → phenology model by Stöckli et al. (2011) provides daily LAI maps (based on MODIS data calibrated with Ensemble Kalman Filter)
 - → significant impact on T2m on large region in spring and summer (typically 1K per 2 LAI in April)
 - \rightarrow mixed impact on T2m *score*... model re-calibration required

Annual cycle for different Phenology-models :



Pheno model by Stöckli et al. minus climatology: (monthly means of daily 15h UTC values, year 2011)



External parameters

- Usage of Harmonized World Soil Database
 - \rightarrow improved information on soil texture, incl. vertical structure
 - \rightarrow work in progress

MeteoSchweiz

TERRA-URB (Wouters, H., KU Leuven)

- Goal: add cheap but realistic bulk parameterization of urban effects mainly by adapted/new urban external parameters (Impervious Surface Area, Antrop. Heat-Flux)
- Benefit: variability of urban heat island well reproduced
- Status: addit. framework to derive optimal bulk parameters for
 any specific city

already good results obtained

operational introduction planned for 09.2018

Objective Calibration of COSMO Model (CALMO)

Method : Omar Bellprat, ETH

- Describing the dependency of a (user oriented) model performance metric (that can be represented by observations) as a function of unsecure and sensitive model parameters by a <u>cheap</u> Meta-Model based on quadratic forms
- Searching for the global maximum (optimal parameter tuple) of the performance metric for the given parameter space (bounded by the valid range of each parameter) by means of the Meta-Model



CALMO: current state

- The method developed at ETHZ has been adapted to NWP, and was applied to calibrate 6 parameters of COSMO-2
- The Meta-Model is able to reasonably reproduce the dependency of the model on the unconfined parameters using a performance function based on Client Oriented Scale of Improvement (COSI) using:
 - T2m daily min/max, 24h precipitation
 - o total column water
 - wind, temperature, humidity at 3 standard pressure levels
- Calibration of COSMO-2, daily 36h forecast, full year 2013

Improvement of 4% of COSI score

- Main desired application:
 - Retuning after introducing more advanced physics, particularly in order to *beat* prior compensating errors



CALMO: problems and inherent chances

- **Optimal values** of some parameters show <u>significant dependency</u> on:
 - annual season
 - climatological regime

functions of specific model-state variables

non-confident model parameters going to be estimated:

• treated as a constant



- New (regression) parameters $\underline{\pi}$ of a possible Statistical Hyper-Parameterization,
 - where $\underline{\pi}$ should be <u>less dependent on the model state</u> (more confident)
- It removes a remaining systematic error (complement of Physical Parameterization),
 - o whereas a Stochastic Parameterization tries to remove a remaining stochastic error



dīn

 $\frac{1}{2}$

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25 85 85

6%

TERRA news

- New unified COSMO / ICON TERRA with COSMO v5.05 To support the COSMO community & avoid duplication of effort
 - \rightarrow significant delay due to unexpected bad results from NWP test suite
 - \rightarrow bad scores due to soil drying in summer in some regions
 - \rightarrow hidden effect in ICON-EU due to active soil moisture analysis
 - → requires new minimal stomatal resistance map... but issue not fully settled







Towards a new prognostic equilibrium surface temperature in combination with SAT and the soil model:

- ✓ Completion of the roughness layer model (TERRA-part)
- Thermal decoupling of a Cover built by roughness elements(canopy) above the dense soil (shading effect)
- ✓ Representation of the thermal energy storage of the roughness layer

Matthias Raschendorfer



Case study: 23.06.2016



COSMO-DE with lateral boundaries from ICON-EU

- ✓ only for rather smooth surfaces; applied filter
- ✓ almost saturated soil due to long standing rain period before
- ✓ almost no clouds due to high pressure situation; + applied filter
- domain averaged daily cycles of near-surface variables



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 n cover layers including the surface of the dense soil (n=0) are connected by long-wave radiation interaction and sensible heat exchange

thermally decoupled roughness elements (shading)

• Only a part of the inner surfaces is connected to A by the resistance chain, the other part is for the inter- surface exchange



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TURBTRAN:
$$T_A, q_{v_A}, p_A, (u_m, v_m)_A \rightarrow r_{S0}^H, r_{0A}^H$$
Deutscher Wetterdienst
Wetter und Klima aus einer HandTERRA: $T_A, q_{v_A}, r_{S0}^H, r_{0A}^H \rightarrow T_S$ valid for next time level may be out of equilibrium

used for **next** time level

 q_{vS}

 q_{vS}^{*}

valid for **this** time level, associated to **current evapotranspiration**

Diagnostic of surface temperature:

S

DWD

Case study: 23.06.2016



COSMO-DE with lateral boundaries from ICON-EU



— ana_Im3_exp_10279 — out_Im3_exp_10279 — out_Im3_rlmk_new_surf-icon-icon-itype_surf=1-lsfluse=T-e_surf=10-c_soil=2-itype_vdif=1
direct analysis of revised TURBDIFF revised TURBDIFF imported from ICON + imported from ICON
T 2m and TD 2m imported from ICON

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EWGLAM/SRNWP Rome 2016