Priority Task: Terra Stand Alone (Terra SAnta) – Final Report

15/08/2016

Task Leader: Yiftach Ziv (IMS)

Goal

Bring TERRA Stand Alone (TSA) source code up to speed with COSMO last version in both aspects of physical schemes and coding standards.

Task	Contributing Scientist(s)	FTE-Years	Start	Deliverables	Date of Delivery	FTEs used	Updated Delivery
1	Y. Ziv (IMS)	0.15	9.2015	Mapping and prioritizing discrepancies from COSMO TERRA module followed by a rewrite of the code accordingly and Keeping TSA code up to date with latest COSMO TERRA version.	2.2016	0.15	2.2016
2	Y. Ziv (IMS)	0.1	1.2016	Comparison of different transfer schemes and decision about implementation of an enhanced transfer scheme to TSA.	5.2016	0.1	9.2016
3	Y. Ziv (IMS)	0.1	6.2015	Defining TSA spin-up time.	9.2016	0.1	9.2016
4	Y. Ziv (IMS)	0.1	9.2015	Report on skill scores for TSA and COSMO-TERRA and on TSA limitations.	9.2016	0.1	9.2016
total		0.45				0.45	

Status report of Sub-Tasks:

Task1: Consolidation of TSA Source Code

Deliverables:

Mapping and prioritizing discrepancies from COSMO TERRA module followed by a rewrite of the code accordingly and Keeping TSA code up to date with latest COSMO TERRA version.

Status:

- Revision of code to adhere to coding standards is complete:
  - Removal of GOTOs, proper declarations, removal of redundant modules and subroutines, etc.
- Consolidation to COSMO 5.3 is complete with one exception:
  - Since TSA is both stand alone and 1 dimensional, it **does not utilize tracers**. The only parameter affected is qv (and qv_bd) which are therefore 4 dimensional in TSA.
- Consolidation to future versions:
  - Any change to TERRA needs to be manually entered to TSA
  - Most recent version (5.5) includes some changes that need to be checked (PT TERRA Tests). Once approved changes may be implemented to TSA
  - It should be mentioned that sometime in the near future a stand-alone version of ICON-TERRA will be introduced.

Task2: Review and Possible Revision of the Transfer Scheme implemented in TSA.

Deliverables: Comparison of different transfer schemes and decision about implementation of an enhanced transfer scheme to TSA.

Status:

- After reviewing TSA and COSMO transfer schemes, it was concluded that implementing a new transfer scheme will demand too many resources for the extent of this PT:
    - TSA is set to run with analysis data as met-forcing. Therefor it is using an old 'Louis Scheme' consisting on transfer coefficients and not calculating the actual momentum, heat and moisture fluxes.
    - COSMO transfer scheme is very elaborate and utilizes data which cannot be easily made available for stand-alone runs.
    - Bridging this gap is only available by developing a new transfer scheme that will consist on current 'Turbdiff' adapted to work as stand-alone. This cannot be performed in the extent of this PT.
    - Comparison between COSMO-TERRA and TSA (sub task 4) shows great similarity between the two, leading, together with the amount of resources required, to conclusion that the effort may be redundant.

Task3: Estimating Spin-Up Time of TSA

Deliverables: Defining TSA spin-up time.

Status:

- Comparison of different spin-up time was conducted by running TSA for 1,2,3,4,5 and 6 years until Jan 1st 2015 and comparing soil water content (W_SO) and soil temperature (T_SO) of the various runs. A few figures of the distributions of differences are attached and discussed shortly at the end of this report.
- It was evident that 6 years run, started on Jan. 1st 2009 has a distinctly different distribution especially for the deeper levels. The reason for that is a change in the climate temperature (t_cl) implemented to COSMO in April 2009 that affects the initial conditions and met-forcing files. As a result 5 years run is to become benchmark.
- Naturally, the longer the run - the better the results, but it seems that after 3 years run only, 95% of the grid-points are within 1K and 2% difference of temperature and water content respectively, from the benchmark. This is the case for all soil types and all depths. Yet, as the soil type gets "lighter" (sand compared to clay & peat), and as depth get larger – larger differences occur more frequently.

