# SMOS validation results from the HOBE site, Denmark

Simone Bircher, Philippe Richaume, Arnaud Mialon, Lucie Berthon, François Cabot, Al Bitar Ahmad, Olivier Merlin, Jean-Pierre Wigneron, Jan Balling, Niels Skou, et al.

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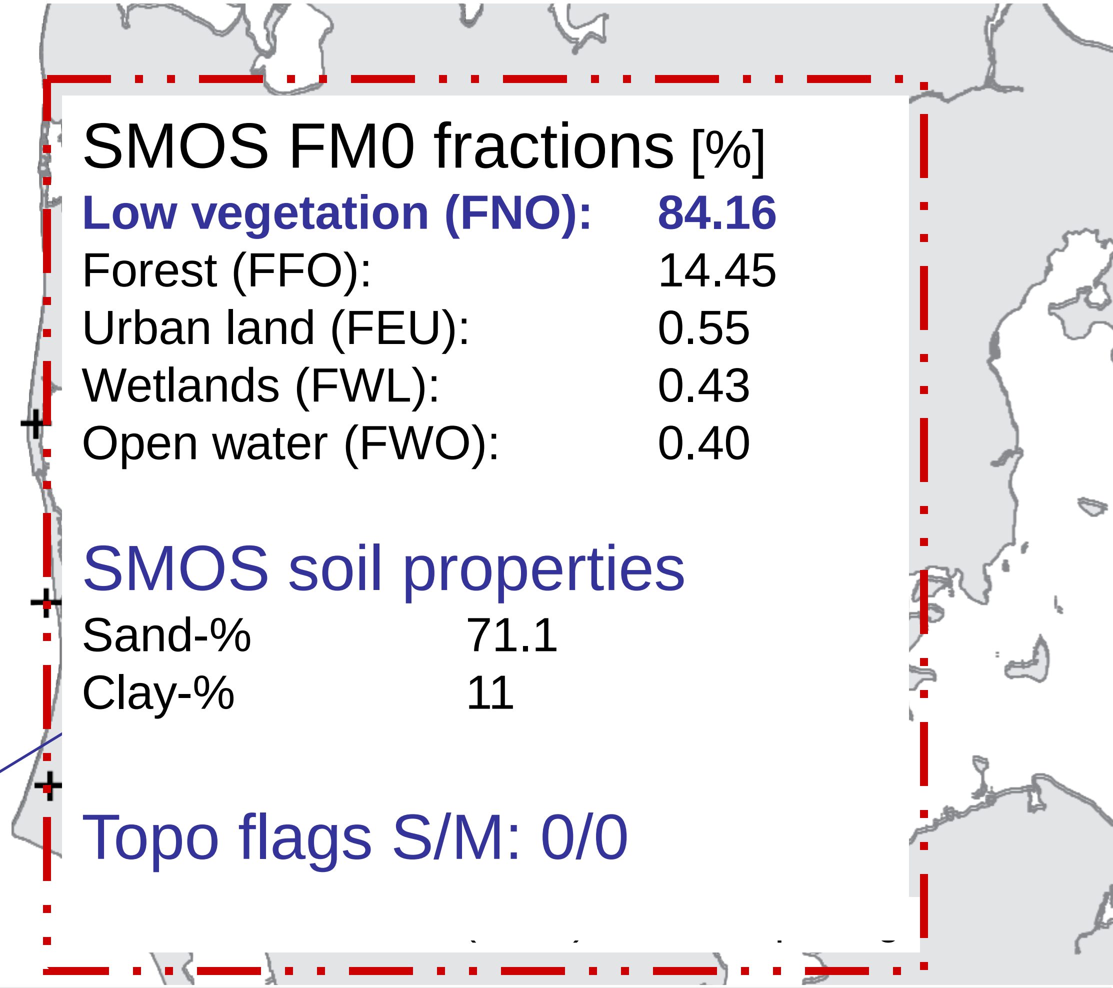
**SMOS Land Applications WORSHOP, 25-27 February 2013, ESRIN, Frascati, Italy**

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

HOBE 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 |

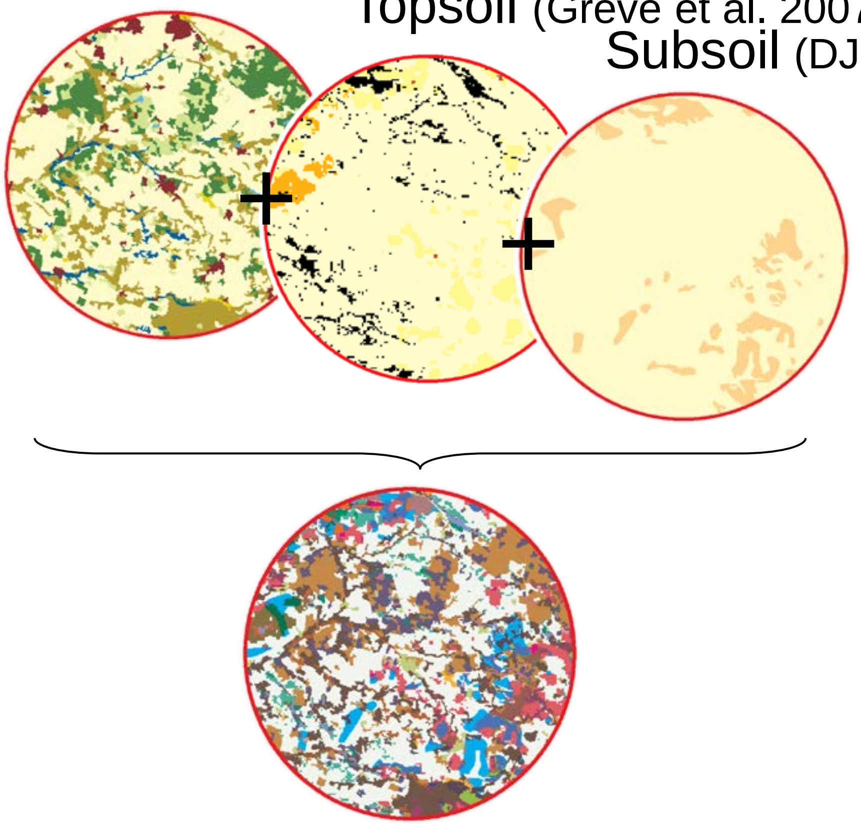
## Topo flags S/M: 0/0

SMOS antenna weighting pattern

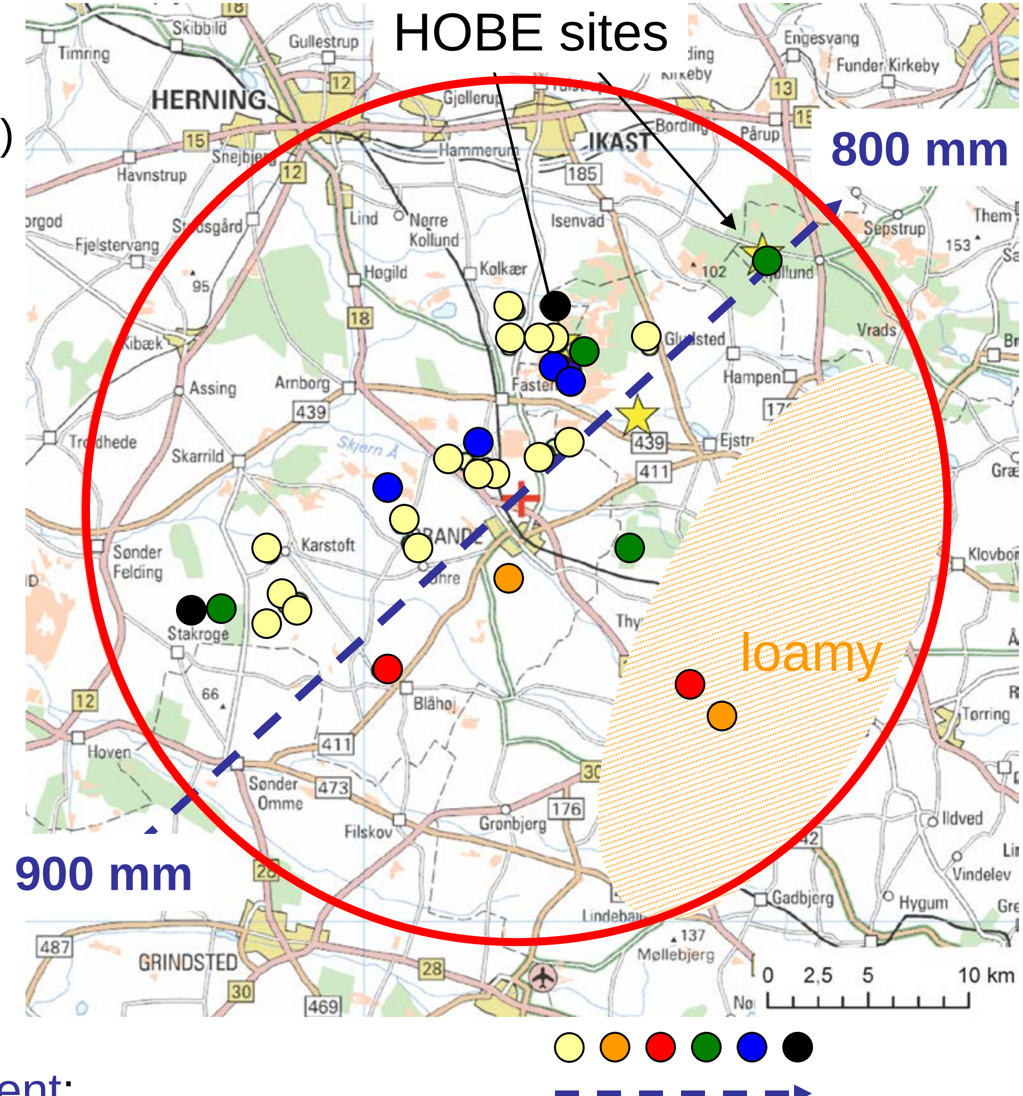
# Soil moisture & temperature network, 30 stations: since Jan 2010

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

Land cover (CORINE2000)
Topsoil (Greve et al. 2007)
Subsoil (DJF)



6 composite classes = 82%



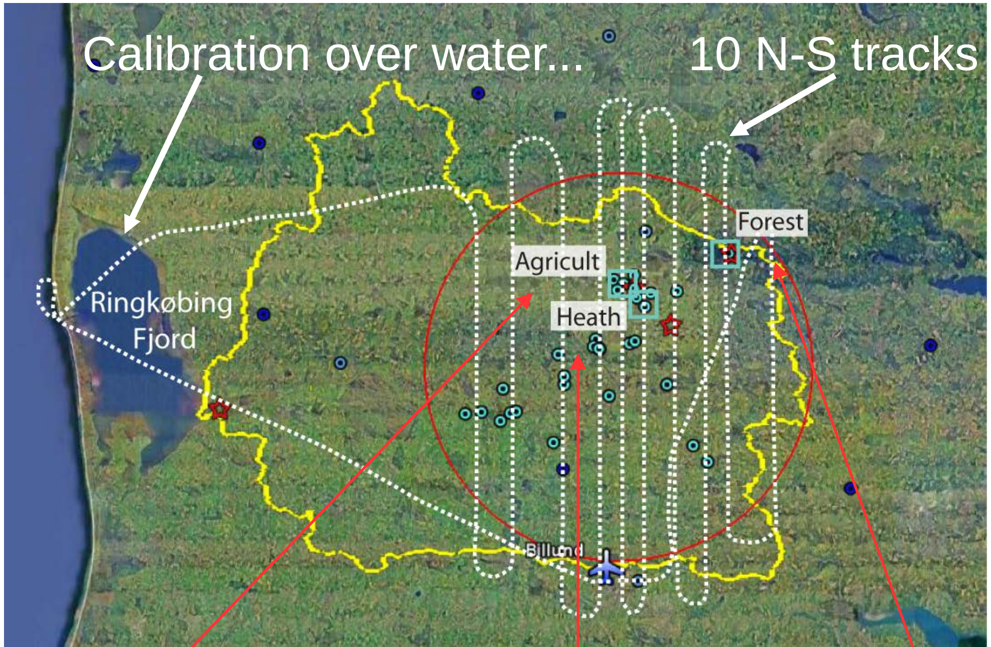

→ stations distributed accordingly...

