Systematic Air Traffic Management in a Regular Lattice

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Outline

- SuperHighway project
- Regular lattice
- Initial simulation results
- Potential advantages and future work

Super Highway Project

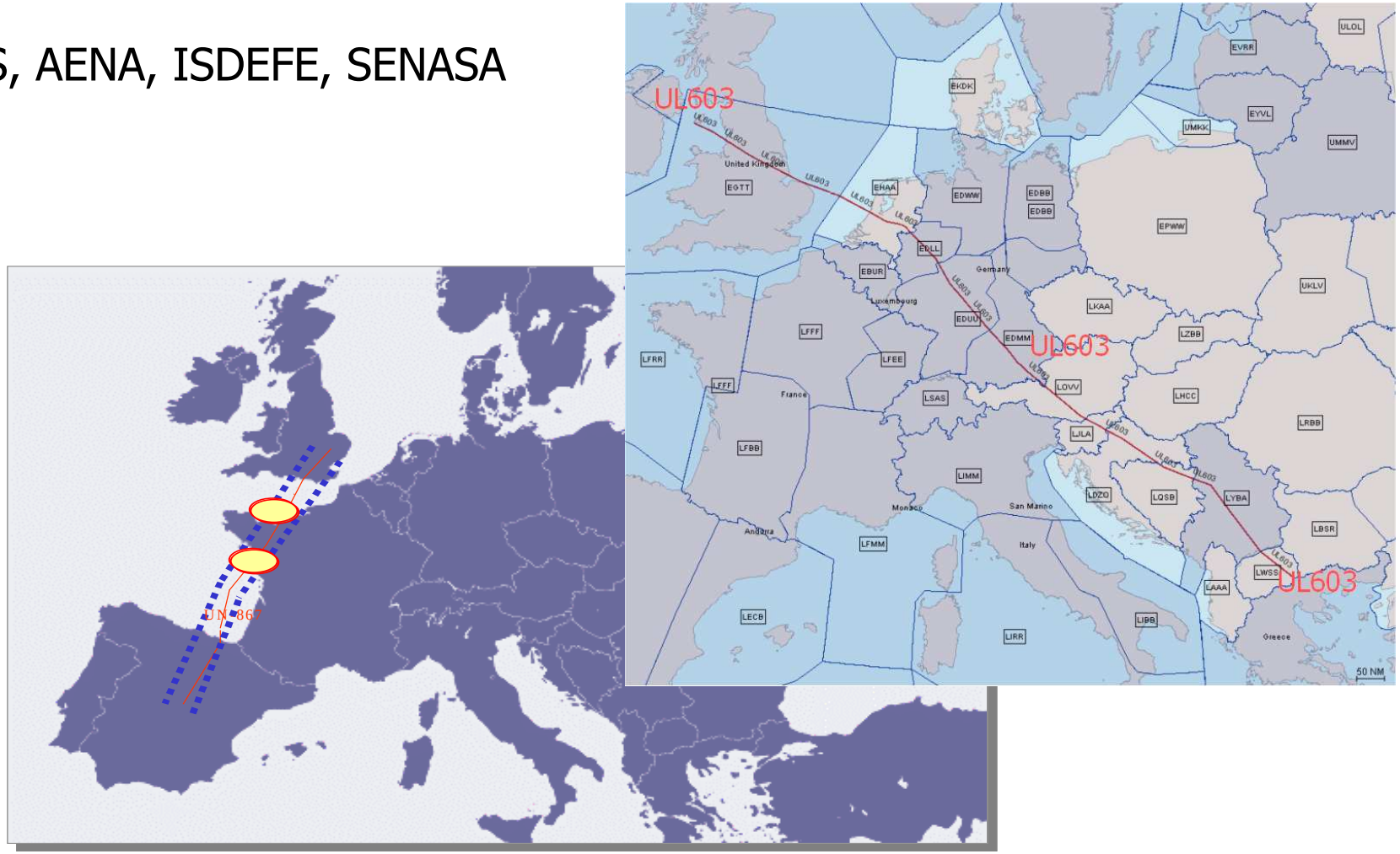
European Commission 6th Framework Programme

Started April 2006, Duration 2 years

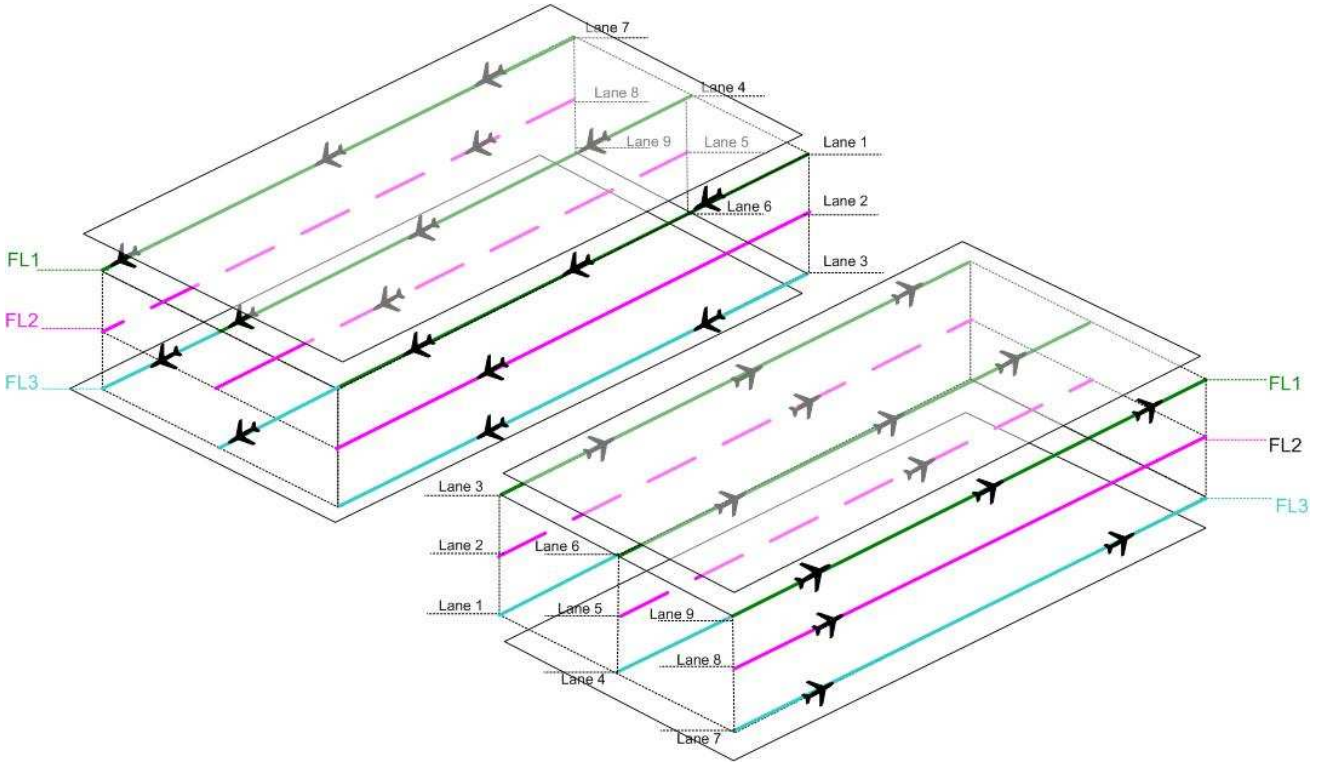
Assessment of two scenarios

Scenario 1

DFS, AENA, ISDEFE, SENASA



Scenario 1


Lane 7
Lane 8
Lane 4
Lane 9
Lane 5
Lane 1
Lane 6
Lane 2
Lane 3
FL1
FL2
FL3
Lane 3
Lane 2
Lane 6
Lane 1
Lane 5
Lane 9
Lane 8
Lane 4
Lane 7
FL1
FL2
FL3

Questions …

Where should the Super Highways be?

How many will there be?

Where will they be in relation to one another?

How will they cross? How will they connect?

What will be the place of Super Highways in a Single European Sky?

What principles would allow systematic airspace design?

Scenario 2 – Regular Lattice - EEC

Enablers

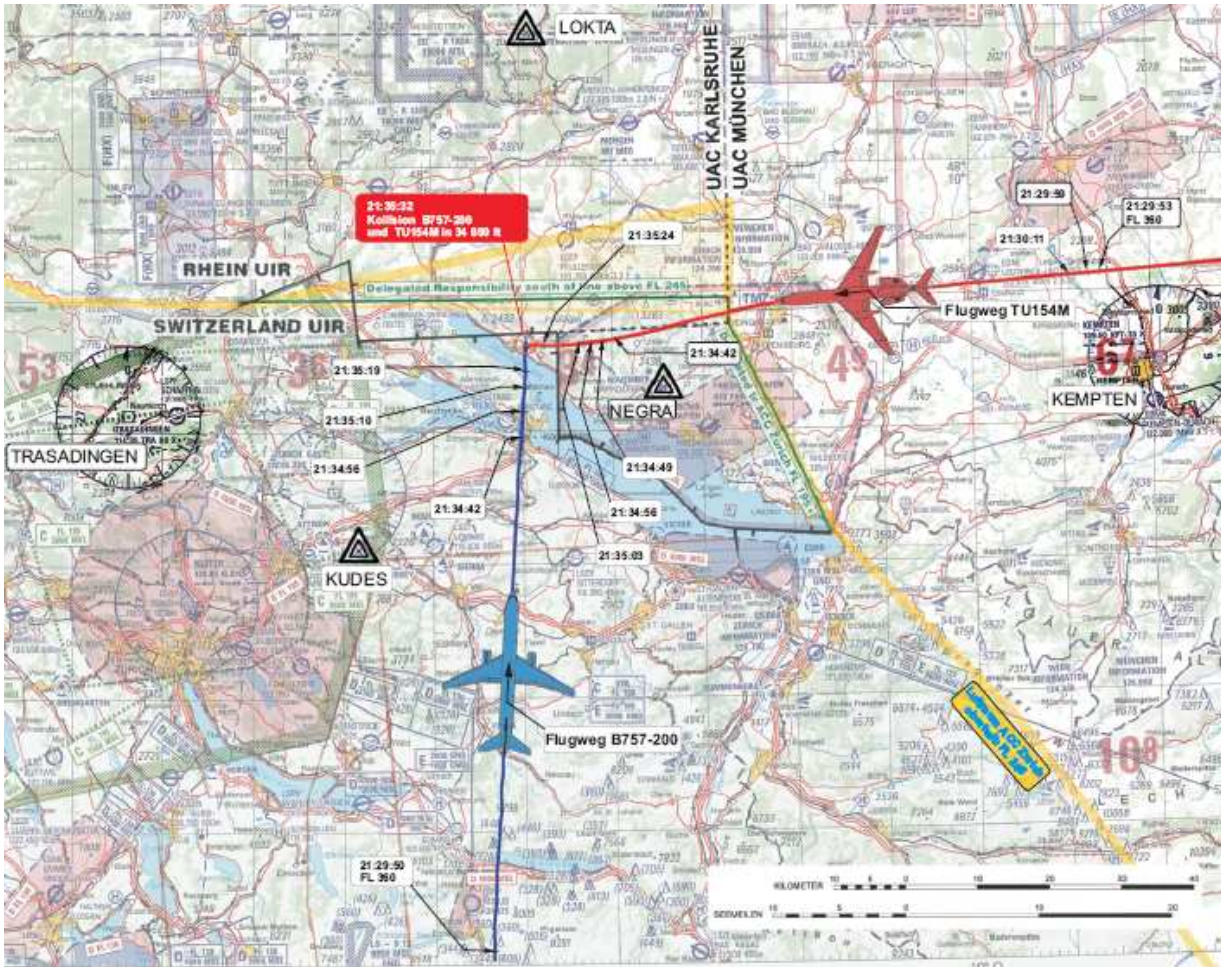
Technical – **area navigation**

The existing route network has grown over time based on navigation from beacon to beacon.

