Trajectory Prediction in North Atlantic Oceanic Airspace by Wind Netxorking

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Plan

- Context and objectives
- Problem modeling
- Simulation results
- Conclusion

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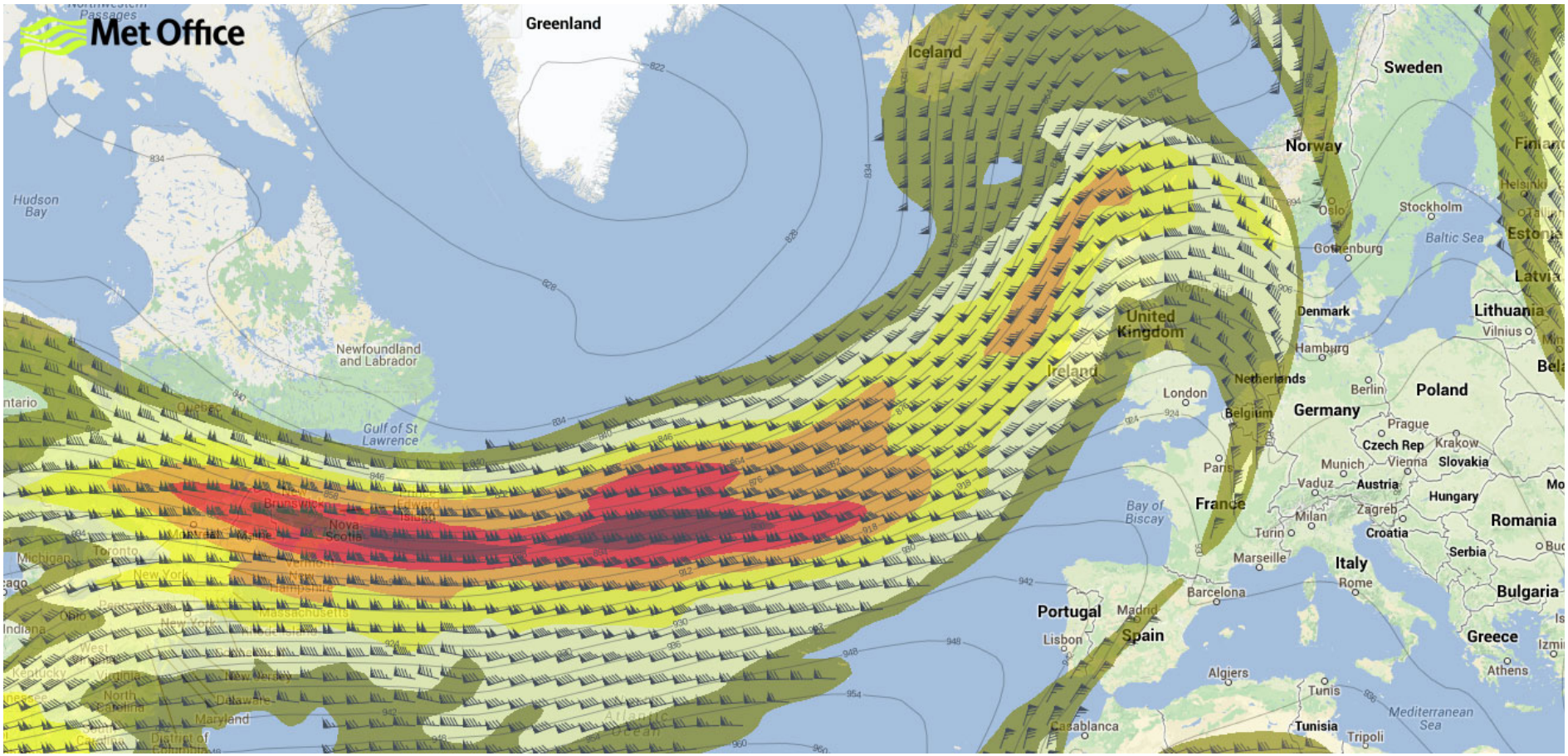
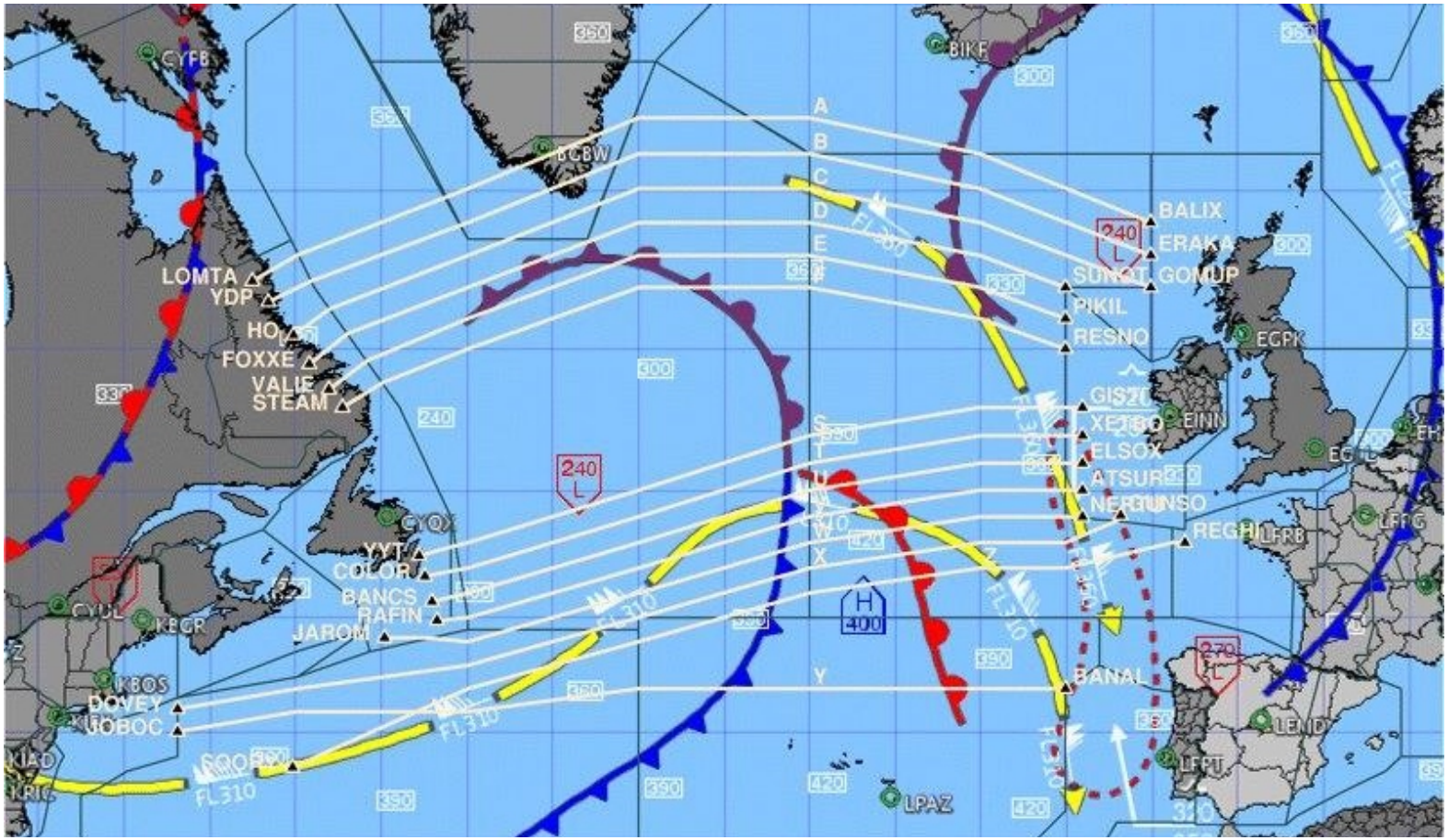
Jet Streams in North Atlantic Oceanic Airspace (NAT)



