Towards correcting ASM data for the Sun-related thermoelectric effect

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With input from
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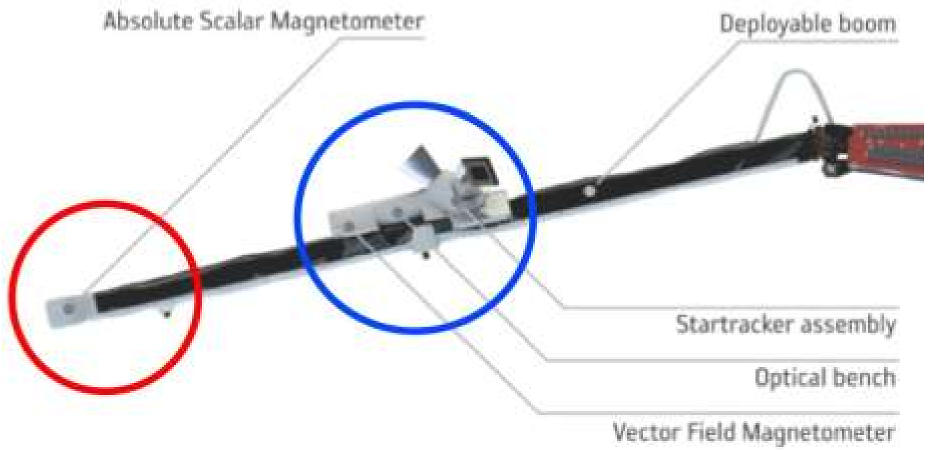
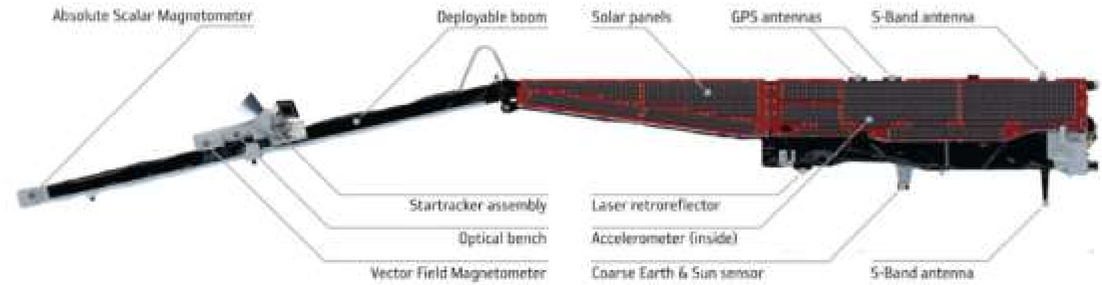
What is the issue about ?



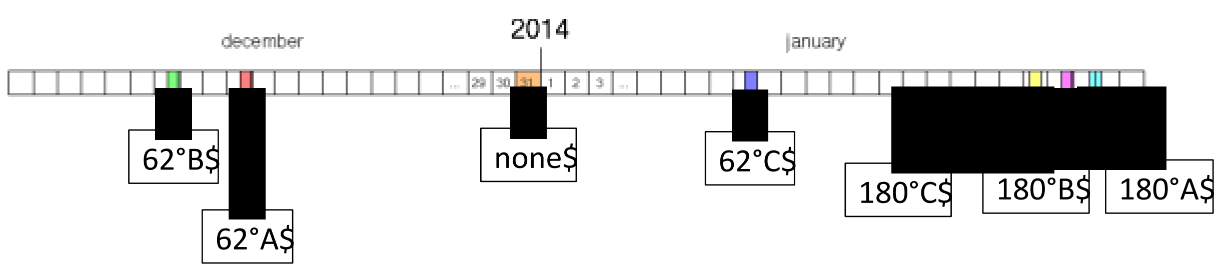
- A **systematic Sun-related discrepancy** has been identified early on **between the ASM scalar readings** at the tip of the boom and **the modulus of the field measured by the VFM instrument** at the middle of the boom, that cannot be accounted for by simple calibration issues -> **a dBSun perturbation is affecting either the VFM, or the ASM, or both** (recall previous presentations)
- Here, **we take advantage of manoeuvres undertaken by the Swarm satellites early in the mission to isolate, parameterize and possibly correct the ASM readings for that part of the perturbation that affects them**.
- This is important because, even though the effect on the scalar readings is small (less than 1 nT), attributing this effect to the VFM could lead to significant erroneous field component corrections (up to several nT)

Recap of manoeuvres of interest

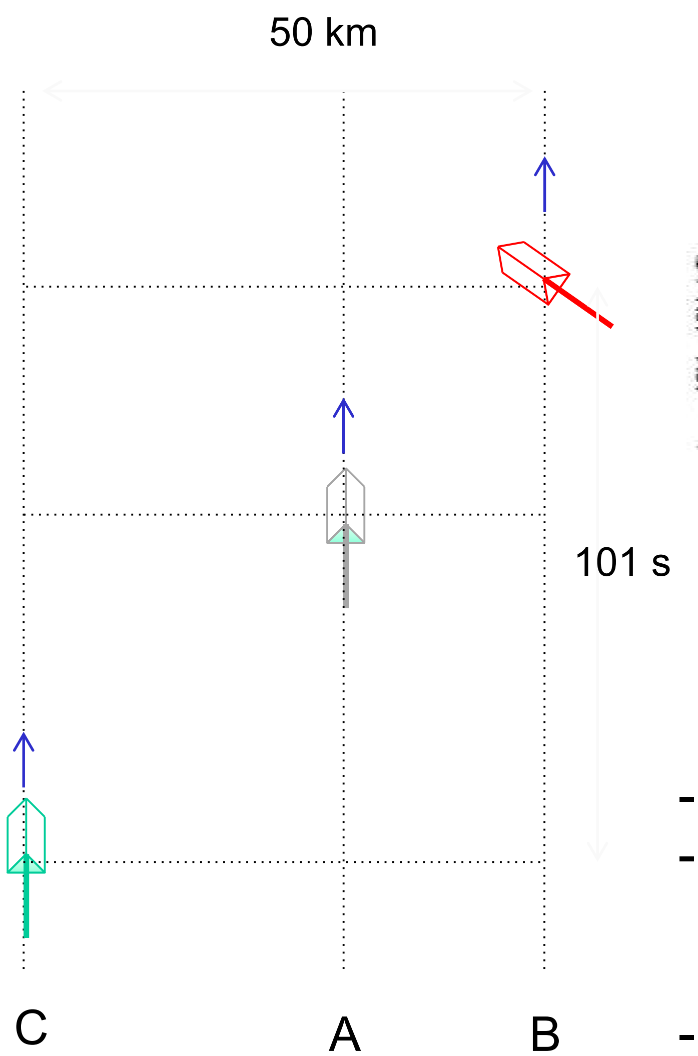
0502 baseline: Scalar ASM data (tip of the boom)



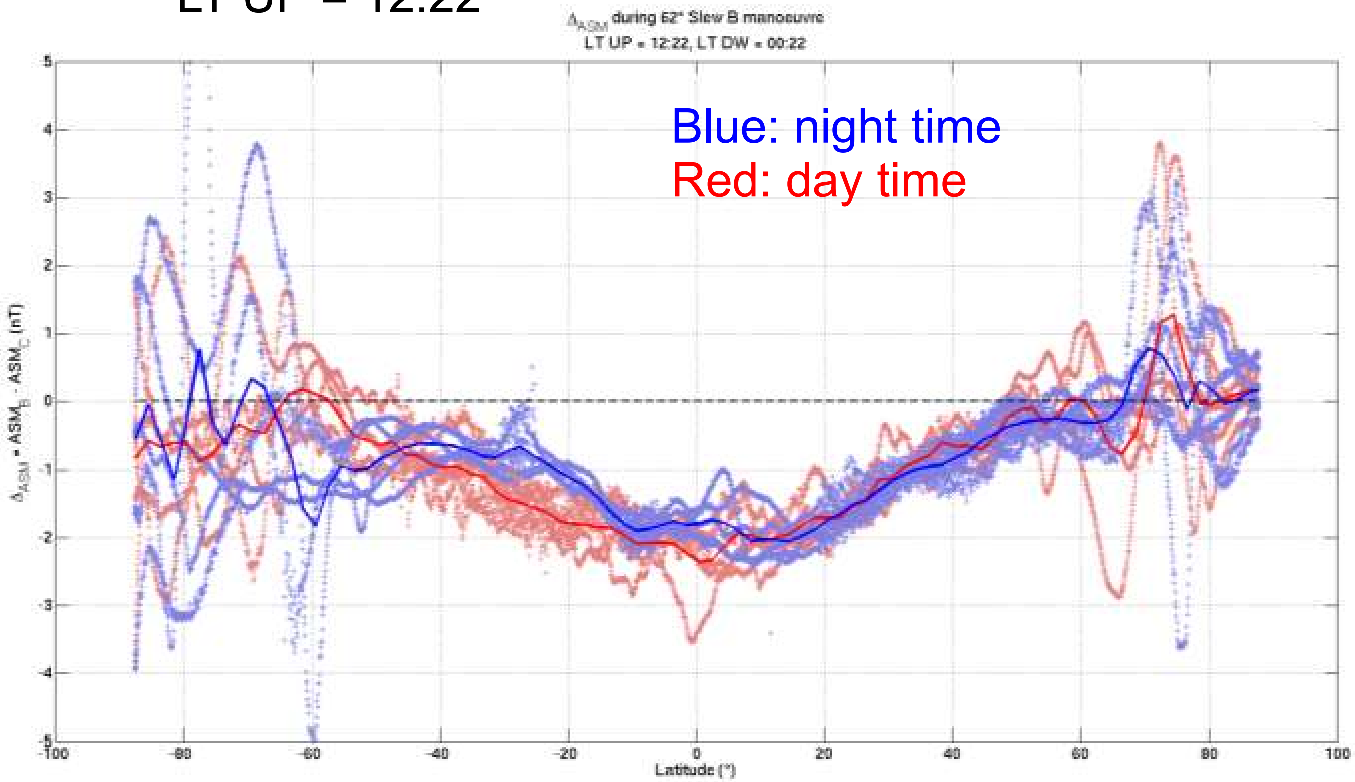
manoeuvres	Begin (UTC)		End (UTC)		0408 DATA AVAILABILITY			LT UP
					A	B	C	
62° A	19/12/13	14:00:00	20/12/13	02:00:00	100%	100%	100%	12:09
62° B	16/12/13	14:00:00	17/12/13	02:00:00	0%	100%	100%	12:22
62° C	09/01/14	11:58:00	09/01/14	23:58:00	100%	100%	100%	10:16
180° A	23/01/14	17:55:00	24/01/14	05:55:00	100%	100%	50%	09:05
180° B	22/01/14	14:20:00	23/01/14	02:20:00	20%	100%	100%	09:10
180° C	21/01/14	06:00:00	21/01/14	18:00:00	100%	100%	100%	09:15
+/- 90° AC	13/05/14	00:49:00	14/05/14	09:51:00	100%	NA	100%	23:15
None	31/12/13	00:00:00	31/12/13	23:59:59	100%	100%	100%	11:05



