The International Soil Moisture Network
www.ipf.tuwien.ac.at/insitu

Wouter Dorigo

Tom Jackson, Matthias Drusch, Peter van Oevelen, Alan Robock, Wolfgang Wagner, many helpful students and data providers

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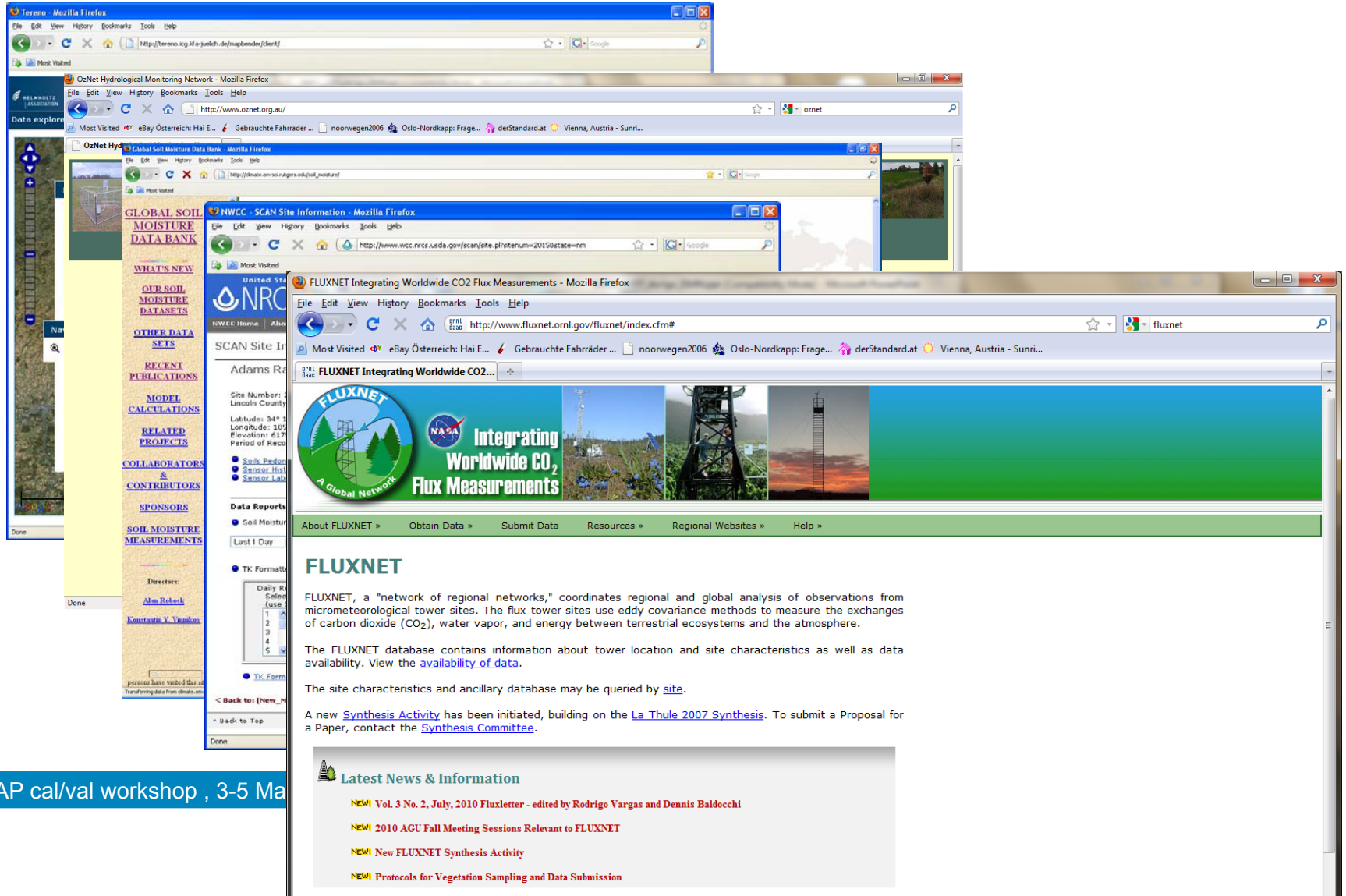
Vienna University of Technology

International Soil Moisture Network

ESA/ESTEC Contracts 22954/09/NL/CT and 4000102722/10/NL/FF/fk

Why International Soil Moisture Network?

- For cal/val of SMAP satellite-based soil moisture products several in situ soil moisture datasets are available

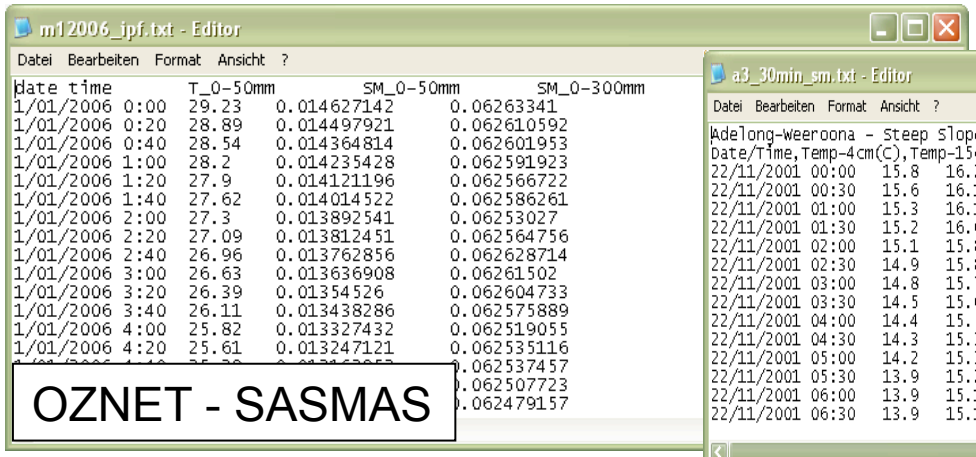


Why International Soil Moisture Network?

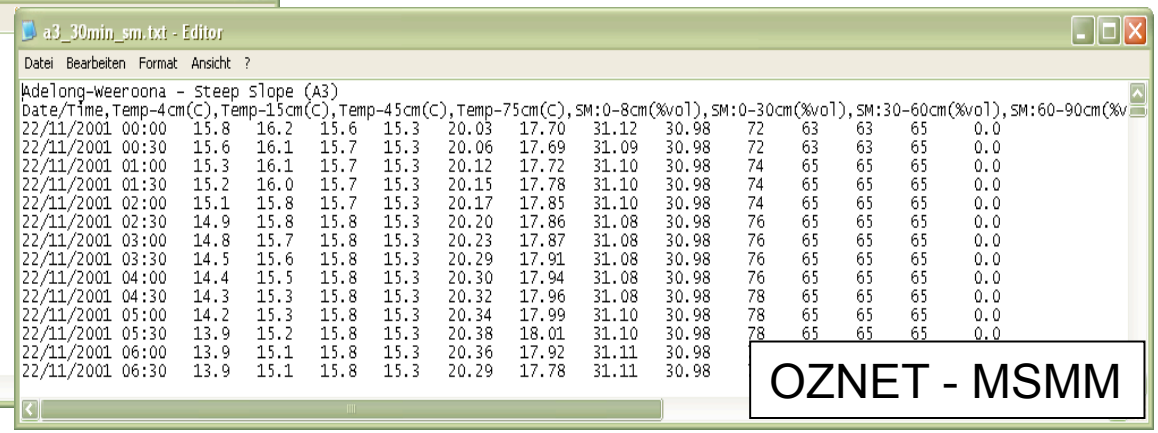
- Data from different networks are extremely heterogeneous
  - No standardised measurements:
    - Different soil moisture definitions (e.g. volumetric, water depth, mass, Soil Moisture Index, plant available water)
    - Different sensors (e.g. hydroprobes, TDR, cosmic ray neutrons , etc.)
    - Different installation depths
    - Different installation positions (vertical, horizontal) → specifies if soil moisture measured at specific depth or over interval
    - Different calibrations
    - Different measurement time intervals, ...

Why International Soil Moisture Network?

- Data from different networks are extremely heterogeneous
  - No standardised data formats (data type, naming, content, NaN)

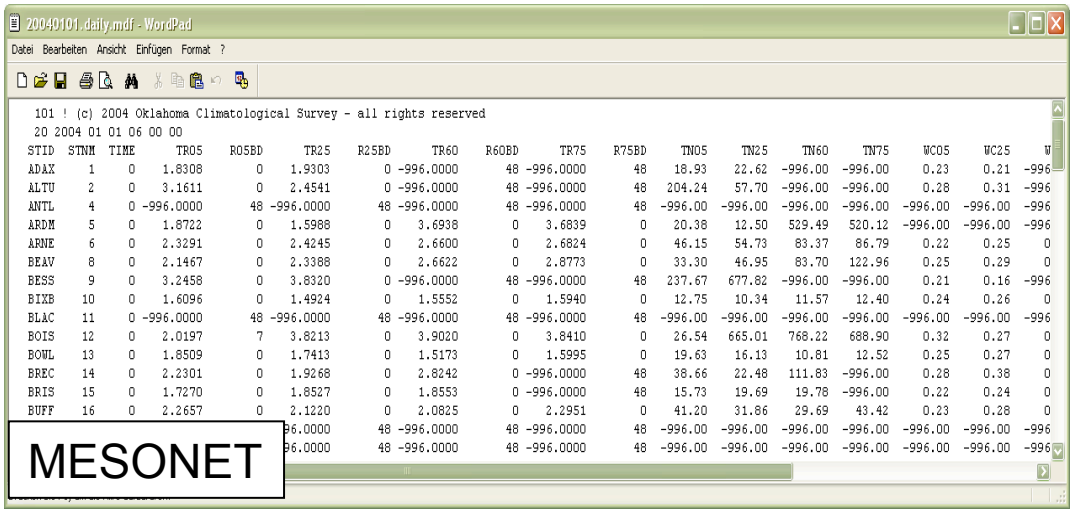


date time	T_0-50mm	SM_0-50mm	SM_0-300mm
1/01/2006 0:00	29.23	0.014627142	0.06263341
1/01/2006 0:20	28.89	0.014497921	0.062610592
1/01/2006 0:40	28.54	0.014364814	0.062601953
1/01/2006 1:00	28.2	0.014235428	0.062591923
1/01/2006 1:20	27.9	0.014121196	0.062566722
1/01/2006 1:40	27.62	0.014014522	0.062586261
1/01/2006 2:00	27.3	0.013892541	0.06253027
1/01/2006 2:20	27.09	0.013812451	0.062564756
1/01/2006 2:40	26.96	0.013762856	0.062628714
1/01/2006 3:00	26.63	0.013636908	0.06261502
1/01/2006 3:20	26.39	0.01354526	0.062604733
1/01/2006 3:40	26.11	0.013438286	0.062575889
1/01/2006 4:00	25.82	0.013327432	0.062519055
1/01/2006 4:20	25.61	0.013247121	0.062535116
			0.062537457
			0.062507723
			0.062479157



Adelong-Weeroona - Steep Slope (A3)

Date/Time	Temp-4cm(C)	Temp-15cm(C)	Temp-45cm(C)	Temp-75cm(C)	SM:0-8cm(%vol)	SM:0-30cm(%vol)	SM:30-60cm(%vol)	SM:60-90cm(%v					
22/11/2001 00:00	15.8	16.2	15.6	15.3	20.03	17.70	31.12	30.98	72	63	63	65	0.0
22/11/2001 00:30	15.6	16.1	15.7	15.3	20.06	17.69	31.09	30.98	72	63	63	65	0.0
22/11/2001 01:00	15.3	16.1	15.7	15.3	20.12	17.72	31.10	30.98	74	65	65	65	0.0
22/11/2001 01:30	15.2	16.0	15.7	15.3	20.15	17.78	31.10	30.98	74	65	65	65	0.0
22/11/2001 02:00	15.1	15.8	15.7	15.3	20.17	17.85	31.10	30.98	74	65	65	65	0.0
22/11/2001 02:30	14.9	15.8	15.8	15.3	20.20	17.86	31.08	30.98	76	65	65	65	0.0
22/11/2001 03:00	14.8	15.7	15.8	15.3	20.23	17.87	31.08	30.98	76	65	65	65	0.0
22/11/2001 03:30	14.5	15.6	15.8	15.3	20.29	17.91	31.08	30.98	76	65	65	65	0.0
22/11/2001 04:00	14.4	15.5	15.8	15.3	20.30	17.94	31.08	30.98	76	65	65	65	0.0
22/11/2001 04:30	14.3	15.3	15.8	15.3	20.32	17.96	31.08	30.98	78	65	65	65	0.0
22/11/2001 05:00	14.2	15.3	15.8	15.3	20.34	17.99	31.10	30.98	78	65	65	65	0.0
22/11/2001 05:30	13.9	15.2	15.8	15.3	20.38	18.01	31.10	30.98	78	65	65	65	0.0
22/11/2001 06:00	13.9	15.1	15.8	15.3	20.36	17.92	31.11	30.98					
22/11/2001 06:30	13.9	15.1	15.8	15.3	20.29	17.78	31.11	30.98					



