

MENNO-JAN KRAAK

MAPS AND TIME

INTRODUCTION

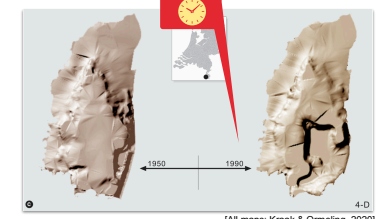
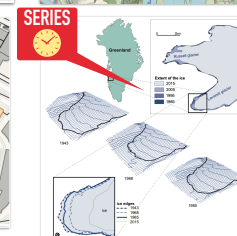
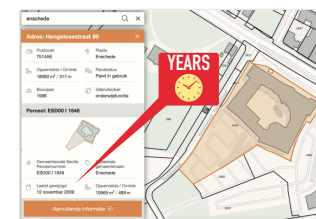
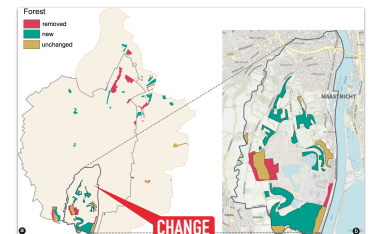
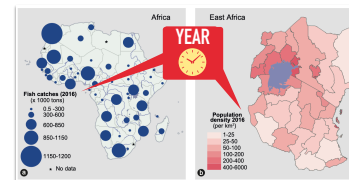
- ▶ Introduction
- ▶ What is Time
- ▶ Representing change
- ▶ Graphic representations
 - Time cartograms
 - Flow maps
 - Space Time Cube
 - Animation

OBJECTIVES

Upon successful completion one should be able to:

- Understand the different notions of time as concept and in maps
- Be able to select appropriate graphic representation

TIME AND MAPS



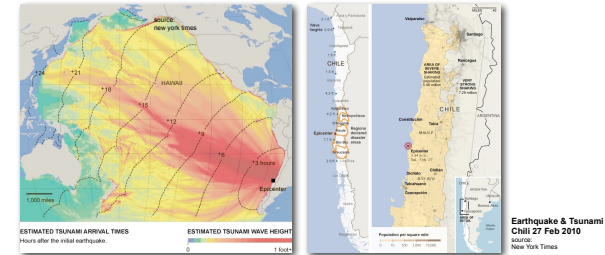
WHY INTERESTED IN TIME?

GIScience perspective:

- ▶ Better understanding of human influence on the environment at all scales (local and global change)
 - analysis of changes over time
 - analysis of patterns of change over time
- ▶ Development of methods / techniques / tools to be able to support problem solving
 - geospatial data handling
 - visualization

CONTEXT: GISCIENCE PERSPECTIVE

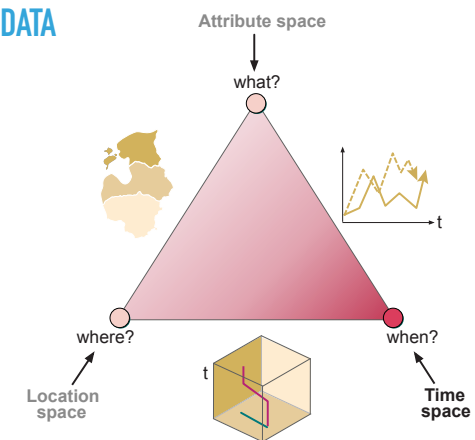
- ▶ For many (global) challenges reference to location - **and time** - is the glue that connects disparate, often incomplete data sources of continually **changing information** about time-critical, evolving real world situations



TEMPORAL QUESTIONS

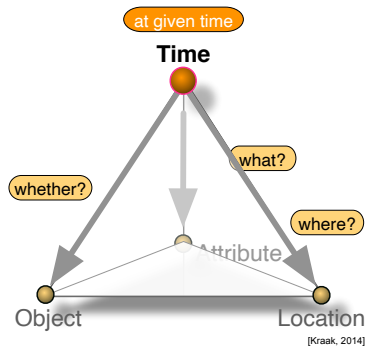
- ▶ When was the last forest fire in the neighborhood?
- ▶ Which areas were affected by mudflows in the week after the storm?
- ▶ In which neighbourhoods did the unemployment rise after closing the factories?

SPATIO-TEMPORAL DATA



[Kraak & Ormel, 2020]

SPATIO-TEMPORAL DATA AND QUESTIONS



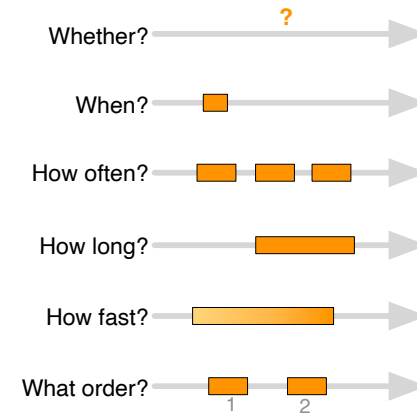
Where + What + When → Whether

Where + What + Whether → When

Where + Whether + When → What

Whether + What + When → Where

TEMPORAL QUESTIONS



WHAT IS TIME?

- Introduction
- **What is Time?**
- Representing change
- Graphic representations
 - Time cartograms
 - Flow maps
 - Space Time Cube
 - Animation

WHAT IS TIME?

- Everyone knows what it is, and few can define it
 - what, then, is time? -
 - if no one asks me, i know -
 - if i wish to explain it to one that asketh, i know not

[st. augustine 400]

- **Time is about change**

PHRASES

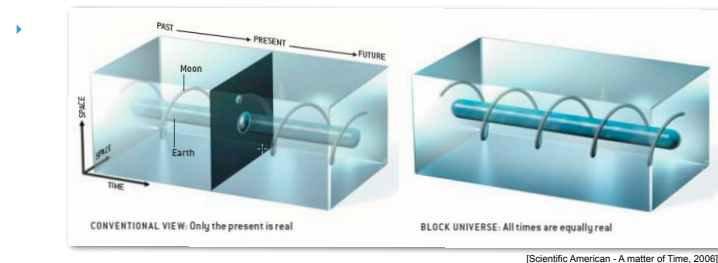
- about time
- against time
- ahead of time
- ahead of one's time
- all the time
- at one time
- at a time
- at times
- before time
- behind time
- for the time being
- half the time
- at the same time
-

128 ENTRIES FOUND IN THE NEW OXFORD DICTIONARY OF ENGLISH

- ▶ time noun
- ▶ [mass noun] the indefinite continued progress of existence and events in the past, present, and future regarded as a whole
- ▶ a point of time as measured in hours and minutes past midnight or noon
- ▶ [mass noun] time as allotted, available, or used
- ▶ an instance of something happening or being done; an occasion
- ▶

PAST, PRESENT, FUTURE

- ▶ How, then, can these two kinds of time, the past and the future be, when the past no longer is and the future as yet does not be?



- ▶ Time as static (the now) versus time as dynamic (as flow)

SCHOOLS OF THOUGHT

▶ Absolute time

Influenced by Newton they see time and space as a kind of container in which objects exist and move, guided by the laws of physics. Space and time function as a kind of reference frame. In other words, time is independent of any physical object, but it describes the 'location' of objects and events during their existence

▶ Relative time

Influenced by Aristotle, who said that time is measure of change, which in turn implies that time does not exist when there is no change. Leibniz and Kant were followers of this viewpoint. Space and time describe relations among objects

PERCEPTION AND STRUCTURE OF TIME

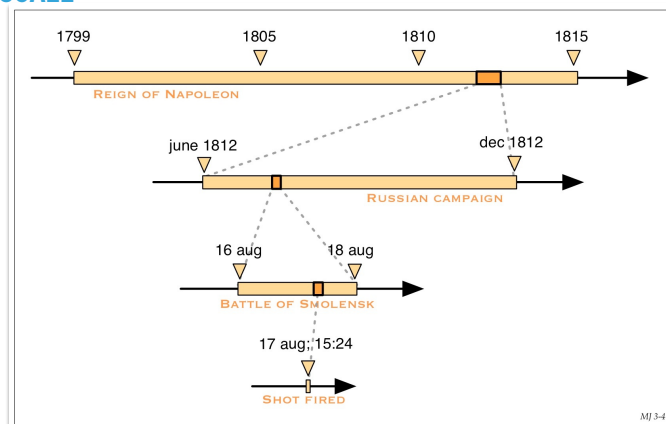
- ▶ Time has an inherent semantic structure, which is one source of increased complexity.
- ▶ By convention, time has a hierarchical system of granularities
 - seconds, minutes, hours, days, weeks... (but different calendar systems)
- ▶ Time contains natural cycles and re-occurrences.
 - regular and relatively predictable: seasons
 - less regular: social cycles like holidays or school breaks, economic cycles, or hurricane season

CALENDARS

	Gregorian	Julian	Hebrew	Islamic	French Republican
START OF CAMPAIGN	24 June 1812	12 June 1812	14 Tammuz 5572	13 Jumada t-Tania 1227	6/I Messidor 20
NAPOLEON IN MOSCOW	15 September 1812	3 September 1812	9 Tishri 5573	8 Ramadan 1227	9/III Fructidor 21
CROSSING OF BEREZINA	27 November 1812	15 November 1812	23 Kislev 5573	22 Dhu l-Qa'da 1227	6/II Frimaire 21
END OF CAMPAIGN	6 December 1812	24 November 1812	3 Teveth 5573	1 Dhu l-Hijja 1227	5/II Frimaire 21
TODAY	27 November 2012	14 November 2012	13 Kislev 5773	13 Muharram 1434	7/I Frimaire 21

