TOWARDS A DEFORMATION MODEL FOR EUROPE USING LEAST-SQUARE COLLOCATION

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INTRODUCTION

- One of the goals of EUREF (Regional Reference Frame Sub-Commission for Europe) is the development of a deformation model for Europe
  - Estimation of a dense velocity grid
  - Using GNSS-based station velocity solutions

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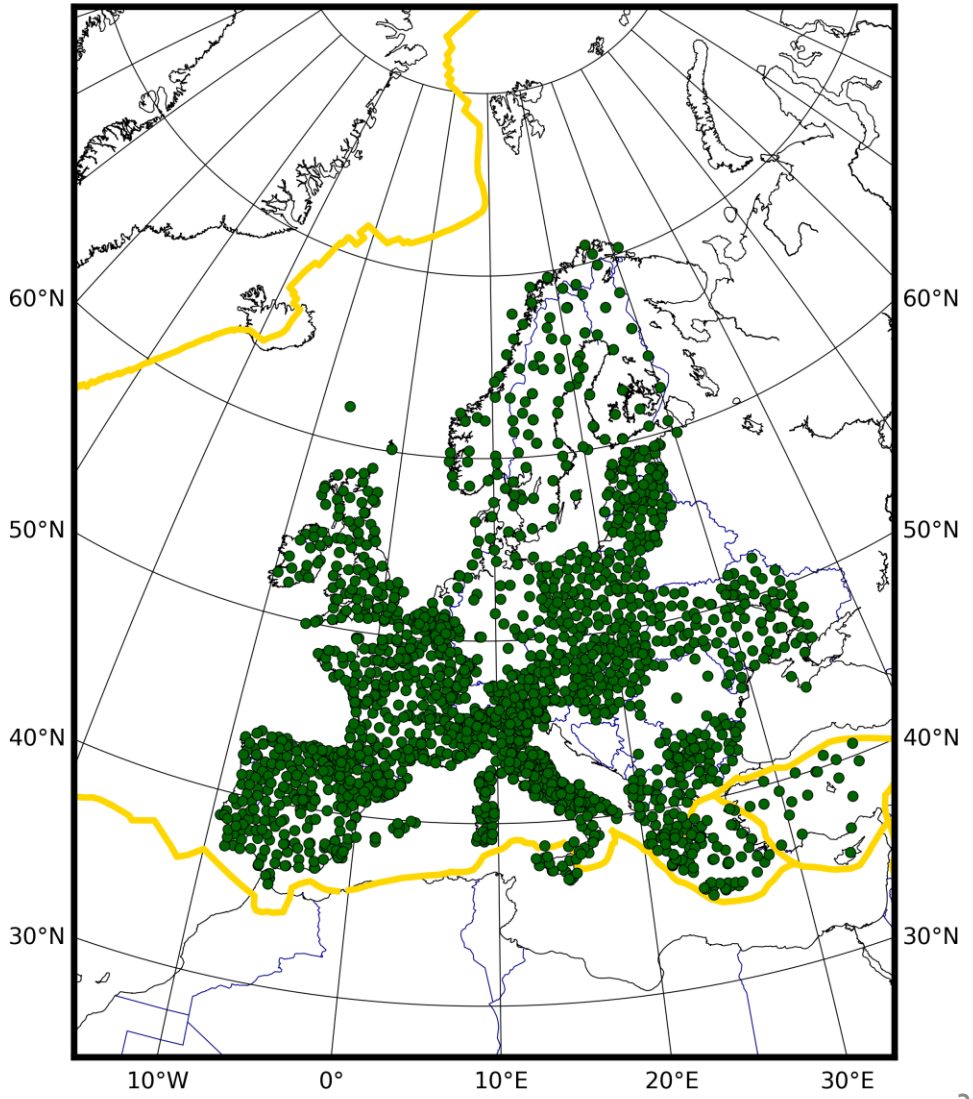
  - For example: "EPN densification" by Kenyeres
    - Regional weekly GNSS solutions (SINEX format) combined to weekly solutions, and station velocities estimated by rigorous stacking of the combined weekly solutions in the CATREF software
    - Data cleaning is an important part of the process and stations with unrealistic velocities (mostly due to short time series in the 2 – 3 years domain) are removed
    - More information: http://epncb.oma.be/_densification/
    - Dataset "EDV14_ENEU_v3.filt" from August 8th, 2018, is used in the following
    - Dataset is in ETRF2000



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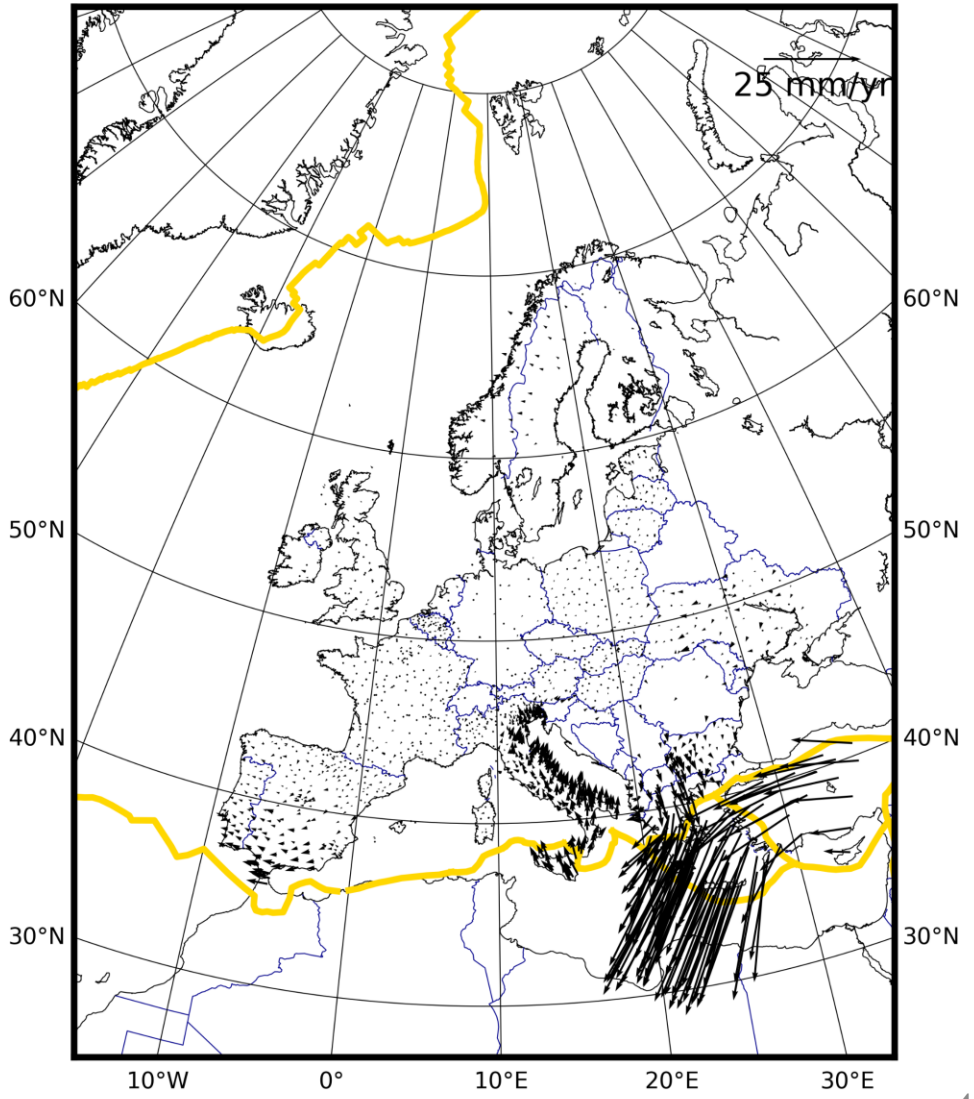
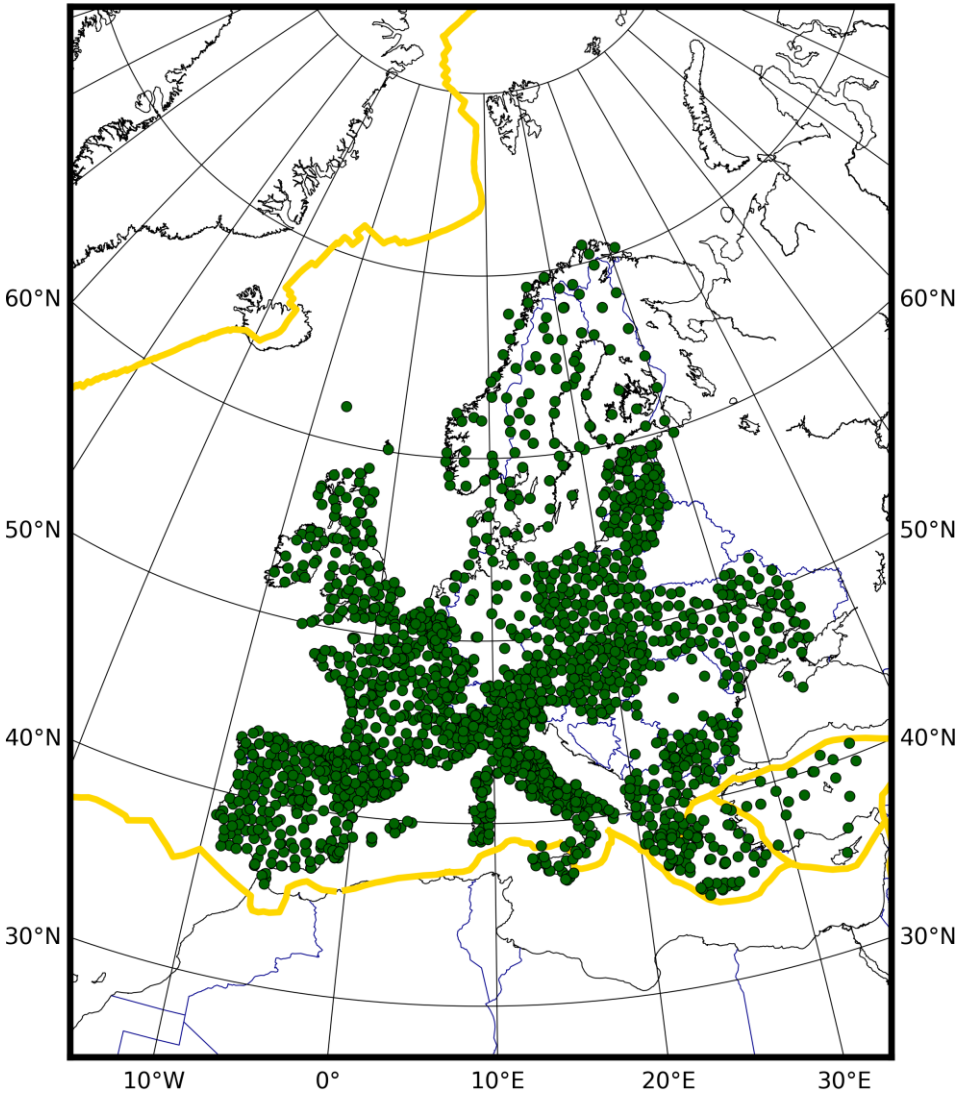
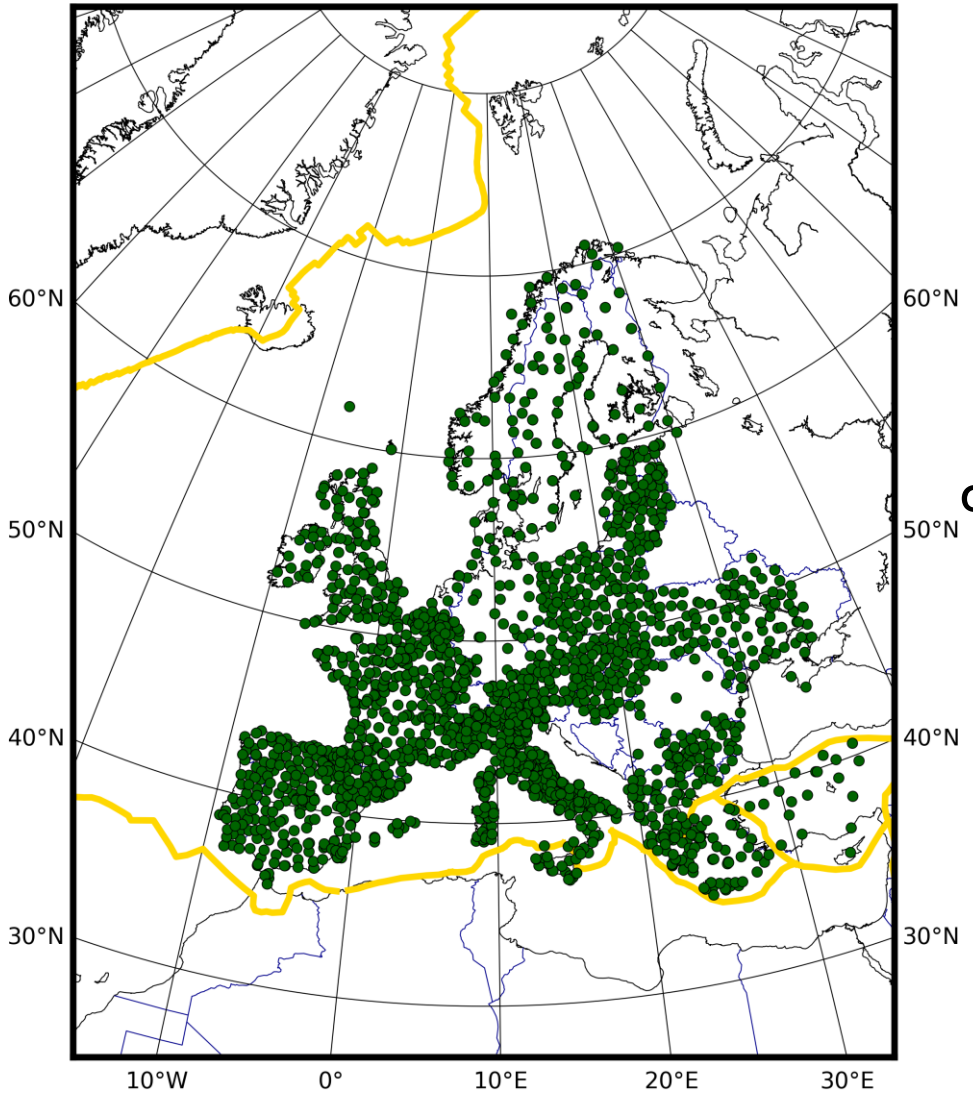


