

**The real-time state  
of the aurora –  
a research to operations need  
with a citizen science (CS)  
solution?**

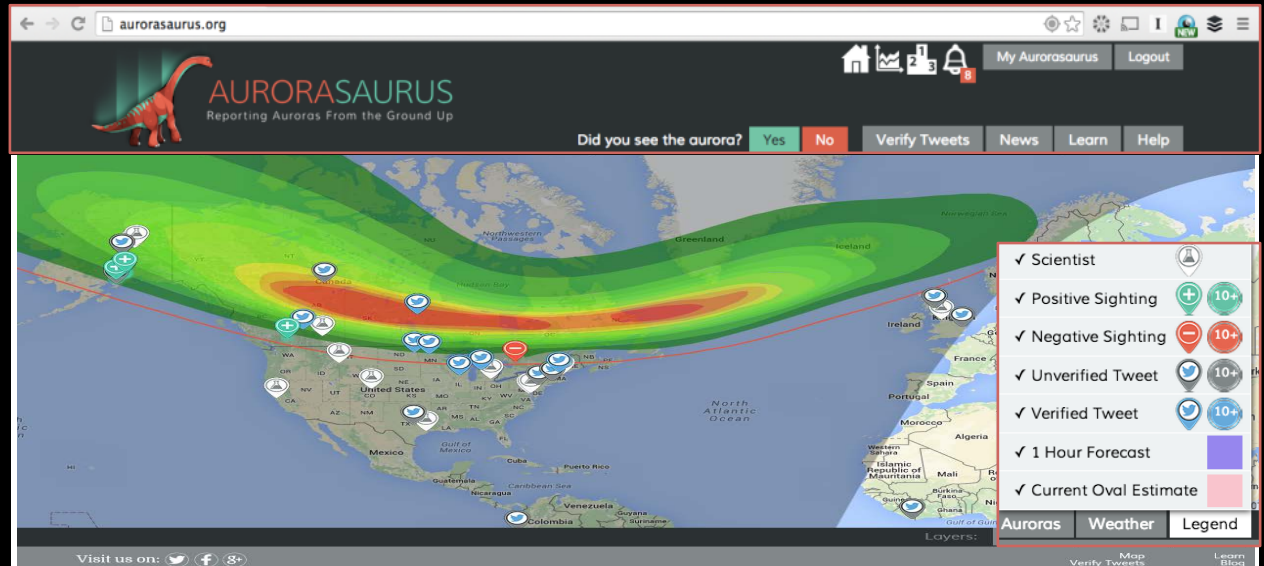
**Liz MacDonald**

e.a.macdonald@nasa.gov

**Burcu Kosar**



Aurorasaurus.org  
Apple iOS & Android apps



## New global, real-time data sources from citizen scientists and tweets Alerts of auroral visibility for the public

In one year, our database has more than **4200** users, more than **2700** reports, and votes on more than **270,000** tweets.

### Selected Papers (of >10 submitted so far)

- MacDonald, E. A., et al., **Aurorasaurus: A citizen science platform for viewing and reporting the aurora**, Space Weather, doi: 10.1002/2015SW001214, 2015.
- Case, N. A., et al., **Mapping Auroral Activity with Twitter**, Geophys. Res. Lett., 42, doi:10.1002/2015GL063709, 2015.
- Case, N. A., et al., **Aurorasaurus and the St Patrick's Day storm**, Astronomy & Geophysics, 56 (3), 2015.
- Case, N. A., E. A. MacDonald, and R. Viereck (2016), **Using citizen science reports to define the equatorial extent of auroral visibility**, Space Weather, 14, doi:10.1002/2015SW001320.
- Tapia, A.; Lalone, Nicolas; (2014) **Crowdsourcing Rare Events: Using Beauty to Draw Participants into Science and Early Warning Systems**, 11th International Conference on Information Systems for Crisis Response and Management (ISCRAM), May 18-21, 2014



Citizen Scientist Images  
March, 2016



*A new, open innovation, geospatial, crowdsourcing,  
open source platform and public-private partnership...*

**Join us!**

**POC: Elizabeth MacDonald, e.a.macdonald@nasa.gov**





# Who are we?

THE 'AURORASAUROS' MAPS THIS YEAR'S  
SPECTACULAR AUORAS

WIRED

- New... global
  - Idea in 2011, full launch in 2014, not possible during last solar max
  - 51% users from US, “aurora enthusiasts”
- Fast... but unpredictable
  - Real-time alerts
  - Multiscale accuracy is a challenge
- Obscure... but beautiful
  - Historical examples of aurora cit sci and crowdsourcing
  - Communication challenges
- Evolving, expanding, continual process
  - Open innovation, open source, extensible, agile
  - Part of a new tech-driven citizen science movement
  - Citizen science projects can monitor weather, disasters, and rare biological phenomena accurately in real-time.
    - <http://citizenscience.gov/>

# Vision

- De  
rea  
inc  
bas



100

# What are the possible ways to know the real-time state of the aurora?

- 1) From solar data
- 2) From solar wind data
- 3) From global imaging
  - a) Space-based not fast
  - b) Ground-based not digitized
- 4) From global magnetometers
- 5) From people

**The most suitable answer remains an open question.**



# Why do we need to know this?

- Threats associated with aurora are highly dynamic and poorly characterized, scintillations/comms, GIC/power, spacecraft charging
- Knowledge; exactly where and when is the aurora?
  - Part of an educated public and stakeholders

## Who is the end user?

- Public, power industry (primarily interested in boundaries), robotic mission operators (spacecraft charging, ISS), satellite communication industries (air, sea, space)

# Motivation

## Why do we need this?

### – Science gaps

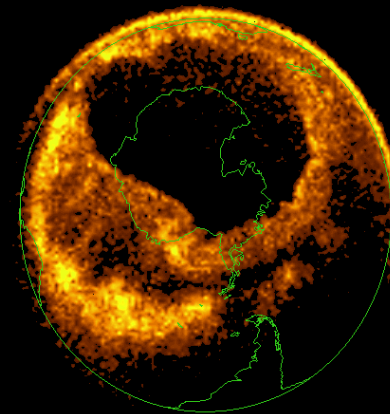
- The evolution of aurora during large storms never fully imaged or characterized
- Aurora is fine scale but models are coarse
- Aurora are tracers of fundamental, global coupling processes and connections are very sparse

### – Communication gaps

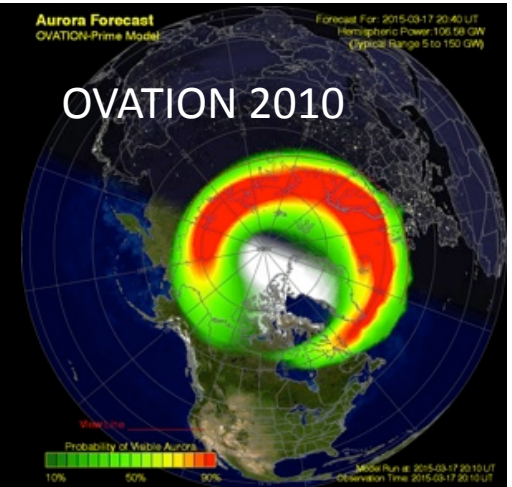
- Inspiring source of engagement
- Not digestible by the public

