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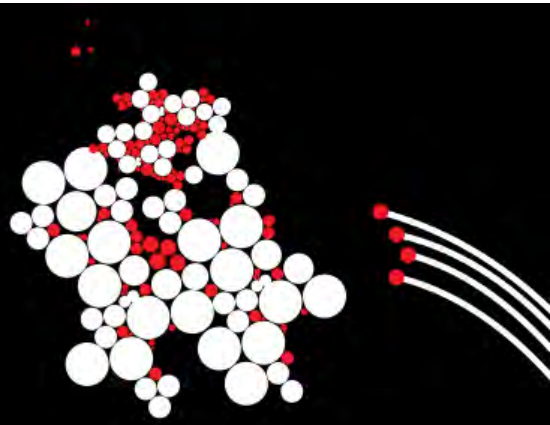
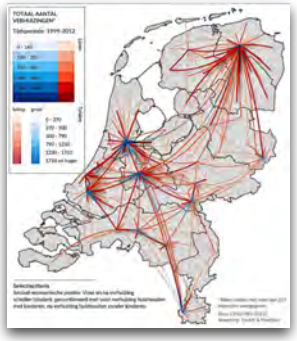
Faculty of Geoinformation Science and Earth Observation



Mapping movement

Menno-Jan Kraak

Mapping movement



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

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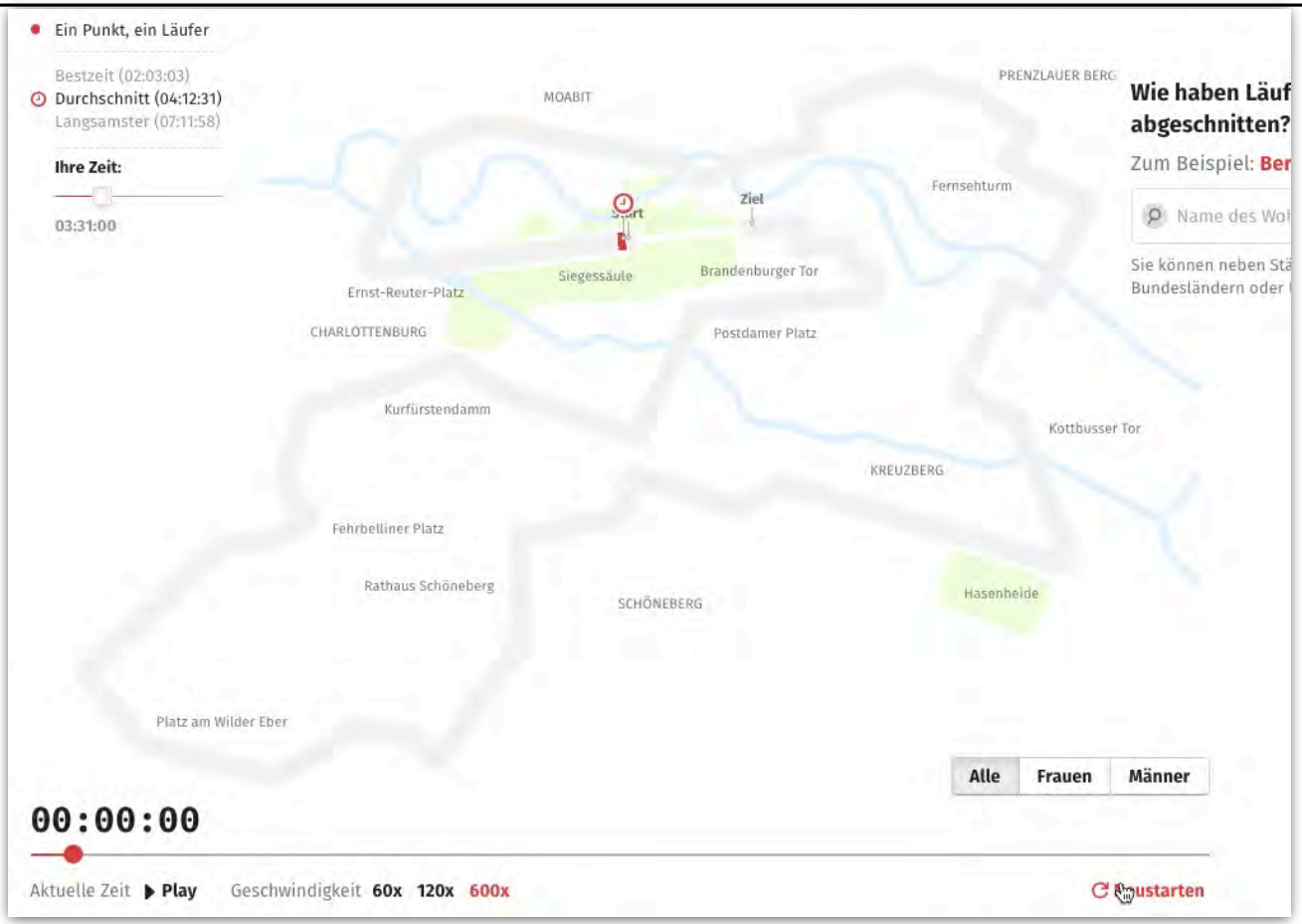
Movement



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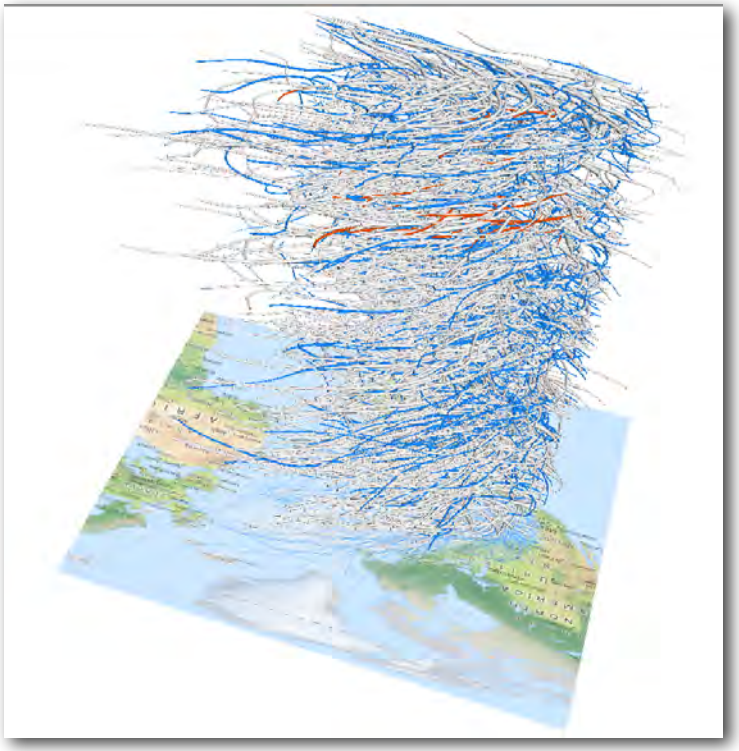
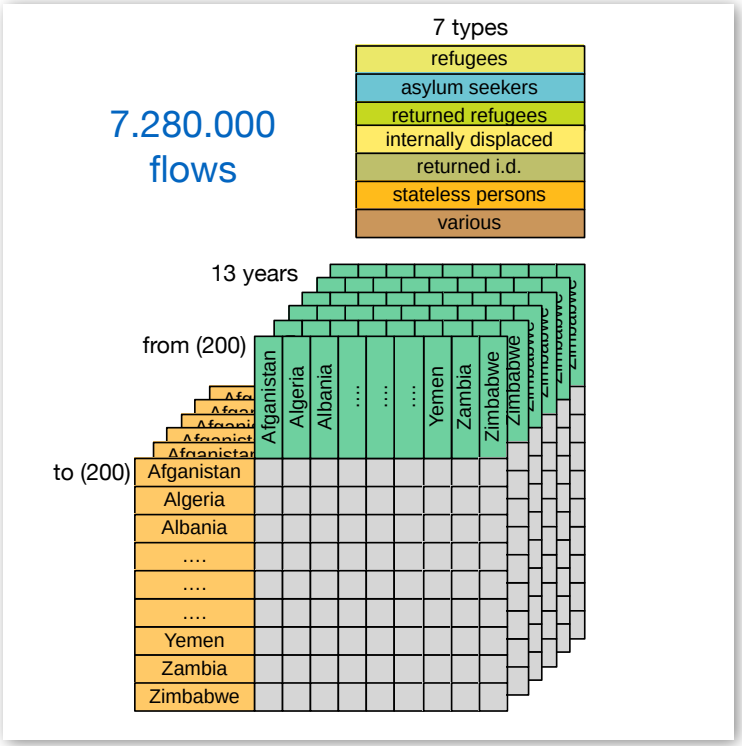
Movement bascis



continuous

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



discrete

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

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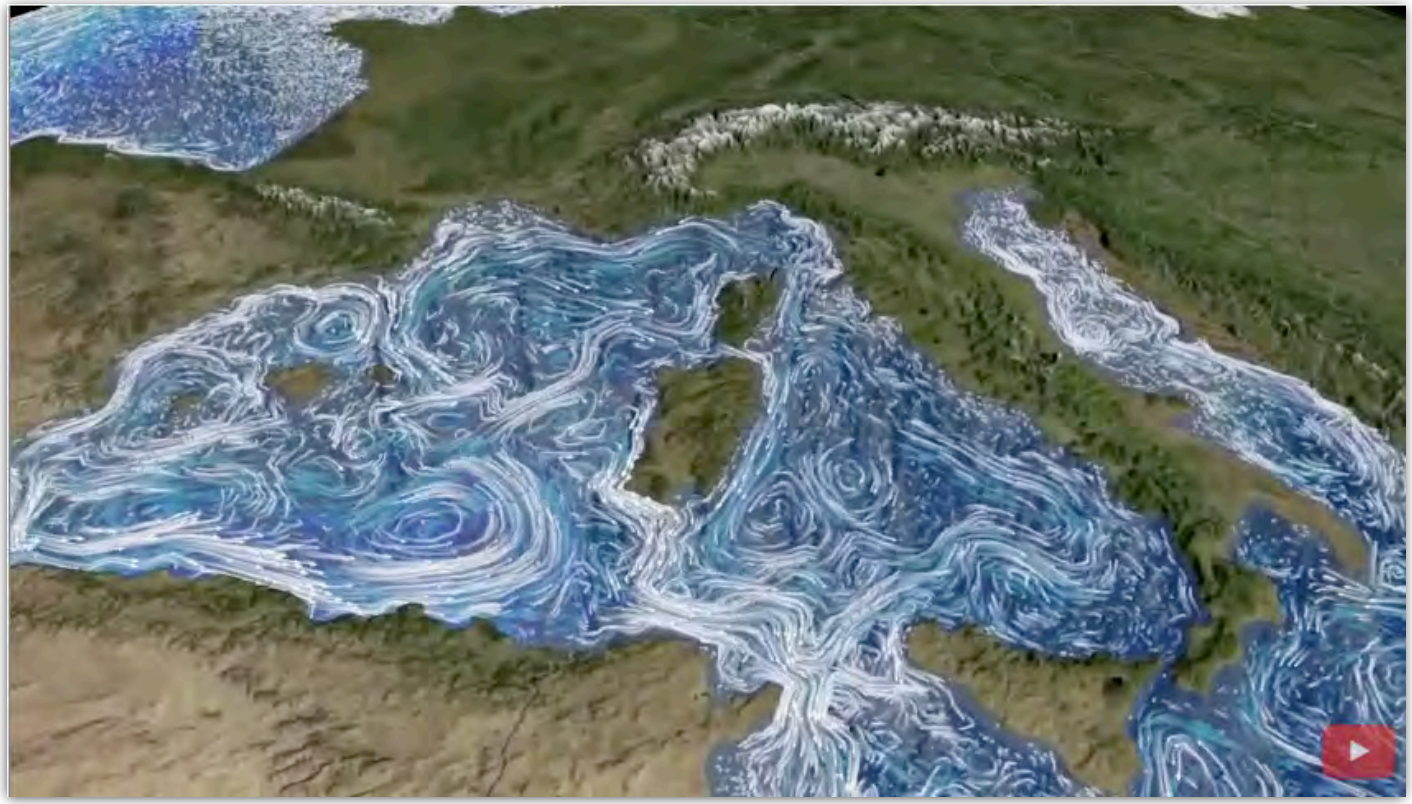
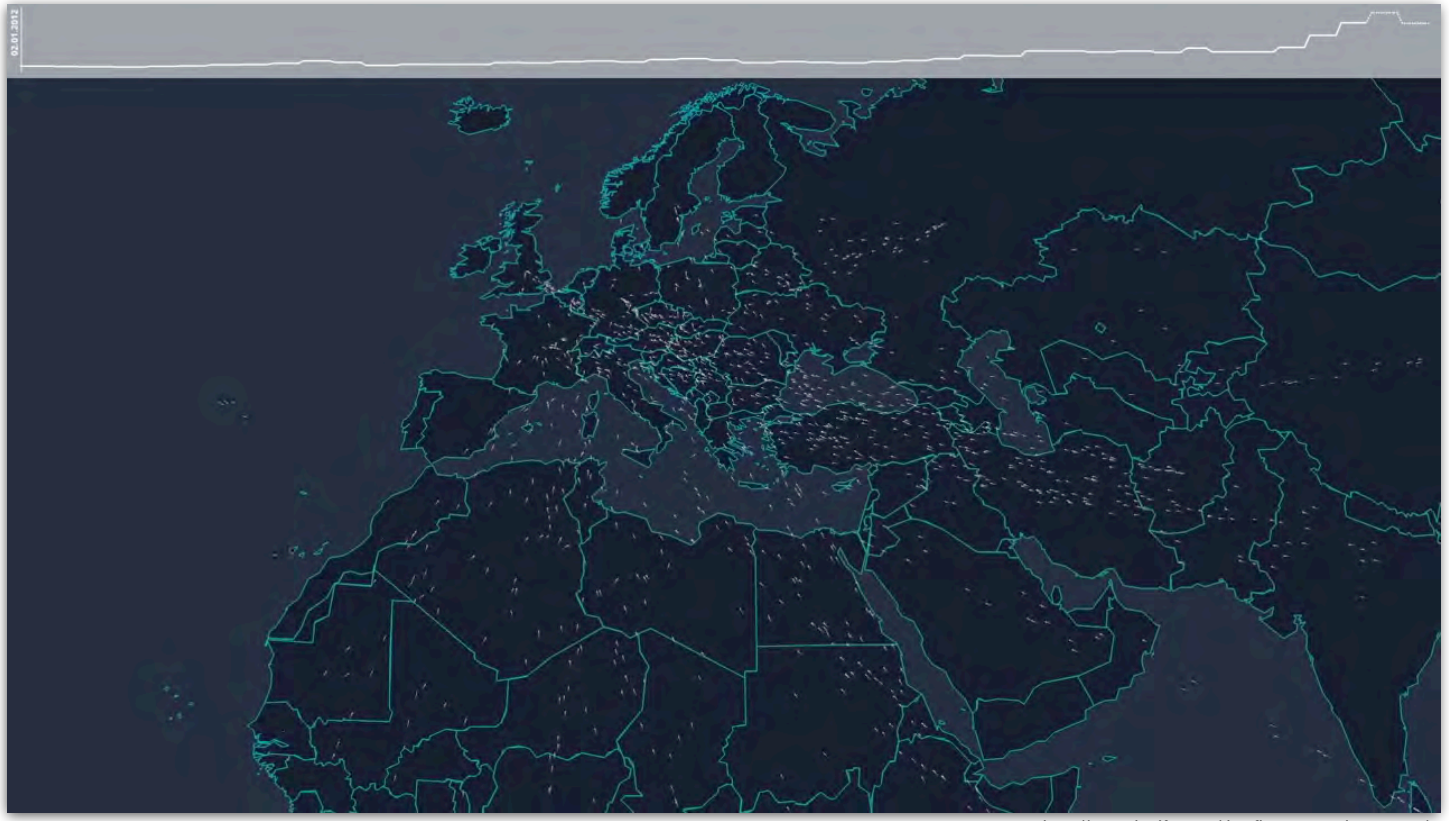
Continuous flows: sea currents



