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Ionospheric Disturbances in Mexican Territory Produced by Objects Entering the Athmosphere from Space

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Abstract

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Keywords: Space Sciences; Atmosphere

1. Introduction

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2. Methodology

2.1. Meteors Database

We selected a sample of meteors which were observed in mexican territory from the Geostationary Lightning Mapper (Goodman et al., 2013). Orignally this project was designed to detect ligthning activity in earth's athmosphere, but has been proven that also can detect bolides entering the athmosphere. The detection comes from two satellites called GOES-16 and GOES-17 orbiting the earth in geostationary orbits. We used the interactive database available at `https://neo-bolide.ndc.nasa.gov/#/`. These data are publicly available and easily downloaded from the same website. For each event we can obtain the recorded trajectory of meteors and the corresponding light curve. THe GLM satellites have an umbral magnitude for detection of -14. At this magnitude, a meteor is considered a bolide, and is expected to be at least decimeter-sized (in diameter) to reach such brightness. In the other hand, too bright meteors will saturate the detectors, and thus, lowering the quality of data. The result of this factors implies that the range in size of the objects in our sample varies in diameter between decimeter to meter size. Each event also has assigned a confidence ratio, from low confidence to high, depending in how bright is the event itself and if the trajectory recorded by GLM ressembles (or not) a straight line. We chose only events whose confidence ratio is high, in oreder to be sure we chose the brightest objects, and thus, in the diameter size of bolides, we favored the meter-sized ones. In table 1 we list the object we chose to do this work, order in chronological order. The columns of the table, from left to right are and ID to enumerate the meteors in the sample, the date and time each meteor was detected, the duration of the detection, their respective coordinates and the estimated height of the meteor over the ground at the time of the detection. GOES-16 and GOES-17 systematically detect the meteors at slightly different positions and at slightly different times, so we calculated the mean of the duration, latitude and longitude reported by both satellites for each event, and used the standard deviation as the uncertainties.

From table 1 is also clear that the duration of all the bolides

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0273-1177/

Table 1. List of meteors passing through Mexico. The events are listed in chronological order. The listed duration, latitude and longitude correspond to the mean of the measurements of both GOES satellites. The uncertainties correspond to the respecting mean deviation.

ID	Date of event	Start Time (UT)	Duration (seconds)	Latitude (deg)	Longitude (deg)	Height (km)
01	2019-05-23	16:36:18	0.197 ± 0.0000	24.30 ± 0.000	−101.60 ± 0.849	28
02	2019-07-18	14:30:30	0.058 ± 0.0000	27.20 ± 0.000	−103.15 ± 0.778	72
03	2019-08-10	11:18:48	0.199 ± 0.0757	21.50 ± 0.000	−102.50 ± 0.849	92
04	2019-10-03	07:55:33	0.106 ± 0.0297	25.65 ± 0.071	−96.25 ± 0.778	74
05	2019-10-09	06:08:11	0.103 ± 0.0078	23.60 ± 0.000	−111.95 ± 0.212	32
06	2019-11-16	09:36:04	0.396 ± 0.0134	20.30 ± 0.000	−100.55 ± 0.919	82
07	2019-11-17	15:36:01	0.116 ± 0.0035	31.70 ± 0.000	−117.70 ± 1.131	88
08	2019-11-19	07:57:40	0.097 ± 0.1138	20.00 ± 0.000	−88.40 ± 1.131	99
09	2019-11-26	13:23:20	0.078 ± 0.0290	23.90 ± 0.000	−108.70 ± 0.849	81
10	2019-12-04	09:42:54	0.173 ± 0.0028	31.50 ± 0.000	−113.65 ± 0.919	77
11	2019-12-15	14:50:49	0.127 ± 0.0134	27.70 ± 0.000	−114.10 ± 0.849	78
12	2019-12-29	16:16:35	0.062 ± 0.0134	29.60 ± 0.000	−116.35 ± 0.919	79
13	2020-01-03	14:10:17	0.113 ± 0.0085	30.20 ± 0.000	−117.65 ± 0.919	74
14	2020-01-06	16:39:27	0.118 ± 0.0042	31.40 ± 0.000	−108.20 ± 0.990	81
15	2020-01-15	15:00:33	0.213 ± 0.1351	19.45 ± 0.071	−95.55 ± 0.919	93
16	2020-02-12	09:25:40	0.210 ± 0.0226	18.90 ± 0.000	−93.50 ± 0.849	90
17	2020-03-03	12:33:27	0.062 ± 0.0007	18.25 ± 0.071	−106.35 ± 0.636	77
18	2020-03-31	19:31:52	0.105 ± 0.0573	28.45 ± 0.071	−112.05 ± 0.636	61
19	2020-04-08	16:25:28	0.120 ± 0.0926	26.10 ± 0.000	−93.90 ± 0.849	78
20	2020-04-18	17:43:25	0.139 ± 0.0106	29.00 ± 0.000	−106.55 ± 0.919	82
21	2020-04-20	16:05:22	0.318 ± 0.1655	28.15 ± 0.071	−97.85 ± 1.061	88
22	2020-04-25	11:03:09	0.323 ± 0.0813	32.15 ± 0.071	−111.60 ± 1.131	84
23	2020-04-28	19:31:52	0.105 ± 0.0573	28.45 ± 0.071	−112.05 ± 0.636	29
24	2020-05-08	10:06:16	0.490 ± 0.0750	21.60 ± 0.000	−92.40 ± 0.849	81
25	2020-07-15	19:58:28	0.693 ± 0.0495	24.00 ± 0.000	−108.35 ± 0.495	53
26	2020-08-07	13:29:57	0.163 ± 0.0057	28.80 ± 0.000	−106.05 ± 0.919	89
27	2020-09-13	16:41:59	0.184 ± 0.0078	28.45 ± 0.071	−113.75 ± 0.919	85
28	2020-09-30	12:28:11	0.100 ± 0.0078	24.90 ± 0.000	−110.90 ± 0.849	83
29	2020-11-16	12:28:11	0.100 ± 0.0078	24.90 ± 0.000	−110.90 ± 0.849	06
30	2020-11-17	12:53:41	0.404 ± 0.0262	23.00 ± 0.000	−102.45 ± 0.919	93
31	2020-12-19	10:18:14	0.407 ± 0.0110	21.95 ± 0.071	−101.60 ± 0.990	98
32	2020-12-23	09:43:01	0.148 ± 0.0014	25.75 ± 0.071	−111.25 ± 0.778	81
33	2020-12-29	15:20:54	0.118 ± 0.0014	16.80 ± 0.000	−102.20 ± 0.707	81
34	2021-03-31	09:01:17	0.753 ± 0.3083	20.15 ± 0.071	−92.95 ± 0.212	24

