Green-GEAR

Can route charging incentivise environmentally-friendly trajectories?

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SESAR Innovation Days

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Outline

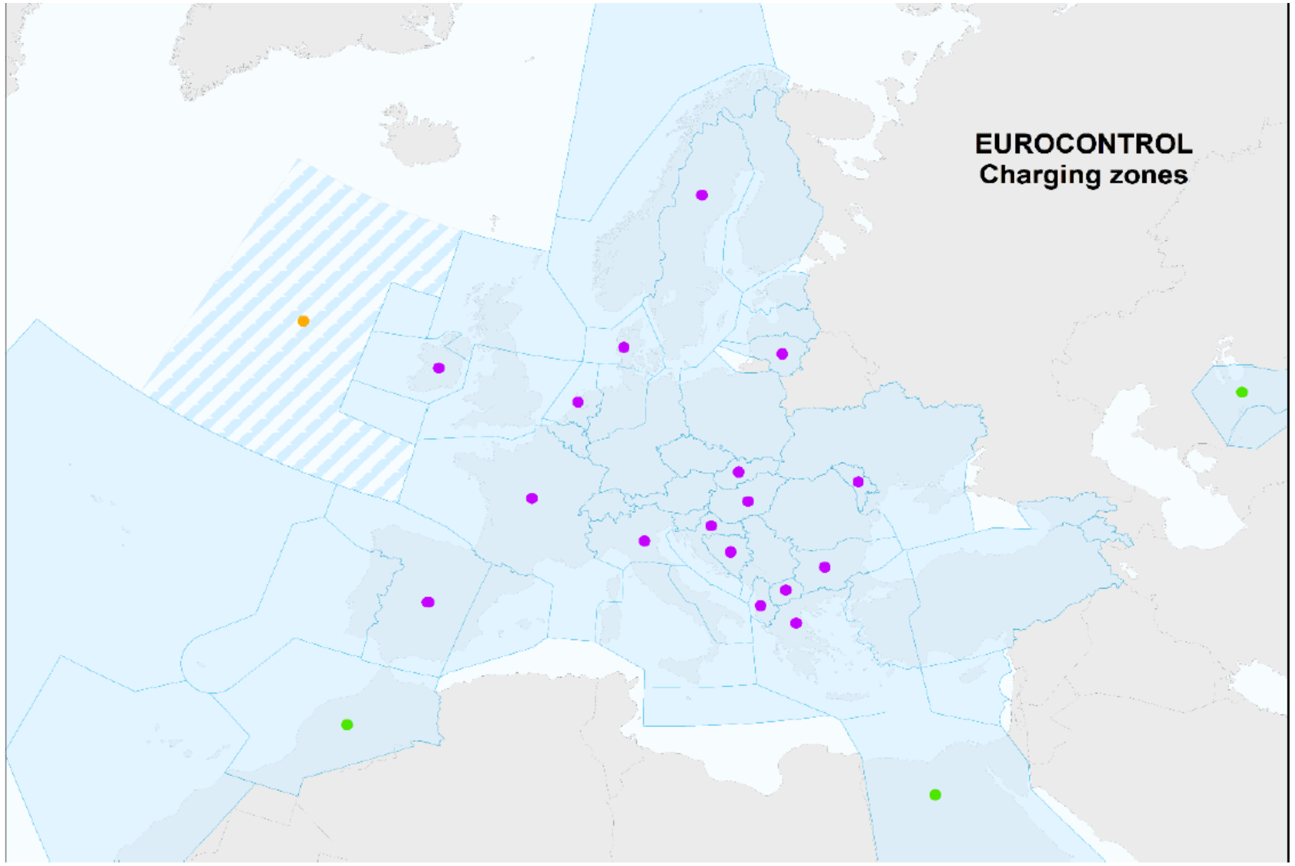
- Current route charging
- Green Route Charging Solution
- Climate hotspots
- SP Survey
- Conclusions

Route charging today

- Charge "is a levy that is designed and applied specifically to recover the costs of providing facilities and services for civil aviation." ICAO Doc9082
- Route per State Overflown (RSO)
  - each State crossed implies a route charge to be paid to the State
- **Unit rate** u_i is set for each charging zone *i*
  - *Unit Rate is a unique tariff per 100 km*
- **Route charge** for a flight is a sum of charges accrued over all crossed charging zones *i*

$$R = \sum_i r_i \qquad r_i = u_i \times n_i$$

- Where route charge in zone *i* is a product of the unit rate u_i and the amount of **service units** n "consumed"



