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Sea Surface Temperature and Air-Sea Interaction in the Mediterranean Region

Direct measurements, satellite estimates and model based assessments

By

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ENEA
CNR Consiglio Nazionale delle Ricerche
ISMAR Istituto di Scienze Marine
GHRSST Group for High Resolution Sea Surface Temperature

Ocean Surface Heat Fluxes

Radiative Fluxes

$$Q_{net} = Q_s - (Q_b + Q_h + Q_e)$$

Turbulent Fluxes

Sources of air-sea heat fluxes data:

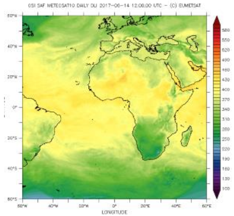
- **Direct** in situ Measurements
- **Models** (Analysis and Re- Analysis)
- **Satellite**
- **From meteorological** variables using bulk formulae

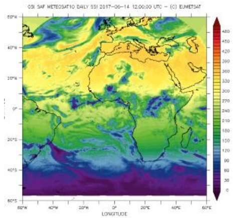
Radiative Fluxes: in situ measurements

Direct: Kipp and Zonen CMP21 and CGR4 radiometers for shortwave and longwave irradiances

Bulk Formulae: using T_{air}, T_{dew}, mslp, Total Cloud Cover (TCC) and SST

Meteosat Downward Longwave Irradiance:





Meteosat Surface Solar Irradiance:

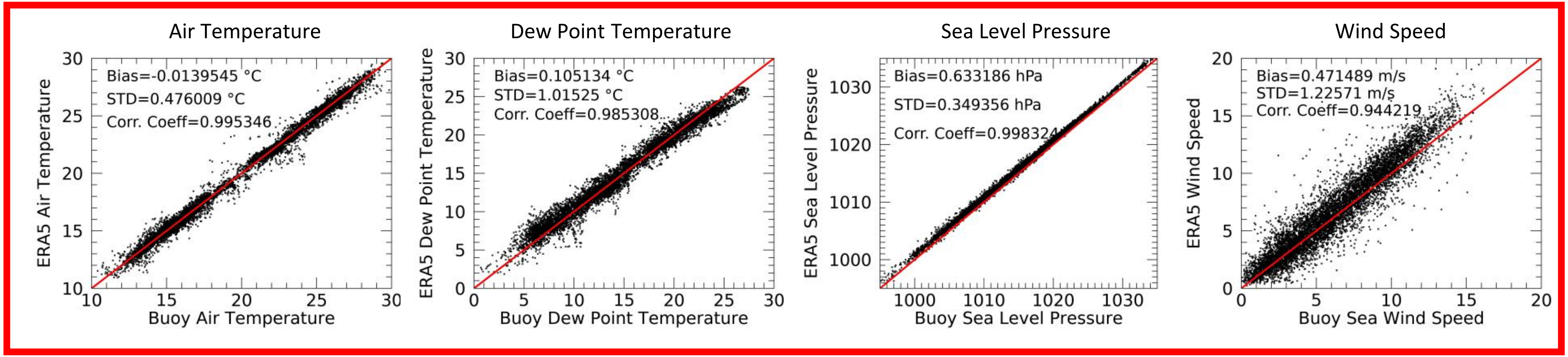
Climate Change Service

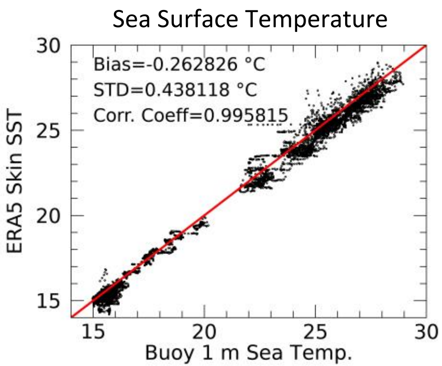
Reanalysis: ERA5 hourly data on single levels from 1979 to present

The surface single level also contain meteorological variables for bulk formulae estimate as well as surface net heat flux components

Step 1: Assessing ERA5 meteorological variables for bulk formula Heat fluxes estimate at the Lampedusa Mooring:

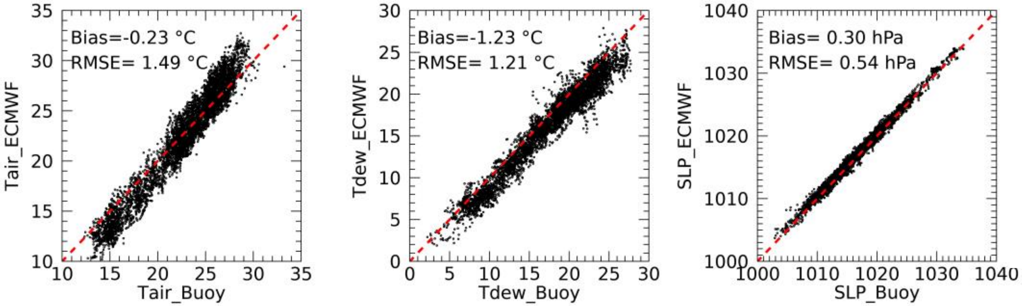
Climate Change Service





ERA5 Documentation: https://www.ecmwf.int/file/267309/url.pdf

IFS DOCUMENTATION – Cy43r3 Operational implementation 11 July 2017

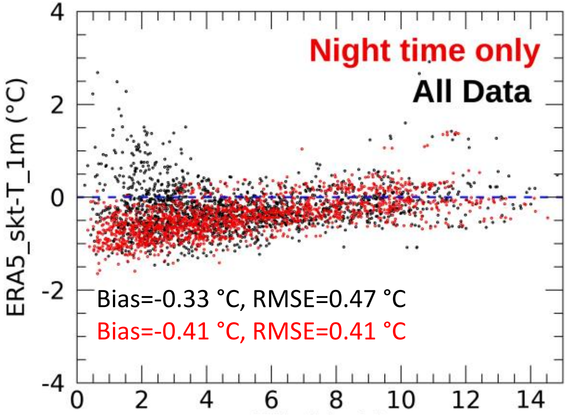


ERA Interim

r Temp.
.26 °C
44 °C
".996

SST skin Bias: wind effect

Model Based Skin effect the wind dependence is directly introduce by Fairall et al. 1996



$$T_{\mathrm{sk}} - T_{-\delta} = \frac{\delta}{\rho_{\mathrm{w}} c_{\mathrm{w}} k_{\mathrm{w}}} (Q + R_{\mathrm{s}} f_{\mathrm{s}})$$

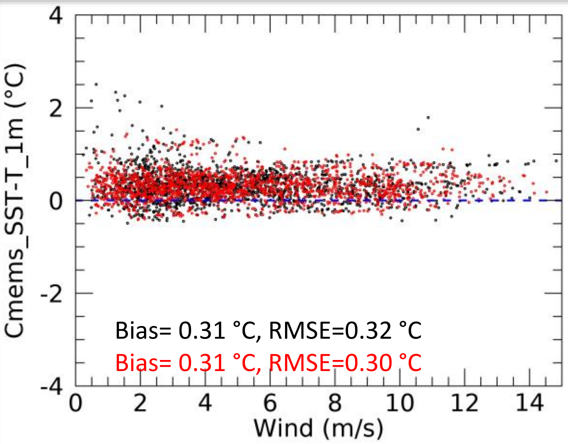
$$\text{with } Q = H + \lambda E + LW$$

R_s is the net solar radiation at the surface, f_s is the fraction of solar radiation absorbed in the skin

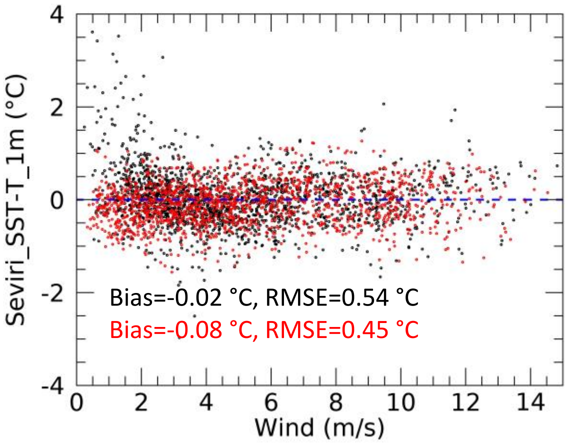
$$f_{\mathrm{s}} = 0.065 + 11\delta - \frac{6.6\,10^{-5}}{\delta}\left(1 - e^{-\delta/0.0008}\right)$$

Thickness of the skin layer

$$\delta = 6\left[1 + \left(\frac{-16 g \alpha_{\mathrm{w}} \nu_{\mathrm{w}}^3}{u_{*\mathrm{w}}^4 k_{\mathrm{w}}^2 \rho_{\mathrm{w}} c_{\mathrm{w}}}(Q + R_{\mathrm{s}} f_{\mathrm{s}})\right)^{3/4}\right]^{-1/3}$$



This is the difference between CMEMS SST and SBE39 at 1 m. CMEM (based on **NEMO OGCM**) is the operational Copernicus service and assimilates Night satellite SST . As for case (b), apparently, there is not wind dependency. In this case, correctly, because it is the first level model temperature. First level thickness is 3 meters.



This is the difference between Seviri SST and SBE39 at 1 m. Seviri is subskin SST. "*Since the coefficient of the SST algorithm are established using in-situ measurements, the retrieved SST is considered to be the sub-skin SST. One could apply a -0.17C (Donlon et al., 2002) to get the skin SST. However this offset is only a very rough conversion term valid at large scale for wind speed exceeding 6 m/sec*." (osi-saf v1.1, 31/5/2016).

