RFI in Airborne and SMOS Data. Aquarius/SAC-D Science Meeting, July 2010

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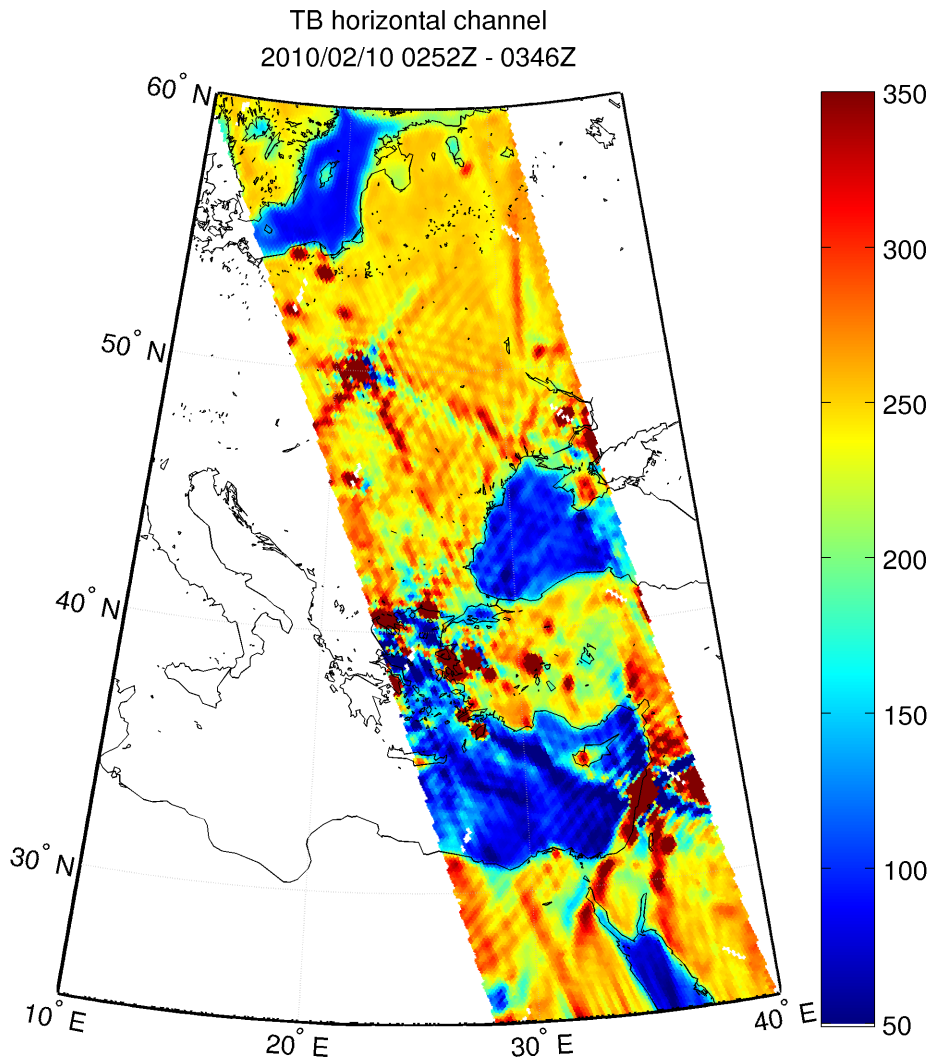
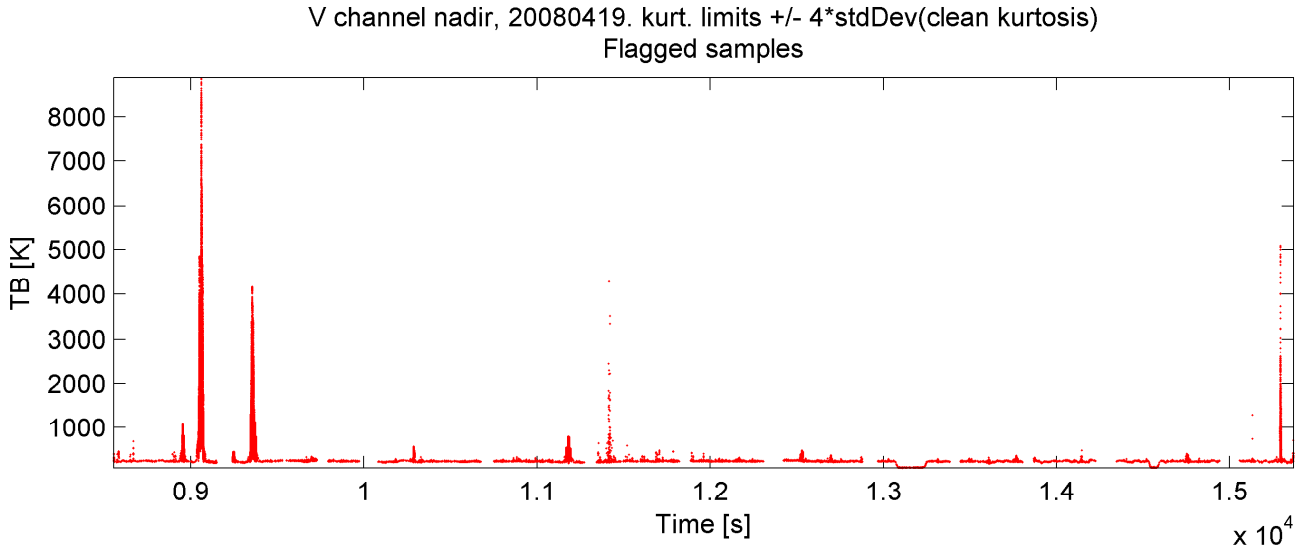

TB horizontal channel
2010/02/10 0252Z - 0346Z
60° N
50° N
40° N
30° N
10° E
20° E
30° E
40° E
350
300
250
200
150
100
50

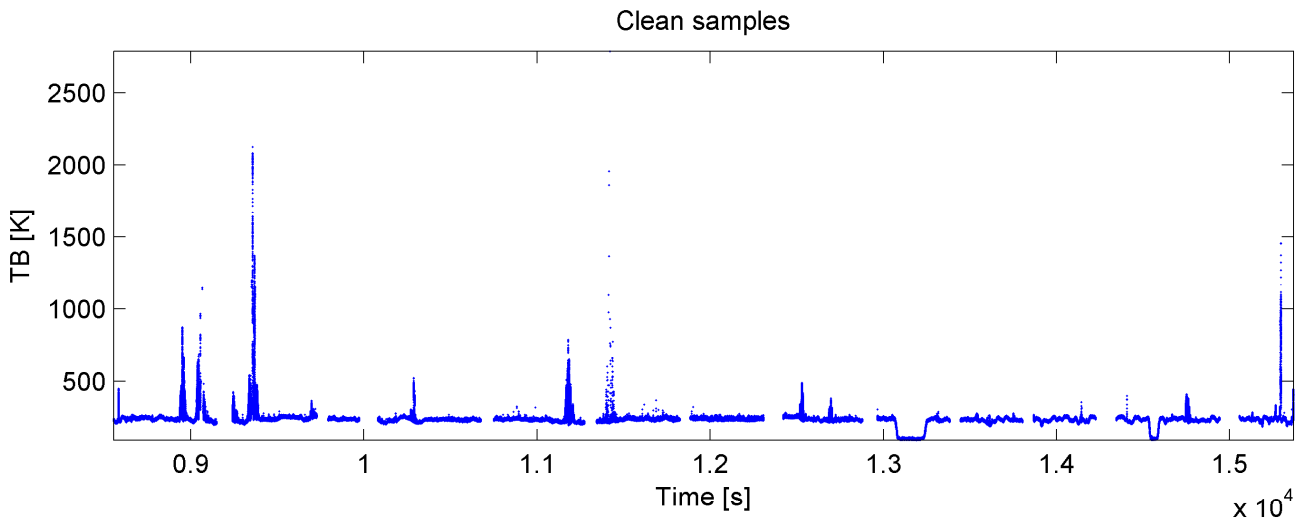
Airborne Data: Experience with Kurtosis

- In general only a few percent of data samples are flagged
- Less in Australia and North Europe
- More in South Europe
- Significant fraction close to airports and cities.
- BUT: is kurtosis fully reliable?
- We know from TB profiles and distribution plots that sometimes significant RFI goes undetected
- This is truly annoying!
- We know that kurtosis has a 50% duty cycle blind spot, and poor sensitivity in general for large duty cycles
- Can we improve the situation?

Standard method: 1 msec & +/- 4 std dev

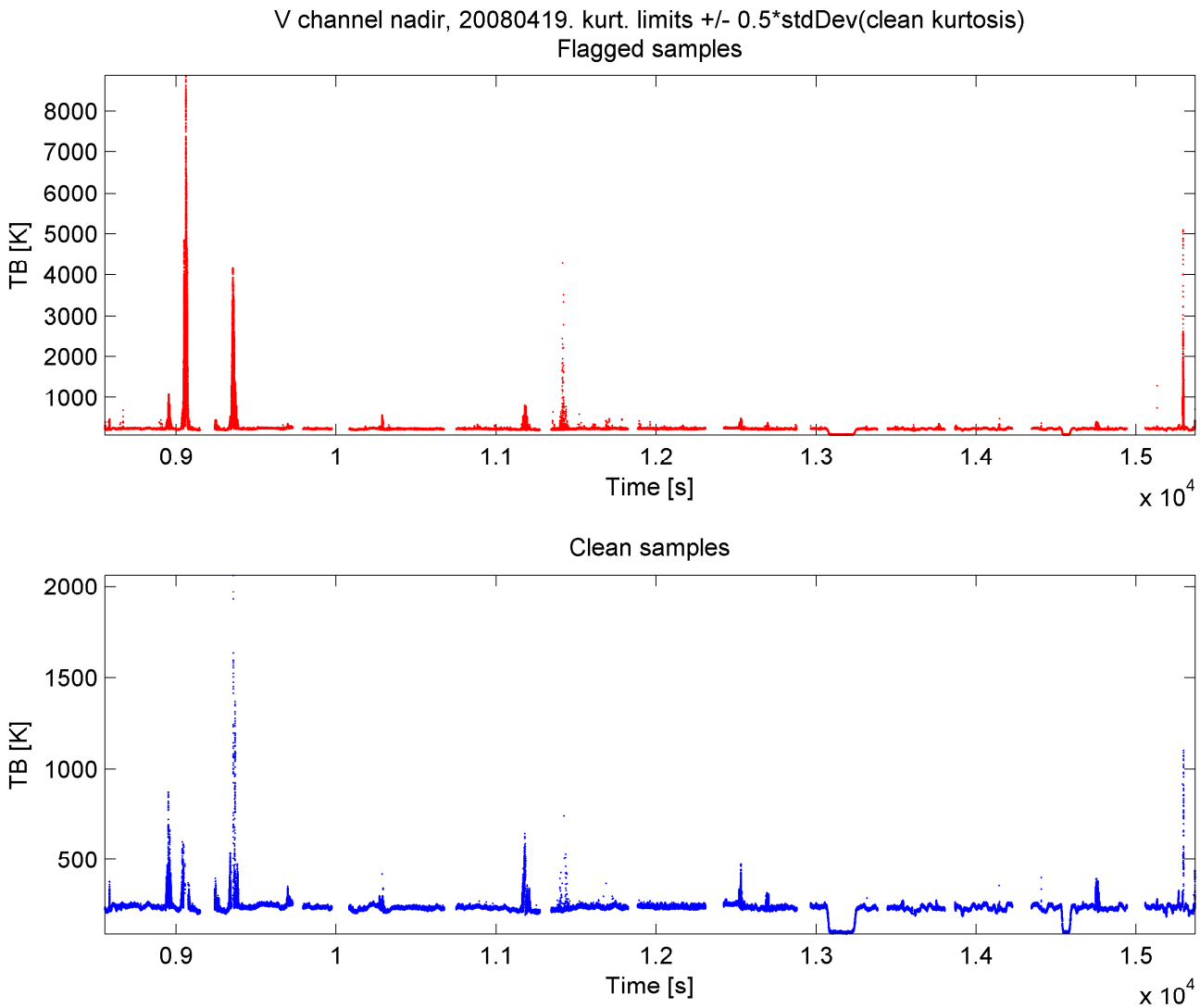


3.5% flagged



0.62% > 350 K

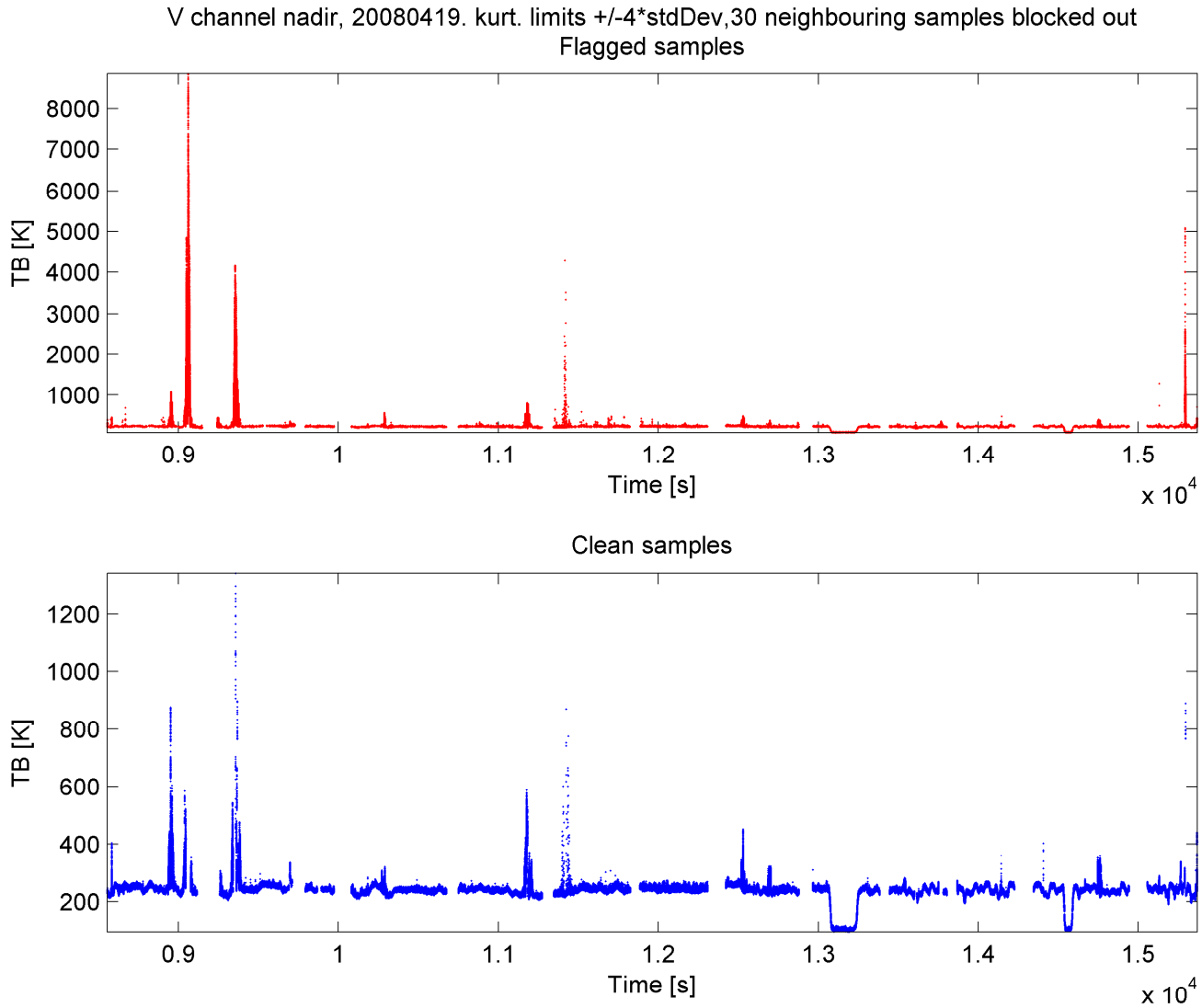
More sensitive method: 1 msec & +/- 0.5 std dev