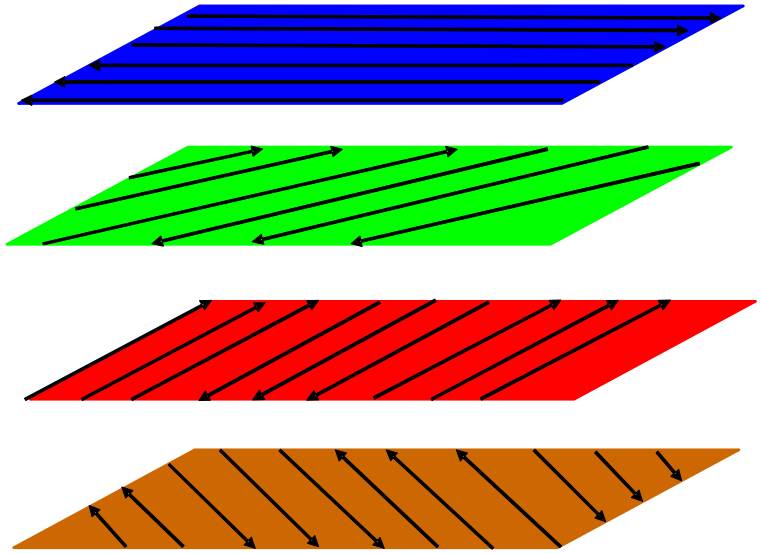
Area navigation allows aircraft to navigate along arbitrary routes, and opens the door to clean-sheet redesign of the route network.

Political – **Single European Sky**

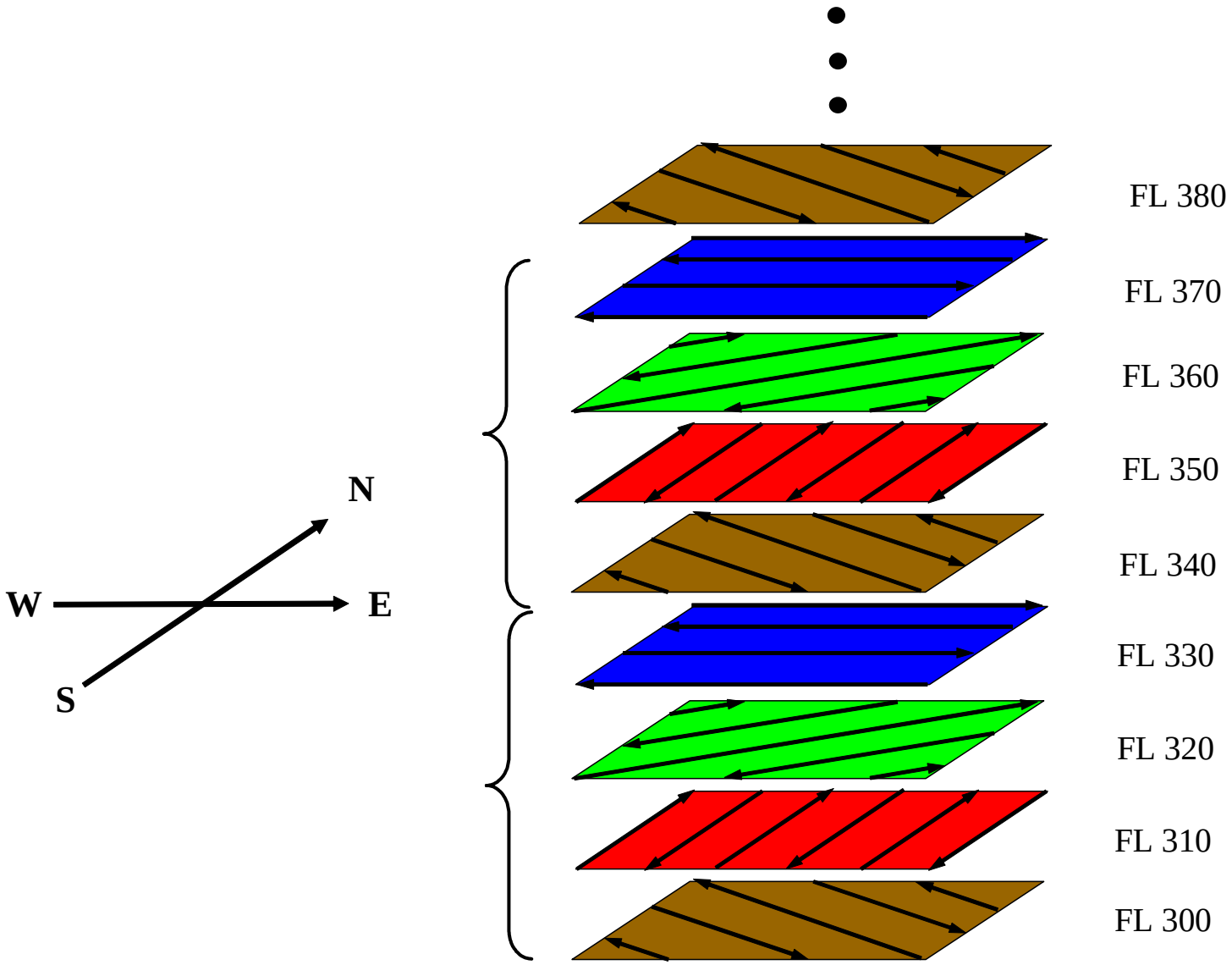
Starting point – safety – crossing conflicts



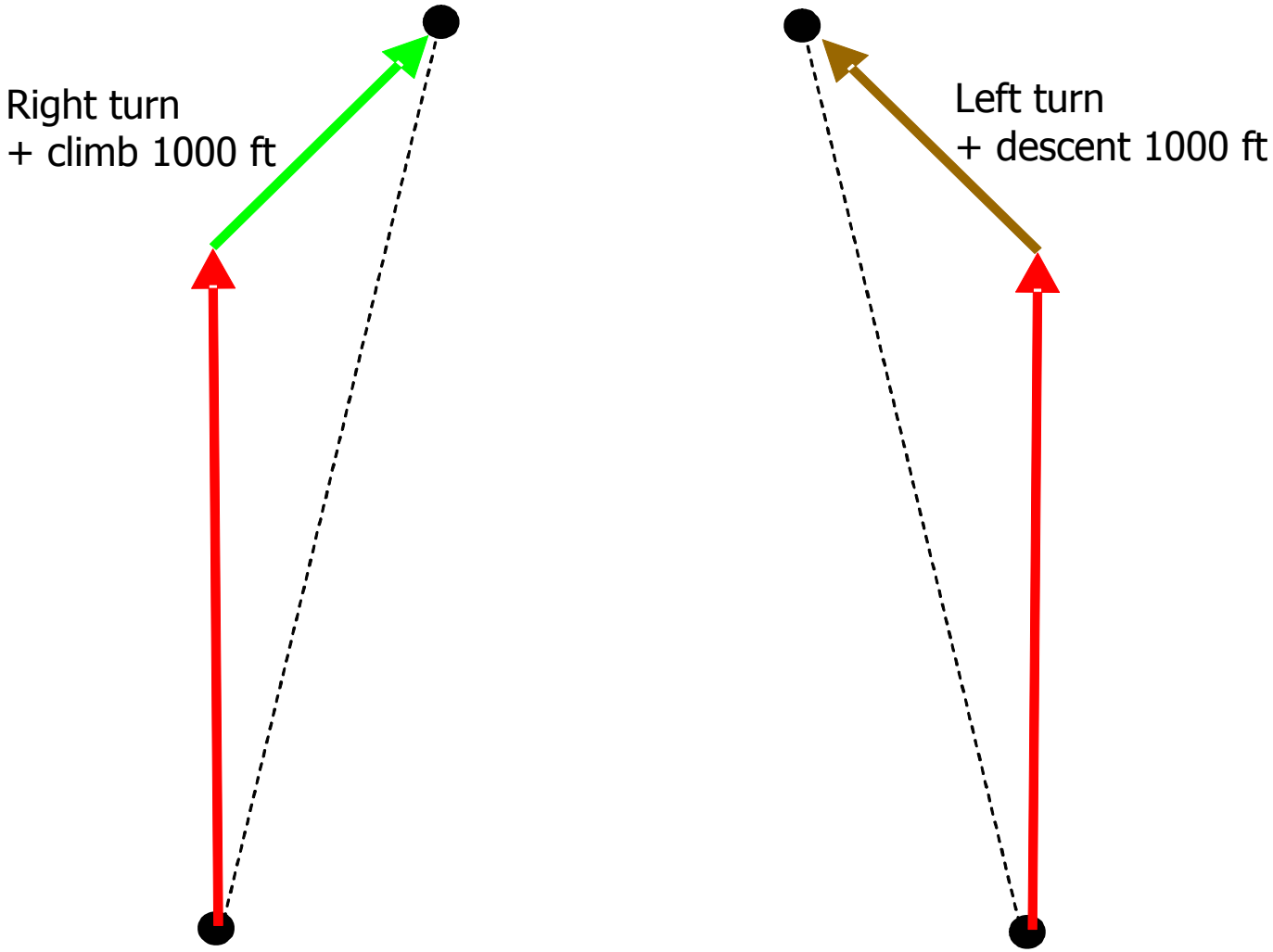
Idea 1: layers of parallel tracks could eliminate crossing conflicts between cruising aircraft



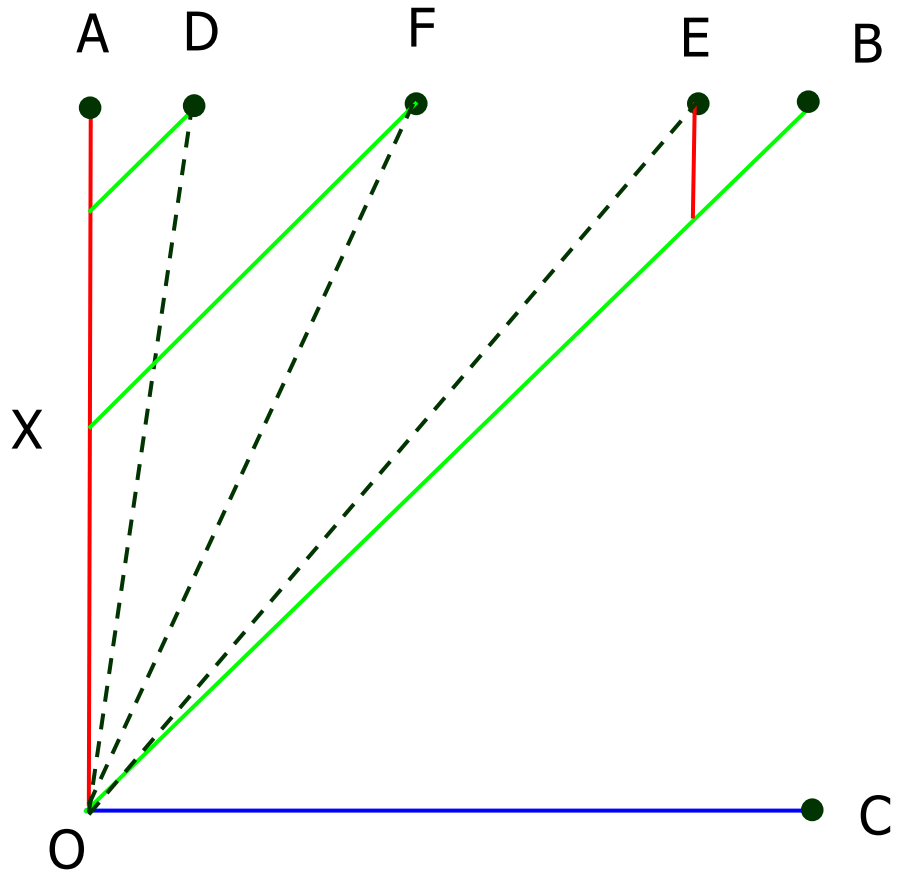
4 layers, 4 pairs (8) of allowed directions of flight


