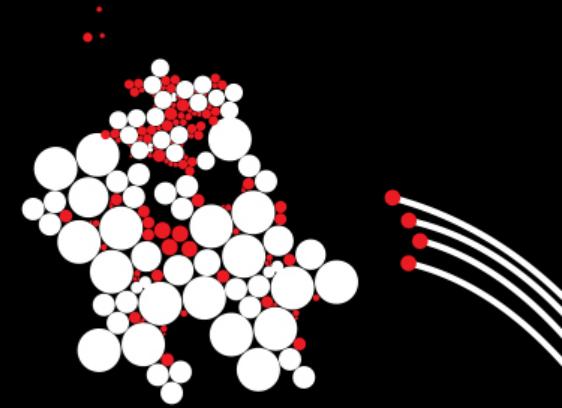
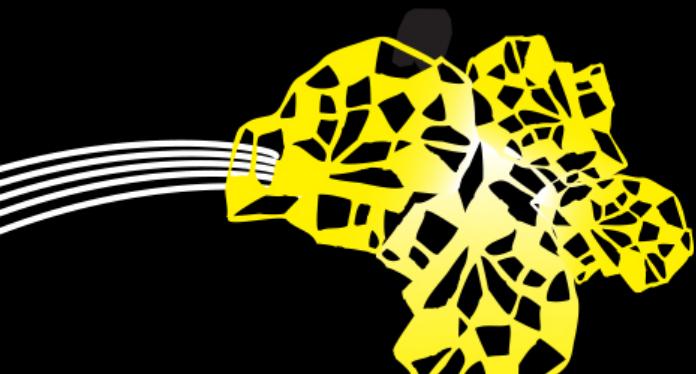


UNIVERSITY OF TWENTE.
Faculty of Geoinformation Science and Earth Observation

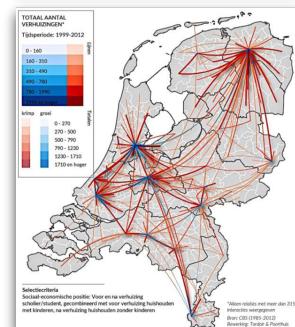
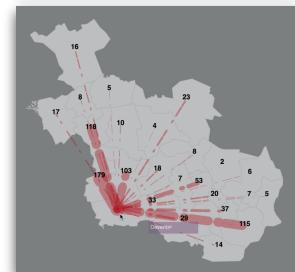
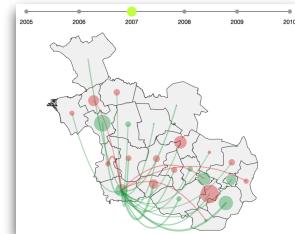


Mapping movement

Menno-Jan Kraak

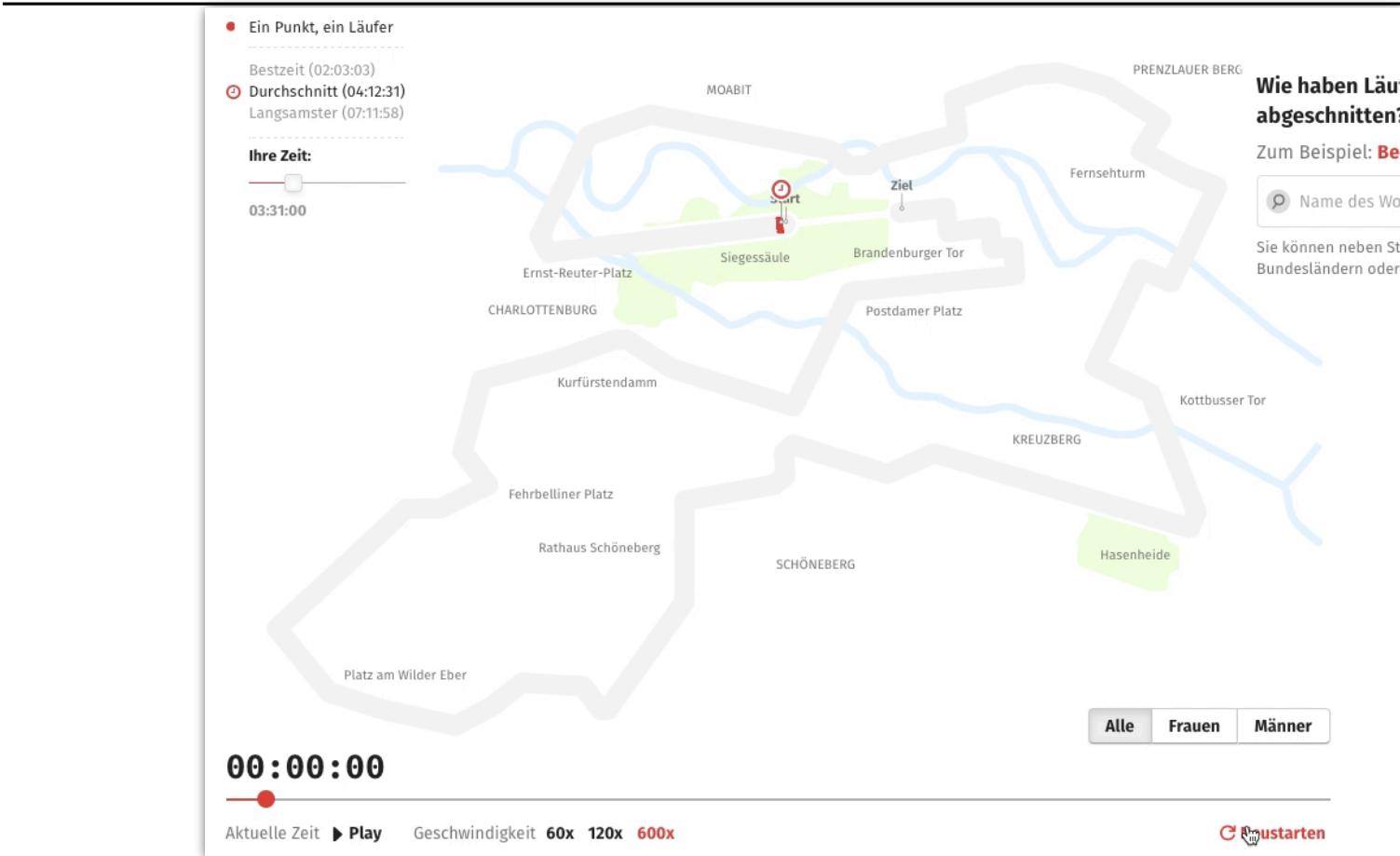


Mapping movement



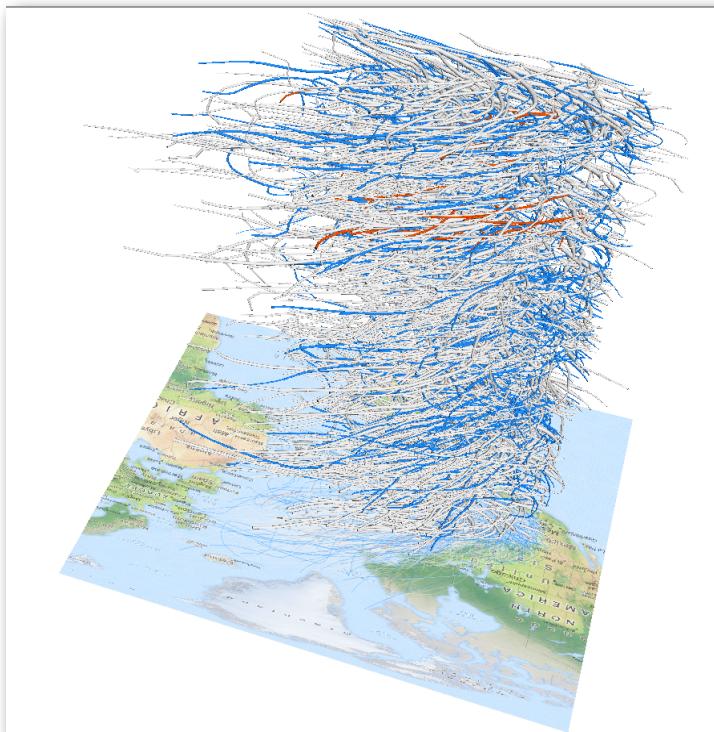
- Introduction
- Movement characteristics
- Movement challenges
- Towards solutions
- Case study: OD matrix visualization
- Conclusions

Movement



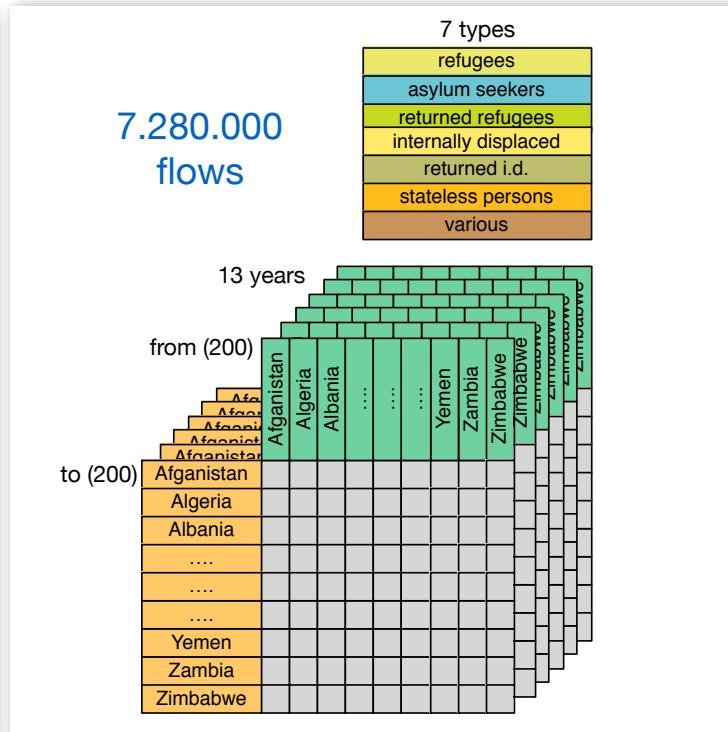
UNIVERSITY OF TWENTE.

Movement basics



continuous

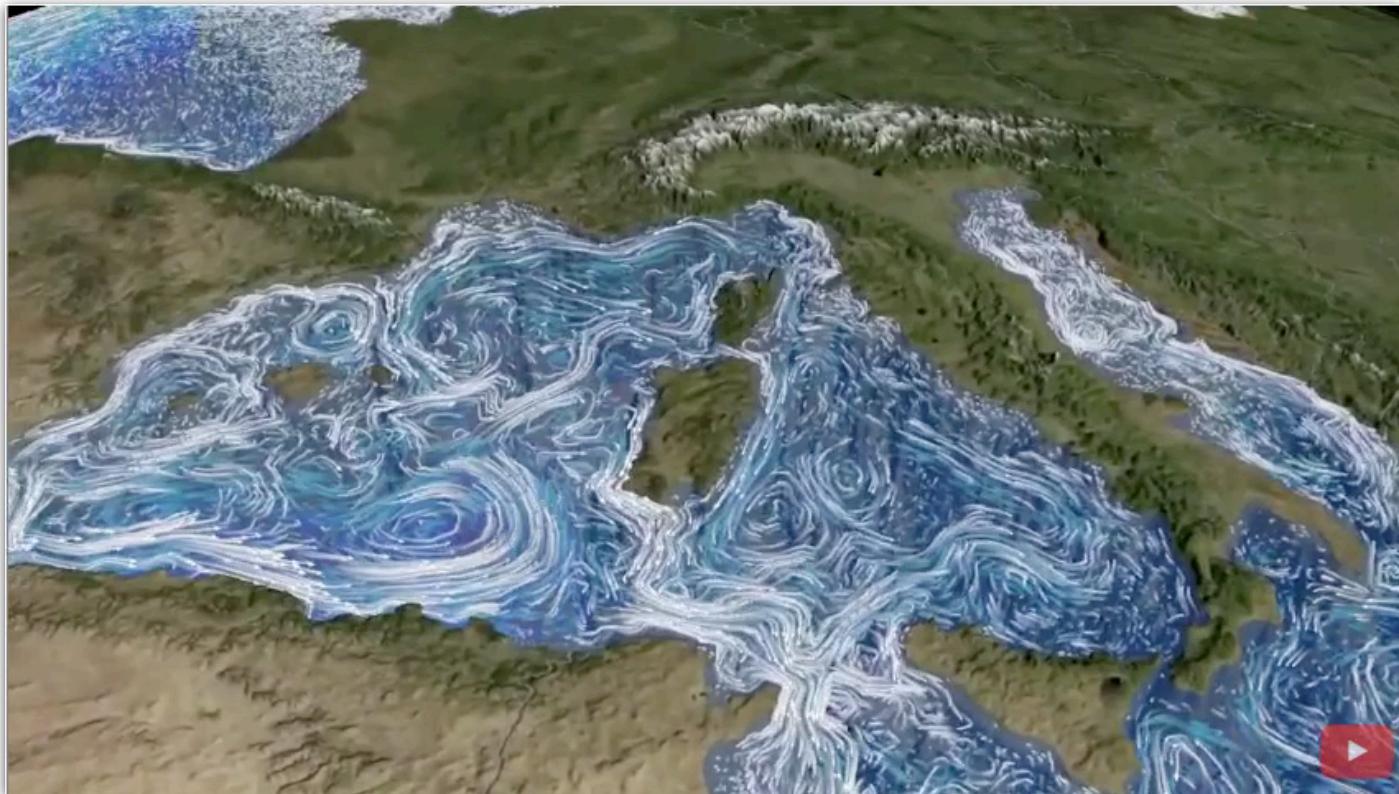
[20 years hurricane paths; Turdukulov and Restios, 2013]



discrete

(<http://popstats.unhcr.org/>)

Continuous flows: sea currents



<https://svs.gsfc.nasa.gov/3820>



UNIVERSITY OF TWENTE.

Flows (refugees)

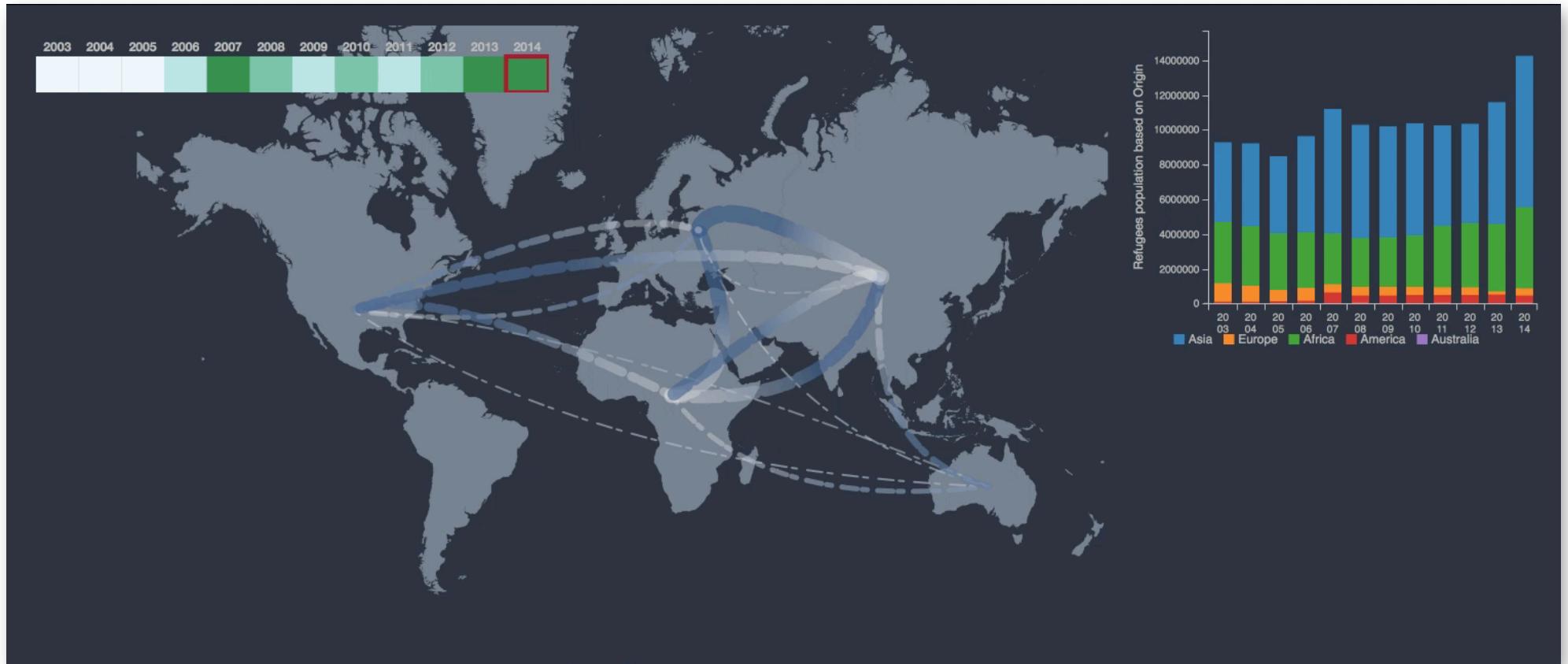


<http://www.lucify.com/the-flow-towards-europe/>

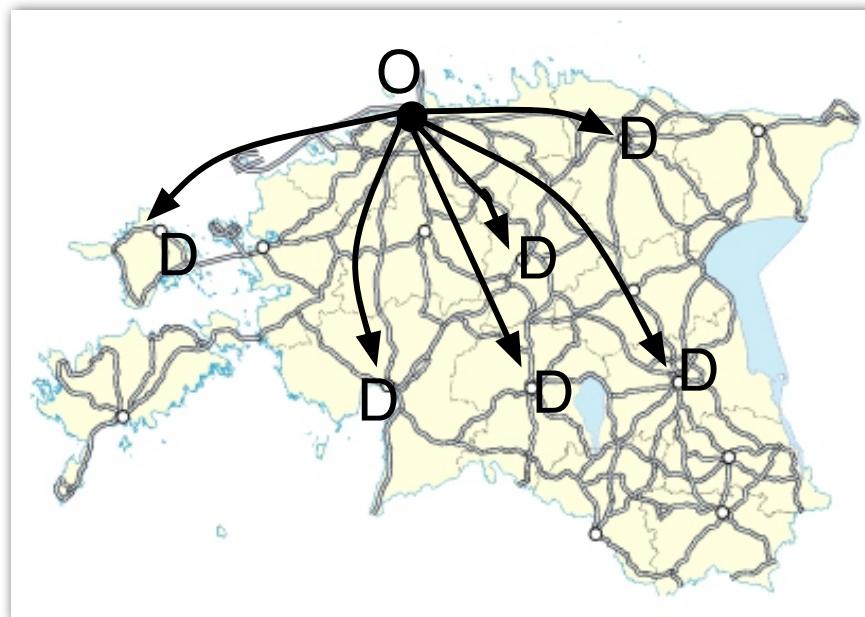


UNIVERSITY OF TWENTE.