65% flagged

0.33% > 350 K

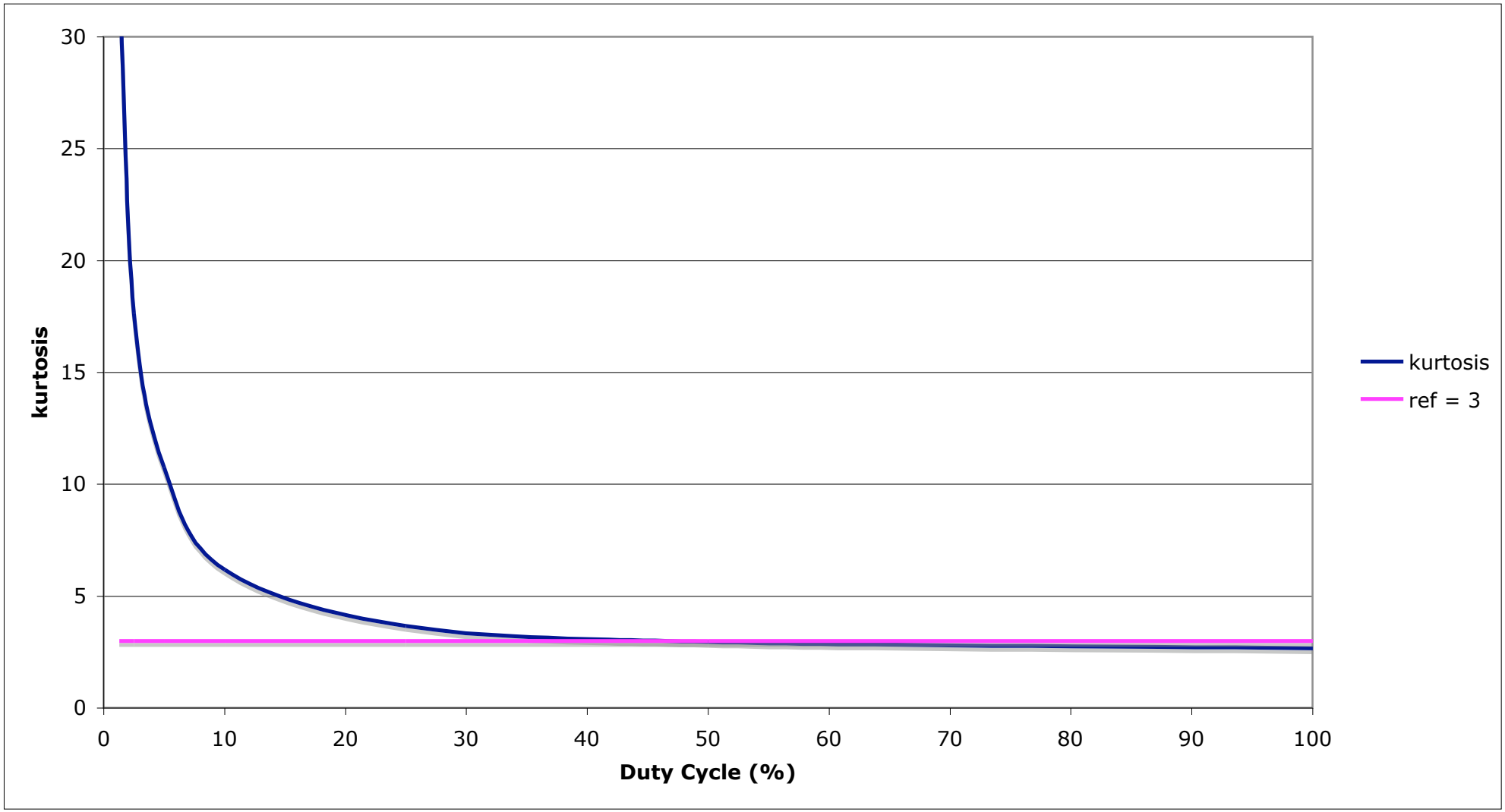
Discard flagged data + 30 neighbors



21% flagged

0.3% > 350 K

RFI contribution to TB constant = 100 K



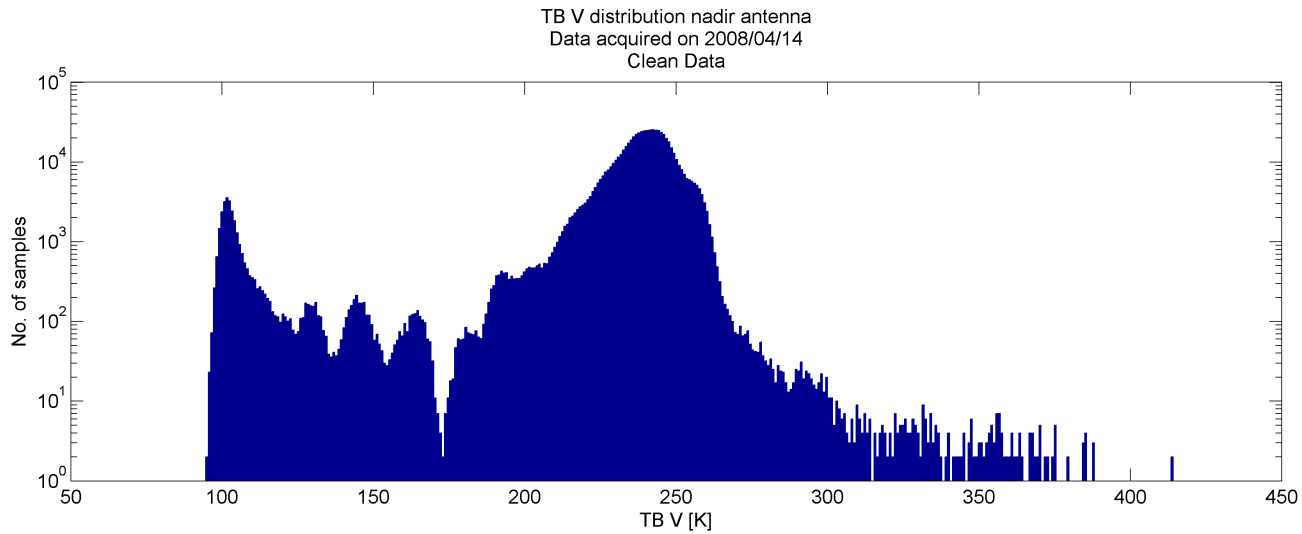
Kurtosis Method and "Blind Spot"

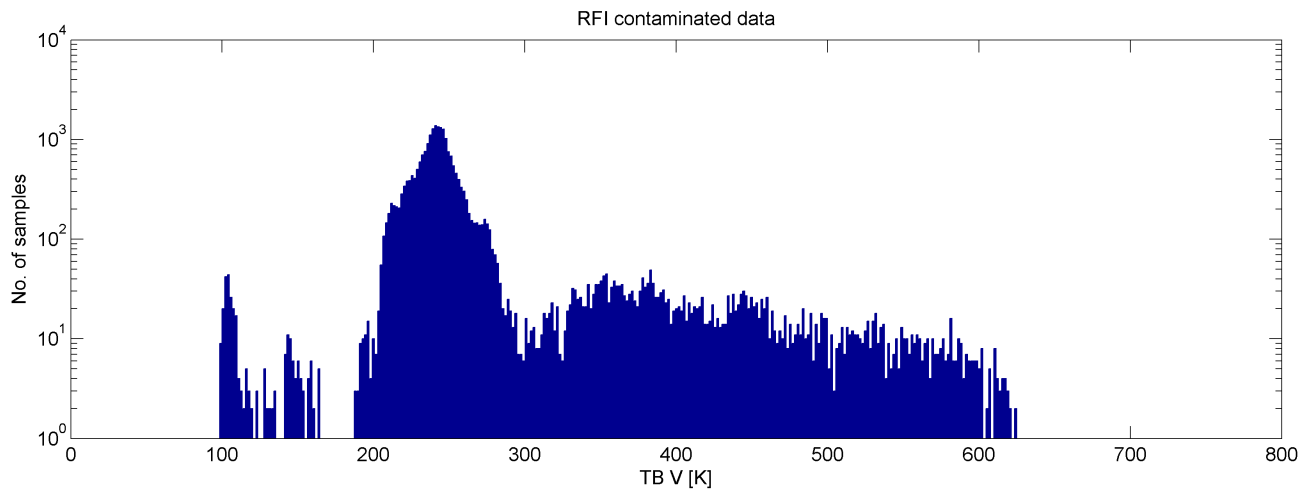
- Note that 50% duty cycle means 50% within radiometer calculation and integration window (1 msec in EMIRAD)
- Sensitivity is very dependent on duty cycle - and of RFI to TB ratio.
- In general: short, large, radar-like pulses very well detected by kurtosis.
- Large duty cycles much more difficult, i.e. missed detection of RFI!
- Possible remedy:
  - calculate kurtosis for different integration periods
  - evaluate together
  - several examples show no dramatic improvement!
- The problem is not the blind spot - but the poor detection of large duty cycles!

Polarimetric Data

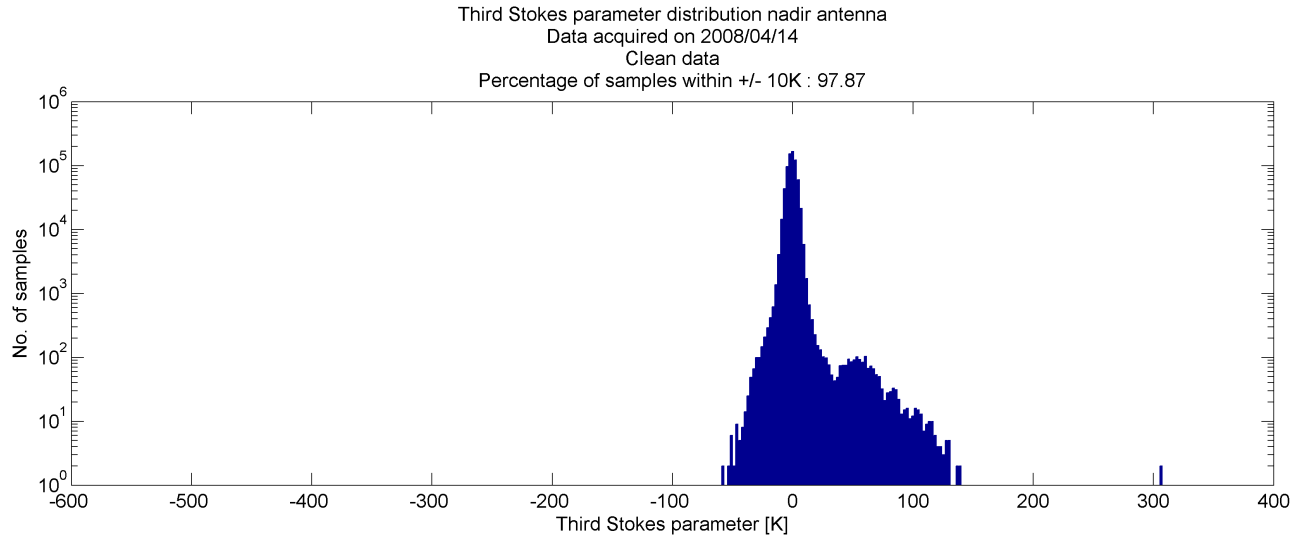
- Natural targets have very small 3rd and 4th Stokes
- Linearly polarized RFI normally not aligned with H and V of our instrument, hence we get 3rd Stokes
- Many surveillance radars use circular polarization, hence we get 4th Stokes
- Experience with EMIRAD shows that often Kurtosis flagged data has significant signals in 3rd and 4th Stokes, but not always. The opposite can also be the case.
- Subject for further investigations
- Anyway, looking for signals in the 3rd and 4th Stokes channels of SMOS can be an important method for RFI detection