Example: 62° Slew Bravo Manoeuvre



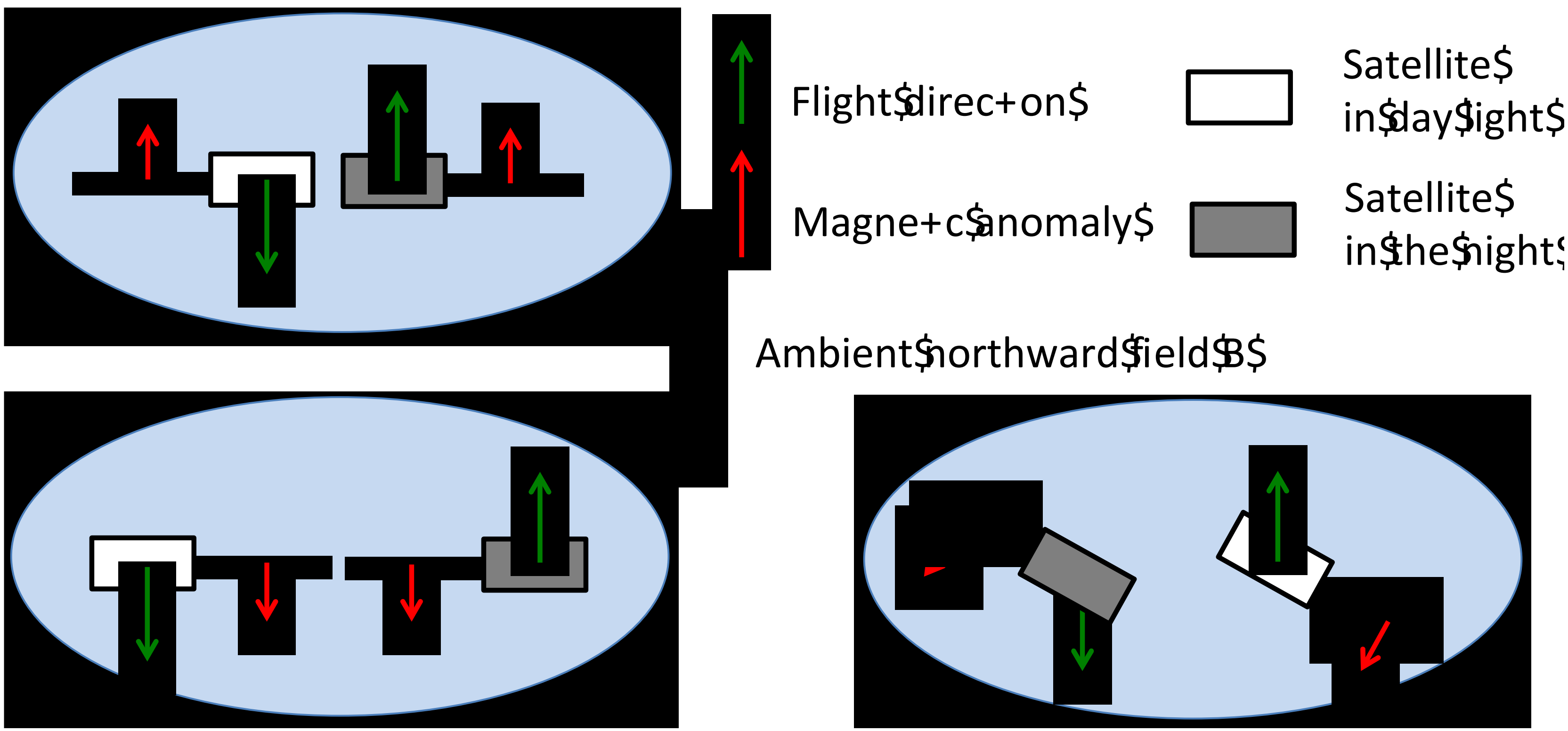
LT UP = 12:22



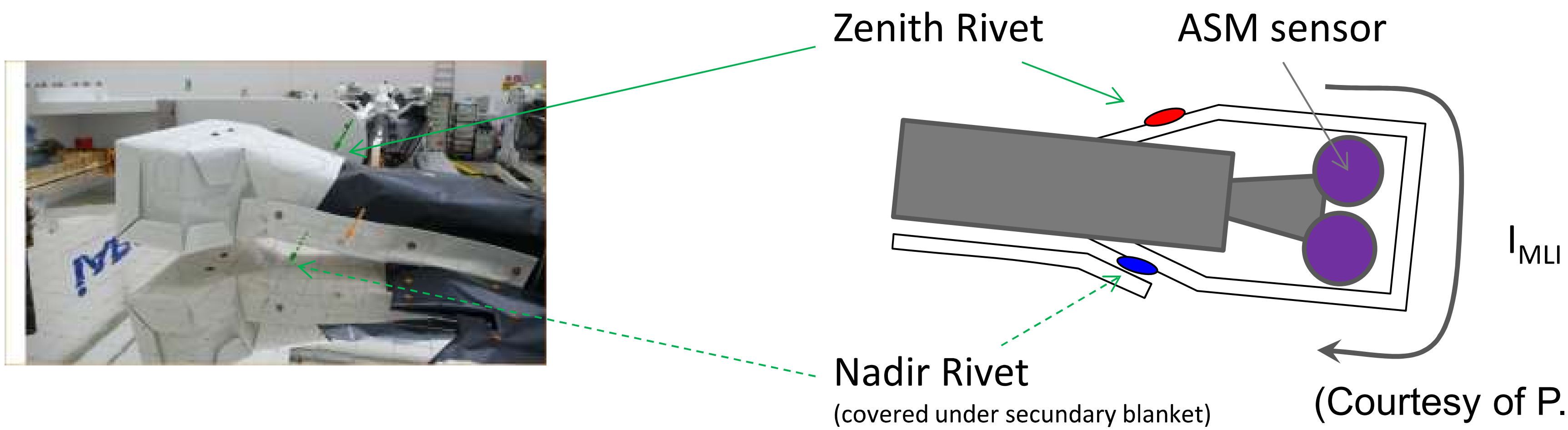
- The discrepancy is **maximum at the equator**
- NO similar discrepancies are found between Charlie and Alpha -> **not related to local ionospheric currents** between Alpha and Bravo
- Amplitudes and signs are **similar during day when moving northwards and at night when moving southwards**

Anomaly direction and sign rules inferred

The fact that disagreements between satellites are only seen for +/- 90° and 62° slew manoeuvres, are maximum at the equator and change sign in specific ways, suggested that **a slight anomalous field is being produced in the horizontal transverse direction** (Y component in the ASM frame of reference), as summarized here, **with a sign depending on whether the satellite is in the day light or not**.



A likely explanation for the ASM scalar anomaly

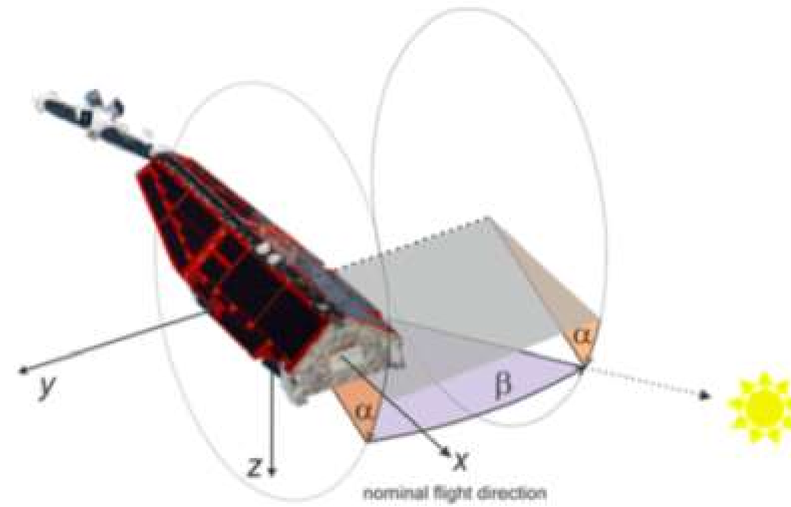


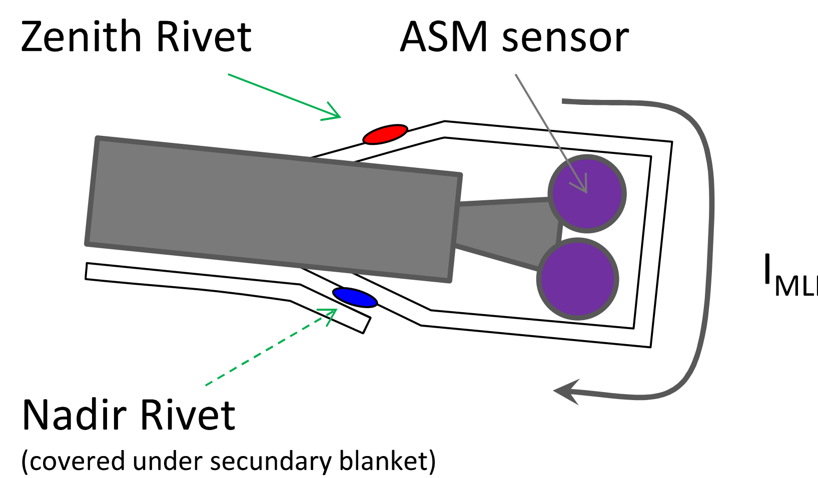
(Courtesy of P. Brauer)

- **The signature found on the ASM** (**along the Y component in the VFM frame of reference**, with **negative** sign when the satellite is **in the day light**, and a **positive** sign when the satellite is **in the dark**) is **consistent with** a possible signal produced by the **thermoelectric effect** identified by P. Brauer **due to the grounding of the Beta cloth** (protecting the ASM) **with the help of two rivets**.
- This model has been tested for confirmation and scaling using all manoeuvres.

dB_Y anomaly model of P. Brauer (provided 06/11/17)

- **Assumed to be of thermal origin, driven by Sun illumination on grounding rivets** (with some thermal inertia)
- **Variables** are defining the Sun position (α,β) coordinates (using the conventions and code of L. Tøffner-Clausen), also taking into account eclipses
- **Parameters** are:
    - Scaling factor from temp difference to disturbance [nT/degC]
    - Pointing angles of Zenith Rivet.
    - Pointing angles of Nadir Rivet.
    - Average temperature of Nadir Rivet in eclipse (T_{Earth})
    - « Solar transmission » through secondary blanket over Nadir rivet





Disagreements predicted during slew manoeuvres

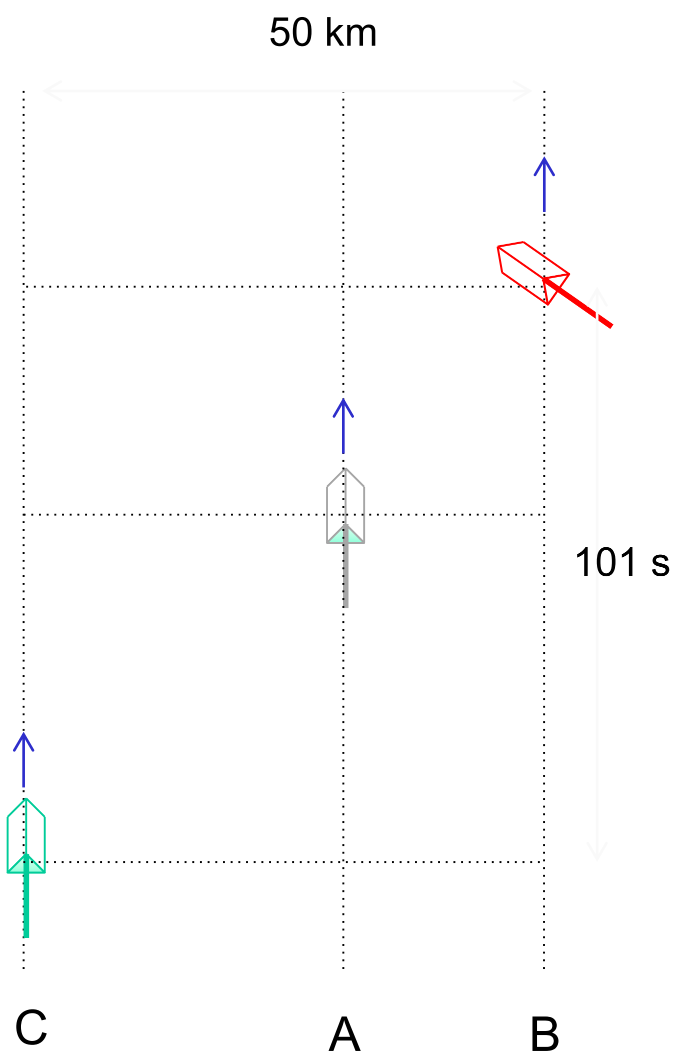
- We assume that the perturbation is negligible on satellite flying nominal (or 180° slew) -> assumption that could later be relaxed
- If the slew manoeuver is on SAT-U, while SAT-V is nominal, the expected signature on the scalar disagreement is :