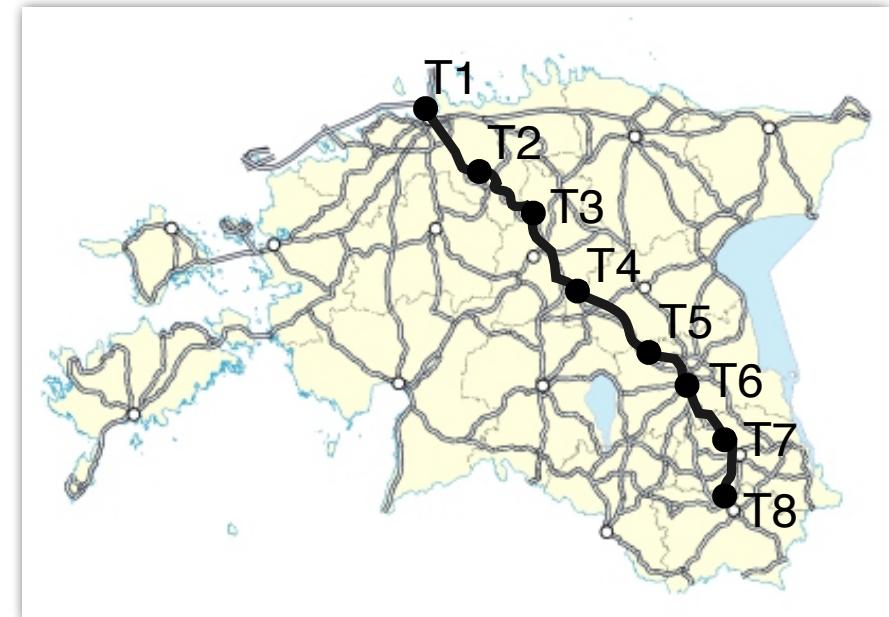
Flows (refugees)



Discrete Movement



Origin - Destination

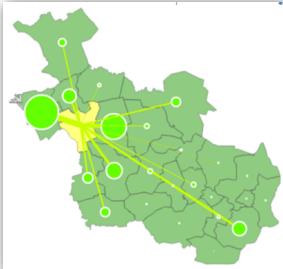


Trajectories

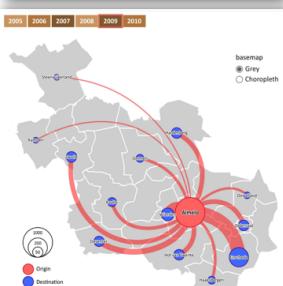


UNIVERSITY OF TWENTE.

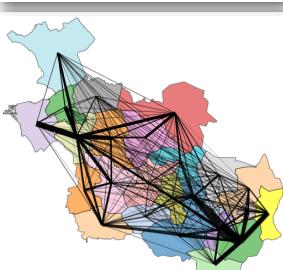
Points of attention



Big Data: Need for mapping tools that are able to deal with huge data amounts of diverse and fuzzy data sources



Movement: Need for graphic representations that map regular and irregular movement cycles in space and time

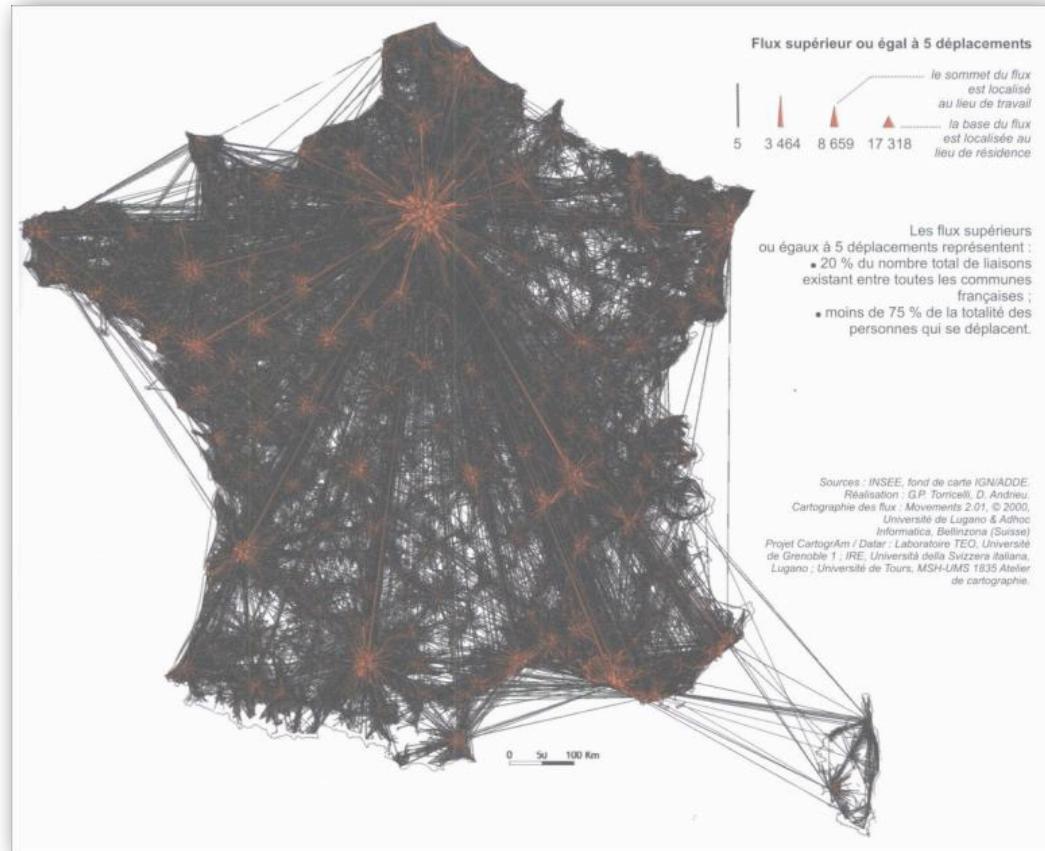


Time: Need to include the temporal dimension in the graphic representation

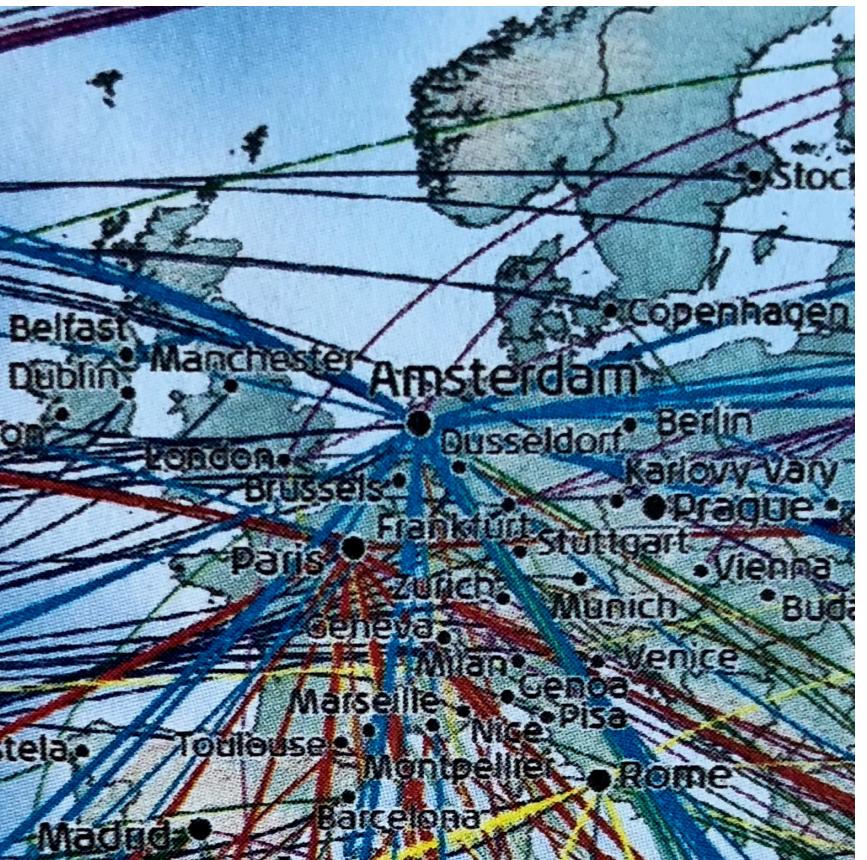
Flows: Need for other types of mobility maps to deal with individual tracks as well as large volumes of aggregated data

Big data

- Volume
- Variety
- Variability
- Velocity
- Veracity

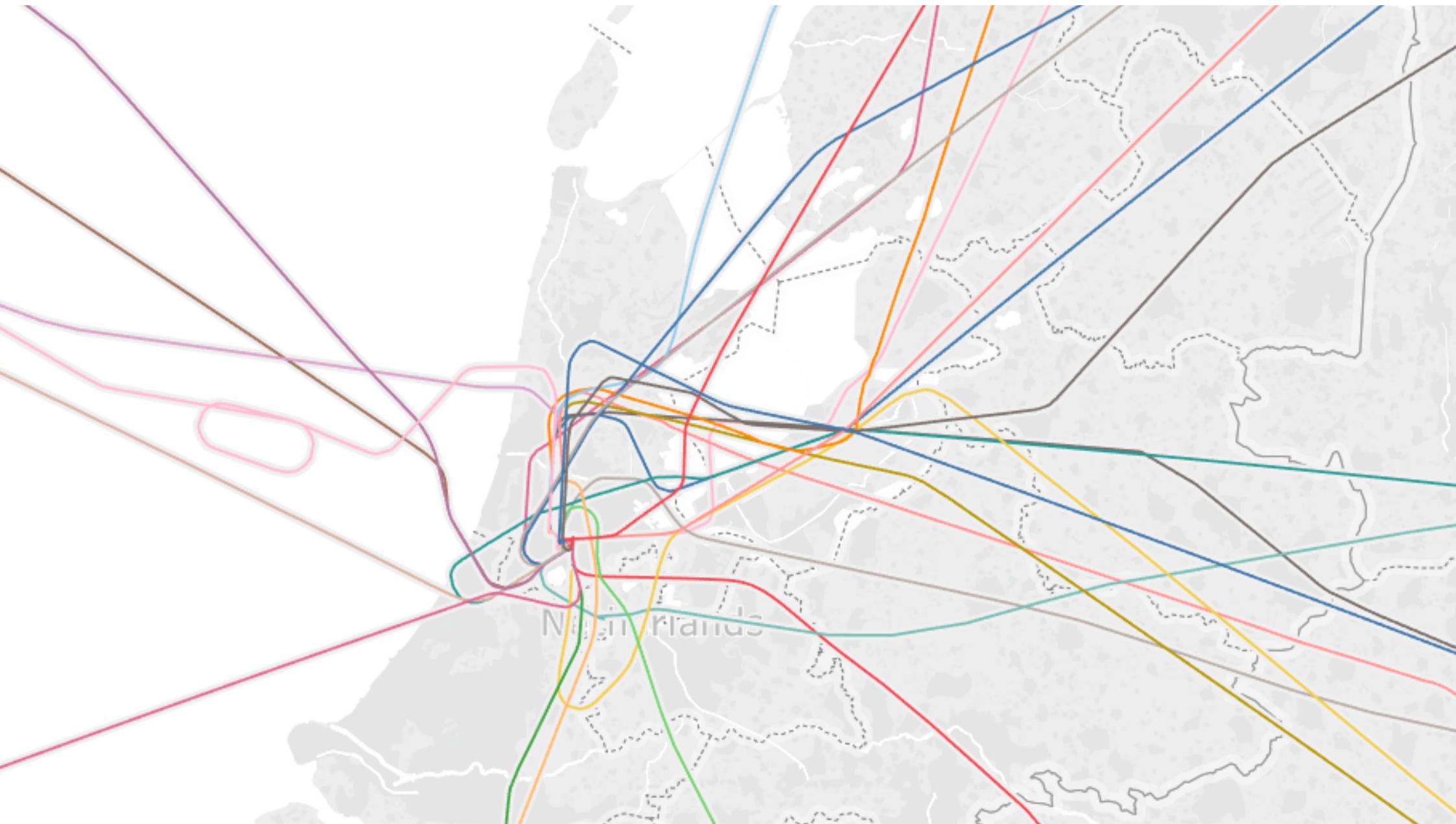


KLM's Holland Herald



UNIVERSITY OF TWENTE.





Movement cycles (example migration)

Permanent migration

- permanent change in residence
- simple origin-destination movement

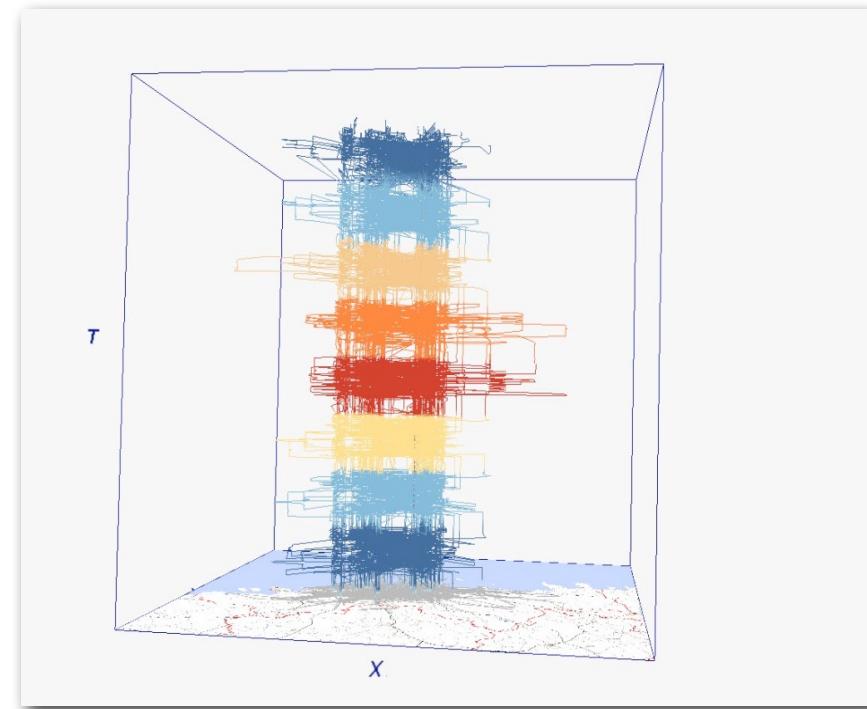
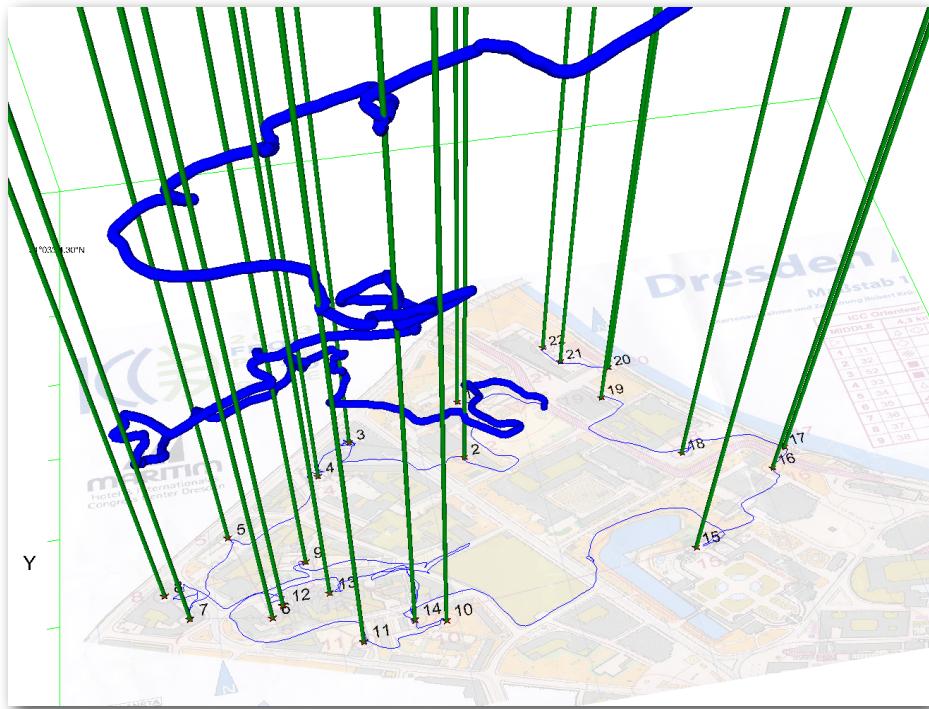
Temporary migration

- short term mobility with no change in permanent residence
- clearly distinguishable temporal cycle (diurnal, weekly or seasonal) and spatial cycle (home-work; home-second home, etc)



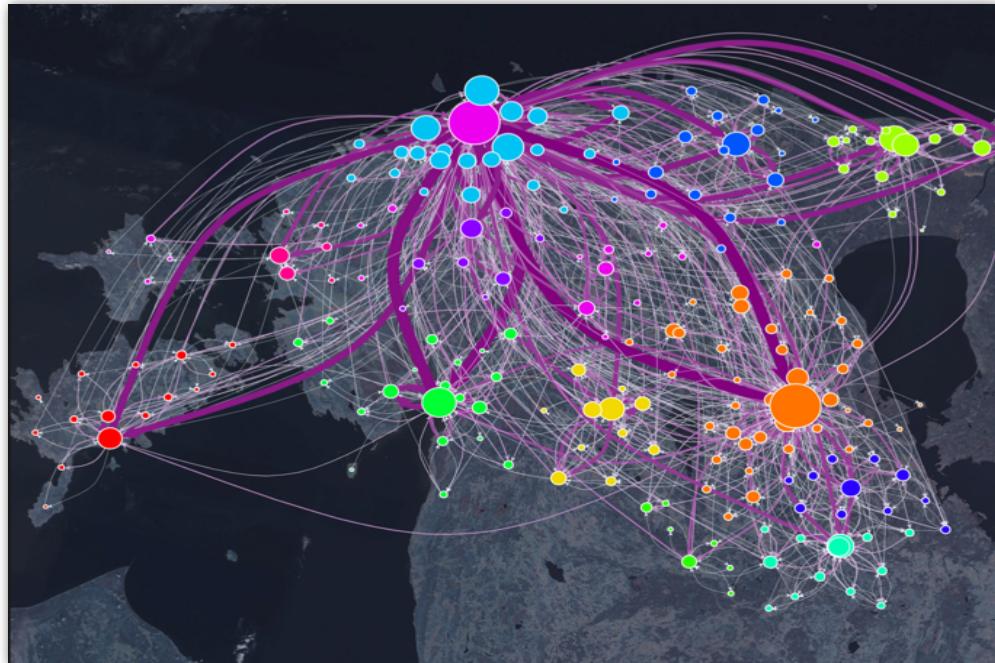
UNIVERSITY OF TWENTE.