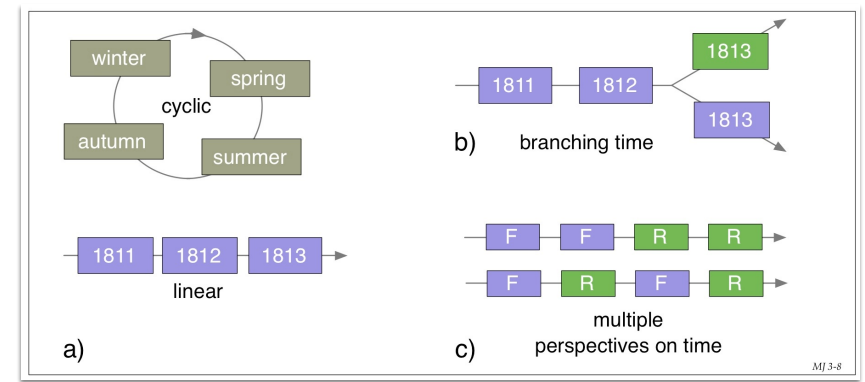
[Kraak, 2014]

TEMPORAL SCALE



MJ 3-4
[Kraak, 2014]

TYPES OF TIME I



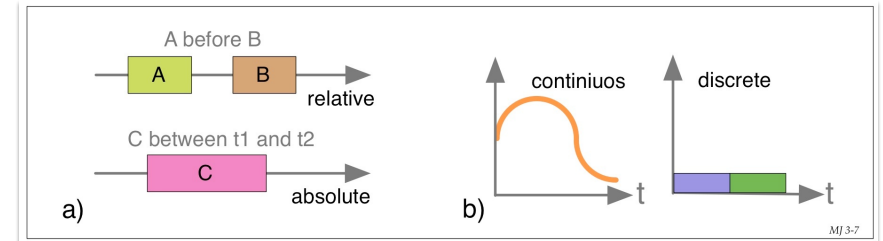
MJ 3-8
[Kraak, 2014]

STRUCTURE OF THE TEMPORAL DIMENSION (MULTIPLE PERSPECTIVES)

- Time with multiple perspectives allows more than one point of view at observed facts (people's observations about hazard events)



TYPES OF TIME II



TYPES OF TIME?

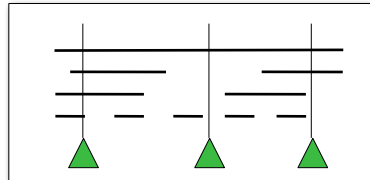
- Valid time
- Transaction time
- World time
- Database time
- Observation time
- Display time
- Historical time
- Excavation time
- Mechanical time
- Biological time
- Body time
- Social time
- Life time
- Sense of time
- Web time
-

DIFFERENT TYPES OF TIME

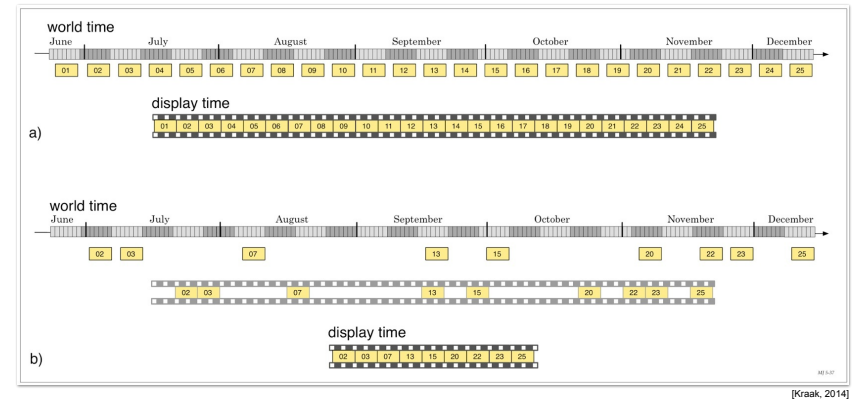


OBSERVE / MEASURE TIME (CHANGE)

- ▶ Change can happen suddenly or gradually
- ▶ Change of some sort is always happening
- ▶ Change can be observed after the fact
- ▶ Change can go unrecorded



WORLD TIME AND DISPLAY TIME



[Kraak, 2014]

PERCEPTION OF TIME

(this lecture)



45 minutes

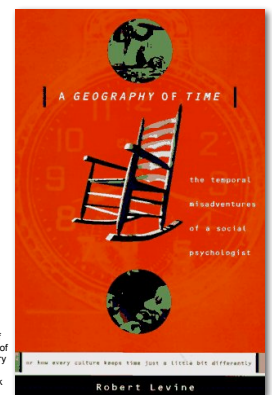


90 minutes

SOCIAL TIME

- ▶ Time talks with an accent
- ▶ Every culture has its own unique set of temporal finger prints
- ▶ To know a people is to know the time values they live by

Levine, R. (1997). A geography of time: the temporal misadventures of a social psychologist, or how every culture keeps time just a little bit differently. Basic Books, New York



REPRESENTING CHANGE

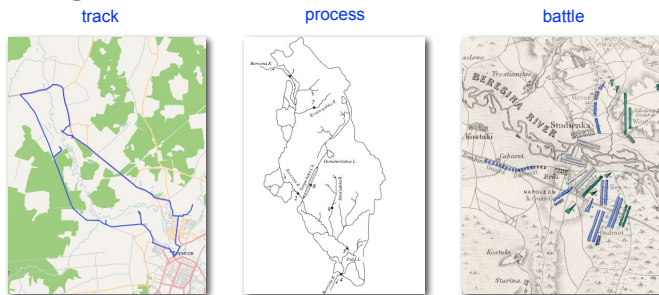
- ▶ Introduction
- ▶ What is Time?
- ▶ **Representing change**
- ▶ Graphic representations
 - Time cartograms
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CHANGE

- ▶ What is change: something is happening > an event
- ▶ What is changing?
- ▶ How to present change

EVENTS

- ▶ Time is about change > events

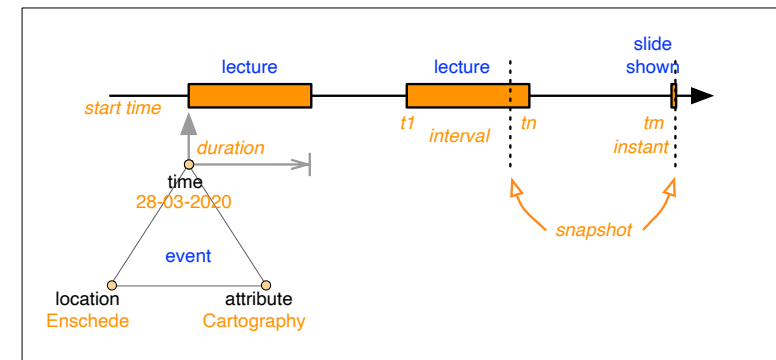


2011 substantial trip Berezina River, Belarus

Water Resources, Vol. 32, No. 2, 2005, pp. 200-203.
Translated from Vodynye Resursy, Vol. 32, No. 2, 2005, pp. 223-226. Original Russian Text Copyright © 2005 by Barmachenko, Wozniak.

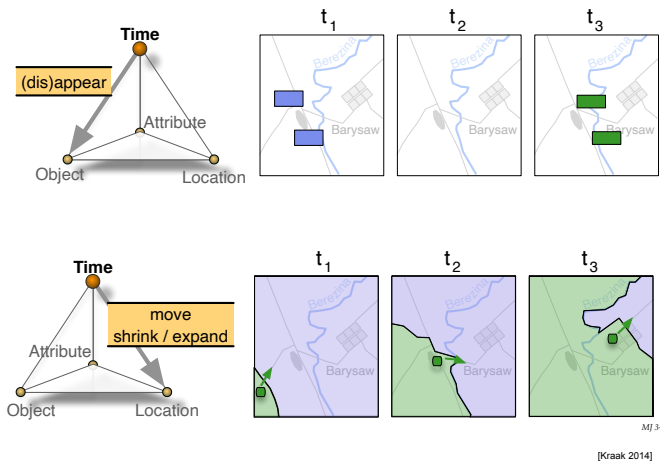
Atlas to Alton's History of Europe, 1850, Plate 79 - Passage of the Berezina, 26, 27 & 28 November 1812

EVENTS

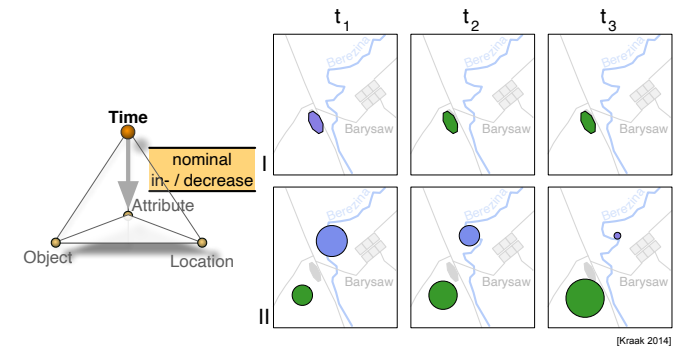


[Kraak, 2014]

CHANGE



CHANGE



ISSUES OF REPRESENTATION

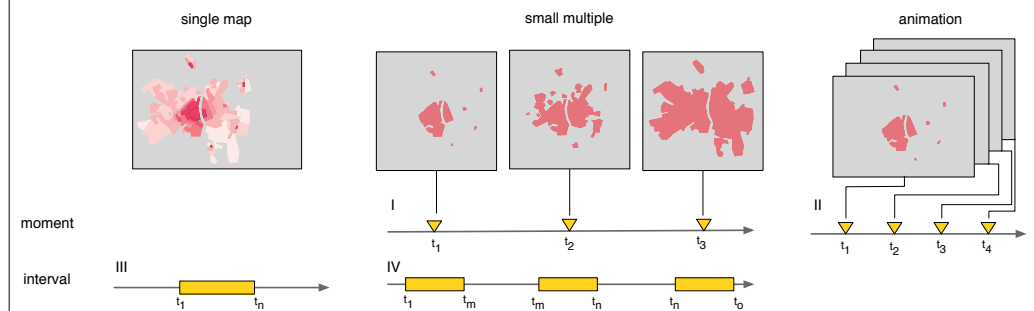
State (static)

What was / is / will be the spatial distribution of a given phenomena at a given time?