## Goals

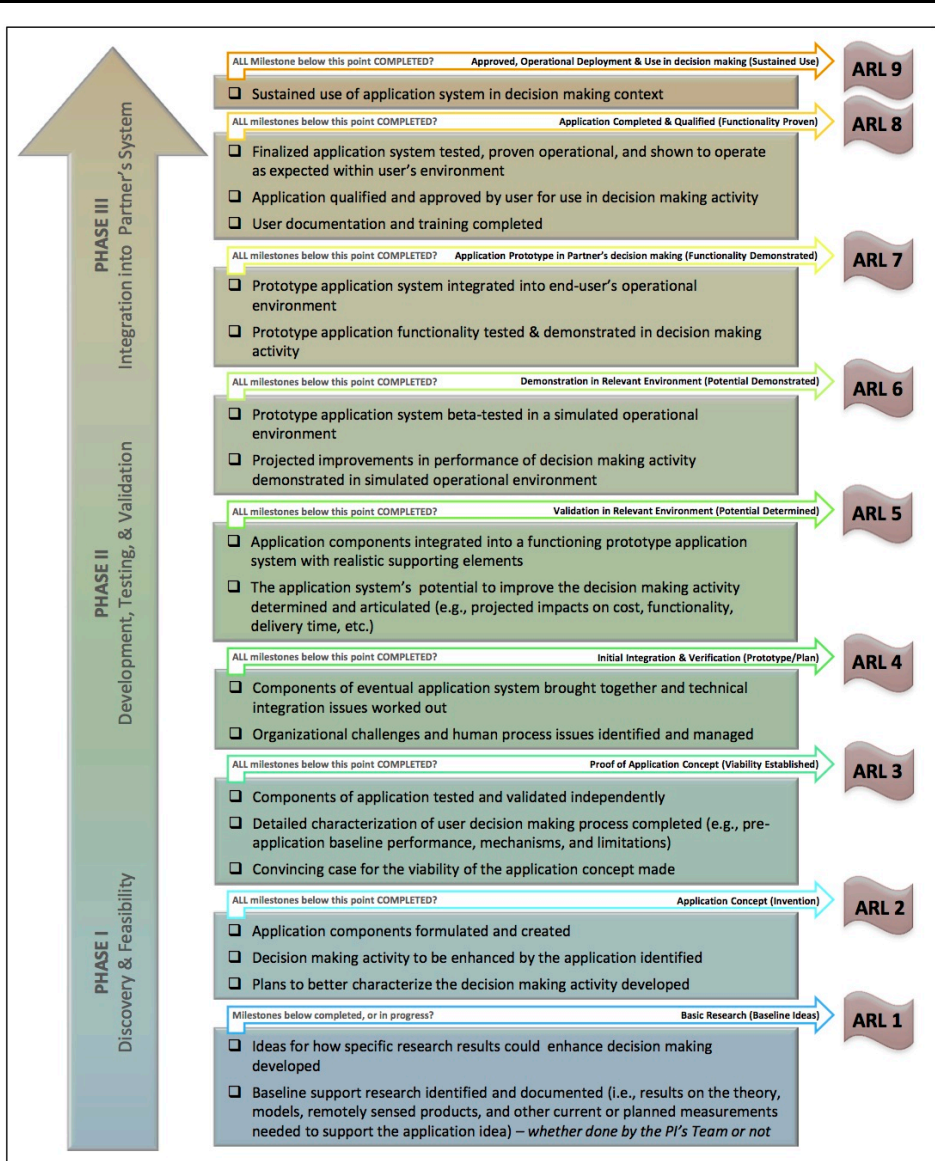
- Better nowcasts and awareness



DE-1, during 1989  
superstorm  
89 073 0151 UT



# What is “Research to Operations” (R2O) for space weather applications?



Resiliency is important. CS may not be a primary source of information but could be a robust, ancillary source of data.

- Customer needs
- Verification and Validation (V&V)
- Errors, uncertainty, flags
- Communication (Araujo-Pradere, Space Weather, 2009)



**Inputs:** New global, real-time data sources from citizen scientists and tweets.



- Hybrid approach, twitter not required. Location required, privacy protected.
- **Outputs:** Sign up to get a free, custom aurora alert for your location.

Did you see the aurora?

Yes

No

A screenshot of the AURORASAURUS mobile application interface. The title bar at the top reads "AURORASAURUS Reporting Auroras From The Ground Up". The main heading is "Make a Report". The form contains several sections: "Location:" with a text input field containing "Saskatoon, SK, Canada"; "When did your observation start?" with date and time pickers for "19 Sep 2014" and "1:45 PM"; "When did your observation end?" with date and time pickers for "19 Sep 2014" and "2:00 PM", plus an "Ongoing?" radio button; "What colors did you see?" with checkboxes for "Red", "Green", "White", and "Pink", where "Red", "Green", and "Pink" are checked; "Other:" with a text input field containing "Another color?"; "What type of aurora did you see?" with radio buttons for "Discrete Arcs", "Diffuse Glow", and "Patches (pulsating)", where "Diffuse Glow" is checked; another "Other:" field with "Something different?"; "Where in the sky was the aurora?" with a dropdown menu set to "Northern Horizon Only"; a final "Other:" field with "Something different?"; and "How active was the aurora?" with a dropdown menu. The status bar at the top shows "Carrier", "1:55 PM", and "100%" battery.


# Inputs: Verifying tweets, a crowd-sourcing data verification activity






CS: Classification

- Registered and anonymous users verify geotagged tweets by reading the tweet and voting “yes” or “no” if they think it is a real-time sighting at correct location
  - Geotags are either embedded or extracted via CLAVIN
  - Minimal training of users
- Verified tweets used in alerts in conjunction with other observations


Sighting Details

 **Vonnie Valkyrie**  
[@ybesser24](#)  
6/23/15 at 1:29 am



Its so beautiful in the night sky the northern lights are dancing all over!  
[#northernlights](#) [#Minnesota](#)



Did They Just See the Aurora?



# Citizen Science Aurora Data

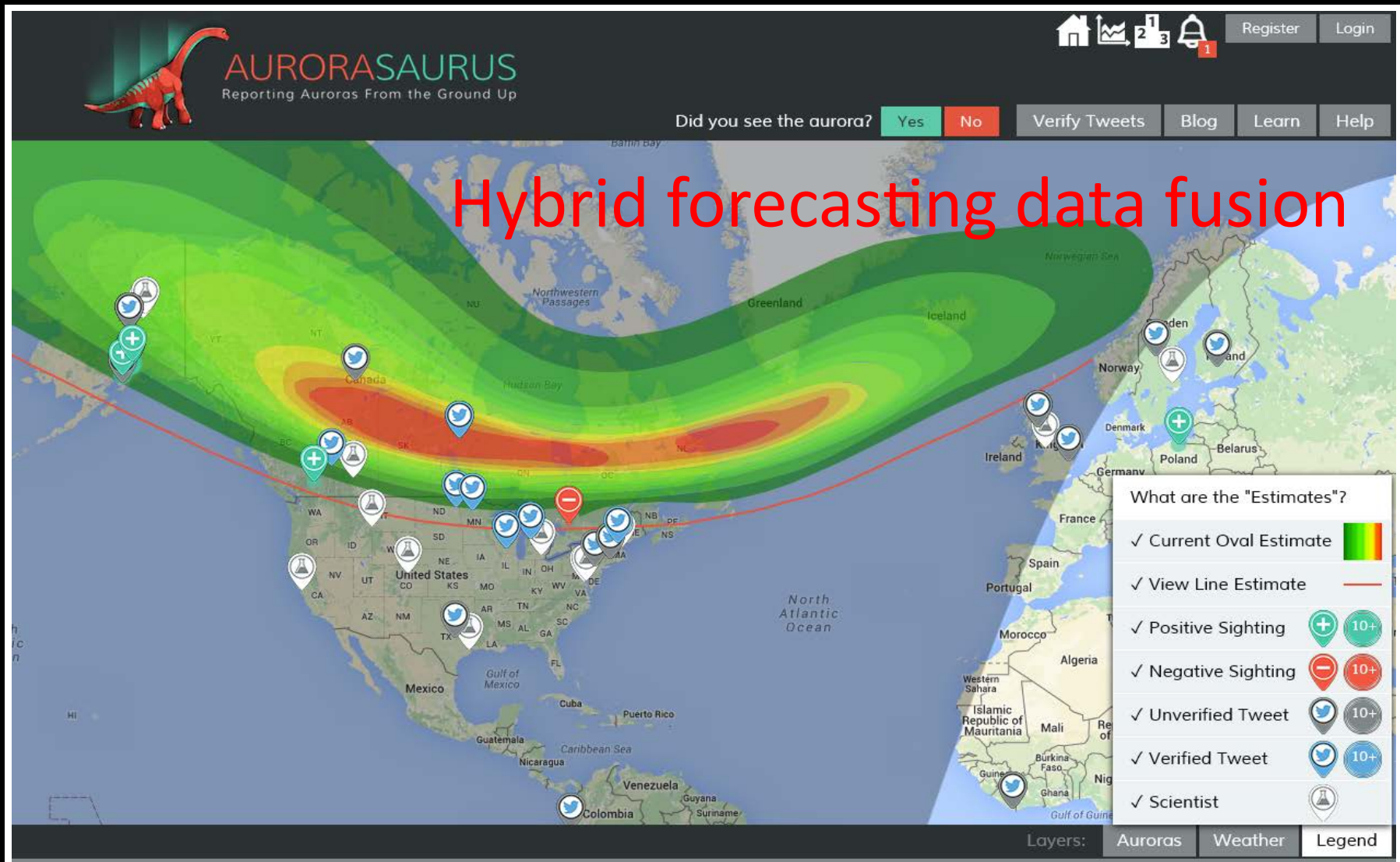
Sighting Details		Sighting Details	
<b>Summary</b>	<b>Details</b>	<b>Summary</b>	<b>Details</b>
 <b>home/school</b> 3/17/15 at 10:15 pm to 3/17/15 at 10:30 pm	Colors Seen: Green, Red Types of Aurora Seen: Diffuse Glow Height in Sky: Northern horizon only Comments: To the naked eye, i was only able to see a possible faint glow. However, the picture that i took shows much more than that. It was a 30 second exposure.		
Observed Near: VA, United States			
			
Classification		Classification	
User saw the aurora		User saw the aurora	

- We have a custom SQL database of all observations

Sighting Details	
 <b>BertoBluFyre</b> <a href="#">@BertoBluFyre</a> 3/18/15 at 12:29 am	
Current view of the <a href="#">#NorthernLights</a> patiently awaiting next substorm <a href="#">#Ottawa</a> <a href="http://t.co/NpOXNUD8ig">http://t.co/NpOXNUD8ig</a>	
	