- The short spin up time is probably a result of a "good" initialization. Each run was initialized with COSMO analysis data of the soil. In order to test the spin up time in the case initial conditions are not available, another 5 years run was conducted. In this run the whole soil column at each grid point received the temperature value of the lowest level (t climate) and the water content value of the top level – meaning that the whole column, besides the top, is totally dry. Figures shown here show that after 5 years the top levels are spun up, while the 2 deepest levels closing the gap rapidly, for both temperature and water content. It seems from the trend that within 7 years, the soil will be spun up.
- **Recommendations:** When running TSA with the soil fully initialized by analysis data, 3 years run will result in differences less than 1K with confidence level of 95% and more and differences less than 2% in water content with confidence level of 90% and more. Depending on research requirements and resources, shorter or longer runs can be employed. However, in the case that a fully initialized soil is not available – if climate soil temperature is available, it is estimated that a 7 years spin-up should suffice. The case where no soil data for initialization is available was not examined here, but it can be inferred that more than 10 years spin-up will be required.

Task4: Verification of TSA and COSMO-TERRA Vs. observations.

Deliverables: Report on skill scores for TSA and COSMO-TERRA and on TSA limitations.

Status:

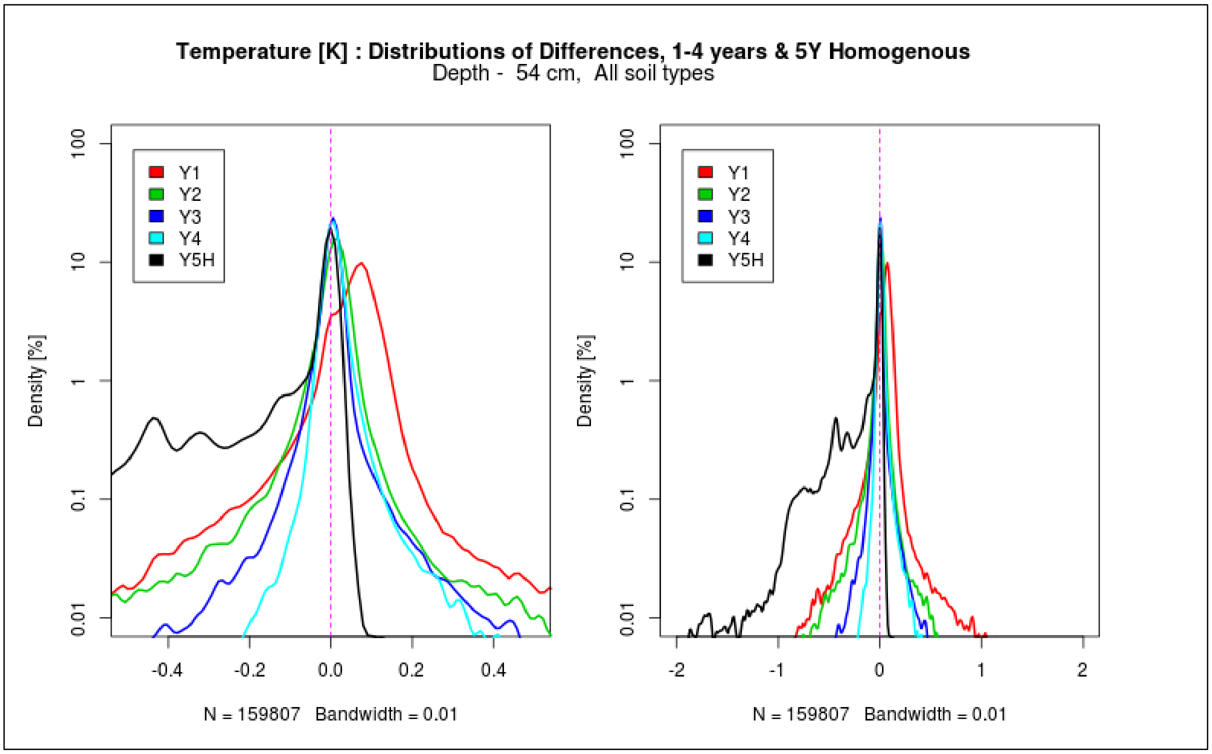
- TSA results and a fully coupled COSMO-TERRA (hereby TERRA) analysis were compared to measurements in 4 locations of the SwissSMEX project: BER (Bern), PAY (Payerne), PLA (Plaffeien) and RHB (Rietholzbach). TSA was run for ~4.5 years starting on 01/01/2010 until 31/07/2014 in resolution of 2.2 km. TERRA data are taken from analyses in COSMO archive with same resolution. Parameters compared are soil temperature (T) and soil water content (WC).
- Depths of measurements are: 5, 10, 30, 50, 80 & 120 cm, while models levels of output are given as 1, 2, 6, 18, 54, 162, 486 & 1458 cm. as a result the chosen measurements levels for verification were 5, 10 & 50 cm to correspond to model levels of 6, 18 & 54 cm.
- For each measuring station one or two model grid-points were selected. The first is the nearest grid-point (shortest distance), and the second was the nearest grid-point having the same soil type as the station. This point was also selected to be in closer height to measuring station.
- While temperature is given in Kelvin for each level, water content is given as the total amount of water in the soil column from the surface to the given level. Therefore, volumetric water content (VWC) was calculated by assuming that the whole slab of soil between 2 model levels has uniform