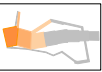
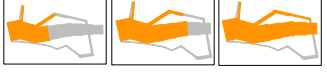
Change (dynamic)

Which elements changed / are changing / will change during a given time span?

REPRESENT CHANGE VISUALLY



HOW CHANGE IS RETRIEVED

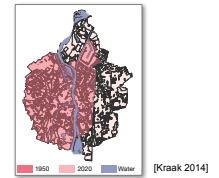
Map Appearance	Information retrieval		
	location	attribute	time
single map			
I		plane	graphical variables
small multiple (series of maps)			
II		plane	spatial deduction
animation			
III		plane	memory deduction

[Kraak, 2014]

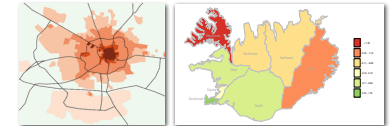
SINGLE MAP

► Dynamics can be suggested by:

- change, e.g. based on overlay of maps of 2 moments
- symbols that give an impression of movement or order
 - value - e.g. for successive stages of urban growth / increase/decrease of a variable over one period
 - arrows - e.g. for paths of wildfires, hurricanes, migration...

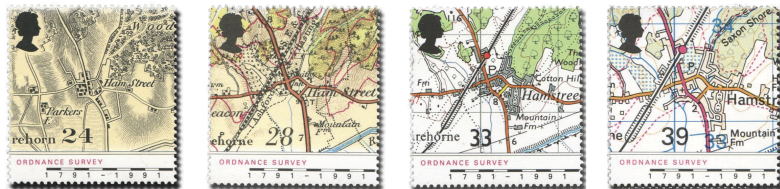


[Kraak 2014]



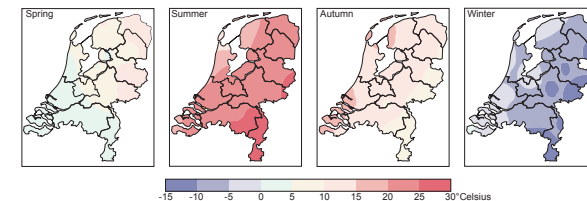
SMALL MULTIPLES

► Spatial dynamics have to be mentally extracted by the user by comparison of spatially separate snap shots of time

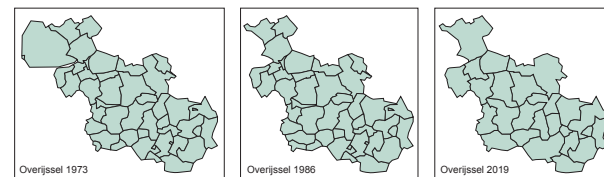


[Kraak & Ormeling 2020 / Royal Mail]

SMALL MULTIPLES

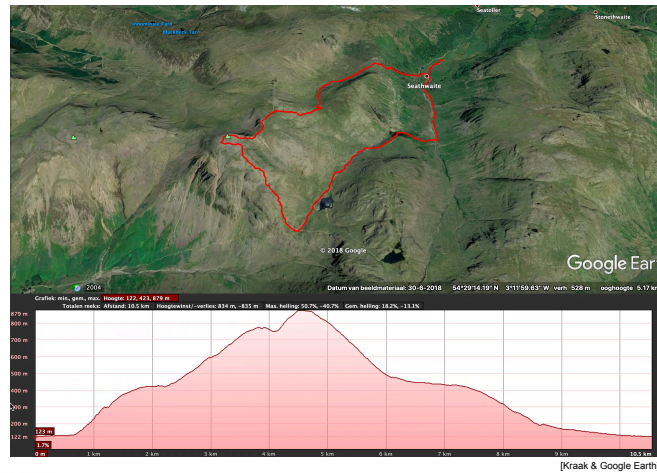


-15 -10 -5 0 5 10 15 20 25 30°Celsius



[Kraak & Ormeling 2020]

ANIMATION



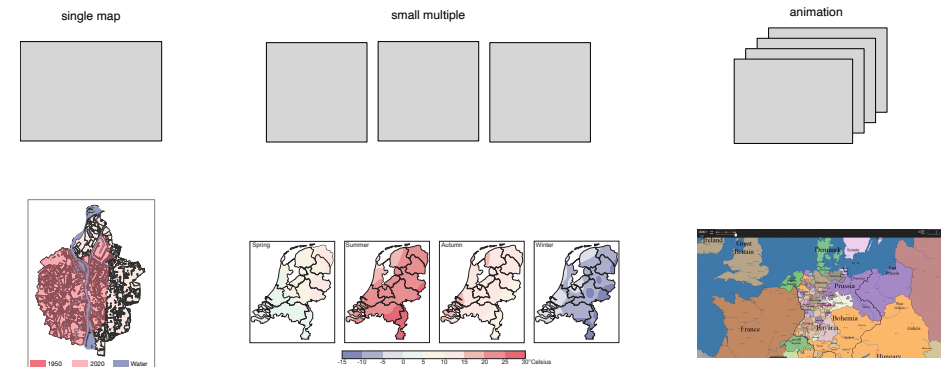
ANIMATION



GRAPHIC REPRESENTATIONS

- ▶ Introduction
- ▶ What is Time?
- ▶ Representing change
- ▶ **Graphic representations**
 - Time cartograms
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REPRESENT CHANGE VISUALLY



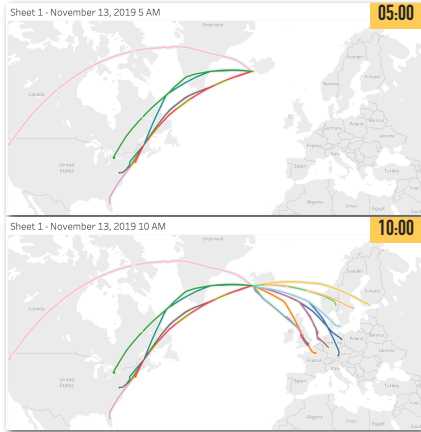
- ▶ What do we see?



[Data source: <https://www.flightradar24.com> / 13 November 2019 produced with Tableau]

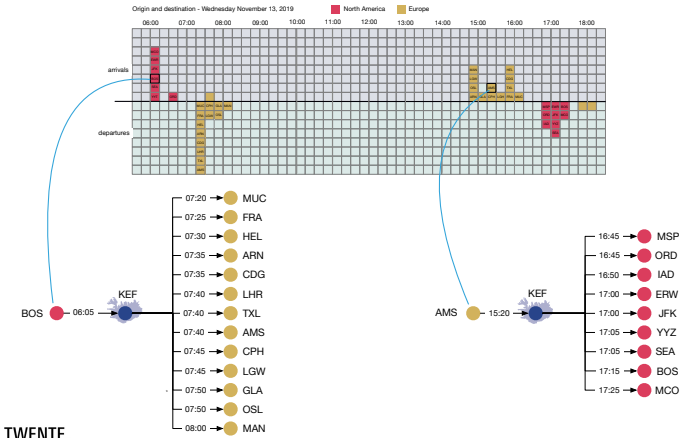
[Data source: <https://www.flightradar24.com> / 13 November 2019 produced with Tableau]

13 NOVEMBER 2019



[Data source: <https://www.flightradar24.com/> / 13 November 2019 produced with Tableau]

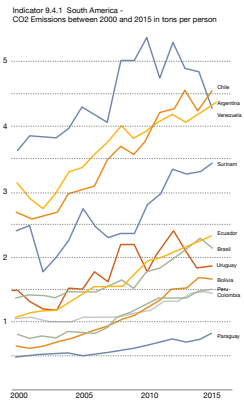
ICELAND AIR: WHAT REALLY HAPPENS



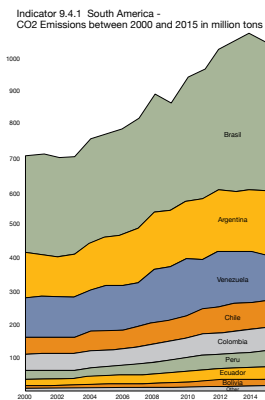
[Kraak & Ormel, 2020]

DIAGRAMS

line chart



stacked area chart

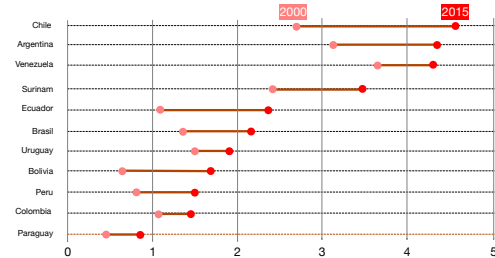


[Kraak MJ, RE Roth, B Ricker, A Kagawa, and G Le Sourd. 2020. Mapping for a Sustainable World. New York: United Nations]