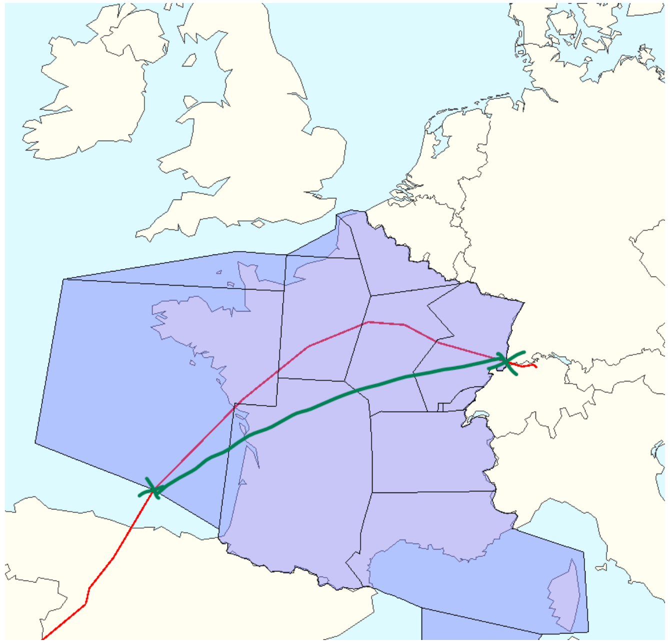
Situation at 31/12/2022

Route charging today

- Service units are a product of distance (d_i) and weight (w_i) factors

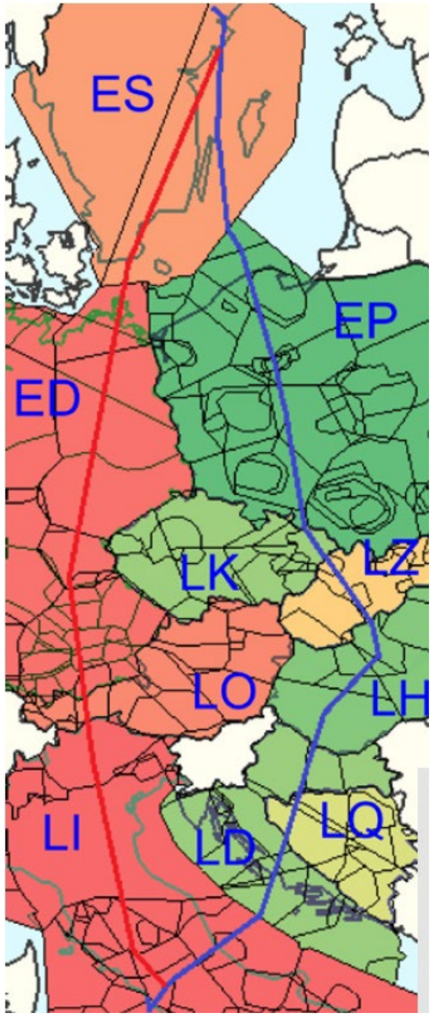
$$n_i = d_i \times w_i \qquad d_i = \frac{GCD}{100} \qquad w_i = \sqrt{\frac{MTOW}{50}}$$

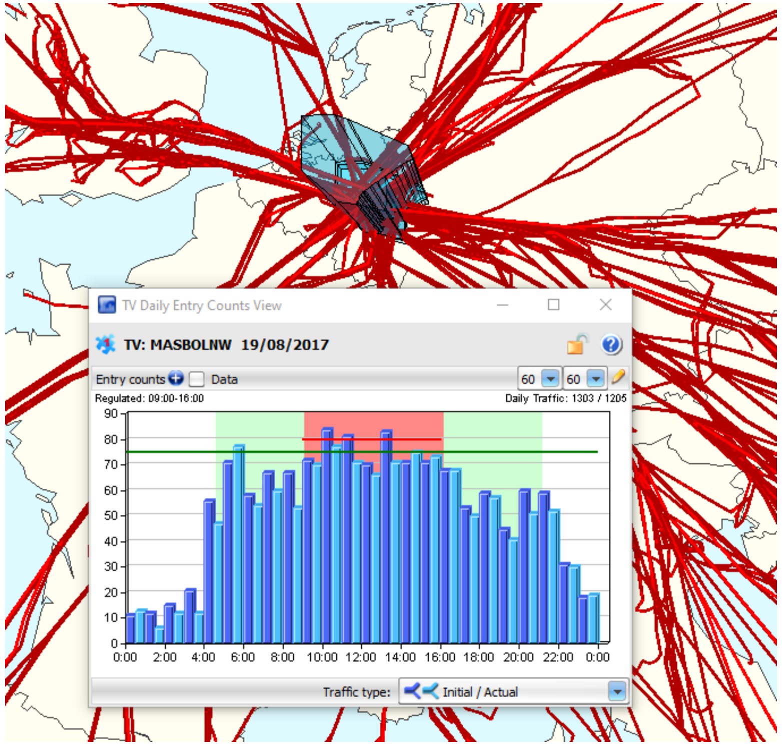
- The **distance factor is proportional** to the great-circle distance (GCD) between entry and exit points to the charging zone
  - if the origin or destination airports are within the charging zone
    - distance is GCD from entry point to the airport coordinates, minus 20 km (for arrival airport)
- **Weight factor** takes the maximum take-off weight into account



