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Expanding TERRA to include 'Snowpolino' and additional snow physics

PT-SAINT / PT-SAINT 2 (?)

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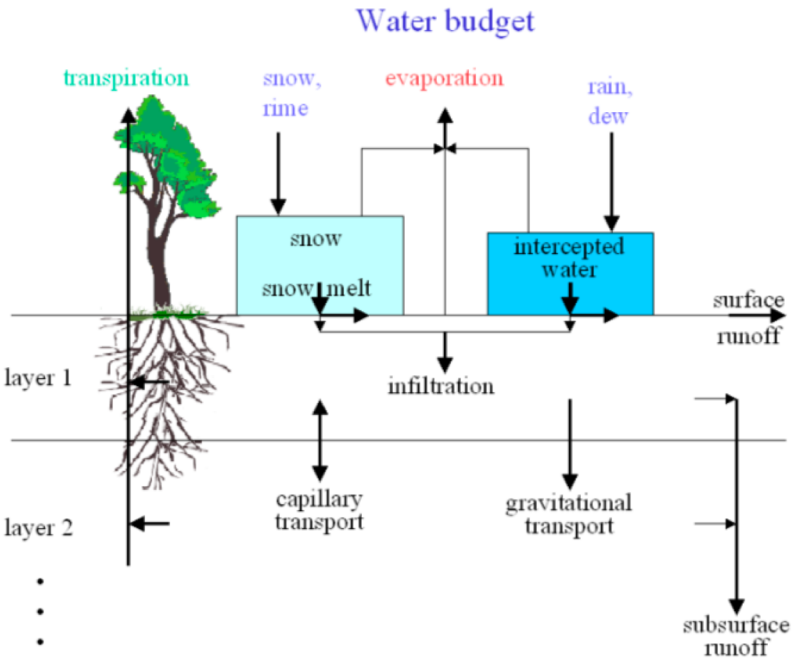
Current snow modelling in TERRA

Single-layer treatment of snow

$$\frac{\partial T_{snow}}{\partial t} = \frac{1}{(\rho c \Delta z)_{snow}} (G_{snow,sfc} - G_{snow} + G_{melt}) \quad \textit{(Heat eq.)}$$

$$\alpha_s = \alpha_{s,max} S_{age} + \alpha_{s,min}(1 - S_{age}) \quad \textit{(albedo eq.)}$$

$$\rho_{snow,age} = \rho_{snow,max} + (\rho^n_{snow} - \rho_{snow,max}) \exp^{\frac{-C_{age}\Delta t}{\tau_\rho}} \quad \textit{(density eq.)}$$



Drawbacks of single-layer modelling of snowpack

- Especially problematic for deeper snowpacks in the Alps
- Melt dynamics are seriously compromised
- SWE estimation problematic due to lack of density stratification

Recent developments in snow modelling in NWP and climate models

Recent multilayer snow model released @ ECMWF / IFS

- Multiple layers of snow
- 'intermediate complexity model'

Impact of multi-layer snow model :

- The mean 'normalized' RMSE for snow depth and SWE reduced by more that 30% for both winter time and spring time
- Improvements in snow depth and SWE due to
  - proper representation of snow density stratification
  - Simulation of sporadic melting of top layers of snow
- Improvement in soil temperature
- Improvements in T2 bias.
- Improvements in ablation period in spring

