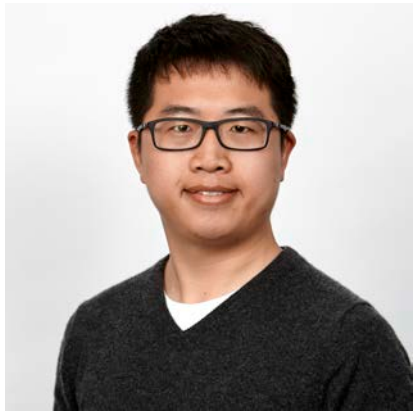
Visualising Geographically-Embedded Origin-Destination Flows:

in 2D and immersive environments

Yalong Yang

Oct 2018

https://vis.yalongyang.com/



Mr. Yalong Yang

PhD started from March 2015

Thesis submitted in Sep 2018, yay!

Monash Immersive Analytics Initiative

A/Prof. Tim Dwyer

Prof. Kim Marriott

A/Prof. Bernie Jenny

Dr. Sarah Goodwin

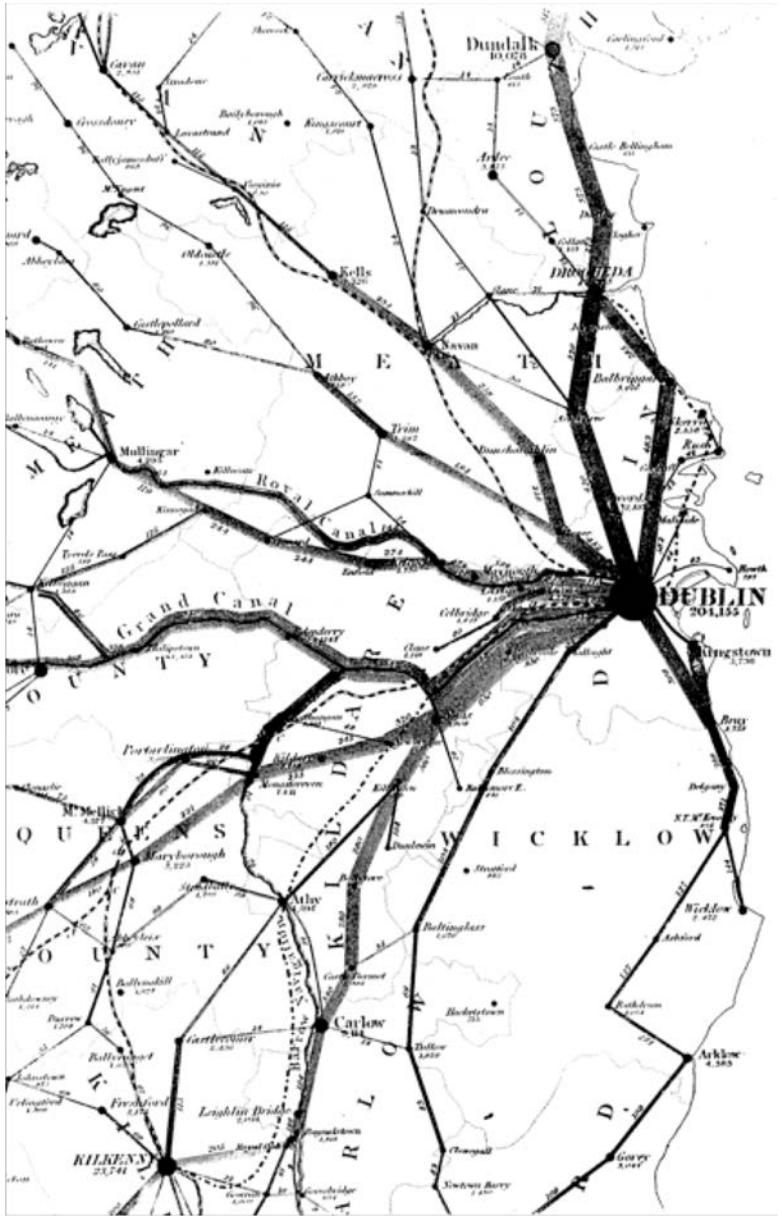
Dr. Caron Chen
(from data61)

What?

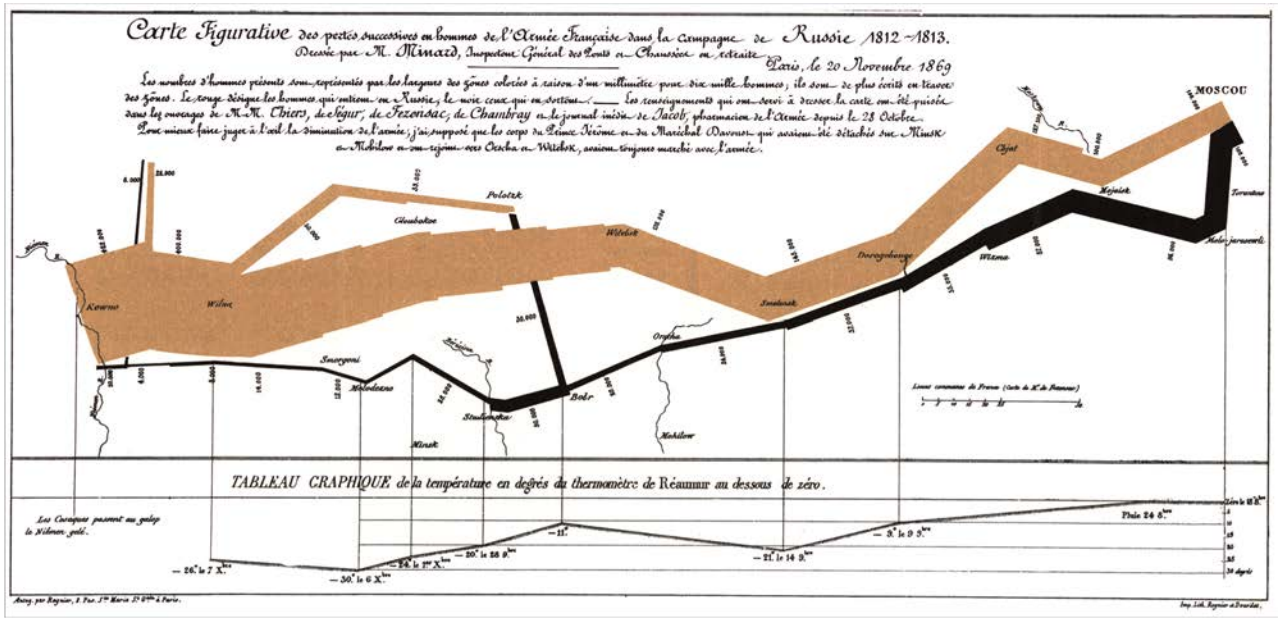
- Properties
  - Geographic information
    - Origins
    - Destinations
  - Quantity
  - Direction

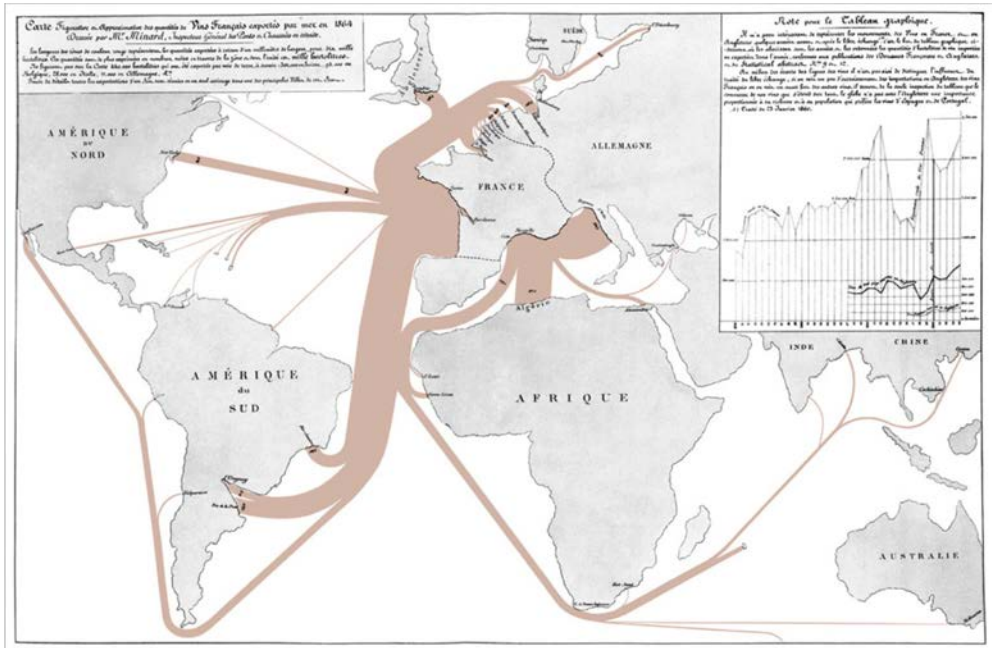
- Spatial Flow Data
  - Migrations [Tobler, 1987]
  - Movement of animals or disease [Gilbert *et al.*, 2005; Guo, 2007]
  - Movement of goods or knowledge [Paci and Usai, 2008]
  - Commuting behaviour [Chiricota *et al.*, 2008]
  - And ……

How?



1837 – first known flow map by Henry Drury Harness





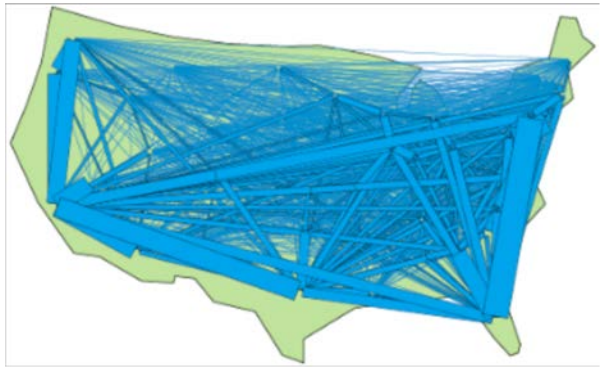
Charles Joseph Minard, *Tableaux Graphiques et Cartes Figuratives de M. Minard*, 1845–1869, a portfolio of his work held by the Bibliothèque de l'École Nationale des Ponts et Chaussées, Paris.

Charles Joseph Minard (1781 - 1870)

- Scalability

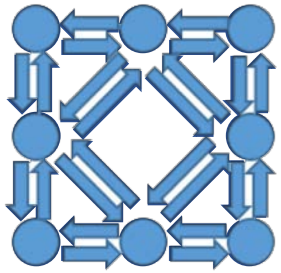
USA figures from [Tobler, 1987]

Migration from CA to other states



All interstate migrations in USA

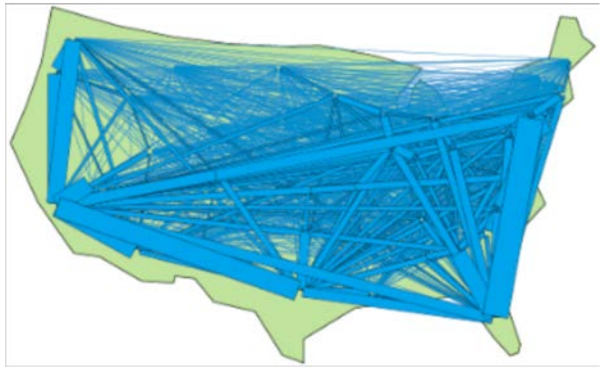
- Embedding geographical context



USA figures from [Tobler, 1987]

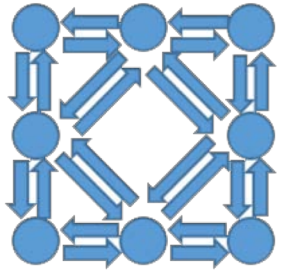
- Scalability

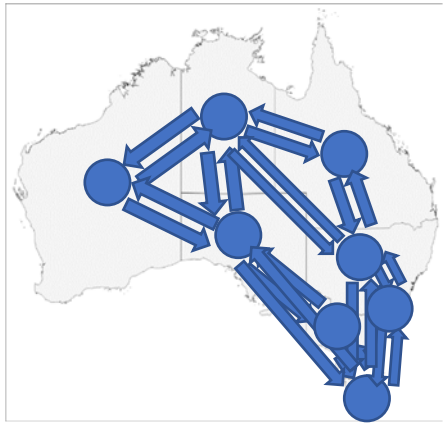
Migration from CA to other states

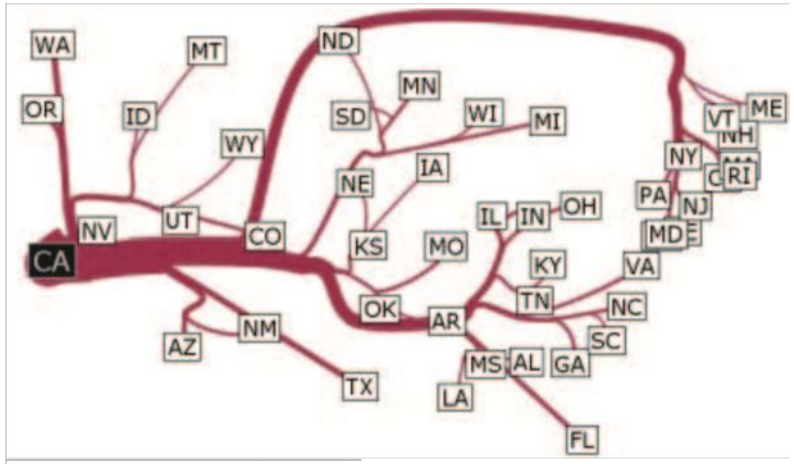


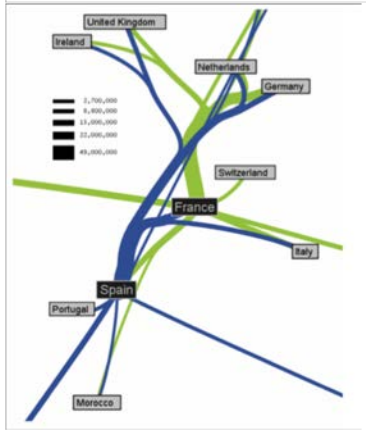
All interstate migrations in USA

- Embedding geographical context







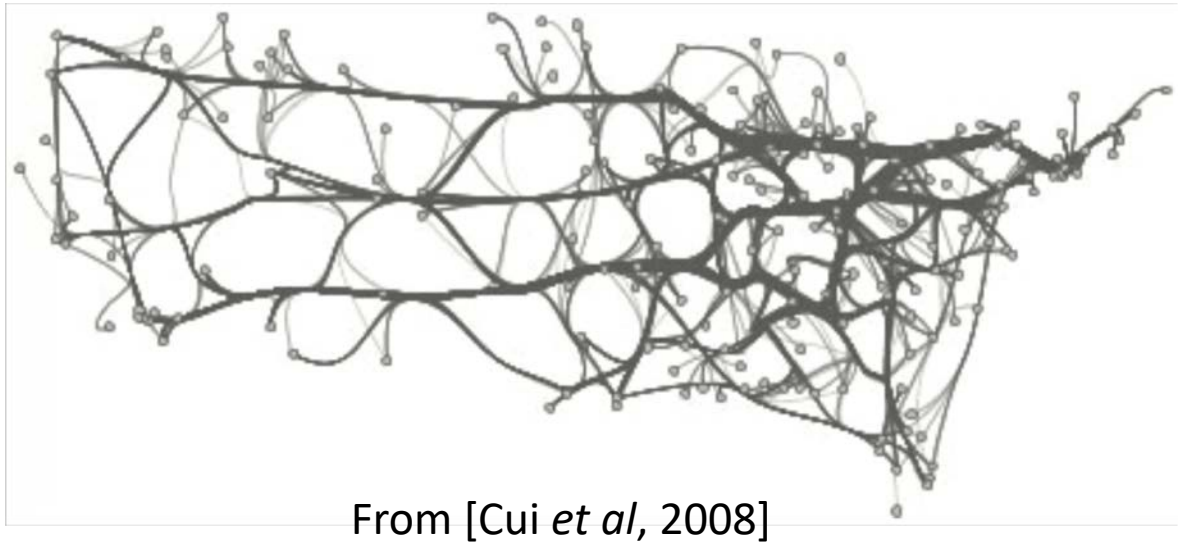


Flow map layout from [Phan *et al*, 2005]

