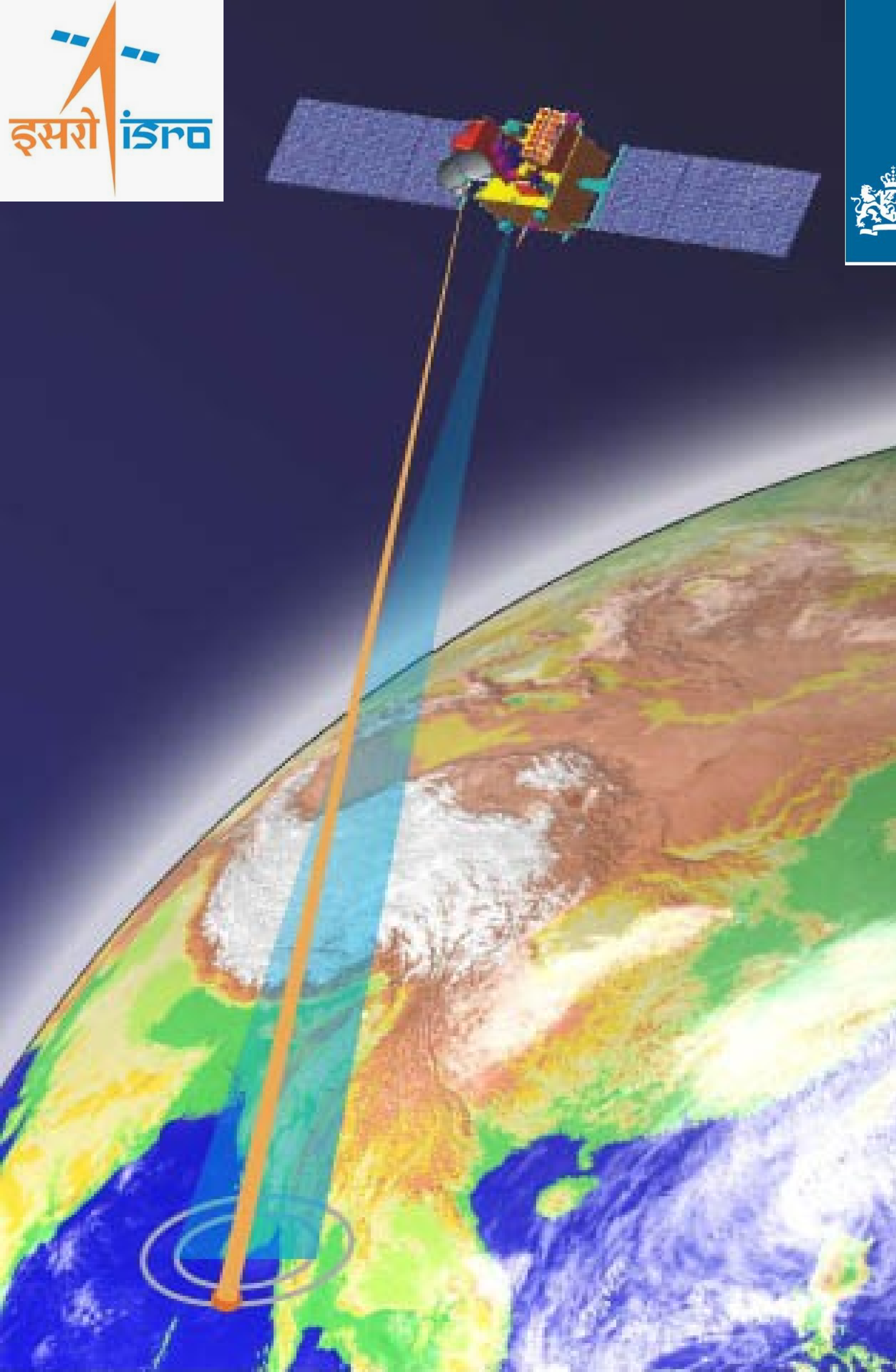

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EUMETSAT

OSI SAF
Ocean and Sea Ice

NWP SAF
Numerical Weather Prediction

OceanSat-2 Scatterometer Calibration and Validation

May 2011

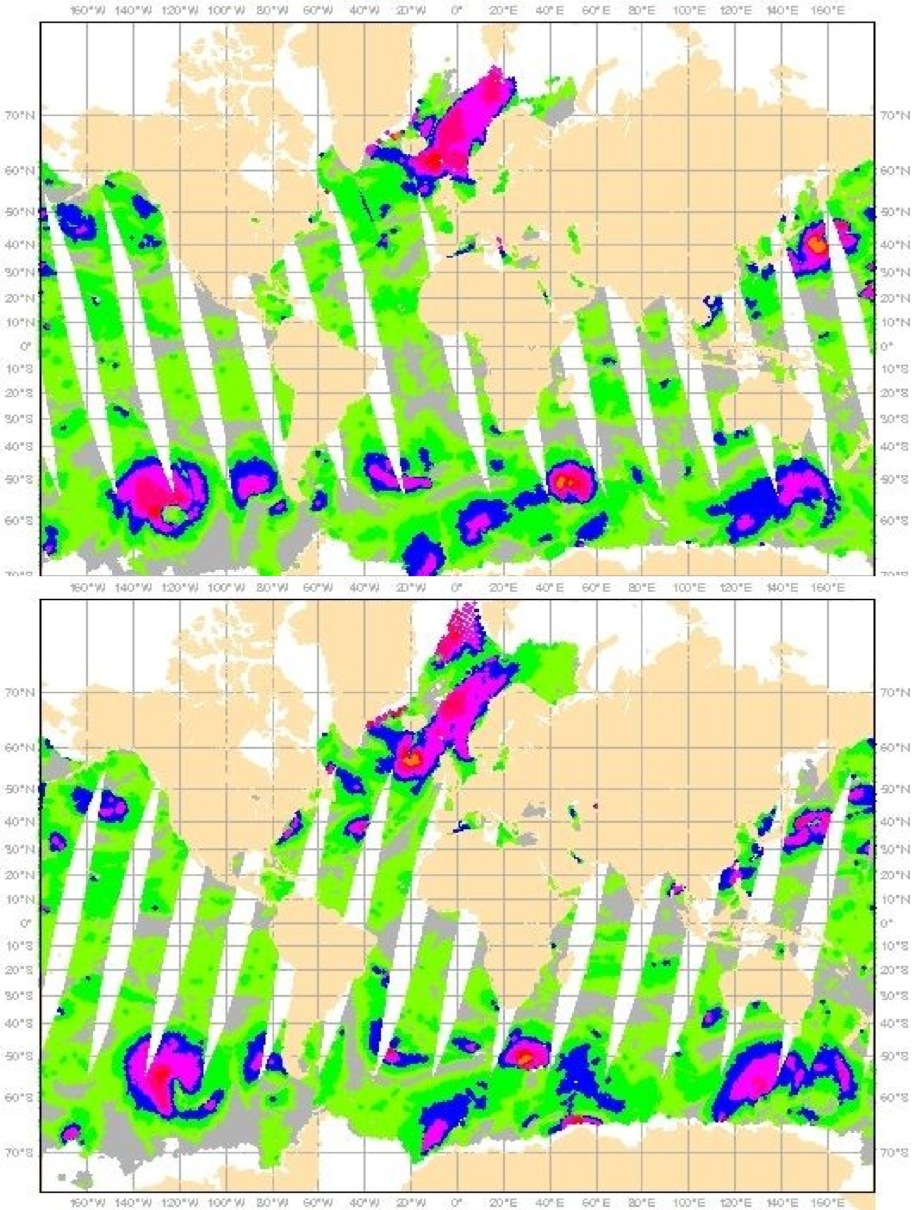
Ad Stoffelen
Anton Verhoef

Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Verkeer en Waterstaat

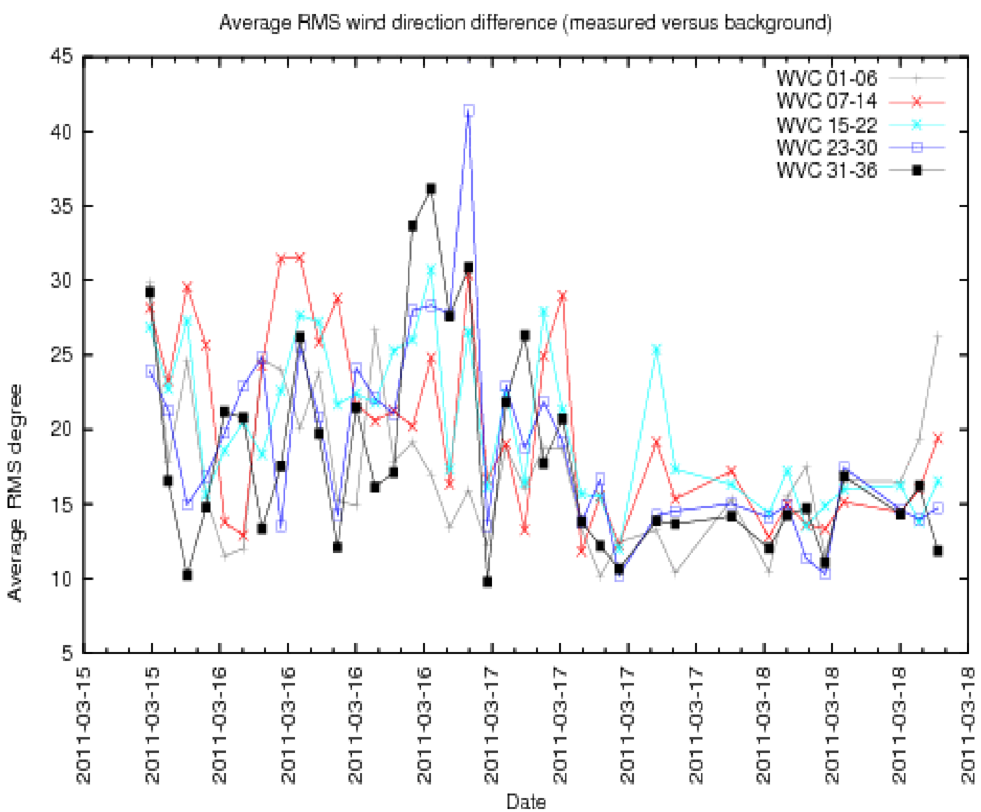
European Involvement OSCAT

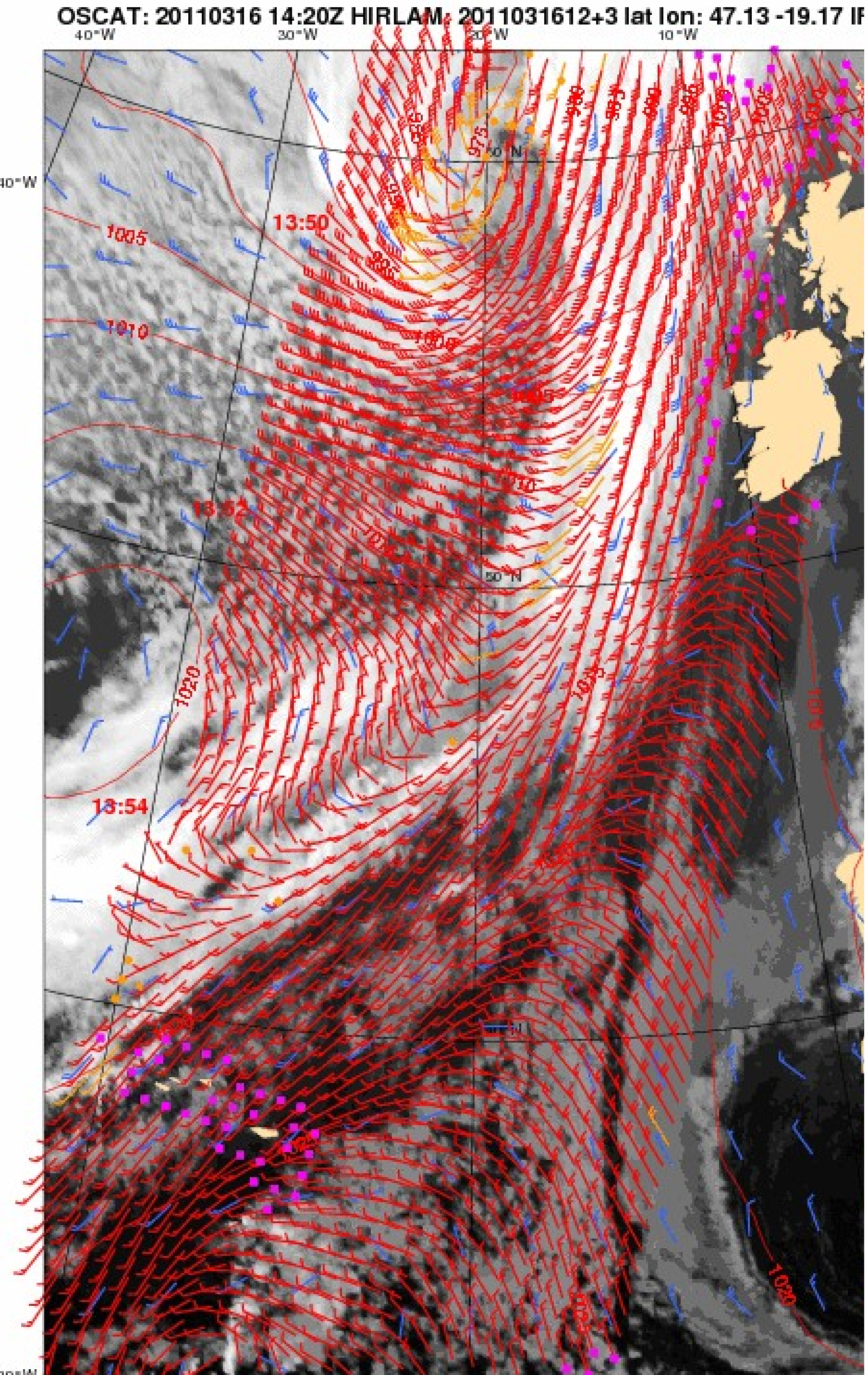
- OceanSat-2 AO project:
  - KNMI (PI), ECMWF, UK Met.Office, Meteo France, IFREMER, CMIMA
  - KNMI contribution in context of EUMETSAT Ocean and Sea Ice SAF and NWP SAF
  - Cal/Val uses European QuikScat heritage
  - OWDP: OSCAT Wind Data Processor (clone SDP)
  - Experimental NRT OWDP at KNMI
- MoUs EUMETSAT-ISRO-NOAA arranging:
  - Global orbit dumps at Svalbard
  - L0 and L1/2 processing in India and at EUMETSAT (backup)
  - Dump, processing and distribution trial ongoing
  - Timeliness within 1 hour through EUMETCAST

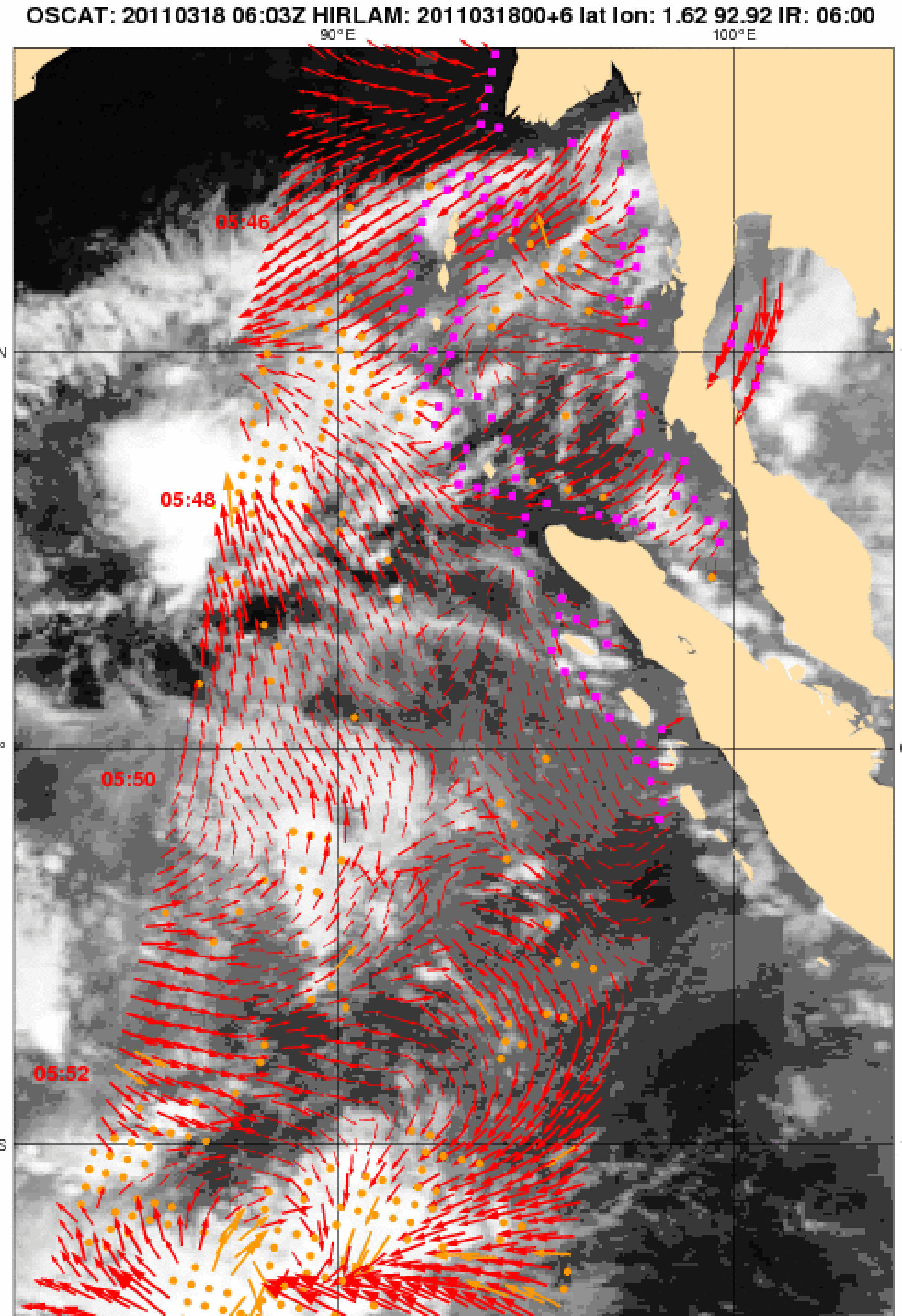
OWDP at KNMI



- Very grateful for NRT data since mid March
- First assessment done




OSCAT: 20110316 14:20Z HIRLAM: 2011031612+3 lat lon: 47.13 -19.17 IR
40°W
30°W
20°W
10°W
13:50
13:52
13:54
1005
1010
1020
50°N


OSCAT: 20110318 06:03Z HIRLAM: 2011031800+6 lat lon: 1.62 92.92 IR: 06:00
90°E
100°E
10°N
0°
10°S
05:46
05:48
05:50
05:52

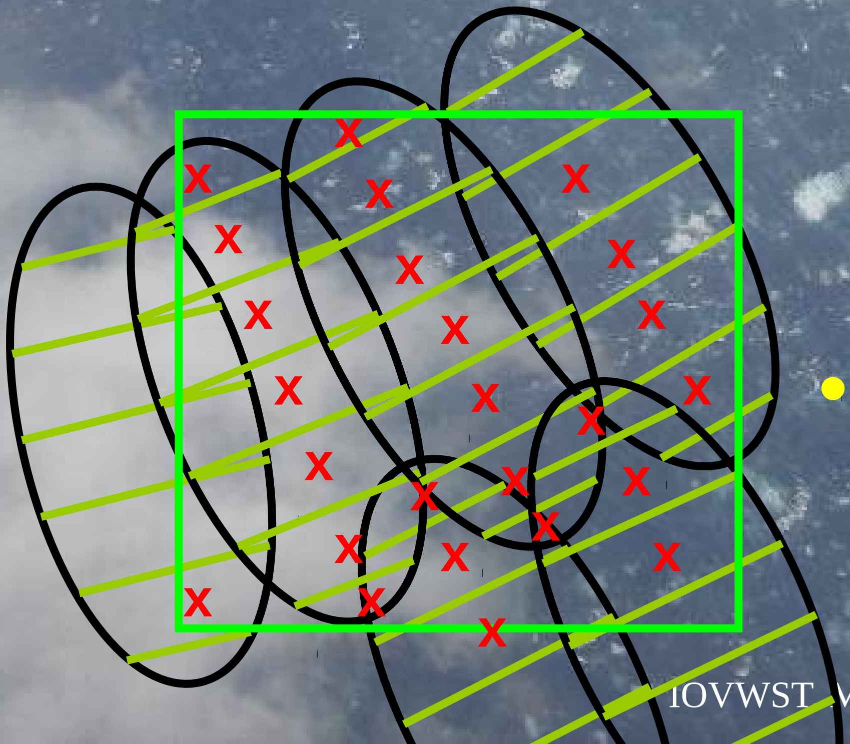
OSCAT AO project principle

- OSCAT provides Ku band Normalized Radar Cross Section, NRCS, or σ^0
- σ^0 is a geophysical quantity with a given true PDF over the world oceans
- All instruments should provide a similar σ^0 PDF
- Ku-band VV and HH provided by SeaSat, NSCAT, SeaWinds and OSCAT
- KNMI's SeaWinds Data Processor (SDP) uses NSCAT GMF
- Since the instruments are similar, we expect that the SeaWinds (QSCAT) wind processing applied to OSCAT σ^0 data produces a PDF similar to the SeaWinds wind PDF
- This would imply intercalibration of OSCAT and QSCAT, a requirement to establish a QSCAT/OSCAT FCDR

➢ Are the OSCAT σ^0 and wind PDFs similar to the QSCAT σ^0 and wind PDFs ?

