SIGNIFICANCE OF SPACE WEATHER IMPACTS ON AUTOMATIC DEPENDENT SURVEILLANCE (ADS) DATA

Erik Schmölter & Jens Berdermann

DLR Institute for Solar-Terrestrial Physics, dept. Space Weather Impact

Automatic Dependent Surveillance (ADS)

Surveillance and management of aircraft and air traffic

Automatic	No external trigger
Dependent	Use of on-board systems
Surveillance	Sharing of information

- ICAO approved system to share aircraft information
  ➔ safe and efficient management

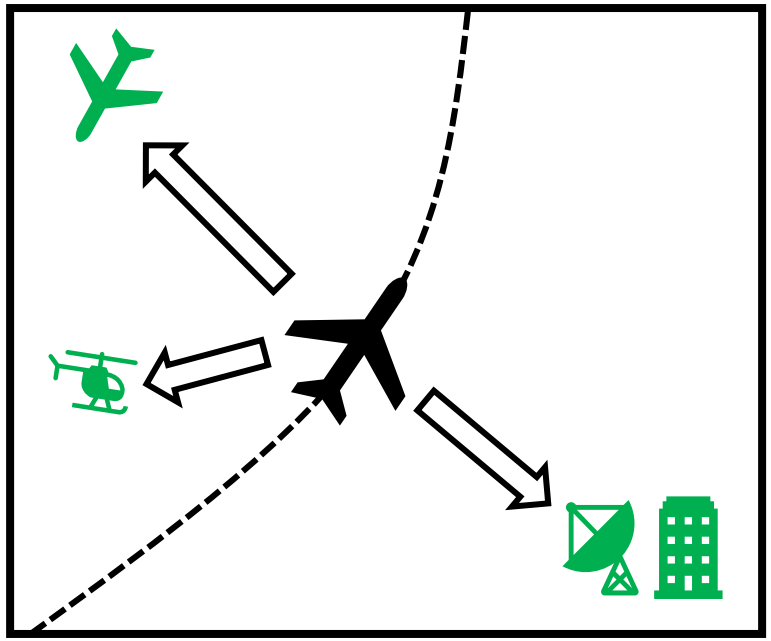
- ADS allows to improve …
  - Situational awareness and visibility of aircraft
  - Environmental impact
  - Air space capacity

Automatic Dependent Surveillance (ADS)

Similar names, but different systems.

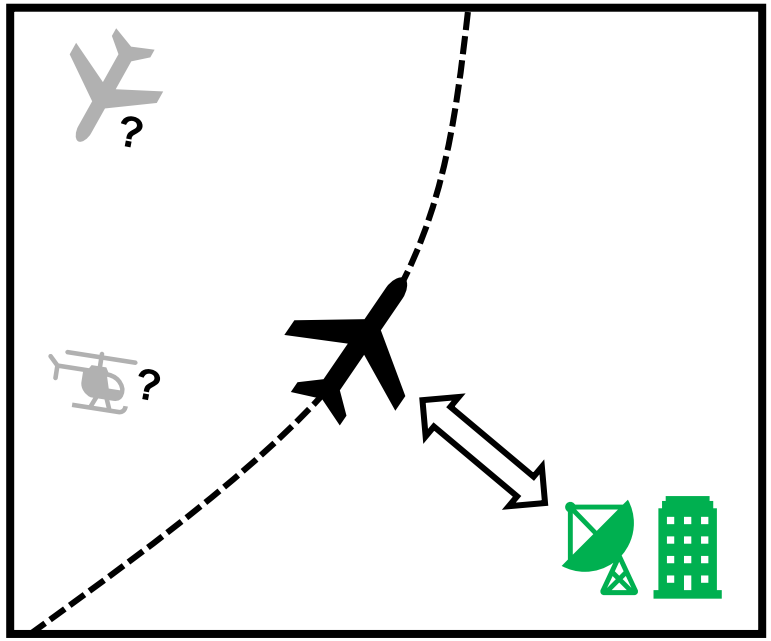
ADS – Broadcast (B)

Aircraft broadcast their identity, position and additional information, which can be used by other aircraft (ADS-B In) or ground systems (ADS-B Out)



ADS – Contract (C)

Aircraft transmit position, altitude, speed and additional information to a specific Air Traffic Services Unit (ATSU) ➔ response to requests in defined contract of aircraft and ground system



Which information are of interest?

ADS – Broadcast (B)

What is broadcasted?

- Identification, horizontal position with latitude and longitude, barometric altitude, quality indicators, …

ADS – Contract (C)

Which contracts can be established?

- Periodic contract: reports at specified time intervals with various groups
- Demand contract: single report according to the periodic contract
- Event contract: report when a specific event occurs ➔ way point change, altitude range, lateral deviation, vertical rate change

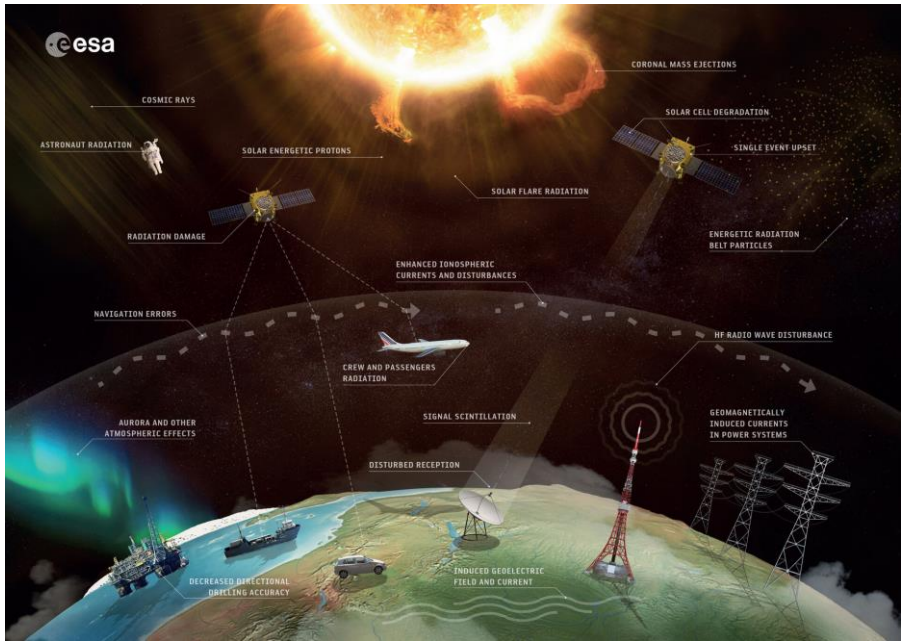
Which groups are included in a report?

