Homogeneity Testing of the Global CCI Soil Moisture Data Record [1]

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[1] Homogeneity of a global multi-satellite soil moisture climate data record, Su, C.-H., D. Ryu, W. Dorigo, S. Zwieback, A. Gruber, C. Albergel, R. H. Reichle, and W. Wagner (2016)

ESA CCI Soil Moisture Background

- **Long term data record from multiple earth observation products...** [1]
    - …by blending different microwave remote sensing instruments (active and passive)

- **Used version: ESA CCI SM v. 2.2 combined product**
    - Monthly time series
    - Break times known, testing for occurrence of inhomogeneity
        - No test for Sep. 1987 (insufficient data)

[1] http://www.esa-soilmoisture-cci.org/
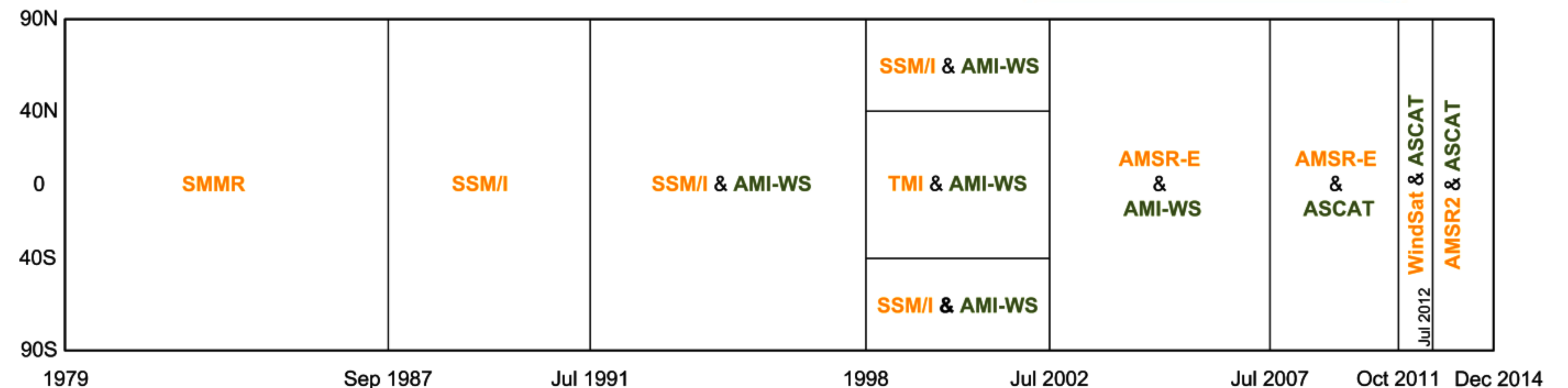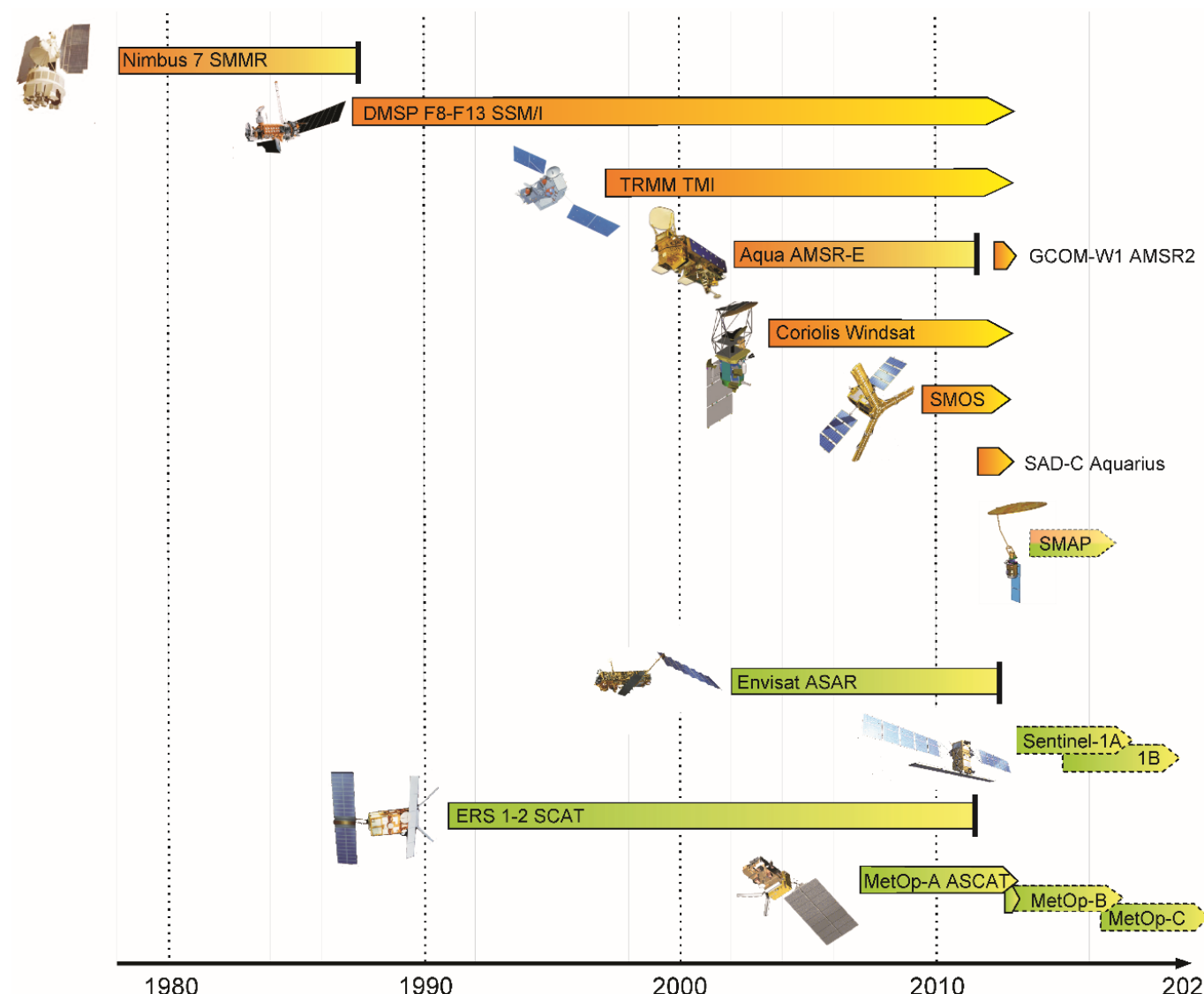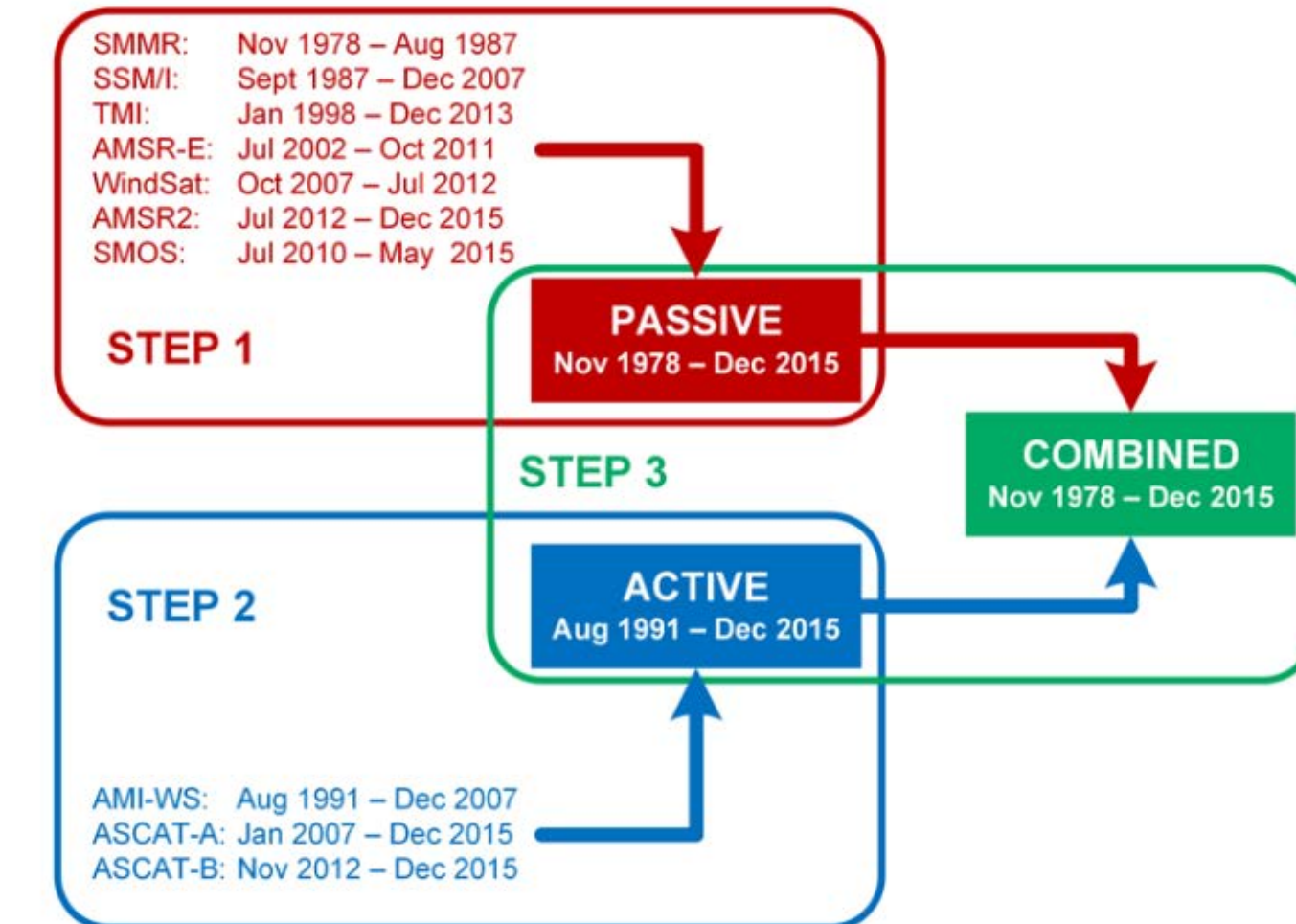
Homogeneity Test Background