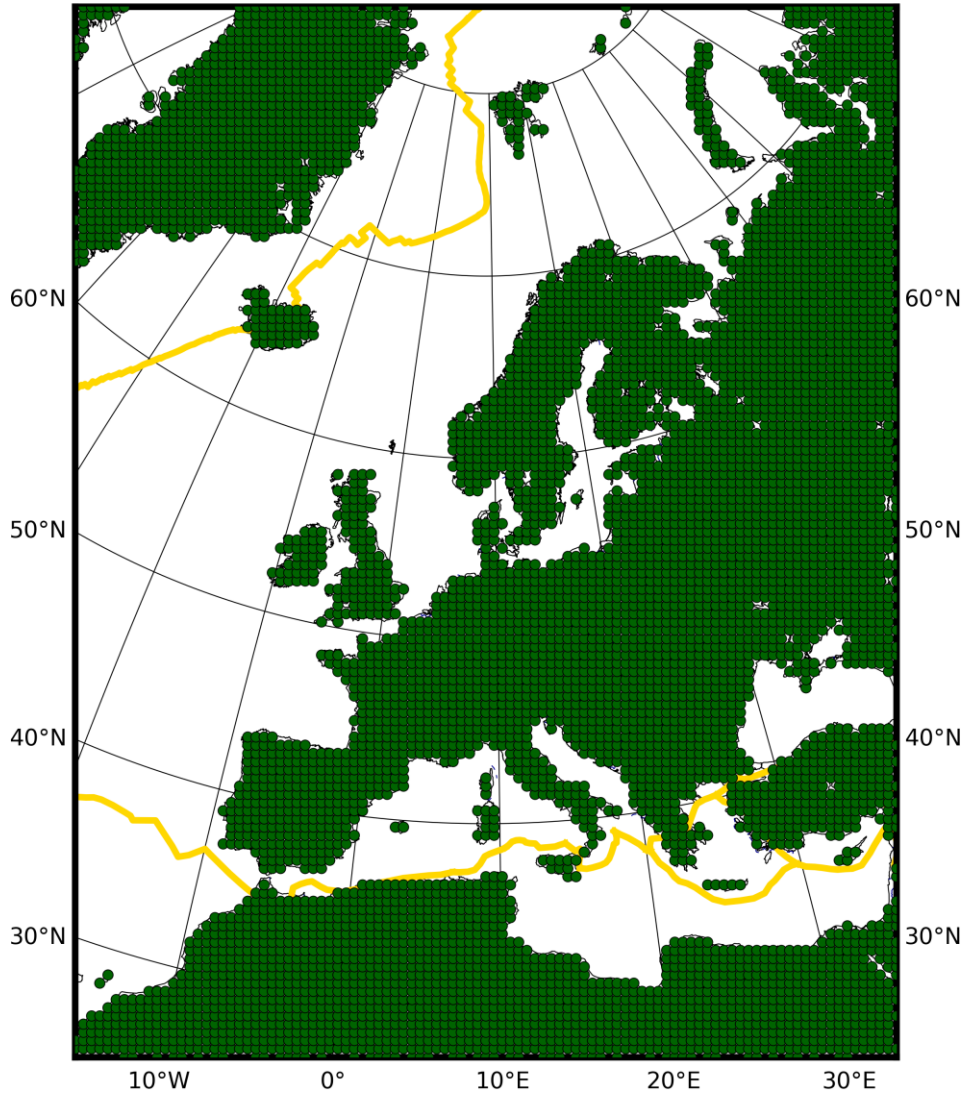
INTRODUCTION



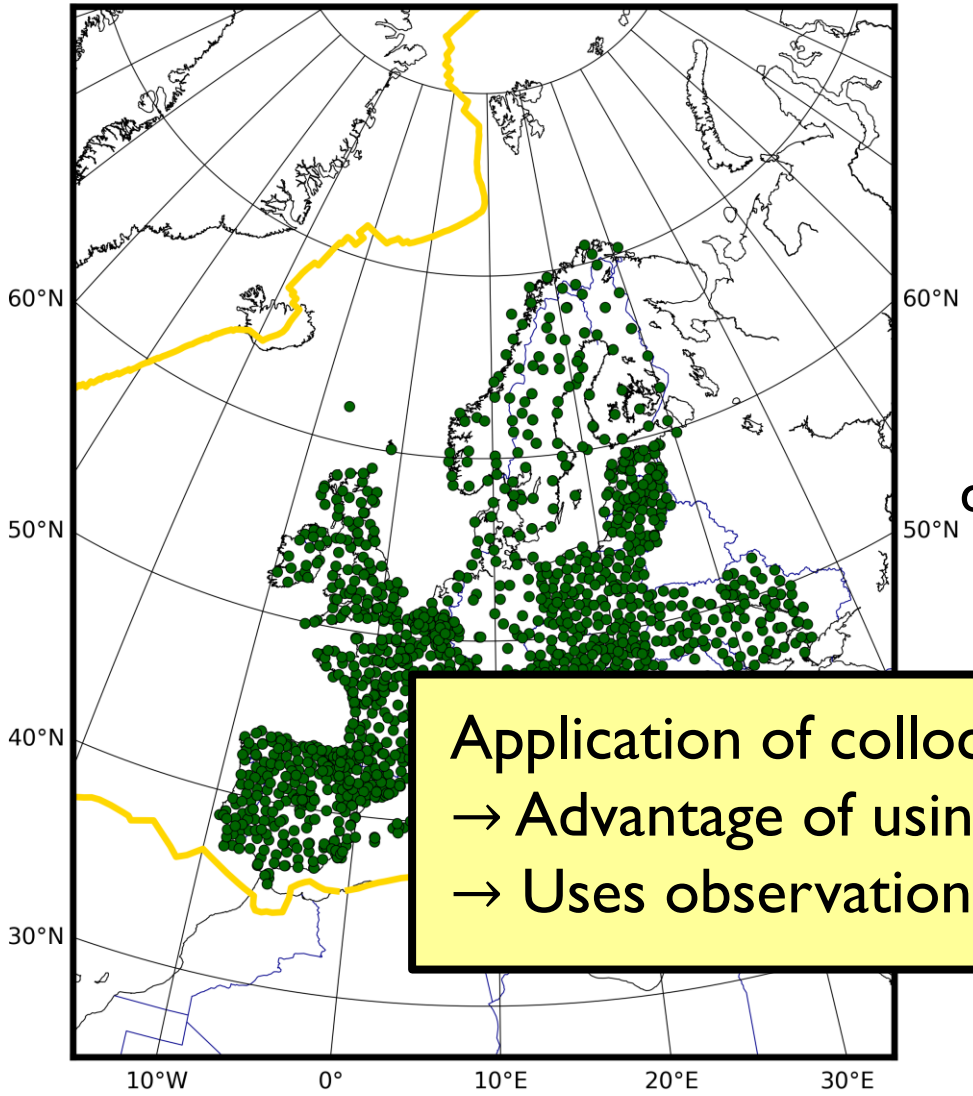
INTRODUCTION



Interpolation to 50 km x 50 km grid (other grids (e.g., denser) are possible)



INTRODUCTION



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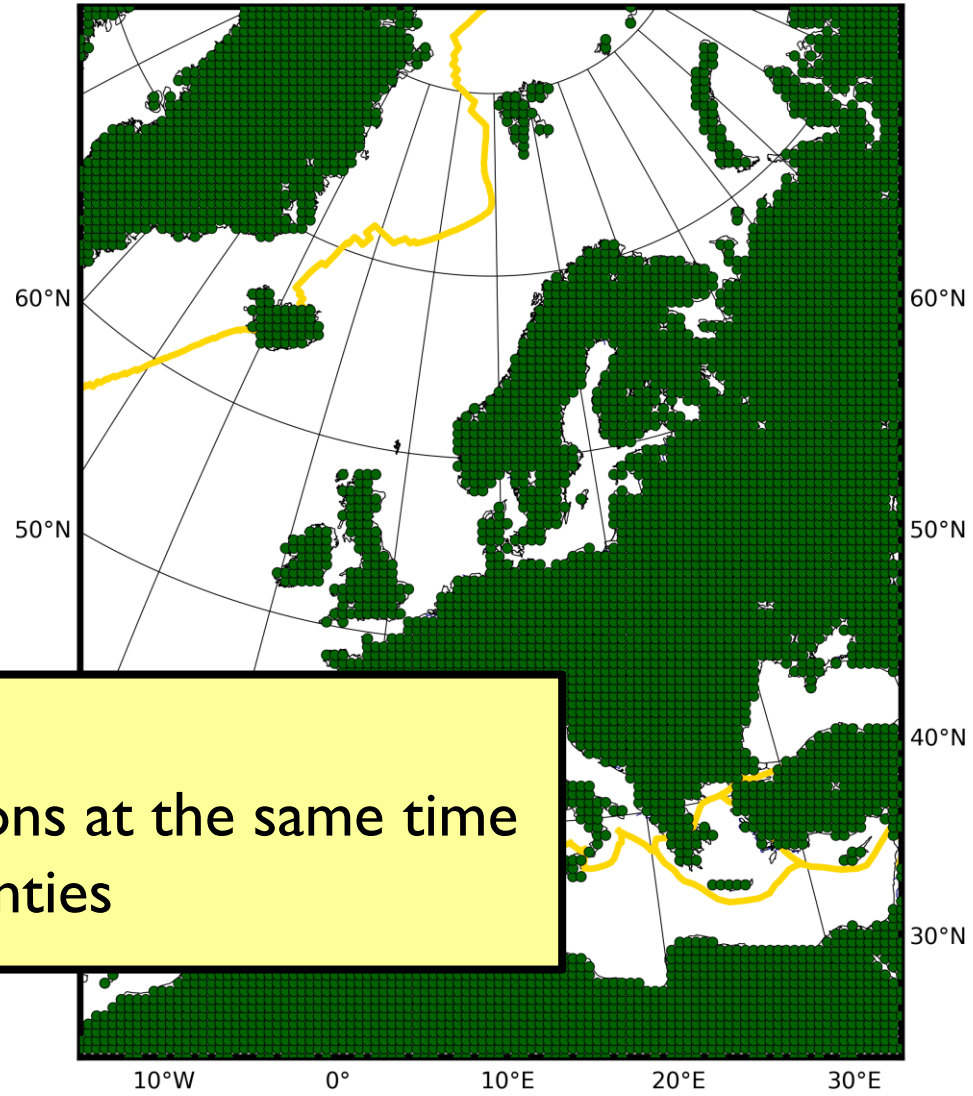


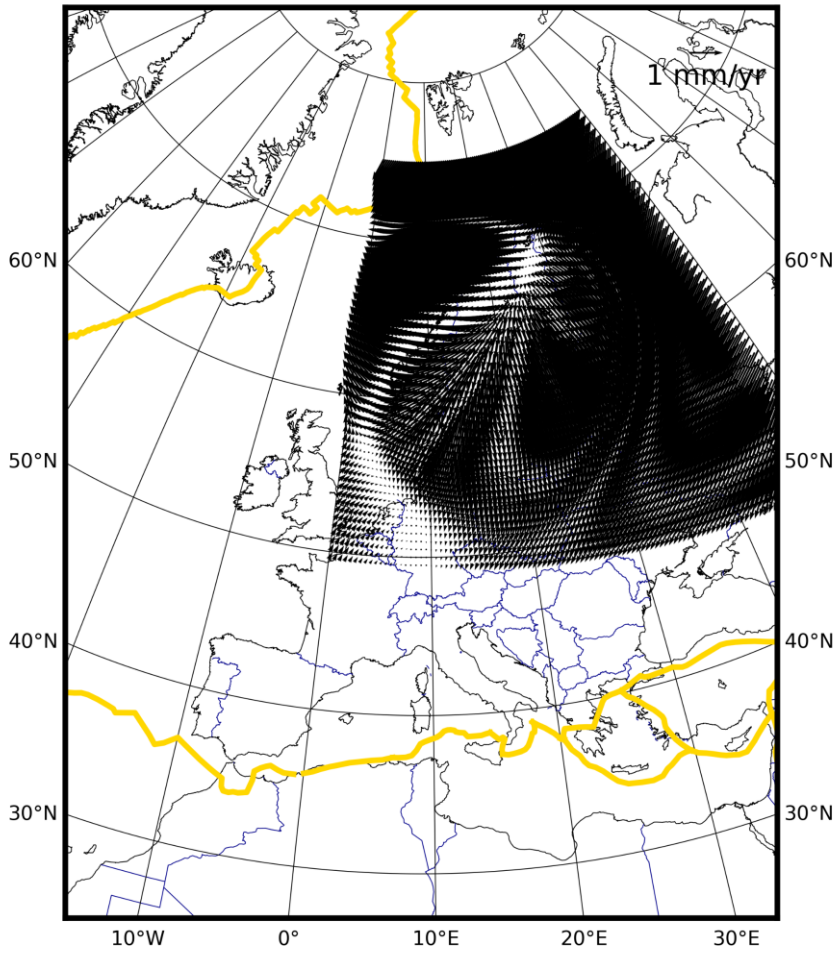
Application of collocation methodology
→ Advantage of using several observations at the same time
→ Uses observations including uncertainties

COLLOCATION (SHORT SUMMARY)

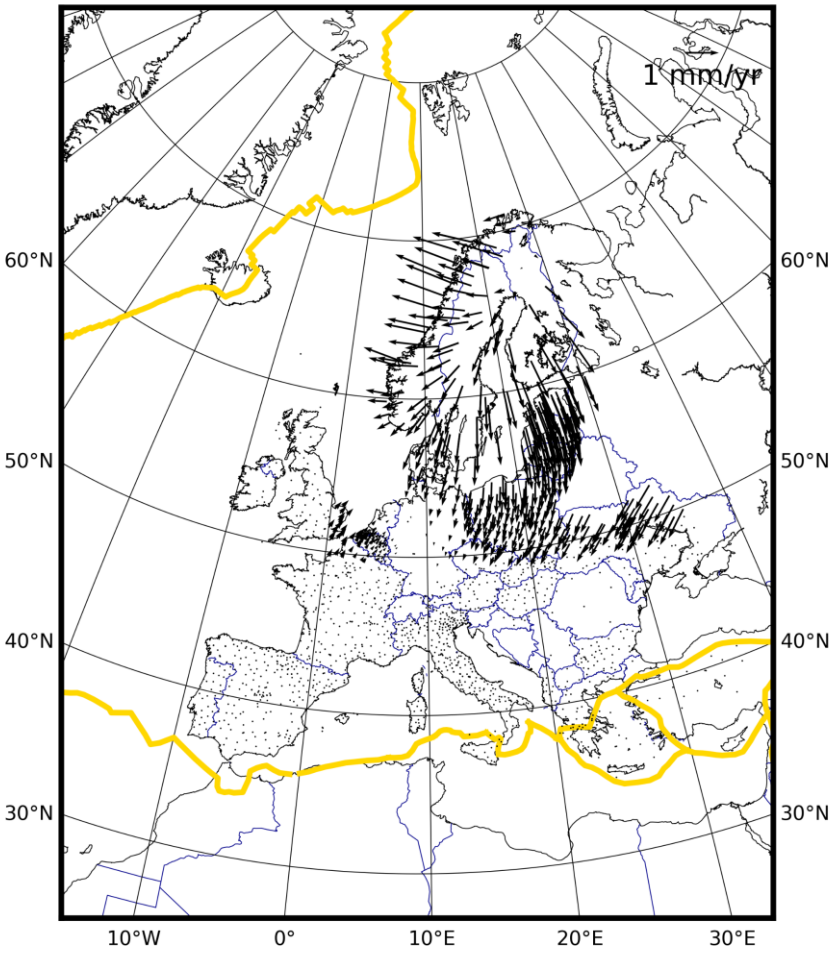
- Velocity data are filtered and interpolated (prediction) using least-square collocation (LSC, based on Moritz, 1980)
  - $l = s + n$
  - l – observations
  - s – signals
  - n – noise
- Signal and noise can be separated and the signal and the corresponding uncertainty can be obtained at observation points or new points
- Calculation involves the estimation of covariance matrices → depends only on the distance between the points and the choice of the covariance function
  → C_0 (signal covariance) and d_0 (correlation length) have to be determined
- All known information should be reduced from the observations before covariance calculation and collocation are applied (e.g., background model, mean value)
  → added afterwards again ("remove-compute-restore")

BACKGROUND MODEL

Background model is reduced from observational data → theoretical GIA (Glacial Isostatic Adjustment) model rotated into ETRF2000 (same reference frame as the GNSS data)

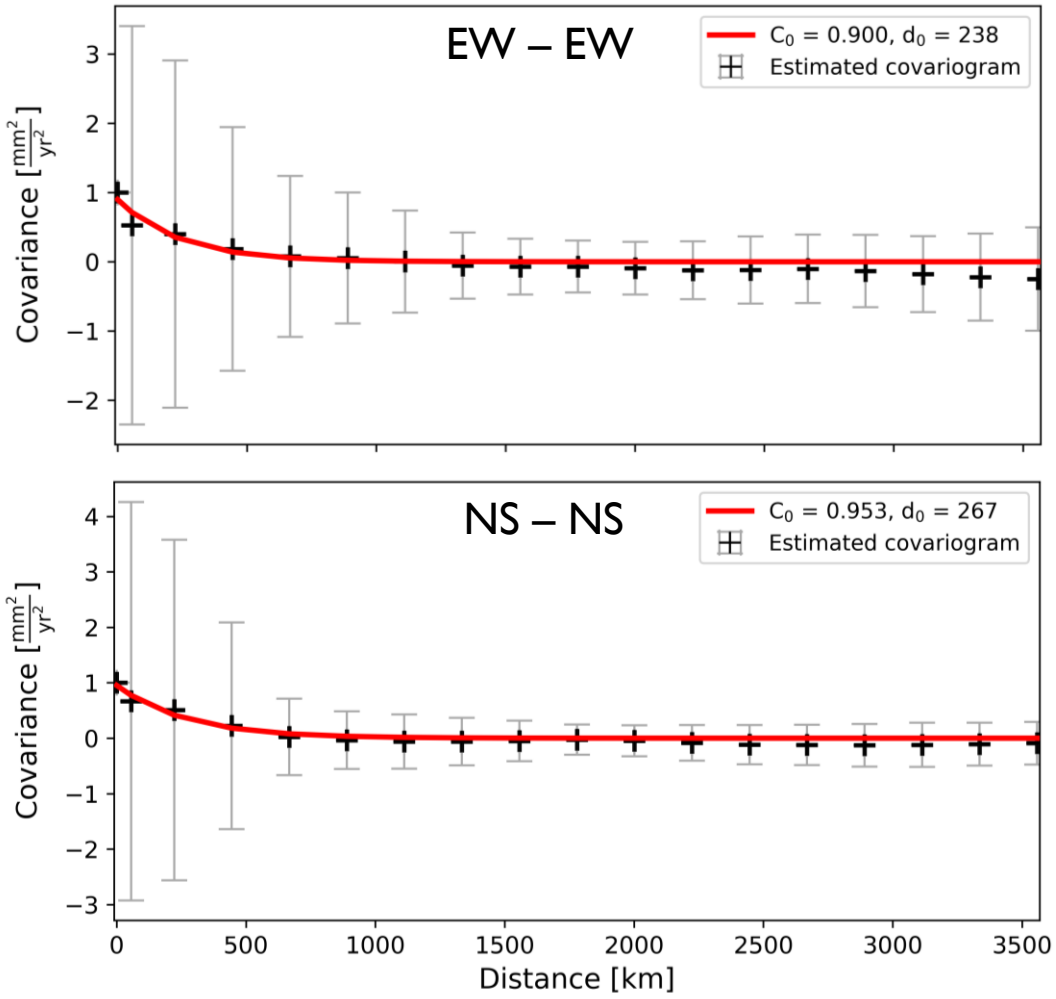


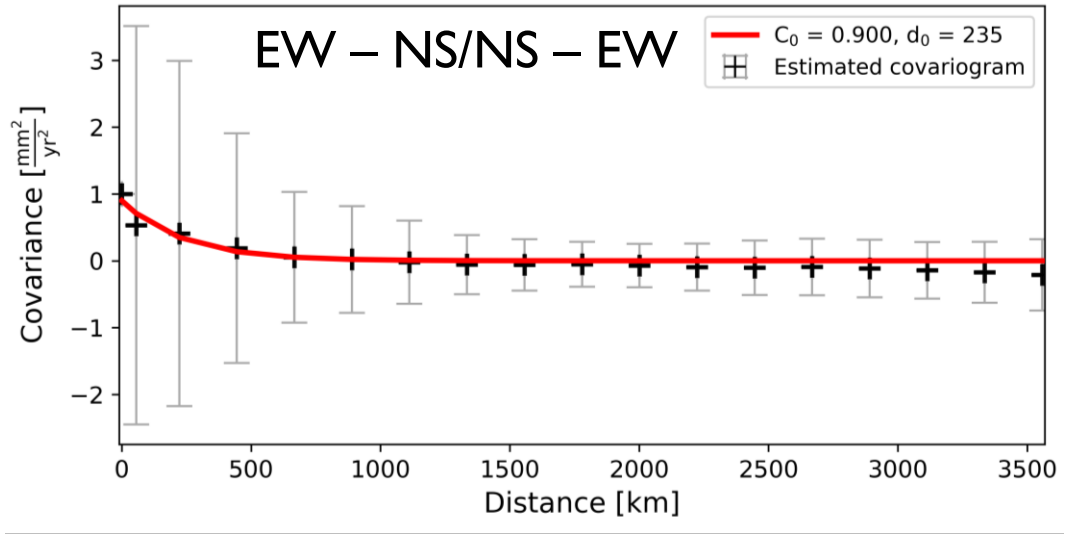
interpolated to observational points



COVARIANCE FUNCTION

Gauss-Markov 1st order used: $K(d) = C_0 \cdot e^{-d/d_0}$ (covariances are normed)





