The Lampedusa Cal/Val site: assessing heat fluxes and high frequency SST estimates in the Mediterranean Sea.

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Consiglio Nazionale delle Ricerche

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The Lab and the lighouse
The Mooring
ENEA Station for Climate Observation
ROBERTO SARAO
Lampedusa Island
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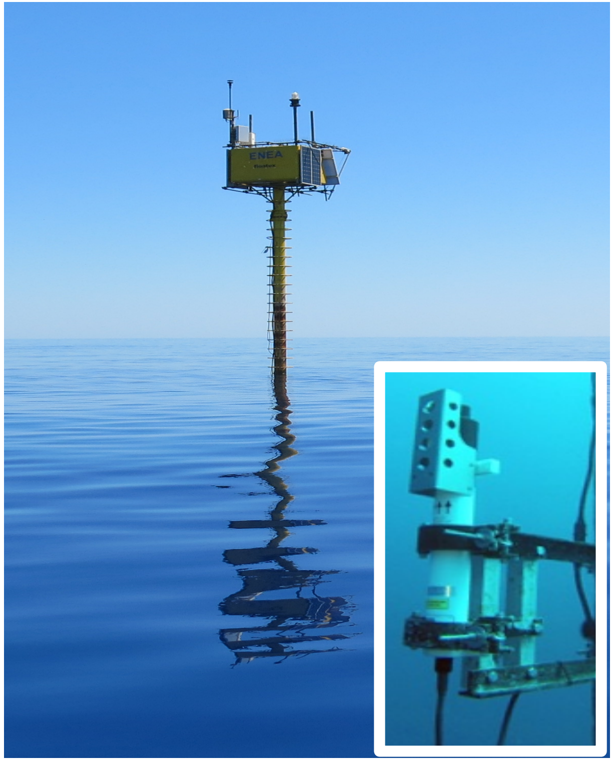
Instruments

- Meteorological station [air pressure, temperature, humidity, wind direction and velocity, precipitation (Vaisala); solar irradiance (Kipp and Zonen)] – since 1999.
- Non-dispersive Infra-red (NDIR) analyzer [atmospheric CO_2 concentration (the system includes a Siemens 5E analyzer)] – weekly samples, since 1992; continuous, since 1998.
- Gaschromatograph [atmospheric concentration of CH_4, N_2O, CFC-11 and CFC-12 (HP 6890)] – weekly samples, since 1997; continuous, since 2006.
- Cavity ring-down spectroscopy analyzer [atmospheric CO_2, CO, CH_4 (Picarro G2401)] – since 2012.
- Brewer MK III spectrophotometer (total ozone, spectral UV irradiance, aerosol optical depth) – since 1998.
- Aerosol lidar [together with University of Rome; aerosol backscattering and depolarization profiles] – since 1999.
- Visible Multi Filter Rotating Shadowband Radiometer [MFRSR; aerosol optical depth at several wavelengths, diffuse-to-direct irradiance ratio, column water vapor, aerosol single scattering albedo (Yankee Environmental Systems MFR-7)]; since 2001.
- Ultraviolet Multi Filter Rotating Shadowband Radiometer [UV-MFRSR; aerosol optical depth at several wavelengths, diffuse-to-direct irradiance ratio (Yankee Environmental Systems UV-MFR-7)]; 2004-2006, restarted in 2010.
- Cimel CE-318 sun-photometer [jointly with Univ. of Modena and Reggio Emilia; part of AERONET] – 2000-2005, restarted in 2010.
- Middleton 4-channel sun-photometer, wide field of view [aerosol optical depth, column water vapour] – since 2013.
- Middleton 4-channel sun-photometer, narrow field of view [aerosol optical depth, column water vapour] – since 2013.
- PM-10 aerosol sampler [Tecora Skypost, daily chemical analyses performed at the University of Florence; FAI Hydra, University of Florence] – since 2004.
- PM-10 aerosol sampler for EC/OC [Tecora Echo PM; daily chemical analyses performed at the University of Florence] – started in 2010.
- Particle soot/absorption photometer [PSAP; aerosol absorption coefficient; LSCE/IPSL] – starting in 2010.
- Precision Spectral Pyranometer [downward shortwave irradiance (Eppley)] – since 2003.
- Precision Infrared Radiometer [downward longwave irradiance (Eppley)] – since 2003.
- Shaded CGR4 pyrgeometer [downward longwave irradiance (Kipp and Zonen)] – since 2007.
- Shaded Precision Spectral Pyranometer [diffuse downward shortwave irradiance (Eppley)] – since 2006.
- CHP1 pyrheliometer [direct normal irradiance (Kippa and Zonen)] – since 2011.
- Photosynthetic radiation radiometer [downward photosynthetically active radiation (Li-cor)] – since 2004.
- Actinic radiation spectrometer [actinic radiation spectra, photodissociation rates (Metcon GmbH)] – since 2004.
- UV-Vis-near IR spectrometer [global spectral irradiance (Satlantic HyperOCR)] – since 2013.
- UV-Vis-near IR spectrometer [diffuse spectral irradiance (Satlantic HyperOCR)] – since 2013.
- CARAGA aerosol sampler [dust/aerosol total deposition; LISA] – started in 2011.
- Total sky imager [cloud cover (Yankee Environmental Systems TSI 440)] – since 2003.
- Water vapor Raman lidar [day/nighttime vertical profiles of water vapor, aerosol extinction (jointly with University of Rome)] – since 2009.
- Vaisala radiosonde [temperature, pressure, humidity, wind (Vaisala Digicora III)] – since 2004.
- SODAR [wind vertical profiles, three components, RSE] – 2006-2010.
- RPG Hat-Pro Microwave radiometer [temperature, water vapour, clouds vertical profiles] – 2009; restarted in 2010.
- IR camera [IR radiance in the atmospheric window (Heitronics)] – 2009; restarted in 2010.
- Ozone analyzer [surface ozone mixing ratio; Province of Agrigento] – 2003, 2006-2007, 2010-2013.
- Ozone analyzer [surface ozone mixing ratio; ISAC/CNR] – since 2014.
- ENEA gas sampling unit [weekly analyses of CFC-113, HCFC-22, HCFC-141b, HCFC-142b, HFC-134a, SF_6, CH_3Cl, CH_3Br, CH_2Cl_2, CCl_4, CH_3CCl_3, Halon-1211, Halon-1301, CH_2Br_2, CH_3I, $CHCl_3$, made at ENEA, Rome] – since 2004.
- NOAA gas sampling unit [weekly analyses of CO_2, CH_4, SF_6, CO, ^{13}C, H_2, ^{18}O, made at NOAA] – weekly analyses since 2006.

