



# Large Solar Events in Historical Context

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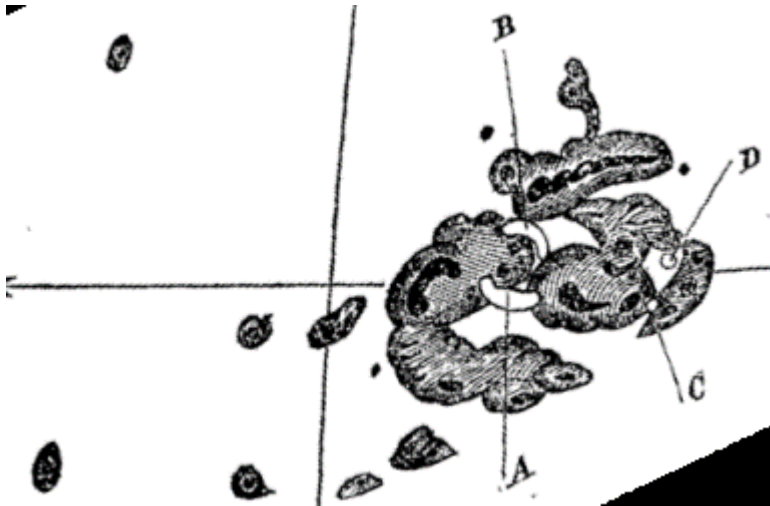
HEPL, Stanford University

AGU Fall 2013, SH23D-02

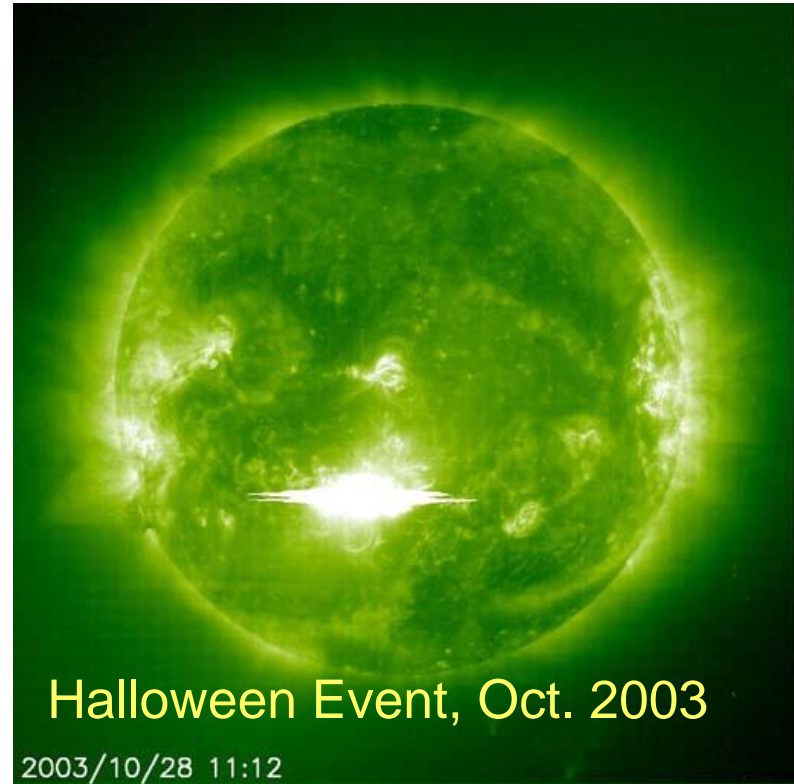
# Indicators of Large Solar Events

- Direct Observations of the Sun
- Low-latitude Aurorae
- Geomagnetic Storms
- Solar Cosmic Rays
- Deposits in Ice Cores (?)

# Solar Observations of Flares



Carrington Event, Sept. 1859

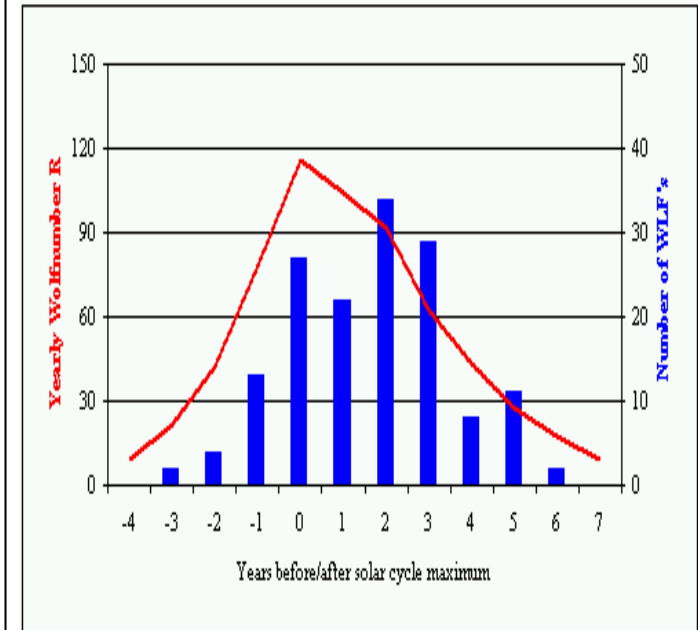
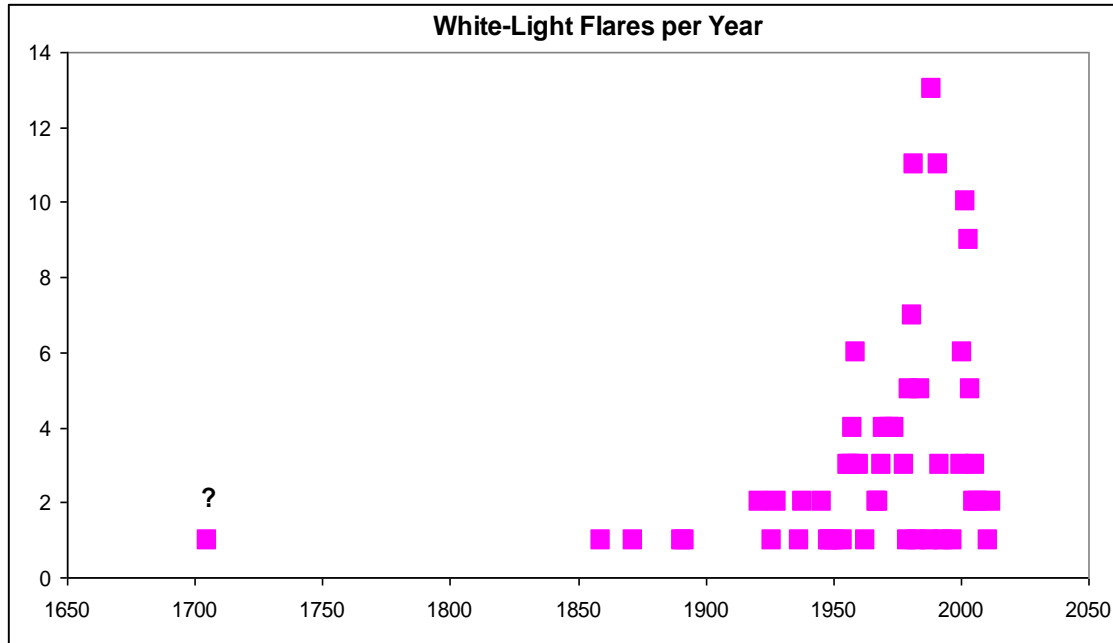


