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Inter-tropical Convergence Zone (ITCZ) analysis using AIRWAVE retrievals of TCWV from (A)ATSR series and potential extension of AIRWAVE to SLSTR

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with contribution from
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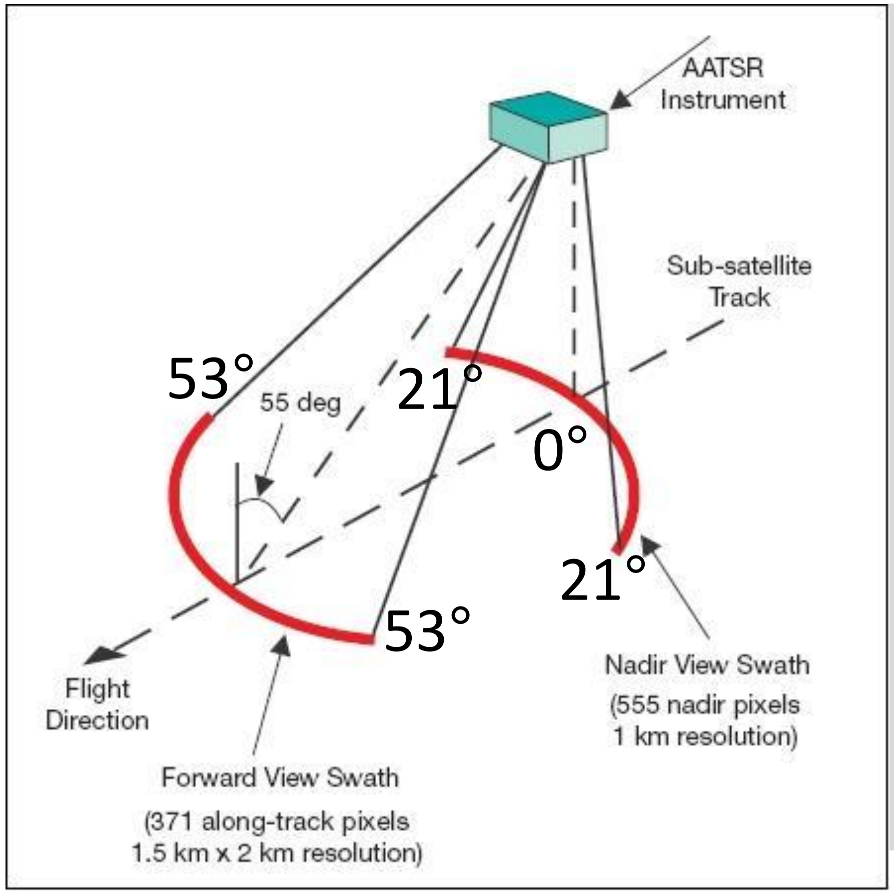
Massimo Ventrucci (UNIBO)

OUTLINE

- AIRWAVE v1 and v2
- Comparison: Satellite (SSMI), Radiosondes (ARSA)
- Application: ITCZ position study
- Future possible extension: SLSTR
- Conclusions

AIRWAVE algorithm: v1



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

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

AATSR/ENVISAT (2002-2012)

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

$$\alpha = \frac{1}{1 - \frac{\Delta\sigma_{FWD}}{\delta \cdot \Delta\sigma_{NAD}}} \qquad \beta = \frac{1}{1 - \frac{\delta \cdot \Delta\sigma_{NAD}}{\Delta\sigma_{FWD}}}$$

$$\delta = \frac{G_{FWD}}{G_{NAD}} \approx \text{constant}$$

- Developed for the retrieval of TCWV from ATSR missions.
- The algorithm exploits the TIR channels of ATSR-like instruments and the dual viewing geometries to infer the TCWV in clear sky.
- The algorithm makes use of a set of tabulated parameters, computed through RTM simulations.
- *In the first version of the algorithm, these parameters were fixed along the whole globe.*

AIRWAVE algorithm: v1

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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 algorithm: v2

In v2, AIRWAVE parameters were calculated accounting for different scenarios.

Scenarios	Effect on RTM inputs
Across track position (-250/250, step: 50)	NADIR and FORWARD angles
Instrument (AATSR, ATSR1, ATSR2)	Slit function
Latitude (TRN,TRS, MDN, MDS, PLN, PLS)	T, p, VMRs, SST, Emissivity
Season (JAN, APR, JUL, OCT)	T, p, VMRs, SST, Emissivity
H2O variability (x0.5, 1, 1.5)	H2O VMR

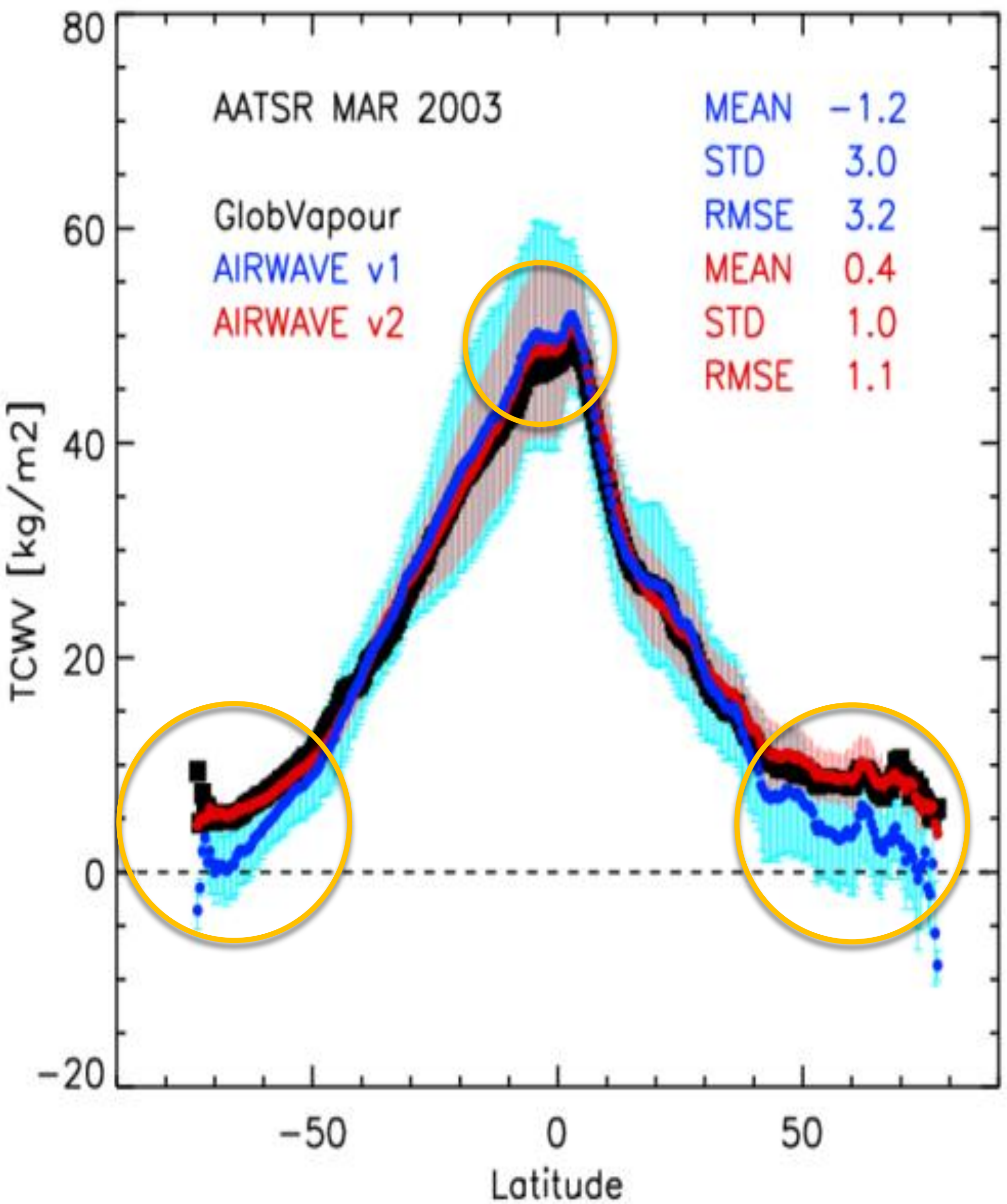
The Advanced Infra-Red WAter Vapour Estimator (AIRWAVE) version 2: algorithm description and quality assessment

Castelli E.[1], Papandrea E.[1,2], Di Roma A.[1], Dinelli B.M.[1], Casadio S.[2], and Bojkov B.[3]

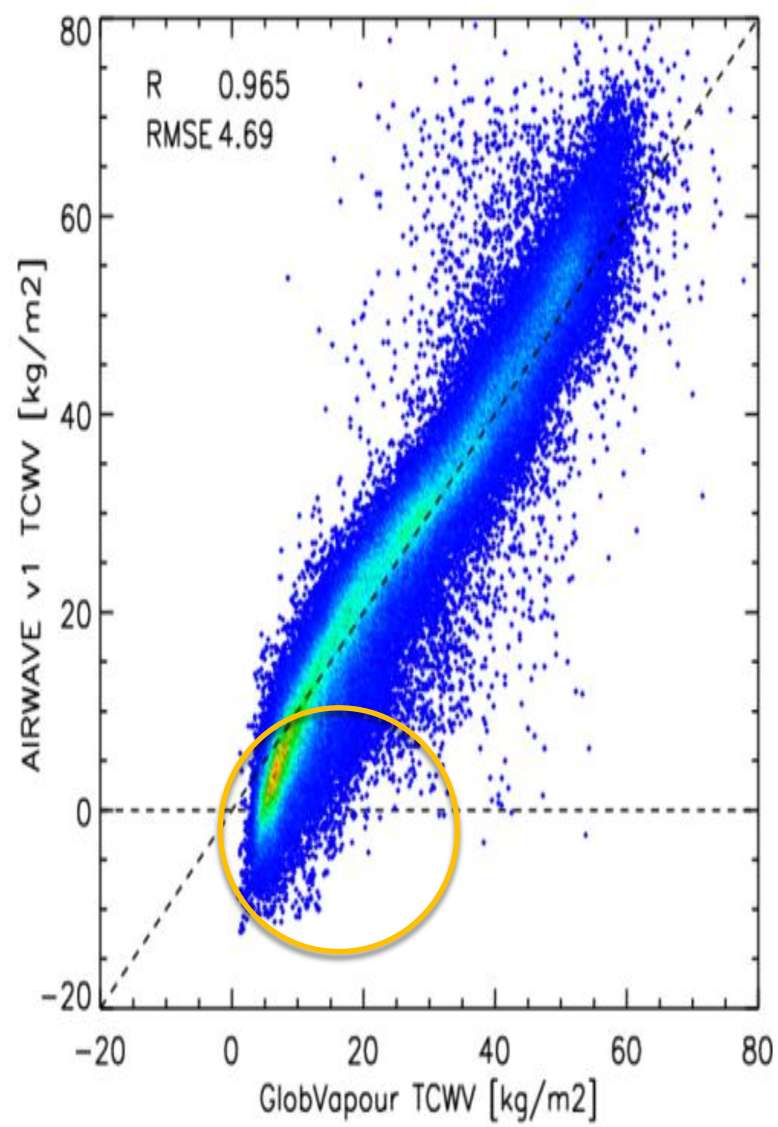
…ready to be submitted

Processed dataset and performance evaluation
SSMI

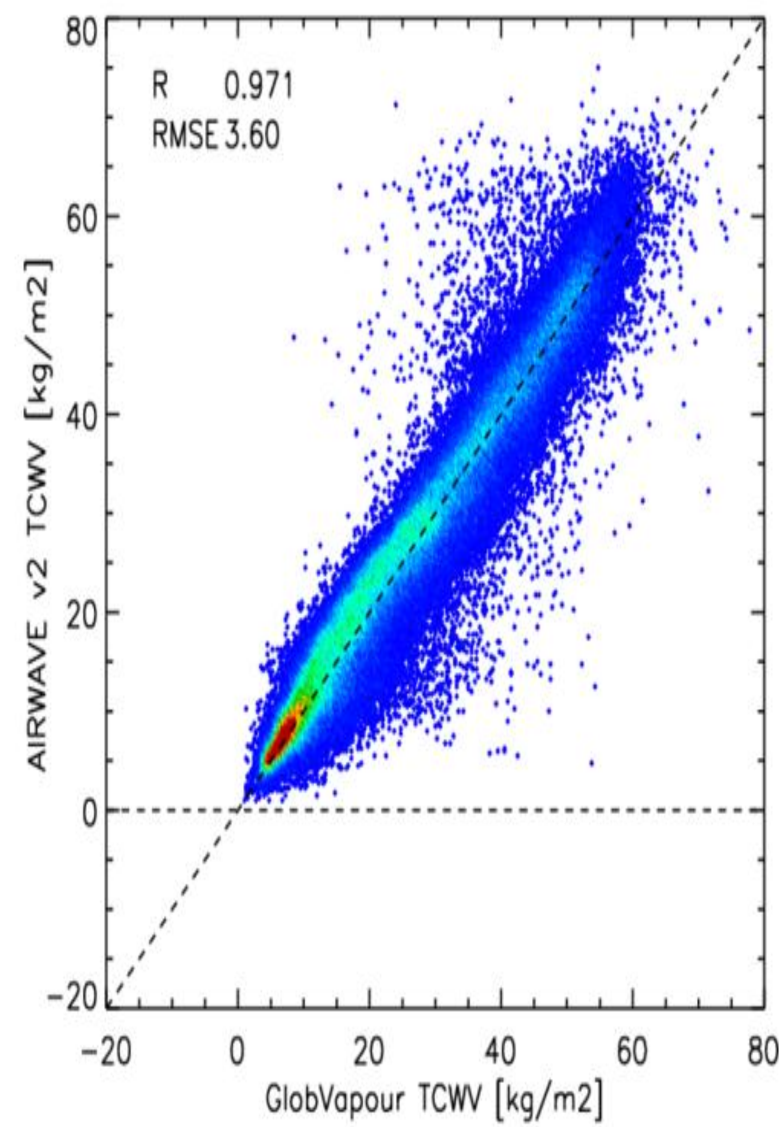
- Full mission processed (from 1991 to 2012)



