“Improvement of wave height forecast in deep and intermediate waters with the use of stochastic methods”

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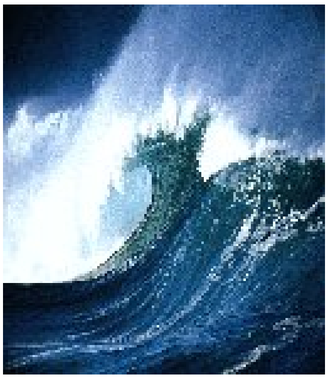
Presentation Structure

1. Introduction
2. Methodology
3. Applications
4. Conclusions

Introduction



Introduction

<u>OBJECTIVE</u>: Improvement of the forecast power of numerical wave models using real time measurements

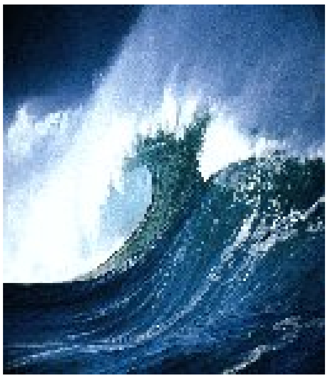
Improvement of wave predictions can be achieved by three different approaches:

- **<u>Data assimilation techniques</u> (require re-run and space coverage)**
- **<u>Stochastic tools</u>**
- **<u>Neural networks techniques</u>**

- **Only a few stochastic applications concerning real time improvement of the wave forecast**
- **Caires & Sterl, 2004: non parametric correction of ERA-40 reanalysis data, using a learning dataset**

In this work a stochastic technique is applied to measured data of wave height for improving forecasts of the wave model

Methodology



Bivariate Linear Regression models

$$\hat{Y}_{t+k\Delta t} = a_k X_{t+k\Delta t} + \beta_k Y_t + \gamma_\kappa$$

$\hat{Y}$: Wave height estimate

Y : Wave height measurement

X : Wave height model forecast

- *k=0,1,2 → < model 0,1,2 >*
- *Trivariate linear model → < model 3>*

Bivariate Non-Linear Regression models

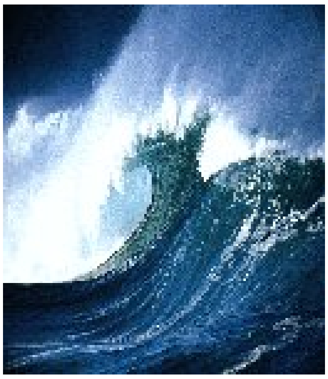
$$\boldsymbol{Y^{\lambda}_{t+\Delta t} = \alpha_1 X^{\lambda}_{t+\Delta t} + \beta_1 Y^{\lambda}_{t} + \gamma_1, \quad \text{if} \quad Y_t \leq c,}$$

$$\boldsymbol{Y^{\lambda}_{t+\Delta t} = \alpha_1 X^{\lambda}_{t+\Delta t} + \beta_2 Y^{\lambda}_{t} + \gamma_2, \quad \text{if} \quad Y_t \geq c}$$

$$\boldsymbol{\gamma_2 = \gamma_1 + (\beta_1 - \beta_2)\, c^{\lambda}} \text{ **(continuity c)**}$$

