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Ocean Reference for SMOS Zero-Baselines Based on Aquarius Brightness Temperature Simulator

(and considerations on two-point calibration of SMOS zero-baselines for satellite cross-calibration)

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Objective and Motivation

The objective of the presented study is:

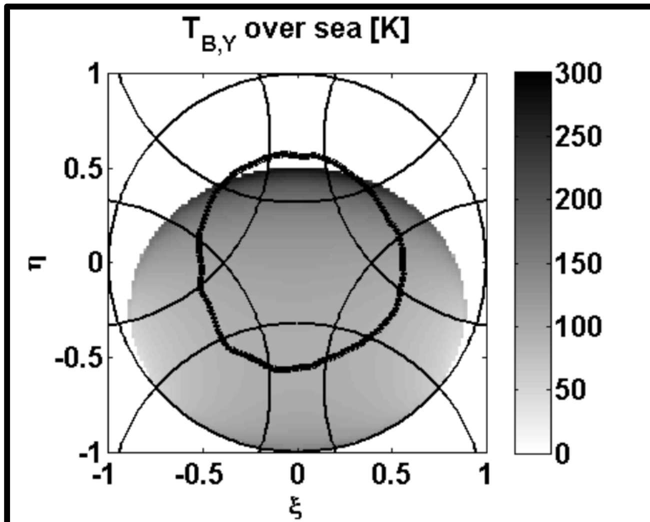
1) Comparison of the "absolute" calibration references utilized by the two missions and thereby improve the consistency and accuracy of the brightness temperature measurements of the missions

2) Considerations on the principles for 2-point calibration for SMOS antenna temperature

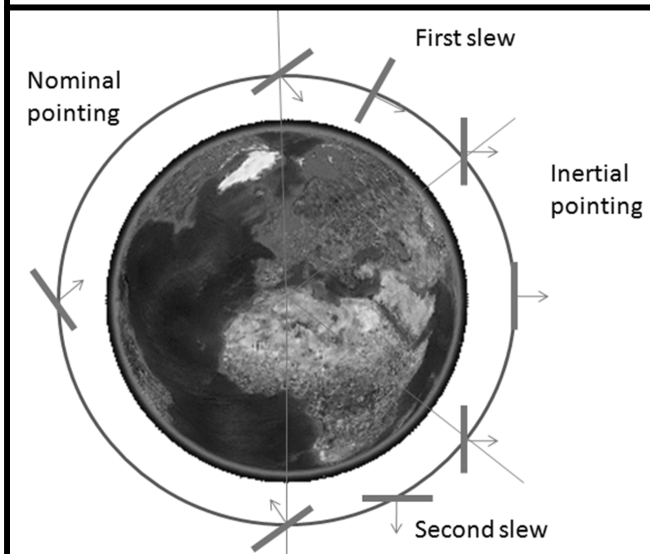
The improved consistency and accuracy will benefit SSS and soil moisture retrieval precision in particular in the sense of long term observations critical to climate change studies

"Absolute" Calibration Characteristics

- SMOS zero-baseline measurements
  - Noise injection technique to ensure stability
  - The same antenna as in the rest of the receivers
  - Calibration based on cold space looks (every two weeks) and front-end model
  - Very big footprint
- Aquarius antenna temperature simulator
  - Accounts for incidence angle within footprint
  - Compensates for land, atmosphere, ice, sky emissions
  - Aquarius antenna pattern
- Adaptation of Aquarius simulator for SMOS zero-baseline measurements
  - Apply antenna patterns and measurement geometry (boresight colocation within 100 m)



Zero-baseline 3dB field of view



SMOS sky calibration procedure

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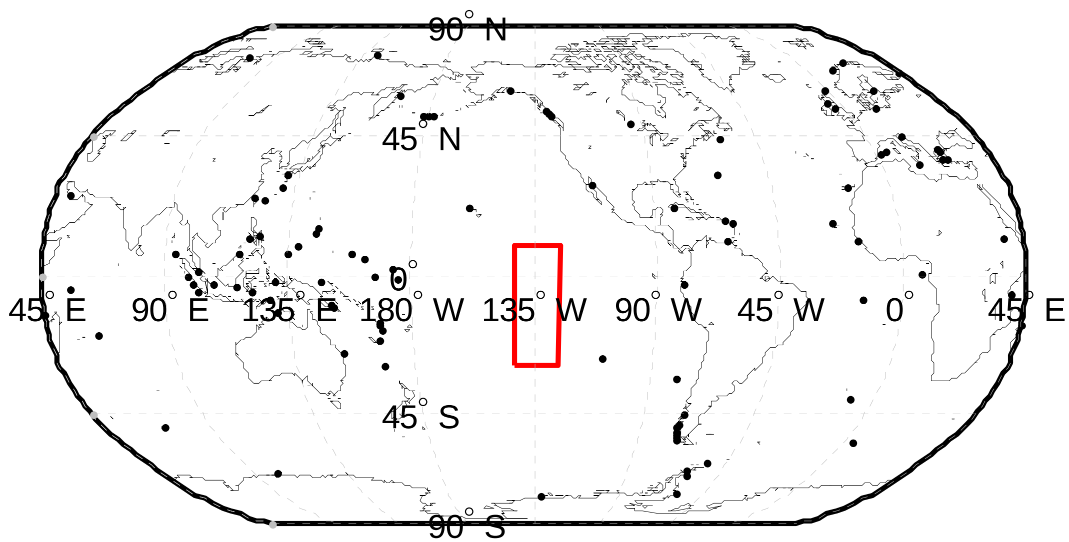
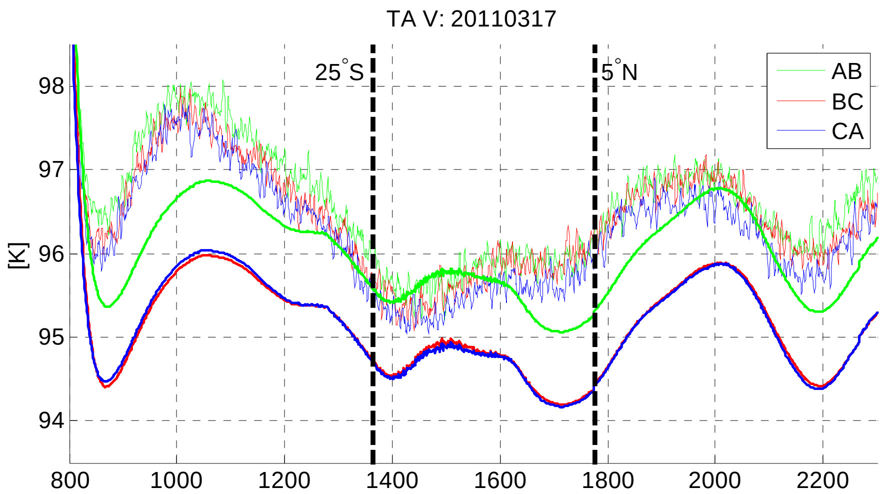
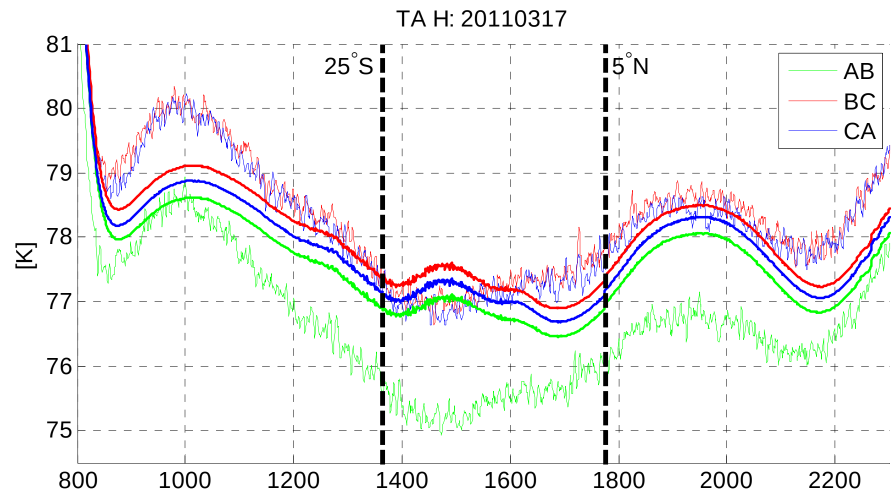
Comparison Strategy

- Test area: 25S to 5N and -140W to -130W in the Pacific
- The area is over Pacific ocean as far away from land contributions as possible; primary contribution from sea with some effects from sky (sun and galaxy) and atmosphere
- Climatological surface condition changes are moderate without strong extremes
- SMOS data version 5.04 i.e. includes the updated antenna model for the zero-baseline radiometers [Kainulainen et al., 2012]

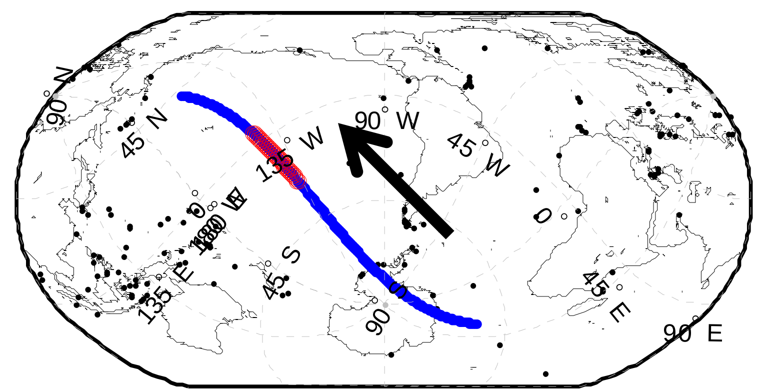


Single overpasses





- The features in the time-series profiles match well with some offset
- Unit AB different from other two unit (known feature)
- Around equatorial crossing (the test region) there is some discrepancy which is under investigation
- It seems that the different components of the simulation do not create this kind of effects



