Hemispheric asymmetries seen in Birkeland currents

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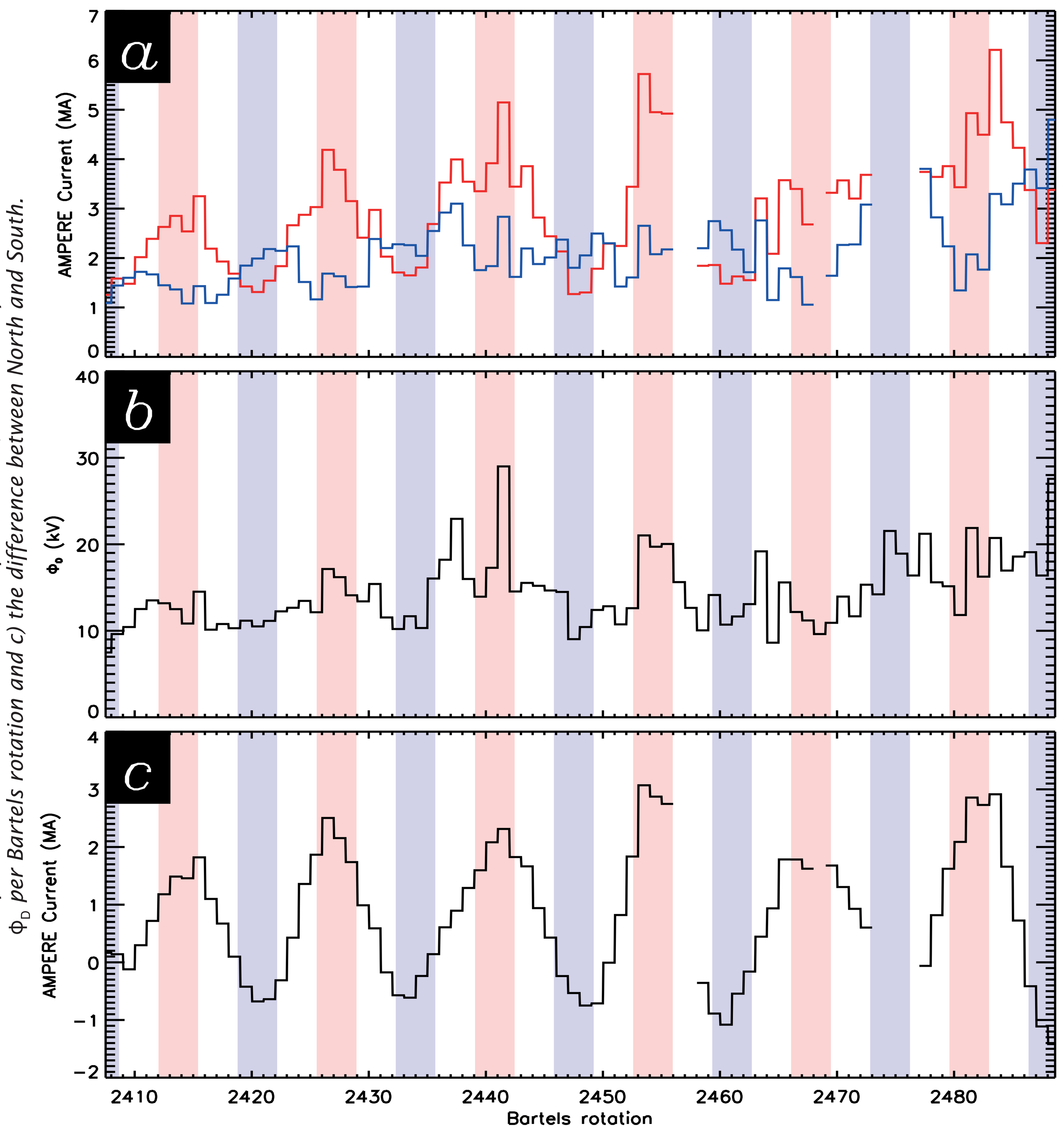
1. Currents driven by magnetic reconnection and ionospheric conductivity

Birkeland current magnitude is correlated with magnetic reconnection rate in a manner which is consistent with a picture of currents driven by dayside reconnection during southward IMF and nightside reconnection during substorms [*Coxon et al., 2014a, b, 2017*]. It is possible to model the amount of field-aligned current flowing due to the amount of dayside and nightside reconnection which is occurring, and *Milan* [*2013*] did this assuming constant conductivity in the ionosphere. Models of ionospheric conductivity are known to depend on the solar zenith angle and on solar flux [*Moen and Brekke, 1993*], and conductivity is known to affect Birkeland current magnitudes [*Fujii et al., 1981, 1987*]. In this study, we examine how conductivity affects the current magnitudes in AMPERE data and uncover a hemispheric asymmetry in this data.