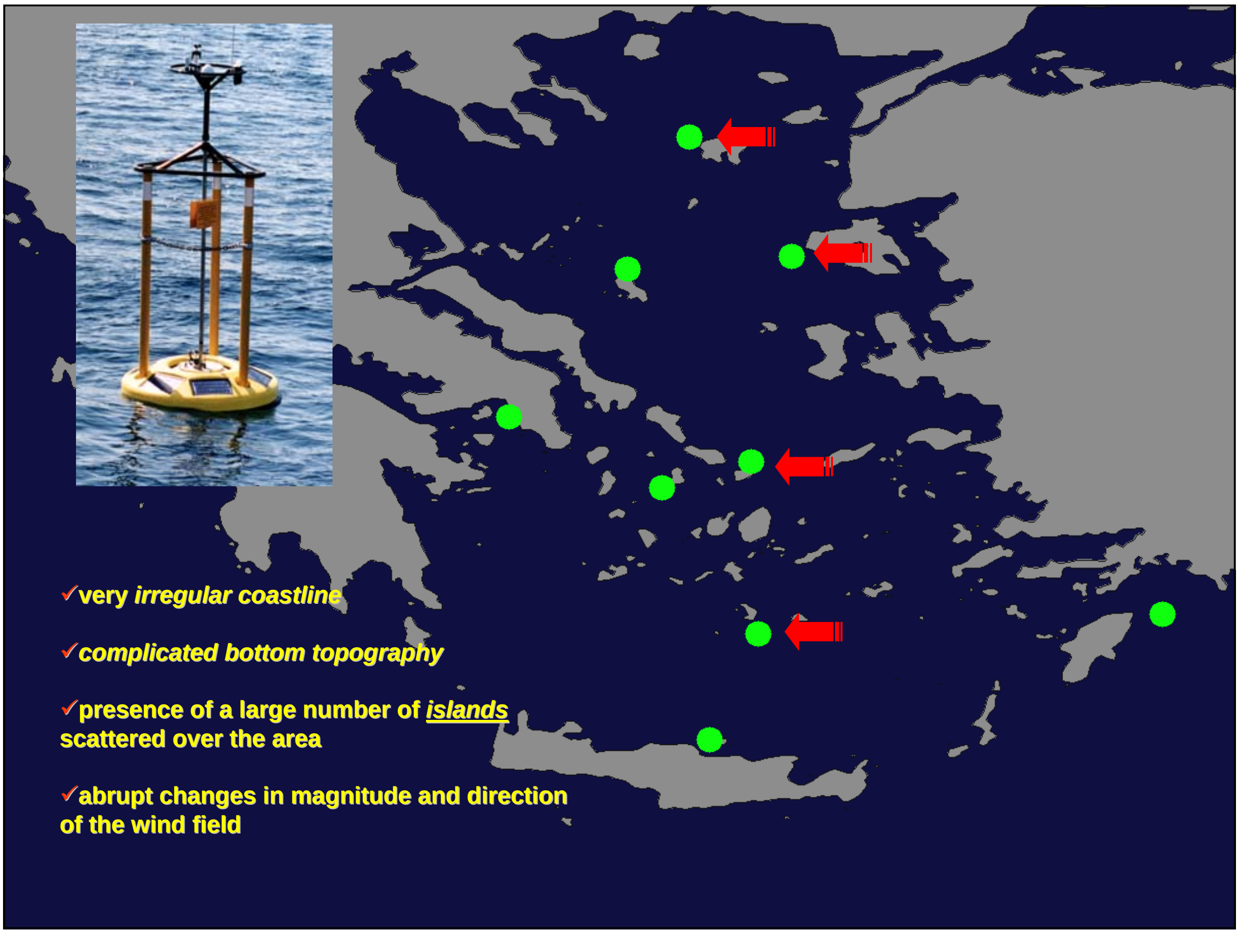
<model 4>

Applications



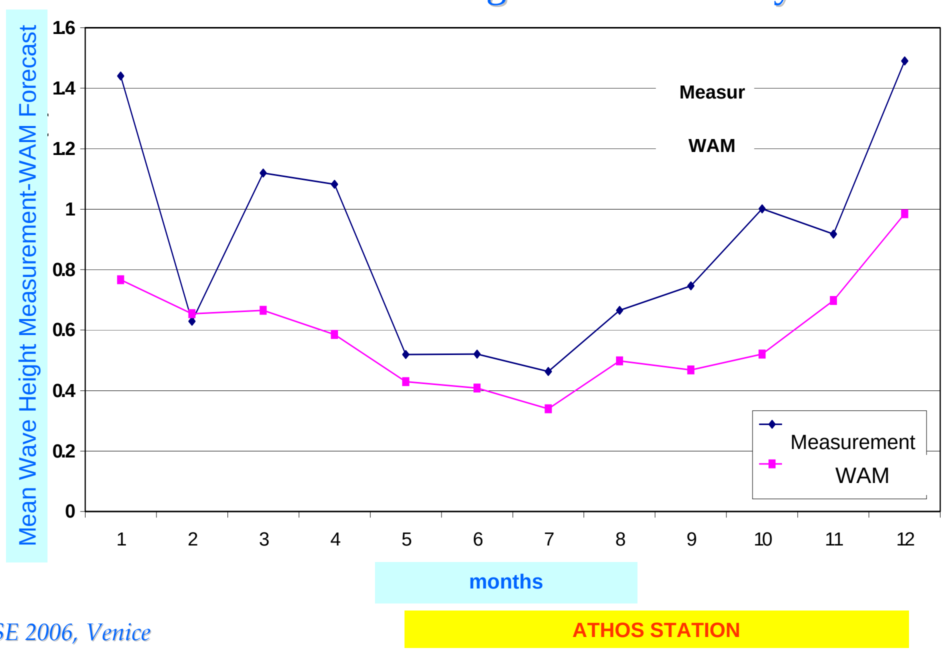
First Application: The Aegean Sea

The Stations Used



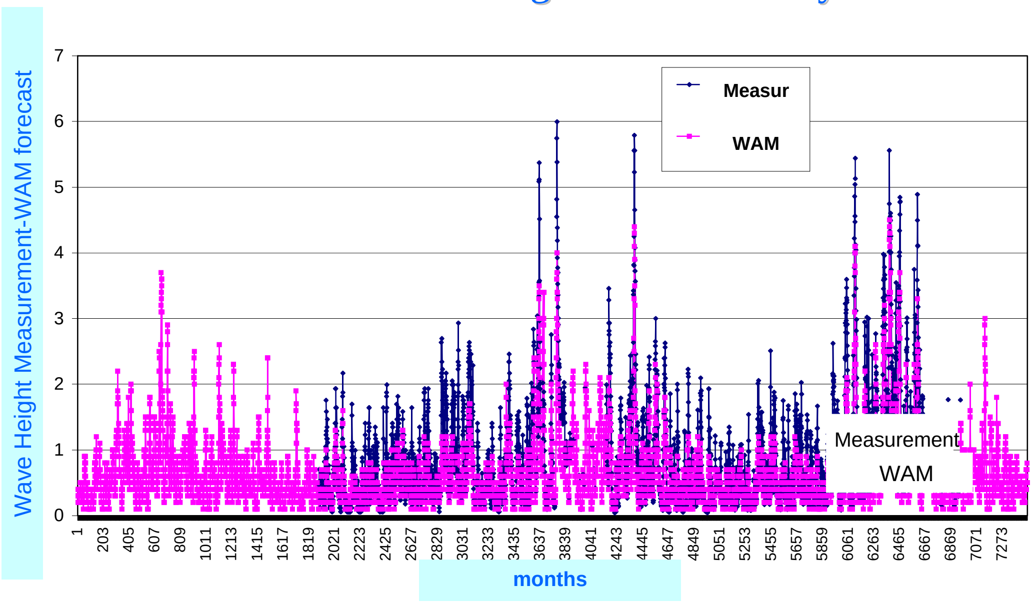
WAM Underestimation