$$S_{UV} = \frac{\Delta B \cdot B}{\|B\|} = \frac{dBSunY_U \cdot Y_U}{F}$$

- Which we compare to the observed disagreement $\Delta_{UV,\,ASM}$

$$R_{UV} = S_{UV} - \Delta_{UV,ASM}$$

Bravo anomaly: 62° Slew Bravo Manoeuvre Observed



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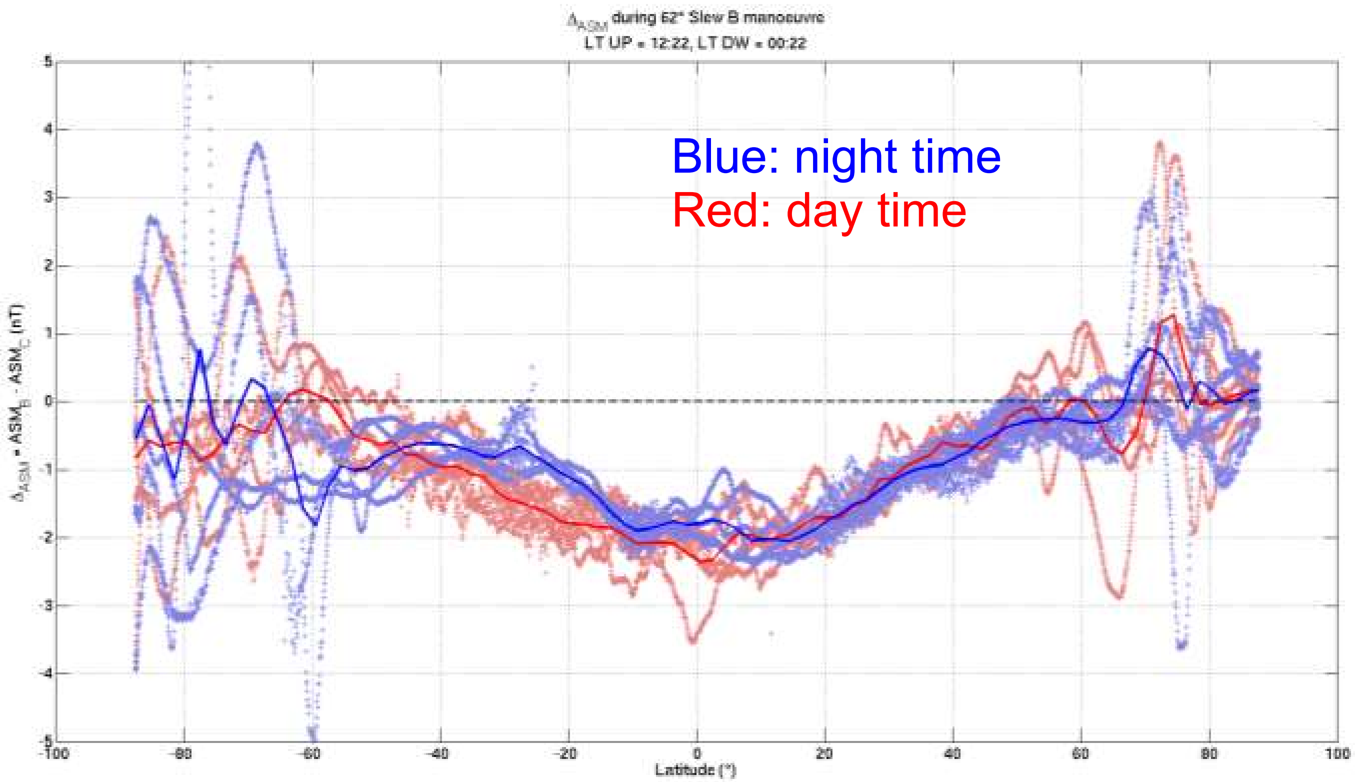
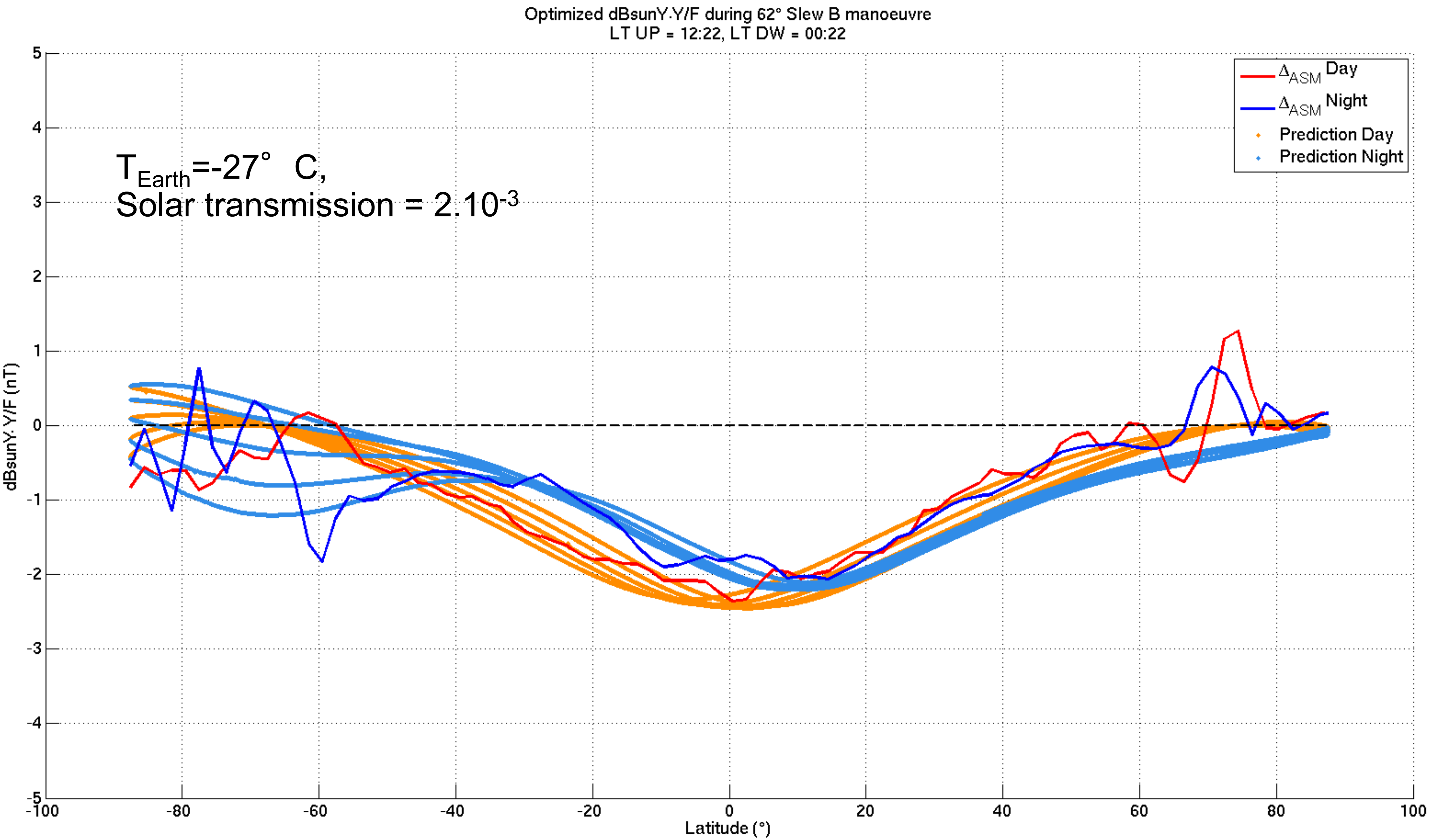
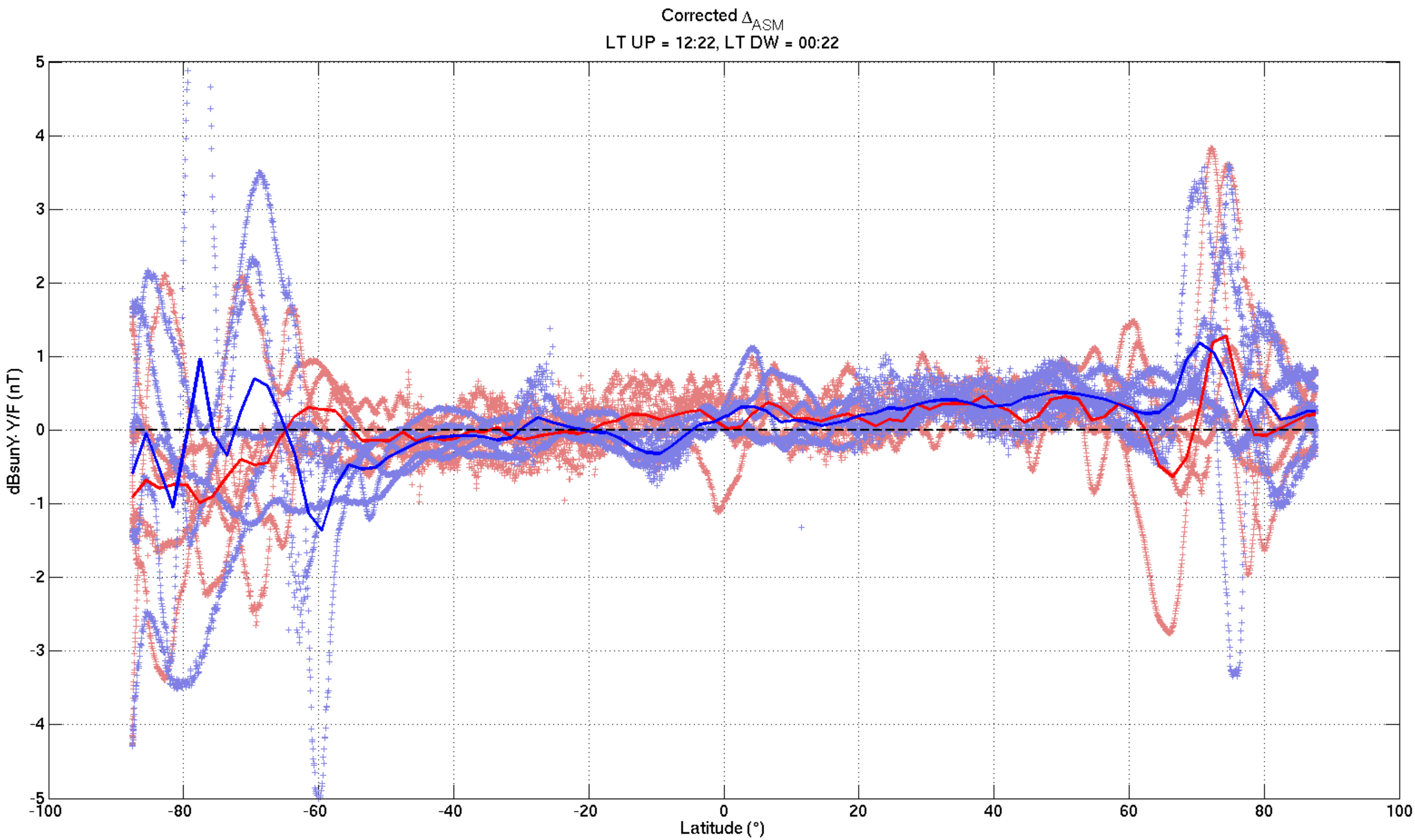


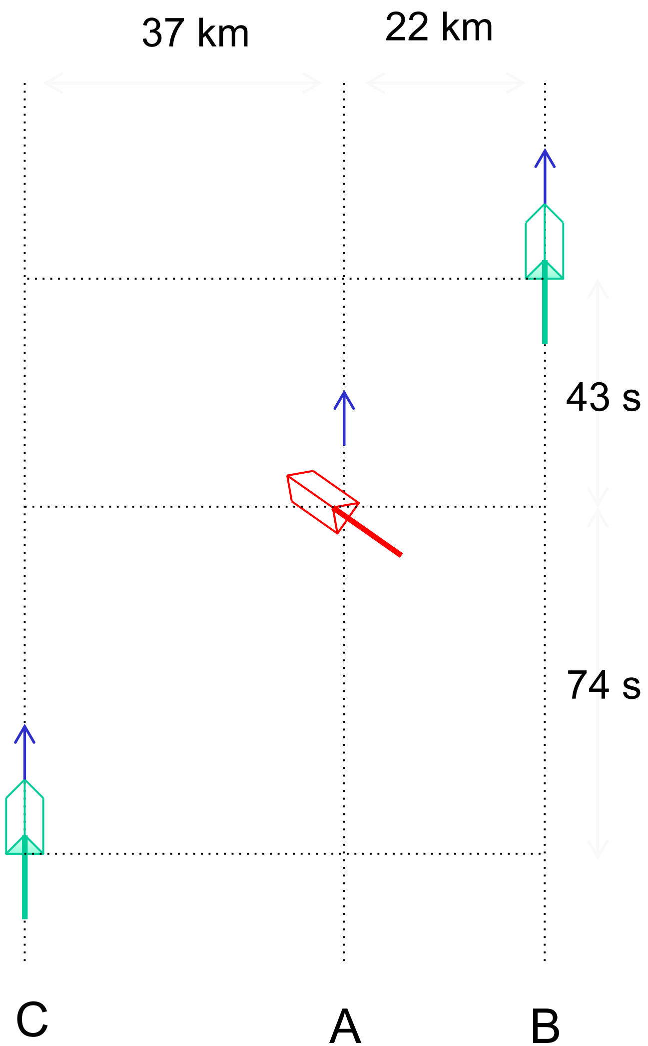
Bravo anomaly: 62° Slew Bravo Manoeuvre Predicted (optimized)