Unintended consequences

- Longer flights to save on route charges
  - about 10% of operational costs
- Increase emissions
- Congestion
- When planning flights do not need to take care of capacity
  - nor is the info available to airlines
  - active regulation is a proxy of delay

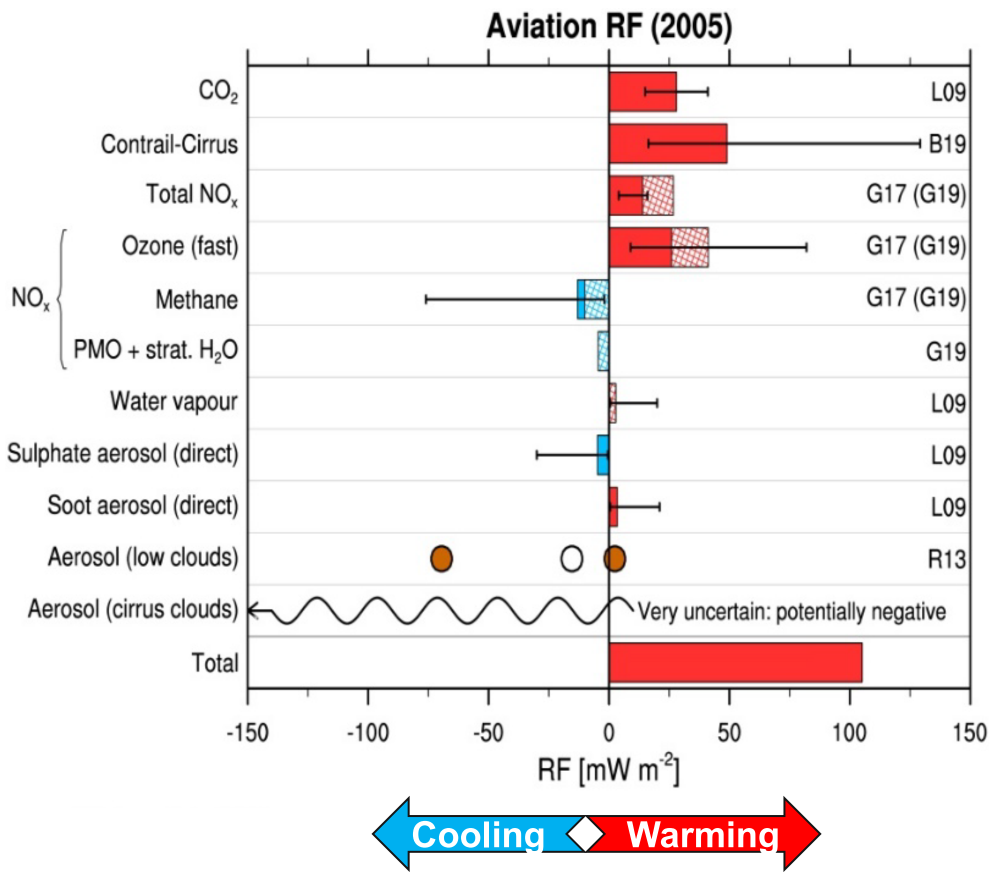




Green Route Charging (GRC) Solution

- Propose business and operational incentivisation of climate-optimised flight planning through route charging
- AUs free to choose trajectory but the most environmentally friendly one should have the least direct costs
- Initial GRC
  - Takes into account CO2 and congestion
- Full GRC
  - Takes into account all aviation emissions

