# Space Weather: From Expert to Non-Expert

Dr. Tamitha Skov

*Millersville University*

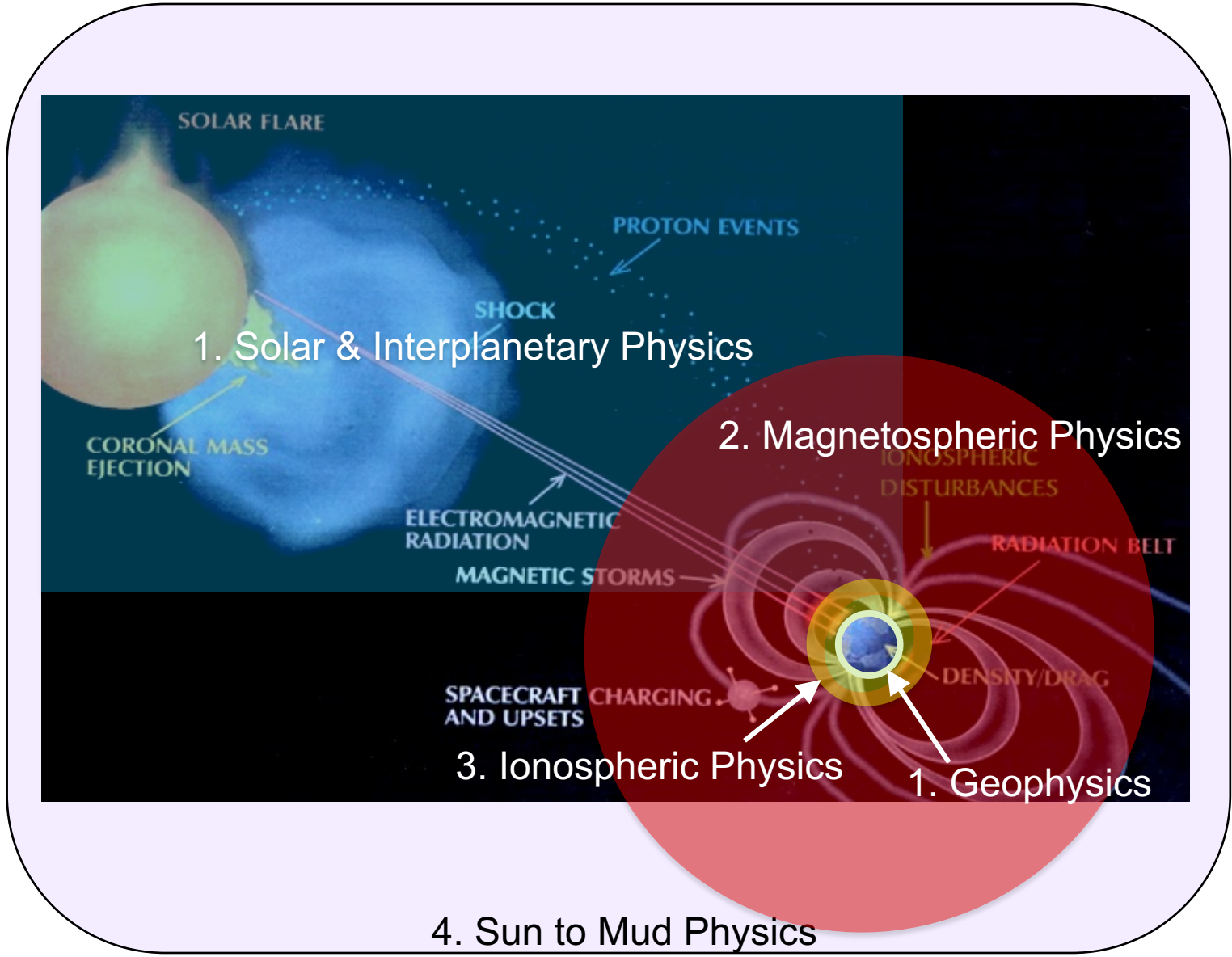
Session: Citizens and Scientists Tackling Space Weather Together
Operational Space Weather Fundamentals
L'Aquila, Italy
17 May 2024

# Introduction

My experience:

1. UCLA
2. Northrop Grumman and The Aerospace Corporation
3. The Aerospace Corporation and Social Media
4. Millersville University and Social Media

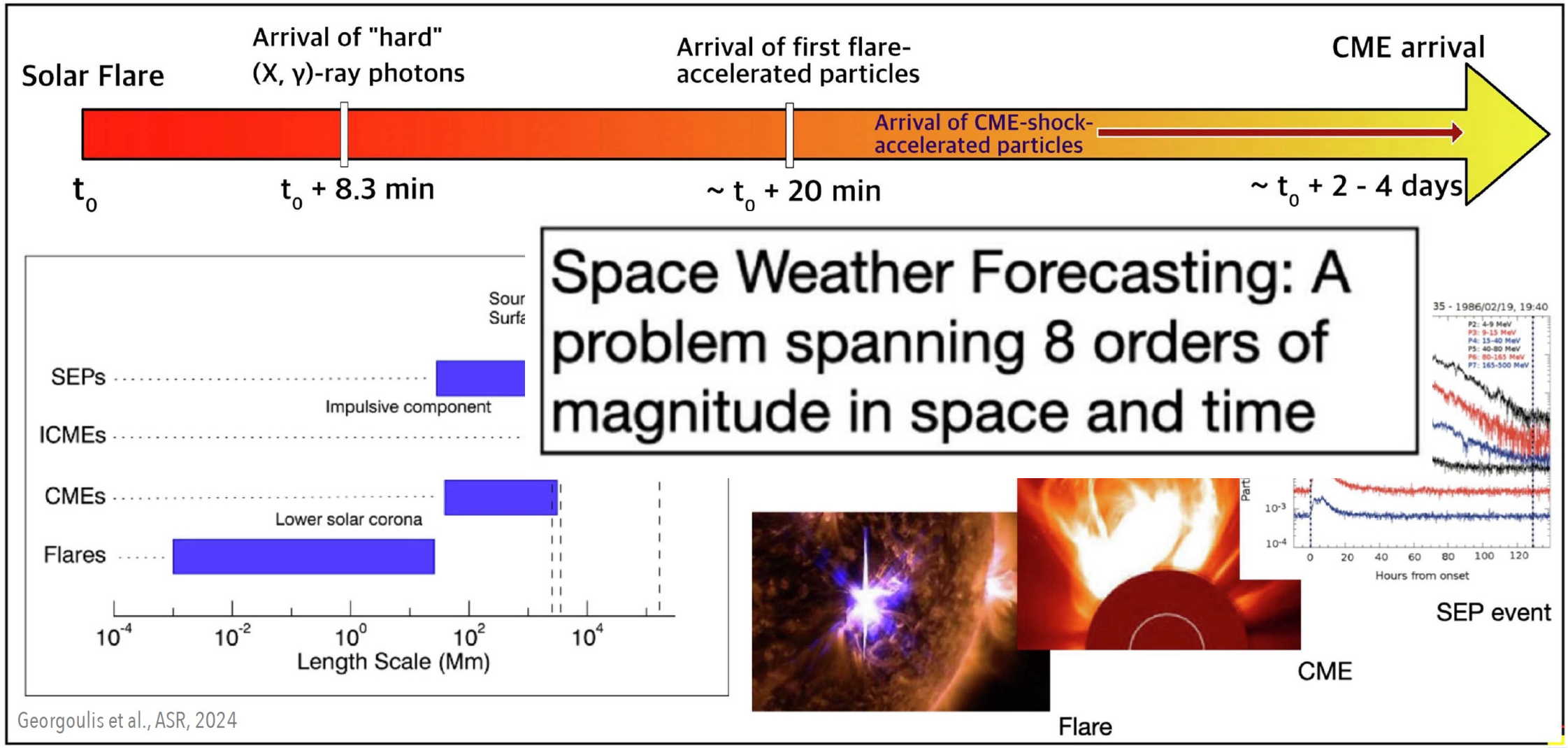
- That heliophysics disciplines are compartmented is common knowledge to experts
- However, many non-experts believe heliophysics is a single regime dominated by solar phenomena
- These conflicting perspectives lead to miscommunication when interacting with non-experts



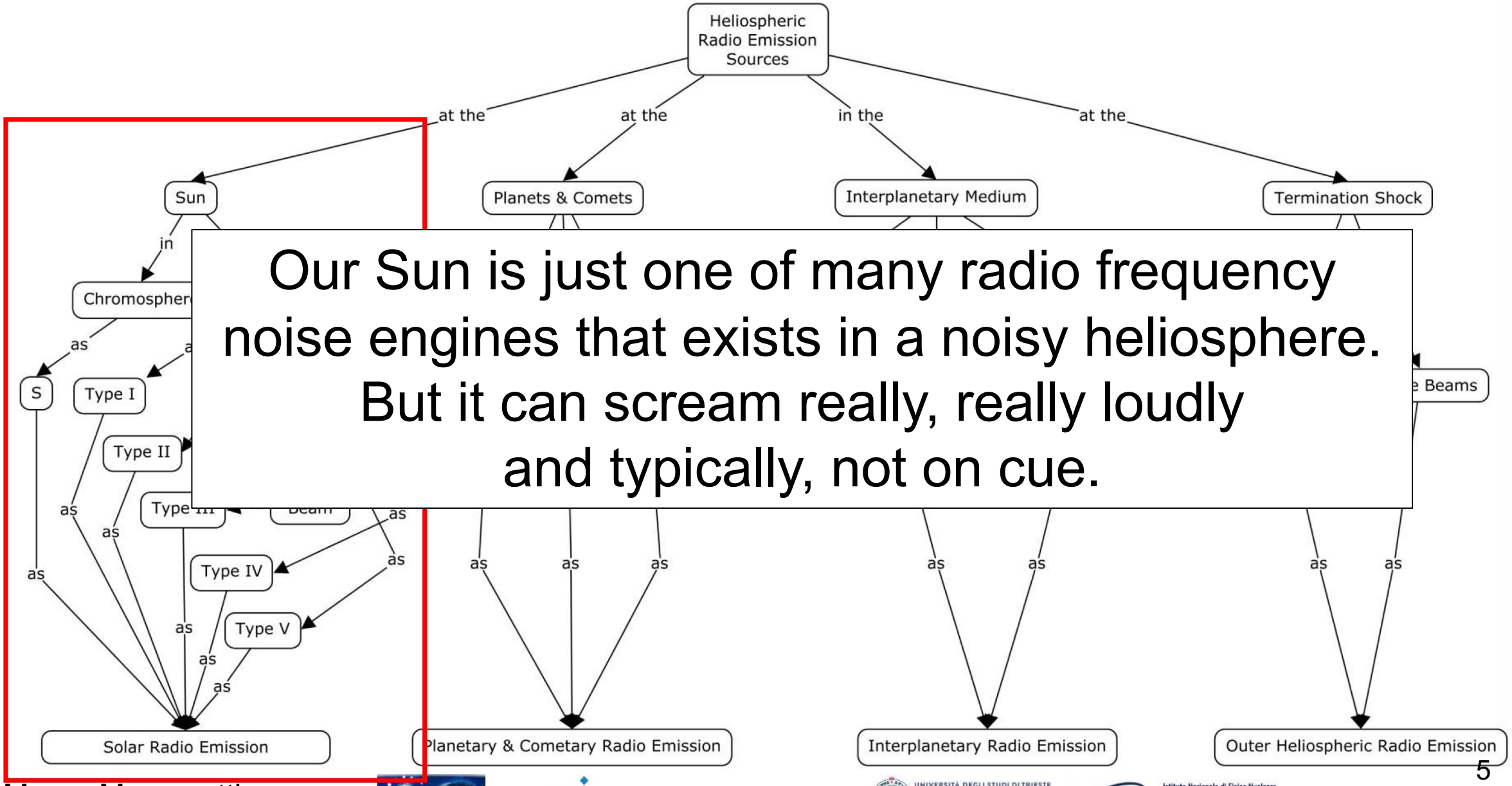
Subject matter experts (aka. “SMEs”) in operational space weather routinely interact with non-experts in daily forecast briefings, strategic planning, and even architecture design

*So let’s recall some of what you’ve learned as a reminder of the immensity of what you may be called upon to translate to the non-expert*