Time



space time cube: paths and stations

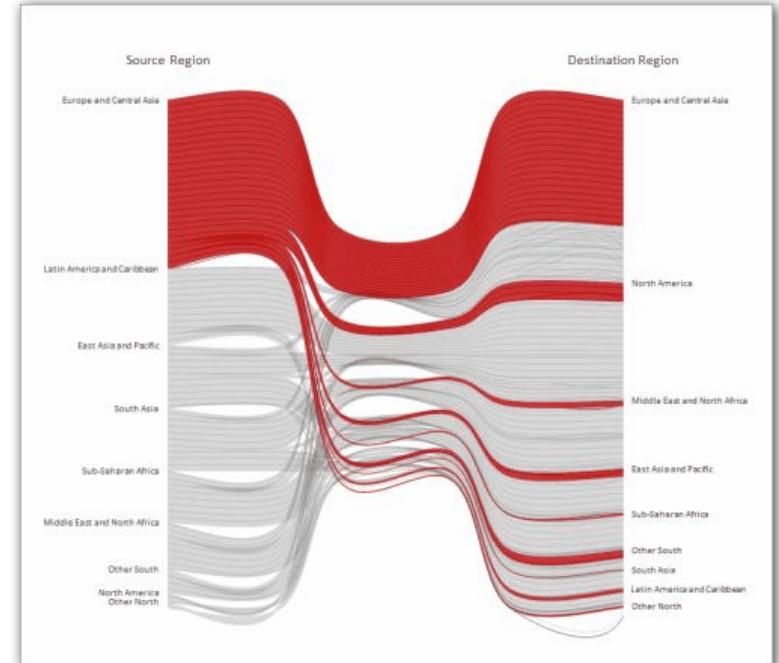
Flows



flow maps



UNIVERSITY OF TWENTE.

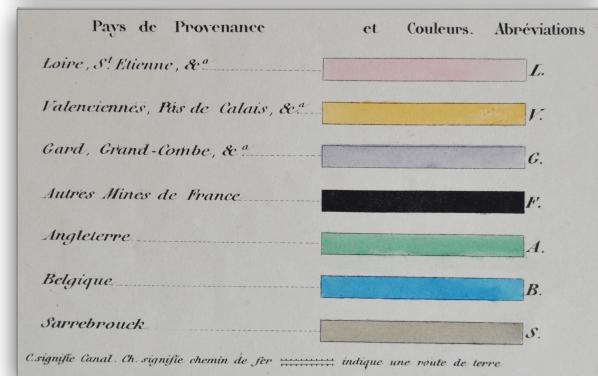
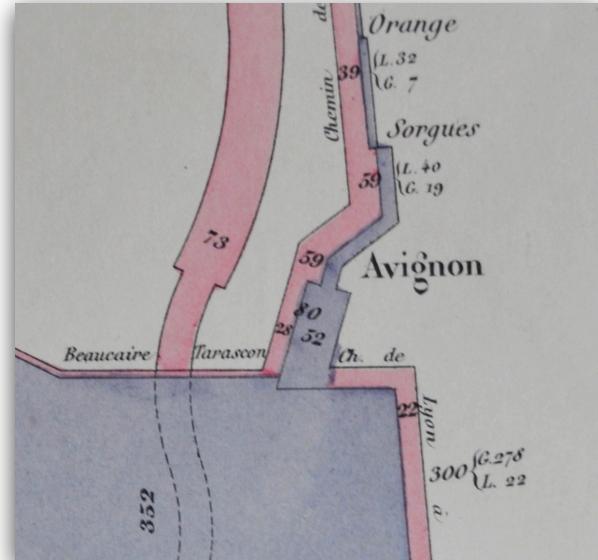


flow charts

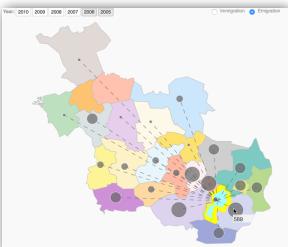
(Migration; <http://2.bp.blogspot.com/-nRCZfaEDAzE/UjxWPayj-gI/AAAAAAAAlqY/GVi5snz4AmY/s1600/cosmograph-in-excel.gif>)

Characteristics

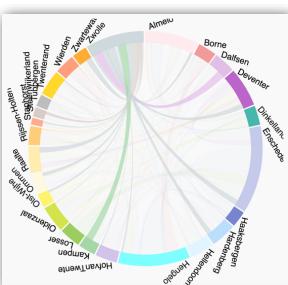
- Location
 - path, trajectory, direction
- Attribute
 - qualitative, quantitative
- Time
 - implicitly (path of path)



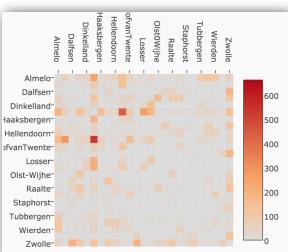
Towards a solution



Geocomputation: algorithms that deal with clutter, are able to aggregate, etc



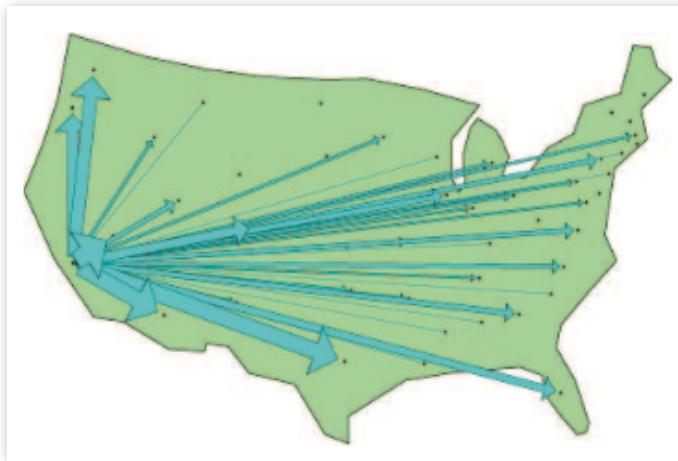
Interaction: visualization strategies to zoom, filter, select, mouse over, linked views, etc



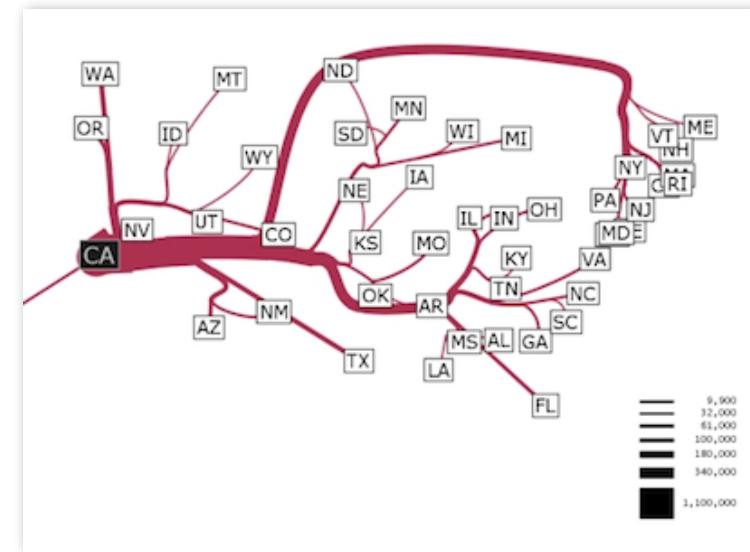
Alternative Representations: 3d flow maps, cartograms, chord diagrams, tree maps, prism maps, etc

Design: optimization of symbology, colors, arrows, dimensionality, etc

Geocomputation



(Migration from California; Tobler 1987)



(Edge bundling; Phan et al, 2005)

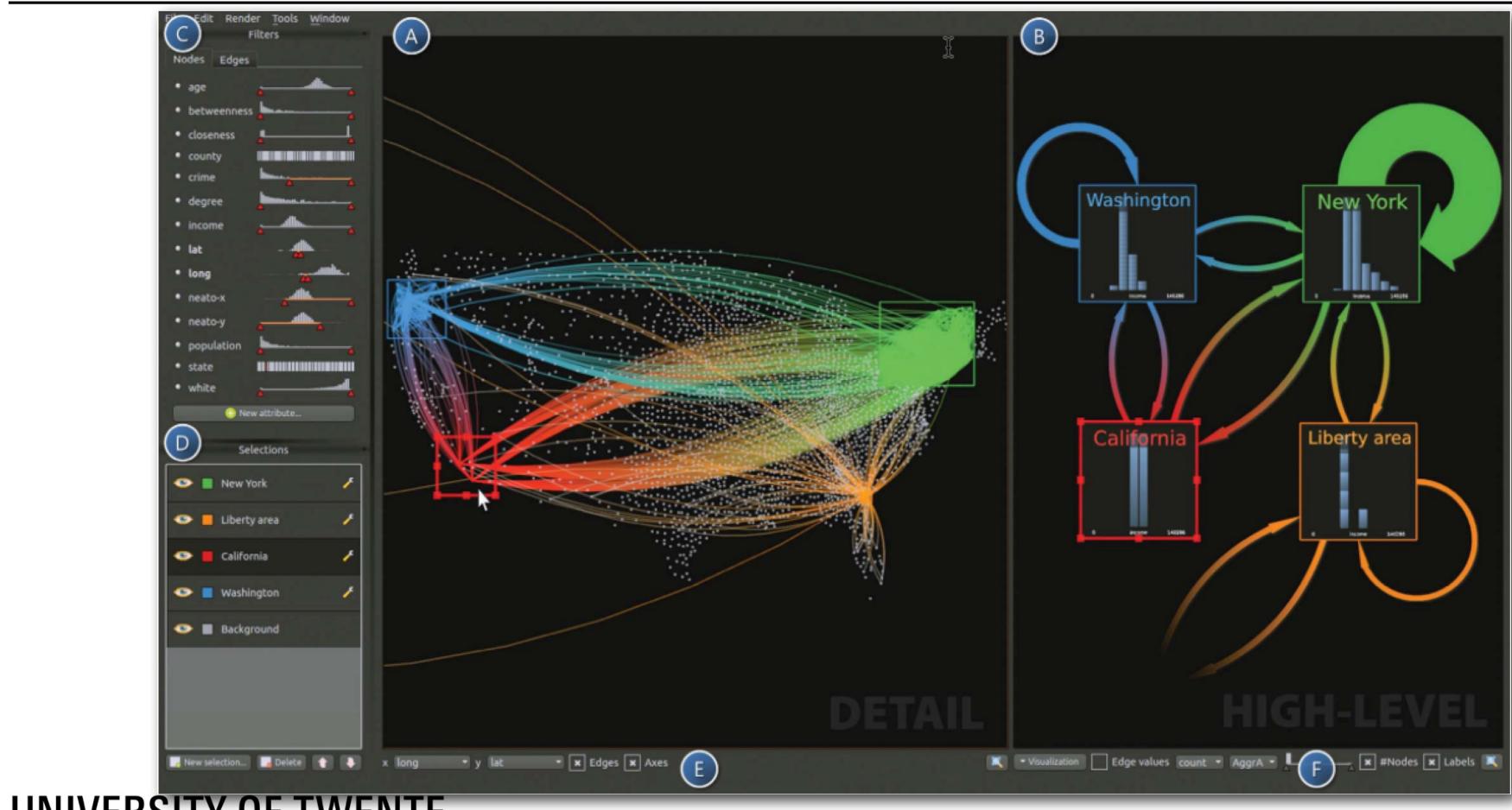


(Forced direct edge bundling; Holten et al, 2009)

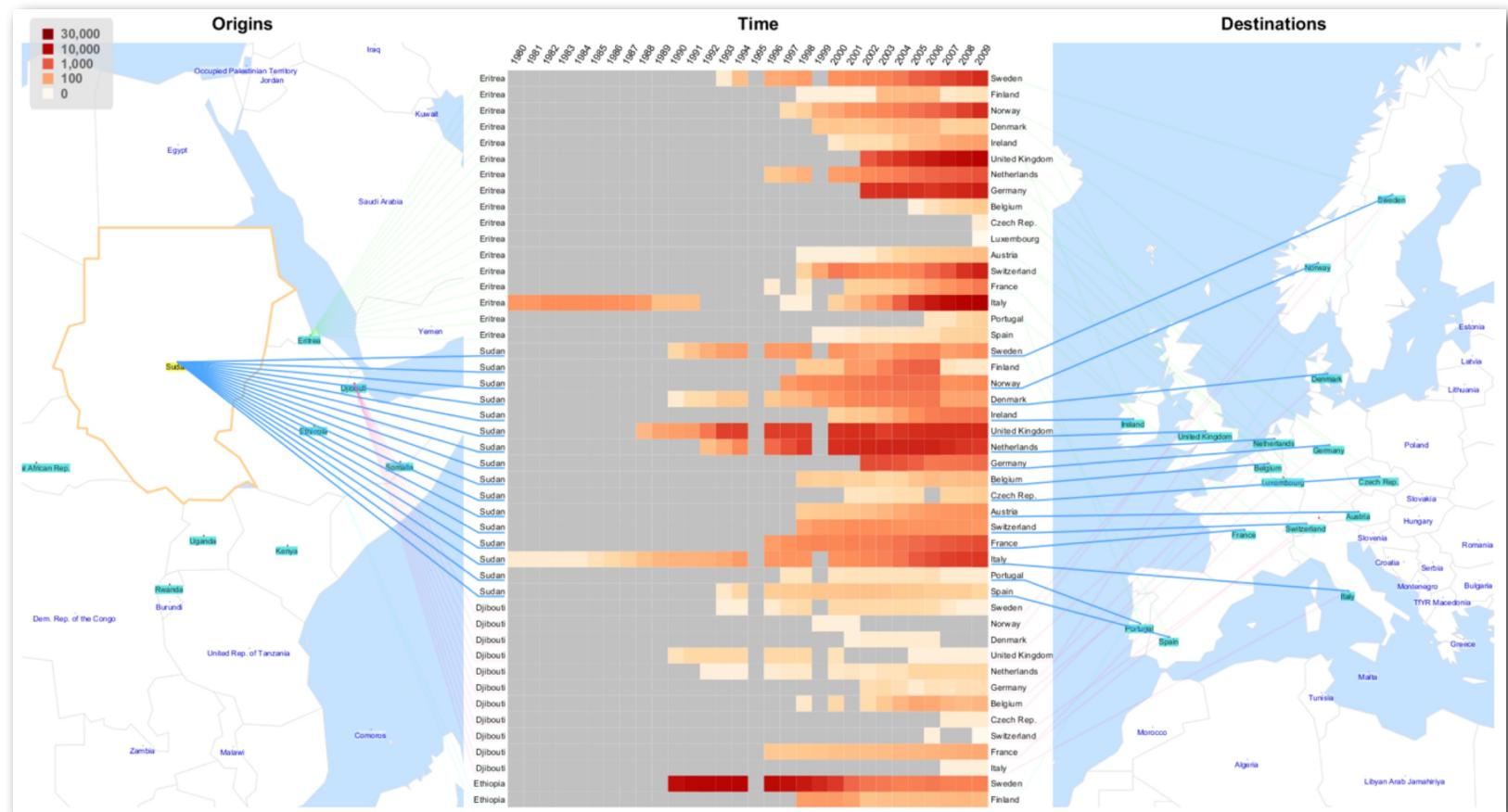


UNIVERSITY OF TWENTE.

