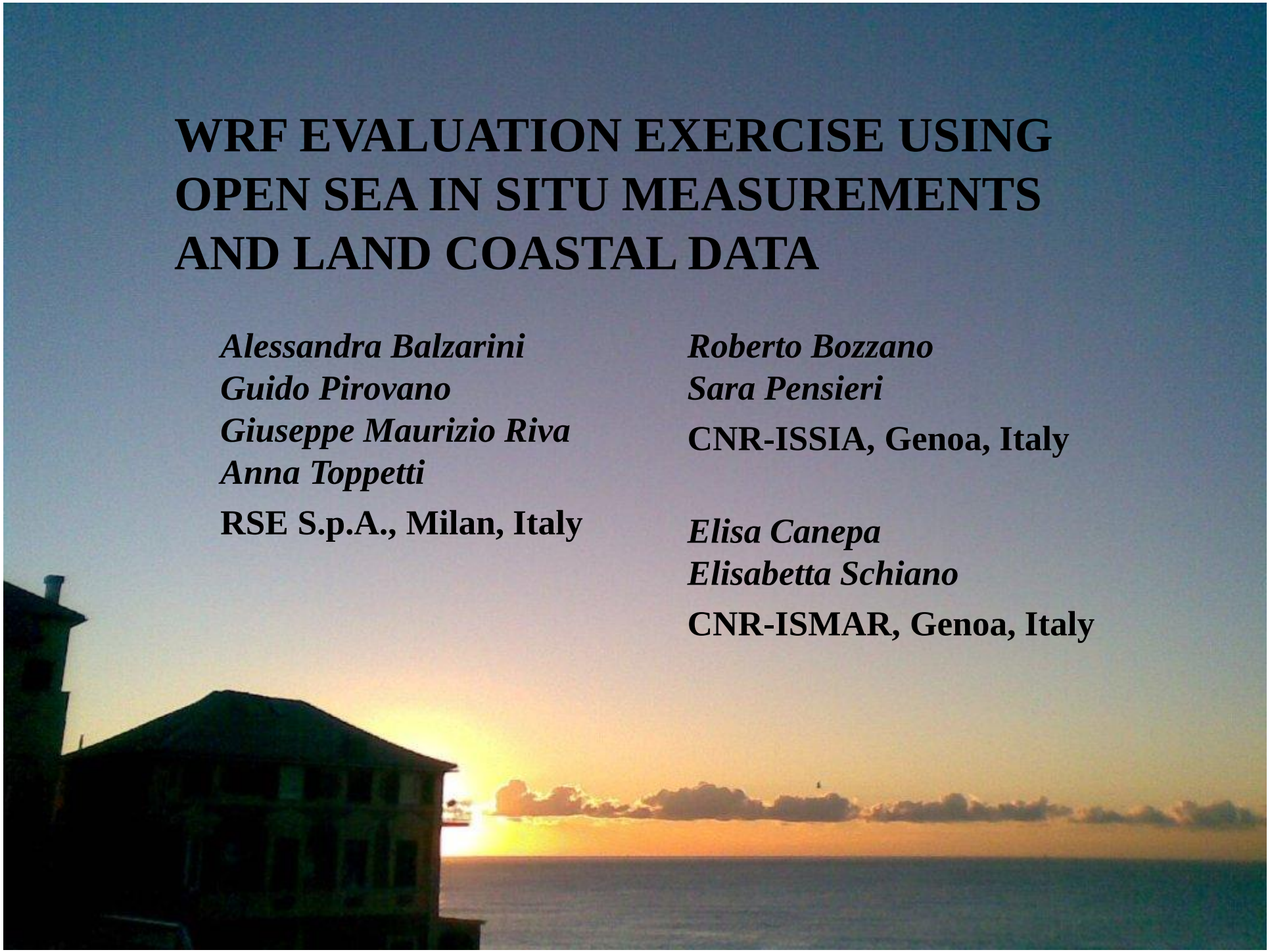

WRF EVALUATION EXERCISE USING OPEN SEA IN SITU MEASUREMENTS AND LAND COASTAL DATA

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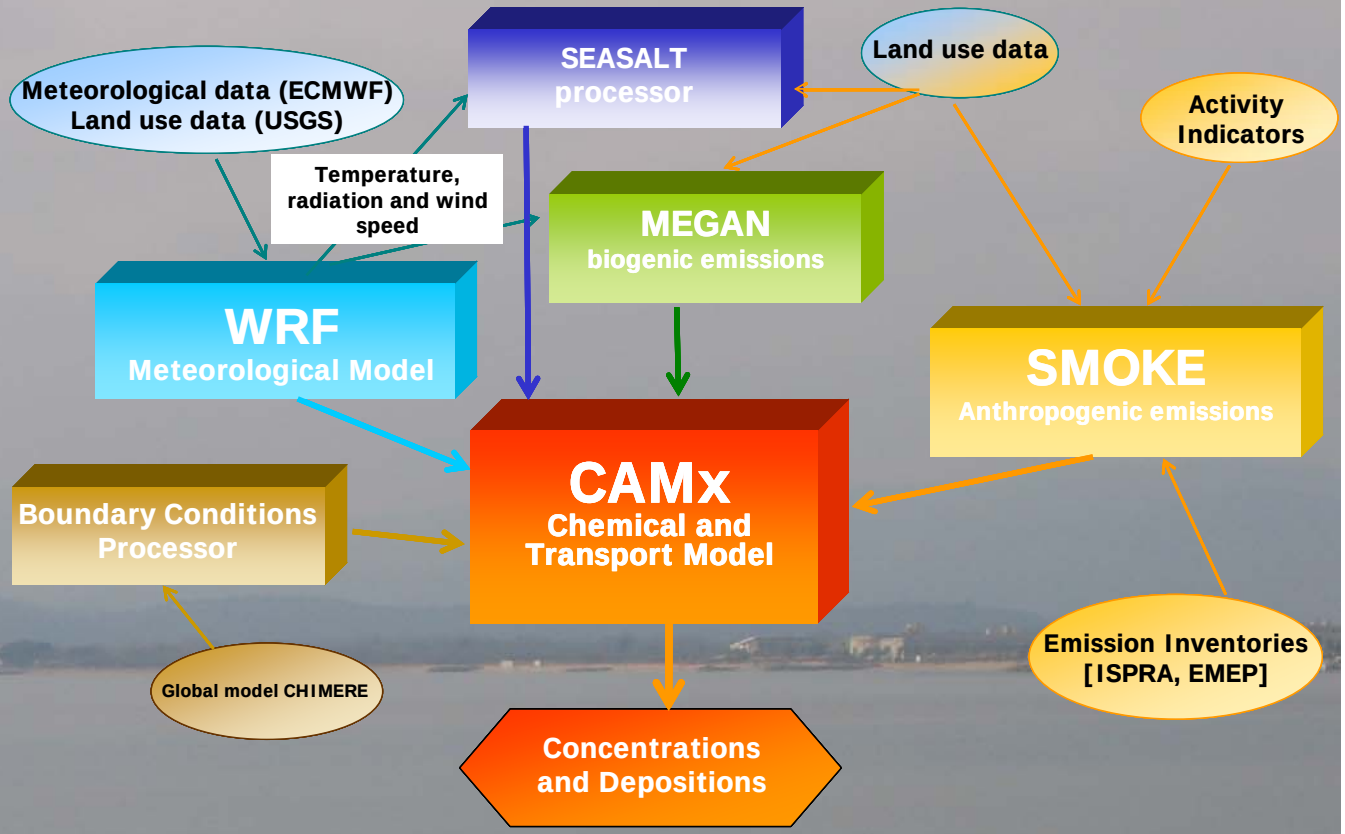
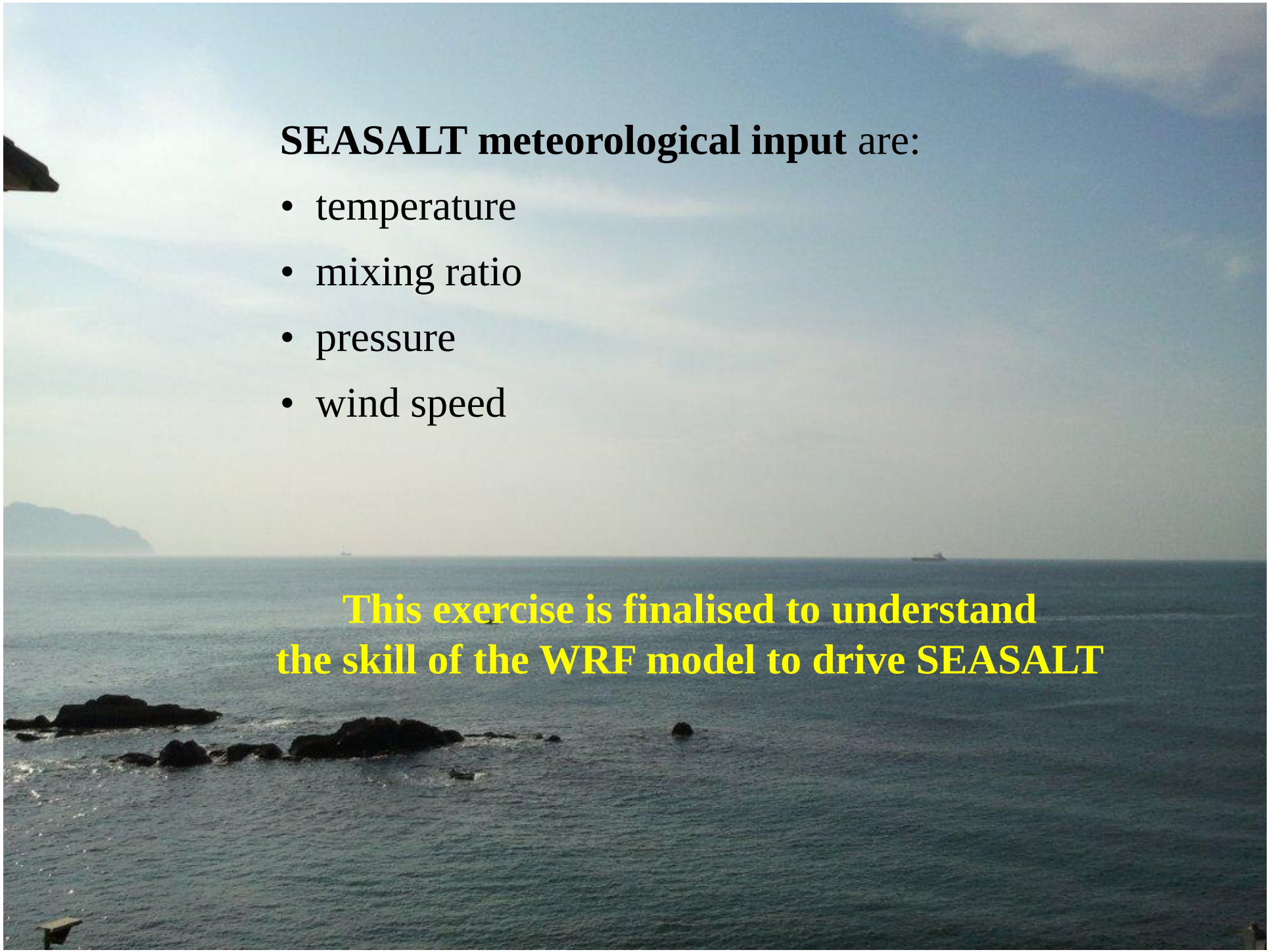
CNR-ISMAR, Genoa, Italy

The **RSE S.p.A.** implemented the system **WRF-SMOKE-CAMx** to simulate dispersion of pollutants in Italy



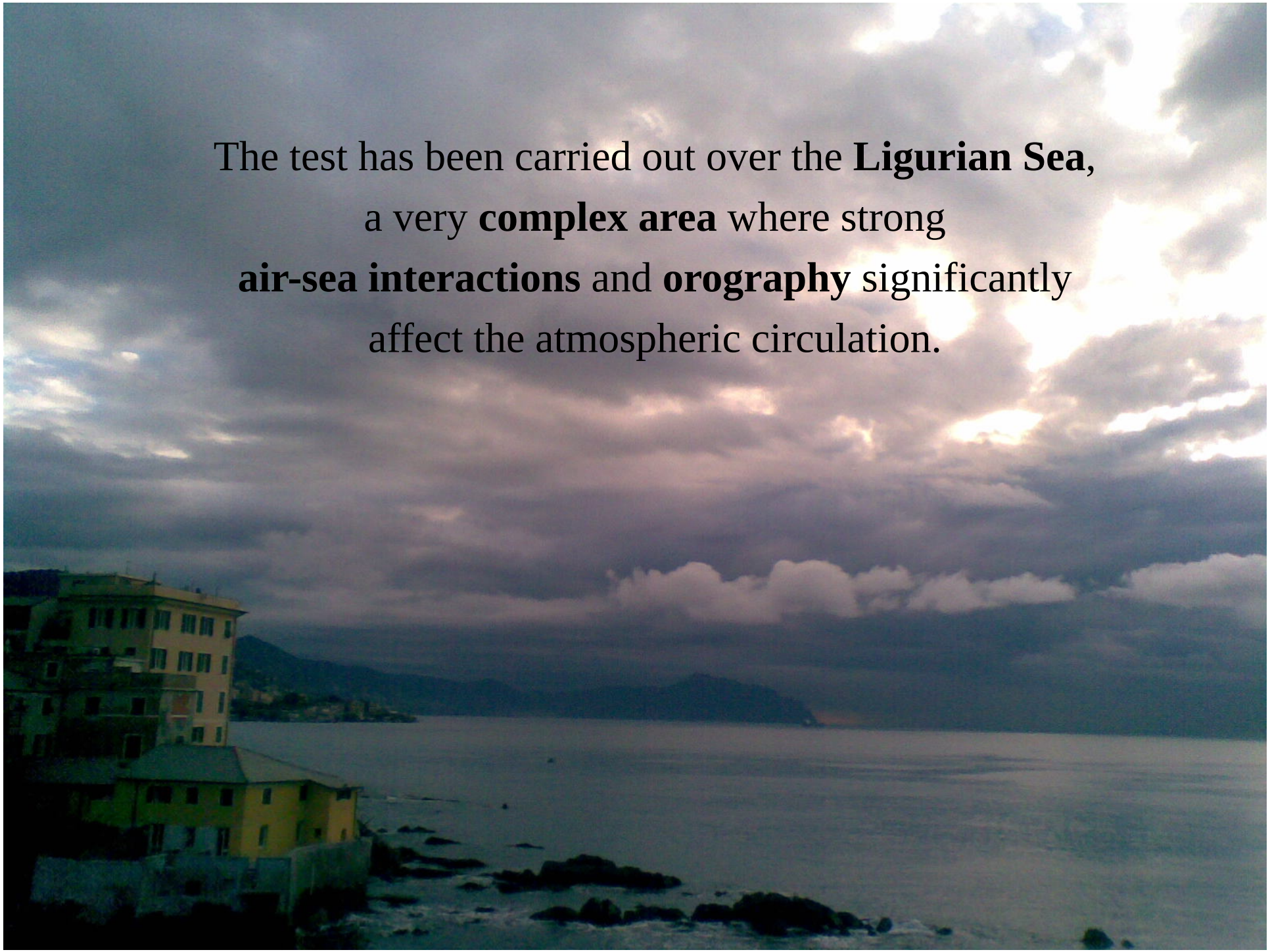
Within this system **aerosol emissions from the sea**, an important factor to correctly predict air pollutant levels, are simulated by the **SEASALT** processor (Gong *et al.*, 2002; Smith and Harrison, 1998).