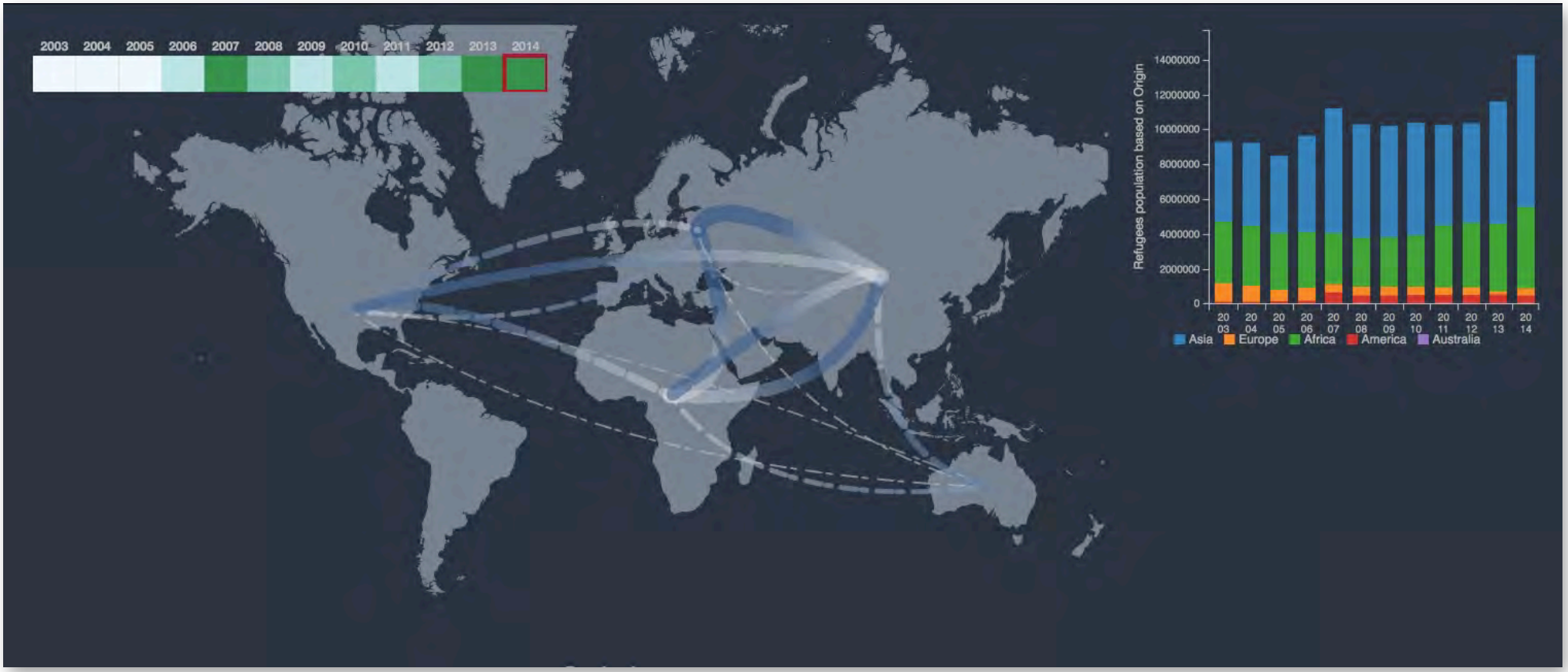
https://svs.gsfc.nasa.gov/3820

Flows (refugees)

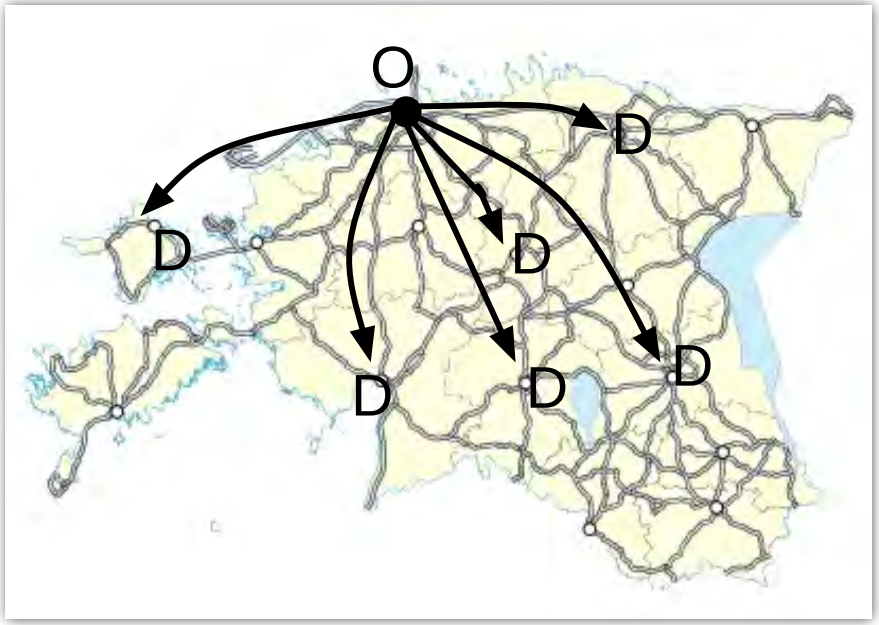


http://www.lucify.com/the-flow-towards-europe/

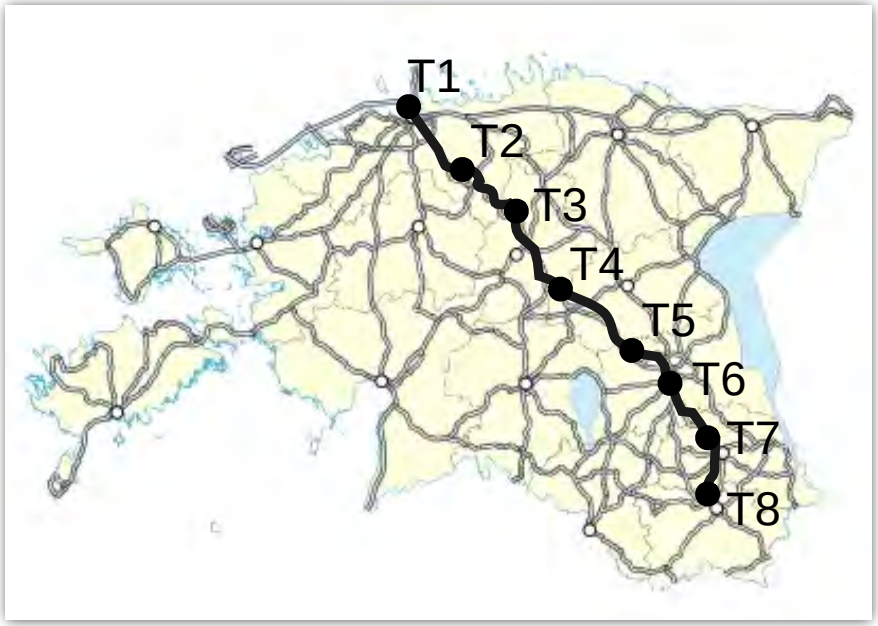
Flows (refugees)



Discrete Movement



Origin - Destination



Trajectories

Points of attention

Big Data: Need for mapping tools that are be 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

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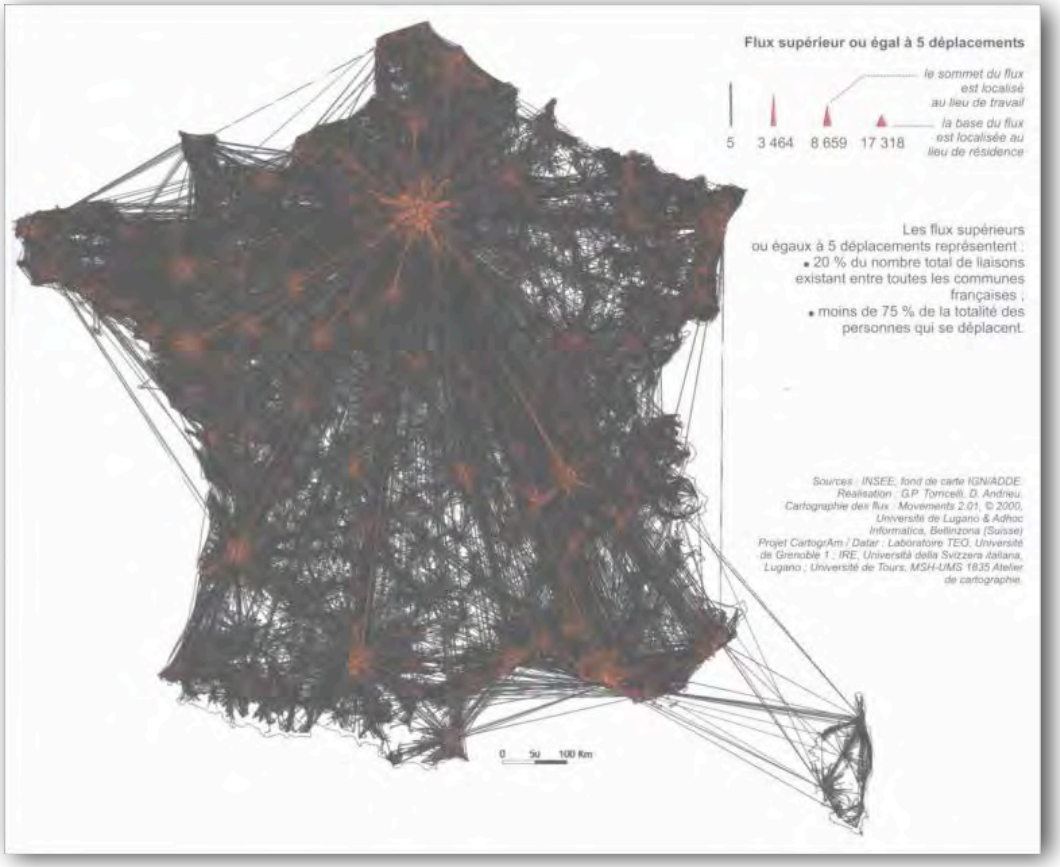
Big data

- Volume
- Variety
- Variability
- Velocity
- Veracity



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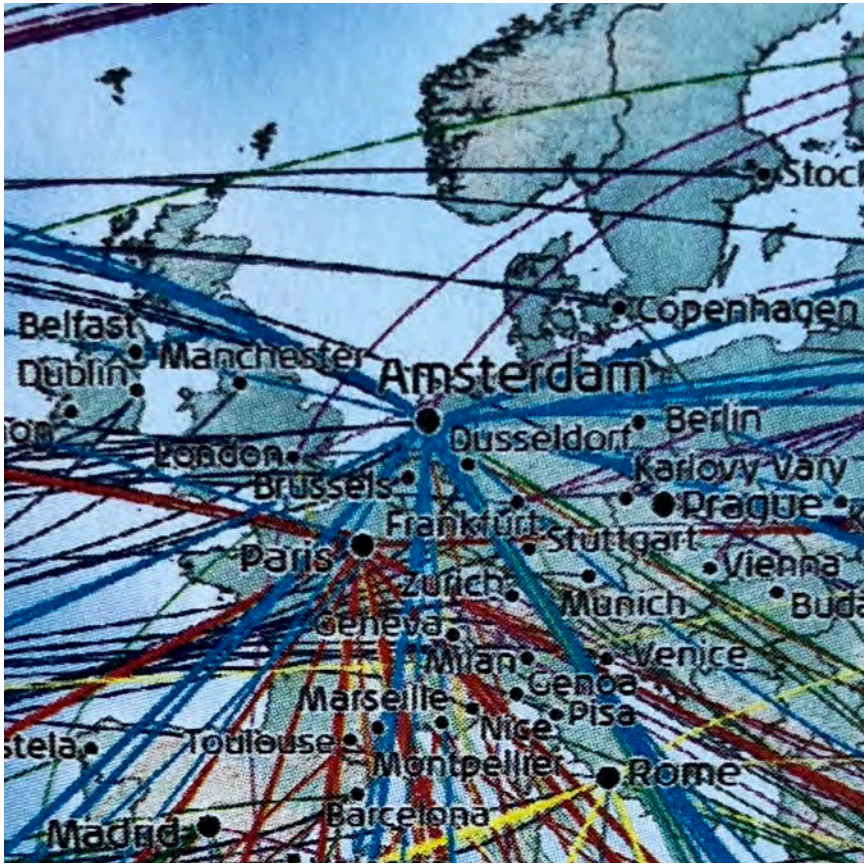
KLM's Holland Herald



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Movement cycles (example migration)

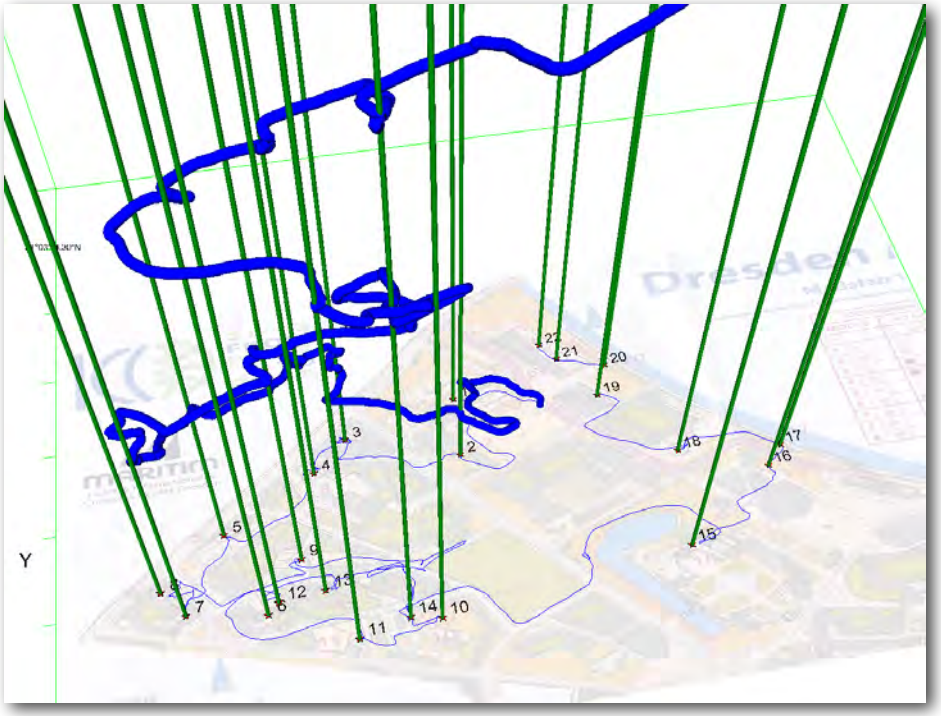
Permanent migration

- permanent change in residence
- simple origin-destination movement

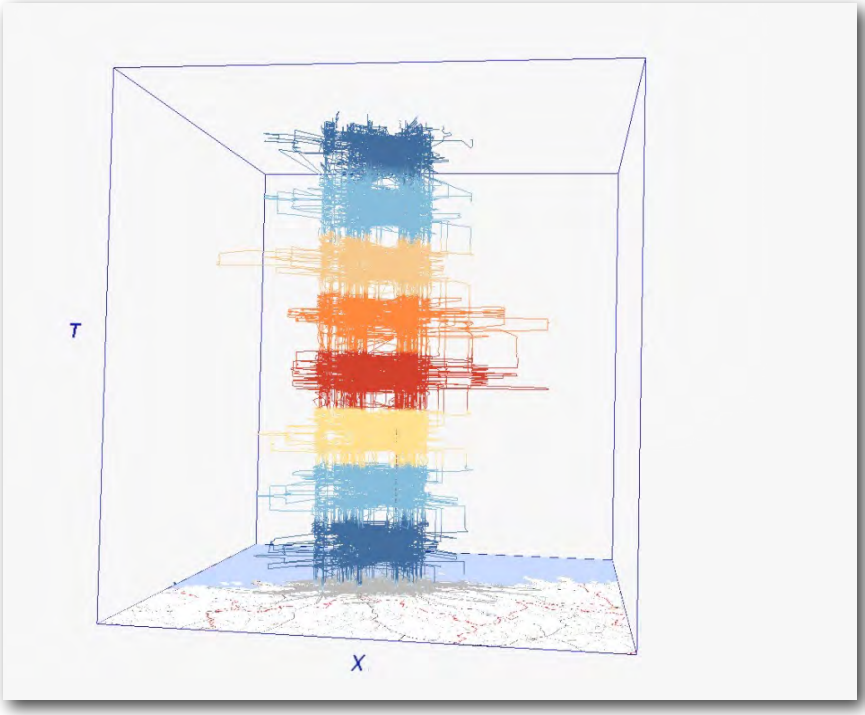
Temporary migration

- 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)

Time



(Orienteering; Kraak et al, 2014)