# Solar weather (the solar end of space weather) at a glance

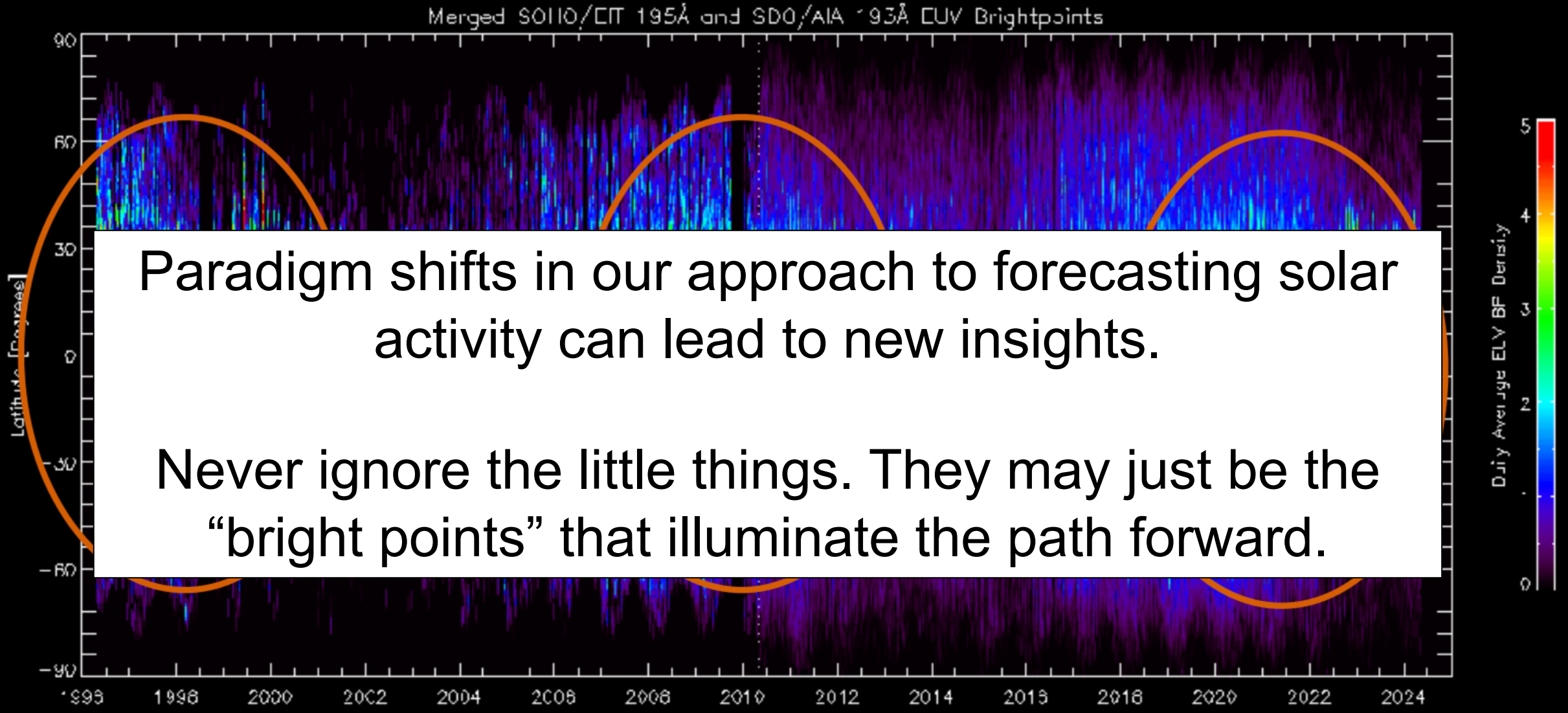


# Radio Emission Sources in Heliosphere




Our Sun is just one of many radio frequency noise engines that exists in a noisy heliosphere. But it can scream really, really loudly and typically, not on cue.

# The EUV BrightPoint Record




Paradigm shifts in our approach to forecasting solar activity can lead to new insights.

Never ignore the little things. They may just be the "bright points" that illuminate the path forward.

In late 2011 - after counting and cataloging 10s of millions of EUV BPs - we noticed a few things upon considering their 'butterfly' diagram:

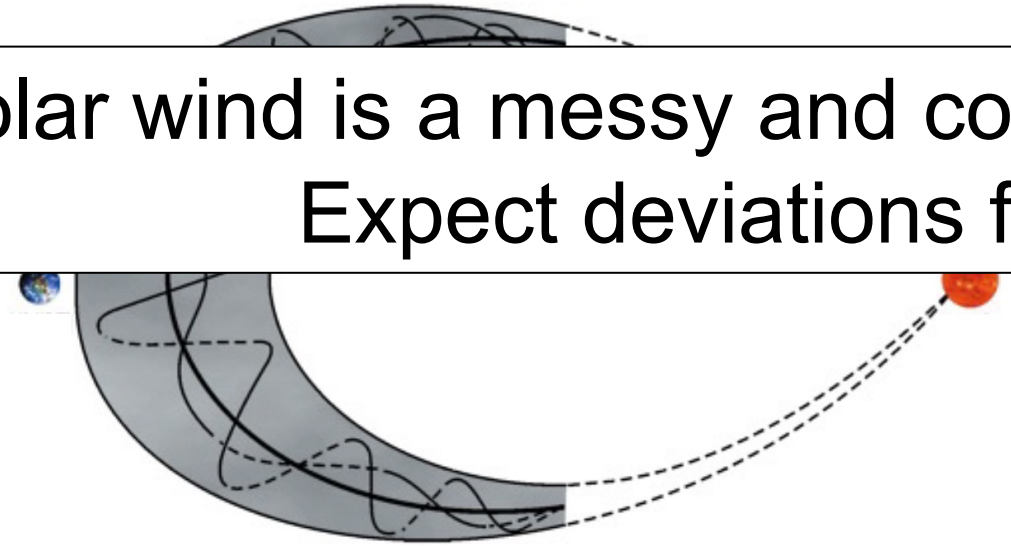
- At times there are **CLEARLY FOUR** 'bands' of EUV BPs.

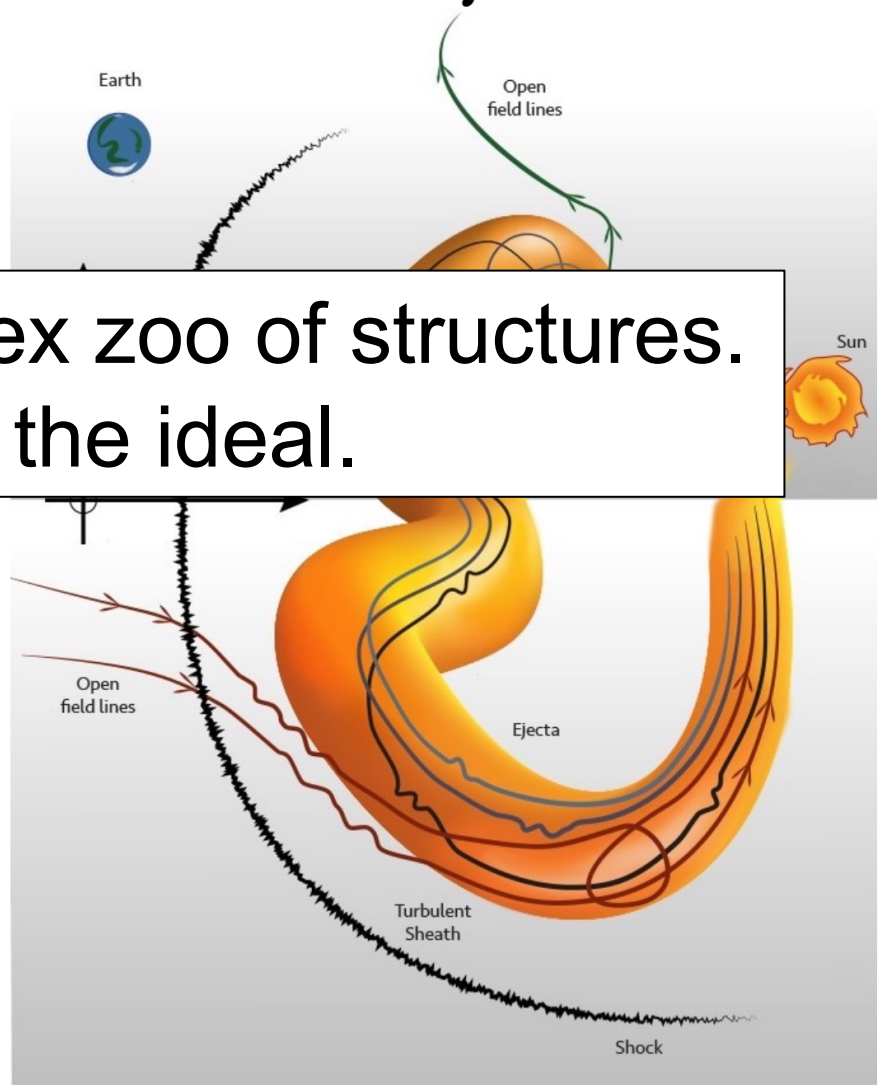
Scott McIntosh

# Complexities

Reality…

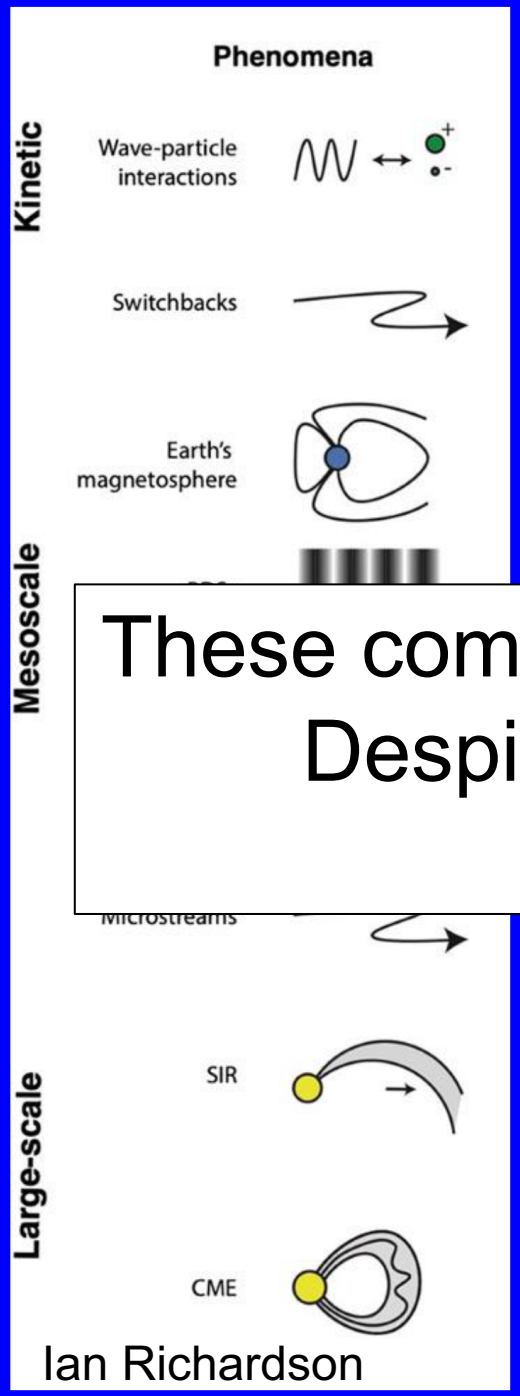
Expectation






Solar wind is a messy and complex zoo of structures.
Expect deviations from the ideal.

Courtesy: Nada Al-Haddad




Ian Richardson

# Summary of Solar Wind Structures (Viall et al., 2021)

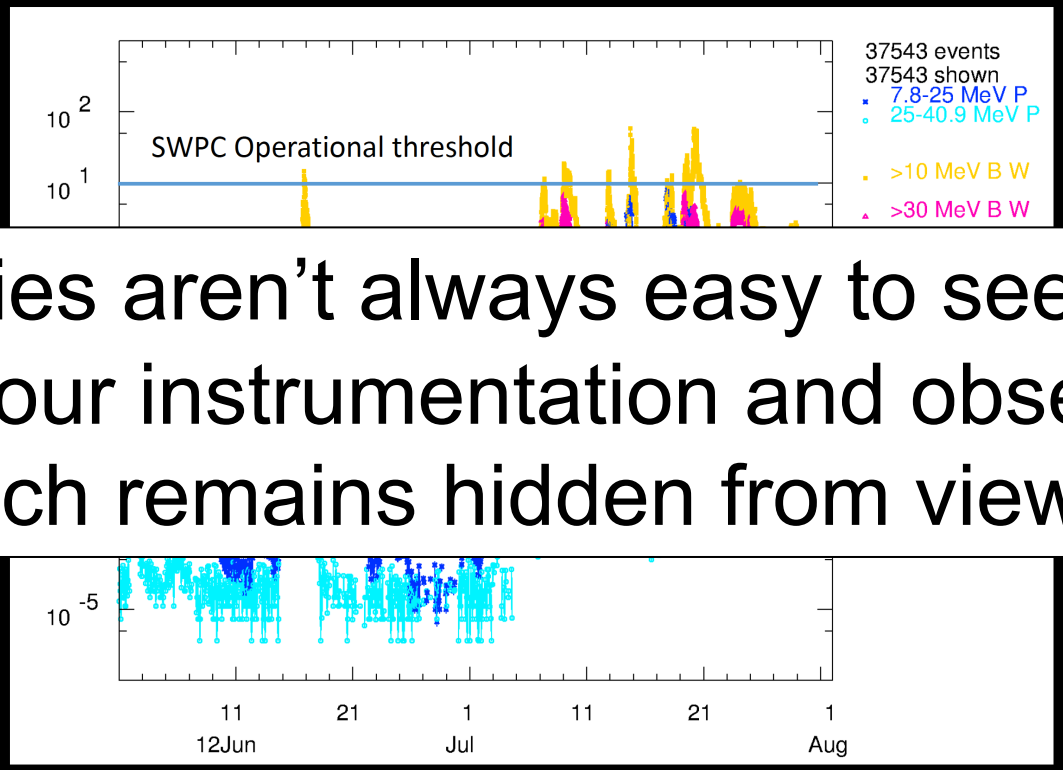
Summary:

The s… …rge scale …

Oper… …71

Solar …

N.B. GOES only sees the "tip of the SEP iceberg"!

