Sunspot data analysis using coherency

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with special thanks to Laure Lefèvre and Fédéric Clette

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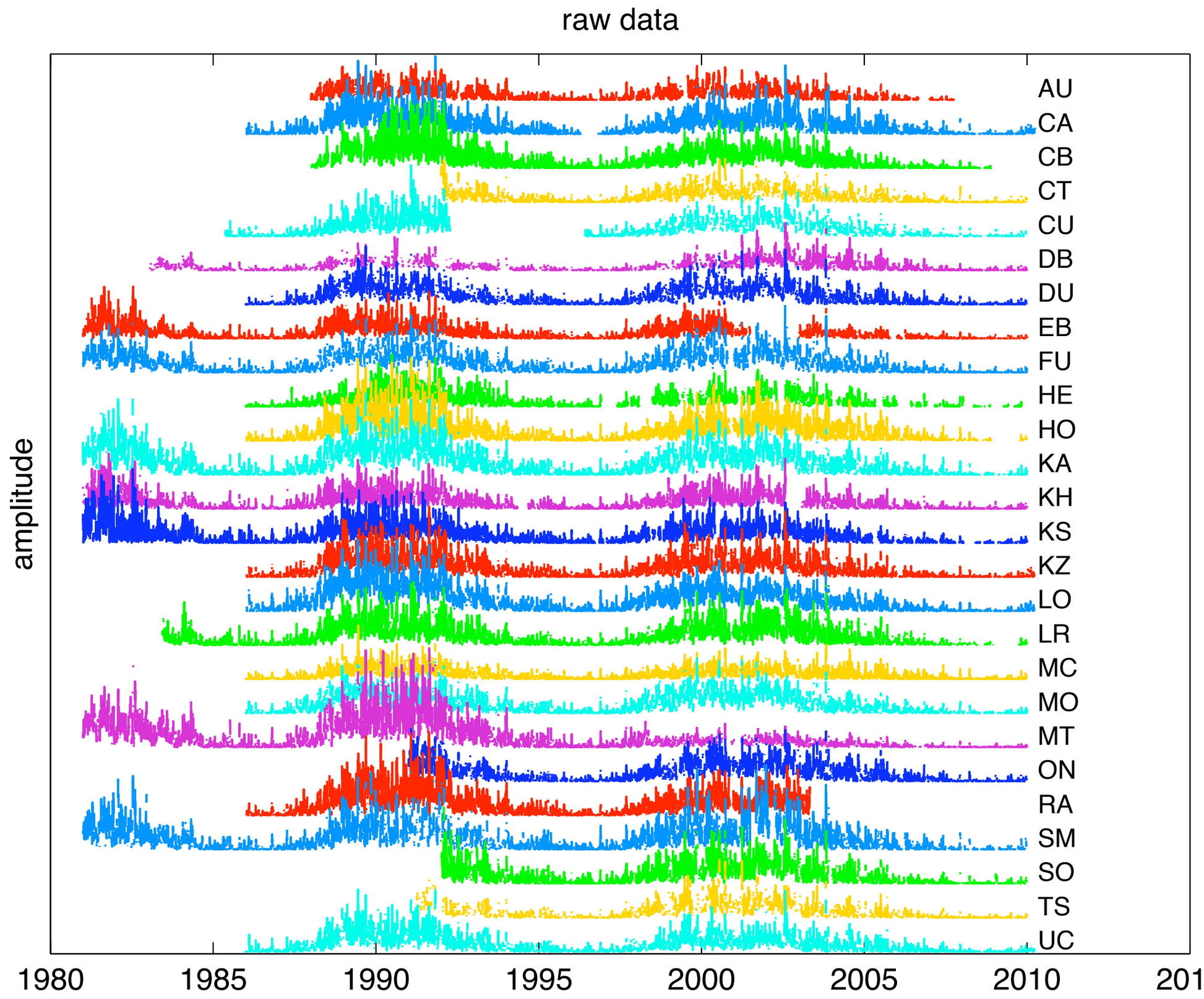
2 questions

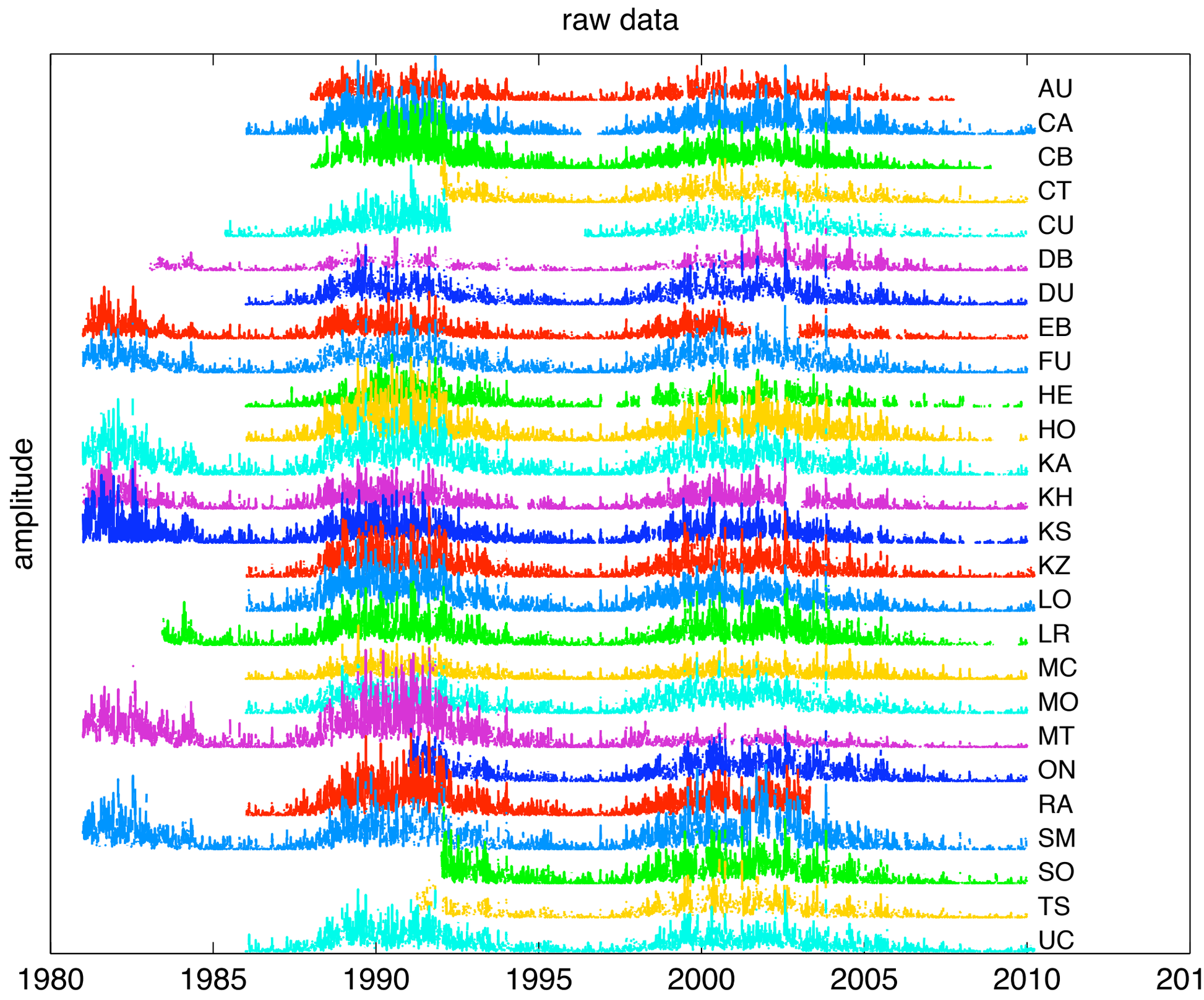
- Data gaps are omnipresent in sunspot records :
  - *Fill them self-consistently to have unbiased statistics ?*

- All solar proxies exhibit the same dynamics :
  - *Do the International & Group sunspot numbers really describe the same physics ?*
  - *How are they related to other solar proxies ?*

