Error Estimation of Altimeter Wind Speed and Significant Wave Height

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Outline

- Introduction
- Error Estimation
- Implementation
- Results
- Conclusions

Introduction – Data Sources -1

- **In-Situ Measurements:**
  - **Buoy / Platform.**
  - **Ground truth.** ***(Is it so?)***
  - **Usually very close to the coast.**
  - **A lot of practical issues.**
  - **Limited coverage (in space and time).**
  - **Northern Hemisphere.**

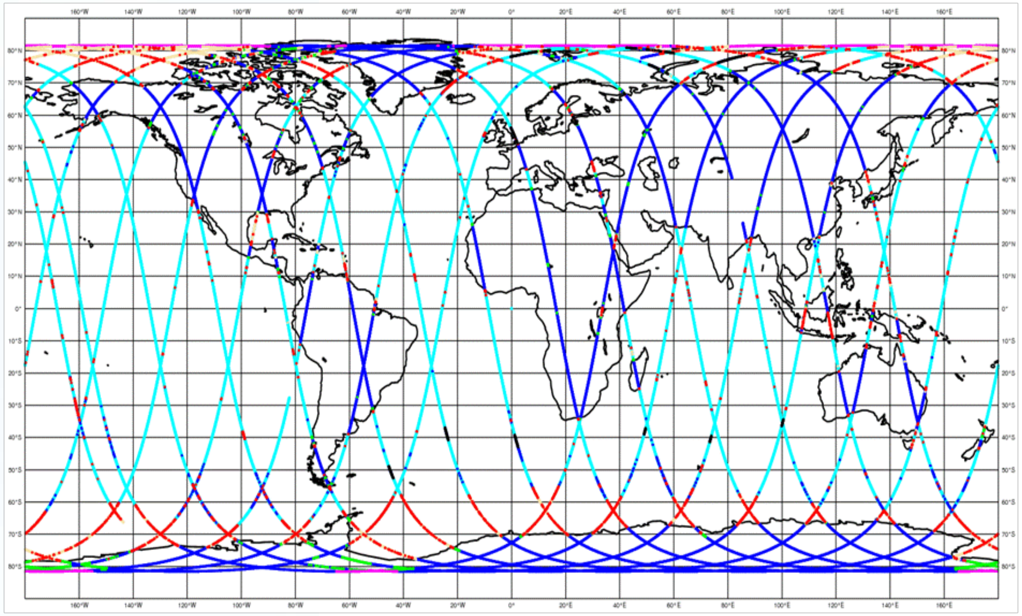
Locations of buoys available through GTS
(January 2011)

Introduction – Data Sources -2

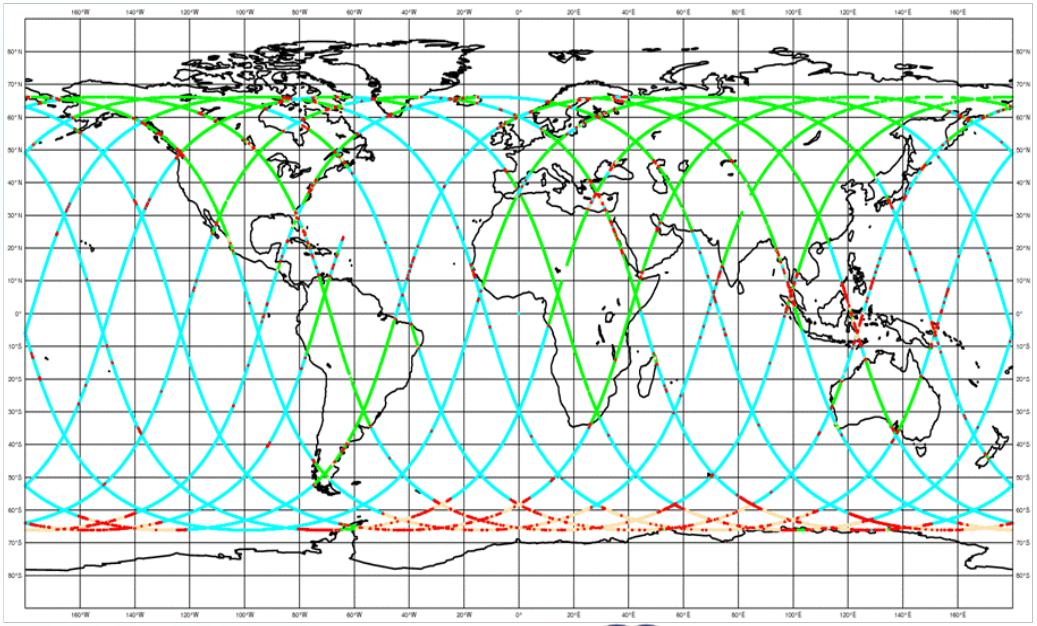
- **Radar Altimeters:**
  - **Global coverage every few days/weeks.**
  - **May not be available when/where needed.**
  - **Not suitable to coastal areas (yet).**
  - **May not be suitable for climate studies.**

