Comparison of land-surface model (LSM) components for ICON-ESM/NWP

List of modeling components used in TERRA-LSM (DWD/COSMO) and ICON-Land/JSBACH4 (MPI-M)

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Modeling component	TERRA	JSBACH4
How is the surface energy balance determined?	Surface temperature is an area weighted average of temperature of snow covered and snow free surface tile fractions. Similar for surface humidity.	Implicit solution of surface energy balance equation (Schulz et al., 2001). Surface temperature and humidity are area-weighted averages of surface tiles (snow cover is treated internally on each tile).
Which coupling is used to the atmosphere?	Explicit coupling, application of the turbulence scheme at the lower model boundary and iterative interpolation	Implicit coupling within vertical diffusion scheme. Parameter aggregation: averaged temperature and humidity are given to atmosphere. Flux aggregation: averaged sensible and latent heat fluxes, to be ported from JSBACH3 to JSBACH4. Explicit coupling also possible.

Modeling component	TERRA	JSBACH
Which approach is used for soil water and heat transfer and how is the soil vertically structured?	Solution of the Richards equation and the heat conduction equation in a multi-level structure (Schrodin and Heise, 2001; Schulz et al., 2016) NWP: 7-layer + 1 climate layer Layer-depths between 1 cm and 14.58 m	• Richards equation for soil water (Hagemann and Stacke, 2014) • Heat conduction equation for multiple soil layers following Warrilow et al. (1986) • Vertical structure flexible per namelist configuration
Can the soil water freeze?	Temperature and soil type dependent computation of fractional freezing/melting of total soil water content in 6 active soil layers (Heise et al., 2006)	Yes (Ekici et al., 2014)
Which approach exists for vegetation?	• One-layer scheme using plant transpiration after Dickinson (1984) • Interception reservoir	• Similar • Dynamic phenology model (leaf area index) • Competition of vegetation types (PFTs): dynamic vegetation; scheme from MPIESM/JSBACH3 is currently re-implemented in JSBACH4 (Reick et al., 2013)

Modeling component	TERRA	JSBACH
Which complexity is used for snow?	• Internal one-layer scheme operational (Schrodin and Heise, 2001) • SNOWPACK-based multi-layer external module (SNOWPOLINO) under development (COSMO-SAINT)	• Internal one-layer scheme (from ECHAM) and multi-layer snowpack scheme (Ekici et al., 2014)
Which complexity and approaches are used for urban areas?	• Modified surface roughness, leaf area index, plant coverage • Implementation of TERRA_URB (Wouters et al., 2017) in progress (COSMO-CITTA')	• None at this time
How are freshwater lakes and mires are considered?	FLake model (Mironov et al., 2010), Mire scheme (Yurova et al., 2014)	Simple lake model including ice (Giorgetta et al., 2013)

Modeling component	TERRA	JSBACH
Which chemistry module/carbon cycle is used in the LSM?	none	• Assimilation of carbon in leaves by photosynthesis and stomatal control for transpiration (based on Knorr, 1998) • YASSO soil carbon model (Goll et al., 2015) • More complex QUINCY bio-geo-chemistry model (MPI-BGC Jena) currently being implemented
How are canopy effects considered?	Skin-layer approach (Schulz and Vogel, 2020)	• Interception of rain and snow on canopy • Canopy radiation model for photosynthesis (Knorr, 1998)
Which approach is used for run-off/ river routing	Simple run-off, no routing	Separation of rainfall and snow melt into surface runoff and infiltration and the calculation of lateral drainage following the Arno scheme (Dümenil and Todini, 1992); Hagemann and Dümenil (1996) hydrologic discharge (HD) model w/ river routing; coupled to ocean model

Summary:

TERRA	ICON-Land/JSBACH
Advantages: • Multi-layer soil model with unique position-dependent TILE approach for subgrid land-use heterogeneities • Optimized for NWP application (process complexity, speed, data assimilation) • Internal DWD development, source code transfer possible (new platforms, models)	**Advantages:** • Implicit coupling to atmosphere suitable for all scales • Flexibility for configuration/implementation of surface tiles, processes and matter pools (carbon, nitrogen, isotopes, etc.) • Self-contained external code repository • Bio-geo-chemistry (full carbon cycle within ESM) • Dynamic vegetation (soon in JSBACH4) • Land cover change (disturbances, land use, forest management) • Hydrologic discharge model (river routing) • Ported to GPU
Disadvantages: • Stability issues for long time steps due to explicit coupling to the atmosphere • No chemistry/carbon cycle • Only simple vegetation – no dynamics • Only simple run-off, no river routing	**Disadvantages:** None … just kidding ☺ • Simple lake model … should use FLake … TBD • Some performance penalty for flexibility and modular, object-oriented infrastructure; but can be further optimized