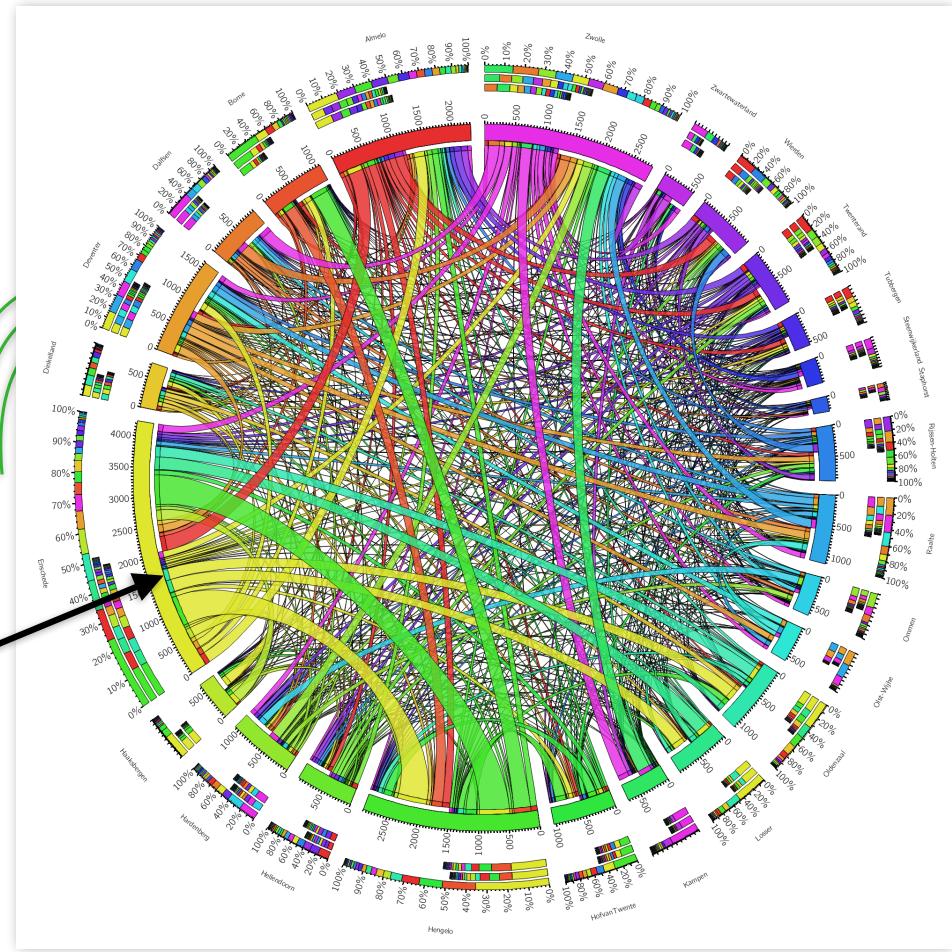
Interaction: detail and overview



Interaction: origin / time / destination

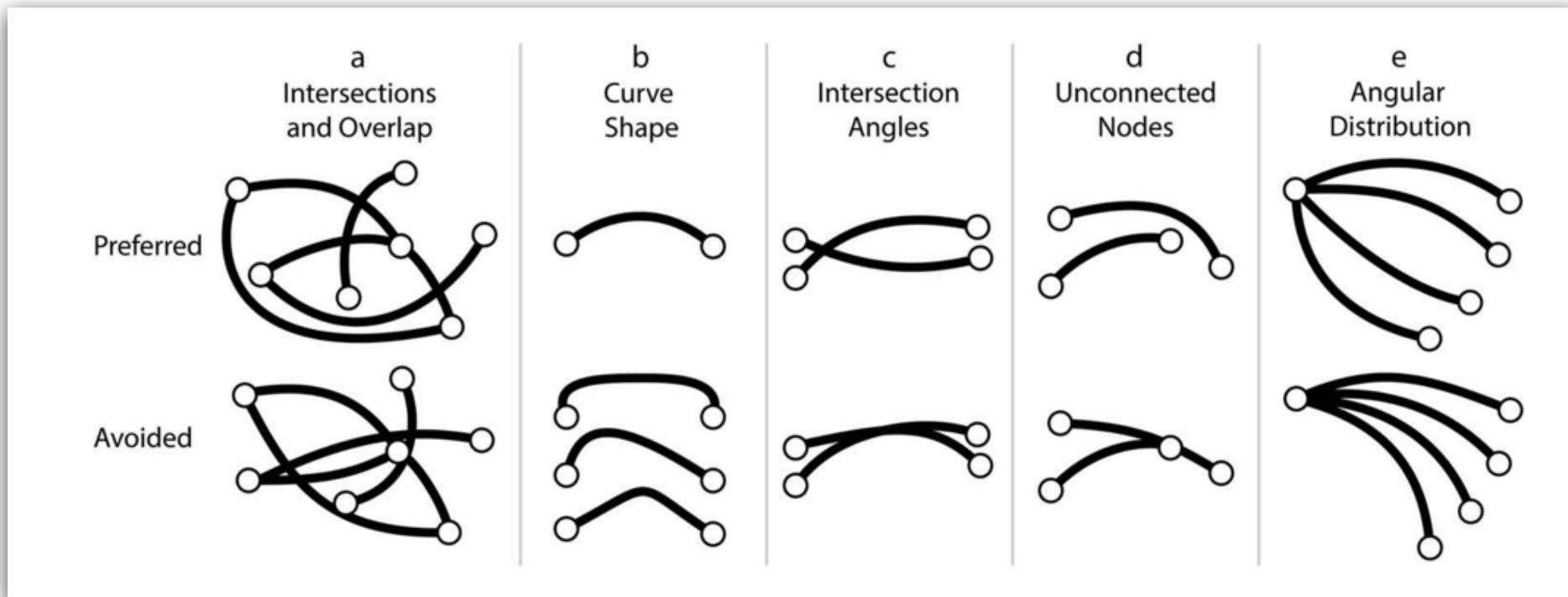


Alternative approaches: chord diagram



(Migration between the 25 municipalities of the province of Overijssel; <http://circos.ca>)

Design principles



Jenny, B, et al. (2016) Design principles for origin-destination flow maps, CAGIS

An example: running

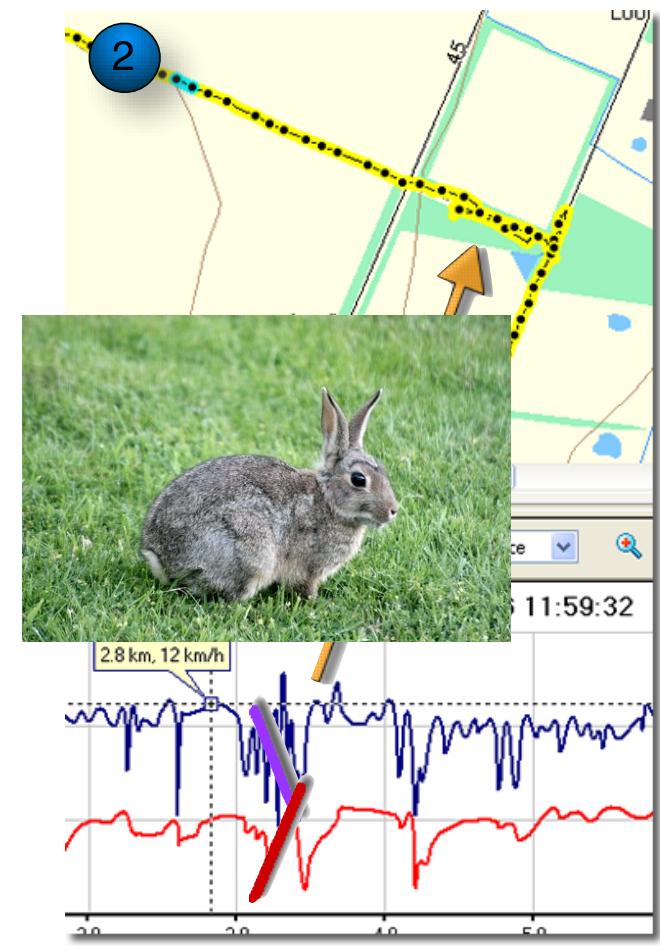
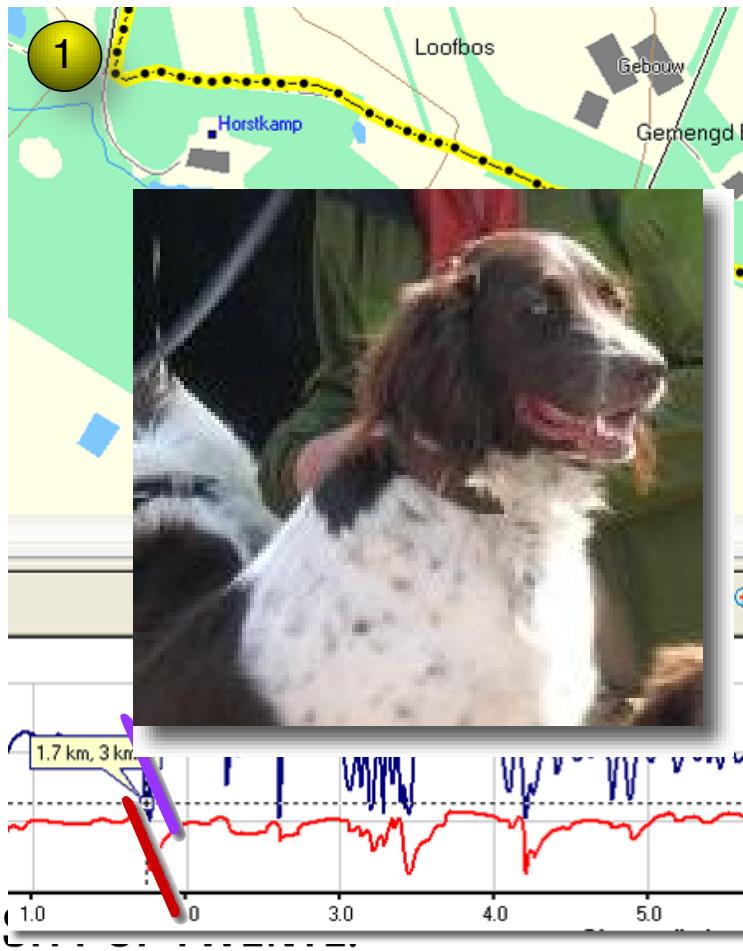
- Alternative insight in performance



An example: running



An example: running



Example: Migration in Iceland



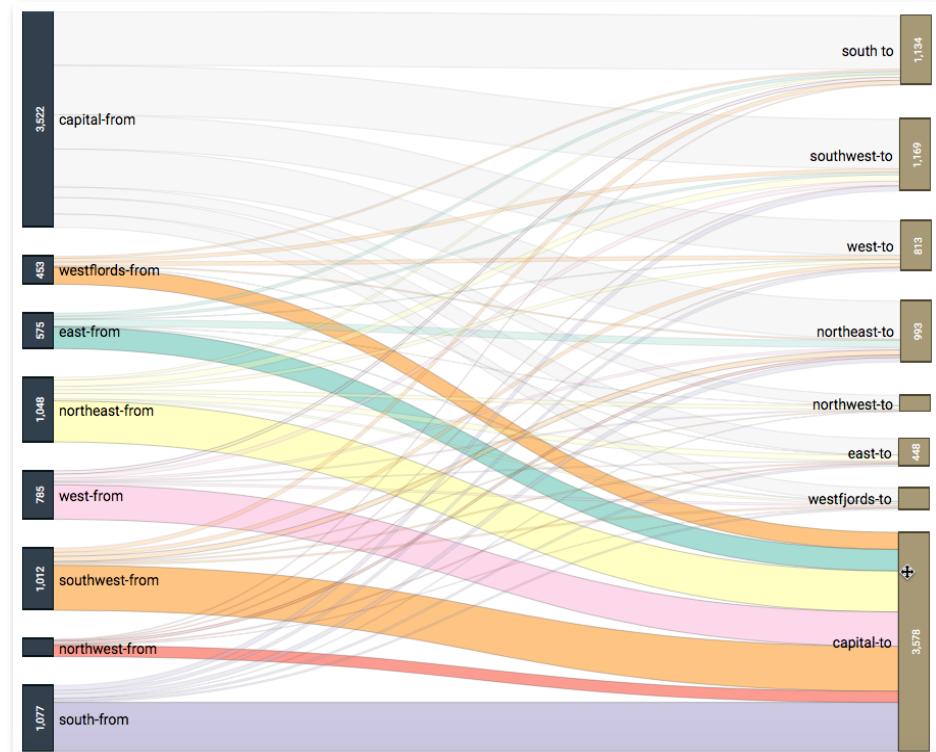
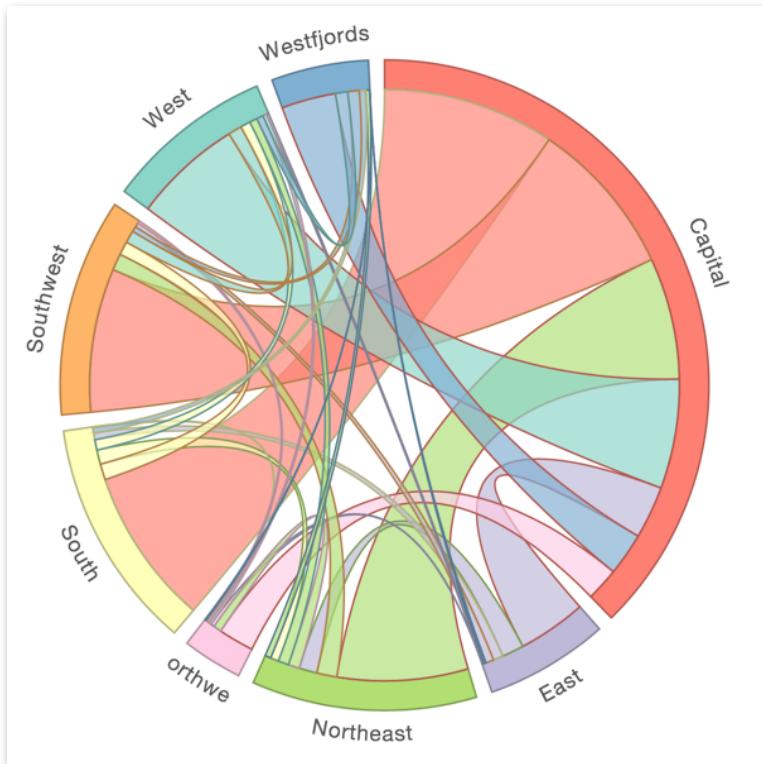
f \ t	Capital	East	Northeast	Northwest	South	Southwest	West	Westfjords
Capital	0	269	622	170	880	804	559	218
East	351	0	112	1	51	41	9	10
Northeast	670	91	0	58	42	103	54	30
Northwest	182	18	41	0	9	12	13	5
South	804	34	73	6	0	81	53	26
Southwest	733	22	85	13	69	0	63	27
West	560	12	40	19	51	69	0	34
Westfjords	278	2	20	0	32	59	62	0

O-D matrix

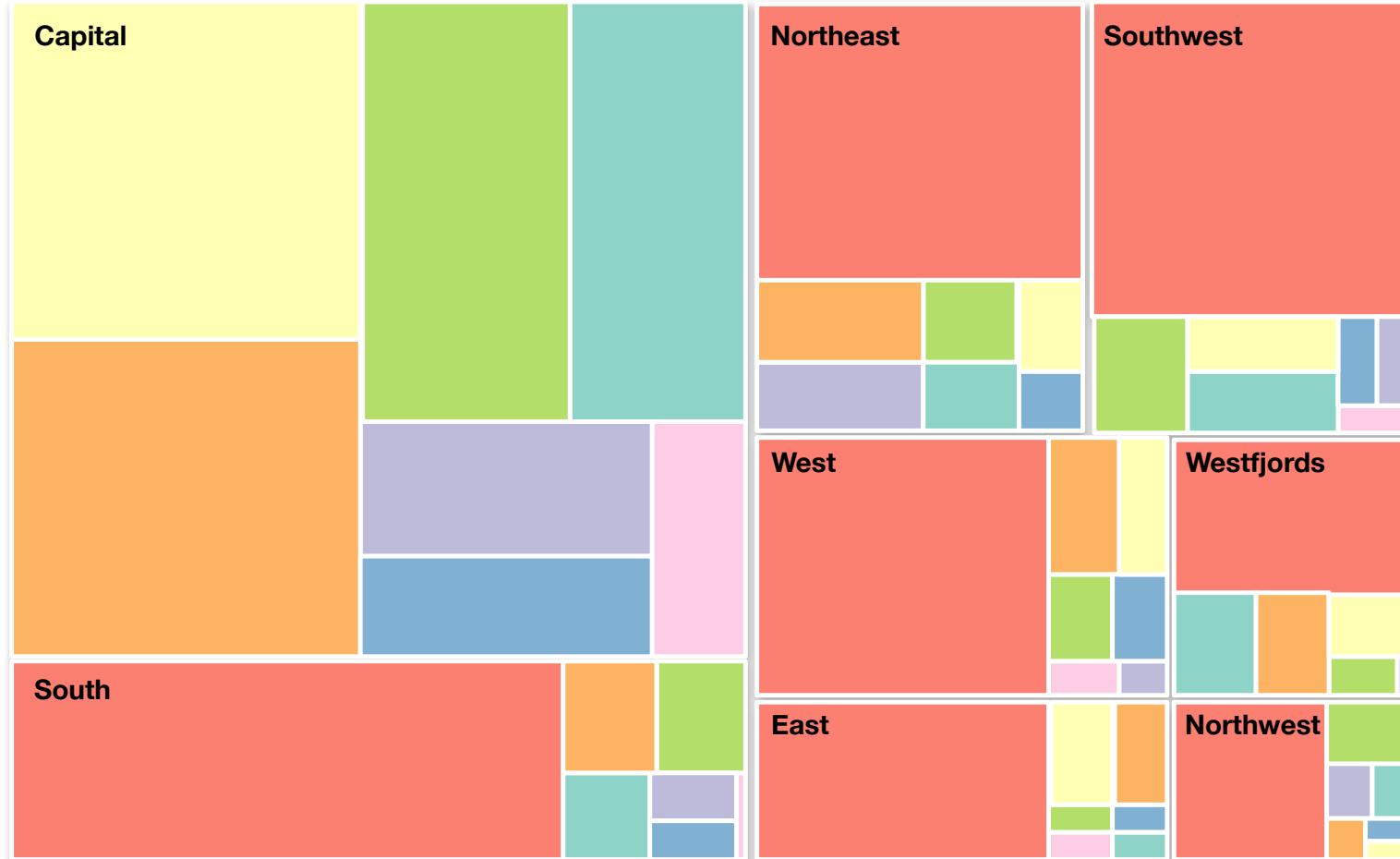
		Capital	Northeast	Northwest	South	Southwest	West	Westfjords	
		Capital	East	East	Northwest	South	Southwest	West	Westfjords
Capital	Capital								
	East								
	Northeast								
	Northwest								
	South								
	Southwest								
	West								
	Westfjords								

> 670
351-670
> 350

Chord diagram and Sankey diagram



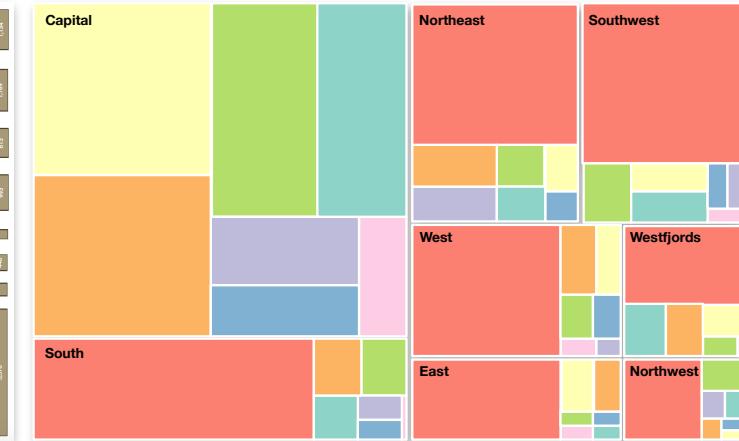
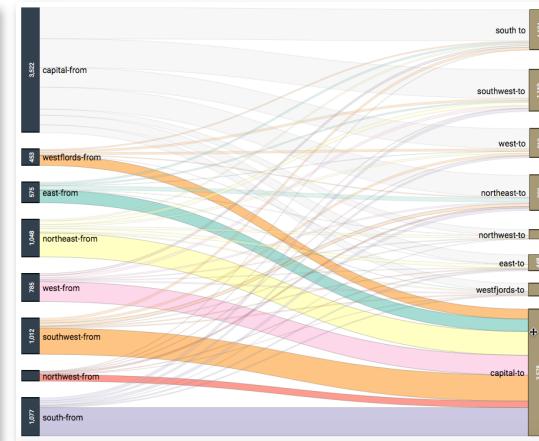
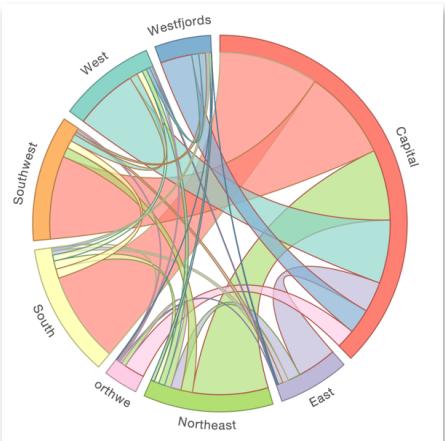
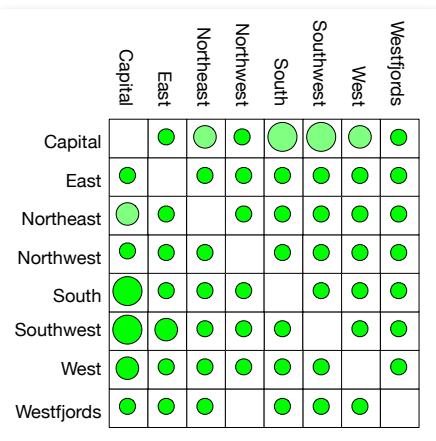
Treemap