→ aligned along long-term precip. gradient:

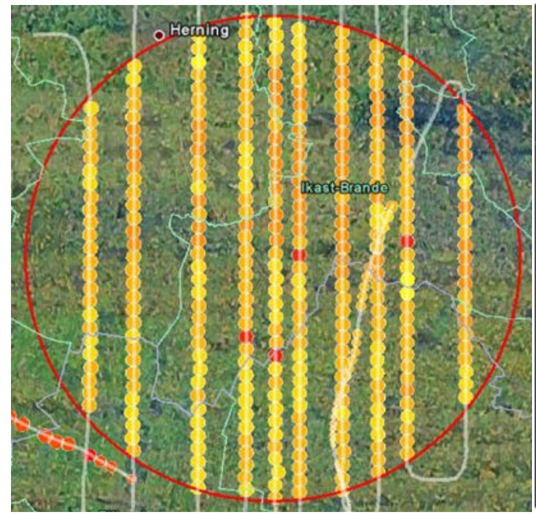
→also covering more loamy area in south-east

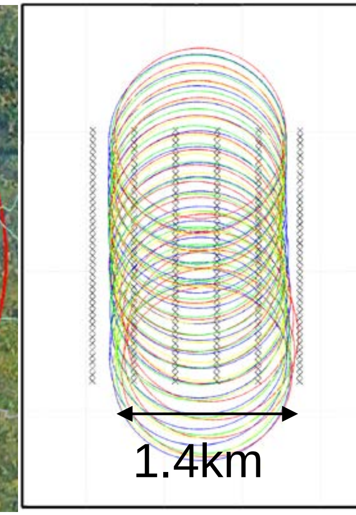
# Airborne Campaign: 26. April – 10. May 2010

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




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

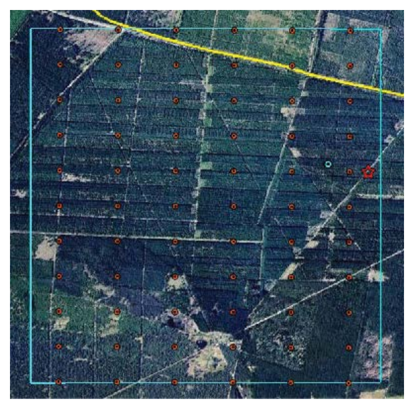




Agriculture

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...

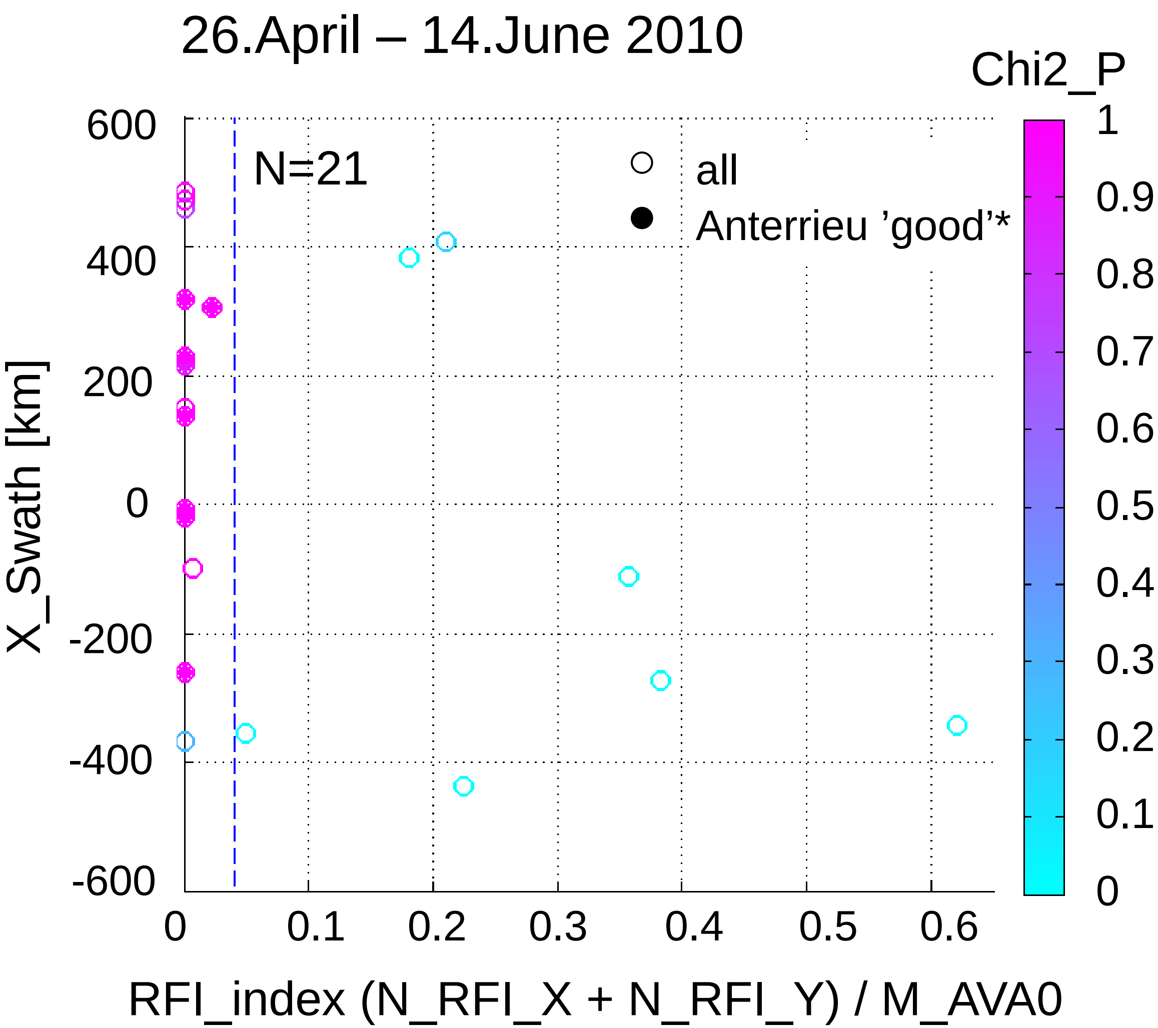
→ Overview of this talk

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



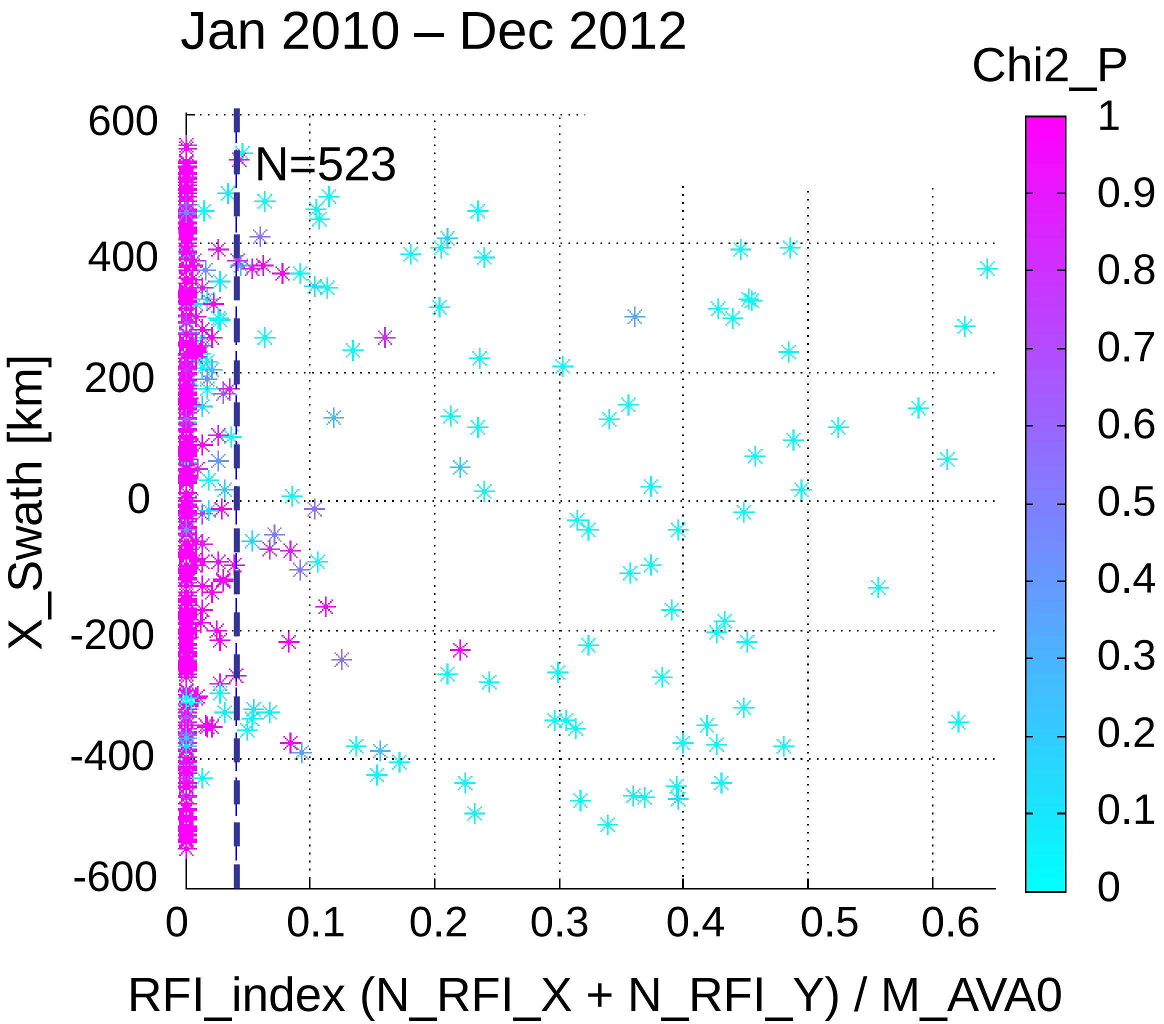

*RFI detection scheme L1A (Anterrieu 2011):