N
W
E
S
FL 380
FL 370
FL 360
FL 350
FL 340
FL 330
FL 320
FL 310
FL 300

Navigating with fixed directions

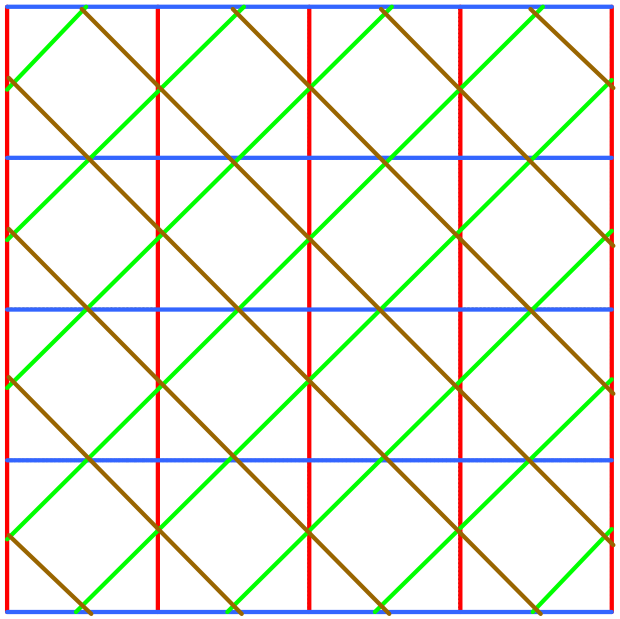


Fixed directions - extra distance flown

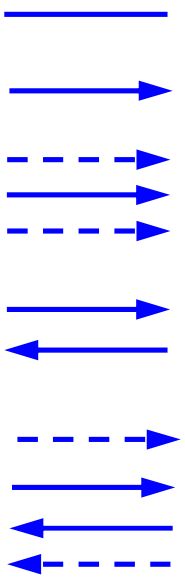


Average ~5.5%, max ~8.2%

Idea 2: regular lattice



Airspace structure and operation same throughout region



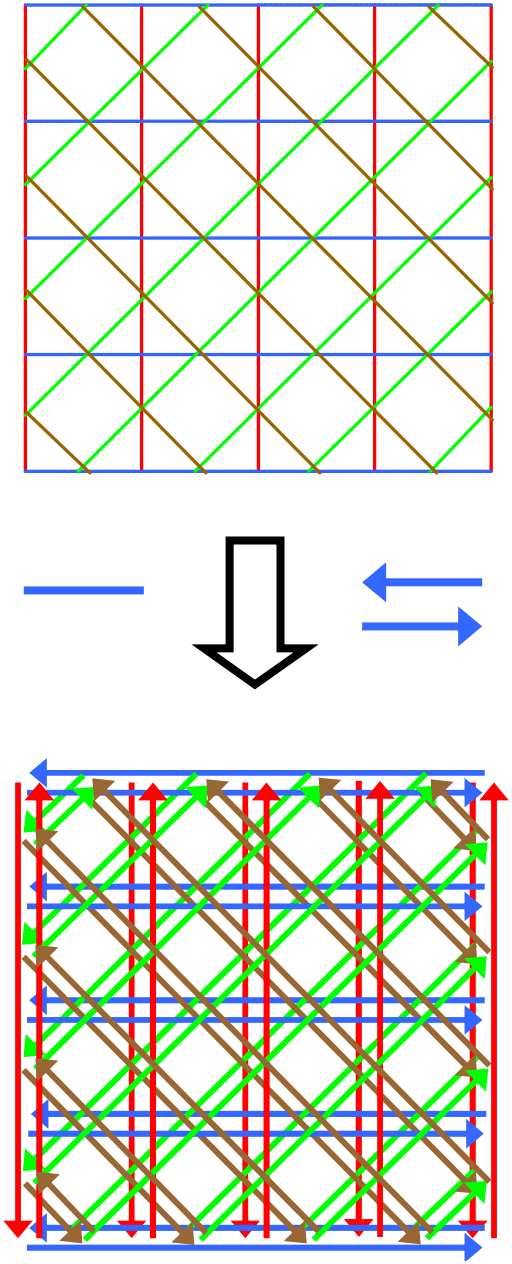
Basic lattice element

Mono-directional route

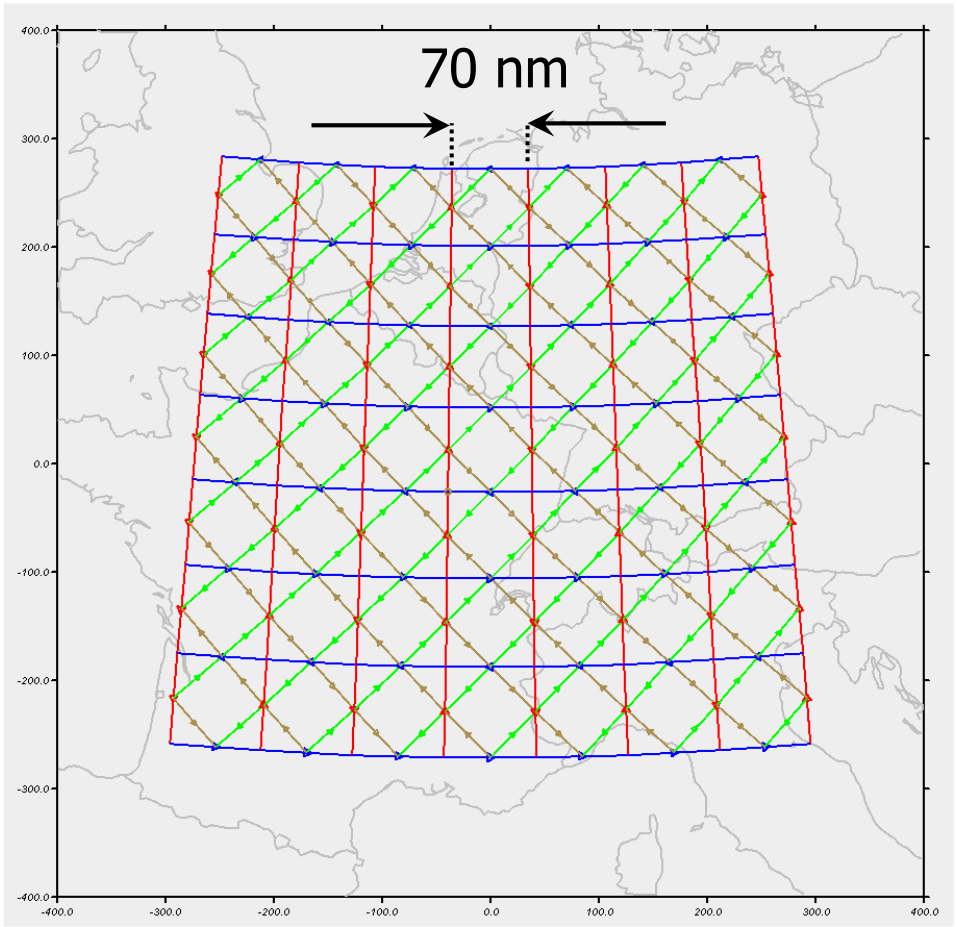
Mono-directional route with joining and leaving lanes

Bi-directional route

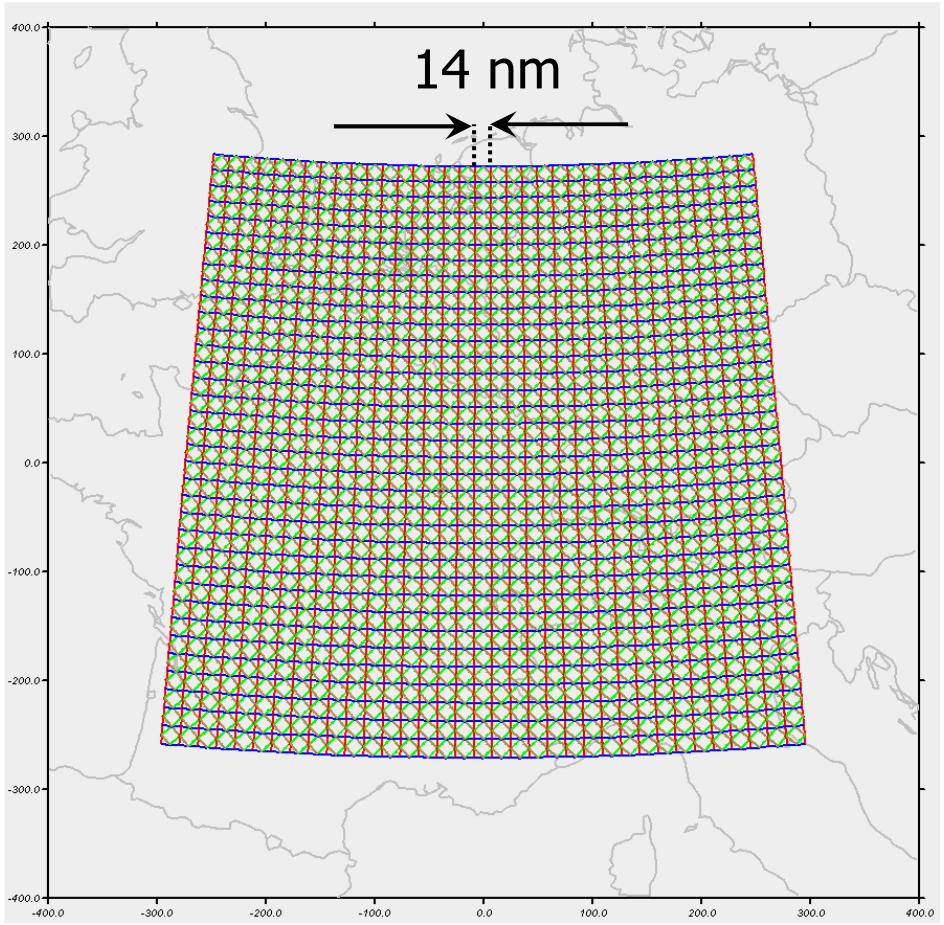
Bi-directional route with joining lanes



Lattice spacing – sparse or dense?