(Tallinn commuters; Kveladze, 2015)

space time cube: paths and stations

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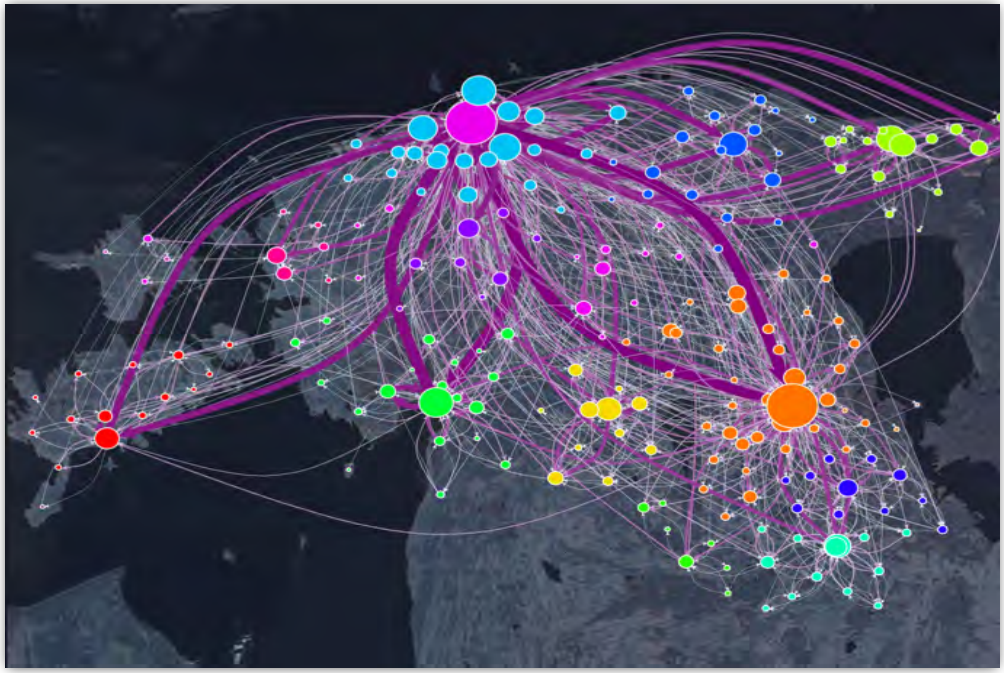
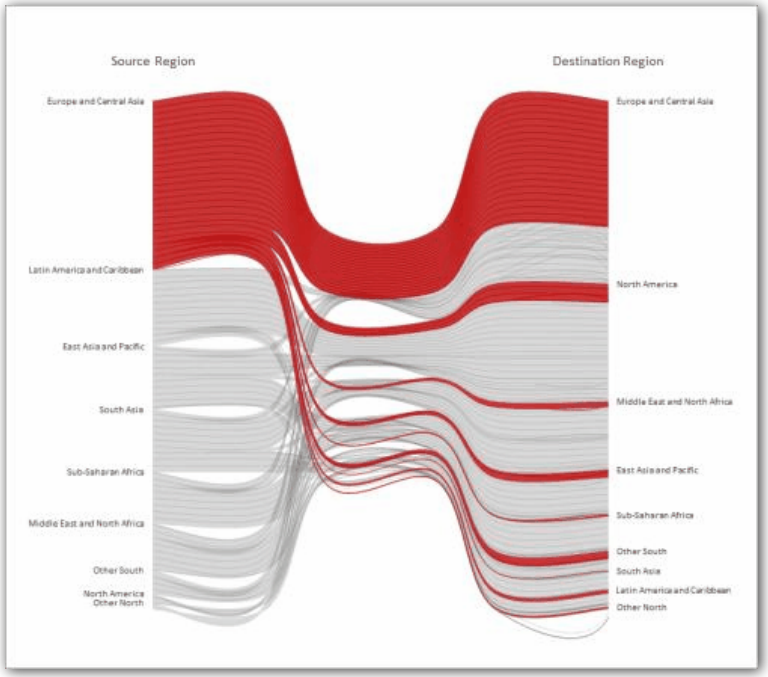
Flows



(Cover Mobile Tartu 2016, Anto Aasa)

flow maps



flow charts

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

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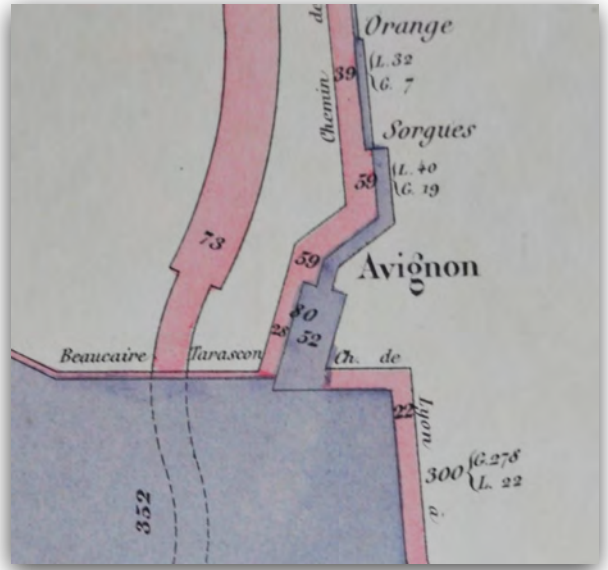
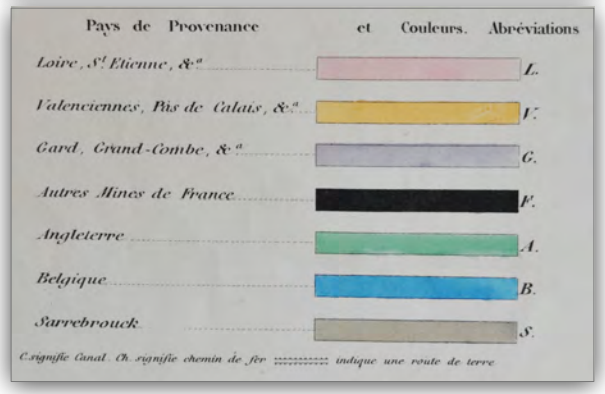
Characteristics

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





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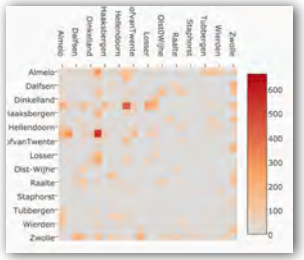
Towards a solution

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

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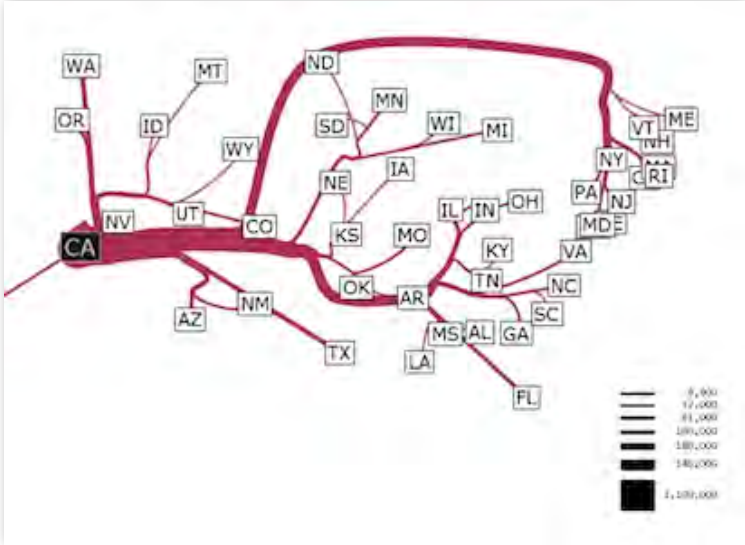
Geocomputation

(Migration from California; Tobler 1987)



(Edge bundling; Phan et al, 2005)

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

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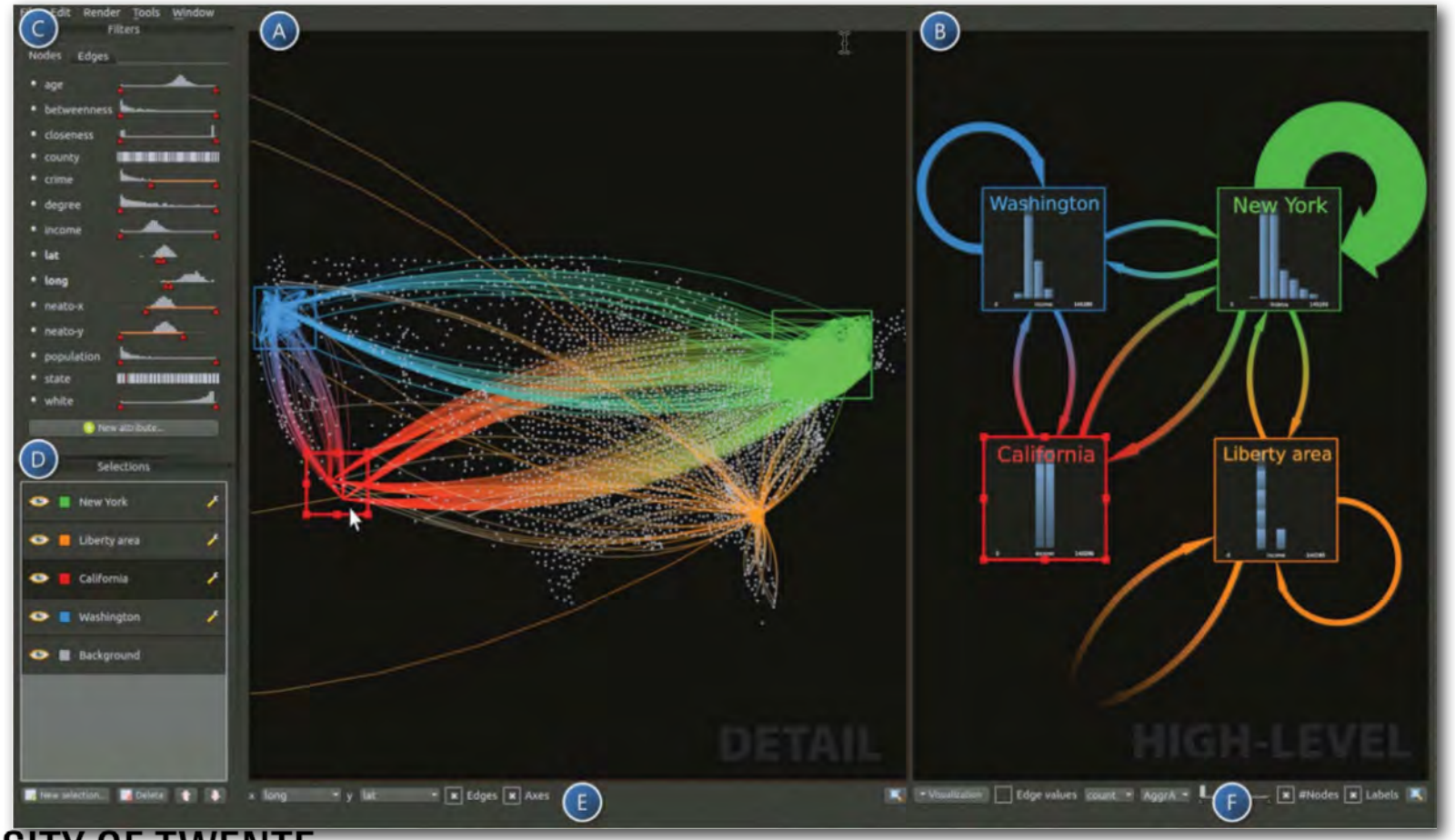
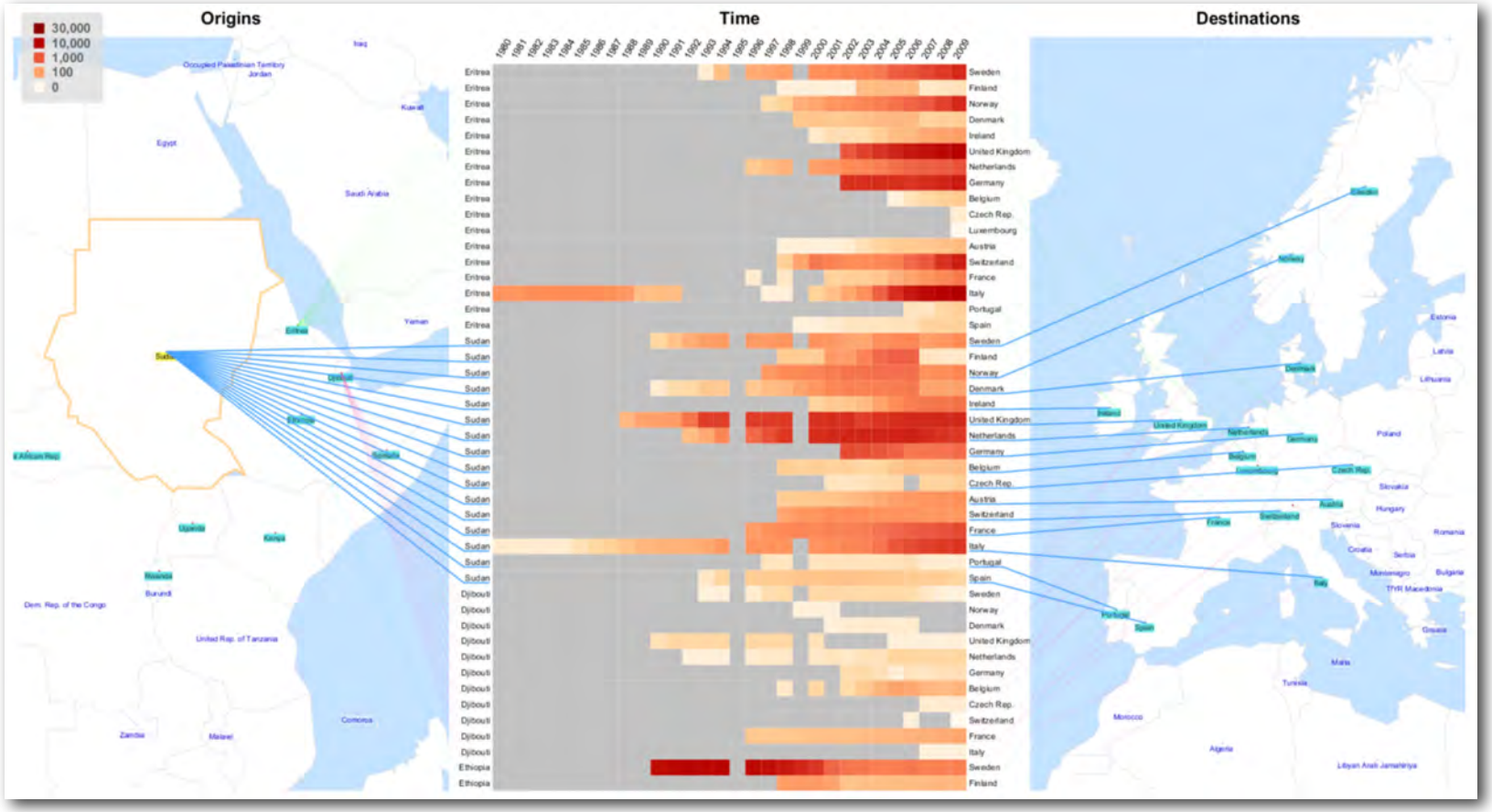
Interaction: detail and overview



(DOSA, a multivariate network explorer ; Elzen et al, 2014)

Interaction: origin / time / destination



(Flowstreets; Boyadin, 2011)

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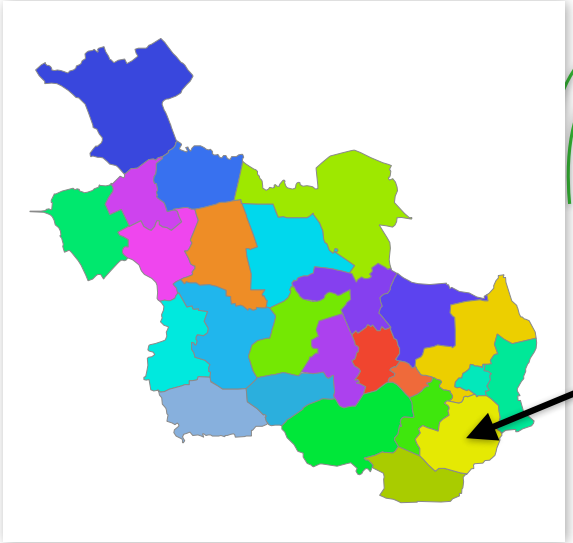
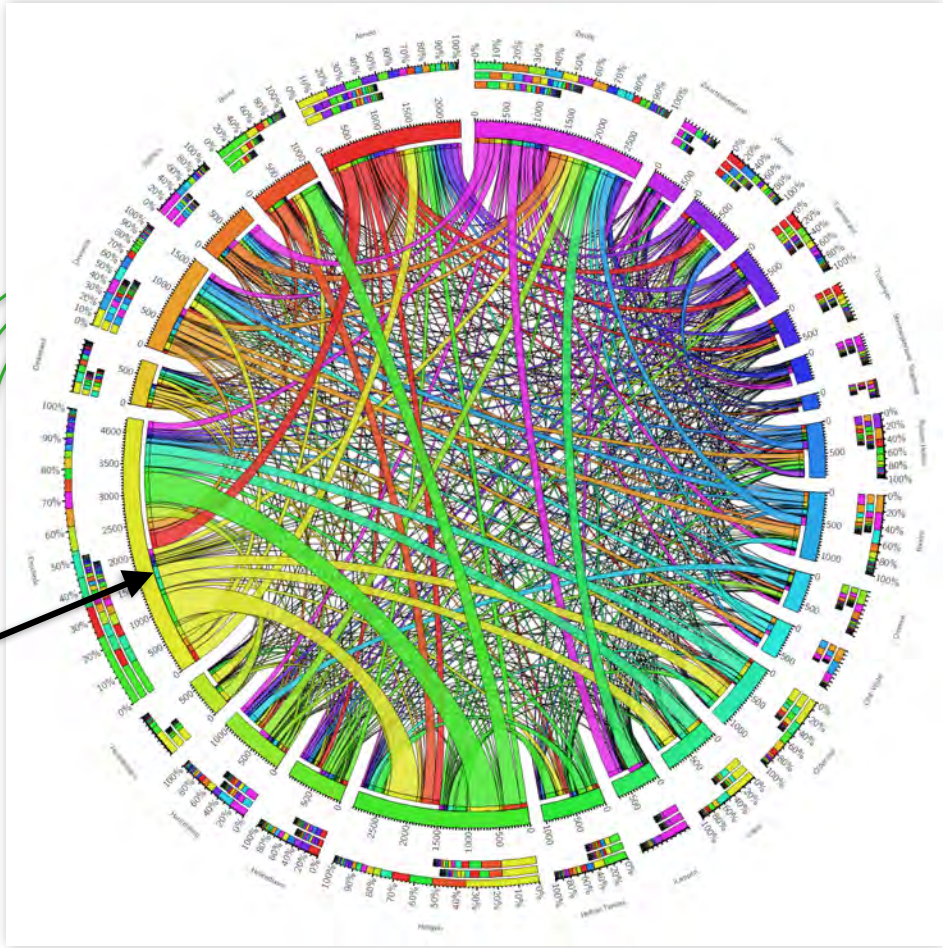
Alternative approaches: chord diagram