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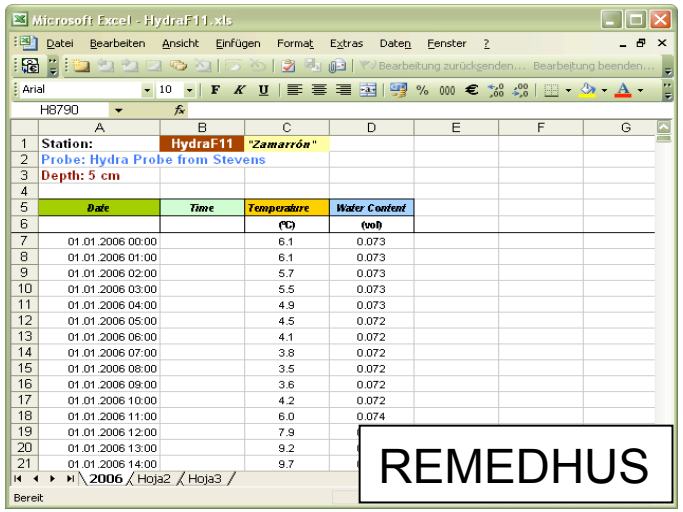
20 2004 01 01 06 00 00

STID	STNM	TIME	TR05	RO5BD	TR25	R25BD	TR60	R60BD	TR75	R75BD	TN05	TN25	TN60	TN75	WC05	WC25	W
ADAX	1	0	1.8308	0	1.9303	0	-996.0000	48	-996.0000	48	18.93	22.62	-996.00	-996.00	0.23	0.21	-996
ALTU	2	0	3.1611	0	2.4541	0	-996.0000	48	-996.0000	48	204.24	57.70	-996.00	-996.00	0.28	0.31	-996
ANTL	4	0	-996.0000	48	-996.0000	48	-996.0000	48	-996.0000	48	-996.00	-996.00	-996.00	-996.00	-996.00	-996.00	-996
ARDM	5	0	1.8722	0	1.5988	0	3.6938	0	3.6839	0	20.38	12.50	529.49	520.12	-996.00	-996.00	-996
ARNE	6	0	2.3291	0	2.4245	0	2.6600	0	2.6824	0	46.15	54.73	83.37	86.79	0.22	0.25	0
BEAV	8	0	2.1467	0	2.3388	0	2.6622	0	2.8773	0	33.30	46.95	83.70	122.96	0.25	0.29	0
BESS	9	0	3.2458	0	3.8320	0	-996.0000	48	-996.0000	48	237.67	677.82	-996.00	-996.00	0.21	0.16	-996
BIXB	10	0	1.6096	0	1.4924	0	1.5552	0	1.5940	0	12.75	10.34	11.57	12.40	0.24	0.26	0
BLAC	11	0	-996.0000	48	-996.0000	48	-996.0000	48	-996.0000	48	-996.00	-996.00	-996.00	-996.00	-996.00	-996.00	-996
BOIS	12	0	2.0197	7	3.8213	0	3.9020	0	3.8410	0	26.54	665.01	768.22	688.90	0.32	0.27	0
BOWL	13	0	1.8509	0	1.7413	0	1.5173	0	1.5995	0	19.63	16.13	10.81	12.52	0.25	0.27	0
BREC	14	0	2.2301	0	1.9268	0	2.8242	0	-996.0000	48	38.66	22.48	111.83	-996.00	0.28	0.38	0
BRIS	15	0	1.7270	0	1.8527	0	1.8553	0	-996.0000	48	15.73	19.69	19.78	-996.00	0.22	0.24	0
BUFF	16	0	2.2657	0	2.1220	0	2.0825	0	2.2951	0	41.20	31.86	29.69	43.42	0.23	0.28	0
					96.0000	48	-996.0000	48	-996.0000	48	-996.00	-996.00	-996.00	-996.00	-996.00	-996.00	-996
					96.0000	48	-996.0000	48	-996.0000	48	-996.00	-996.00	-996.00	-996.00	-996.00	-996.00	-996



	A	B	C	D
1	Station:	HydraF11 "Zamarrón"		
2	Probe: Hydra Probe from Stevens			
3	Depth: 5 cm			
4				
5	Date	Time	Temperature	Water Content
6			(°C)	(vol)
7	01.01.2006 00:00		6.1	0.073
8	01.01.2006 01:00		6.1	0.073
9	01.01.2006 02:00		5.7	0.073
10	01.01.2006 03:00		5.5	0.073
11	01.01.2006 04:00		4.9	0.073
12	01.01.2006 05:00		4.5	0.072
13	01.01.2006 06:00		4.1	0.072
14	01.01.2006 07:00		3.8	0.072
15	01.01.2006 08:00		3.5	0.072
16	01.01.2006 09:00		3.6	0.072
17	01.01.2006 10:00		4.2	0.072
18	01.01.2006 11:00		6.0	0.074
19	01.01.2006 12:00		7.9	
20	01.01.2006 13:00		9.2	
21	01.01.2006 14:00		9.7	

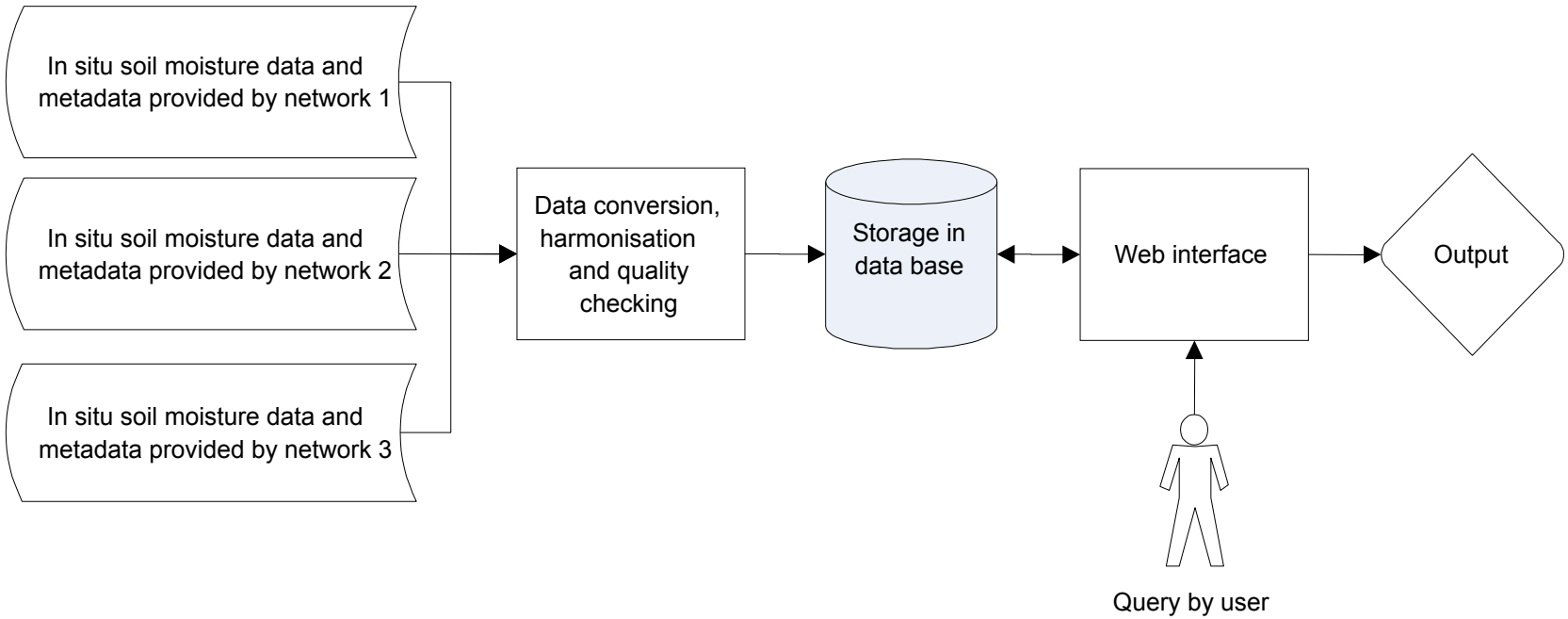
Why International Soil Moisture Network?

- … and in distribution methods
  - Means of distribution (Email, ftp, http)
  - Metadata often insufficient and not standardised
    - On the SM measurements themselves (Quality flags, sensor details, etc.)
    - Additional meteorological variables (P, T, etc.)
    - Site information (soil parameters, altitude, slope, land cover/use, etc.)
  - Irregular availability: hourly (SCAN) to provision upon request (SMOSMANIA)

So, for a distributed quantitative comparison there is a need for:

Harmonisation of measurements
Standardisation of data and metadata
Centralised web hosting facility