Radiation change

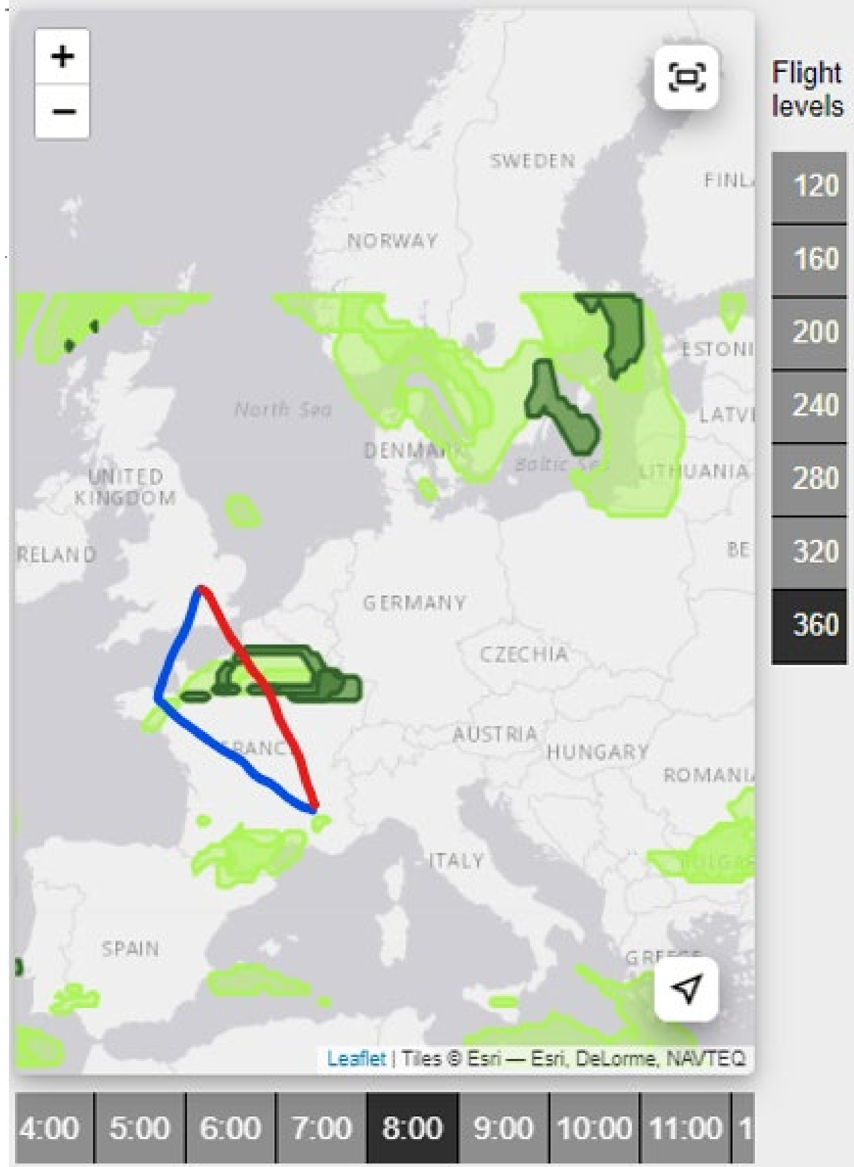


Based on Lee et al. 2009
Grewe et al. (2017,2019)

Full GRC Solution

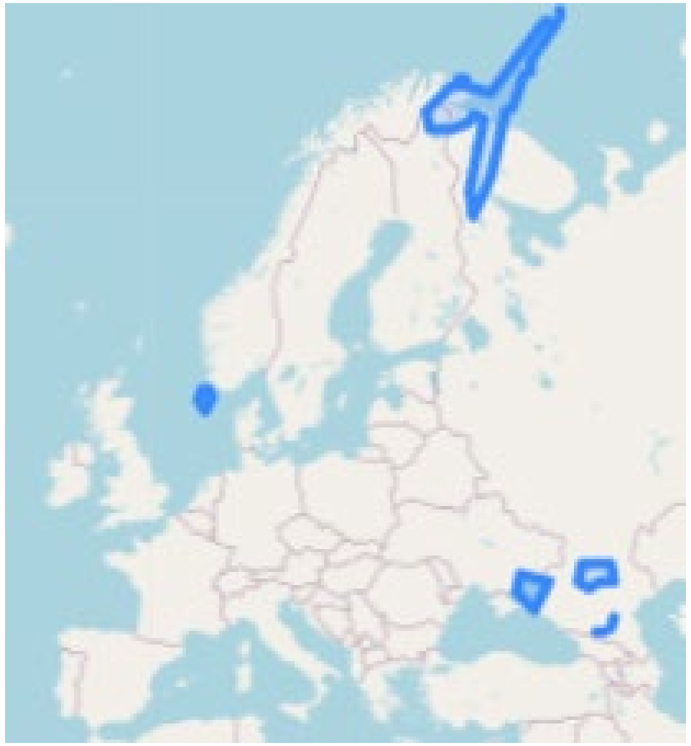
- Full GRC:

- Where the crossing of a **climate hotspot** would entail an *increase* of route charges (e.g. a modulation) and avoidance would entail some form of compensation (‘rebate’) in terms of lower route charges for avoiding the hotspot
- Two components:
  - Climate hotspots
  - Airlines’ willingness to pay



Climate hotspots

- Radiative forcing of aviation
  - about one-third CO2 effects, and
  - about two-thirds non-CO2 effects
- Contrails represent largest single contribution of non-CO2 impacts
  - large uncertainty
- Non-CO2 effects strongly depend on the state of the atmosphere
- Climate hotspot
  - is a volume of airspace where the atmospheric conditions are such that flying through it creates much higher climate impact
- CLIMaCCF and ERA5 data



