Use of Sudden Ionospheric Disturbance Monitors to Detect Coronal Mass Ejections

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Agenda

1. Overview of the Research
2. What is a CME?
3. What are SID Monitors?
4. Methodology
5. Results
6. Conclusions
7. What’s Next?
8. Questions

CME (Infrared)

Overview

Hypothesis

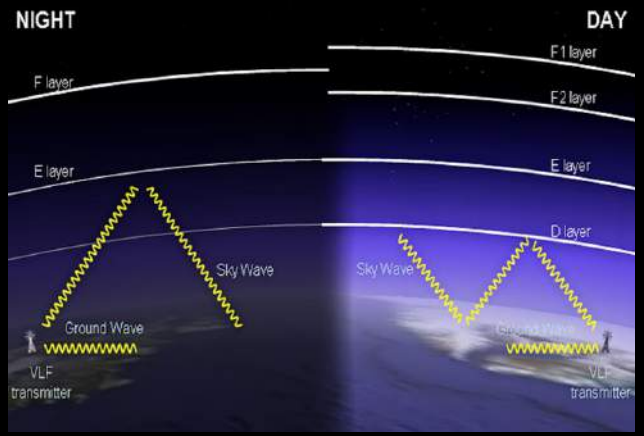
- Do coronal mass ejections have an effect on Earth’s ionosphere?

When?

- February through July, 2011

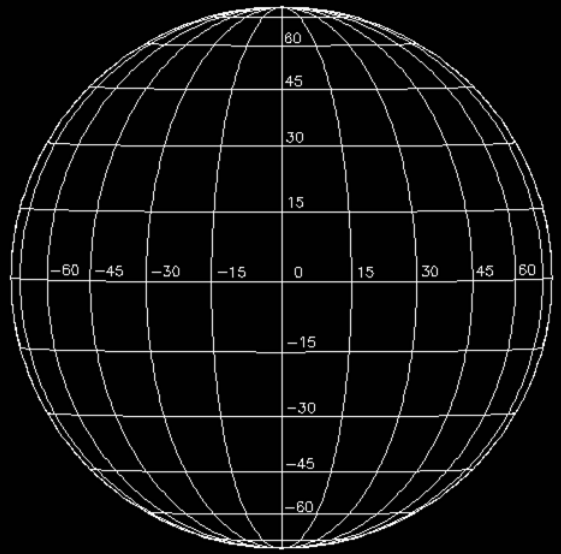
Where?

