# COMBINED ACTIVE-PASSIVE (CAP) ALGORITHM FOR SSS AND WIND VECTOR RETRIEVAL

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**CAL/VAL Workshop**

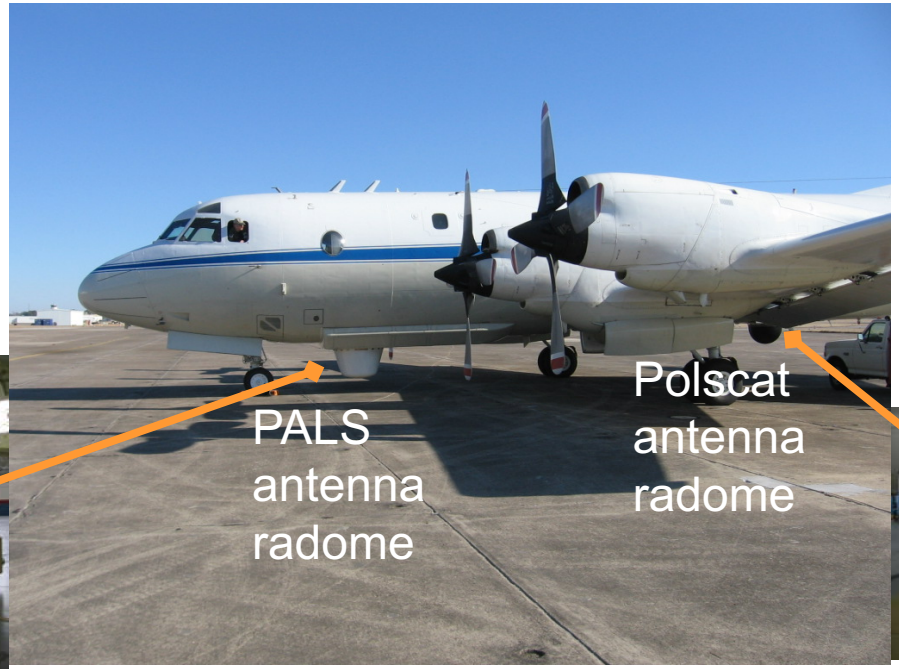
# OUTLINE

- Aquarius GMF
- Stepwise algorithm (inc. current baseline)
- CAP Algorithm
- Performance Comparison
- Summary

# PALS and POLSCAT Installation on P-3 for the 2009 High Wind Campaign

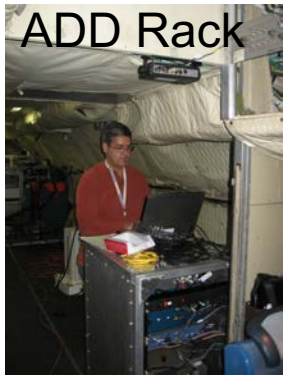
- PALS: Passive/Active L-band Sensor

- POLSCAT: Ku-band scanning radar, providing ocean surface wind observations

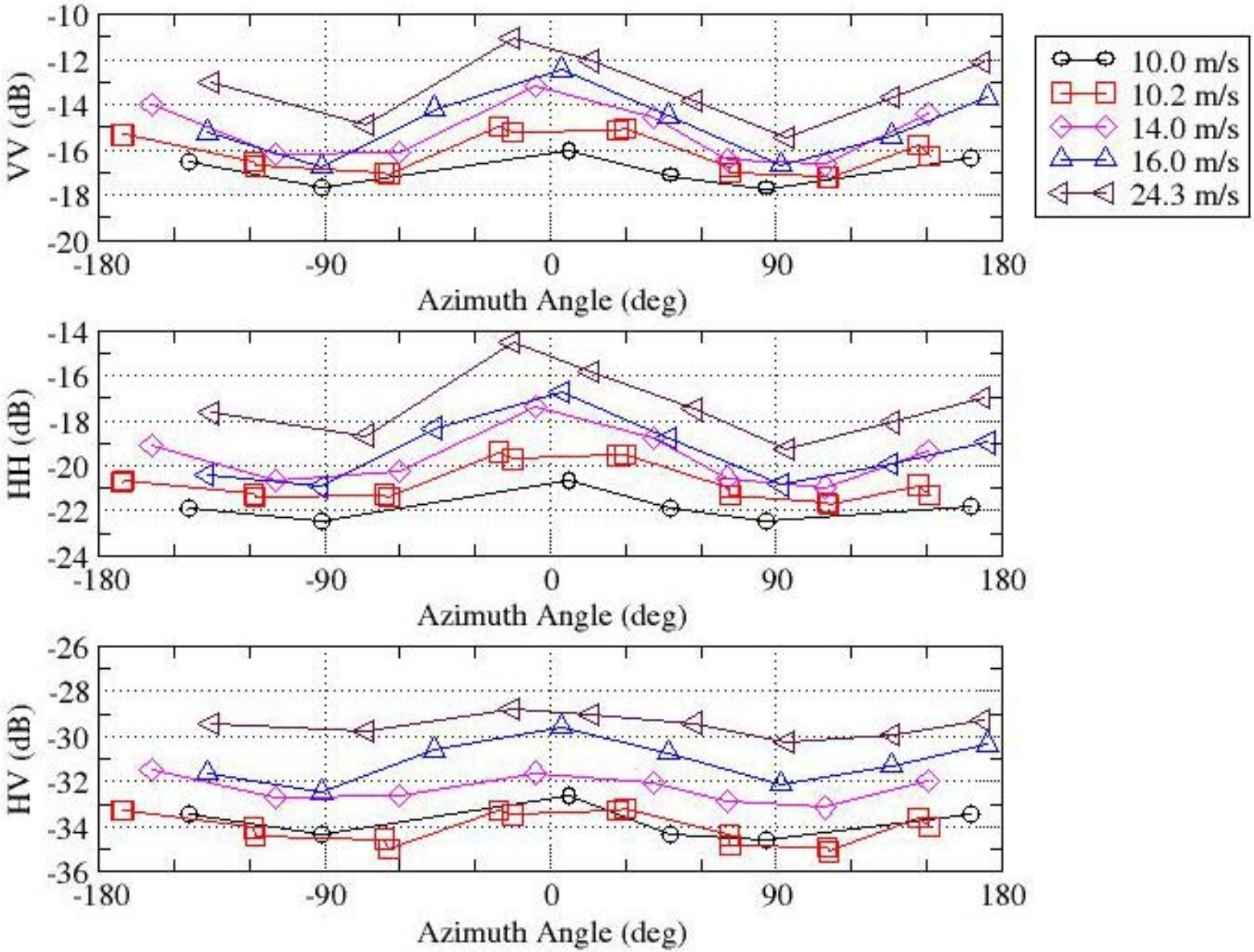




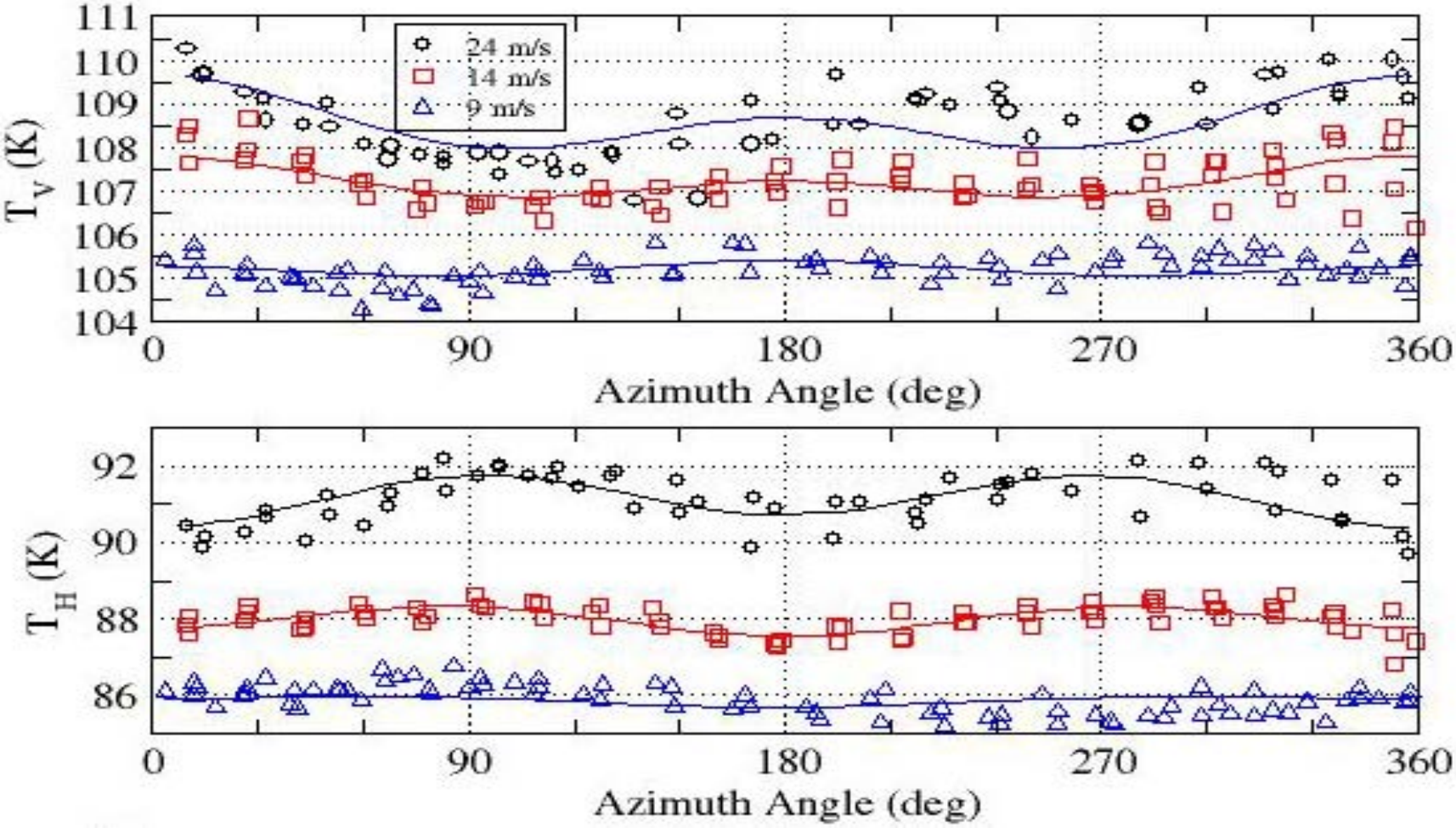




# Airborne PALS Sigma0 Dependence on Wind direction
# All Star Pattern Flight Data



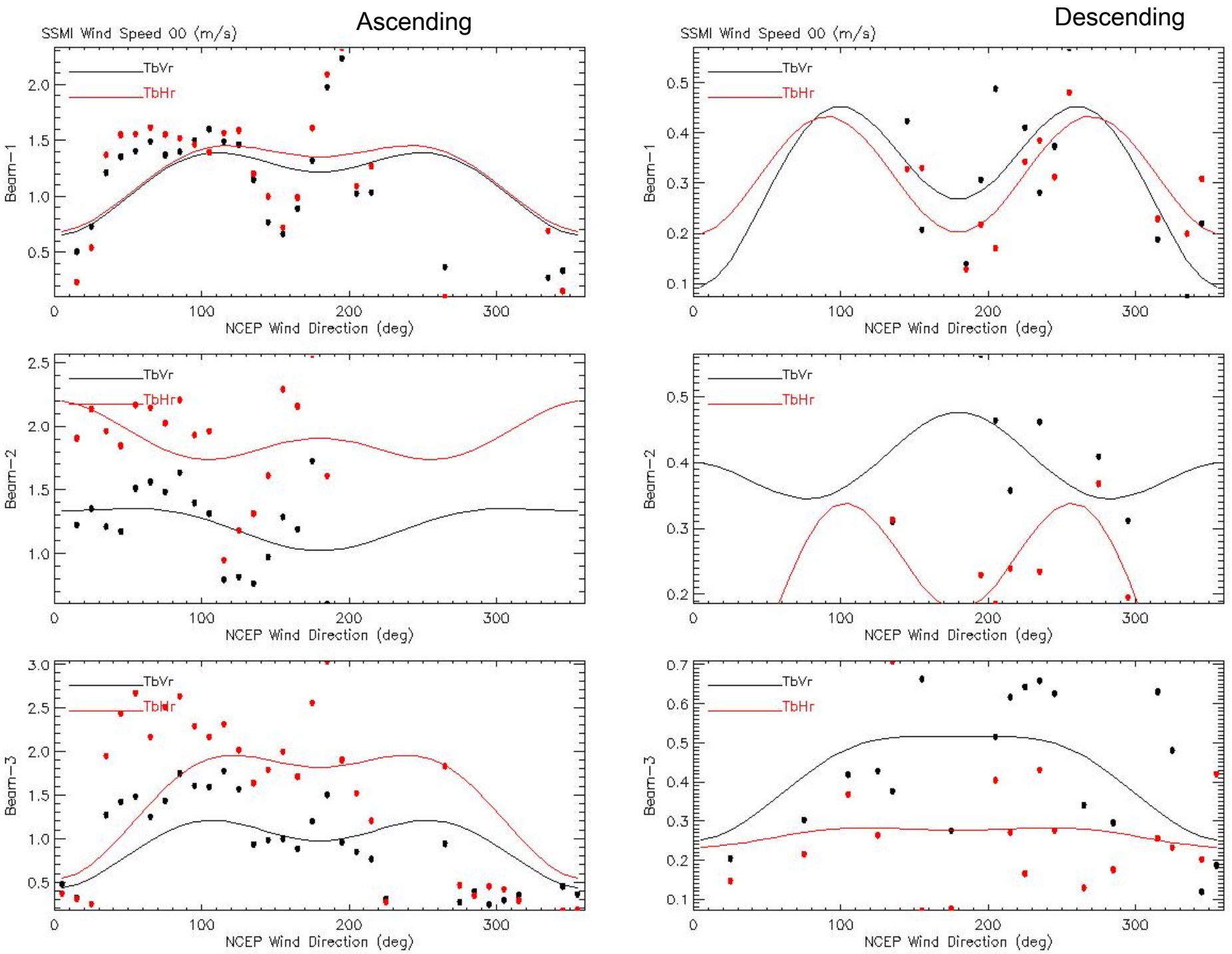
# PALS Radiometer TB Dependence on Wind Direction
# Circle Flight Data