- Basic (latitude, longitude, and altitude), flight identification, earth reference, air reference, airframe identification group, meteorological, …

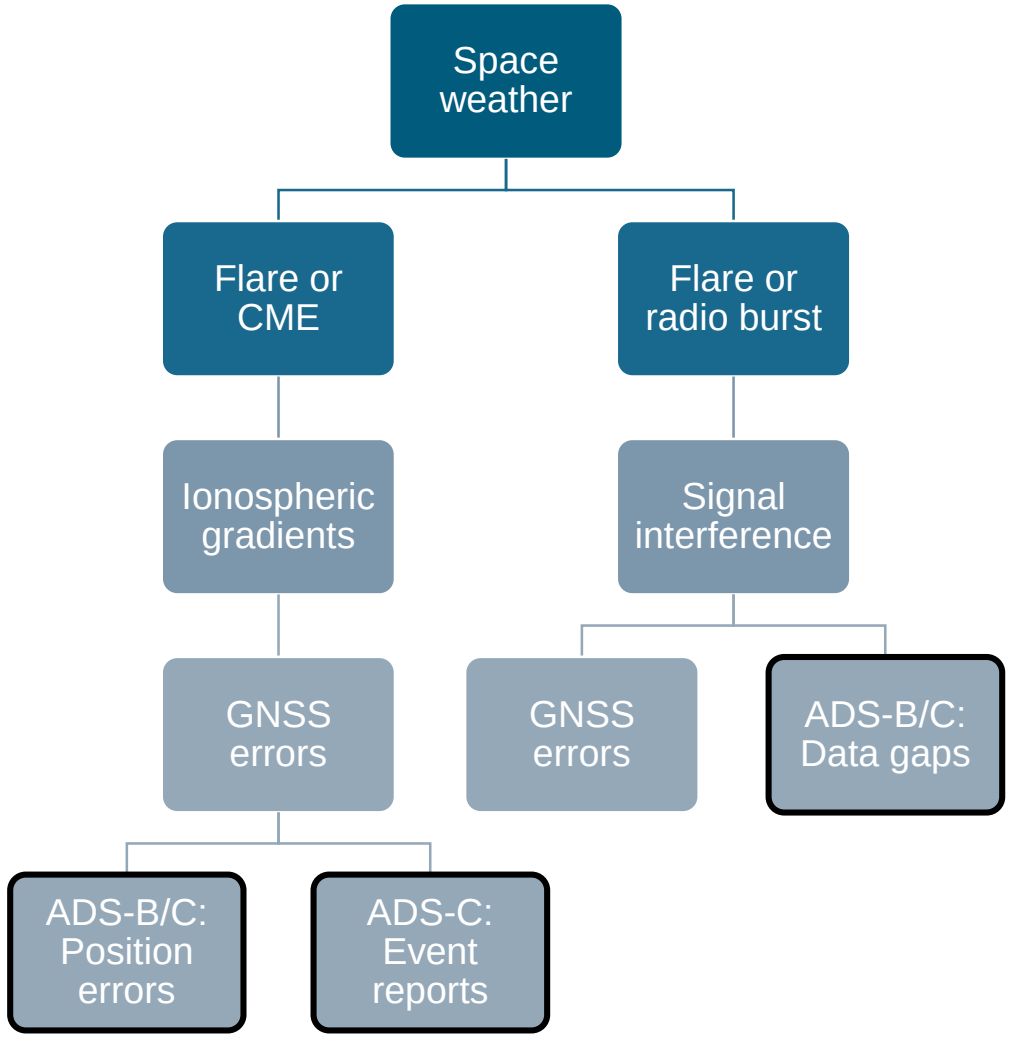
Which events are possible candidates to affect ADS-B/C?