- Ionosphere: 70 -100 km above surface

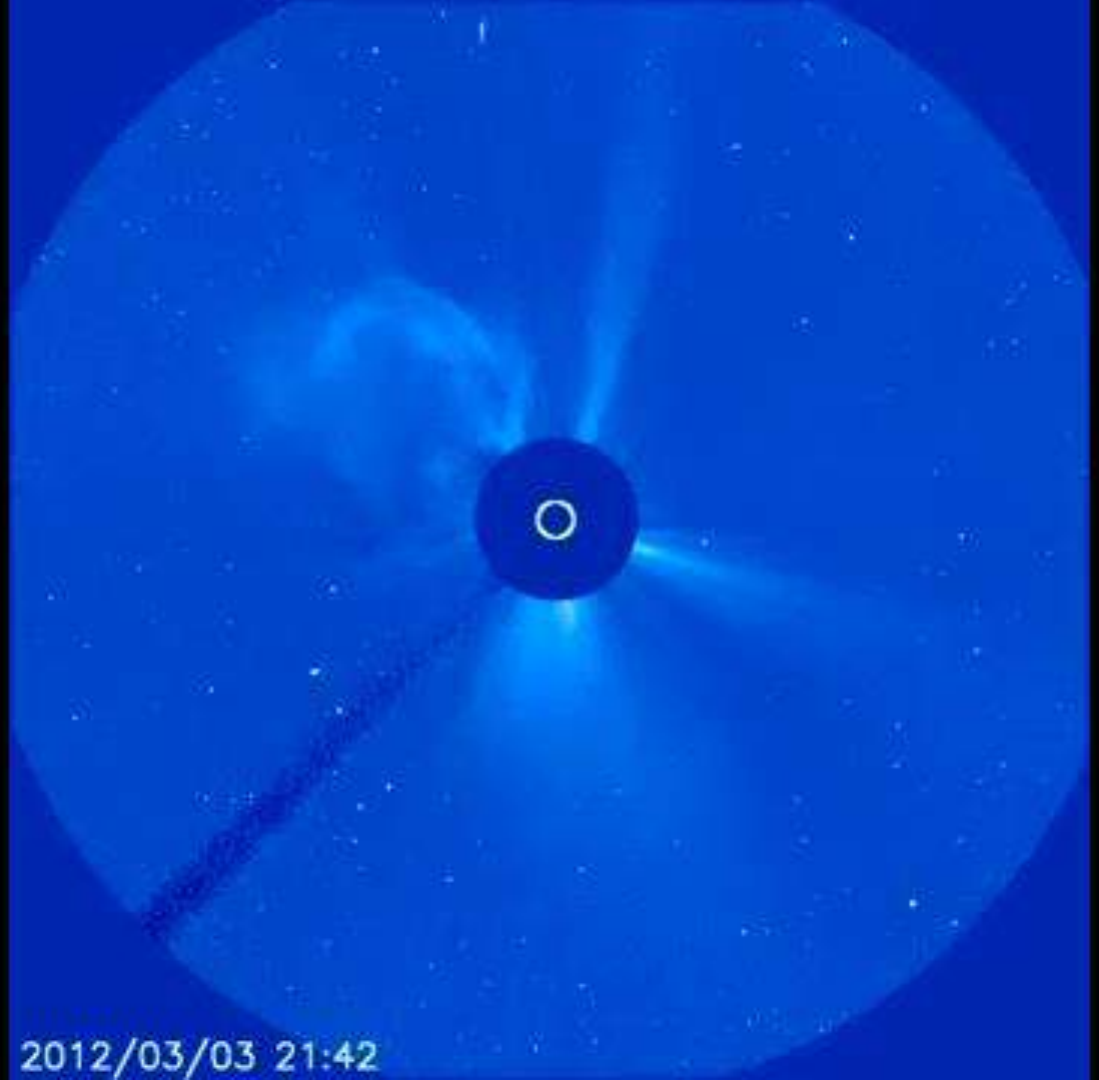


What is a CME?

- CME: Coronal Mass Ejection
- Giant cloud of solar particles
- LASCO/SOHO CME Catalog
- Earth directed?
  - Halo type
  - +/- 80º central position angle
  - > 50º angular width
  - Disregard all other CMEs

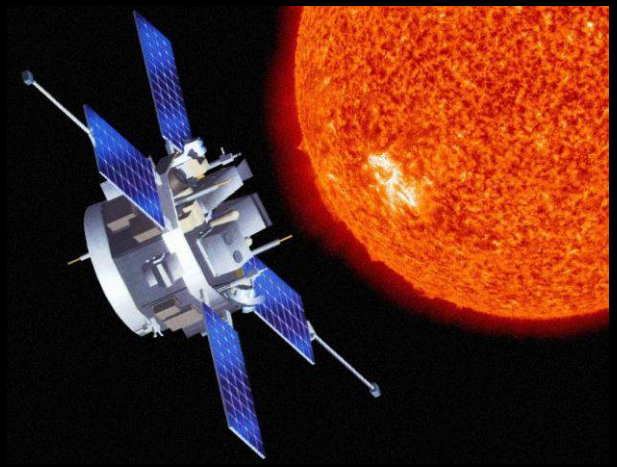


Halo type CME with resulting proton shower



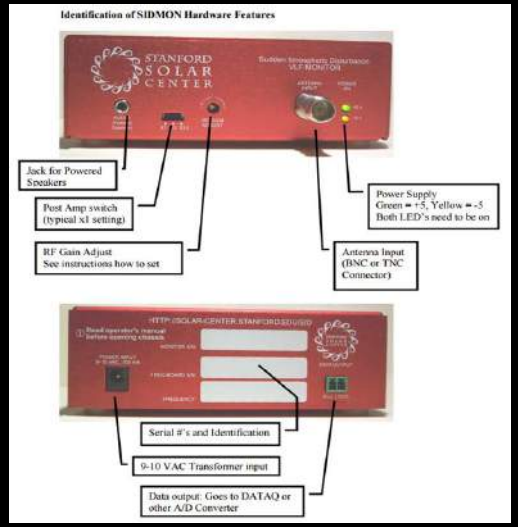
What are the Impacts of CMEs?

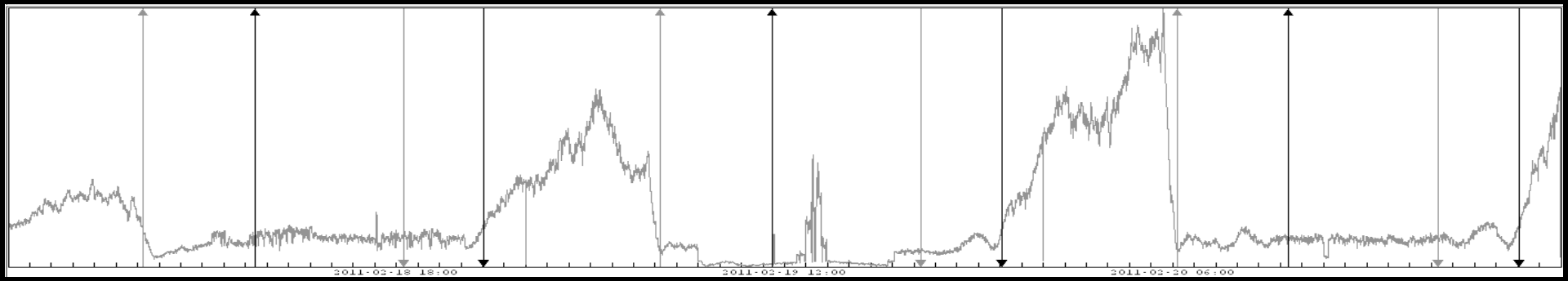
- Can disrupt satellite communications
- Can disrupt radio signals
- Pose a threat to commercial aircraft
- Can cause auroras near the Polar Circles



What is a SID Monitor?

