Distributed Computer Systems Lab
http://disco.informatik.uni-kl.de

Bringing up OpenSky

A large-scale ADS-B sensor network for research

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Flight plan

- Introduction to ADS-B
  - Technology, Problems
- OpenSky: What's that?
  - Architecture, Challenges, Numbers
- (Some) Initial Research
  - Measurements, Results, Problems

Introduction to ADS-B

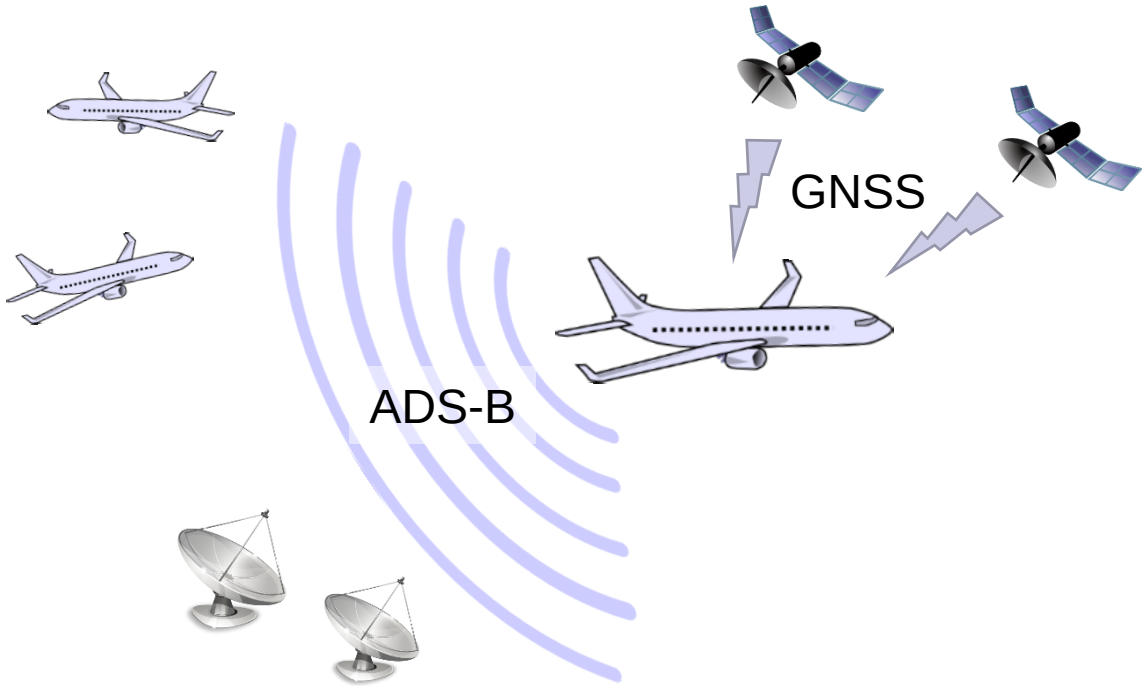
- ADS-B is…

  Automatic: always on (no interrogation necessary)

  Dependent: on-board systems provide surveillance data

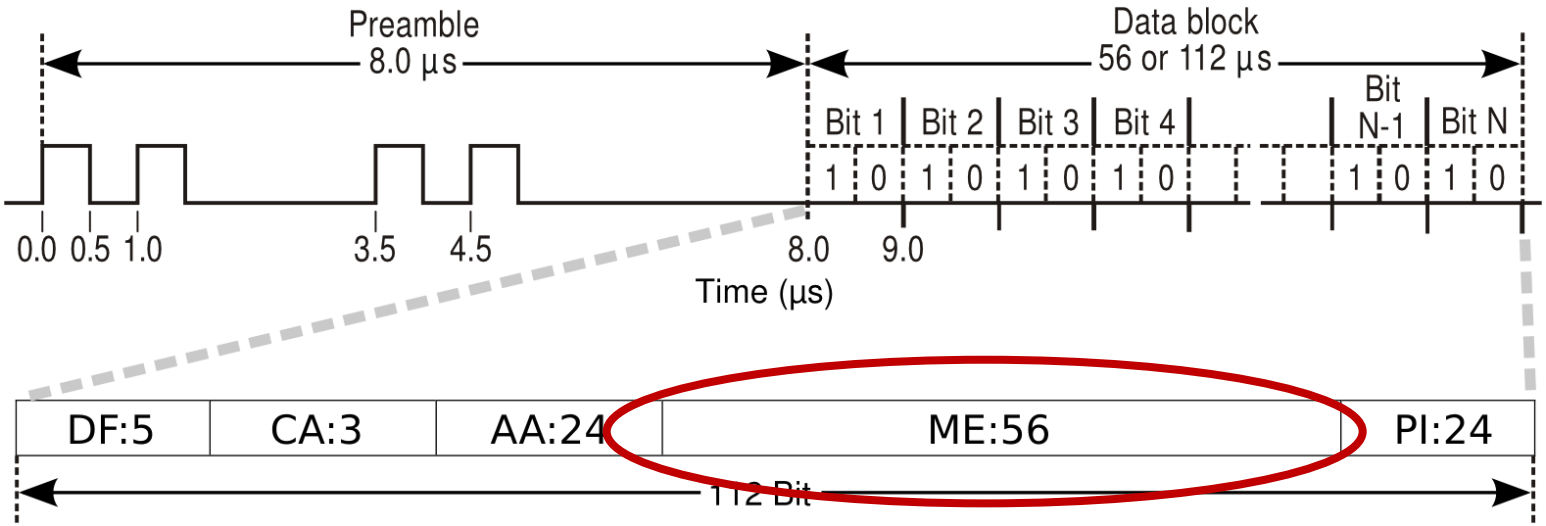
  Surveillance: provides precise position, speed, identification, status, …

