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Observation of TGF at High Latitude by the ASIM mission

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UNIS The University Centre in Svalbard

NTNU Det skapende universitet

The aim of the project

Abstract:

- Terrestrial Gamma-ray Flashes (TGFs) are short burst of gamma radiation originating from thunderclouds. They propagate upwards and are then detected by satellites such as AGILE, Fermi and ASIM.
- ASIM is the first mission specifically designed for the study of thunderstorm-related phenomena; it is also placed on the ISS and as such can for the first time detect TGF events up to more than 51 degrees in latitude.
- Highest latitude previously reached: 38 degrees (RHESSI).

Key points:

- For this study: high latitude = 35 – 51 degrees. 11 events already observed.

- Events associated with temperate region thunderstorms, different from the ones produced by deep convection at equatorial and tropical latitudes; moreover, TGFs at such latitudes are expected to experience greater absorption in the troposphere, which makes them more difficult to detect.

- In this work we then present the first high-latitude TGFs ever observed and their characteristics, including meteorological contest and associated radio observations.

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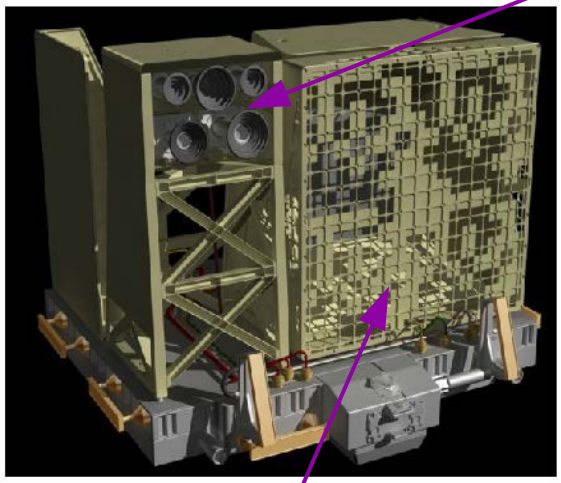
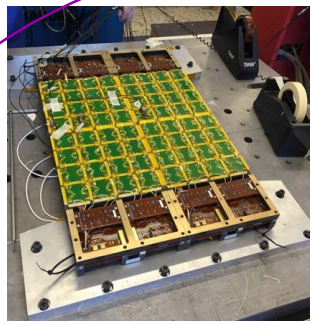
The ASIM instrument on the ISS

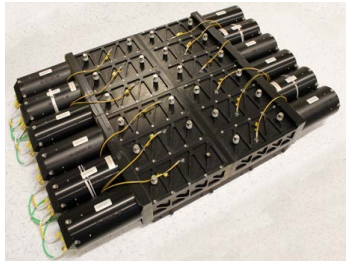


MMIA:
3 photometers
(777nm, 337nm,
180-230nm)
2 cameras (optical)
Flash images

MXGS



LED:
50-400 keV, 1.4 us,
16000 pixels
imaging



HED:
300 keV – 30+ MeV,
<1 us
12 BGO
Lightcurves

Cross-trigger between
MMIA and MXGS, <10us
relative timing accuracy

T. Neubert, The ASIM Mission on the International Space Station, 2019
N. Østgaard, The Modular X- and Gamma-Ray Sensor (MXGS) of the ASIM Payload on the International Space Station, 2019
O. Chanrion, The Modular Multispectral Imaging Array (MMIA) of the ASIM Payload on the International Space Station, 2019

A global map of the events (July 2018 – November 2019)

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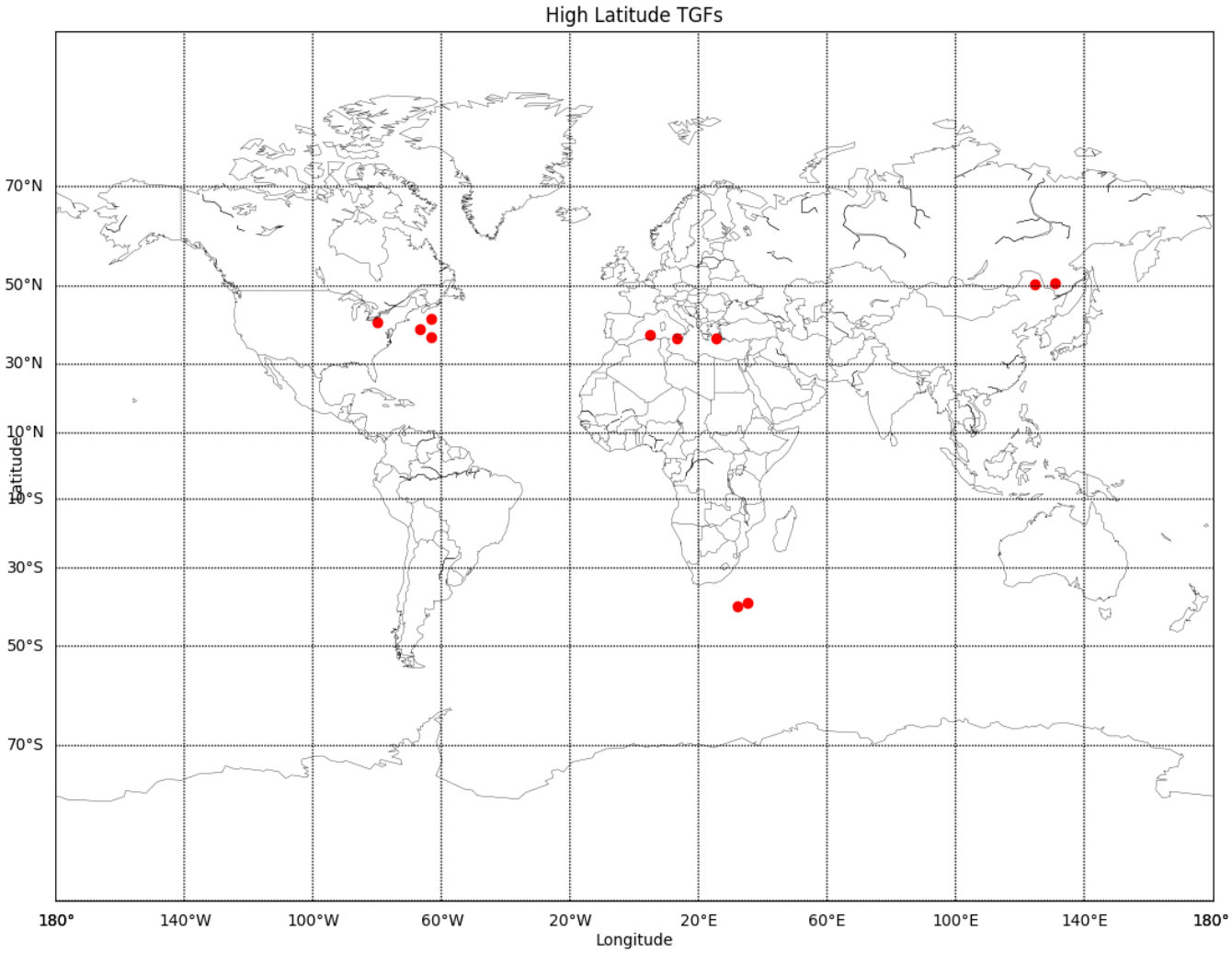