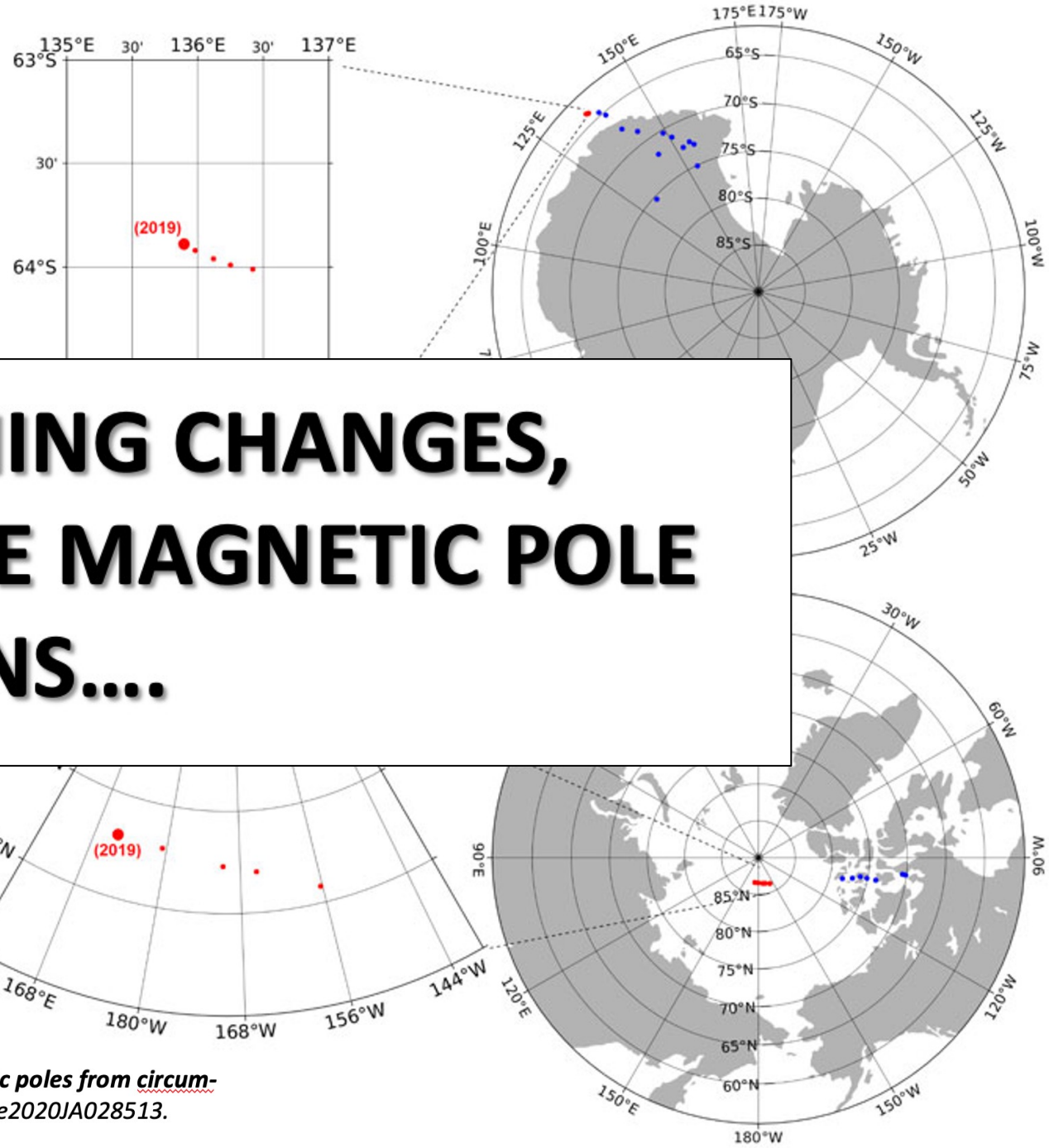



Comparison of GOES and SOHO/EPHIN shows the high …

These complexities aren't always easy to see or categorize. Despite all our instrumentation and observations, much remains hidden from view.

Incomplete understanding of the solar sources of solar wind, in particular, slow solar wind and mesoscale structures, and their link with in-situ observations. (Parker Solar Probe, Solar Orbiter, PUNCH)

**EVERYTHING CHANGES, EVEN THE MAGNETIC POLE POSITIONS….**




**EVERYTHING CHANGES, EVEN THE MAGNETIC POLE POSITIONS….**

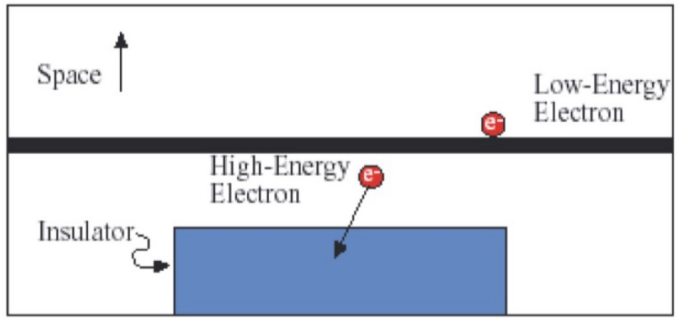
**The magn**
**northwest**
**speeds. While the**
**moves at a speed**
**72 km per year, t**
**at about 5-9 km**

Domenico Di Mauro and Stefania Lepidi

*Regi, M., Di Mauro, D., & Lepidi, S. (2021).* ***The location of the Earth's magnetic poles from circum-terrestrial observations.*** *Journal of Geophysical Research: Space Physics, 126, e2020JA028513.*

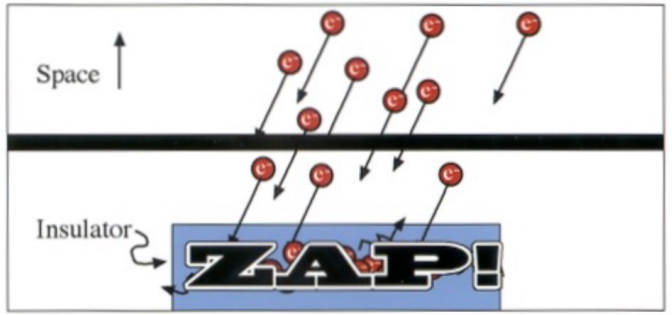
# Impact of High Energy Particles on Satellites

## High-energy electrons cause deep-dielectric charging




1. High-energy electrons can penetrate the satellite

[*Baker et al.,*




2. Discharge (electrical spark) that

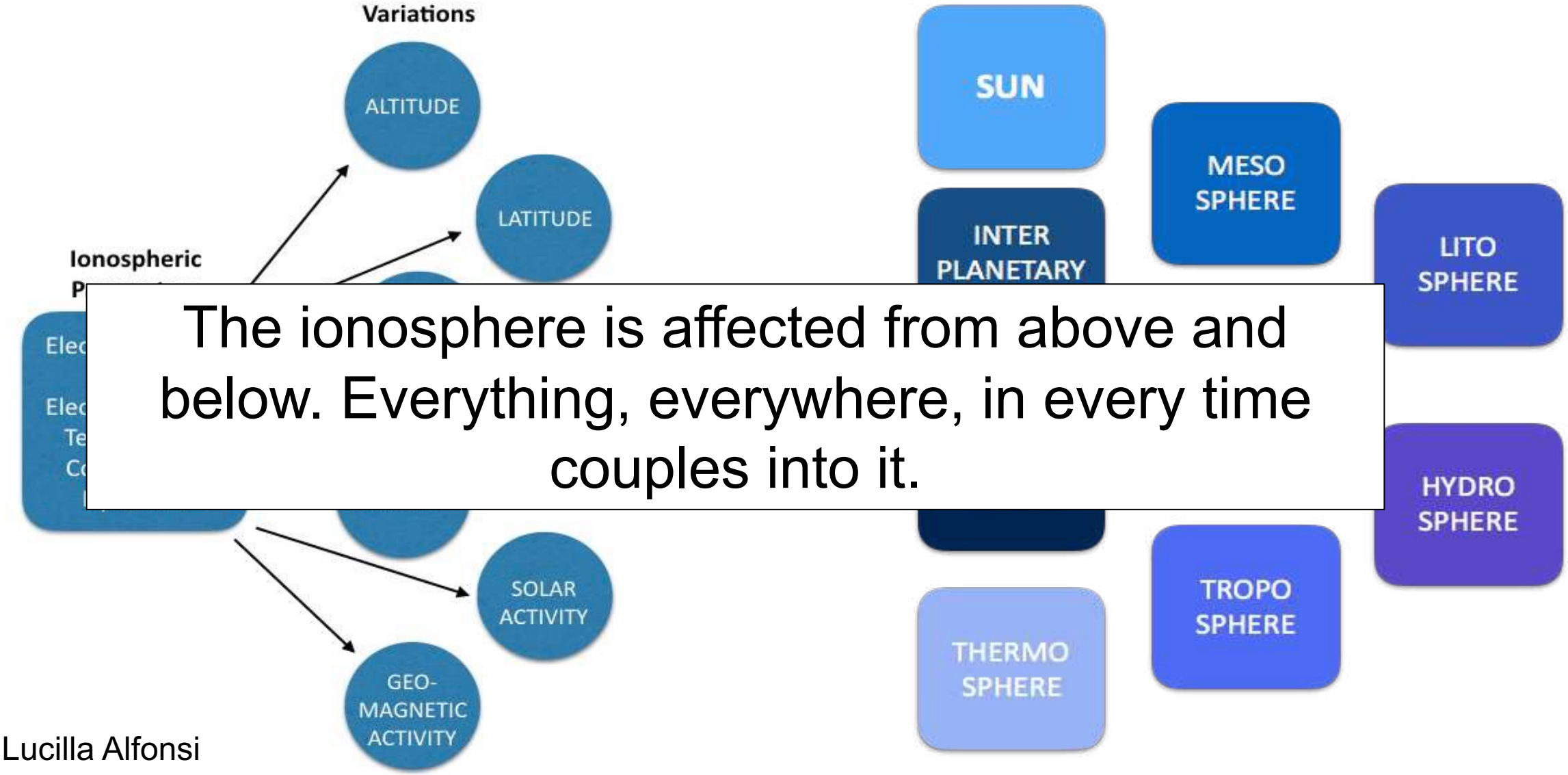

*Image Credit: L. J. Lanzerotti, Bell Laboratories, Lucent Terchnologies, Inc.*

**A backpack of energetic particles can ruin your entire day.**

- Over 1,000 active satellites; Supporting €125B/yr industry
- Satellite navigation essential for modern life

Avg. total satellite costs ~500 M€

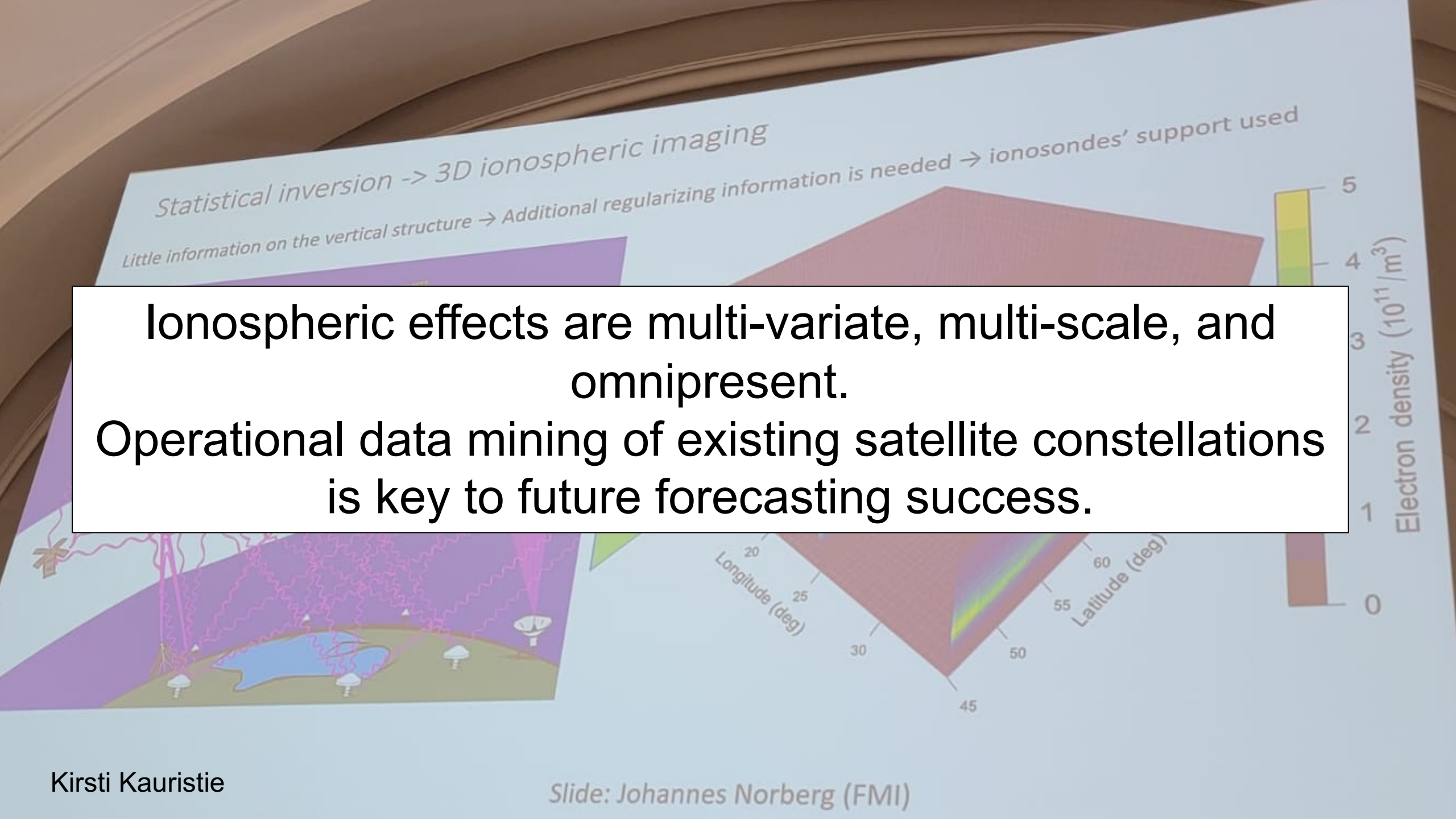
# Ionospheric variability




The ionosphere is affected from above and below. Everything, everywhere, in every time couples into it.