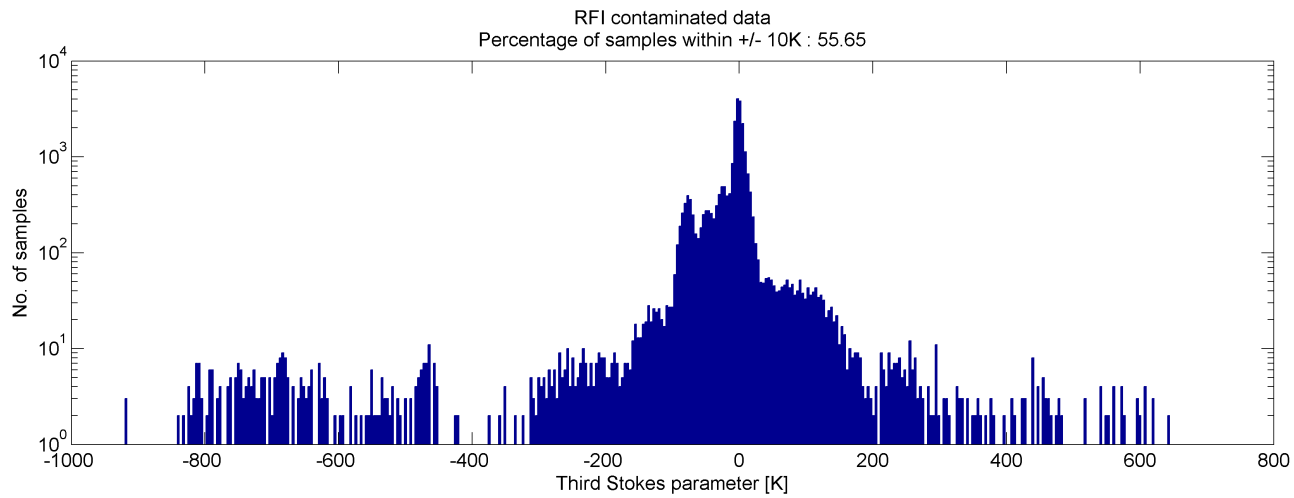
TBV Distribution



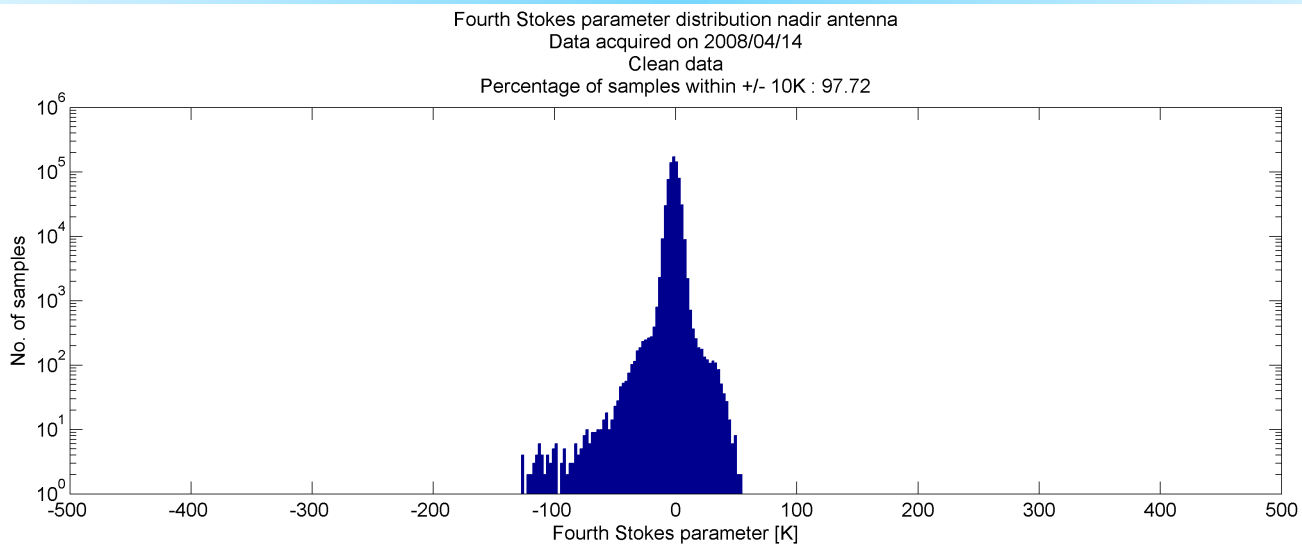


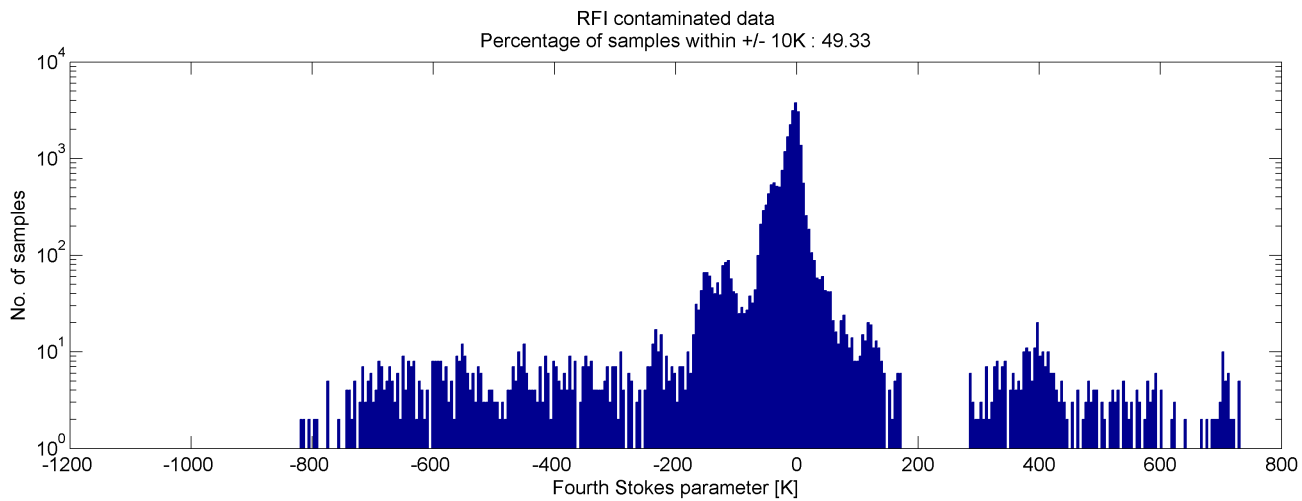
3rd Stokes Distribution



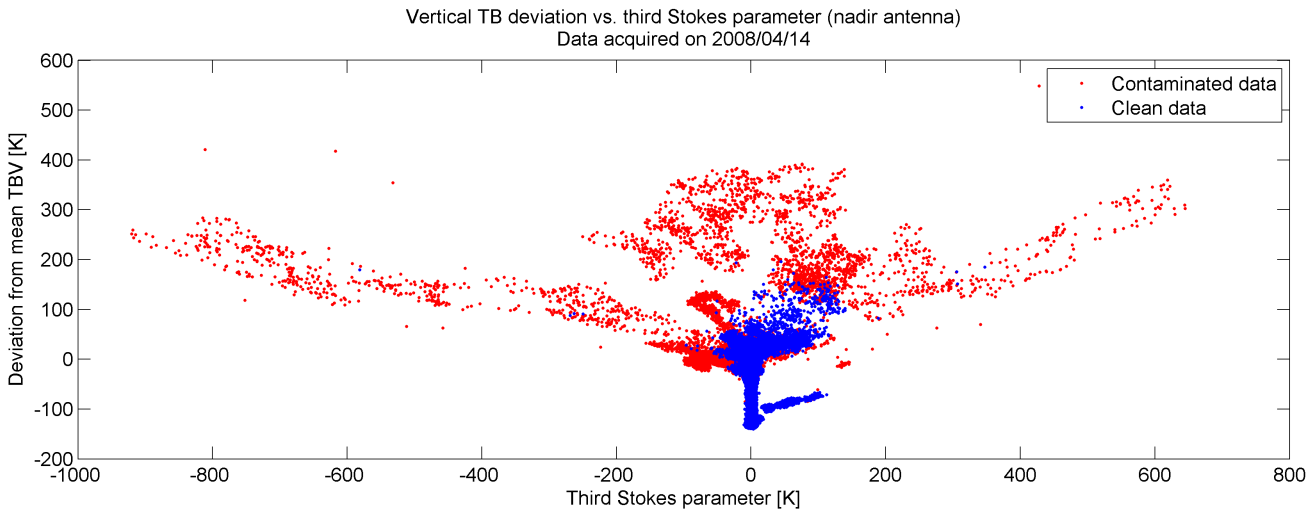


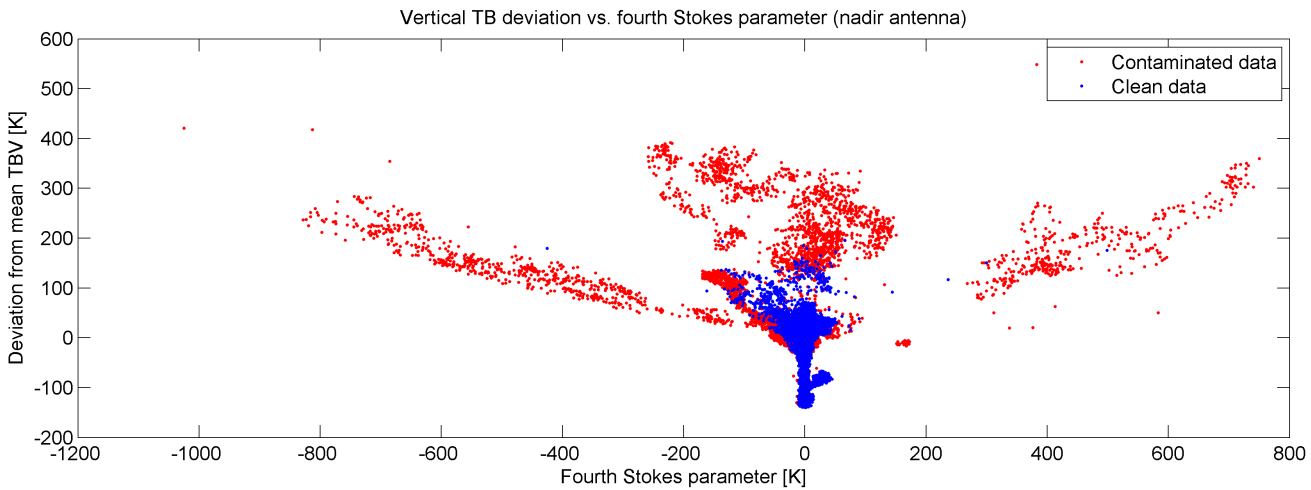
4th Stokes Distribution



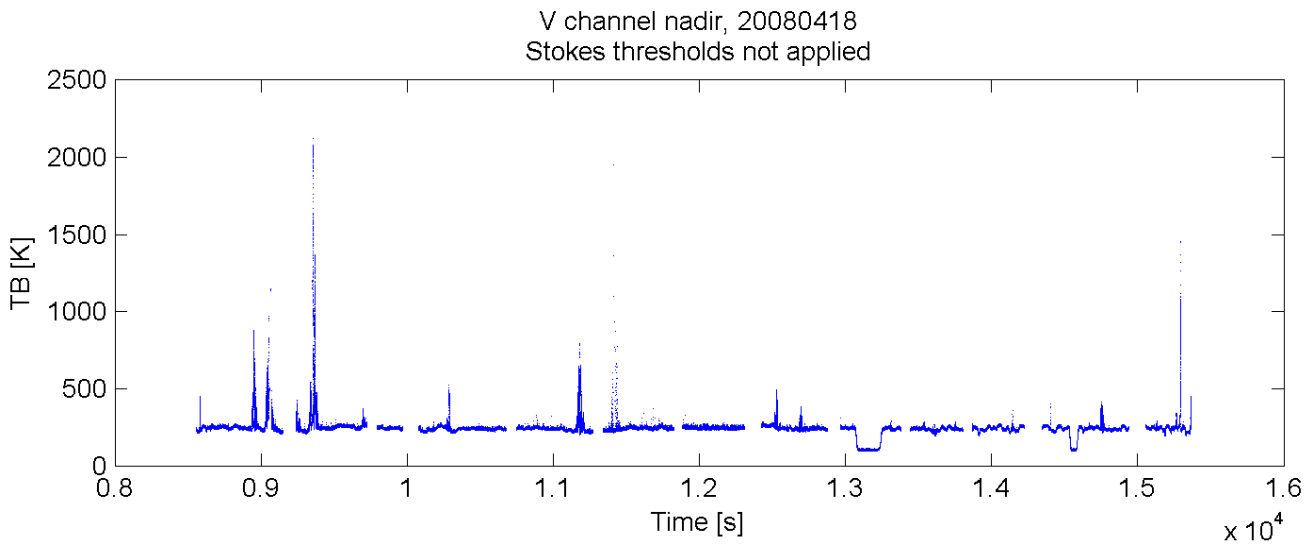


TBV vs. 3rd & 4th Stokes (EMIRAD, München)