Raw sunspot data



What we would like to have



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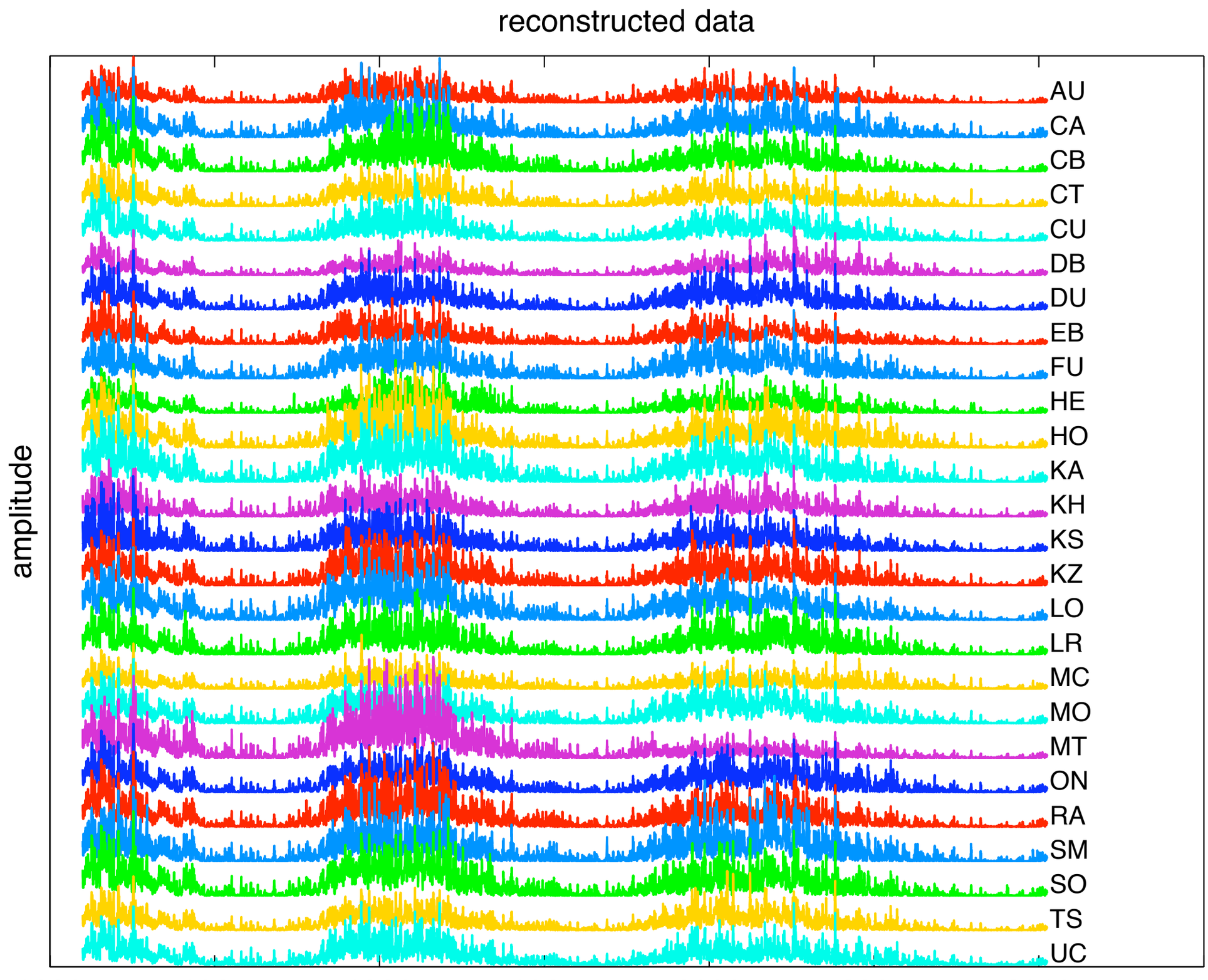
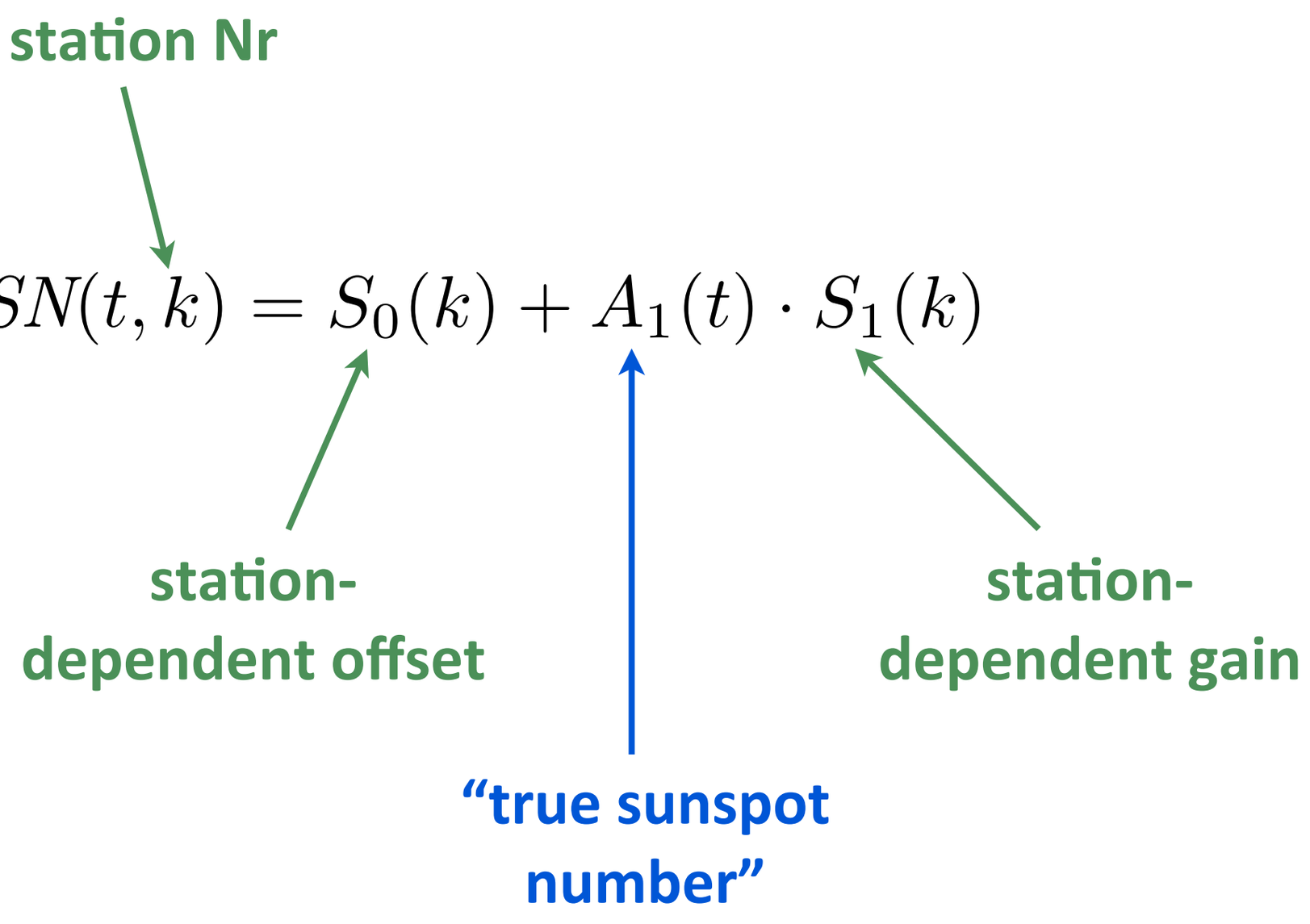