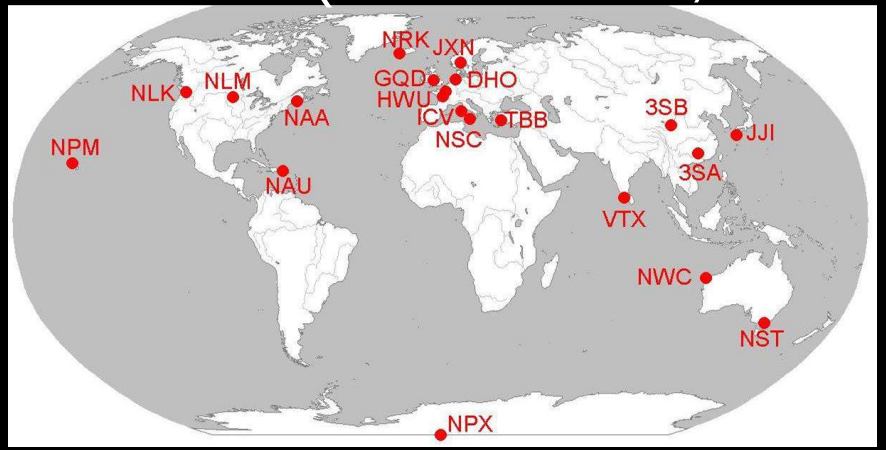
- SID: Sudden Ionospheric Disturbance
- Measures the intensity of VLF waves
- Normally used to identify if solar flares are geoeffective





Obtaining the Data Online

- SOHO/LASCO CME Catalog
- SID Monitors in Vienna
  - JXN (Novik, Norway)
  - FTA (Saint-Assise, France)



