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**Dept.:**

*Astronomy  
and  
Space Physics*

**Instructor:**

*Andris Vaivads*

**Examiner:**

*Annika Olsson*

# Parallel electric fields in space

**Observations by Cluster satellites inside the auroral zone at altitudes above the main acceleration region**

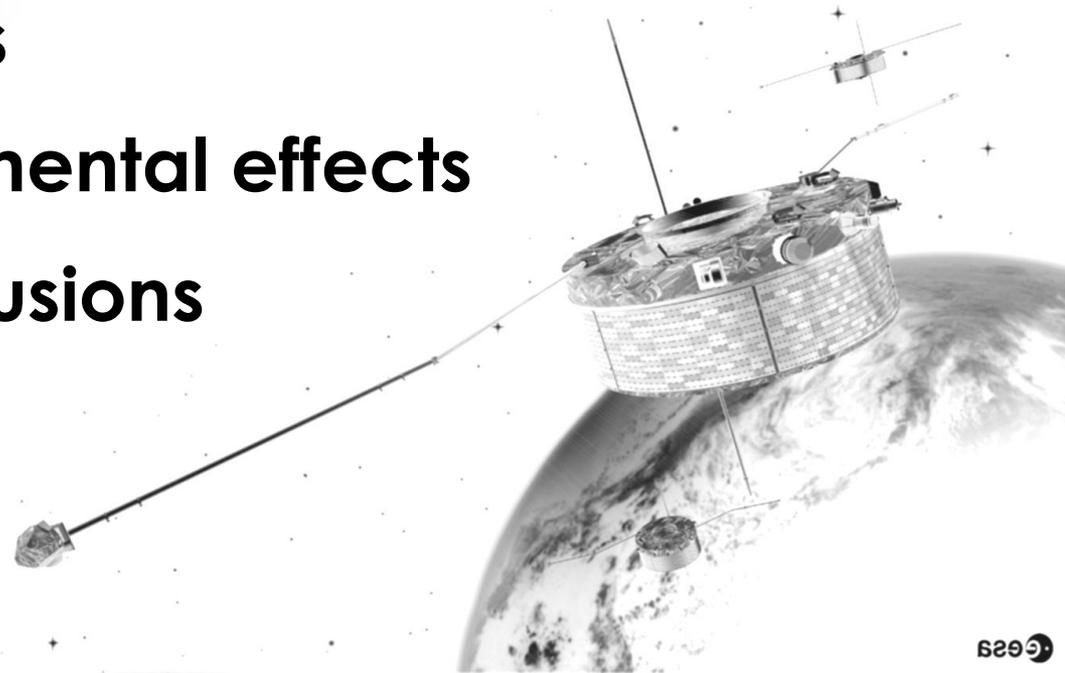
***Presentation of Master Thesis  
by Erik Bergman***





# Contents

- ❑ Introduction
- ❑ Handling the data
- ❑ Selection strategy
- ❑ Results
- ❑ Instrumental effects
- ❑ Conclusions

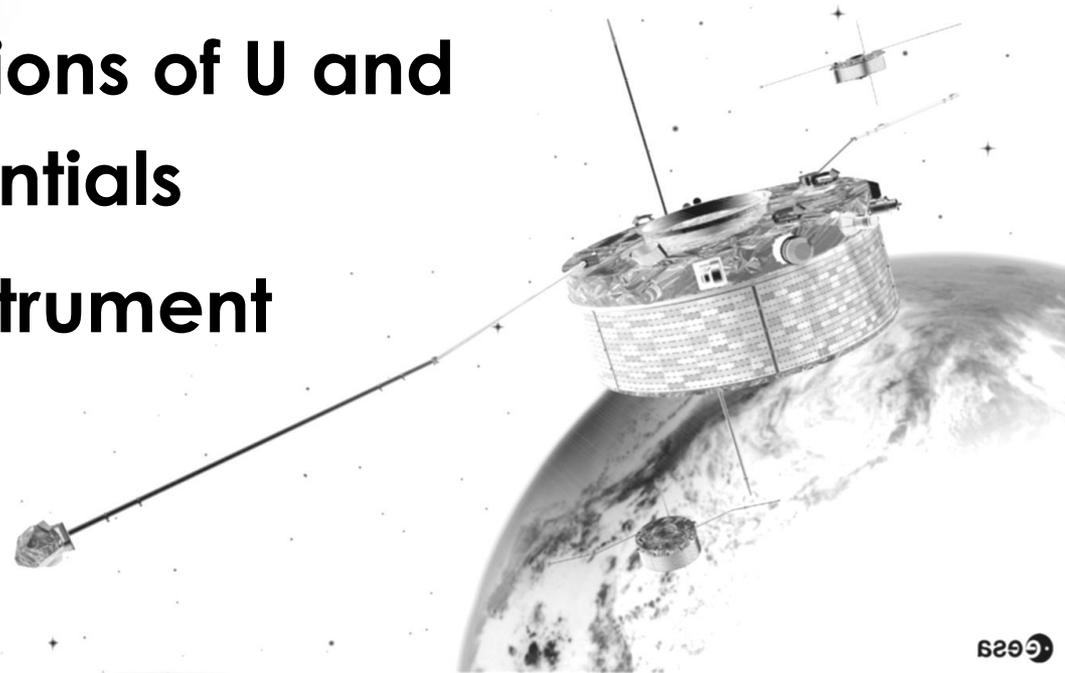




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# Introduction

- ❑ Discrete auroras
- ❑ Auroral oval
- ❑ Potential models
- ❑ Predictions of U and O-potentials
- ❑ EFW instrument



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# Discrete auroras



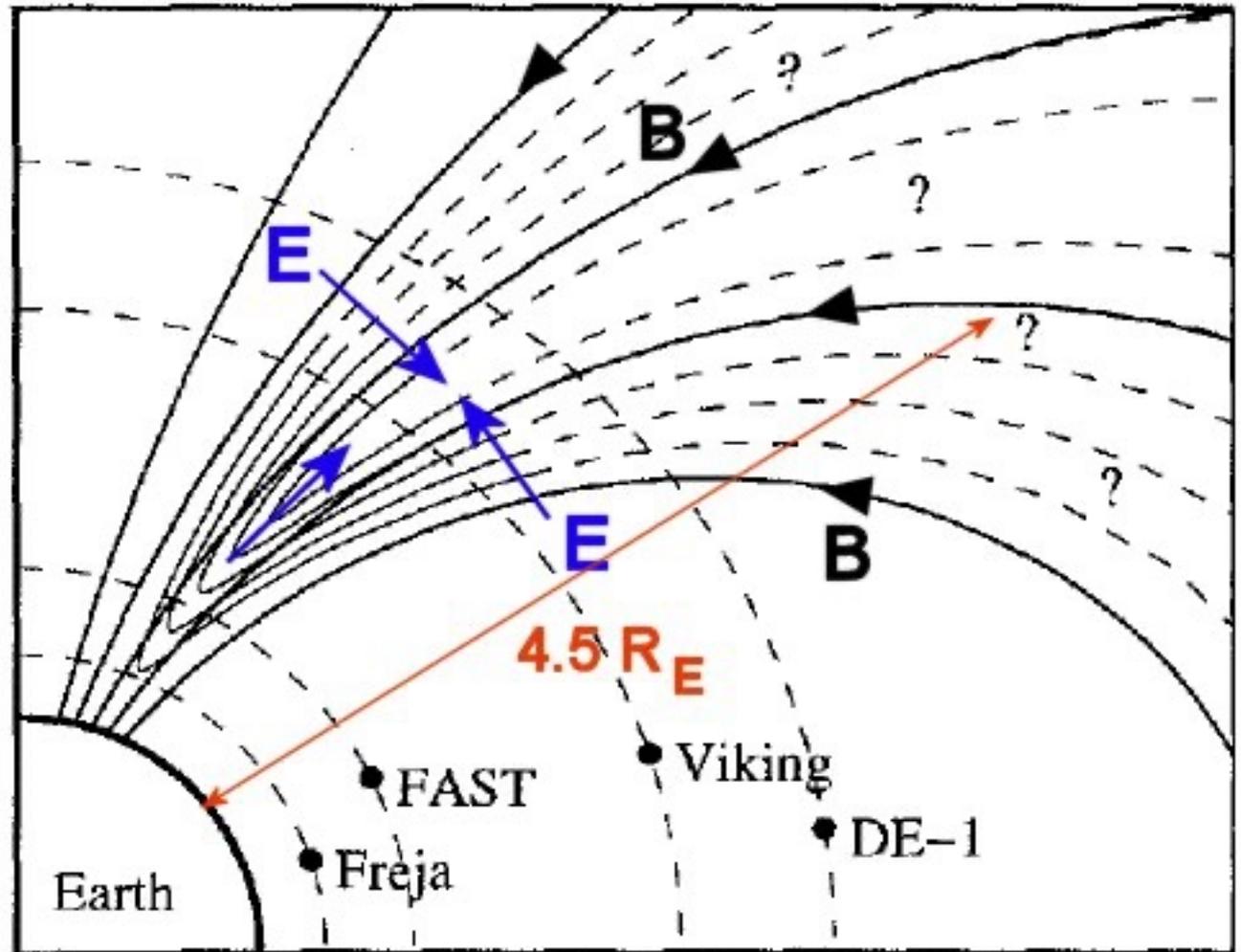
**Discrete auroral arcs:**

- **Caused by electrons accelerated by parallel E-fields usually at 1-2  $R_E$**
- **North-South, 100 m – 80 km, typically 5 km**
- **Mapped to Cluster altitude ( $\sim 4.5 R_E$ ) this equals 50 km**
- **At Cluster speed ( $\sim 5$  km/s) the size of parallel E-fields would be  $\sim 10$  seconds**

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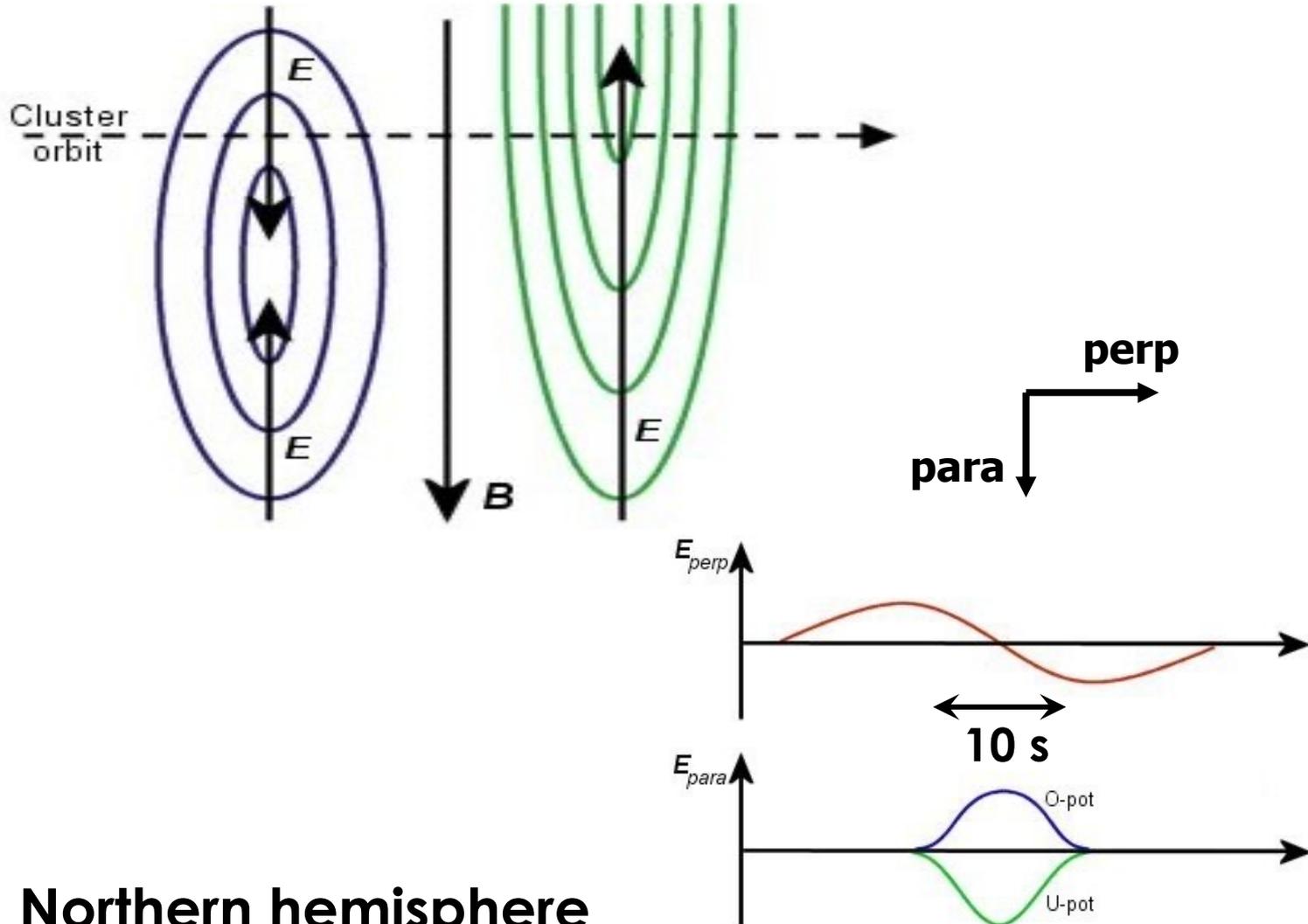
# Potential models



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# Predictions of U and O-pot



Northern hemisphere

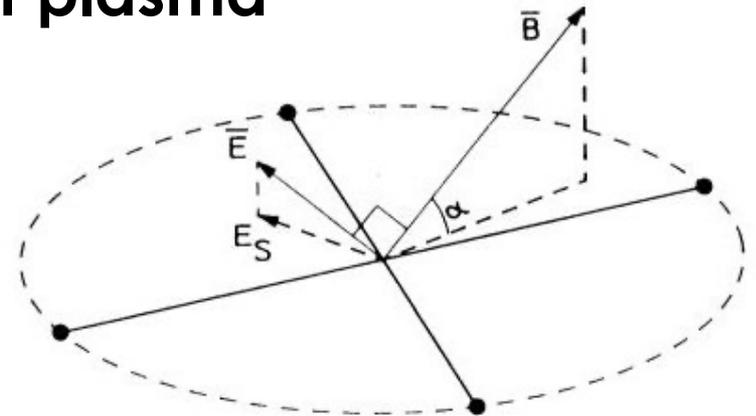
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# Electric Field and Wave experiment

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- Four identical probes
- Voltage mode, to measure electric fields, only in spinplane
- Current mode, to measure density and temperature of plasma



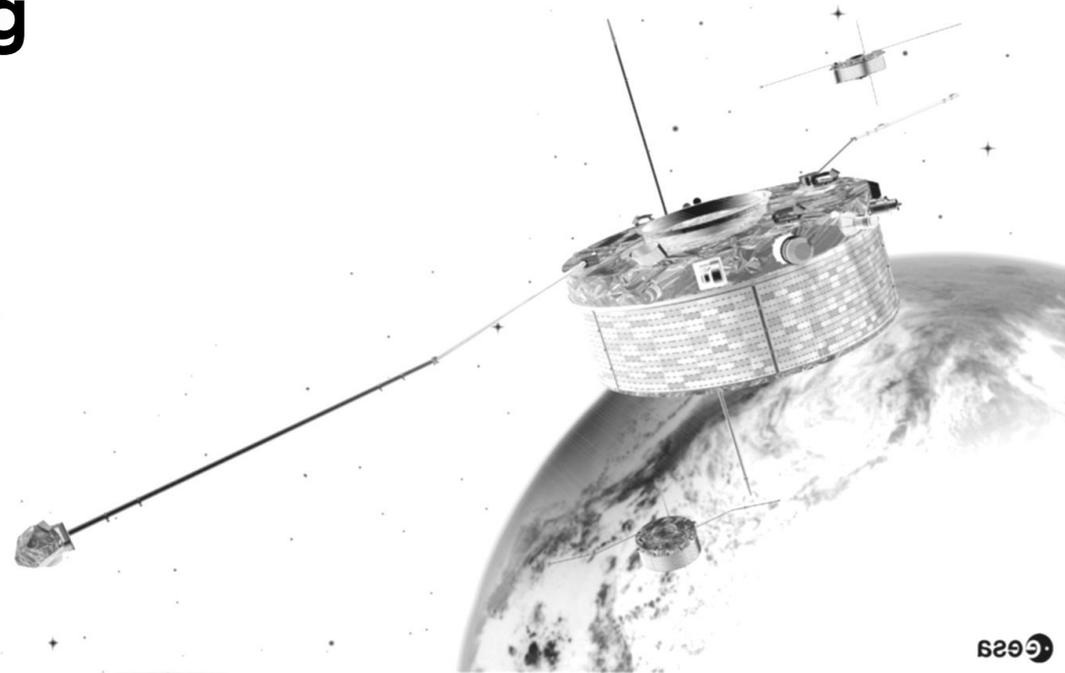


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# Handling the data

- ❑ **Coordinate systems**
- ❑ **Calculations and assumptions**
- ❑ **Filtering**

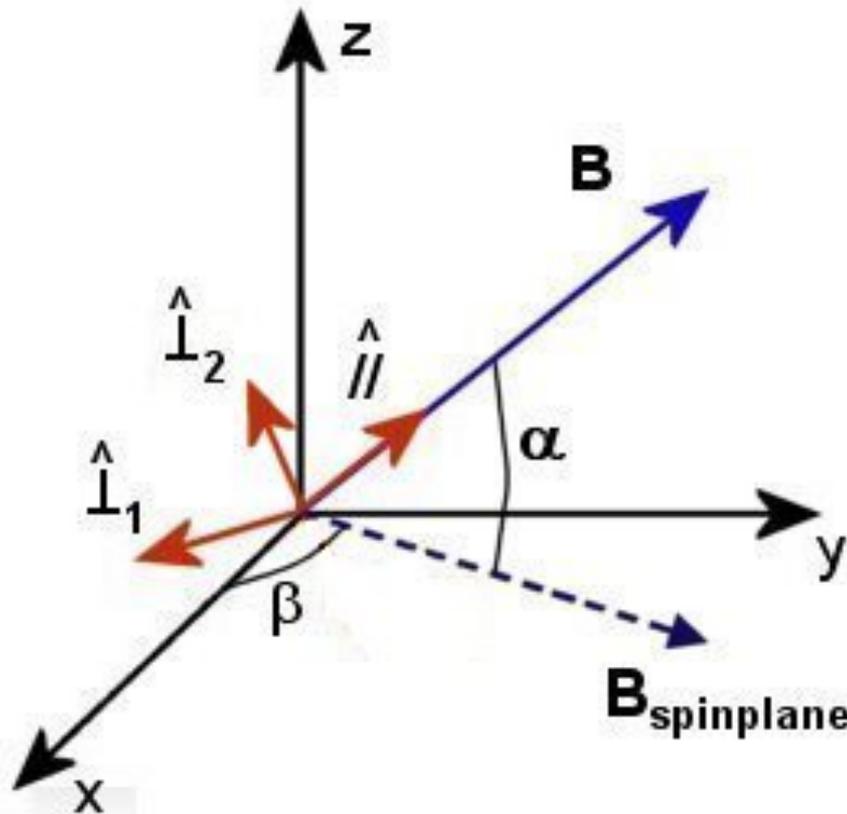
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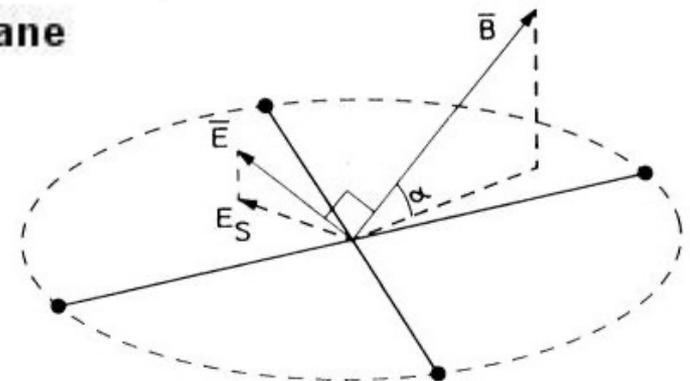
# Coordinate systems



$$\hat{\mathbf{l}}_1 = \text{norm}(\mathbf{B} \times \hat{\mathbf{z}})$$

$$\hat{\mathbf{l}}_2 = \text{norm}(\hat{\mathbf{l}}_1 \times \mathbf{B})$$

$$\hat{\mathbf{l}}_{\parallel} = \text{norm}(\mathbf{B})$$





# Calculations and assumptions

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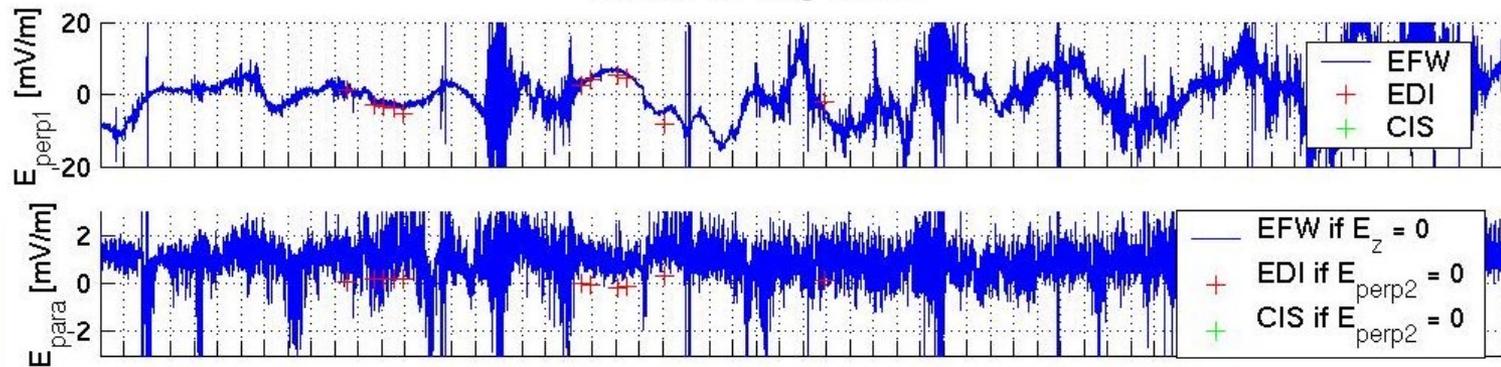
|                                      | $E_z = 0$               | $E_{\parallel} = 0$             | $E_{\perp_2} = 0$               |
|--------------------------------------|-------------------------|---------------------------------|---------------------------------|
| $\mathbf{E} \cdot \hat{\parallel} =$ | $E_{\parallel}^{E_z=0}$ | 0                               | $E_{\parallel}^{E_{\perp_2}=0}$ |
| $\mathbf{E} \cdot \hat{\perp}_1 =$   | $E_{\perp_1}$           | $E_{\perp_1}$                   | $E_{\perp_1}$                   |
| $\mathbf{E} \cdot \hat{\perp}_2 =$   | $E_{\perp_2}^{E_z=0}$   | $E_{\perp_2}^{E_{\parallel}=0}$ | 0                               |



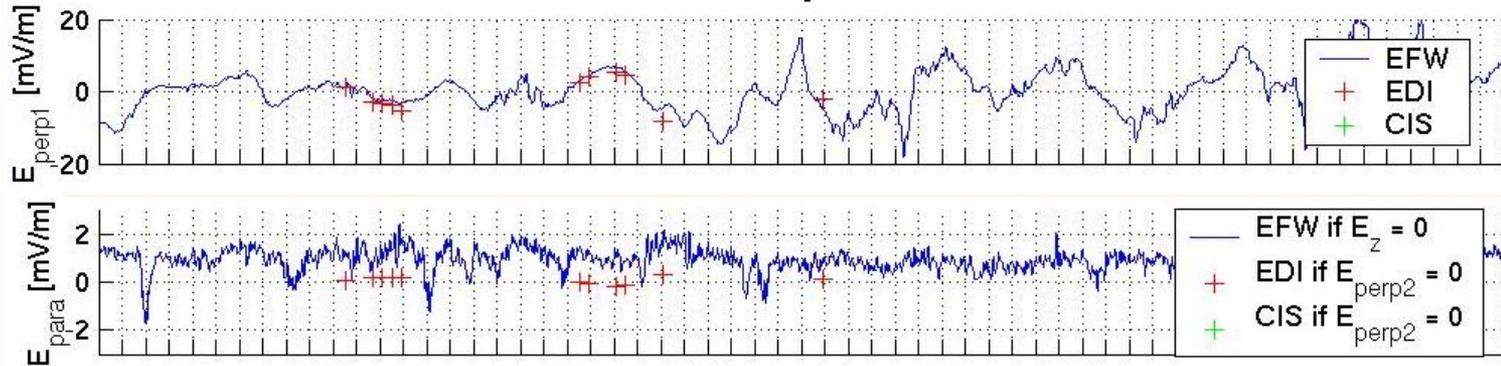
# Filtering

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Without any filter



With 0.7 Hz lowpass filter



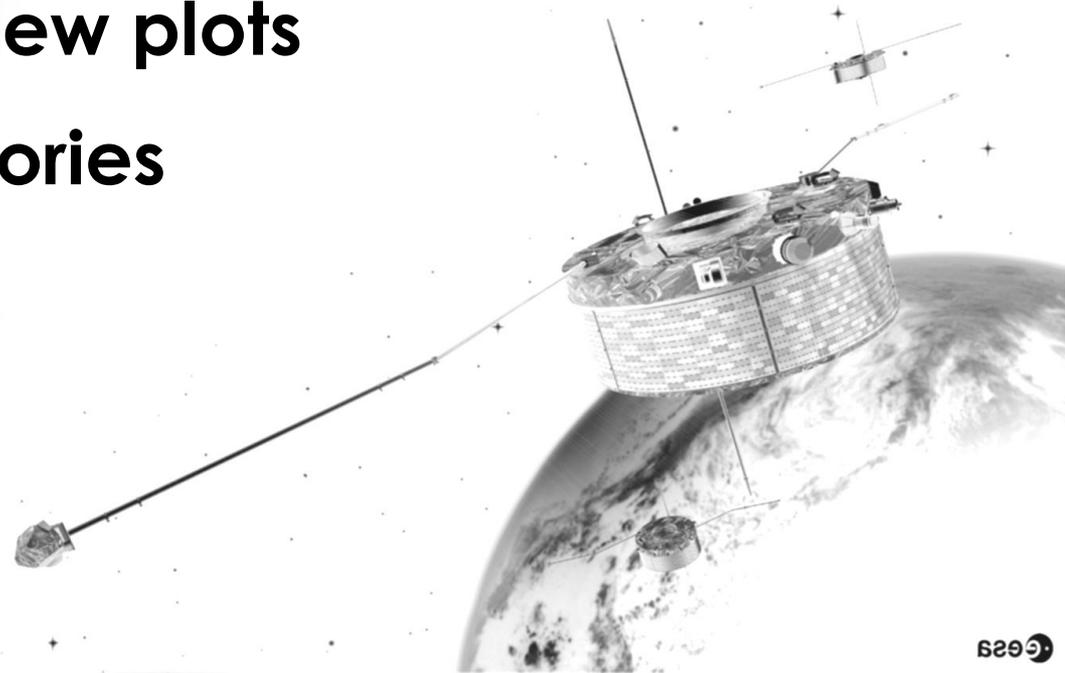


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# Selection strategy

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- ☐ **Orbits**
- ☐ **Quicklook plots**
- ☐ **Overview plots**
- ☐ **Catagories**