Measurements through POSEIDON System



WAM Underestimation

Measurements through POSEIDON System



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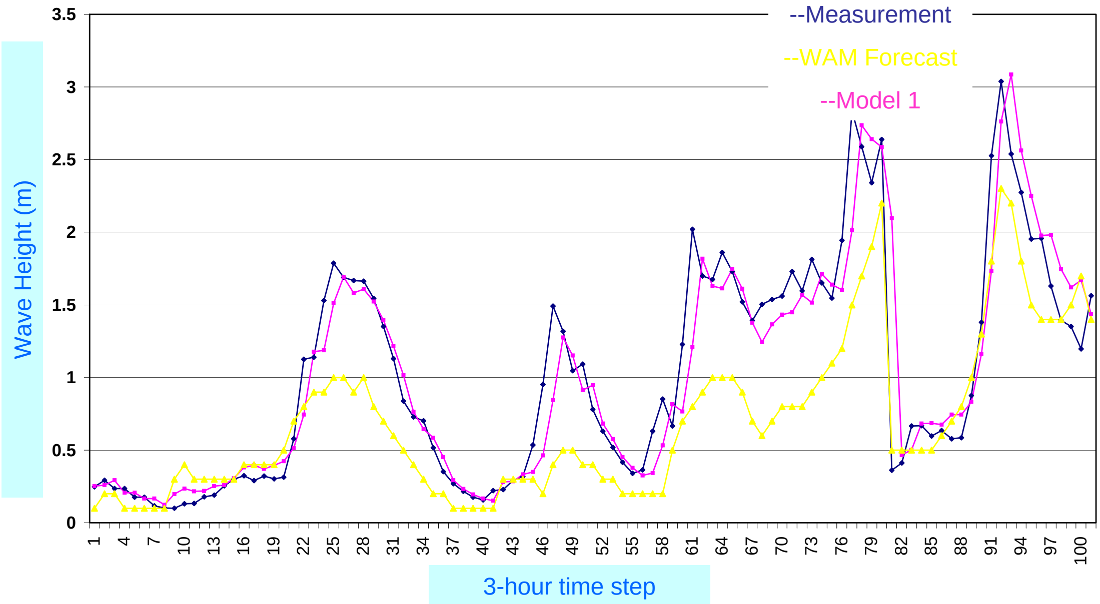
ATHOS STATION