3176 data points selected when era5, SEVIRI, sbe39, wind and CMEMS SST are all available at the same hour.

ERA5 meteorological data seems to have a relatively small Bias and Standard Deviation respect to "Sea truth"

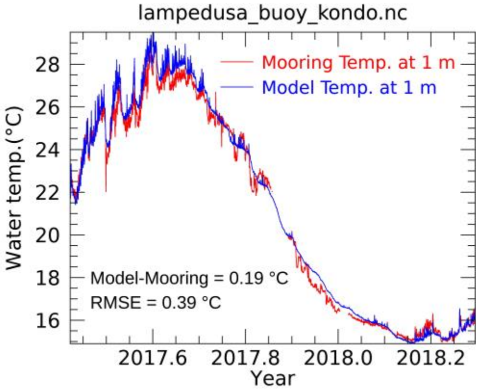
But

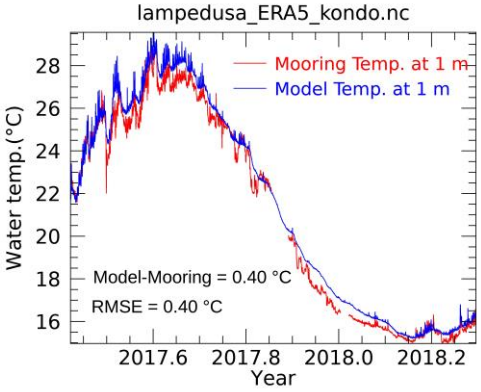
How can we evaluate if this "small bias" is "small enough"?

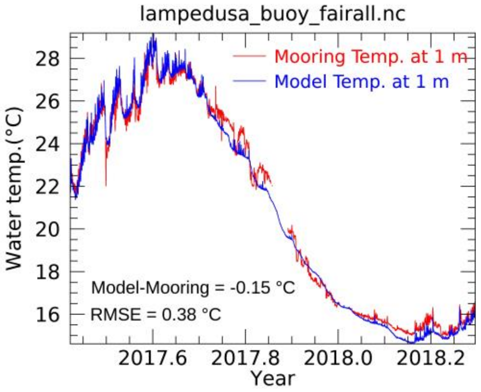
A possible assessment can be done by evaluating the impact on a simulation of the upper ocean structure evolution under directly measured (from the buoy instruments) or modelled (ERA5) heat and momentum fluxes internally computed by the model.

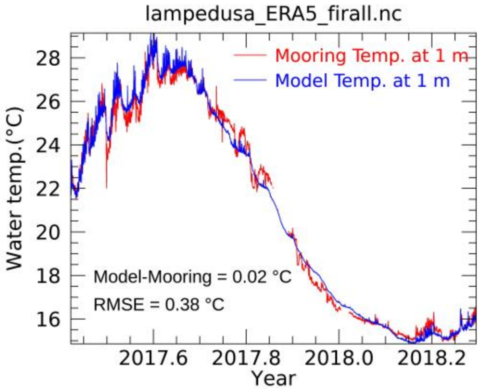
GOTM Simulations from June 4 1917 00:00 until April 18 2018 23:00

Water Temperature at the variable depth of the SBE39 Sensors [0.9-1.6 m)