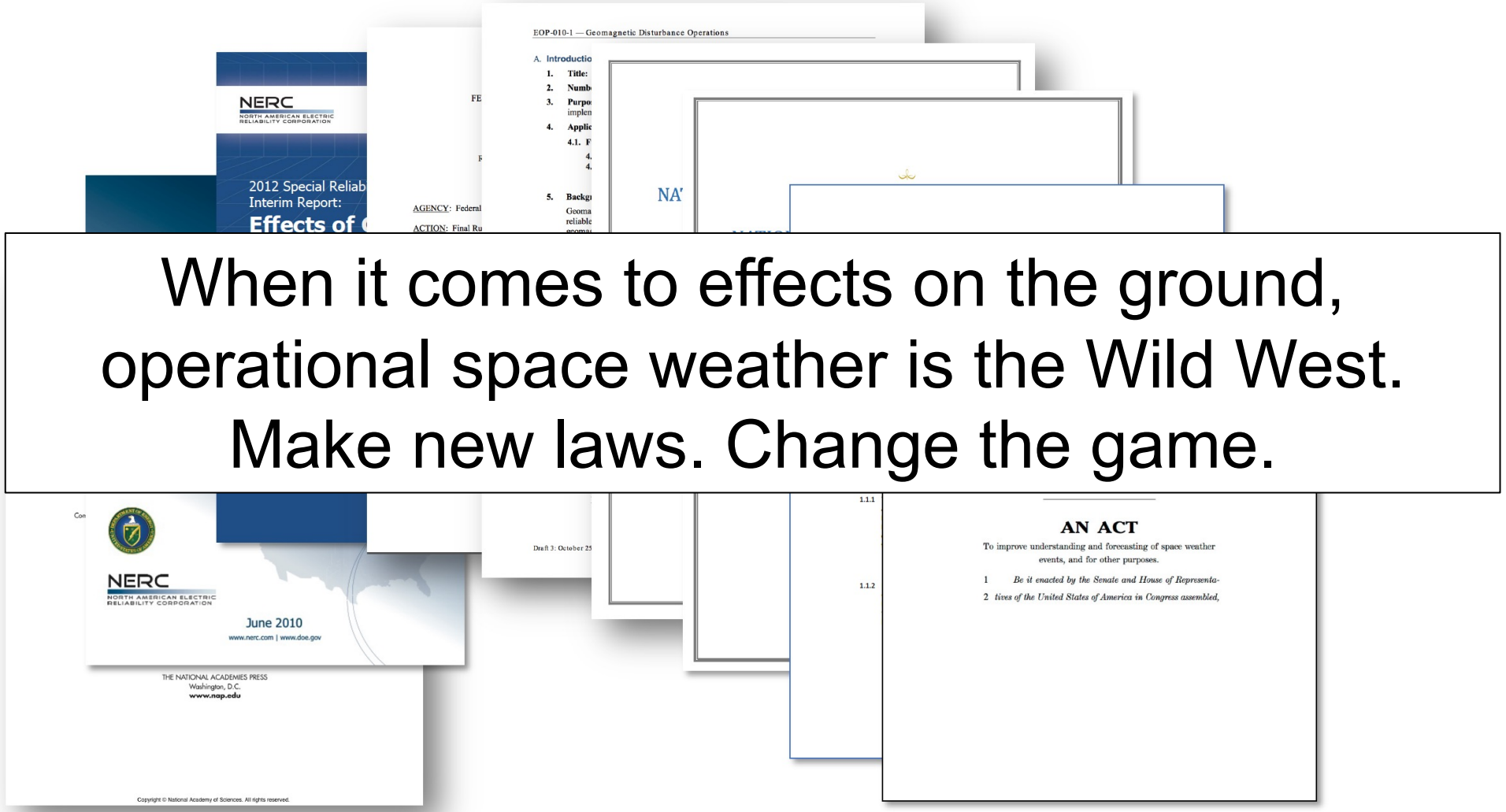
Lucilla Alfonsi

Inspired by the lesson from Prof. Mendillo (BU) @ International School of Space Science (ISSI), L'Aquila (Italy), Prof. Sandro Radicella




Ionospheric effects are multi-variate, multi-scale, and omnipresent.
Operational data mining of existing satellite constellations is key to future forecasting success.

# Brief history of the high-level US interest in GICs



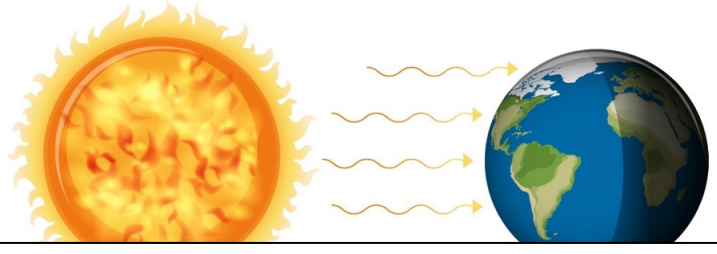

When it comes to effects on the ground, operational space weather is the Wild West. Make new laws. Change the game.

Anti Pulkkinen

Do not be lulled into thinking models can solve all our problems.
Modeling is no silver bullet.

ROYAL OBSERVATORY OF BELGIUM

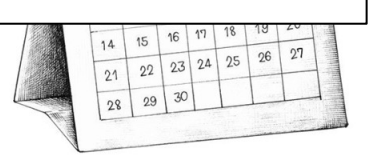
# What is needed for operational service provision?



- **Service definition**
- **Dat**
- **Op**
- **Pro**
- **Shi**
- **Supporting Personnel**
- **Robust IT infrastructure**

Just when it seems that everything is working according to plan,
inevitably there will be a power outage.

It's what you do during these times that matter most.
You improvise. You adapt. You overcome.



Yana Maneva

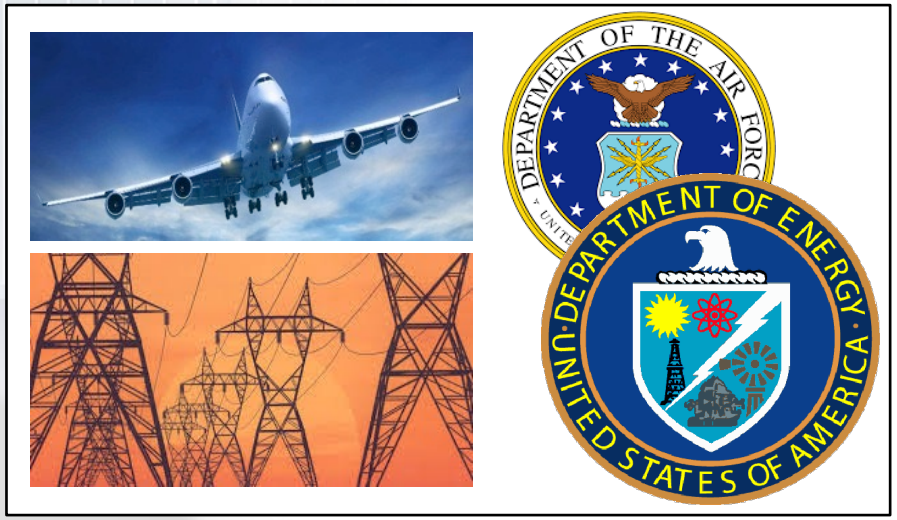
Now, let’s look at how perspectives in the non-expert world have changed over the years.

# Needs in Space Industry Sectors are Broadening










# Public Perception of Space Weather Then and Now

**Then, circa 2014 (Solar Cycle 24 Maximum):**

- Few people knew what space weather was, they thought you were joking
- NGT famously said, “When I think of Space Weather, I think of weather on other planets.”
- We had to invoke the Carrington-Class event in order to capture public attention

**Now, circa 2024 (approaching Solar Cycle 25 Maximum):**

- A large number of space environment forecasters, subject matter experts (SMEs), and stakeholders are active on social media
- Tens of thousands of local ”field reporters” including citizen scientists, engineers, and enthusiasts continually generate anecdotal reports of space weather impacts across sectors
- This paradigm shift is creating an atmosphere of accountability that presents new challenges for both academic & operational communities
- The public knows of space weather, but it is through a different kind of lens than we might expect

# Impacts of the Mobile Phone Camera Revolution

*Cell phone camera CCDs sensitive enough to capture low-light events including Aurora*

**Michele Esposito** @mikkelemikkele · May 11

#aurora from Sant'Oreste (RM)
#Auroraborealis

1 9 1.3K

**Ilkin Mammadli** @ilkinma

Northern Lights captured in t

#BabarAzam #solarstorm
#BreakingNews #Kızılcıkserl

#solarstorm

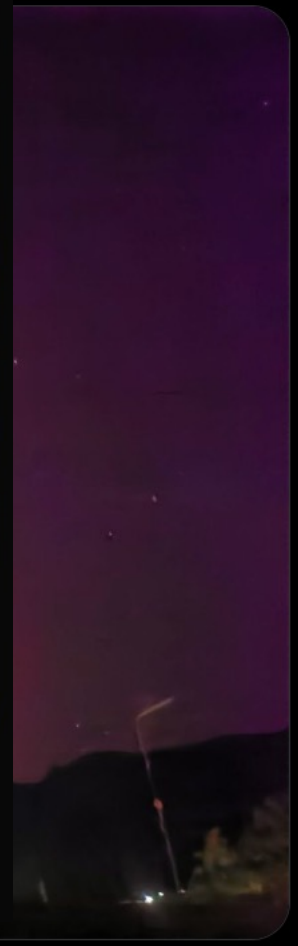
**Giuseppe Petricca** @gmrpetricca · May 11

From #Chieti, #Abruzzo, Central #Italy! (42.3°N)

#aurora #solarstorm #Italia #auroraboreale


You

2 17 1.8K



1 5 712

**tronautiCAST co-h** @RikyUnrea · May 11

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***The public knows of space weather, but thanks to pop-culture, the Carrington-Class event has taken on a new meaning***

# The Carrington-Class Event as Modern Space Weather

Pet names for a Carrington-Class Event Today:

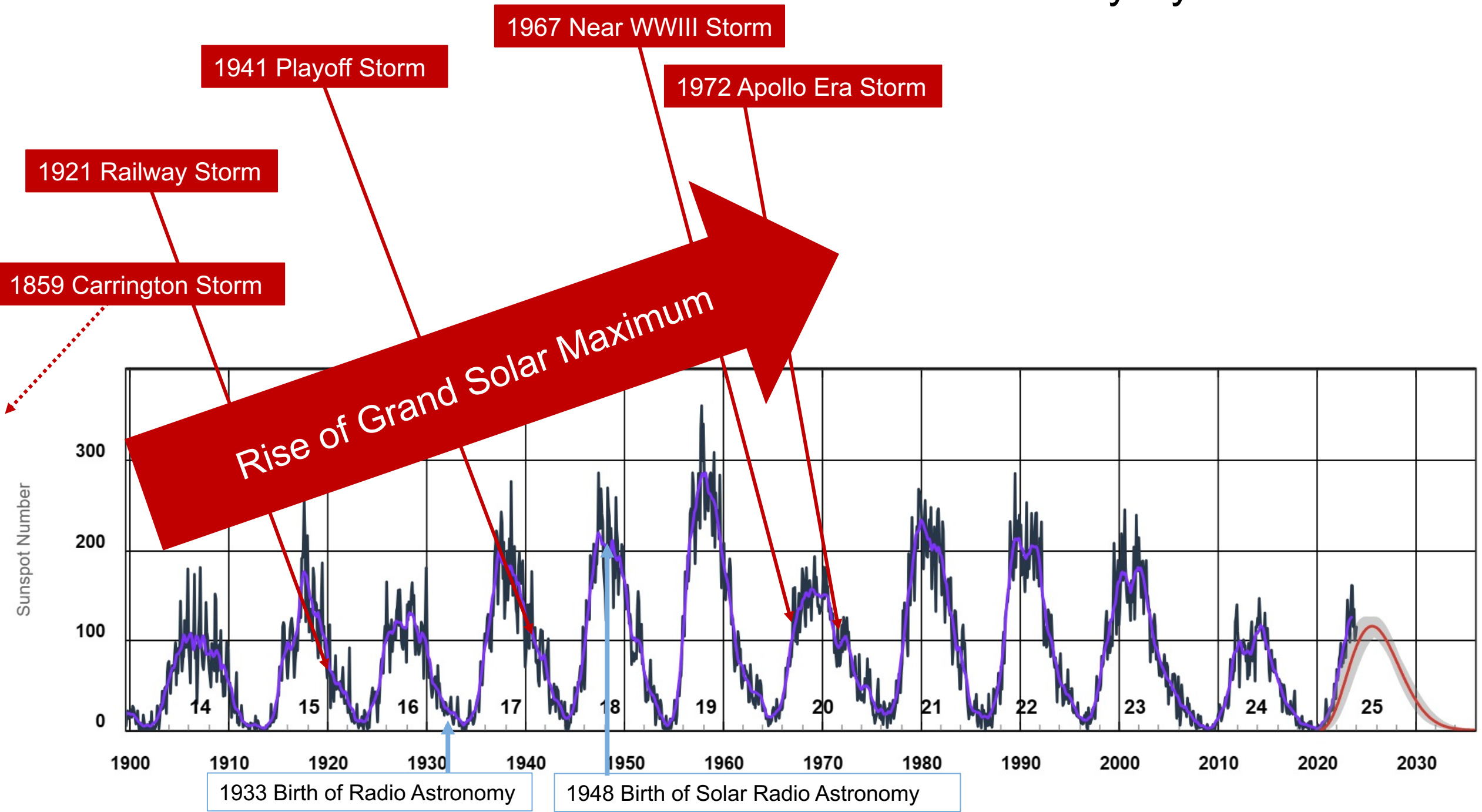
- Mega-Flare
- Kill-Shot
- Micro-Nova
- Power Grid Destroyer
- Armageddon from the Sun
- God's Wrath
- Black Swan

*Basically, it is any space weather event that spells doomsday for Earth's weakening magnetic field, all our technology, and ultimately all life on Earth*


***Solar Attack*** (also called ***Solar Strike***) is a 2006 television film by CineTel Films and Lions Gate Entertainment, starring Mark Dacascos, Joanne Kelly and Louis Gossett Jr.