L2A

- Contains "slice" σ^0
- Slices form an "Egg"
- An egg is one radar return



- A WVC view is build from slices

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OSCAT Wind Data Processor - OWDP

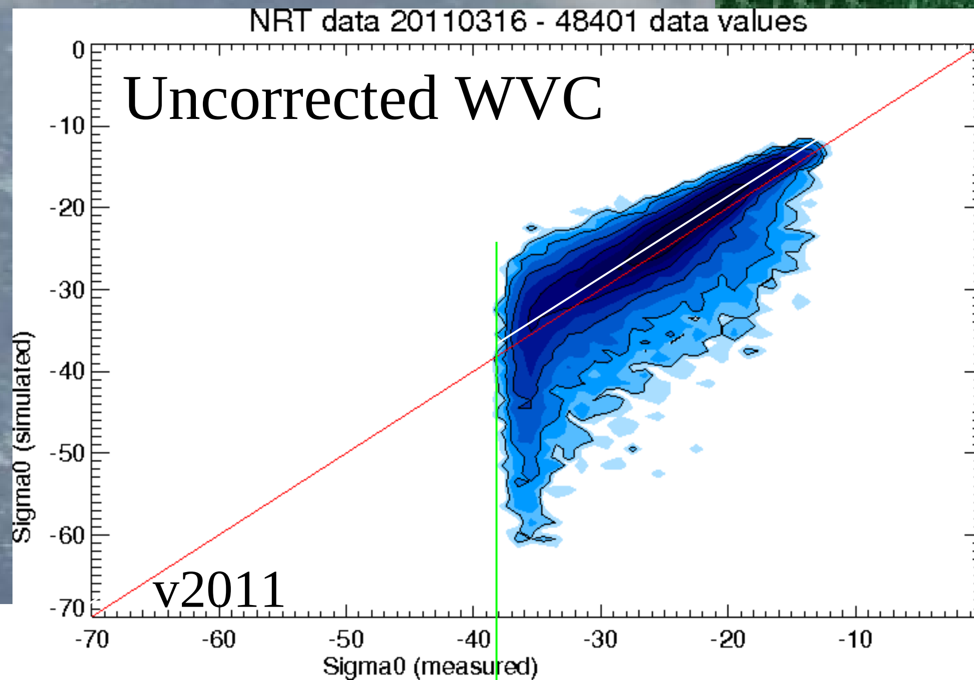
- We compute WVC σ^0 for each view as

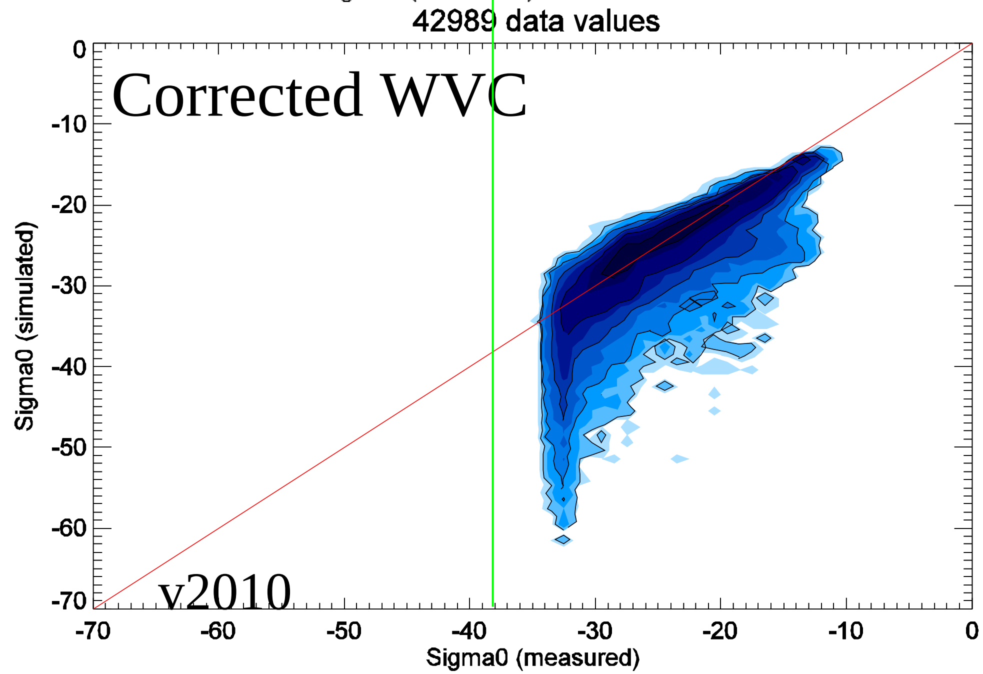
$$\sigma^0 = \frac{\sum_S \alpha_S^{-1} \sigma_S^0}{\sum_S \alpha_S^{-1}}$$

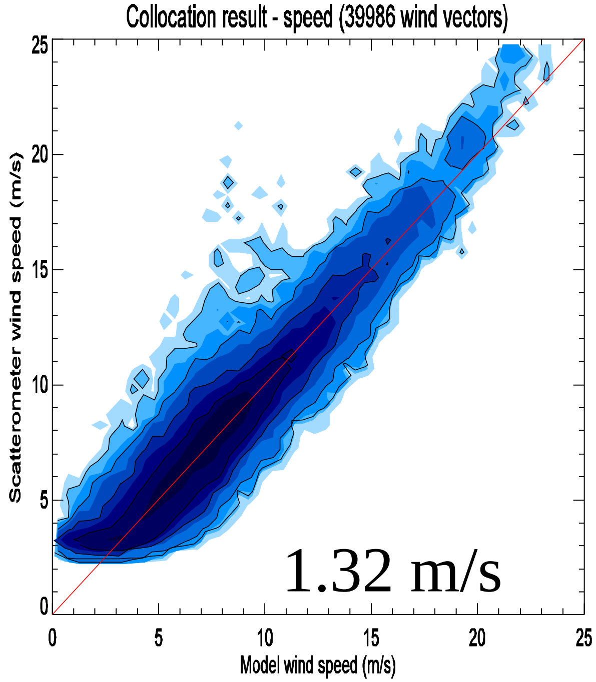
- α_S^{-1} is a measure of the slice area
- Several egg footprints in one WVC
- Except in case of (L2A sigma0 flags):
  - Sigma0 is poor
  - Kp is poor
  - Invalid footprint
  - Footprint contains saturated slice
- SeaWinds data processor (SDP) clone

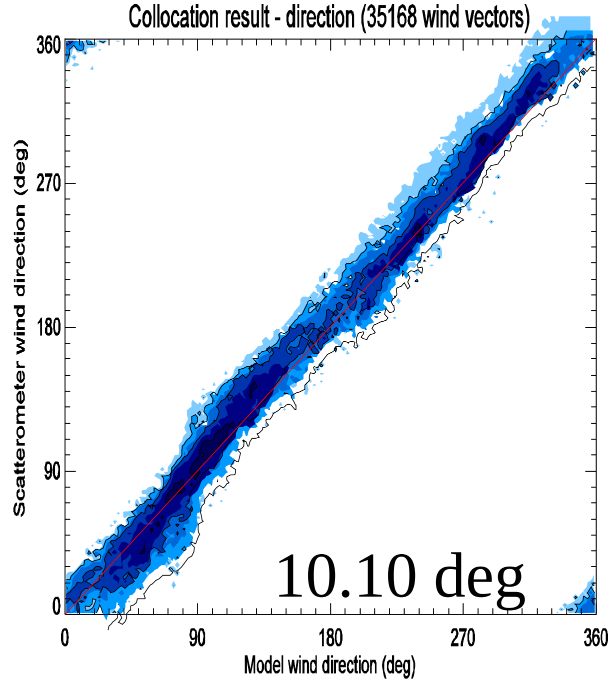
L2A WVC σ^0

- Median of v2011 σ^0 pdf ~1 dB low
- v2011 σ^0 pdf truncated at
  -38 dB (-37 dB)
- Improved w.r.t. KNMI truncation in v2010 at -34 dB
- Further analysis ongoing, e.g., of –ve σ^0





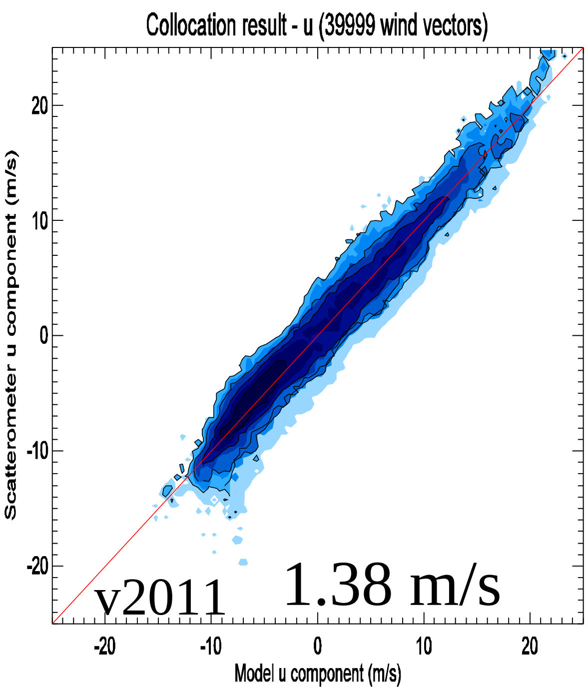


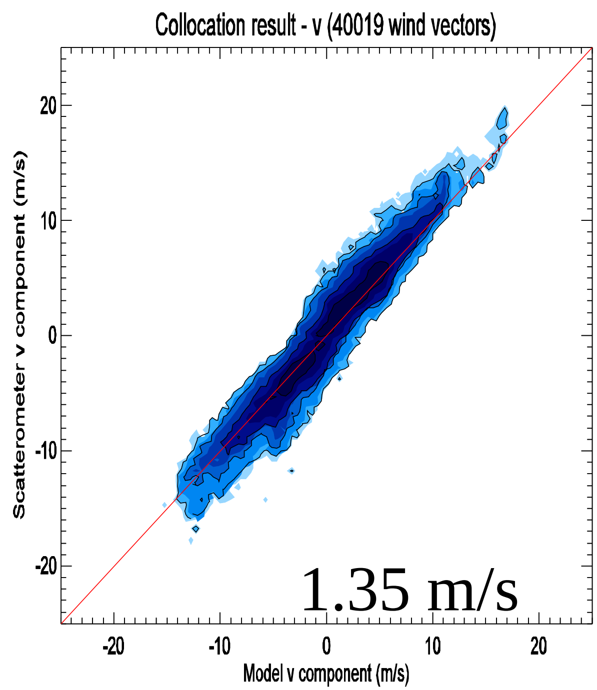


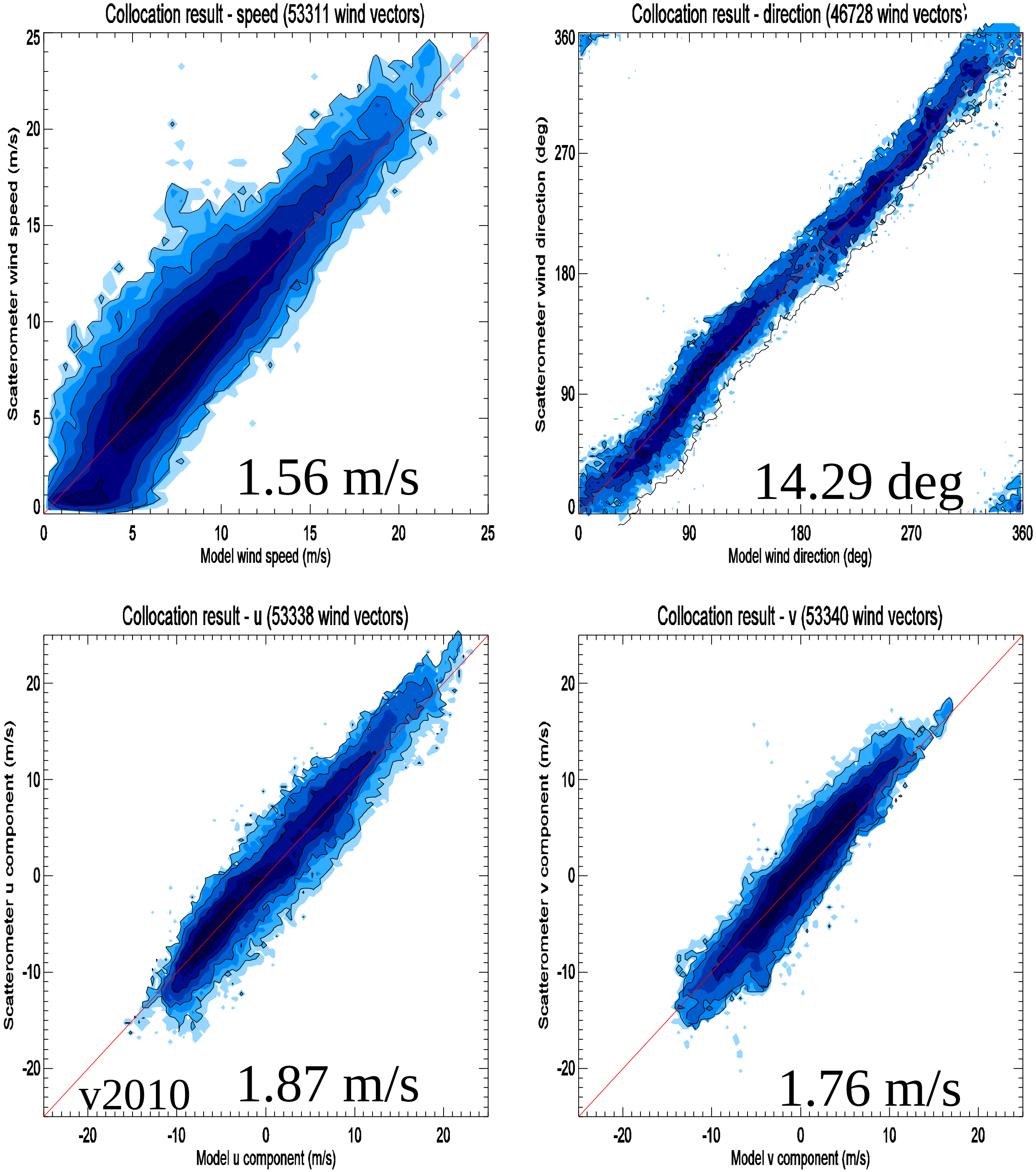
OWDP vs ECMWF

- 1dB corrected σ^0
- SDs given
- OSCAT MLE norm
- ➢ Speed bias vanished
- ➢ Improved wind direction
- ➢ Reduced cut-off due to σ^0 PDF at ~2 m/s
- ➢ VRMS diff. ECMWF

  1.9 m/s (as SDP25)
- ➢ Lower than OSI SAF VRMS error requirement of 2 m/s







ISRO L2B vs ECMWF

- SDs of differences given
- Outliers reason for degradation w.r.t. OWDP ?

➢ Bias at low speeds

➢ Vector RMS difference of 2.6 m/s (>2 m/s)

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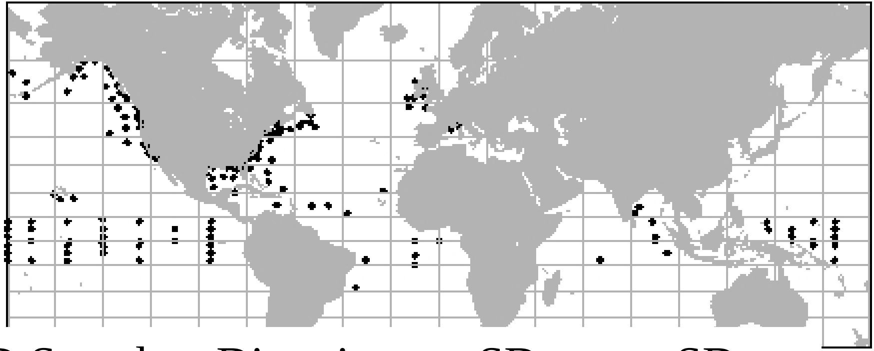
Buoy summary – OSCAT -



OSCAT 50-km product SDs v2010	SD Speed m/s	Direction degree	SD *u* m/s	SD *v* m/s
L2B, collocated OWDP, ≥ 6 m/s	1.34	19.40	2.41	2.30
OWDP, collocated L2B, ≥ 6 m/s	1.33	16.67	2.02	2.12

- OWDP winds verify better with buoys than ISRO L2B does (in vector RMS)
- OWDP provides winds closer to the coast
- Low OWDP winds are relatively poor due to the backscatter PDF bias
- v2011 is improved in this respect

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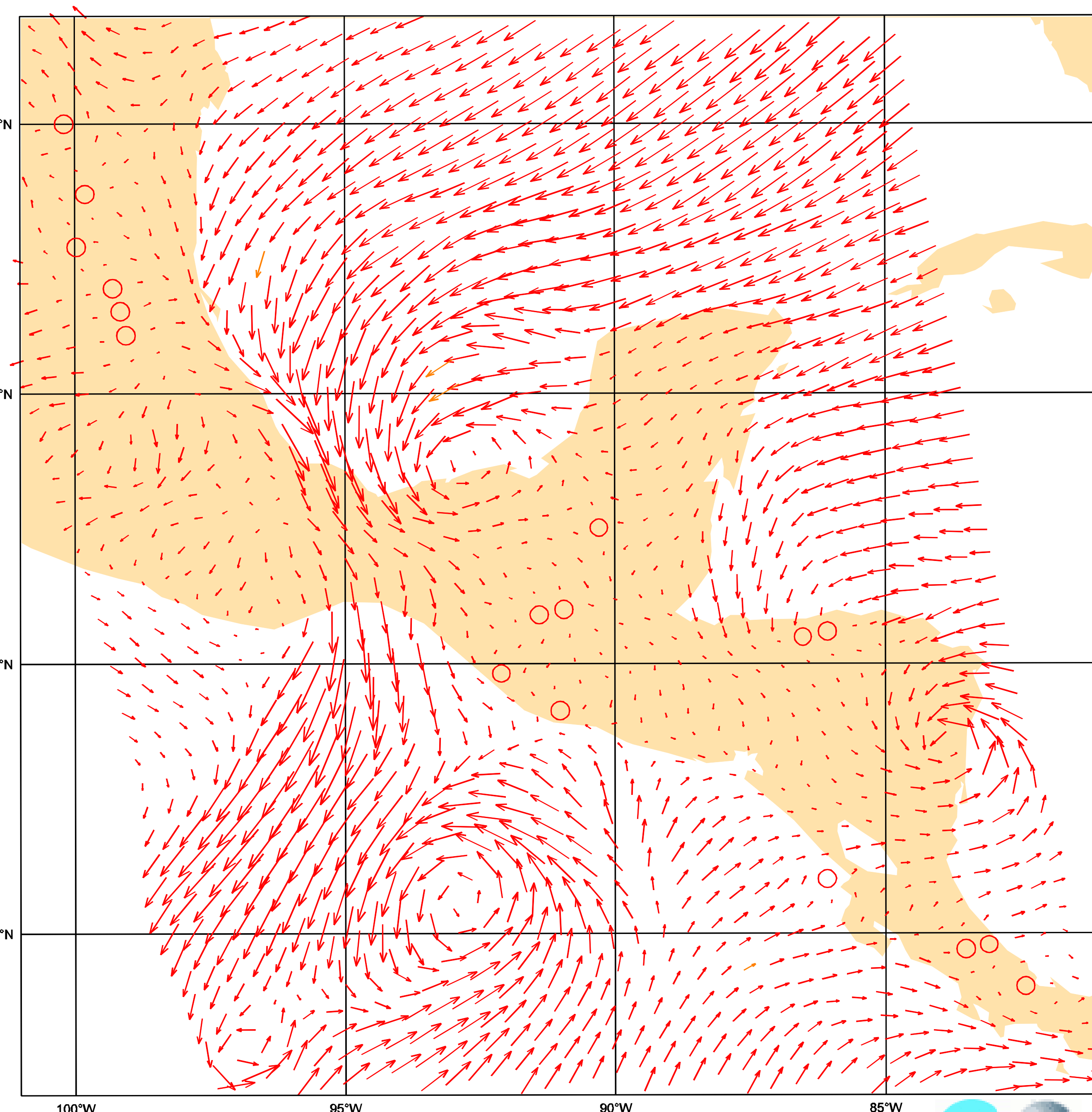
ECMWF