Halloween Event, Oct. 2003

2003/10/28 11:12

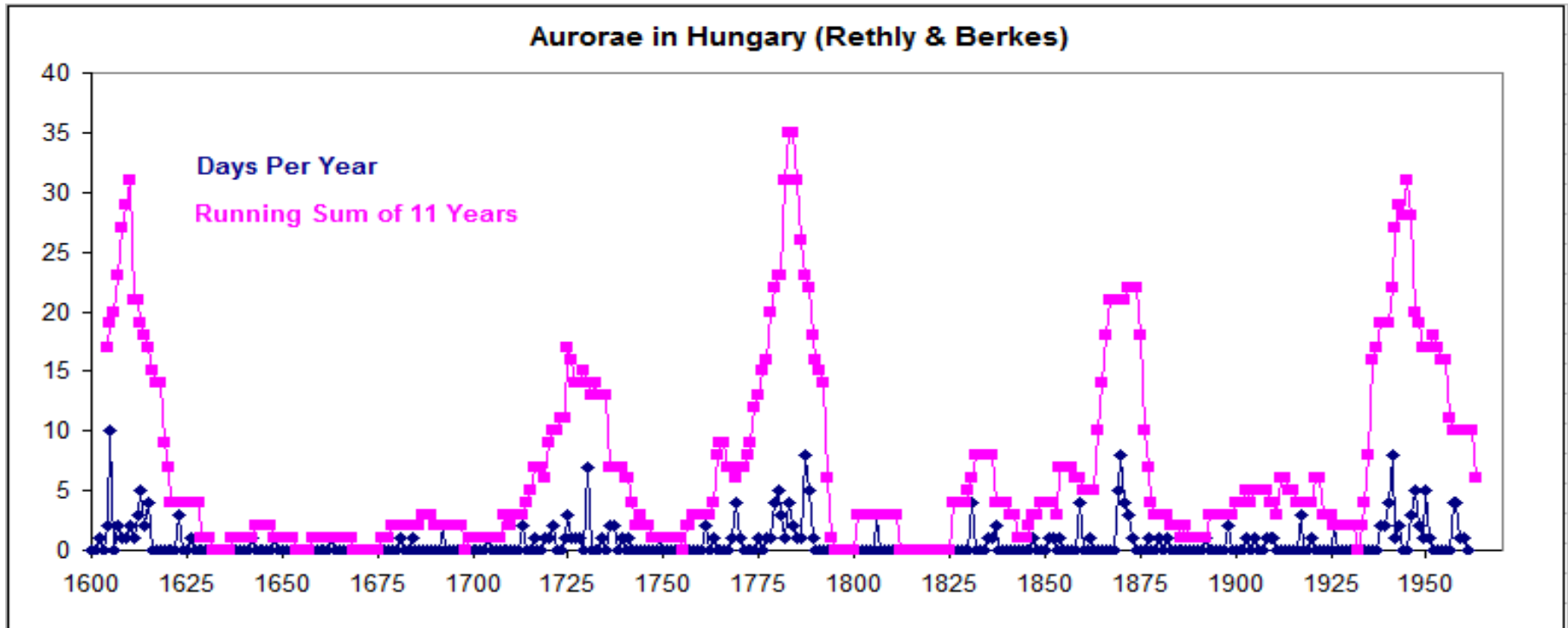
The more energetic ones are visible in White Light,  
so we turn to those observations