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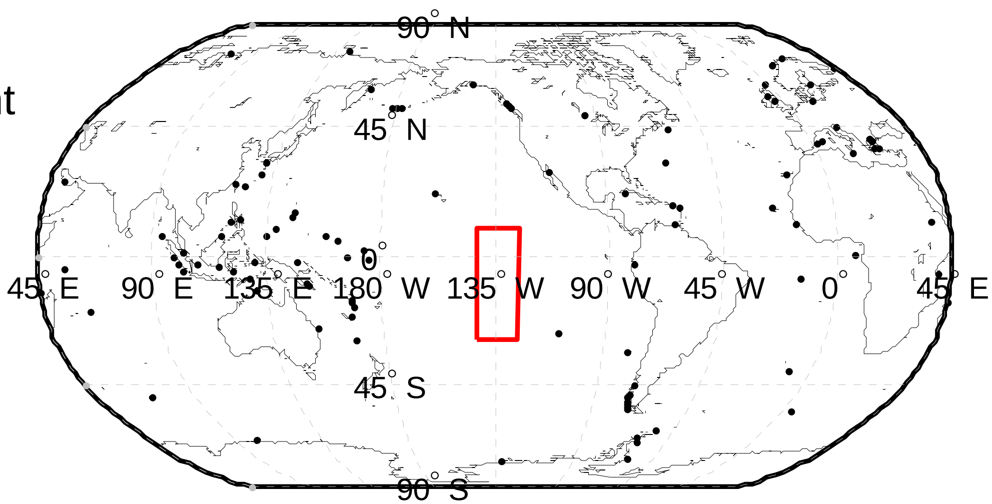
Long-term comparisons over Pacific test area

- Period of 2 years: 2011-2012 (2010 and most recent data is being incorporated – however early 2010 includes a few months of settling anyway)
- Ascending and descending compared separately
- Three NIR units: only two addressed here since it has been concluded that the third is unreliable
- For each over-pass of the area all measurements are simulated and then both measurement and simulation are averaged
  - Dispersion for each overpass
  - Comparison results is slightly different depending on the orbit



Measurements over test area 2011-2012

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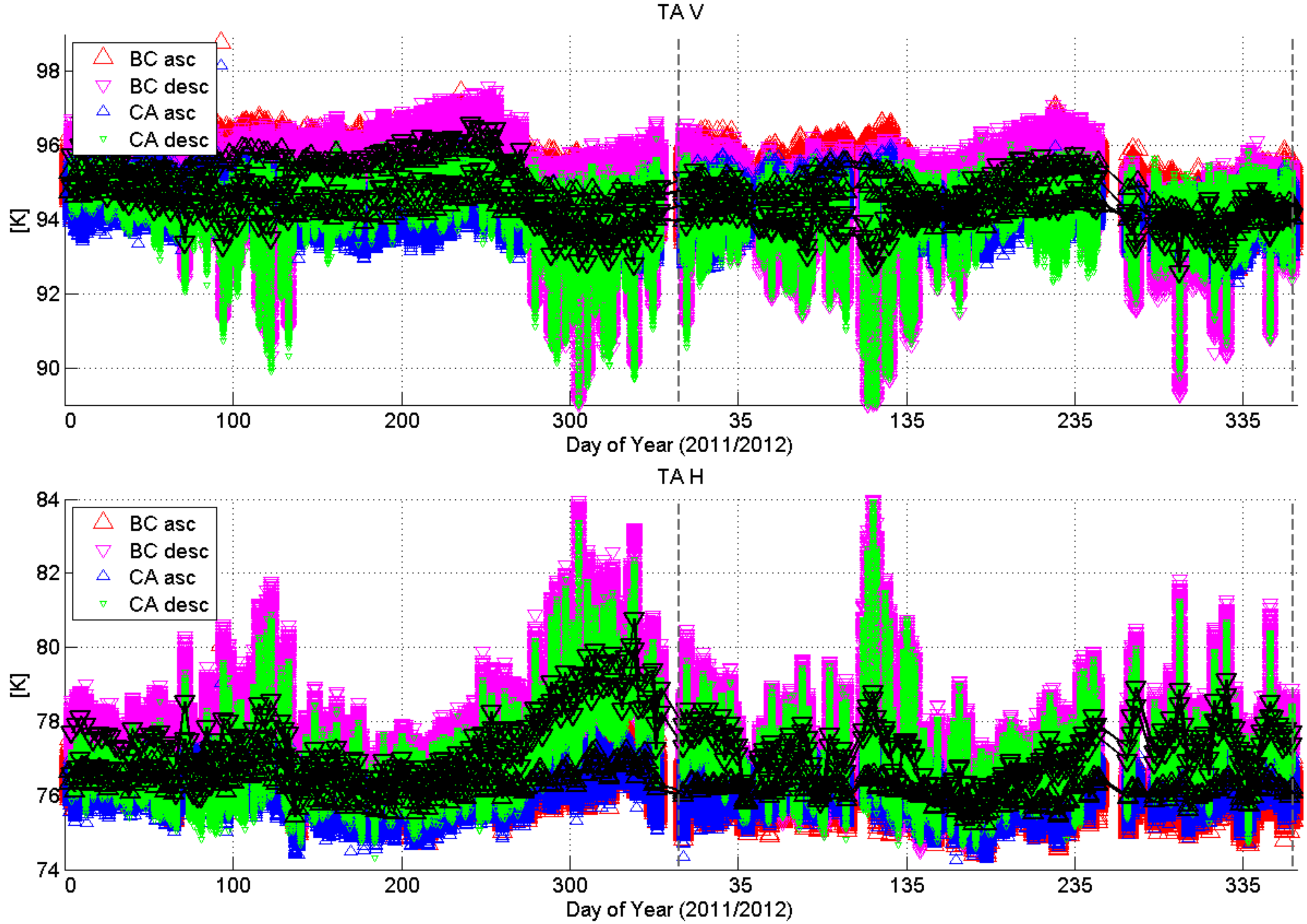
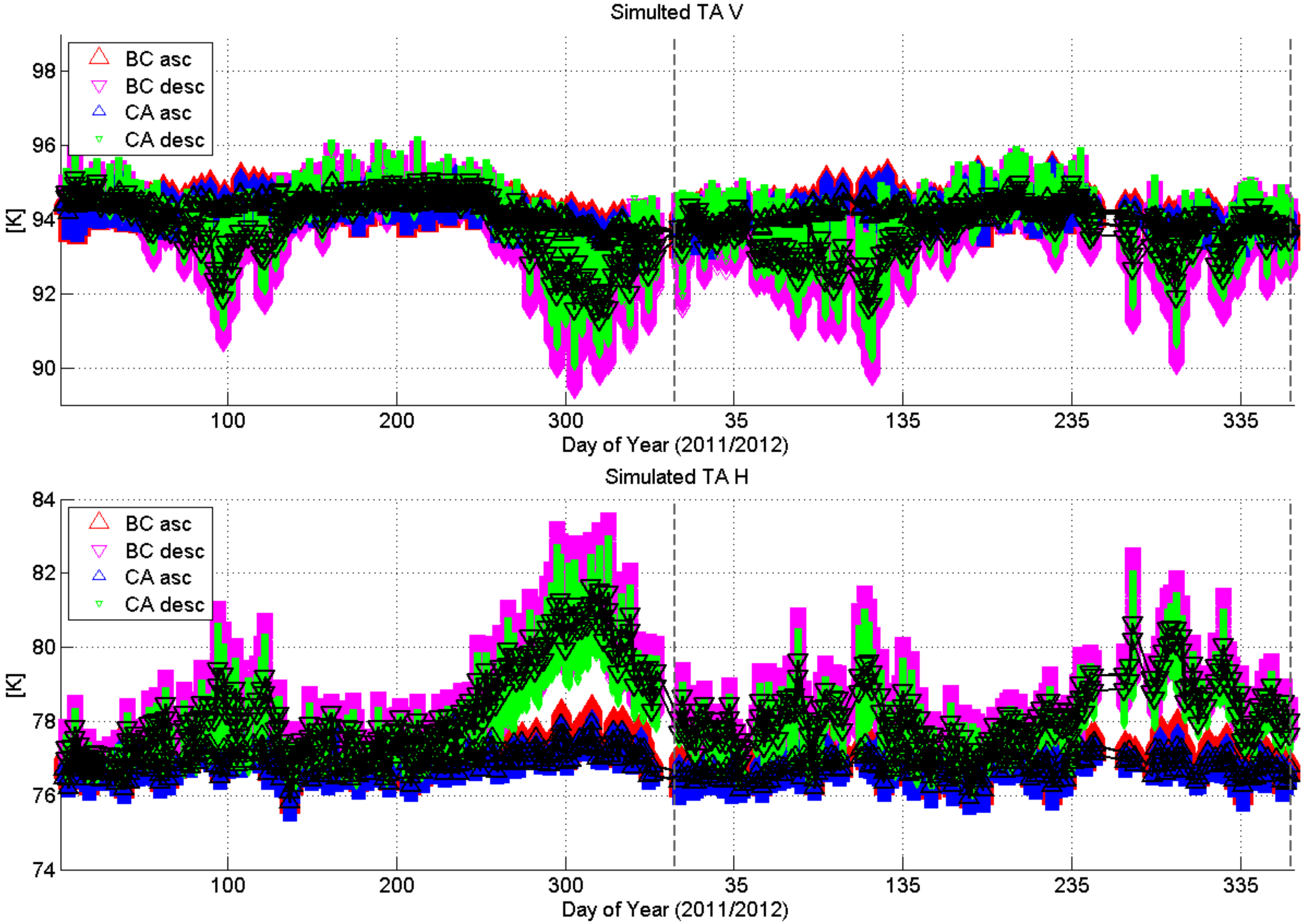
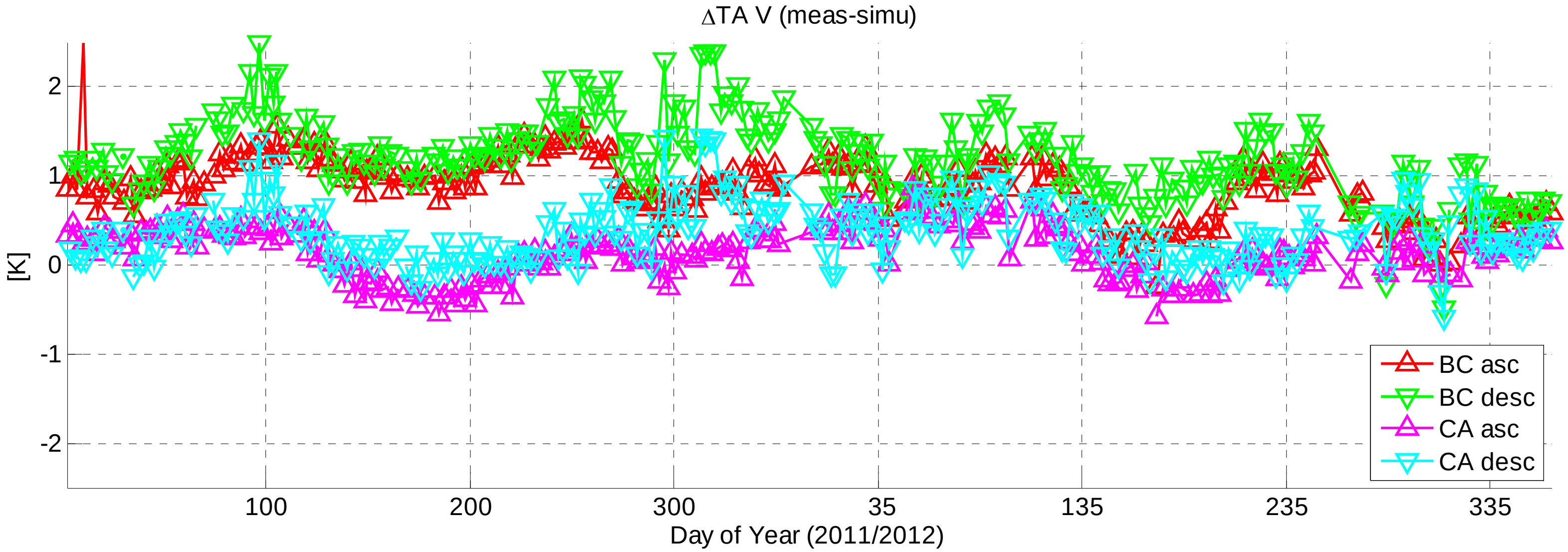
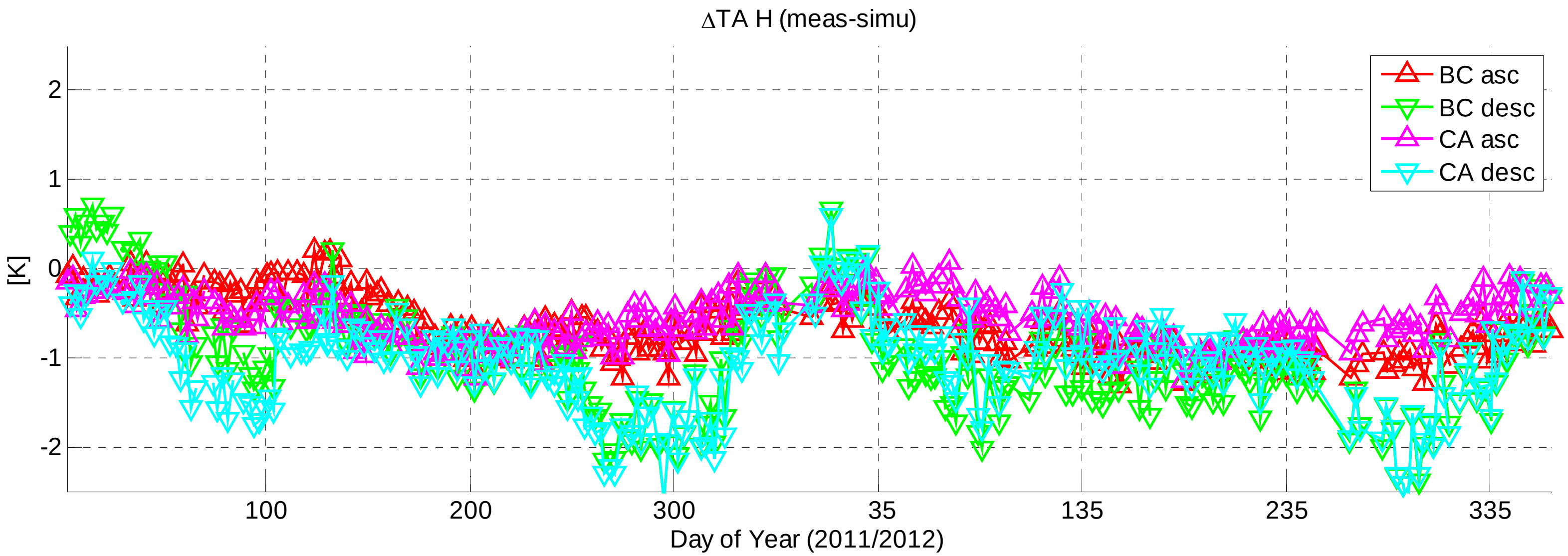