An impact due to space weather could occur, since …

- Transmission via VHF and SATCOM
- Positioning via GNSS

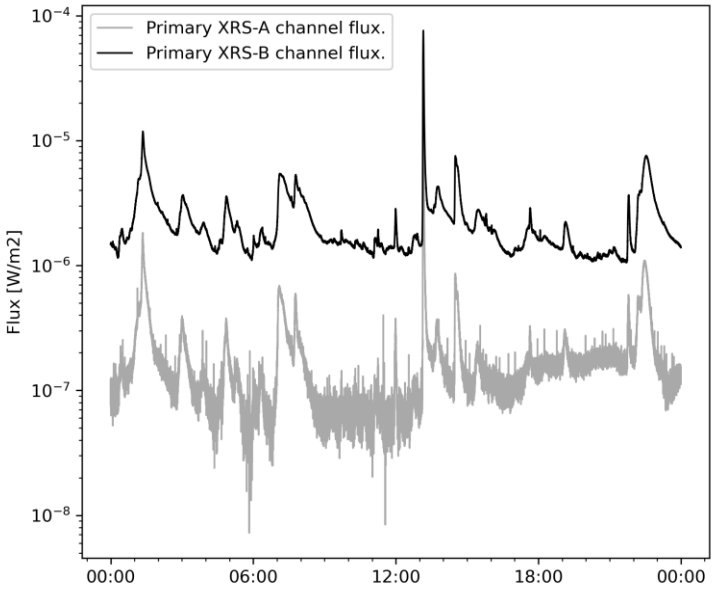


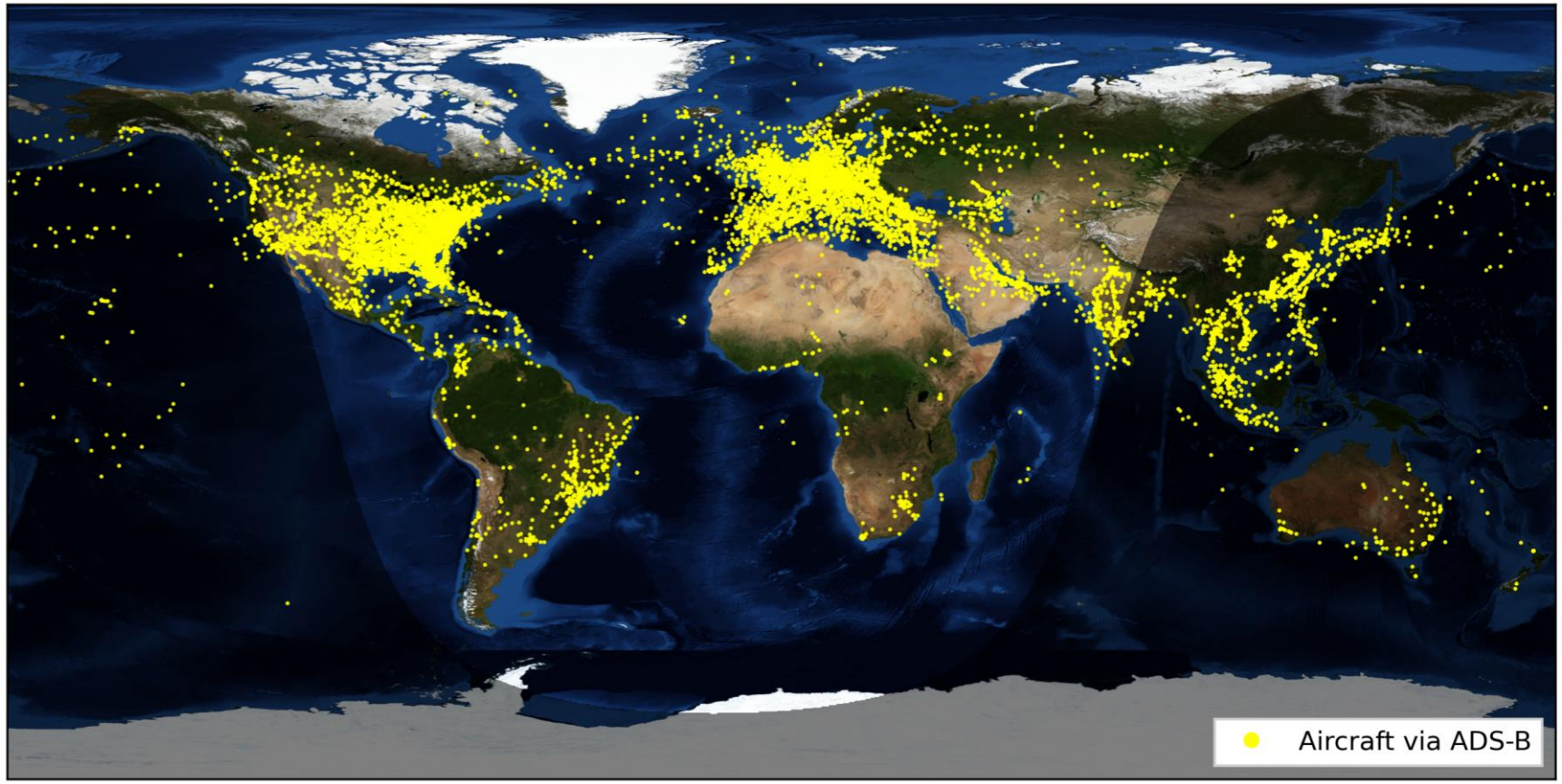
Source: https://www.esa.int/ESA_Multimedia/Images/2018/01/Space_weather_effects