Wind speed $\sim$ 100 kts (up to 200 kts)
Wind direction: West $\Rightarrow$ East

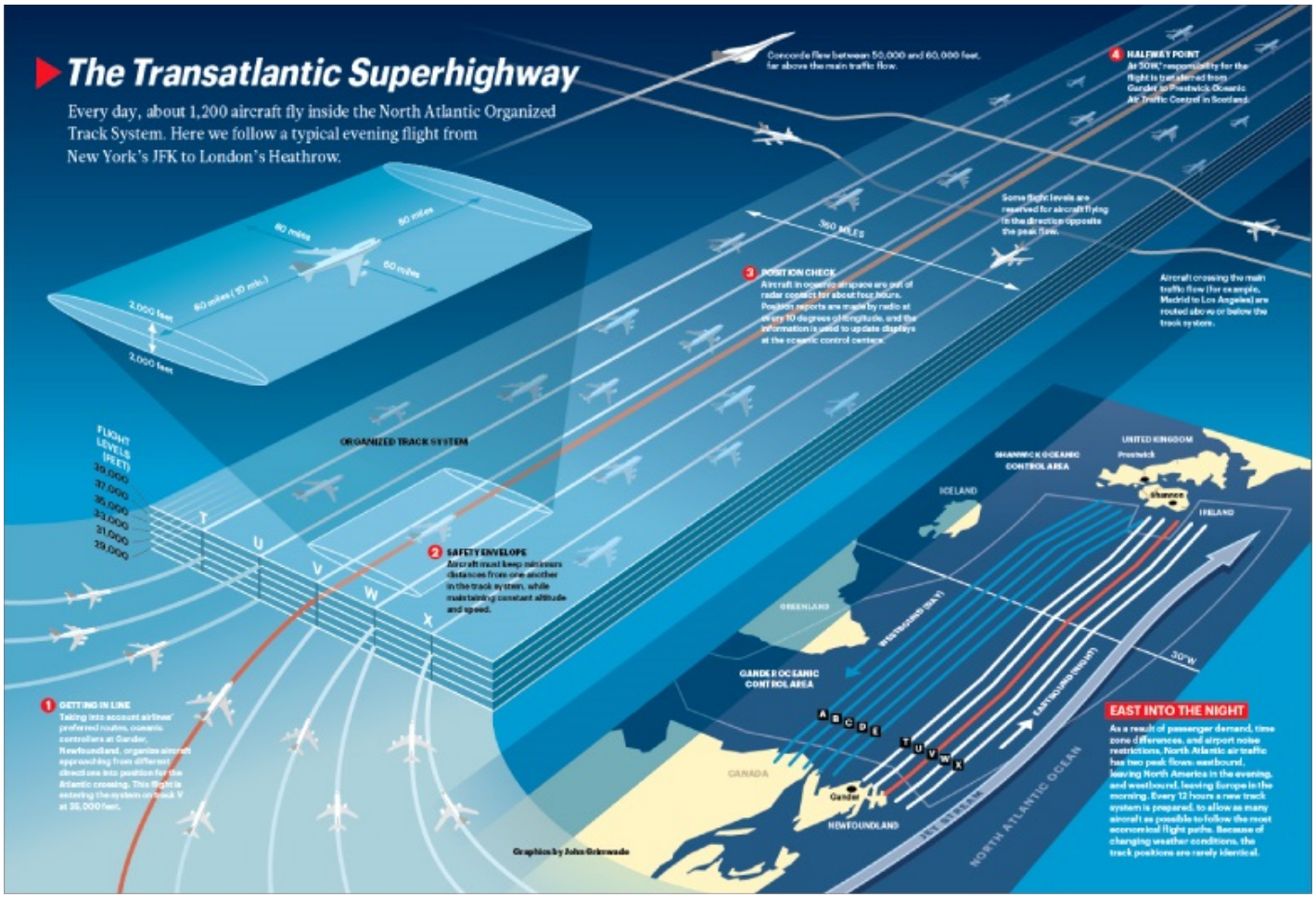
Organized Track System (OTS) in NAT



Eestbound: 0100-0800 UTC
Westbound: 1130-1900 UTC

5-8 tracks, 7-9 waipoints,
$\sim$9 flight levels (FLs)

Separation standards on OTS



Vertical:

1000 feet (1 FL)