  Broadcast: all nearby aircraft or ground stations receive the data



ADS-B Communication Link

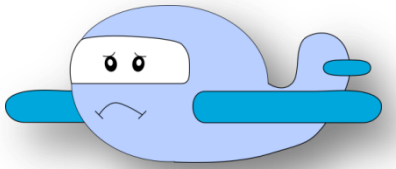
- Two different data links specified
  - Universal access transceiver (UAT) for general aviation
  - Mode S Extended Squitter (ES) for scheduled air traffic
- OpenSky records Mode S ES ADS-B messages
- Mode S provides 1 Mbit link on the 1090 MHz band



- ME field filled with data (position, velocity, status, ID, …)

Why ADS-B matters

- Higher traffic density requires higher accuracy
  - Aviation authorities decided to do a major upgrade
- Mandatory by 2020 for most air spaces worldwide
  - ADS-B is crucial function of next generation ATM system
  - But already widely deployed: about 60% of commercial aircraft are upgraded to ADS-B
- ADS-B is still experimental
  - Not yet certified for operational use
  - Massive security concerns



- Aspects such as security, capacity, applications require extensive investigation by independent research community
- Raw large-scale data was unavailable
  - Other sources (such as flightradar24, flightplans) only provide abstracted, sometimes delayed data or charge per query

Air Traffic Communication on IPSN '14

Airplanes Aloft as a Sensor Network for Wind Forecasting

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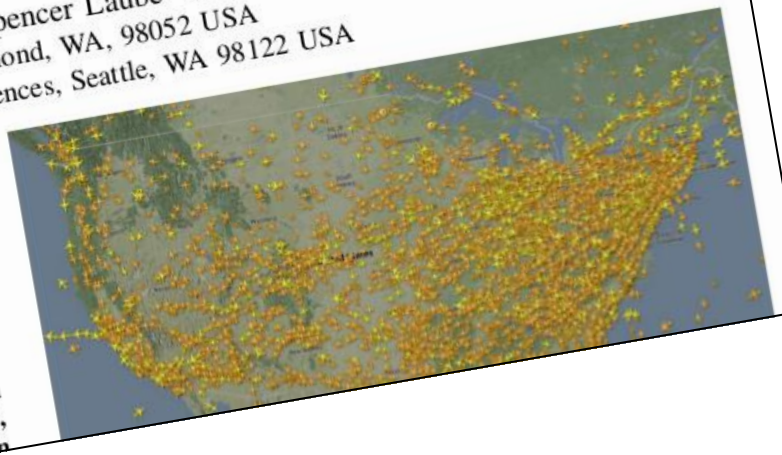
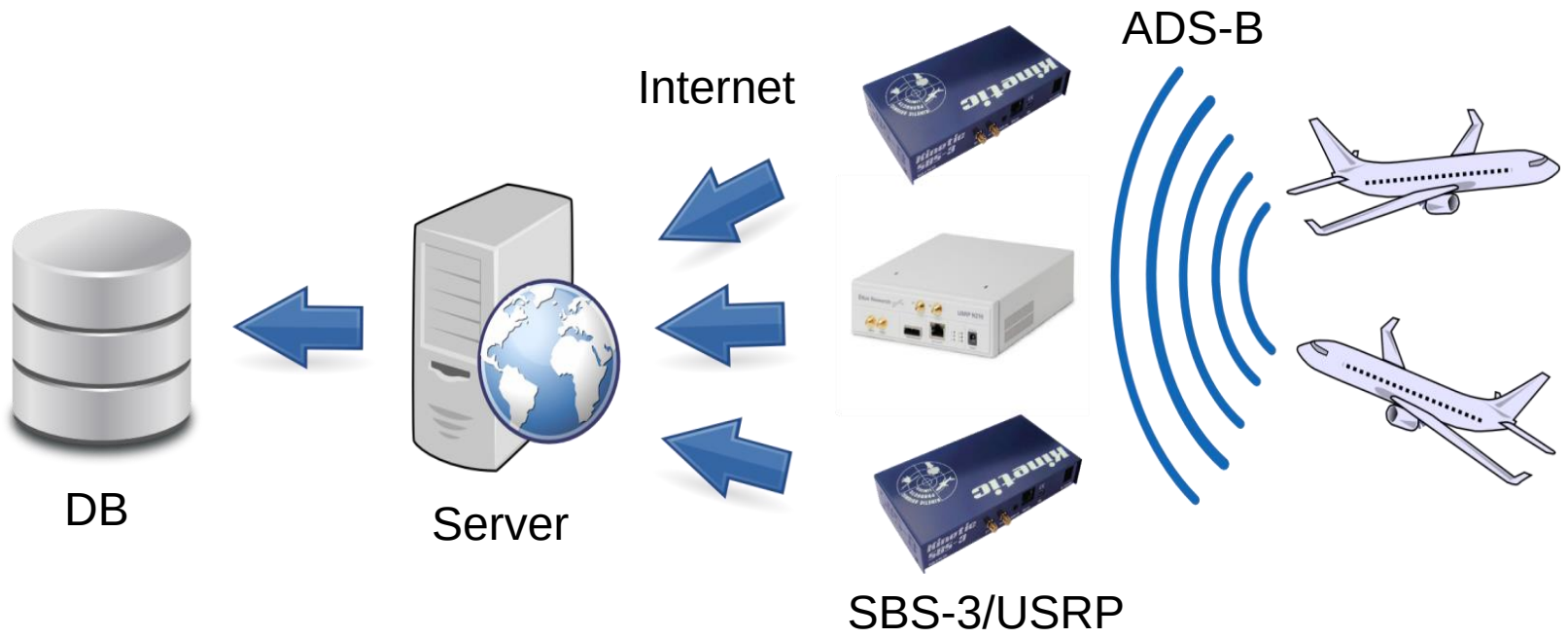


