

ADVANCING DROUGHT ASSESSMENT IN EUROPE THROUGH TEMPORAL-SCALE INTEGRATION

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Motivation:

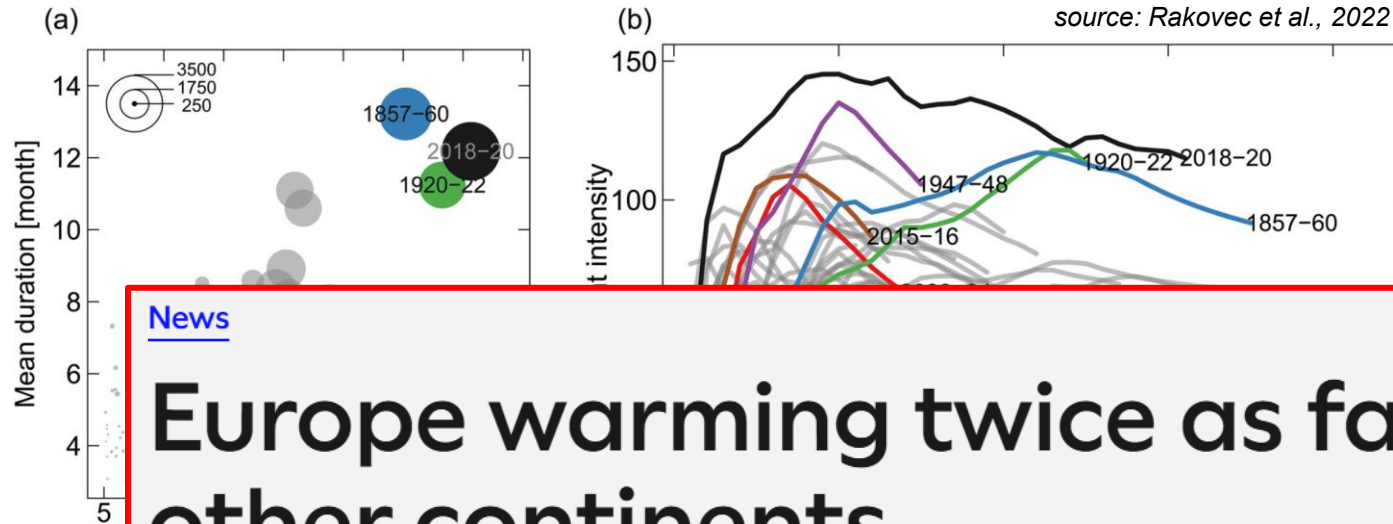
1. study of hydroclimatic variations – climate/hydrological indices and models (different input parameters, methods, etc.) – under-/overestimation of physical changes,
2. the real-time observations from geodetic systems – hydrology, cryosphere, ocean science, etc. – hydrogeodesy,
3. geodetic techniques limitations – spatial/temporal resolution (GRACE), spurious effects (GPS), data processing (GRACE/GPS), etc.,
4. data combination – exploiting strengths and overcoming weaknesses,
5. signal decomposition (Klos et al., 2023) – more trusted signals for hydrogeodesy.

Research goal:

Determination of a new **temporal-scale MDSI** (Multivariate Drought Severity Index) based on geodetic observations – a step towards strengthening the credibility of merged (GPS, GRACE) short-term, seasonal and long-term hydroclimate signals to assess the drought characteristics.

Study area:

1. Europe – a persistent and evolving drought crisis,



News

Europe warming twice as fast as other continents

By Emma Caton

First published 26 June 2023

2. Southern Europe – persistent droughts
3. Central Europe – exceptional summer droughts in 2018 and 2022, sharply reducing river discharge and agricultural productivity,
4. Northern Europe – emerging moisture deficits during unusually warm seasons.

Pre-processing and data selection:

GPS:

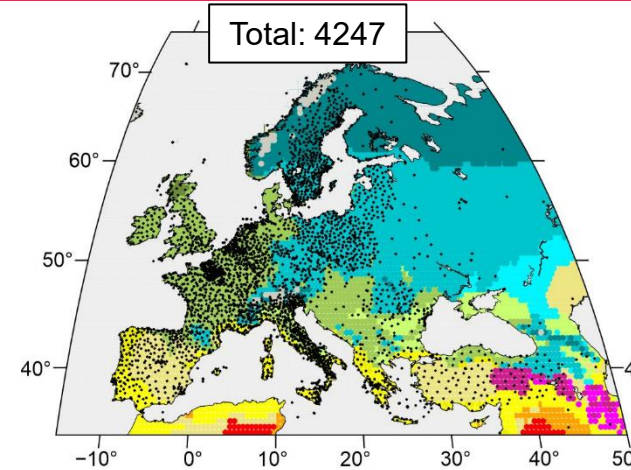
- **4247 daily** GPS station position time series (NGL),
- offsets/outliers removing,
- non-tidal loading and GIA corrections.