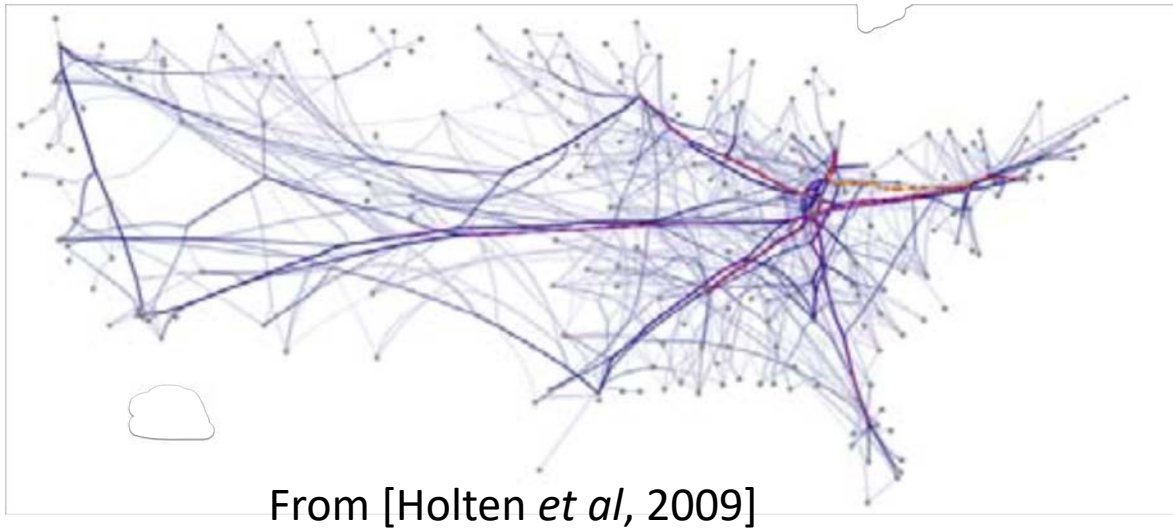
Spiral Tree layout [Verbeek *et al*, 2011]

☑ ***Alleviate visual clutters for one-to-many flows***

☒ ***Crossings and overlaps with many-to-many flows***



From [Cui *et al*, 2008]



From [Holten *et al*, 2009]

☑ ***Easy to look at the overall "skeleton"***

☒ ***Hard to distinguish individual flows***

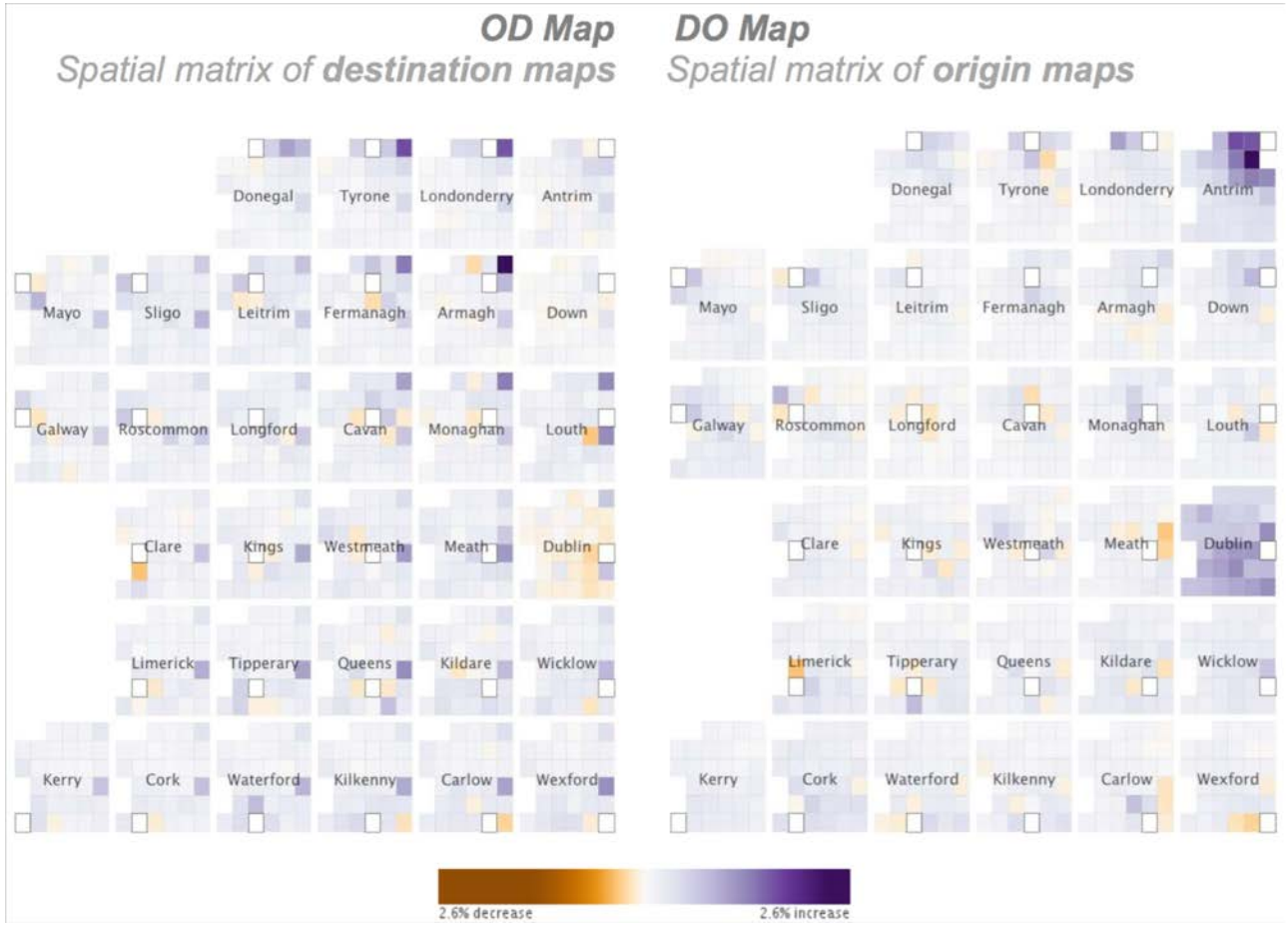
OD Matrix

	WA	NT	QLD	SA	NSW	VIC	TAS
WA		2.5K	9.7K	3.0K	9.0K	8.4K	1.5K
NT	2.0K		4.2K	1.7K	2.8K	2.6K	0.3K
QLD	9.2K	5.8K		5.8K	41.4K	19.6K	3.2K
SA	2.8K	2.5K	5.0K		5.2K	6.0K	0.7K
NSW	8.2K	3.1K	37.1K	5.8K		21.8K	2.2K
VIC	9.5K	2.6K	20.8K	7.9K	24.8K		3.5K
TAS	1.6K	0.3K	2.9K	0.6K	2.2K	2.6K	

☑ ***Scalable***

☒ ***No spatial context***

OD Maps



Transformation from geographical map to an OD Cell

- ☑ ***Scale to large data***
- ☑ ***Can identify individual flows***
- ☒ ***Missing some spatial context***
- ☒ ***Not tested with a controller study***

Design – Motivations

Flow map

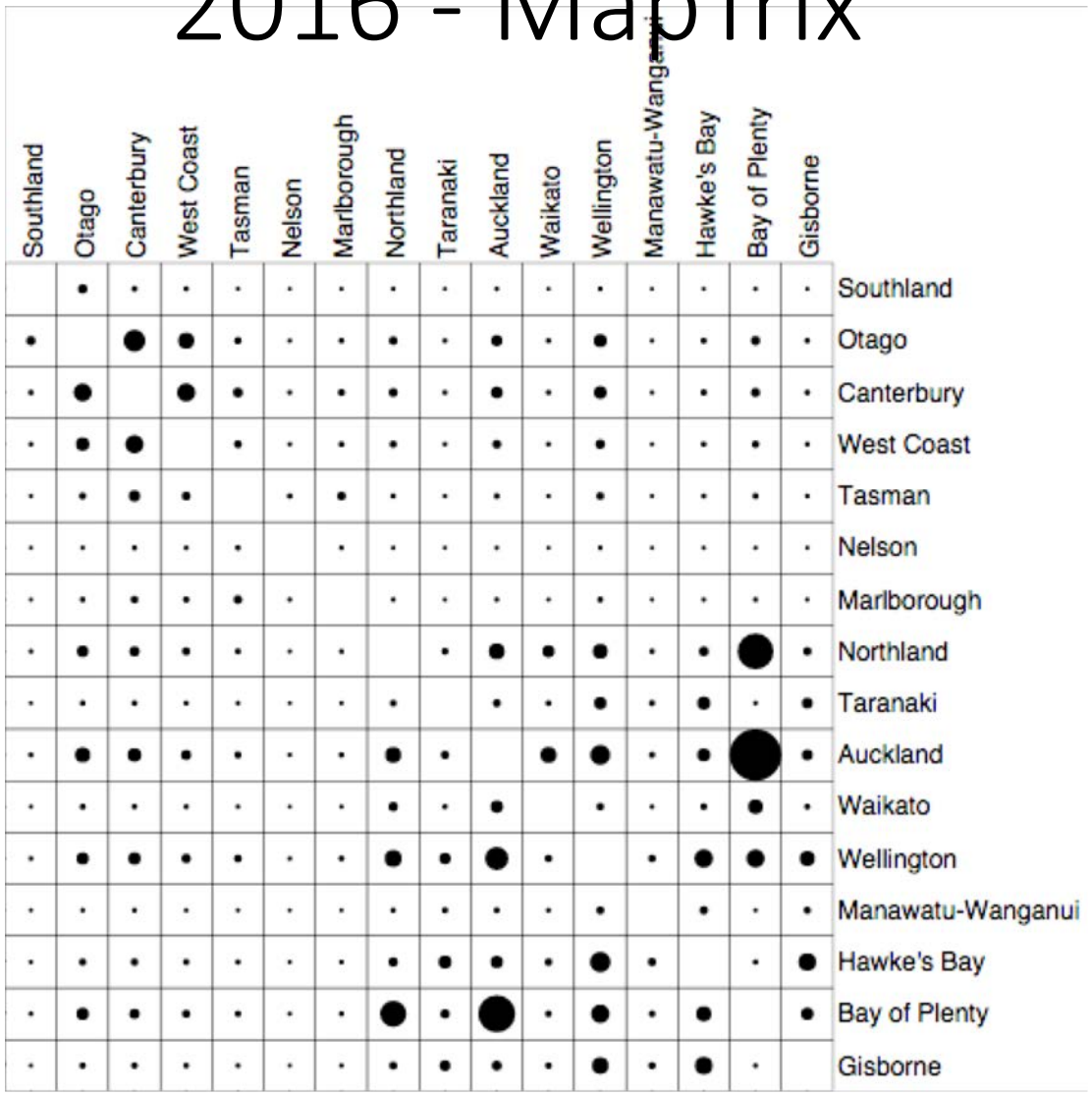
Intuitive
but not scalable

OD Matrix

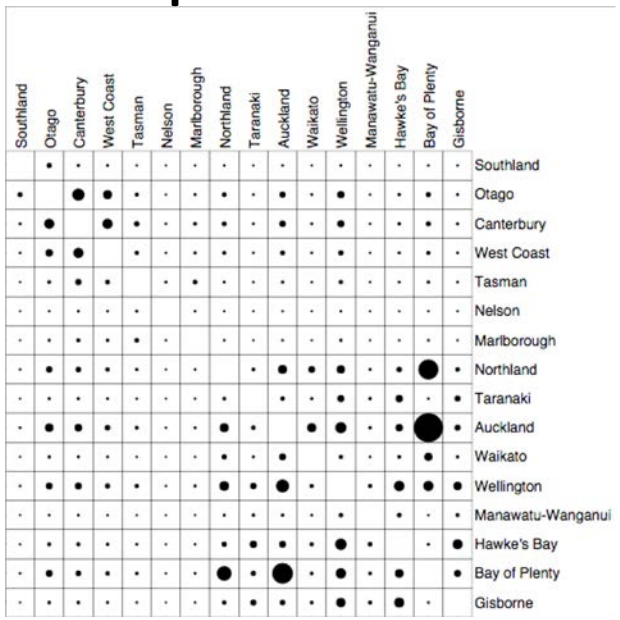
	WA	NT	QLD	SA	NSW	VIC	TAS
WA		2.5K	9.7K	3.0K	9.0K	8.4K	1.5K
NT	2.0K		4.2K	1.7K	2.8K	2.6K	0.3K
QLD	9.2K	5.8K		5.8K	41.4K	19.6K	3.2K
SA	2.8K	2.5K	5.0K		5.2K	6.0K	0.7K
NSW	8.2K	3.1K	37.1K	5.8K		21.8K	2.2K
VIC	9.5K	2.6K	20.8K	7.9K	24.8K		3.5K
TAS	1.6K	0.3K	2.9K	0.6K	2.2K	2.6K	