Typical Daily Coverage of:

Envisat



Jason-2



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Introduction – Data Sources -3

- **Models:**
  - **Global coverage and as frequent as few minutes/hours.**
  - **Produces forecasts which is crucial for operational uses.**
  - **Ability to make “hindcast” (or “reanalysis”).**
  - **Suitable for climate studies (e.g. ECMWF ERA-Interim and ERA-CLIM).**
  - **Modelling issues: parameterizations, resolution, ... etc.**

Introduction – Errors in the Measurements

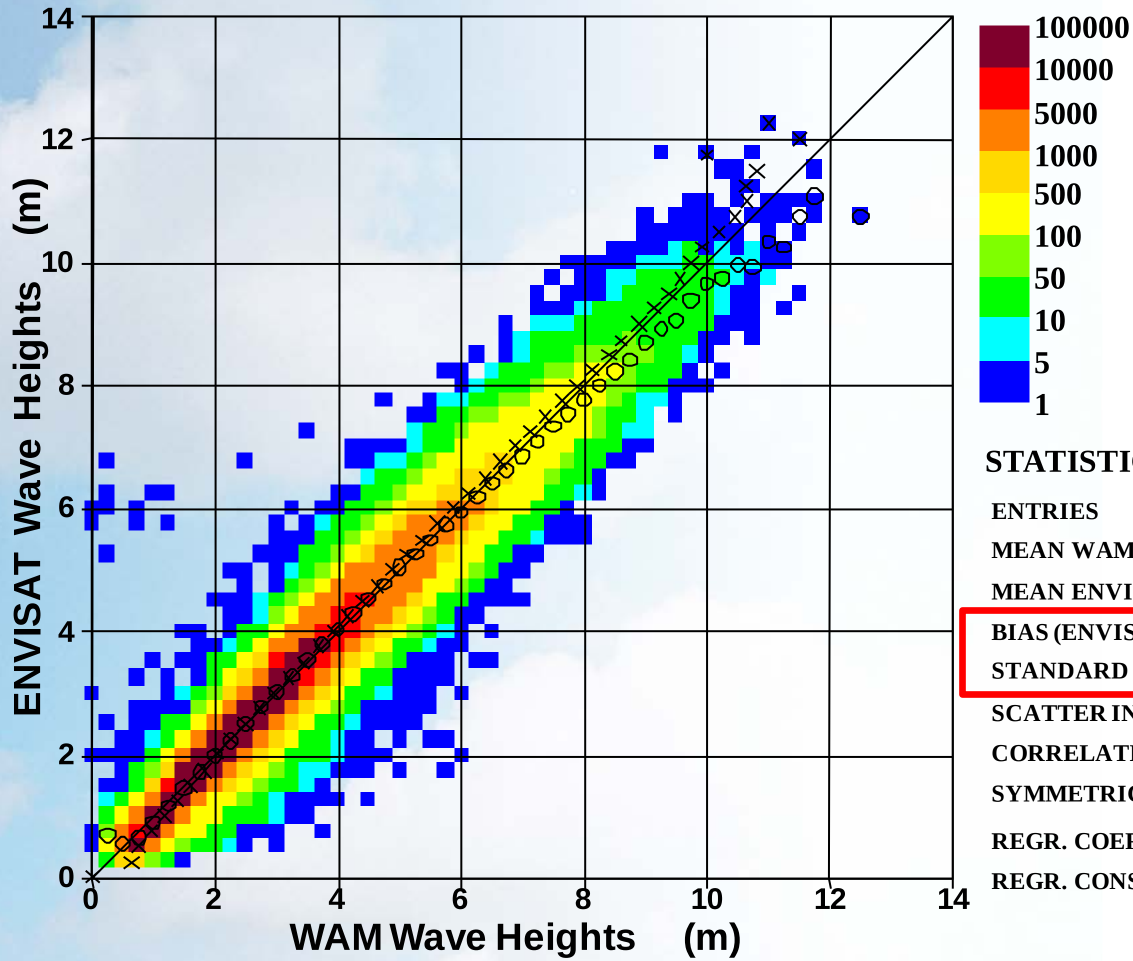
- **Error = Measurement – Truth**
- **Truth is usually unknown.**
- **Statistical description:**
  - **Systematic error → bias or mean difference.**
  - **Random error → variance or standard deviation.**