- **Blending of observation products**
  - Temporal/Spatial resampling (24H, 0.25°)
  - Error characterization, rescaling of observation data
  - Combine active and passive product

- **Inhomogeneities in the merged products**
  - Due to different sensor characteristics (frequency, polarization, radiometric accuracy)
  - Undercut usefulness of product for long time studies

- **Detection and correction of breaks**
  - Detected by comparison with reference time series
  - Receive bias corrected time series
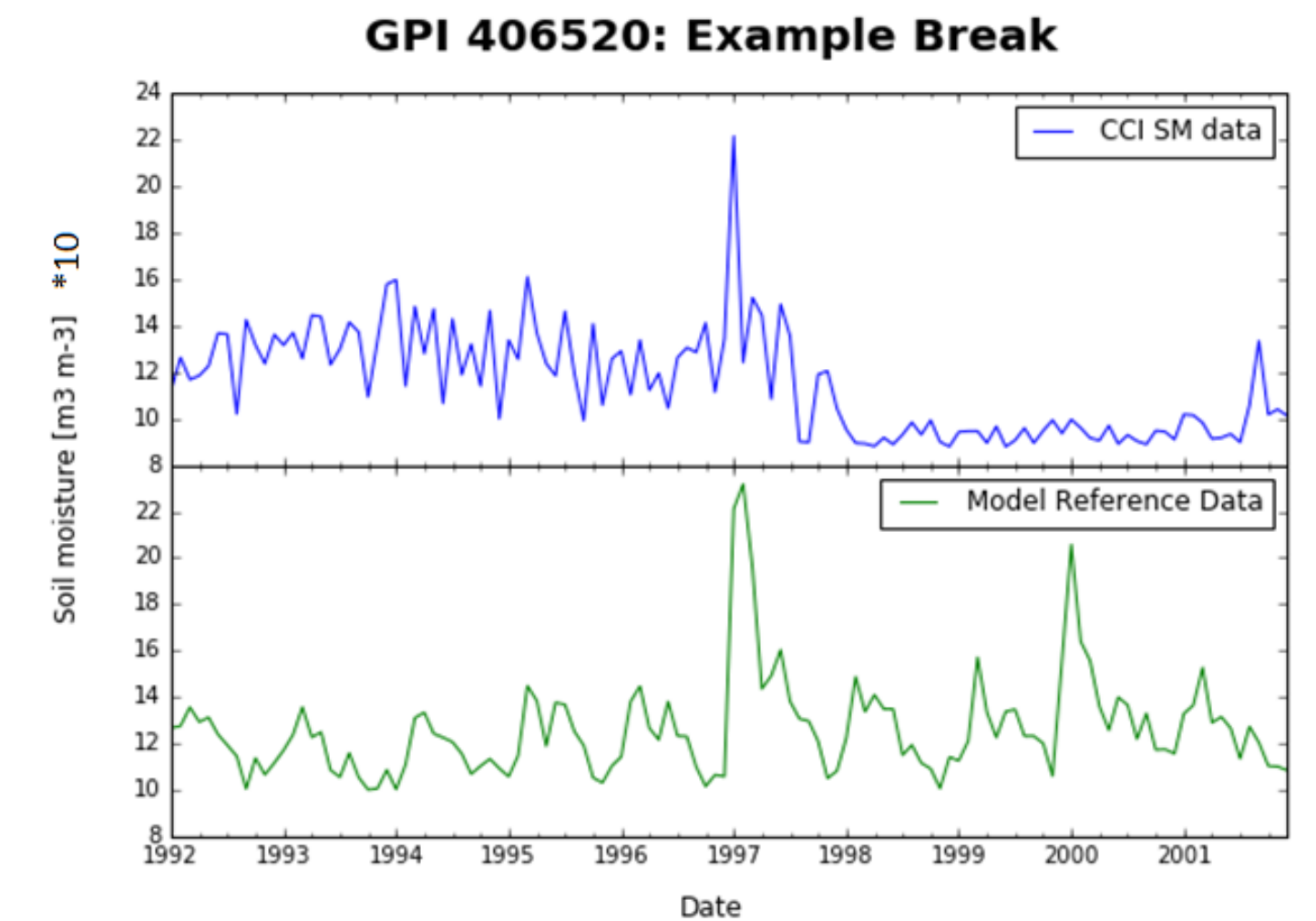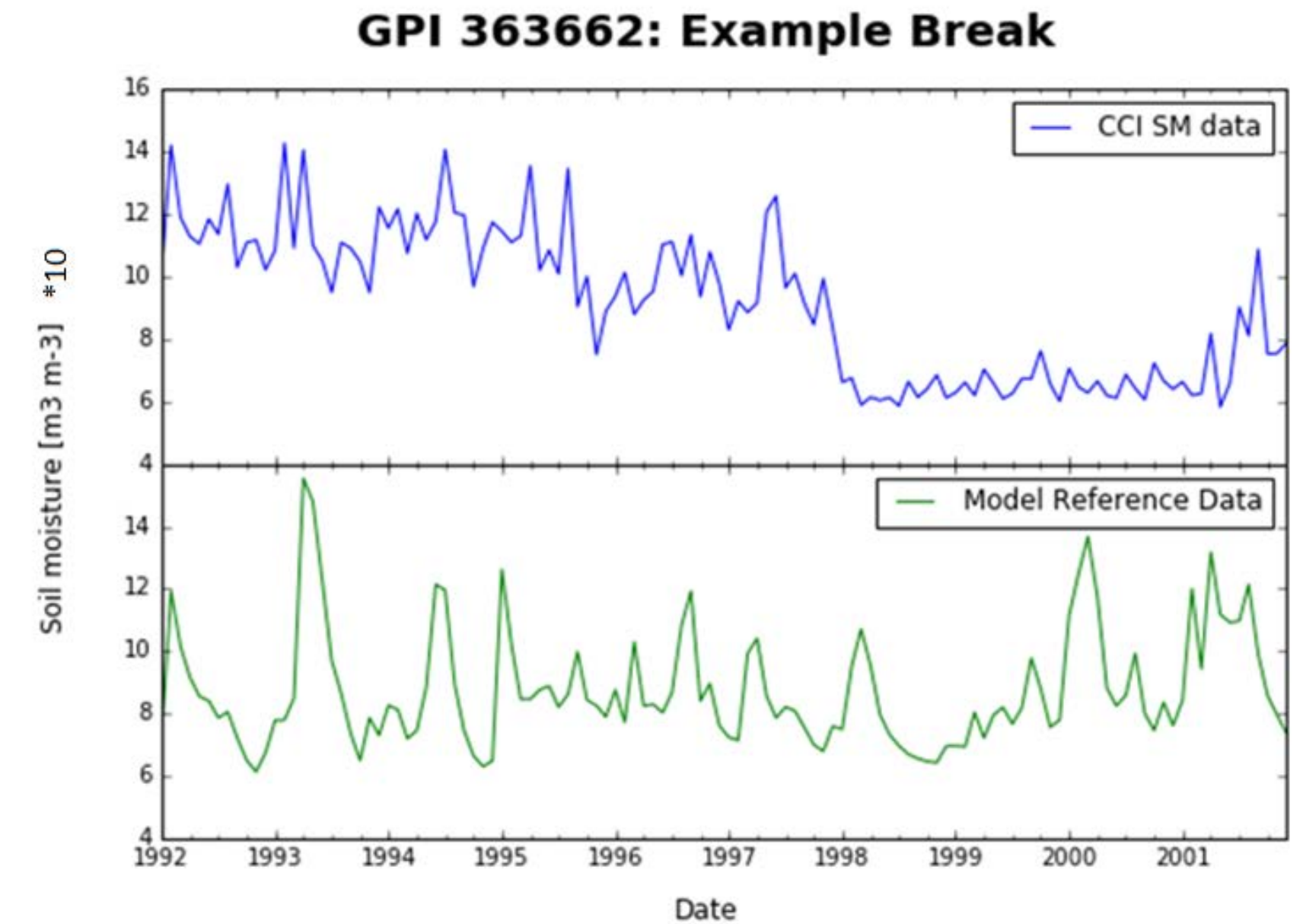
Reference Datasets