Scalable
but missing spatial context

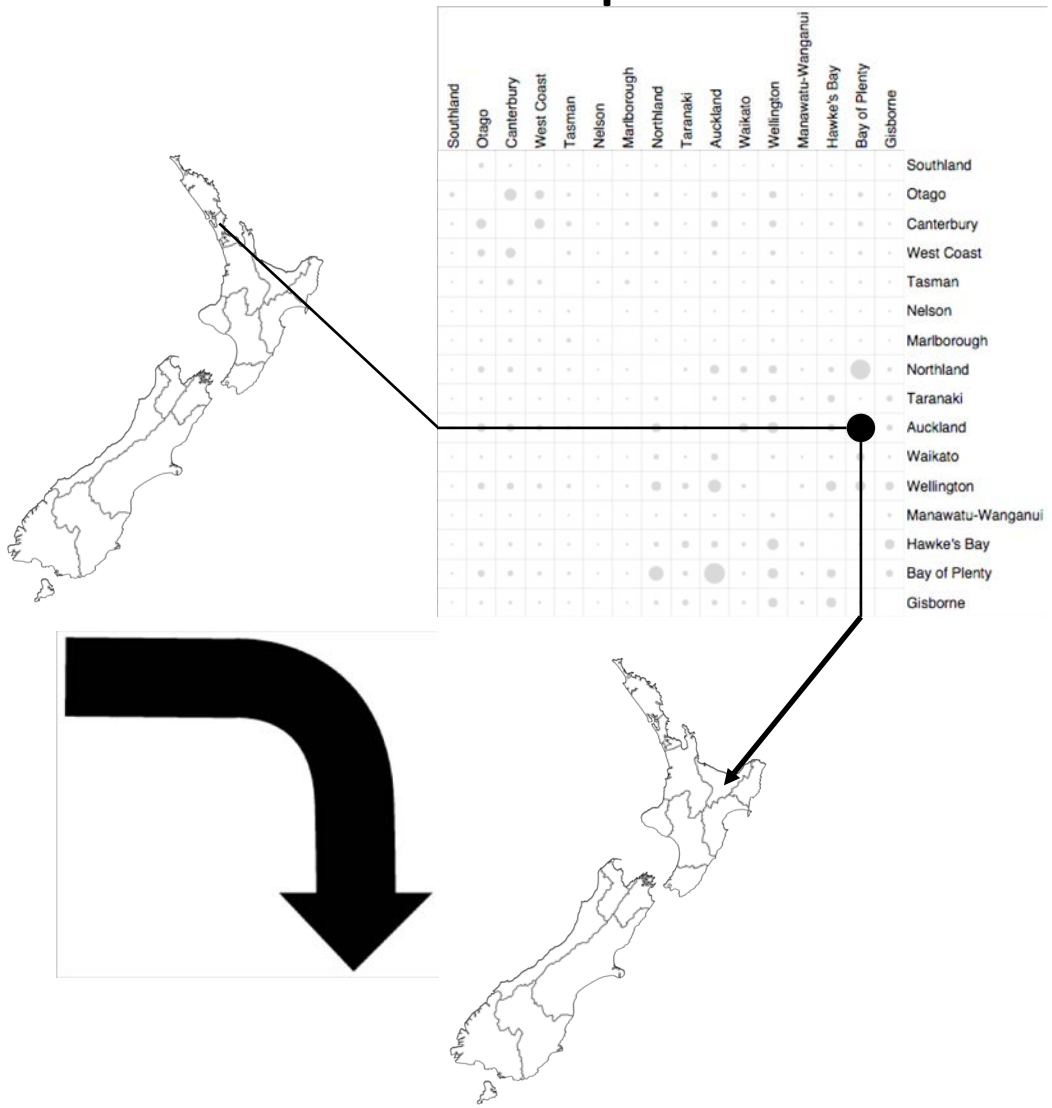
2016 - MapTrix



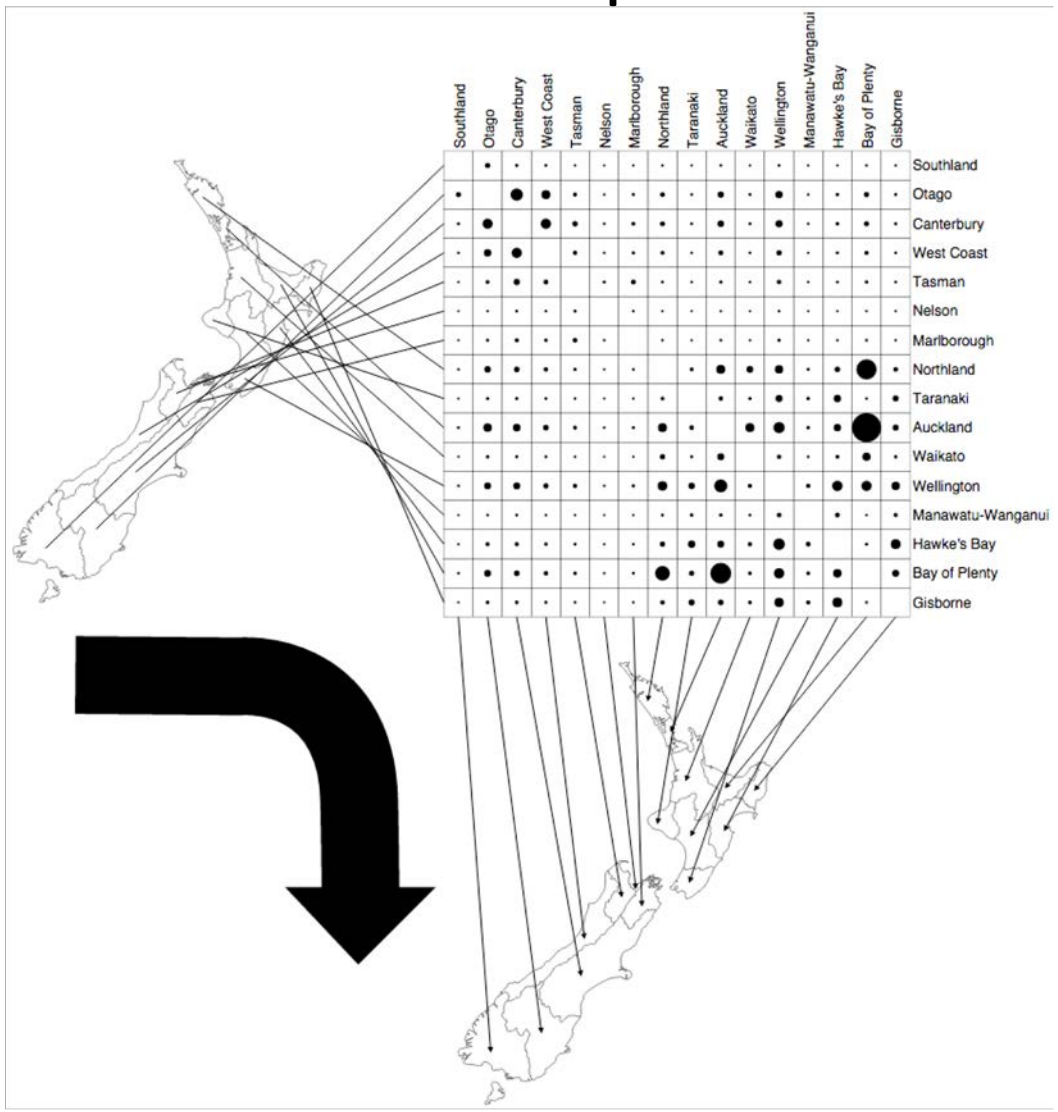
2016 - MapTrix



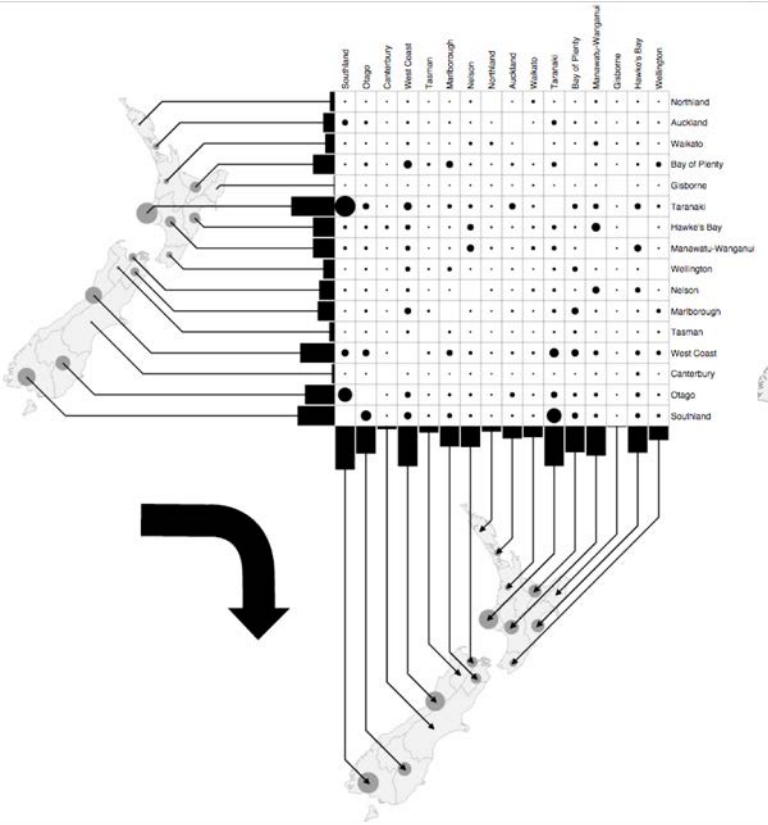
2016 - MapTrix

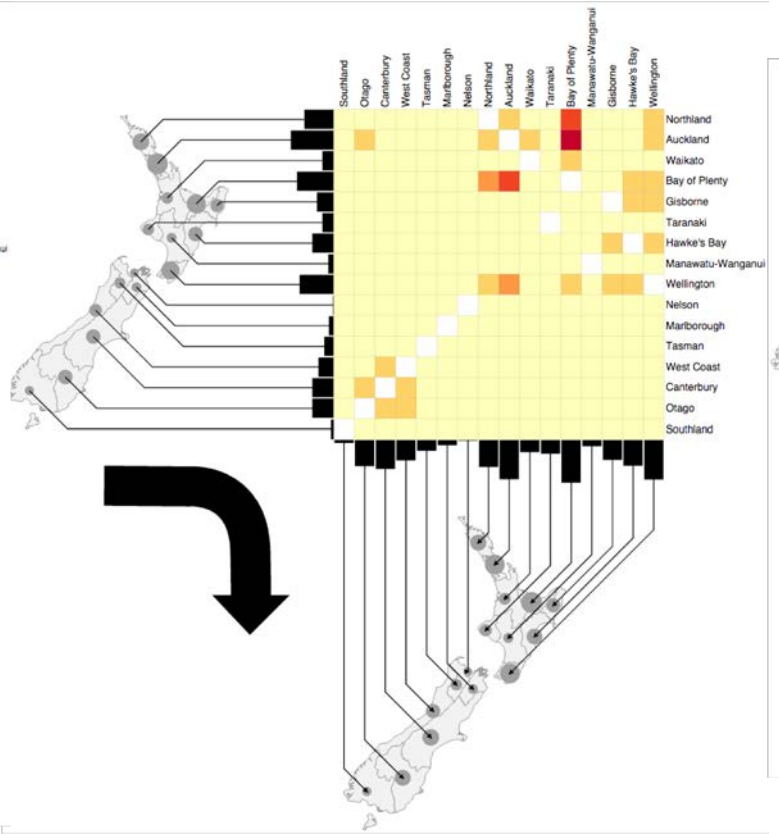


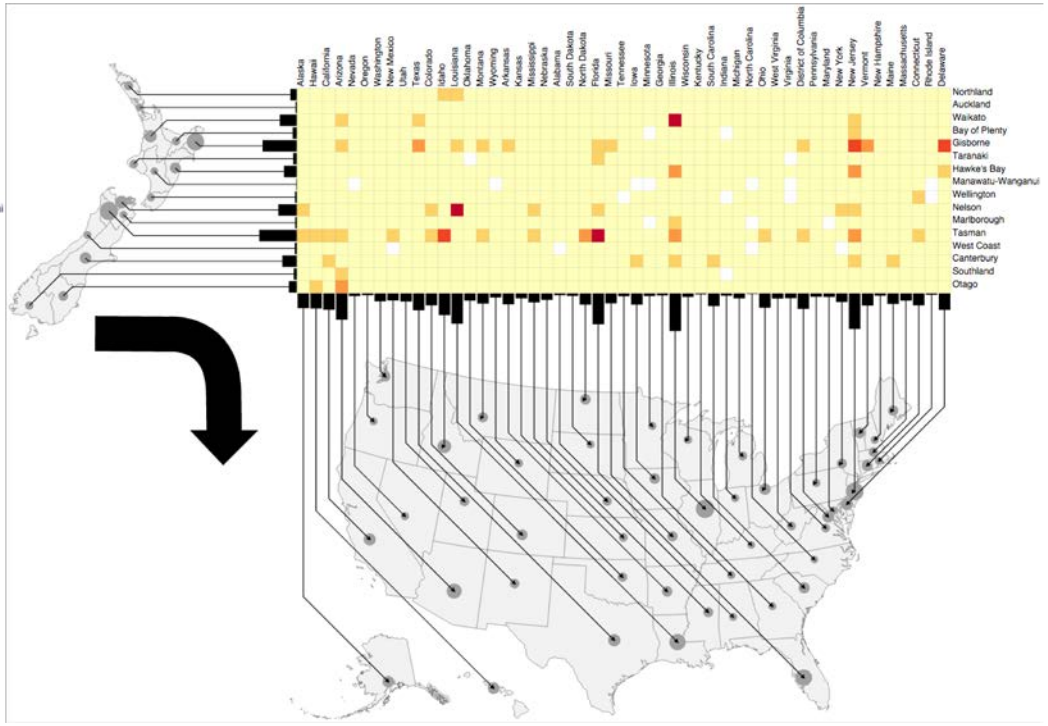
2016 - MapTrix



2016 - MapTrix





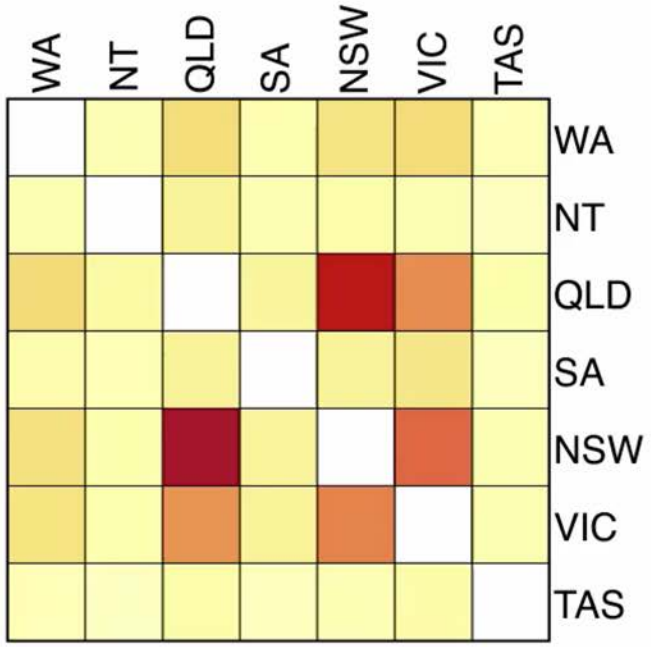


☑ No-crossings within leader lines

☒ Rows and columns are in different orders

☑ Capable of presenting flows from ***origins*** to ***different destinations***

2016 – MapTrix Final Design

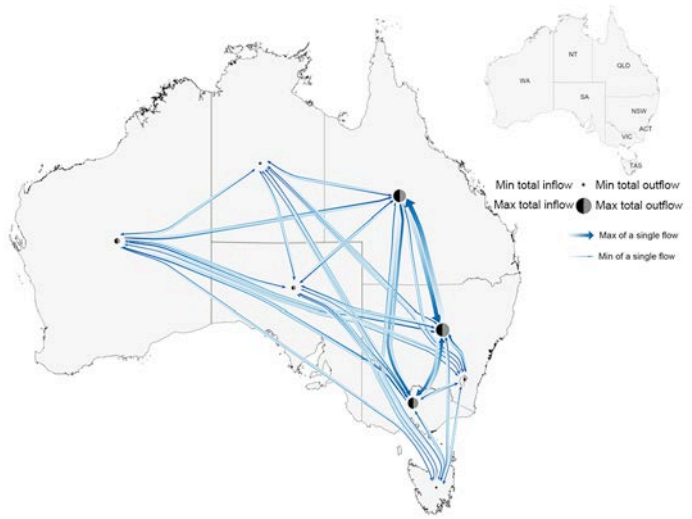