AMPERE data [*Anderson et al., 2000; Waters et al., 2001*] can be processed to yield Birkeland current magnitudes from 2010–2015, which is long enough to identify seasonal and diurnal variations in AMPERE data. To achieve this, we integrate the total upward current and downward current, and then add the two together to get the total current; we then calculate the mean average both as a function of Bartels rotation and hour of the day in order to examine diurnal and seasonal variations in the data.

Figure 1: Data from 2010–2015 showing a) mean total current per Bartels rotation in the Northern Hemisphere (red) and Southern Hemisphere (blue), b) mean dayside reconnection rate Φ_D per Bartels rotation and c) the difference between North and South.



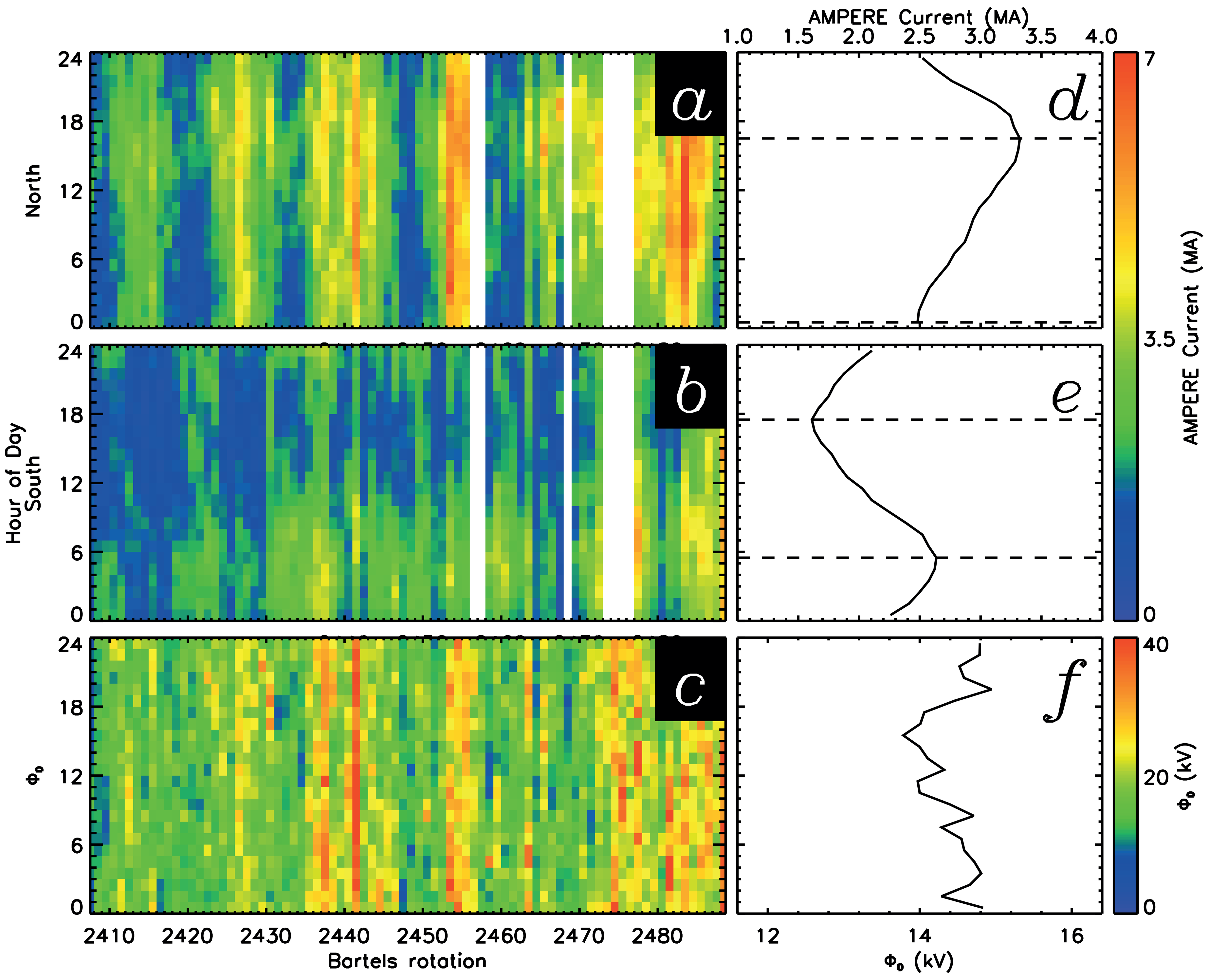


Figure 2: Data from 2010–2015 showing the current magnitude in the Northern (a) and Southern (b) Hemispheres alongside Φ_D (c) for the time of day and Bartels rotation.