Bravo anomaly: 62° Slew Bravo Manoeuvre Comparison after removing predicted anomaly



Alpha anomaly: 62° Slew Alpha Manoeuvre Observed



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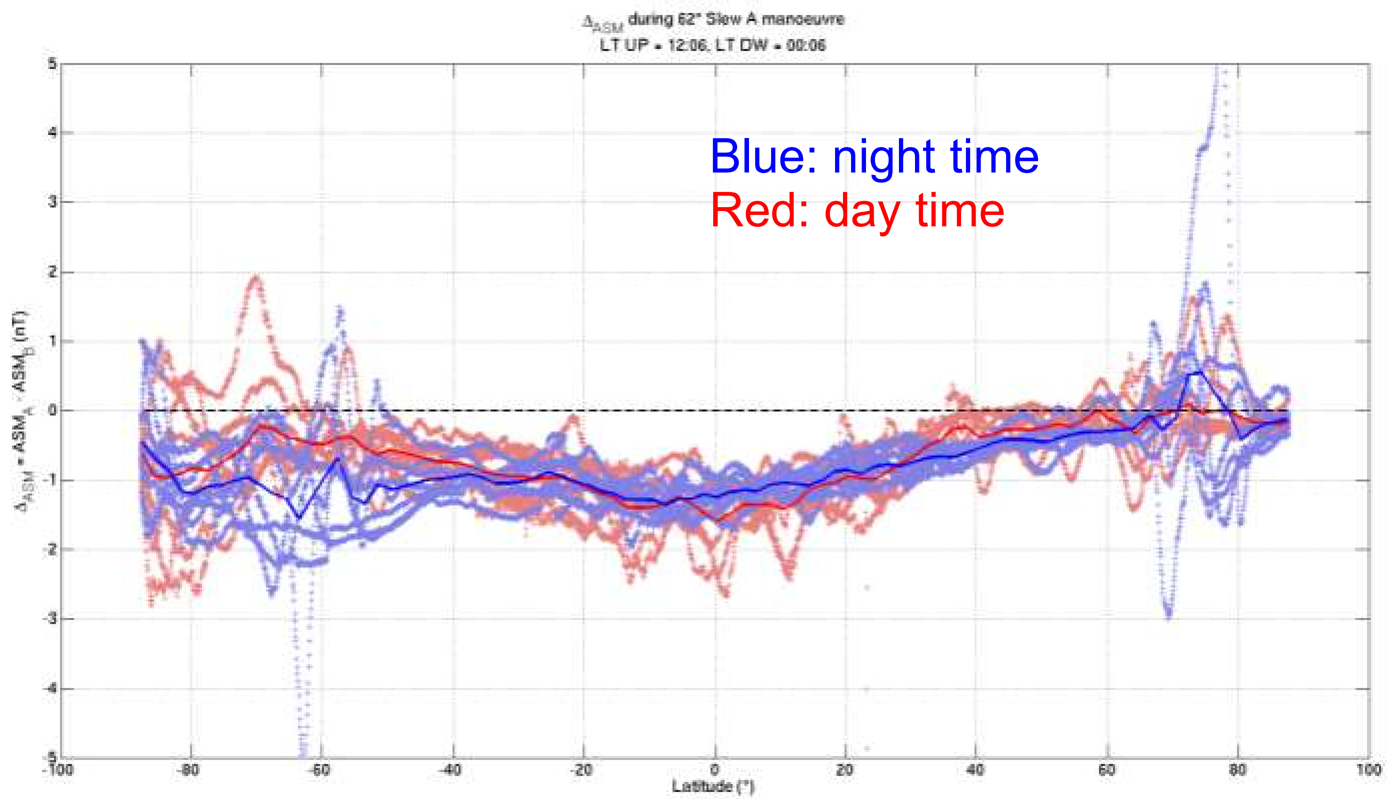
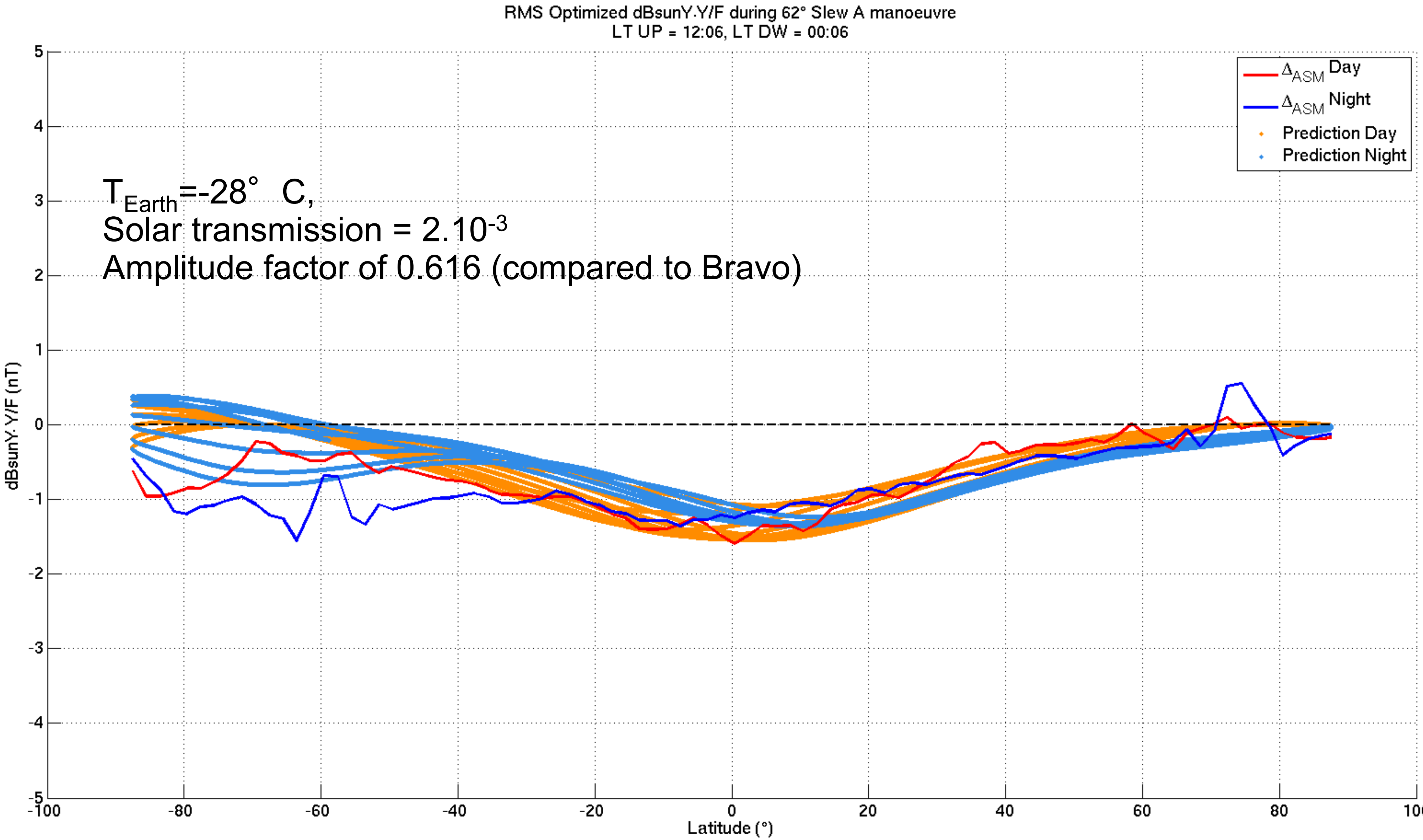
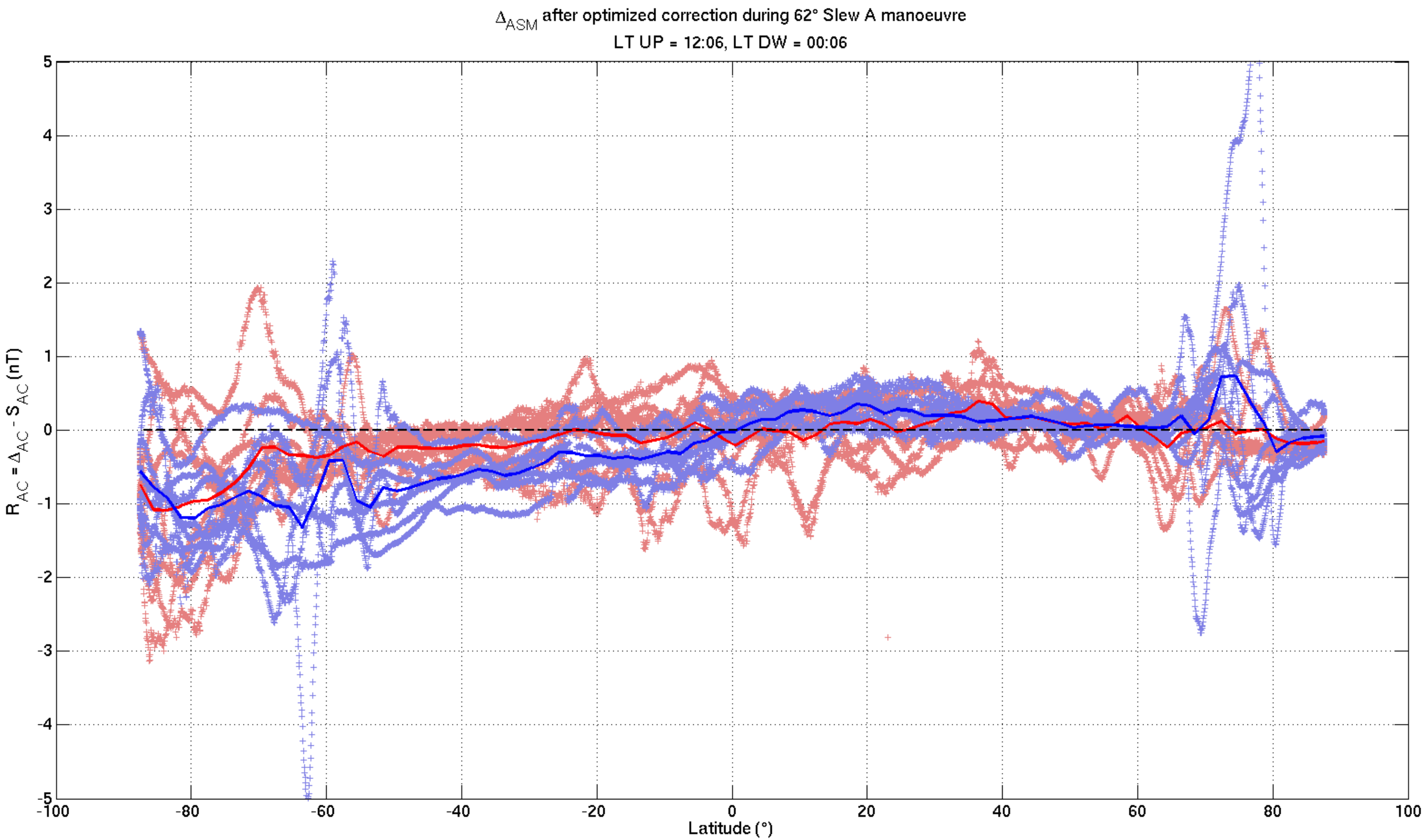


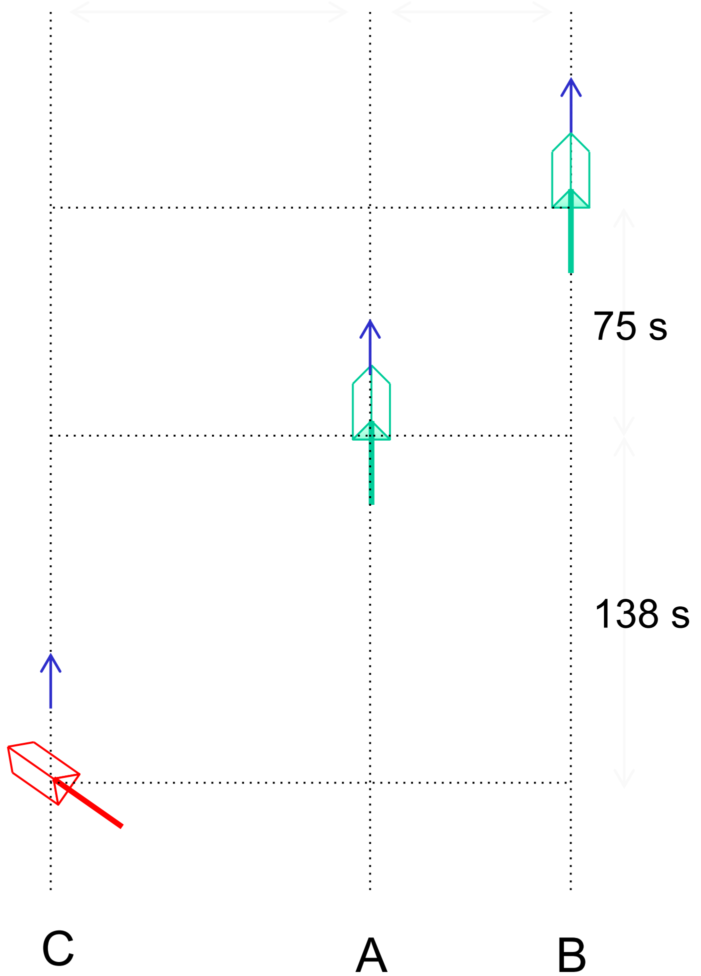
Alpha anomaly: 62° Slew Alpha Manoeuvre Predicted (optimized)



