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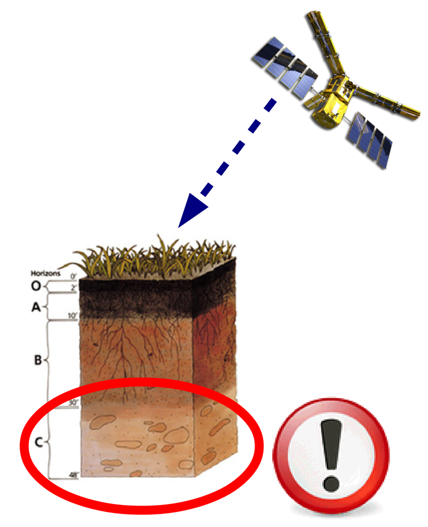
New Initializations of TERRA for Climate Simulations



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Motivation

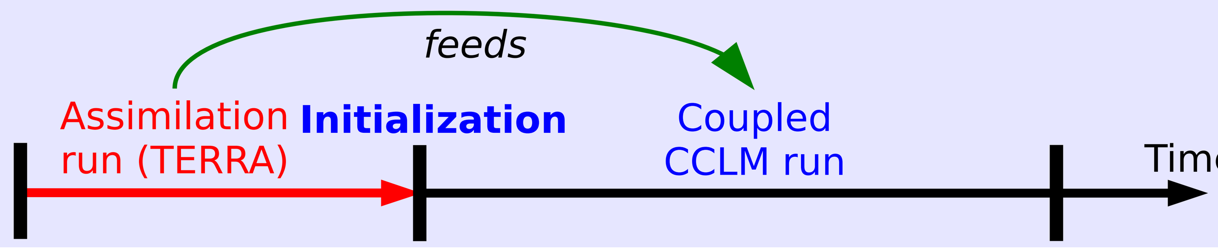
Medium-range climate prediction: partly an initial value problem...

WEATHER	SEASONAL/ DECADAL	CLIMATE
initial value problem	← Both →	boundary value problem

- Deep soil has long-term memory → potential climate predictability
- Realistic land surface initialization (in COSMO's TERRA) beneficial
- Prognostic target variables: *soil moisture & soil temperature*

Approaches using TERRA-ML_offline

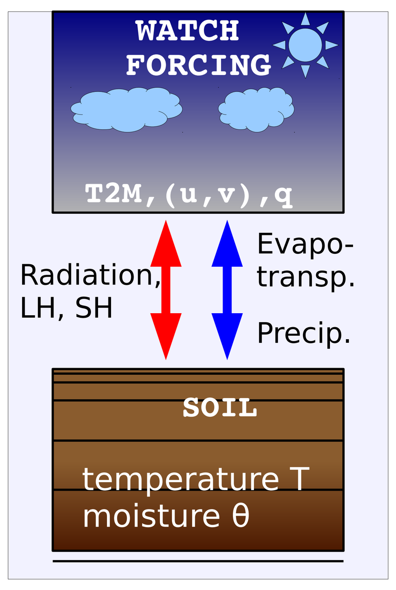
Assimilation runs in advance of the climate simulations, with...
(1) Assimilation of land surface forcing products
(2) Assimilation of soil-related observations
→ Both systems under development / partly ready



1 Measurement-Driven Soil Analysis 1

Principle

Long-term run of offline model with optimized forcing data: WATCH surface forcing data set[1]
→ Adjustment of (deep) soil over long time range (years)



Advantages

✓Comparably simple application
✓Can be used for *any* region and *any* time period in between 1979-2012
✓Ensures CCLM-balanced initial surface conditions

Challenges

◇Relies on forcing data quality (region-dependent?)
◇Spin-up period has to be sufficiently long

2 Ensemble Data Assimilation 2

Principle

- Assimilation of soil-related observations (satellites) into TERRA with sequential ensemble filters
- ETKF[2] or new development, ETPF[3]

Advantages

✓Fast convergence, within months
✓Deals with uncertainties
✓Allows joint state & parameter estimation