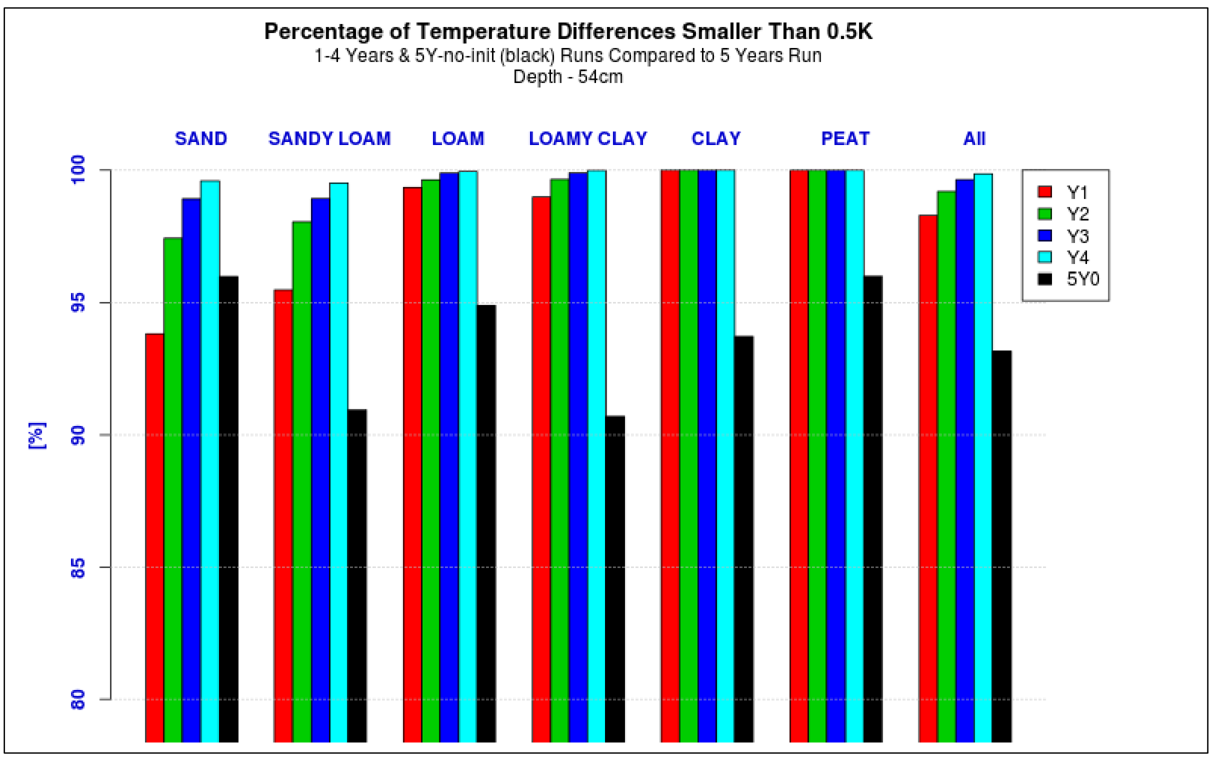
distribution of water content by the formula: $\frac{W_i - W_{i-1}}{D_i - D_{i-1}}/10$. Where W is model water content, D is model level, i is level at bottom of slab and i-1 level at top of slab.