DIAGRAMS

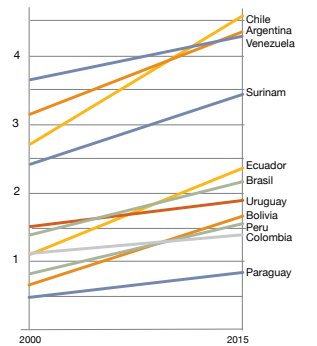
dumbbell chart

Indicator 9.4.1 South America - Compare CO2 Emissions between 2000 and 2015 in tons per person



slope chart

Indicator 9.4.1 South America - Compare CO2 Emissions between 2000 and 2015 in tons per person

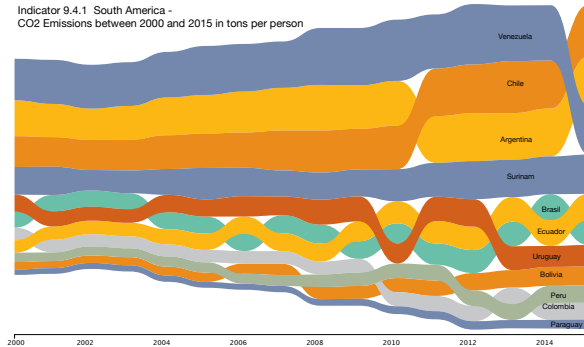


[Kraak MJ, RE Roth, B Ricker, A Kagawa, and G Le Sourd. 2020. Mapping for a Sustainable World. New York: United Nations]

DIAGRAMS

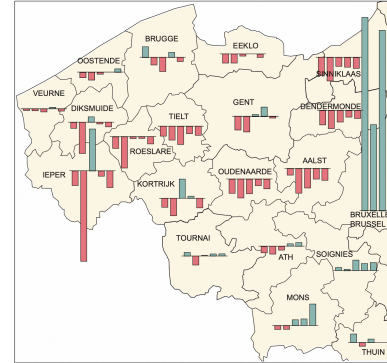
sorted stream graph

Indicator 9.4.1 South America -
CO2 Emissions between 2000 and 2015 in tons per person

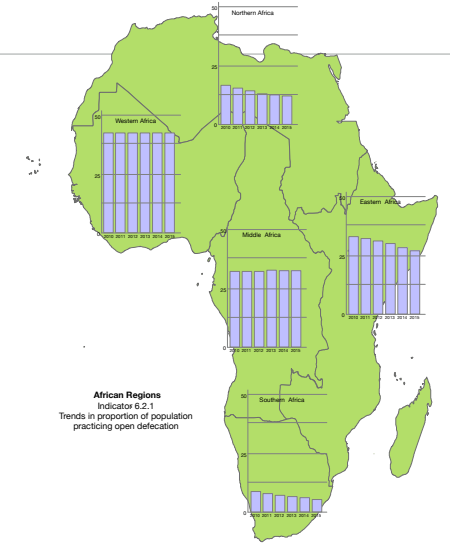


[Kraak MJ, RE Roth, B Ricker, A Kagawa, and G Le Sourd. 2020. Mapping for a Sustainable World. New York: United Nations]

DIAGRAM MAPS

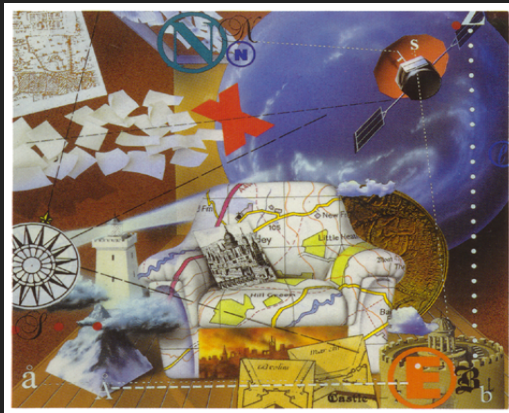


[Kraak & Ormeling, 2020]



African Regions
Indicator 6.2.1
Trends in proportion of population
practicing open defecation

[Kraak MJ, RE Roth, B Ricker, A Kagawa, and G Le Sourd. 2020. Mapping for a Sustainable World. New York: United Nations]



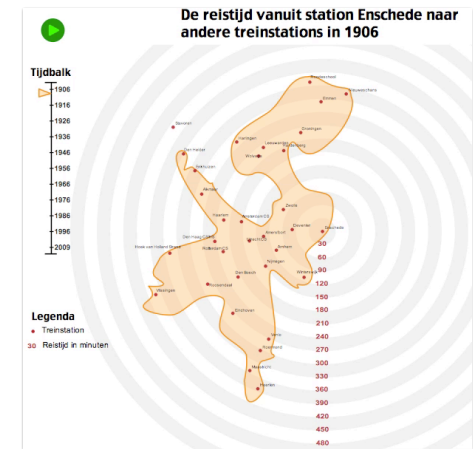
MENNO-JAN KRAAK

MAPS AND TIME

TIME CARTOGRAM

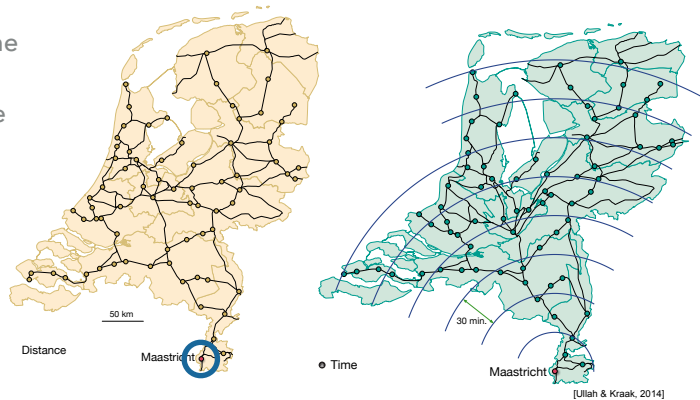
- ▶ Introduction
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HUNDRED YEARS OF TRAVELING FROM ENSCHEDE BY TRAIN

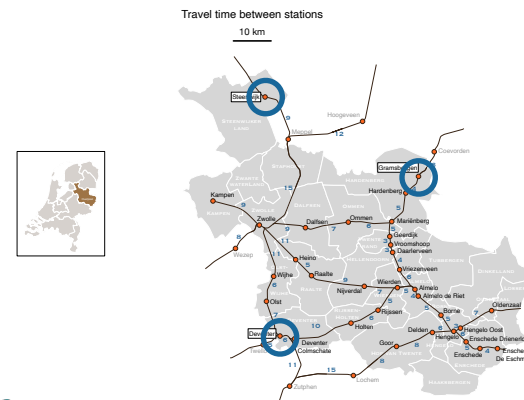


PRINCIPLE OF TIME CARTOGRAMS

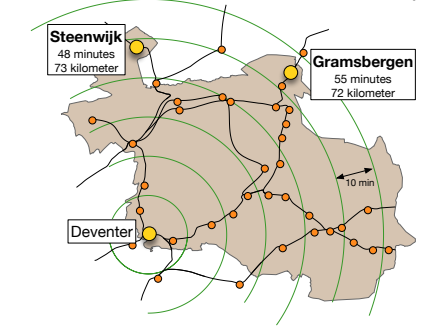
- ▶ In a time cartogram the geographic surface is adapted to travel time



TIME CARTOGRAM



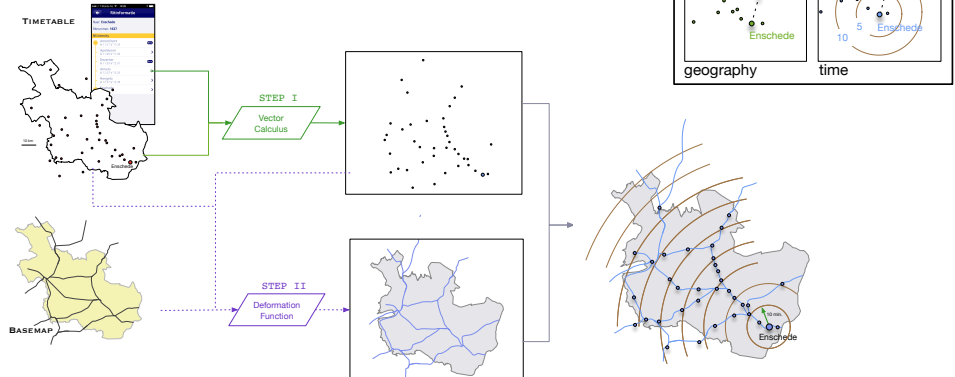
Travel time from Deventer b)