	
Sighting Verification	
Tweet confirmed to be a positive sighting	



# Answering the public's #1 question about aurora – Where can I see it?? Help us verify the view line



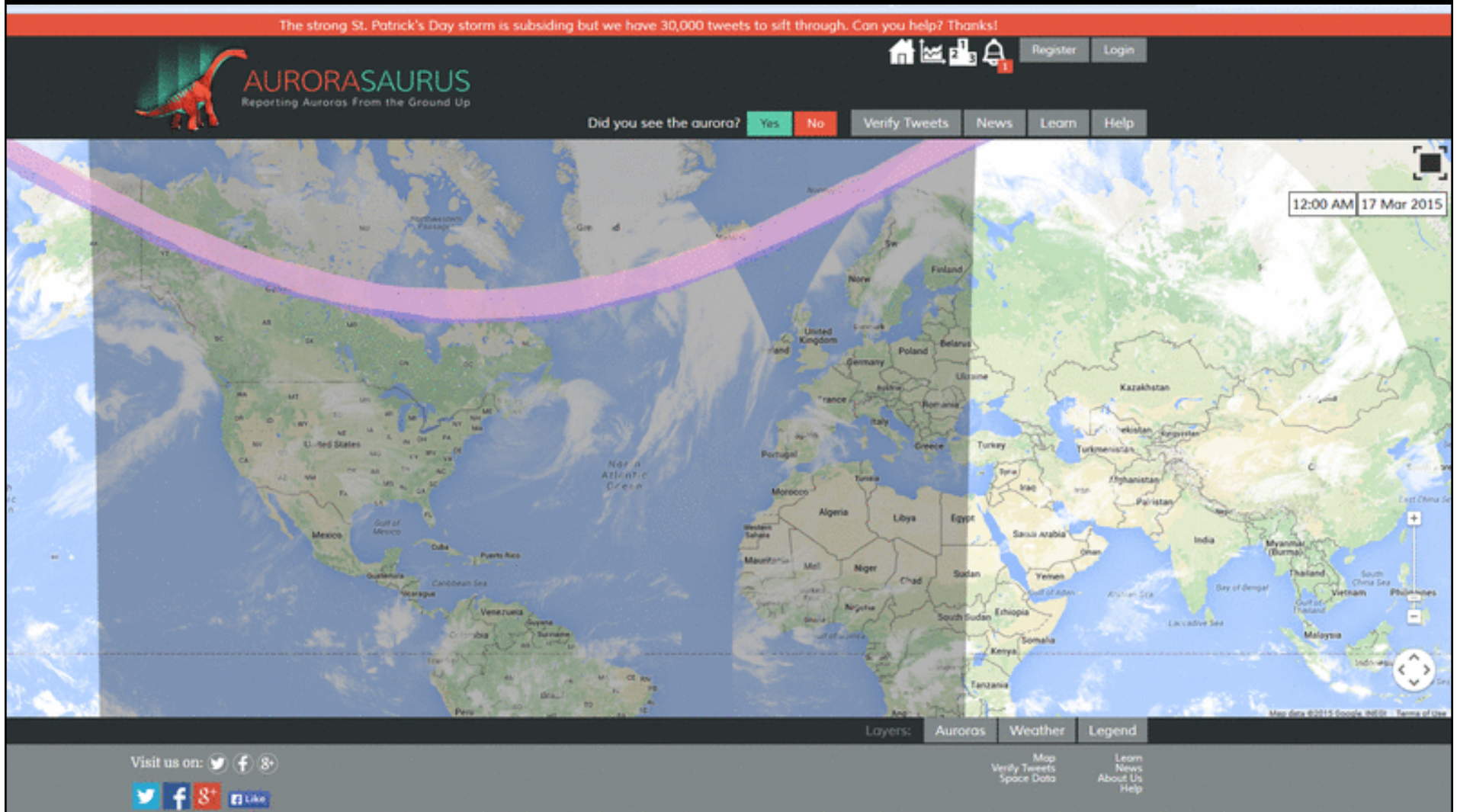
# March 17, 2015 Storm of the Decade

Preliminary numbers for 3/17/15:

134 observations, 234 verified tweets (out of 30,000+),  
~400 new users (50% increase), 312 location based alerts

Case et al., Astronomy  
and Geophysics, 2015  
[bit.ly/StPaddysDayStorm](http://bit.ly/StPaddysDayStorm)

The strong St. Patrick's Day storm is subsiding but we have 30,000 tweets to sift through. Can you help? Thanks!



**AURORASAURUS**  
Reporting Auroras From the Ground Up

Did you see the aurora?  Yes  No

12:00 AM 17 Mar 2015

Layers: Auroras Weather Legend

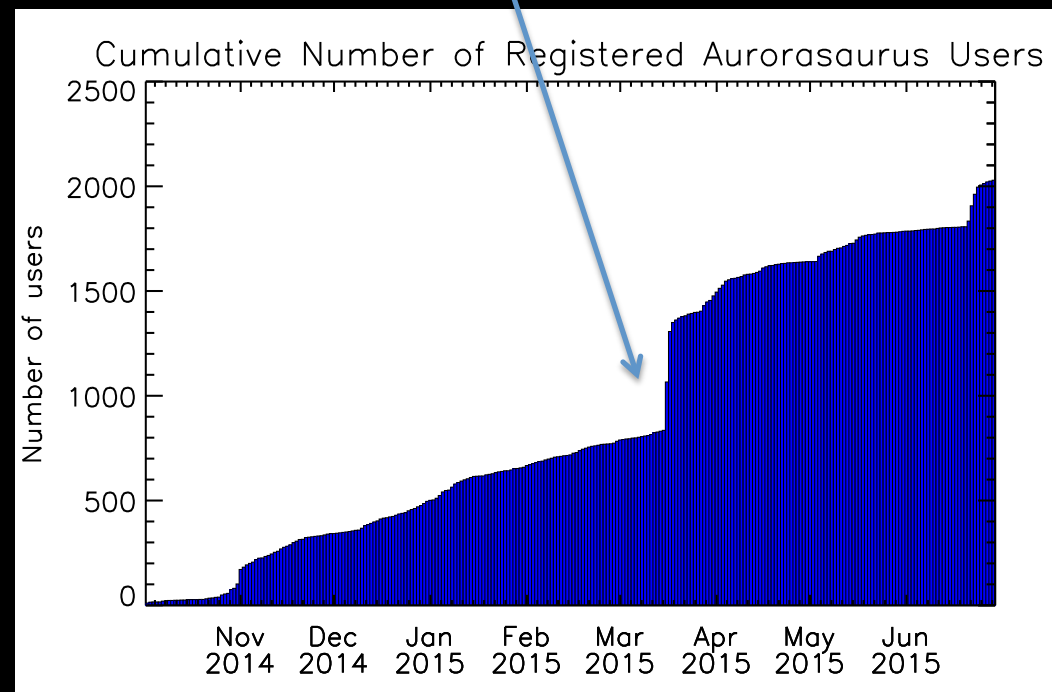
Visit us on: [Twitter](#) [Facebook](#) [Google+](#) [f Like](#)

Map Verify Tweets Space Data Learn News About Us Help

# What do the observations look like so far?

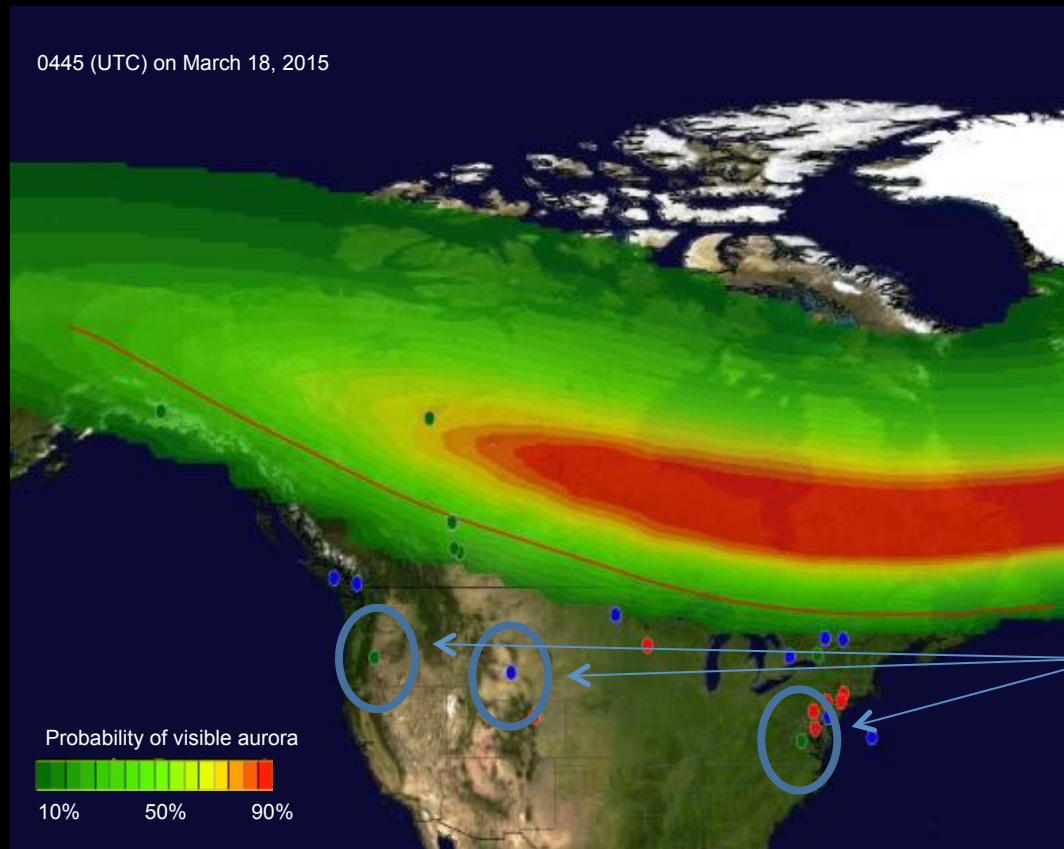
- ~1k reports, ~64% positive, 36% negative
- ~40% anonymous
- Total tweets 785k
- Can get location on ~20%, of those
- ~1k, 0.1% are up-voted as aurora sightings
- ~18k, 2% are down-voted
- 91k total votes (not anonymous)