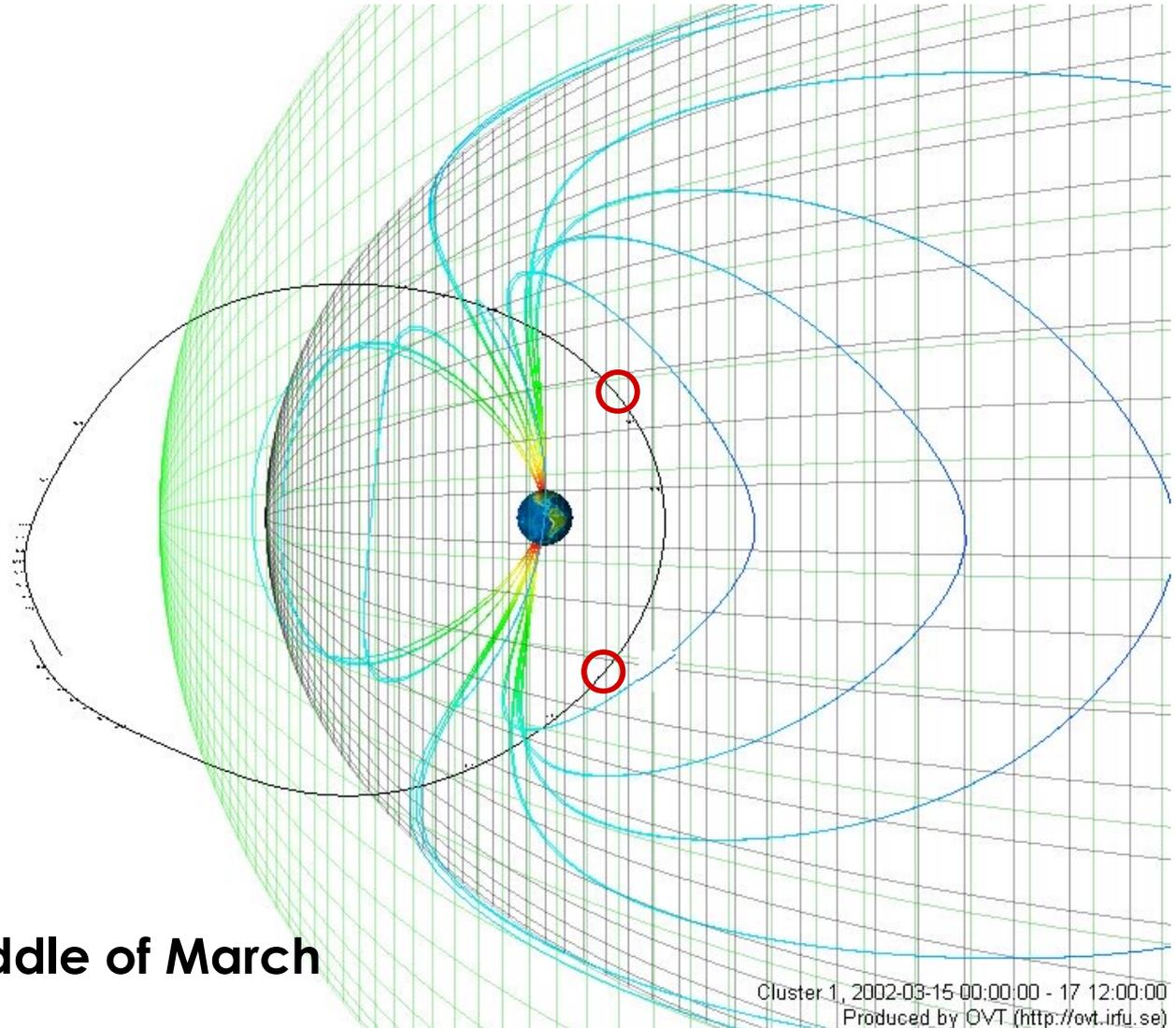




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# Orbits



**Middle of March**

Cluster 1, 2002-03-15 00:00:00 - 17 12:00:00  
Produced by OVT (<http://ovt.ifu.se>)

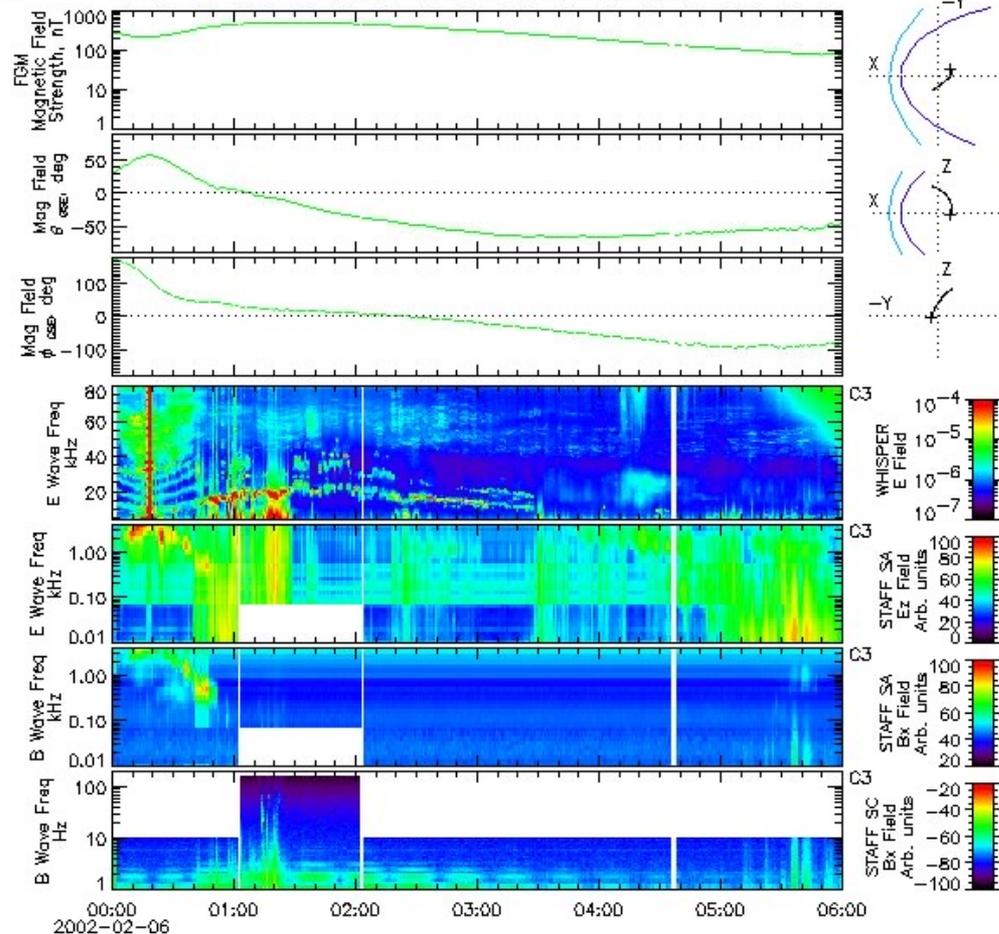


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# Quicklook Plot



Cluster Quicklook 6-hour: Fields & Waves  
2002-02-06 00:00-06:00



Last Updated: Thu Aug 22 14:47:52 2002

<http://www.cluster.lac.uk/cadswab/>

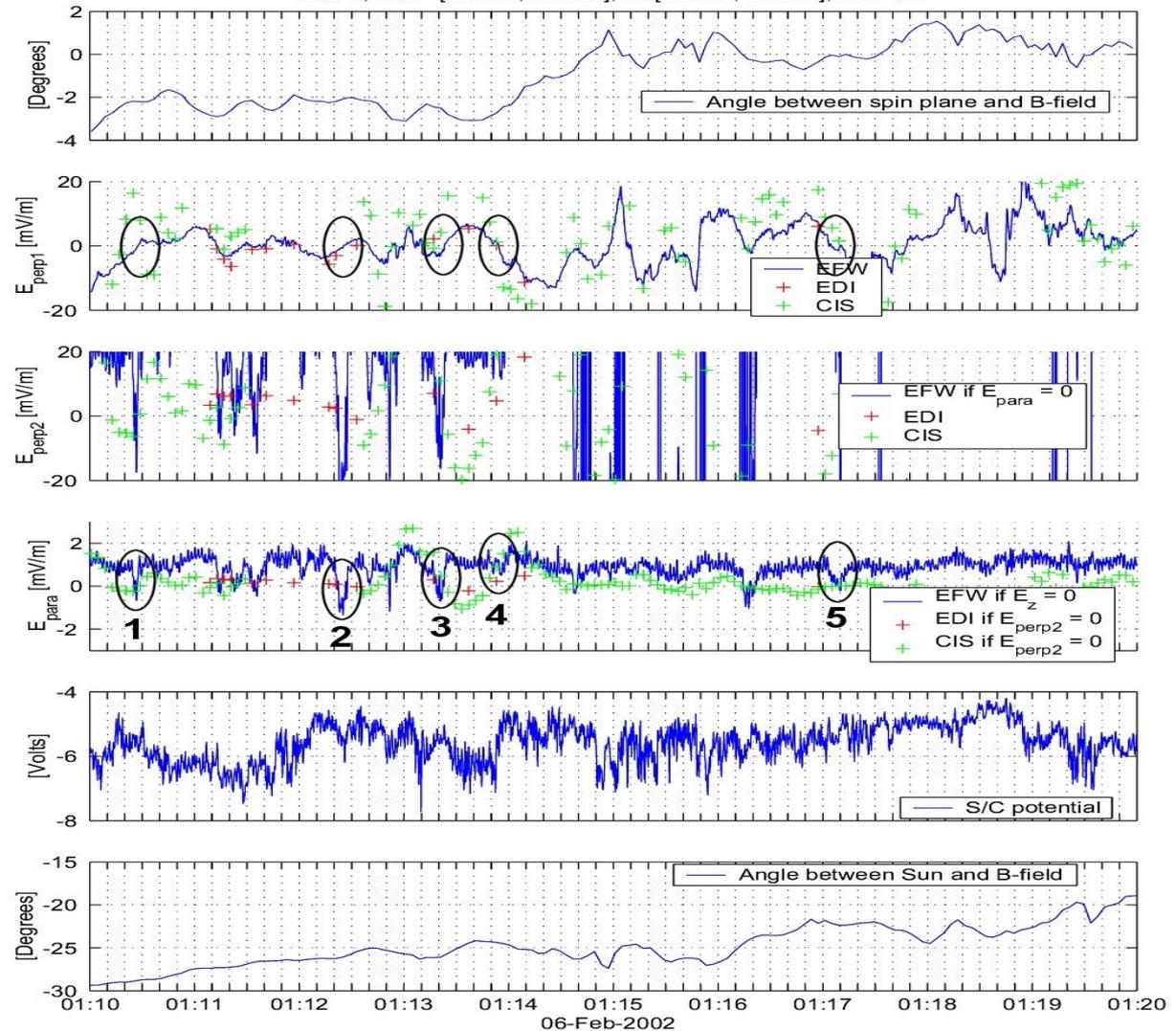
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# Overview Plot

S/C-3, ILAT=[67.602, 69.158], R=[4.5538, 4.6226], filter=0.7



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# Catagories

- **500 zero crossings (Jan-May, 2001-2002)**
- **57 events selected for closer inspection**
- **Divided into four sub catagories**
  - **16 – No activity**
  - **23 – No perpendicular activity**
  - **5 – Too active**
  - **13 – Good events**
- **5 events selected from the good**

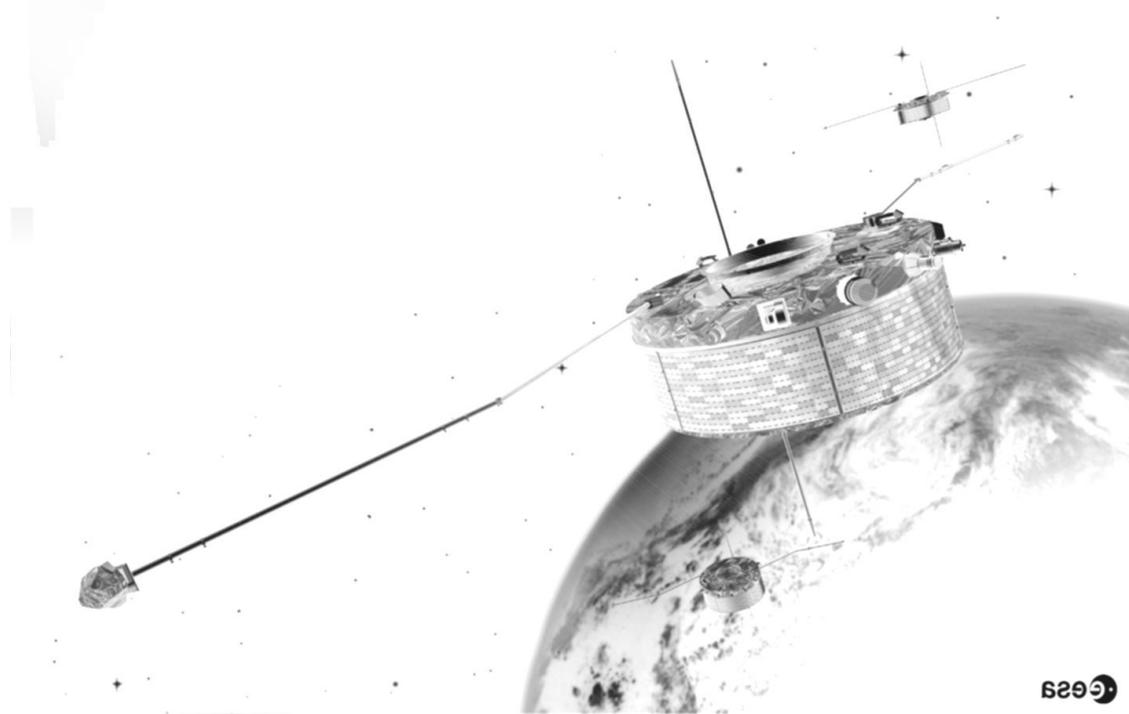


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# Results

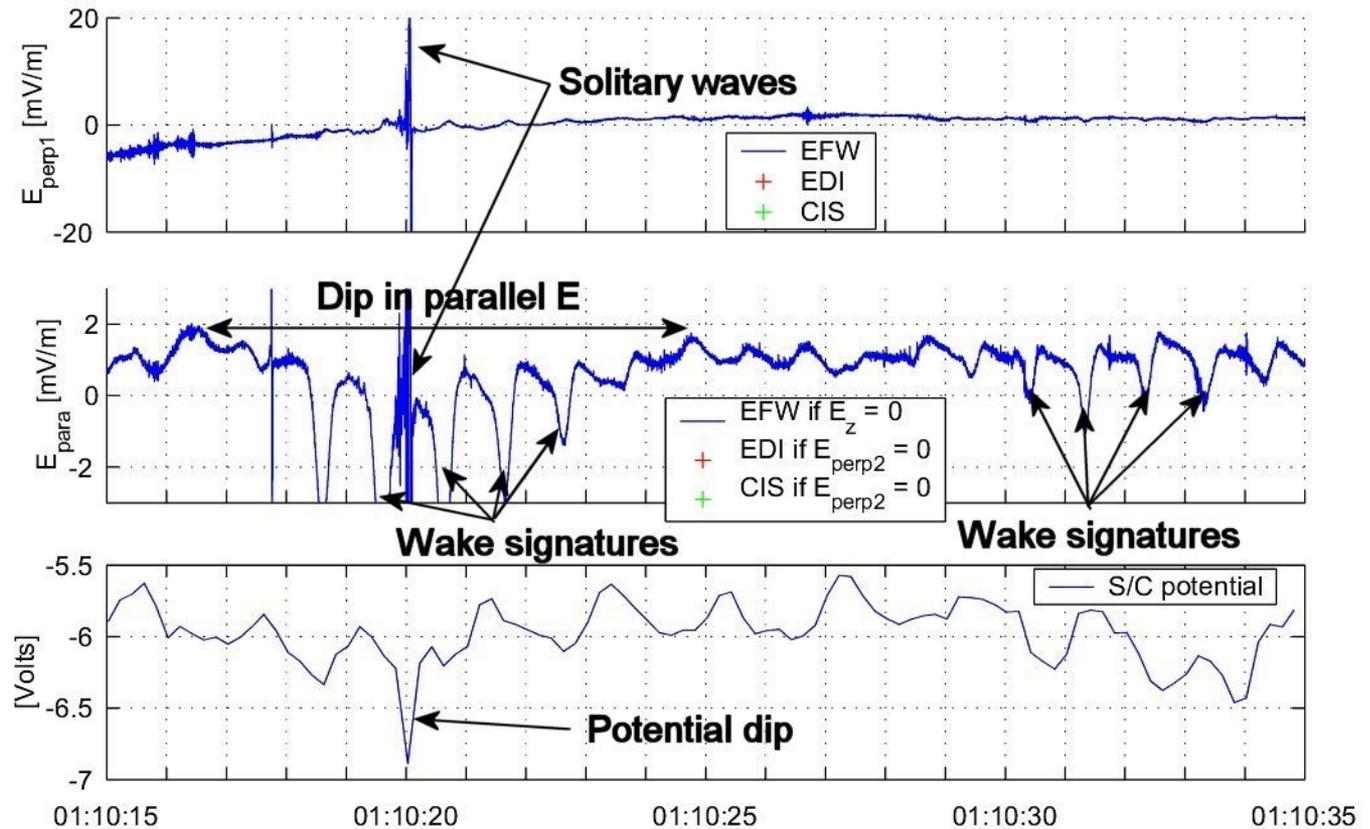
- ☐ **Parallel DC electric fields**
- ☐ **Double layers and solitary waves**
- ☐ **Waves**





# Parallel DC electric fields

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# Parallel DC electric fields

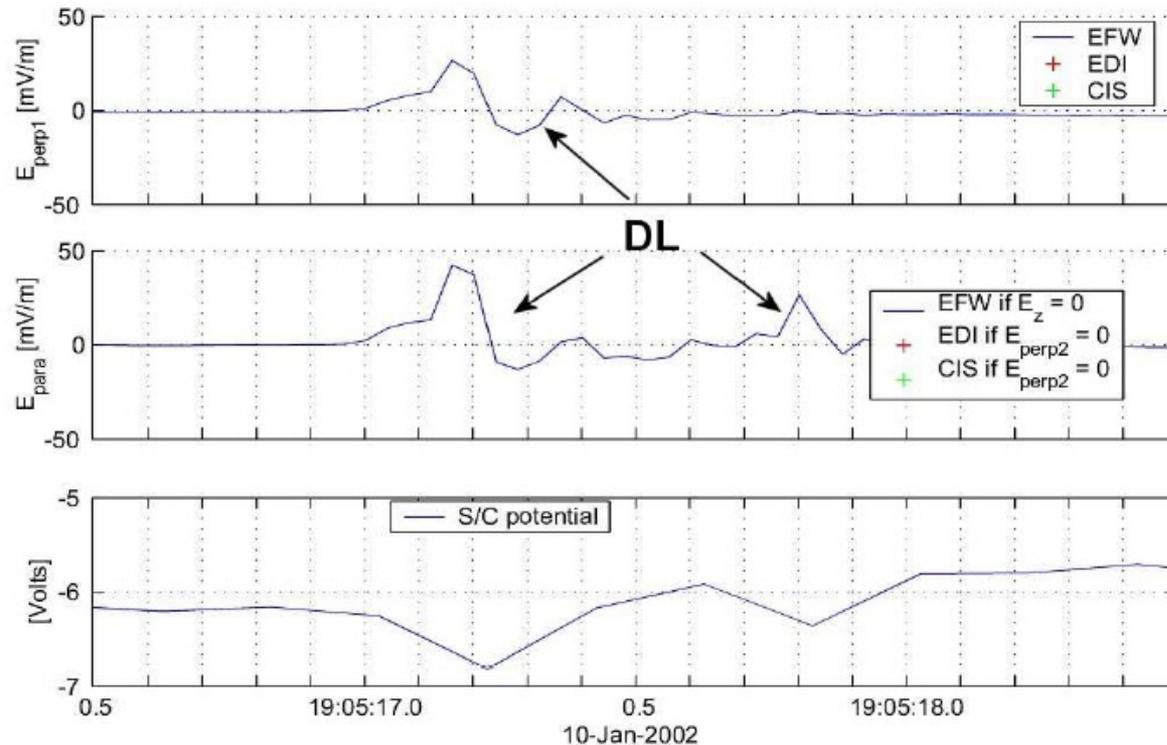
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| Event | Time [UT]         | S/C | Hemisphere | Duration [s] | Ampl [mV/m] |
|-------|-------------------|-----|------------|--------------|-------------|
| 1     | 19:05:10-19:05:20 | 3   | SH         | 10           | 1           |
| 2     | 01:10:17-01:10:25 | 2   | NH         | 8            | 1.5         |
| 2     | 01:10:20-01:10:32 | 4   | NH         | 12           | 1           |
| 2     | 01:12:19-01:12:25 | 2   | NH         | 6            | 1           |
| 2     | 01:12:21-01:12:28 | 3   | NH         | 7            | 1           |
| 2     | 01:17:03-01:17:15 | 3   | NH         | 12           | 1           |
| 2     | 01:17:02-01:17:07 | 4   | NH         | 5            | 1           |
| 3     | 22:47:50-22:48:00 | 3   | NH         | 10           | 0.5         |
| 5     | 09:52:54-09:53:04 | 3   | SH         | 10           | 0.5         |

**All electric fields are upwards**



# Double layers and solitary waves



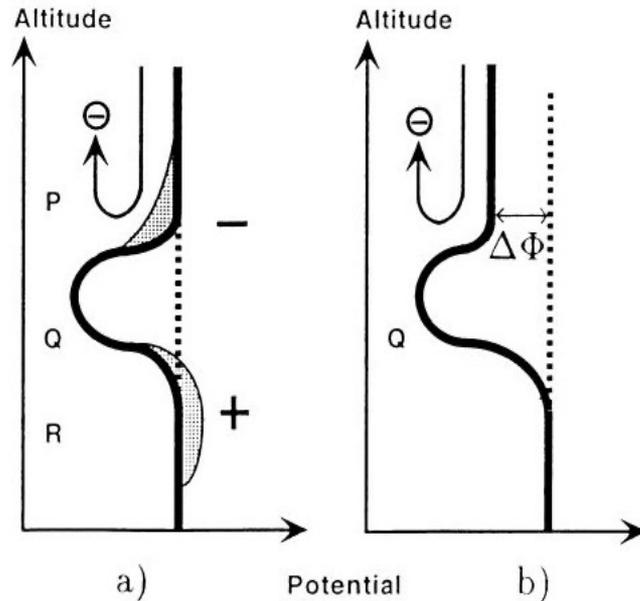
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| Event | Time [UT]       | S/C | Hemisphere | Conv/Div   | P-P ampl [mV/m] | Pot drop [V] |
|-------|-----------------|-----|------------|------------|-----------------|--------------|
| 1     | 19:05:17.0-17.5 | 3   | SH         | Diverging  | 50              | 80           |
| 1     | 19:05:17.6-18.0 | 3   | SH         | Diverging  | 30              | 50           |
| 2     | 01:10:20.0-20.1 | 2   | NH         | Converging | 100             | 0            |
| 4     | 14:28:09.2-09.6 | 3   | NH         | Converging | 15              | 10           |

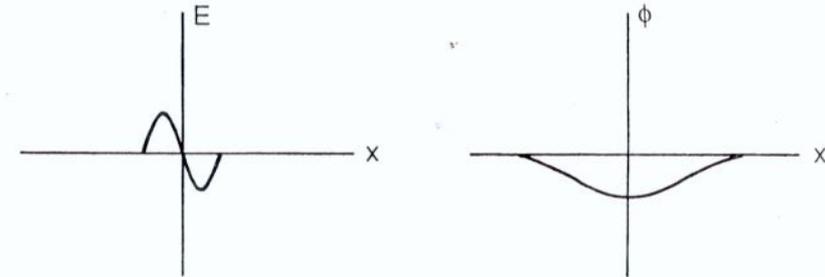


# DL and SW theory

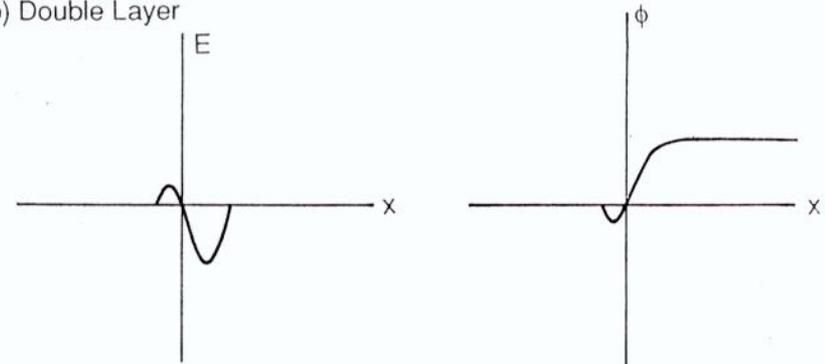
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(a) Solitary Wave



(b) Double Layer



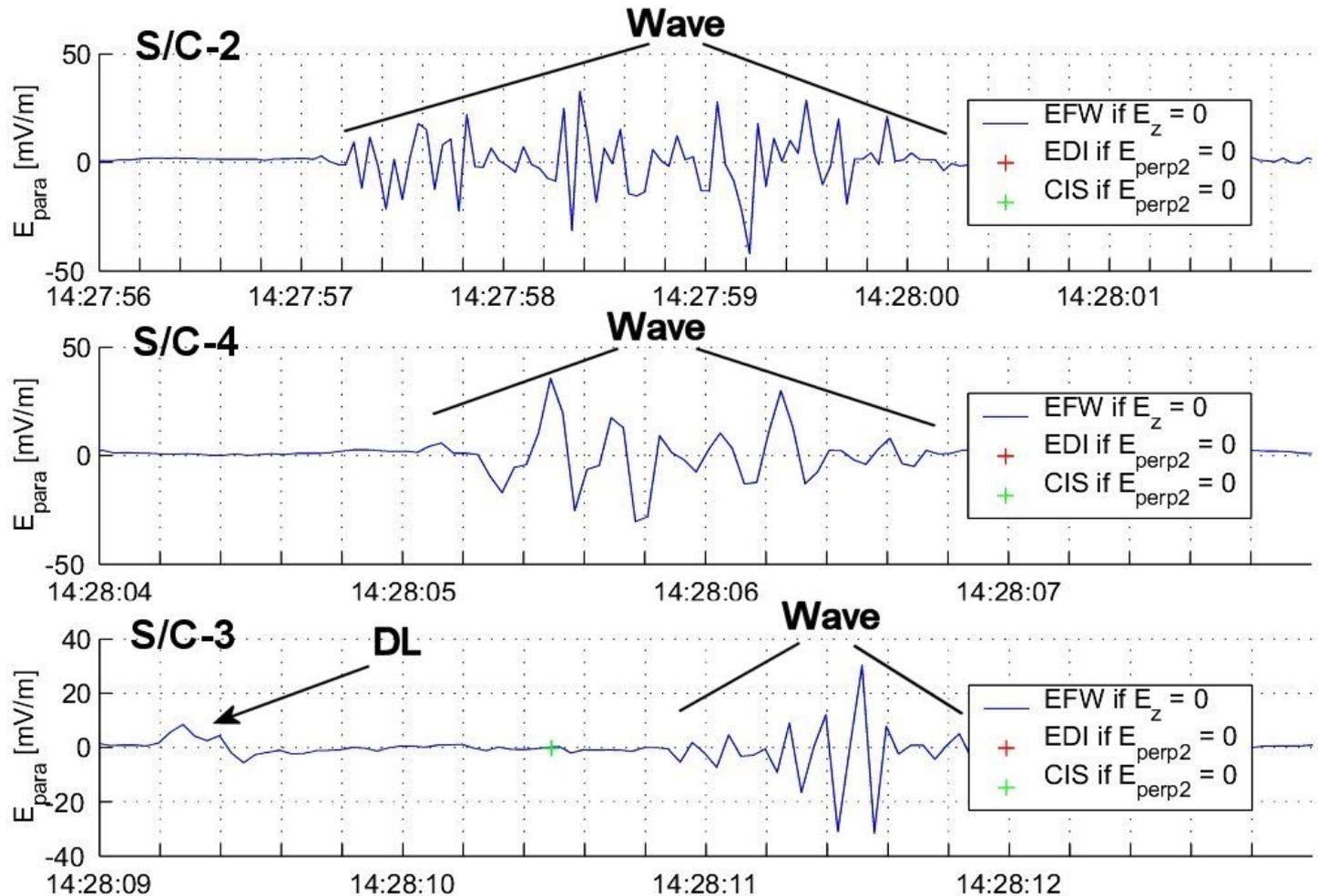
- **Accompanied by a decrease in plasma density**



