SMOS validation results from the HOBE site, Denmark

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HOBE Center for Hydrology
Hydrological Observatory

CESBIO

DTU Space
National Space Institute

DTU

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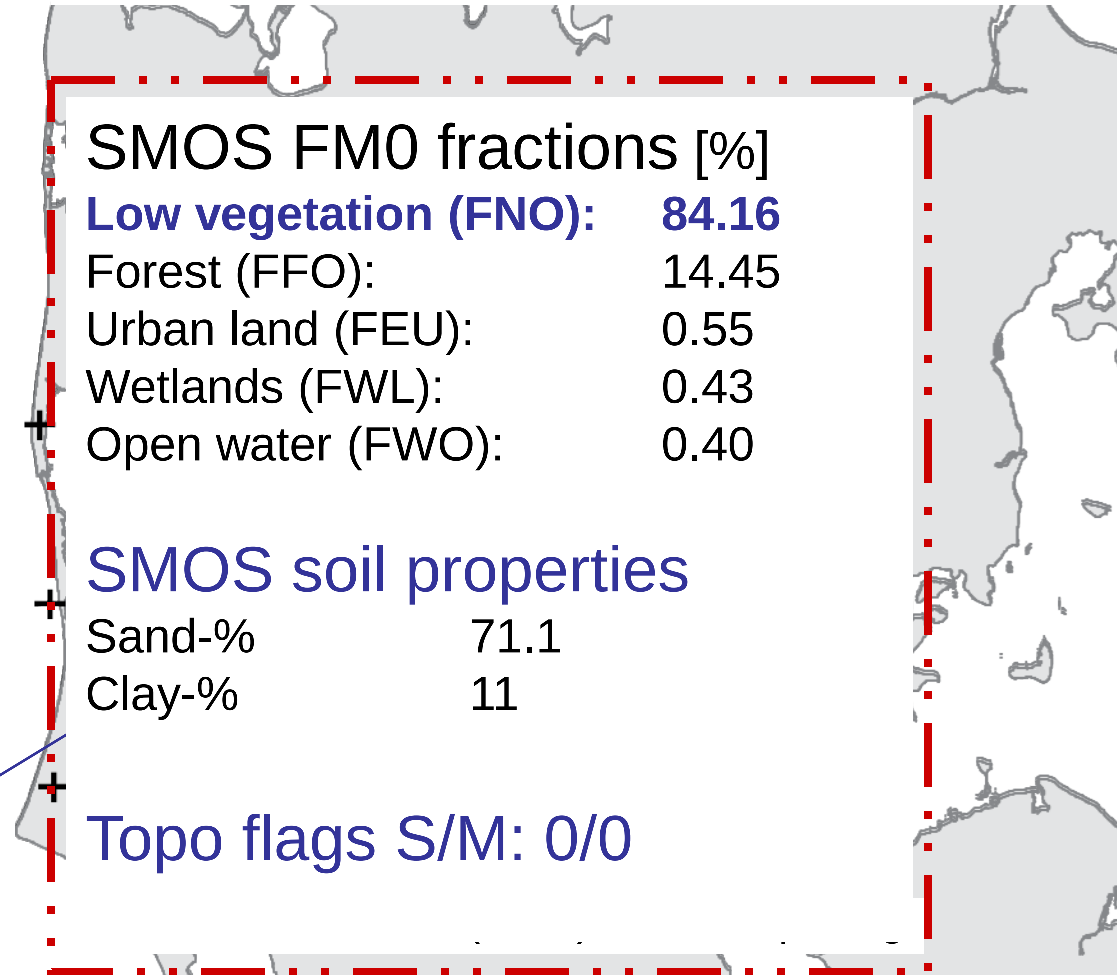
SMOS Land Applications WORSHOP, 25-27 February 2013, ESRIN, Frascati, Italy

Danish SMOS Validation site: Skjern River Catchment (~2500 km^2)

Hydrological OBsErvatory: 4 study sites
+ precipitation/climate stations (Danish Meteorological Institute, DMI)

SMOS "pixel" around
DGG node 2002029
~80% signal contribution



SMOS FM0 fractions [%]

Low vegetation (FNO):	**84.16**
Forest (FFO):	14.45
Urban land (FEU):	0.55
Wetlands (FWL):	0.43
Open water (FWO):	0.40

SMOS soil properties

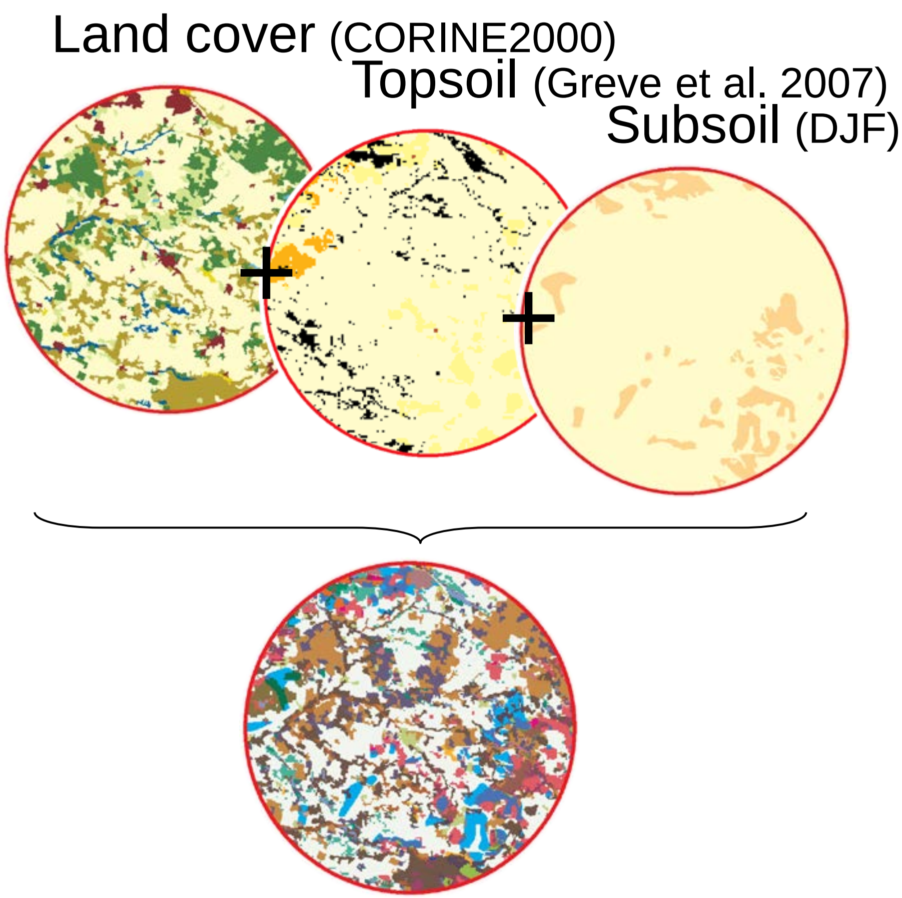
Sand-%	71.1
Clay-%	11

Topo flags S/M: 0/0

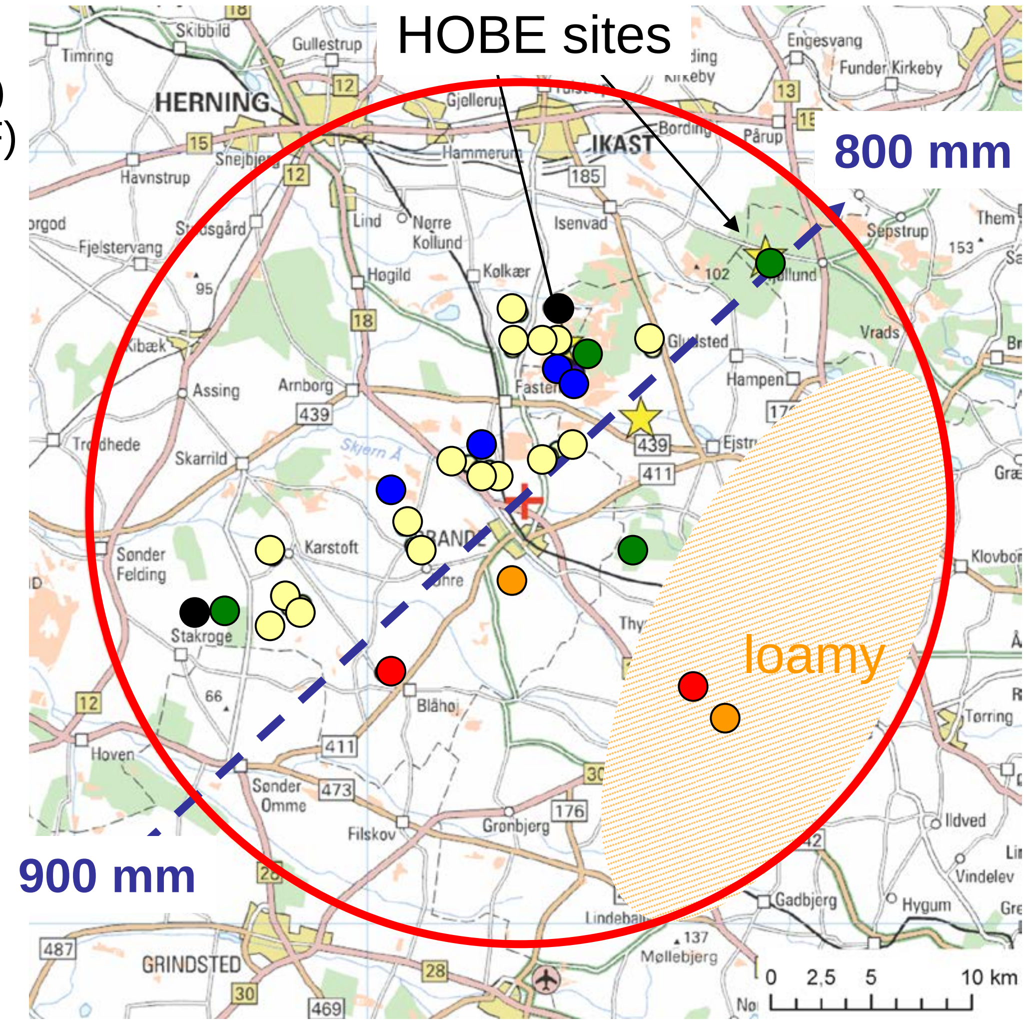
SMOS antenna weighting pattern

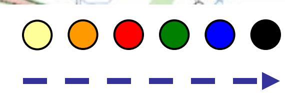
Soil moisture & temperature network, 30 stations: since Jan 2010

Decagon 5TE sensors at 0-5, 20-25 and 50-55cm depth + organic layer



6 composite classes = 82%





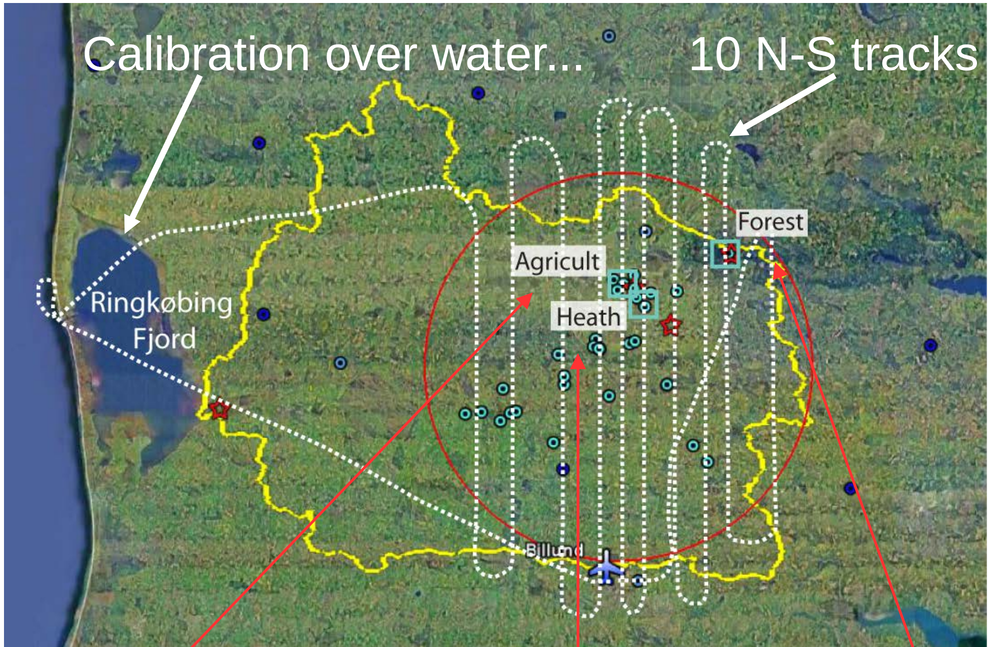
→ stations distributed accordingly...