SEASALT meteorological input are:

- temperature
- mixing ratio
- pressure
- wind speed

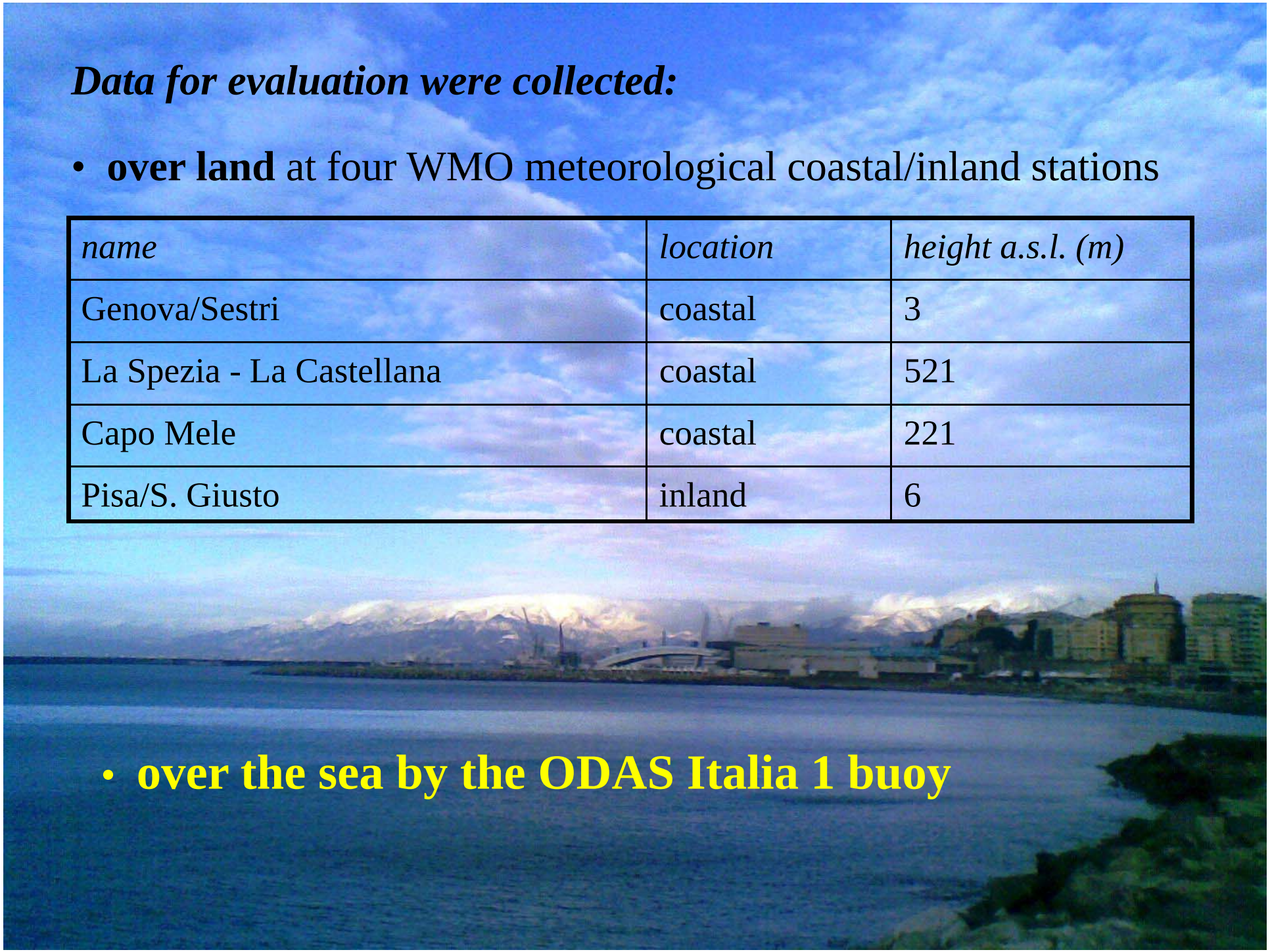
This exercise is finalised to understand the skill of the WRF model to drive SEASALT


The test has been carried out over the **Ligurian Sea**,
a very **complex area** where strong
air-sea interactions and **orography** significantly
affect the atmospheric circulation.

Data for evaluation were collected:

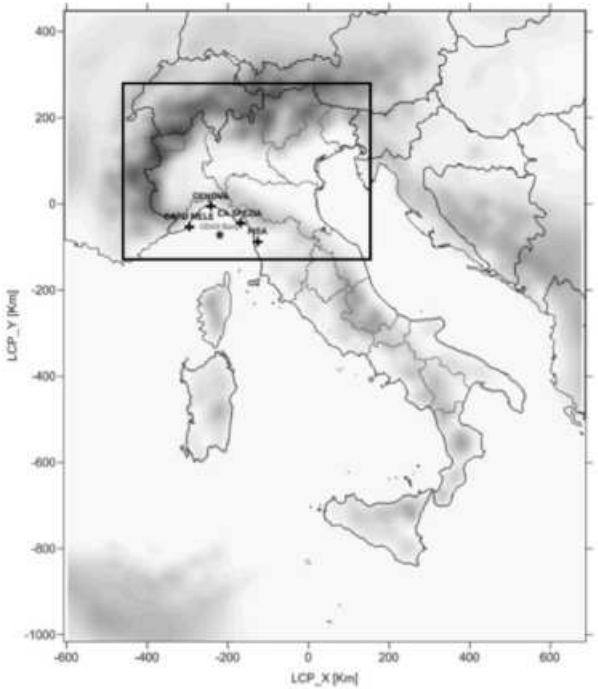
- **over land** at four WMO meteorological coastal/inland stations

name	*location*	*height a.s.l. (m)*
Genova/Sestri	coastal	3
La Spezia - La Castellana	coastal	521
Capo Mele	coastal	221
Pisa/S. Giusto	inland	6