# White-Light Flares



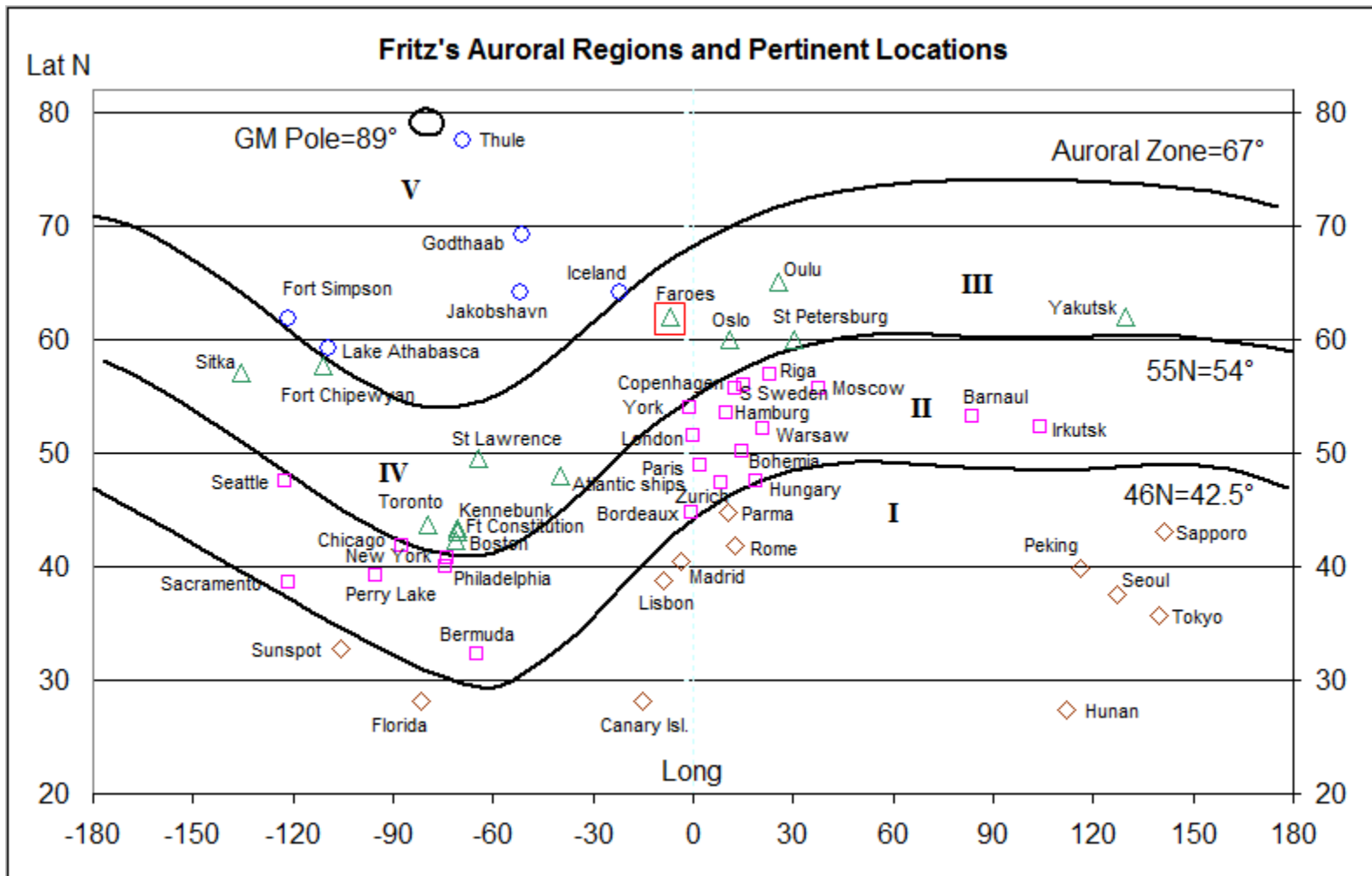
We are just becoming better at observing the White-Light Flares,  
But the solar cycle phase relationship is likely to be correct

# Aurorae in Central Europe

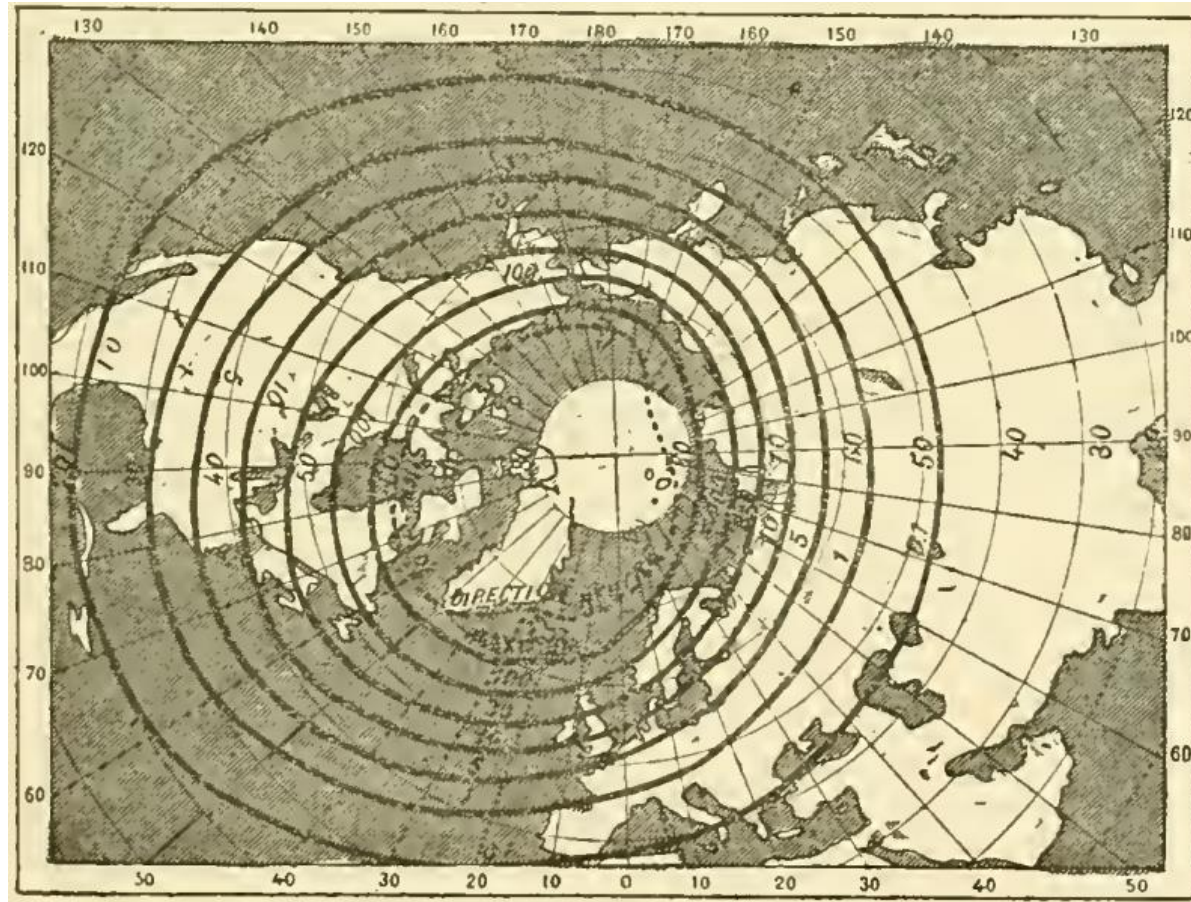


Unfortunately, people do not observe aurorae on a systematic basis any more...

# Auroral 'Regions'



# Fritz Calculated and Published his 'isochasm' map at the end of the 19<sup>th</sup> Century



And it has not been updated since...



We do have some data much further back in time ...

