Water vapour total column from ATSR-like instruments: the design and application of the Advanced Infra-Red Water Vapour Estimator (AIRWAVE) tool

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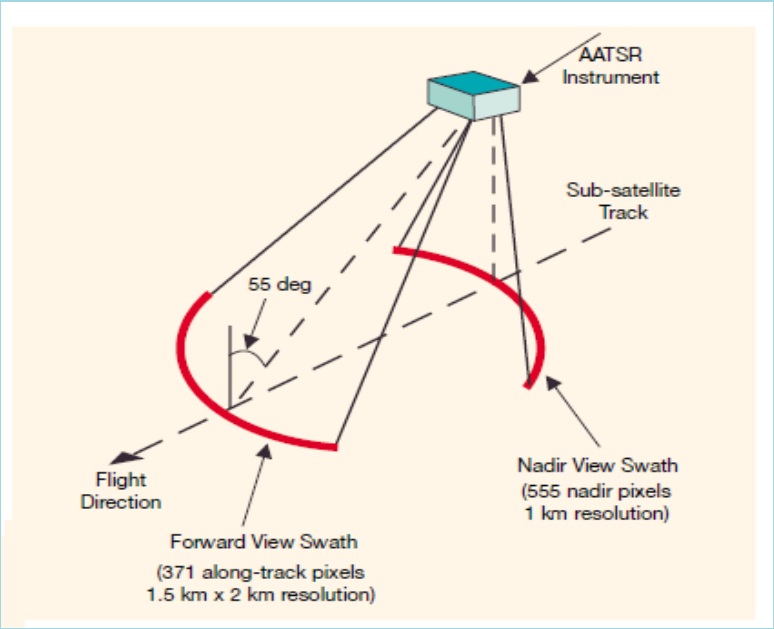
(A)ATSR series

- The ATSR series of instruments (ATSR-1 on ERS-1, ATSR-2 on ERS-2 and AATSR on ENVISAT) were designed to measure the Sea Surface Temperature (SST)
- They have measured continuously from 1991 to 2012 with overlaps
- A similar instrument (SLSTR) will be on board the Sentinel 3 satellite
- The instruments measured the Earth radiation on several spectral bands with two viewing geometries: Nadir (NAD) and Forward (FWD)

Channel	Central Wavelength	Bandwidth	Primary application	ATSR-1	ATSR-2	AATSR
0.55 µm	0.555 µm	20 nm	Chlorophyll		x	x
0.66 µm	0.659 µm	20 nm	Veg. Index		x	x
0.67 µm	0.865 µm	20 nm	Veg.Index		x	x
1.6 µm	1.61 µm	0.3 µm	Cloud mask	x	x	x
3.7 µm	3.70 µm	0.3 µm	SST	x	x	x
11 µm	10.85 µm	1.0 µm	SST	x	x	x
12 µm	12.00 µm	1.0 µm	SST	x	x	x

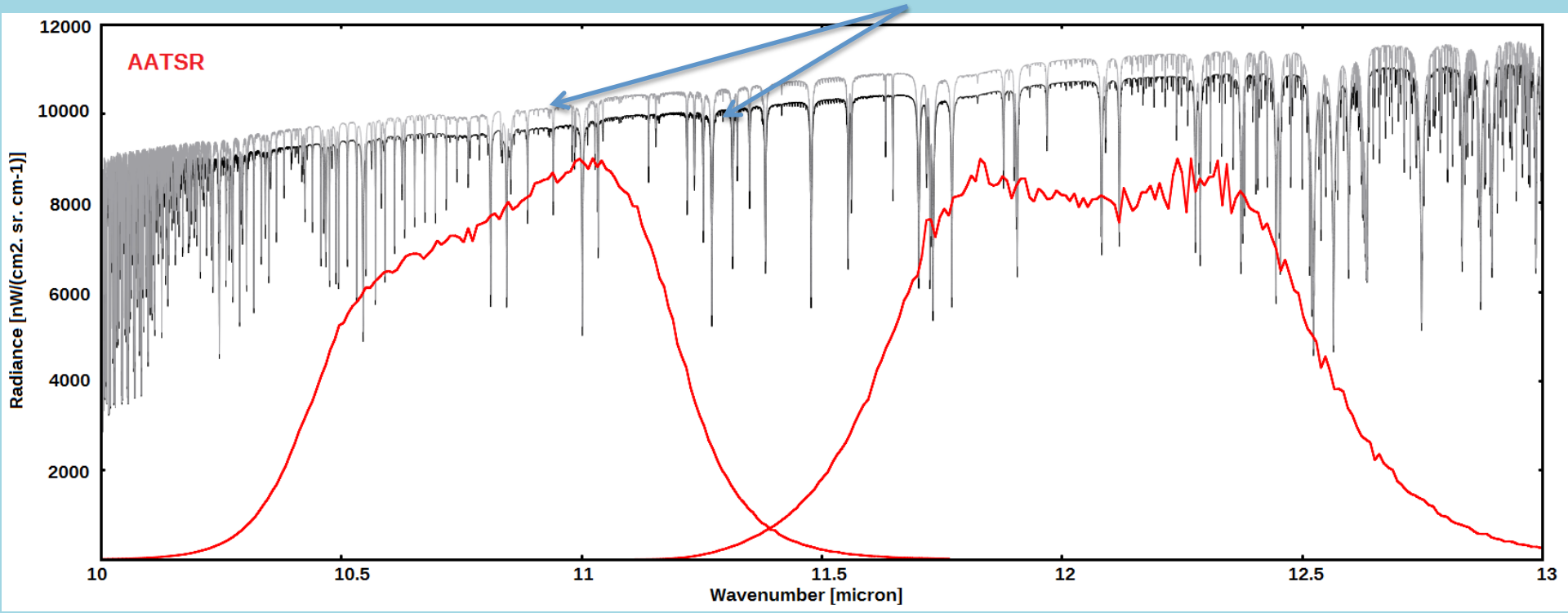
AATSR on ENVISAT

(A)ATSR viewing geometries

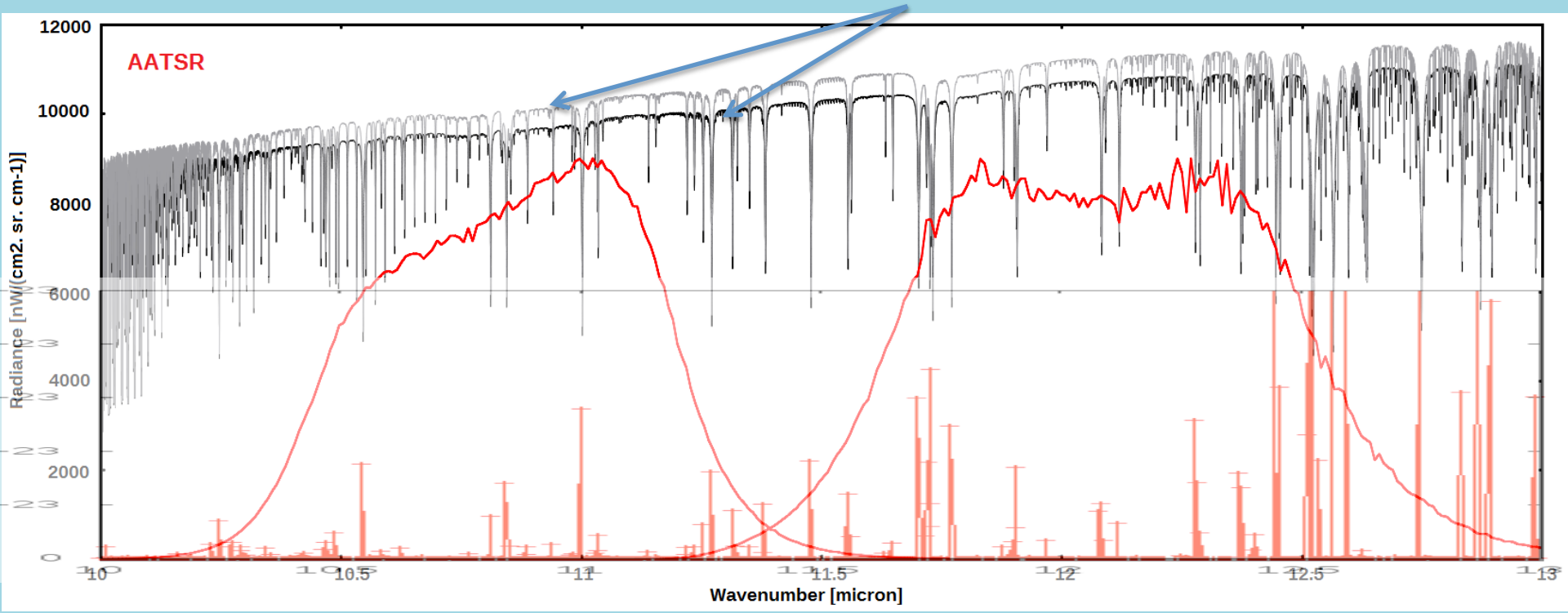


Brightness Temperatutres (BT) from 11 and 12 μm (A)ATSR channels used for SST retrieval (1kmx1km resolution).