- Example wind field



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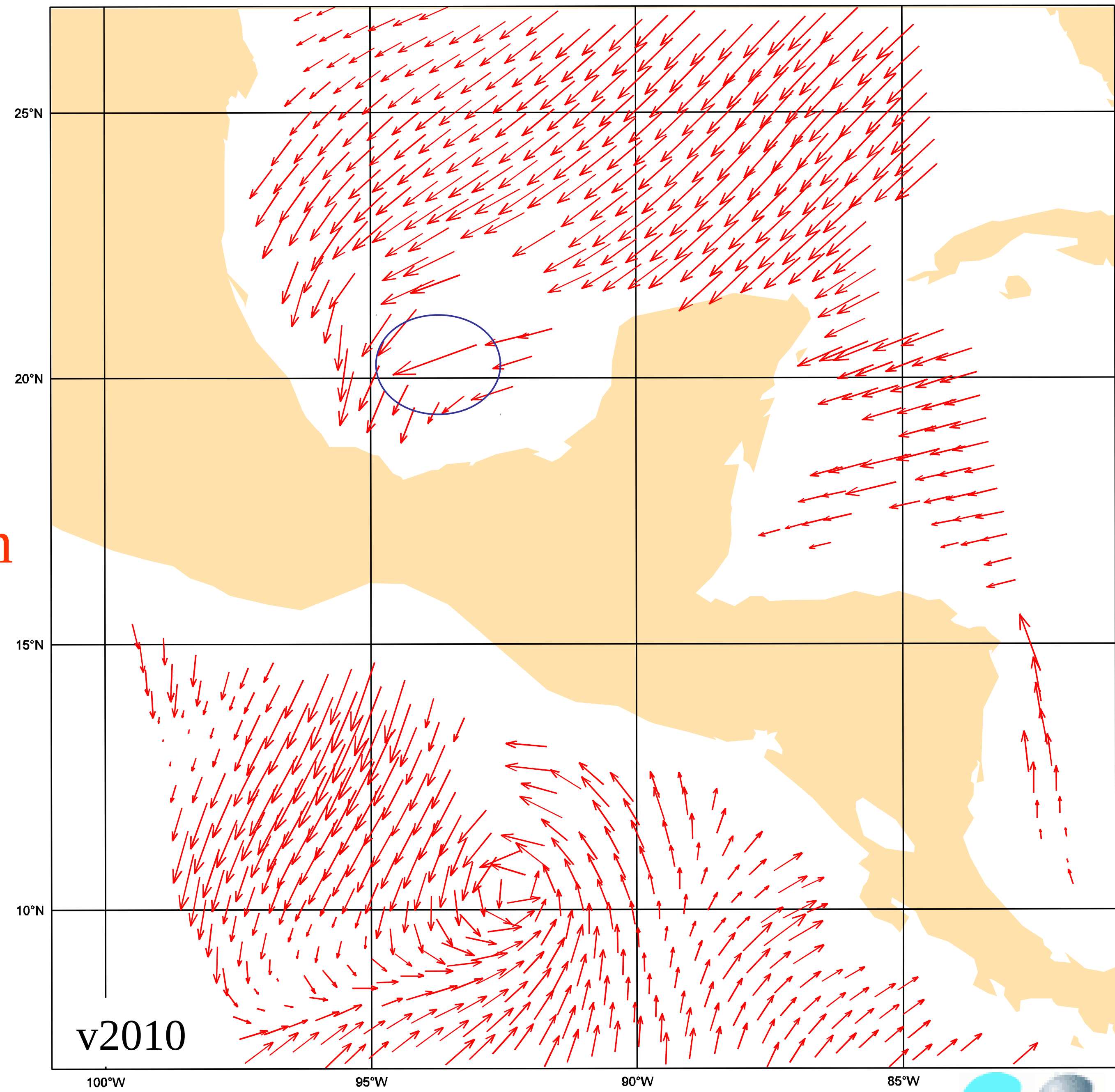
L2B

- Shear
- Straight streamlines
- ➢ Wind direction continuity constraint in AR
- Speed outlier (in rainy area)



OWDP

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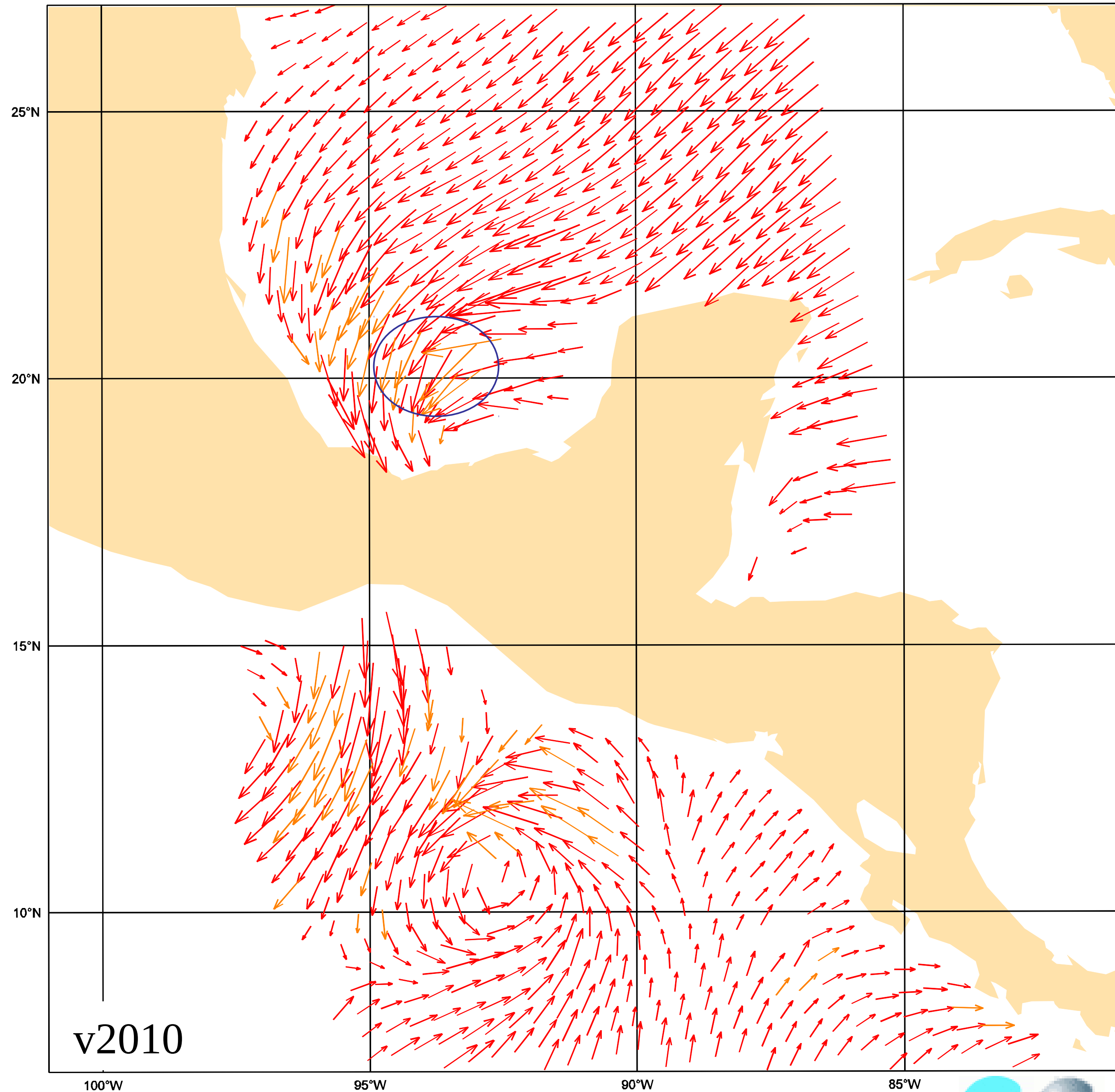
- Rotation and shear
- Explicit constraints in 2DVAR
- Consistency
- Rain flagged orange by normalised MLE (2%)



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Preliminary analysis

- 2011 ISRO data presents a clear step forward
- OSCAT provides useful measurements from space fulfilling user requirements
- σ^0 PDF biased and cut off for lower winds; fixes are needed
- Verification within spec. against buoys > 4 m/s;
- Ambiguity removal in ISRO L2B seems too smooth
- A 6-month reprocessed data set has recently been provided
- More detailed analysis to be done, i.e., check MLE norm analysis (*Kp*), rain flagging and QC, sea ice (Bayesian algorithm)

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Technical issues/user expectations

- Need controlled processing software update procedures with users in loop (parallel streams)
- QA and automated product quality flag (in OWDP)
- Service messages
- BUFR; is used for OWDP
  - QuikScat template;
  - WMO approval by EUMETSAT
- All useful items of BUFR message filled; e.g., input winds used for AR not in ISRO L2B at the moment
- NRT; as timely as possibly feasible
- Handle on orbit duplication

Conclusions

- NRT data stream on EUMETCAST
- OWDP and monitoring run experimentally at KNMI
- OSI SAF OWDP winds are within requirements; OSCAT does look like QSCAT
- Experimental version of OWDP will be made available
- Further analysis of the data is needed

➢ A high-quality FCDR of OSCAT and QSCAT appears well feasible

References

Publications on SDP, 2DVAR, sea ice, QC/rain, stress, buoy verification, … :

www.nwpsaf.org **scat@knmi.nl**

www.osi-saf.org

www.knmi.nl/scatterometer/publications/

www.knmi.nl/publications/; search "Stoffelen"

WVC slice averaging

- We compute WVC σ^0 and Kp α, β, γ for each view as

$$\sigma^0 = \frac{\sum_S \alpha_S^{-1} \sigma_S^0}{\sum_S \alpha_S^{-1}}$$

$$\alpha = \left(\sum_S \alpha_S^{-1} \right)^{-1}, \beta = \left(\sum_S \beta_S^{-1} \right)^{-1}, \gamma = \left(\sum_S \gamma_S^{-1} \right)^{-1}$$

A Wind Vector Cell (WVC) contains several egg footprints

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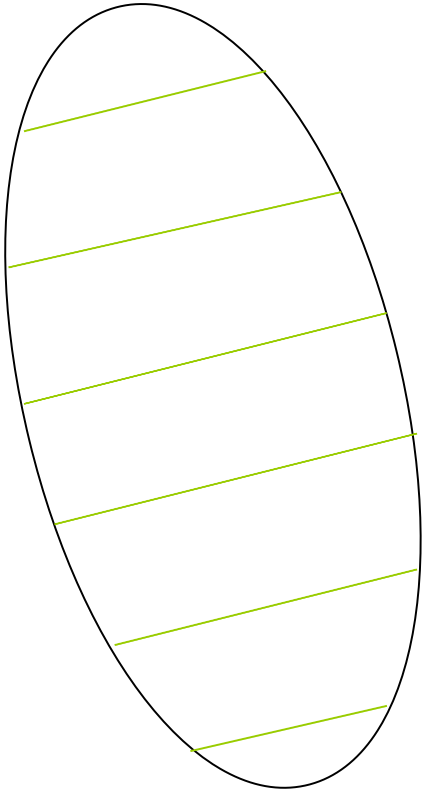
Recapitulate L2A slices

- $Kp_S^2 = \alpha_S + \beta_S / SNR_S + \gamma_S / SNR_S^2$
  $= f_S(\sigma^0_S)$ for a slice of given size

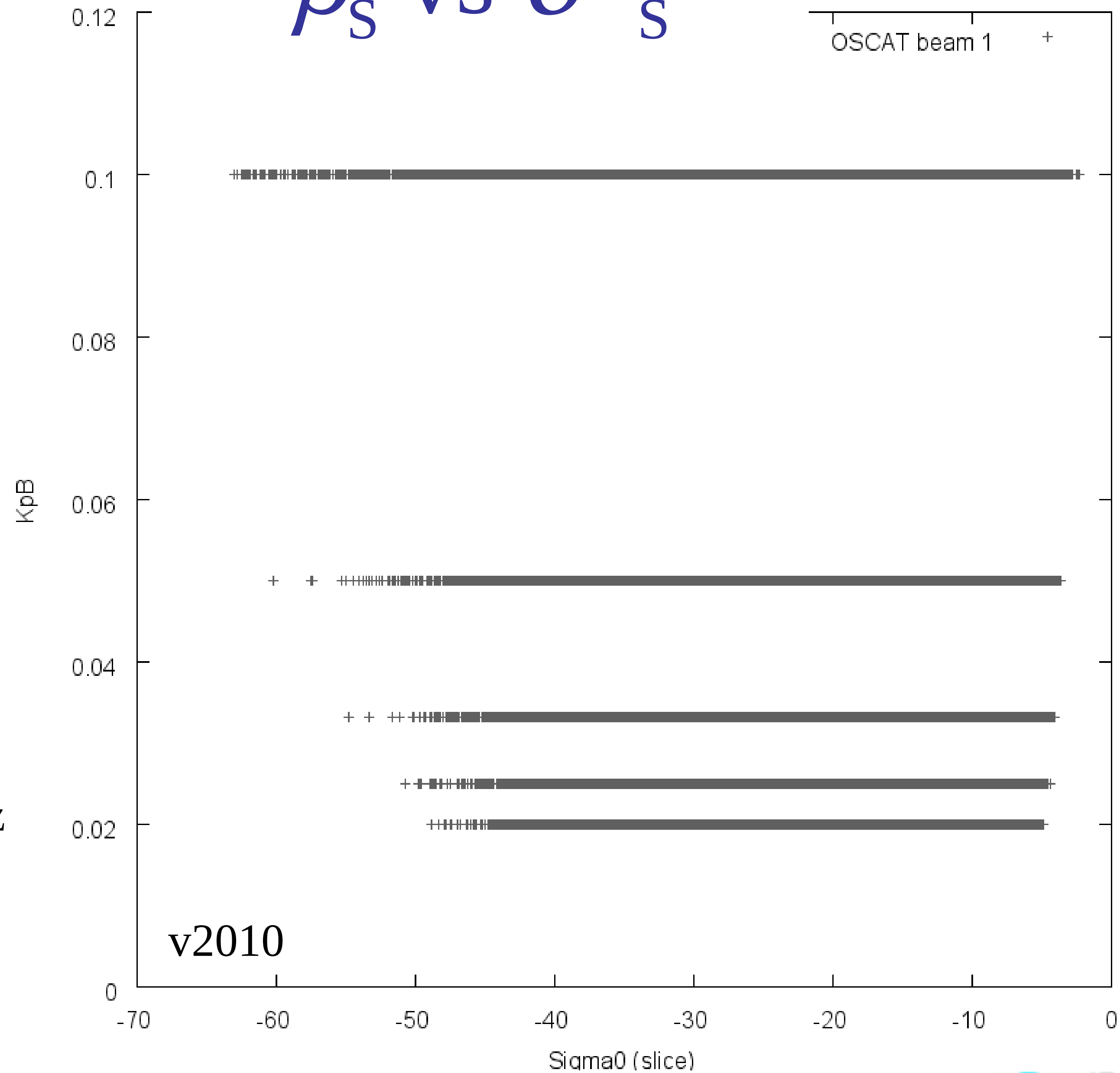
- α_S, β_S, γ_S and SNR_S depend on slice bandwidth B_S

- α_S / β_S and α_S / γ_S constant

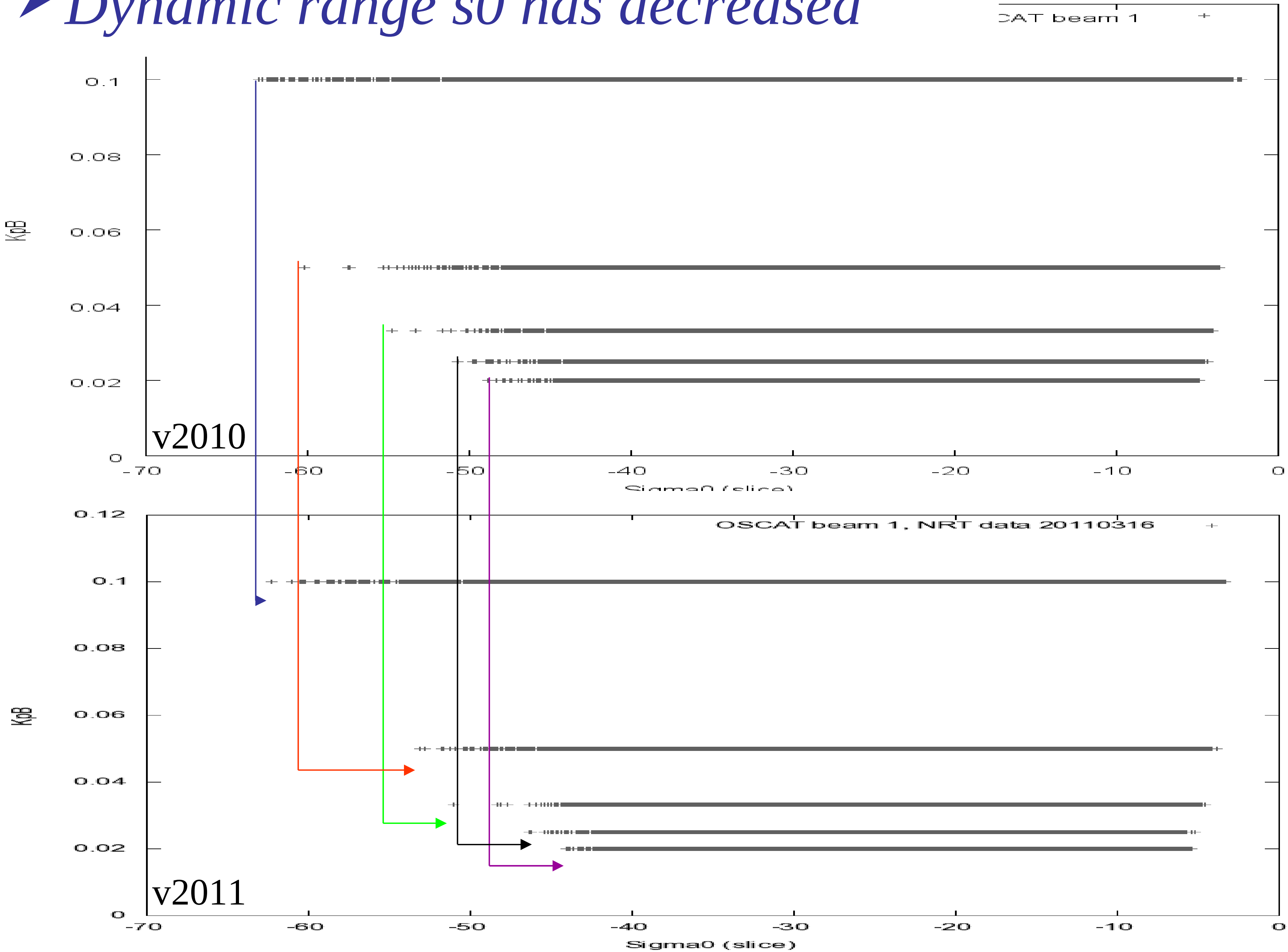


β_S vs σ^0_S

- $\beta_S = 2(B_S T_G)^{-1}$
- $T_G = 2.097$ ms
- 5 different B_S values, i.e., 5 slice types $\approx (50,40,30,20,10)$ kHz