Sparse



Dense

Lattice spacing

Directly affects number and total length of tracks
i.e. physical capacity

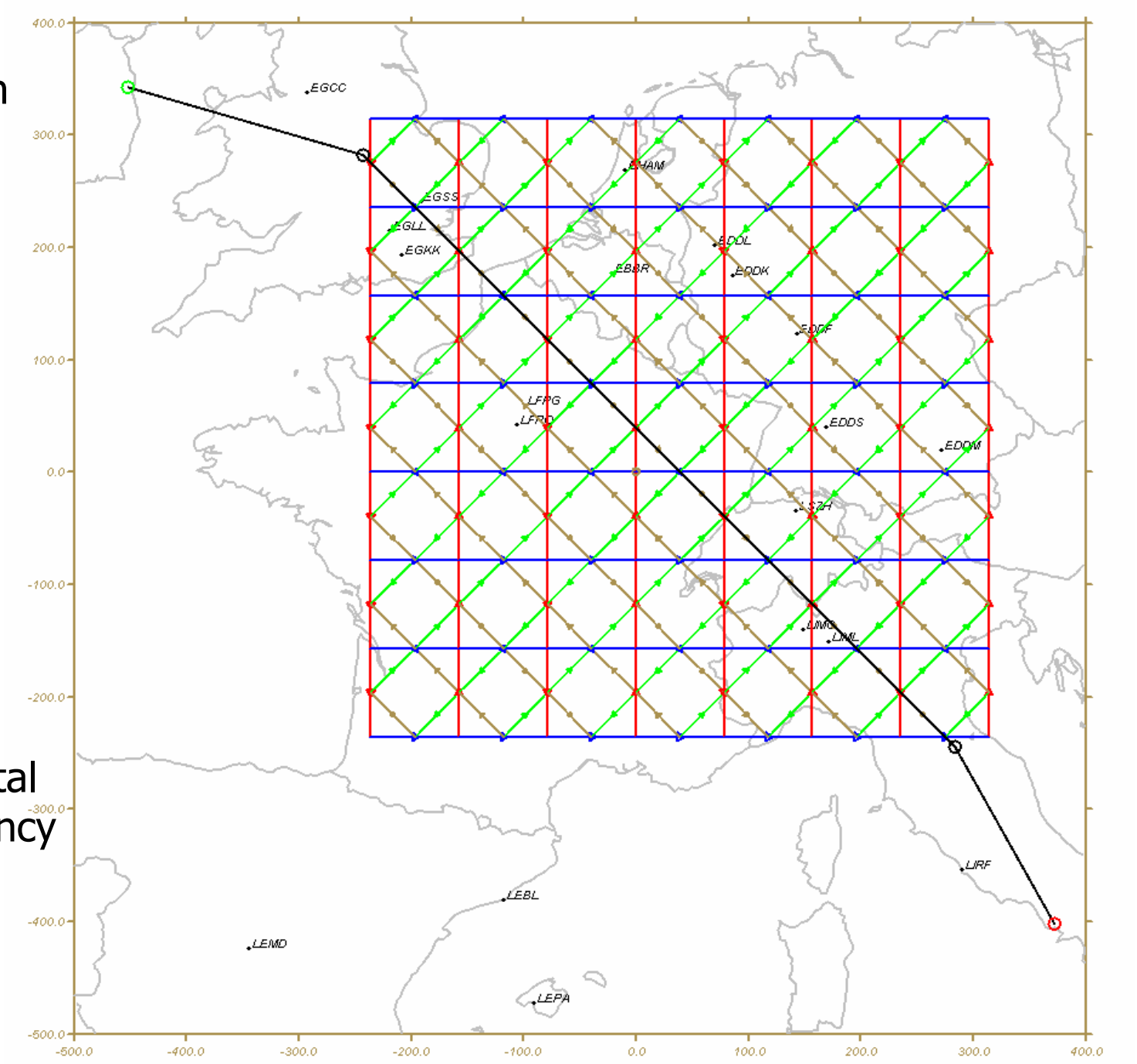
Number of conflicts, workload

Mode of operation for climbing/descending aircraft
– 3D “crossing free” OR “opportunistic”