Overview ISMN

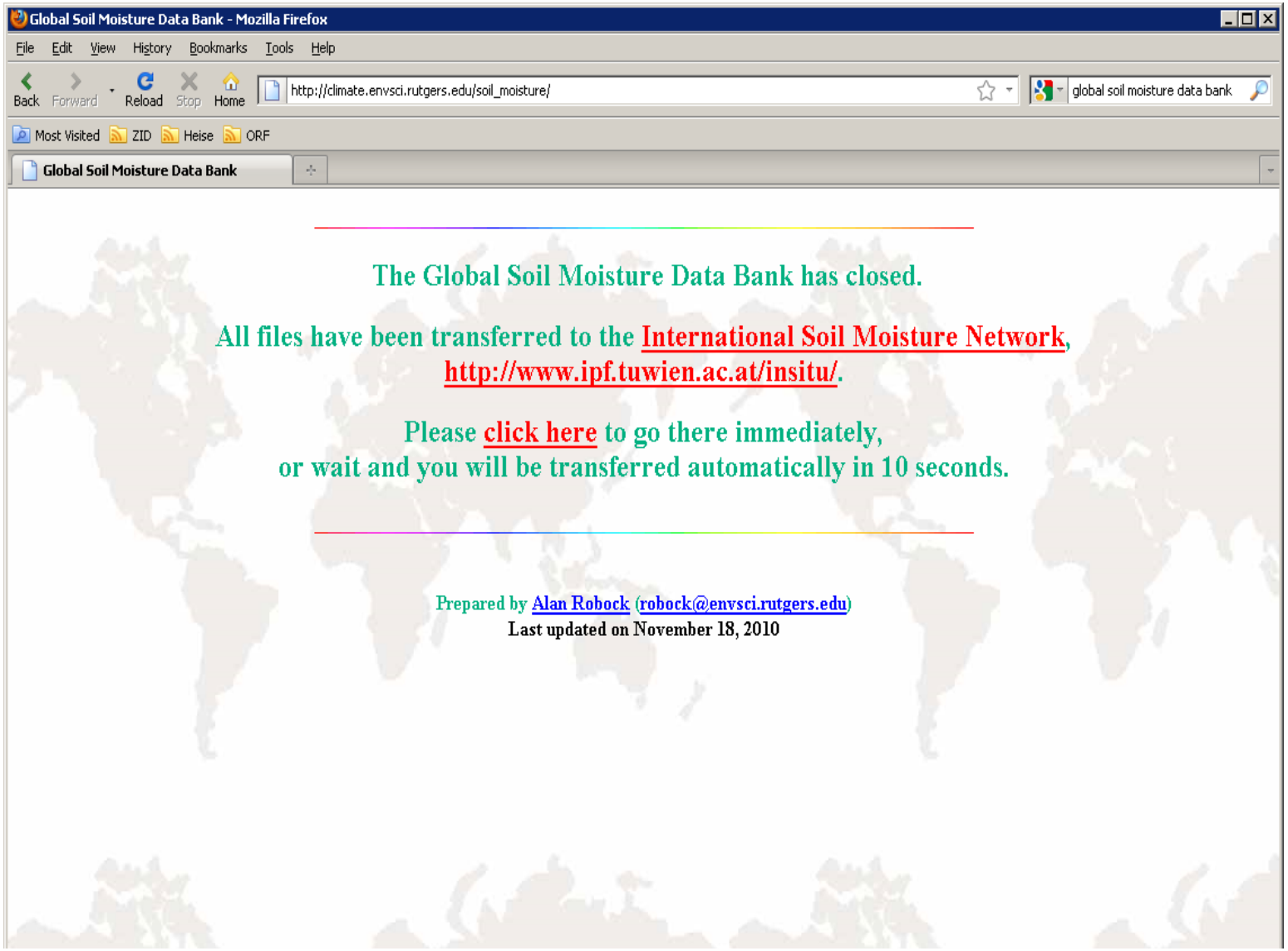


Overview of networks

- 20 networks

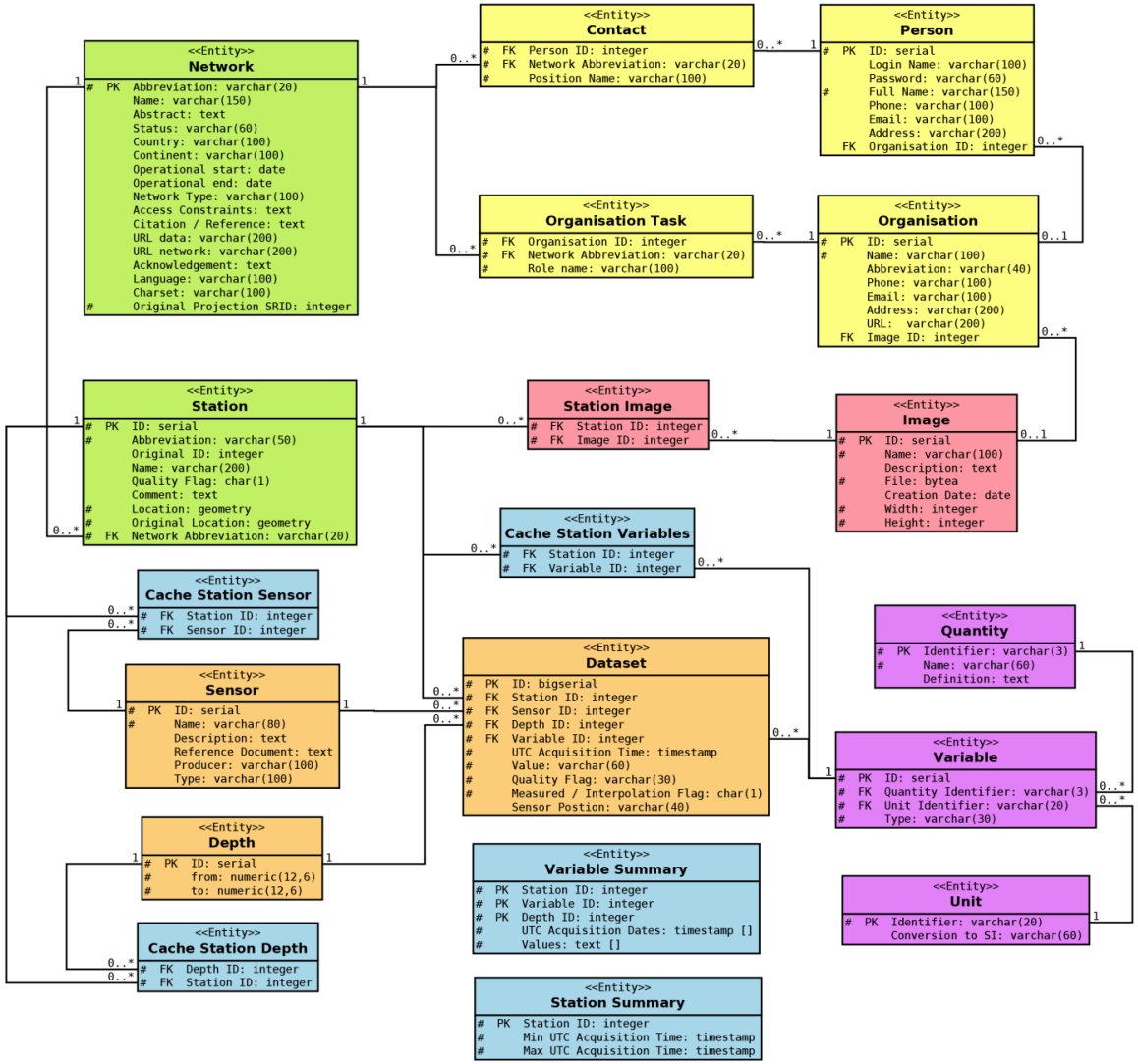
Name	Country	Stations
CALABRIA	Italy	5
CAMPANIA	Italy	2
CHINA	China	40
CNR-IRPI	Italy	4
ICN	USA	19
IOWA	USA	6
MOL-RAO	Germany	2
MONGOLIA	Mongolia	44
OZNET	Australia	64
REMEDHUS	Spain	18
RUSWET-AGRO	Former Soviet Union	78
RUSWET-GRASS	Former Soviet Union	122
RUSWET-VALDAI	Former Soviet Union	3
SMOSMANIA	France	12
SWEX_POLAND	Poland	2
UDC_SMOS	Germany	11
UMSUOL	Italy	1

Overview of networks



Database design

- Hierarchy: network > station > data set
- Store one variable at different depths
- Store different variables at same depths
- Depth is expressed as interval to address varying sensor positions and measurement methods



Data harmonization

- Temporal resampling to 1 hour
- All soil moisture measurements are converted into volumetric soil moisture [$m^3\ m^{-3}$]
- No homogenisation over depth

Measured unit	Equation used to convert them into volumetric water content (% volume)
Gravimetric water content $w = M_w / M_s$	$\Theta = w \cdot \rho_b / \rho_w$
Degree of saturation $s = V_w / V_f$	$\Theta = s \cdot f$
Equivalent Depth of Water per Depth of Soil $D_{eq} = \Theta \cdot \Delta z$	$\Theta = \Delta z / D_{eq}$
Plant available water $PAW = \Theta - \Theta_{wp}$	$\Theta = PAW + \Theta_{wp}$
Water volume ratio $v_w = V_w / V_s$	$\Theta = v_w / (1 + e)$

Quality control

- Quality is automatically checked and flagged according to CEOP flags (GEWEX)

Flag value	Definition
C	Reported value exceeds output format field size OR was negative precipitation.
M	Parameter value missing OR derived parameter can not be computed.
D	Questionable/dubious
U	Unchecked

Quality control

- C: Exceeding range

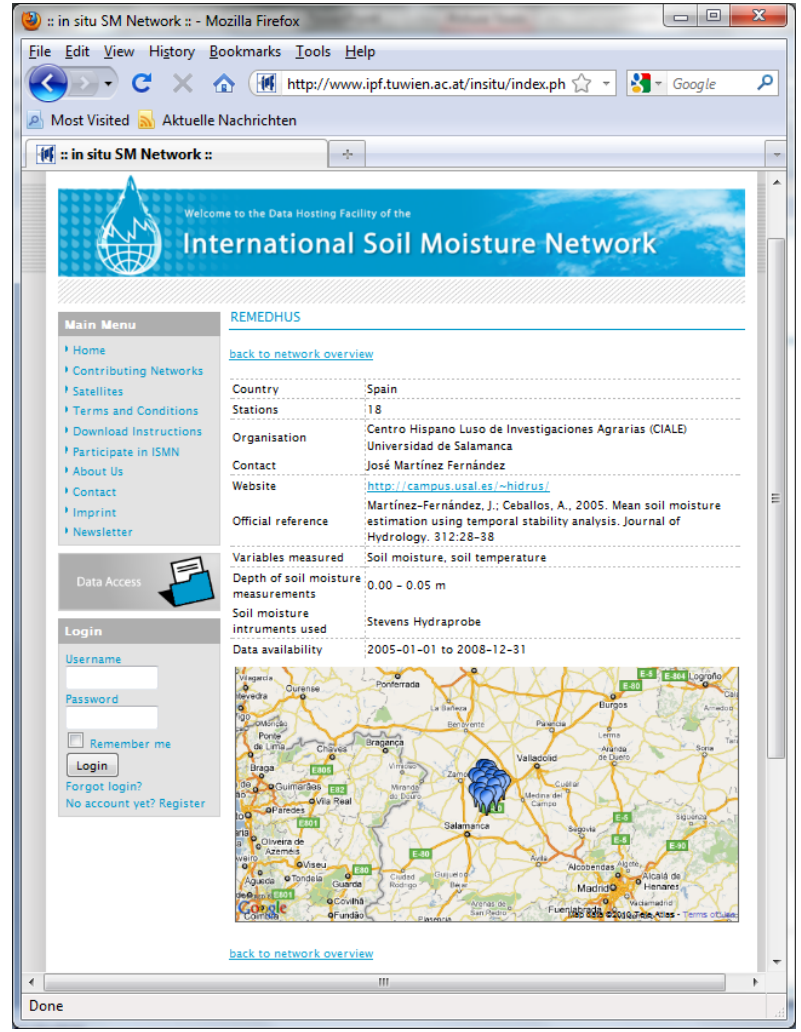
Variable name	Variable range
Soil moisture	0 – 0.6 m^3m^{-3}
Soil temperature	-60 – 60 °C
Air temperature	-60 – 60 °C
Precipitation	0 – 100 mm h^{-1}
Soil suction	0 – 2500 kPa
Saturation point	variable

- Questionable/dubious (D)

1	Valid soil moisture measurement in combination with a negative soil temperature (measured at same depth)
2	Valid surface soil moisture measurement in combination with a negative air temperature
3	A decreasing or stable surface soil moisture content (with respect to the previous time step) while precipitation is measured