→X/Y snapshots RFI <50%

→total nr. X/Y snapshots >110

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

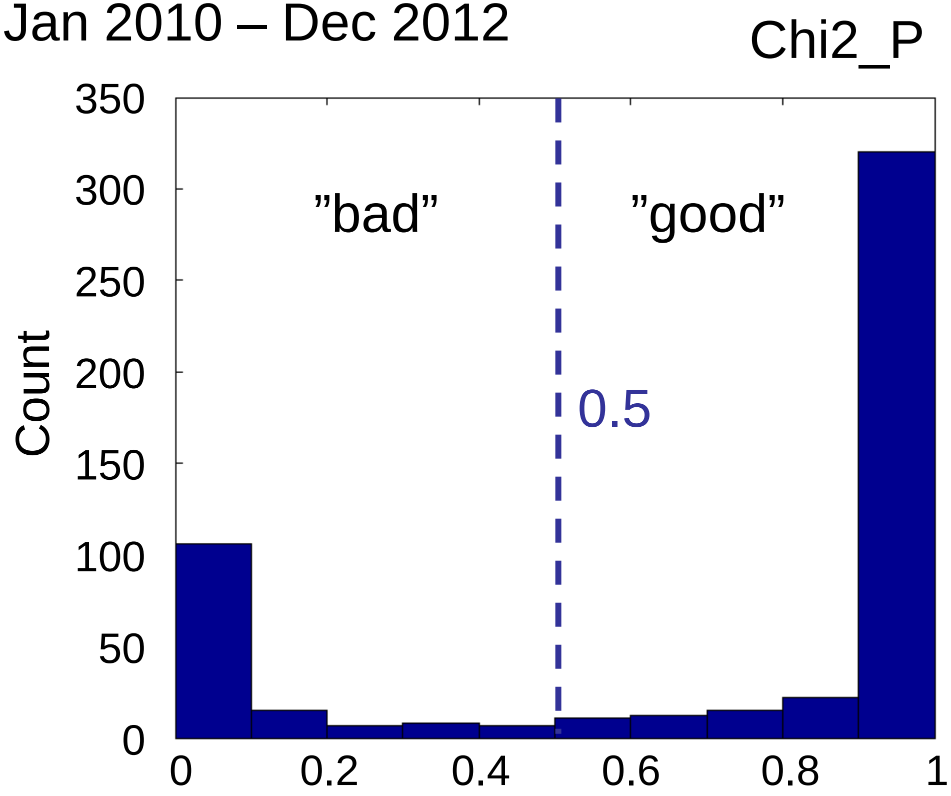
# SMOS data filtering – selected data quality indicators

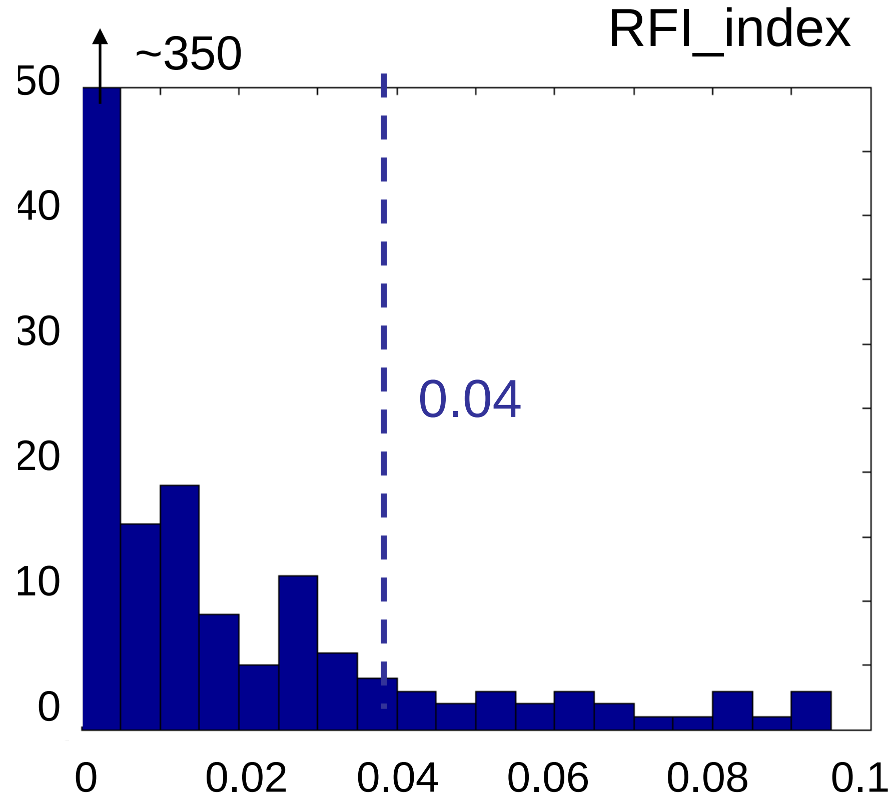



Generally:
- Small RFI_index = high Chi2_P
- High Chi2_P over entire X_Swath

→ Define RFI_index threshold for filtering...

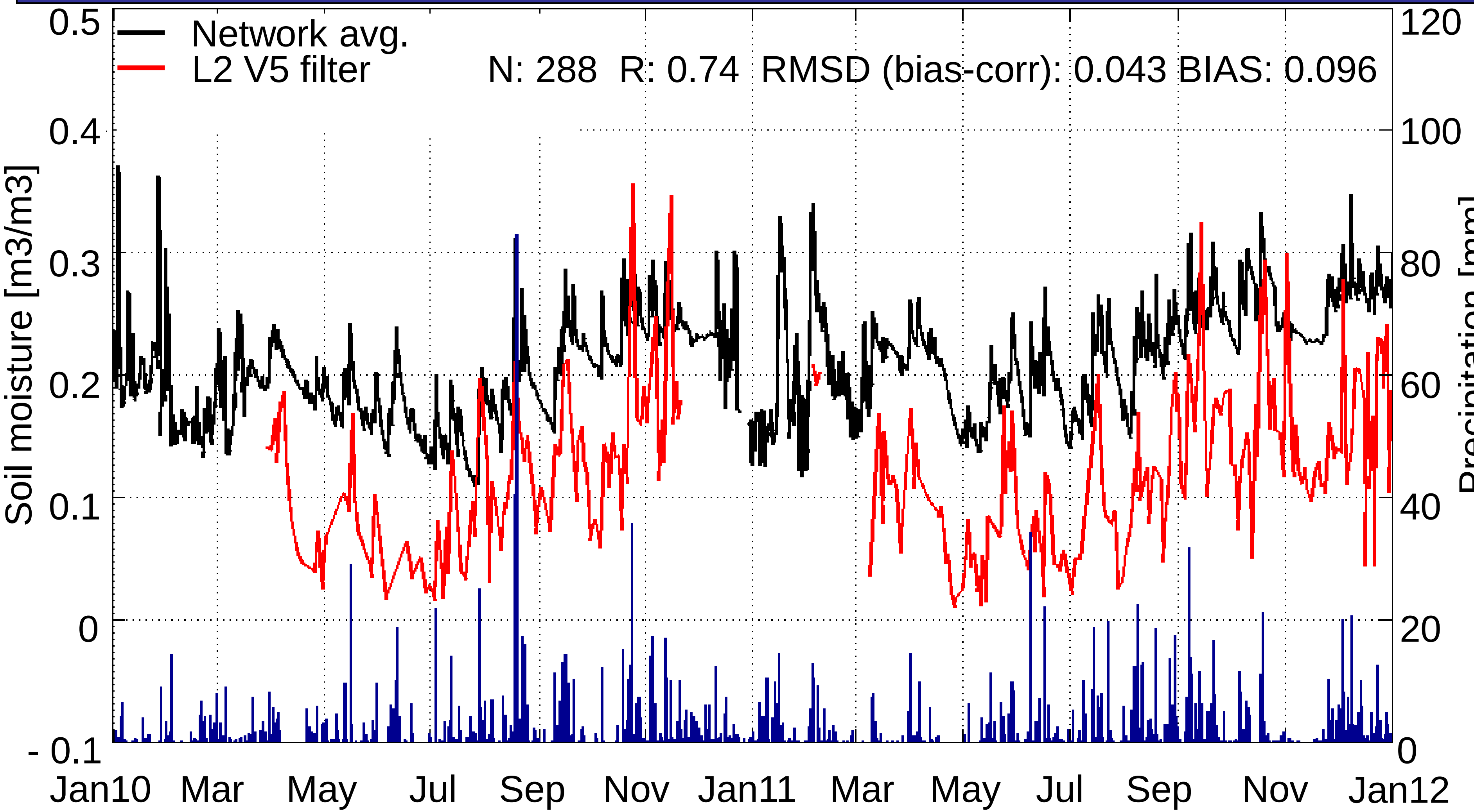
## Jan 2010 – Dec 2012



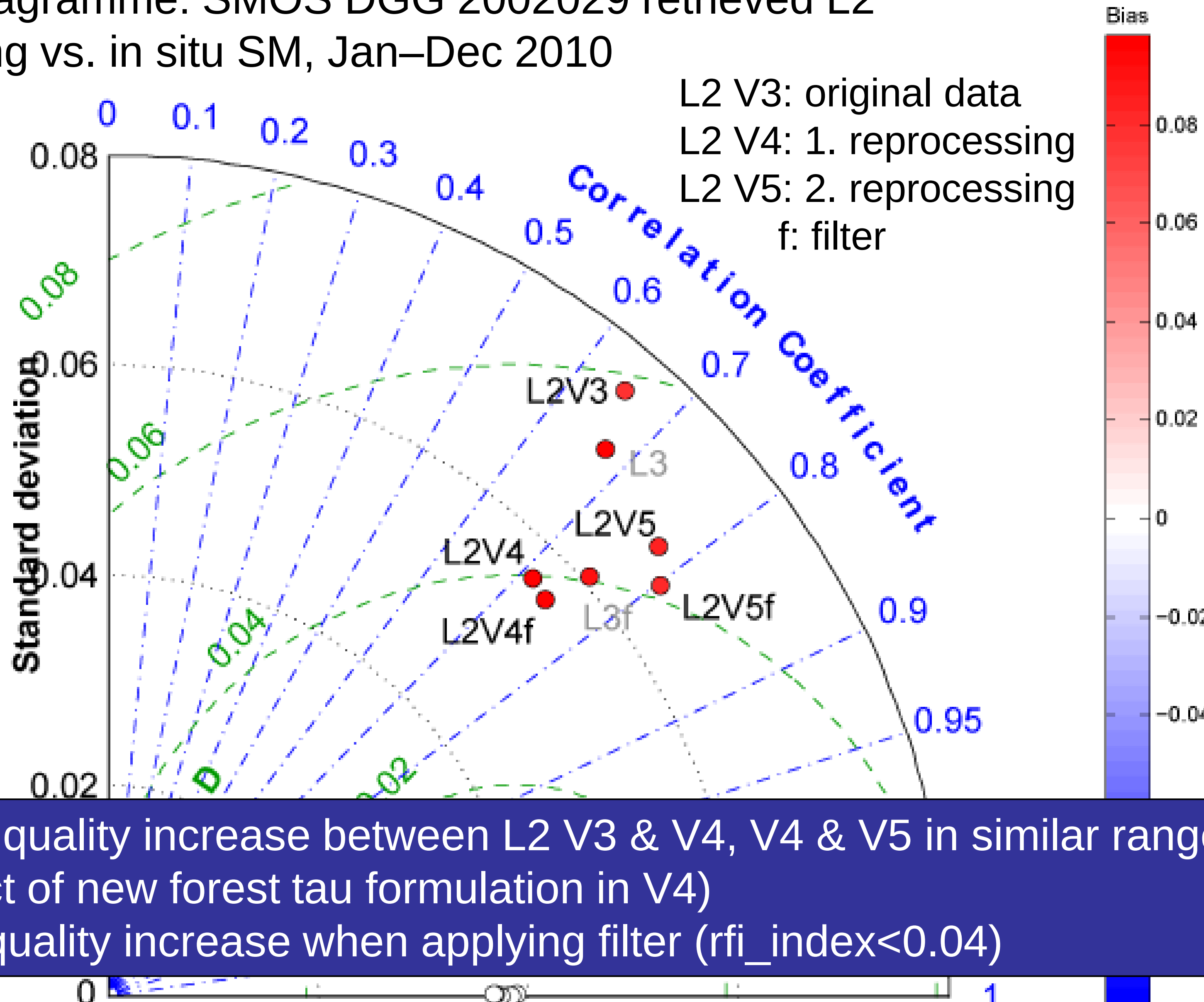

| Classification [%] | 26.Apr-14.Jun2010 | | | Jan2010-Dec2012 | | |
|---|---|---|---|---|---|---|
| | T=0.03 | T=0.04 | T=0.05 | T=0.03 | T=0.04 | T=0.05 |
| RFIX<T:Correct(Chi2P>0.5) | 92.9 | 92.9 | 86.7 | 88.4 | 87.7 | 87.7 |
| Wrong(Chi2P<0.5) | 7.1 | 7.1 | 13.3 | 11.6 | 12.3 | 12.9 |
| RFIX>T:Correct(Chi2P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