detection last less than a second. This obsevation suggests that the bolides remain undetected by the GLM satellites until they get fragmented due to stagnation presure when they release a huge amount of energy and thus they become detectable.

2.2. GPS data

This material is based on services provided by the GAGE Facility, operated by UNAVCO, Inc., with support from the National Science Foundation and the National Aeronautics and Space Administration under NSF Cooperative Agreement EAR-1724794.

We got RINEX data from 3 to 7 stations depending of the event location and data availability that surround the event place in all directions as possible. A list of the stations where we got RINEX data is available in table . Most of the stations lie in mexican territory, but in some cases we required data from other stations to cover events near the mexican frontier at north or south.

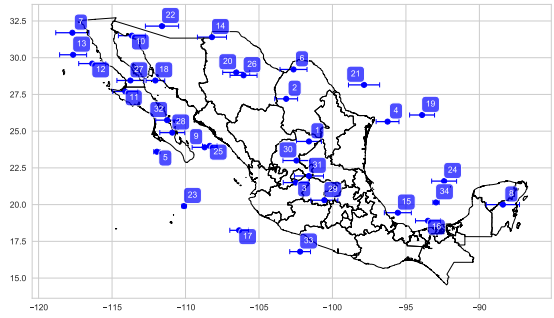

Fig. 1. Positions of events from table 1. The label of each point correspond to the ID (first column) of the referred table.

Table 2: List of GPS stations used for this work.