- Relative testing for breaks needs reference data for comparison

  - MERRA2 [1]

    - Globally modeled geophysical parameters by NASA
    - Long term dataset, high temporal resolution
    - Rescaled to monthly resolution

  - In-situ data from ISMN [2]

    - Only data from stations in USA used
    - Soil moisture from merging…

      ...sensors in multiple depths (<0.1m)

      …from multiple stations

    - Merged stations correspond to 643 ground points

[1] https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/

[2] http://ismn.geo.tuwien.ac.at/

http://www.geo.tuwien.ac.at/insitu/data_viewer/ISMN.php
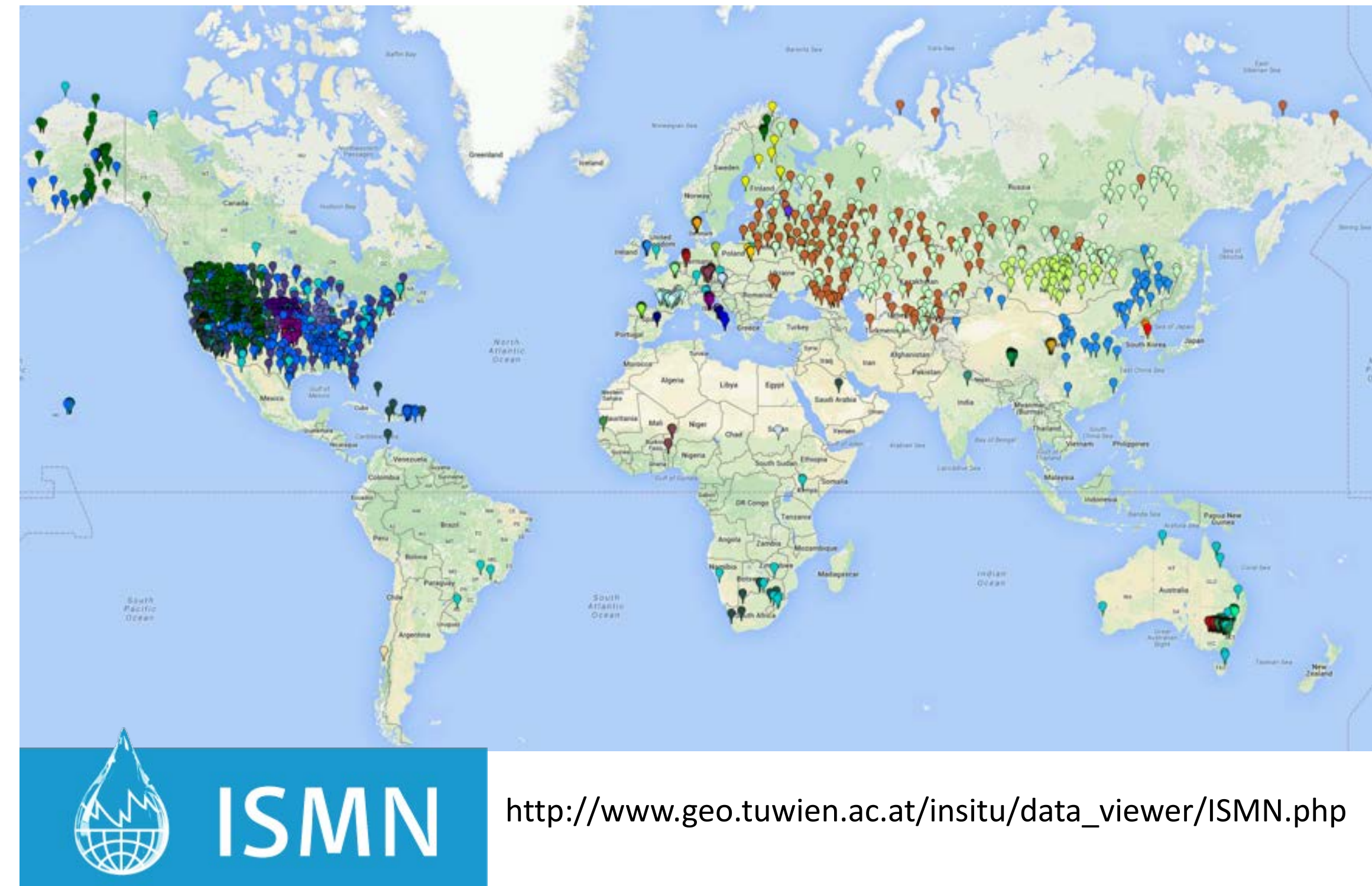
Wilkoxon (WK) Rank Sum Test

- Compares the statistical significance of correspondence in distributions of 2 ordered and ranked datasets

  - Two-sided test for comparison of rank mean values of test values before/after CCI SM blending times („break times")

  - Test values: difference time series

    - "Test data (CCI) - reference data (model/in-situ)"
    - Comparison of distributions of rank sums of set 1 and set 2
    - Chosen significance level: 1%

      Tolerance interval to accept/decline hypothesis that both data sets are from distributions with no significant shift in mean values