Climate hotspots

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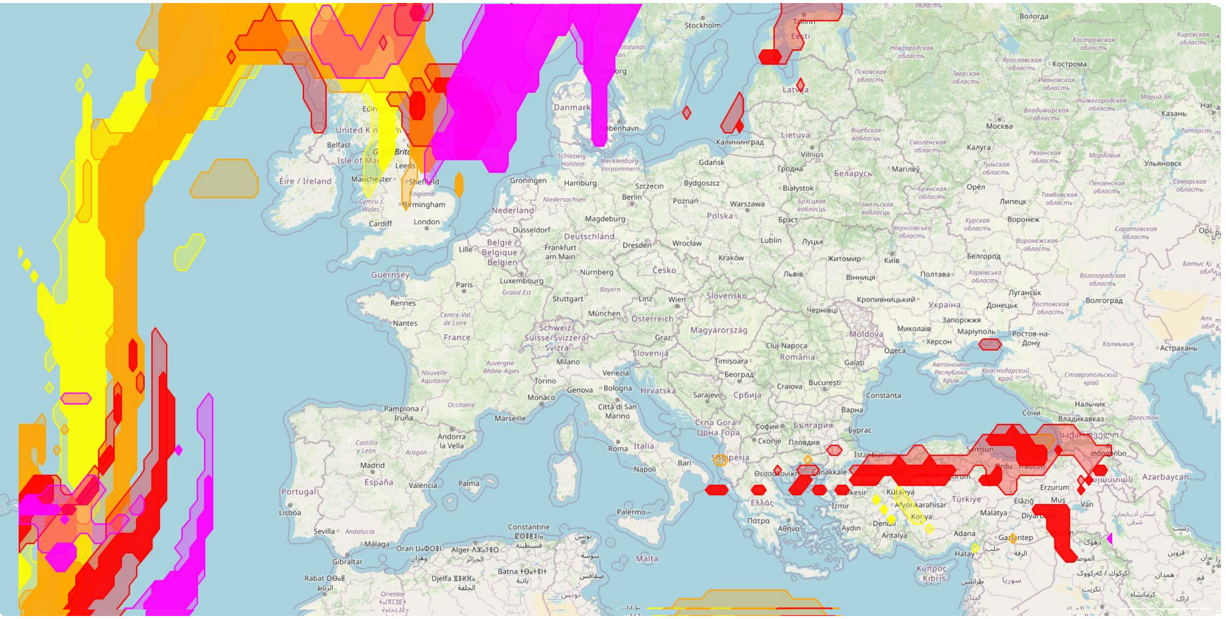
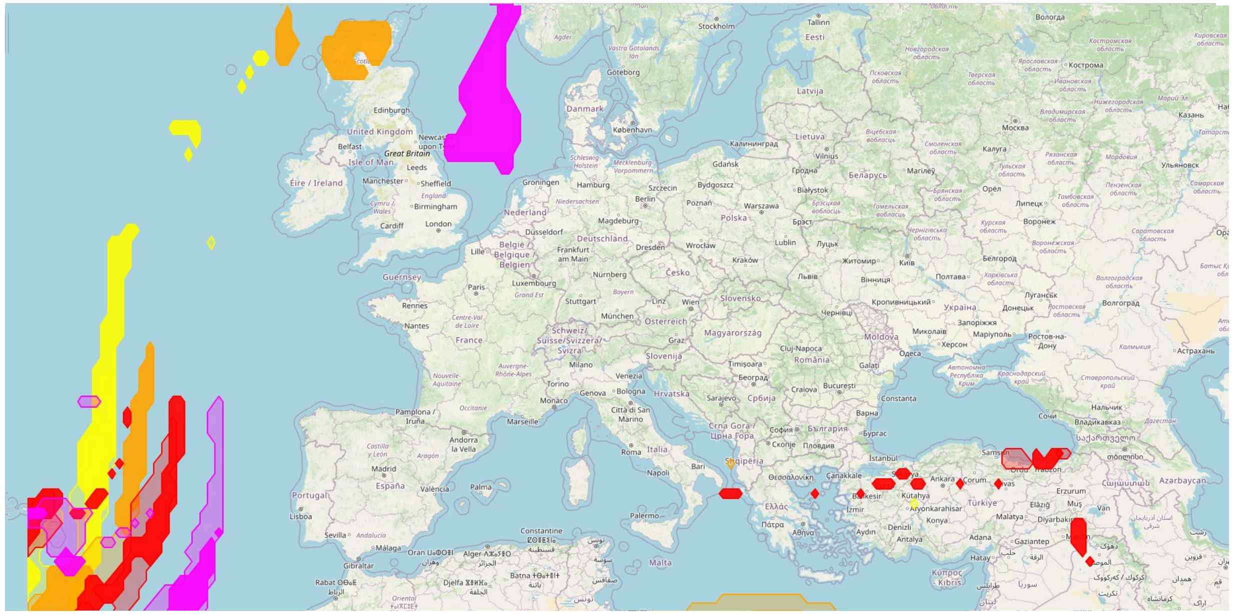
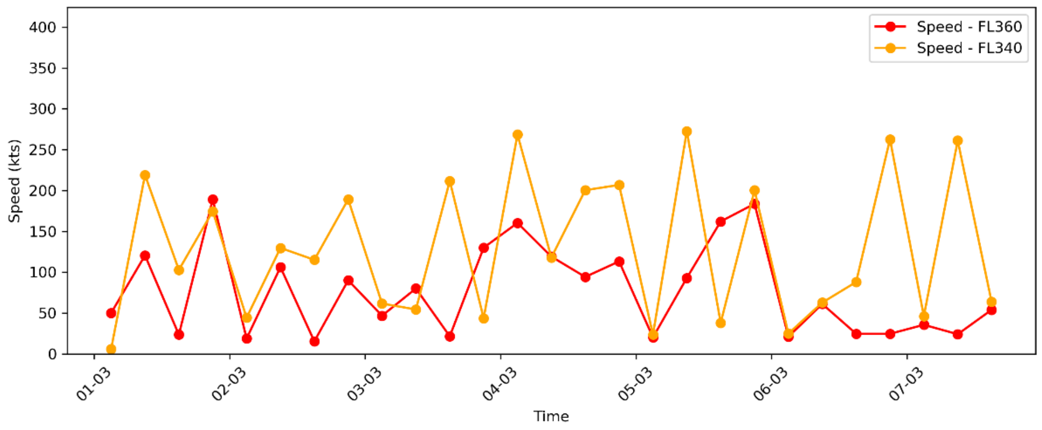