(A)ATSR 11 and 12 μm channels



(A)ATSR 11 and 12 μm channels



The AIRWAVE algorithm

- AIRWAVE (Advanced Infra-Red Water Vapour Estimator) using:
  - the BTs measured in the 11 and 12 µm channels in FORWARD and NADIR view acquired in cloud free scenarios over the seas
  - Calculations from Radiative Transfer Forward Models
  - Sea surface Emissivity database
- Computes the Total Column of Water Vapour (TCWV) from the ATSR Series at very high spatial resolution (1km x 1km)
- Main advantages:
  - Use of RTM calculations no empirical adjustments
  - Fast retrieval

Description of the AIRWAVE algorithm

- The algorithm is based on :
  1. the relation between the IR radiance at TOA observed by ATSR @ 11 and 12 µm and the atmospheric optical depth (mainly due to Water and CO_2)
  2. The same TCWV is observed by the Forward and Nadir views
- Makes use of a simple expression

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

$$\Phi_{NAD} = \frac{\ln\left(\frac{J_{NAD_1}^{\lambda_1}}{J_{NAD_2}^{\lambda_2}}\right) - E_{NAD} - \Delta\tau_{CO2} - const}{\Delta\sigma_{NAD}}$$

radiances emissivity scaled water vapour cross section

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

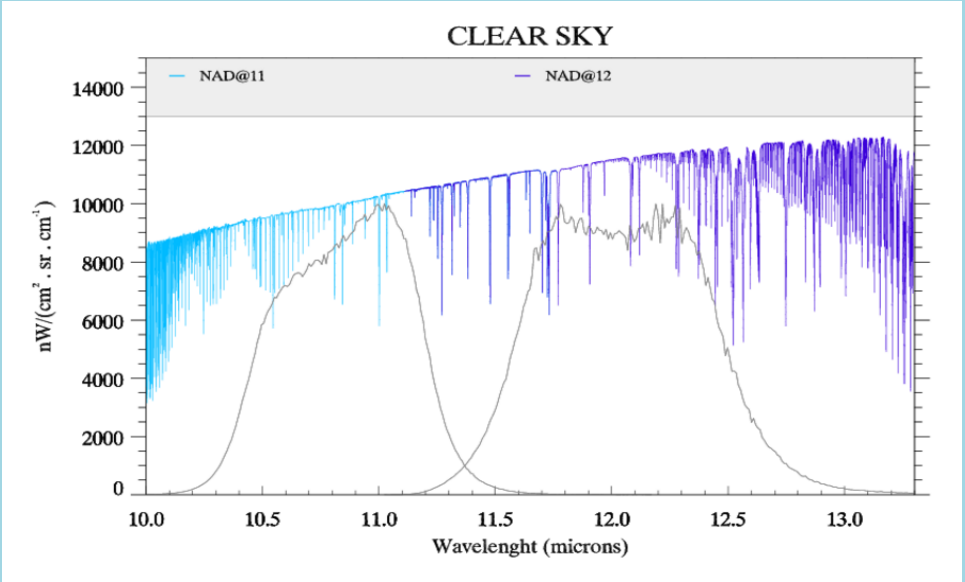
The AIRWAVE algorithm

RTM calculations and retrieval parameters

- The "**G**" parameter express the ratio between the radiance contribution at TOA given by the atmosphere and the surface.
- In the AIRWAVE algorithm the "**G**" parameter is calculated through the use of a RTM specifically developed to simulate (A)ATSR radiances.

RTM model

- Atmospheric optical depth computed with the algorithm developed for MIPAS (GBB_clouds) injected to the DISORT solver
- High resolution spectra (0.0005 cm^{-1}) convolved with ATSR filter functions to simulate BTs at 11-12 µm



The AIRWAVE algorithm

RTM calculations and retrieval parameters

- We have simulated two different atmospheric scenarios Tropical and Mid-Latitude

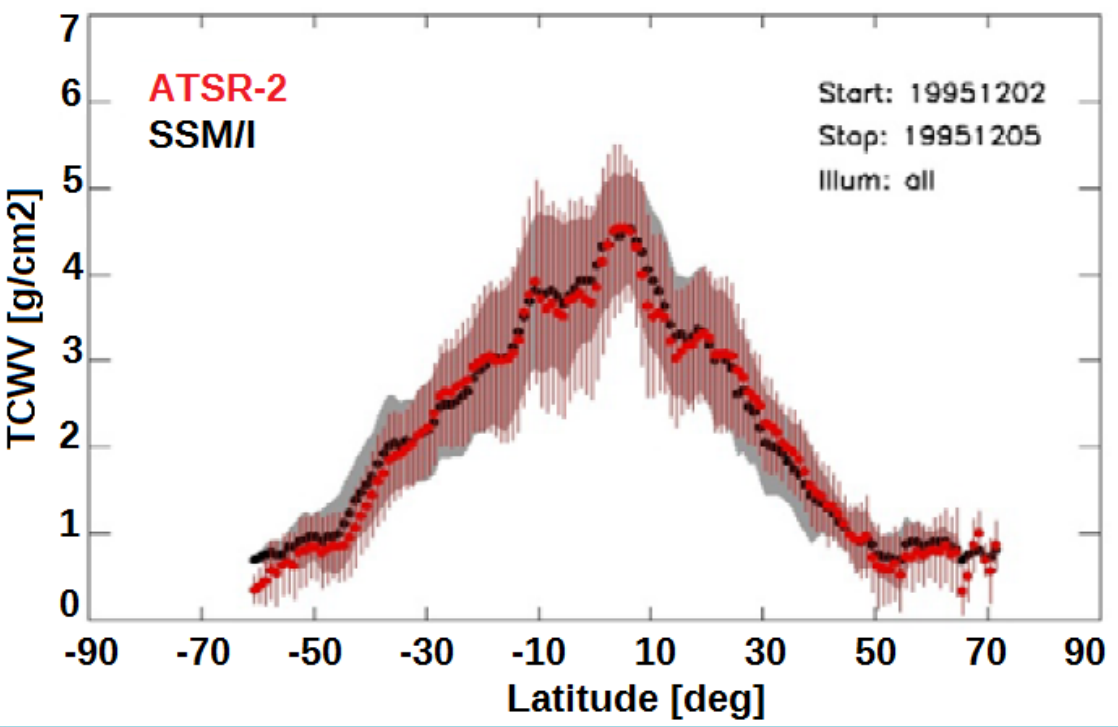
G_{FWD}/G_{NAD} ratio	Tropical	Mid-Latitude
ATSR-1	1.6654	1.6153
ATSR-2	1.6434	1.5885
AATSR	1.6364	1.5779

- Tropical&Mid-Latitude parameters are used. The final set of parameters used for the first implementation of AIRWAVE to compute TCWV are:

	λ_1 [μm]	λ_2 [μm]	$\Delta\sigma_{NAD}$	$\Delta\sigma_{FWD}$	δ	α	β
ATSR-1	10.9159	11.9107	1.49	2.41	1.65	50.7	-49.7
ATSR-2	10.9302	12.0485	1.74	2.78	1.63	50.5	-49.5
AATSR	10.8445	12.0321	1.90	3.02	1.62	53.1	-52.1

The AIRWAVE algorithm
application and validation

- AIRWAVE has been integrated in the ESA GRID environment (GPOD) for the bulk processing of the whole ATSR missions (1991-2012): TCWV retrieved at 1x1 km^2 and degraded to 0.25°x0.25° spatial resolution for validation purposes.