	C_0 $[mm^2/yr^2]$	d_0 $[km]$
[redacted]		
NS – NS	0.953 ± 0.076	267 ± 51
[redacted]		

COVARIANCE FUNCTION

Note: the 250 km is the 1/e value
- not the value of half power

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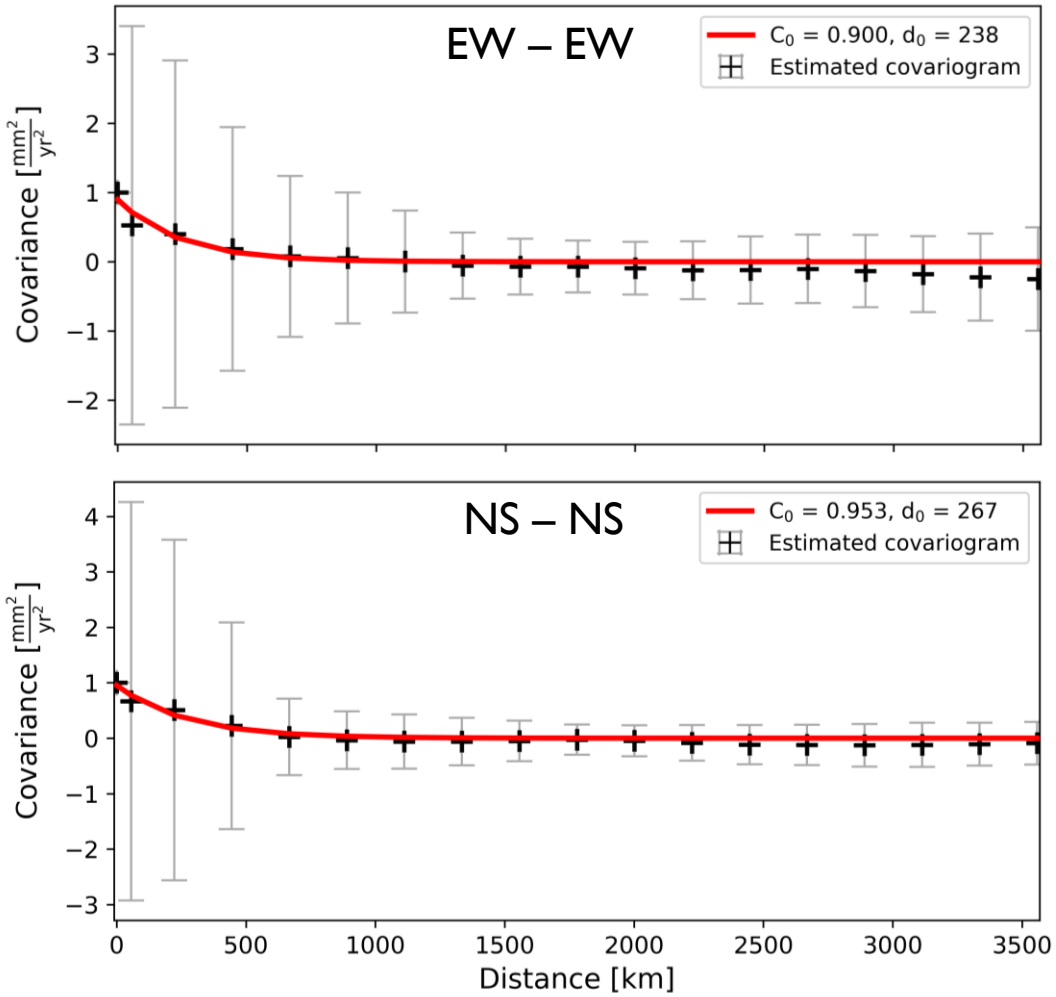
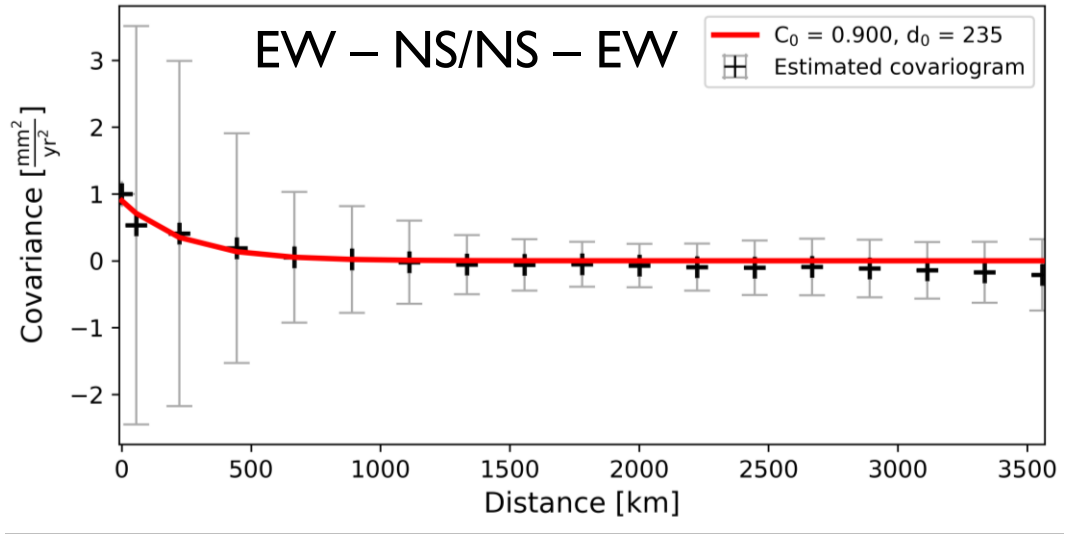
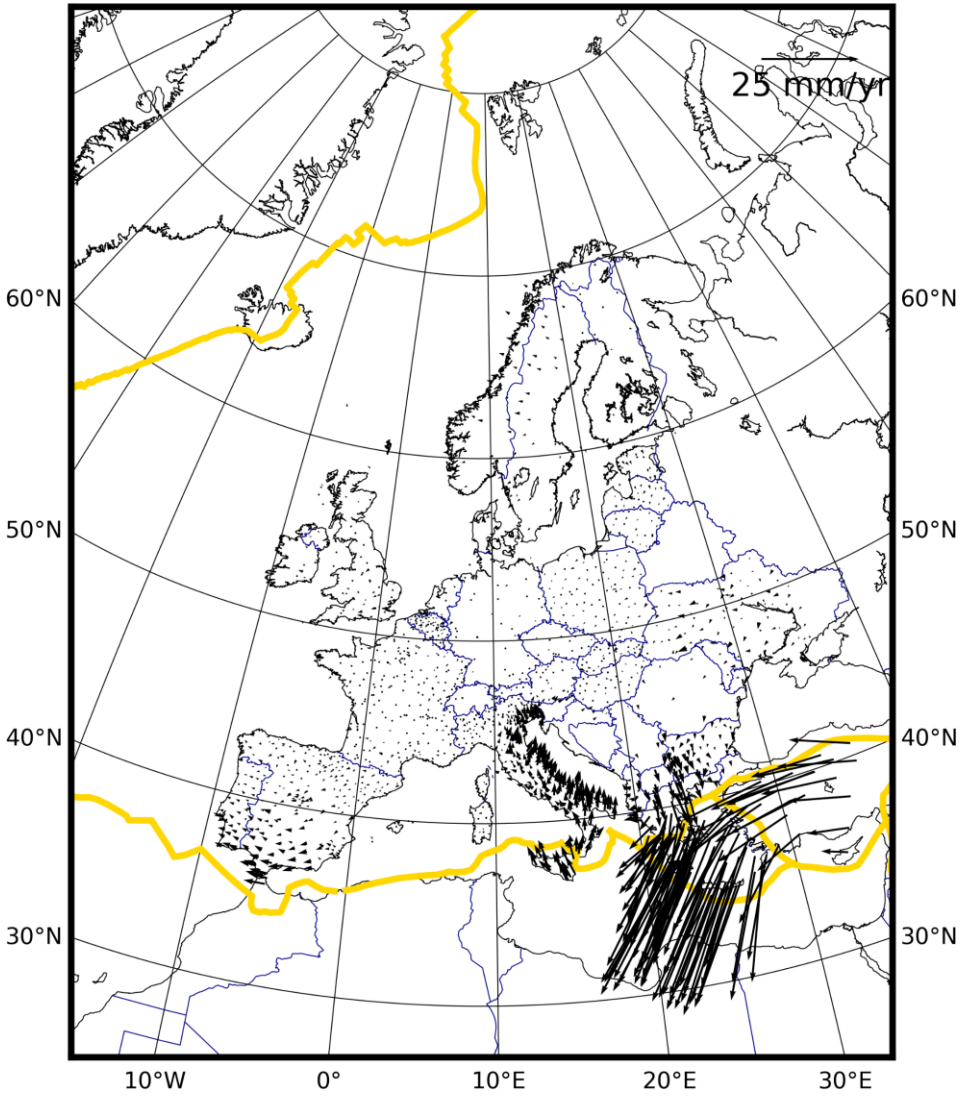




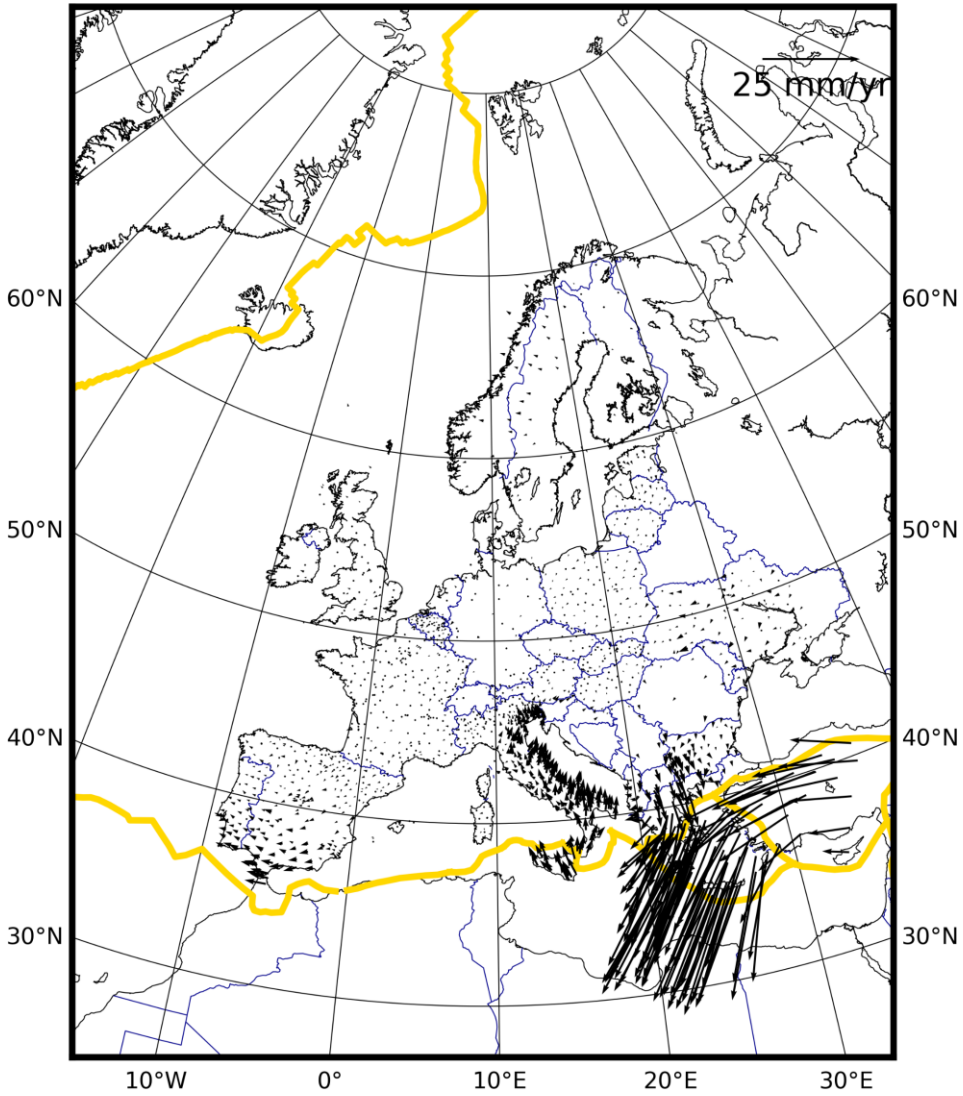
	$C_0\ [mm^2/yr^2]$	$d_0\ [km]$
[redacted]		
NS – NS	0.953 ± 0.076	267 ± 51
[redacted]		
Final	1.0	250

COLLOCATION – FILTERING



Separation of the observation into a signal and noise component

→ Filtering



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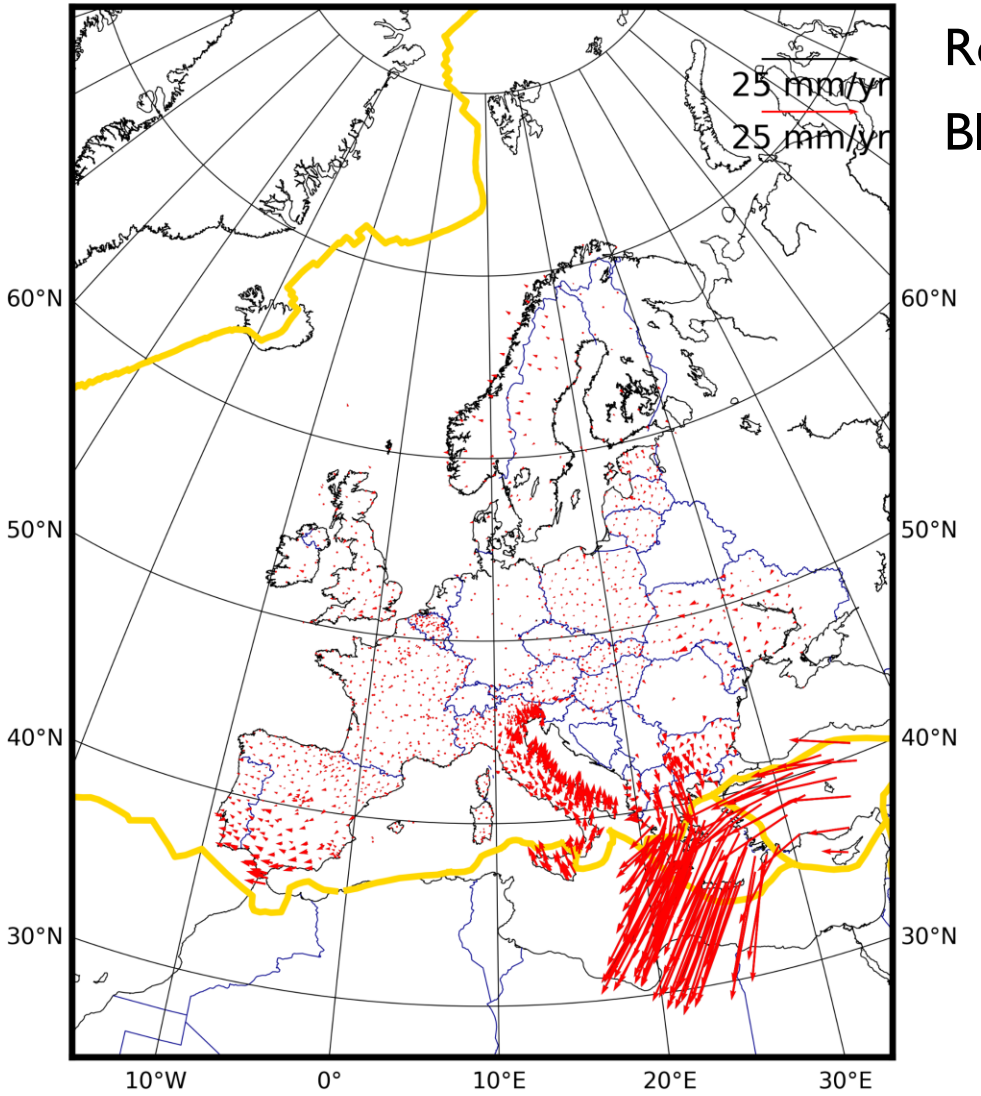