Alpha anomaly: 62° Slew Alpha Manoeuvre
Comparison after removing predicted anomaly



Charlie anomaly: 62° Slew Charlie Manoeuvre Observed



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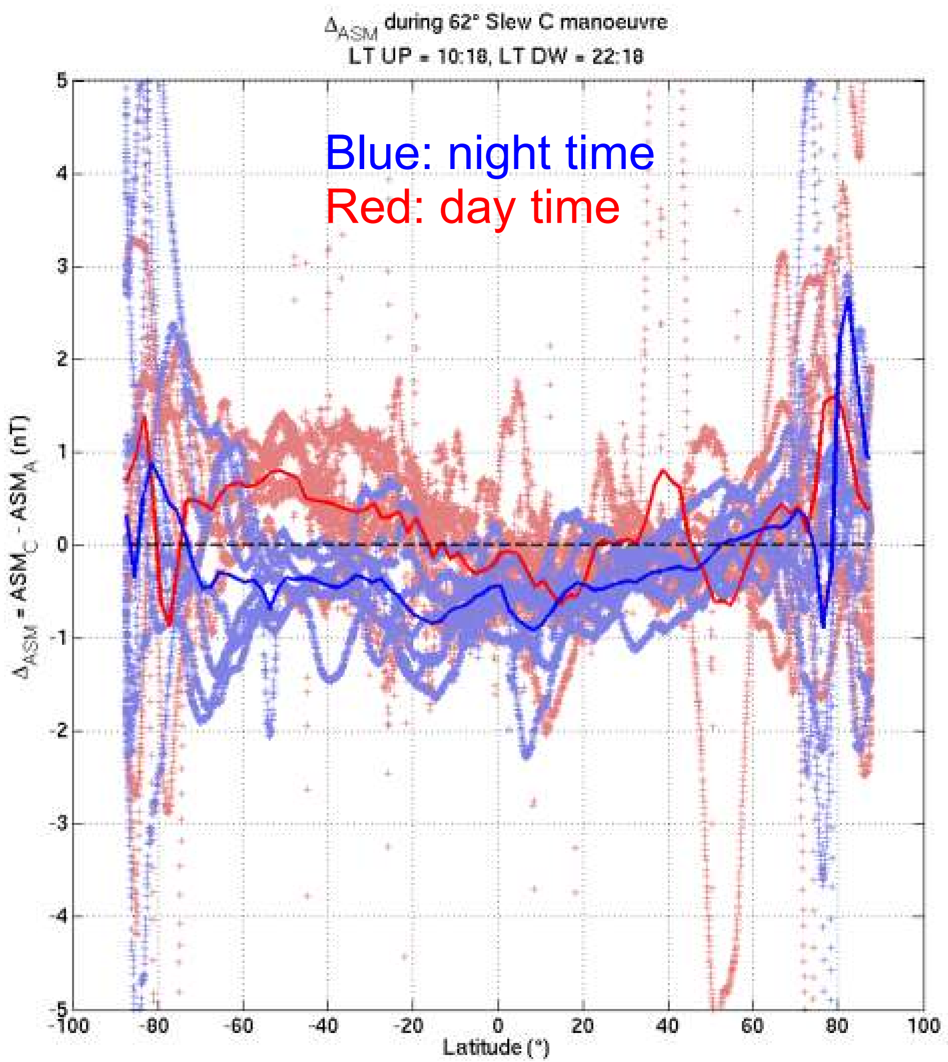
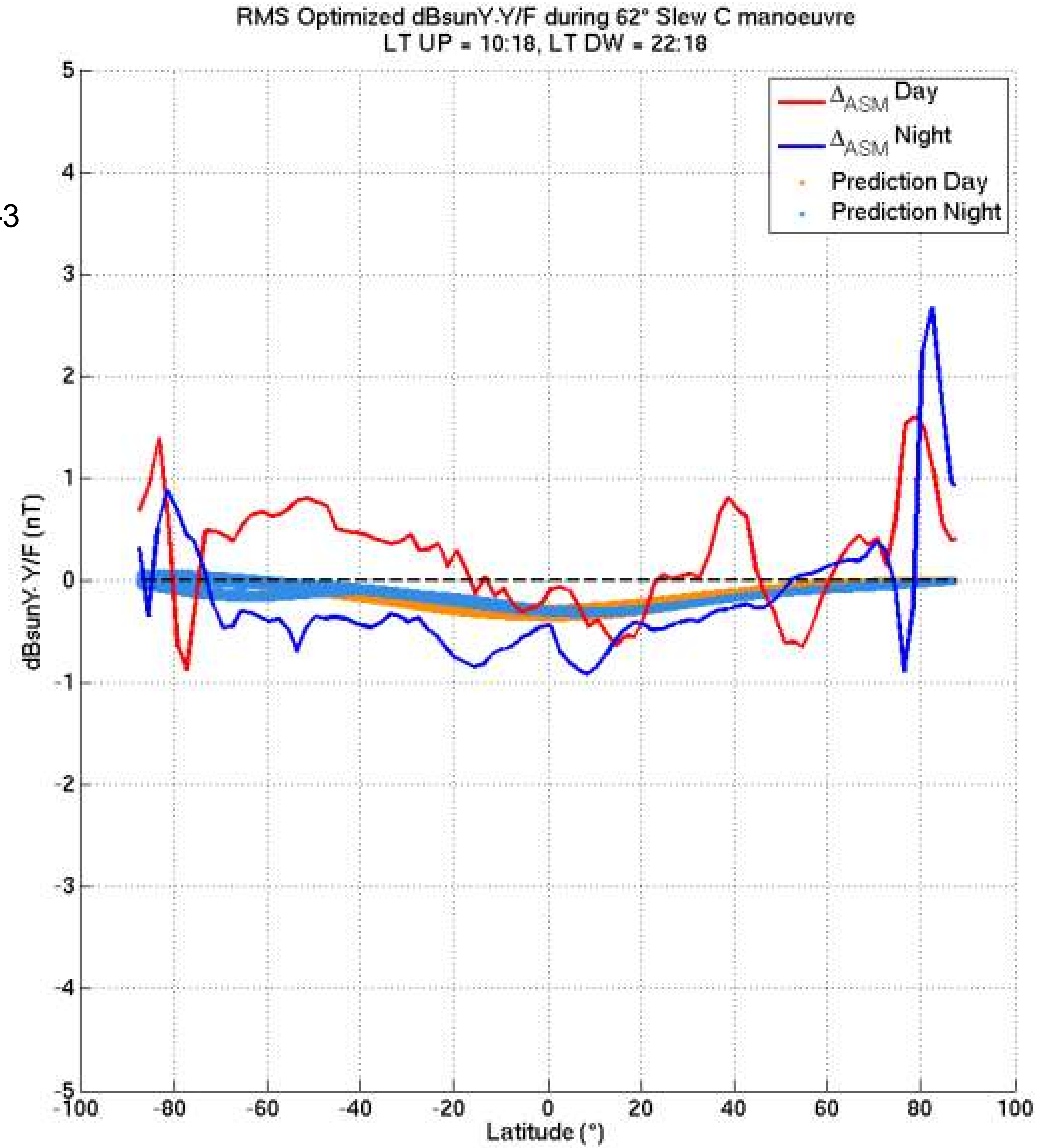
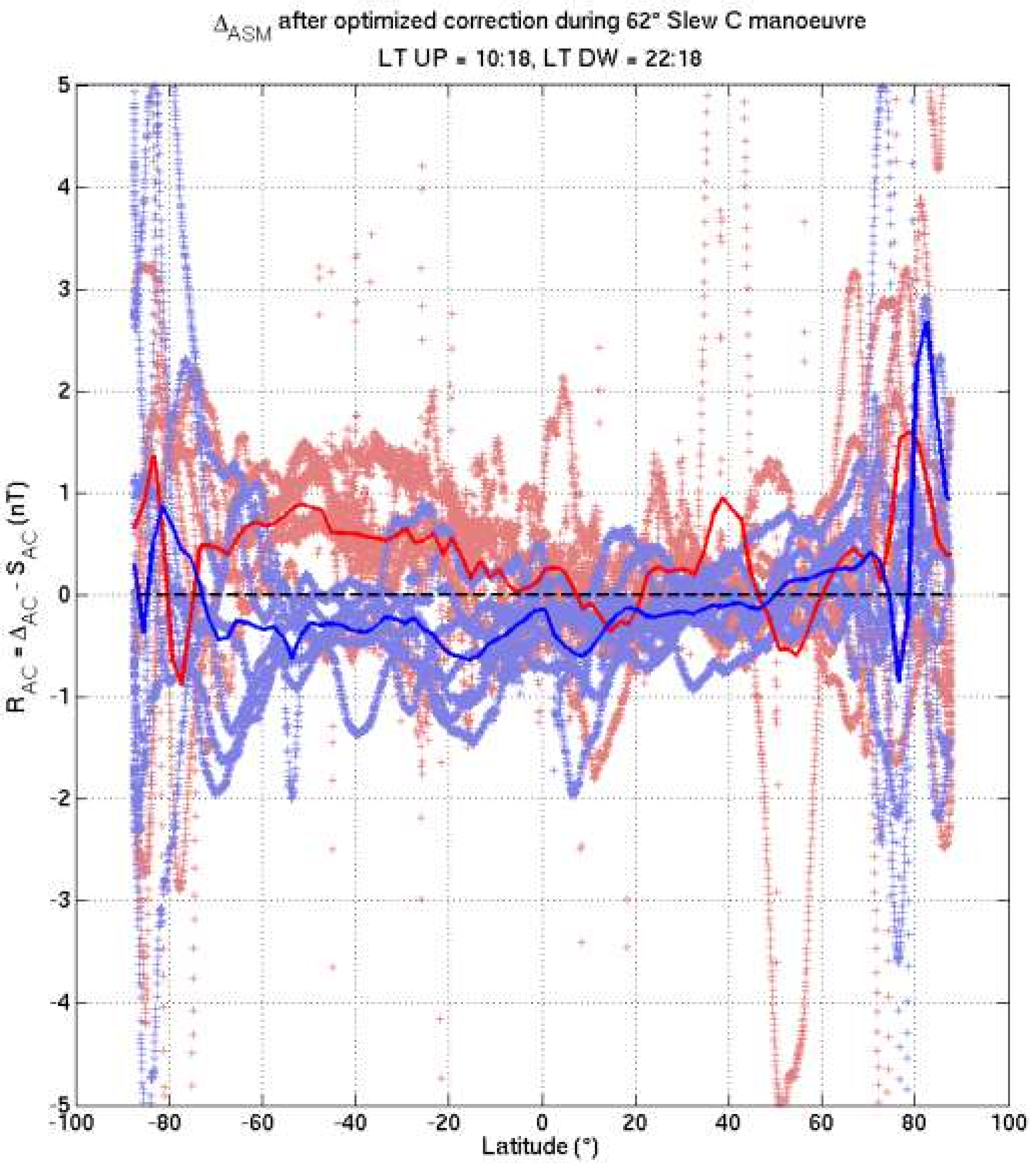


Charlie anomaly: 62° Slew Charlie Manoeuvre Predicted (optimized)

T_{Earth}=-27° C,
Solar transmission = 2.10^{-3}
Amplitude factor of 0.147
(compared to Bravo)



Charlie anomaly: 62° Slew Charlie Manoeuvre Comparison after removing predicted anomaly