# Aquarius Radiometer GMF Ascending/Descending

W. Tang

Nov. 17, 2011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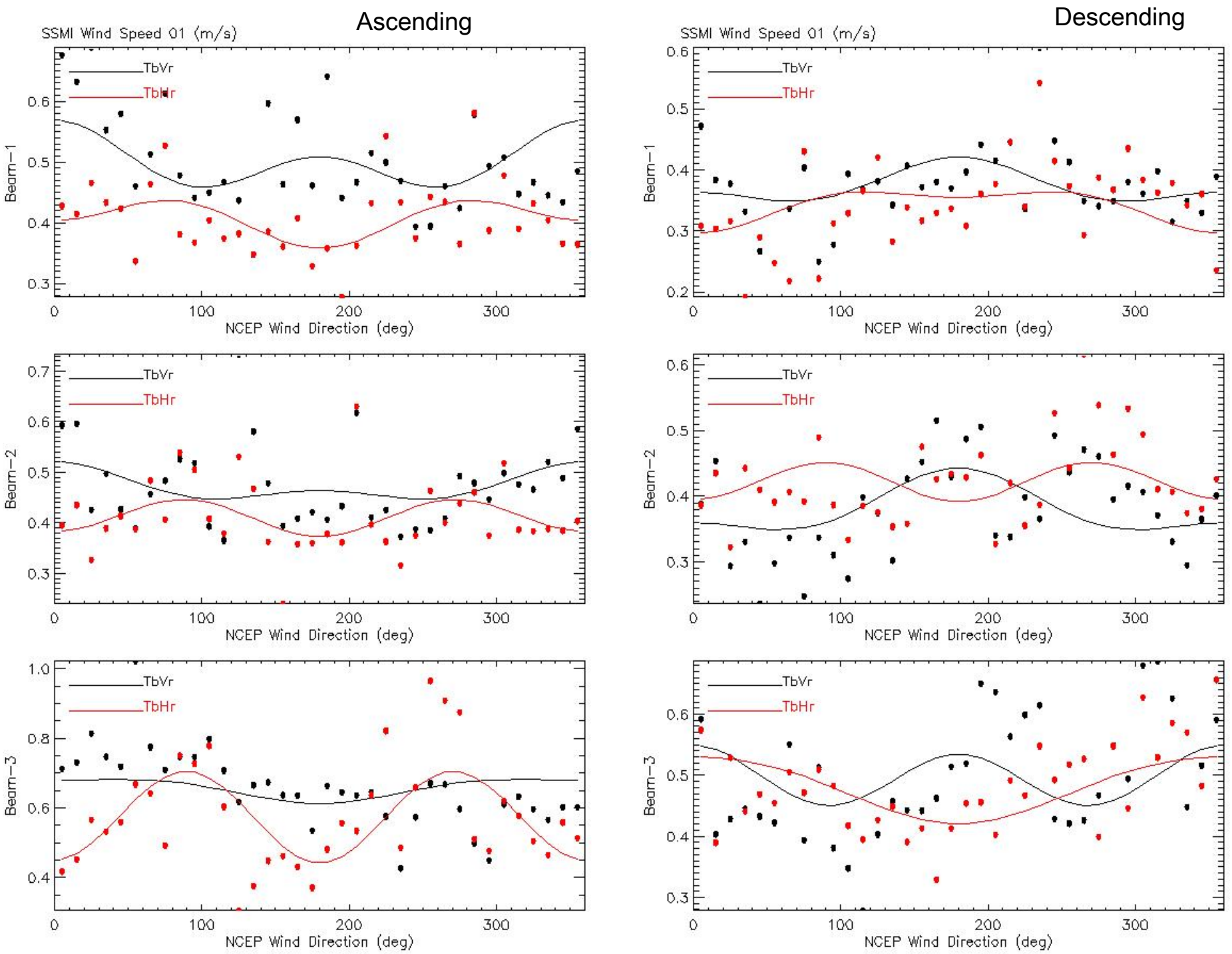
Descending
SSMI Wind Speed 00 (m/s)
SSMI Wind Speed 00 (m/s)
TbVr
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)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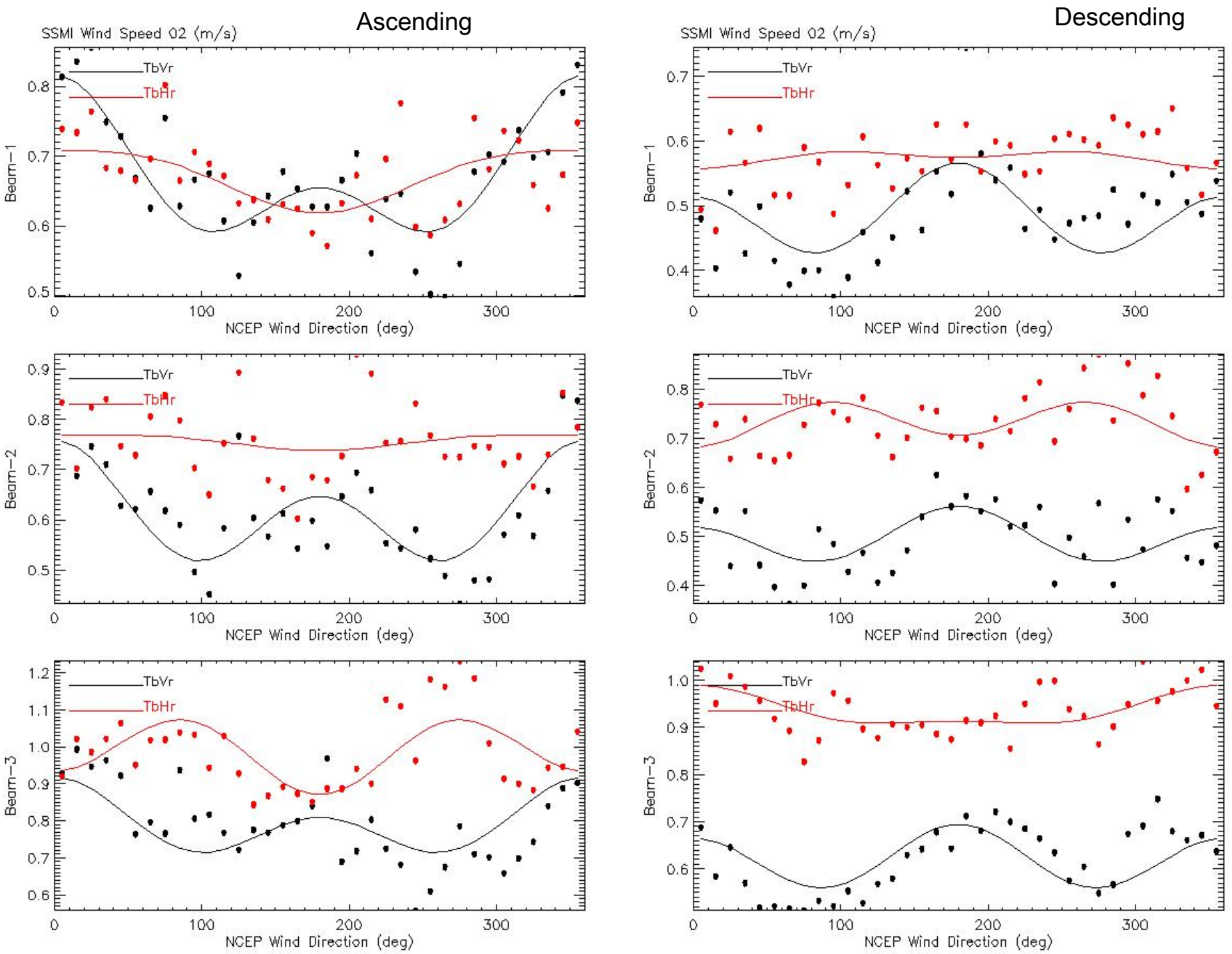
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)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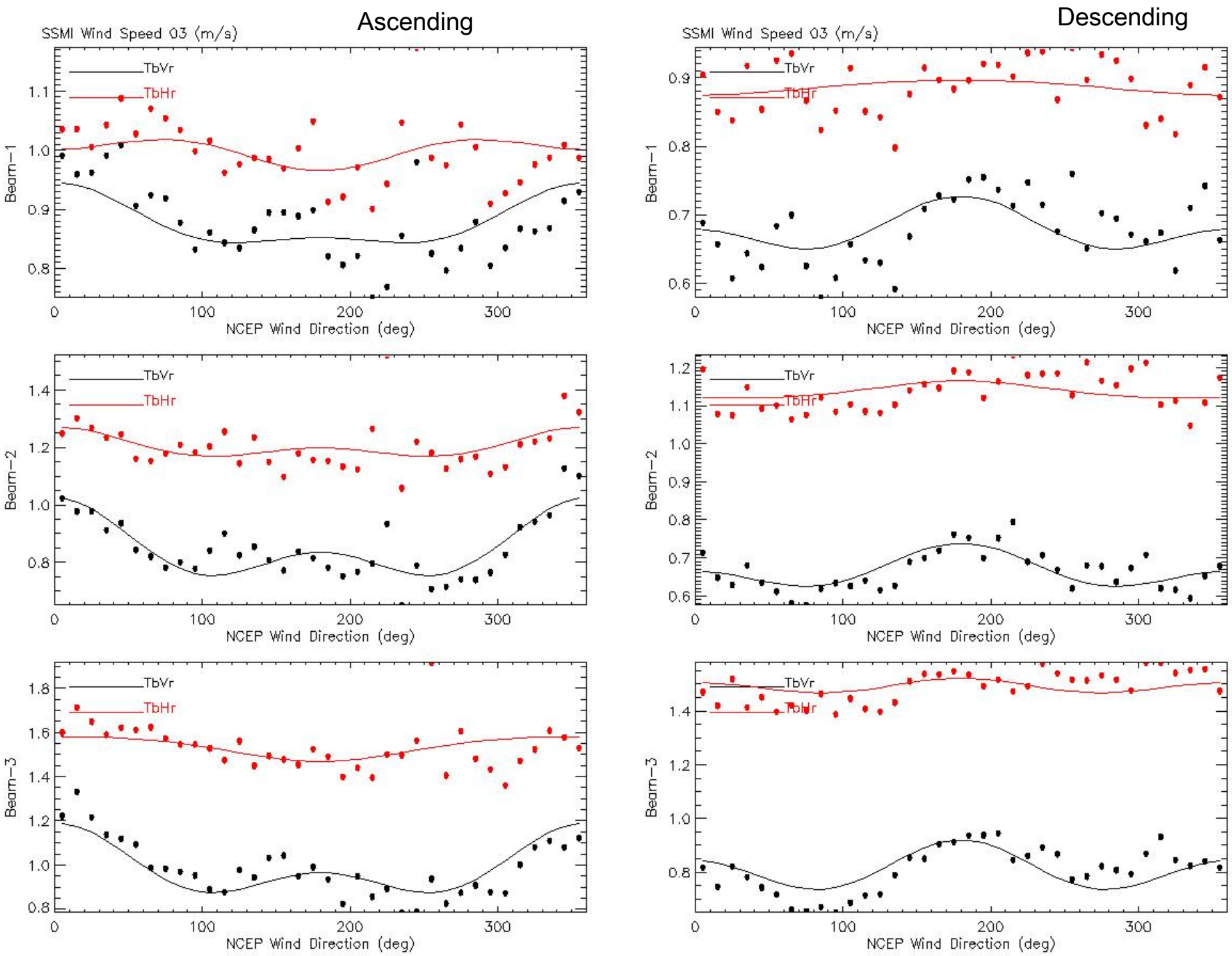
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)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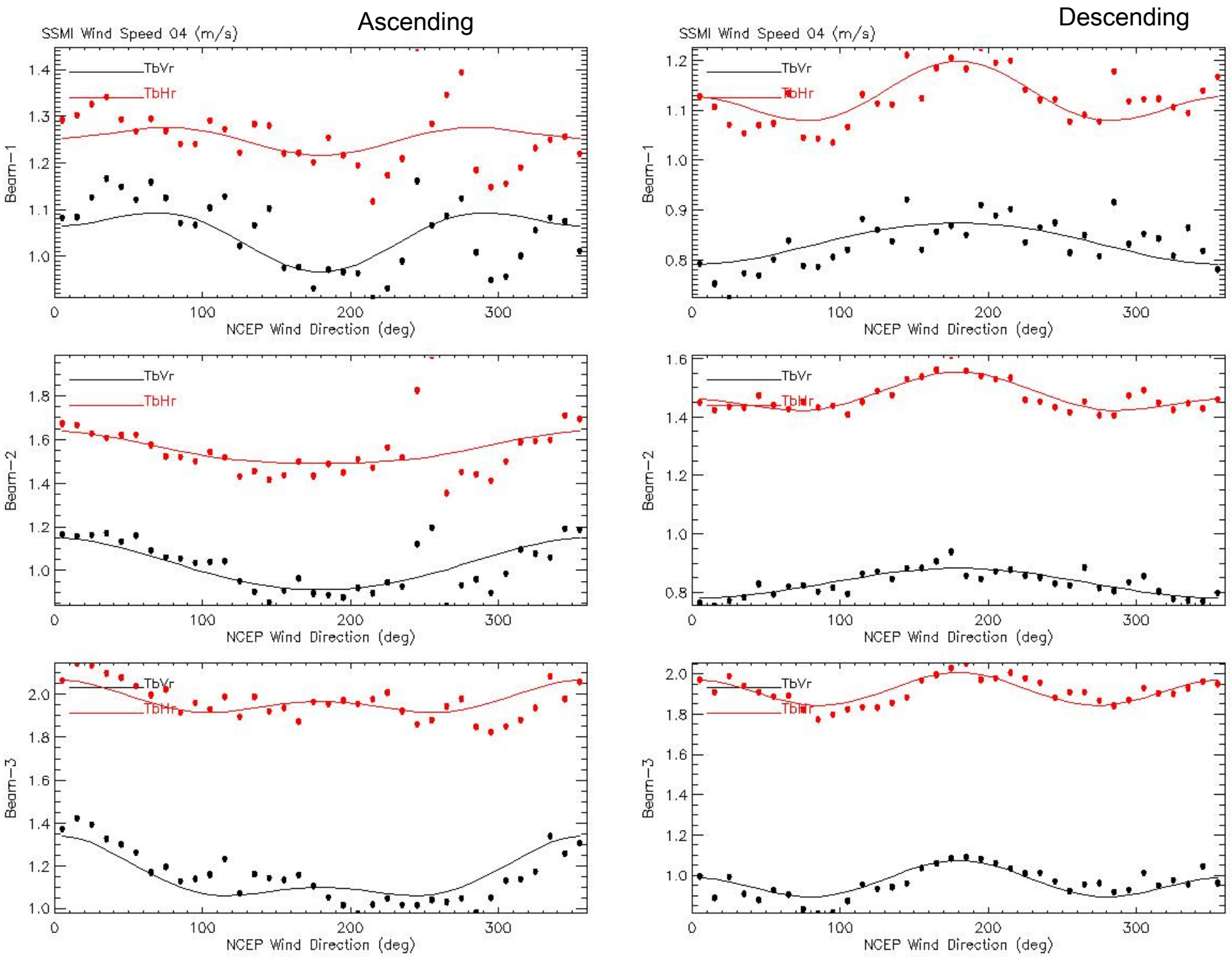
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)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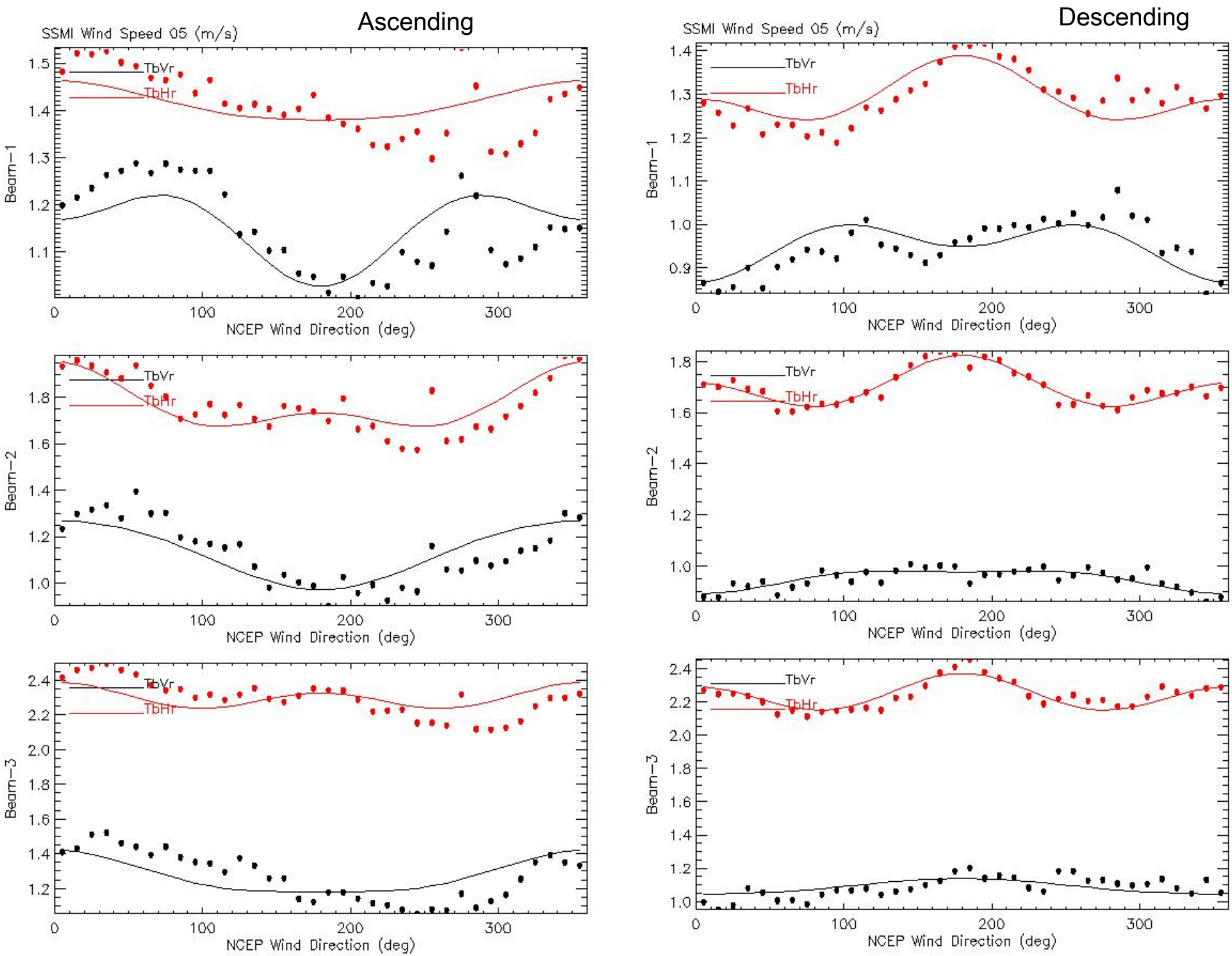
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)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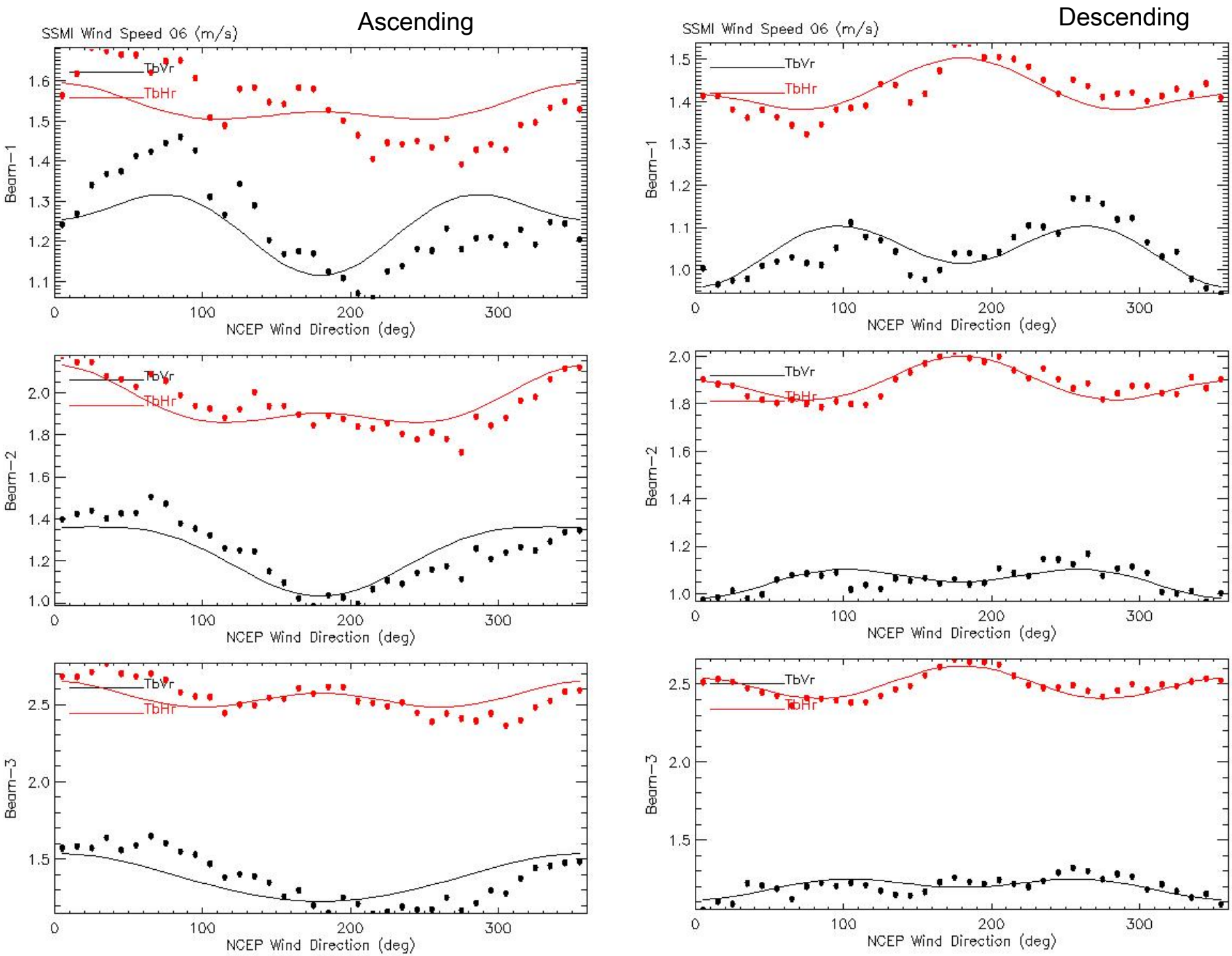
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)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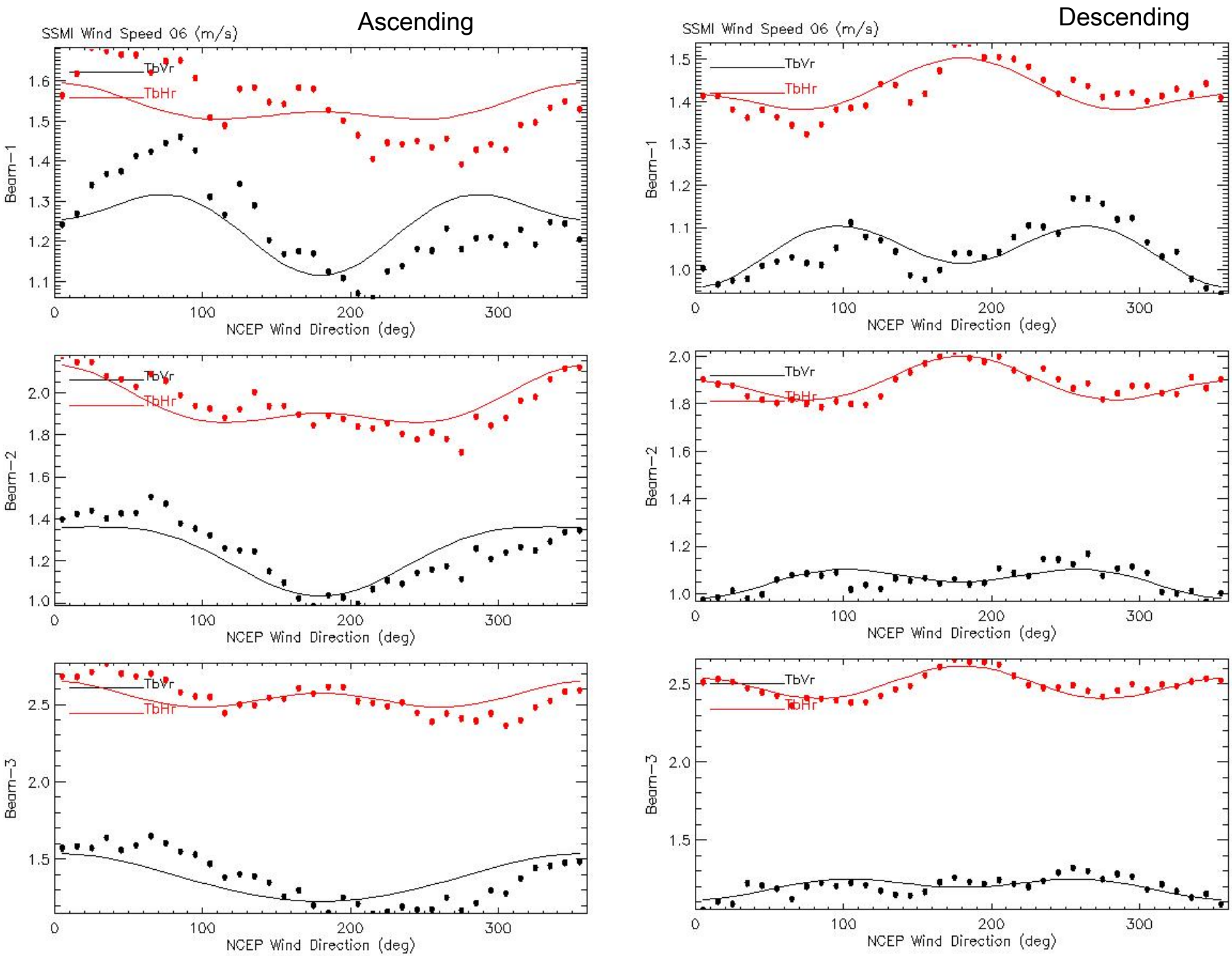
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)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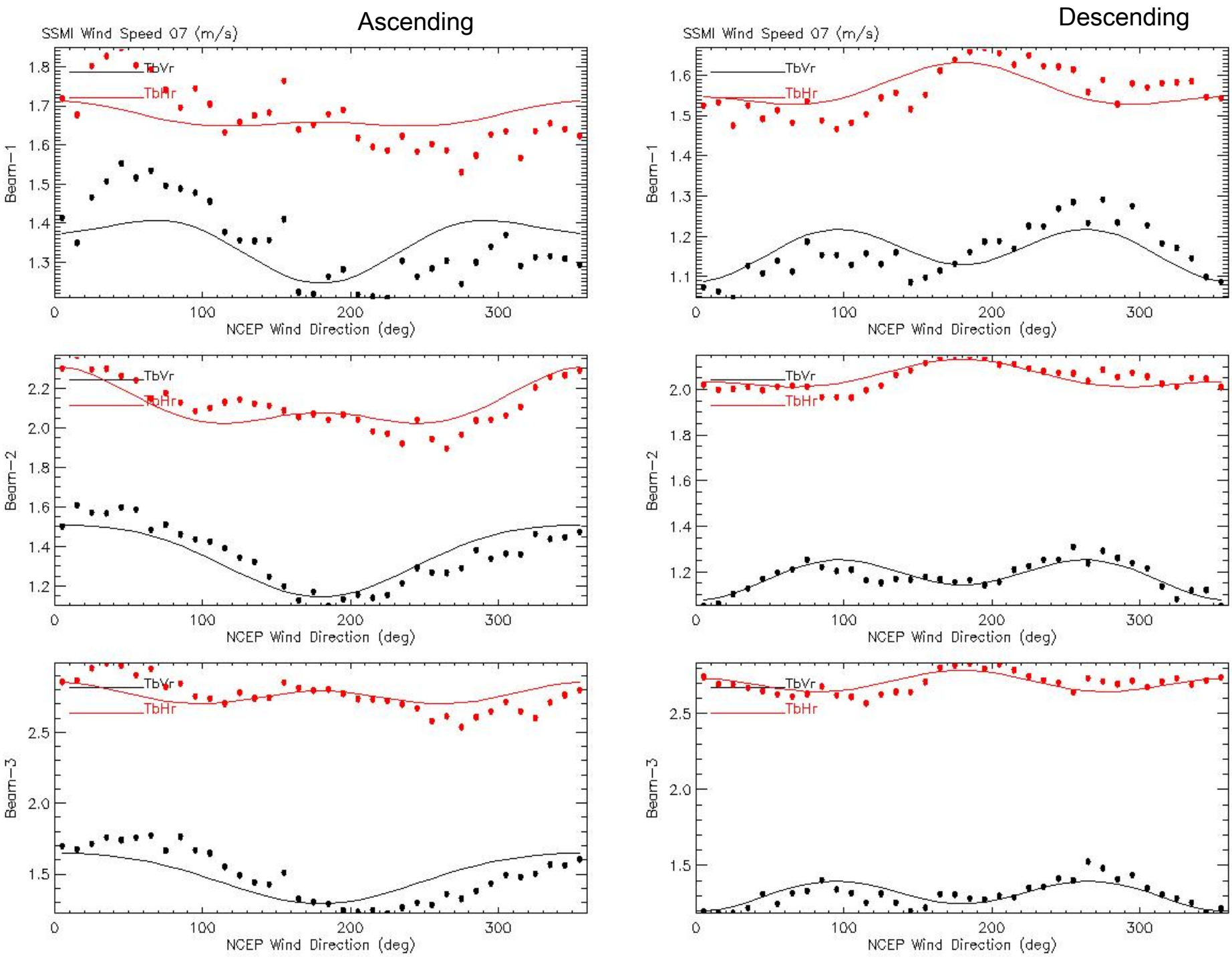
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)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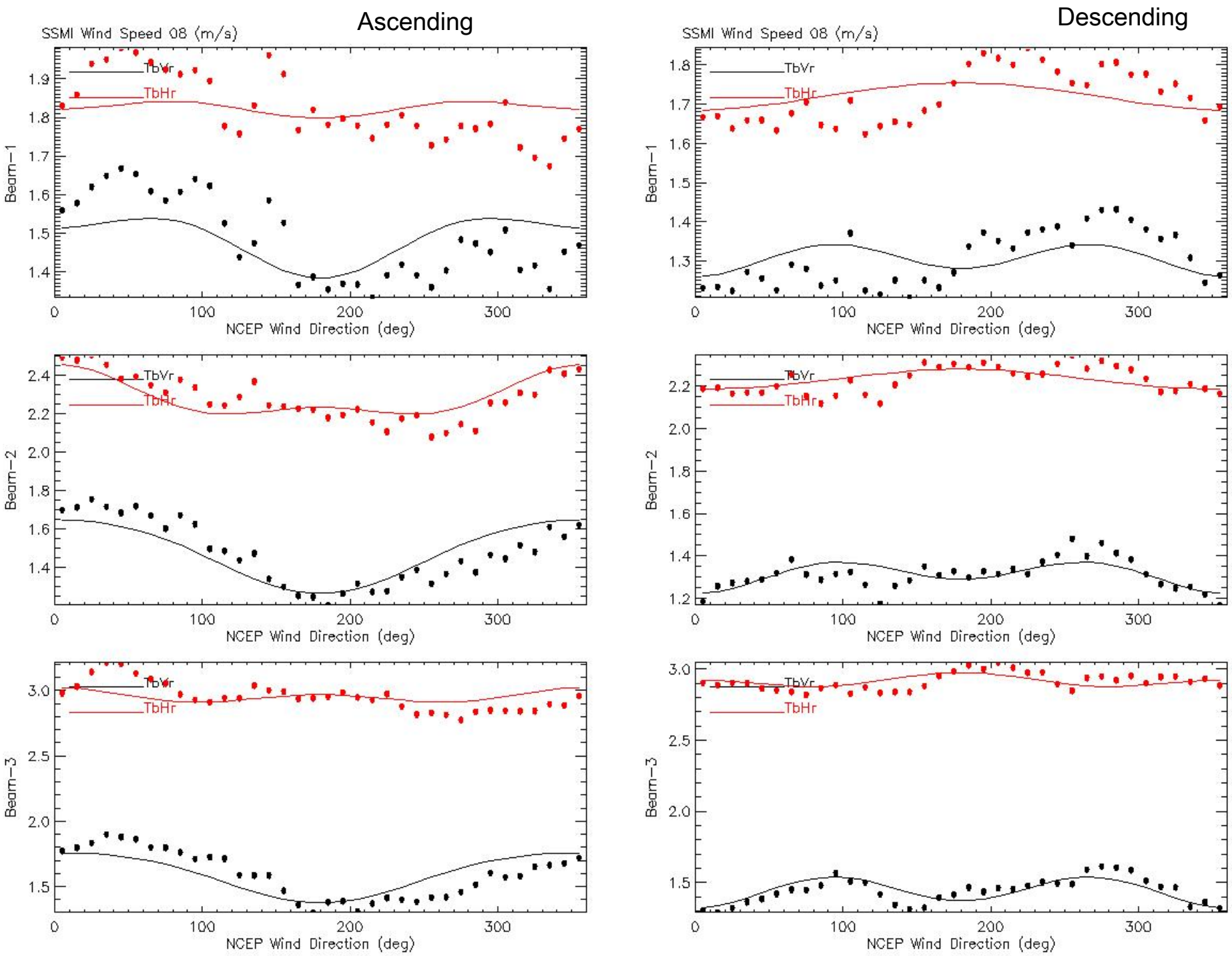
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)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Descending
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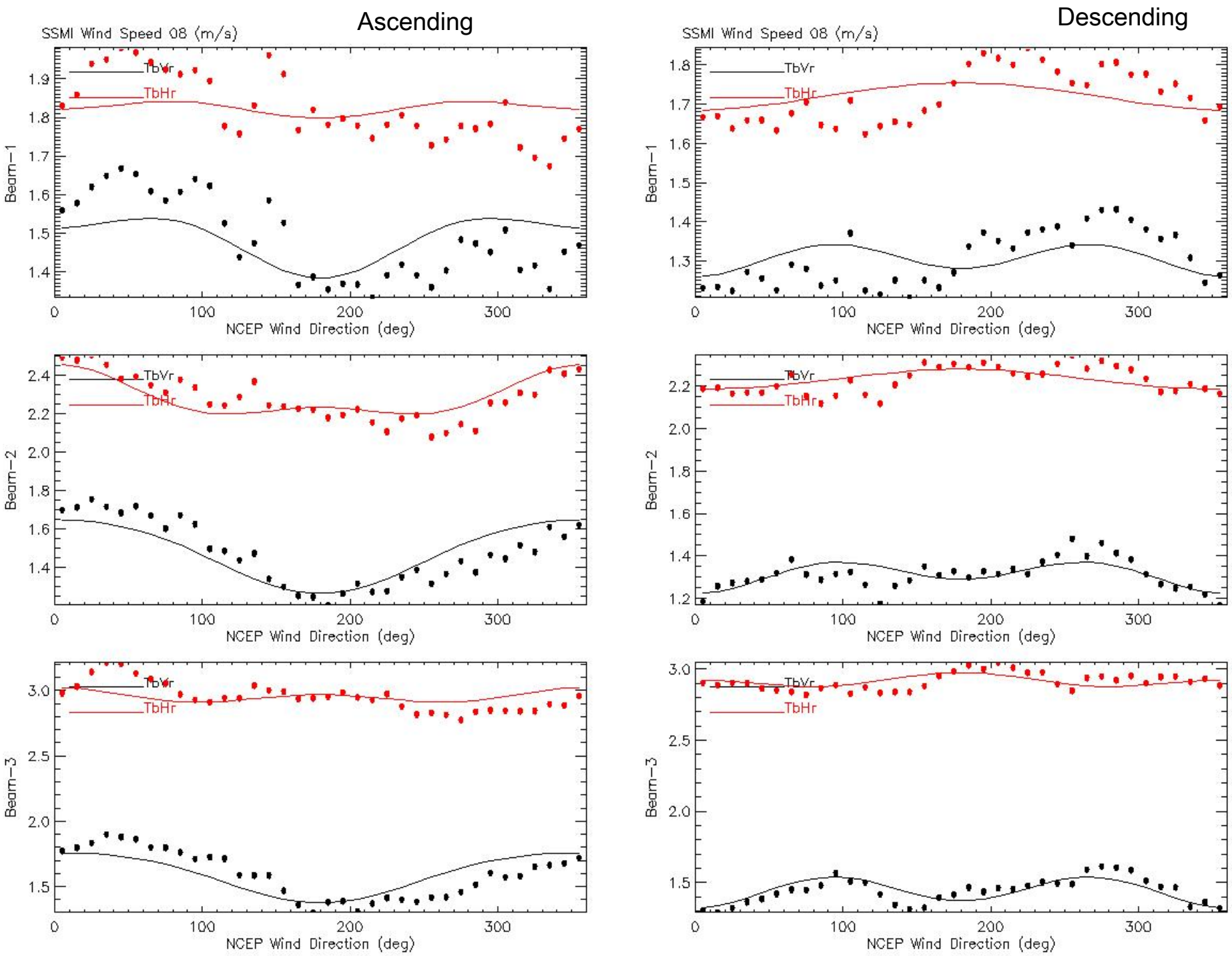
TbVr
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)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Descending
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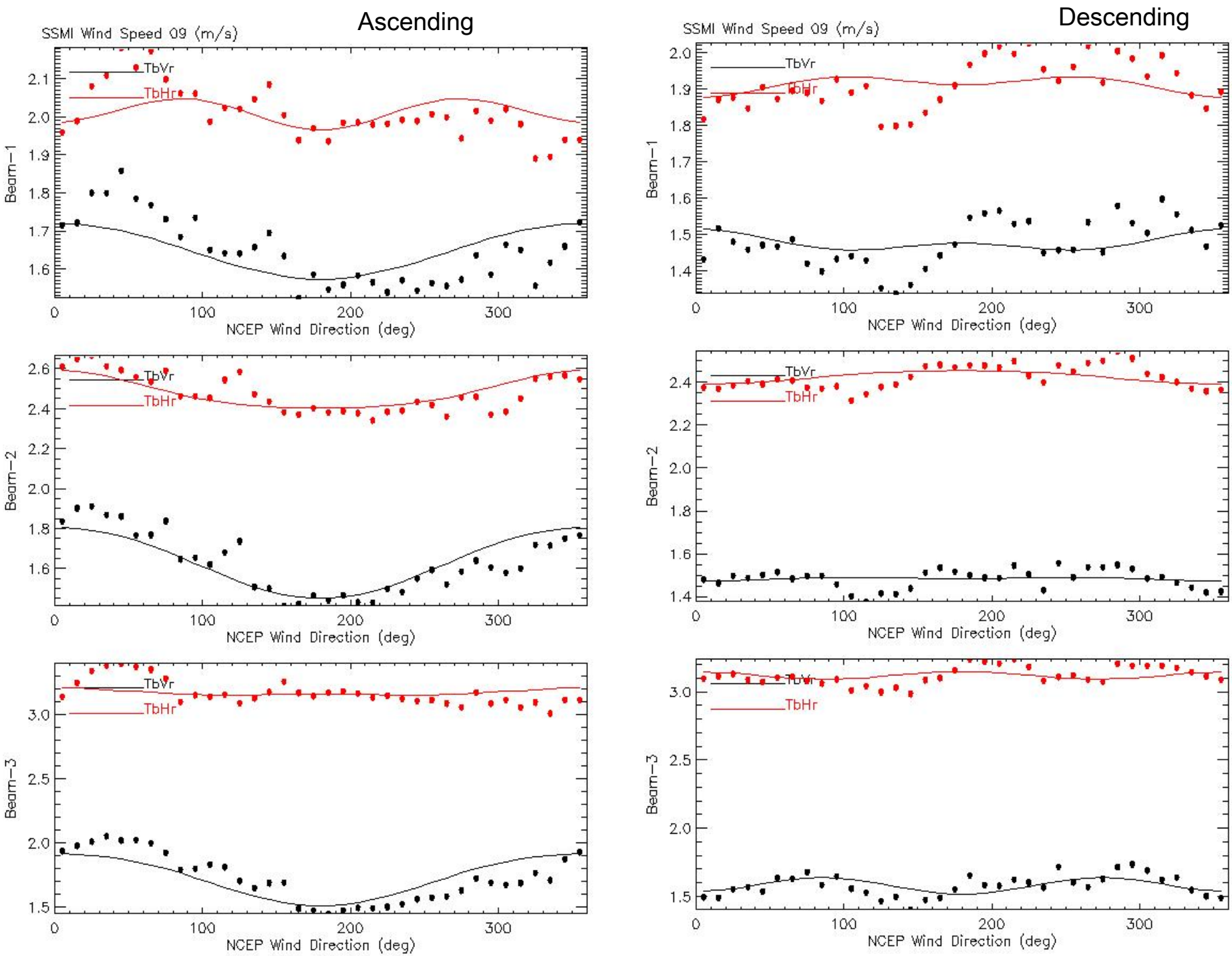
SSMI Wind Speed 08 (m/s)
TbVr
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)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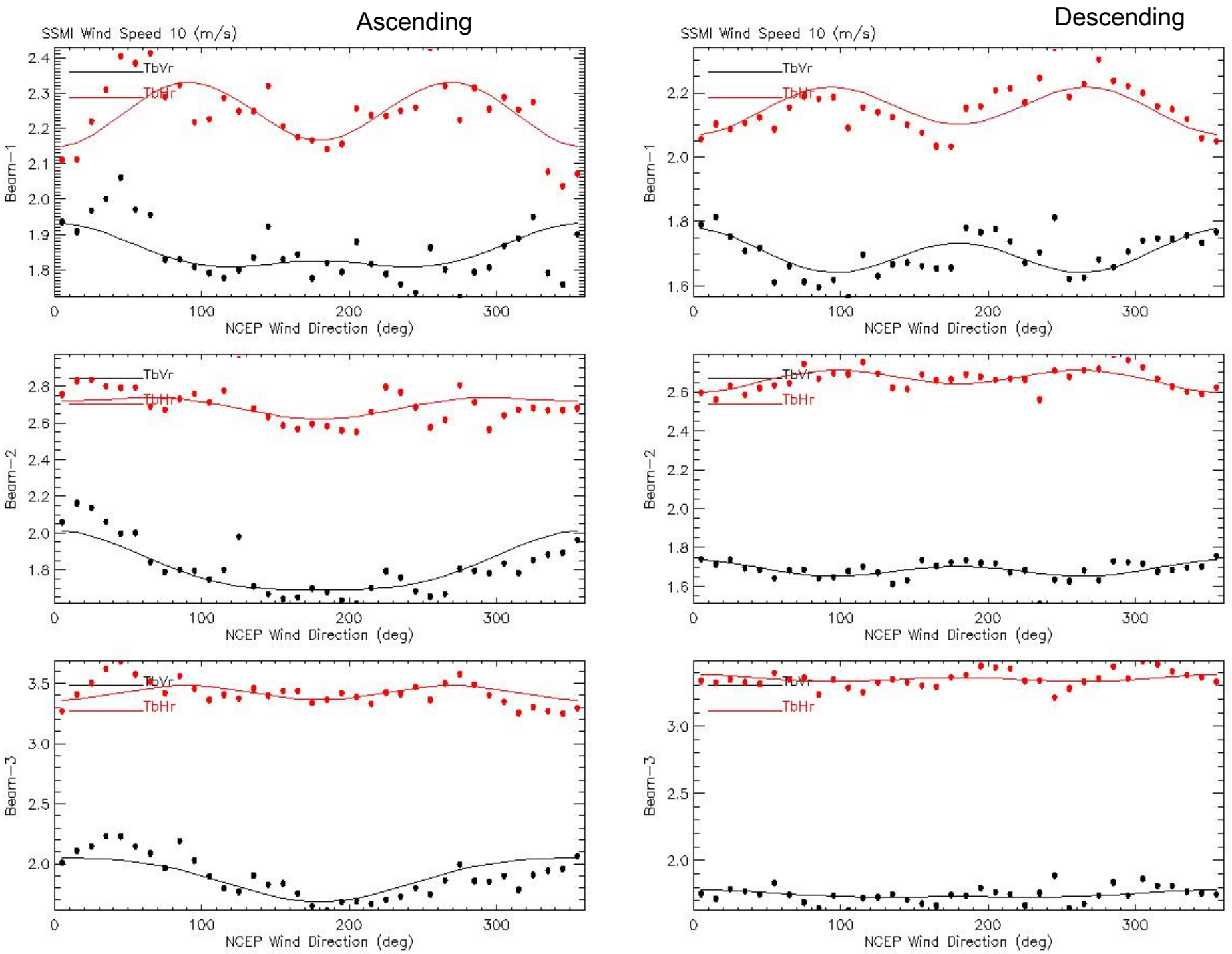
SSMI Wind Speed 09 (m/s)
TbVr
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)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Descending
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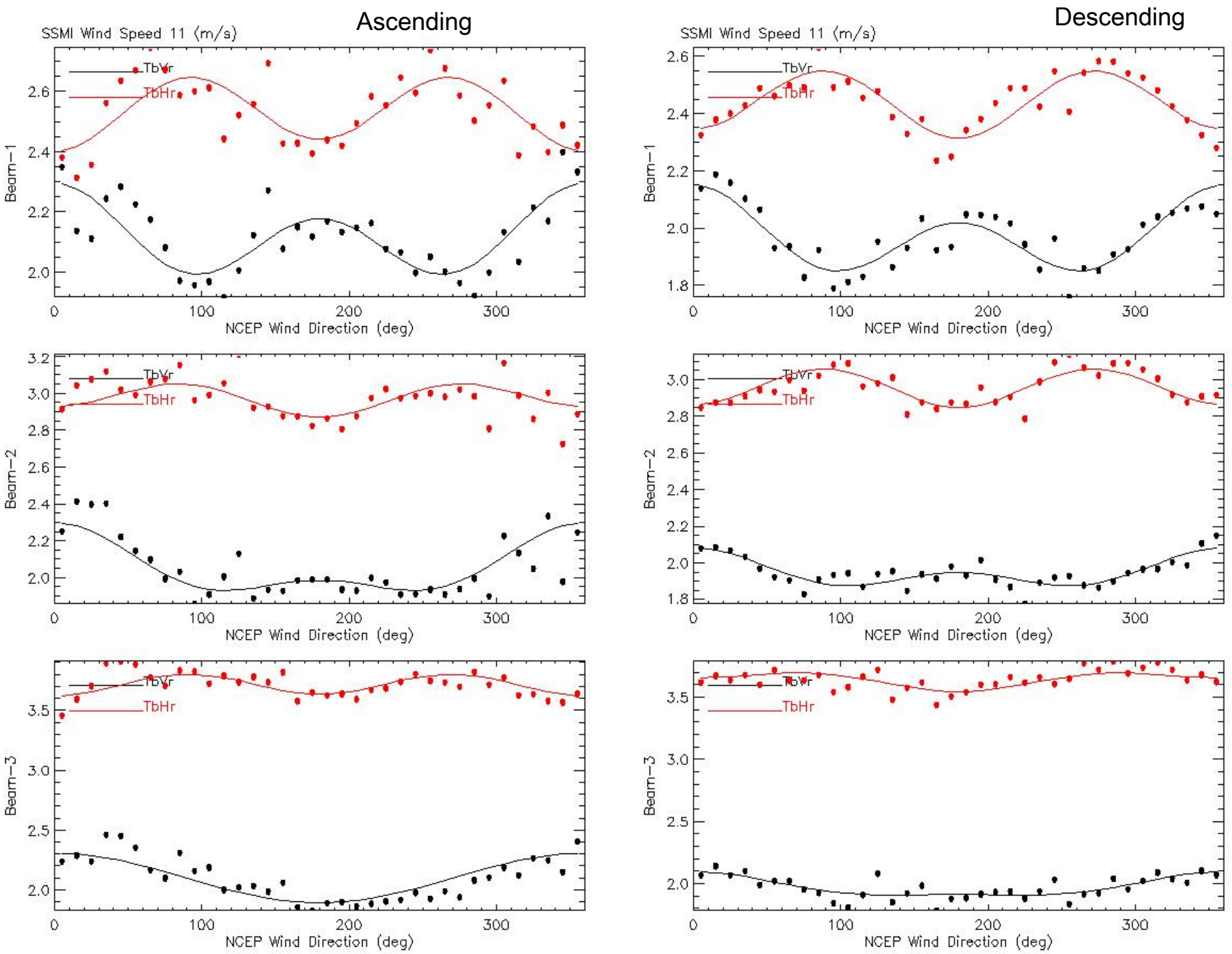
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)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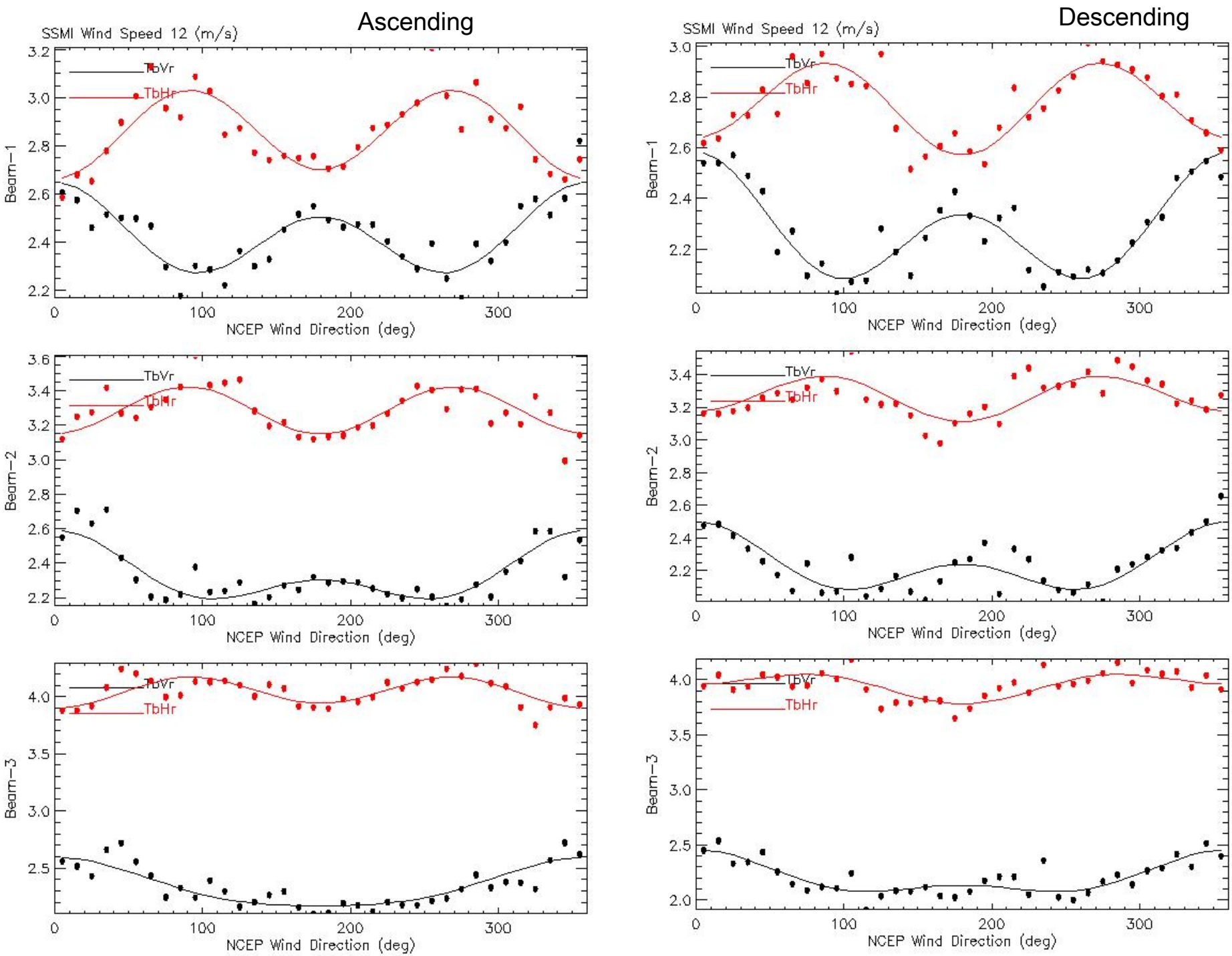
TbVr
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)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Descending
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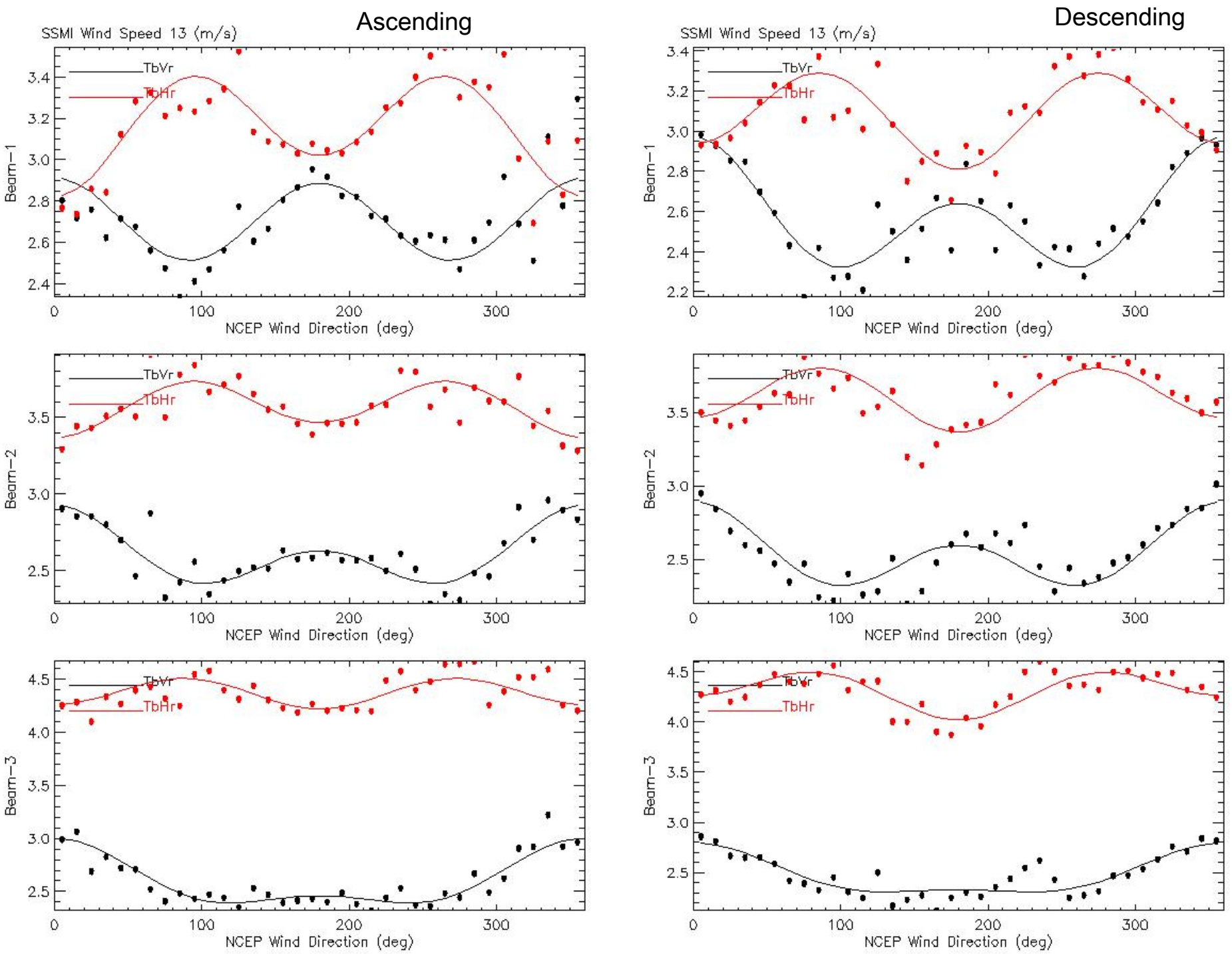
TbVr
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)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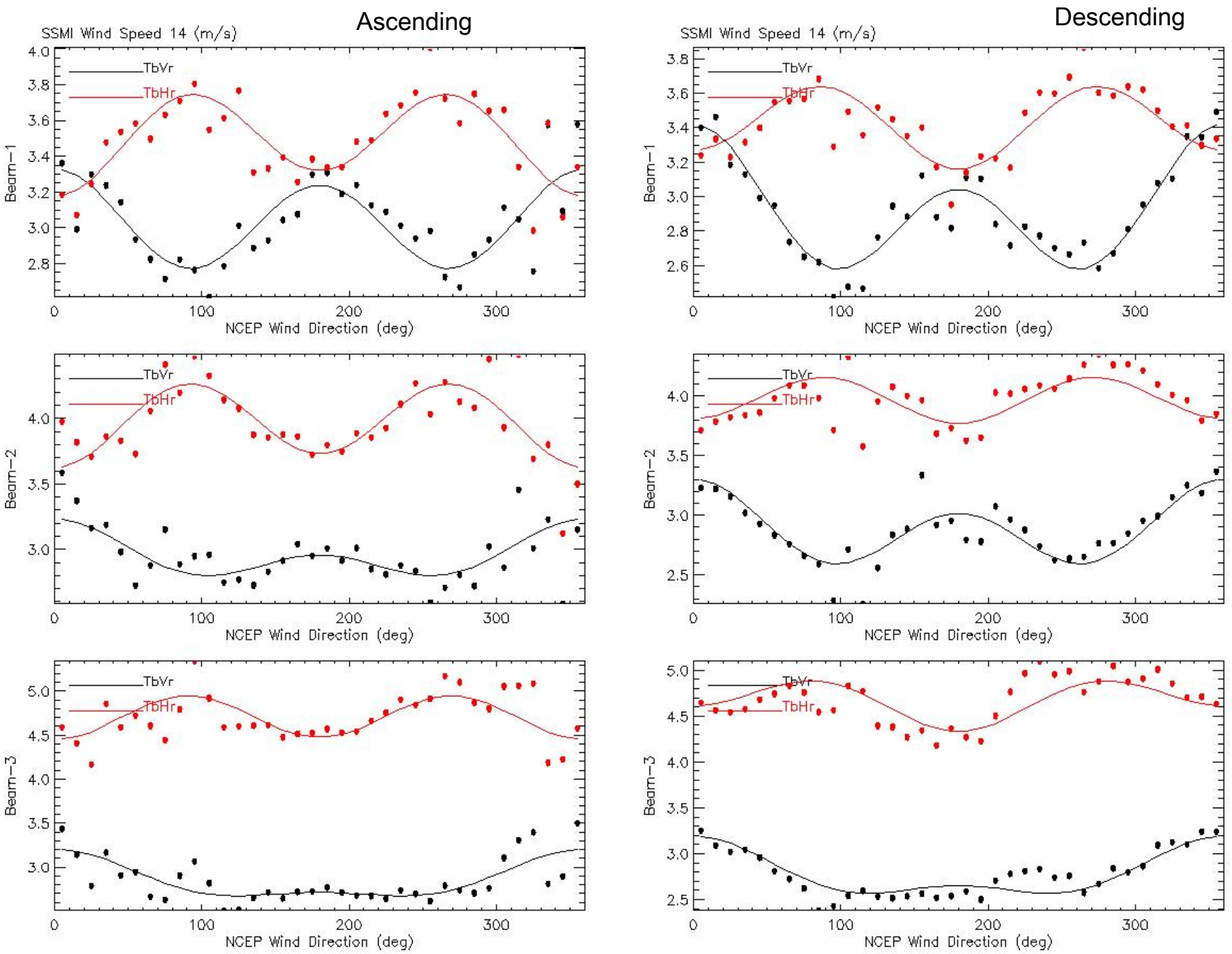
Descending
SSMI Wind Speed 13 (m/s)
SSMI Wind Speed 13 (m/s)
TbVr
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)