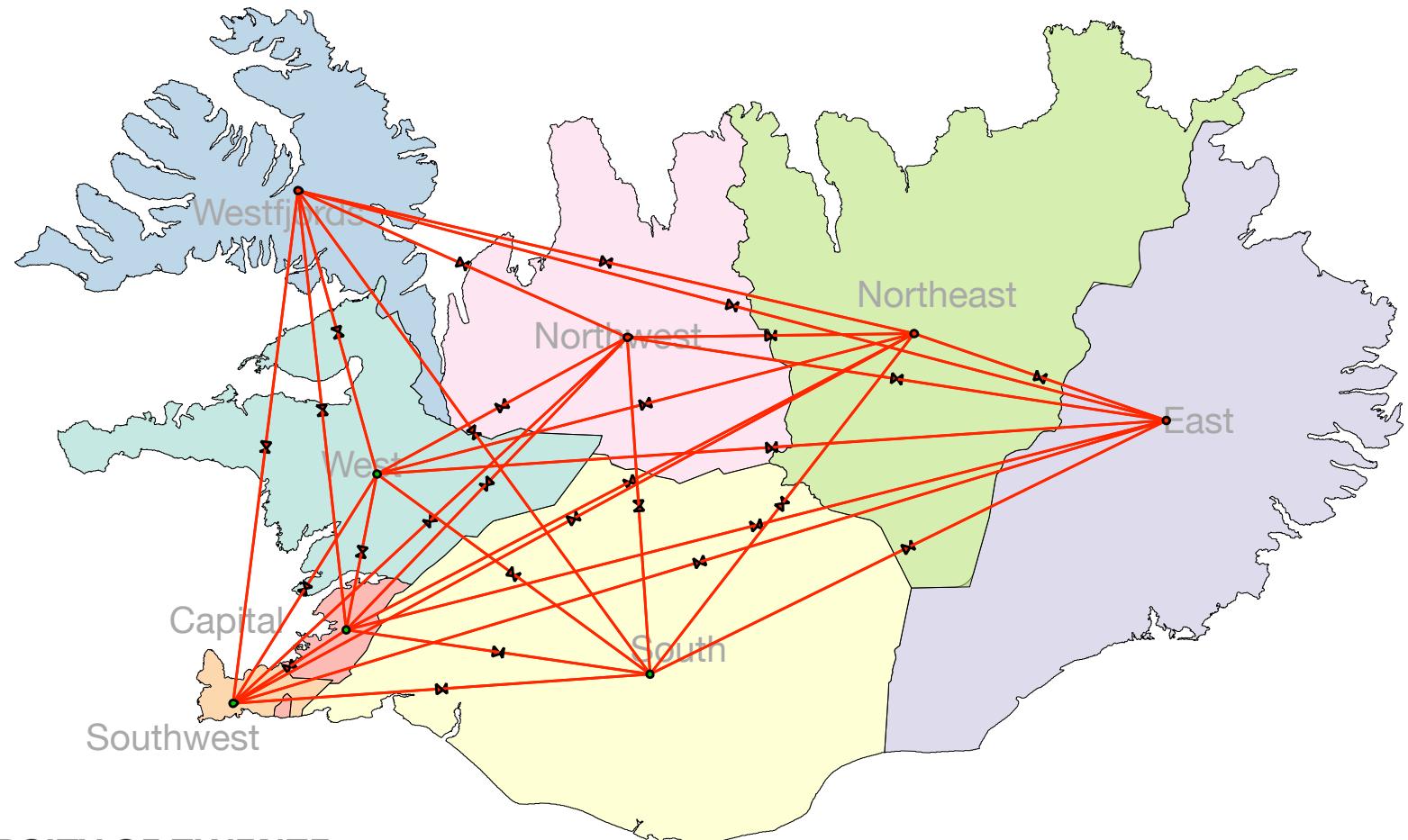
UNIVERSITY OF TWENTE.

Lost geography

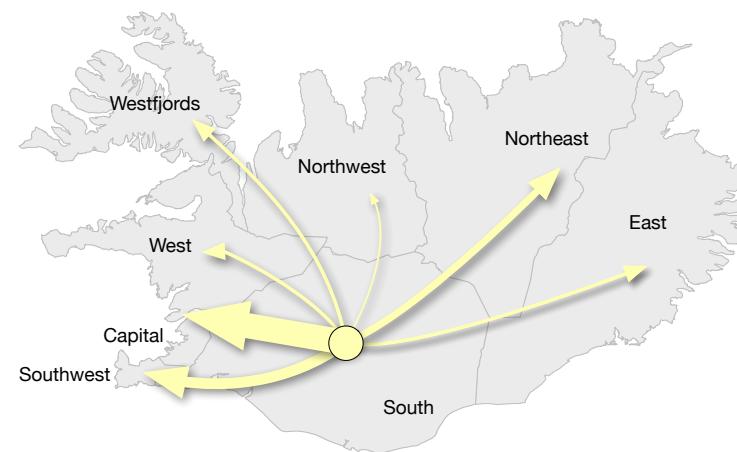
- Alphabetical order?



O-D network and the geography

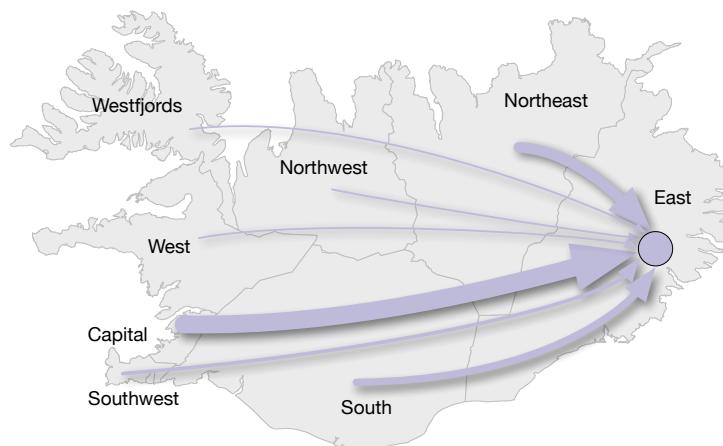


From one origin to all destination



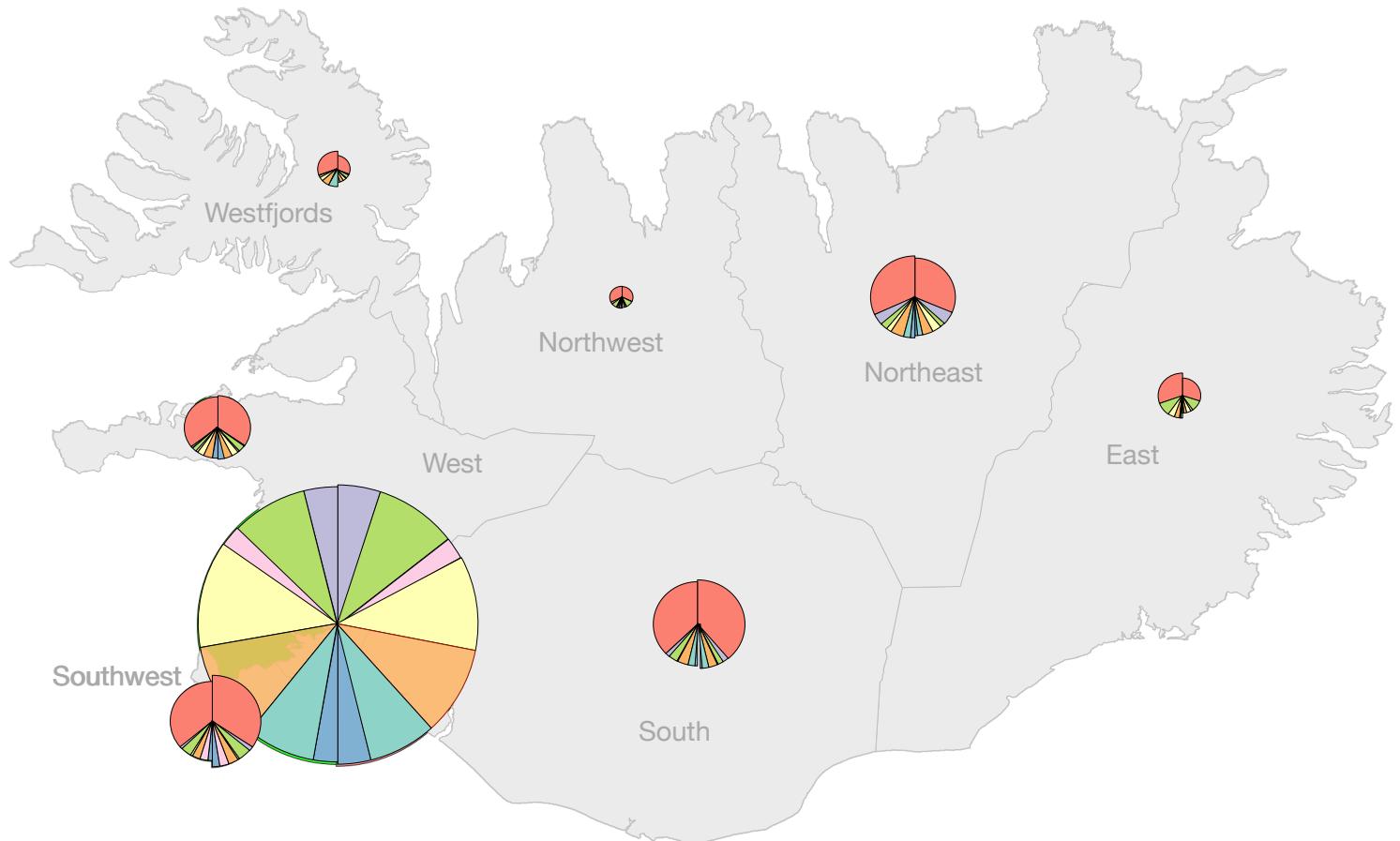
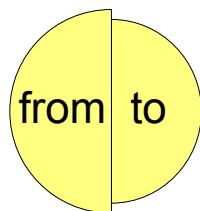
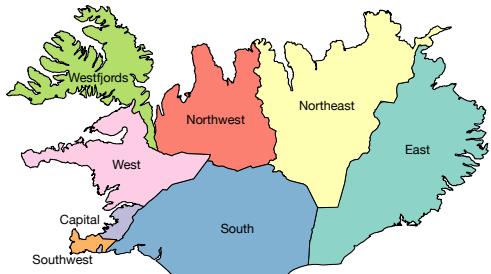
$t \setminus f$	Capital	East	Northeast	Northwest	South	Southwest	West	Westfjords
Capital	0	269	622	170	880	804	559	218
East	351	0	112	1	51	41	9	10
Northeast	670	91	0	58	42	103	54	30
Northwest	182	18	41	0	9	12	13	5
South	804	34	73	6	0	81	53	26
Southwest	733	22	85	13	69	0	63	27
West	560	12	40	19	51	69	0	34
Westfjords	278	2	20	0	32	59	62	0

From all origins to one destination

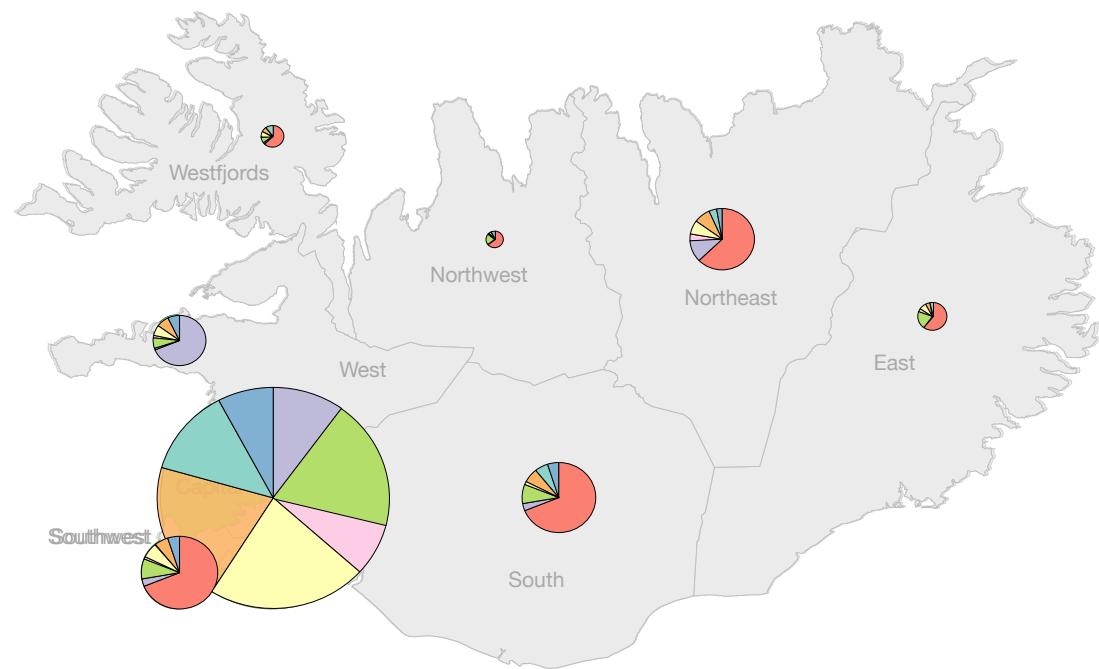
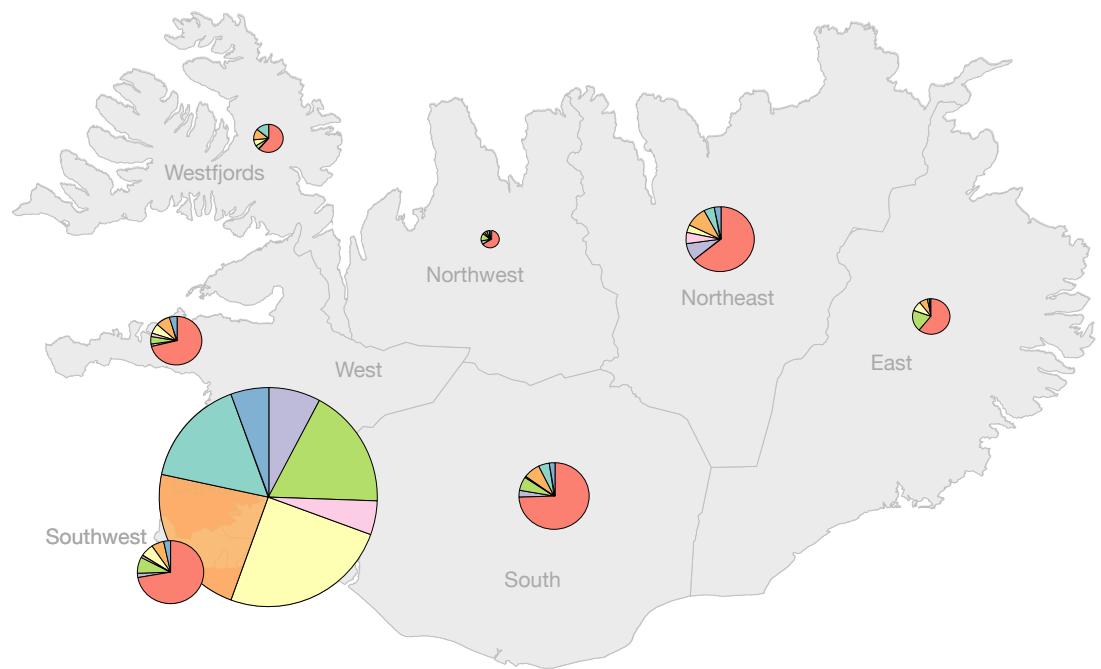


f \ t	Capital	East	Northeast	Northwest	South	Southwest	West	Westfjords
Capital	0	269	622	170	880	804	559	218
East	351	0	112	1	51	41	9	10
Northeast	670	91	0	58	42	103	54	30
Northwest	182	18	41	0	9	12	13	5
South	804	34	73	6	0	81	53	26
Southwest	733	22	85	13	69	0	63	27
West	560	12	40	19	51	69	0	34
Westfjords	278	2	20	0	32	59	62	0

