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

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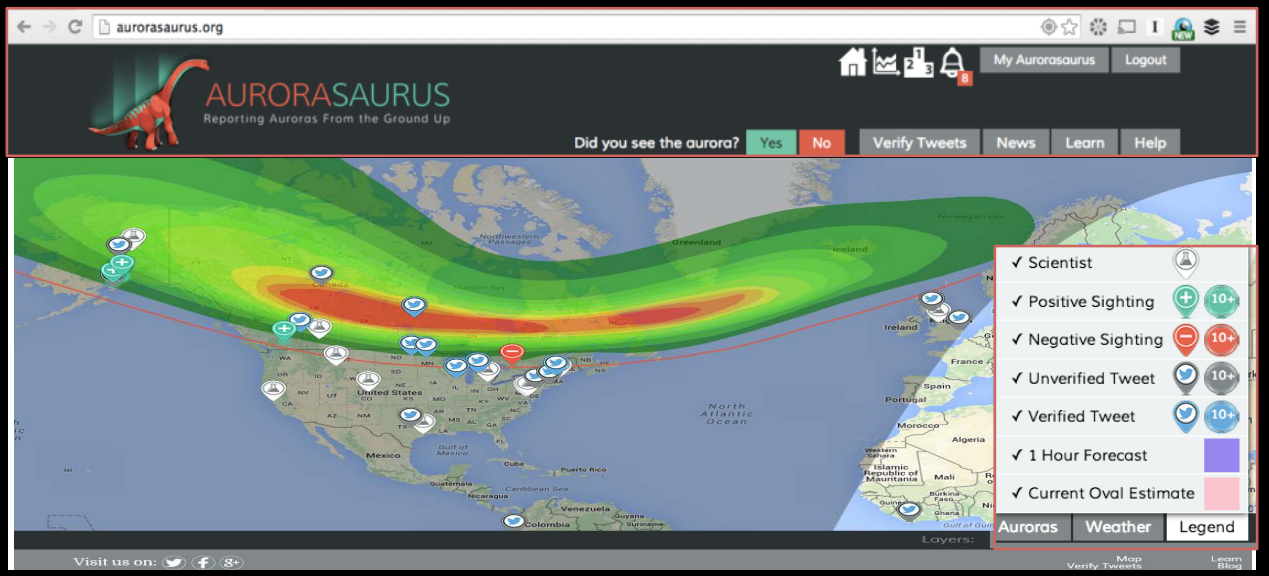
nsf

AURORASAURUS

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

AURORASAURUS

NSF

The Pennsylvania State University 1855

New Mexico CONSORTIUM

Science Education Solutions

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

Join us!

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

NASA Goddard

Who are we?

- 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

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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.

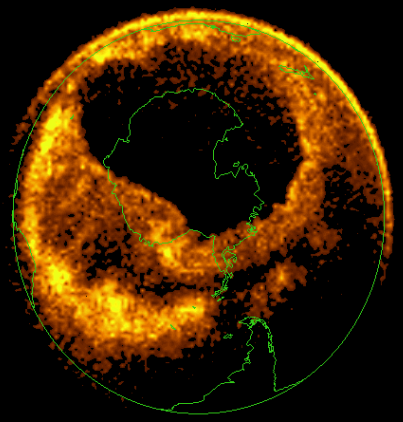
Why do we need to know this?

- 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

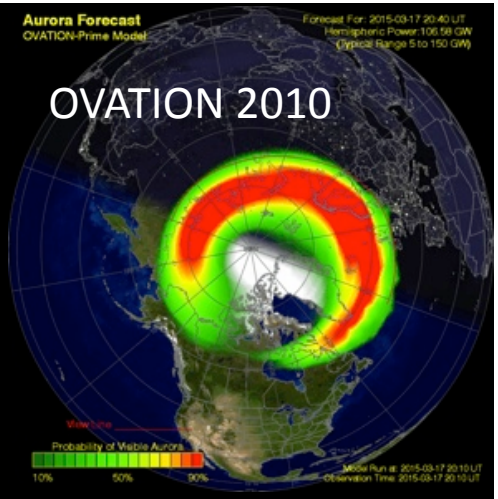
Who is the end user?

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

Motivation



DE-1, during 1989 superstorm



OVATION 2010

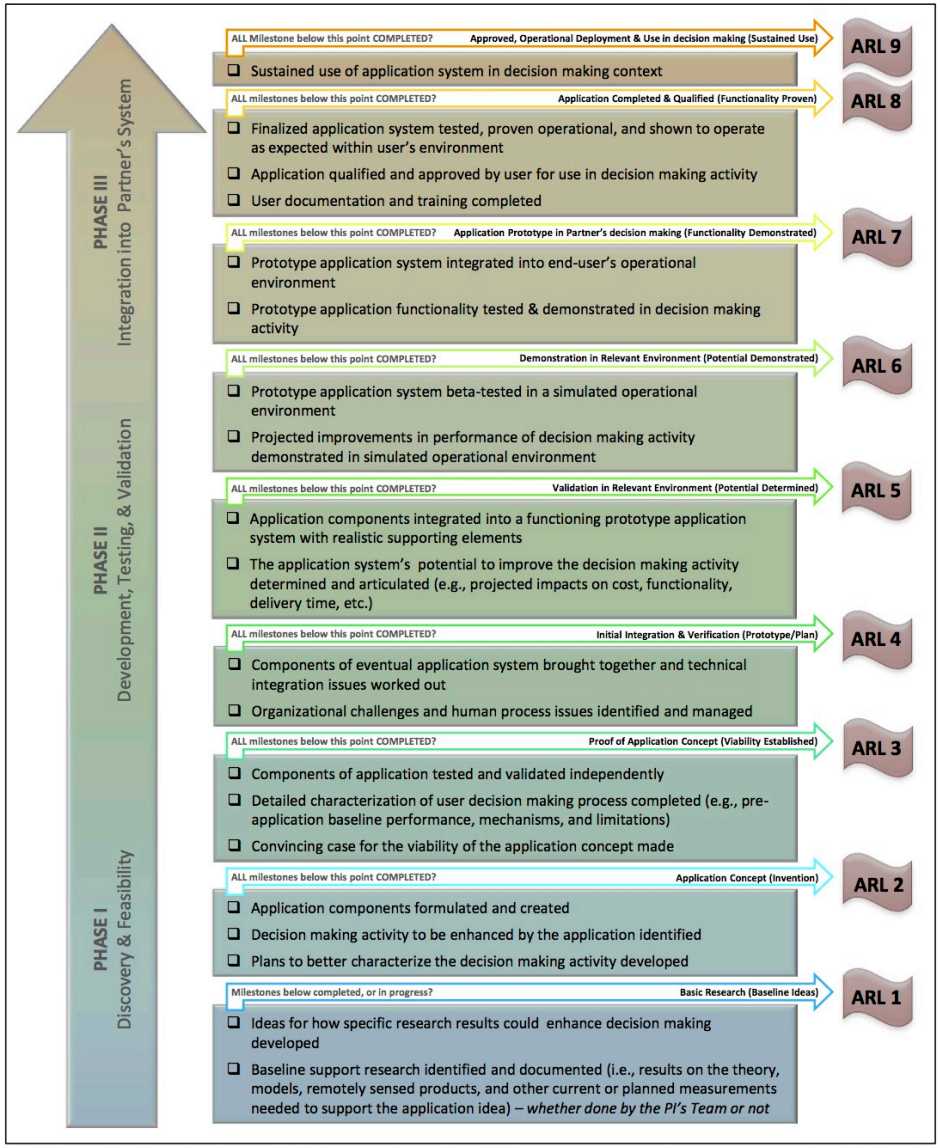
Why do we need this?

- 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

What is "Research to Operations" (R2O) for space weather applications?



NASA Application Readiness Level (ARL) Milestones. Progression of NASA Applied Sciences projects is represented vertically (y-axis). While some projects may complete some milestones out of phase with this upwards vertical progression, the ARL for each project is

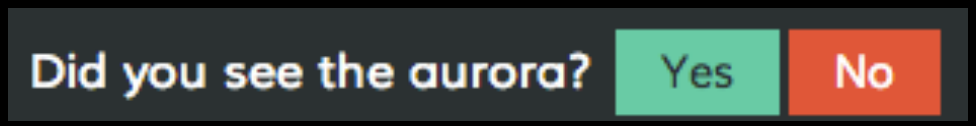
Resiliency is important. CS may not be a primary source of information but could be a robust, ancillary source of data.

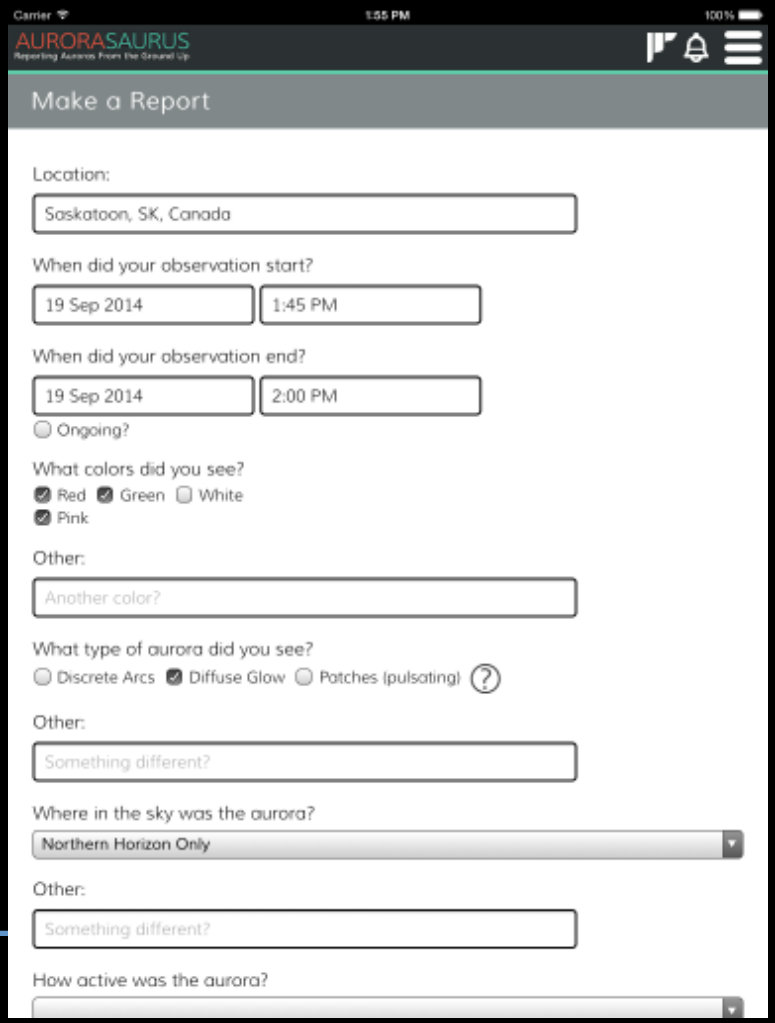
- Customer needs
- Verification and Validation (V&V)
- Errors, uncertainty, flags
- Communication

(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.