2. Diurnal and seasonal variations

Fig.1 shows the mean the current magnitudes per Bartels rotation for the Northern Hemisphere (NH, red) and Southern Hemisphere (SH, blue) and dayside reconnection rate (Φ_D) in the top two panels, and then shows the difference between north and south on the bottom panel. The pink and blue columns highlight the NH's summer and winter respectively, and show that the amount of current in each hemisphere is larger in that hemisphere's summer. Fig. 2 shows the same data, but subdivided into hour of day and Bartels rotation on the left-hand side (a–c), with the right-hand panels showing the average of each quantity during different hours of the day (d–f), showing a diurnal variation. The diurnal variation leads to currents maximising at roughly 6 and 18 UT; the geomagnetic pole in the NH is located approximately six hours behind Greenwich (UTC–6).

3. Hemispheric asymmetry in the data

Fig. 1a shows the amount of current in the NH is always larger than that in the Southern Hemisphere, except for during the SH's summer, at which time the southern current dominates. This is better highlighted by Fig. 1c, in which a positive number indicates more current flowing in the NH. If the two hemispheres was symmetrical, the graph would be centred in the y-axis on 0 MA. The fact that Fig. 1c is centred on 1 MA demonstrates that, in terms of Birkleland currents, the NH dominates the SH even at the equinox, when no hemispheric effect is expected.

This hemispheric asymmetry is not without precedent. *Tulunay and Grebowsky* [*1987*] found that electron densities were higher in the Northern Hemisphere, which may indicate higher conductivity. Ionospheric convection velocities are generally higher in the Northern Hemisphere [*Förster et al., 2007; Förster and Haaland, 2015; Cnossen and Förster, 2016*], which is also consistent with measurements of higher current density.

4. Modifying the model

Fig. 3a shows the *Milan* [*2013*, M13] model, and the correlation with AMPERE observations of AMPERE current, averaged diurnally and per Bartels rotation. The model achieves a correlation with the NH data of 0.77 and with the SH data of 0.67. The M13 model assumes a conductivity in the auroral zone, and so we take the model of *Moen and Brekke* [*1993*, MB93] assuming a constant solar flux input, and we replace the assumed conductivity with the modelled conductivity in Fig. 3b, slightly changing the correlations. In Fig. 3c, we combine the MB93 prediction outside the auroral zone with the M13 assumption within the auroral zone, significantly enhancing the correlation of the model with the AMPERE data from both the NH and SH. Fig. 3d shows the inclusion of the solar flux in the MB93 model; this does not yield a better correlation.

J. C. Coxon et al. (2016), Seasonal and diurnal variations in AMPERE observations of the Birkeland currents compared to modeled results, JGR, doi:10.1002/2015JA022050