→ aligned along long-term precip. gradient:

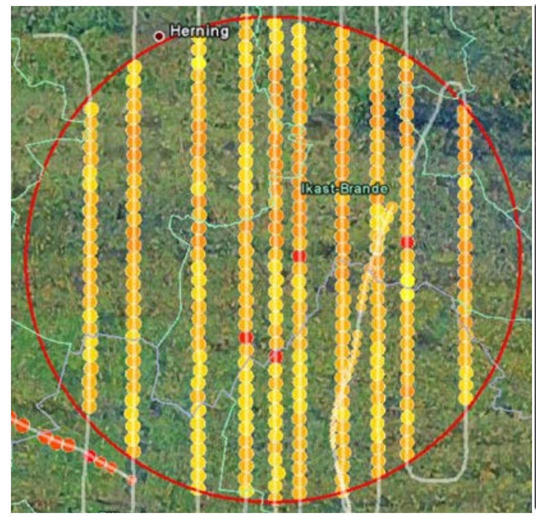
→also covering more loamy area in south-east

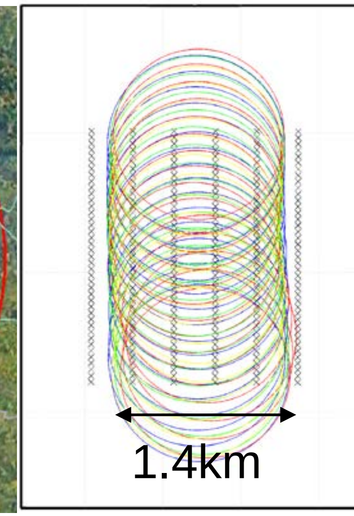
Airborne Campaign: 26. April – 10. May 2010

4 flights & ground sampling, 29/04, 02/05, 04/05, 09/05, SMOS overpass ~ 6:30



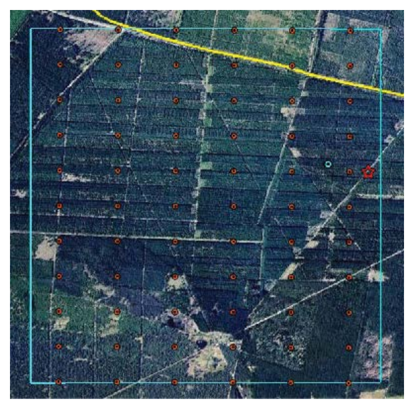
L-band radiometer EMIRAD (DTU Space), 0&40º Ө, H&V





Agriculture

Heath



Forest

Delta-T theta probe readings + gravimetric samples of mineral & organic layers

Roughness, veg. water content, land cover info

Ø 90% Sand - 3% Clay

Campaign: results presented at several occasions and compiled in publications...

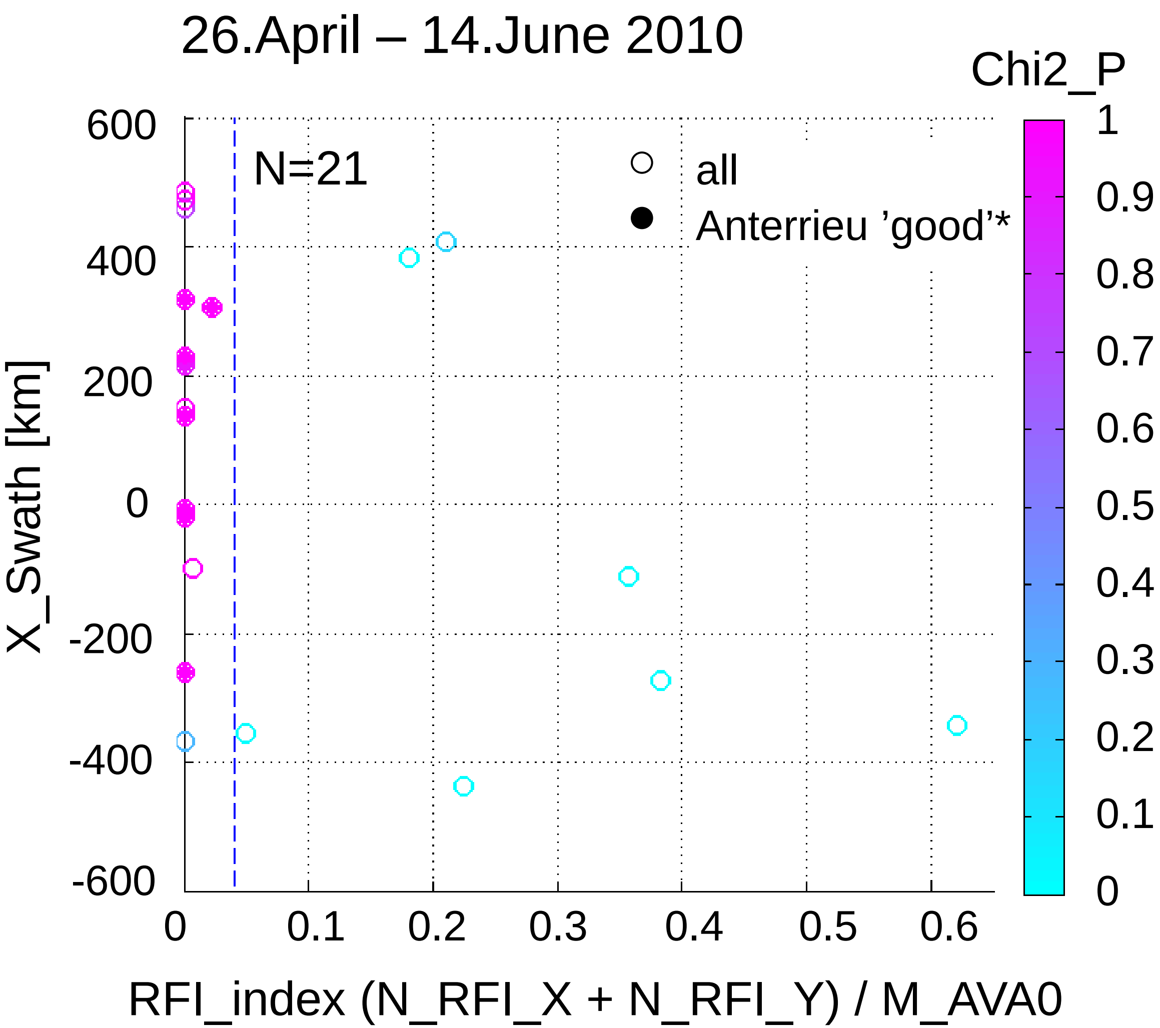
→ Overview of this talk

1. SMOS DGG 2002029: detailed temporal analysis of retrieved SMOS soil moisture by means of network data
   - SMOS data filtering
   - Different L2 versions
   - L2 vs. L3

2. SMOS DGG transect from west to east coast : analysis of changing open water fraction

3. Retrieved SMOS soil moisture using the Dobson vs. Mironov Dielectric Mixing model

SMOS data filtering – selected data quality indicators



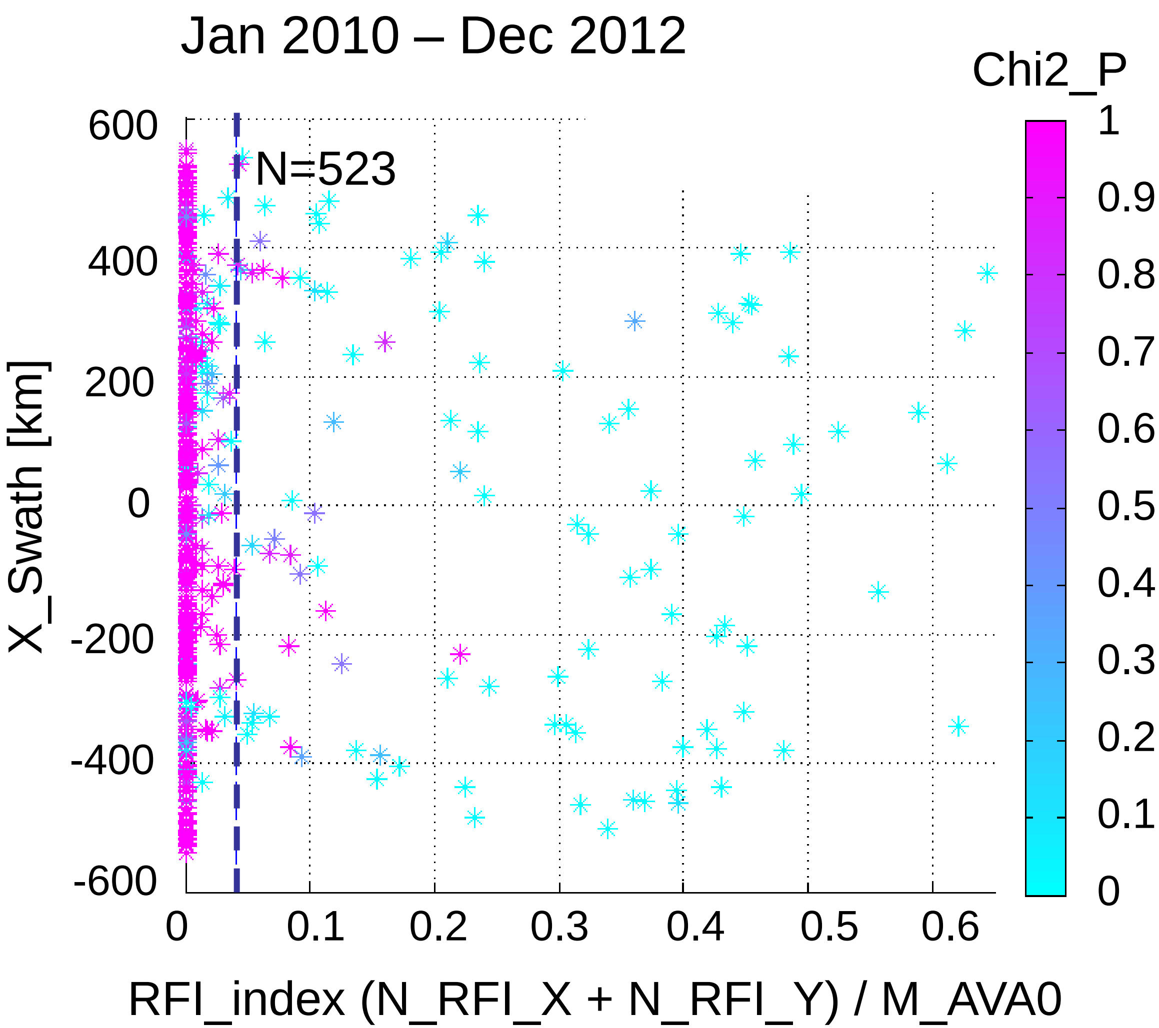
*RFI detection scheme L1A (Anterrieu 2011):

→X/Y snapshots RFI <50%

→total nr. X/Y snapshots >110

→All Anterrieu 'good'
- small RFI_index
- high Chi2_P

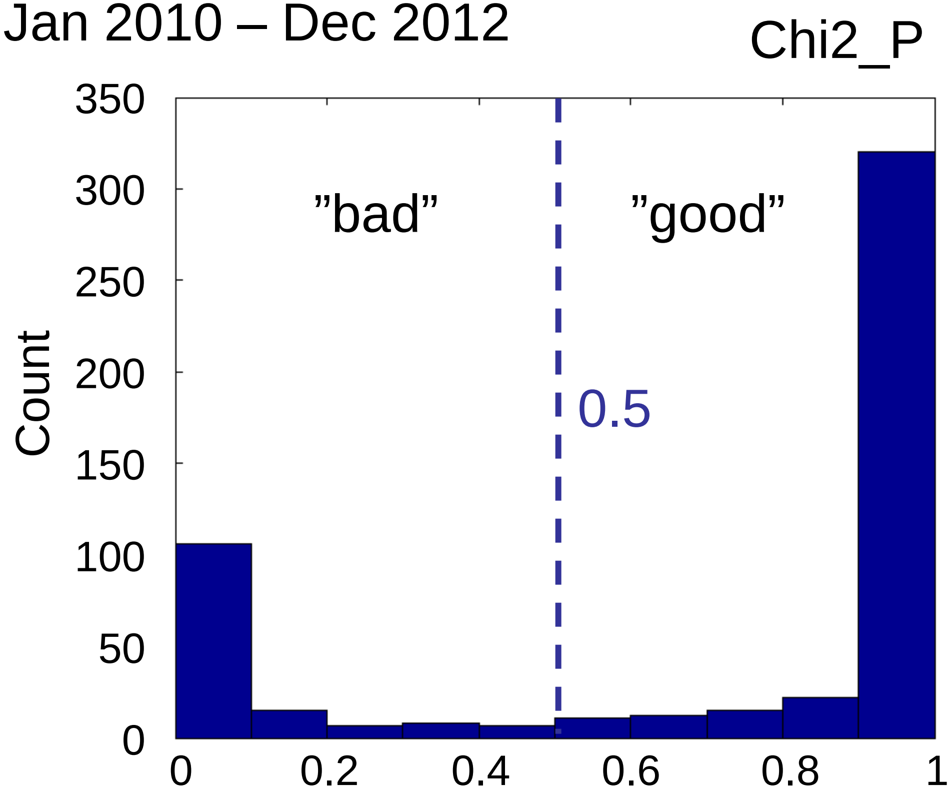
SMOS data filtering – selected data quality indicators

