Swarm Langmuir Probe Ion Drift, Density and Effective Mass Product: Estimating Key Ionospheric Parameters using Faceplate and Langmuir Probe Data

UNIVERSITY OF CALGARY

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I. P. Pakhotin, J. K. Burchill, M. Förster, R. Marchand, A. Olowookere, L. Lomidze

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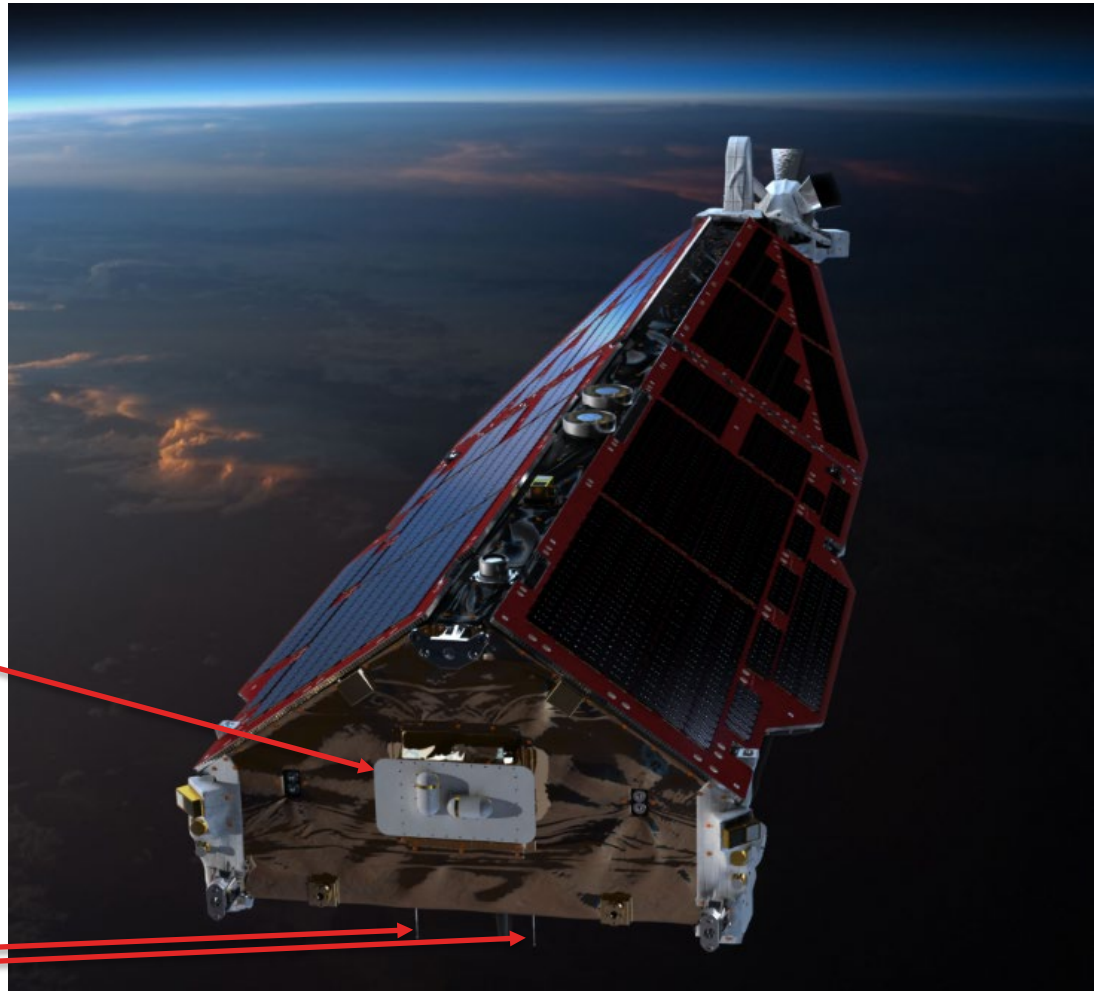
SLIDEM



Credit: @esa_swarm/Twitter

SLIDEM Mathematics

Estimation of Swarm along-track Ion Drift, Density and Effective Mass

- Presently, Swarm Level 1b LP ion density product is estimated from ion admittance:

$$d_s = \frac{\partial I}{\partial V_b} = -\frac{2N_s q_s^2}{m_s v_s}\pi r_p^2$$

- 100% O+, zero along-track ion drift is assumed
- In a realistic ionosphere and at higher latitudes, these assumptions will be routinely violated

SLIDEM Mathematics (cont.)