Lateral

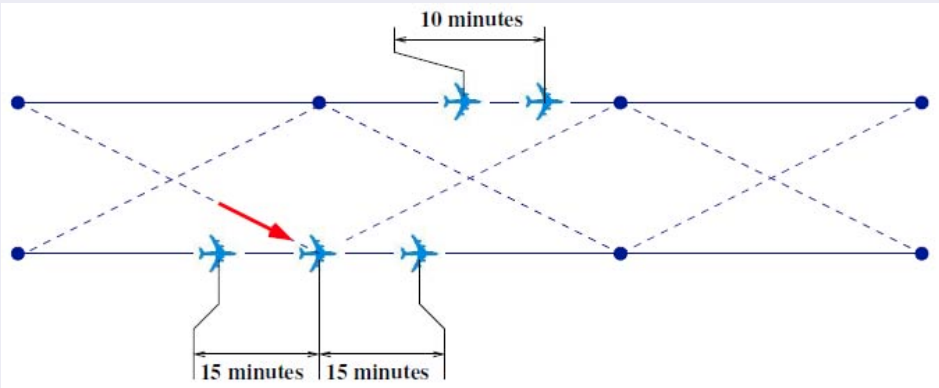
60 NM (1°)

Longitudinal

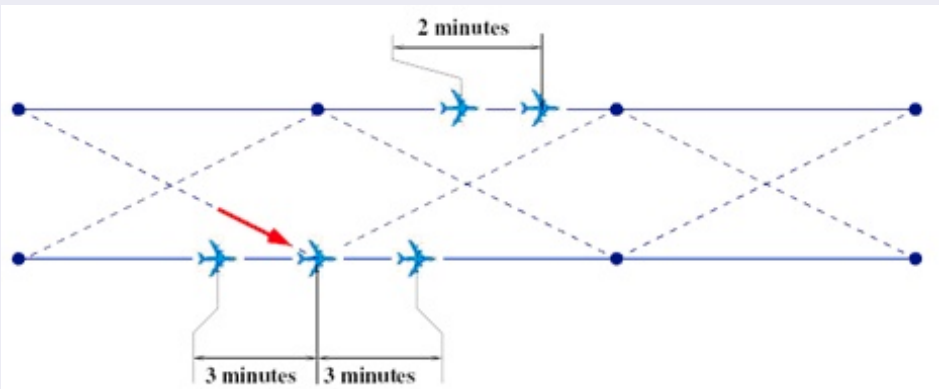
in minutes

Longitudinal separation standards (LSS)

Current LSS



Reduced LSS



New surveillance/broadcast services (ADS-B)

Trajectory prediction methods

Current trajectory prediction

- Meteorological forecast (MF), wind maps
- Rough data $\Rightarrow$ Prediction errors

Wind Networking (WN) approach

- Meteological measurements (wind speed) by aircraft
- Exchanging measured data between aircraft (broadcast technologies)
- Updating the initial prediction using more recent and precise data

WN objectives

- Improvement of cruising time prediction
- Improvement of conflict prediction

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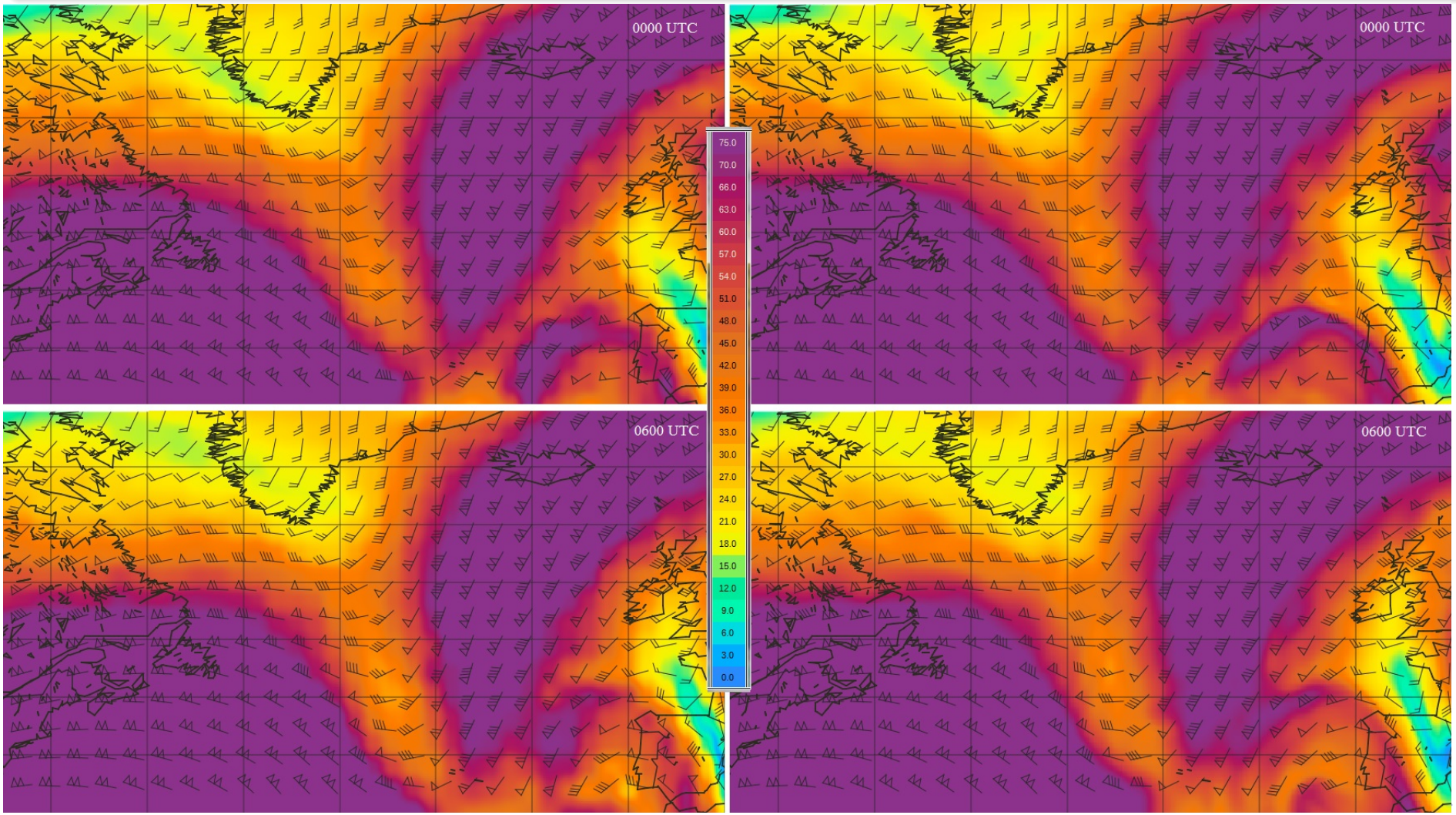
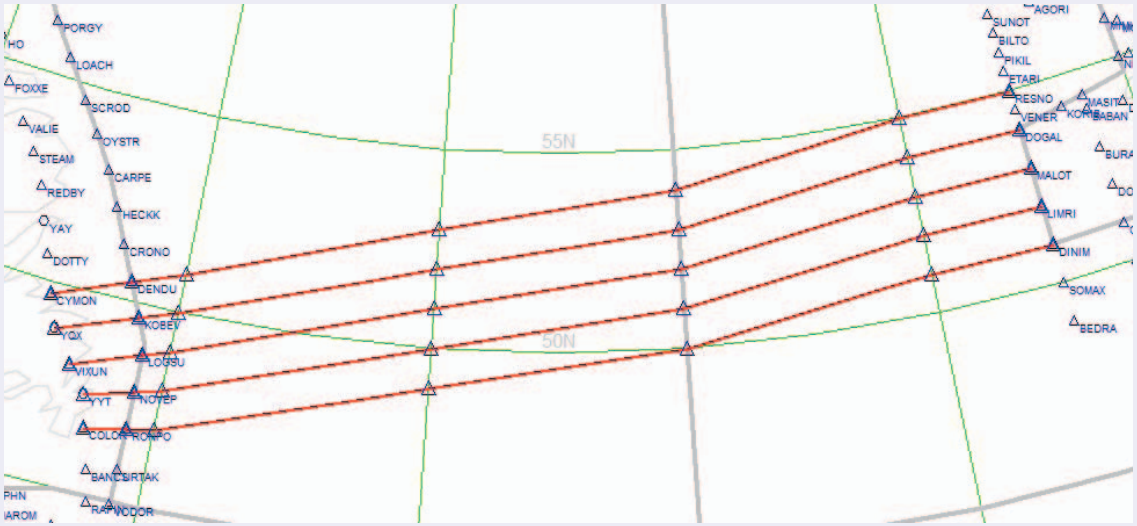
Real and forecast wind models