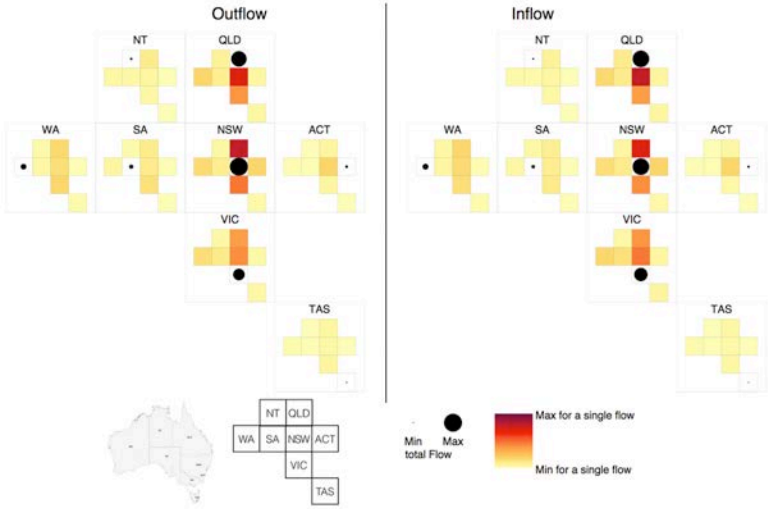
VIS 2016

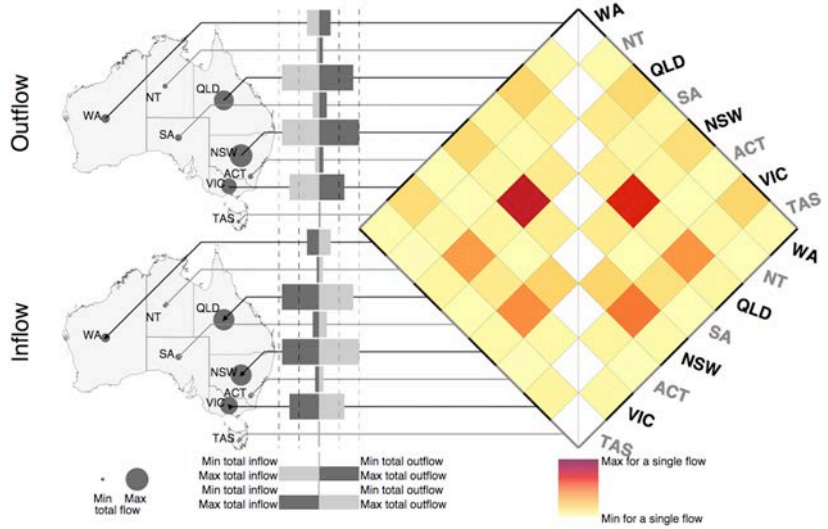
Honorable Mention Award

☑ Keep origins and destinations in the same order

User study





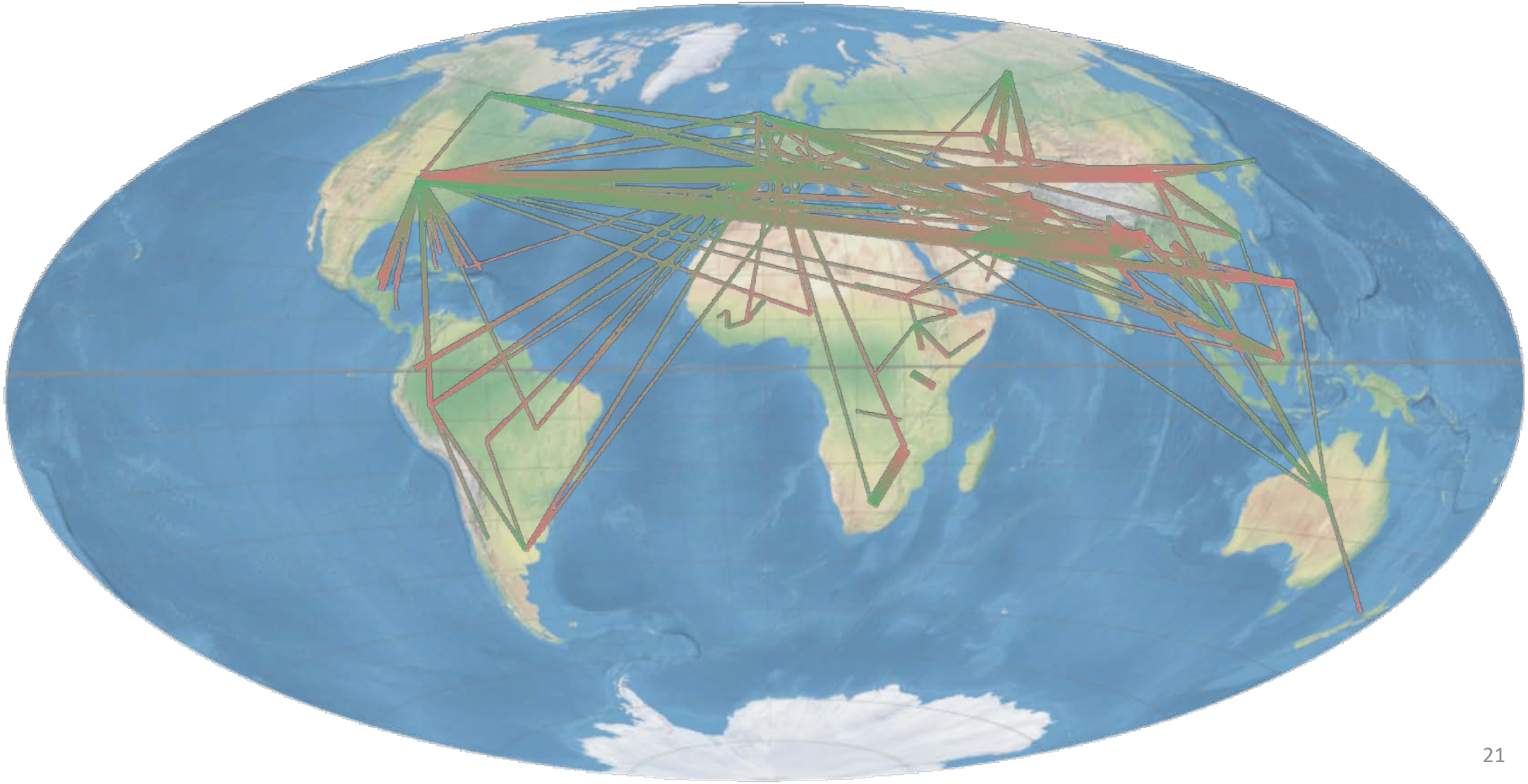


- All perform well in the small data set (AU).
- MapTrix and OD Maps had better performance than flow maps in larger data sets.

Immersive Environments

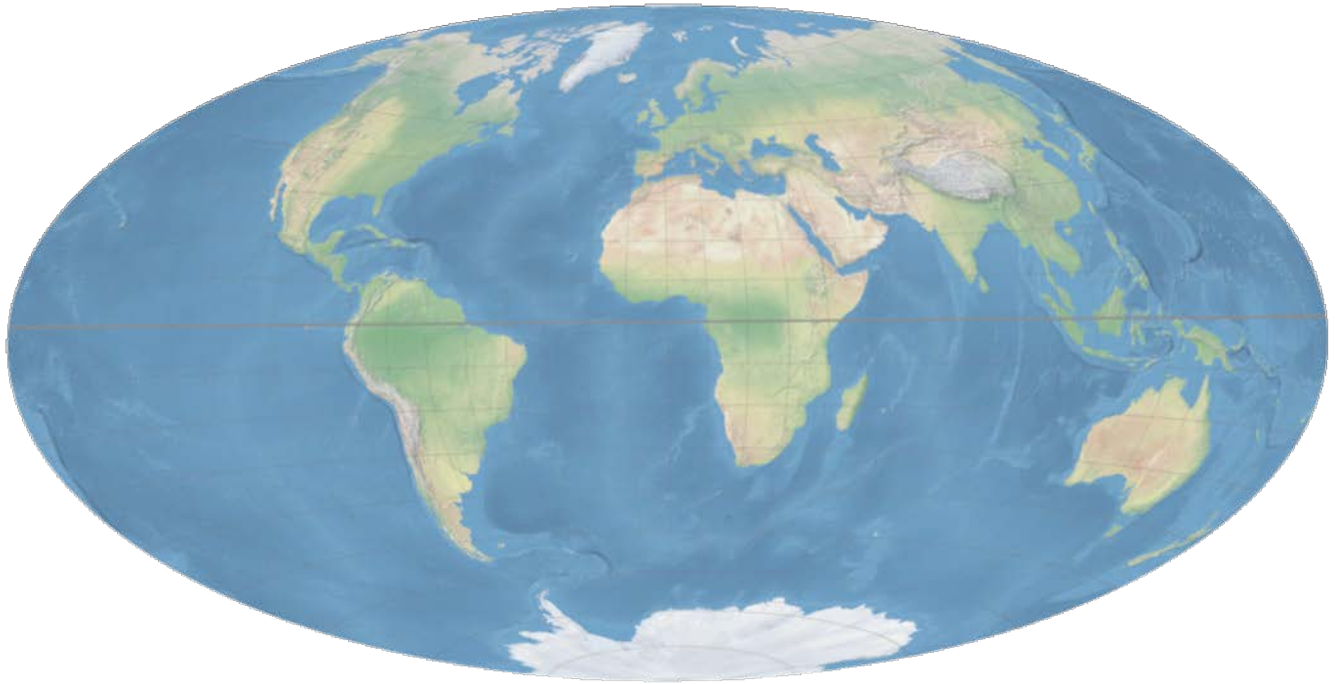
Prepare for a future without physical screens.

Flow Map

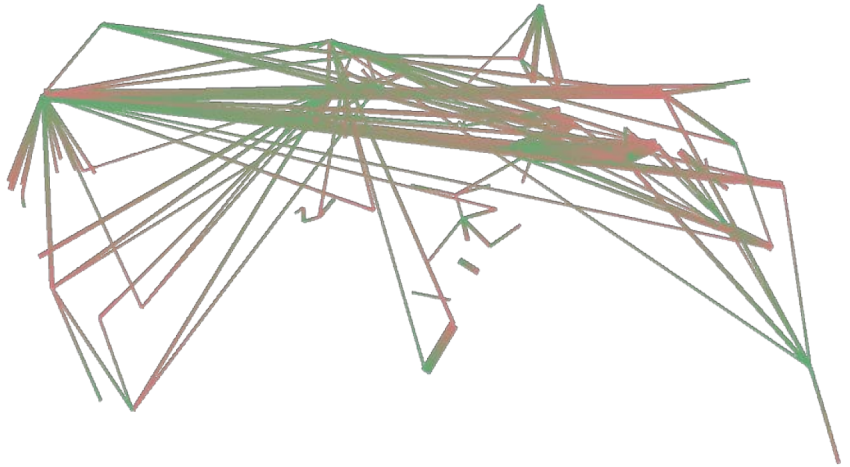


Flow Map

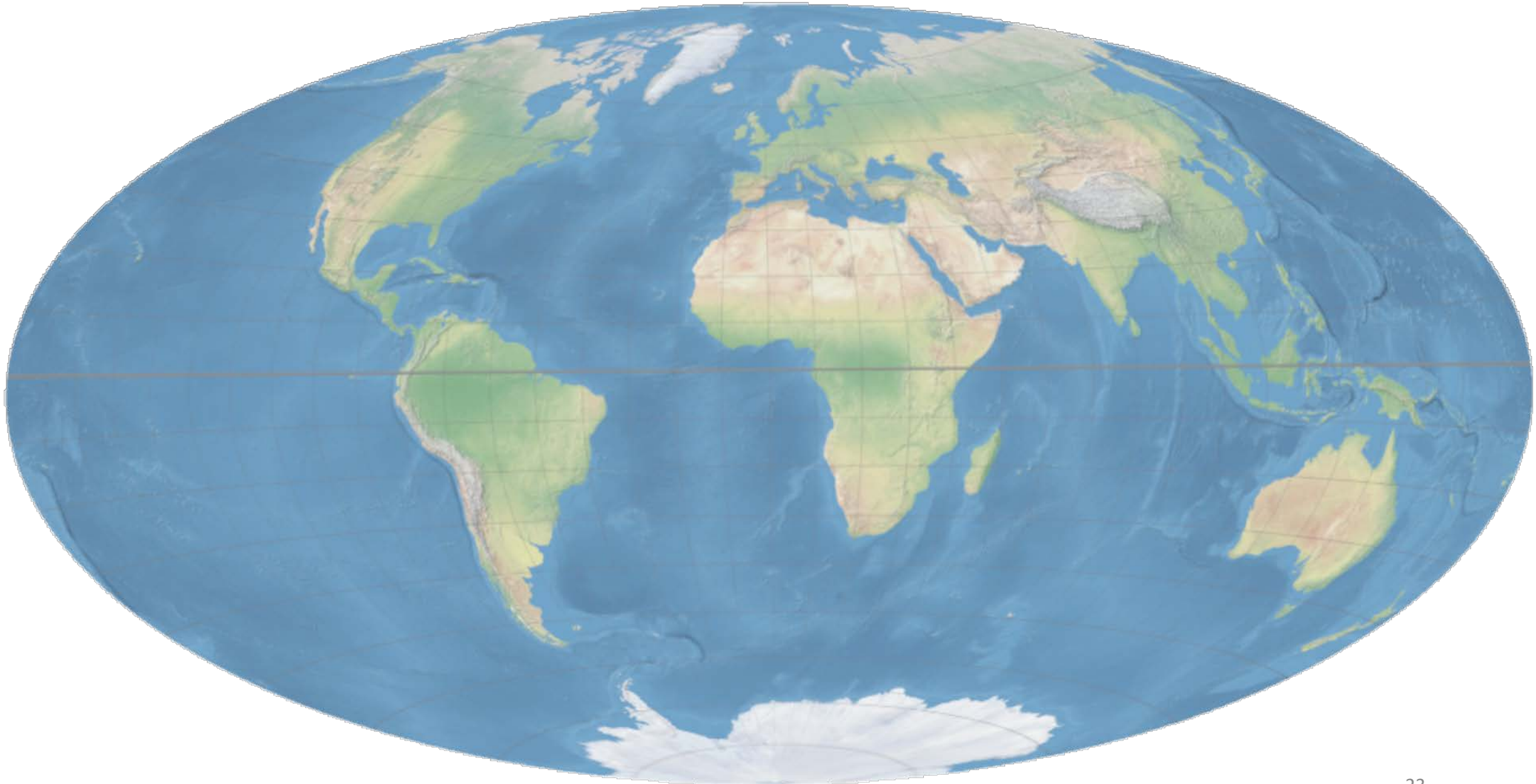
- Two components [Dübel *et al.*, 2014]