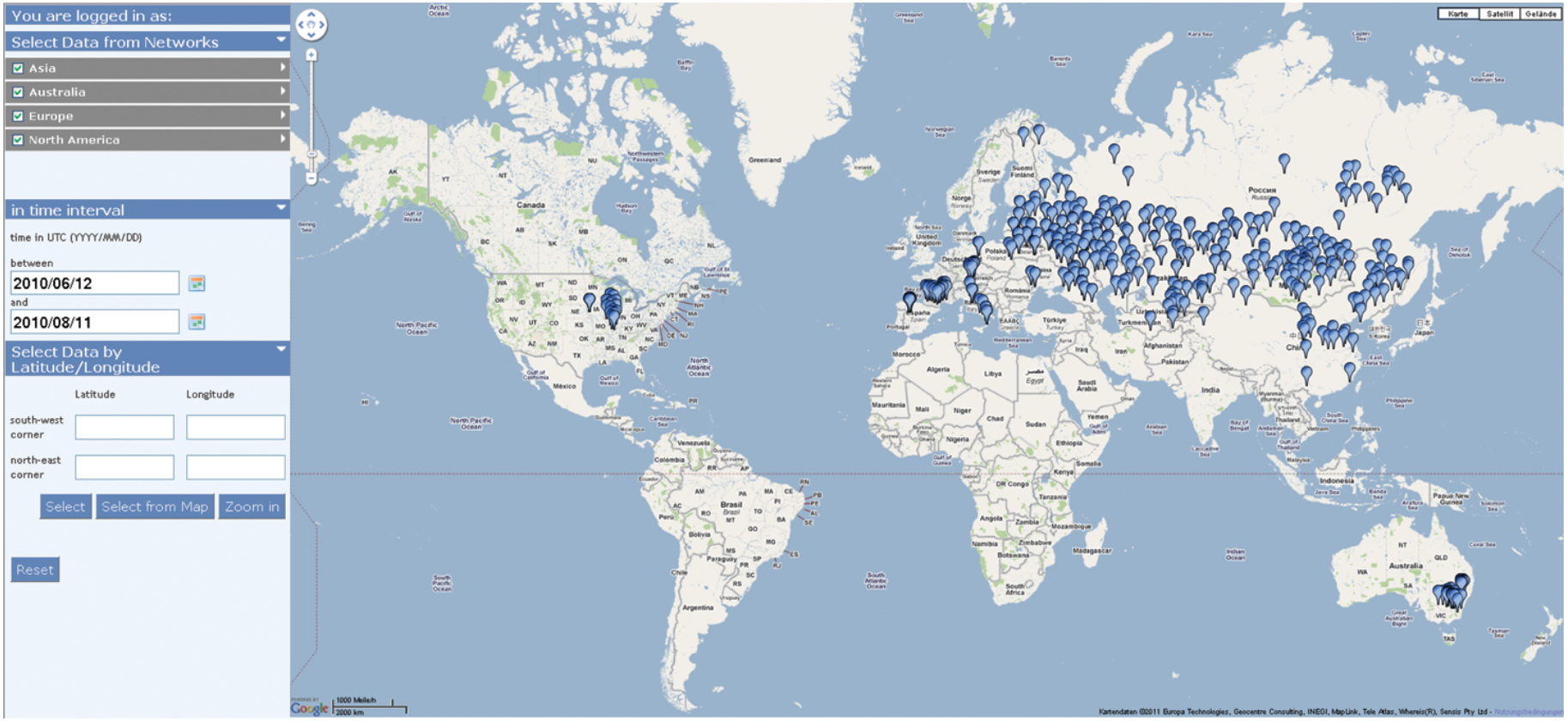
Web portal

- http://www.ipf.tuwien.ac.at/insitu



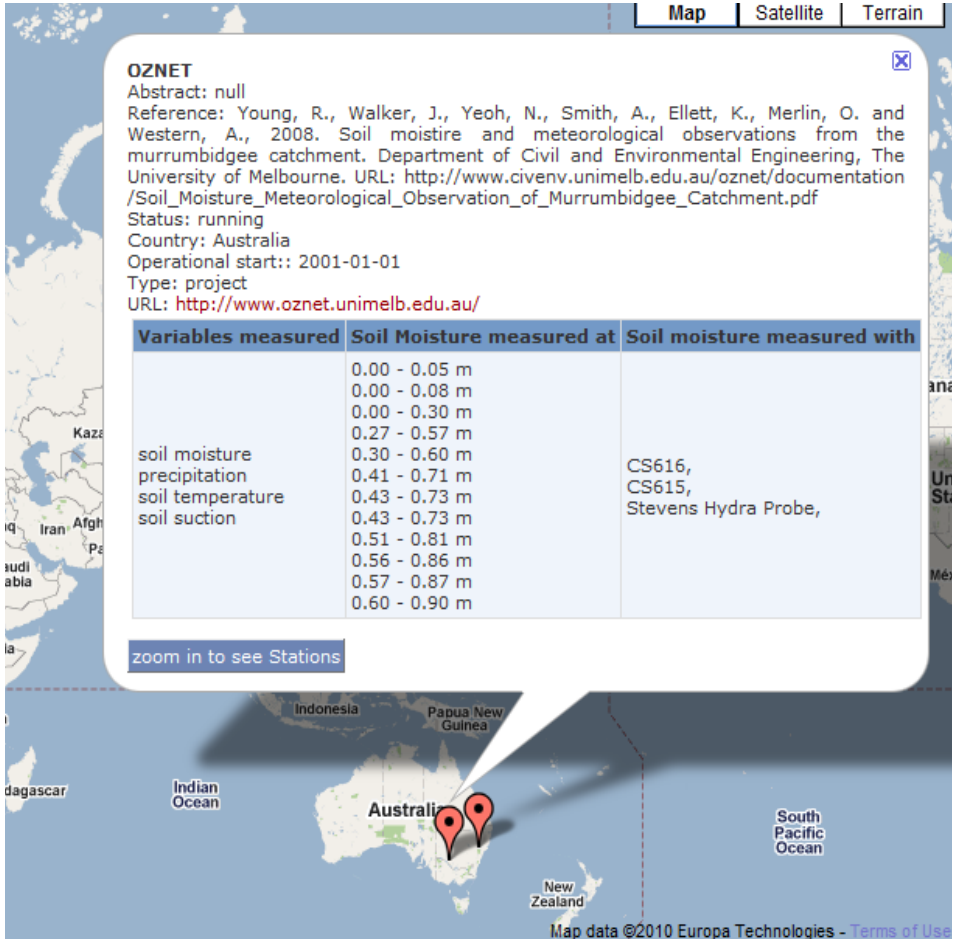
Web portal

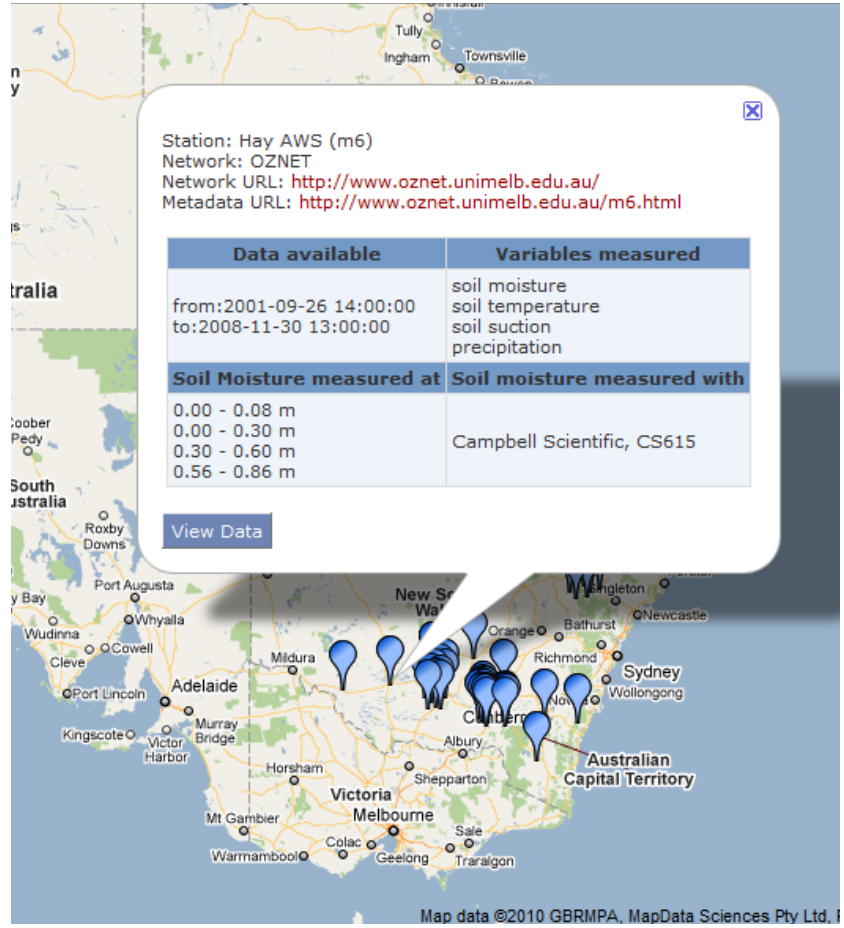
- Download portal



Web portal

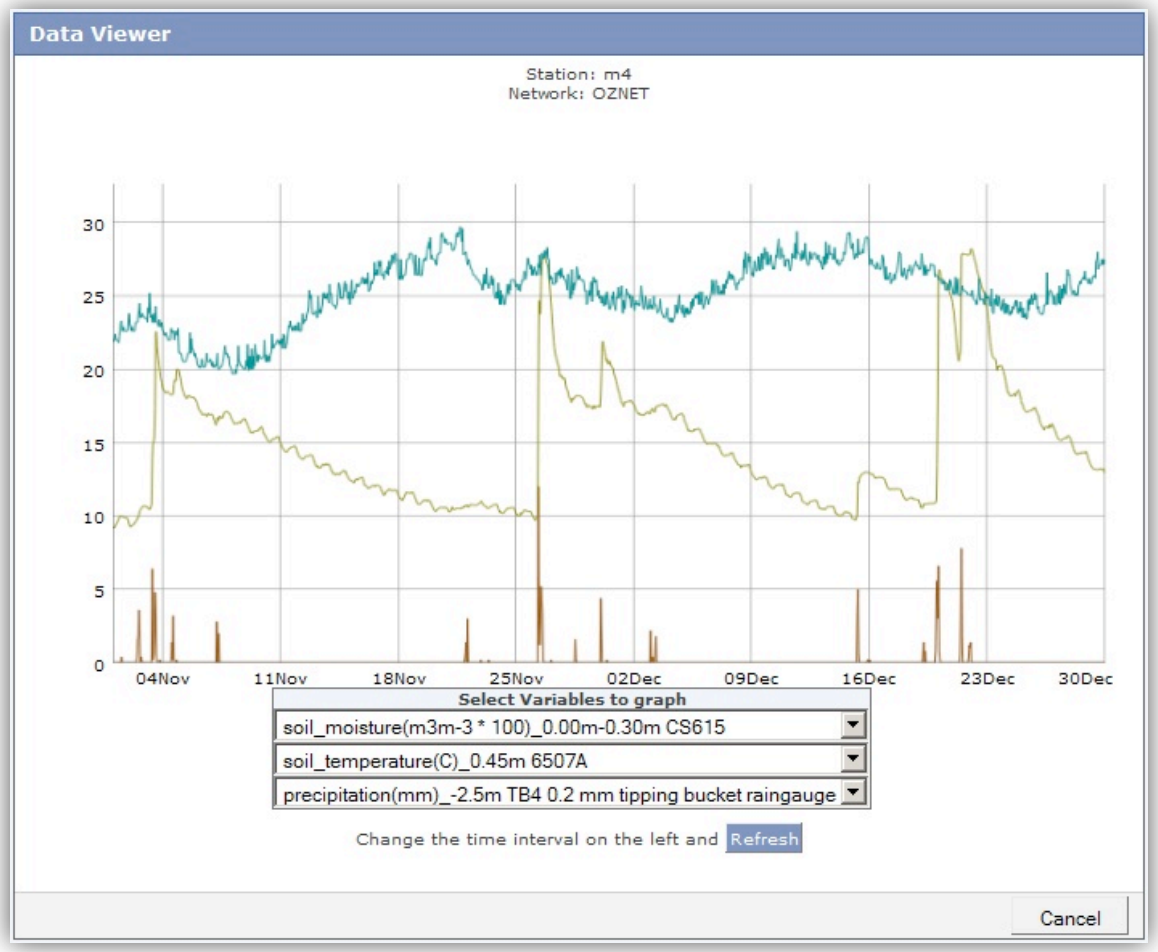
- Network and station info





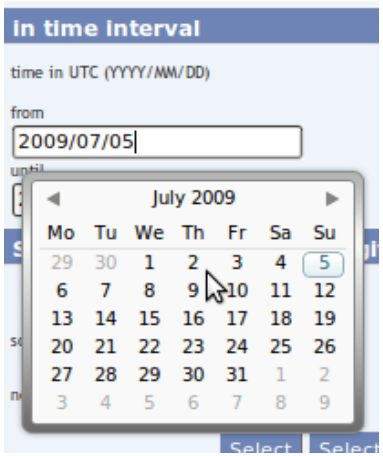
Web portal

- Data viewer

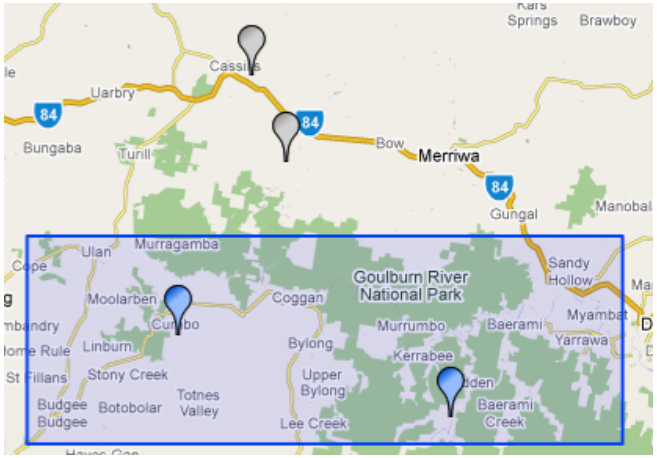


Web portal

- Data selection via GUI
  - Time

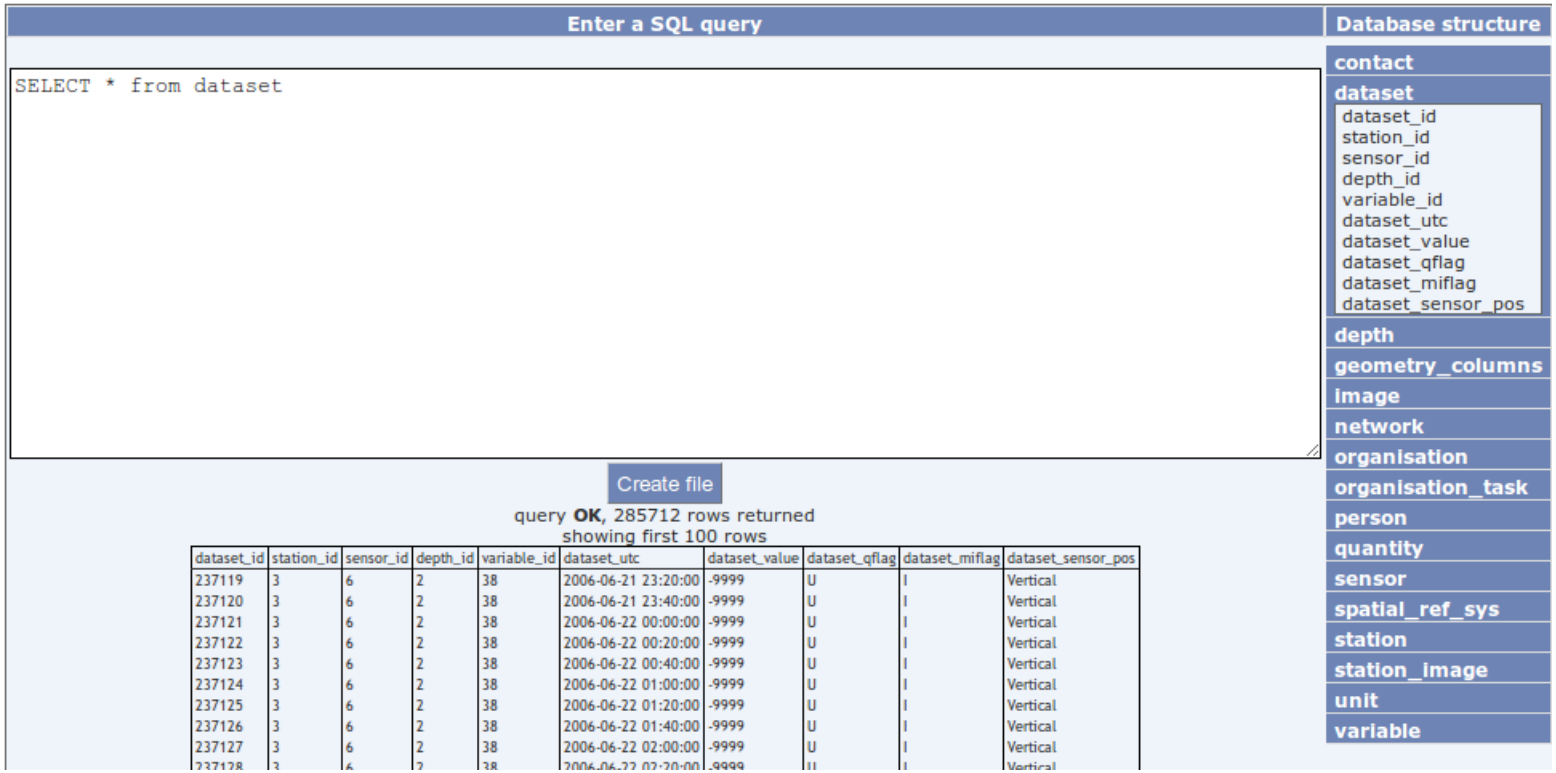


  - Geographical extension



Web portal

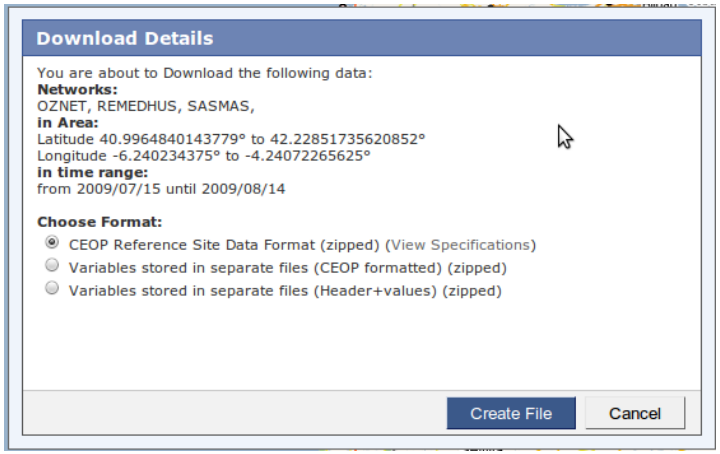
- Advanced download via SQL query



dataset_id	station_id	sensor_id	depth_id	variable_id	dataset_utc	dataset_value	dataset_qflag	dataset_miflag	dataset_sensor_pos
237119	3	6	2	38	2006-06-21 23:20:00	-9999	U	I	Vertical
237120	3	6	2	38	2006-06-21 23:40:00	-9999	U	I	Vertical
237121	3	6	2	38	2006-06-22 00:00:00	-9999	U	I	Vertical
237122	3	6	2	38	2006-06-22 00:20:00	-9999	U	I	Vertical
237123	3	6	2	38	2006-06-22 00:40:00	-9999	U	I	Vertical
237124	3	6	2	38	2006-06-22 01:00:00	-9999	U	I	Vertical
237125	3	6	2	38	2006-06-22 01:20:00	-9999	U	I	Vertical
237126	3	6	2	38	2006-06-22 01:40:00	-9999	U	I	Vertical