JAMES | Journal of Advances in Modeling Earth Systems

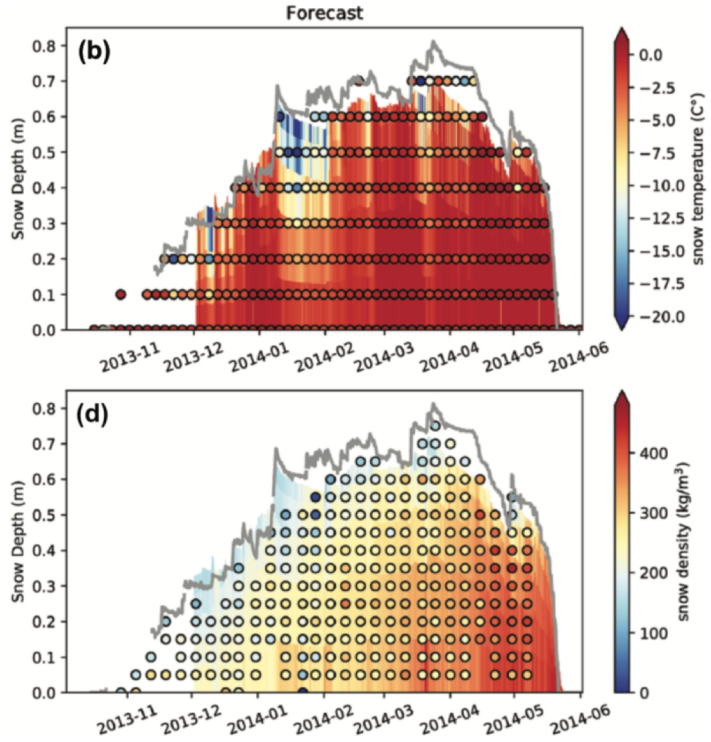
RESEARCH ARTICLE
10.1029/2019MS001725

Impact of a Multi-Layer Snow Scheme on Near-Surface Weather Forecasts

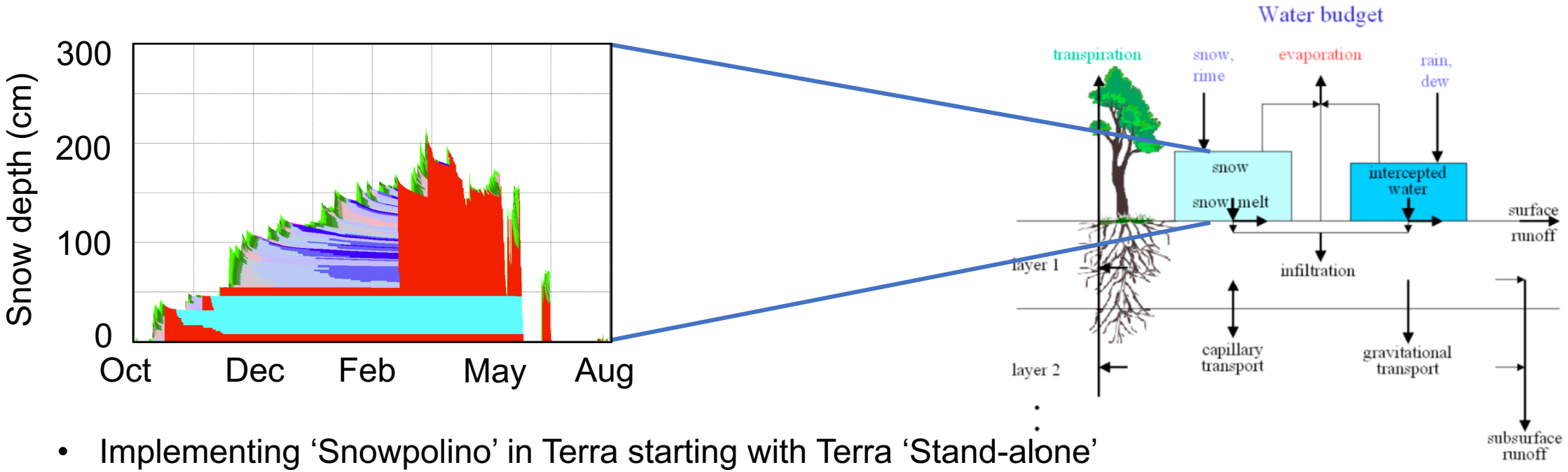
Gabriele Arduini[1], Gianpaolo Balsamo[1], Emanuel Dutra[2], Jonathan J. Day[1], Irina Sandu[1], Souhail Boussetta[1], and Thomas Haiden[1]