Model 1



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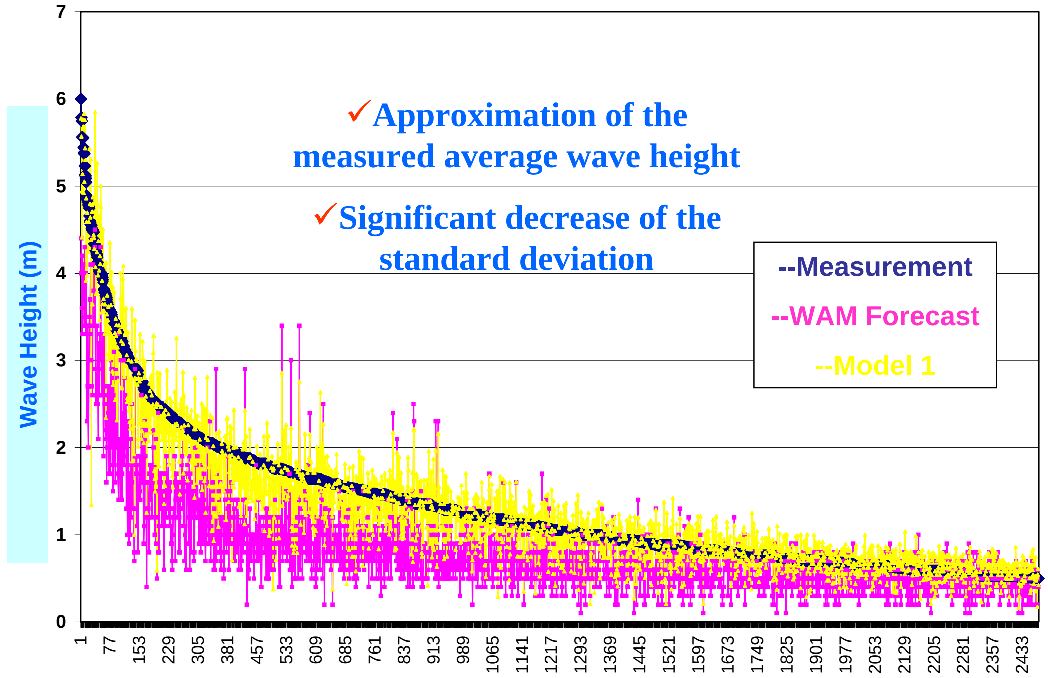
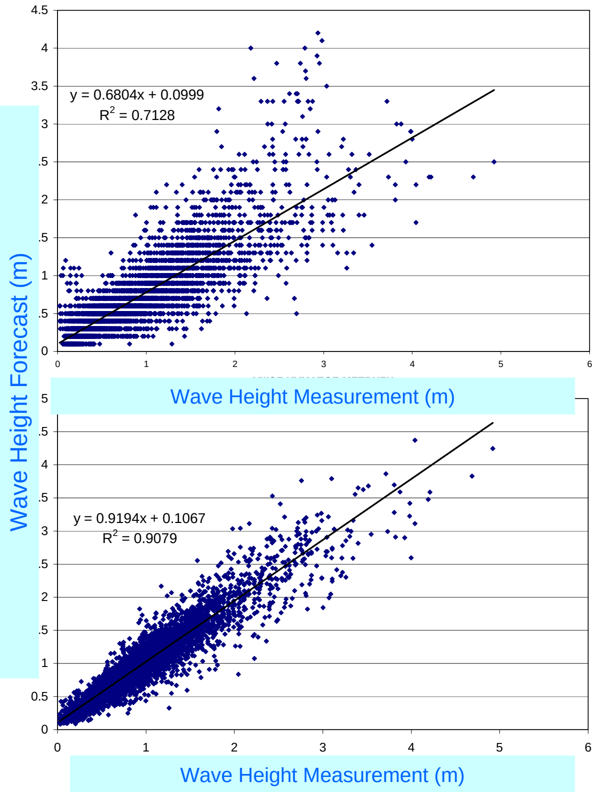
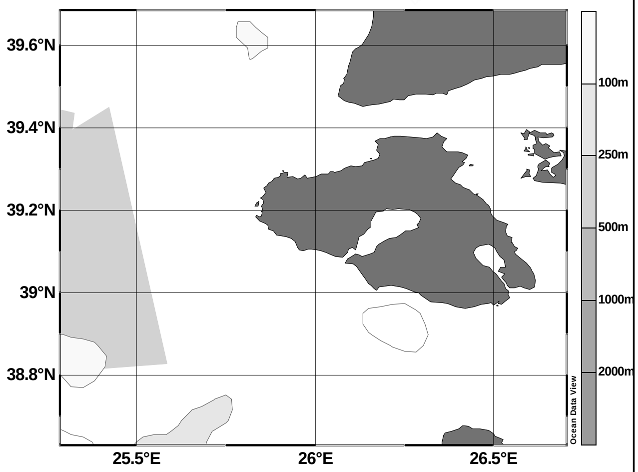
ATHOS STATION