AIRWAVE v1

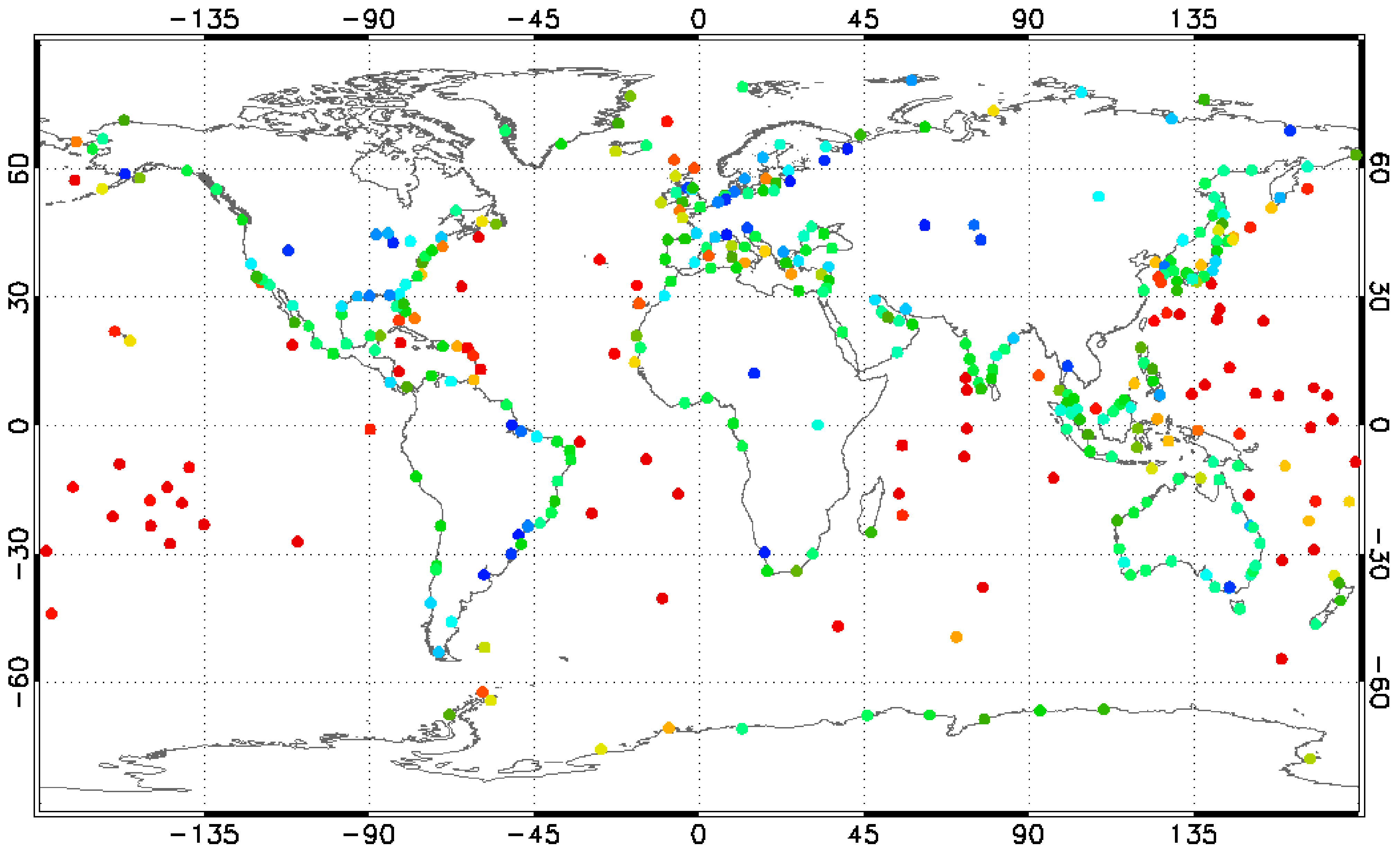


AIRWAVE v2



Processed dataset and performance evaluation

ARSA

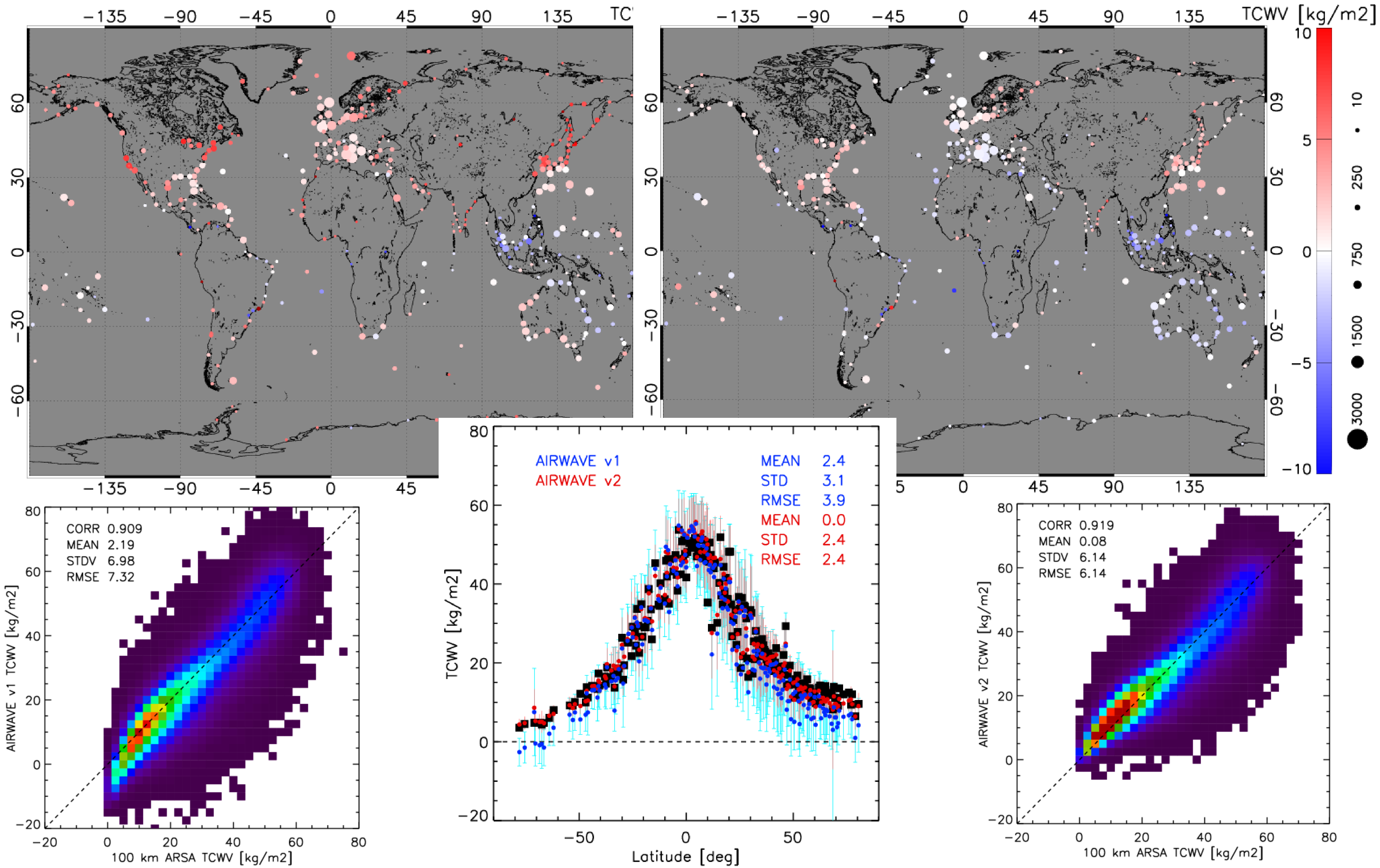


Colors=% of ATSR sea measurements in a 100 km radius around the station (about 500 stations)

Processed dataset and performance evaluation

ARSA

ARSA-AIRWAVE

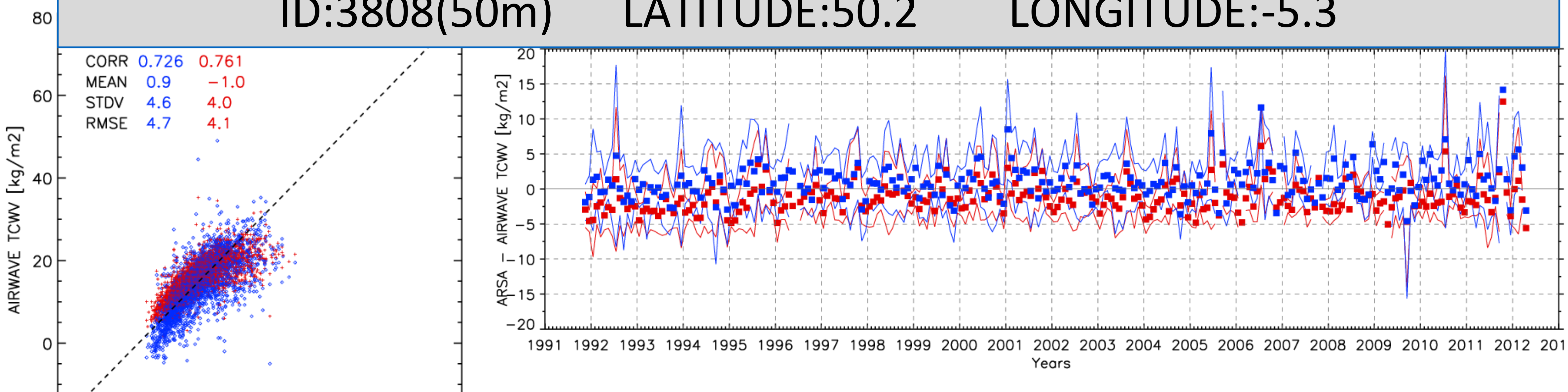


Processed dataset and performance evaluation

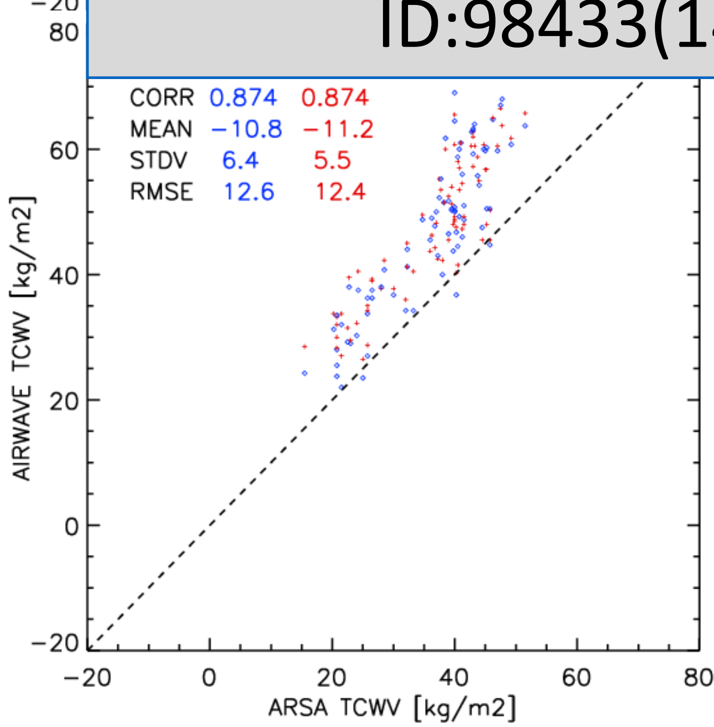
ARSA

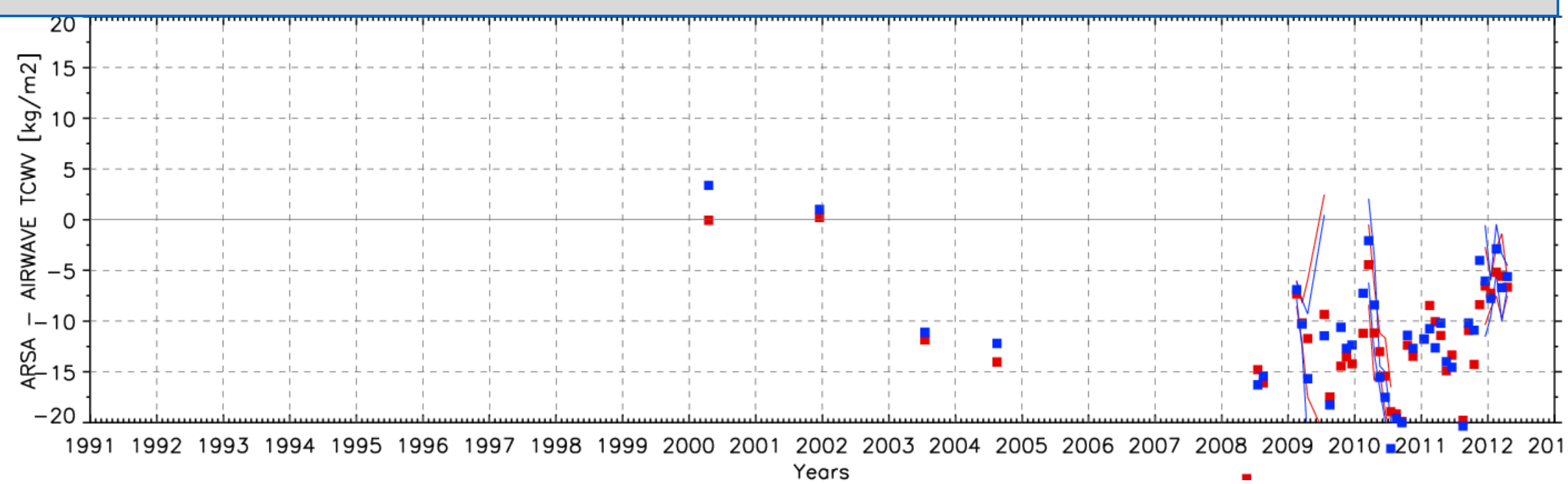
Evaluation station by station…

ID:3808(50m) LATITUDE:50.2 LONGITUDE:-5.3



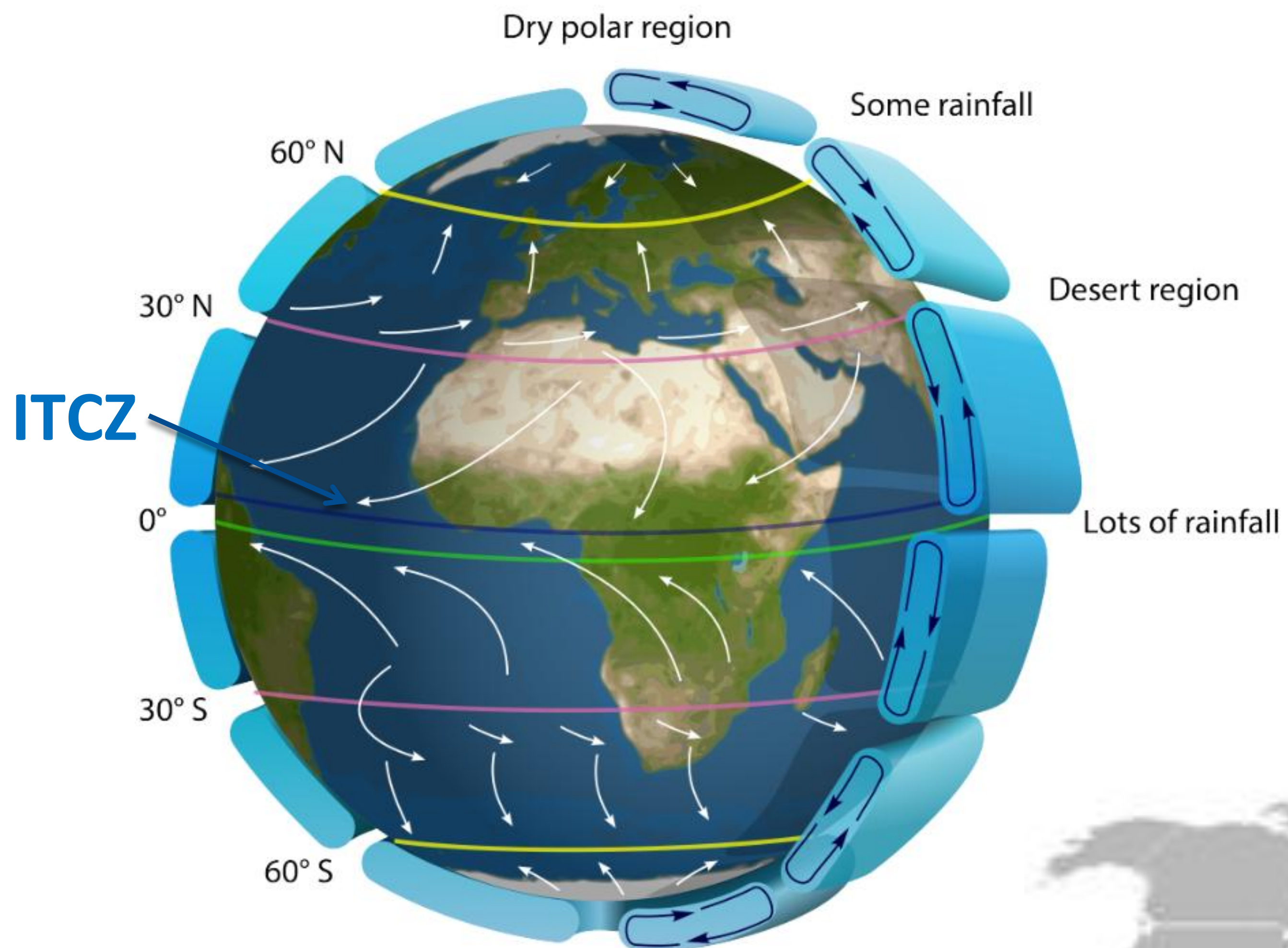
ID:98433(14m) LATITUDE:14.6 LONGITUDE:121.4



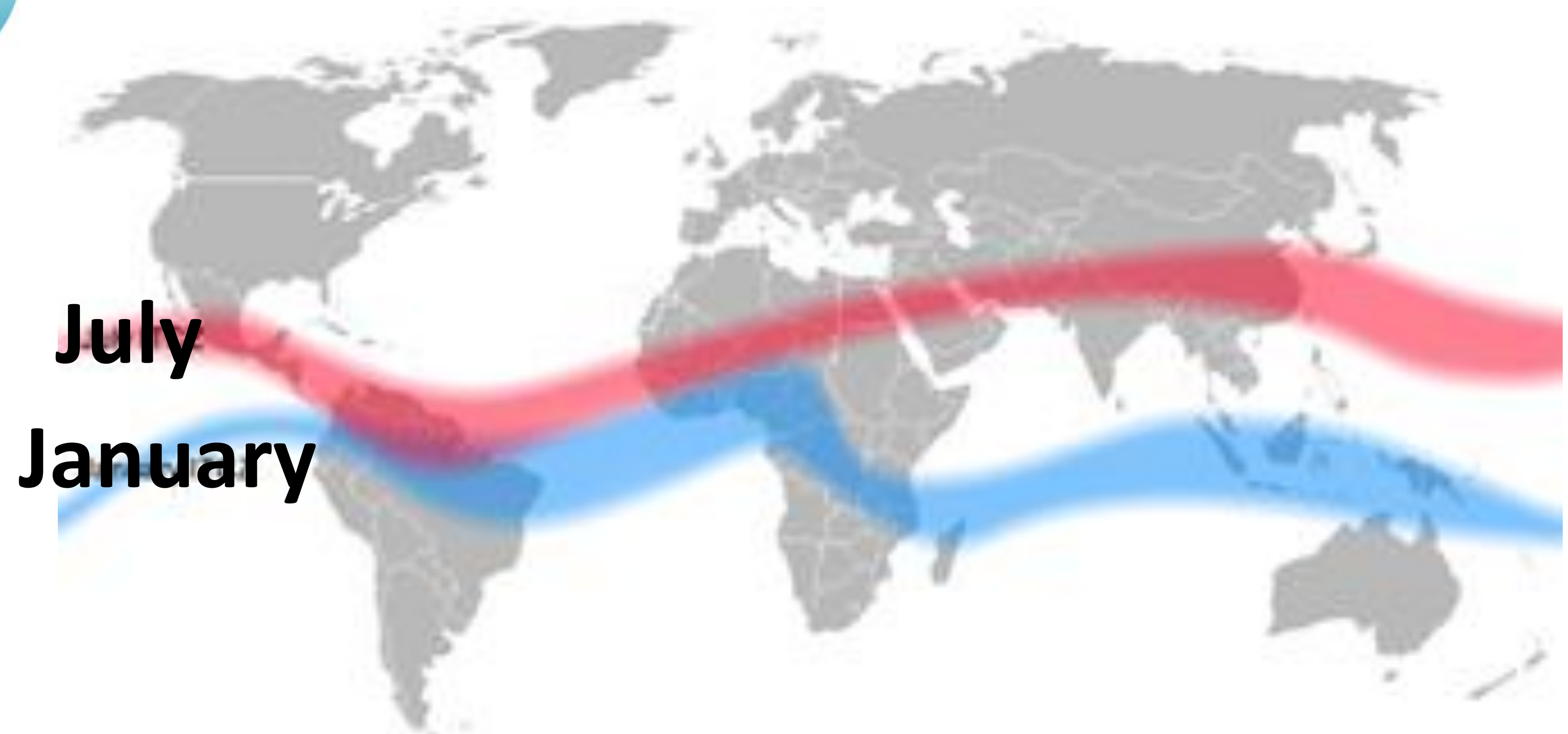


…extension of the work to common ARSA (CNRS) / IGRA (NOAA) stations [different p levels integrated TCWV, different quality checks, etc…]:
it is possible to look at possible discrepancies

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.