[1]European Centre for Medium-Range Weather Forecasts, Reading, UK, [2]Instituto Dom Luiz (IDL), Faculdade de Ciências, Universidade de Lisboa, Lisbon, Portugal

Key Points:
- A multilayer snow scheme is implemented in the ECMWF Integrated Forecasting System (IFS) and evaluated in offline and coupled simulations
- The new multilayer snow



Multi-layer snow model within TERRA (PT-SAINT)

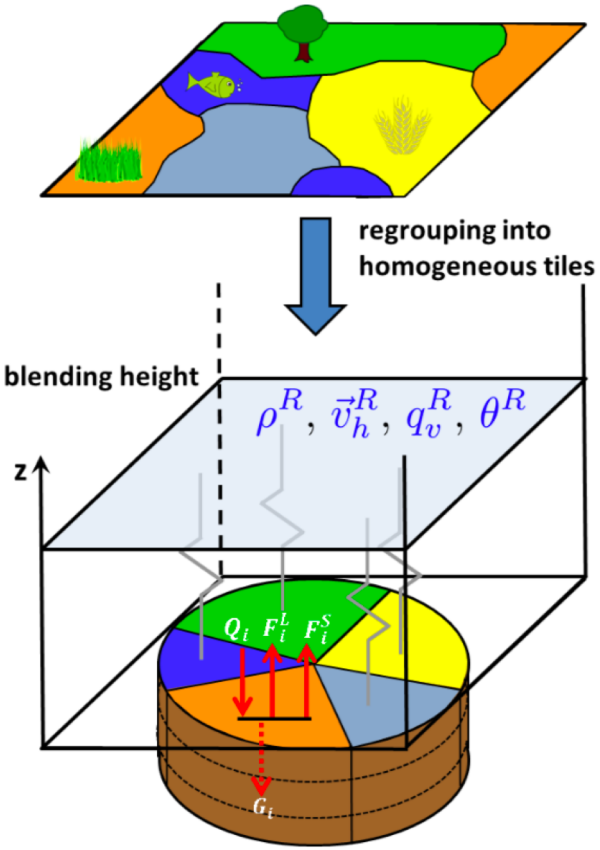


- Implementing ‘Snowpolino’ in Terra starting with Terra ‘Stand-alone’
  - For better comparison with station data (eg. using the IMIS network by SLF/WSL)
  - Spinup / climate scale sims / hindcasting / comparison with satellite remote sensing
- TSA development should carry forward into COSMO and ICON
- Snowpolino in COSMO already implemented as separate model
  - 25 layers of snow within memory / computational budgets for operational use !
- Snowpolino brings ‘up-to-date’ parametrizations (albedo / densification / conductivity) etc.

Multi-layer snow model within TERRA (PT-SAINT 2)

Bringing SNOWPOLINO to ICON's 'tiled' approach

- Implementation within TERRA should bring all of Snowpolino's improvements and benefits to ICON (including for operational use)
- Testing for the 'tiled' approach in ICON critical (?)
- Updates to surface-atmosphere coupling methodolgy in ICON ? Implications for 'Snowpolino / TERRA' ?



Multi-layer snow model within TERRA (PT-SAINT 2)

Additional physics: Snow on forest canopies

- In the northern hemisphere, 19% of annually snow-covered areas are forested.
- Proper representation of snow-canopy interactions crucial for capturing snow cover and melt dynamics.
- Specifically important for hydrological modelling, at all scales – ranging from global water budget assessment to flood and drought forecasting, water resources management including irrigation and hydropower applications.
- Additional motivation : Satellite based remote sensing of SWE (holy grail of snow hydrology)