Comparisons with SSM/I and ECMWF data over 3 days in different years show that the
Mean bias < ± 0.1 g/cm^2 (± 2 %)
RMS < 0.4-0.5 g/cm2

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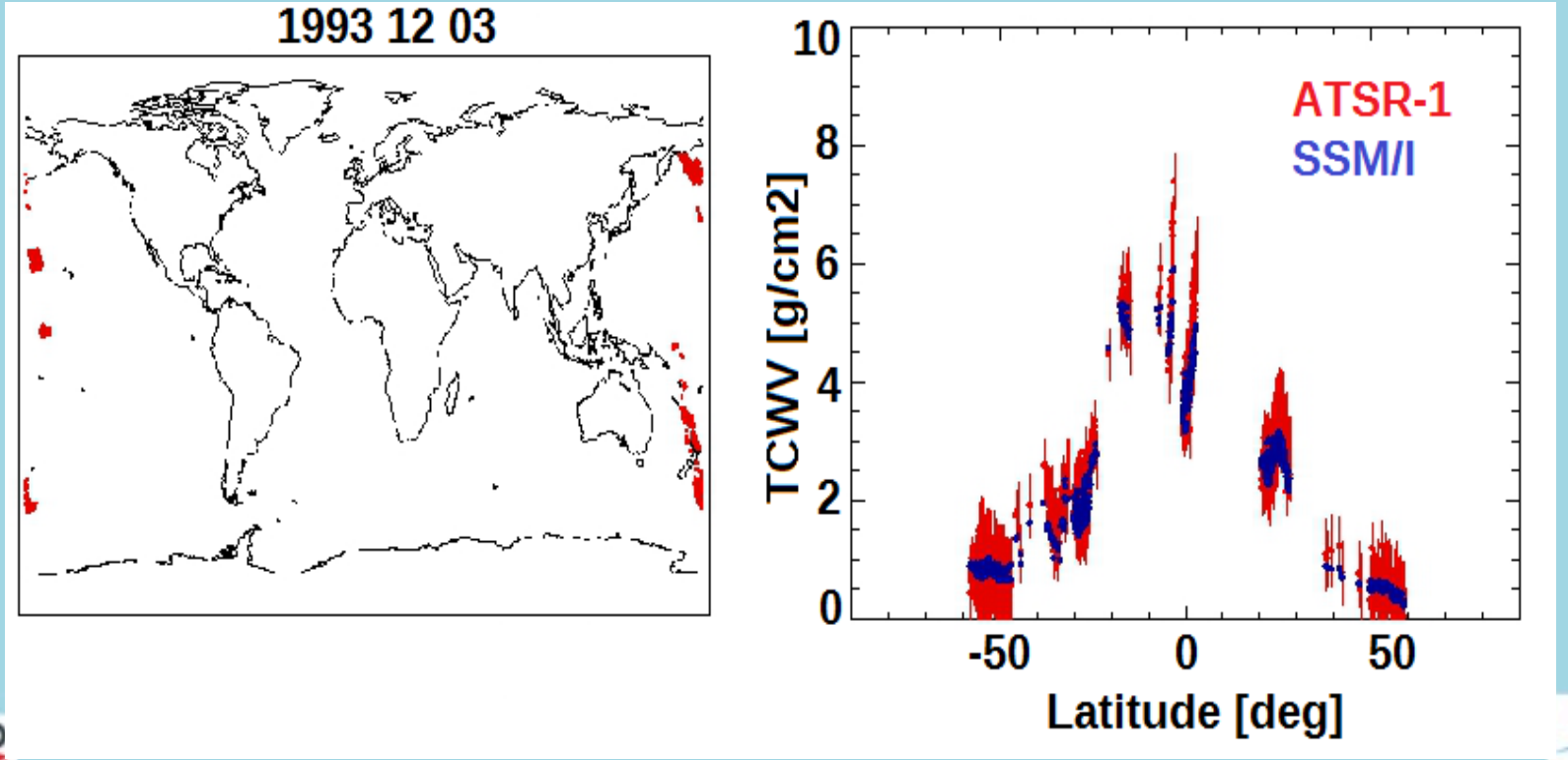

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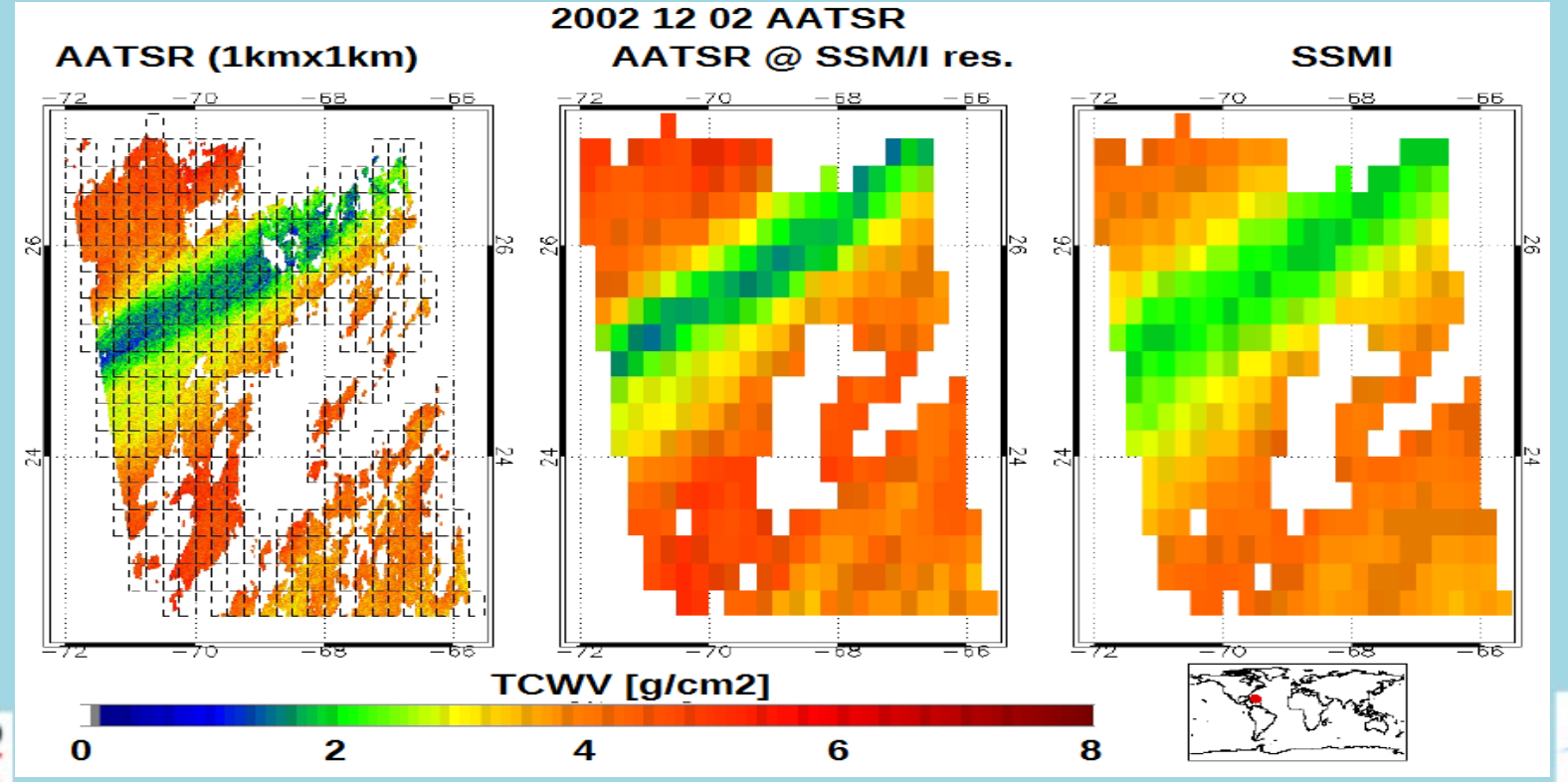