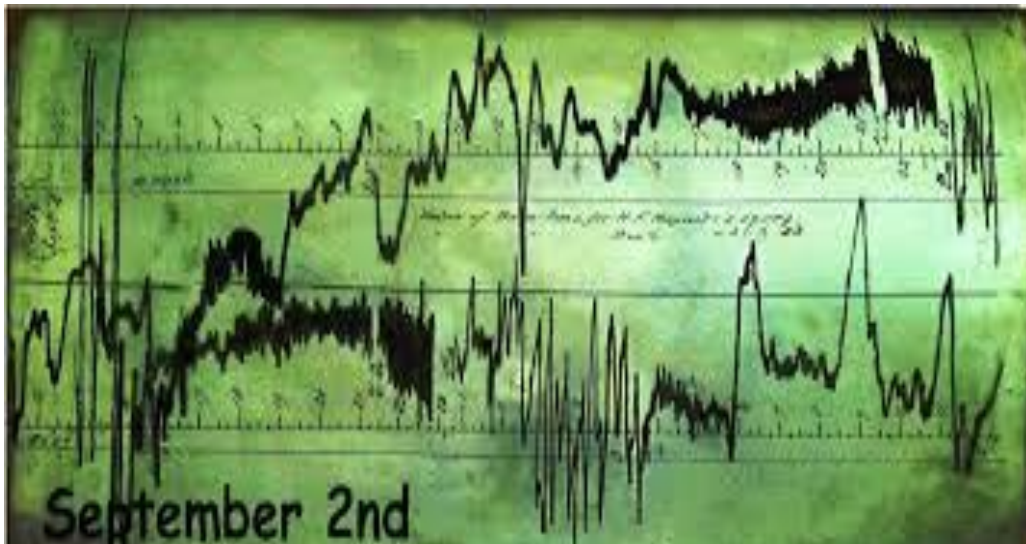


567 BC

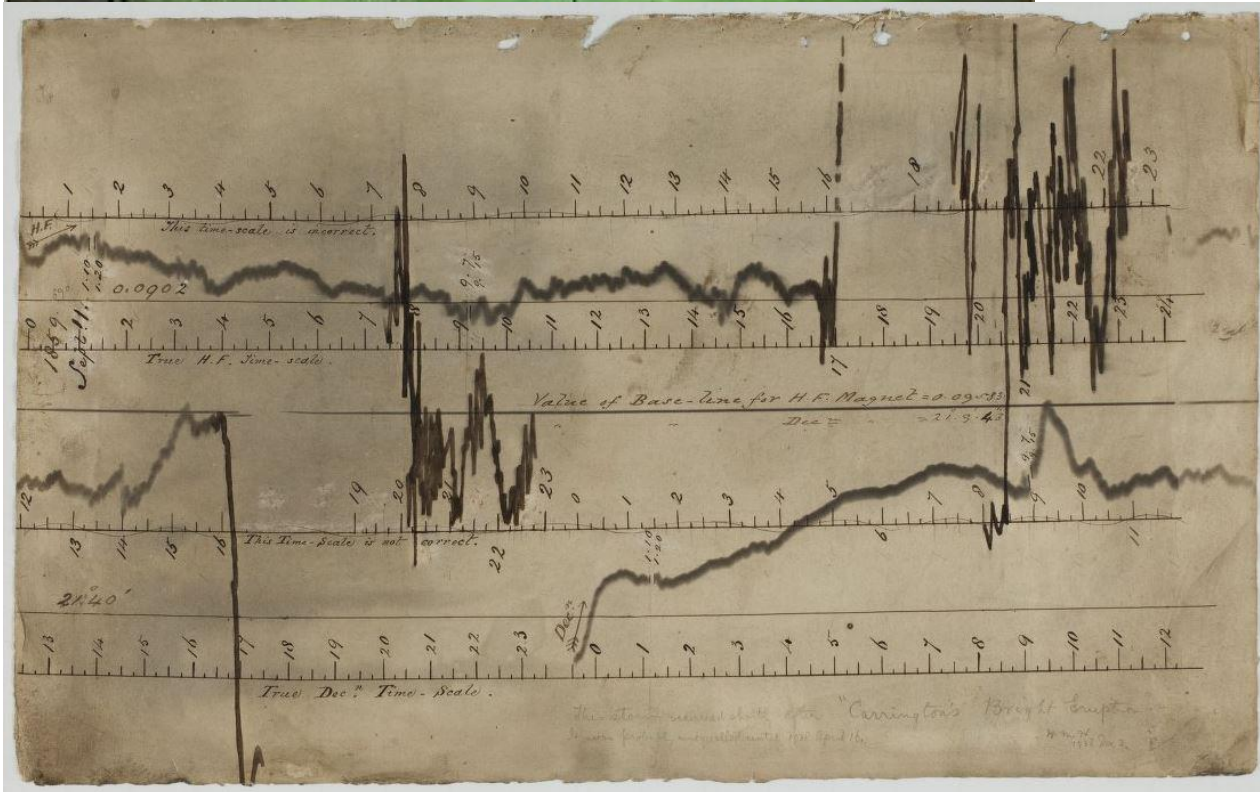
But it is hard [impossible] to 'calibrate' such observations

1: The reverse of the Babylonian tablet (VAT 4956) that contains the record of the aurora in 567 BC. (Staatliche Museen, Berlin/Olaf M Teßmer)