- Perform WK Test for each time frame of 3 consecutive break times

  - Total of 6 break times tested
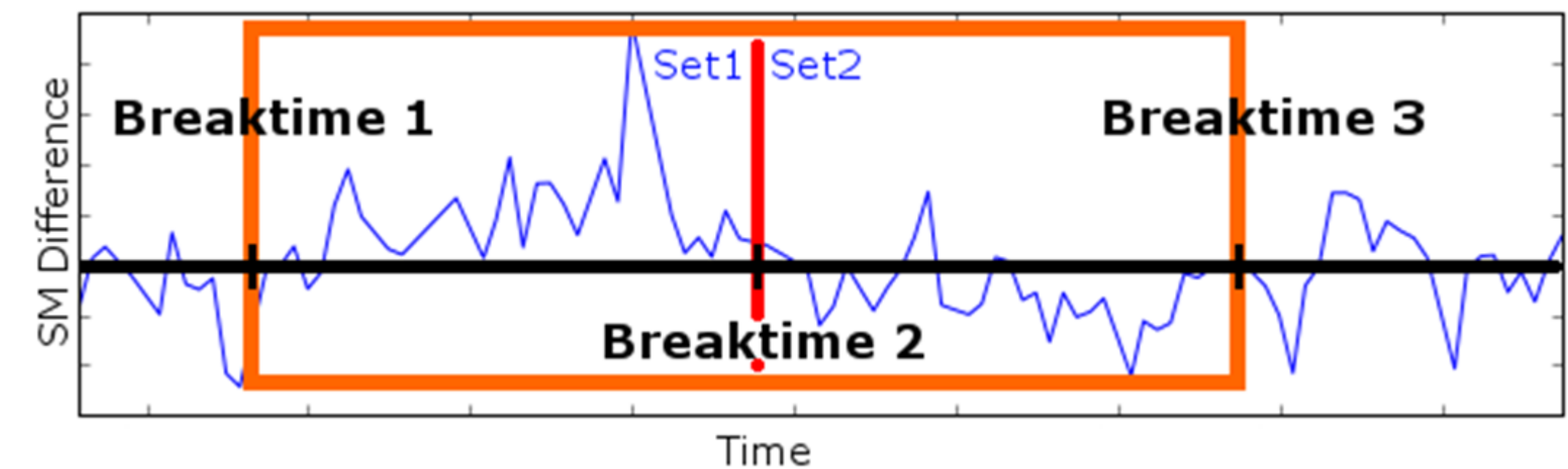
Fligner-Killeen (FK) Variance Test

- Tests for homogeneity of variances of 2 data groups based on ranks

  - Same input data sets as described for WK Test (difference series between break times)

  - Ranking of absolute differences to data set medians

  - Normalize rankings using inverse CDF of standard normal distribution over rank values

  - Fligner-Killeen statistics (FK) from difference between set means and overall mean and variance by χ^2 approximation

  - Comparison p-value from χ^2 distribution from FK statistics to set reference value $\alpha = 0.01$

    - Break is found if p-value $< \alpha$

$$FK = \frac{\sum_{j=1}^{k=2} n_j * (m_j - M)^2}{s^2}$$

n…Set size   M…overall mean
m…Set mean   s²…overall variance

Test Results CCI SM 2.2 global (RTM)

CCI|merra2|Breaktime:1991-08-01

CCI|merra2|Breaktime:1998-01-01

| Wilkoxon |
| Fligner-Killeen |
| Both |
| None |

Ground Points Tested: 24.22%
WK (of Tested): 17.39%
FK (of Tested): 3.82%
Both (of Tested): 1.26%

Ground Points Tested: 45.92%
WK (of Tested): 26.44%
FK (of Tested): 7.37%
Both (of Tested): 3.34%

CCI|merra2|Breaktime:1991-08-01

CCI|merra2|Breaktime:1998-01-01

| Tested |
| Not tested (data length) |
| Not tested (low correlation) |
| Not tested (other reason) |

Total ground points: 243883
Tested: 24%
Not tested (data length): 16%
Not tested (low correlation): 43%
Not tested (other reason): 17%

Total ground points: 243883
Tested: 46%
Not tested (data length): 4%
Not tested (low correlation): 36%
Not tested (other reason): 14%

Test Results CCI SM 2.2 global (RTM)

CCI|merra2|Breaktime:2002-07-01

Wilkoxon
Fligner-Killeen
Both
None

Ground Points Tested: 41.20%
WK (of Tested): 40.32%
FK (of Tested): 10.71%
Both (of Tested): 5.56%

CCI|merra2|Breaktime:2007-01-01

Ground Points Tested: 51.94%
WK (of Tested): 28.43%
FK (of Tested): 12.43%
Both (of Tested): 5.35%

CCI|merra2|Breaktime:2002-07-01

Tested
Not tested (data length)
Not tested (low correlation)
Not tested (other reason)

Total ground points: 243883
Tested: 41%
Not tested (data length): 6%
Not tested (low correlation): 40%
Not tested (other reason): 12%

