Global OMI Aerosol Single Scattering Albedo evaluation using ground-based AERONET

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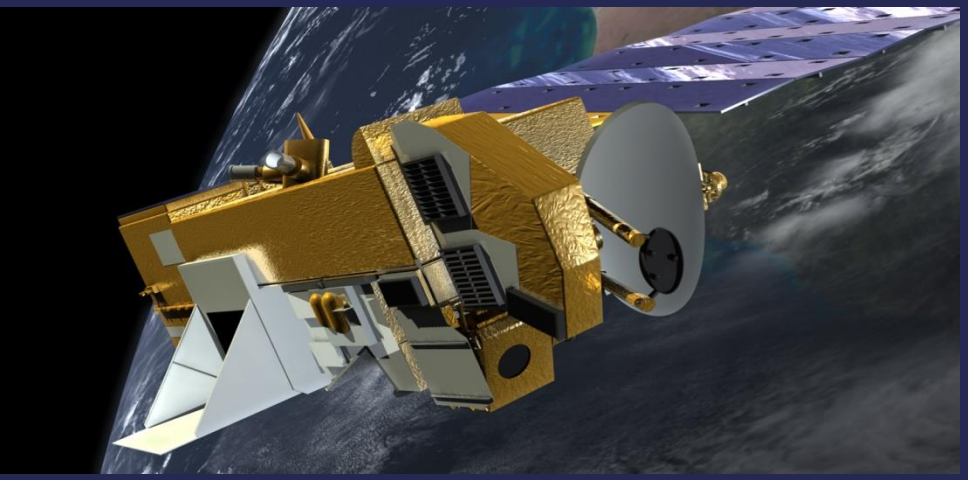

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- Anthropogenic and natural aerosols are the strongest source of uncertainty in considerations of present and future climate change (IPCC, 2013)
- In general, aerosols, through scattering and absorption, mainly of solar radiation, cause a cooling of the Earth's surface and a warming of the atmosphere.
- However, there is a great diversity in aerosol radiative and heating/cooling effects, which depend on various parameters, complex processes, and factors, e.g. their position with respect to underlying Earth surfaces and/or clouds.
- Apart from others, the radiative effects of aerosols critically depend on their physical and chemical properties, and ultimately on their optical and radiative properties.
- The three fundamental aerosol optical properties are the aerosol optical depth (AOD), **single scattering albedo (SSA)** and asymmetry parameter.

- SSA describes the relative strength of scattering and absorption in total extinction

$$SSA = \frac{\text{AOD scattering}}{\text{AOD total extinction (scattering+absorption)}}$$

- SSA varies with aerosol types

- Aerosol SSA products on global and climatological scales are an essential requirement
- OMI sensor onboard Aura satellite has been the first sensor that delivered the global aerosol SSA product with reliable accuracy

Present Study

- In this study, we perform an evaluation of the retrieved OMI Single Scattering Albedo (SSA) data through comparisons against daily SSA products from **541** globally distributed Aerosol Robotic Network (AERONET) **stations**, for a **15-year period (2005-2019)**

- The comparison is performed at 440 nm (or 443 nm) and 500 nm, using the available (i) *OMAERUVd (PGE Version V1.8.9.1) SSA data at 354 nm, 388 nm, and 500 nm*, and (ii) the *AERONET SSA data at 440 nm (or 443 nm) and 667 (or 675) nm*

- The comparison is made on an annual and seasonal basis, in order to reveal possible seasonally dependent patterns, as well as on a climatological and a year-to-year basis. Comparisons are also made on a local and regional scale in order to identify possible geographically dependent patterns, pointing to features/problems associated with specific aerosol types.

Data and Methodology

OMI and AERONET data

Two different types of SSA data, satellite and ground based ones, are used in the study:

- **Satellite Data set OMI:** OMAERUVd Daily L3 (1° x 1°latitude-longitude) aerosol Single Scattering Albedo (SSA) data, available at **354, 388, 500 nm**
- **Ground Data set AERONET (reference):** Daily average Version 3 (Almucantar Level 2.0 Inversion) Single Scattering Albedo (SSA) data, available at **440 (or 443) nm and 667 (or 675) nm**
- Study period: 2005 – 2019
- The comparison is made at two wavelengths: **440 (or 443) nm** and **500 nm**

OMI	AERONET
440 nm (or 443 nm) *(interpolated from 388nm and 500nm)*	**440 nm (or 443 nm)**
500 nm	500 nm *(interpolated from 440 nm (or 443 nm) and 667 nm (or 675 nm)*

Methodology

The interpolation was performed using the Angstrom exponent.

$$\alpha = - \frac{log \frac{AOD_{\lambda_1}}{AOD_{\lambda_2}}}{log \frac{\lambda_1}{\lambda_2}}$$

where α, λ, AOD_{λ} denote the Angstrom exponent, wavelength and Aerosol Optical depth at the wavelength λ (Scattering or Absorption).

Assuming as constant the Angstrom exponent, the AOD for a new wavelength is computed by:

$$AOD_{\lambda new} = AOD_{\lambda_1} \left(\frac{\lambda new}{\lambda_1} \right)^{-\alpha}$$

Scattering and Absorption AODs are calculated using this method.

Finally, the Single Scattering Albedo is calculated.

Methodology

The comparison is made on an annual and seasonal basis performing linear regressions and computing descriptive statistics:

- for ALL OMI (Level3 1 deg pixel) – Aeronet (station) paired data
- for each individual AERONET station

In the results, the following statistical metrics are presented:

Results		
Correlation Coefficient (R)	Slope	Slope error
Mean OMI value	Mean AERONET value	Bias (Mean OMI – Mean AERONET
Intercept	RMSE (S)	Number of pairs
Percentage of absolute differences within ± .03 (± .05)		Number of stations used

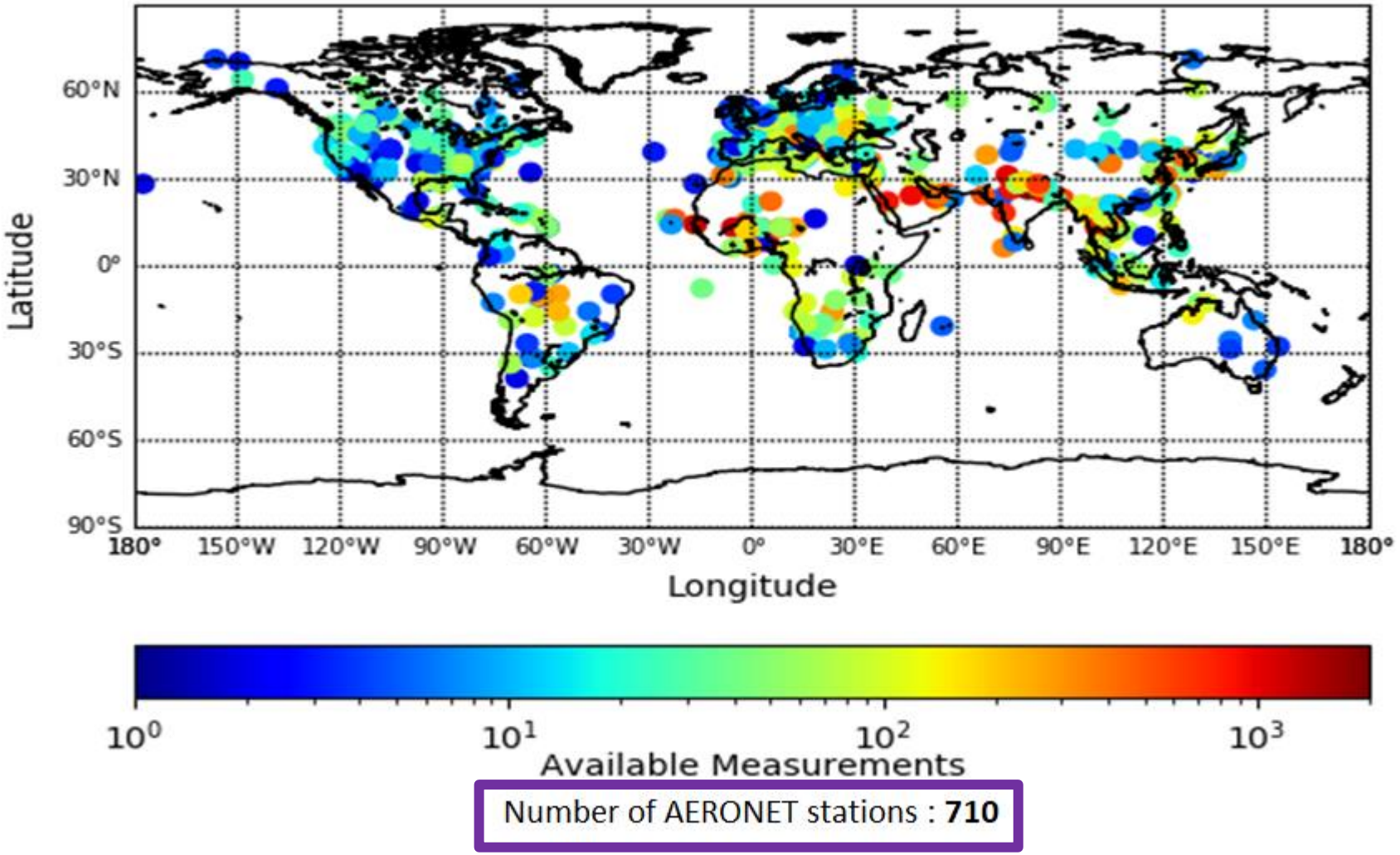
- The comparisons are performed on a pixel level
- Each AERONET station data are compared with those of the OMI pixel in which the station is located

Results and discussion

Results and discussion

- **Data Availability**

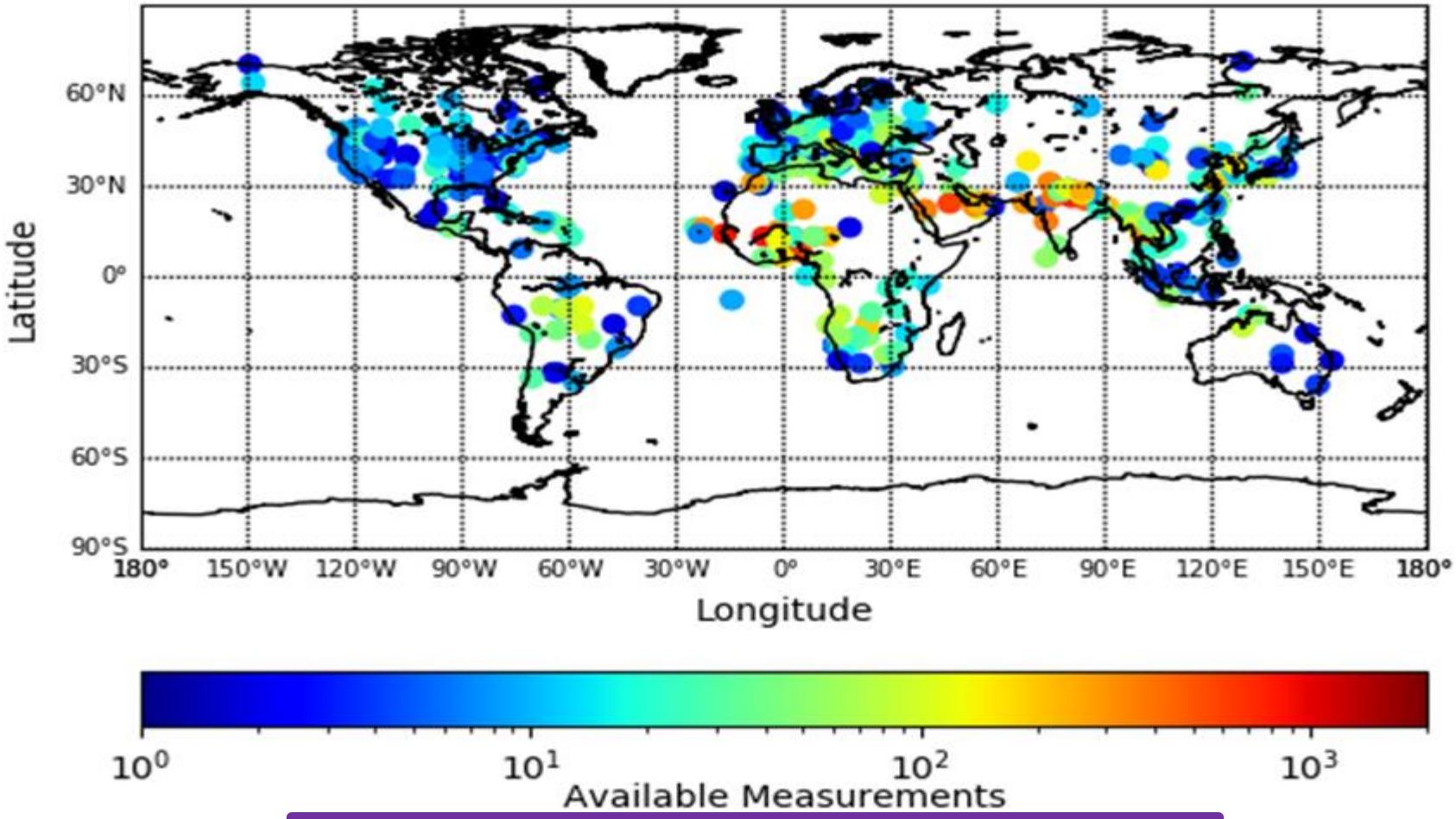
Global AERONET stations
Number of Available Measurements for Period: 2005-2019



- Those AERONET stations are used, for which at least two days of inversion data are available over the time period 2005- 2019. The color scale represents the number of available data for each station
- Satisfactory spatial coverage, better for Europe and America and less for Asia, Africa, Australia