- As expected, temperature is better forecasted than water content, which by nature is very locale and more difficult to predict. Correlation (least squares method) of temperature curves for all depths is above 0.95, which is not surprising since seasonality is rather easy to predict. However, in most cases WC correlation lags only a little behind, with values above 0.75. RMSE is usually within 2K in T and 8% in WC, but gets as high as 5K and 25% in T and WC respectively. In these cases the major factor for the high RMSE is a strong bias, usually model under-predicts both T and WC. It is noteworthy that in some cases differences between 2 measurements in the same site can be of the same magnitude.
- Second grid-point selected was sometimes better and sometimes worse. In all cases differences between grid-points were not significant.
- It seems that model reacts more extremely to changes in weather – it is usually over warming in 12Z and during summer, and over cooling at 00Z and winter. In all winters covered by this verification, model T of upper soil levels got below zero, while with measurements it happened only once in the late winter of 2011.
- TERRA is always, and in all parameters, better than TSA. The first suspect is the transfer scheme that differs between the two models, but it cannot be certain, since not all other parameters are equal (nor can they ever be). However in the daily cycle TERRA reacts more extremely than TSA resulting in over estimation at 12Z and underestimation at 00Z.
- Comparing TSA to TERRA shows high uniformity, strengthening the usability of TSA as a "mock-up" for TERRA when long runs in great numbers are expected. However, a rather significant bias as high as 5K and 10% in T and WC respectively, is evident in deeper levels.
- Regarding spin-up, a comparison of the first 2 years of the model run (leaving out the first 6 months) to the last 2 years, shows some improvement, as expected. Improvement is a little more significant for WC than for T.
- Further attempt was made to compare model results and measurements to SMAP satellite soil moisture data, but results were available for only 3 months (radiometer antenna of satellite became inoperative) and no conclusion could be made.
- Conclusions:
    - Both TERRA and TSA are depicting soil processes rather well.
    - COSMO-TERRA is always better, probably due to the full transfer scheme.
    - TSA has a negative bias (under estimation of temperature) in almost all cases
    - Both configurations tend to freeze the soil in winter too soon, too deep and too strong.

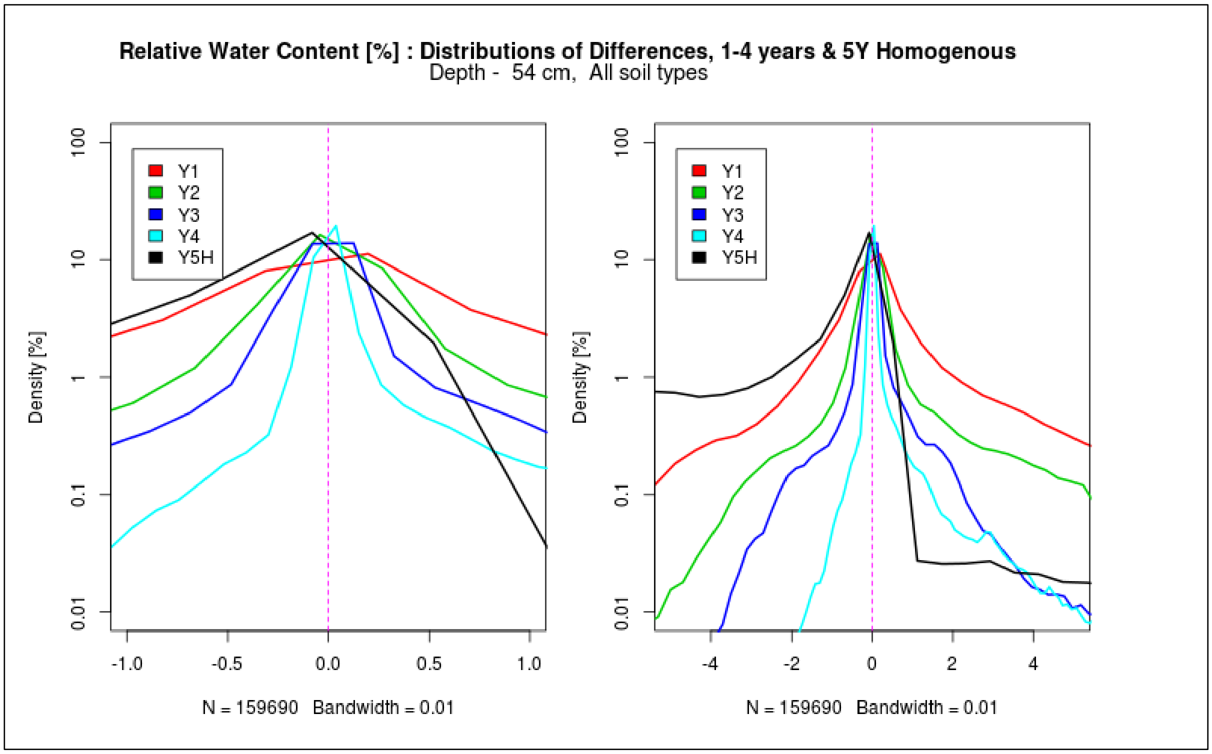
Some figures (only a little taste):