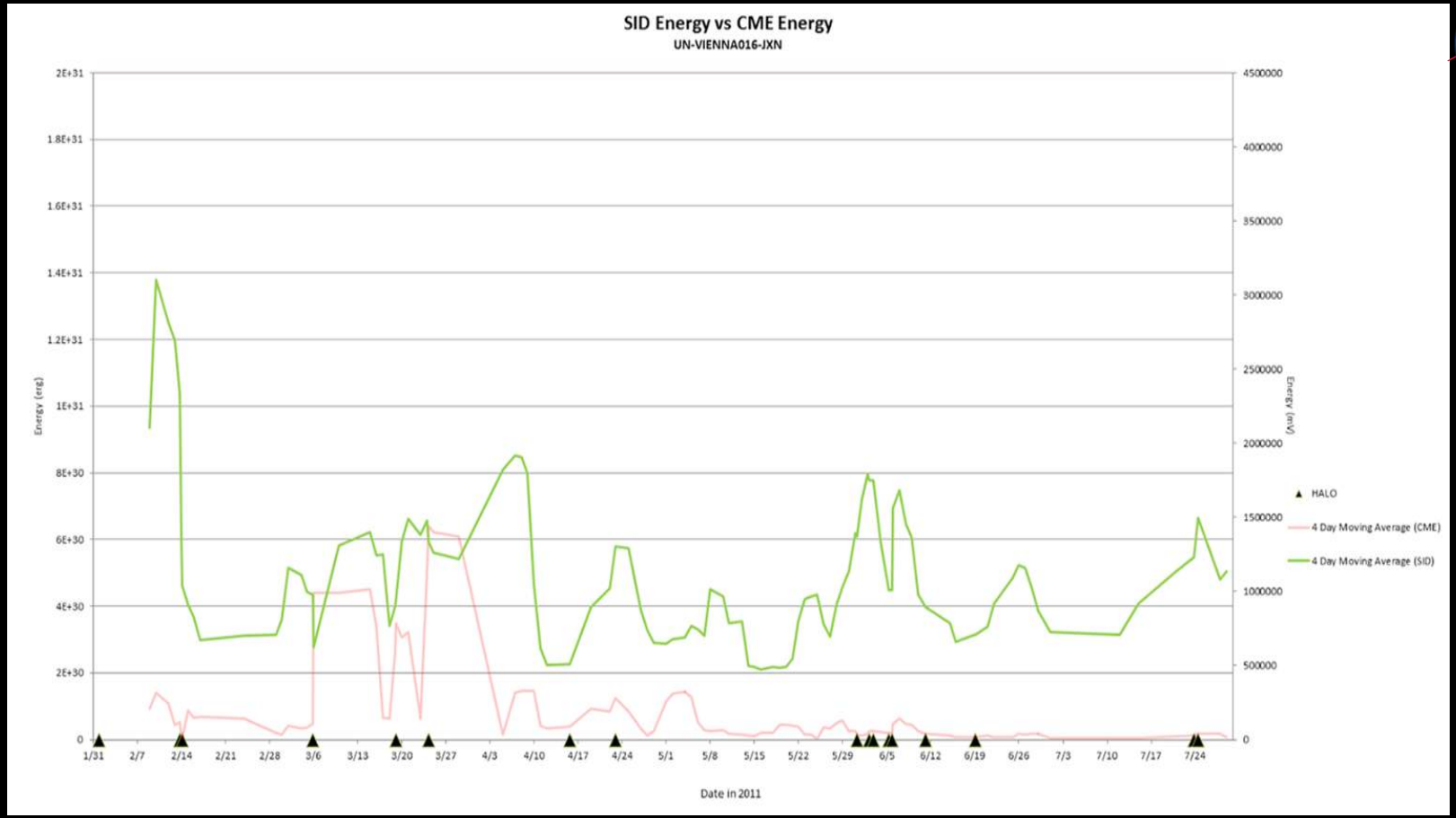
Examples of Raw Data

SID

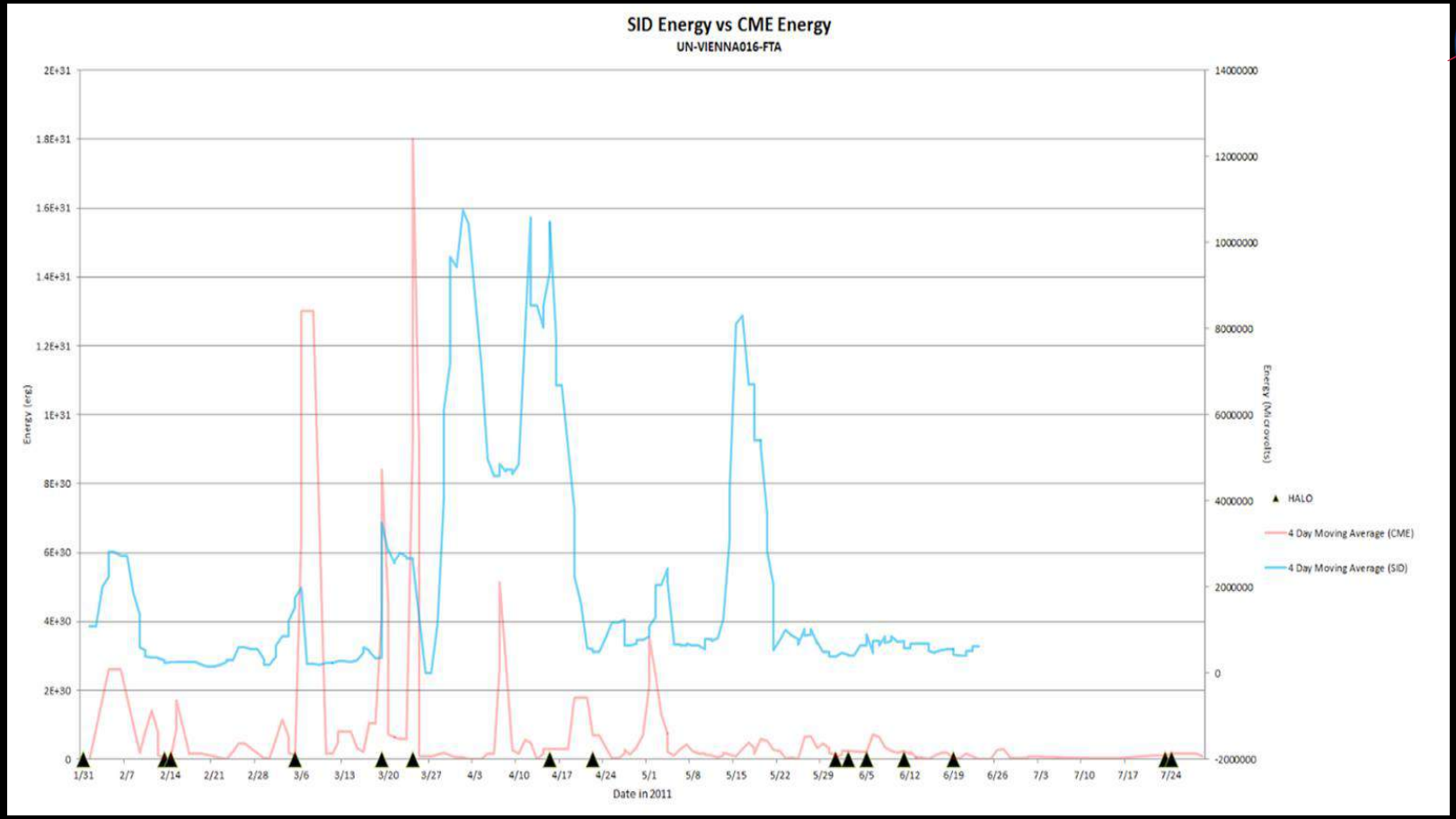
```
# Site = DAISYSG
# Contact = ericgibert@yahoo.fr
# Longitude = 103.8
# Latitude = 1.367
# UTC_Offset = +08:00
# TimeZone = SGT
# UTC_StartTime = 2015-08-02 00:00:00
# LogInterval = 5
# LogType = filtered
# MonitorID = 1
# StationID = NWC
# Frequency = 19800
#UTC_EndTime=2015-08-02 23:59:55
#DataMin=0.000000000000000
#DataMax=47.265107133289995
#dataquality_average_v0.1=0.077631
#dataquality_max_v0.1=2.286371
2015-08-02 00:00:00, 6.971210687940000
2015-08-02 00:00:05, 7.027664643360000
2015-08-02 00:00:10, 8.296631614650000
2015-08-02 00:00:15, 9.565598585949999
2015-08-02 00:00:20, 10.834565557239999
2015-08-02 00:00:25, 12.103532528540001
2015-08-02 00:00:30, 13.372499499830001
2015-08-02 00:00:35, 14.641466471130000
2015-08-02 00:00:40, 15.910433442420000
2015-08-02 00:00:45, 17.179400413720000
2015-08-02 00:00:50, 18.448367385010002
2015-08-02 00:00:55, 19.717334356309998
2015-08-02 00:01:00, 20.986301327600000
2015-08-02 00:01:05, 22.321612113699999
```