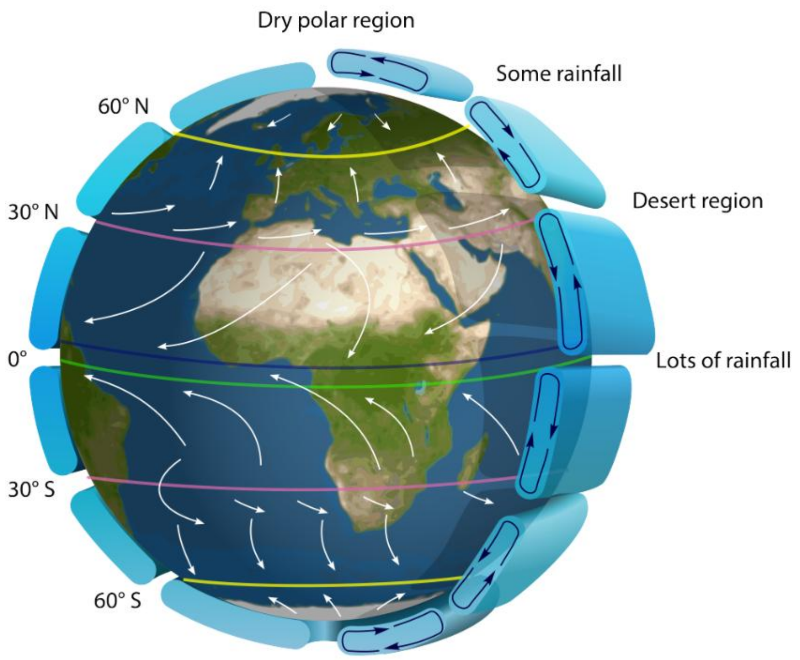


Inter-tropical Convergence Zone(ITCZ) analysis

Variation in the location of the ITCZ affects rainfall in many equatorial nations, and so in the wet and dry seasons of the tropics.
Longer term changes of the ITCZ can result in severe droughts or flooding in nearby areas.

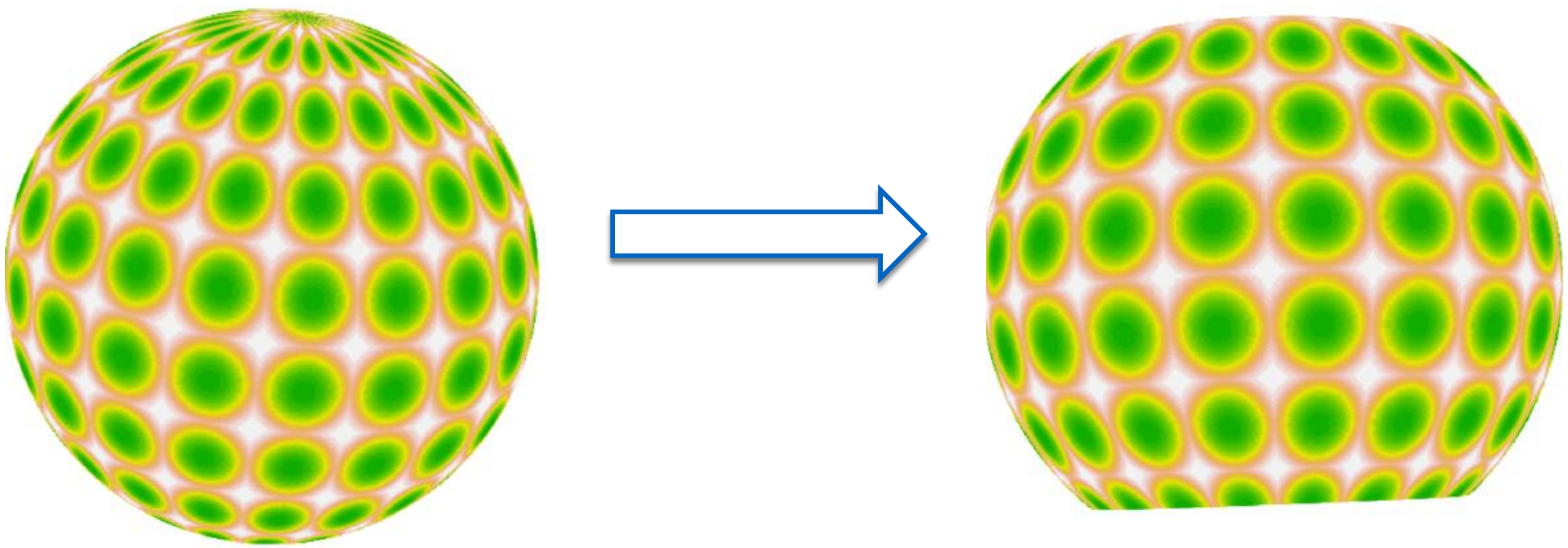
Understanding its variability is essential for improving global climate models.

Our goal: Study the ITCZ position

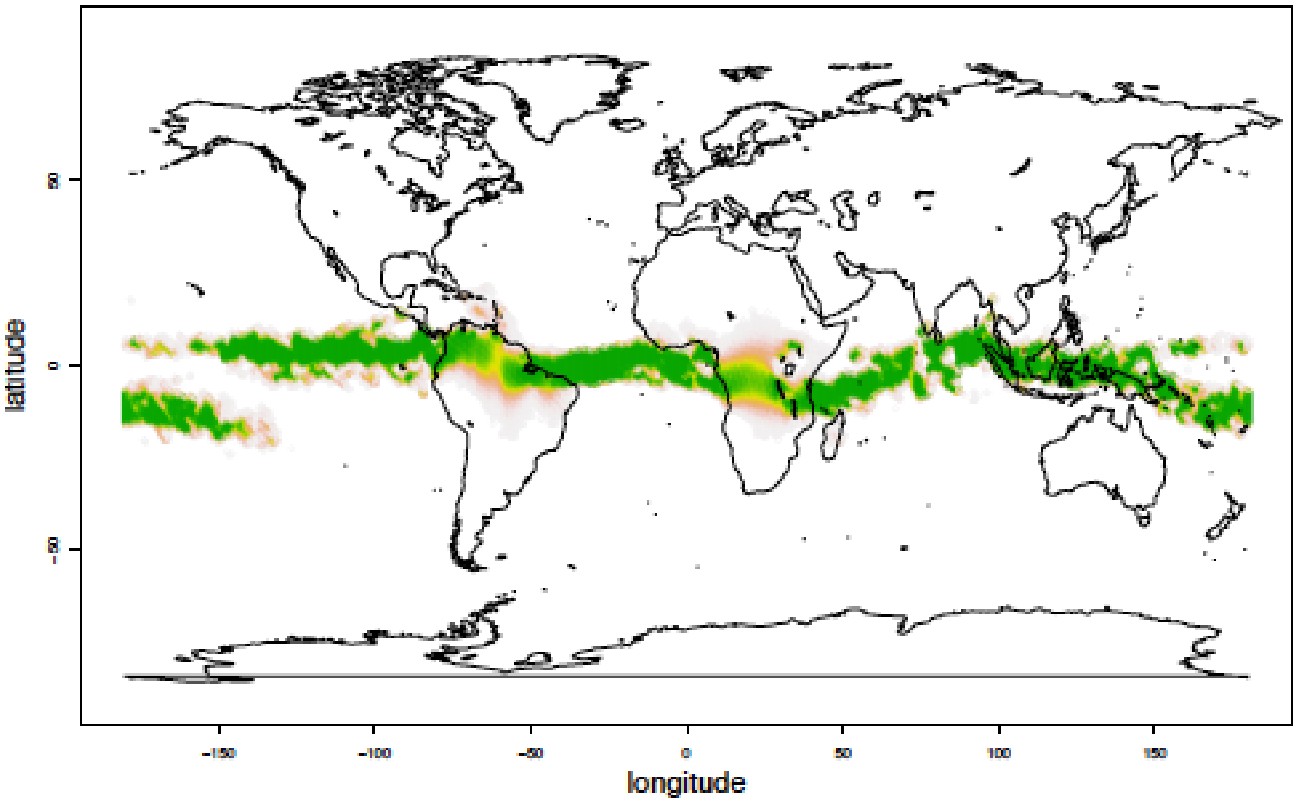


A model is used to fit the TCWV dataset and find the ITCZ (collaboration with Dept. of Statistics - University of Bologna)

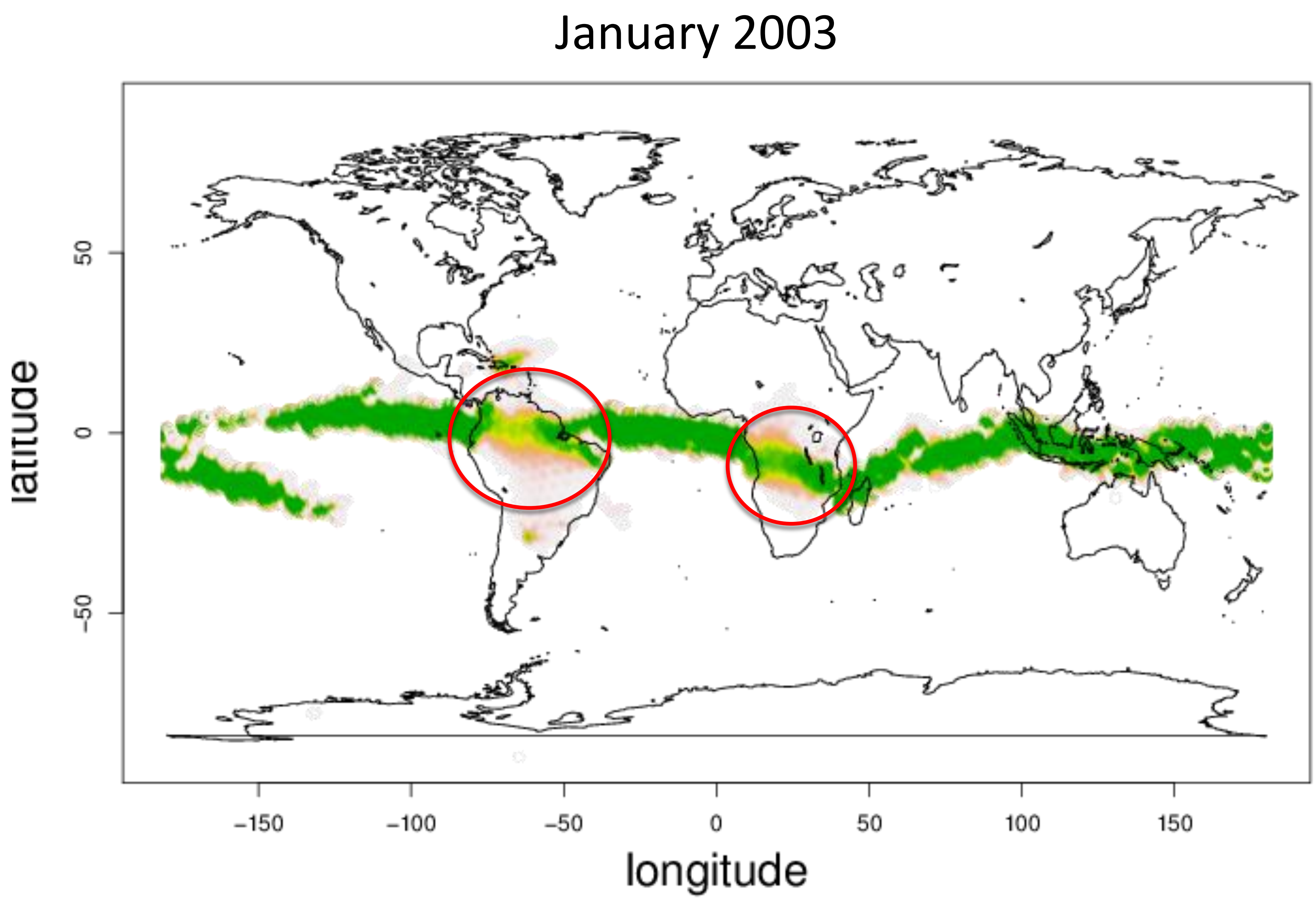
Use of a grid modeled on the globe (*set of (cubic) B-splines* not equally spaced in latitude/longitude but equally spaced on the globe).



The ITCZ found as a probability distribution of the location of maximum TCWV.



Application of new model to AIRWAVE dataset of TCWV

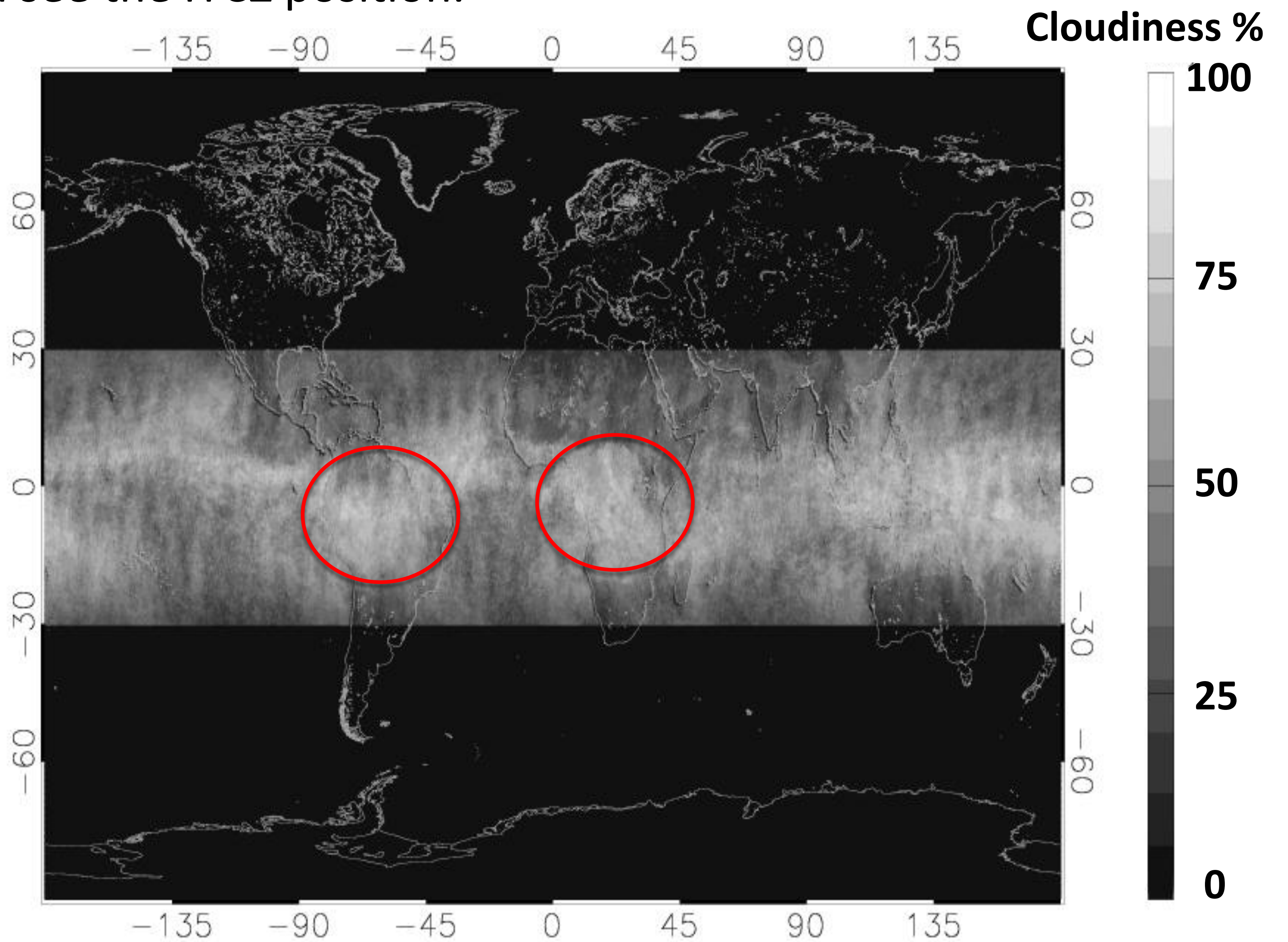


with the new representation we can clearly see that data on **land** are interpolated (lower probability). The use of the distribution instead of the line allows to detect the double ITCZ and to **quantify the extent of the ITCZ region** (as ITCZ high latitude, lower latitude and central position).

An estimate of ITCZ position over land can be inferred from ATSR cloudy measurements. Moreover *over sea the cloud information is a correlative information that should improve the results* obtained with TCWV.