L2 V3: original data
L2 V4: 1. reprocessing
L2 V5: 2. reprocessing
f: filter

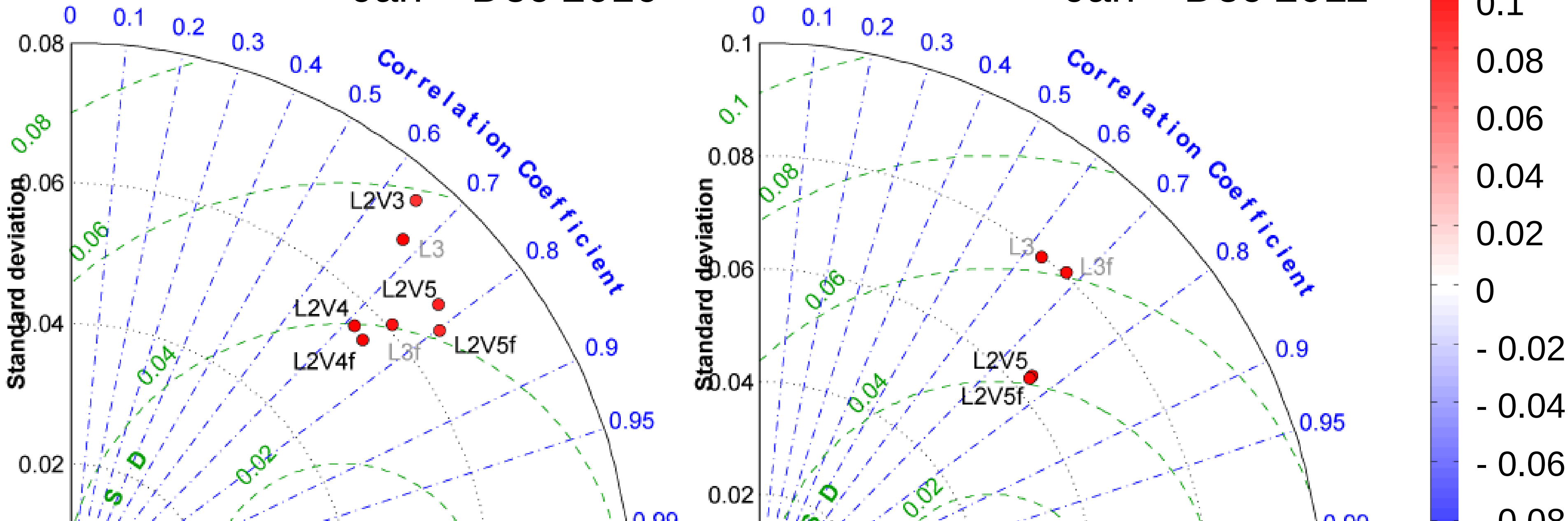



→Clear quality increase between L2 V3 & V4, V4 & V5 in similar range (high impact of new forest tau formulation in V4)
→Also quality increase when applying filter (rfi_index<0.04)

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

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

Jan – Dec 2010 | Jan – Dec 2011 | **Bias**




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

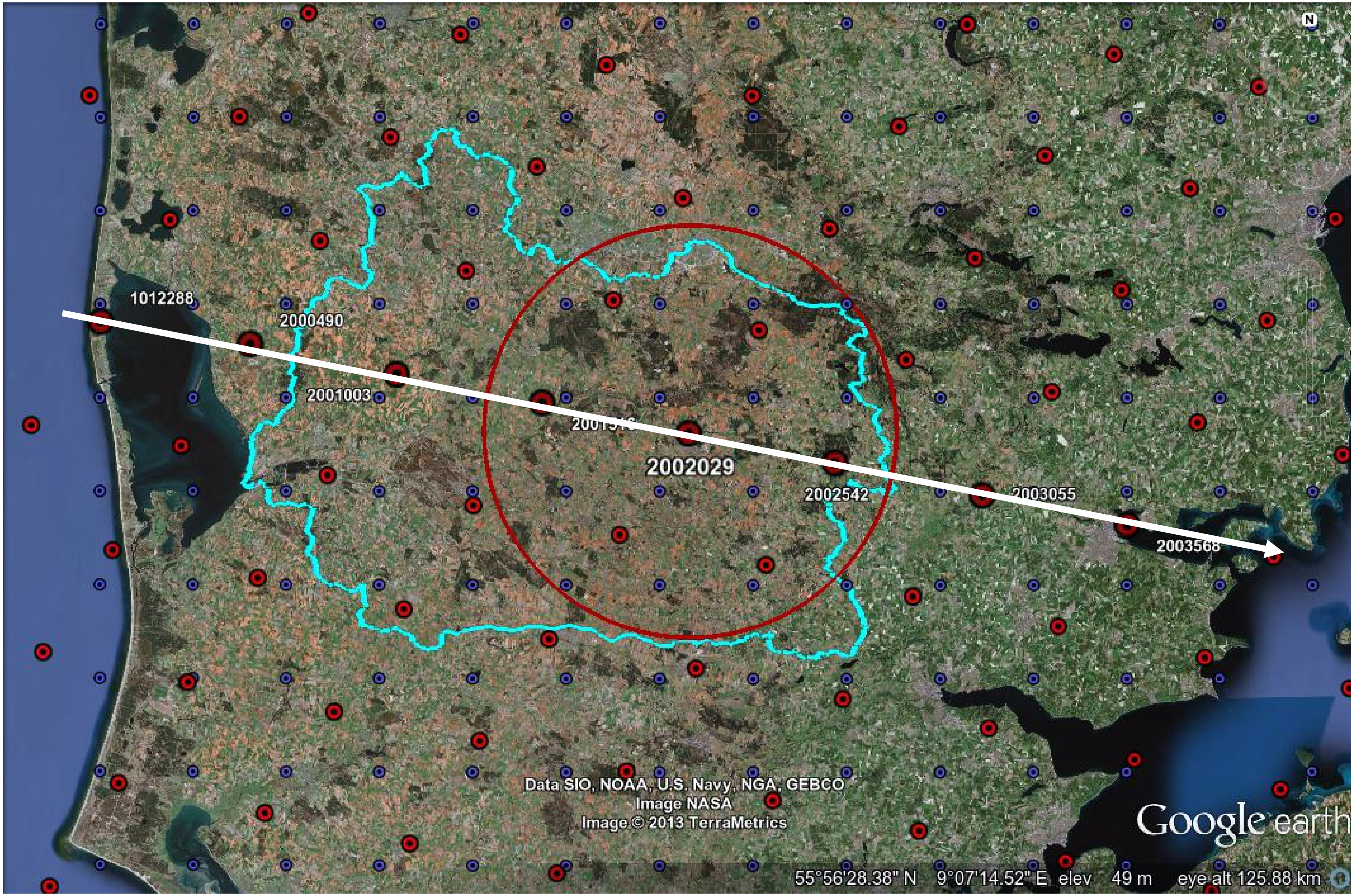
Number of retrievals

| | all | filtered |
|---|---|---|
| L2V3 | 106 | |
| L3 | 148 | 108 |

| | all | filtered |
|---|---|---|
| L3 | 208 | 197 |

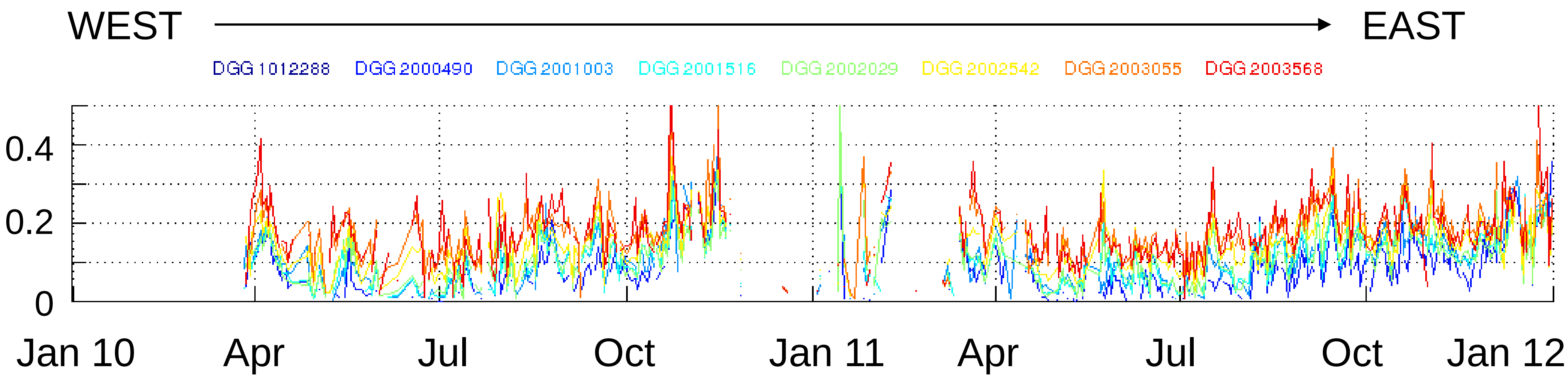
→ in 2011 L3 clearly less good, while L2 stays in a similar range as in 2010 - however, decreasing network quality!