Small spacing, slow climbing aircraft

Extra distance flown when rerouting around reserved areas

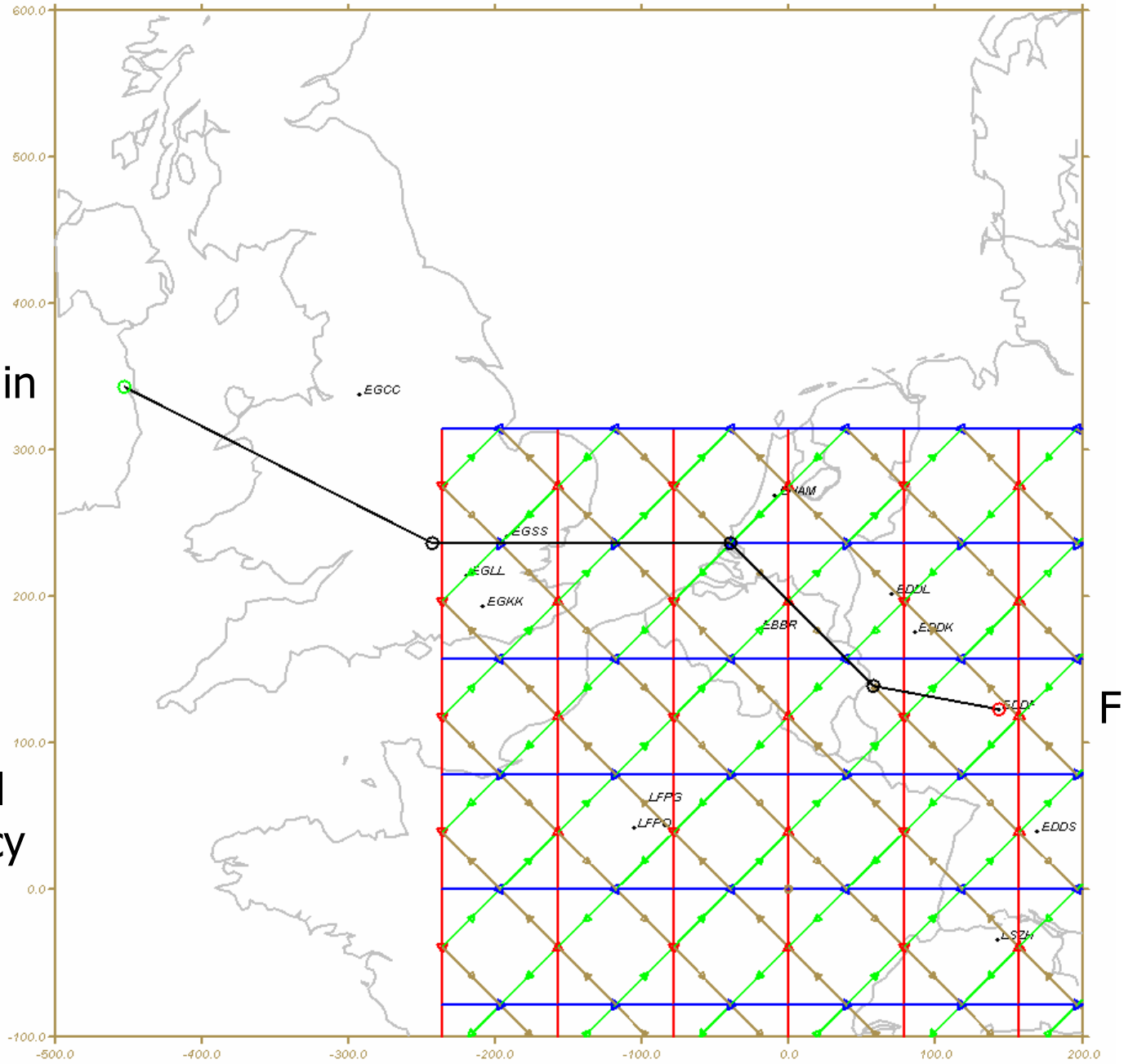
Dublin



Horizontal inefficiency 1.02

Napoli

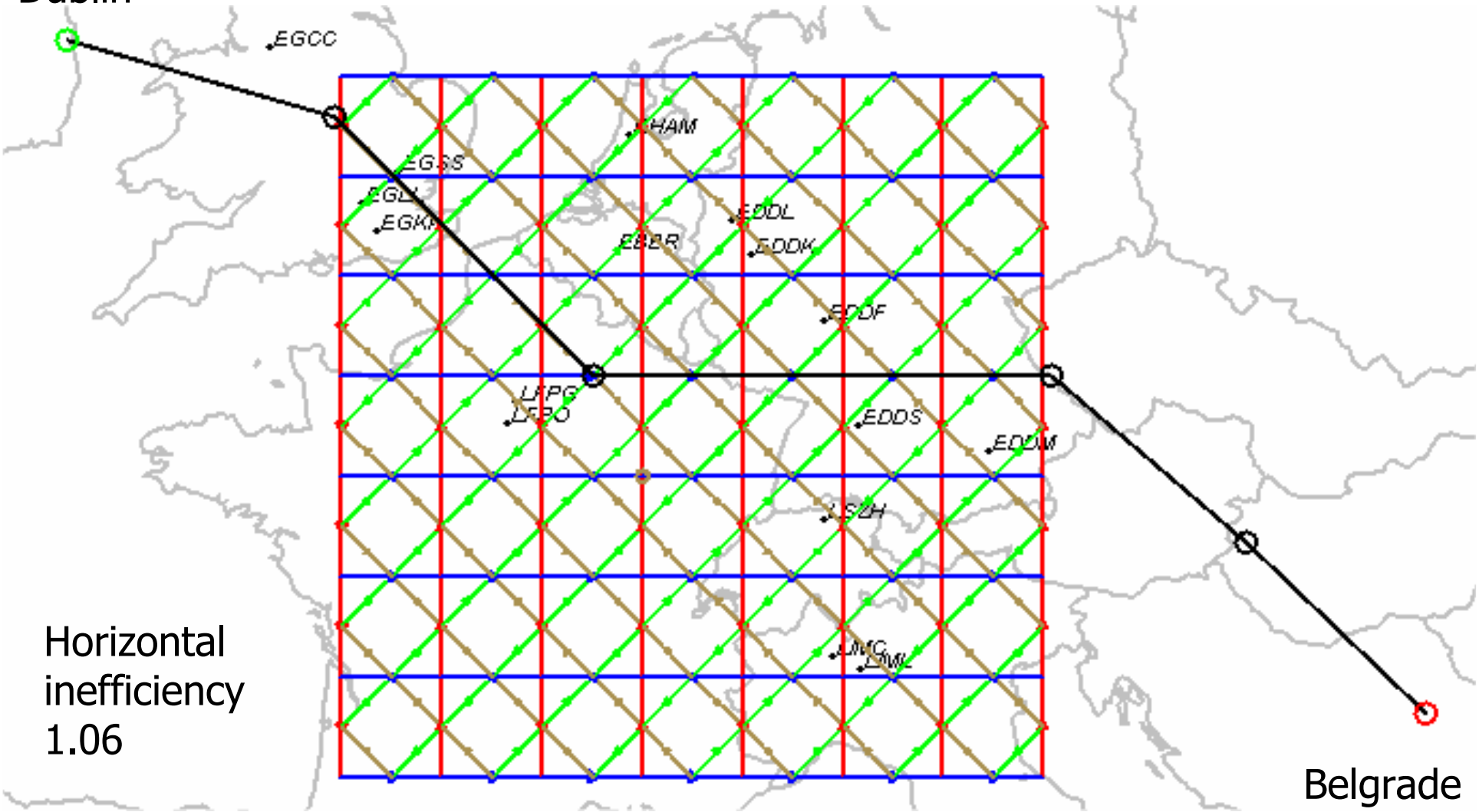
Dublin



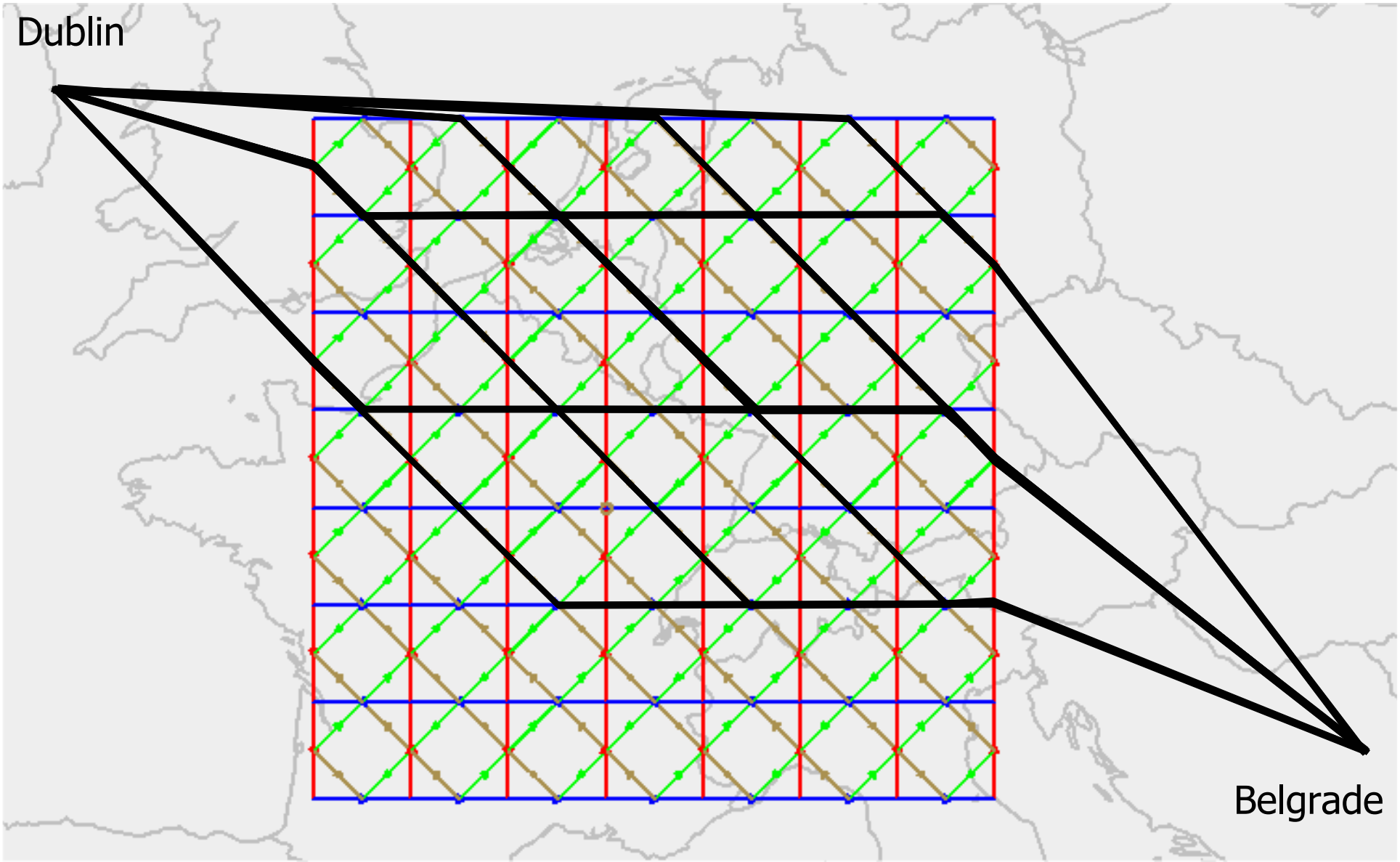
Frankfurt

Horizontal inefficiency 1.05

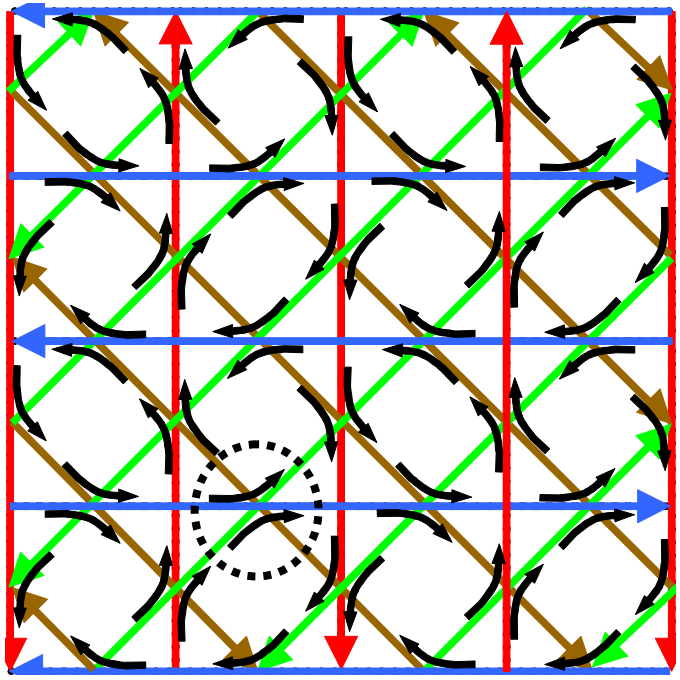
Dublin

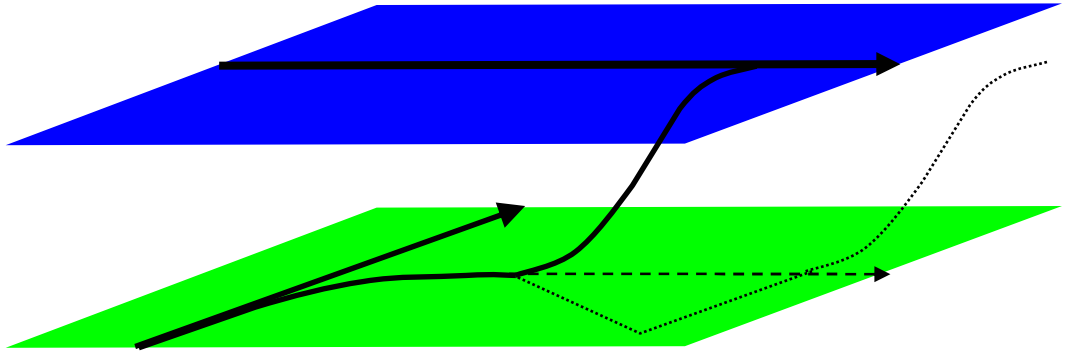


Belgrade

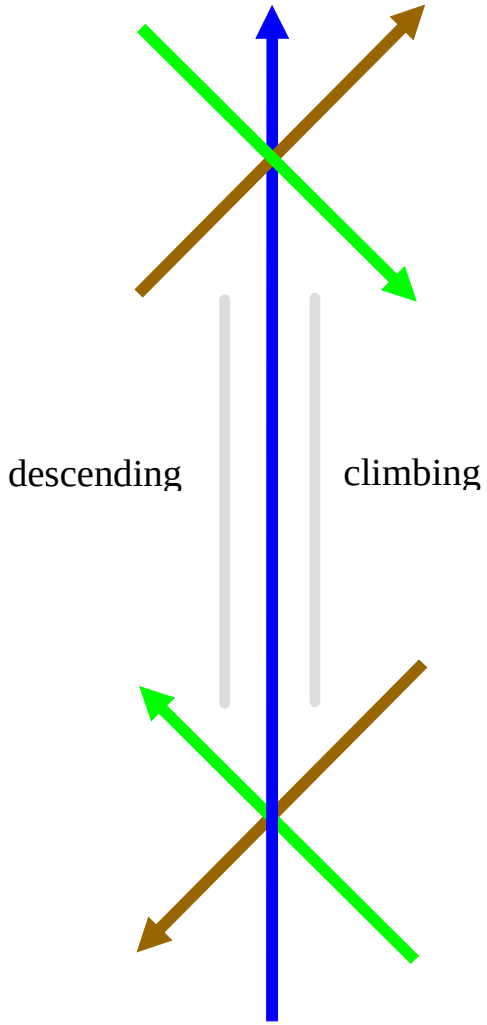

Dublin
Belgrade

Turning and merging

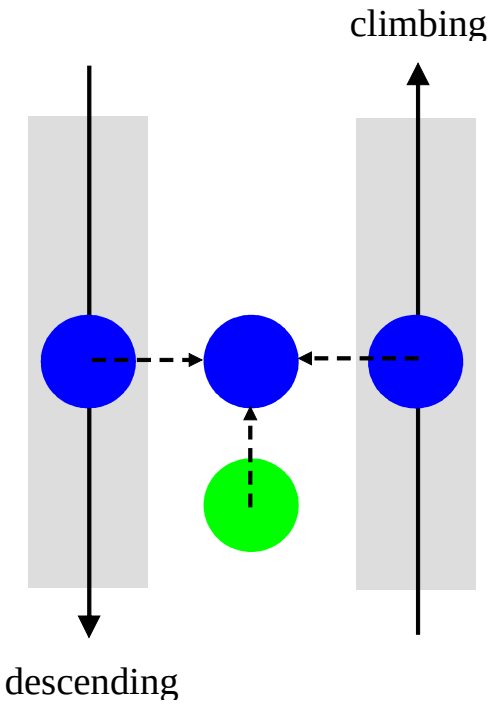




Climbing and descending lanes



Horizontal view



Vertical view

Fast-time simulation

Define a volume of interest – similar to core area
~ 500 nm x 500 nm, beginning at FL300

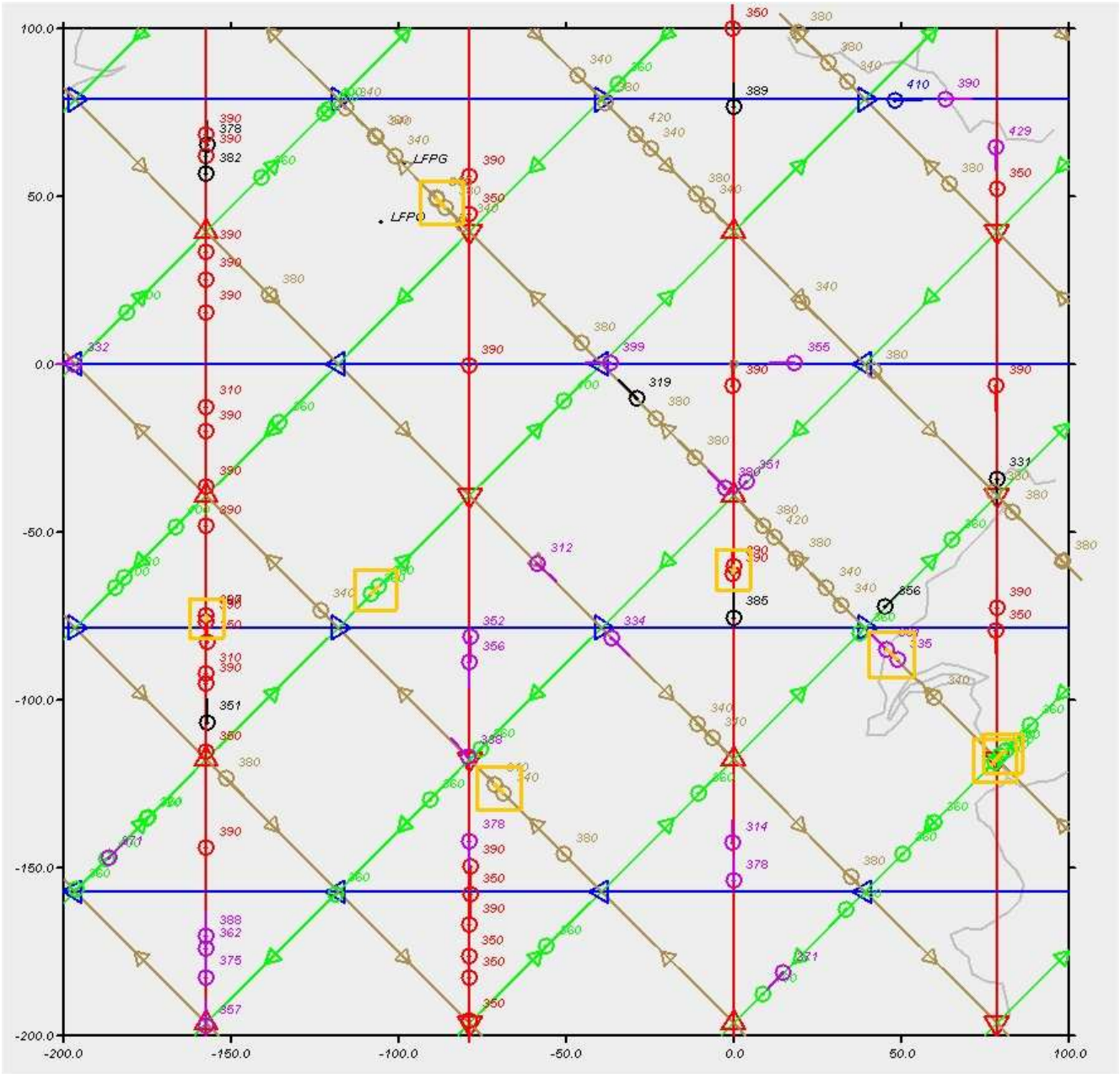
Subset SESAR 2005 traffic (entering the volume of interest)