***Abstract*—We explore the feasibility of using commercial aircraft as sensors for observing weather phenomena at a continental scale. We focus specifically on the problem of wind forecasting and explore the use of machine learning and inference methods to harness air and ground speeds reported by aircraft at different locations and altitudes. We validate the learned predictive model with a field study where we release an instrumented high-altitude balloon and compare the predicted trajectory with the sensed winds. The experiments show the promise of using airplane in flight as a large-scale sensor network. Beyond making predictions, we explore the guidance of sensing with value-of-information**

OPENSKY
NETWORK

What is OpenSky??

- Goal: collect ADS-B data at a large scale for research
- Low-cost sensors are distributed to volunteers
- Data and metadata are collected via the Internet and stored in a central DB



Sensors

- Kinetic Avionic's SBS-3
  - Ethernet and USB interface
  - 50ns rolling timestamp
  - Supports reception of voice communication

- Ettus' Universal Software Radio Periphal (USRP)
  - Provides additional information such as
    - Received Signal Strength
    - Signal –to-noise Ratio
    - Confidence Level
  - Requires Gigabit Ethernet connection or intermediate host

Sensors

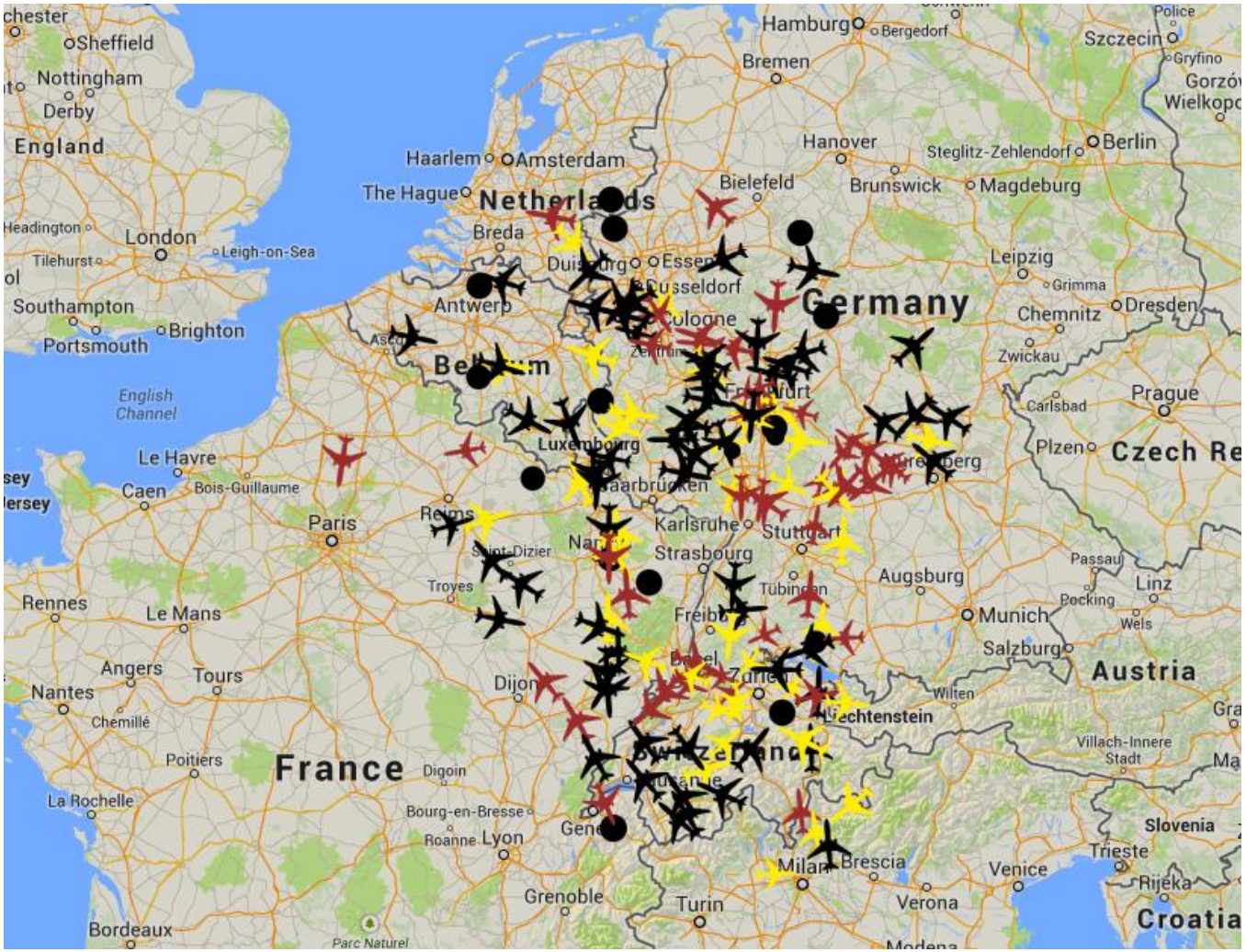
Motivated Volunteers

Current Status

- 11 nodes deployed in Central Europe