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

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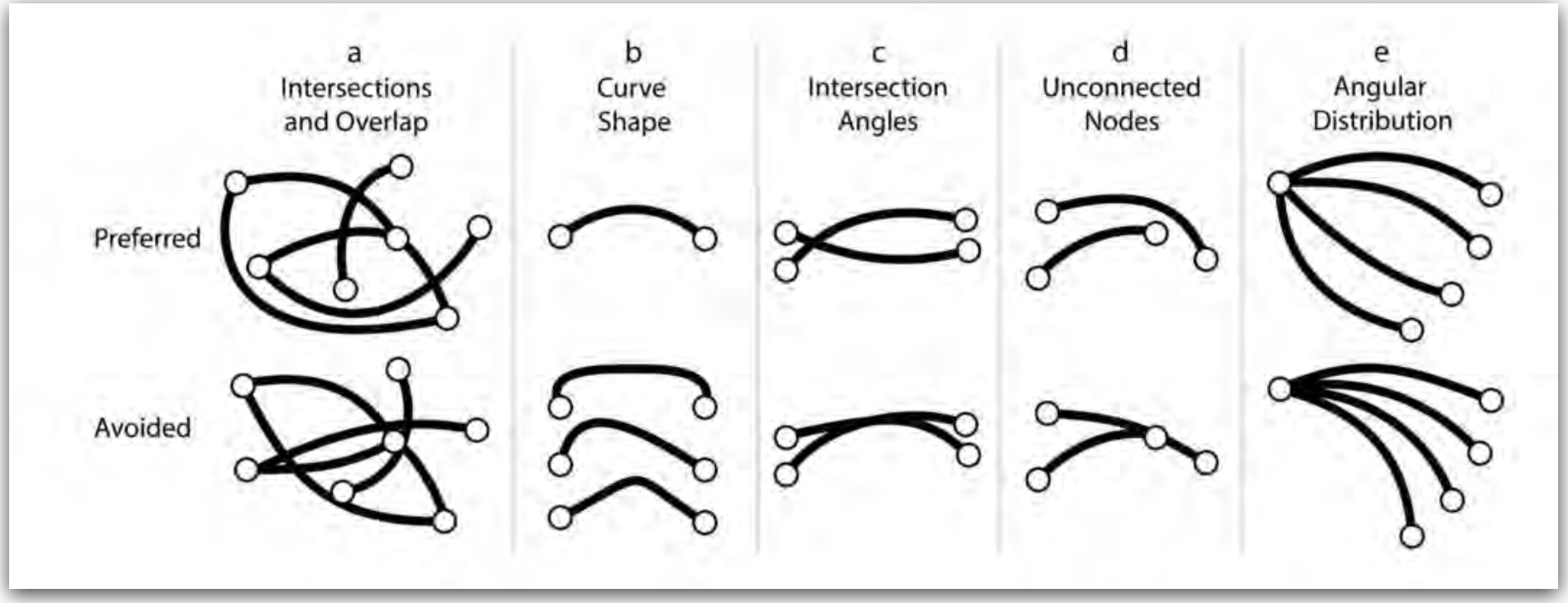
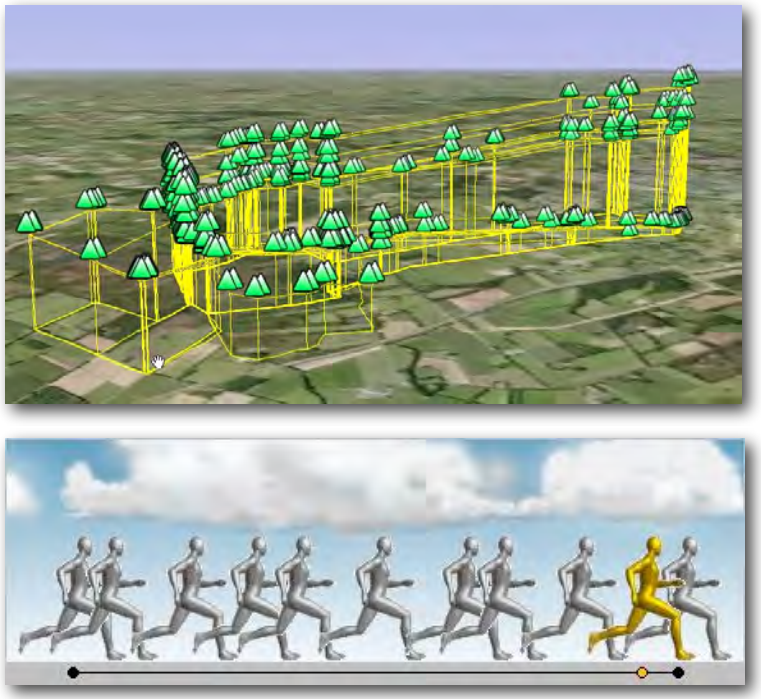
Design principles



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

An example: running

- Alternative insight in performance



An example: running

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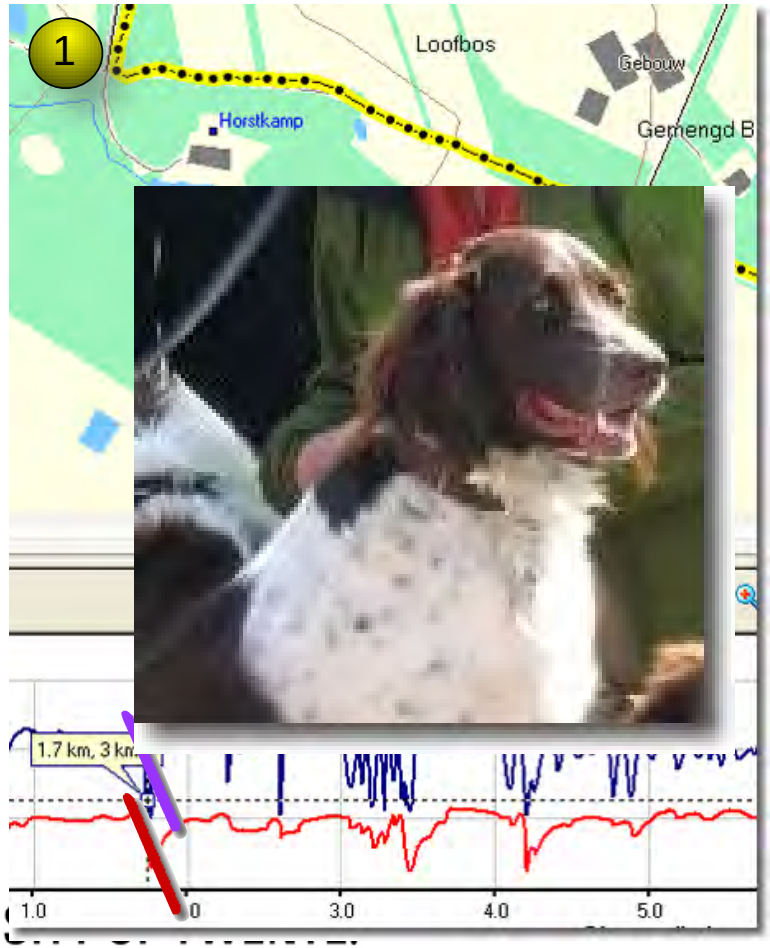
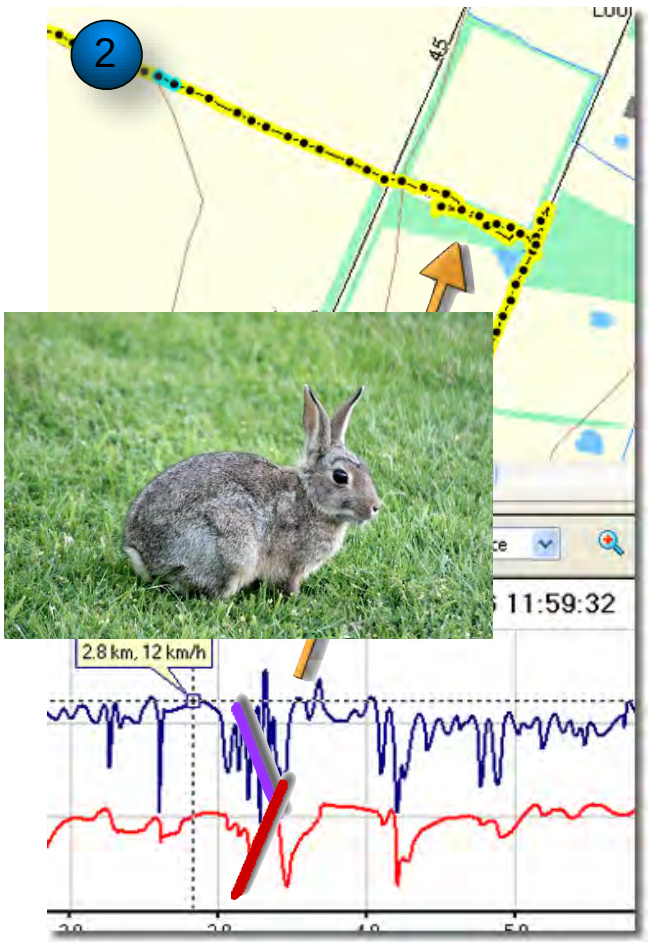
An example: running





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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

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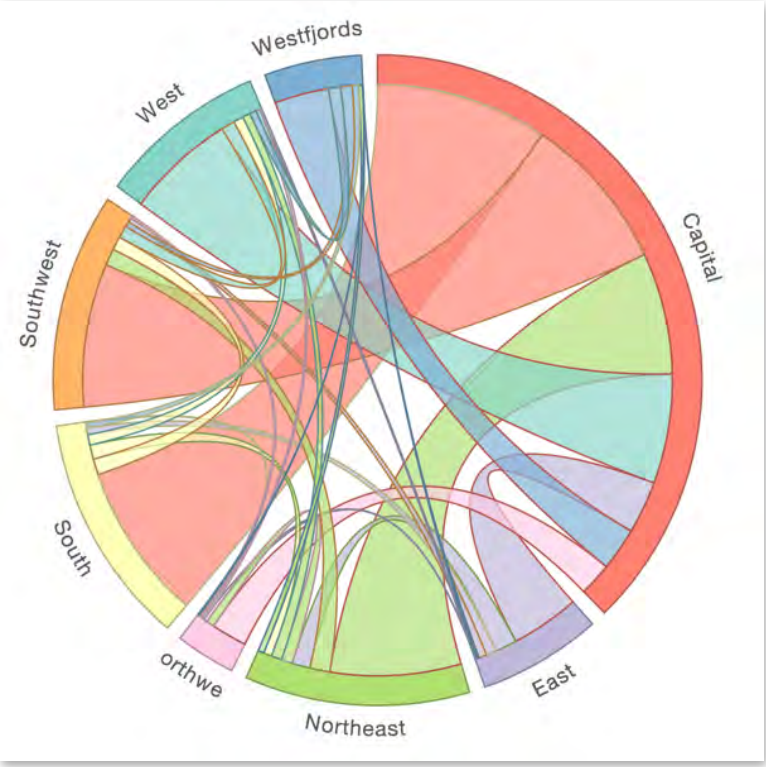
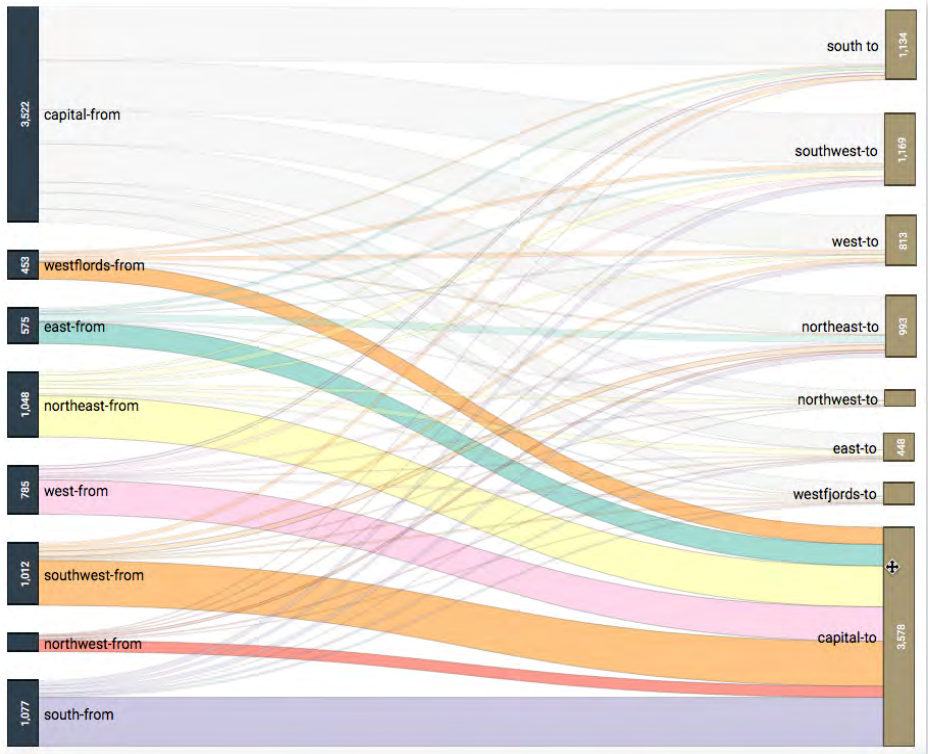
Chord diagram and Sankey diagram