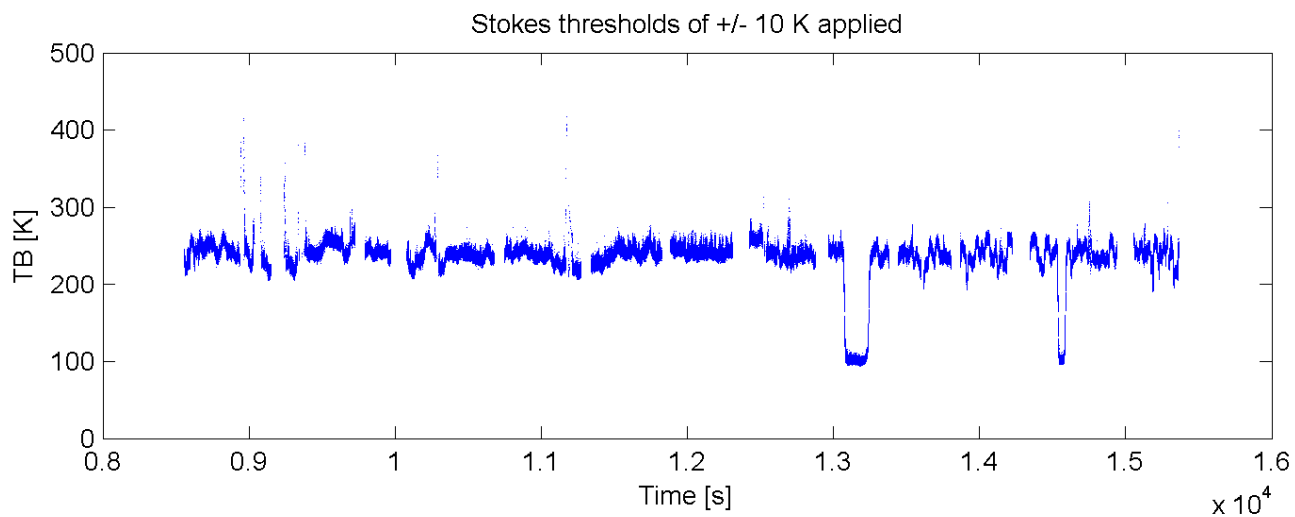




Kurtosis AND ±10 K threshold for 3rd and 4th Stokes

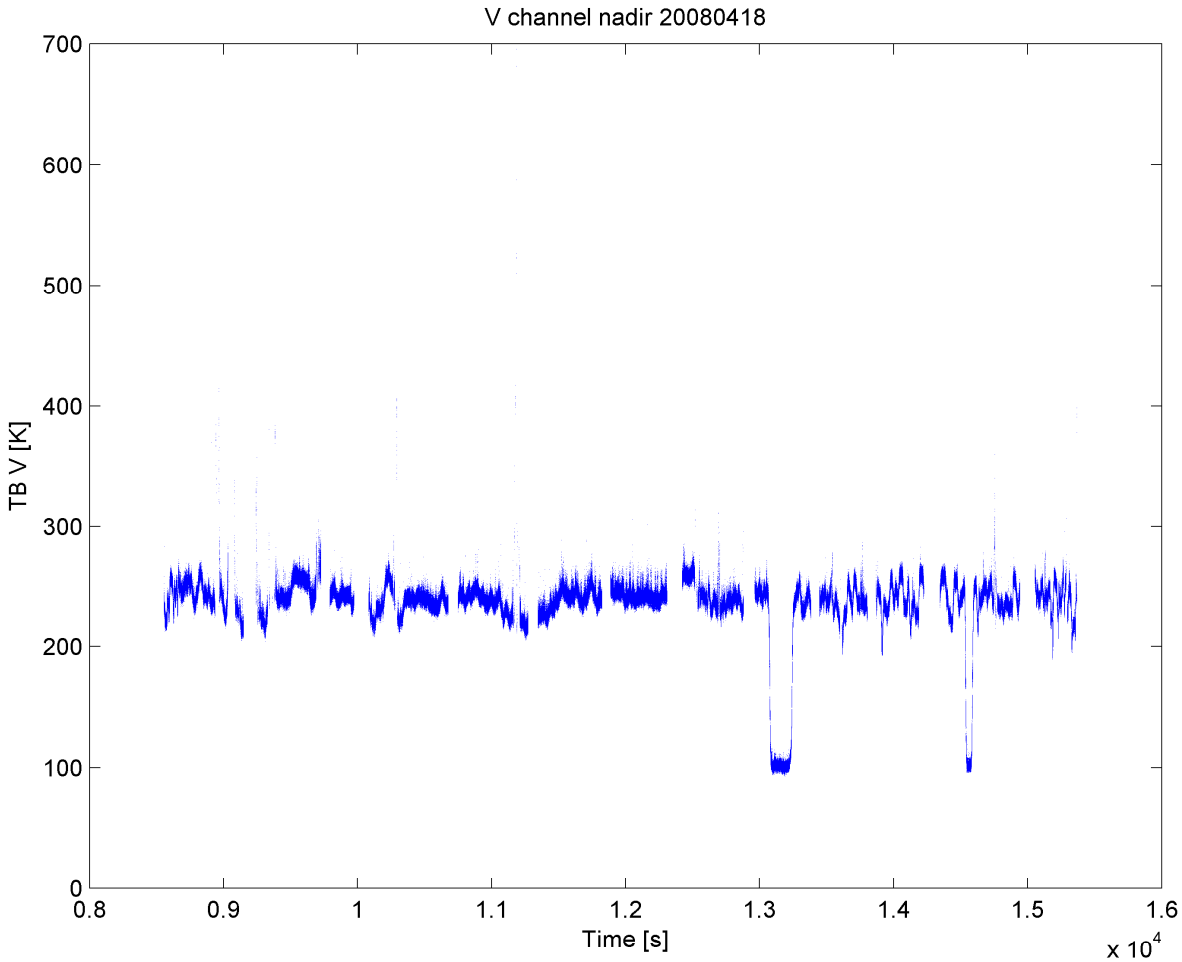


3.5% flagged



16% flagged

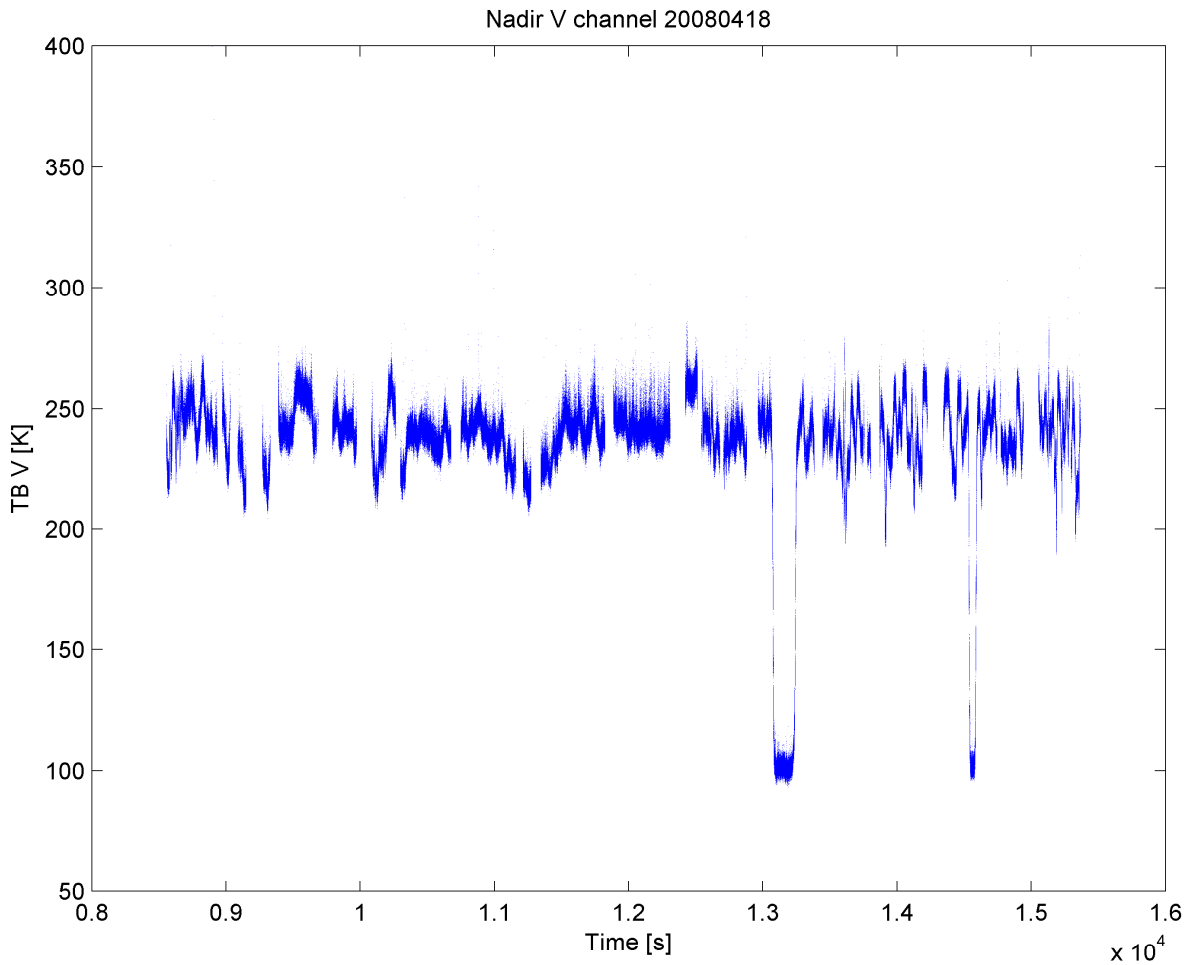
±10 K Threshold for 3rd and 4th Stokes Applied



15% flagged

0.01% > 300 K

Thresholds for Std. Dev. of 3rd and 4th Stokes



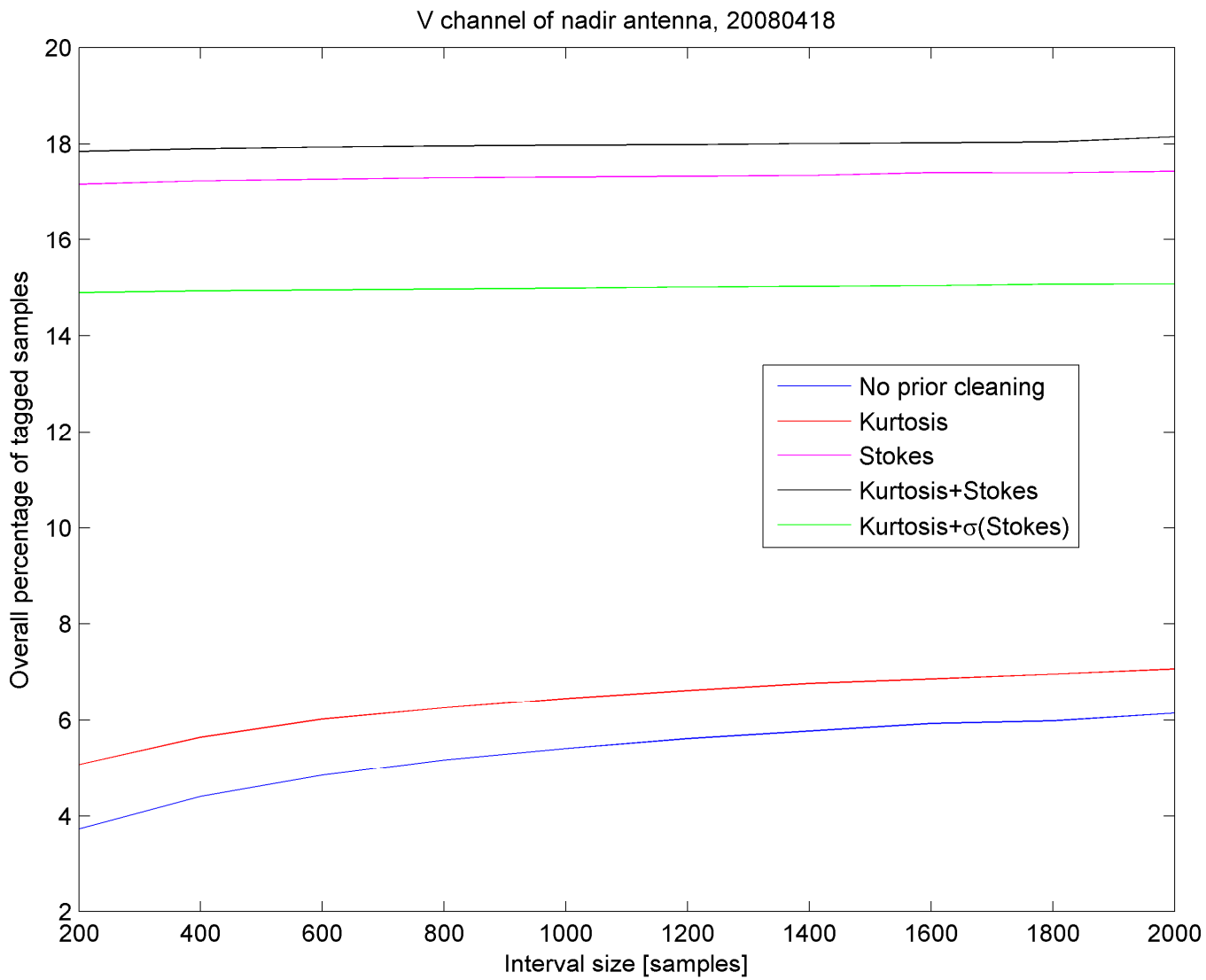
14% flagged

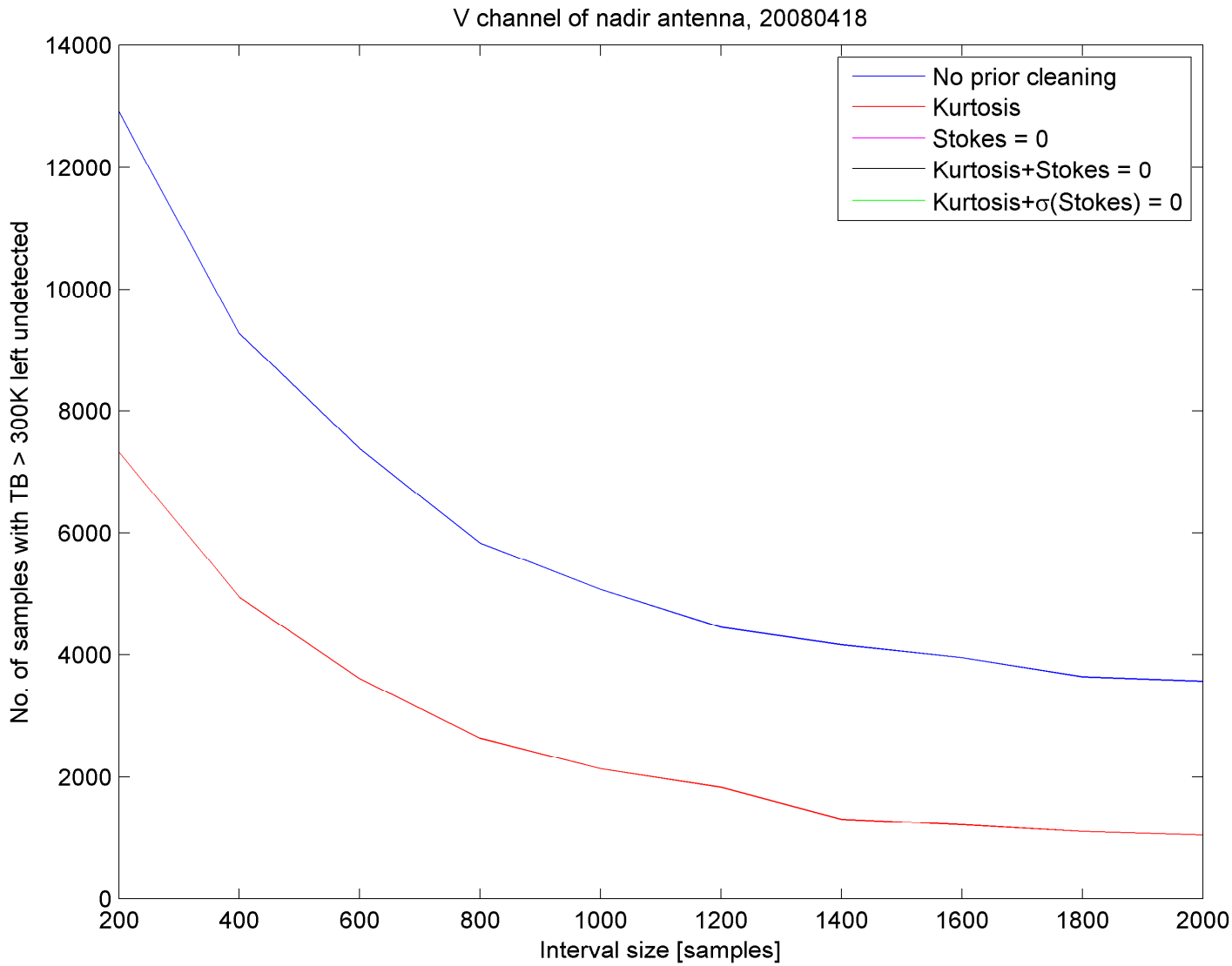
0.001% > 300 K

Glitch Detector

- Developed by Ruf et al.
- Each sample compared with mean of neighboring samples
- Discarded if it exceeds by a threshold
- No. of neighboring samples is parameter

- Glitch detector cleans up very well after polarimetry has been used!


V channel of nadir antenna, 20080418
Overall percentage of tagged samples
Interval size [samples]
No prior cleaning
Kurtosis
Stokes
Kurtosis+Stokes
Kurtosis+σ(Stokes)
20
18
16
14
12
10
8
6
4
2
200
400
600
800
1000
1200
1400
1600
1800
2000

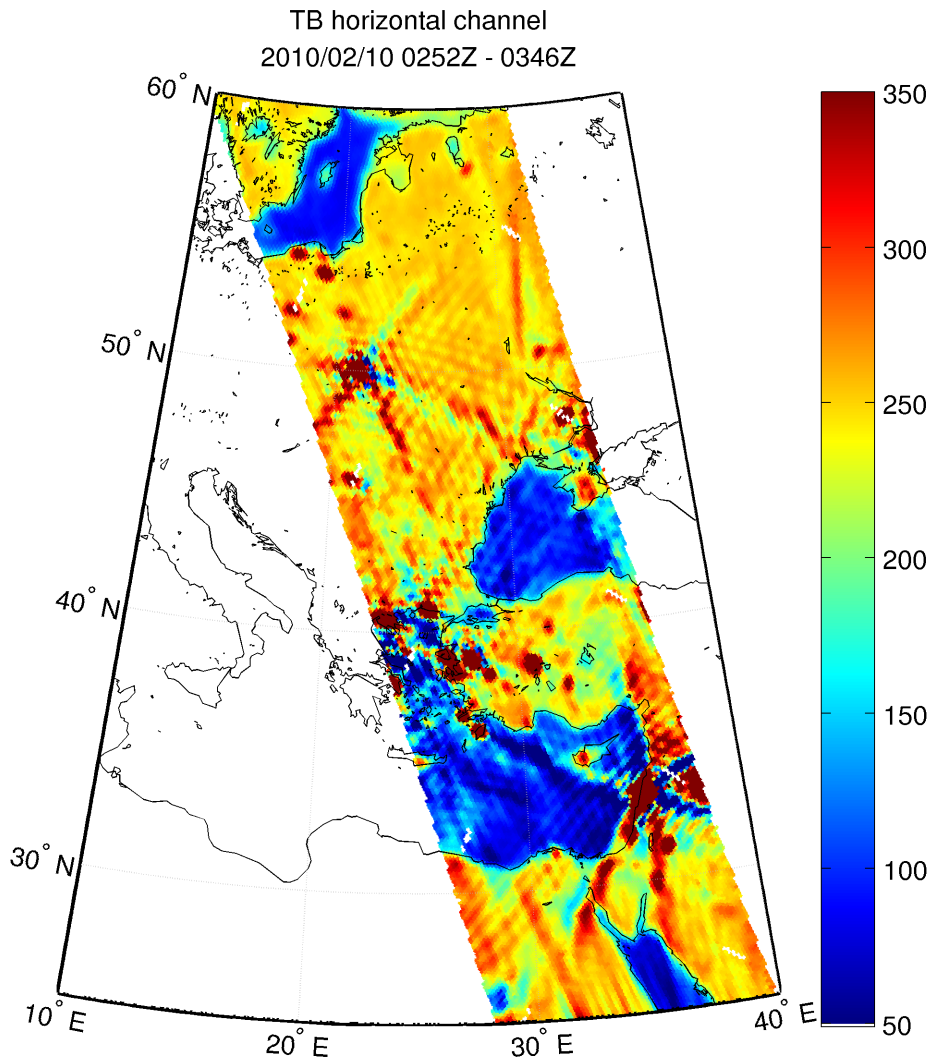

V channel of nadir antenna, 20080418
No prior cleaning
Kurtosis
Stokes = 0
Kurtosis+Stokes = 0
Kurtosis+σ(Stokes) = 0
No. of samples with TB > 300K left undetected
Interval size [samples]
0
2000
4000
6000
8000
10000
12000
14000
200
400
600
800
1000
1200
1400
1600
1800
2000