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# Waves

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# Instrumental effects

- **Wake effects**
  - Physical
  - Potential
- **Offsets**
- **Interference from WHISPER**





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# Conclusions

## Possible interpretations of the results

### **Upward $\sim 1$ mV/m parallel E-fields**

- Too small, could be instrumental effects
- Could be U associated (not likely at this altitude)
- Could be lower part of O
- U on top of O (not probable)

### **Lack of downward parallel E-fields**

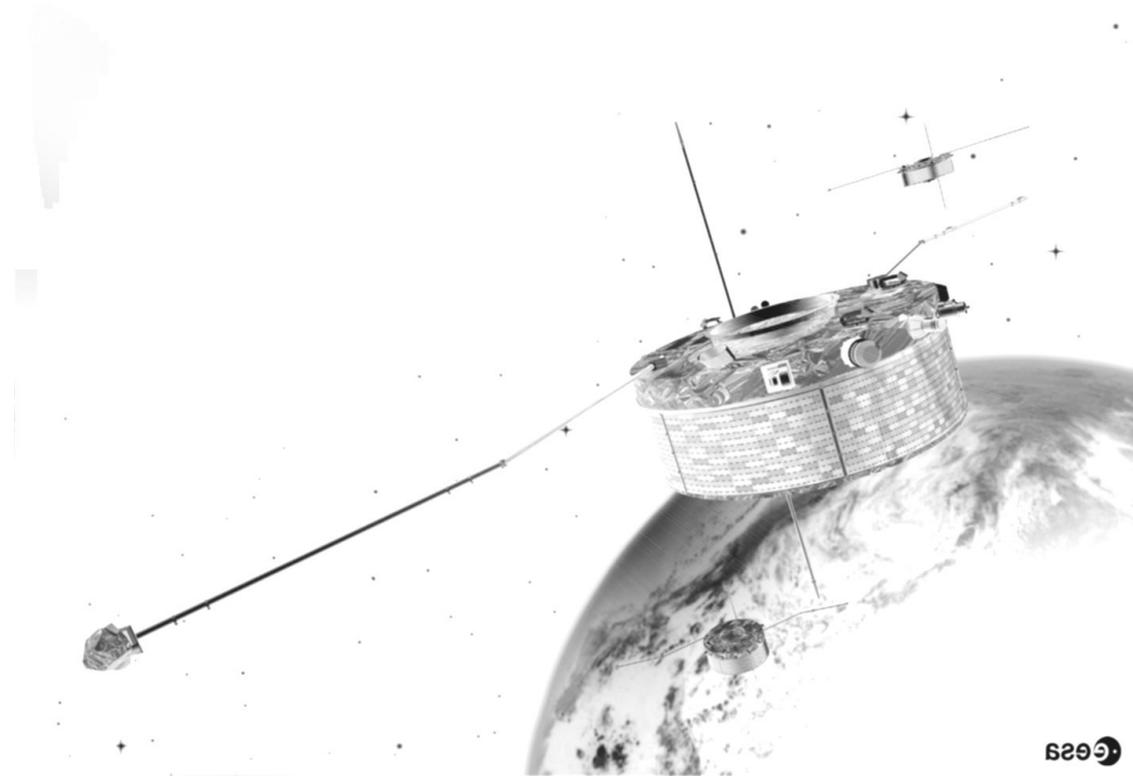
- Cluster measure above O, too high altitude
- Downward fields associated with O should be  $\sim 0.1$  mV/m at this altitude, i.e. not measurable



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# The End

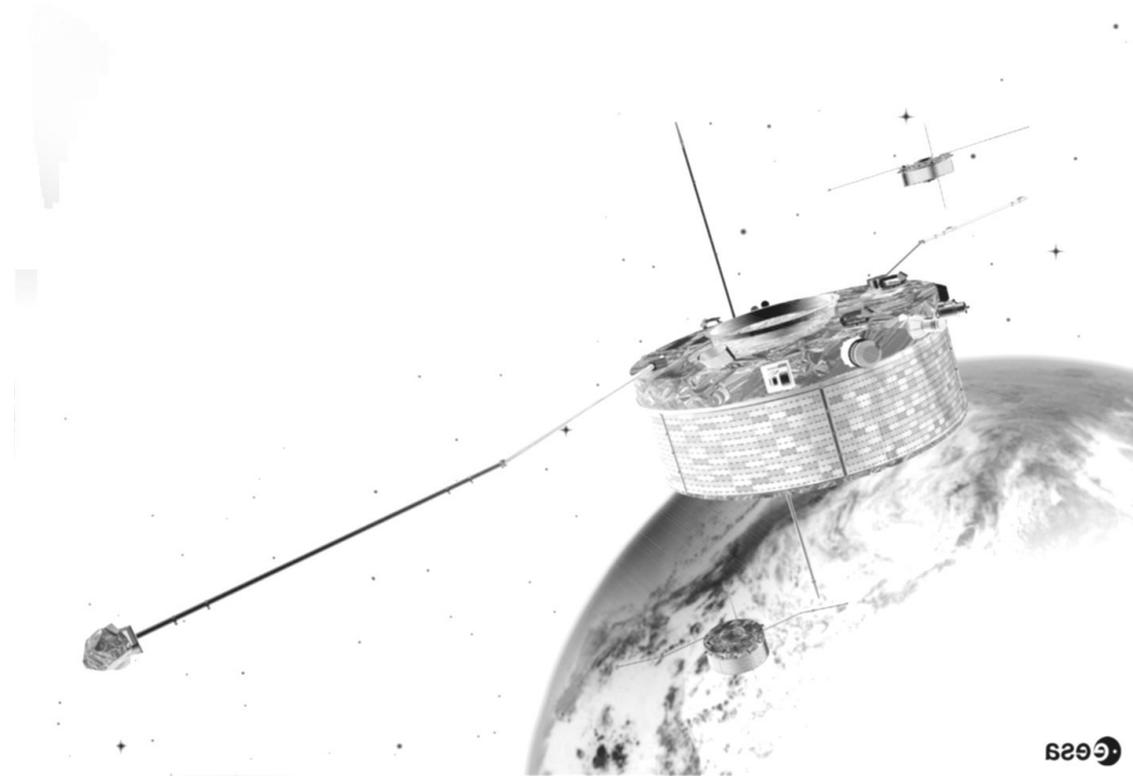
## Thank you for listening





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# Extra plots





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**2002-01-10**

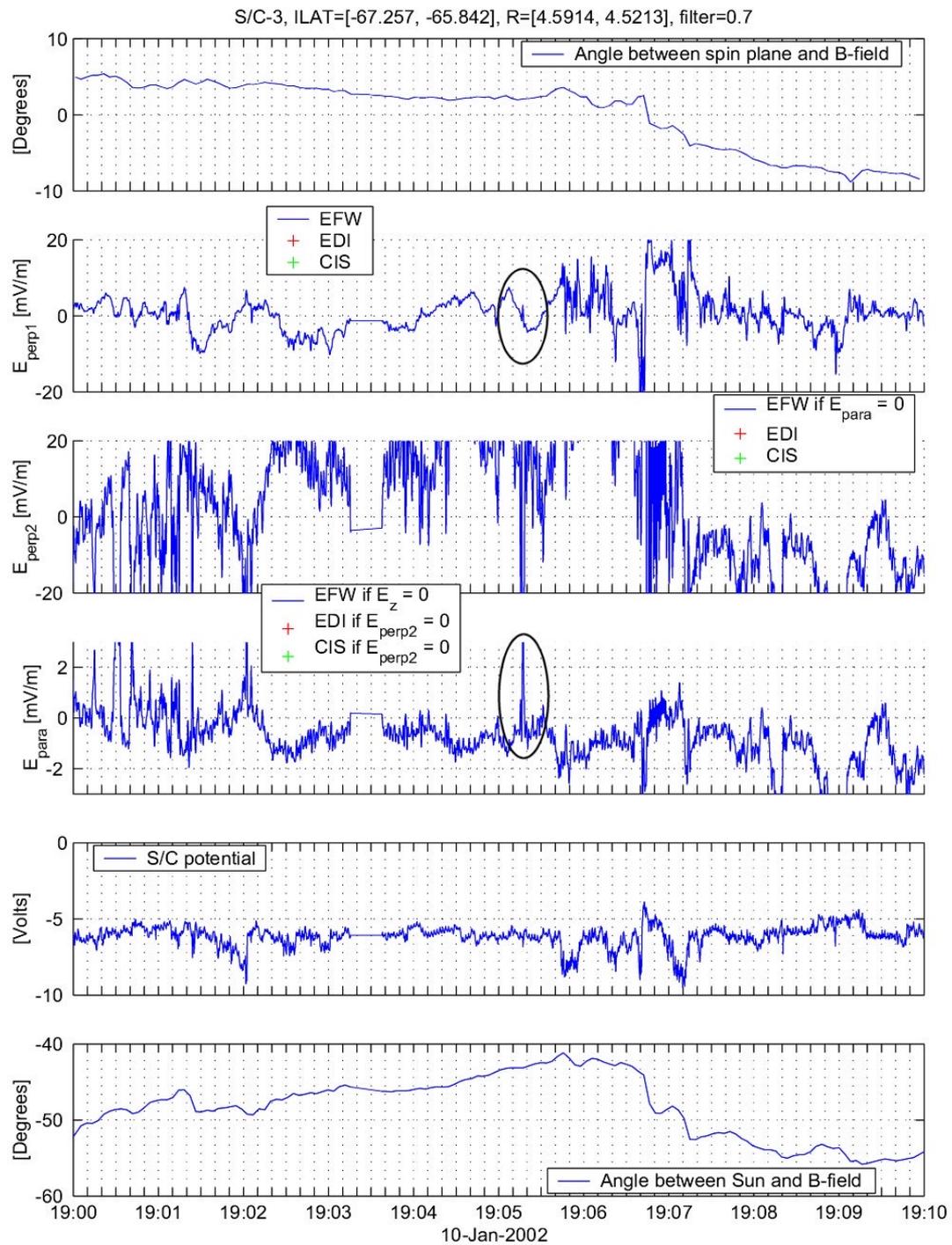


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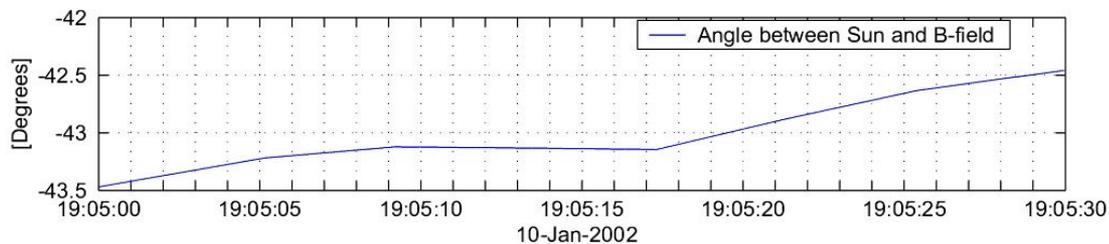
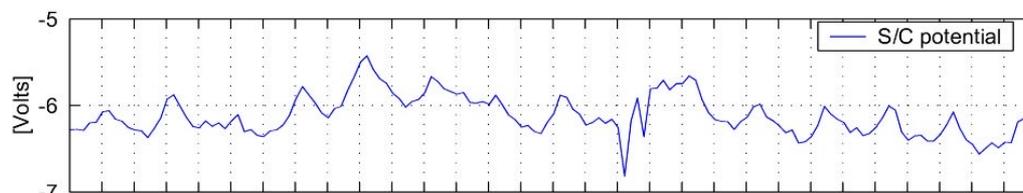
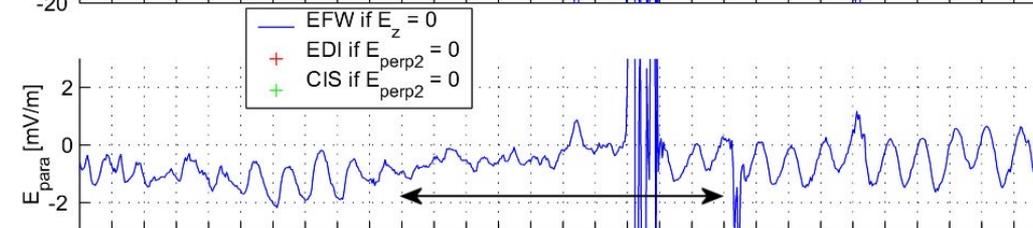
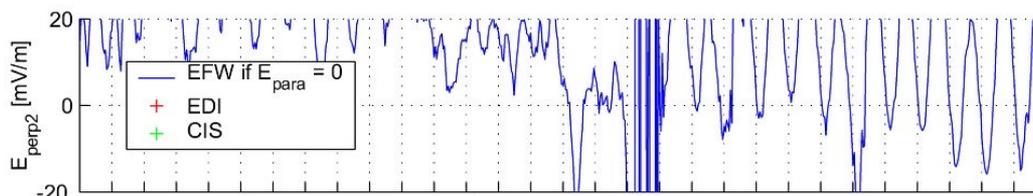
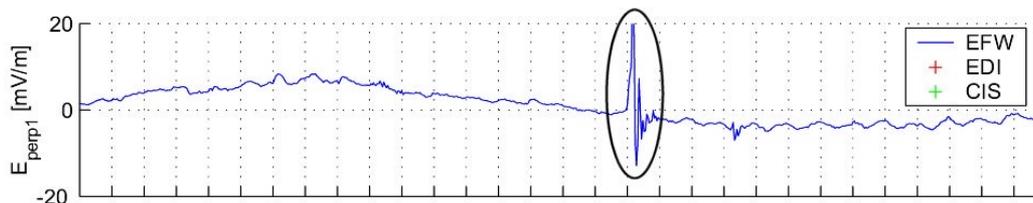
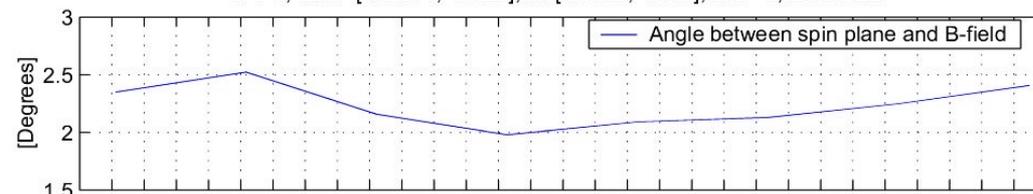
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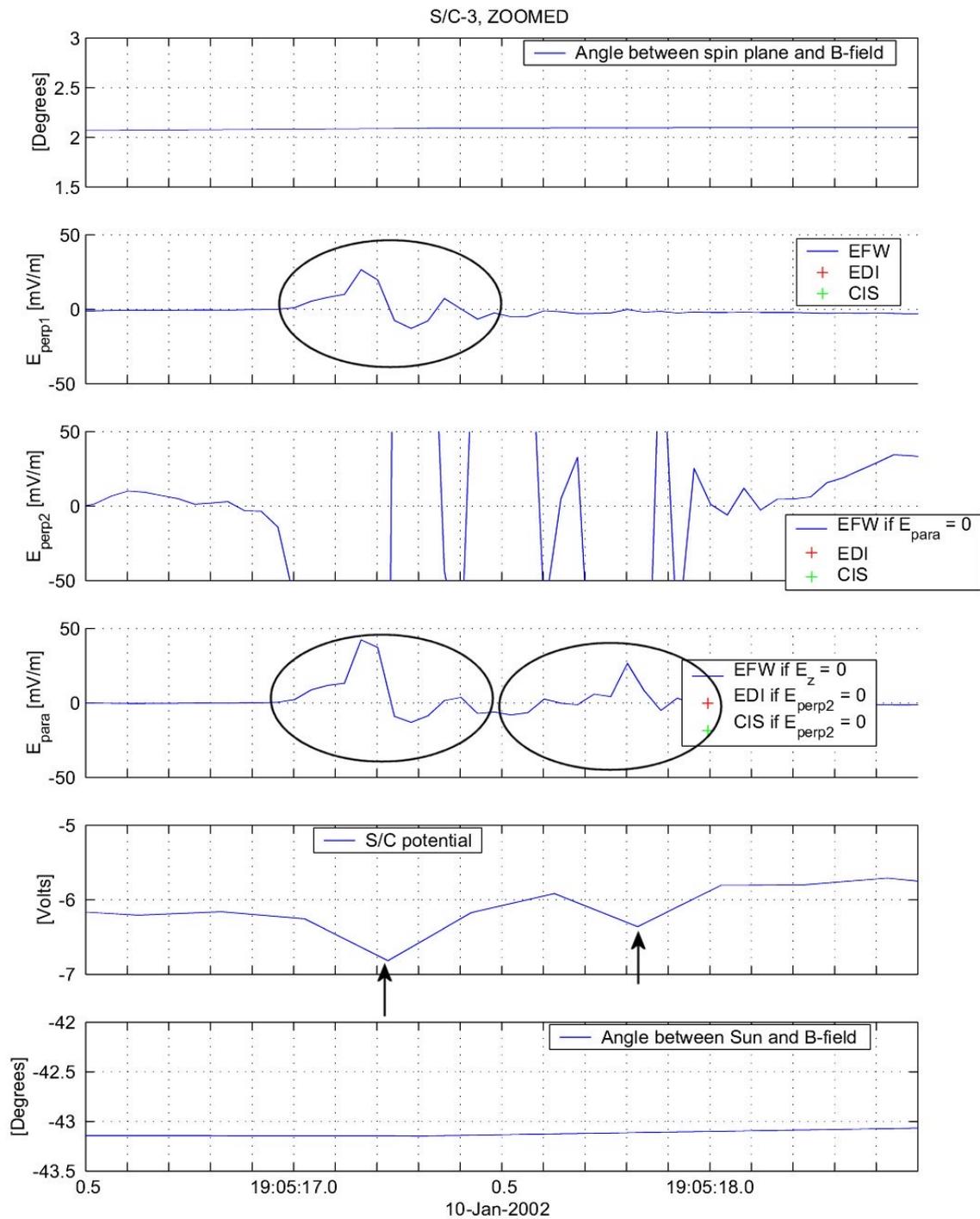
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10-Jan-2002