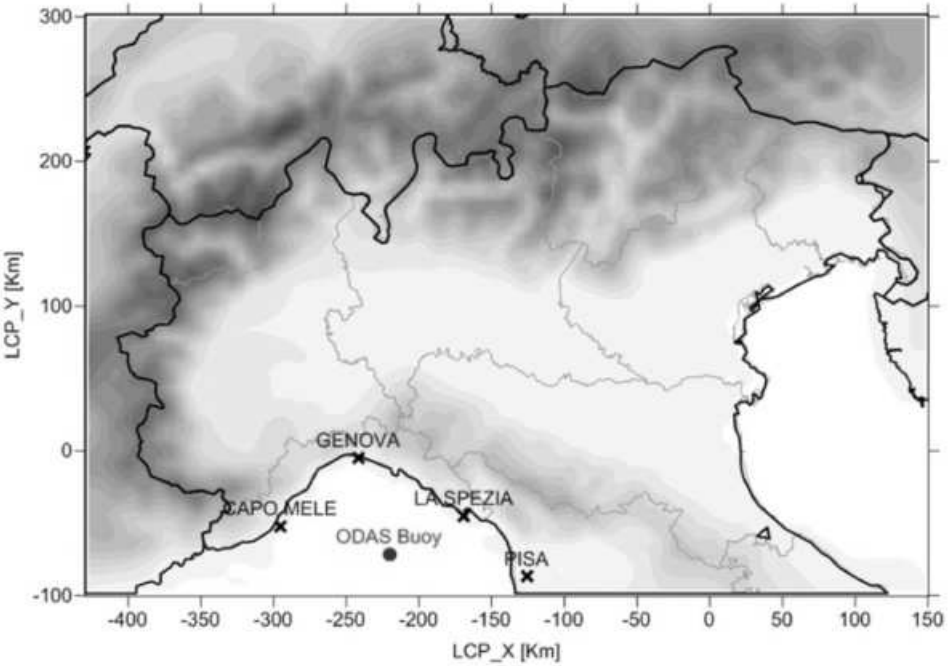


- **over the sea by the ODAS Italia 1 buoy**

The 15 km resolution WRF domain

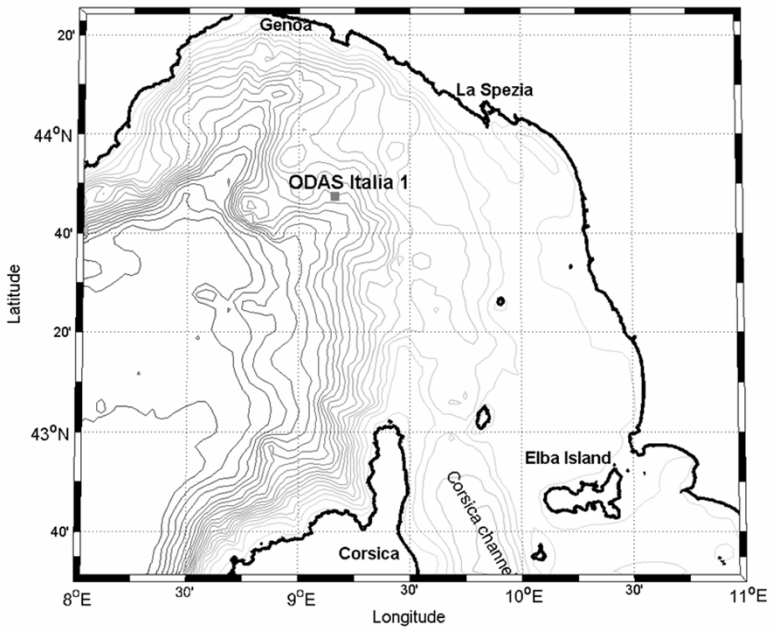


Detail of the Northern Italy area where meteorological stations are located



ODAS Italia 1: the only spar buoy in the Mediterranean sea

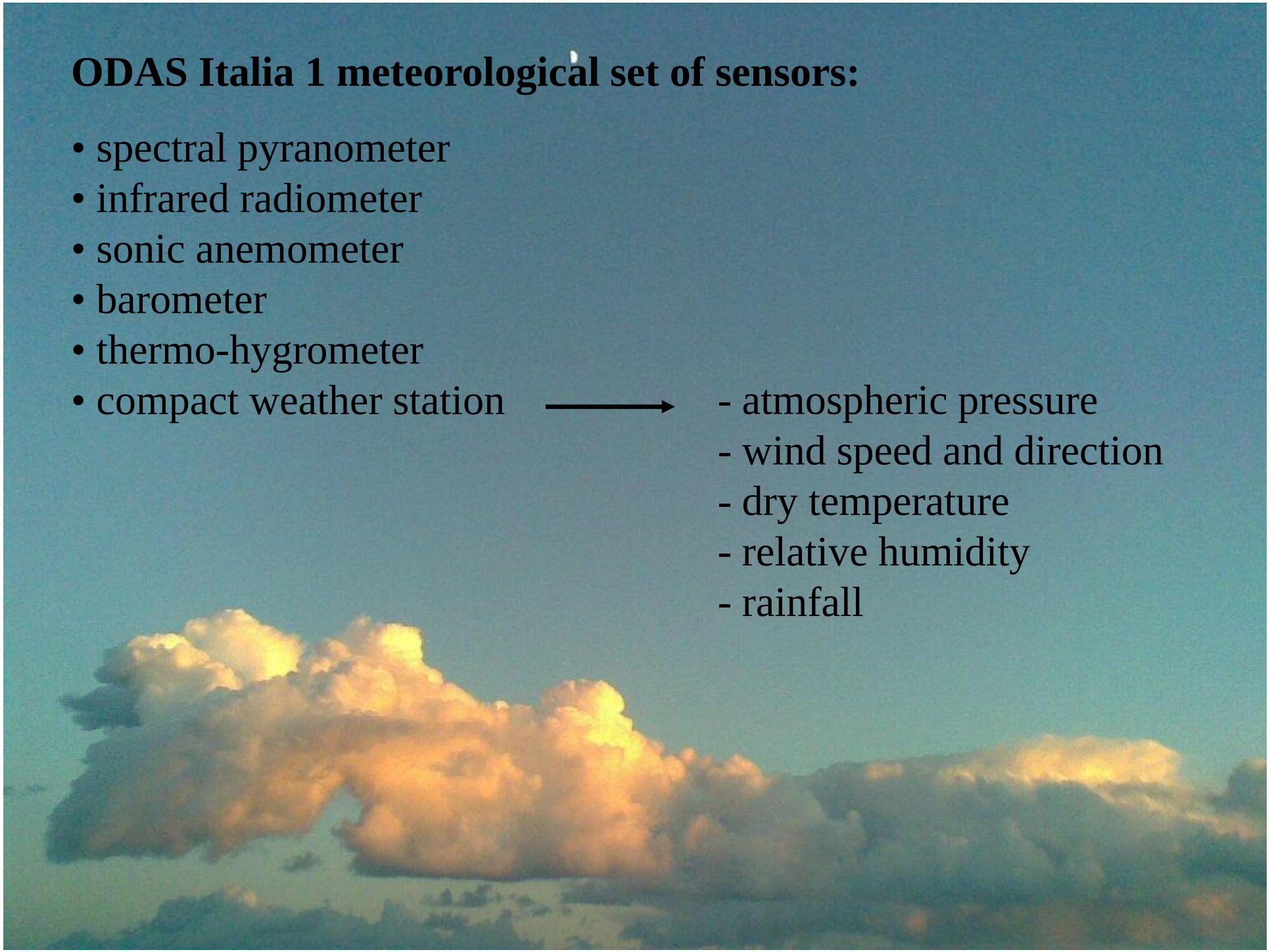
http://www.odas.ge.issia.cnr.it

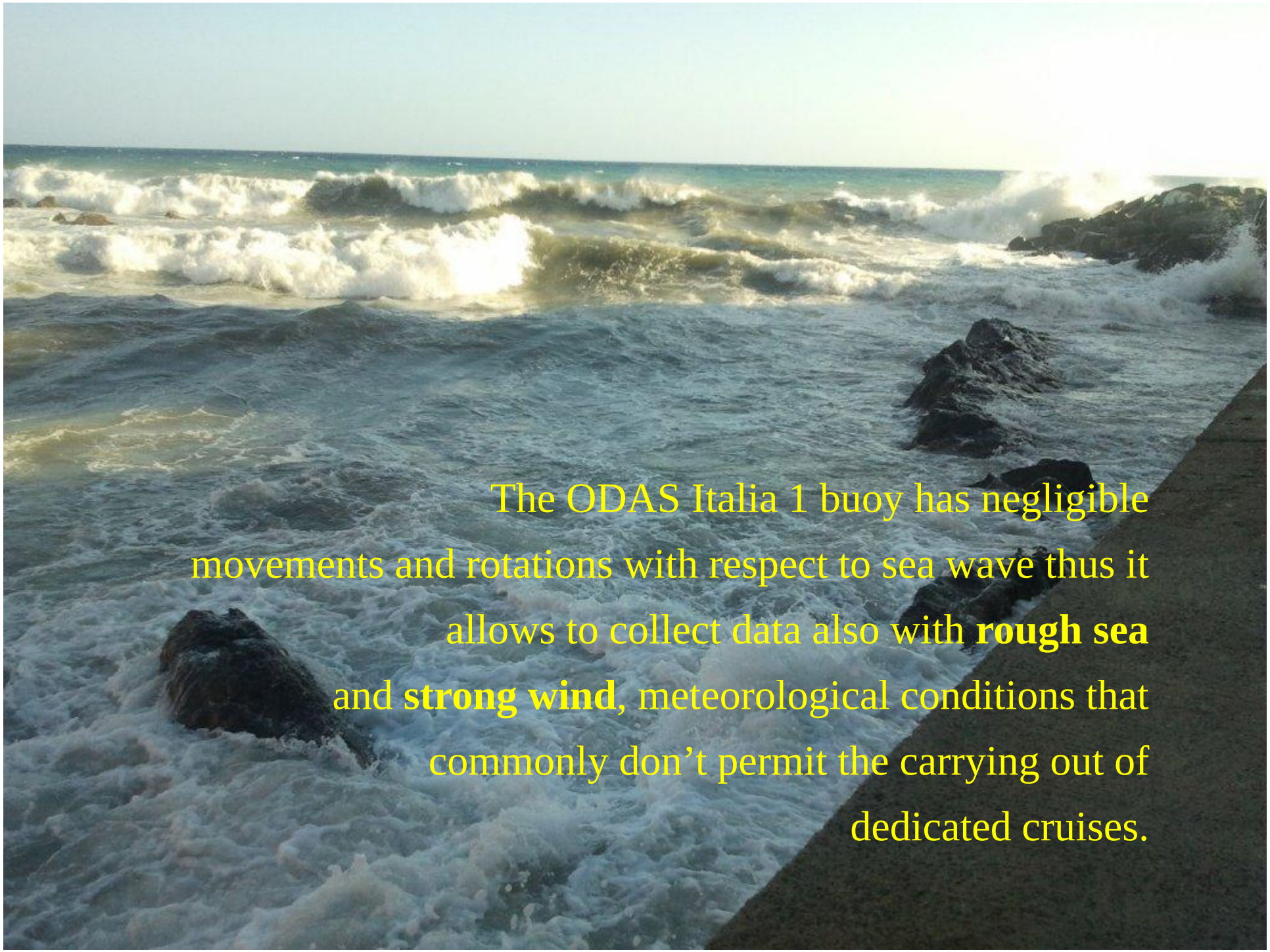


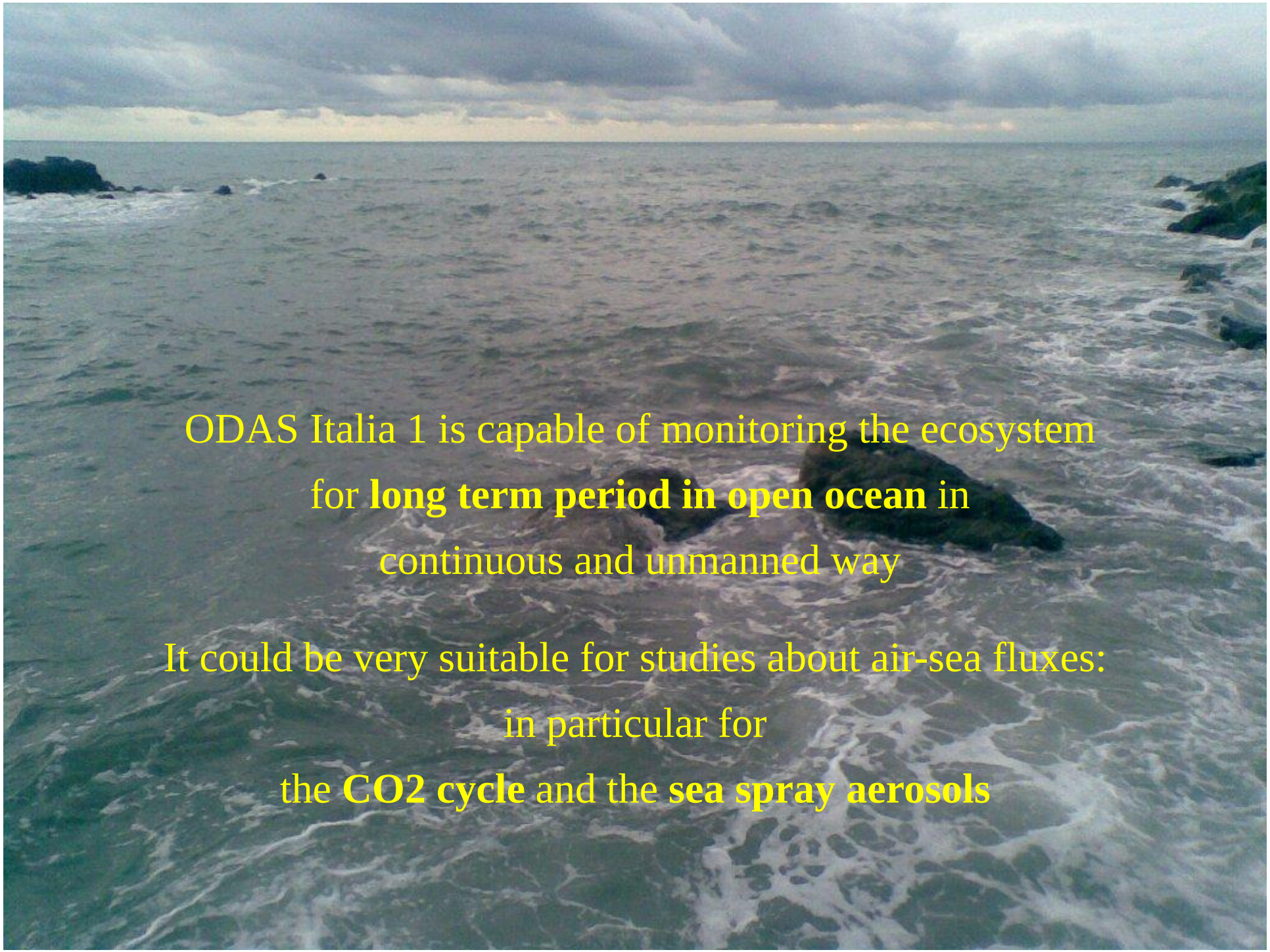
It is moored in the Ligurian Sea on a seabed of **1270 m** at about **75 km** far from the coast.

ODAS Italia 1 meteorological set of sensors:

- spectral pyranometer
- infrared radiometer
- sonic anemometer
- barometer
- thermo-hygrometer
- compact weather station ⟶
  - atmospheric pressure
  - wind speed and direction
  - dry temperature
  - relative humidity
  - rainfall

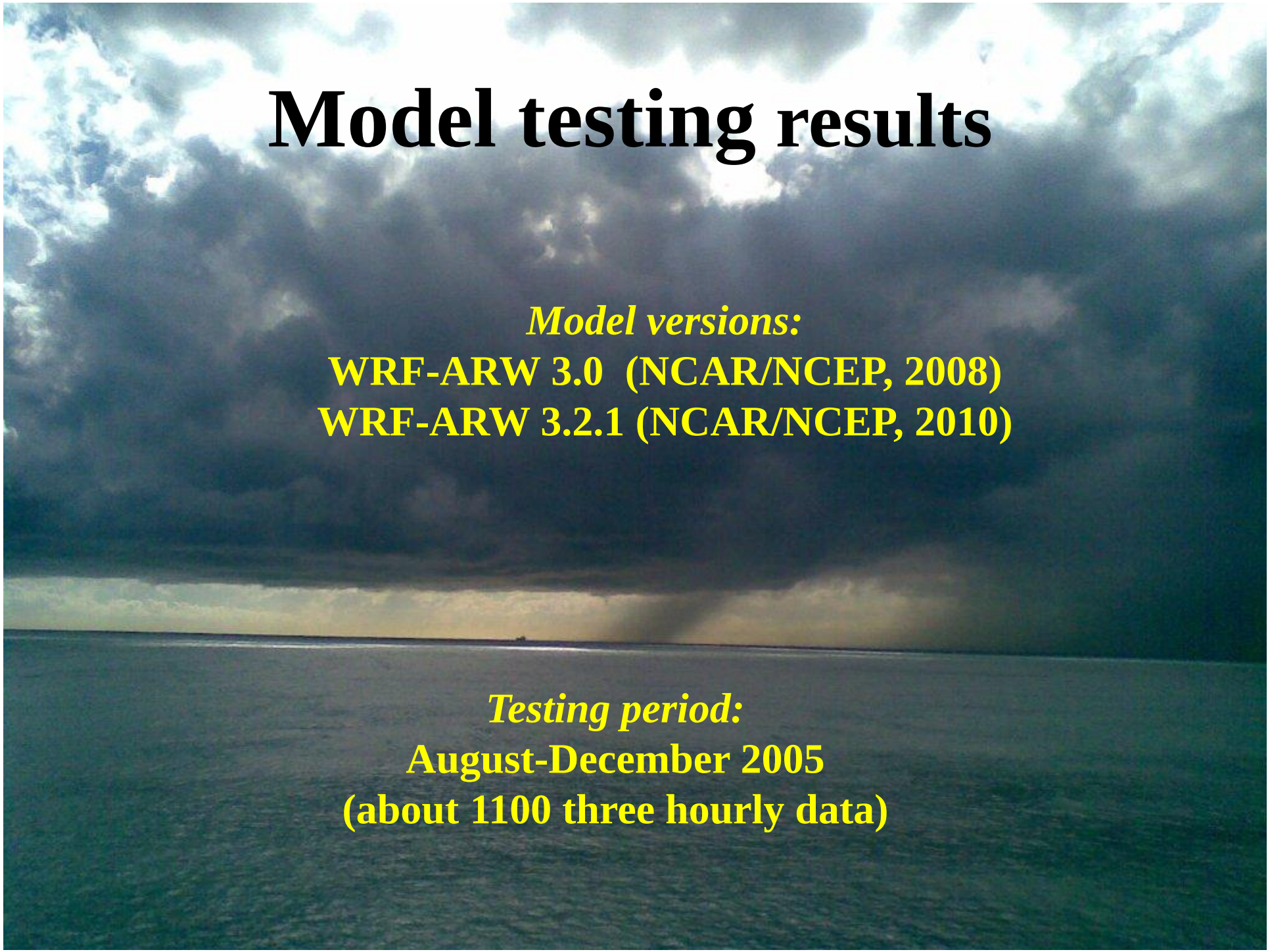



The ODAS Italia 1 buoy has negligible
movements and rotations with respect to sea wave thus it
allows to collect data also with **rough sea**
and **strong wind**, meteorological conditions that
commonly don’t permit the carrying out of
dedicated cruises.



ODAS Italia 1 is capable of monitoring the ecosystem
for **long term period in open ocean** in
continuous and unmanned way

It could be very suitable for studies about air-sea fluxes:
in particular for
the **CO2 cycle** and the **sea spray aerosols**



Model testing results

Model versions:

WRF-ARW 3.0 (NCAR/NCEP, 2008)

WRF-ARW 3.2.1 (NCAR/NCEP, 2010)

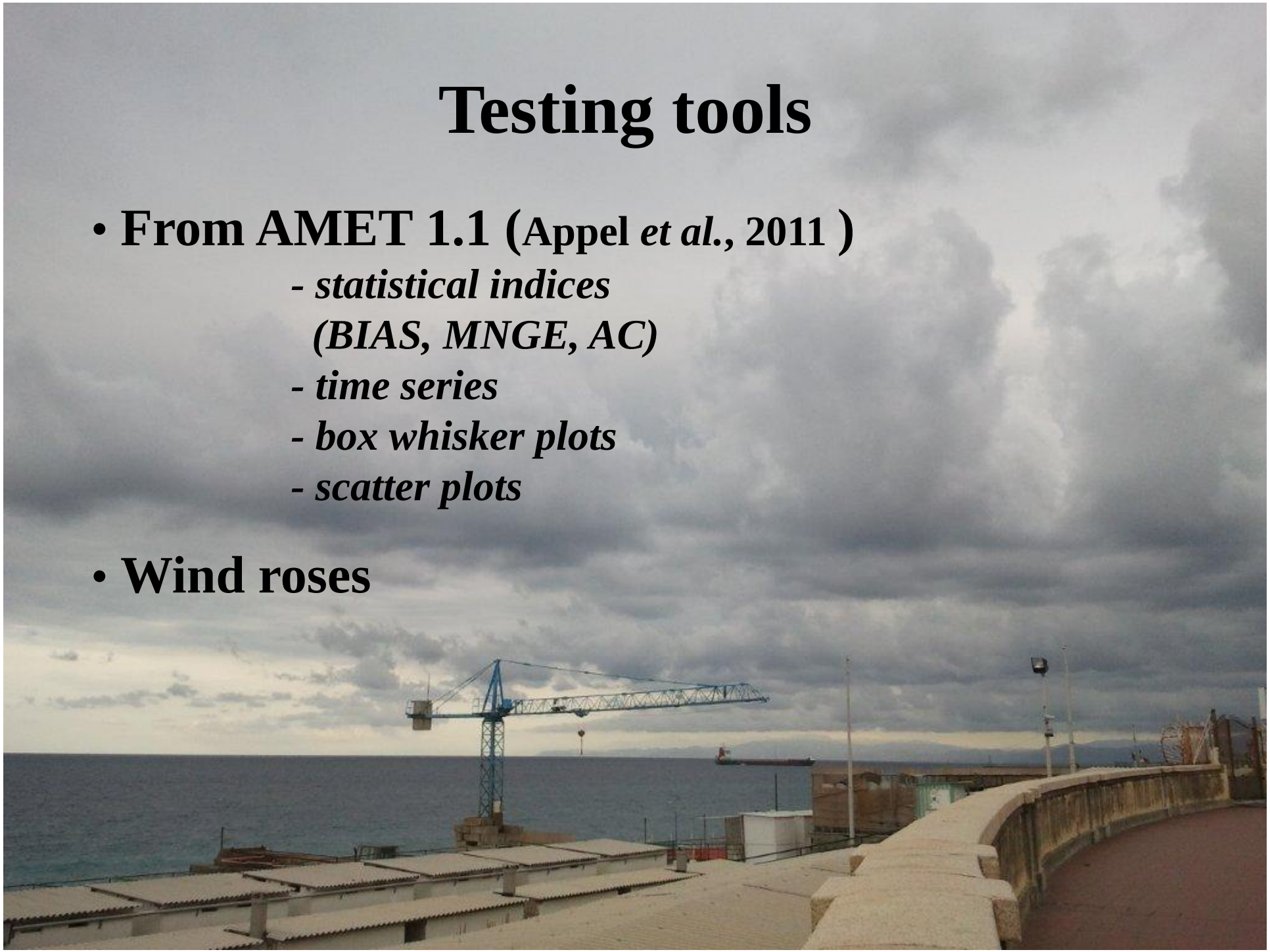
Testing period:

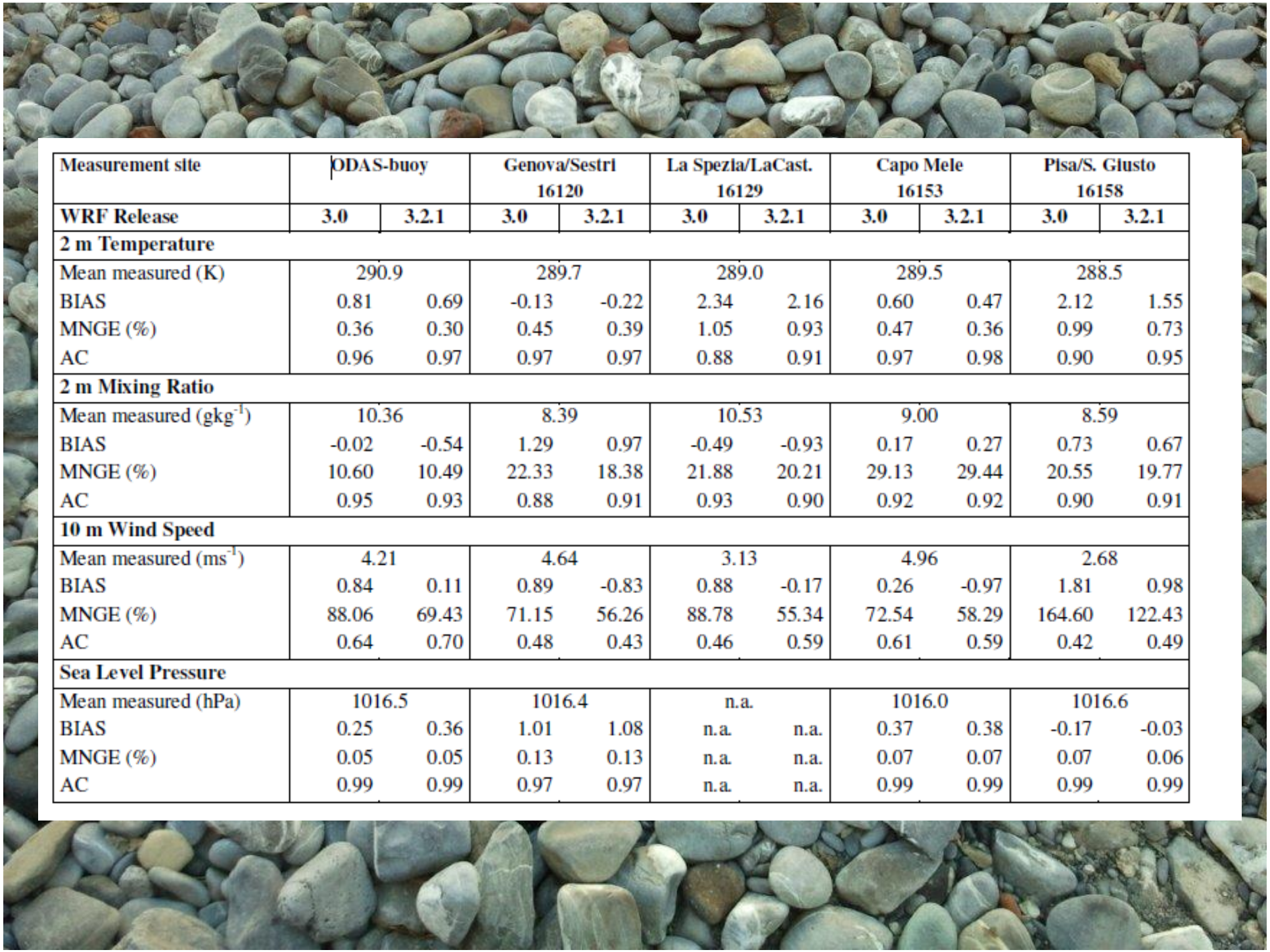
August-December 2005

(about 1100 three hourly data)