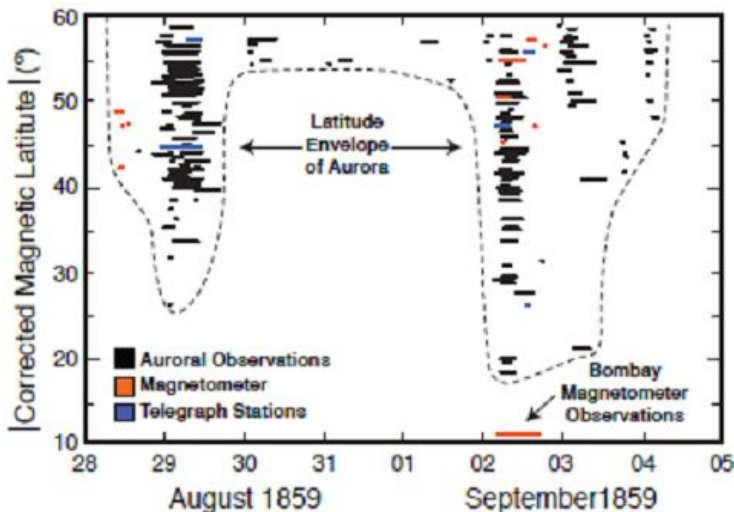
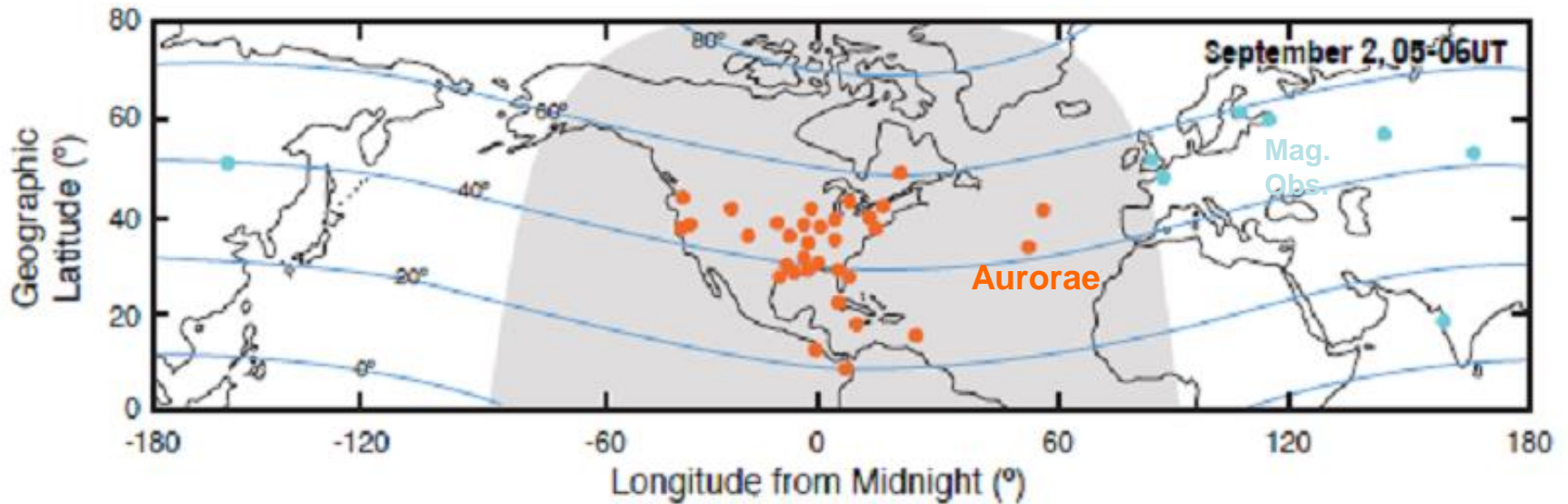
# Geomagnetic Recordings extend back to the 1830s



Here are two of the Carrington 1859 Event

A problem is that the recordings went off the scale for large event...

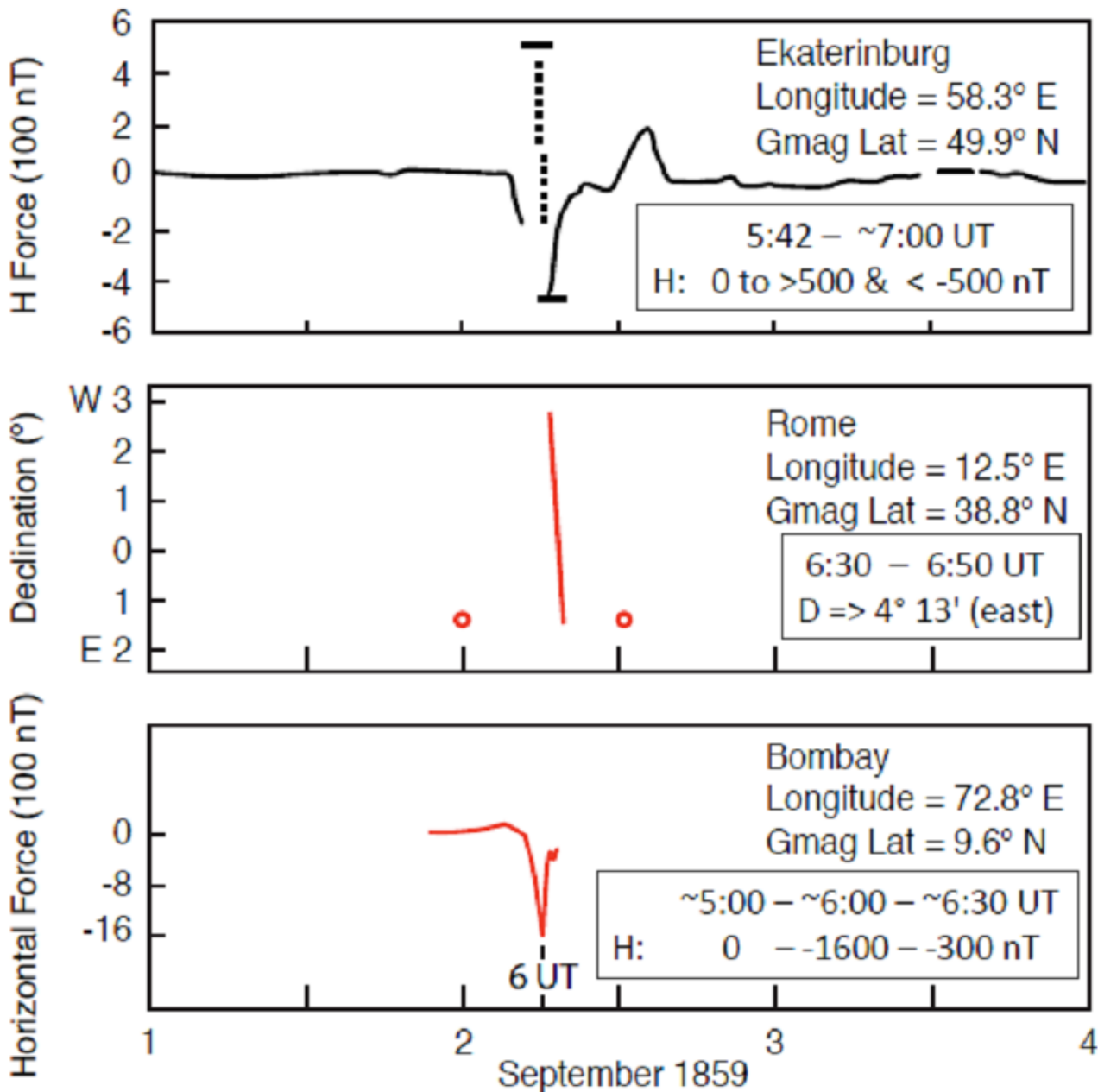
# The Combination of Geomagnetic Records and Auroral Sightings tells us a bit more



Carrington Event again...