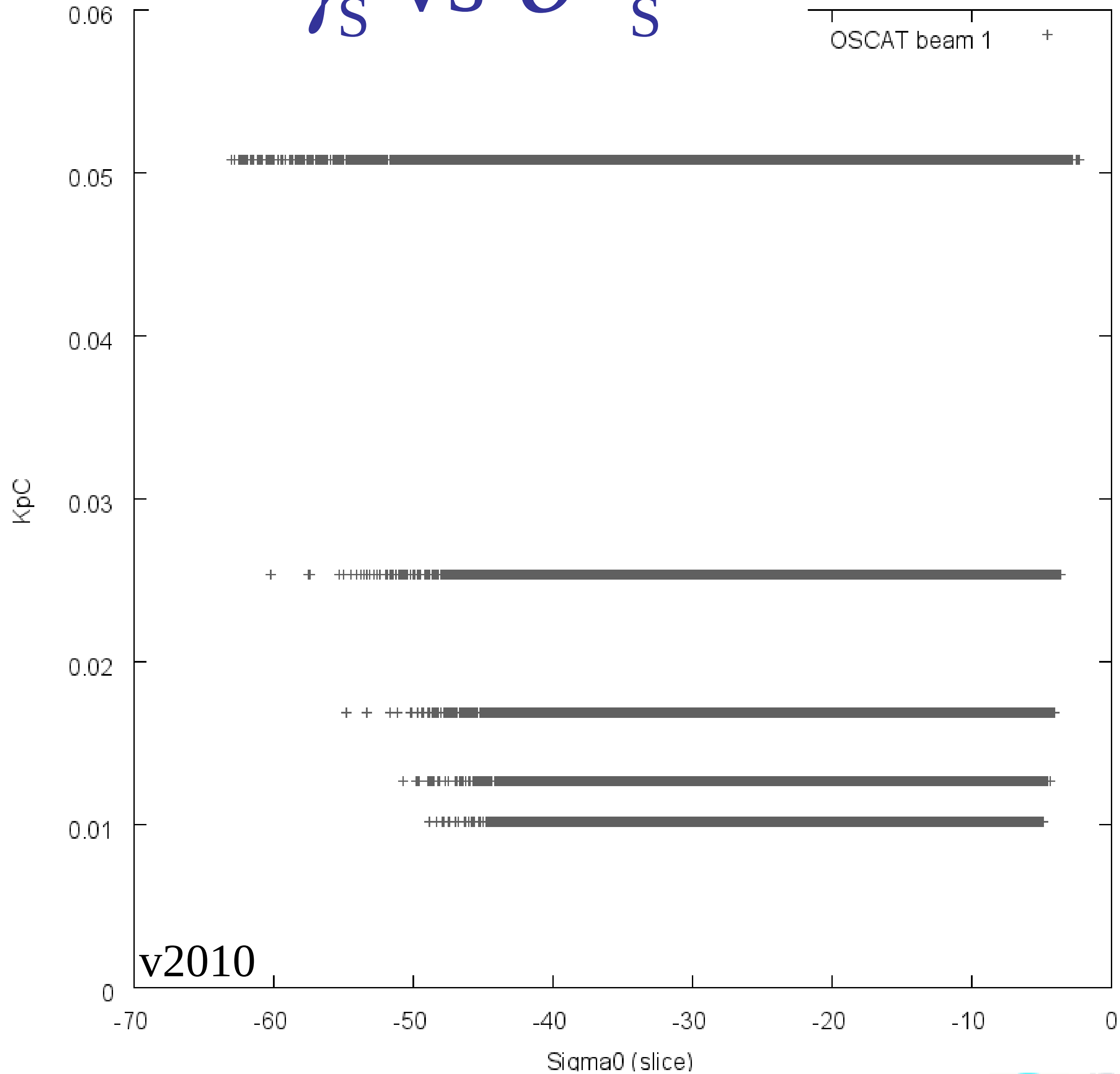
➢ *Dynamic range s0 has decreased*



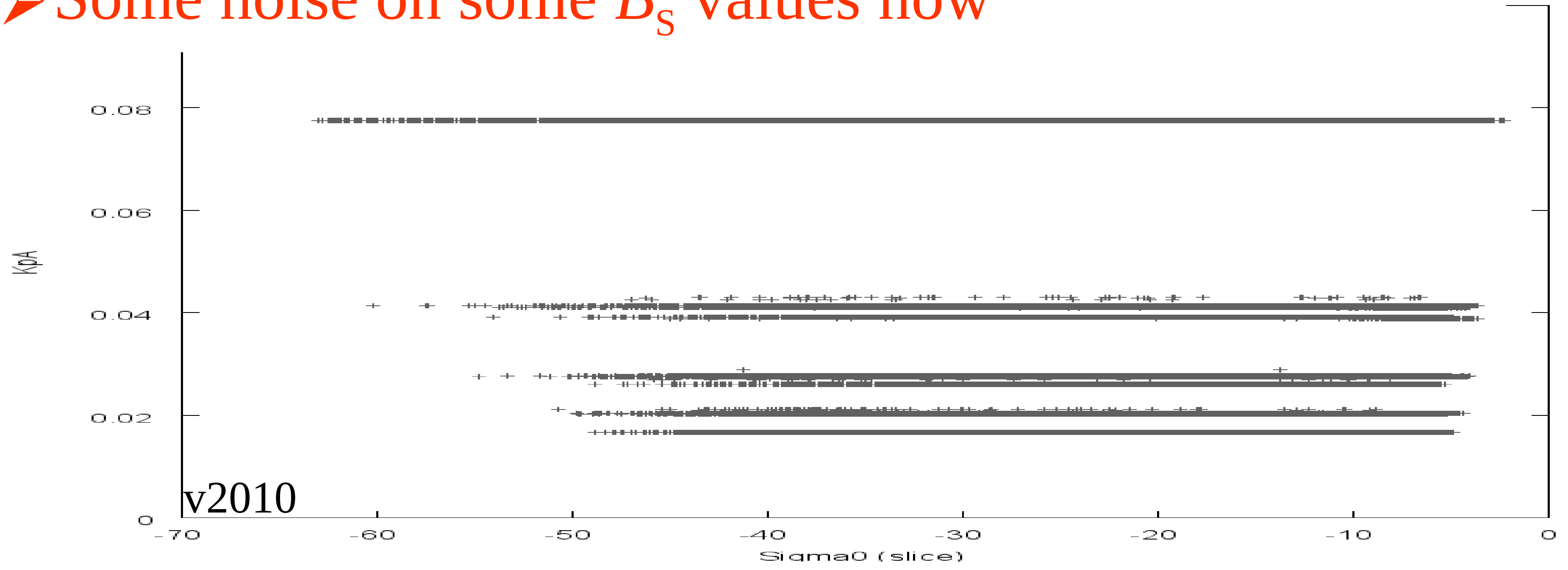
γ_S vs $\sigma^0{}_S$

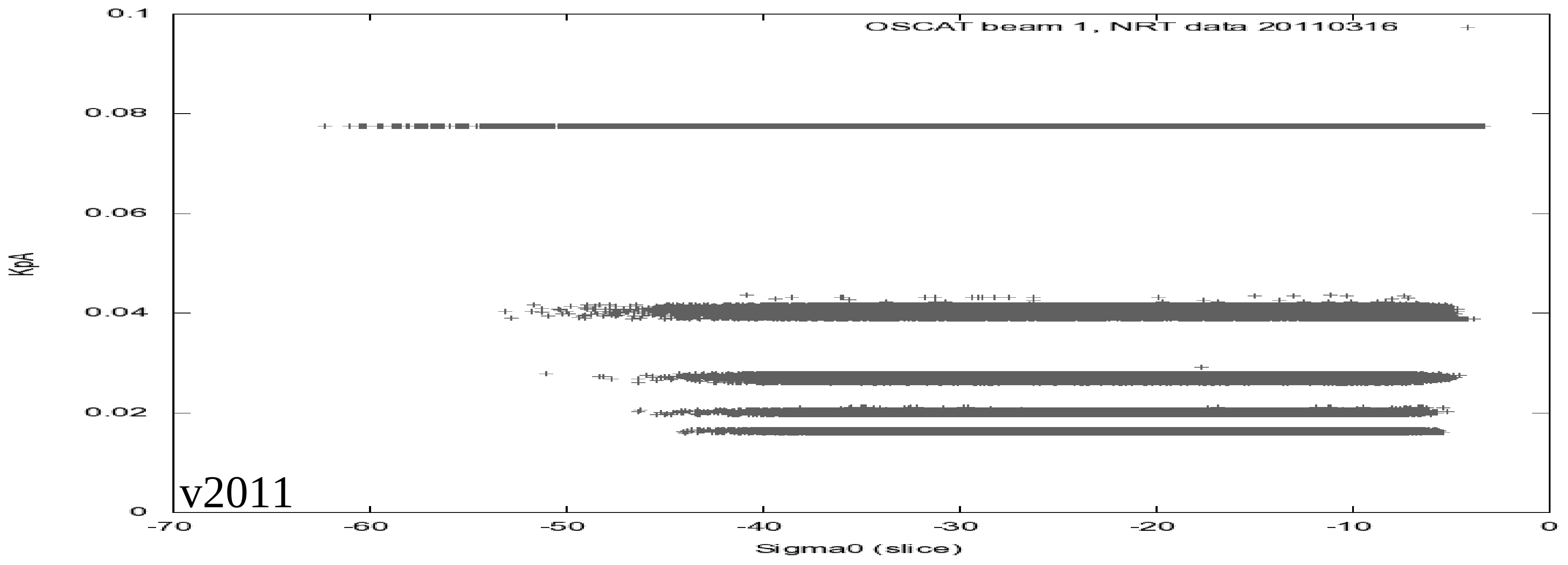
- $\gamma_S = (B_S T_G)^{-1} (1+B_S/B_N)^{0.5} \approx \beta_S / 2$
- $B_S/B_N << 1$

  $(1+50/1245)^{0.5} = 1.02$
- 5 different B_S



➤Some noise on some B_s values now





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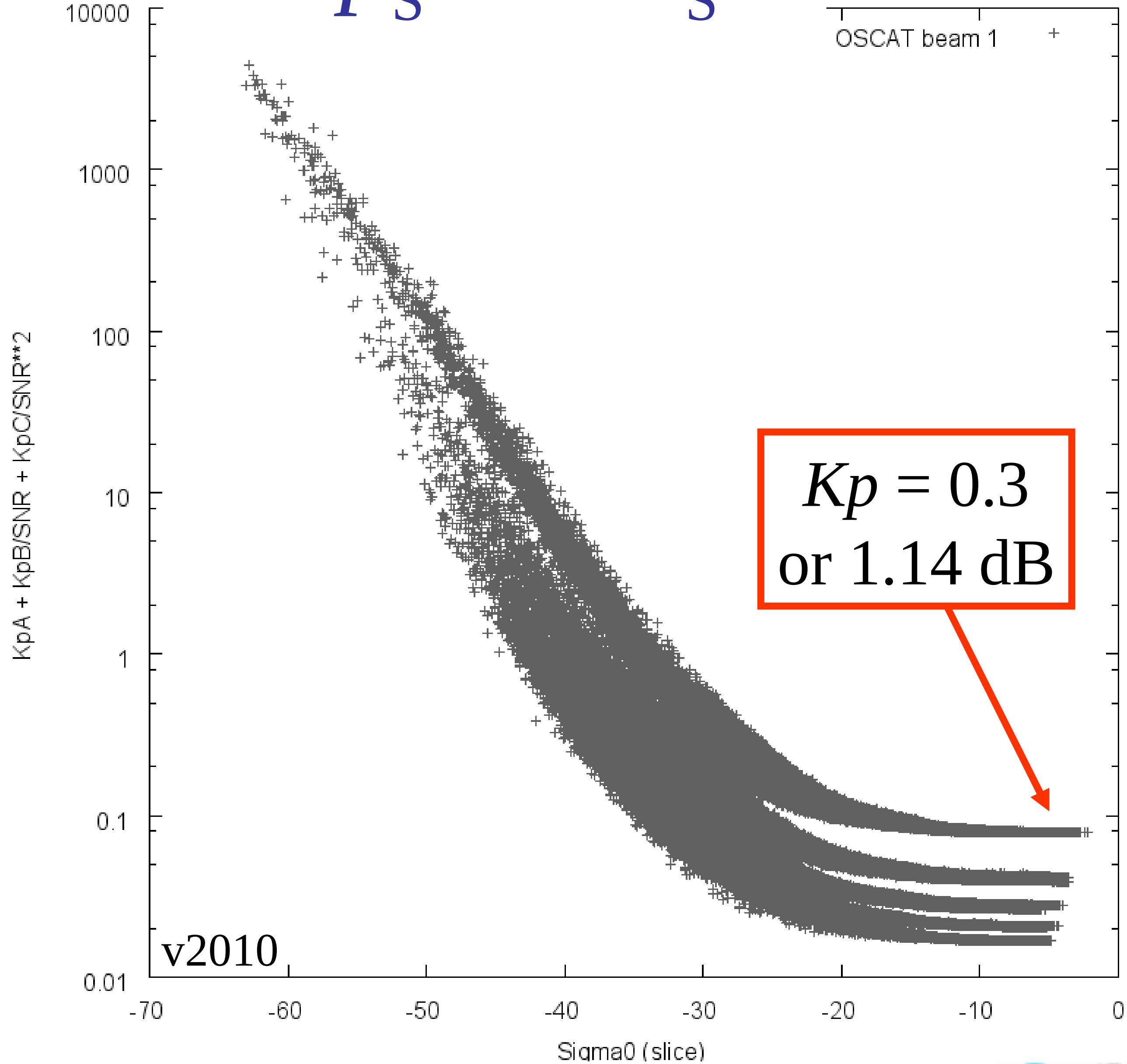
Kp_S vs σ^0_S

- $Kp_S^2 = \alpha_S + \beta_S / SNR_S + \gamma_S / SNR_S^2 \approx f_S(\sigma^0_S)$ for each of the 5 slice types



L2A $\sigma^0{}_s$

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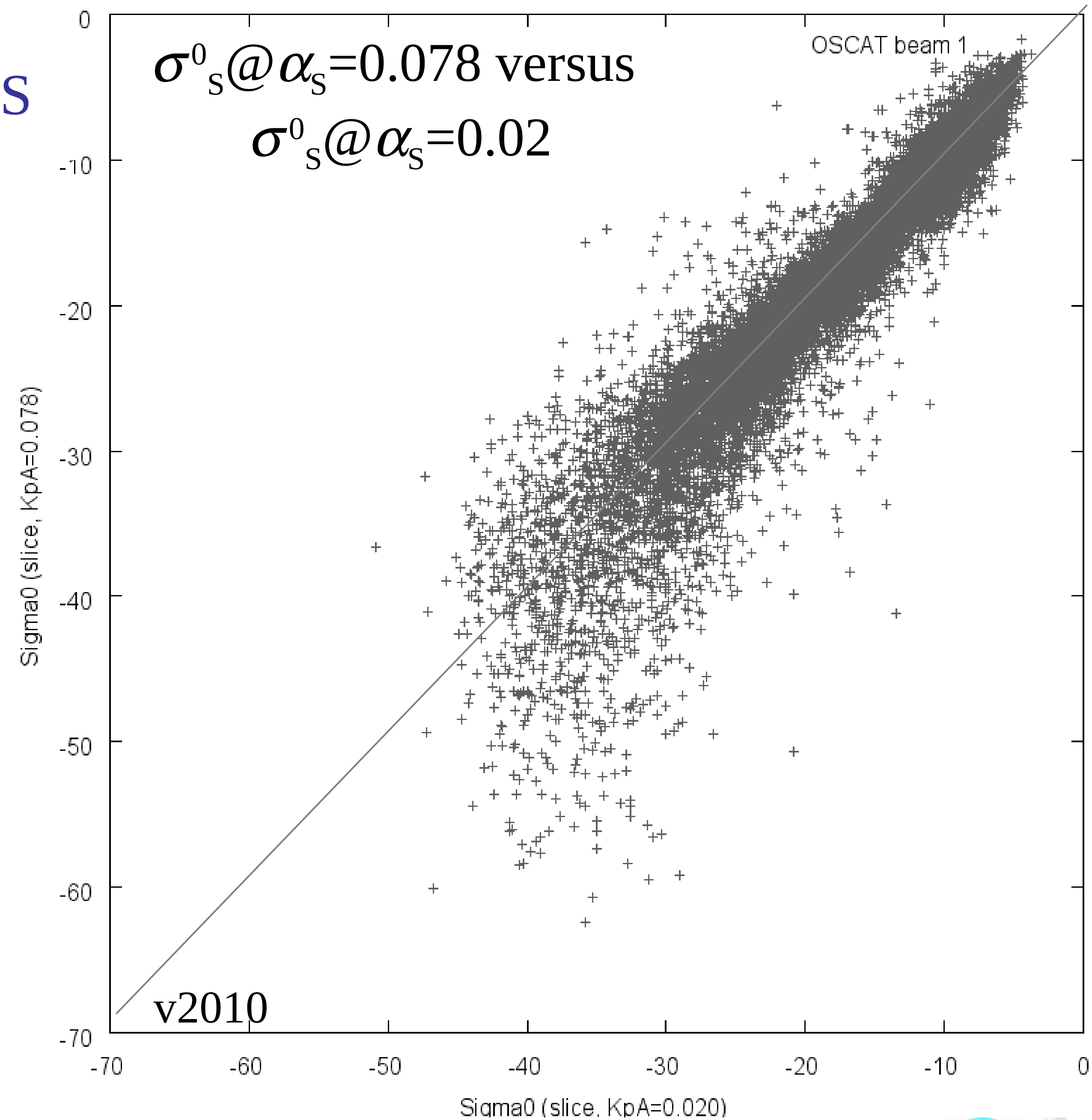
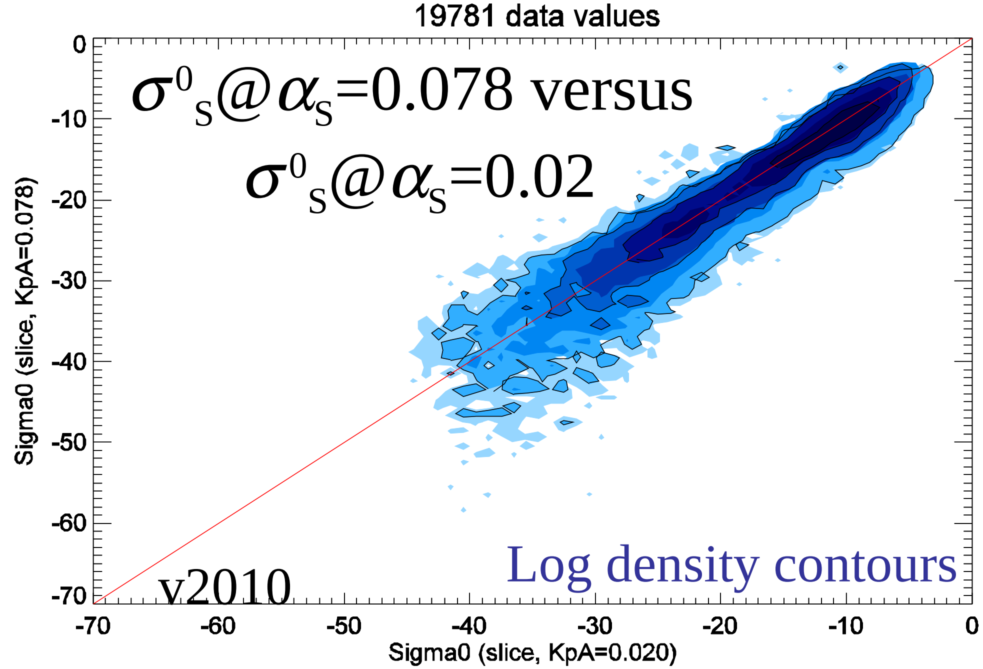
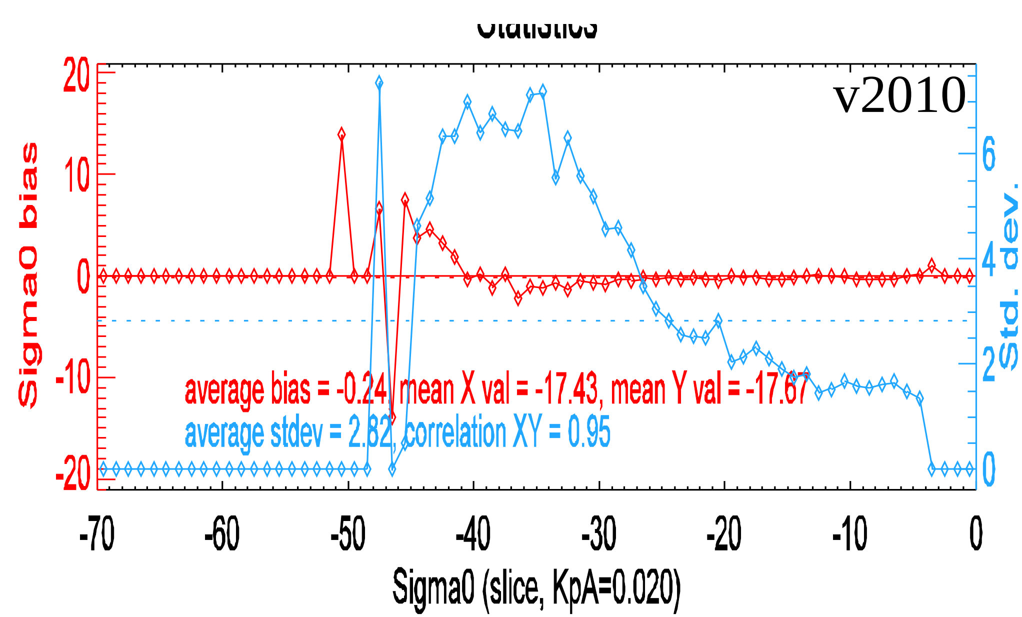
- Collocated $\sigma^0{}_s$ in a WVC
- Forward outer view
- Other views are similar