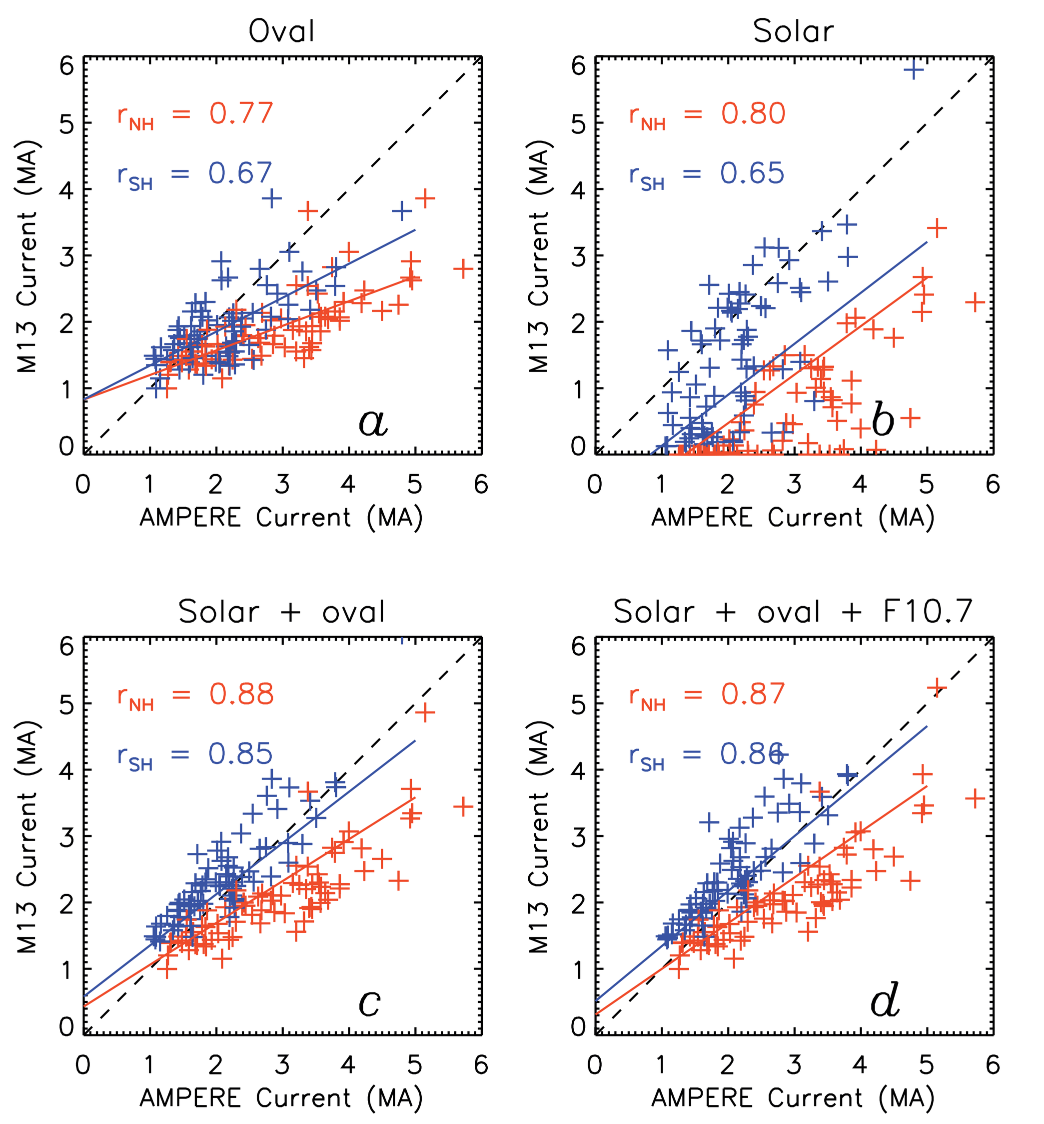


Figure 3: Panels showing the corrspondence of AMPERE data to the Milan [2013] model for a) the conductance of Milan [2013], b) the conductance of Robinson and Vondrak [1984] with constant solar flux, c) the addition of a) and b), d) as for c), but with varying solar flux.

5. Conclusions

We detect a large-scale variation in the AMPERE-derived Birkeland currents which is consistent with diurnal and seasonal variations due to changes in conductivity as a result of a change solar zenith angle. We test the M13 model against the observations and find that it reproduces the large-scale behaviour of the AMPERE system well once modified with better estimates of the ionospheric conductivity due to photoionisation, and thus we infer that Birkeland current magnitude is a function of magnetic reconnection rate and ionospheric conductivity.

We detect a hemispheric asymmetry in the data, indicating that the NH current is systematically stronger than the SH current. We find that this is consistent with previously reported hemispheric asymmetries in the literature and we conclude that this may be a real physical effect as opposed to an artefact of the AMPERE data processing, but more work is needed with other datasets to verify our observations.

References: Fujii et al. [1981], doi:10.1029/GL008i010p01103; Fujii and Iijima [1987], doi:10.1029/JA092iA05p04505; Tulunay and Grebowsky [1987], doi:10.1016/0032-0633(87)90043-2; Moen and Brekke [1993], doi:10.1029/92GL02109; Anderson et al. [2000], doi: 10.1029/2000GL000094; Waters et al [2001], doi:10.1029/2000GL012725; Förster et al., [2007], doi:10.5194/angeo-25-1691-2007; Milan [2013], doi: 10.1002/jgra.50393; Coxon et al. [2014a], doi:10.1002/2014JA020138; Coxon et al. [2014b], doi:10.1002/2014JA020500; Förster and Haaland [2015], doi:10.1002/2014JA020774; Cnossen and Förster [2016], doi:10.1002/2015JA021750; Coxon et al. [2017], doi:10.1002/2017JA023967