Ascending
Descending
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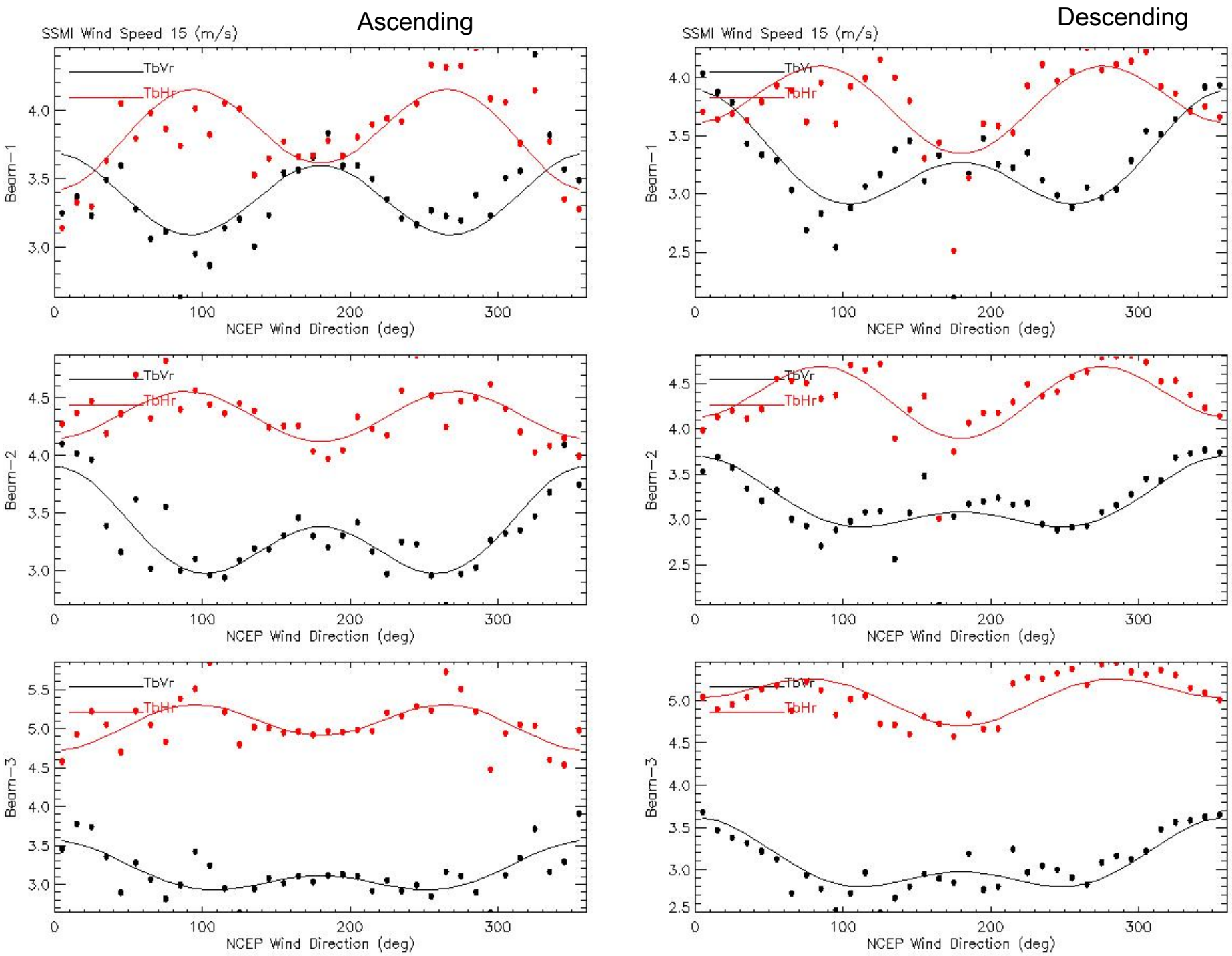
SSMI Wind Speed 14 (m/s)
TbVr
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)