L2A $\sigma^0{}_S$, Kp_S

- Analysis of $\sigma^0{}_S$ slices collocated in a WVC
  - No bias
  - Increasing noise for decreasing $\sigma^0{}_S$ largely compatible with Kp_S : e.g., SD of 1.5 dB at -5 dB





-ve σ^0_s

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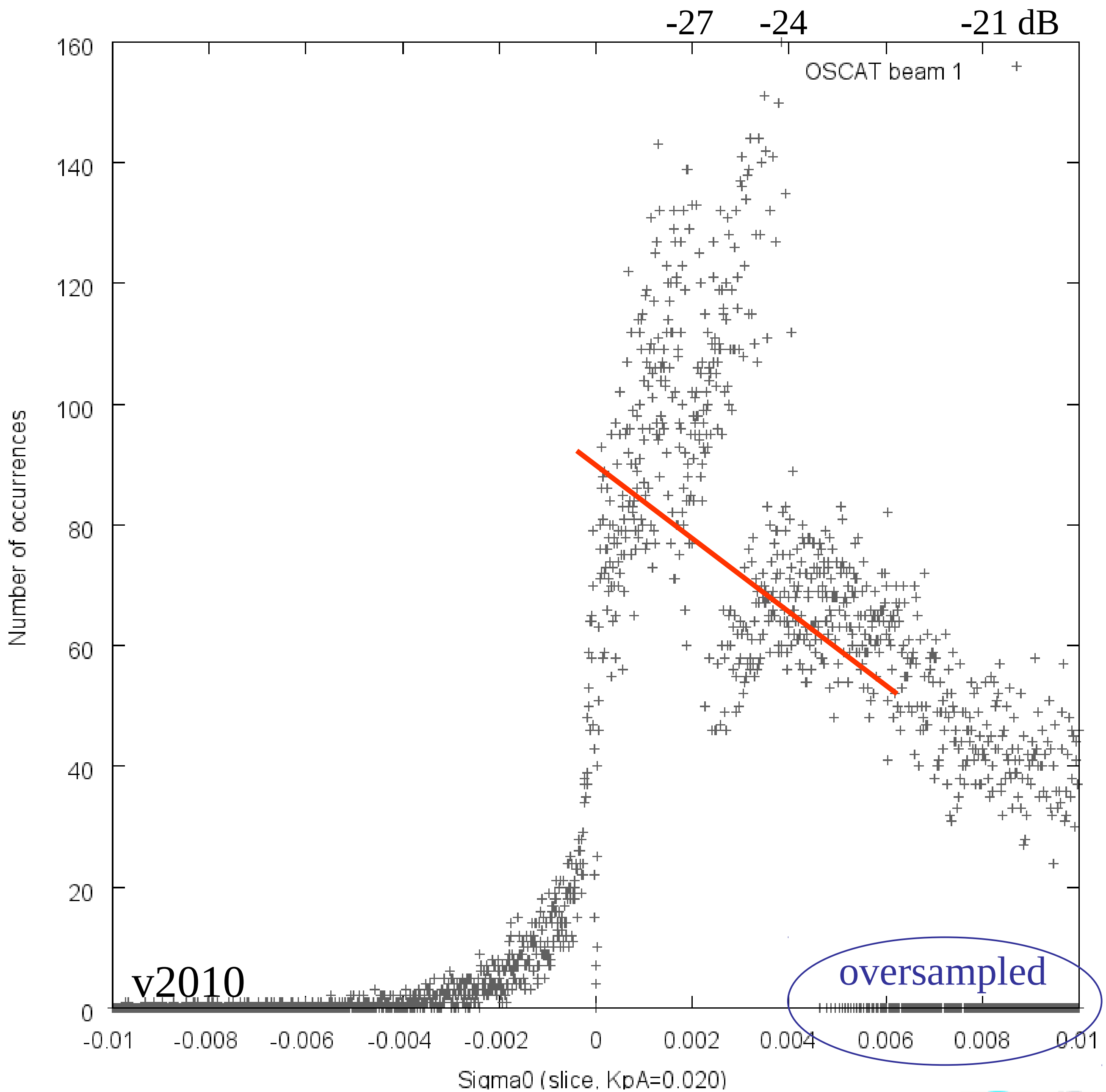
- Decaying distribution around zero?
  - Check ECMWF
- Small PDF dip at zero



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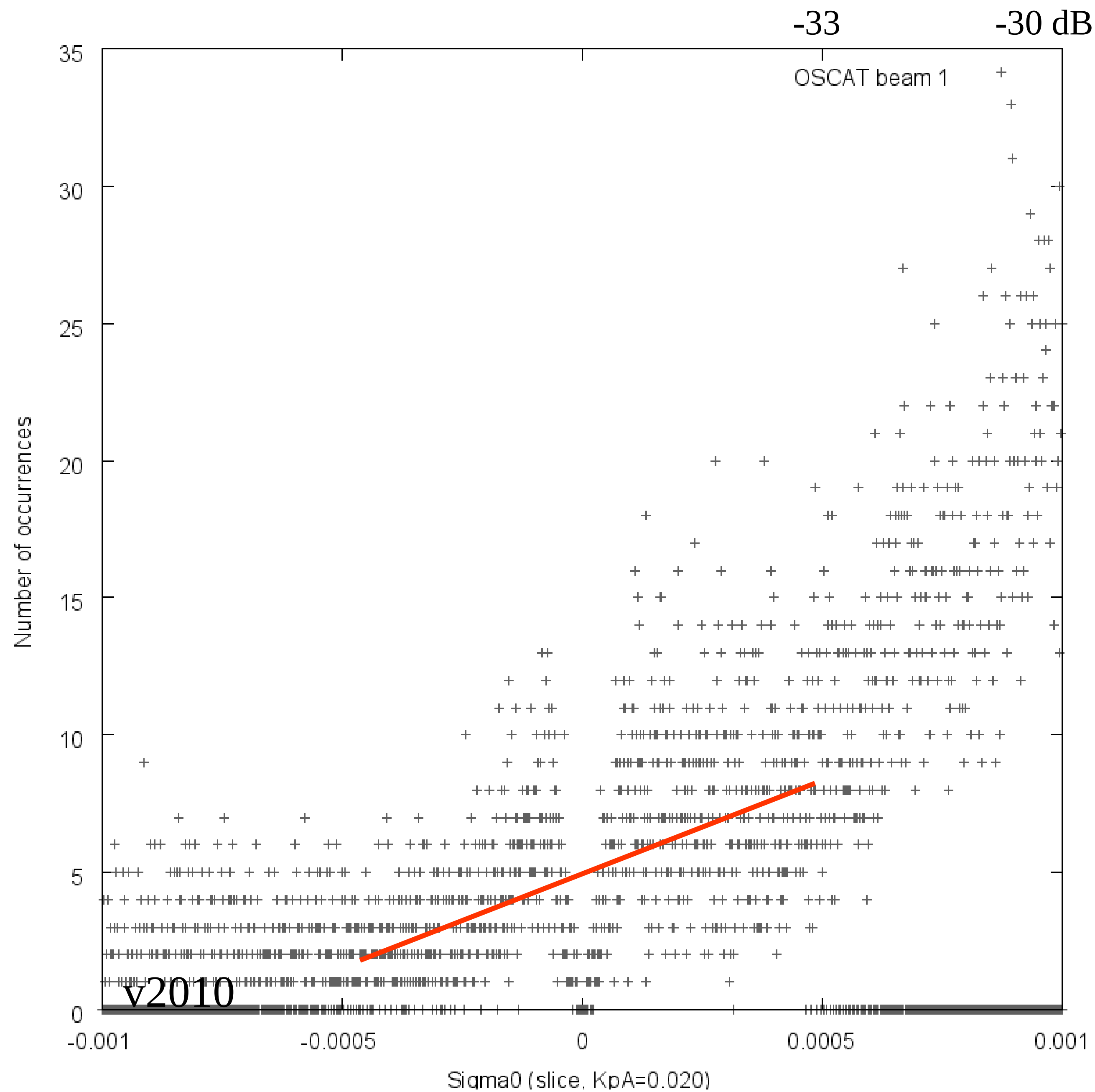
-ve σ^0_S

- $\alpha_S = 0.20$
- Sloping distribution around zero as expected
- Small PDF dip at zero



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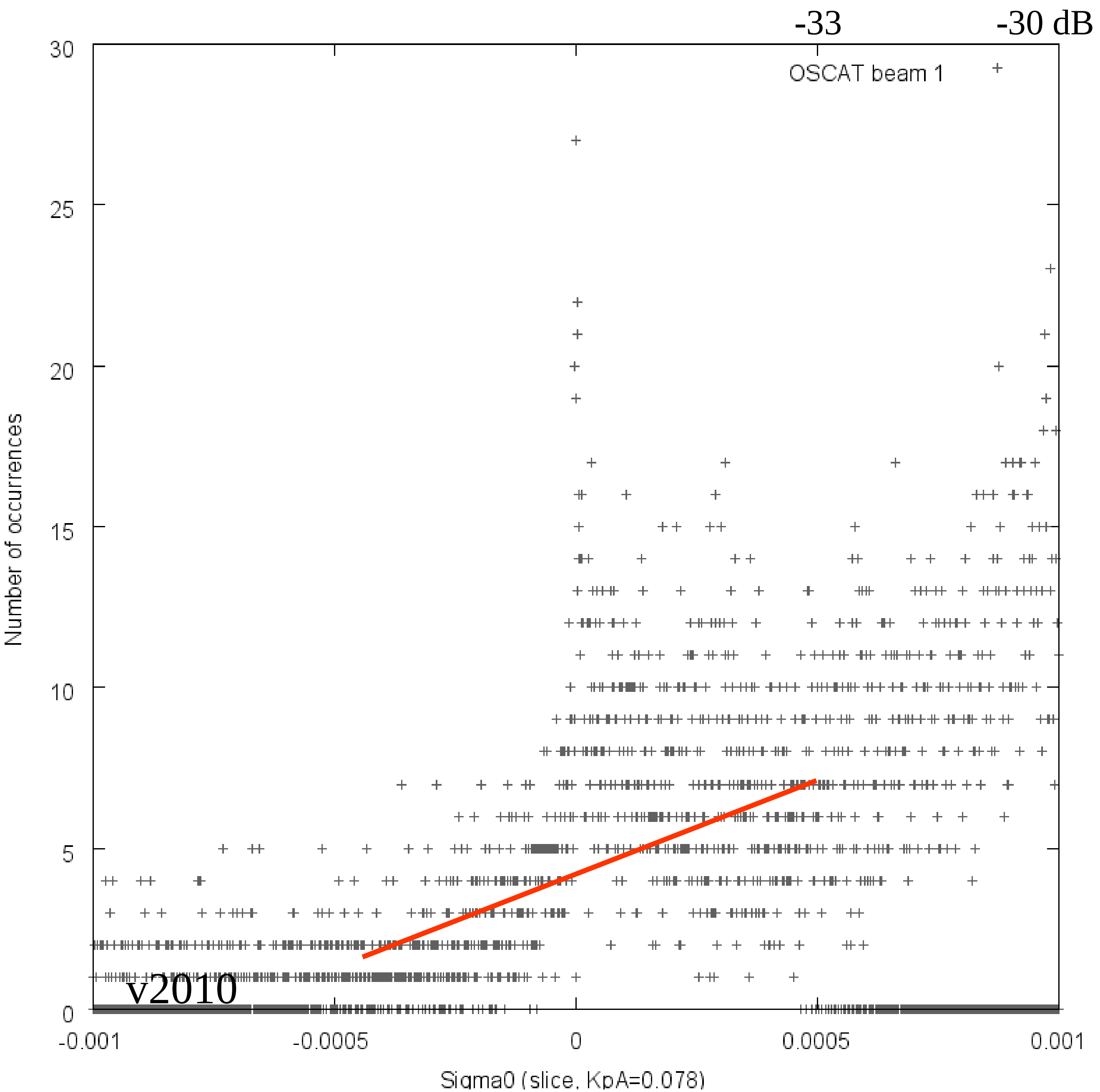
-ve σ^0_s

- $\alpha_s = 0.78$
- Sloping distribution around zero as expected
- Small PDF peak at zero



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WVC slice averaging (1)

- In a WVC the ocean backscatter for a given view is assumed constant, e.g., σ^0
- A measured slice backscatter can be written as
  $\sigma^0{}_S = \sigma^0 (1+t_S\, Kp_S)$
  with t_S a random sample from N(0,1)
- Different slices have different t_S and Kp_S (i.e., $G_S{}^2 A_S / R_S{}^4$)
- So, for a constant σ^0, the $\sigma^0{}_S$ and Kp_S in a WVC vary
- Kp_S varies with $<\sigma^0>$, but is modelled as a function of $\sigma^0{}_S \neq <\sigma^0>$, i.e., including t_S

➢ How to exclude t_S?

- The Kp_S component ratios of α_S/β_S and α_S/γ_S are independent of $\sigma^0{}_S$ and for given $\sigma^0{}_S$, α_S is proportional to Kp_S
- Since $<\sigma^0>$ is assumed invariant in a WVC, α_S provides appropriate weight ratios in averaging the different $\sigma^0{}_S$ in a WVC

WVC slice averaging (3)

- WVC view *SNR* is obtained from slice signal power

$$P_S = X_S \sigma^0{}_S = 2 \cdot SNR_S / \beta_S$$

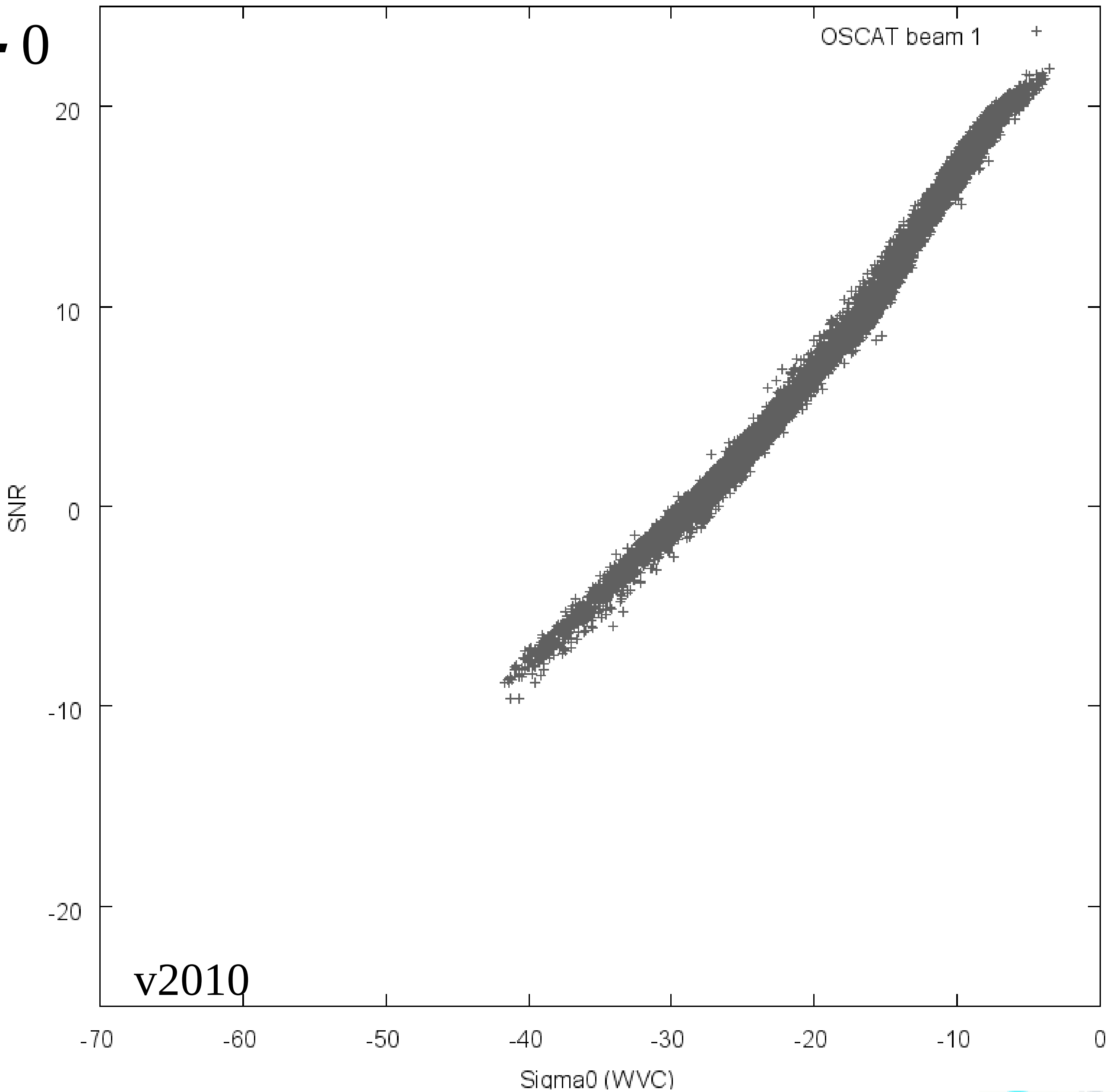
$$P = \sum_S P_S$$

$$SNR = \beta \cdot P / 2$$

- Such that $Kp^2 = \alpha + \beta / SNR + \gamma / SNR^2$ is obtained for each backscatter view in a WVC
- *Kp* is used for normalisation of *MLE* and in *p*(*MLE*)