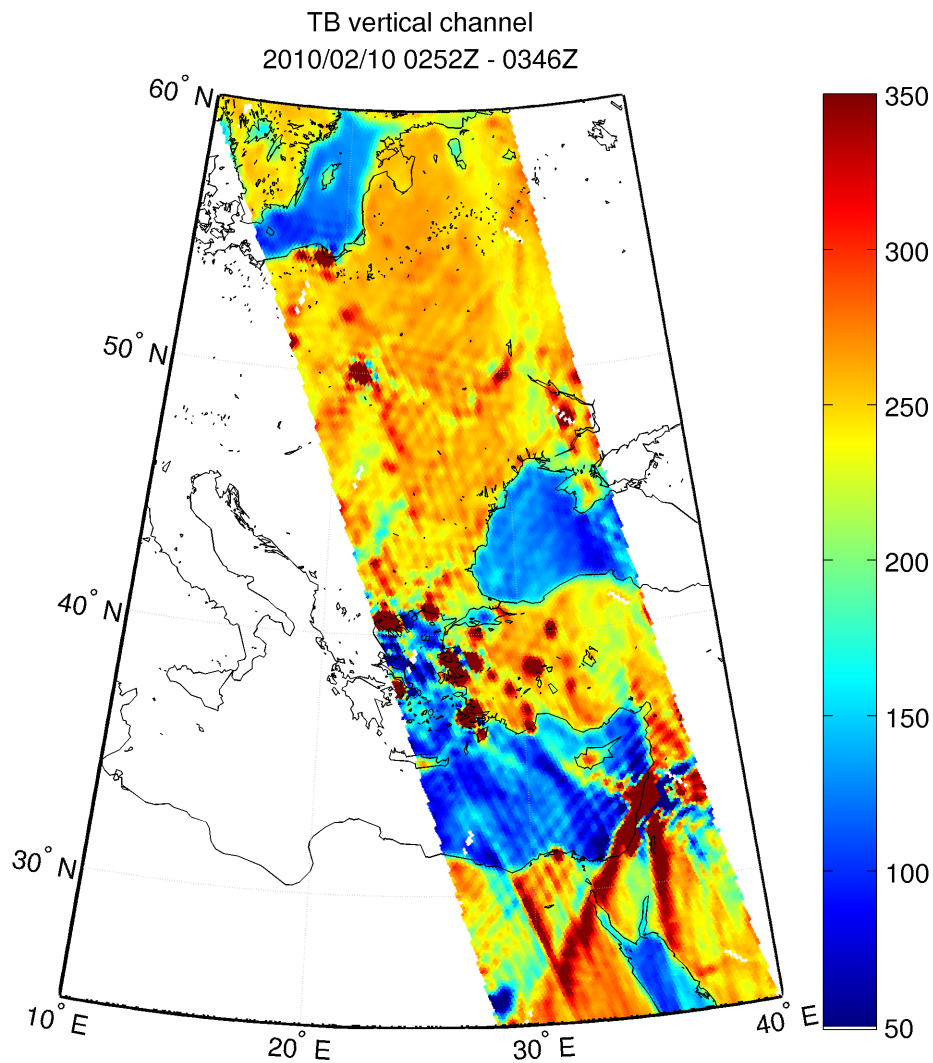
Conclusions From Airborne Measurements

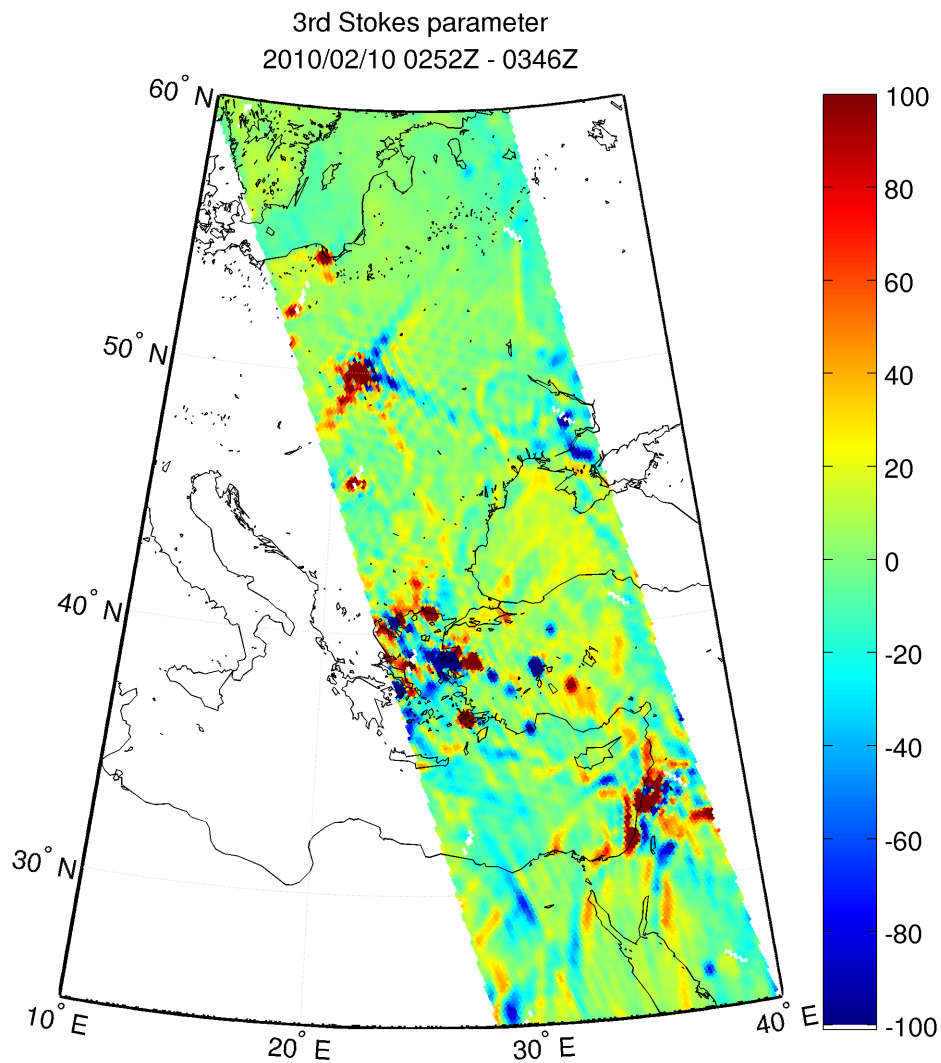
- RFI is generally there
- RFI is very variable in nature, time, and space
- DTU flights have generally experienced 1% RFI flagging over rural research areas - no problem for science data when you know
- Kurtosis flagging often works quite well
- Some additional cleaning is often needed

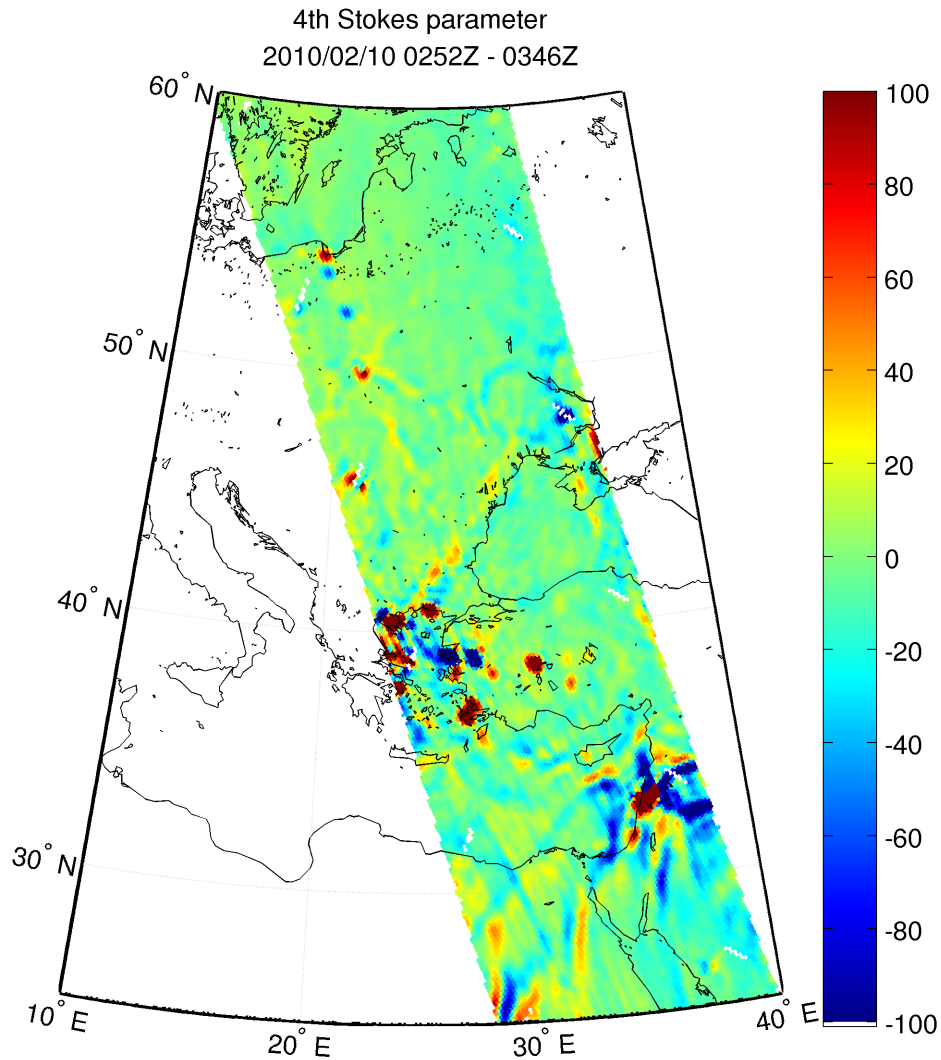
- Signatures in the 3rd and 4th Stokes channels indicate RFI
- A combination of kurtosis and the above is a powerful tool.
- But also polarimetry alone seems to work well
  - especially using the standard deviation of the 3rd and 4th Stokes parameters as indicators

- Glitch detector cleans up very well after polarimetry has been used!


TB horizontal channel
2010/02/10 0252Z - 0346Z
60° N
50° N
40° N
30° N
10° E
20° E
30° E
40° E
350
300
250
200
150
100
50


TB vertical channel
2010/02/10 0252Z - 0346Z
60° N
50° N
40° N
30° N
10° E
20° E
30° E
40° E
350
300
250
200
150
100
50

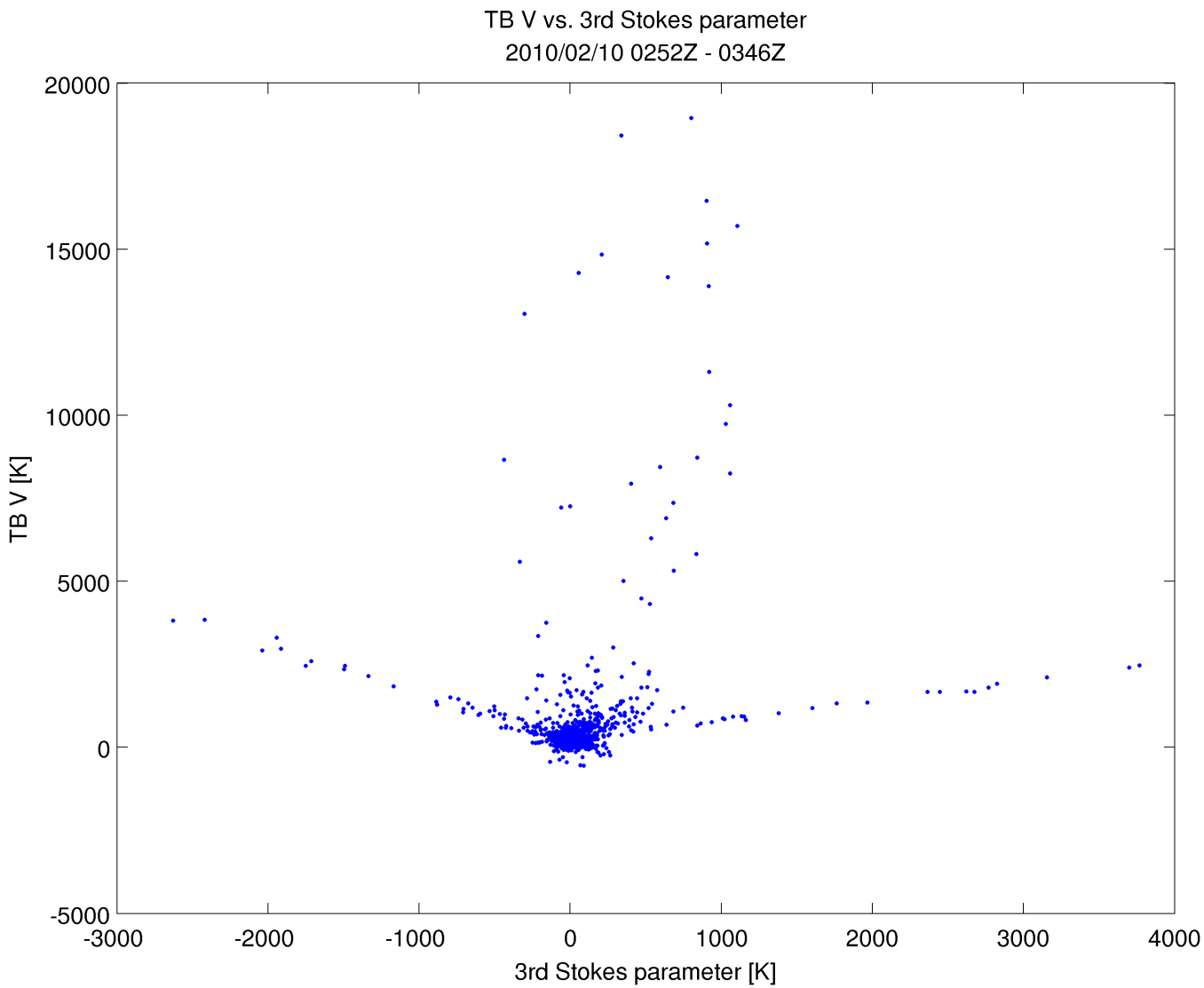

3rd Stokes parameter
2010/02/10 0252Z - 0346Z
60° N
50° N
40° N
30° N
10° E
20° E
30° E
40° E
100
80
60
40
20
0
-20
-40
-60
-80
-100