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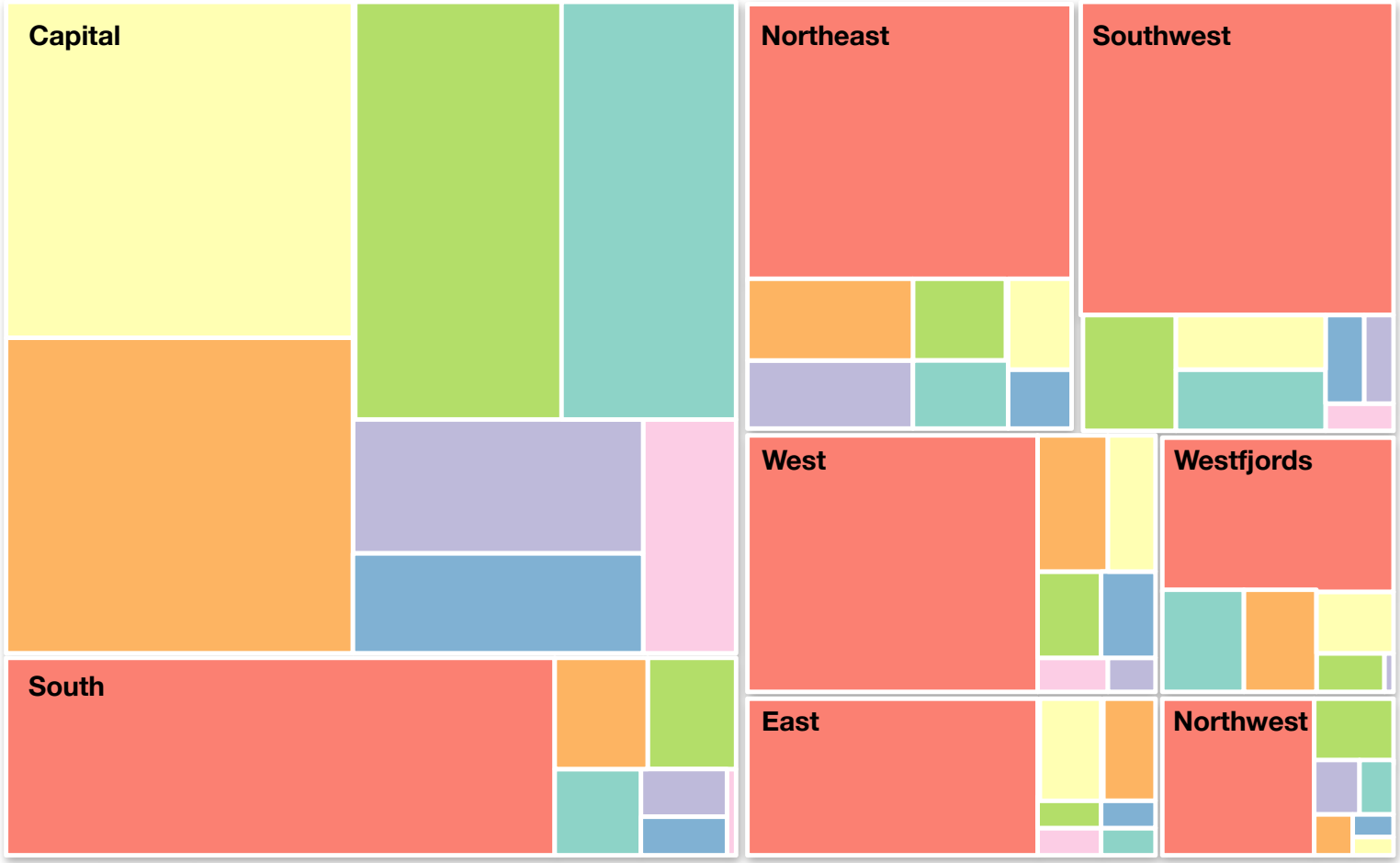
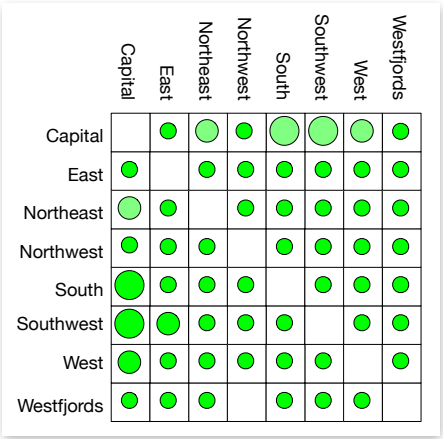
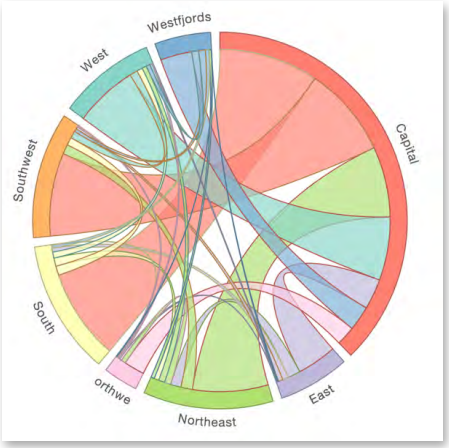
Treemap

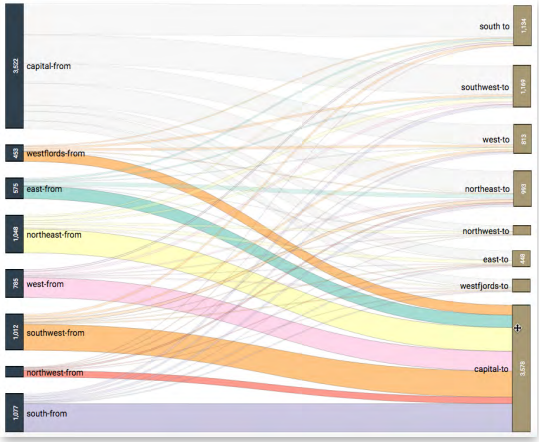

Capital
Northeast
Southwest
West
Westfjords
South
East
Northwest

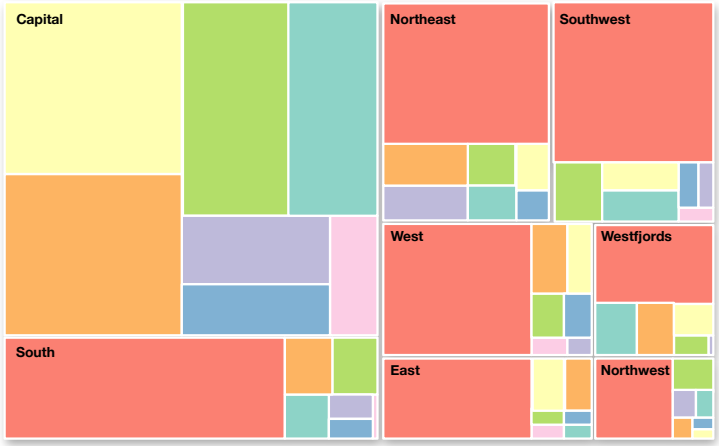
Lost geography

- Alphabetical order?









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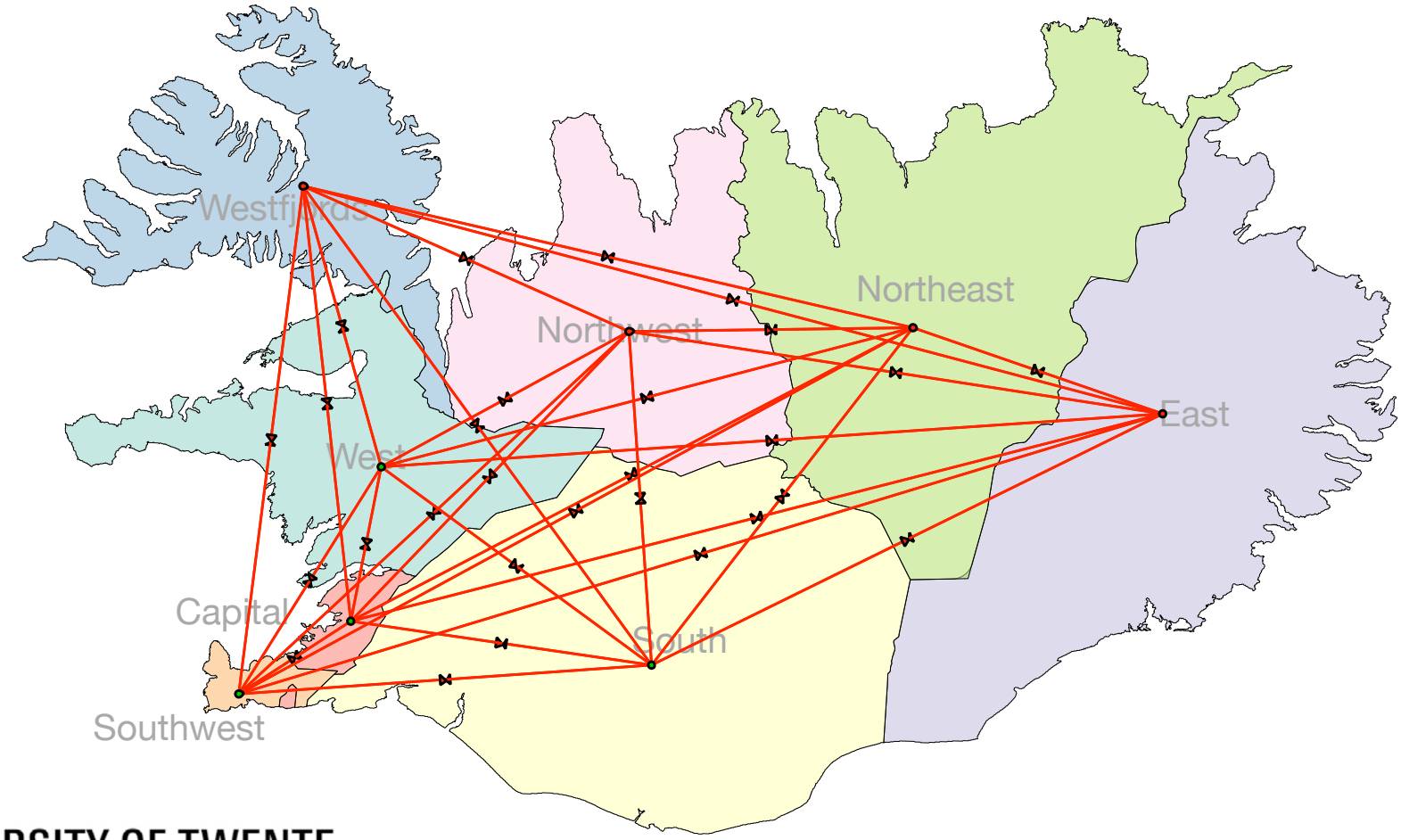
O-D network and the geography



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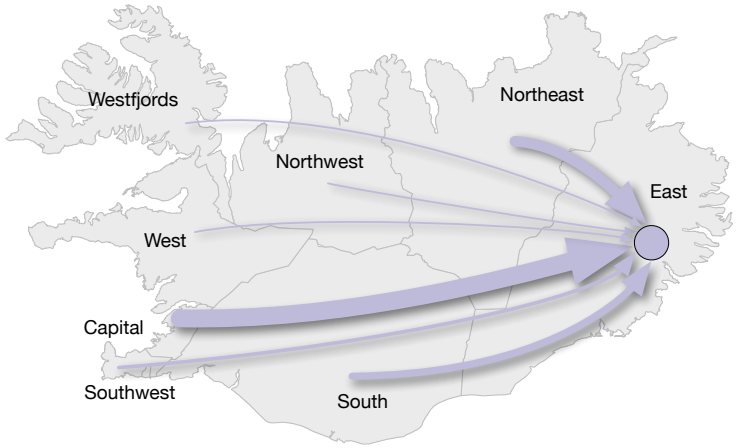
From one origin to all destination

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

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
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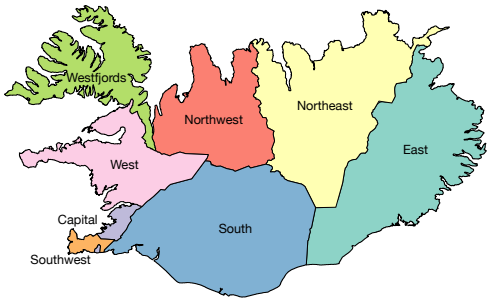
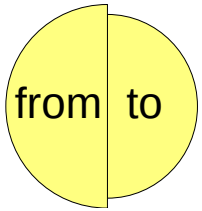
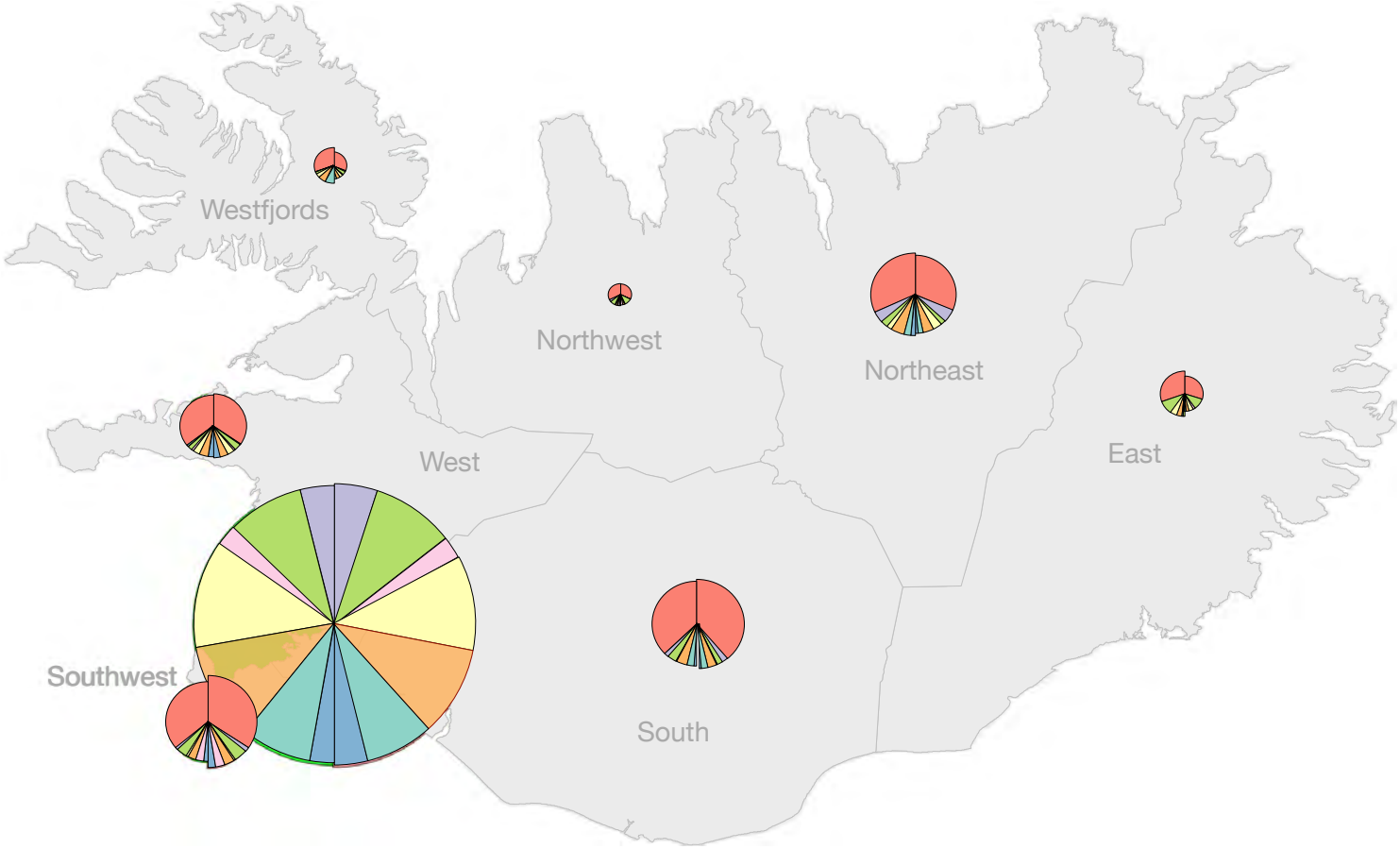
Southwest	733	22	85	13	69	0	63	27
West	560	12	40	19	51	69	0	34
Westfjords	278	2	20	0	32	59	62	0

Migration from (left) and to (right)