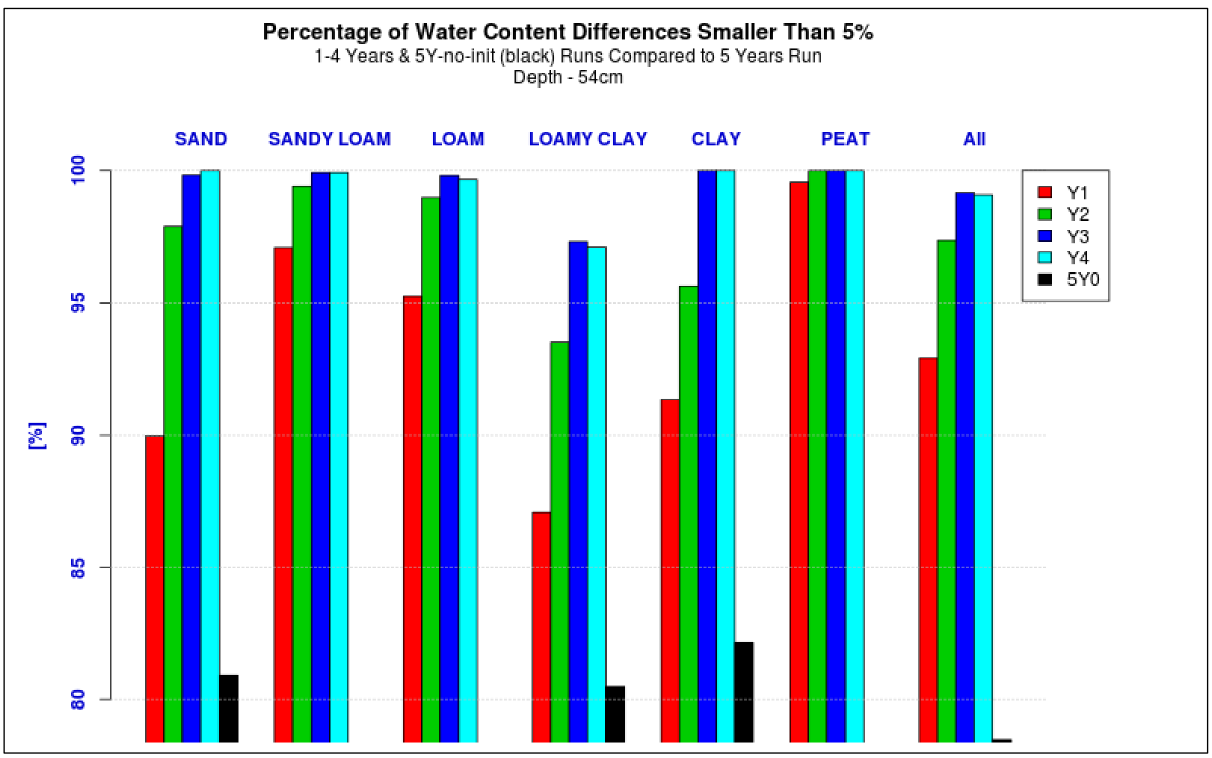
Spin up:





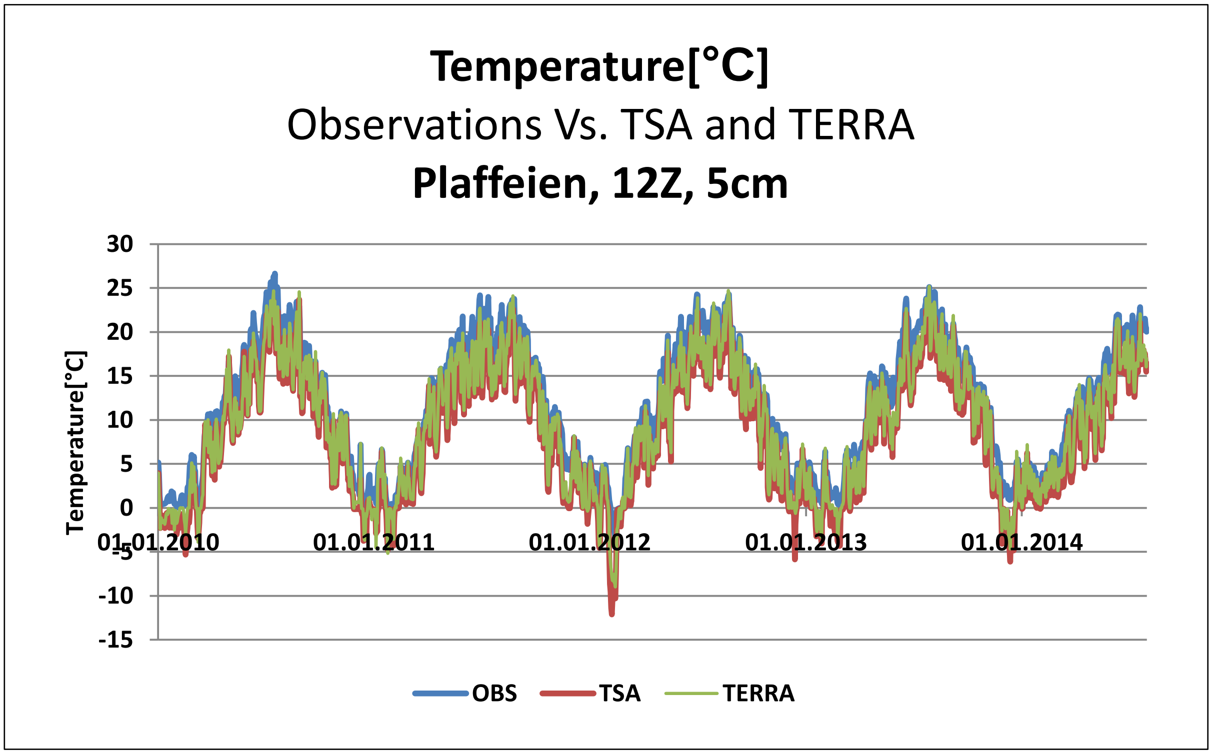
Both panels show distribution of differences between benchmark 5 years run and other runs: 1 to 4 years runs (Y1-Y4) and 5 years homogenous run (5Y0/Y5H). Top panel show PDFs (logarithmic) of differences for entire domain – right figure shows differences from -2K to +2K while left figure from -0.5K to +0.5K. Bottom panel shows which percentage of the differences is smaller than ± 0.5K for each soil type.