A table of the events (July 2018 – November 2019)

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Date & time	ISS position	duration	BGO counts	CZT counts	MMIA	Corr stroke	Radio data
2018-Jul-11 04:40:43.457977	37.4643 - 63.0745	137us	58	30	yes	WWLLN GLD360	ENTLN
2018-Sep-19 19:26:31.174343	37.0284 13.2947	872us	77	22	yes	WWLLN GLD360	ENTLN
2018-Oct-08 12:38:30.279529	37.9320 5.0118	68us	46	no	no	GLD360	ENTLN
2018-Nov-07 05:45:39.991225	39.4908 - 66.5283	95us	51	29	yes	WWLLN GLD360	ENTLN
2019-Jan-30 08:14:50.492591	-40.1778 32.1287	163us	106	no	no	ENTLN	ENTLN, M.Fullekrug
2019-Jun-13 04:32:02.784997	50.5180 124.7032	36us	45	no	no	no	no
2019-Aug-20 13:06:44.942240	41.1241 - 79.8917	191us	80	no	no	GLD360 LINET	ENTLN, LINET
2019-Aug-30 08:15:37.402629	42.1362 - 63.3404	73us	97	no	no	WWLLN	ENTLN
2019-Sep-06 18:15:00.813463	50.6611 131.0906	121us	142	no	no	WWLLN	ENTLN
2019-Nov-07 09:59:38.773365	-39.4031 35.1491	47 us	30	no	no	ENTLN	ENTLN
2019-Nov-13 03:15:44.385009	37.0133 25.4919	206 us	26	no	no	WWLLN GLD360	ENTLN

The aim of the project /2

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Questions:

- How was the thunderstorm environment?
  - Why was it able to produce a TGF?

- Is the waveform compatible with the ones usually associated with TGFs from tropical latitudes?
- Is the number of events we collected statistically compatible with lightning distribution at high-lat, as observed from space, accounting for higher atmospheric absorption due to lower tropopause? Is there something more?

Method:

- TGF data from July 2018 to November 2019
- Lightning data from: WWLLN, GLD360, ENTLN
- Auxiliary lightning data from: ENTLN, LINET, local campaigns, geostationary satellites
- Correlation with strokes within 30ms (including correction for propagation time)

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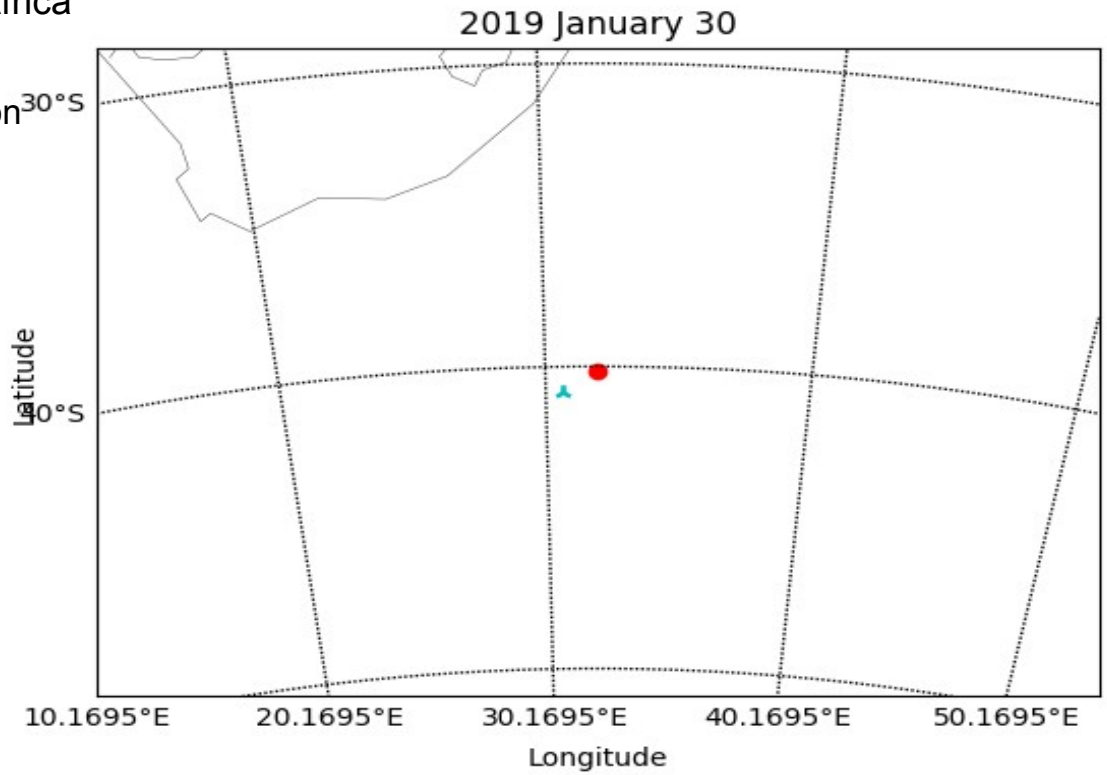
January 30th, 2019