Participation spikes with activity





# 60% of our user's positive observations are below the view line during this event



Case et al., 2016

Aurorasaurus observations provide “ground-truth” for auroral models and estimates.

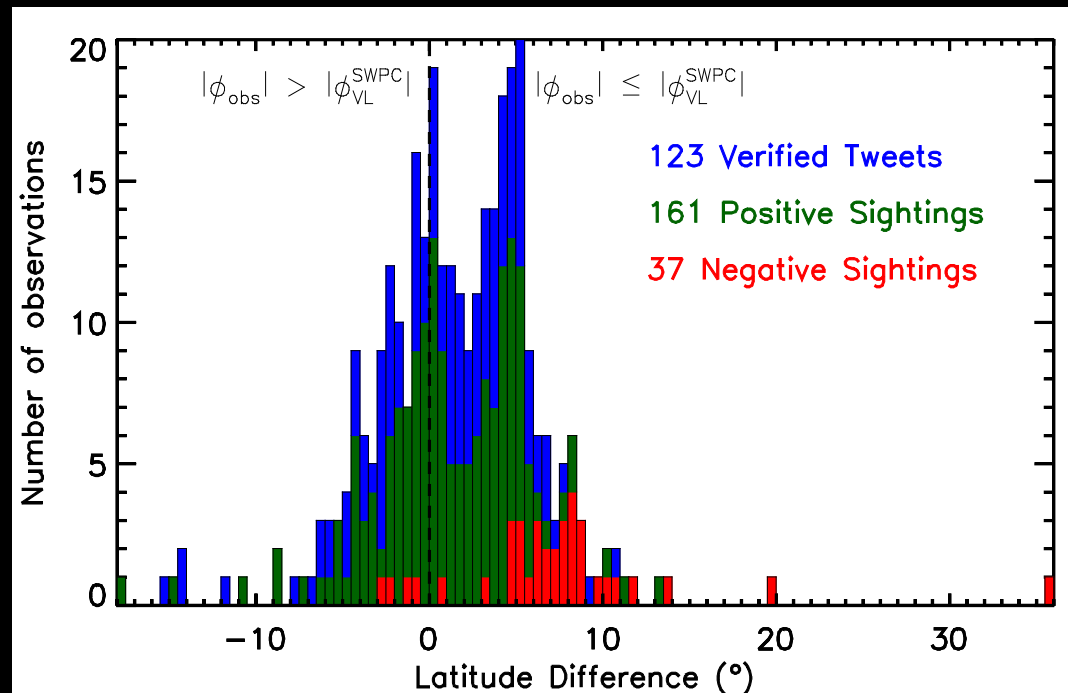
(left) Example OVATION Prime (2013) output for a 15min period in the St. Patrick's day (2015) storm. Green and blue dots indicate where the aurora was seen from.

Much further south than the model (and associated view line) predicts. Substorms?

Can test auroral precipitation estimates for visible aurora.

# Potential Uses

- Work is currently underway to compare observations with SWPC's "view line". Offer potential improvements.
  - View line: an estimate of the most equatorward latitude from which an aurora would be visible, spanning a range of longitudes.
- Real-time alerts of auroral visibility.
- Validation of auroral oval/precipitation models.
- Observations during periods of interest can be isolated and compared to other data sets.



**Figure 4.** The latitude difference between the observations and the SWPC estimated view-line is shown.

# Aurorasaurus Space Science Results

- Rich data is plentiful and can be attained through this platform
- Integrated data is actionable to improve alerts for visibility of the aurora

## Citation:

Case, N. A., E. A. MacDonald, M. Heavner, A. H. Tapia, and N. Lalone (2015), Mapping auroral activity with Twitter, *Geophys. Res. Lett.*, 42, 3668–3676, doi:10.1002/2015GL063709.

- 1 Use of solar wind power as a concept to help explain
- 2 auroral strength to the non-specialist

N. A. Case<sup>1,2</sup>, E. A. MacDonald<sup>1,2</sup> and H. K. Connor<sup>2,3</sup>

SPACE WEATHER, VOL. ???, XXXX, DOI:10.1002/

- 1 Using citizen science observations to define the
- 2 equatorial extent of the visible aurora

N. A. Case<sup>1,2</sup>, E. A. MacDonald<sup>1,2</sup> and R. Viereck<sup>3</sup>

## Aurorasaurus and the St Patrick's Day storm

**Nathan A Case, Elizabeth A MacDonald and Kasha G Patel** examine the spectacular response of citizen scientists to a once-in-a-decade geomagnetic storm.



1 An aurora photo taken by an Aurorasaurus user near Berlin, Germany

A&G • June 2015 • Vol. 56 • www.astrongeo.com

AGU PUBLICATIONS

Space Weather

RESEARCH ARTICLE  
10.1002/2015SW001214

**Key Points:**  
• Citizen science project collecting aurora observations

**Aurorasaurus: A citizen science platform for viewing and reporting the aurora**

E. A. MacDonald<sup>1,2</sup>, N. A. Case<sup>1,2</sup>, J. H. Clayton<sup>3</sup>, M. K. Hall<sup>3</sup>, M. Heavner<sup>1,4</sup>, N. Lalone<sup>5</sup>, K. G. Patel<sup>1,2</sup>, and A. Tapia<sup>5</sup>

- 1 A real-time hybrid aurora alert system: cc
- 2 citizen science observations with an aurora
- 3 model

N. A. Case,<sup>1,2</sup> D. Kingman,<sup>1</sup> and E. A. MacDonald<sup>1,2</sup>

Human Computation (2015) xx:xx:xx  
© 2015, Case et al. CC-BY-3.0  
ISSN: 2330-8001, DOI: 10.15346/xx

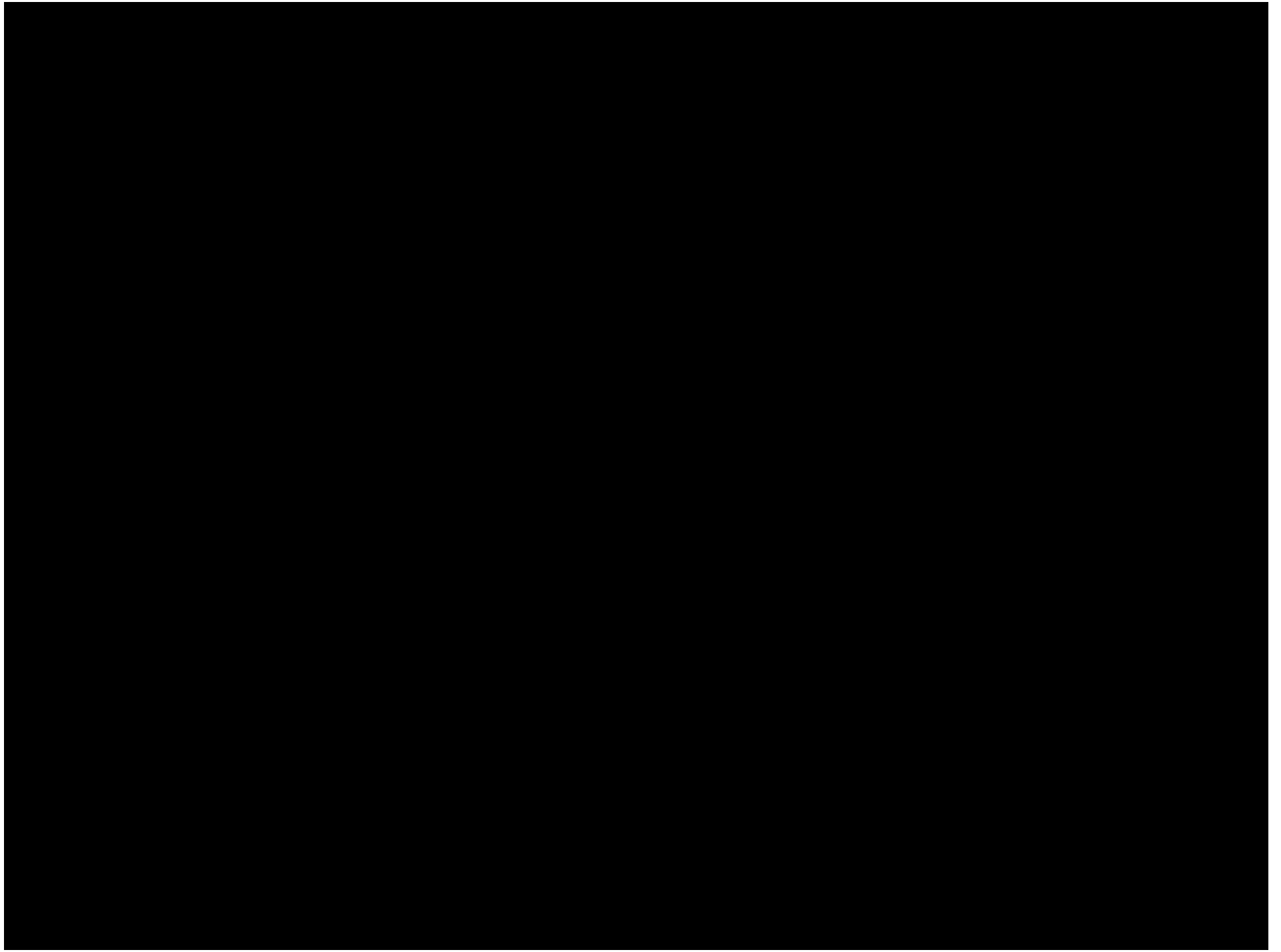
**Determining the Accuracy of Crowdsourced Tweet Verification for Auroral Research**

