

# Reconstructing Aircraft Turn Manoeuvres for Trajectory Analyses Using ADS-B Data



9<sup>th</sup> SESAR Innovation Days

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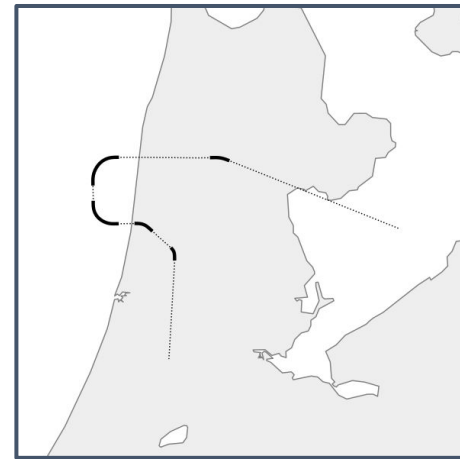
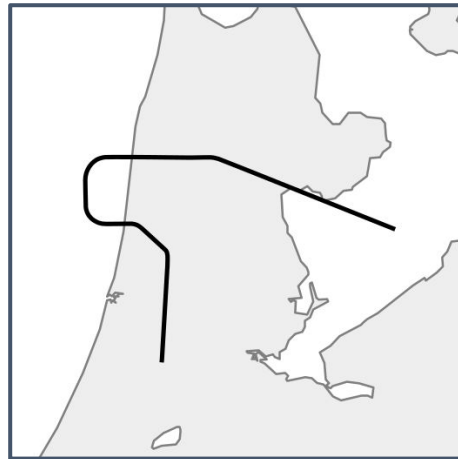
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- Introduction and background
- Methods for extracting turn segments in ADS-B trajectory data
- Estimation of turn manoeuvres parameters
- Verification of results with additional Mode S data
- Discussions and conclusions

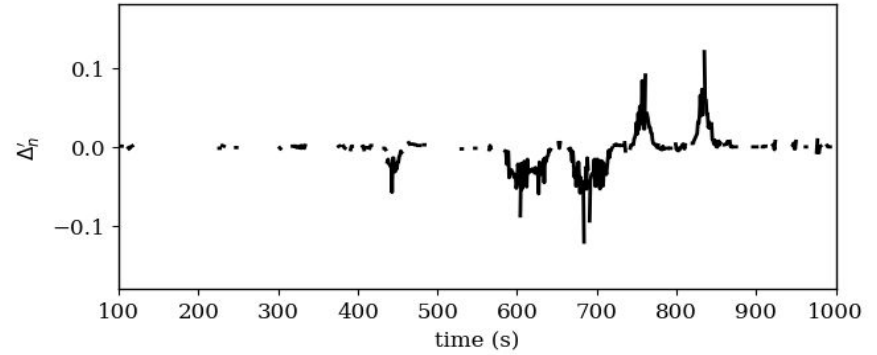
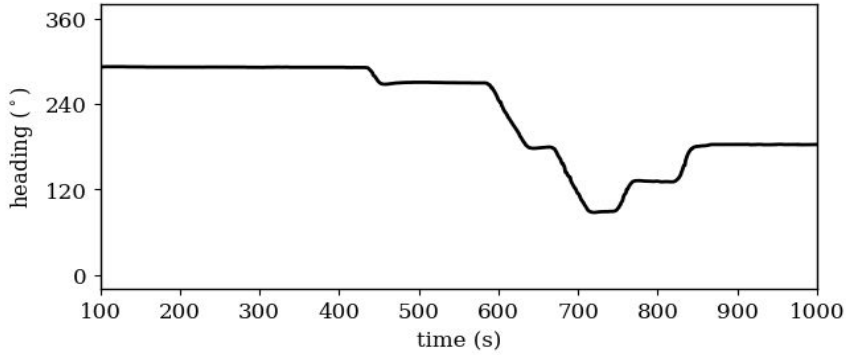
# Introduction and background