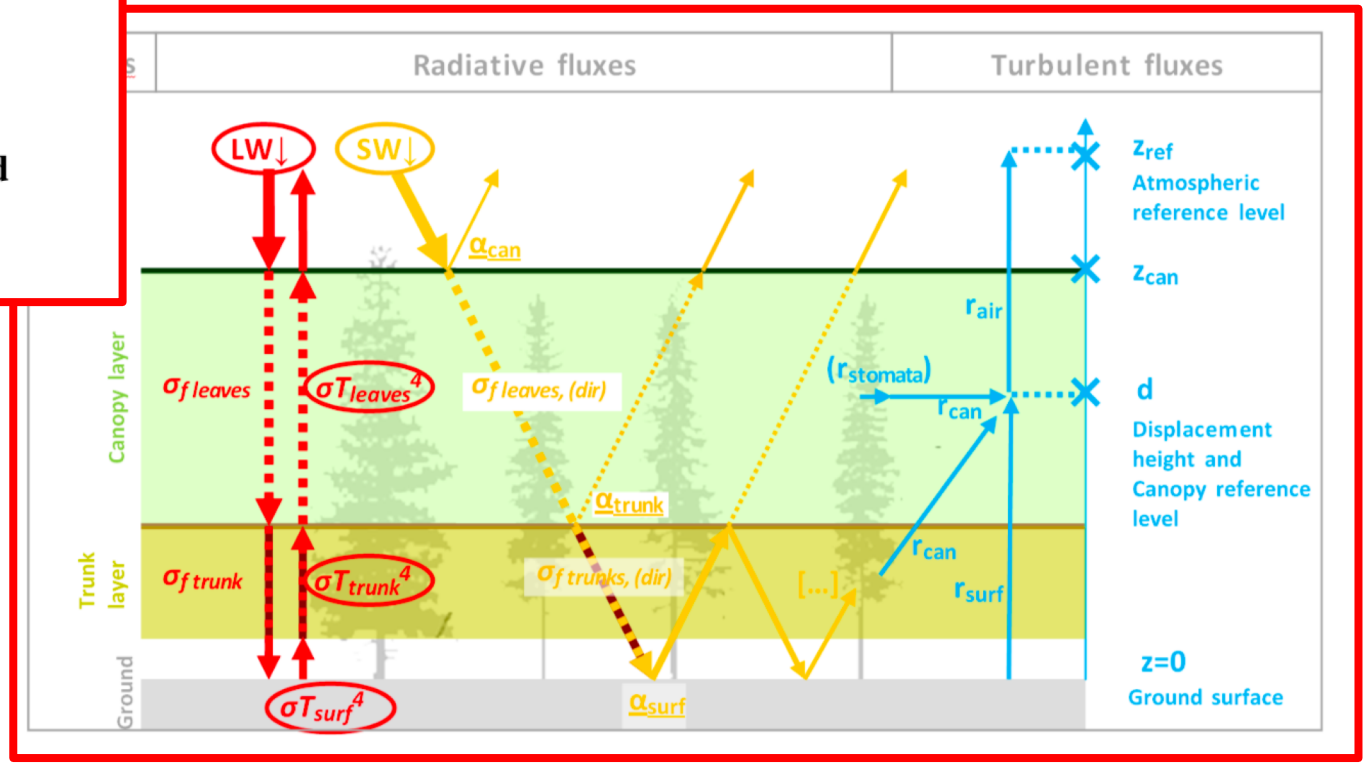
Multi-layer snow model within TERRA (PT-SAINT 2)

Additional physics: Snow on forest canopies

Geosci. Model Dev., 8, 2379–2398, 2015
www.geosci-model-dev.net/8/2379/2015/
doi:10.5194/gmd-8-2379-2015

Geoscientific Model Development
Open Access

A two-layer canopy model with thermal inertia for an improved snowpack energy balance below needleleaf forest (model SNOWPACK, version 3.2.1, revision 741)

