AIRWAVE-related studies: validation, current applications and possible extensions of TCWV products

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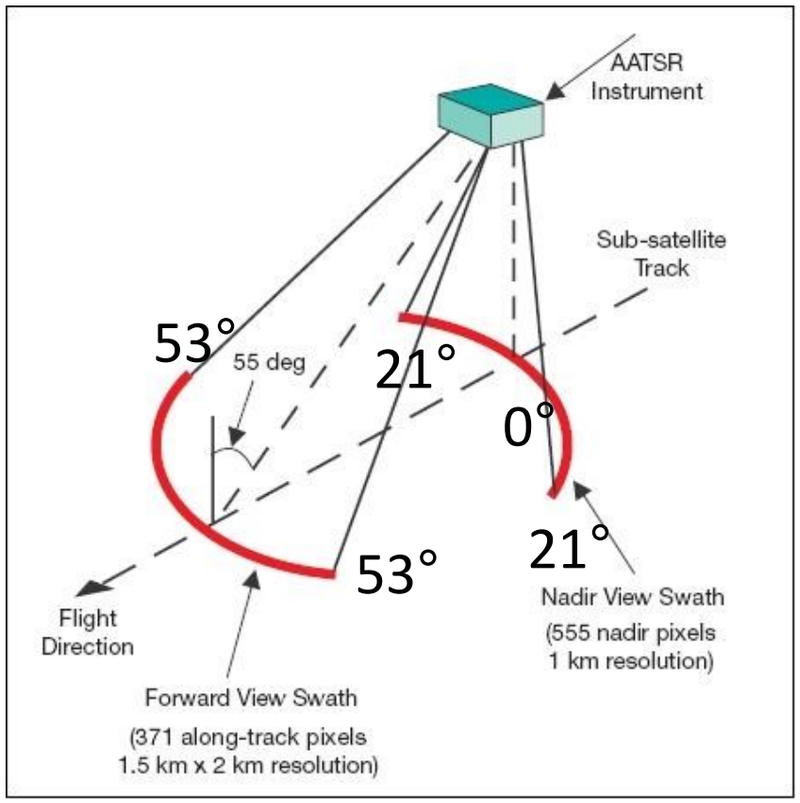
with contribution from
BM Dinelli and E. Castelli (CNR-ISAC)
S. Casadio and E. De Grandis (SERCO)

AIRWAVE algorithm: v1



ATSR-1/ERS-1
(1991-1996)

ATSR-2/ERS-2
(1995-2003)

AATSR/ENVISAT
(2002-2012)

$$TCWV = \alpha \cdot \Phi_{NAD} + \beta \cdot \Phi_{FWD}$$

AIRWAVE algorithm: TCWV retrieval for day & night – cloud free/water scenes using two dual view TIR measurements from Along Track Scanning Radiometer (ATSR) series.

1 TCWV value from 4 measured BTs.

AIRWAVE needs:

- The instrument filter functions (**measured**)
- The viewing angles (**known**)
- The absorption cross sections (**RTM**)
- The sea surface emissivity (**model**)

AIRWAVE do not need:

- The atmospheric or sea surface temperature a priori / initial guess
- The fitting/calibration to independent TCWV dataset

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Total column water vapour from along track scanning radiometer series using thermal infrared dual view ocean cloud free measurements: The Advanced Infra-Red WAter Vapour Estimator (AIRWAVE) algorithm

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AIRWAVE v1 validation

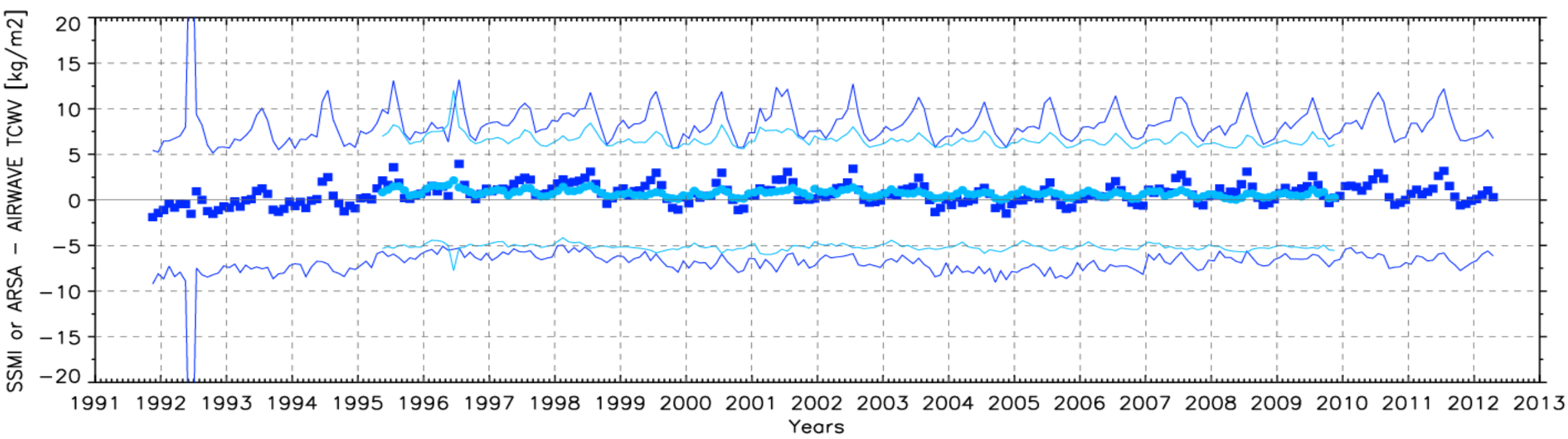
Papandrea et al., "Validation of the Advanced Infra-Red Water Vapour Estimator (AIRWAVE) Total Column Water Vapour using Satellite and Radiosonde products", Annals of Geophysics (accepted "minor revisions")

SSM/I

SSM/I-F13 (1995-2009) daily mean at spatial grid resolution 0.25°x0.25° satellite products.

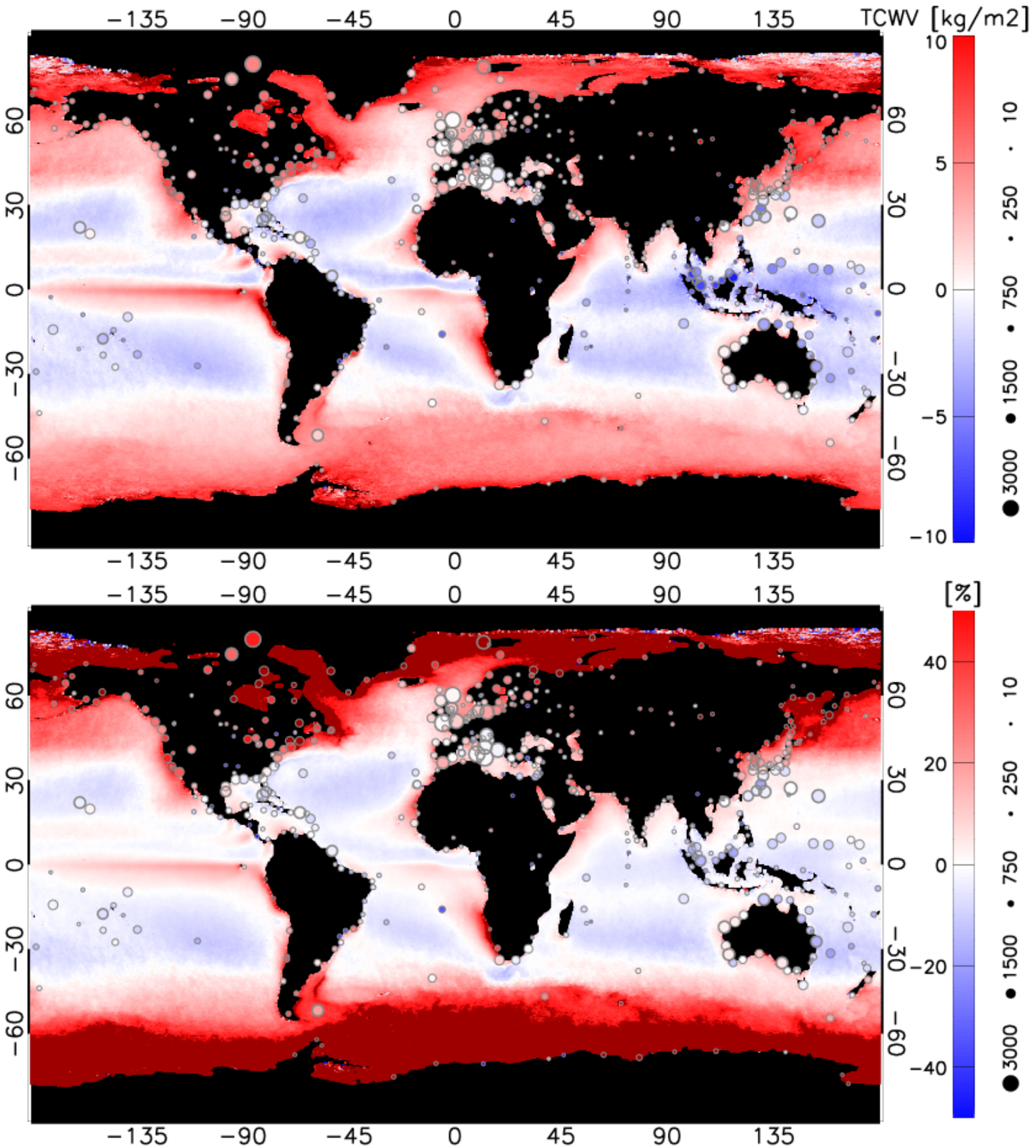
ARSA

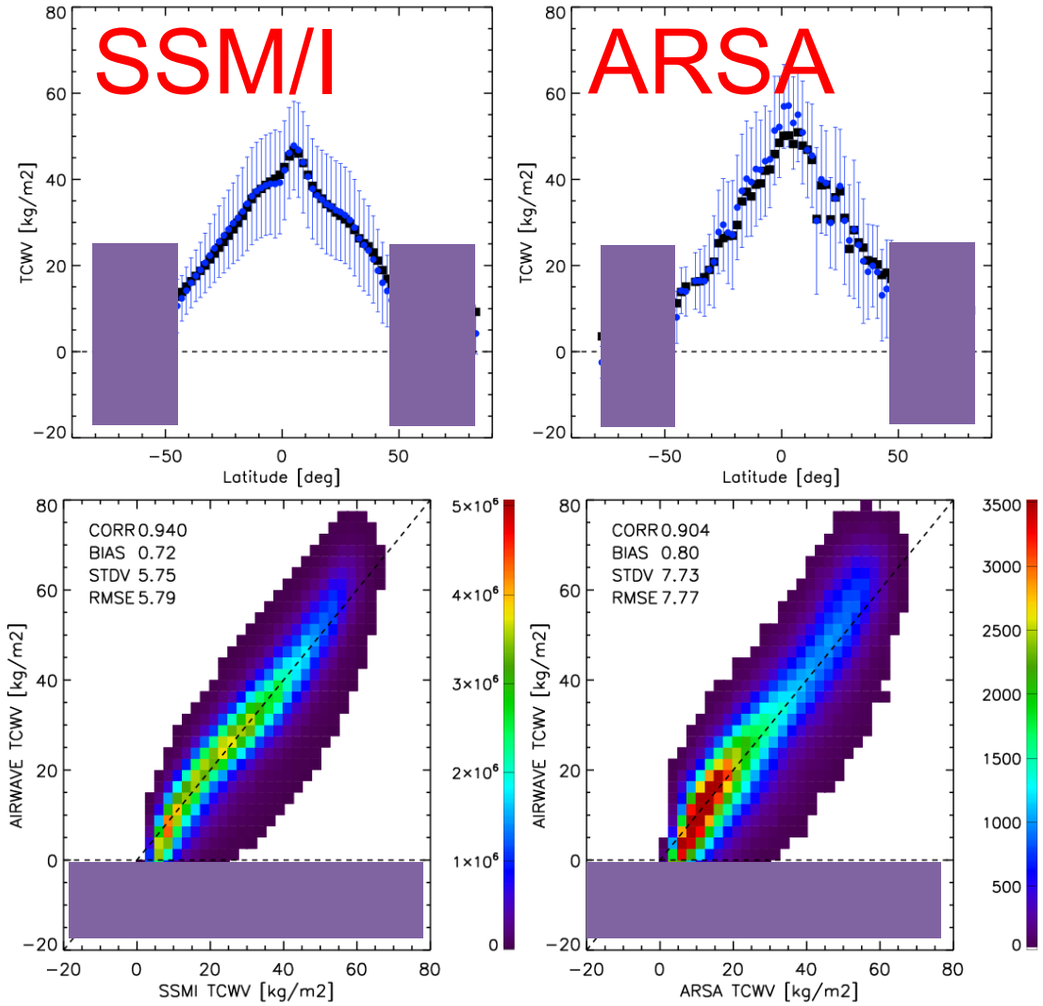
The data inserted in the archive have passed different quality control tests in order to be free of gross errors. They cover all the ATSR time period.



SSM/I-AIRWAVE TCWV and ARSA-ARWAVE TCWV monthly mean trends. The difference between the correlative measurements and AIRWAVE TCWV ± STDV is also reported.

AIRWAVE v1 validation





Overall bias of 0.7 kg/m2 (3%): polar and coastal regions.

No evident drift in the biases and correlated standard deviations thus highlighting the stability of the AIRWAVE TCWV and its very good accuracy.

Improvement: reduction of the bias and spread, especially in polar areas.

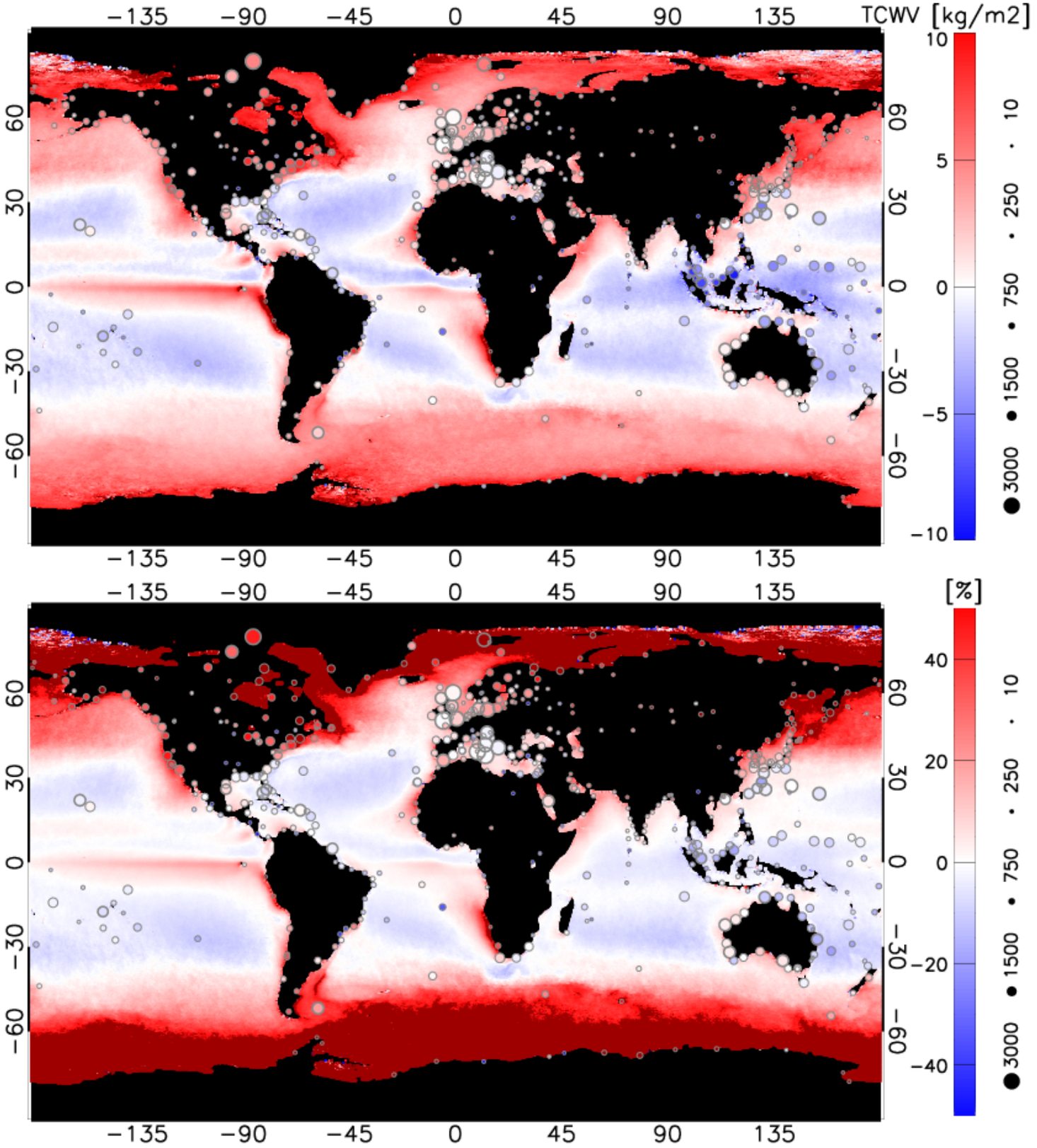
AIRWAVE v2

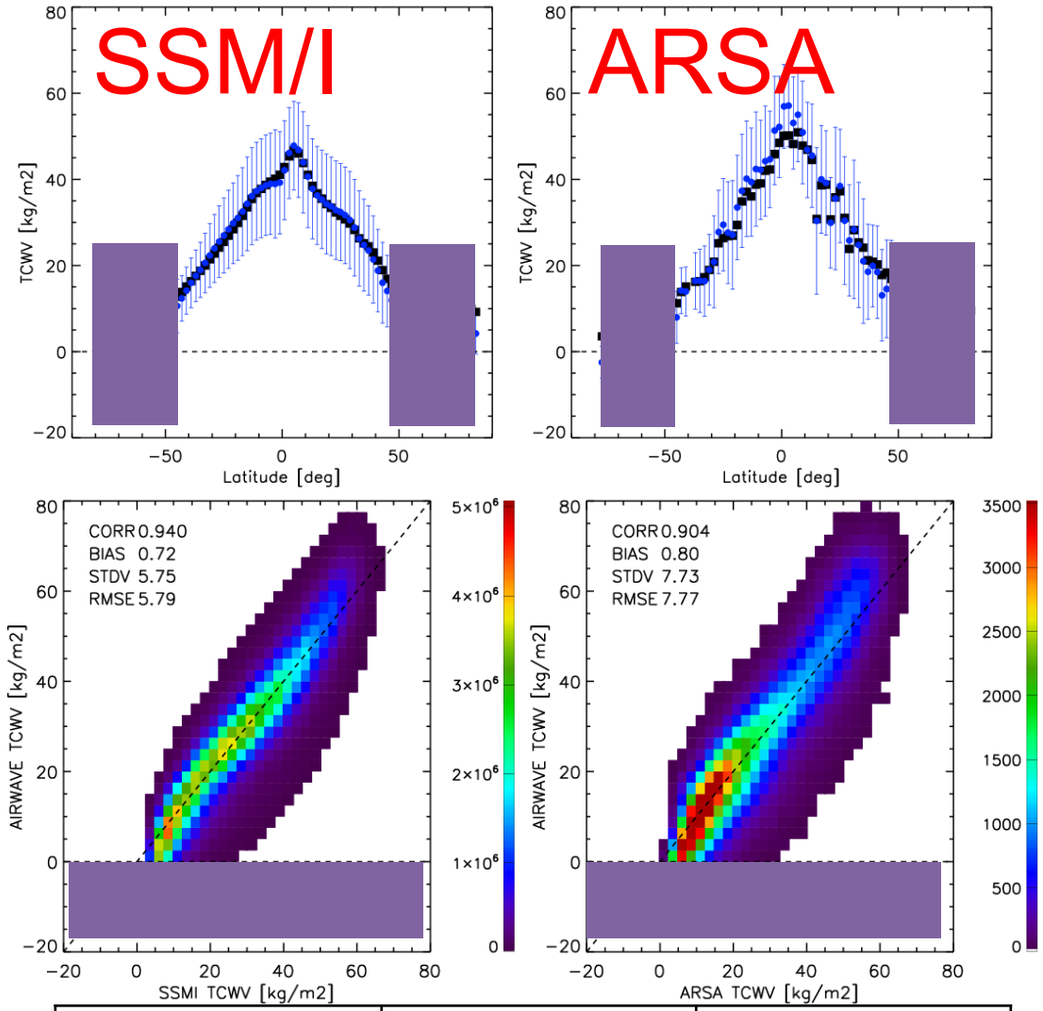
In v1, AIRWAVE parameters were fixed along the globe.
In v2, they were calculated accounting for different scenarios:
11 Across track positions, 6 latitude bands, 4 seasons

Error Budget on retrieved TCWV

- Impact of noise error: 0.037 K random perturbation on BTs for ATSR-2 and AATSR and 0.1 K for ATSR-1 → 9/18 % ATSR-1, 3/5% ATSR-2, AATSR
- Impact of CFC-11, CFC-12, CO_2 variations from beginning to end of each mission → less than 0.07%
- Impact of HNO_3, CFC-11, CFC-12, CO_2 latitudinal variations→ less than 0.5% worst: HNO_3
- Impact of wind effect. Absolute and relative differences are expressed in function of the reference wind speed of 3 m/s → 0/2% worst: polar and 25m/s
- Impact of atmospheric temperature (3.0 K random perturbation on input profiles) →4/7%