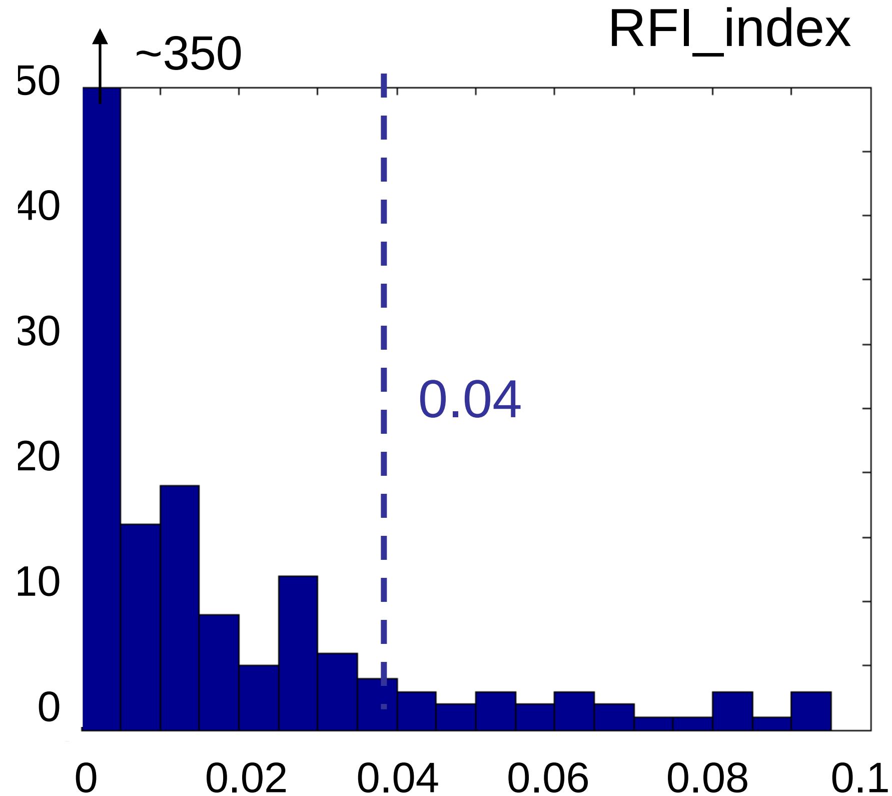


Generally:
- Small RFI_index = high Chi2_P
- High Chi2_P over entire X_Swath

→ Define RFI_index threshold for filtering...

Jan 2010 – Dec 2012

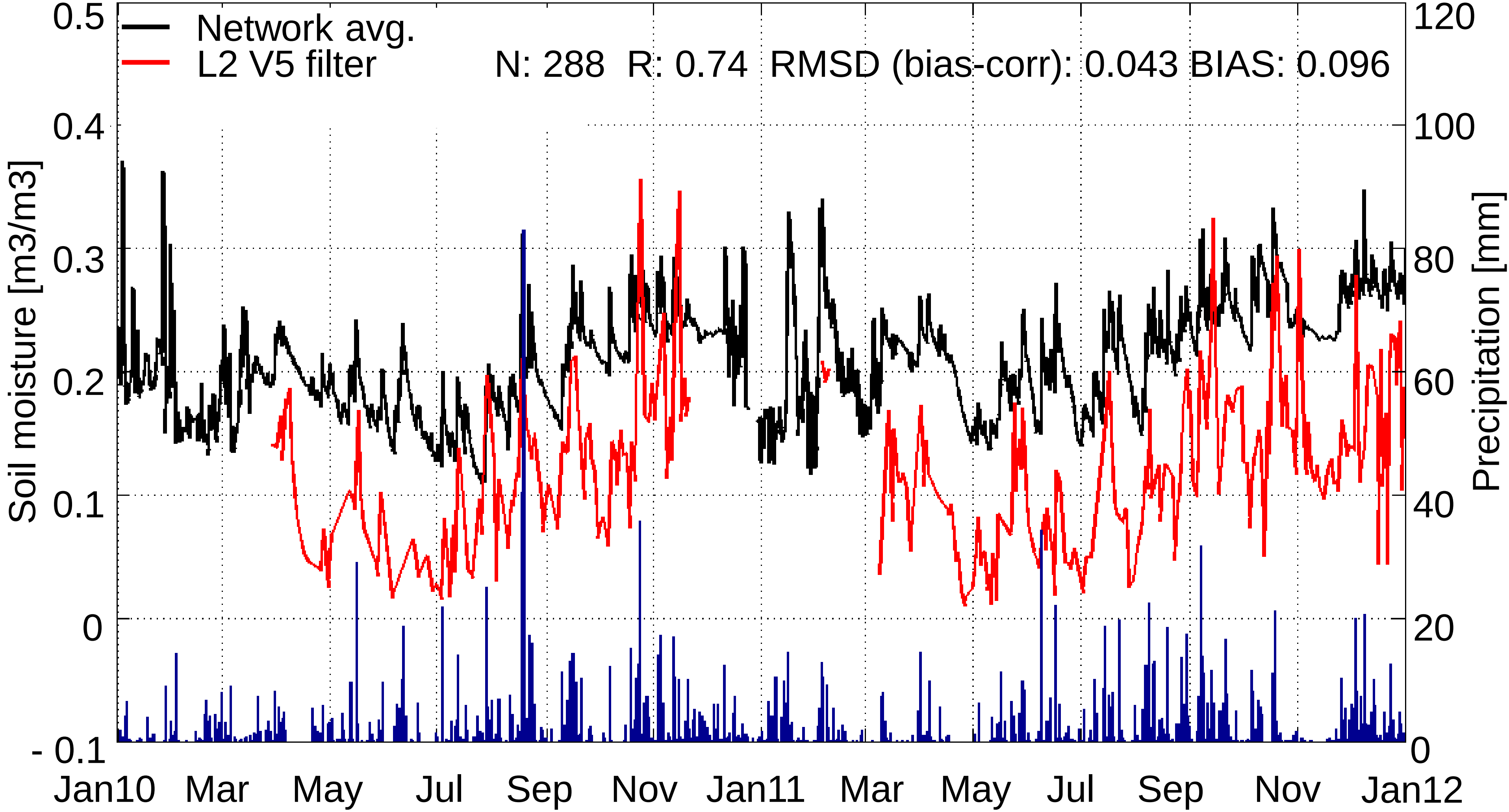




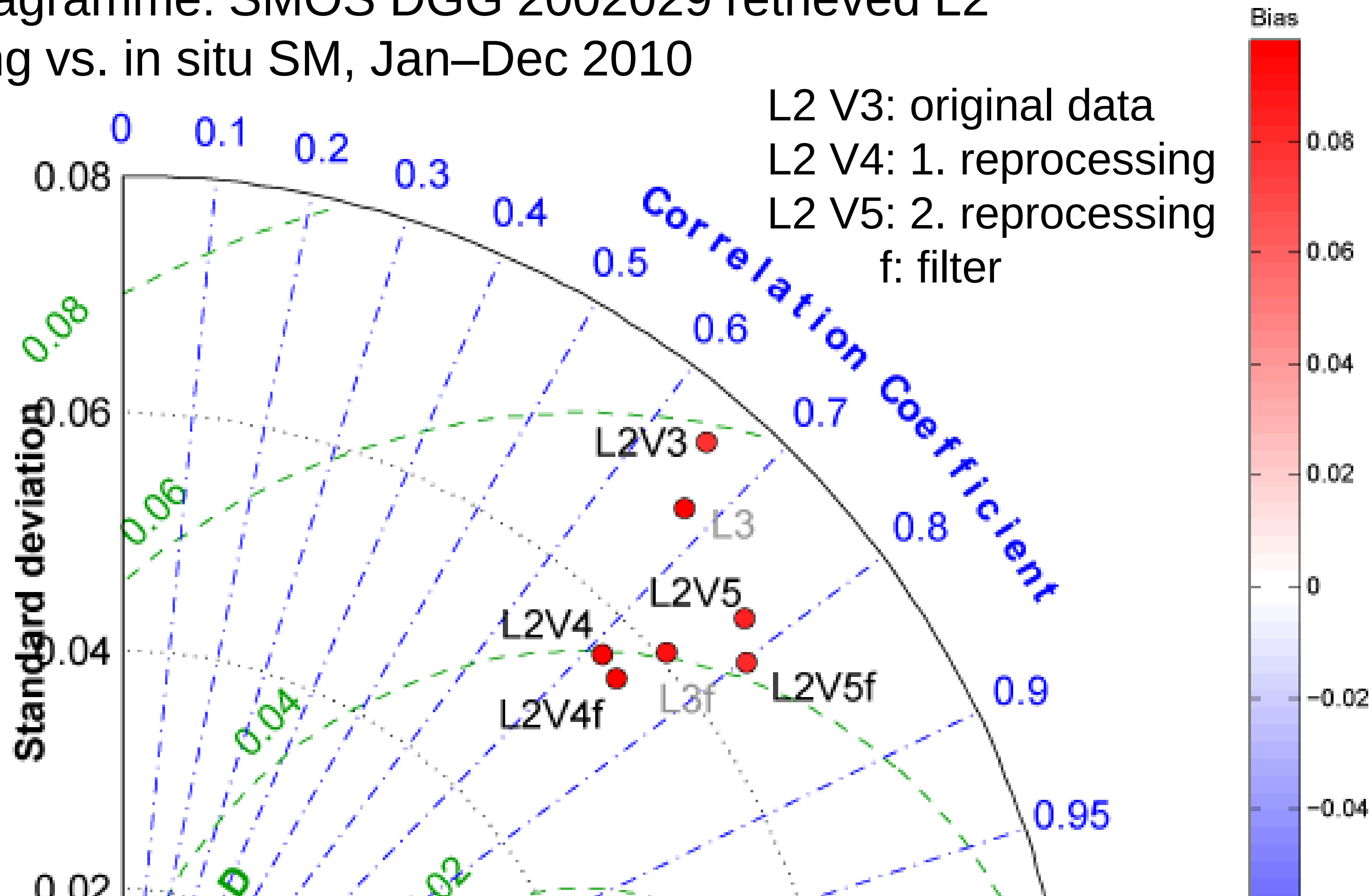
Classification [%]	26.Apr-14.Jun2010 T=0.03	T=0.04	T=0.05	Jan2010-Dec2012 T=0.03	T=0.04	T=0.05
RFIX<T:Correct(Chi2P>0.5)	92.9	92.9	86.7	88.4	87.7	87.7
Wrong(Chi2P<0.5)	7.1	7.1	13.3	11.6	12.3	12.9
RFIX>T:Correct(Chi2P<0.5)	100.0	100.0	100.0	81.4	85.2	86.4
Wrong(Chi2P>0.5)	0.0	0.0	0.0	18.6	14.8	13.6

→ Over 2-year timespan good agreement between SMOS L2 and in situ soil moisture in terms of temporal correlation and bias-corrected RMSD