## In the future how could this be relevant?

- Prototype system could be operationalized?
- International participation could be encouraged
- All data publically available
- More advanced citizen sensors

## In the event of an extreme storm...

- Real-time assessment and visualization is important
- Aurora is visible for variable amounts of time
- Models have high uncertainties, ground truth knowledge is important to assess impact.





## **Citizen science observations of the aurora: reported on our website and on Twitter.**

Observations may include:

- Time and location (compulsory)
- Color(s), level of activity, type(s), height in the sky and a photo


Data span from November 2014 – present

More than 3000 users

Over **2,000 observations**, including:

- 600 positive sightings
- 1200 verified tweets, 70% accurate
- Spanning several continents!
- Real-time verified alerts
  - 2 levels
- ~88% respond to alerts
- ~50% of information is near-real-time

# How to reach a virtual community with educational content? In person, blog

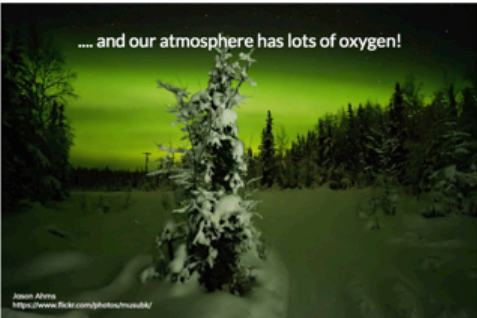
 **AURORASAURUS**

**WHY** is green the most common color for an aurora?

Aurora can appear in many colors, but green is the most common. You may have seen an eerie green glow in the sky or in a science fiction movie.



SciFi has it right and here's why!

The green light comes from excited oxygen atoms...



.... and our atmosphere has lots of oxygen!


While nitrogen is the most common element in our atmosphere, oxygen is the most common element at the altitude where aurora occur (100 - 500 km).


You may recall that excited oxygen atoms can emit red or green light, depending on how much extra energy they have. So, why aren't red aurora more common?

It's all about timing and collisions.

When two atoms collide, energy is transferred between them.



1 second



1 second

If an oxygen atom is excited to the energy level corresponding to green...



... and it has no collisions...

... then it will emit light after 1 second.

If an oxygen atom is excited to the energy level corresponding to red...

... and it has no collisions...

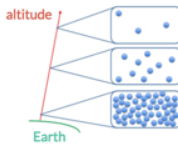
... then it will emit light after 110 seconds.

110 seconds


It may seem short to you, but 110 seconds is a long time for an excited oxygen atom to avoid collisions!

Because it takes so long, red light is only emitted in the higher regions of the atmosphere (above 200 km) where atoms and molecules rarely collide.






altitude ↑

Earth




Blue, pink, and violet may also appear, especially near the lower boundary of aurora, due to higher levels of nitrogen below 100 km. But these colors are much less common than green.

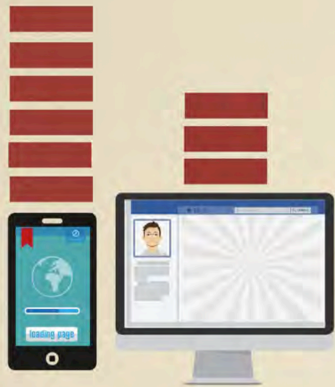


Join us to explore aurora:  
**AURORASAURUS.ORG**



Copyright Science Education Solutions. Request permission to use. v032715

Out of a survey sent to all of our users, around 400 people responded and provided the following data on how they use Aurorasaurus.



### Social media

64% have the Aurorasaurus app  
43% follow us on [Twitter](#) or [Facebook](#)

### How often do you visit Aurorasaurus?

includes website use only

Only during big auroral events	23%
Every day	2%
A few times a week	32%
Once	28%
Never	15%

### Education level

95% have taken college or high school level science classes  
38% have science degrees

### Interest in auroras

68% are strongly interested in auroras

- ➡ 55% are described as "aurora enthusiasts"
- ➡ 30% participate in other online aurora communities

### Did you look for the aurora?

after receiving a notification from Aurorasaurus about a nearby visible aurora

Yes, by myself	54%
Yes, with others	34%
No	12%

After receiving a notification from Aurorasaurus about a nearby visible aurora, 88 percent of people went took action to see the aurora



Citizen science is about falling in love with the world more.

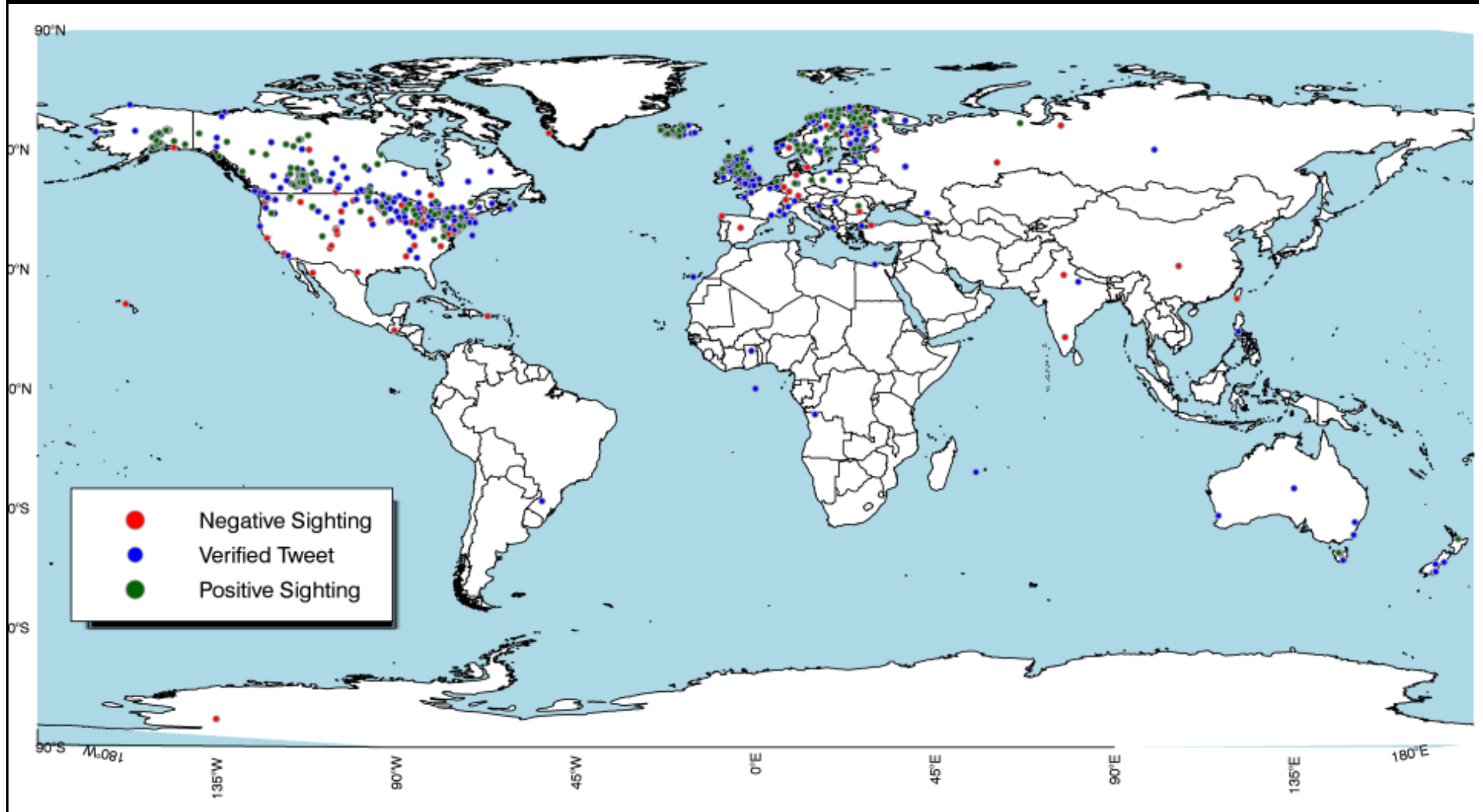
Sharman Russell, author of *Diary of a Citizen Scientist*

Crowdsourcing [ ] information may be a secondary source of data, but it is a primary source of public engagement.