Our model: coherency

- Assumption: all records describe the same observable



Our model: coherency

- Add first order correction to account for discrepancies

$$SSN(t,k) = S_0(k) + A_1(t) \cdot S_1(k) + A_2(t) \cdot S_2(k)$$

- Add more higher order (= small) corrections if needed

$$SSN(t,k) = S_0(k) + \sum_i A_i(t) \cdot S_i(k)$$

Our model: coherency

$$SSN(t,k) = S_0(k) + \sum_i A_i(t) \cdot S_i(k)$$

- The *amplitudes* $A_i(t)$ and *sources* $S_i(k)$ are estimated by Singular Value Decomposition (SVD)
  - similar to principal component analysis

- Data gaps are filled by using the first dominant terms
  - this is done iteratively, see [Dudok de Wit, A&A 533 (2011)]
  - a multiscale approach is used
  - validation by bootstrapping

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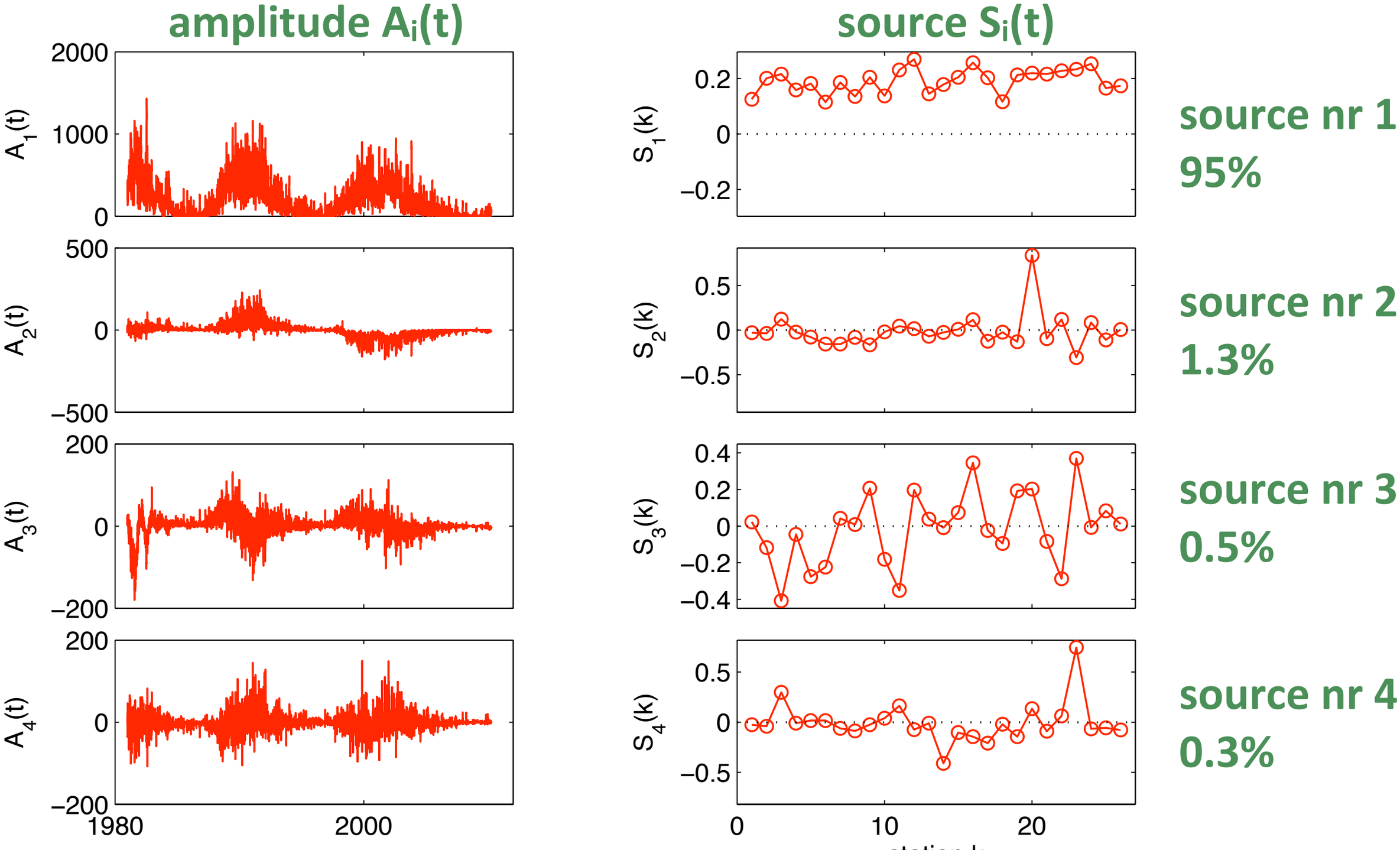
Gaps are filled while ensuring that their statistical properties vs all the other variables remain unaffected