Red – original data

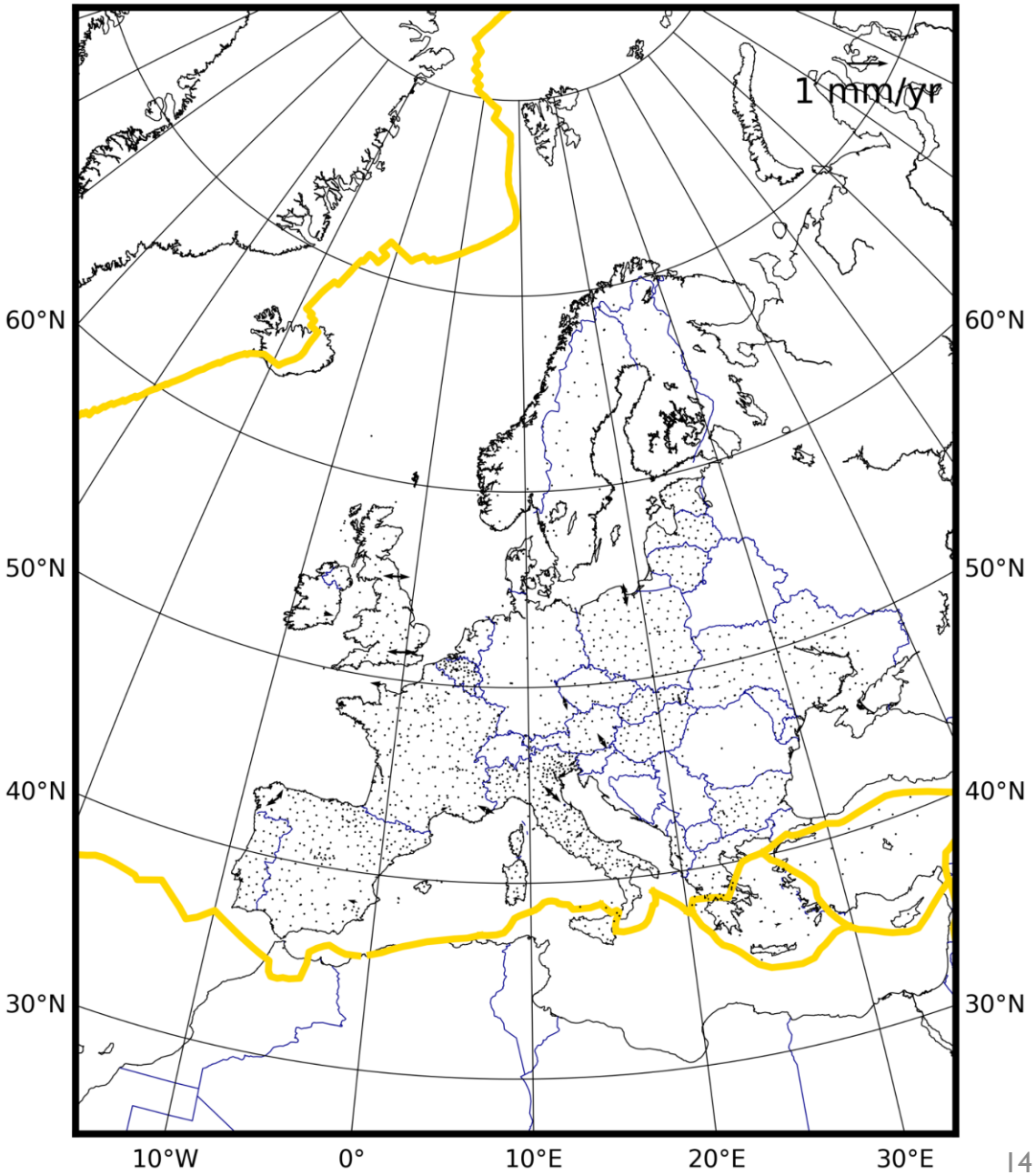
Black – collocated (filtered) data

COLLOCATION – FILTERING

- Comparison of observed to collocated (filtered) data (mm/yr)

Entire area

EW	-0.354	0.341	0.0	0.028



COLLOCATION – FILTERING

- Comparison of observed to collocated (filtered) data (mm/yr)

Entire area

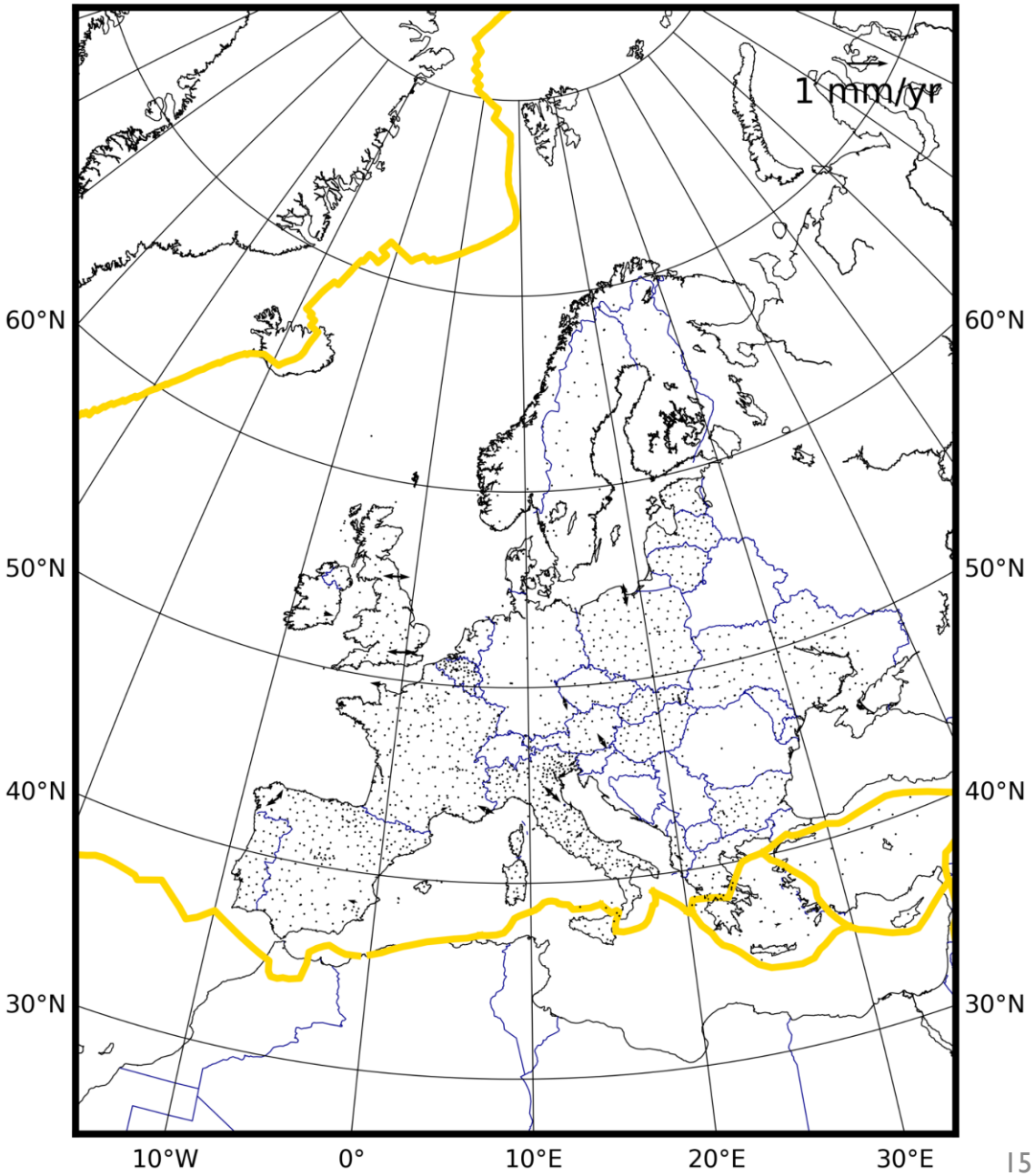
EW	-0.354	0.341	0.0	0.028

Germany

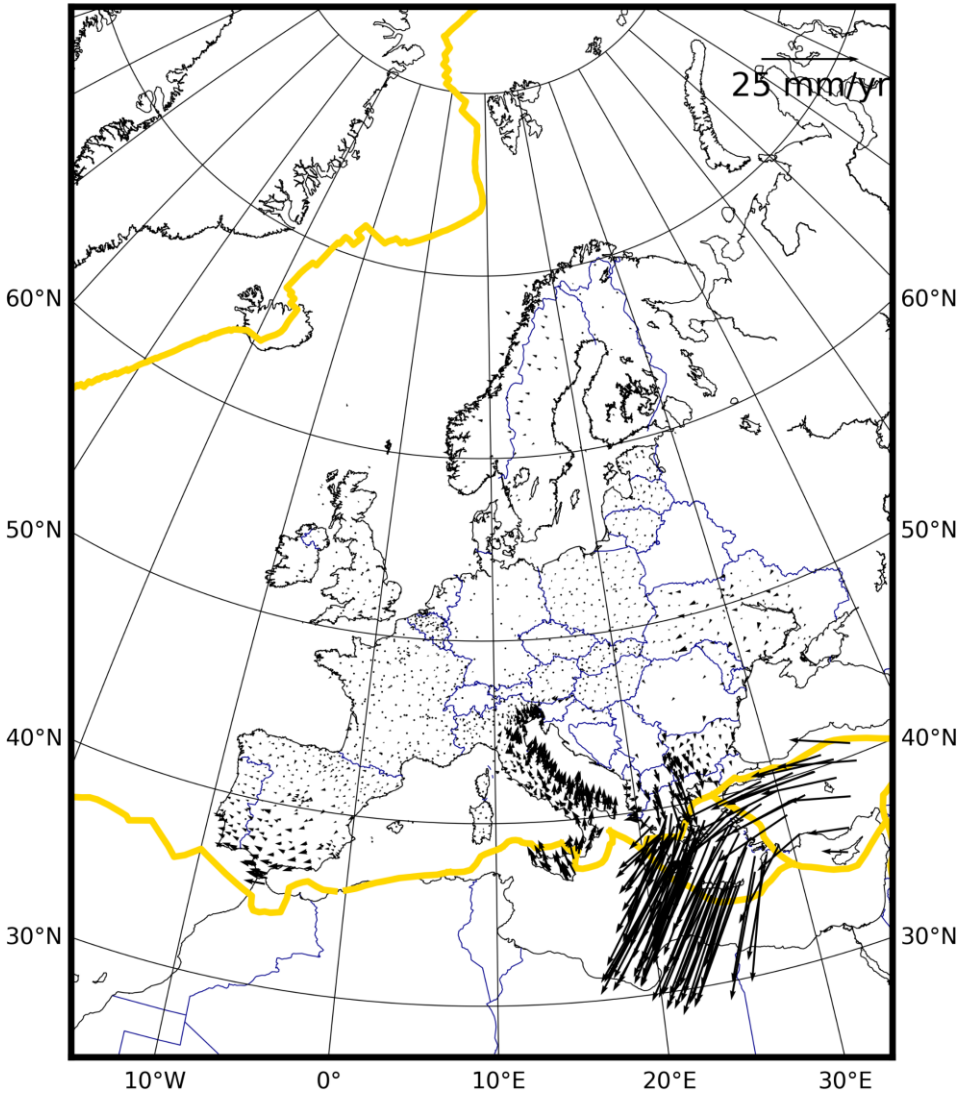
EW	-0.042	0.041	0.0	0.010

Italy

EW	-0.212	0.193	0.0	0.029

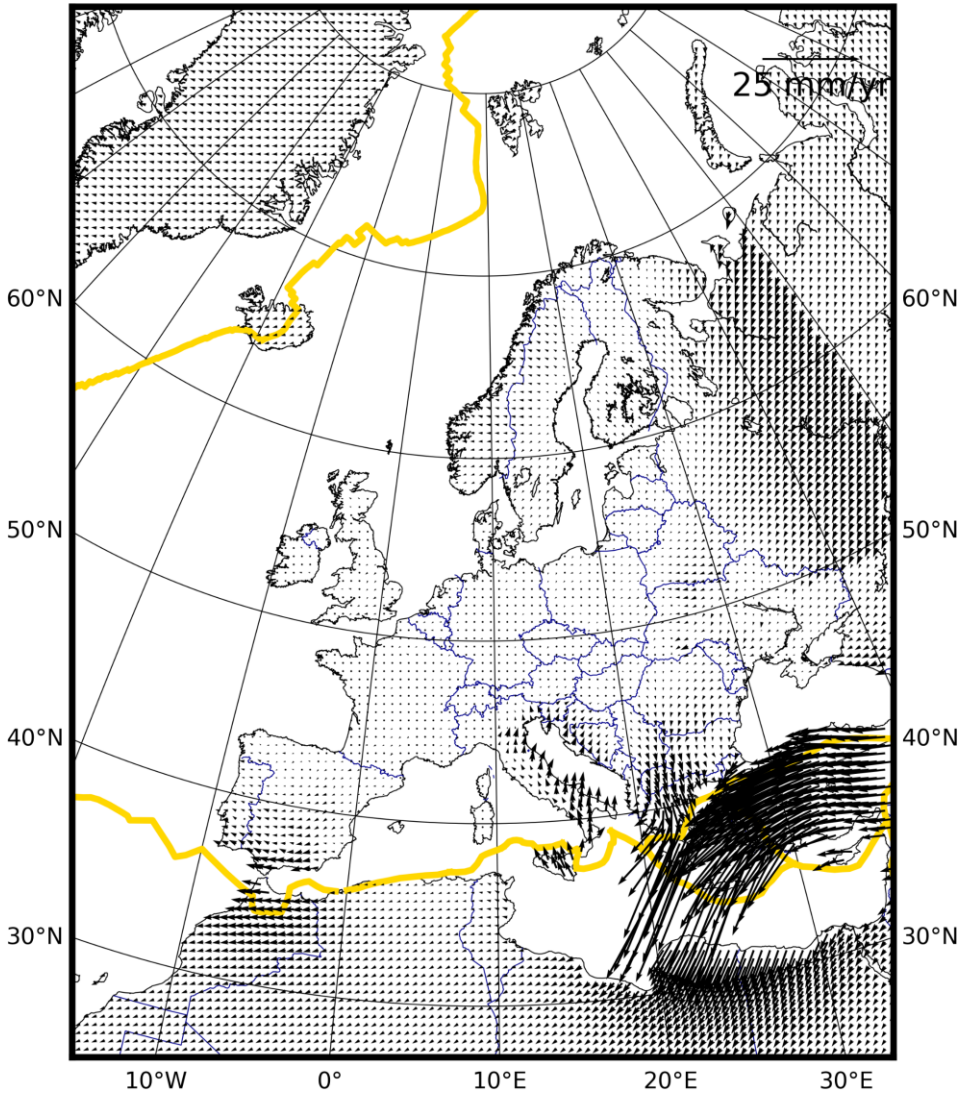


COLLOCATION – INTERPOLATION



Prediction of the signal at new points

→ Interpolation



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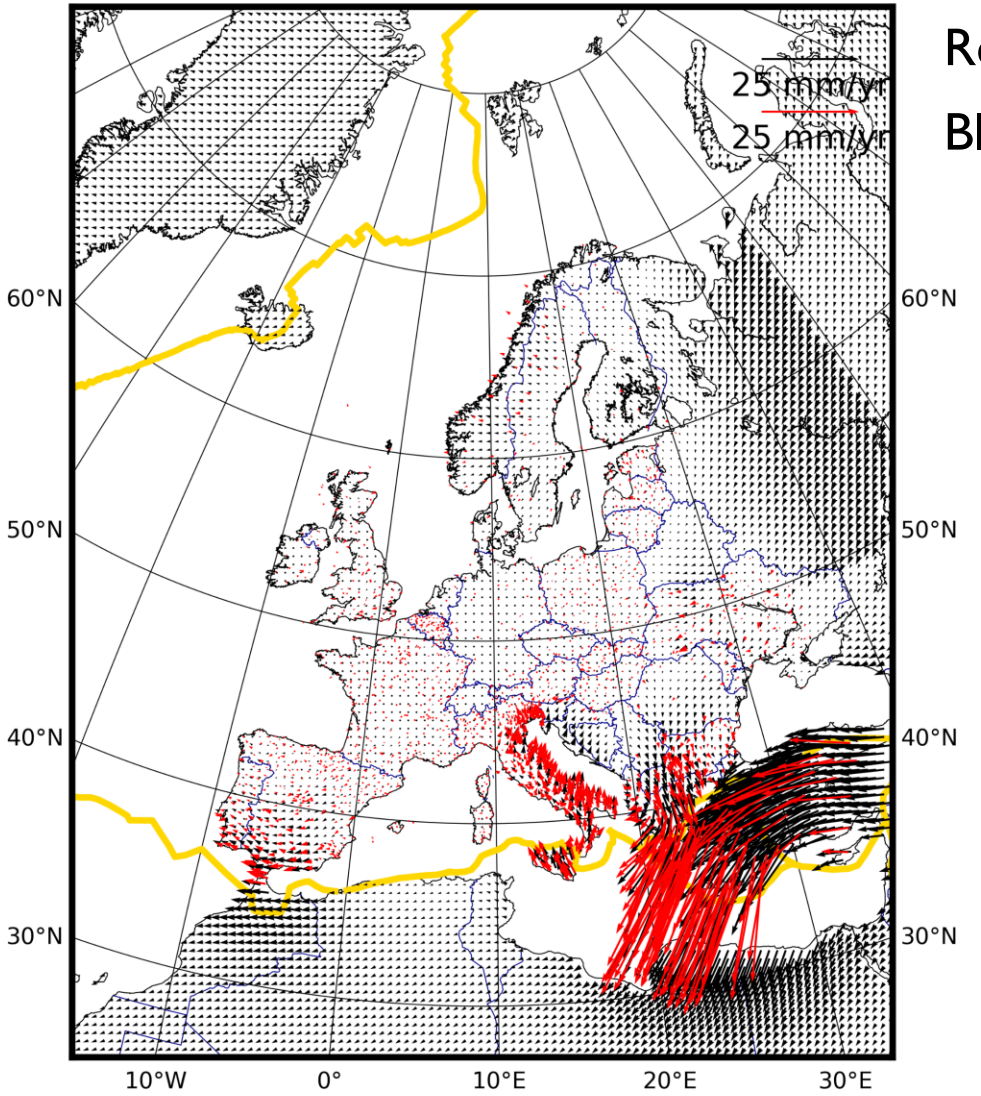