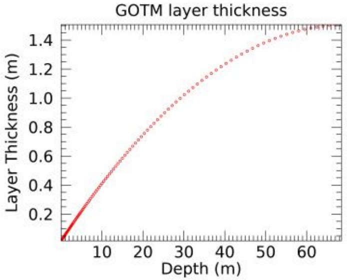


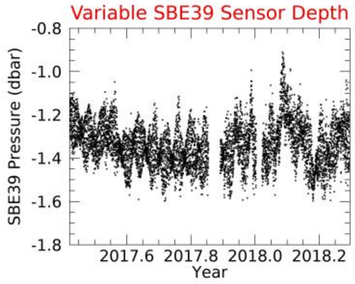






70 levels from 0 to 70 m

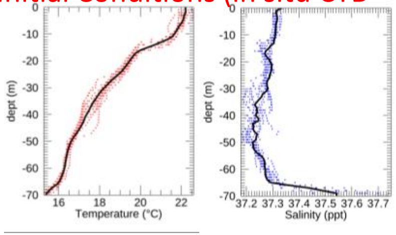


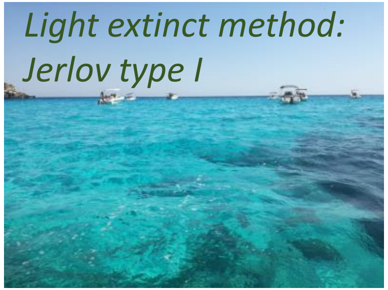


Model Setup

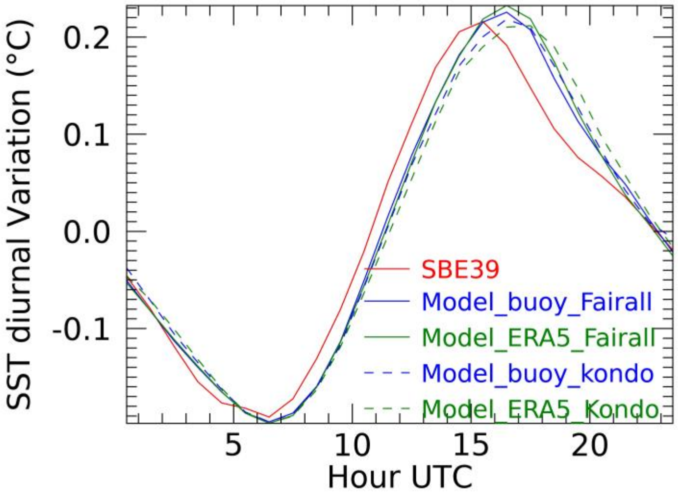
- *The model uses meteorological parameters and computes internally heat and momentum fluxes using Reed (1977) for SW Irradiance, Bignami (1995) for LW Irradiance and Kondo (1975) or Fairall (1996) for turbulent fluxes*
- *Second order coefficient of Kantha & Clayson (1994).*

Initial Conditions (in situ CTD



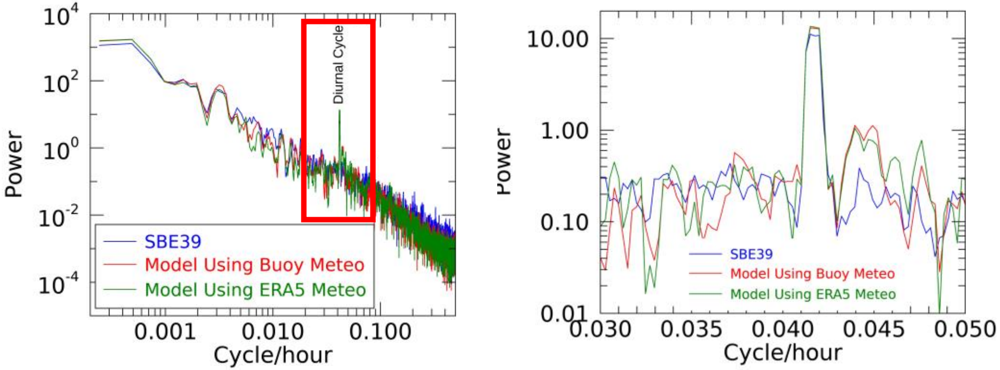


Mean Diurnal Variability from June 4 1917 00:00 until April 18 2018 23:00

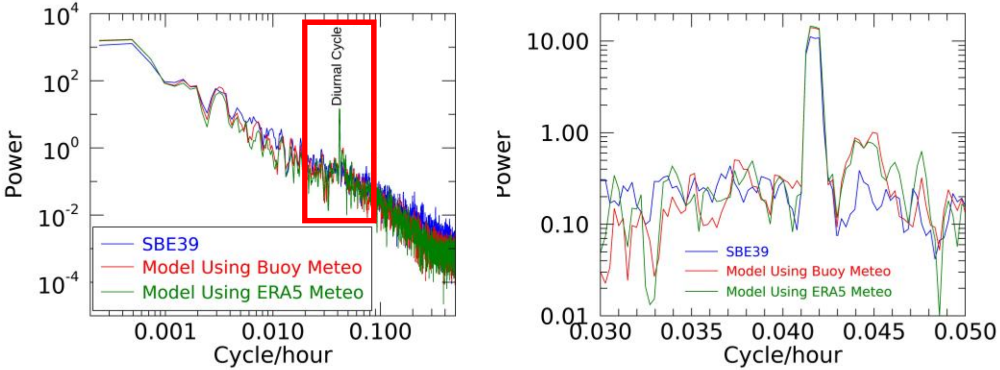


The definition of the time in the different data sets is still an issue.

Spectral Analysis: GOTM Simulation of 1m Temperature using KONDO



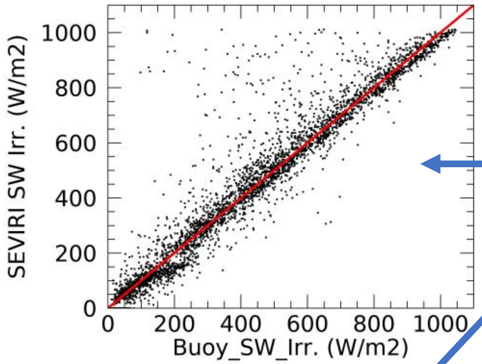
Spectra Analysis GOTM Simulation of 1m Temperature using Fairall