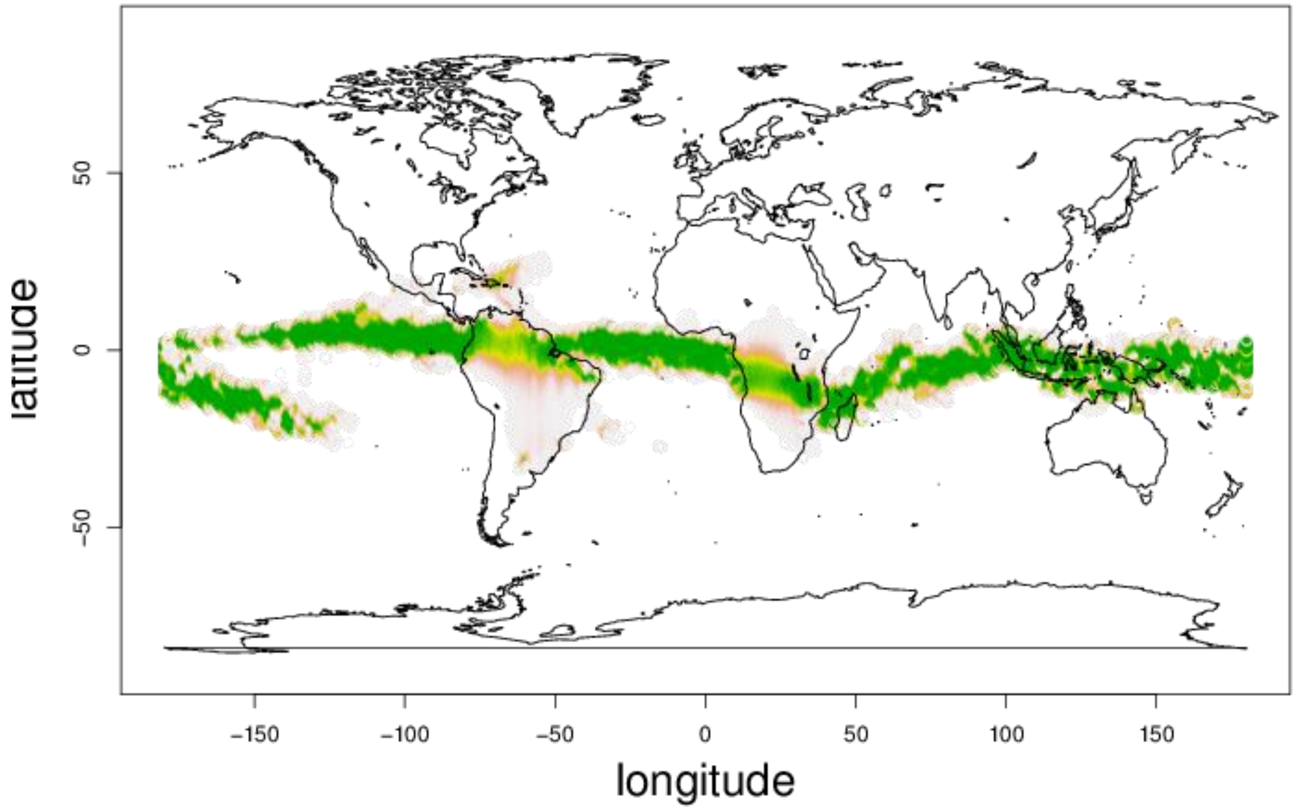
Into AIRWAVE datasets cloudy measurements are discarded. We can therefore give an estimate for each month of the amount of clouds in each region, and around the tropics we can see the ITCZ position.

Data limited to +/- 30 lat

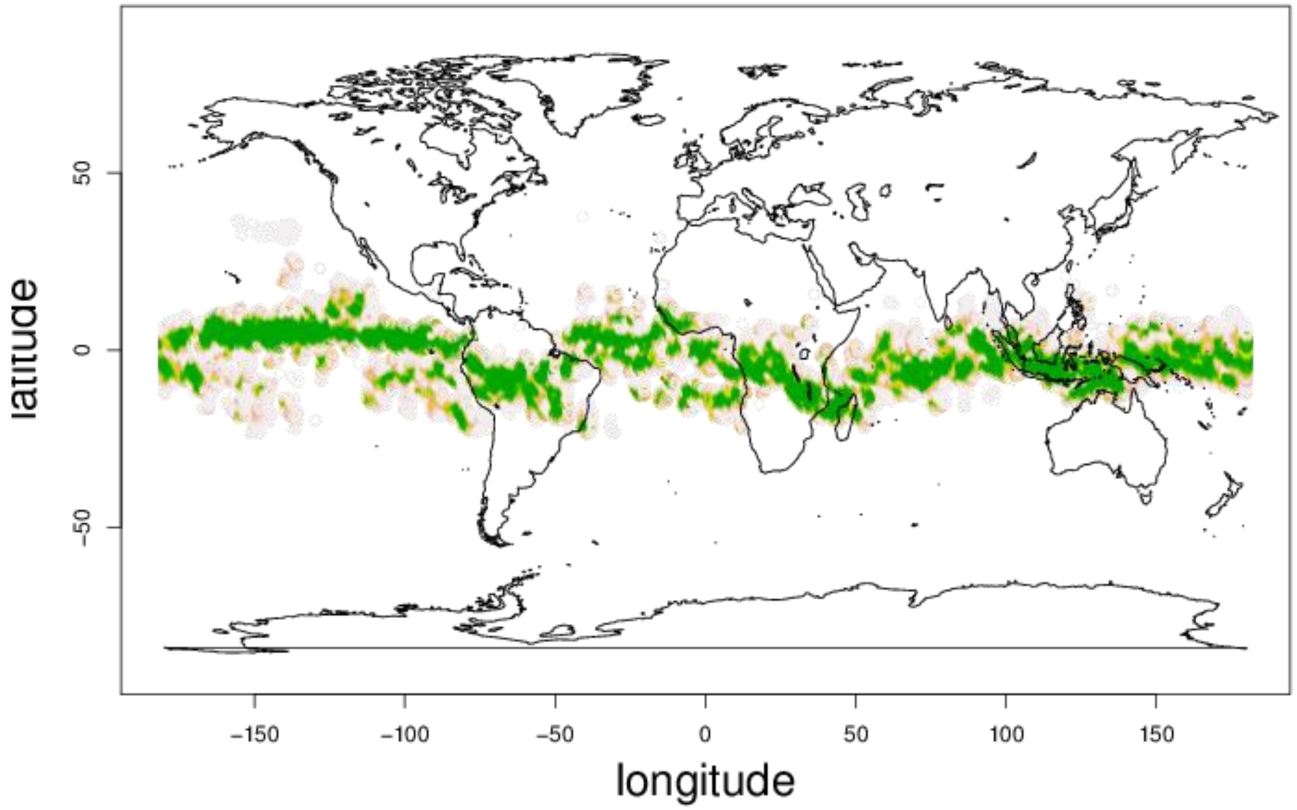


Application of new model to ATSR Cloudy measurements and to TCWV (January 2003) - Comparison with GlobVapour

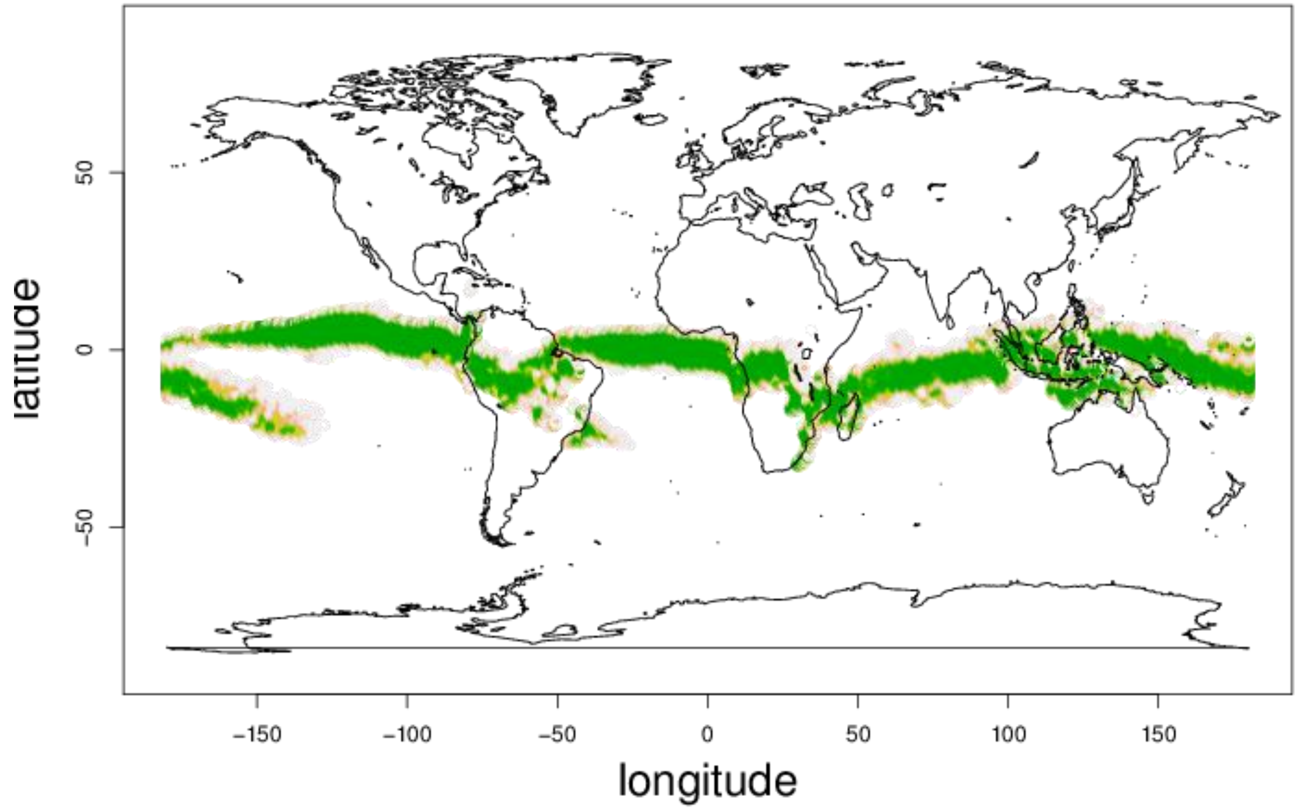
AIRWAVE TCWV dataset



ATSR Cloud dataset



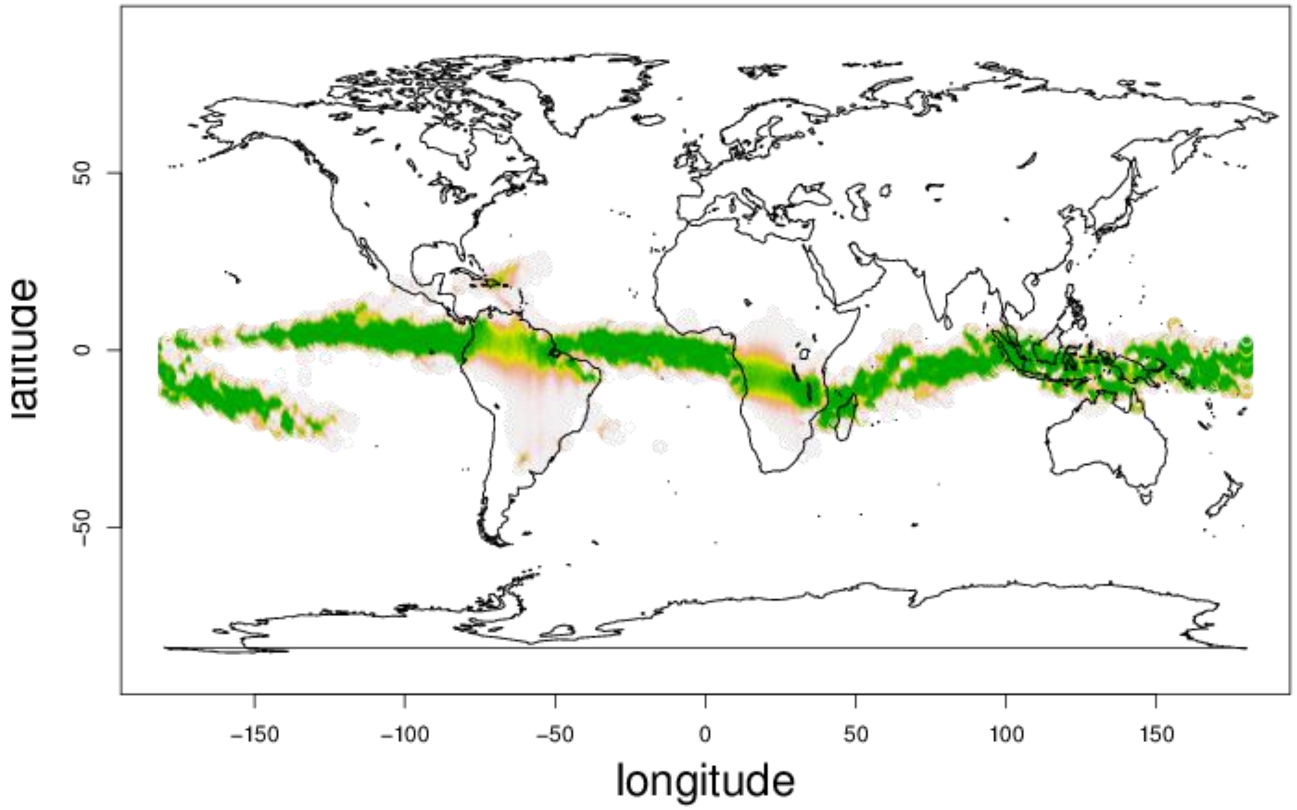
GlobVapour TCWV dataset*



*GlobVapour:
Dataset of MERIS (UV-VIS) and SSMI (MW) TCWV daytime
spatial resolution : 0.5x0.5 deg.
time range: 2003-2008

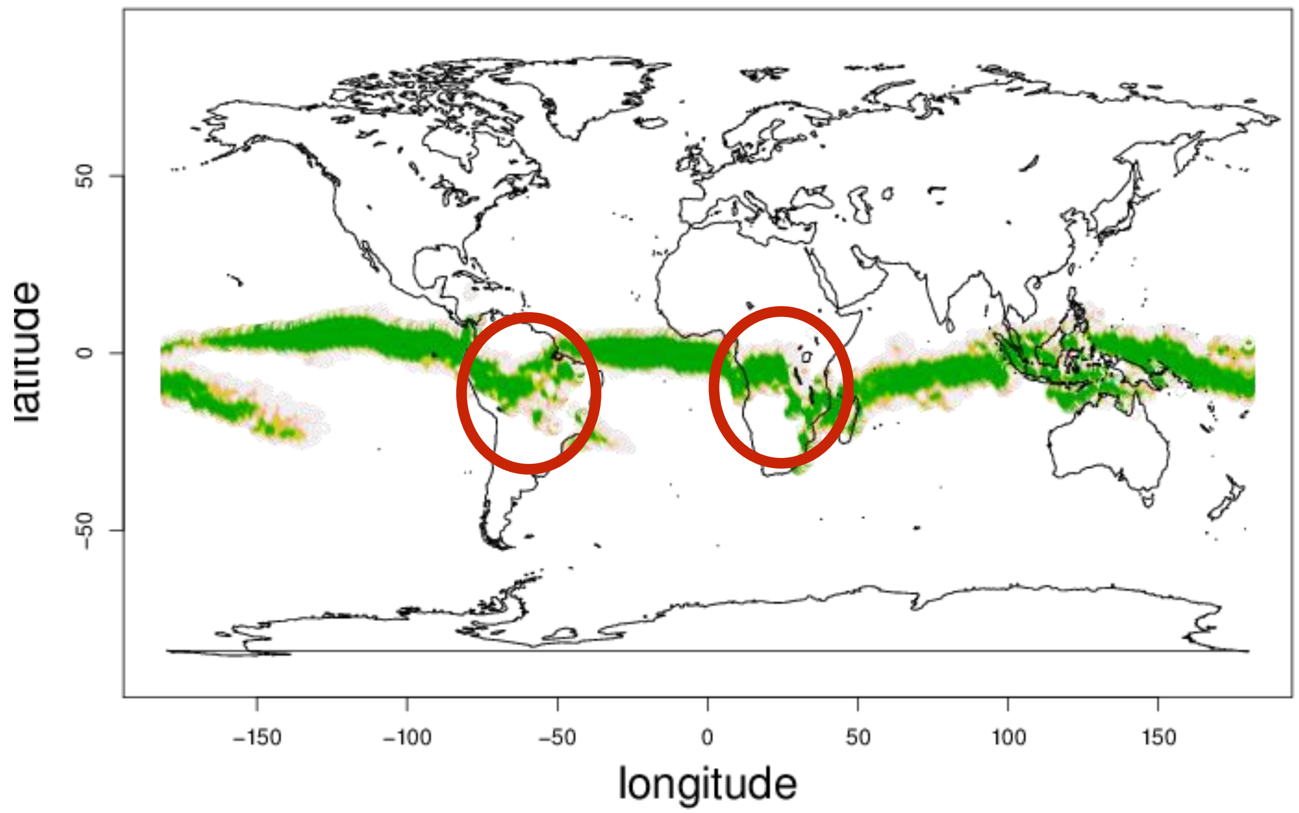
Application of new model to ATSR Cloudy measurements and to TCWV (January 2003) - Comparison with GlobVapour