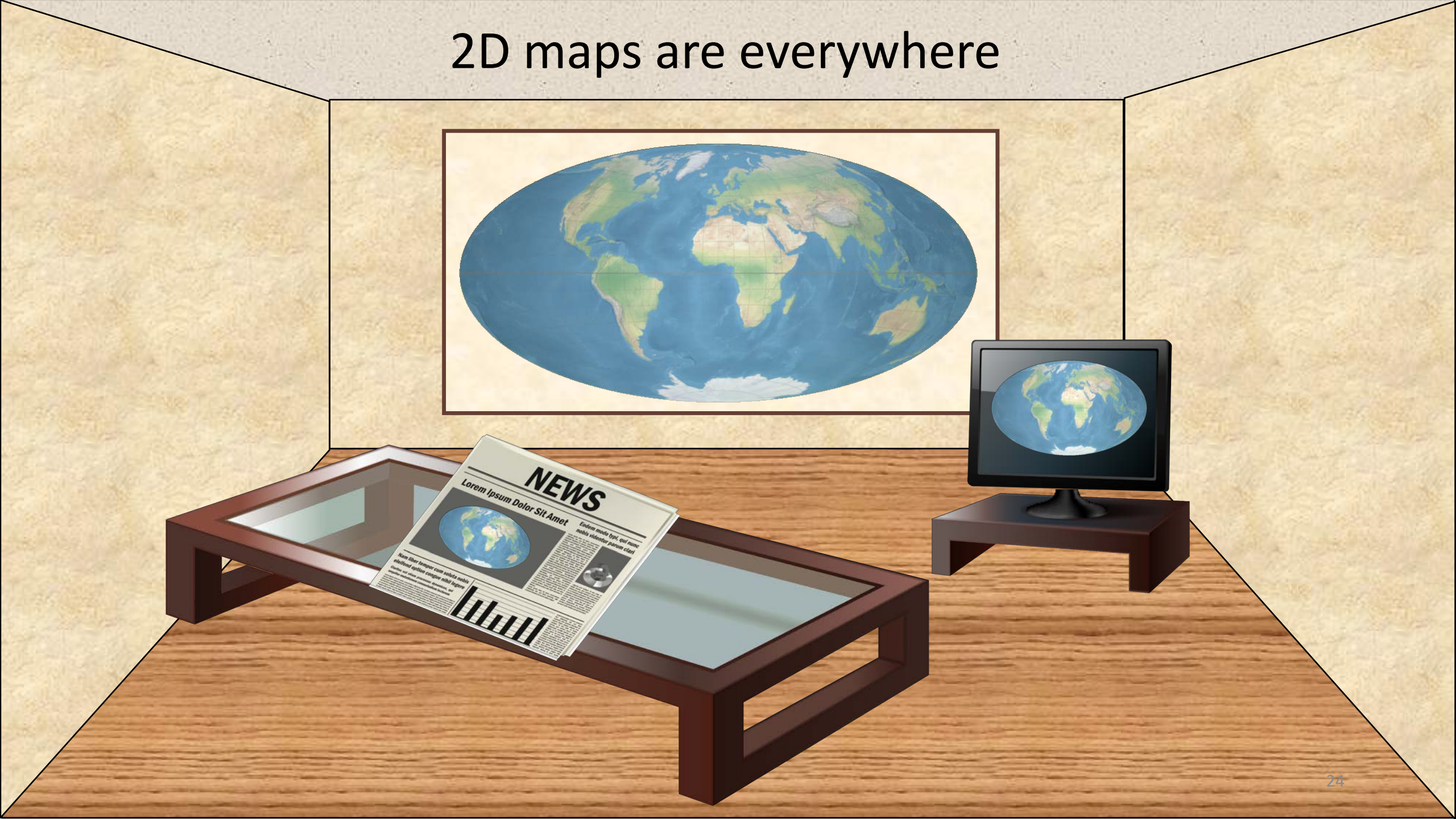
Reference space



Flows

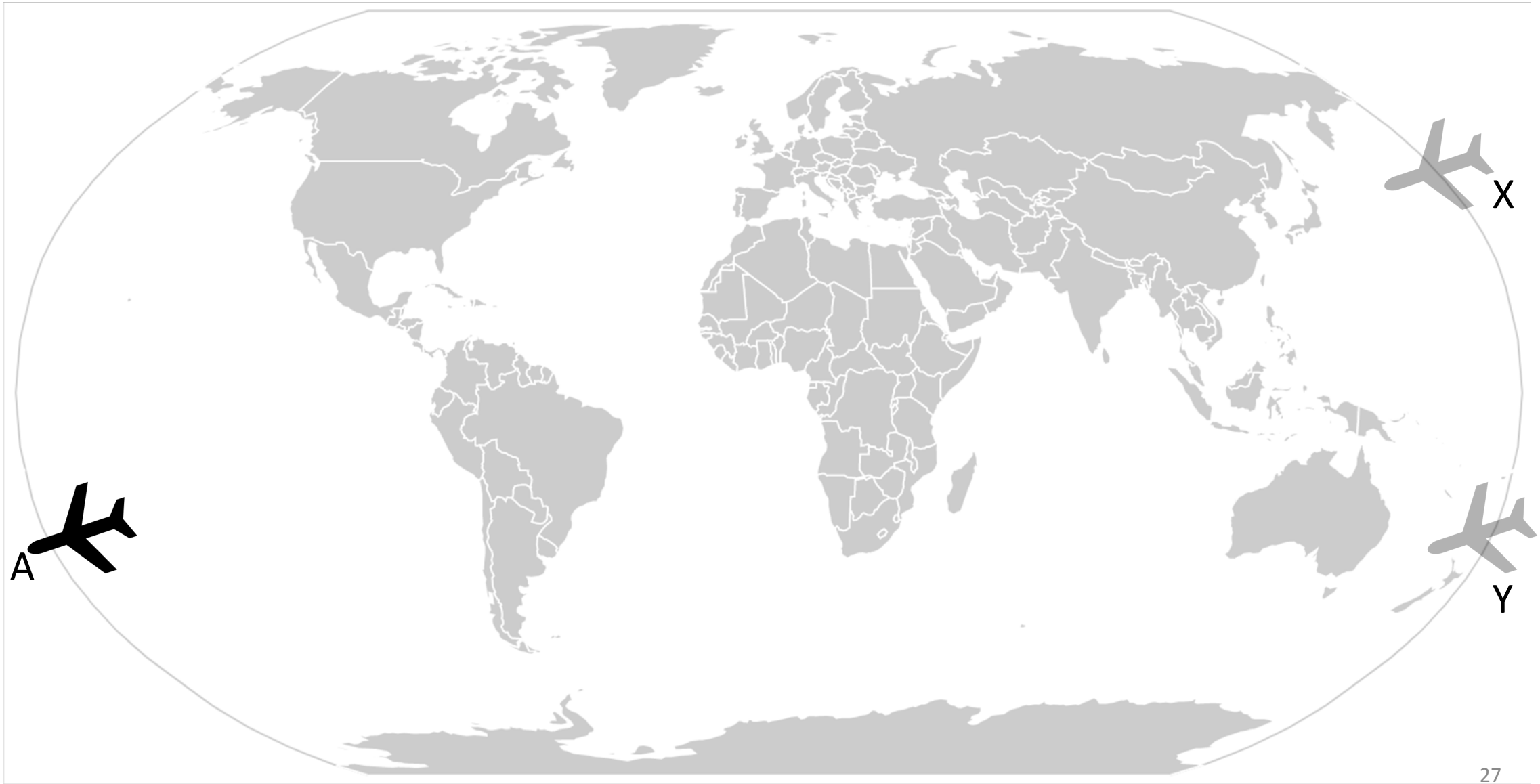


2D maps are everywhere

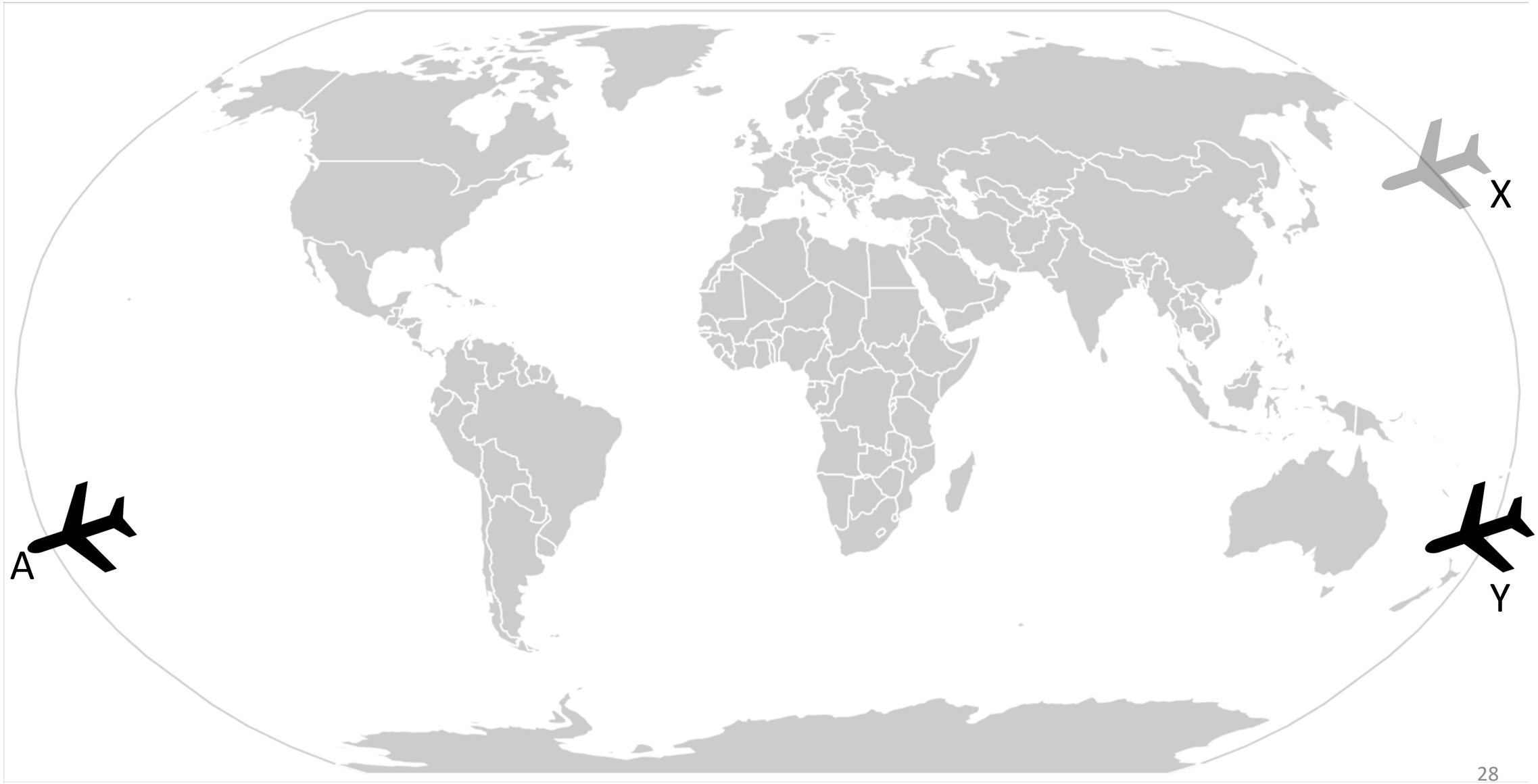


Distortion

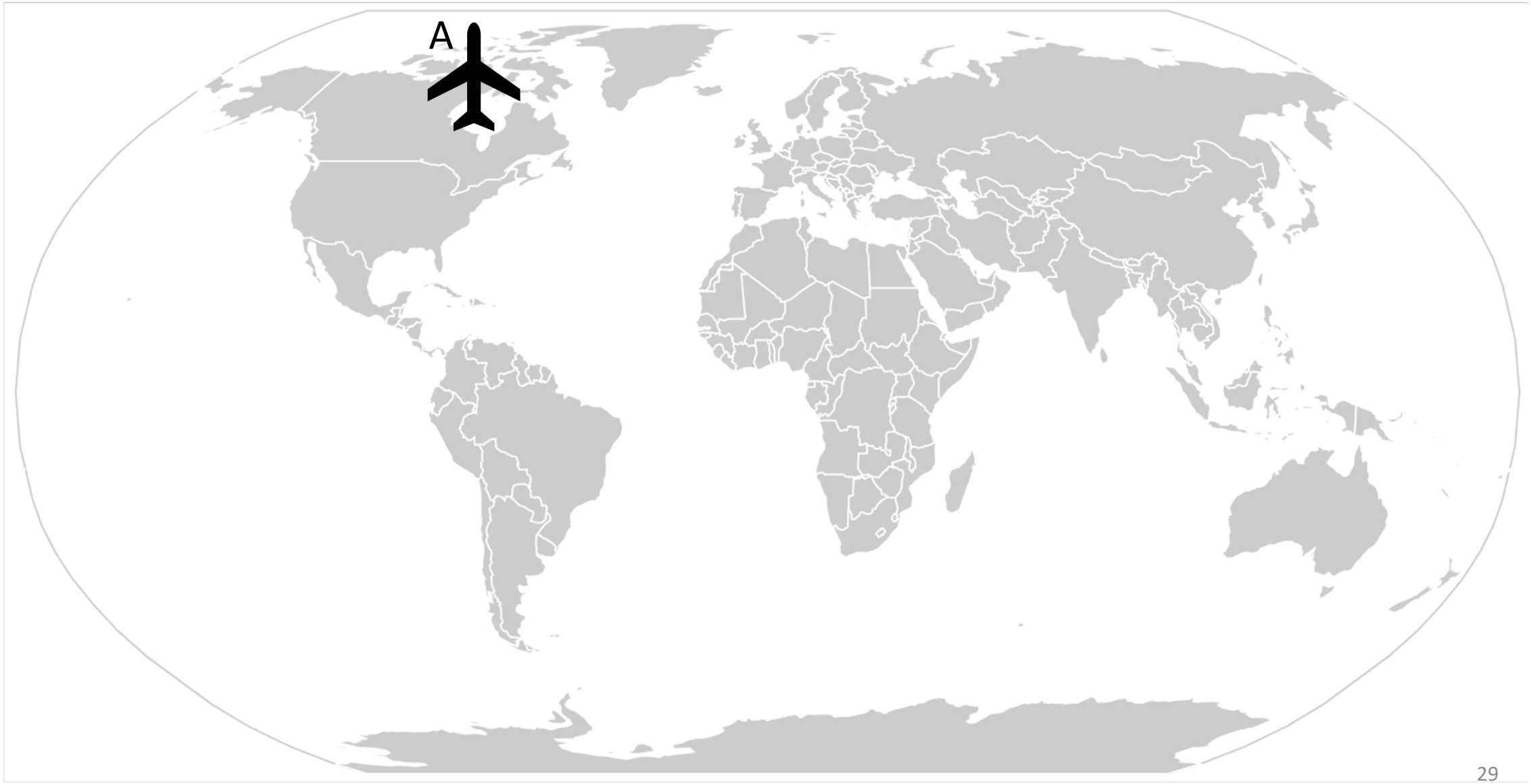
Image from [Jenny *et al.*, 2017]


A
X
Y

Discontinuity [Hruby *et al.*, 2013 & 2018]



Discontinuity [Hruby *et al.*, 2013 & 2018]



