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Visual Analysis of the Evolution of Moisture Transport Patterns in the North Atlantic for different Climate Scenarios

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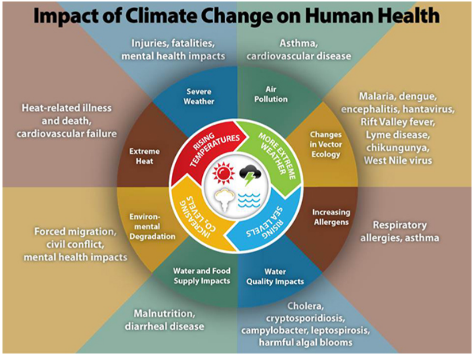
Abteilung für Bild- und Signalverarbeitung

Introduction

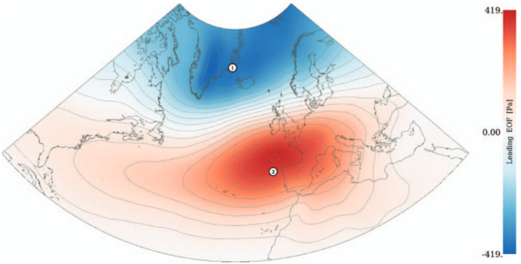
- climate change is far more than just global avg. temperature rising
- climate change has a lot of complicated consequences (regarding air pressure, winds, oceans ...)

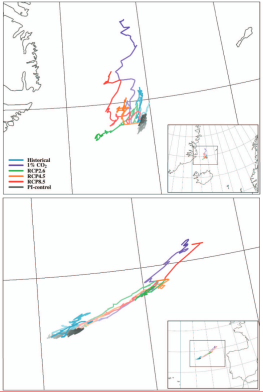


Source: CDC

Example: Change of North Atlantic Oscillation

See Vietinghoff *et al.* [20]





Research Question

How do the Patterns of Moisture Transport change in the face of various climate scenarios in the North-East Atlantic?

The Max Planck Institute - Grand Ensemble

- released in 2019 by Maher *et al.* [13]

```
MPI-GE
 ├─ $RCP-SCENARIO
 │   └─ $SIMULATION-TYPE
 │       └─ $FIELD-TYPE
 │           └─ $MEMBER
 │               └─ $VERSION
 │                   └─ field.nc
 └─ historical
```

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- RCP-SCENARIO: IPCC term of climate change intencity, 3 different levels available

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- RCP-SCENARIO: IPCC term of climate change intencity, 3 different levels available
- TYPE: area (land, ocean **atmosphere**)
- FIELD: different types of scalar fields

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The Max Planck Institute - Grand Ensemble