Space weather impacts on ADS-B

First results: Solar flare May 1st 2023

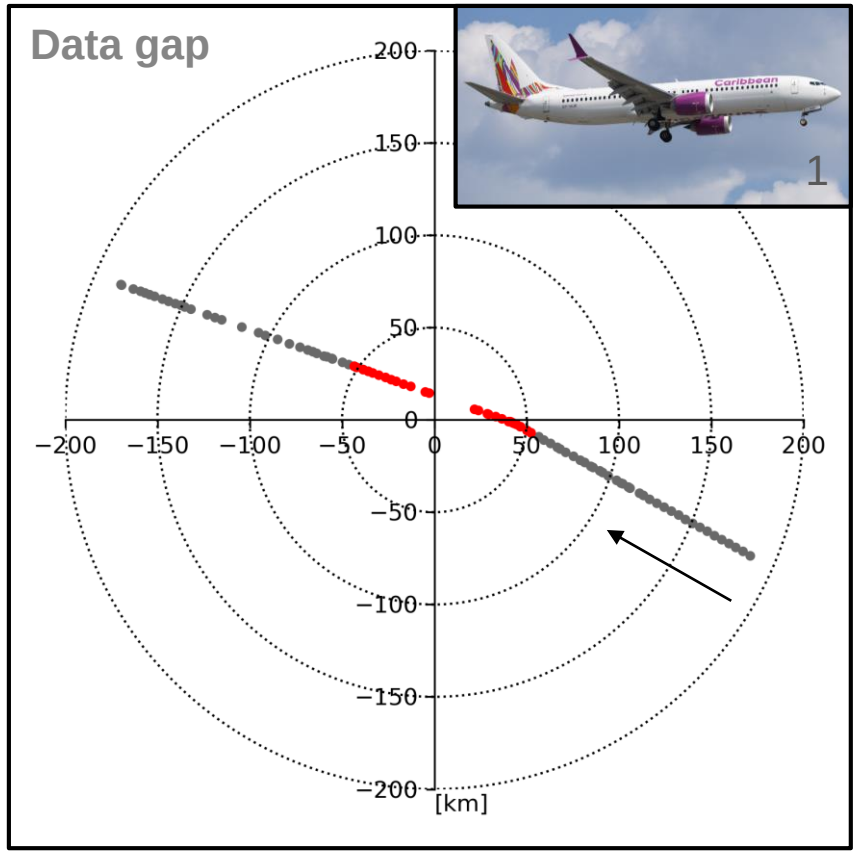


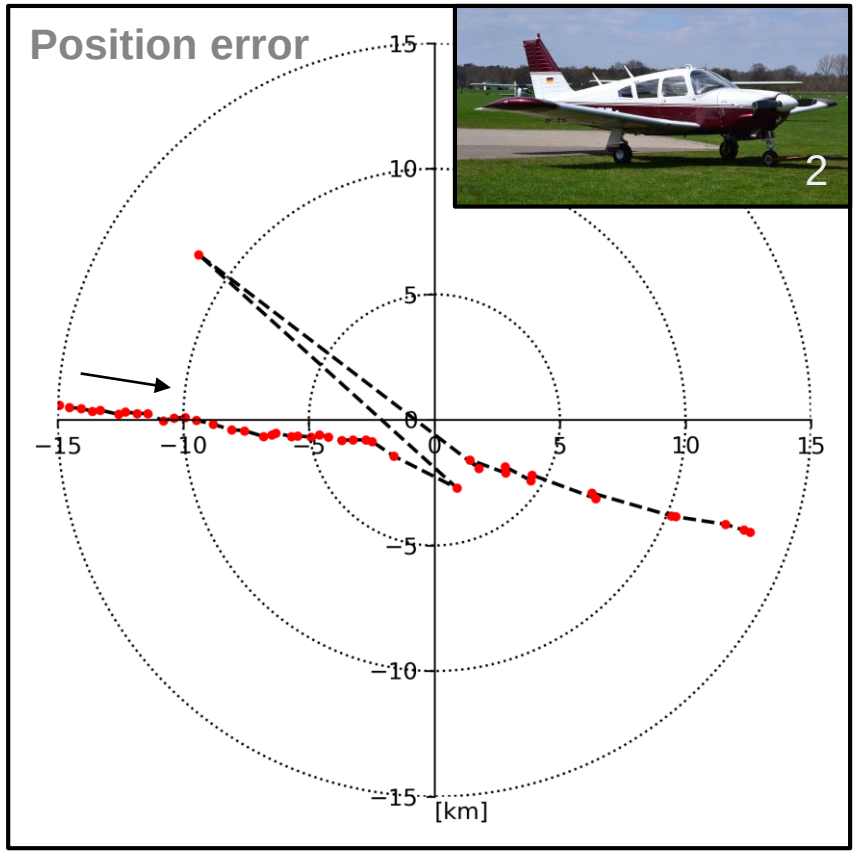


- Approx. 14000 aircraft recorded during M-class flare 1st May 2023 (13:02-13:09)
- Expected impacts: data gaps, position errors

Space weather impacts on ADS-B

First results: Solar flare May 1st 2023





Red dots (●): ADS-B messages during flare (13:02-13:09)
Arrow (➔): Flight direction

1 source: https://www.jetphotos.com/photo/11081148
2 source: https://commons.wikimedia.org/wiki/File:Piper_PA-28R-200_Cherokee_Arrow_%28D-EATT%29_02.jpg

Space weather impacts on ADS-B

First results: Solar flare May 1st 2023

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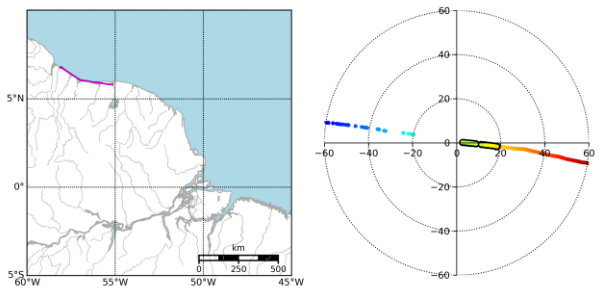
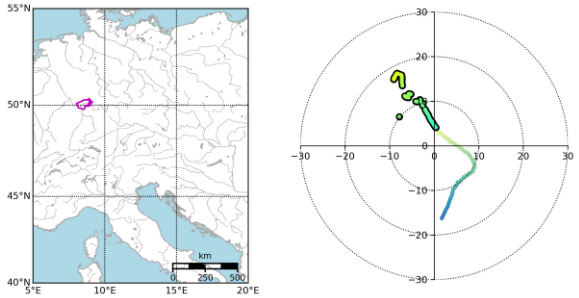
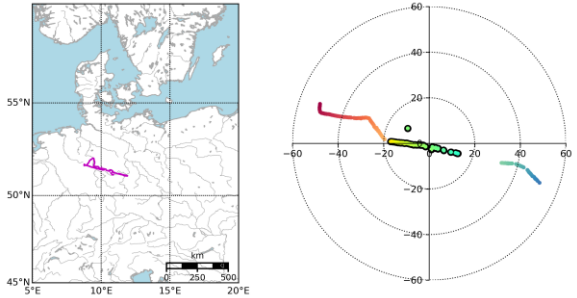