Observation of an Aurorae at Apia [corr. Geom. Lat] 15 degrees is the lowest latitude aurora known in May 1921

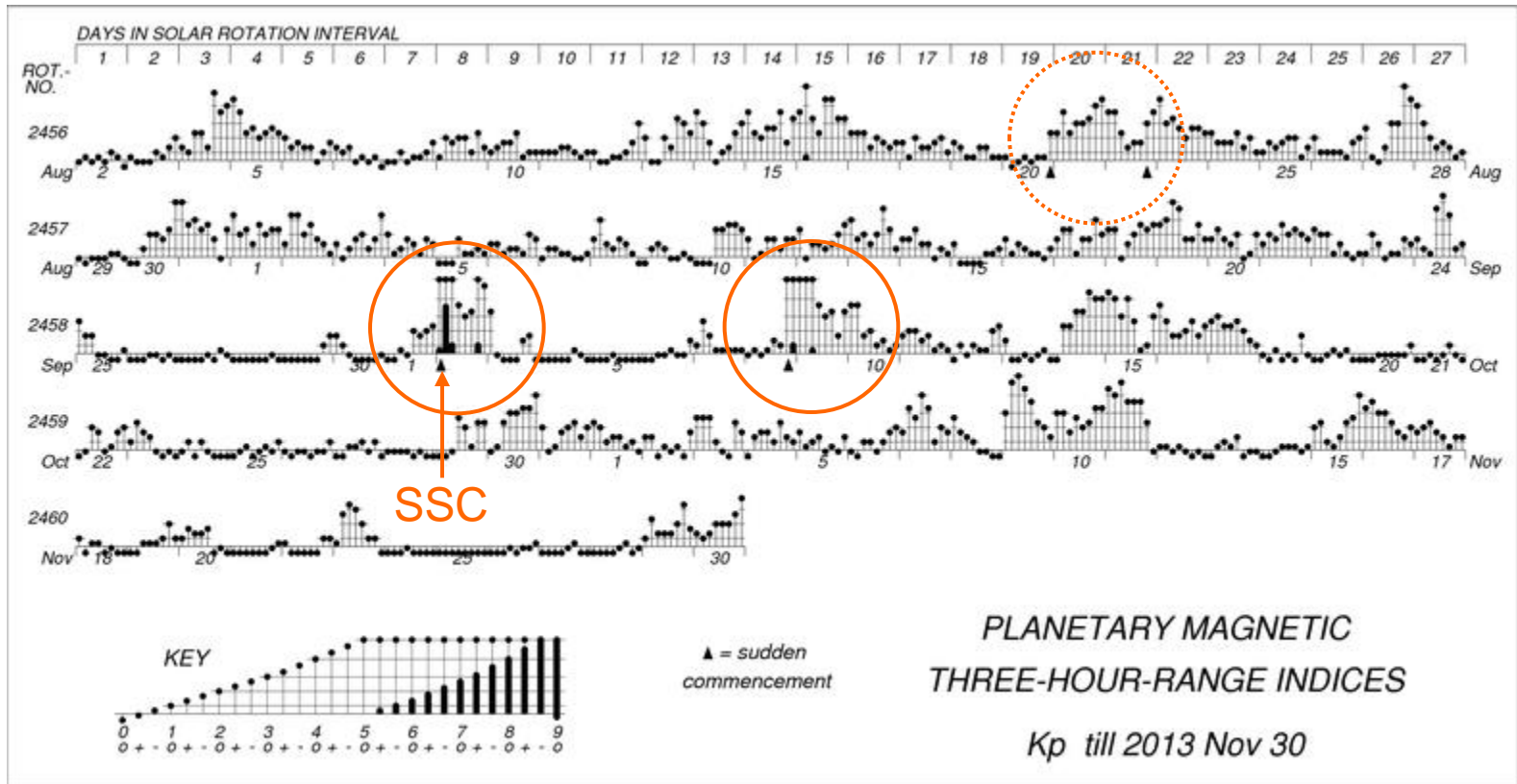
# How large was the 1859 event?



The currents associated with aurorae are local and their effects can be very large [ $\sim 4000$  nT] so will likely 'contaminate' the record making it hard to extract Dst



# Sudden Storm Commencements



The shockwave preceding a solar wind CME produces a sharp compression signature in the geomagnetic record, a SSC