CME

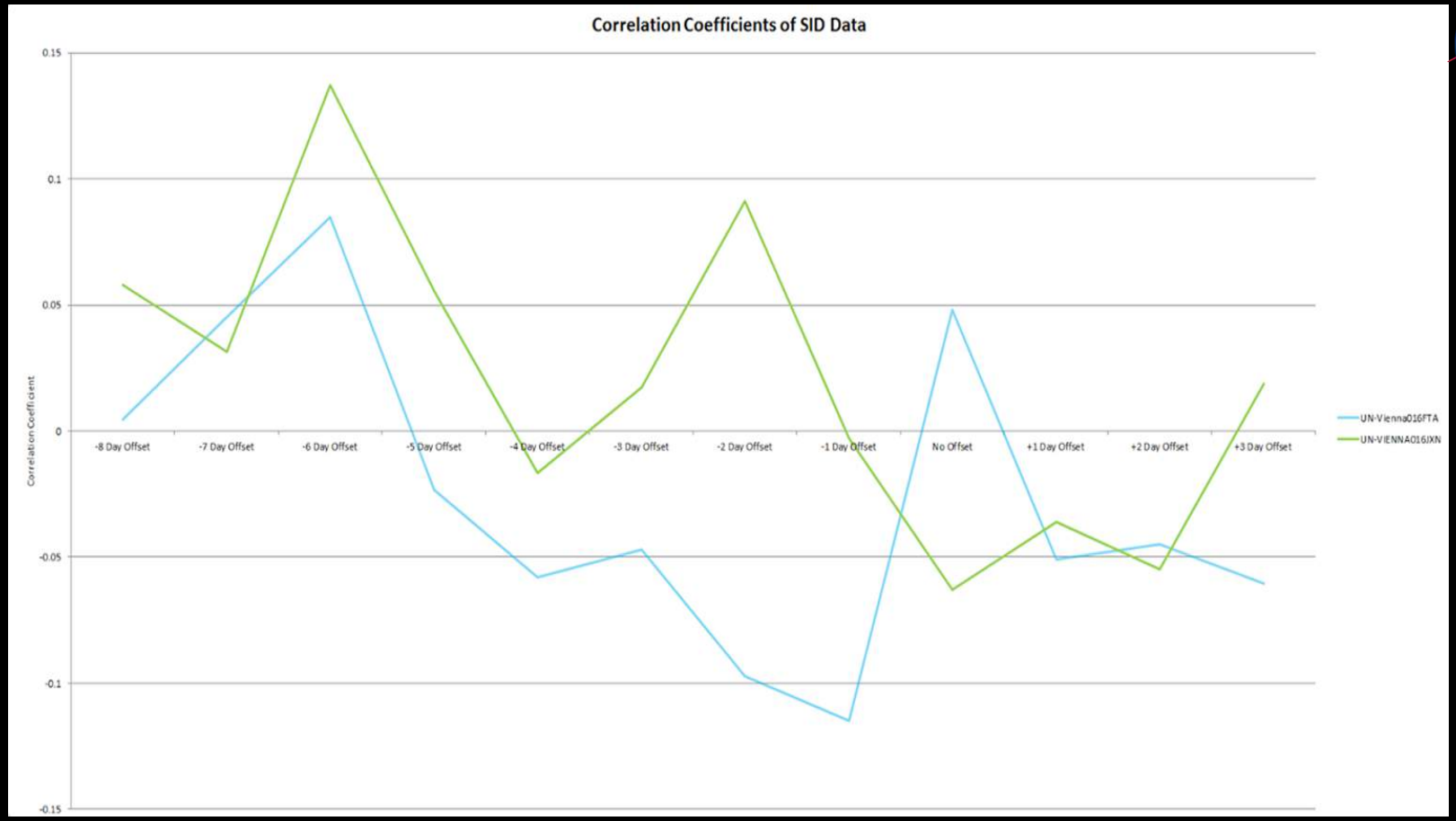
First C2 Appearance Date Time [UT]		Central PA [deg]	Angular Width [deg]	Linear Speed [km/s]	2nd-order Speed at final height [km/s]	2nd-order Speed at 20 Rs [km/s]	Accel [m/s²]	Mass [gram]	Kinetic Energy [erg]	MPA [deg]	Movies, plots, & links	Remarks
2011/06/01	02:36:05	235	25	235	343	390	5.7*1	2.0e+14	5.6e+28	226	C2 C3 195 PHTX DST Java Movie	Poor Event
2011/06/01	05:12:05	113	79	259	387	435	6.9*1	5.5e+14	1.9e+29	113	C2 C3 195 PHTX DST Java Movie	
2011/06/01	07:36:07	303	5	515	439	0	-35.4*1	----	----	310	C2 C3 195 PHTX DST Java Movie	Very Poor Event; Only C2
2011/06/01	13:25:52	268	5	404	493	1497	88.1*1	----	----	270	C2 C3 195 PHTX DST Java Movie	Very Poor Event; Only C2
2011/06/01	16:36:07	234	22	284	192	0	-38.0*1	4.4e+13	1.8e+28	238	C2 C3 195 PHTX DST Java Movie	Poor Event; Only C2
2011/06/01	17:00:05	300	7	329	386	826	25.5*1	----	----	301	C2 C3 195 PHTX DST Java Movie	Very Poor Event; Only C2
2011/06/01	17:36:05	93	64	198	140	0	-17.9*1	2.3e+14	4.6e+28	82	C2 C3 195 PHTX DST Java Movie	Poor Event; Only C2
2011/06/01	18:36:06	112	189	361	425	433	4.1*1	----	----	98	C2 C3 195 PHTX DST Java Movie	Partial Halo
2011/06/01	18:48:06	301	19	464	441	267	-7.3*1	----	----	311	C2 C3 195 PHTX DST Java Movie	Poor Event
2011/06/01	20:48:05	311	16	548	526	270	-10.6*1	----	----	310	C2 C3 195 PHTX DST Java Movie	Very Poor Event; Only C2
2011/06/01	23:24:13	30	57	429	430	430	0.1*1	5.0e+13	4.6e+28	23	C2 C3 195 PHTX DST Java Movie	
2011/06/02	01:48:06	314	11	423	457	790	20.0*1	----	----	315	C2 C3 195 PHTX DST Java Movie	Very Poor Event; Only C2
2011/06/02	02:00:07	232	43	535	510	305	-9.0*1	8.0e+13	1.1e+29	242	C2 C3 195 PHTX DST Java Movie	Poor Event
2011/06/02	07:24:05	74	61	253	199	0	-37.9*1	1.4e+14	4.4e+28	75	C2 C3 195 PHTX DST Java Movie	Poor Event; Only C2
2011/06/02	08:12:06	Halo	360	976	999	996	3.6	----	----	98	C2 C3 195 PHTX DST Java Movie	
2011/06/02	14:00:07	34	18	260	272	287	0.9*1	----	----	41	C2 C3 195 PHTX DST Java Movie	Poor Event
2011/06/02	14:24:06	89	67	460	623	795	22.4*1	6.4e+14	6.8e+29	88	C2 C3 195 PHTX DST Java Movie	
2011/06/02	17:12:07	280	7	520	626	1277	61.6*1	----	----	280	C2 C3 195 PHTX DST Java Movie	Poor Event; Only C2
2011/06/02	17:36:05	247	7	628	607	355	-12.2*1	----	----	253	C2 C3 195 PHTX DST Java Movie	Poor Event; Only C2
2011/06/02	18:24:06	310	7	414	308	0	-31.1*1	----	----	316	C2 C3 195 PHTX DST Java Movie	Poor Event; Only C2
2011/06/02	20:00:07	24	6	311	317	334	0.8*1	----	----	34	C2 C3 195 PHTX DST Java Movie	Very Poor Event
2011/06/02	23:05:53	36	10	322	359	461	6.2*1	----	----	35	C2 C3 195 PHTX DST Java Movie	Very Poor Event
2011/06/03	02:48:05	292	25	370	232	0	-46.9*1	6.2e+13	4.3e+28	292	C2 C3 195 PHTX DST Java Movie	Very Poor Event
2011/06/03	04:38:55	313	8	381	303	0	-46.9*1	----	----	317	C2 C3 195 PHTX DST Java Movie	Very Poor Event; Only C2
2011/06/03	05:48:05	296	9	369	399	456	3.9*1	----	----	297	C2 C3 195 PHTX DST Java Movie	Poor Event
2011/06/03	08:12:05	300	10	376	423	471	4.8*1	----	----	297	C2 C3 195 PHTX DST Java Movie	Poor Event
2011/06/03	10:12:06	163	162	69	143	263	2.9*1	----	----	162	C2 C3 195 PHTX DST Java Movie	Poor Event; Partial Halo
2011/06/03	12:36:06	317	60	353	347	347	-0.4*1	1.1e+15	6.7e+29	298	C2 C3 195 PHTX DST Java Movie	
2011/06/03	18:48:07	321	35	275	245	0	-6.7*1	8.2e+13	3.1e+28	322	C2 C3 195 PHTX DST Java Movie	Poor Event; Only C2