Ascending
Descending
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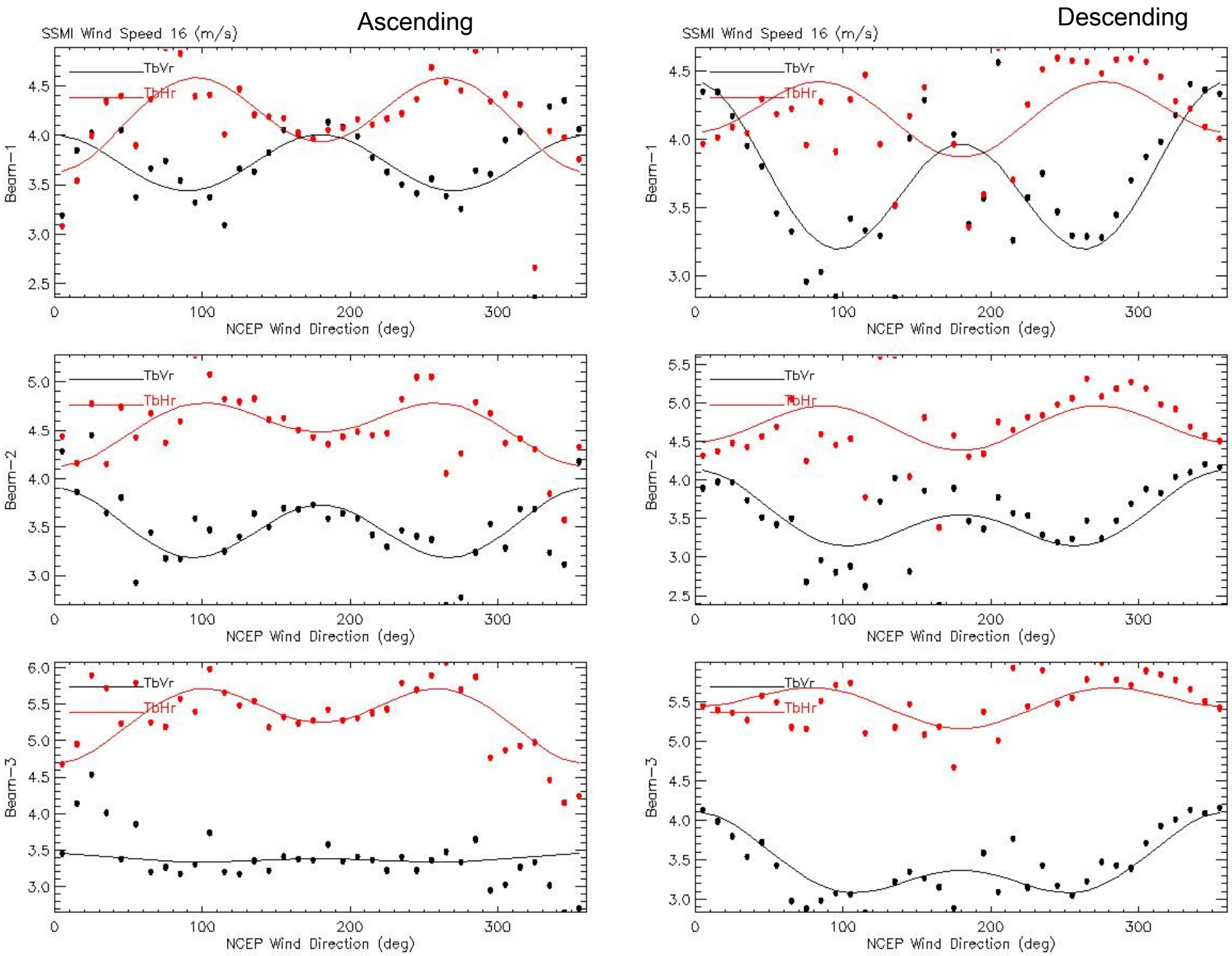
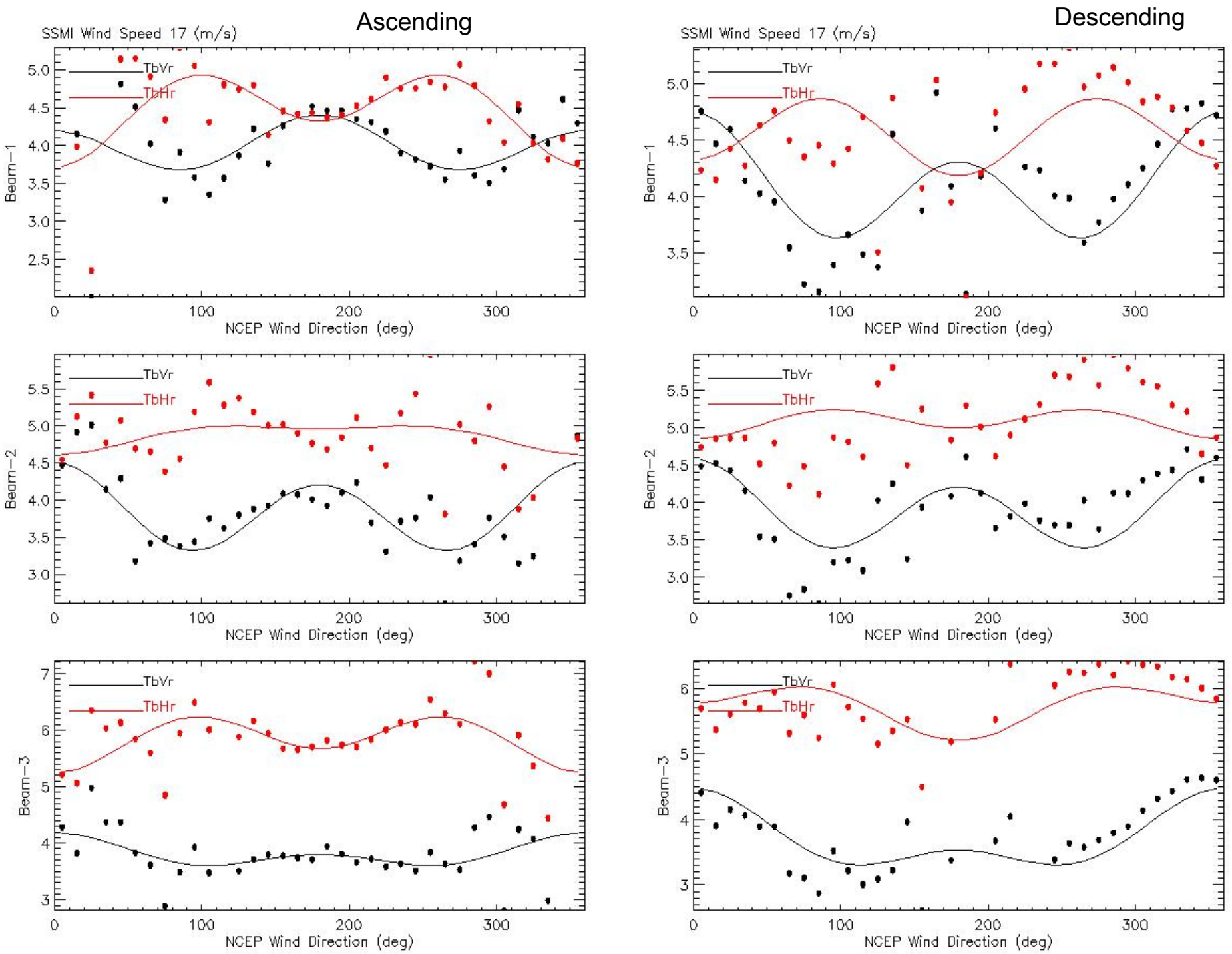
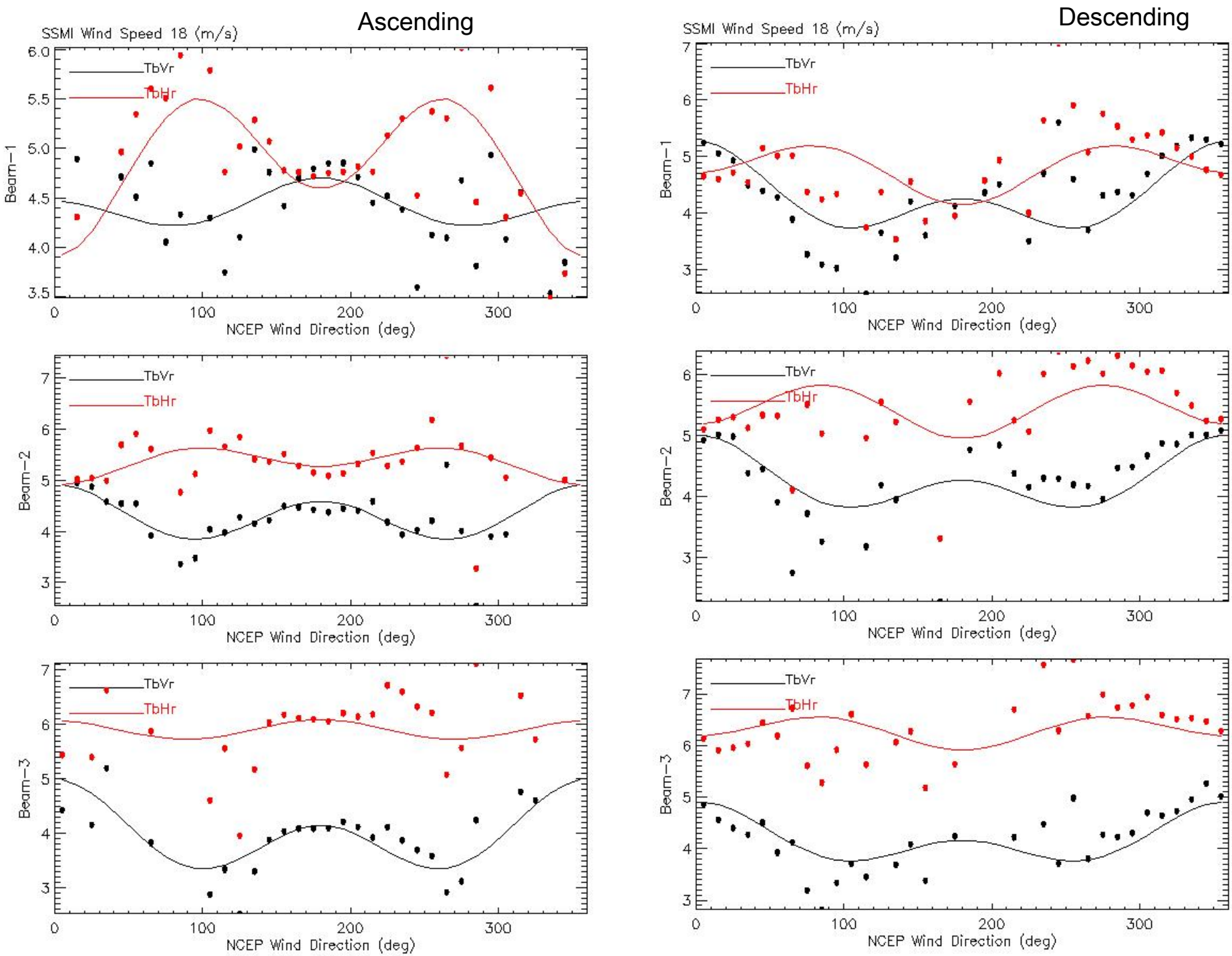
TbVr
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)


Ascending
Descending
SSMI Wind Speed 16 (m/s)
TbVr
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)


Ascending
Descending
SSMI Wind Speed 17 (m/s)
SSMI Wind Speed 17 (m/s)
TbVr
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)


Ascending
Descending
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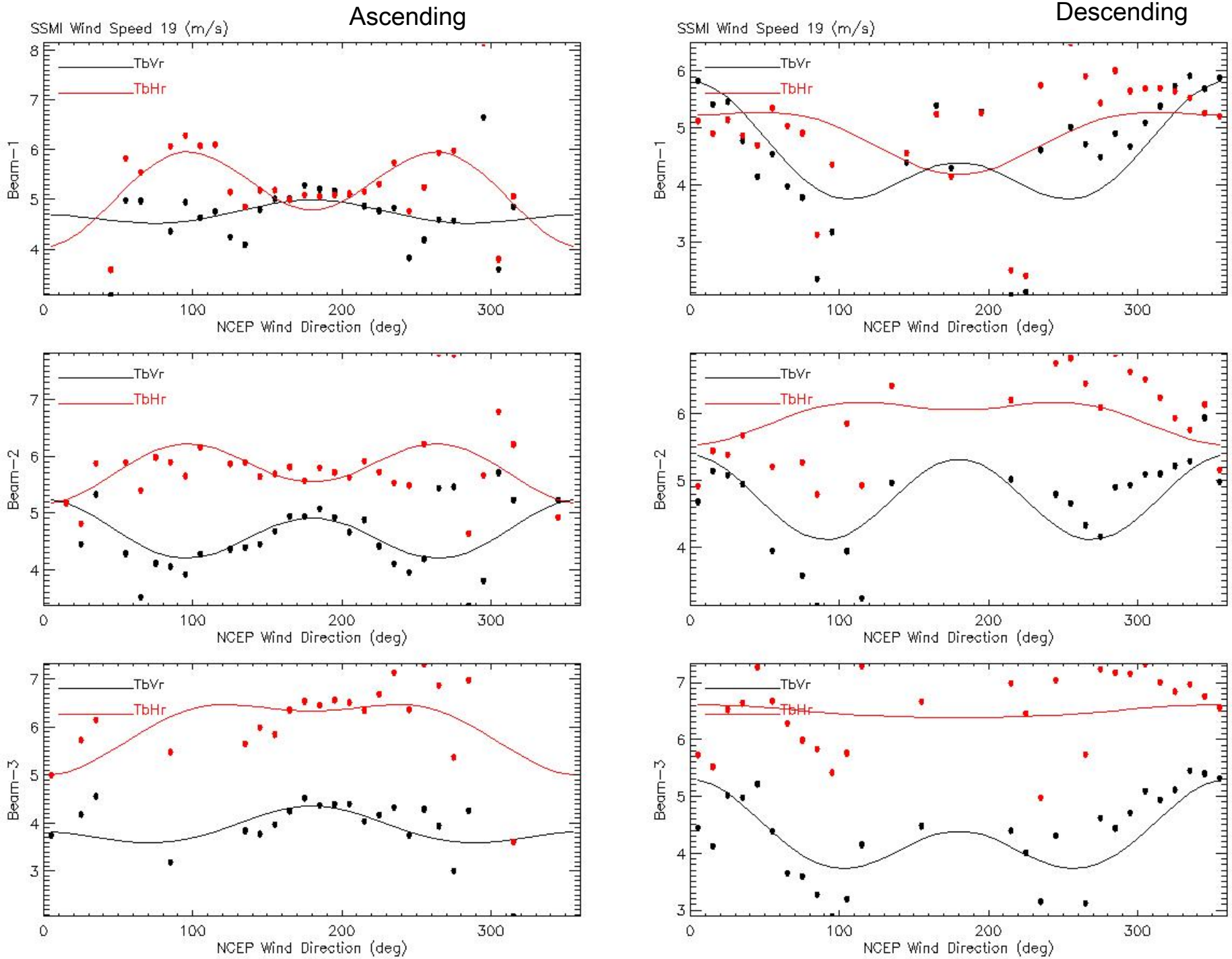
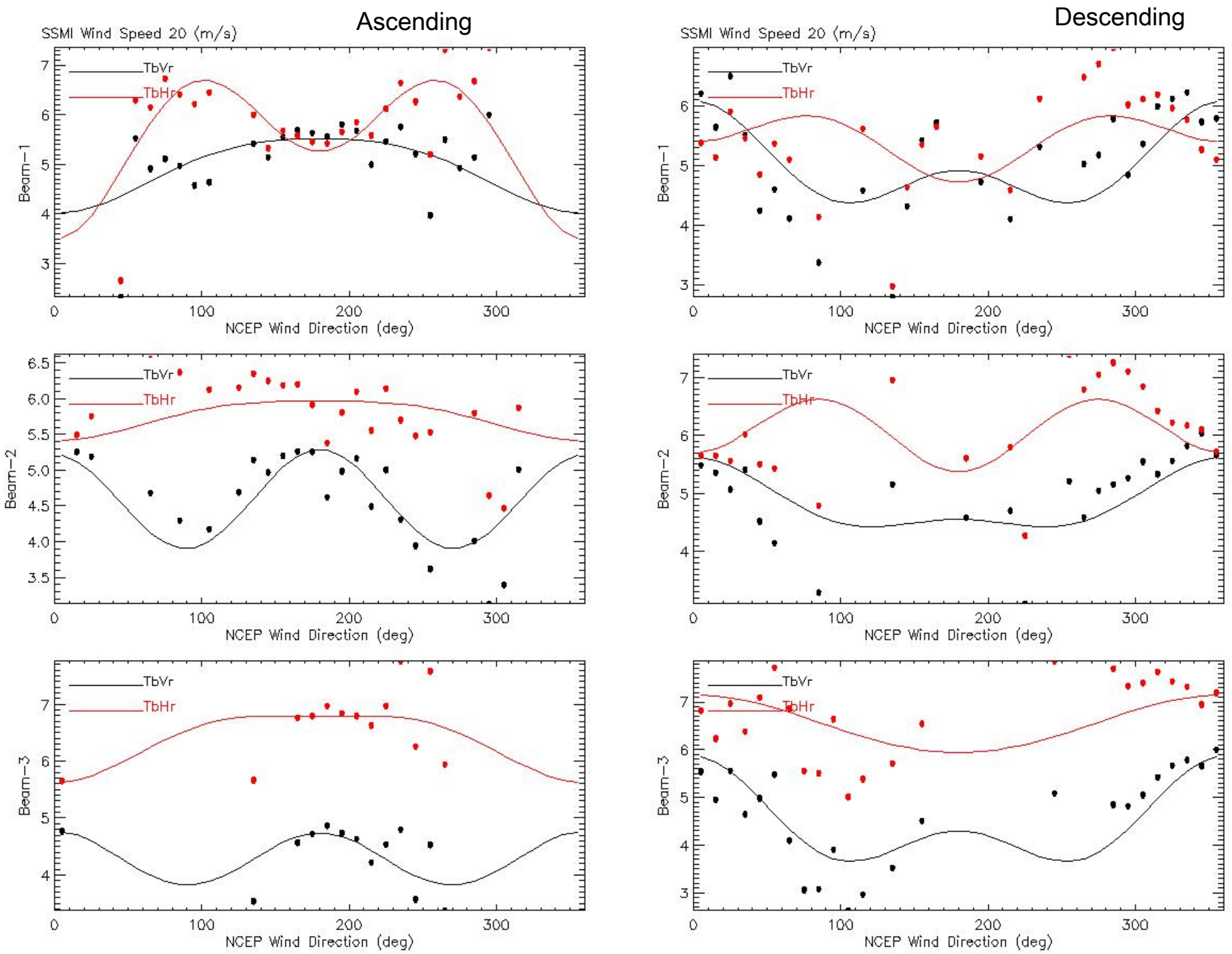
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)


Ascending
Descending
SSMI Wind Speed 19 (m/s)
TbVr
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)
0
100
200
300