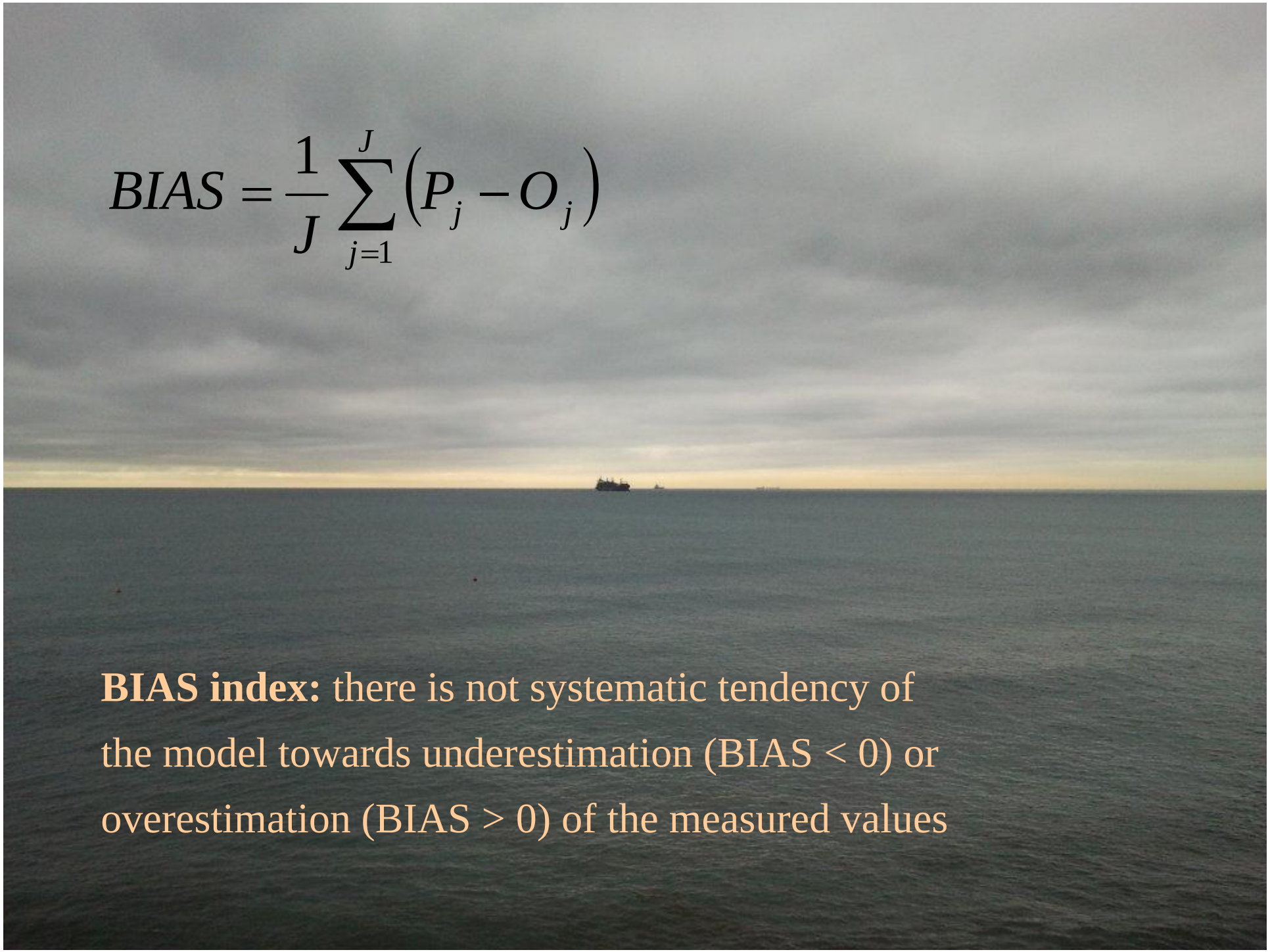
Testing tools

- **From AMET 1.1 (Appel *et al.*, 2011)**
  - ***statistical indices (BIAS, MNGE, AC)***
  - ***time series***
  - ***box whisker plots***
  - ***scatter plots***
- **Wind roses**





Measurement site	ODAS-buoy		Genova/Sestri 16120		La Spezia/LaCast. 16129		Capo Mele 16153		Pisa/S. Giusto 16158	
WRF Release	**3.0**	**3.2.1**	**3.0**	**3.2.1**	**3.0**	**3.2.1**	**3.0**	**3.2.1**	**3.0**	**3.2.1**
2 m Temperature										
Mean measured (K)	290.9		289.7		289.0		289.5		288.5	
BIAS	0.81	0.69	-0.13	-0.22	2.34	2.16	0.60	0.47	2.12	1.55
MNGE (%)	0.36	0.30	0.45	0.39	1.05	0.93	0.47	0.36	0.99	0.73
AC	0.96	0.97	0.97	0.97	0.88	0.91	0.97	0.98	0.90	0.95
2 m Mixing Ratio										
Mean measured (gkg^{-1})	10.36		8.39		10.53		9.00		8.59	
BIAS	-0.02	-0.54	1.29	0.97	-0.49	-0.93	0.17	0.27	0.73	0.67
MNGE (%)	10.60	10.49	22.33	18.38	21.88	20.21	29.13	29.44	20.55	19.77
AC	0.95	0.93	0.88	0.91	0.93	0.90	0.92	0.92	0.90	0.91
10 m Wind Speed										
Mean measured (ms^{-1})	4.21		4.64		3.13		4.96		2.68	
BIAS	0.84	0.11	0.89	-0.83	0.88	-0.17	0.26	-0.97	1.81	0.98
MNGE (%)	88.06	69.43	71.15	56.26	88.78	55.34	72.54	58.29	164.60	122.43
AC	0.64	0.70	0.48	0.43	0.46	0.59	0.61	0.59	0.42	0.49
Sea Level Pressure										
Mean measured (hPa)	1016.5		1016.4		n.a.		1016.0		1016.6	
BIAS	0.25	0.36	1.01	1.08	n.a.	n.a.	0.37	0.38	-0.17	-0.03
MNGE (%)	0.05	0.05	0.13	0.13	n.a.	n.a.	0.07	0.07	0.07	0.06
AC	0.99	0.99	0.97	0.97	n.a.	n.a.	0.99	0.99	0.99	0.99



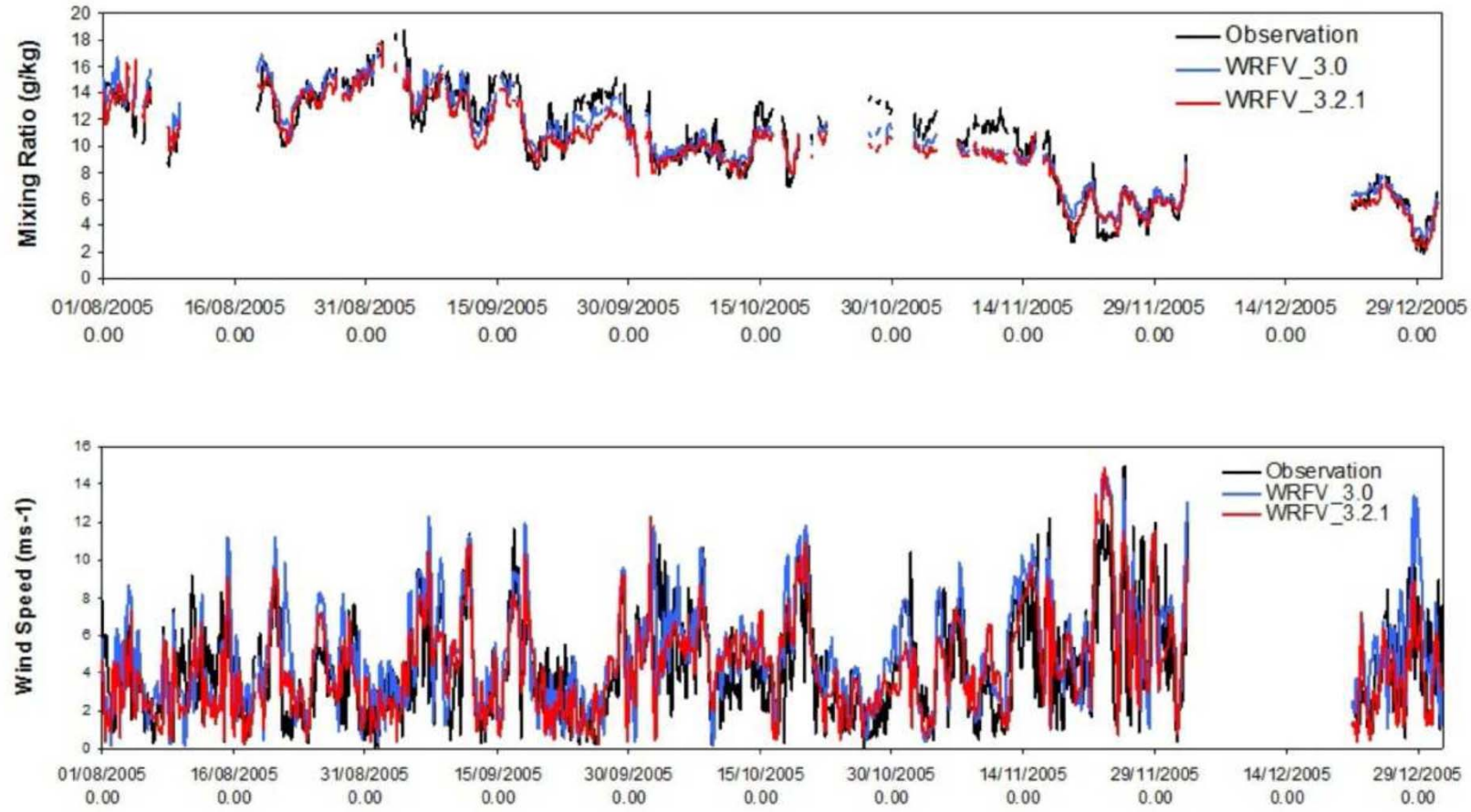
$$BIAS = \frac{1}{J}\sum_{j=1}^{J}\left(P_j - O_j\right)$$

BIAS index: there is not systematic tendency of the model towards underestimation (BIAS < 0) or overestimation (BIAS > 0) of the measured values

$$MNGE = \frac{1}{J}\sum_{j=1}^{J}\frac{\left|P_j - O_j\right|}{O_j}\%$$

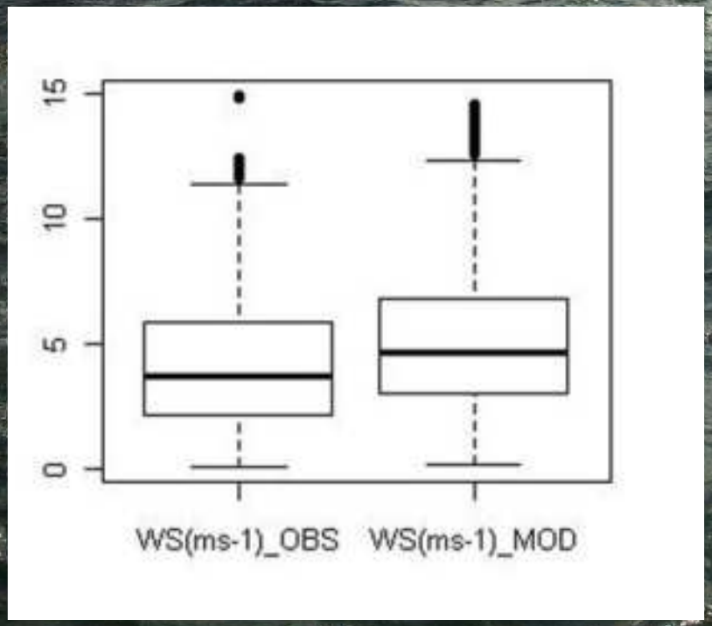
$$AC = \frac{\sum_{j=1}^{J}\left(P_j - M_o\right)\left(O_j - M_o\right)}{\left[\sum_{j=1}^{J}\left(P_j - M_o\right)^2 \sum_{j=1}^{J}\left(O_j - M_o\right)^2\right]^{1/2}}$$

- **WRF-ARW 3.2.1** overall performs better than WRF-ARW 3.0
- AC > 0.9 for temperature, mixing ratio, pressure
- MNGE < 1% for temperature, pressure
- **wind speed** simulation is the most critical one