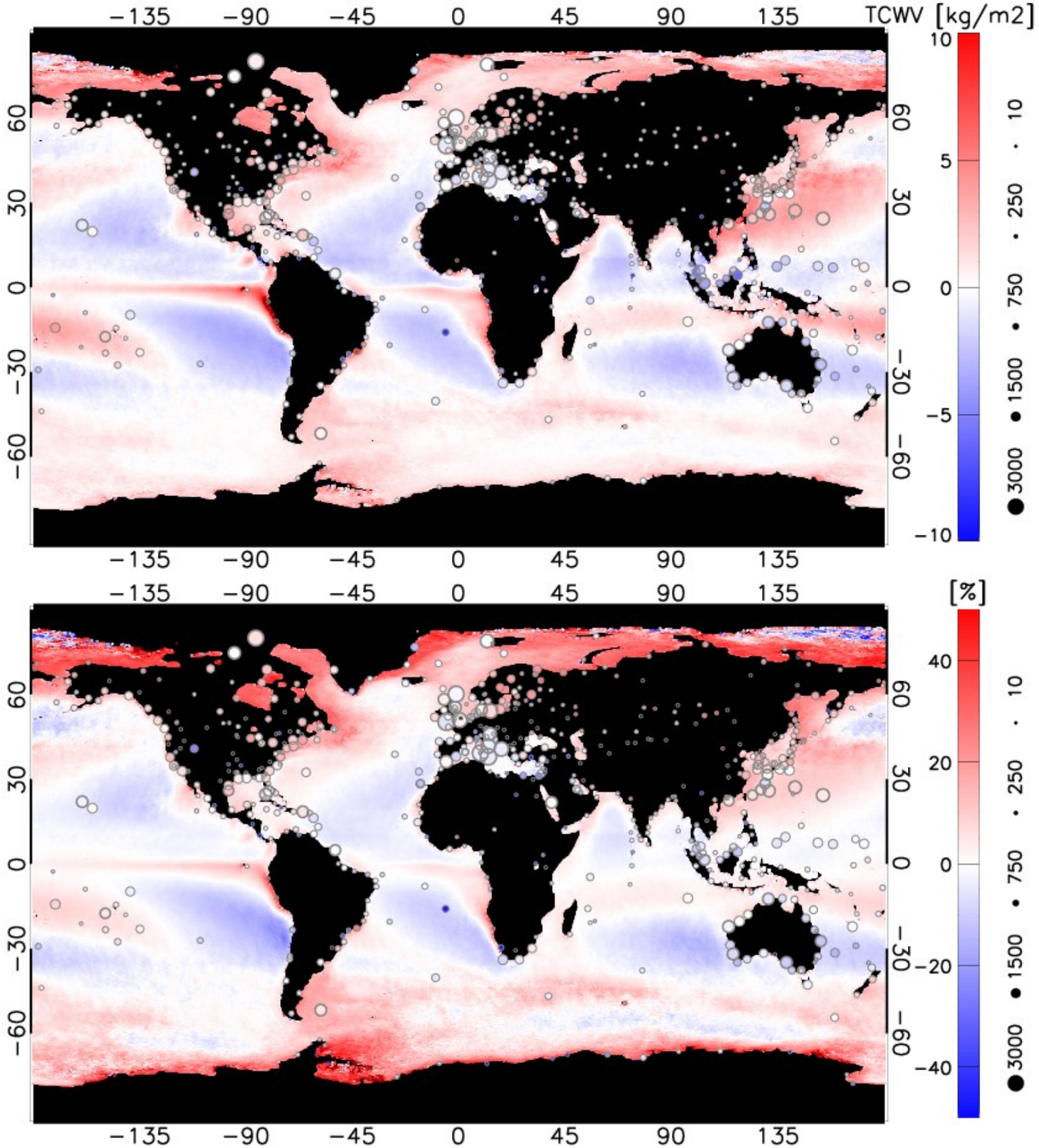
AIRWAVE v1 validation

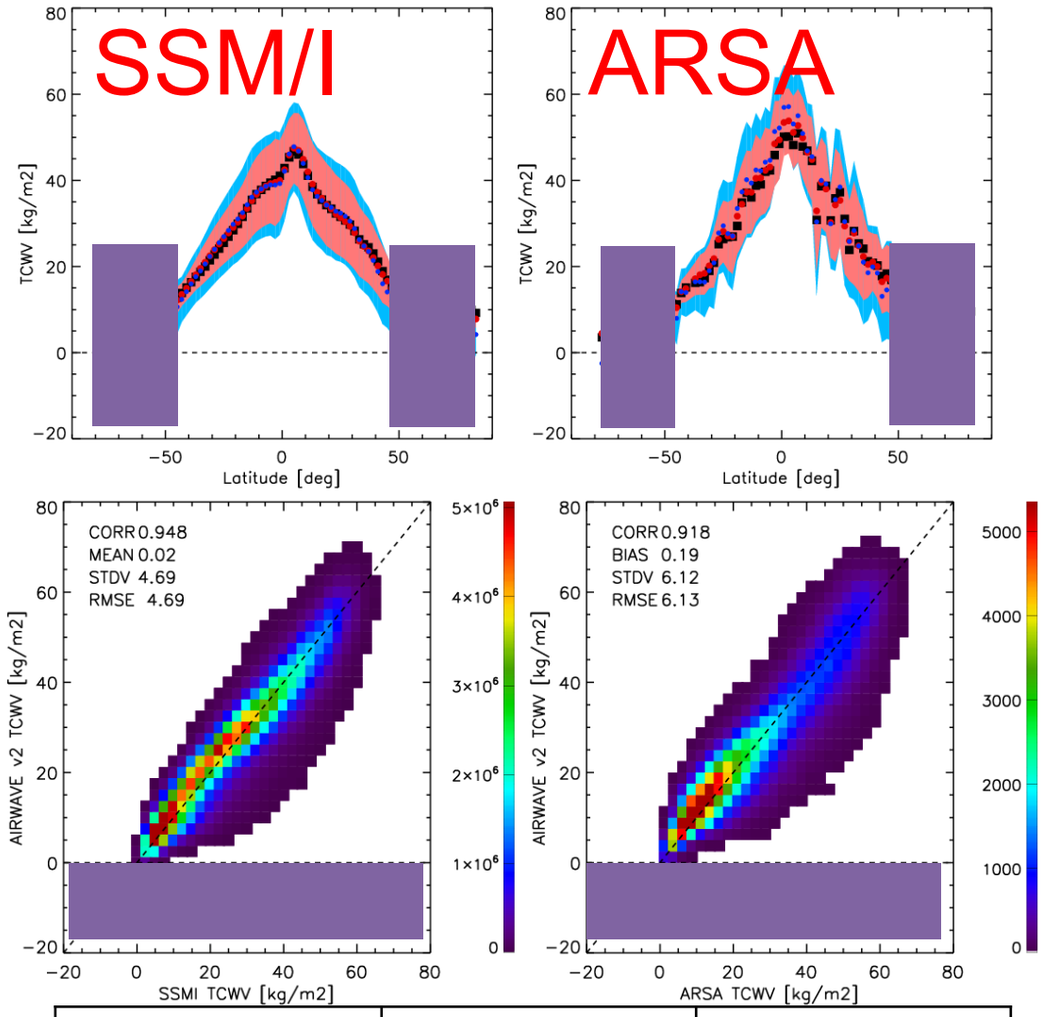




		SSM/I-AIRWAVE			ARSA-AIRWAVE		
Instrument	Scenario	N·10^5	BIAS	STDV	N·10^5	BIAS	STDV
			kg/m^2			kg/m^2	
All	**Global**	**3110**	**0.72**	**5.75**	**3.01**	**0.80**	**7.73**
All	Equator	1560	-0.17	5.57	0.87	-2.40	7.74
All	Midlat	1380	1.12	5.89	1.80	1.69	7.44
All	Polar	170	5.55	5.14	0.35	4.12	6.47
ATSR-1	Global	190	1.15	6.17	0.48	0.23	7.62
ATSR-2	Global	1390	0.80	5.87	1.00	1.13	7.65
AATSR	Global	1520	0.58	5.77	1.53	0.75	7.81

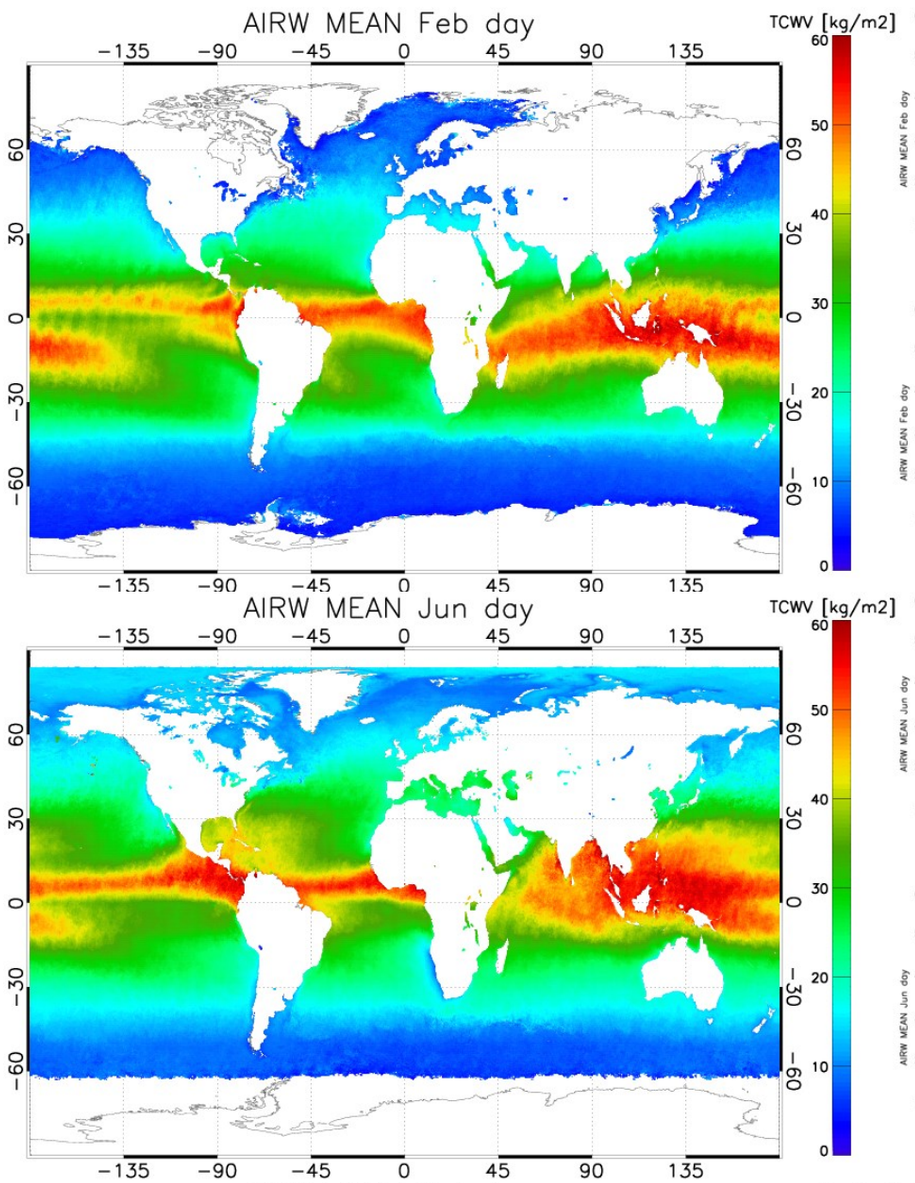
AIRWAVE v2 validation

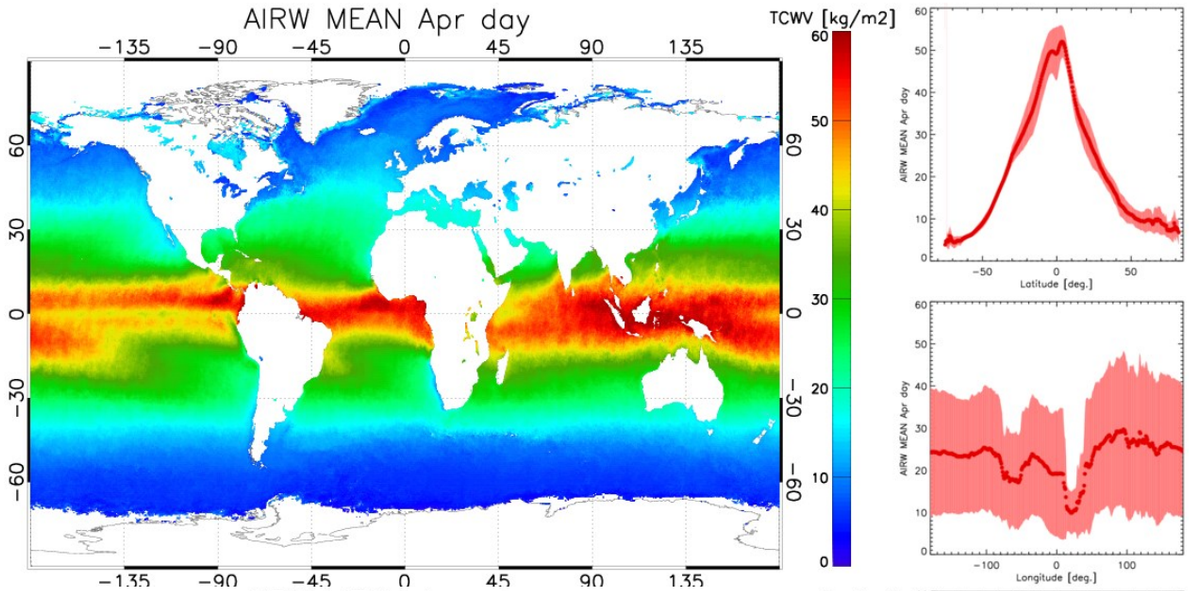


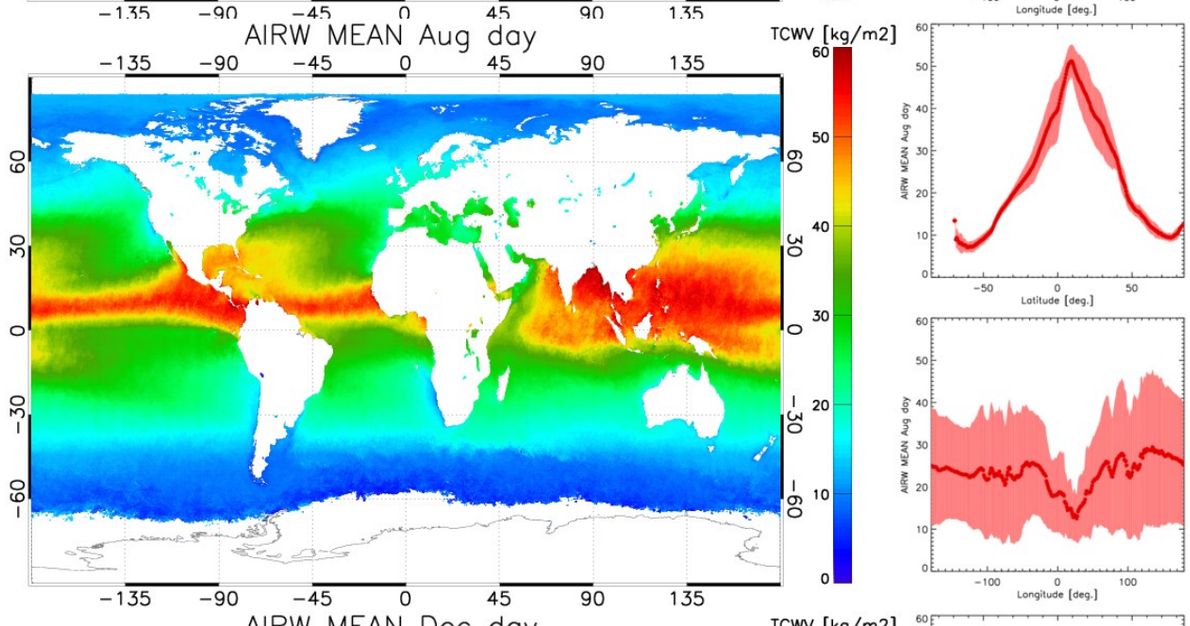


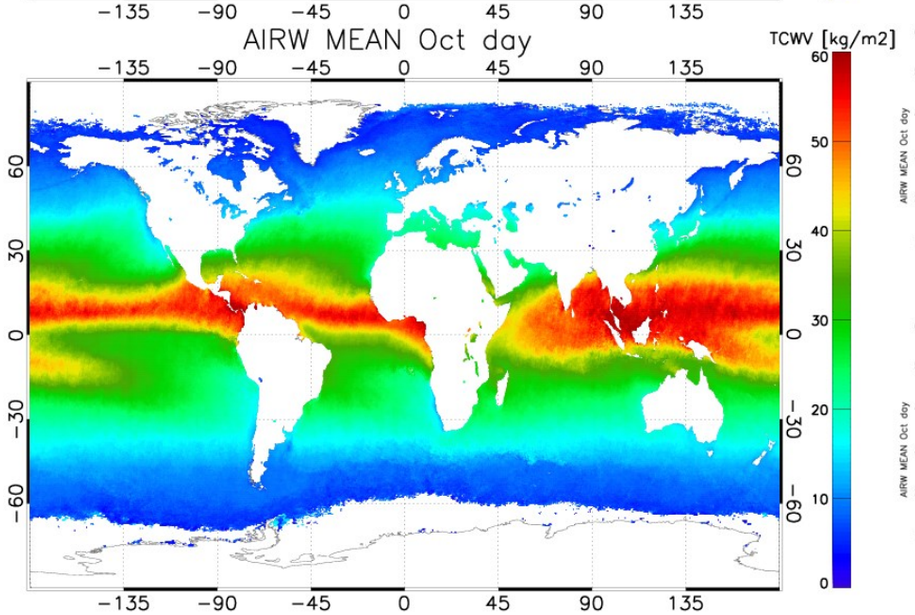
		SSM/I-AIRWAVE			ARSA-AIRWAVE		
Instrument	Scenario	N·10^5	BIAS	STDV	N·10^5	BIAS	STDV
			kg/m^2			kg/m^2	
All	**Global**	**3110**	**0.02**	**4.69**	**3.01**	**0.19**	**6.12**
All	Equator	1560	-0.17	4.79	0.87	-0.70	6.60
All	Midlat	1380	0.07	4.84	1.80	0.49	6.10
All	Polar	170	1.32	3.51	0.35	0.86	4.59
ATSR-1	Global	190	-0.20	5.17	0.48	-0.71	6.24
ATSR-2	Global	1390	0.24	4.77	1.00	0.70	6.04
AATSR	Global	1520	-0.16	4.70	1.53	0.13	6.11

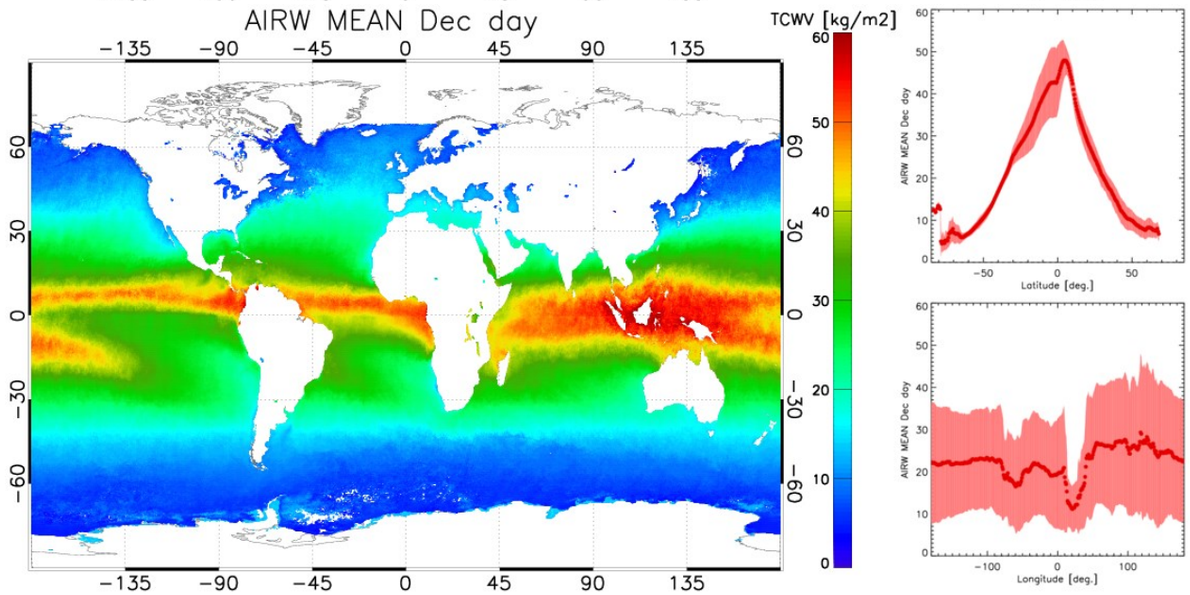
Monthly means day over the whole ATSR period