→ But SMOS soil moisture significantly lower than in situ observations



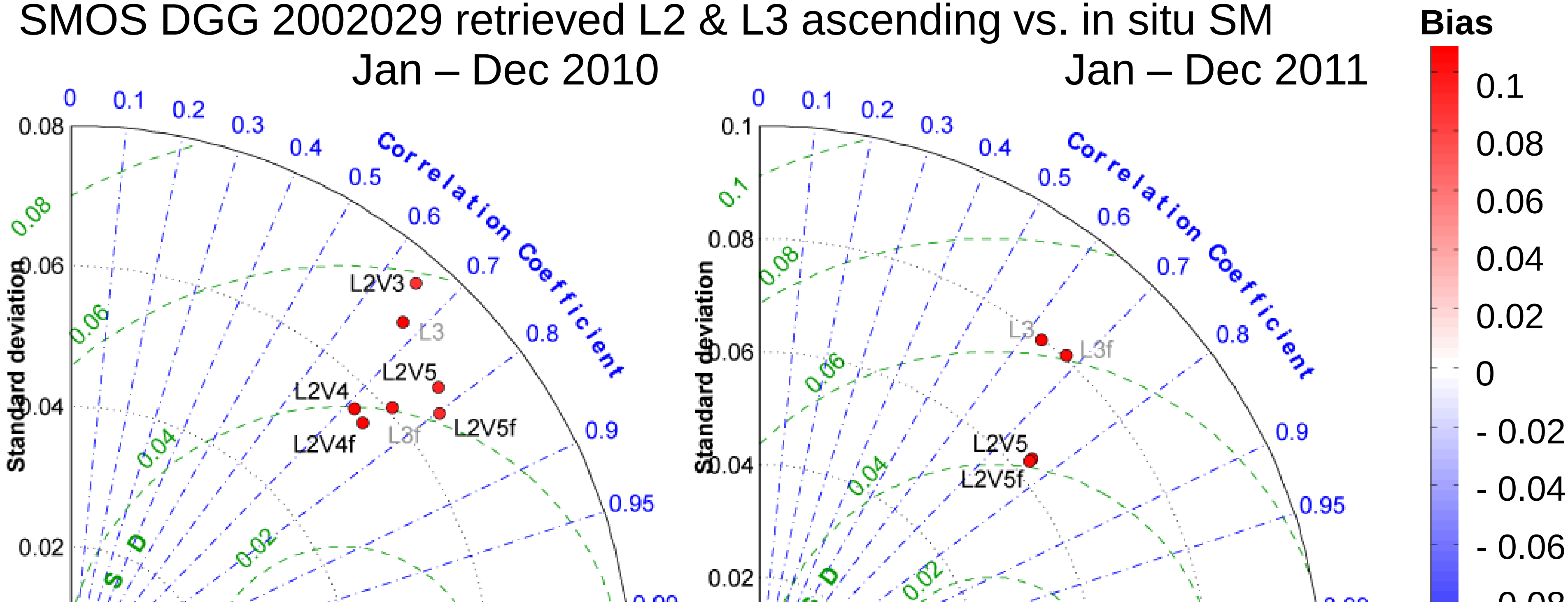
Taylor diagramme: SMOS DGG 2002029 retrieved L2 ascending vs. in situ SM, Jan–Dec 2010



- → Clear quality increase between L2 V3 & V4, V4 & V5 in similar range (high impact of new forest tau formulation in V4)
- → Also quality increase when applying filter (rfi_index<0.04)

- → L3 in similar range as L2 V4 & V5 when filtered

SMOS DGG 2002029 retrieved L2 & L3 ascending vs. in situ SM



→ Number of retrievals increasing from L2 V3 to V5, from L2 to L3 (unfiltered) as well as from 2010 to 2011

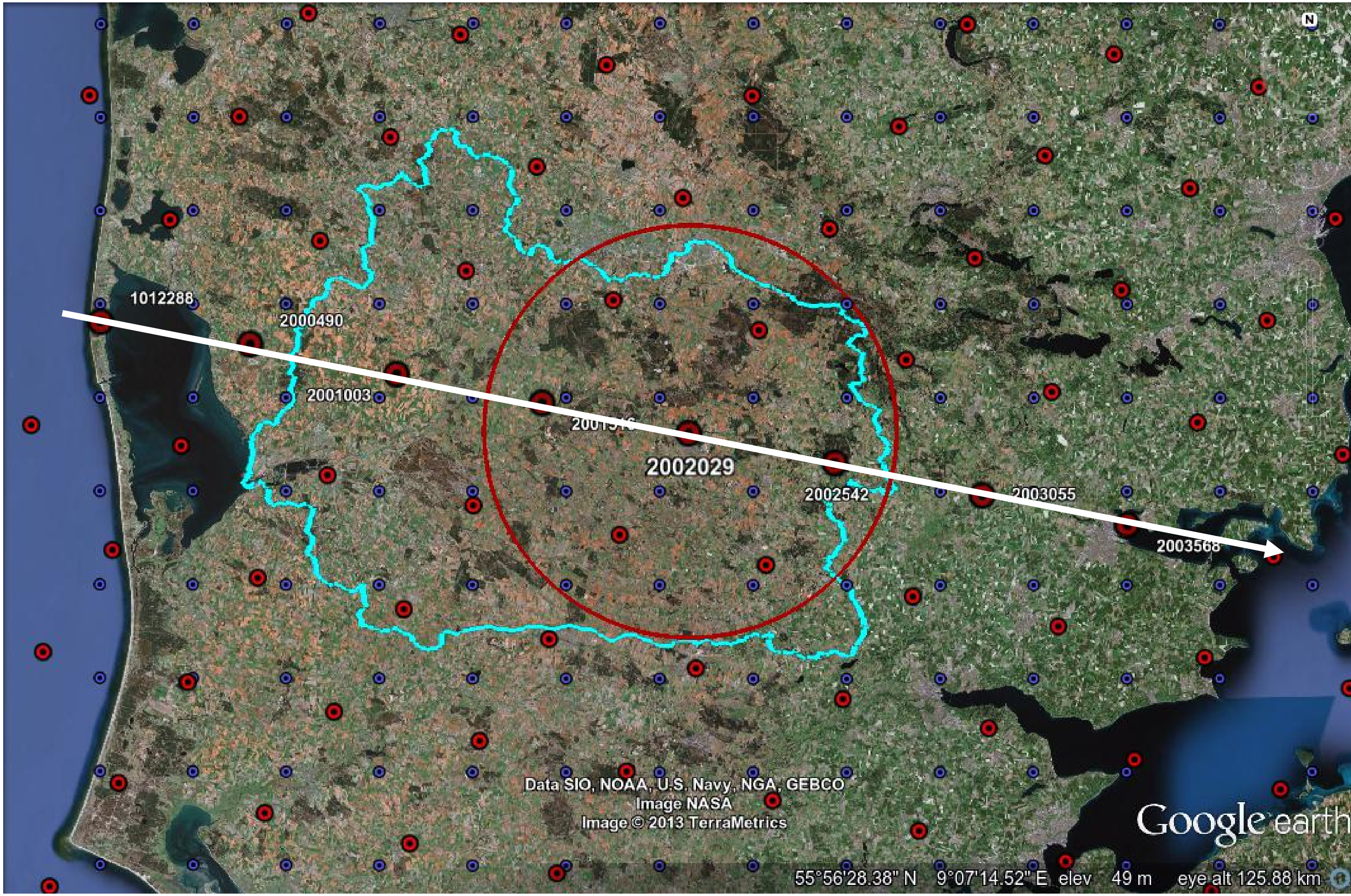
Number of retrievals

	all	filtered		all	filtered
L2V3	106				
L3	148	108	L3	208	197

→ in 2011 L3 clearly less good, while L2 stays in a similar range as in 2010 - however, decreasing network quality!

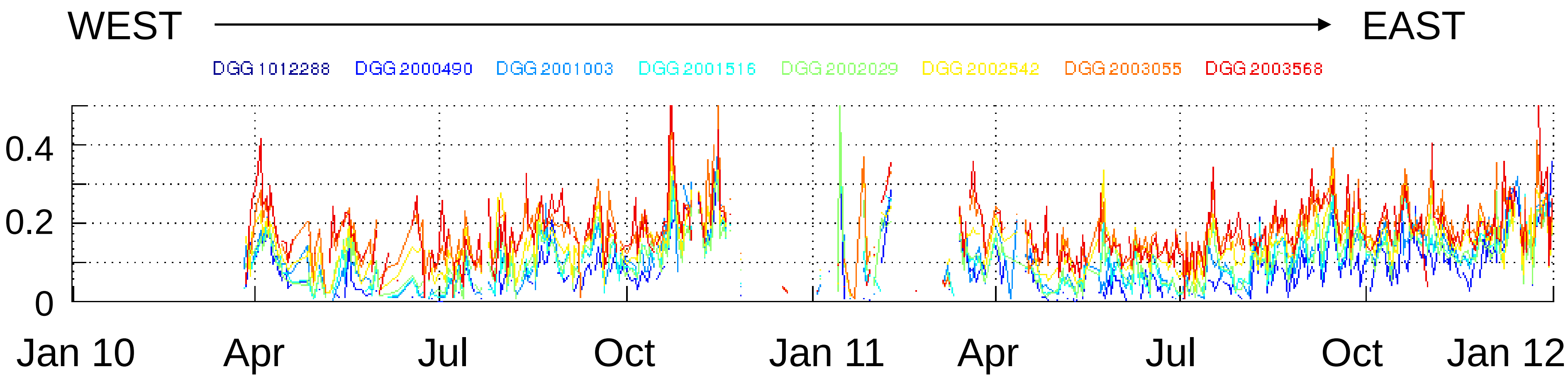
2010 2011

SMOS DGG transect west – east coast

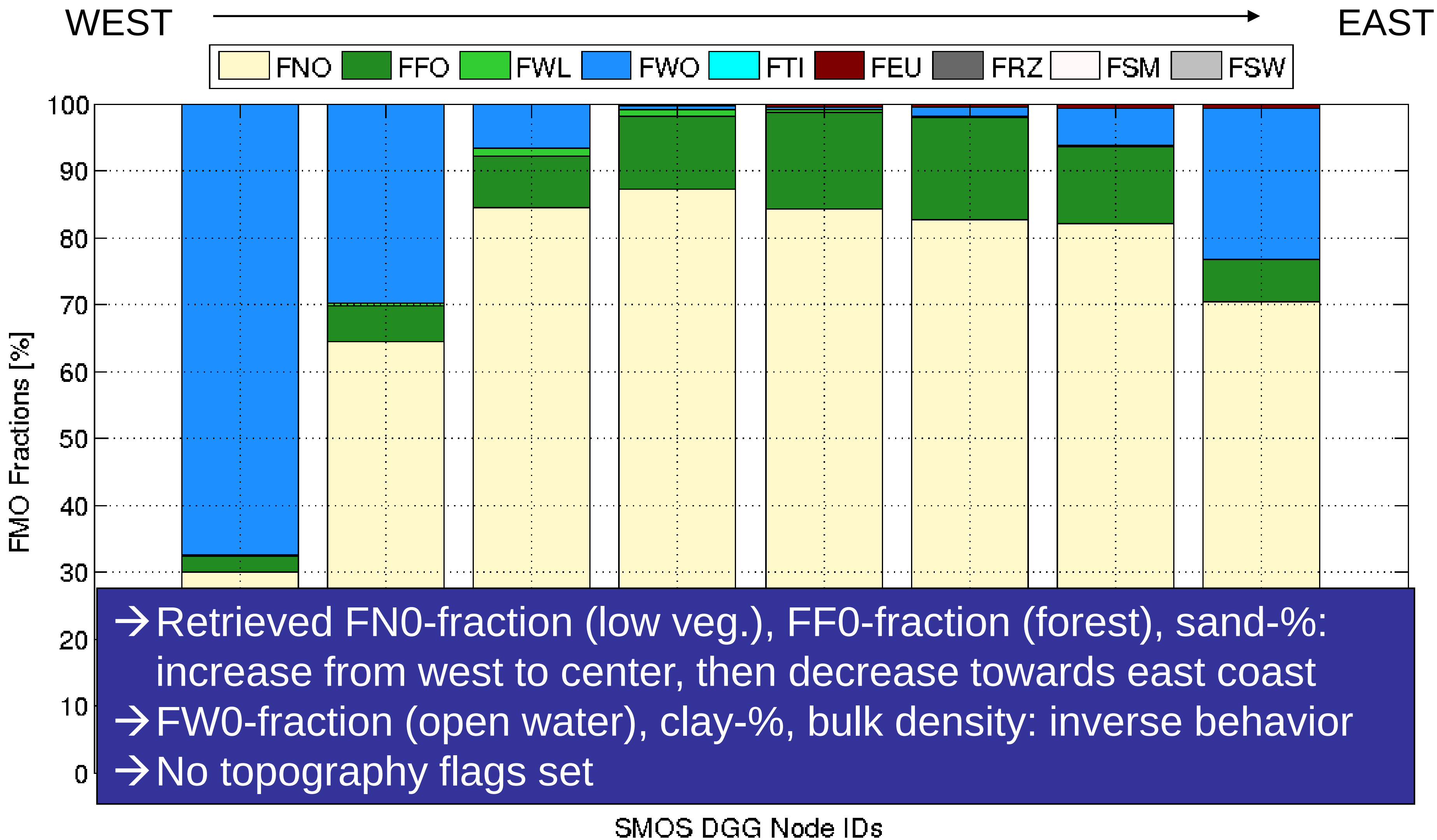


SMOS DGG nodes   10km precipitation grid (Danish Meteorological Institute)