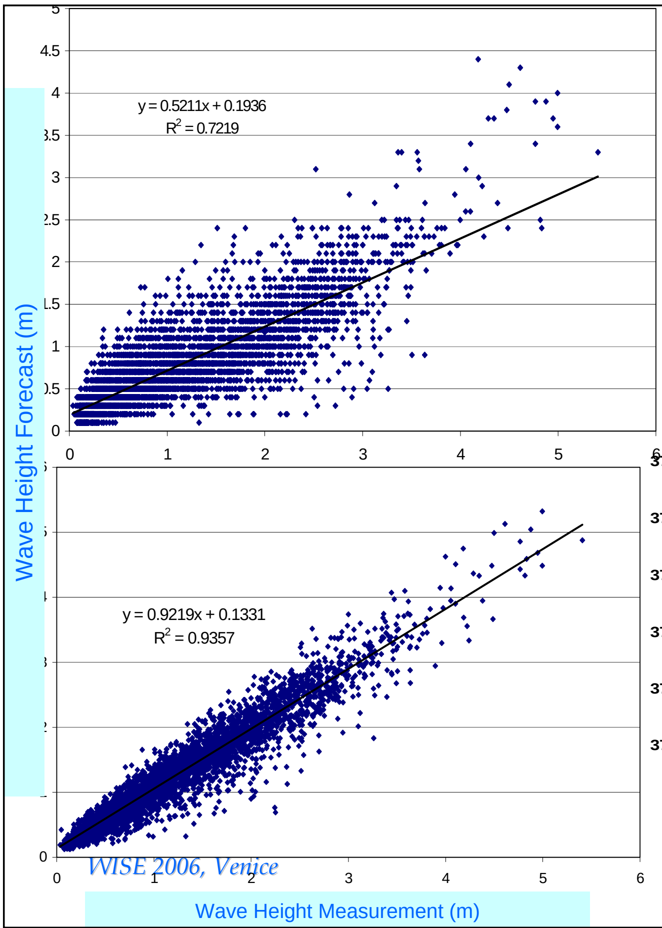
Wave Height (m)
0
1
2
3
4
5
6
7
✓Approximation of the measured average wave height
✓Significant decrease of the standard deviation
--Measurement
--WAM Forecast
--Model 1
1 77 153 229 305 381 457 533 609 685 761 837 913 989 1065 1141 1217 1293 1369 1445 1521 1597 1673 1749 1825 1901 1977 2053 2129 2205 2281 2357 2433