*Solar Attack* concerns large coronal mass ejections (CMEs) that cause the Earth's atmosphere to burn, potentially suffocating all life on Earth. All of this happens during a time of political tension between the United States and Russia. Disaster is eventually averted by the detonation of nuclear missiles at the poles, releasing vapor that extinguishes the burning methane caused by the CMEs.[1]

# Timeline of Extreme Solar Storms over the Solar Activity Cycle since 1900



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1859 Carrington Storm

**1942**

**Mark 1**, First electromechanical computer, using mechanical devices, weighed 5 tons, it used about 750,000 parts

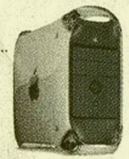
**1946**

**ENIAC**, First Electronic High-Speed, General-Purpose Computer Using Vol

UNI[illegible] first commercially marketed computer, used to tabulate the U.S. Census, occupied 943 cu. ft.

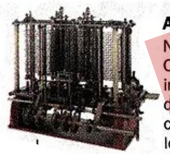
**Apple II**
At a price of $1,298, the compact machine was one of the first massively popular personal computers

**1992**
IBM introduces ThinkPad 700 the industry's first laptop with a thin film transistor display.



**Power Mac G4**
The first personal computer to deliver more than 1 billion floating-point operations per second

**Colossus**
The e[illegible]onic [illegible], with [illegible]00 vacuum tubes, helped the British crack German codes during WW II



**Analytical engine**
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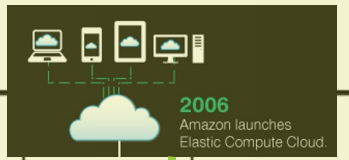
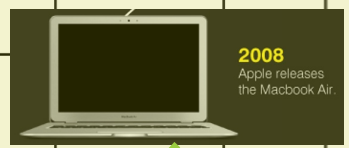
WiFi invented and released for the first time to consumers

1997



**2006**
Amazon launches Elastic Compute Cloud.



**2008**
Apple releases the Macbook Air

Rise of Grand Solar Maximum

Sunspot Number

200

100

0

14 15 16 17 18 19 20 21 22 23 24 25

1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020 2030

1933 Birth of Radio Astronomy

1948 Birth of Solar Radio Astronomy

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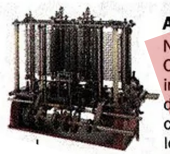

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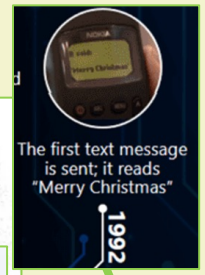
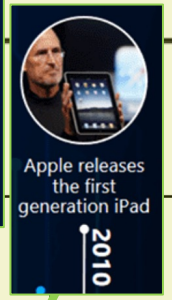
**Mobira Senator**
Finnish company Mobira Oy, a precursor to Nokia, introduced its first car phone, the Mobira Senator NMT-450. It weighed about 22 pounds.

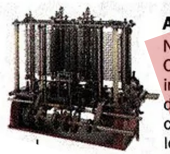



**2002**
**BlackBerry 5810**
Made by Research In Motion, the 5810 was a cellphone with organizer functions and a keyboard for thumbs; a wired headset was mandatory.

**2007**
**Apple iPhone**
Hundreds of people lined up outside Apple stores to buy the first iPhone, priced at $499 (4GB) and $599 (8GB).





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**2020**
Zoom surpasses 300 million daily online meeting participants

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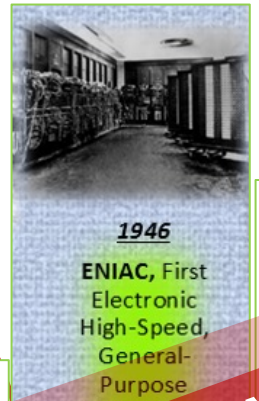

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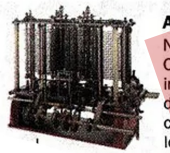

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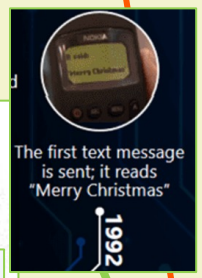

The first text message is sent; it reads "Merry Christmas"

1992

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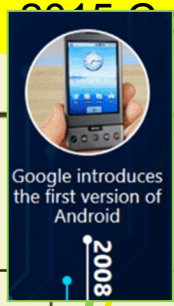
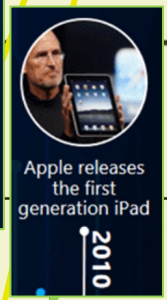


Google introduces the first version of Android

2008



Apple releases the first generation iPad

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2017

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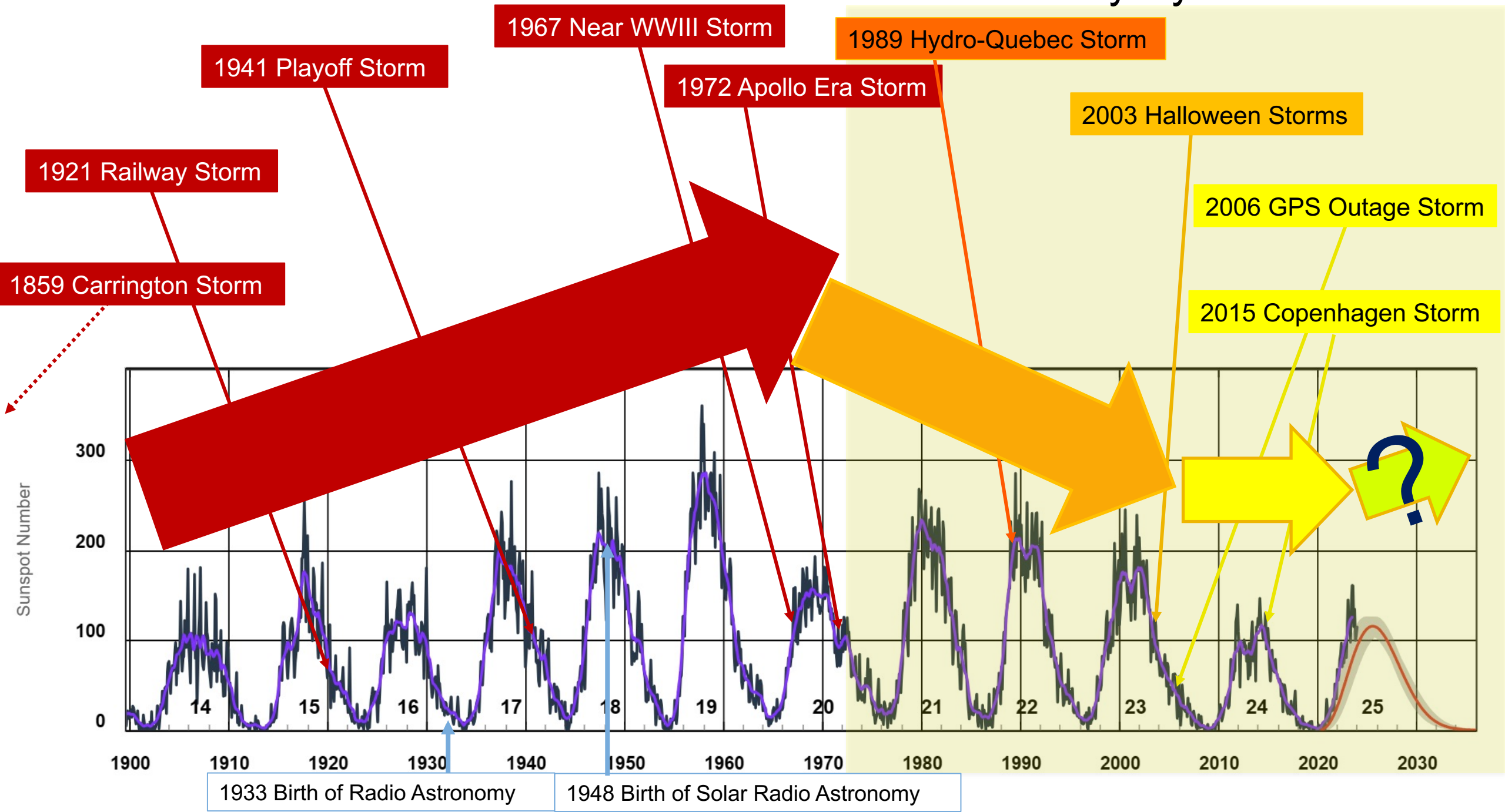

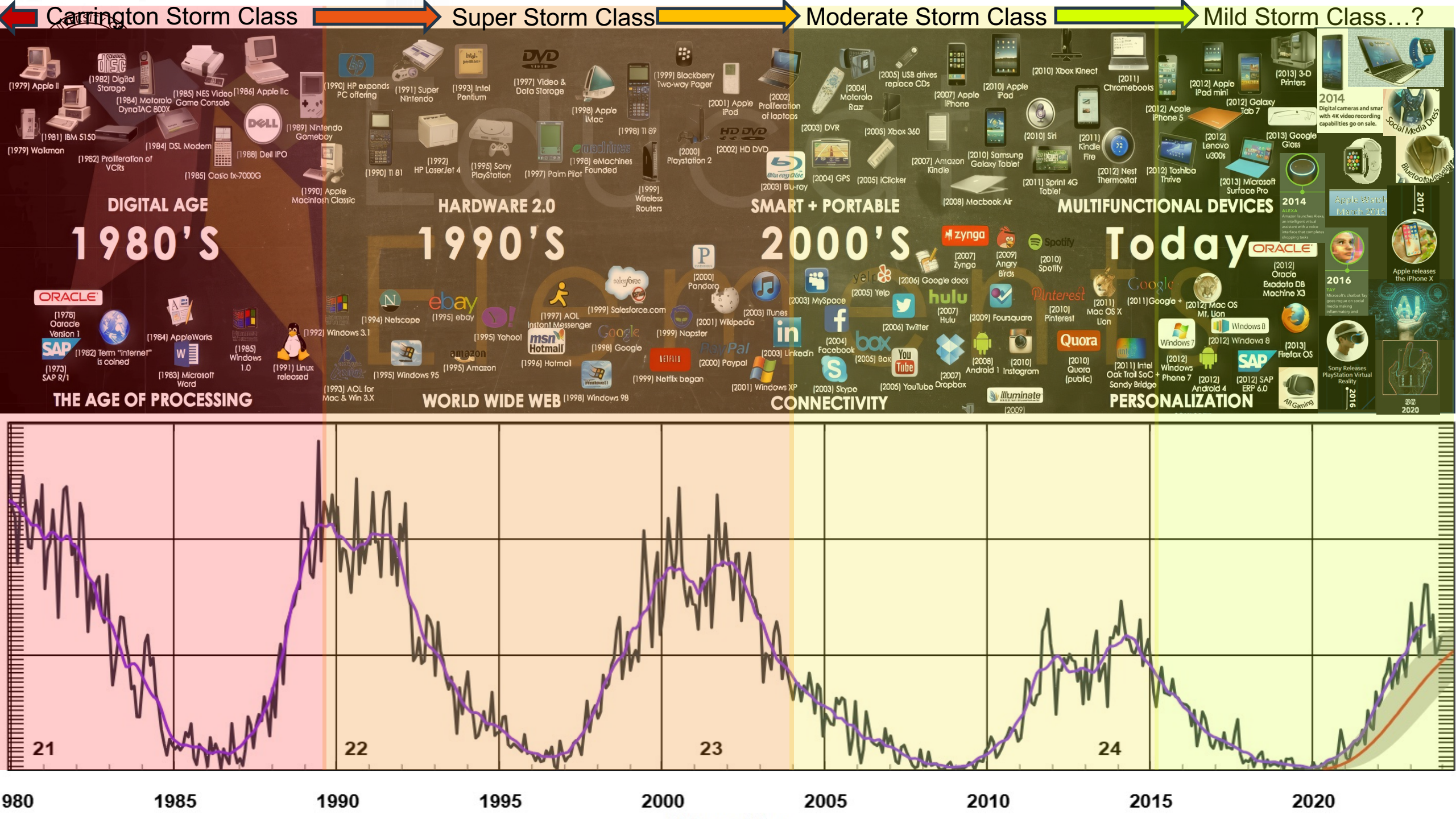
Carrington Storm Class
Super Storm Class
Moderate Storm Class
Mild Storm Class…?
DIGITAL AGE
1980'S
THE AGE OF PROCESSING
HARDWARE 2.0
1990'S
WORLD WIDE WEB
SMART + PORTABLE
2000'S
CONNECTIVITY
MULTIFUNCTIONAL DEVICES
Today
PERSONALIZATION
21
22
23
24
980
1985
1990
1995
2000
2005
2010
2015
2020