Current Status

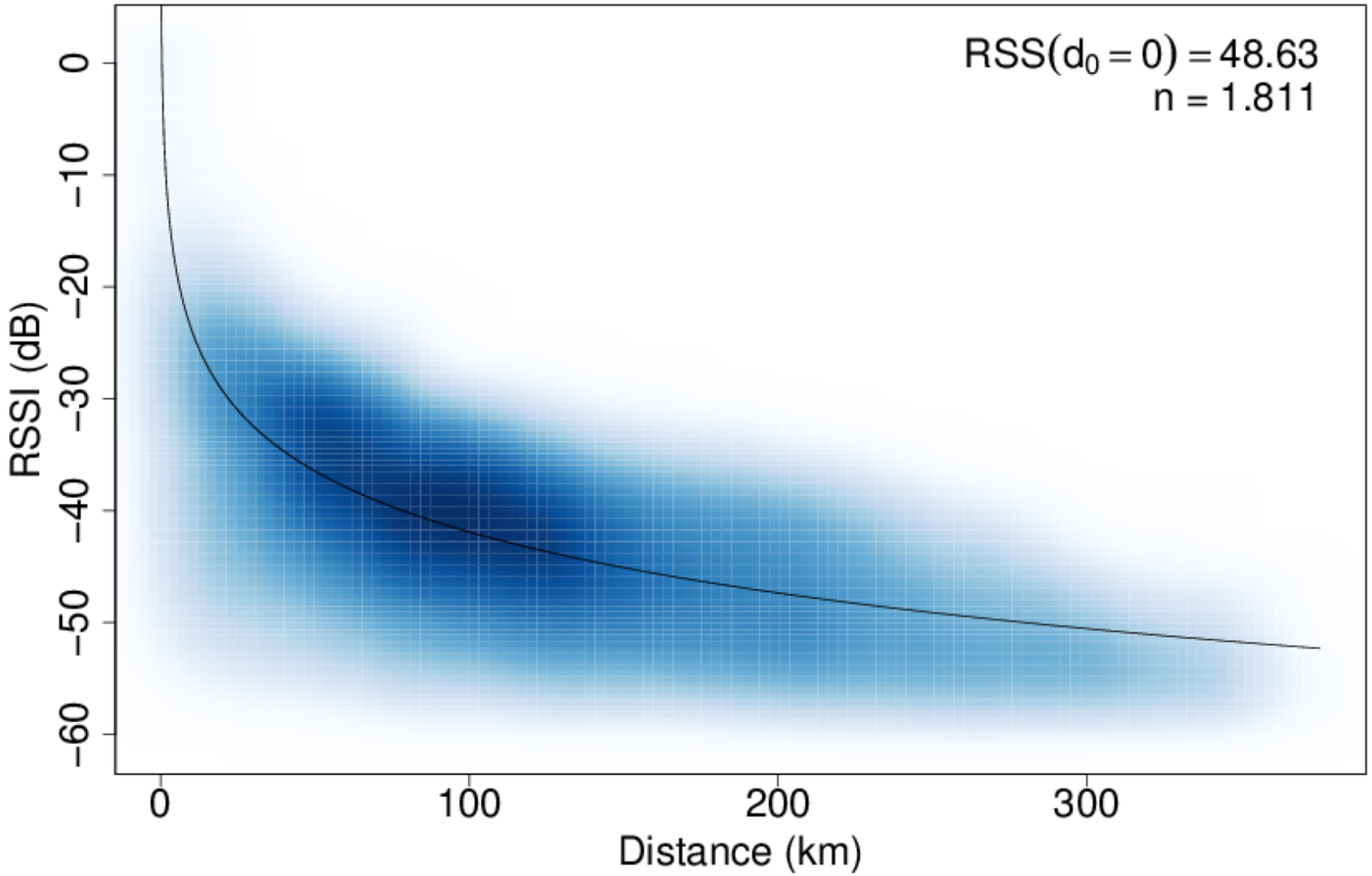
- Coverage



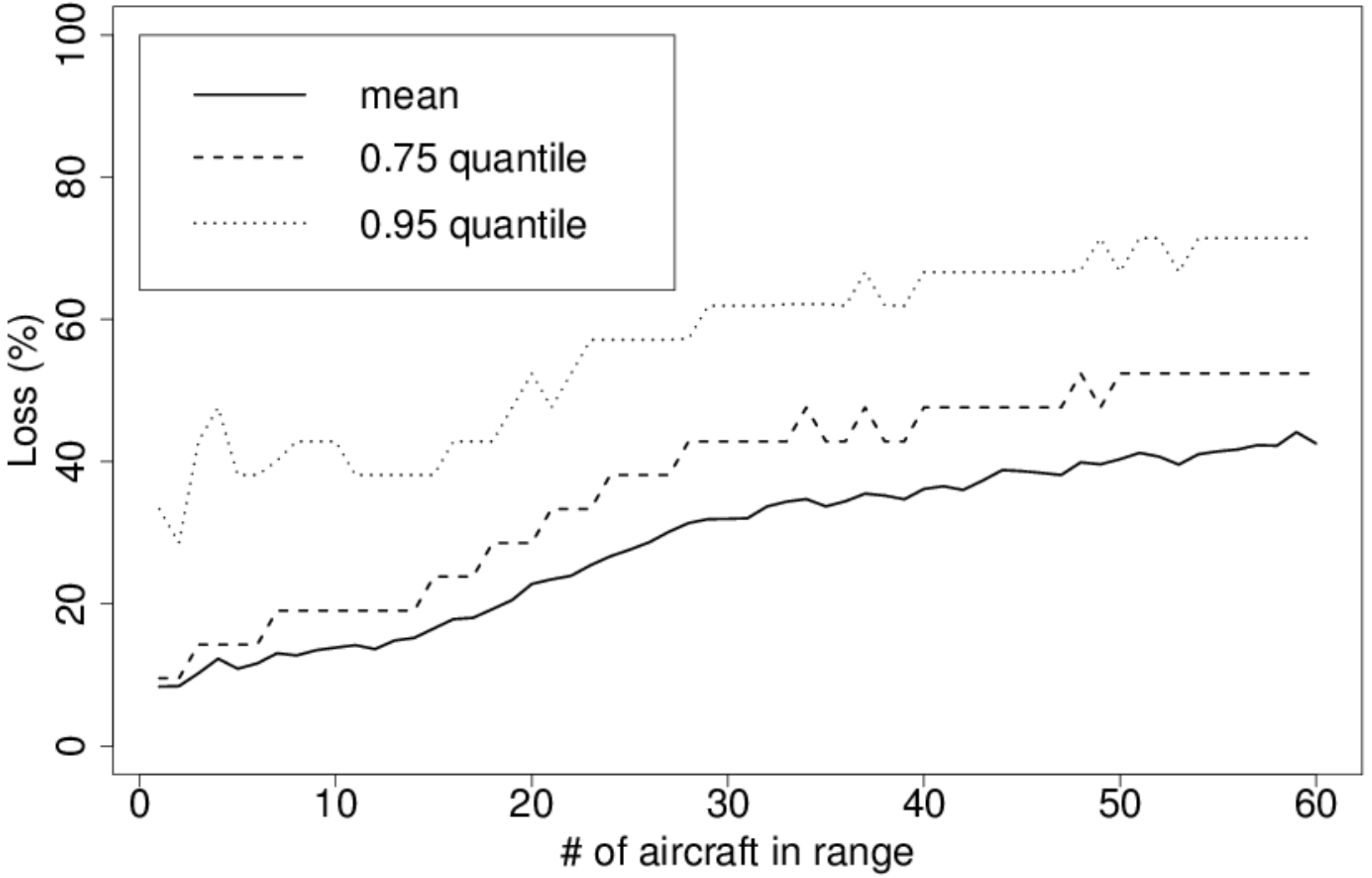
Some Numbers

- More than 5 billion messages so far
  - Depending on the daytime, we receive 10-500 messages per second
- We've seen almost 2 million flights
  - 8,000 new flights per day
- We see 30% of all flights in Europe
  - Although only ~60% of all aircraft are equipped with ADS-B by now
- Our database grows about 2 Gigabytes/day

1090ES Data Link: Range

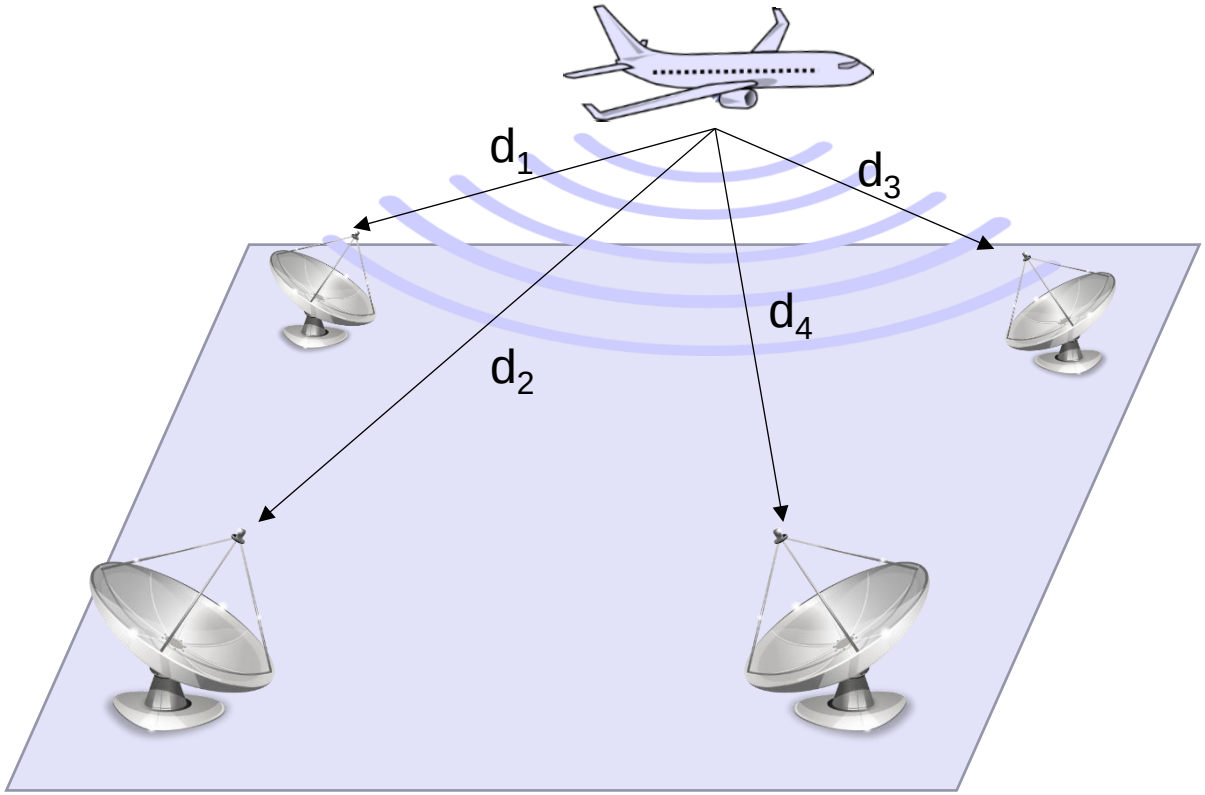


1090ES Data Link: Loss



What's the quality of OpenSky's data?

- Example Application: Wide-area multilateration (WMLAT)



- WMLAT as a "benchmark" for OpenSky

Why WMLAT?