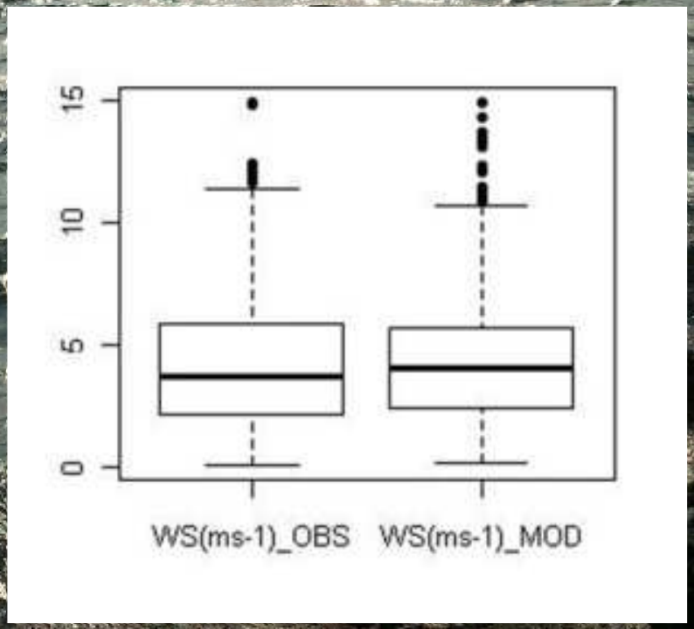


ODAS Italia 1 buoy:
2 m mixing ratio and 10 m wind speed time series

ODAS Italia 1 buoy:
10 m wind speed box whisker plots

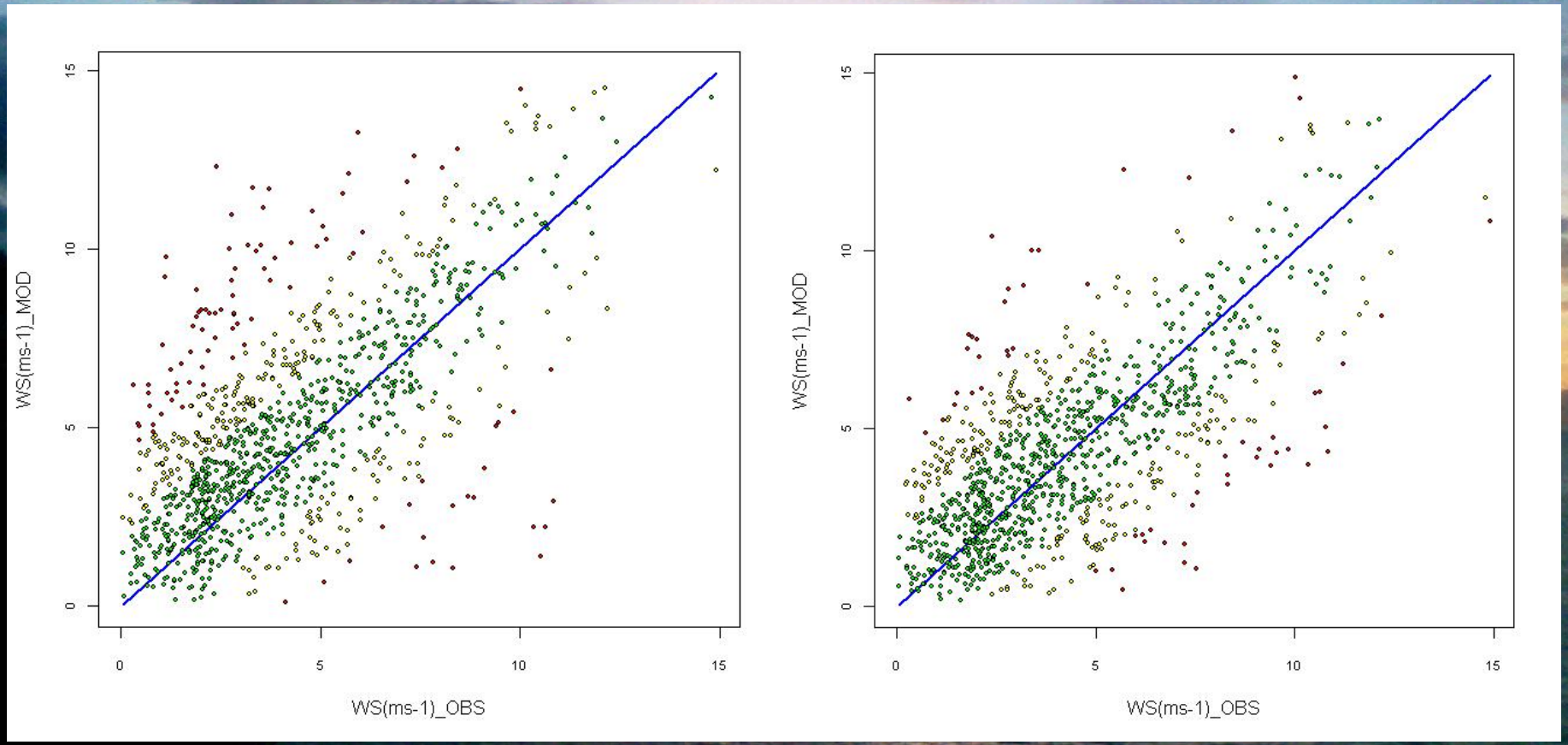


WRF-ARW 3.0



WRF-ARW 3.2.1

ODAS Italia 1 buoy:
scatter plots 10 m wind speed

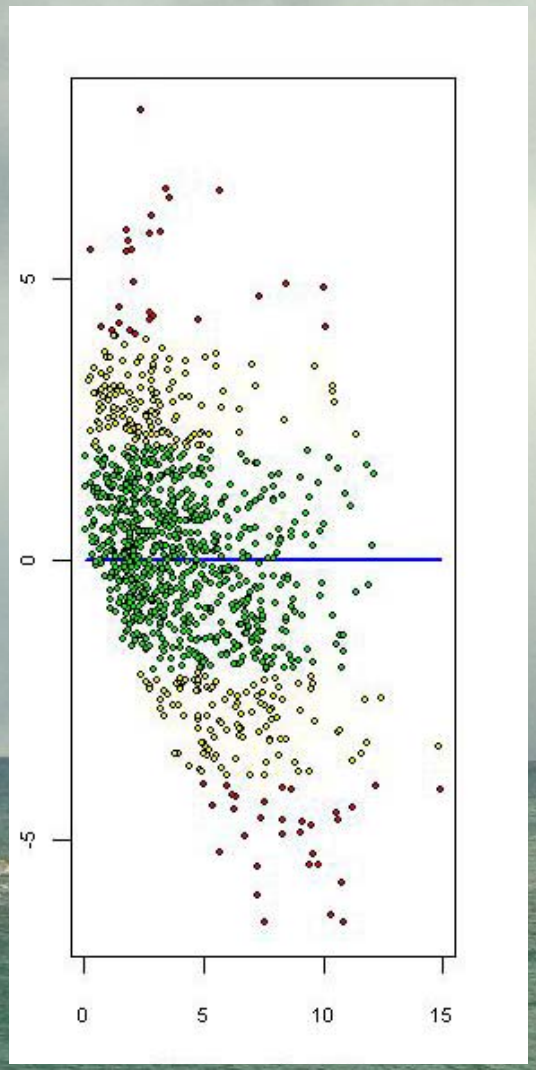


WRF-ARW 3.0 **WRF-ARW 3.2.1**

ODAS Italia 1 buoy:

WRF-ARW 3.2.1

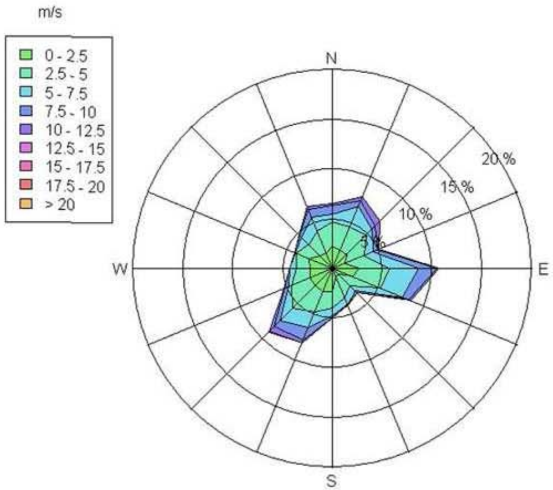
10 m wind speed

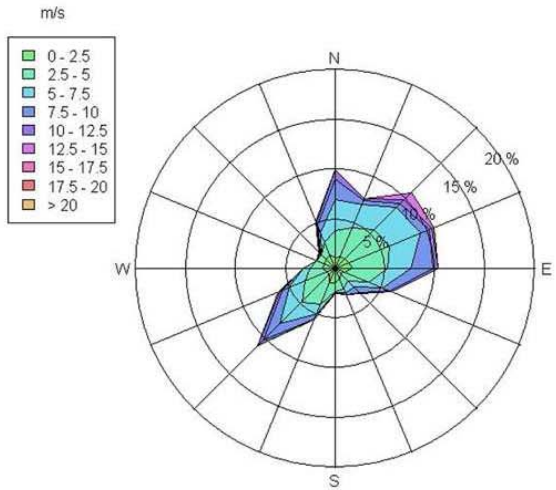


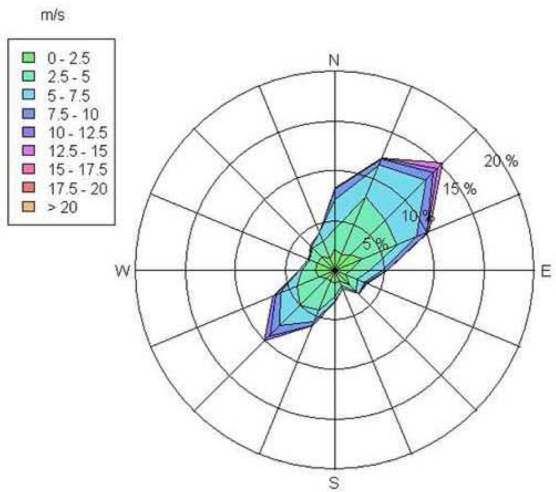
(MOD-OBS)_ WS(ms-1)

WS(ms-1)_OBS

ODAS Italia 1 buoy: 10 m wind roses







Observed *WRF-ARW 3.0* *WRF-ARW 3.2.1*

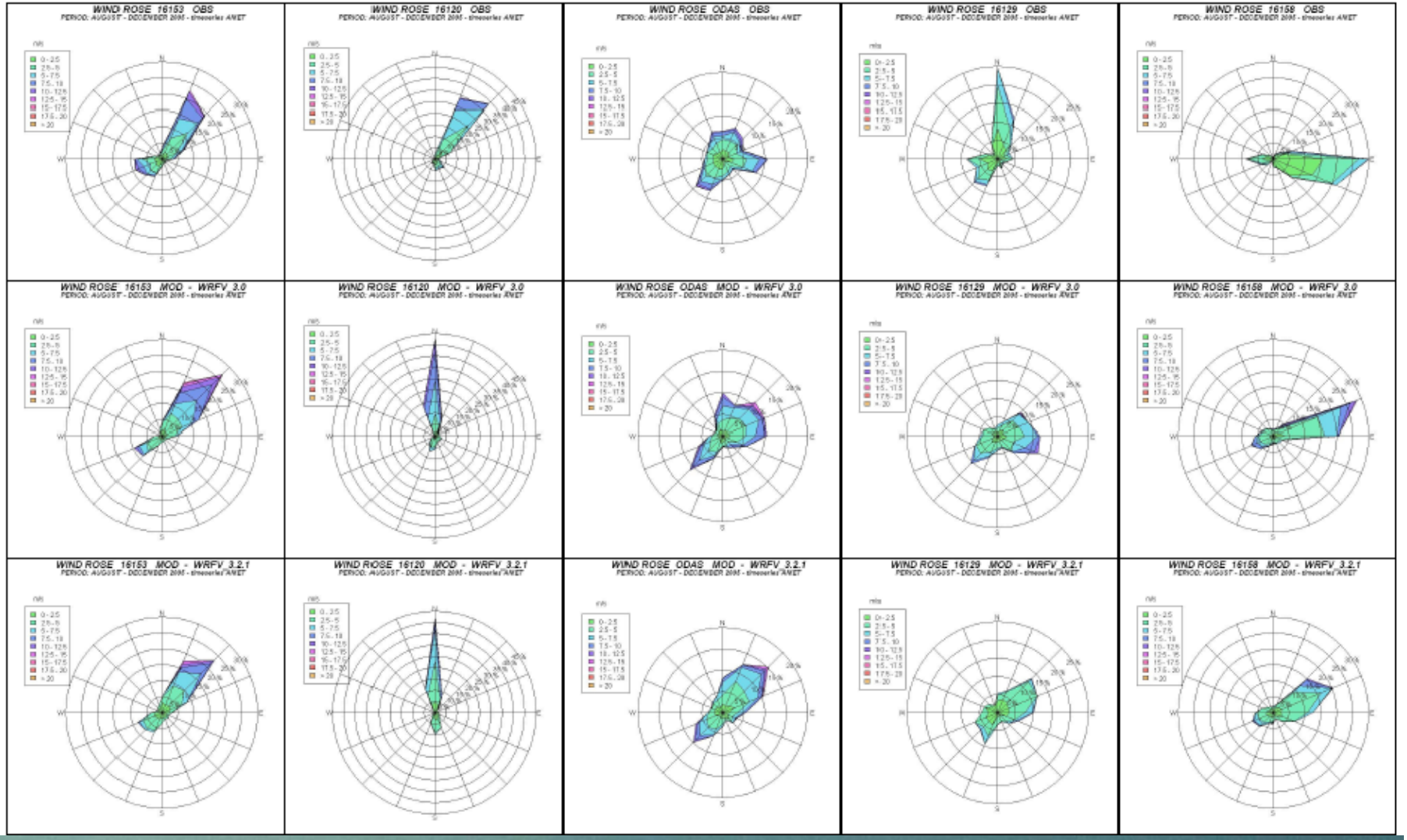
All stations: 10 m wind roses

Capo Mele *Genova* *ODAS* *La Spezia* *Pisa*

OBS

3.0

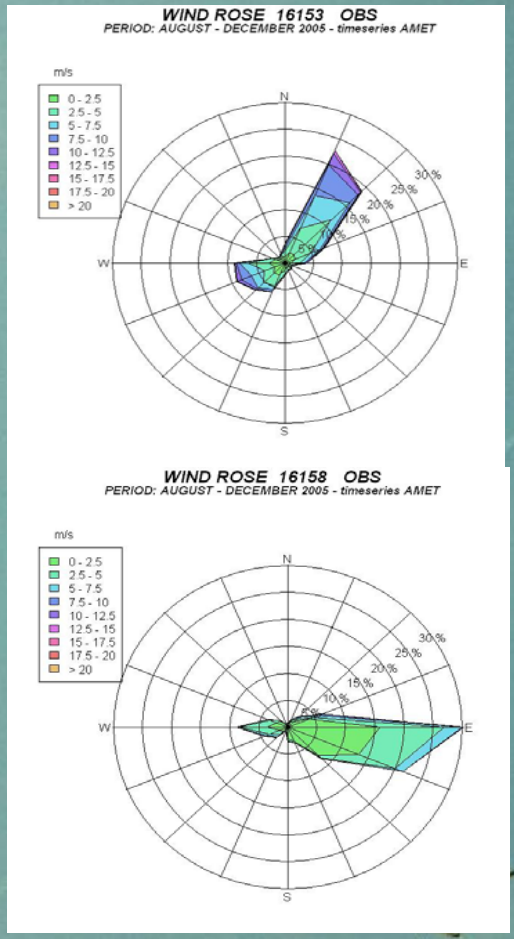
3.2.1

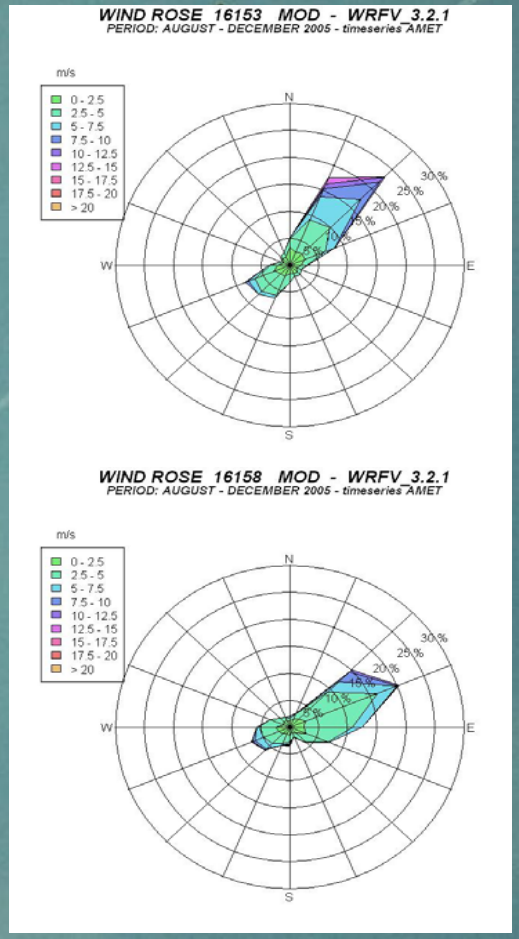


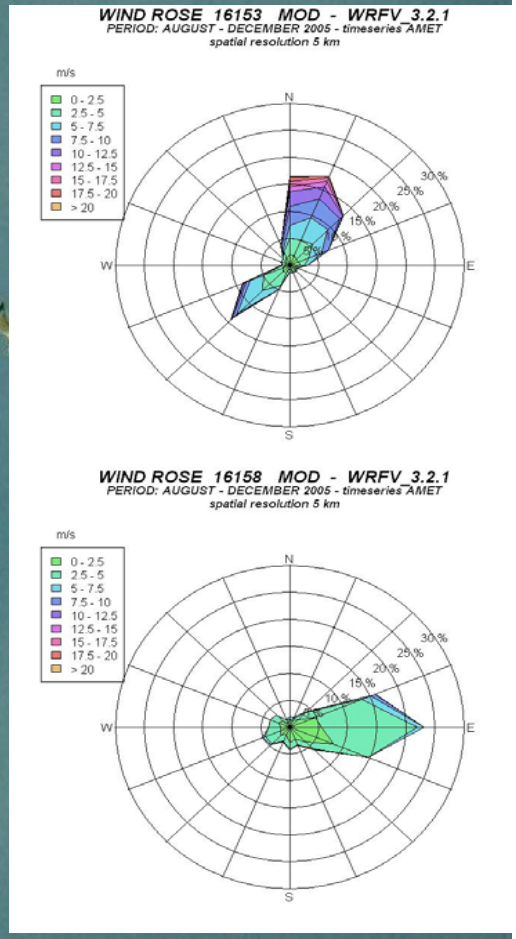
WRF-ARW 3.2.1
15 km vs. 5 km domain grid step: 10 m wind roses

