A Comparison of Modeled Auroral Boundaries with Observations from Citizen Scientists

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1. Introduction
Over the past year, the citizen science project Aurorasaurus has collected new, globally-distributed, ground-based observations of the aurora and has integrated these with space-based estimates of auroral activity. A case study of these observations was compared to the NASA Space Weather Prediction Center’s (SWPC) Aurora Forecast product which is built upon the Oval Variation, Assessment, Tracking, Intensity, and Online Nowcasting (OVATION) Prime (2010) auroral precipitation model.

The observations in this case-study demonstrated that over 60% of the positive aurora observations occurred at latitudes equatorward of the SWPC predicted “view-line”. New scaling parameters were determined from the relationship of the differences in latitude between the positive observations and the view-line, and the maximum probability of visible aurora. The implementation of this view-line, in the Aurorasaurus real-time alert system, is also demonstrated.

2. Observations
The observations made by citizen scientists, see Table 4 for an example, are of three forms:

- **Verified tweets**: posts made on Twitter (called “tweets”) that have been verified by Aurorasaurus users as sightings of the aurora. Manually inspected by Aurorasaurus team for this case study.
- **Positive sightings**: sightings of the aurora provided by Aurorasaurus users and reported on the website or mobile apps.
- **Negative sightings**: reports from Aurorasaurus users stating that an aurora was not visible.

As shown in Figure 2, the observations in this case study span a range of magnetic latitudes, longitudes, and times of activity. Though there is a clear preference toward observations being made in the pre-midnight sector (i.e. 20:00-04:00).

3. Auroral Oval
We utilize the OVATION Prime (2013) aurora forecast model to determine the location of the auroral boundary. OVATION Prime (2013) is a well-used, accurate, auroral precipitation model that can be run in real-time. The model is driven by Newell's magnetospheric coupling function \( \mathcal{D}(\phi, V) \) which is determined using solar wind data, such as the solar wind velocity \( V \) and interplanetary magnetic field (IMF) strength \( B \) and direction (\( \theta \), the IMF clock angle).

\begin{equation}
\frac{dn}{d\phi} = \mathcal{D}(\phi, V) \cdot \left( \frac{V}{B} \right) \cdot \sin(\theta)
\end{equation}

The OVATION Prime (2013) auroral precipitation data is inputted into the NOAA Space Weather Prediction Center’s aurora forecast product to produce a representation of where an aurora may be visible (see Figure 3).

4. Comparison with the SWPC aurora forecast product
The SWPC aurora forecast product converts auroral precipitation data into a more user-friendly output. It scales the energy flux, \( \psi \), into a “probability of visible aurora”, \( P(A) \), and indicates this likelihood of visible aurora on a geographic map.

\begin{equation}
P(A) = 10 + \frac{\psi}{\frac{M}{2}}
\end{equation}

The forecast product also determines the most equatorward longitude from which an aurora may be visible, for each longitude. This estimate is known as the “view-line”, i.e. an aurora should be visible at locations on, or poleward of, the view-line. For each longitude, the latitude of the maximum probability of visible aurora, \( \phi_{max} \), is scaled poleward by the value of the maximum probability, \( P(A)_{max} \).

\begin{equation}
\delta\phi = P(A)_{max} \cdot \left( \frac{L}{M_{max}} + 3 \right)
\end{equation}

In Figure 4, the latitude of the citizen science observations is compared to the SWPC estimated view-line. We find that 62% of positive observations (i.e. verified tweets and positive sightings) are located equatorward of the view-line. Thus suggesting the SWPC view-line is often too conservative in its estimate.

6. Aurorasaurus output
Alongside the SWPC forecast product, the new Aurorasaurus view-line is calculated in real-time and shown on the Aurorasaurus homepage (as demonstrated in Figure 7). This is a real-time indicator of where an aurora might be visible from. Additionally, any current observations are also shown on the map.

These three data sources (the SWPC auroral oval, Aurorasaurus view-line, and citizen science observations) allow the Aurorasaurus project to issue aurora visibility alerts to its users when an aurora is predicted to be visible near them.

7. Conclusions
Using nearly 300 observations of the aurora, provided by citizen scientists, we were able to determine the equatorial boundary, both in the northern and southern hemispheres, of where an aurora might be seen based on its intensity. We found that the current SWPC estimate was conservative and that an aurora was often visible further equatorward than estimated. By adapting the view-line parameters, using the observations in this case-study, we were more able to accurately represent the maximum distance from which an aurora might be visible. Some caveats, and areas for future investigation, include determining the effects of auroral height, observational bias and sudden aurora brightening (i.e. substorms).

The work presented here also forms part of the wider Aurorasaurus output, which alerts its users as to when they might be able to see an aurora via personalized alerts.

References & Acknowledgements

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