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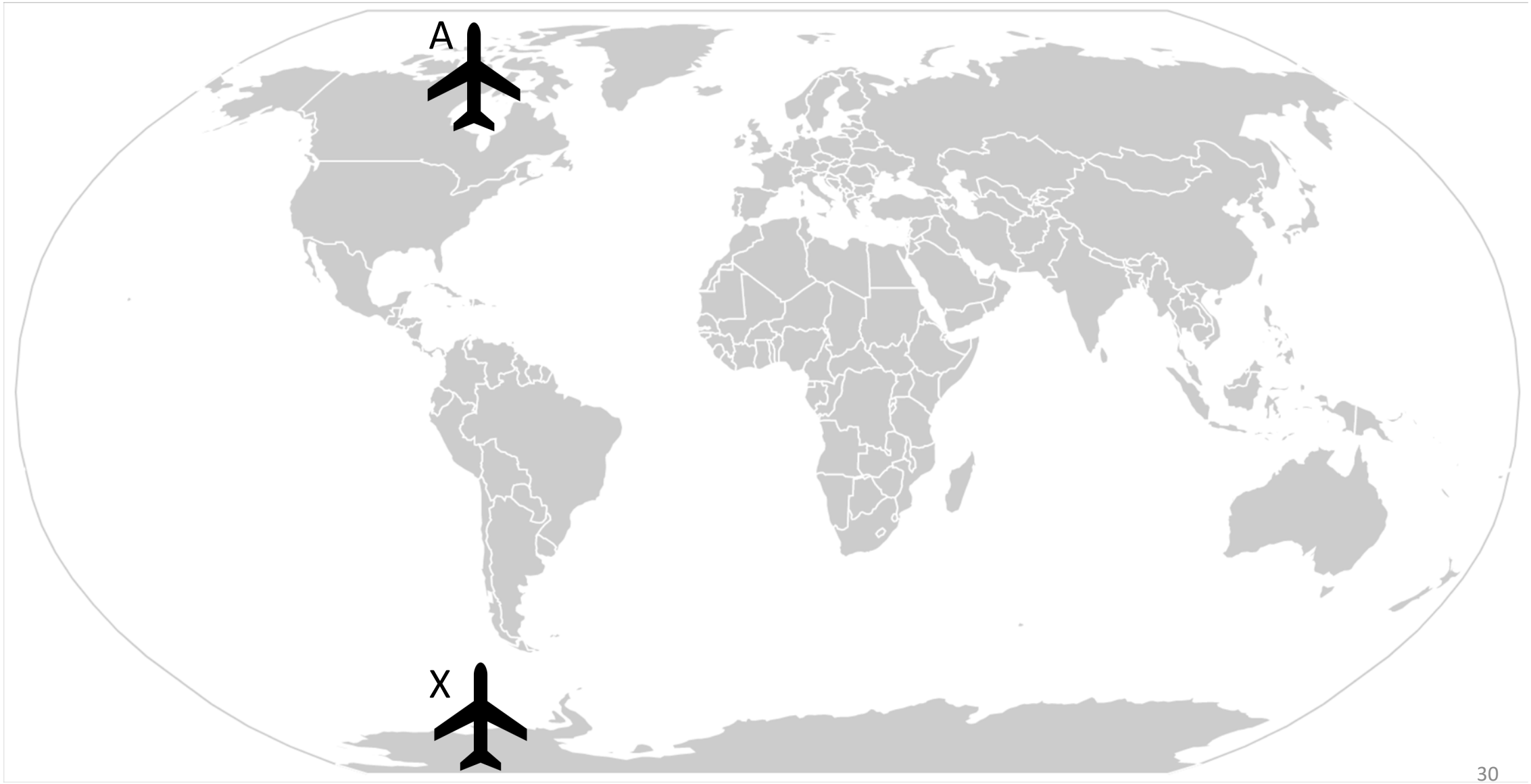
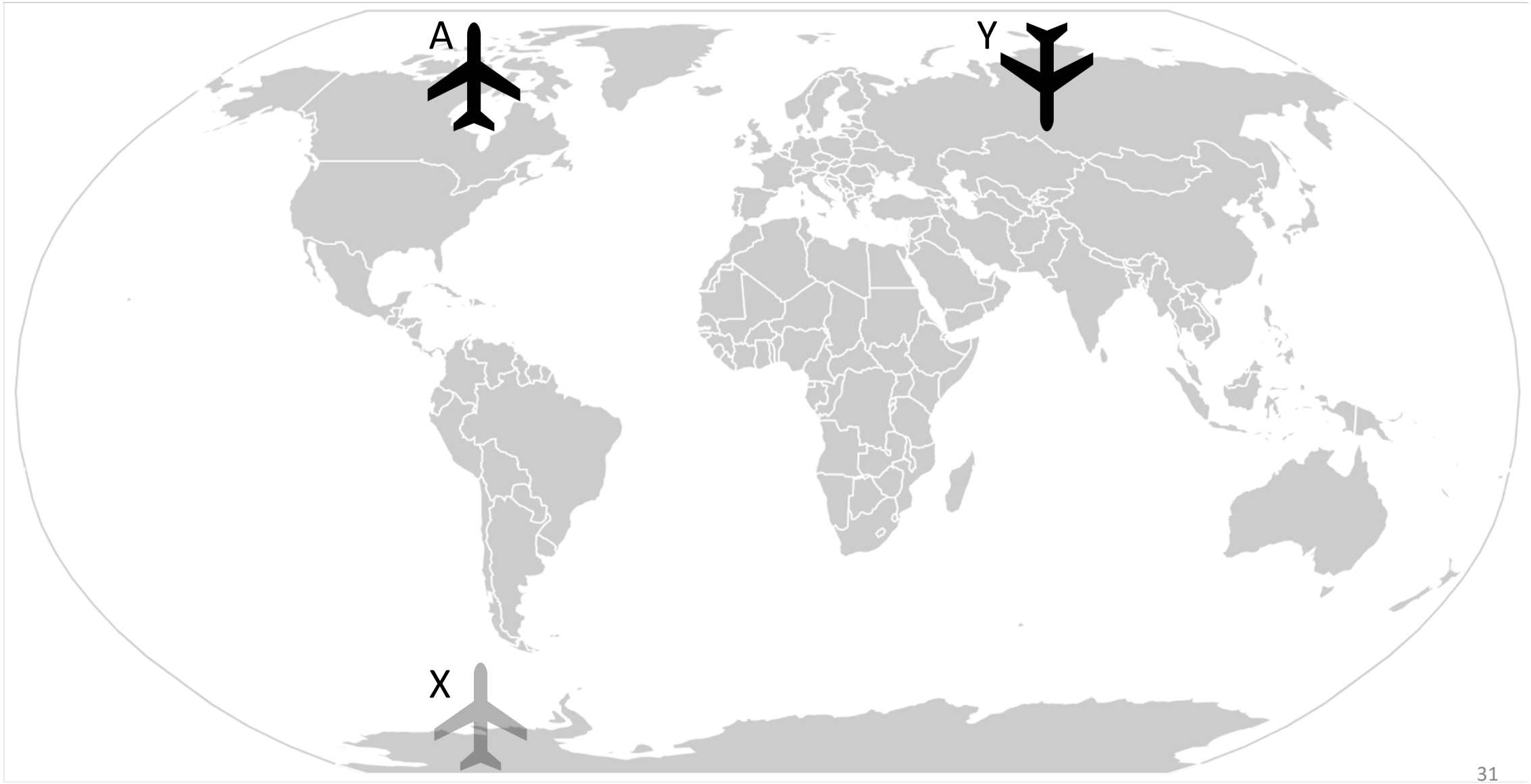
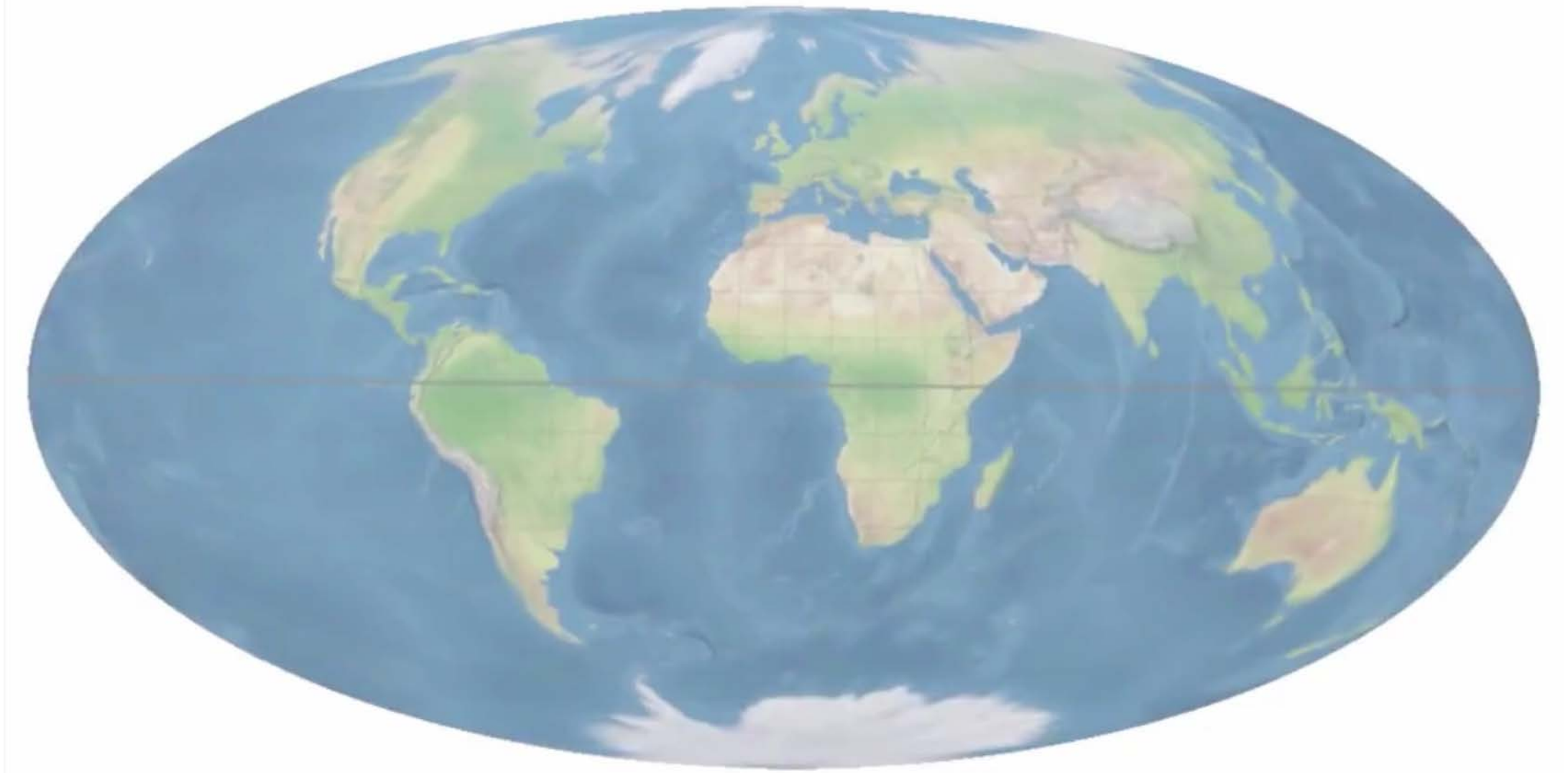
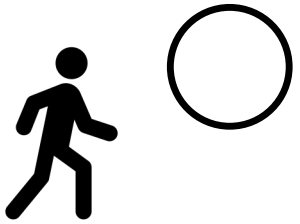


Discontinuity [Hruby *et al.*, 2013 & 2018]



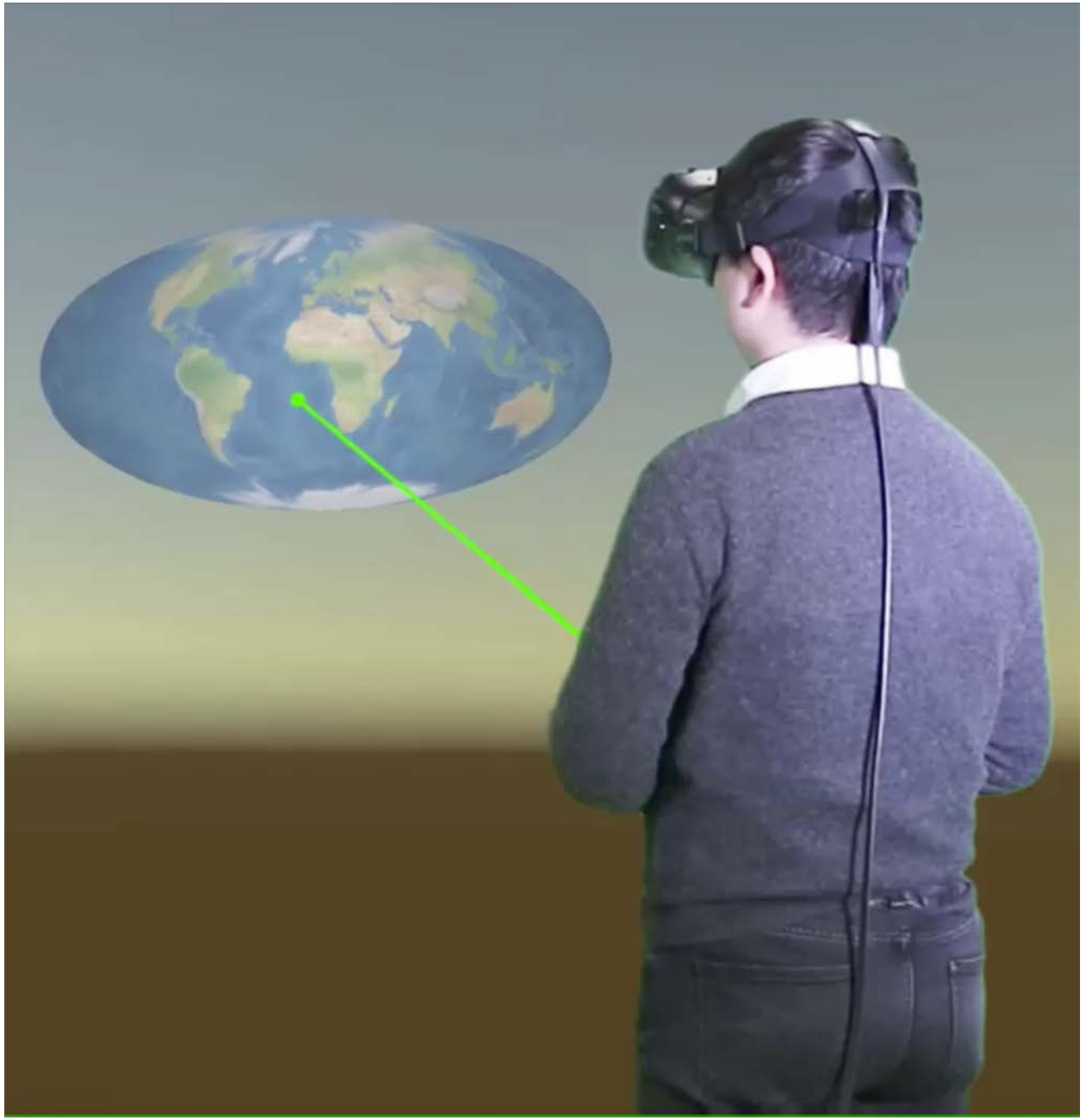
Why not try the other way?





Exocentric globe

- Pros
  - No projection distortion
- Cons
  - Limited filed of view (FoV)
    - Hemisphere
  - High perceptual distortion on edges
- Geo-rotation
  - Compensation for FoV



Interactive flat map

- Pros
  - Whole world in FoV
- Cons
  - Projection distortion
  - Medium perceptual distortion
  - Discontinuity at edges
- Geo-rotation
  - Compensation for discontinuity and projection distortion

Other alternatives?

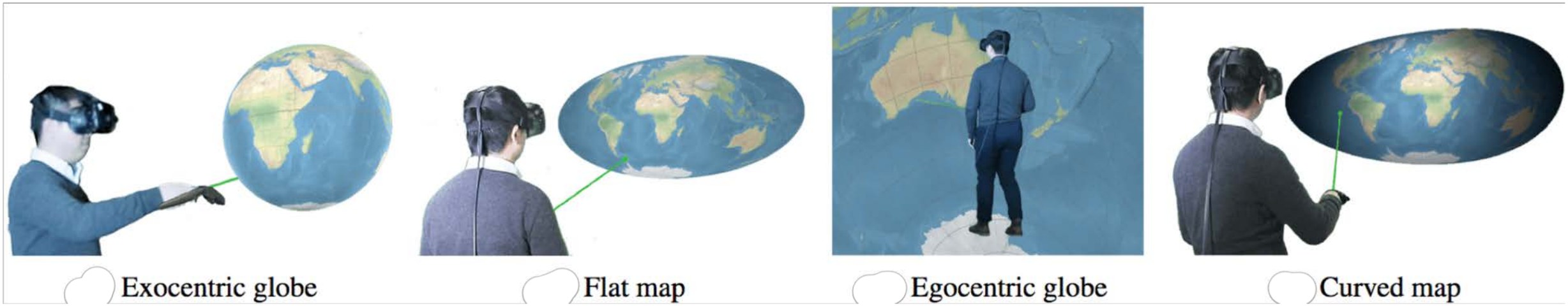
Egocentric globe

- Pros
  - No projection distortion
  - **Most immersive**
  - **Low perceptual distortion**
- Cons
  - **Motion sickness**
  - Limited filed of view (FoV)
    - Hemisphere
- Geo-rotation
  - Compensation for FoV

Curved map

- Pros
  - Whole world in FoV
  - **Low perceptual distortion**
- Cons
  - Projection distortion
  - Discontinuity at edges
- Geo-rotation
  - Compensation for discontinuity and projection distortion

Evaluation



- 32 participants
- 3 tasks
- 9 repetitions each task
- Training
  - Interaction training
  - Task training
- Statistical tests