CCI|merra2|Breaktime:2007-01-01

Total ground points: 243883
Tested: 52%
Not tested (data length): 2%
Not tested (low correlation): 35%
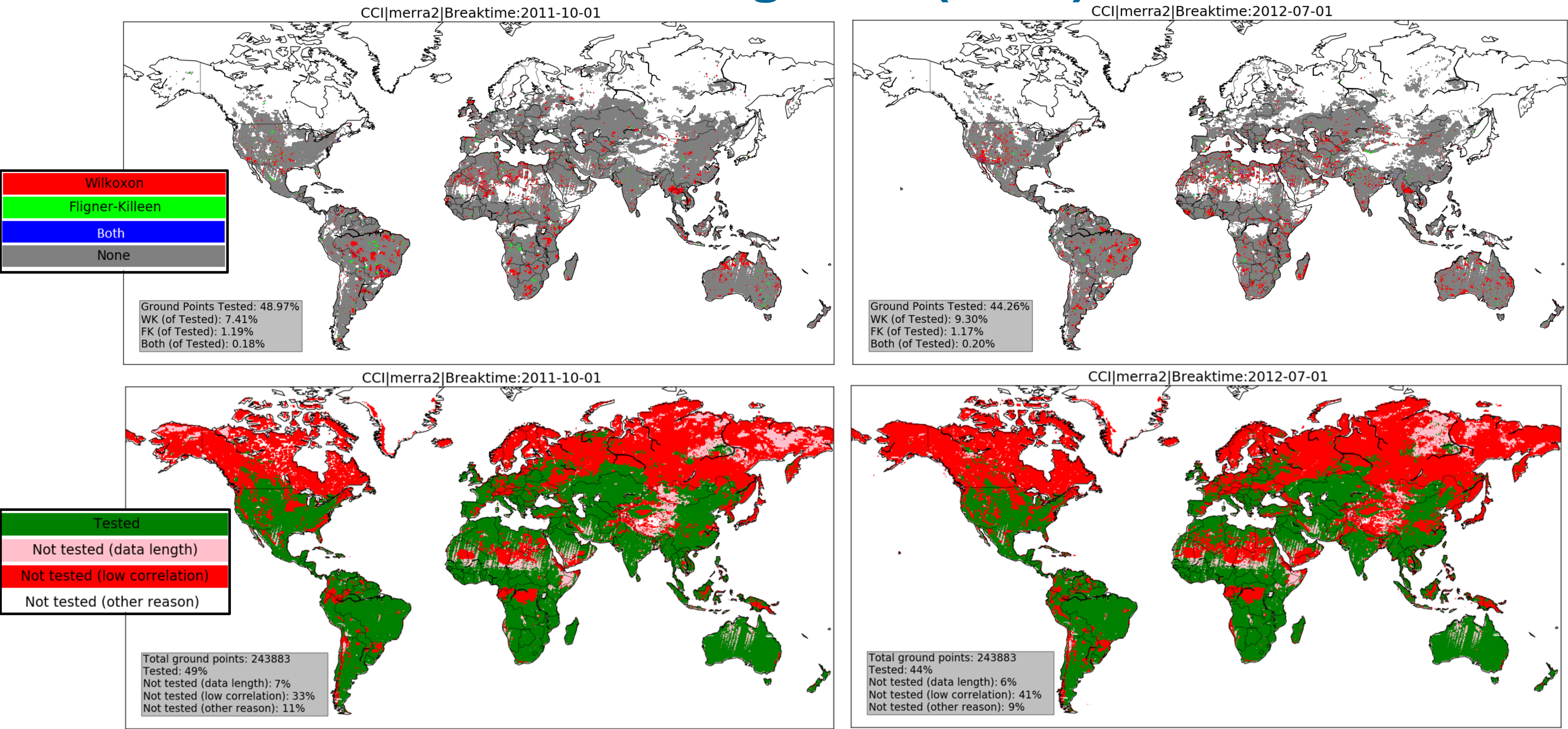Not tested (other reason): 11%

# Test Results CCI SM 2.2 global (RTM)

Longest Homogeneous Period (RTM)