ICAO ID 3d0f95



ICAO ID 3d112a



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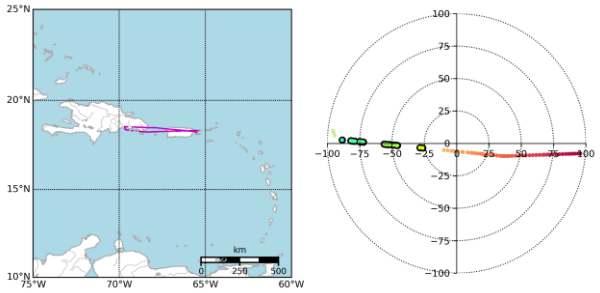

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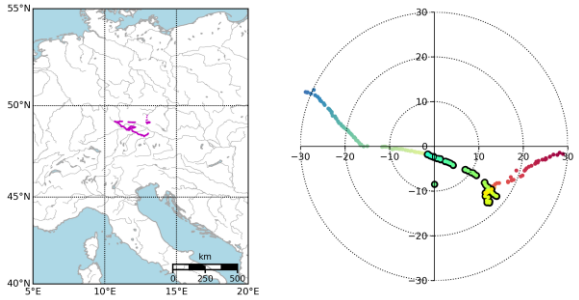
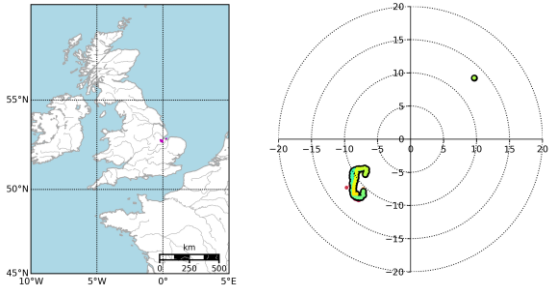


ICAO ID 4012dd



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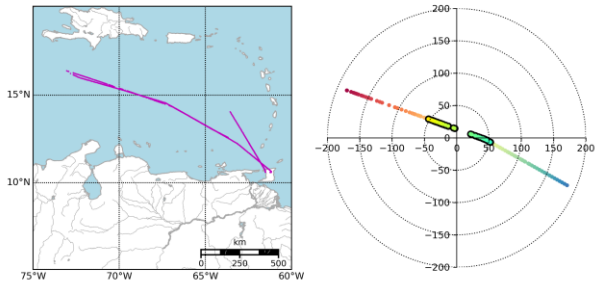
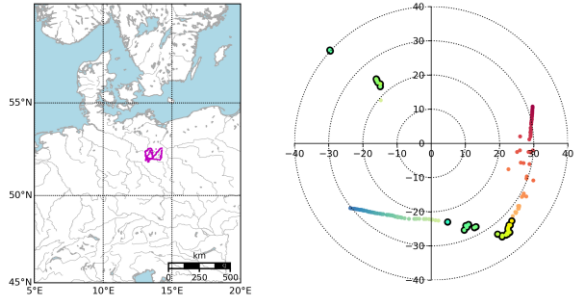


ICAO ID 3d094d



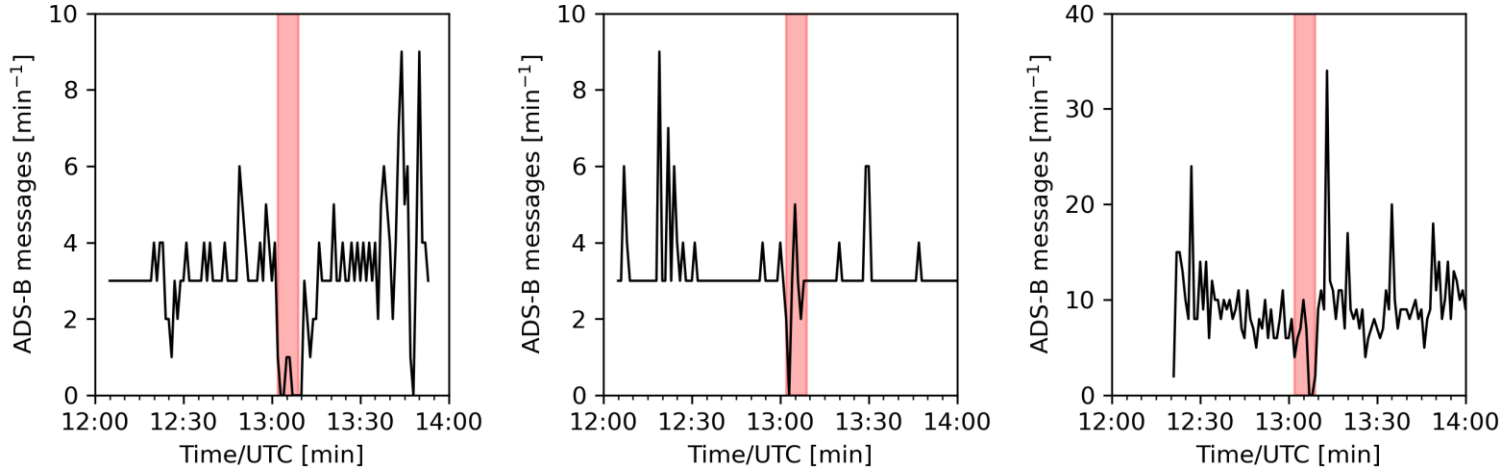
Features during solar flare:

1. Data gaps
2. Position errors ➔ Jumps, Deviations

Detection of data gaps and position errors?