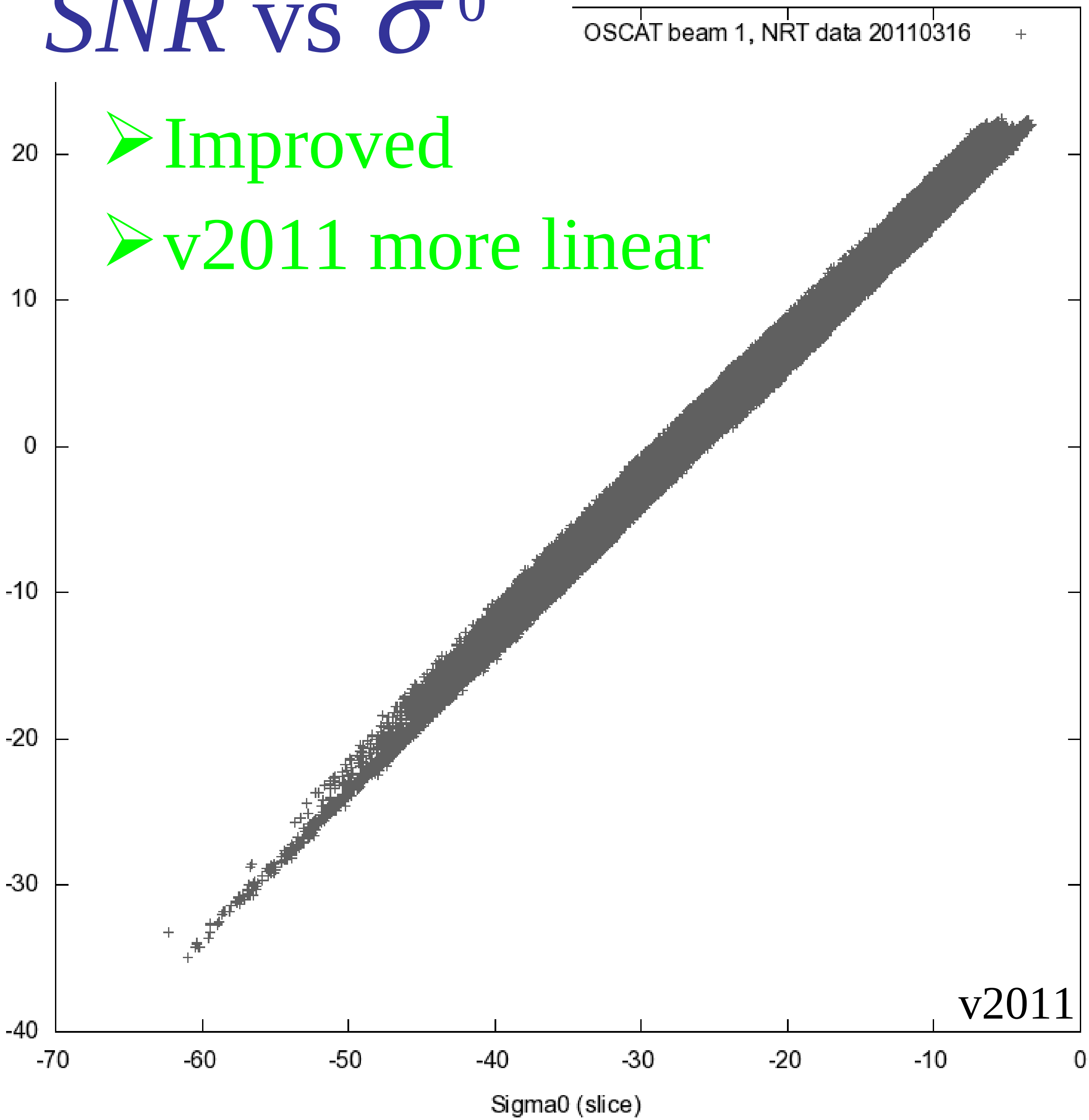
SNR vs σ^0

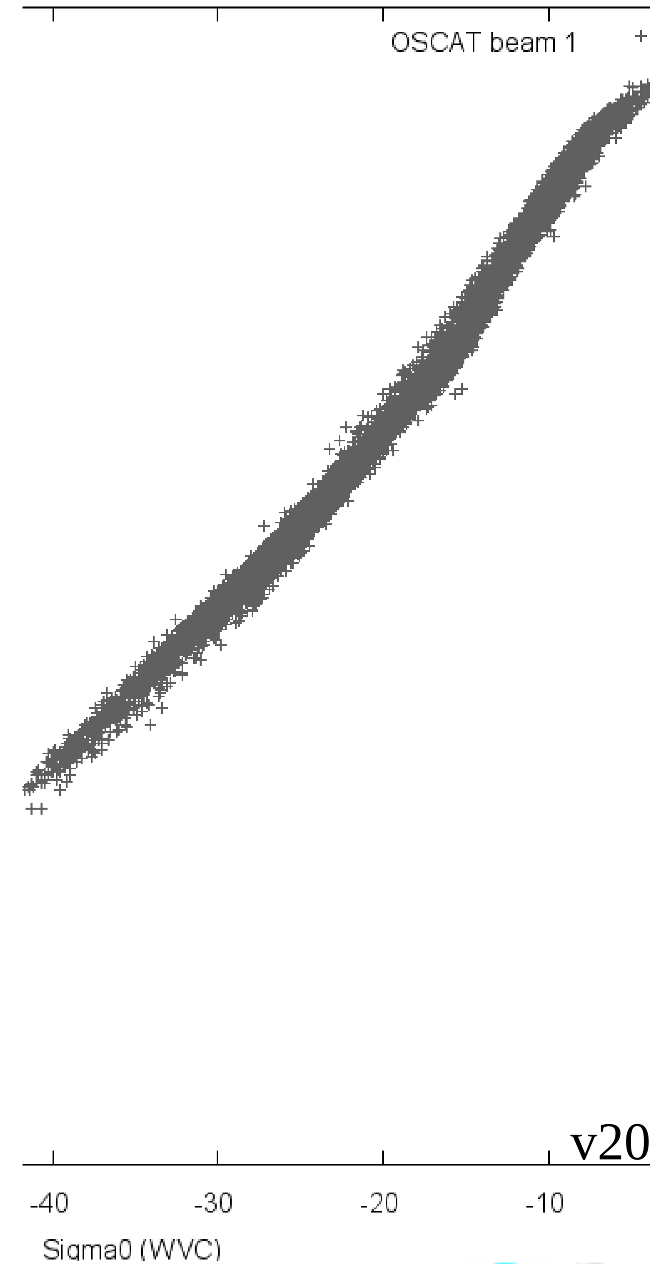
- Appears consistent with L1B results (eggs)



SNR vs σ^0

- Improved
- v2011 more linear





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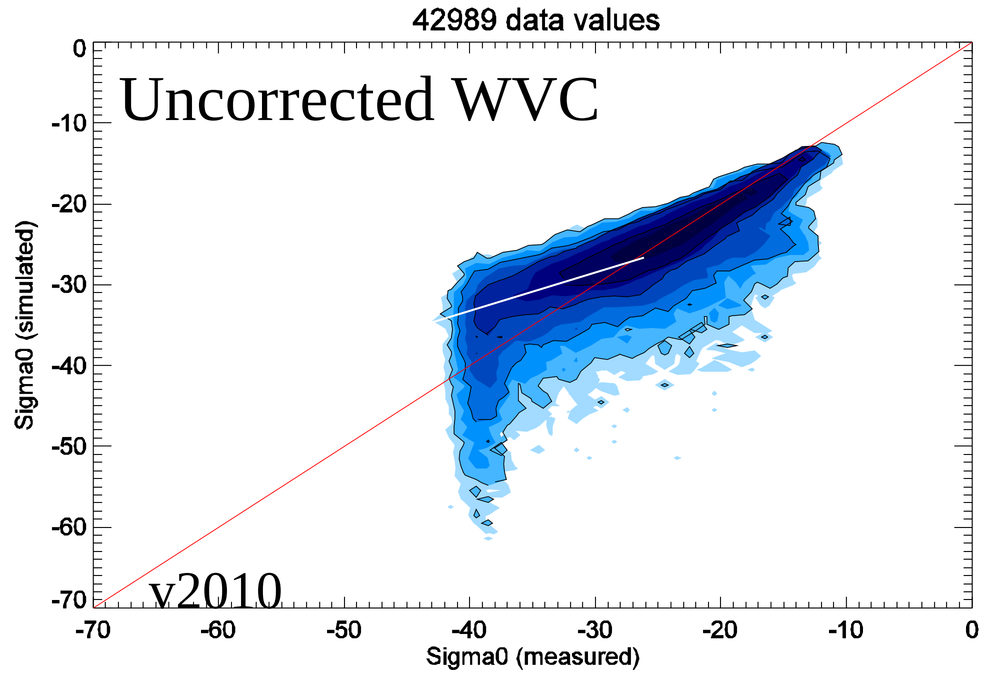
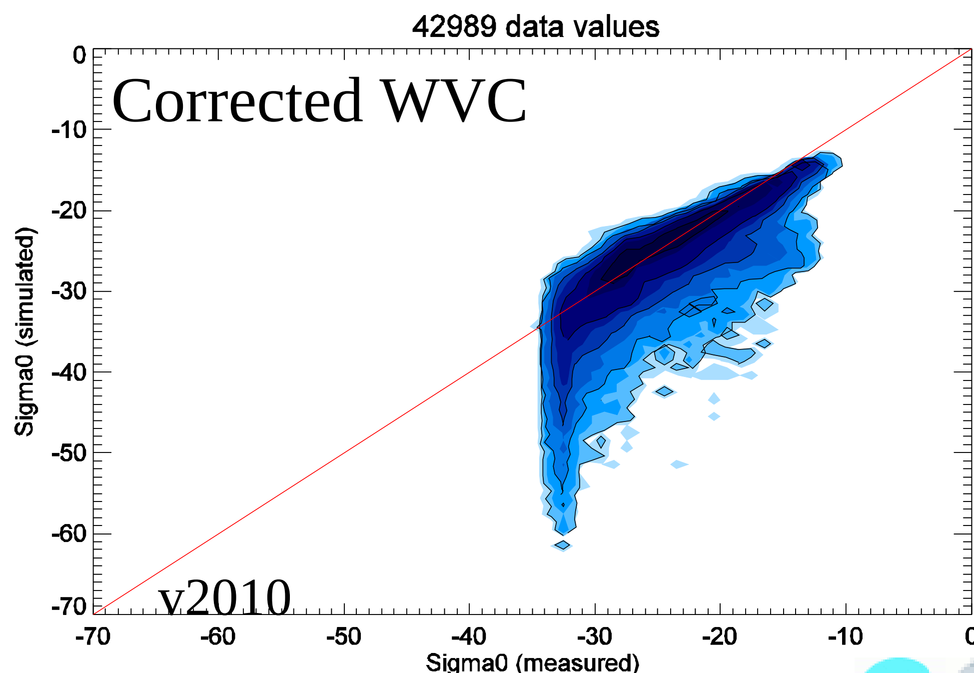
L2A WVC σ^0

- Log density contour plot of simulated ECMWF and measured L2A WVC σ^0
- Median of pdf not on diagonal
- σ^0 bias below -27 dB

➢ Ad hoc correction further truncates PDF at -33 dB !

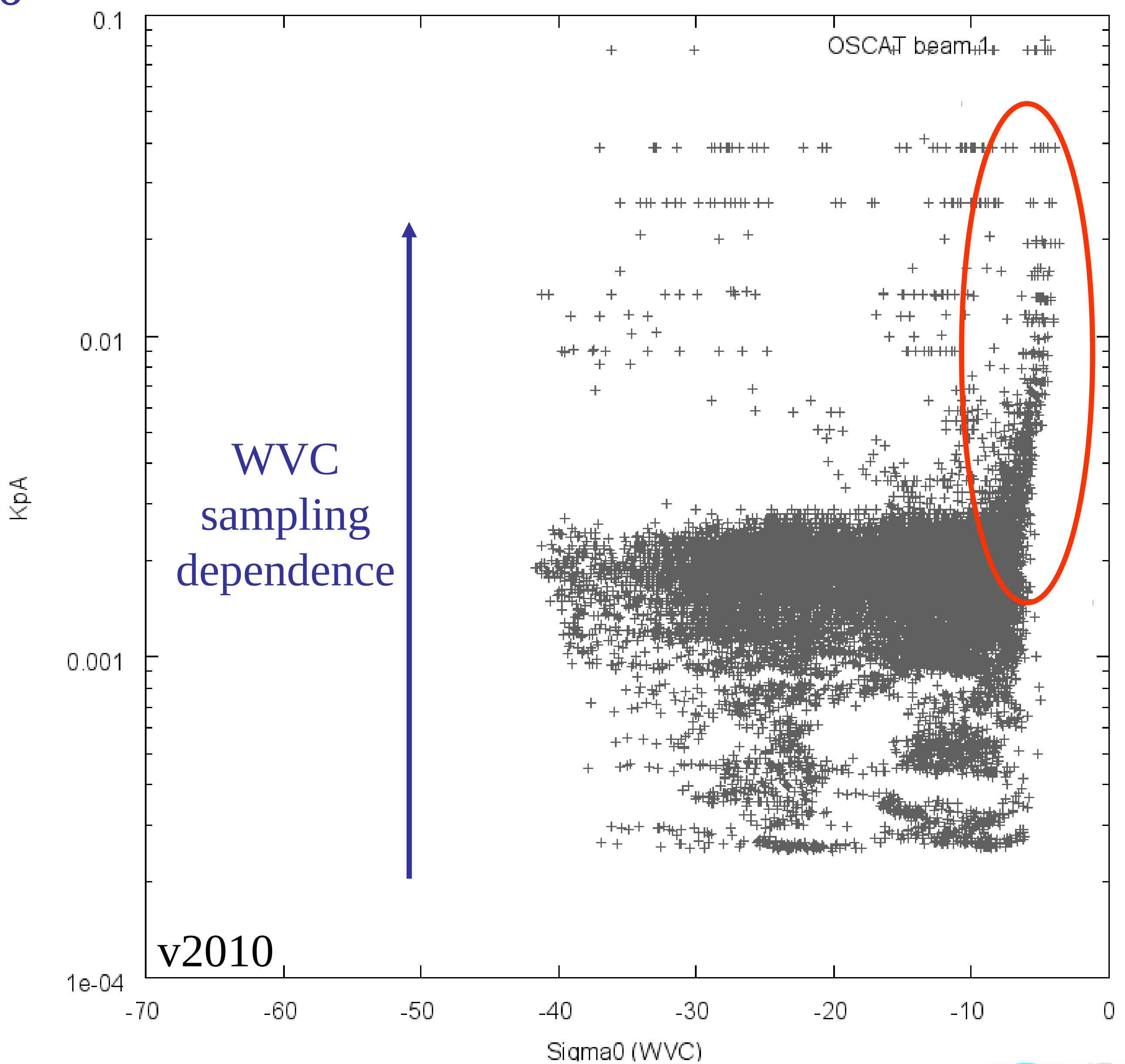




α vs σ^0

- Depends only on varying B_s contributions (T_p is fixed)
- B_s is fixed per slice type

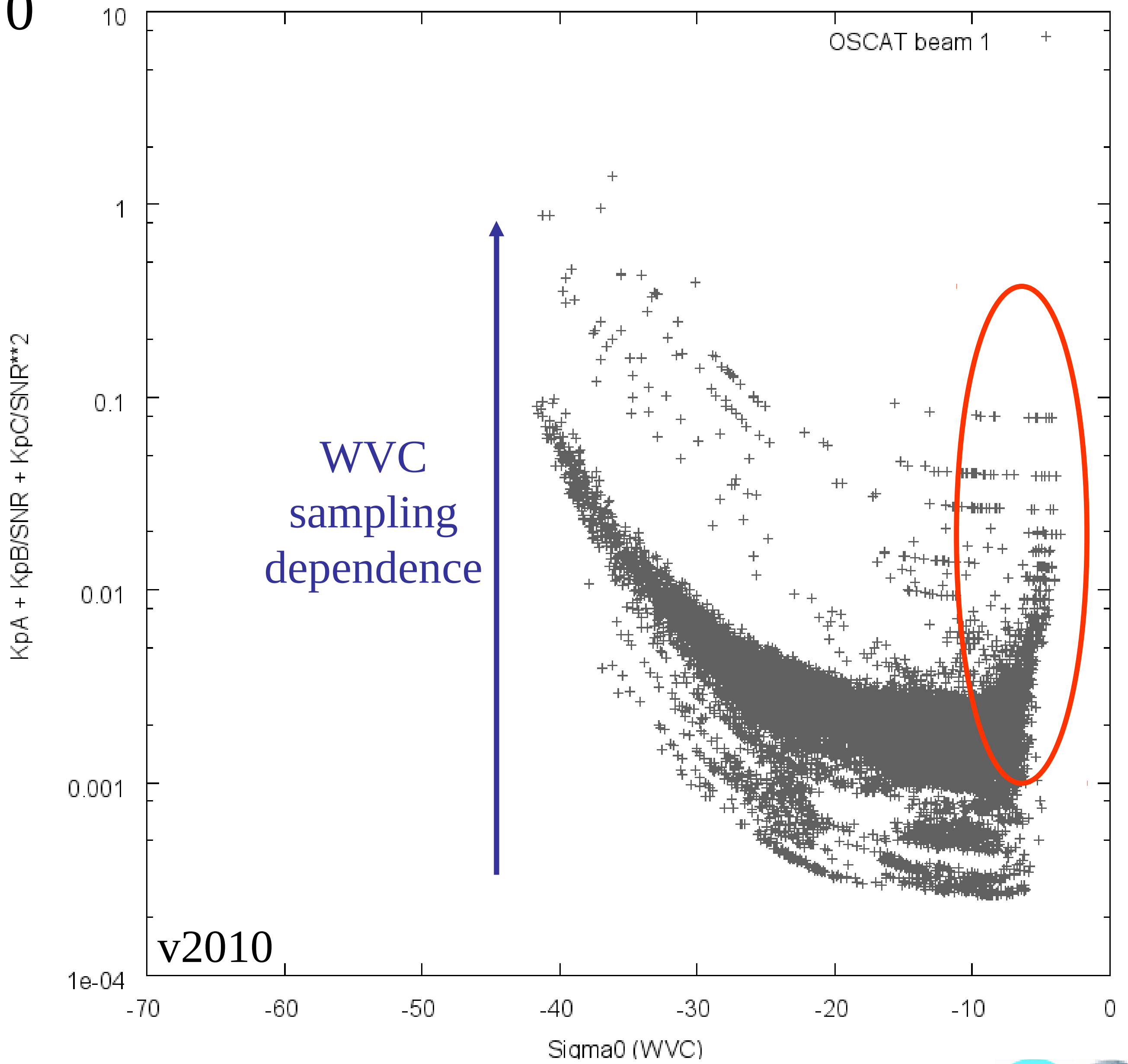
➢ High σ^0 has fewer slices contributing ?



Kp vs σ^0

- α, β and γ behave the same, so does Kp

➢ High σ^0 has fewer slices contributing ?