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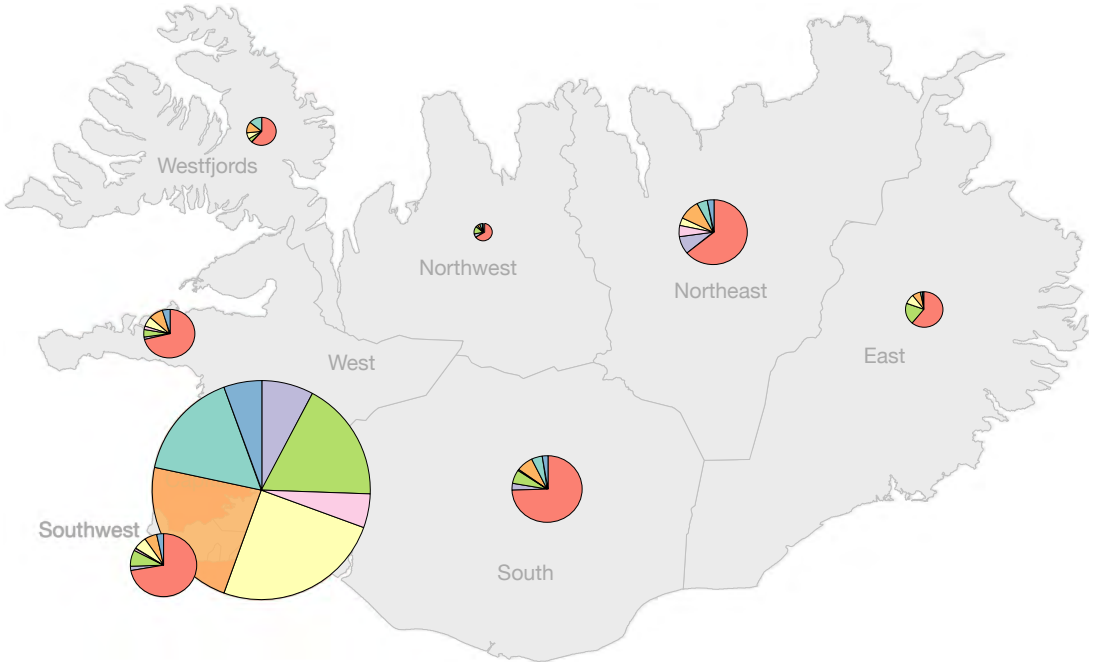
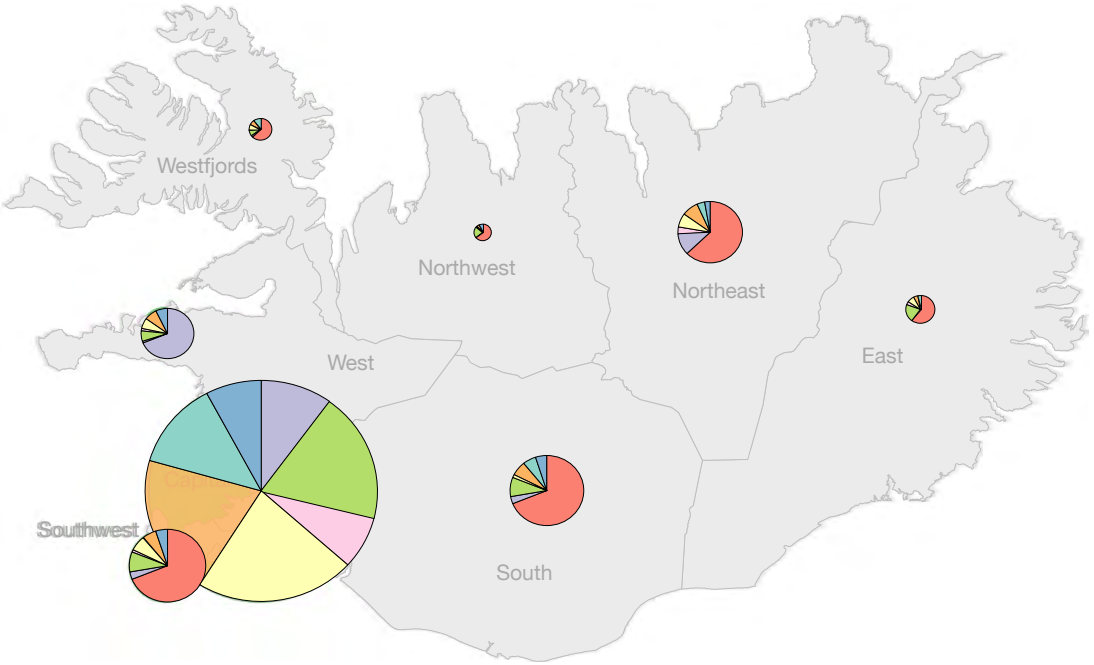
Migration from (left) and to (right)





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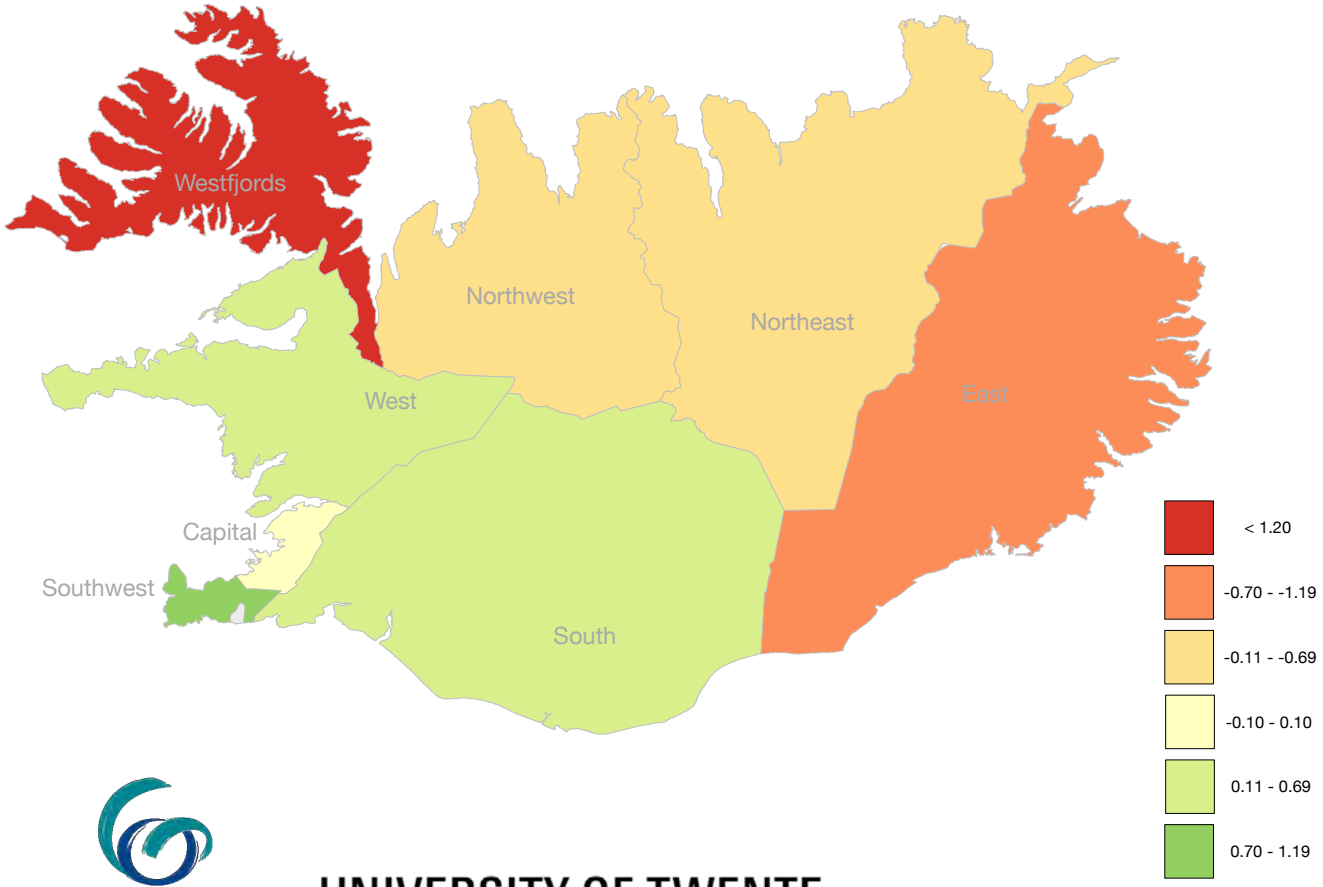
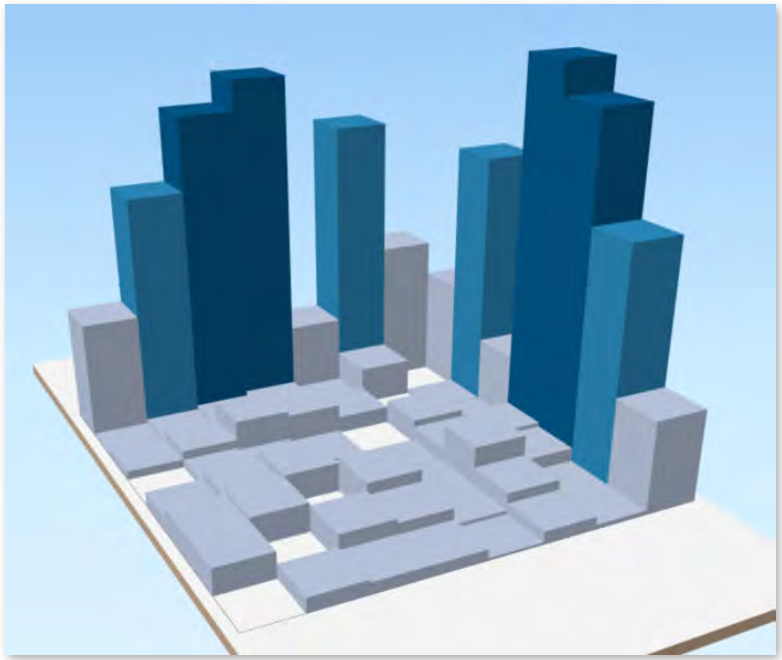
Relative and absolute migration





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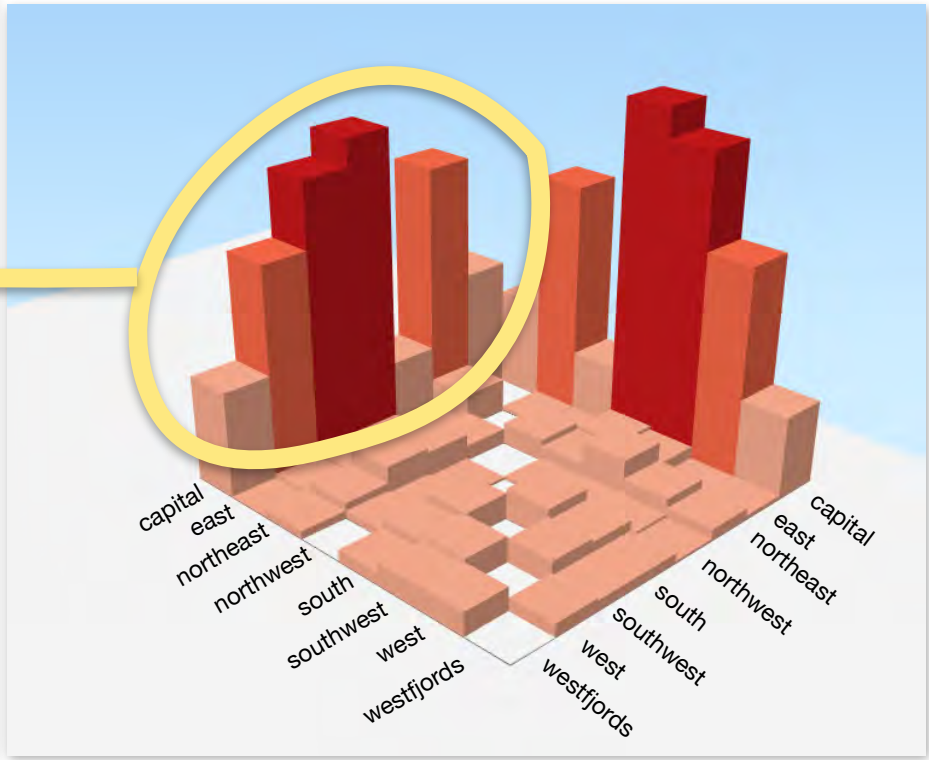
3D O-D matrix

All is relative



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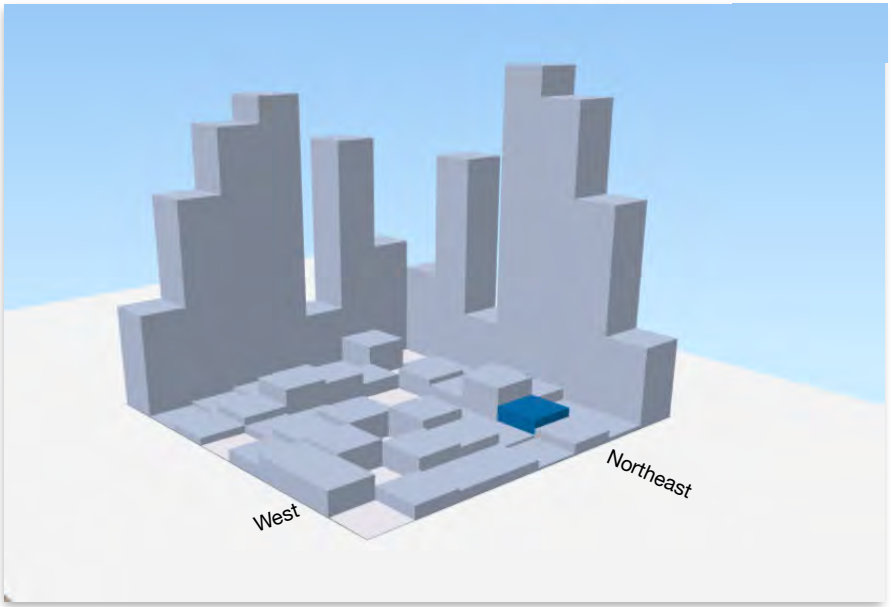
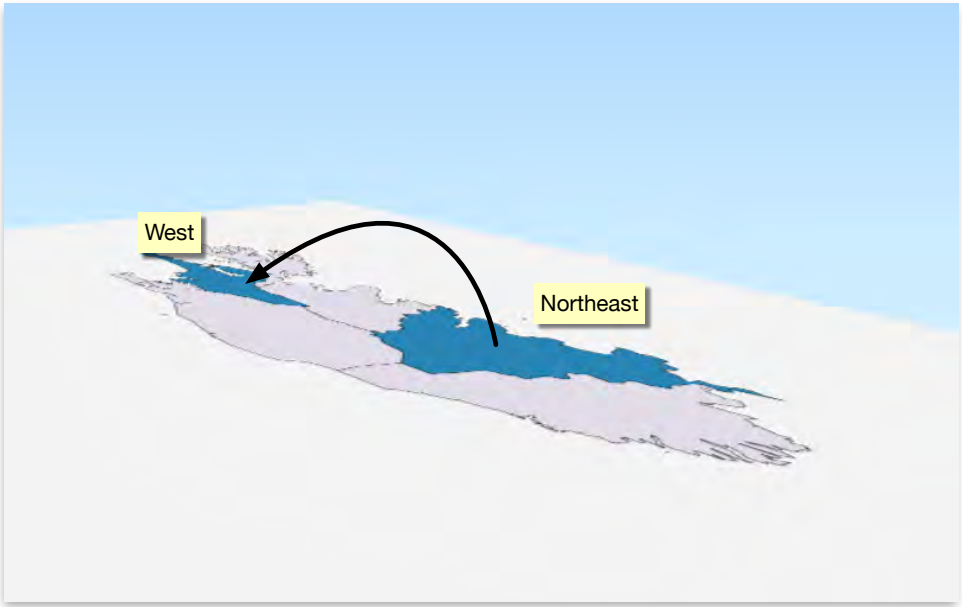
Link OD matrix and map





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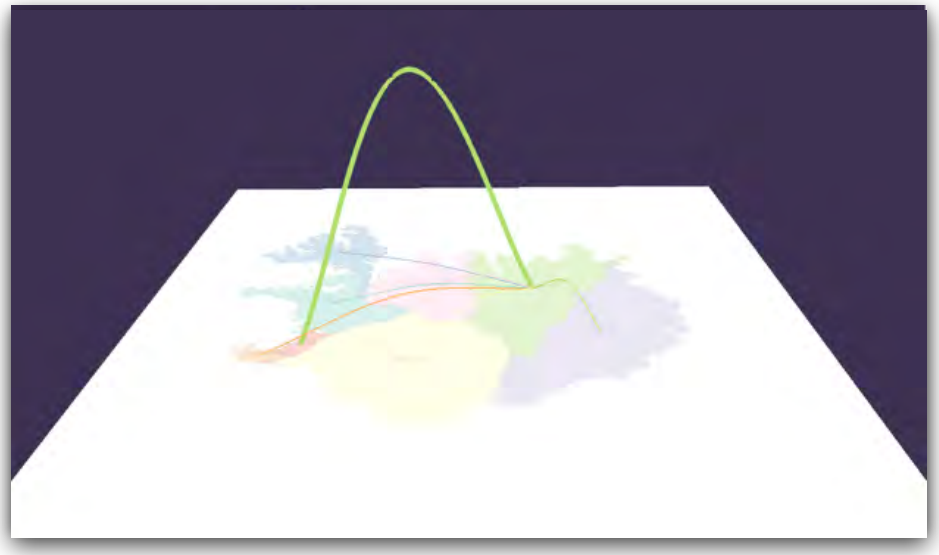
(3D) map