Rate/position changes of ADS-B records with various parameters:

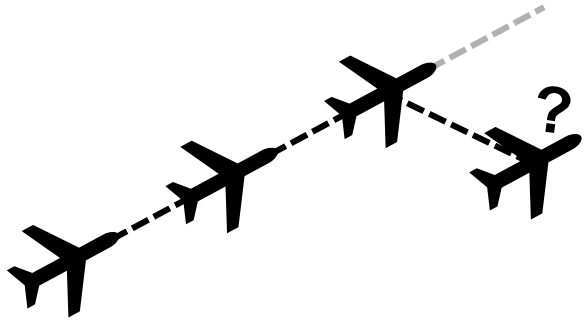
- Aircraft type
- Region, local time and air traffic
- Flight phase, maneuver or speed
- Weather

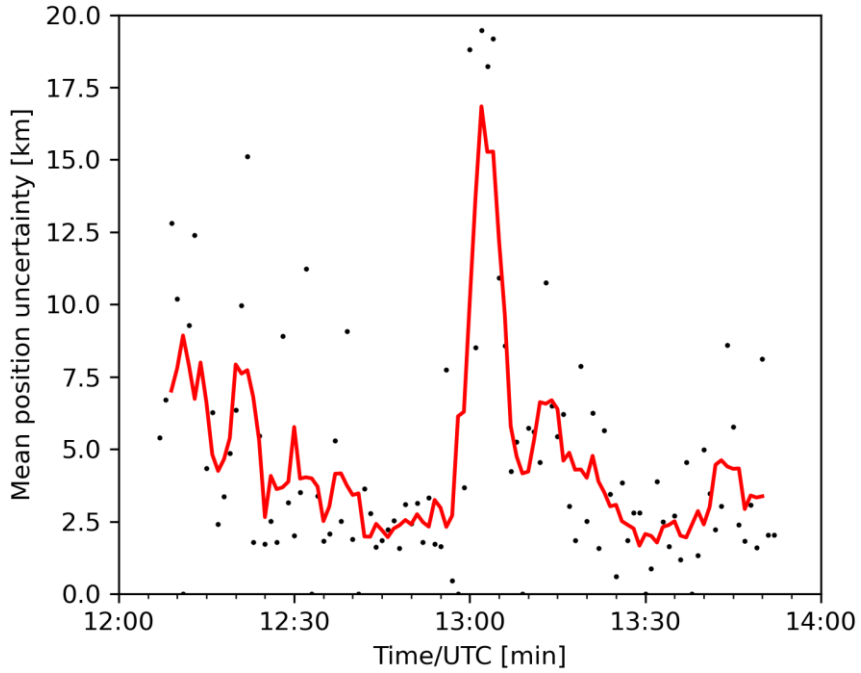


Detection of data gaps and position errors?

Detection of position errors:

- Unusual distances along flight tracks can be detected, but are often related to data gaps
- Clear increase of mean position uncertainty during solar flare time up to 13:30 UT



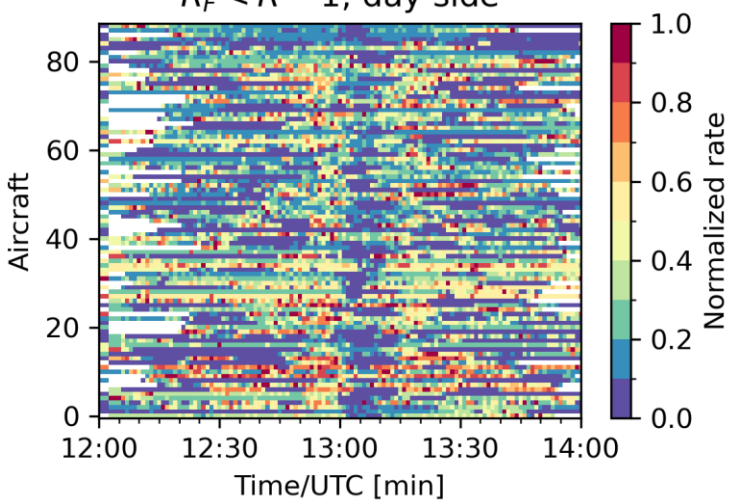


Detection of single tracks?

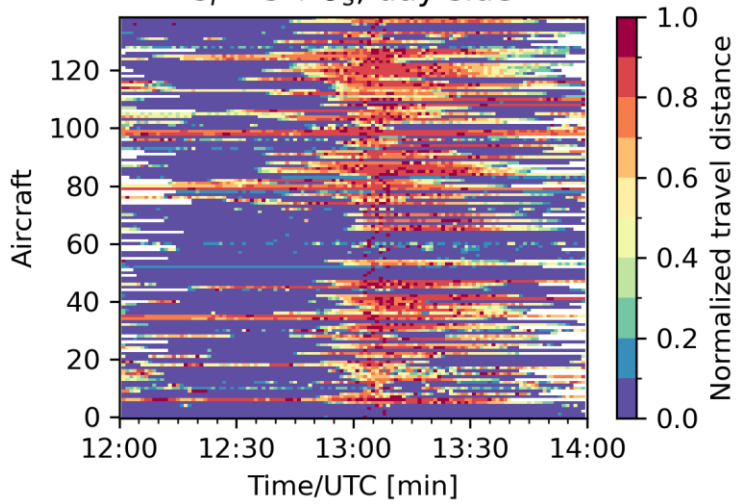
Detection of data gaps and position errors?