GRIB data: 10 December 2013, 200 hPa

Forecast wind | Real wind



OTS model



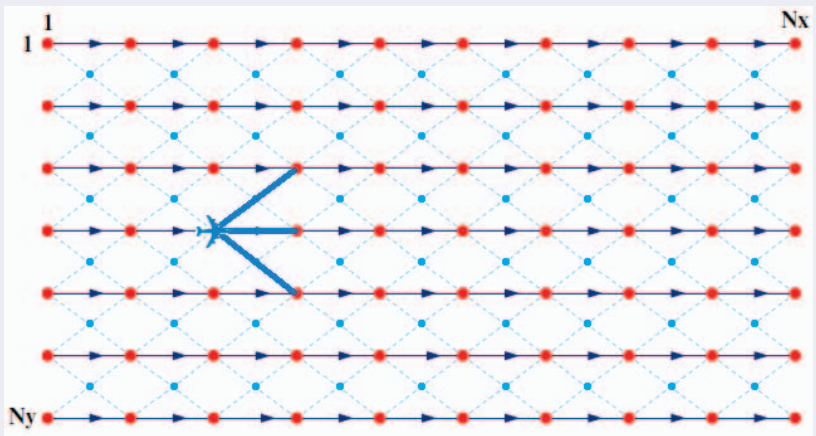
10 December 2013, Eastbound OTS

5 tracks

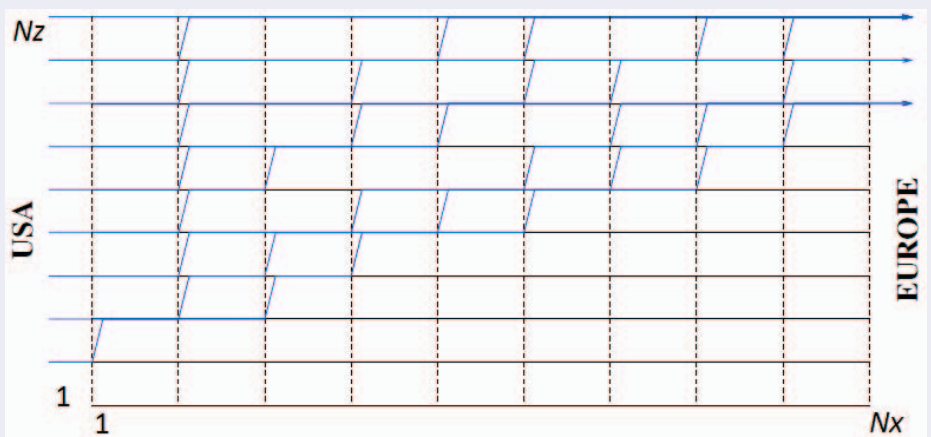
8 WPs

9 FLs

Horizontal section: nodes, links



Vertical section: altitude profiles



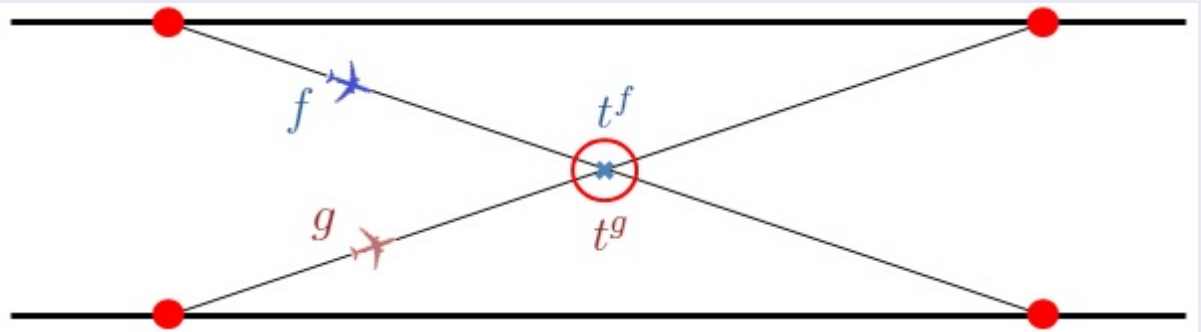
Flight model and flight conflicts

Flight input data

- Entry track
- Exit track
- Track entry time
- Air speed at waypoints
- FLs at waypoints
- Re-routing waypoints