AIRWAVE TCWV dataset

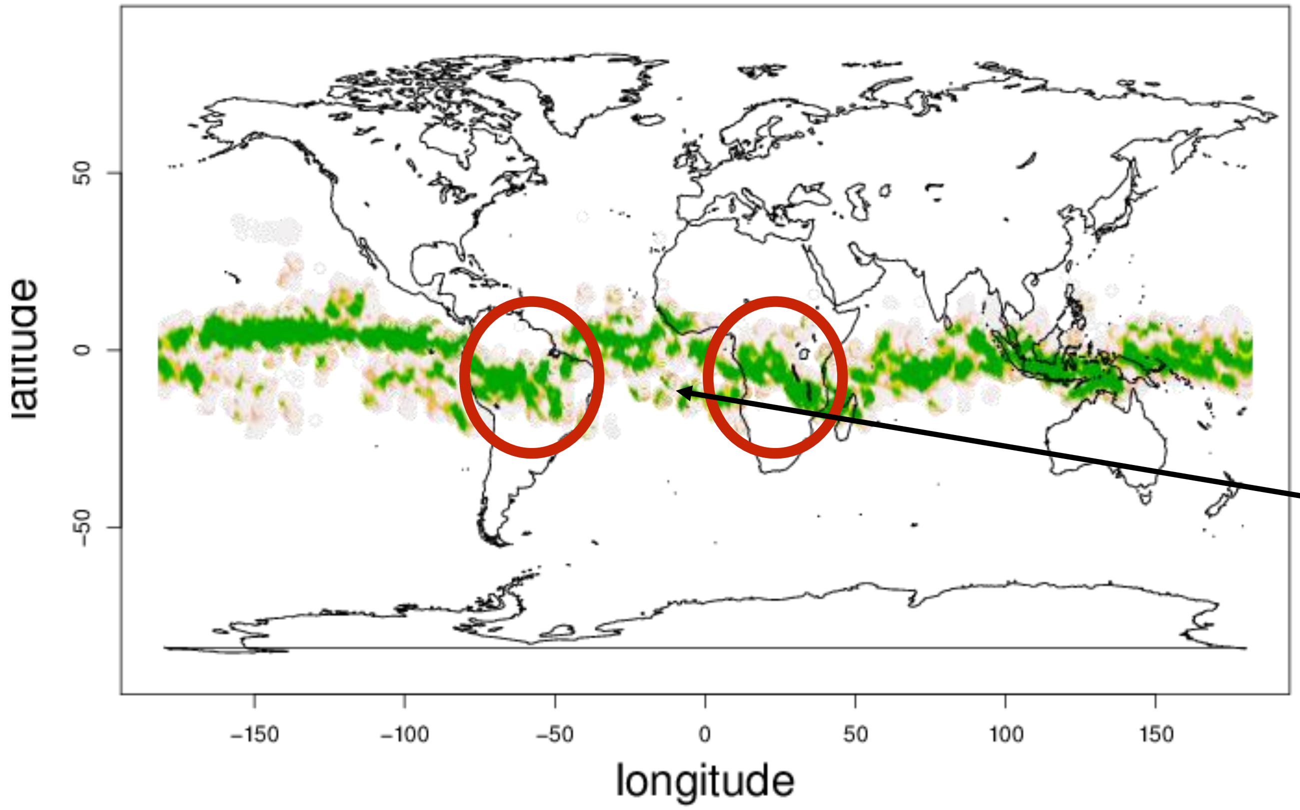


Raw approximations over land
Good over sea

GlobVapour TCWV dataset



ATSR Cloud dataset



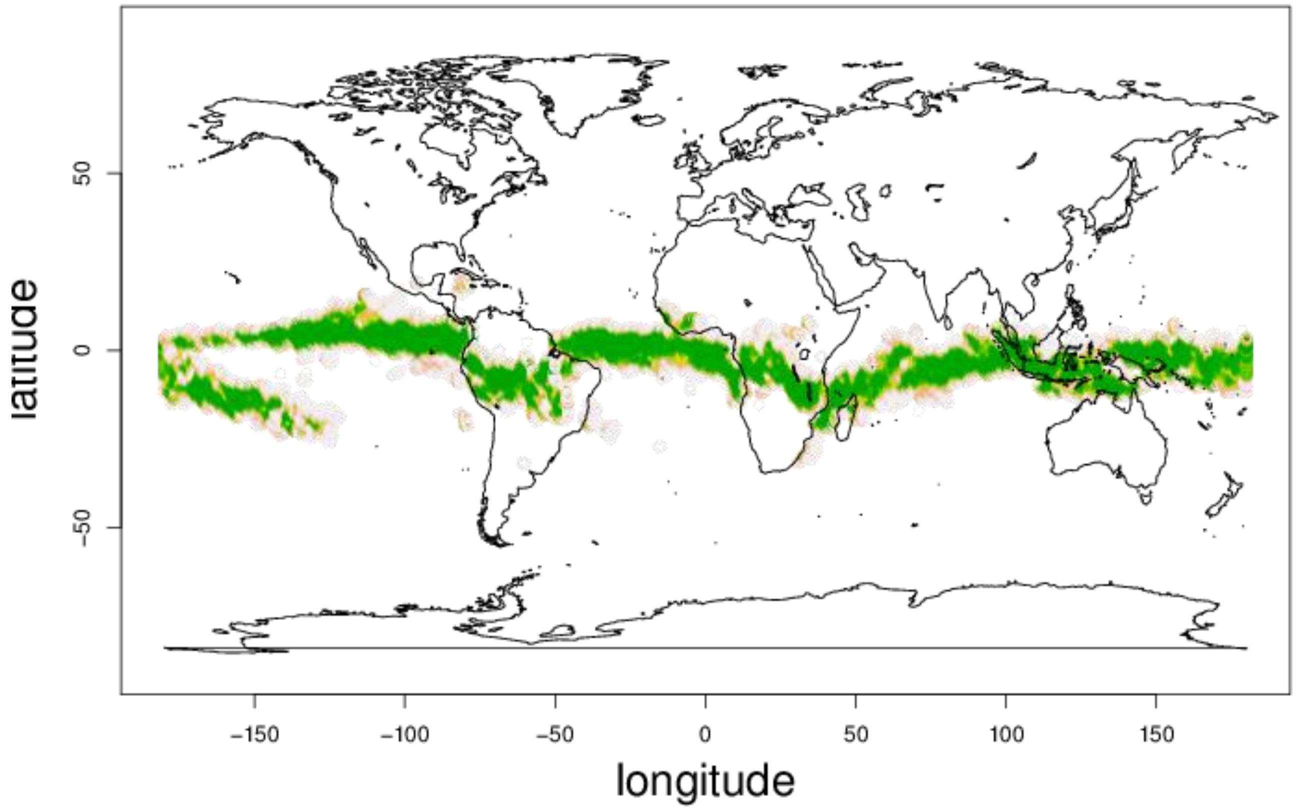
Good over land

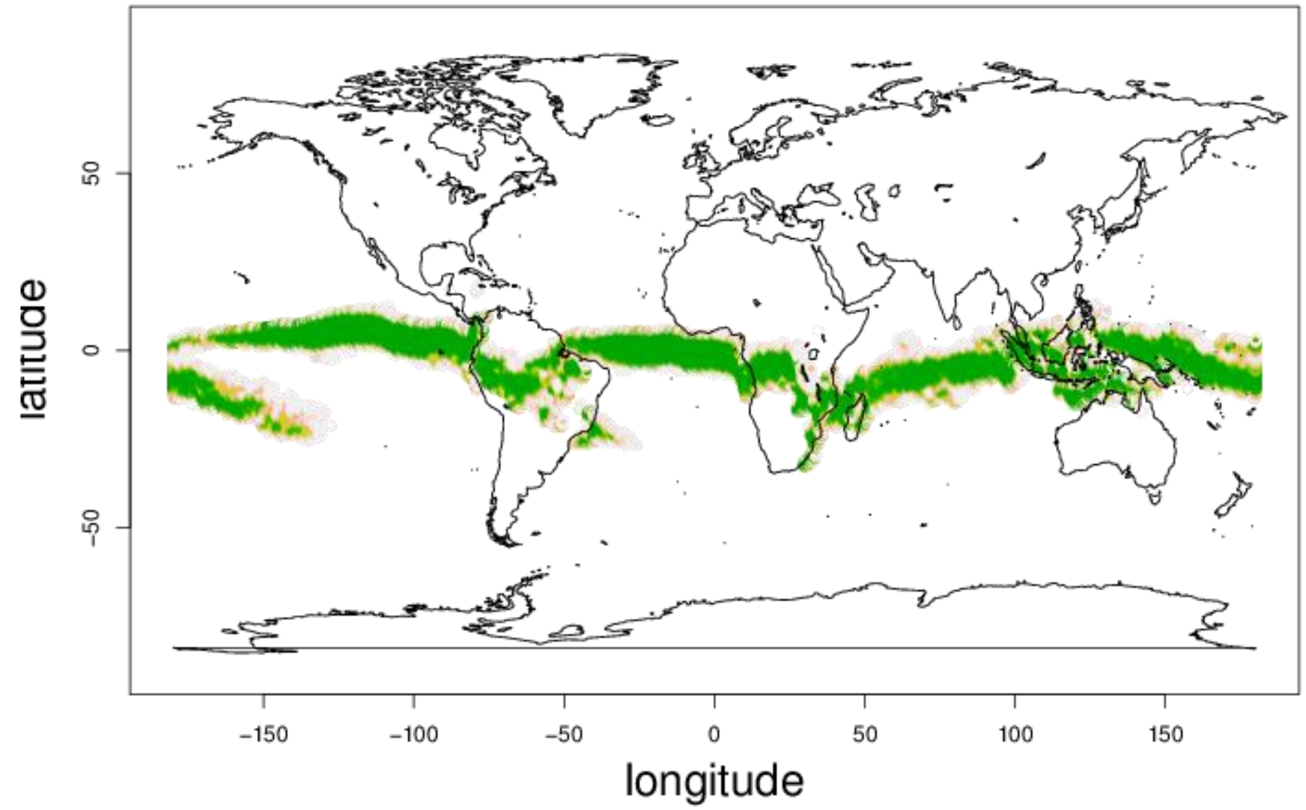
Application of new model to merged ATSR Cloudy measurements and TCWV (January and June 2003) - Comparison with GlobVapour