- With multi-ion species, their admittances sum. In this case, m_s is replaced by effective mass M_eff:

$$\frac{1}{M_{eff}} = \frac{1}{N_i}\sum_{i=1}^{S} N_s \frac{1}{m_s}$$

- Unlike average mass, the effective mass is sensitive to a small proportion of light ions e.g. H+
- SLIDEM adds TII faceplate current:

$$I_{FP} = -N_i e v_i A_{FP}$$

SLIDEM Mathematics (cont.)

- At low latitudes, the ion drift may be assumed zero, yielding ion density and effective mass estimates:

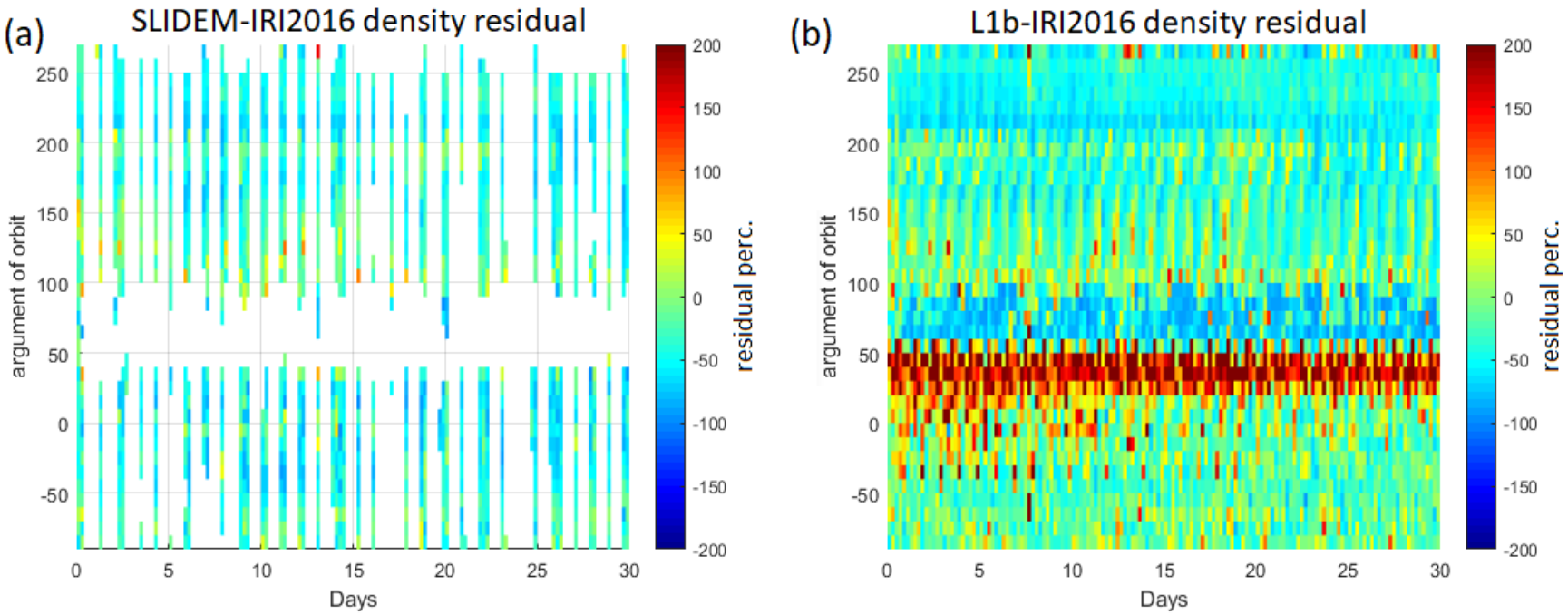
$$N_i = -\frac{I_{FP}}{A_{FP} e\, v_{sat}}$$

$$M_{eff} = \frac{2e\pi r_p^2 I_{FP}}{d_i A_{FP} v_{sat}^2}$$

- If M_eff may be estimated, e.g. from IRI, along-track ion drift in satellite reference frame may be estimated using:

$$v_i = \sqrt{\frac{2e\pi r_p^2 I_{FP}}{d_i A_{FP} M_{eff}}}$$

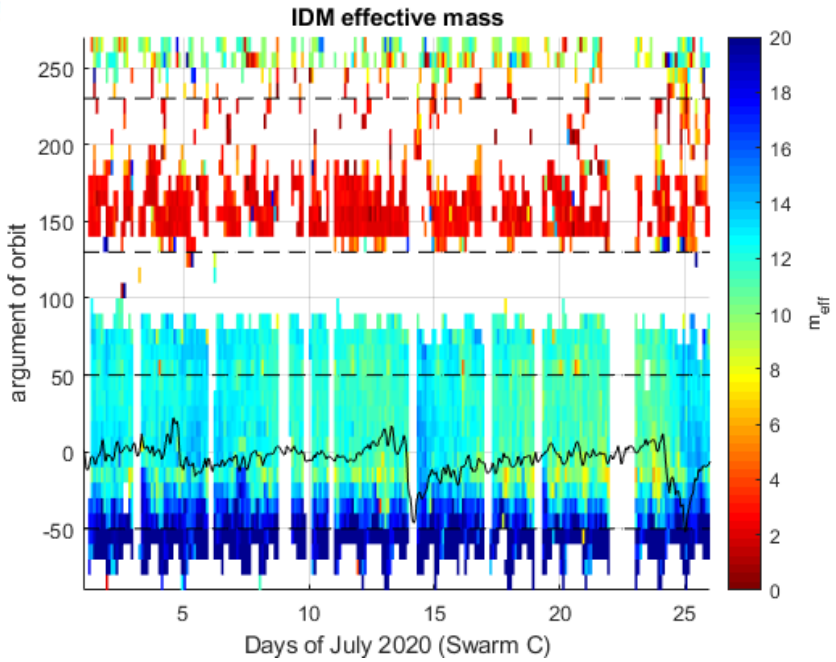
Results - density

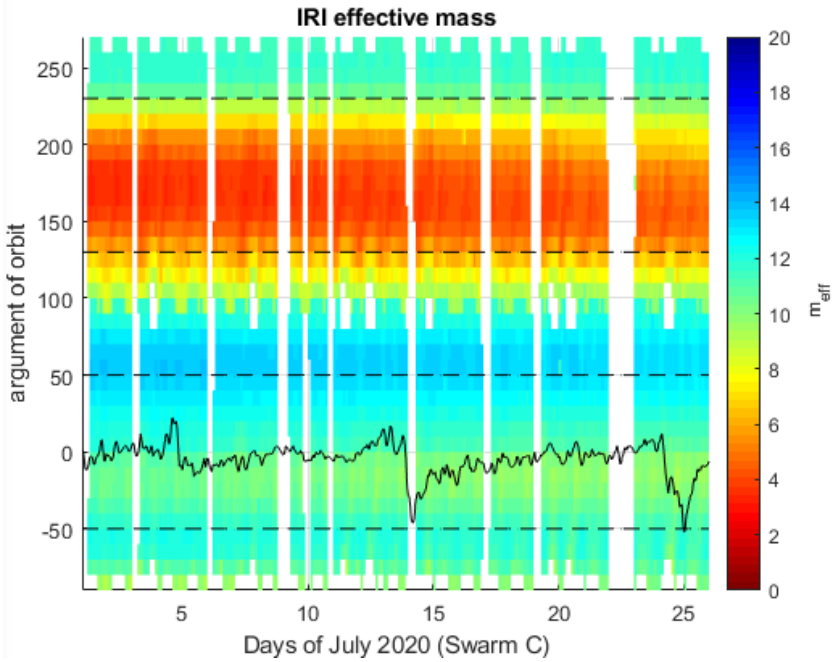


- On nightside, light ions lead to lower effective mass and thus an over-estimation of density in the L1b product. SLIDEM resolves this

- This is corroborated both by comparison with IRI-2016 (above) and ISR-spacecraft conjunctions