SID Energy vs CME Energy: UN-VIENNA 016-JXN

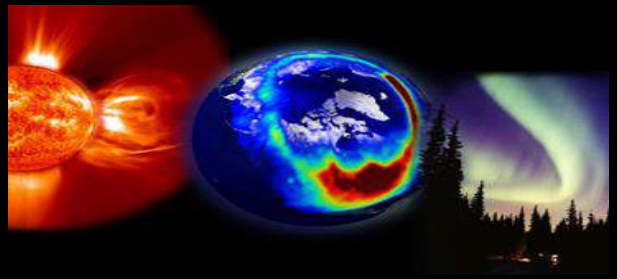


SID Energy vs CME Energy: UN-VIENNA 016-FTA



Correlation Coefficients of SID Data
(Halo type CMEs not included)

Conclusions



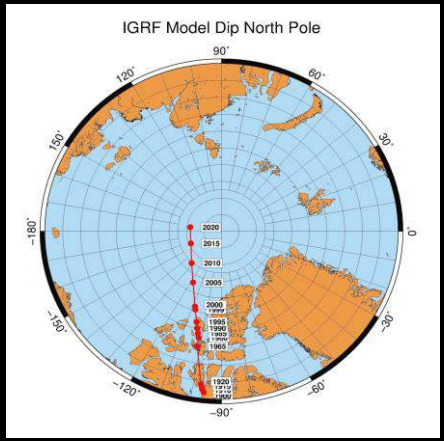
- Using SID monitors is a valid way to determine whether a CME was geoeffective.
- A 6-day offset appears to correlate CME kinetic energy with SID measured reflectivity.
- Missing data - skewed correlations between CME & SID data sets

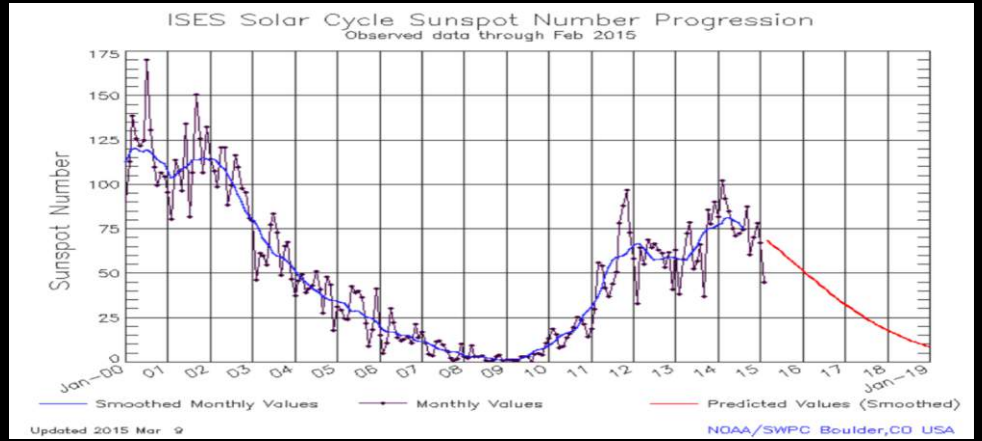
Why is this Important?