Error Estimation - Introduction 1/2

- **In practice, the truth is unknown.**
- **Bias cannot be found in absolute sense.**
  Always, a *reference* is required.
  (will not be considered here.)
- **Traditionally, estimation of the random error is done against a reference.**
- **Example: Comparison of significant wave height from 3 Altimeters (Envisat, Jason-1, Jason-2) against ECMWF wave mode (WAM).**

Global comparison between Altimeter and ECMWF wave model (WAM) first-guess SWH values

(From 02 February 2010 to 01 February 2011)



STATISTICS	Envisat	Jason-2	Jason-1
ENTRIES	1125908	1425055	1382997
MEAN WAM	2.6014	2.7073	2.6939
MEAN ENVISAT	2.5851	2.7041	2.8078
BIAS (ENVISAT - WAM)	-0.0163	-0.0032	0.1140
STANDARD DEVIATION	0.2733	0.2826	0.3232
SCATTER INDEX	0.1051	0.1044	0.1200
CORRELATION	0.9786	0.9791	0.9738
SYMMETRIC SLOPE	1.0026	0.9983	1.0397
REGR. COEFFICIENT	1.0163	0.9753	1.0025
REGR. CONSTANT	-0.0587	0.0637	0.1072

Error Estimation – Introduction 2/2

- **For two systems (*X* and *Y*) measuring the same truth at the same location and time; it is assumed that:**

  $$\text{Error Variance} = N^{-1}\ \Sigma(X_i - Y_i)^2 \ - \text{Bias}^2$$

- **But this is just the "difference" not the "error" unless system Y is "error-free" (which is highly unlikely).**

- **Using 3 (or more) systems instead of 2 solves this problem.**
  ➔ "Triple Collocation Technique".

Error Estimation – Triple Collocation

- Given measurements from 3 **independent** measuring systems (X_p , p=1, 2, 3) collocated to detect the truth T at the same location and time.

- Each measurement X_p consists of a *unknown* truth T (calibrated with $\boldsymbol{\beta_p}$) and an *unknown* error e_p as follows:
  $$X_{p_i} = \beta_p T_i + e_{p_i}$$

- The unknown error variance can be written as:
  $$\langle e_p^2 \rangle = 0.5\left[\langle (X_p - X_{p1})^2 \rangle + \langle (X_p - X_{p2})^2 \rangle - \langle (X_{p1} - X_{p2})^2 \rangle\right]$$
  <..> is the average, *p*1&*p*2 refer to the other 2 systems.

- This assumes there **<u>is no correlation between the errors</u>** in the triplets.
  Calibration constants, $\boldsymbol{\beta_p}$, are found by iteration.

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Implementation – Data Preparation