Results – Effective Mass





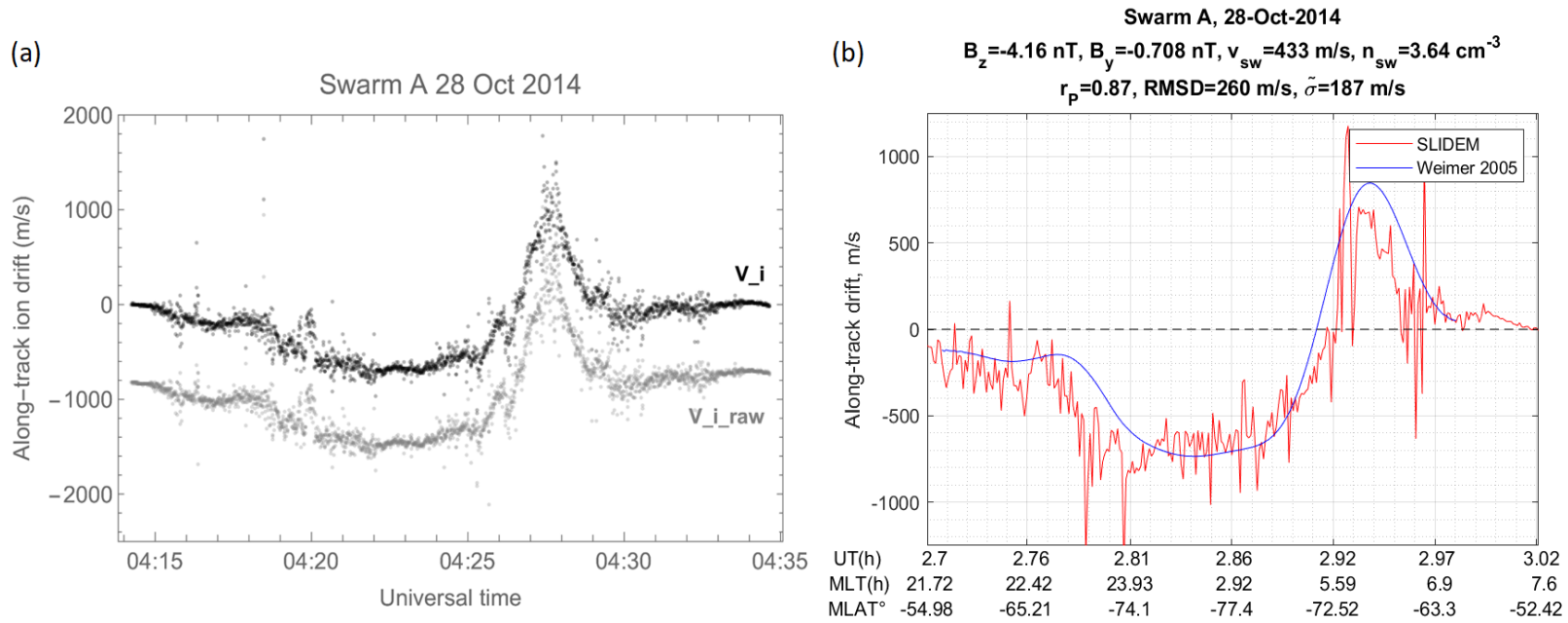
- Allows Swarm to be used as a light ion detector (but without spectrometry)

- Small variations from 100% O+ have significant impact on effective mass

- Evidence of ion outflow in the hours following geomagnetic storm main phase

- Cannot be seen on IRI since plasma composition (Truhlik et al., 2015) driven by F10.7