- Summation of length of consecutive homogeneous periods

  - Not tested pixels count as breaks

  - White=never tested

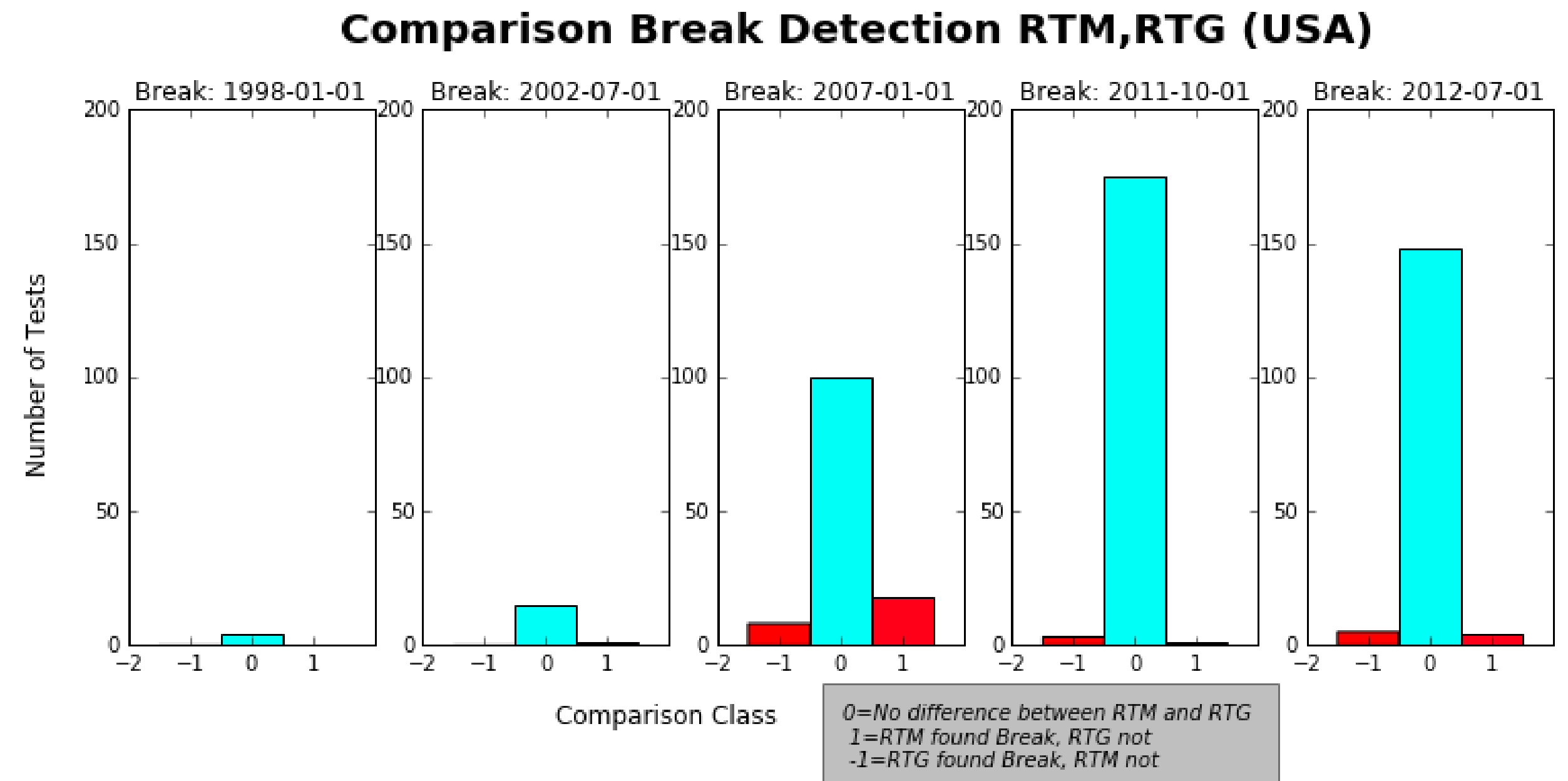 - Max. length = 27.5 years

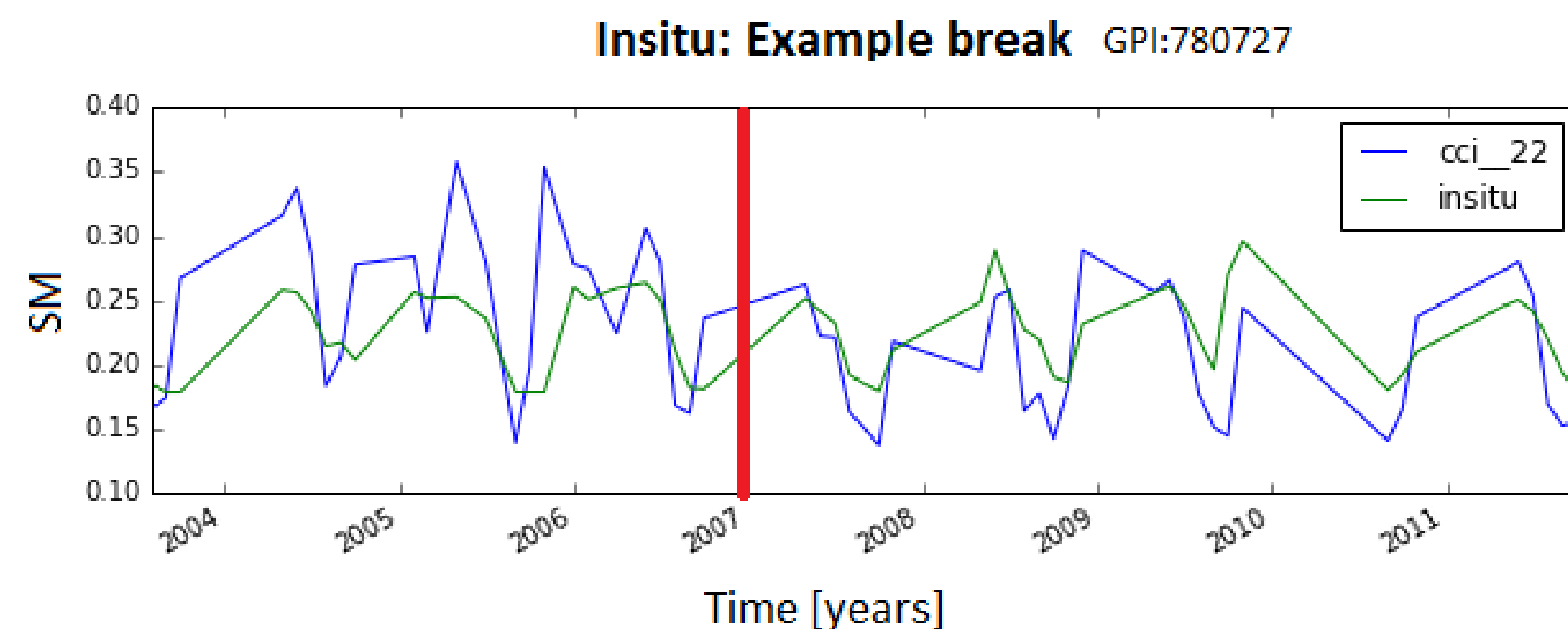- Problematic areas for testing