237127	3	6	2	38	2006-06-22 02:00:00	-9999	U	I	Vertical
237128	3	6	2	38	2006-06-22 02:20:00	-9999	U	I	Vertical

Web portal

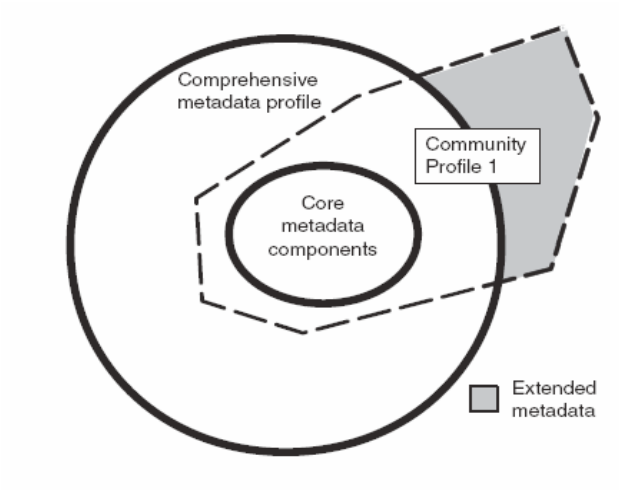
- Output: CEOP standards for file naming, data formatting and quality flagging

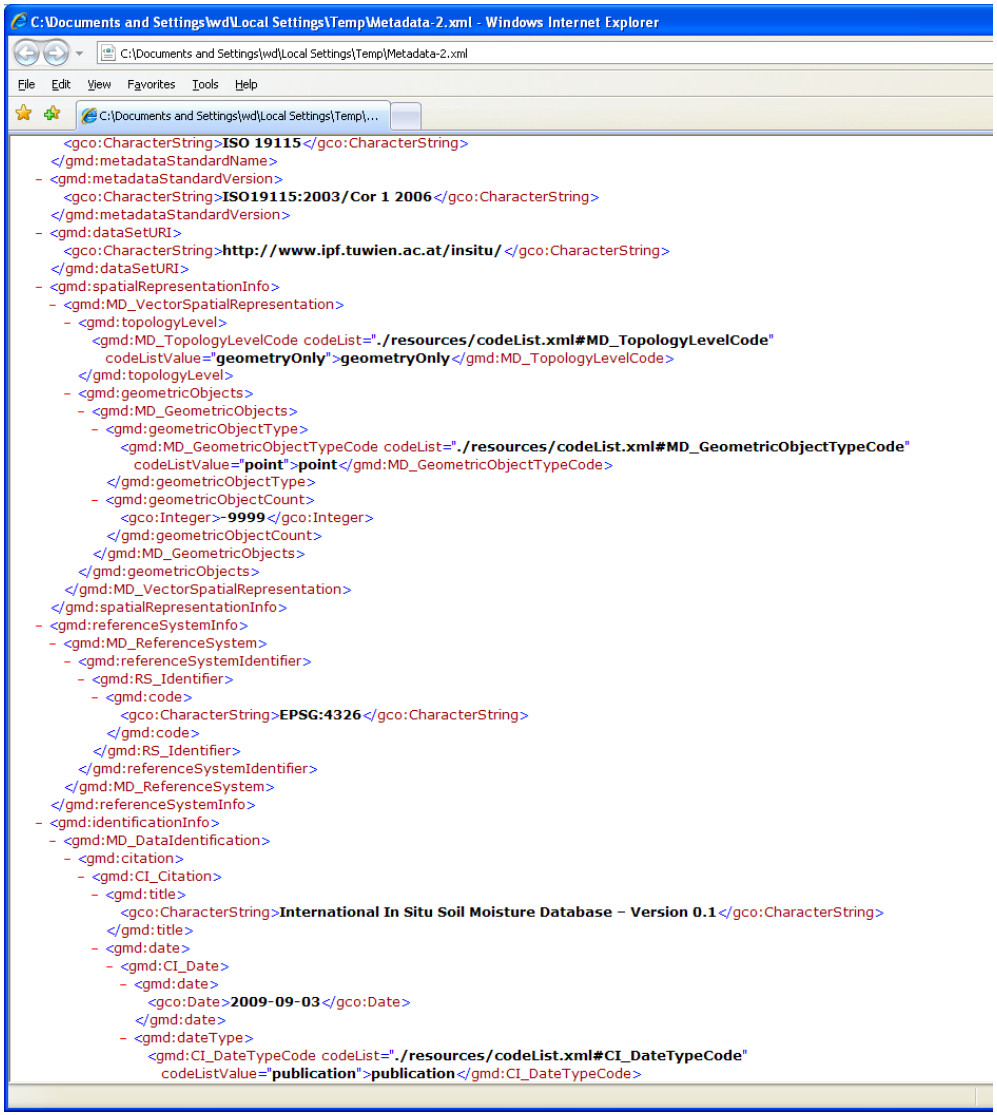


Variable name	C format	Missing Value	Final Units/Equations/Notes
UTC Nominal Date/Time	16 chars	N/A	yyyy/mm/dd HH:MM, where MM is 00 or 30, only
UTC Actual Date/ Time	16 chars	N/A	yyyy/mm/dd HH:MM
CSE Identifier	10 chars	N/A	Fill name with underscores, not spaces.
Reference Site Identifier	15 chars	N/A	Fill name with underscores, not spaces.
Station Identifier	15 chars	N/A	Fill name with underscores, not spaces.
Latitude	f10.5	-99.99999	decimal degrees. South is negative.
Longitude	f11.5	-999.99999	decimal degrees. West is negative.
Elevation	f7.2	-999.99	meters
Sensor Height	f7.2	-999.99	meters; Height of sensor. Positive above ground level. Negative below ground.
Soil Temperature	f8.2	-999.99	Celsius
Soil Temperature Flag	1 char	M	See Table 5
Soil Moisture	f8.2	-999.99	percent. Volumetric water content.
Soil Moisture Flag	1 char	M	See Table 5