Testing the models with the 90° Alpha/Charlie manoeuvres

Phase	C	A
1	↑	↑
2	↑	→
3	←	→
4	←	↓
5	↓	↓
6	↓	←
7	→	←
8	→	↑
9	↑	↑

We now apply the dBSun corrections to all satellites, using the parameters inferred from the Alpha, Bravo and Charlie slew manoeuvres, and check that they correctly account for the anomalies during the 90° Alpha/Charlie manoeuvres

Testing the models with the 90° Alpha/Charlie manoeuvres

Phase	C	A
1	↑	↑
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7	→	←
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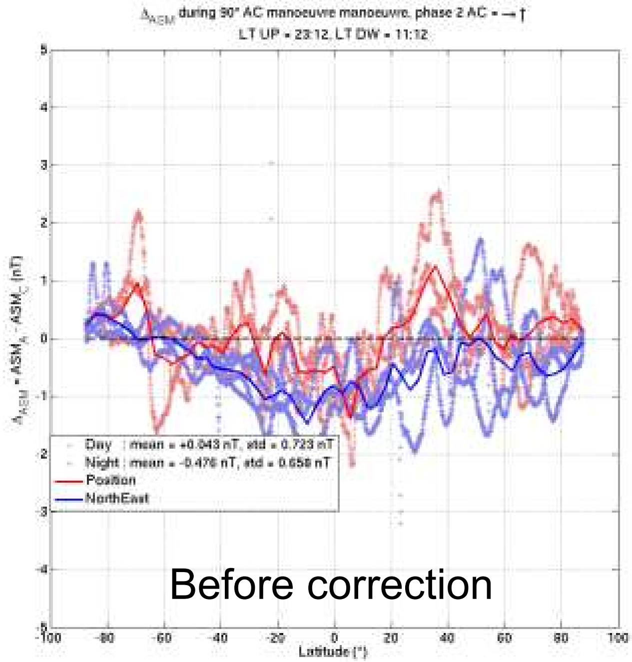
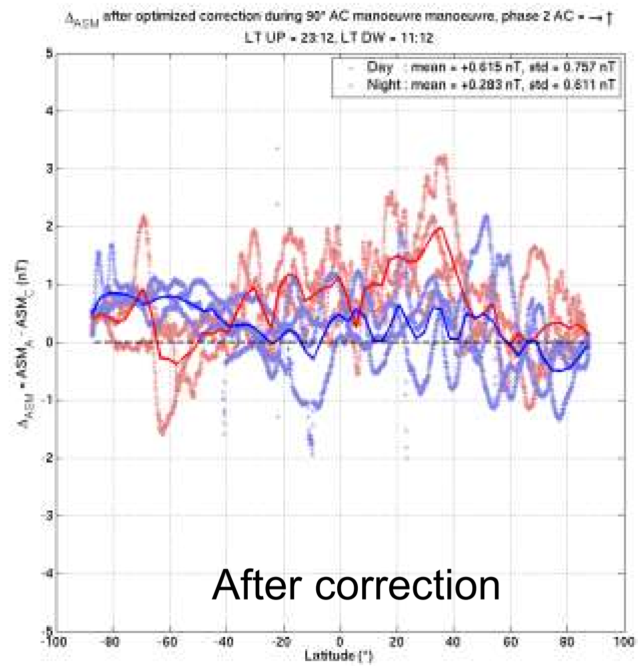
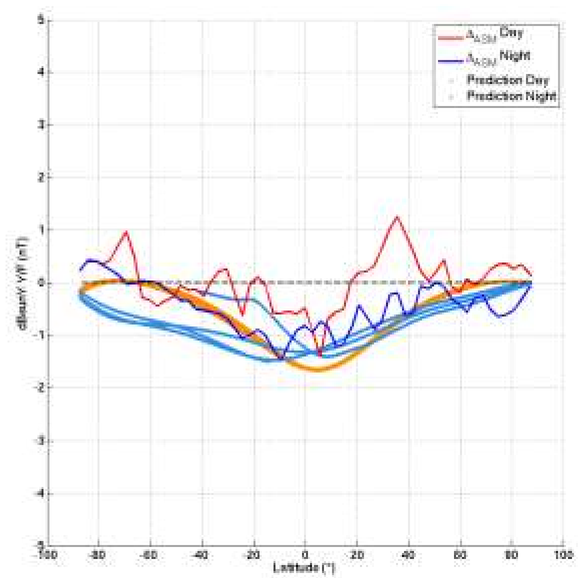
9	↑	↑







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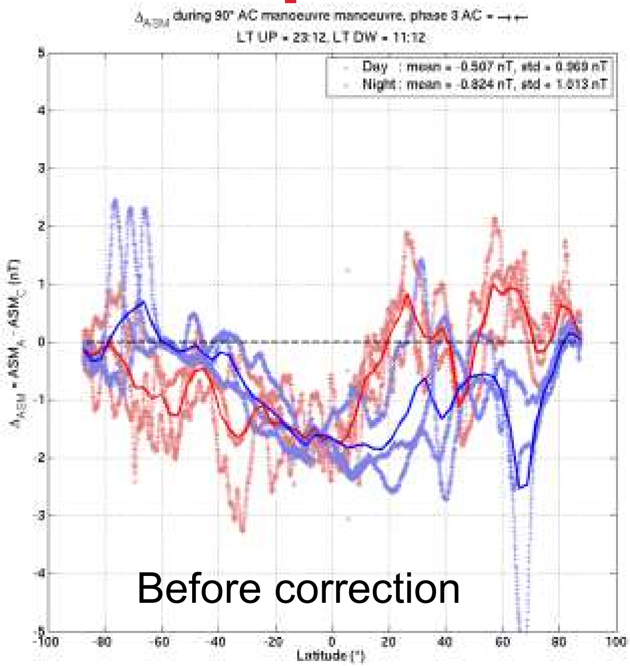

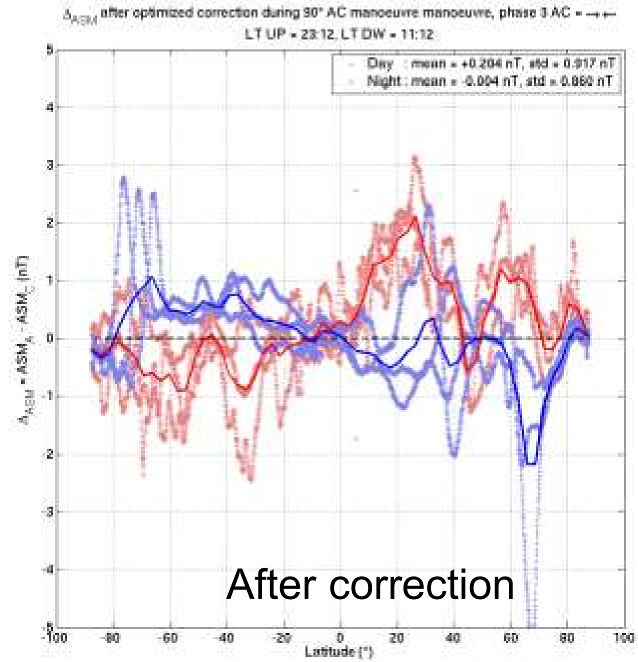

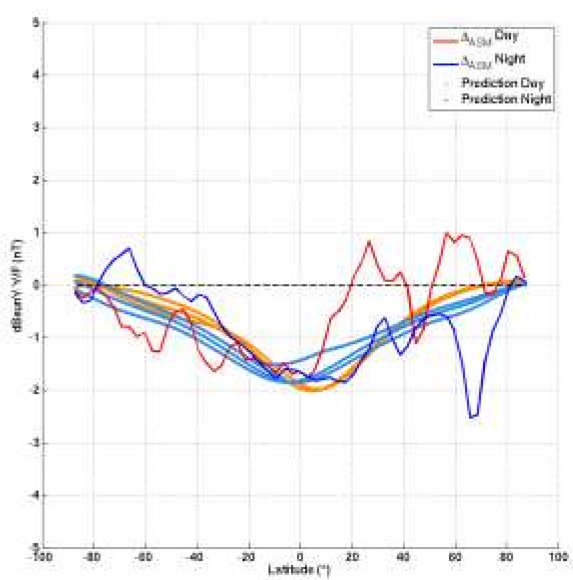

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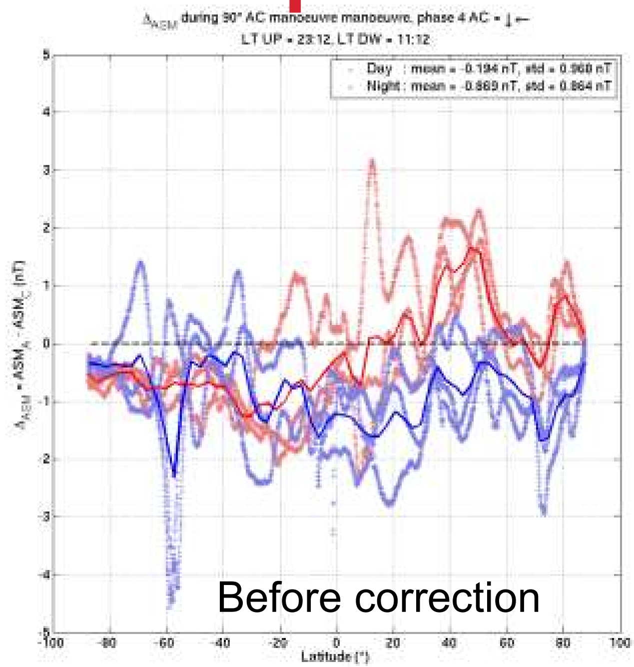
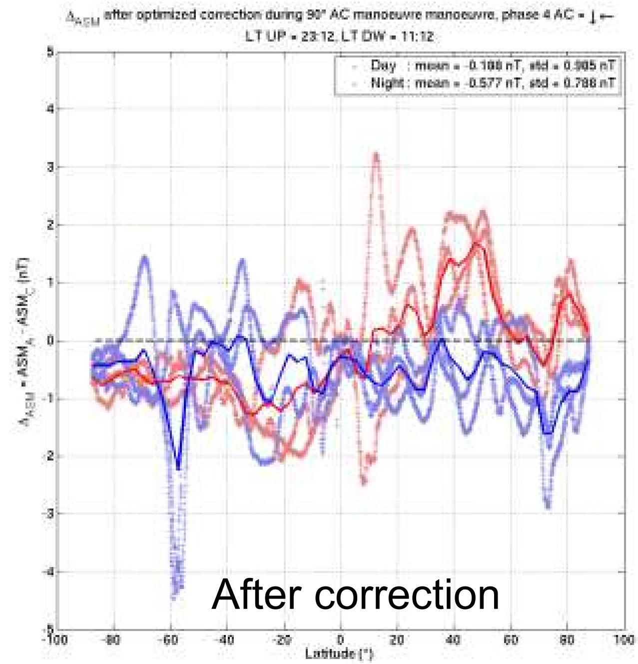
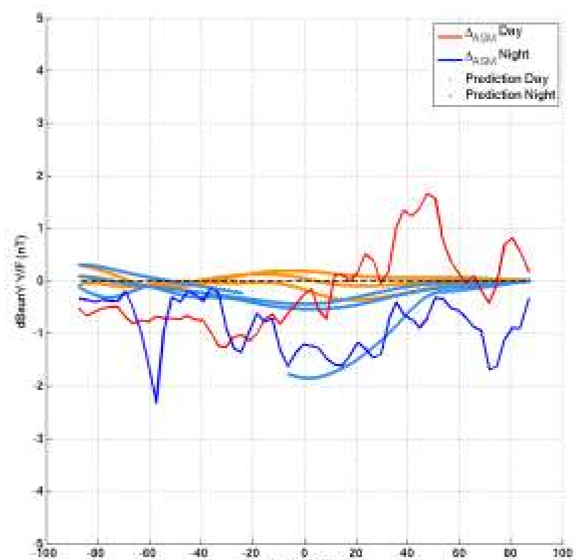
9	↑	↑