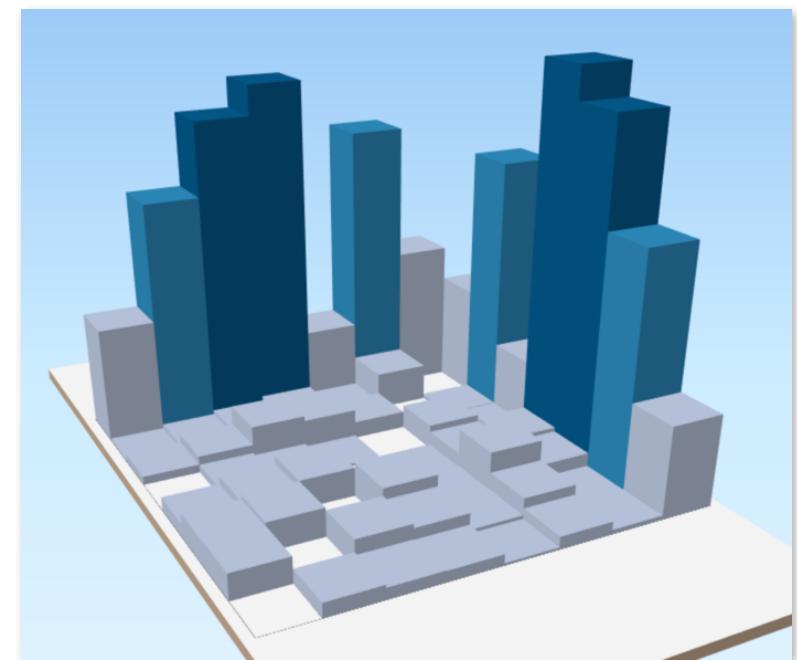
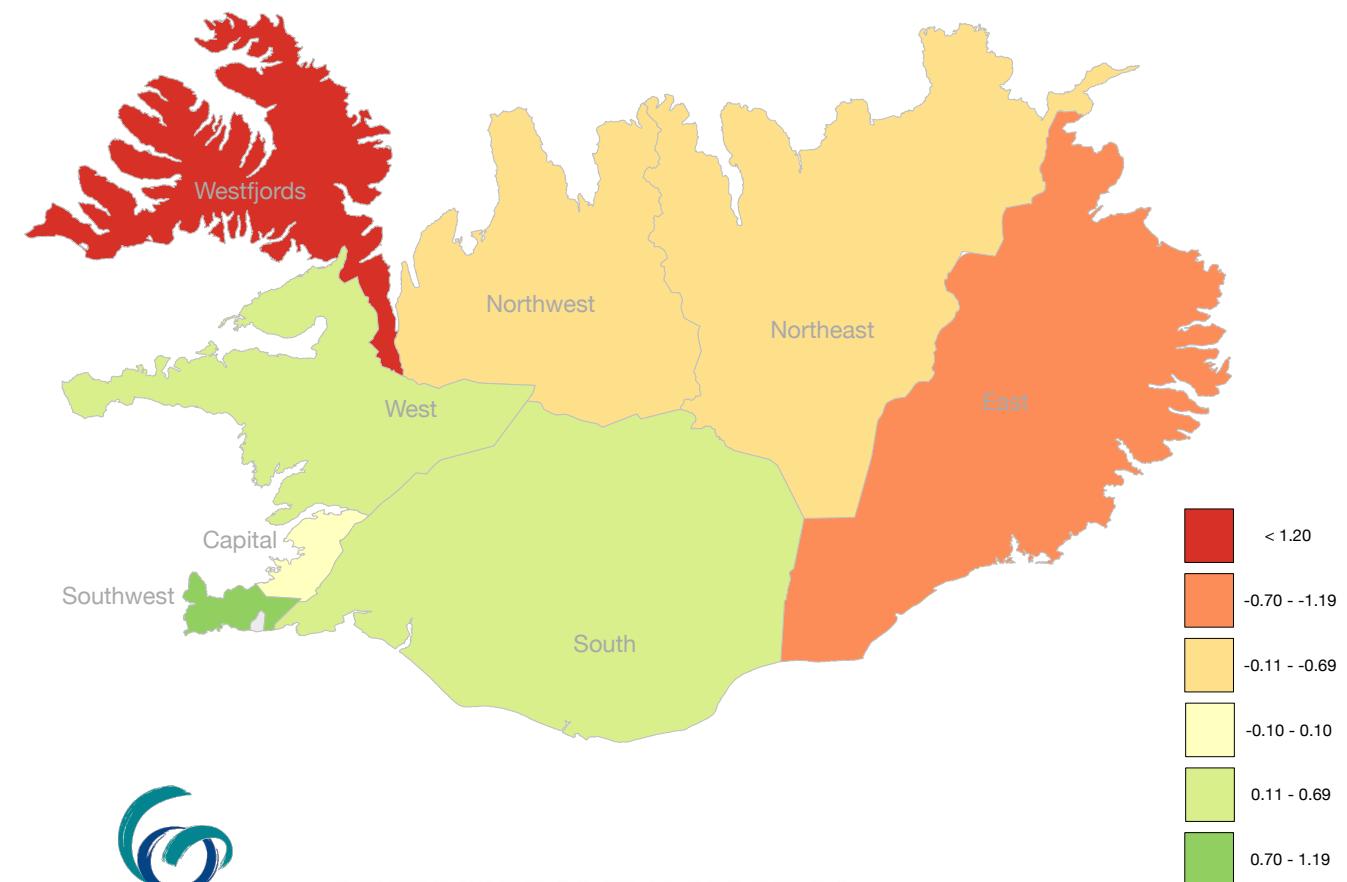
Migration from (left) and to (right)



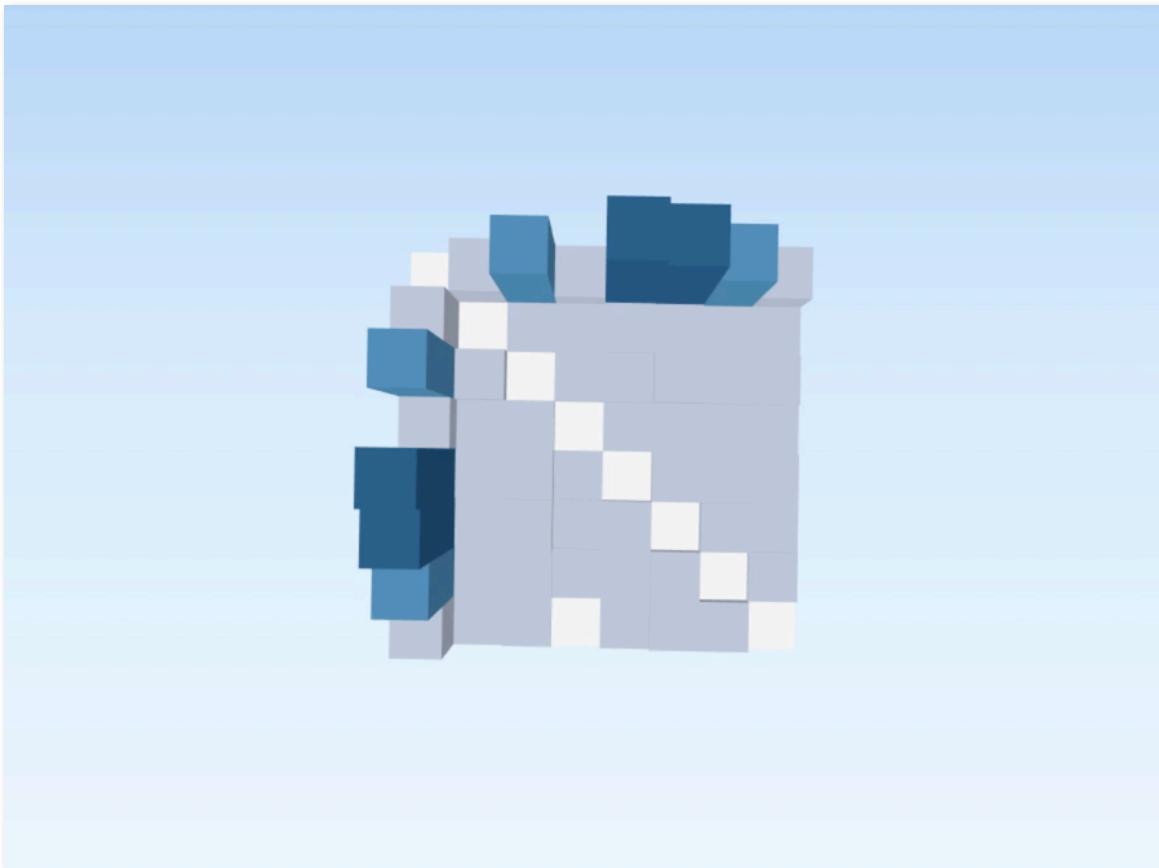
Migration from (left) and to (right)



Relative and absolute migration

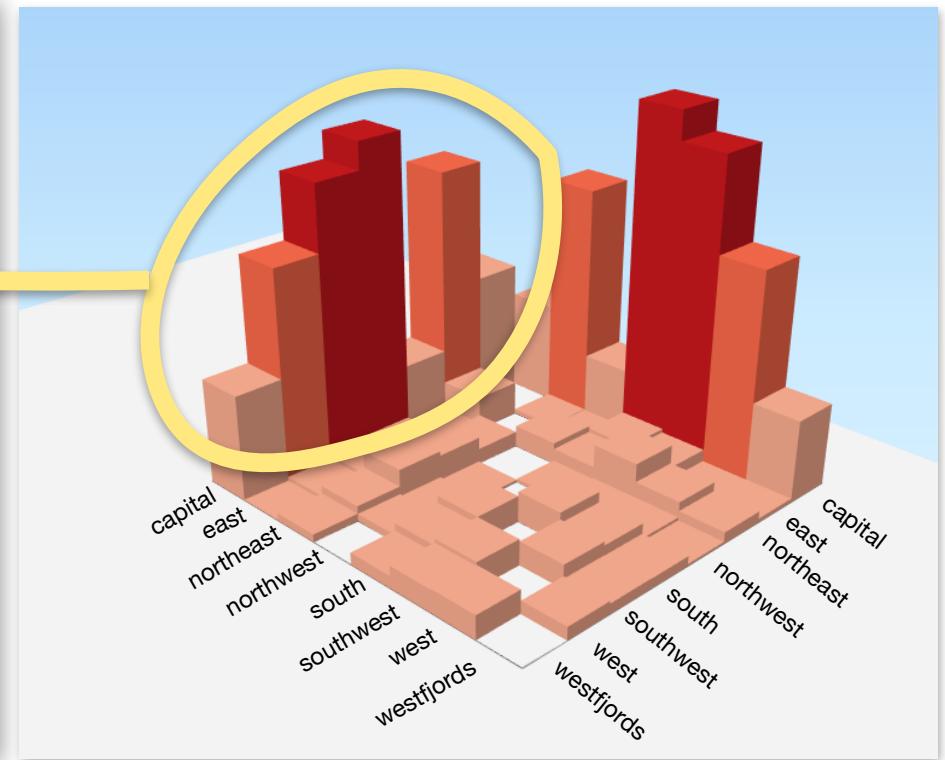
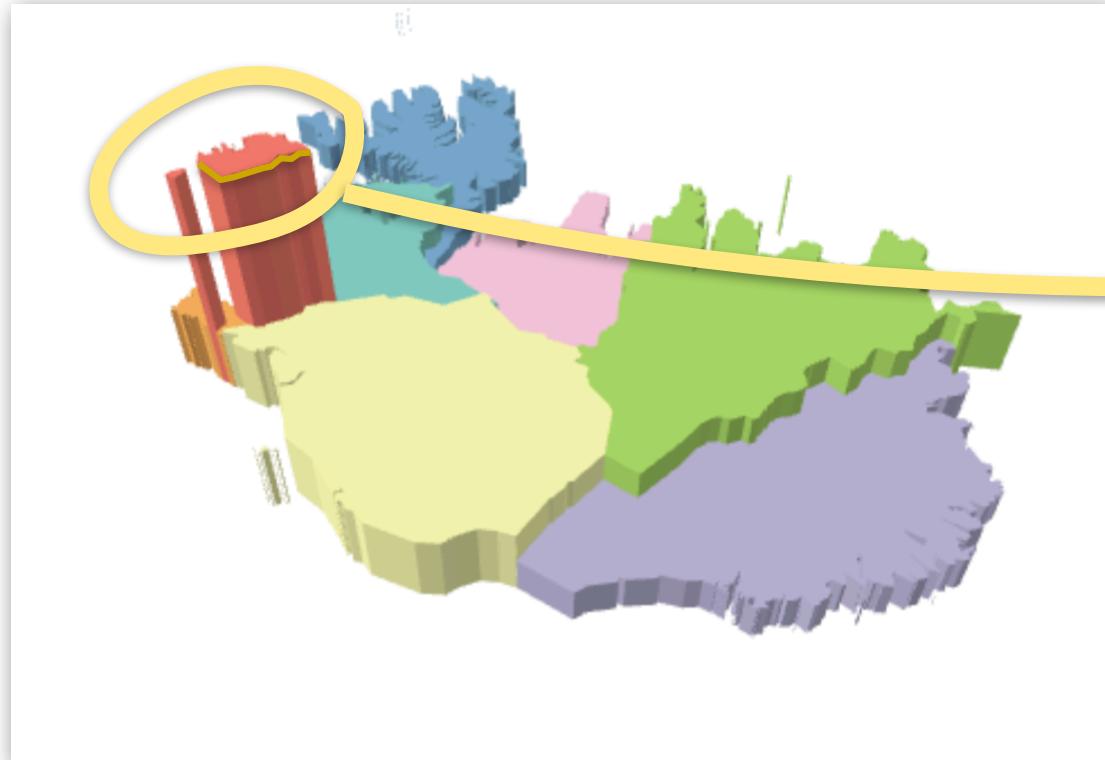


3D O-D matrix

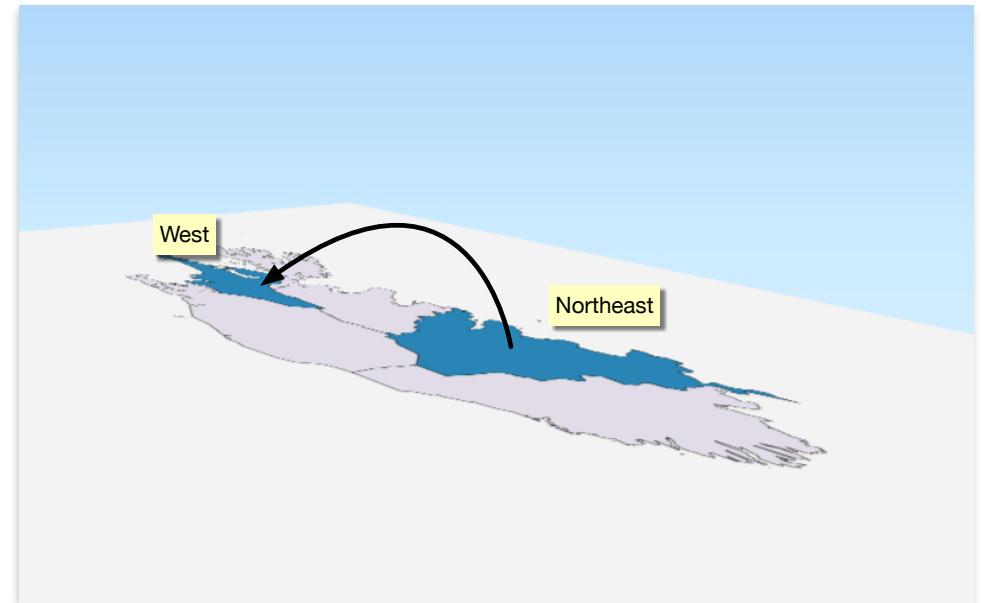
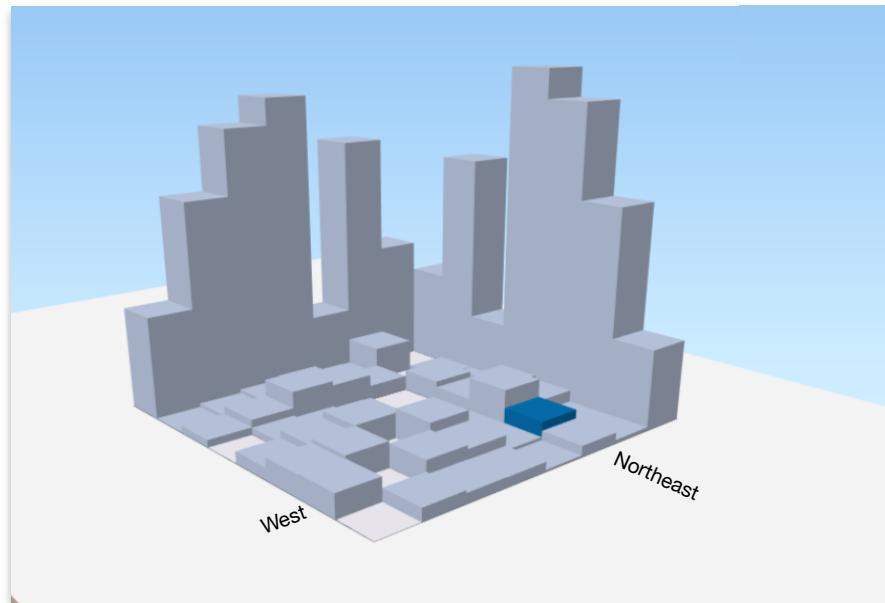


UNIVERSITY OF TWENTE.