Results – Along-Track Ion Drift



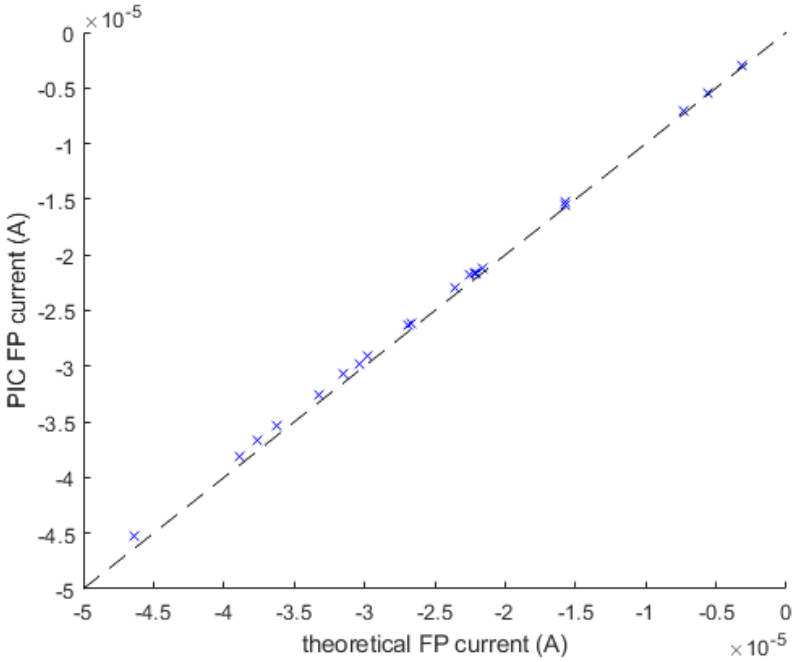
- At high latitudes, effective mass estimated from IRI-2016

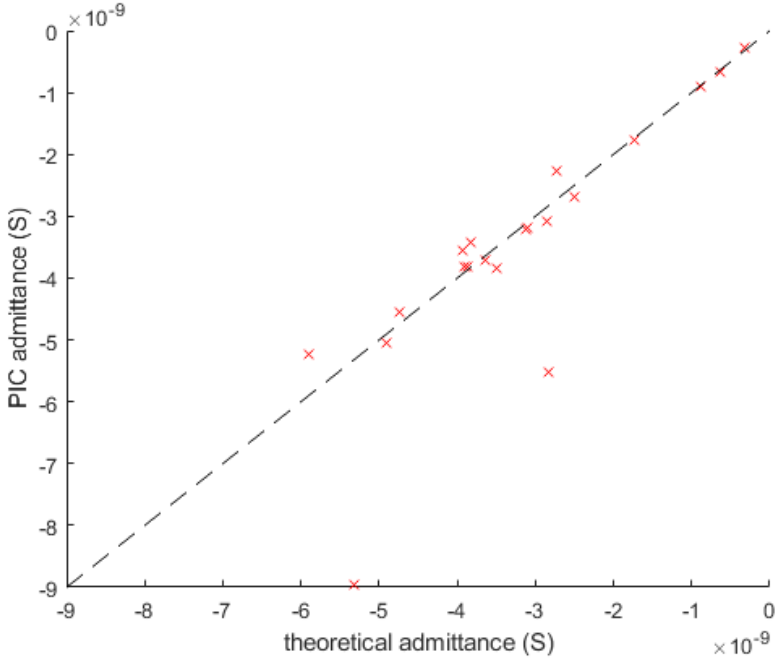
- V_i now the subject of the equation, along-track drift is derived

- Detrend of auroral zone crossings is used to make values ->zero at low latitudes

- Good agreement with Weimer (2005) electric field model

PIC Simulations





- Several PTetra PIC simulations have been carried out by Richard Marchand and Akinola Olowookere to test the assumptions inherent in SLIDEM methodology

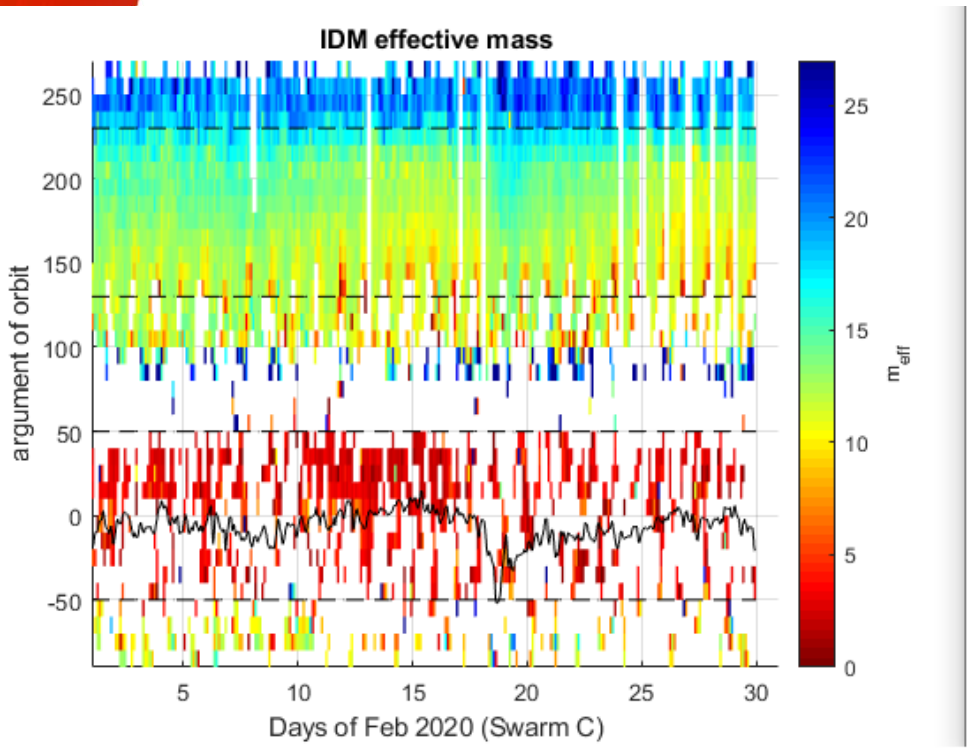
- ISR/Swarm conjunctions were selected, parameters of ion and electron temperature, densities, B-field, spacecraft potential, species % were chosen from a range of sources