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**2002-02-06**



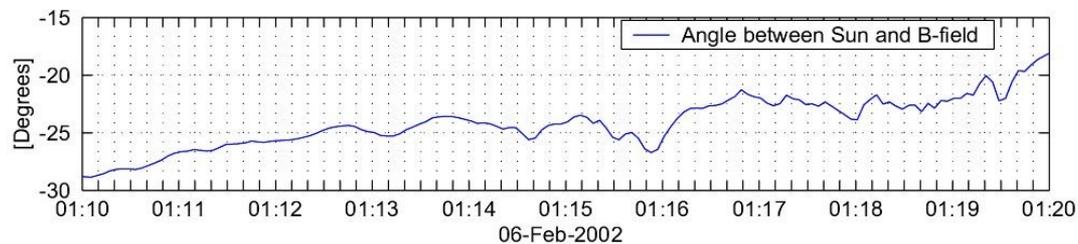
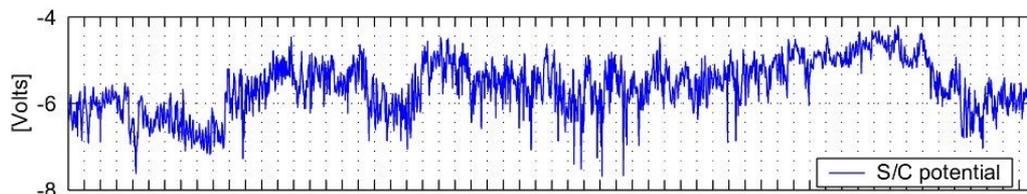
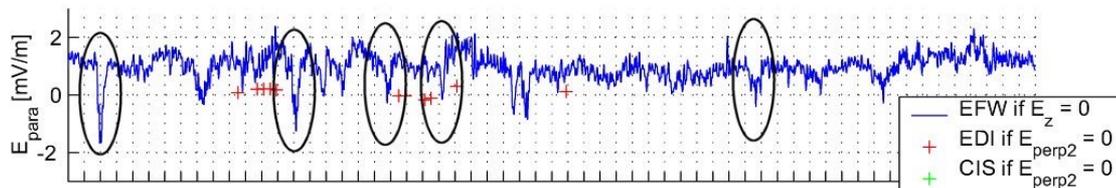
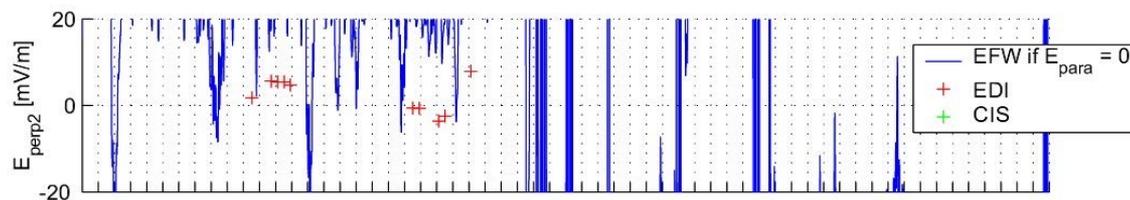
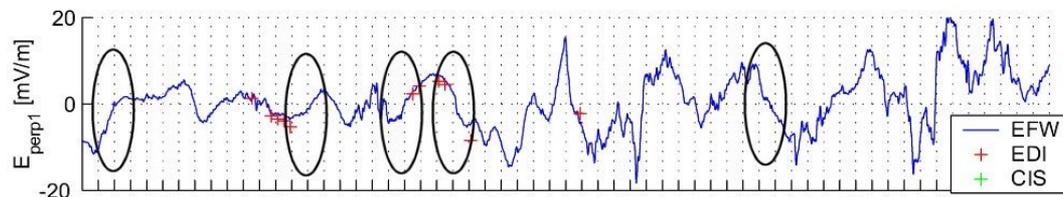
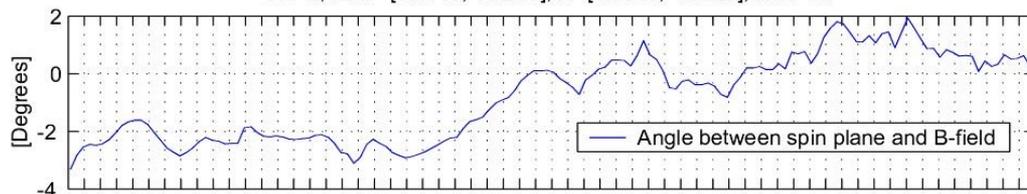
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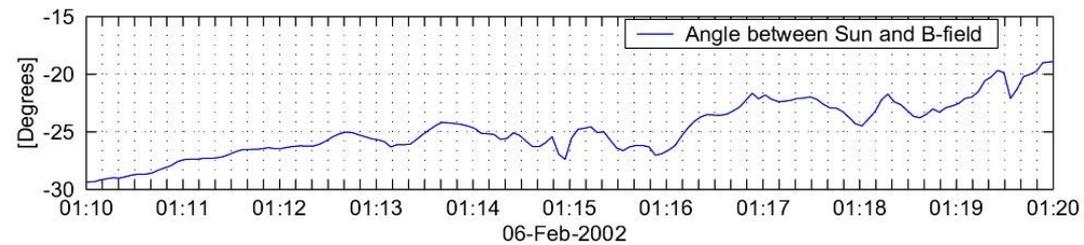
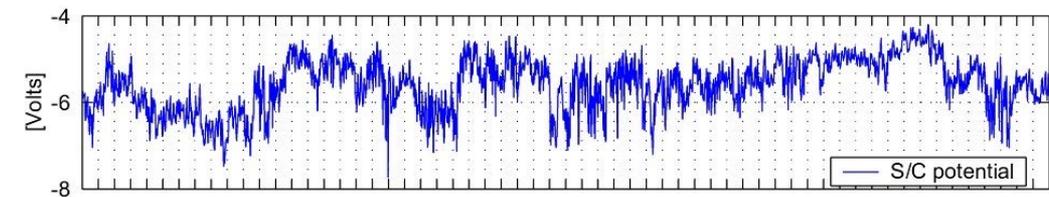
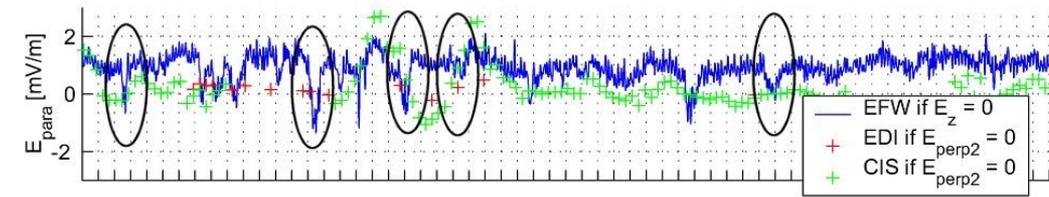
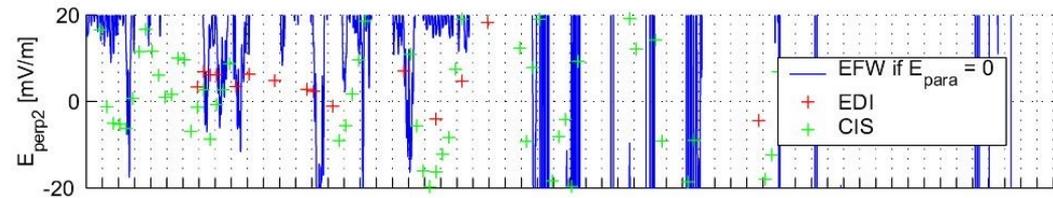
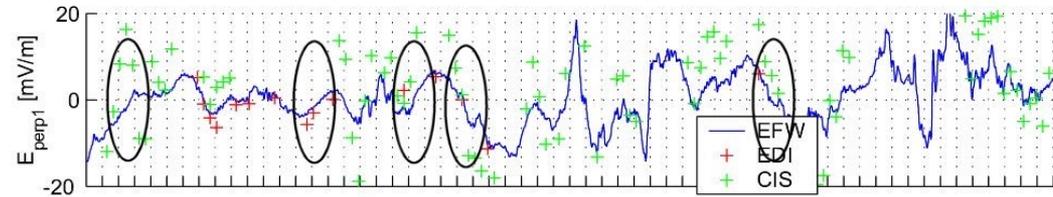
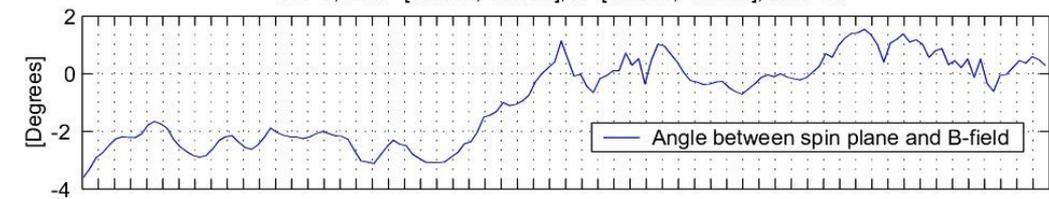
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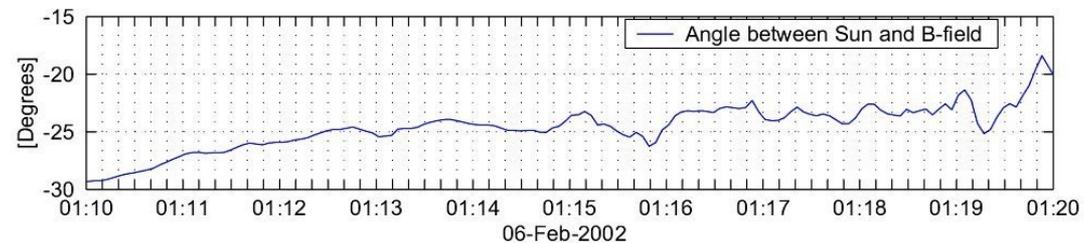
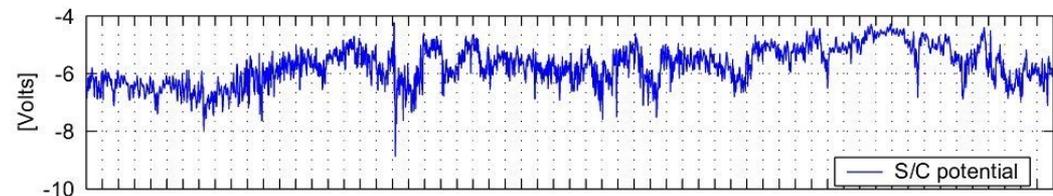
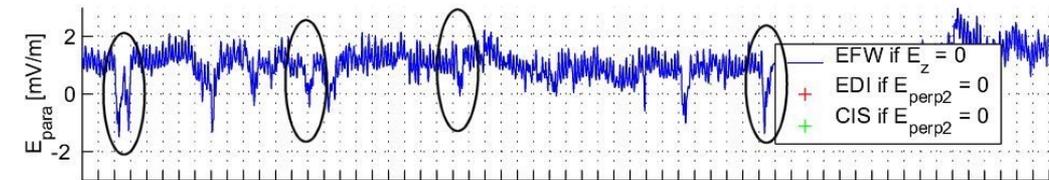
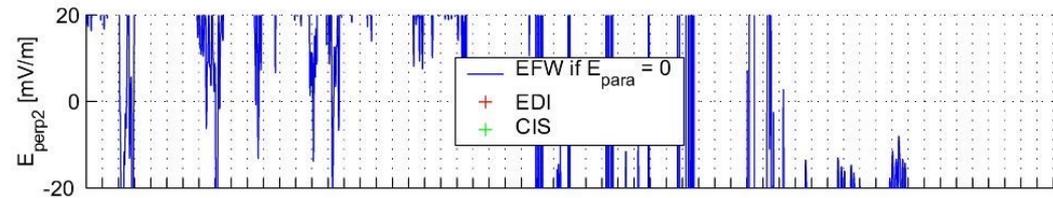
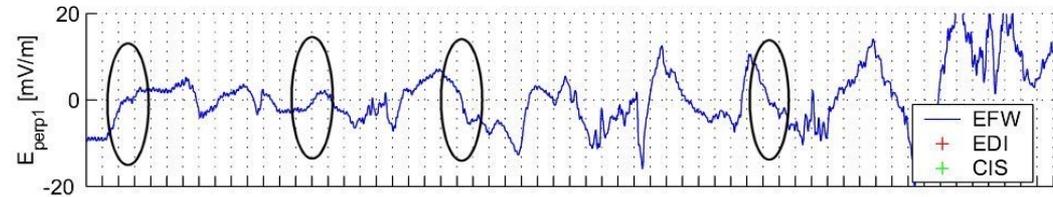
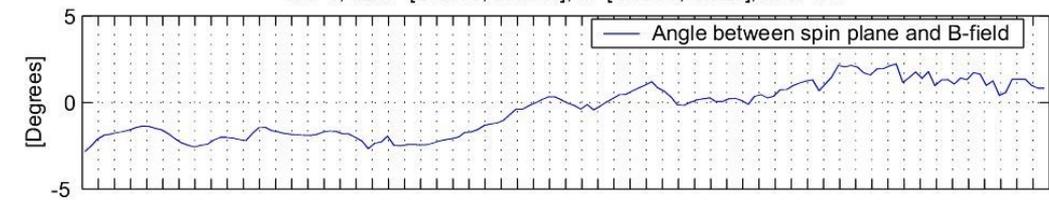
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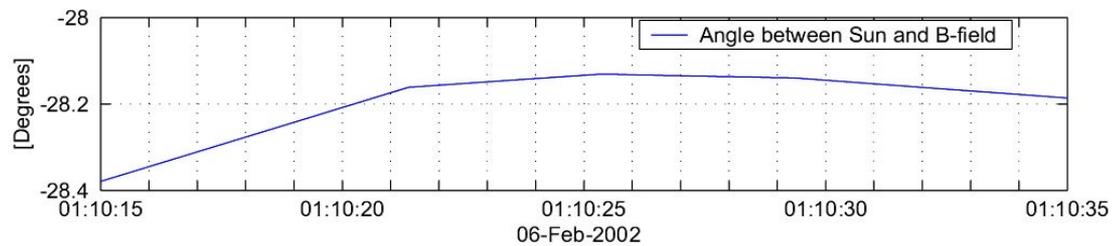
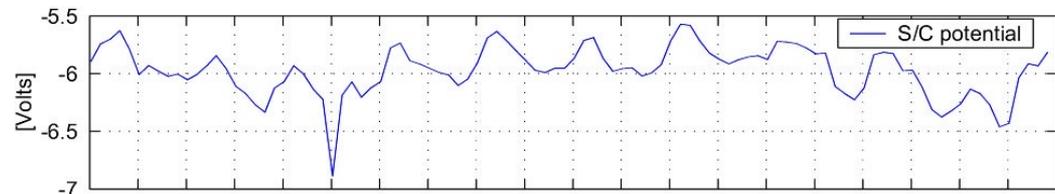
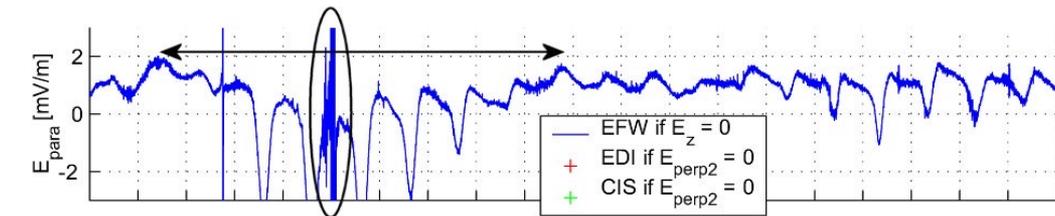
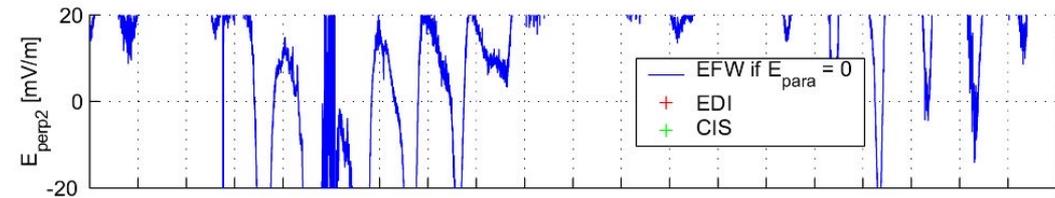
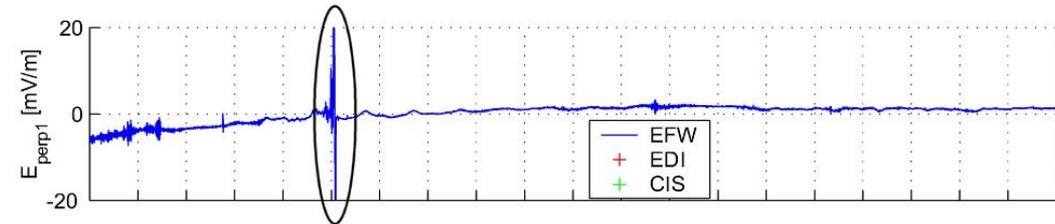
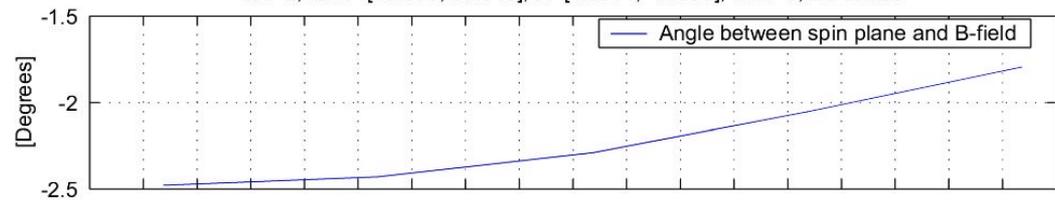
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SW LIST

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BACK

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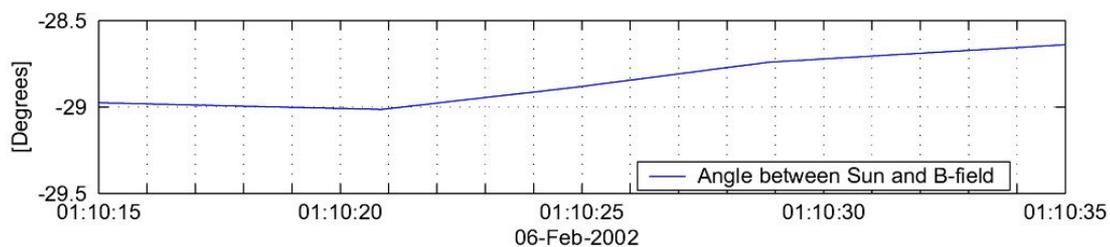
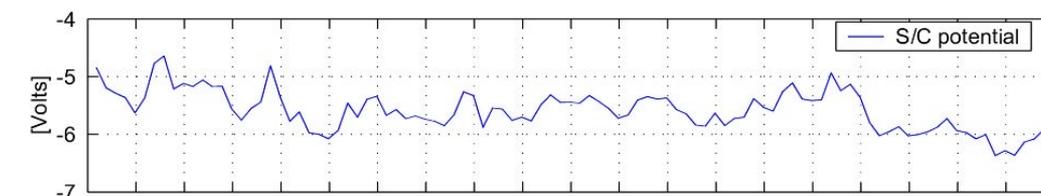
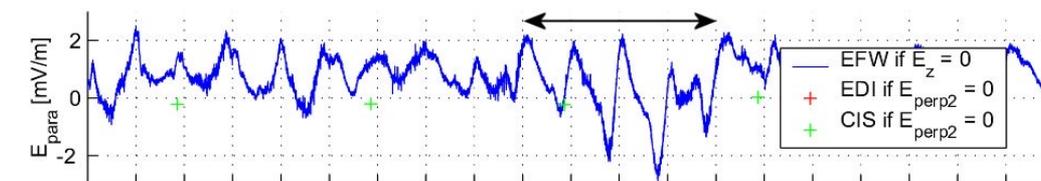
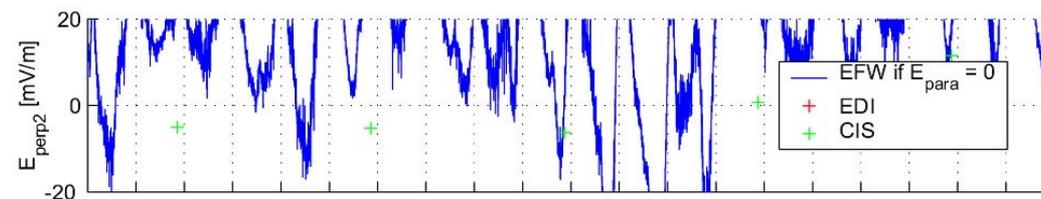
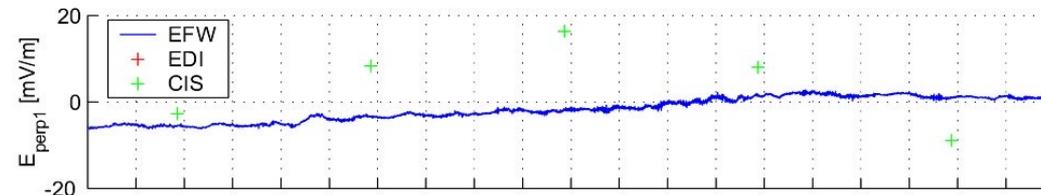
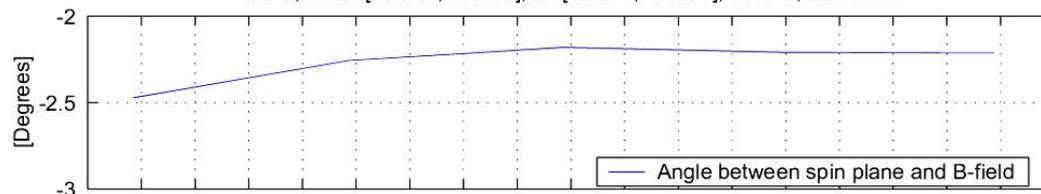
DC LIST

SW LIST

UP

BACK

S/C-3, ILAT=[67.649, 67.699], R=[4.5558, 4.5579], filter=0, ZOOMED





UPPSALA  
UNIVERSITET

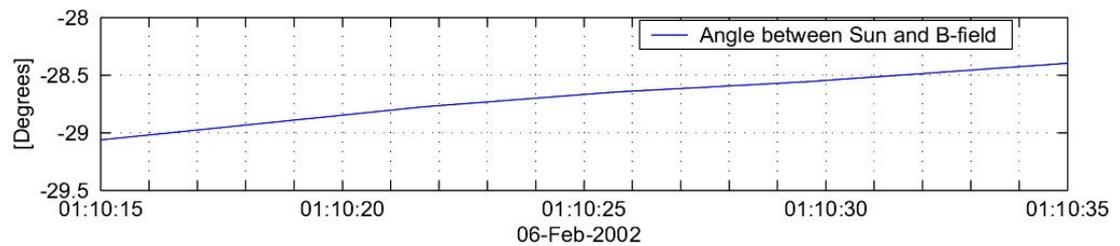
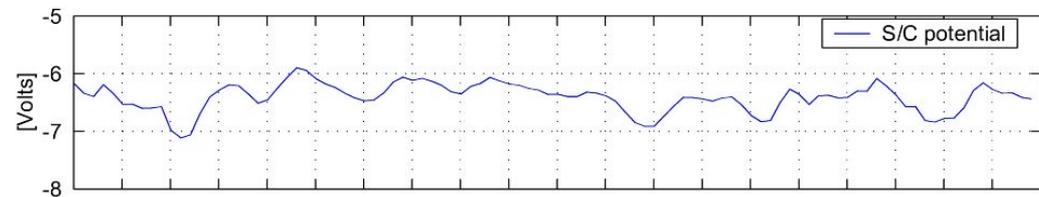
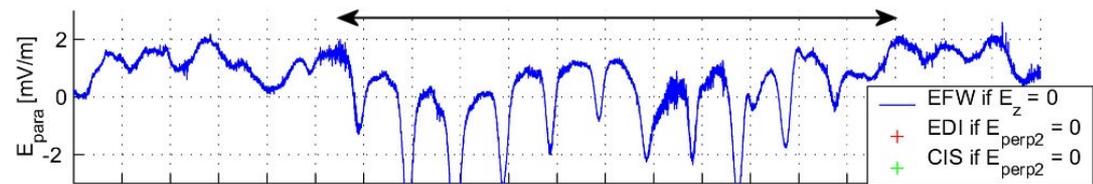
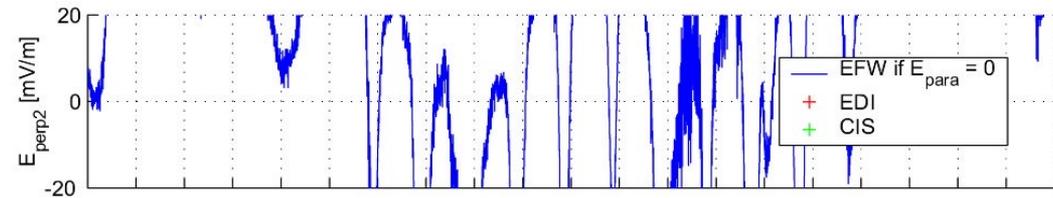
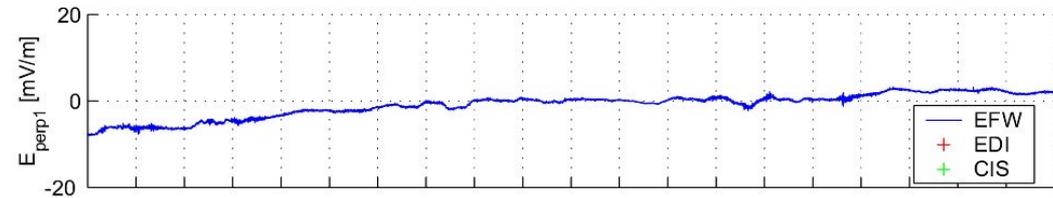
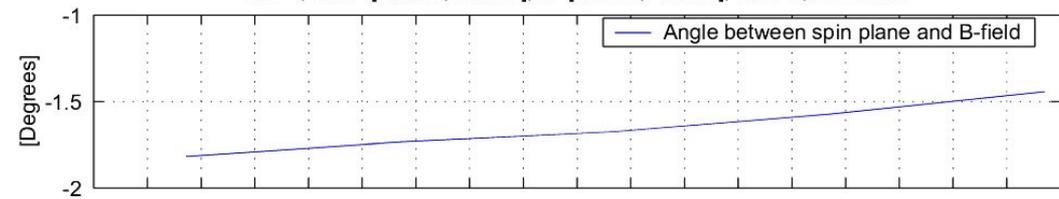
DC LIST

SW LIST

UP

BACK

S/C-4, ILAT=[67.732, 67.784], R=[4.5553, 4.5575], filter=0, ZOOMED





UPPSALA  
UNIVERSITET

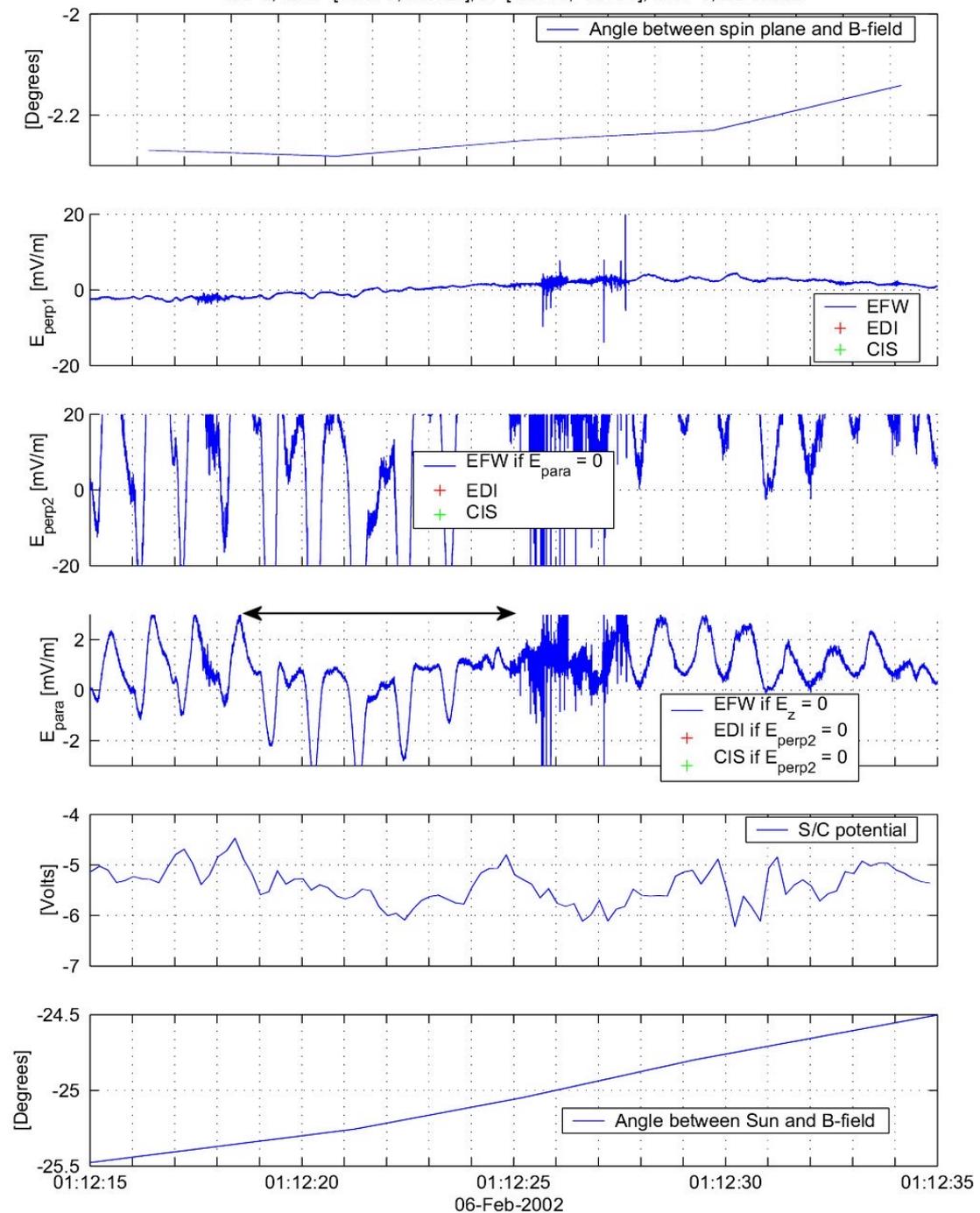
DC LIST

SW LIST

UP

BACK

S/C-2, ILAT=[68.076, 68.127], R=[4.5716, 4.5739], filter=0, ZOOMED





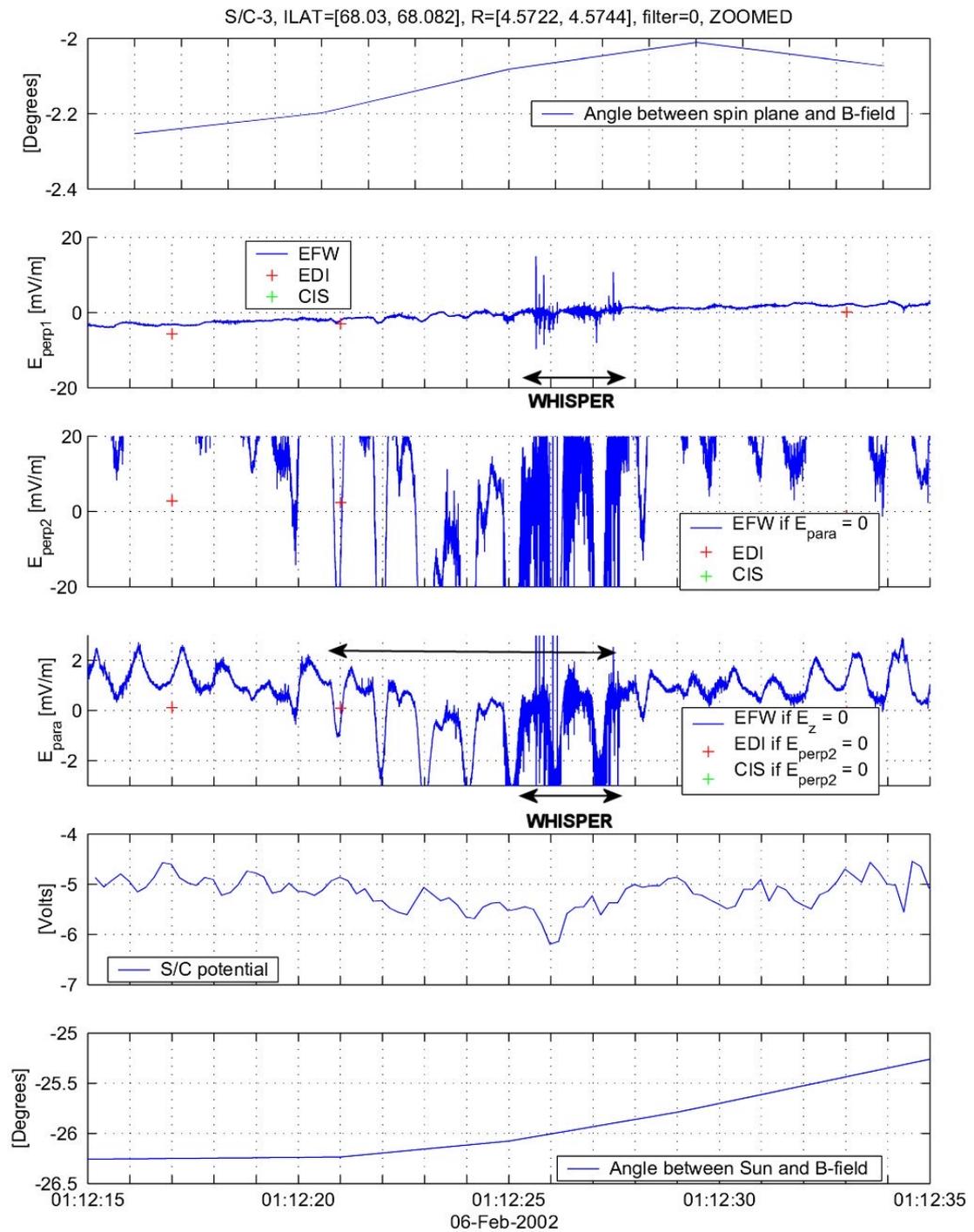
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UNIVERSITET