GRACE/GRACE-FO:

- **monthly JPL mascon** solution (RL06.3_v04),
- $0.5^{\circ} \times 0.5^{\circ}$ grid,
- data gap not interpolated.

Reference data:

- temperature (GISTEMP), precipitation (GPM IMERG), soil moisture index, SPEI-12, GLWS hydrological model.



Methodology:

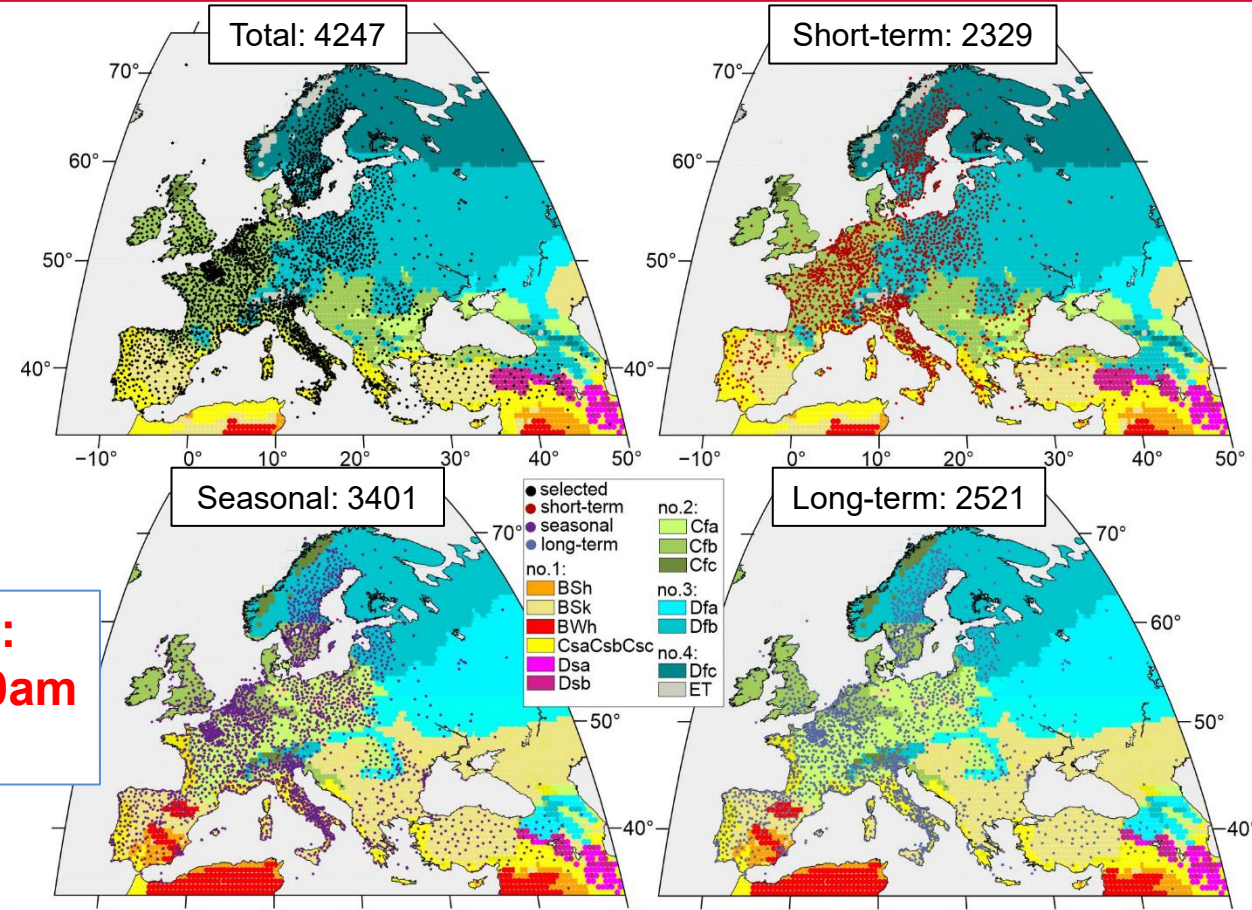
Wavelet decomposition:

- **Meyer** mother wavelet (Meyer, 1990), short-term (from 2 to 9 months), seasonal (from 7 months to 1.4 year), long-term (from 1.1 year upwards).

