

Reference Trajectories for Performance Review (et al. ;-)

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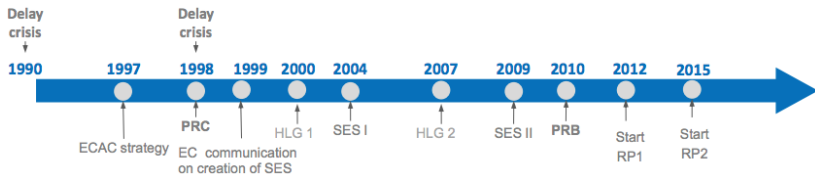
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Who and Why

Performance Review Commission

- PRC setup in 1995 by EUROCONTROL as an **independent** entity to review its Member States' ANS performance

introduce strong, transparent and independent performance review and target setting to facilitate more effective management of the European ATM system, encourage mutual accountability for system performance



- supports the PRC work programme and EC on SES framework
 - OPS analysis
 - financial/cost analysis
- feeds into ICAO performance framework
 - GANP (Doc 9750), Manual on ANS economics (Doc 9161)
 - supports ICAO Paris office for EUR region
- EU-US comparison
- collaborate w/ international partners (Brasil, Japan, Singapore, China)
- PRU Data Portal <http://ansperformance.eu/>

Status Quo

Trajectories

Trajectories are a building block for Performance Indicators' calculation

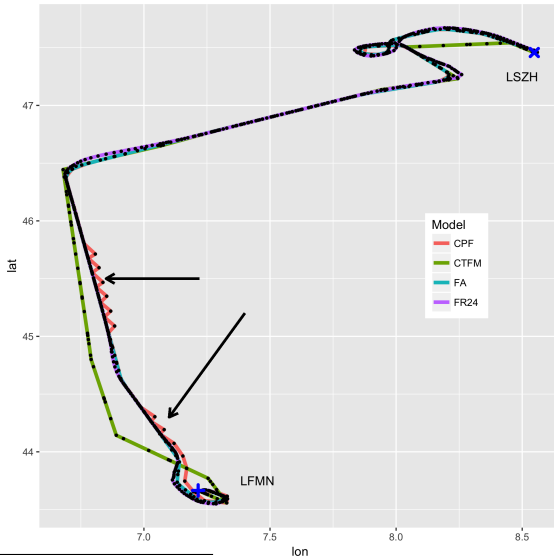
- 4D intersection with airspaces ==> counting flights
- flown distances
- horizontal flight efficiency (en-route)
- vertical flight efficiency (en-route and continuous descent)
- traffic complexity
- additional ASMA time, i.e. time spent in terminal airspace (holding, point merge, ...)

Which Trajectories

- FTFM or Model 1: from (last) **F**light **P**lan (FPL)
- RTFM or Model 2: from FTFM when flight is regulated (i.e. *delayed*)
- CTFM or Model 3: change Model x if CPR/MSG shows enough deviation
- CPF: based on CPRs
- all good for NM purposes: ATFCM mandate
- BUT...

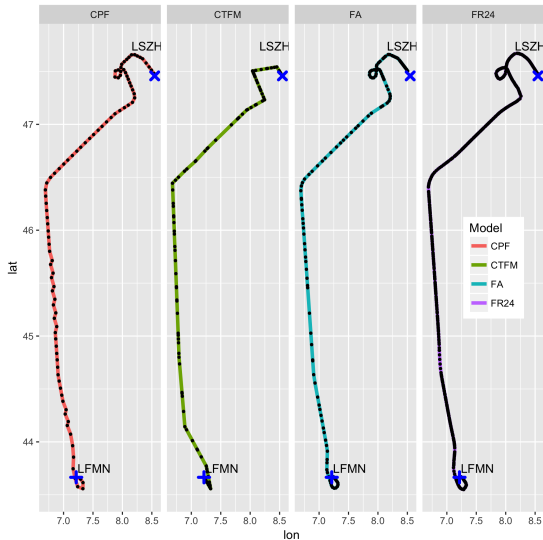
[illegible]

Trajectories¹ from NM 1/2



¹just an example and not representative of all NM trajectories

Trajectories² from NM 2/2



²just an example and not representative of all NM trajectories

Observations 1/2

- FTFM: used to predict sectors load
- CPF: zig-zag due to two overlapping radar reporting position and NM picking one few times, then the other, than back...
- CTFM
 - *missed* the side of the departure (East instead of West)
 - does not capture holding at Zurich
 - it sticks to FTFM unless reality deviated too much from it
 - 20 NM horizontally
 - 5 min in time
 - 1000 ft vertically