Web portal

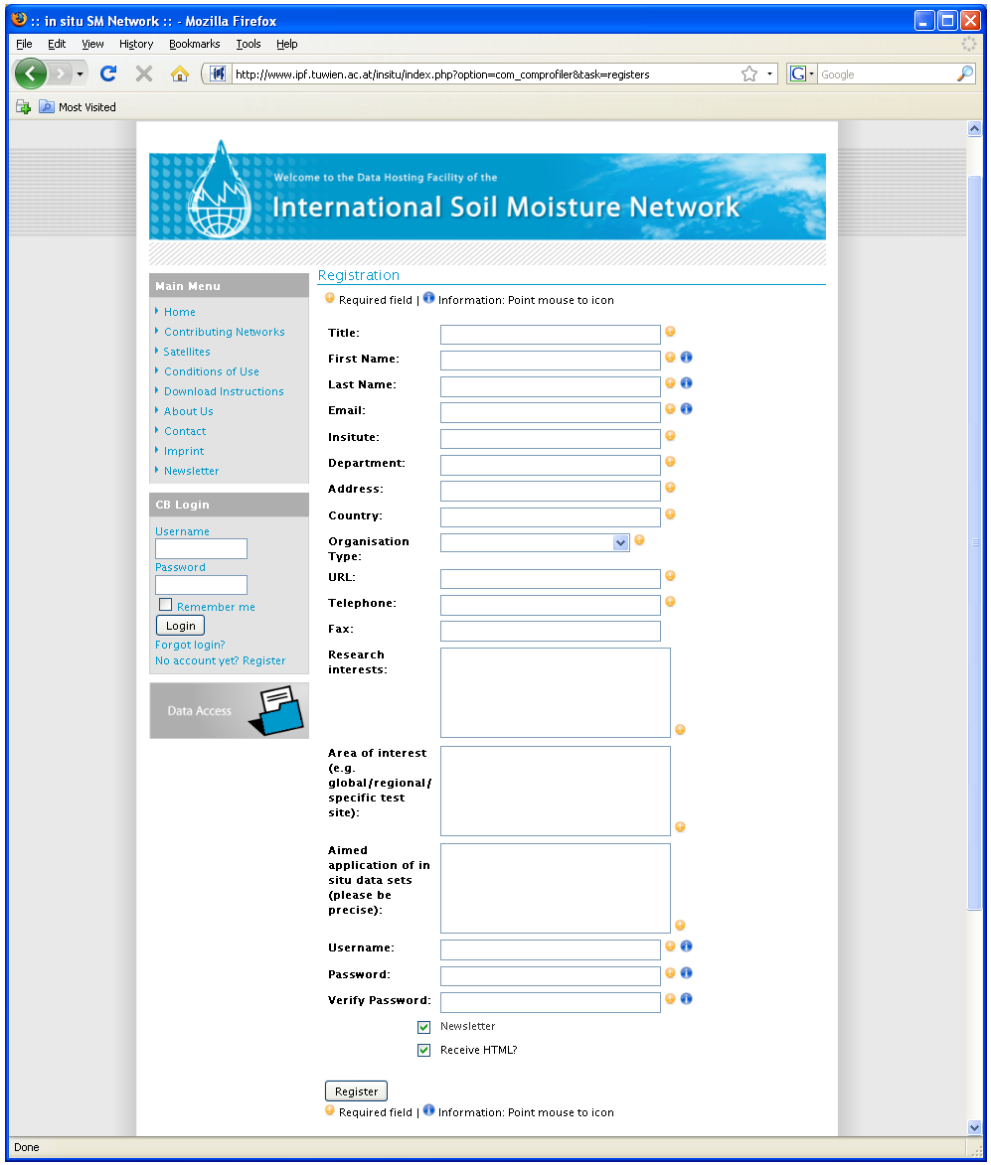
- Standardisation of metadata
- ISO 19115 and EU INSPIRE
- Output as XML
- Any other (US) data standards desired?





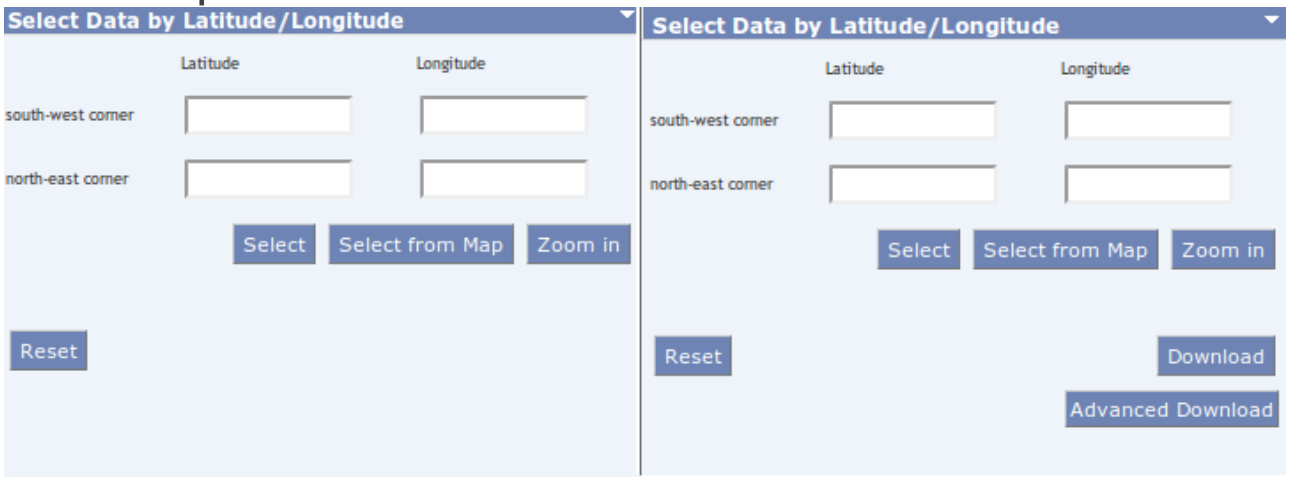
Web portal

- Full data access only for registered AND screened users.
- Data providing networks and ISMN must be cited