Aircraft have nominal mass

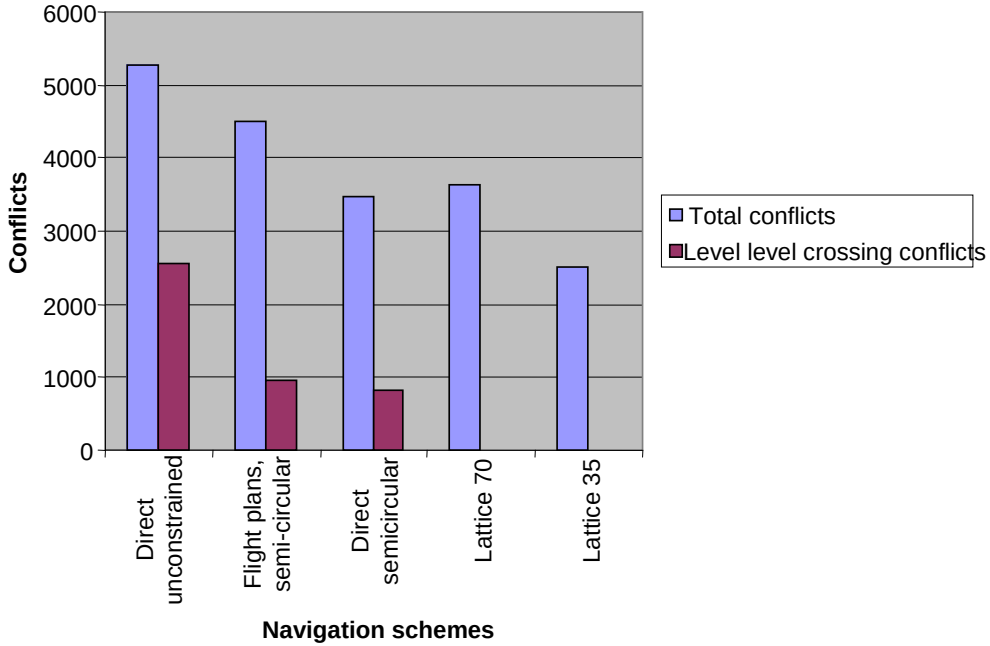
Vary routing and cruise level allocation scheme within volume of interest

Measure number of conflicts and total fuel consumption

Preliminary results


LFPG
LFPO
100.0
50.0
0.0
-50.0
-100.0
-150.0
-200.0
-200.0
-150.0
-100.0
-50.0
0.0
50.0
100.0

Conflicts



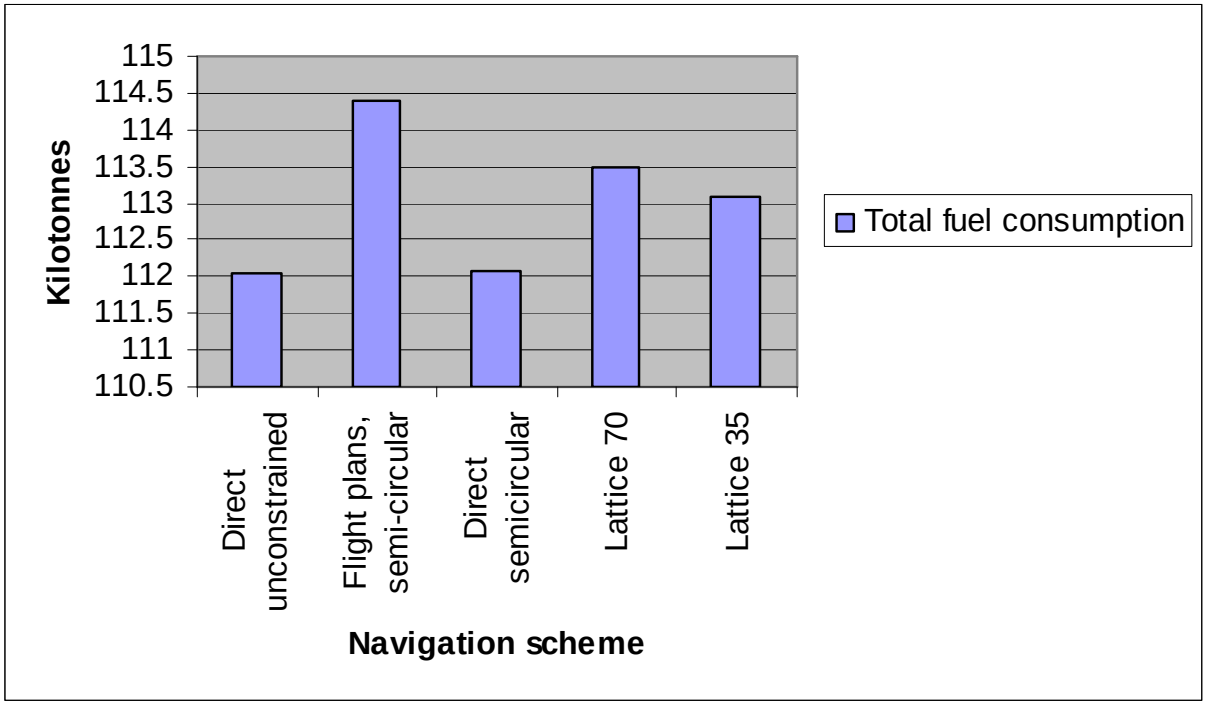
No crossing conflicts between cruising aircraft

Lattice 70 nm, 5% increase in total number of conflicts

55% same direction, climbing/descending through level
Suggests need to separate climbing/cruising/descending

Need to perform flow management (ground holding) for lattice rather than use departure times for current routes and sectors

Total fuel consumption



Total fuel, lattice 70nm, +1.3% compared with direct routes, semi-circular rule baseline

Potential advantages

- Regular structure allows replication of airspace design solutions throughout a region
- Common operating procedures throughout a region
- Elimination of crossing conflicts between cruising aircraft.
- Two easily identifiable populations – “stable” (low monitoring), “transition” (higher monitoring)
- Multiple routes facilitate traffic distribution and rerouting around reserved areas

Further investigation

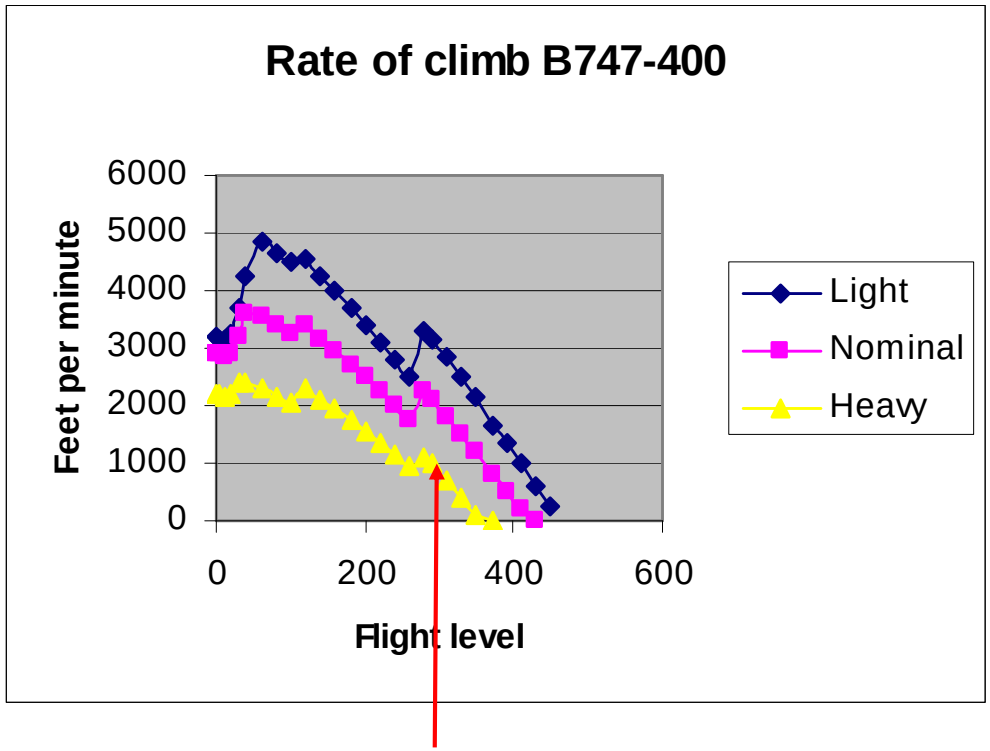
- Improve model of aircraft mass
- Investigate use of joining/leaving lanes to separate climbing/descending/cruising aircraft
- Apply suitable flow management algorithm
- Operational feasibility
- Rerouting around reserved areas
- Sectorisation, workload and capacity
- 2020 traffic

Comments / questions / suggestions ?


STOP

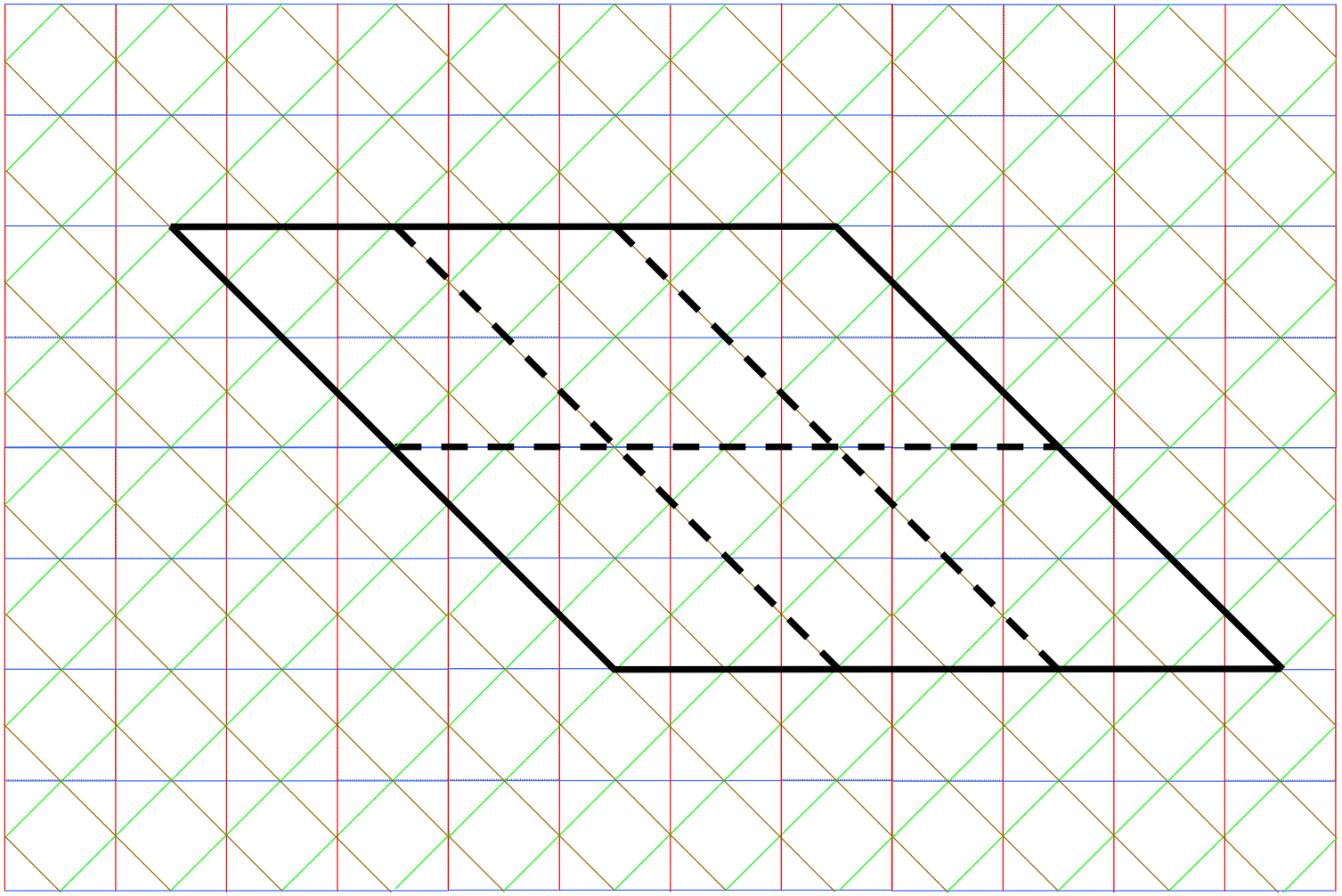
#	Horizontal navigation	Cruise level allocation scheme	Total number of flights entering volume of interest	Total number of conflicts	Conflicts in which one or both aircraft are moving vertically			Conflicts in which both aircraft are level			Total fuel consumption / kilotonnes
					Total	Same direction	Crossing	Total	Same direction	Crossing	
1	Fly direct	Unconstrained	12710	5266	2687	119	2568	2579	18	2561	112.055
2	Fly direct	Semi-circular	12641	3469	2627	111	2516	842	17	825	112.063
3	Flight plan routes	Semi-circular	12512	4506	3441	967	2474	1065	93	972	114.4
4	Lattice, spacing >= 70 NM	Lattice	11855	3631	3201	2006	1195	430	430	0	113.5
5	Lattice, spacing >= 35 NM	Lattice	11996	2514	2274	1042	1232	240	240	0	113.1