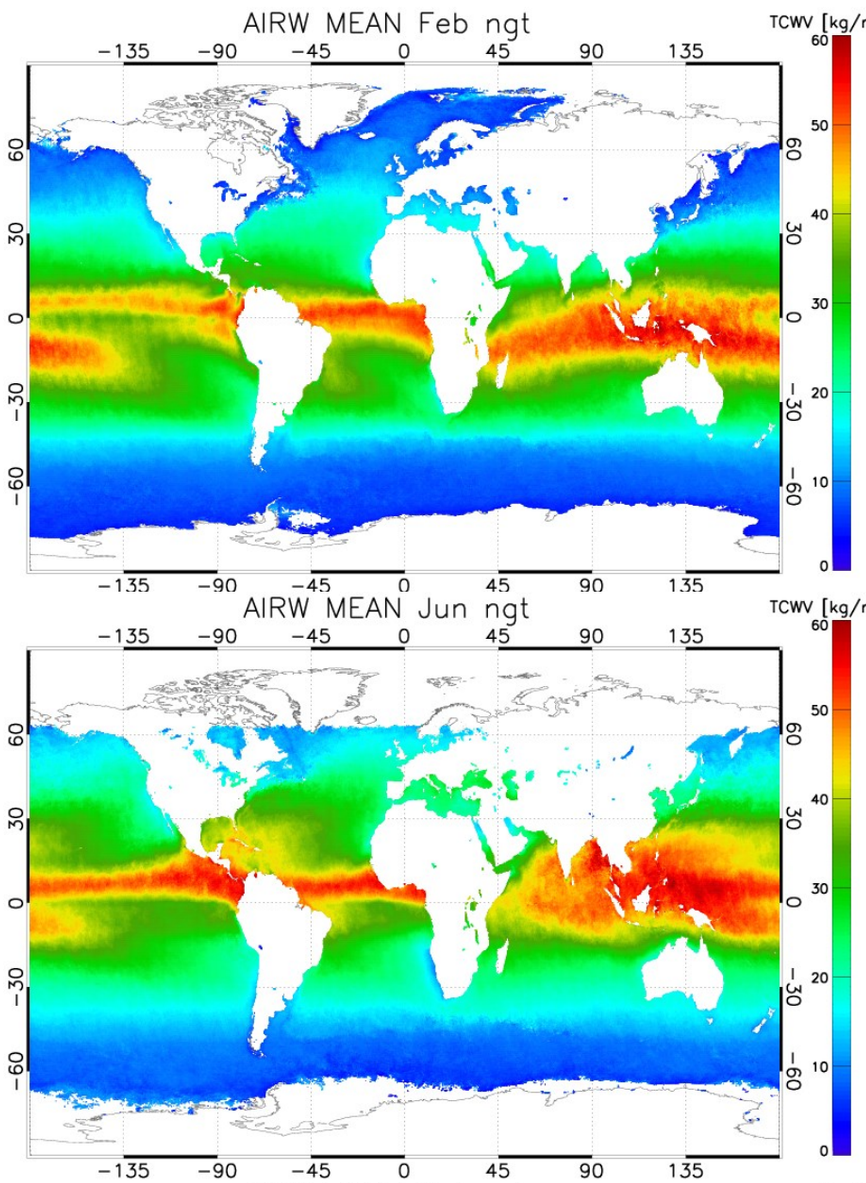


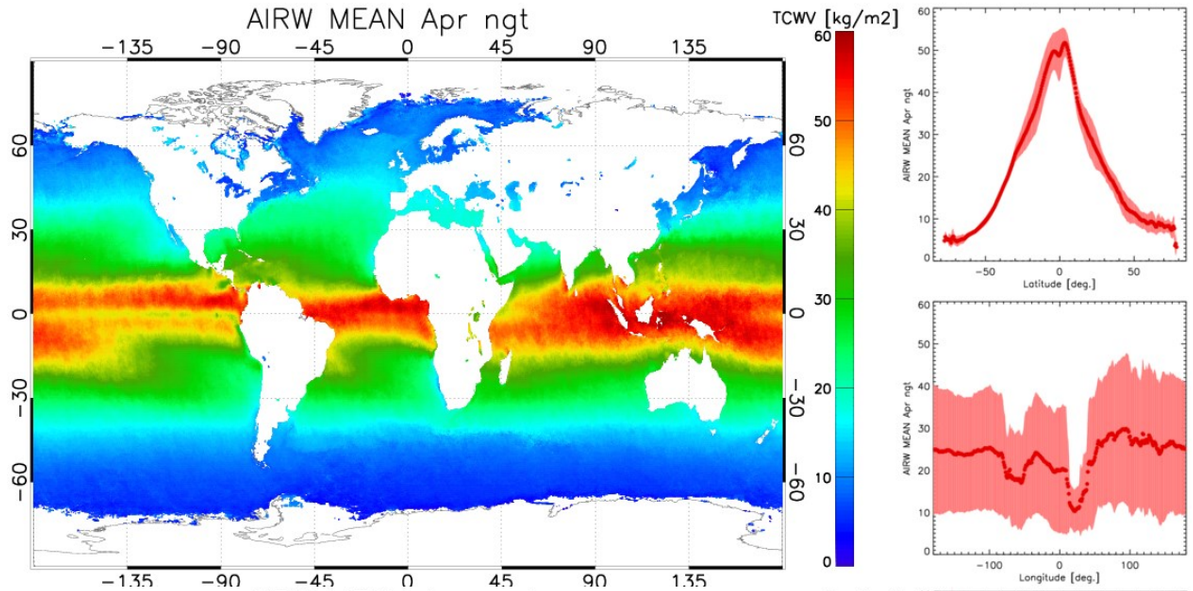


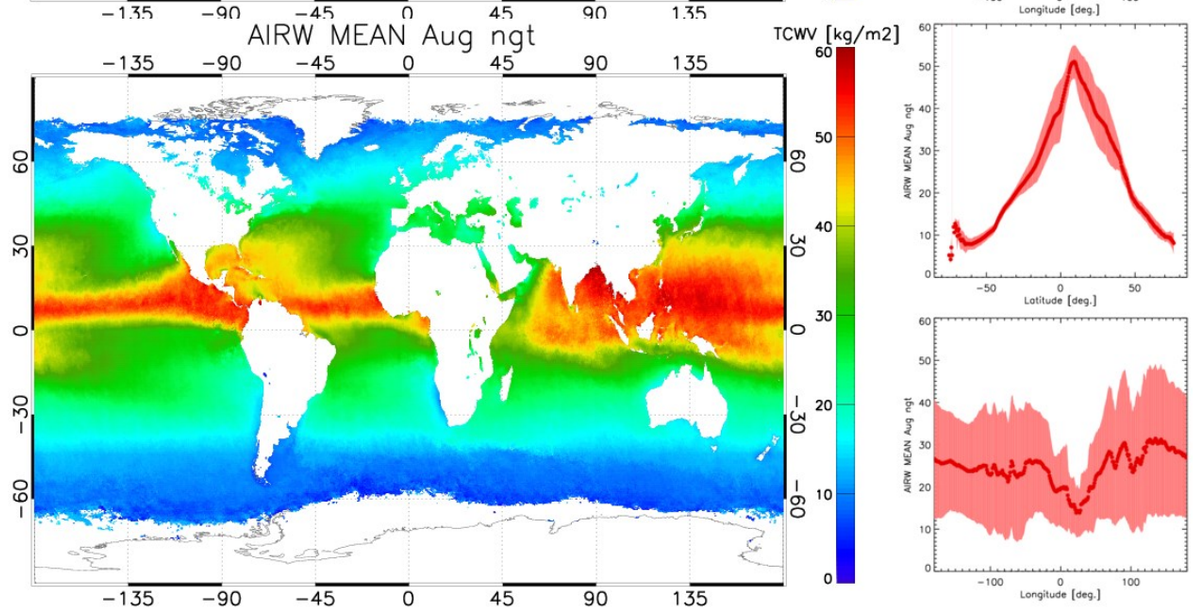


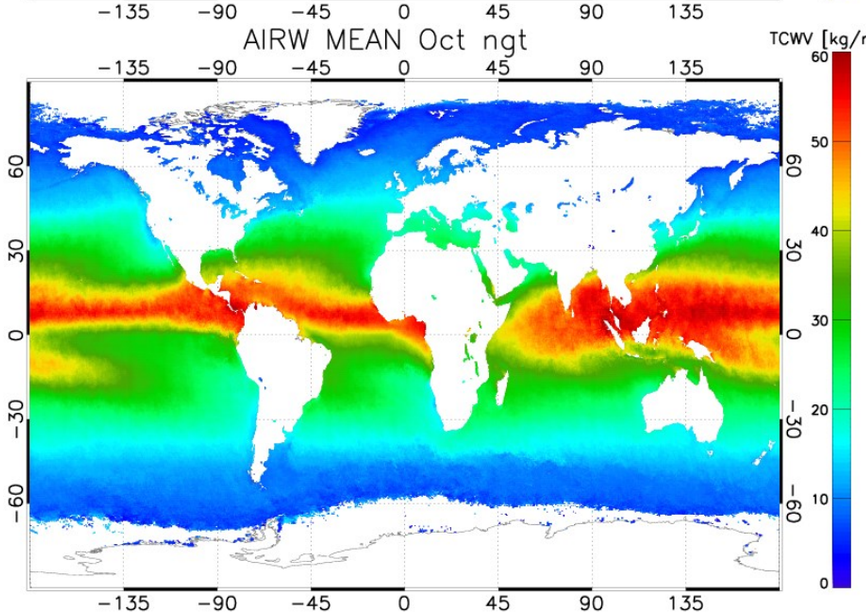


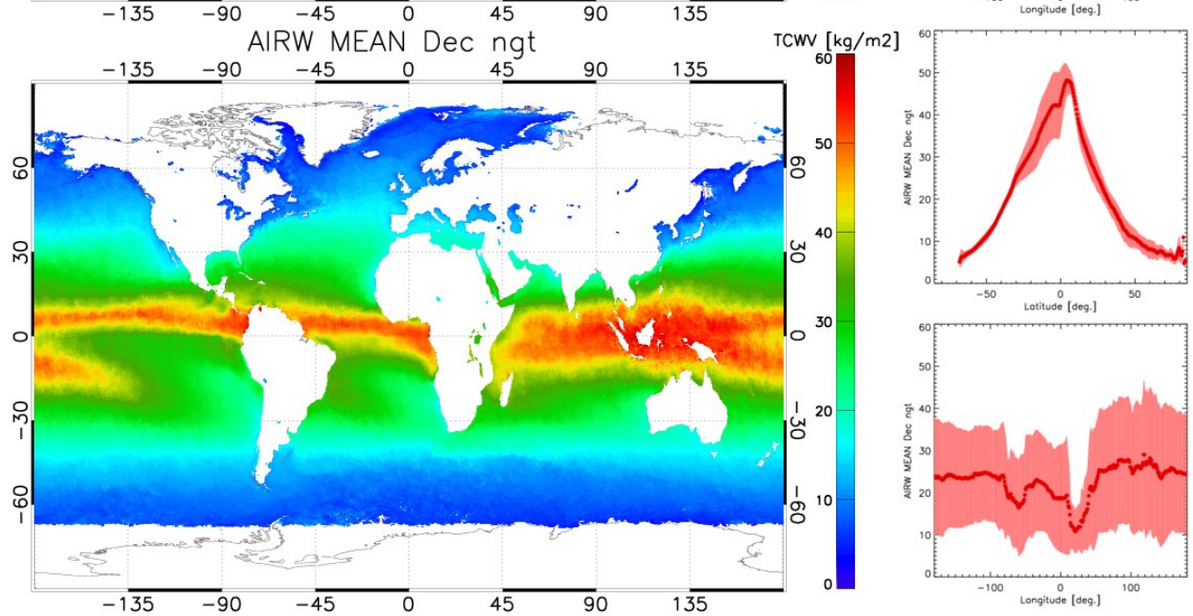
Monthly means night over the whole ATSR period



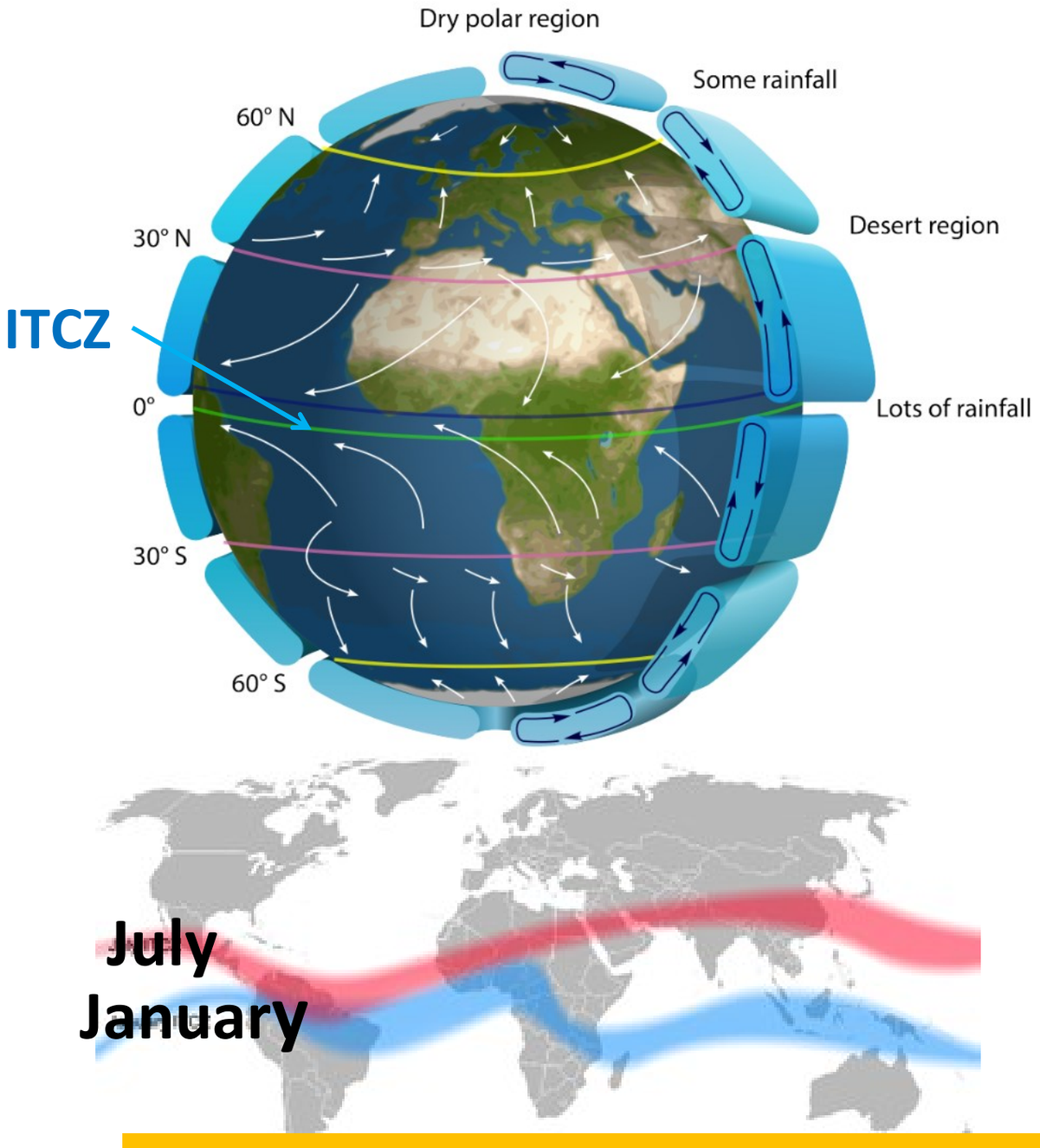








Inter-tropical Convergence Zone(ITCZ) analysis



- The ITCZ is the area near the equator where the northeast and southeast trade winds come together.
- It appears as a band of clouds, usually thunderstorms, circling the globe close to the equator.

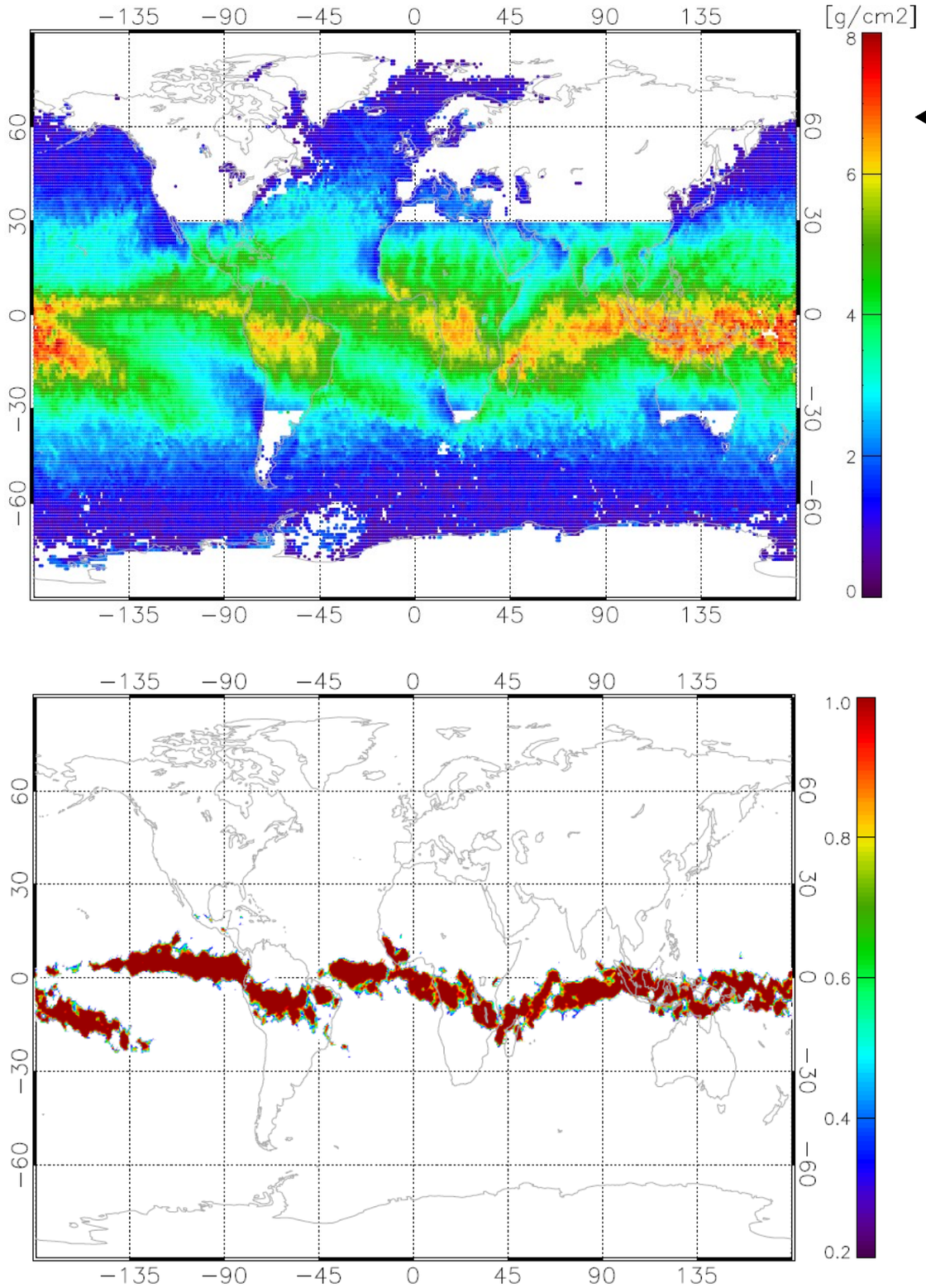
WHY IS IT IMPORTANT?

- Variation in the location of the ITCZ affects rainfall in many equatorial nations, and so in the wet and dry seasons of the tropics (severe droughts or flooding may occur).
- Understanding its variability is essential for improving global climate models.

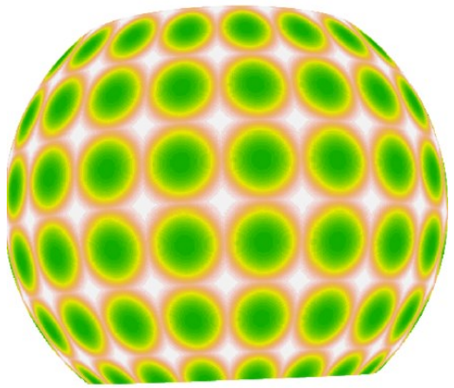
For this analysis we use:
1) the newly available long term TCWV+Cloud datasets from ATSR instrument series.
2) a Bayesian geodesic P-spline approach specifically developed (Unibo) to model data on the globe, providing tools for ITCZ detection.

Inter-tropical Convergence Zone(ITCZ) analysis

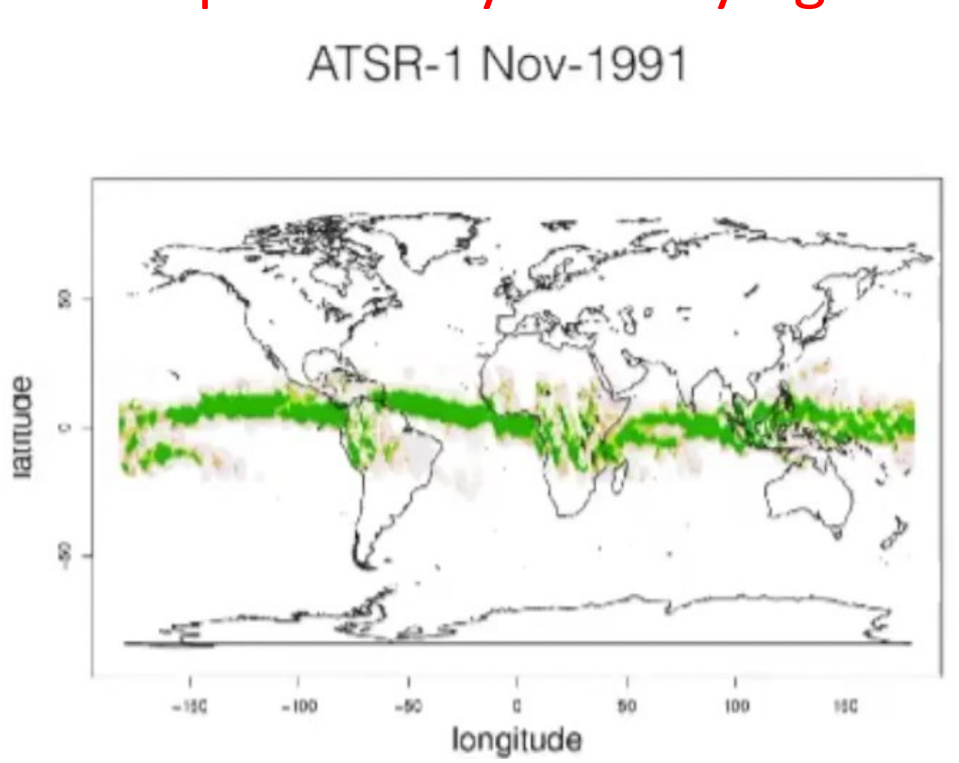
For each available month in the ATSR series we created aggregate products.