- Timestamp: 08:14:50.492591 (10:23:21 local time)
- Coordinates: -40.1778 32.1287 (South Africa)
- Correlating strokes detected by ENTLN only
- Radio measurements from South Africa

- Case 2019-Nov-07 is from same region



O: ISS coordinates
+: ENTLN strokes

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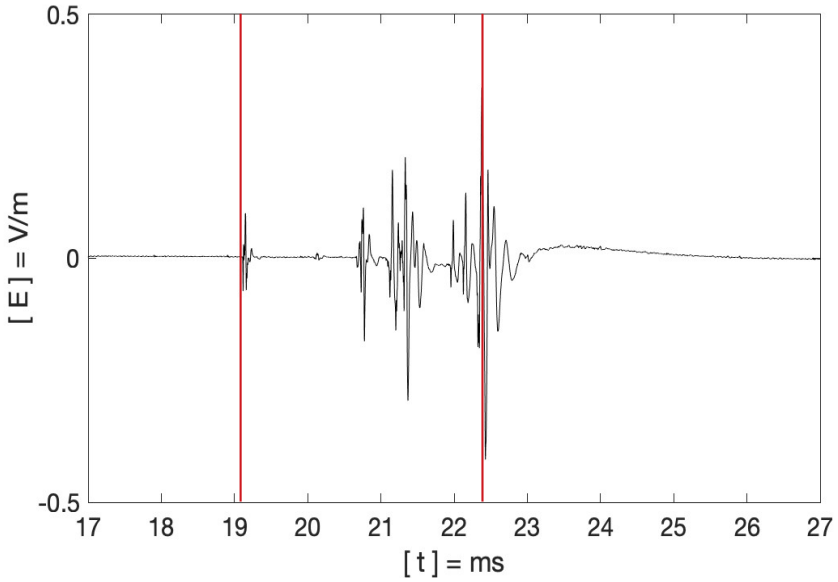
January 30th, 2019: radio data (by M. Fullekrug)



← Global (all frequency bands) waveform as recorded by M. Fullekrug from South Africa (– : parent stroke).

4 pulses of increasing amplitude, time incompatible with sky waves.
TGF may be on first or last pulse (2 ENTLN candidate strokes).

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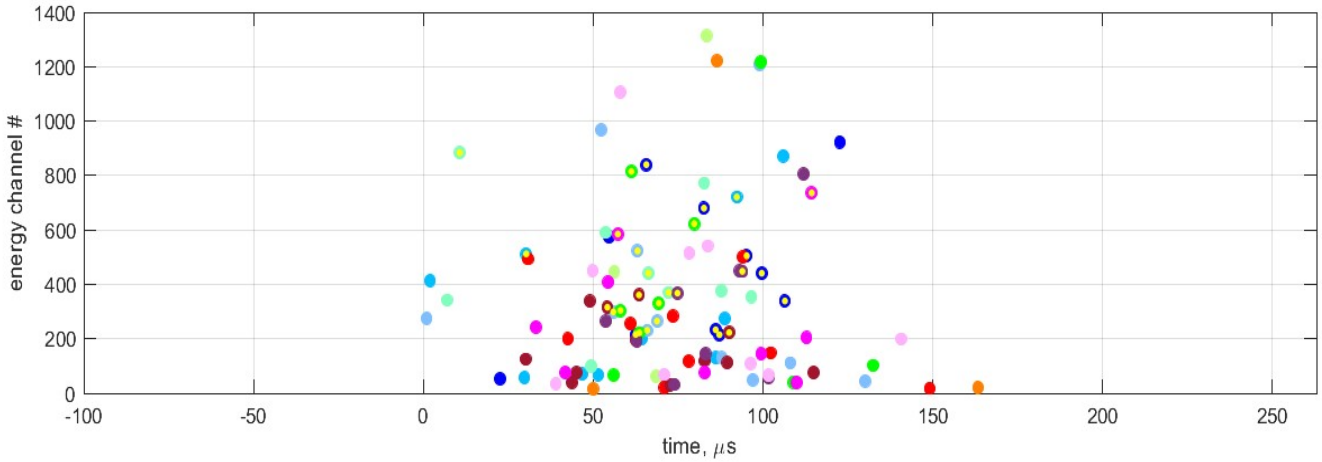
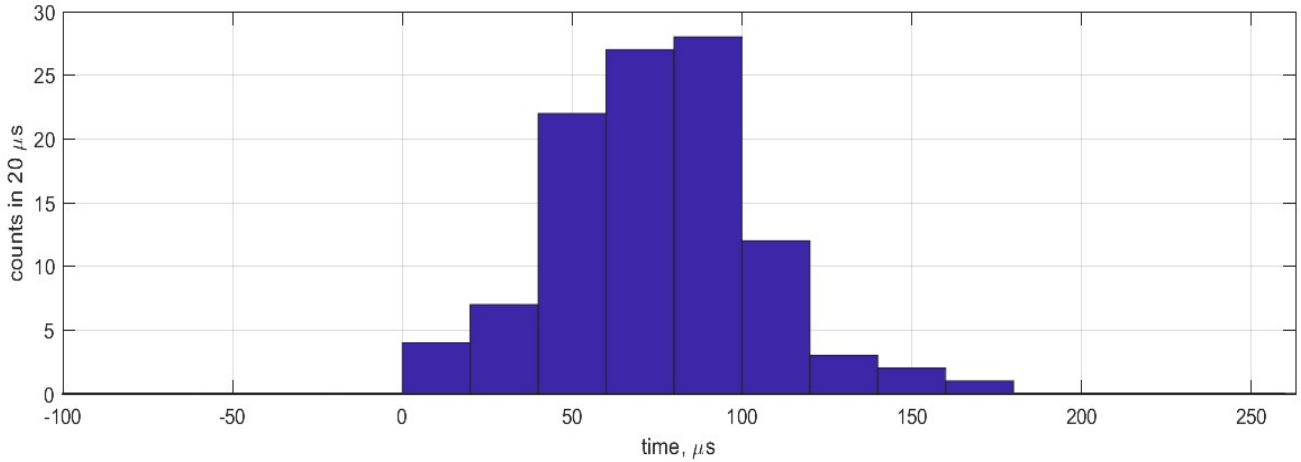
January 30, 2019: Lightcurve (BGO)