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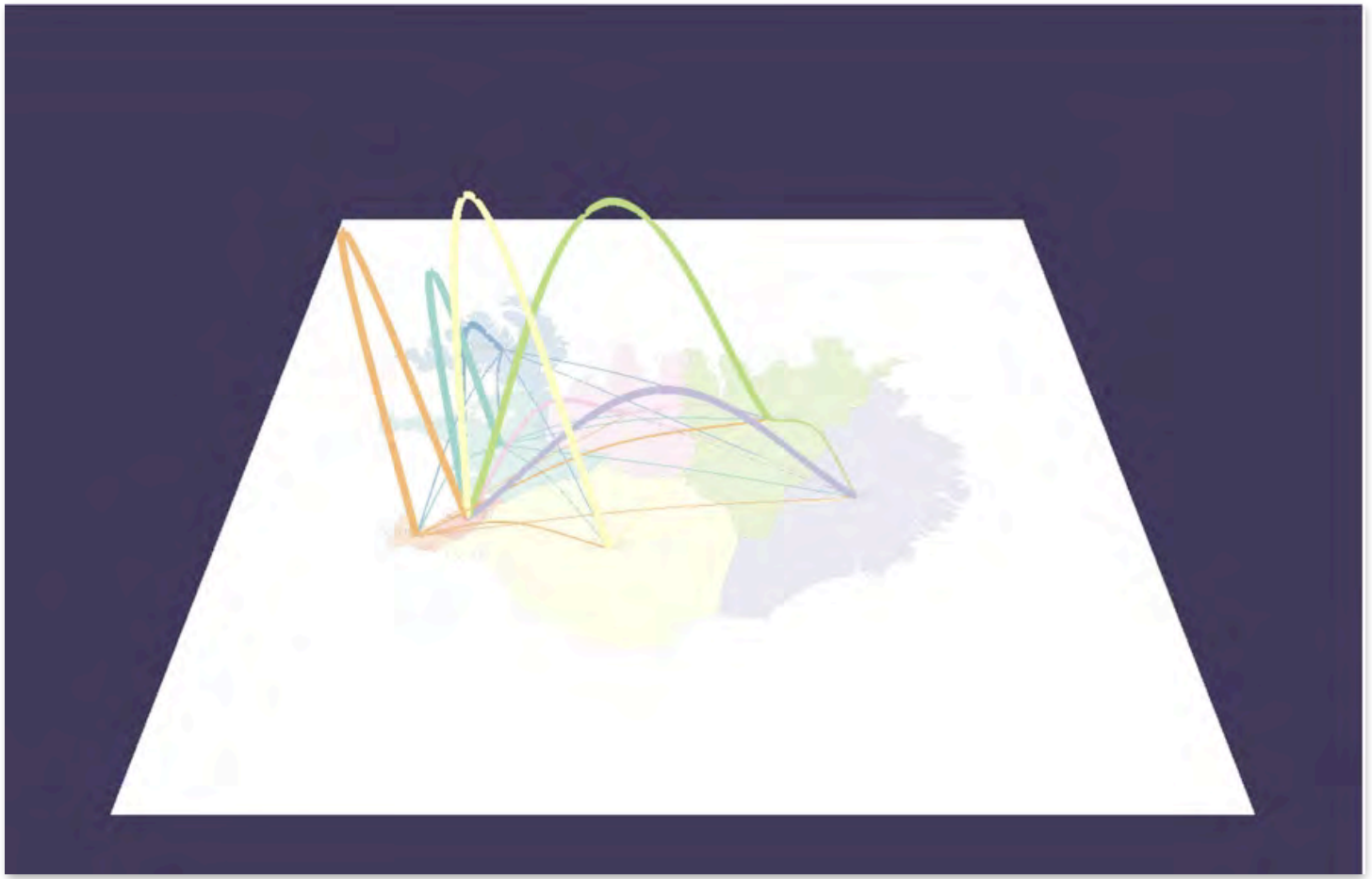
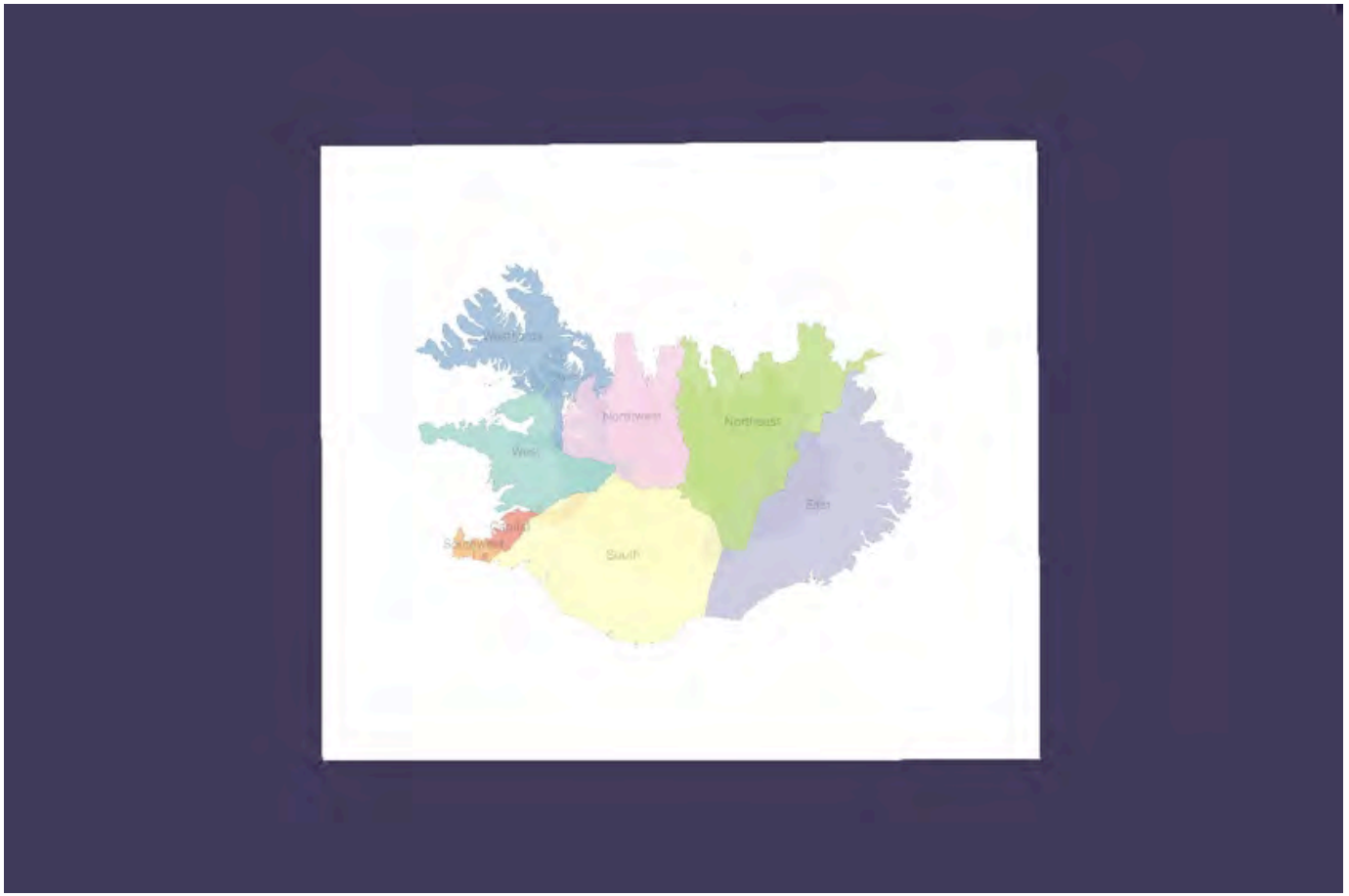
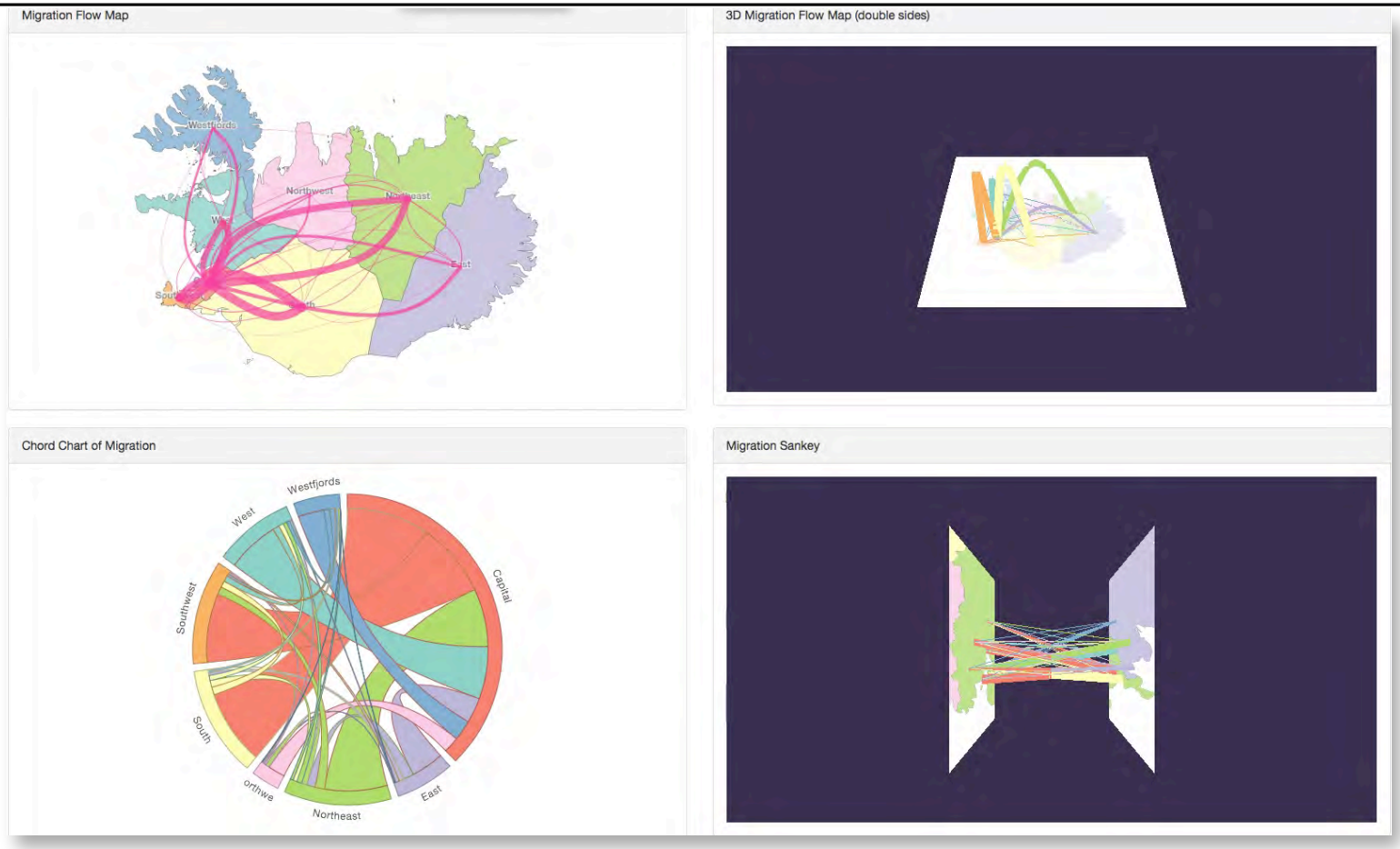
3D map



3D Sankey



Dashboard approach



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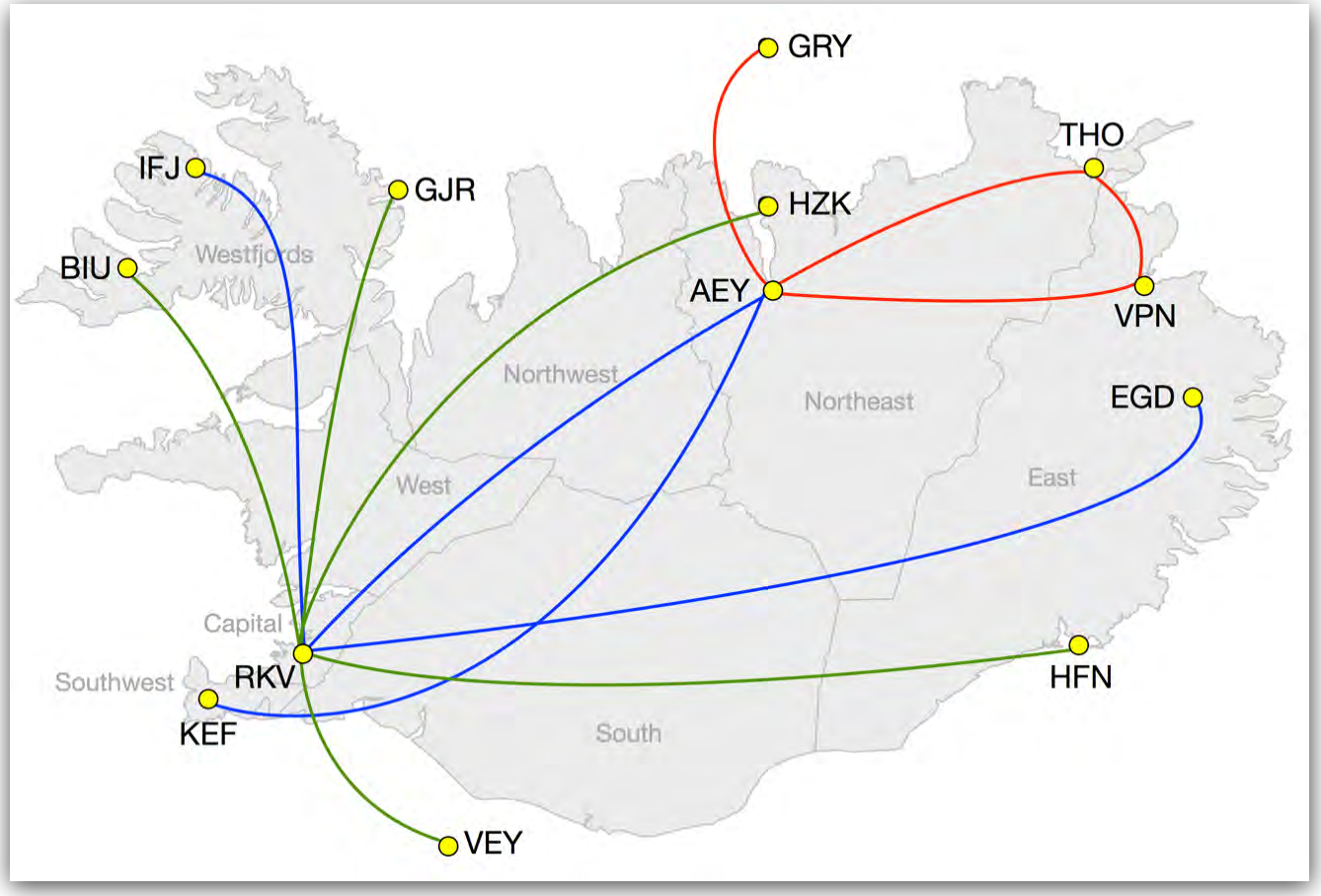
Temporal granularity and A-symmetric O-D matrix



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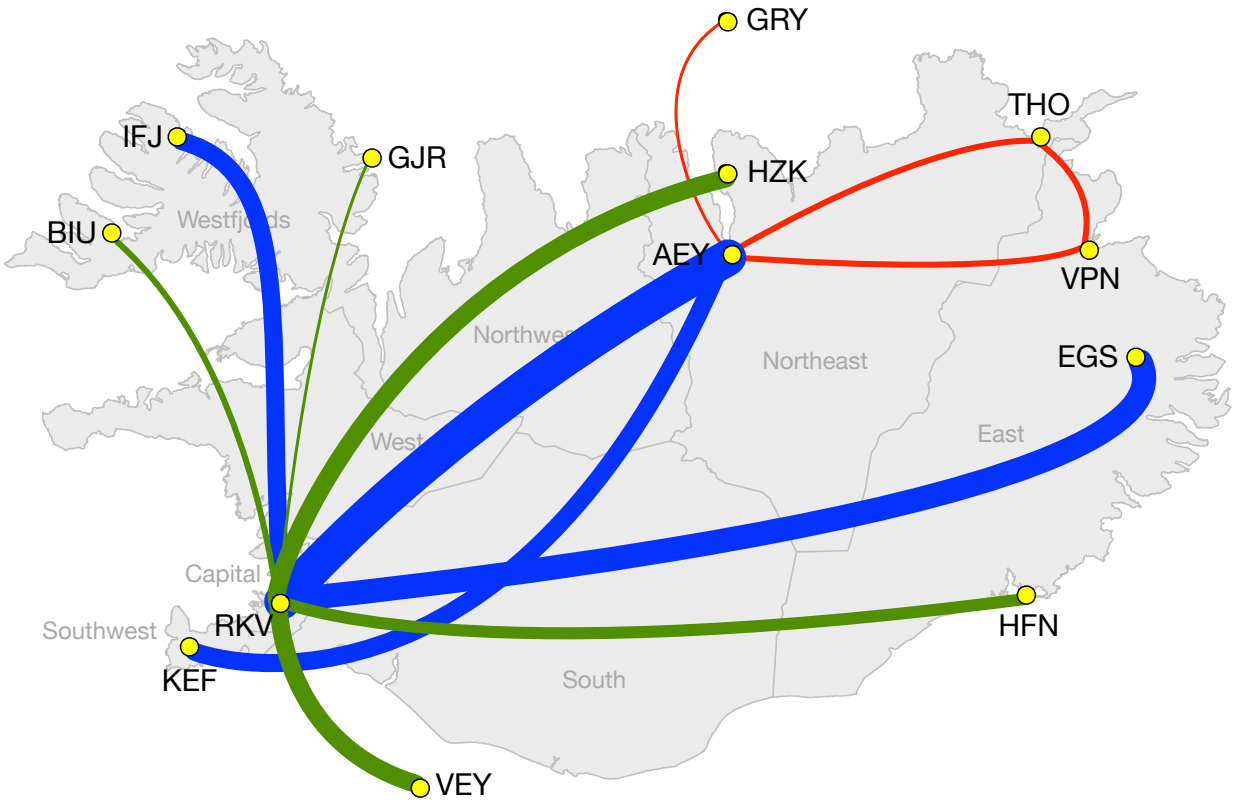
Frequency of connections