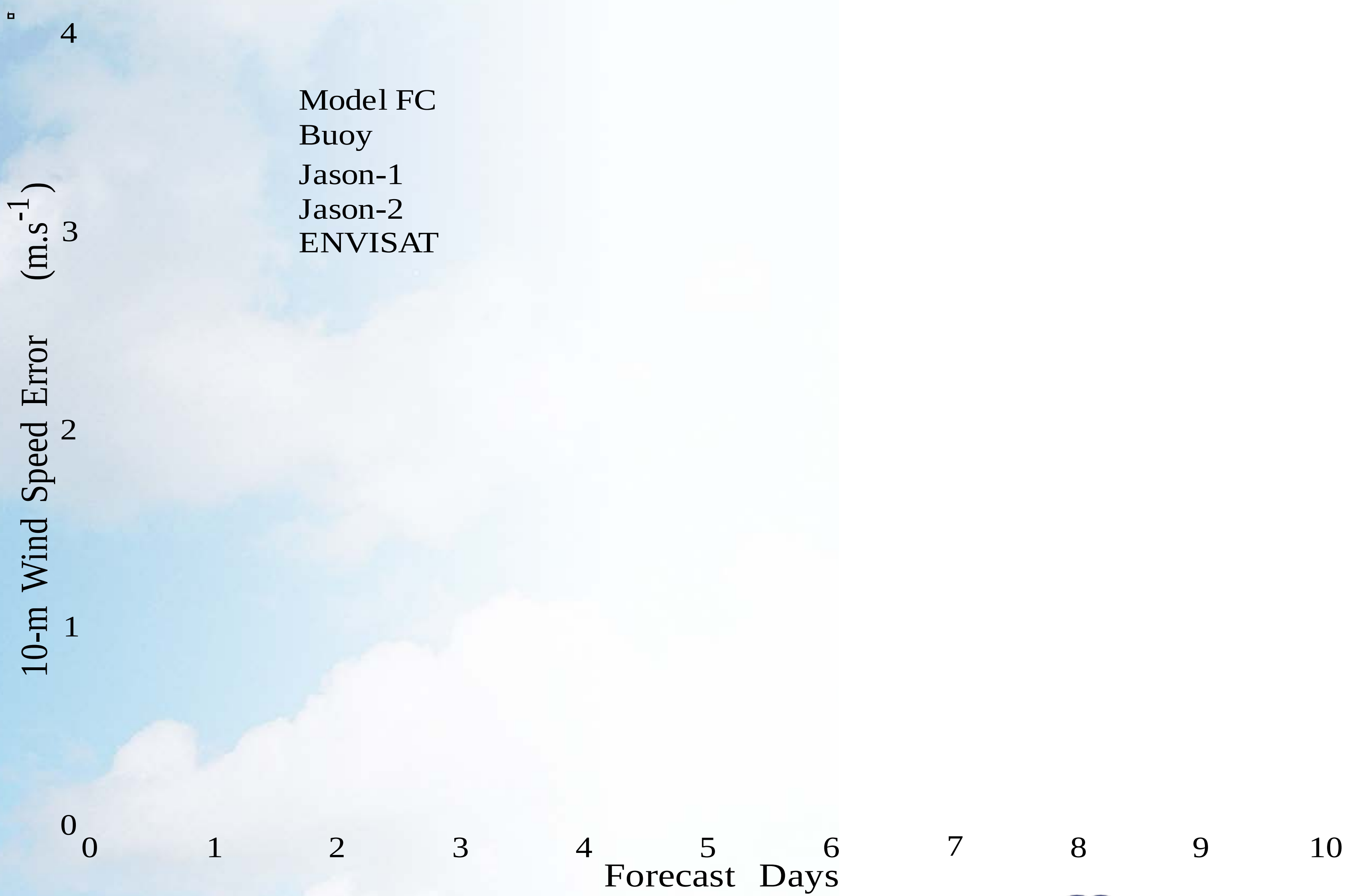
- Quality control of buoy and Altimeter data.
- Triple collocation of significant wave height (SWH) & surface wind speed (U_{10}) between *1 August 2009 – 31 July 2010*:
  - Model Forecast (8 FC steps), ENVISAT, Buoys
  - Model Forecast (8 FC steps), Jason-2, Buoys
  - Model Forecast (8 FC steps), Jason-1, Buoys
- i.e. 24 "different" data sets.
- A collocation is rejected if:
  - Obvious erroneous data.
  - Inhomogeneous conditions at buoy and Altimeter locations.