The dominant source terms

$$SSN(t,k) = S_0(k) + \sum_i A_i(t) \cdot S_i(k)$$



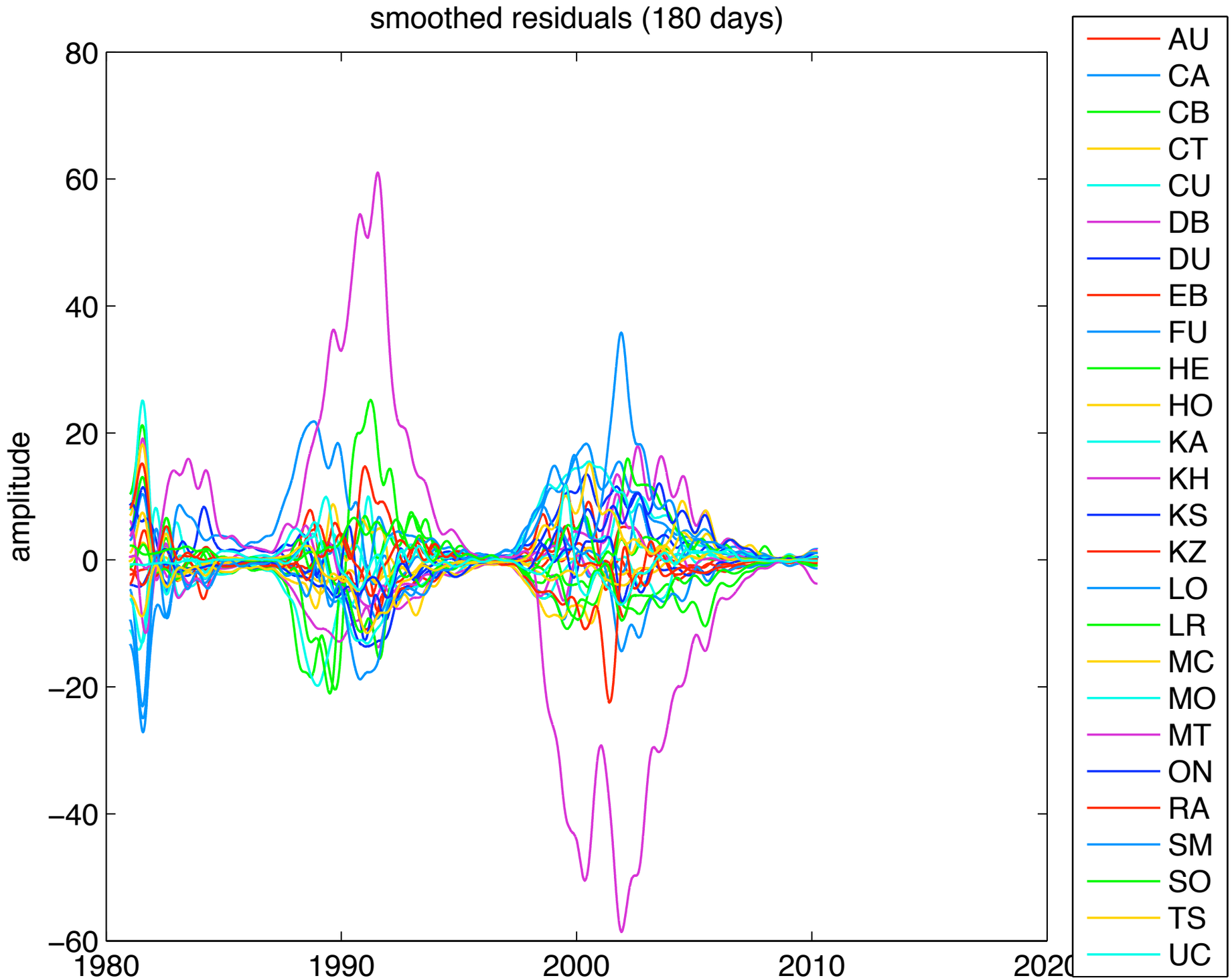
source nr 1
95%

source nr 2
1.3%

source nr 3
0.5%

source nr 4
0.3%

Residual error for each station



Residual error, smoothed over 180 days

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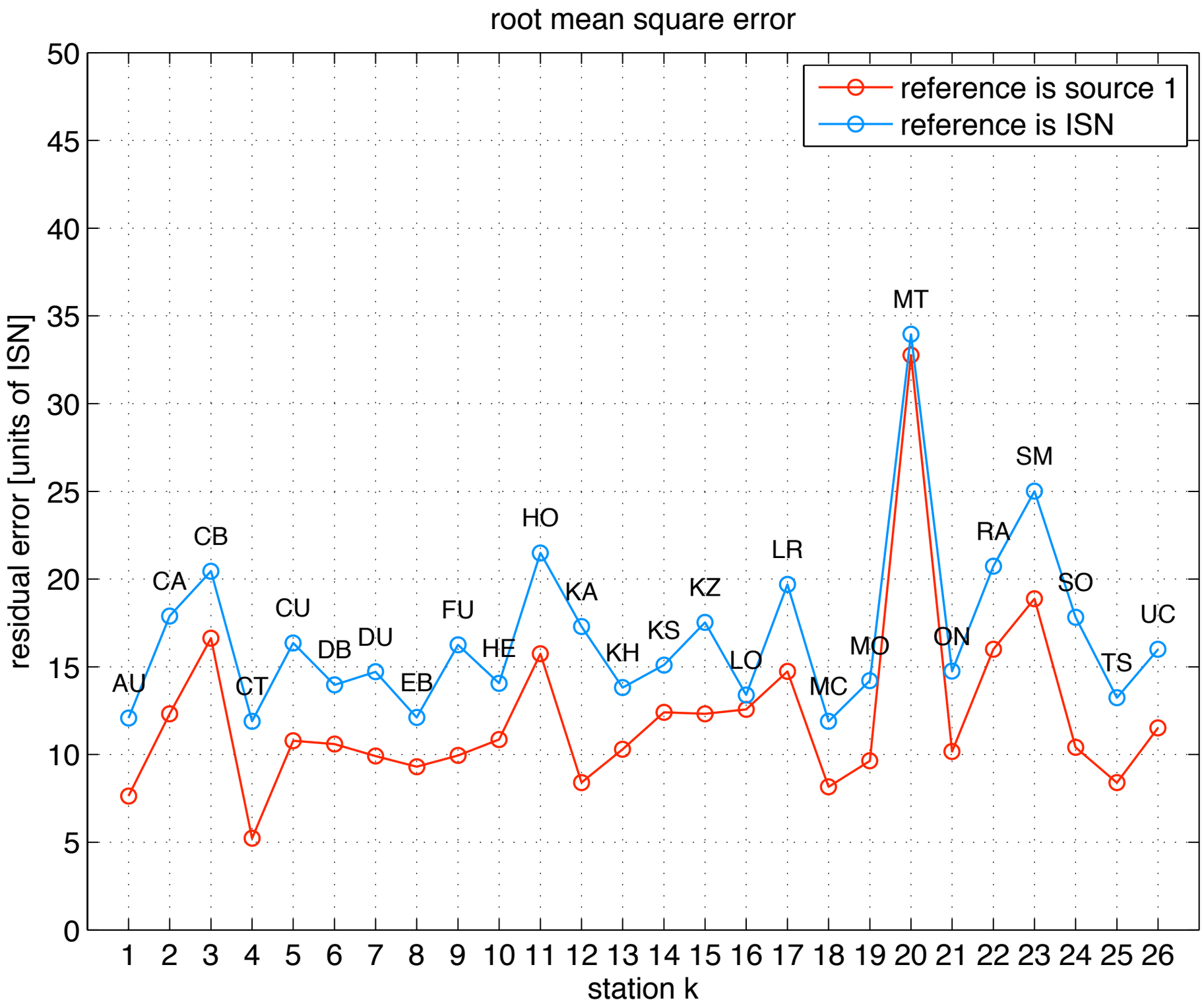
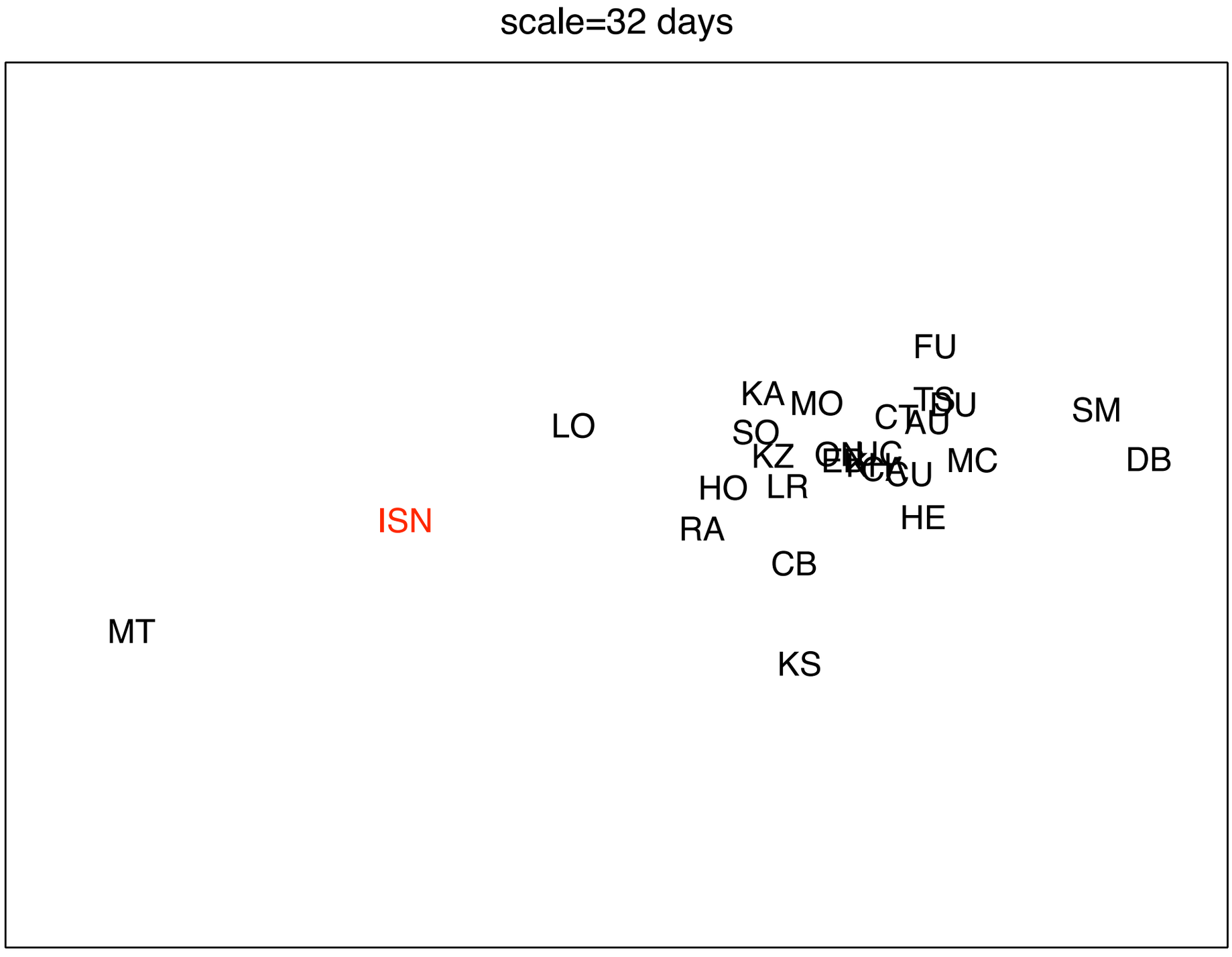
Residual error for each station



Can’t we find a more global representation of all this ?