	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	
THO	5												0
VEJ										12			
VPN	0										5		



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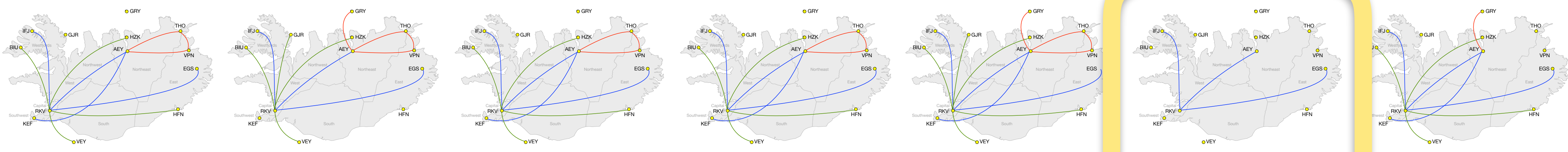
Temporal granularity

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



Mo Tu We Th Fr Sa Su

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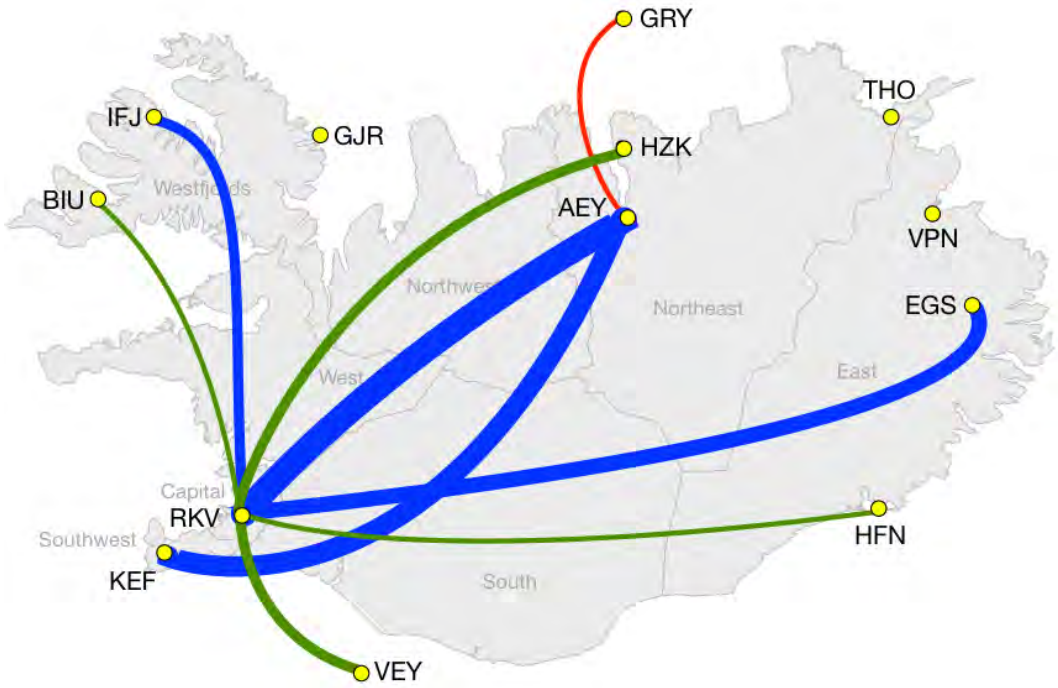
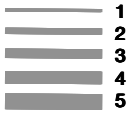
Flying a week in Iceland





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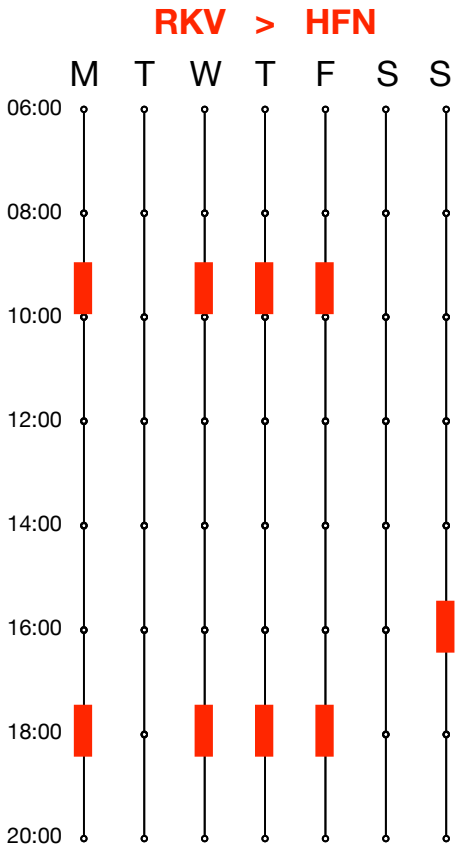
	AEY	BIU	EGS	GJR	GRY	HFN	HZK	IFJ	KEF	RKV	THO	VEJ	VPN
	M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S
AEY					0 1 0 0 1 0 1				2 0 1 4 2 0 4	5 5 5 5 5 3 5	0 0 0 0 0 0 0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

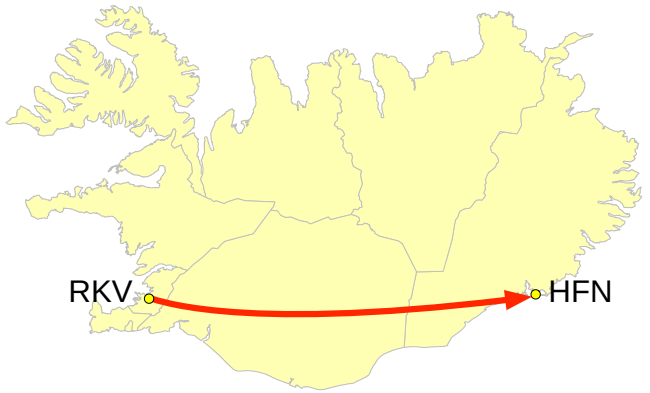
RKV >	HFN						
	M	T	W	T	F	S	S
06:00							
07:00							
08:00	:55 (09:50)		:55 (09:50)	:55 (09:50)	:55 (09:50)		
09:00							
10:00							
11:00							
12:00							
13:00							
14:00							:30 (15:30)
15:00							
16:00							
17:00	: 30 (18:25)		:30 (18:25)	:30 (18:25)	:30 (18:25)		
18:00							
19:00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

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							

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							





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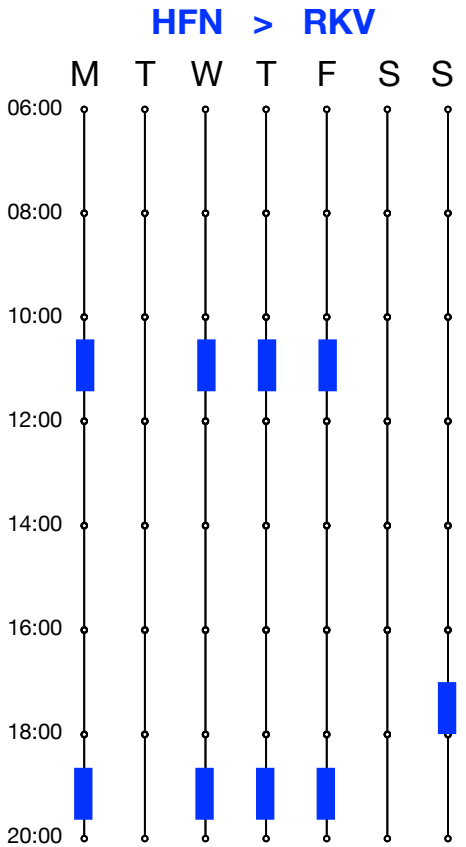
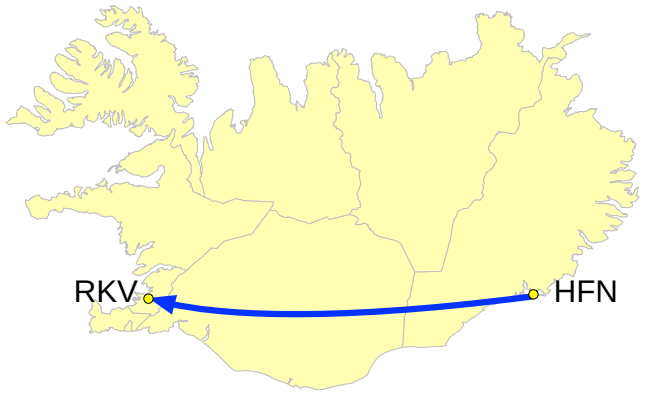
From Höfn to Reykjavik

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							





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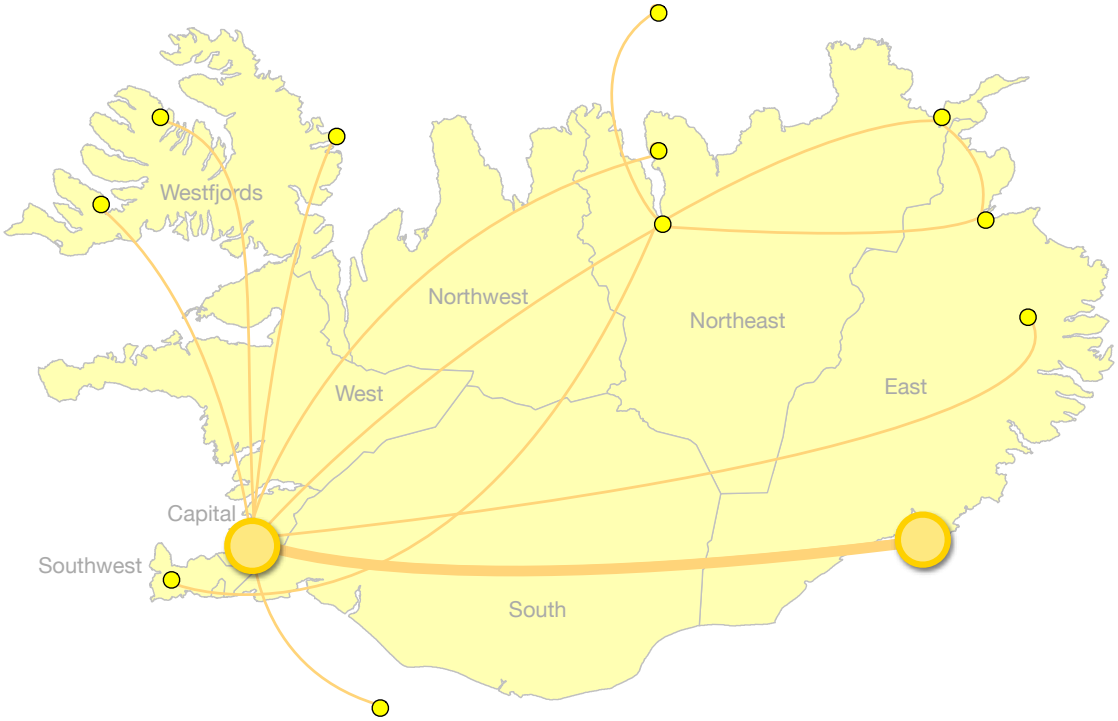

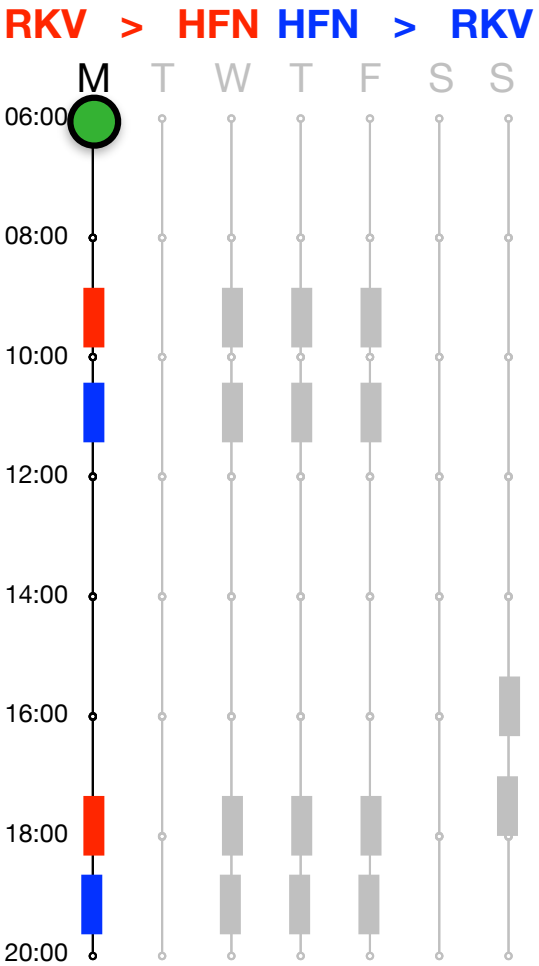

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Let’s make the world a better place with maps

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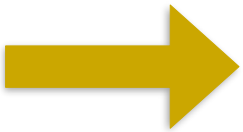
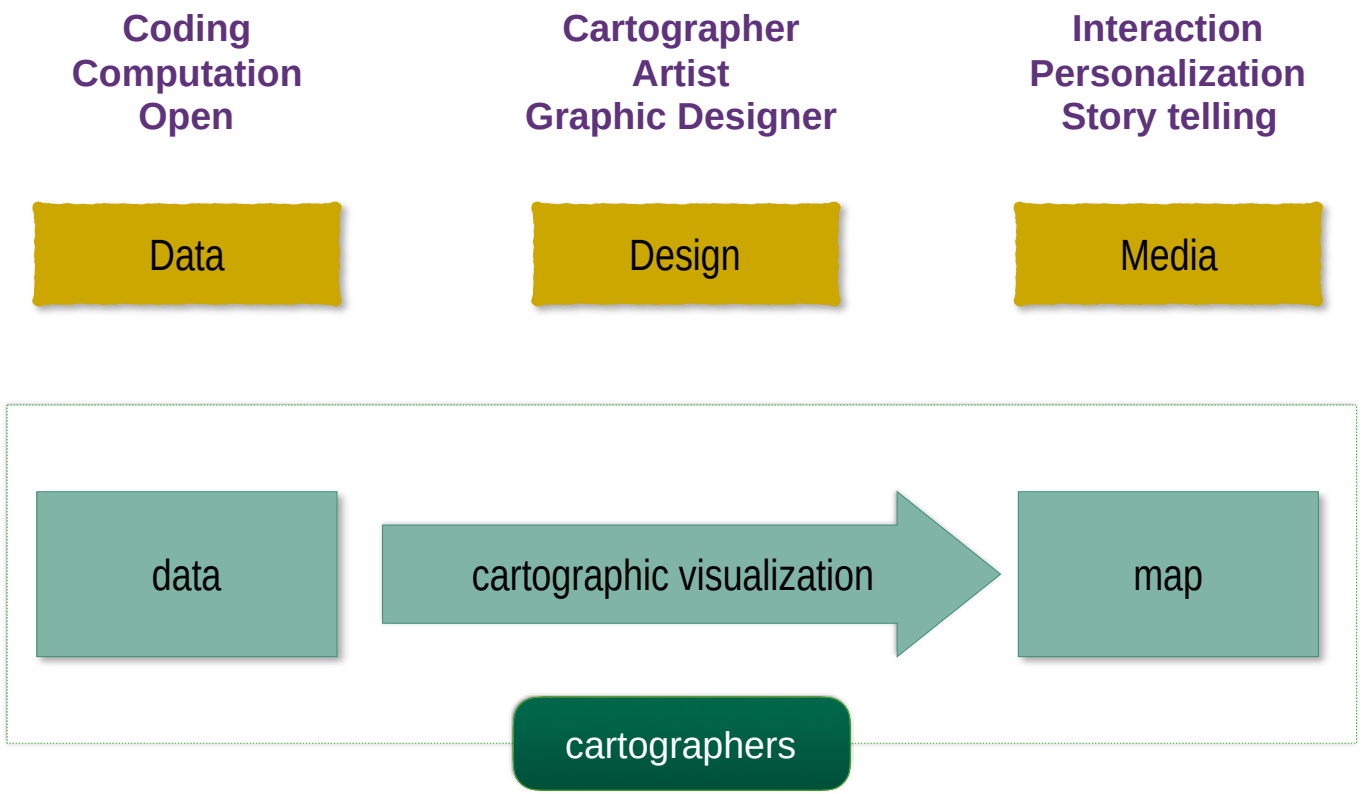
Discusion and conclusion

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