DC LIST

SW LIST

UP

BACK





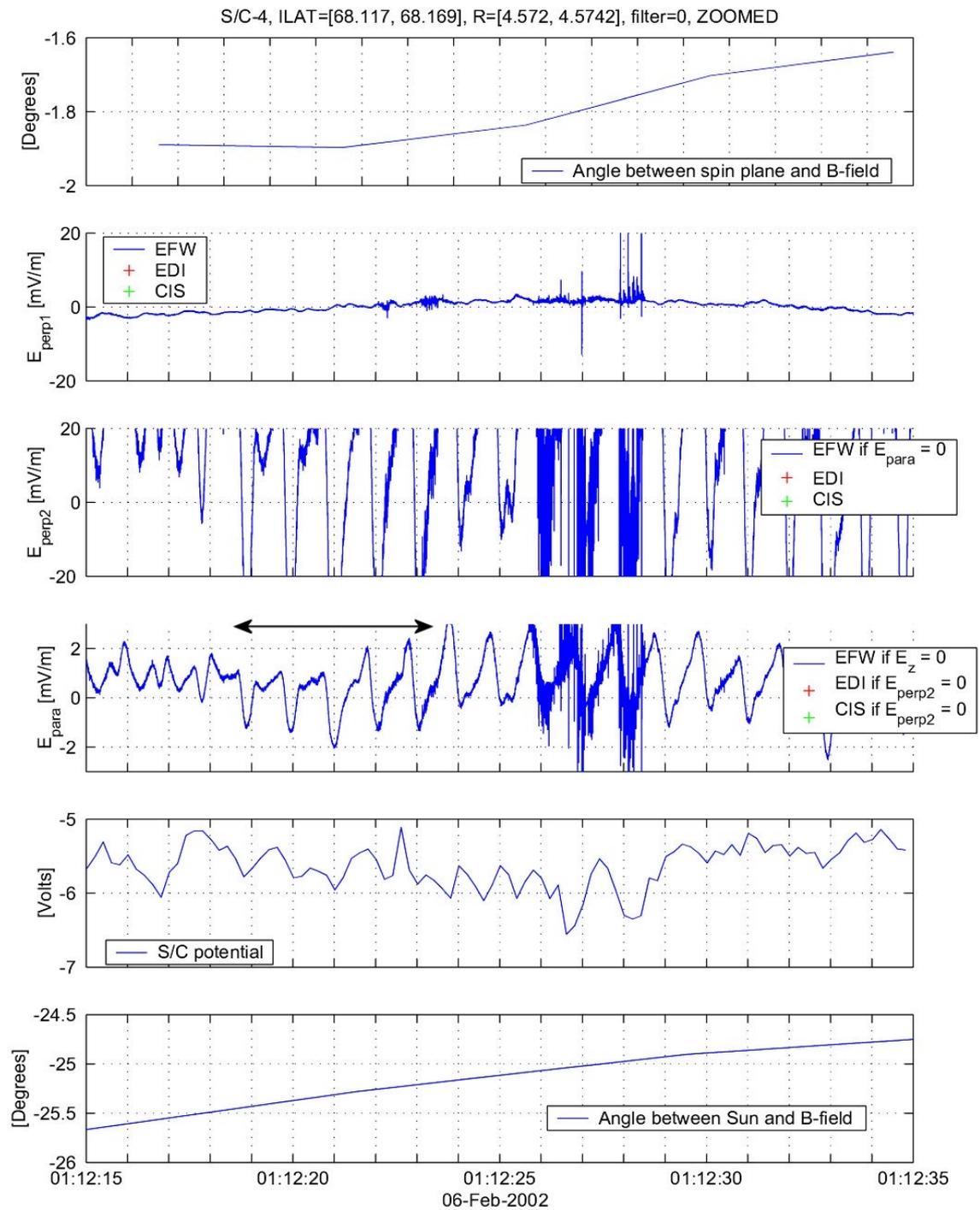
UPPSALA  
UNIVERSITET

DC LIST

SW LIST

UP

BACK





UPPSALA  
UNIVERSITET

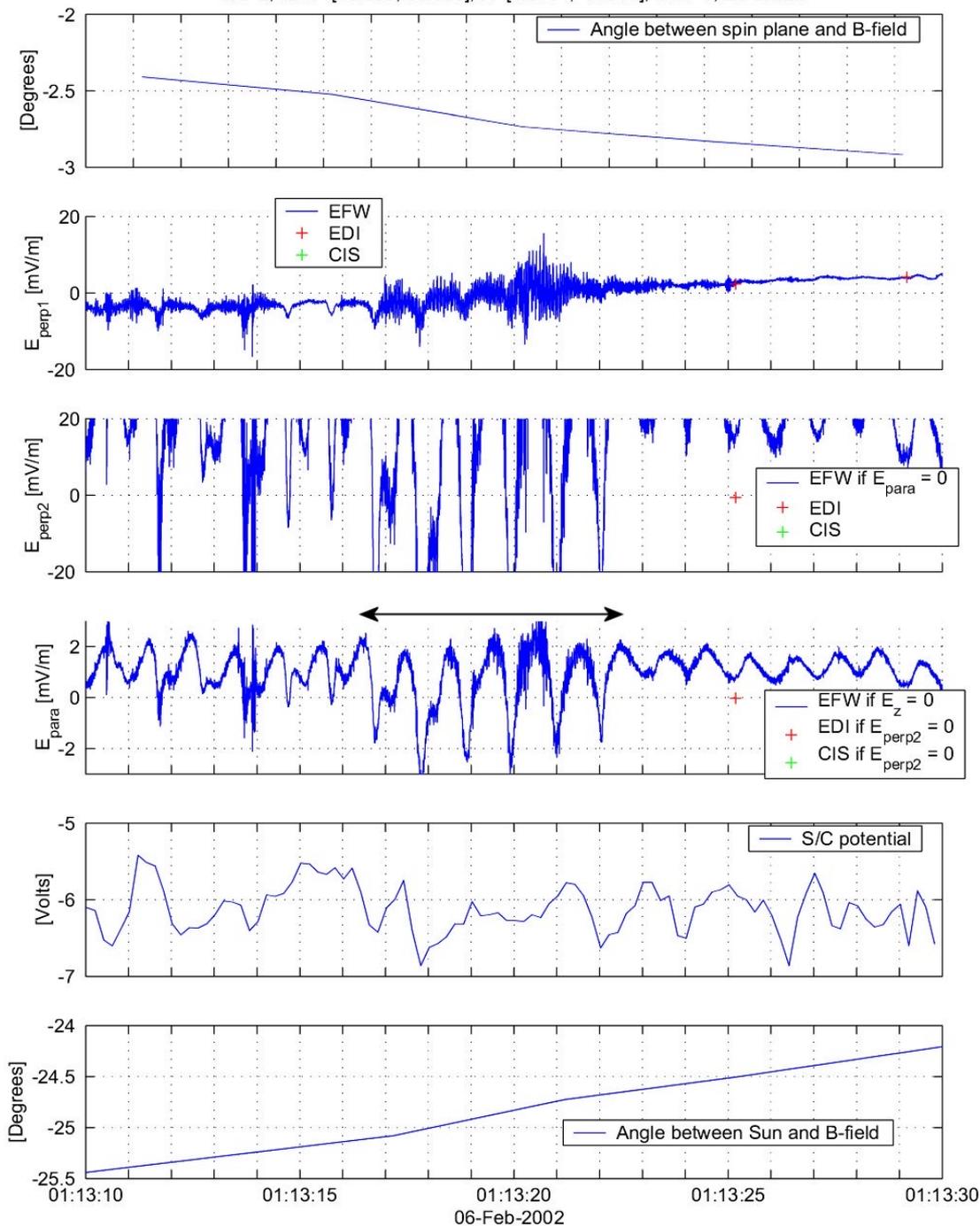
DC LIST

SW LIST

UP

BACK

S/C-2, ILAT=[68.253, 68.305], R=[4.5794, 4.5817], filter=0, ZOOMED





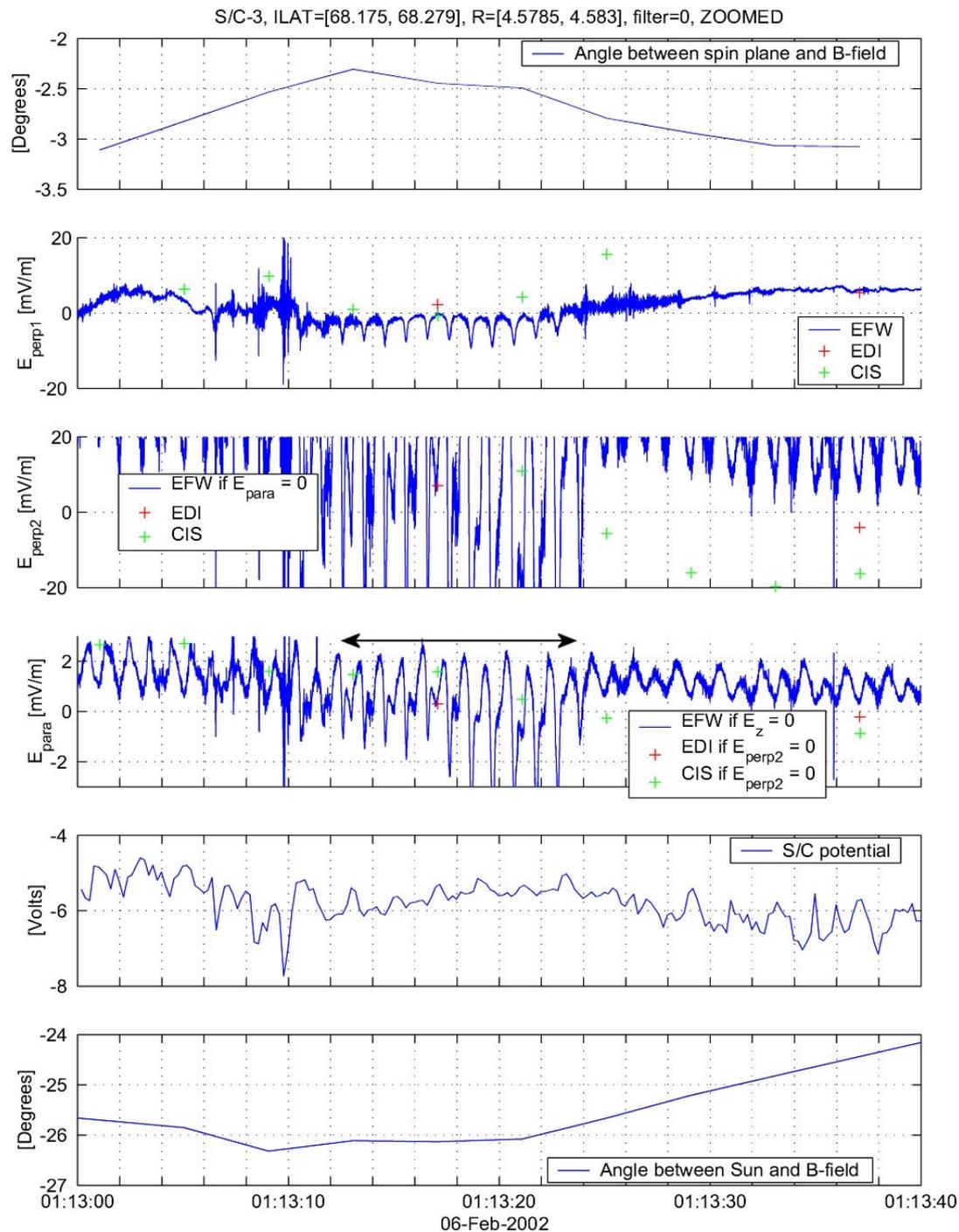
UPPSALA  
UNIVERSITET

DC LIST

SW LIST

UP

BACK





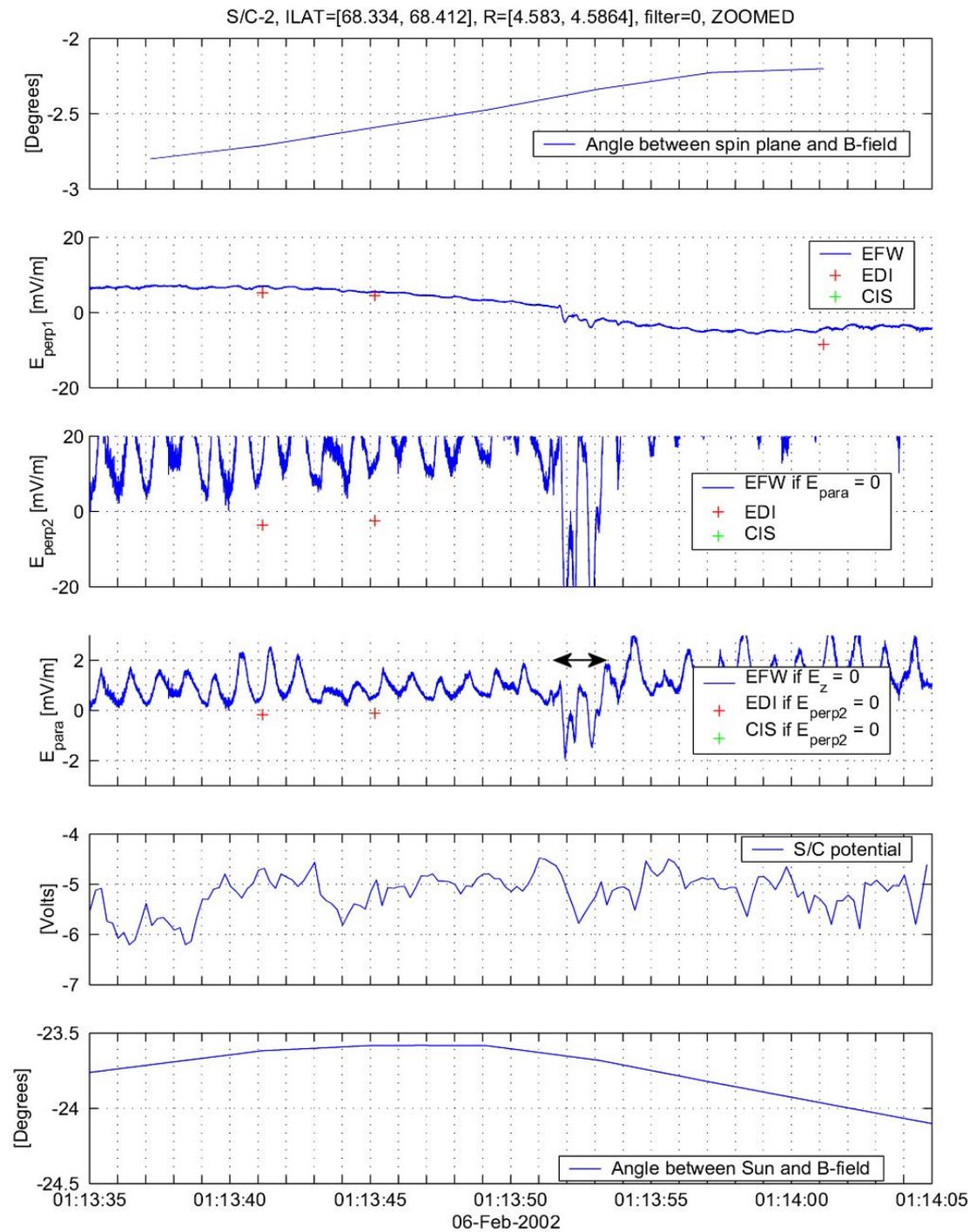
UPPSALA  
UNIVERSITET

DC LIST

SW LIST

UP

BACK





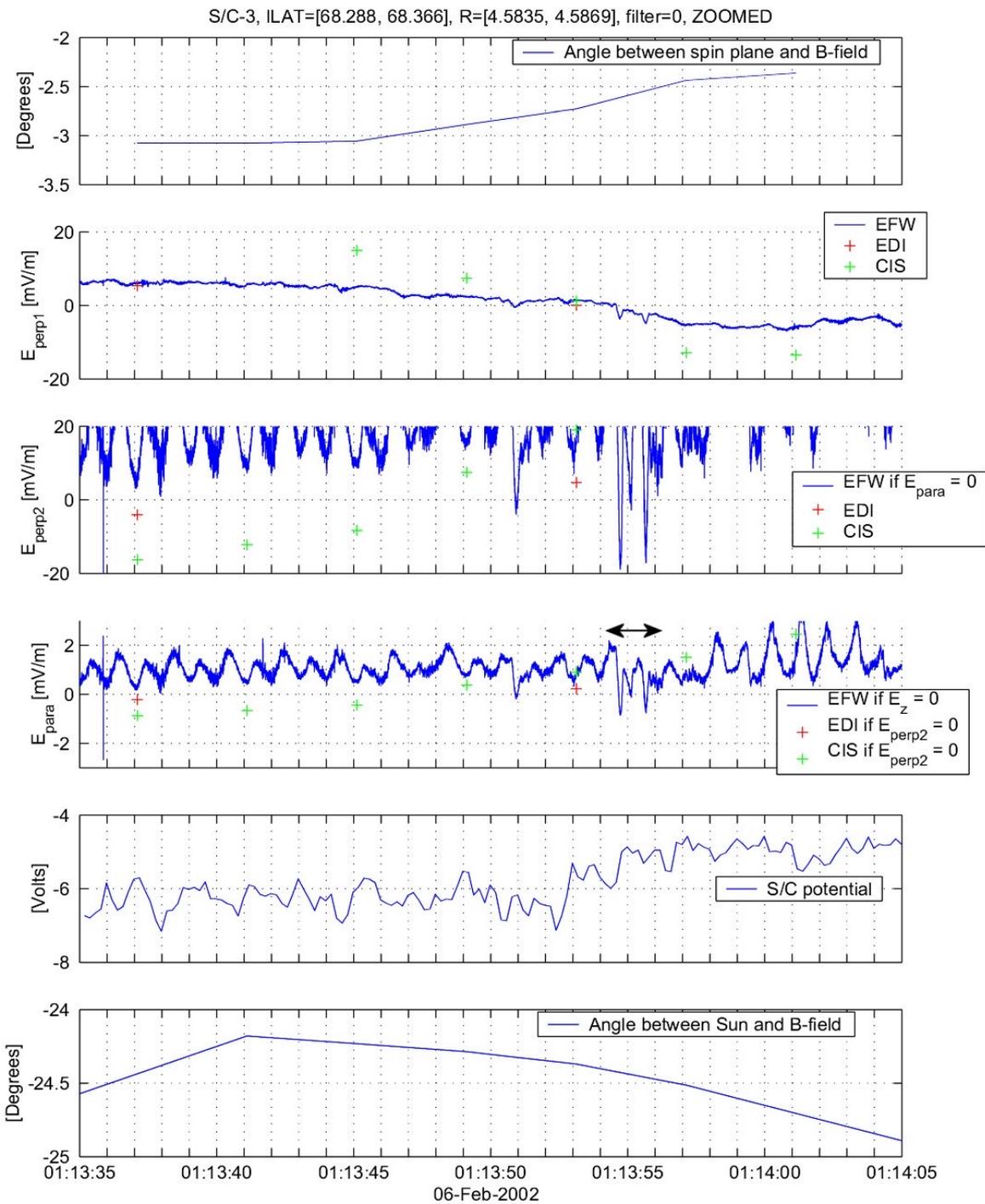
UPPSALA  
UNIVERSITET

DC LIST

SW LIST

UP

BACK





UPPSALA  
UNIVERSITET

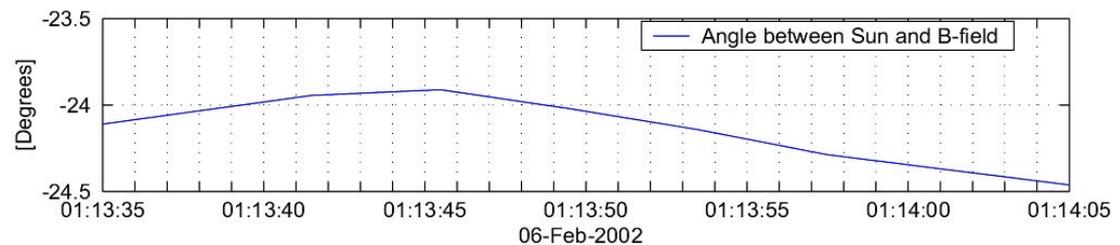
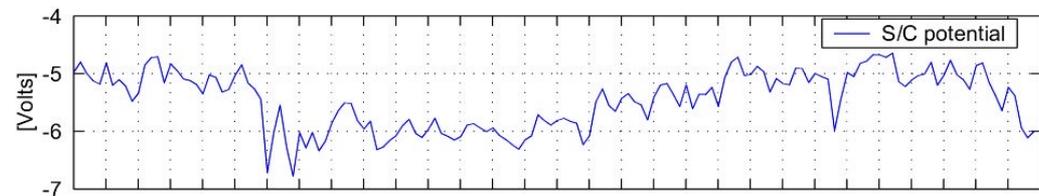
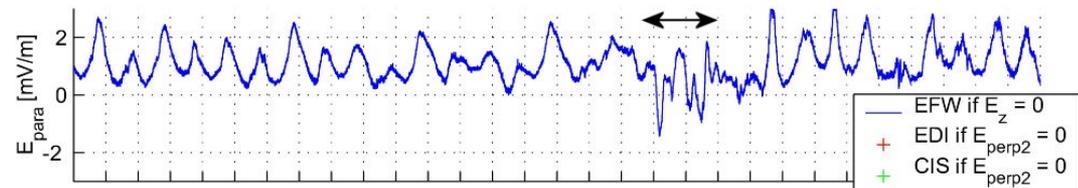
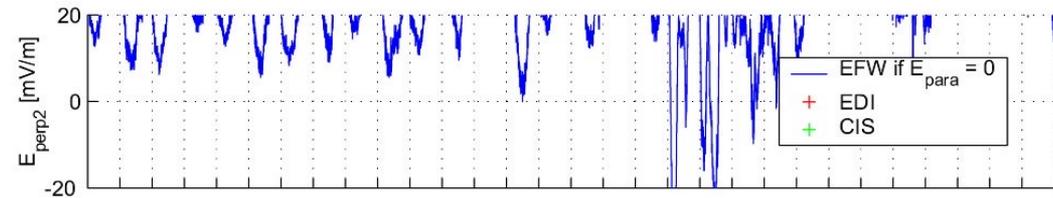
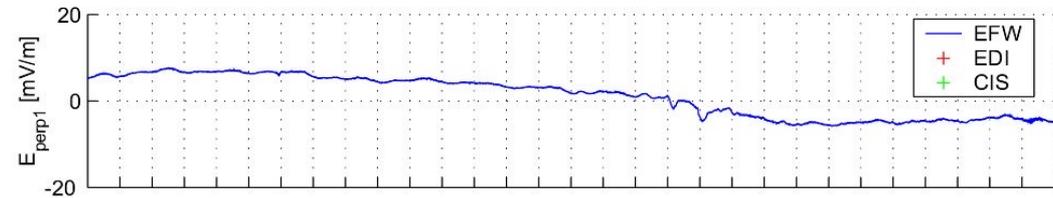
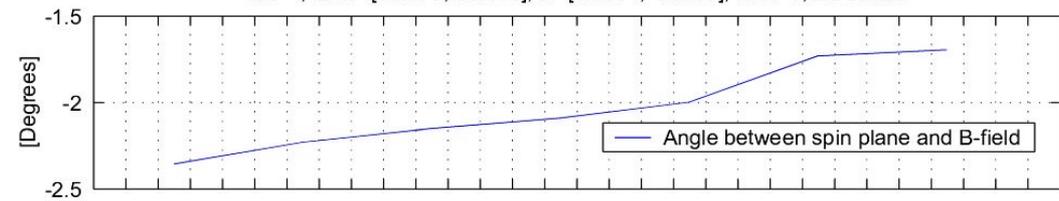
DC LIST

SW LIST

UP

BACK

S/C-4, ILAT=[68.376, 68.455], R=[4.5834, 4.5869], filter=0, ZOOMED





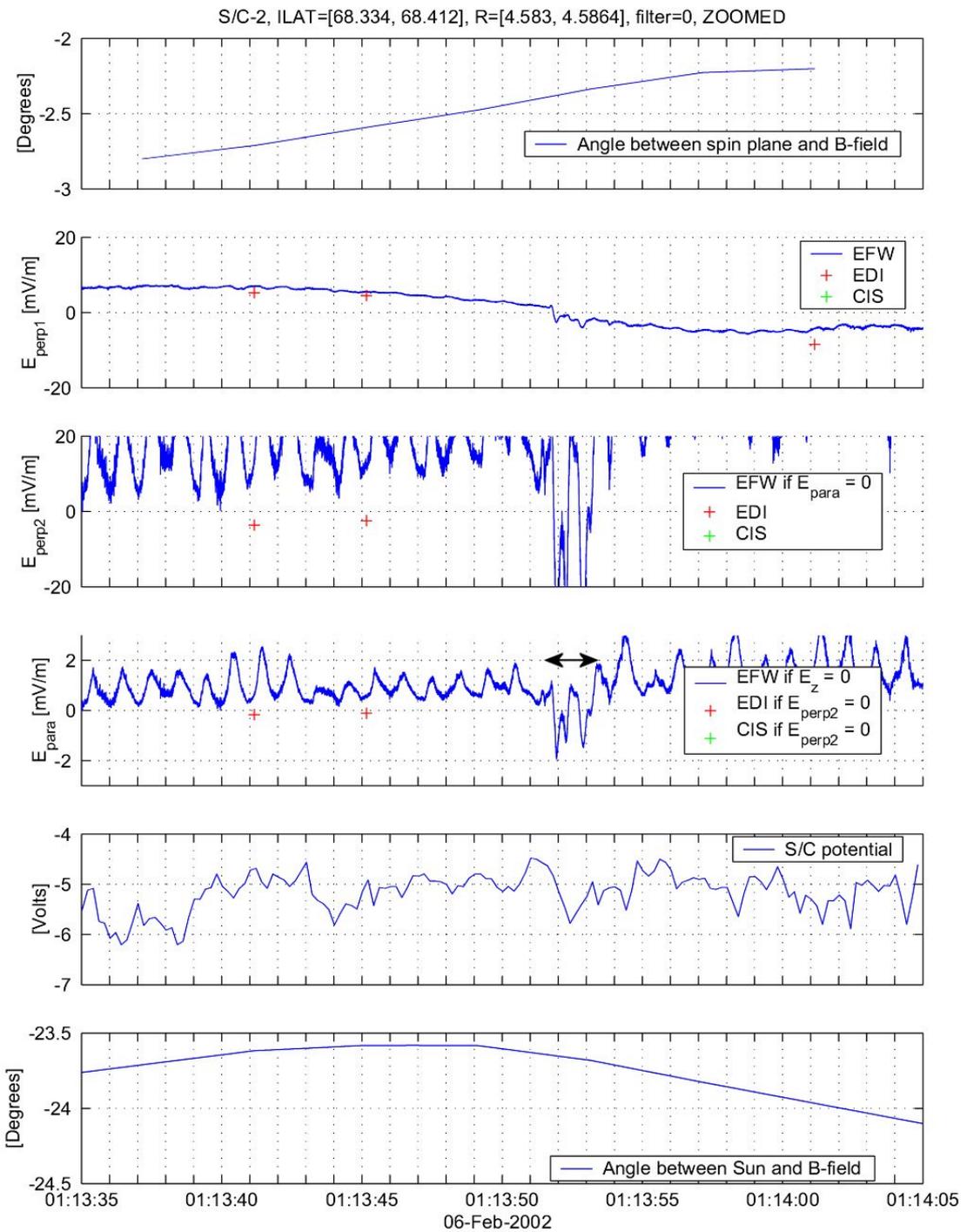
UPPSALA  
UNIVERSITET

DC LIST

SW LIST

UP

BACK





UPPSALA  
UNIVERSITET

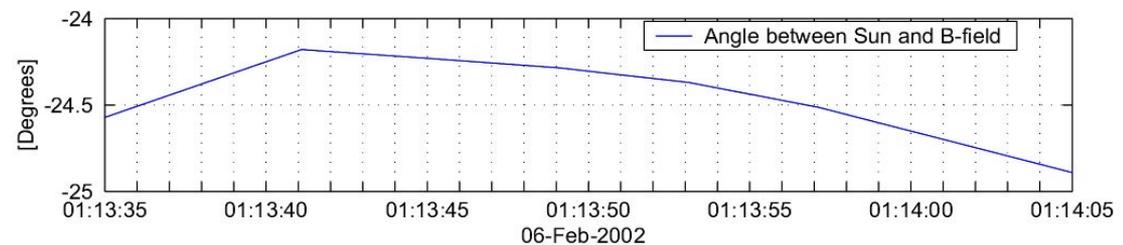
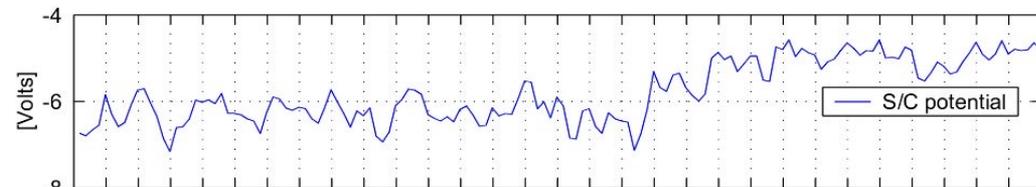
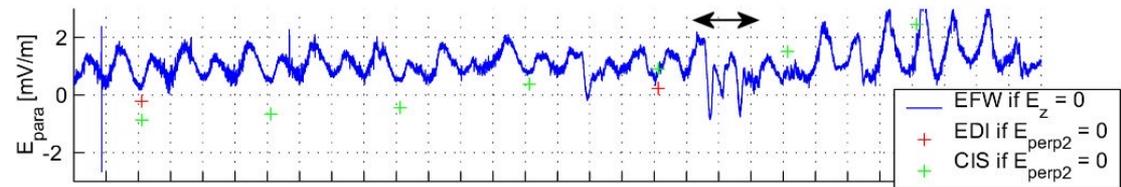
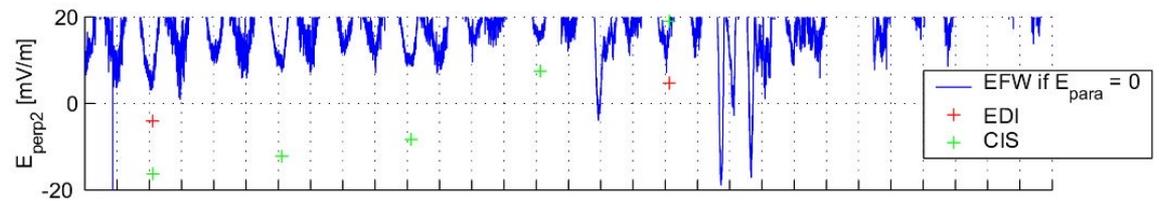
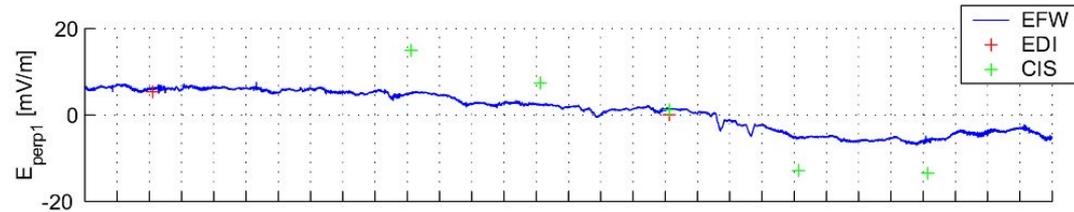
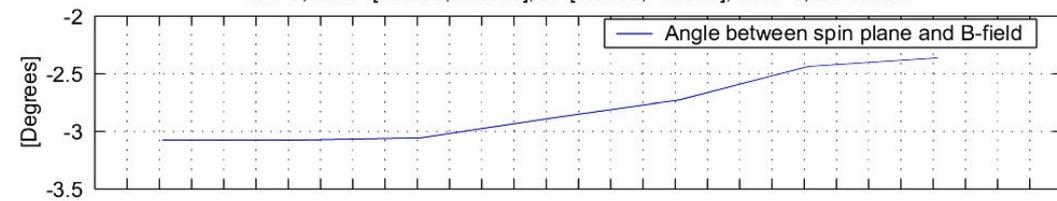
DC LIST