Benchmarking:

- Klos et al. (2023) approach,
- GLWS hydrological model release 2.
- Clustering for 4 climate zones: present and future.

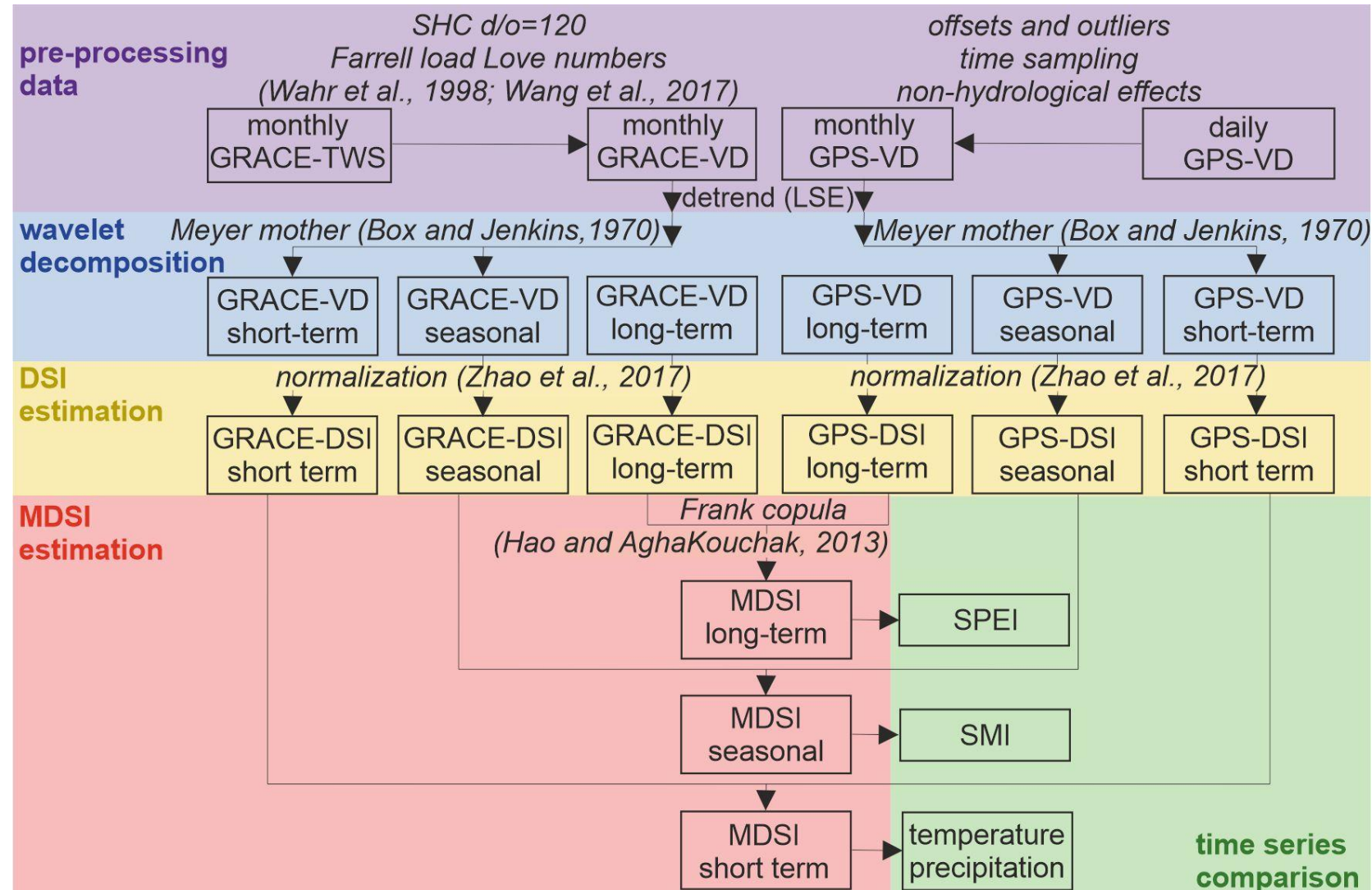
Session S1:
11:30am-11:50am
Klos et al.



*the **present** (top row) and **future** (bottom row) Köppen-Geiger climate classification zones over Europe (Beck et al., 2018).