Simulations over test area 2011-2012



Difference over test area 2011-2012





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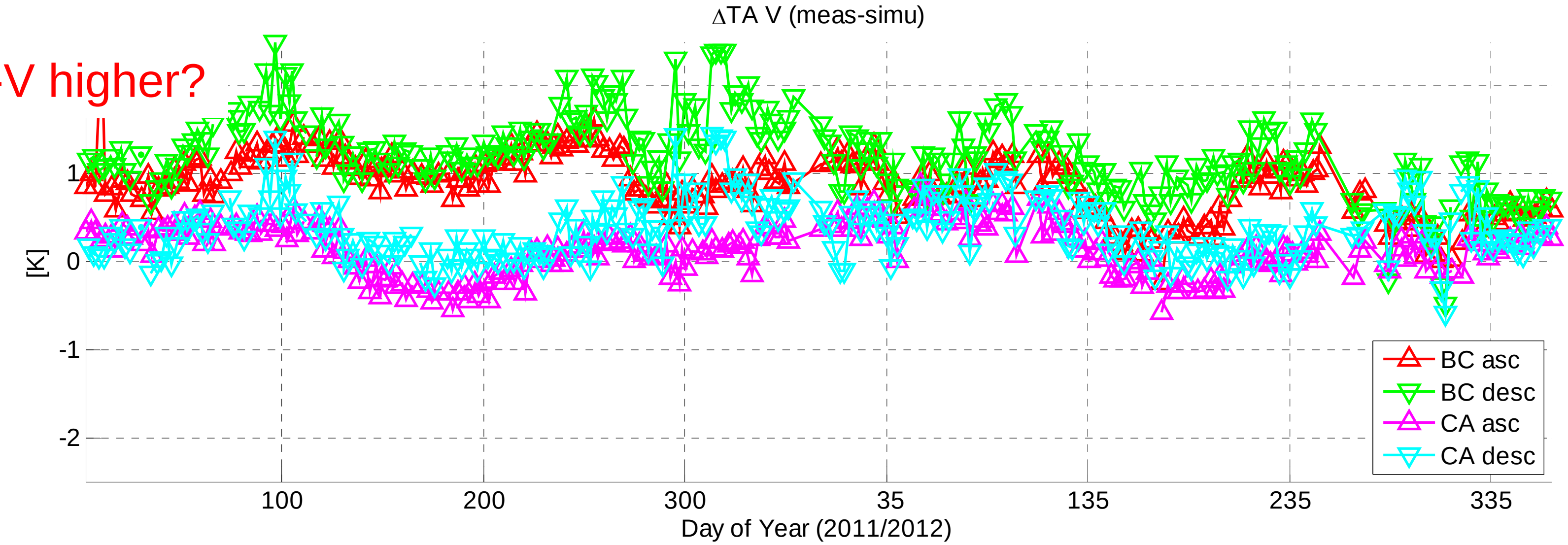
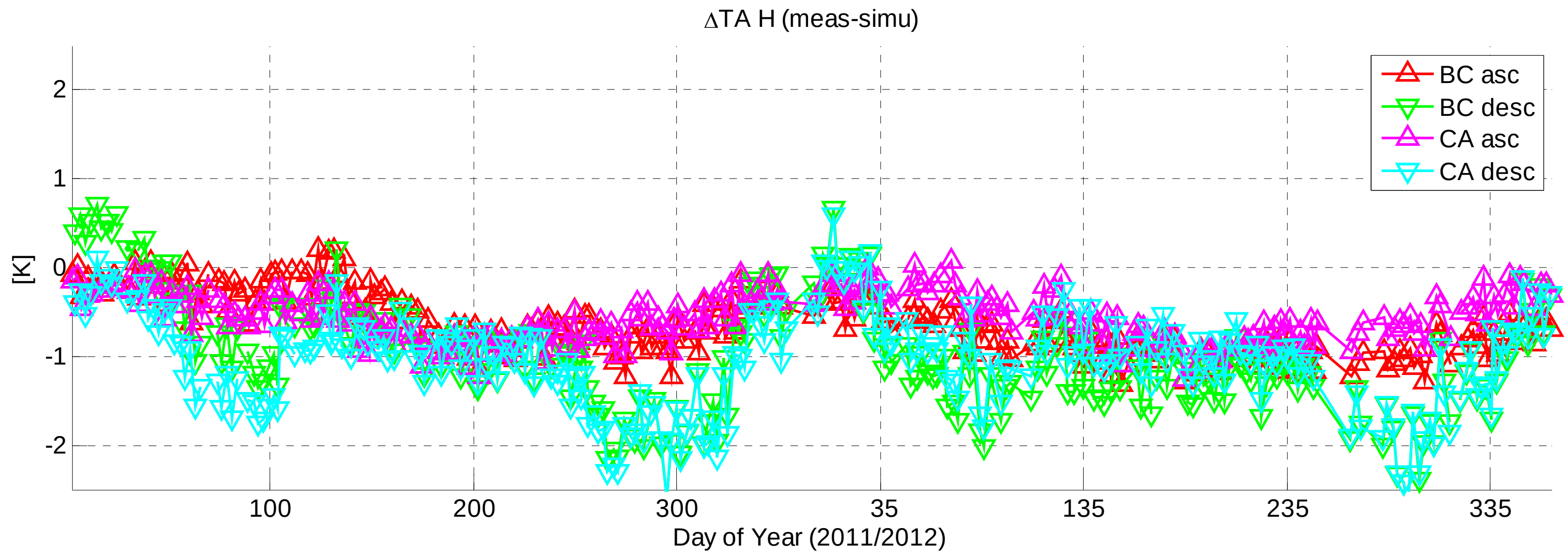
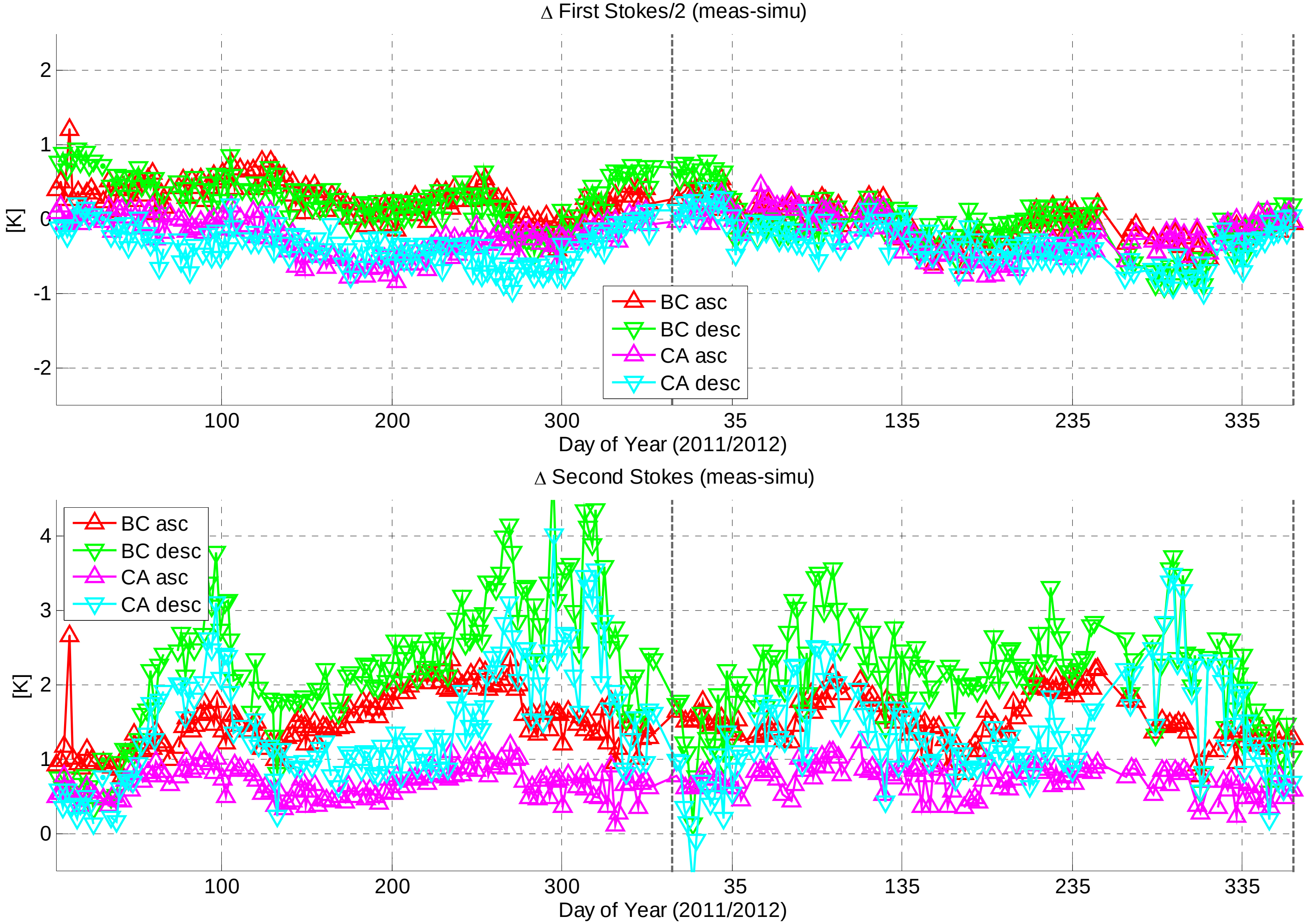
Difference over test area 2011-2012