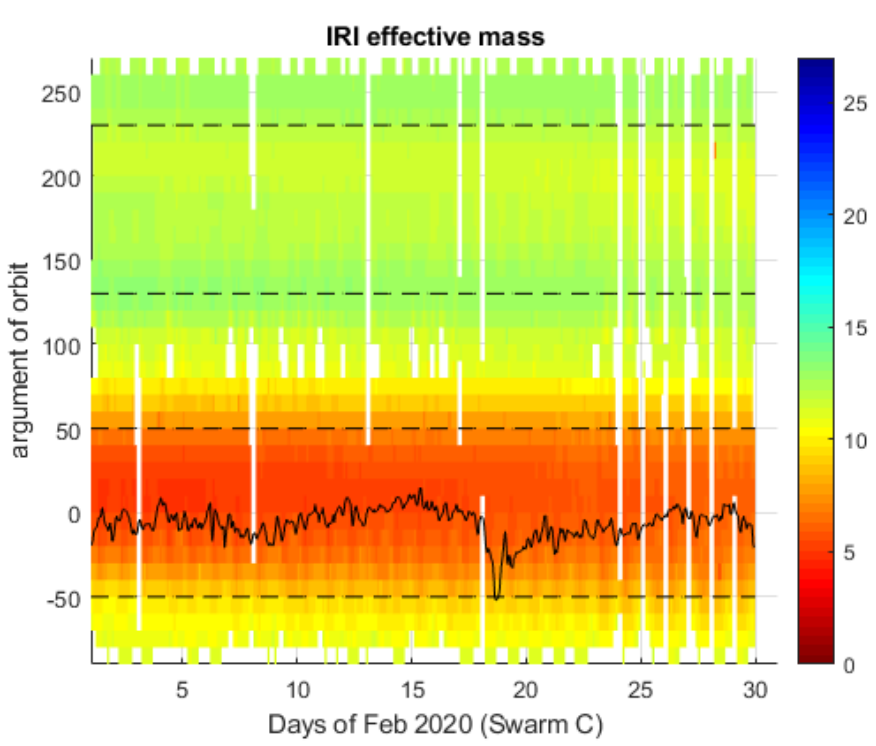
- PTetra simulated FP current and admittance generally exhibited good agreement with those predicted using SLIDEM methodology – investigation of outliers is ongoing

Conclusions

- A new Swarm data product has been developed: effective mass, improved density, along-track ion drift
- Product has been validated against IRI-2016, ground ISR conjunctions, spacecraft-spacecraft conjunctions, Weimer (2005) electric field model
- Project is currently in Phase 2, SLIDEM data can be obtained from the ESA server, integration with ViRES is ongoing
- The entire mission dataset for all 3 satellites has been generated
- Paper is in review, preprint: https://assets.researchsquare.com/files/rs-1322241/v1_covered.pdf?c=1644425348