Ascending
Descending
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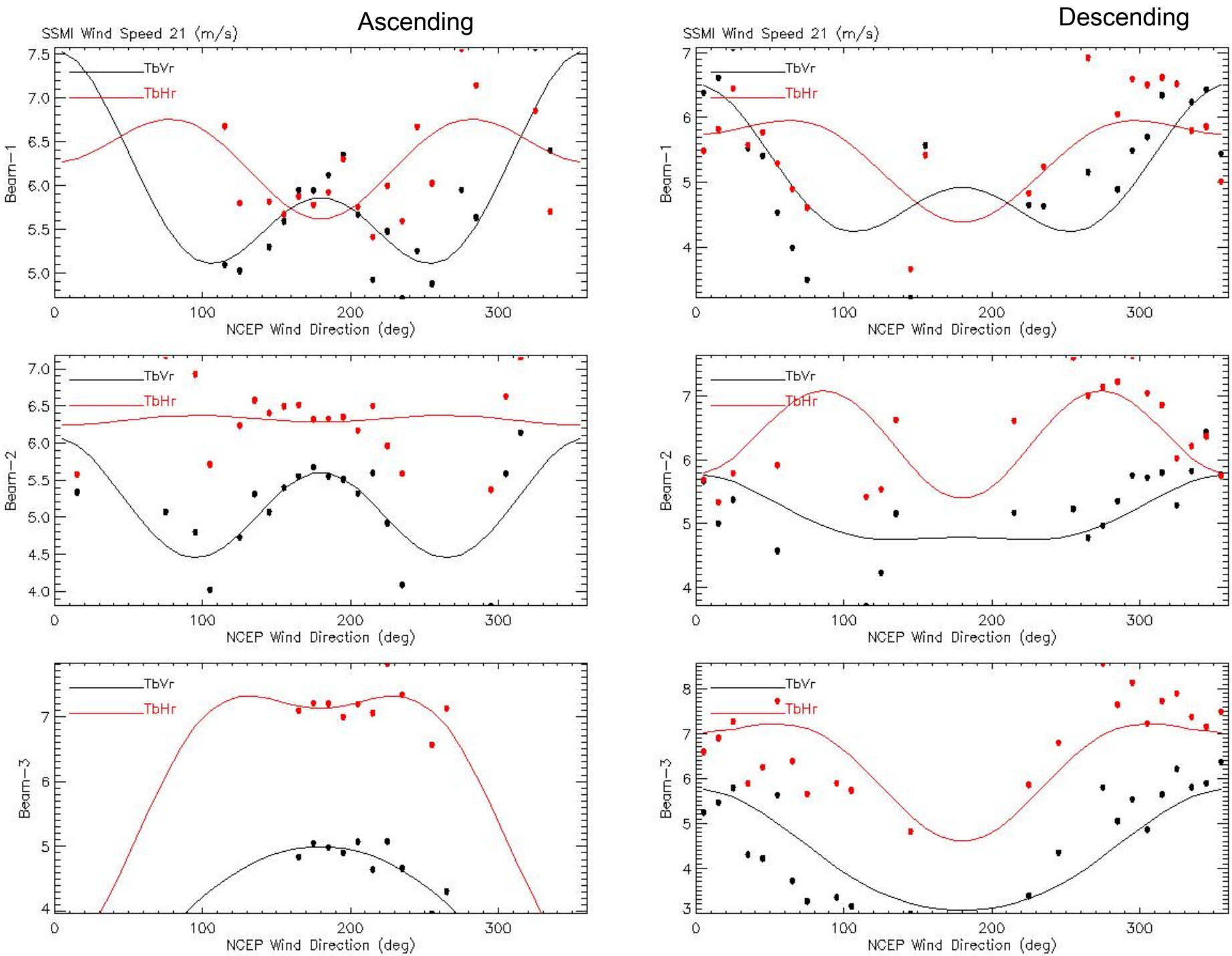
TbVr
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)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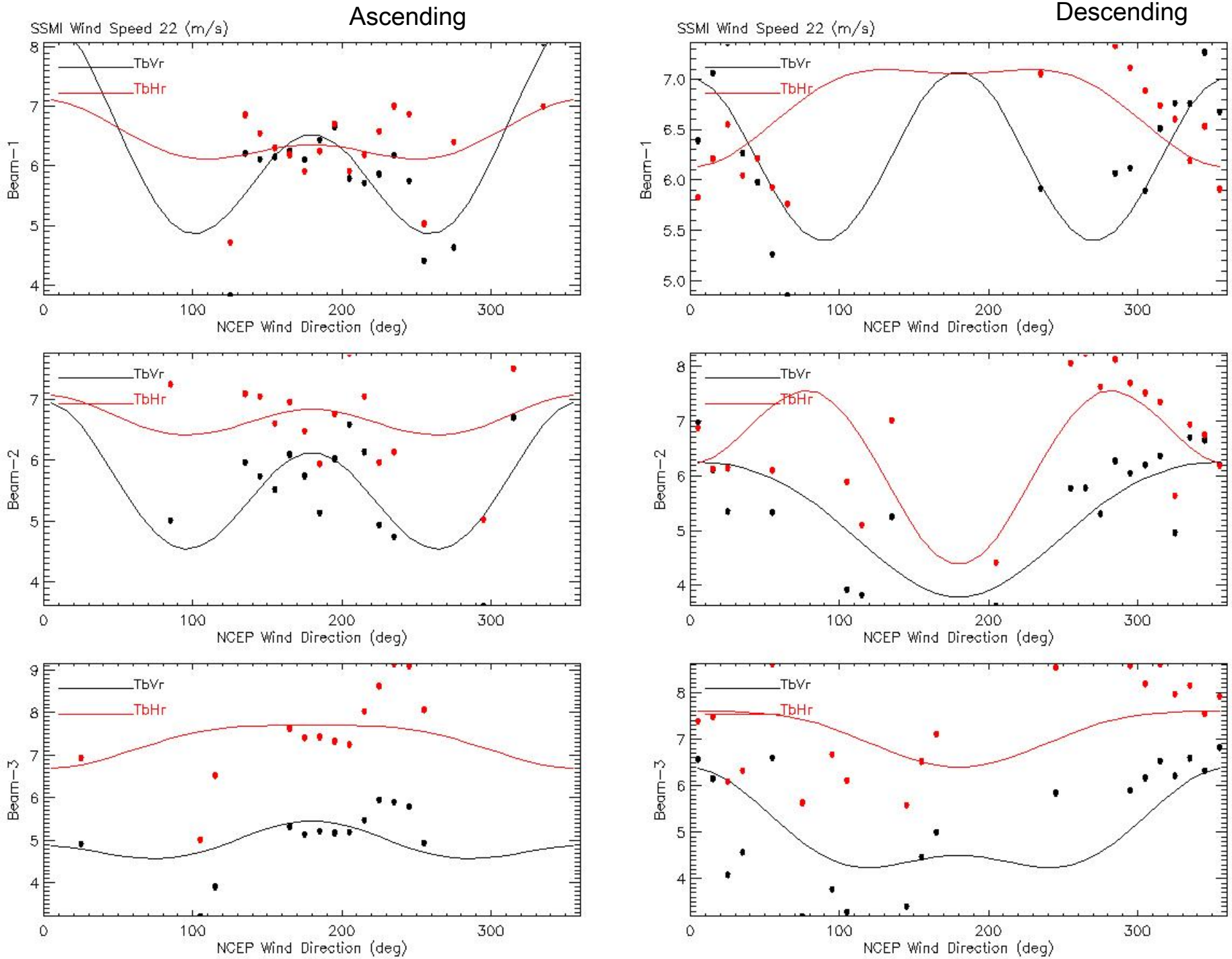
Beam-3
NCEP Wind Direction (deg)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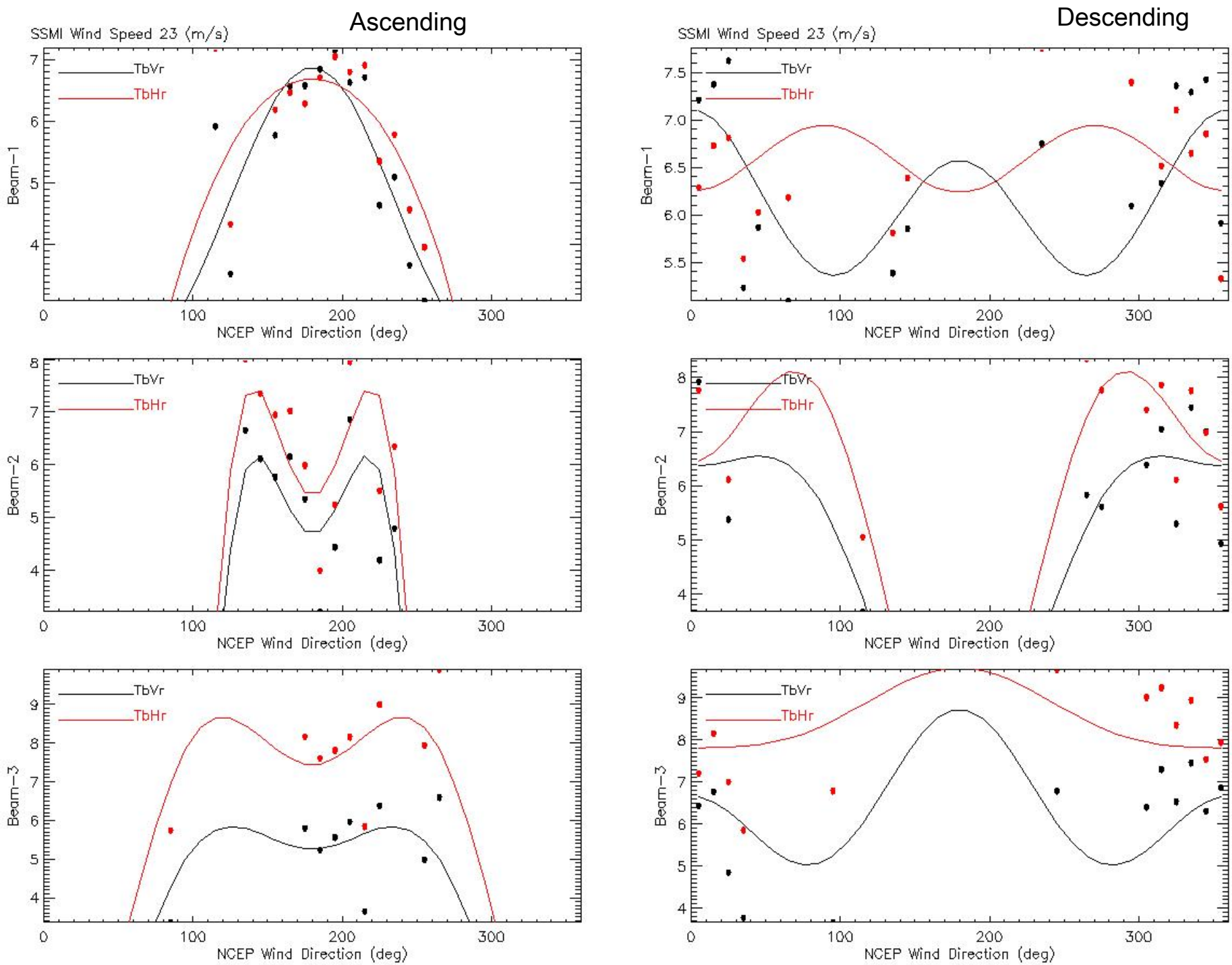
Beam-3
NCEP Wind Direction (deg)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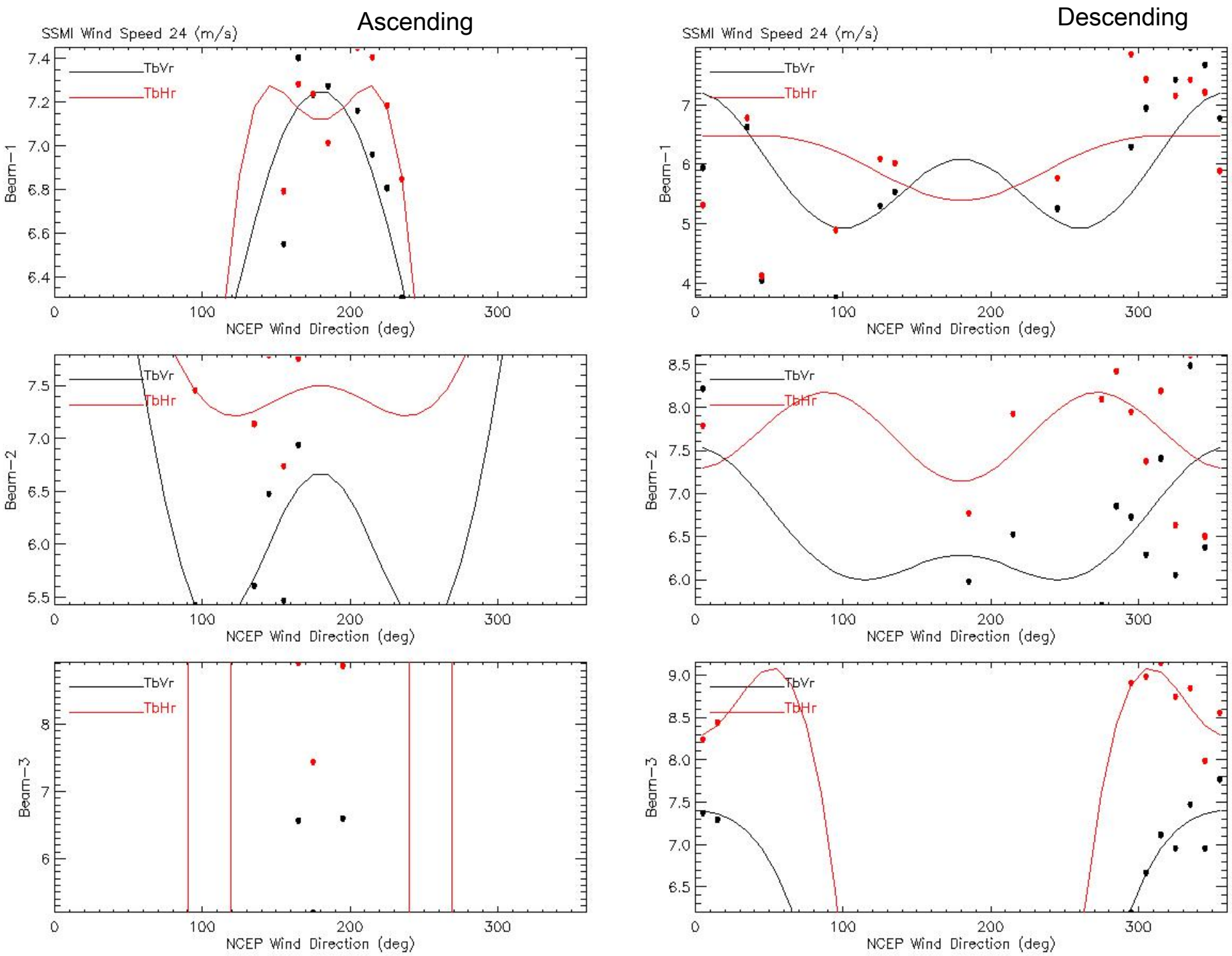
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)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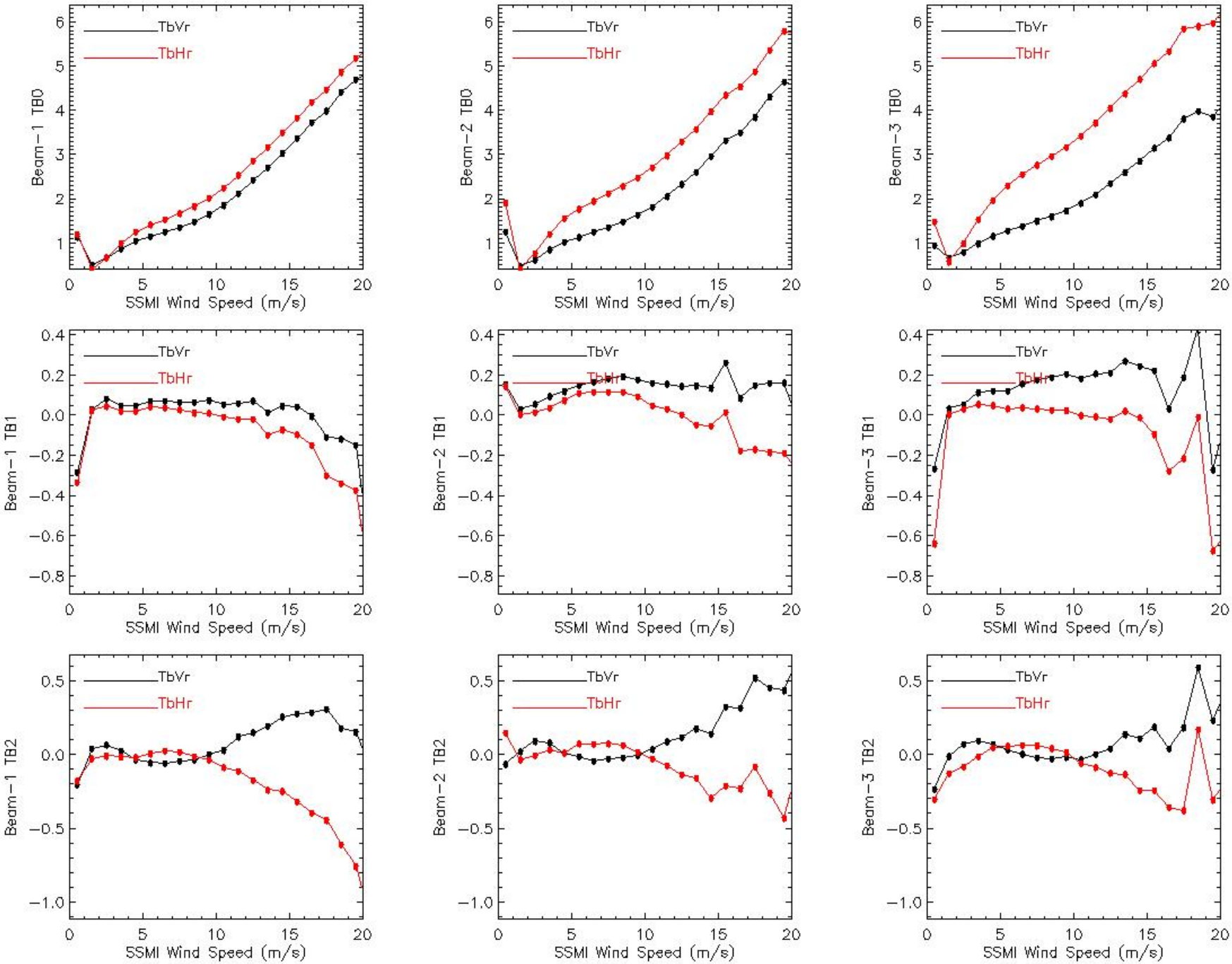
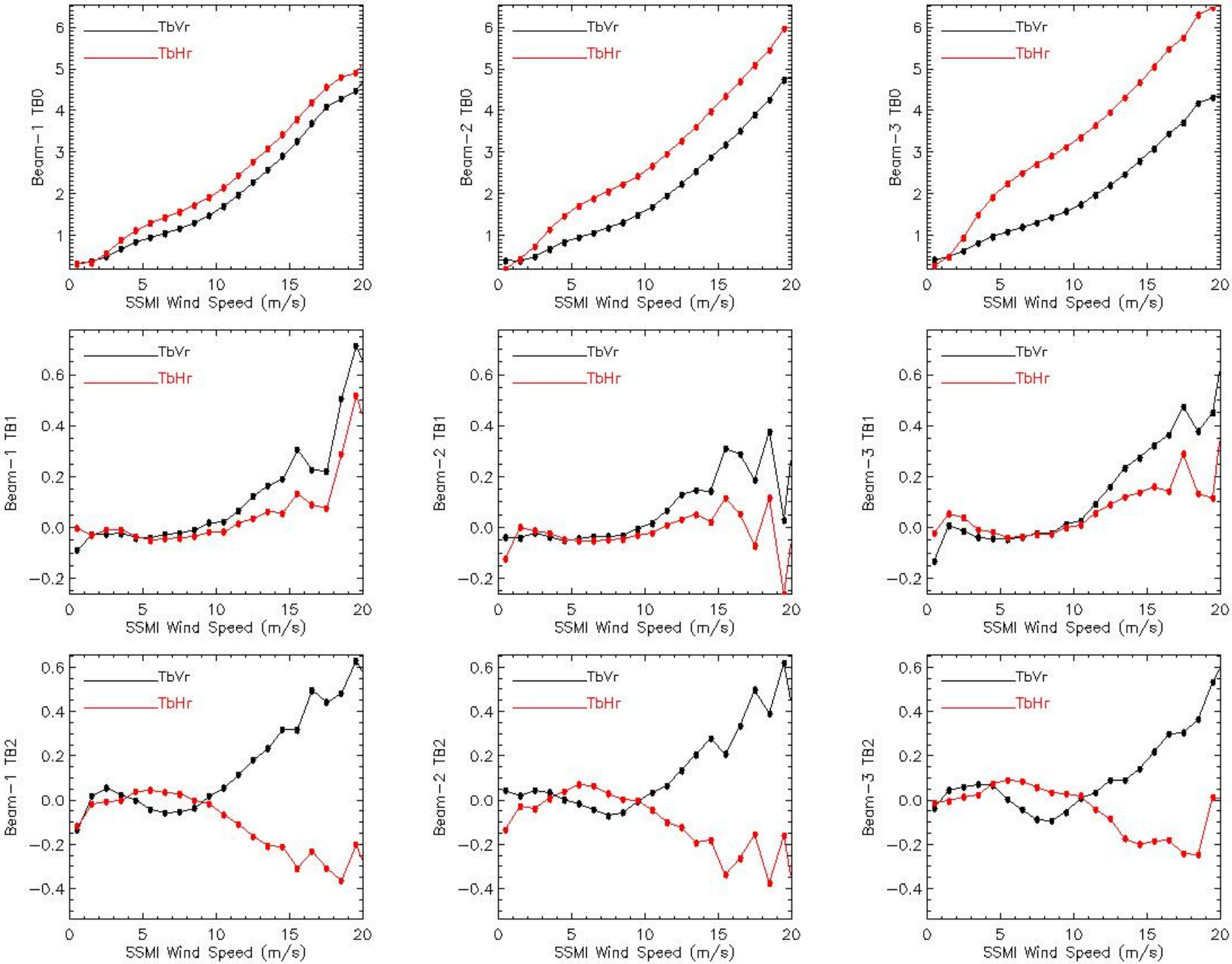
SSMI Wind Speed 24 (m/s)
SSMI Wind Speed 24 (m/s)
TbVr
TbHr
Beam-1
Beam-2
Beam-3
NCEP Wind Direction (deg)

Ascending

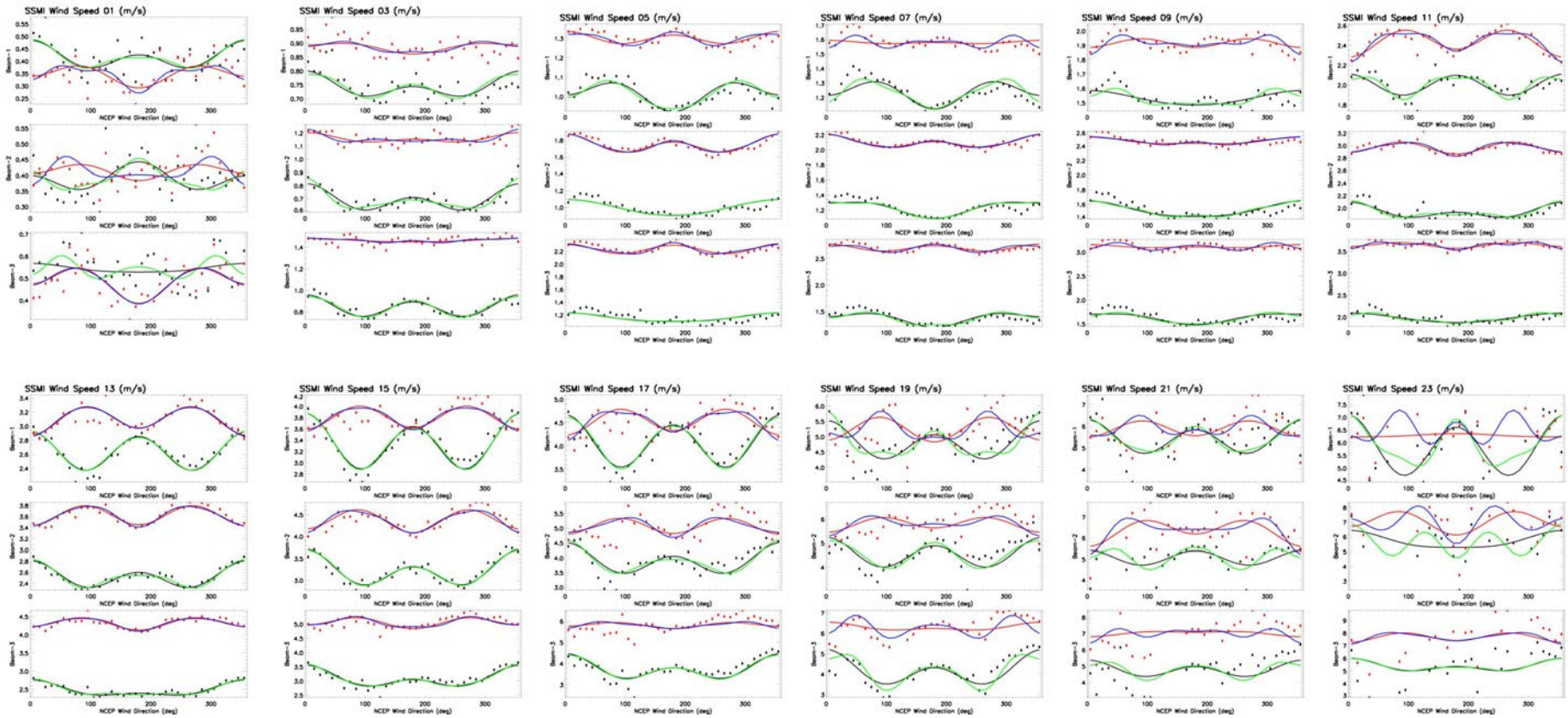

TbVr
TbHr
Beam-1 TB0
Beam-2 TB0
Beam-3 TB0
Beam-1 TB1
Beam-2 TB1
Beam-3 TB1
Beam-1 TB2
Beam-2 TB2
Beam-3 TB2
SSMI Wind Speed (m/s)

Descending


TbVr
TbHr
Beam-1 TB0
Beam-2 TB0
Beam-3 TB0
Beam-1 TB1
Beam-2 TB1
Beam-3 TB1
Beam-1 TB2
Beam-2 TB2
Beam-3 TB2
SSMI Wind Speed (m/s)

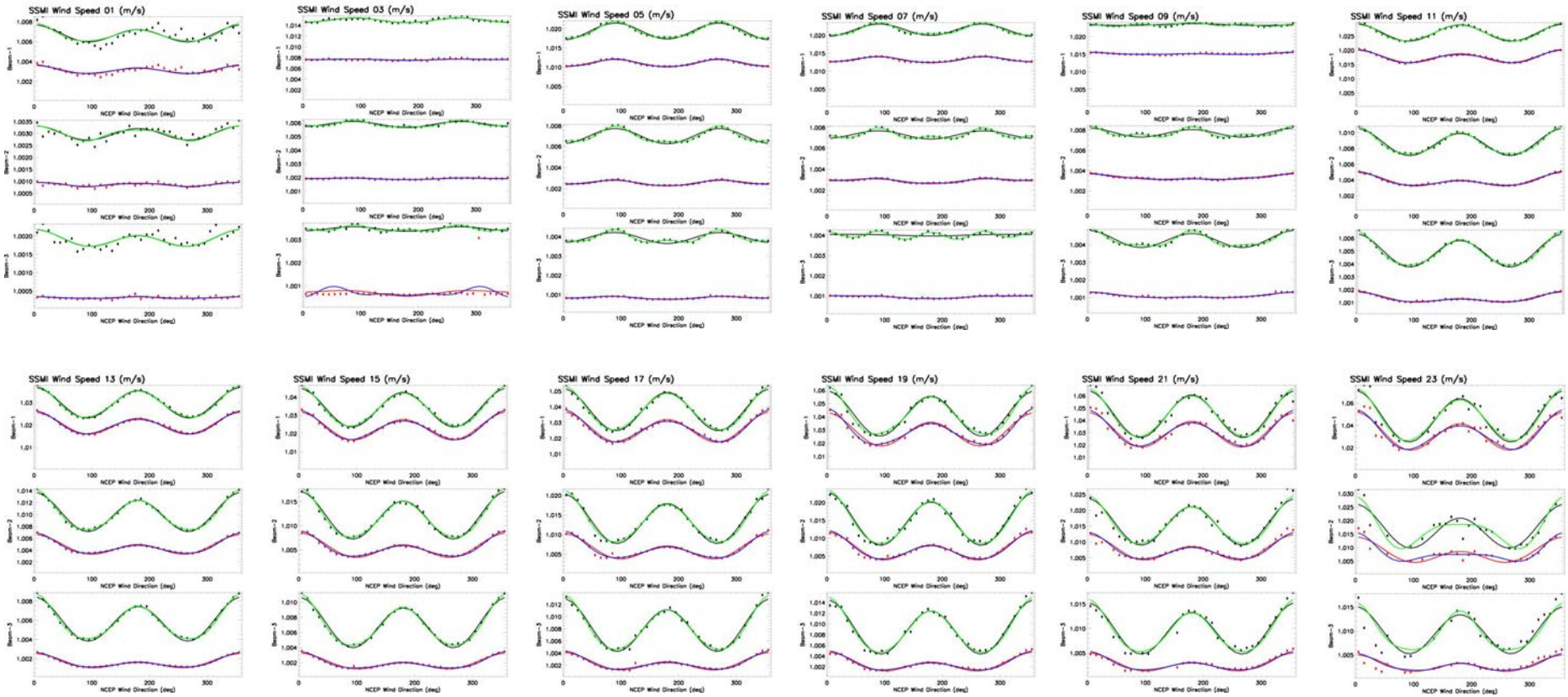
# TB vs Wind Speed and Direction

- Matchup with SSMI Wind Speed and NCEP Wind Direction
  - Not quite sufficient matchup samples for >20 m/s wind speed