No.1: hot (BSh) and cold (BSk) semi-arid, hot desert (BWb), hot- (Csa), warm-(Csb) and cold-summer Mediterranean, and humid continental (Dsa, Dsb) climate zones,
No.2: humid subtropical (Cfa), oceanic (Cfb) and subpolar oceanic (Cfc) climate zones,
No.3: humid continental (Dfa and Dfb) climate zones,
No.4: subarctic (Dfc) and tundra (ET) climate zones.

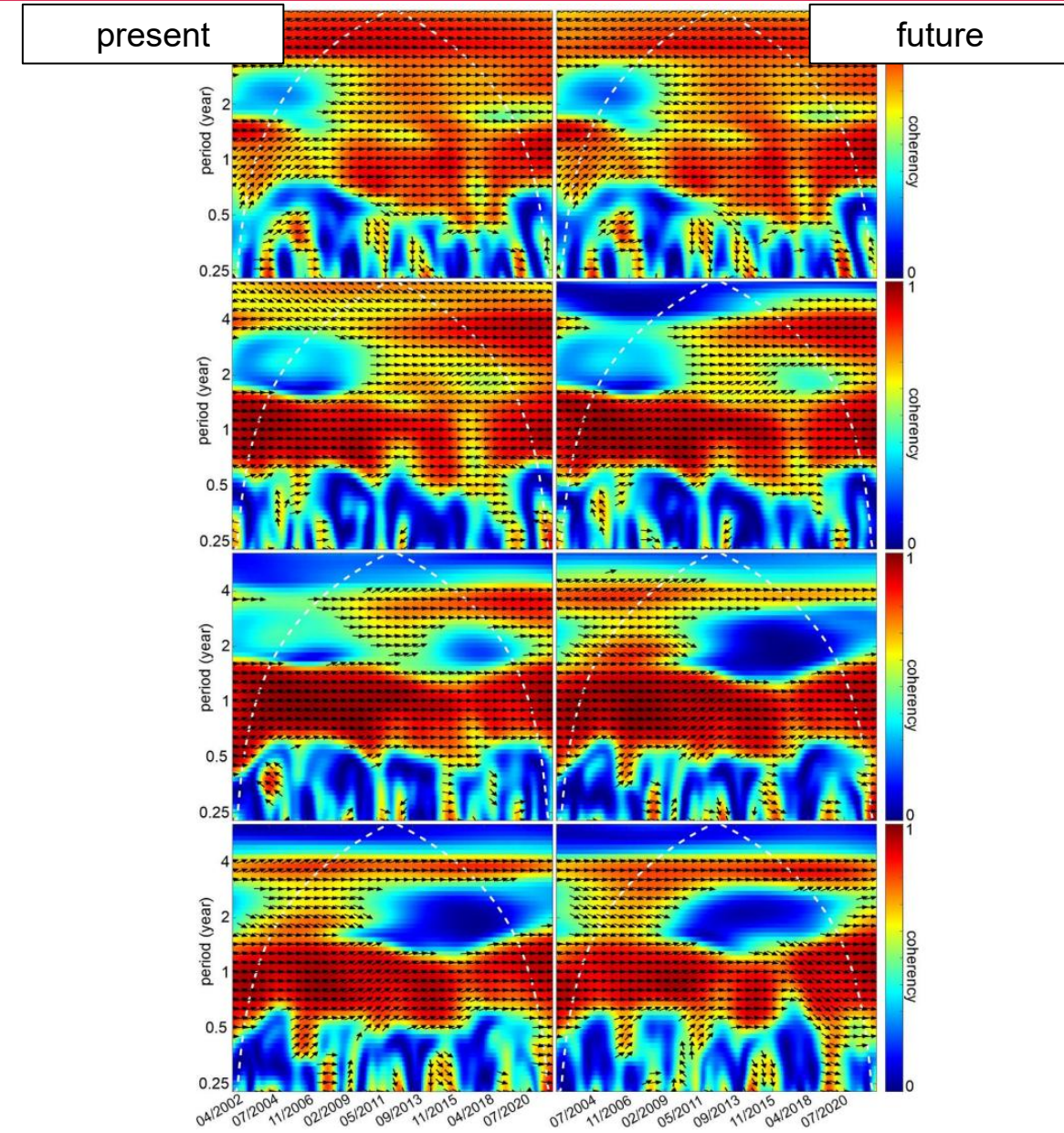
Temporal-scale Multivariate Drought Severity Index: GPS- and GRACE-DSI



short-term: 2 – 9 months,
seasonal: 7 months – 1.4 years,
long-term: >1.1 years.