Station name	Latitude	Longitude	Date of events		Citation
BAR1[15]	33.48	-119.03	2019-12-29	2020-01-03	UNAVCO Community, Hudnut, Kenneth, King, Nancy, Aspiotes, Aris G., Borsa, Adrian A., Determan, Daniel N., Galetzka, John E., Stark, Keith F., 2005, SCIGN-PBO Nucleus GPS Network - BAR1-Santa Barbara Island One P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5668BHN.
BLYT[1]	33.61	-114.71	2019-12-29	2020-01-03	Hudnut, Kenneth, King, Nancy, Aspiotes, Aris G., Borsa, Adrian A., Determan, Daniel N., Galetzka, John E., Stark, Keith F., 2006, SCIGN USGS GPS Network - BLYT-Blythe P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5HT2MKK.
CN23	17.26	-88.78	2019-11-19 2020-02-12	2020-01-15	UNAVCO Community, 2012, COCONet GPS Network - CN23-BelmopanBZCR2012 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5Q23XJH.
CN25	16.23	-92.13	2020-01-15		UNAVCO Community, 2014, COCONet GPS Network - CN25-ComitandDMEX2012 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T57W69G7.
GCFS	19.31	-81.18	2019-11-19		Watts, Anthony, 2016, COCONet GPS Network - GCFS-G_CAYMAN_CYM2014 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/7ETV-X536.
GMPK[1]	33.05	-114.83	2019-12-04		UNAVCO Community, Hudnut, Kenneth, King, Nancy, Aspiotes, Aris G., Borsa, Adrian A., Determan, Daniel N., Galetzka, John E., Stark, Keith F., 2005, SCIGN-PBO Nucleus GPS Network - GMPK-Glamis Peak P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/WCHN-H687.
GUAT[2]	14.59	-90.52	2020-02-12		DeMets, Charles, Cosenza-Muralles, Beatriz, 2021, Central America 2018 - Guatemala, The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/KH2R-K704.
GUAX[1]	28.88	-118.29	2019-10-09 2019-12-29 2020-03-31 2020-09-13 2020-12-23	2019-12-15 2020-01-03 2020-07-15 2020-09-30	Hudnut, Kenneth, King, Nancy, Aspiotes, Aris G., Borsa, Adrian A., Determan, Daniel N., Galetzka, John E., Stark, Keith F., 2001, SCIGN USGS GPS Network - GUAX-Isla Guadalupe P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5GX48T2.
IAGX	29.03	-113.17	2019-12-04		Gonzalez-Ortega, Alejandro, Galetzka, John E., Gonzalez, Javier, 2018, CICESE REGNOM GPS Network - IAGX-iagxREGNOMmx2018 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/DGWN-A627.

INEG	21.85	-102.28	2020-07-15	2020-08-07	No citations were found
			2020-09-30	2020-11-16	
			2020-11-17	2020-12-19	
KVTX	27.55	-97.89	2019-05-23	2019-07-18	UNAVCO Community, 2007, PBO GPS Network - KVTX-KingsvilleTX2006 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5J38QH8.
			2019-08-10	2019-10-03	
			2019-11-17	2020-04-08	
			2020-04-18	2020-04-20	
			2020-05-08	2020-08-07	
MDO1	30.68	-104.02	2019-07-18		No citations were found
MGO5	30.68	-104.02	2020-04-20	2020-08-07	No citations were found
MGW3	29.62	-89.95	2020-04-08	2020-04-20	No citations were found
			2020-05-08		
OXTH	16.29	-95.24	2020-01-15	2020-02-12	DeMets, Charles, Cabral-Cano, Enrique, 2008, Oaxaca GPS Network - OXTH-Tehuantepec P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5Q81B5V.
OXUM[3]	15.66	-96.50	2021-03-31		Cabral-Cano, Enrique, Salazar-Tlaczani, Luis, 2015, TLALOCNet - OXUM-oxum_tnet_mx2001 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5J964RP.
P001	31.95	-112.80	2020-04 25		UNAVCO Community, 2008, PBO GPS Network - P001-Organ_PipeAZ2007 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5DR2SGP.
P014	31.97	-11.09	2019-12-04	2019-12-29	UNAVCO Community, 2008, PBO GPS Network - P014-Sahuarita_AZ2007 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5DJ5CMK.
			2020-01-03	2020-01-06	
			2020-04-25		
P807	30.49	-98.82	2019-11-17	2020-01-06	UNAVCO Community, 2012, PBO GPS Network - P807-EcRockStPkTX2012 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5TQ5ZKM.
			2020-04-20	2020-11-17	
PLPX	31.59	-115.15	2019-12-04		UNAVCO Community, 2011, PBO GPS Network - PLPX-Las_PintasMX2010 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5K64G3T.
PTEX	32.29	-116.52	2019-12-29	2020-01-03	UNAVCO Community, 2011, PBO GPS Network - PTEX-Testerazo_MX2011 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5610XBP.
			2020-09-13	2020-12-23	