AIRWAVE TCWV and cloud coverage converted into TCWV from AATSR data for January 2003.

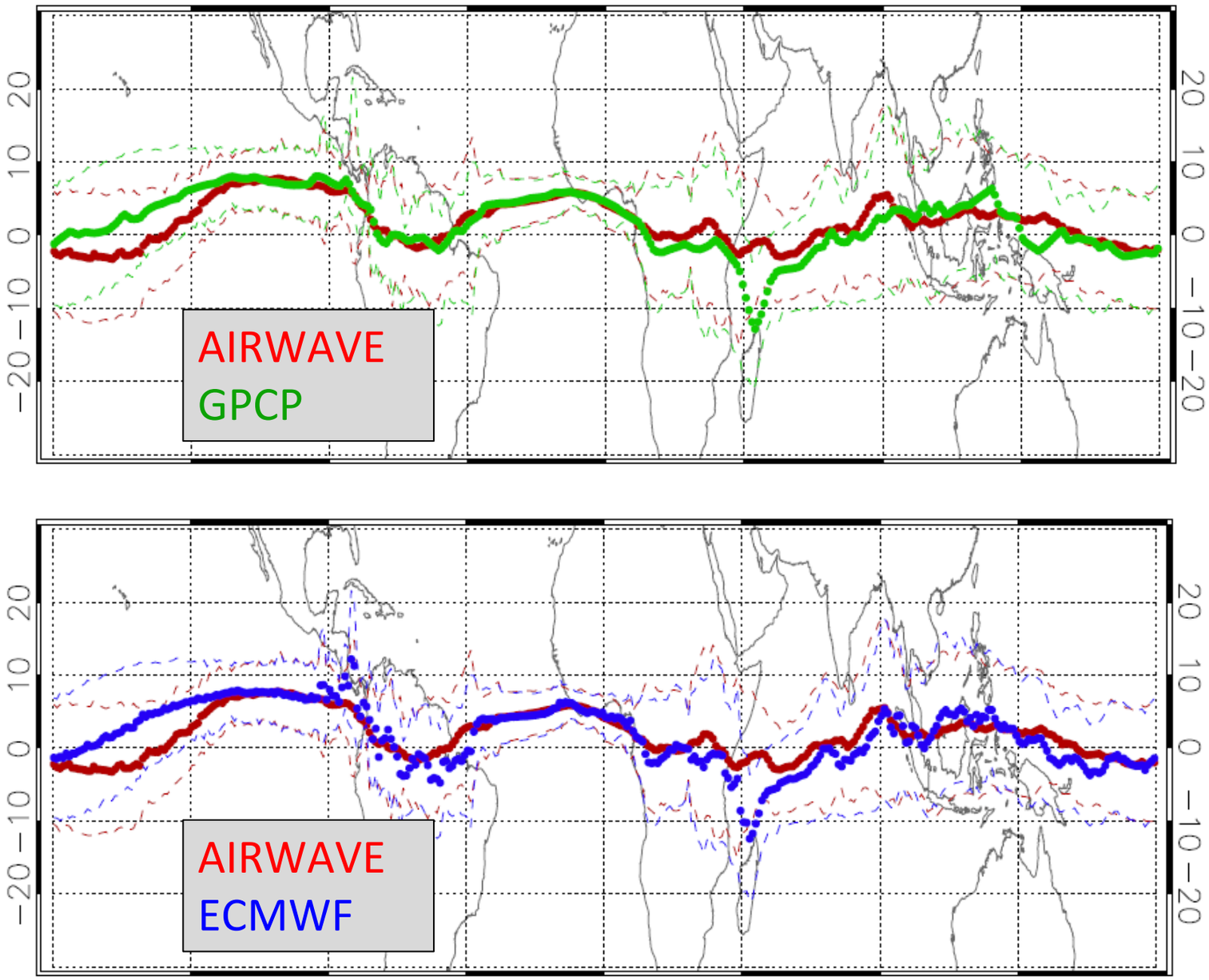


a-posteriori probability identifying the ITCZ



Inter-tropical Convergence Zone(ITCZ) analysis

GPCP=Global Precipitation Climatology Project (NOAA V2.3 dataset, 1979-present).
ECMWF CP=Convective Precipitation field from the ECMWF data archive: precipitation (rain plus snow) that is produced by the convection scheme.



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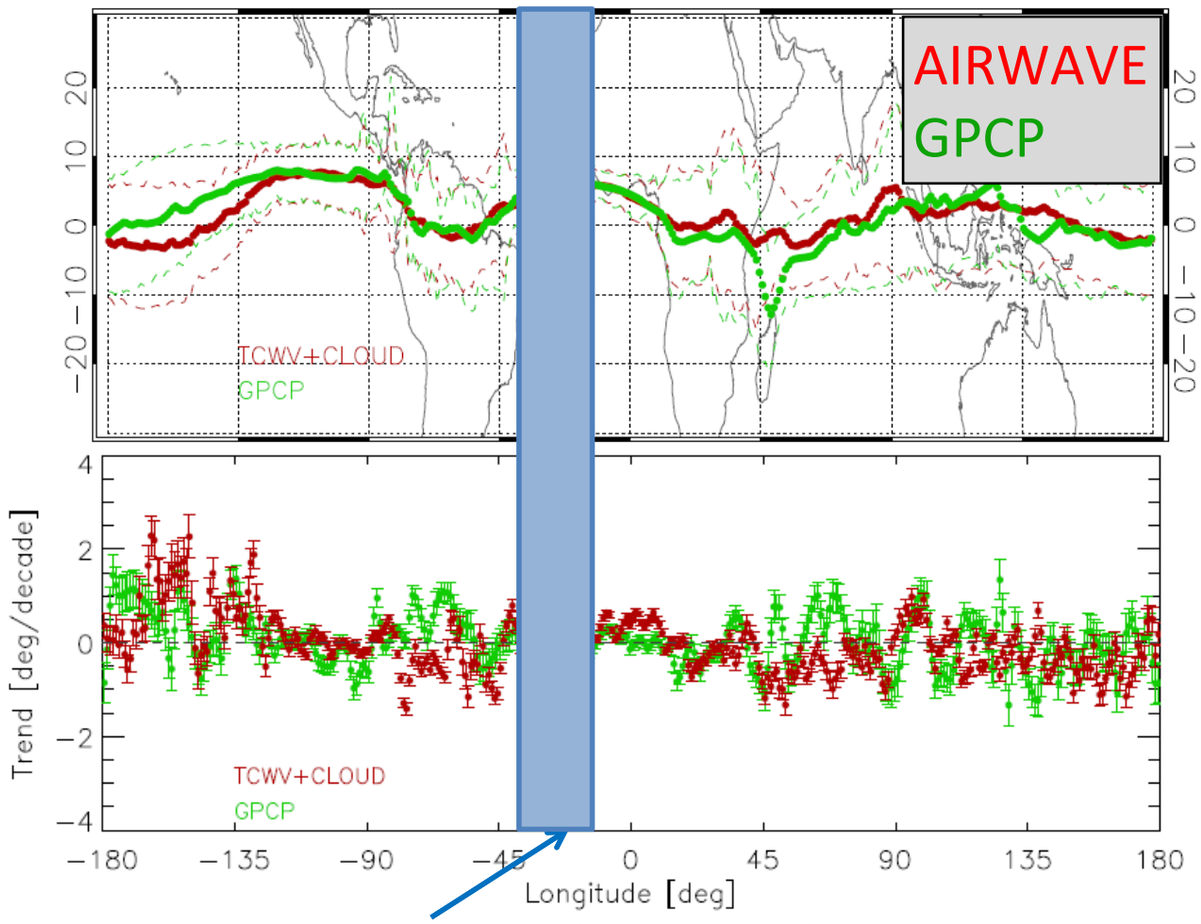

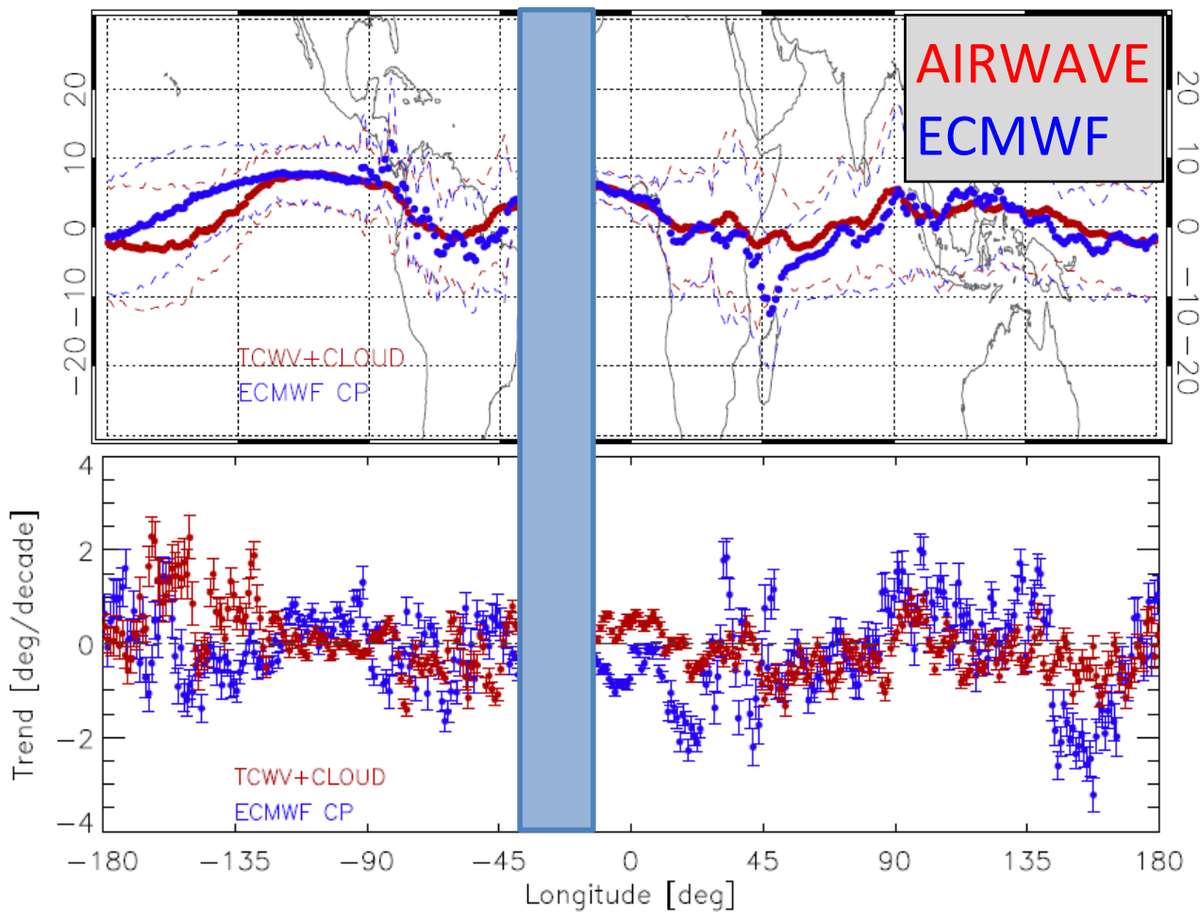

The Atlantic region (10–40 W) is where our results are more precise. In this region we find no significant trend. Similar findings are reported in literature.

to be submitted soon…

ITCZ trend analysis via Geodesic P-spline smoothing of the AIRWAVE TCWV and cloud frequency datasets

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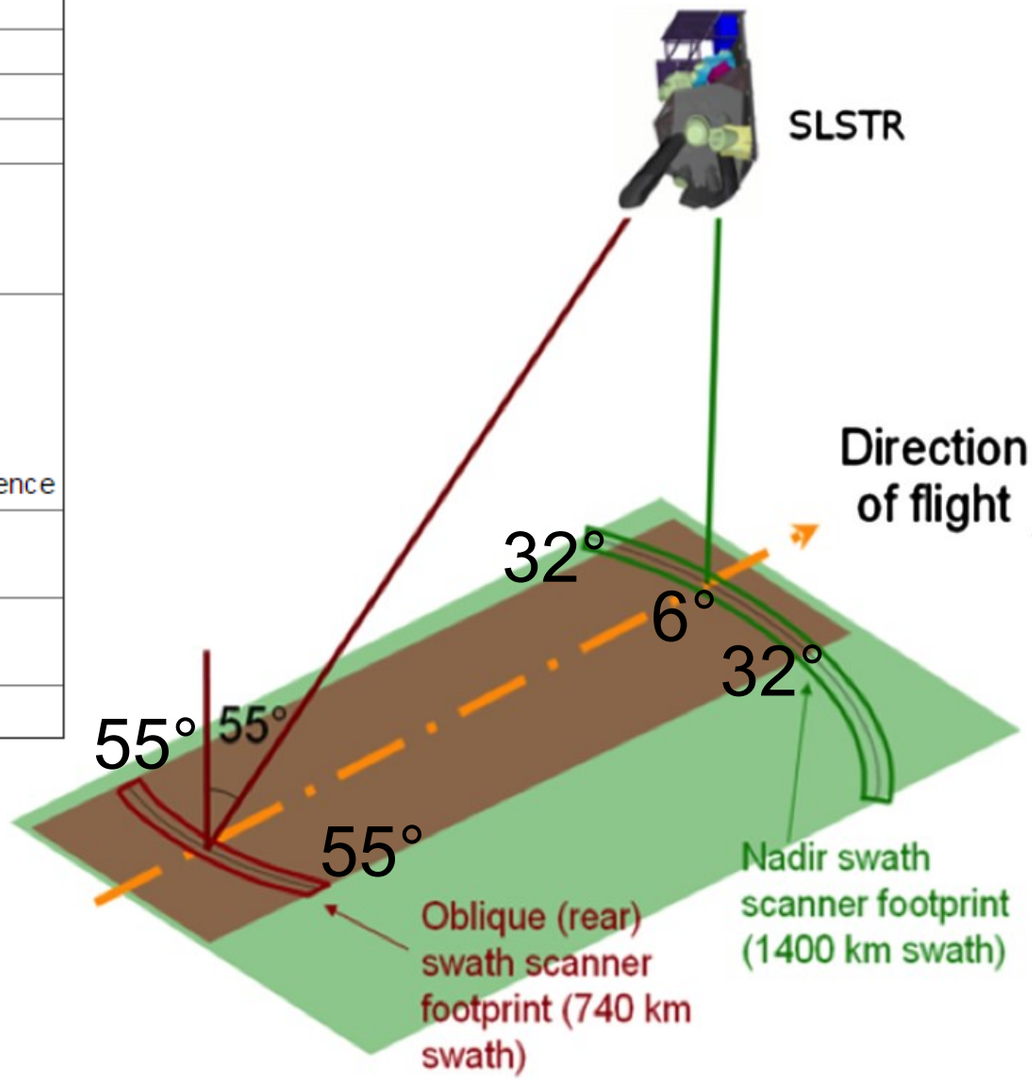
[1]Istituto di Scienze dell'Atmosfera e del Clima, ISAC-CNR, Via Gobetti 101, 40129 Bologna, Italy
[2]Serco s.p.a.,Via Sciadonna 24-26, 00044 Frascati, Italy
[3]Dipartimento di Scienze Statistiche "Paolo Fortunati", Universita' di Bologna, Via delle Belle Arti, 41, 40126 Bologna, Italy
[4]Dipartimento di Fisica e Astronomia, Universita' di Bologna, Viale Berti Pichat 6/2, 40127 Bologna, Italy

Possible AIRWAVE extension: SLSTR measurements

Specifications

	Capability	SLSTR Specifications
Swath	Nadir view	> 1 400 km
	Oblique view	> 740 km
Global Coverage Revisit Times	1 satellite (dual view)	1.9 days (mean)
	2 satellites (dual view)	0.9 days (mean)
	1 satellite (nadir view)	1 day (mean)
	2 satellites (nadir view)	0.5 day (mean)
Spatial Sampling interval at Sub-satellite point (km)		0.5 km VIS-SWIR 1 km IR-Fire
Spectral channel centre (mm)	VIS	0.55; 0.659; 0.865
	SWIR	1.375; 1.610; 2.25
	MWIR/TIR	3.74; 10.85; 12
	Fire 1/2	3.74; 10.85
Radiometric Resolution	VIS (Albedo =0.5%) SWIR (Albedo =0.5%)	SNR > 20 SNR > 20 SNR = Signal-to-Noise Ratio
	MWIR (T =270K) TIR (T=270K) Fire 1 (<500 K) Fire 2 (<400 K)	NEΔT < 80 mK NEΔT < 50 mK NEΔT < 1 K NEΔT < 0.5 K NEΔT = Noise-Equivalent Temperature Difference
Radiometric Accuracy	VIS-SWIR (Albedo = 2-100%)	< 2% (Beginning of Life) <5% (End of Life)
	MWIR –TIR (265 – 310 K) Fire (< 500 K)	< 0.2 K (0.1 K gola) < 3 K
Design Lifetime		7.5 years

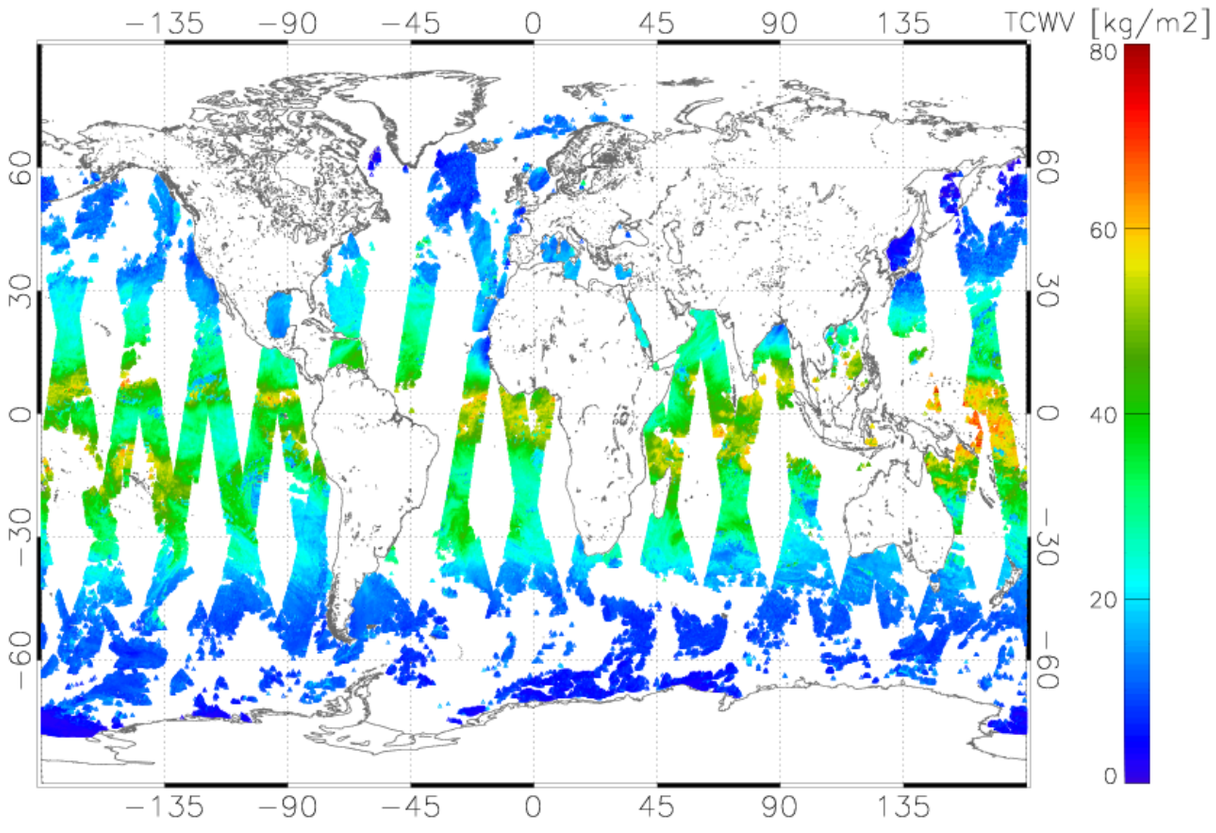
Changes w.r.t. ATSR:
-filter function
-angles (re-run RTM)



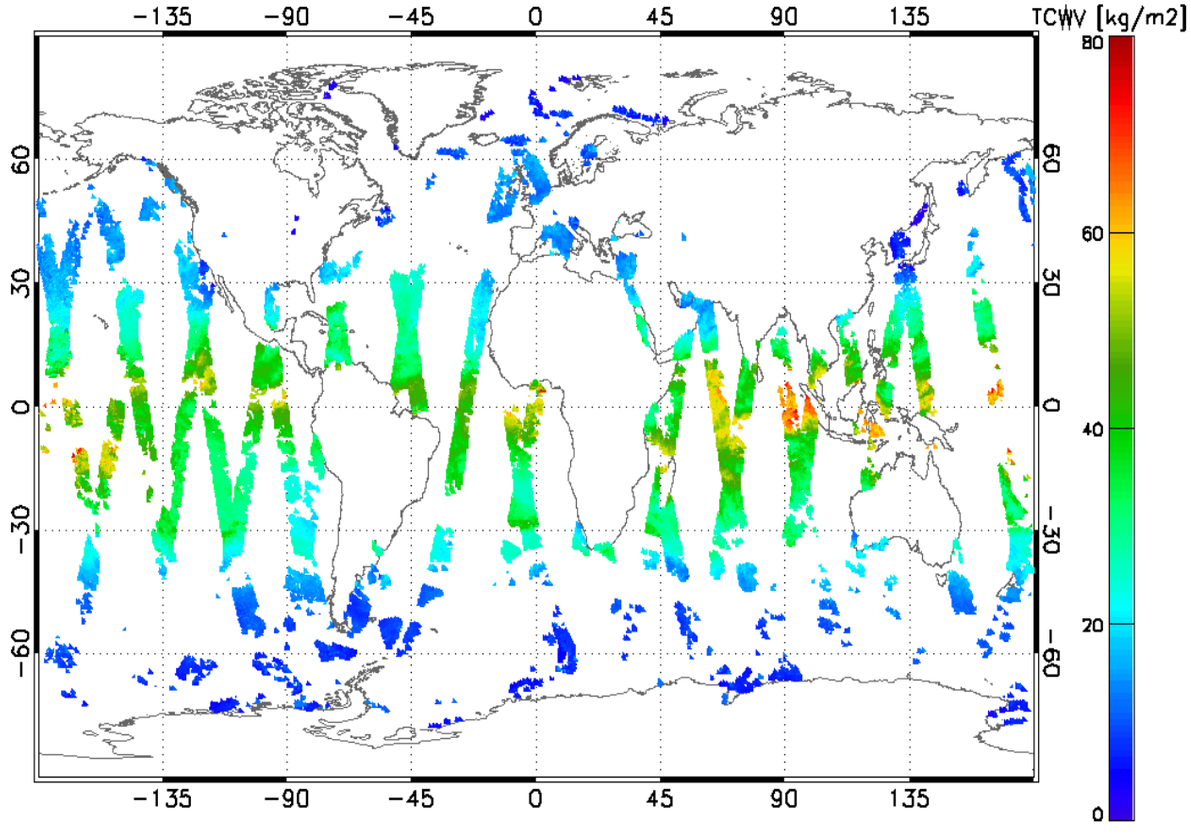
AIRWAVE v2: application to SLSTR measurements

- Up to now we analysed one day of SLSTR data representing three seasons (one complete day of JAN, APR, JUL 2017).
- The random error due to noise is reduced: about 0.02K in both channels for SLSTR, 0.037K for ATSR-2/AATSR and 0.1K for ATRS-1.
- An example for January 2017 is reported below. For comparison one day of AATSR data is shown.