merged AIRWAVE TCWV and Cloud dataset

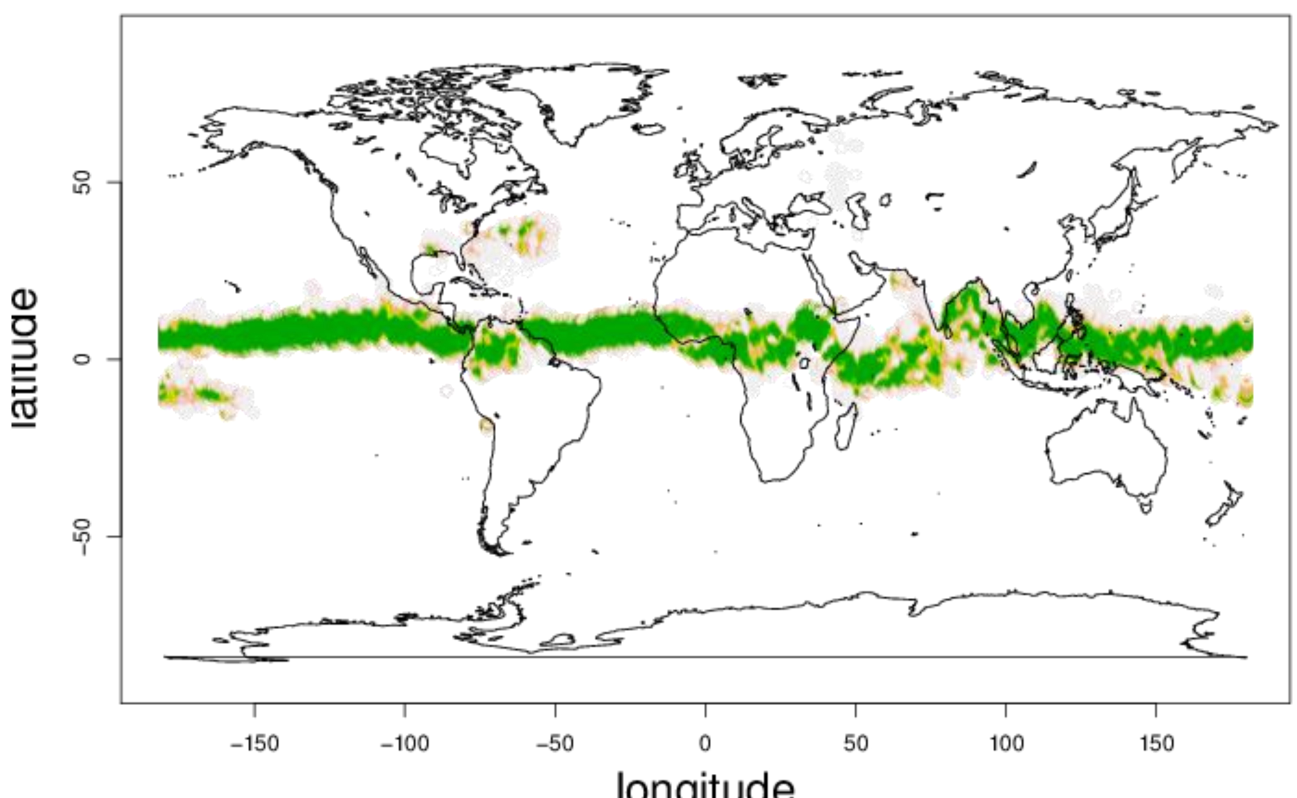
GlobVapour TCWV dataset

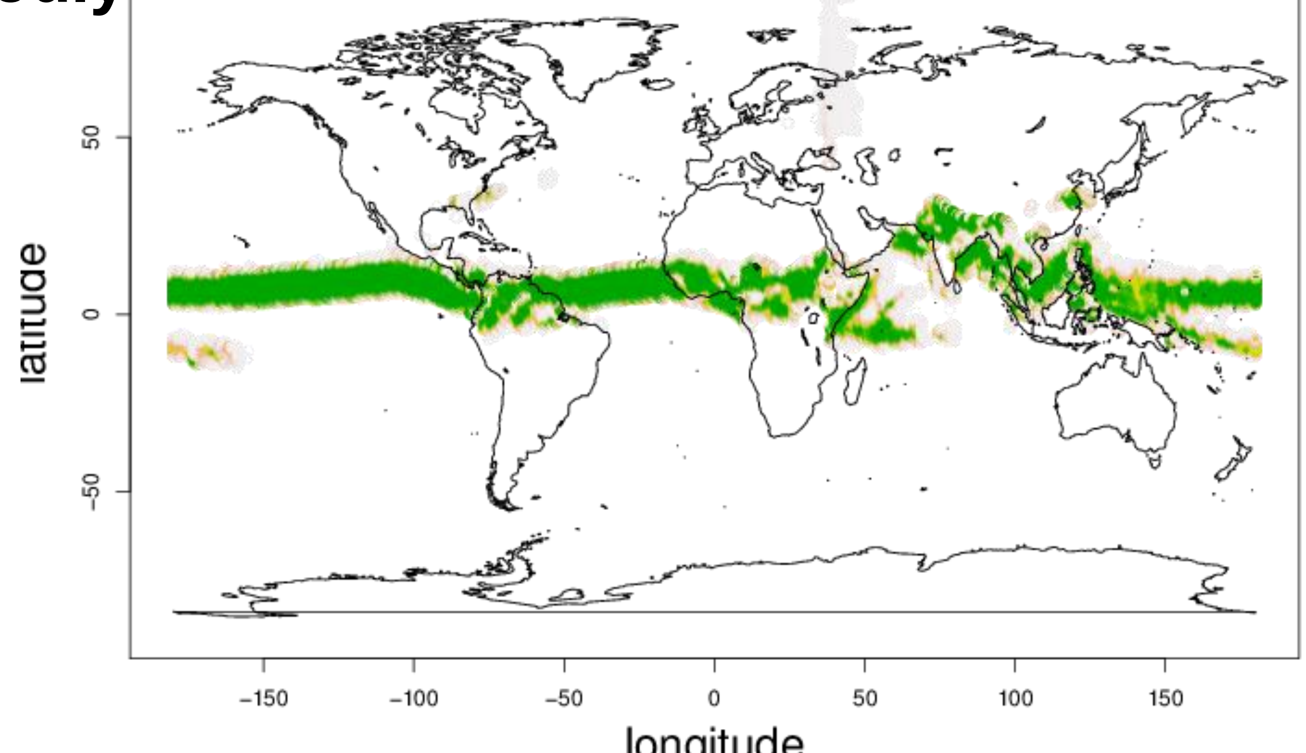
January





July



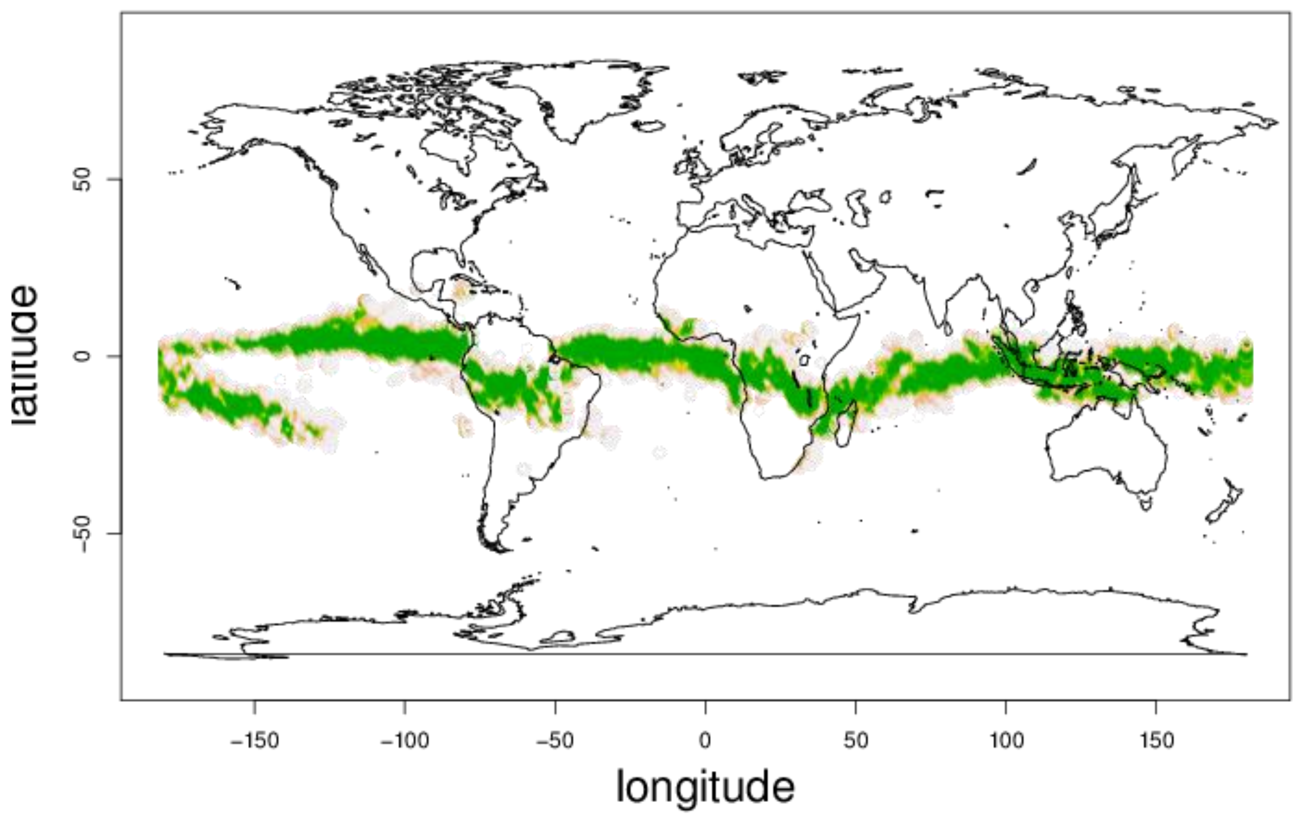


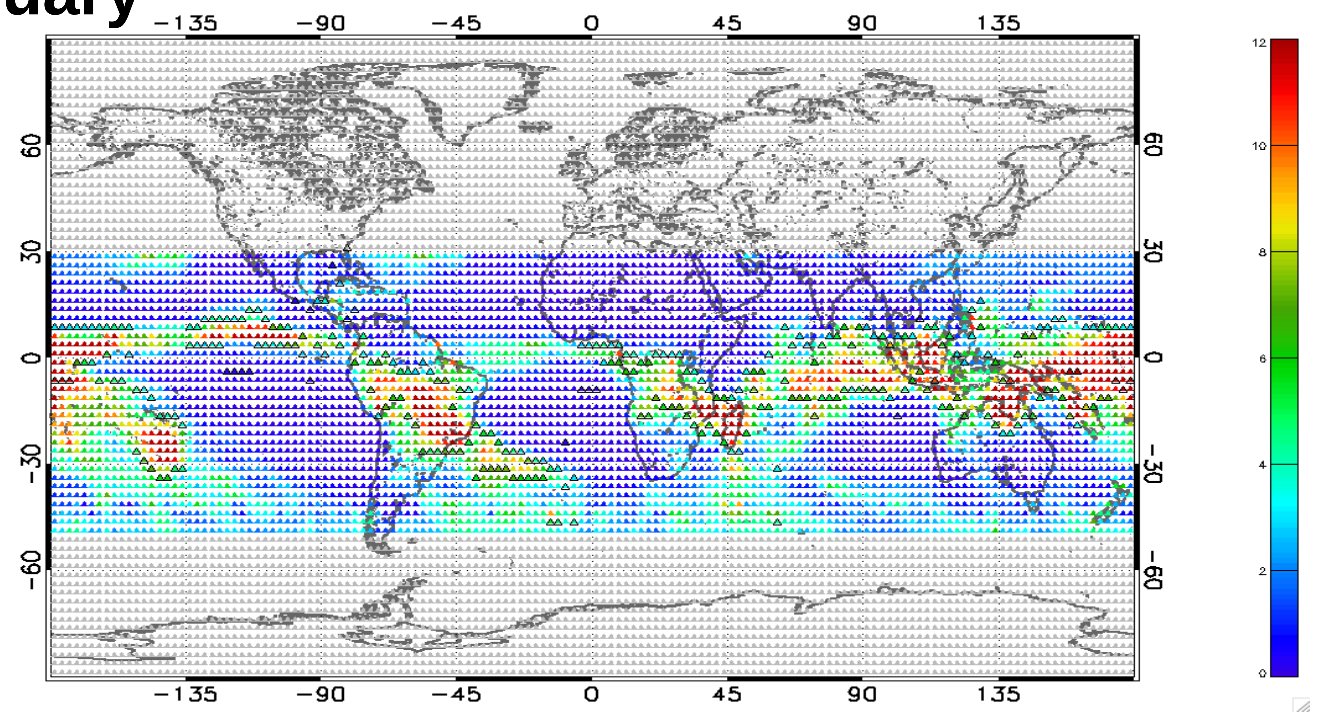
Application of new model to merged ATSR Cloudy measurements and TCWV (January and June 2003) - Comparison with GPCP

merged TCWV and Cloud AIRWAVE dataset

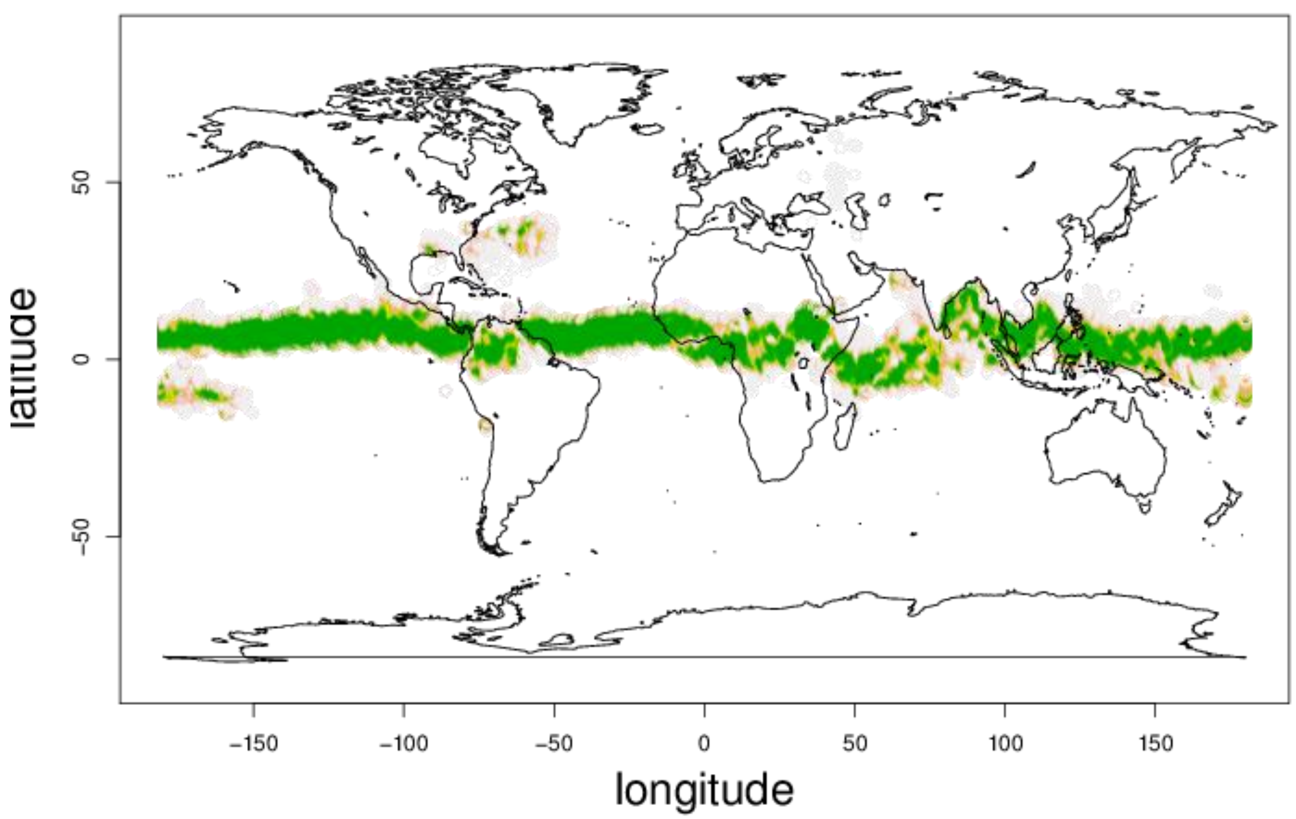
GPCP precipitation dataset

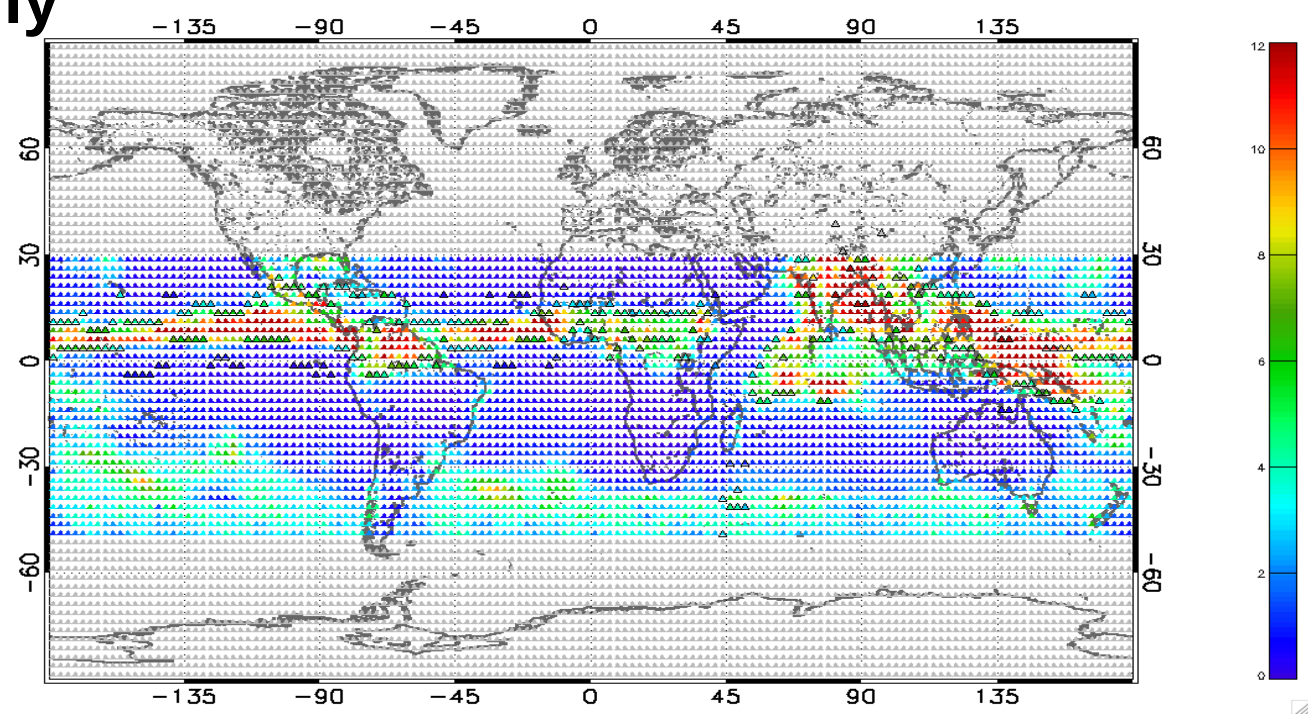
January



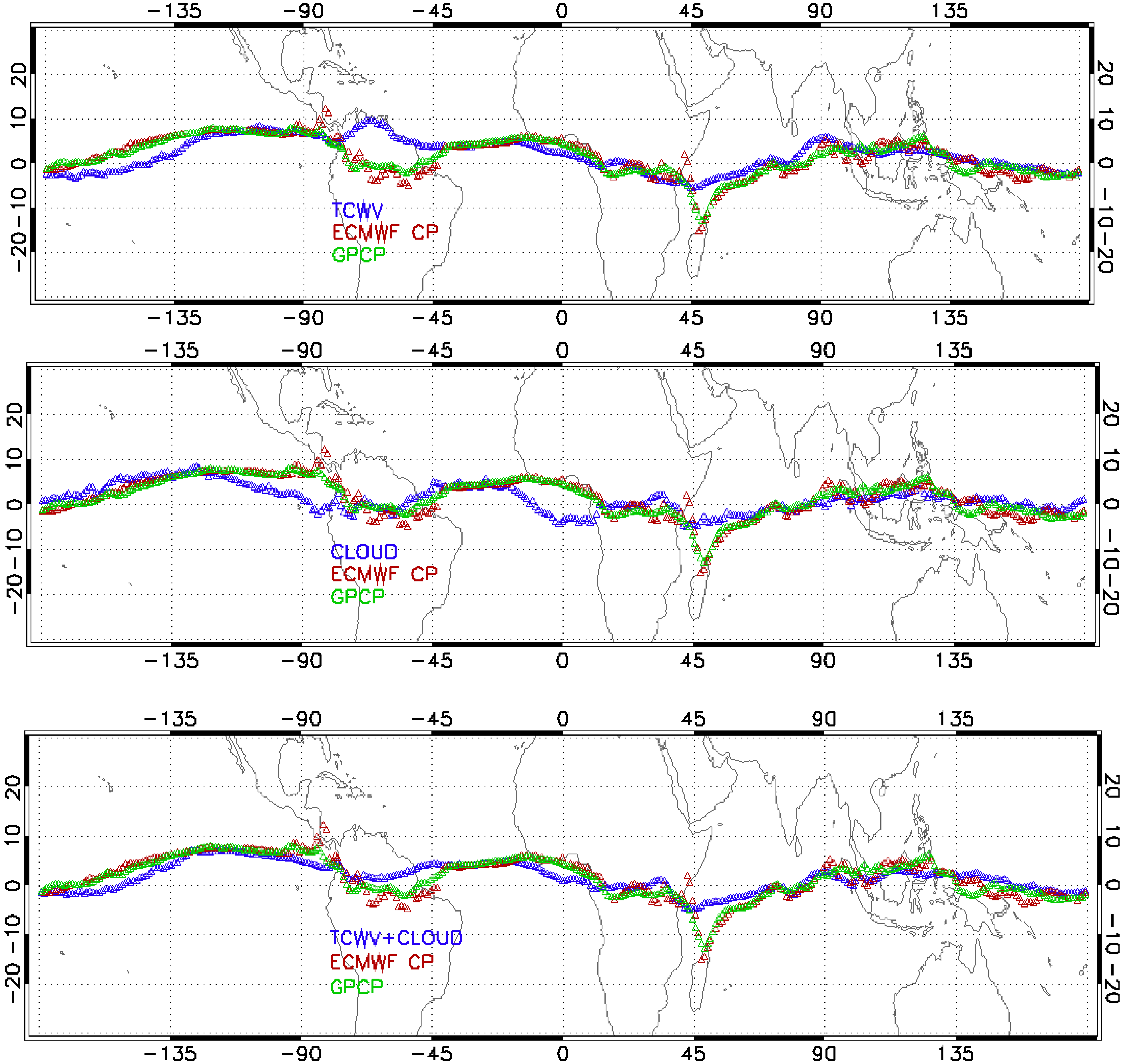


July





ITCZ central position: mean value, coverage of all datasets 1991-2012



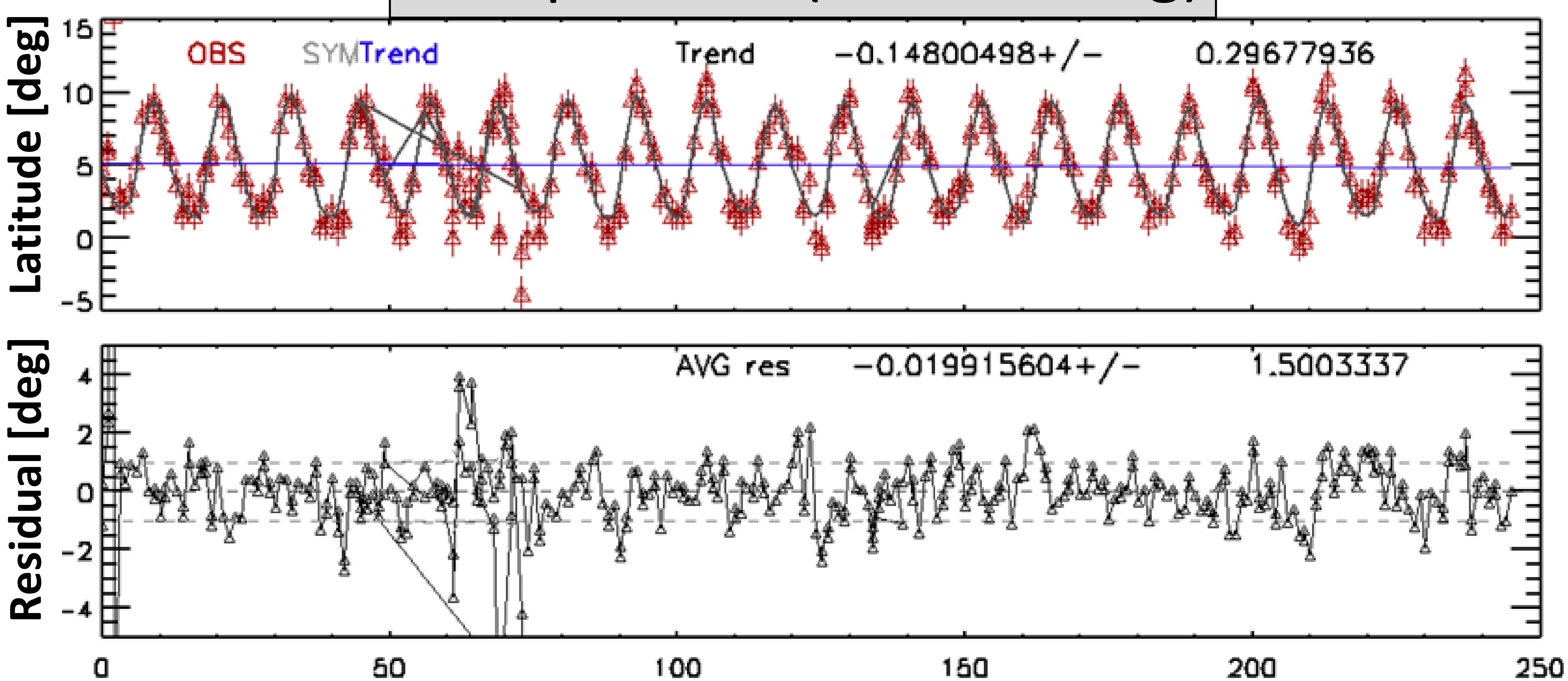
Trends analysis

$$f(k) = a + bt + \sum_{n=1}^{8}\left(c_n \cos\left(\frac{\omega t}{n}\right) + d_n \sin\left(\frac{\omega t}{n}\right)\right) + e \cdot \mathrm{ONI}$$