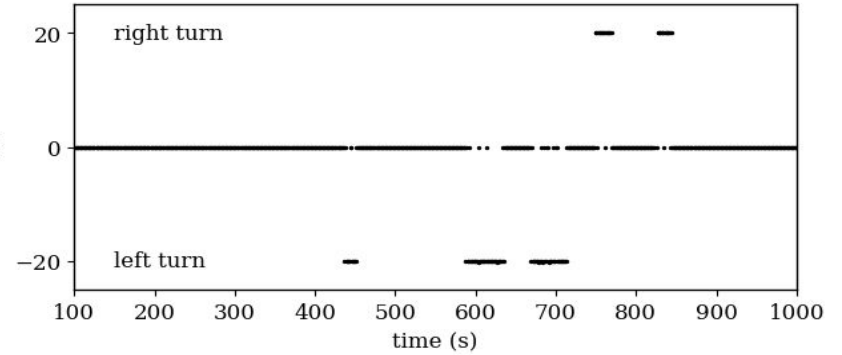
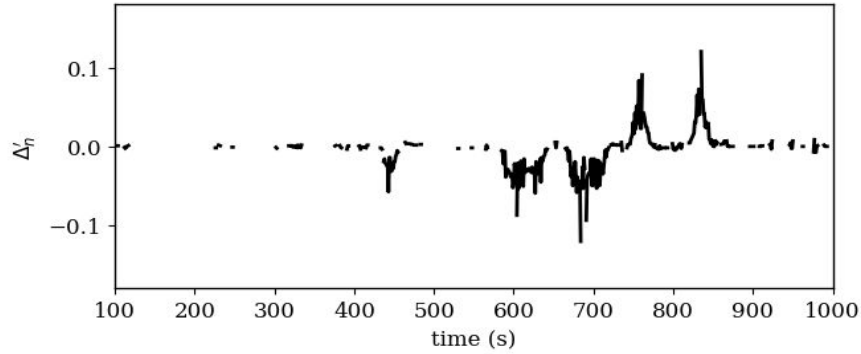
# Research question:

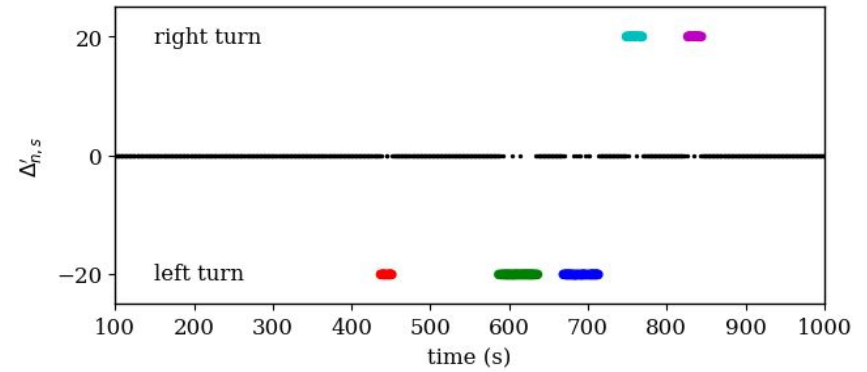
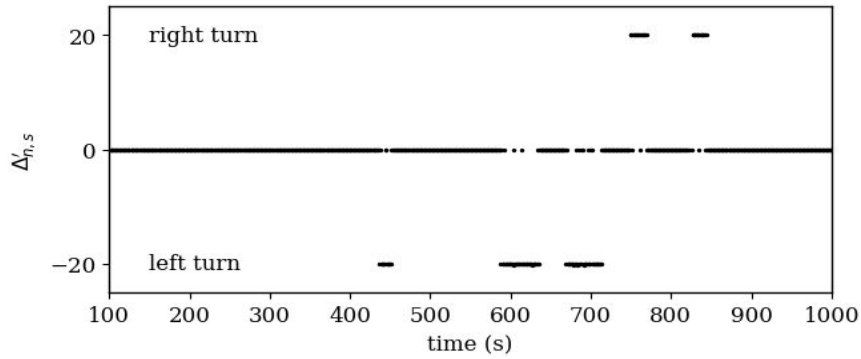
Is it possible to estimate turn parameters using ADS-B data?