Result summary

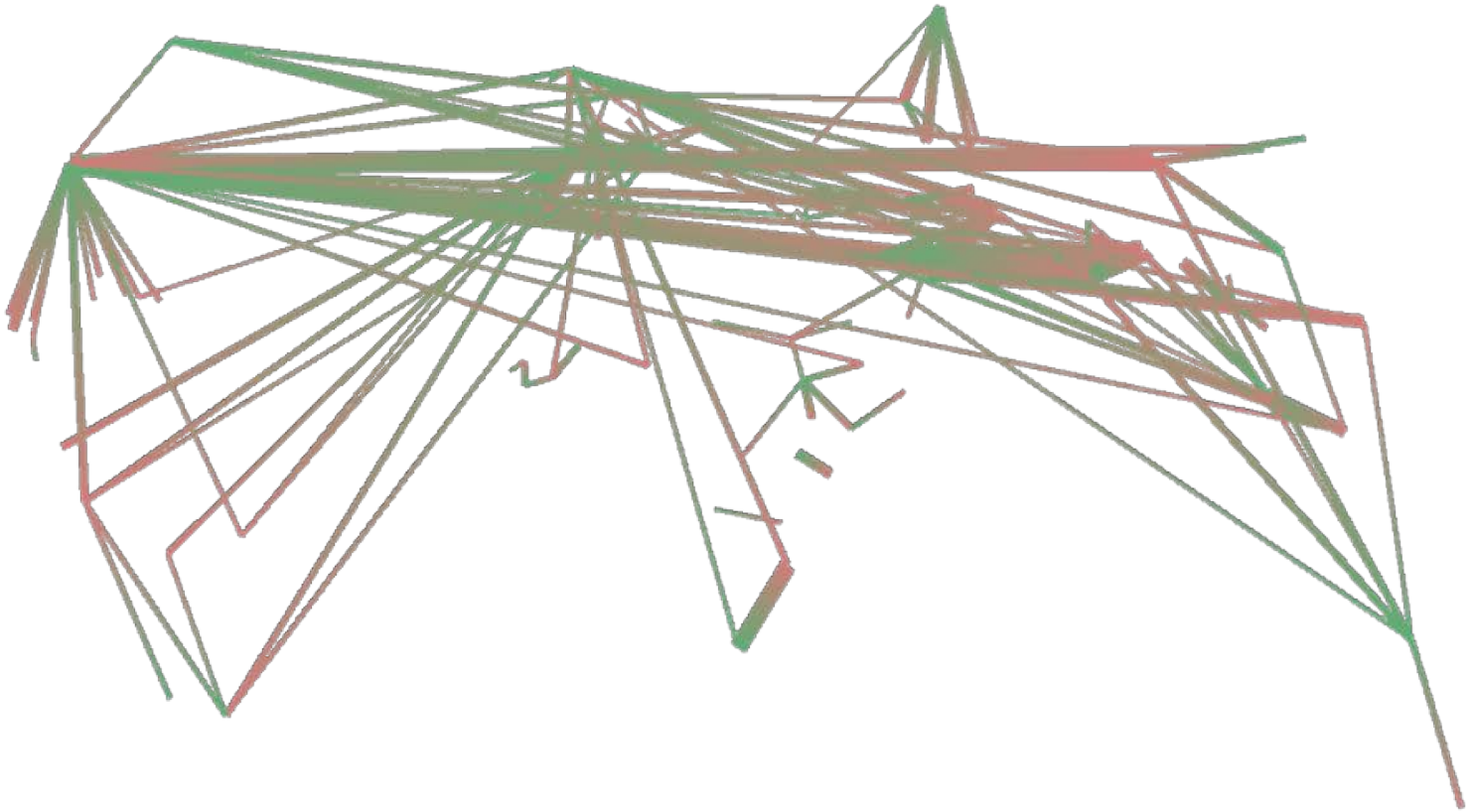
- *Exocentric globe* was overall the best.

- *Flat map* was time-efficient for area comparison.

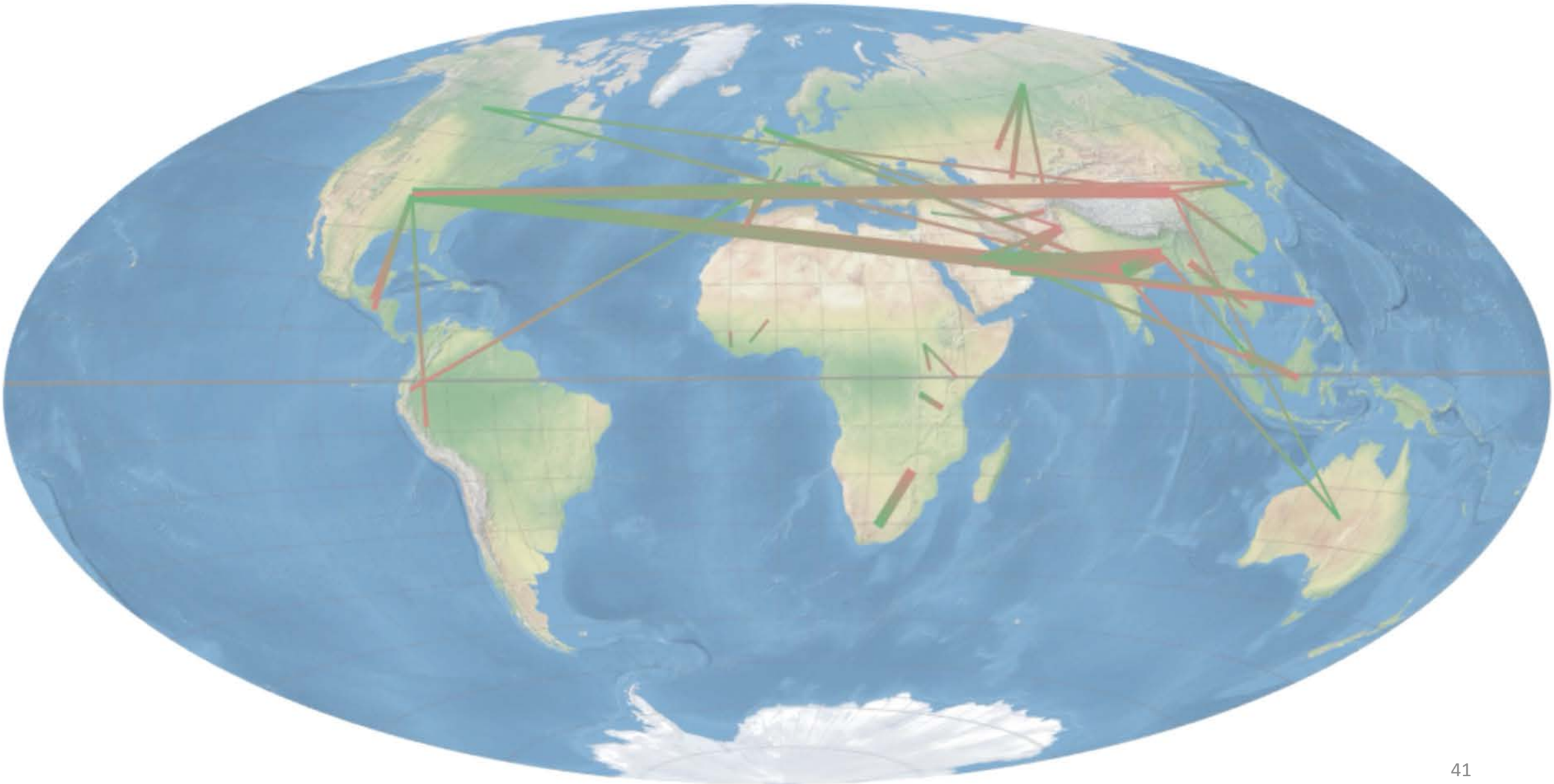
- *Egocentric globe* was not a good choice. Strong motion sickness was reported.

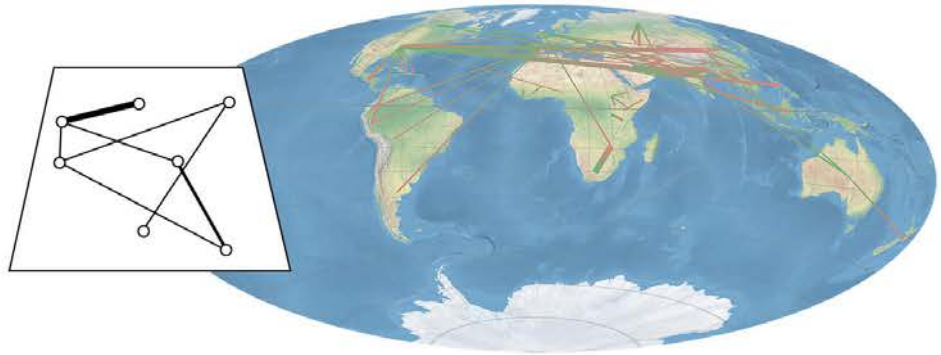
- *Curved map* was generally an improvement of flat map, but participant felt more motion sickness.

How to represent the flows?