# SMOS DGG transect west – east coast

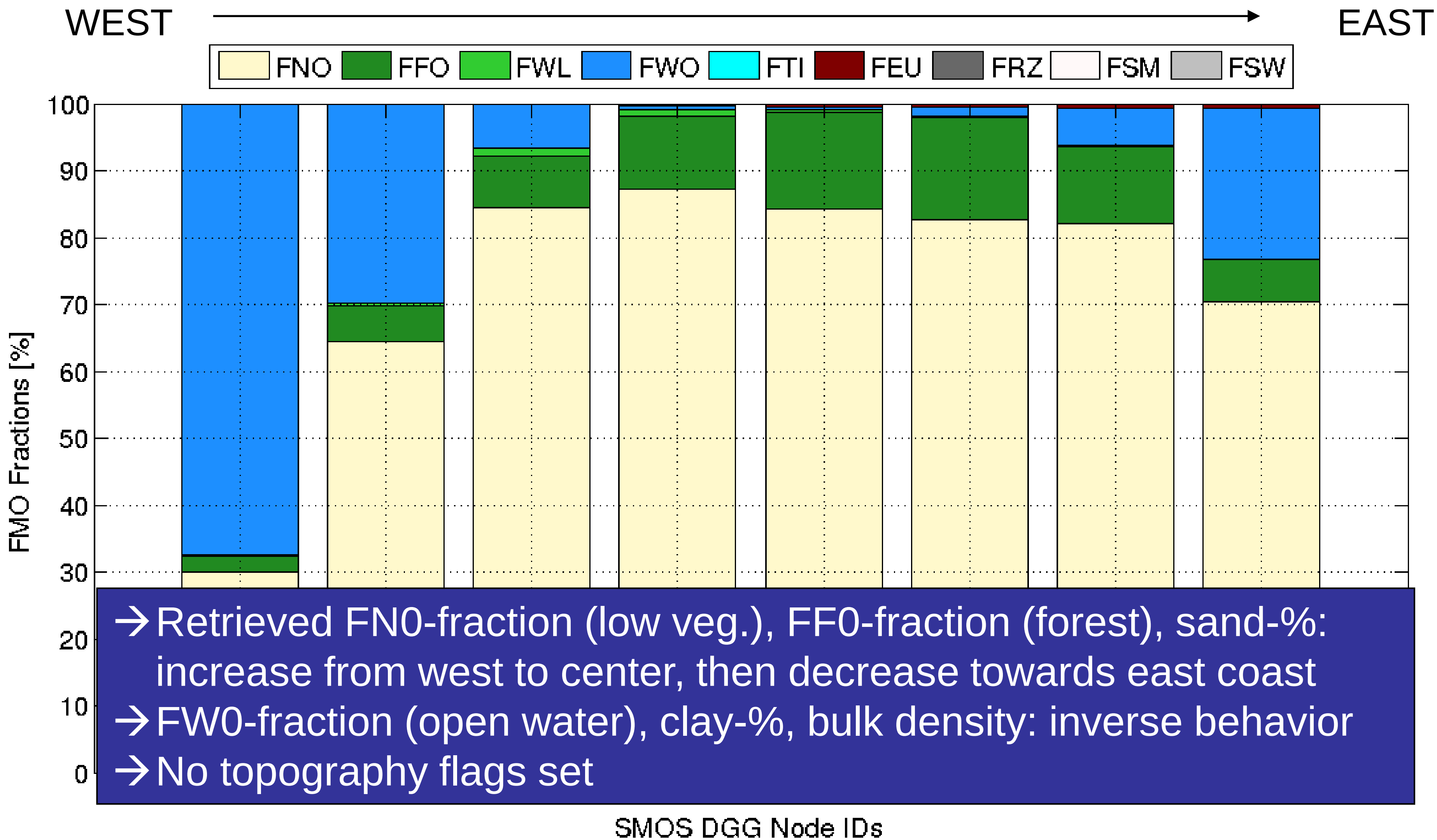



SMOS DGG nodes    10km precipitation grid (Danish Meteorological Institute)

Retrieved L2 SMOS soil moisture [m³/m³], Jan 2010 – Dec 2011

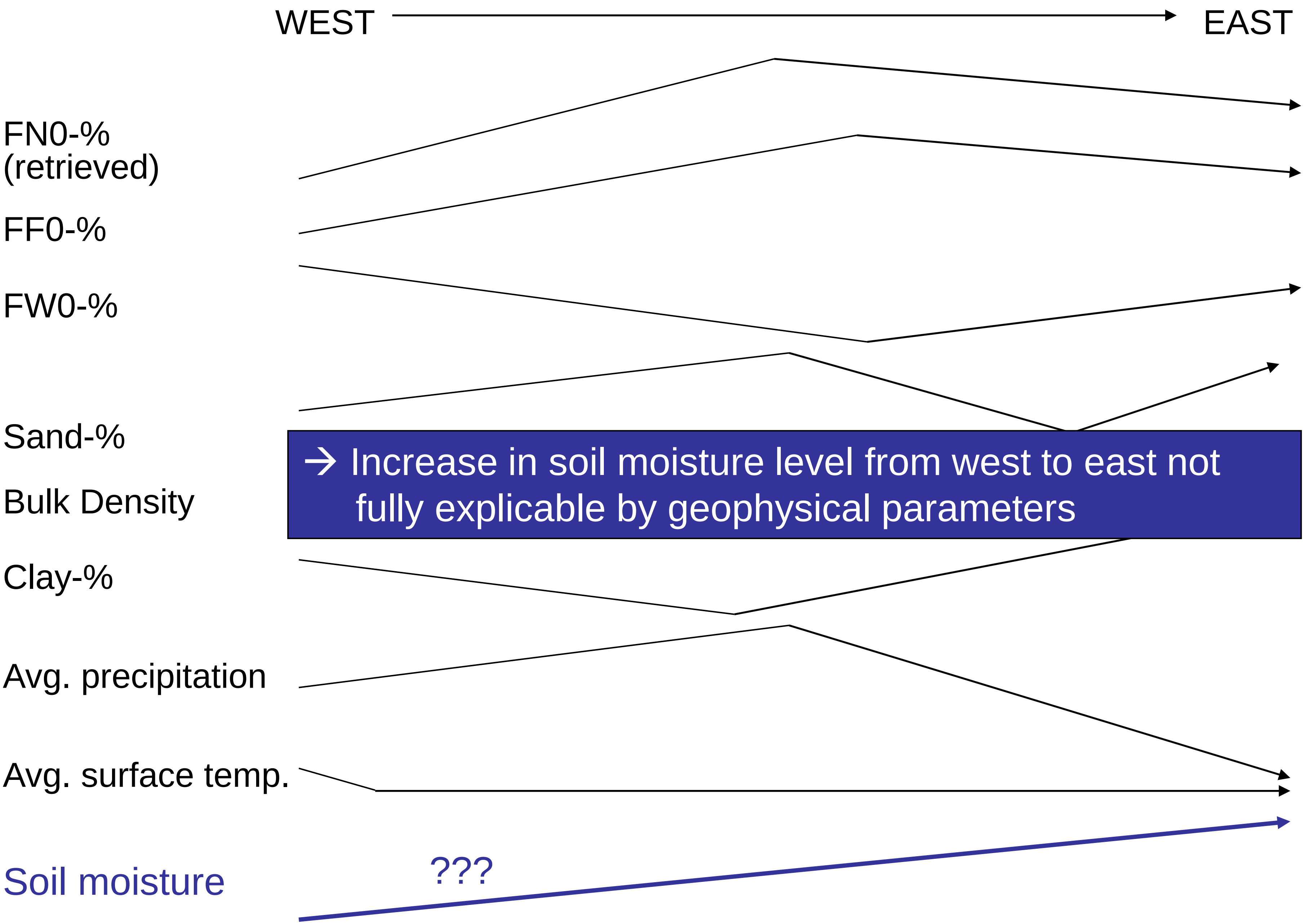



→ Increase in soil moisture level from west to east...



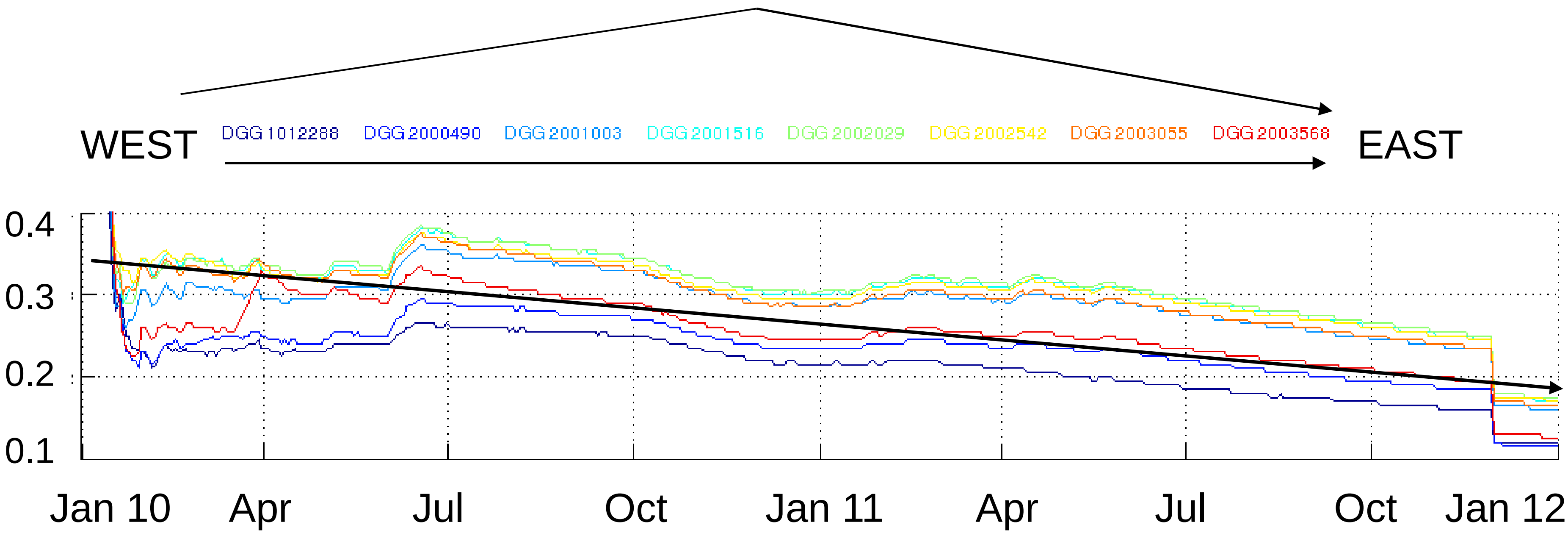

- → Retrieved FN0-fraction (low veg.), FF0-fraction (forest), sand-%: increase from west to center, then decrease towards east coast
- → FW0-fraction (open water), clay-%, bulk density: inverse behavior
- → No topography flags set

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 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 |