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

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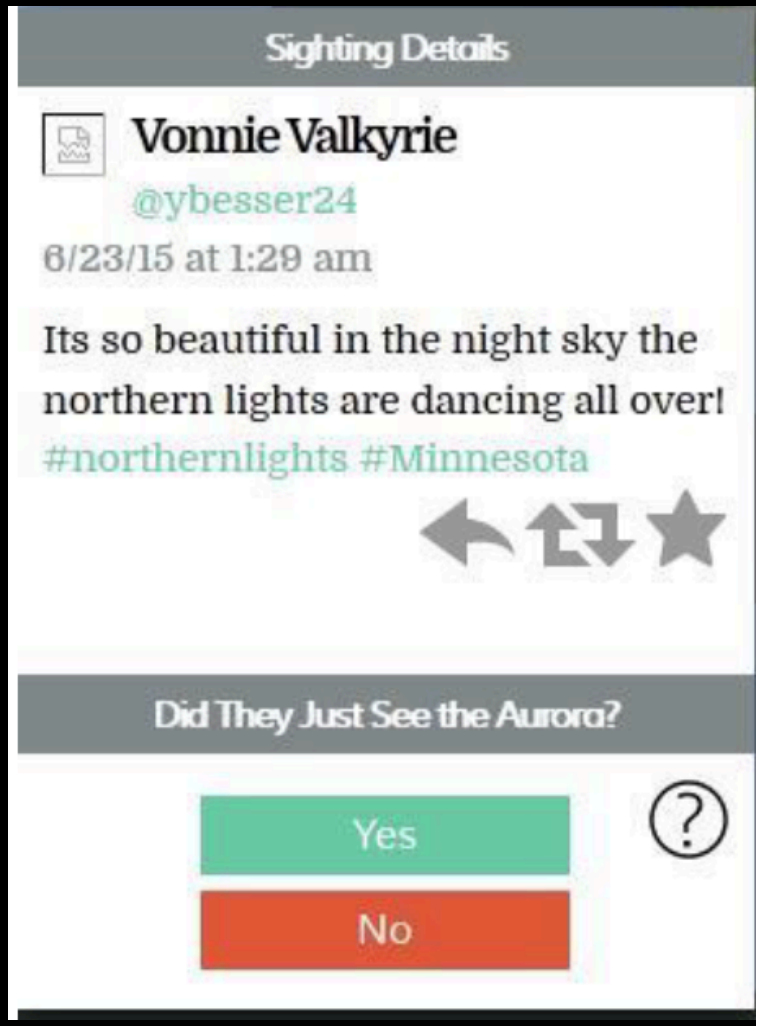
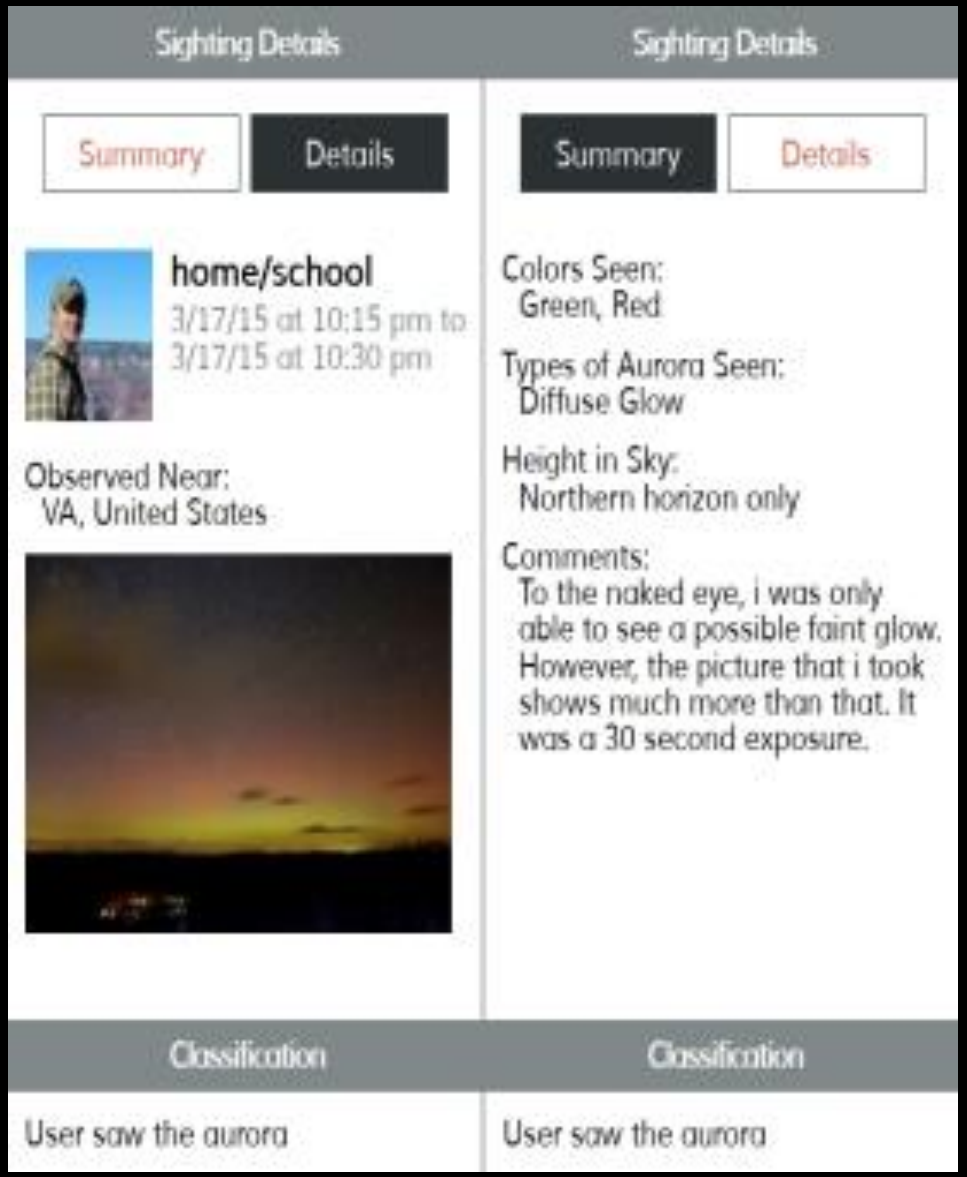
CS: Classification