Wavelet coherence:

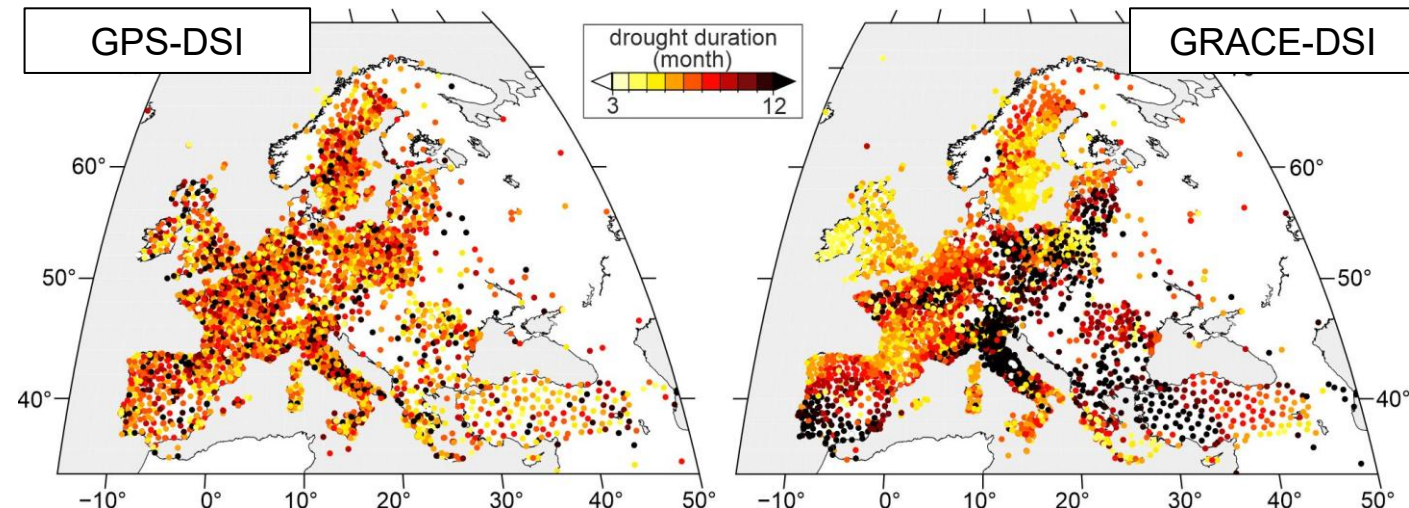
- GPS vs GRACE: strong coherency at seasonal-to-multiannual scale,
- interannual (2–4 yr) signals: coherence >0.6 , mainly after 2010,
- sub-6-month periods: coherence weak and intermittent, except during extreme dry/wet events,
- arrows: GPS and GRACE are in-phase for >6 months signals; local phase shifts (~ 3 months) at higher frequencies.



Drought signatures:

- GRACE-DSI: West → East (5-9+ months); >12 months in Poland, Italy, Spain, Turkey,
- GPS-DSI: coverage of extreme GRACE-DSI values and mining/volcanic activity; the non-zonal increase,
- dry-condition frequency: similar for both techniques (~13-17%),
- wet-condition frequency: diverges sharply: ~30% (GRACE) vs ~10% (GPS).