Web portal

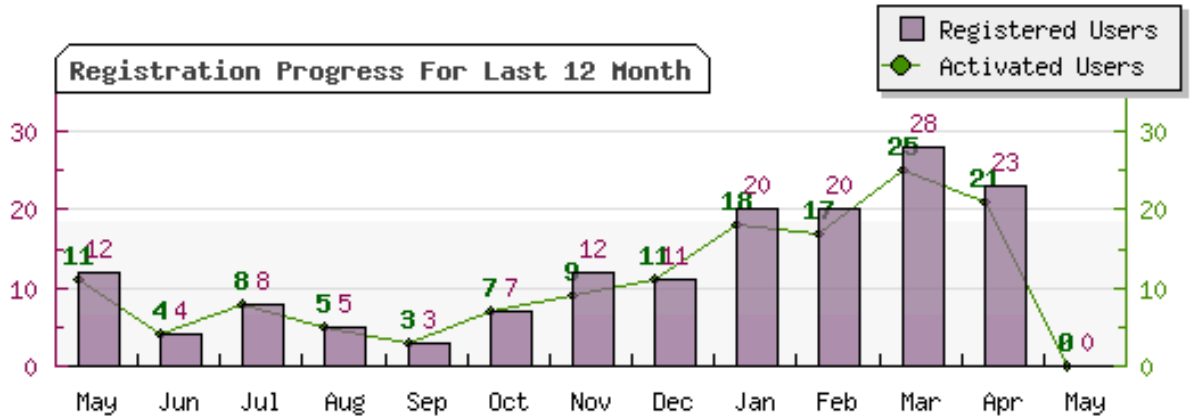
- No download options

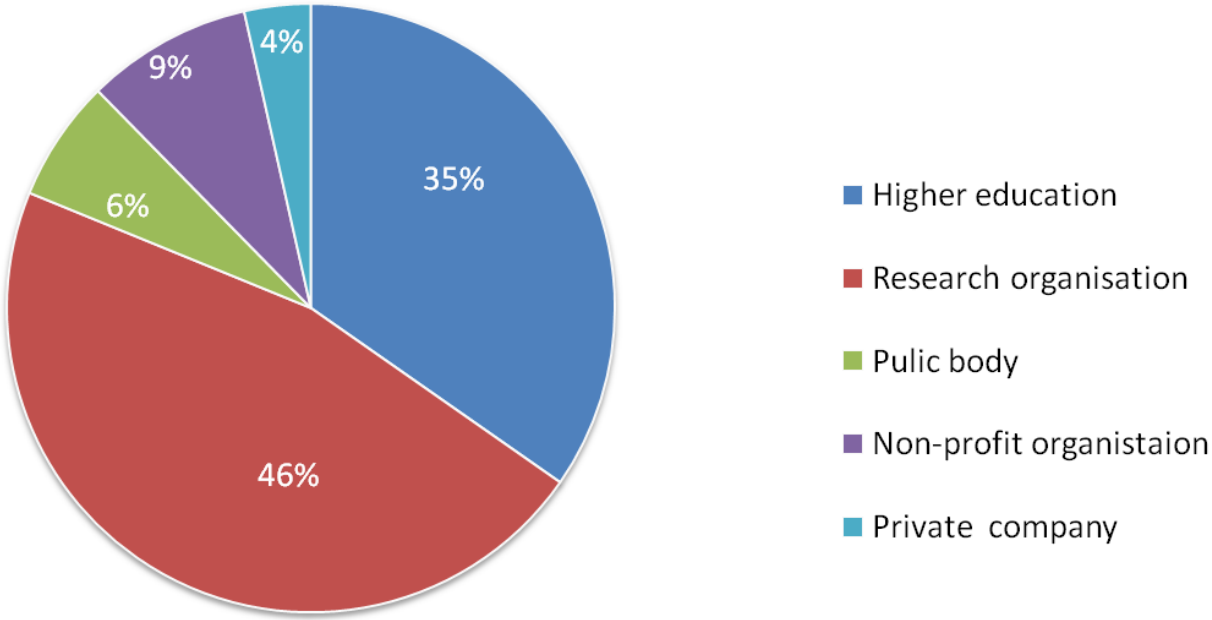


- Zoom level restriction

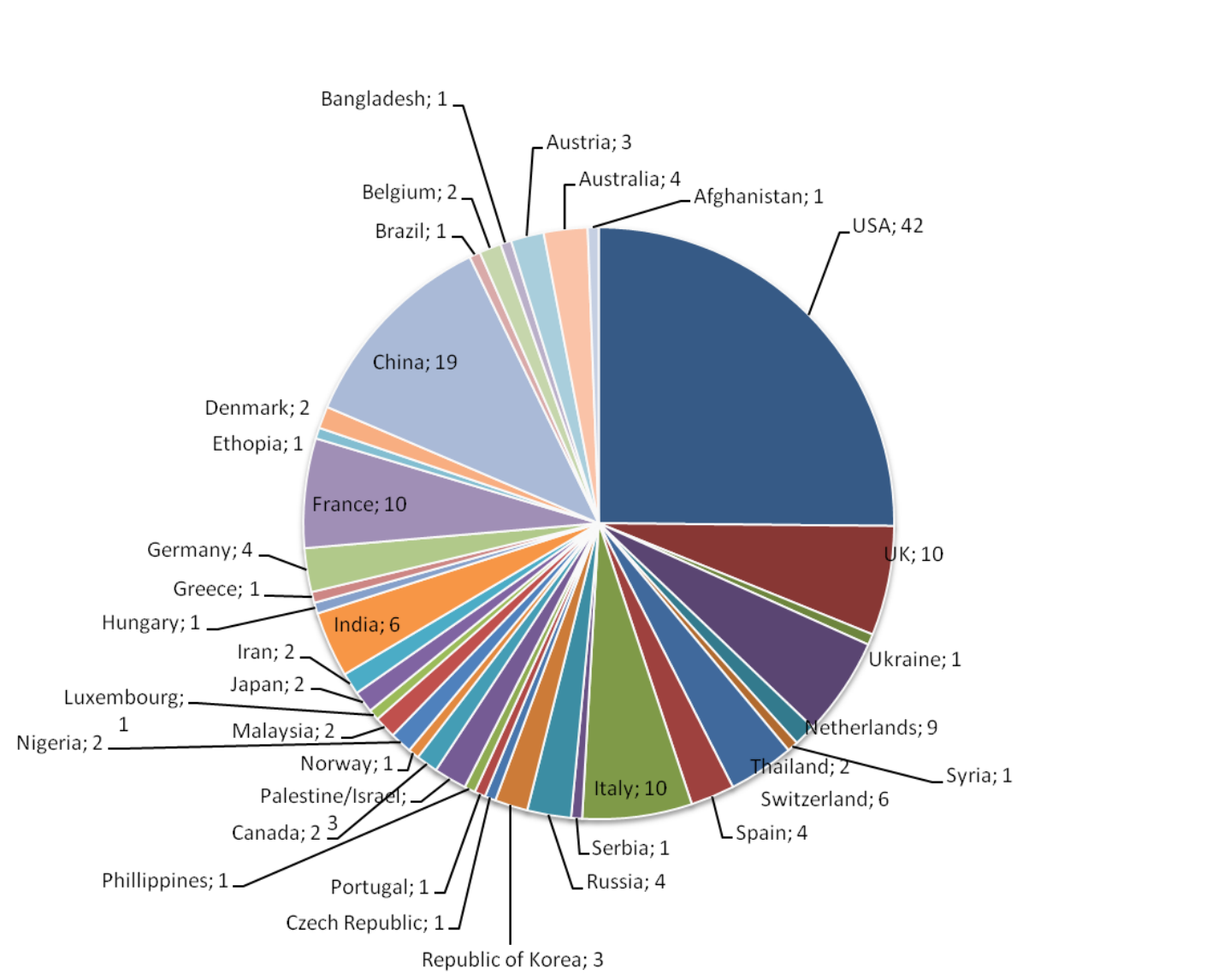
User experiences

- ~170 users





User experiences



User experiences

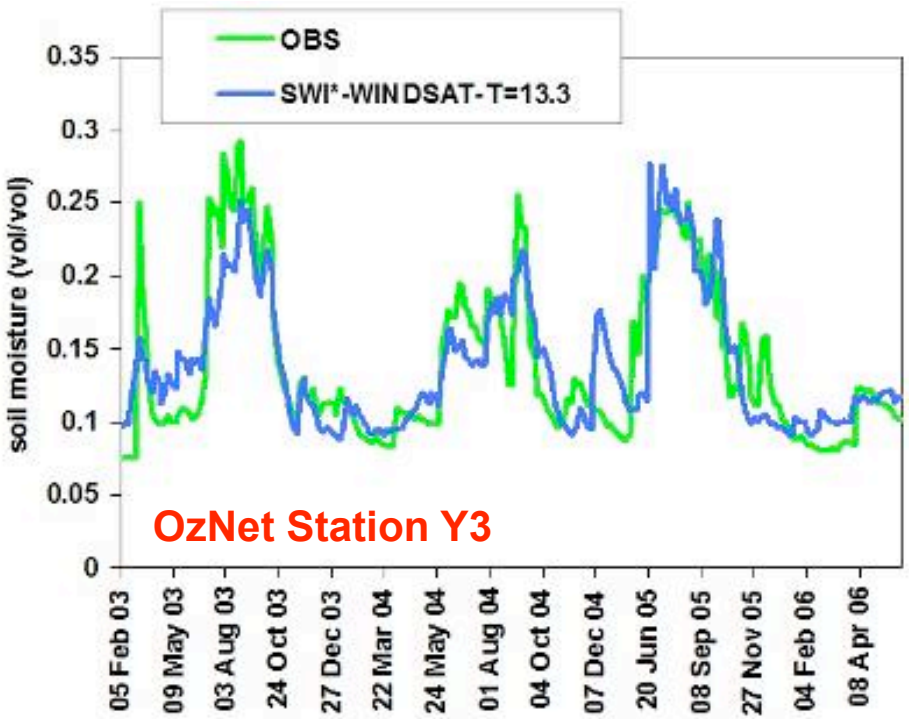
- User feedback

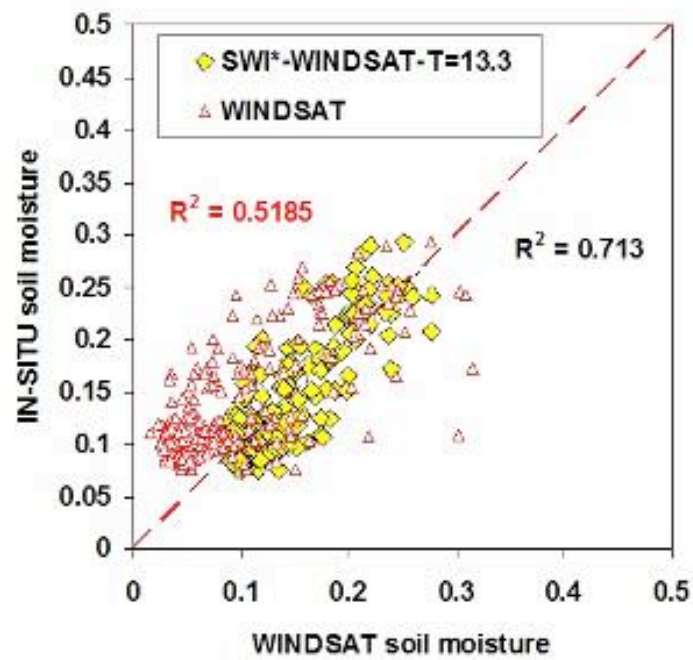
"I can say that it was easy to register and download the data. It is also easy to share my data sets and to include them in the website. Moreover, I think that the website is a very good opportunity to have data from several parts of the world. Therefore, for the first time, the ISMN allows to test and validate satellite sensors and model in a very robust way."

Luca Brocca, June 2010, describing his experiences with the ISMN

User experiences

- Several validation studies
  - WindSat





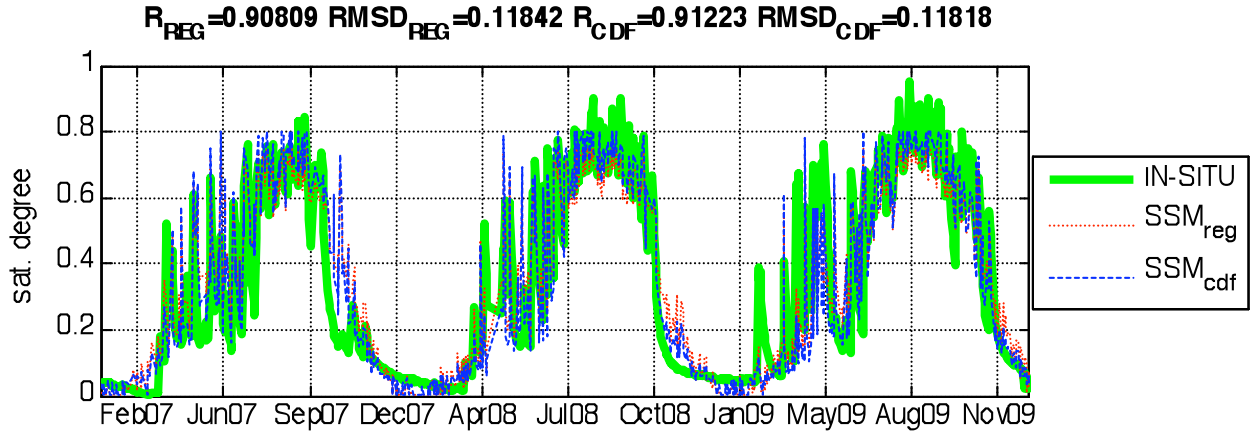
WINDSAT

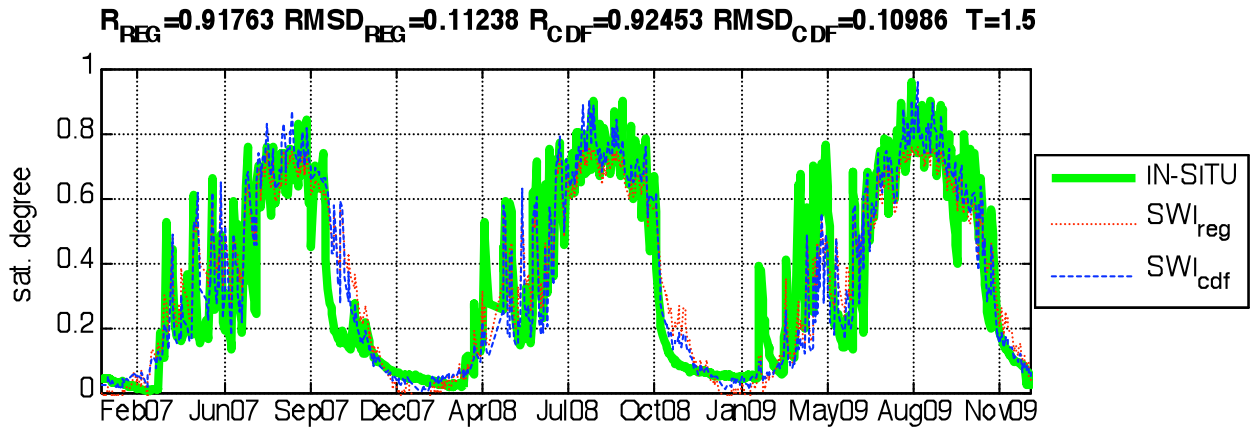
R_{ms}=	0.720
R_{SWI}=	0.844
$RMSD_{SWI*}$=	0.030

Courtesy: Luca Brocca

User experiences

- ASCAT TU Wien
  - AMMA (Station BT)

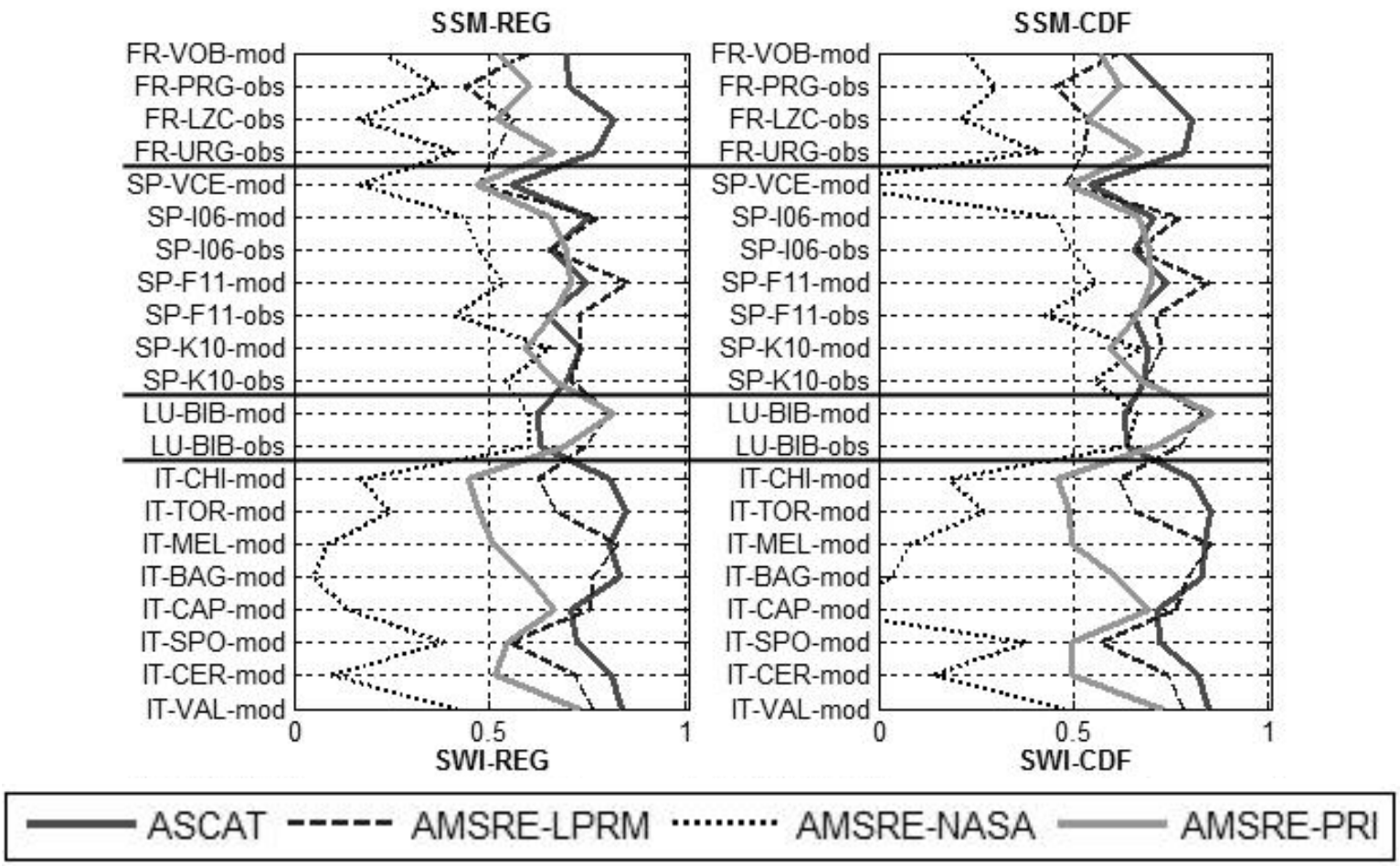




Courtesy: Luca Brocca

User experiences

- Intercomparison (pearson‘s R) across several sites in Europe



Brocca et al., subm.