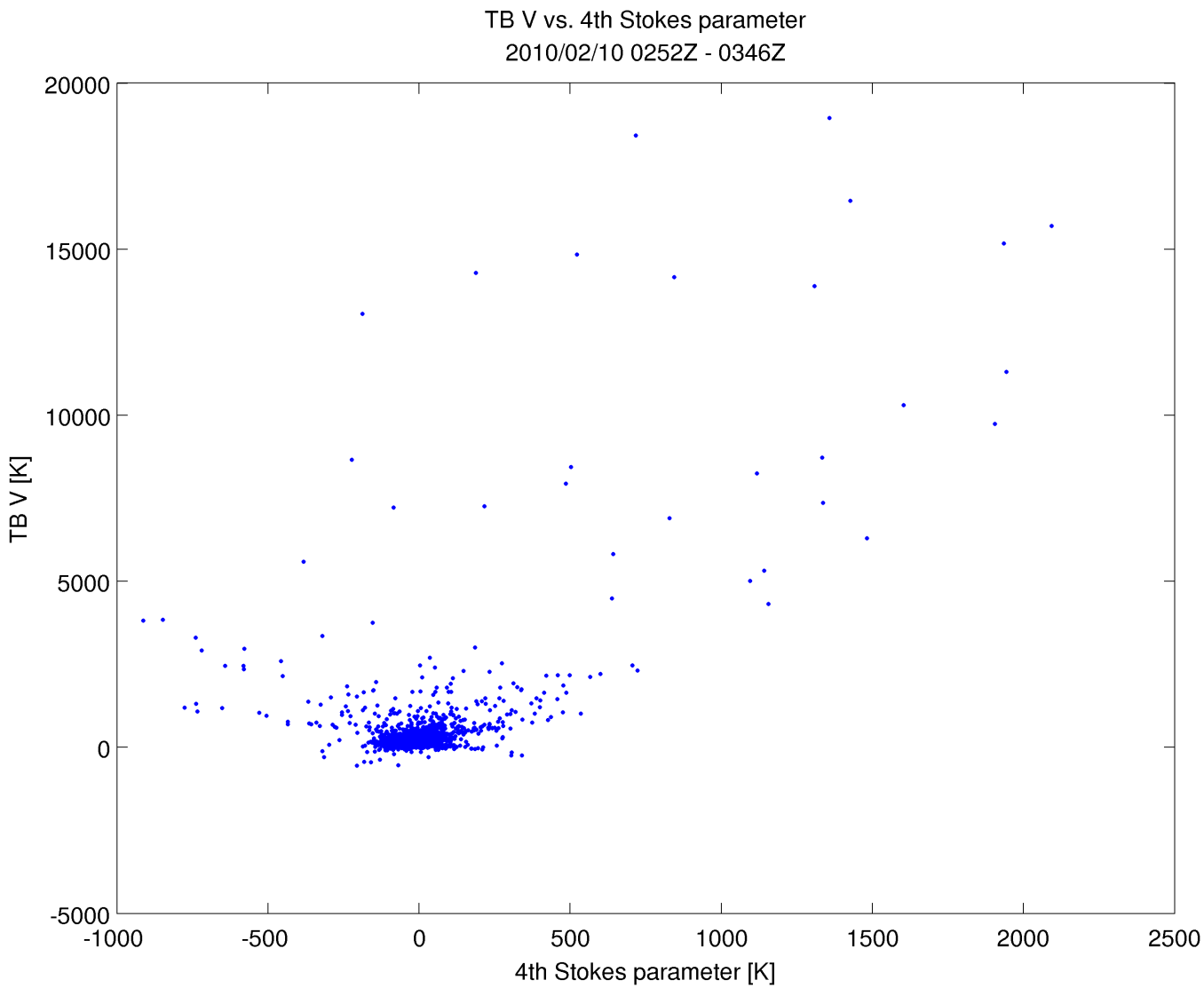

4th Stokes parameter
2010/02/10 0252Z - 0346Z
60° N
50° N
40° N
30° N
10° E
20° E
30° E
40° E
100
80
60
40
20
0
-20
-40
-60
-80
-100

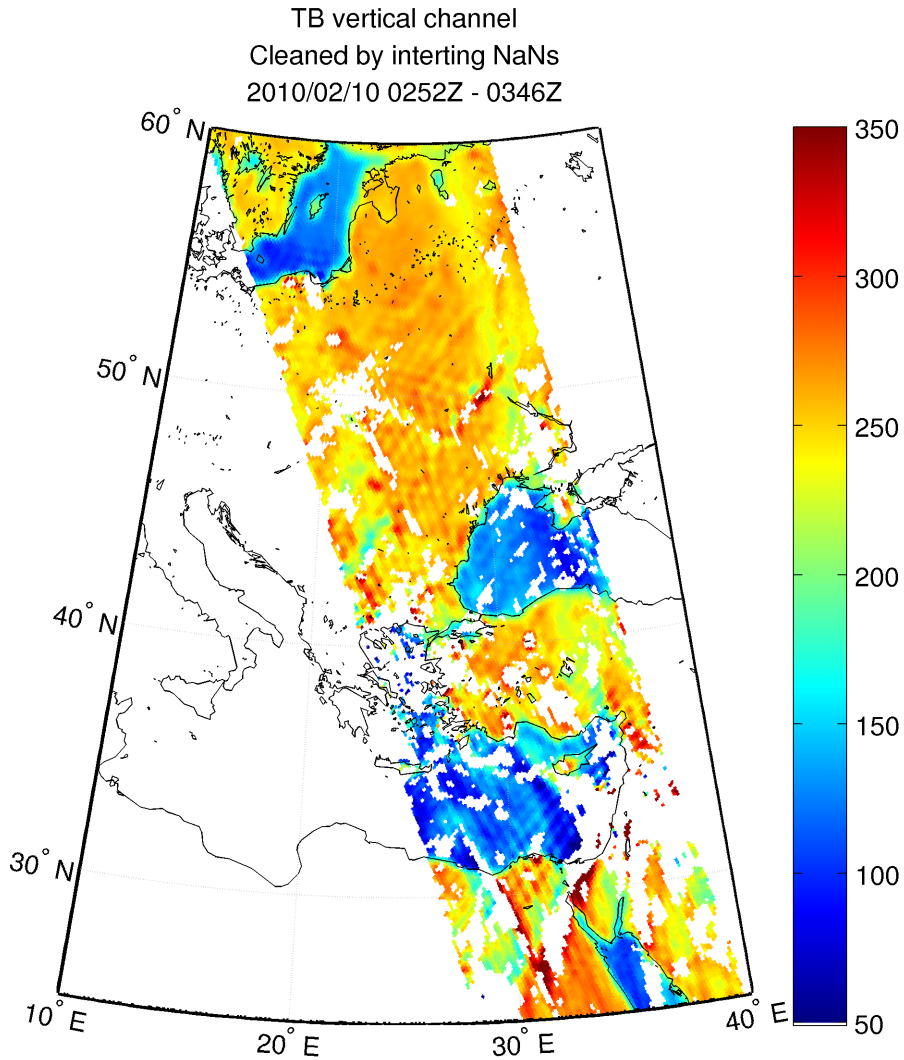
SMOS Polarimetric Mode

Mode:	1	2	3	4	1'	2'	3'	4'
Time:		1 τ		2 τ		3 τ		4 τ
Result:	VV	HH/HV/VH			HH	VV/VH/HV		

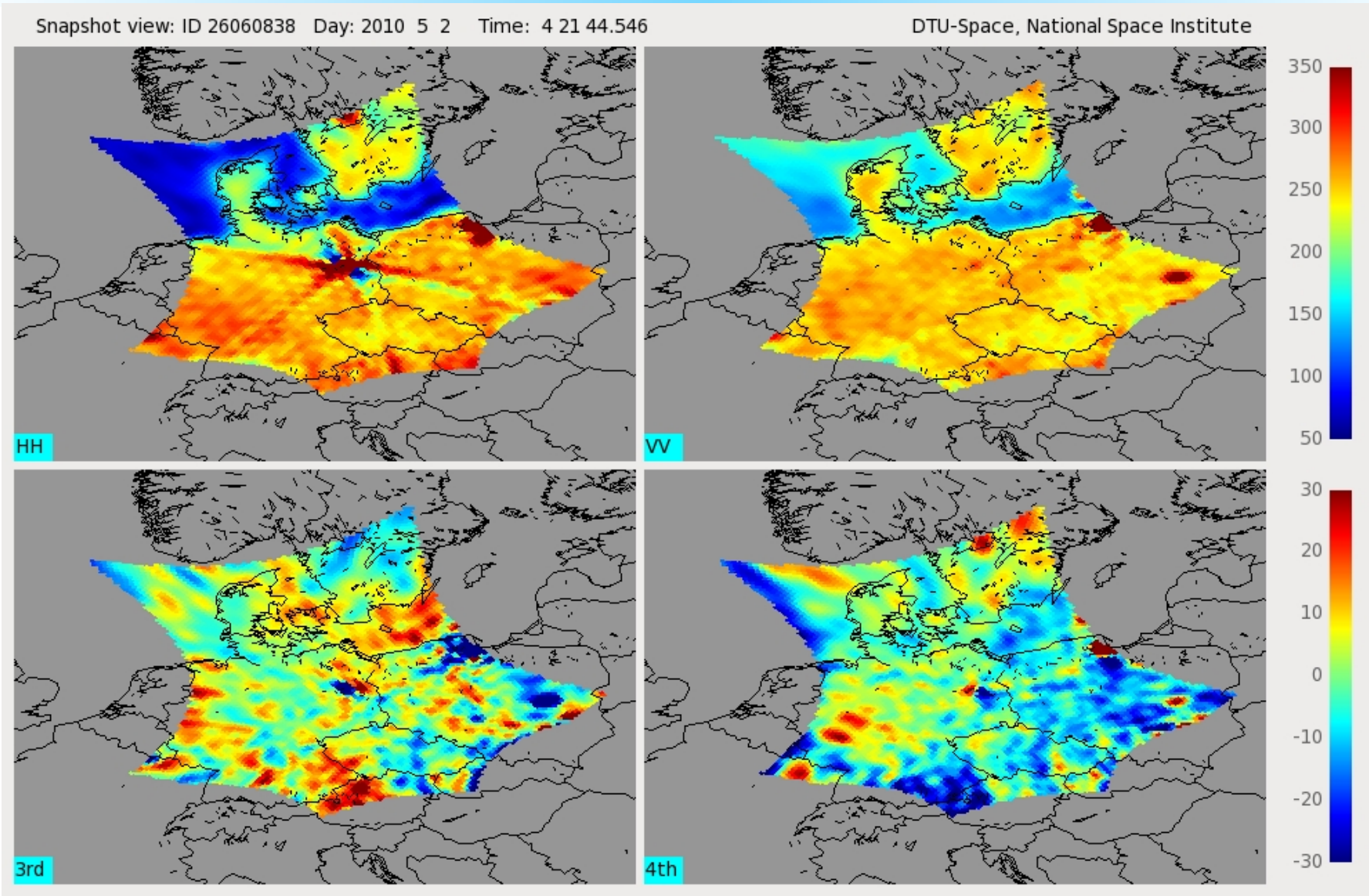
SMOS MEASURES DIFFERENT POLARIZATIONS SEQUENTIALLY


TB V vs. 3rd Stokes parameter
2010/02/10 0252Z - 0346Z
TB V [K]
20000
15000
10000
5000
0
-5000
-3000
-2000
-1000
0
1000
2000
3000
4000
3rd Stokes parameter [K]

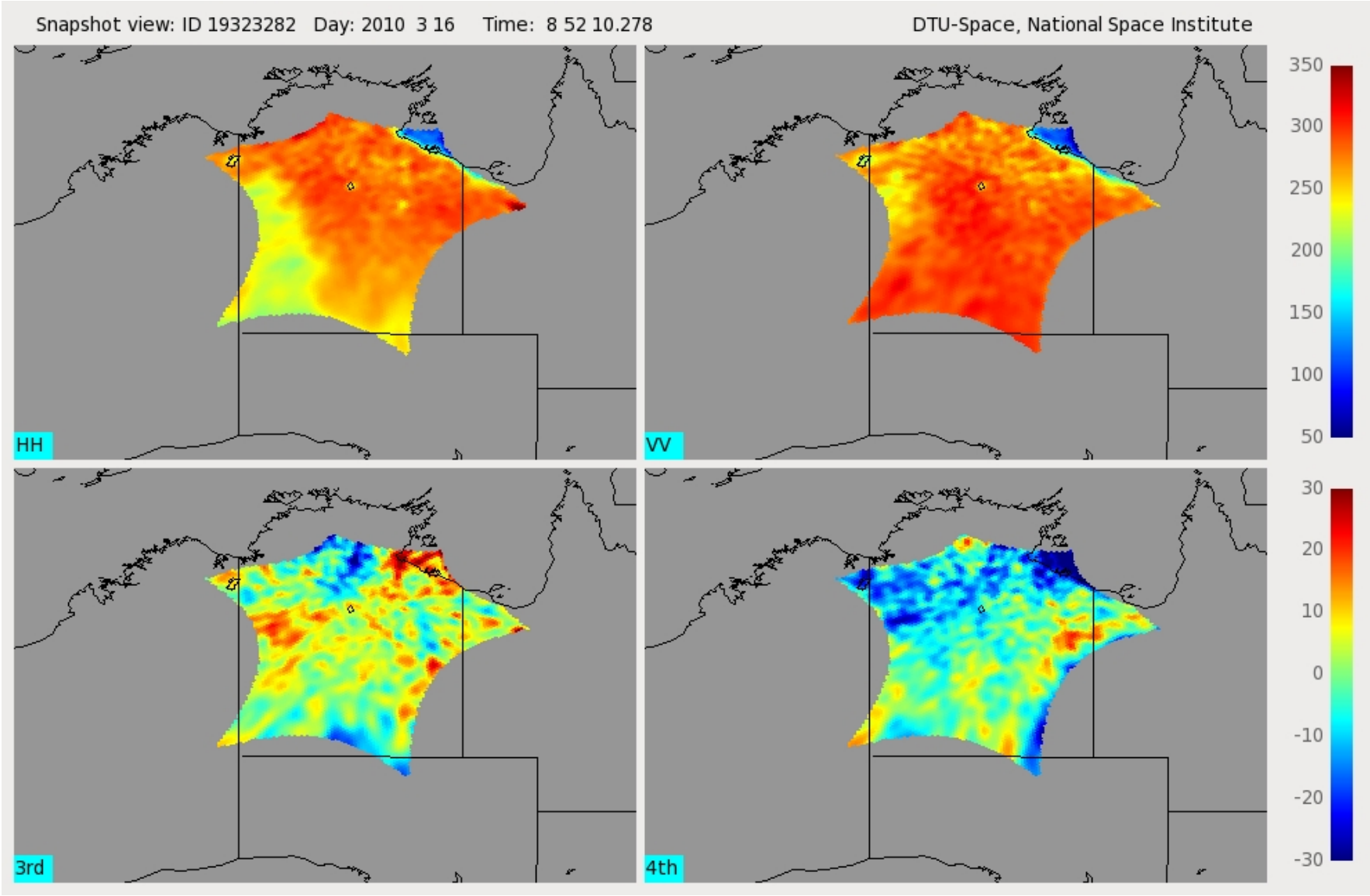

TB V vs. 4th Stokes parameter
2010/02/10 0252Z - 0346Z
TB V [K]
4th Stokes parameter [K]
20000
15000
10000
5000
0
-5000
-1000
-500
0
500
1000
1500
2000
2500


TB vertical channel
Cleaned by interting NaNs
2010/02/10 0252Z - 0346Z
60° N
50° N
40° N
30° N
10° E
20° E
30° E
40° E
350
300
250
200
150
100
50