BC-V higher?

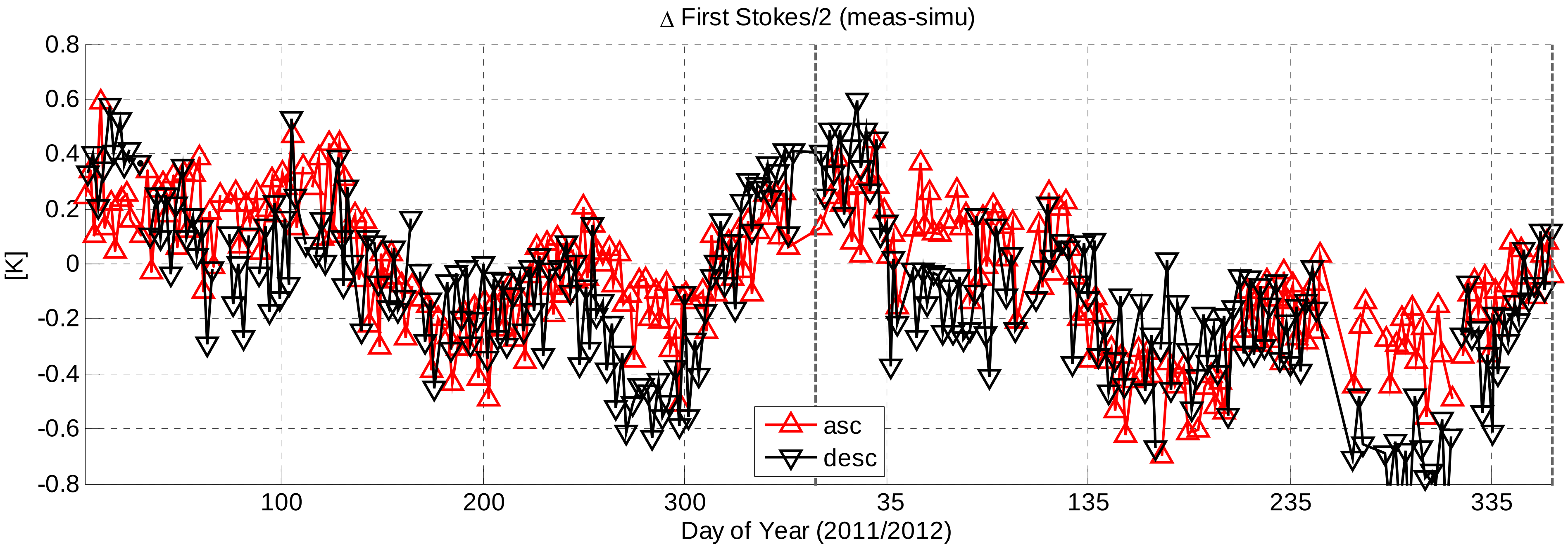




Difference over test area 2011-2012

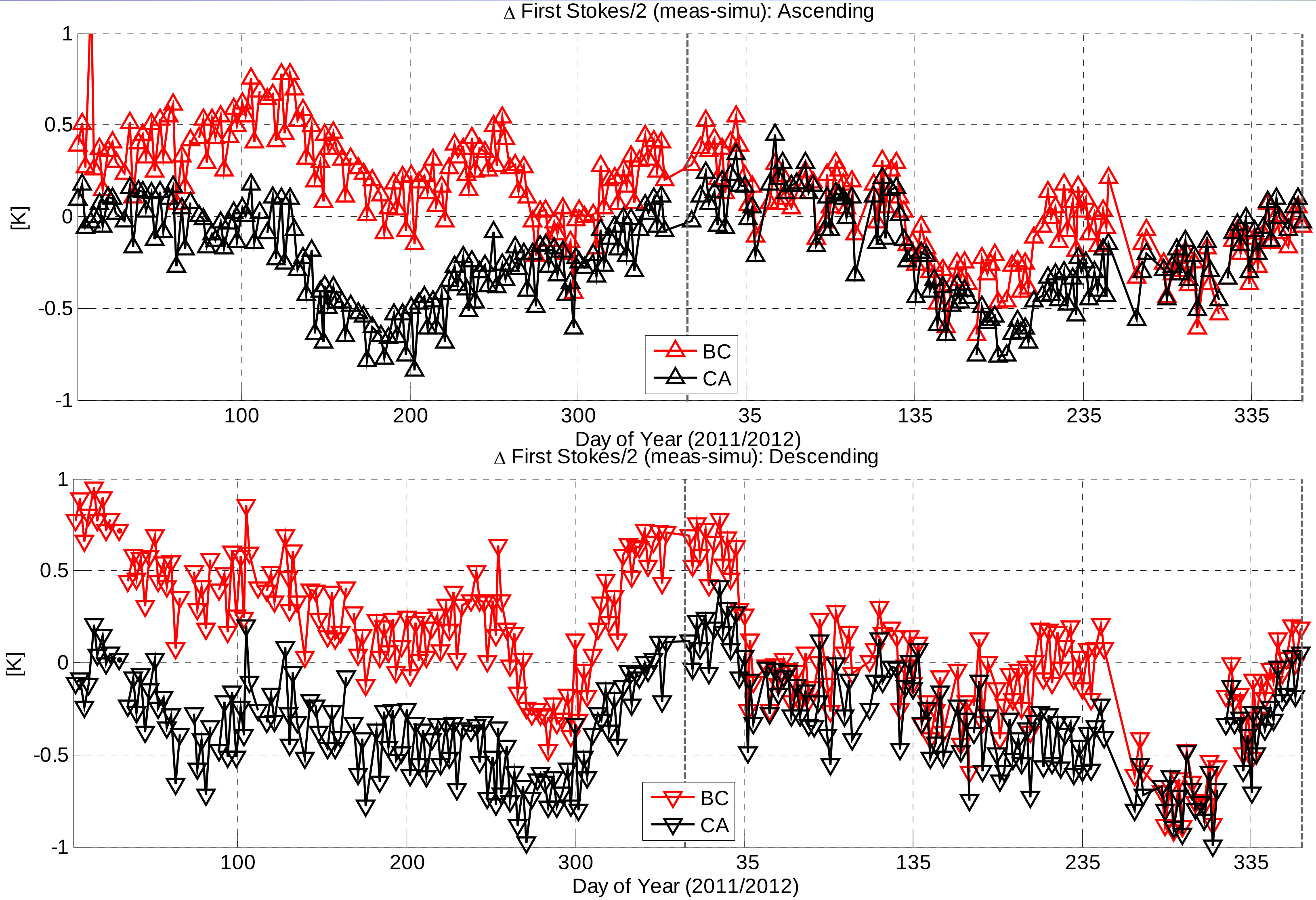


1st Stokes (div 2) difference over test area : Units Averaged



- Combined result from BC/CA units would indicate overall long-term drift, however, this is driven only by one of the units (next slide)…