Retrieved L2 SMOS soil moisture [m^3/m^3], Jan 2010 – Dec 2011

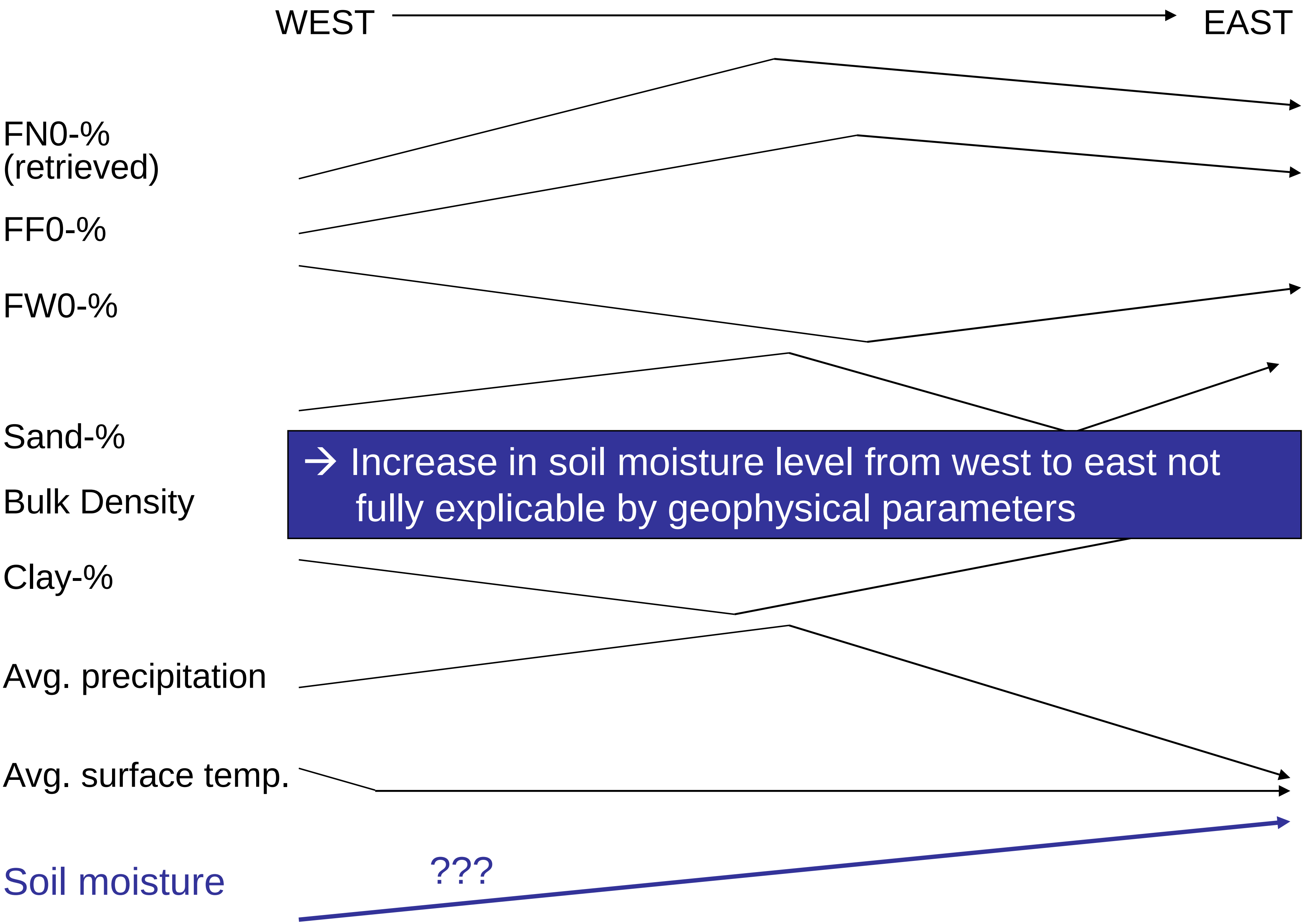


→ Increase in soil moisture level from west to east...



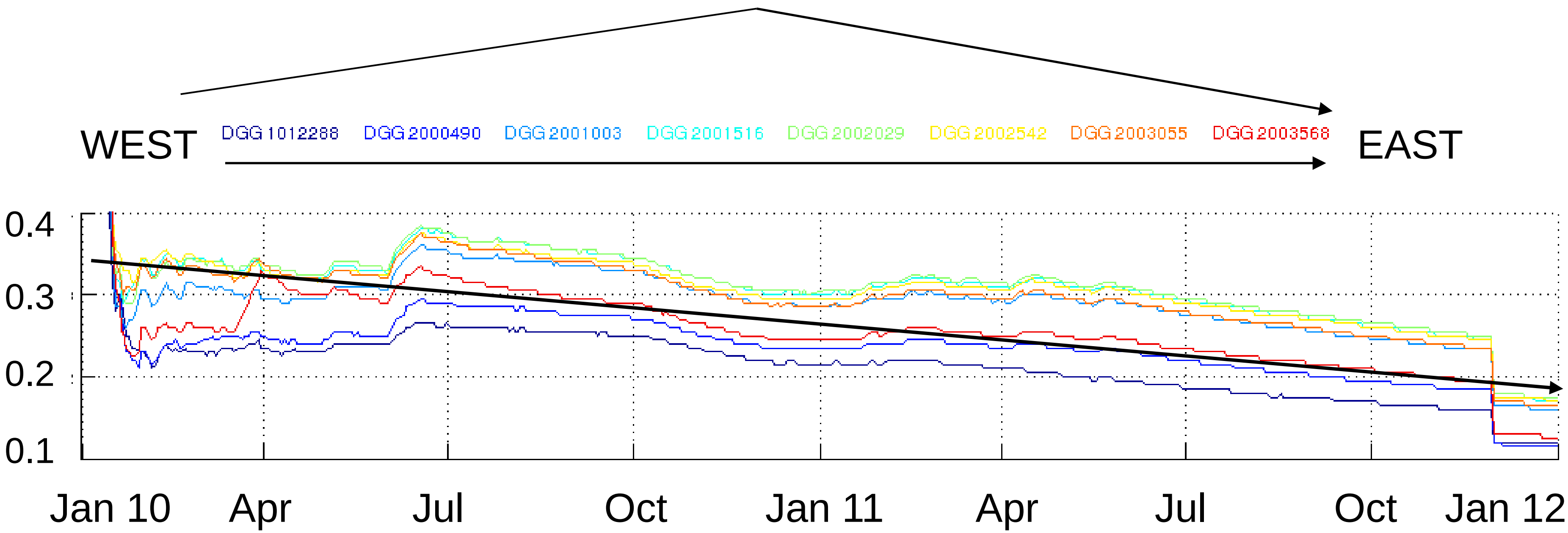
- → Retrieved FN0-fraction (low veg.), FF0-fraction (forest), sand-%: increase from west to center, then decrease towards east coast
- → FW0-fraction (open water), clay-%, bulk density: inverse behavior
- → No topography flags set

Sand-%	62.2	65.0	69.6	73.3	71.1	63.5	54.5	47.1
Clay-%	15.5	13.6	11.6	10.4	11.0	13.6	16.9	20.3
Bulk Dens.	0.96	0.89	0.86	0.87	0.88	0.94	1.09	1.26
Topo S/M	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0



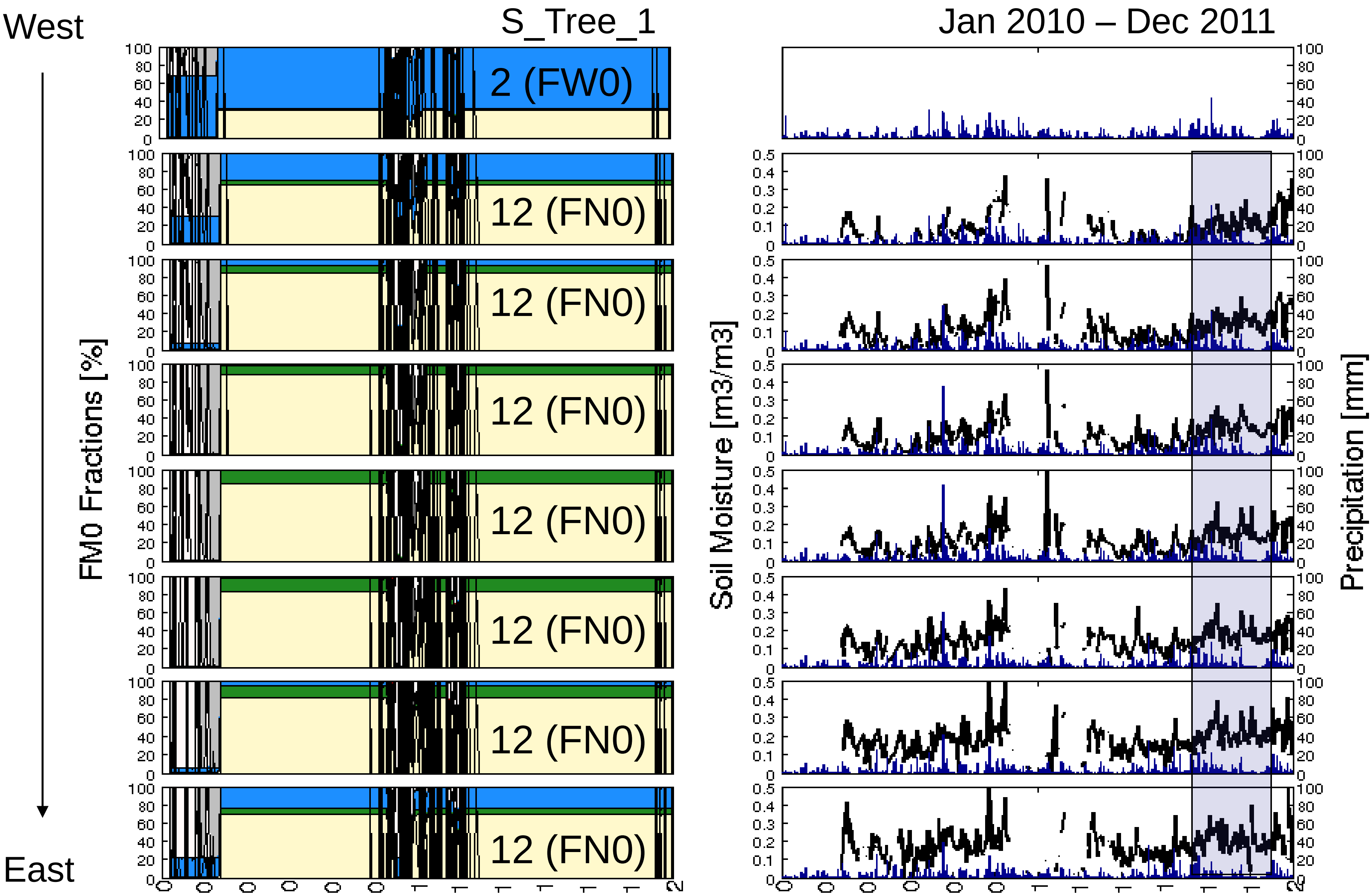
→ Increase in soil moisture level from west to east not fully explicable by geophysical parameters