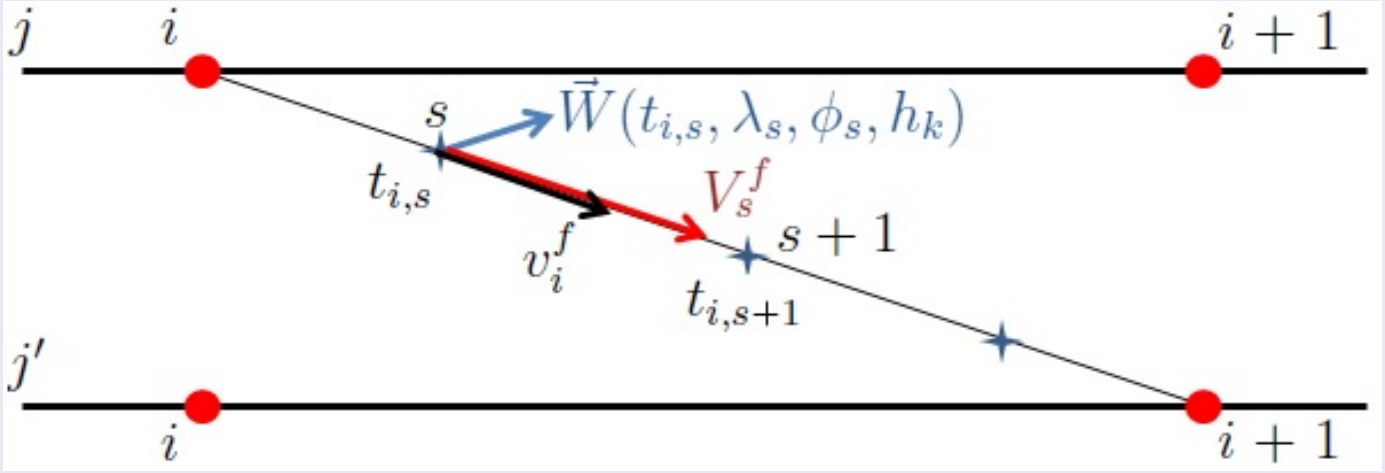
On-route conflicts

- Conflicts on nodes: violation of LSS
- Conflicts on links: overtaking

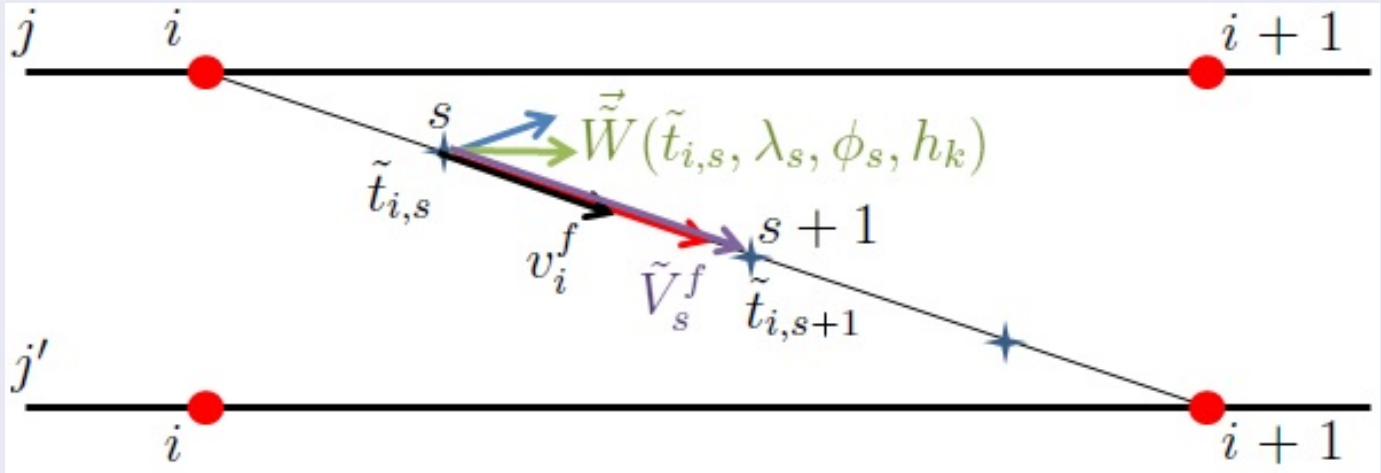


Flight simulation

Flight simulation with real winds

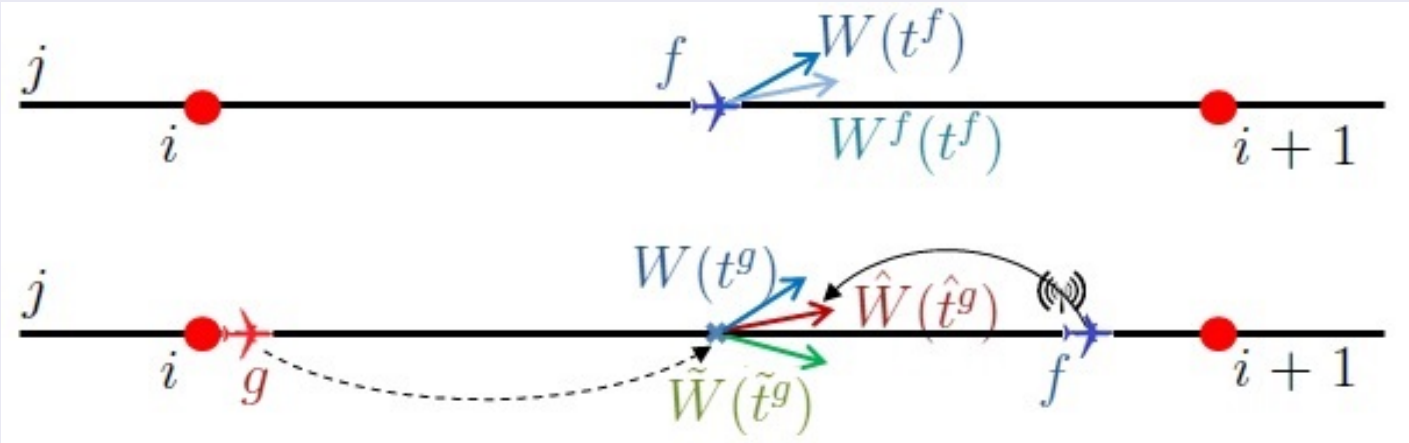


Flight prediction with forecast winds



Wind networking concept

Aircraft f precedes aircraft g on the same track



Wind adjusting by networking

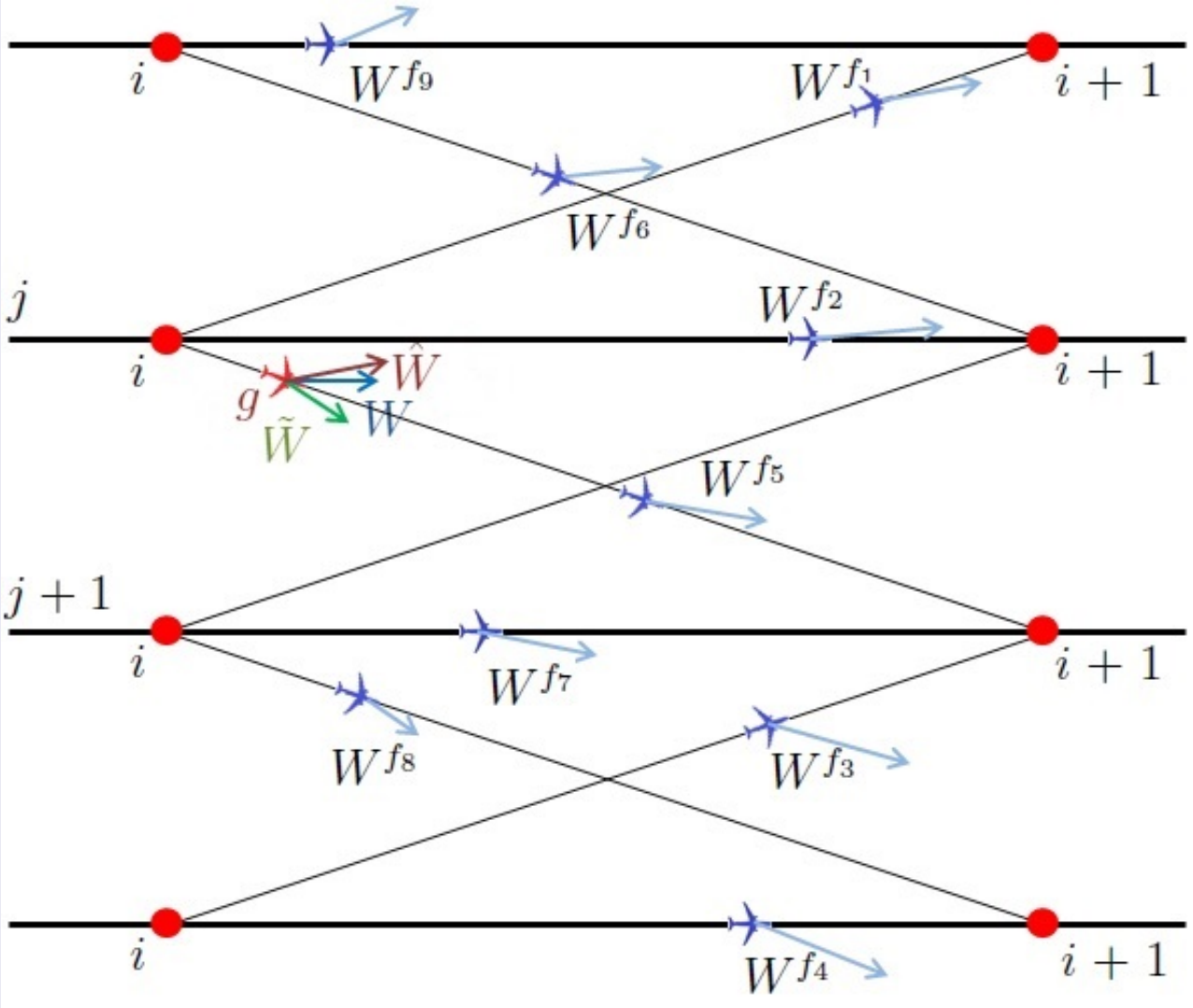
Real wind $W(t_g, \lambda, \phi, h)$ $\Leftrightarrow$ Real time t_g

Estimated wind $\tilde{W}(\tilde{t}_g, \lambda, \phi, h)$ $\Leftrightarrow$ Estimated time $\tilde{t}_g$

Adjusted wind: $\hat{W}(\hat{t}_g, \lambda, \phi, h) \approx W^f(t_f, \lambda, \phi, h)$ $\Leftrightarrow$ Adjusted time $\hat{t}_g$

Wind networking with interpolation

Aircraft $f_1, ..., f_m$ precede aircraft g on the same or close tracks



Adjusted wind:
$\hat{W}(\hat{t}^g, \lambda, \phi, h) =$
$F[W^{f_n}],\ n = 1, ..., m$

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Criteria of comparison: MF vs WN

The errors of prediction of the time of passing the aircraft route points

- t - real time of passing the waypoint
- $\tilde{t}$ - estimated time of passing the same waypoint
- $\hat{t}$ - adjusted time of passing the same waypoint
- $\tilde{e} = \tilde{t} - t$ - prediction error with estimations
- $\hat{e} = \hat{t} - t$ - prediction error with adjustements