Global AERONET stations

Number of Available **Matchups** for Period: 2005-2019



Number of AERONET stations participating in the comparison : **541**

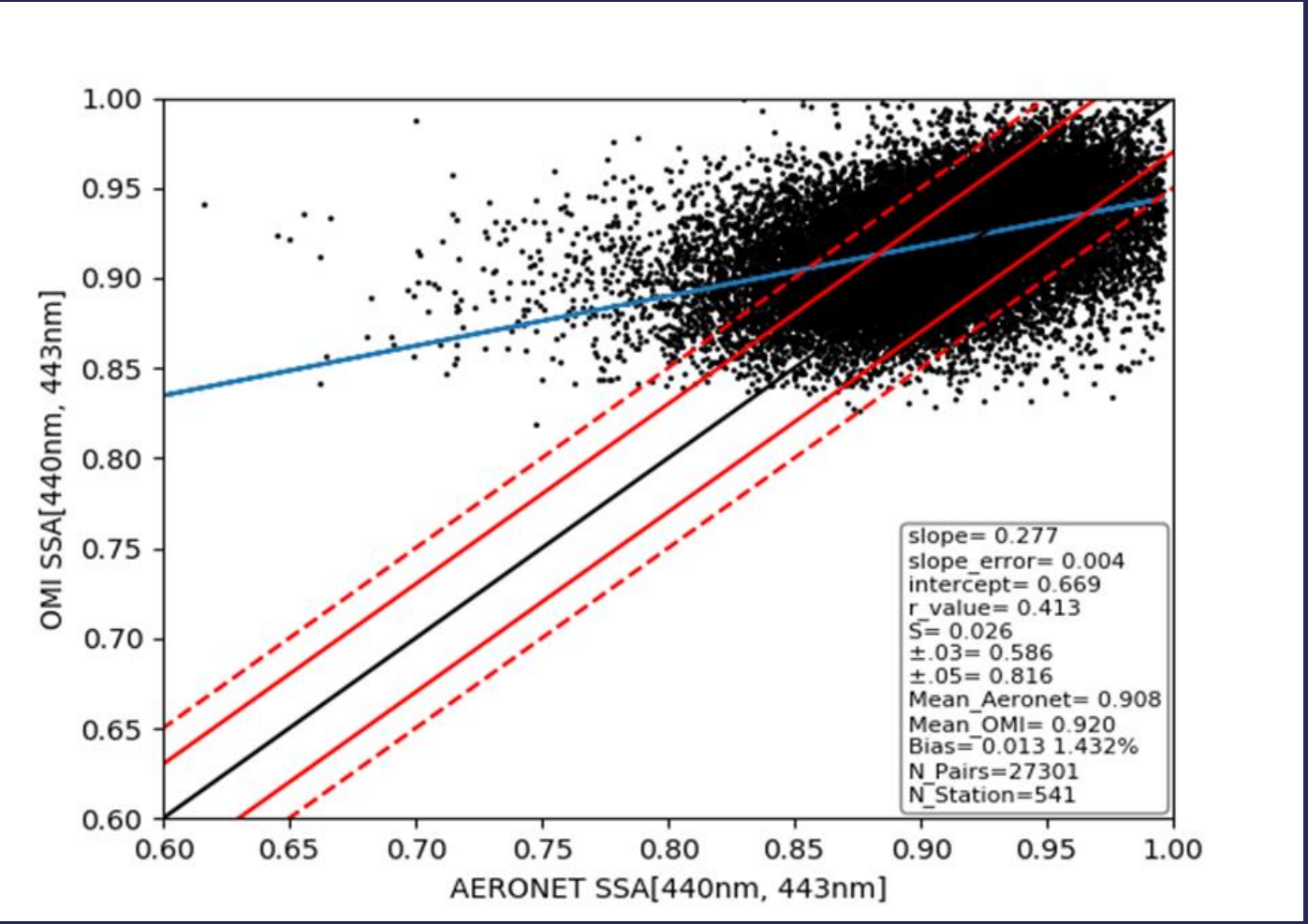
Finally, only AERONET stations having at least two available OMI-AERONET inversion matchups were selected and used .The color scale represents the number of available matchup points for each station.

169 stations did not fulfill this criterion and were omitted. Finally, **541 stations** participated in the comparison

Results and discussion

- Data Availability
- **Global Overall Comparison**
  - **annual basis**
  - seasonal (boreal seasons) basis

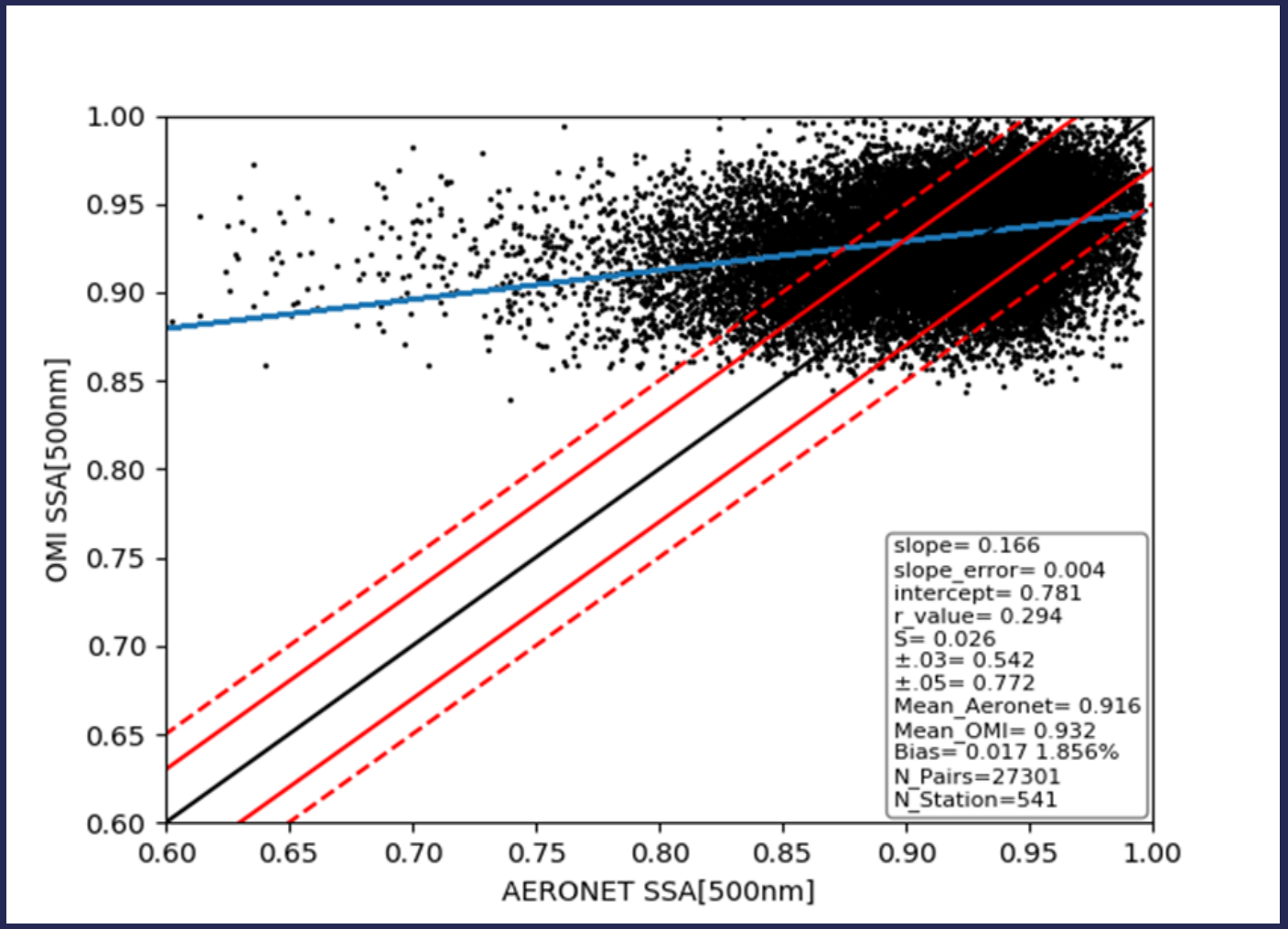
OMI versus AERONET SSA at 440 (443) nm (Period: 2005-2019)



About 58% (81%) of OMI-AERONET matchups agree within the absolute difference of ±0.03 (±0.05)

There is a small Bias (1.4%) and RMSE (2,8%)

OMI versus AERONET SSA at 500 nm (Period: 2005-2019)



About 54% (77%) of OMI-AERONET matchups agree within the absolute difference of ±0.03 (±0.05)

Again, a small Bias and RMSE values

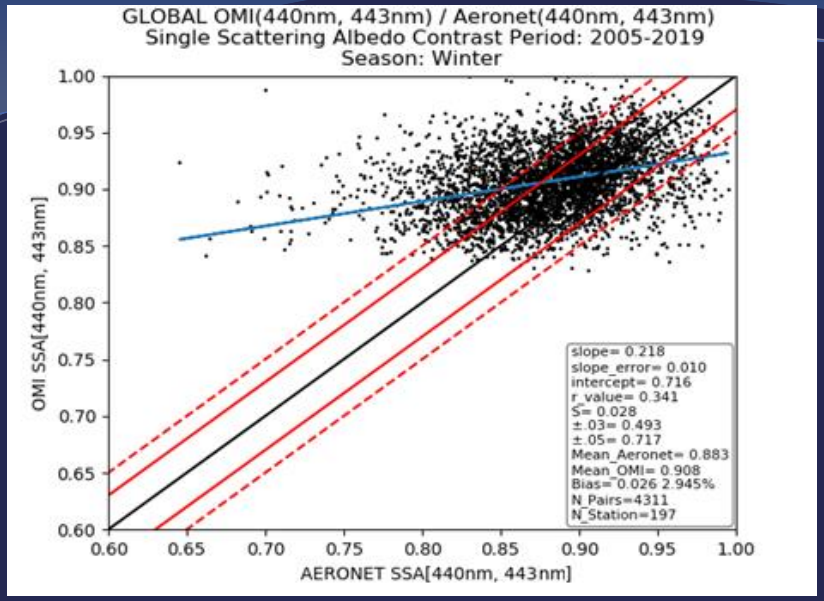
Slightly worse comparison at 500nm than 440(443)nm

Results and discussion

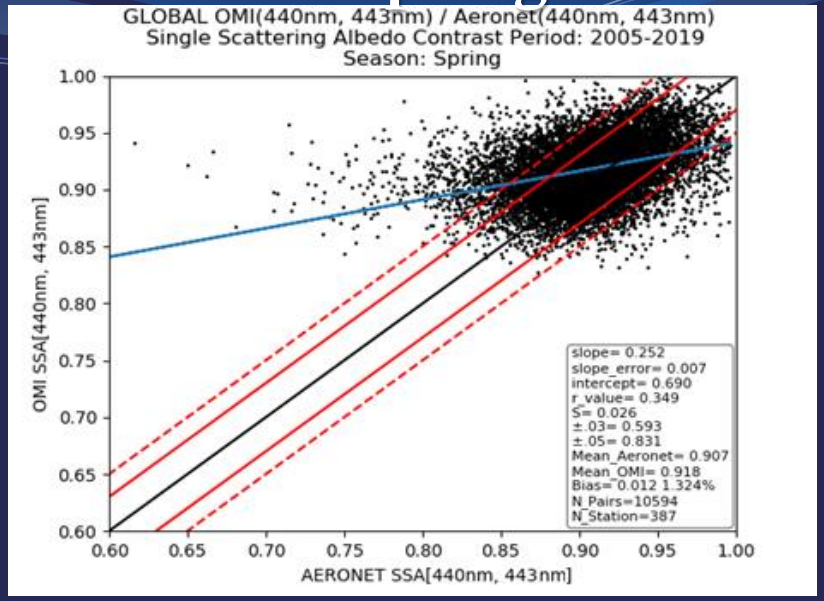
- Data Availability
- **Global Overall Comparison**
  - annual basis
  - **seasonal (boreal seasons) basis**