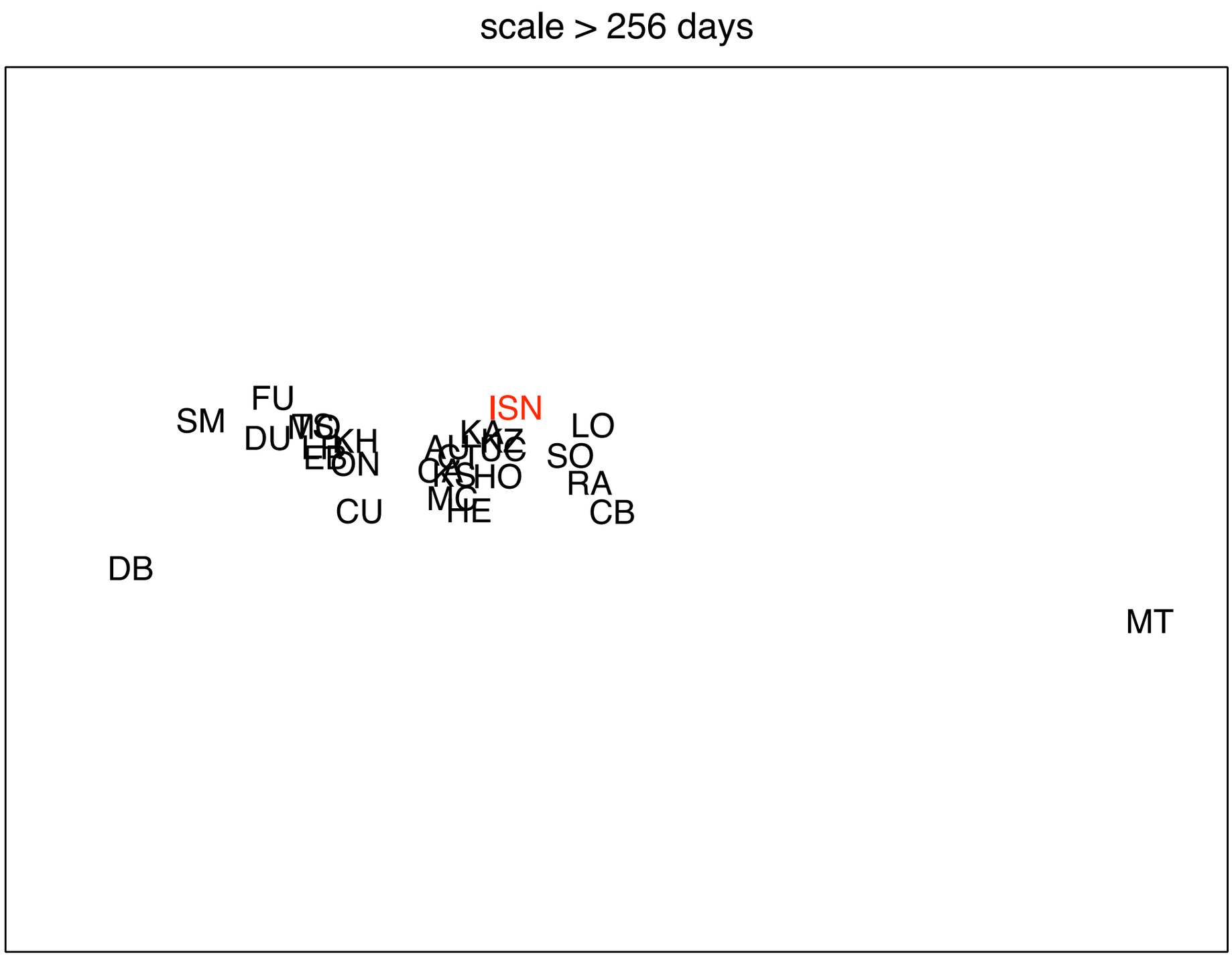
Similarity map



Solar rotation time scales

The distance between stations reflects their degree of similarity

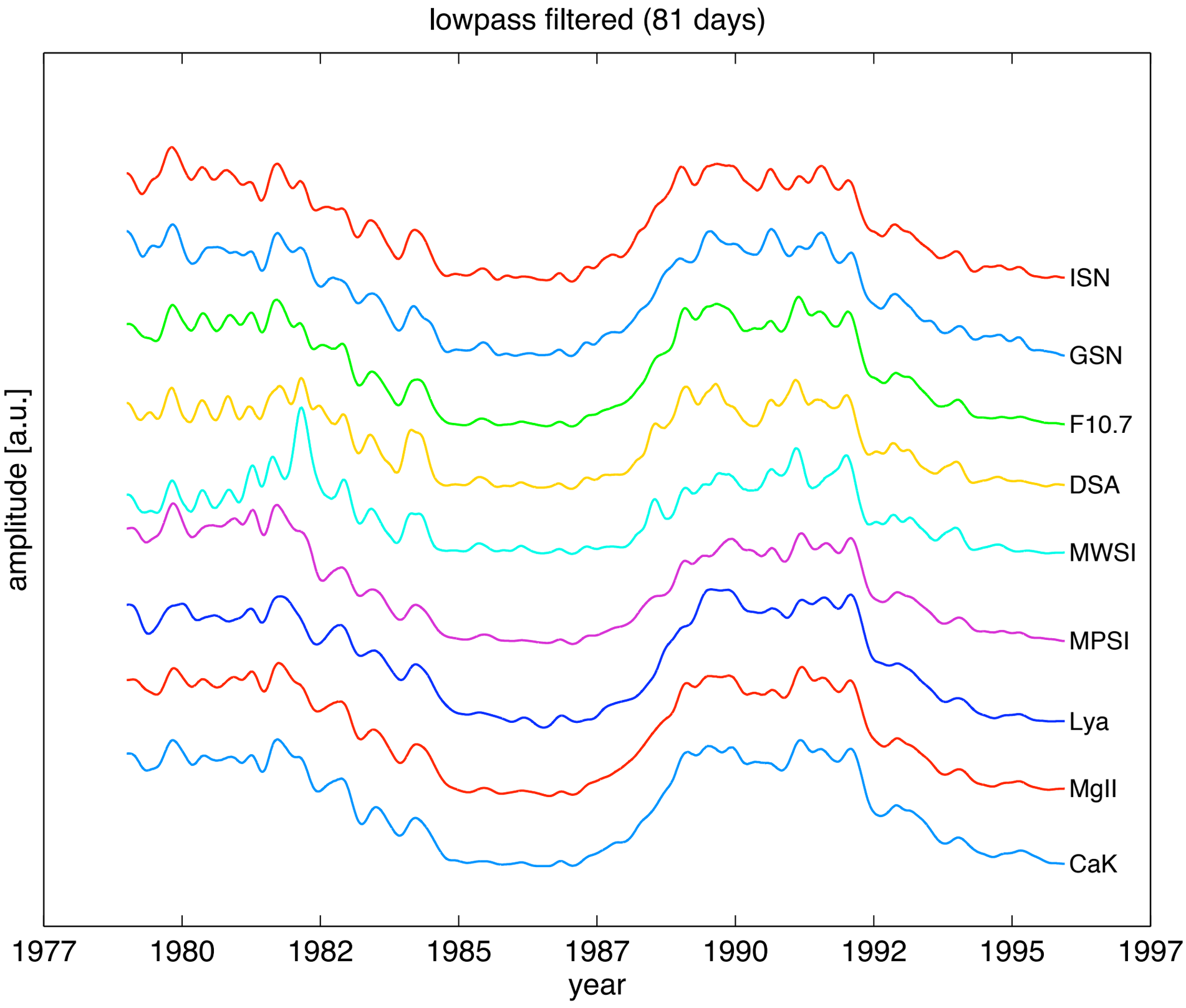
Similarity map



Solar cycle time scales

Comparing the Group SN and the International SN