Capo Mele

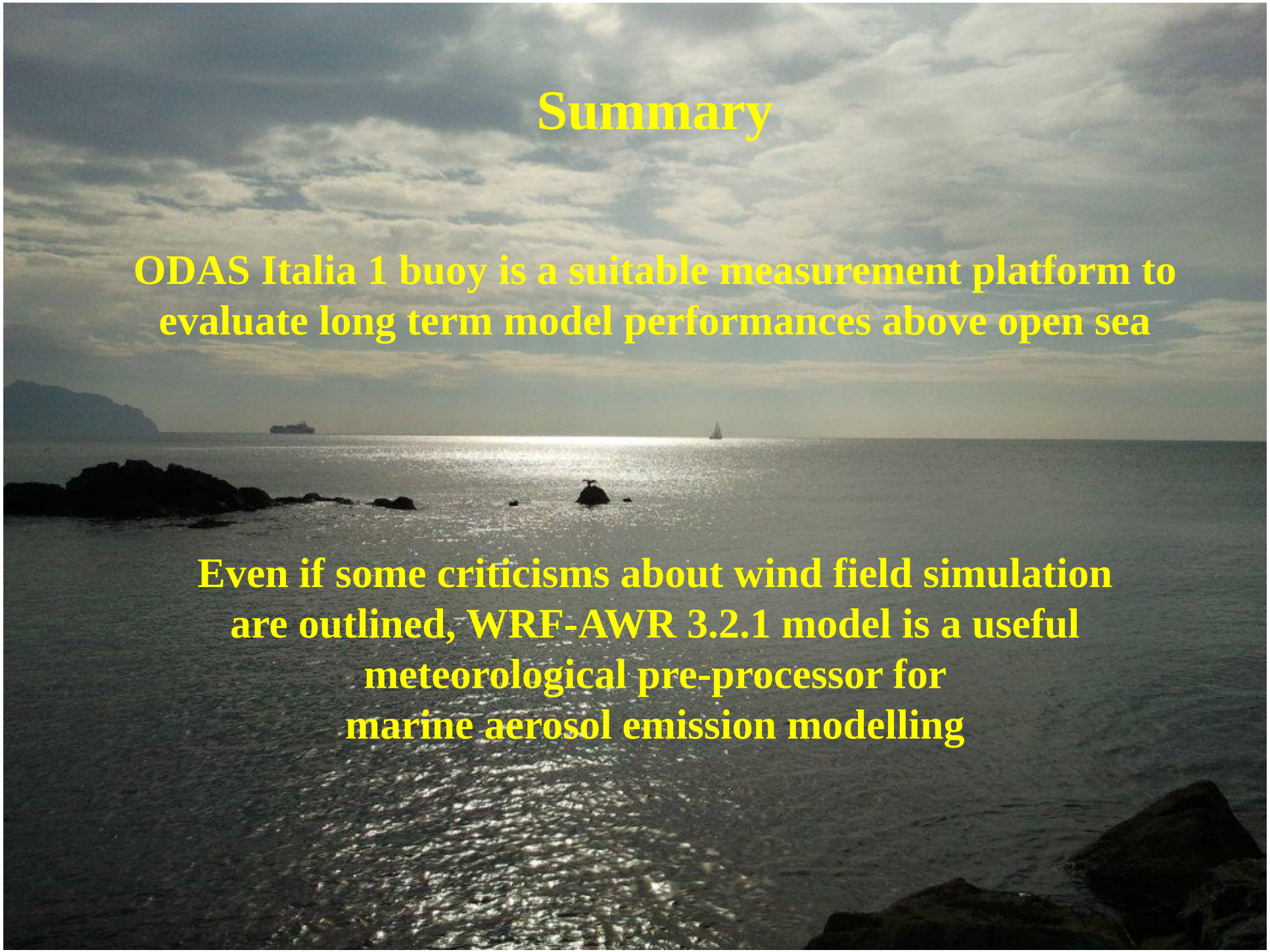
Pisa







Observed *15 km grid step* *5 km grid step*

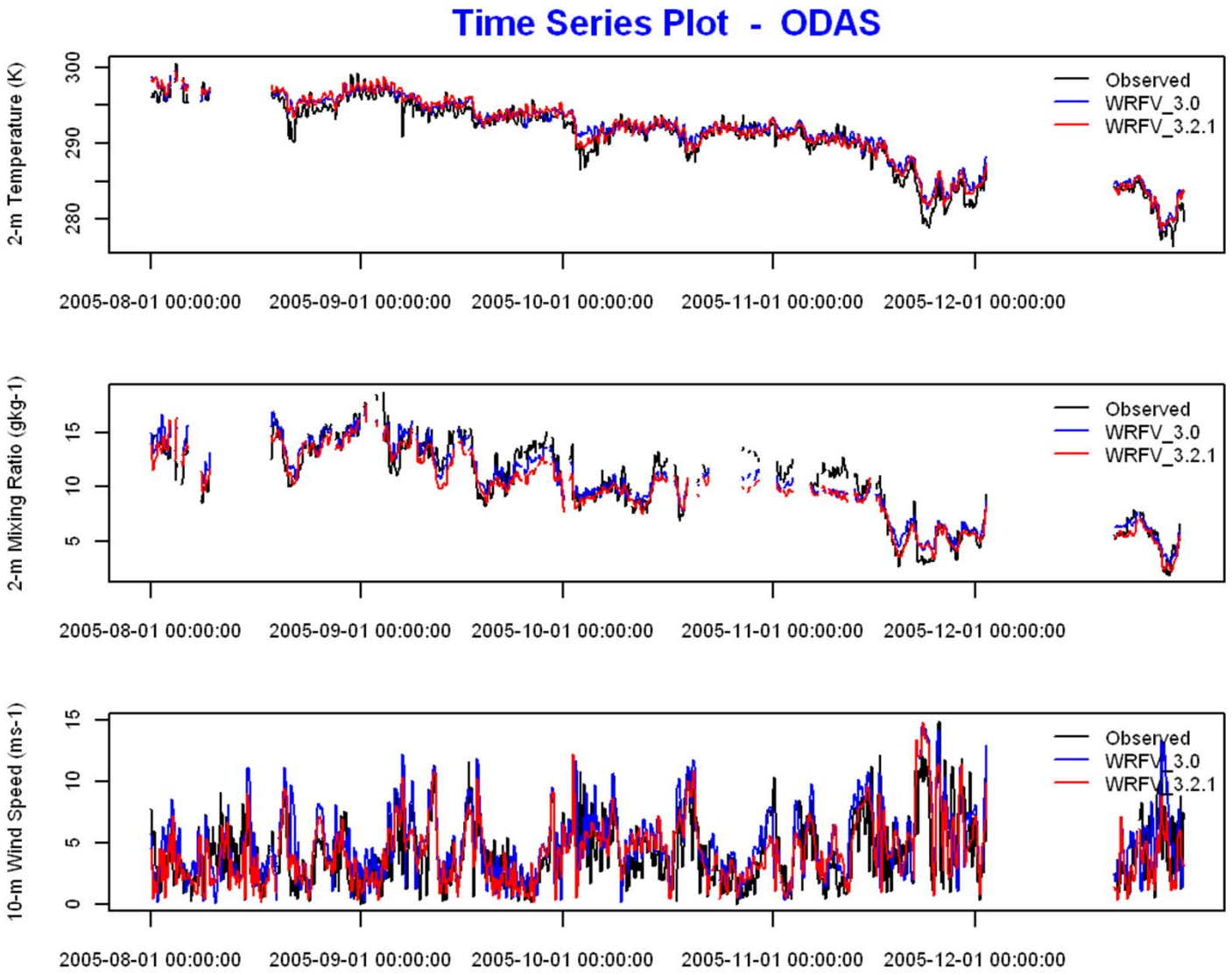


Summary

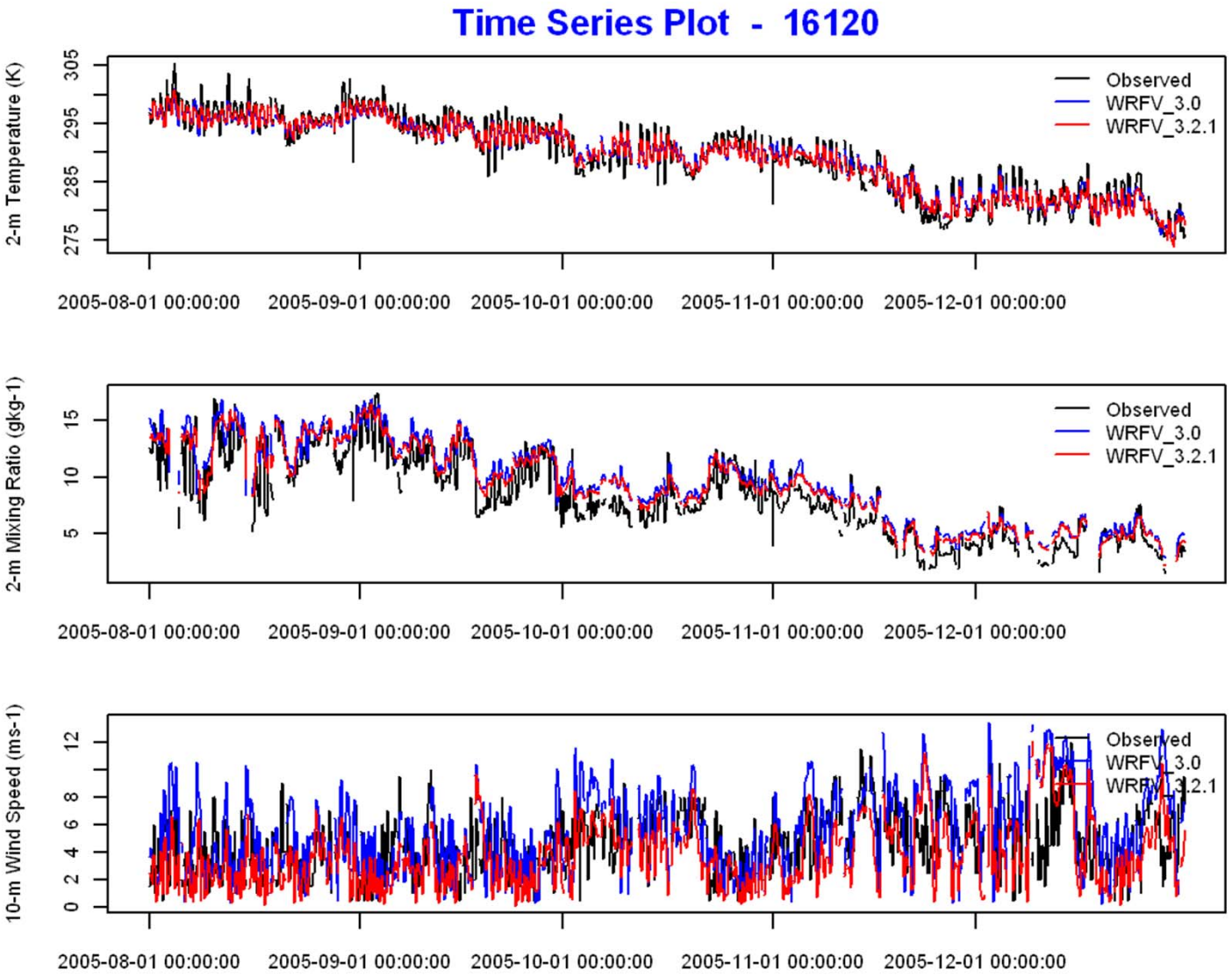
ODAS Italia 1 buoy is a suitable measurement platform to evaluate long term model performances above open sea

Even if some criticisms about wind field simulation are outlined, WRF-AWR 3.2.1 model is a useful meteorological pre-processor for marine aerosol emission modelling

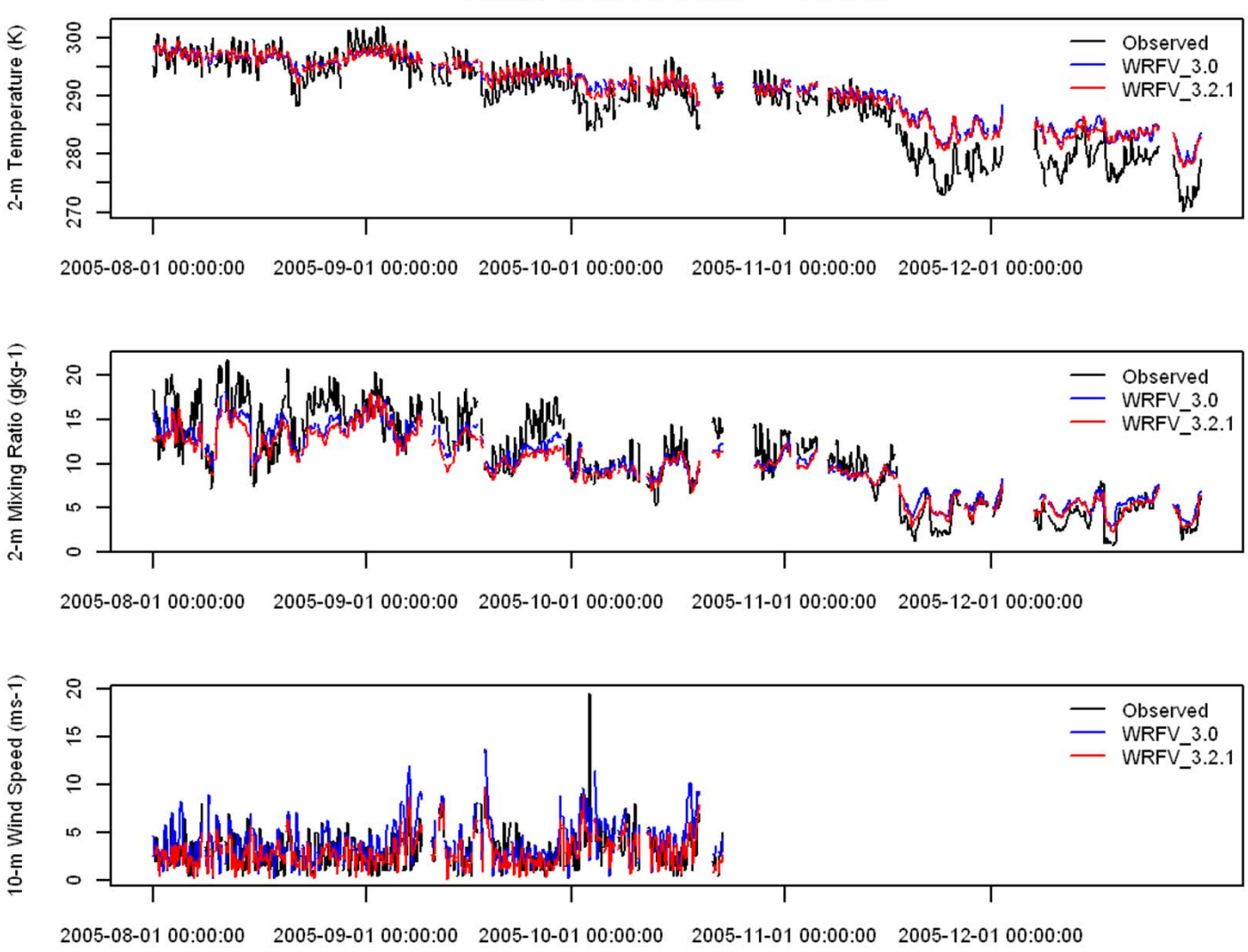

Thank you!
Photographs by Corrado F. Ratto


Time Series Plot - ODAS
2-m Temperature (K)
300
290
280
Observed
WRFV_3.0
WRFV_3.2.1
2005-08-01 00:00:00
2005-09-01 00:00:00
2005-10-01 00:00:00
2005-11-01 00:00:00
2005-12-01 00:00:00
2-m Mixing Ratio (gkg-1)
15
10
5
Observed
WRFV_3.0
WRFV_3.2.1
2005-08-01 00:00:00
2005-09-01 00:00:00
2005-10-01 00:00:00
2005-11-01 00:00:00
2005-12-01 00:00:00
10-m Wind Speed (ms-1)
15
10
5
0
Observed
WRFV_3.0
WRFV_3.2.1
2005-08-01 00:00:00
2005-09-01 00:00:00
2005-10-01 00:00:00
2005-11-01 00:00:00
2005-12-01 00:00:00