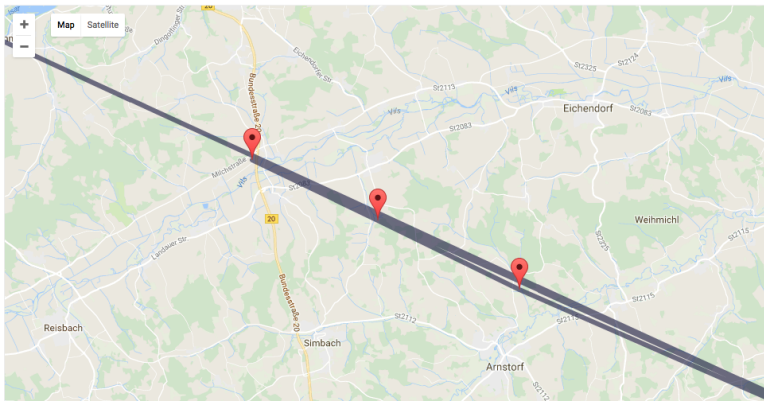
Observations 2/2

ADS-B:

- can be noisy, especially time (back-forth zig-zag):
 - receiver dependent
 - feeder dependent
 - needs server side quality assurance
 - artifacts seen w/ FlightRadar24 and FlightAware
- BUT some sources are better than others
 - OpenSky Network is great at receiver quality assessment

ADS-B zig-zag

click



Take flight ASL334 on 16th Feb 2015 (and sort the position reports by timestamp)

[Open](#)

SID/STAR and RWY

- NM models of approach/departure are simple
 - **good** for ATFCM mandate
 - **good** for system design (complexity, maintainability, performance [CPU/memory])
- trajectory through SID/STAR are straight lines from last CPR to Point Fix to Aerodrome
- RWY L/C/R are not taken into account when connecting to en-route trajectory
- also NM systems build trajectories with SW designed for OPS (memory and time constraint), i.e. limited time span
- BUT not OK for studying holding patterns
- and we need better ones for analysis of Continuous Descent Operations (CDO)

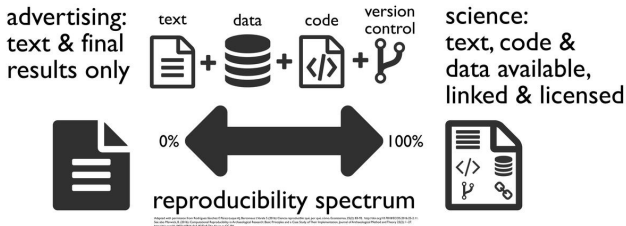
What's new

- ADS-B
 - easier to get than
 - ANSP radar, or
 - airline data or
 - airport ground movements
 - air and (more and more) ground
- SDR (**S**oftware **D**efined **R**adio):
 - cheap electronics: 15\$ DBV TV dongle
 - free software (!): dump1900
- ubiquitous internet connectivity
 - the long tail effect: “small” % of aviation enthusiasts multiplied by huge numbers of internauts → makes big enough feeders for FA, FR24, OSN, ADS-B Exchange, . . .
 - cheap/fast enough to spare capacity to feed ADS-B data
 - other aeronautical info *easily* available

Our Goal

Philosophy

- science not marketing

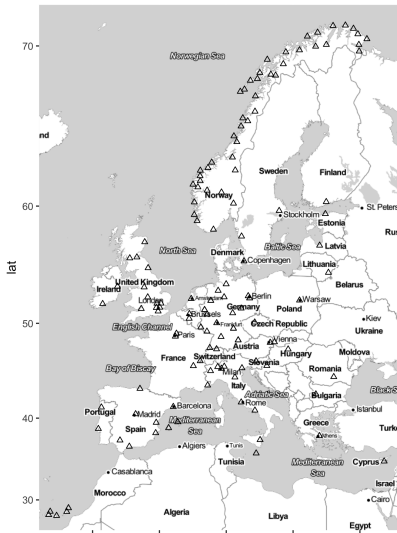


- be open to scrutiny (methodology, data, results)
- engage / collaborate with various communities
 - stakeholders (ANSPs, Airports, Airlines, International Organisations)
 - aviation enthusiasts (OSN, ...)
- give back: from tax payers (States money + passengers fees) back to citizens (research community, industry, general public)

Our Approach

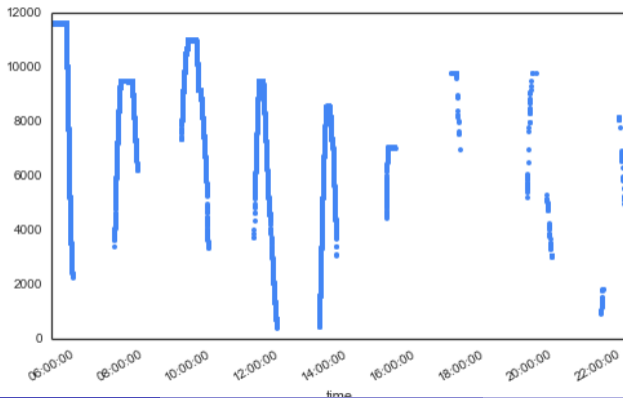
Complementarity 1/2

- use CPR with ADS-B and APT data



Complementarity 2/2

- ADS-B alone knows nothing about APTs (from Alexander Renz-Wieland and Hugo Wallenburg. *Airport quality: holding and go-arounds*. Centrum Wiskunde & Informatica (CWI), Amsterdam, 2016.)