AIRWAVEv2 SLSTR

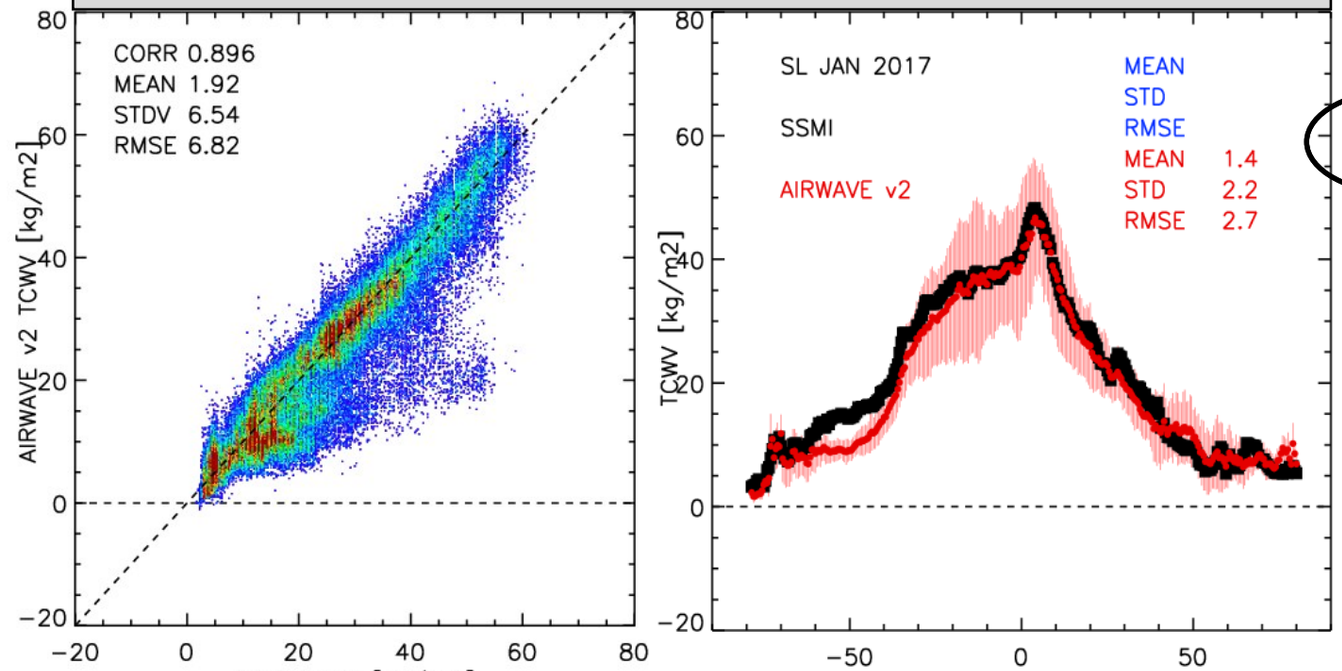


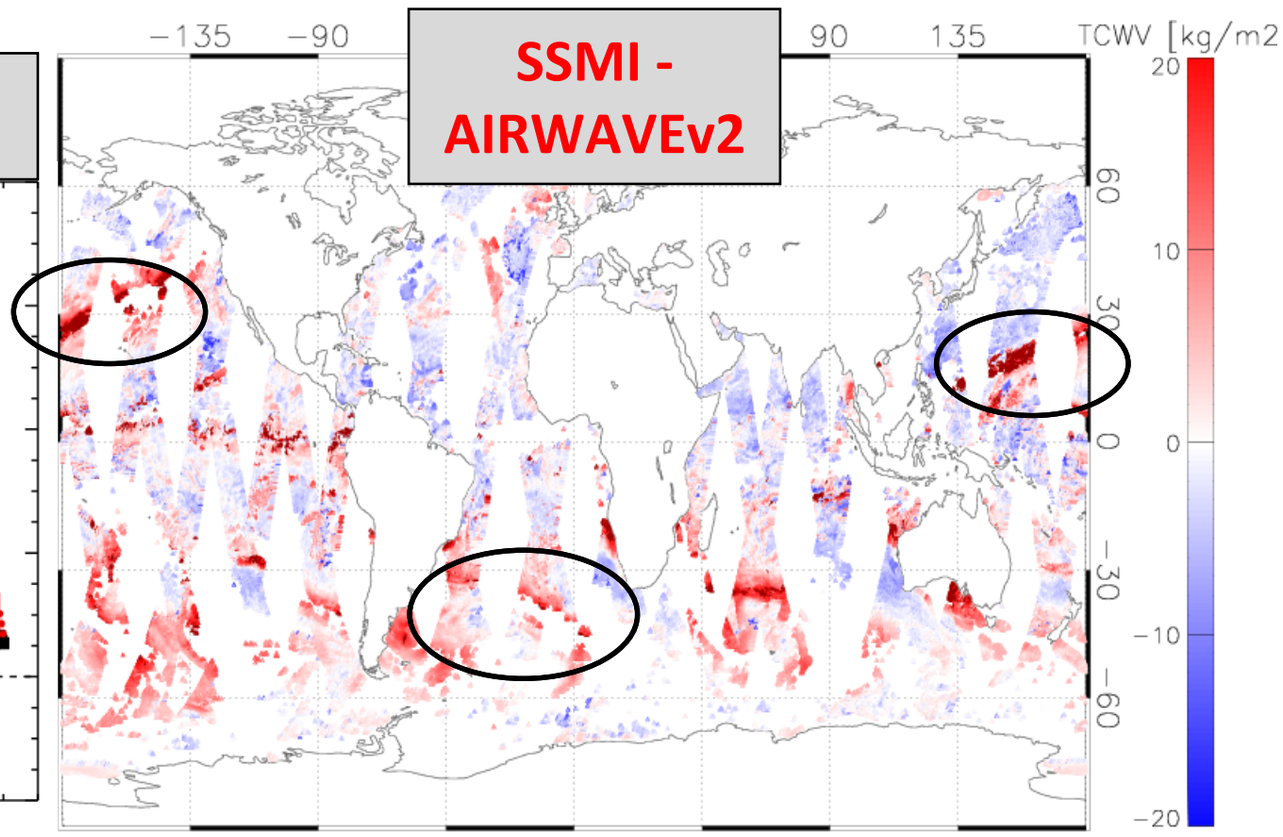
AIRWAVEv2 AATSR

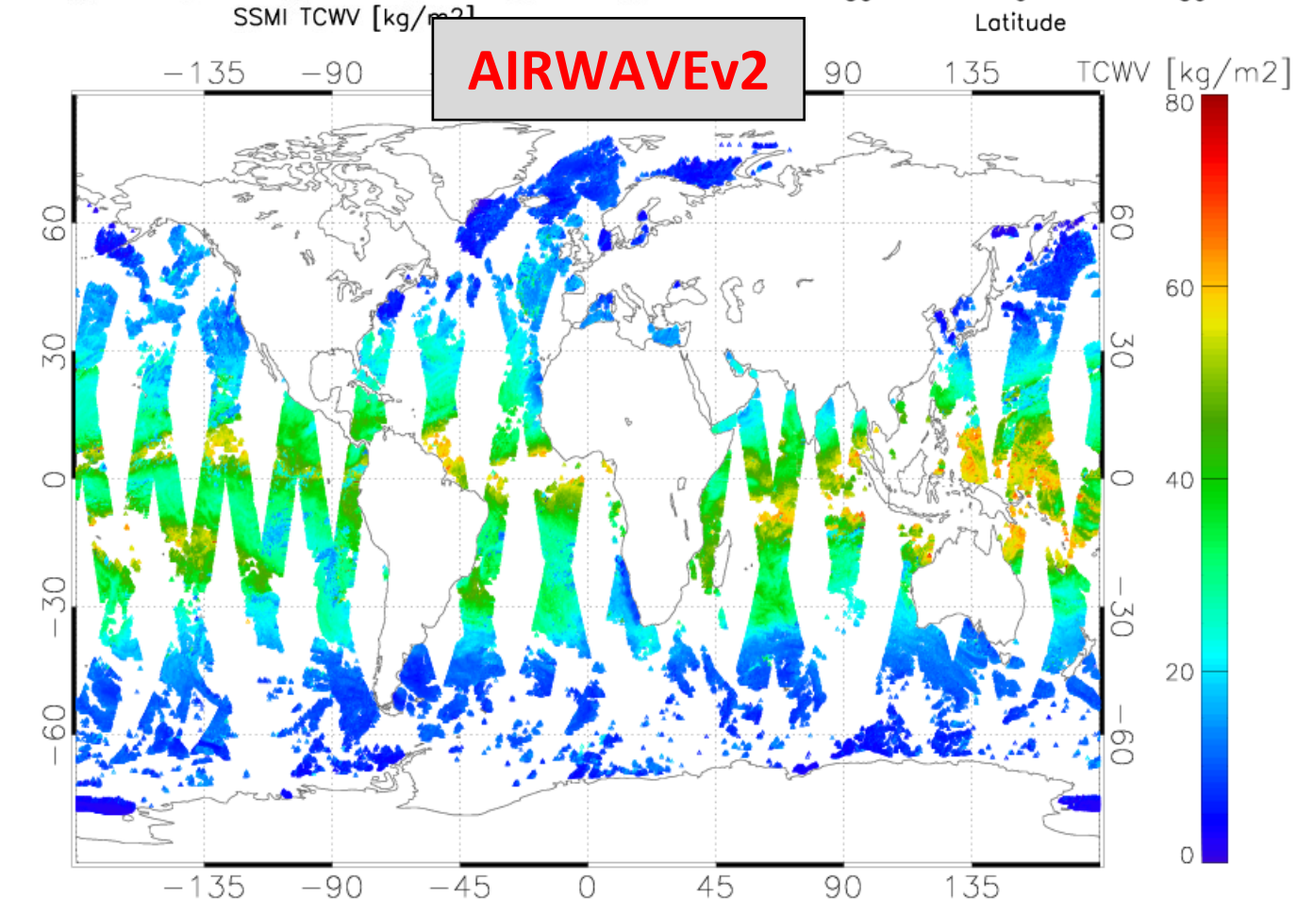


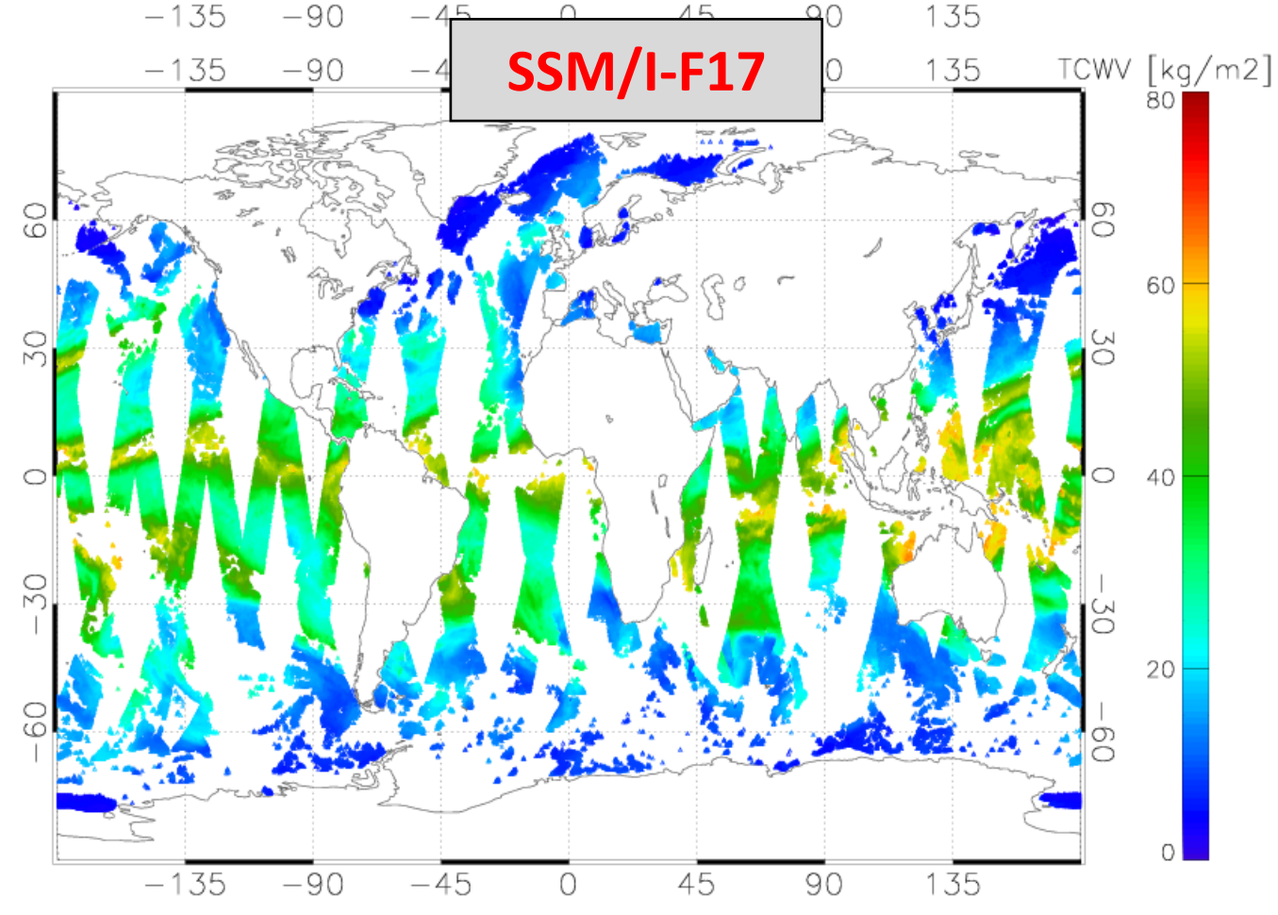
AIRWAVE v2: application to SLSTR measurements