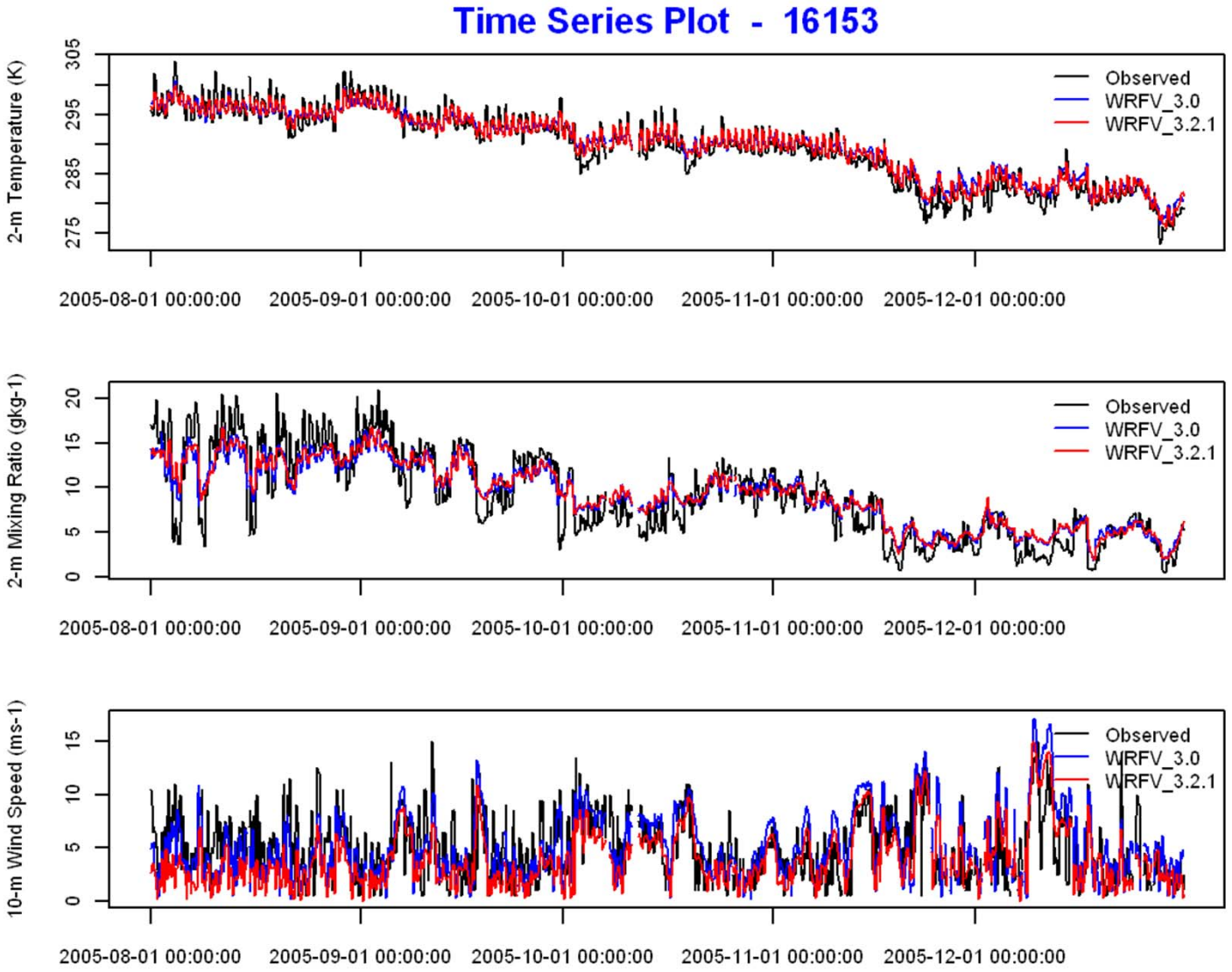
Genova/Sestri WMO station



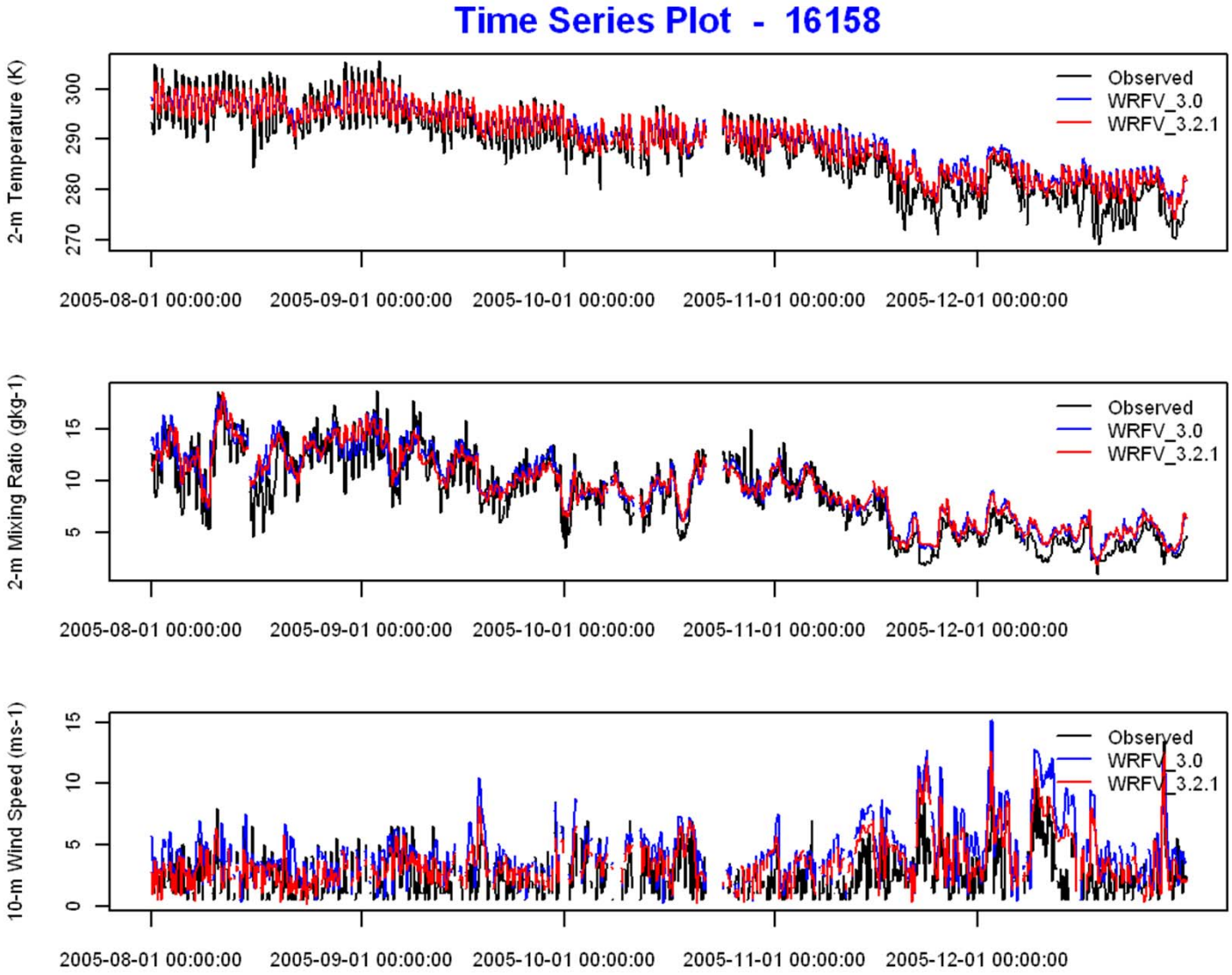
La Spezia – La Castellana WMO station



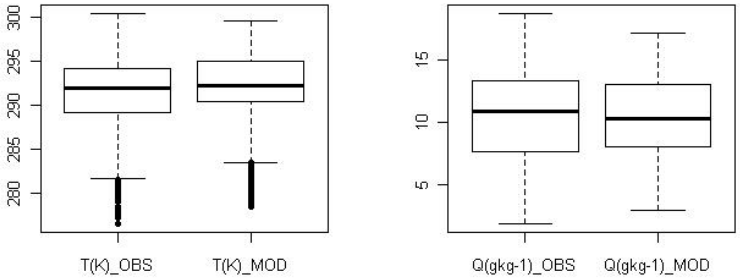
Capo Mele WMO station

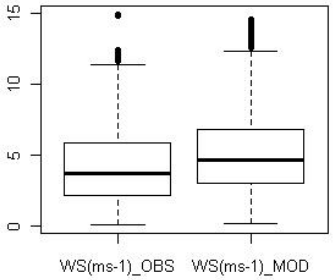


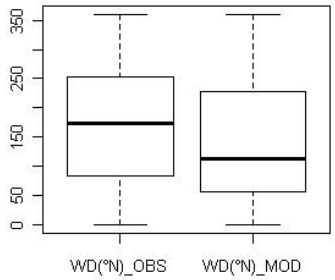
Pisa/S. Giusto WMO station



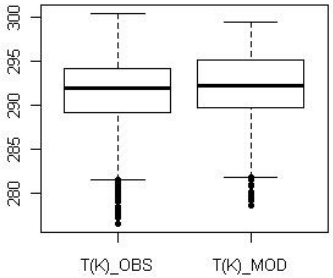
Obs and Mod Box Plots - ODAS - WRFV_3.0

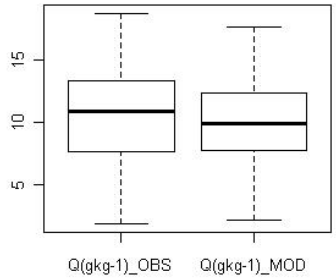


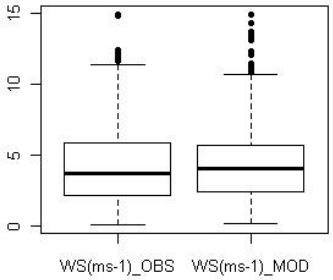


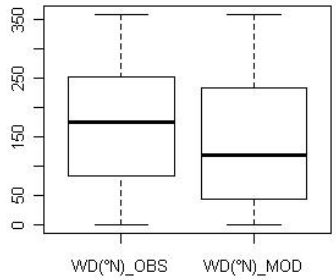


Obs and Mod Box Plots - ODAS - WRFV_3.2.1

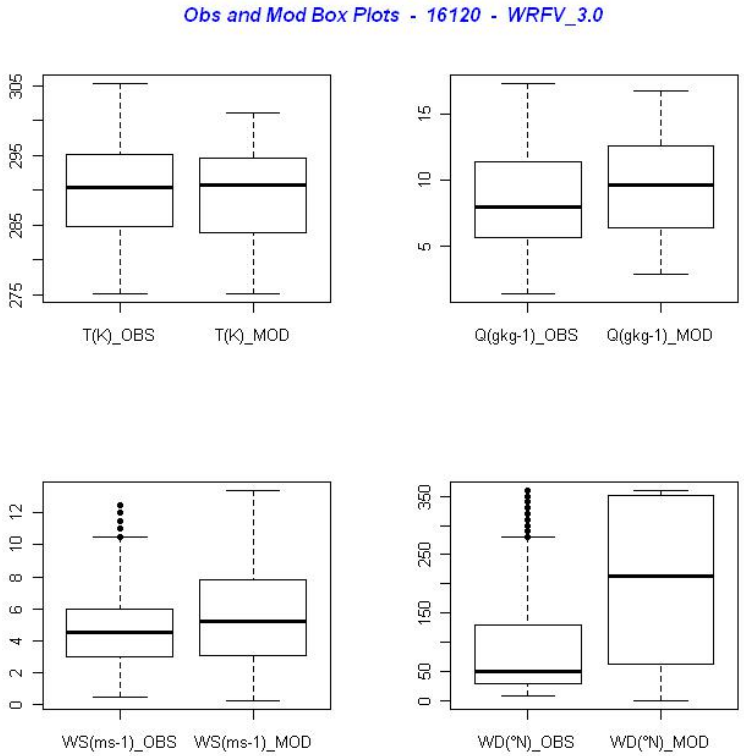


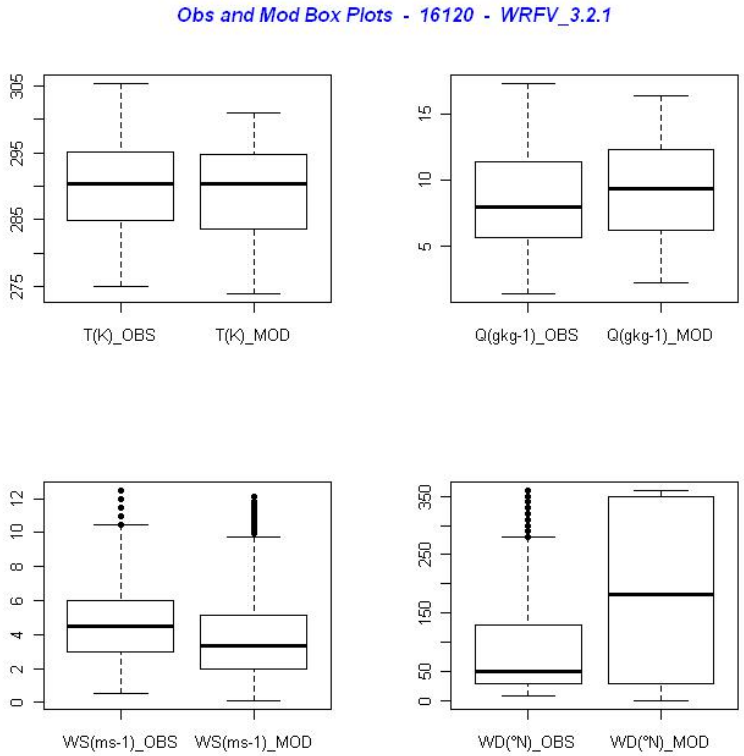




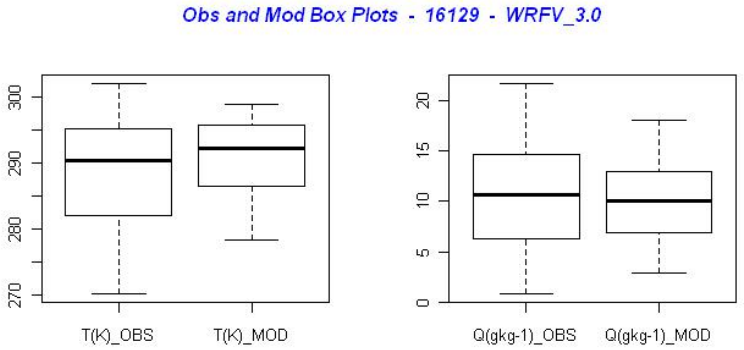


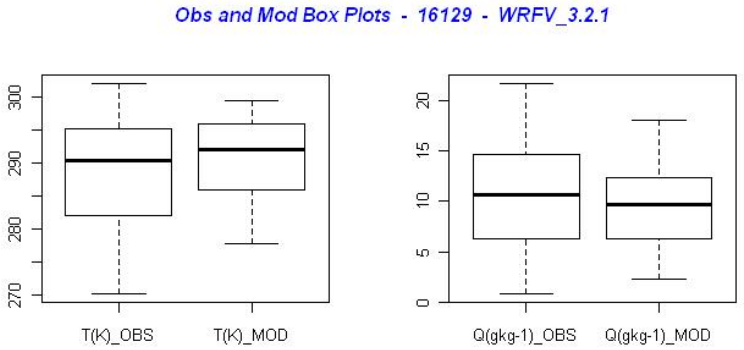
Genova/Sestri WMO station



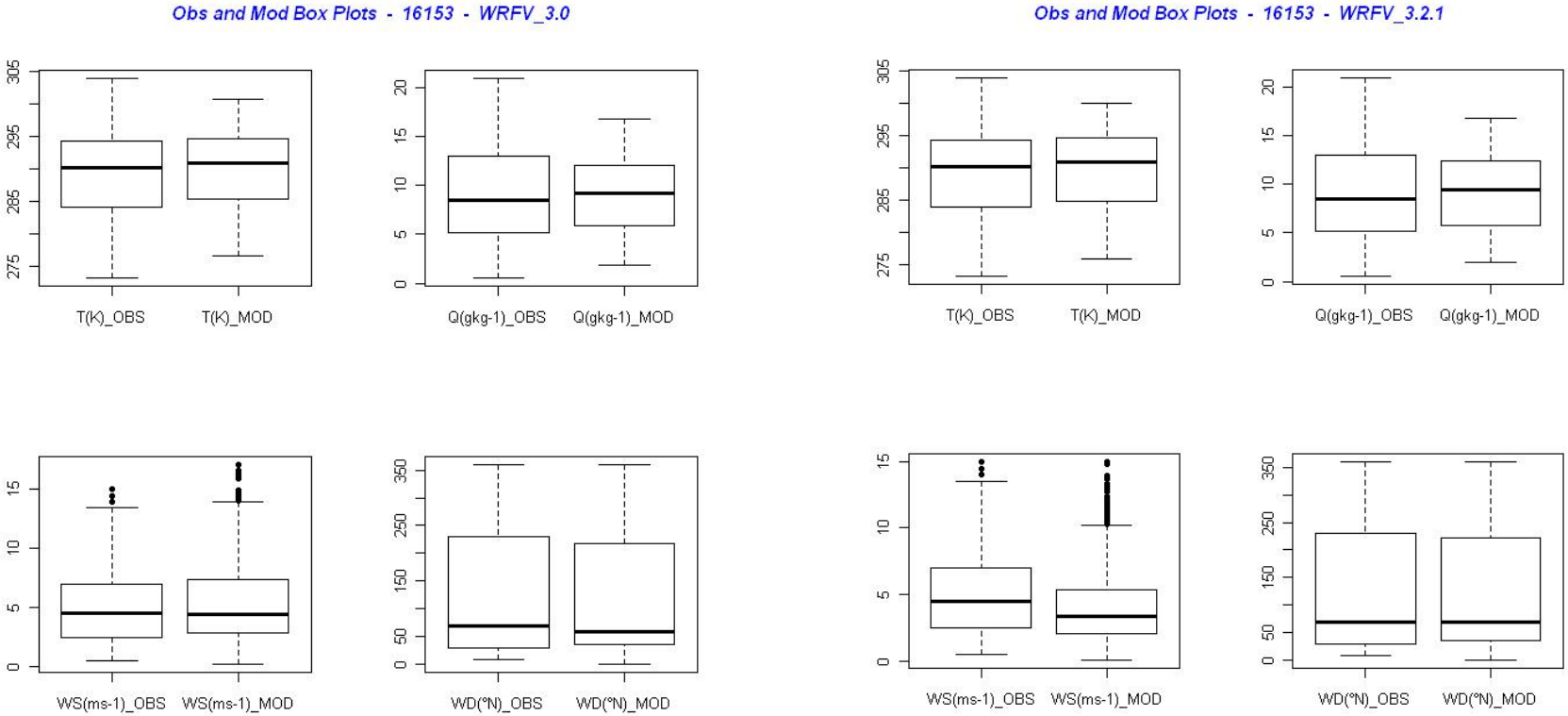


La Spezia – La Castellana WMO station

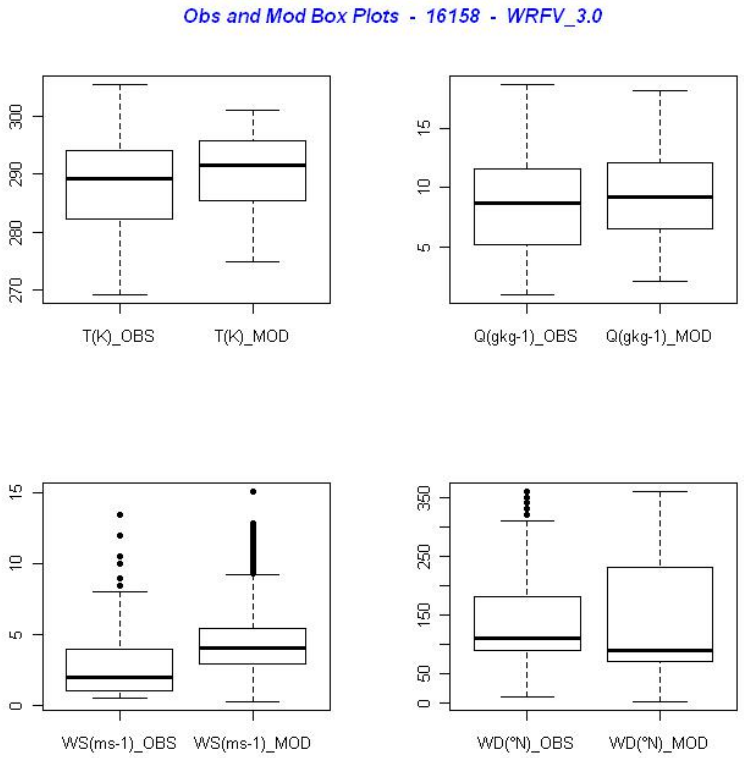


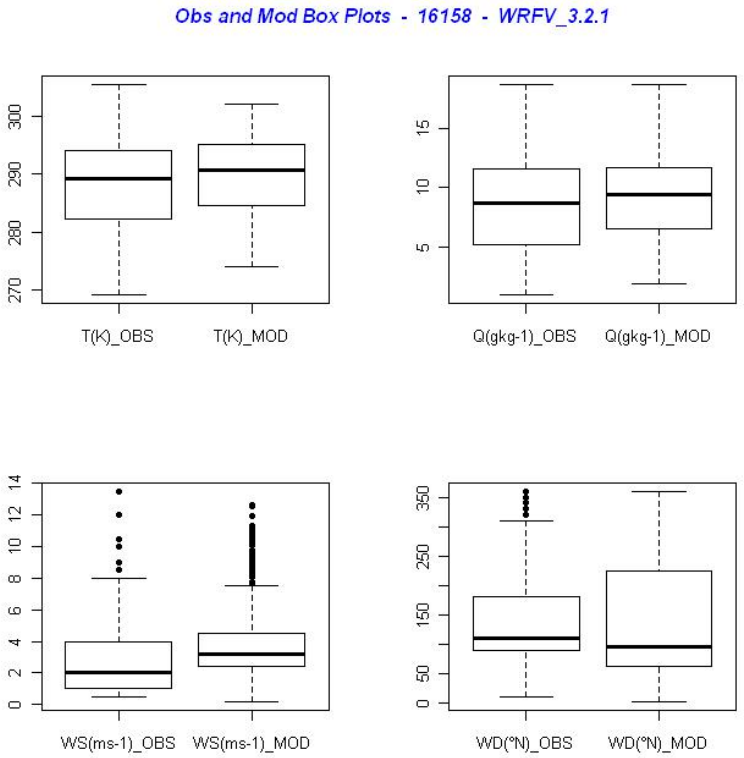


Capo Mele WMO station

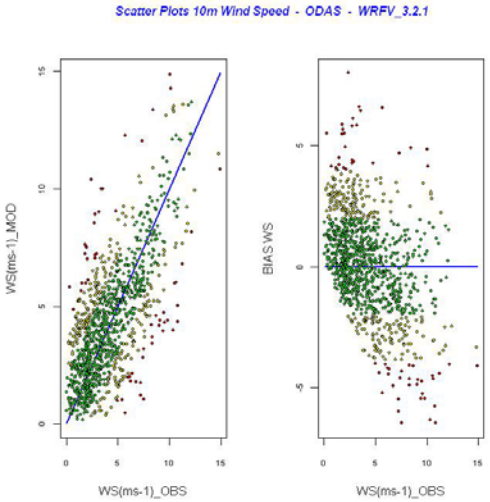


Pisa/S. Giusto WMO station

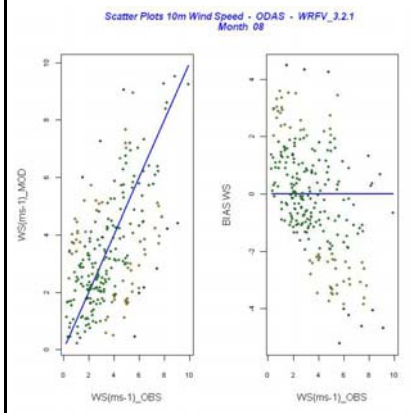




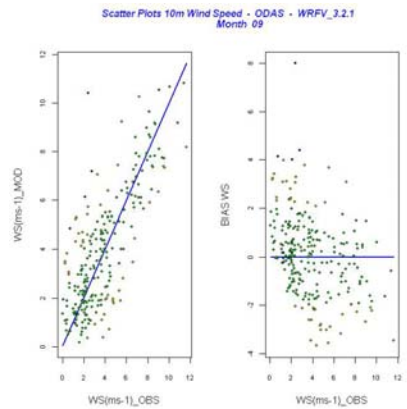