Lattice spacing

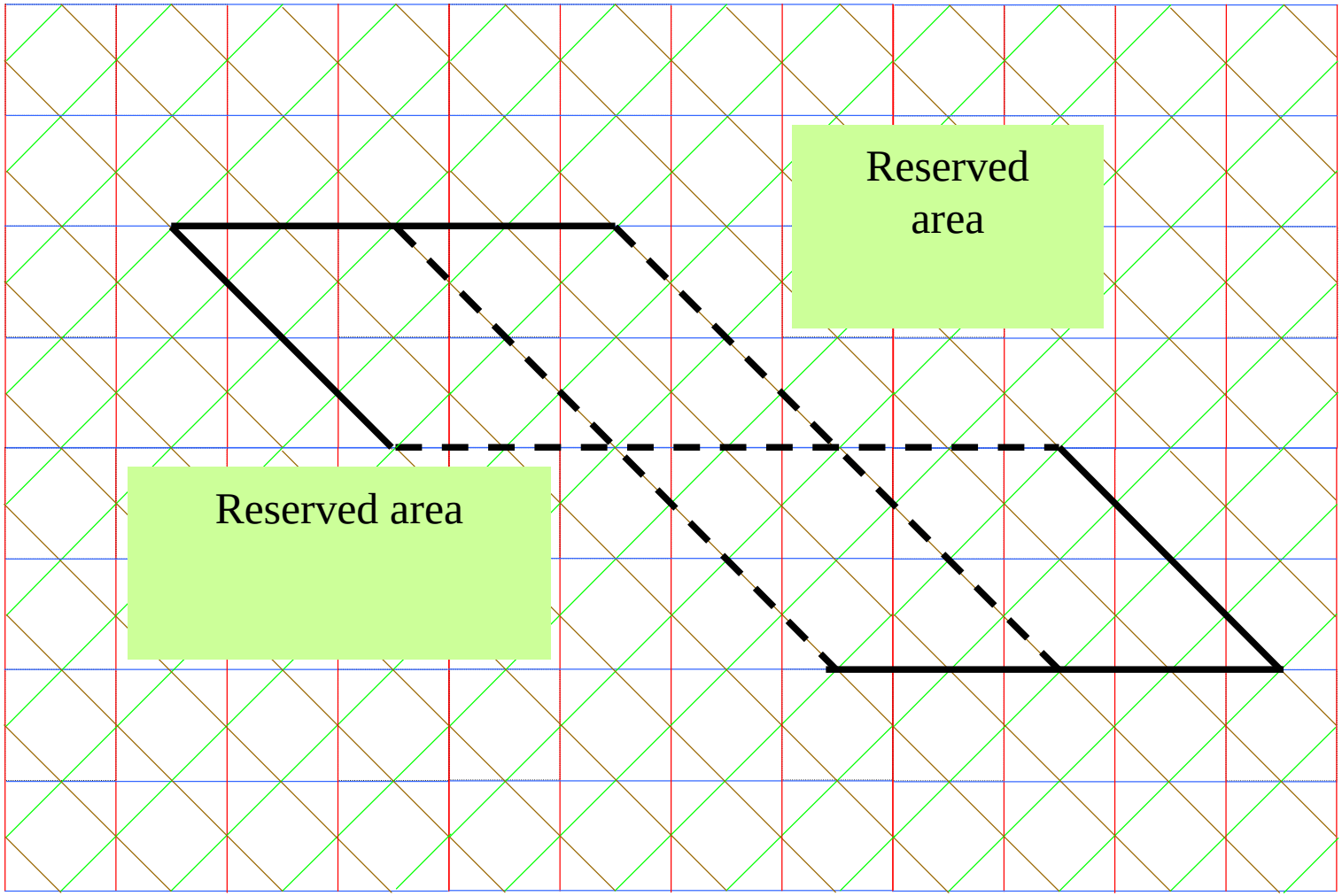


Heavily loaded aircraft climb slowly (< 1000 ft/min) near cruising altitudes (> FL 300)

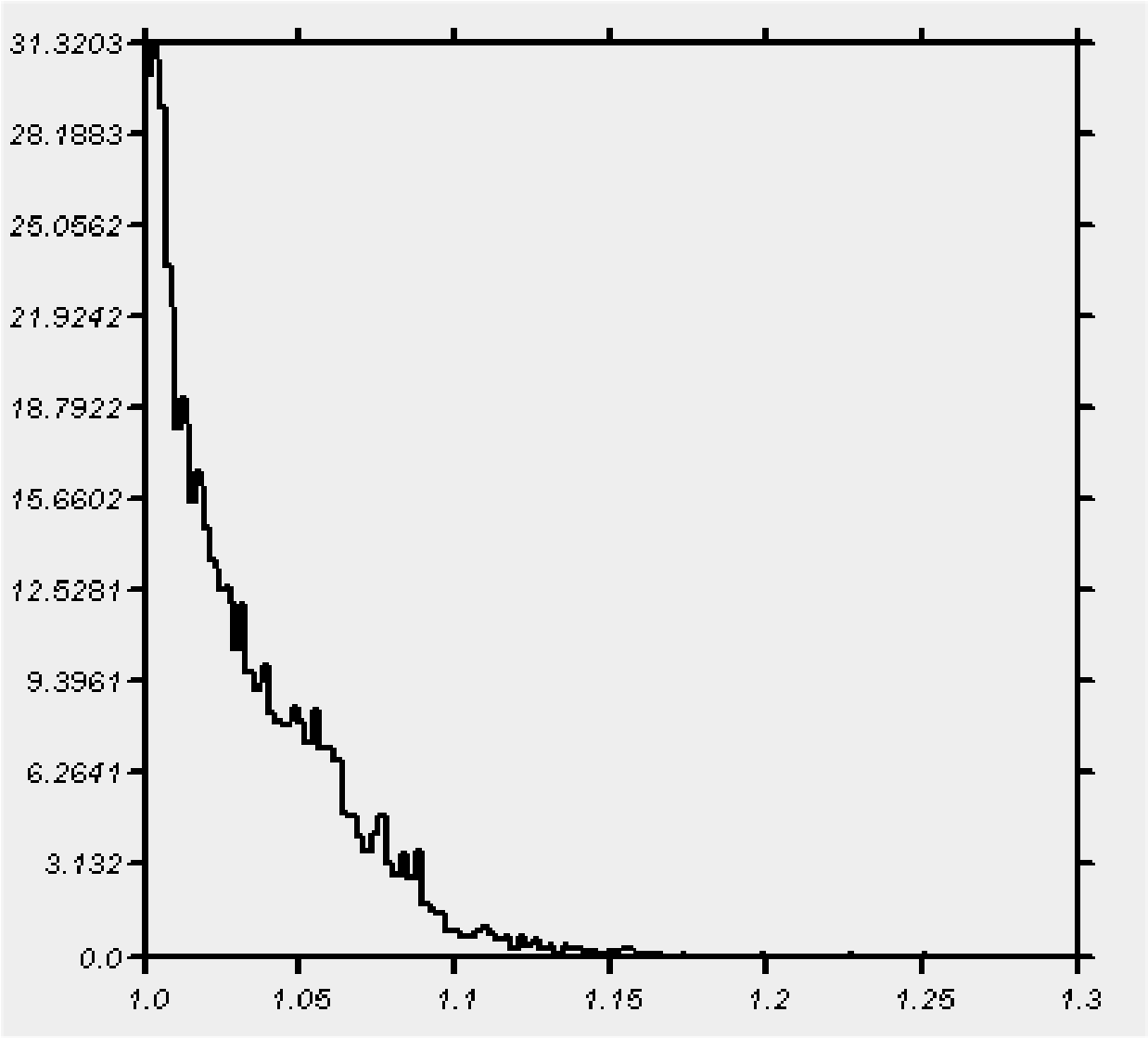
Flexible use of airspace - dense lattice (1)



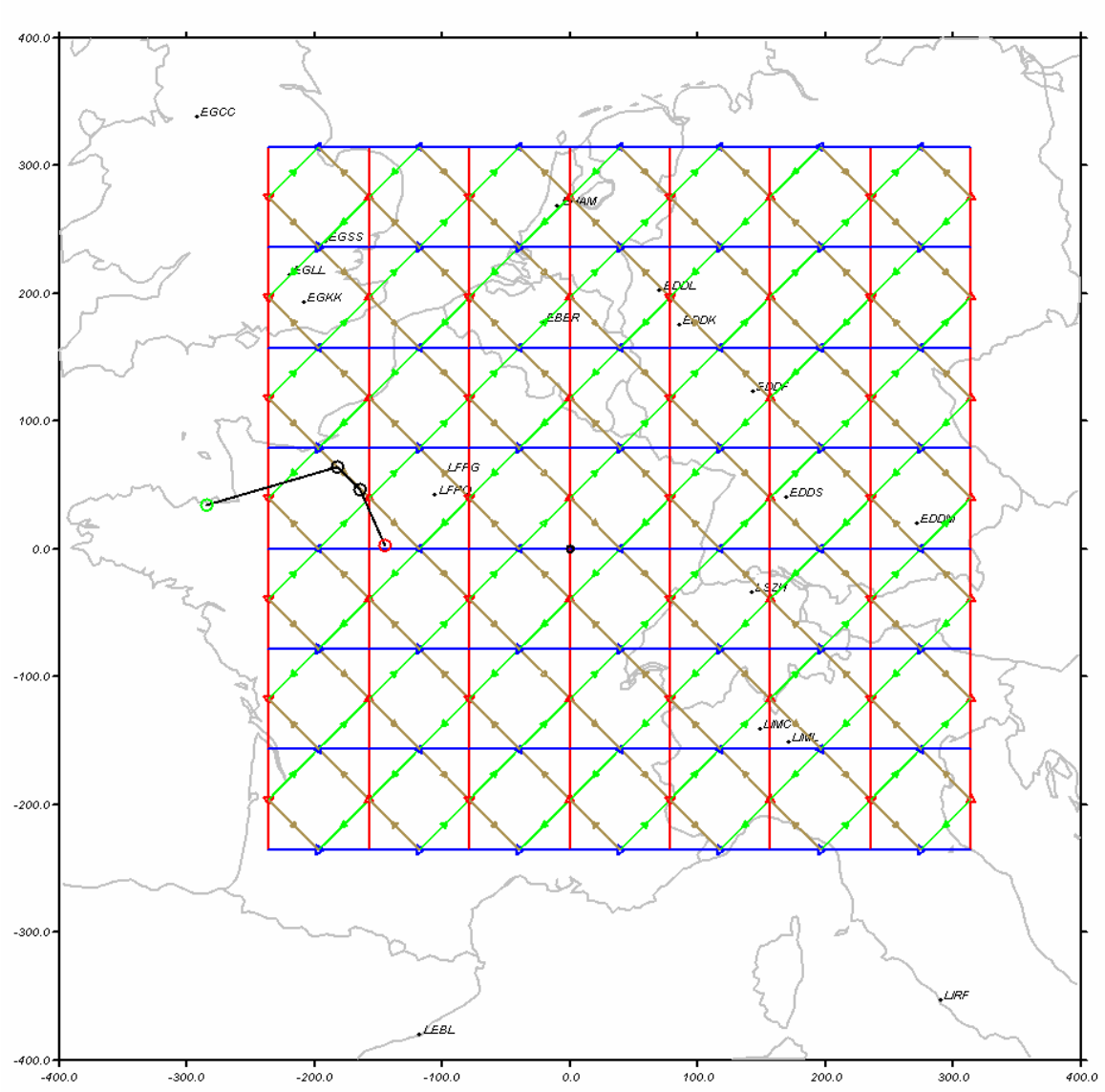
Flexible use of airspace - dense lattice (2)