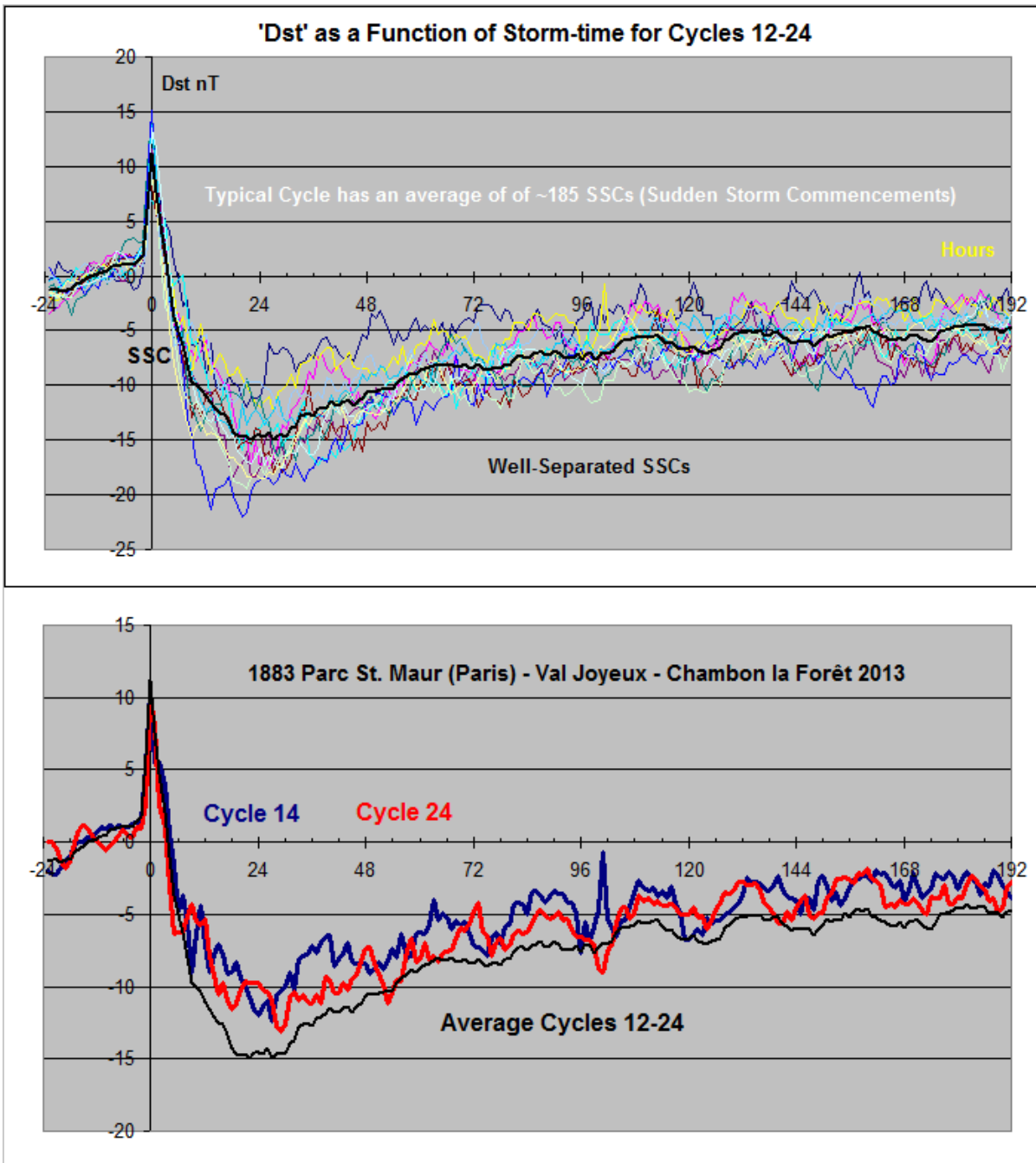
# Analysis of 130 years of Geomagnetic Storms

The horizontal component of the geomagnetic field at a typical storm rises abruptly at the SSC.

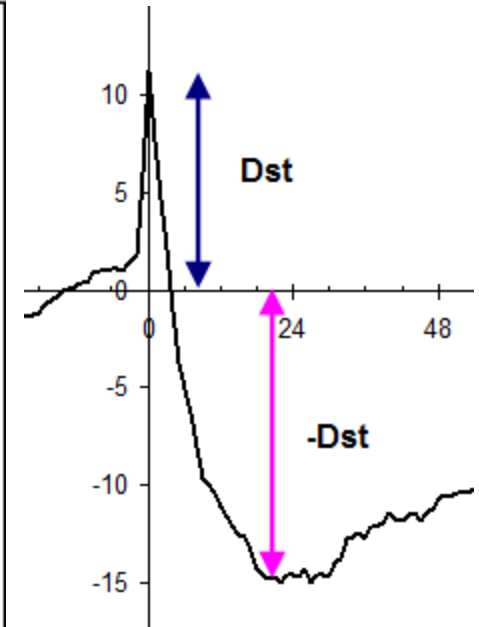
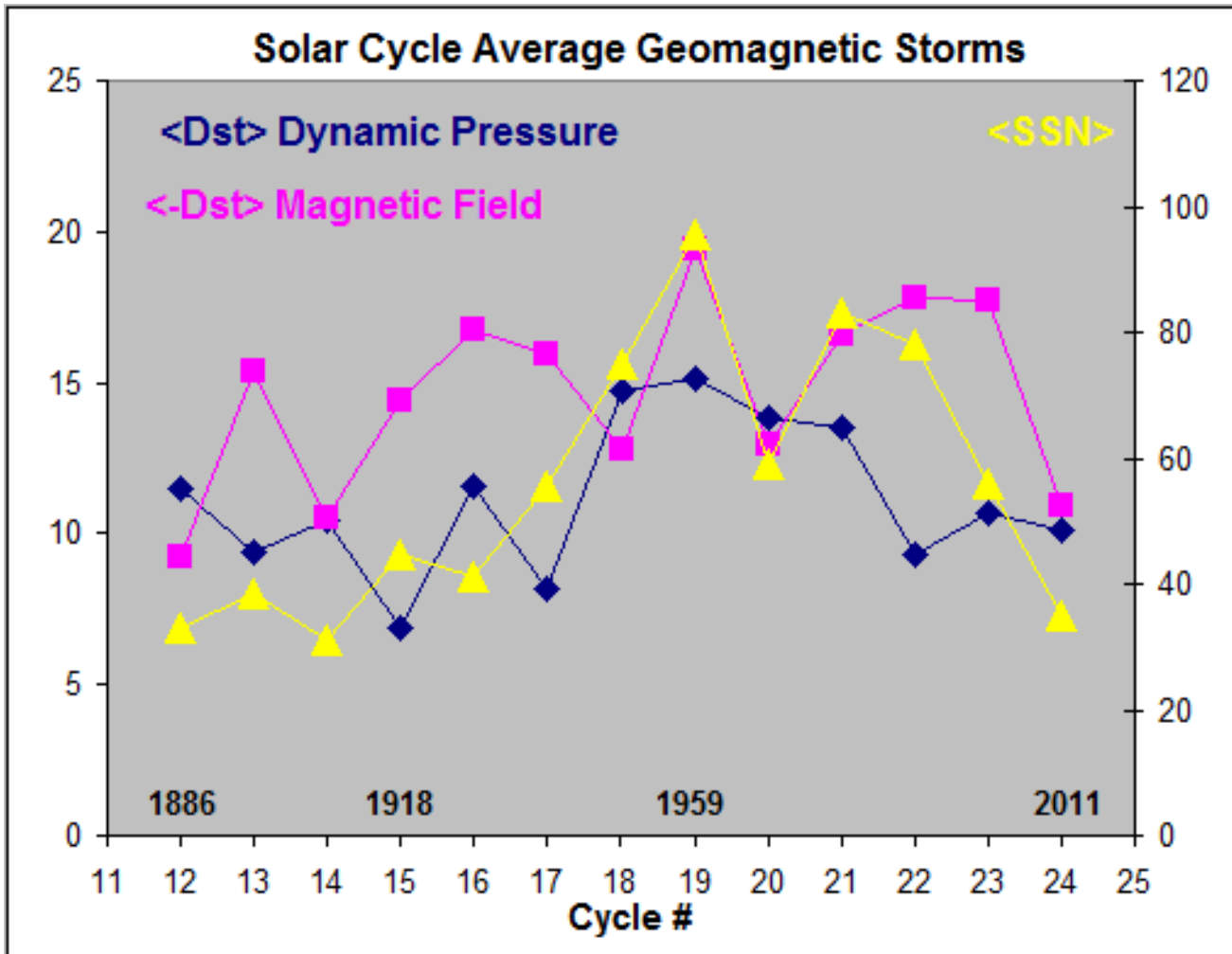
Then falls sharply when the ring current builds to reach a minimum about a later.