1st Stokes (div 2) difference over test area: Units Separately



1^{st} Stokes (div 2) difference over test area: Units Separately

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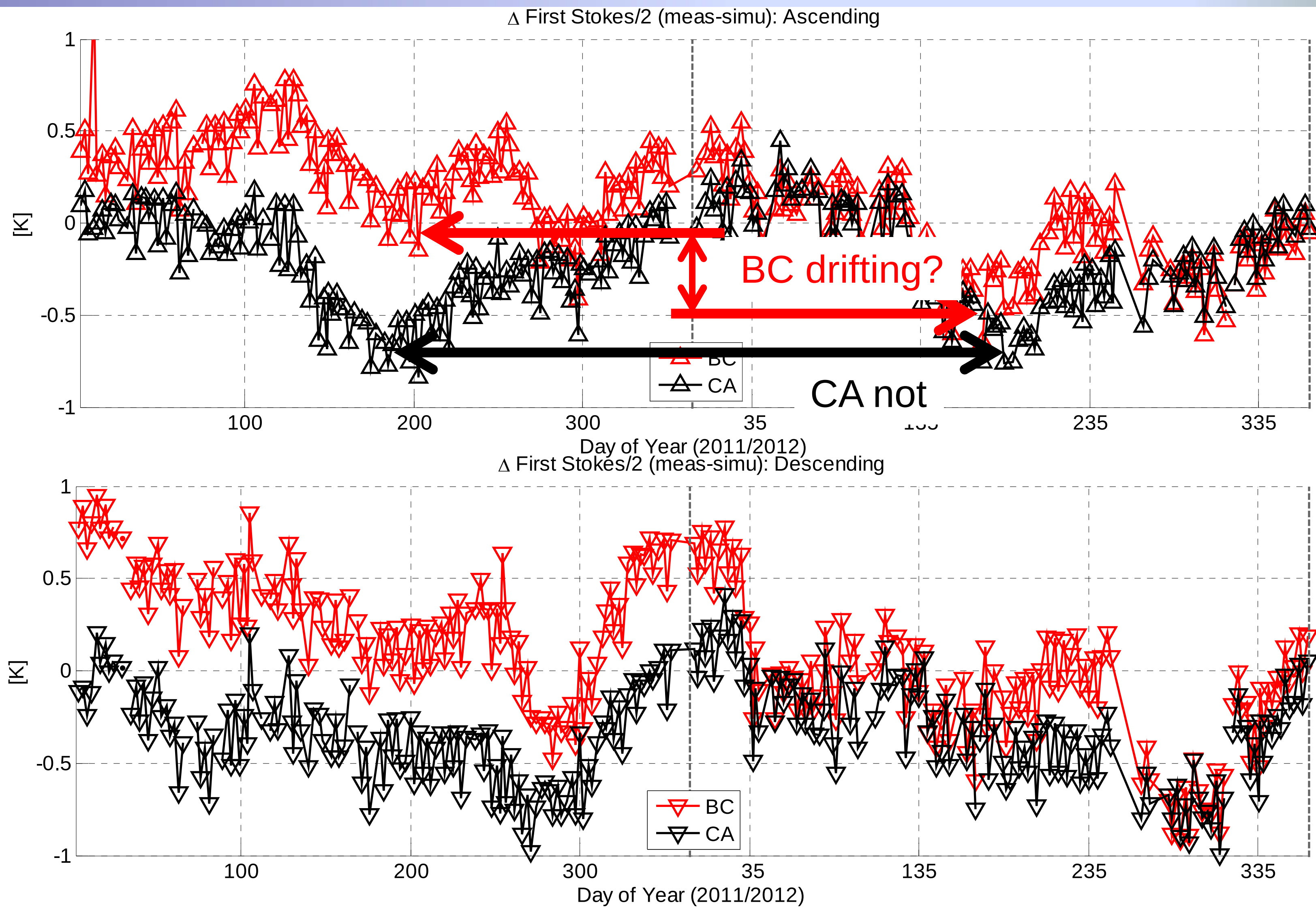

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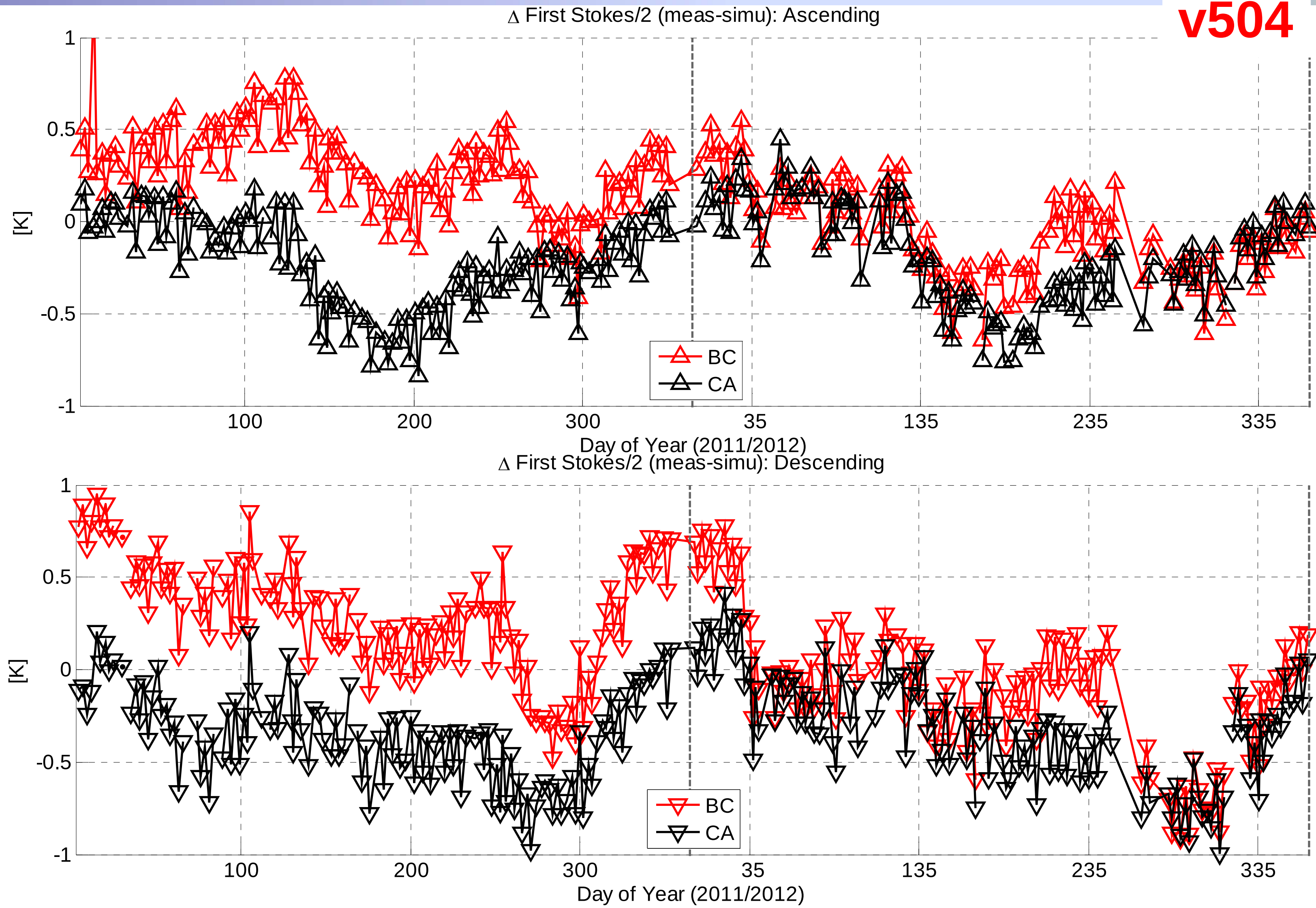
1st Stokes (div 2) difference over test area: Units Separately