RFI probability [%] , Jan 2010 – Dec 2011

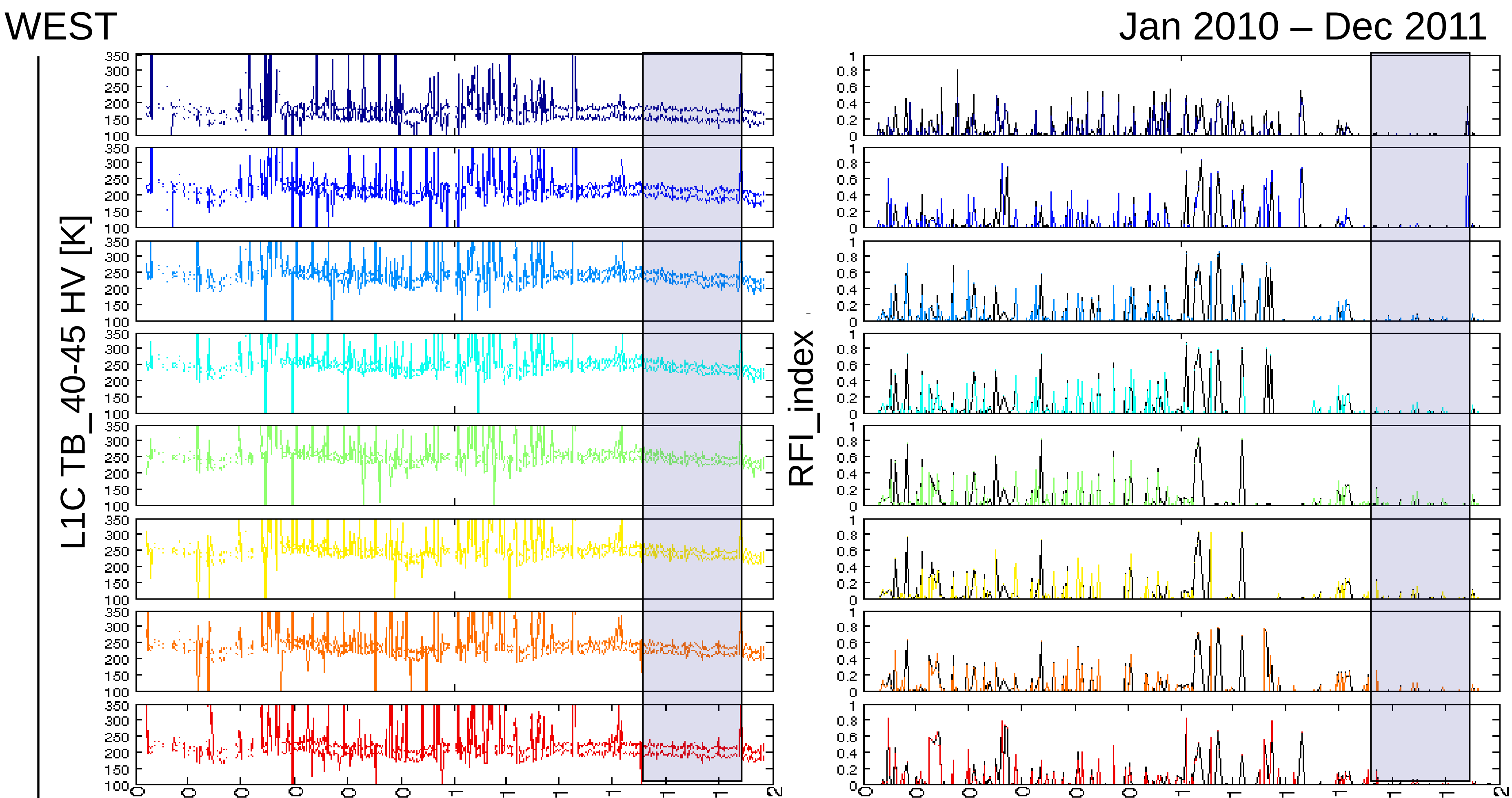


→ Increase from west coast to center and again decrease towards east coast
→ Does not seem to explain west-east soil moisture trend either

→ However, clear decreasing trend in RFI prob. over time for all DGGs!

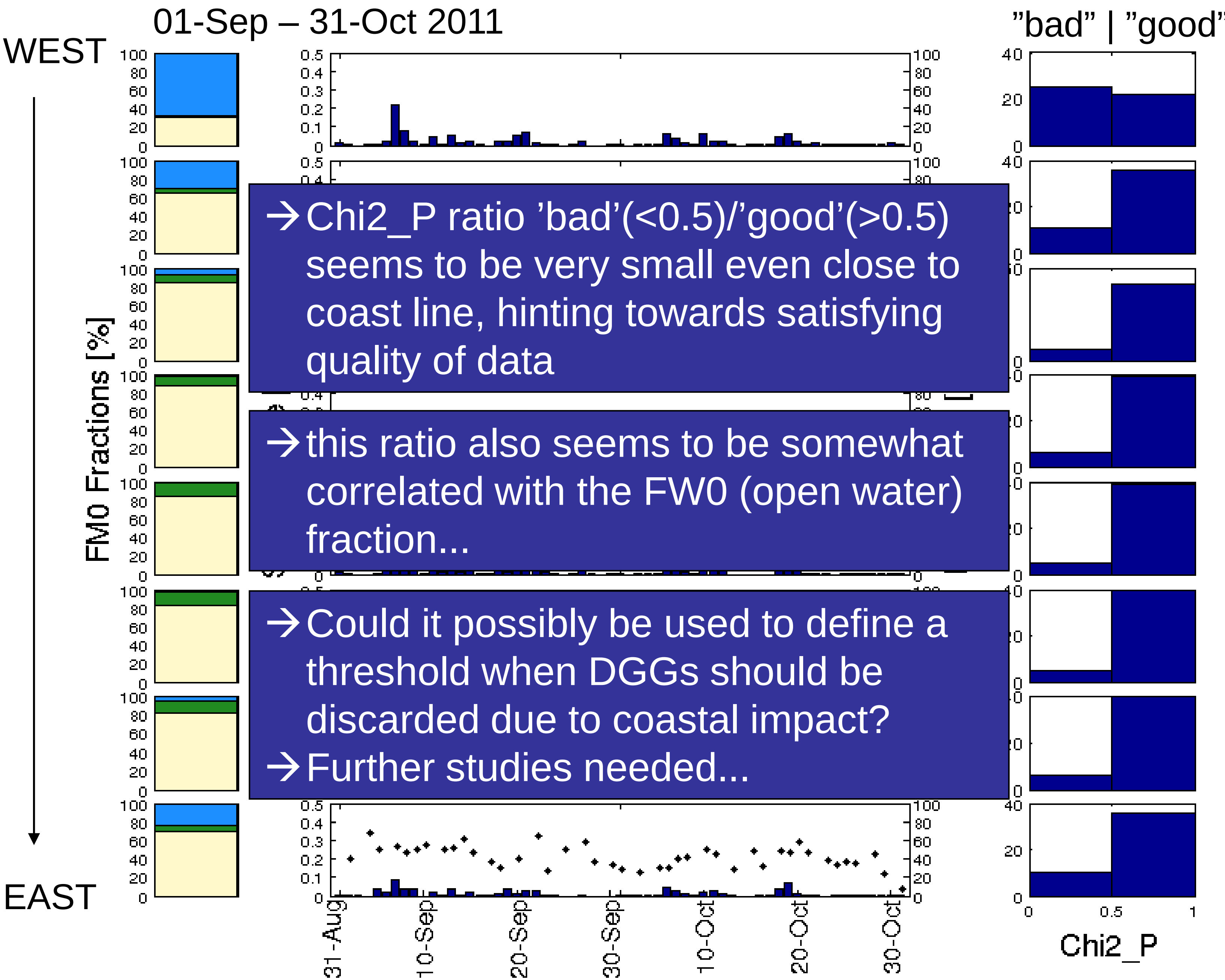


→No retrieval for S_Tree_1 class 2 (FWO = open water)



... in correspondance with significant less noise in SMOS L1C TBs and much smaller RFI_index after mid 2011!

→Hint towards sudden improvement in SMOS data quality (also keep increased number of retrievals in 2011 and decreasing RFI_P in mind...)



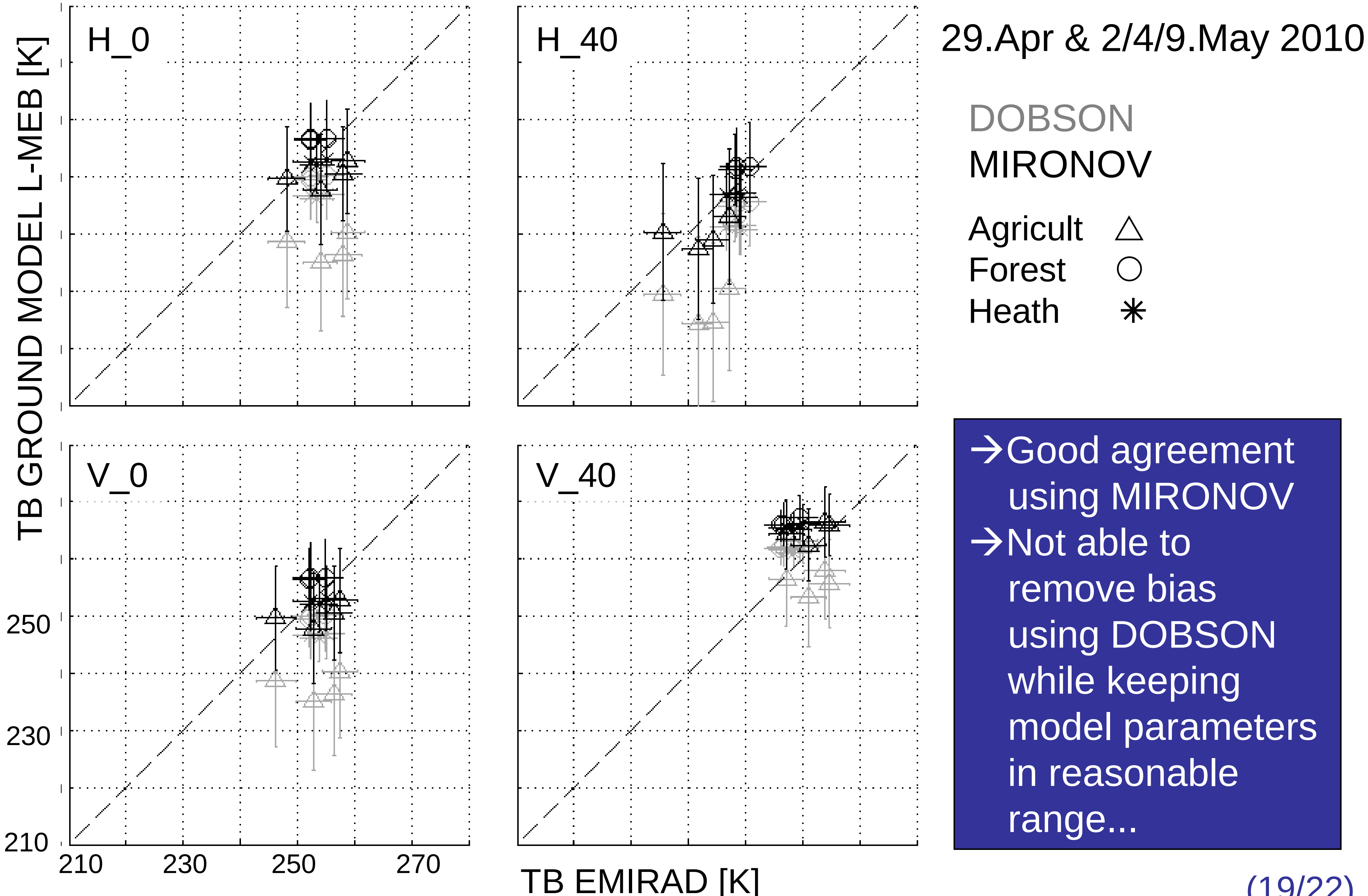
→ Chi2_P ratio ’bad’(<0.5)/’good’(>0.5) seems to be very small even close to coast line, hinting towards satisfying quality of data

→ this ratio also seems to be somewhat correlated with the FW0 (open water) fraction...

→ Could it possibly be used to define a threshold when DGGs should be discarded due to coastal impact?

→ Further studies needed...