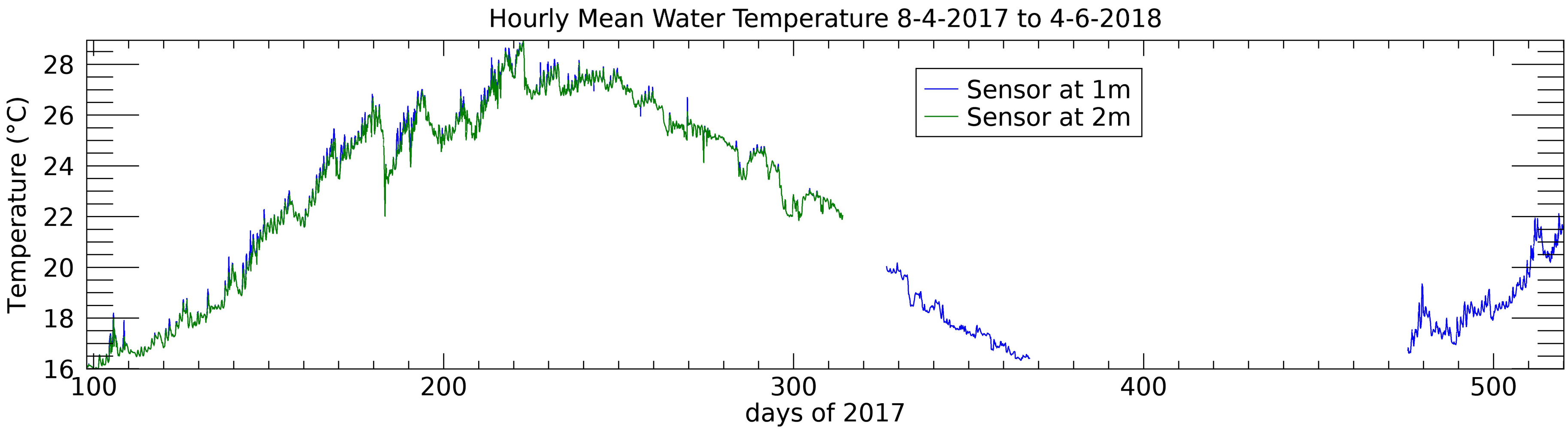
The Lampedusa Cal/Val Site



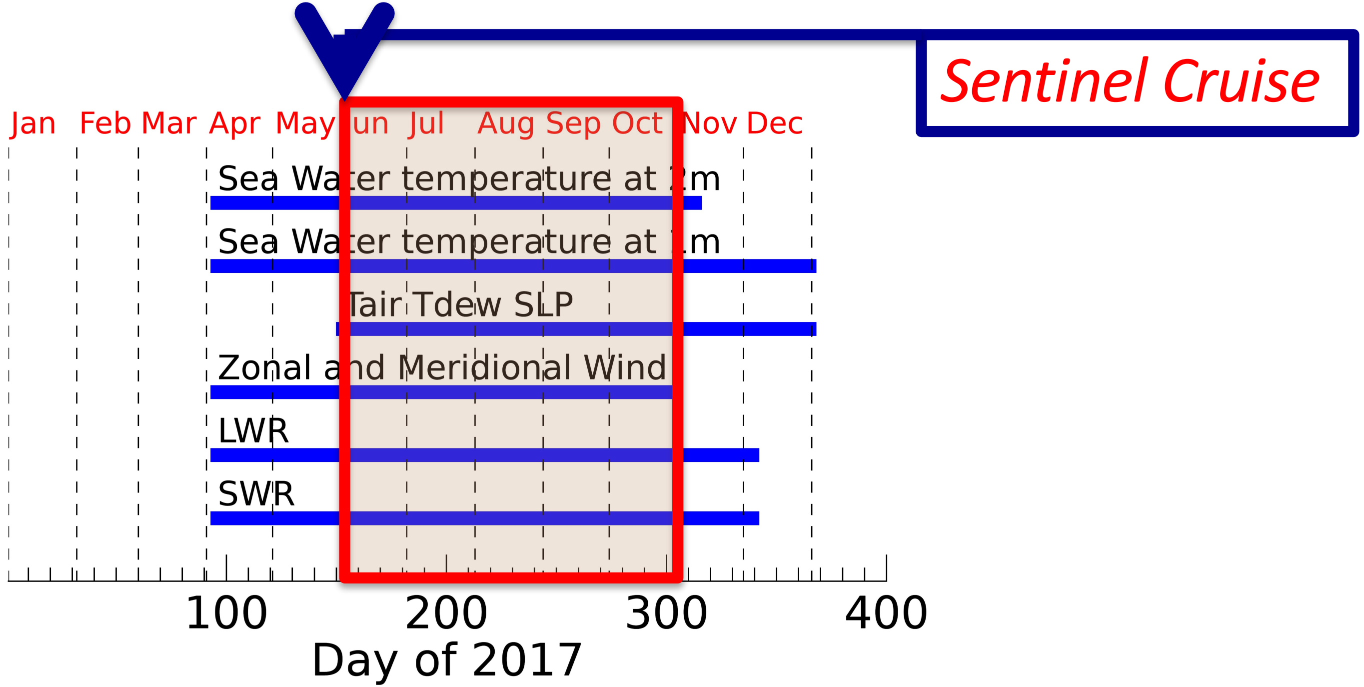
Operational sensors:

- **Vaisala MAWS401 meteorological station;**
- **Kipp and Zonen CMP21 and CGR4 radiometers for shortwave (SW) and longwave (LW) irradiances;**
- **two Seabird SBE 39 sensors at 1 and 2 m depth, acquired every minute**;
- **a Seabird SBE 37-ODO CTD for temperature, salinity, and dissolved oxygen at 18 m depth**; (foundation)
- 6 Satlantic OCR507 radiometers for up- and down-welling radiances/irradiances at 2.5 and 6 m depth.
- Additional sensors for upwelling shortwave and longwave irradiances, down- and upwelling spectral solar radiation, and downwelling irradiance in 7 bands.