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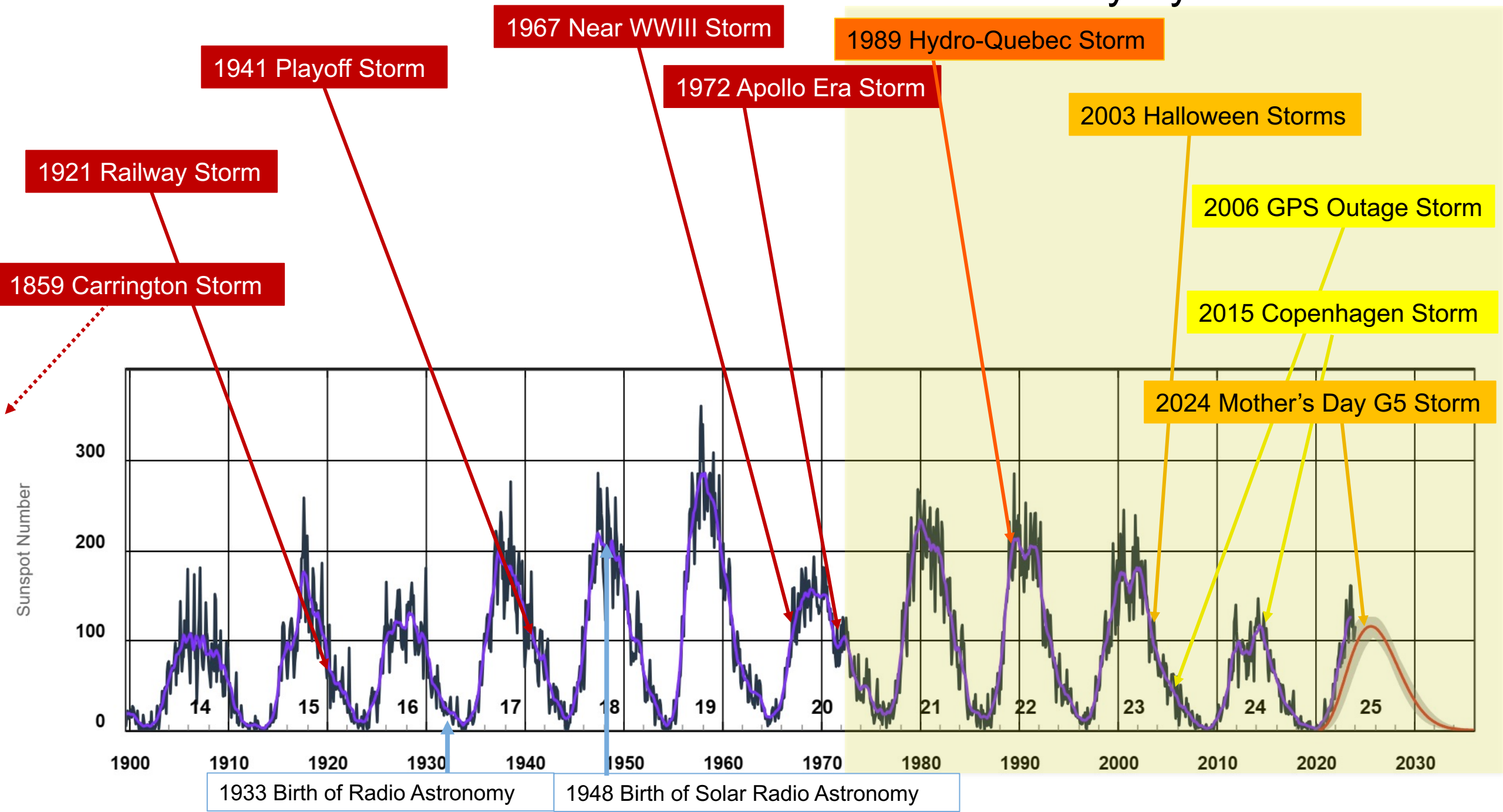


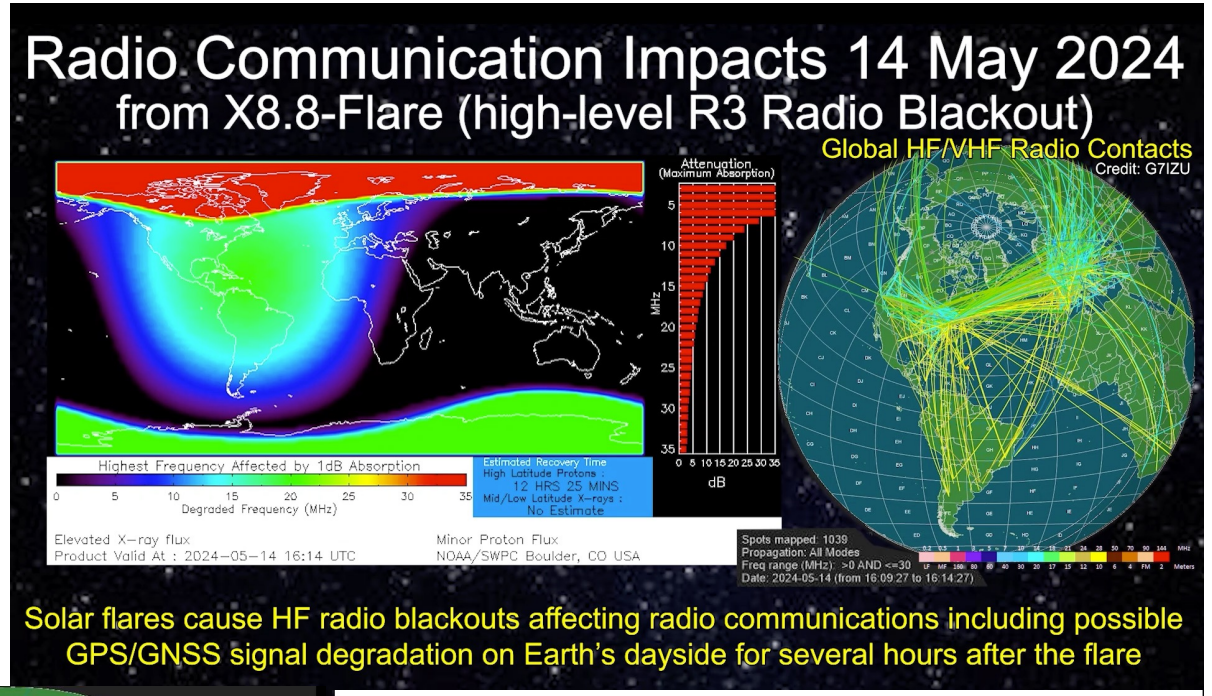
# Impacts of Region 3644 & Mother's Day Geomagnetic Storm 10 May 2024

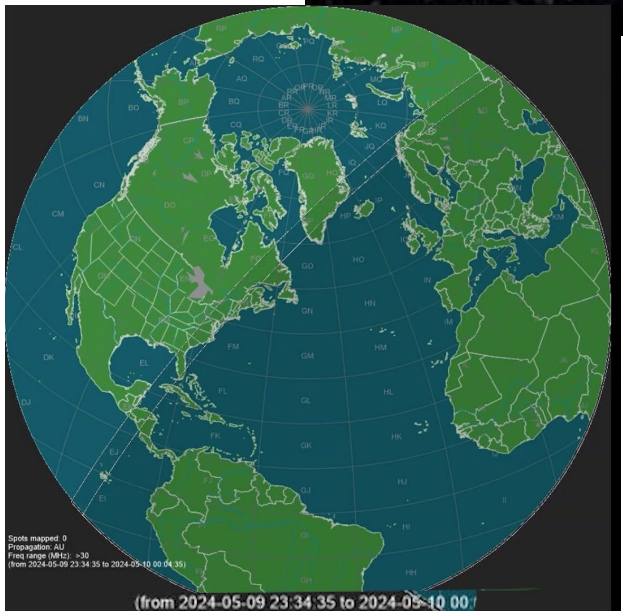
## Evolution of Region 3644

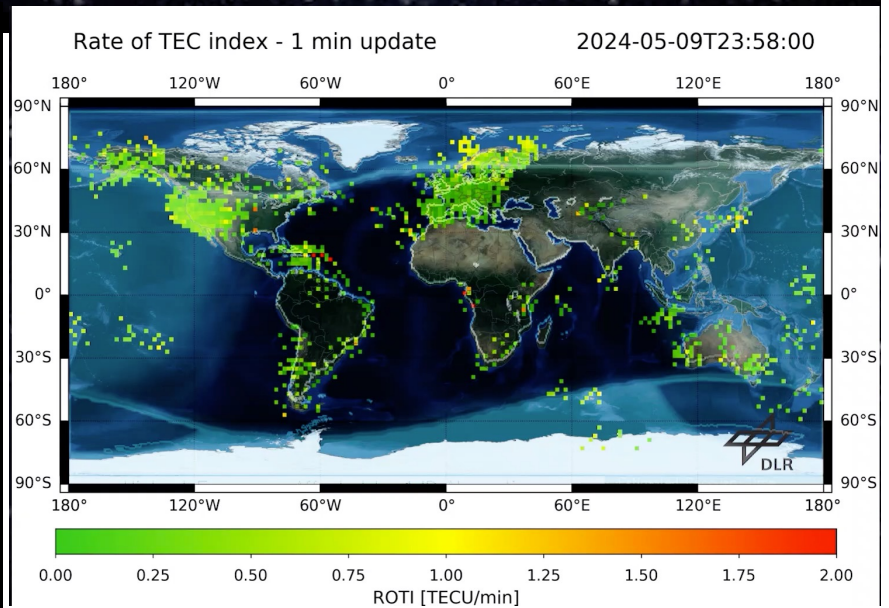
- 10 X-flares
  - *including the largest of this cycle)*
- 1 G5-storm
  - *largest since 2005)*

IMPACTS

- HF/VHF Radio Blackouts
- Aviation
- GPS Scintillation Risk
  - *Evolution of ROTI*
- Precision Farming
- Starlink
- Auroral Scatter