- Synchronization
  - Uses time difference of arrival
  - Accuracy depends on quality of synchronization
  - Our sensors provide a 50ns rolling timestamp
- Coverage
  - Requires the coverage of an area by at least 4 sensors
  - Bad constellations result in a high delusion of precision
- Relevance
  - Used in areas where radar is not possible (e.g. mountainous areas)
  - Implemented along with ADS-B
  - Commercial systems are extremely expensive

WMLAT Coverage

Results

- Different sources of noise
  - Timestamp's 50ns resolution
  - Dilution of precision
  - ADS-B provided positions can be inaccurate
- Average horizontal error of 295m (median 165m)
  - Despite the *timestamp's inaccuracy* of our COTS sensors
- Altitude cannot be determined with OpenSky
  - Very high *dilution of precision*, since sensors have similar altitudes

Conclusion

- OpenSky provides a great source of data for different research areas, including
  - Security
  - Performance
  - Capacity planning
  - Coverage planning
- In fact, 6 groups are already working with its data

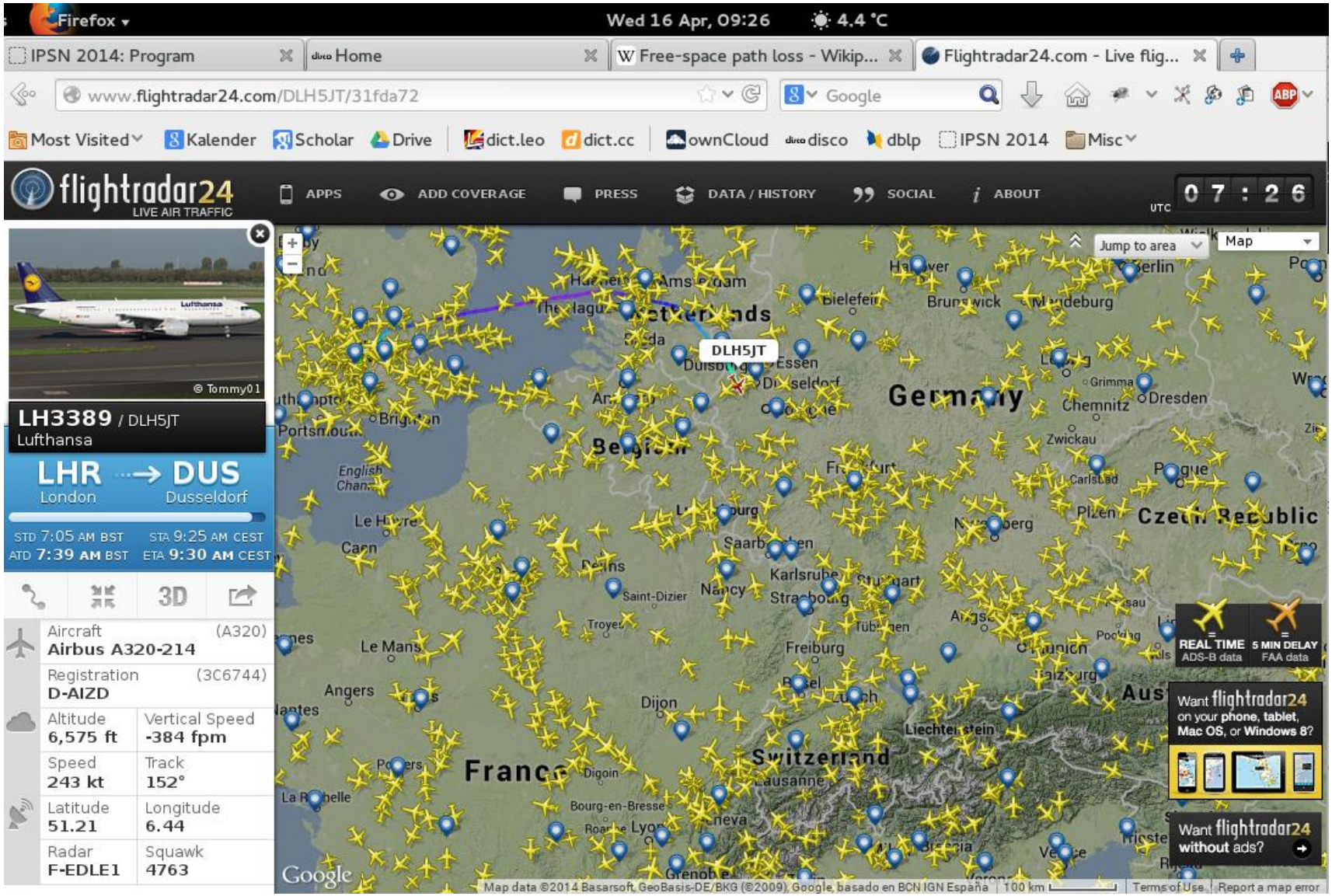
- Everyone is invited to contribute to OpenSky with a sensor
  - Contributors can have access to OpenSky's data
  - Check your national regulations