- Foundation for future research
  - Can CMEs be predicted from looking at SID data?
  - Can we help prevent impacts on the ionosphere if we know how a CME affects it?
- Financial implications
- Safety (Radiation)
- Carrington Event (1859)

Future Applications

- Find a way to quantify missing data
- Estimate CME travel times
- Expansion of data beyond 6 months
- Use SID monitors closer to the magnetic poles





Acknowledgements

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National Science Foundation
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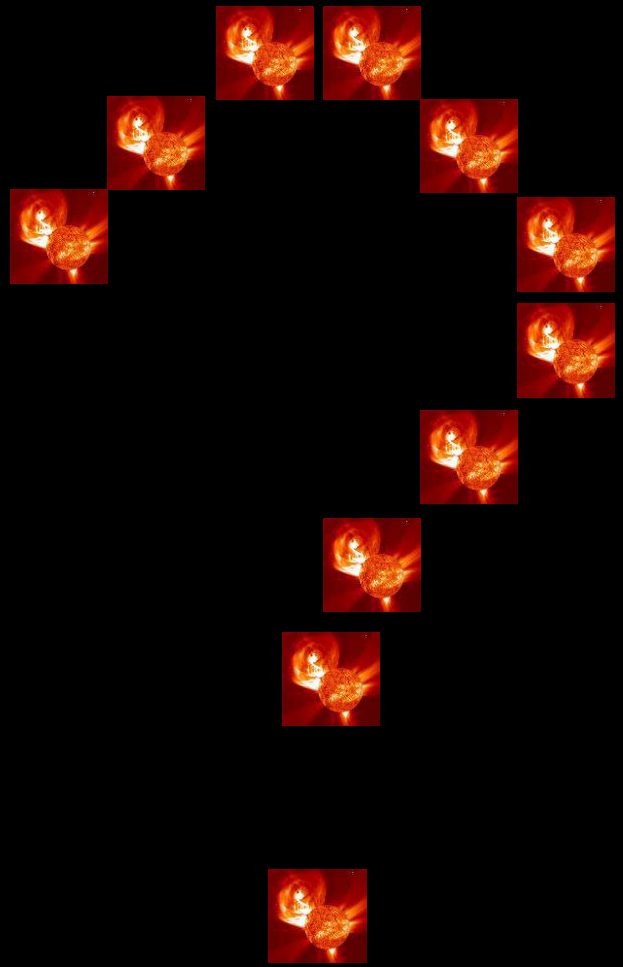
Stanford University Solar Center

References

http://sid.stanford.edu/database-browser

http://cdaw.gsfc.nasa.gov/CME_list

Questions?

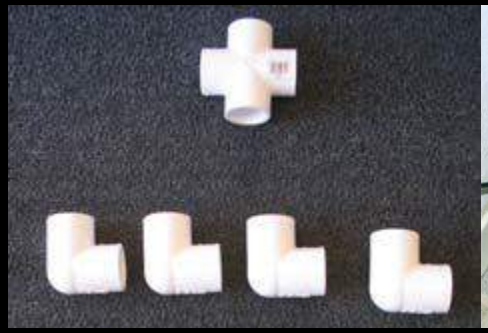


How to Get Involved

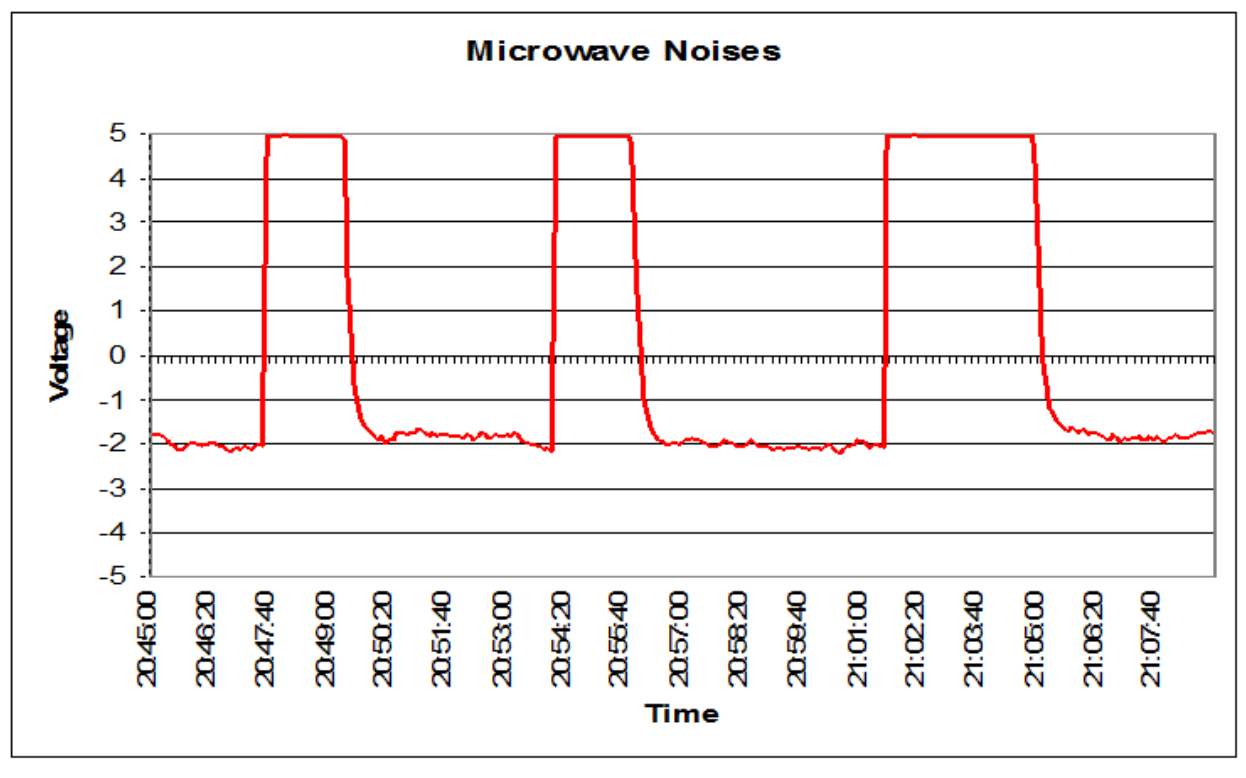
SID monitors are now being made available to schools and institutions that wish to contribute to the database.