SMOS View of Europe

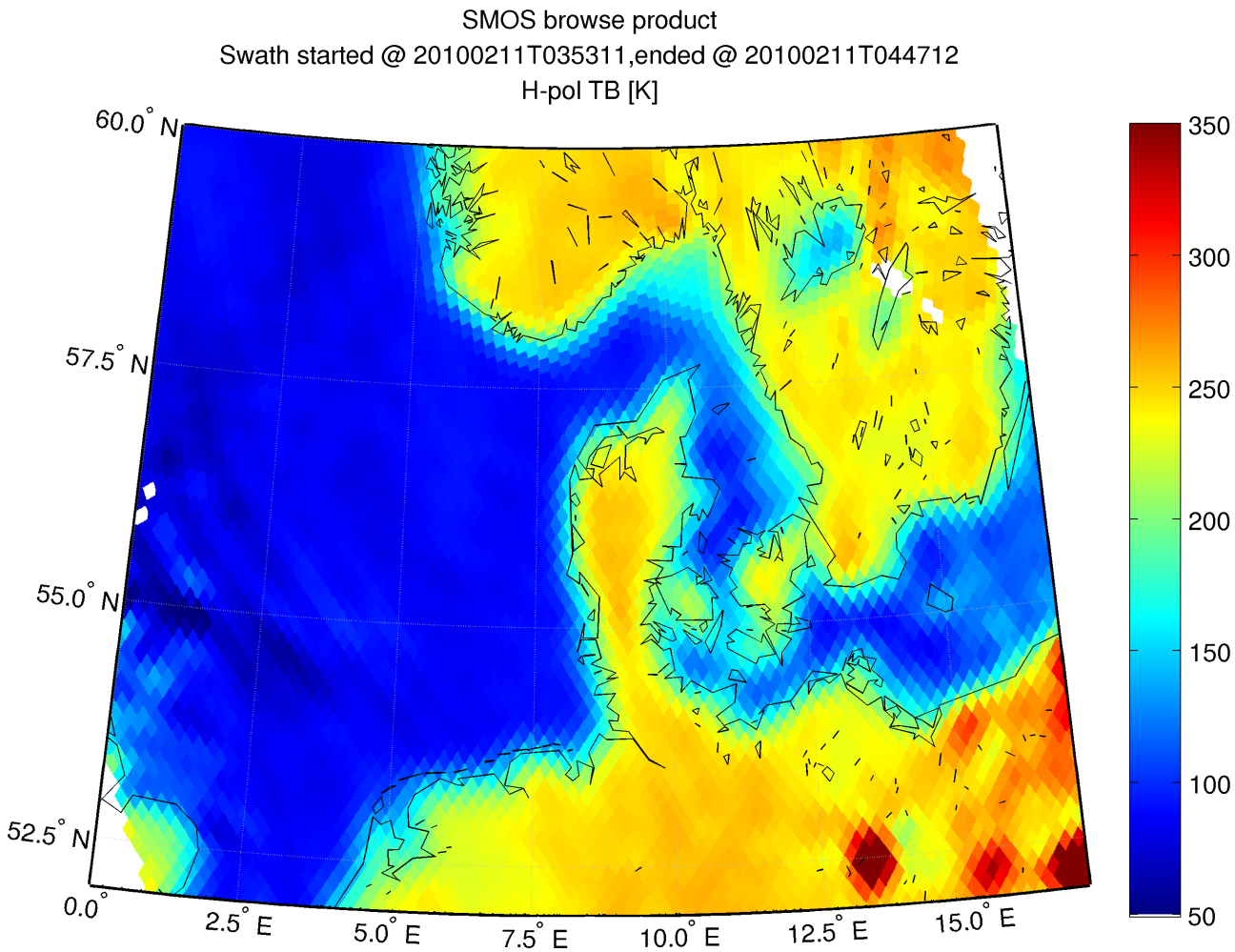


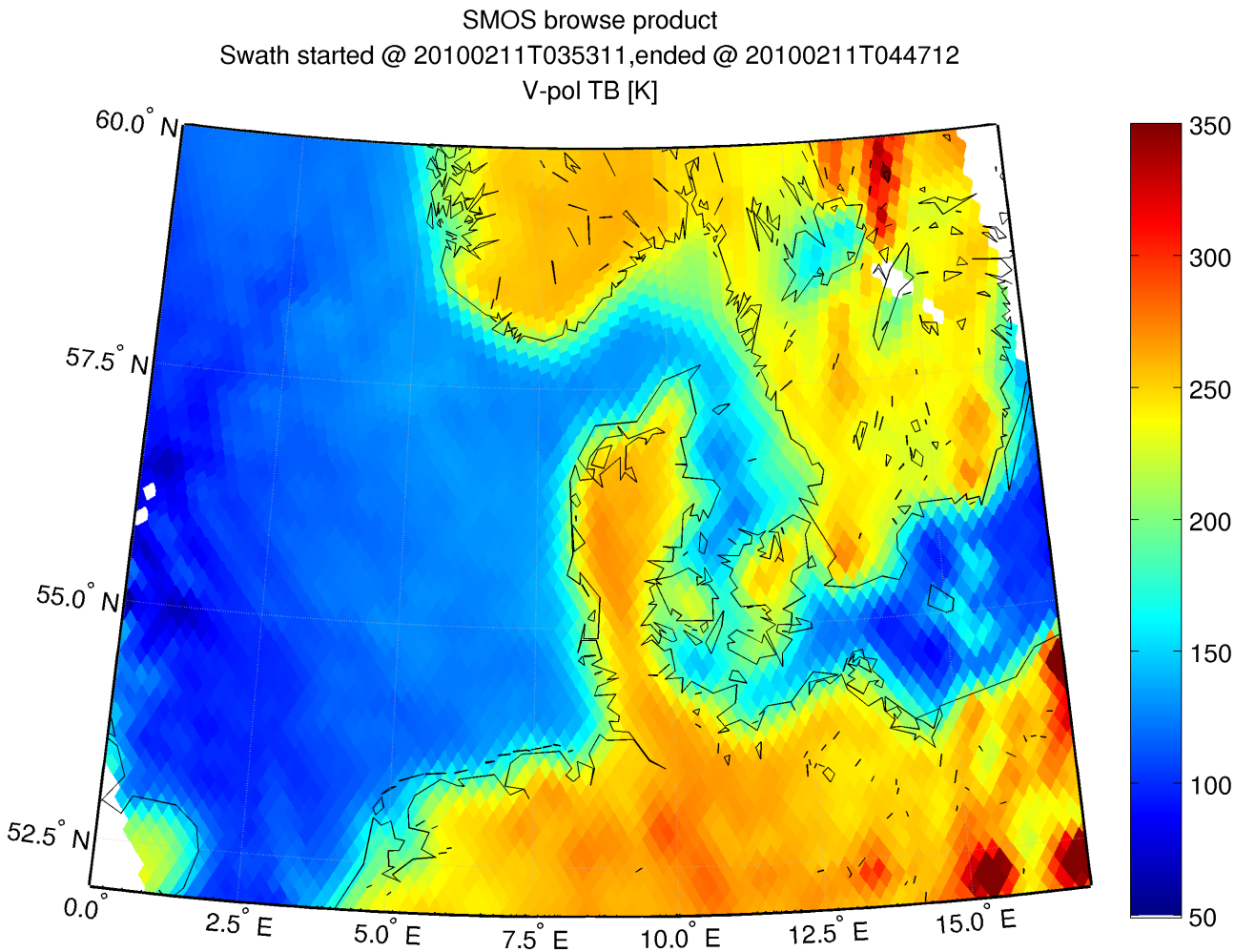
SMOS View of Australia

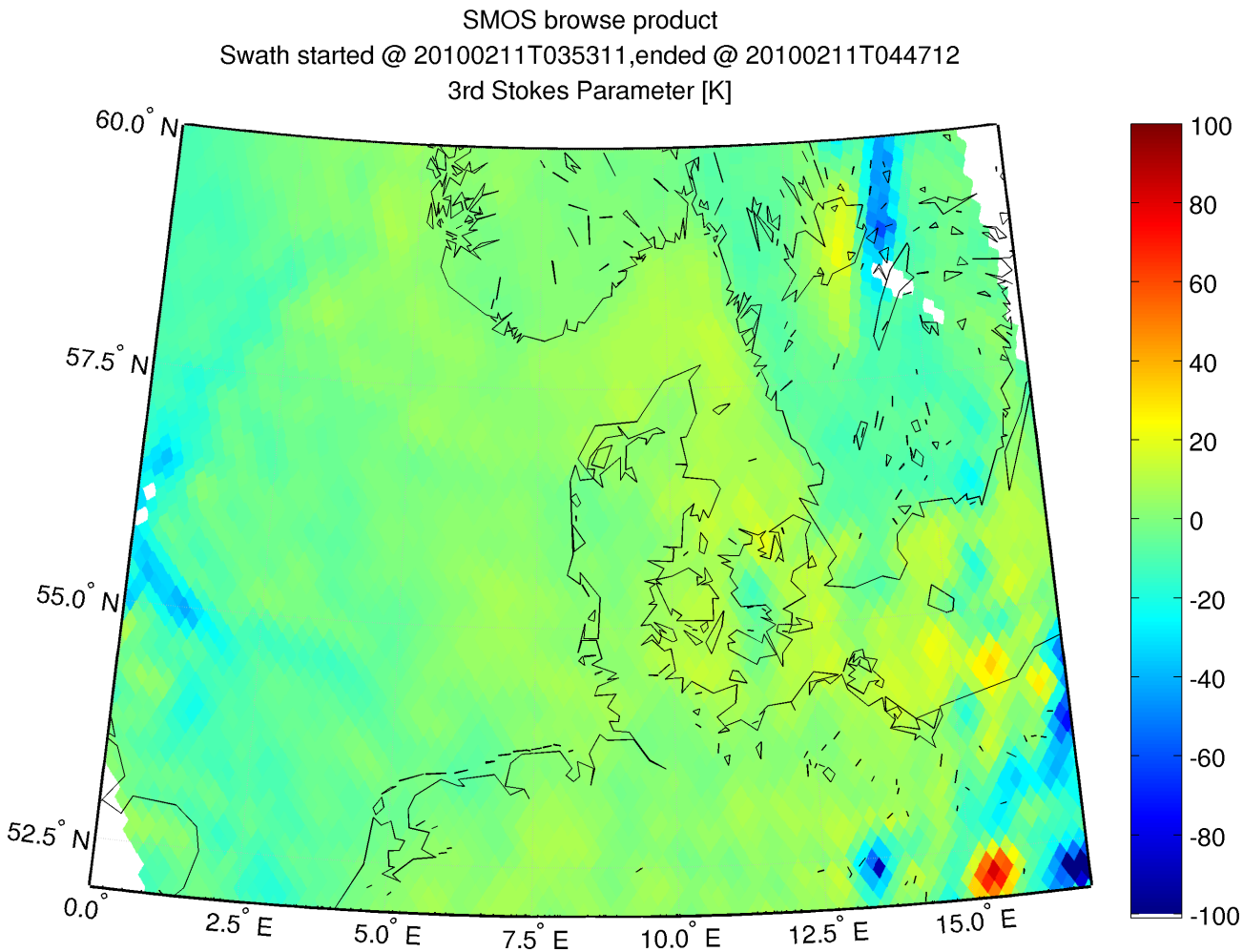


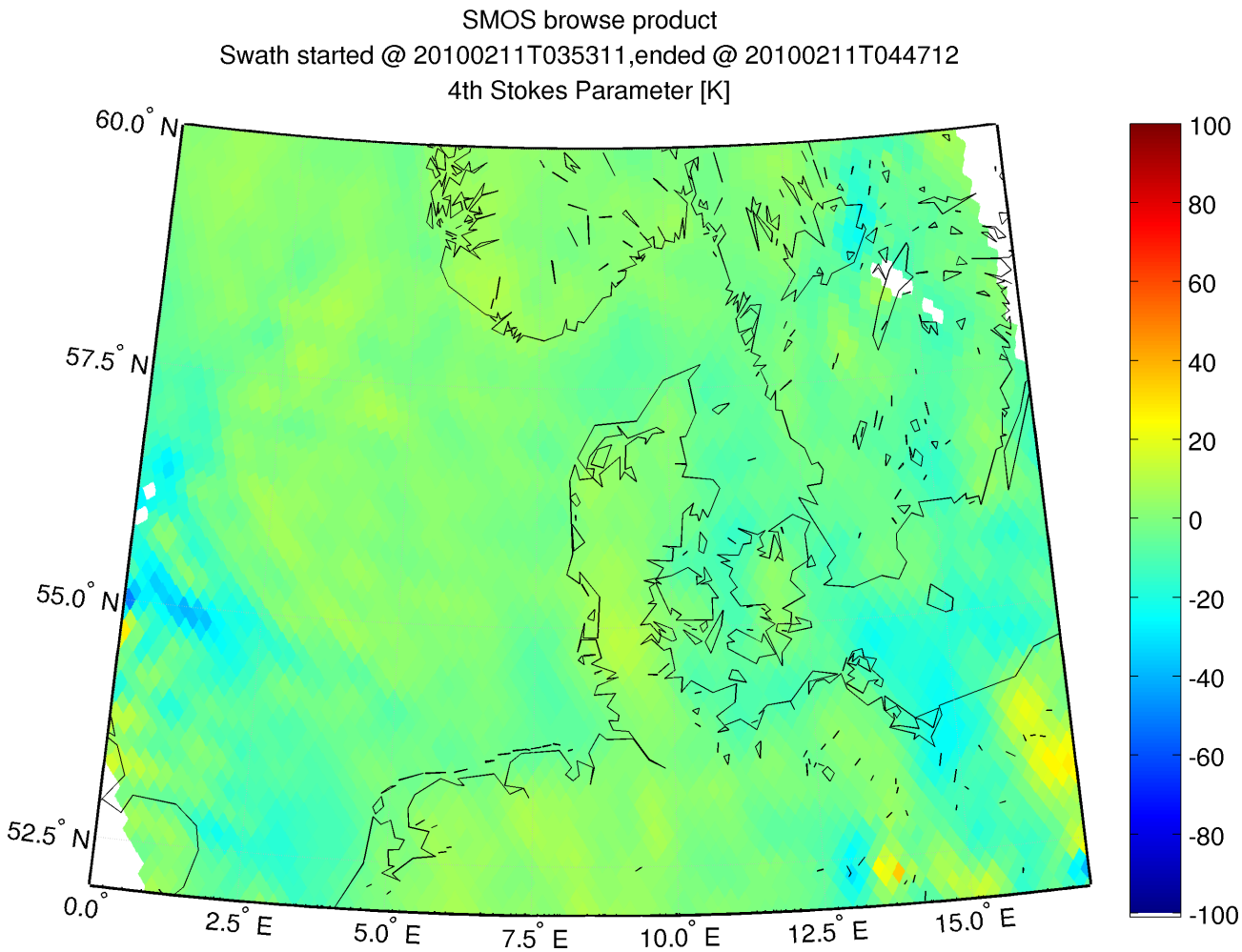
Conclusion

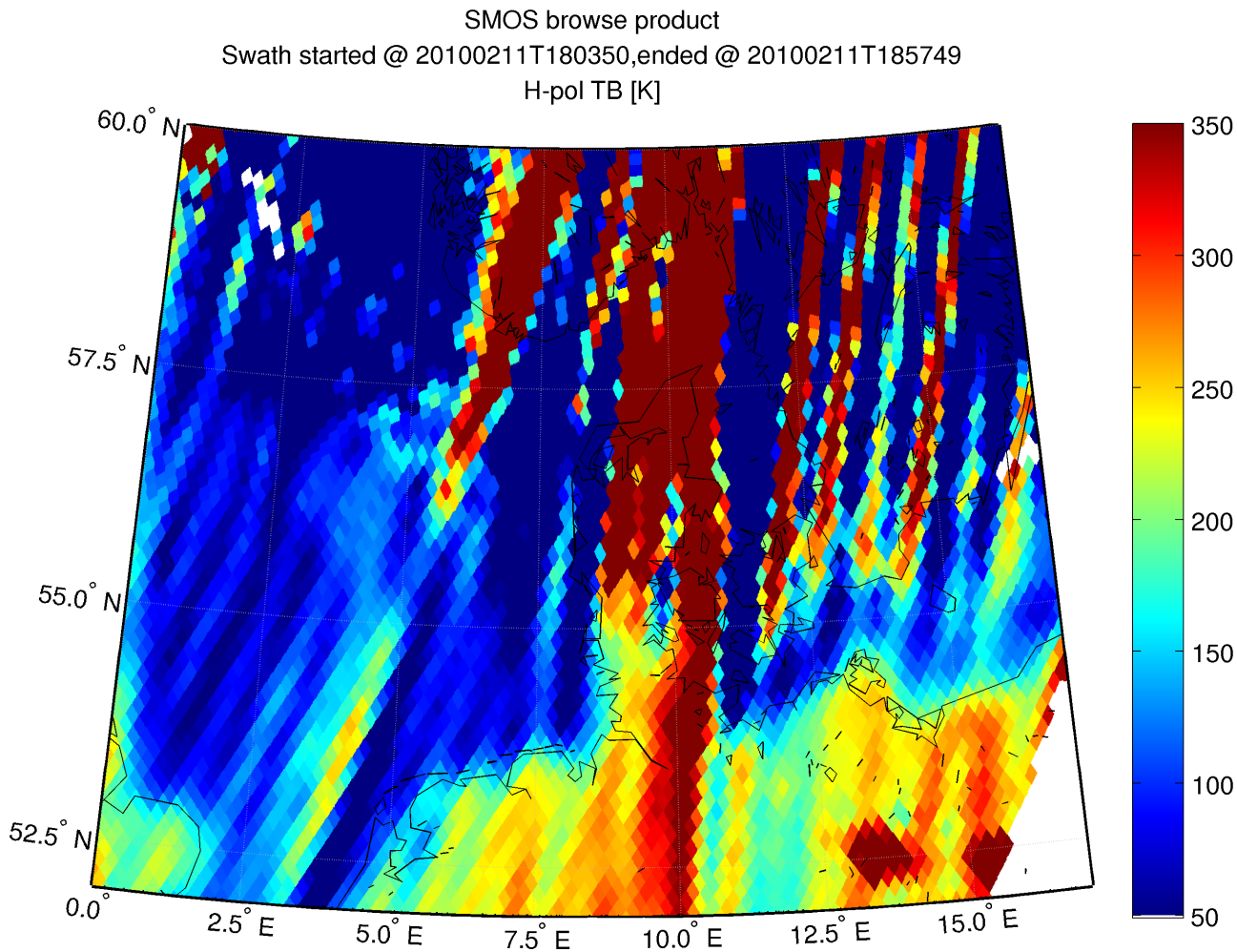
- RFI is generally there
- RFI is very variable in time, and space
- Polarimetric signatures from SMOS looks like airborne ditto!
  - hence methods investigated using airborne data can be applied.
- Polarimetry looks promising
- Glitch detector after polarimetry looks very promising