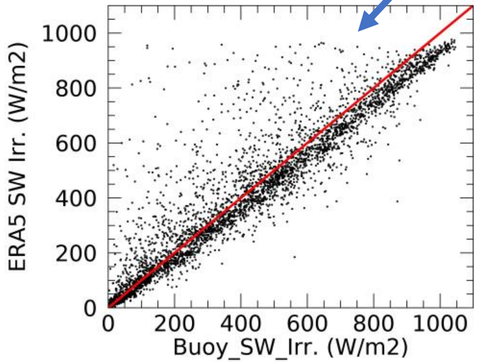
Radiative Fluxes estimate

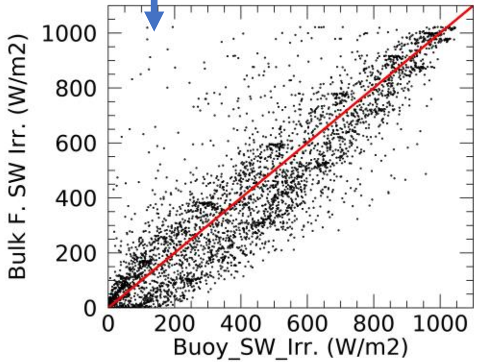
From Bulk Parameterization to Radiative Transfer Models and Satellite estimates.

Shortwave Irradiances



ShortWave Irradiance			
	Bias	RMSE	Correlation
SEVIRI-Buoy	5.2	60.9	0.979
ERA5-Buoy	0.7	75.0	0.966
Met_Based-Buoy	-7.1	93.4	0.948

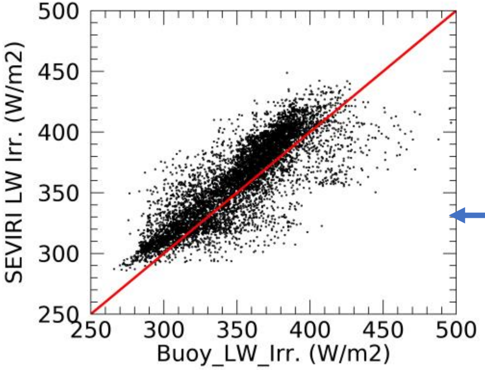


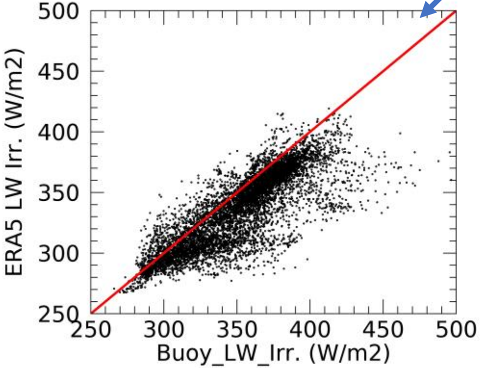


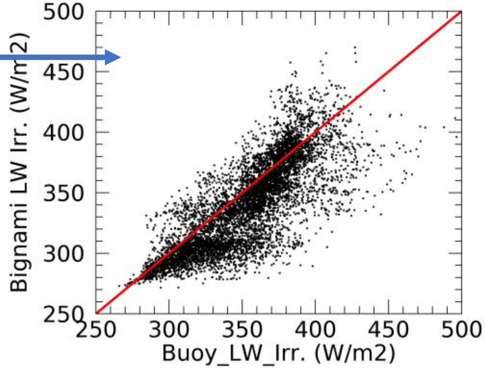
Longwave Irradiances

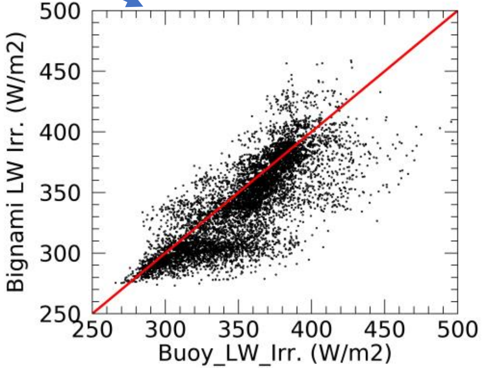
	Bias	RMSE	Correlation
SEVIRI - Buoy	8.4	19.9	0.829
ERA5 - Buoy	-15.5	19.9	0.818
(1) Met_Based - Buoy	-12.0	22.9	0.795
(2) Met_Based - Buoy	-12.1	22.7	0.791

(1) GOTM Runned using Buoy Meteo Data and Fairall 1996
(2) GOTM Runned Using ERA5 Meteo Data and Fairall 1996