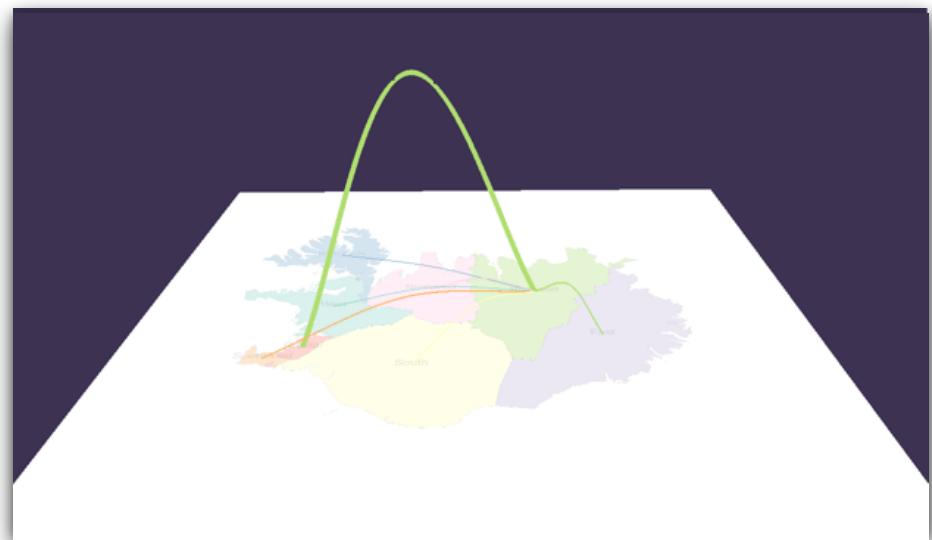
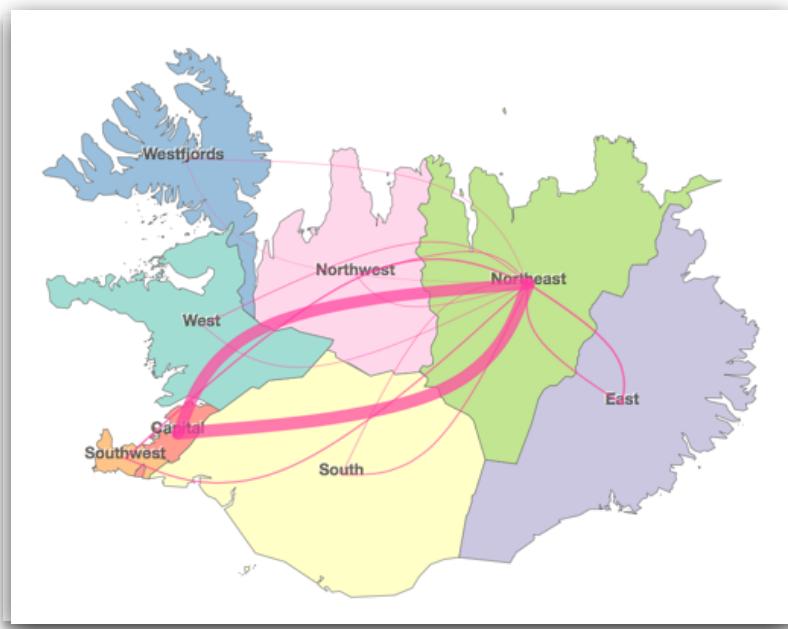
All is relative