MAPPING TRAVEL TIME



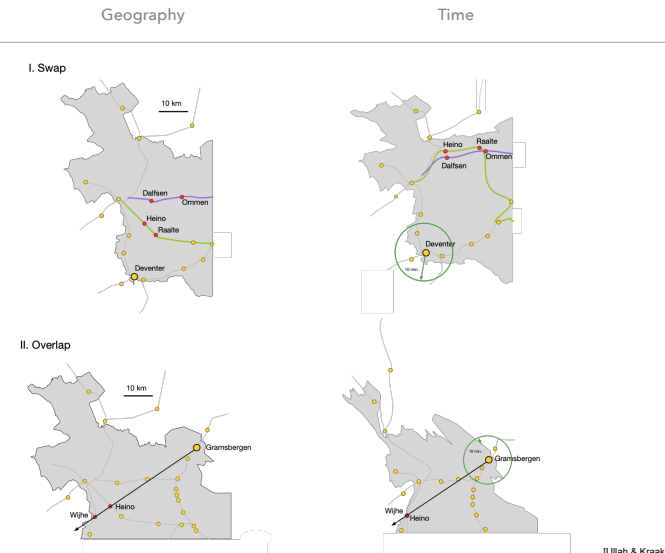
CREATING TIME CARTOGRAMS



THE SHAPE OF OVERIJSSSEL

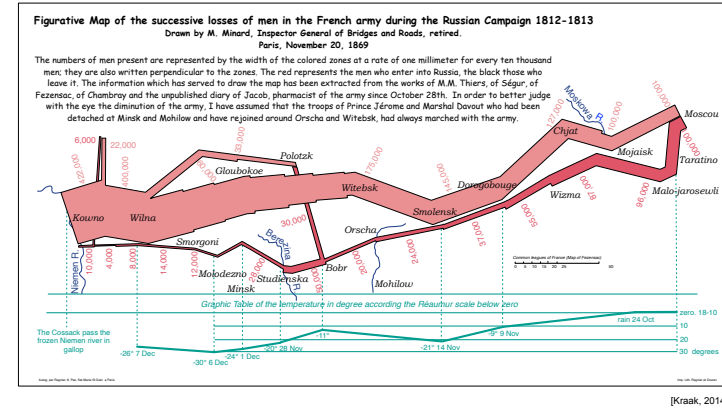


POTENTIAL ERRORS

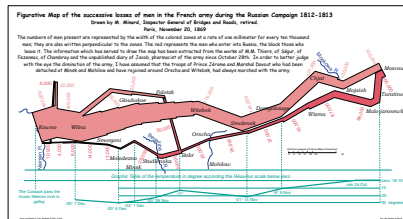


TEKST

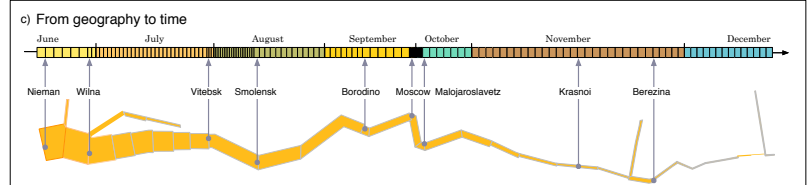
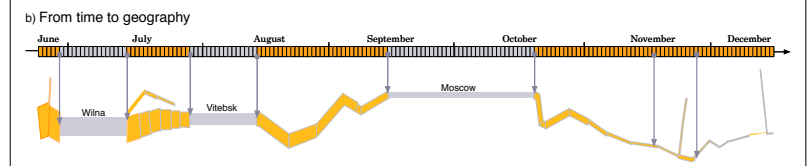
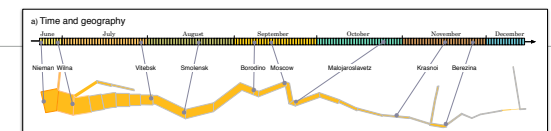
MINARD'S CLASSIC



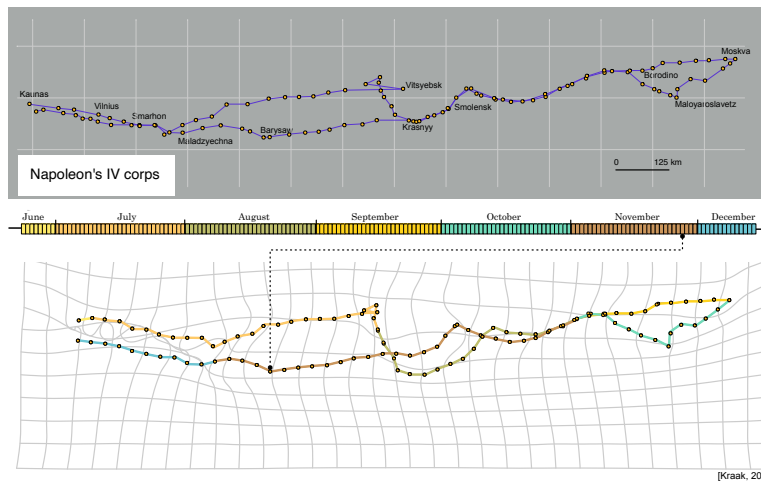
INTRODUCING TIME



PLAY WITH TIME



PLAY WITH TIME

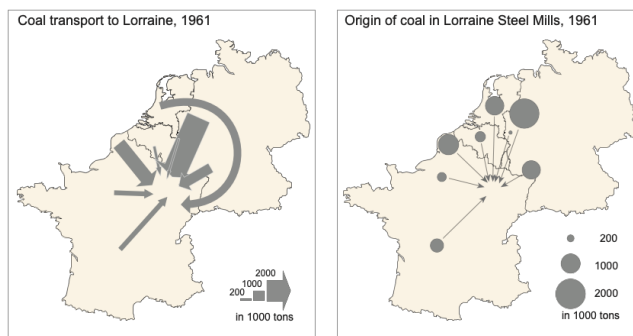


FLOW MAPS

- ▶ Introduction
- ▶ What is Time?
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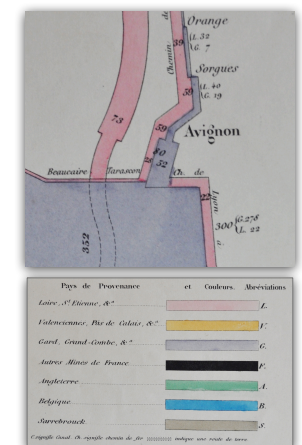
FLOWMAPS

- ▶ Flow maps represent characteristics of movement between origin and destination (nodes). The path between origin and destination (links) can express the qualitative or quantitative nature of the movement or flow.

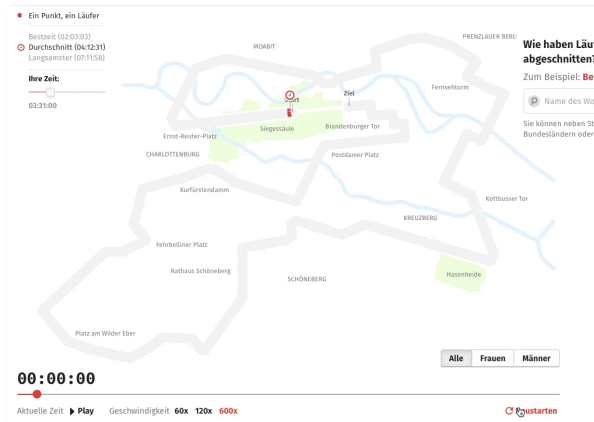


FLOWMAPS

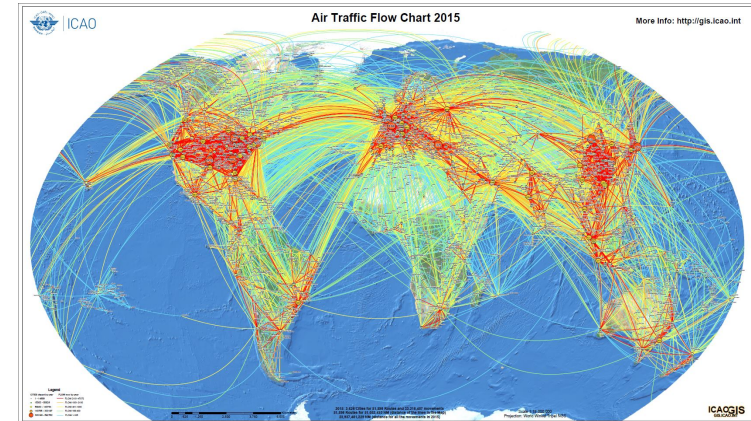
- ▶ Location
 - path, trajectory, direction
- ▶ Attribute
 - qualitate, quantitative
- ▶ Time
 - implicitly (path of path)



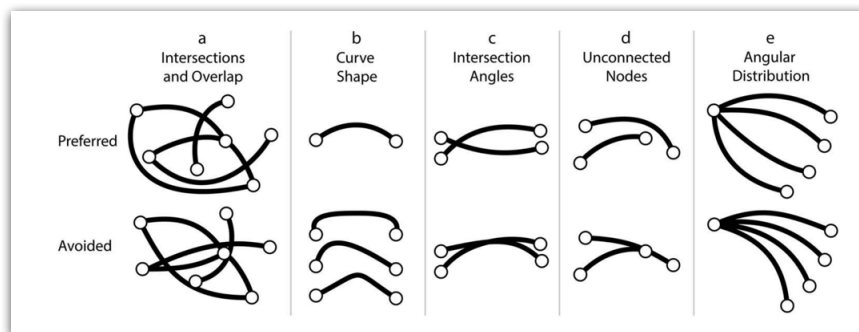
RUNNING: BERLIN MARATHON



FLOWMAPS AND VISUAL CLUTTER



DESIGN PRINCIPLES

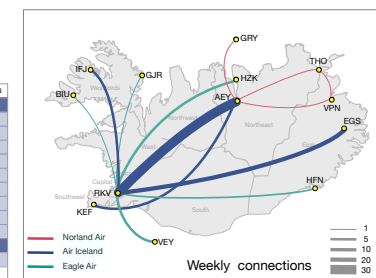


Jenny, B. et al. (2016) Design principles for origin-destination flow maps, CAGIS