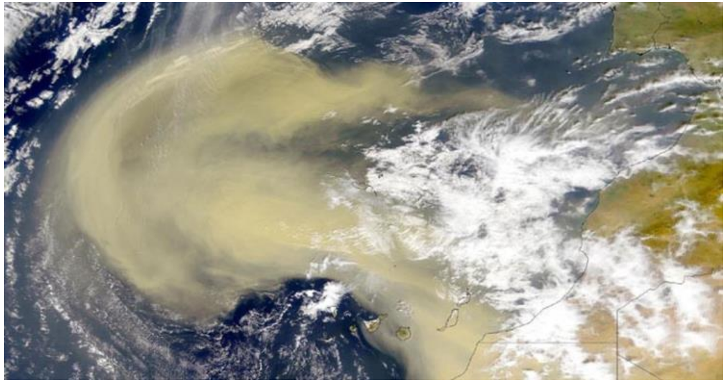




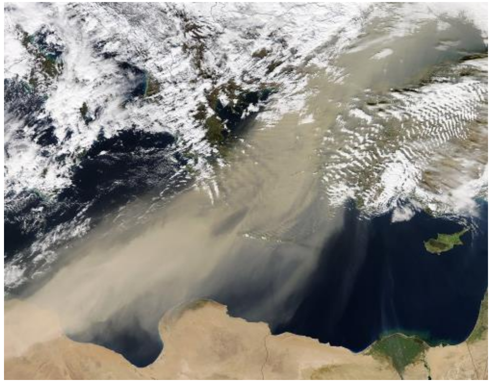


Atmospheric dust events and impact on SST and heat fluxes estimate

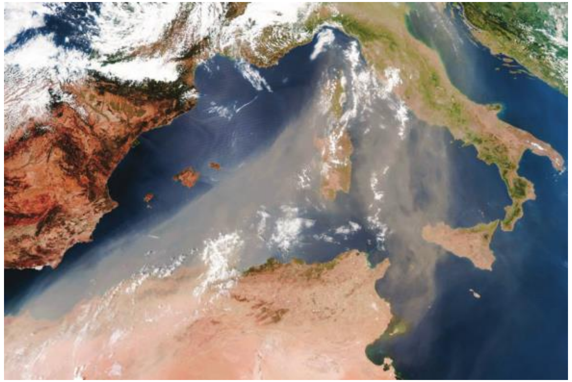
Saharan Dust Invading The Atlantic Ocean



Saharan Dust Reaching Crete



Saharan Dust In the central and west Med



The Lampedusa Climate Observatory for aerosols effect studies

Cimel CE-318

The Cimel CE-318 is a multi-wavelength automatic sun-photometer that measures direct solar irradiance and sky radiance at seven bands centered at 340 nm, 380 nm, 440 nm, 500 nm, 675 nm, 870 nm, 939 nm, and 1020 nm (10 nm FWHM), with a field of view of 1.2°.

The photometer is programmed to perform either direct sun or sky radiance measurements several times during the day, for airmass values below 7. The direct sun measurements are made at all seven wavelength bands. The **aerosol optical depth** is derived at 340 nm, 380 nm, 440 nm, 500 nm, 675 nm, 870 nm, and 1020 nm using the Beer-Bouguer law, after removing the extinction due to Rayleigh scattering, ozone and other gas absorption. The 939 nm channel is used to estimate the **column water vapor**.

Additionally, the instrument measures sky radiance in four bands (440, 675, 870, and 1020 nm) along the solar principle plane (at fixed azimuth angle equal to the sun azimuth and changing the scattering angle) and along the solar almucantar (at fixed elevation angle and changing the azimuth angle). Using the inversion of Dubovik and King [A flexible inversion algorithm for the retrieval of aerosol optical properties from sun and sky radiance measurements, JGR, 105, 20673-20696, 2000], the aerosol size distribution in the size range 0.1-15 μm, the phase function and refractive indices are derived.

The instrument was first operated by the University of Modena and Reggio Emilia from 2000 to 2005. Since March 2010 the instrument is operated on the roof of one of the ENEA buildings jointly by ENEA and the University of Modena and Reggio Emilia.

The instrument was calibrated in 2009 and 2011 at the NASA GSFC facility, and in 2013 at the GOA facility under ACTRIS.

The Cimel installed at the ENEA laboratory is part of the Aerosol Robotic Network (AERONET) and is identified with the #172.

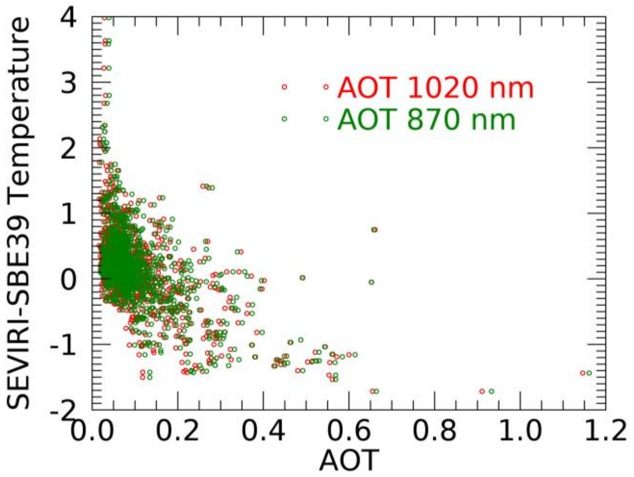
Aerosol Effects on SST Retrieval (June 2017 - April 2018)