v504



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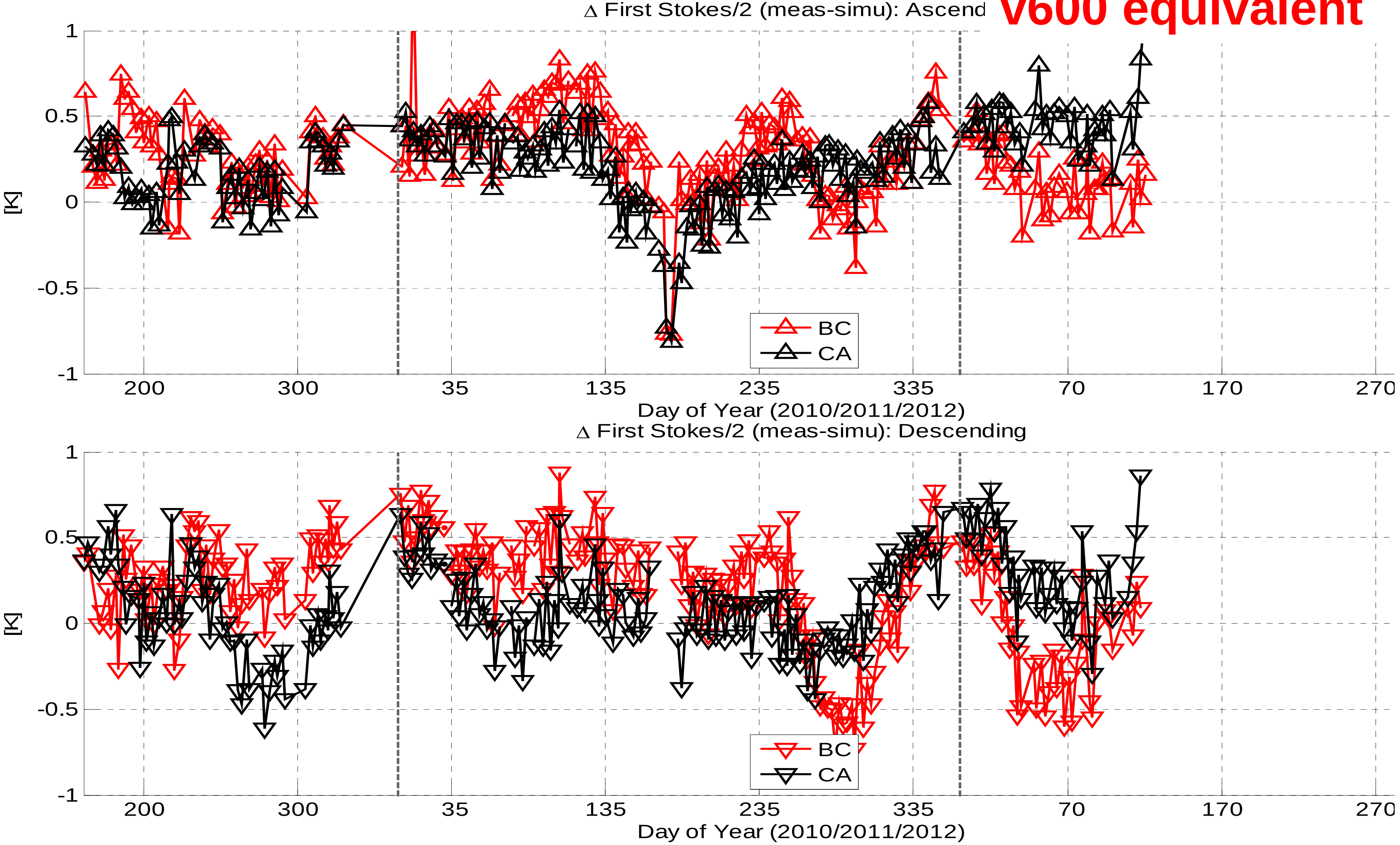
1st Stokes (div 2) difference over test area: Units Separately

v600 equivalent



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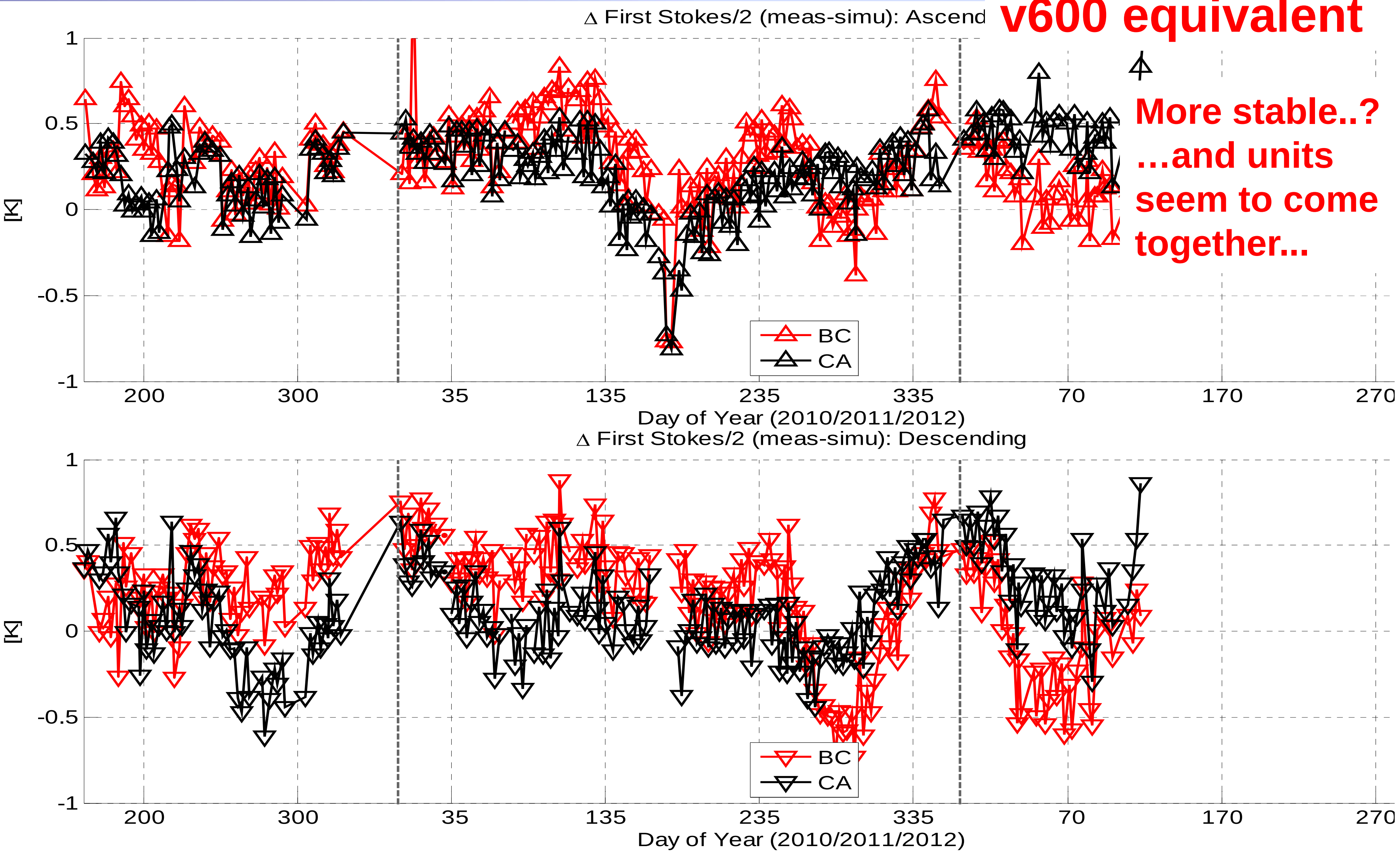
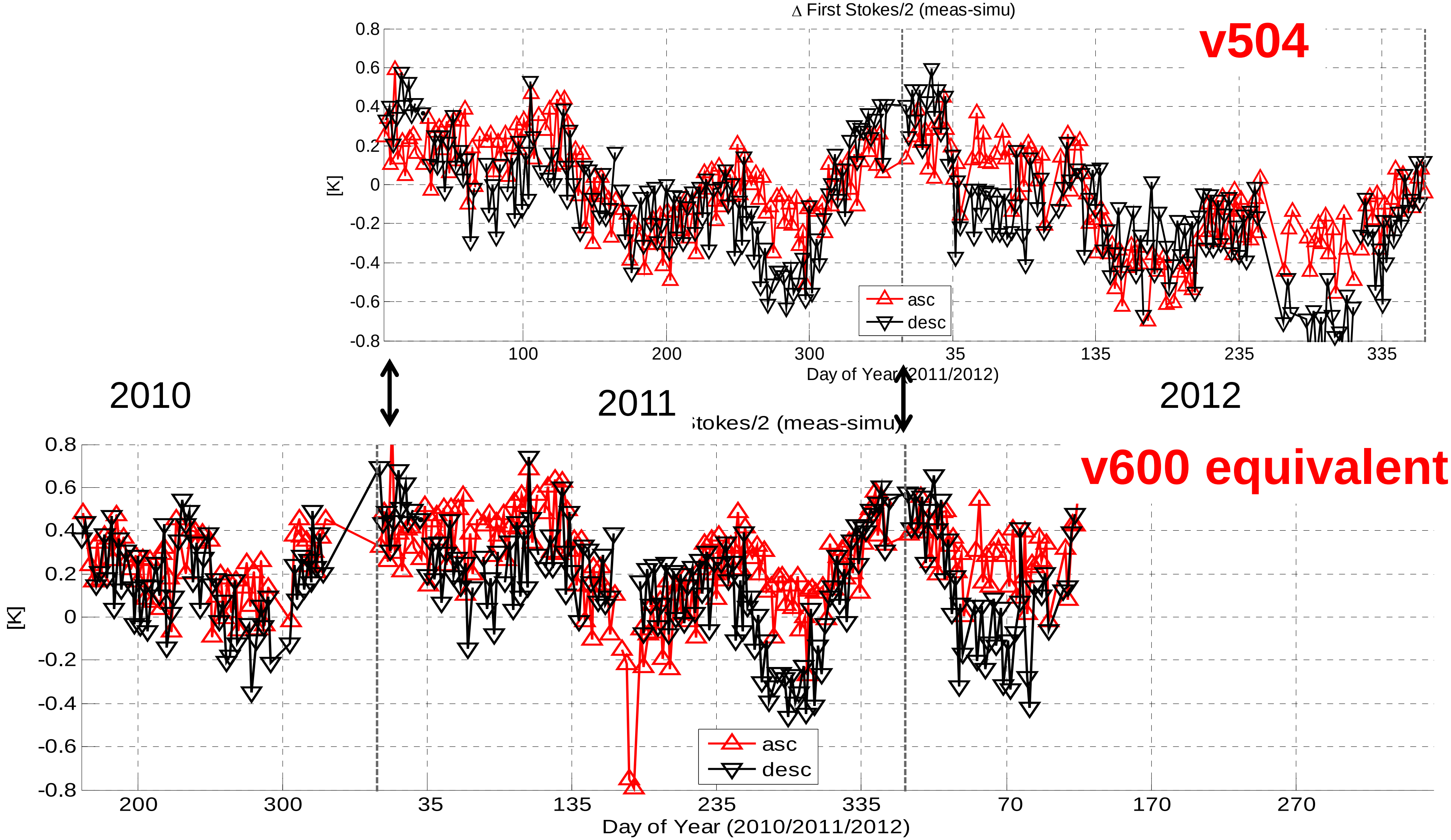
1st Stokes (div 2) difference over test area: Units Separately