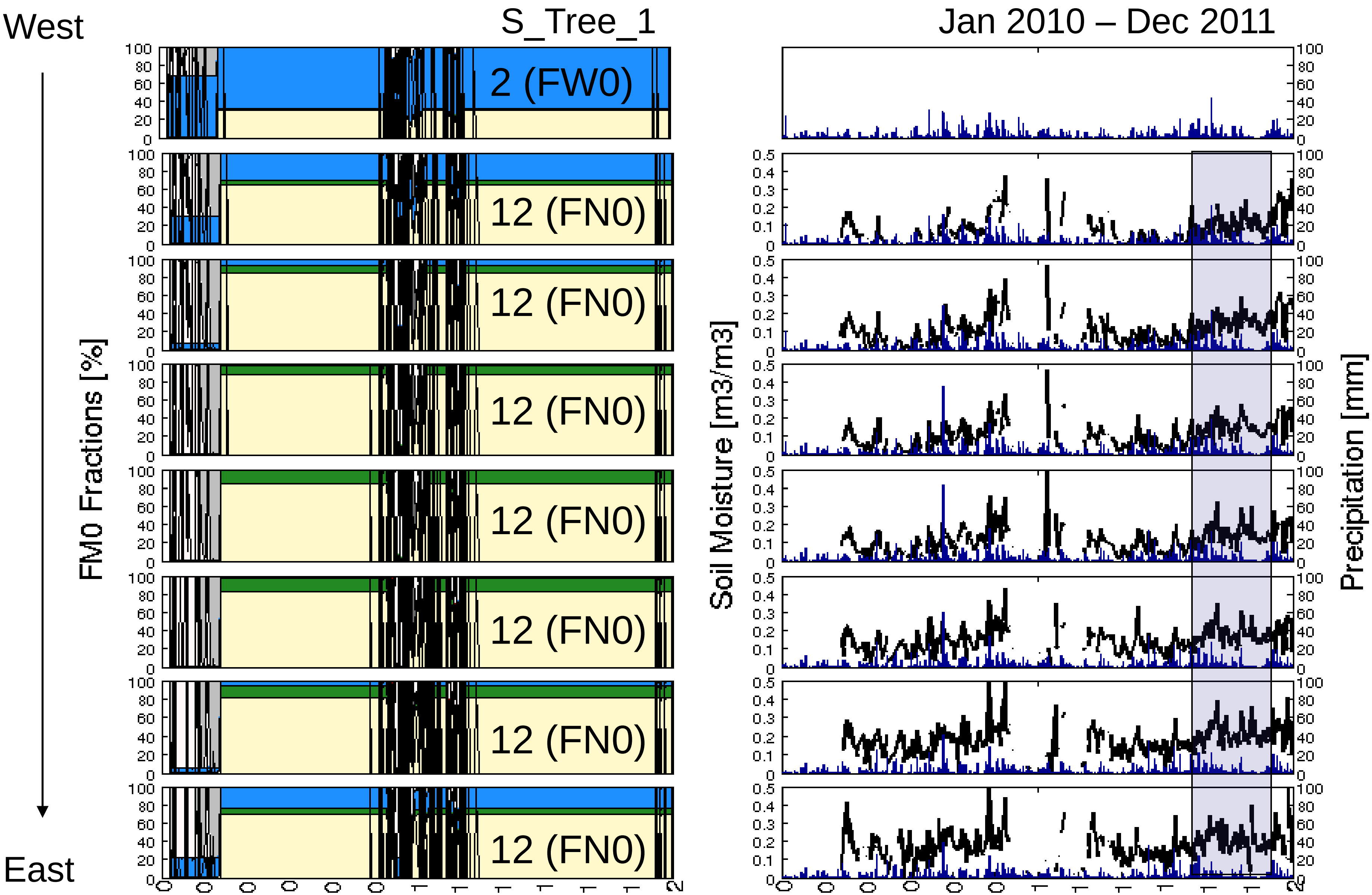

→ Increase in soil moisture level from west to east not fully explicable by geophysical parameters

# 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

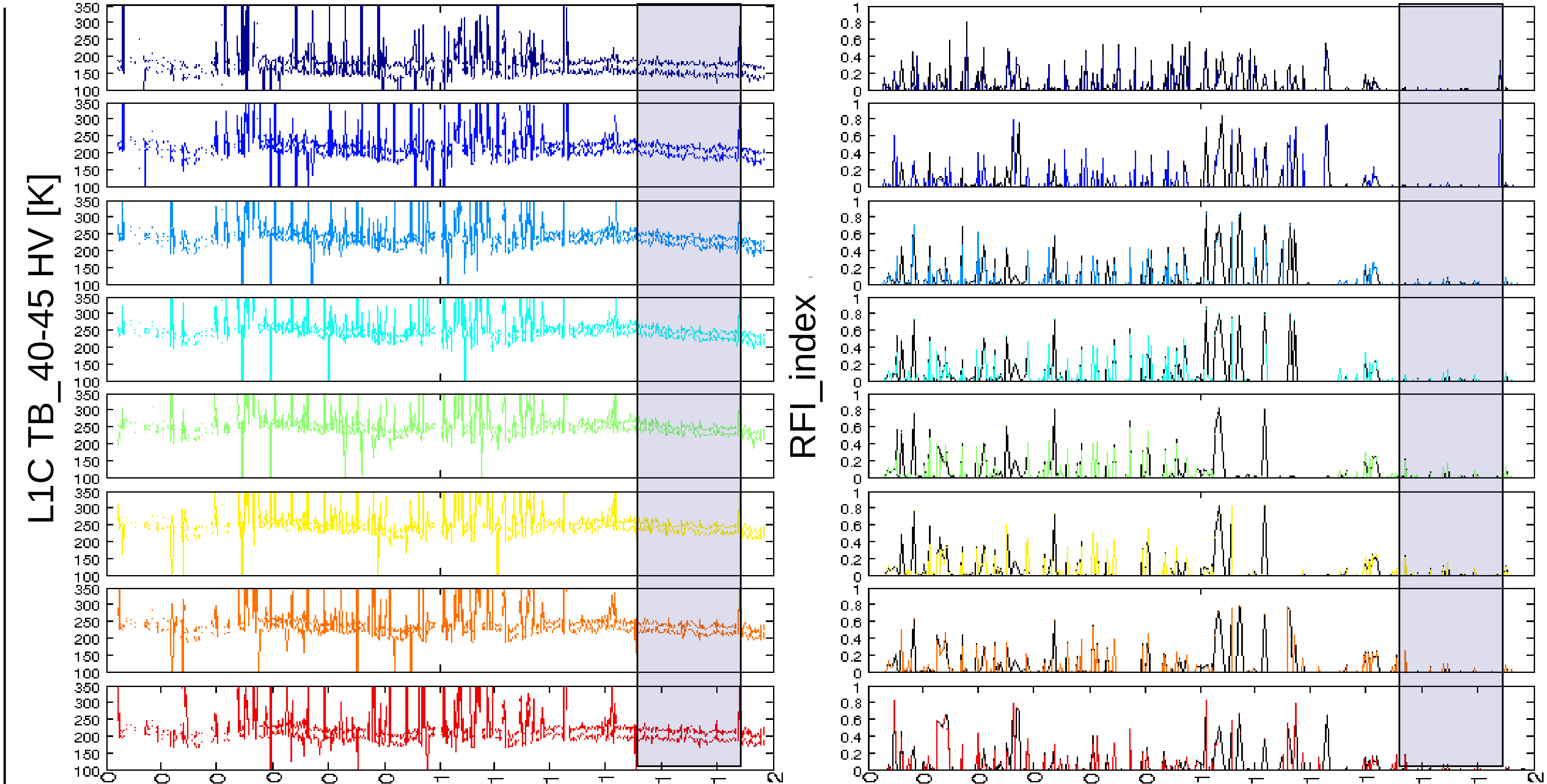
→ However, clear decreasing trend in RFI prob. over time for all DGGs!




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

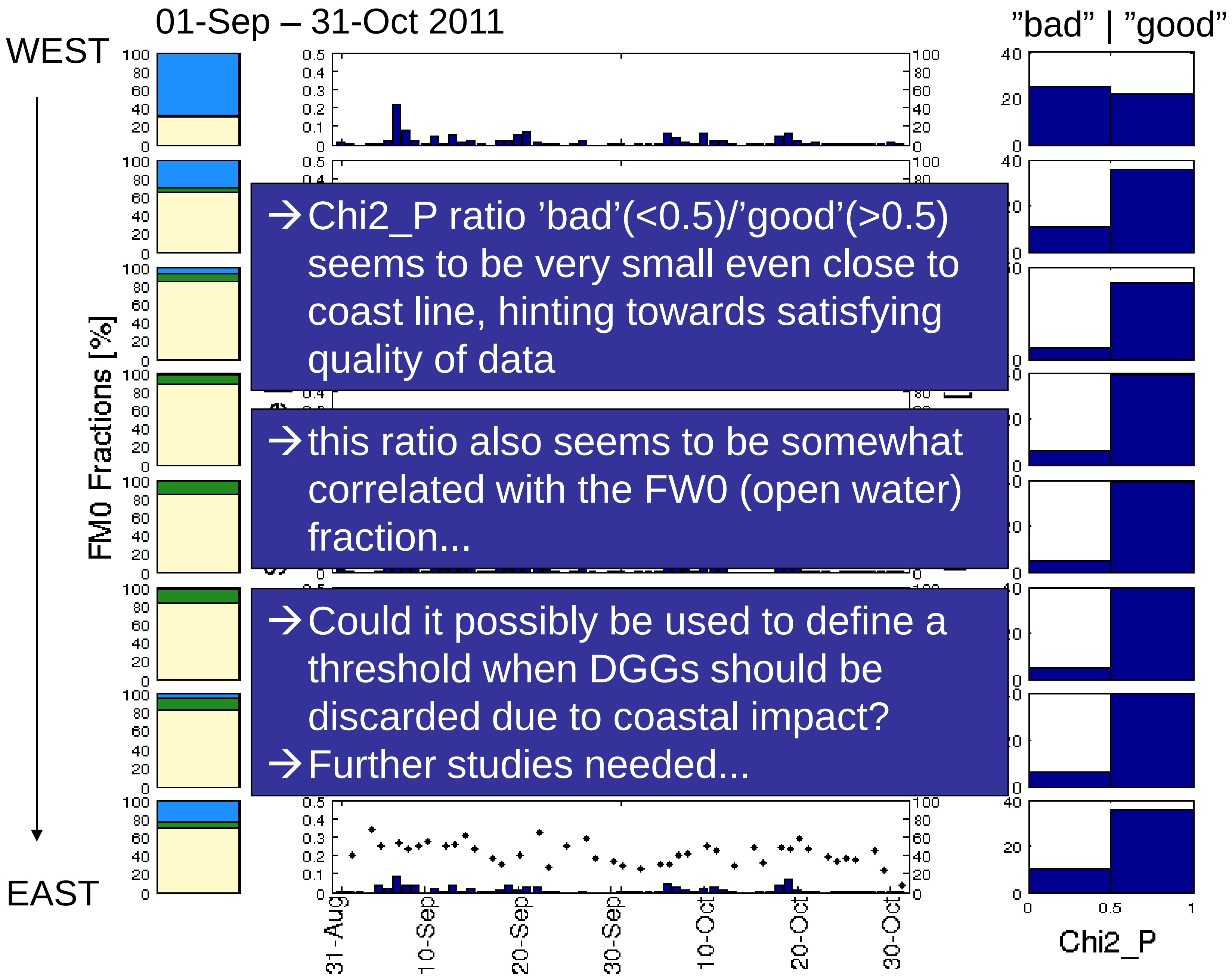
WEST

Jan 2010 – Dec 2011




... 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...)