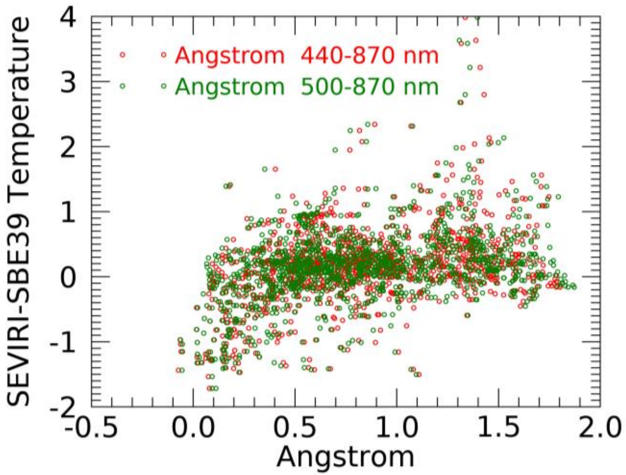
Aerosol AOT measurement at the Lampedusa Climate Observatory are based on:

1. Visible Multi Filter Rotating Shadowband Radiometer [MFRSR; since 1999].
2. Cimel CE-318 Sun Photometer [part of AERONET, since 2000].
3. Brewer MK III spectrophotometer [total ozone, spectral UV irradiance, UV aerosol optical depth; since 1998].
4. Ultraviolet Multi Filter Rotating Shadowband Radiometer [UV-MFRSR; 2004-2006, restarted in 2010].
5. Carter-Scott Sun photometers [since 2013].

Additional measurements

1. Aerosol lidar [together with University of Rome; since 1999]
2. PM10 chemical composition [together with Univ. f Florence; since 2004].

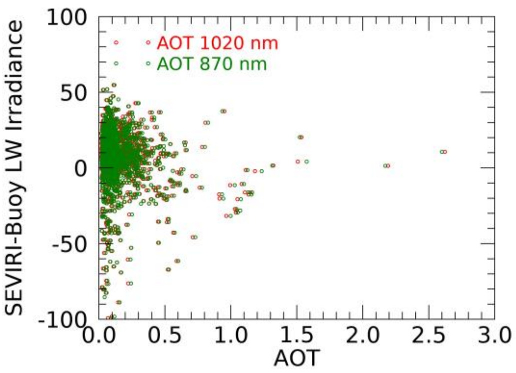


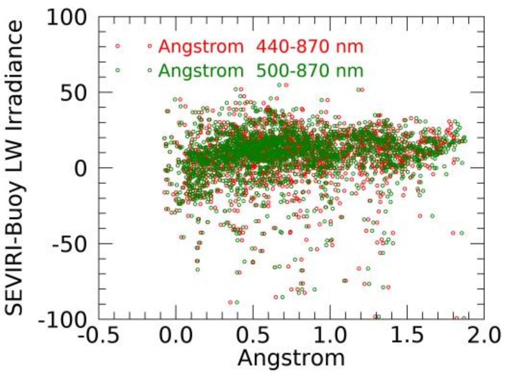


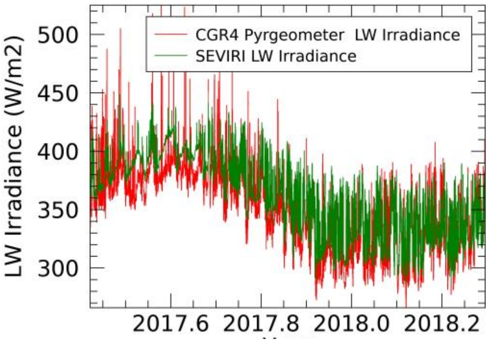
Values of AOT at 870 and 1020 nm > 0.15 can be used as indicator of Desert Aerosols; they can be identified also from values of the Ångström exponent < 0.5 (e.g., Pace et al., 2006).

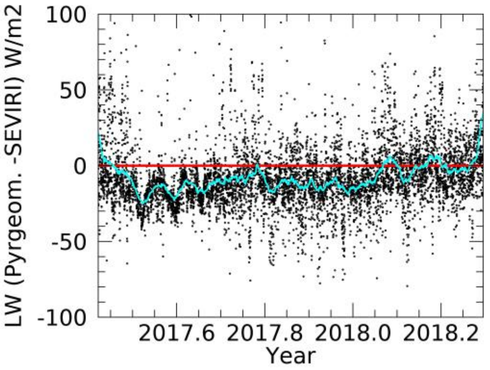
LW Irradiance: Aerosols effects on Satellite estimate?