- 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

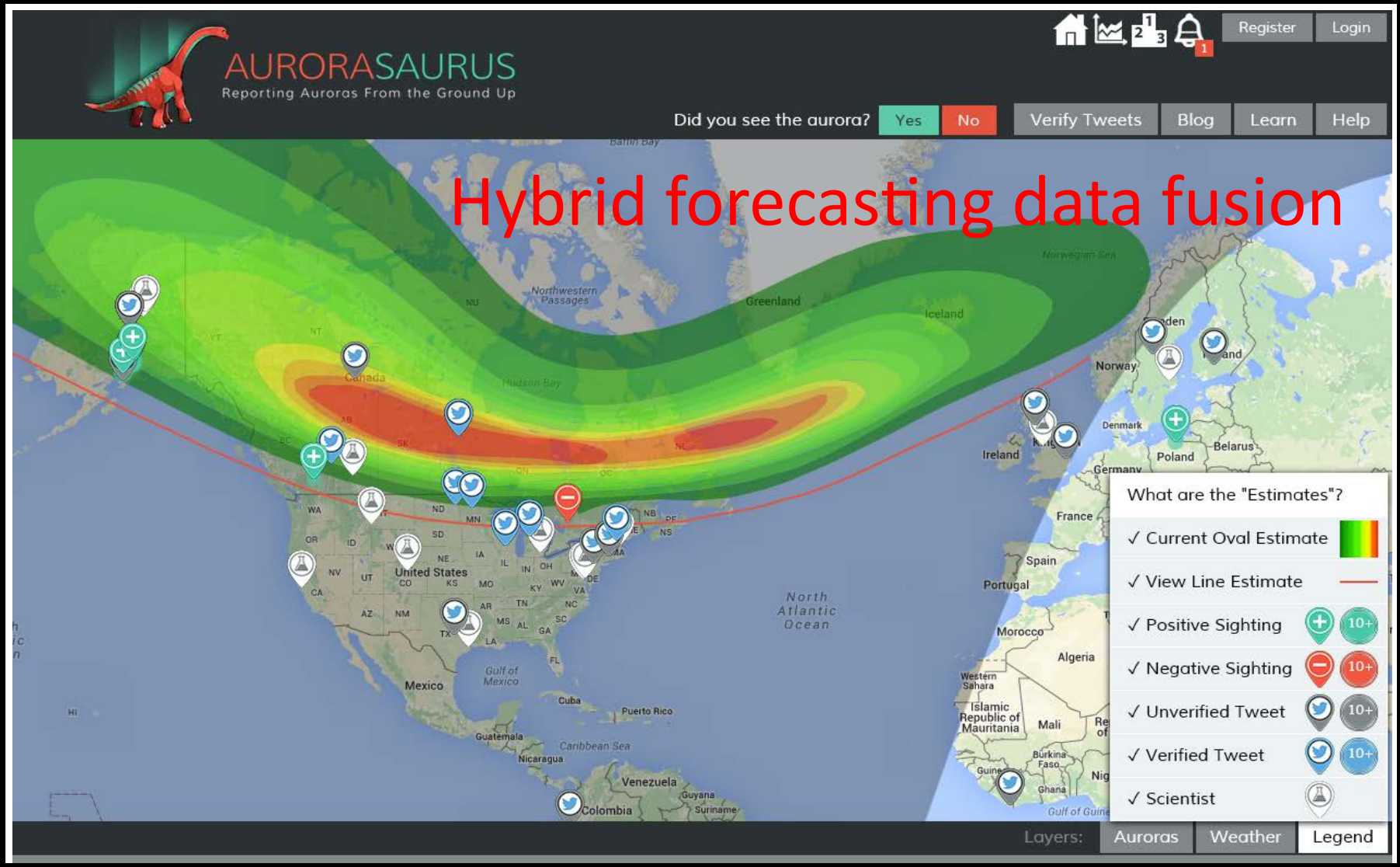


Citizen Science Aurora Data



- We have a custom SQL database of all observations

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

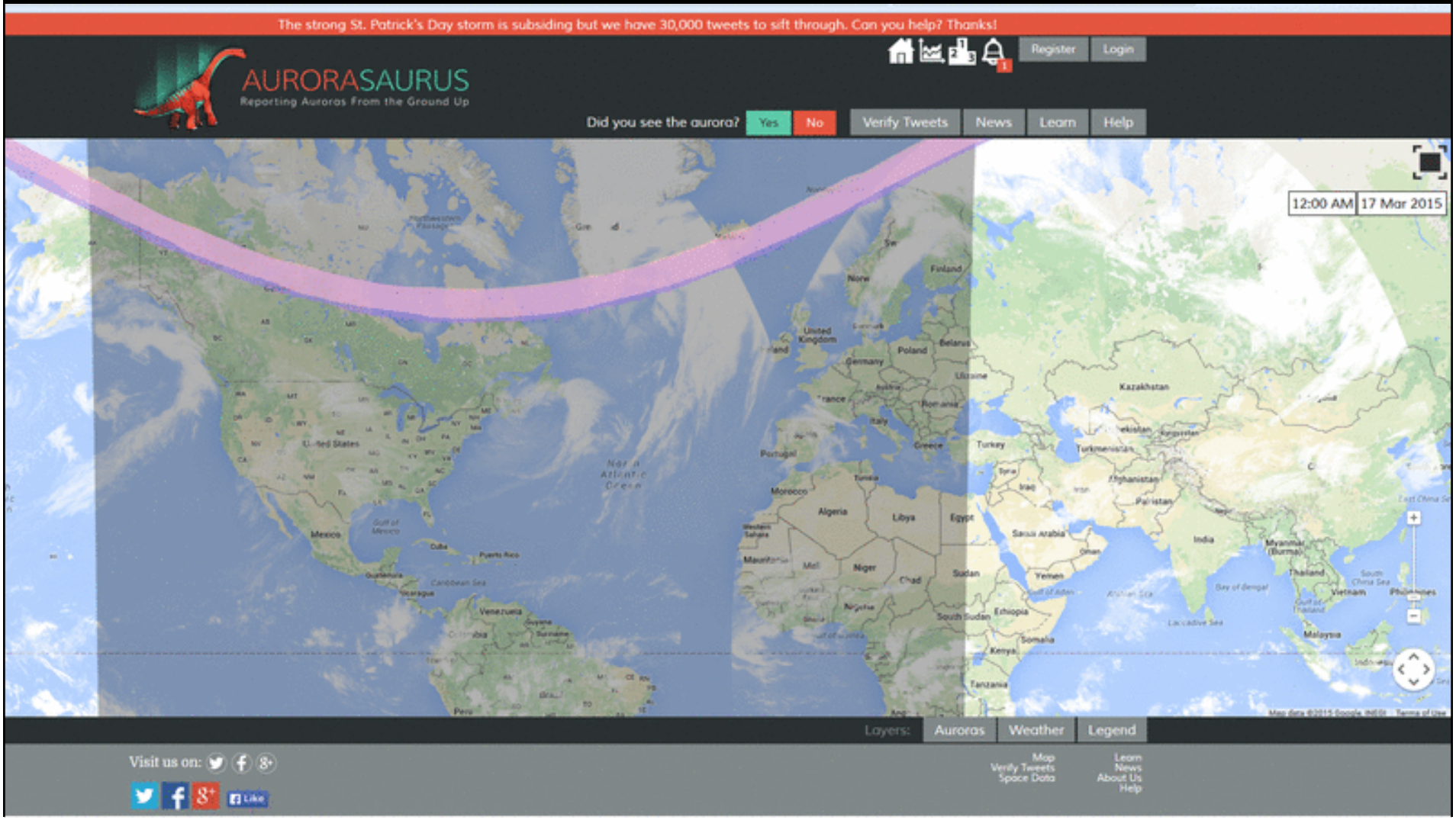
Preliminary numbers for 3/17/15:

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

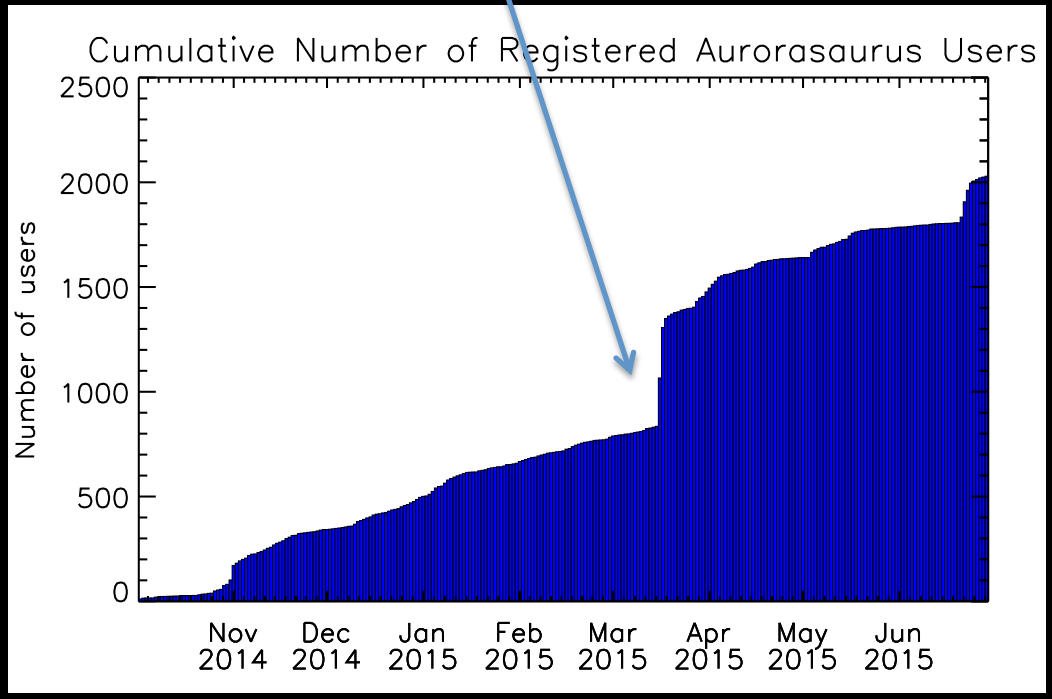


What do the observations look like so far?

- ~1k reports, ~64% positive, 36% negative
- ~40% anonymous

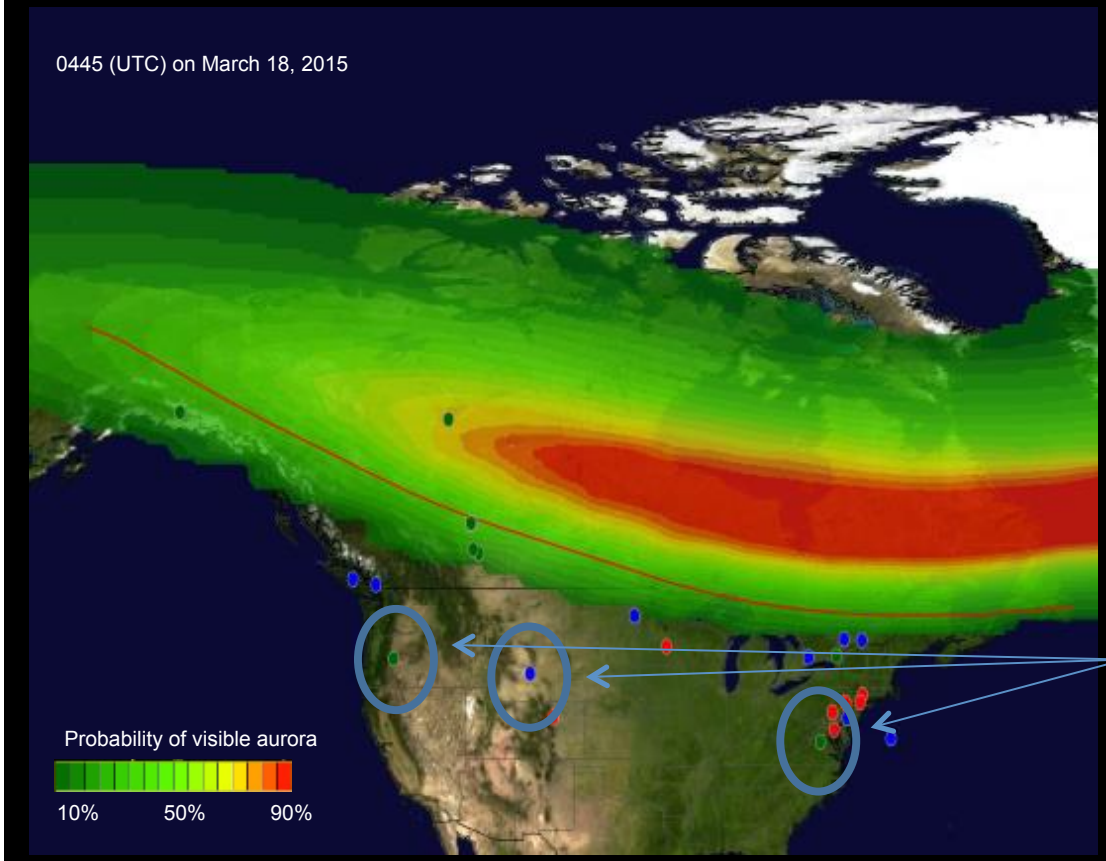
- Total tweets 785k
- Can get location on ~20%, of those
- ~1k, 0.1% are up-voted as aurora sightings
- ~18k, 2% are down-voted
- 91k total votes (not anonymous)

Participation spikes with activity



Case et al., Human Computation, submitted, 2015

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.