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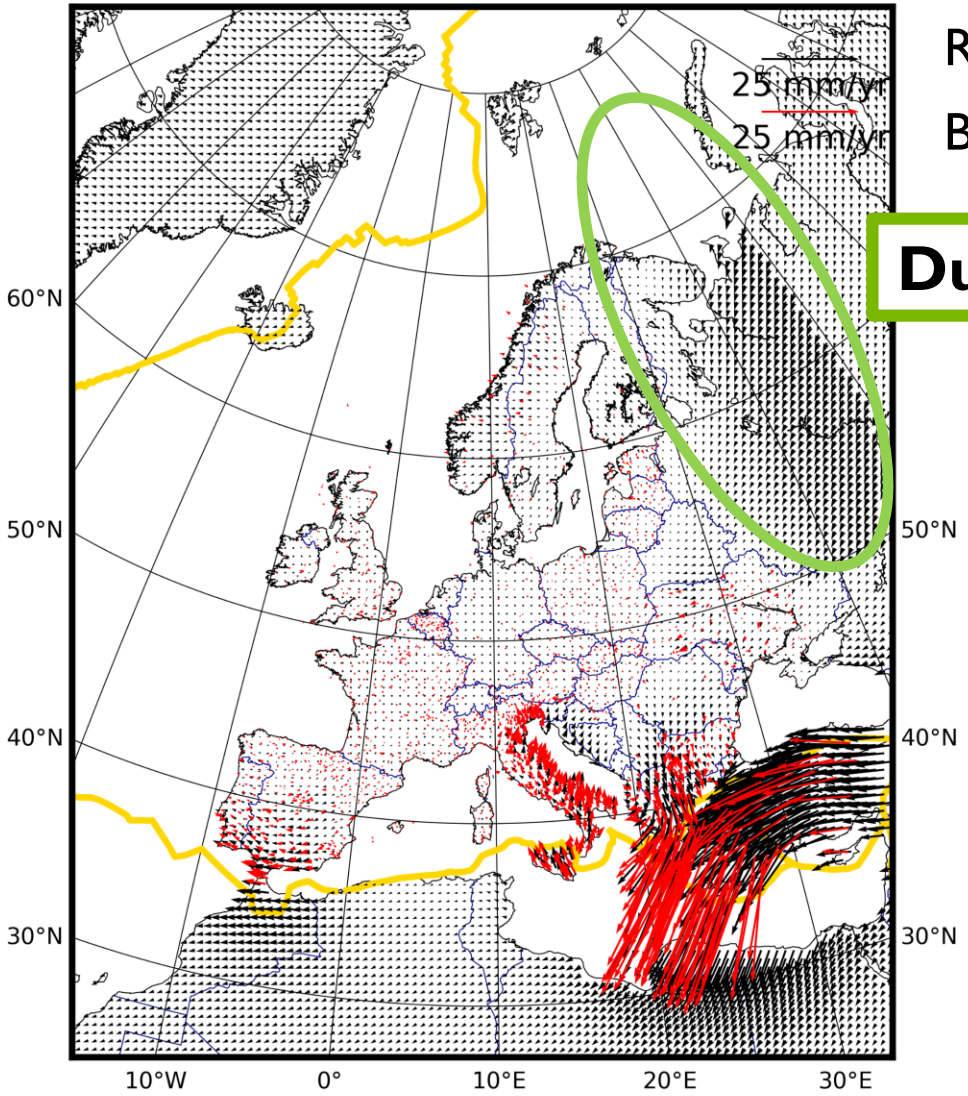

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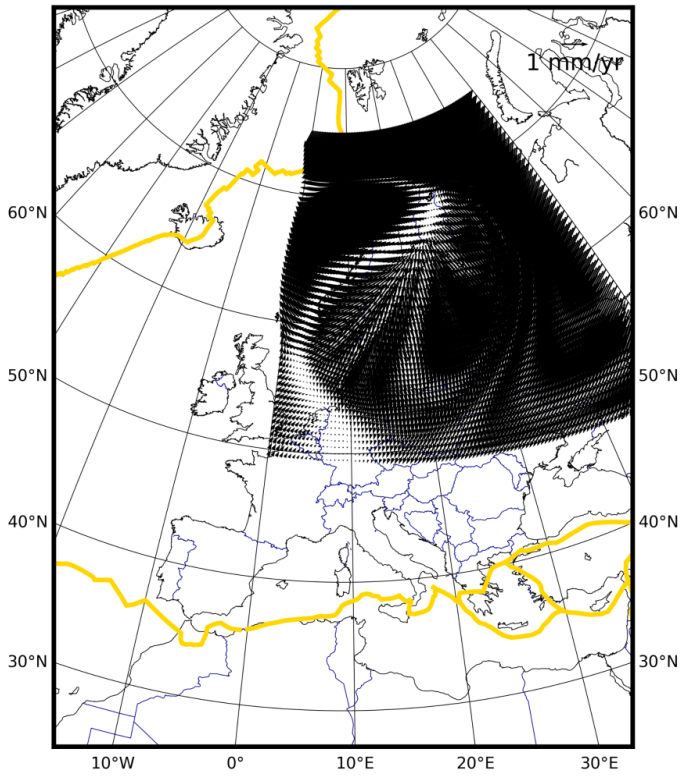
Due to background model



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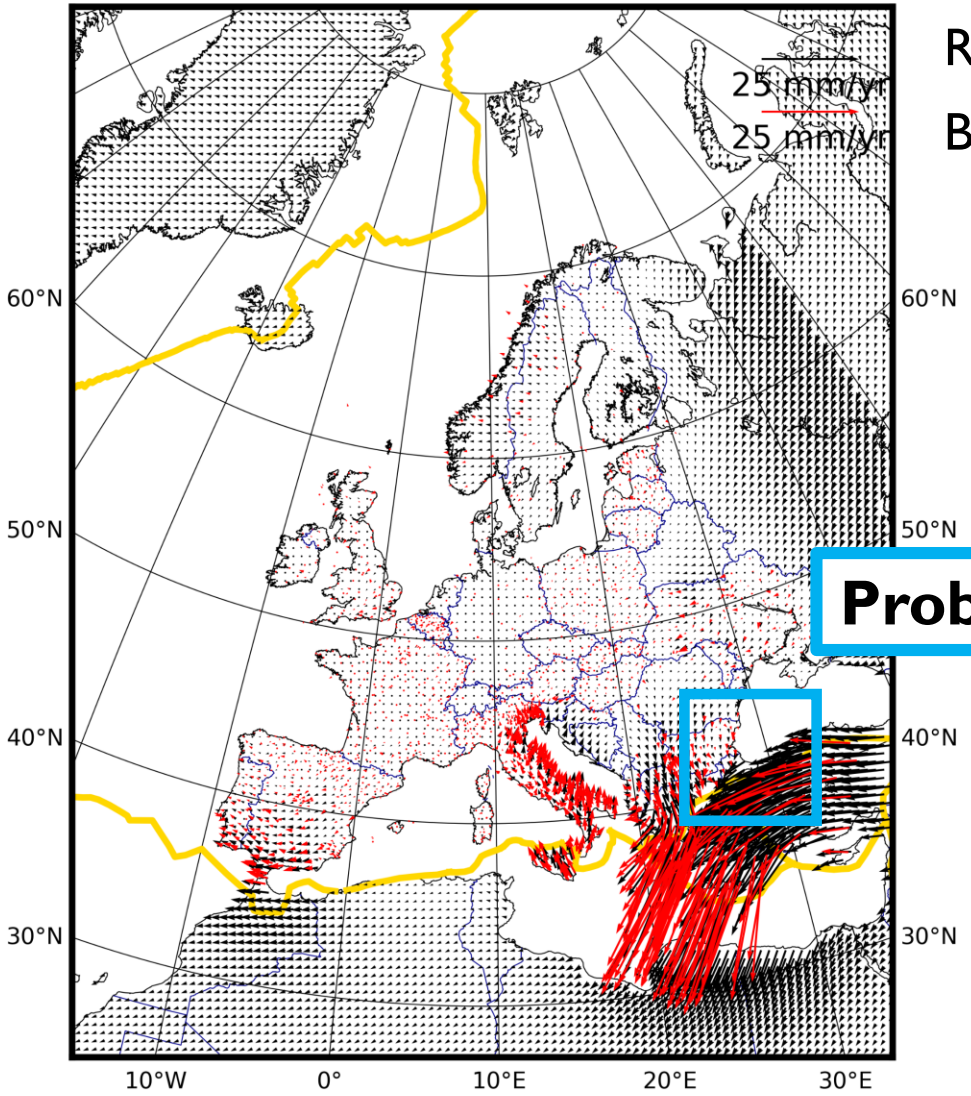

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Problem along plate boundaries

COLLOCATION WITH PLATE BOUNDARIES

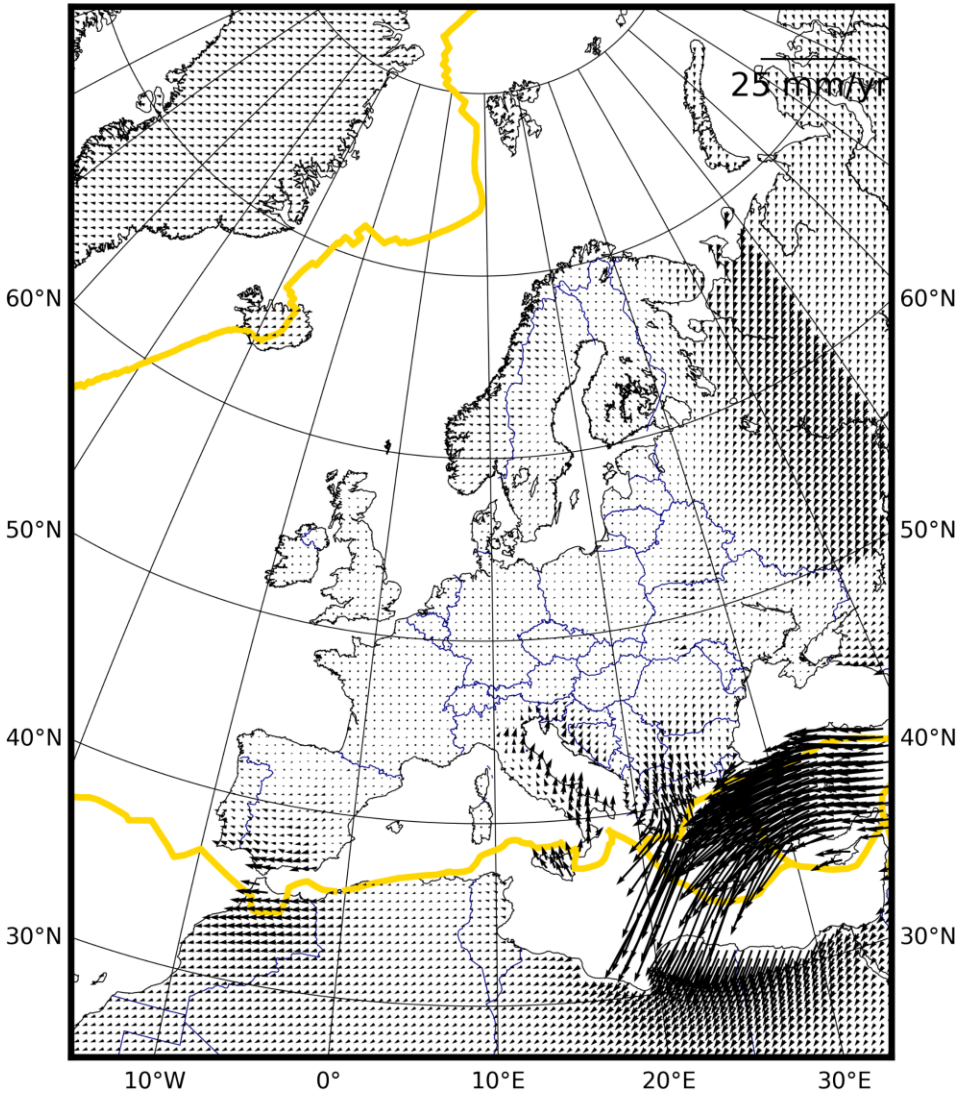
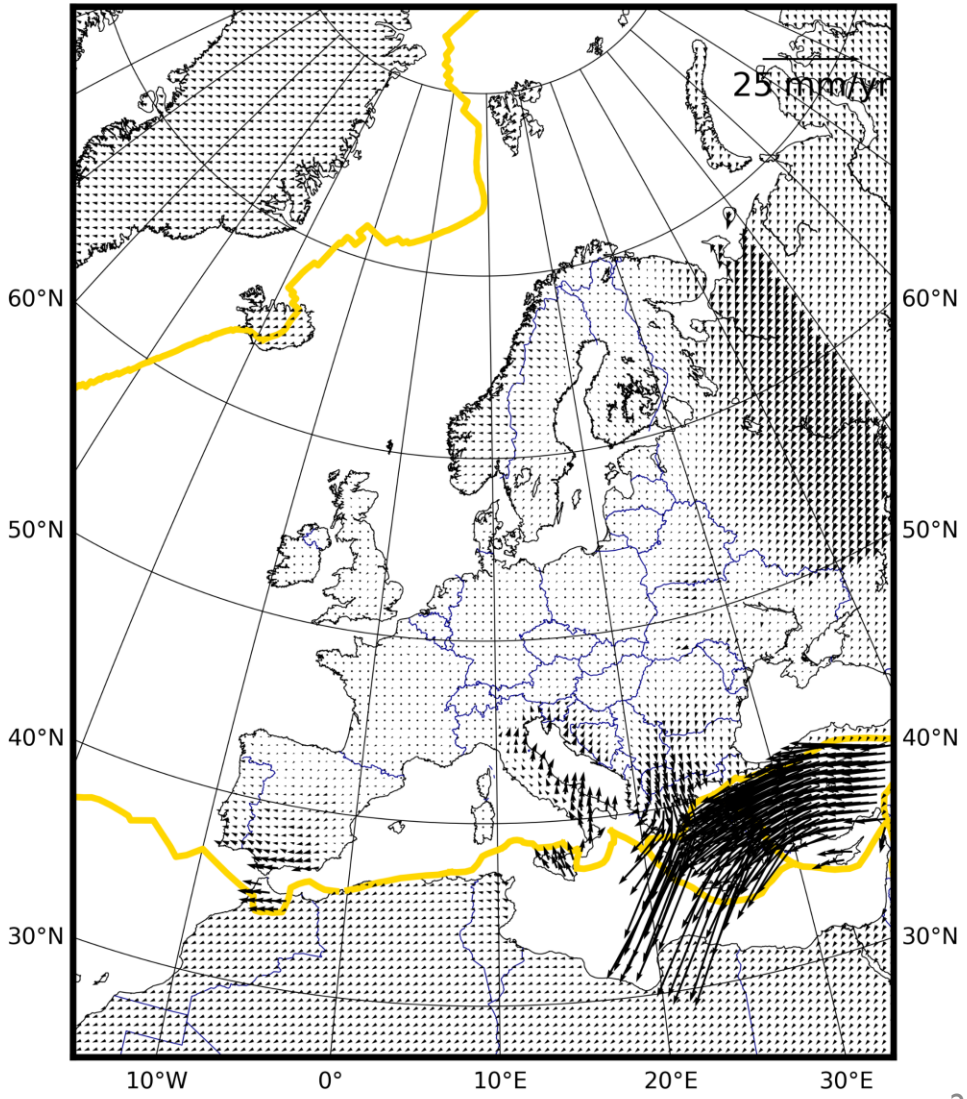