1st Stokes (div 2) difference over test area: Units Averaged



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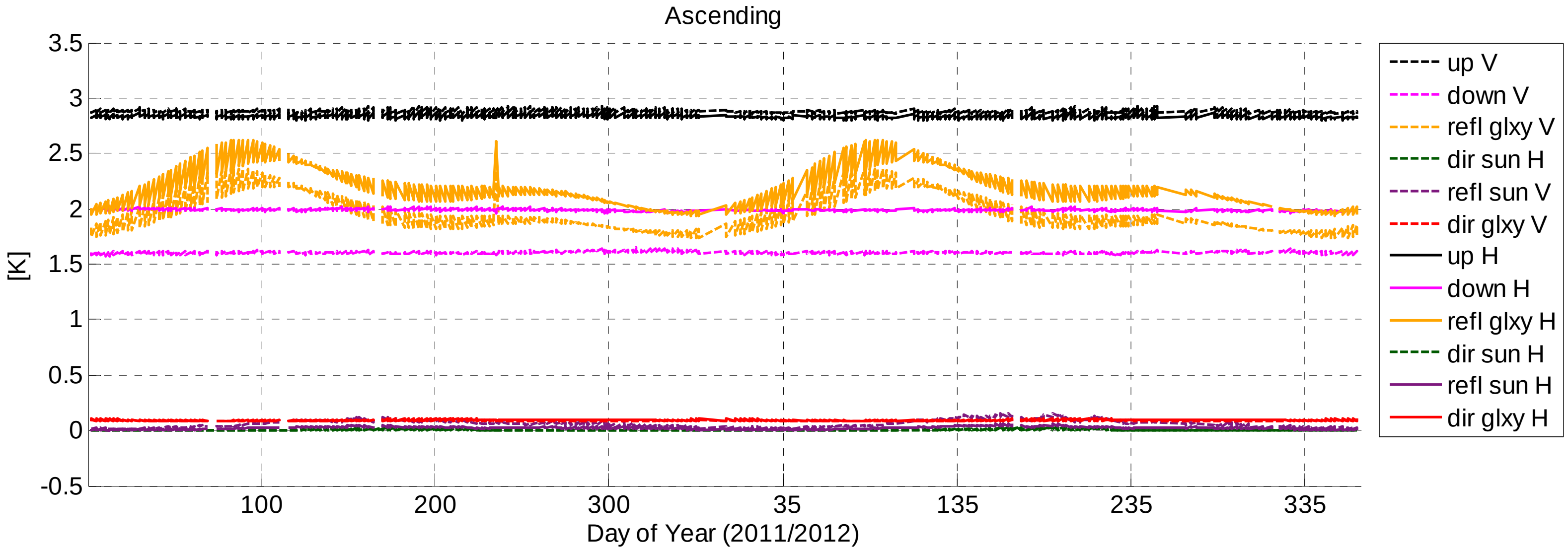
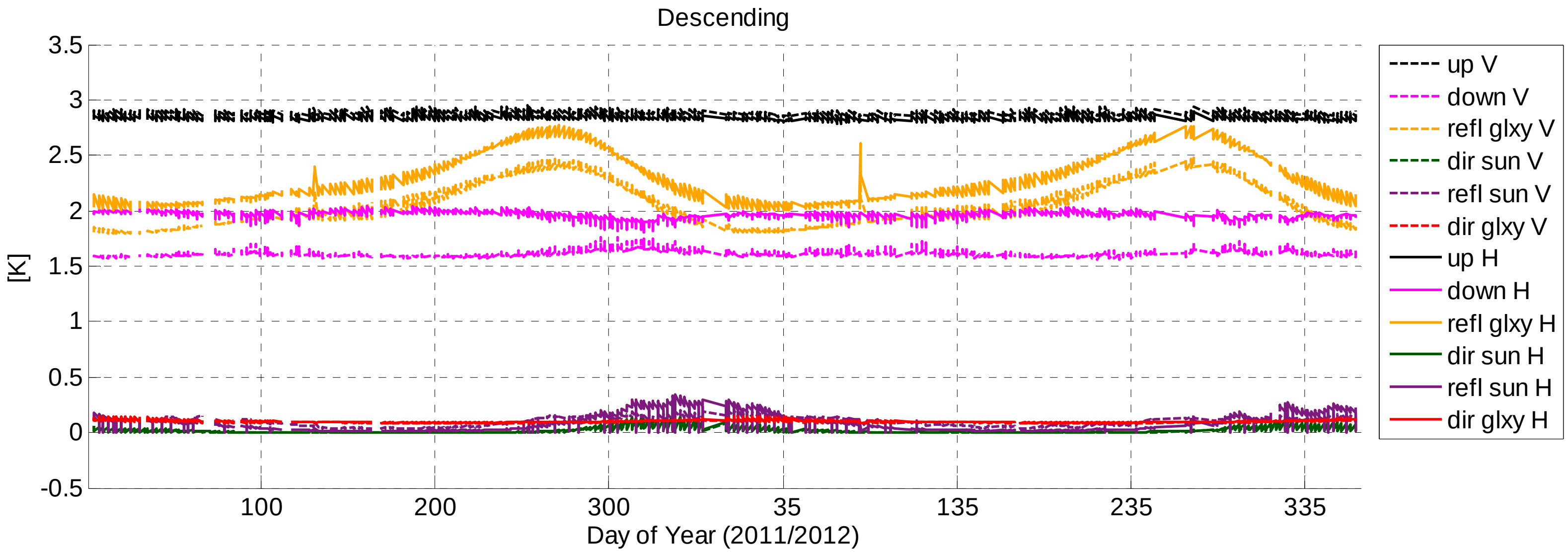
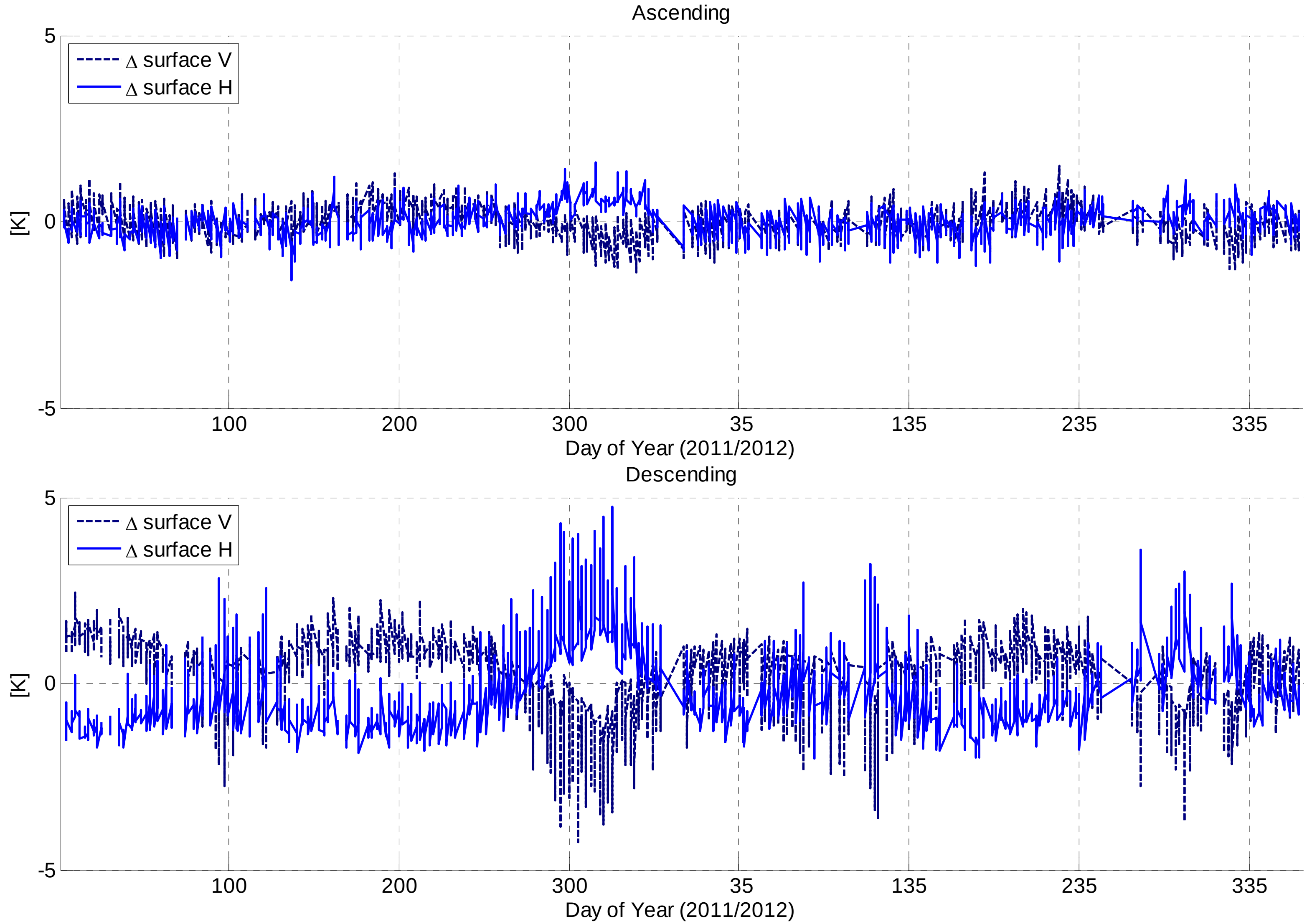
Simulator components over test area





Simulator components over test area



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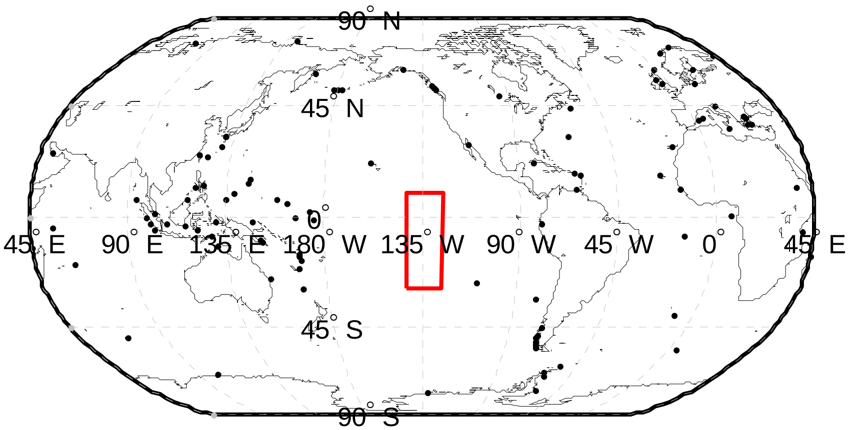
Long-term comparison summary