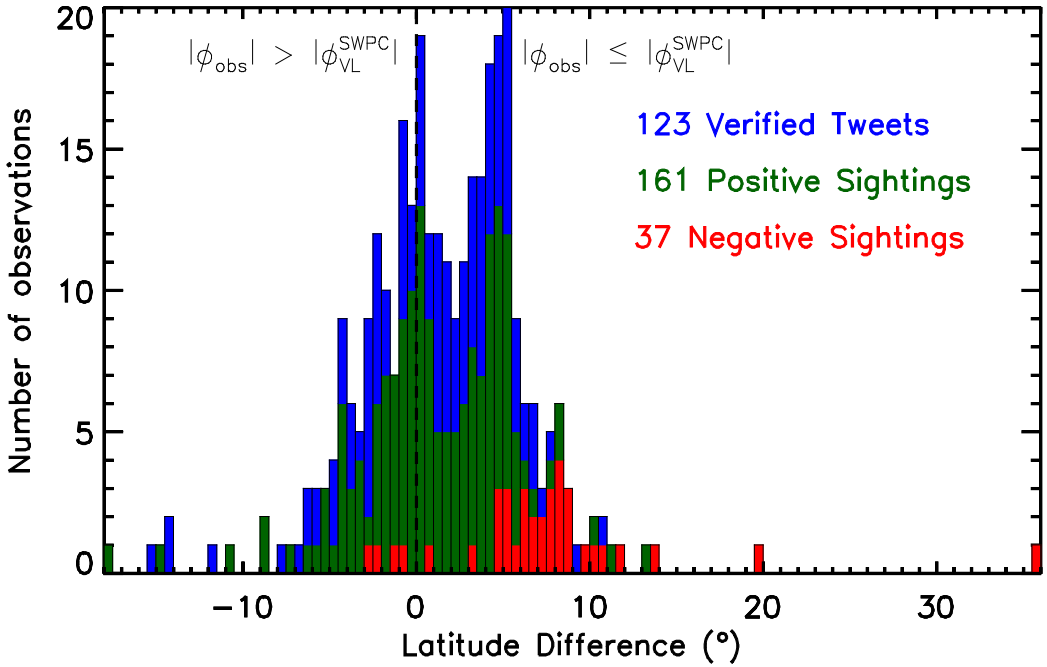


Figure 4. The latitude difference between the observations and the SWPC estimated view-line is shown.

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.

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

N. A. Case[1,2], E. A. MacDonald[1,2] and H. K. Connor[2,3]

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

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

N. A. Case[1,2], E. A. MacDonald[1,2] and R. Viereck[3]

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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.

AGU PUBLICATIONS

Space Weather

RESEARCH ARTICLE
10.1002/2015SW001214

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

Key Points:
- Citizen science project collecting aurora observations

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

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

N. A. Case,[1,2] D. Kingman,[1] and E. A. MacDonald[1,2]

Human Computation (2015) xx:xx:xx

ISSN: 2330-8001, DOI: 10.15346/xx

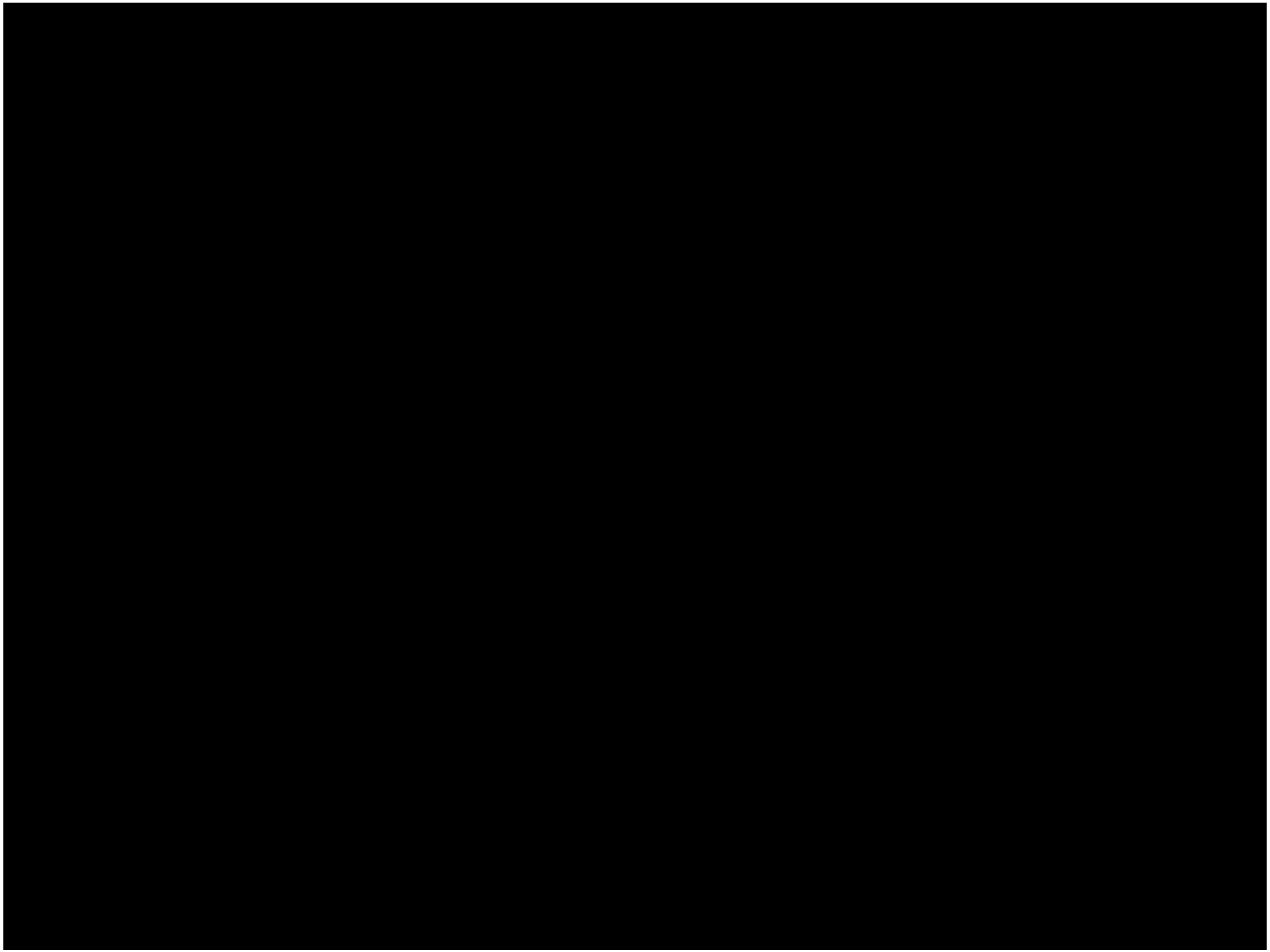
Determining the Accuracy of Crowdsourced Tweet Verification for Auroral Research