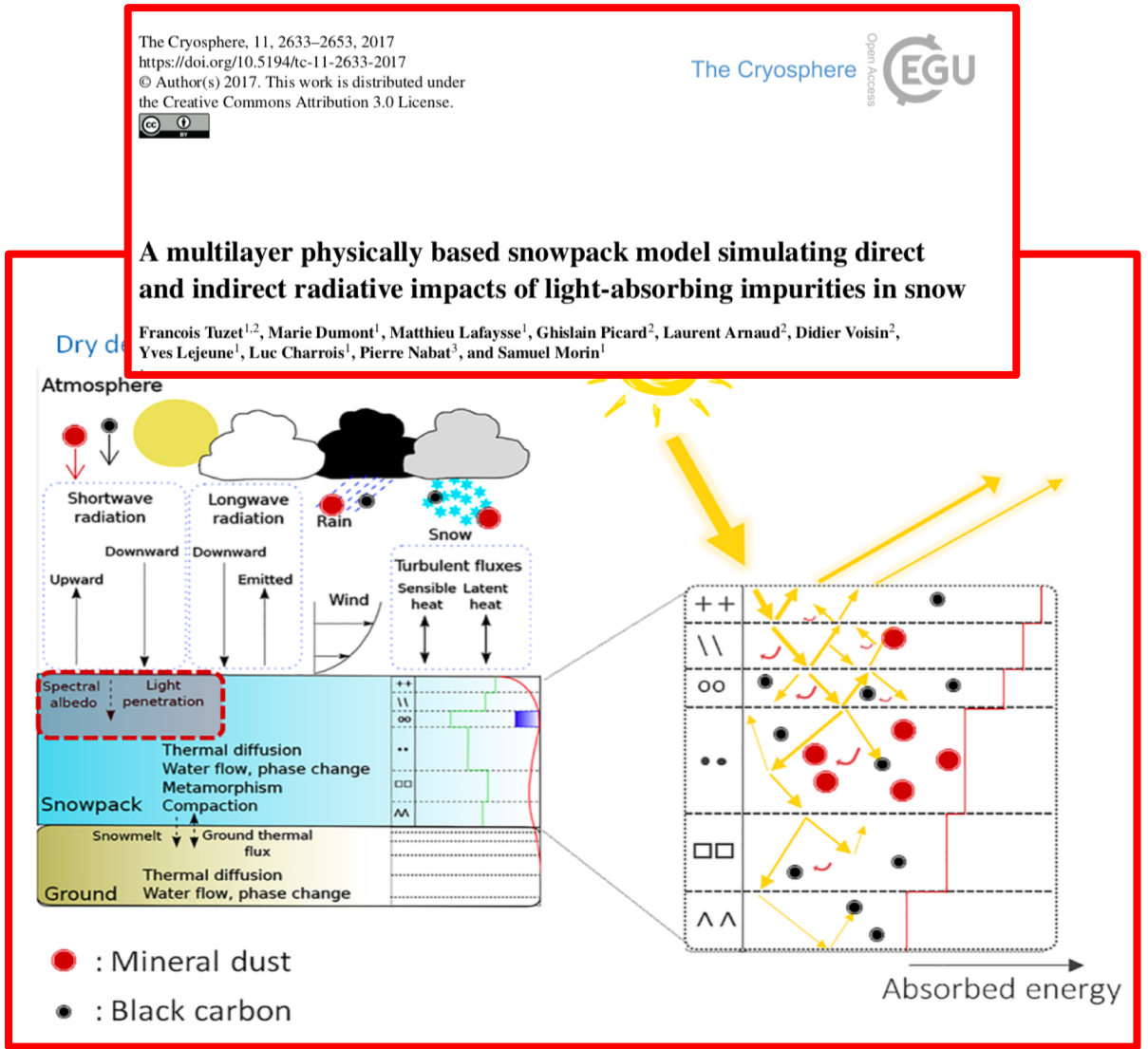


- Trunk and leaf spaces seperated
- Simple radiative transfer through caonpy including effect of snow accumulation in the leaf space
- Consistent energy and mass balance in the two-layer canopy

Multi-layer snow model within TERRA (PT-SAINT 2)

Additional physics: Aerosols and their impact on snow albedo

- Not much to say after Anika's awesome talk yesterday !
- Need for multi-layer snow modelling is clearly motivated by this problem
- Snowpolino is equiped by design to easily be expanded to tackle this issue.
- Guidance from Anika's thesis work as well as recent implementations in CROCUS



Thank you!
Questions or Comments?

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