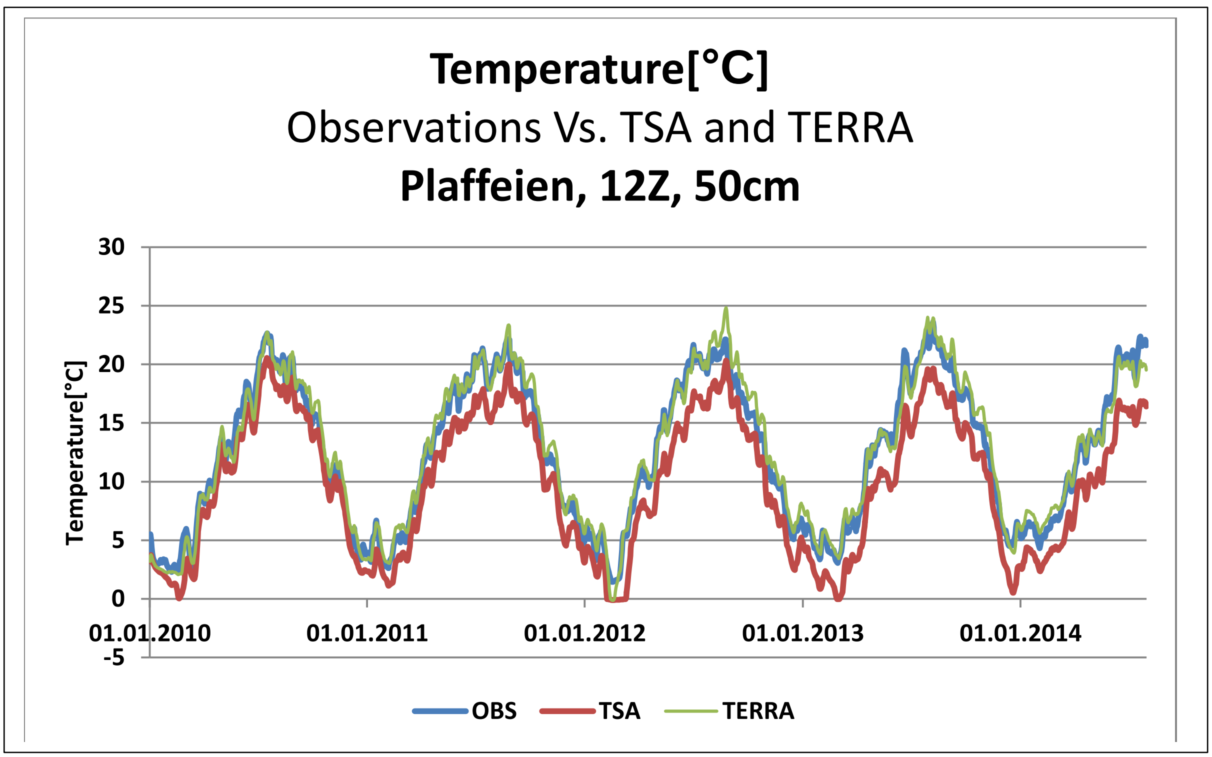




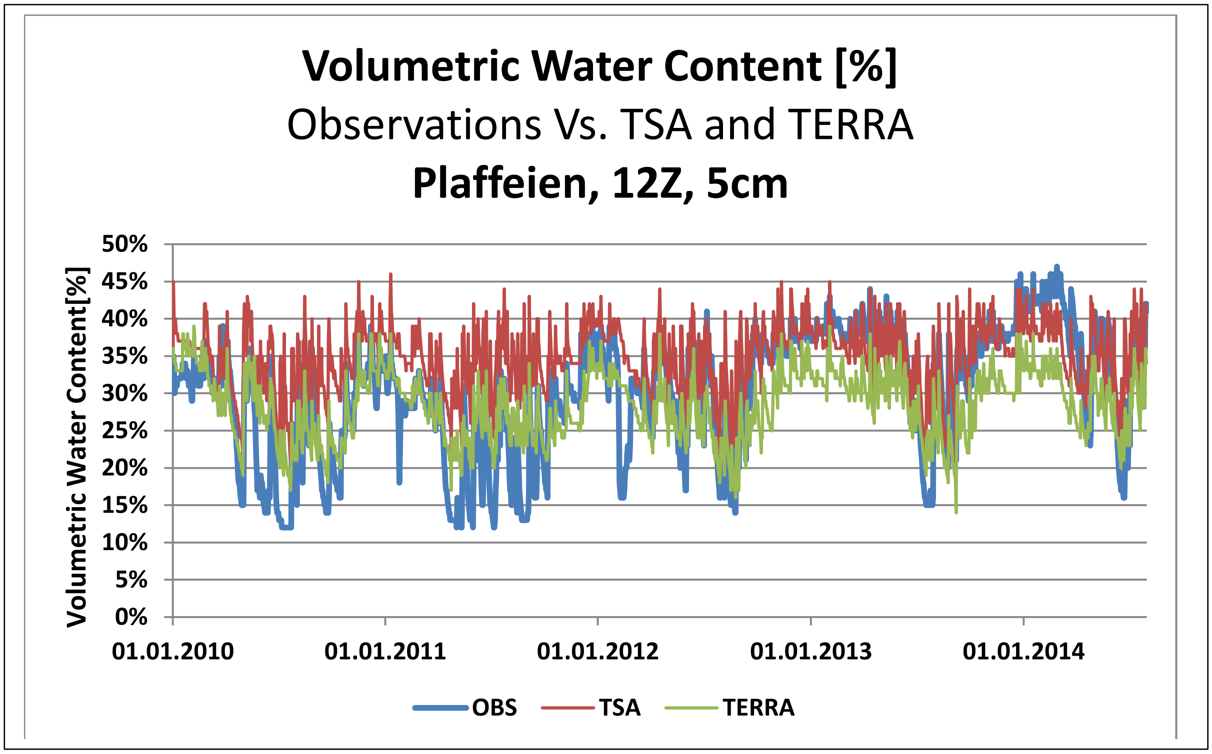
Both panels show distribution of differences between benchmark 5 years run and other runs: 1 to 4 years runs (Y1-Y4) and 5 years homogenous run (5Y0/Y5H). Top panel show PDFs (logarithmic) of differences for entire domain – right figure shows differences from -5% to +5% while left figure between -1% and +1%. Bottom panel shows which percentage of the differences is smaller than ± 5% for each soil type.