TIME AND FLOW MAPS

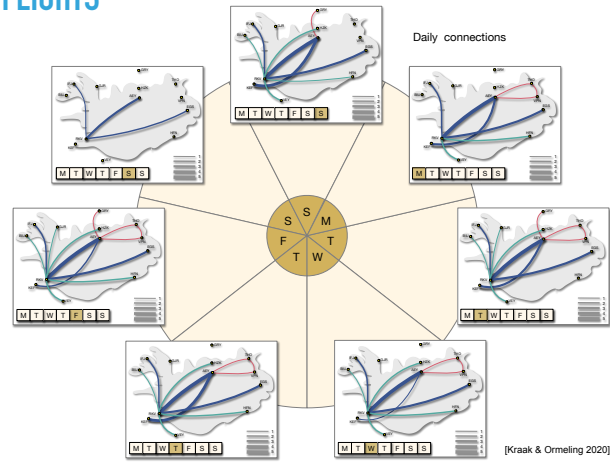
Origin Destination of weekly connections

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

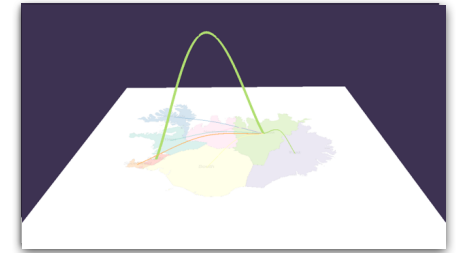
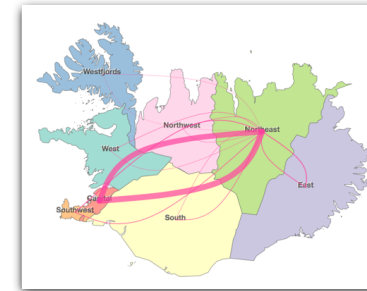


[Kraak & Ormeling 2020]

ICELAND DOMESTIC FLIGHTS

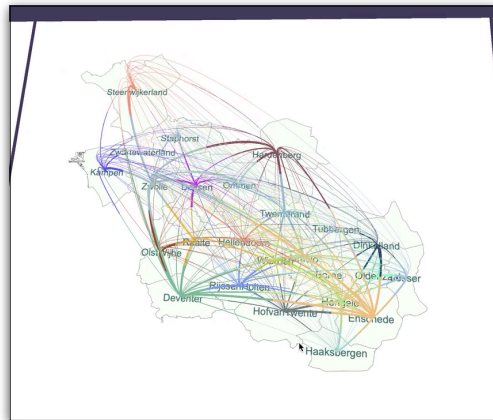


FLOW MAPS IN 3D



[Gu & Kraak & 2020]

EXPERIMENTATION IN 3D AND VR

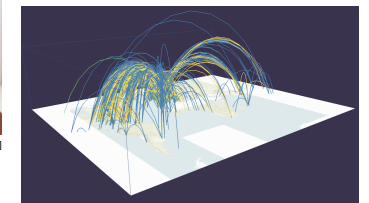
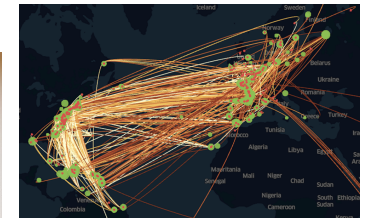


[Gu & Kraak & 2020]

ANALYTICS ENVIRONMENT VIRTUAL REALITY, USABILITY



[Gu & Kraak & 2020]



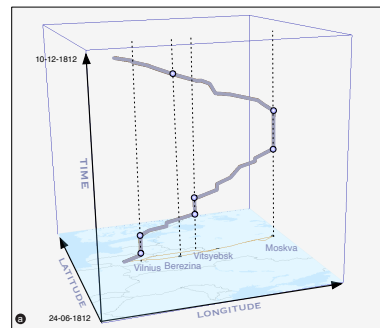
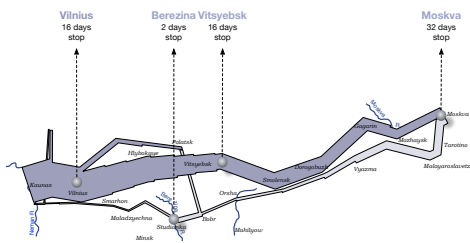
MENNO-JAN KRAAK

MAPS AND TIME

SPACE TIME CUBE

- ▶ Introduction
- ▶ What is Time?
- ▶ Representing change
- ▶ Graphic representations
 - Time cartograms
 - Flow maps
 - Space Time Cube
 - Animation

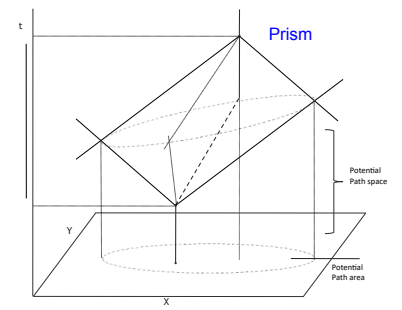
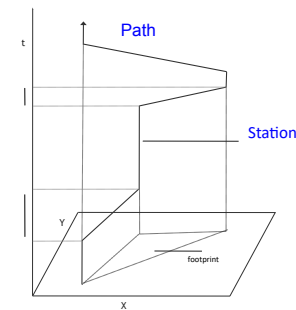
SPACE-TIME-CUBE



[Kraak & Ormeling, 2020]

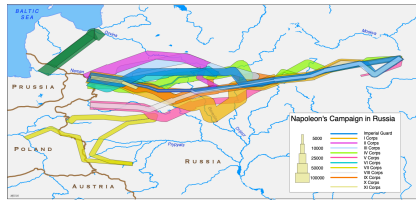
ELEMENTS OF THE SPACE-TIME-CUBE

- ▶ Path
- ▶ Stations
- ▶ Prism

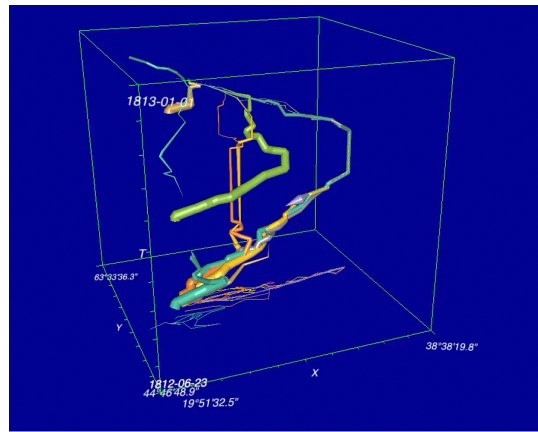


[Kiveladze, 2016]

SPACE-TIME-CUBE

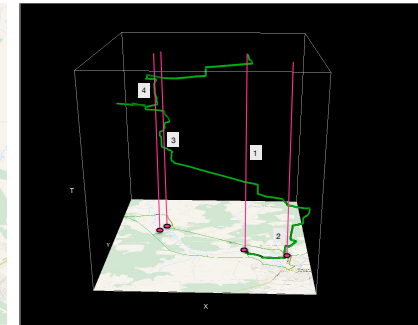
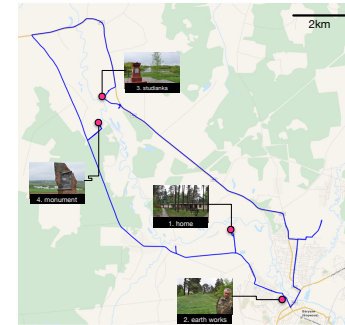


[Kraak, 2014]



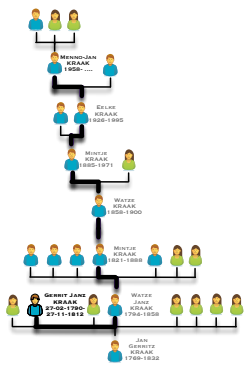
[Kveladze, 2016]

SPACE-TIME CUBE

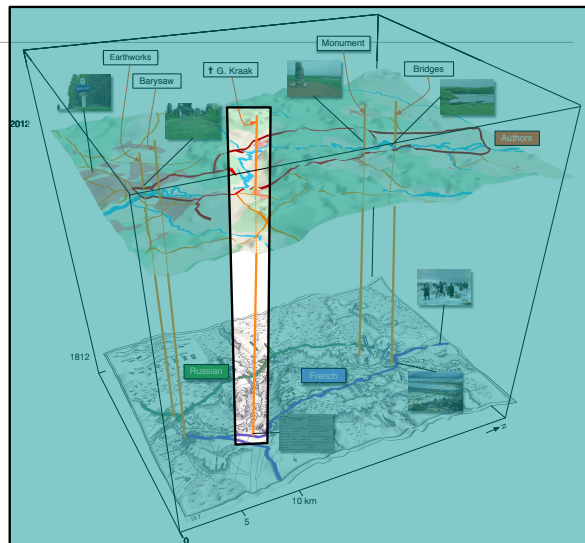


[Kveladze & Kraak, 2017]

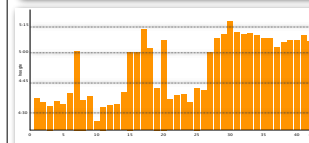
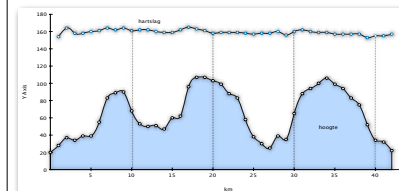
EXPLORE TIME



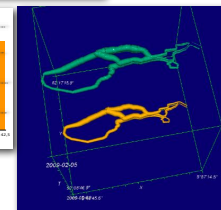
[Kraak, 2014]