JAN 2017



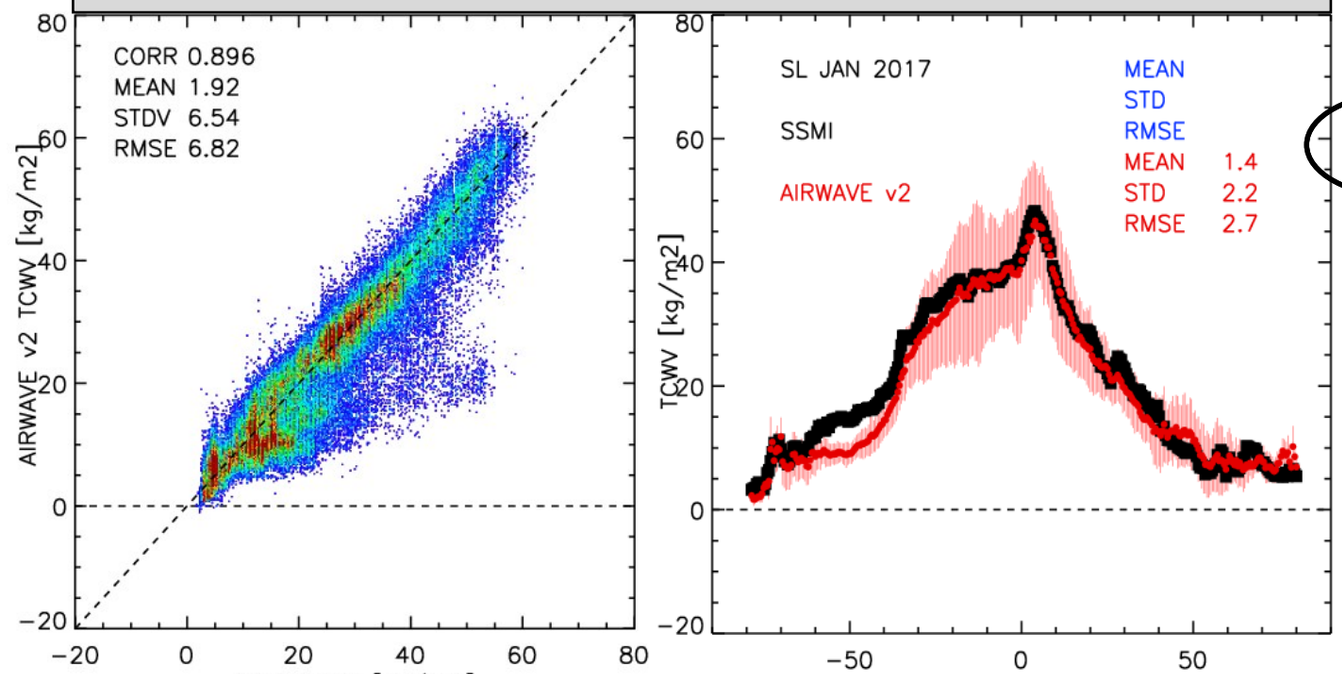


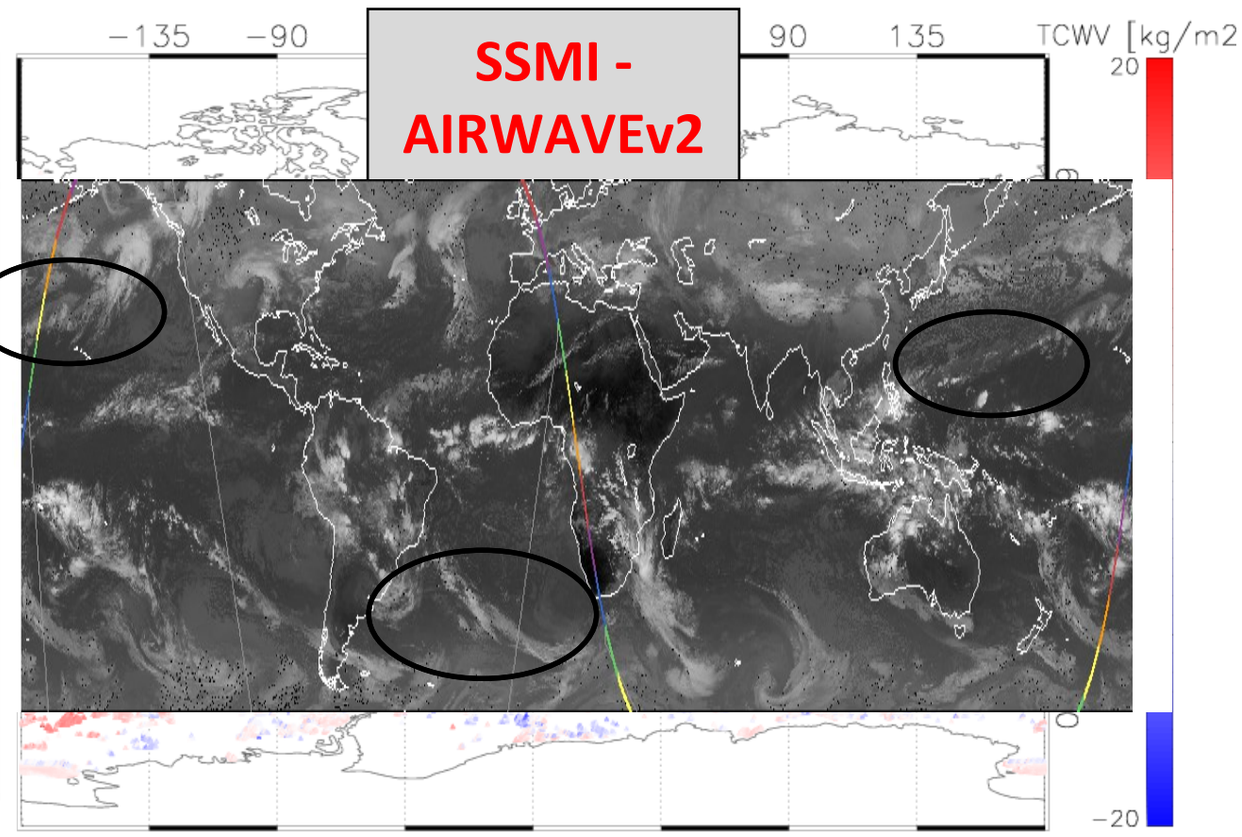


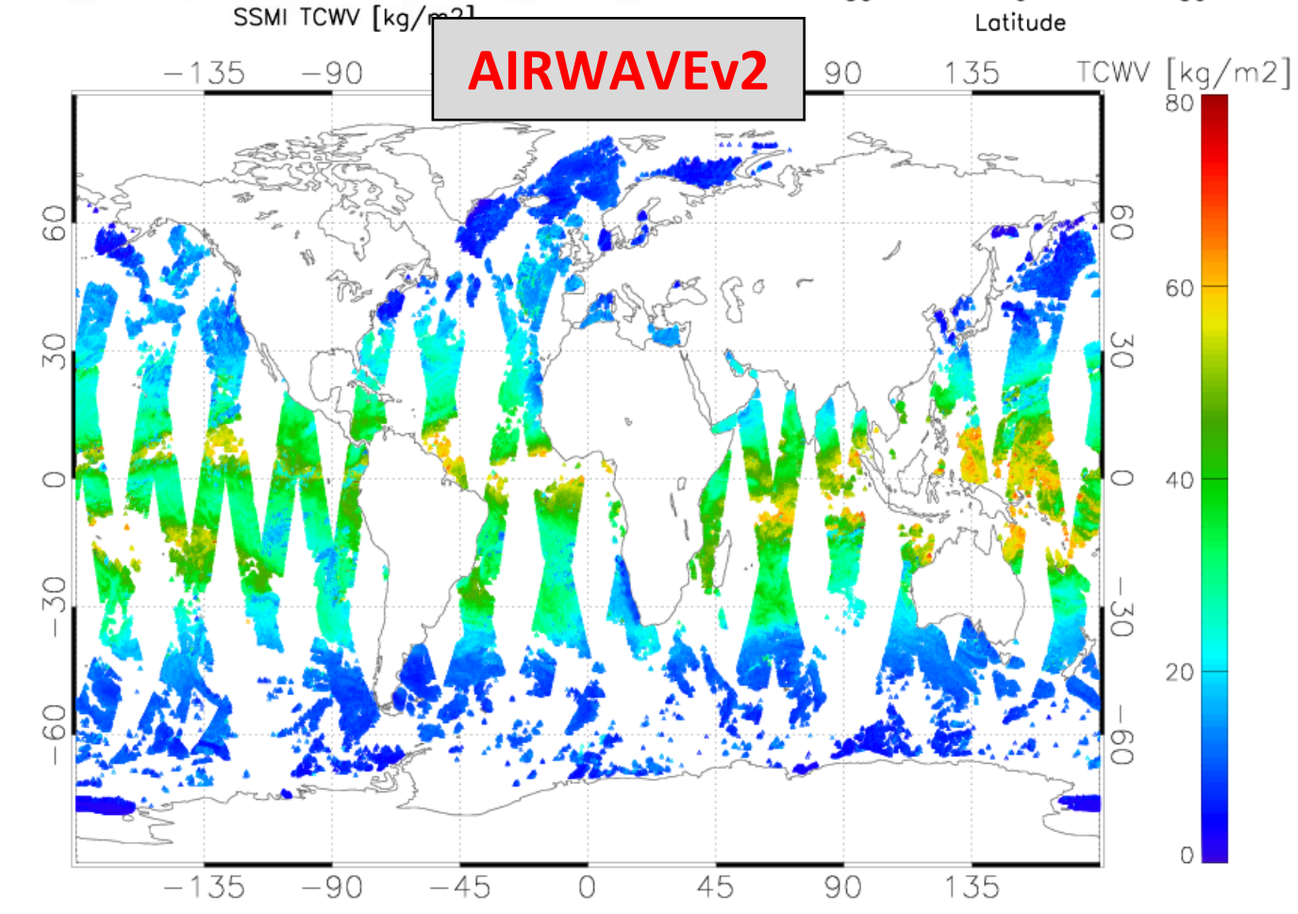


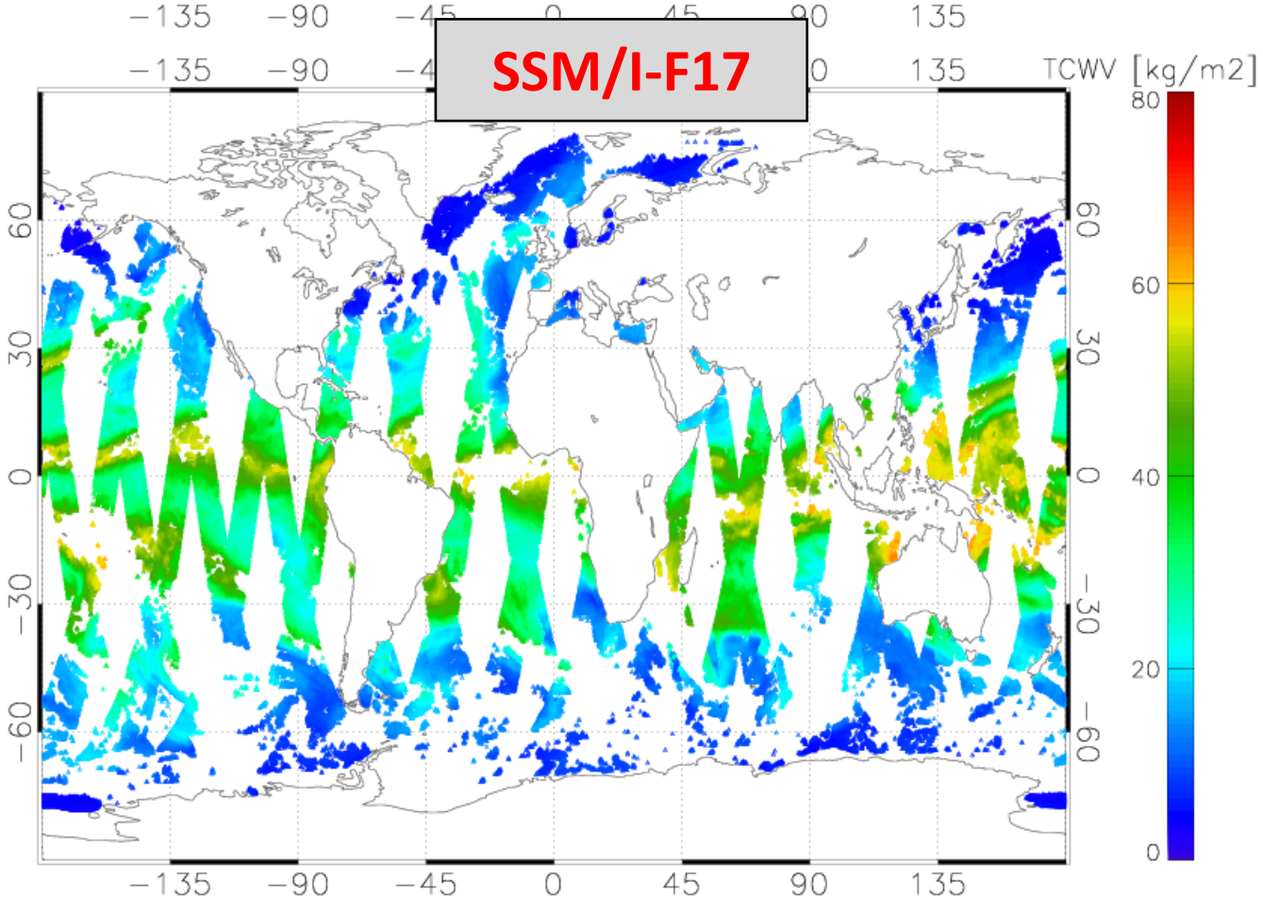
AIRWAVE v2: application to SLSTR measurements

JAN 2017



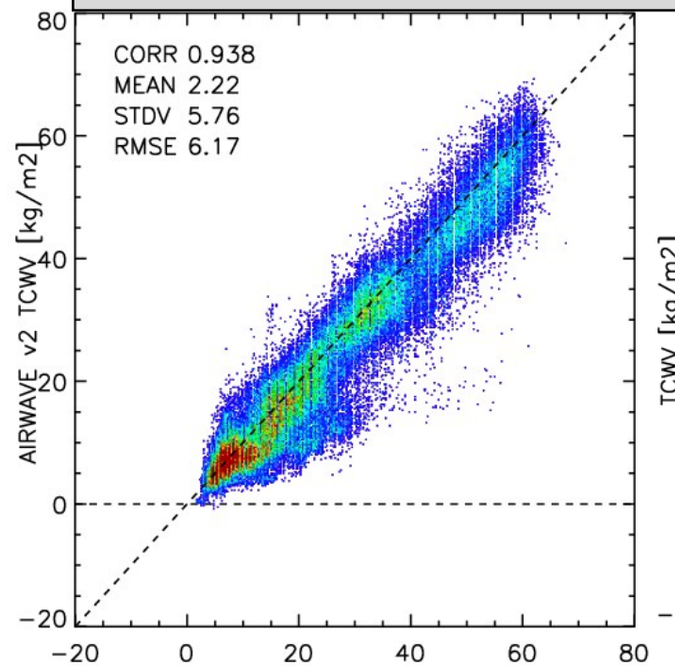


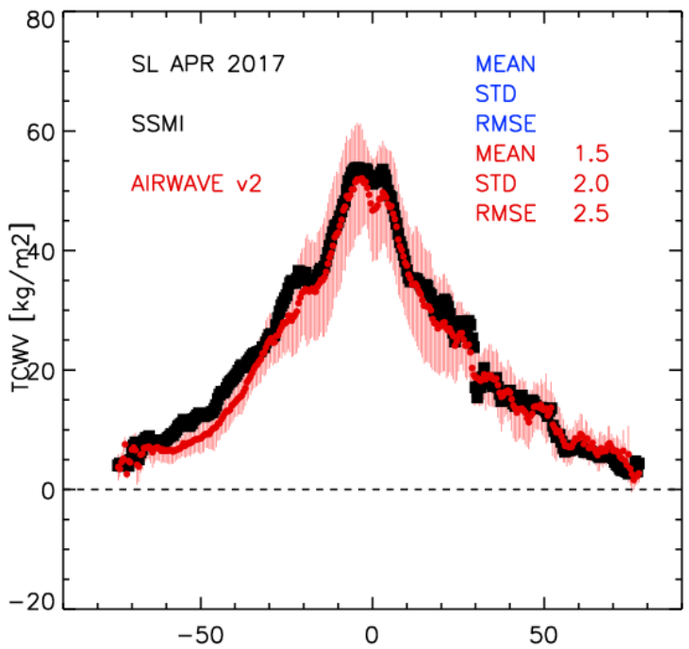


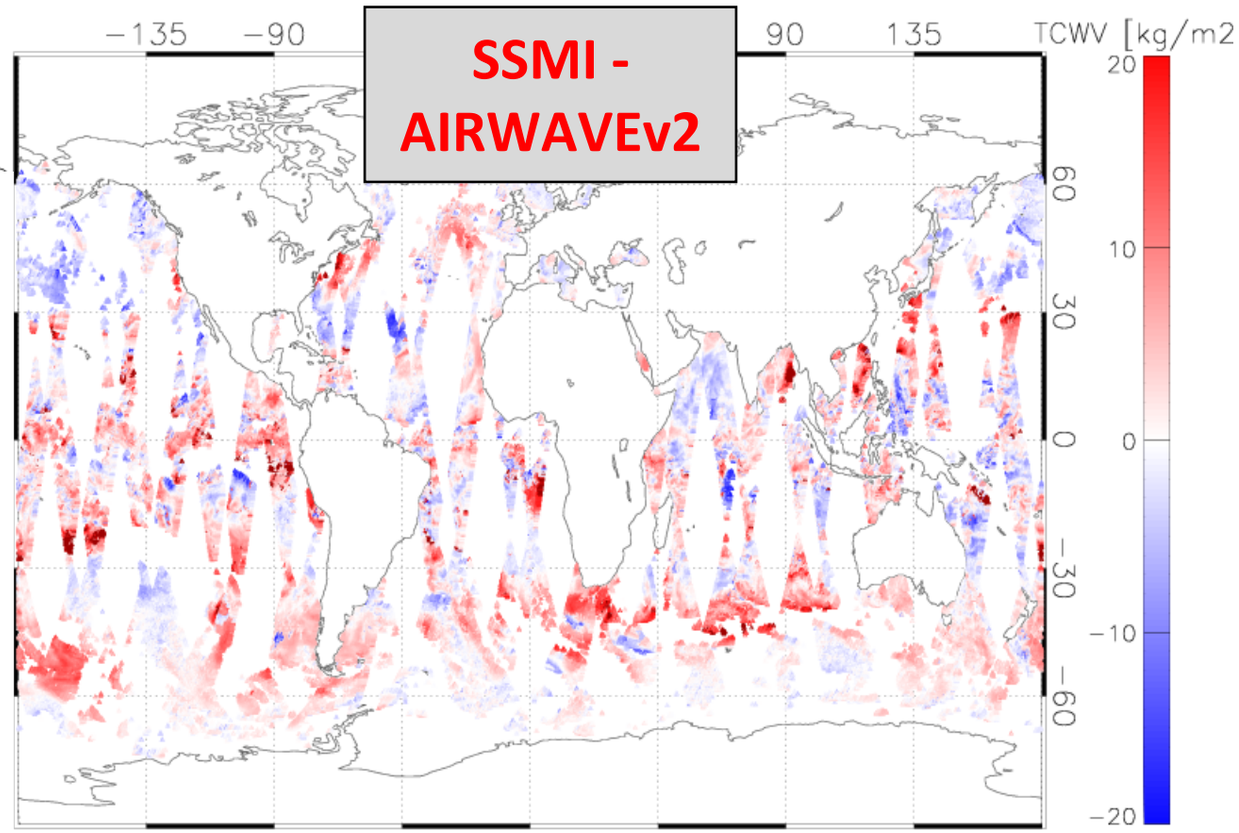


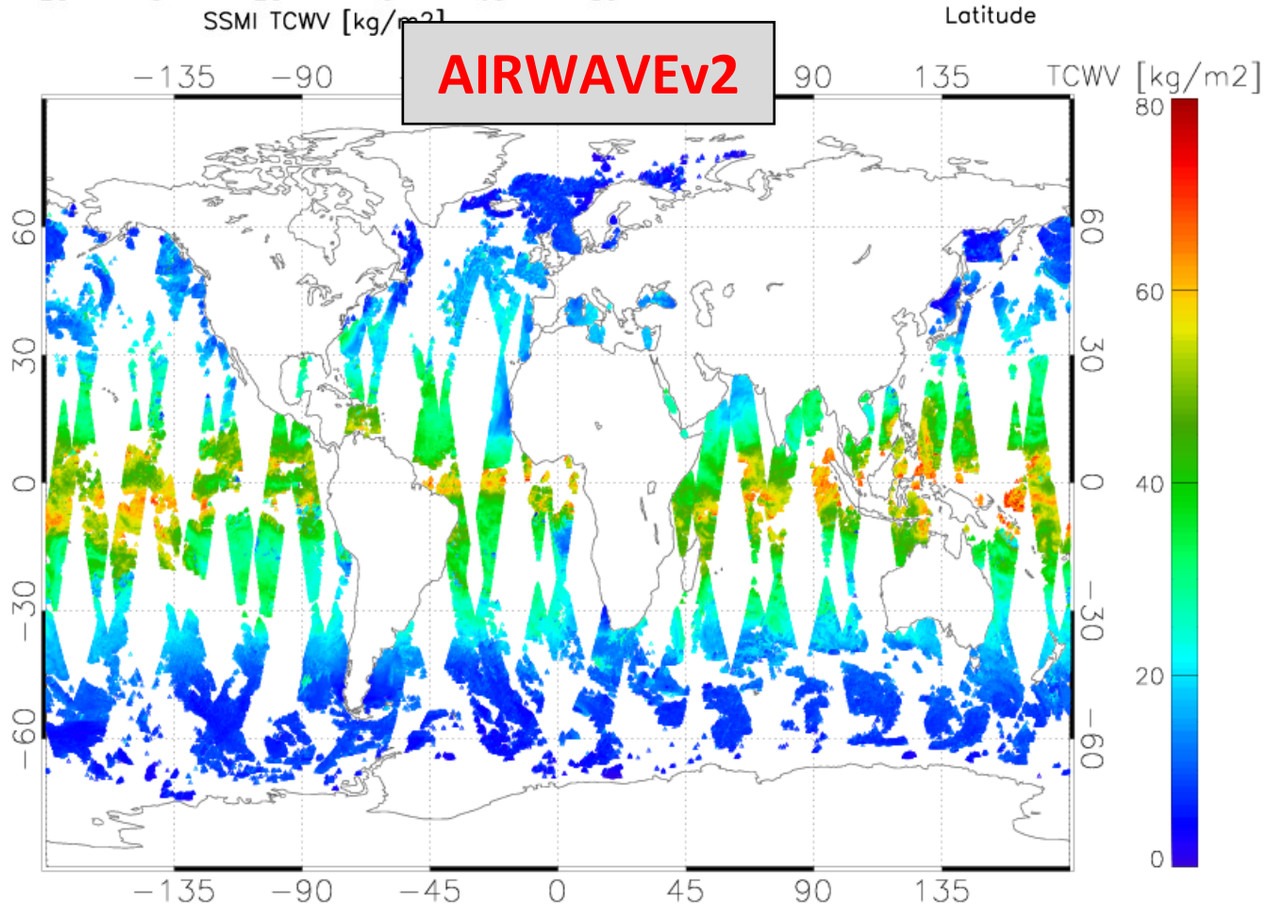
AIRWAVE v2: application to SLSTR measurements