Michael Fienen, Social Water project



# Backup

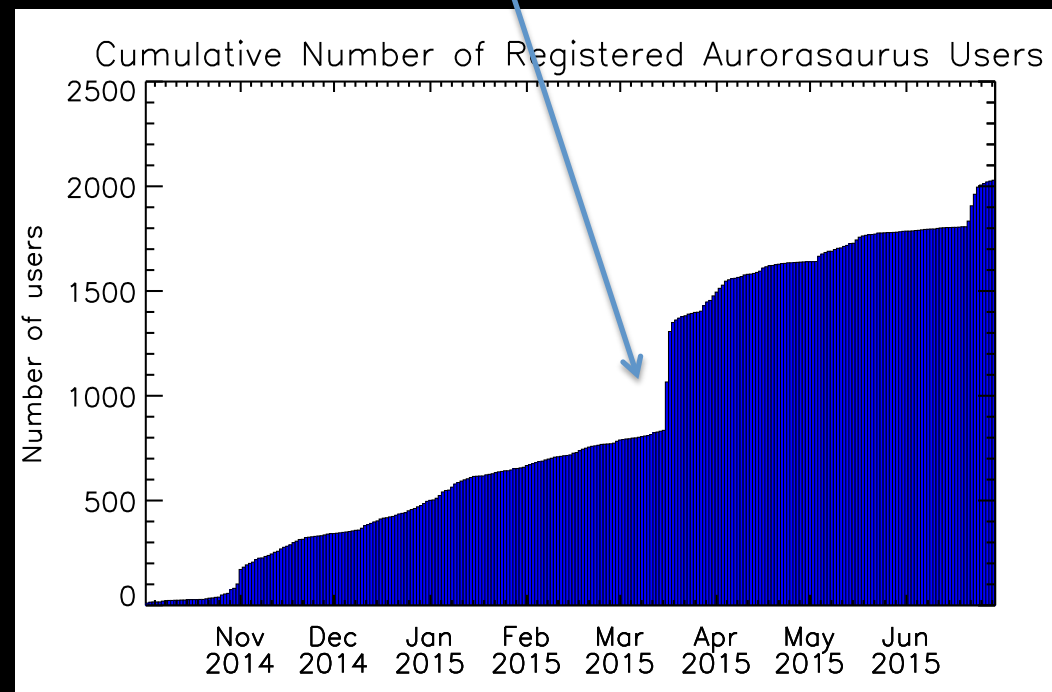




# What do the observations look like so far?

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- ~40% anonymous
- Total tweets 785k
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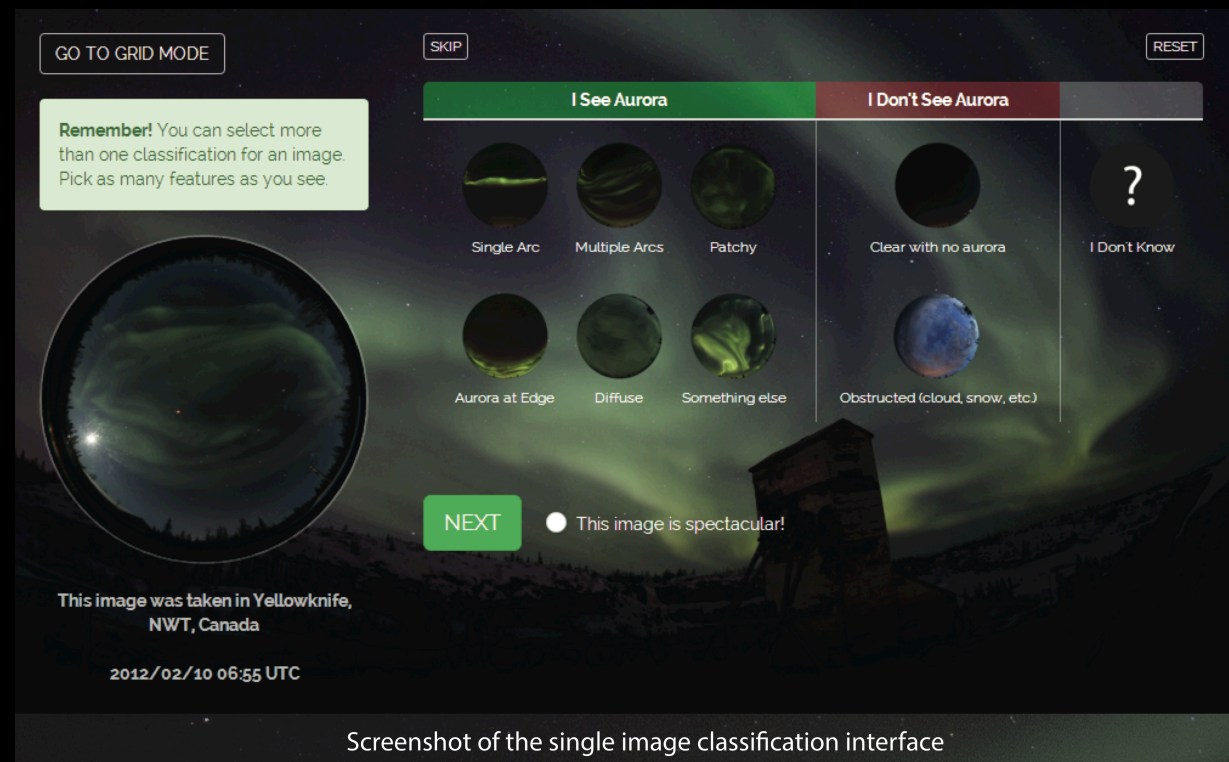
Participation spikes with activity





# Image classification

- Zooniverse has paved the way
- Partnering to offer more ways to participate and learn



Screenshot of the single image classification interface

# Science papers by the group thus far

*not all published yet, see me for a full list*

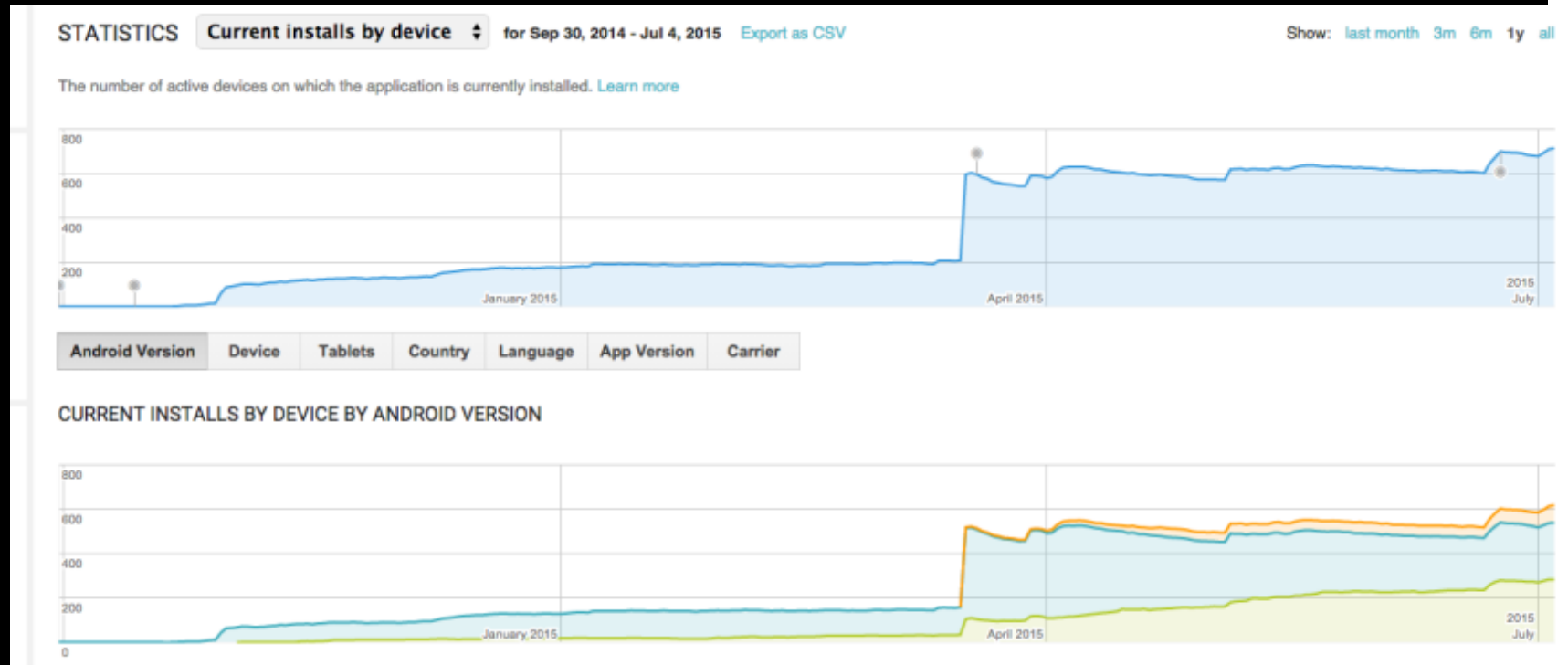
- Tweets as correlated to geomagnetic storms, GRL
- Solar wind power for the non-specialist, SW
- Aurorasaurus overview, SW
- Case study on how people's observations compare to the view line estimate, SW
- Efficacy of our real-time tweet verification system, Human Computation
- Building a better view line, SW
  