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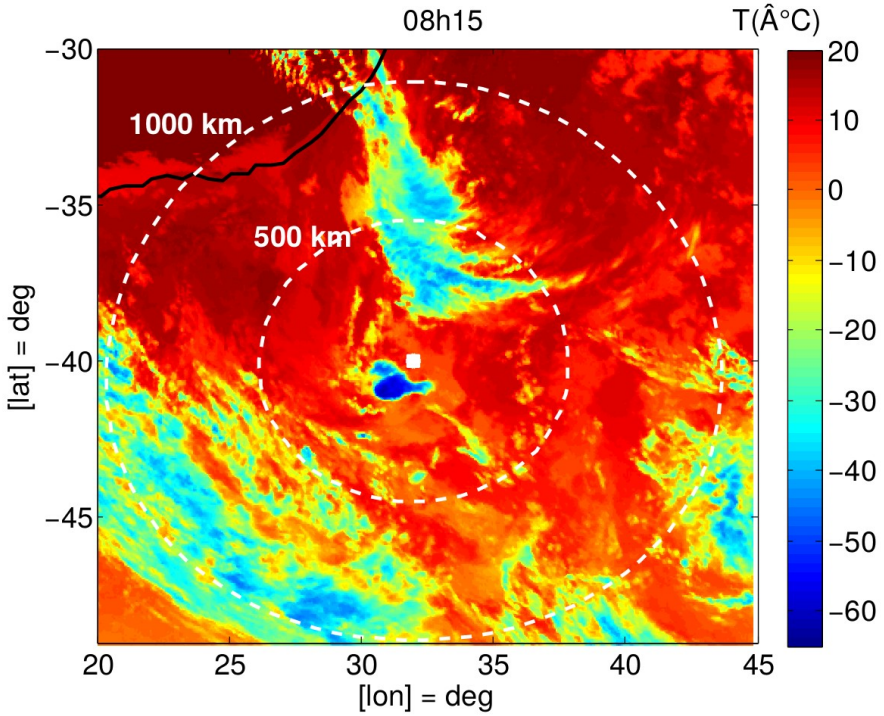
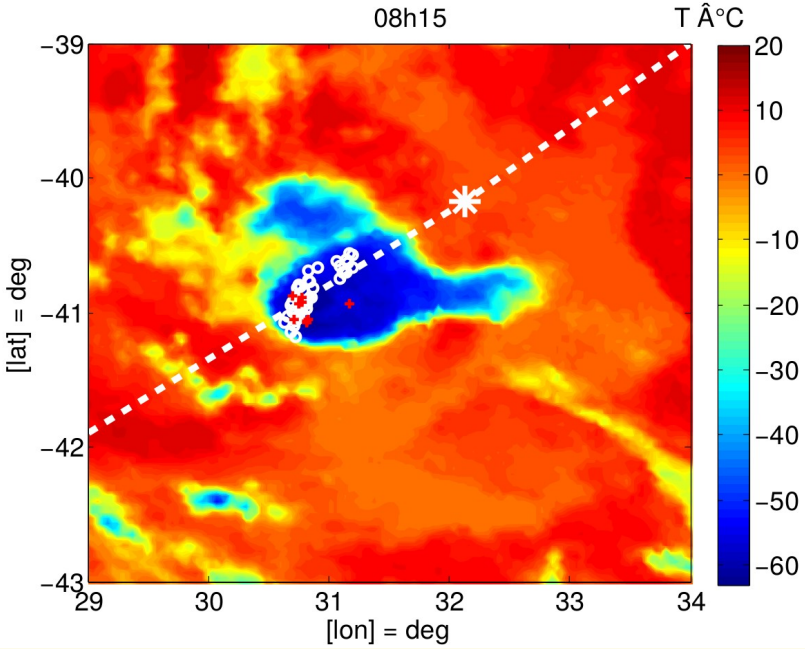
January 30th, 2019: meteorological environment (by S. Soula)



Storm started on Jan 29th inland, decayed during night and intensified again Jan 30th in the morning → TGF came after cycle of decay and re-activation

Lightning activity from 8:10am to 8:20 am
White = -CG
Red = +CG



Minimum temperature at TGF time: -62° C

Absolute minimum temperature: -65.1° C
@ 8:45am (~minimum lightning activity)

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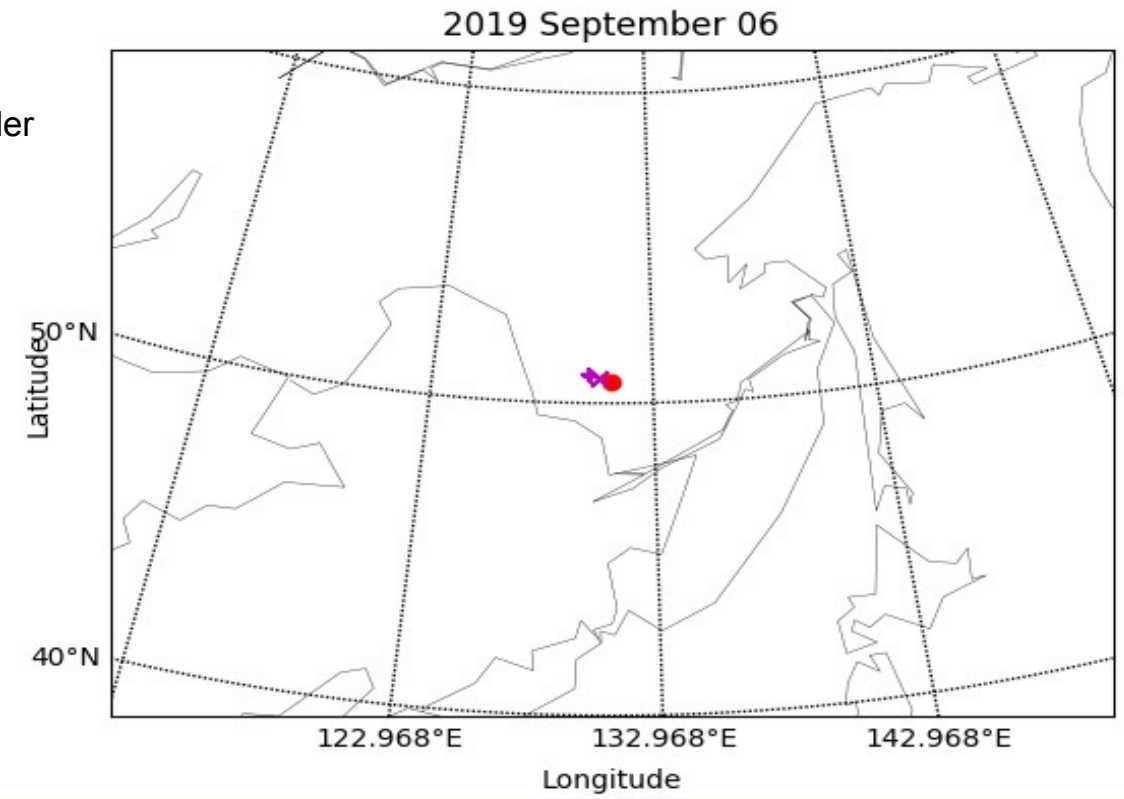
September 06th, 2019