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

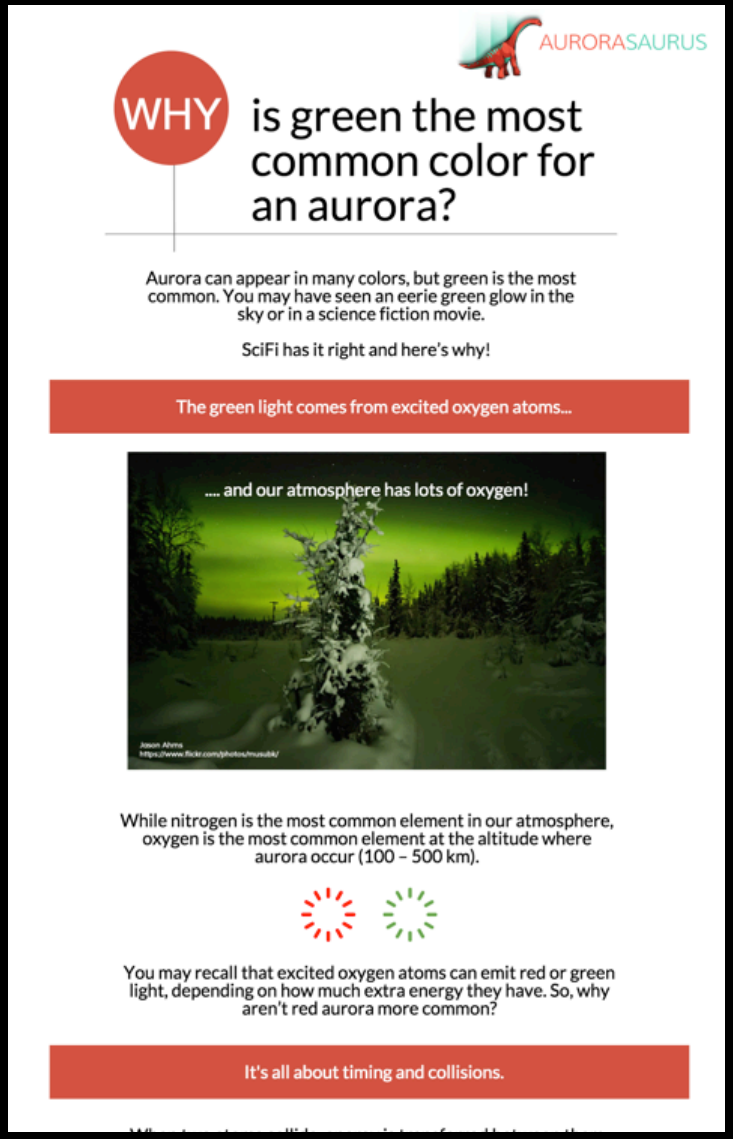
Data span from November 2014 – present

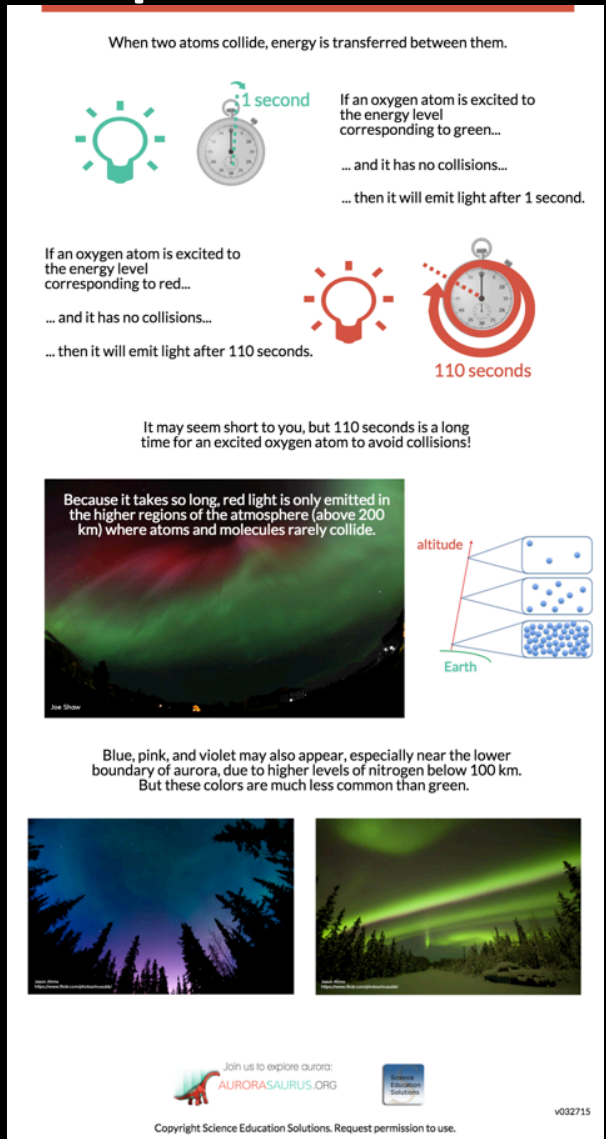
More than 3000 users

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

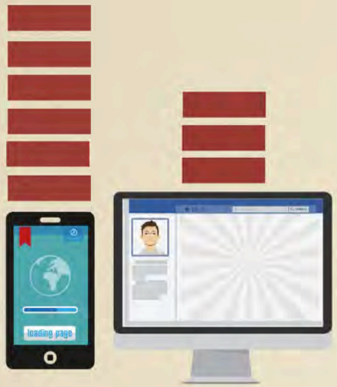
- 600 positive sightings
- 1200 verified tweets, 70% accurate
- Spanning several continents!
- Real-time verified alerts
    - 2 levels
- ~88% respond to alerts
- ~50% of information is near-real-time

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





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 an 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

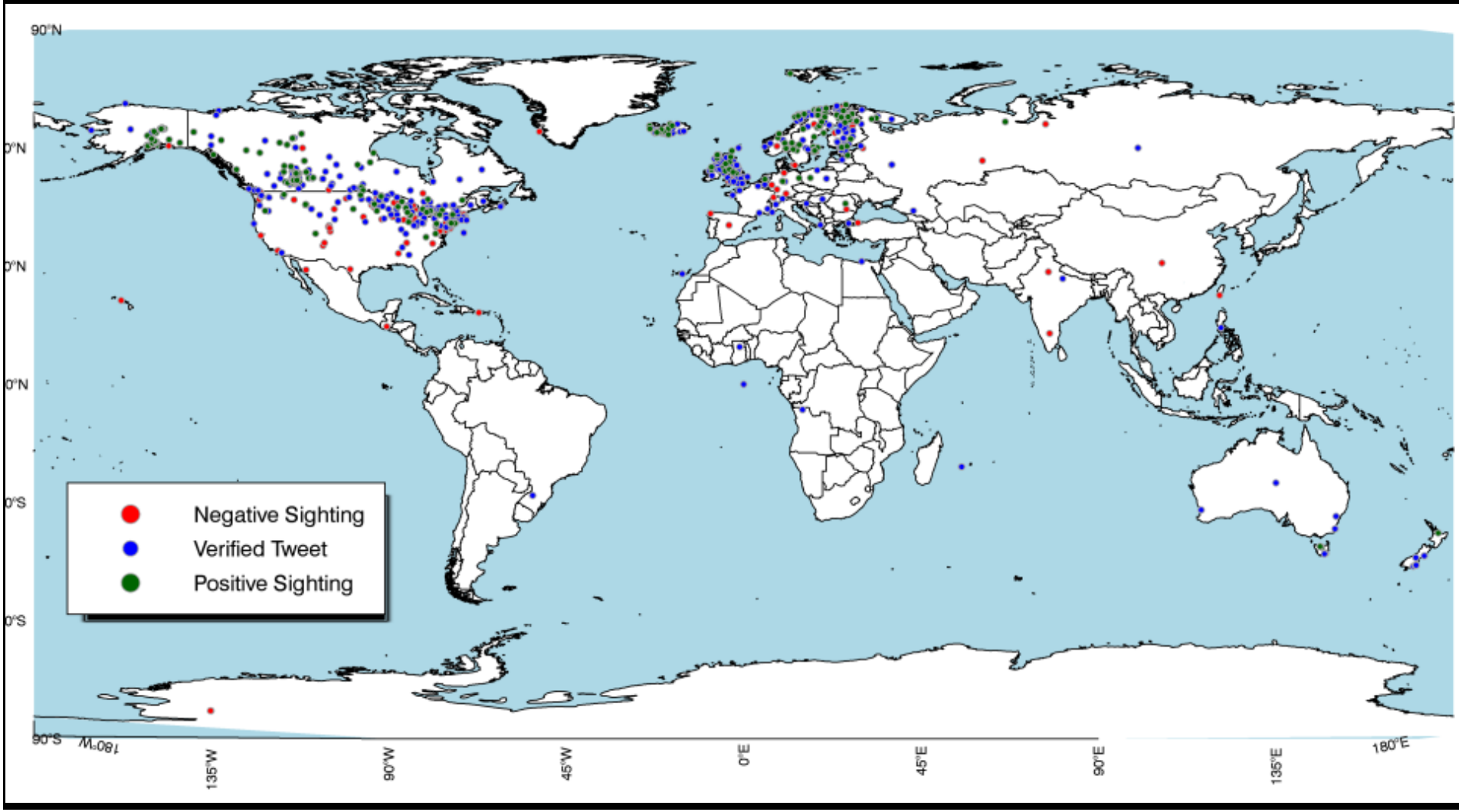
Citizen science is about falling in love with the world more.

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


90°N
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0°S
0°S
90°S
180°W
135°W
90°W
45°W
0°E
45°E
90°E
135°E
180°E
Negative Sighting
Verified Tweet
Positive Sighting

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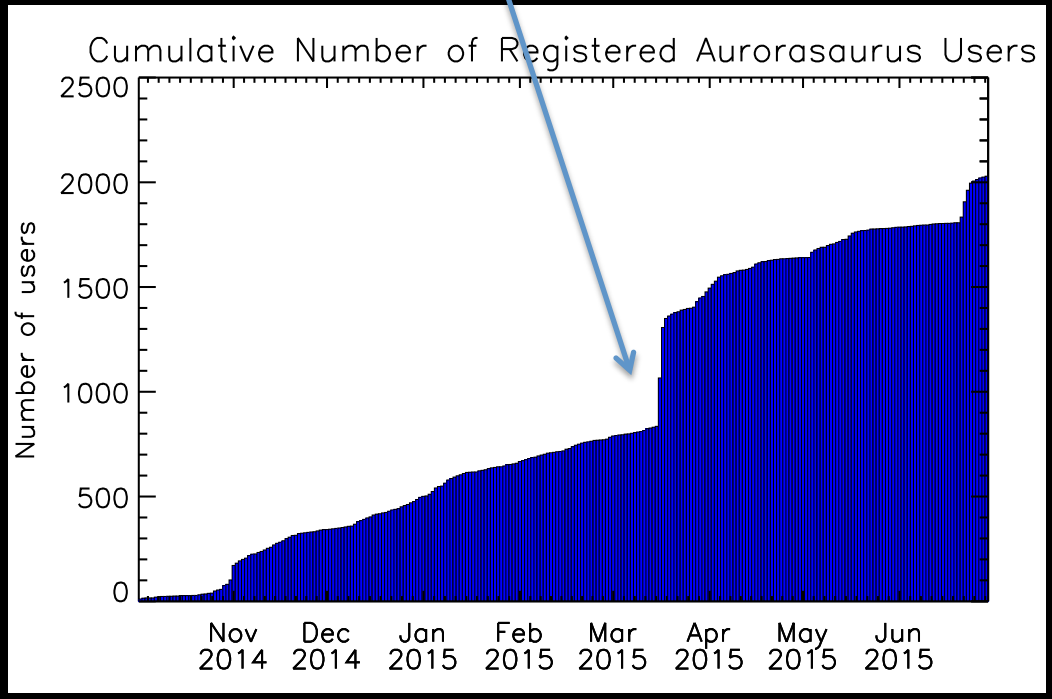
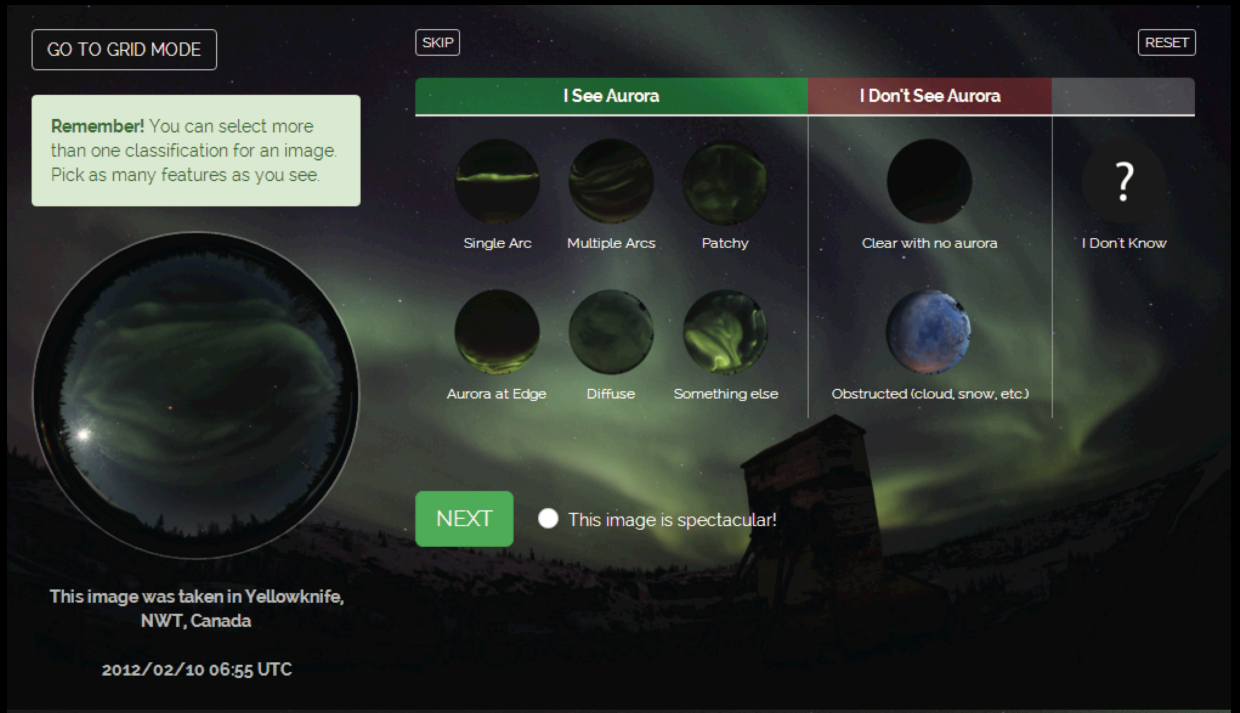