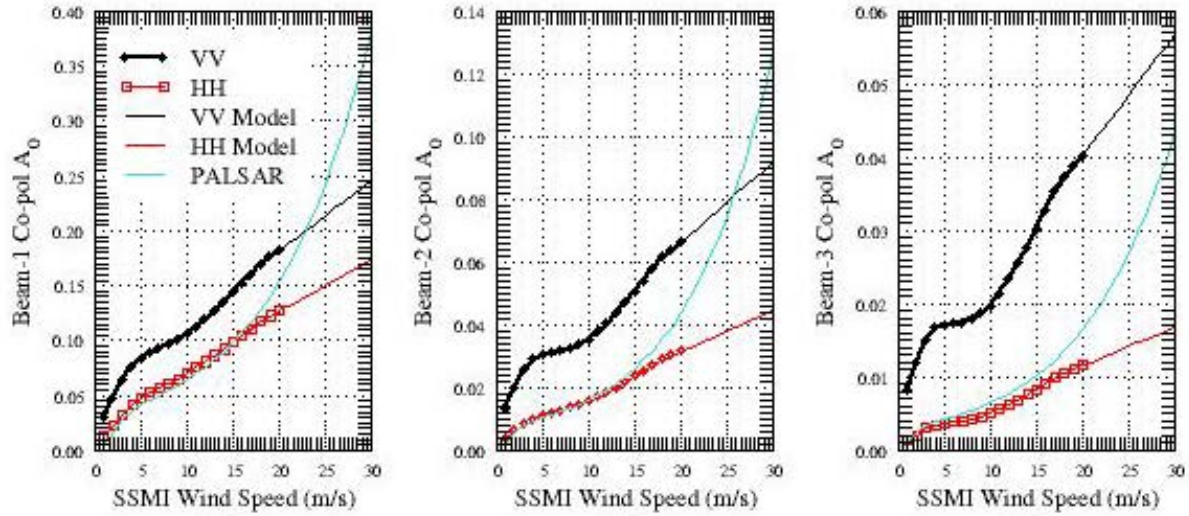
# Sigma0 vs Wind Speed and Direction

- Match up with SSMI wind speed and NCEP Wind direction

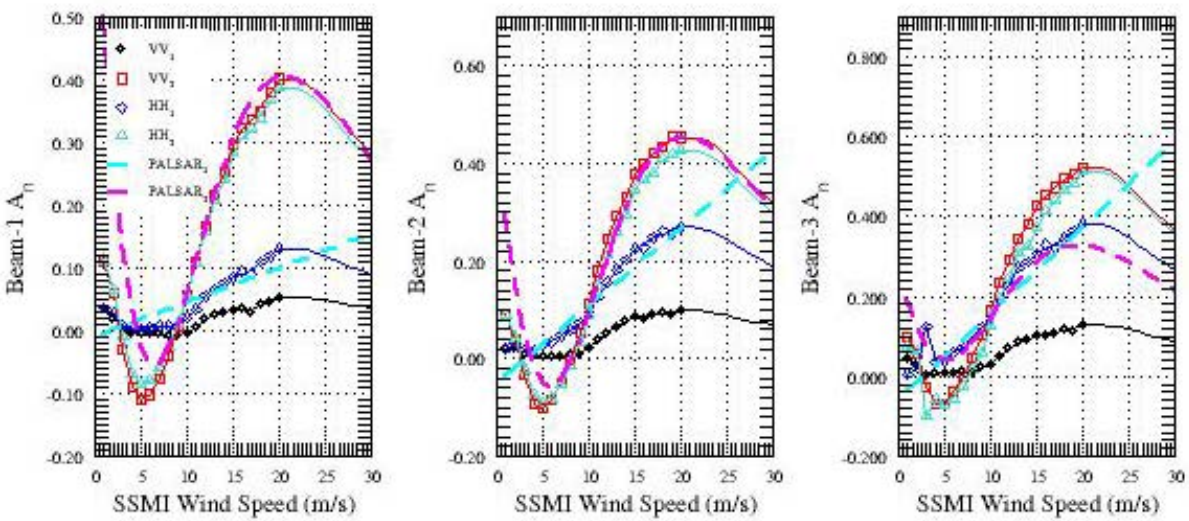


# Aquarius $\sigma_0$ GMF

- ALOS PALSAR model function to within 1 dB after a constant adjustment of Aquarius sigma0s by a factor of 1.5




- Ocean ar
are withir



# Aquarius Wind and SSS Retrievals
# Stepwise Algorithm

- Wind Speed Retrieval Algorithm (Alex):
  - Retrieve Wind Speed from Scatterometer VV+HH data using the NCEP wind direction as ancillary
  - Select the ambiguity closest to the NCEP wind speed

$$F_{scat}(W) = \frac{(\sigma_{0VV} - \sigma_{0VVm})^2}{(k_p \sigma_{0VV})^2} + \frac{(\sigma_{0HH} - \sigma_{0HHm})^2}{(k_p \sigma_{0HH})^2}$$

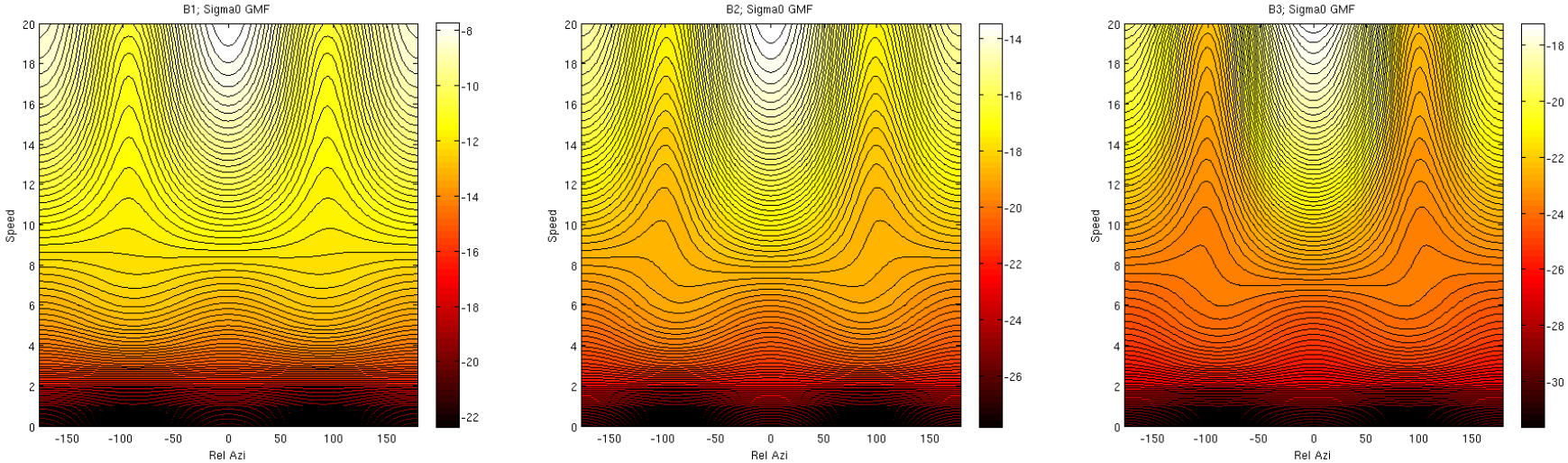
- TB Correction and Salinity Retrieval:
  - Correct TB using the scatterometer wind speed and NCEP wind direction
  - Flat surface TB=TB-dTB(Scat speed, NCEP direction)
  - Retrieve the salinity

- Accuracy limited by the NCEP Wind Direction Errors for wind speed estimate and directional correction for TB

# Contour Plot of Model Sigma0

Alex, 10/18/2011

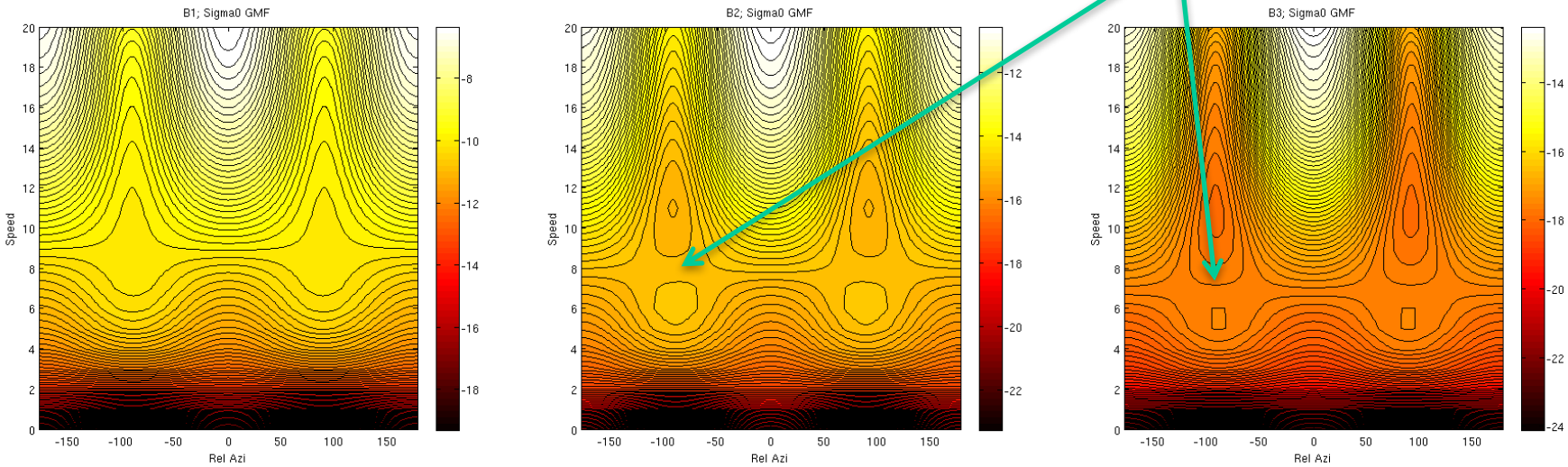
## HH GMF




Not monotonic in speed for some directions!

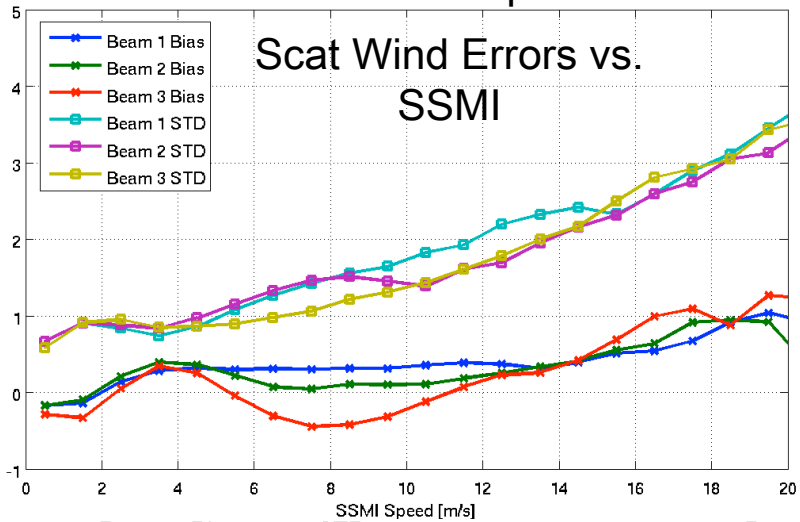
Ambiguities in speed!

## VV GMF

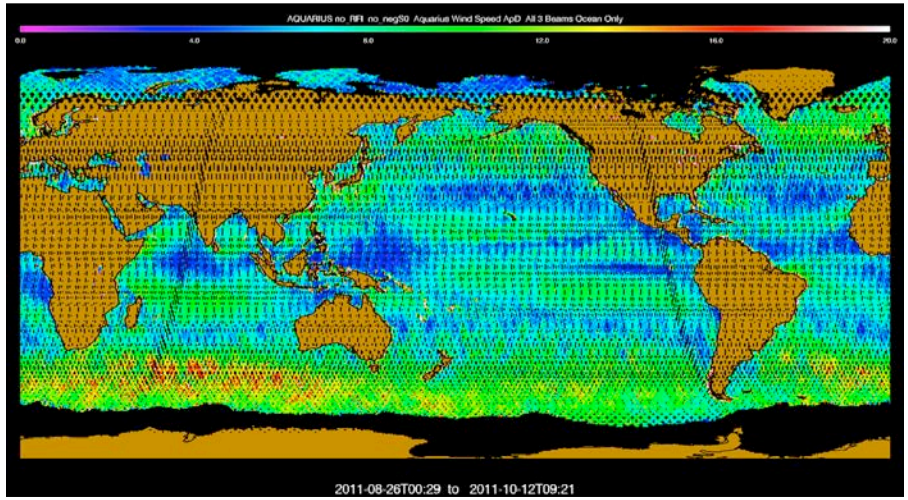


# Aquarius Scatterometer Wind Retrieval in good agreement with SSM/I

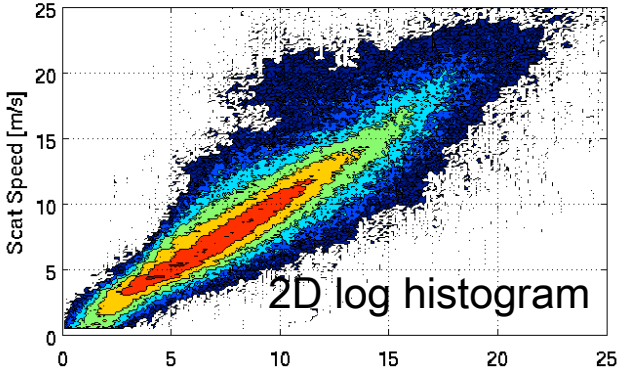
- Maximize objective function in speed, for a given wind direction.
- Objective Function: obj = $-[(s0_{vv}-gmf\_s0_{vv})/s0_{vv}]^2 - [(s0_{hh}-gmf\_s0_{hh})/s0_{hh}]^2$
- Standard deviation of scat speed – SSMI speed:
  - Beam 1: 1.6 m/s; Beam 2: 1.5 m/s; Beam 3: 1.4 m/s
  - STD < 2 for all speeds less than 12 m/s



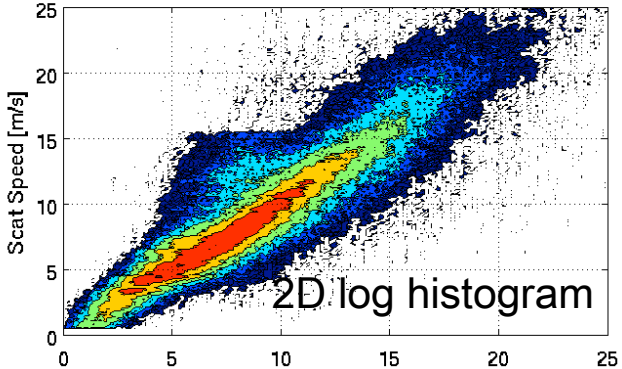

Scat Wind Speed Map



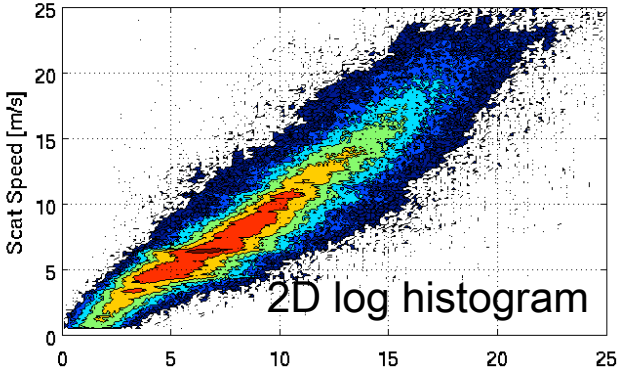

Beam 1; Bias: 0.329; STD: 1.613




Beam 2; Bias: 0.214; STD: 1.522




Beam 3; Bias: -0.060; STD: 1.444



# Aquarius CAP Algorithm for SSS and Wind Retrievals

- CAP Algorithm: Retrieve SSS, Wind Speed and Direction Using Combined Passive and Active (CAP) Data
- Select the ambiguity closest to the NCEP winds in direction

$$F_{pol}(SSS,W,\phi)=\frac{(I-I_m)^2}{2\Delta T^2}+\frac{(\sqrt{Q^2+U^2}-\sqrt{Q_m^2+U_m^2})^2}{2\Delta T^2}+\frac{(\sigma_{0VV}-\sigma_{0VVm})^2}{(k_p\sigma_{0VV})^2}+\frac{(\sigma_{0HH}-\sigma_{0HHm})^2}{(k_p\sigma_{0HH})^2}$$

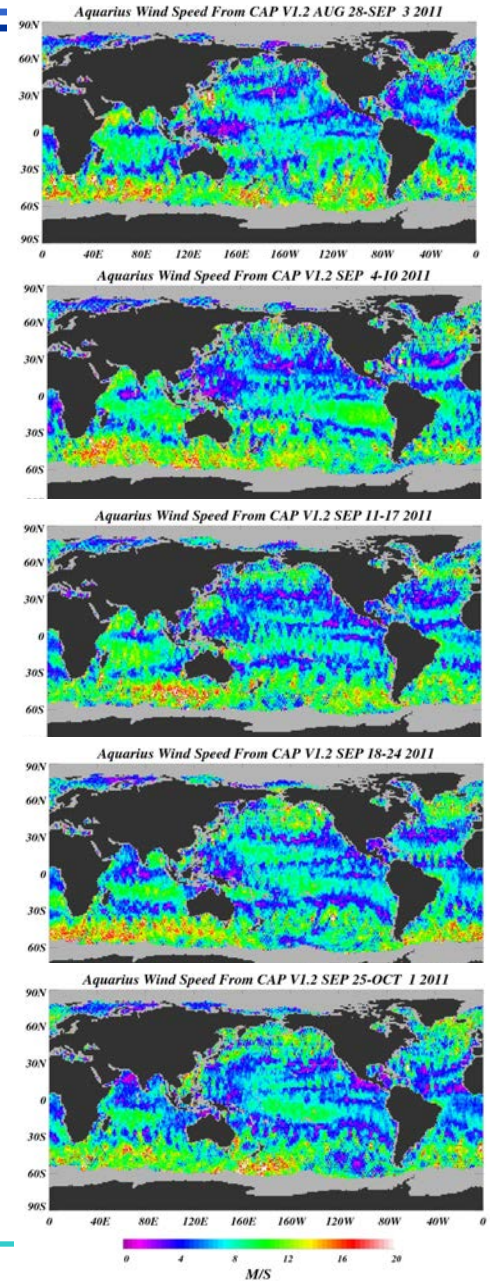
$$I=T_{BV}+T_{BH}$$

$$Q=T_{BV}-T_{BH}$$

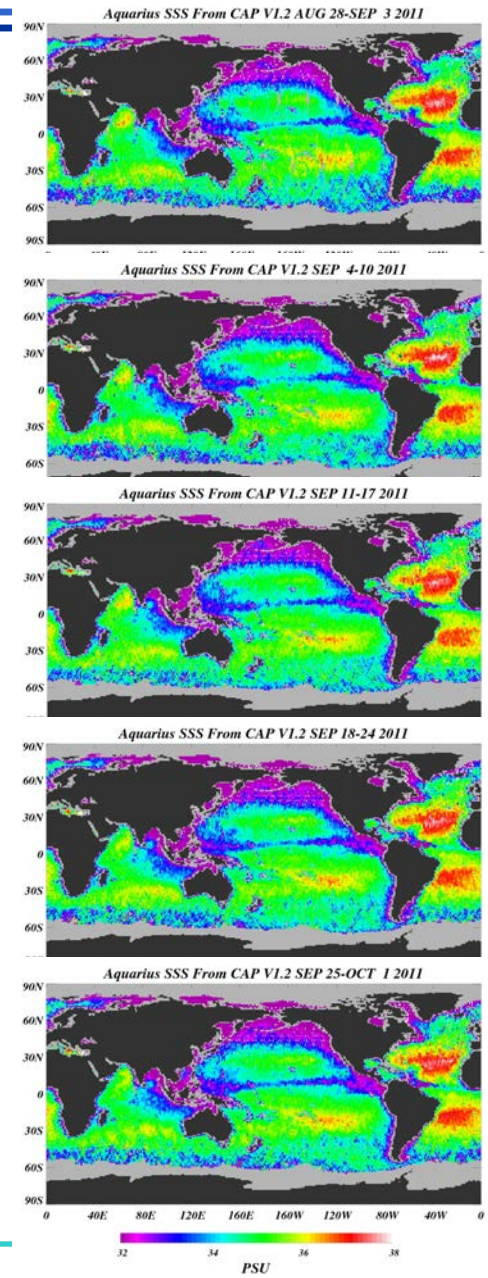
- Tested the algorithms using the Aquarius V1.1 and V1.2 data