$$\omega = \frac{2\pi}{T} \qquad T = 3\,months$$

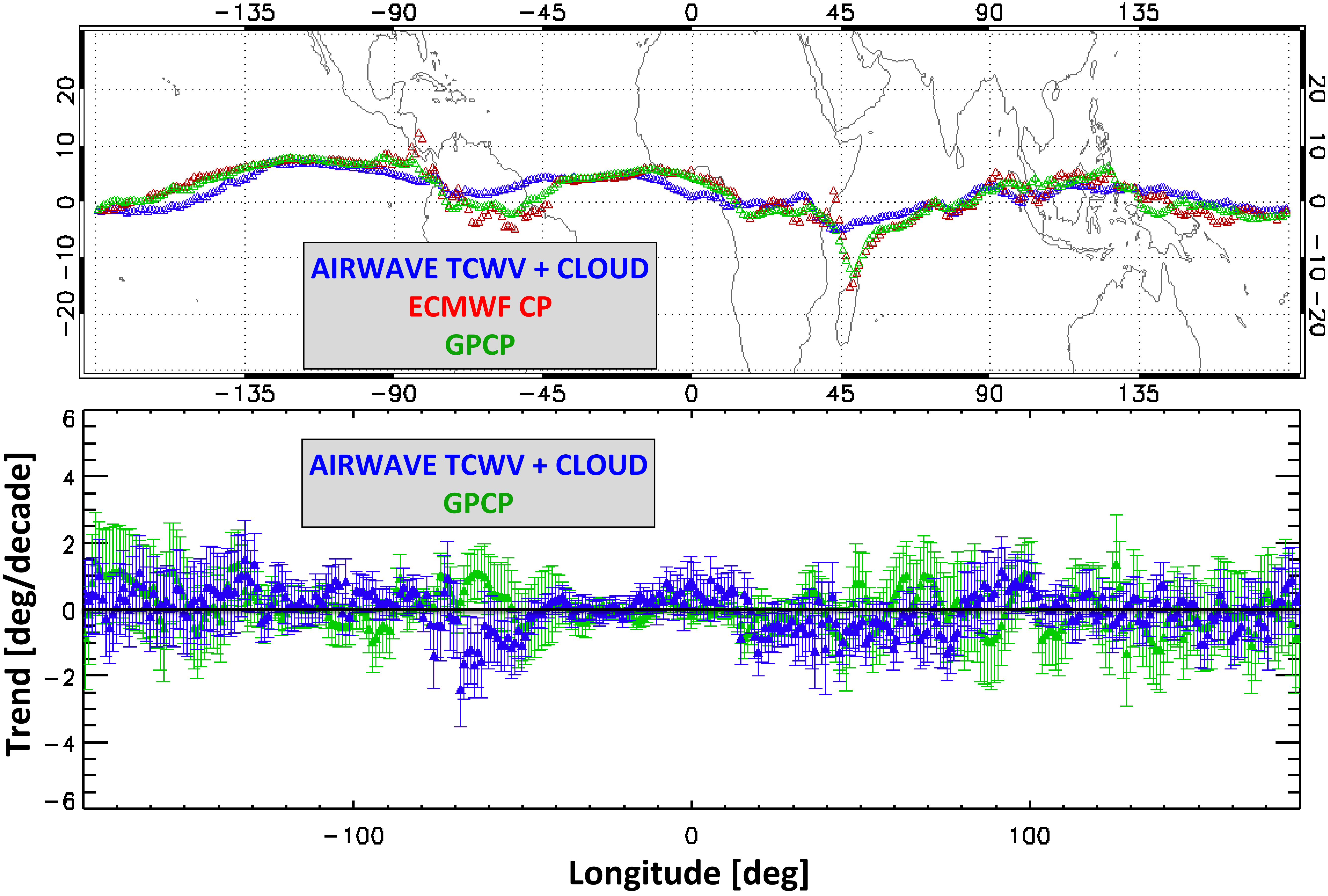
ONI = Oceanic Niño Index
(3-month SST Anomaly for Niño)

ITCZ position (LON=20 deg)

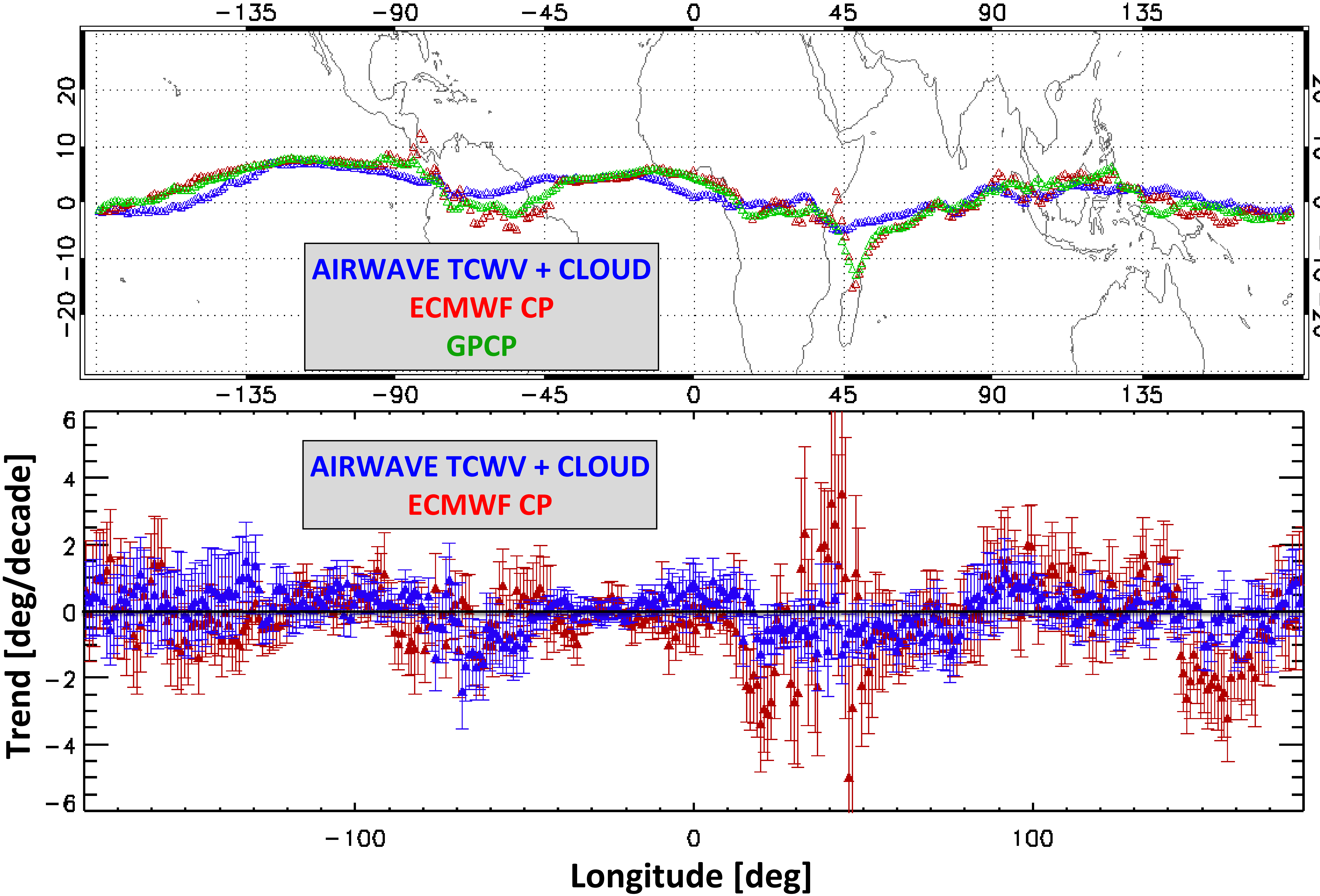


Months since November 1991

ITCZ central position: trend 1991-2012 vs GPCP and ECMWF CP



ITCZ central position: trend 1991-2012 vs GPCP and ECMWF CP



AIRWAVE v2: application to SLSTR measurements

The Sea and Land Surface Temperature Radiometer (SLSTR) has a strong heritage from AATSR instrument on Envisat

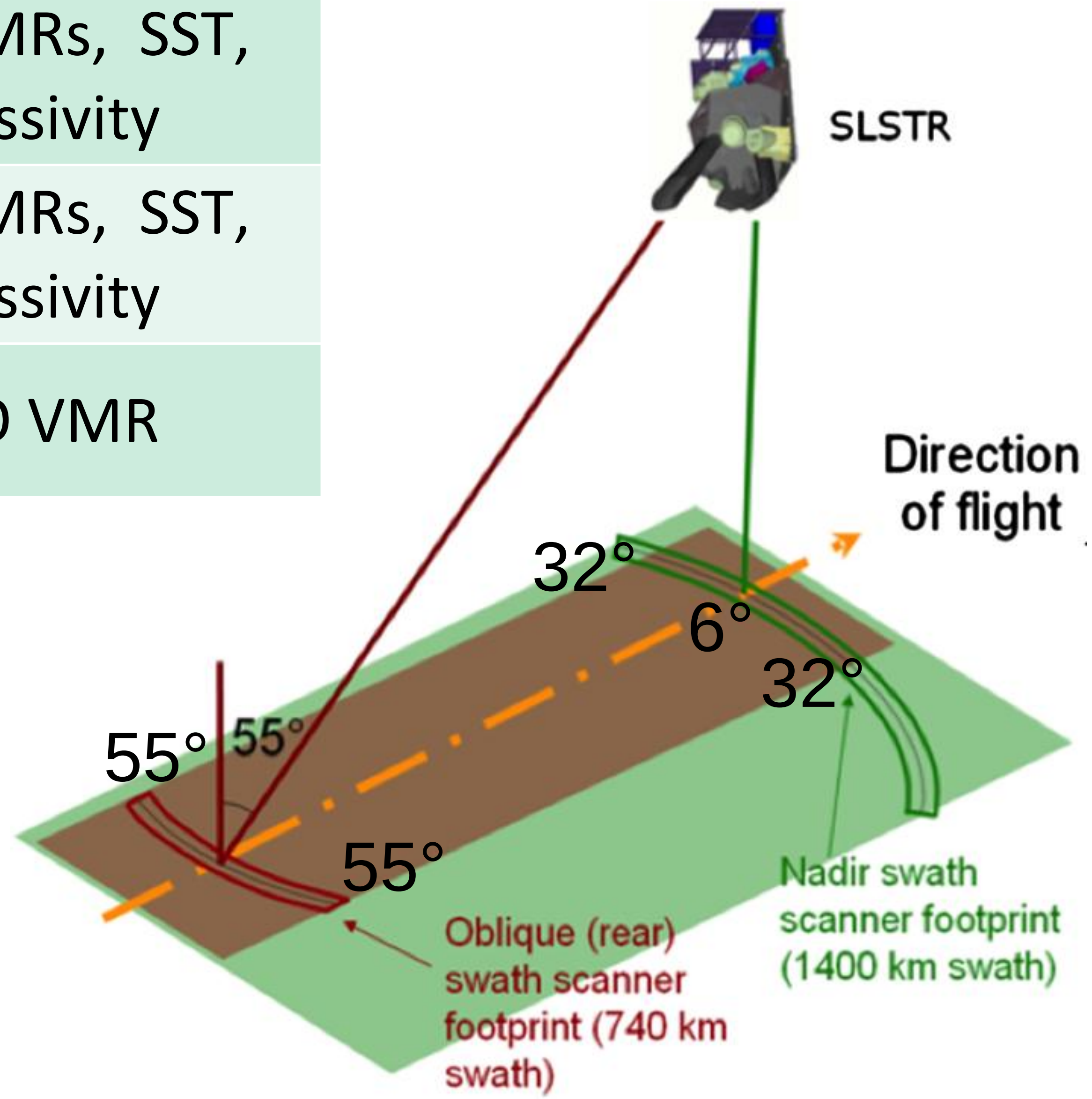
Satellite	Date
Sentinel 3A	16.02.2016
Sentinel 3B	2017
Sentinel 3C	2021
Sentinel 3D	202x

Specifications

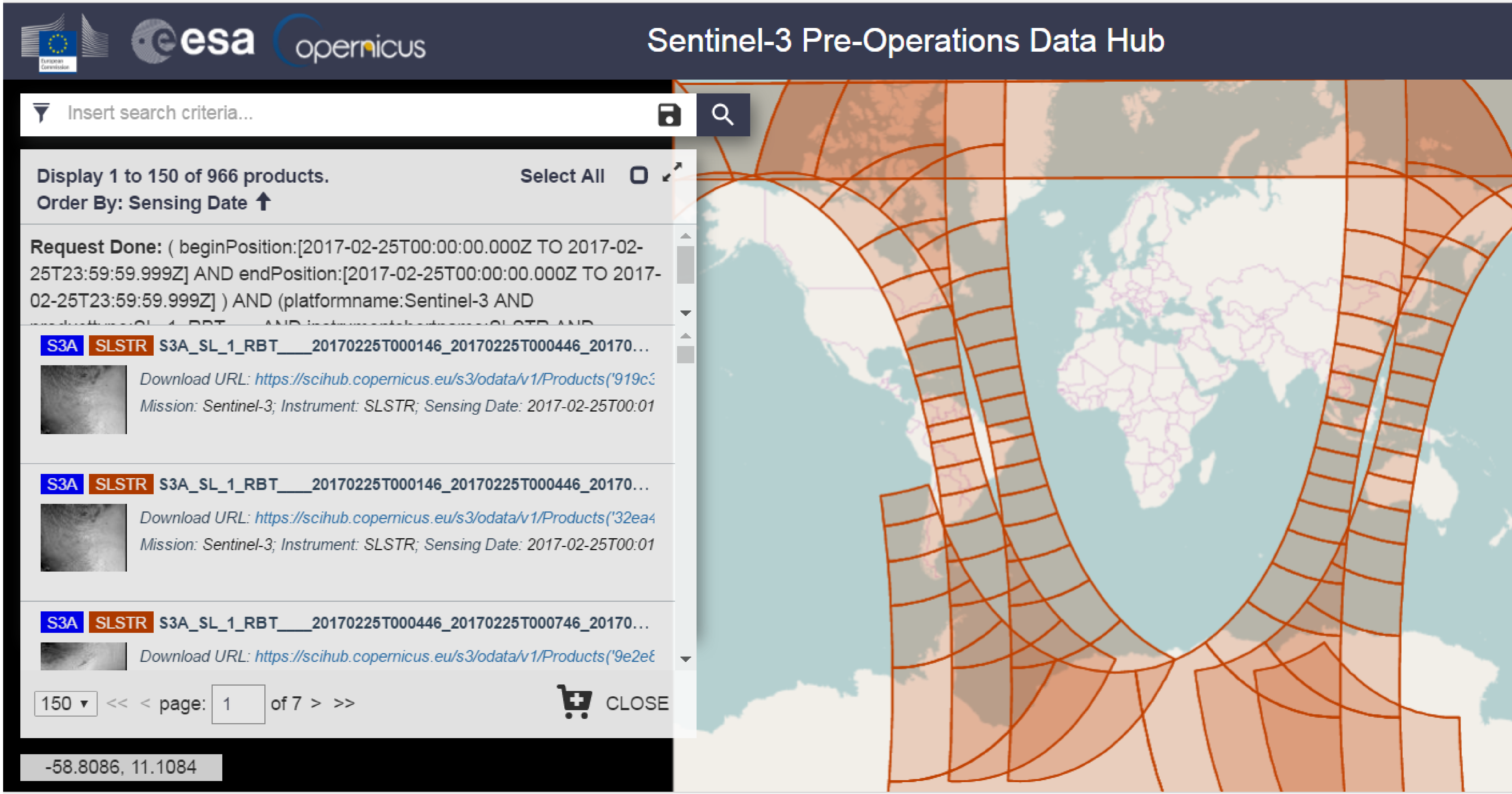
	Capability	SLSTR Specifications
Swath	Nadir view	> 1 400 km
	Oblique view	> 740 km
Global Coverage Revisit Times	1 satellite (dual view)	1.9 days (mean)
	2 satellites (dual view)	0.9 days (mean)
	1 satellite (nadir view)	1 day (mean)
	2 satellites (nadir view)	0.5 day (mean)
Spatial Sampling interval 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