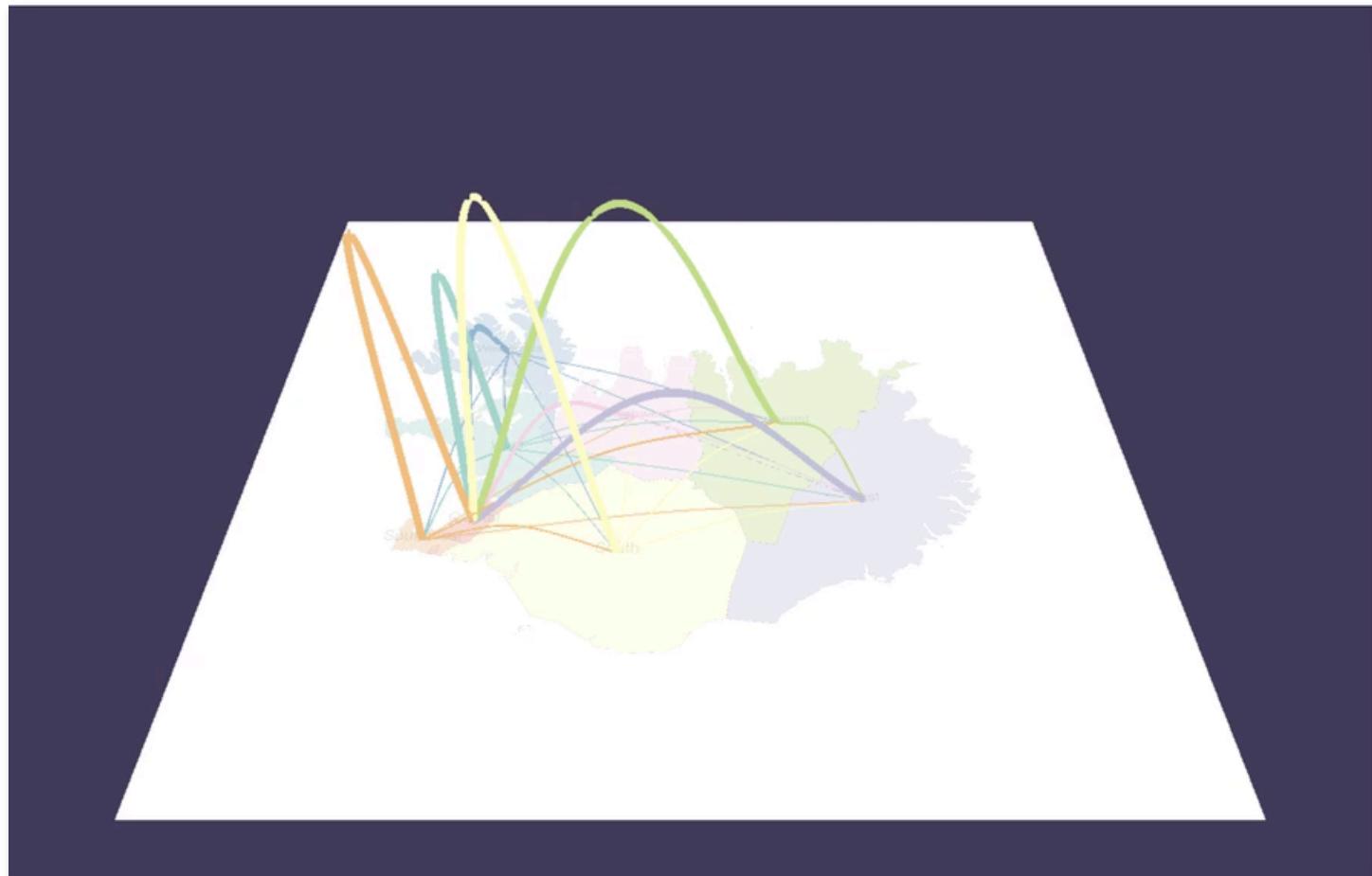
Link OD matrix and map



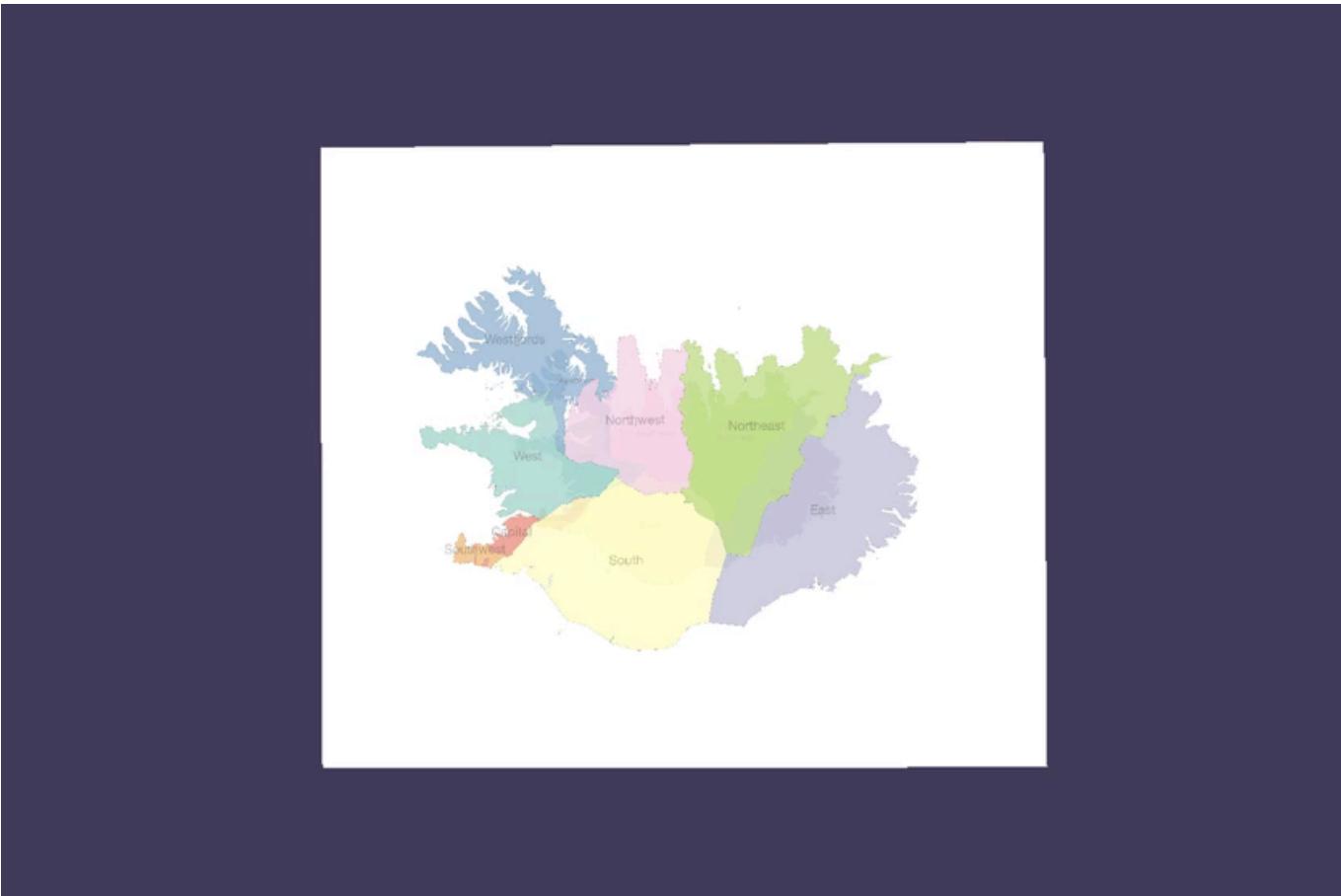
(3D) map



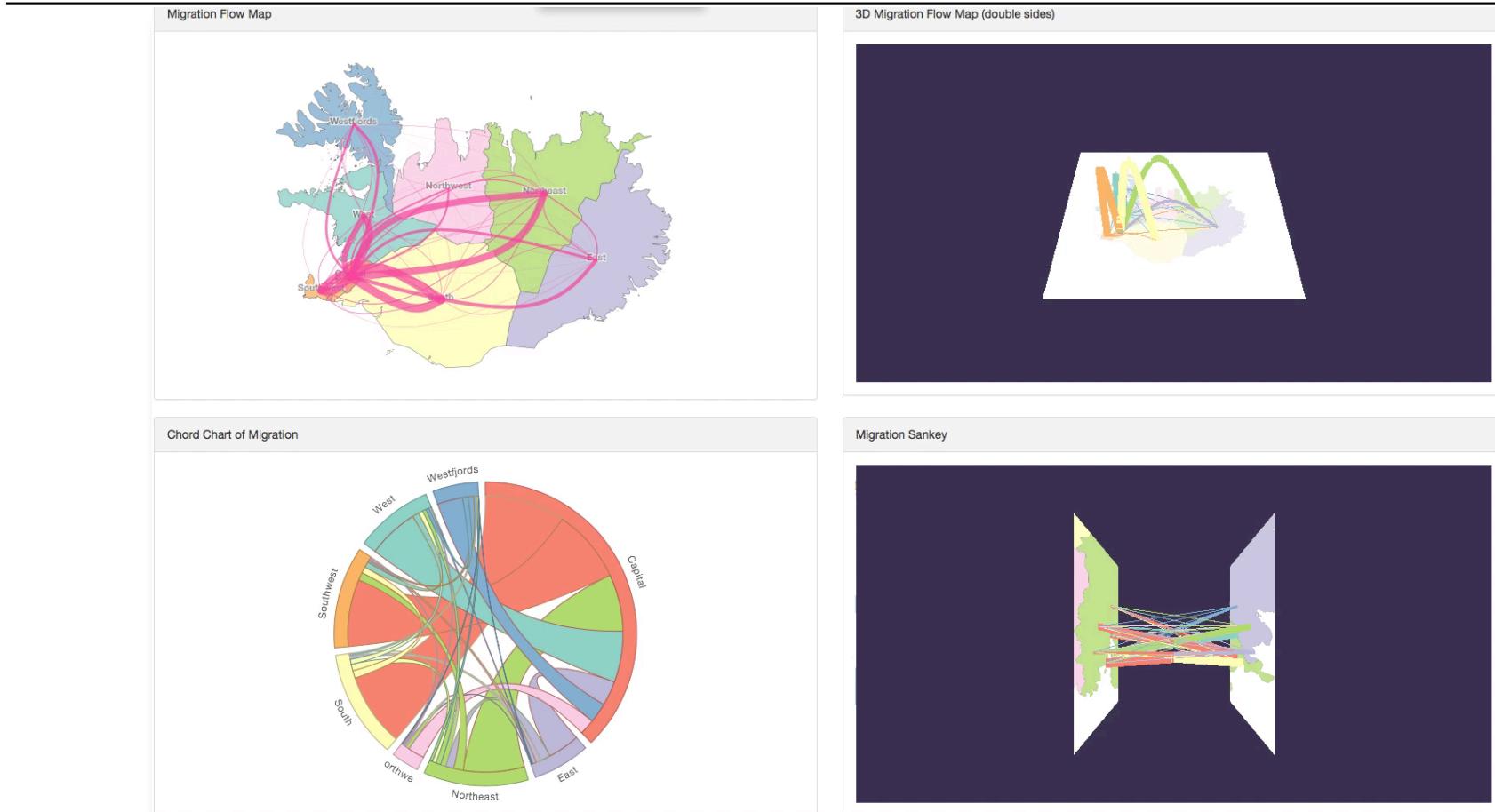
3D map



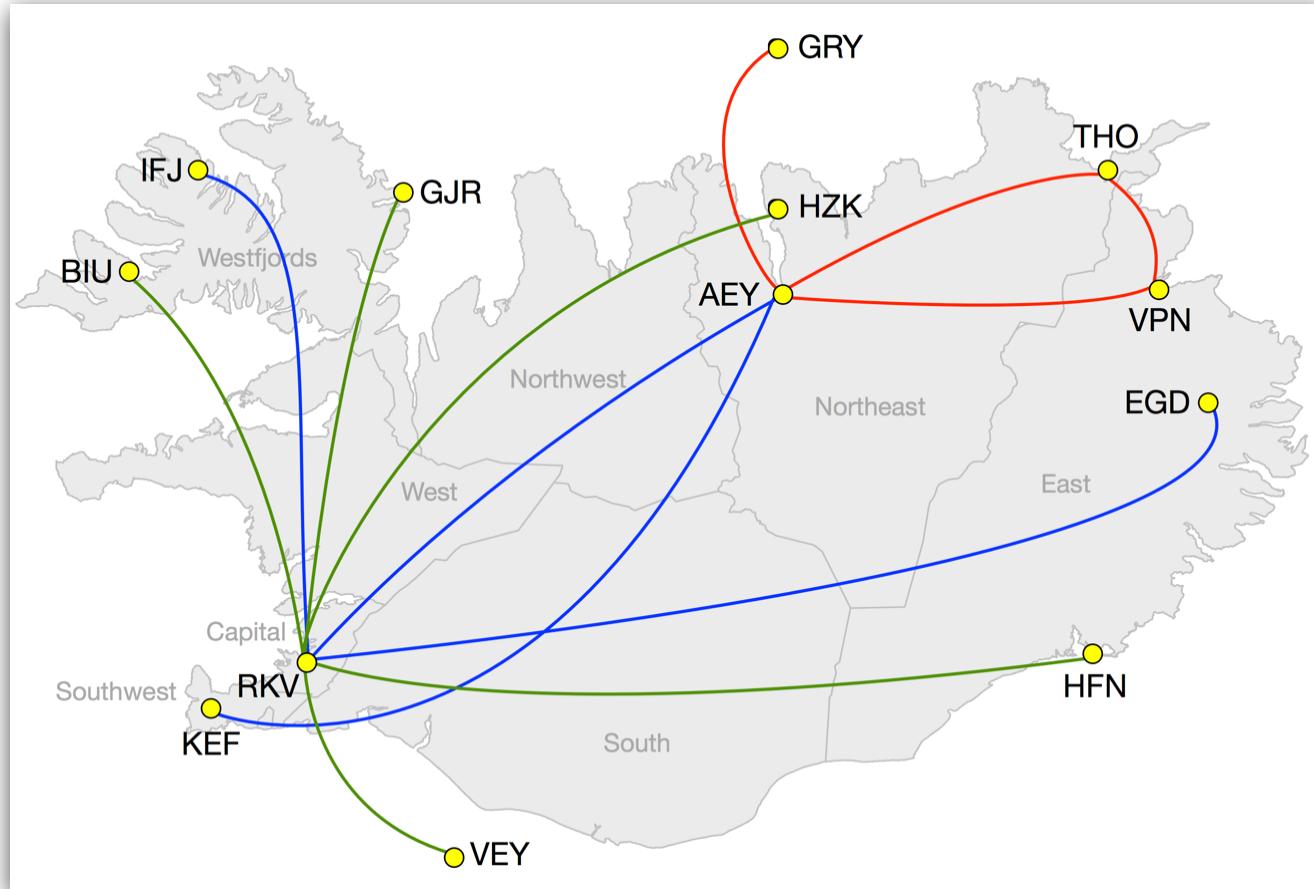
3D Sankey



Dashboard approach

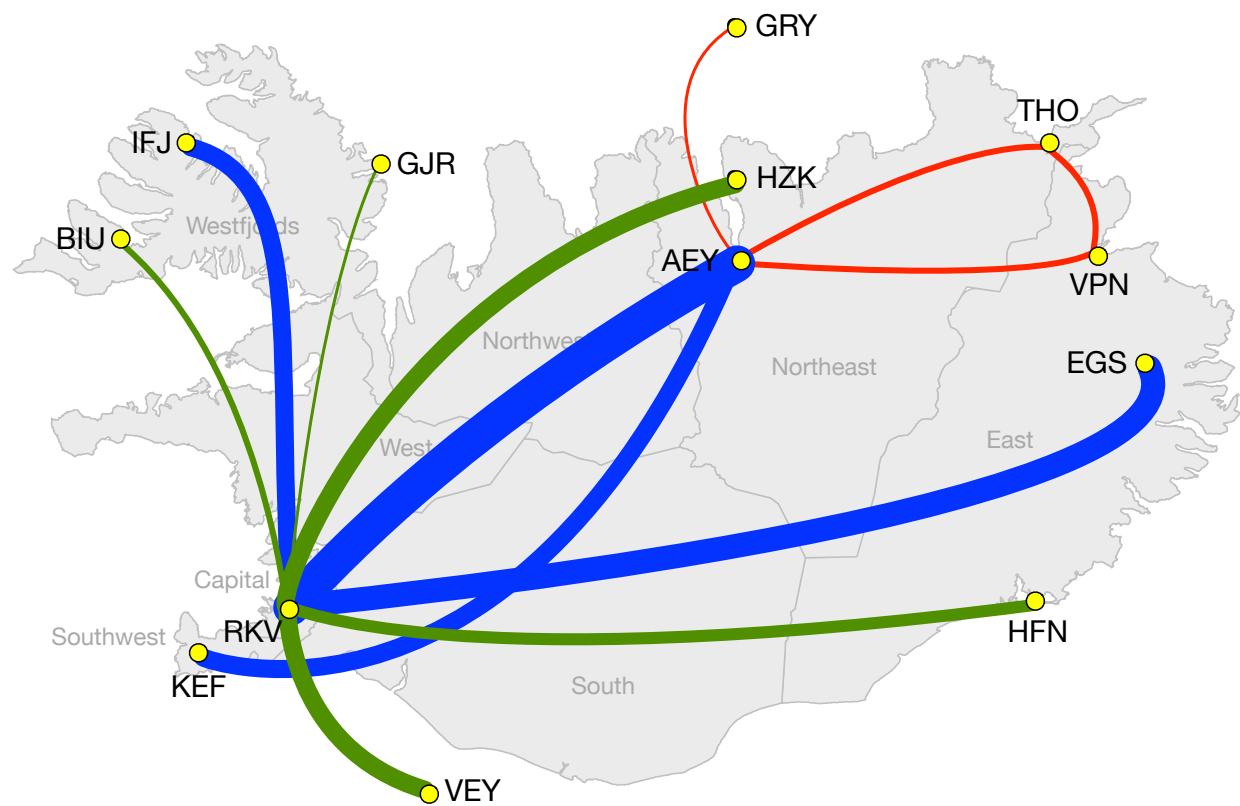


Temporal granularity and A-symmetric O-D matrix



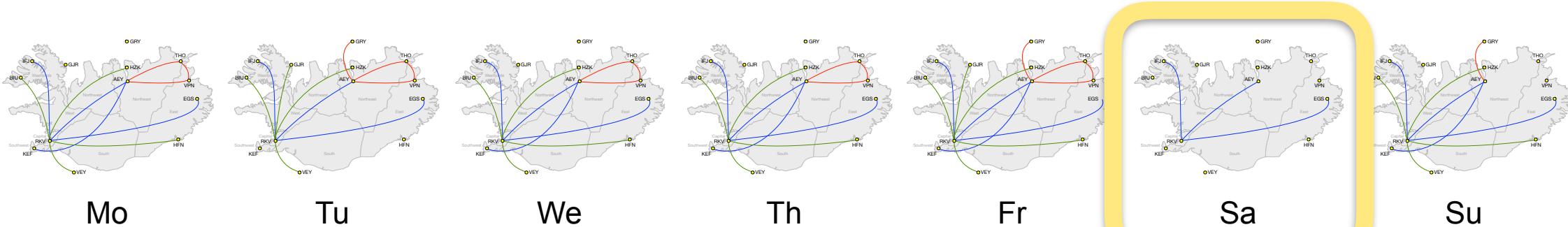
Frequency of connections

	AEY	BIU	EGS	GJR	GRY	HFN	HZK	IFJ	KEF	RKV	THO	VEJ	VPN
AEY					3				13	33	0		5
BIU											6		
EGS											22		
GJR											2		
GRY	3												
HFN											9		
HZK											12		
IFJ										13			
KEF	13												
RKV	33	6	22	2		9	12	13				12	0
THO	5												
VEJ										12			
VPN	0									5			

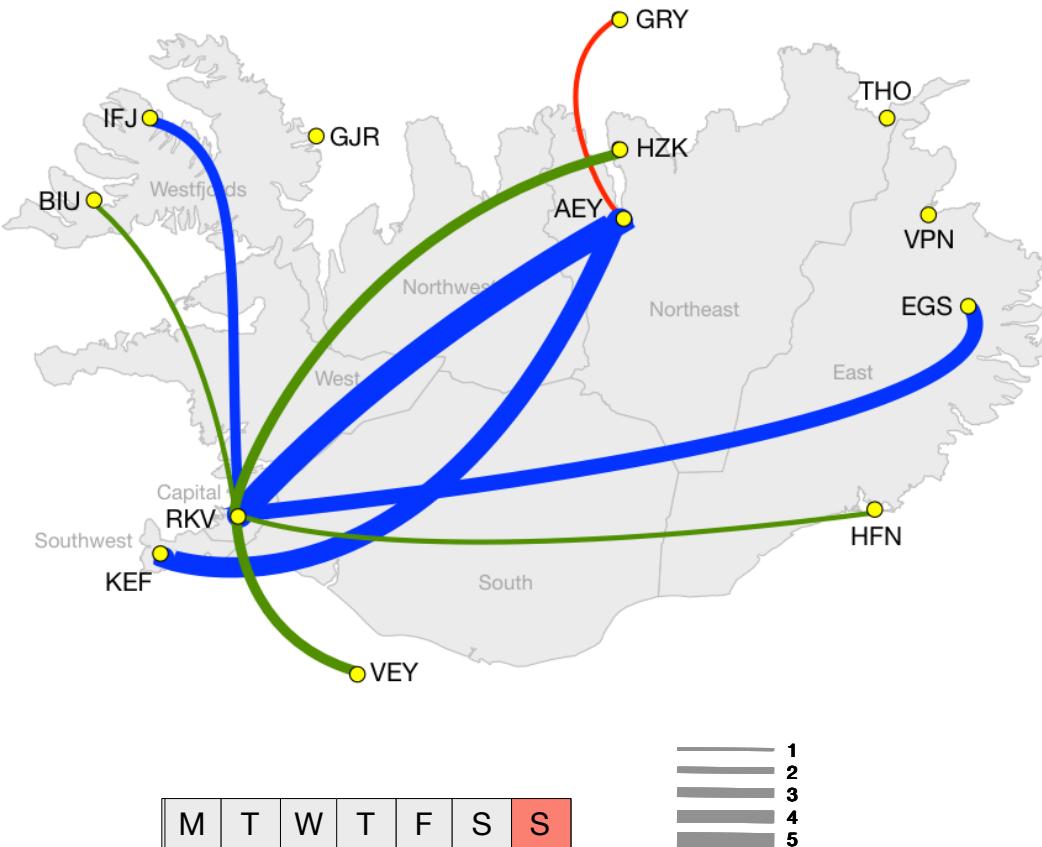


Temporal granularity

	AEY	BIU	EGS	GJR	GRY	HFN	HZK	IFJ	KEF	RKV	THO	VEJ	VPN			
	MT	WT	TF	SS	MT	WT	TF	SS	MT	WT	TF	SS	MT	WT	TF	SS
AEY								0 1 0 0 1 0 1								
BIU											1 1 1 1 1 0 1					
EGS											3 3 3 3 3 2 3					
GJR											0 1 0 0 1 0 0					
GRY	0 1 0 0 1 0 1										2 0 2 2 2 0 1					
HFN											2 2 2 2 2 0 2					
HZK											2 2 2 2 2 1 2					
IFJ																
KEF	2 0 1 4 2 0 4															
RKV	5 5 5 5 5 3 5	1 1 1 1 1 0 1	3 3 3 3 3 2 3	0 1 0 0 1 0 0				2 0 2 2 2 0 1	2 2 2 2 2 2 1 2							
THO	1 1 1 1 1 0 0												2 2 2 2 2 0 2	0 0 0 0 0 0 0		
VEJ	0 0 0 0 0 0 0											1 1 1 1 1 0 0				
VPN																



Flying a week in Iceland



	AEY		BIU		EGS		GJR		GRY		HFN		HZK		IFJ		KEF		RKV		THO		VEJ		VPN				
	M	T	W	T	F	S	M	T	W	T	F	S	M	T	W	T	F	S	M	T	W	F	S	M	T	W	F	S	
AEY																													
BIU																													
EGS																													
GJR																													
GRY	0	1	0	0	1	0	1																						
HFN																													
HZK																													
IFJ																													
KEF	2	0	1	4	2	0	4												5	5	5	5	3	5	0	0	0		
RKV	5	5	5	5	5	3	5	1	1	1	1	1	0	1	3	3	3	3	2	3	0	1	0	0	1	0	0	0	
THO	1	1	1	1	1	0	0								2	0	2	2	2	0	1	2	2	2	2	2	0	2	0
VEJ																													
VPN	0	0	0	0	0	0	0																						

RKV >	HFN					
	M	T	W	T	F	S
06:00						
07:00						
08:00	:55 (09:50)		:55 (09:50)	:55 (09:50)	:55 (09:50)	
09:00						
10:00						
11:00						
12:00						
13:00						
14:00						:30 (15:30)
15:00						
16:00						
17:00	:30 (18:25)		:30 (18:25)	:30 (18:25)	:30 (18:25)	
18:00						
19:00						
20:00						

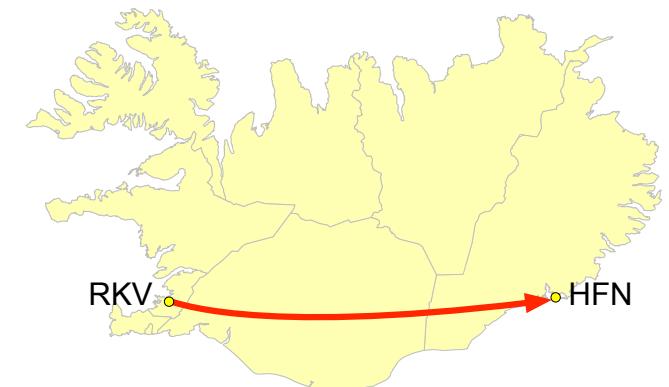
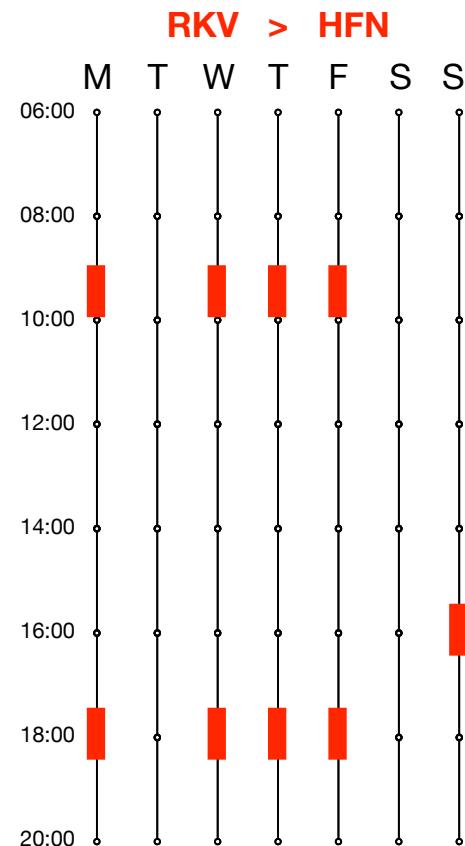
RKV >	HFN					
	M	T	W	T	F	S
06:00						
07:00						
08:00						
09:00						
10:00	:10 (11:10)			:10 (11:10)	:10 (11:10)	:10 (11:10)
11:00						
12:00						
13:00						
14:00						
15:00						
16:00						:00 (17:00)
17:00						
18:00	:45 (19:45)			:45 (19:45)	:45 (19:45)	:45 (19:45)
19:00						
20:00						



UNIVERSITY OF TWENTE.

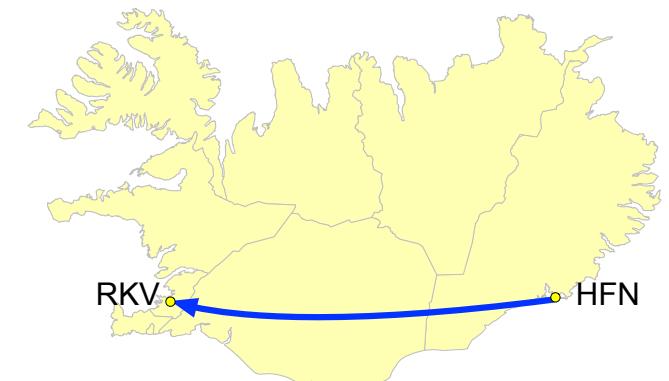
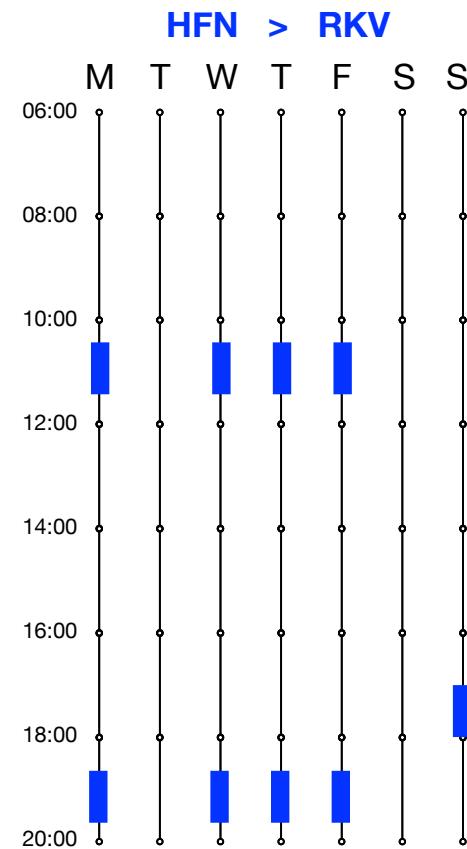
From Reykjavik to Höfn

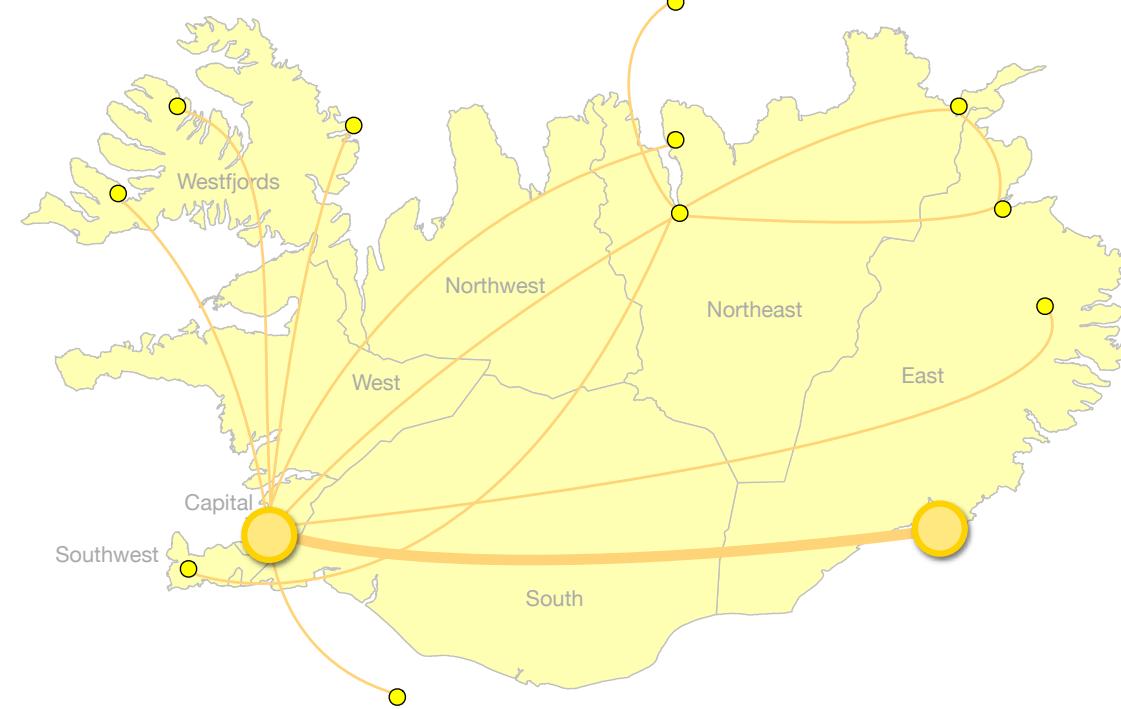
RKV >	HFN						
	M	T	W	T	F	S	S
06:00							
07:00							
08:00	:55 (09:50)		:55 (09:50)	:55 (09:50)	:55 (09:50)		
09:00							
10:00							
11:00							
12:00							
13:00							
14:00						:30 (15:30)	
15:00							
16:00							
17:00	:30 (18:25)		:30 (18:25)	:30 (18:25)	:30 (18:25)		
18:00							
19:00							
20:00							



From Höfn to Reykjavík

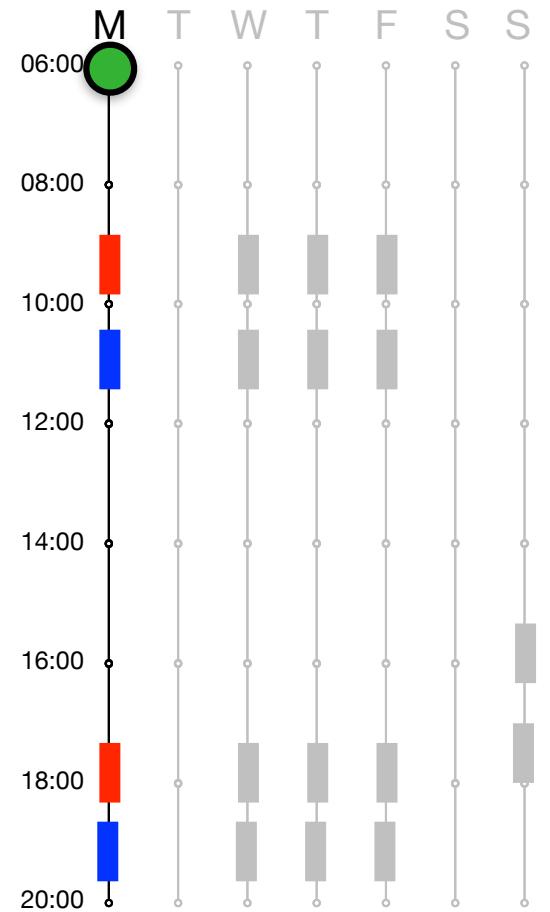
HFN >	RKV					
M	T	W	T	F	S	S
06:00						
07:00						
08:00						
09:00						
10:00	:10 (11:10)		:10 (11:10)	:10 (11:10)	:10 (11:10)	
11:00						
12:00						
13:00						
14:00						
15:00						
16:00					:00 (17:00)	
17:00						
18:00	:45 (19:45)		:45 (19:45)	:45 (19:45)	:45 (19:45)	
19:00						
20:00						





UNIVERSITY OF TWENTE.

RKV > HFN HFN > RKV





Let's make the world a better place with maps



UNIVERSITY OF TWENTE.

Discussion and conclusion

Needs

- go beyond traditional visualizations
- include the temporal dimension
- deal with individual tracks as well as aggregated
- map regular and irregular movement cycles
- map virtual and physical travel
- deal with huge diverse and fuzzy data



Solutions

- variation on traditional representations
- integrate spatial and non-spatial
- interactivity
- alternative approaches
- strategies (overview > detail)
- ...
- ...

Future of cartography