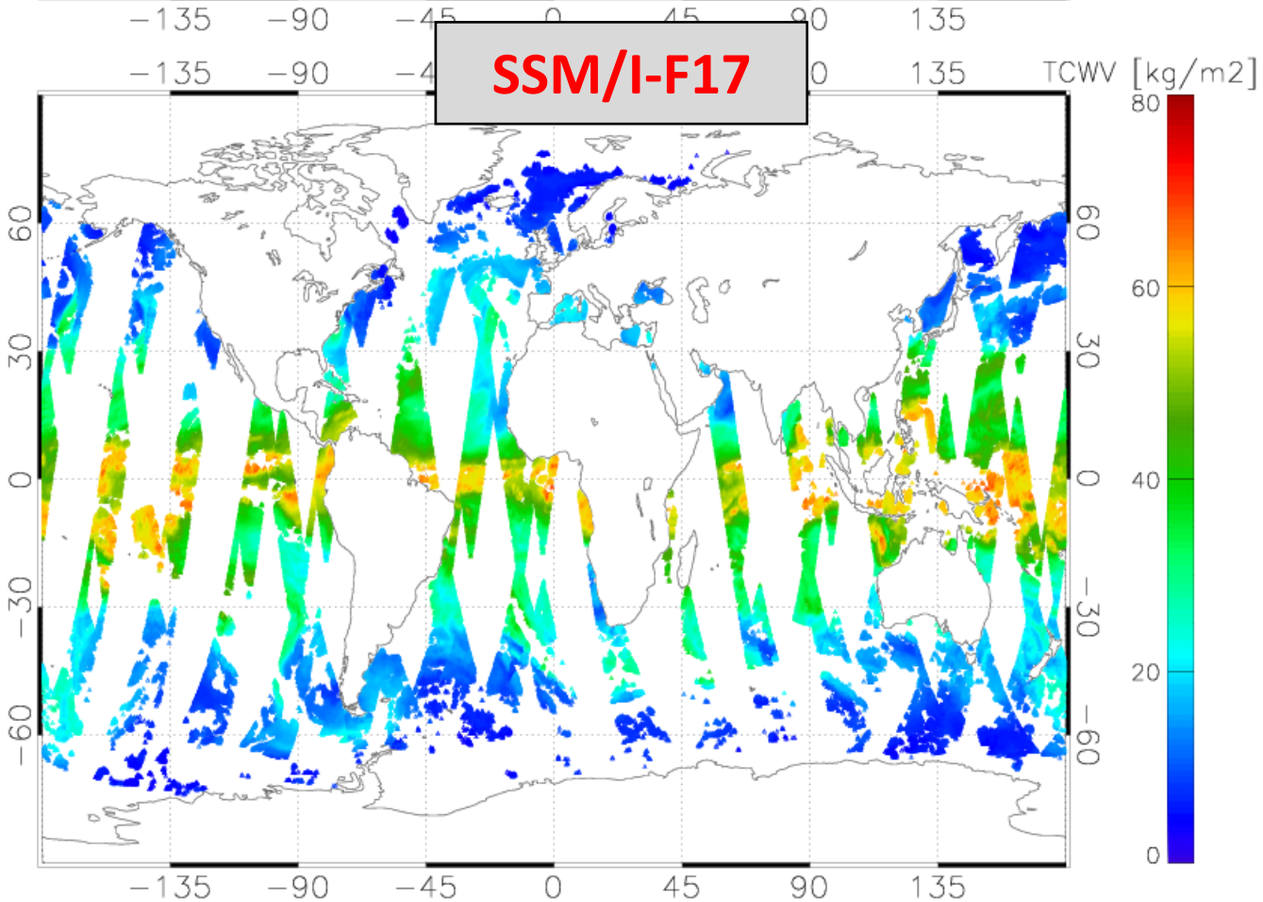
APR 2017





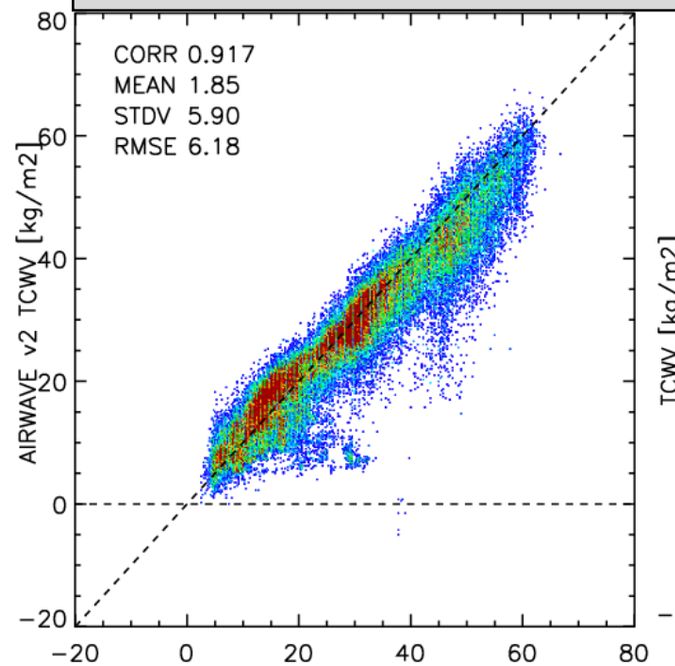


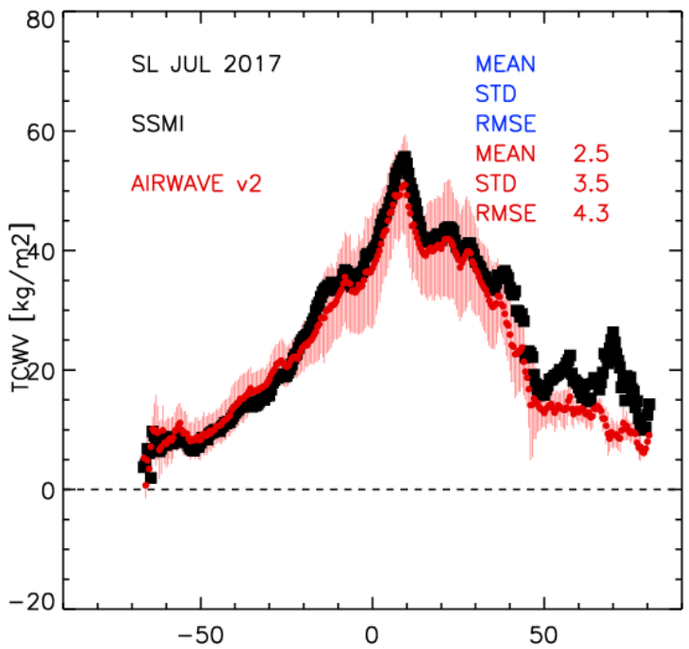


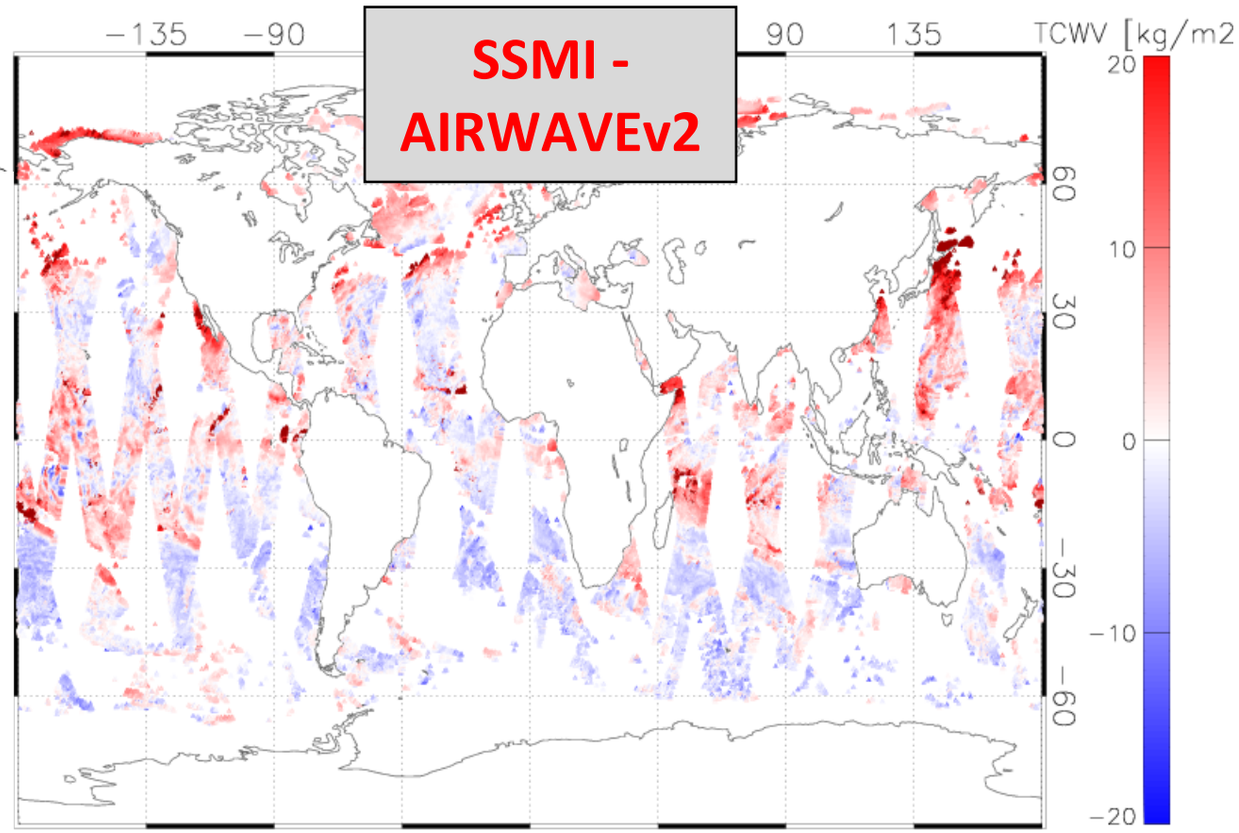


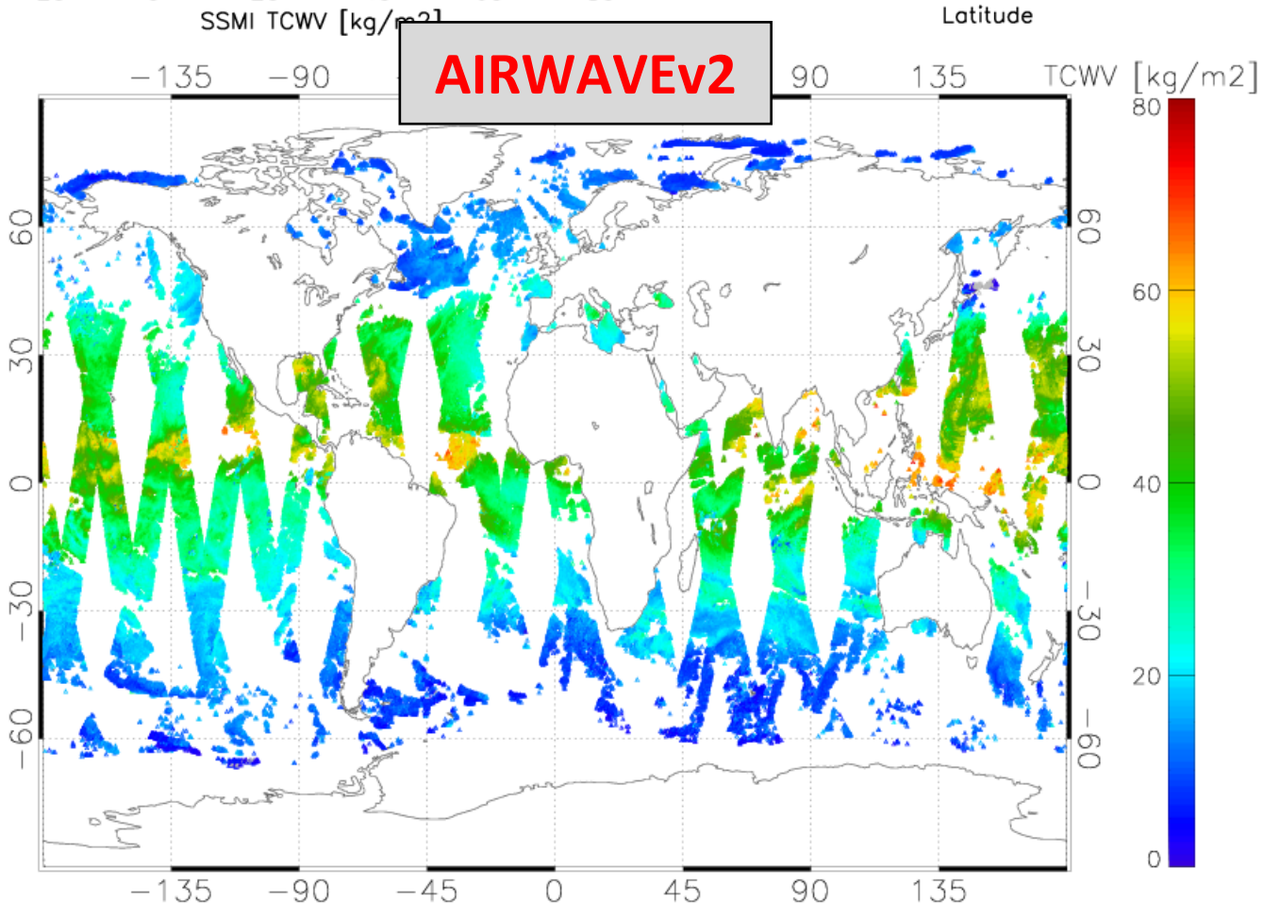
AIRWAVE v2: application to SLSTR measurements

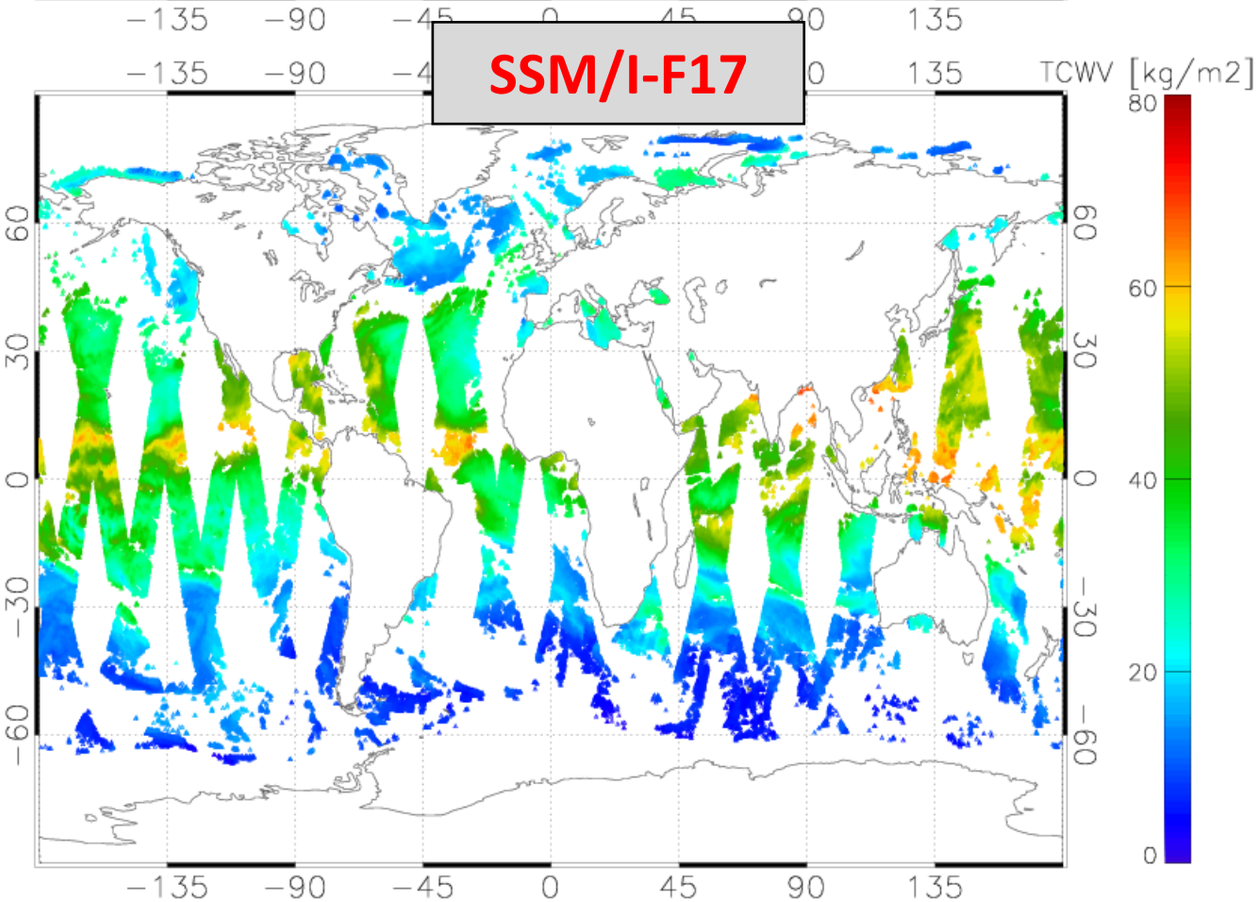
JUL 2017











Possible AIRWAVE extension: LAND

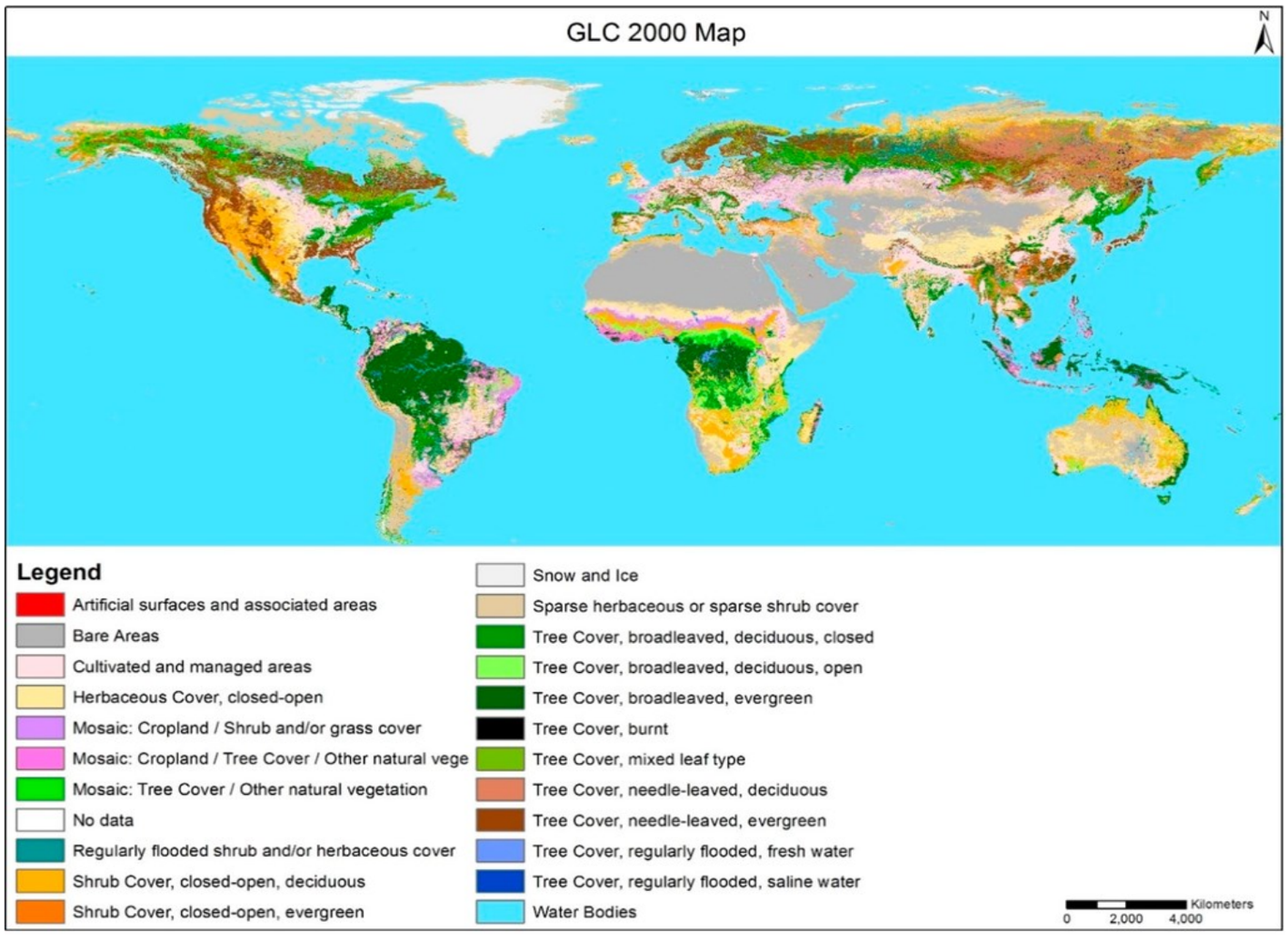
AIRWAVE single-view “fundamental” equation

radiance — surface emissivity — wavenumber

$$\ln\left(\frac{J_1^{\lambda_1}}{J_2^{\lambda_2}}\right) = \ln\left(\frac{F_1^{\lambda_1}}{F_2^{\lambda_2}}\right) + \ln\left(\frac{\varepsilon_1^{\lambda_1}}{\varepsilon_2^{\lambda_2}}\right) + \ln\left(\frac{\gamma_1^{\lambda_1}}{\gamma_2^{\lambda_2}}\right) + \lambda_2 \cdot \tau_2 - \lambda_1 \cdot \tau_1$$

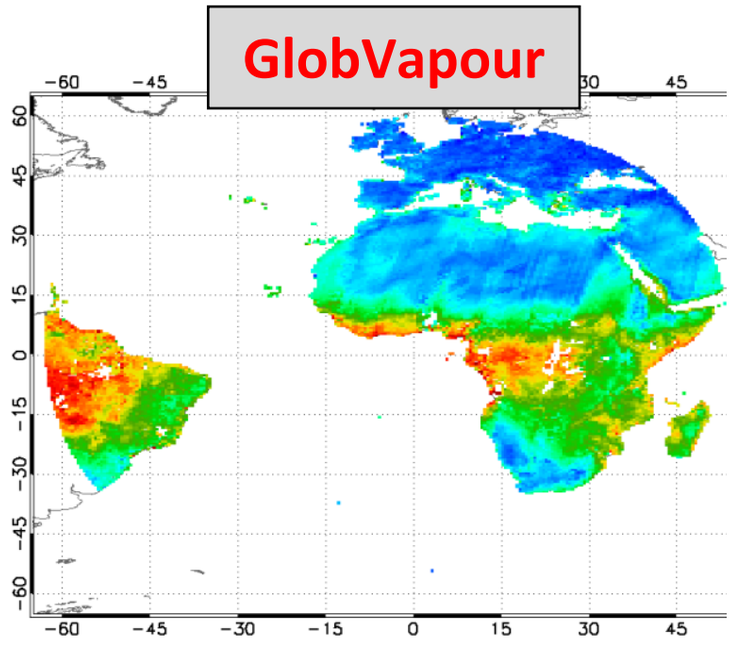
surface + atmosphere — constant — optical thickness

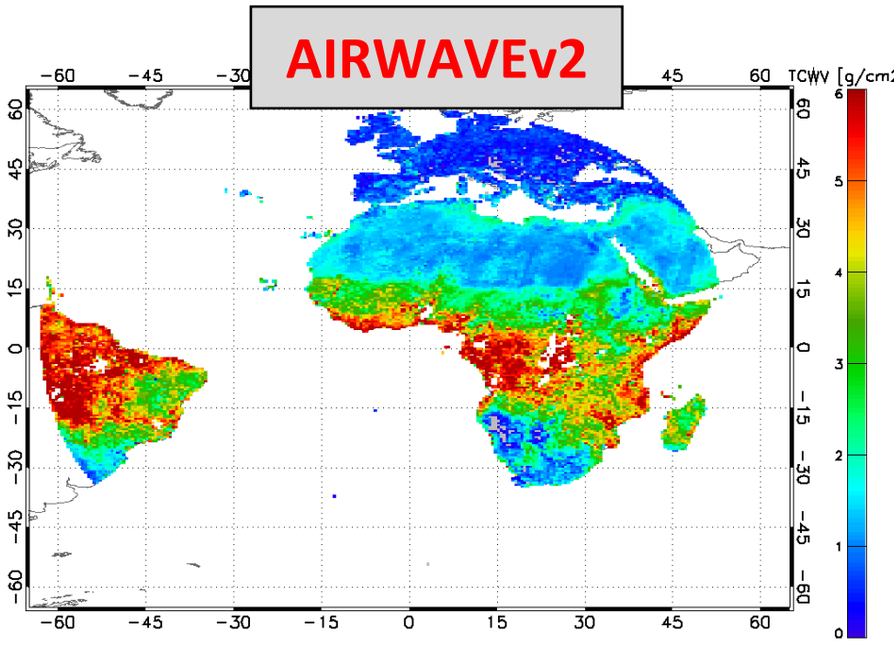
Over Land: **SURFACE EMISSIVITY** depends on: surface type, vegetation coverage, viewing angles.