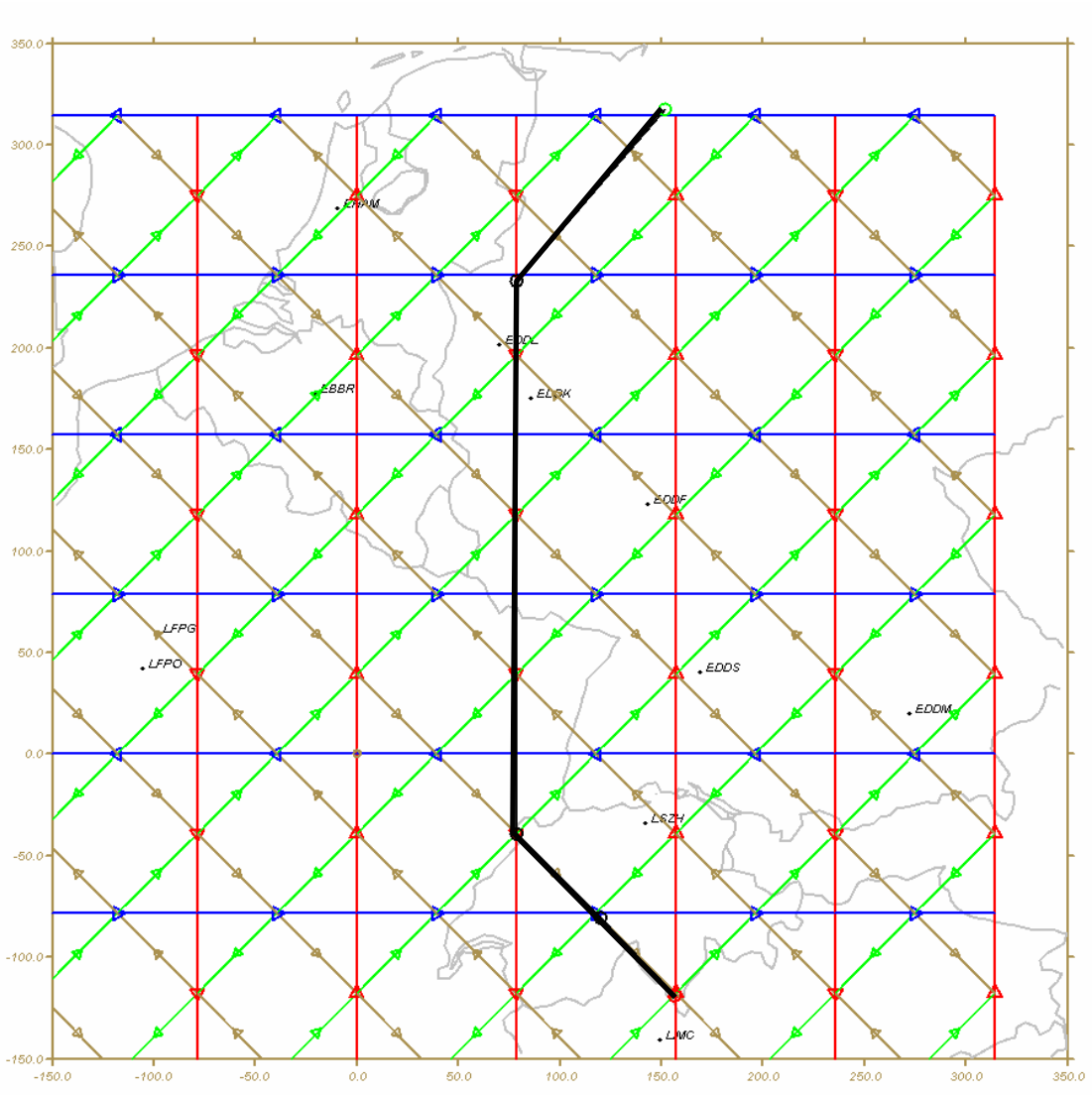
Distribution of horizontal inefficiency



Horizontal inefficiency 1.25



Bremen



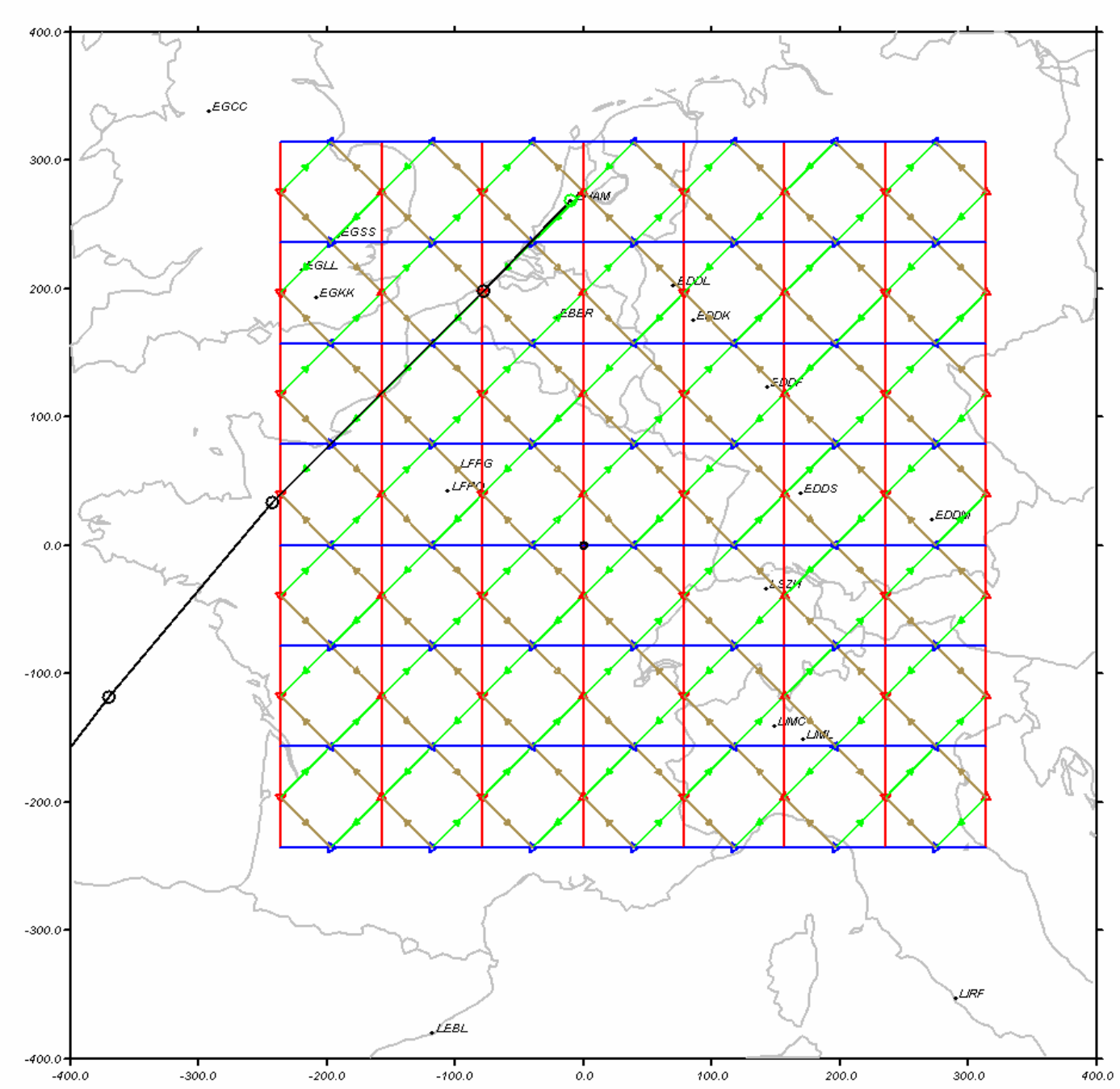
Horizontal inefficiency 1.14

Lugano

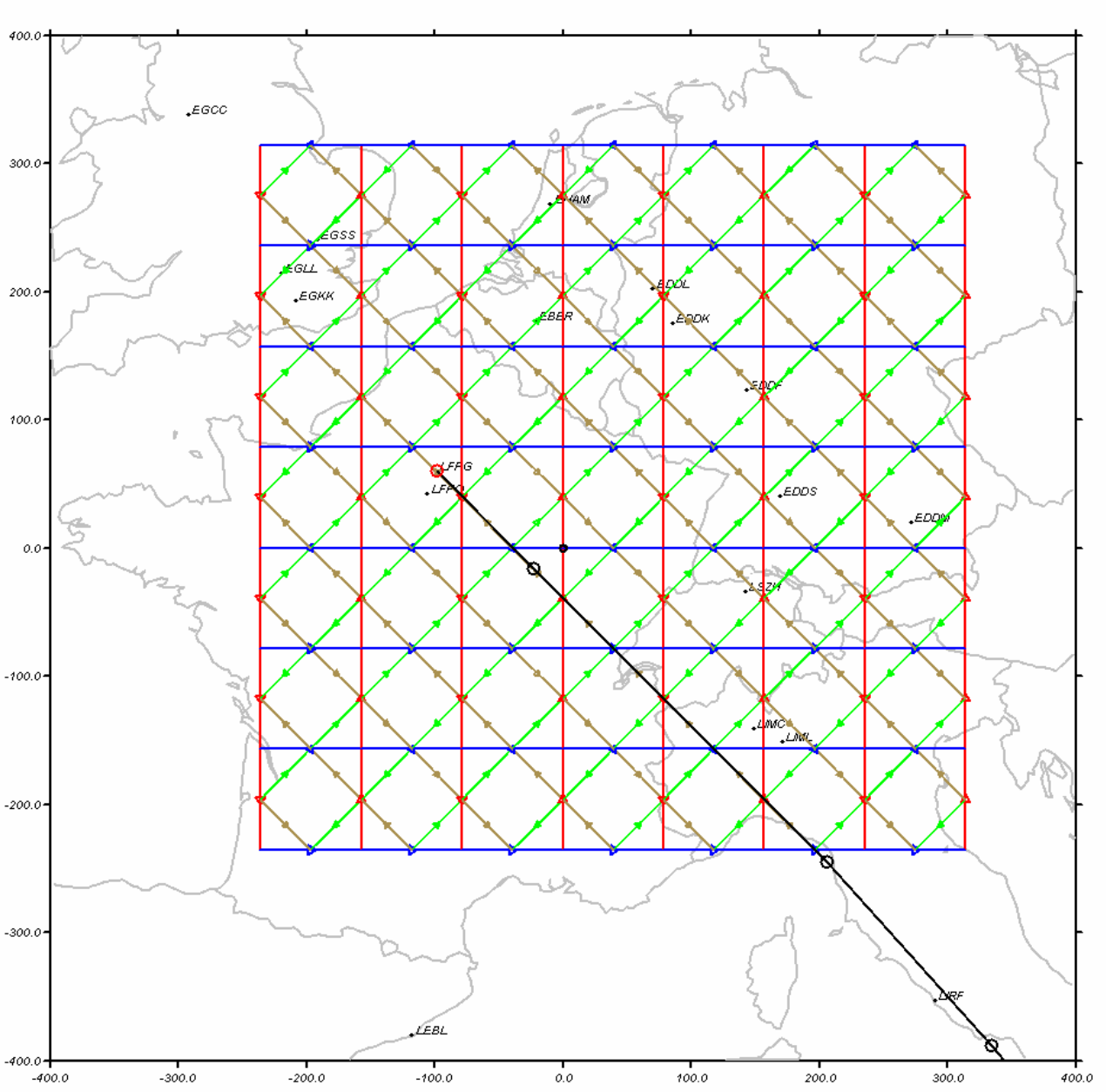
Amsterdam

Horizontal inefficiency 1.00007

Sao Paolo



Paris CdG



Horizontal inefficiency 1.00008

La Reunion