SDP25 vs ECMWF

speed

1.29 m/s

direction

11.30 deg

east component

1.28 m/s

north component

1.40 m/s

- SDs of differences given
- SeaWinds Data Processor (SDP)

OWDP vs ECMWF

1.33 m/s

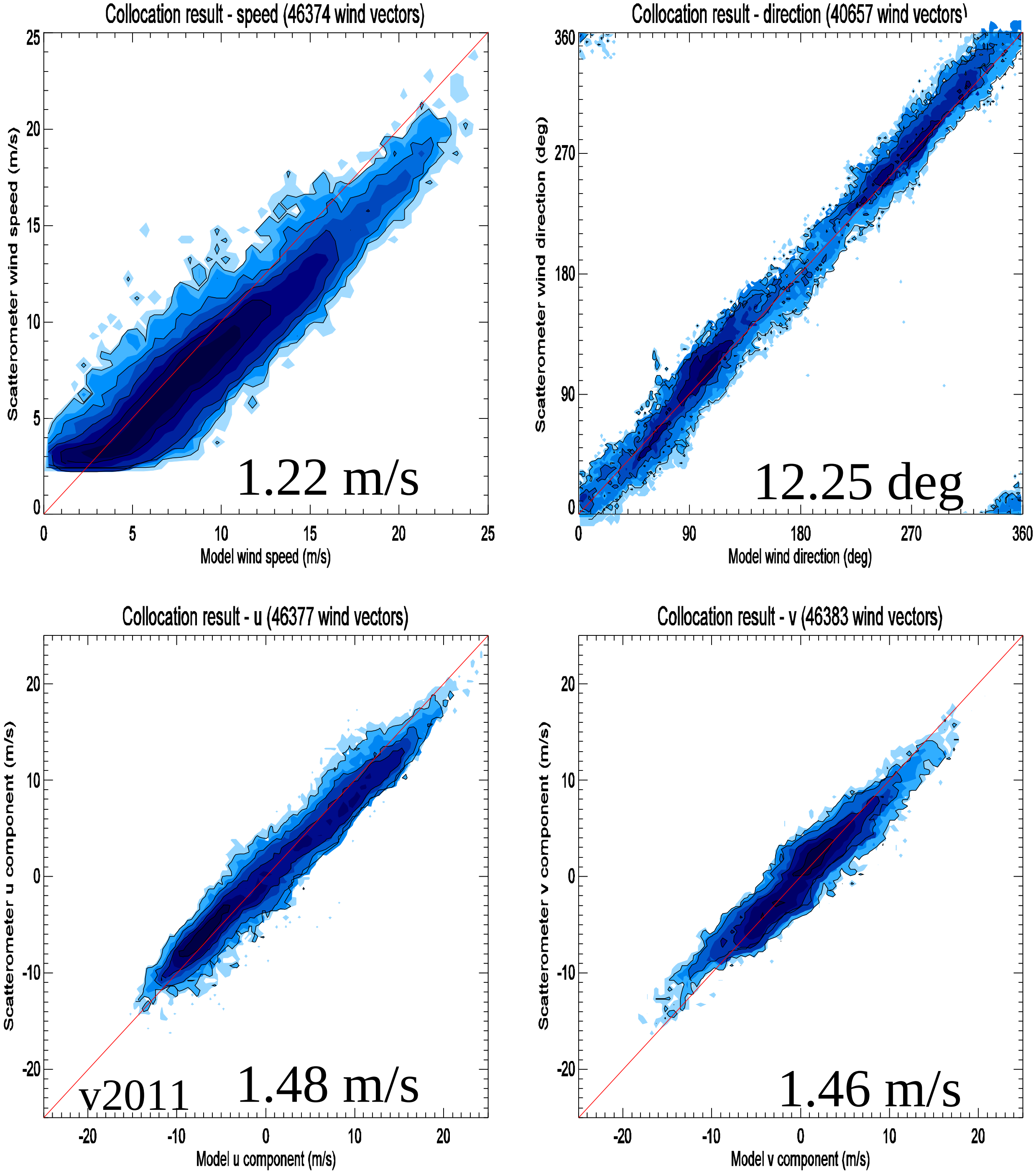
13.85 deg

v2010 1.62 m/s

1.55 m/s

- Corrected σ^0
- SDs given
- Now 5% QC as for QuikScat; similar to L2B
- OWDP improves w.r.t. L2B
- No speed bias
- Cut-off due to σ^0 PDF at 3 m/s
- No outer swath processed yet in OWDP

OWDP vs ECMWF



- Uncorrected σ^0
- SDs given
  - 5% QC as for QuikScat; similar to L2B
  - OWDP improves w.r.t. v2010
  - Speed bias of ~0.9 m/s
  - Reduced cut-off due to σ^0 PDF at ~2 m/s

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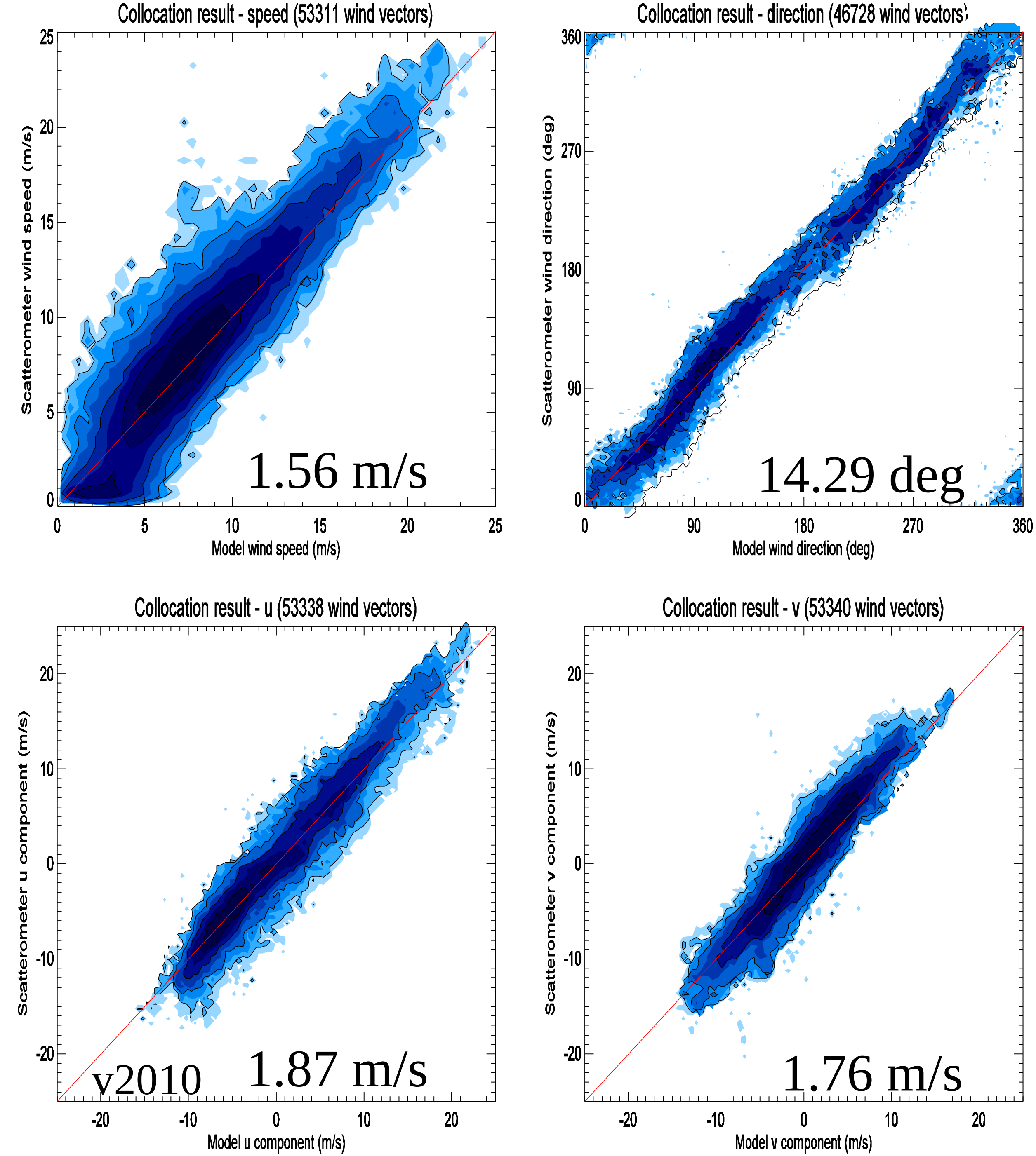
L2B

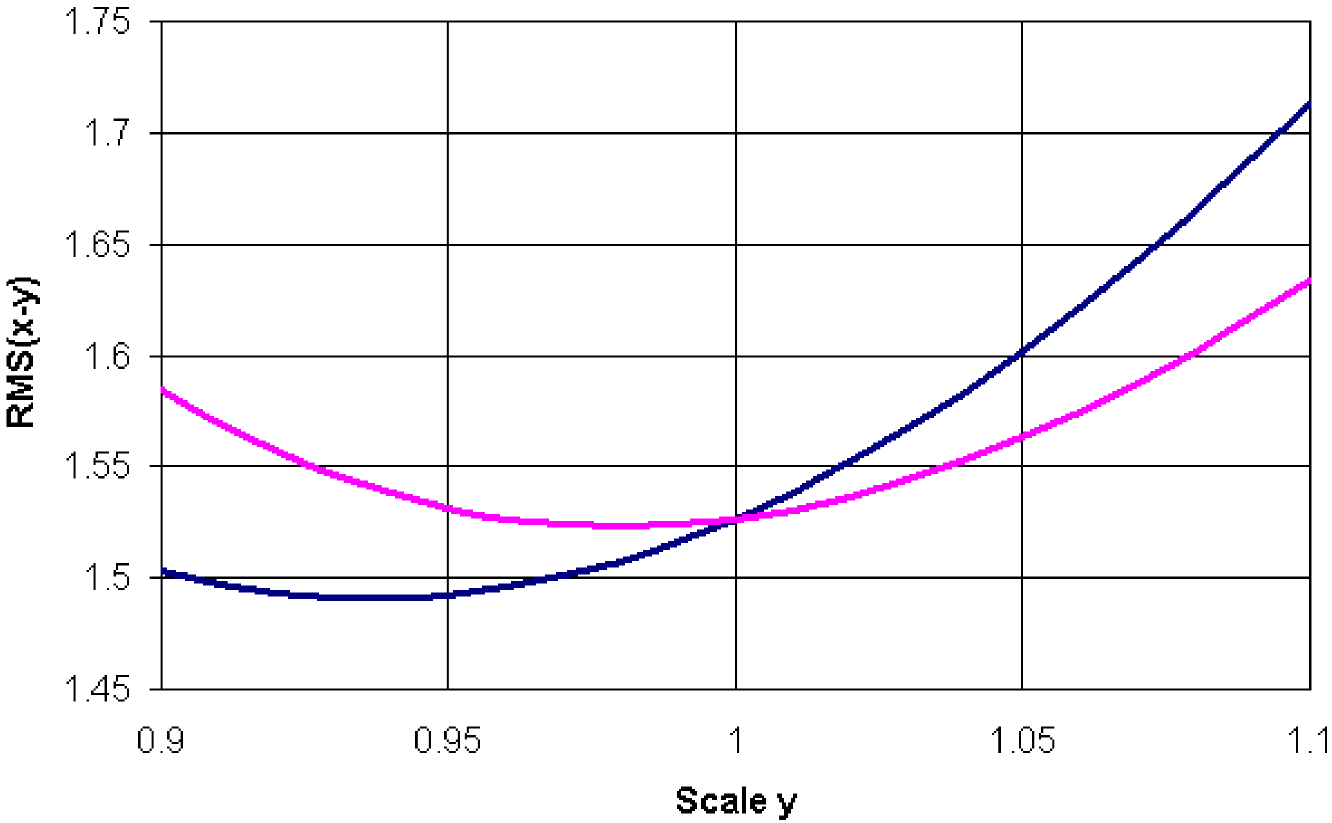
- Without WVC flags:
  - Rain present/doubtful
  - High winds, possibly rain contamination



ISRO L2B vs ECMWF

- SDs of differences given
- Outliers reason for degradation w.r.t. QDP ?
  - ➢ Bias at low speeds

Effect of scale error on RMS



$x = t + \delta_x$

$\langle x \rangle = \langle t \rangle$

$\langle x^2 \rangle = \langle t^2 \rangle + \langle \delta_x^2 \rangle$

$\langle t^2 \rangle = \sigma^2$

$\langle \delta_x \rangle = 0 \; ; \langle \delta_x^2 \rangle = \varepsilon_x^2$

$y = s\,(t + \delta_y)$

$\langle y \rangle = s \langle t \rangle$

$\langle y^2 \rangle = s^2(\langle t^2 \rangle + \langle \delta_y^2 \rangle)$

$\langle \delta_y \rangle = 0 \; ; \langle \delta_y^2 \rangle = \varepsilon_y^2$

- Downscaling reduces RMS(x-y)
- RMS(x-y)/√s provides better measure
- Calibrate before error assessment

$\mathrm{RMS}(x-y) = \sqrt{\langle (x-y)^2 \rangle}$

$= \sqrt{(1-s)^2\sigma^2 + \varepsilon_x^2 + s^2\varepsilon_y^2}$

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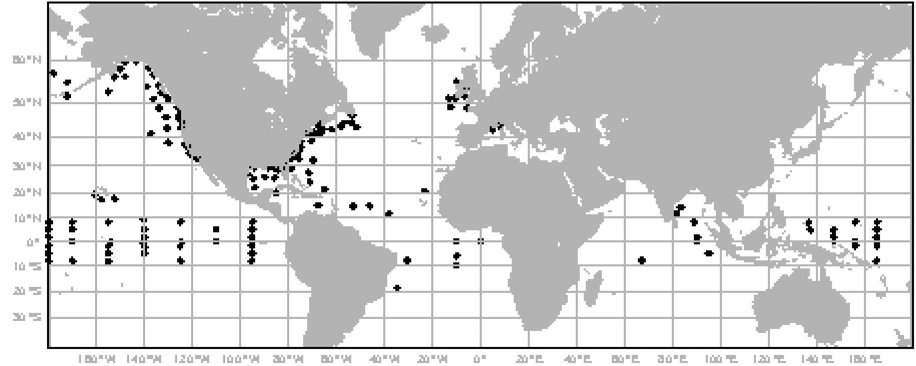
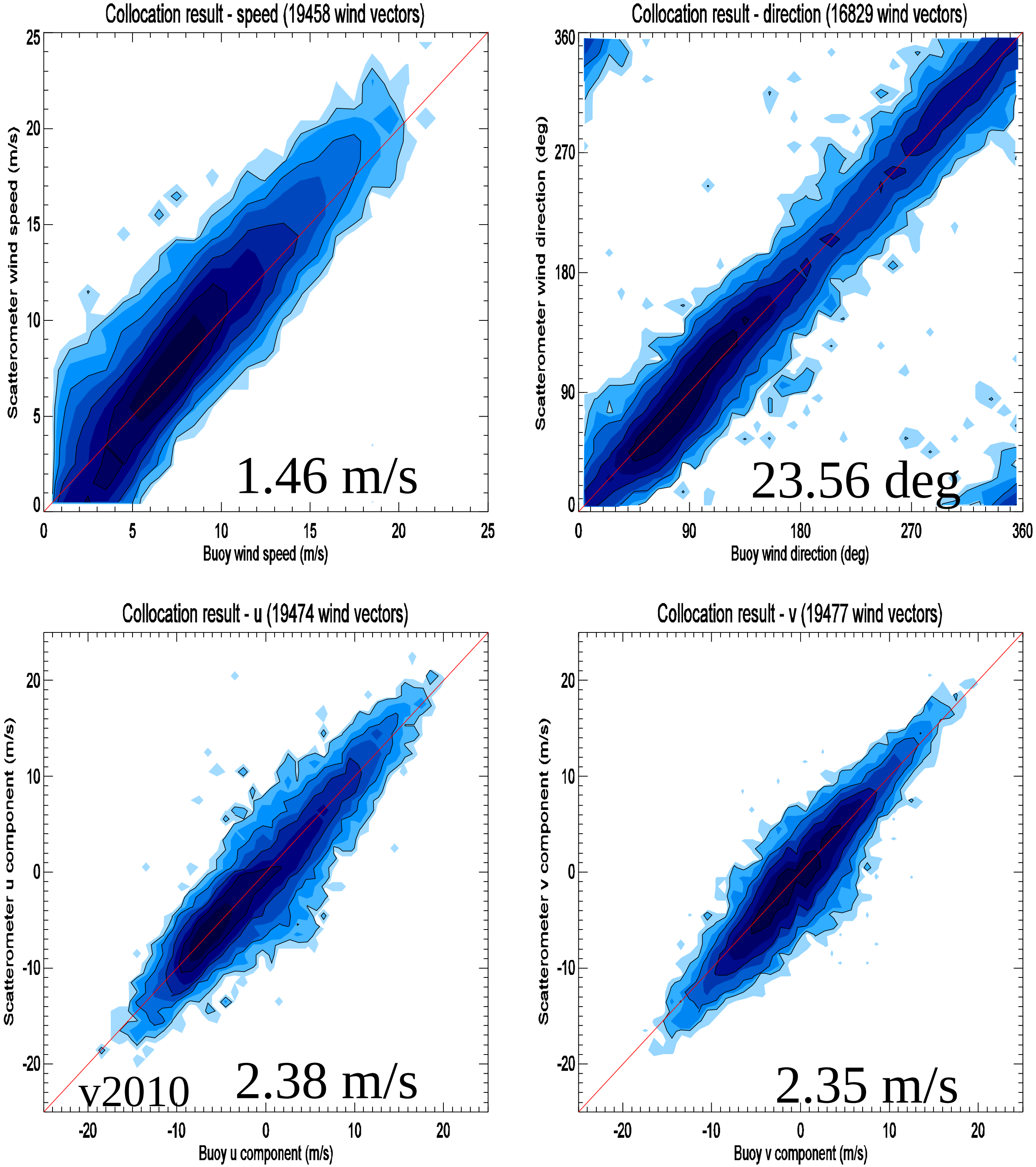
Buoy verification - QuikScat -



SeaWinds 25-km product	# wind vectors	speed bias	stdev *u*	stdev *v*
NOAA product, including **outer swath**	3845	0.25	2.54	2.51
NOAA product, no outer swath data	3276	0.20	2.47	2.18
OSI SAF, no outer swath data	3061	-0.48	1.79	1.88
NOAA product, collocated OSI SAF	2954	0.15	2.19	1.99
OSI SAF, collocated with NOAA product	2954	-0.49	1.76	1.83

- Outer swath winds appear degraded in NOAA product
- OSI SAF winds verify better with buoys than NOAA does (in RMS)
- OSI SAF wind is biased low
- OSI SAF collocation much helps NOAA wind SD and bias (rain)
- NOAA QC has modest impact on OSI SAF product



L2B vs buoys

- SDs of differences given
- 131 buoys
   - Speed outliers near 15 m/s indicate rain
   - Wind direction outliers may be AR problem