Plate boundaries included

→ distance between stations on different plates is increased

→ but distance for stations on the same plate is kept the same



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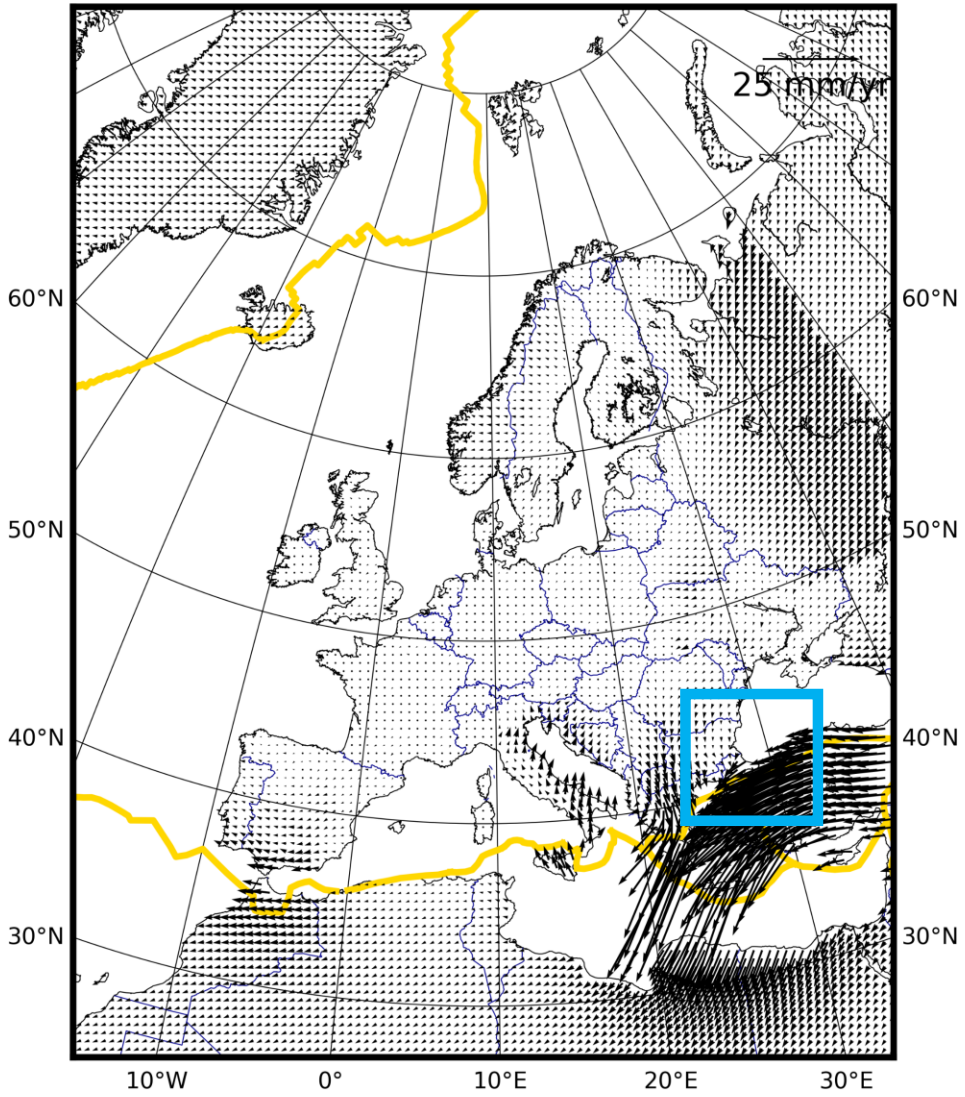

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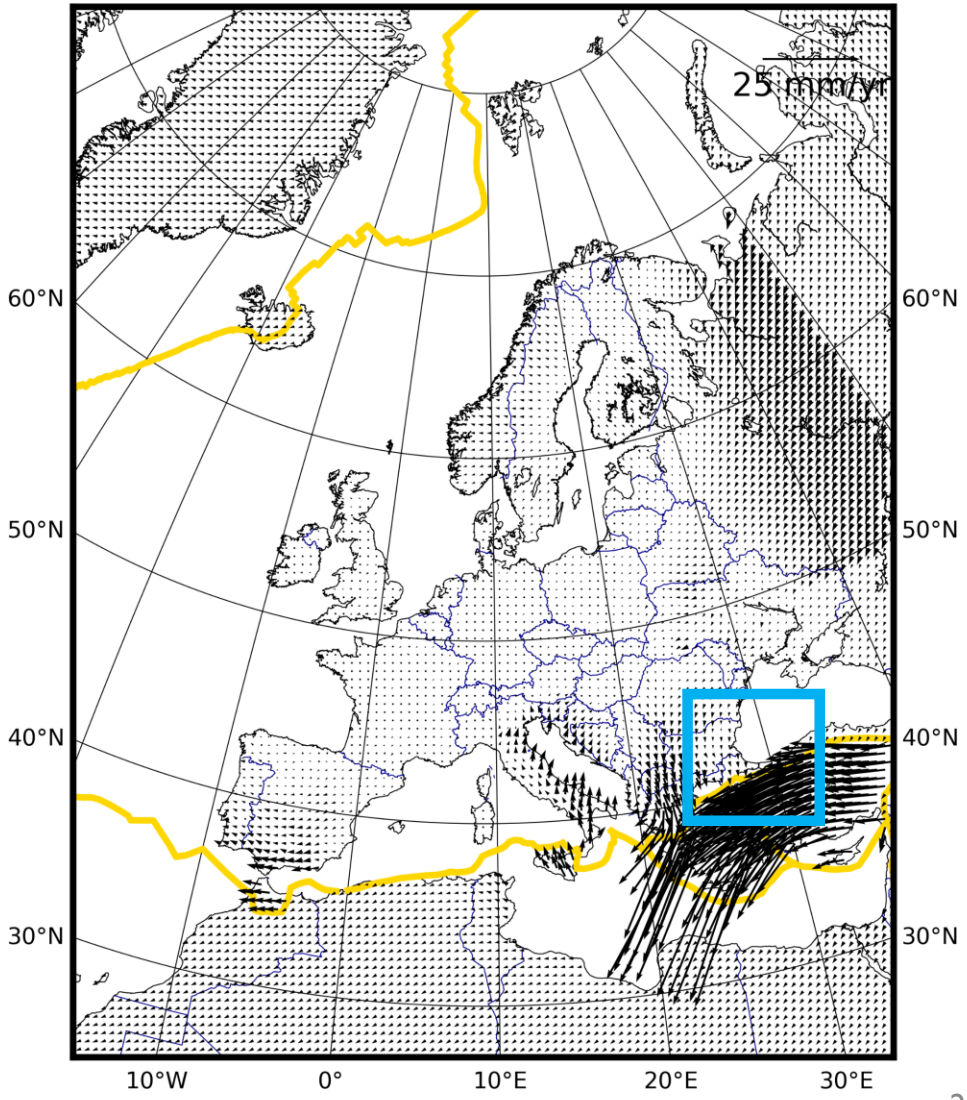
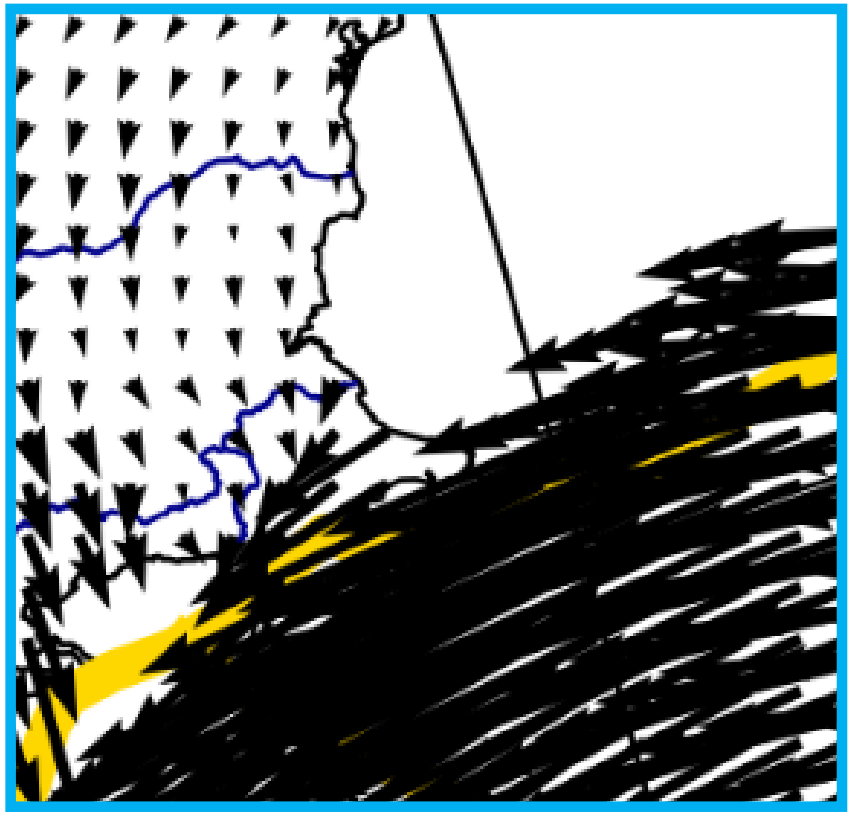
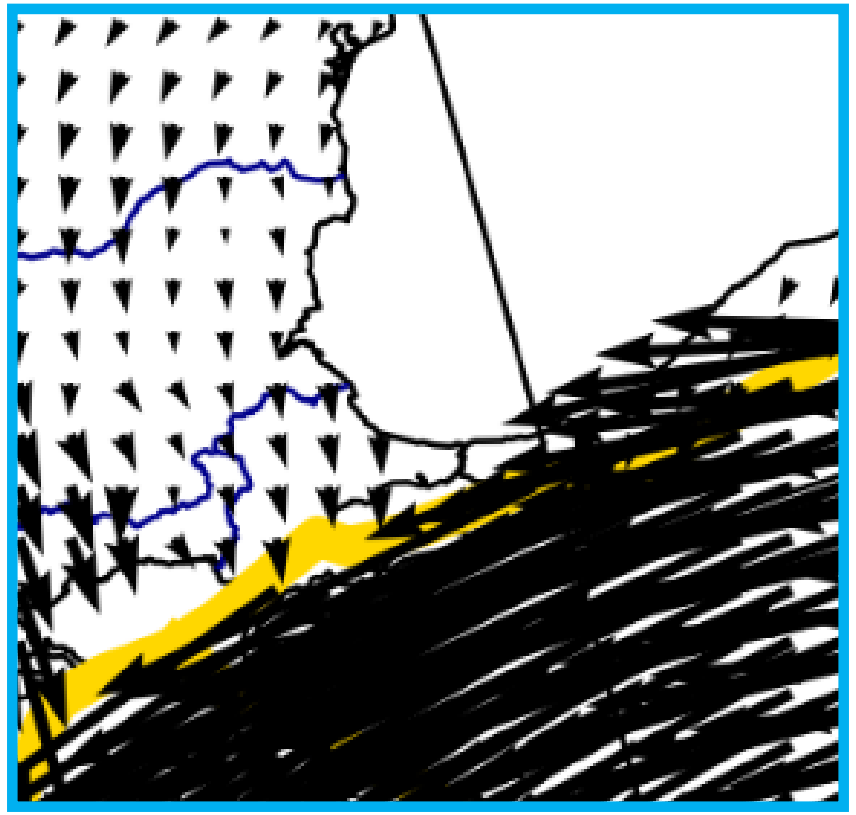


COLLOCATION WITH PLATE BOUNDARIES

Collocation without plate boundaries



Collocation with plate boundaries



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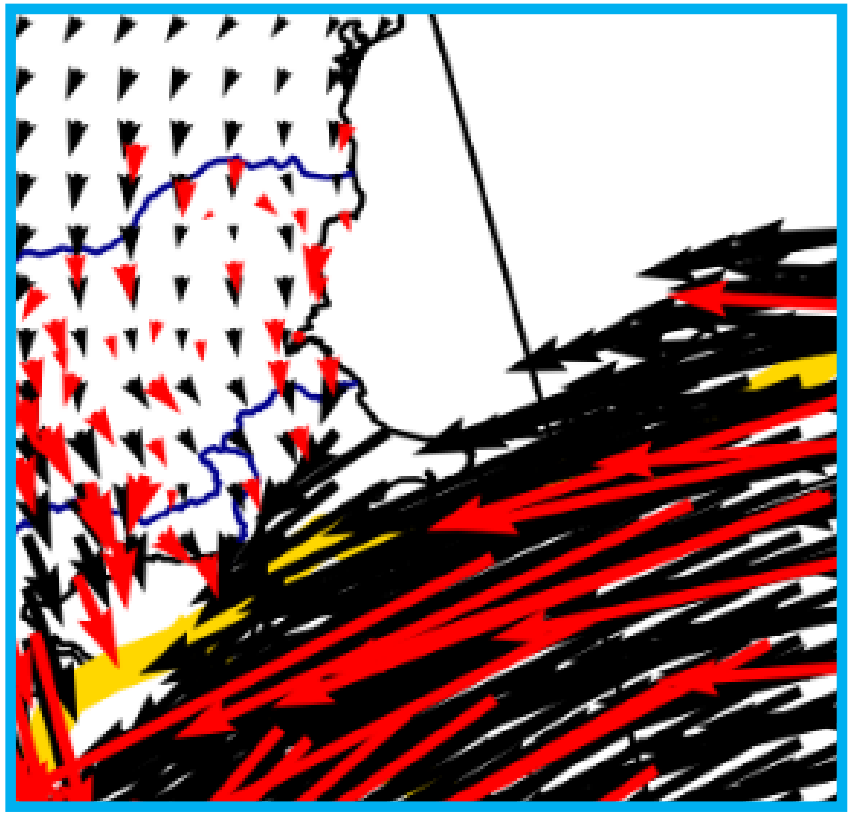

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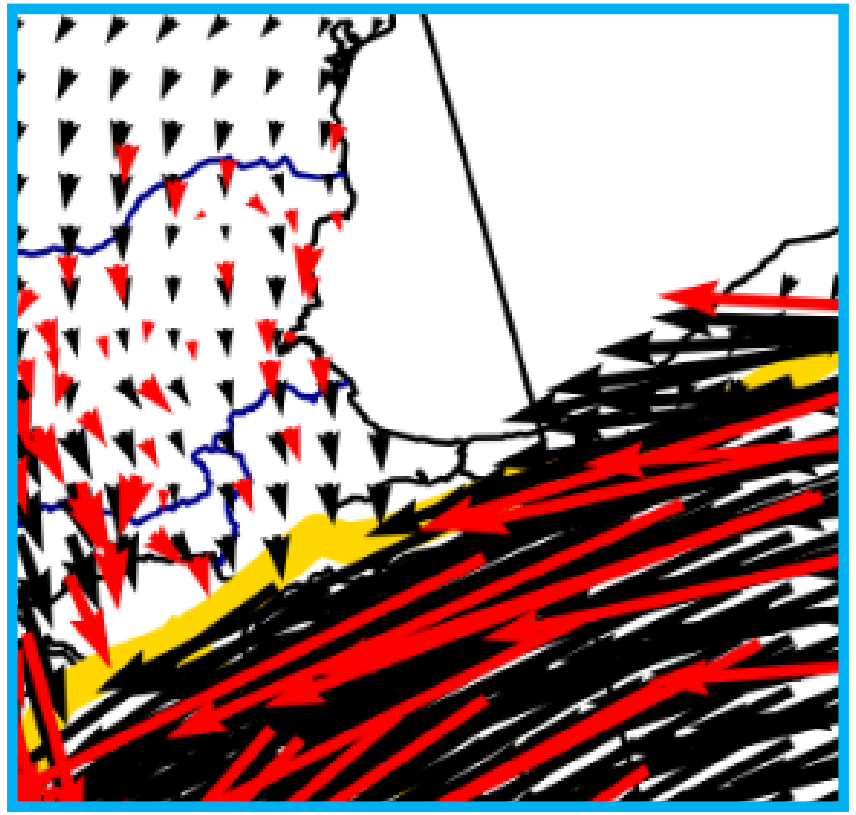

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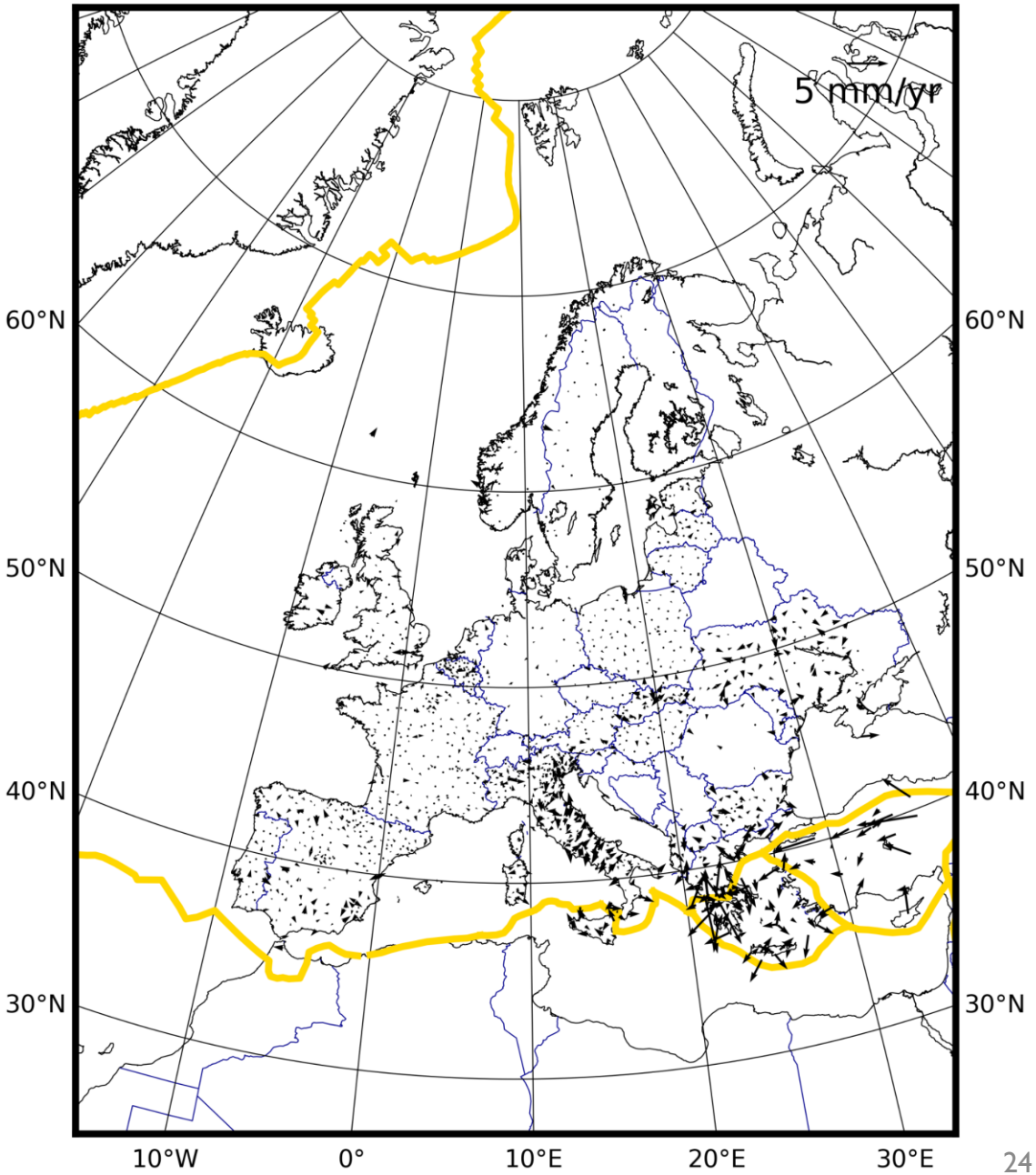
COLLOCATION – FILTERING