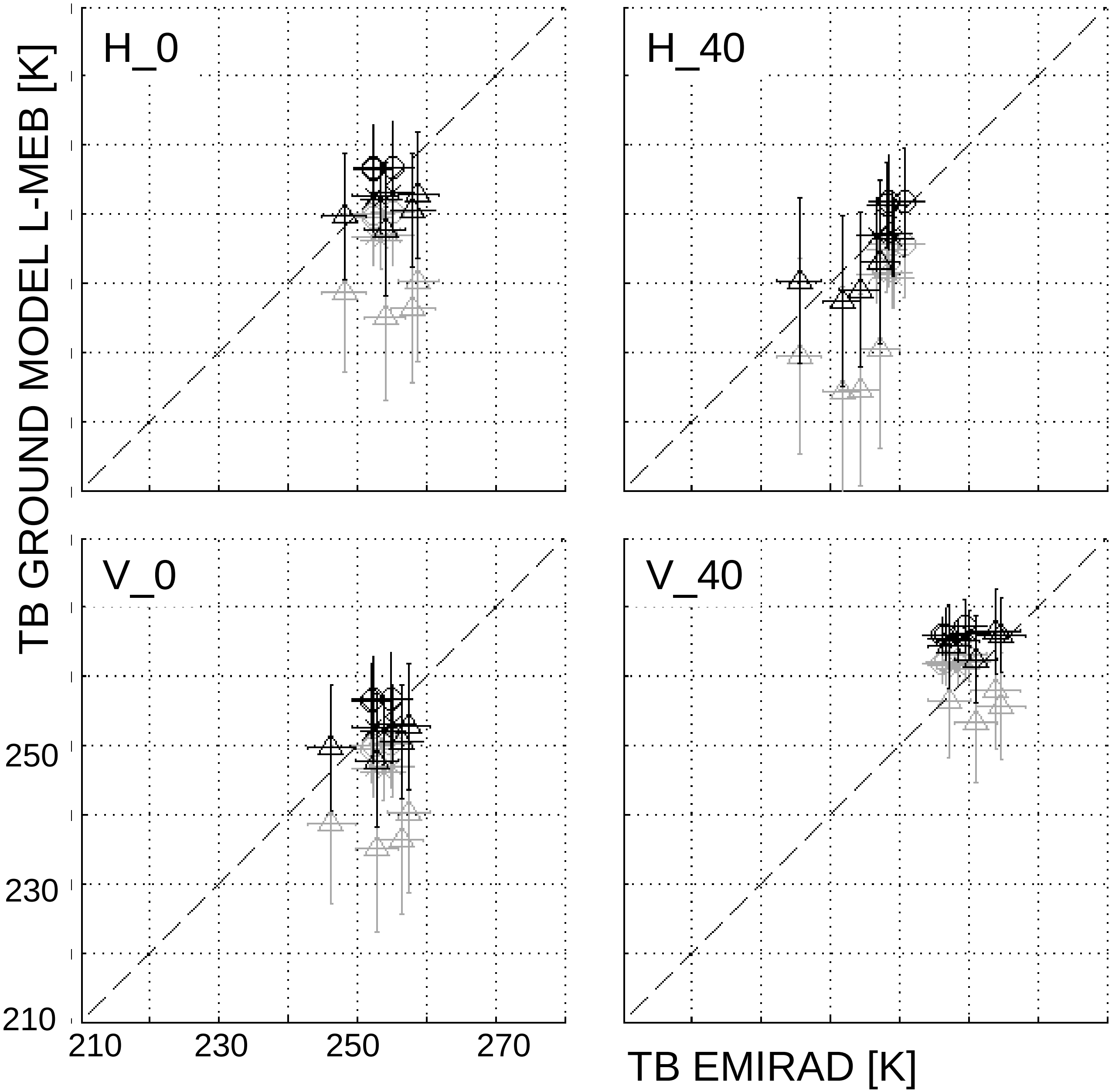

→ Chi2_P ratio 'bad'(<0.5)/'good'(>0.5) seems to be very small even close to coast line, hinting towards satisfying quality of data

→ 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




29.Apr & 2/4/9.May 2010

DOBSON
MIRONOV

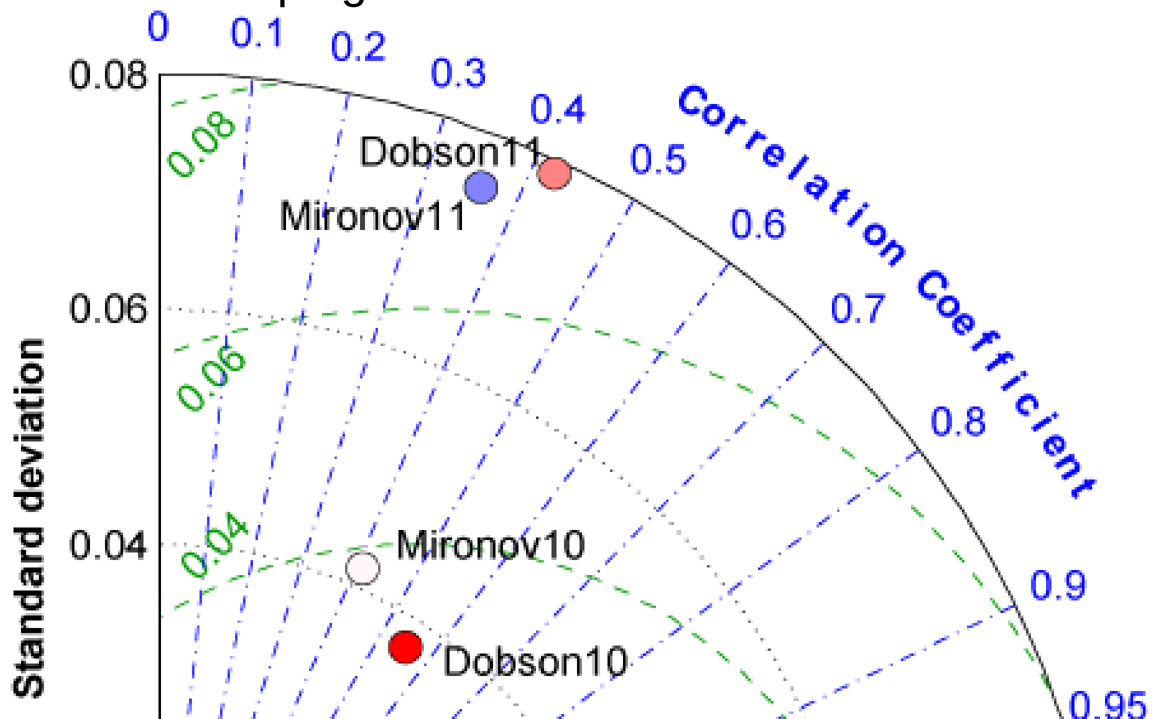
Agricult △
Forest ○
Heath ✳

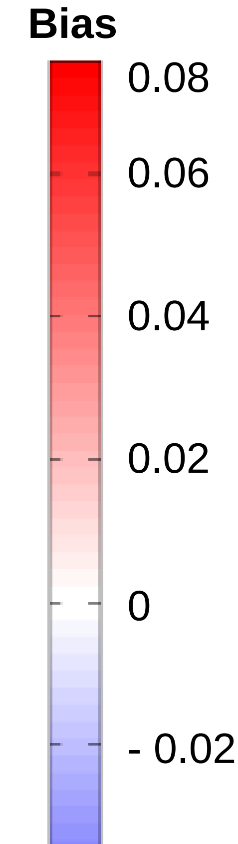
→Good agreement using MIRONOV
→Not able to remove bias using DOBSON while keeping model parameters in reasonable range...

# 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

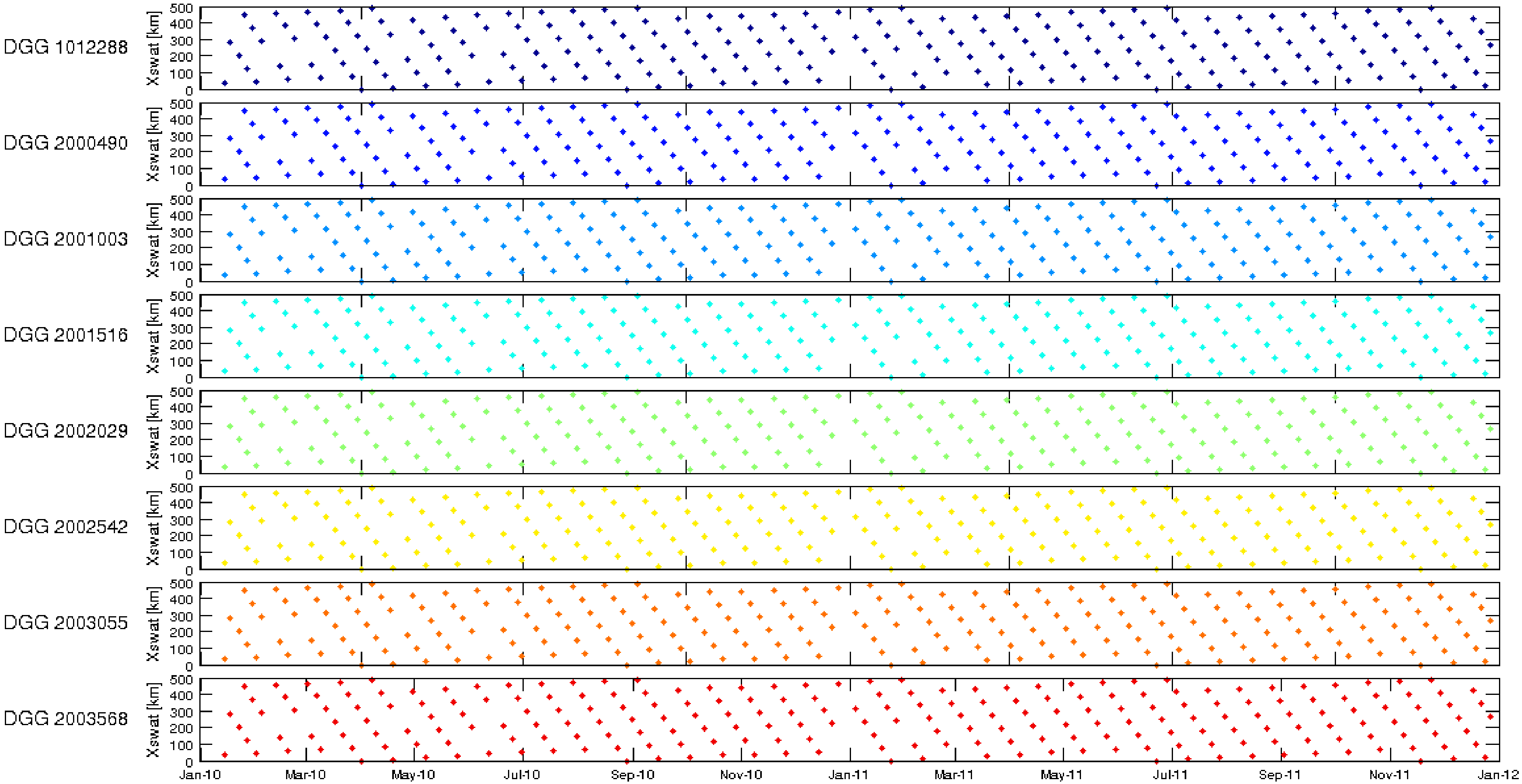
## Dobson/Mironov

- 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)