Top panel: superposed epoch for the 13 cycles 1883-2013.

Bottom: cycle 14 and cycle 24 are very alike



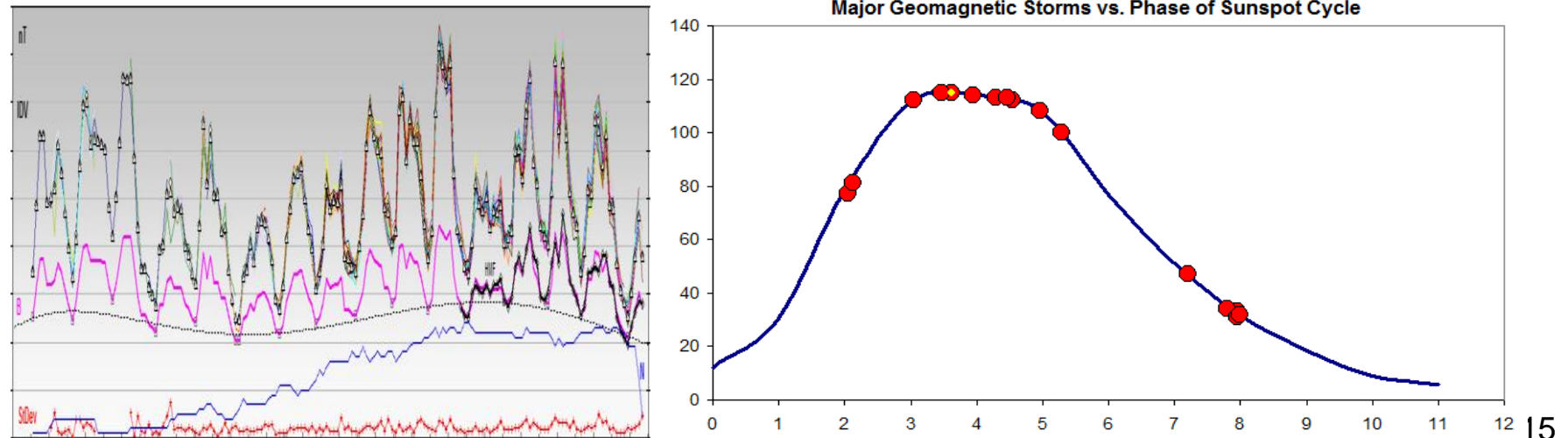
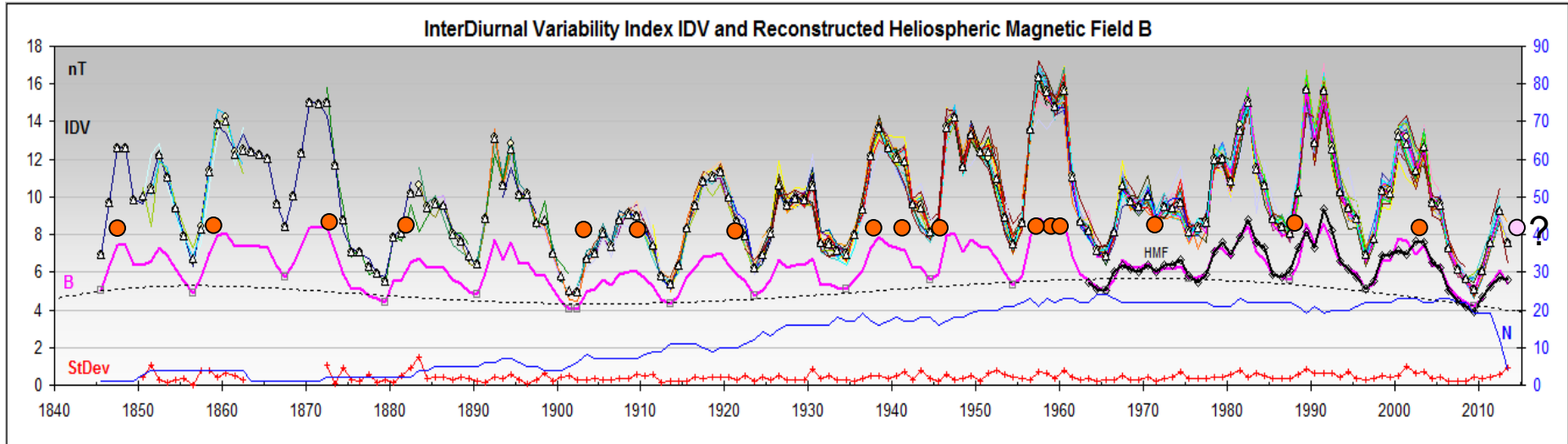
# Solar Inter-Cycle Variation of Dst



Weak dependence  
on Sunspot Number

We are now back to  
conditions prevailing  
a century ago

# 170 Years of Large Geomagnetic Storms





# Conclusions

- The historical record is spotty
- The auroral records lacks calibration
- The geomagnetic record is in better shape and we are learning to interpret it.
- Solar activity is at present down to that of a century ago
- But large solar events can occur at any activity level.

# Abstract

Large Solar Events result in Major Geomagnetic Storms and Extensive Auroral Displays. With the modern understanding of these phenomena we can confidently interpret the historical record, which for geomagnetic events stretches back to the 1830s and for the plainly visible with the naked eye auroral events for much longer than that. I discuss the historical data and put solar cycle 24 in proper perspective [as far as we can - assuming the Sun does not surprise us].