All solar proxies exhibit strong similarities



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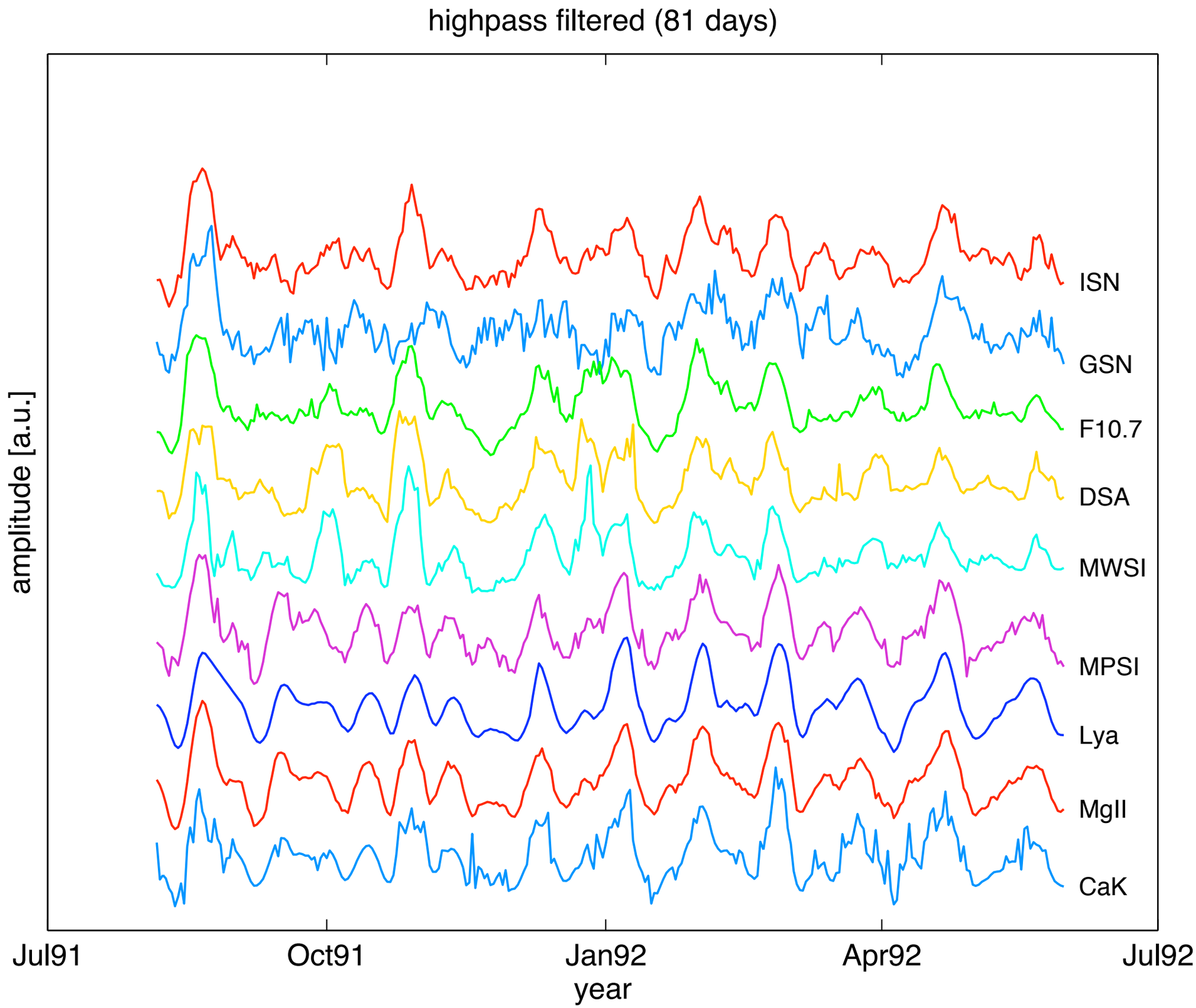
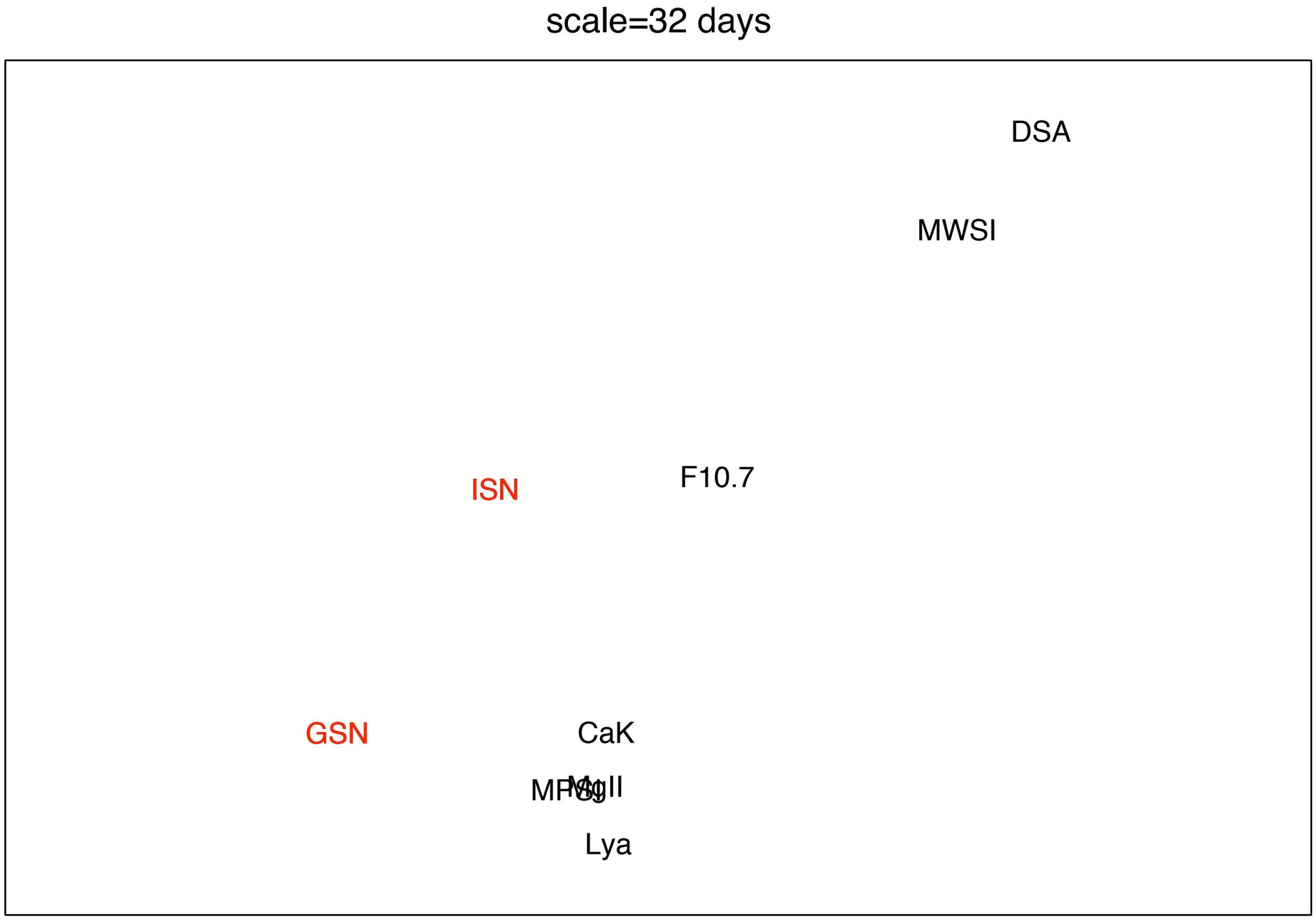


Method

- We use the same method as before, see [Dudok de Wit et al., GRL 36 (2009)]