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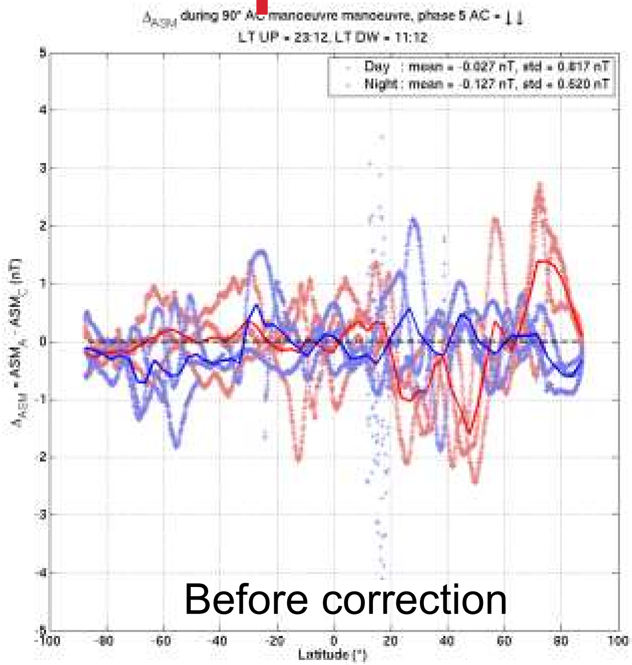

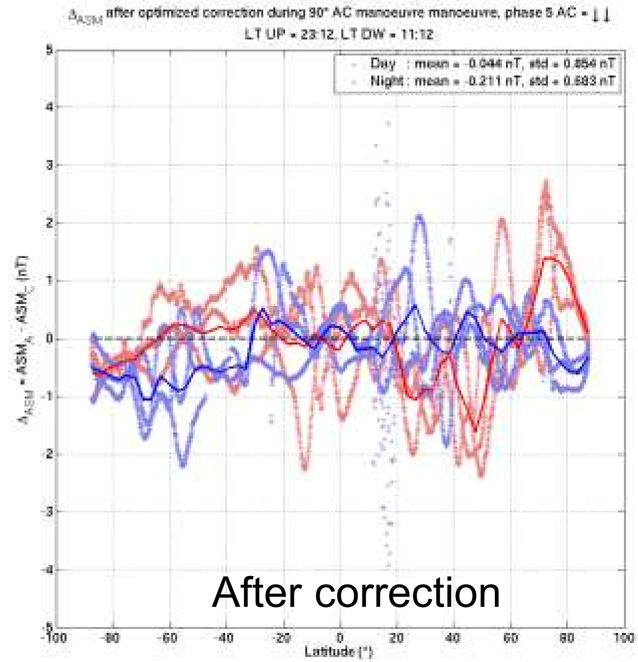

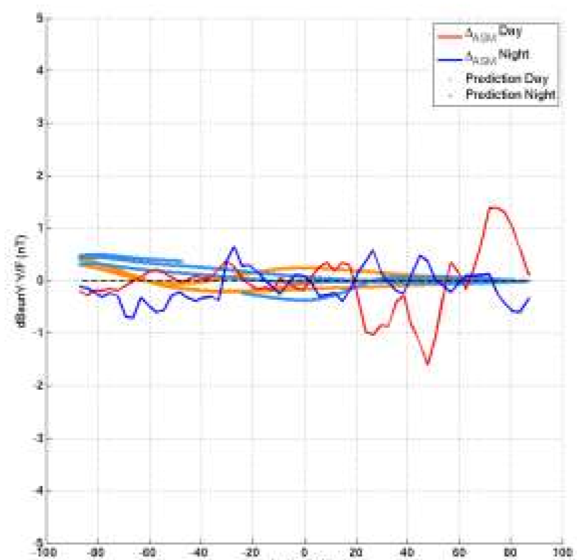

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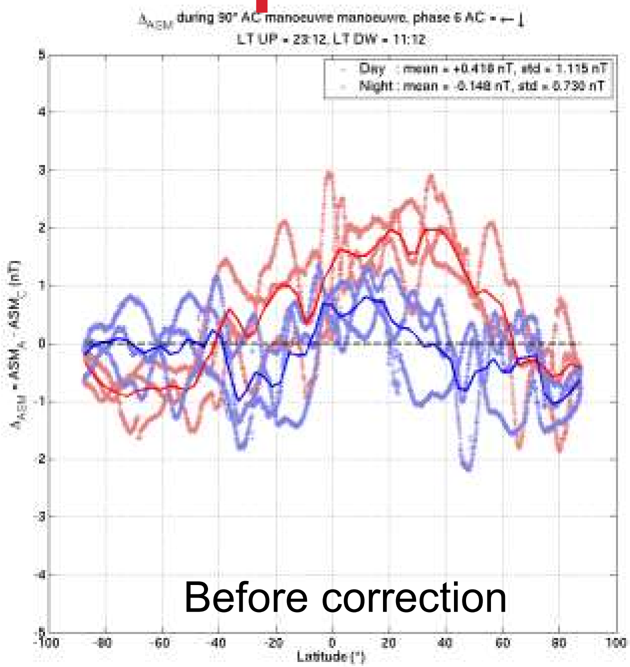

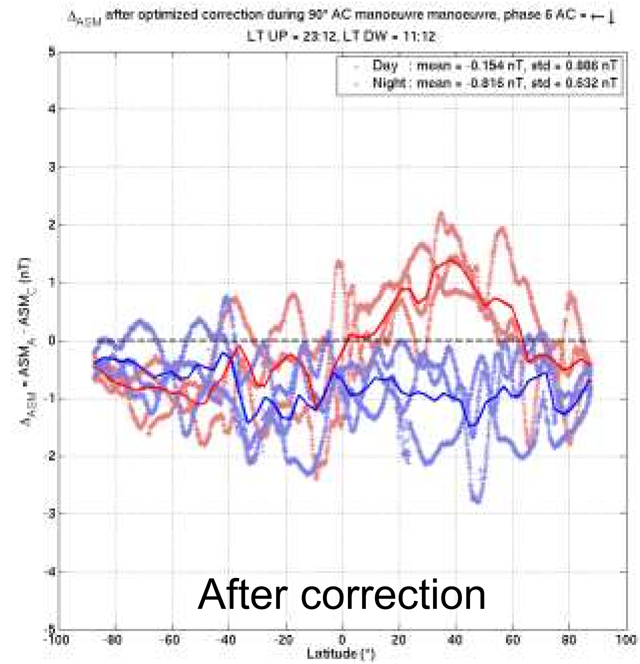

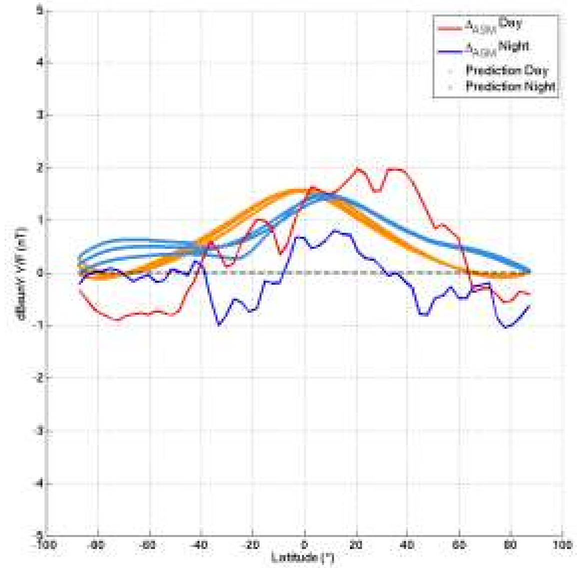

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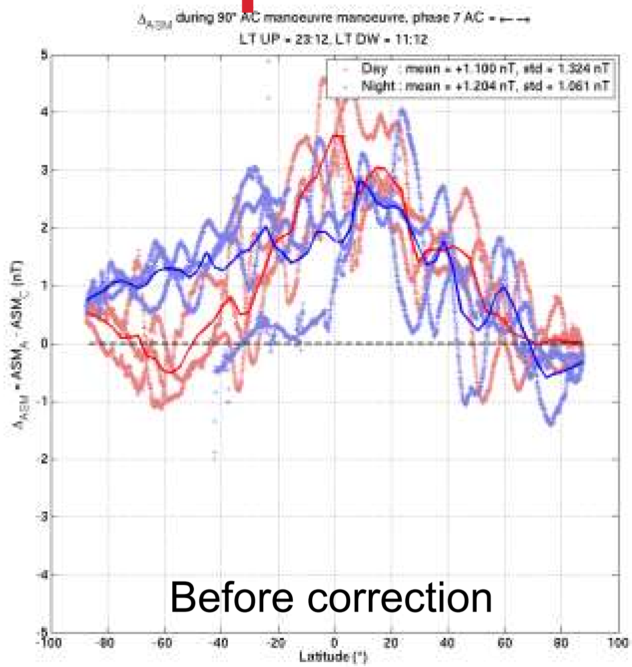

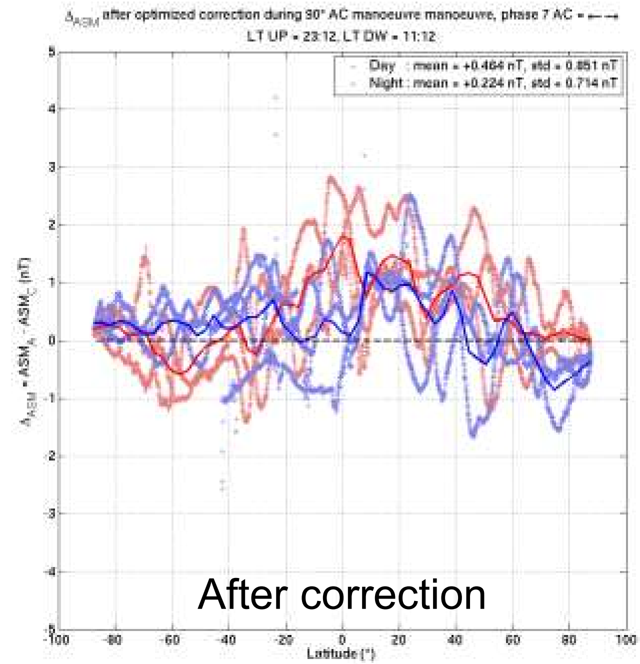

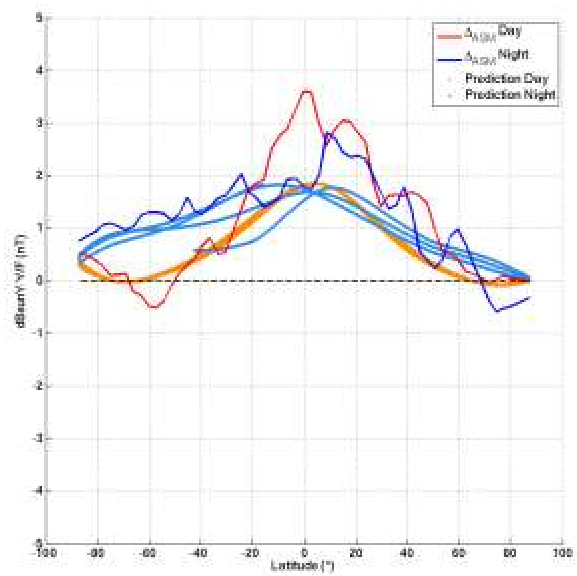

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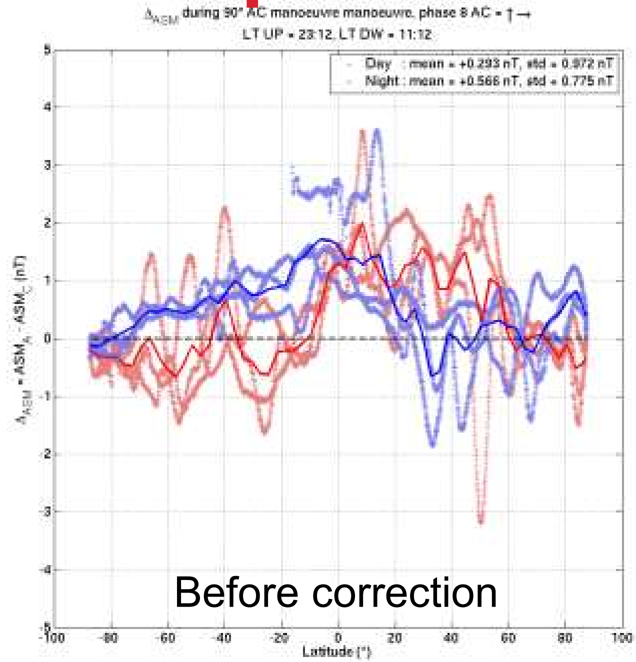