Water temperature time series



Data used for this work

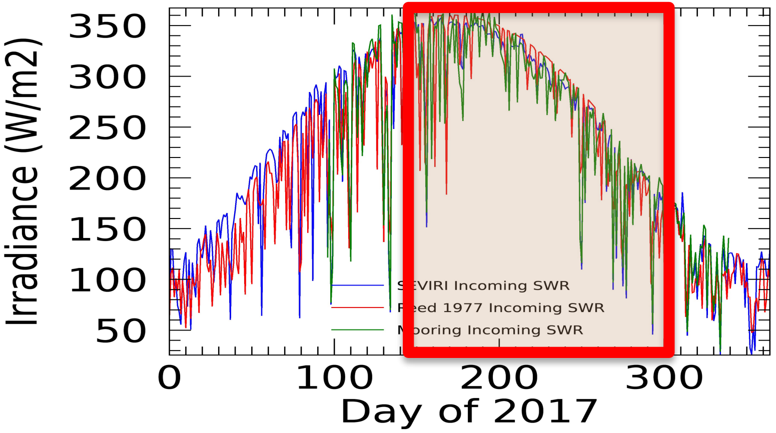


(*) Hourly SST from SEVIRI. Data voids interpolated using M-SAA (Multi-Channel Singular Spectral Analysis). Kondrashov, D., & Ghil, M. (2006). Spatio-temporal filling of missing points in geophysical data sets. *Nonlinear Processes in Geophysics*, *13*(2), 151-159.

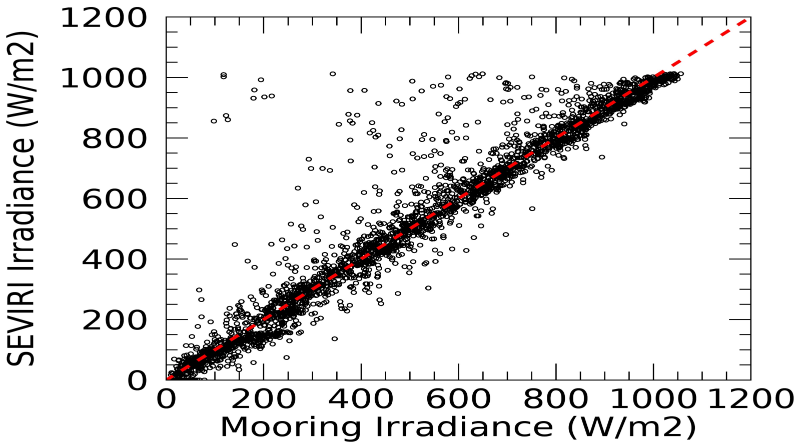
Shortwave irradiance

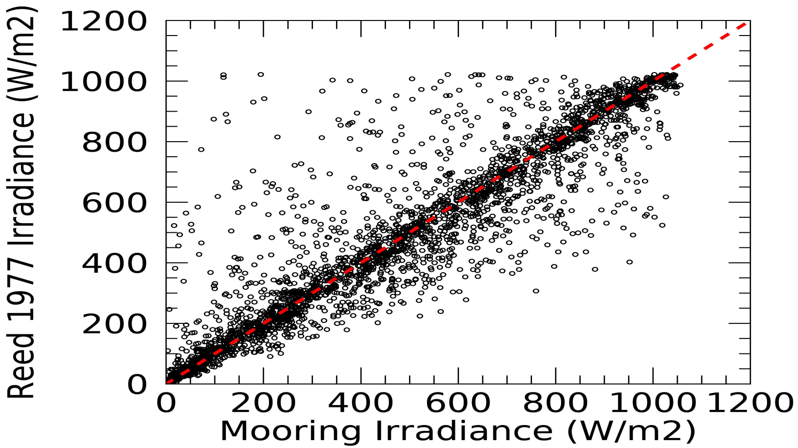
Comparison between Buoy, satellite and bulk formulae (Reed, 1977) estimates based on ECMWF (interim + Reed, 1977) Total Cloud Cover