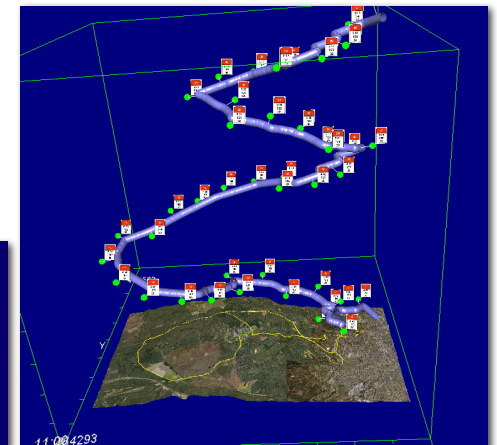
ANNOTATED SPACE-TIME-CUBE



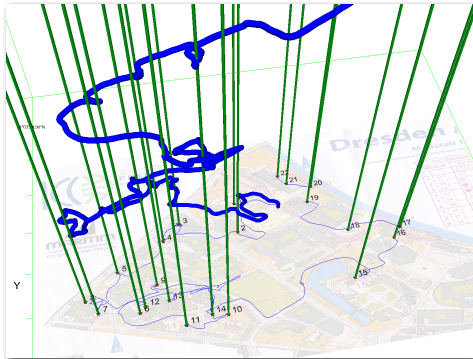
[Kraak, 2009]



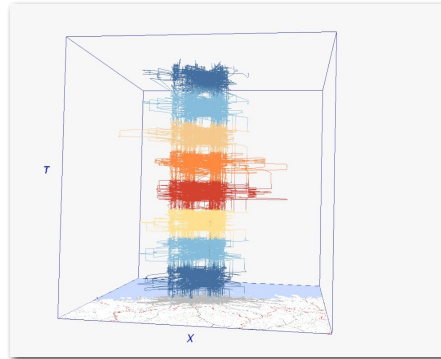
MJ's Marathon



SPACE-TIME-CUBE



(Orienteering: Kraak et al., 2014)

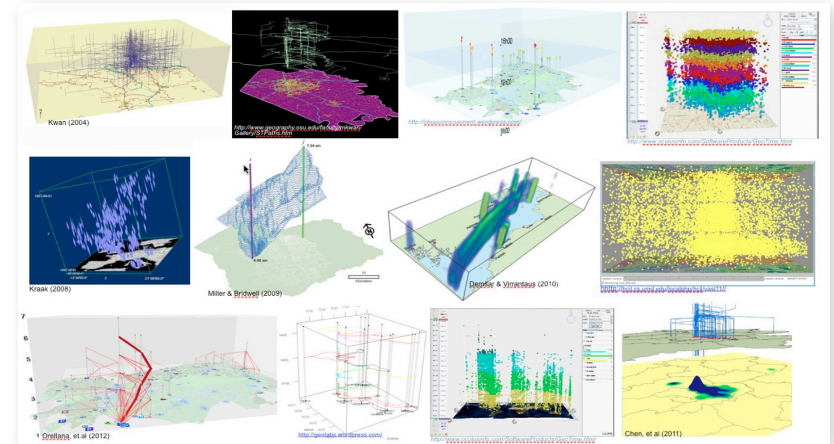


(Tallinn commuters: Kveladze, 2015)



UNIVERSITY OF TWENTE.

EXAMPLES



UNIVERSITY OF TWENTE.

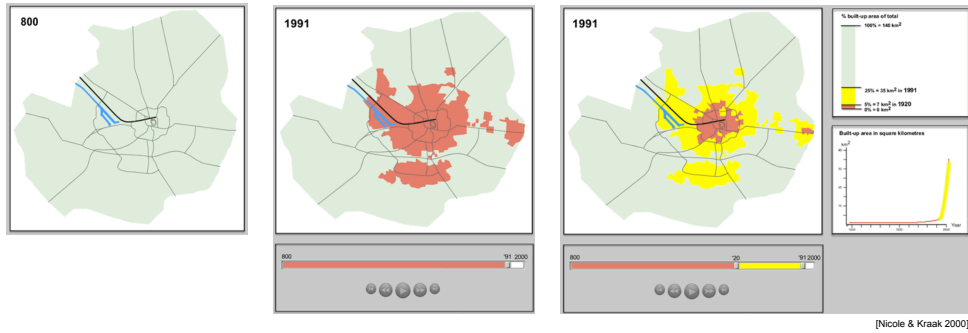
MENNO-JAN KRAAK

MAPS AND TIME

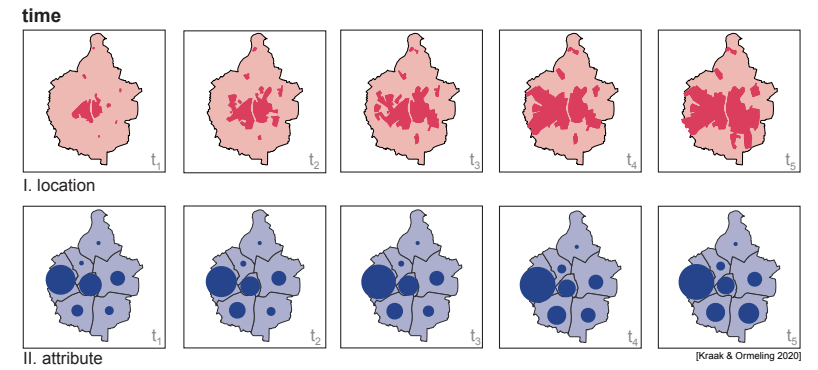
ANIMATION

- ▶ Introduction
- ▶ What is Time?
- ▶ Representing change
- ▶ Graphic representations
 - Time cartograms
 - Flow maps
 - Space Time Cube
 - Animation

ANIMATION

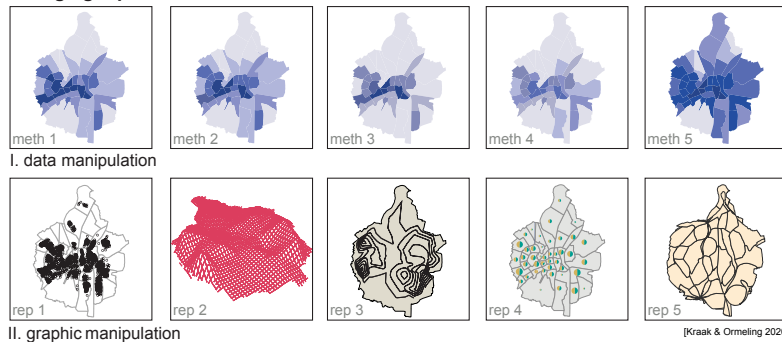


ANIMATION



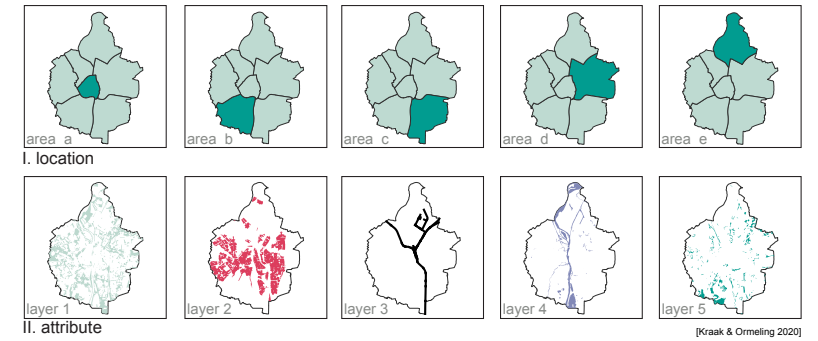
ANIMATION

changing representation



ANIMATION

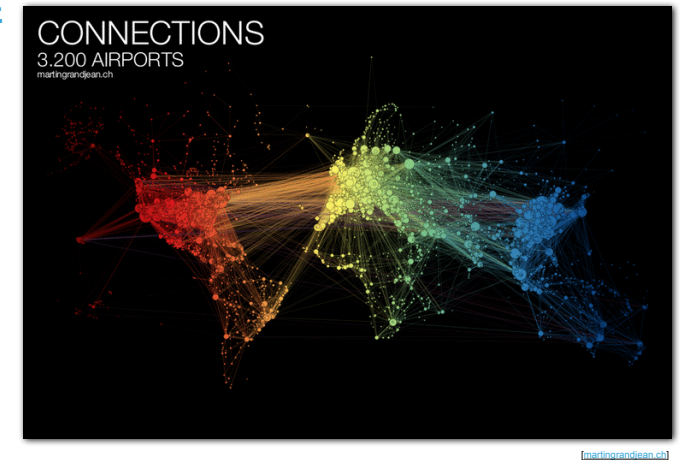
successive build-up



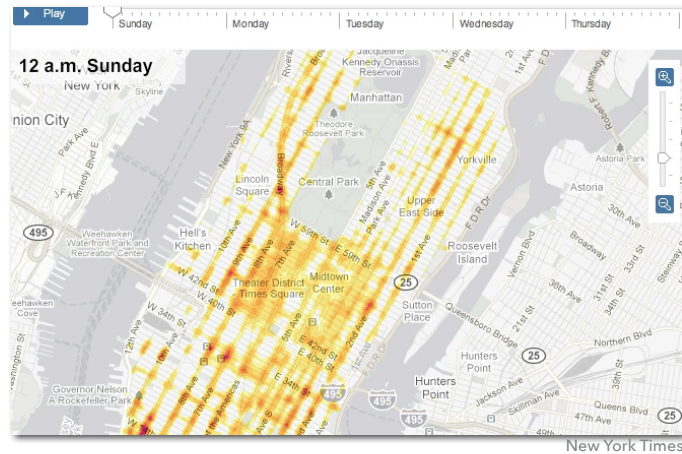
FLY THROUGH



CHANGING PERSPECTIVE



TRAFFIC INTENSITY MANHATTAN

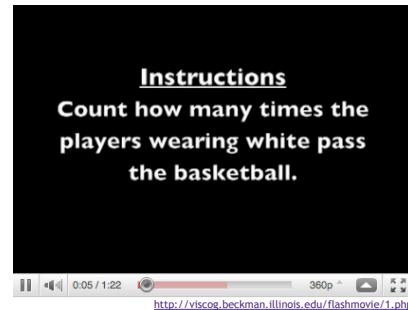


ROAD SALT IN THE NETHERLANDS



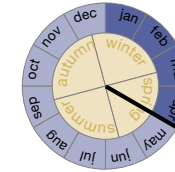
PERCEPTION PROBLEMS WITH CHANGE

- change blindness
- failure to detect change, because:
 - ▶ there are too many changes
 - ▶ changes are too slow/too fast
 - ▶ the view is temporarily interrupted (e.g. due to eye movements)