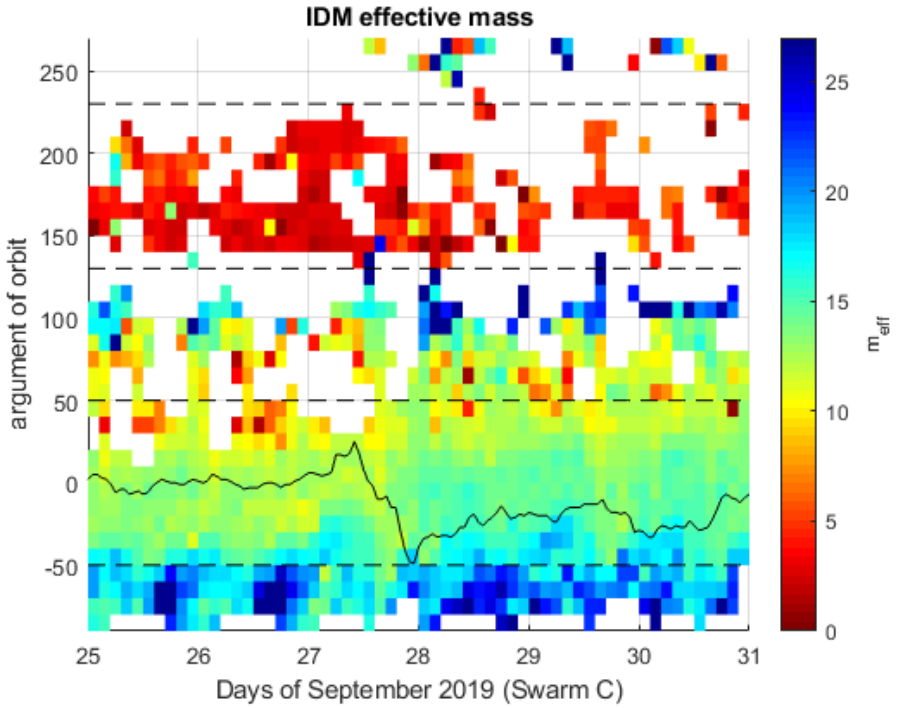
Additional Slides

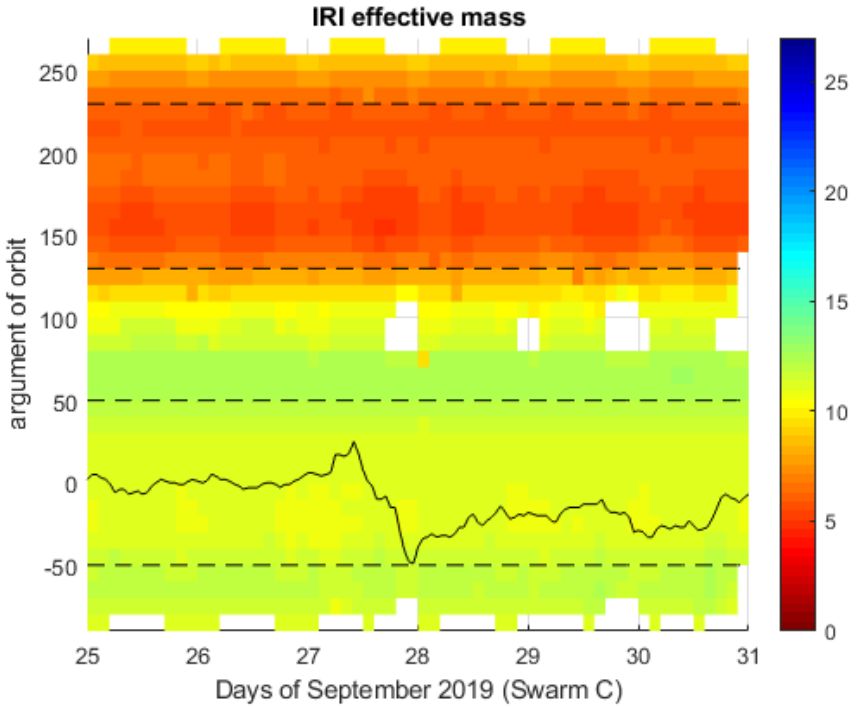




Sometimes, the O+ enhancements are not seen

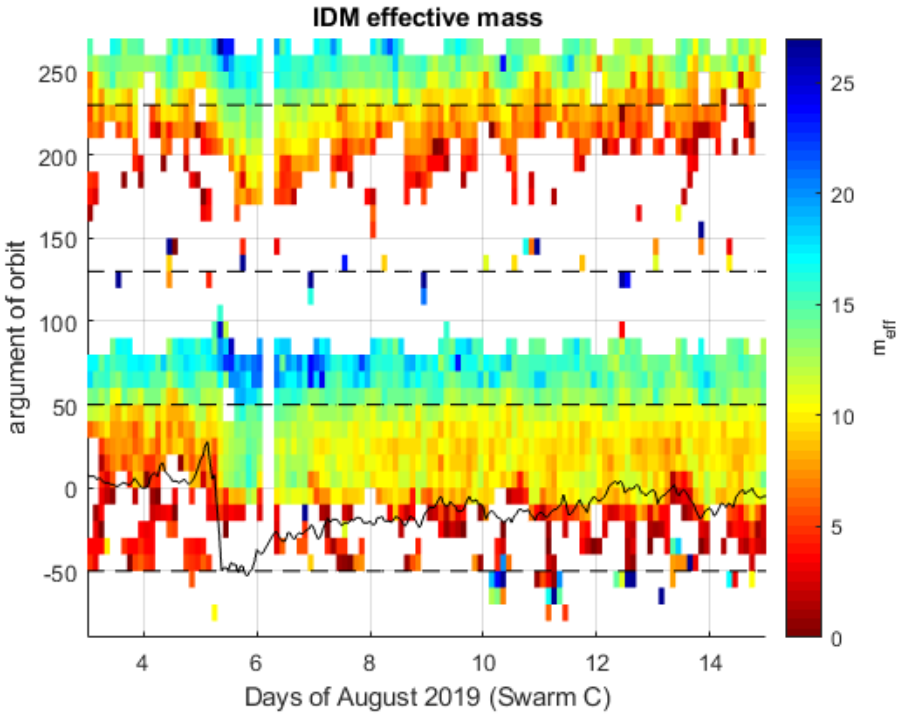