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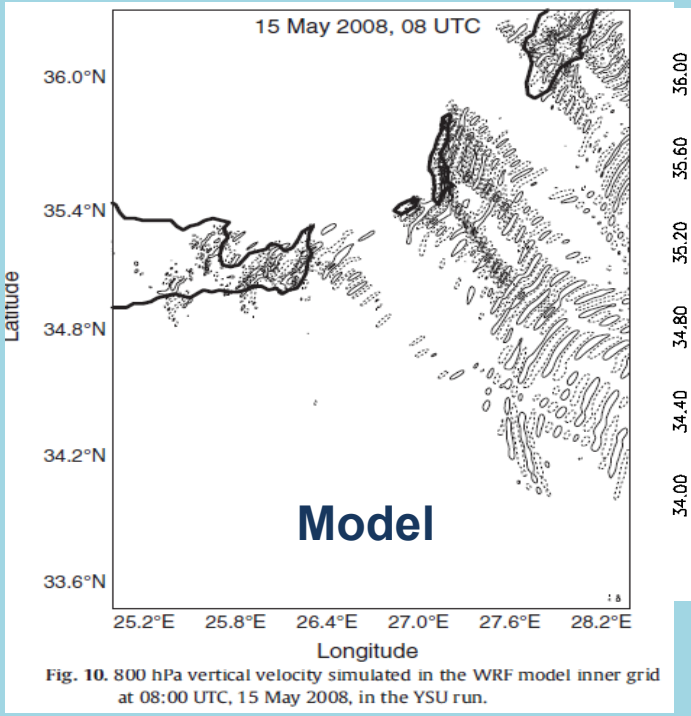
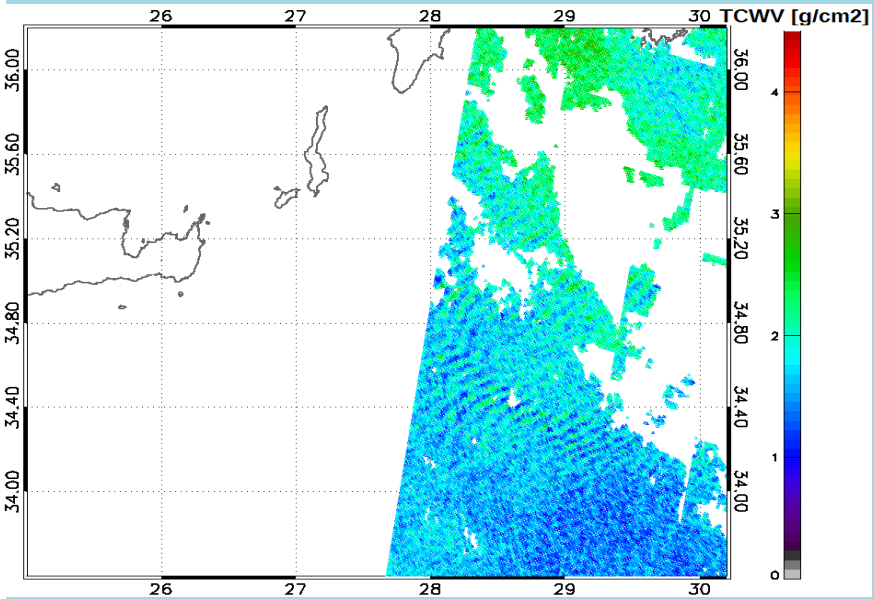


Fig. 10. 800 hPa vertical velocity simulated in the WRF model inner grid at 08:00 UTC, 15 May 2008, in the YSU run.



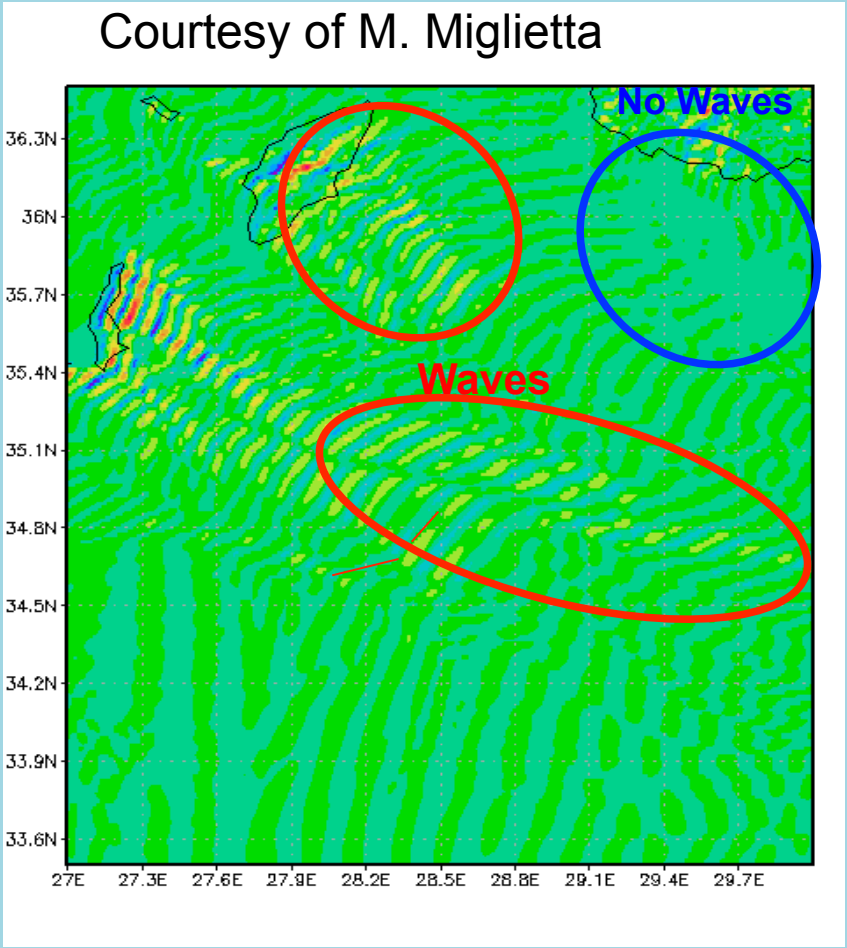
ATSR

From Miglietta et al., "A comparison of WRF model simulations with SAR wind data in two case studies of orographic lee waves over the Eastern Mediterranean Sea" Atmospheric Research, 102-121,2013.