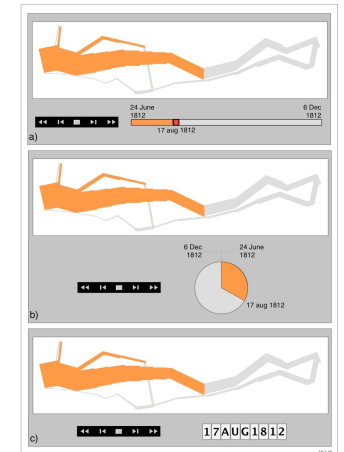


ANIMATION AND TIME

jan feb mar apr may jun jul aug sep oct nov dec

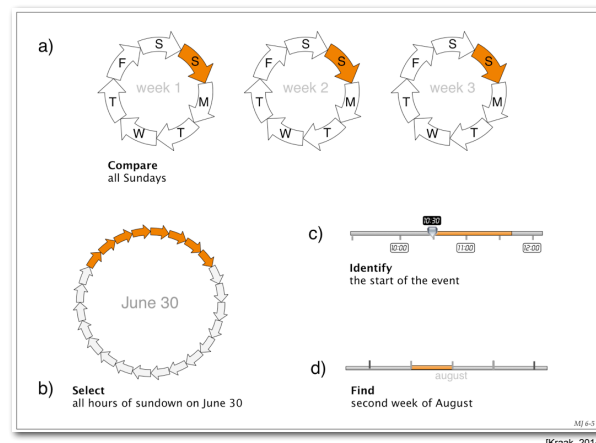


[Kraak & Ormeling 2020]



[Kraak, 2014]

TEMPORAL ACTION



[Kraak, 2014]

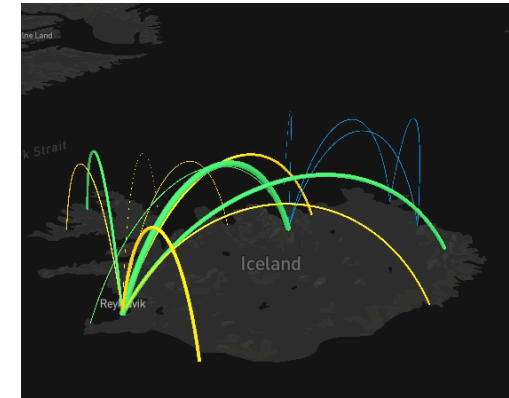
MENNO-JAN KRAAK

MAPS AND TIME

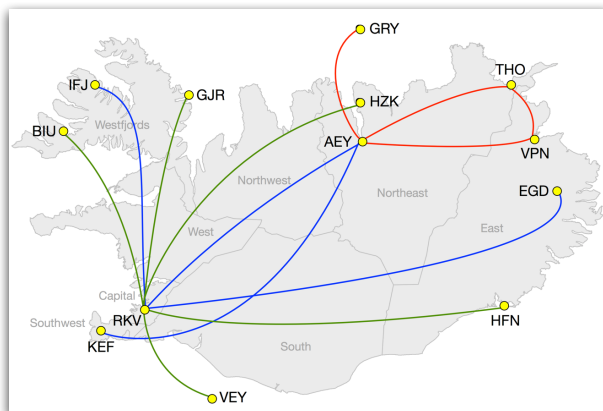
TIME AND OD DATA

- Introduction
- What is Time?
- Representing change
- Graphic representations
 - Time cartograms
 - Flow maps
 - Space Time Cub
 - Animation
- Time and OD data

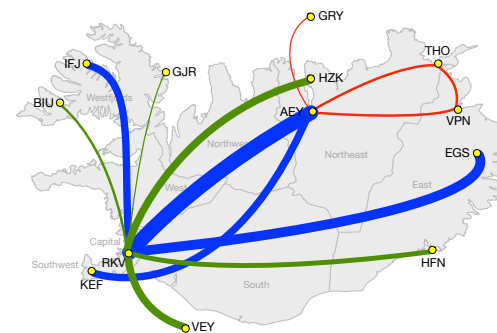
DOMESTIC FLIGHTS CONNECTIONS IN 3D



TEMPORAL GRANULARITY AND A-SYMMETRIC O-D MATRIX

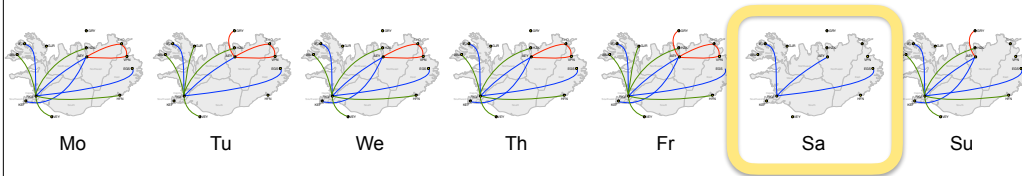


FREQUENCY OF CONNECTIONS

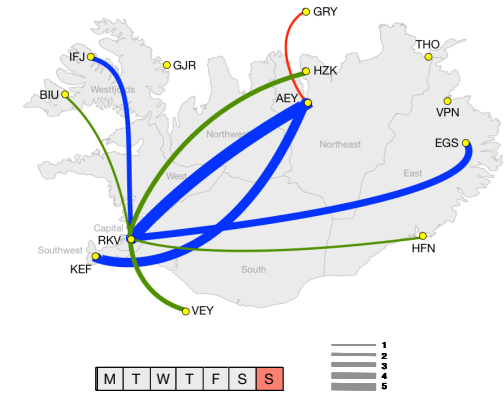


	AEY	BIU	EGS	GJR	GRY	HFN	HZK	IFJ	KEF	RKV	THO	VEJ	VPN
AEY					3				13	33	0		5
BIU										6			
EGS										22			
GJR										2			
GRY	3												
HFN										9			
HZK										12			
IFJ										13			
KEF	13												
RKV	33	6	22	2		9	12	13				12	
THO	5												0
VEJ										12			
VPN	0			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

	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				
BIU													1 1 1 1 1 0
EGS											0 0 0 0 0 0 0		
GJR											1 1 1 1 1 0 1		
GRY	0 1 0 0 1 0 1										3 3 3 3 3 3 2		
HFN											0 1 0 0 1 0 0		
HZK											2 0 2 2 2 0 1		
IFJ											2 2 2 2 2 0 2		
KEF											2 2 2 2 2 1 2		
RKV	2 0 1 4 2 0 4												
THO	5 5 5 5 5 5 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	1 2 2 2 2 0 3	2 2 2 2 2 1 2				2 2 2 2 2 0 2	
VEJ	1 1 1 1 1 0 0												0 0 0 0 0 0
VPN	0 0 0 0 0 0 0									2 2 2 2 2 0 2	1 1 1 1 1 0 0		



ONE WEEK OF FLYING IN ICELAND

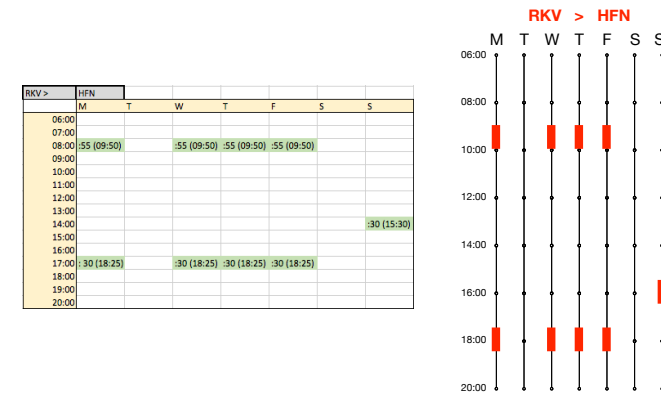


TEMPORAL GRANULARITY: ZOOM-IN

	AEY		BU		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
AEY																												
BU																												
EGS																												
GJR																												
GRY																												
HFN																												
HZK																												
IFJ																												
KEF																												
RKV																												
THO																												
VEJ																												
VPN																												

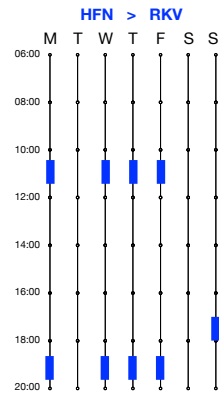
RKV >	HFN					
M	T	W	T	F	S	S
06:00						
07:00						
08:00	:55 (09:50)					
09:00						
10:00						
11:00						
12:00						
13:00						
14:00						
15:00						
16:00						
17:00	:30 (18:25)					
18:00						
19:00						
20:00						

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



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							



BETWEEN REYKJAVIK AND HÖFN