440/443 nm

Winter

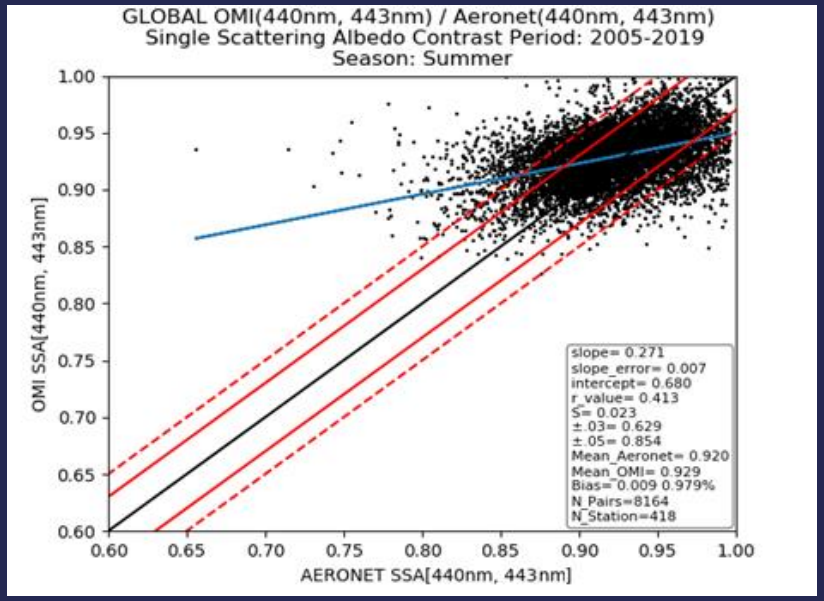


Spring

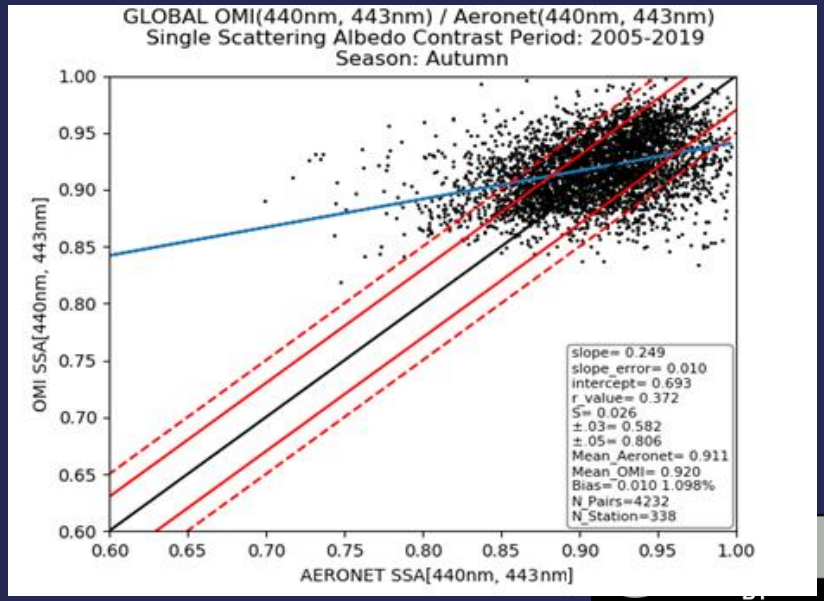


Slight seasonal differences, better agreement in summer

Summer

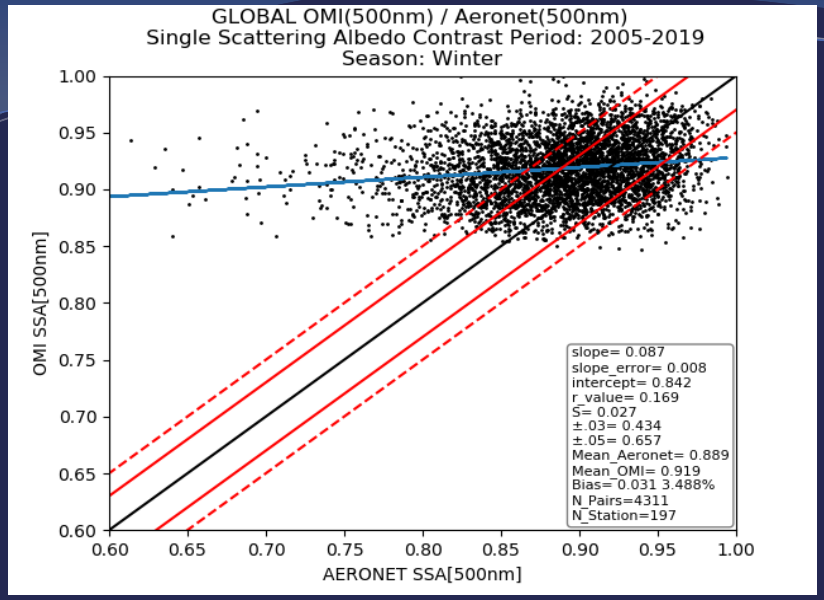


Autumn

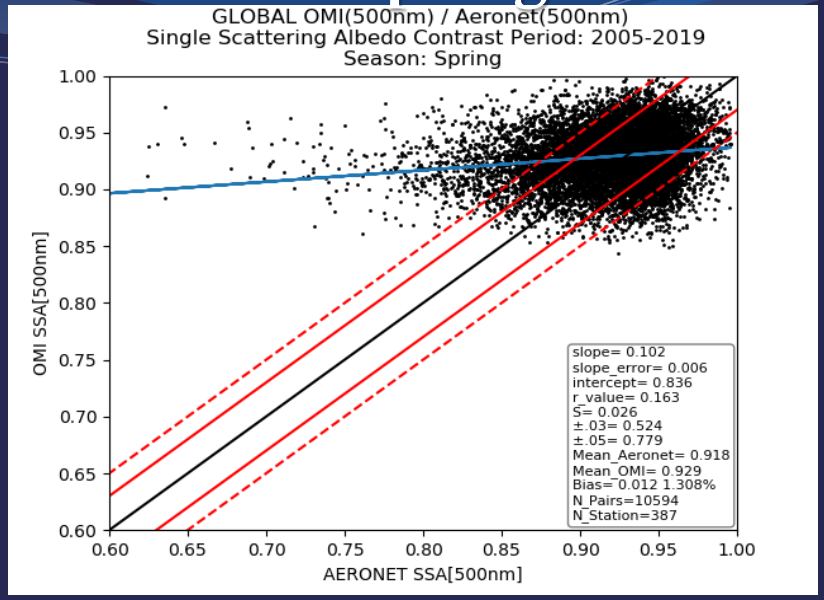


500 nm

Winter

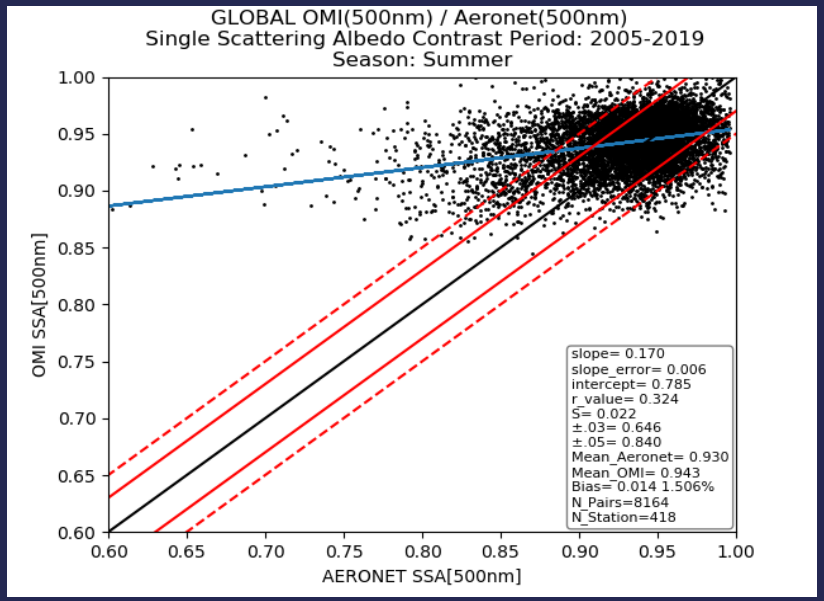


Spring

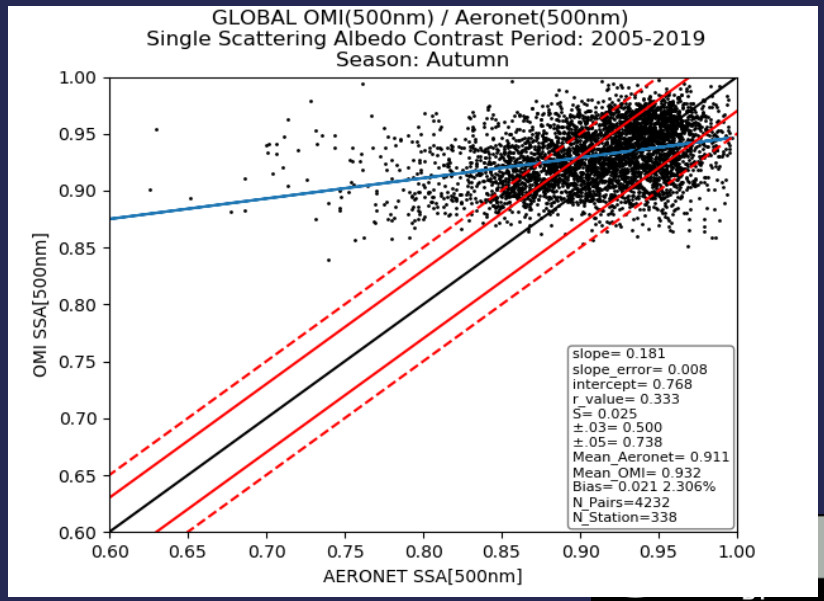


Slight seasonal differences, better agreement in summer

Summer



Autumn



Results and discussion

- Data Availability
- Global Scatter Plots Contrast
- **Comparison on an Individual Station Level Basis. Results for:**
  - **R (Correlation Coefficient)**
  - **Bias**

Correlation Coefficient

The following Figures show the computed **Correlation Coefficient (R)**, for each individual AERONET station, for the two comparison wavelengths, **440 nm (or 443 nm) and 500 nm**

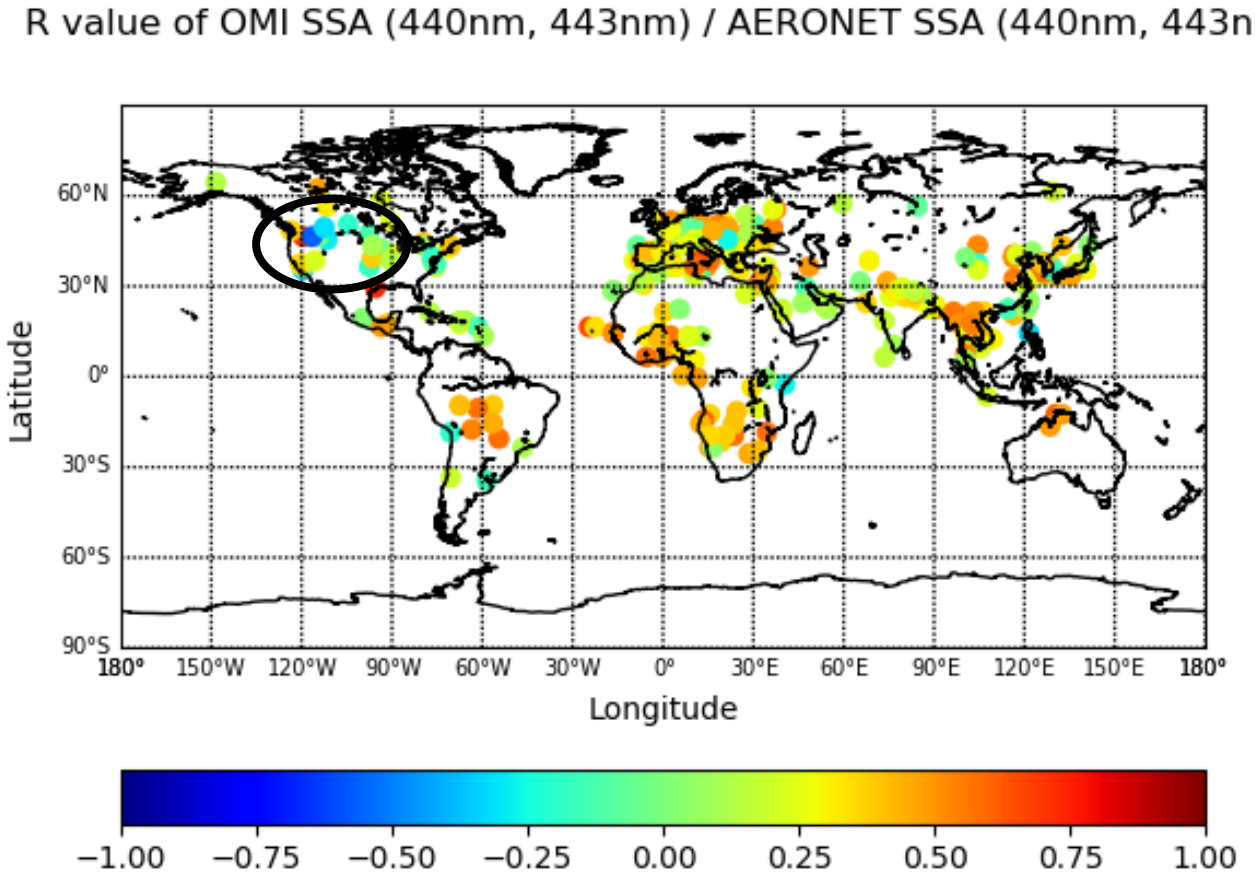
The effect of the availability of OMI and AERONET data pairs on the comparison is assessed by making comparisons for stations for which at least **10, 50 and 100 common pairs** are available

The seasonal effects are assessed performing the **comparison**, apart from annual, also on a **seasonal basis**

Correlation Coefficient

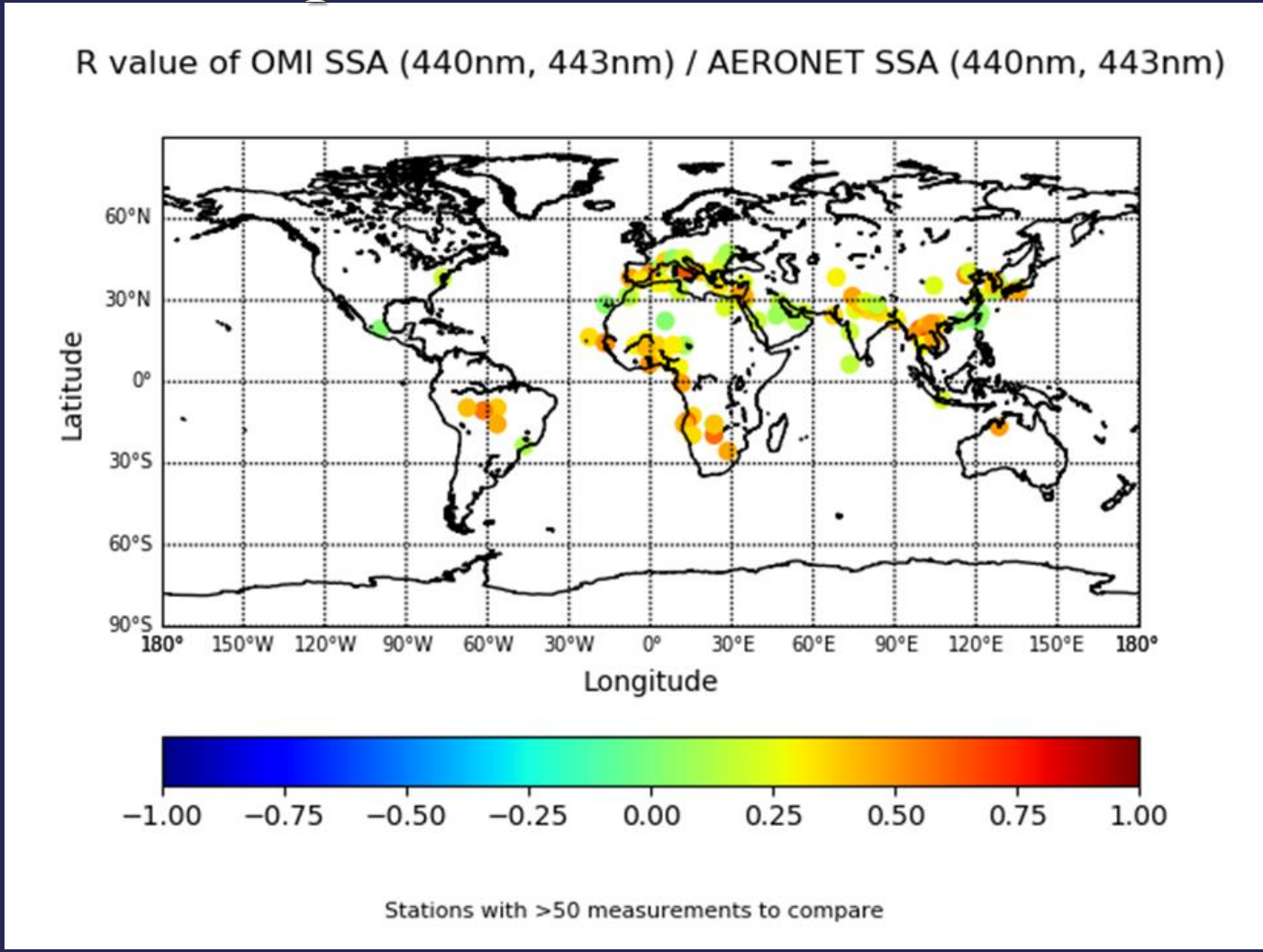
- **Comparison on annual basis**
- Comparison on seasonal basis