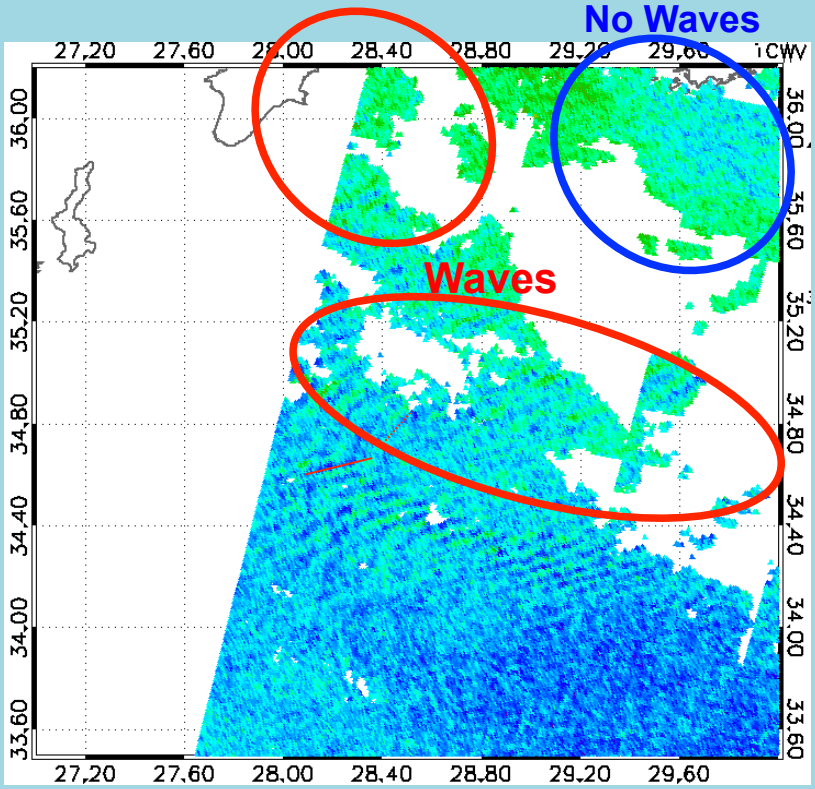
The AIRWAVE algorithm

Lee Waves

Courtesy of M. Miglietta



MODEL



ATSR

The AIRWAVE algorithm

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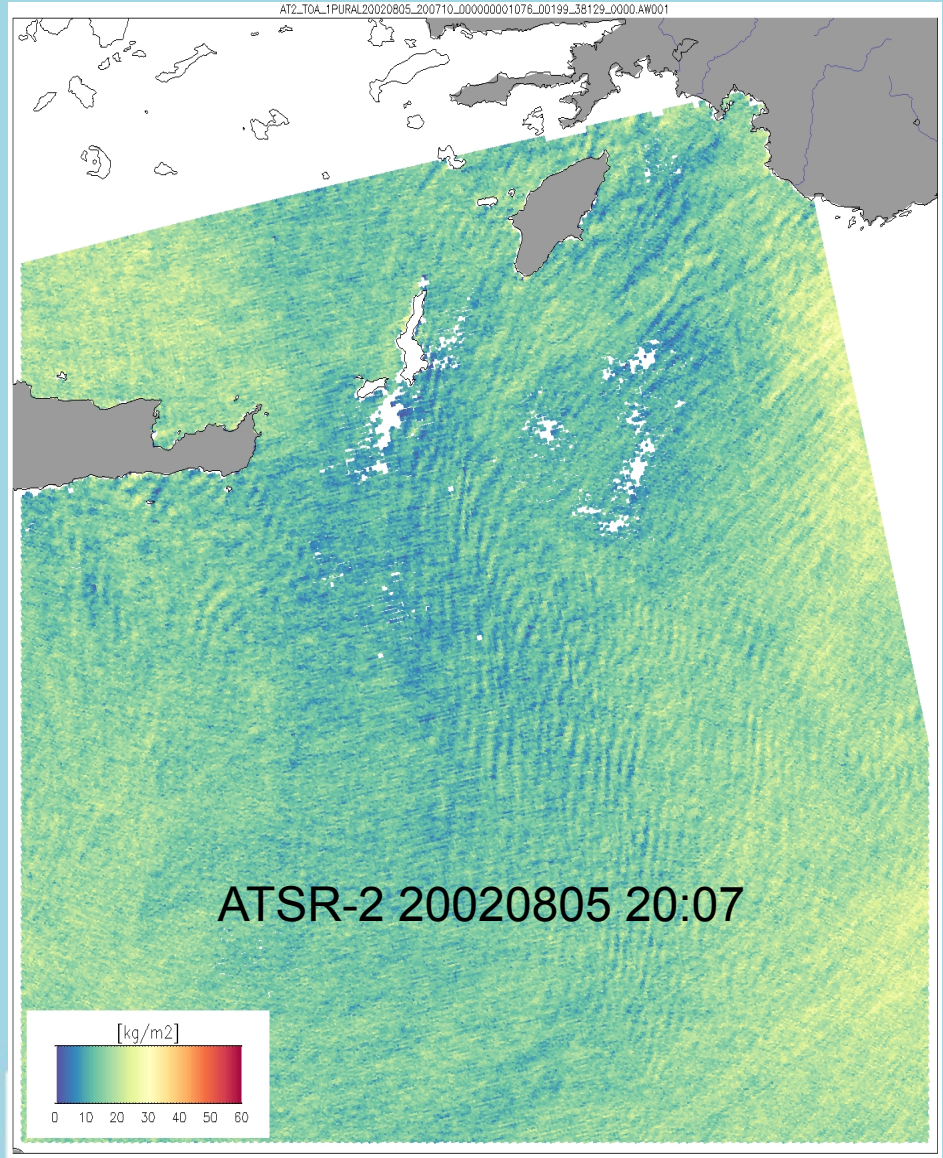