Dobson/Mironov: Campaign results model in-situ vs. EMIRAD TB

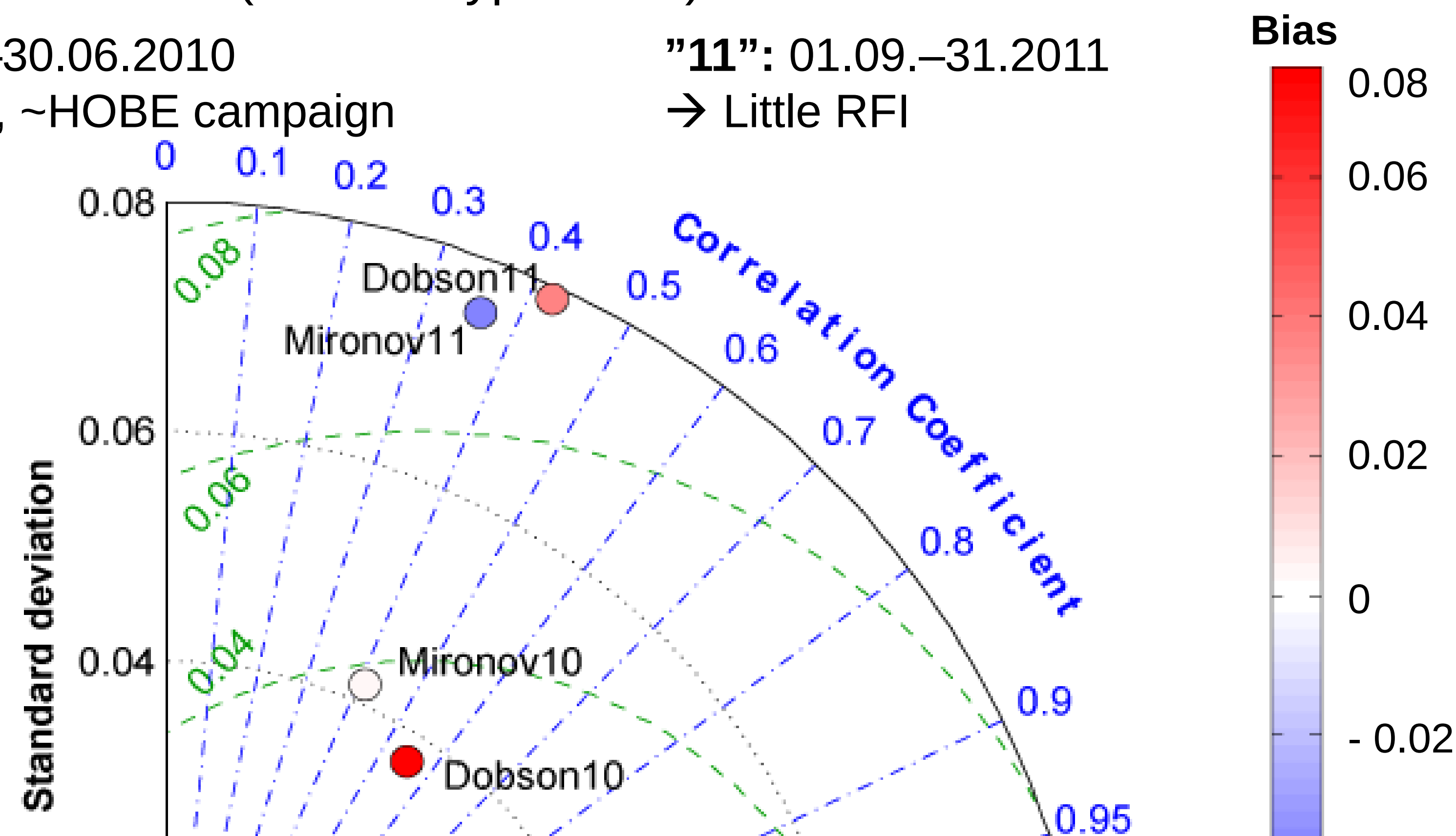


- → Good agreement using MIRONOV
- → Not able to remove bias using DOBSON while keeping model parameters in reasonable range...

Taylor diagramme: SMOS DGG2002029 retrieved ascending soil moisture using Dobson/Mironov (L2 Prototype V551) vs. 0-5cm in situ SM

"10": 01.05.–30.06.2010
→Lots of RFI, ~HOBE campaign

"11": 01.09.–31.2011
→ Little RFI



→R and RMSD not meaningful due to short timespans (cross-check with L2 2.reproc.), but bias shows interesting feature:
in "RFI-polluted" period 2010 Mironov unbiased (0.005 m3/m3), while Dobson clearly too dry (0.076 m3/m3) = in accordance with EMIRAD-in situ model comp.
in "RFI-free" period 2011 Mironov too wet (-0.036 m3/m3), while dry-bias Dobson is halfed (0.036 m3/m3)

SMOS pixel, DGG node 2002029

Soil properties	Sand [%]	Clay [%]	Bulk Density [g/cm3]
SMOS	71	11	0.87
InSitu	~ 89	~3.5	1.23

→SMOS: too low sand-%/bulk density, too high clay-% ?

Roughness parameter HR

SMOS: 0.1

In situ: ~0.6-0.8

→SMOS: too low HR ?

- →Increasing sand-% would dry the system and could potentially lead to a good fit with Mironov in RFI-free periods...
- →Increasing HR could possibly lower the retrieved SMOS Tau which was also found to be higher than in situ data during the campaign
- →More studies over longer timeframes needed!

Conclusions/Outlook

DGG 2002029

- Good agreement SMOS – in situ (R, RMSD), but with distinct SMOS dry bias
- Clear SMOS soil moisture data quality increase from L2 V3 to V4/5 and when applying rfi_index<0.04 filter
- L3 does not seem to have fully reached L2 quality yet

DGG Transect west-east

- West-east soil moisture level increase seems to be unexplicable by geophysical parameters only → explanation?
- Seems less pronounced after mid 2011, in correspondance with less L1C TB noise and decreased RFI probability → sudden improvement in SMOS data quality
- Chi2_P </>0.5 ratio hints to satisfying data quality close to coastline

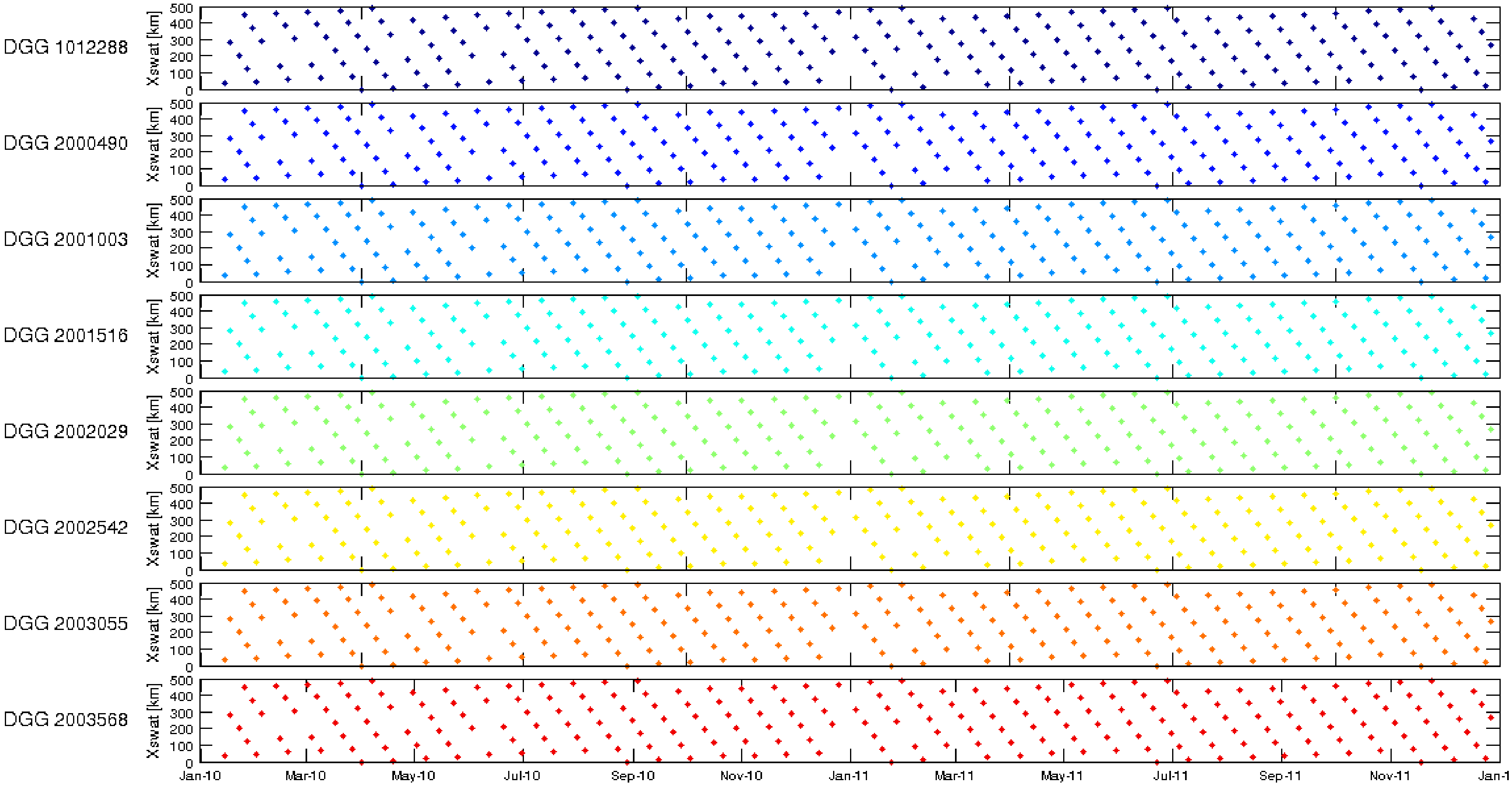
Dobson/Mironov

- During ”RFI-polluted” period bias removed using Mironov, during ”RFI-free” period Mironov too wet, Dobson bias halfed
- However, increasing sand-% and HR could increase soil moisture/lower tau level?

To come: SMOSHiLat – emissions of high latitude organic surface layers


Thank you very much for your attention...
...questions?

DGG Transect – X_Swath



→ for all DGGs equal, no anomalies detectable...

Results SMOS compared to in situ

(Bircher et al. 2010, 2012a, 2012b, 2013)

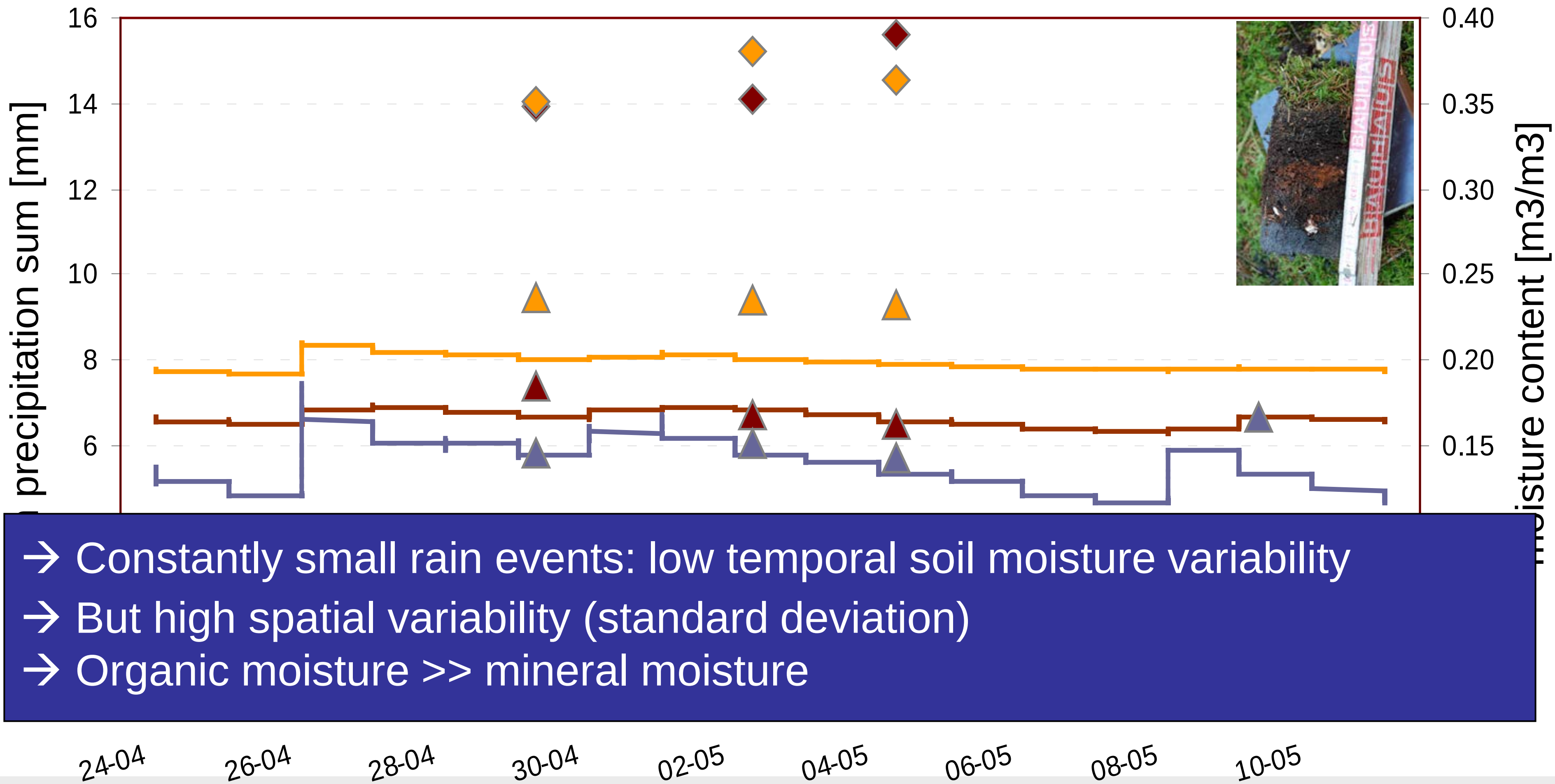
		Campaign short-term	Network long-term
TB L1C		offset	
Soil moisture	initial		clear trend,higher
	retrieved		clear trend,lower
		clear trend,same range	
Tau	initial	trend,higher,noisy	
	retrieved		
		lower	
HR			clear trend,same range
Surface temp.		lower	lower
Sand-%		higher	higher
Clay-%		lower	lower
Bulk density		Mironov better Dobson	
Dielectr. mixing model		(2x2km scale)	

Campaign 0-5 cm soil moisture

Theta probe recalibrated
(patch avg.)