SW LIST

UP

BACK

S/C-3, ILAT=[68.288, 68.366], R=[4.5835, 4.5869], filter=0, ZOOMED





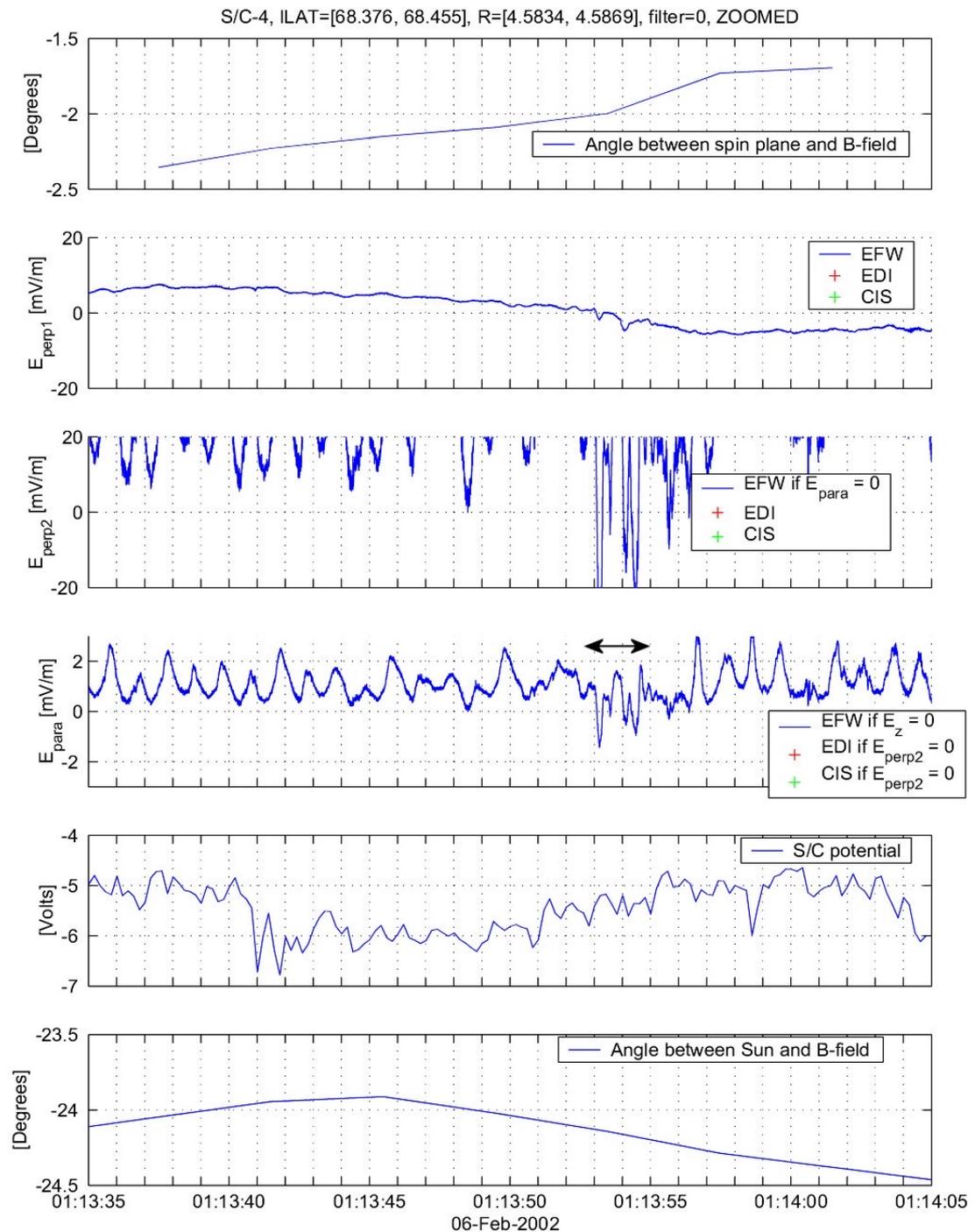
UPPSALA  
UNIVERSITET

DC LIST

SW LIST

UP

BACK





UPPSALA  
UNIVERSITET

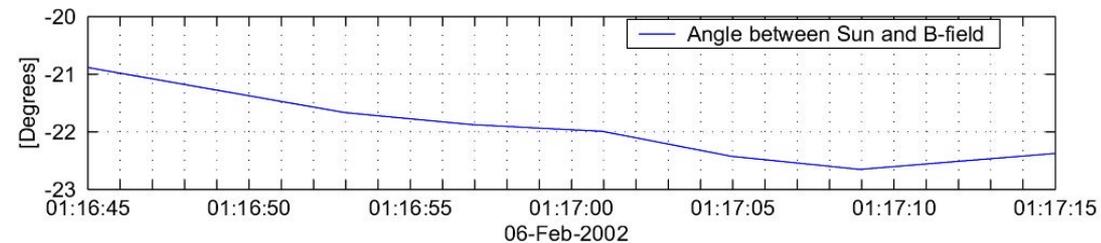
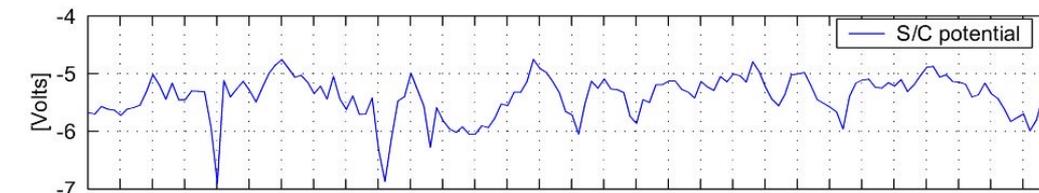
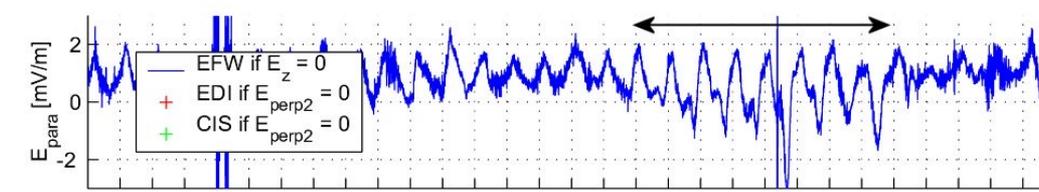
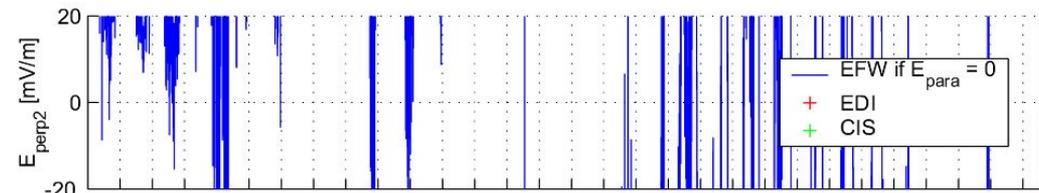
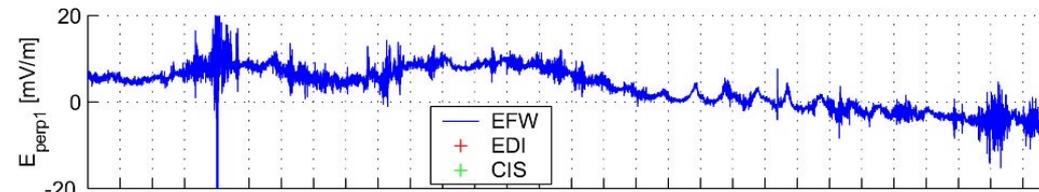
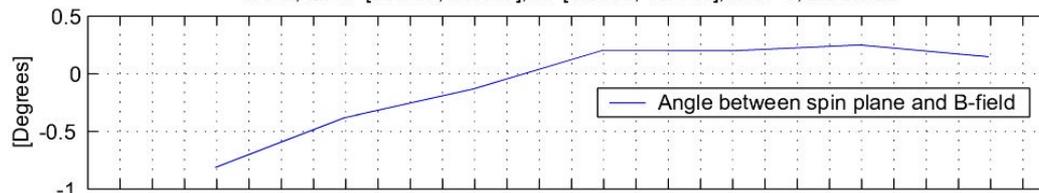
DC LIST

SW LIST

UP

BACK

S/C-2, ILAT=[68.957, 69.037], R=[4.6109, 4.6145], filter=0, ZOOMED





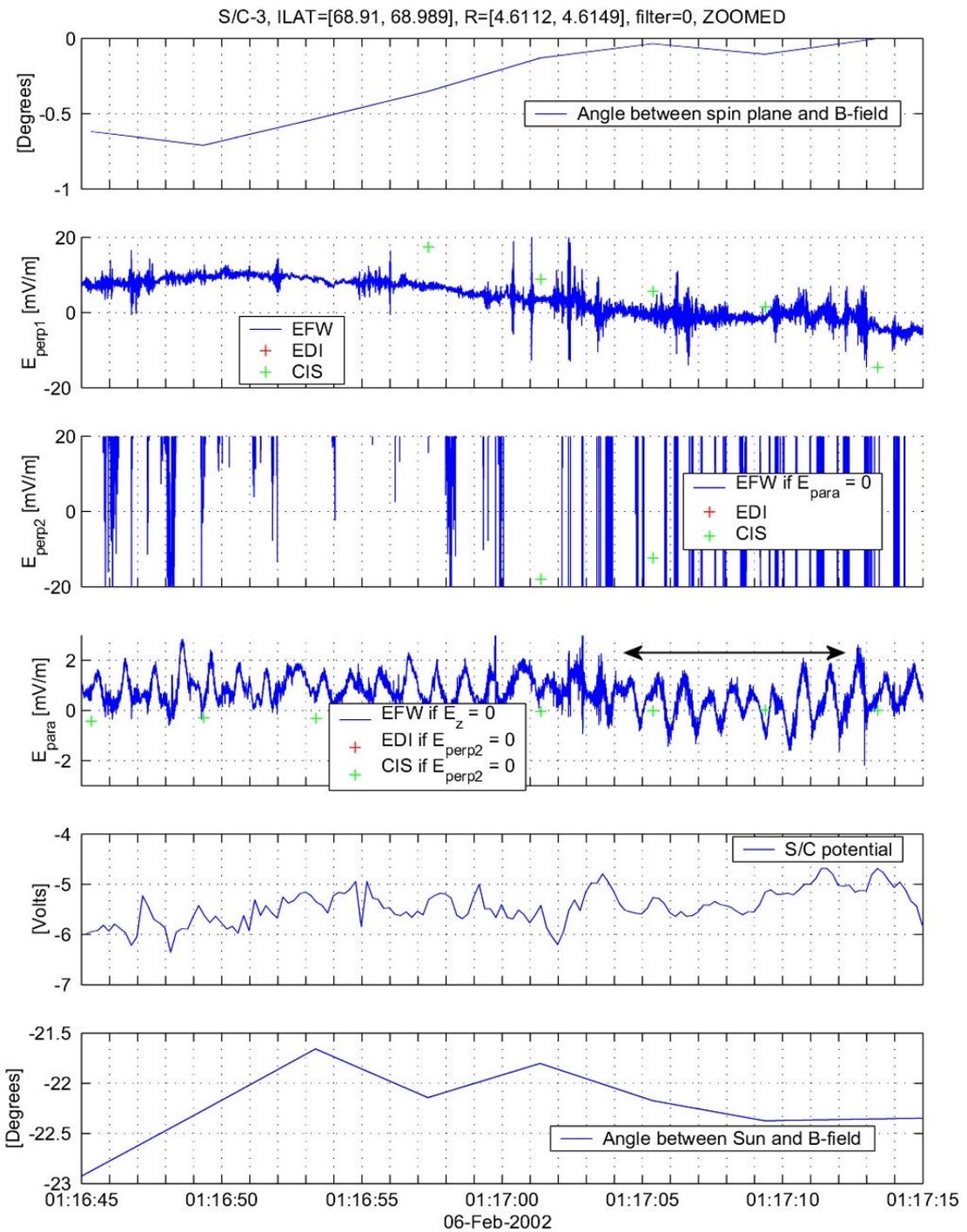
UPPSALA  
UNIVERSITET

DC LIST

SW LIST

UP

BACK





UPPSALA  
UNIVERSITET

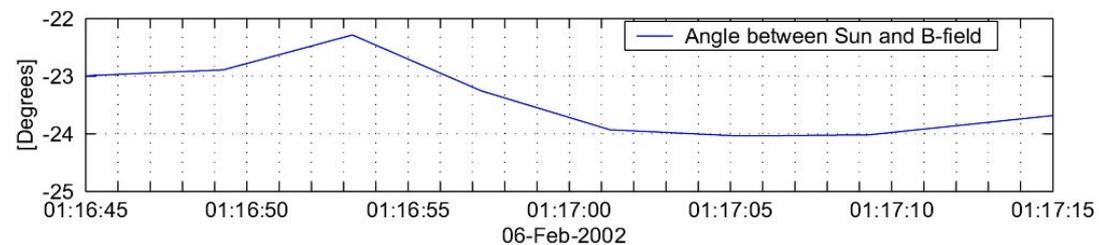
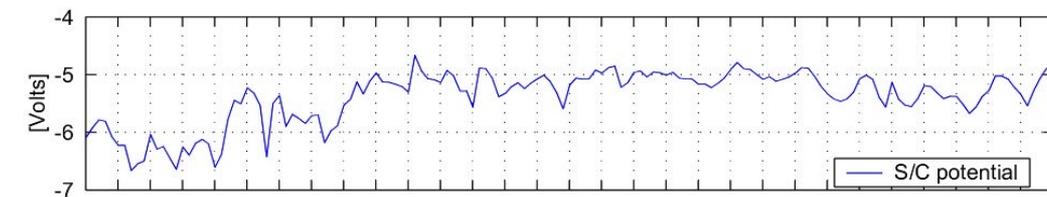
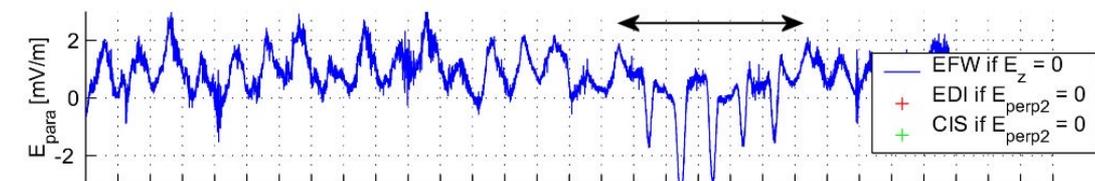
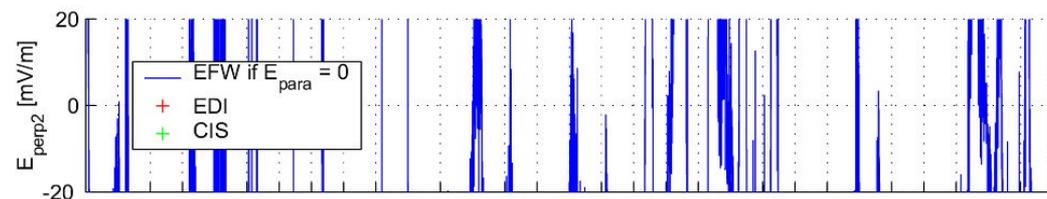
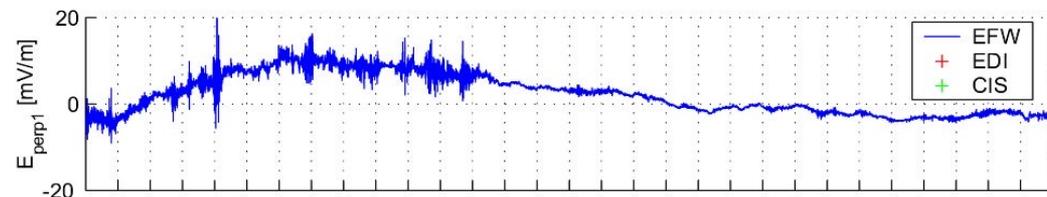
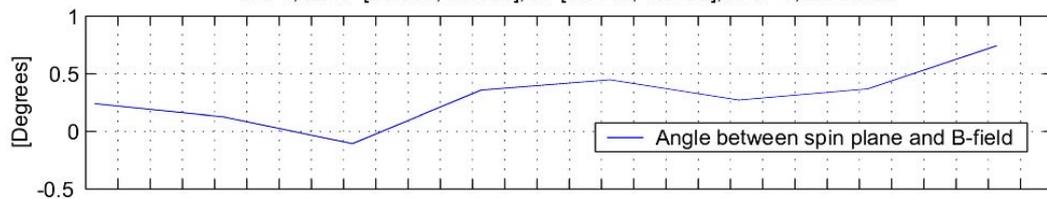
DC LIST

SW LIST

UP

BACK

S/C-4, ILAT=[69.001, 69.081], R=[4.6115, 4.6152], filter=0, ZOOMED





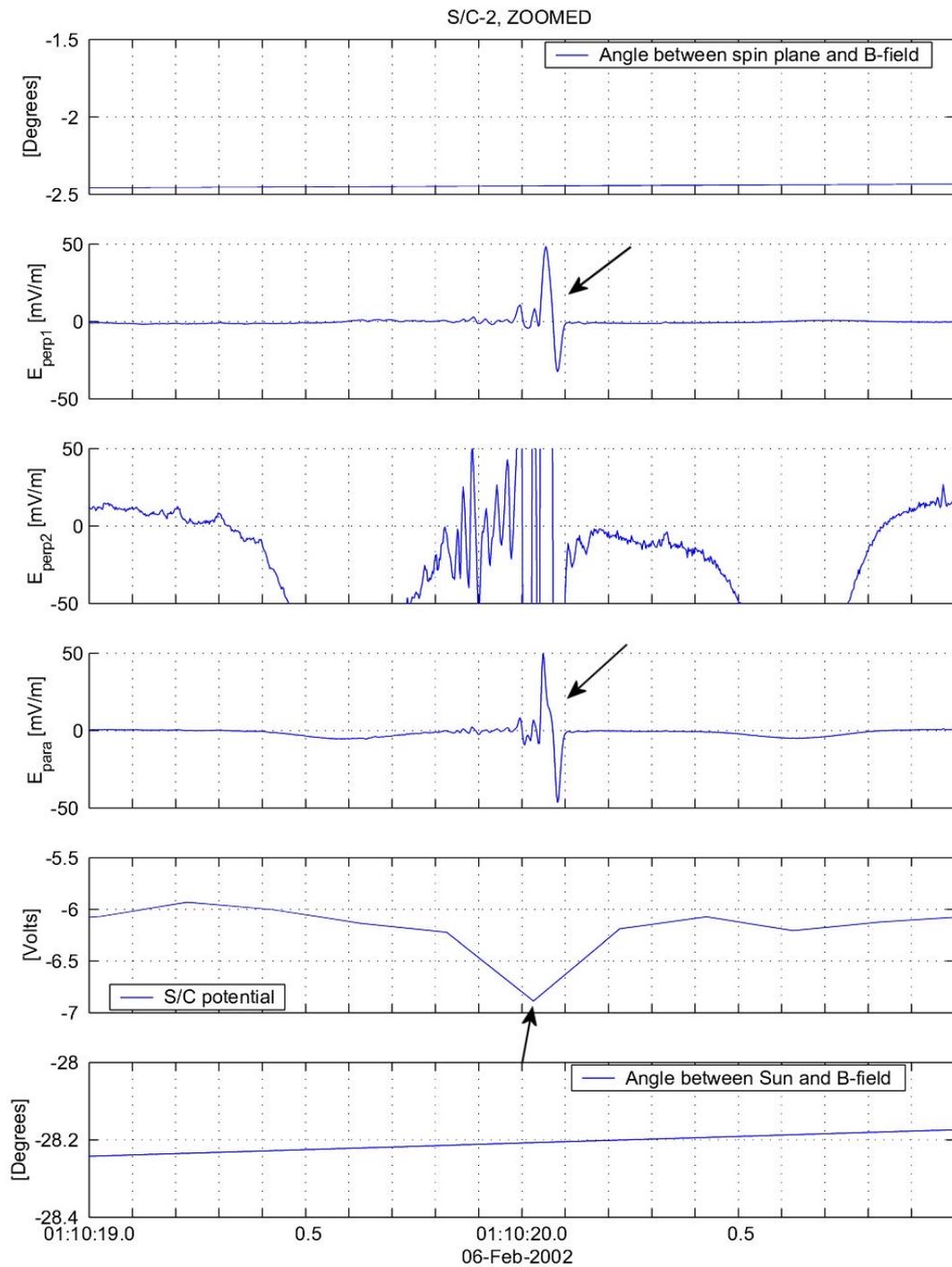
UPPSALA  
UNIVERSITET

DC LIST

SW LIST

UP

BACK





UPPSALA  
UNIVERSITET

**2002-02-17**

**DC LIST**

**SW LIST**

**BACK**



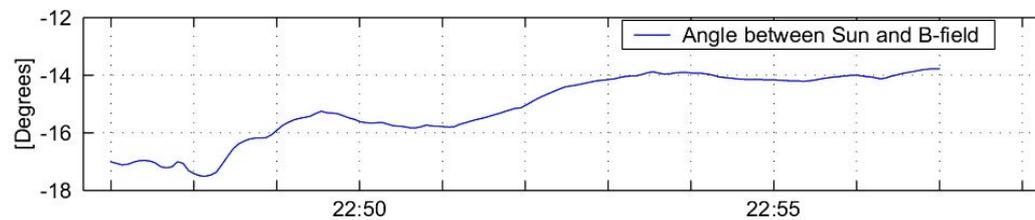
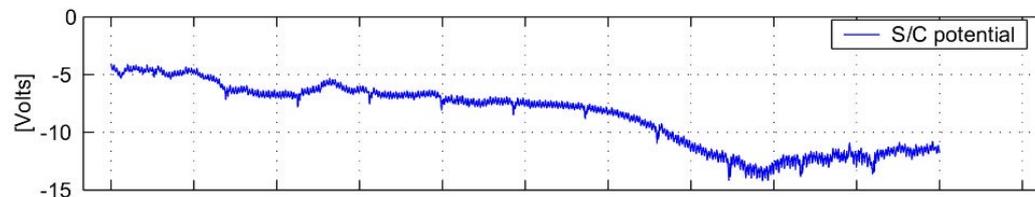
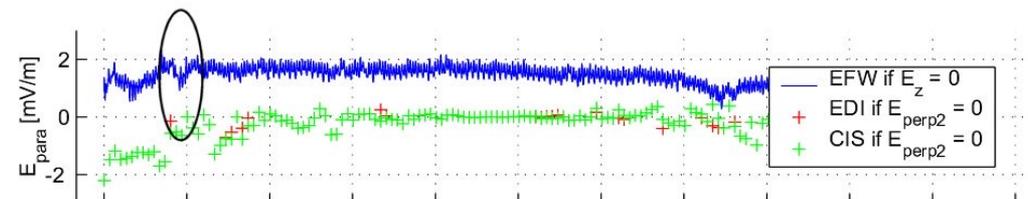
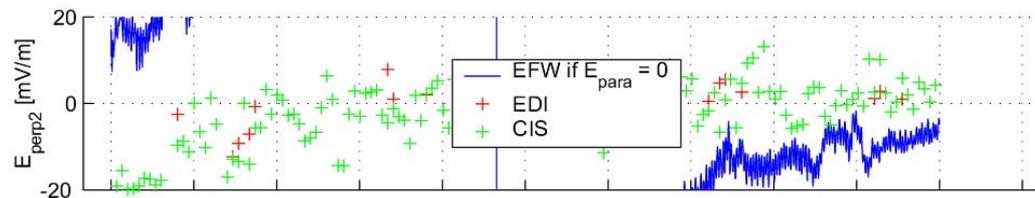
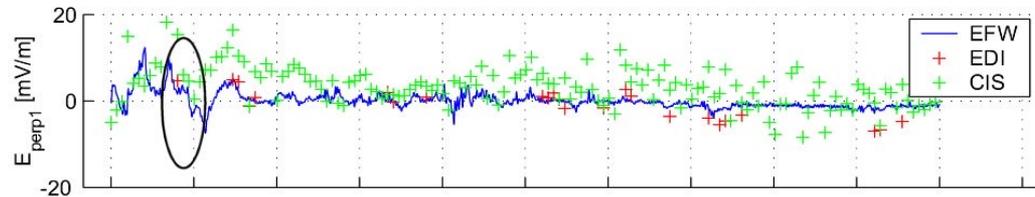
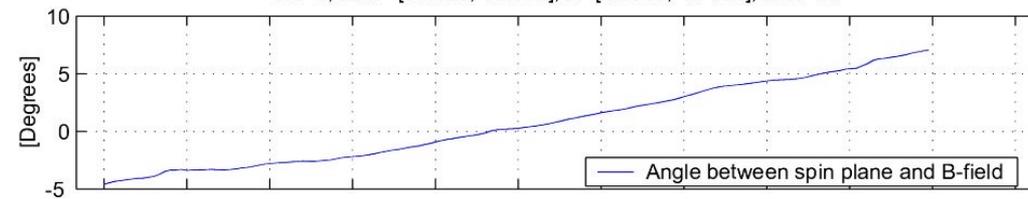
UPPSALA  
UNIVERSITET