RG06	32.63	-107.86	2020-04-25		Sheehan, Anne, 2007, Rio Grande Rift GPS Network - RG06-RG06FaywodNM2006 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5668BFR.
RG07	32.50	-106.84	2020-01-06		Sheehan, Anne, 2007, Rio Grande Rift GPS Network - RG07-RG07CrucesNM2006 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5KD1W45.
SG33	31.77	-106.51	2019-11-17 2020-08-07	2020-04-18	Harder, Steven, Kaip, Galen, Montana, Carlos, 2004, SuomiNet-G GPS Network - SG33-UTEP P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T50863KQ.
TGMX	20.87	-86.87	2021-03-31		UNAVCO Community, 2015, COCONet GPS Network - TGMX-PtoMor_TG_MX2015 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5154FB7.
TNAM	20.54	-103.97	2020-03-03 2020-09-30 2020-11-17	2020-07-15 2020-11-16 2020-12-19	UNAVCO Community, 2014, TLALOCNet - TNAM-TNAM_TNET_MX2014 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5QF8R4R.
TNAT	18.13	-98.04	2020-01-15		UNAVCO Community, 2014, TLALOCNet - TNAT-TNAT_TNET_MX2014 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5G15Z4S.
TNBA	28.97	-113.55	2019-10-09 2019-12-15 2020-01-03	2019-11-26 2019-12-29	UNAVCO Community, 2015, TLALOCNet - TNBA-TNBA_TNET_MX2014 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T57M0688.
TNCC	18.79	-103.17	2020-03-03		UNAVCO Community, 2015, TLALOCNet - TNCC-TNCC_TNET_MX2015 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T50R9MSK.
TNCM	19.50	-105.04	2020-03-03	2020-04-28	UNAVCO Community, 2014, TLALOCNet - TNCM-TNCM_TNET_MX2014 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5B856FW.
TNCN	18.55	-101.97	2020-11-16	2020-12-29	UNAVCO Community, 2016, TLALOCNet - TNCN-TNCN_TNET_MX2016 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5610XQM.

TNCU	28.45	-106.79	2019-05-23 2019-08-10 2019-12-15 2020-03-31 2020-07-15 2020-11-17	2019-07-18 2019-11-17 2020-01-06 2020-04-18 2020-08-07 2020-12-19	UNAVCO Community, 2014, TLALOCNet - TNCU-CuauhtemocTN2014 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5V69GV2.
TNGF	19.33	-99.18	2020-11-16	2020-12-29	Cabral-Cano, Enrique, Salazar-Tlaczani, Luis, 2016, TLALOCNet GPS Network - TNGF_Geofisica-UNAM_Mexico_City_TNET_mx2015 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T53X851M.
TNHM	29.08	-110.97	2019-10-09 2019-12-04 2019-12-29 2020-03-31 2020-07-15 2020-09-13 2020-12-23	2019-11-26 2019-12-15 2020-01-03 2020-04-18 2020-08-07 2020-09-30	UNAVCO Community, 2014, TLALOCNet - TNHM-hermosilloTN2014 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5KP80FV.
TNMS	20.53	-104.80	2019-10-09 2019-12-15 2020-07-15	2019-11-26 2020-03-03	UNAVCO Community, 2014, TLALOCNet - TNMS-TNMS_TNET_MX2014 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T56H4FQ5.
TNNP	16.12	-97.14	2020-04-28		Cabral-Cano, Enrique, Salazar-Tlaczani, Luis, DeMets, Charles, 2016, TLALOCNet - TNNP-tnnp_tnet_mx2015 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5N29V96.
TNNX	17.41	-97.22	2020-01-15 2020-12-29	2020-02-12 2021-03-31	UNAVCO Community, 2014, TLALOCNet - TNNX-TNNX_TNET_MX2014 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T52R3PZ0.
TNPP	31.34	-113.63	2019-12-04 2020-04-25	2020-03-31	UNAVCO Community, 2015, TLALOCNet - TNPP-TNPP_TNET_MX2015 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5CC0Z0M.
TNSJ	16.17	-96.49	2020-12-29		UNAVCO Community, 2016, TLALOCNet - TNSJ-tnsj_tnet_mx2015 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T59S1PF1.
TSFX	30.93	-114.81	2020-09-13	2020-12-23	Gonzalez-Ortega, Alejandro, Galetzka, John E., Gonzalez, Javier, 2018, CICESE REGNOM GPS Network - TSFX-tsfxREGNOMmx2016 P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/AGEA-2G27.