- Overall very good consistency over the 2-year comparison period
  - Antenna temperature for ascending and descending are significantly different for zero-baselines
  - Much bigger variation of the signal in the descending orbits
- Differences between measurement and simulation experience some evolution:
  - Clear seasonal signal in the difference
  - BC-unit experiencing long-term drift (which affects the average of the two units), but CA-units apparently stable

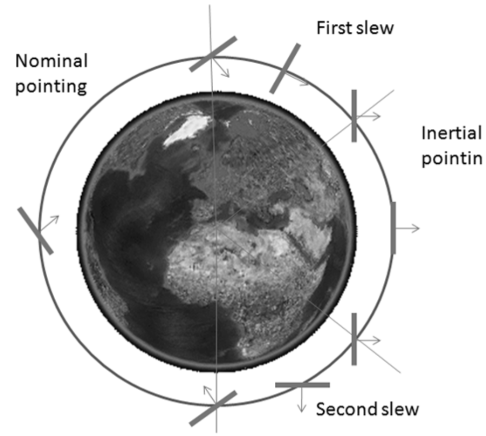


Considerations on the two-point calibration for SMOS zero-baselines

Baseline calibration of zero-baselines

- Currently, one-point calibration principle (cold sky maneuvers):
  - Antenna temperature retrieval (simplified form simplified further by assuming physical temperature of antenna, T_p, equals to internal load, T_U)

$$T_A = -L_A T_N \eta + L_A T_U + T_p(1 - L_A) = -L_A T_N \eta + T_U$$



  - Determine noise injection level using the reference target

$$T_N = \frac{T_U - T_{A,0}}{L_A \eta_0}$$

  - Antenna loss comes from separate measurements (on-ground or in-orbit [Corbella et al., 2012])
- Robust approach - however, changes in the physical temperature of the antenna cause errors if the loss of the antenna is not accurately known
- Measured antenna temperature is based only on the modeling of emission of CMB and celestial objects
  - This is the only well-known homogeneous target that covers the 3-dB beam of zero-baselines

Two-point calibration of zero-baselines

- If more reference targets were available, how to implement in the calibration
- Use of two calibration points in the determination of the calibration parameters
  - Antenna temperature retrieval

$$T_A = -L_A T_N \eta + T_U$$
$$= A\eta + B$$

  - Gain and offset parameters can now be solved with as usual

$$A = \frac{T_{A,1} - T_{A,2}}{\eta_1 - \eta_2} \qquad B = \frac{T_{A,2}\eta_1 - T_{A,1}\eta_2}{\eta_1 - \eta_2}$$

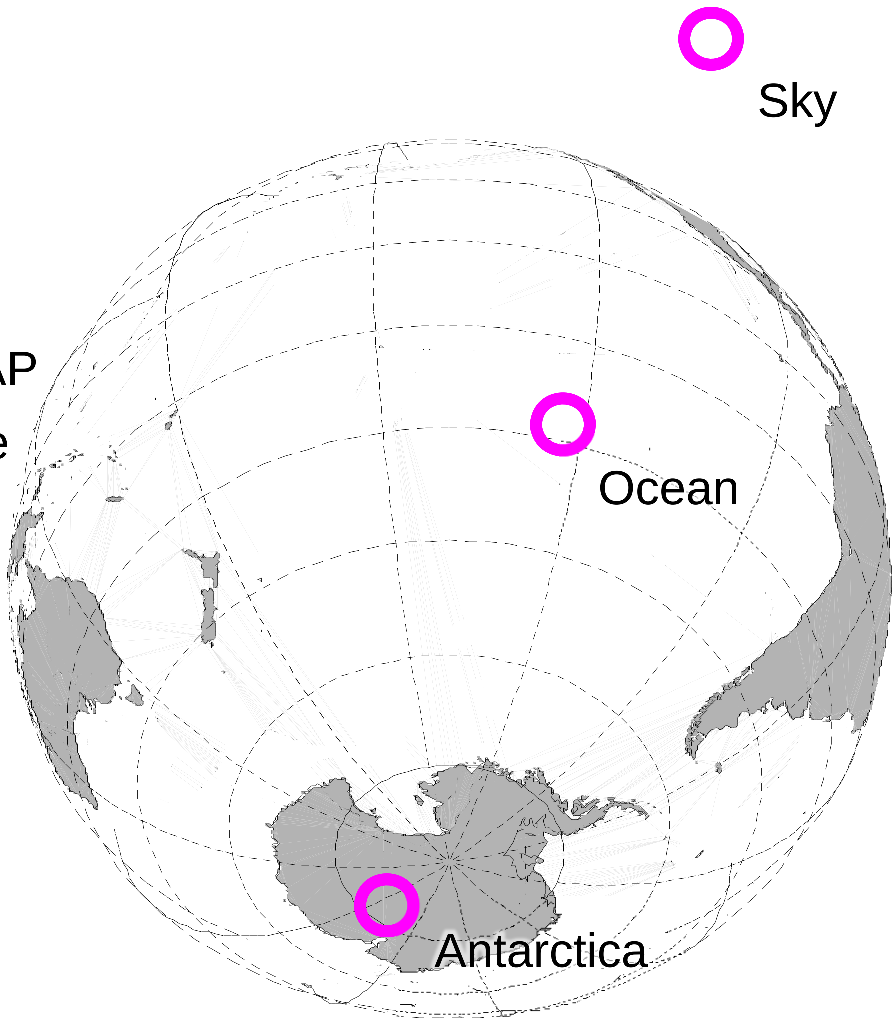
  - From which the noise injection temperature can again be solved

$$A = -L_A T_N \qquad T_N = -\frac{A}{L_A} = \frac{T_{A,1} - T_{A,2}}{L_A(\eta_1 - \eta_2)}$$

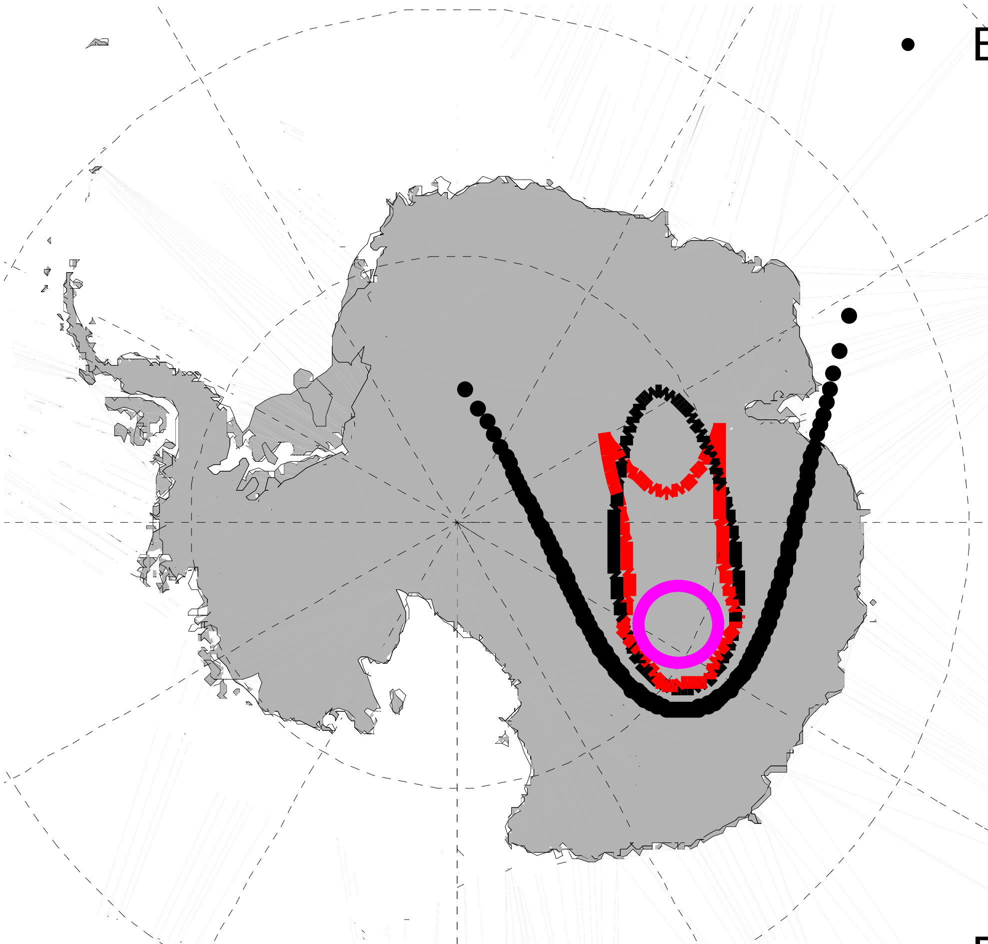
- This would ensure that the retrieved antenna temperature intersects both calibration references

Calibration References

- Typical target areas (in addition to cold sky) are oceans and Antarctica
  - Antarctica currently used for validation by SMOS
  - Ocean currently used for calibration by Aquarius
  - Both will be used for calibration by SMAP
  - Ocean: single area or full ocean surface
- How do these targets rate in terms of reliability of emission models (over incidence angle)?
  - No real consensus
- Zero-baseline 3-dB footprint goes over the horizon; the application of these targets not straightforward (but perhaps possible based on the results presented on previous slides)



Relating zero-baselines to reference targets



Black = zero-baseline (40º and 60º)
Red = alias-free FOV

- Basically two options
  1. Model target value for the zero-baseline footprint
     - Modeling over the horizon
  2. Model target value for the SMOS alias-free FOV (or part of it) and transfer the comparison result to zero-baseline
     - Relating portions of the interferometric image to zero-baselines
     - If the measurement does not match with the reference the main contributors is not only zero-baselines but also antenna patterns
- Both options are implementable; the question is their accuracy

Two-point calibration summary

- Two-point calibration could be implemented for zero-baselines of SMOS
- There needs to be consensus of which targets to use and with which models to make it worth while for implementation
  - Does not necessarily have a big improving effect on SMOS - the real gain in cross-calibration of the three missions
  - Which ice and ocean model (exactly)?
  - Also consensus on contributing sources needed