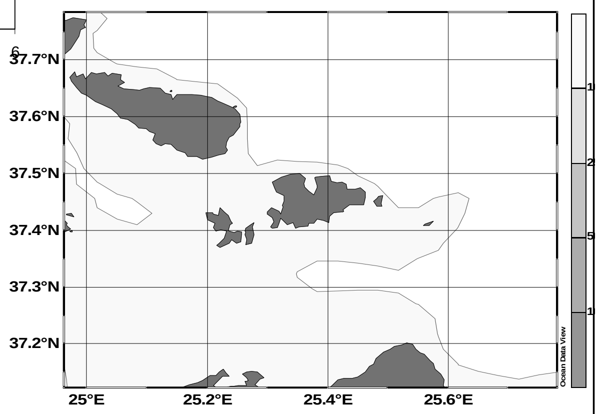


Wave Height Forecast (m)
y = 0.6804x + 0.0999
R^2 = 0.7128
Wave Height Measurement (m)
y = 0.9194x + 0.1067
R^2 = 0.9079
Wave Height Measurement (m)



39.6°N
39.4°N
39.2°N
39°N
38.8°N
25.5°E
26°E
26.5°E
100m
250m
500m
1000m
2000m
Ocean Data View





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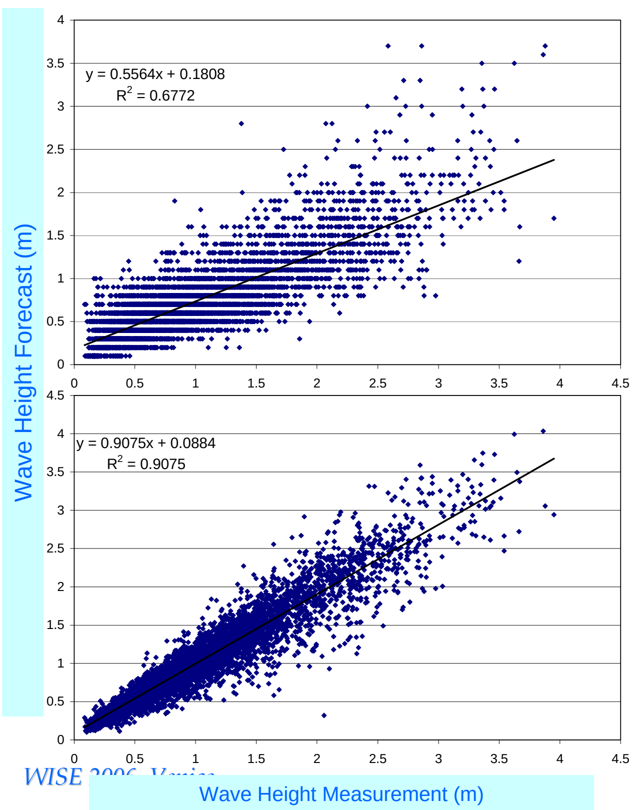