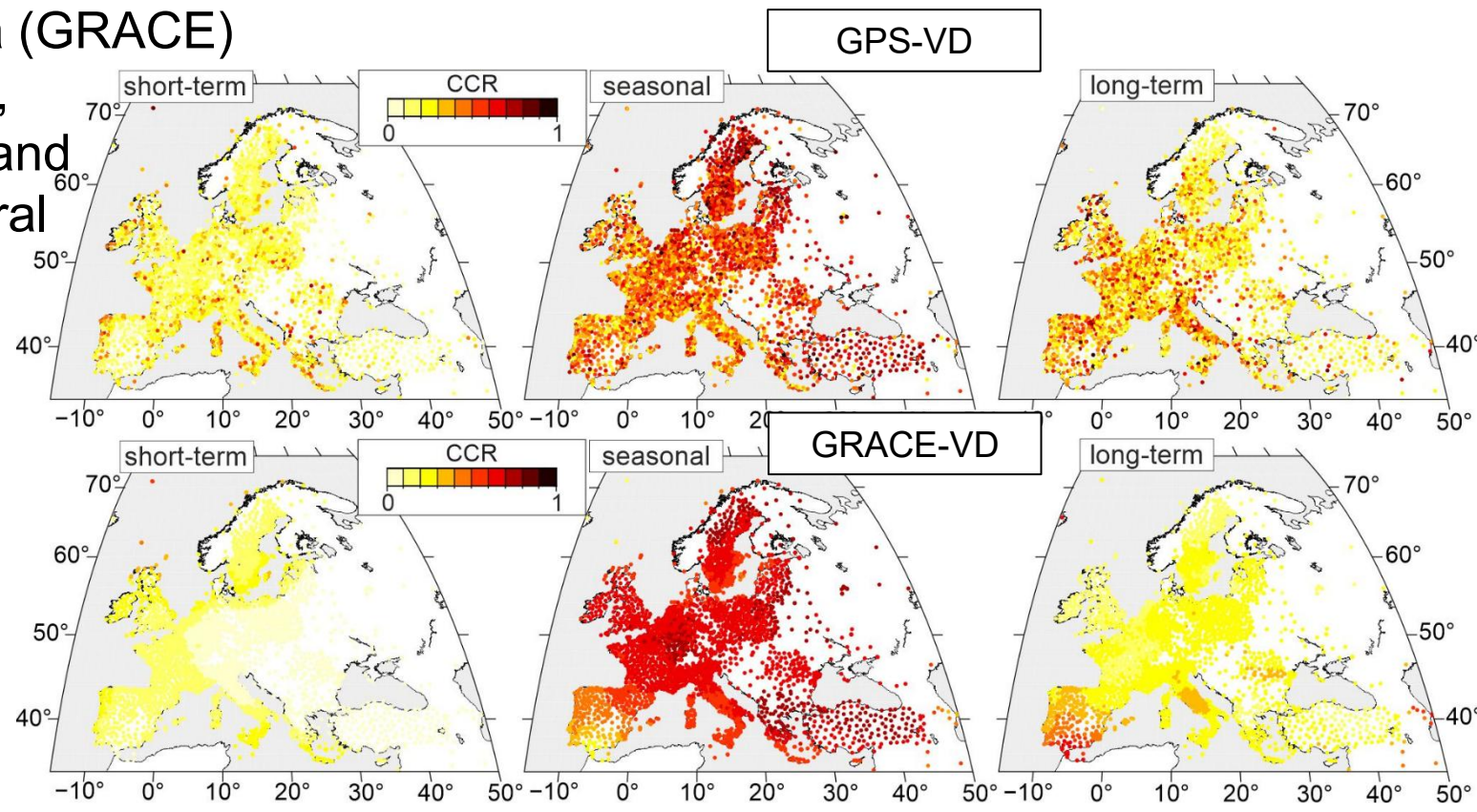
Zone	dry		wet	
	GRACE	GPS	GRACE	GPS
No. 1	10	8	13	11
No. 2	7	8	11	9
No. 3	8	7	12	8
No. 4	7	7	11	8



Ratio of signal components:

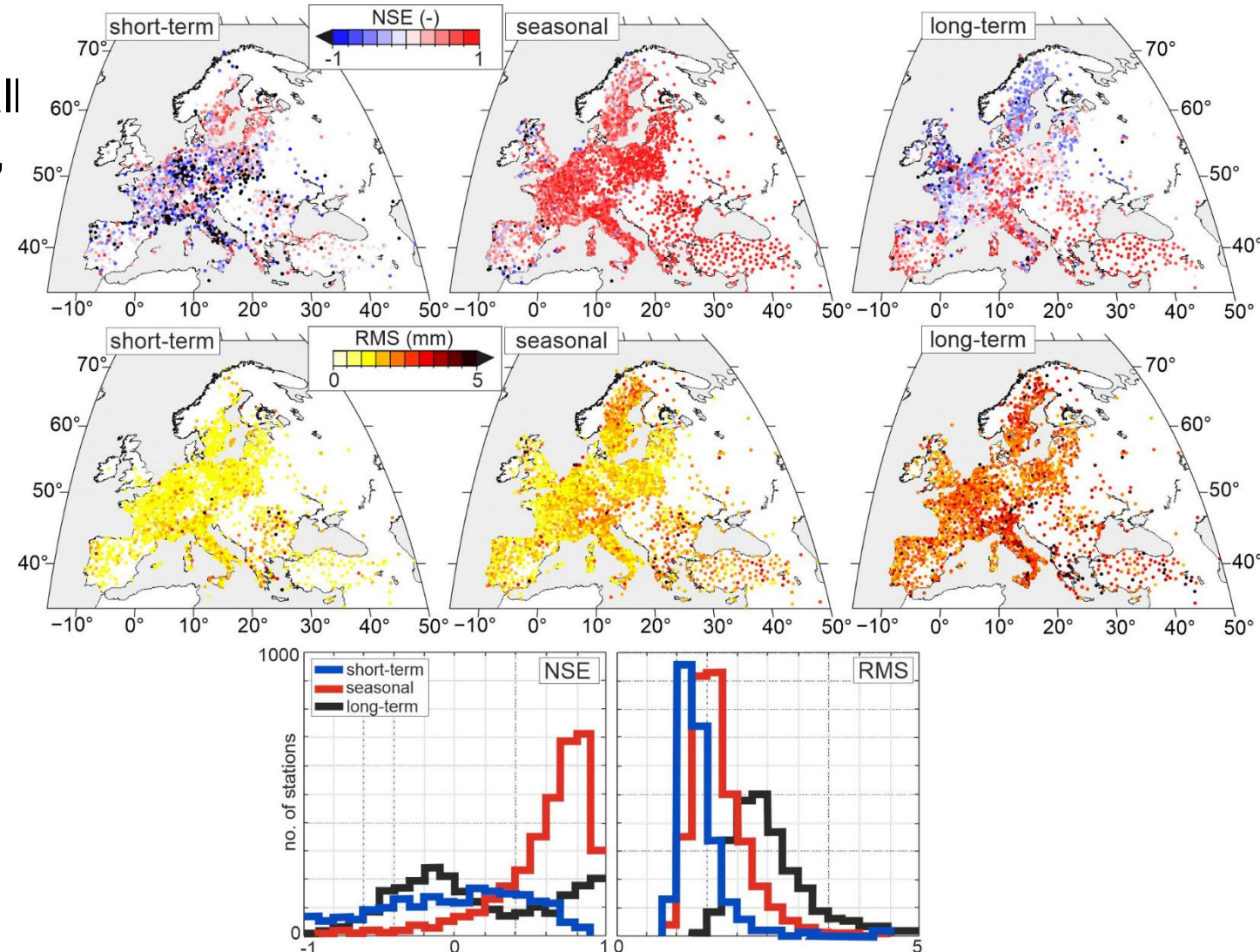
- the contribution of each component to the total GPS- (top) and GRACE-VDs (bottom row),
- seasonal**: CCR>0.5 for 91% (GRACE) and 51% of stations (GPS) over Europe ,
- long-term**: Iberian/Apennine Peninsula (GRACE) and central and western Europe (GPS),
- short-term**: coastal regions (GRACE) and regions exposed to anthropogenic/natural factors (GPS).

	median	
	GRACE	GPS
Short-term	0.17	0.21
Seasonal	0.64	0.50
Long-term	0.22	0.27



VD spatio-temporal analysis:

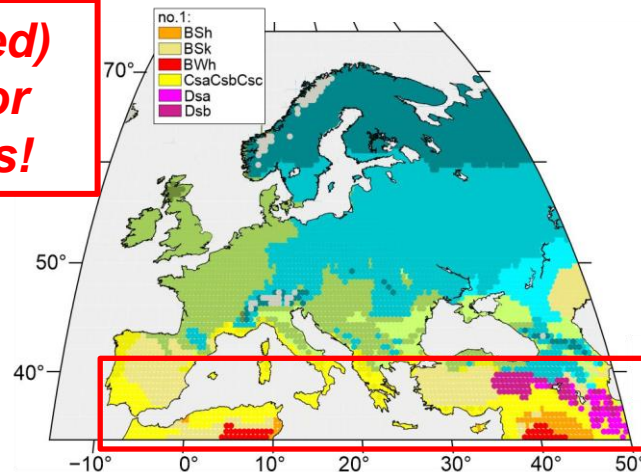
- the present climate classification zones,
- **seasonal**: $NSE > 0$ for 92% of stations; small RMS -> good representation of amplitudes,
- **long-term**: $NSE > 0$ for central-southern Europe; high RMS -> spatial filtering, or non-hydrological factors,
- **short-term**: negative NSE; small RMS -> minor amplitude differences.