- Using beauty and curiosity to respond to alerts, ISCRAM (Information Systems for Crisis Response and Management) proceedings
- Planning a citizen science project

# How does it work?

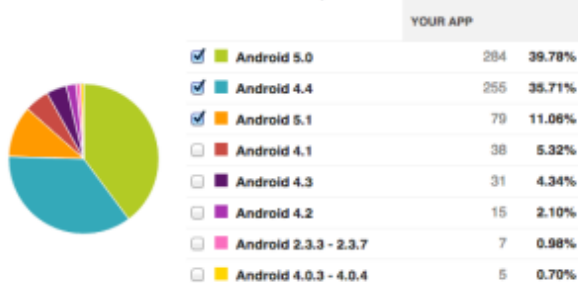
- Real-time use
  - alerts
- Retrospective Use
  - Science and education
- Flexible web architecture
  - Professional software development
  - Phonegap App for Apple iOS and Android 4.1 and above
  - Uses Amazon Web Services, Twitter API, Mezzanine
  - SQL(Postgres), Python, Django, JavaScript, CSS/LESS, HTML, PostGIS, Grunt, Supervisor, Java (CLAVIN), Git, NOAA SWPC data
  - Need alternate real-time cloud layer



# App downloads ~1500 current installs



CURRENT INSTALLS BY DEVICE ON JUL 4, 2015



<https://play.google.com/apps> Compatible for all but 2%





Google analytics, initial peek ~50,000 sessions ~1-6 min.  
 Mobile/web equally popular. Blog is ~10% as popular, Learn is  
 1%. Bounce rate ~60%, what is “good”?

- Active time

Jun 22, 2015 - Jun 23, 2015

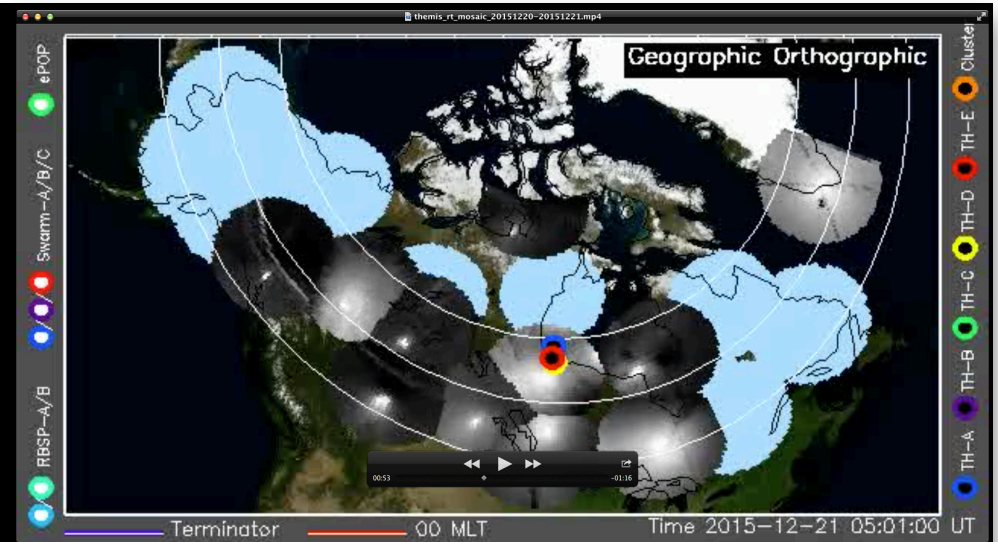
	Sessions	Avg. Session Duration	Bounce Rate	Goal Conversion Rate
Aurorasaurus				
Aurorasaurus (UA-55108991-1)				
All Web Site Data	1,842	00:02:48	57.87%	0.00%
Aurorasaurus Blog (UA-55108991-2)				
All Web Site Data	178	00:00:39	77.53%	0.00%
Aurorasaurus Desk.com (UA-55108991-3)				
All Web Site Data	16	00:00:20	68.75%	0.00%
AurorasaurusMobile (UA-55108991-4)				
All Mobile App Data	1,652	00:05:56	0.00%	0.00%

- All time

	Sessions	Avg. Session Duration	Bounce Rate
Aurorasaurus			
Aurorasaurus (UA-55108991-1)			
All Web Site Data	26,774	00:02:06	65.42%
Aurorasaurus Blog (UA-55108991-2)			
All Web Site Data	4,236	00:01:01	79.34%
Aurorasaurus Desk.com (UA-55108991-3)			
All Web Site Data	657	00:01:32	46.73%
AurorasaurusMobile (UA-55108991-4)			
All Mobile App Data	12,736	00:02:52	0.00%

# A few other examples

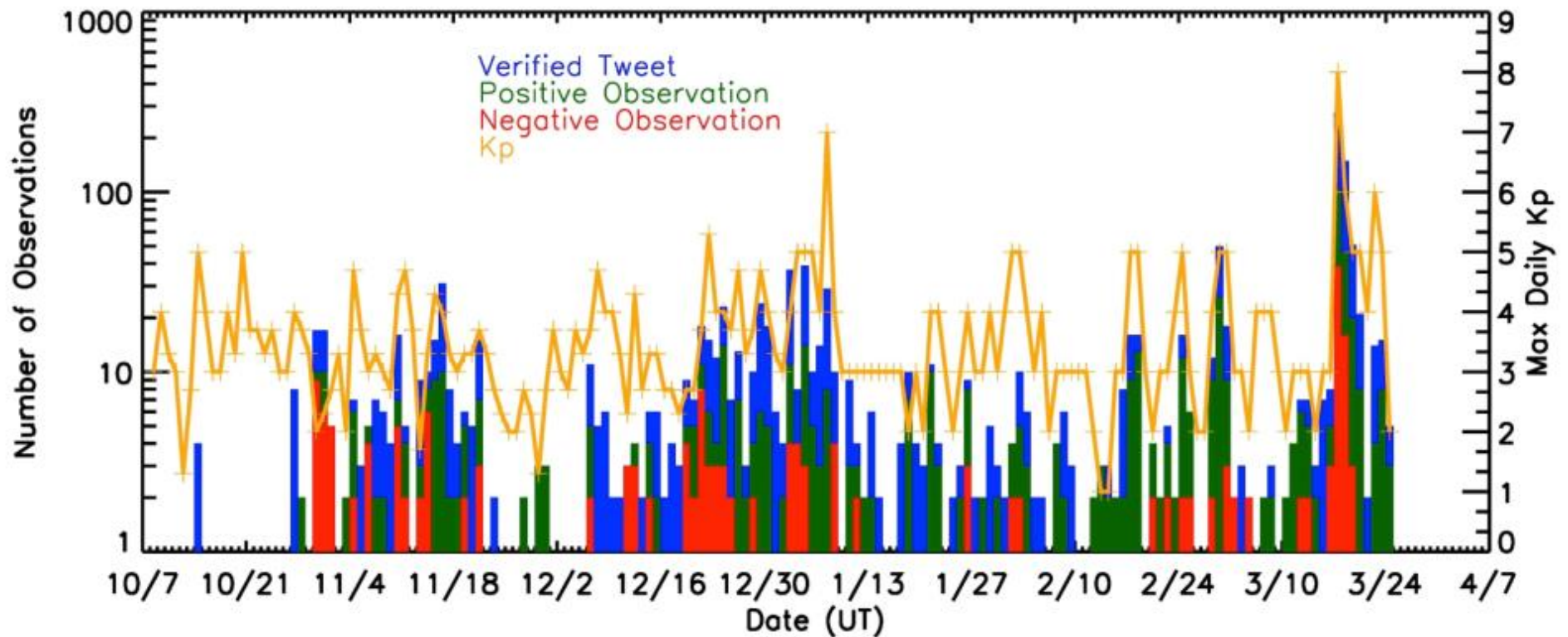
- Rare aurora captured by Alan Duffy, Saskatoon