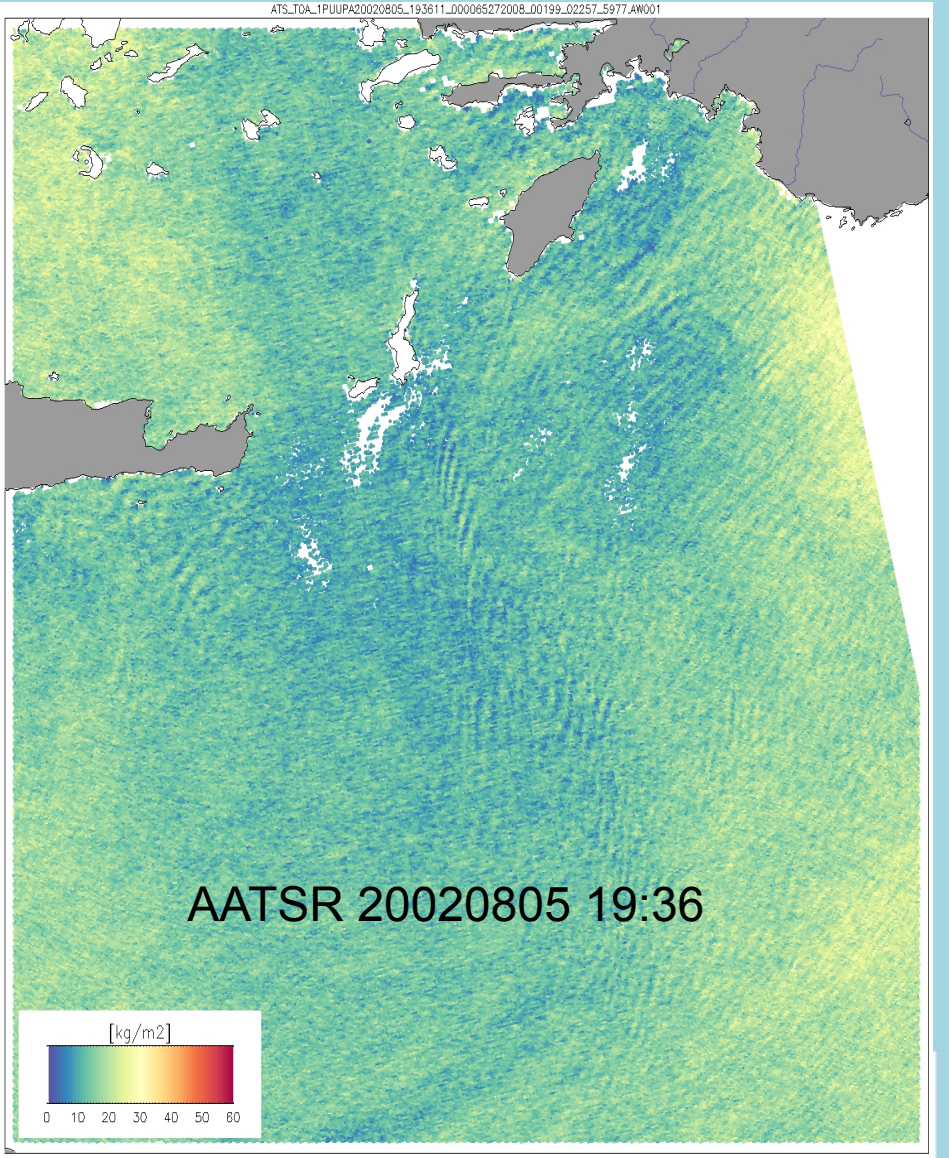

The AIRWAVE algorithm

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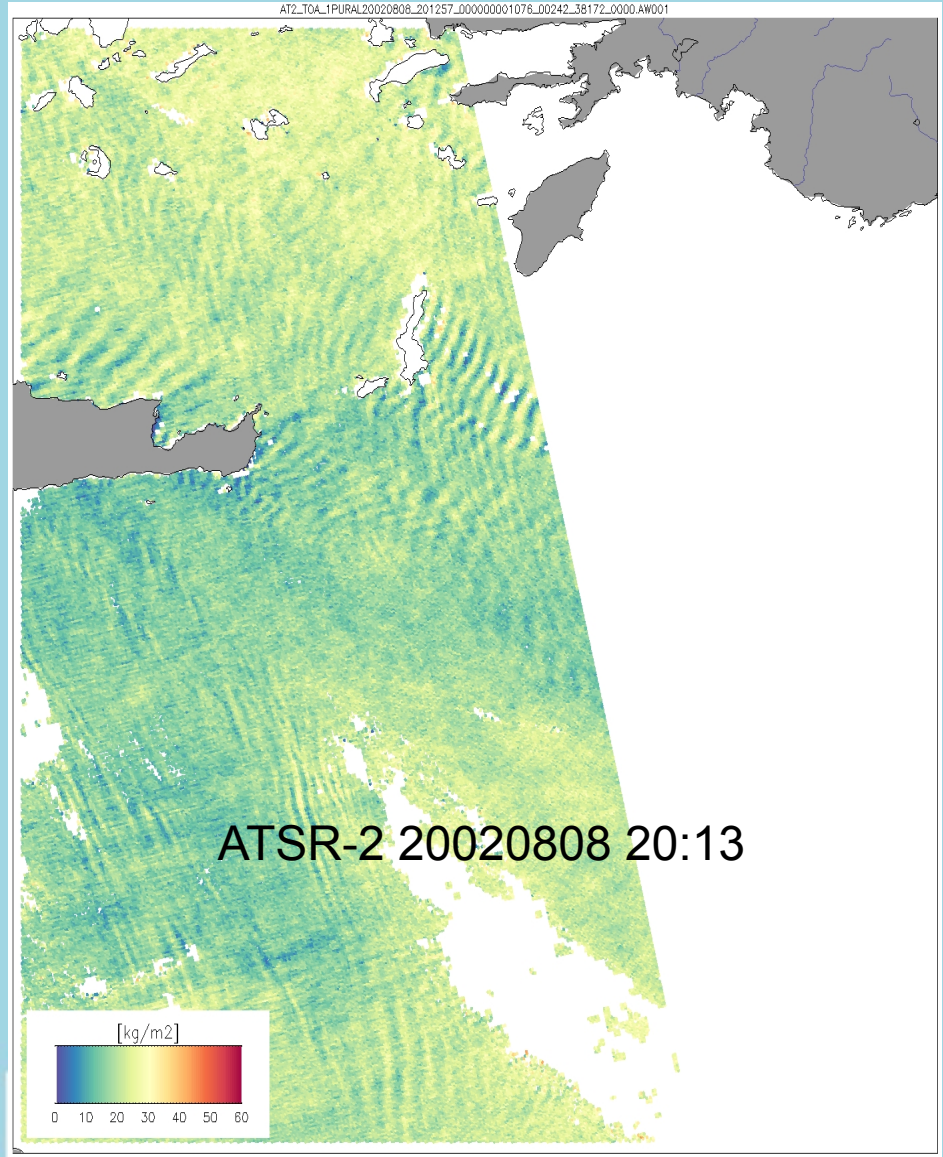