Case et al., Human Computation, submitted, 2015

Image classification

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



Screenshot of the single image classification interface

Darren Chaddock[1], Emma Spanswick[1], D. Megan Gillies[1], Annie Quinney[2], Eric Donovan[1], Maribeth Murray[2]

Science papers by the group thus far

not all published yet, see me for a full list

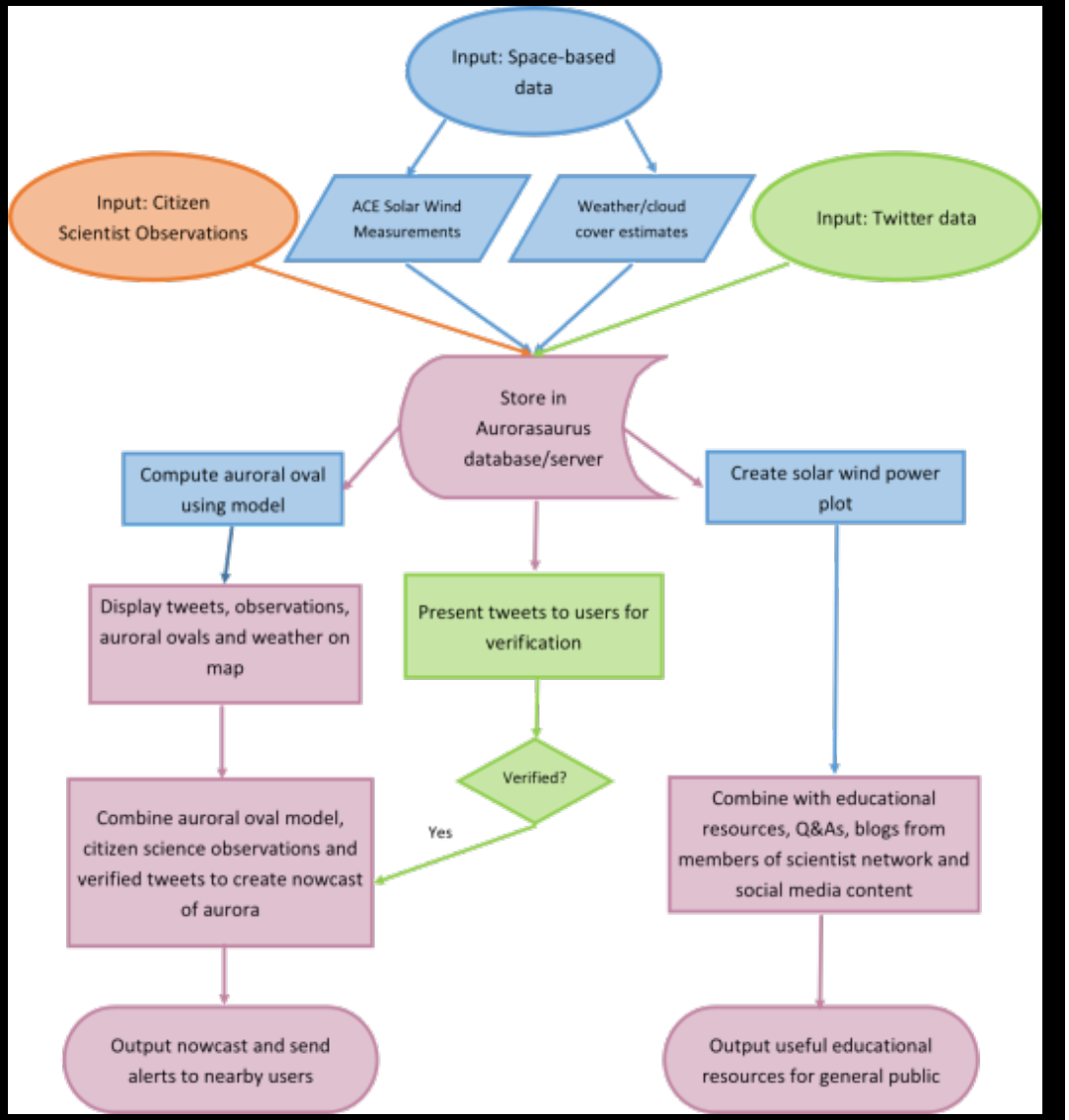
- Tweets as correlated to geomagnetic storms, GRL
- Solar wind power for the non-specialist, SW
- Aurorasaurus overview, SW
- Case study on how people's observations compare to the view line estimate, SW
- Efficacy of our real-time tweet verification system, Human Computation
- Building a better view line, SW

- Using beauty and curiosity to respond to alerts, ISCRAM (Information Systems for Crisis Response and Management) proceedings
- Planning a citizen science project

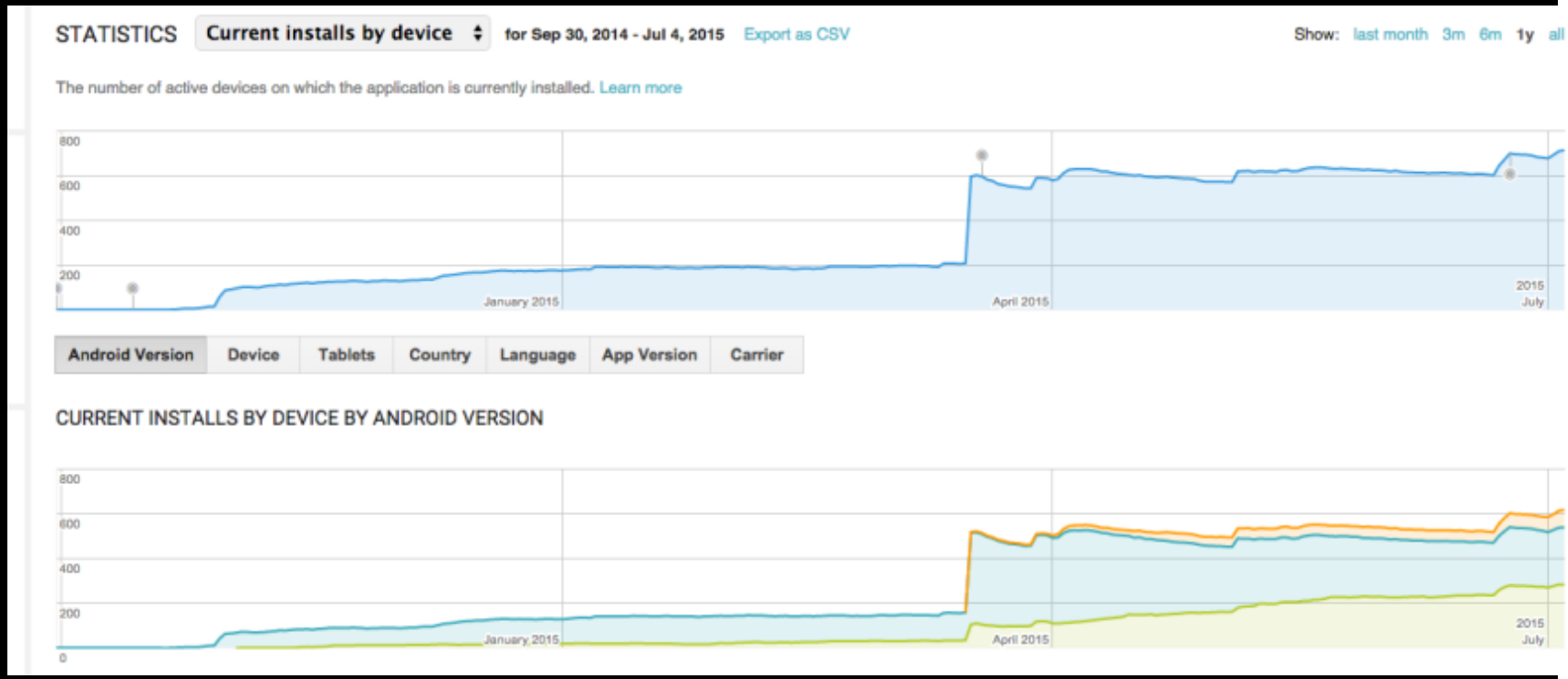
How does it work?