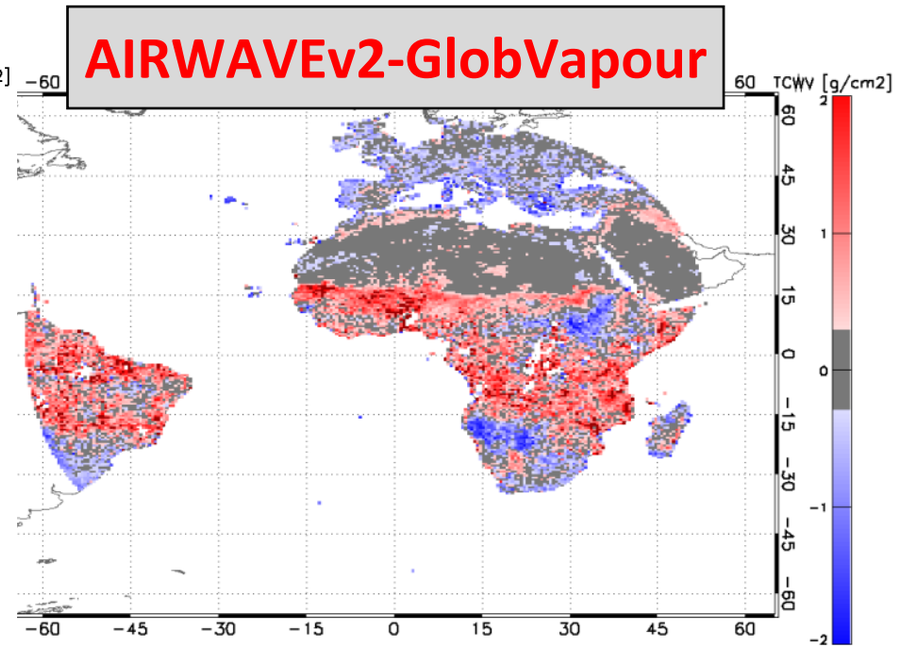


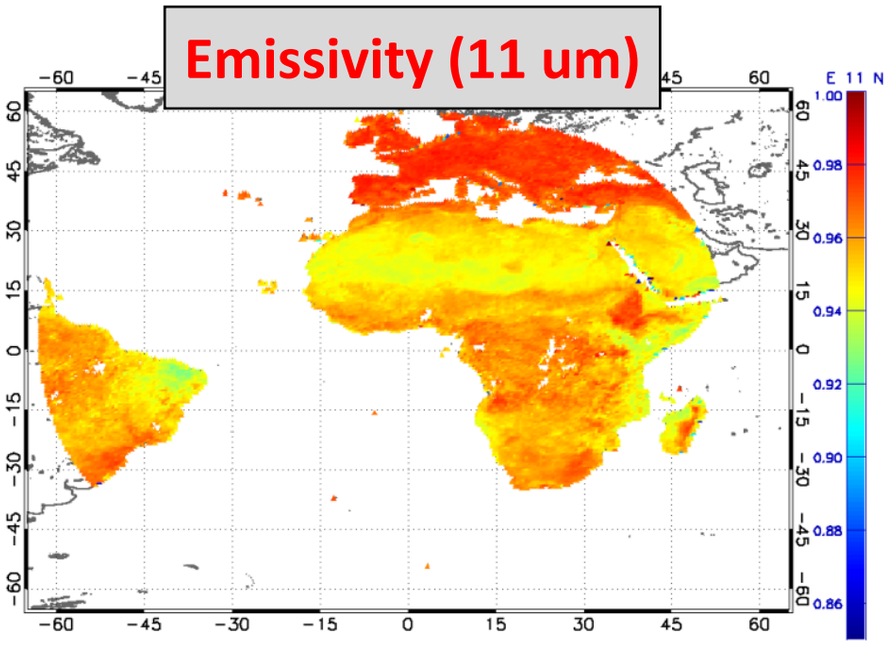
Possible AIRWAVE extension: LAND

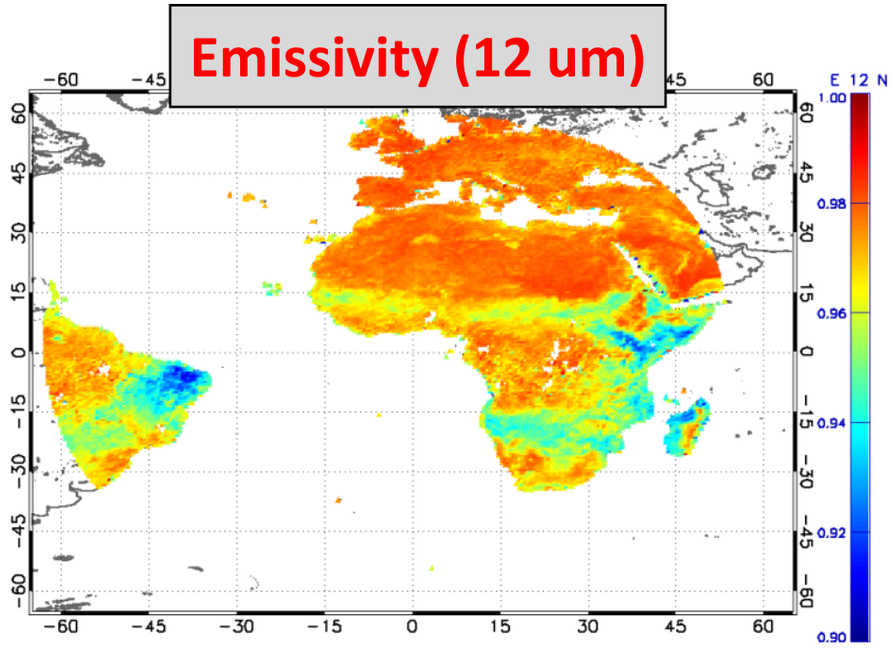
IREMIS (http://cimss.ssec.wisc.edu/iremis/) [Bare Areas fixed] emissivity

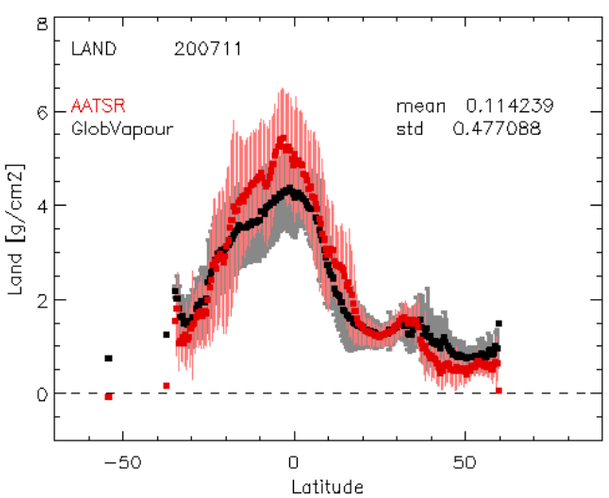


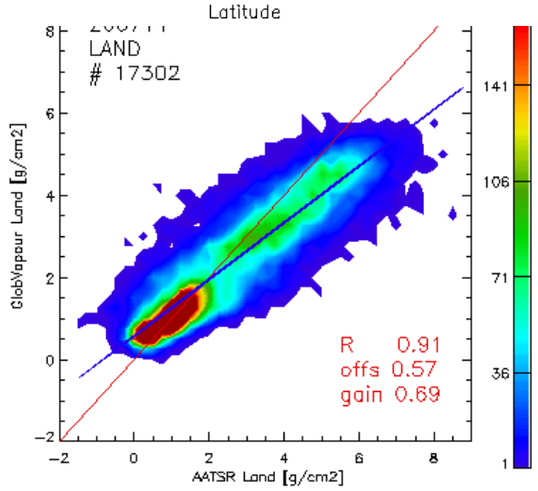






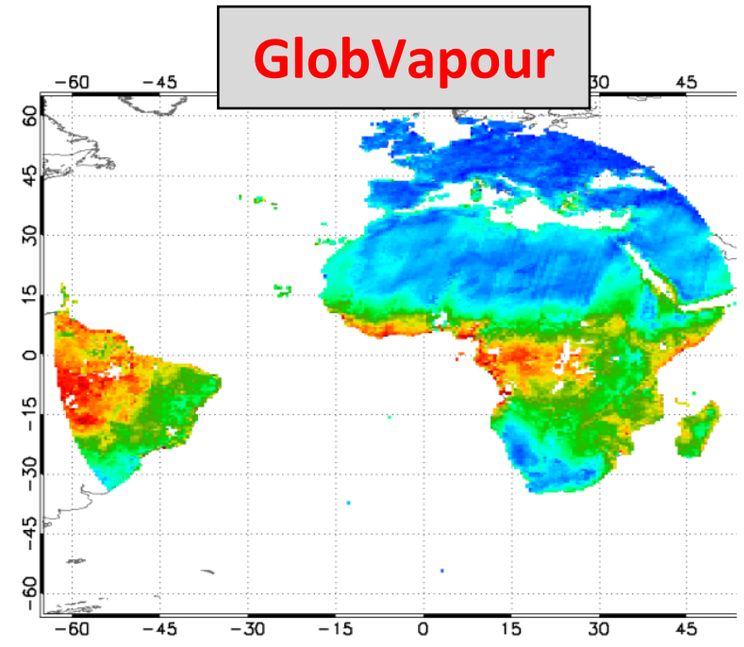


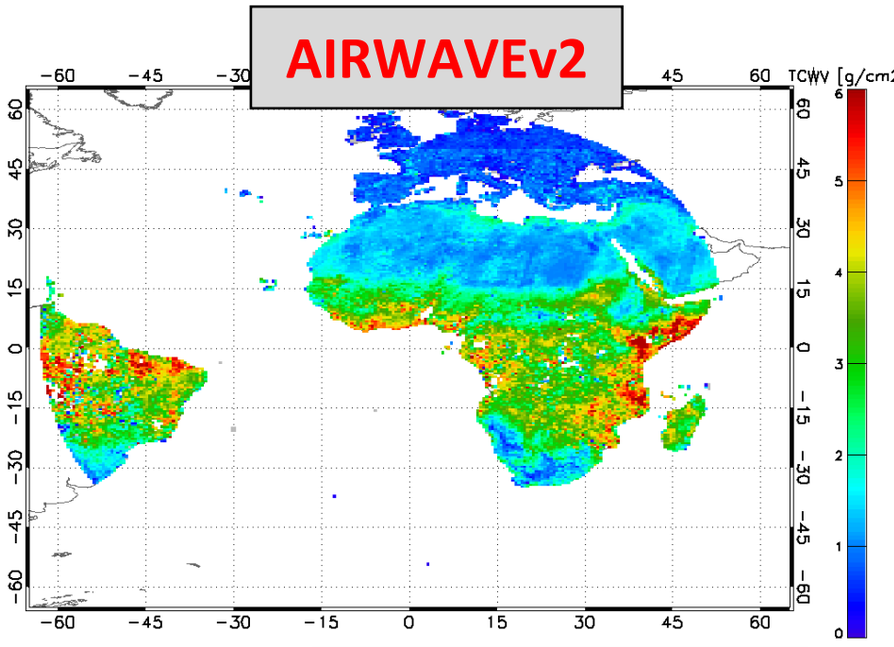


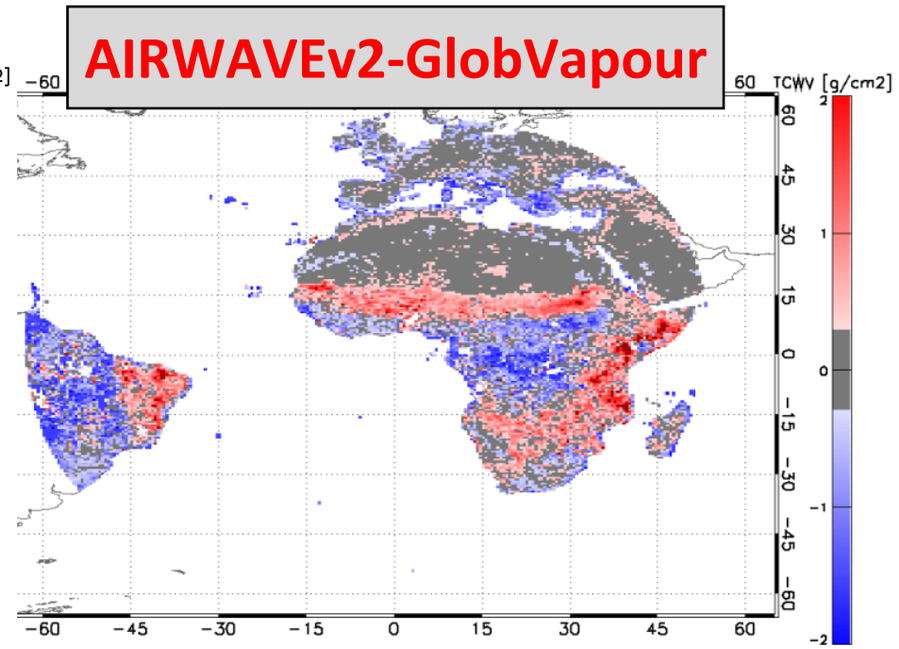


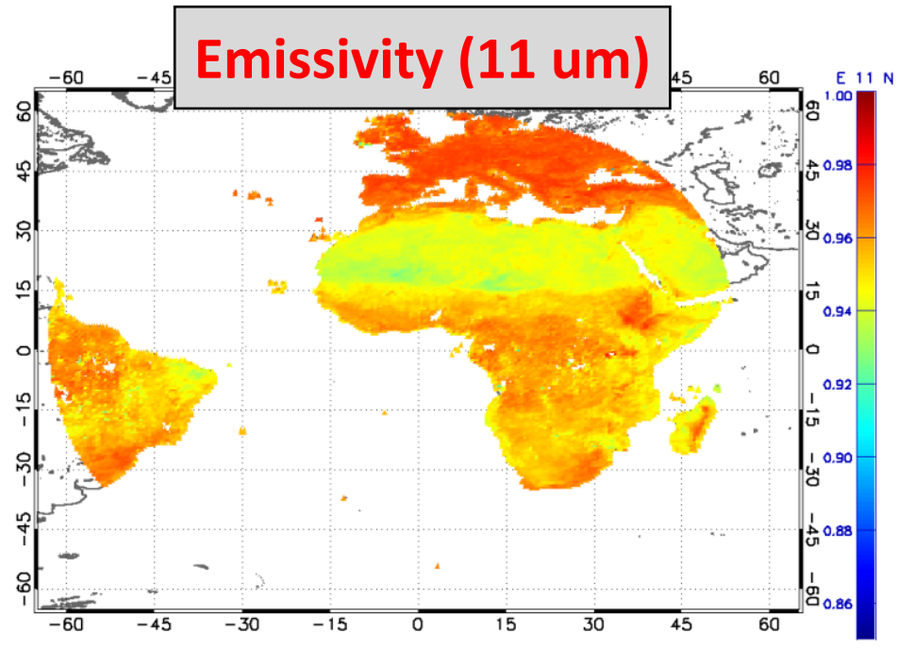
Possible AIRWAVE extension: LAND

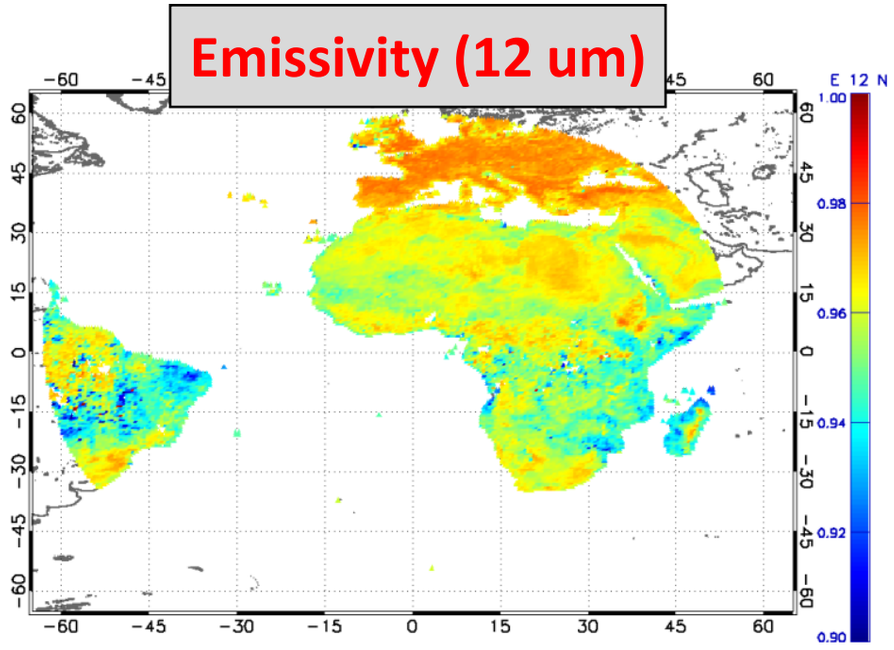
SEVIRI (courtesy from Unibas) [Bare Areas fixed] emissivity

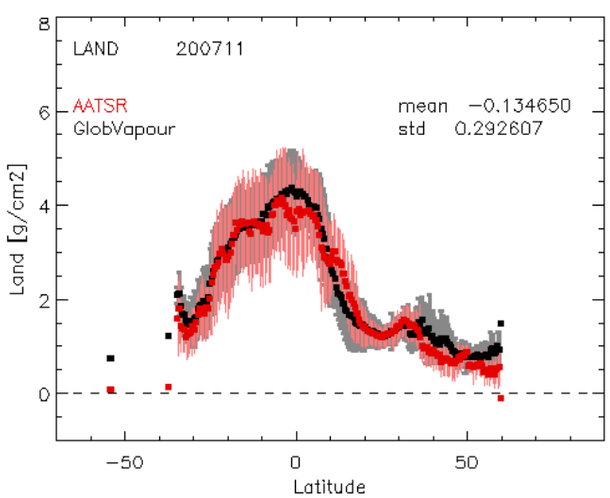


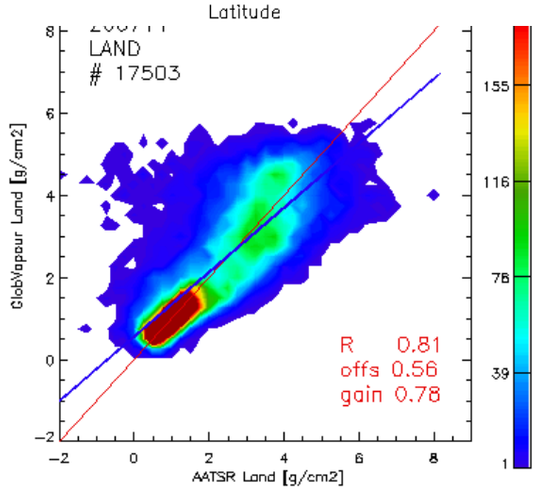












WP Outreach since last Lille Cal/Val

AIRWAVE v1 validated with ARSA (in situ) and SSMI (satellite) products.

[*E. Papandrea et al., paper accepted with minor revision*].

AIRWAVE v2 reduces the bias and the spread mainly at high latitudes and in coastal regions

[*paper in preparation*].

ITCZ position trend: study with AIRWAVE TCWV monthly means + “cloudy land” measurements

[*paper in preparation*].

ITCZ trend analysis via Geodesic P-spline smoothing of the AIRWAVE TCWV and Cloud datasets

[*E. Castelli et al., EUMETSAT meteorological satellite conference 2017, ESRIN, Oct 2017*].

On the contribution of 20 years of ATSR data and geodesic P-Spline efficient spatial smoothing method to ITCZ trend analysis

[*E. Castelli et al., Toulouse, France, Proc. of the 2017 conference on Big Data from Space (BiDS’17)*].

P-spline smoothing for spatial data collected worldwide

[*F. Greco et al., submitted to Spatial Statistics*].

WP Outreach since last Lille Cal/Val

Exploiting the high spatial resolution of AIRWAVEv2 TCWV data to retrieve the WTC for coastal altimetry in view to its application to Sentinel-3

[*C. Lázaro et al., OSTST 2017, Miami, Oct 2017*].

AIRWAVE: an algorithm for the retrieval of the total column of water from the measurements of the ATSR series and Sentinel 3/SLSTR

[*B.M. Dinelli et al., 13th Int. Work. on Greenhouse Gas Measurements from Space, Helsinki, Jun 2017*].

SLSTR TCWV retrieval using the AIRWAVE approach

[E. Castelli et al. *EUMETSAT meteorological satellite conference 2017, ESRIN, Oct 2017*].

AIRWAVE: ATSR-like TCWV

[S. Casadio et al., 7th G-VAP Workshop, Leicester, Oct 2017].