Correlation Coefficient (R)
Comparison on annual basis



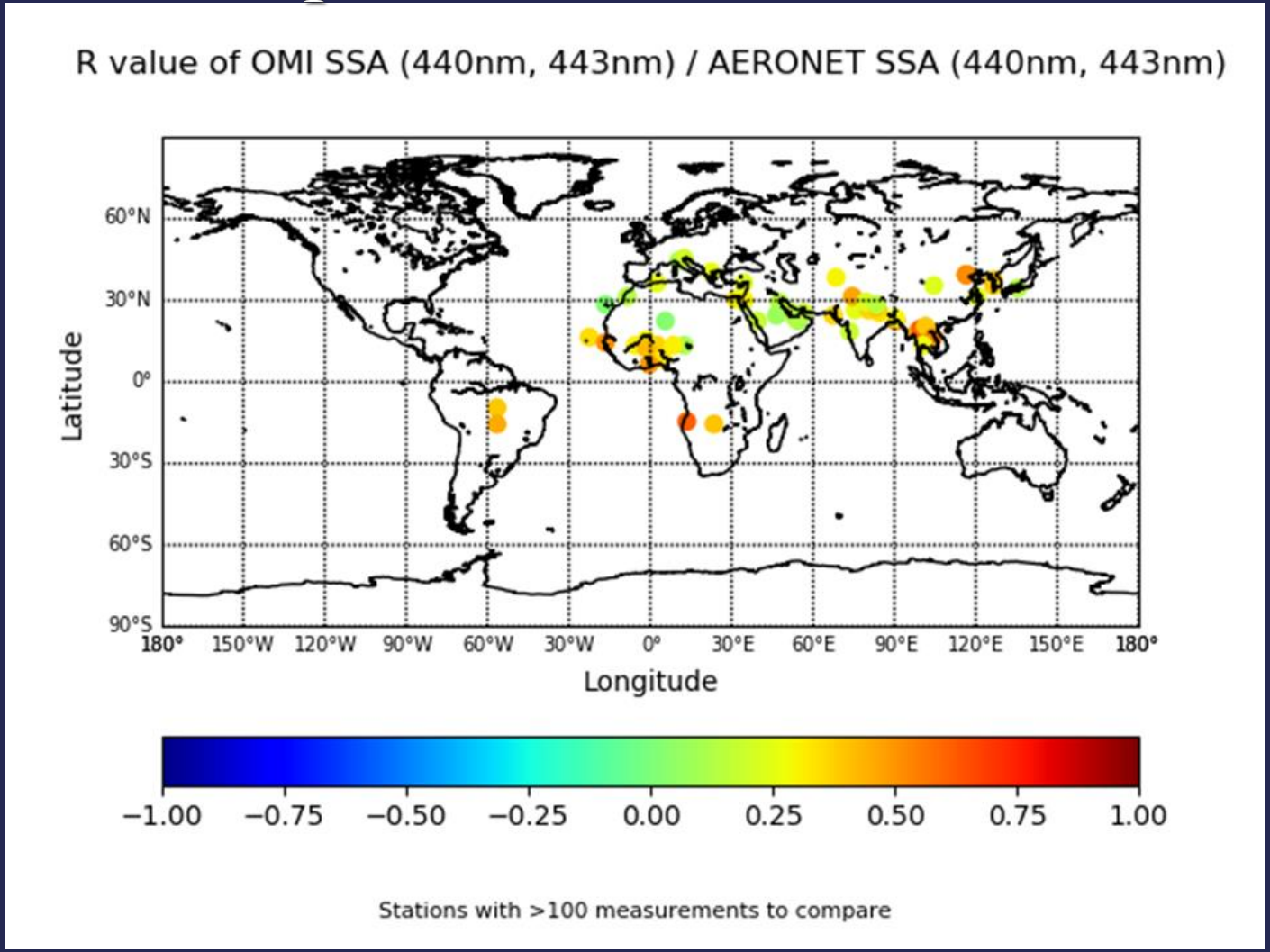
For station fulfilling the criterion of availability of at least 10 **common pairs,** there are mostly positive correlation coefficients (**in 281 out of 322 stations**), but there also some negative R values, mainly over North America (also over eastern Europe)

Correlation Coefficient (R)
Comparison on annual basis



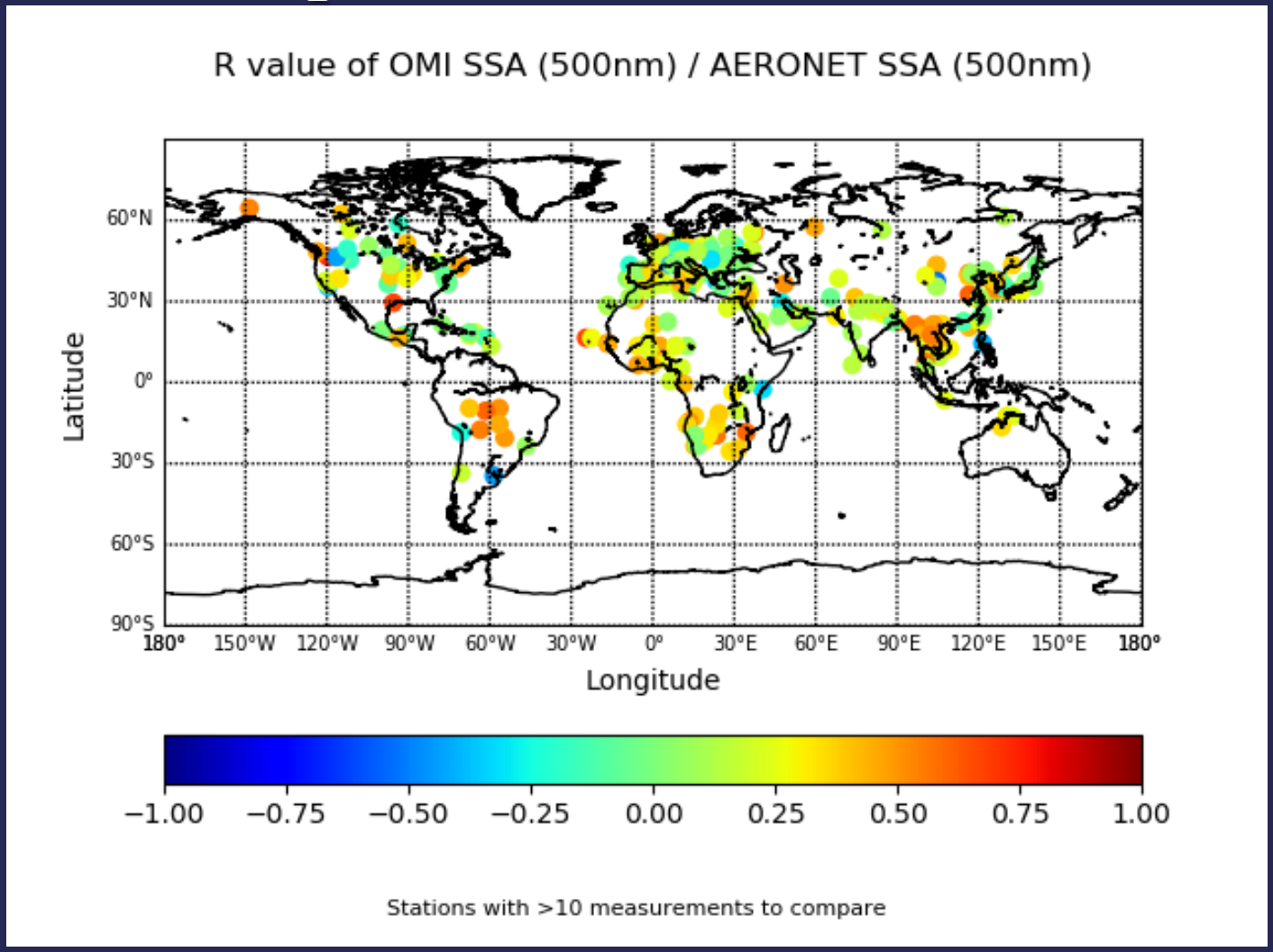
When the more strict availability criterion of at least 50 **common pairs is applied**, the negative correlations disappear (**120 out 122 stations** with positive R values)

Correlation Coefficient (R)
Comparison on annual basis



Not any essential change is observed applying the even more strict availability criterion of at least 100 **common pairs** (instead of 50 pairs)

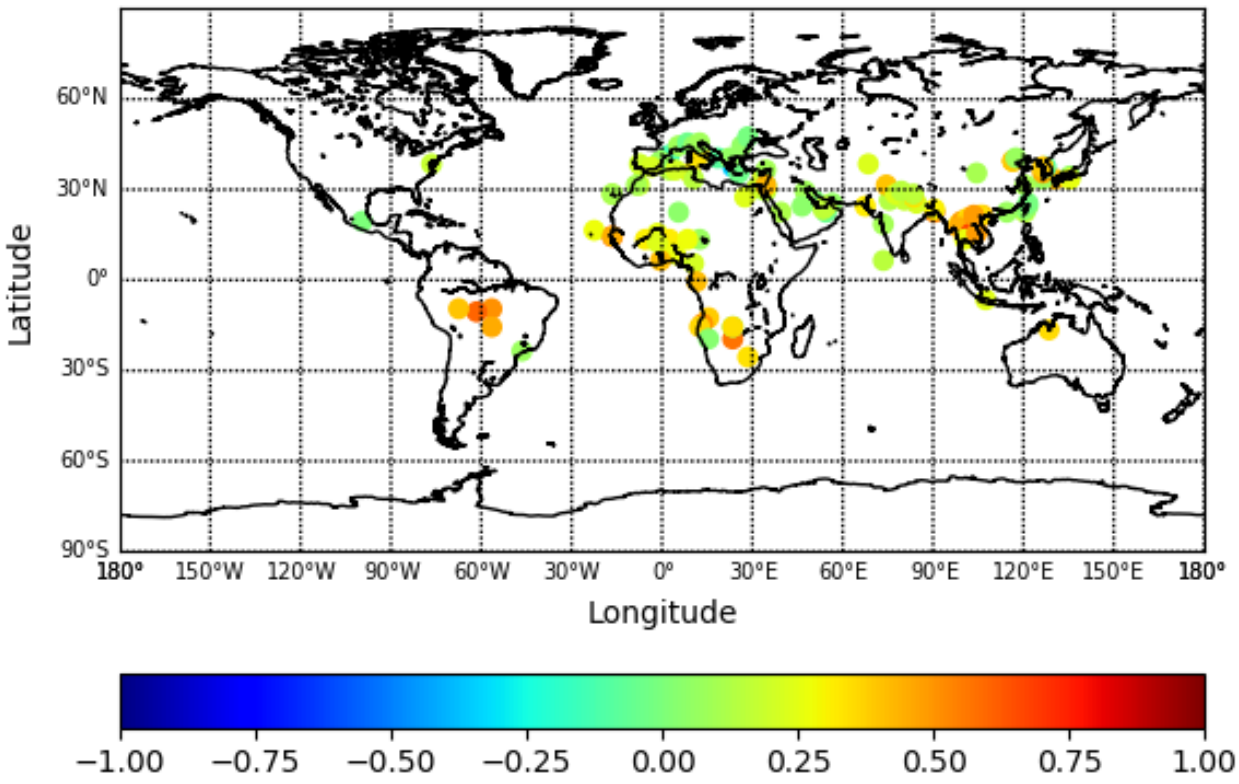
Correlation Coefficient (R)
Comparison on annual basis



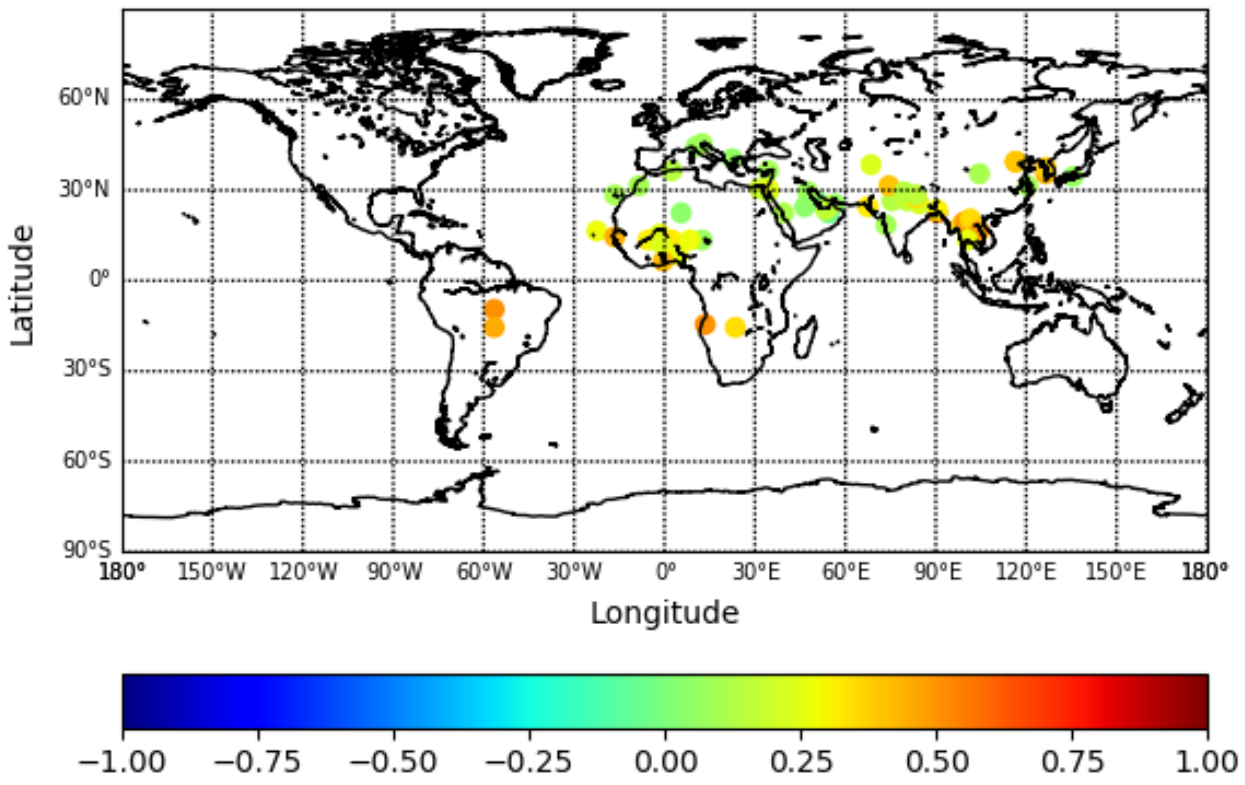
Similar geographical patterns of R for 500 nm with those obtained for 440(443) nm