- released in 2019 by Maher *et al.* [13]
- RCP-SCENARIO: IPCC term of climate change intencity, 3 different levels available
- TYPE: area (land, ocean **atmosphere**)
- FIELD: different types of scalar fields
- MEMBER: 100 different simulations
  $\rightarrow$ uncertain scalar fields

```
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│           └─ $MEMBER
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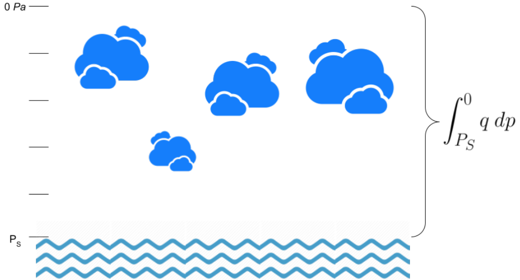
Quantifyinig Moisture (Transport) - Water Vapor Integration

1. Integrated Water Vapor (IWV) [3, 5, 7, 12]
2. **Integrated Water Vapor Transport (IVT)** [1, 2, 10, 14, 15, 19, 22]
3. Moisture Budgets [18, 21]



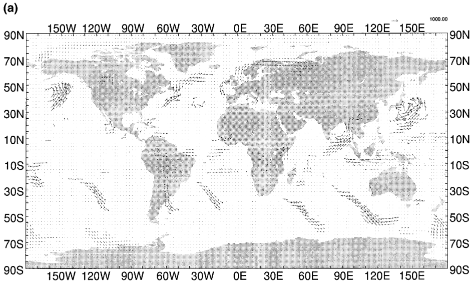
Integrated Water Vapor Transport

Proposed by Zhu and Newell, 1998 [22]:

- Goal: find **atmospheric rivers**

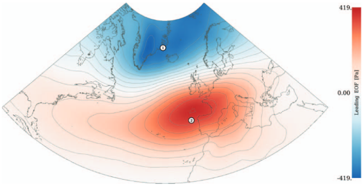
$$Q' = \hat{\mathbf{i}}\frac{1}{g}\int_{P_0}^{300hPa} \overline{q'u'}dp + \hat{\mathbf{j}}\frac{1}{g}\int_{P_0}^{300hPa} \overline{q'v'}dp$$

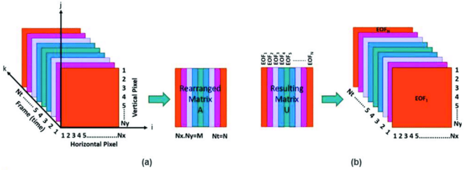
Since then in most cases: $||IVT||_2 \rightarrow$ Scalar field [1, 2, 10, 14, 15, 19]



Pattern Analysis with EOF

- *very* closely related to PCA
- widely used in geospatial sciences (see review paper from Hannachi *et al.* [8])
- can be used for dimensionality reduction, pattern recognition ...
- applied to IVT fields [2, 9, 16]
- **Plan**: Apply a similar windowed approach as Vietinghoff *et al.*





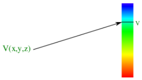
Source: researchgate

Visualizing Uncertain Fields

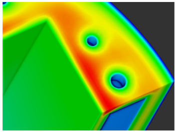
Problem of high dimensionality: 2D scalar field, 100 members, change over time

Ideas:

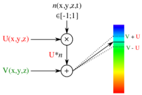
- reduce to mean
- Uncertain isocontours (see first presentation)
- use animated Perlin noise to visualize uncertainty (see Coninx *et al.* [4])
- Visualizing Time: probably just an animation
- TODO: evaluate uncertainty vis. survey [11]



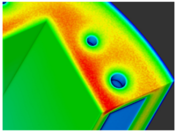
(a) *Classical color scale visualization*



(b) *Example of color scale visualization of a temperature field*



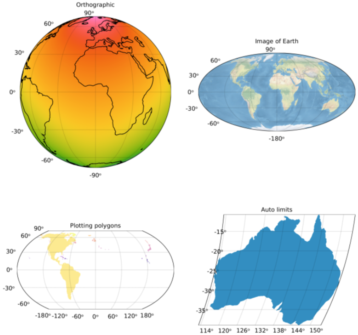
(c) *Our method: the color scale lookup is biased by a Perlin noise weighted by uncertainty data*



(d) *Example of our visualization*

Techstack

- dataset preparation: CDO [17]
- algorithm implementation: Julia [6]
- Important libraries:
  - (Geo)Makie for Visualisation
  - KMarkert/EmpiricalOrthogonalFunctions.jl



Literature I

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Literature II

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Literature III

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The Max Planck Institute - Grand Ensemble [13]

Field Types

- 32 different fields for the atmosphere
- Resolution: Lat/Long: $1.875°$, Time: monthly averages, Vertical: 26 Levels from 10 to 100000 *Pa*
- Examples: evaporation, preciptation, horizontal wind speed, specific humidity

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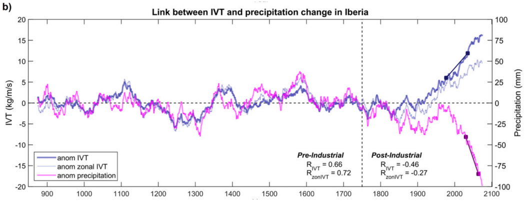
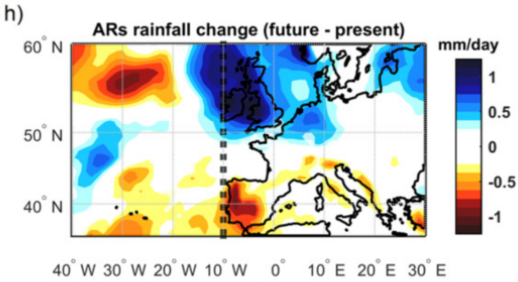
Integrated Water Vapor Transport





My current plan

1. Filter the MPI-GE for my needs
2. Generate an IVT field from the MPI-GE
3. Implement a similar windowed EOF approach as in [20] to track changes in moisture transport patterns
   - maybe apply concept of atmospheric rivers to the analysis
   - maybe also implement/use some other analyses from similar work
4. Visualize the uncertain Scalar Fields over time

Moisture Budgets

$$\frac{1}{g}\frac{\delta}{\delta t}\int_0^{P_s} q dp = -\nabla \cdot \frac{1}{g}\int_0^{P_s}(qv)dp + E - P$$