AIRWAVE v2: application to SLSTR measurements

Scenarios	Effect on RTM inputs
Across track position (-450/450, step: 90)	NADIR and FORWARD angles
Instrument (SLSTR)	Slit function
Latitude (TRN,TRS, MDN, MDS, PLN, PLS)	T, p, VMRs, SST, Emissivity
Season (JAN, APR, JUL, OCT)	T, p, VMRs, SST, Emissivity
H_2O variability (x0.5, 1, 1.5)	H_2O VMR

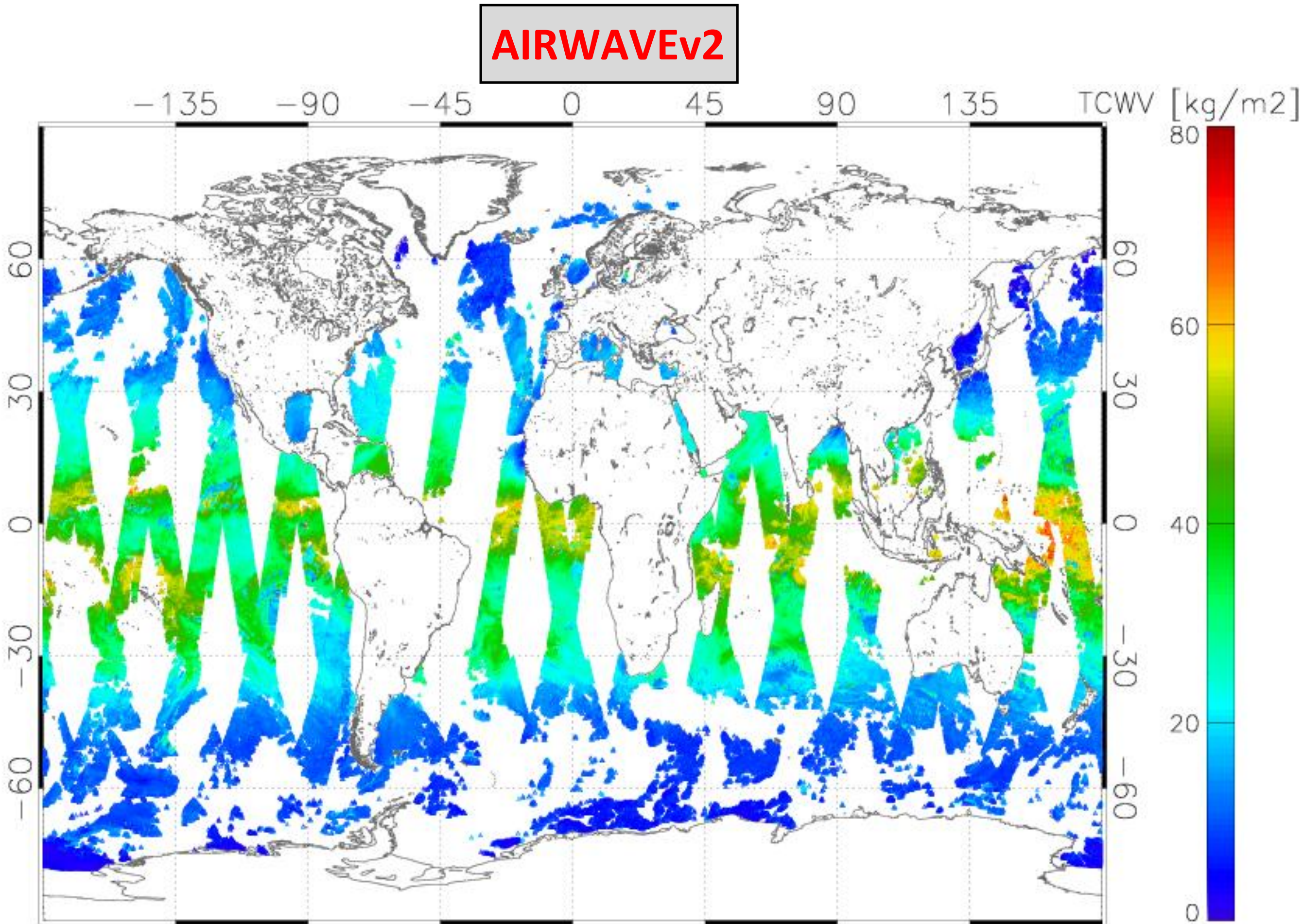


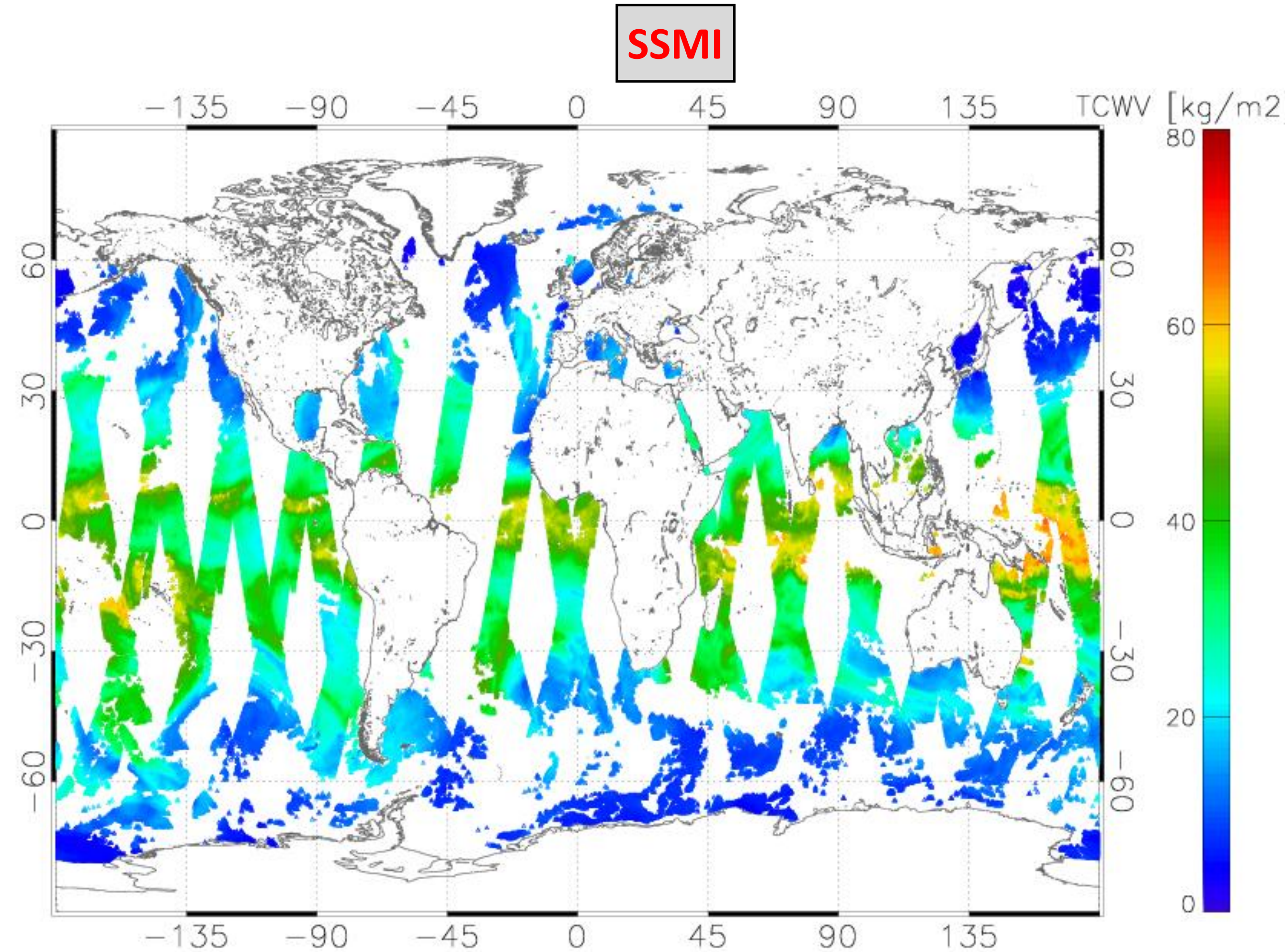
AIRWAVE v2: application to SLSTR measurements

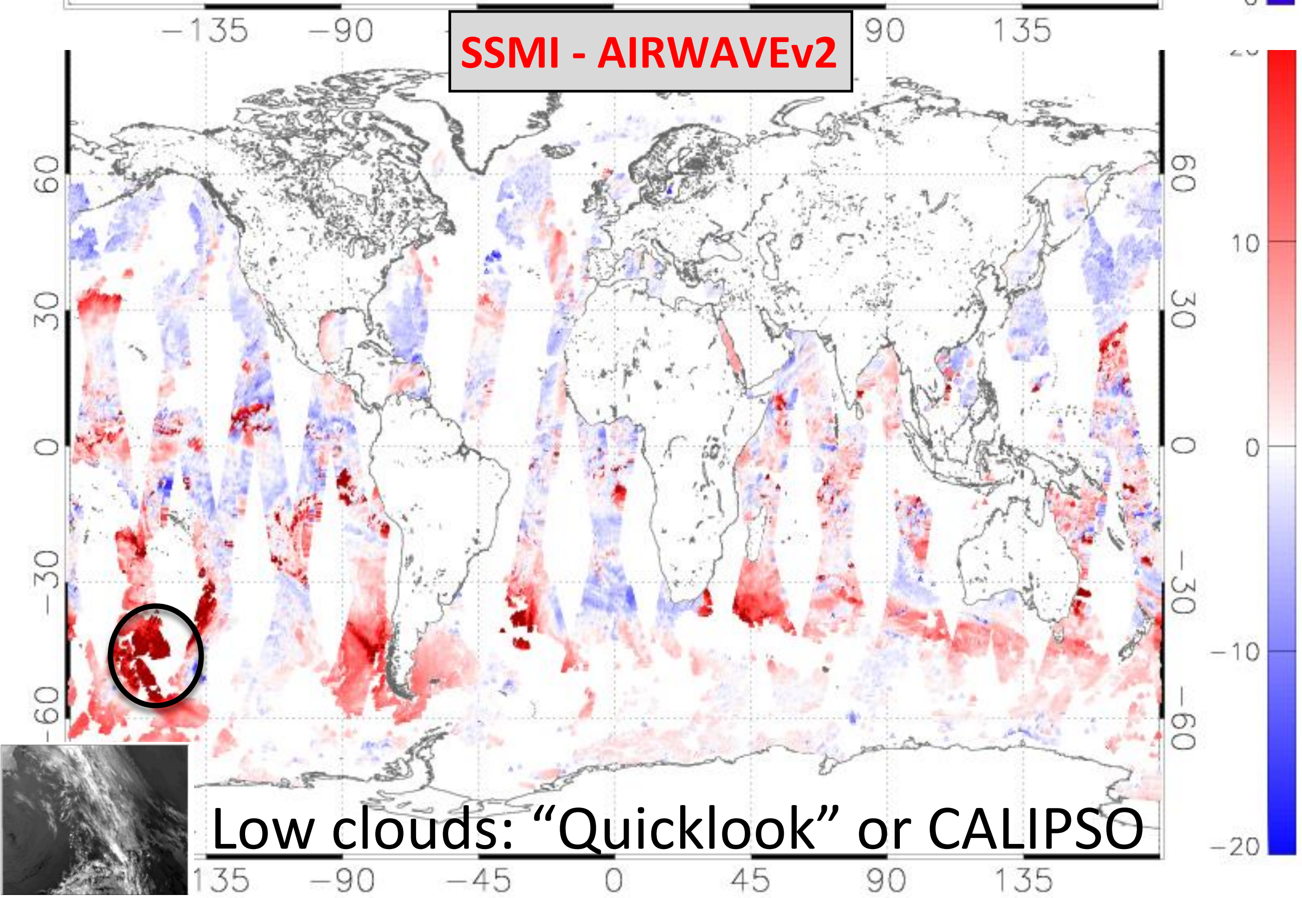


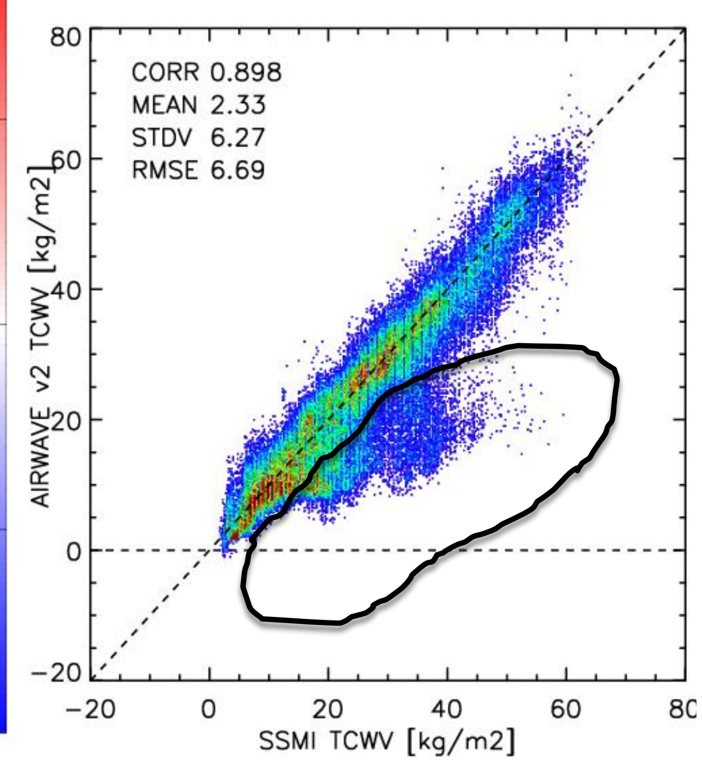
About 500 products/day (about every 3min sensing time)

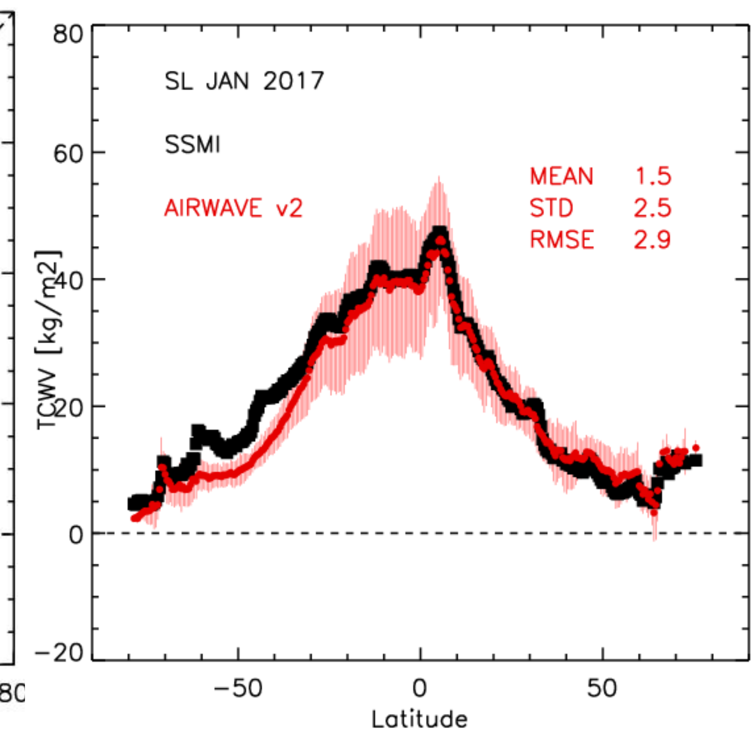
AIRWAVE v2: application to SLSTR measurements











Conclusions

- AIRWAVE v2 reduces the bias and the spread mainly at high latitudes respect to v1. Compared with SSMI and ARSA.

- ITCZ position trend: feasible with AIRWAVE TCWV monthly means + “cloudy” measurements.

- It is possible to apply AIRWAVE to SLSTR/S3 measurements: first results are encouraging!

Thank You!

The GNSS-derived Path Delay (GPD) algorithm was developed by the University of Porto aiming at computing the wet troposphere correction (WTC) for coastal regions where Micro-wave Radiometer (MWR) observations are invalid, envisaging the recovery of the Radar Altimeter (RA) data in these regions. The GPD-derived WTC is based on a space-time optimal interpolation that combines path delays measured by MWR and computed at more than 800 coastal/island Global Navigation Satellite System) GNSS stations.

Its most recent version, the GPD Plus (GPD+) estimates the WTC globally relying also on path delay observations from 19 scanning imaging MWR on-board various remote sensing missions. After adequate tuning, the GPD+ is applicable to any altimetric mission with or without an on-board MWR, as CryoSat-2 for which only a NWM-derived WTC would be, otherwise, available. To ensure consistency and WTC long term stability, and prior to their use in the GPD+, path delay observations from all radiometers were previously inter-calibrated with respect to the Special Sensor Microwave Imager (SSM/I) and SSMI/I Sounder (SSM/IS).

In the context of IDEAS+ (WP 3327, J. Bouffard), AATSR AIRWAVE V2 was used to estimate the WTC through GDP+, preliminary results were presented at the 10th Coastal Altimetry Workshop (Florence, 21-24 February 2017).

The image below displays the "measure of improvement" in RA Sea Level Anomaly (SLA) when using AIRWAVE with respect to ERA-I and MWR (ESA) TCWV.

"SLA Var. diff at crossovers " > 0 => degradation

"SLA Var. diff at crossovers " < 0 => improvement

As can be seen, for this particular application AIRWAVE performances are similar to ECMWF and much better than ESA MWR.