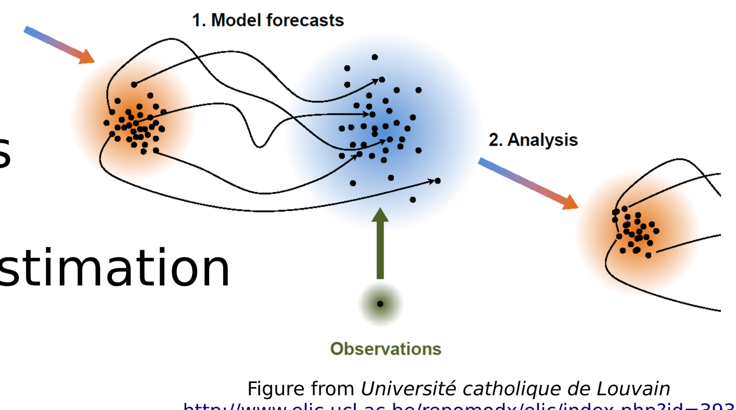


Figure from *Université catholique de Louvain* http://www.elic.ucl.ac.be/repomodx/elic/index.php?id=393

Challenges

◇Observation quality & availability?
◇Information transfer to deep soil?
◇Technically extensive, tuning required...

Technical Issues & State of Work

System ready ✓

- TERRA can be run with WATCH forcing data
- Transfer scheme for offline version revised
- New lower BC for soil temperature: *no flux*

Forcing variables:
T_{2m}, $|v|_{10m}$, q_{2m}, P_{10m}, SwDown, LwDown, Rain, Snow

Usage

Workflow:
I/O = NetCDF

Precprocess WATCH (spatial/temp. interpolation) → Prepare initial fields & ext. param. → Run TERRA parallelized → Process model output

EnDA system partly ready

PDAF Parallel Data Assimilation Framework

- TERRA was implemented into PDAF[4]
- Efficient analysis steps & iteration with ensemble forecasts

Usage

- Single column version ready & working ✓
- Spatial version with localization: final development
→ parallelization to be done

First Application Results

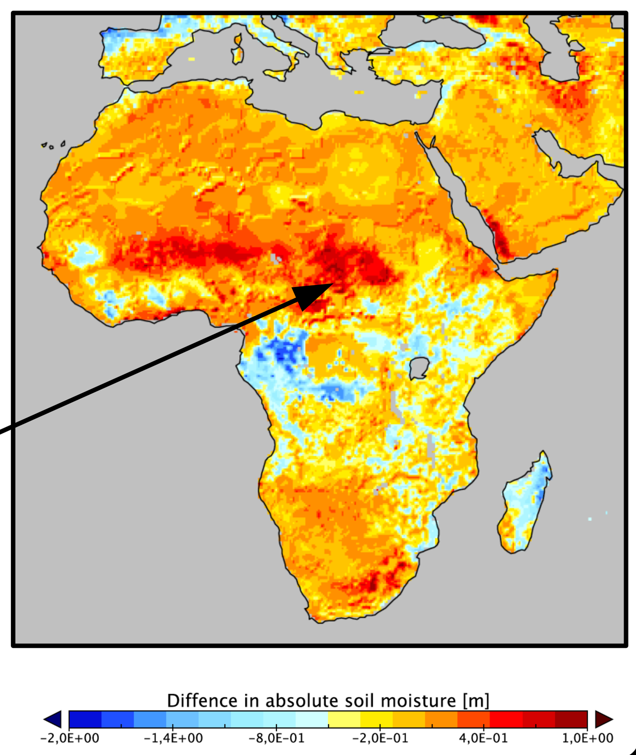
Regional applications

↪Performed runs for Europe & Africa
↪WATCH+TERRA exhibits no model drift
↪Reasonable soil dynamics over long range
↪To be used in MiKliP regional simulations

Example: Africa

↪Significant differences to usual ERA-based CCLM initial land surface fields
↪E.g. Sahel too wet
- precipitation bias?