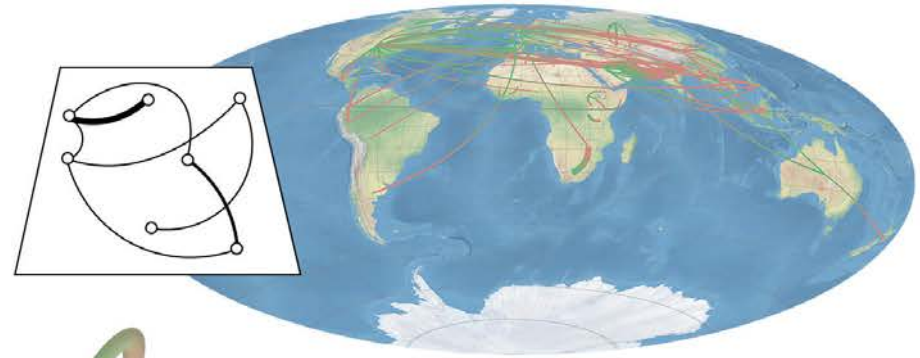


Flow maps

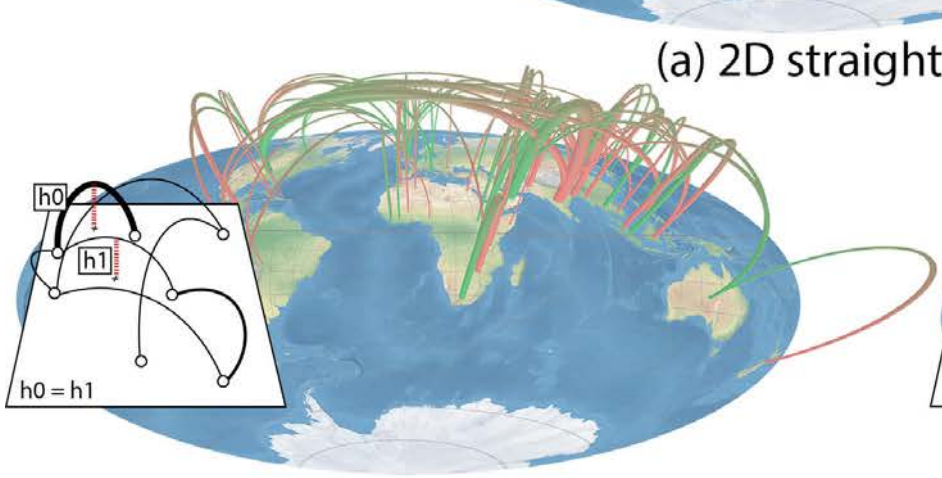




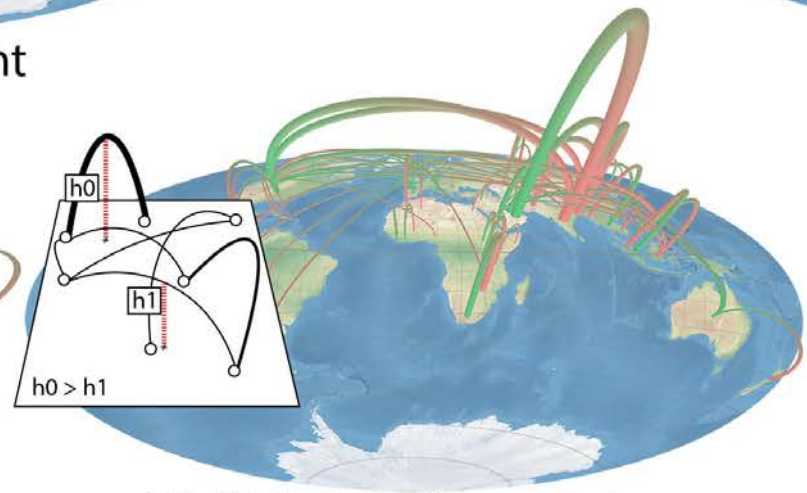
(a) 2D straight



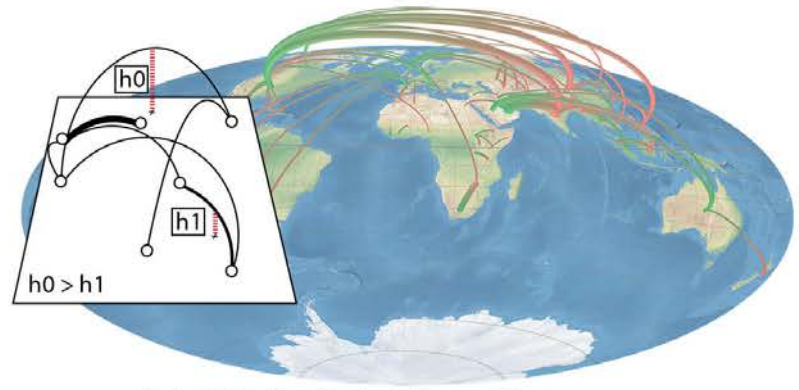
(b) 2D curve



(c) 3D constant height

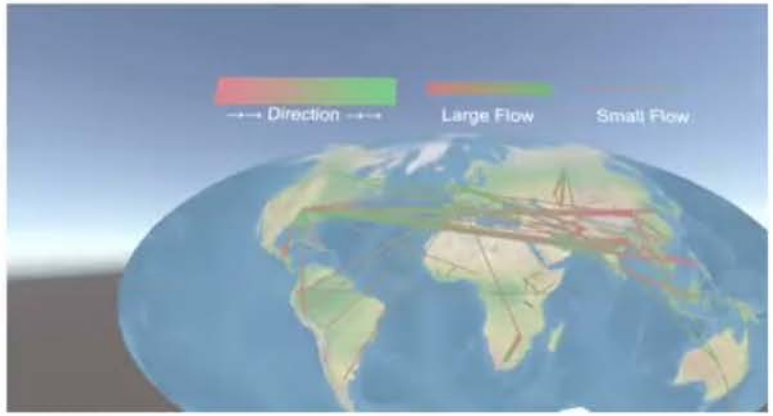


(d) 3D height for quantity

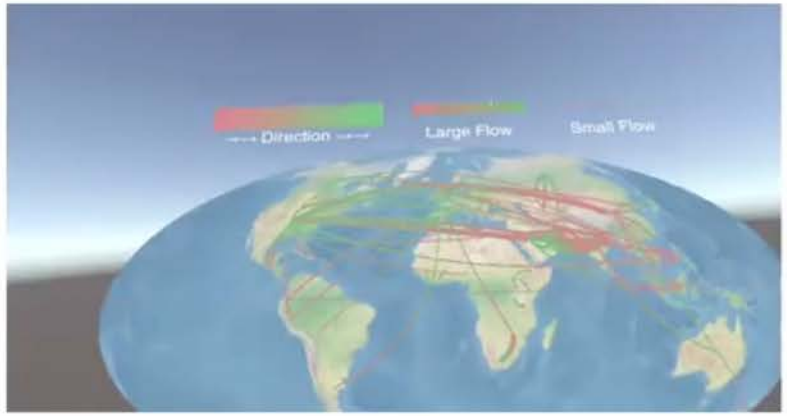


(e) 3D height for distance

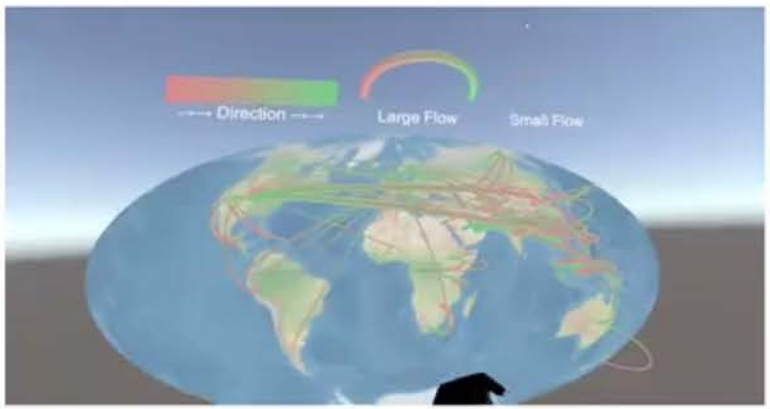
Study 1: 2D and 3D Flows on Flat Maps



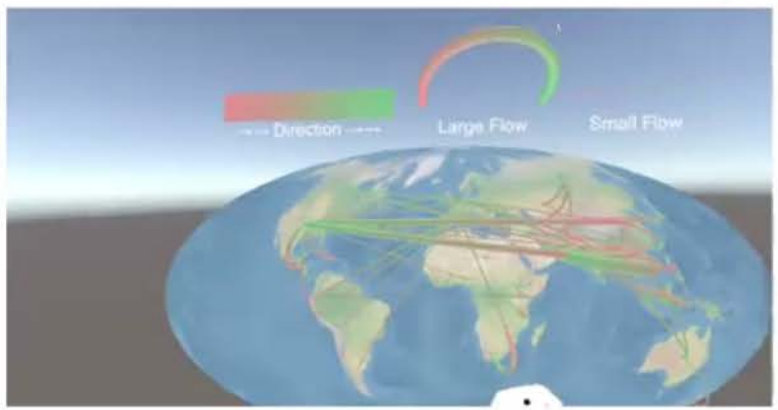
2D Straight



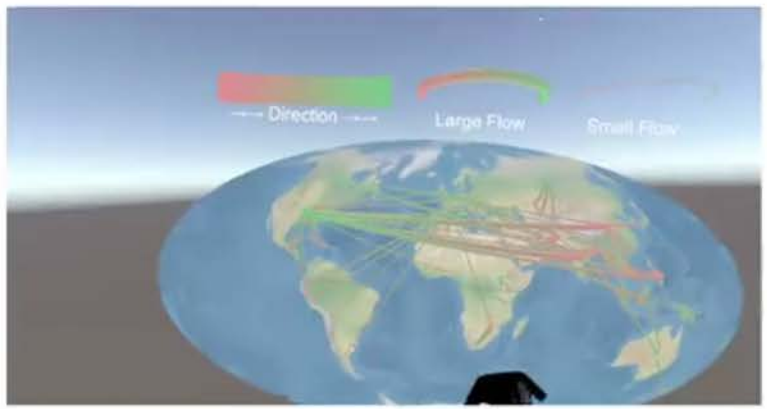
2D Curve



3D Constant



3D Quantity

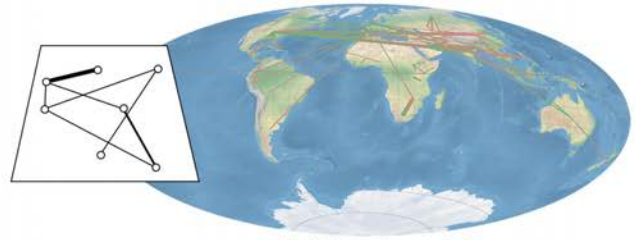


3D Distance

Key findings

3D Height for Distance

- *More accurate* than the other 3D conditions and both 2D visualisations. It was also the preferred visualisation.

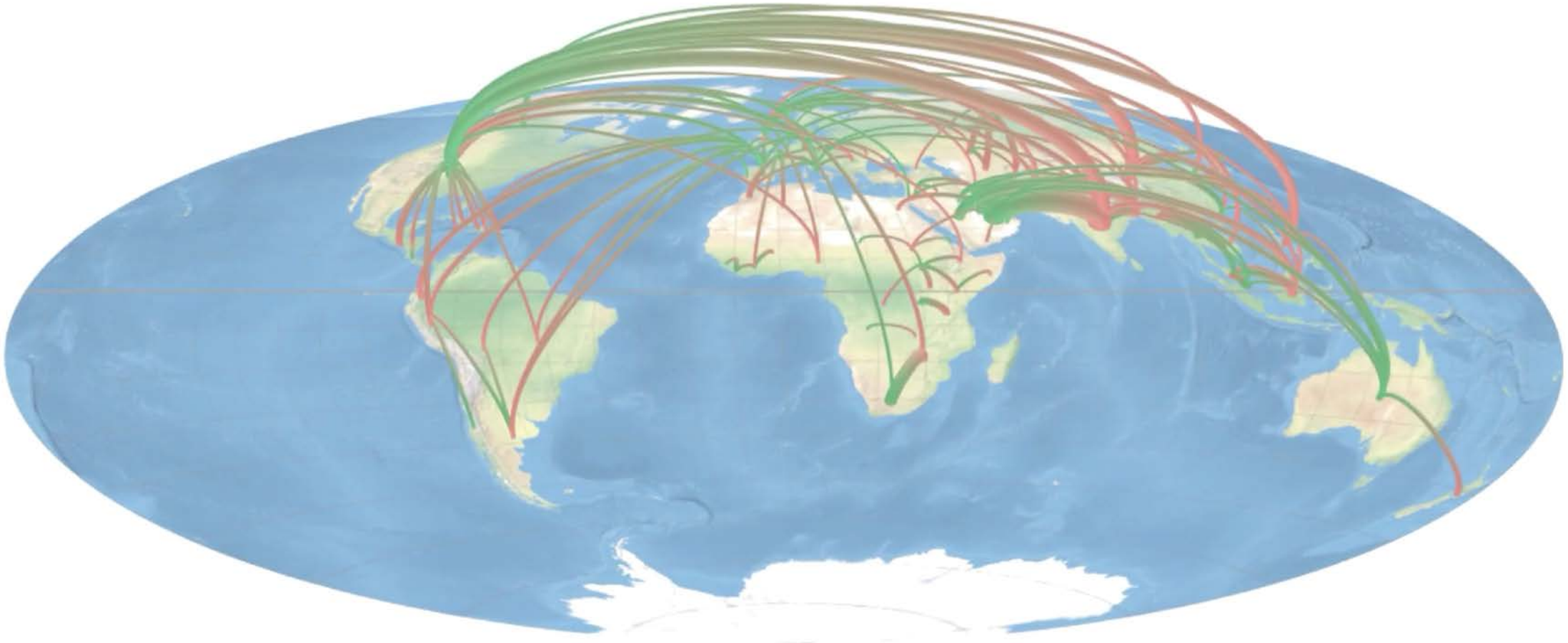


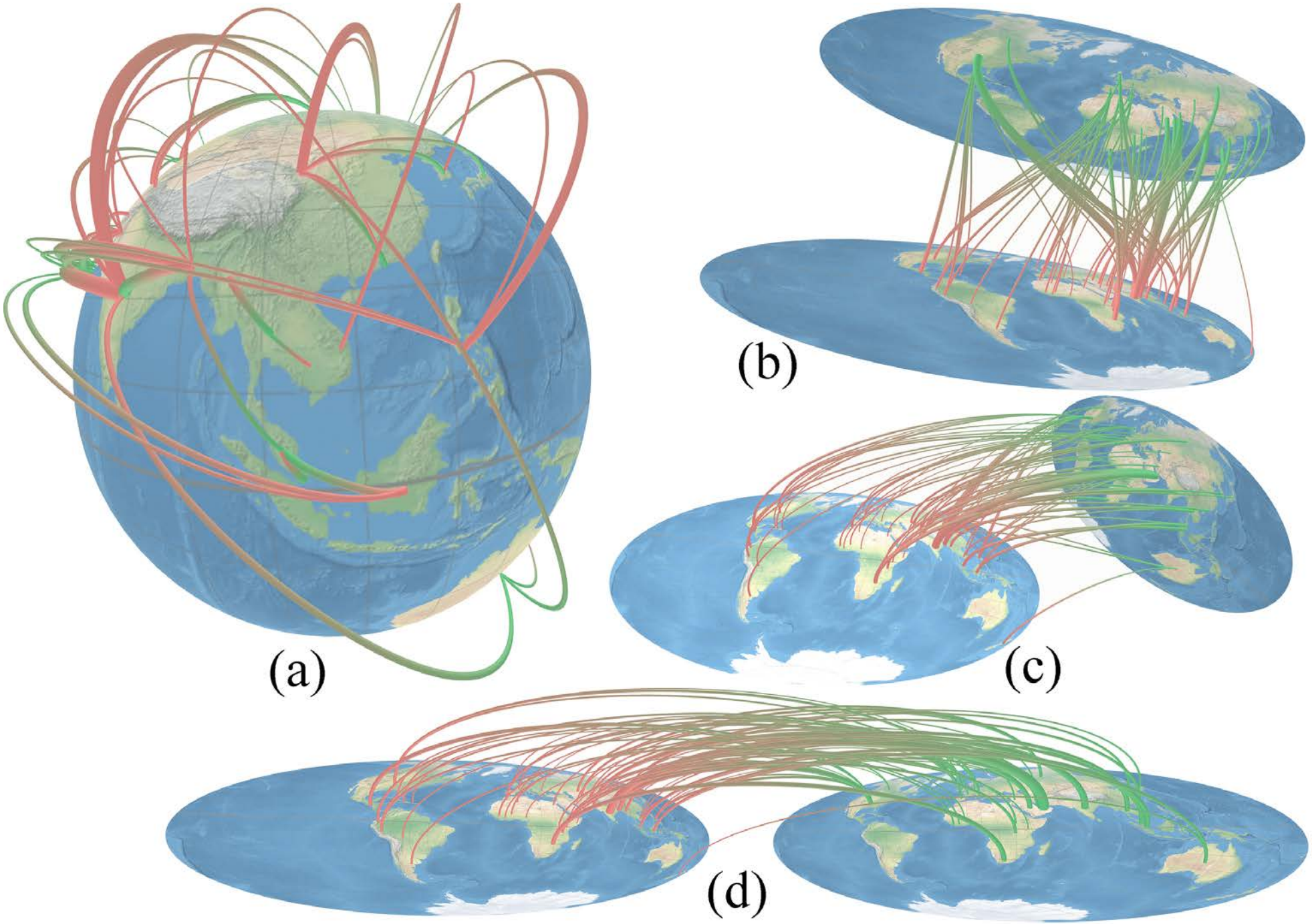
2D Straight

- *Was the fastest* in almost all conditions but least preferred. Less accurate than 3D distance.

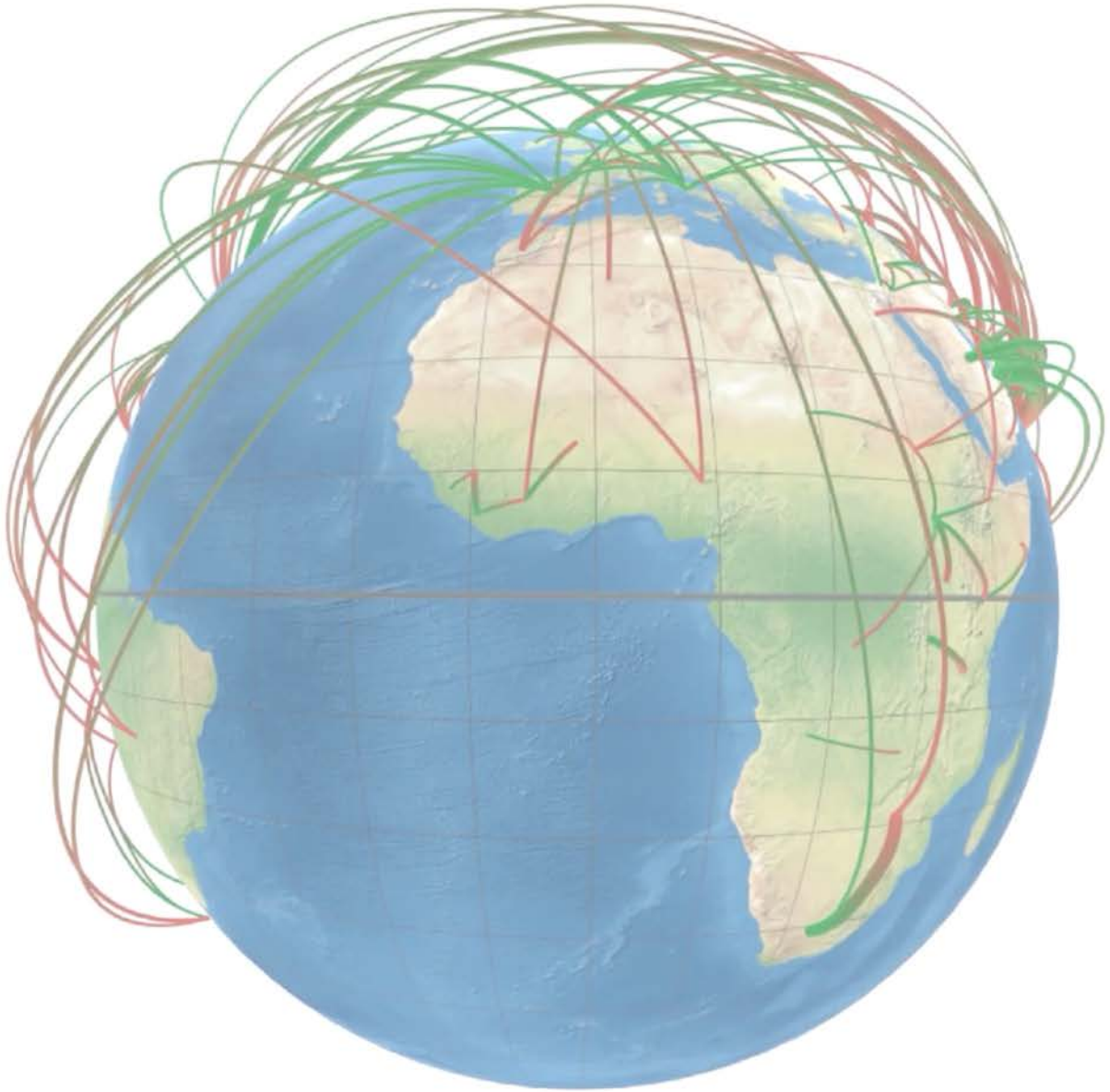
- Participants tended to look more often *from the side* in 3D conditions than in 2D conditions.
- Participants tended to *interact with the map more* in 3D conditions than 2D conditions.

Can flow maps be more 3D?

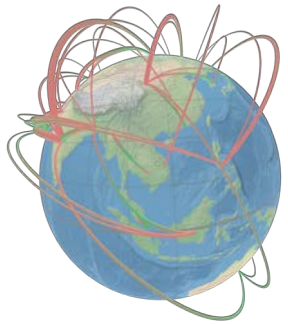


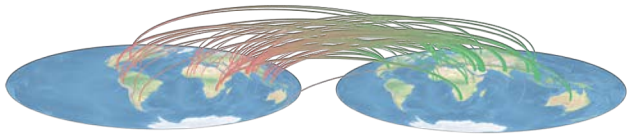

(a)
(b)
(c)
(d)

It's never just about 3D.



Key findings





- User performance with the globe was significantly *more accurate* than with 2D straight and MapsLink.

- MapsLink *was significantly slower* than other representations and that participants spent most of their time moving the maps in MapsLink (more than 80% in average)

Thank you!

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