The same is valid for all availability criteria (>10, >50 and >100 common pairs)

Correlation Coefficient (R)
Comparison on annual basis



Correlation Coefficient (R)
Comparison on annual basis

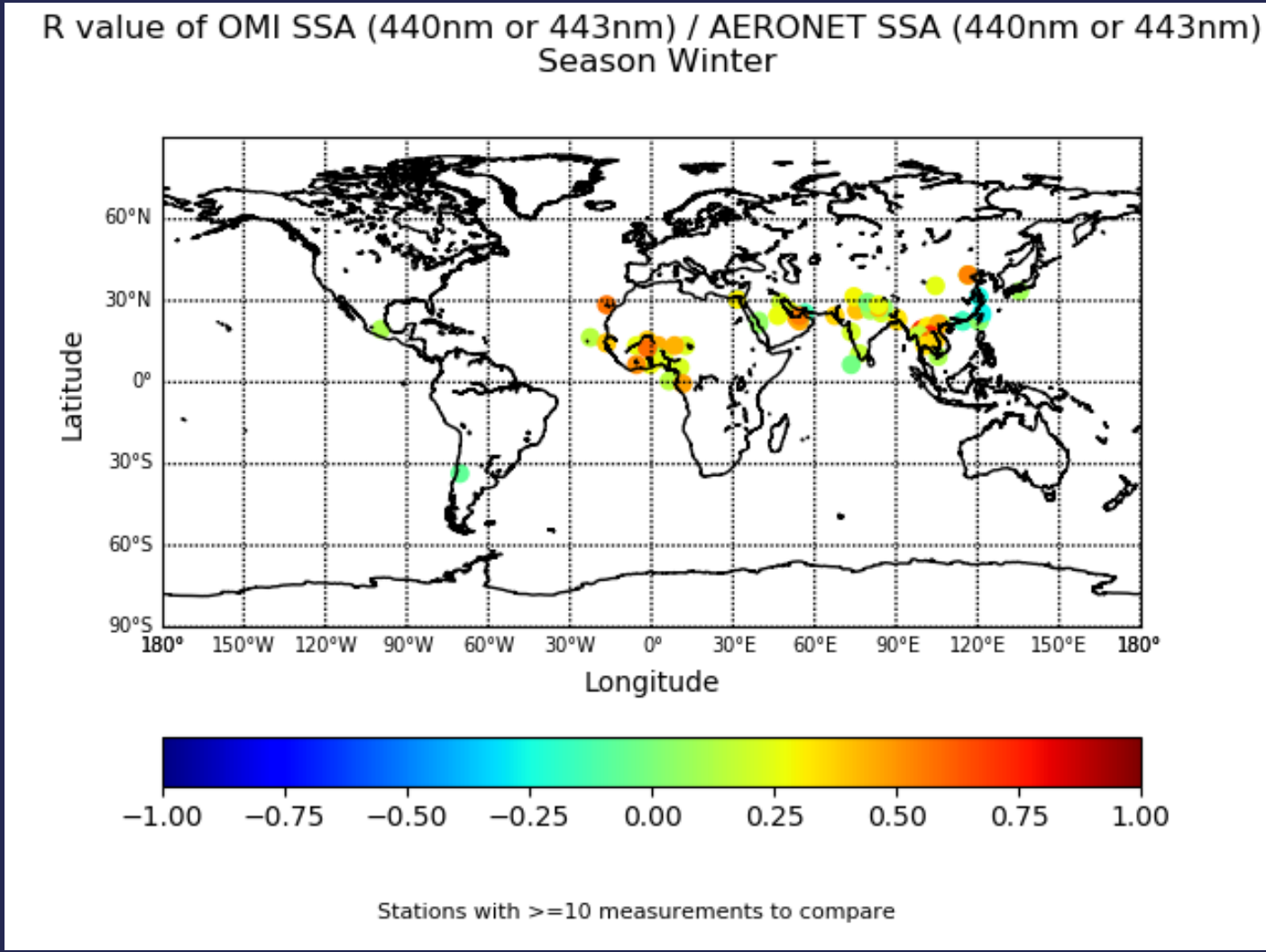


Correlation Coefficient

- Comparison on annual basis
- **Comparison on seasonal basis**

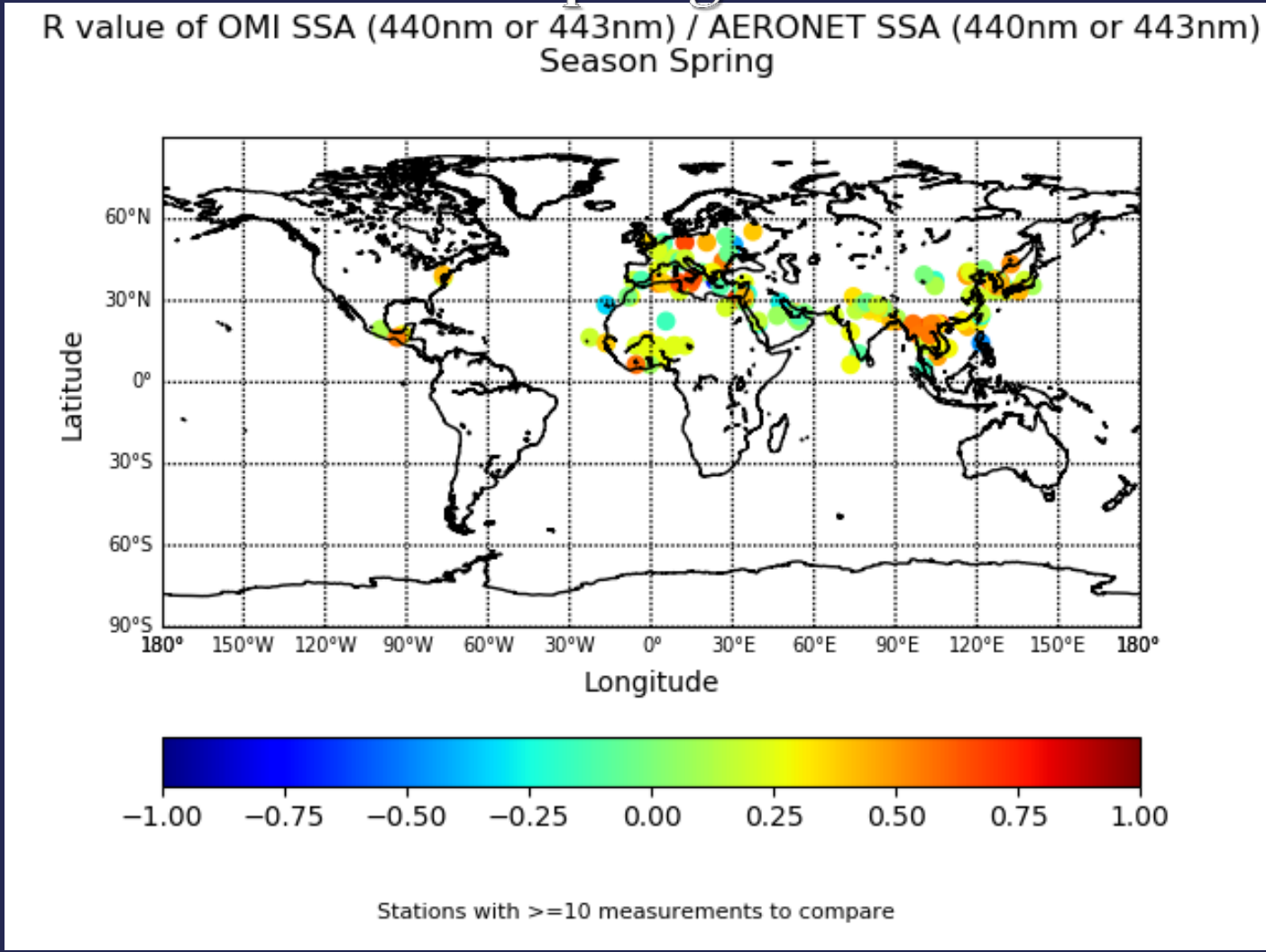
  (results only for criterion >10 measurements)

Correlation Coefficient (R)
Comparison on seasonal basis
Winter



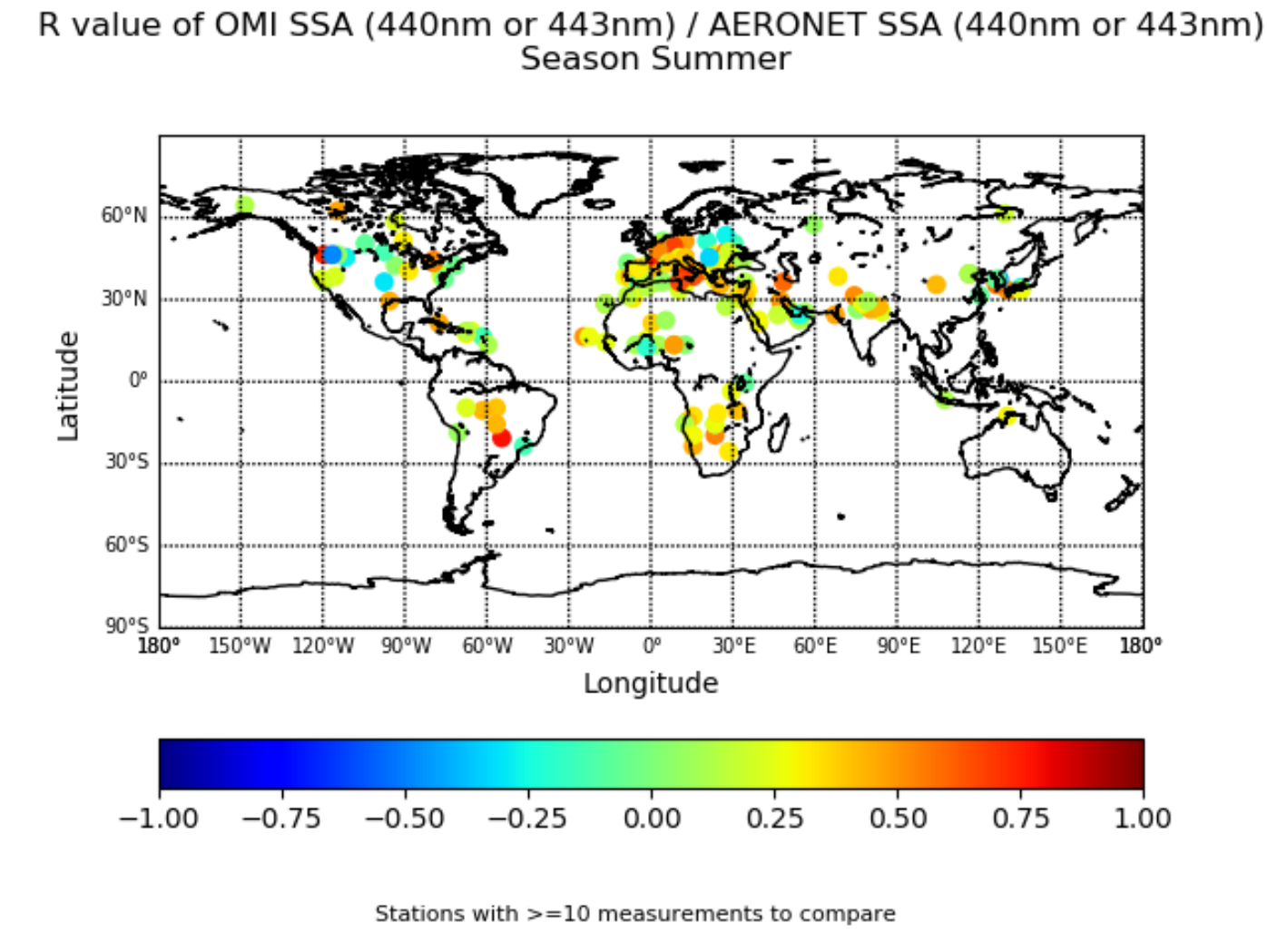
Positive correlation coefficients in winter (59 out of 72 stations) mainly over sub-Sahel and central Africa and south Asia, but there are negative R values over India

Correlation Coefficient (R)
Comparison on seasonal basis
Spring



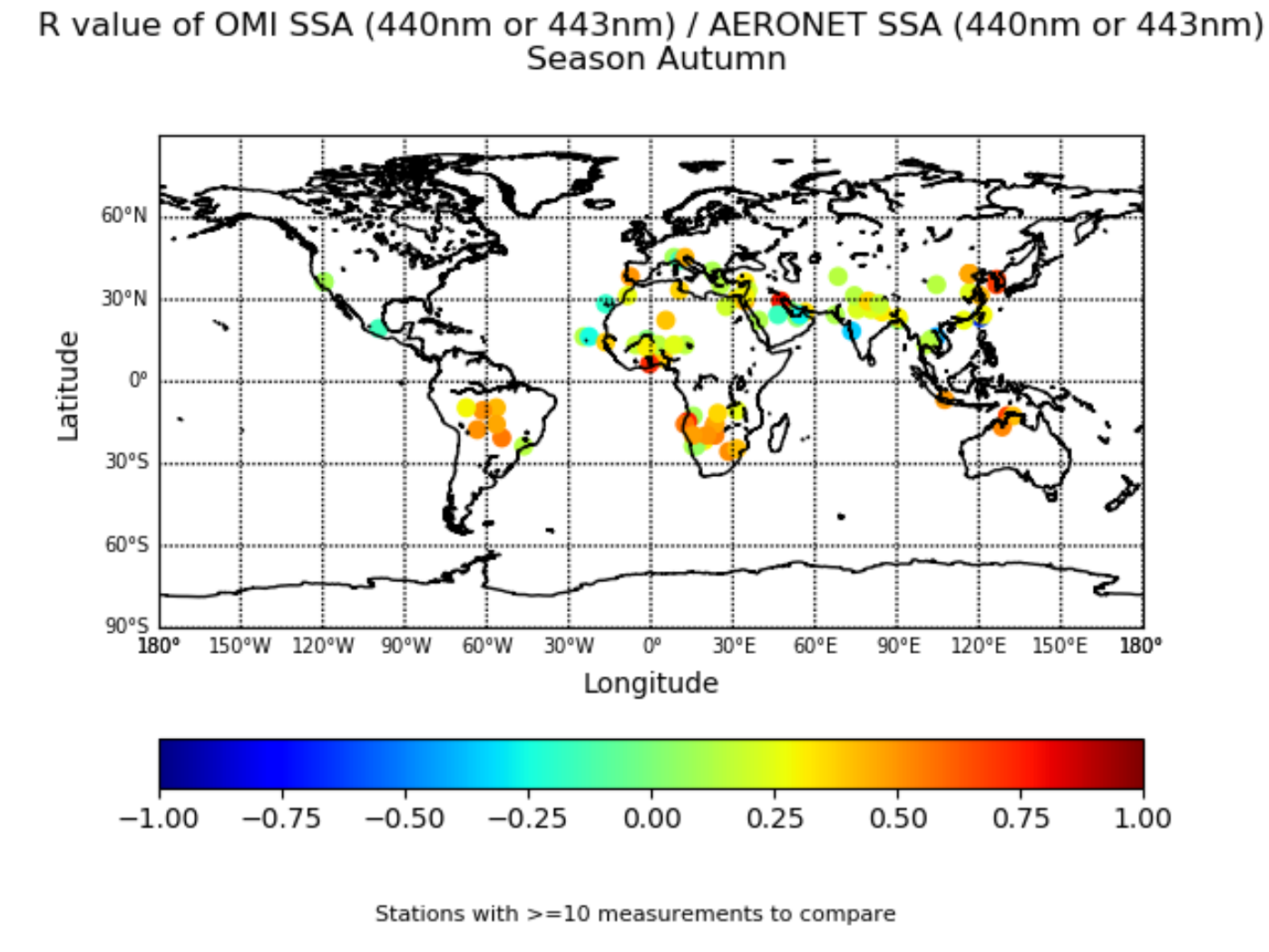
In spring, there are mixed patterns (positive and negative R values) over Europe (negative R in eastern part) and North Africa. Positive correlation coefficients in most of other areas (as in winter).