- Comparison of observed to collocated (filtered) data → cross-validation (mm/yr)

Entire area

EW	-7.230	2.872	0.0	0.519



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Entire area

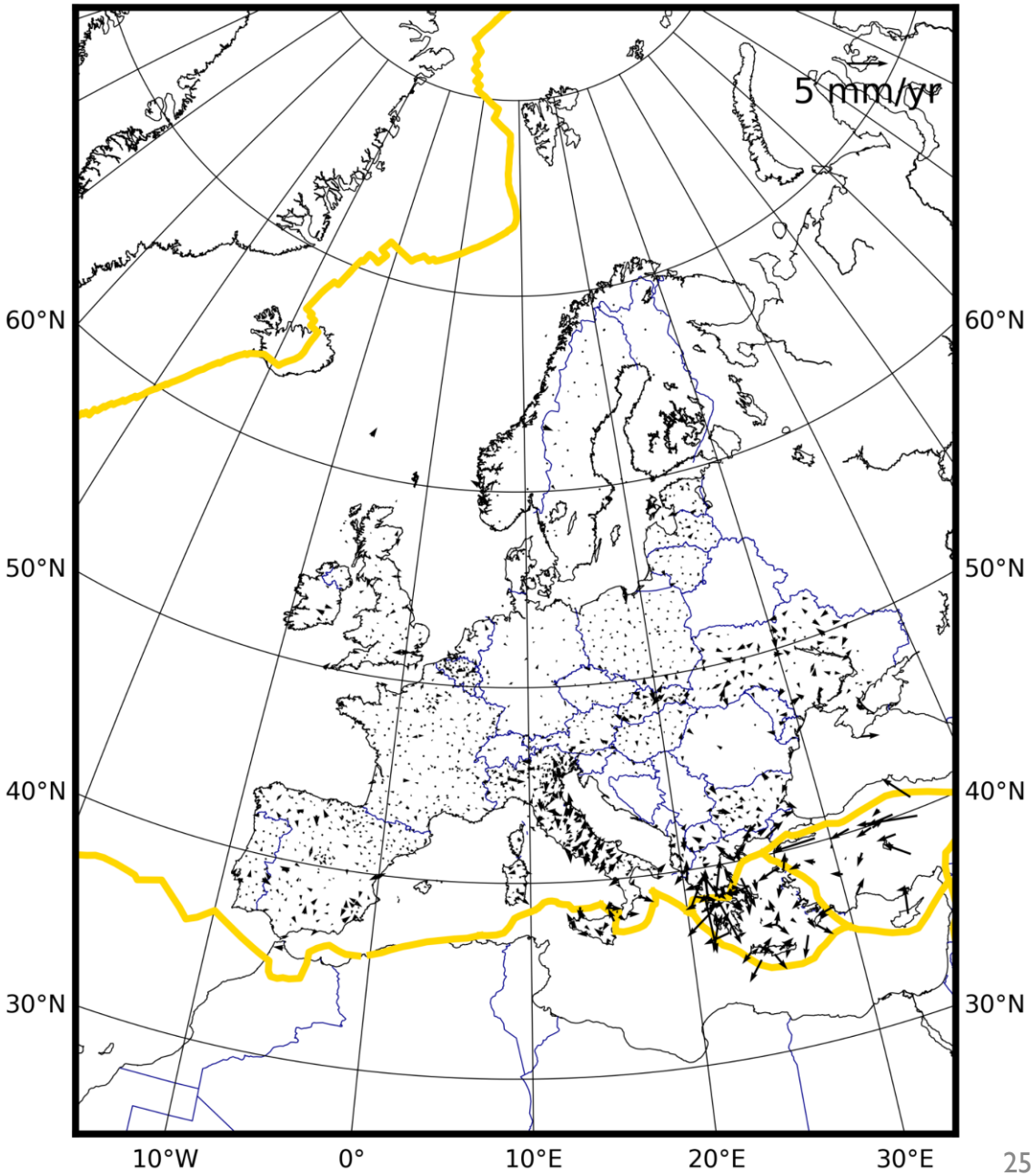
EW	-7.230	2.872	0.0	0.519

Germany

EW	-0.441	0.508	0.029	0.229

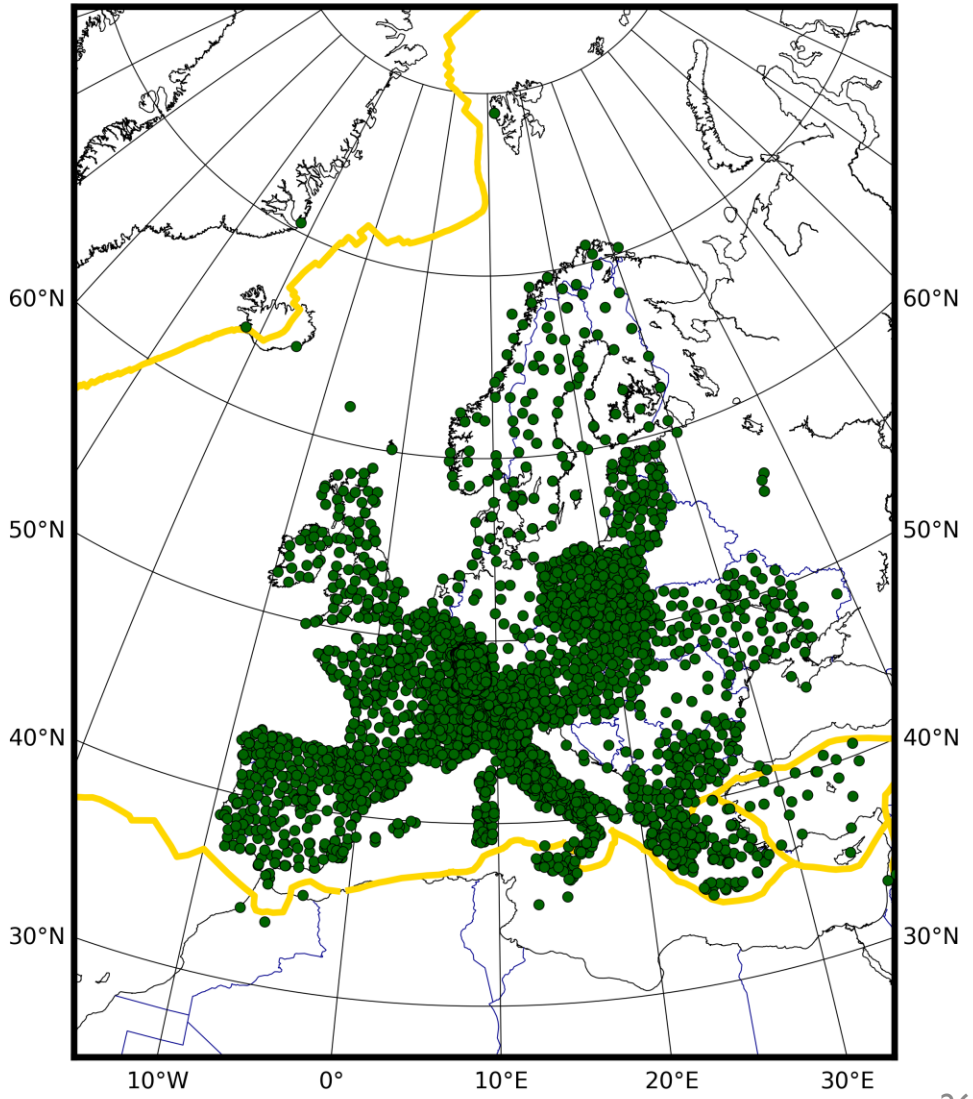
Italy

EW	-1.348	1.824	0.047	0.461

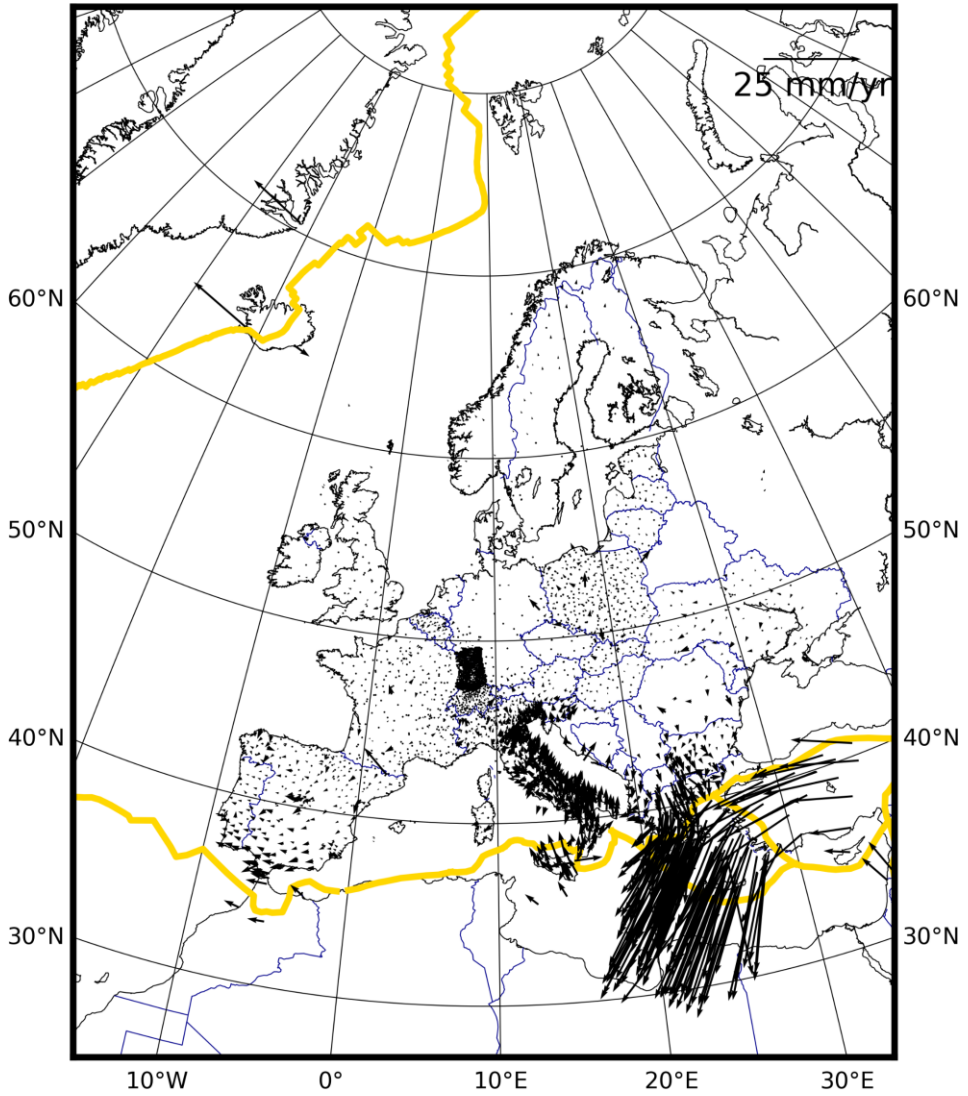


COLLOCATION – EUROPEAN DENSE VELOCITIES

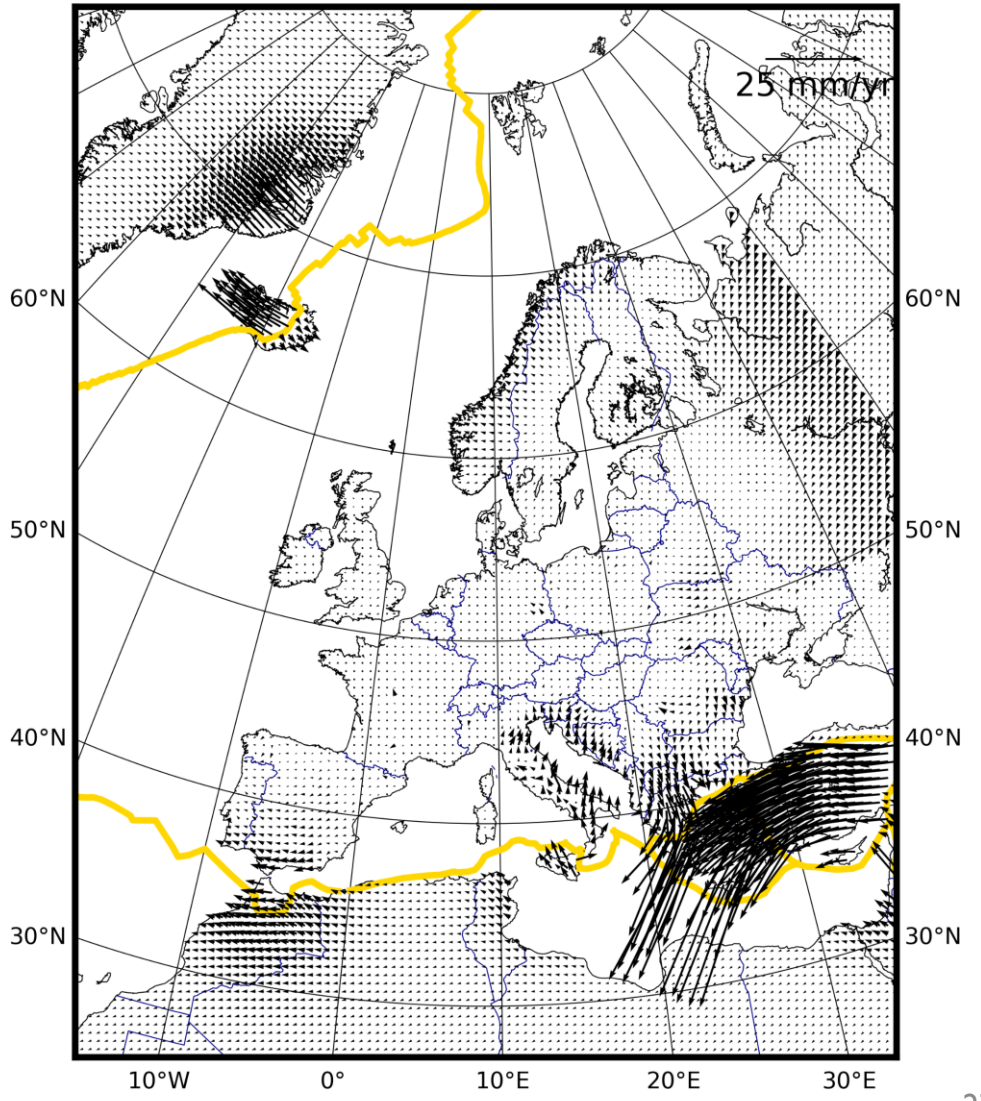
- A different dataset can be used as well:
  - "European Dense Velocities" by Lutz & Brockmann
    - Some 25 velocity solutions provided (including the EPN densification) in well defined reference frames (preferably ETRF2000) compared and combined
    - Data cleaning is ongoing
    - More information: http://pnac.swisstopo.admin.ch/divers/dens_vel/index.html
    - Dataset "VELF_20180911.STA" from September 12th, 2018, is used in the following
    - Dataset is in ETRF2000