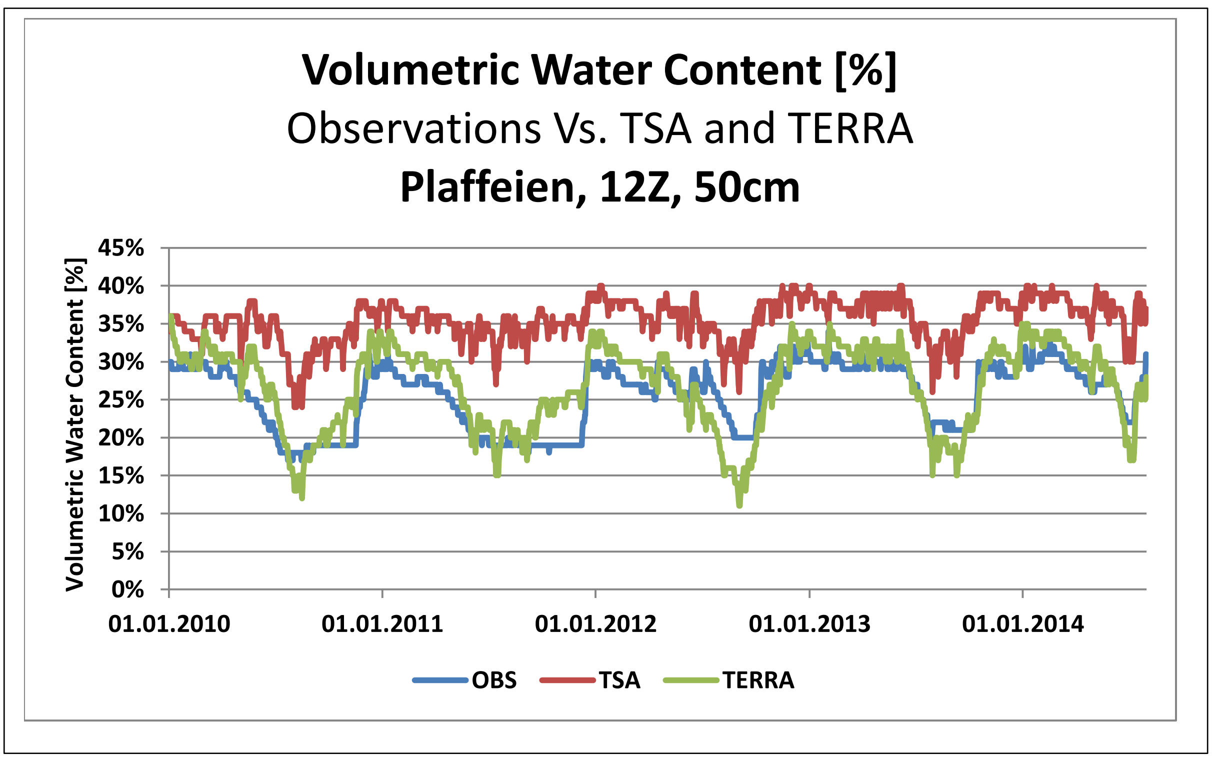
Verification:





Both panels show time series of temperature [℃] of measurements (blue), TSA data (red), TERRA data (green) for Plaffeien. All data taken for 12Z. Top panel shows data for 5 cm depth. Bottom shows data for 50 cm depth.





Both panels show time series of volumetric water content [%] of measurements (blue), TSA data (red), TERRA data (green) for Plaffeien. All data taken for 12Z. Top panel shows data for 5 cm depth. Bottom shows data for 50 cm depth.