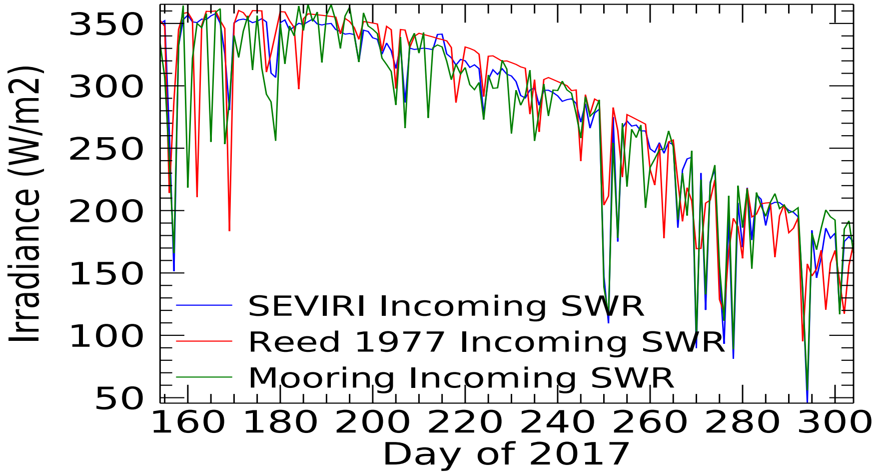
Shortwave Irradiance



	Bias	RMS
Sat - Mooring	4.3 W/m^2	61.8 W/m^2
Reed - Mooring	2.2 W/m^2	89.2 W/m^2

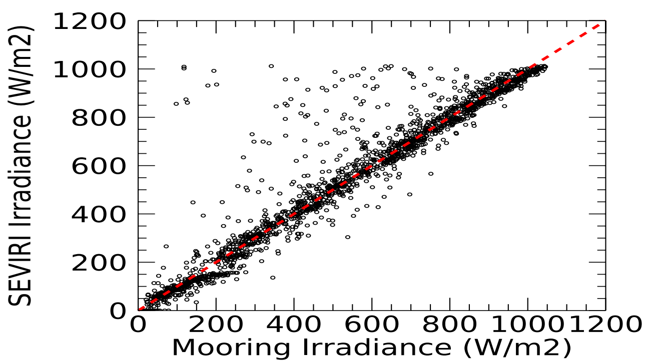


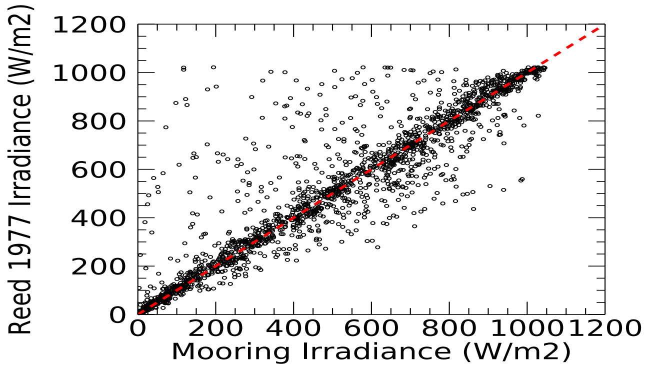




From June 3rd to October 31st

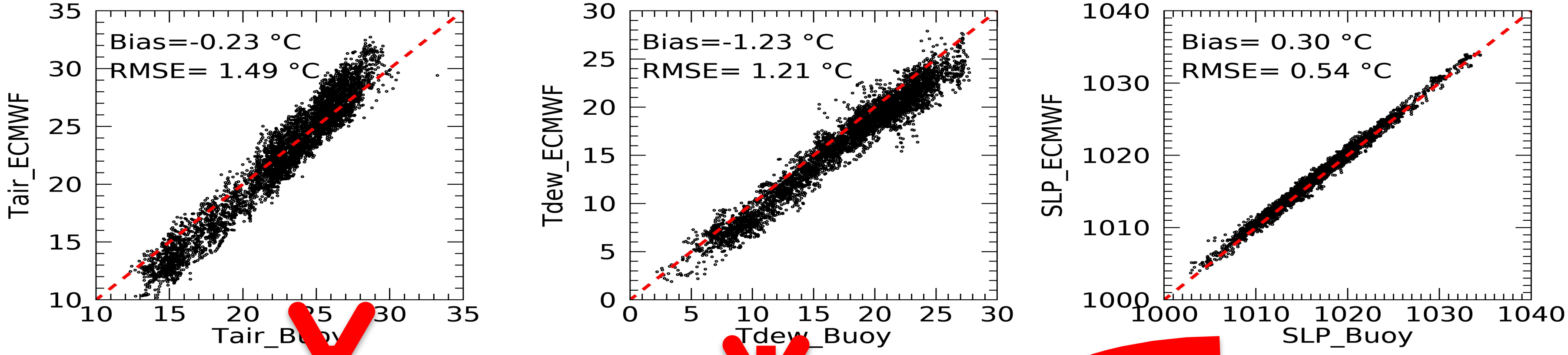
	Bias	RMS
Sat - Mooring	5.8 w/m²	68.0 w/m²
Reed- Mooring	9.0w/m²	91.0 w/m²





Downward atmospheric longwave irradiance

Comparison between Buoy and ECMWF (interim) parameters used by bulk formula (Bignami et al. 1995) to estimate Longwave Irradiance.