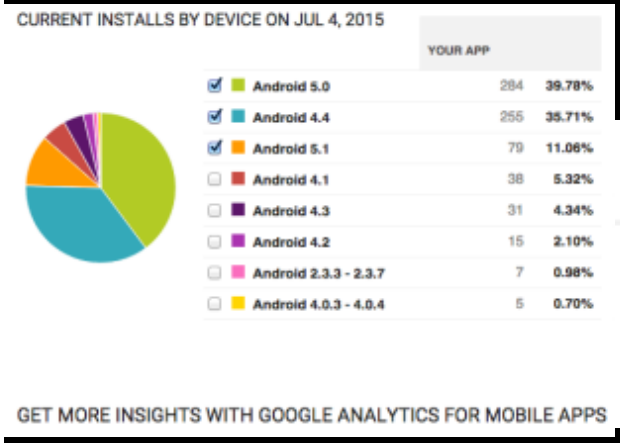
- Real-time use
  - alerts
- Retrospective Use
  - Science and education

- 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

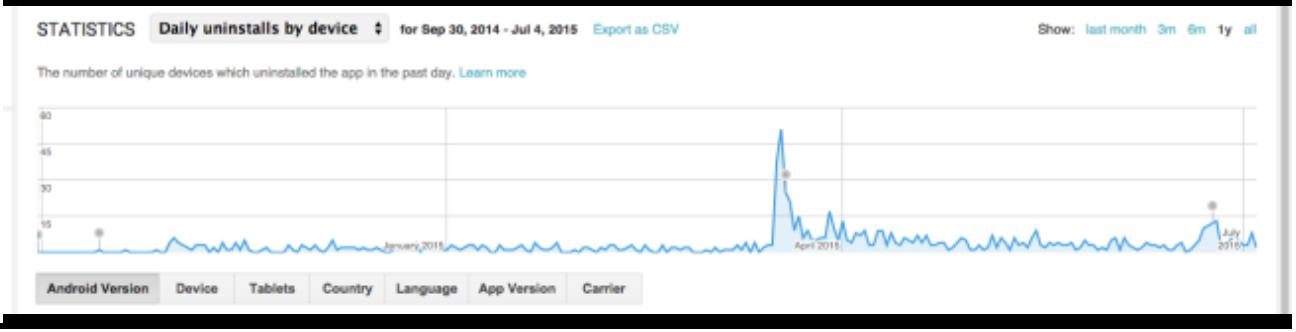


App downloads ~1500 current installs





https://play.google.com/appsCompatible 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%

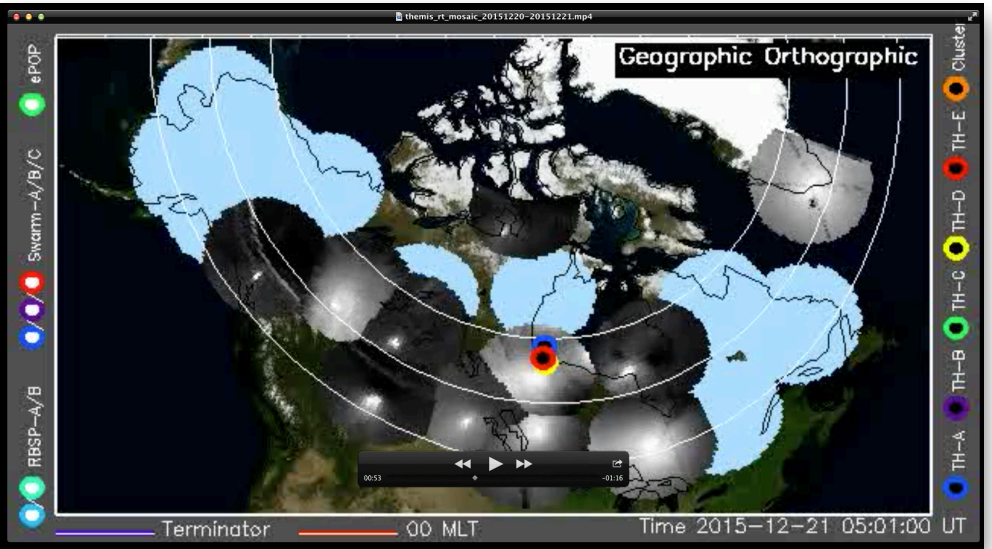
- All time

	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%

This table was gen

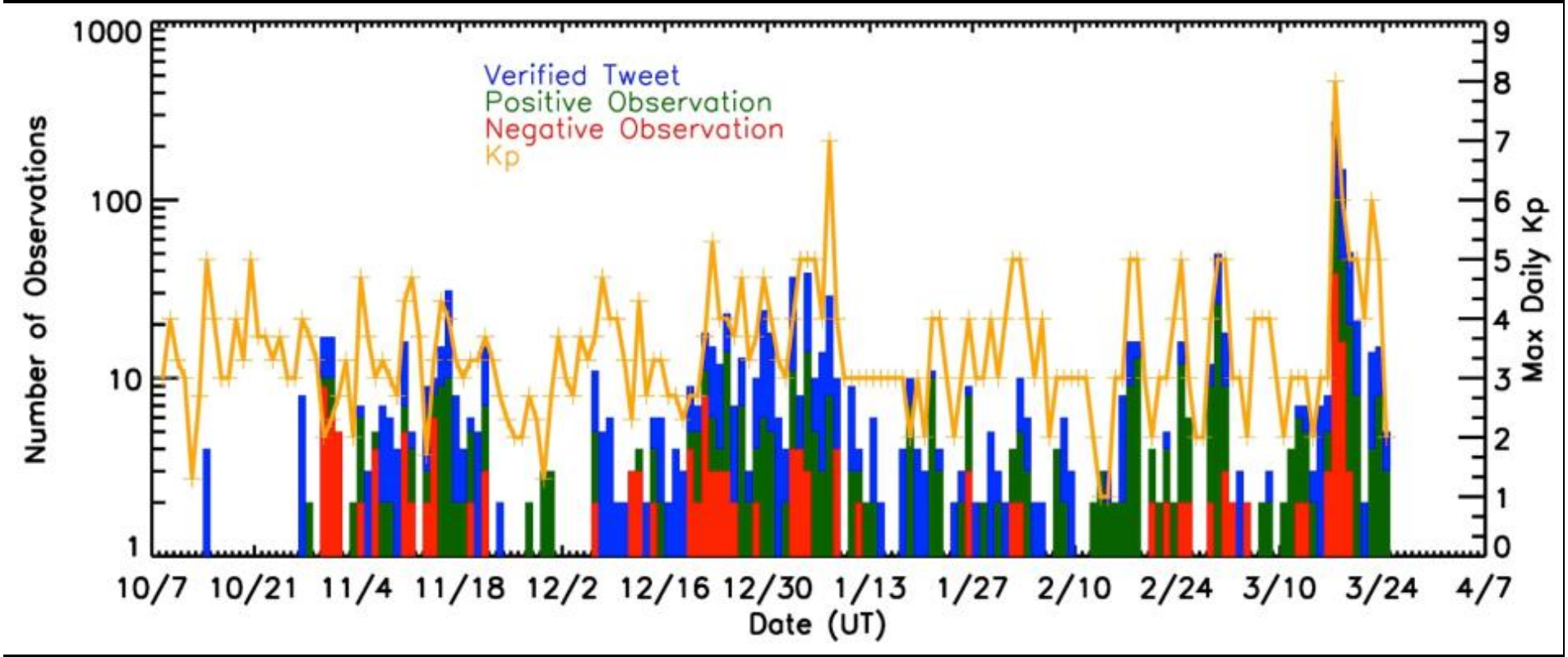
A few other examples

- Rare aurora captured by Alan Duffy, Saskatoon



Compare to ground based cameras and in situ spacecraft

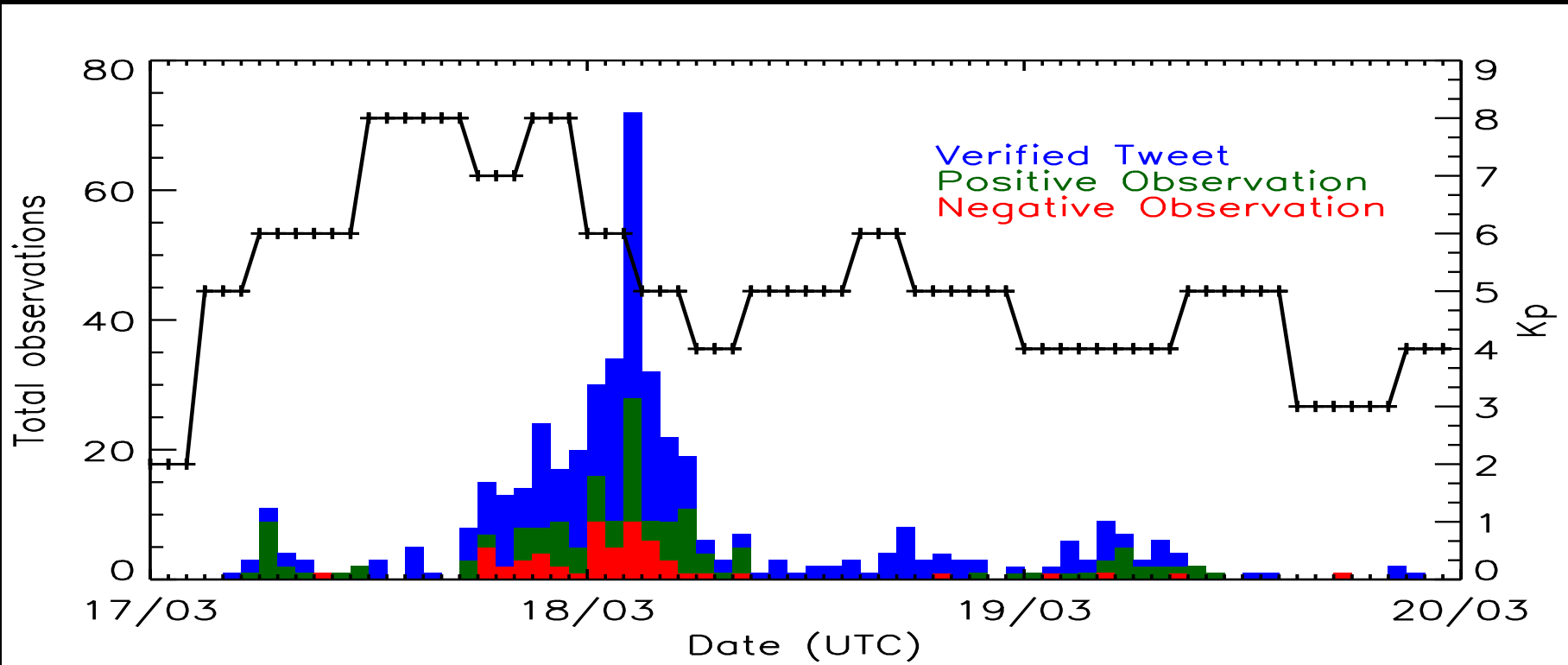
Tweets and observations correlate with geomagnetic activity