DC LIST

SW LIST

BACK

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17-Feb-2002



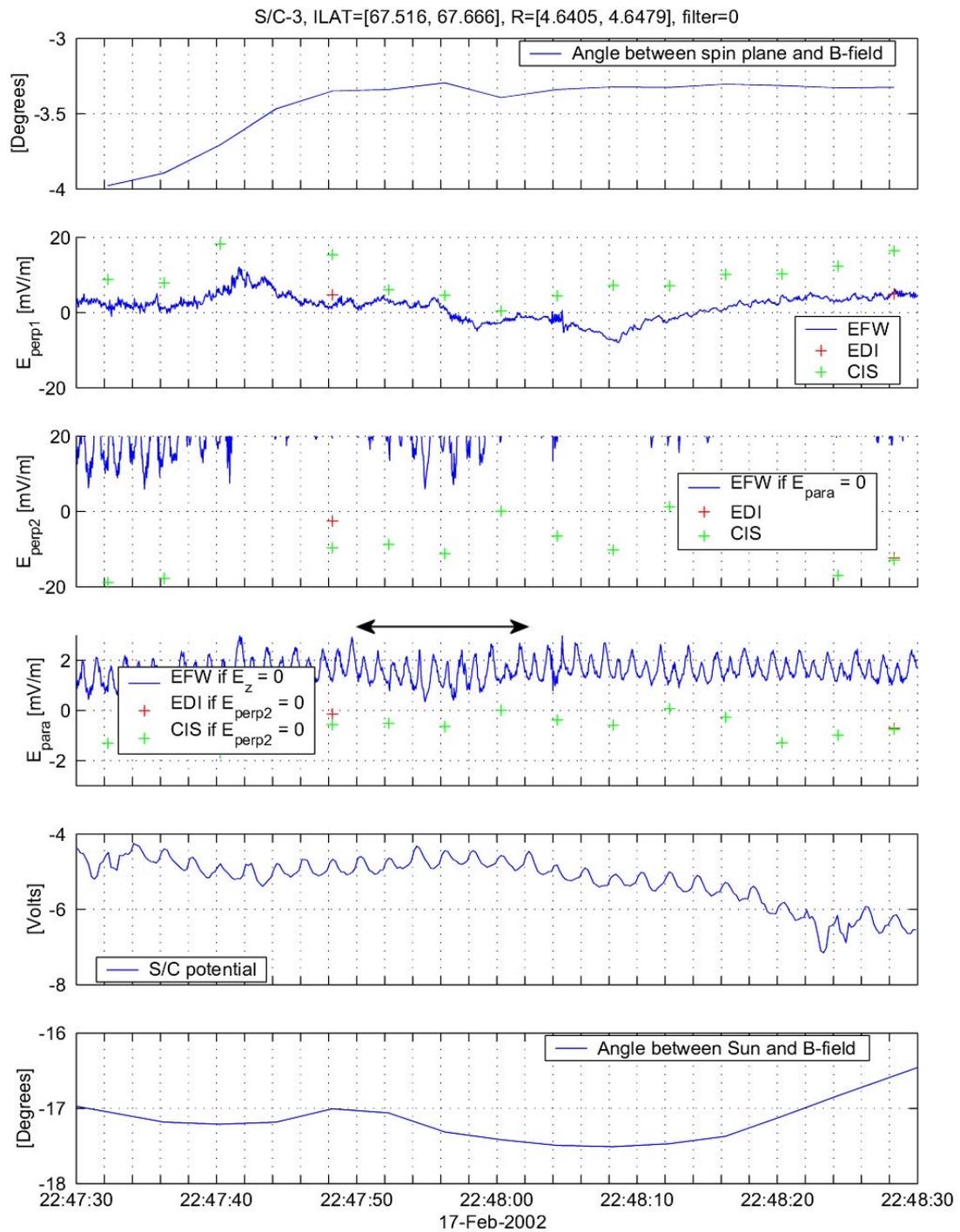
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UNIVERSITET

DC LIST

SW LIST

UP

BACK





UPPSALA  
UNIVERSITET

**2002-03-06**



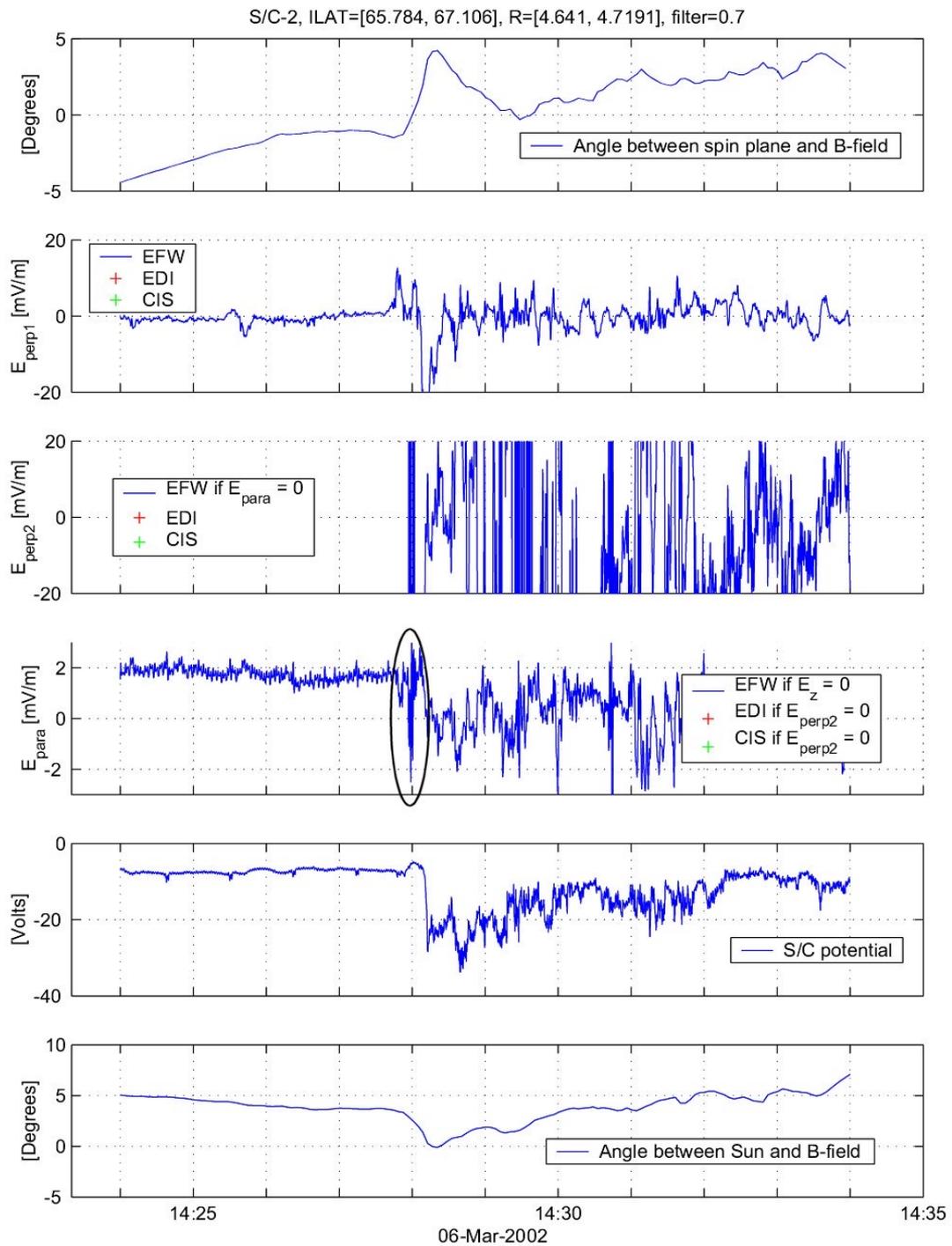
UPPSALA  
UNIVERSITET

WAVES

DC LIST

SW LIST

BACK





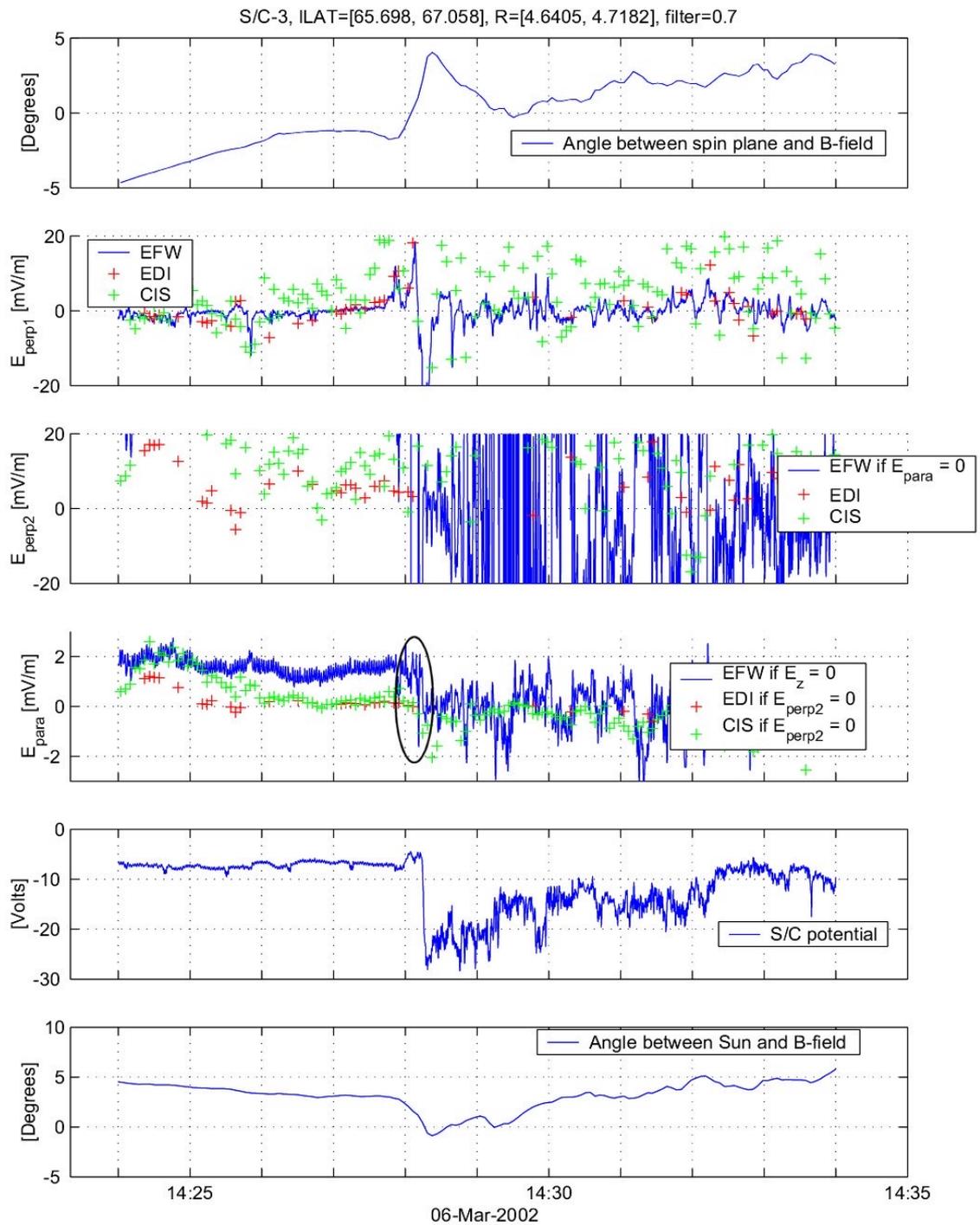
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UNIVERSITET

WAVES

DC LIST

SW LIST

BACK





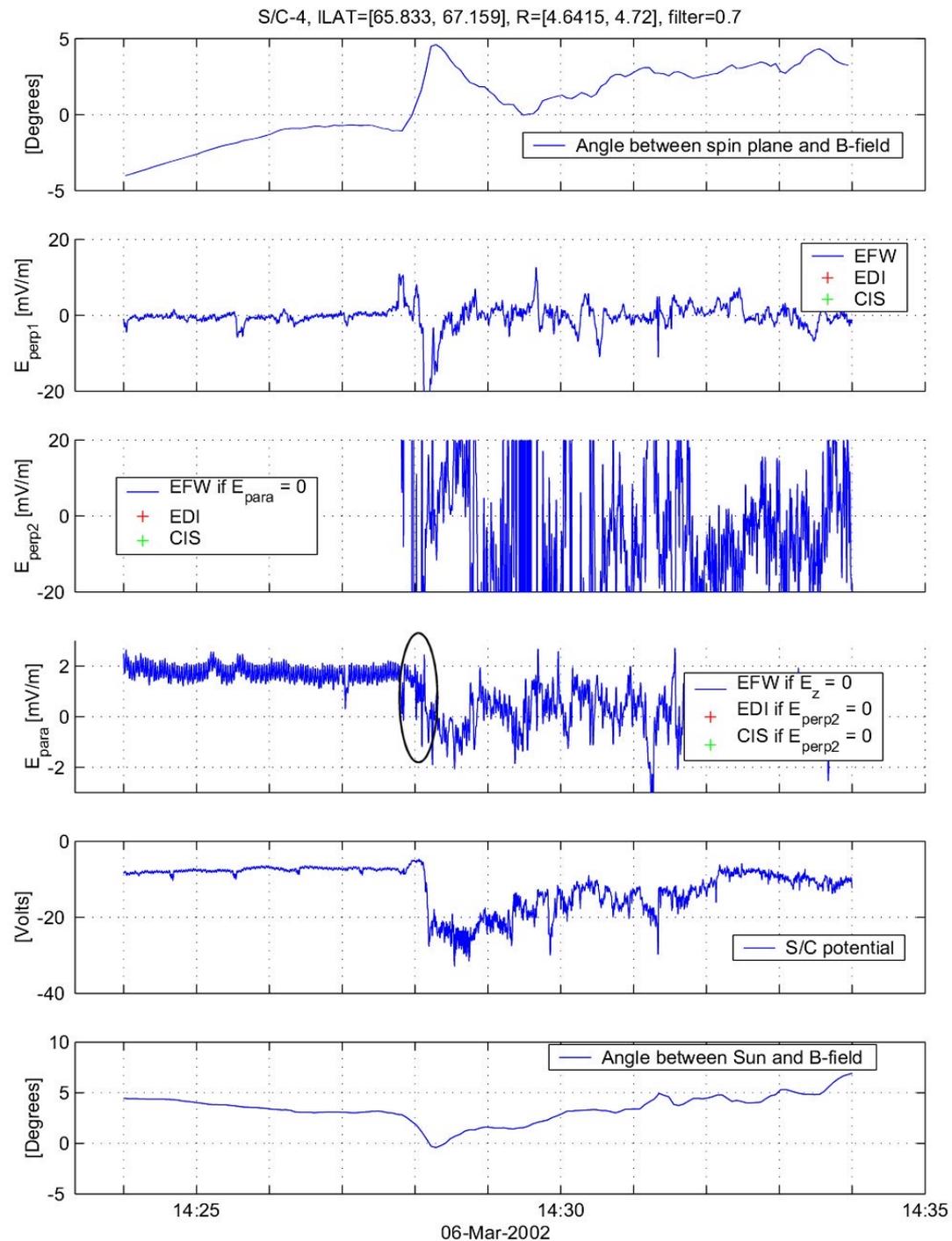
UPPSALA  
UNIVERSITET

WAVES

DC LIST

SW LIST

BACK





UPPSALA  
UNIVERSITET

WAVES

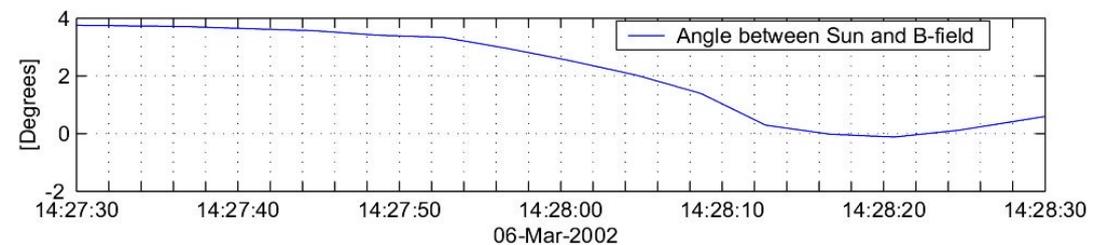
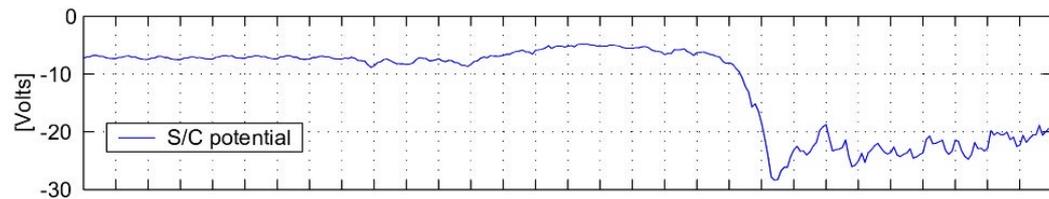
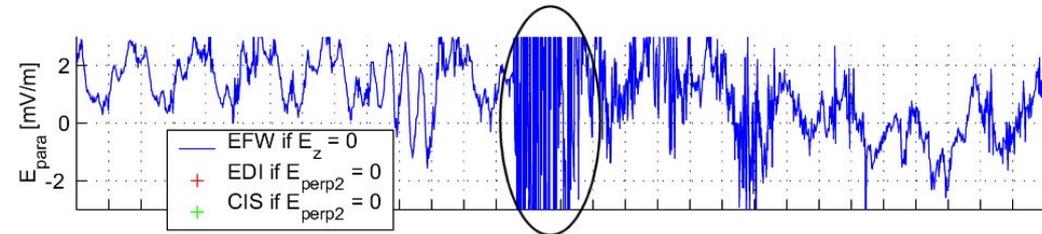
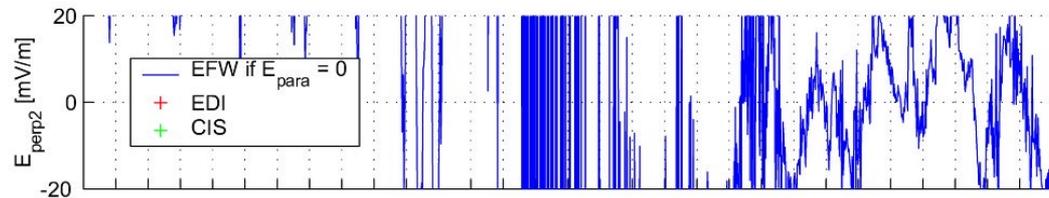
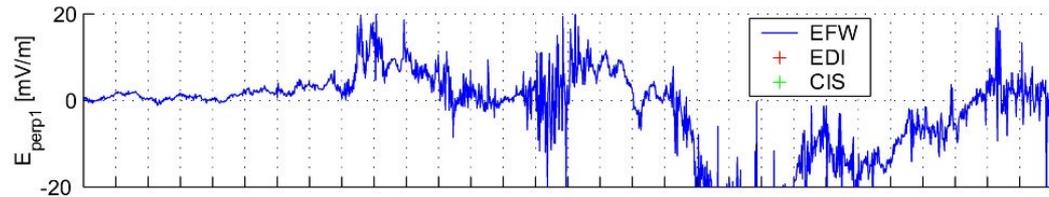
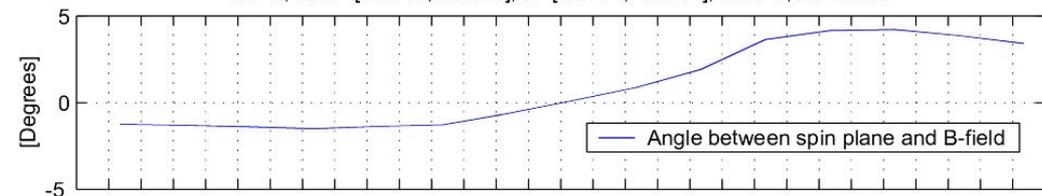
DC LIST