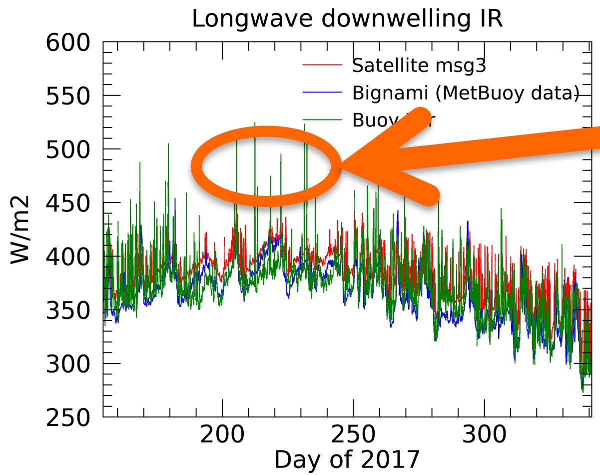


Air Temperature

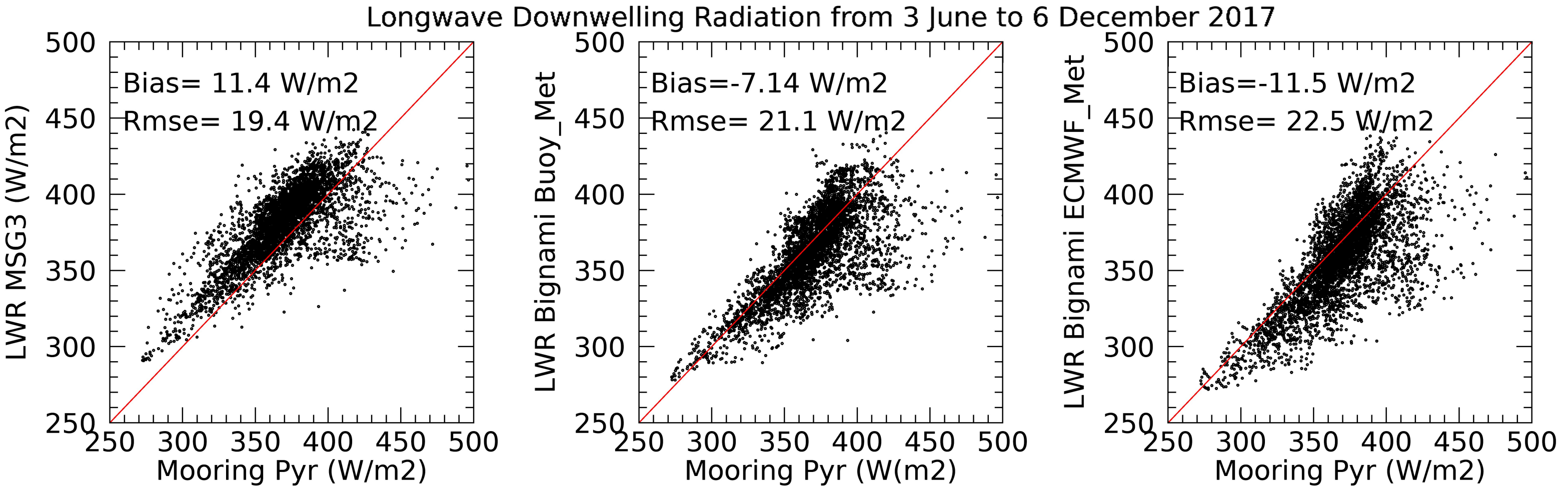
Vapor Pressure

$$IR\downarrow = \sigma T_a^4\left(0.684 + 0.0056\cdot e\right)\left(1 + 0.1763\cdot c^2\right)$$

Total Cloud Cover



Small cloud passing in the field of view of the CGR4 Pyrgeometer



$$IR\downarrow/\sigma T_a^4 = (0.684 + 0.0056\cdot e)(1 + 0.1763\cdot c^2)$$

C=0, Clear sky data only (based on ECMWF TCC): the ratio of IR down /(sigma *T_a^4) is a linear function of water vapor e.

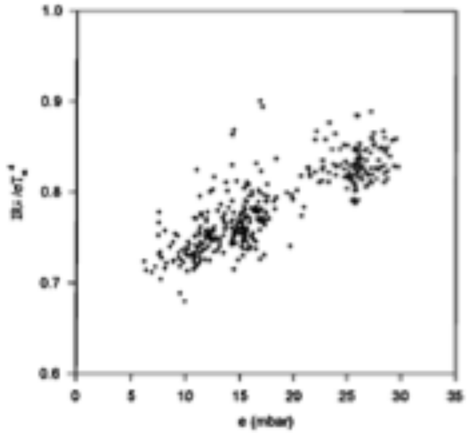
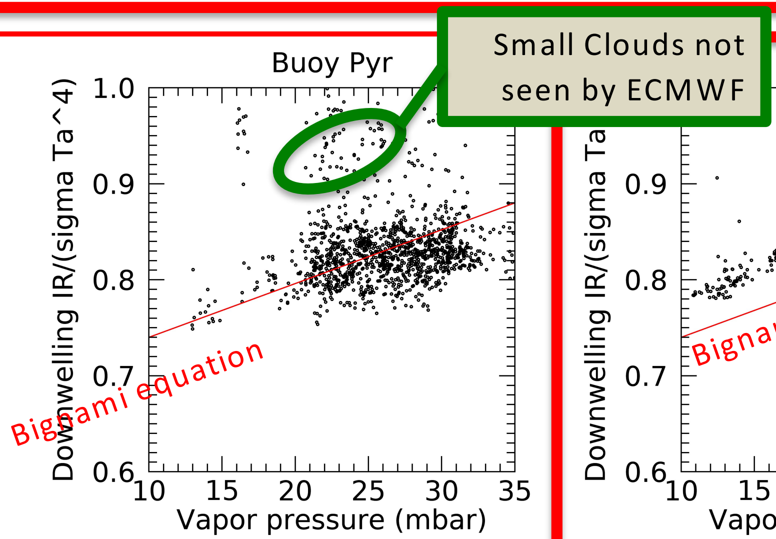
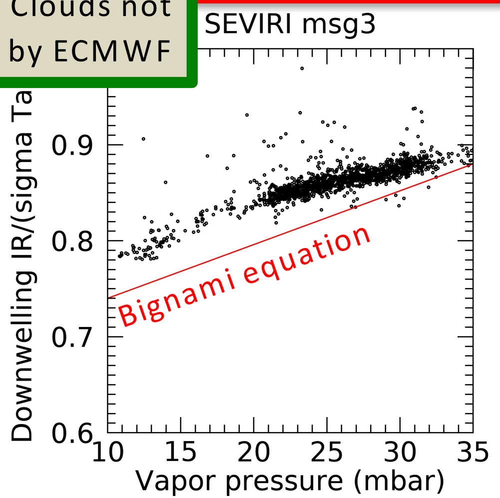