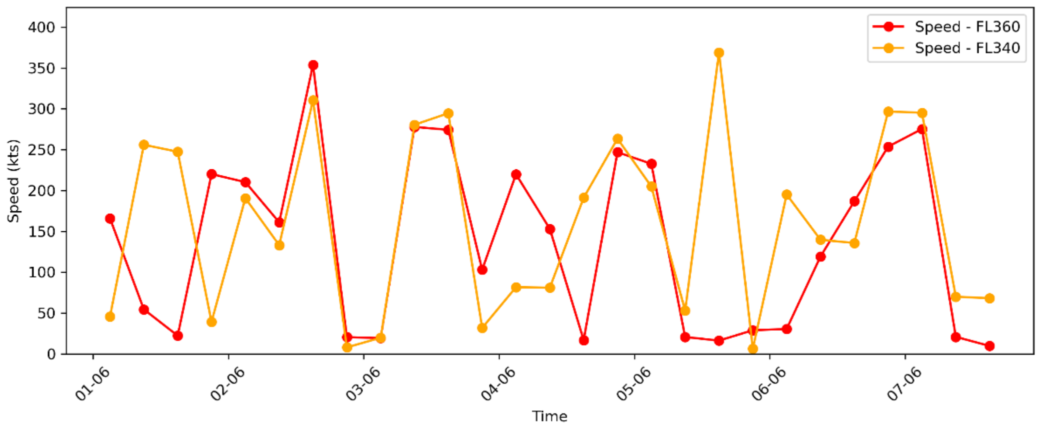
December 03 2019, 95th percentile

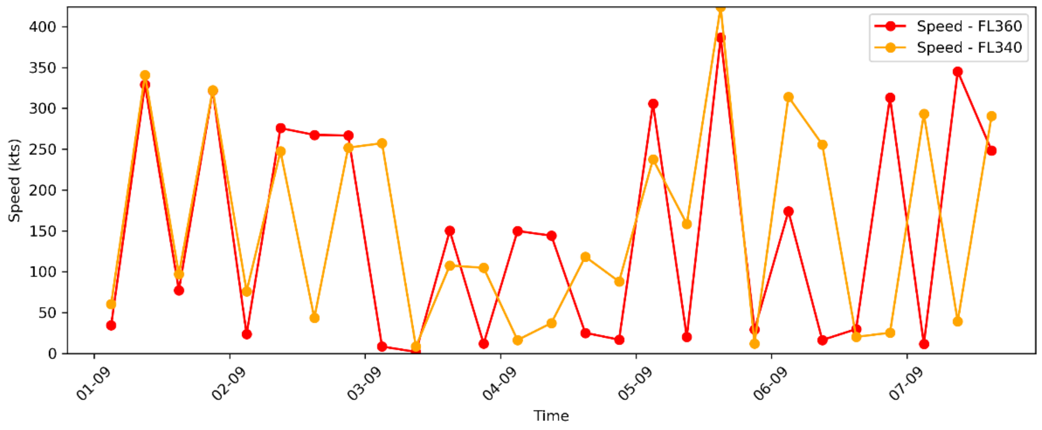


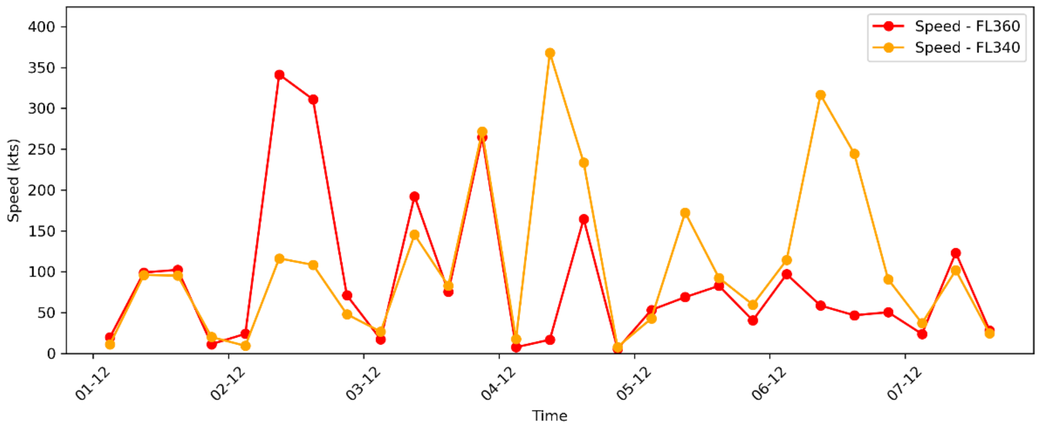
December 03 2019, 99th percentile

Climate hotspots









Stated preference survey

- Stated preference:
- Respondents state their values / preferences, rather than inferring values from actual choices in revealed preference

- Revealed preference has disadvantages:
  - typically based on executed trajectories
  - weakly capable of evaluating future choice sets
  - based on weaker inference
- Adaptive SP
  - subsequent choices dependent on previous ones

- We are interested in 4 attributes:
  - cost sensitivity: fuel and route charges - 7 levels,
  - short arrival delay aversion: 50th percentile delay time – 3 levels,
  - long arrival delay tolerance: 90th percentile delay time – 4 levels,
  - environmental consideration: environmental impact – 3 levels

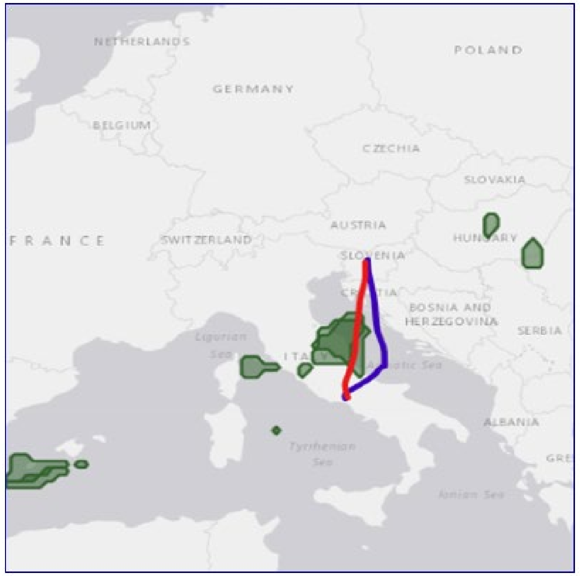
- Survey is composed of:
  - introduction and demographics
  - screen and attribute identification tasks
  - choice tasks

SP survey

In the first column, **“50% chance of an arrival delay of up to 15 min”** means there is a 50% chance that the flight will be delayed by 15 minutes or less.

“10% chance of an arrival delay of more than 40 min” means there is a 10% chance that the flight will be delayed by more than 40 minutes.

“**Environmental impact**” refers to the climate impact a flight can cause by flying through a ‘climate hotspot’, or avoiding one. A 'climate hotspot' is a volume of airspace where the atmospheric conditions are such that flying through it creates much higher climate impact than flying through other areas (e.g., a region where persistent warming contrails are very likely to get formed).



The figure above gives an example of the environmental impact of two trajectories. The blue one mostly avoids climate hotspots (in green), and thus creates a ‘**low**’ environmental impact. The red trajectory crosses a climate hotspot and thus has a ‘**high**’ environmental impact.

Among these three, which is the **best option**? (We’ve greyed out any features that are the same, so you can just focus on the differences.)