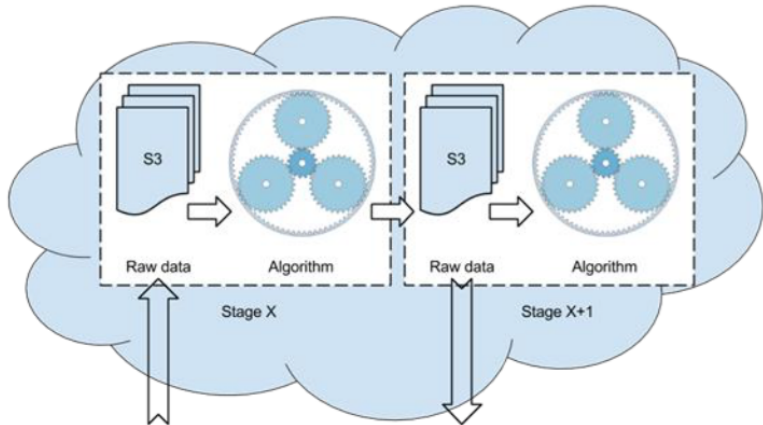
Possible Uses

- reproduce our results
- complement/evolve our methodology (OK, maybe EVEN criticize it!)
- CORPUS for research/analysis:
 - compare solutions
 - focus on research topics (not waste time again and again on collecting/cleaning trajectory data)
 - define a usable, geographically and temporally extensive dataset
 - machine learning
 - European studies
 - multi-year studies
 - simulations

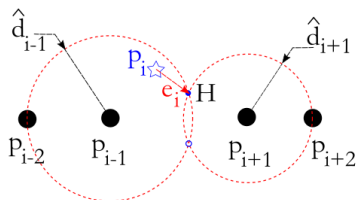
Done and ToDo

Feasibility Study (end 2016 - beg 2017)

- Pipeline setup via AWS & scaling opportunities
- Sharing of resources
- First implementation of trajectory and airspace intersections



Error at point i



$$\hat{d}_{i-1} = \hat{v}_{i-1}(t_i - t_{i-1}) \text{ and } \hat{e}_i = \min(e_i - \frac{\gamma}{2}(e_{i-1} + e_{i+1}), 0)$$

$\gamma \in [0, 1]$ modulates the error propagation from the 2 neighboring points

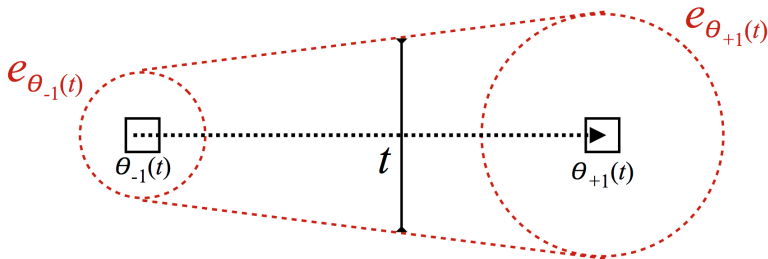
Procedurally $\hat{e}_i$ is calculated as follows:

1. sort all points by e_i
2. calculate $\hat{e}_i$
3. (if $\gamma \neq 0$) repeat step 2. until $\hat{e}_i$ converges.

Trajectory Error

$$E = \frac{1}{|t|} \sum_t (\hat{e}_{\Theta_{+1}(t)} - \hat{e}_{\Theta_{-1}(t)}) \frac{t - t_{\Theta_{+1}(t)}}{t_{\Theta_{-1}(t)} - t_{\Theta_{+1}(t)}}$$

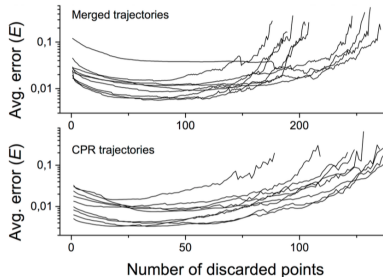
graphically $\hat{e}_{\Theta_{+1}(t)} - \hat{e}_{\Theta_{-1}(t)}$ is the black segment



Total error

```

(A) E = total_error(T)
(B) for i in T
    remove node i from T
    E_i = total_error(T)
(C) if (min(E_j) < E)
    permanently delete node j from T
    E = E_j
    goto (B)
  
```



Future (end 2017 - beg 2018)

- **Production**

- Fuse all ADS-B, CPRs, Airport movements: different algorithms?
- Reference Trajectory Dataset:
 - Curated
 - Open (algorithms, datasets)
 - Derived/supporting datasets: fleet, airspaces, etc.
- use and compare ref trajectories for PI's
- explore/expand ADS-B and other data sources
 - OpenSky Network 
 - ADS-B Exchange
 - ...
- (think about) exploit predictive models to “fill the gaps”

**** BUILD a COMMUNITY ****