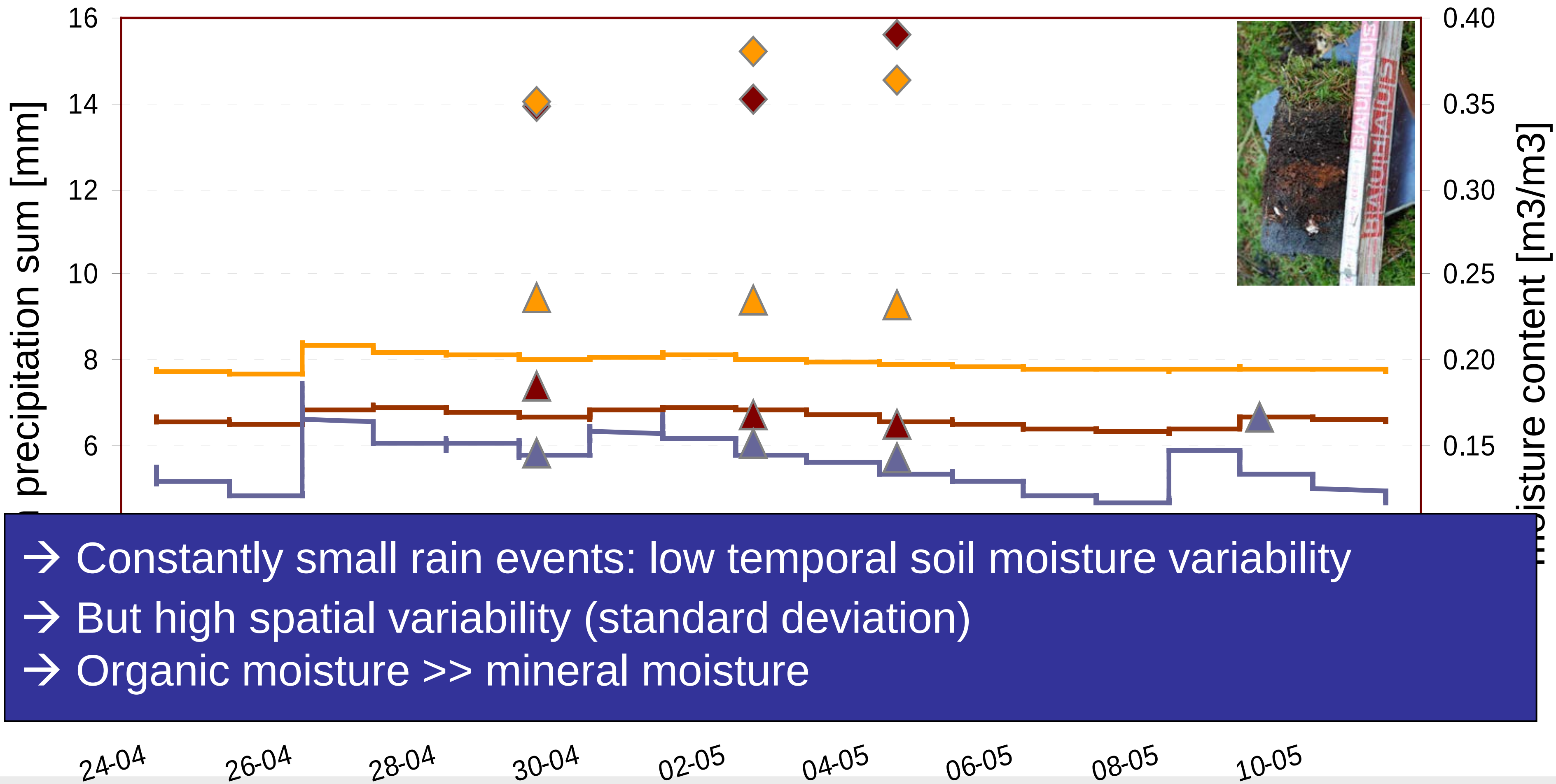
| | | Campaign<br>short-term | Network<br>long-term |
|---|---|---|---|
| TB L1C | | offset | |
| Soil moisture | initial | | clear trend,higher |
| | retrieved | | clear trend,lower |
| | | clear trend,same range | |
| Tau | initial | trend,higher,noisy | |
| | retrieved | | |
| | | lower | |
| HR | | | 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.)

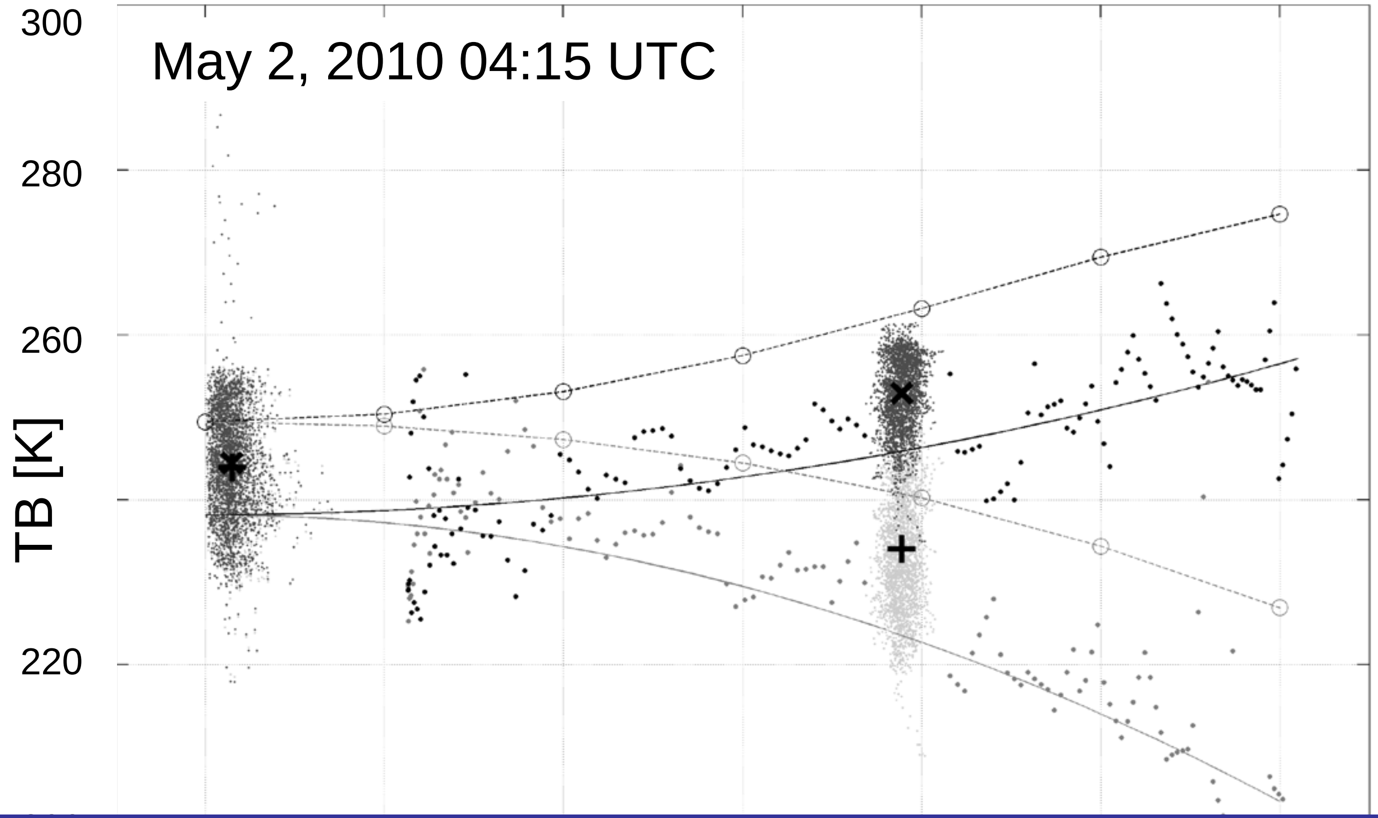
**Decagon 5TE**
(1 network station within patch)

| | 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

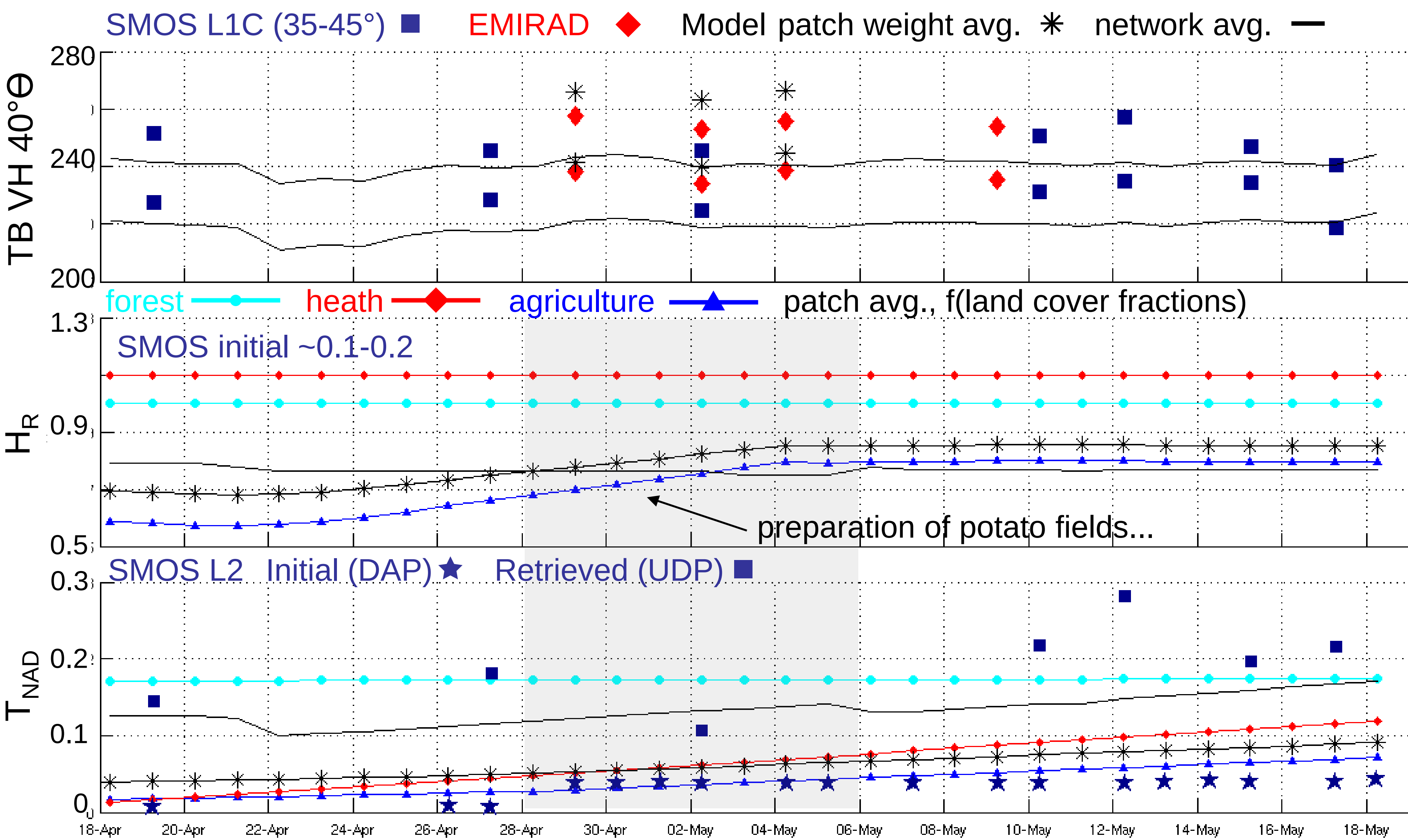
# Campaign results: Avg. In situ vs. EMIRAD vs. SMOS L1C TB




- →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

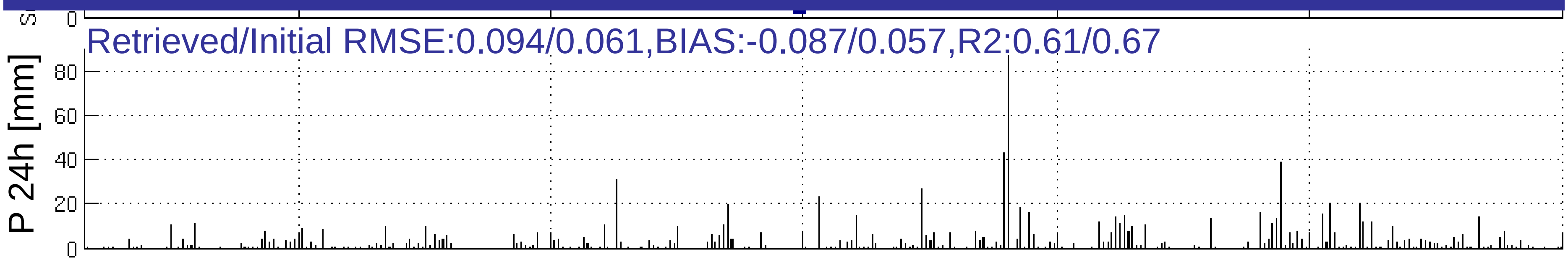


# Network results: soil moisture, precipitation, temp. Jan-Dec 2010

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