- Timestamp: 18:15:00.813463 (02:59:22 local time)
- Coordinates: 50.6611, 131.0906 (Russia)
- Correlating strokes detected by WWLLN and GLD360
- Waveforms from ENTLN

- Case of 2019-Jul-11 across the border on the left



O: TGF (ISS coordinates)
+: WWLLN strokes (same sec)
X: VAISALA strokes (same sec)

Correlating stroke

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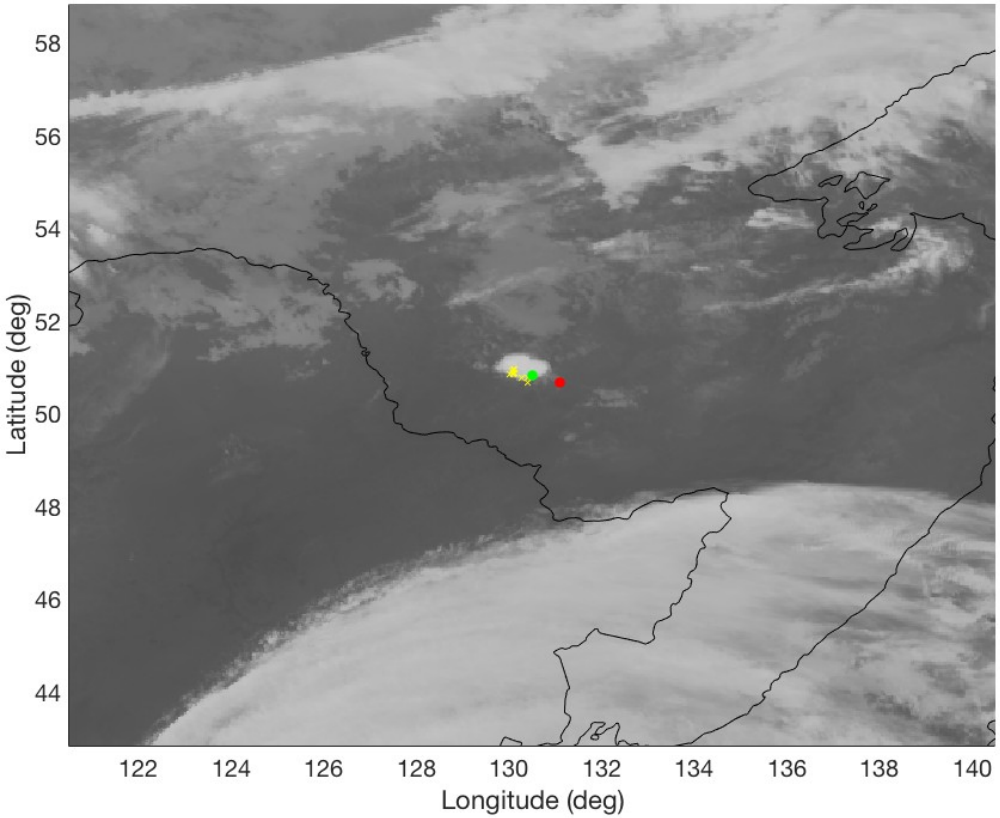
September 06th, 2019

red: TGF (ISS coordinates)
green: correlating WWLLN stroke
yellow: WWLLN strokes +/- 15 min

TGF produced in compact, isolated thunderstorm with low flash activity. Structure similar to the January 30th case.