Additional Slides

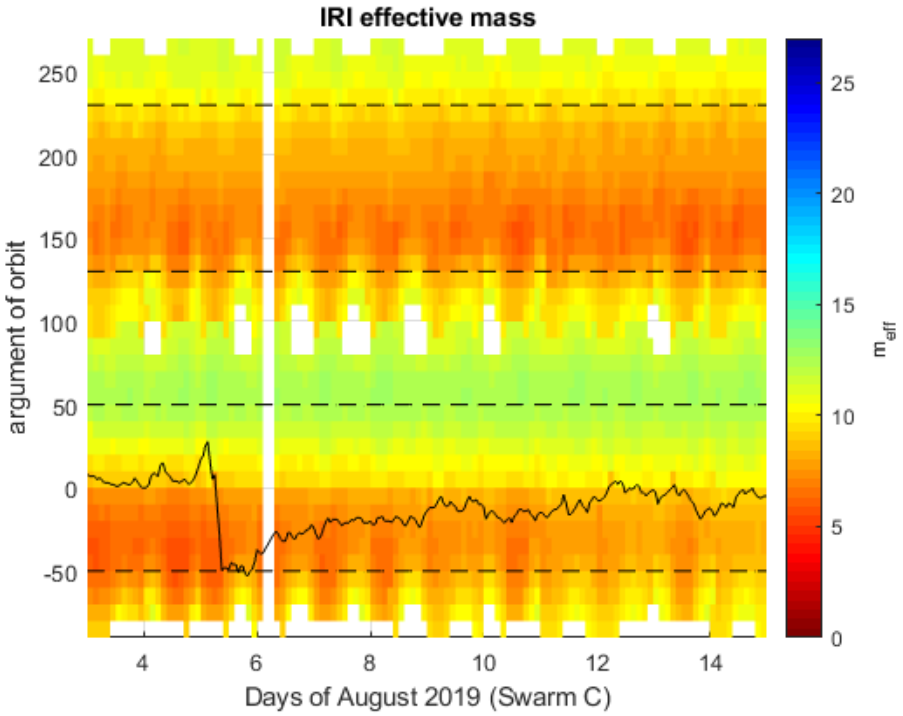




O+ enhancement seen on dayside but not nightside?

Additional Slides





It seems the O+ comes inwards from higher latitudes?