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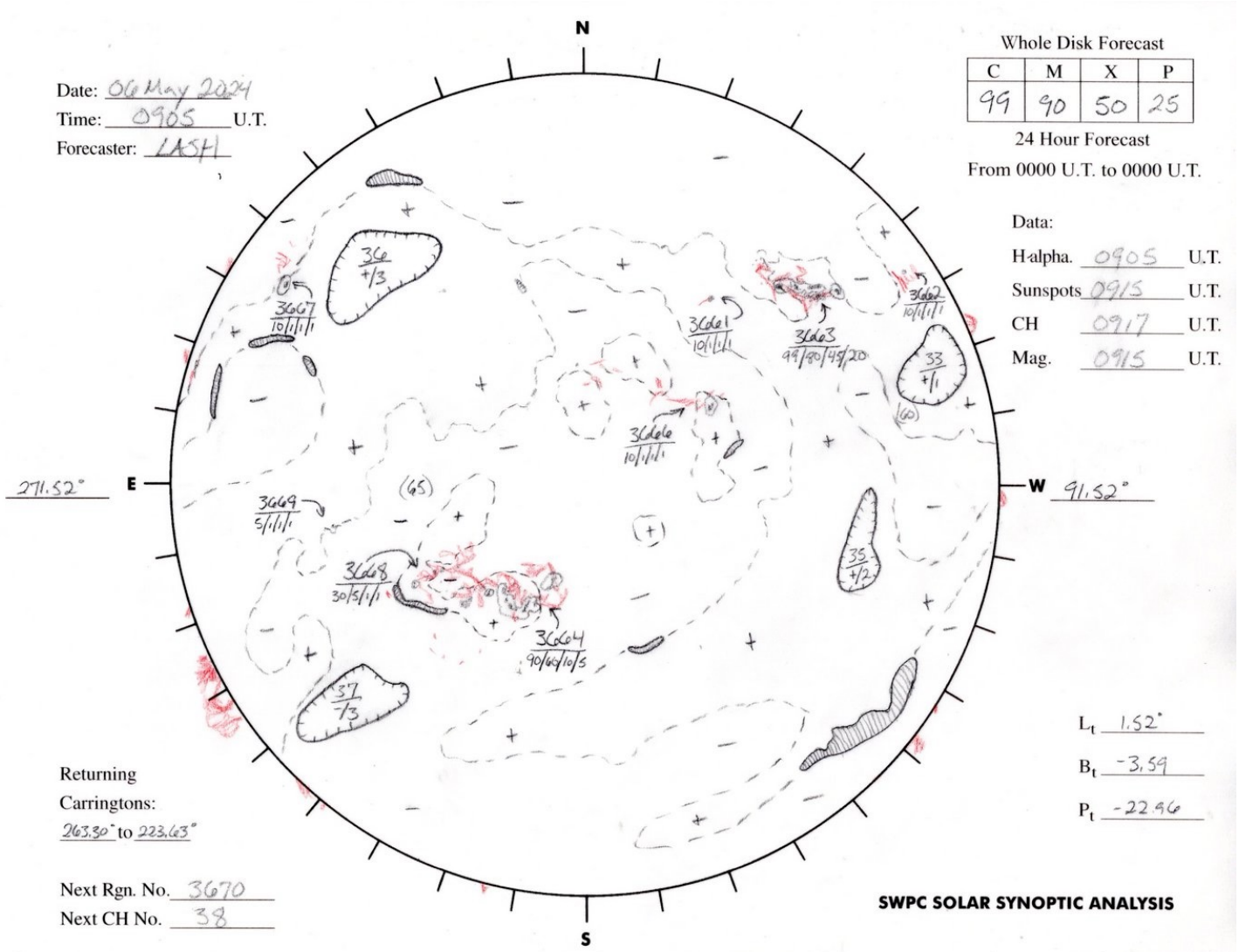
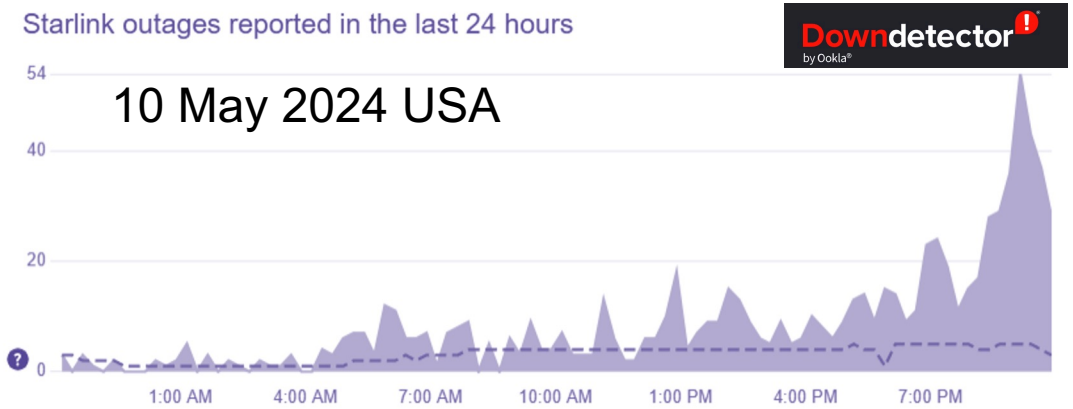
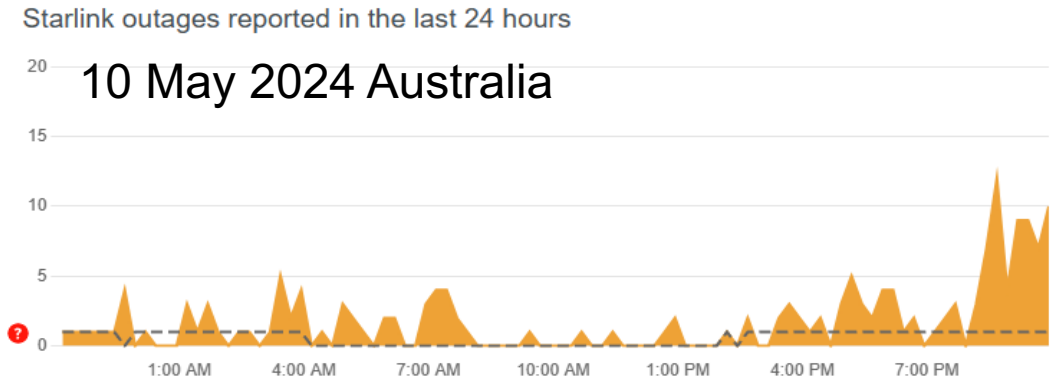
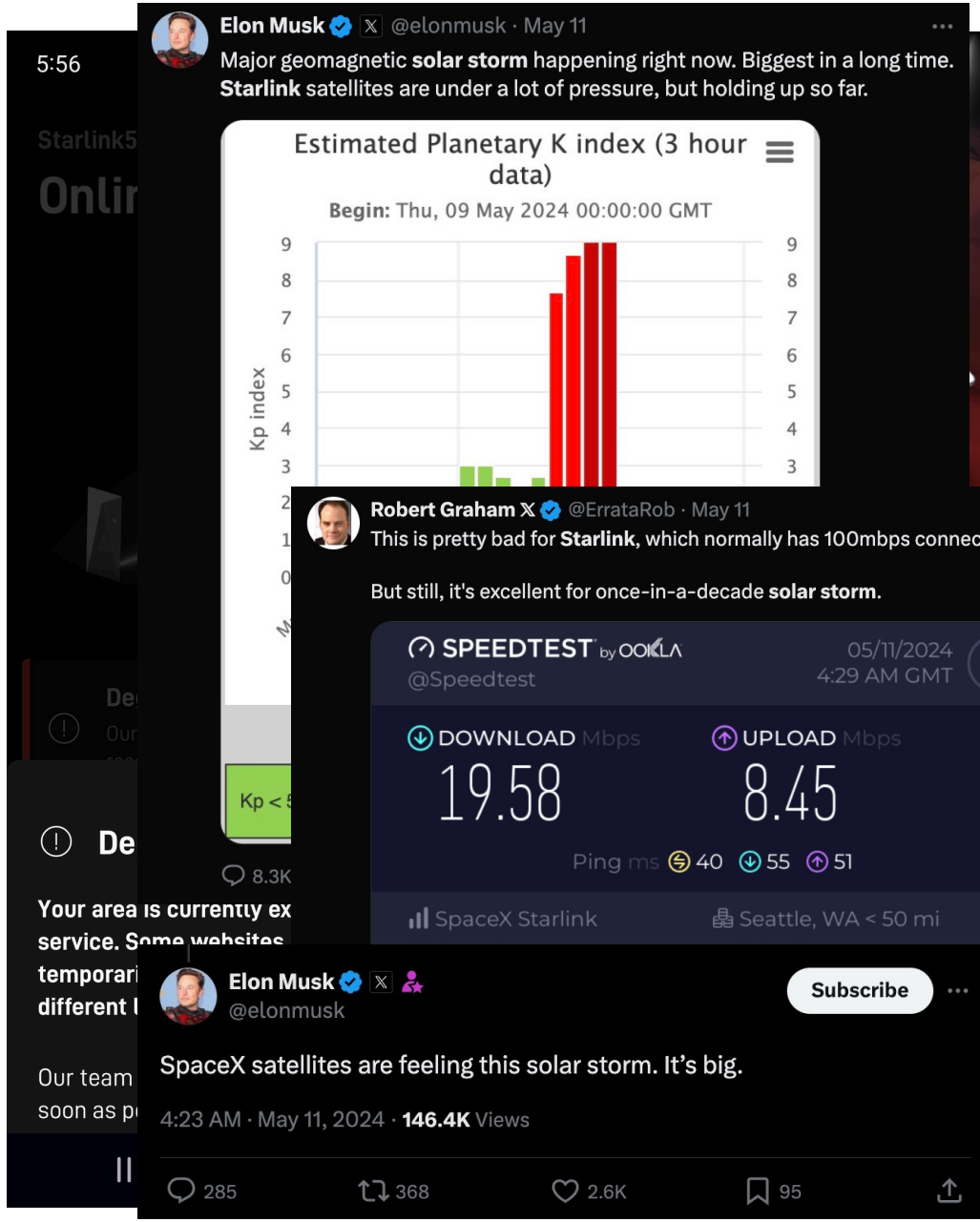


# Starlink “Degraded Service” During 10- 12 May 2024







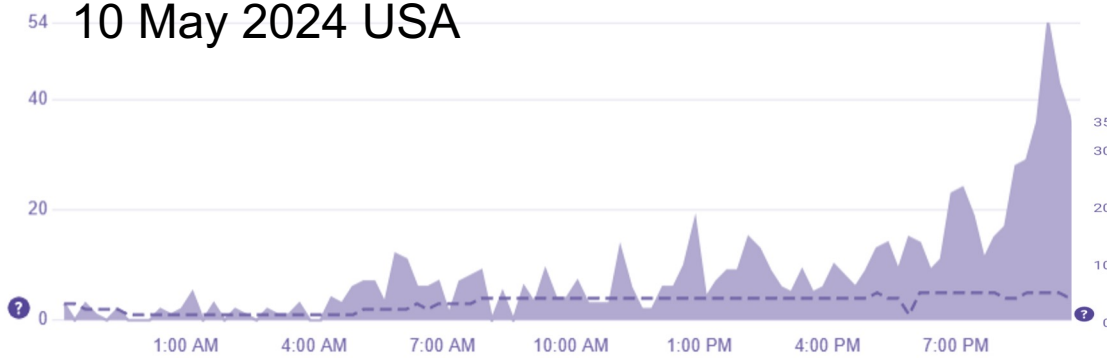



# Starlink “Degraded Service” During 10- 12 May 2024

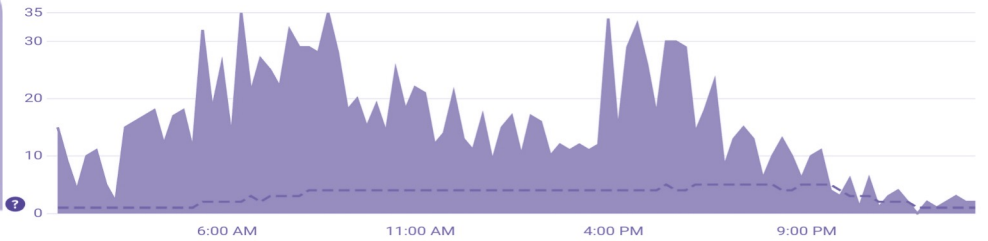
Downdetector by Ookla®

Starlink outages reported in the last 24 hours

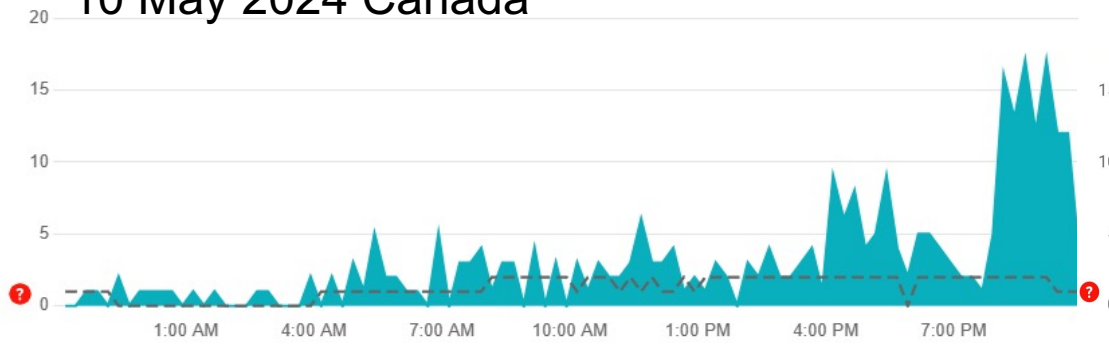
## 10 May 2024 USA



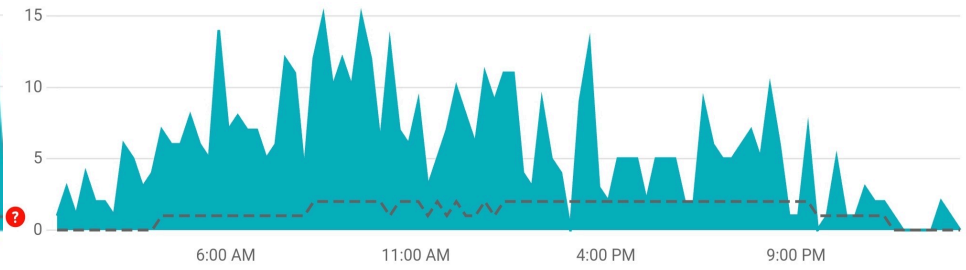

## 12 May 2024 USA




## 10 May 2024 Canada




## 12 May 2024 Canada

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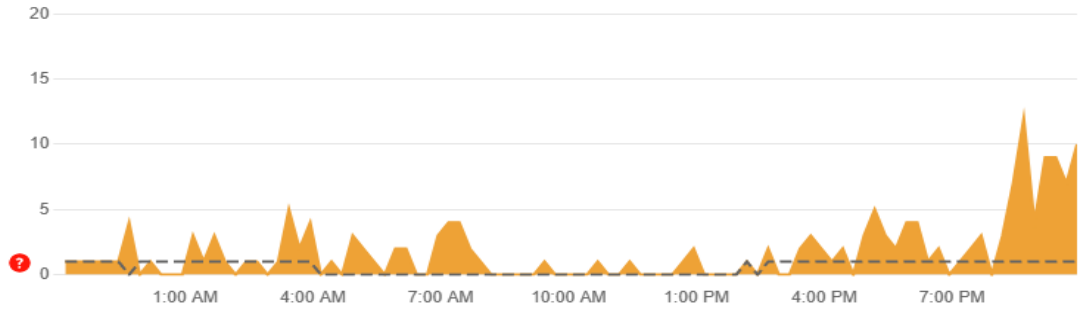


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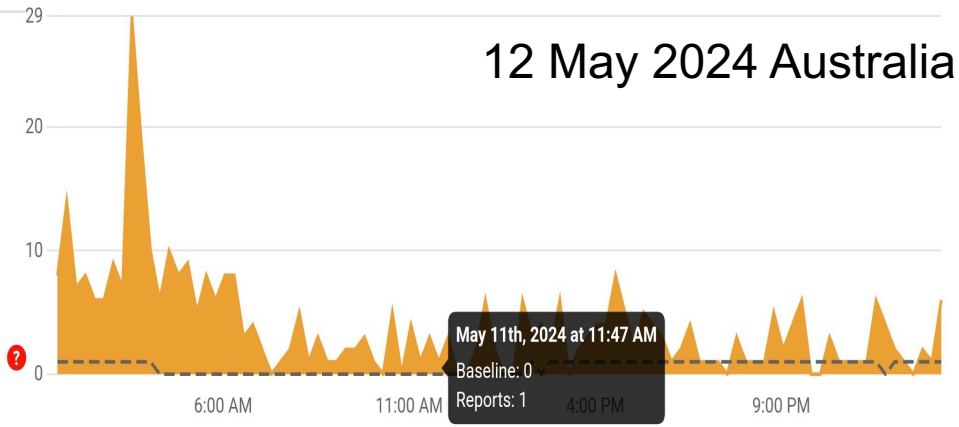

# Mother's Day G5 Storm Dramatically Affects Precision Farming

JOHN DEERE | LANDMARK IMPLEMENT

## Geomagnetic Storm Aff
## Signals - May 2024

**Friday, May 10 - 5:00pm Update:**

We are seeing GPS issues across our e
other levels of GPS. We are currently t

*posted on Saturday, May 11, 2024 in News/Blog*

**Saturday, May 11 - 9:00am Update:**

Yesterday, we sent out a text message advising customers to turn off their RTK and use a grace period of SF2 or SF3. We believe that the SF2 and SF3 accuracy is also extremely compromised as well due to this storm. Due to the way the RTK network works, the base stations were sending out corrections that have been affected by the geomagnetic storm and were causing drastic shifts in the field and even some heading changes that were drastic. Because SF2 and SF3 do not receive all of these corrections, those signals weren't affected as much, but we do suspect that the

When you head back into these fields to side dress, spray, cultivate, harvest, etc. over the next several months, we expect that the rows won't be where the AutoPath lines think they are. This will only affect the fields that are planted during times of reduced accuracy. It is most likely going to be difficult - if not impossible - to make AutoPath work in these fields as the inaccuracy is most likely inconsistent.

