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PREFACE

Special issue "The 13th International Conference on Substorms"

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The Thirteenth International Conference on Substorms (ICS-13) was held September 25–29, 2017, in Portsmouth, New Hampshire, USA. The conference featured 64 oral scientific presentations, including 5 one-hour-long Socratic dialogs with broad participation, and 27 poster presentations. Approximately 100 scientists attended, including many students. Following the pattern established in previous conferences, participants were invited to submit papers inspired by the conference to a special issue of Earth, Planets and Space. The resulting papers span an impressive range of substorm-related topics as well as a range of techniques including modeling, ground- and space-based optical imaging, radioscience, satellite plasma measurements, and magnetometry.

Ieda et al. (2018) present an interesting highly time-resolved case study of a substorm onset observed simultaneously with ground-based and satellite-based optical instruments. The study reveals that brightening followed by polar motion seen in the satellite-based data coincides with brightening and poleward expansion in the ground-based images but comes a few minutes after the "Akasofu initial brightening" seen in the ground-based data. The explanation remains uncertain, but may possibly be attributed to the limited spatial resolution of the satellite-based data. Potential implications for definition and identification of substorm onsets are discussed in the paper.

Lyons et al. (2018) examine sixty substorms occurring during eighteen geomagnetic storms, using the wide geographic coverage of the THEMIS all-sky imagers (ASIs). The data provide strong evidence of onsets triggered by plasma sheet flow bursts appearing as streamers in the optical aurora data. The data also give an opportunity to compare substorms during CME-generated geomagnetic storms versus those occurring during High-Speed Stream type storms, revealing interesting differences in the number and cadence of substorms during each type.

Spencer et al. (2018) use solar wind data from the ACE satellite together with a low-dimensional energy-conserving state space model for substorm dynamics of the nightside magnetosphere to predict AL index time series and other substorm indicator parameters. In seven case studies, the model reproduces substorm events both in approximate time duration and activity level, when compared with actual AL or SML data.

Liang et al. (2018) examine optical imaging data during twelve substorms, focusing on the spectroscopic lines characteristic of proton precipitation during the late growth stage feature called the "transitional stage to substorm onset" in which the electron-excited emissions intensify and beading occurs along the optical arc form. Surprisingly, in contrast to the electron emissions, the proton lines increase minimally during this transitional stage and only increase strongly afterward. Liang et al. (2018) show that the muted proton aurora effect cannot be completely explained by, for example, spatial spreading of the proton auroras. It may have important implications for explaining late growth phase and onset phenomena such as TSSO.

Antonova et al. (2018) explore the relationship between substorms and variations in outer radiation belt electrons, both statistically and by consideration of adiabatic acceleration of electrons in the relaxing magnetic field in the wake of the substorm. They put forth that the substorms occurring in the storm recovery phase are of particular importance for affecting trapped particle populations.

Vorobjev et al. (2018) investigate a large number of isolated substorms, finding an unexpected relationship between their intensity and the solar wind dynamic

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pressure (unexpected because the usual energy coupling parameters do not depend strongly on dynamic pressure). While interpretation is uncertain, they show evidence that the dynamic pressure is correlated with energy coupling parameters during the late growth phase of substorms, and they put forth that the enhanced coupling creates conditions leading to the subsequent substorm being more intense.

Two papers focus attention on the famous "Saint Patrick's Day Storm" of 2015. Kozyreva et al. (2018) illustrate new tools and techniques by applying them to the many substorm-like disturbances that occurred during the lengthy recovery phase of the Saint Patrick's Day Storm. They develop a virtual magnetogram technique similar to that employed by, for example, the SuperMag facility, and including consideration of localized geomagnetic variations dB/dt. The case study shows evidence suggesting differences in locations of the variations versus the canonical onset location which may have implications for predicting geomagnetically induced currents.

Suji and Prince (2018) also investigate the Saint Patrick's Day storm, combining observations and modeling to independently estimate the local Joule heating and the global Joule heating during each of five substorms occurring during the storm main and recovery phases. Local Joule heating is only a small fraction of global Joule heating for the substorms occurring during main phase but a large fraction of global Joule heating for those during recovery phase. The authors put forth the possible explanation that during storm main phase, there are several pathways whereby energy may be deposited into the ionosphere, and hence the proportion of global Joule heating associated with the substorm during main phase is small, whereas during storm recovery phase, when the system is no longer being strongly externally driven, piled up magnetic flux in the tail is redistributed between dayside and nightside via substorms, and hence the proportion of global Joule heating associated with the recovery phase is large.

Finally, LaBelle (2018) probes a natural auroral radio emission, called medium frequency burst (MFB), which characterizes substorm onsets and has potential to serve for timing or location of onsets. The cause of these emissions has not been established but is believed to be related to Langmuir wave excitation. MFB occurs primarily at frequencies of several MHz, well above the electron gyrofrequency, but an outstanding mystery is the nature of occasional occurrences below the gyrofrequency, previously speculated to be whistler mode. LaBelle (2018) presents the first measurements of the polarization of these low-frequency MFB emissions, showing them to be left-polarized and hence LO-mode not whistler mode. The observation places constraints on the source altitude of the emissions.

These nine papers herald advances in a variety of aspects of auroral substorms, and they provide the basis for better understanding of polar substorms and the underlying ionospheric and magnetospheric processes.

Abbreviations
ACE: advanced composition explorer; AL: amplitude lower; ASI: all-sky imager; CME: coronal mass ejection; ICS: international conference on substorms; LO: left/ordinary polarization; MFB: medium frequency burst; SML: super mag lower; THEMIS: time history of events and macroscale interactions during substorms; TSSO: transitional stage to substorm onset.

Authors' contributions
All authors of this article served as the guest editors for this special issue. JL prepared this preface with the agreement of the other authors. All authors read and approved the final manuscript.

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