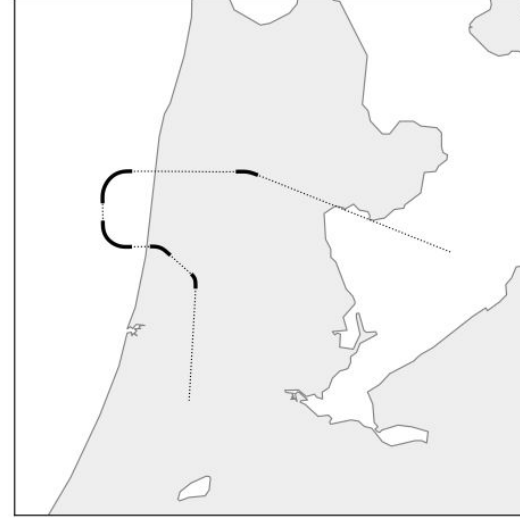
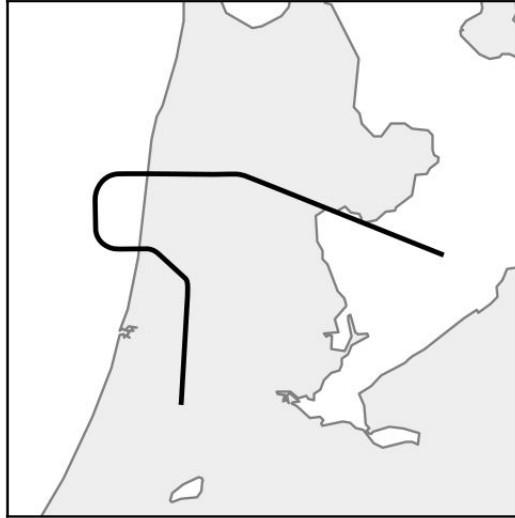
# Step 1: Extraction of turn manoeuvres





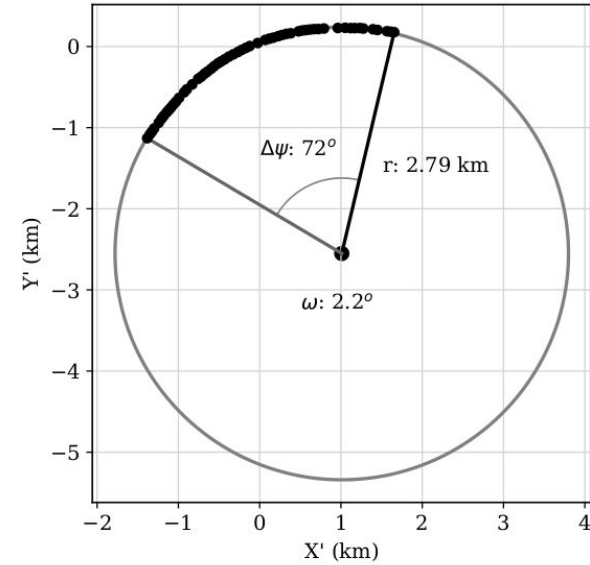
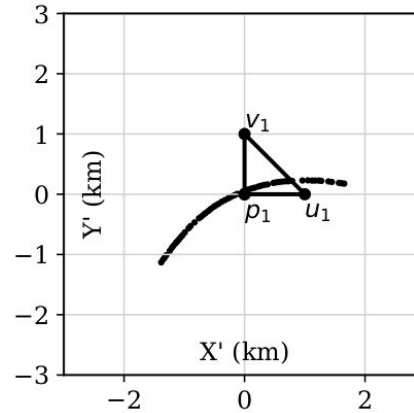
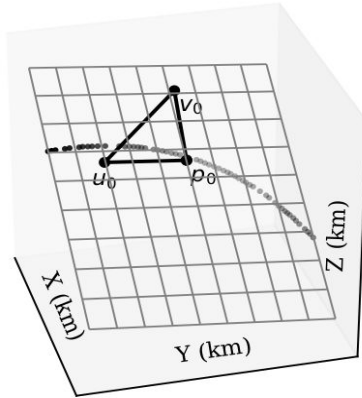