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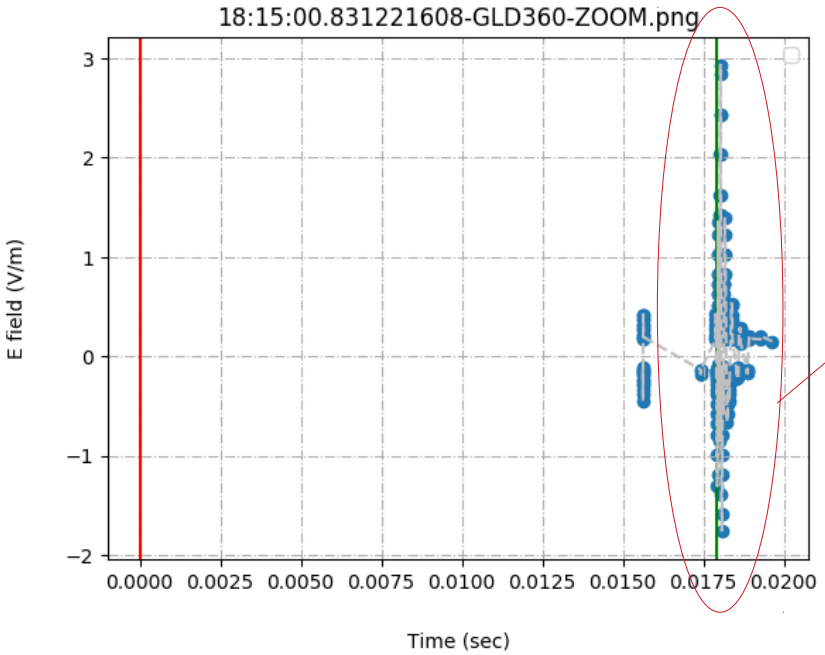
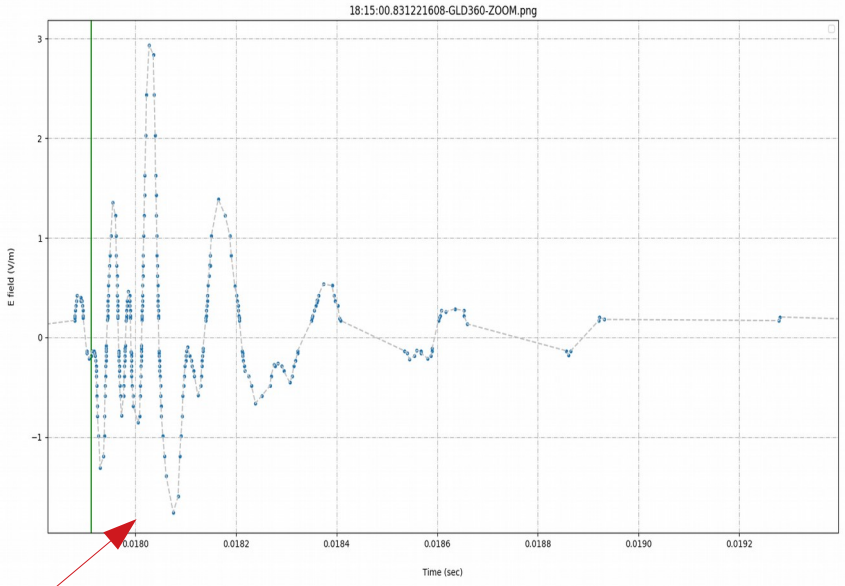
September 06th, 2019: waveform (ENTLN)

– : TGF
– : stroke (GLD360)
O : waveform





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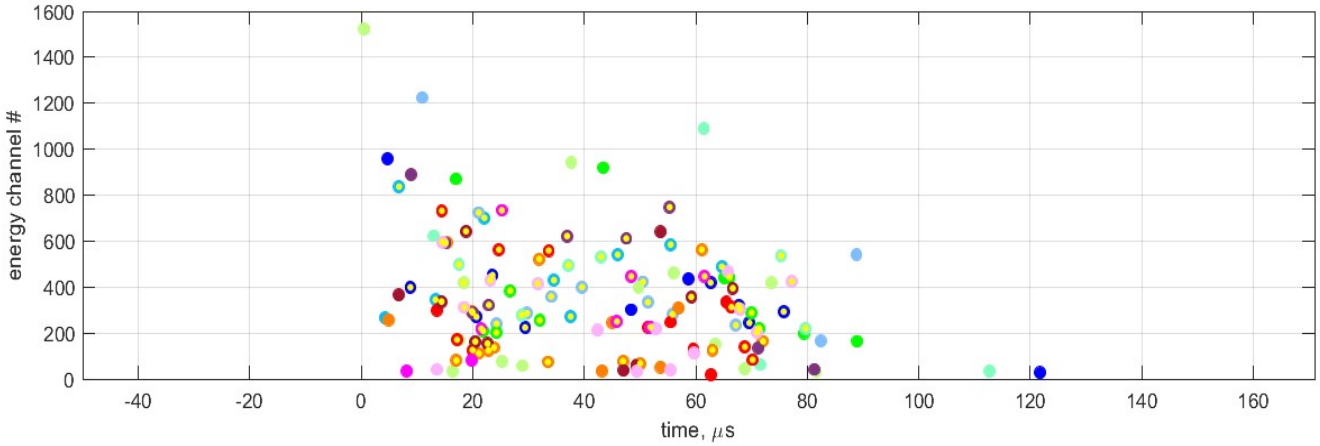
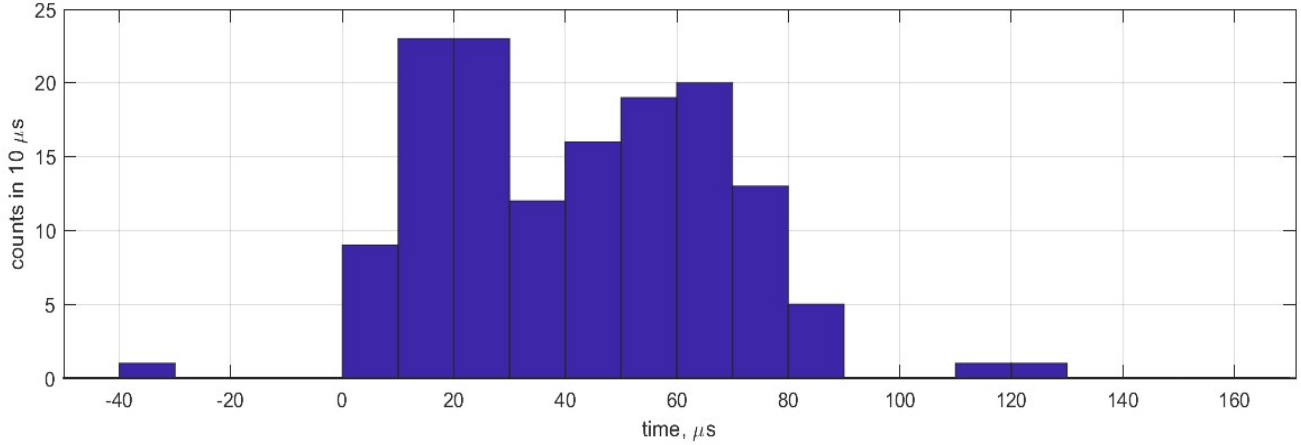
September 06, 2019: Lightcurve (BGO)





Dip = detector saturation (this is not a multipulse TGF)

Summary & Acknowledgments

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- 11 events recorded at high latitude (>35 deg) over the period July 2018 – November 2019
- 4 “chimneys”: U.S.A. atlantic coast, Mediterranean Sea, ocean east of S. Africa, north-east China / south-east Russia
- Most events were produced over smaller storms, but associated strokes are intense ones
- More in-depth meteorological analysis undergoing, as well as analysis of the radio recordings

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- The authors with to thank ICARE consortium for providing Meteosat images.