Fig.1: STANDARD – NEW of soil moisture initial fields at 2001-01-01 in last soil layer



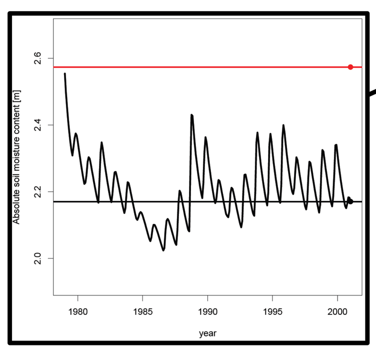
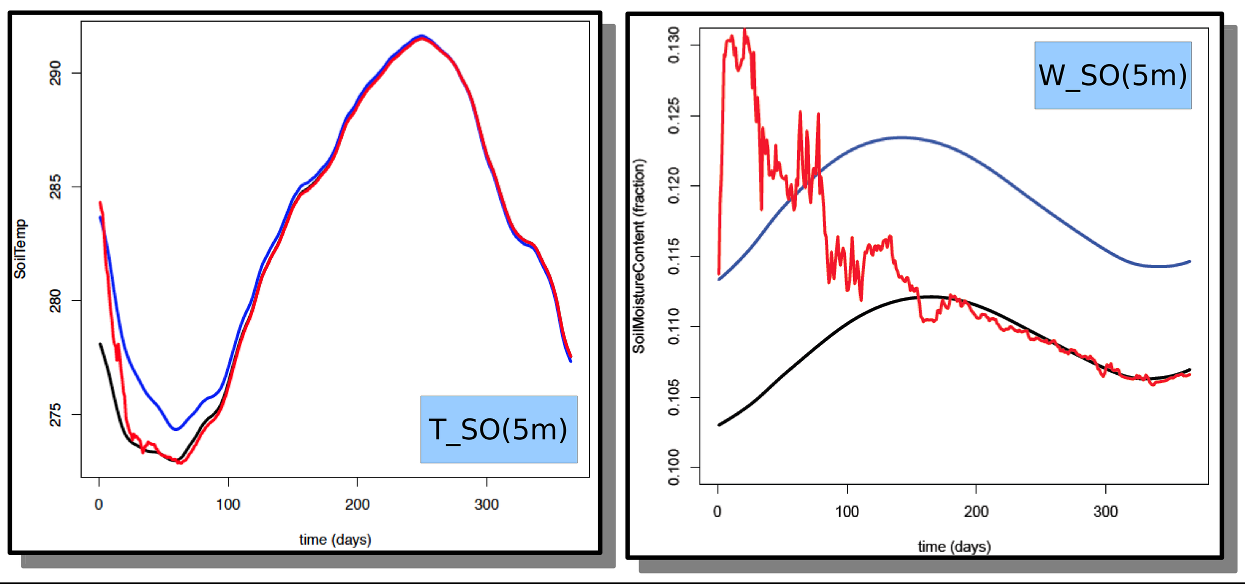


Fig.2:Temporal evolution of deep soil moisture in WATCH+TERRA 1979-2001
Red dot = standard initial cond. at 2001-01-01

Twin experiments

↪Reconstruction of truth with synthetic observations
↪Information transfer possible to intermediate depths
↪Analysis potentially faster than spin-up
↪Requires observations of sufficient quality

Fig.3,4: Analysis (**red**) and spinup (**blue**) versus truth (**black**) with observations of 1st layer only, for soil temp. & moisture



Summary & Next Steps

→ A framework to spin up TERRA-ML by applying WATCH forcing data to generate initial conditions for CCLM runs has been finalized.

Tool availability

Easy usage → Potential benefit for other future CCLM simulations

Assessment: Impact of new initial conditions?

Decadal predictions for Europe & Africa currently running

→ TERRA-ML has been successfully put into ensemble data assimilation mode.

Finalization of EnDA environment

Towards a coherent Ensemble-TERRA-PDAF framework

Application on regional scale

Usage of real satellite observations

References

[1] EU project "Water and Global Change" (WATCH, 2007-2011), http://www.eu-watch.org/data_availability
[2] Hunt, B. R et.al., 2007: Efficient data assimilation for spatiotemporal chaos: A local ensemble transform Kalman filter. *Physica D*, 230, 112–126.
[3] Tödter, J, B.Ahrens (2014): A Second-Order Exact Ensemble Square Root Filter, *tbs*
[4] Nerger, L., W.Hiller (2013): Software for Ens.-based Data Assimilation Systems - Implementation Strategies & Scalability. Comp. & Geosc. 55,110-118.

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