From: Rome Fiumicino Airport (LIRF) **To:** Helsinki Airport (EFHK)
Aircraft type: B738 **Scheduled departure time:** 1300 UTC
Block time: 178 min **Number of connecting passengers:** 30

(1 of 1)

Fuel and route charges	6600 €	6000 €	8300 €
50% chance of having an arrival delay of up to	15 min	10 min	10 min
10% chance of having an arrival delay of more than	90 min	90 min	90 min
Environmental impact	Low	Low	Medium
	○	○	○

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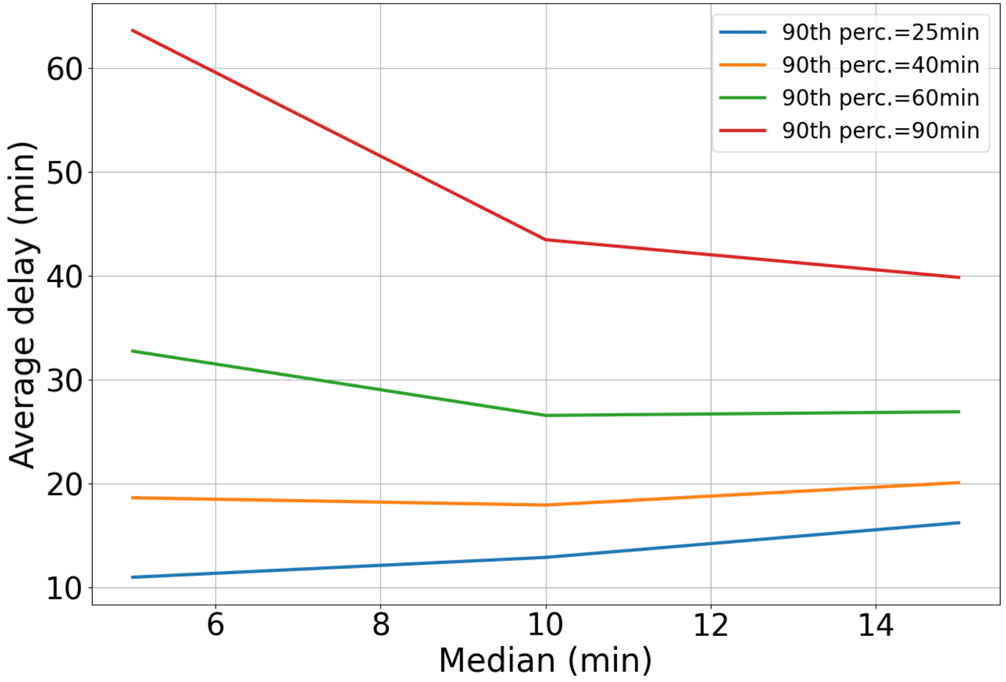
SP survey

Test results – value of time, risk aversion

- Consortium members provided 20 responses

- Value of time
  - Assumes a comparison of an expected arrival delay compared to a certain value of cost
- Two delay related variables, testing the adversity of airlines
  - to **short**, relatively certain delays - median
  - and **long**, quite uncertain delays - 90th percentile



SP results

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Estimation

- Three models:
  - I: cost + expected delay
  - II: cost + expected delay + uncertainty
  - III: cost + expected delay + uncertainty + environmental impact

Model	Coefficients	Value	Std err	p-value
I	α_{cost}	-1.1e-3	1.6e-4	4.9e-12
	α_{exp}	-3.3e-1	3.7e-2	$\leq$ 1.0e-13
II	α_{cost}	-1.1e-3	1.7e-4	2.4e-11
	α_{exp}	-2.9e-1	4.1e-2	4.7e-12
	α_{std}	-8.5e-2	2.5e-2	5.6e-4
III	α_{cost}	-9.8e-4	1.7e-4	1.5e-8
	α_{exp}	-3.0e-1	4.2e-2	2.0e-12
	α_{std}	-8.6e-2	2.5e-2	4.9e-4
	α_{env}	-5.7e-1	1.9e-1	3.4e-3

- Value of time and risk aversion:

Model	Value of time (euros per minute)	Risk aversion
I	308 $\pm$ 79	N/A
II	253 $\pm$ 75	0.29 $\pm$ 0.13
III	302 $\pm$ 96	0.29 $\pm$ 0.13

- Different airline types:

Type of players	VoT	Risk aversion	Environmental concern
Expensive network carrier	1743 $\pm$ 1332	0.11 $\pm$ 0.16	0.58 $\pm$ 0.43
Cheap regional carrier	158 $\pm$ 98	0.61 $\pm$ 0.49	0.58 $\pm$ 62
Environmental friendly regional carrier	73 $\pm$ 65	0.74 $\pm$ 0.82	0.82 $\pm$ 0.81

Conclusions

- Addressing total climate impact
- Two components analysed
- SP survey completed
  - Utilities being defined
- Climate impact
  - need to agree on the definition
  - a hotspot may be very easily avoided by changing the FL
  - hotspots are particularly dynamic, which presents a challenge
- Need to define the modulations and rebates
- Need to incorporate into the model to assess the new route charging scheme

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Thank you!