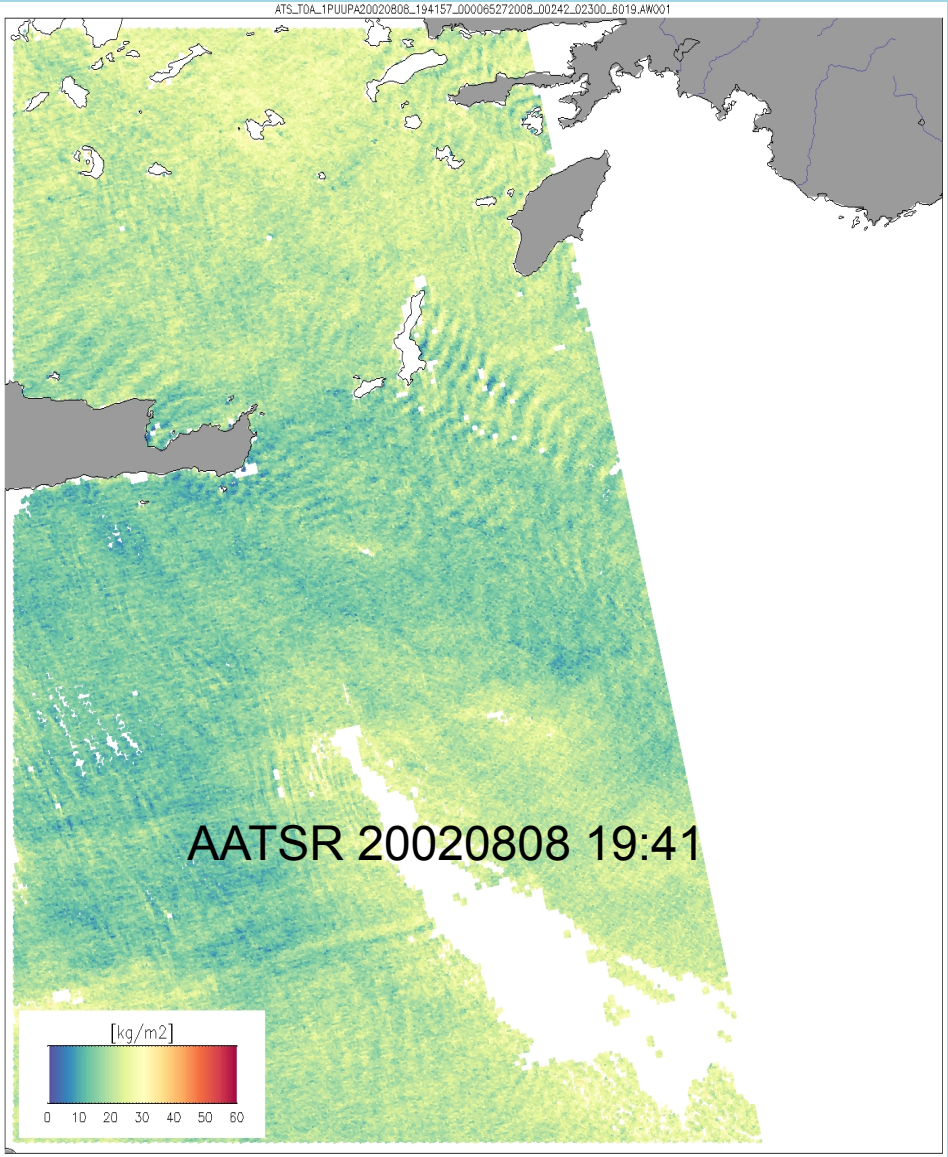

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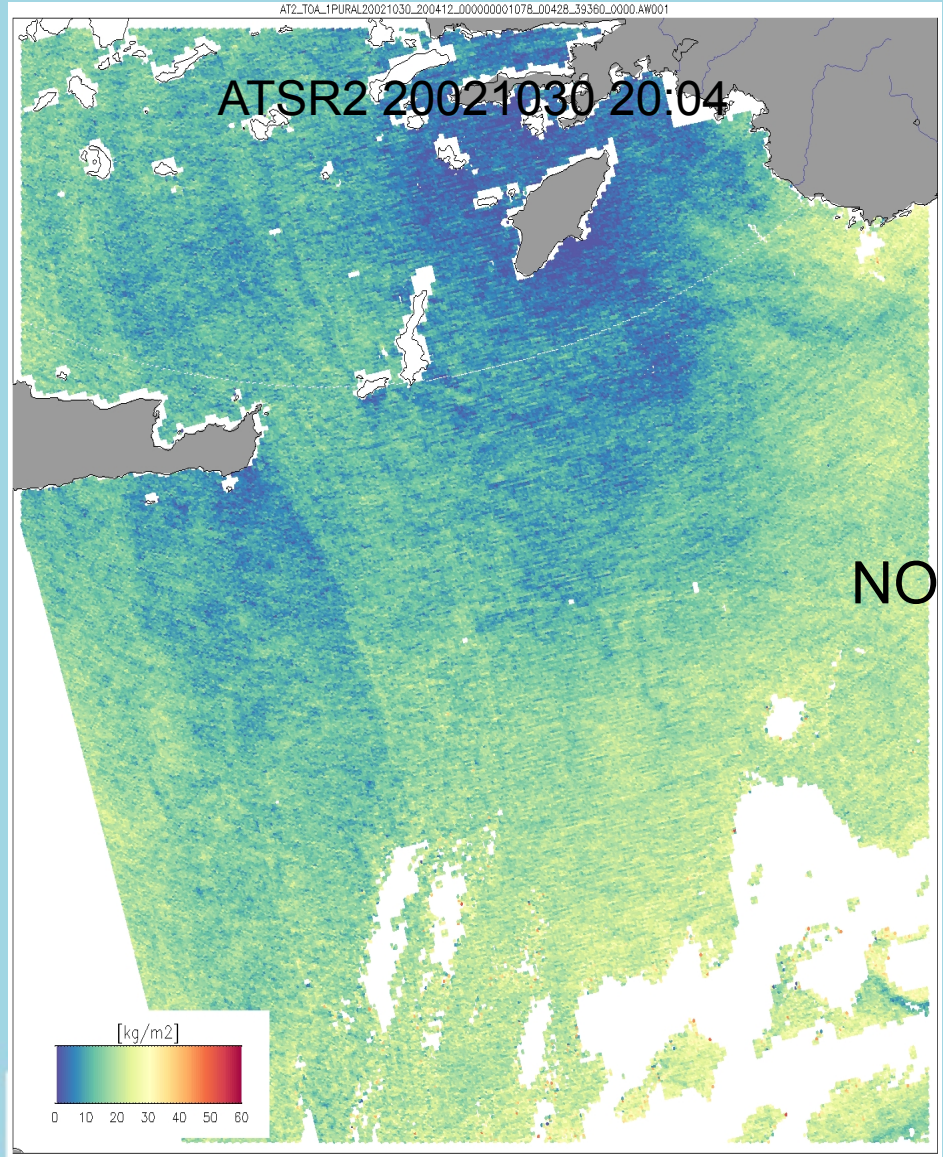
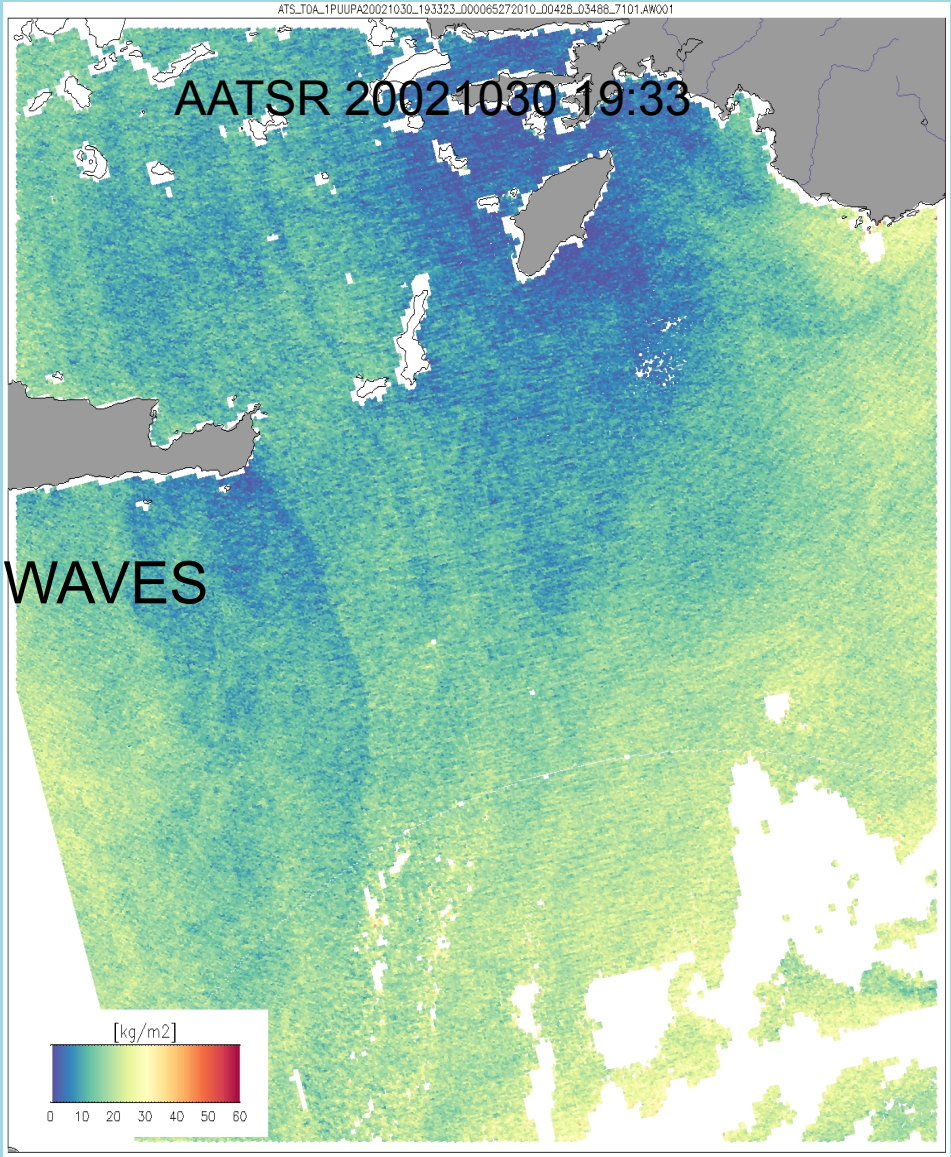
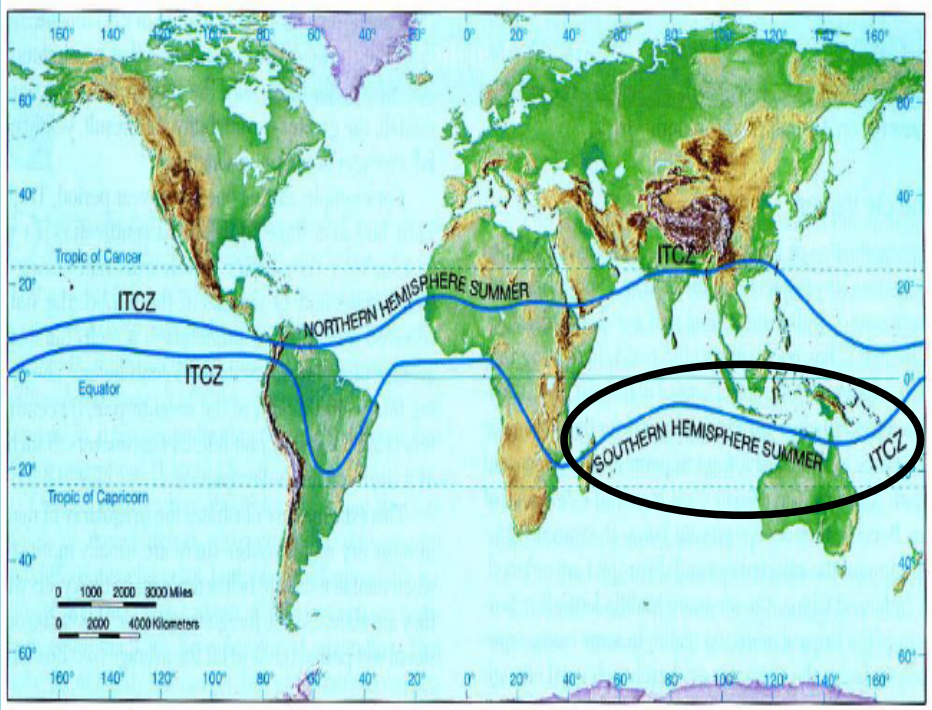