  - Artic, subarctic areas

  - Rain forest areas

  - Europe (before 2002)

Length of Longest Homogeneous Period
CCI|merra2

Period Length [years]:
8 10 12 14 16 18 20 22 24
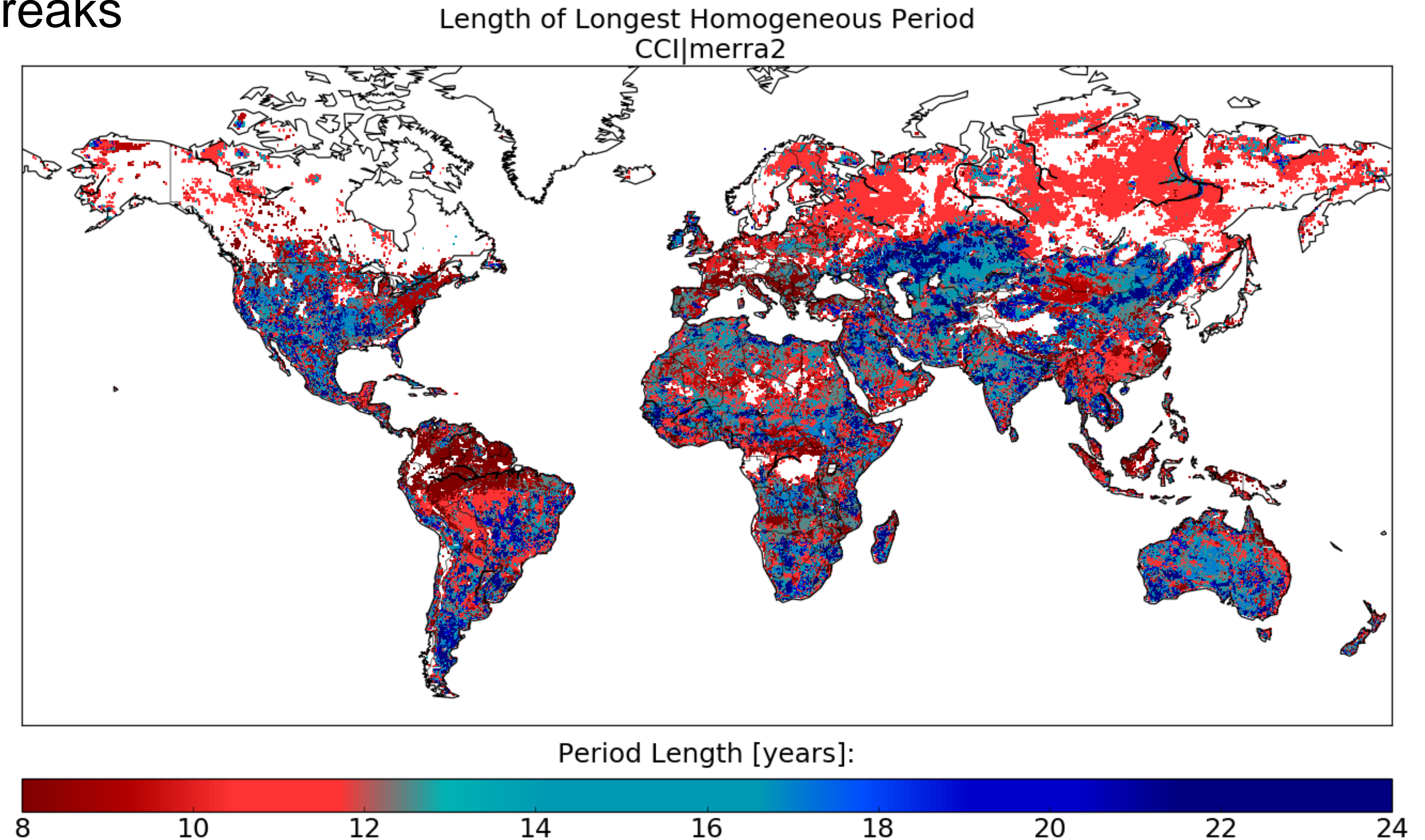
Test confirmation with ISMN in-situ data (RTG)