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Thanks!

More information about ASIM:

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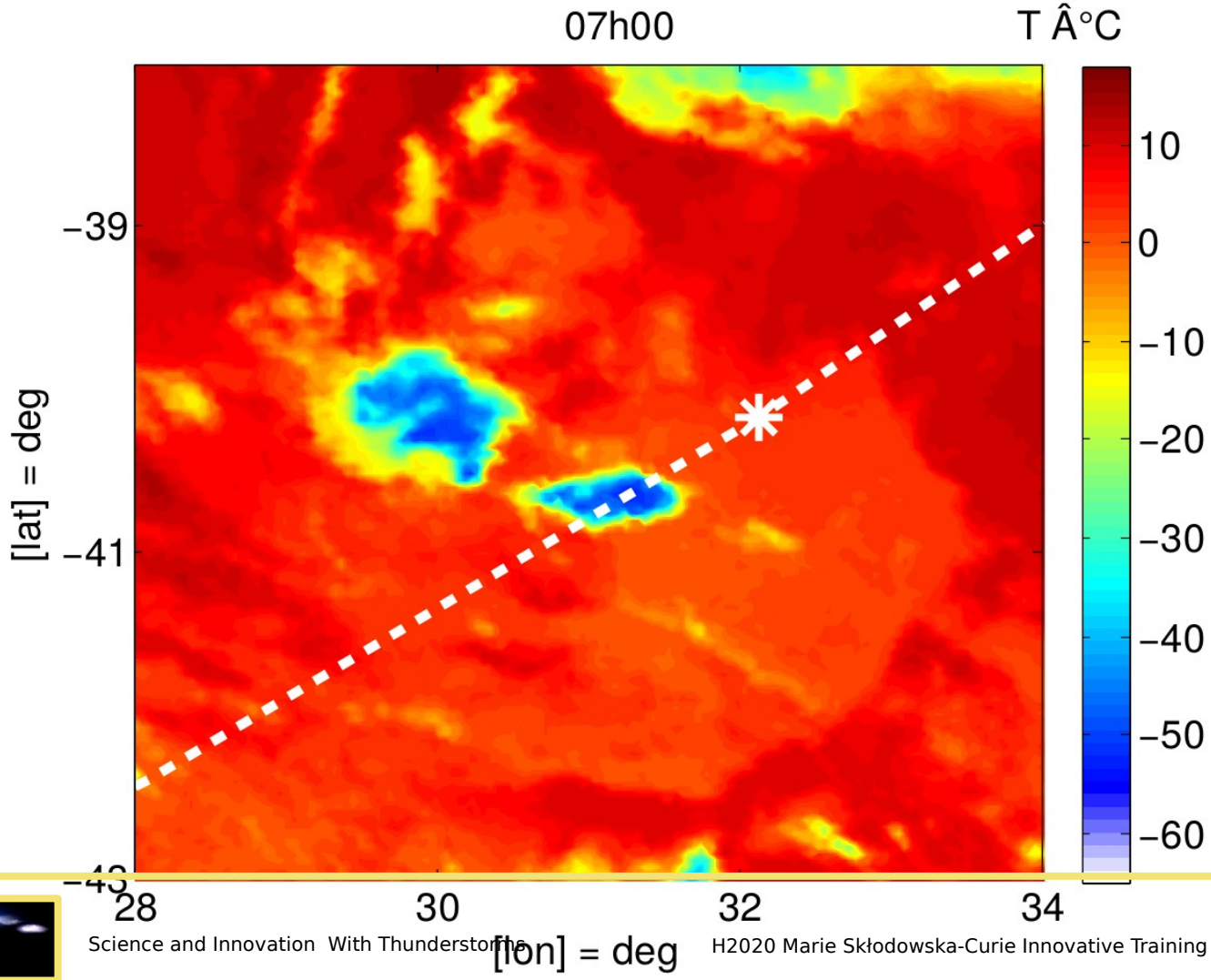