Correlation Coefficient (R)
Comparison on seasonal basis
Summer



In summer, there are both positive and negative R values over Europe (negative in its eastern part). Negative R is also found in North America

Correlation Coefficient (R)
Comparison on seasonal basis
Autumn



In autumn, positive correlation appears over most areas (86 out of 100 stations)

Bias

The following Figures show the computed **Bias ($SSA_{OMI} - SSA_{AERONET}$)** for individual AERONET stations, for the two comparison wavelengths, **440 nm (or 443 nm) and 500 nm**

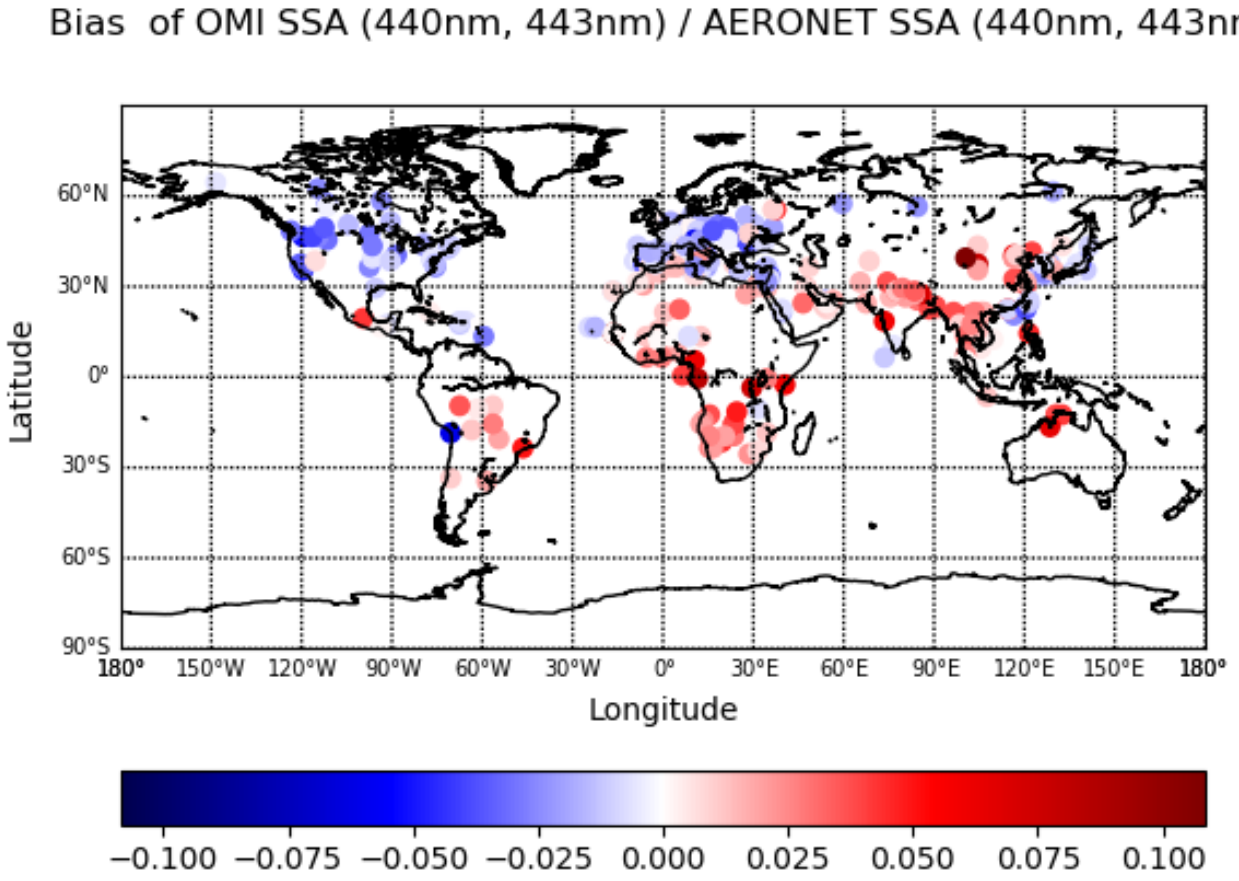
The effect of the availability of OMI and AERONET data pairs on the comparison is assessed by making comparisons for stations for which at least **10, 50 and 100 common pairs** are available

The seasonal effects are assessed performing the **comparison**, part from annual, also on a **seasonal basis**

Bias

- **Comparison on annual basis**
- Comparison on seasonal basis

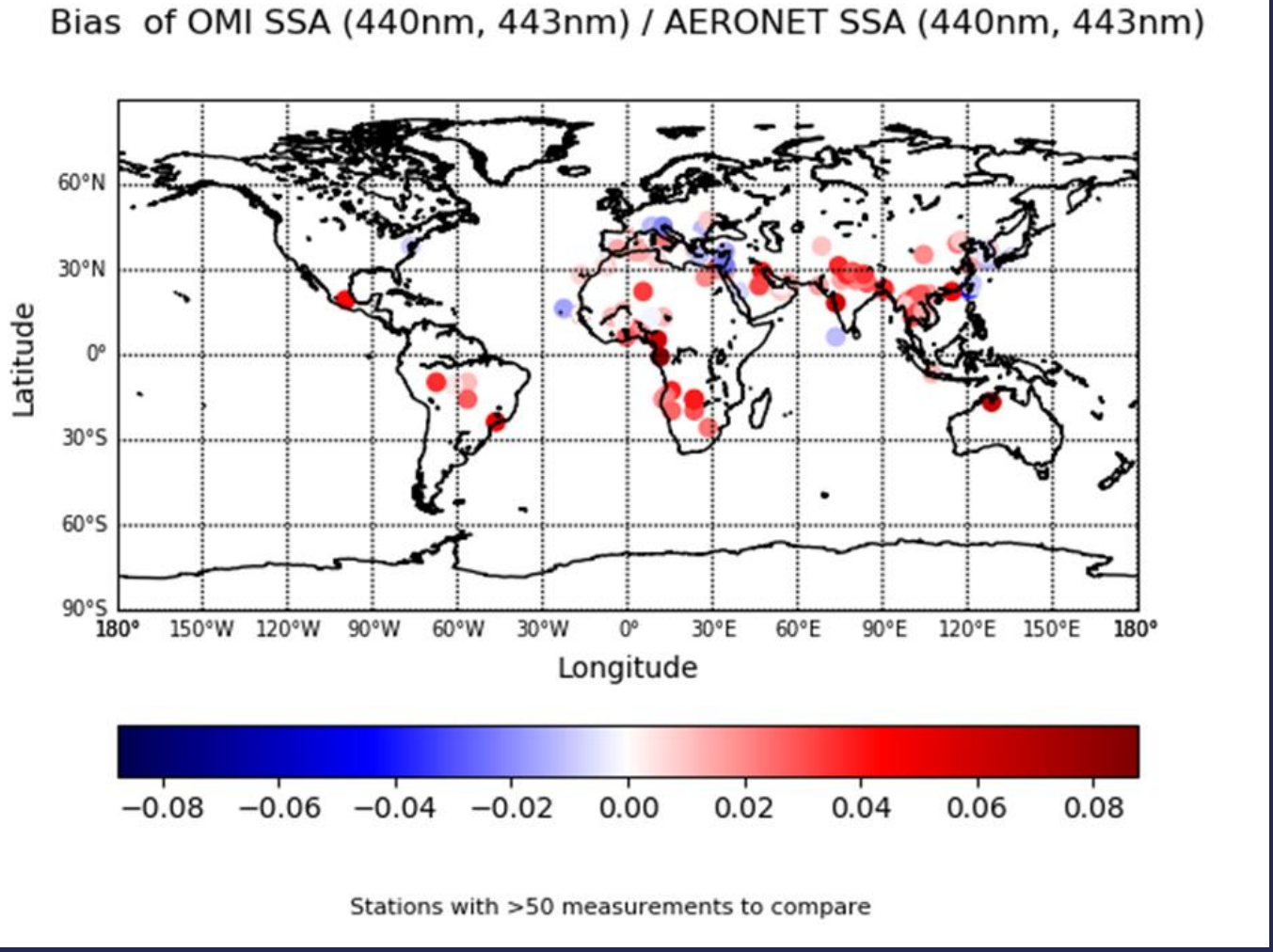
Bias
Comparison on annual basis



Different patterns, mainly an underestimation over North America and Europe, and an overestimation over southeast Asia and south Africa (especially strong over central Africa)