Results

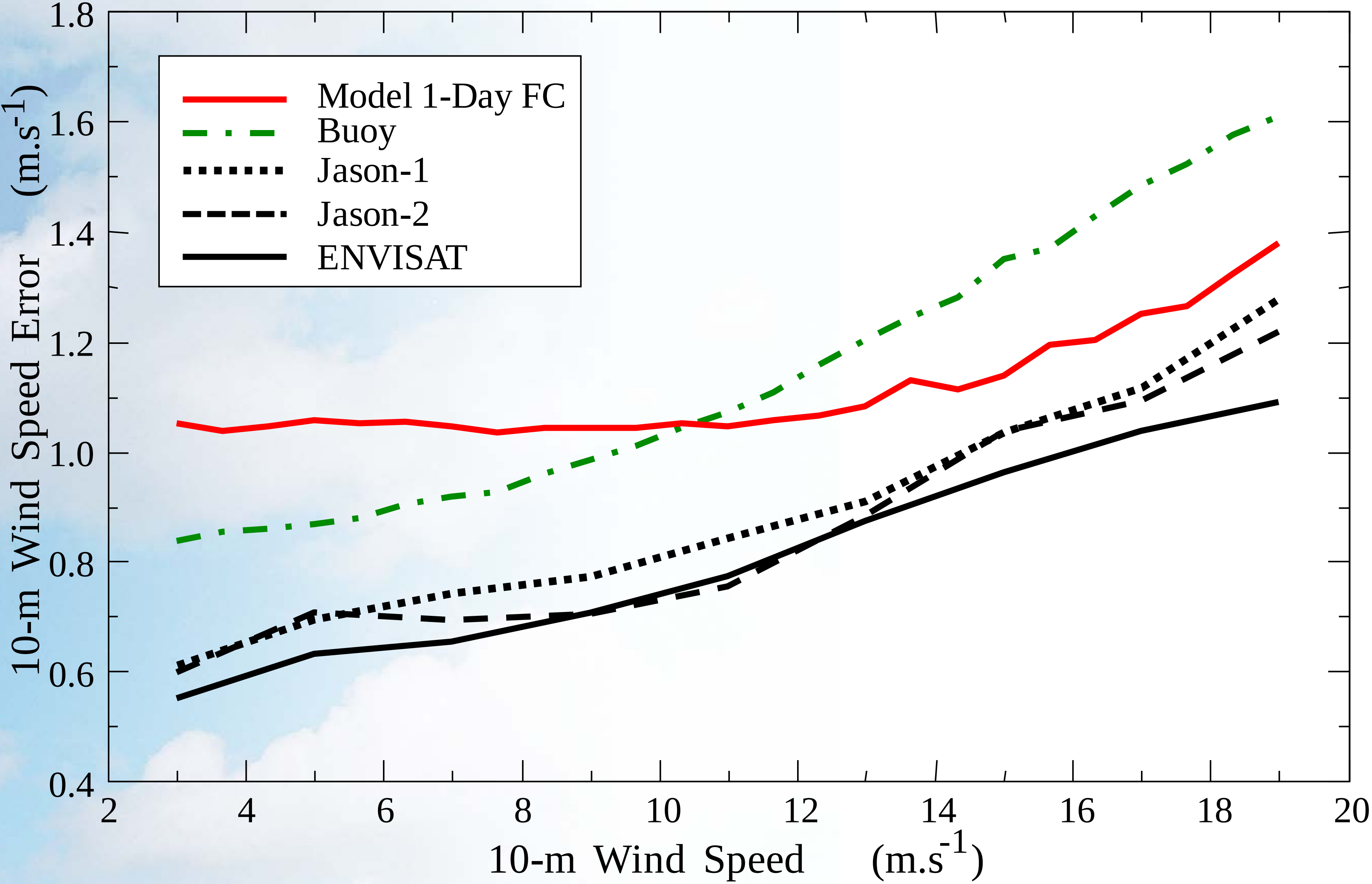
- Standard deviation of absolute random error of surface wind speed:
  - Buoys: ~1.0 m/s.
  - Envisat: ~0.8 m/s;   Jason-2/1: ~0.9 m/s.
  - Model 1-day forecast: ~1.1 m/s
    (Model analysis should be much better.)

- Standard deviation of absolute random error of significant wave height:
  - Buoys: ~0.21 m.
  - Env.: ~0.13 m; Jas.-2: ~0.12 m; Jas.-1: ~0.18 m.
  - Model 1-day forecast: ~0.27 m.
    (Model analysis should be much better.)