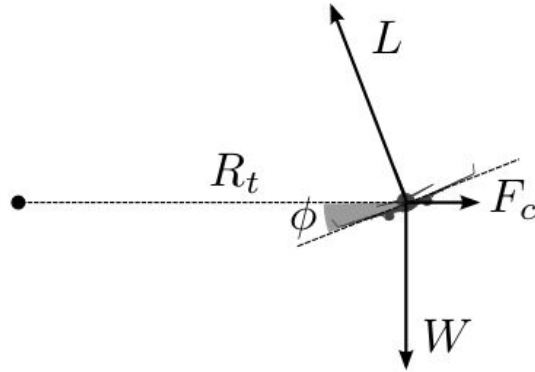




## Step 2: Estimation of turn parameters (radius, bank angle, rate)

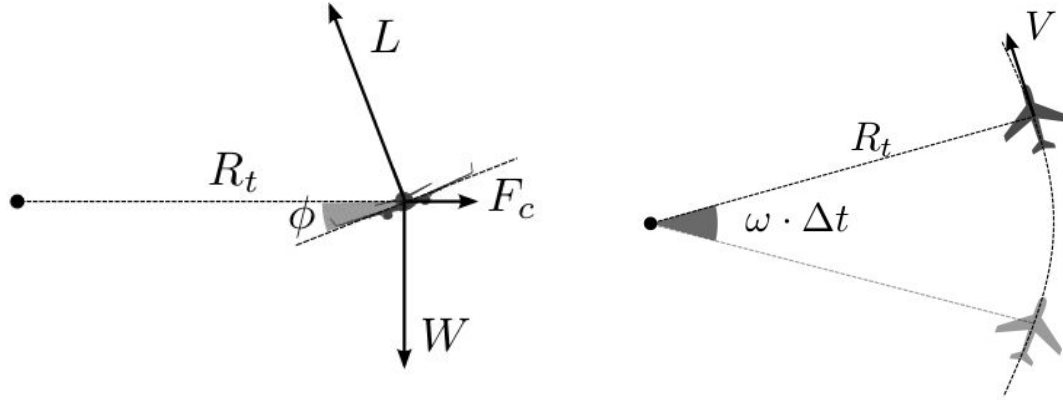
## Transformation and regression





$$F_c = L \sin \phi = \frac{W}{g} \frac{V^2}{R_t}$$
$$W = L \cos \phi \cos \gamma$$

$$\phi = \arctan \left( \frac{V^2 \cos \gamma}{g R_t} \right)$$

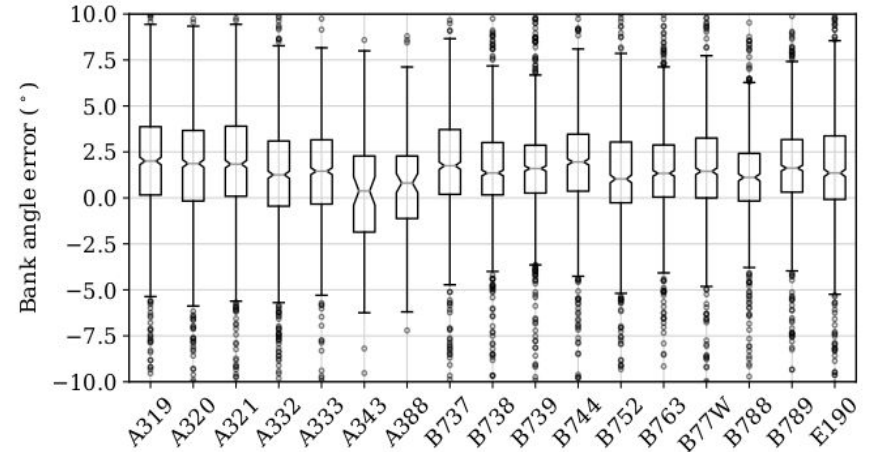
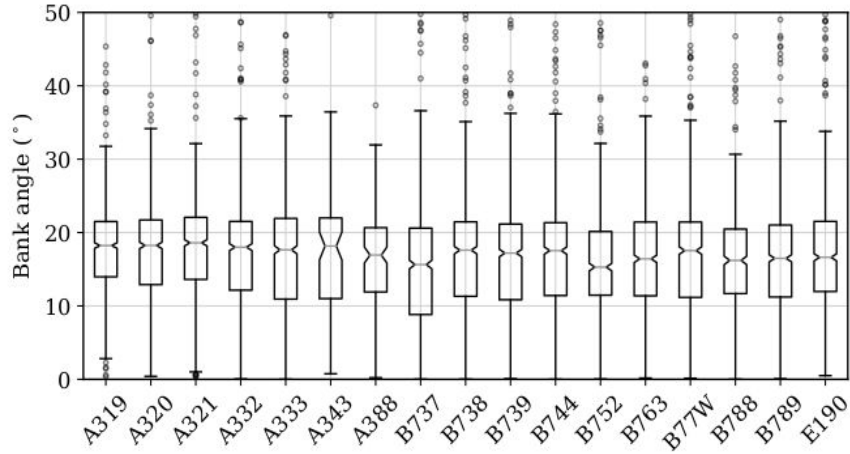


$$n = \frac{1}{\cos \phi \cos \gamma}$$
$$\omega = \frac{d\psi}{dt} = \frac{V}{R_t}$$