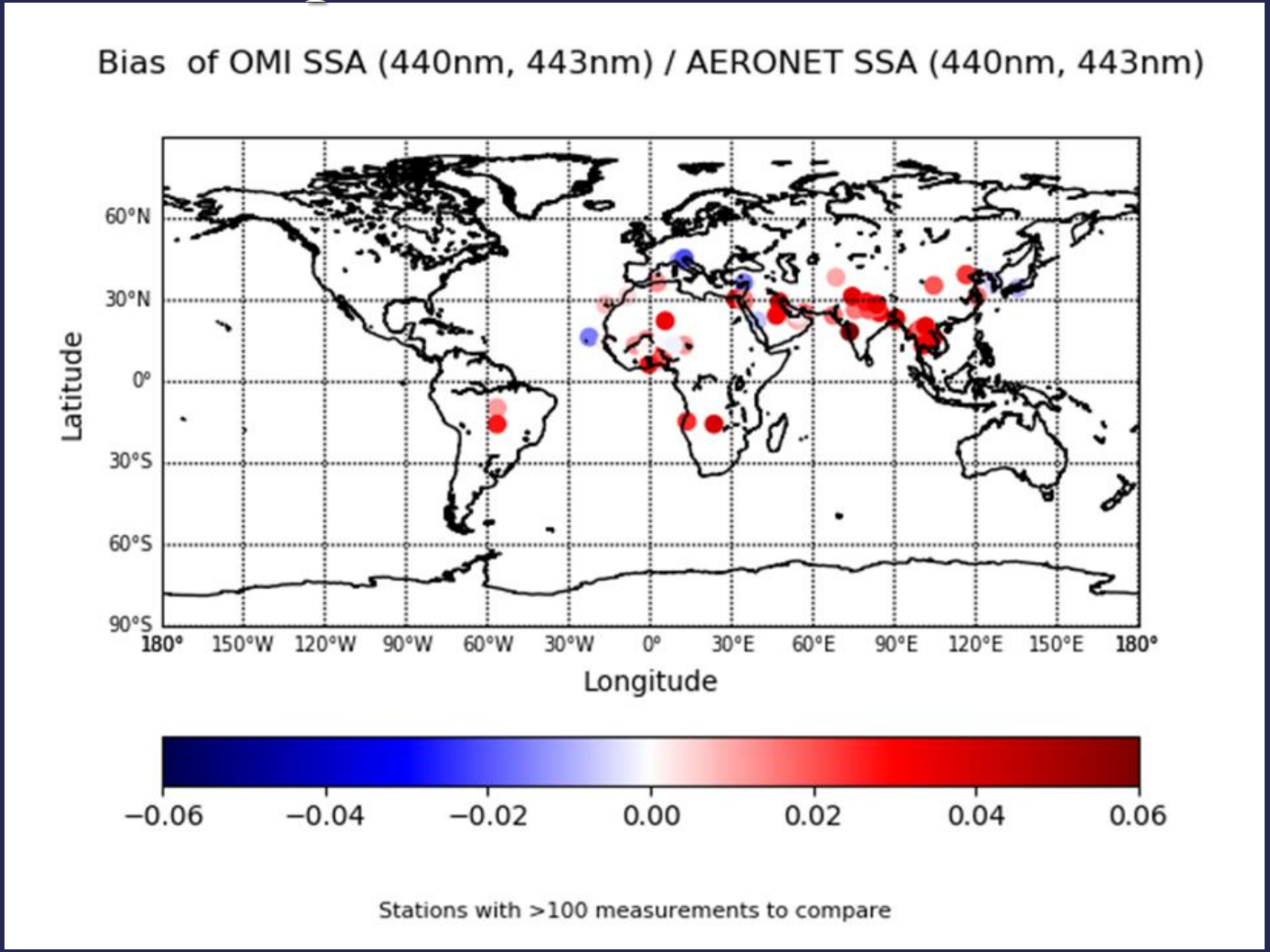
Bias

Comparison on annual basis



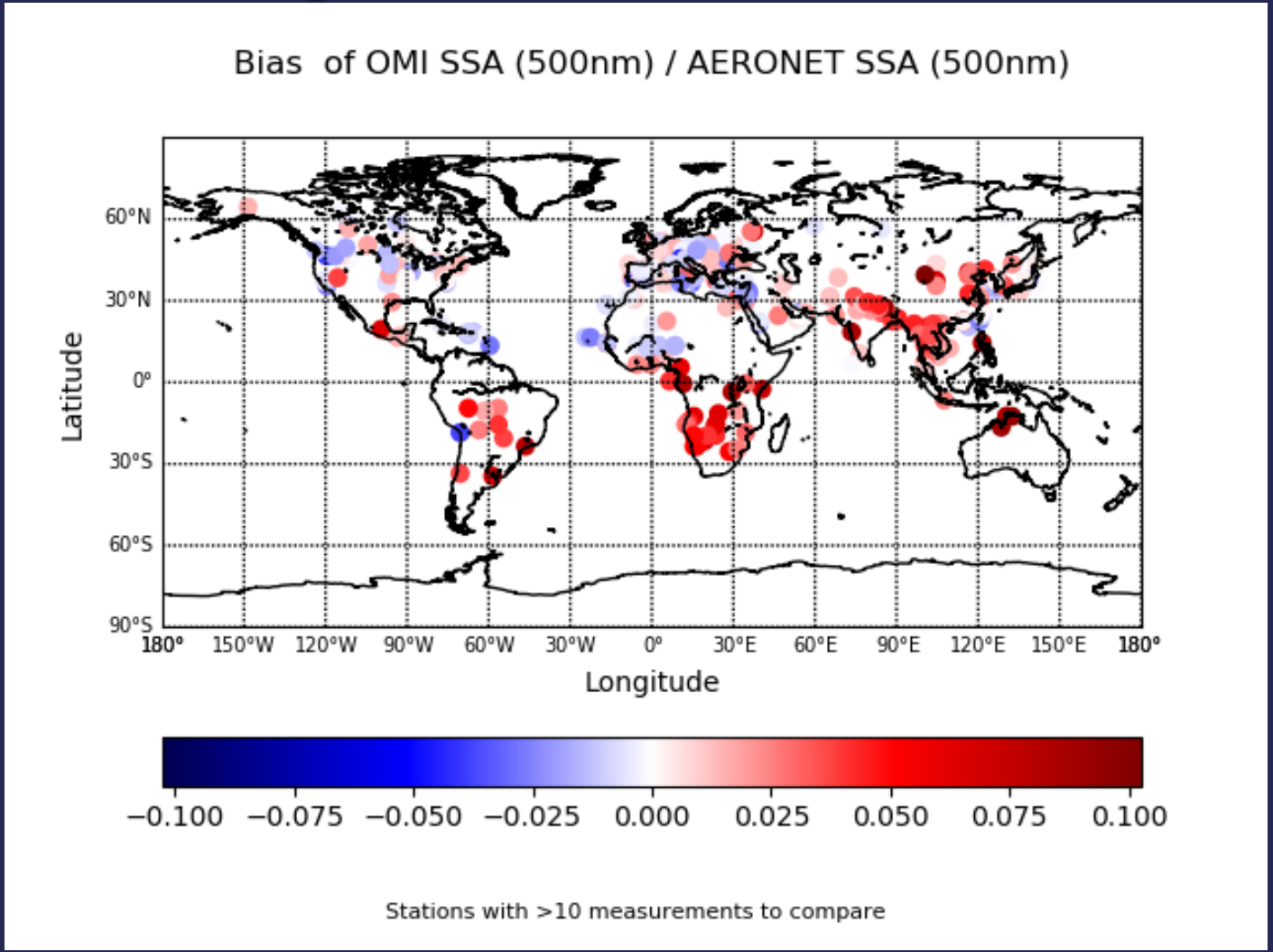
The underestimation over north America and Europe disappears when more severe availability criteria (availability of at least 50 common pairs) are applied (same with the disappearance of negative R values over the same areas for same availability criteria)

Bias
Comparison on annual basis



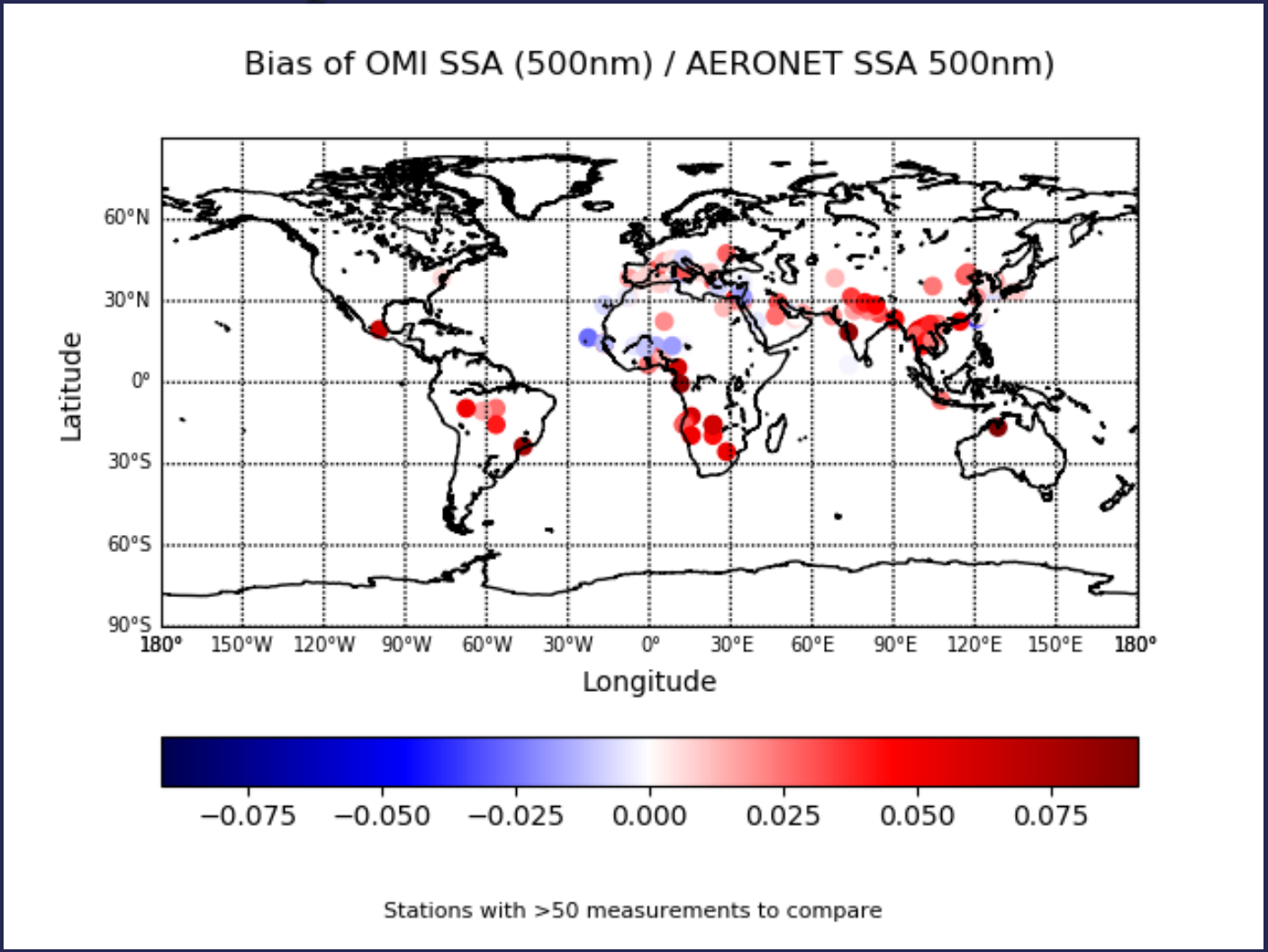
Results for the availability criterion of at least 100 common pairs are similar to those for at least 50 stations

Bias
Comparison on annual basis



Similar results (geographical patterns) with those obtained for 440(443) nm except for a slightly smaller underestimation over North America and Europe

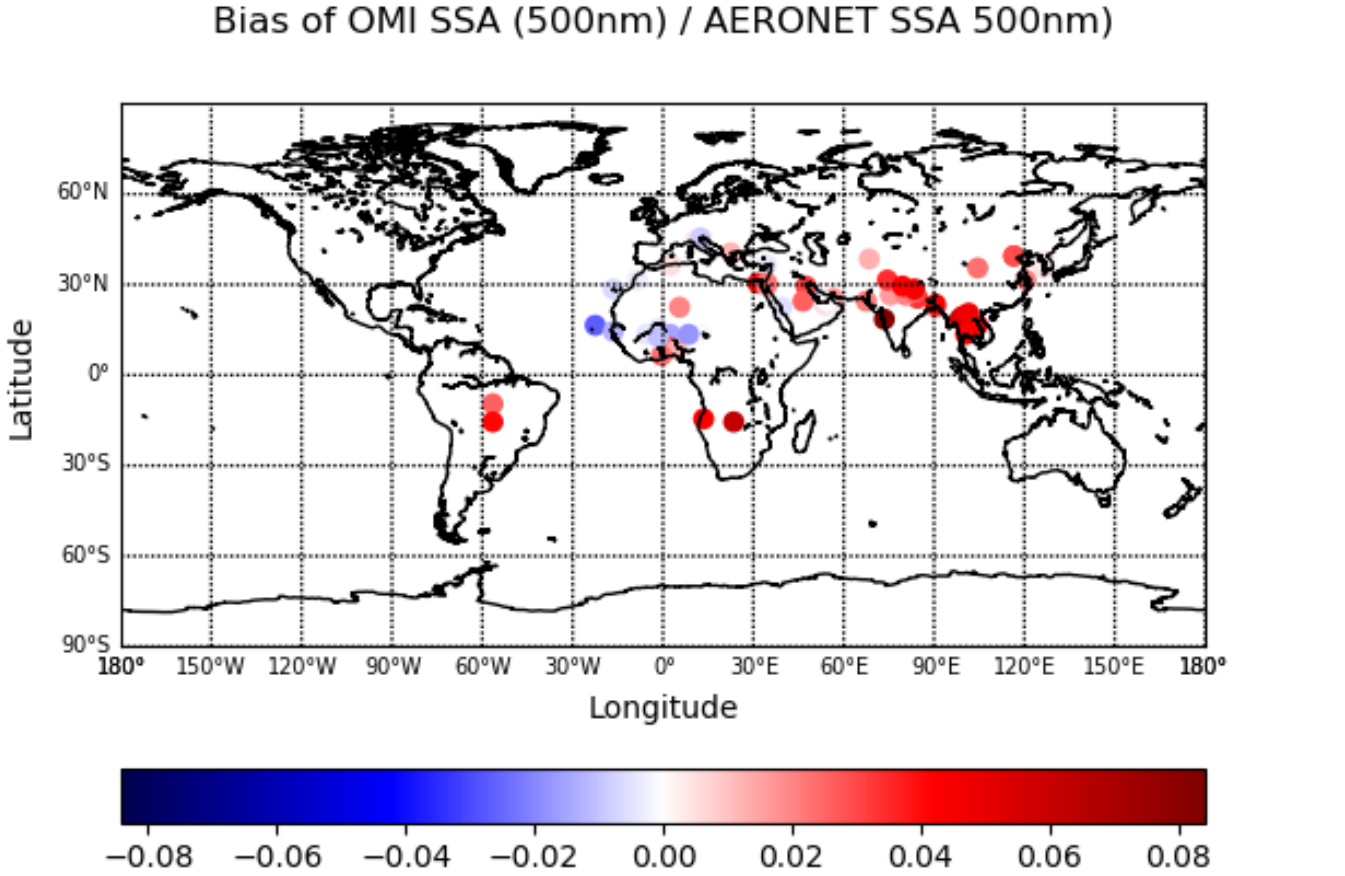
Bias
Comparison on annual basis



Similar results (geographical patterns) with those obtained for 440(443) nm except for a slightly smaller underestimation over North America and Europe

Bias

Comparison on annual basis



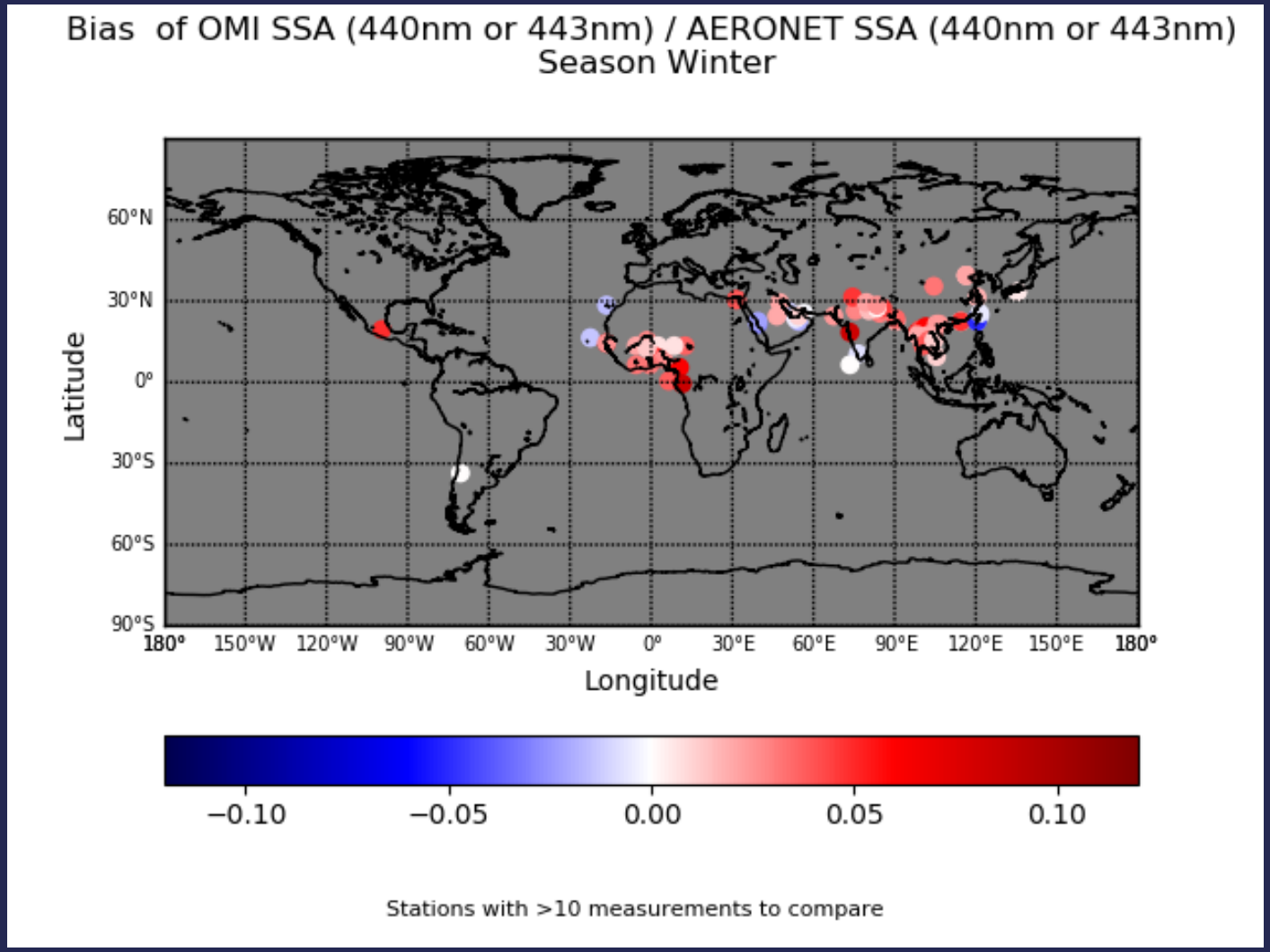
Similar results (geographical patterns) with those obtained for 440(443) nm except for a slightly smaller underestimation over North America and Europe