COLLOCATION – EU DENSE VELOCITIES

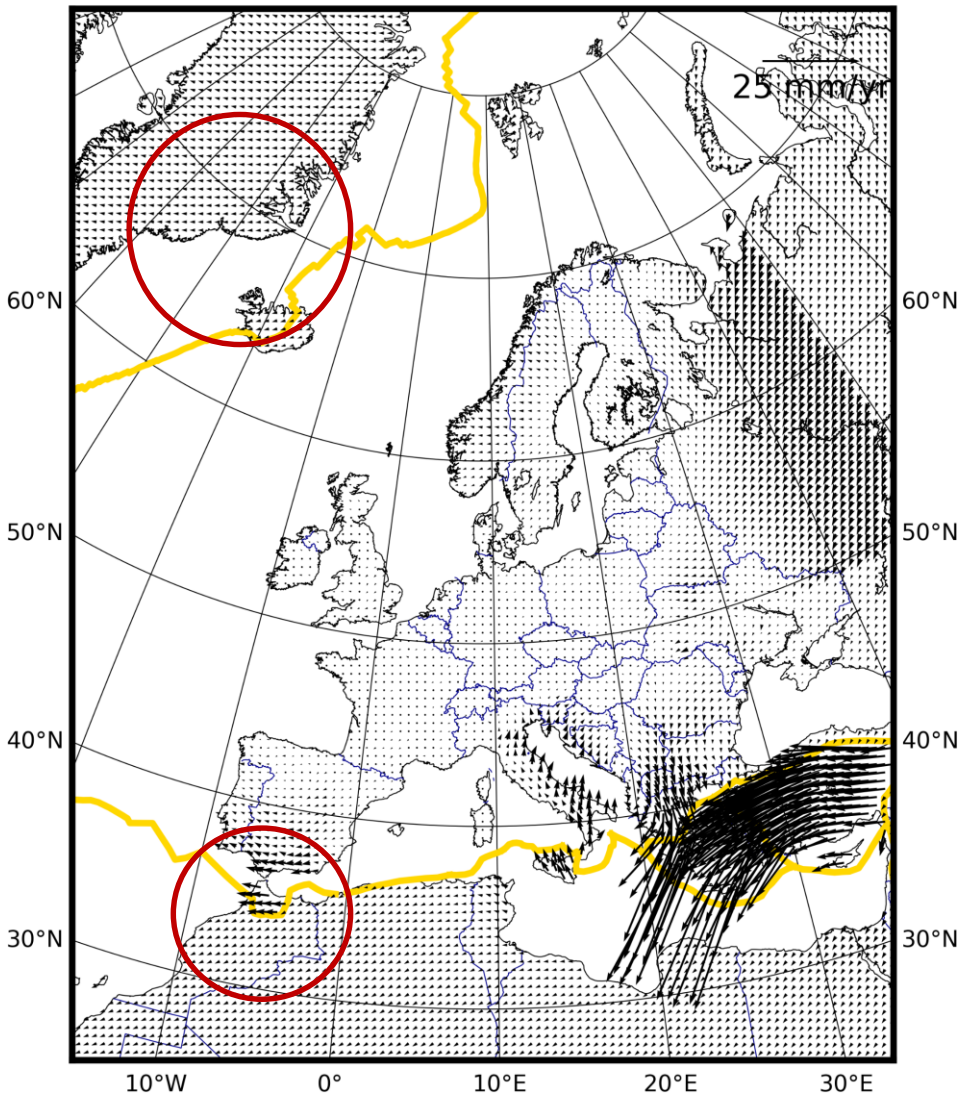


Collocation including plate boundaries

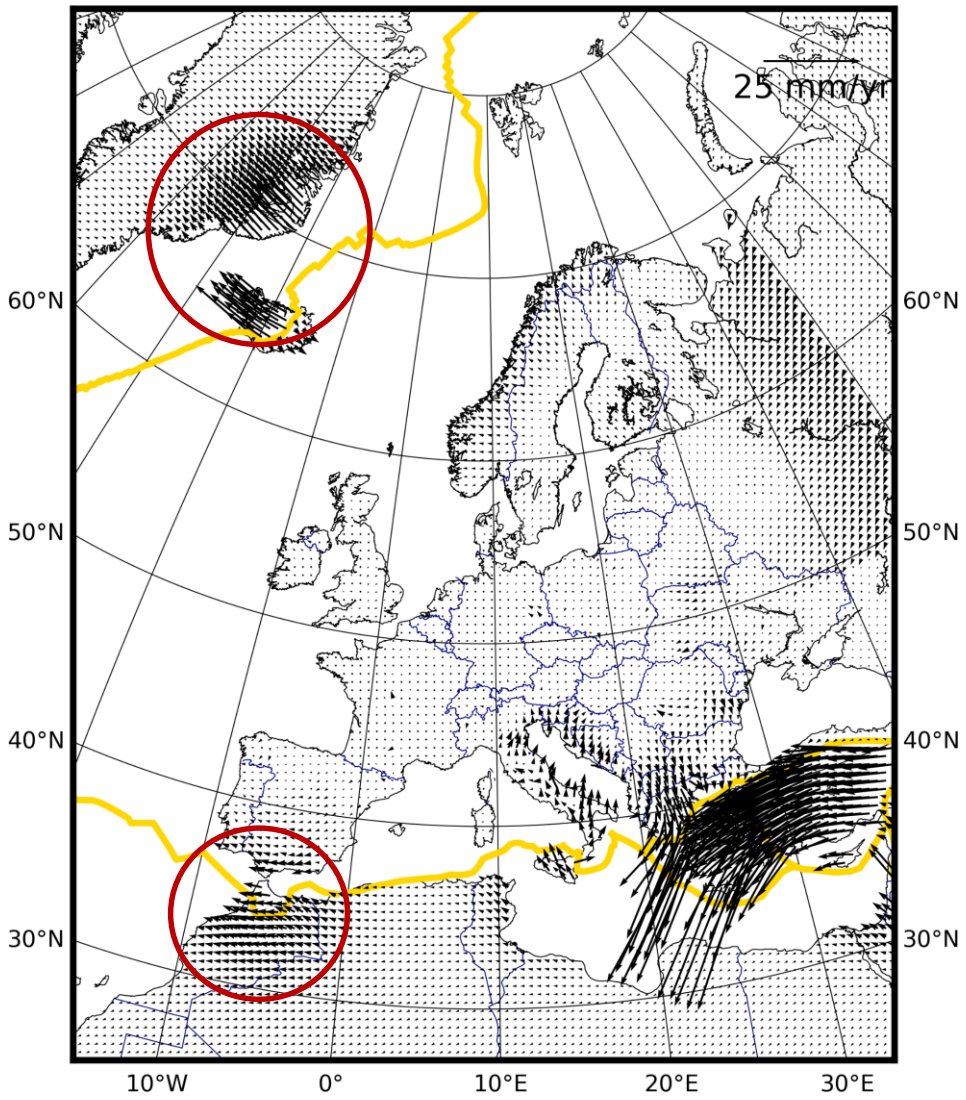


COLLOCATION – COMPARISON

EPN densification



EU Dense Velocities



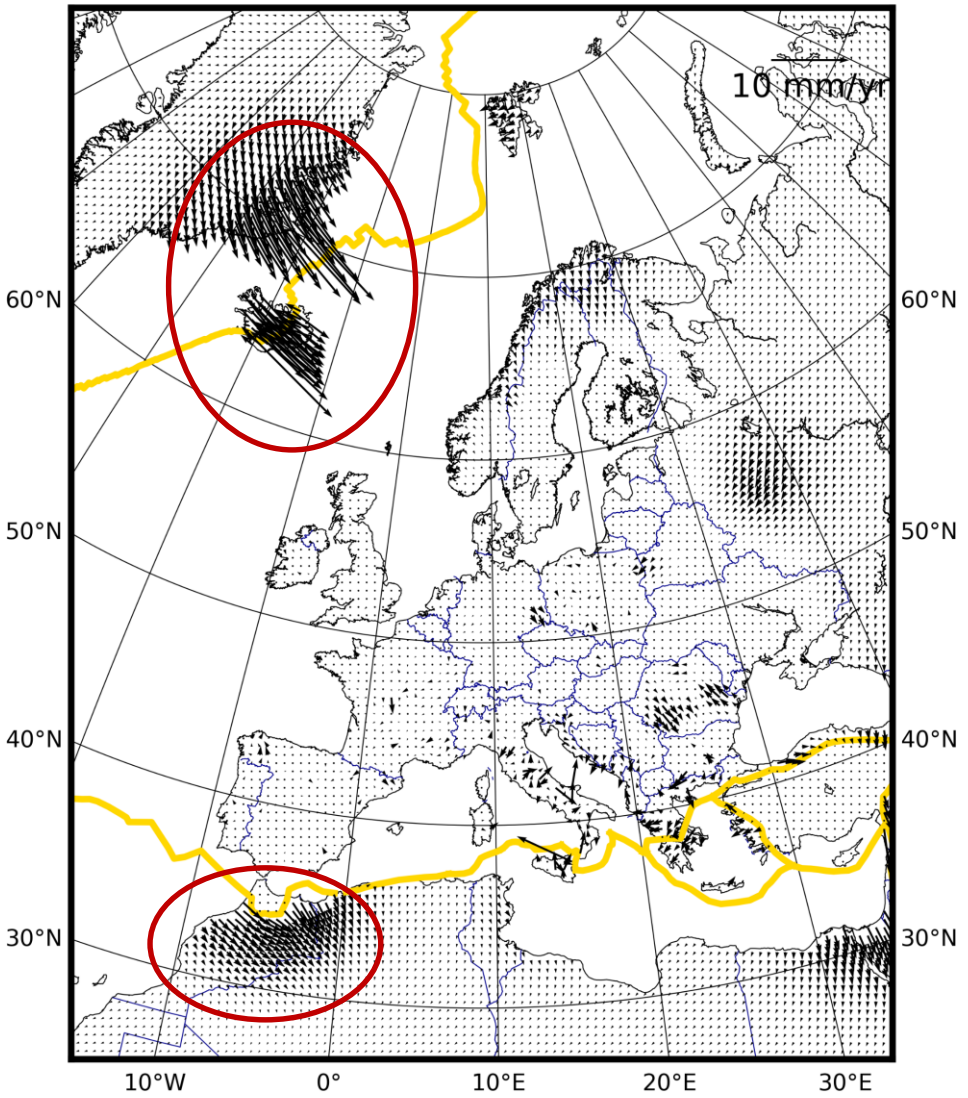
COLLOCATION – COMPARISON

- Difference between collocated velocity fields obtained from EPN densification and EU Dense Velocities (mm/yr)

Entire area

EW	-6.751	15.369	-0.011	0.990	0.991

EPN densification – EU Dense Velocities



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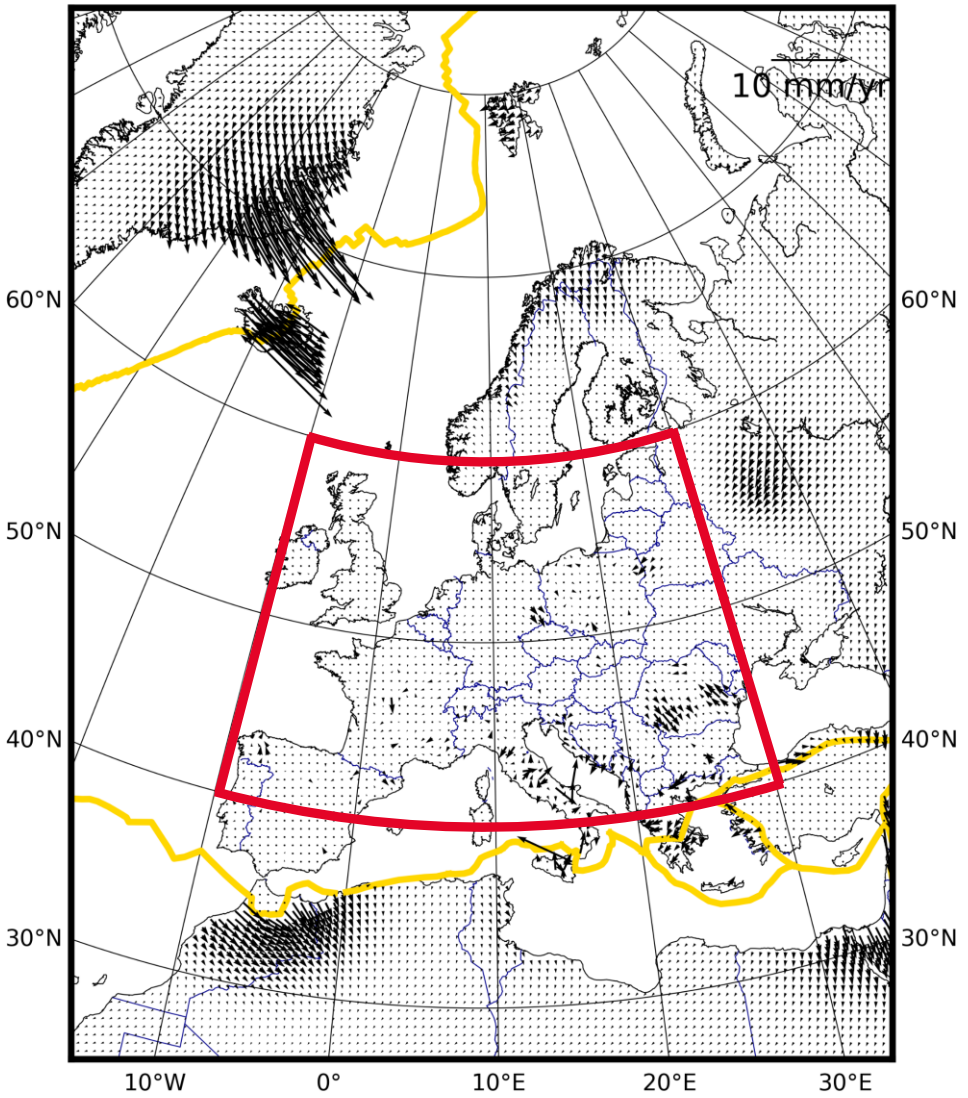
Entire area					
EW	-6.751	15.369	-0.011	0.990	0.991
Central Europe					
NS	-2.950	3.663	-0.038	0.359	0.361

EPN densification – EU Dense Velocities



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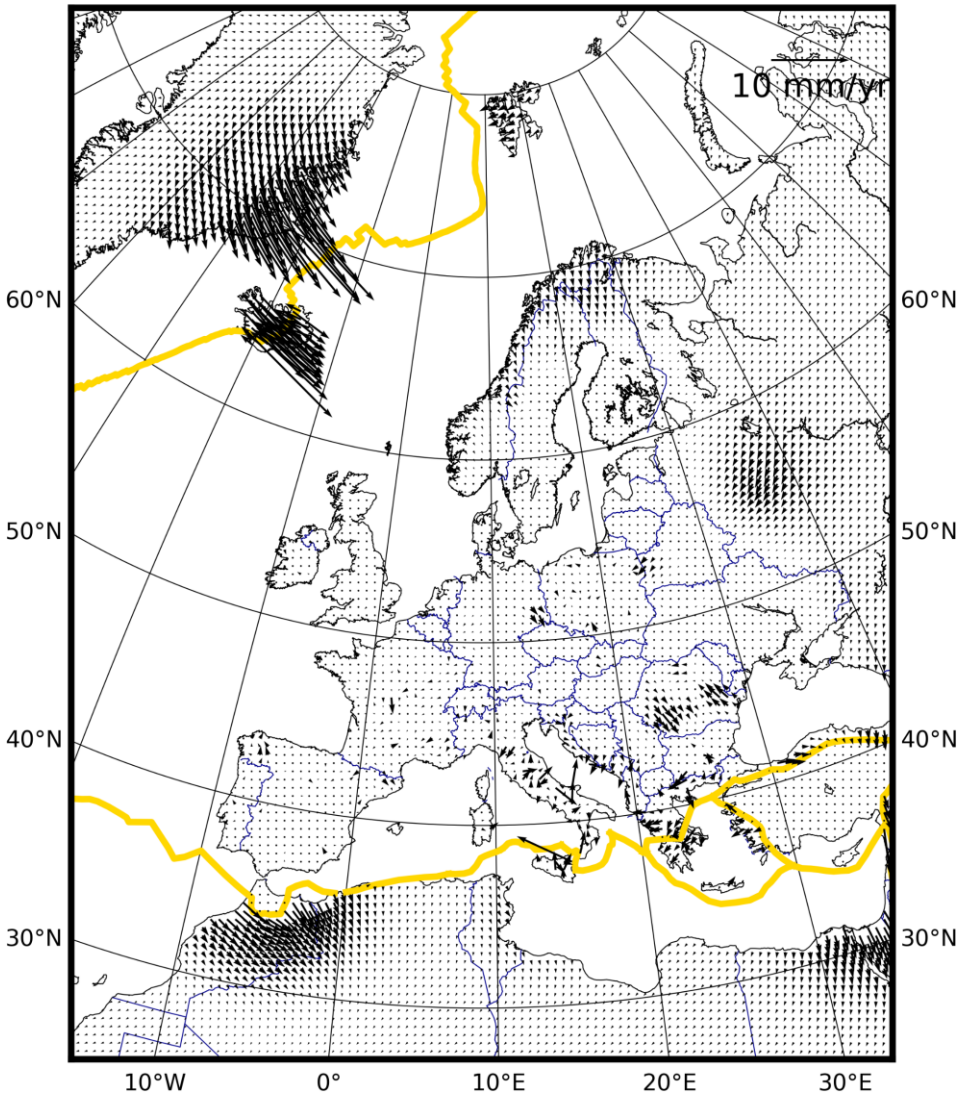
Entire area					
EW	-6.751	15.369	-0.011	0.990	0.991
Germany					
NS	-1.615	0.286	-0.108	0.226	0.251
Italy					
NS	-2.423	3.874	0.175	0.866	0.884

EPN densification – EU Dense Velocities



SUMMARY

- Deformation model (velocity grid) for Europe obtained
- Collocation uses both horizontal components at the same time as well as including their correlation (follows Legrand, 2007)
- Plate boundaries implemented in collocation → provides better estimates of the horizontal velocities
- Vertical component can be also added in the collocation procedure (not shown here)
- Uncertainties can be calculated as well (formal standard error of the LSC)
- Cross-validation done to obtain an external estimate of the uncertainty
- Outlook:
  - Implementing non-stationarity in covariance calculation → done now (will be presented at IUGG)
  - Increasing grid density as well as using high-resolution coastlines to cover all areas on land in Europe

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THANK YOU FOR YOUR ATTENTION!