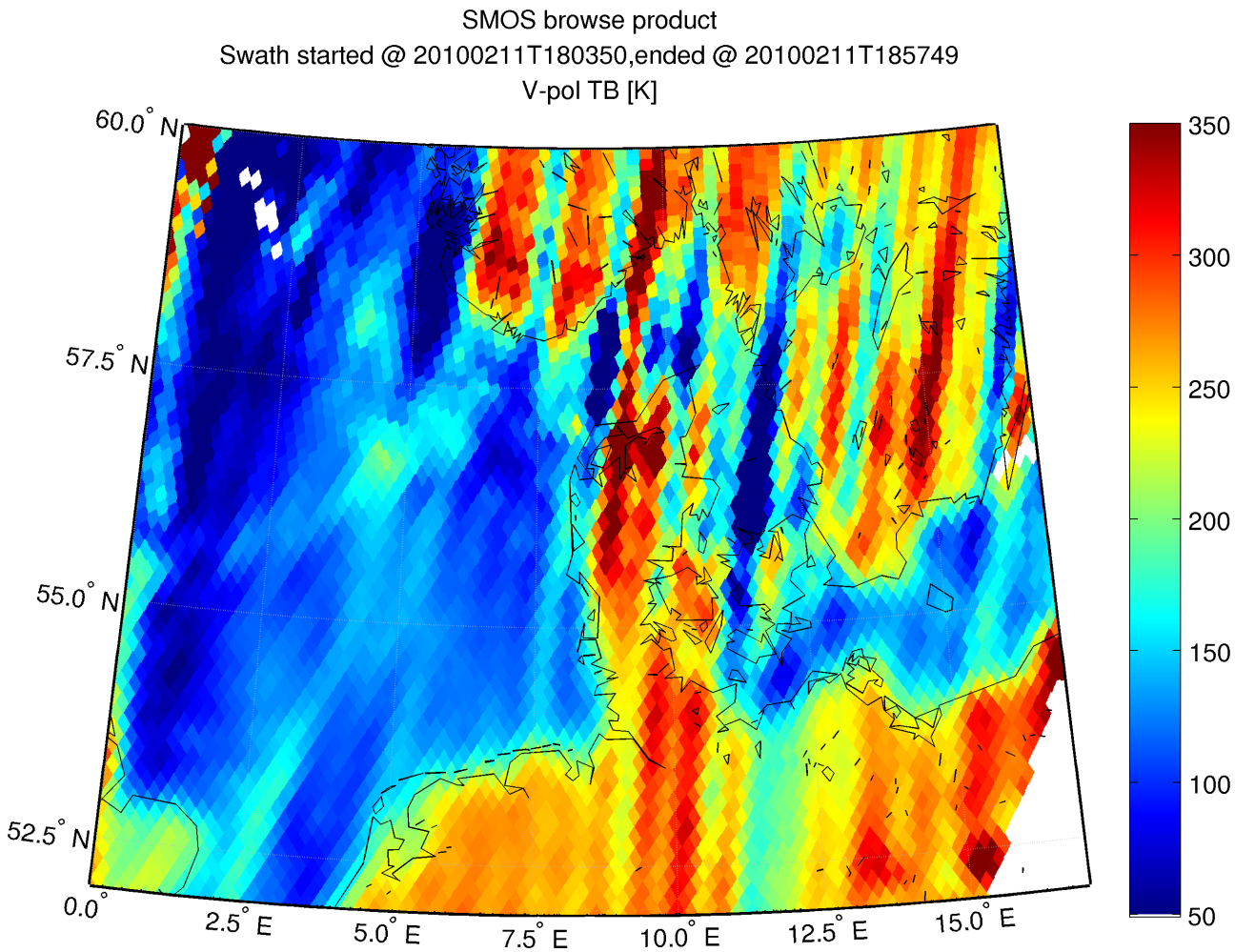

SMOS browse product
Swath started @ 20100211T035311,ended @ 20100211T044712
H-pol TB [K]
60.0° N
57.5° N
55.0° N
52.5° N
0.0°
2.5° E
5.0° E
7.5° E
10.0° E
12.5° E
15.0° E
350
300
250
200
150
100
50

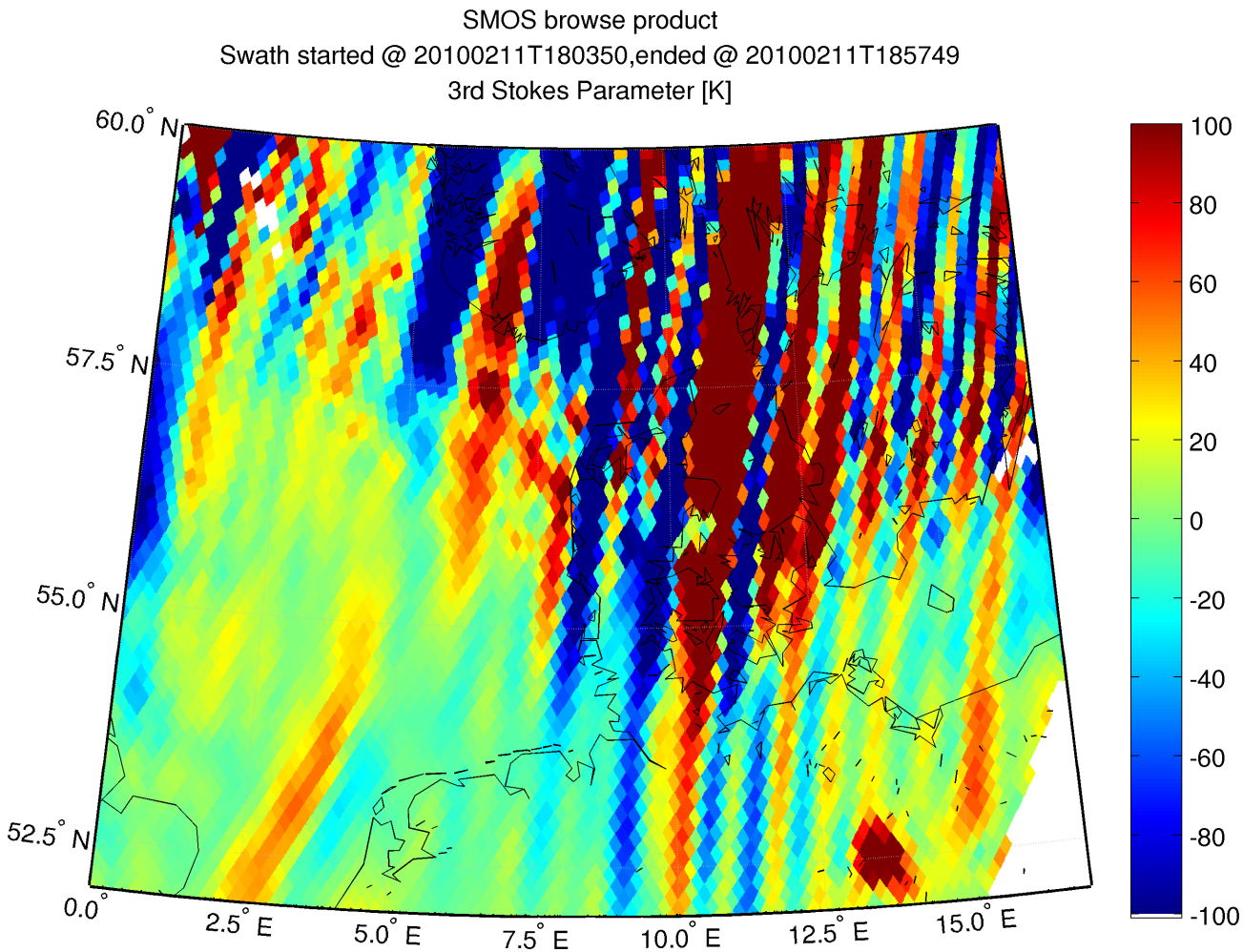

SMOS browse product
Swath started @ 20100211T035311,ended @ 20100211T044712
V-pol TB [K]
60.0° N
57.5° N
55.0° N
52.5° N
0.0°
2.5° E
5.0° E
7.5° E
10.0° E
12.5° E
15.0° E
350
300
250
200
150
100
50

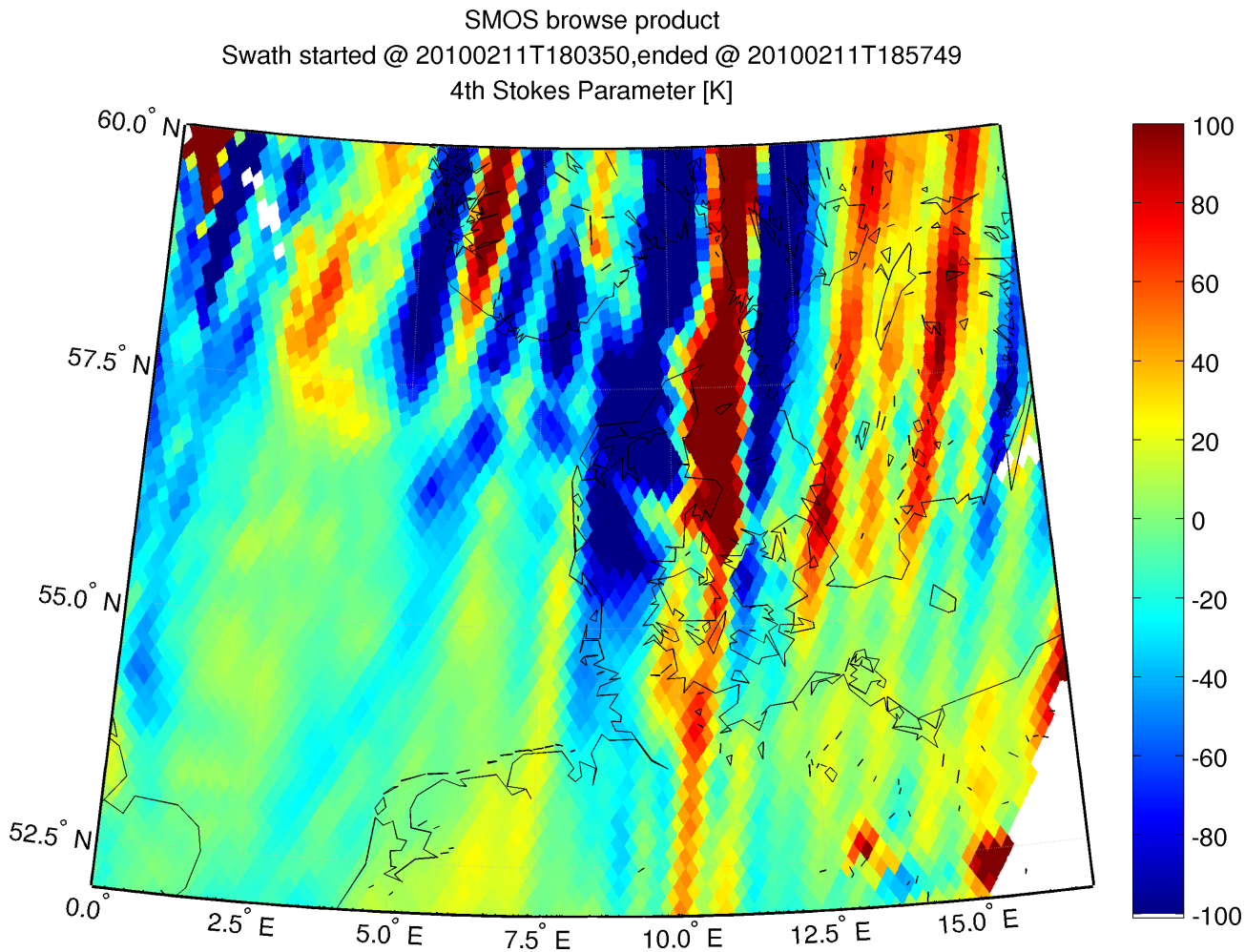

SMOS browse product
Swath started @ 20100211T035311,ended @ 20100211T044712
3rd Stokes Parameter [K]
60.0° N
57.5° N
55.0° N
52.5° N
0.0°
2.5° E
5.0° E
7.5° E
10.0° E
12.5° E
15.0° E
100
80
60
40
20
0
-20
-40
-60
-80
-100


SMOS browse product
Swath started @ 20100211T035311,ended @ 20100211T044712
4th Stokes Parameter [K]
60.0° N
57.5° N
55.0° N
52.5° N
0.0°
2.5° E
5.0° E
7.5° E
10.0° E
12.5° E
15.0° E
100
80
60
40
20
0
-20
-40
-60
-80
-100


SMOS browse product
Swath started @ 20100211T180350,ended @ 20100211T185749
H-pol TB [K]
60.0° N
57.5° N
55.0° N
52.5° N
0.0°
2.5° E
5.0° E
7.5° E
10.0° E
12.5° E
15.0° E
350
300
250
200
150
100
50


SMOS browse product
Swath started @ 20100211T180350,ended @ 20100211T185749
V-pol TB [K]
60.0° N
57.5° N
55.0° N
52.5° N
0.0°
2.5° E
5.0° E
7.5° E
10.0° E
12.5° E
15.0° E
350
300
250
200
150
100
50


SMOS browse product
Swath started @ 20100211T180350,ended @ 20100211T185749
3rd Stokes Parameter [K]
60.0° N
57.5° N
55.0° N
52.5° N
0.0°
2.5° E
5.0° E
7.5° E
10.0° E
12.5° E
15.0° E
100
80
60
40
20
0
-20
-40
-60
-80
-100


SMOS browse product
Swath started @ 20100211T180350,ended @ 20100211T185749
4th Stokes Parameter [K]
60.0° N
57.5° N
55.0° N
52.5° N
0.0°
2.5° E
5.0° E
7.5° E
10.0° E
12.5° E
15.0° E
100
80
60
40
20
0
-20
-40
-60
-80
-100