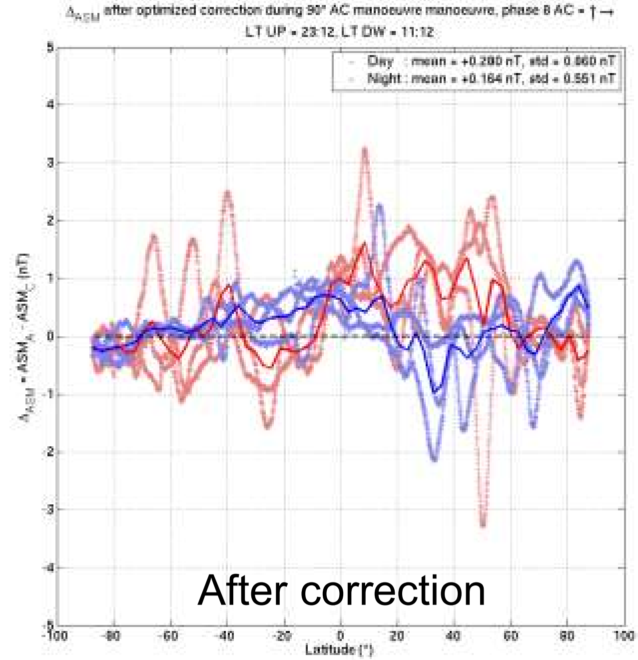

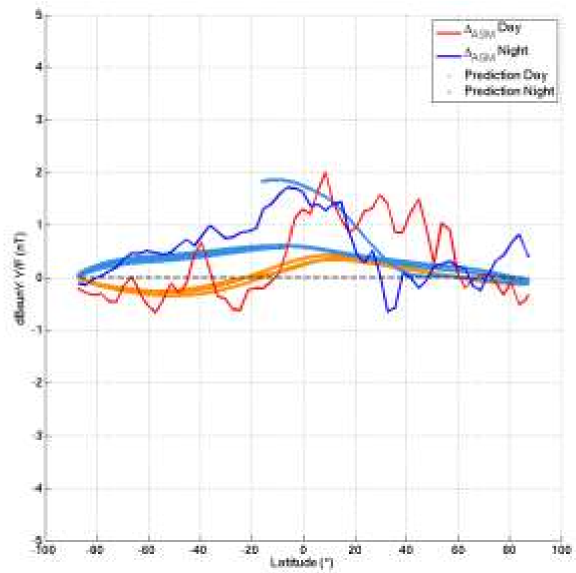

Testing the models with the 90° Alpha/Charlie manoeuvres

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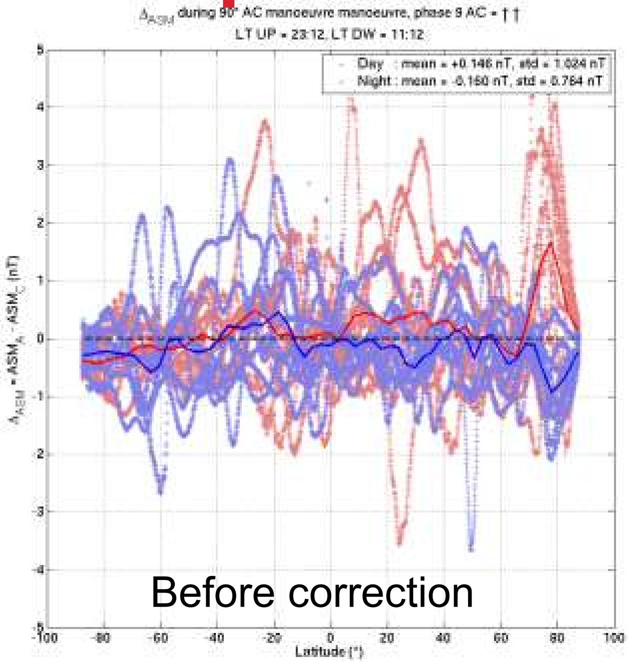
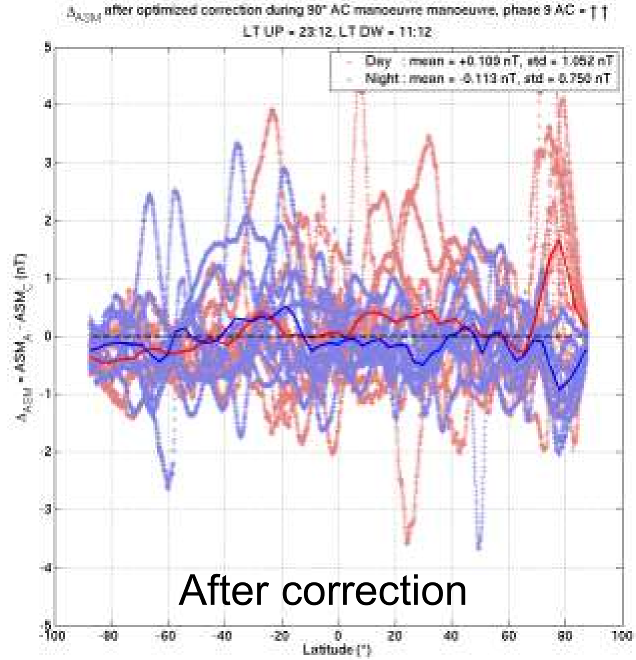
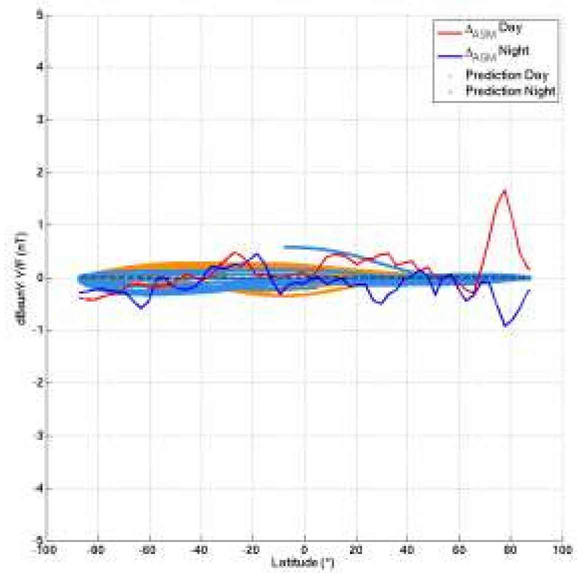
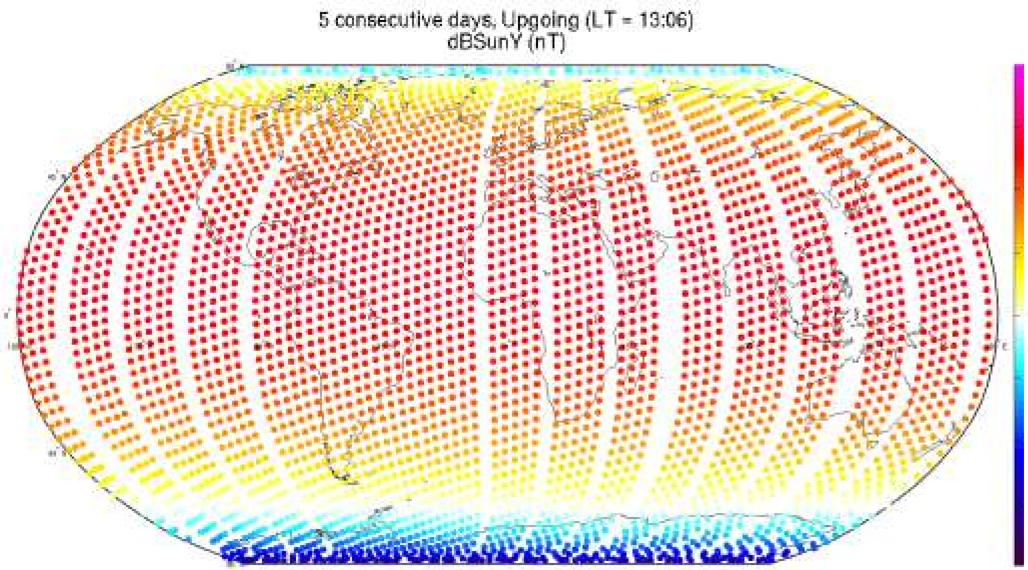




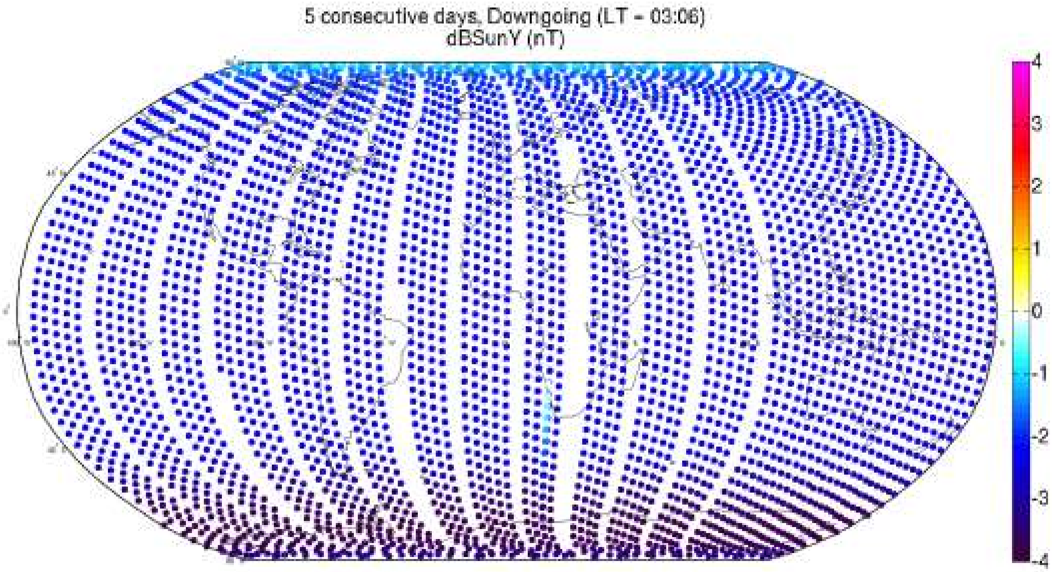


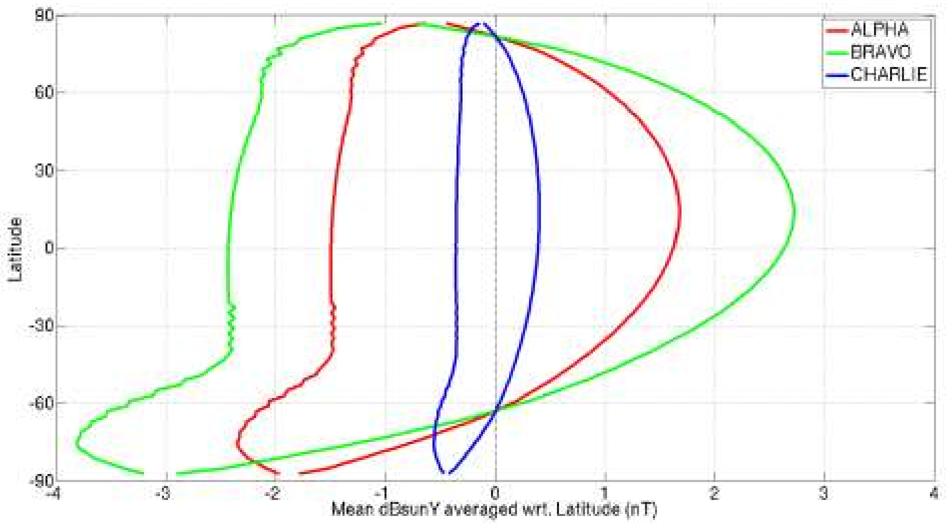
Typical dBSun_Y prediction for Bravo (maps) and all satellites (average of latitudinal profiles)

LT: 13:06



LT: 01:06





Peak to Peak amplitudes:
Alpha: - 2.3 nT -> + 1.8 nT
Bravo: - 3.8 nT -> + 2.8 nT
Charlie: - 0.5 nT -> + 0.5 nT

Conclusion and way forward

- The **perturbation model of P. Brauer is doing an encouraging job at accounting for the anomalies observed during manoeuvres.**
- Results point at a **strong effect on the Y component of Bravo (3-4 nT), weaker on Alpha (2 nT) and small on Charlie (0.5 nT)**
- Currently, the parameters of the model are (poorly) constrained by the ASM scalar data during 62° slew manoeuvres and tested on the 90° manoeuvres.
- **A joint simultaneous inversion for all manoeuvres could improve the perturbation model**

-> more work to be done...

- **Another avenue for testing/improving the correction model could be to test the ability of the correction to lead to "better" geomagnetic field models when using ASM-V experimental data...** But this is not trivial (see presentation by Vigneron et al. "Geomagnetic field modelling based on ASM-V experimental data")
- **This is an important issue: we do not want to correct the VFM data for a perturbation which is in fact affecting the ASM instrument !**