Supplies of monitors are limited but are most frequently placed in schools with under-represented populations.

Build Your Own SID Antenna!

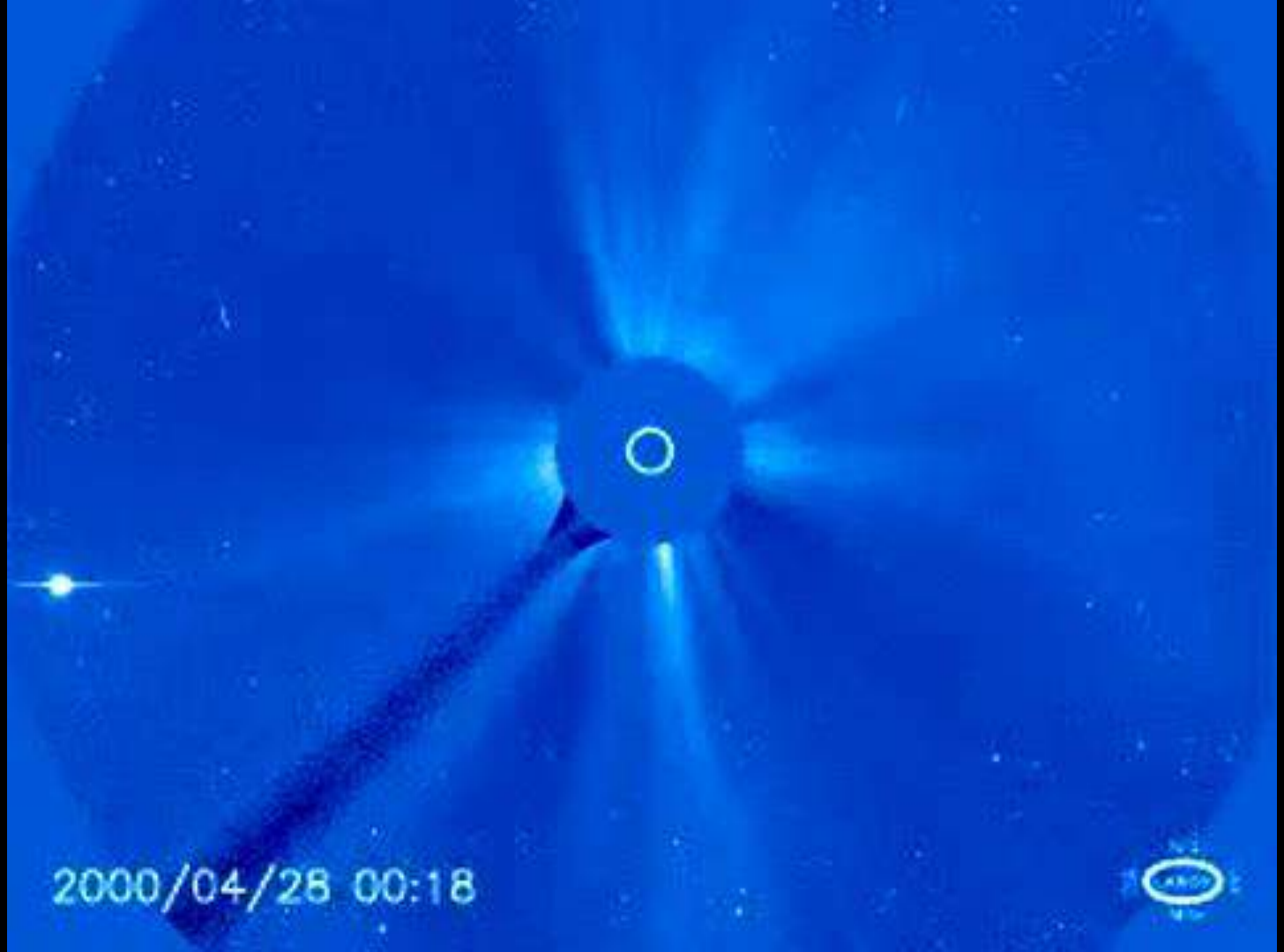


Causes of Interference



Example of a 1000 Watt microwave 1 meter away from the SID antenna. After 30 meters the noise seems to attenuate to very minor levels.

Other equipment that may interfere with SID monitors include…

Vacuum cleaners, Gas lamps and small electric motors.

CME (x-ray)