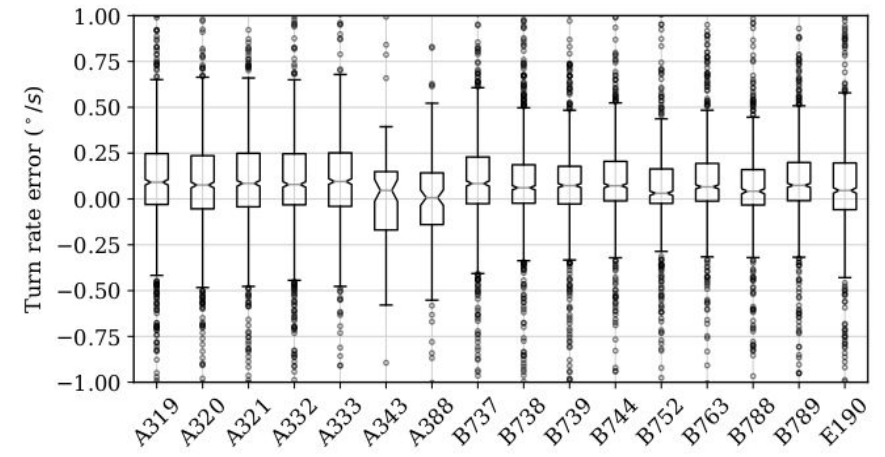
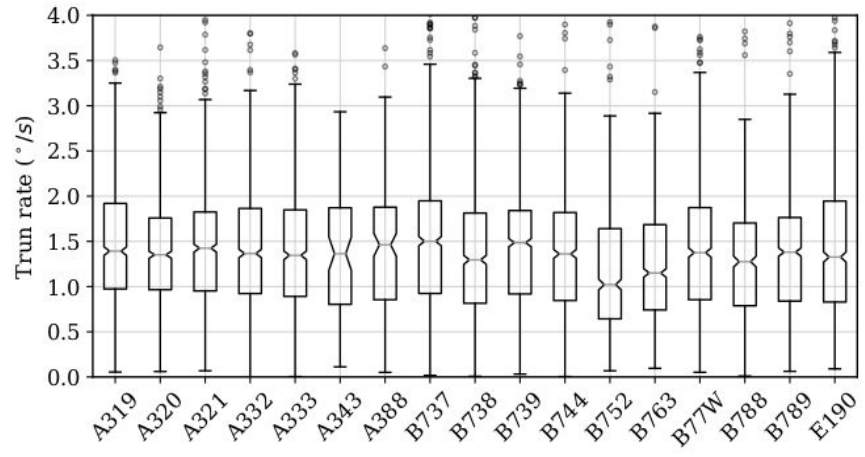
# Step 3: Verification of the results

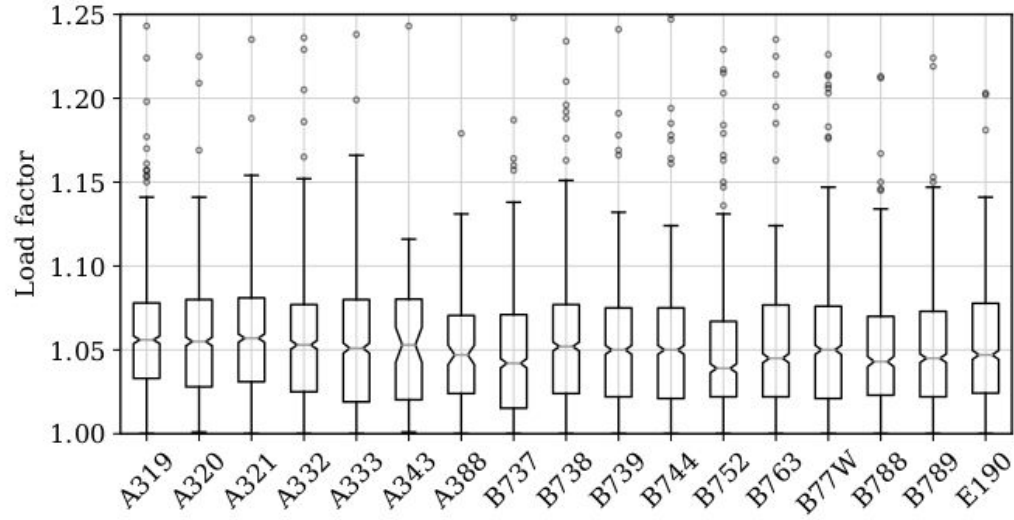
- Mode S Enhanced Surveillance (EHS)
- Track and turn report
  - Roll angle
  - Track angle
  - Track angle rate
- Drawbacks:
  - Low update rate
  - Not always available