Figure 6 from Bignami et al. 1995

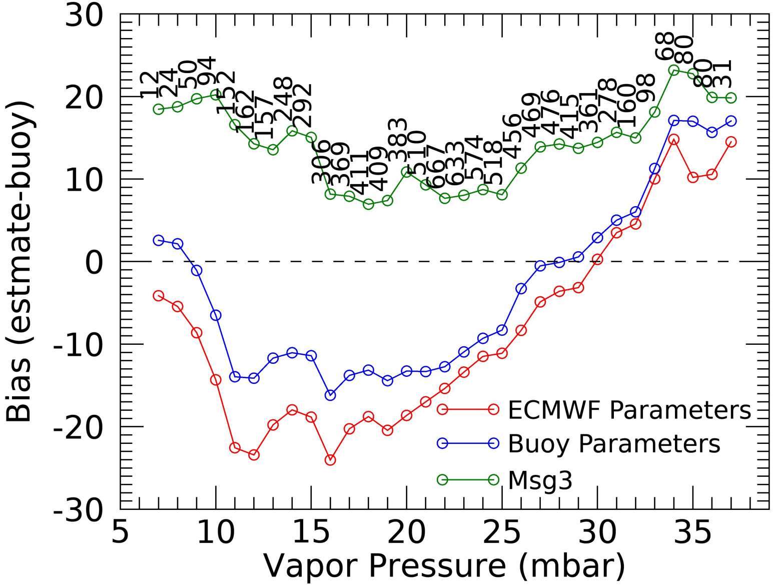


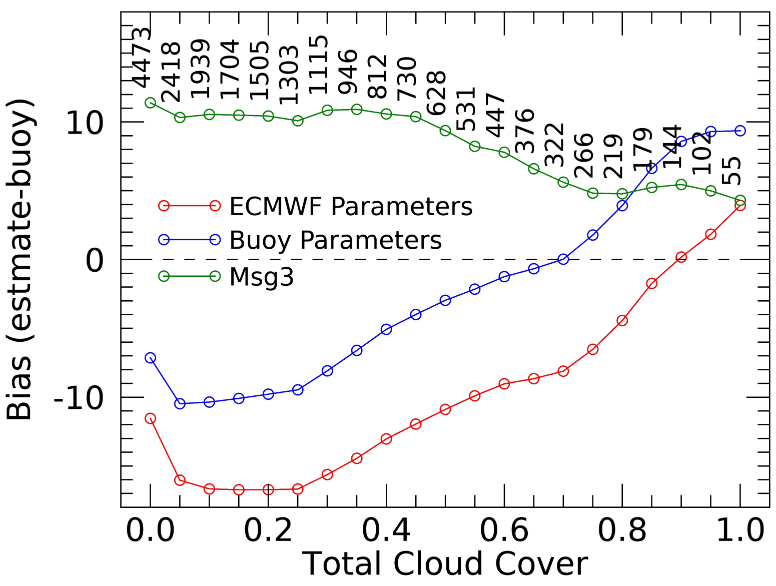
Downwelling IR measured by the buoy as well as all the met parameters used



Downwelling IR measured by Satellite and meteo parameters measured on the buoy

Water vapor and cloud cover dependence of the LW Irradiance Bias





SEVIRI msg3 LW Irradiance bias is less water vapor dependent than bulk formulae derived estimates.

Turbulent Fluxes

We tested two, among several, parameterizations for the exchange turbulent coefficients

A. Birol Kara, Harley E. Hurlburt, And Alan J. Wallcraft (2005). Stability-Dependent Exchange Coefficients for Air–Sea Fluxes. Journal Of Atmospheric And Oceanic Technology

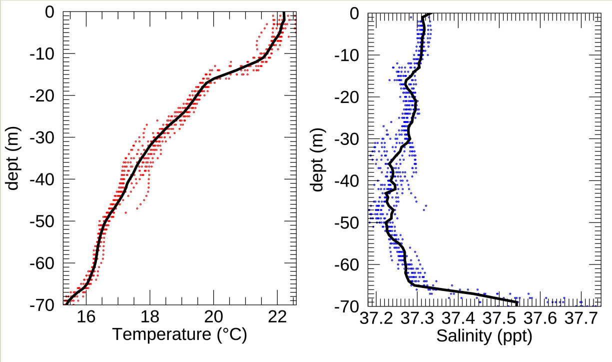
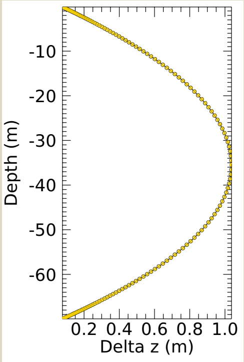
Kondo, J., (1975), Air-sea bulk transfer coefficients in diabatic condition, Boundary-Layer Meteorology, 9, 91–112.

From Jun 3 to October 31
(all data are measured at the Mooring)

Latent Heat Flux →	Kara	ECMWF =	-99.5 W/m^2
		Buoy data =	-97.2 W/m^2
	Kondo	ECMWF =	-99.3 W/m^2
		Buoy data =	-93.4 W/m^2
Sensible Heat Flux →	Kara	ECMWF=	-5.1 W/m^2
		Buoy data =	-5.2 W/m^2
	Kondo	ECMWF =	-3.9 W/m^2
		Buoy data =	-5.1 W/m^2

Impact of air-sea flux parameterization on the upper ocean vertical structure evolution

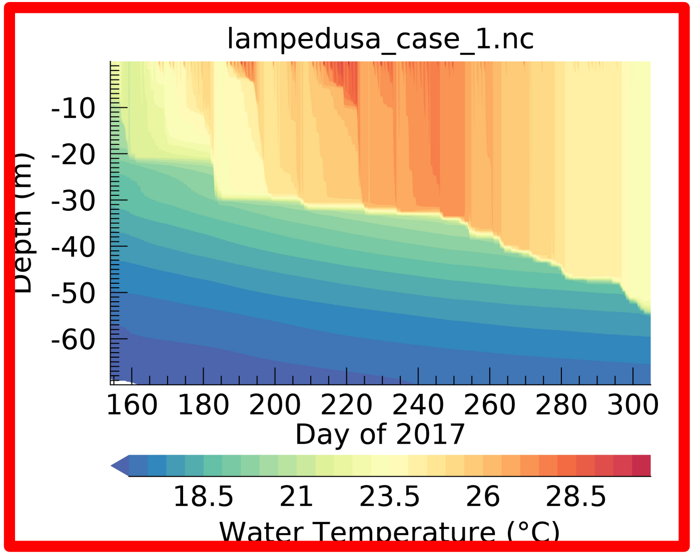
GOTM: General Ocean Turbulence Model

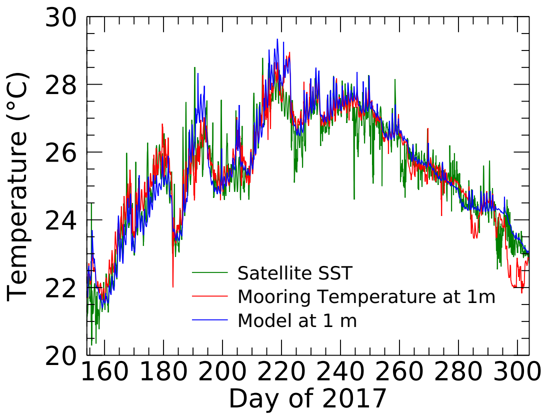
Initial Conditions	Vertical Levels	Configuration
CNR – Sentinel 2017 Cruise: Diurnal cycle experiment from 3 05:00 to 4 of June 2017 08:14 at the mooring site: 35.49°N, 12.47°E. 	Max depth=70 40 vertical levels of increasing thickness from surface/bottom to the interior 	• turbulence Model calculating TKE and length scale • dynamic equation (k-epsilon style) • dynamic dissipation rate equation • constant stability functions • ………… • ………

Heat and momentum fluxes at the air-sea interface were prescribed rather than computed by the model.