	Bias	RMSE	Correlation
SEVIRI - Buoy	8.4 W/m^2	19.9 W/m^2	0.829







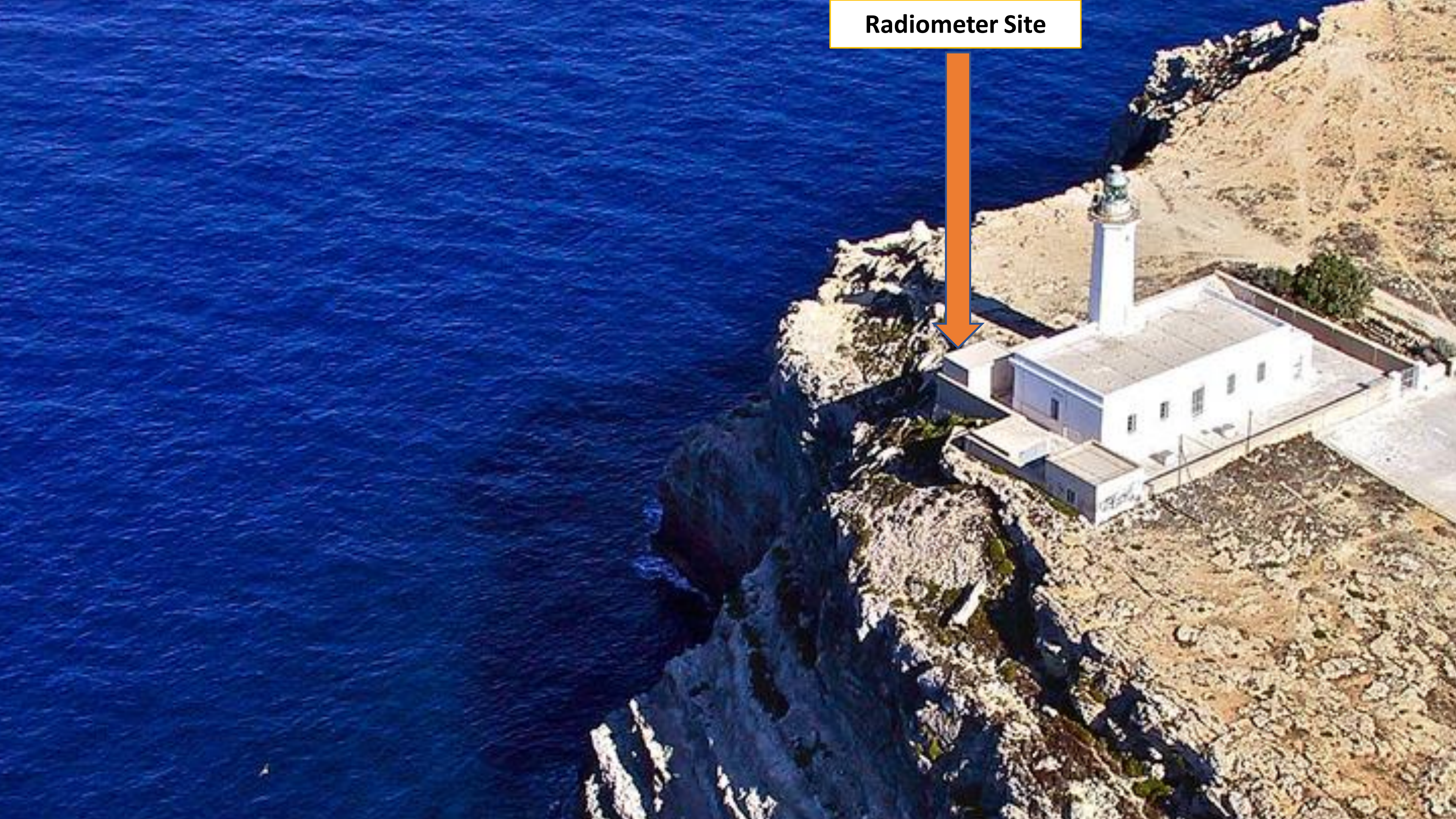


The OSI SAF algorithm is a bulk parametrization that uses NWP model outputs to calculate a clear sky Downward Longwave Irradiance (DLI), corrected according to satellite derived cloud information:

$$LW \downarrow = \left(\varepsilon_o + (1 - \varepsilon_0 C)\right)\sigma T_a^4$$

Where C is related to the Infrared Cloud Amount and ε_0 is the clear sky emissivity

Details in http://www.osi-saf.org/lml/doc/osisaf_cdop2_ss1_pum_geo_flx.pdf


Radiometer Site

Summuary

1. Recent Re-analysis (ERA5) have made an excellent work in reproducing essential meteorological variables .for air-sea heat flux estimate.
2. The inclusion of hourly time resolution had contribute to ameliorate the products, including a better description of the diurnal cycle
3. Radiative heat fluxes estimates either from satellite or form model are good but can be ameliorate
4. The study of the aerosols effect on on radiative components of the heat fluxes is promising and the Lampedusa station is certainly a interesting site for these study considering the variety of atmospheric conditions experienced by the island.