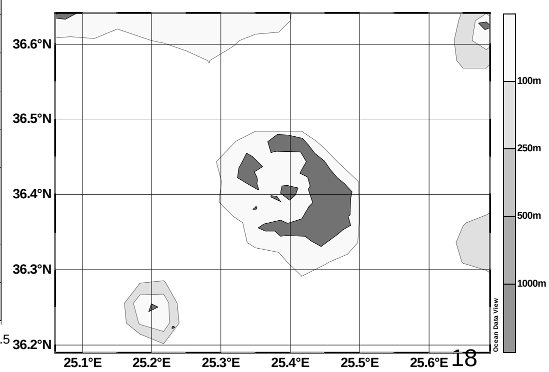

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Summary Table

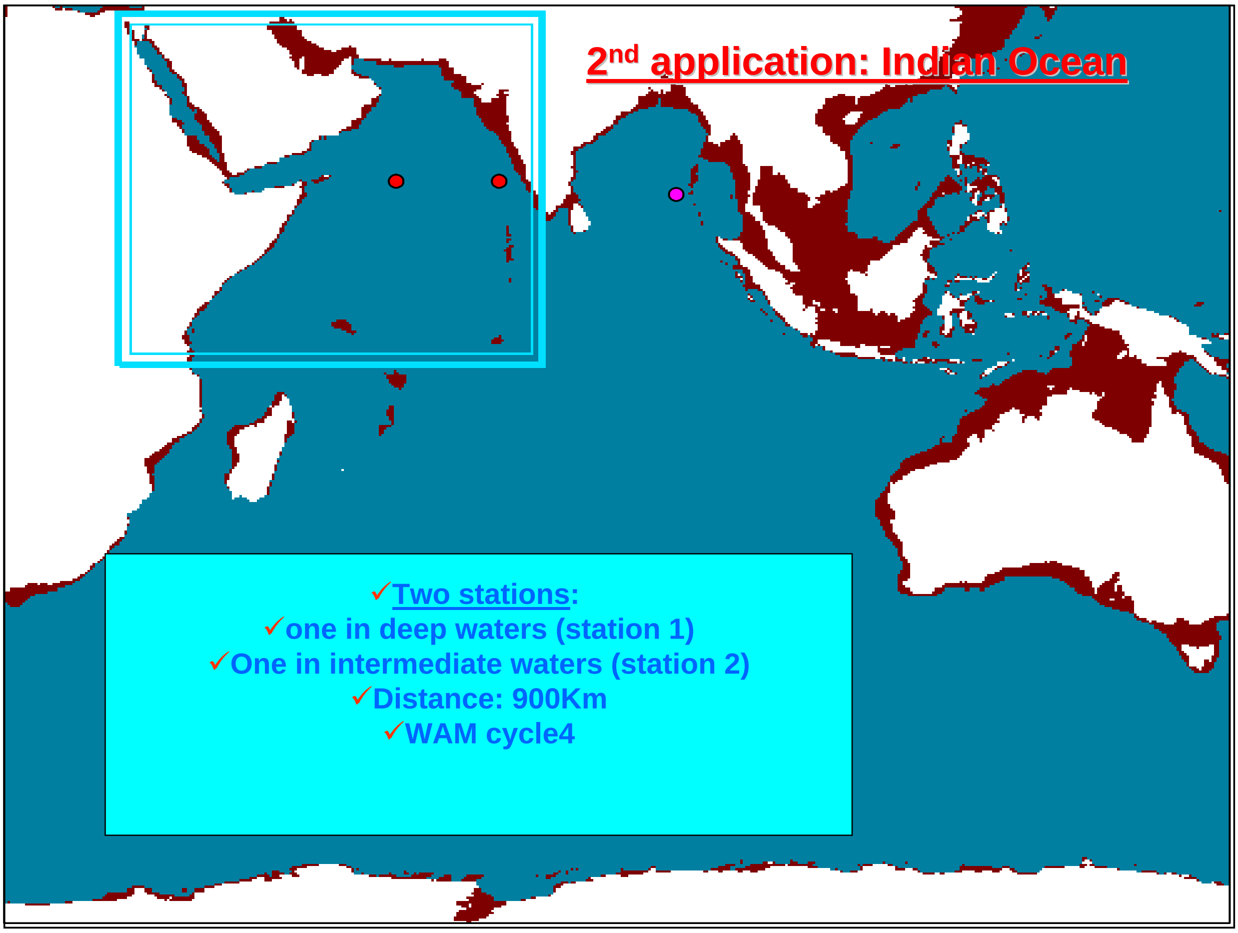
	R^2 Athos	R^2 Lesvos	R^2 Mykonos	R^2 Santorini
WAM MODEL	*0.781*	*0.713*	*0.722*	*0.676*
MODEL 1	0.920	0.892	0.927	0.906
MODEL 2	0.865	0.813	0.860	0.820
MODEL 3	0.924	0.895	0.931	**0.911**
MODEL 4a	0.929	0.897	**0.936**	0.909
MODEL 4b	**0.929**	**0.898**	0.935	0.908

Total improvement obtained:

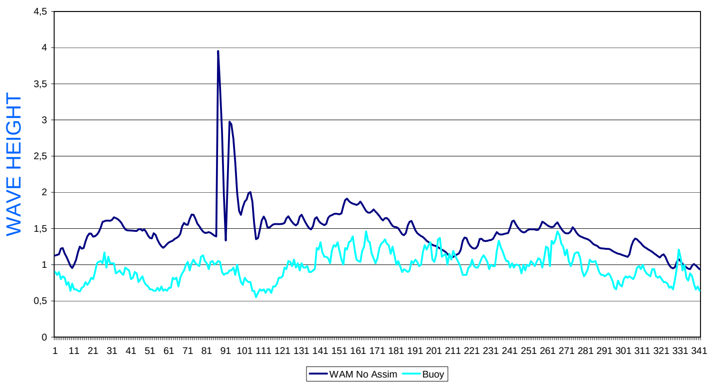
- **For all four stations**
- **For all four models tested**
- **For all periods of implementation**
- **For high and low values of the wave height**
- **No outliers**