- Case et al., GRL, 2015

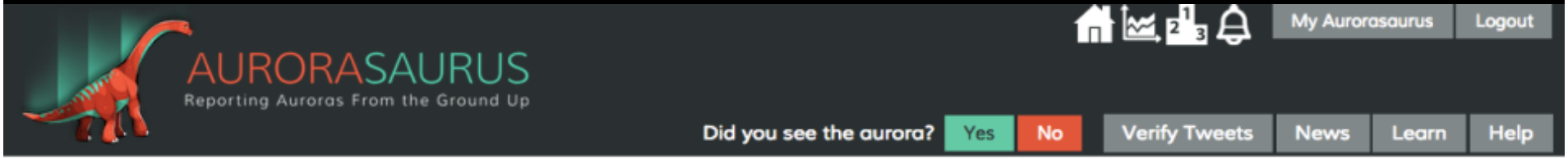
St. Patrick's Day storm of the decade

- 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

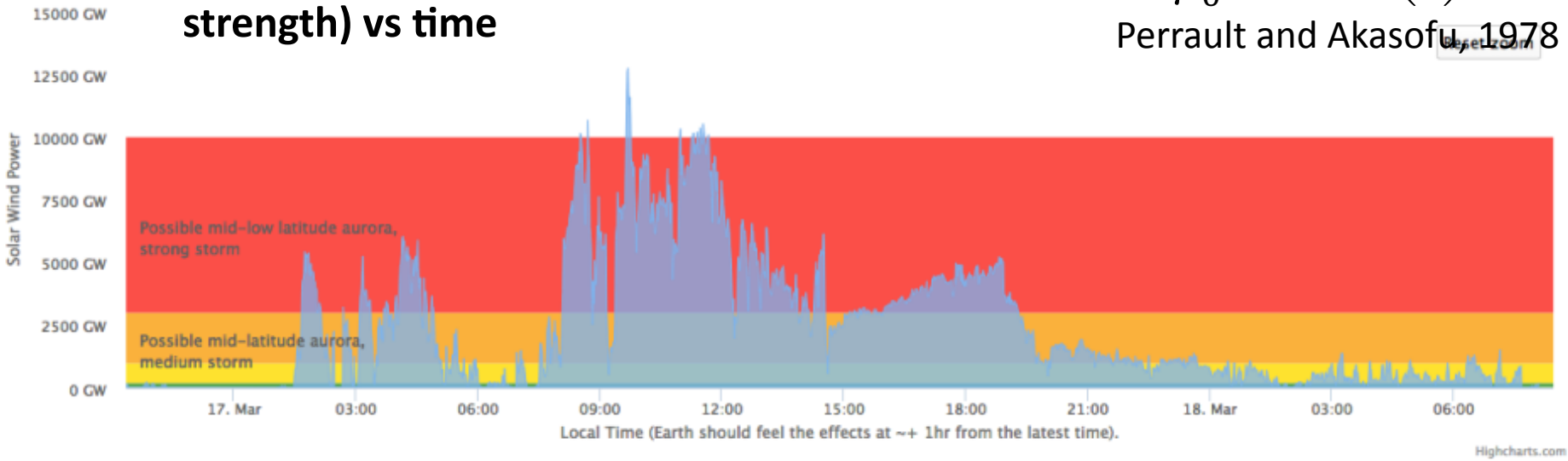
- Improving research, connections to CCMC and space weather
- Connection to missions, education, and outreach



Solar wind power (related to auroral strength) vs time

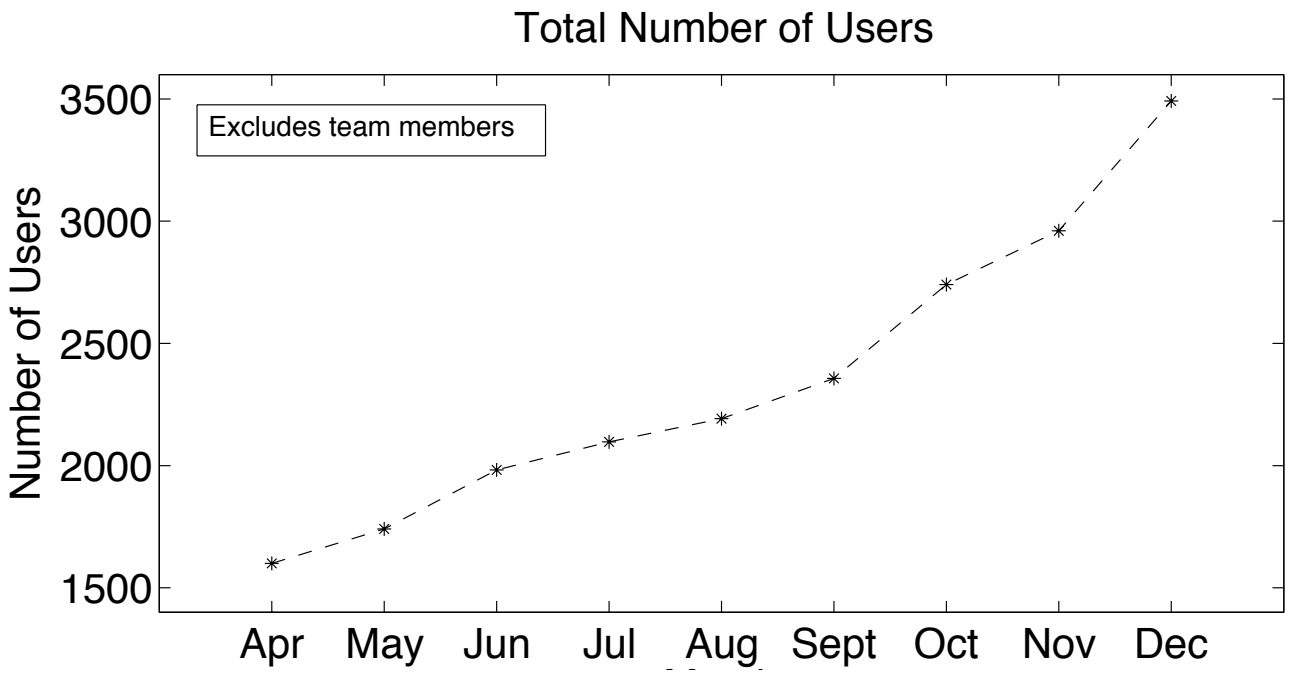
$$\varepsilon = \frac{4\pi}{\mu_0} v B^2 \sin^4\left(\frac{\theta}{2}\right) l_0^2$$

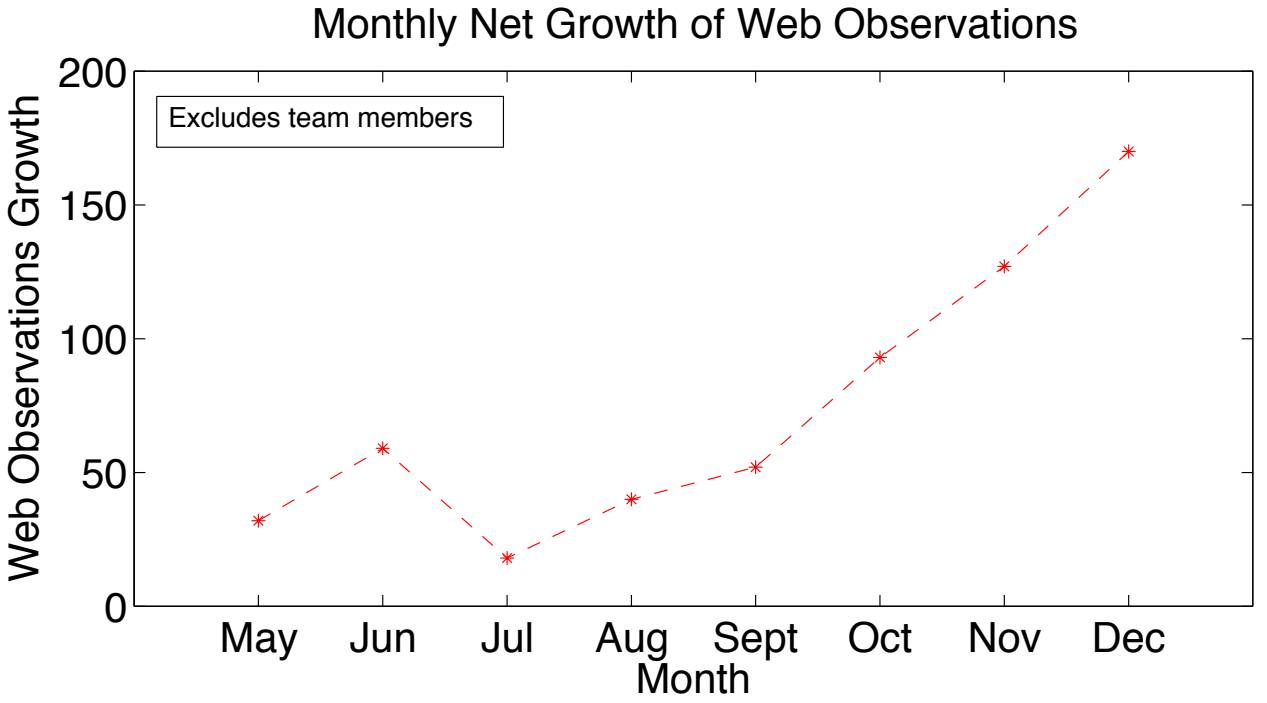
Perrault and Akasofu, 1978



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.

[redacted]





[redacted]