UAGU	21.92	-102.32	2019-05-23	2019-07-18	Cabral-Cano, Enrique, Salazar-Tlaczani, Luis, 2015, TLALOCNet -
			2019-08-10	2019-10-03	UAGU-uagu_tnet_mx2008 P.S., The GAGE Facility operated by UN-
			2019-11-17	2019-11-26	AVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/
			2019-12-15	2020-04-18	10.7283/T5513WK7.
UCOE[3]	19.81	-101.69	2019-08-10	2020-11-16	Cabral-Cano, Enrique, Salazar-Tlaczani, Luis, 2015, TLALOCNet -
			2020-11-17	2020-12-19	UCOE-ucoe_tnet_mx2003 P.S., The GAGE Facility operated by UN-
					AVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/
					10.7283/T51834VW.
UGEO[4]	20.69	-103.35	2019-08-10		Marquez-Azua, Bertha, DeMets, Charles, Cabral-Cano, En-
					rique, Salazar-Tlaczani, Luis, 2015, TLALOCNet - UGEO-
					ugeo_tnet_mx1998 P.S., The GAGE Facility operated by
					UNAVCO, Inc., GPS/GNSS Observations Dataset, https:
					//doi.org/10.7283/T58S4N9N.
UHSL	29.57	-95.65	2020-04-08		Wang, Guoquan, 2014, HoustonNet GPS Network - UHSL-
					SugarLandUSA2014 P.S., The GAGE Facility operated by UNAVCO,
					Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/
					T55X271S.
UHWL	30.06	-94.98	2020-12-19		Wang, Guoquan, 2014, HoustonNet GPS Network - UHWL-West Lib-
					erty Airport(Deep) P.S., The GAGE Facility operated by UNAVCO,
					Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/
					T53R0R5P.
UNPM	20.86	-86.86	2019-11-19	2020-01-15	UNAVCO Community, 2012, COCONet GPS Network - UNPM-
			2020-02-12	2020-05-08	Puerto_Morelos_MX_2007 P.S., The GAGE Facility operated by UN-
					AVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/
					10.7283/J1GD-5S40.
USMX	29.82	-109.68	2019-12-29	2020-01-03	Bennett, Rick, 2004, Northwest Mexico GPS Network - USMX-
			2020-01-06	2020-04-25	Universidad de la Sierra P.S., The GAGE Facility operated by UN-
			2020-08-07	2020-09-30	AVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/
					10.7283/T5W957CQ.
UXAL[3]	19.52	-96.92	2019-10-03	2020-01-15	Cabral-Cano, Enrique, Salazar-Tlaczani, Luis, 2015, TLALOCNet -
			2020-02-12	2020-04-08	UXAL-uxal_tnet_mx2005 P.S., The GAGE Facility operated by UN-
			2020-05-08	2020-12-19	AVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/
			2021-03-31		10.7283/T5DJ5D1C.
WEPD	29.69	-95.23	2020-04-20		Wang, Guoquan, 2014, HoustonNet GPS Network - WEPD-
					willmselementary P.S., The GAGE Facility operated by UNAVCO,
					Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/
					T5NZ85RB.
WMOK	34.74	-98.78	2020-04-20		UNAVCO Community, 2005, PBO GPS Network - WMOK-
					WichitaMtnOK2005 P.S., The GAGE Facility operated by UNAVCO,
					Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/
					T59021Q6.

WWMT[1]	33.96	-116.65	2019-12-29	2020-01-03	Hudnut, Kenneth, King, Nancy, Aspiotes, Aris G., Borsa, Adrian A., Determan, Daniel N., Galetzka, John E., Stark, Keith F., 2006, SCIGN USGS GPS Network - WWMT-Whitewater Mountain P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5H993F2.
YESX	28.38	-108.92	2019-11-26	2019-12-15	Bennett, Rick, 2004, Northwest Mexico GPS Network - YESX-Yecora P.S., The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/T5RJ4GPF.
			2020-01-06	2020-04-18	
			2020-04-28	2020-07-15	

Related articles:
[1]Hudnut (2002), [2]Garnier et al. (2021), [3]Graham et al. (2016)
[4]B. Marquez-Azua, E. Cabral-Cano, F. Correa-Mora and C. DeMets, 2004. A model for Mexican neotectonics based on Nationwide GPS measurements, 1993-2001, Geofisica Internacional, v. 43, p.319-330
[5]Hudnut, K. W., Y. Bock, J. E. Galetzka, F. H. Webb, and W. H. Young, The Southern California Integrated GPS Network (SCIGN), Proceedings of the International Workshop on Seismotectonics at the Subduction Zone, Y. Fujinawa (ed.), NIED, Tsukuba, Japan, pp. 175-196, 1999

3. Bolides physical parameters

Enter Raul's work here

4. Ionospheric background and vTEC maps

Ionospheric perturbations also can take place due to space weather and geomagnetic storms. So, in order to discard such events we investigated the space weather in the day each event occured. In figure (name) we present the geomagnetic *Kp* index for some events. We discarded events whose Kp index is equal or grater than 4 in the day of the event or shortly before. Also we present in figure (name) the vTEC perturbation maps for the same events in a three day series, centered in the event date. The estimated meteor trajectory, obtained from the GLM data is presented in black, continous line, while the linear fit to the GOES-16 and GOES-17 data are presented with the red dashed line, and work as boudary errors.

5. Discussion

Enter discussion here

6. Acknowledgments

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