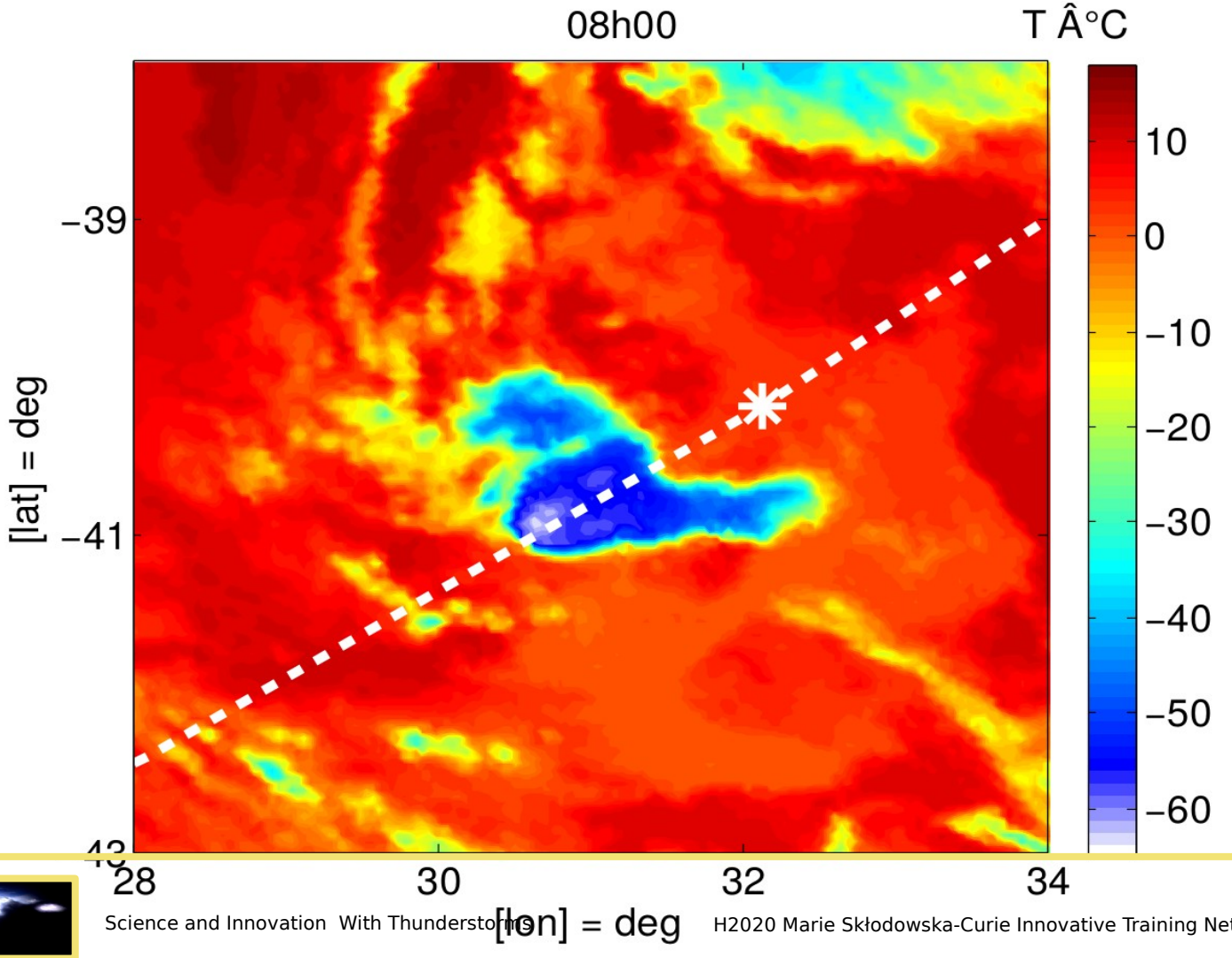
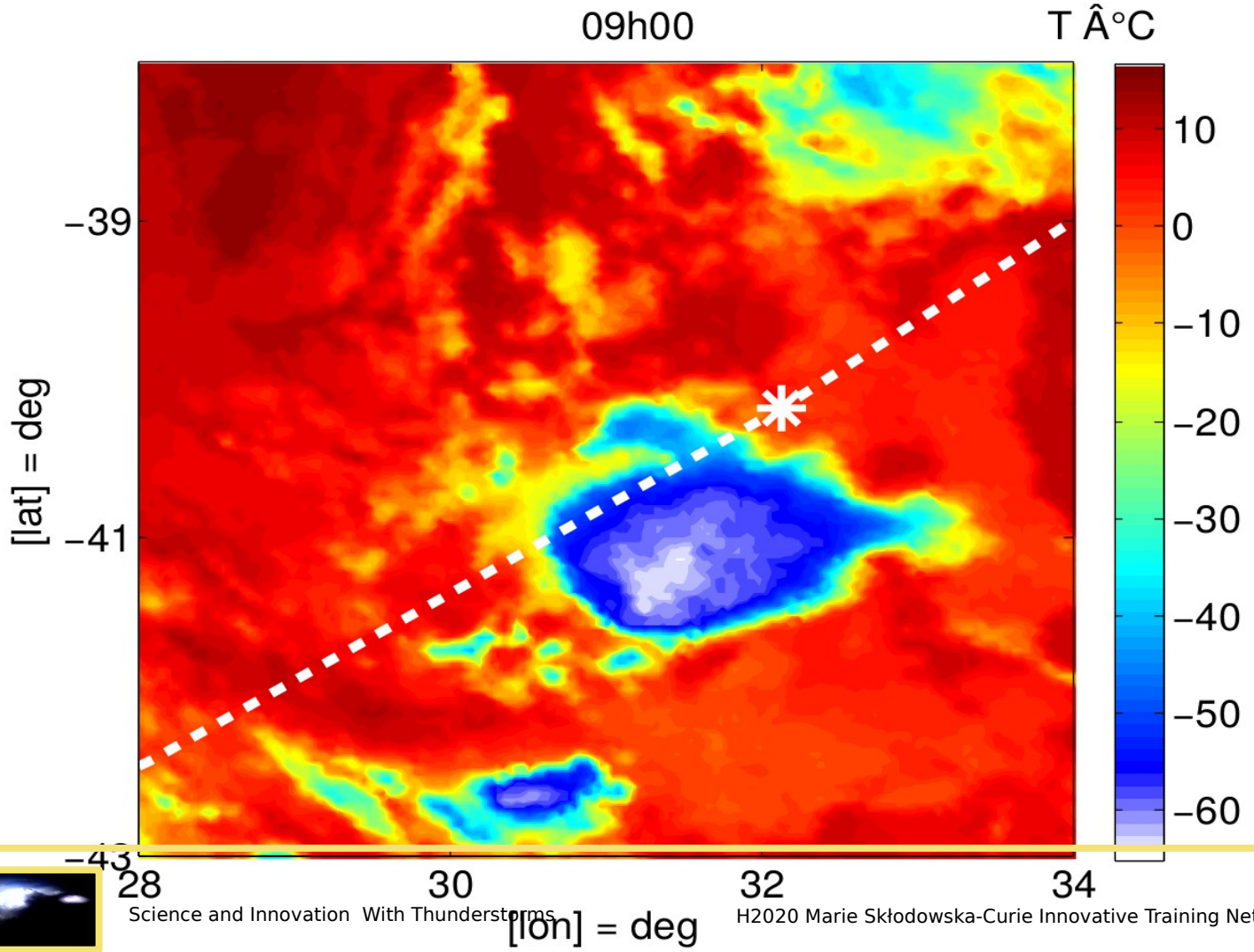
January 30, 2019: storm evolution



January 30, 2019: storm evolution



January 30, 2019: storm evolution



January 30, 2019: storm evolution