- Visit http://opensky-network.org for more information

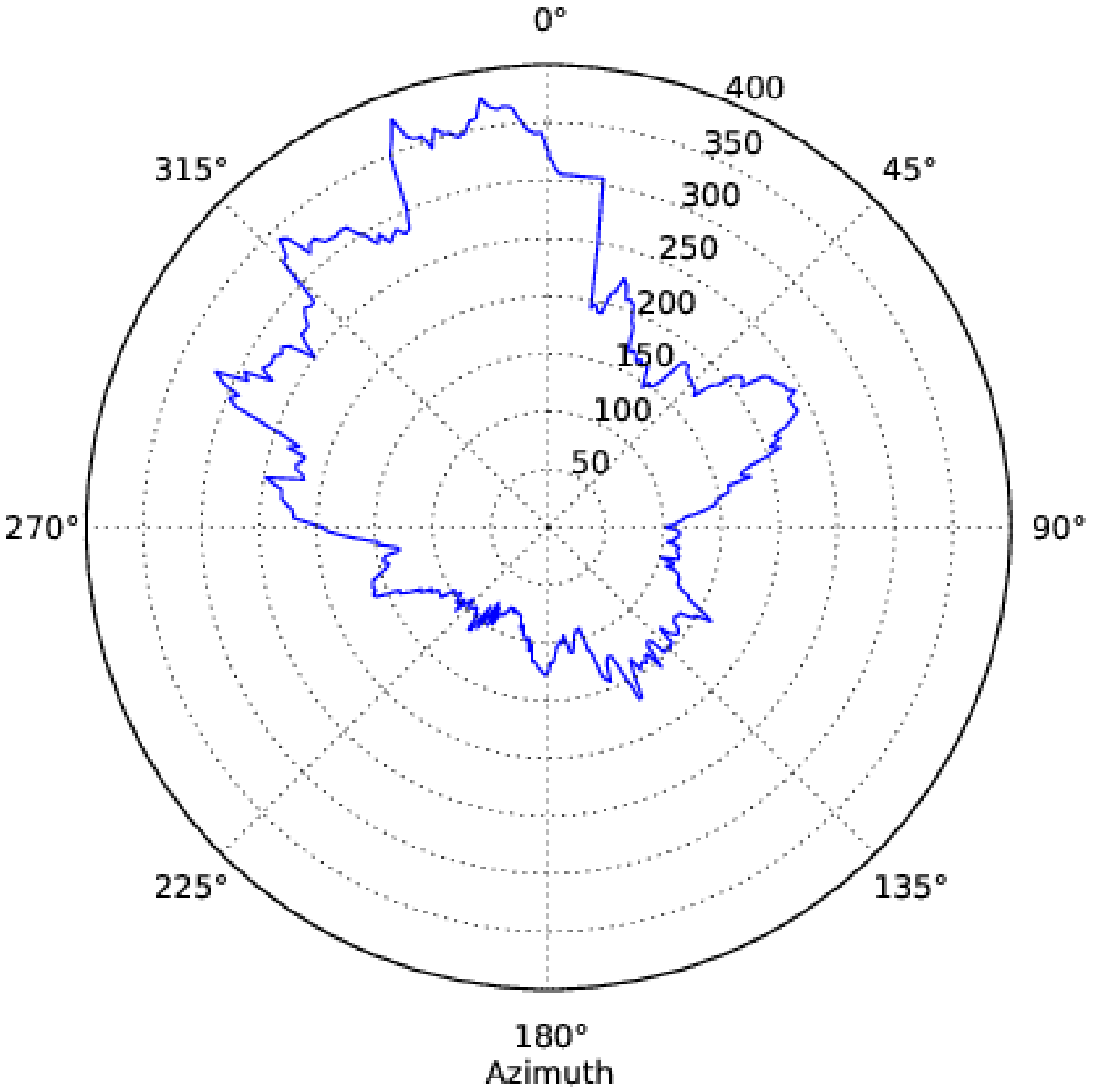
Q&A

Thanks for your attention

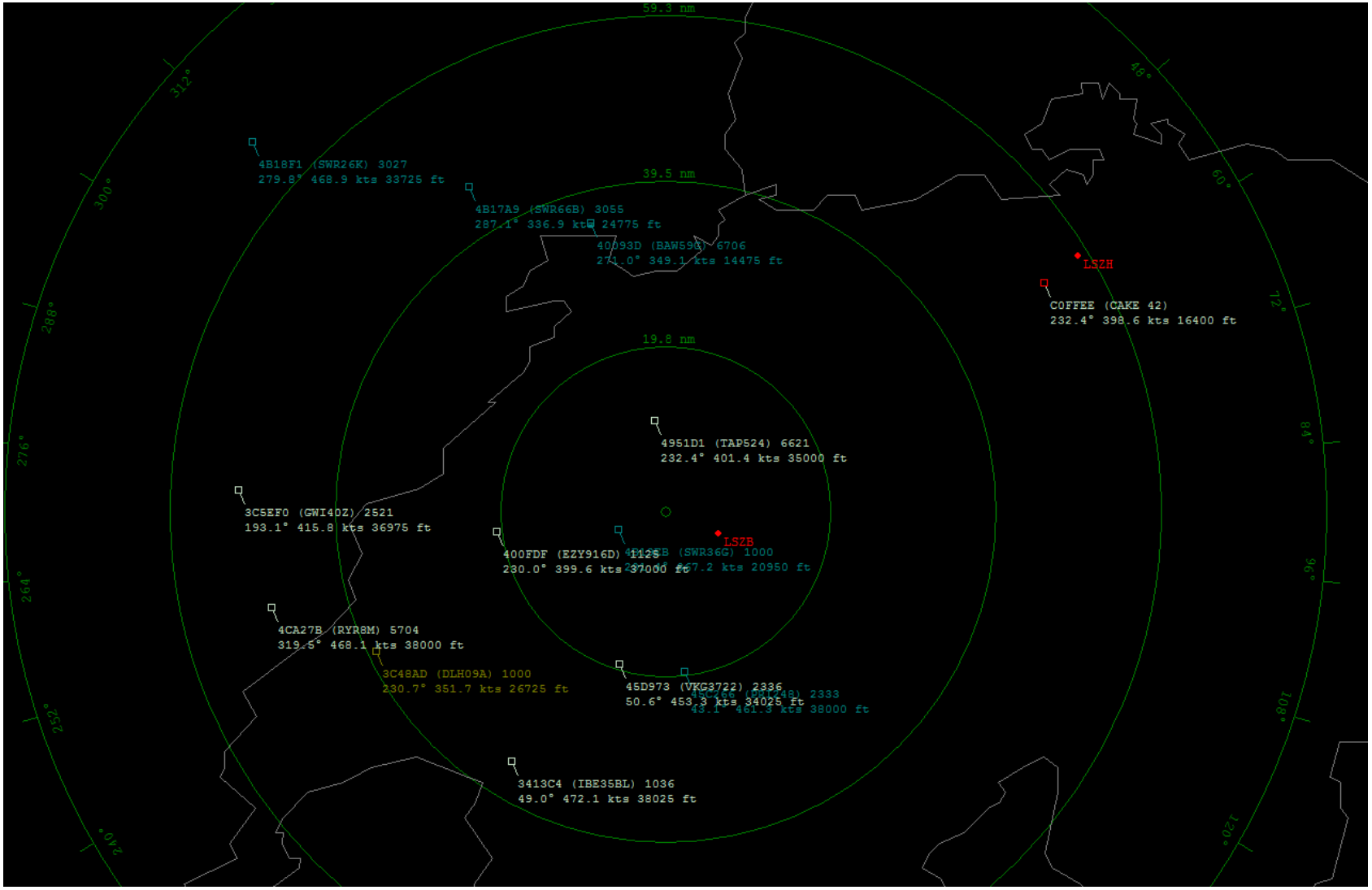