Bias

- Comparison on annual basis
- **Comparison on seasonal basis**

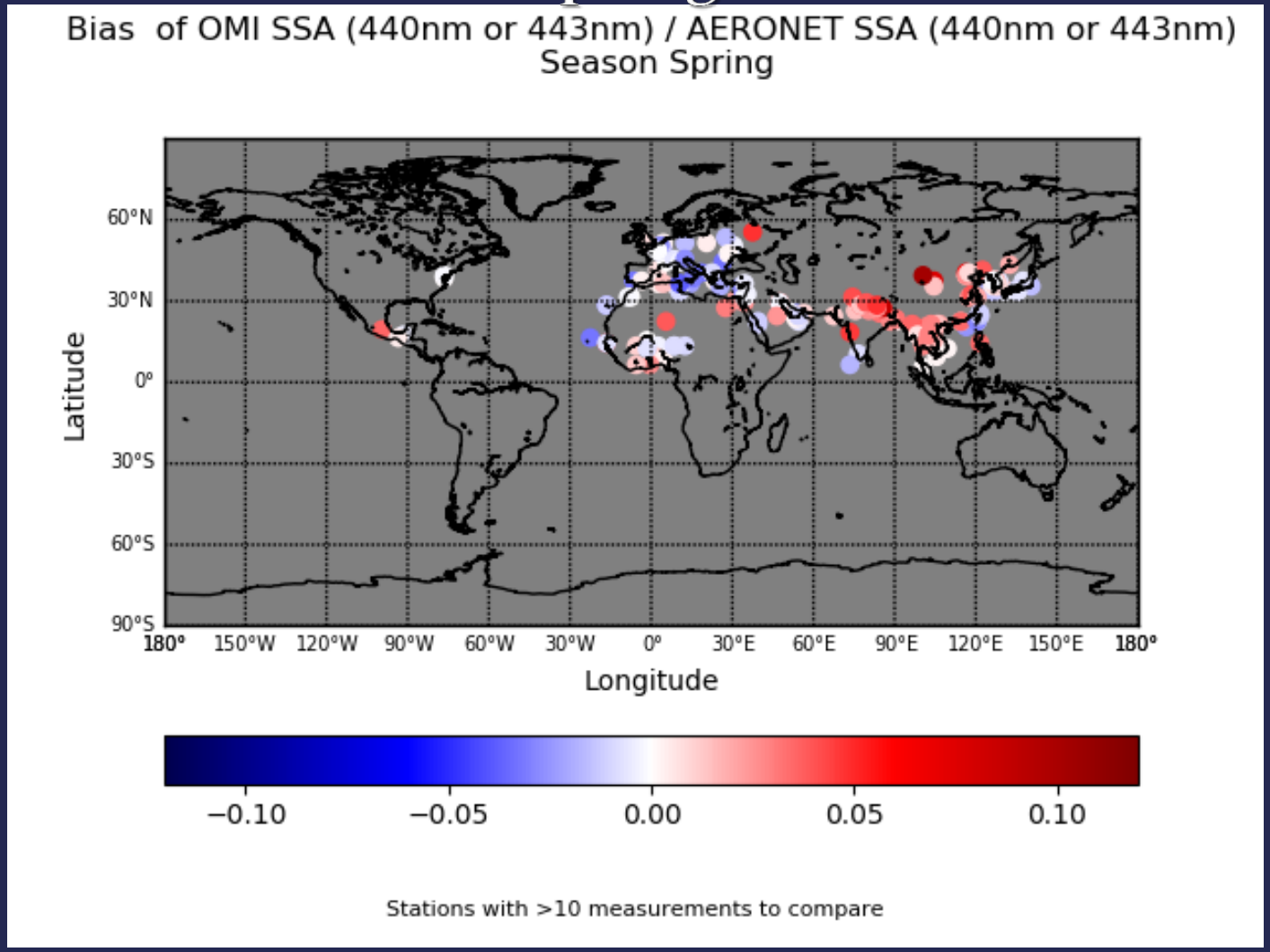
  (only for availability >10 common data pairs)

Bias
Comparison on seasonal basis
Winter



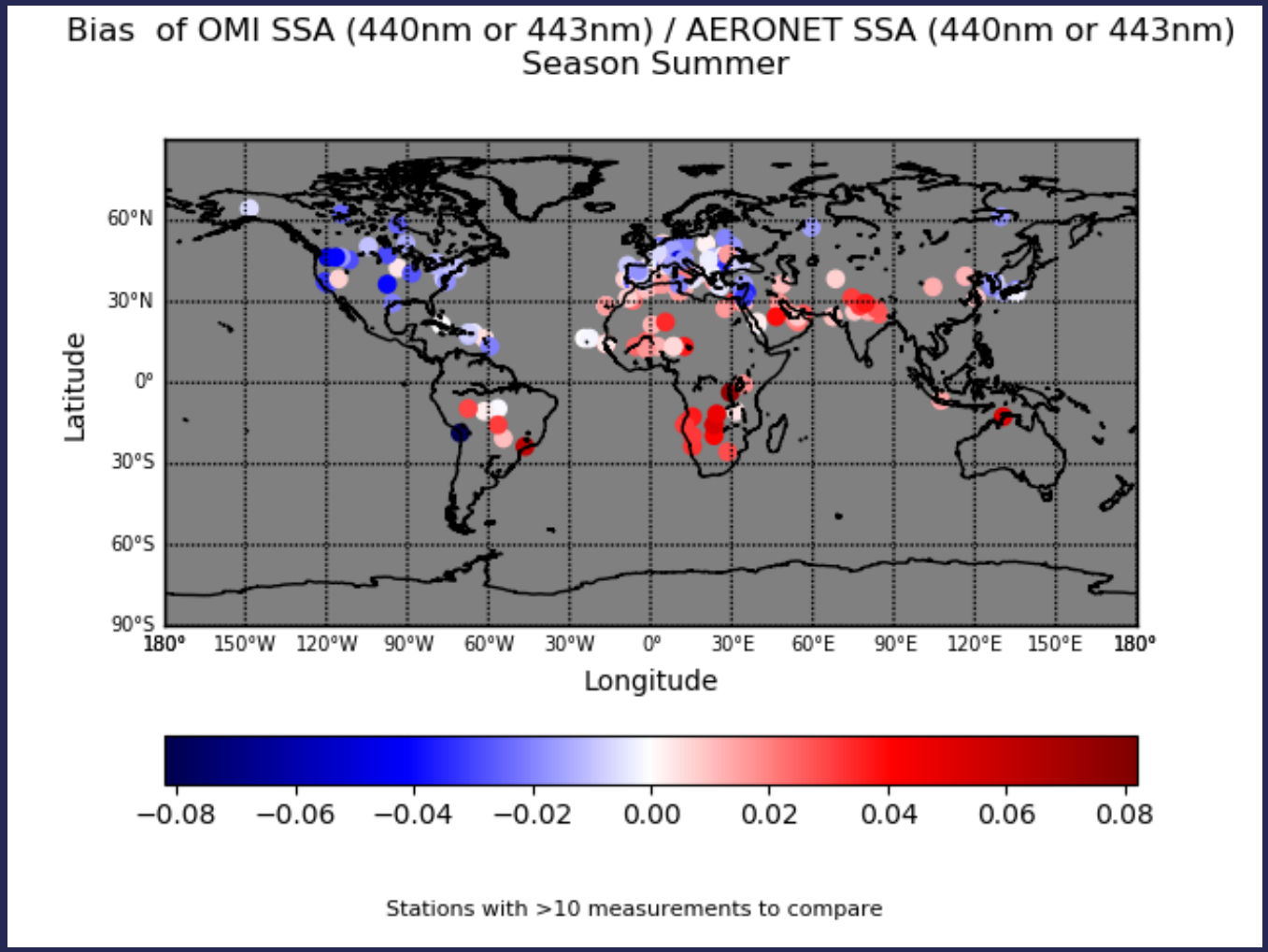
In winter, there is an over estimation of OMI SSA in areas of biomass burning

Bias
Comparison on seasonal basis
Spring



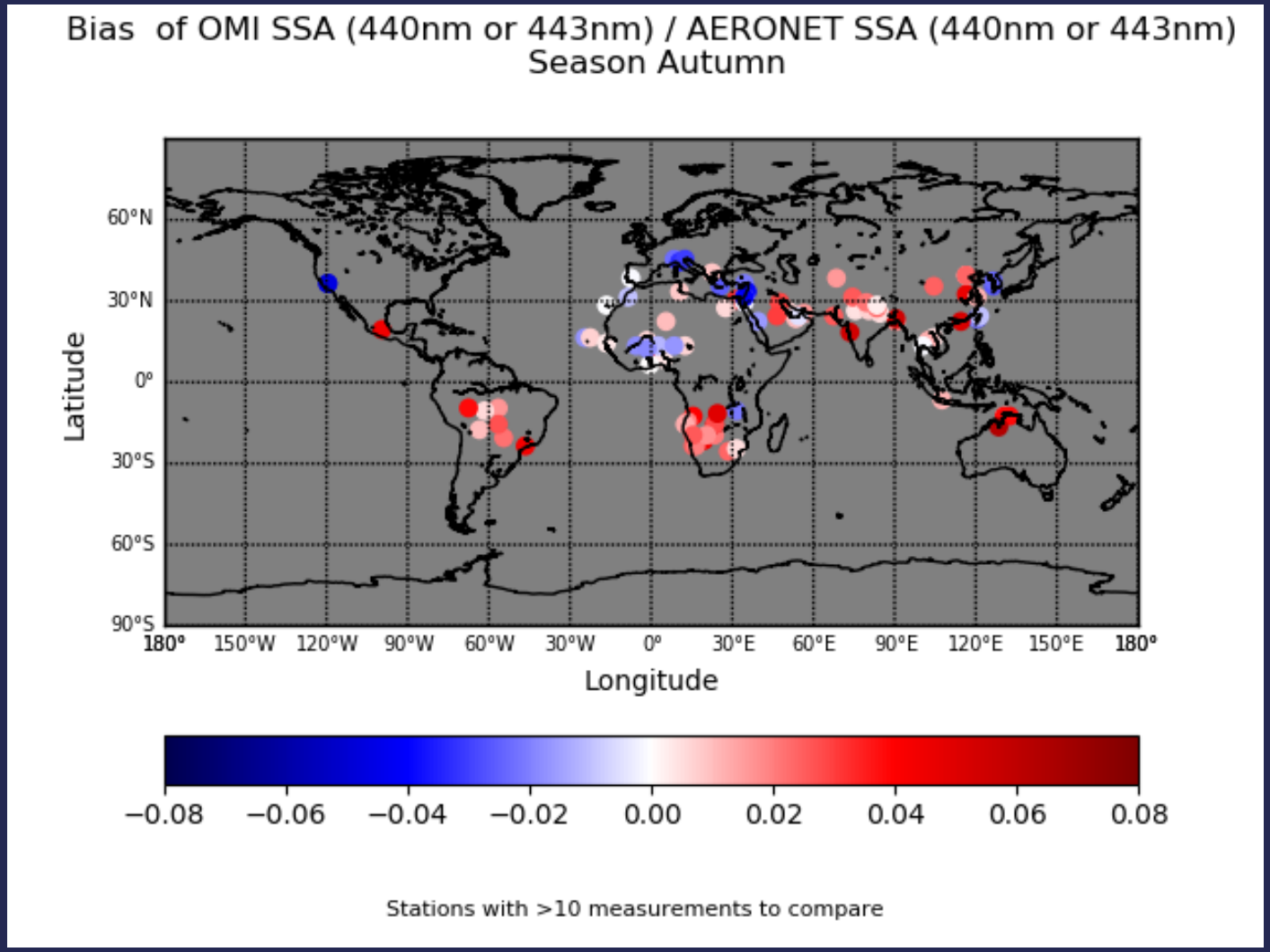
In spring, there are mixed patterns: underestimation over Europe and over estimation over Asia

Bias
Comparison on seasonal basis
Summer



In summer, there is an over estimation of OMI SSA in areas of biomass burning (southern Africa and Amazonia). In contrast, there is under estimation over urban European and North American areas

Bias
Comparison on seasonal basis
Autumn



In autumn, similar results with summer, except from the absence of underestimation over Europe and North America

Conclusions

An evaluation of the retrieved OMI Single Scattering Albedo (SSA) data has been attempted through comparisons against daily SSA products from **541** globally distributed Aerosol Robotic Network (AERONET) **stations**, for a **15-year period (2005-2019).** The analysis shows that:

- **about 58% (81%) of OMI-AERONET matchups agree within the absolute difference of ±0.03 (±0.05) for the 440 (443) nm comparison**
- **The comparison for 500 nm is inferior to that for 440 (443) nm, e.g. including smaller percentages, ab**out 54% (77%) of OMI-AERONET matchups agreeing within the absolute difference of ±0.03 (±0.05)
- For both wavelengths, an OMI overestimation is found for AERONET SSA values below 0.8, leading to a small slope value
- The comparison reveals ***slight seasonal differences, with a better agreement in summer***
- ***OMI tends to*** underestimate SSA over urban areas, and to overestimate SSA over areas where bio-mass burning occurs
- A potential source of error in the OMI-AERONET SSA comparison can be the uncertainty associated with the OMI retrievals at 388nm and the extrapolation applied to obtain the AOD/SSA at 440(443)nm and 500nm