- Implementation of different detection approaches
- Test with other time intervals
- Manual check

Data gaps



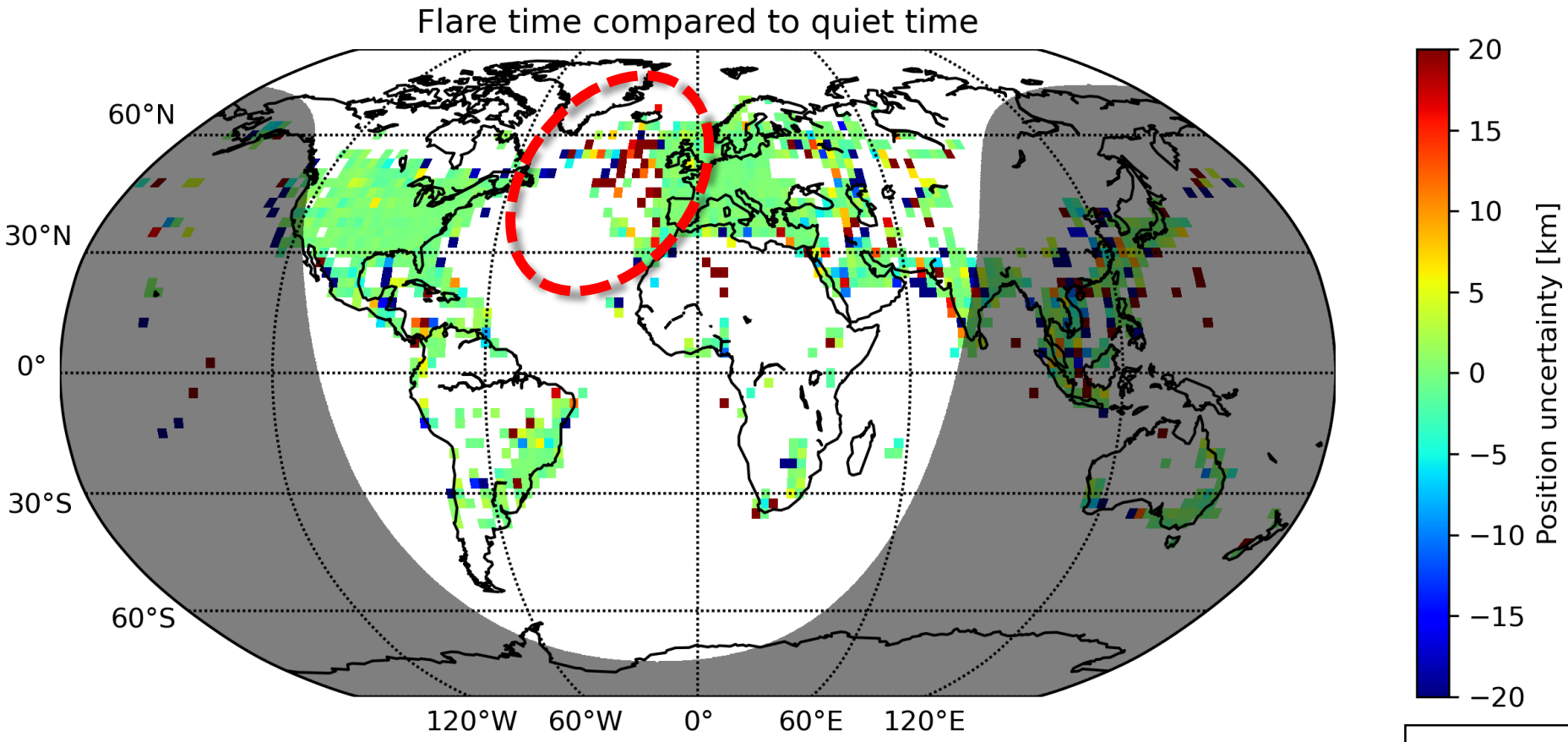
Position errors



Impacted: 1-2%

But is it really the flare impact?

Detection of data gaps and position errors?



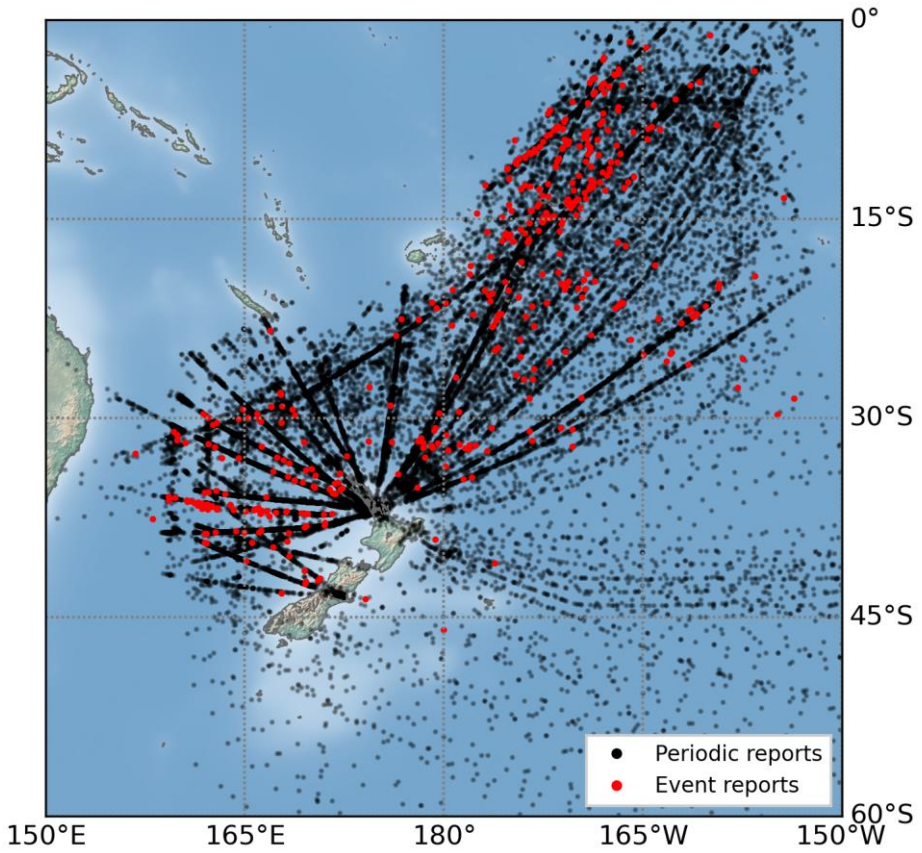
But is it really the flare impact?