Aircraft	Number of turns	Number of validations	
		Bank angle	Turn rate
A319	992	814	814
A320	999	805	805
A321	994	830	829
A332	998	798	799
A333	998	853	851
A343	82	70	70
A388	159	107	106
B737	998	753	753
B738	996	820	819
B739	1001	823	823
B744	1000	850	849
B752	721	596	596
B763	990	842	842
B77W	999	789	13
B788	577	465	465
B789	999	837	837
E190	974	728	728







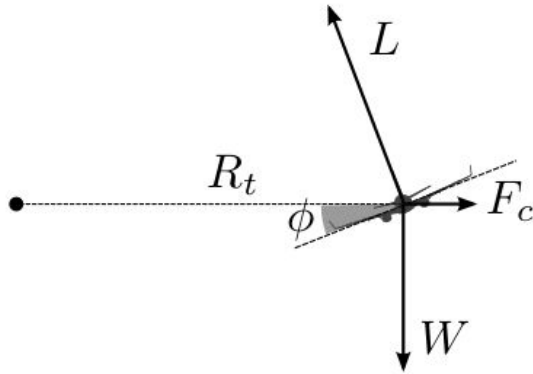


# Benefits of the research

I. Provides a better understanding of turn performance in trajectory analysis based on ADS-B

II. Applying the proposed method to other types of data is possible (radar data, MLAT data)

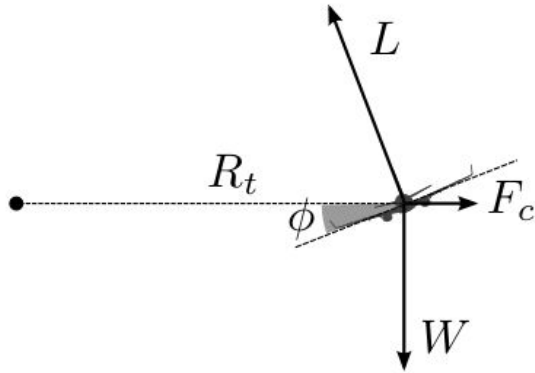
### III. Provides better estimation of lift and drag during the turns



$$F_c = L \sin \phi = \frac{W}{g} \frac{V^2}{R_t}$$

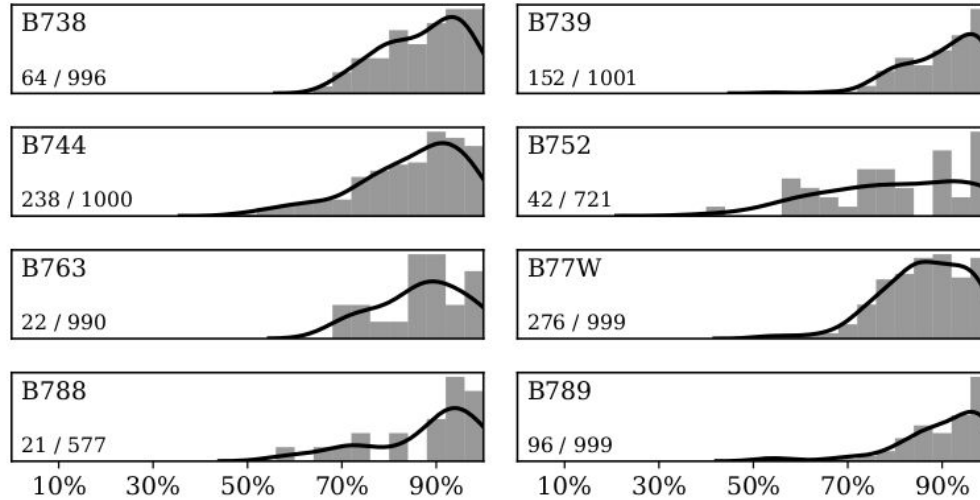
$$W = L \cos \phi \cos \gamma$$

## IV. Reveals further information on aircraft weight



$$\tilde{m}_{max} = \frac{W_{max}}{g} = \frac{L_{max}}{ng} = \frac{C_{L,max}}{ng} \frac{1}{2} \rho V^2 S$$

## IV. Reveals more information on aircraft weight



- Proposed a simple approach to study aircraft turns using ADS-B data
  - Included a serie of steps to estimate turn radius, bank angle, load factors
- Methods can be used for other types of trajectory data
- Results validated with Mode S Enhanced Surveillance data
- Provided more insight into aircraft performance analysis using open surveillance data
- Limitations and future work:
  - Handling strong wind during turns
  - Using estimated parameters to reduce trajectory prediction uncertainty



Thank you!

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