- All proxies are displayed on a 2D map so that their distance reflects their similarity
  - done separately for each time scale (rotational/cycle)

Similarity map: solar rotation scales



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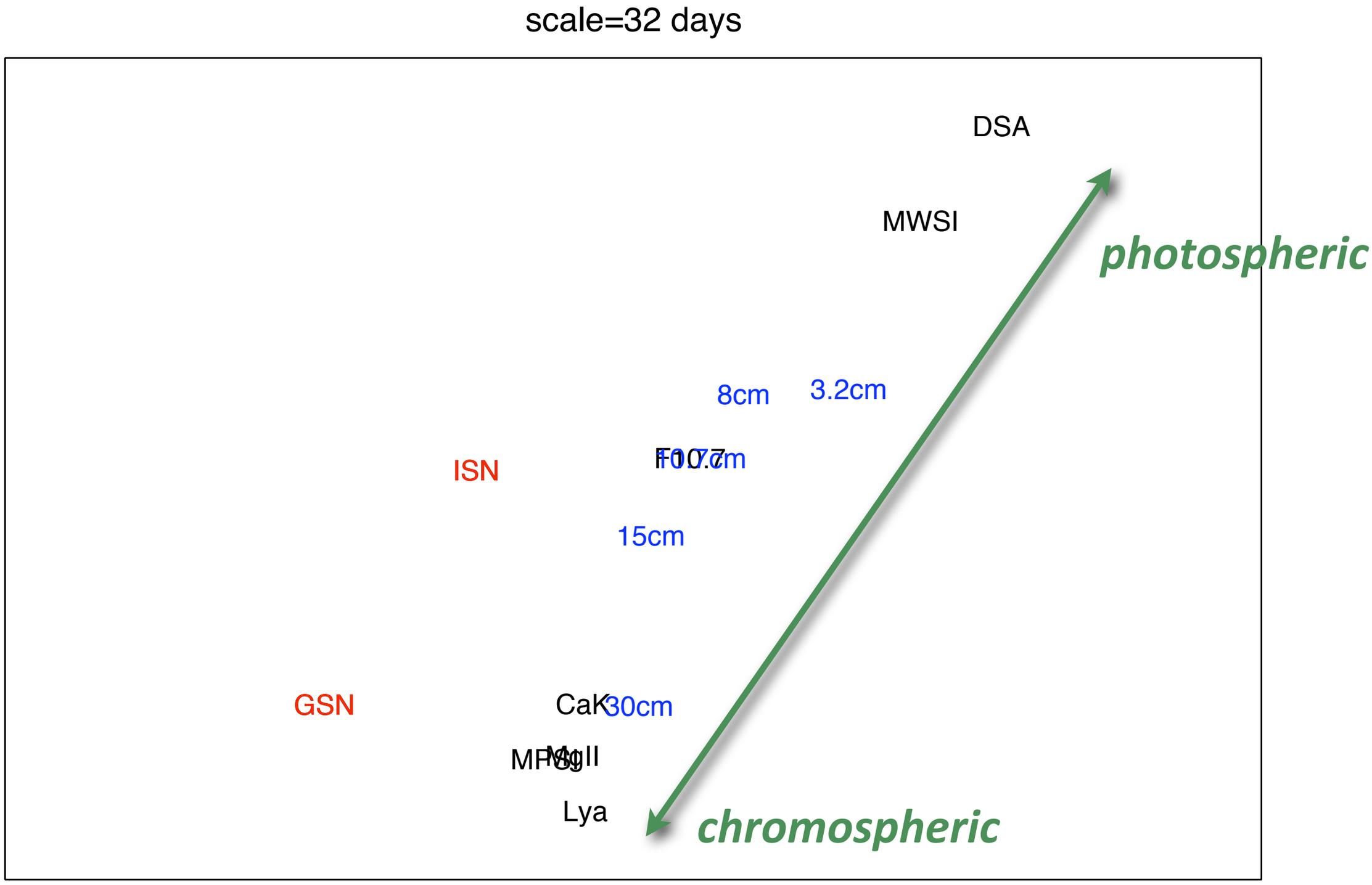
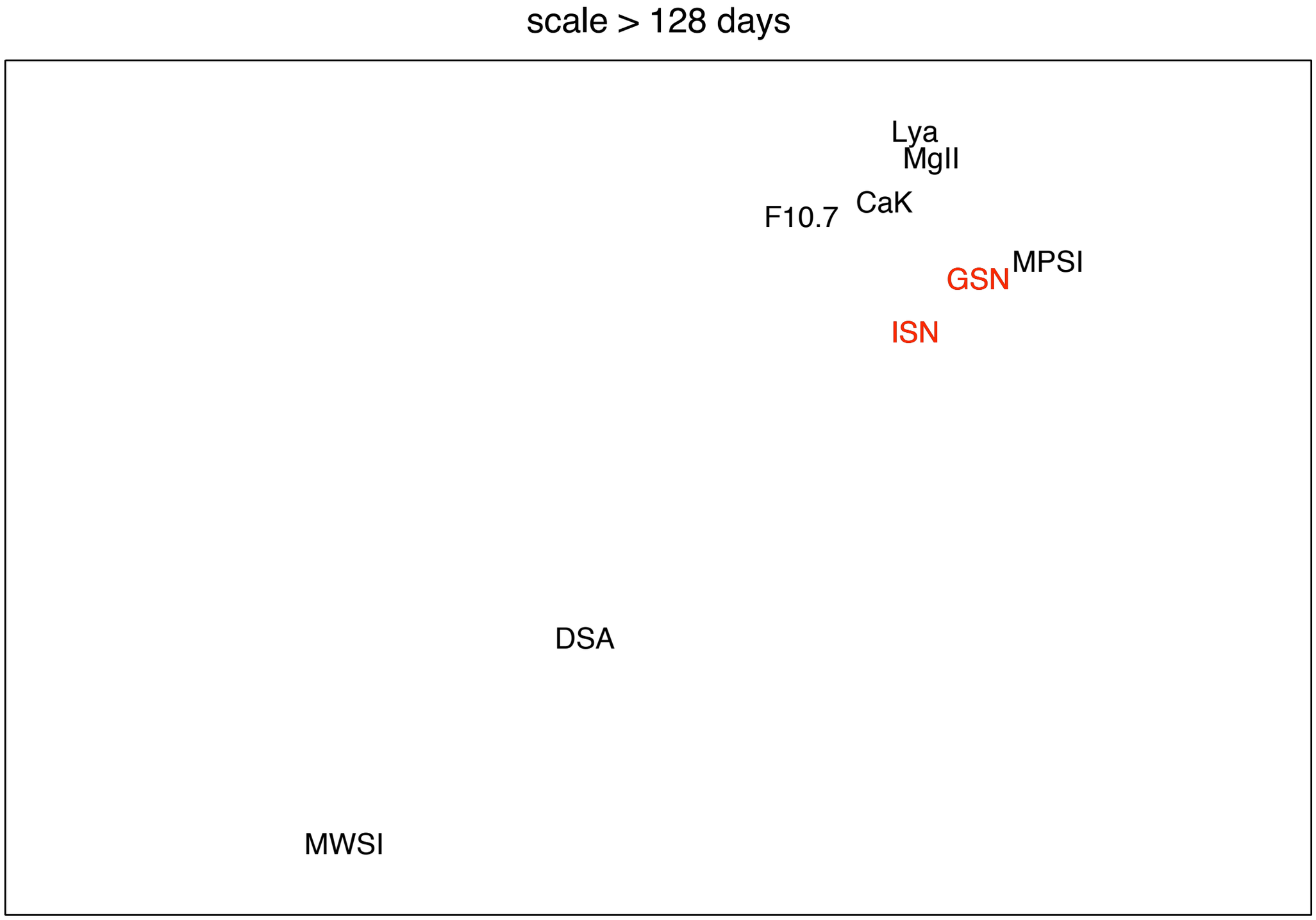
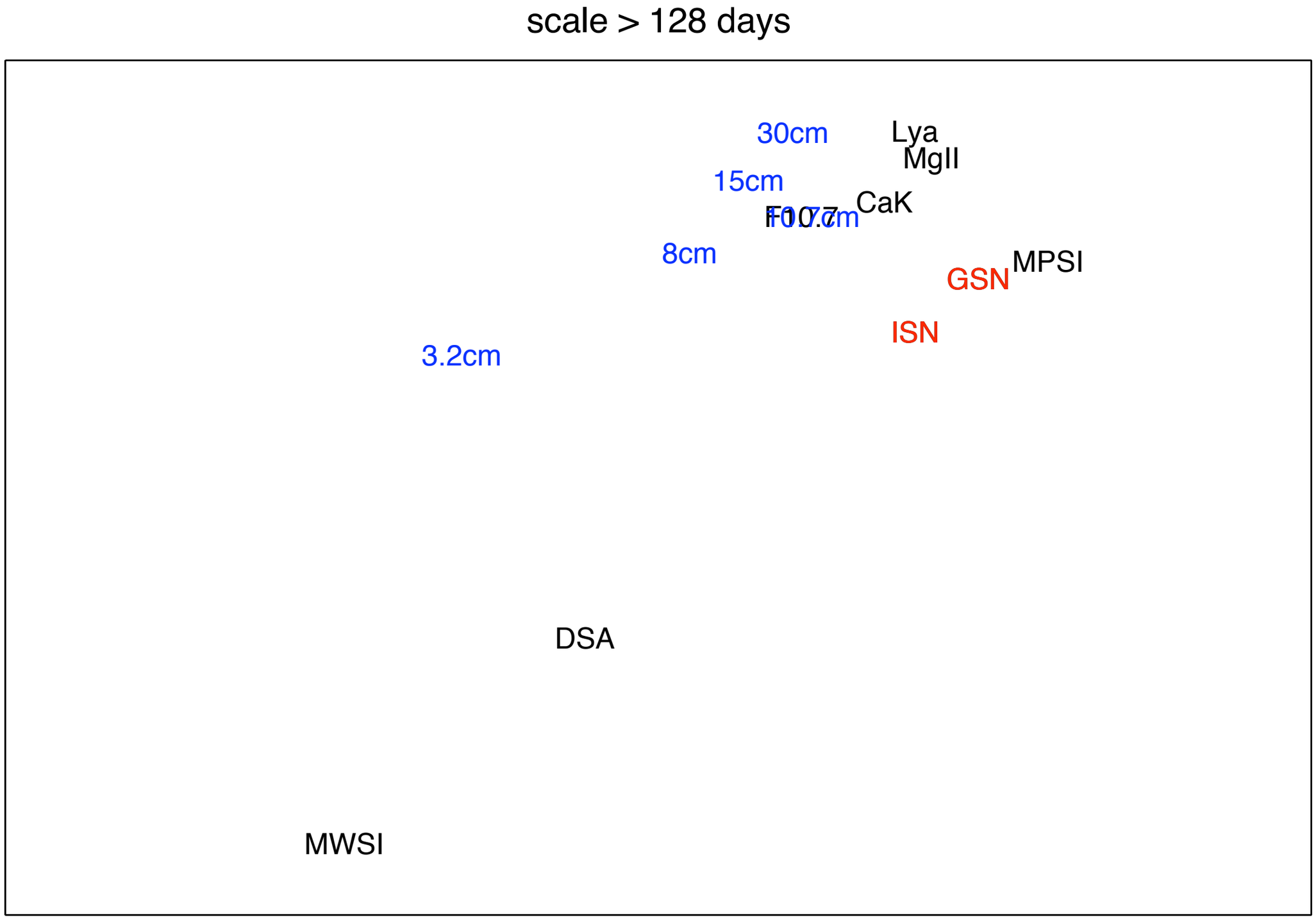