Wind speed - ODAS – WRF V_3.2.1



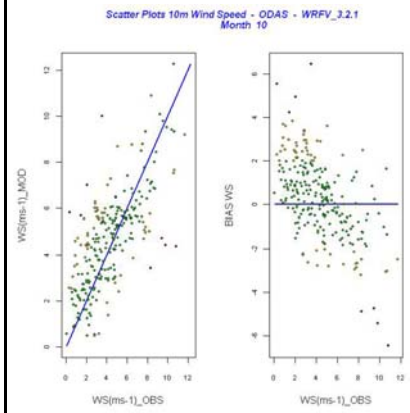
AUGUST



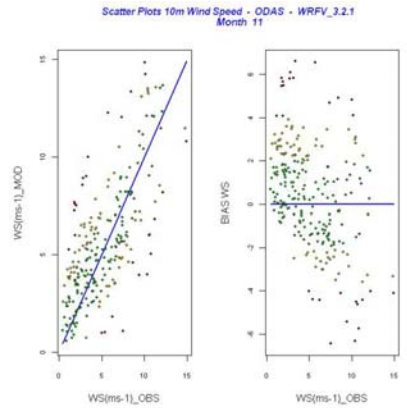
SEPTEMBER



OCTOBER



NOVEMBER



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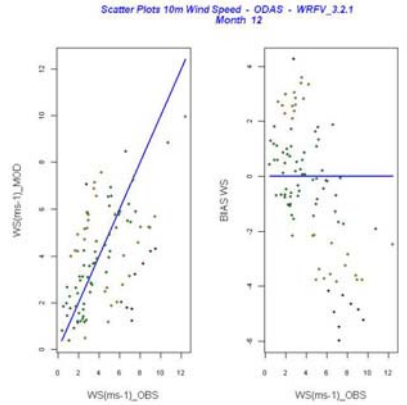
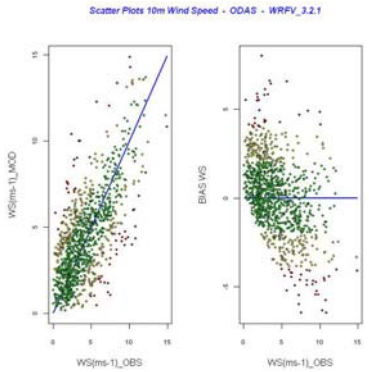
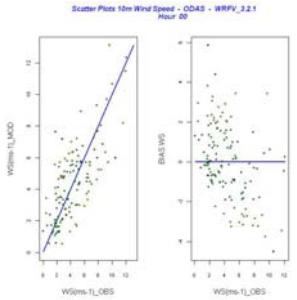


Wind speed - ODAS – WRF V_3.2.1



Hour 00



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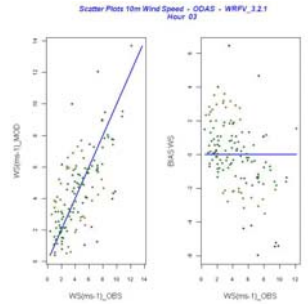
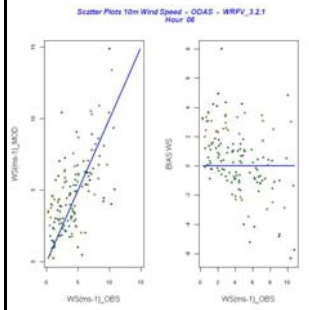
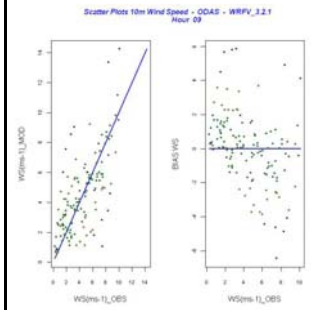


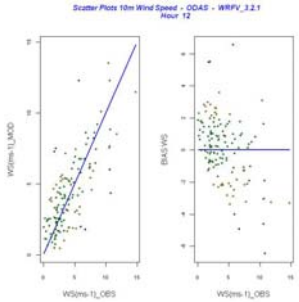
Hour 06



Hour 09



Hour 12



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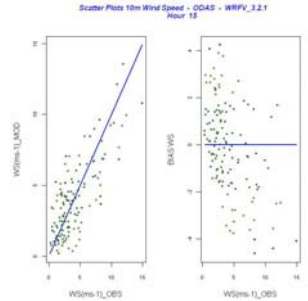

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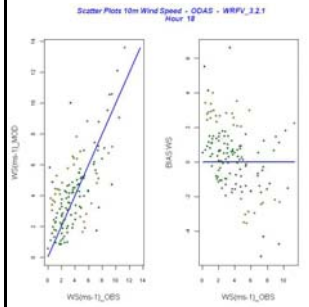
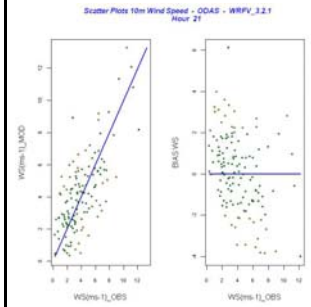


Hour 21



WRF-ARW configuration

- **mp_physic:** WMS5 (Hong et al., 2004, Hong and Lim, 2006)
- **bl_pbl_physics:** YSU (Hong et al., 2006)
- **sf_surface_physics:** Noah LSM (Chen and Dudhia, 2001)
- **sf_sfclay_physics:** MM5 – Monin Obukhov