Conflict prediction errors: evaluate the difference between

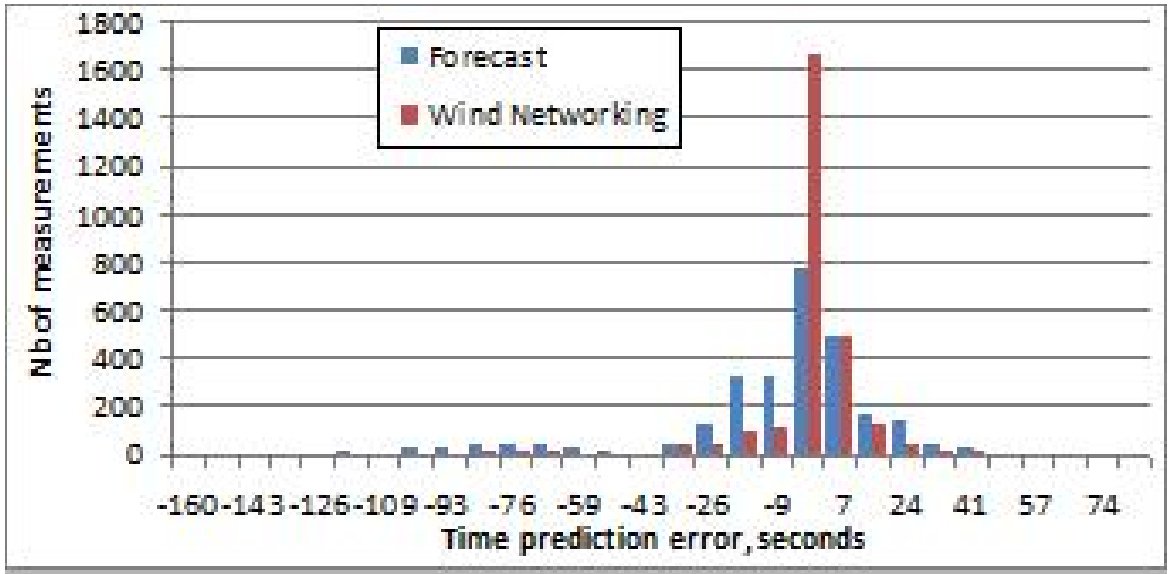
- the number of real and predicted conflicts:
  - Conflicts that are predicted and would happen in the reality (C_t)
  - Conflicts that are predicted but would not happen in the reality (false alarm) (C_p)
  - Conflicts that are not predicted but would happen in the reality (**urgency**) (C_r)
- real and predicted conflict duration times.

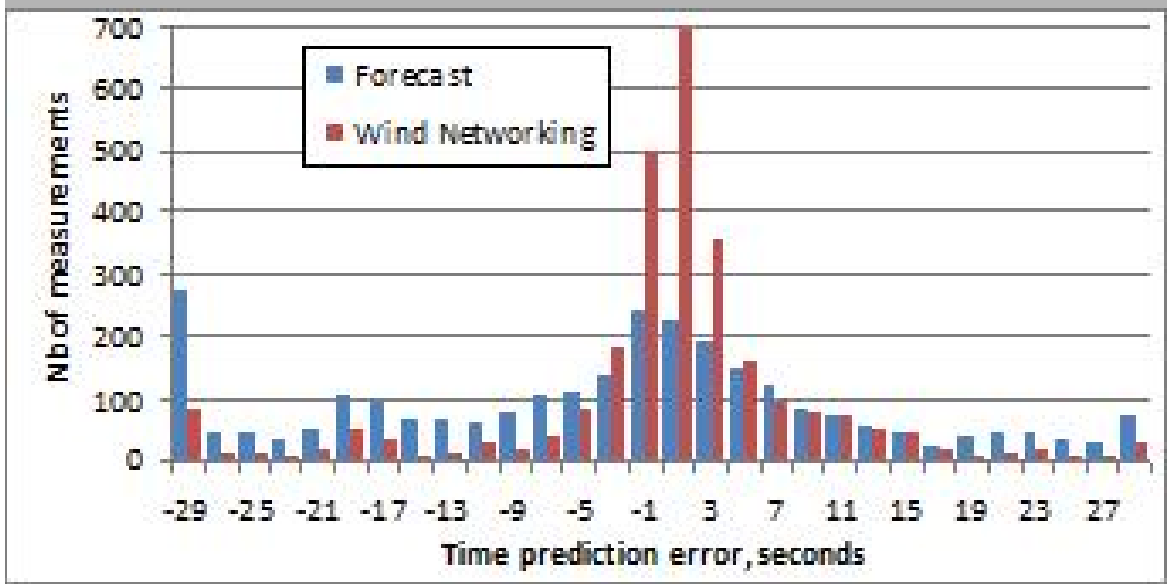
Time prediction comparison. Test for 378 flights

- 10 Decembre 2013
- 378 aircraft (real flight plans)
- 2646 measurements of waypoint time passing

Prediction error statistics (seconds)

	MF	WN
Mean	16.36	6.40
Var	22.05	12.21





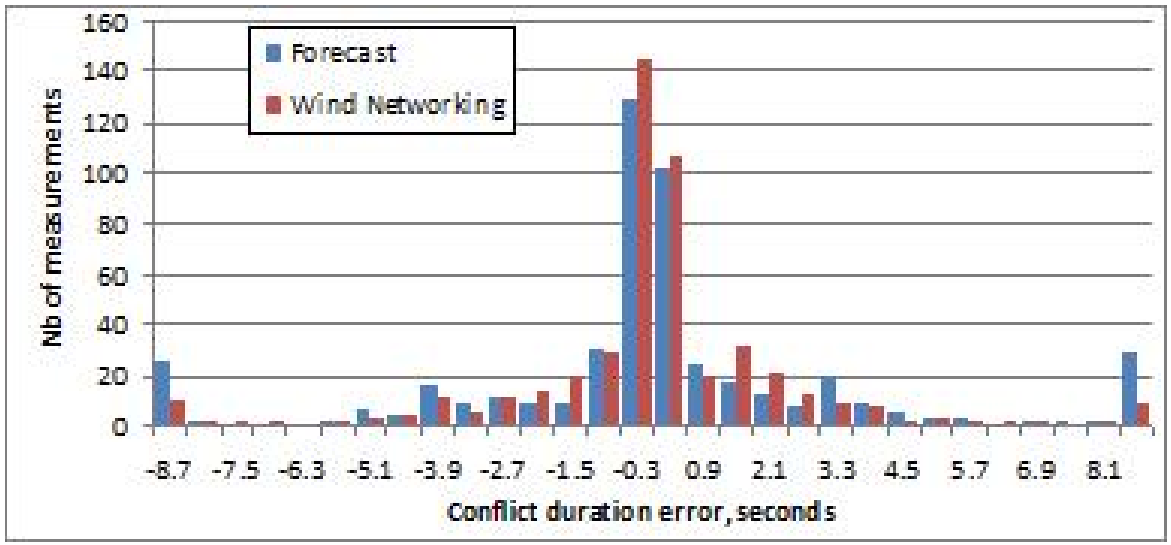
Conflict prediction comparison. Test for 378 flights