Summary and outlook

- ISMN was successfully implemented
  - 20 networks
  - >500 stations
  - Period 1952-2011
  - Low cost (open source)
- Only shortly after going online, the ISMN seems to evolve as the integrated distribution platform for in-situ soil moisture measurements
  - Integration of Robock‘s Global Soil Moisture Data Bank
  - Data of several networks are distributed only through ISMN (e.g. CALABRIA, CAMPANIA, REMEDHUS, SMOSMANIA, GSMDB)

Summary and outlook

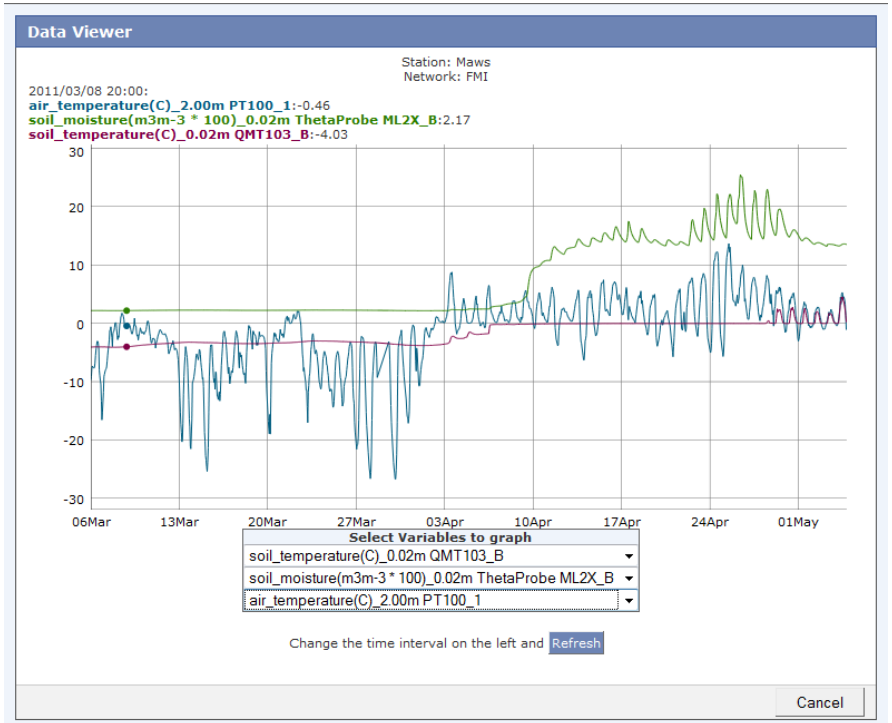
- Many additional networks interested in participating
  - Fluxnet (Global)
  - SCAN (USA)
  - COSMOS (USA)
  - TERENO (Germany)
  - SwissSMEX (Switzerland)
  - Valencia Anchor Station (Spain)
  - Delaware Environmental Observing System (DEOS; USA)
  - Climate Reference Net (USA)
  - USDA dense networks (USA)
  - Many others (including SMOS cal/val teams)

  - **We strongly encourage also other networks to participate!**

Summary and outlook

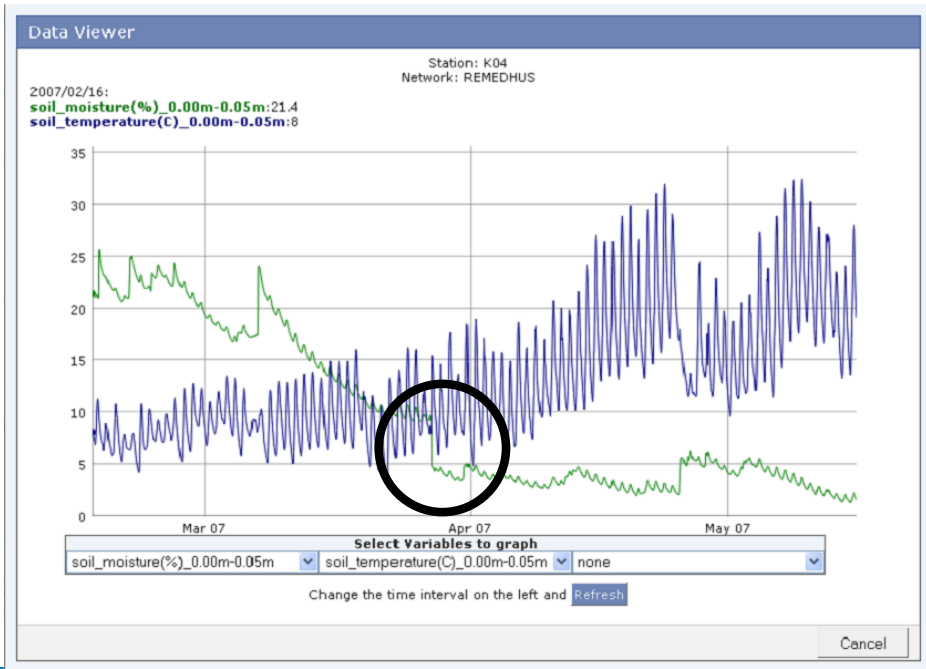
- Ongoing automation of processing new incoming datasets
  - Only works if networks provide their data in a **standardised** and **automized** way
  - Is full automation possible for all networks?
- Implementation of Near Real-Time Datasets
  - Several NRT datasets available in Finland, Germany, US (SCAN, COSMOS)

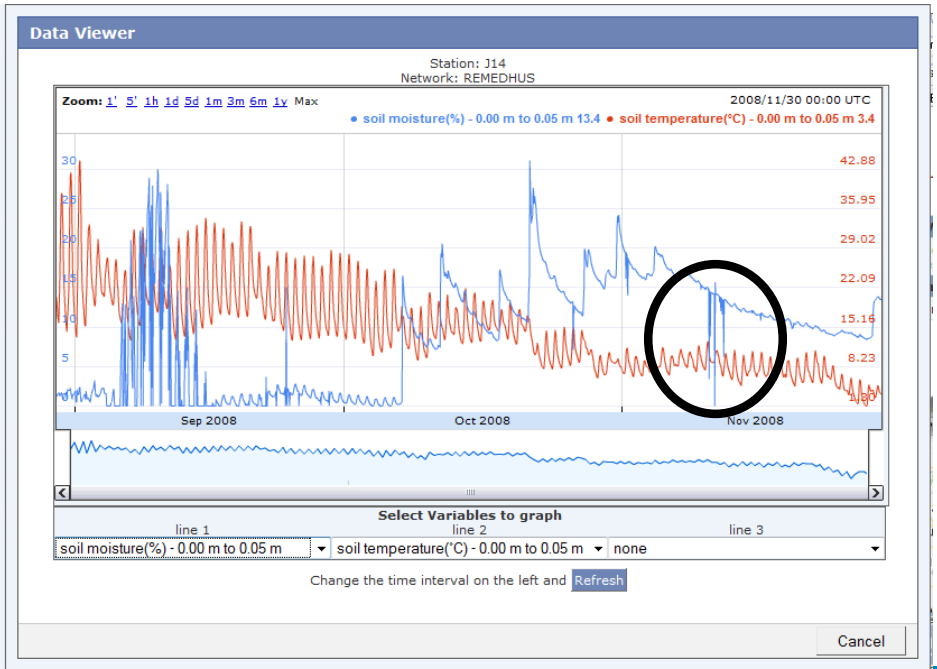
```
==============================================================================
Data file example:
==============================================================================

#1;date-stamp(yyyy-mm-dd)
#2;Time-stamp (hh:mm:ss; UTC)
#3;Hydraprobe Analog (2.5 Volt);sm;% vol;0.00;0.05;vertical
#4;Hydraprobe Analog (2.5 Volt);sm;% vol;0.00;0.10;vertical
#5;Hydraprobe Analog (2.5 Volt);sm;% vol;0.00;0.20;vertical
#6;Hydraprobe Analog (2.5 Volt);sm;% vol;0.00;0.50;vertical
#7;Hydraprobe Analog (2.5 Volt);sm;% vol;0.00;1.00;vertical
#8;Hydraprobe Analog (2.5 Volt);ts;degree C;0.0000;0.050;vertical
#9;Hydraprobe Analog (2.5 Volt);ts;degree C;0.0000;0.10;vertical
#10;Hydraprobe Analog (2.5 Volt);ts;degree C;0.0000;0.20;vertical
#11;Hydraprobe Analog (2.5 Volt);ts;degree C;0.0000;0.50;vertical
#12;Hydraprobe Analog (2.5 Volt);ts;degree C;0.0000;1.00;vertical
#13
$
2002-01-01;00:00:00;22.10;21.11;20.00;18.23;15.32;15.22;14.12;13.65;12.32;12.33
2002-01-01;01:00:00;22.10;21.11;20.00;18.23;15.32;15.22;14.12;13.65;12.32;12.33
2002-01-01;02:00:00;22.10;21.11;20.00;18.23;15.32;15.22;14.12;13.65;12.32;12.33
```



Summary and outlook

- Some data still contain outliers
  - Can we improve quality control ?
  - Reliable quality flags are important for operational use of data.
- Systematic differences and drifts
  - Characterisation of stations (temporal stability, systematic errors)
  - Required for reliable validations





Summary and outlook

- Long-term operation
  - What other networks will participate?
  - Official SMAP cal/val portal?
  - How can funding and operation be guaranteed beyond 2012?

- Dorigo, W., van Oevelen, P., Wagner, W., Drusch, M., Mecklenburg, S., Robock, A., Jackson, T. (2011). A New International Network for in Situ Soil Moisture Data. *Eos Transacations American Geophysical Union* 92(17): 141-142.

Eos, Vol. 92, No. 17, 26 April 2011

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PAGES 141–148

A New International Network for in Situ Soil Moisture Data

PAGES 141–142

The International Soil Moisture Network (ISMN) is a new data-hosting center where

of organizations means that global studies incorporating ground-based soil moisture measurements are tedious to perform.

To overcome these issues, the Global Energy and Water Cycle Experiment

The network itself is managed at the Vienna University of Technology. The first phase of ISMN has been completed—it involved designing and implementing the system and ingesting the first data sets. The second phase, which began in January 2011, entails the implementation of an improved quality control system, inclusion of additional networks, and the development of a plan that works toward full automation and near–real time ingestion of data sets. Sub-

- Dorigo, W.A., Wagner, W., Hohensinn, R., Hahn, S., Paulik, C., Drusch, M., Mecklenburg, S., van Oevelen, P., Robock, A., Jackson, T. (2011). The International Soil Moisture Network: a data hosting facility for global in situ soil moisture measurements. *Hydrolology Earth System Sciences Discusions 8. 1609-1663*.

Many thanks to all networks contributing to ISMN!

http://www.ipf.tuwien.ac.at/insitu

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