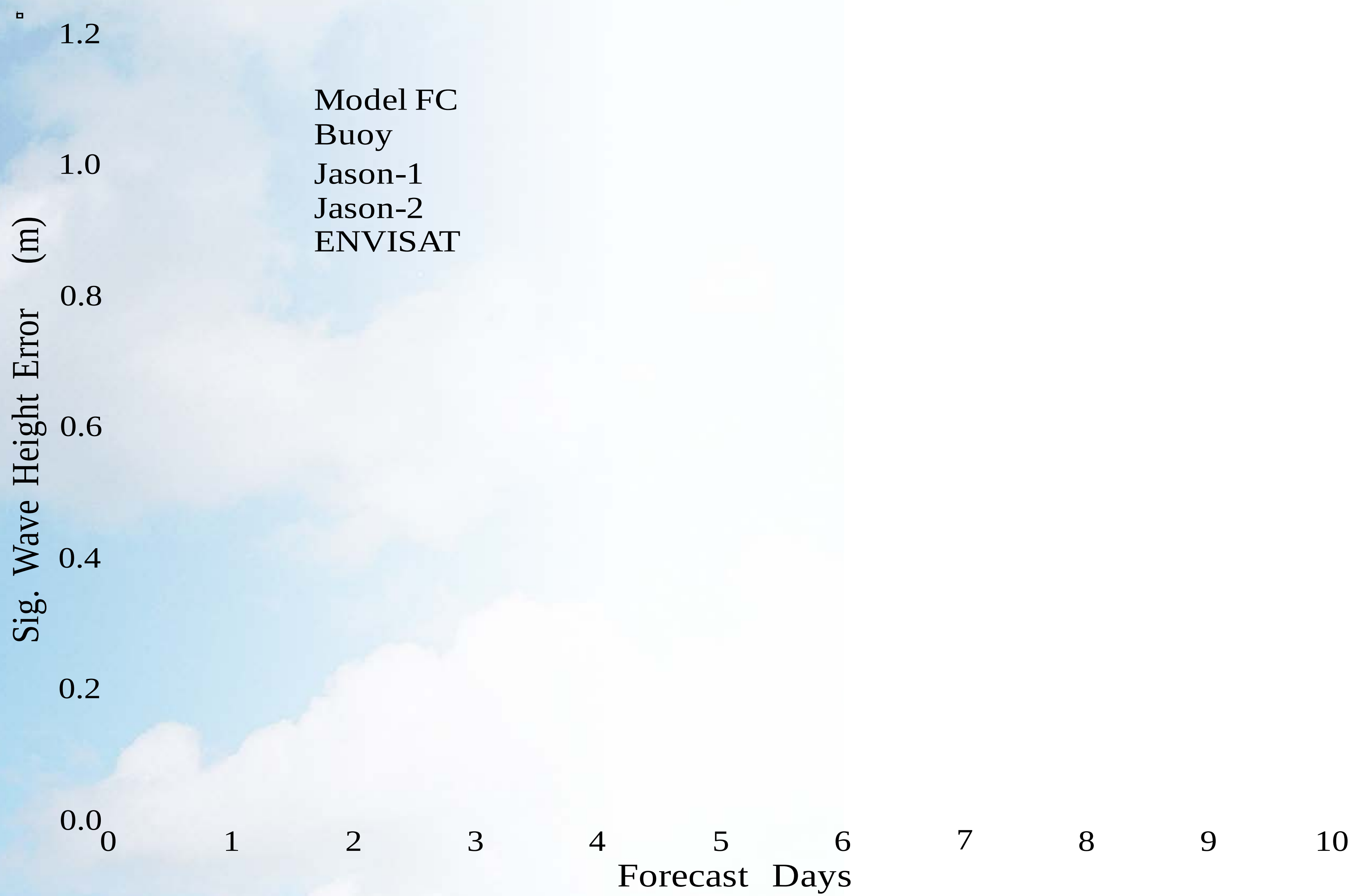
Evolution of Wind Speed Error, $(\langle e_p^2 \rangle)^{1/2}$, vs FC range