Compare to ground based cameras and in situ spacecraft



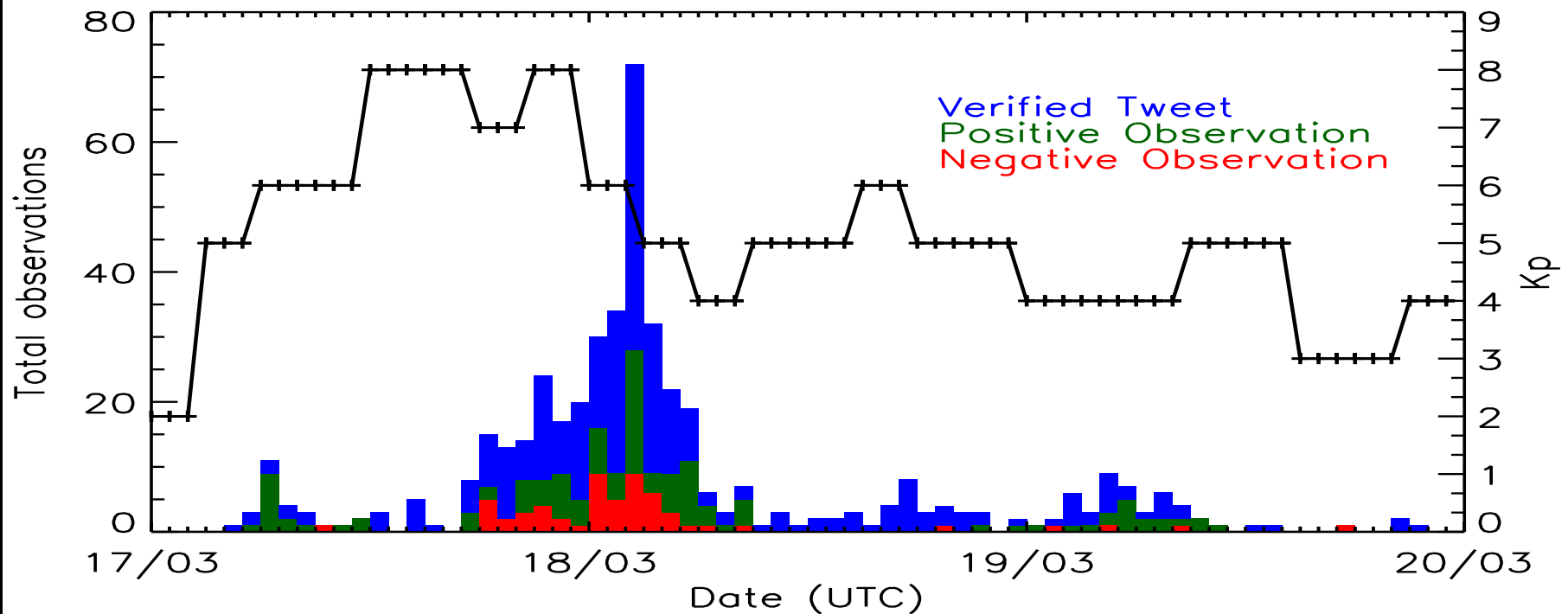
# Tweets and observations correlate with geomagnetic activity



- Case et al., GRL, 2015

# St. Patrick's Day storm of the decade

- Aurorasaurus shows 70 reports per hour max
  - Geographic, population bias
- Put these reports on a Google map in real-time



# Space science is core to our mission

- Improving research, connections to CCMC and space weather
- Connection to missions, education, and outreach



**AURORASAURUS**  
Reporting Auroras From the Ground Up



My Aurorasaurus

Logout

Did you see the aurora?

Yes

No

Verify Tweets

News

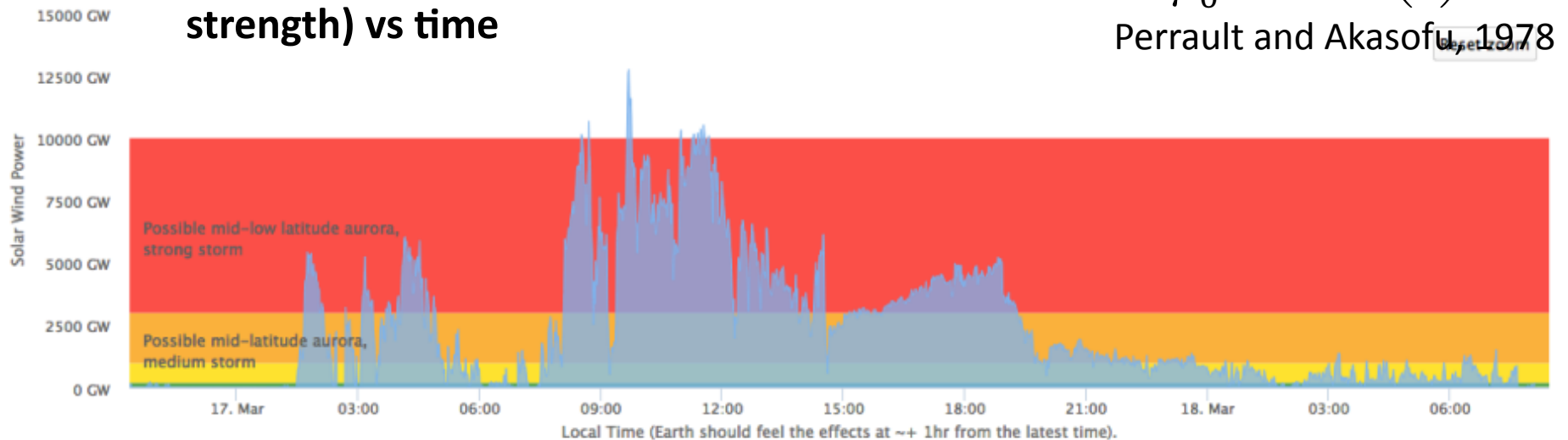
Learn

Help

## Solar wind power (related to auroral strength) vs time

$$\varepsilon = \frac{4\pi}{\mu_0} v B^2 \sin^4 \left( \frac{\theta}{2} \right) l_0^2$$

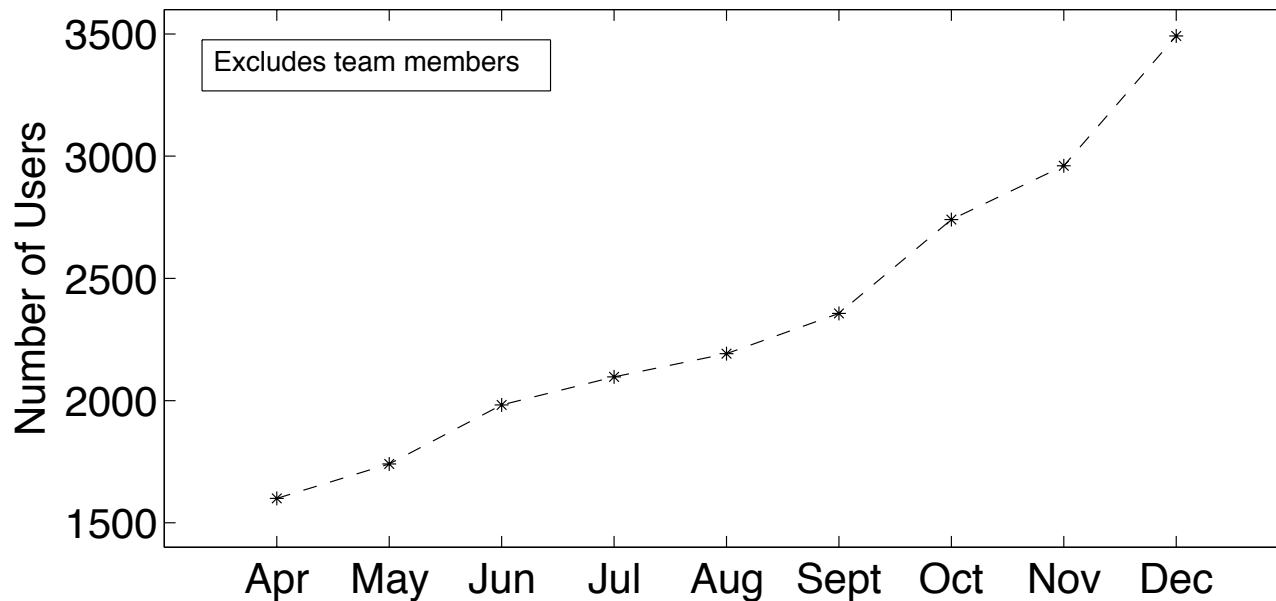
Perrault and Akasofu, 1978



This graph shows the strength of solar wind power, a real-time indicator of how strong aurora will be in about one hour. The solar wind power corresponds to the energy released by the sun over time. The more energy released, the higher the power and the stronger the aurora will be.



### Total Number of Users



### Monthly Net Growth of Web Observations