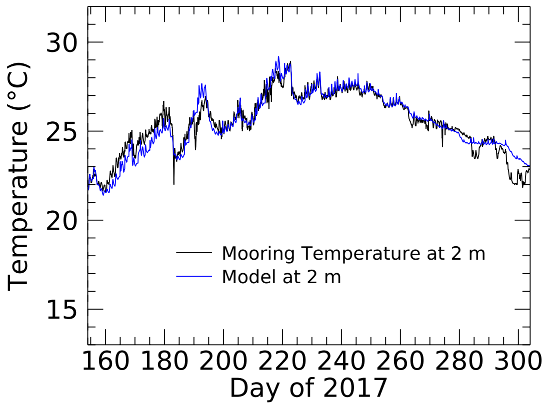
Forcing the Model, Case 1: Radiative fluxes directly measured at the mooring and turbulent fluxes derived from bulk formulas (Kondo 1975) using meteorological parameters measured at the mooring. Initial conditions Sentinel 2017 Cruise Temperature and Salinity casts.

June 3rd - October 31st





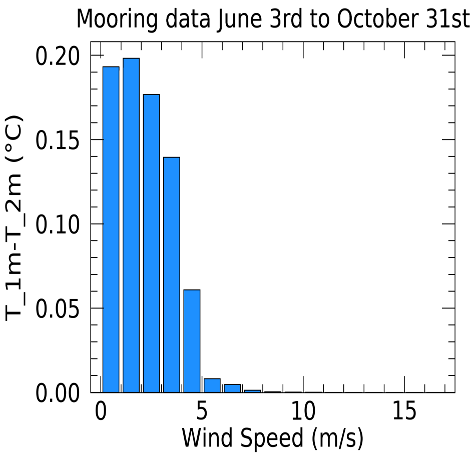
Bias (Model – Buoy)=0.02 °C
RMS=0.51 °C
R=0.9556

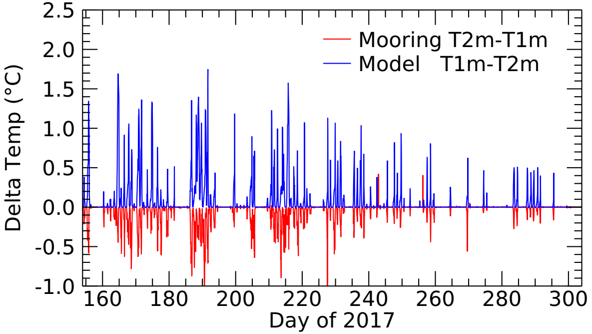


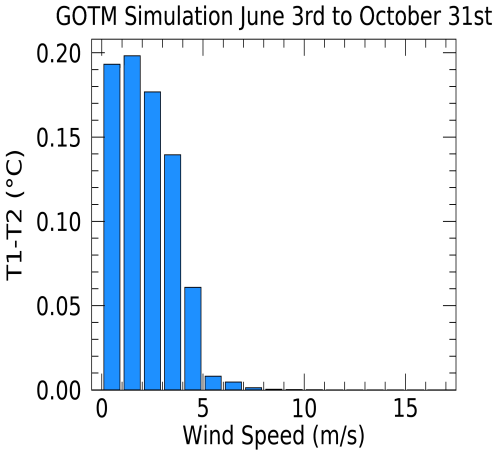
Bias (Model – Buoy)=-0.01 °C
RMS=0.51 °C
R=0.9555

Satellite-Buoy 1 m Bias=0.09 °C RMS=0.60 °C R=0.935

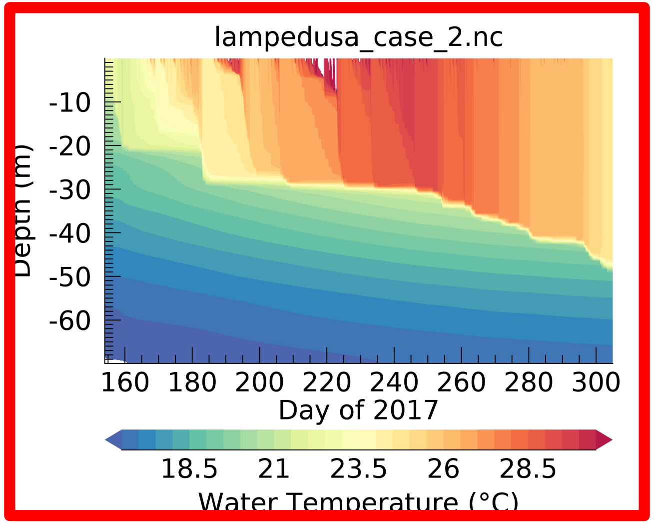
Forcing the Model, Case 1: ***Comparison between modeled and measured temperatures at the surface, 1 and 2 meters as function of the wind speed***