Yueh and Chaubell, IEEE TGRS, in press

# Time Series of AQ-CAP SSS and Wind Speed from V1.2 Evaluation

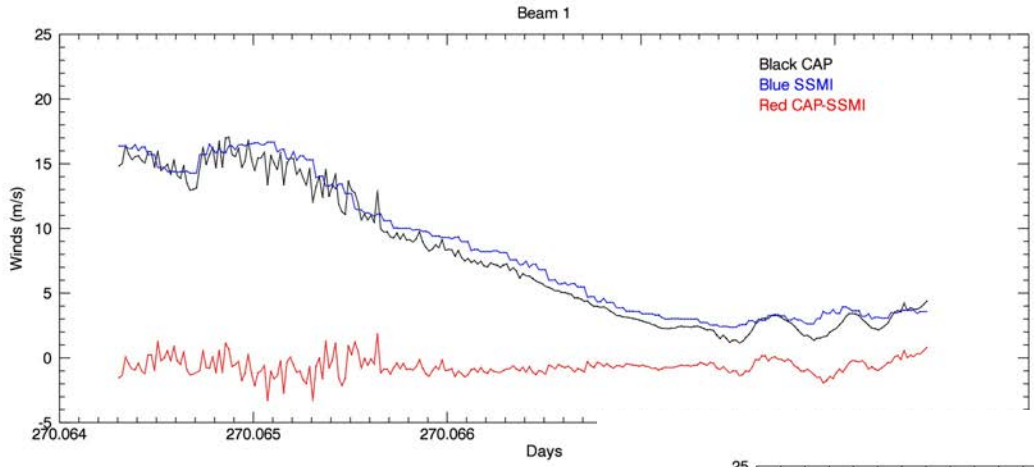


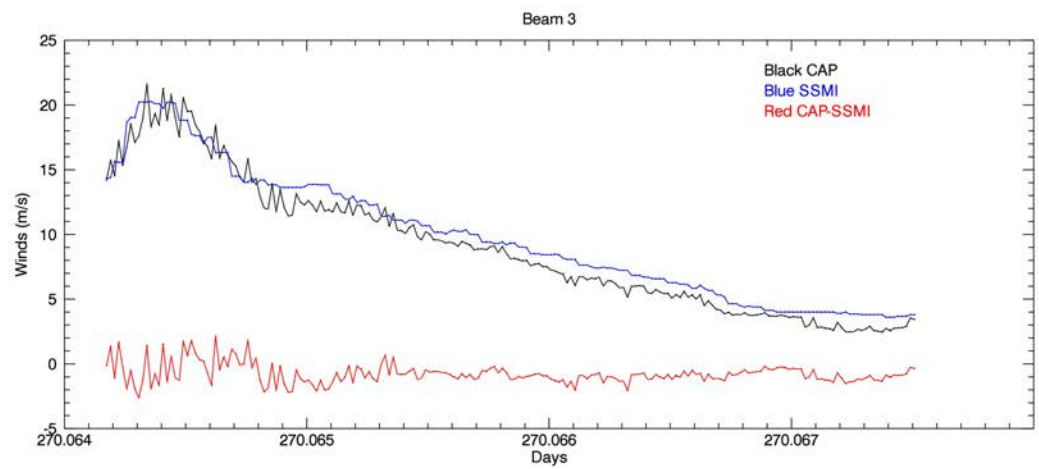

- Time series

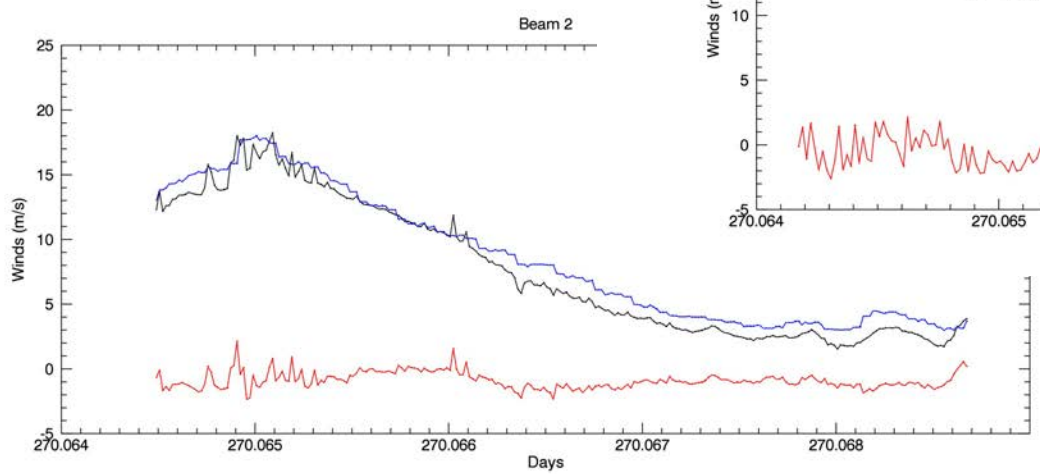


# Time Series of AQ-CAP and SSMI Winds

- Aquarius CAP winds agree well with SSM/I

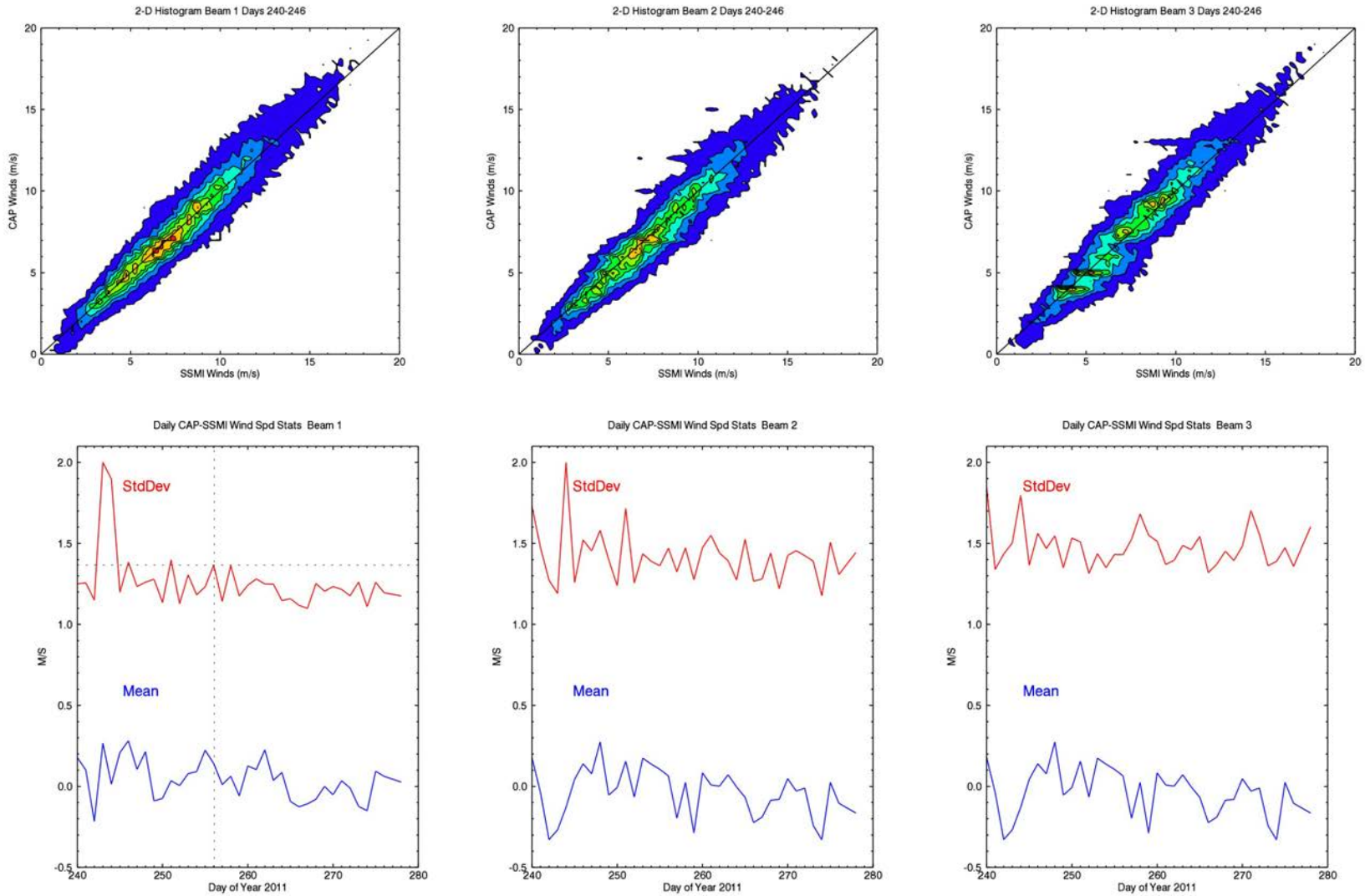


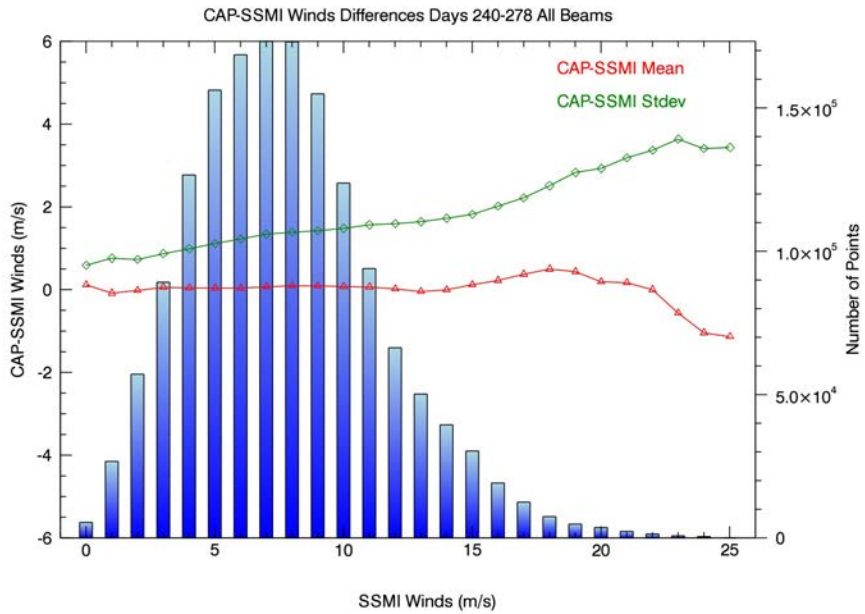
# Comparison of Wind Speed Retrievals with SSM/I

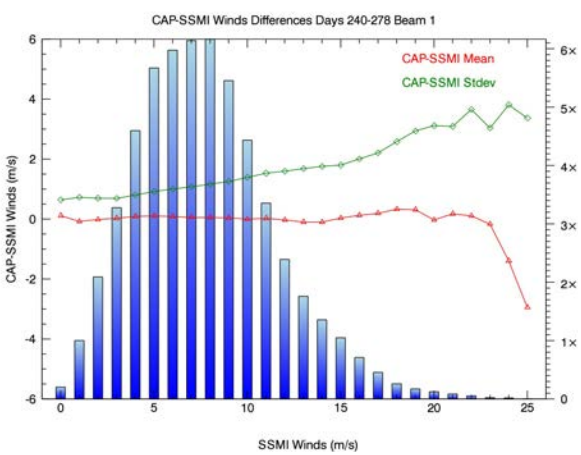
- Aquarius CAP winds agree well with SSM/I

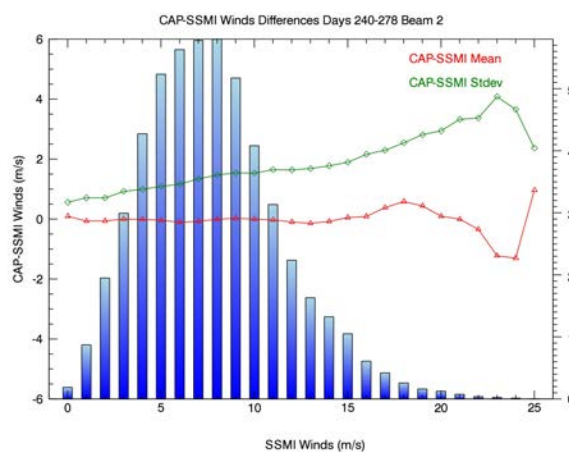


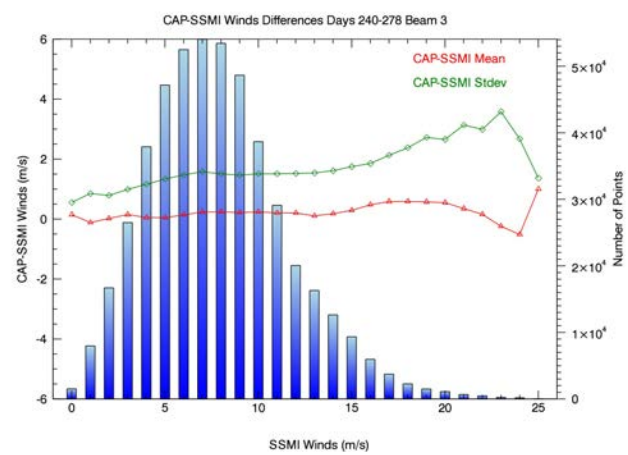
# Small Wind Speed Bias with SSM/I

- The AQ CAP Wind Speed is essentially unbiased against the SSMI winds



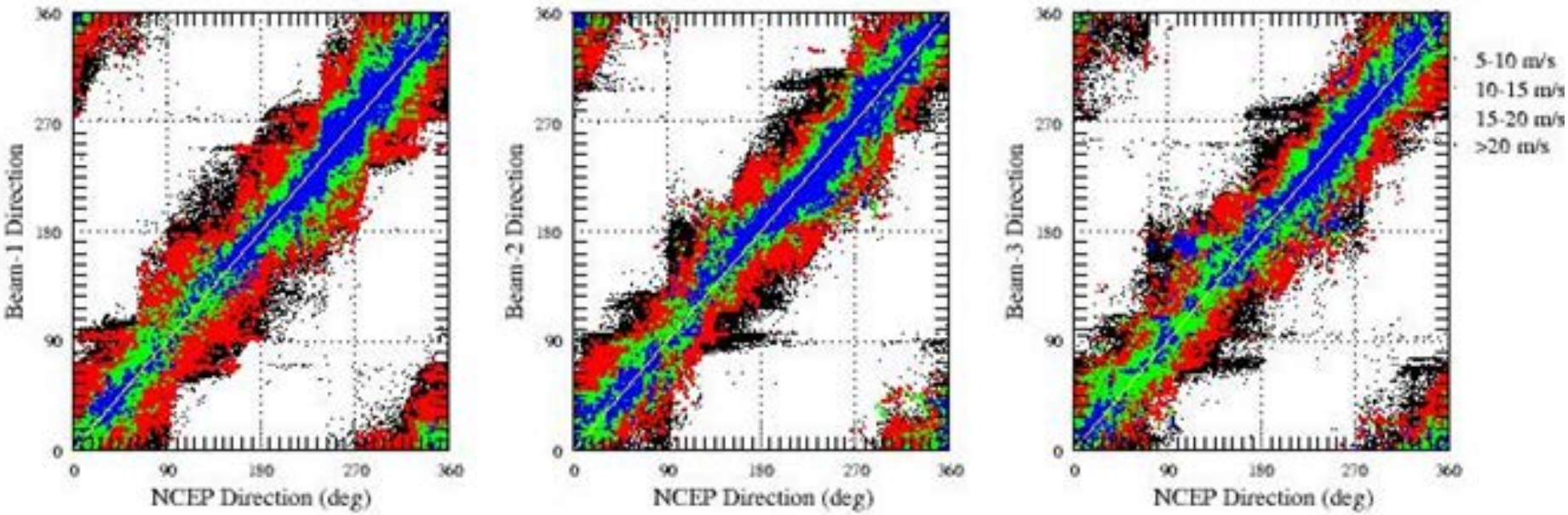



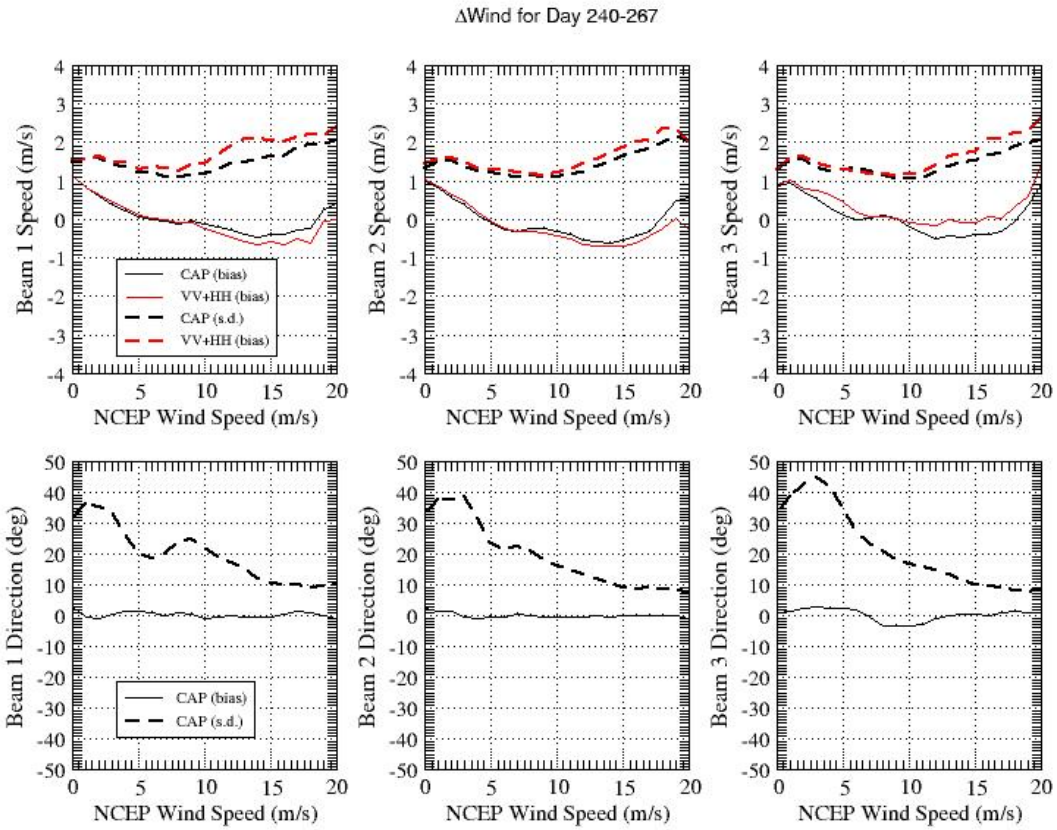
# Wind Direction Comparison with NCEP

- The scatter of the closest ambiguity reduces with wind speed



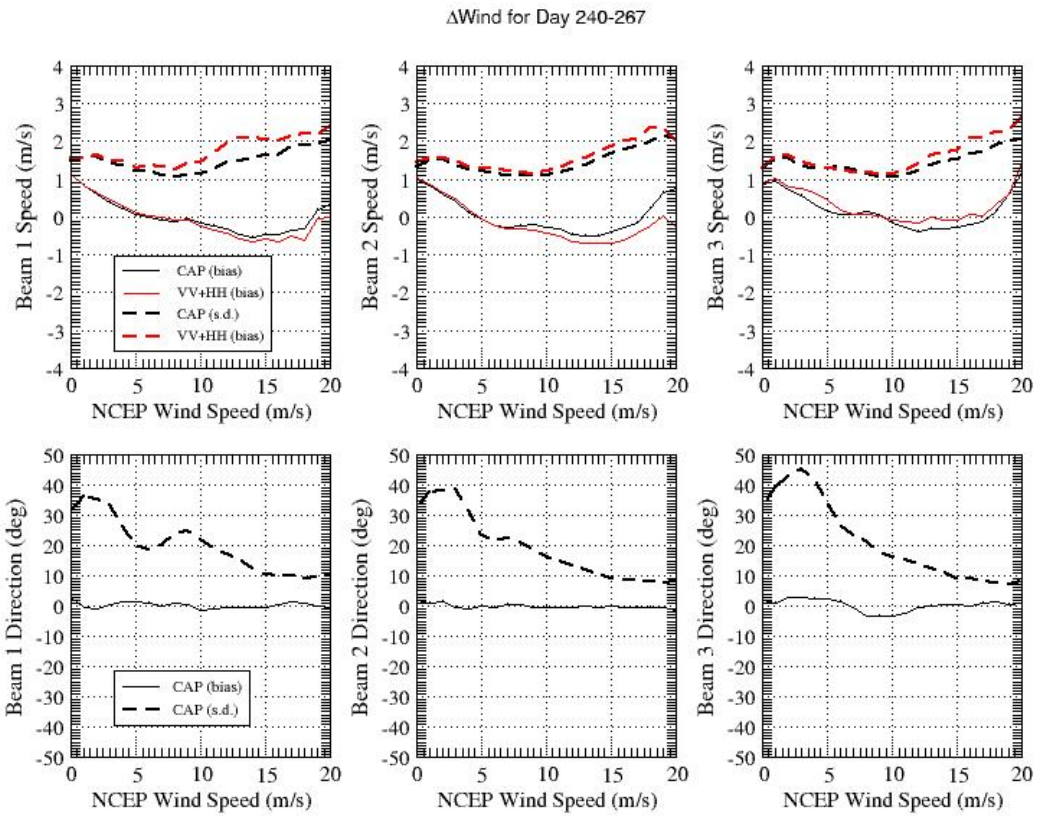
# Comparison of Wind Speed Retrievals with NCEP

- Aquarius CAP winds agree well with NCEP
  - Use the latest GMF from V1.2 and Meissner-Wentz dielectric model
  - standard deviation of speed difference < 1.5 m/s for 0-15 m/s
  - Standard deviation of direction difference < 20 deg for mid-to high winds



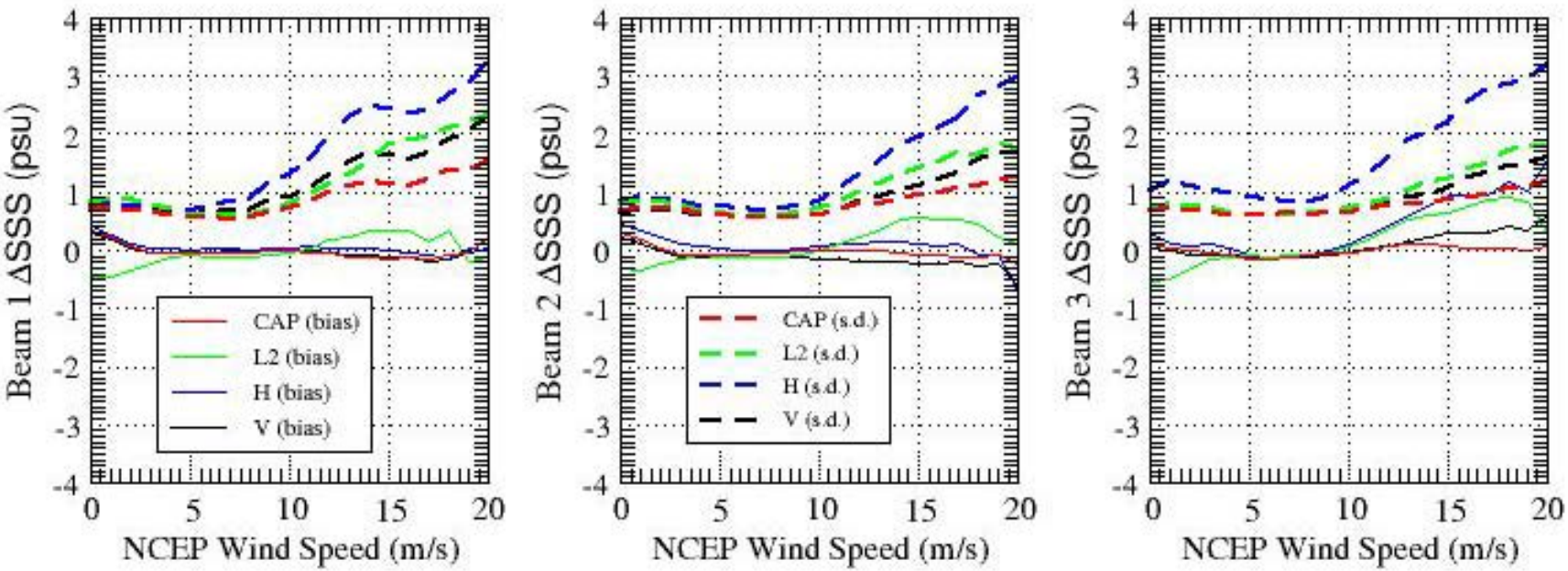
# Comparison of Wind Speed Retrievals with NCEP

- Aquarius CAP winds agree well with NCEP
  - Use the latest GMF from V1.2 and Klein-Swift dielectric model
  - standard deviation of speed difference < 1.5 m/s for 0-15 m/s
  - Standard deviation of direction difference < 20 deg for mid-to high winds



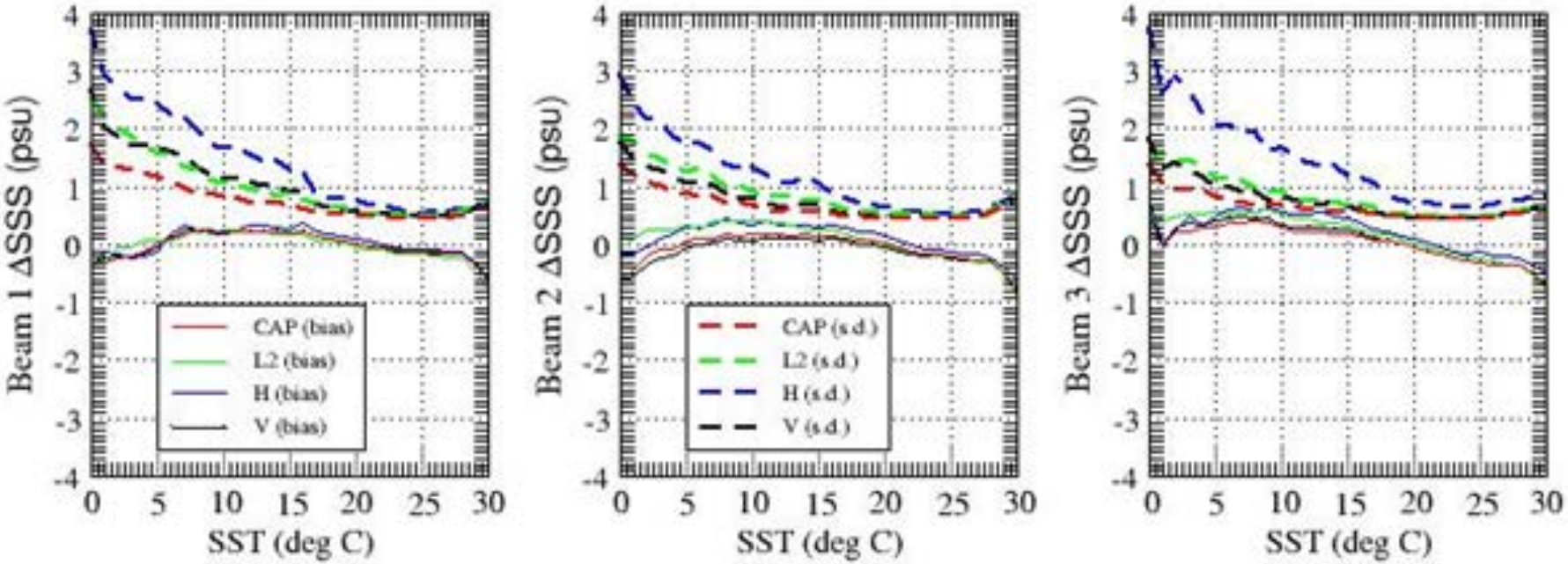
# Comparison of SSS Retrievals with HYCOM vs. Widn Speed

- Aquarius CAP SSS has the best agreement with Hycom
  - 20 to 50 percent better than L2 SSS (V1.2) or three-step algorithms (V1.2) for > 15-20 m/s
  - V1.2 SSS bias varies significantly over wind speed
  - CAP SSS is nearly unbiased from 0-20 m/s.



# Comparison of SSS Retrievals with HYCOM vs. SST

- Aquarius CAP SSS has the best agreement with Hycom
  - 20 to 50 percent better than L2 SSS or three-step algorithms under 10 deg C
  - CAP SSS Bias is near zero
  - All retrievals have a systematic dependence
    - Bias in the dielectric model?