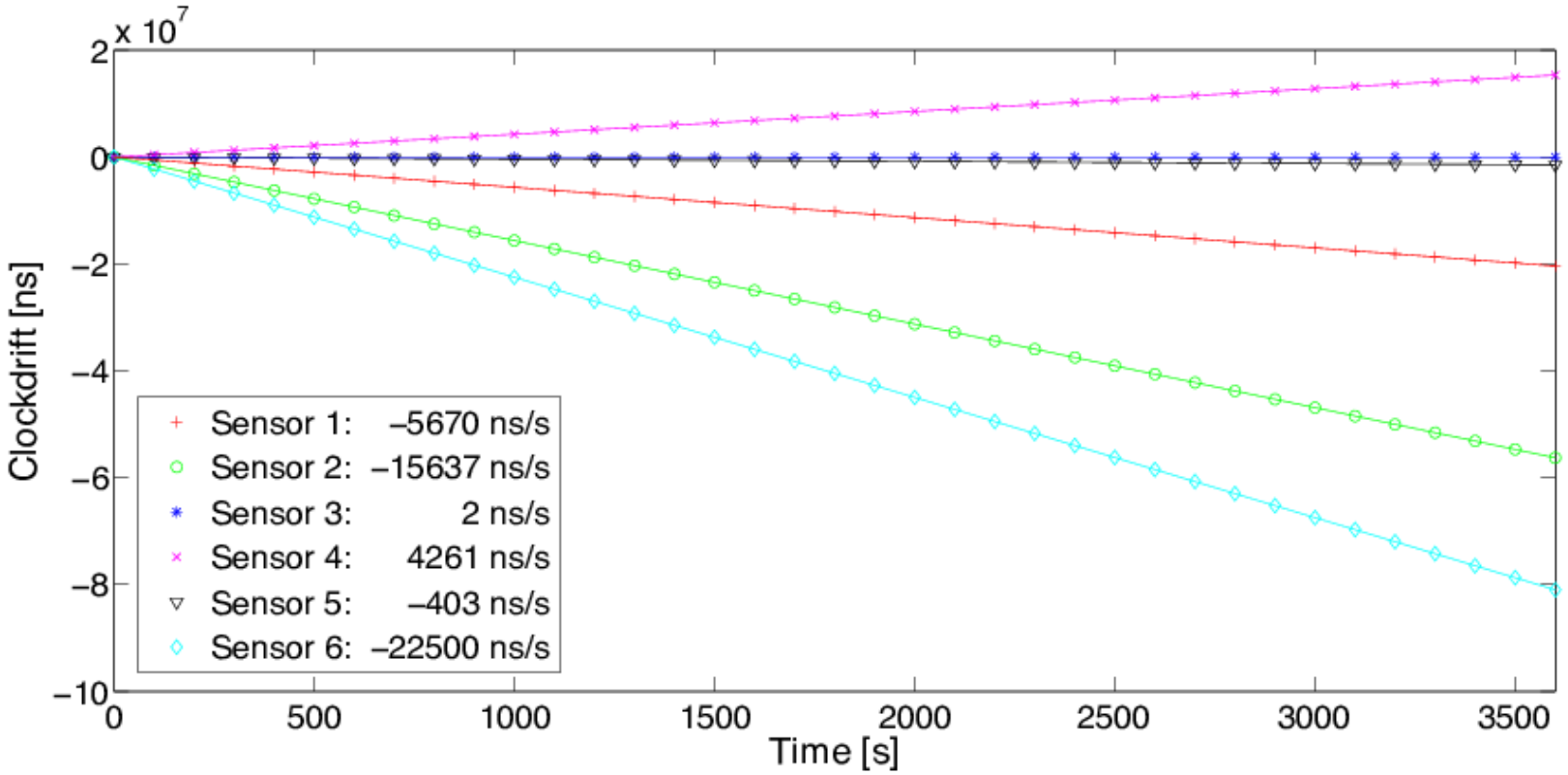
Flightradar24



Range


0°
45°
90°
135°
180°
225°
270°
315°
400
350
300
250
200
150
100
50
Azimuth

Ghost Aircraft Injection



Clock Drift SBS-3