Space weather impacts on ADS-C in NZ airspace

- Event reports in contracts (C) are triggered and send whenever the aircraft exceeds defined thresholds, e.g. distance from the expected position.

- Difference to ADS-B data: Information when position is unexpected is provided ➔ question:

What is the source for the event reports?



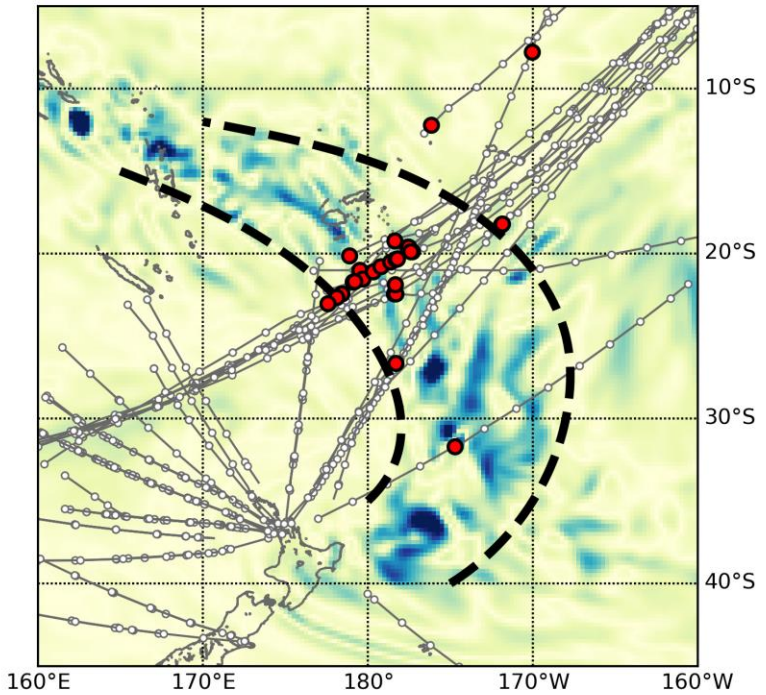
ADS-C reports during September 2017 in New Zealand airspace

Space weather impacts on ADS-C in NZ airspace

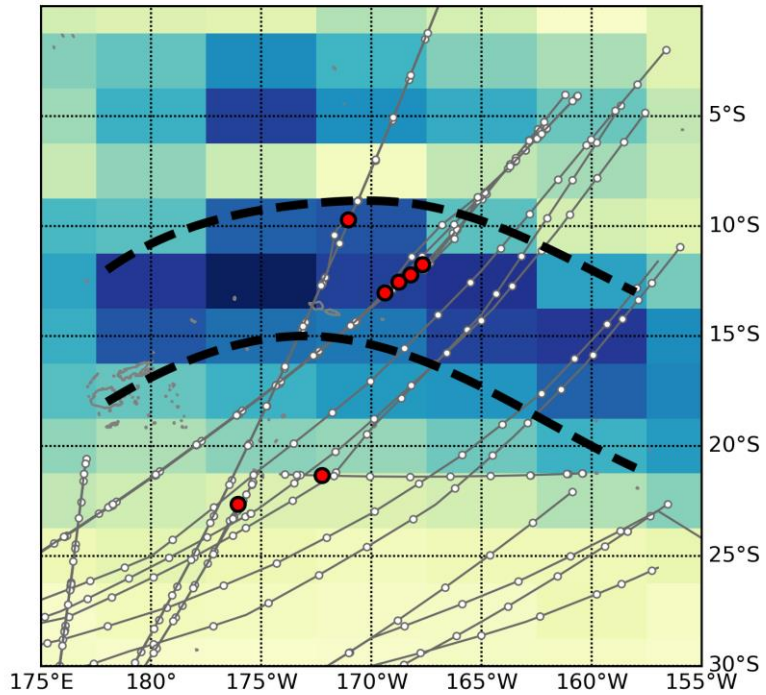
- The study of different periods shows that **offsets in position and altitude occur during severe weather and space weather**.

- **GNSS errors** cause reported offsets during space weather events when no actual track changes are performed.

Severe Weather



Severe Space Weather



Submitted to: IEEE TAES
Weather and Space Weather driven Variability of ADS-C Reports in New Zealand Airspace

Events (red dots ●) with position or altitude offsets are reported when aircraft pass severe weather or space weather (areas between dashed lines - - -).

Conclusion & Outlook

- First result indicate detectable impacts during space weather events

- Further analysis with more data covering various events required

Data

GOES-R Level 2 Data: https://www.ngdc.noaa.gov/stp/satellite/goes-r.html

CDDIS GNSS Atmospheric Products: https://cddis.nasa.gov/Data_and_Derived_Products/GNSS/atmospheric_products.html

ERA5 hourly data on single levels from 1940 to present: https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=overview

ADS-B Exchange Sample Data: https://www.adsbexchange.com/products/historical-data/

ADS-C records were provided by courtesy of the Airways Corporation of New Zealand and the FAA William J. Hughes Technical Center.