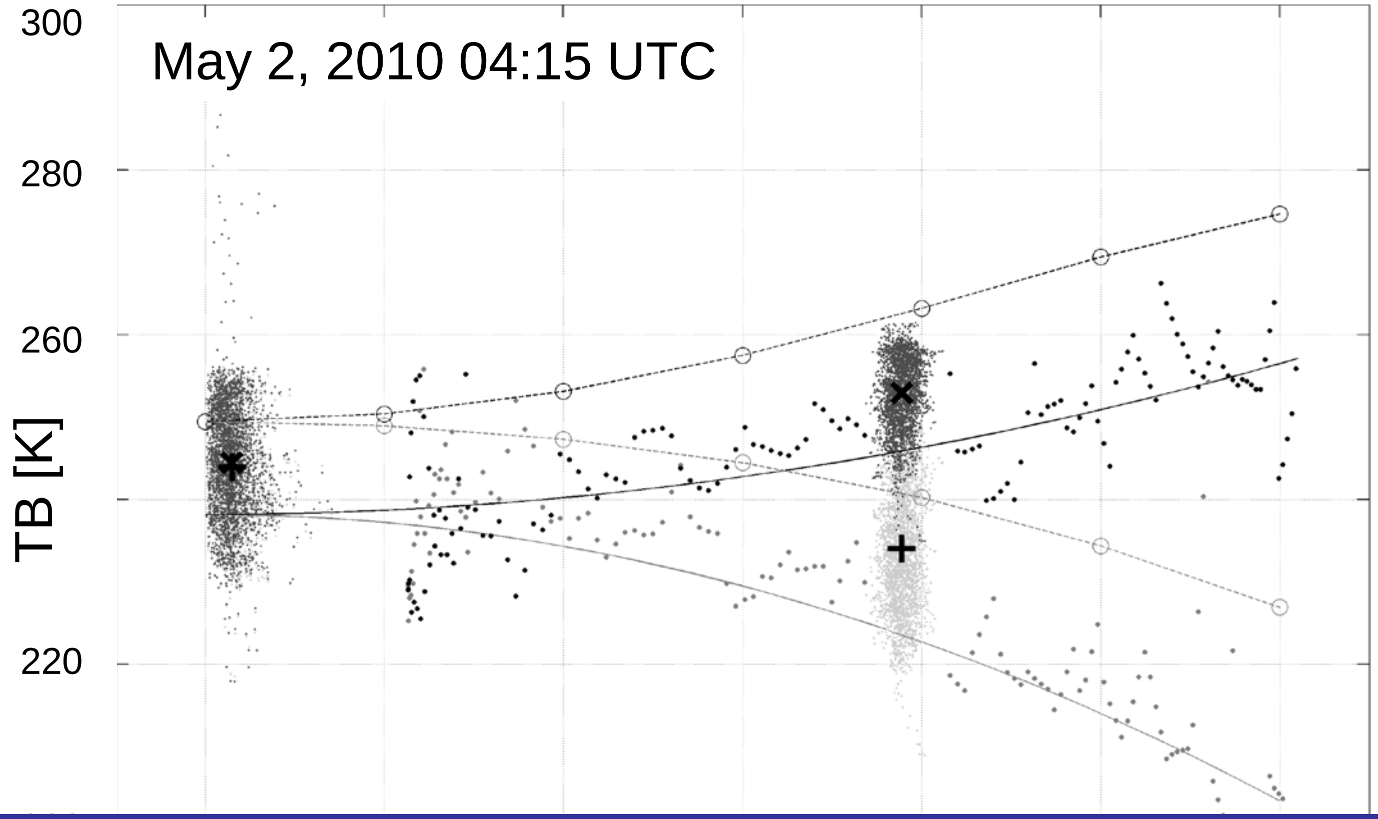
Decagon 5TE
(1 network station within patch)

	Forest	(std)	Heath		Agriculture	
Mineral	▲	(0.081)	▲	(0.111)	▲	(0.037)
Organic	◆	(0.126)	◆	(0.163)		



→ Constantly small rain events: low temporal soil moisture variability
→ But high spatial variability (standard deviation)
→ Organic moisture >> mineral moisture

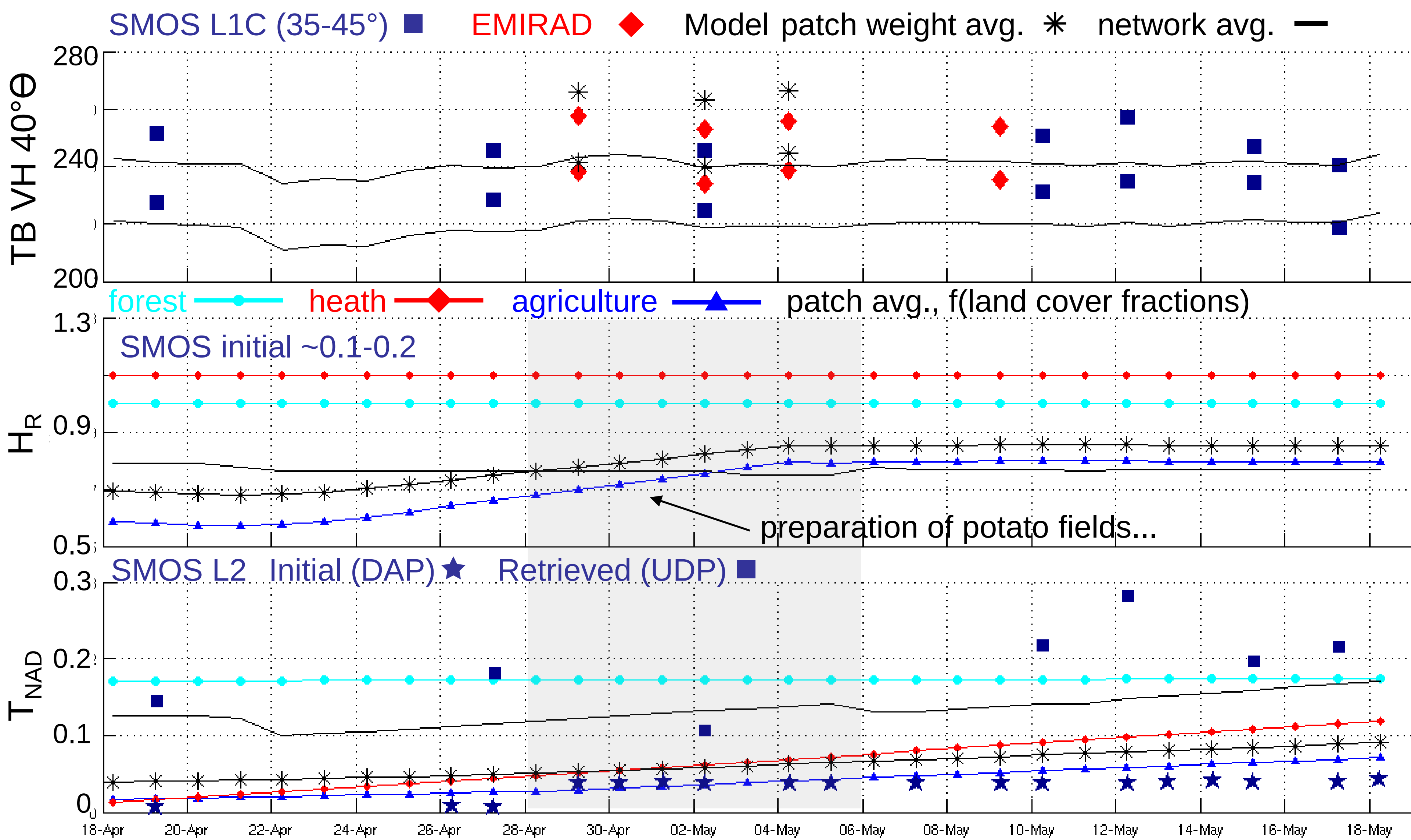
Campaign results: Avg. In situ vs. EMIRAD vs. SMOS L1C TB



- →EMIRAD in comparable range with SMOS L1C, small positive bias
- →Mean modeled TBs distinct positive bias
- →Partly scale effects: patch data 'dry' sandy conditions only
- →Advantage of step-wise comparison, BUT only one campaign date without SMOS RFI-contamination...

Campaign results: TB, H_R, T_{NAD} 18.Apr.–18.May 2010

FMO fractions (L2 DAP): 84. 1% FNO → S_TREE_1 (L2 UDP): 12

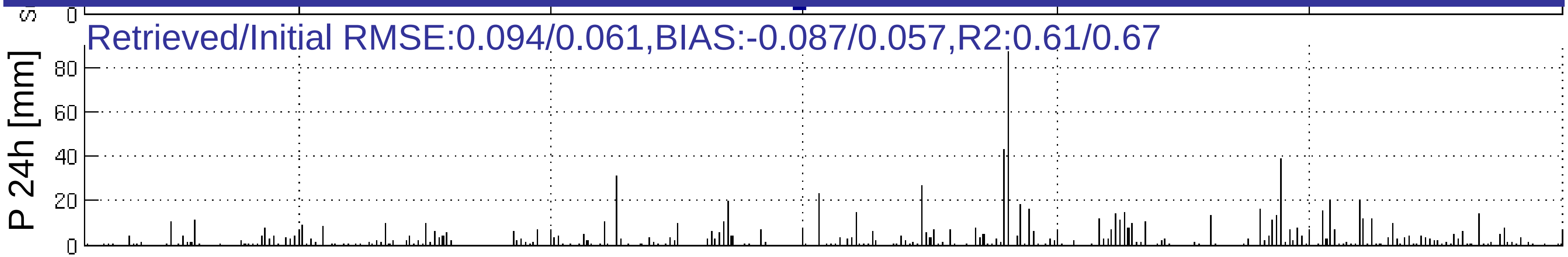


Network results: soil moisture, precipitation, temp. Jan-Dec 2010

NW avg 0-5cm SM   Temp.   SMOS L2Initial, ECMWF   SMOS retrieved

→ Very good agreement between in-situ 0-5cm T and SMOS initial surface T

→ No significant uncertainties expected from this parameter...



→ Precipitation seems to be reflected in soil moisture data

→ R^2 values confirm clear trend between SMOS and in-situ SM data, with a tendency of SMOS to overestimate the dynamics

→ Positive/negative bias between SMOS intitial/retrieved & in-situ data

Results: SMOS soil moisture - modeled soil moisture Teuling (avg. Voulund & Gludsted) and Daisy (avg. V&G and avg. all stations)

	Teuling avg V&G			Daisy avg V&G			avg all stations		
	R	RMSE	BIAS	R	RMSE	BIAS	R	RMSE	BIAS [m3/m3]
-1cm	0.52	0.085	-0.050	0.82	0.073	-0.062	0.83	0.084	-0.075
-2cm	0.63	0.078	-0.060	0.83	0.074	-0.064	0.83	0.085	-0.076
-3cm	0.72	0.080	-0.065	**0.84**	0.074	-0.064	**0.84**	0.085	-0.077
-4cm	0.78	0.083	-0.068	**0.84**	0.074	-0.064	0.83	0.086	-0.077
-5cm	**0.80**	0.085	-0.070	**0.84**	0.074	-0.064	0.83	0.086	-0.077
-6cm	0.79	0.086	-0.071	0.82	0.095	-0.086	0.82	0.101	-0.093
-7cm	0.77	0.088	-0.072	0.82	0.095	-0.086	0.82	0.101	-0.093
-8cm	0.74	0.089	-0.073	0.82	0.095	-0.086	0.82	0.101	-0.093
-9cm	0.71	0.090	-0.073	0.82	0.096	-0.086	0.82	0.101	-0.093
-10cm	0.68	0.090	-0.074	0.82	0.096	-0.086	0.81	0.102	-0.093

SMOS – in situ: R: 0.84, RMSE: 0.086 m3/m3, BIAS: -0.077 m3/m3

→ Best correlation between SMOS and modeled soil moisture at 3-5cm depth, statistics remain in same range as for SMOS - in situ data comparison

→ As average Voulund/Gludsted drier than overall network average: deeper layer corresponding best with SMOS data, dry bias slightly reduced

→ Teuling gives ’clearer’ picture: more variation between results of different layers