- **RTG follows same principles as RTM**

- **RTG confirms findings from RTM**
  - Number of tests depends on
    - Station measurement timeframe
    - RTM coverage

- **No in-situ measurements for Aug 1991 at stations around GPIs tested in RTM**


Comparison Break Detection RTM,RTG (USA)

0=No difference between RTM and RTG
1=RTM found Break, RTG not
-1=RTG found Break, RTM not

Insitu: Example break   GPI:780727

Break time	08-1991	01-1998	07-2002	01-2007	10-2011	07-2012
#RTM ∩ #RTG	0	4	16	129	179	160

Time Series Adjustment

- Correction only performed if any test found inhomogeneity
  - Not performed if correlation between CCI data and reference data low/insignificant

- Correction of additive / multiplicative biases in SM values
  - Linear rescaling of values after break time
    - Matching of regression relations before/after break time
  - Regression coefficients directly from test data series and reference data series

- Definition of reference time frame (before/after) break time necessary

Examples: Time series correction after break
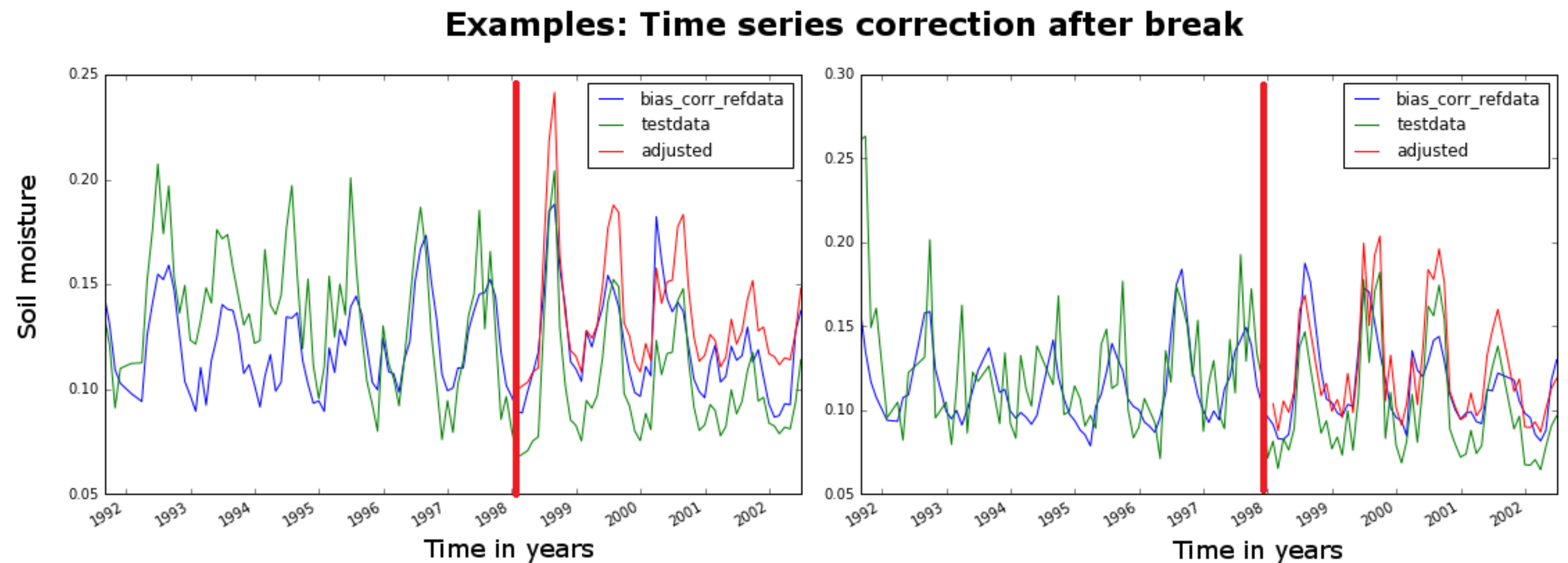
Conclusion

- RTM detects breaks for all break times

    - 2 break detection tests were implemented (WK test, FK test)

    - Break times 07-2002 and 01-2007 show large number of inhomogeneities

    - Break times 10-2011 and 07-2012 show less detected inhomogeneities

    - Number of tested pixels increases over time

        - CCI temporal coverage increases over time

        - Correlation threshold with model reference excludes tests in northern hemisphere

    - GLDAS: alternative for MERRA2 model

- RTG for stations in the USA confirms findings

- Correction of SM time series is ongoing work

- Newer versions of CCI SM (also active/passive product only) are tested

- More tests may be implemented in the future