SW LIST

UP

BACK

S/C-2, ILAT=[66.348, 66.481], R=[4.6741, 4.6819], filter=0, ZOOMED





UPPSALA  
UNIVERSITET

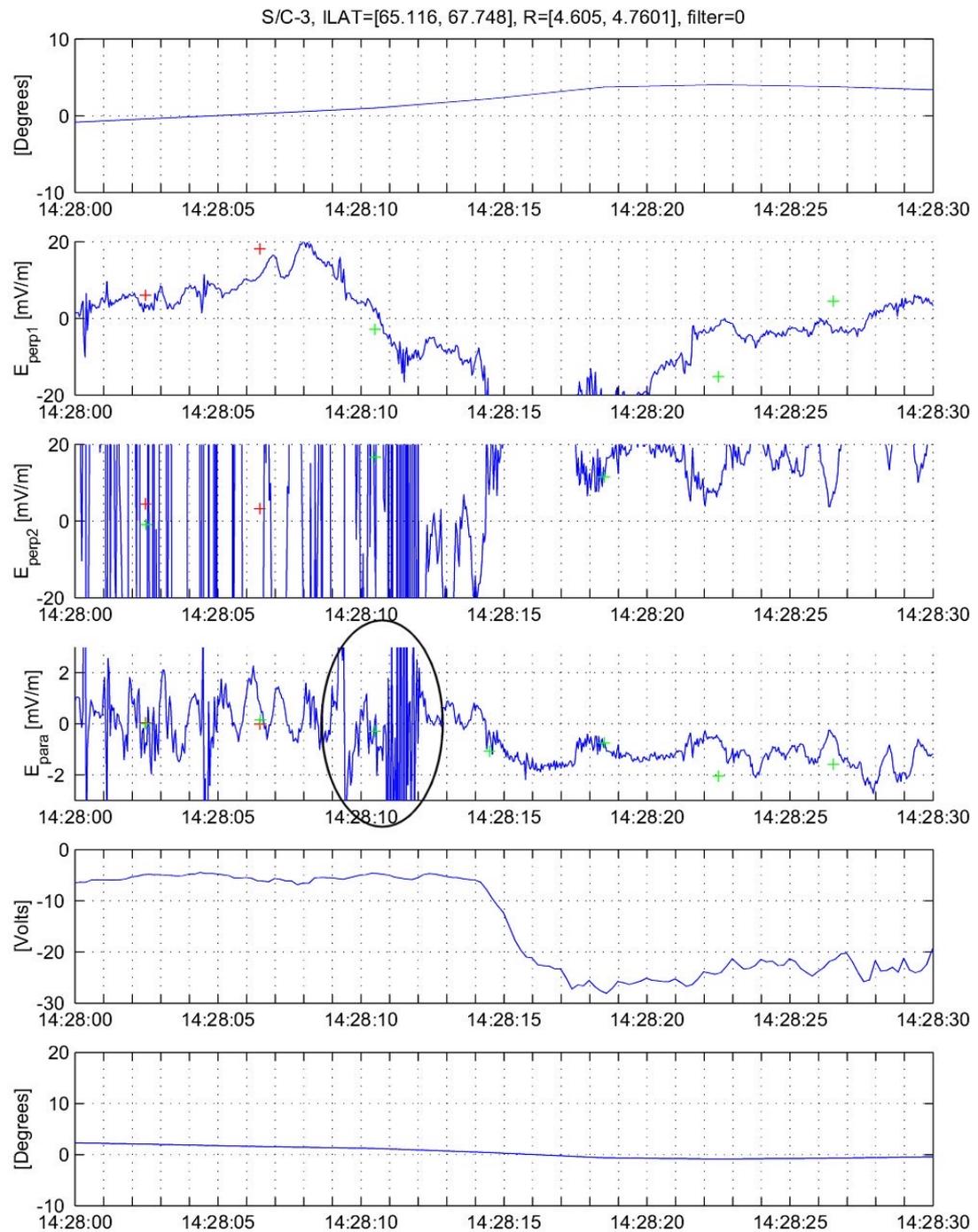
WAVES

DC LIST

SW LIST

UP

BACK



06-Mar-2002



UPPSALA  
UNIVERSITET

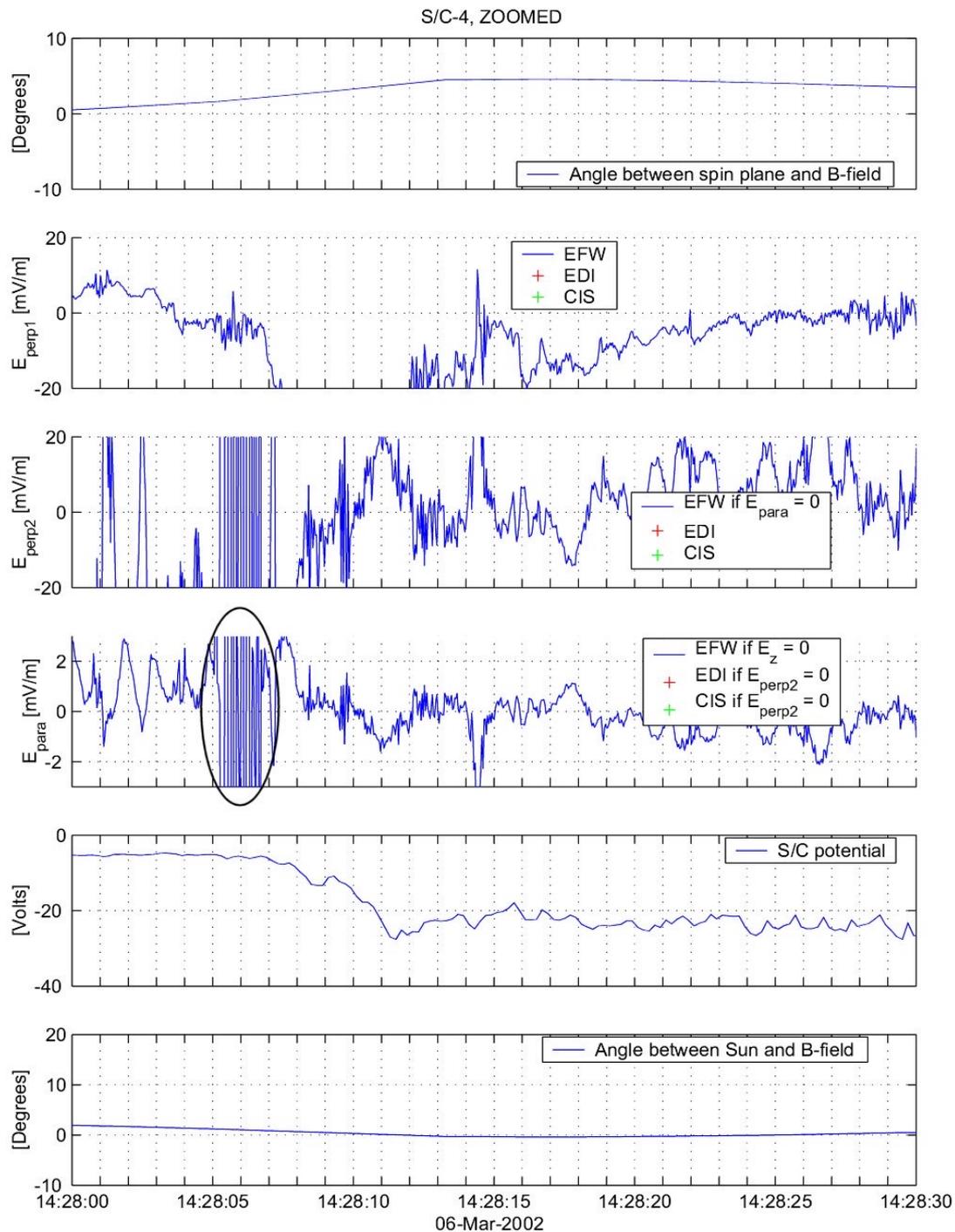
WAVES

DC LIST

SW LIST

UP

BACK





UPPSALA  
UNIVERSITET

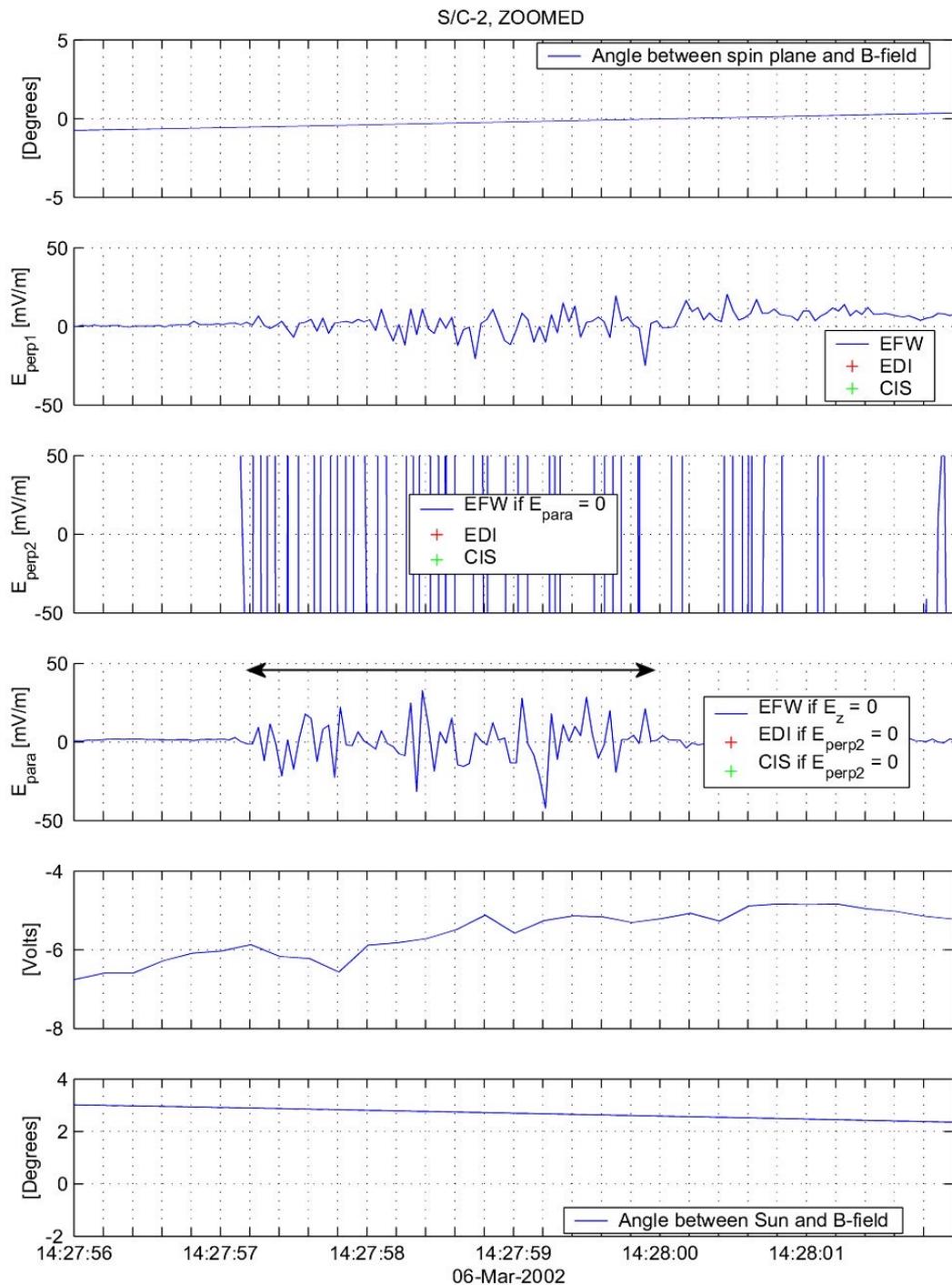
WAVES

DC LIST

SW LIST

UP

BACK





UPPSALA  
UNIVERSITET

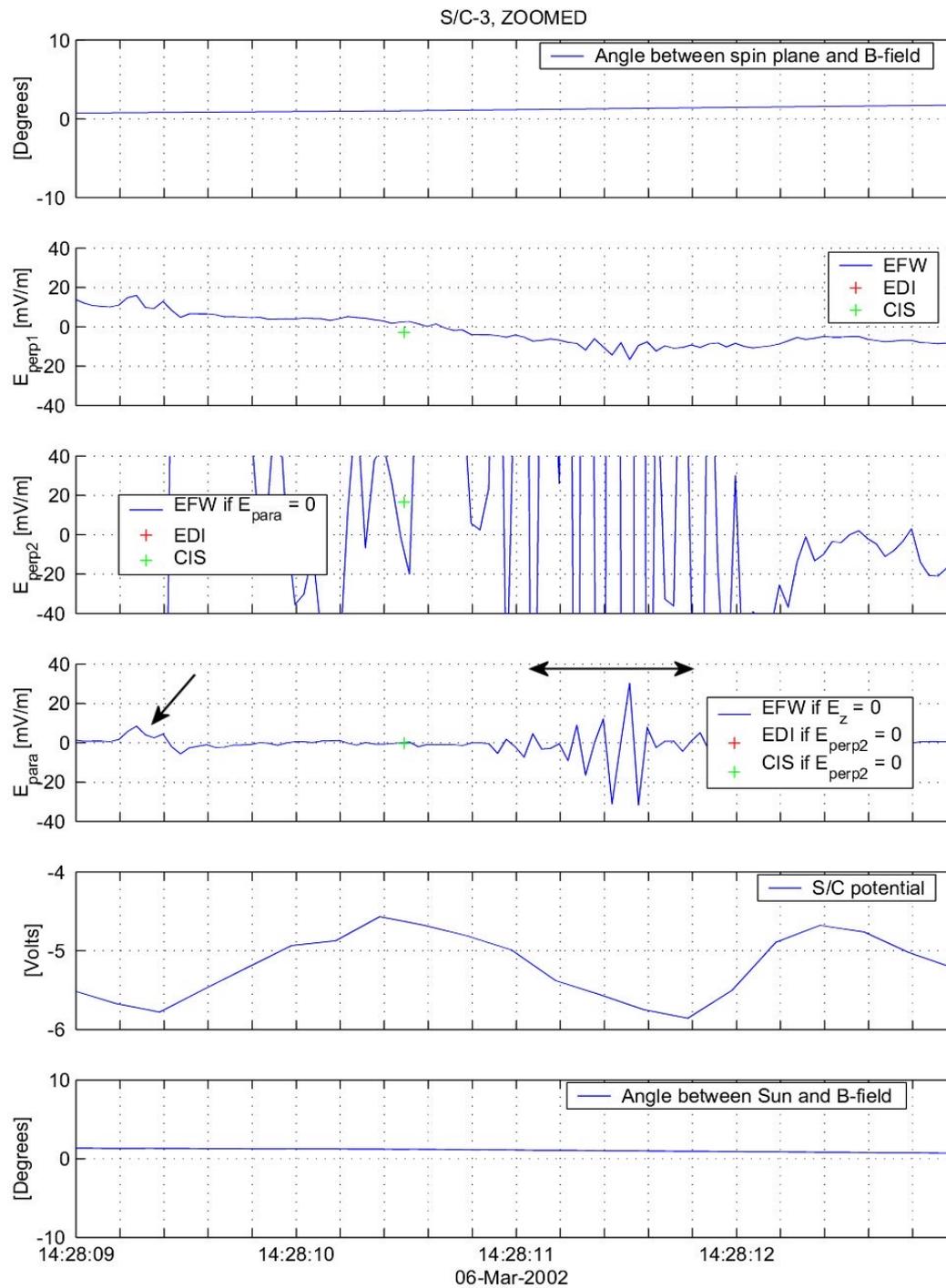
WAVES

DC LIST

SW LIST

UP

BACK





UPPSALA  
UNIVERSITET

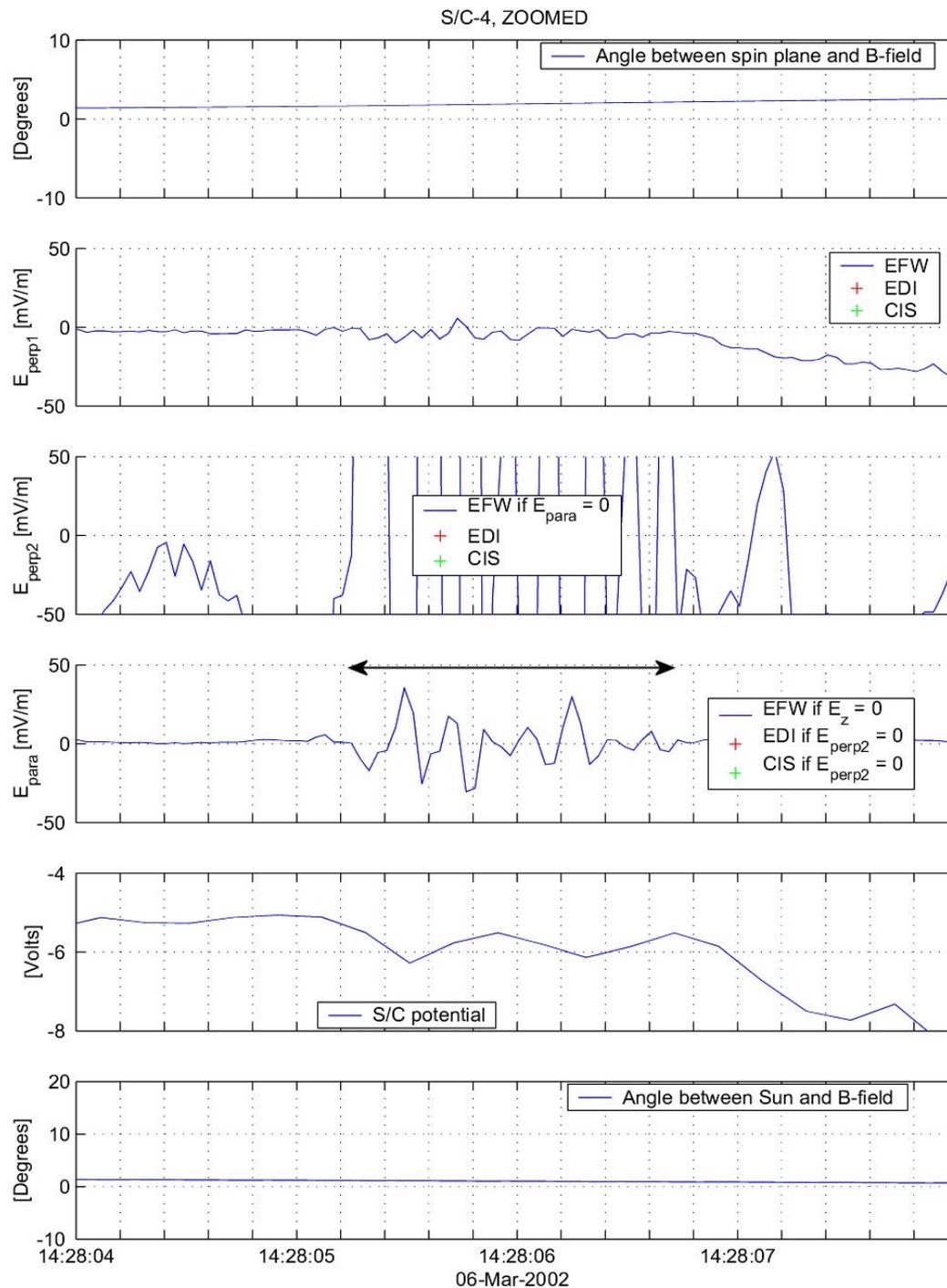
WAVES

DC LIST

SW LIST

UP

BACK





UPPSALA  
UNIVERSITET

**2002-03-18**

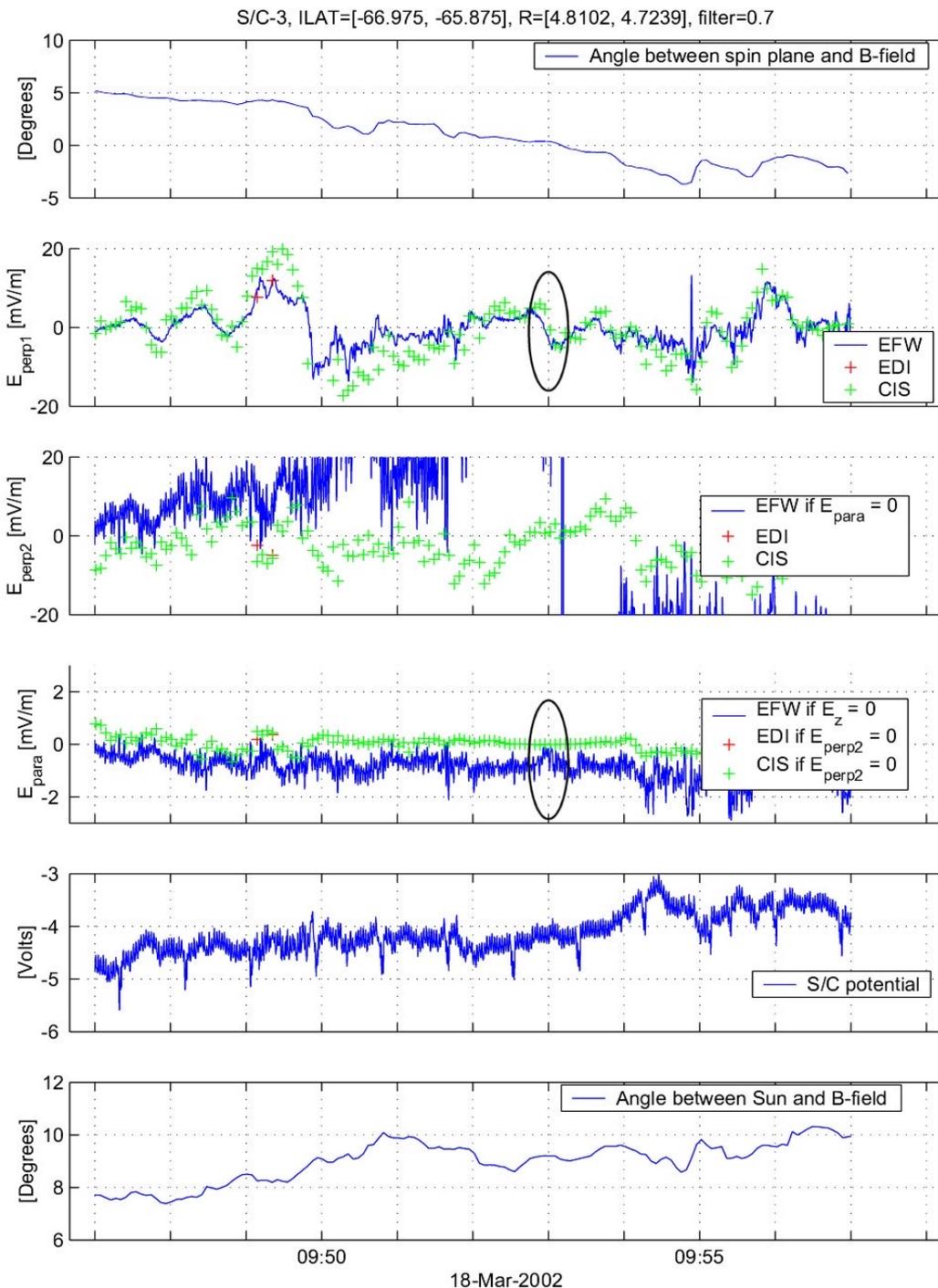


UPPSALA  
UNIVERSITET

DC LIST

SW LIST

BACK



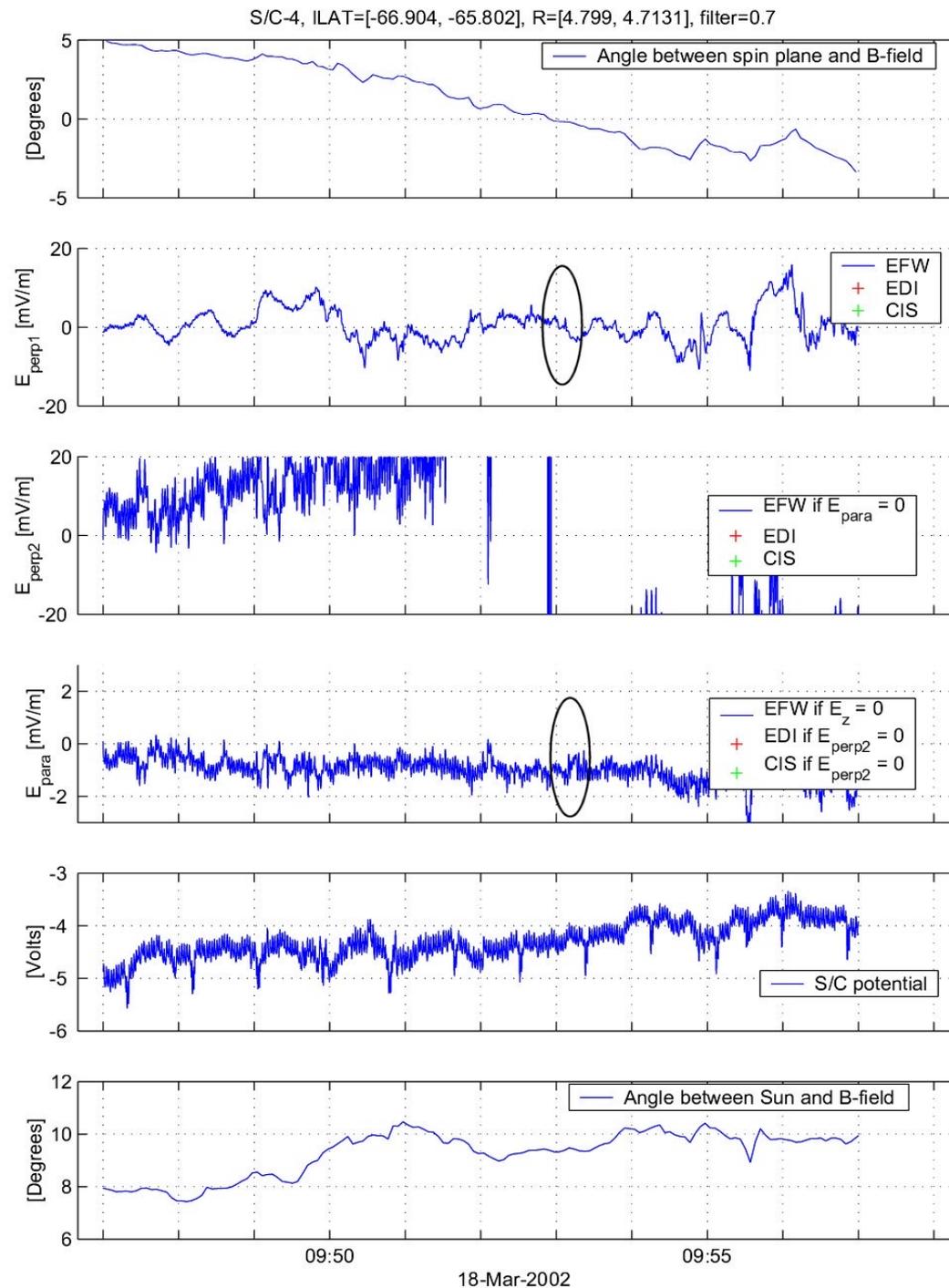


UPPSALA  
UNIVERSITET

DC LIST

SW LIST

BACK





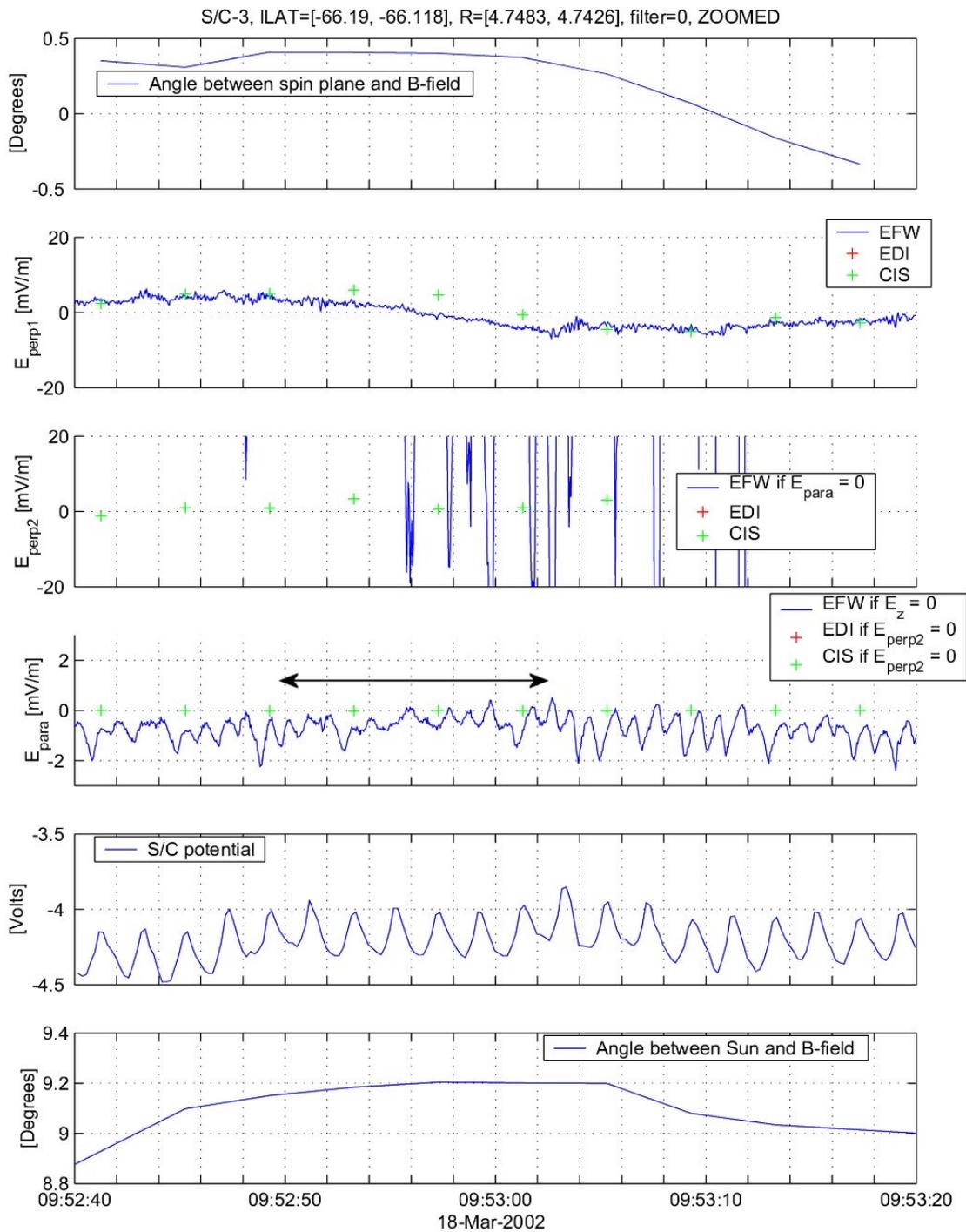
UPPSALA  
UNIVERSITET

DC LIST

SW LIST

UP

BACK





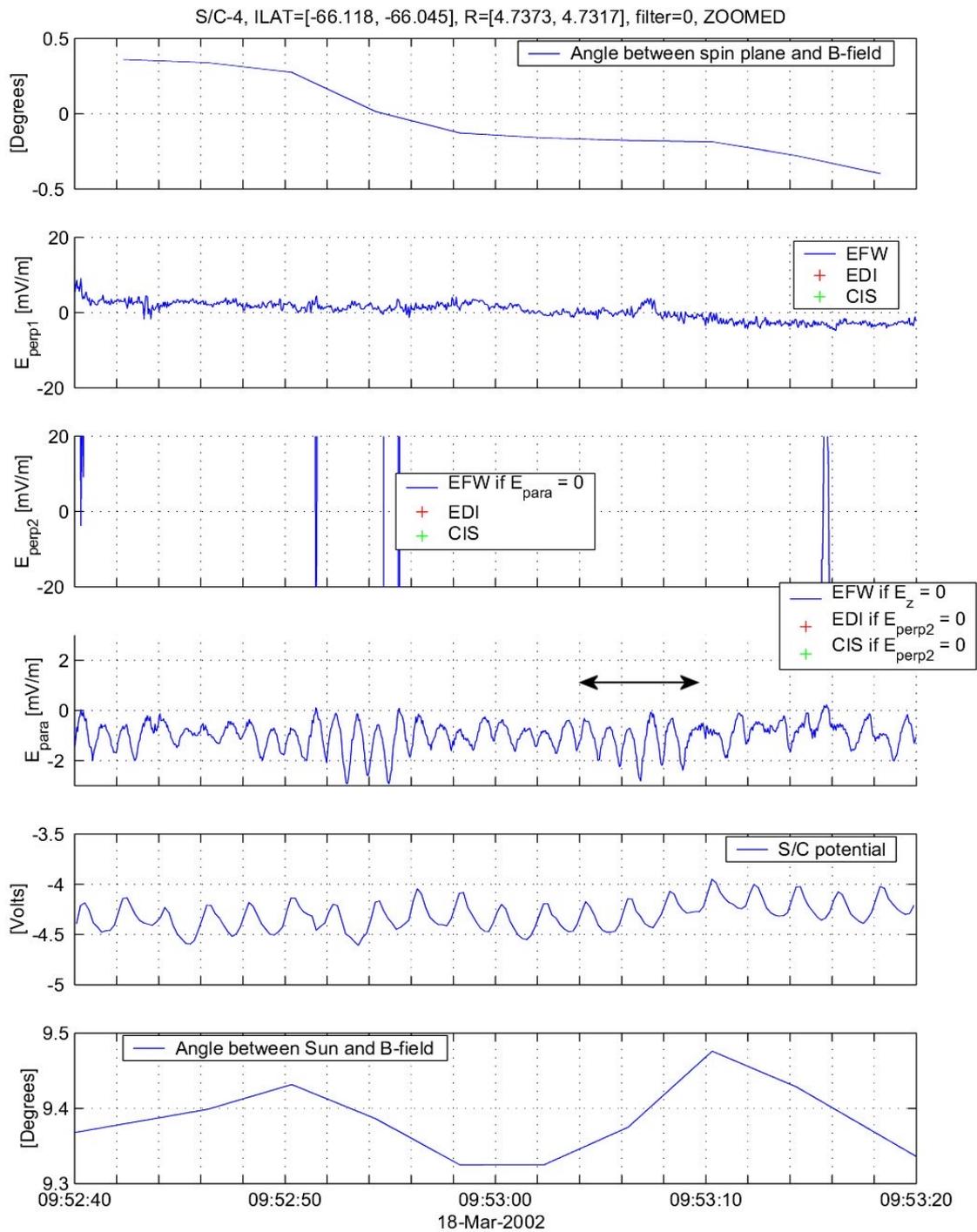
UPPSALA  
UNIVERSITET

DC LIST

SW LIST

UP

BACK





UPPSALA  
UNIVERSITET