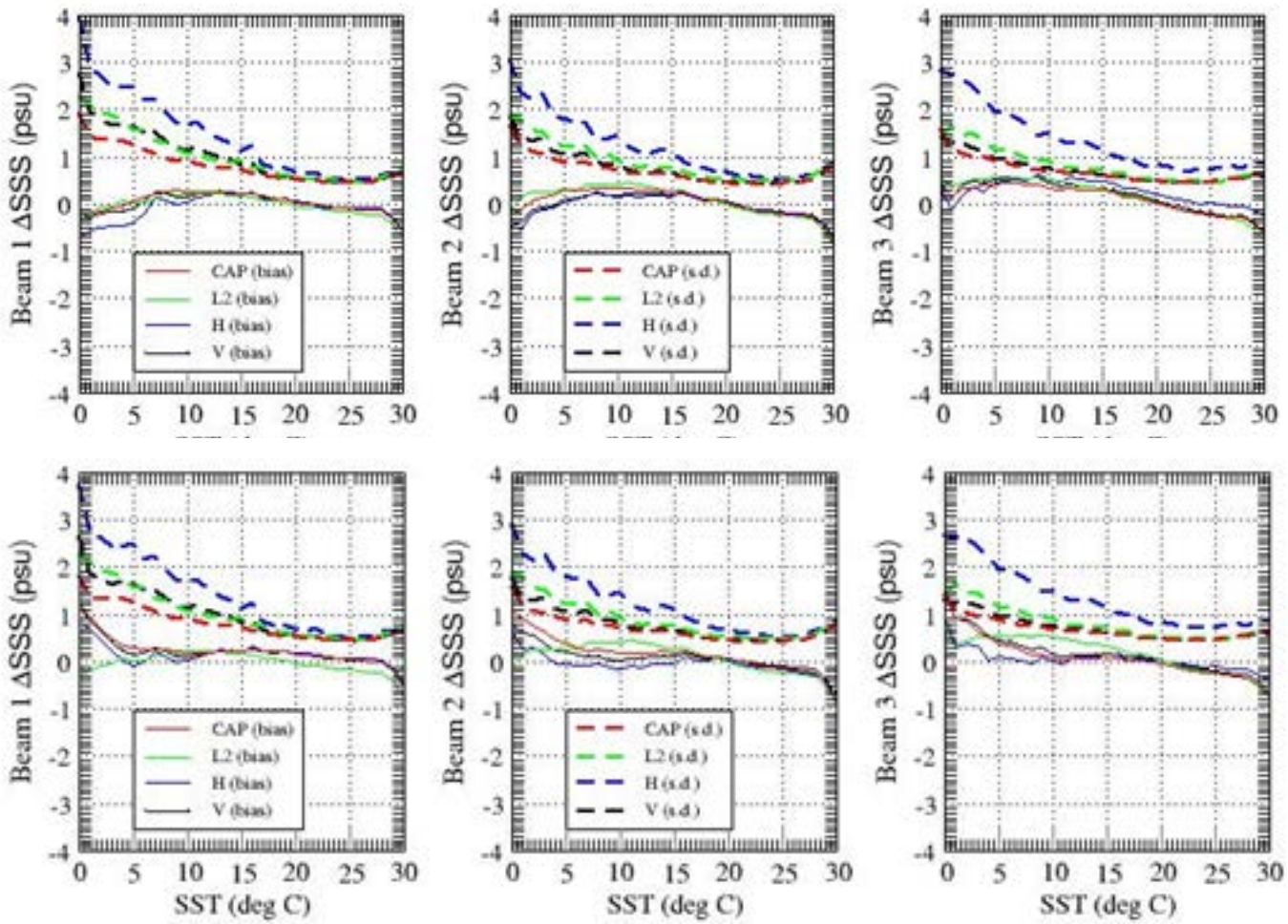


# Sensitivity to Dielectric Model
# Meissner-Wentz vs Klein-Swift

- The standard deviations are about the same
- Neither is unbiased
- KS has a positive bias for <5 deg C, while MW has a negative bias
- KS bias varies less than MW for 15 to 30 deg C

MW

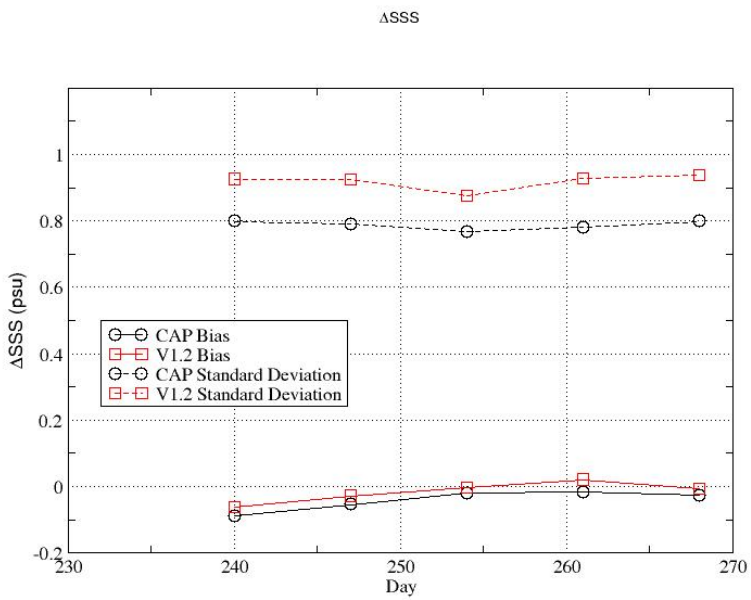
KS



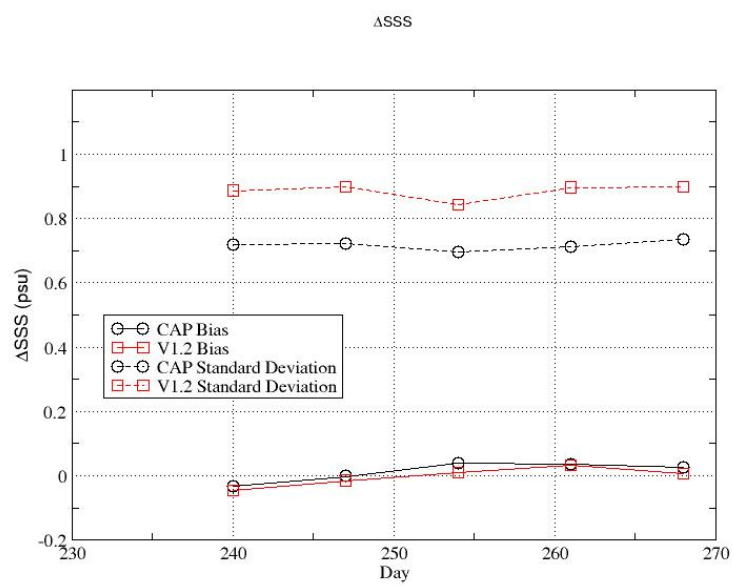
# BIAS and Standard Deviation VS Time

- CAP s.d. is smaller by about 25%
  - 0-50 m/s, >0 deg C, 50>CAP speed>0, and SSS > 0
  - Aquarius V1.2: 0.92 psu (no average); 0.88 psu (4 blocks)
  - CAP: 0.8 psu (no average); 0.7 psu (4 blocks)

No average



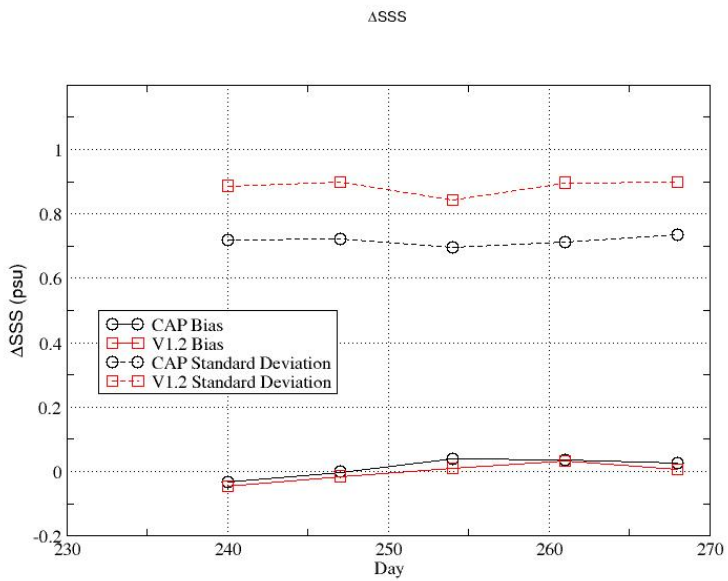

Average over 4 blocks



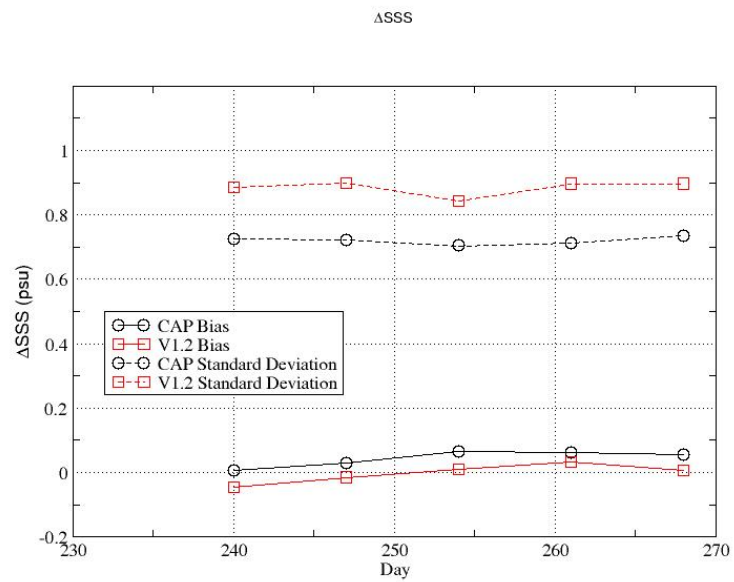
# BIAS and Standard Deviation VS Time

- MW and KS have similar daily global averaged biases and s.d.
- CAP s.d. is smaller by about 25%
  - 0-50 m/s, >0 deg C, 50>CAP speed>0, and SSS > 0
  - Average over 4 blocks

MW

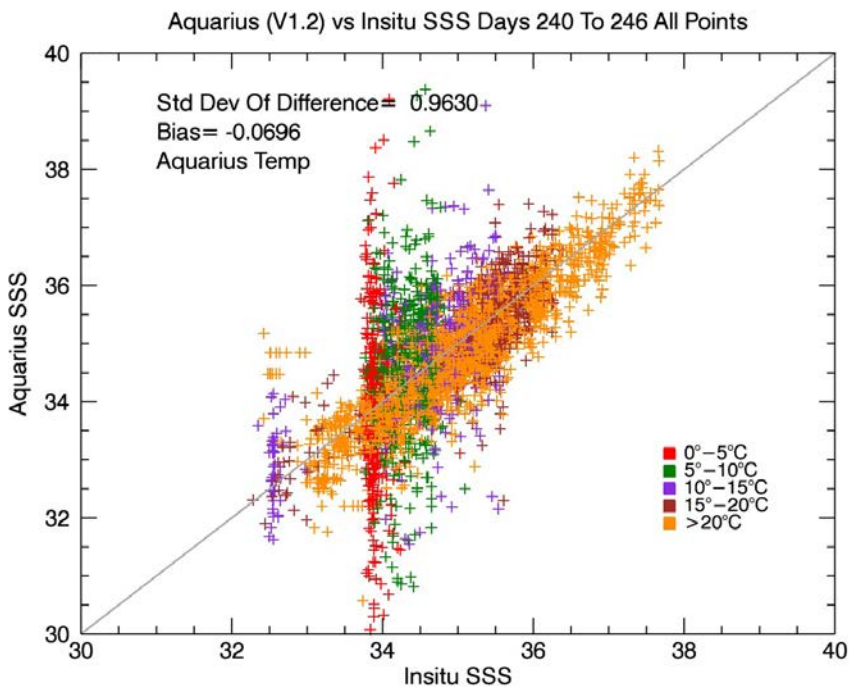


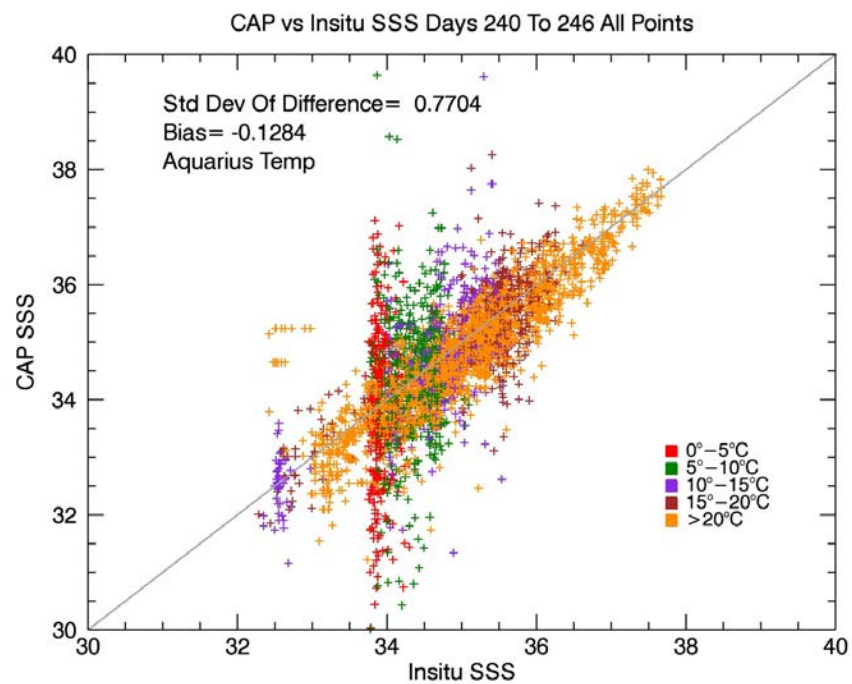

KS



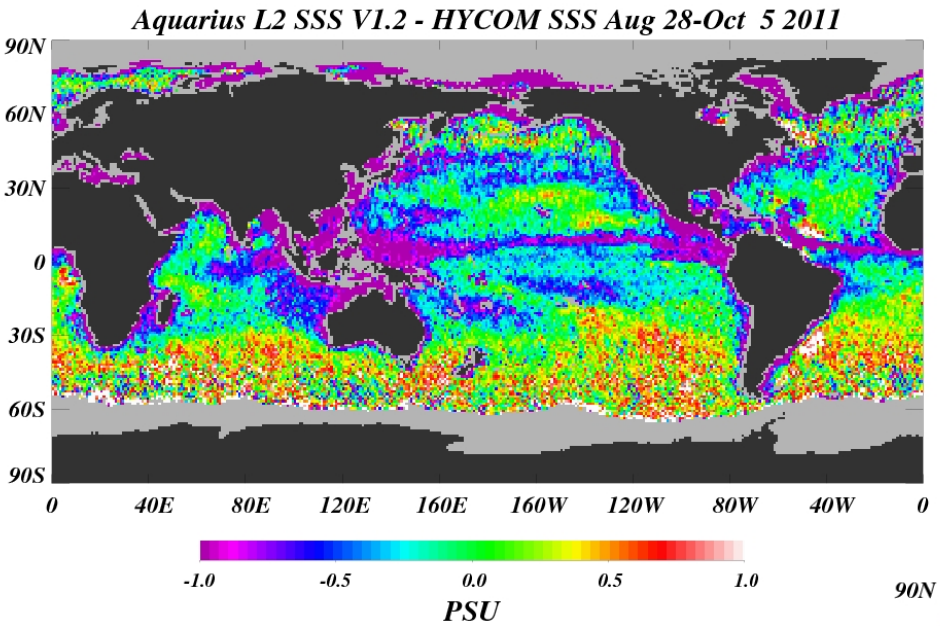
# Comparison of SSS Retrievals with In Situ

- Aquarius CAP SSS has better agreement with In Situ
  - In particular, the scatter for red and purple clusters has reduced.

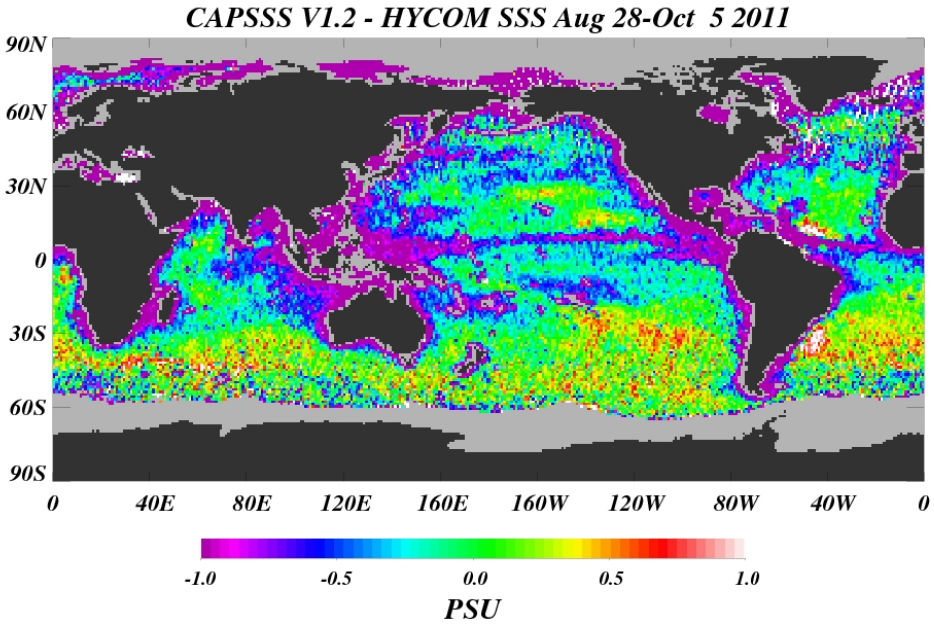


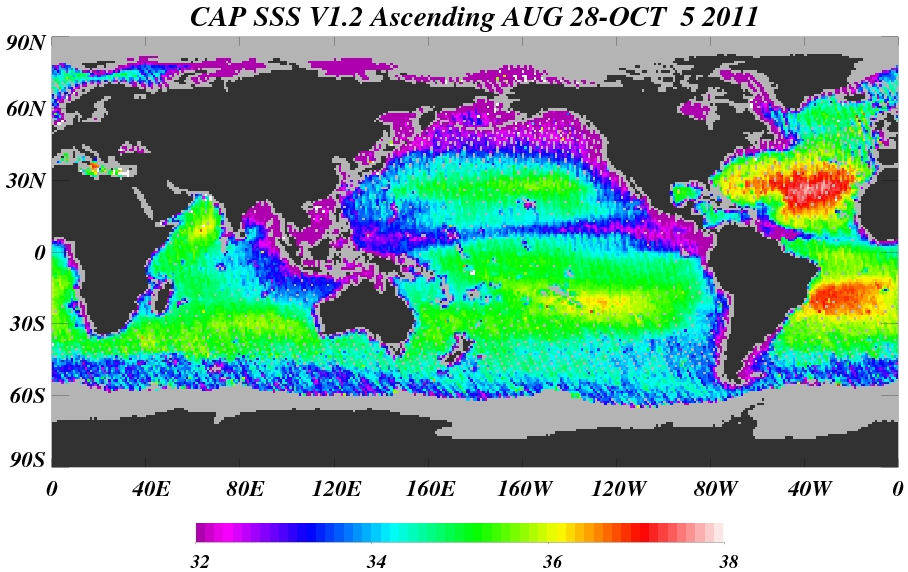
# Aquarius SSS vs. HyCom

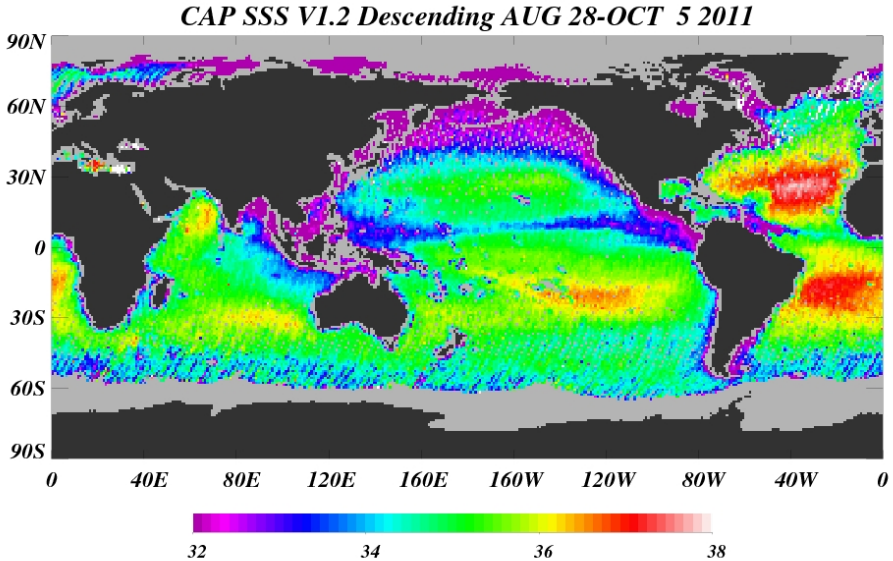


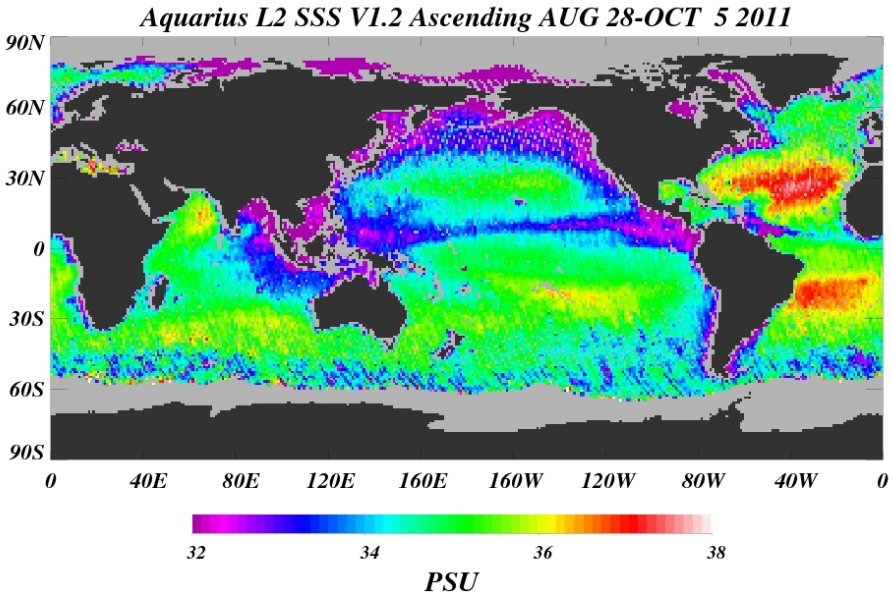

- CAP removes many large biases, which are probably caused by the regional errors in the NCEP winds

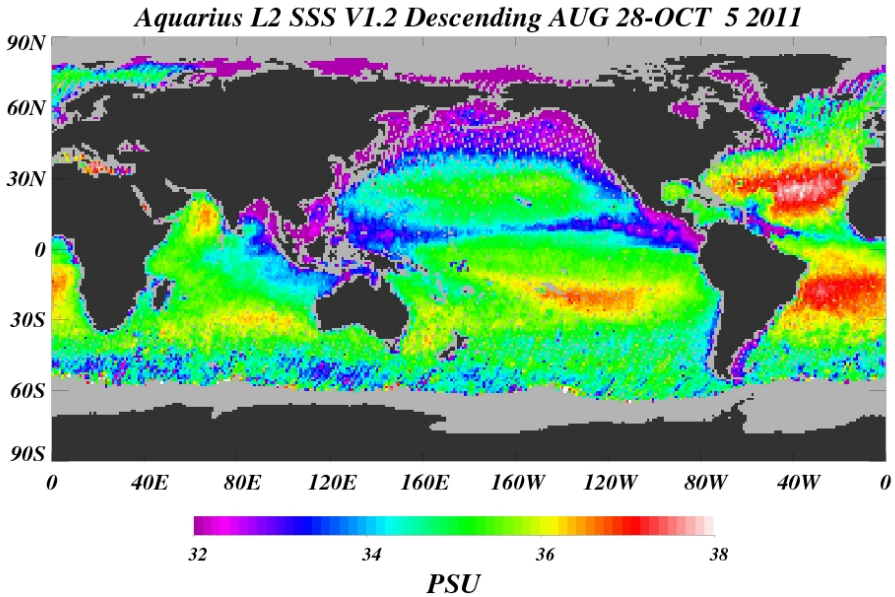


# Ascending and Descending SSS



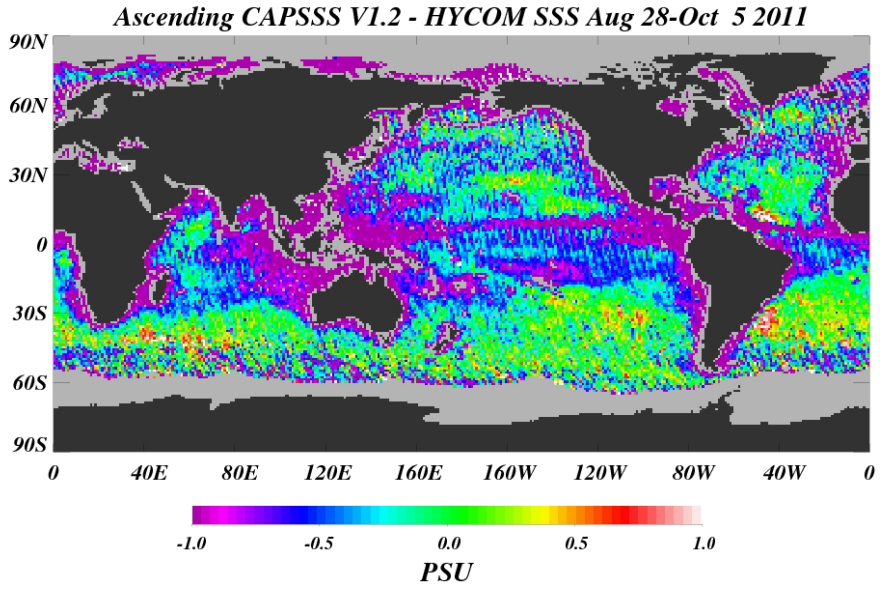



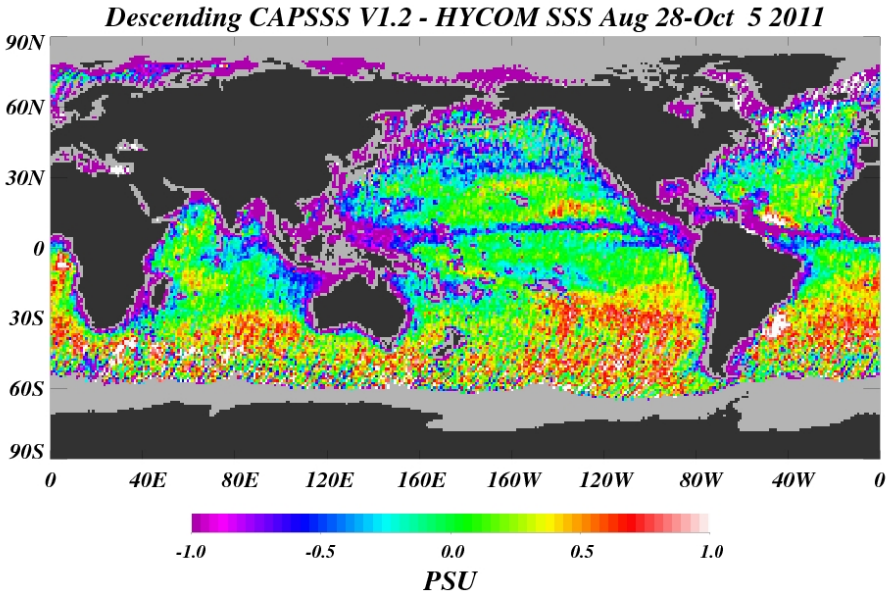



# Ascending and Descending Bias

- Systematic large biases in descending SSS in southern ocean



# Summary

- CAP can produce consistent SSS and wind retrievals
- CAP SSS is more accurate by about 25% on average and 50-100% for high winds
- CAP SSS is nearly unbiased vs SST, while V1.2 SSS bias varies significantly over SST
- CAP wind direction accuracy is better than 20 deg for mid-high winds, and can reach as low as 10 degrees
- CAP wind speed is nearly unbiased against SSMI wind speed

# Future Work

- Improve the GMF for high winds
- Improve SSS retrieval using improved dielectric model (particularly for low and high SSTs)
- Develop a better ambiguity selection approach