✓Increase of the forecast time step decreases the predictive accuracy of our technique

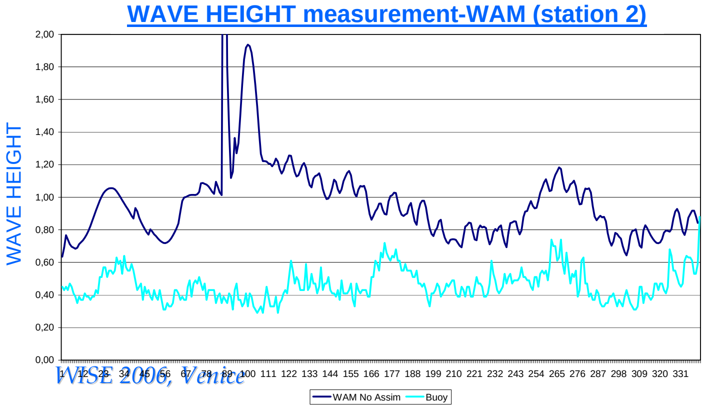
✓Our technique's R^2 equals WAM's for forecasts horizon more than 3 days



WAVE HEIGHT measurement-WAM (station 1)



WAVE HEIGHT measurement-WAM (station 2)



- WAM overestimation
- Active Swell Subroutine
- Outliers for two days both in deep and intermediate waters

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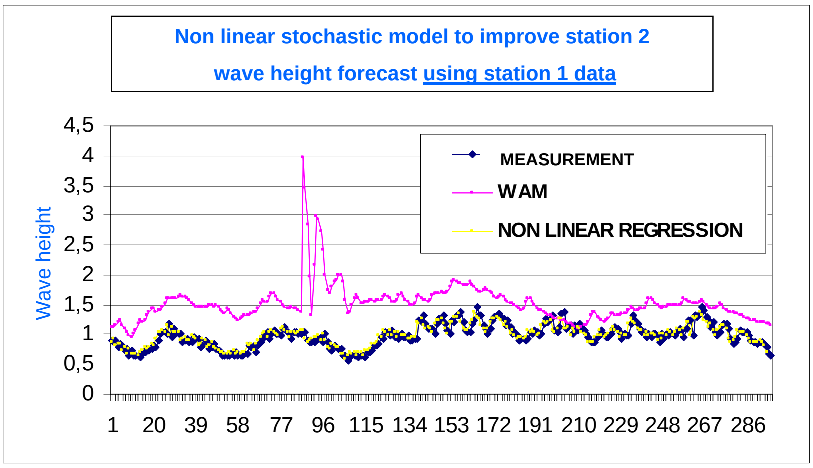
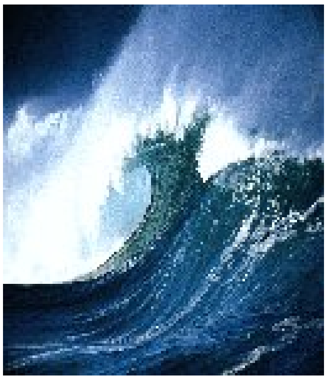


- Remarkable improvement
- Coefficient of determination ($R^2=0.9$)
- Approximation of the measured average wave height
- Absorbing the outliers
- K time step selection

Conclusions



- All models improve significantly the forecast in applications tested
- The parameters (weights) in all models indicate the same performance in all stations and in all periods of implementation
- The relation between measurements and predictions seems to be the same (error source, systematic error)
- If we have/measure the wave height for a small period of 3-4 months irrespectively of the season, we can:

1. Estimate the variable weights and then
2. Significantly improve in real time the forecast of the wave model without re-running it and within an area of considerable extent containing the point of measurement

- Stochastic models are a useful tool for wave forecast. Future research is needed