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machine is receiving from the base station due to the geomagnetic storm. GPS accuracy will still likely be reduced due to the storms.

We apologize for the inconvenience.

https://landmarkimp.com/news/news/blog/geomagnetic-storm-affecting-gps-signals--may-2024/

# Mother's Day G5 Storm Dramatically Affects Precision Farming

Then, after veering far off course, the tractor made a sudden left turn and tried to loop around in a complete circle, to Nemec's chagrin.

Hues of pink and green lit up night skies as far south as Arkansas this weekend as the earth experienced its largest geomagnetic storms in nearly 20 years. But farmers, who were racing to get crops seeded in decent weather with enough time to meet crop insurance deadlines, were less dazzled by the storms' other impacts as they scrambled to adjust to the messy GPS problems that hampered use of their high-tech machinery.

"It is a really tough time of year for this to be going on," said Lovas, who works for GK Technology in Halstad, Minnesota.

Farmers across the nation may have been disrupted. Roughly 12% of U.S. farms were recorded as using GPS applications in 2019, though the technology was used on roughly 40% of U.S. farm acreage, according to the USDA Economic Research Service. It has fairly wide acceptance in the Corn Belt with GPS use spanning "well over half" of the region's agricultural acreage.

https://www.agri-pulse.com/articles/21096-solar-storms-throw-off-farmers-gps-systems-in-the-heat-of-planting

# Mother's Day G5 Storm Dramatically Affects Precision Farming

AGRICULTUREDIVE Deep Dive Events Press Releases

Crops Meat Dairy

## Geomagnetic storm s navigation systems

The massive solar storm that splashed the nort farming operations at the peak of planting seas

Published May 15, 2024

By S.L. Fuller and Sarah Zimmerman

The northern lights fill the sky with green ribbons of electrical charged particles over the barn and pastures at Greaney's Turkey Farm in Mercer, Maine on May 11, 2024. *Michael Seamans via Getty Images*

AGRICULTUREDIVE Deep Dive Events Press Releases Topics

While the solar storm is considered a one-off event, it raises questions about the future reliability and security of agriculture technology as farmers increasingly adopt digital solutions, according to Curt Covington, senior director of institution credit at AgAmerica Lending. The event could also deter some farmers from adopting technology down the line.

"If anything came from this, it's the importance of being proactive in protecting our food system and having a response plan in place to avoid large-scale disruption," Covington said in an email to Agriculture Dive.

*Editor's note: This story has been updated to include comments from AgAmerica Lending.*

https://www.engadget.com/the-geomagnetic-storm-is-a-nightmare-for-farmers-relying-on-precision-agriculture-tech-180252016.html

# EHang Expands to Shenzhen Luohu District for Innovative Model with Pilotless Passenger-Carrying eVTOL and Cultural Tourism

January 26, 2024 By : EHang

# EHang Successfully Obtains Type Certificate for EH216-S Passenger-Carrying UAV System Issued by Civil Aviation Administration of China

## EHang's Certified EH216-S Pilotless Passenger-Carrying Aerial Vehicles Debut Commercial Flight Demonstrations in Guangzhou and Hefei

December 28, 2023 By : EHang

The certified EH216-S pilotless passenger-carrying aerial vehicles have successfully completed debut commercial flight demonstrations in Guangzhou and Hefei respectively. Read More>>



EHang has forged a strategic partnership with the Bureau of Culture, Radio, Television, Tourism, and Sports of Luohu District, Shenzhen. Read More>>

# Lessons Learned from Terrestrial Meteorologists

Harry Volkman: First Broadcast Meteorologist


John Morales: Meteorologist for FEMA Region 4


**Then, Circa 1960:**

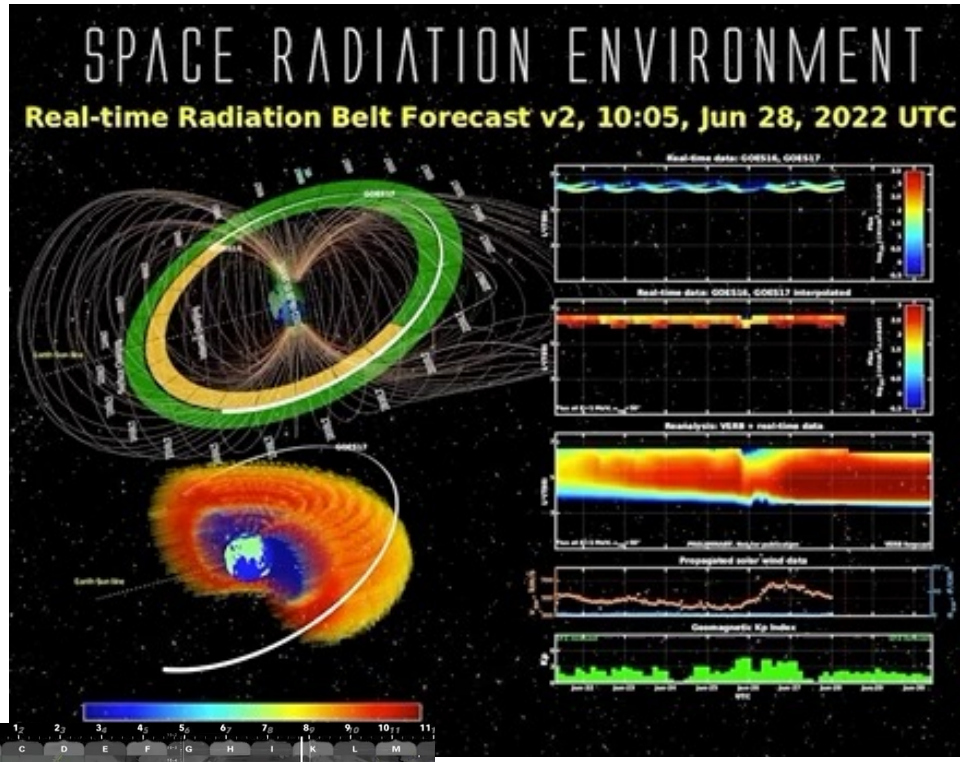
- Terrestrial weather had similar origins and growing pains communicating to the general public
- Meteorologist Harry Volkman was the first to transition military weather forecasts into the public domain
- He demonstrated effective communication was key to informing non-experts without eliciting fear and panic

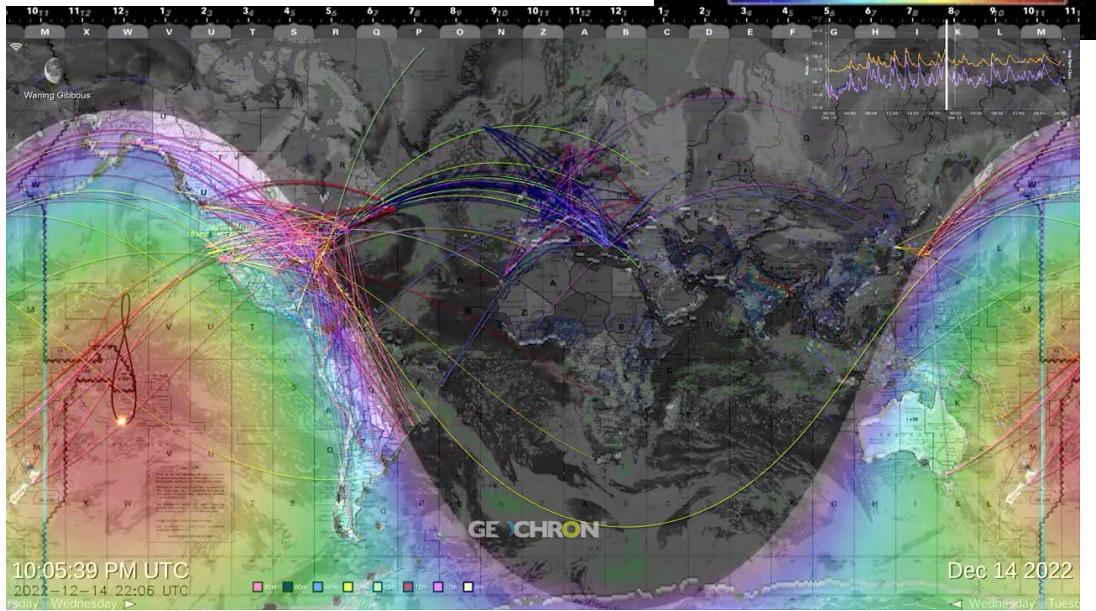
**Now, Circa 2024:**

- Emmy winning meteorologist John Morales works in arguably the most challenging market with extremely complex weather conditions in South Florida
- He admits communicating effectively is still key to informing without perpetuating fear
- Balancing the use of scientific language for accuracy with simple language for clarity (and brevity) remains non-trivial
- Bridging the gap between experts and non-experts is going to take some time

# Bridging the Gap Between Expert and Non-Expert

- Social media is acting as an unofficial laboratory test-bed for scientific model development, as well as for discussion, cross-disciplinary research, and training of SMEs
- Reciprocity exists as public awareness also grows through this “informal training”
- Non-experts are also exploiting this online repository of space weather information, training, and data
  - *more aware of environmental impacts across technology areas and space sectors*
  - *University-accredited training programs catering to the operational space weather community*
  - *Data products that communicate more pictorially*
  - *Aggregation of data showing interrelationships between different regimes*

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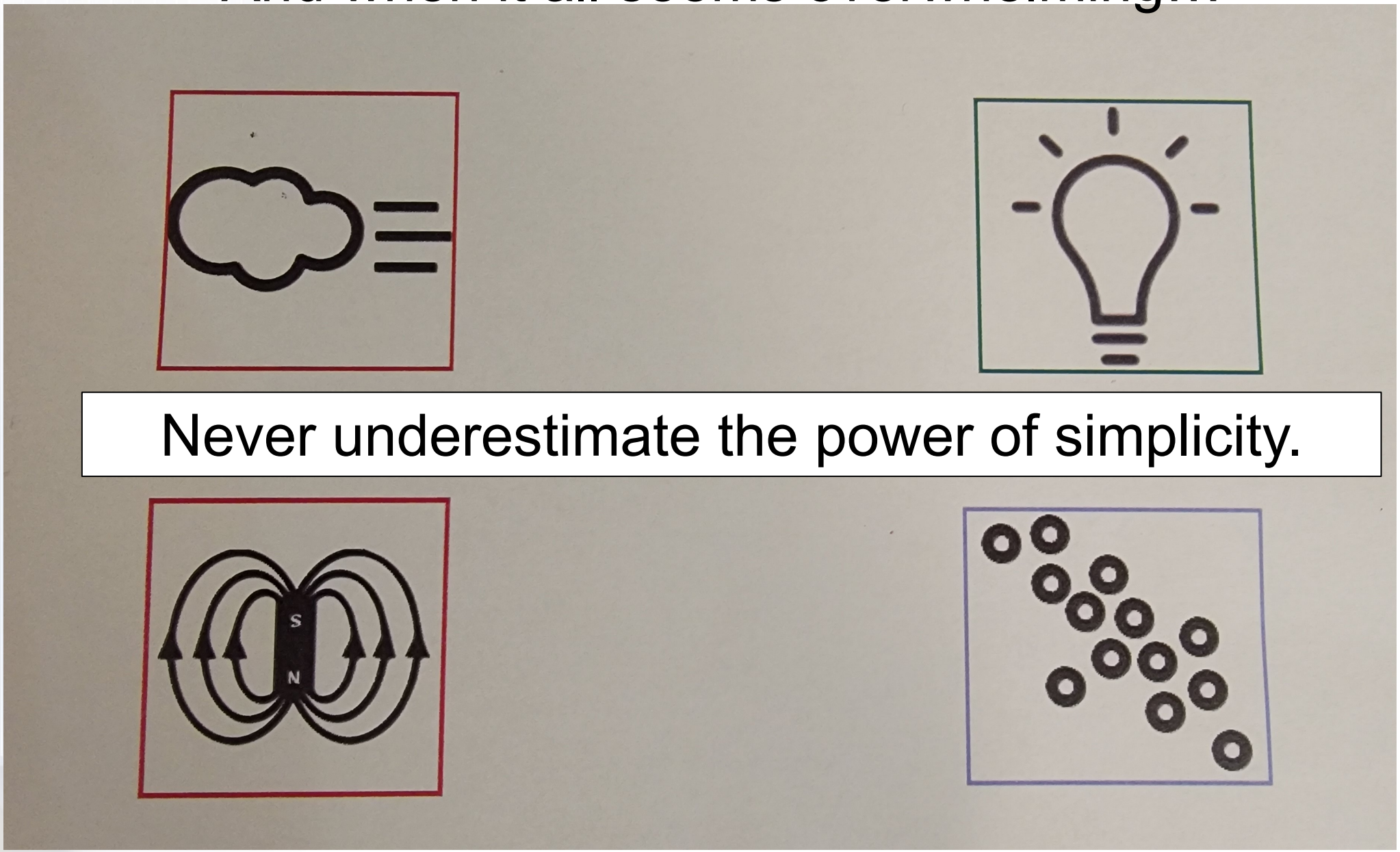
# And when it all seems overwhelming…




Petra Vanlommel