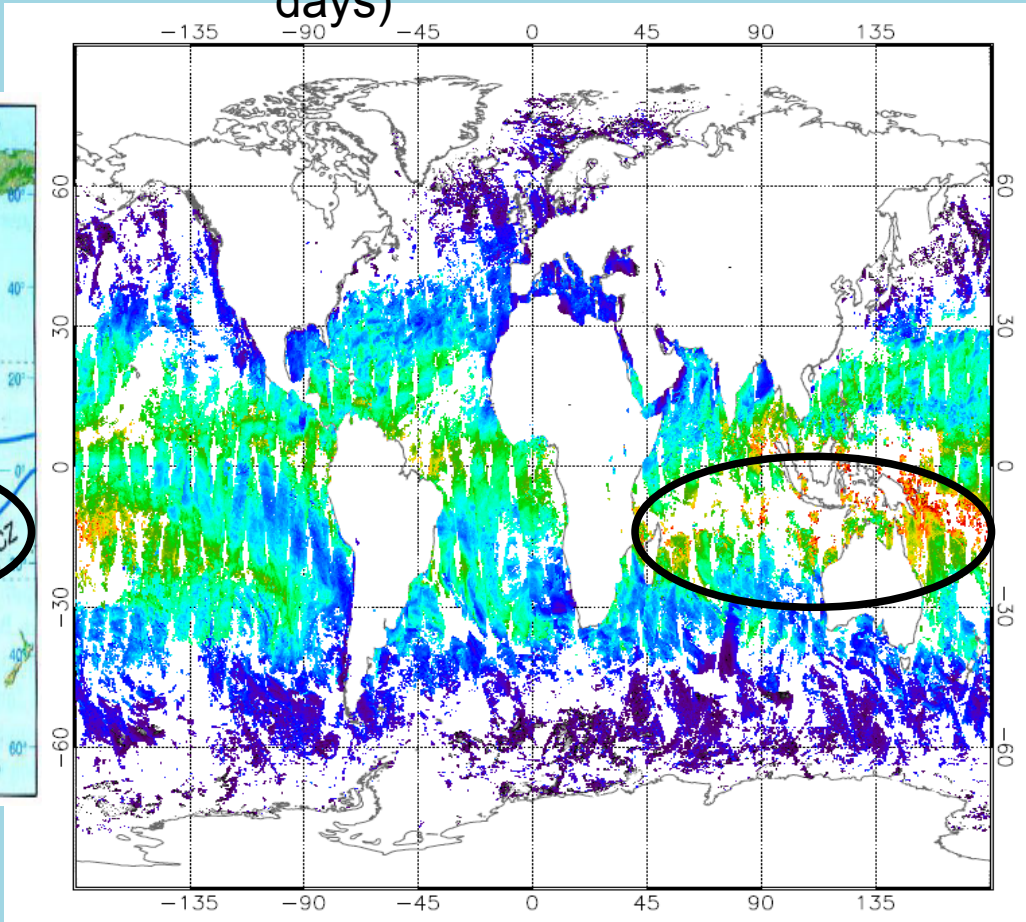


NO WAVES

InterTropical Convergence Zone (ITCZ) and TCWV

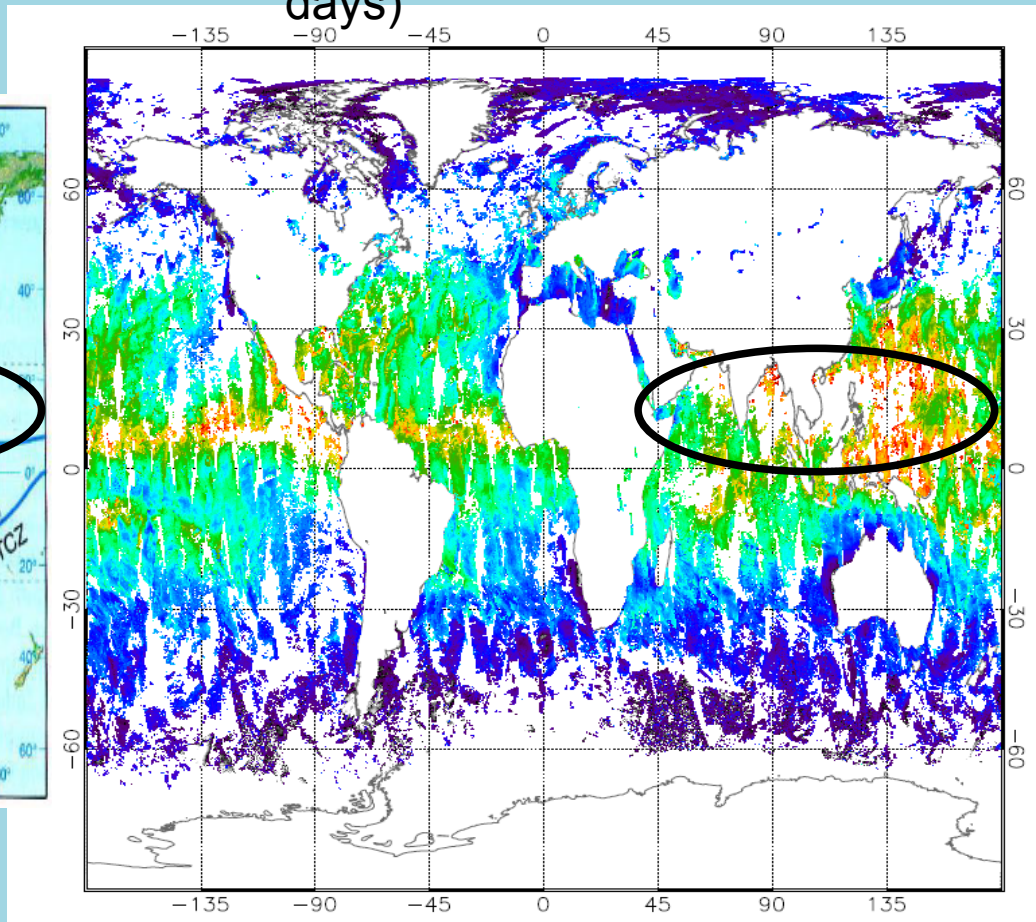
AATSR February 2008 (5 days)





InterTropical Convergence Zone (ITCZ) and TCWV

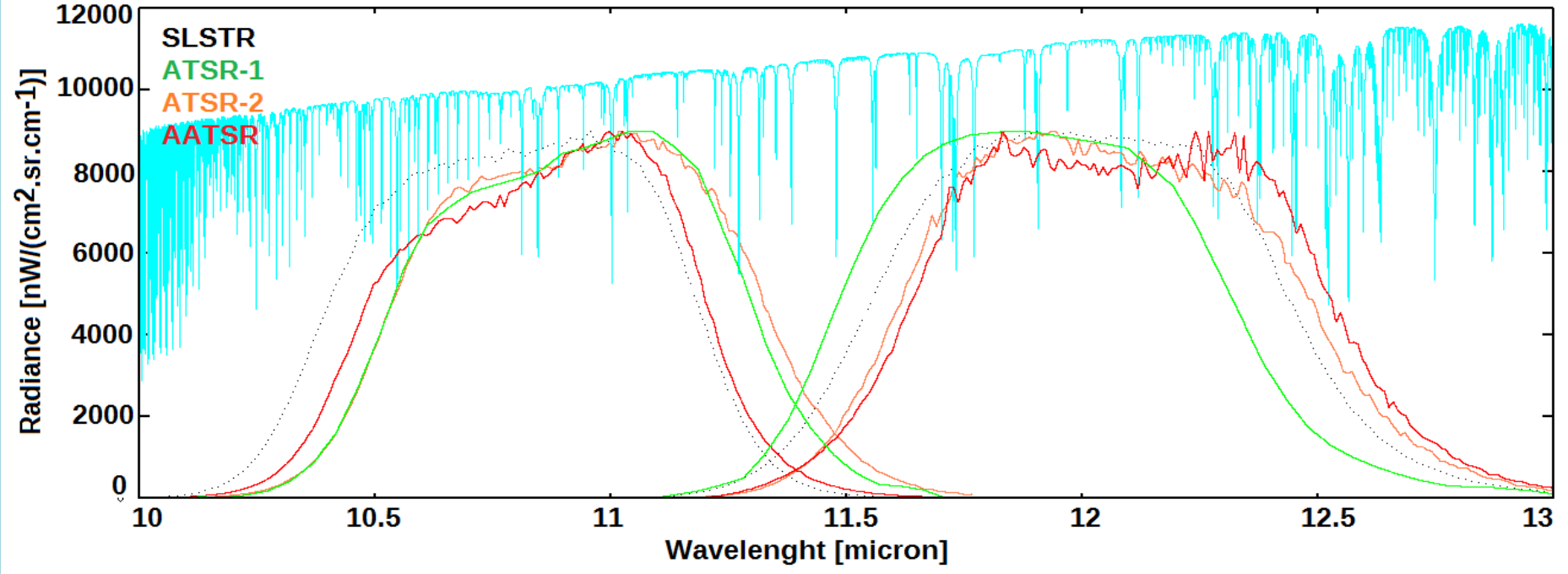
AATSR August 2008 (5 days)



AIRWAVE extension to SLSTR

AIRWAVE can be easily extended to SLSTR instrument on board Sentinel 3.

Preliminary calculation based on filter functions for the 11 and 12 µm channels from C. Pelloquin, J. Nieke (EOP-PVP) "Sentinel-3 OLCI and SLSTR simulated spectral response functions", Technical Note Ref: S3-TN-ESA-PL-316 have been performed.



G_{FWD}/G_{NAD} ratio	Tropical	Mid-Latitude
SLSTR	1.652	1.596

Conclusions

- The AIRWAVE algorithm allows the retrieval of day and night TCWV over sea at very high spatial resolution from the ATSR Series (1 km x 1 km).
- The algorithm exploits radiances of the 11 and 12 μm channels in FORWARD and NADIR viewes acquired over the sea in cloud free scenarios.
- It is a fast retrieval based on tabulated calculations from a Radiative Transfer Forward Model and sea surface Emissivity database.
- Application to (A)ATSR data produces a dataset of 21 years of TCWV data (1991-2012) and preliminary comparisons show an excellent agreement with SSM/I measurements.
- The dataset can be used to study several atmospheric processes (Lee waves, ITCZ)
- Algorithm improvements are in progress and include: investigation of impact of different atmospheric conditions, creation of look-up tables for different atmospheric scenarios and surface conditions, evaluation of a better approach for the selection of retrieval parameters.

- The algorithm can be easily extended to SLSTR measurements.