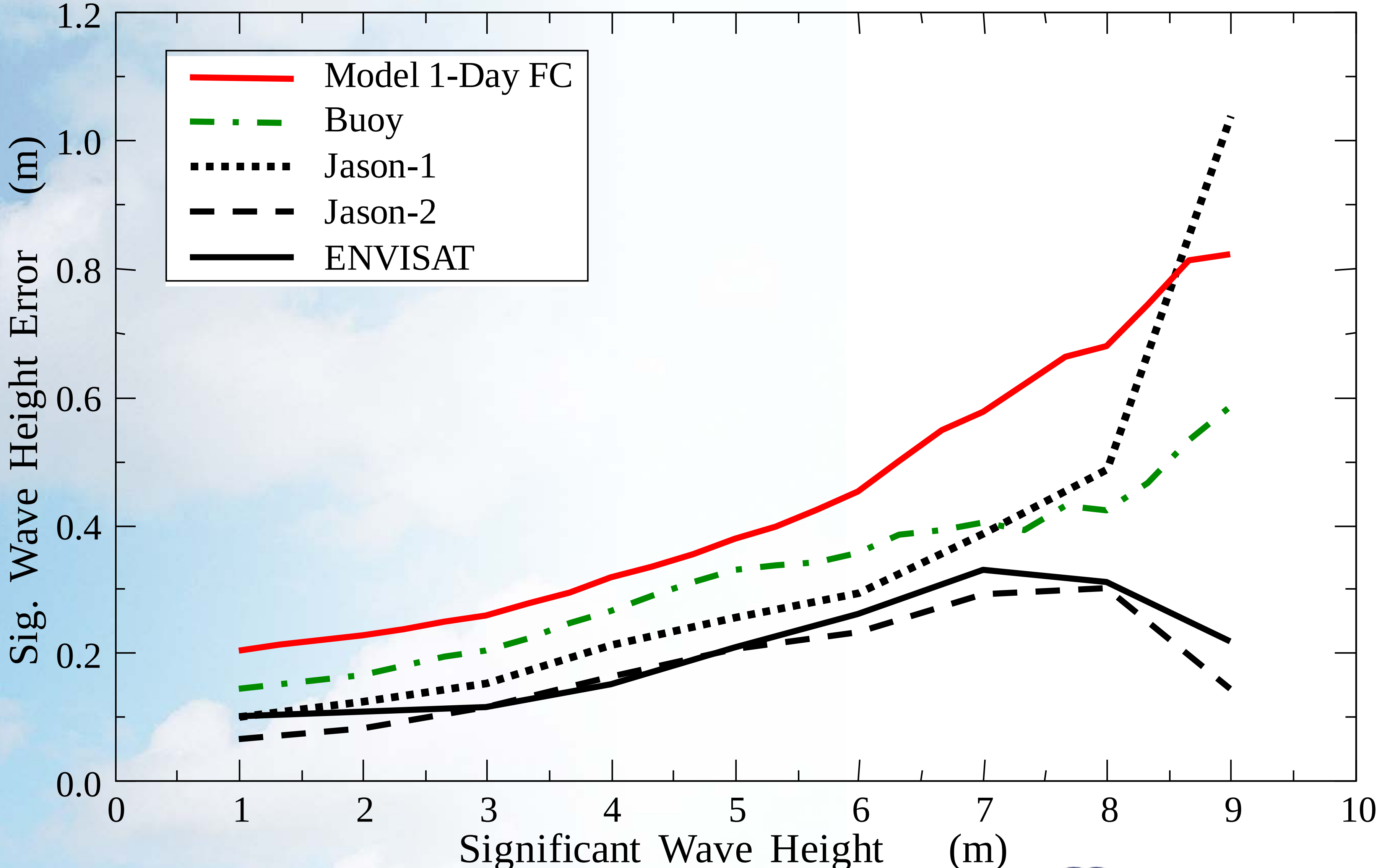
Surface Wind Speed Error , $(\langle e_p^2 \rangle)^{1/2}$, wrt Wind Speed



Evolution of SWH Error, $(\langle e_p^2 \rangle)^{1/2}$, in the Forecast



SWH Error , $(<e_p^2>)^{1/2}$, w.r.t. SWH



Conclusions – *1/2*

- **For the wind and wave data considered here:**
  - **Altimeter measurements have the lowest errors.**
  - **Short-term model forecasts have comparable accuracy with buoys. It was proven elsewhere that model analysis is the best (i.e. even better than Altimeters; Janssen et al., 2007).**

Conclusions – *2/2*

- **Results were obtained mainly for NH (buoy coverage). However, there is no reason to restrict their validity globally.**
- **Triple collocation technique leads to the same results from 3 (x8) different data sets ➔ robust.**
- **The results were verified by preliminary results of another totally different approach.**