Similarity map: solar cycle scales



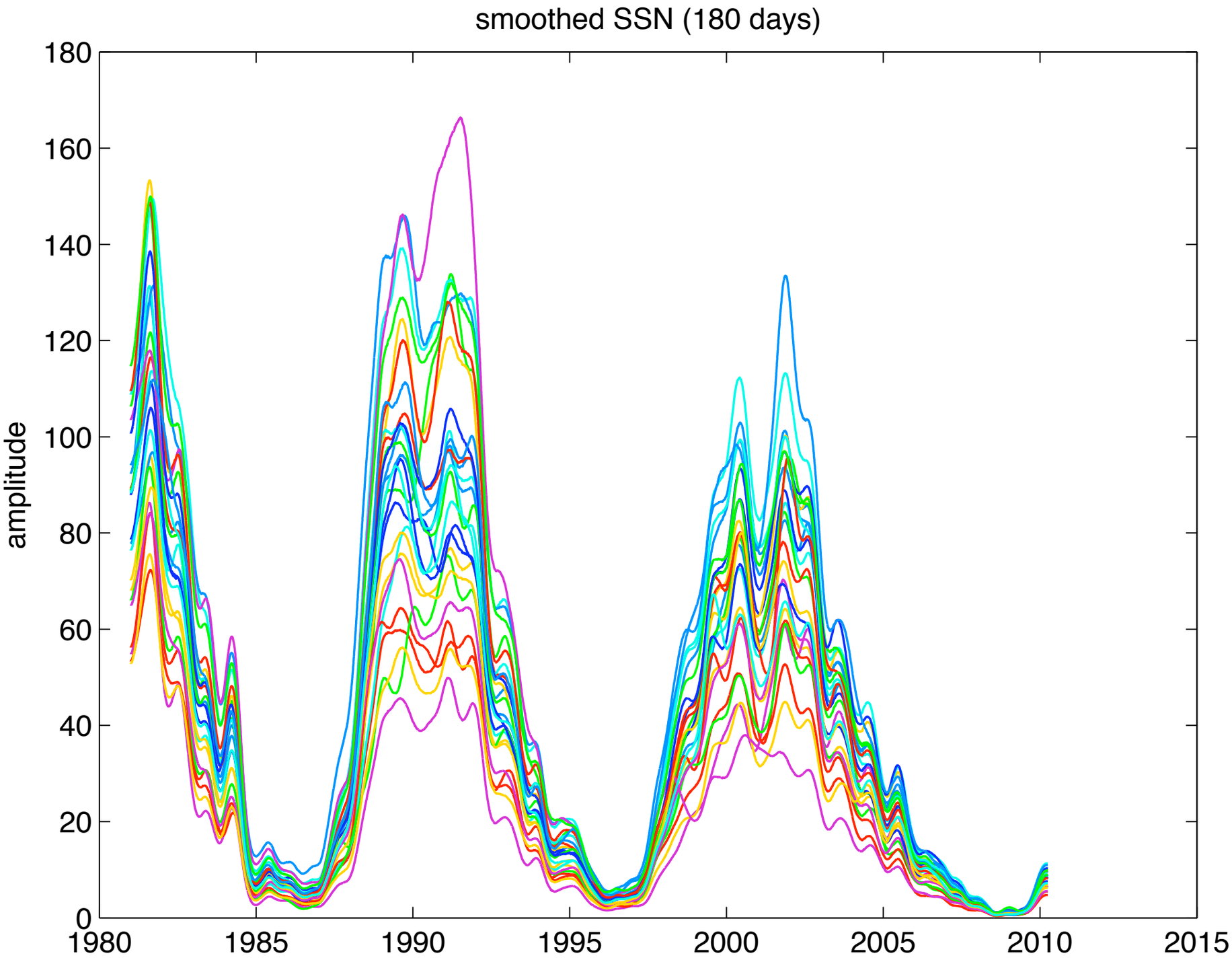
Similarity map: solar cycle scales



Conclusions

- Focus on **commonalities** (or discrepancies) between different stations/proxies
- The ISN and GSN do not describe the same physics as other solar proxies
- The similarity between these proxies is scale-dependent
  - good agreement on medium time-scales does not imply good agreement on long time-scales!
- Multi-wavelength radio observations are a boon

Smoothed sunspot numbers



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