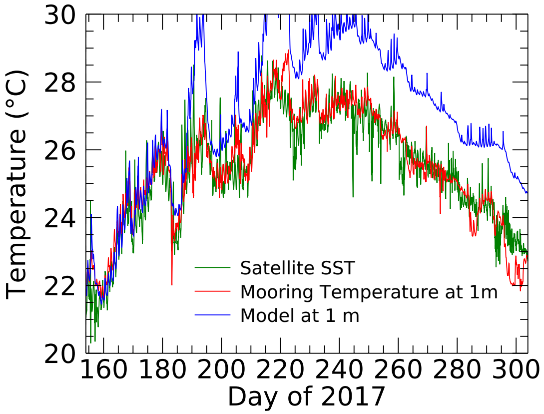


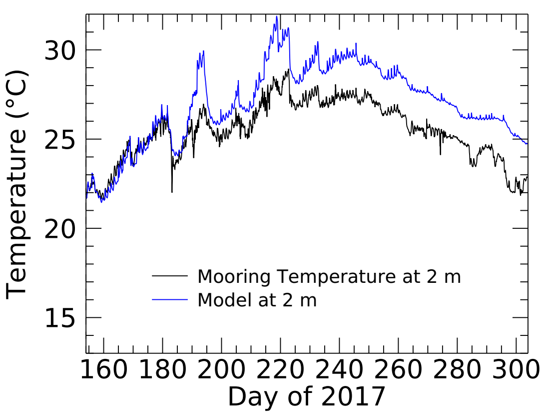




Forcing the Model, Case 2: Radiative fluxes from msg3 and turbulent fluxes derived from bulk formulas (Kondo 1975) using meteorological parameters measured at the mooring. Initial conditions Sentinel 2017 Cruise Temperature and Salinity casts.







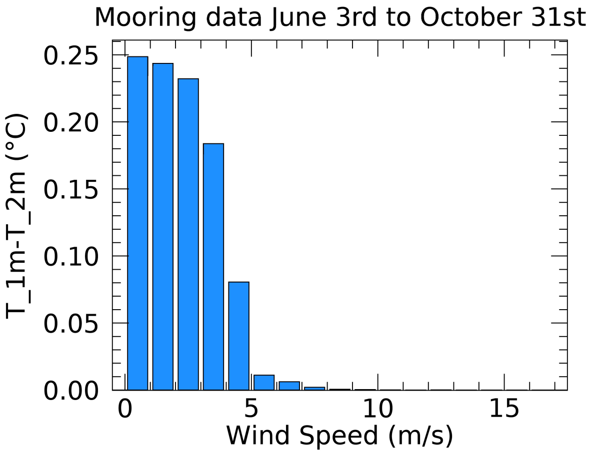
Bias (Model – Buoy)=1.50 °C
RMS=0.99 °C

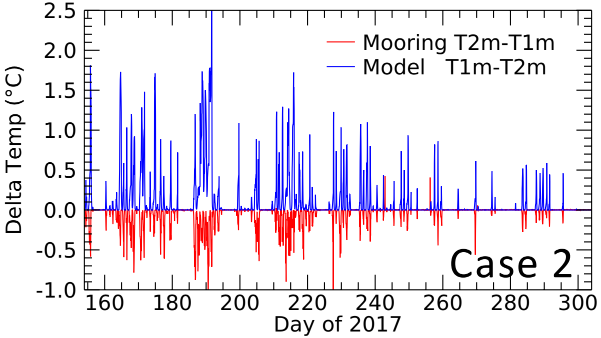
R=0.911

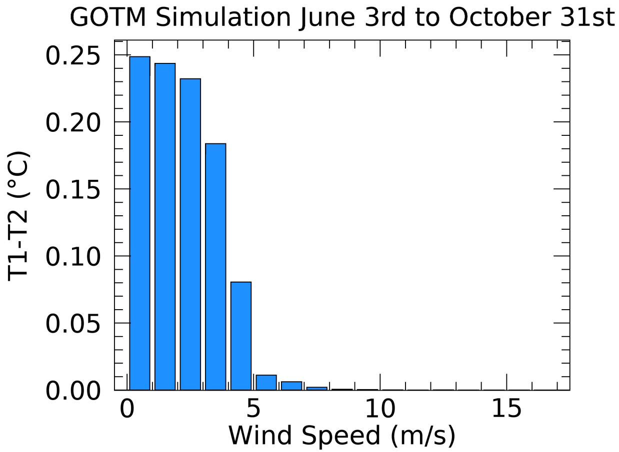
Bias (Model – Buoy)=1.50 °C
RMS=1.00 °C

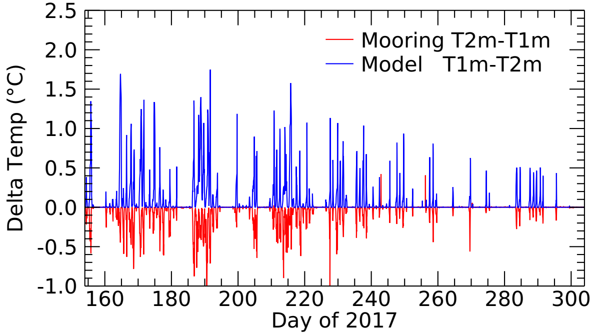
R=0.910

Forcing the Model, Case 2:









Conclusions

1. The Lampedusa climate observatory including land and ocean based measurements is an unique opportunity for air-sea interaction studies and cal/val activities.
2. A precise estimate of the air-sea momentum and heat fluxes are essential for the model t correctly reproduce the upper ocean structure. Positive Bias in radiative fluxes estimates direct impact on model output, the result is an evident extra heating of mixed layer.
3. Hourly satellite estimates of radiative fluxes have a lot of potentiality in describing the hig frequency variability of the air-sea physics but our results (even if limited to single site an short period) suggest the need of a refinement of the algorithm or adaptation to specific regional conditions to reduce the bias between measurements and satellite estimation.
4. Estimation of shortwave irradiance cannot be simply based on bulk formulae (like Reed) which the total cloud cover is the input (as many OGCM does). High frequency variability aerosols due, for instance, to Sahara dust event cannot be neglected or simply treated as seasonal varying corrections of the atmospheric trasmittance.
5. The effect of the wind on temperature difference between 1 and 2 meter of depth and w the surface is evident and can be modeled.


See you in Lampedusa!