OWDP vs buoys

1.37 m/s

23.91 deg

- SDs of differences given
- 158 buoys
- ➢ Cut-off visible in f and u
- ➢ Improved QC w.r.t. L2B, particularly visible in speed PDF
- ➢ 27 additional coastal buoys; more coastal winds in OWDP than L2B

v2010

2.27 m/s

2.20 m/s

OWDP vs buoys at L2B WVCs

1.25 m/s

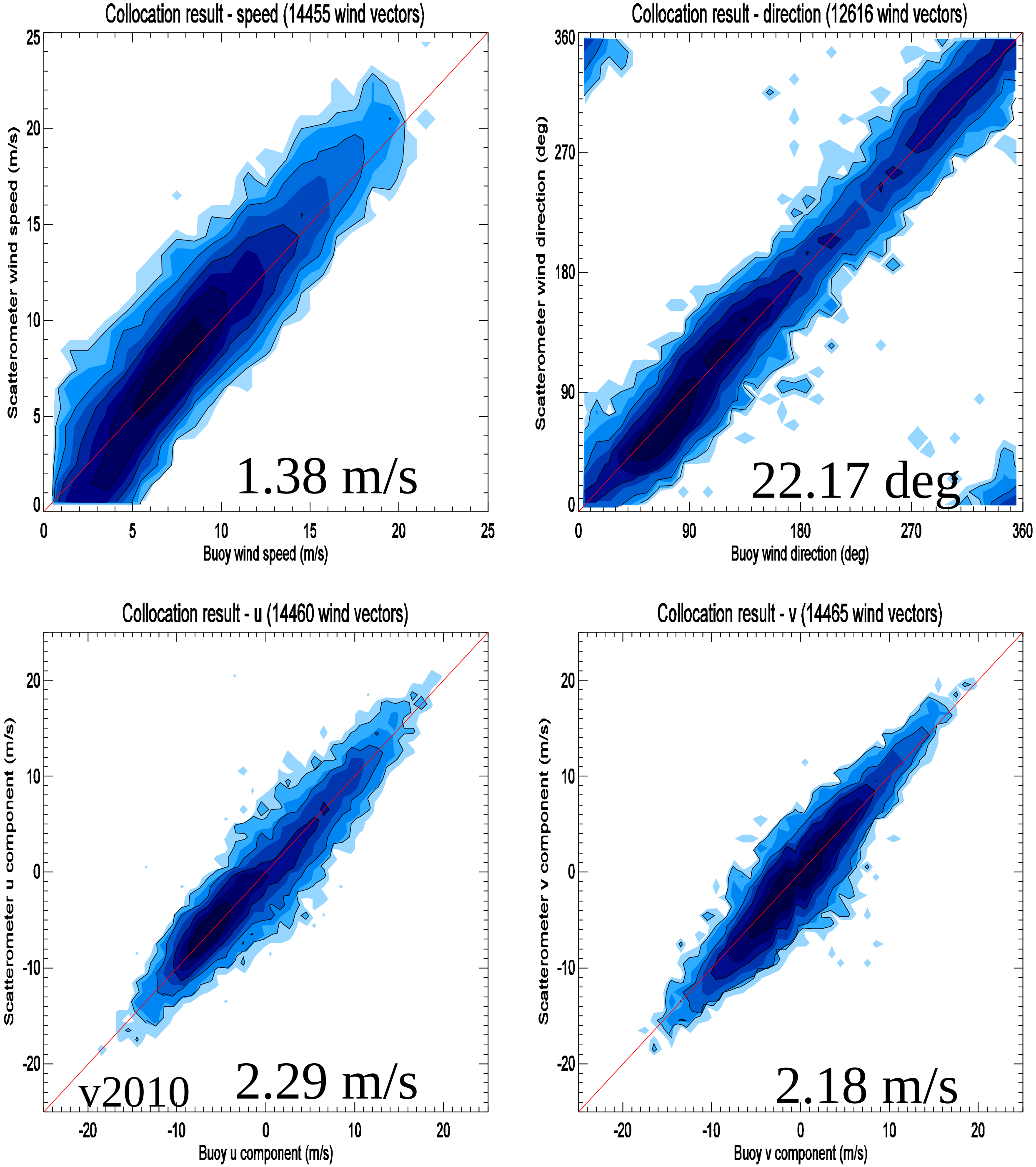
22.82 deg

v2010

2.11 m/s

2.06 m/s

- SDs given
- 130 buoys
- 28 (extratrop.) buoys removed
- Vector RMS within SAF specs!
- Wind direction remains noisy



L2B vs buoys at OWDP points

- SDs given
- 130 buoys

➢ Collocation improves OWDP scores, particularly direction; 20 near-coast buoys drop out

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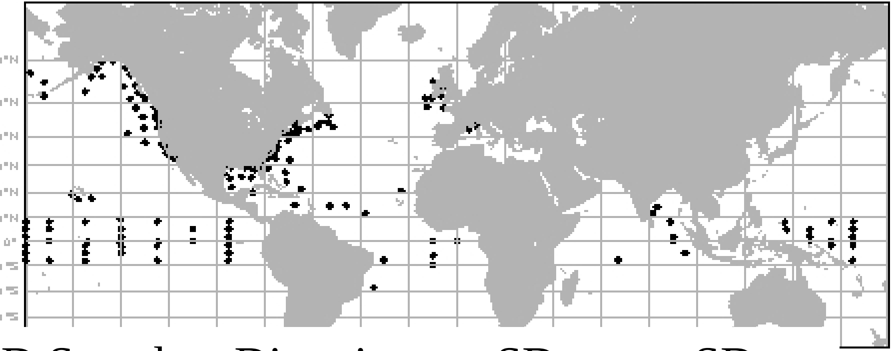
Buoy summary – OSCAT -



OSCAT 50-km product SDs v2010	SD Speed m/s	Direction degree	SD *u* m/s	SD *v* m/s
L2B, 131 buoys	1.46	23.56	2.38	2.35
OWDP, 158 buoys	1.37	23.91	2.27	2.20
L2B, 130 buoys, collocated OWDP	1.38	22.17	2.29	2.18
OWDP, 130 buoys, collocated L2B	1.25	22.82	2.11	2.06
L2B, collocated OWDP, ≥ 6 m/s	1.34	19.40	2.41	2.30
OWDP, collocated L2B, ≥ 6 m/s	1.33	16.67	2.02	2.12

- L2B includes outer swath winds in first row, while OWDP and L2B do not in the other rows
- OWDP winds verify better with buoys than L2B does (in vector RMS)
- Low OWDP winds are relatively poor due to the backscatter PDF biases (this results in a lowsy u component, but a very reasonable v component)

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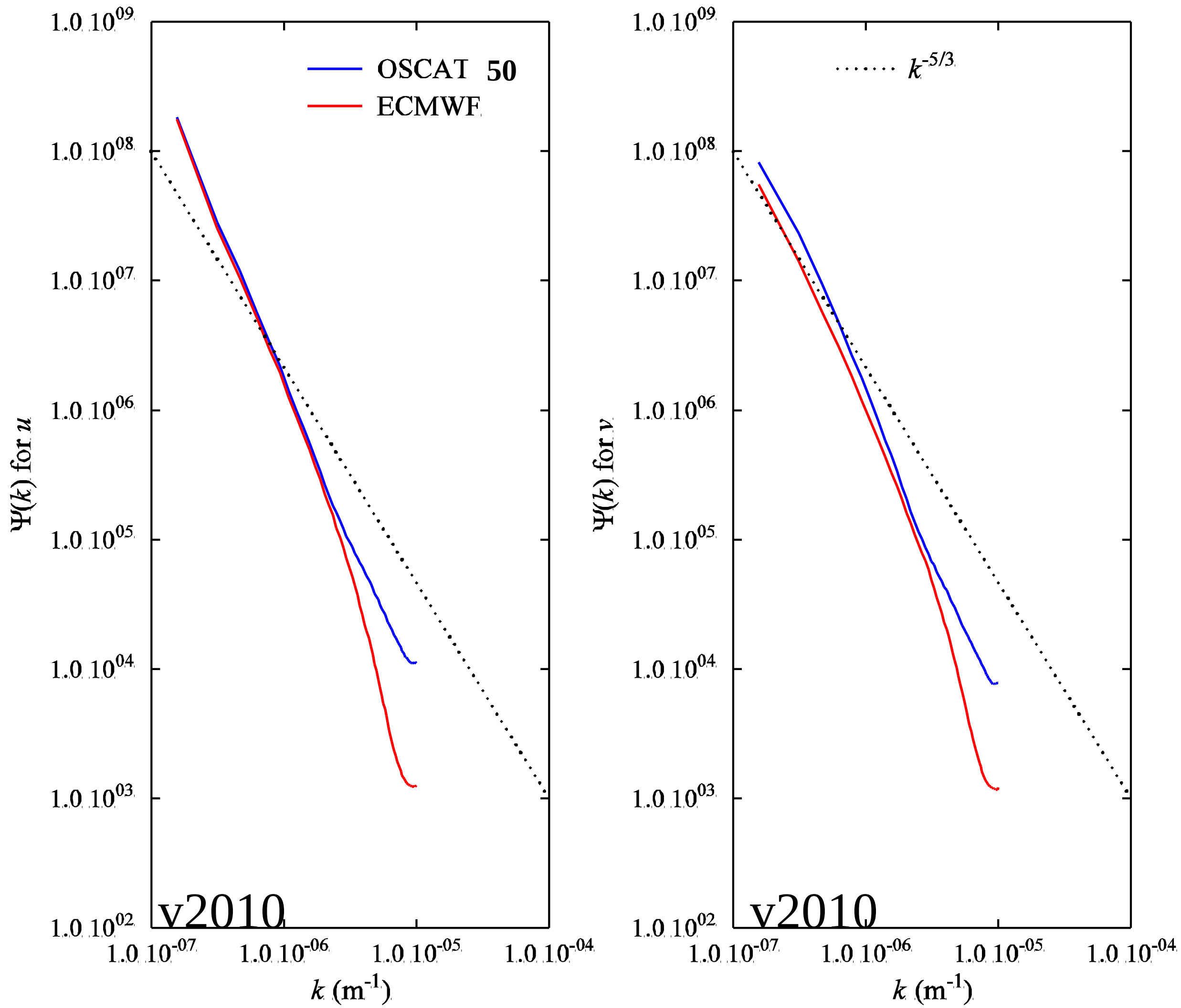
L2B spectra



- ISRO spectra show increased variance at small scales w.r.t ECMWF

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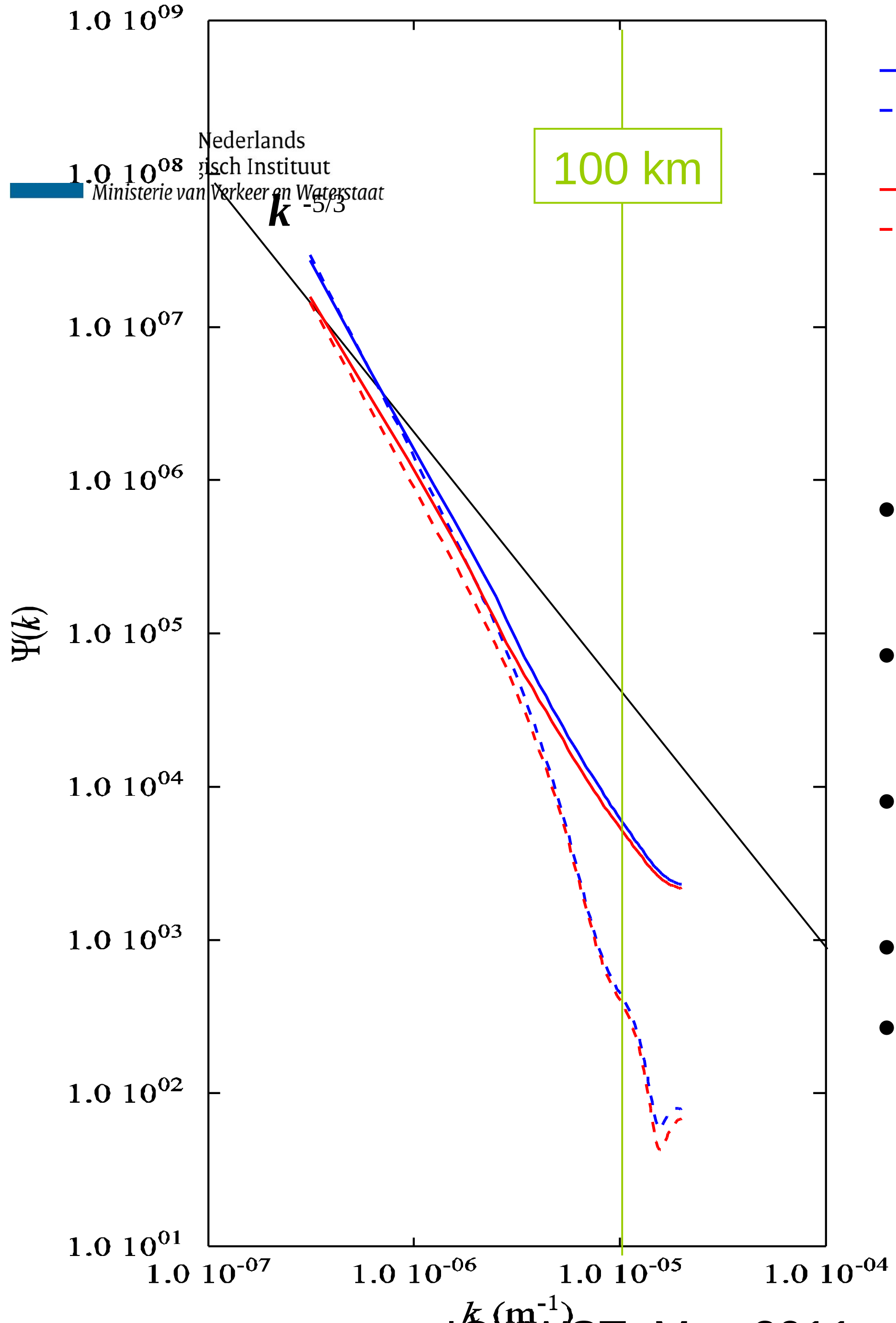


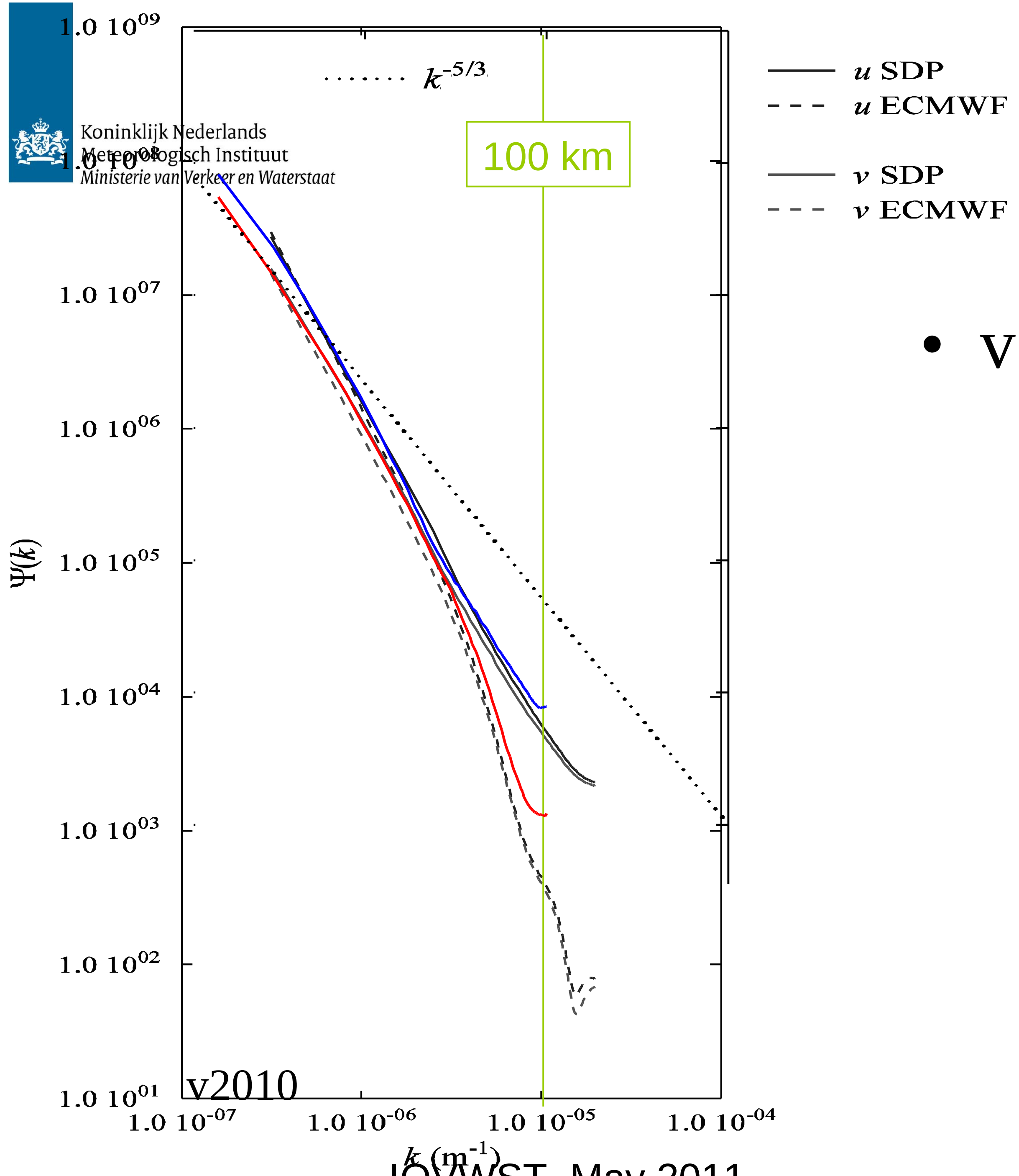
SDP@25 (MSS)

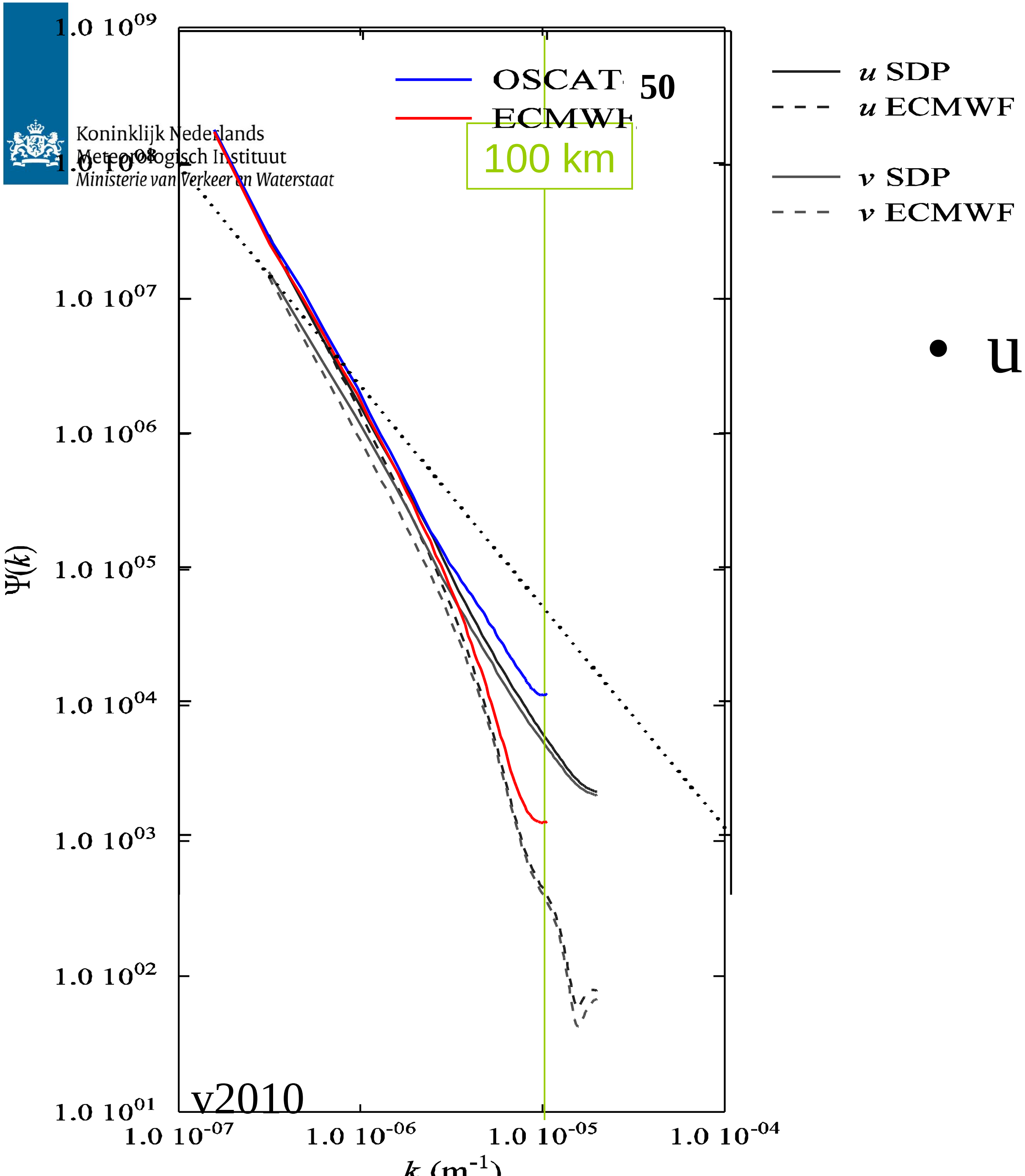
- SeaWinds contains small scales down to 50 km
- Smooth decay, same for u and v
- Indication of noise floor, probably due to rain
- Similar to NOAA products
- $\boldsymbol{k}^{-2.1}$ and not $\boldsymbol{k}^{-1.7}$ like ASCAT

Stoffelen et al., IOVWST, 2010

L2B spectra

- v component





L2B spectra

- u component

OWDP spectra

- OWDP has slightly more small-scale variance in v component than ISRO