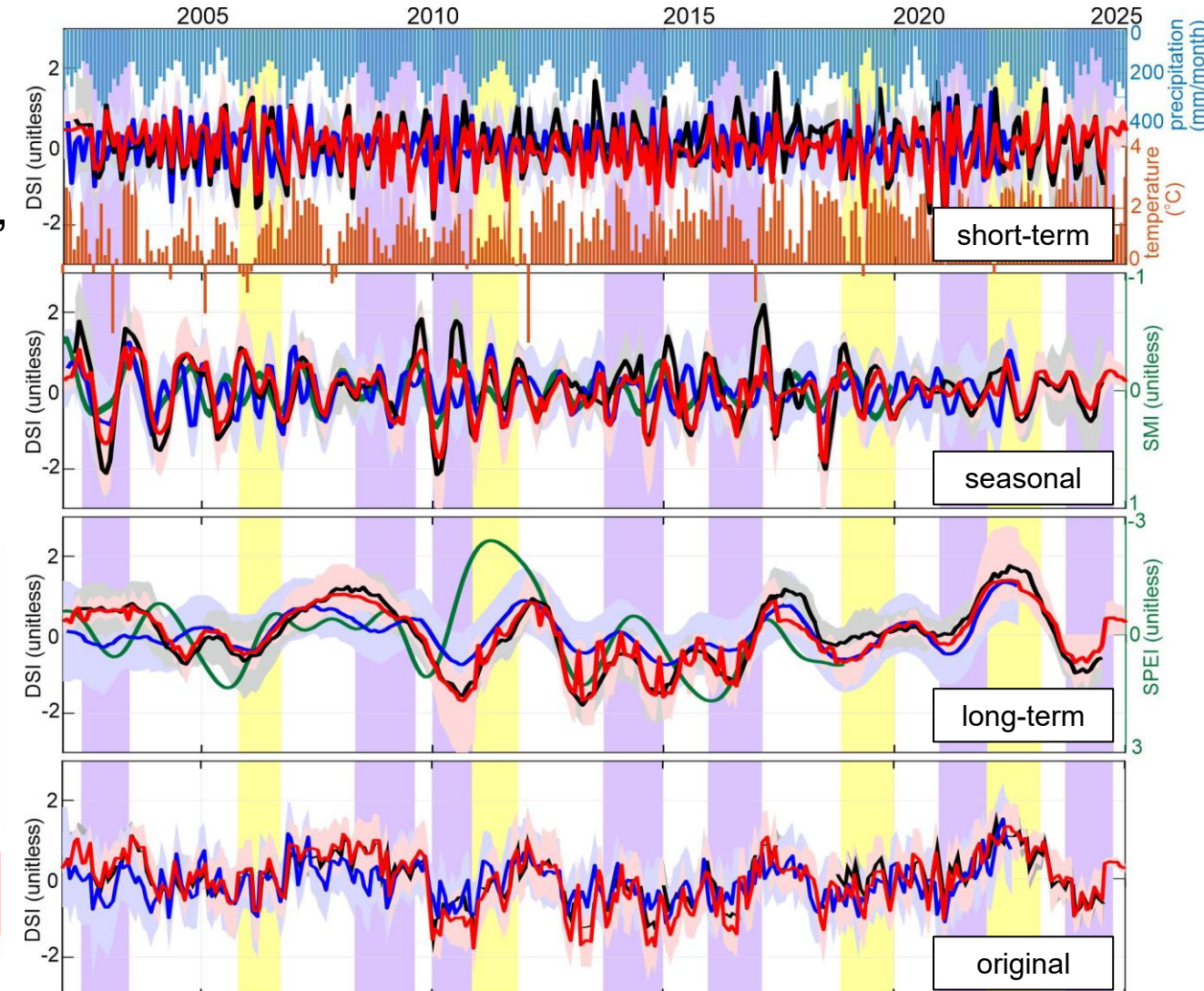
Decomposed MDSI: zone No.1

- all (short-term, seasonal, long-term and total) MDSIs detect most dry and wet events,
- limitations of total MDSI:
 - not sensitive to rapid sign changes (short-term),
 - challenges in clearly identifying seasonal variations (seasonal),
 - not evident multi-long trends in total MDSI (long-term).

Total (non-decomposed) MDSI under-detects or misses several events!



GRACE-DSI, GPS-DSI and MDSI time series



1. The seasonal signals dominate for both GPS and GRACE monthly series.
2. The strongest coherence (NSE) is observed for seasonal signals, which confirms the good amplitude and phase consistency; then long-term, and short-term.
3. All versions of MDSI can detect major droughts and wet events.
4. The decomposition of signals may provide a better understanding of a particular drought type or category (e.g., meteorological or hydrological), drought onset, and how it develops.

Thank you very much
for your attention!

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