Number of conflicts:

	MF	WN
C_t	460	462
C_p	11	7
C_r	12	10

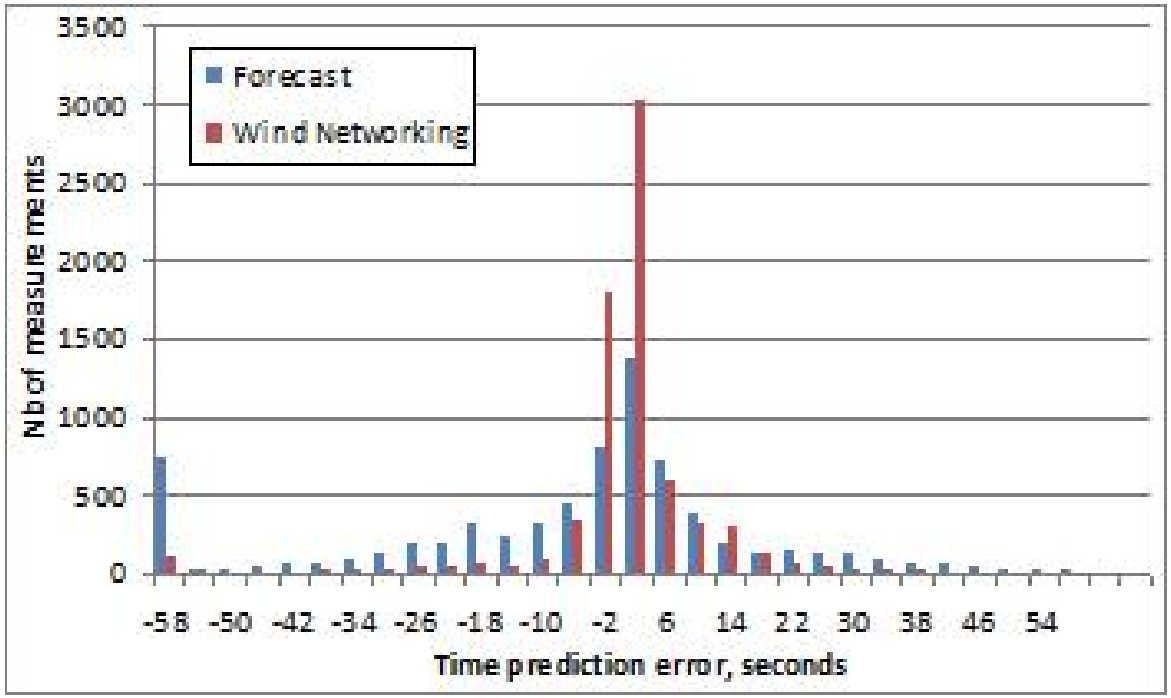
Total conflict duration prediction error (min)

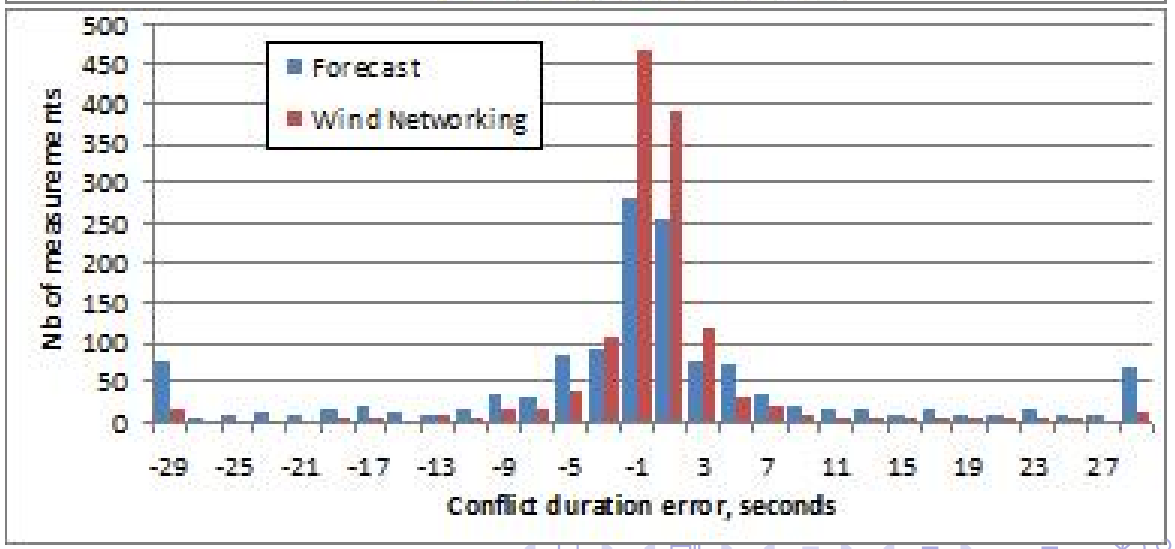
MF	WN
46.29	21.63



Prediction methods comparison. Test for 1000 flights

	MF	WN
Mean prediction error (seconds)	22.35	5.83
Number of conflicts:		
C_t	1175	1229
C_p	48	13
C_r	70	16
Total conflict duration prediction error (min)	242.7	63.4





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Conclusion

- Implementing new technologies enables aicraft to exchange the measured meteorological data with each other directly
- The data obtained with wind networking is much more accurate than the initial estimations
- Adjusted predictions of cruising time and conflicts are much closer to the reality
- Wind networking evolves great amelioration of flight prediction
- Wind networking is especially efficient in dense traffic conditions
- Future work: to apply the concept in other dense areas (ex. big terminal maneuvering areas).

Thank you for your attention!