Towards a scatterometer-based high resolution ocean wind forcing

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Sapporo, Japan
\[ U_{10N} = \sqrt{\frac{\rho}{\langle \rho \rangle}} U_{10S} \]

- **Beaufort Force 0**
  - *Wind Speed*: Less than 1 knot
  - *Sea*: Sea like a mirror

- **Beaufort Force 3**
  - *Wind Speed*: 7-10 knots
  - *Sea*: Wave height 0.6-1m (2-3ft), large wavelets, crests begin to break, any foam has glassy appearance, scattered whitecaps

- **Beaufort Force 6**
  - *Wind Speed*: 22-27 knots
  - *Sea*: Wave height 0.8-1.2m (2.5-4ft), larger waves begin to form, spray is present, white foam crests are everywhere

- **Beaufort Force 9**
  - *Wind Speed*: 41-47 knots
  - *Sea*: Wave height 1.2-1.8m (4-6ft), high waves, dense streaks of foam along direction of the wind, wave crests begin to topple, tumble, and roll over, spray may affect visibility
Scatterometer Sampling Errors
Assessment Of The Maximum Global Daily Coverage

Scatterometer Constellation (2013)

Real Constellation (RC): ASCAT-A&B (9:30/21:30); OceanSat-2 (12:00/00:00); HY-2A (6:00/18:00)

<table>
<thead>
<tr>
<th></th>
<th>ASCAT-A</th>
<th>ASCAT-B</th>
<th>OSCAT</th>
<th>HSCAT</th>
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<tr>
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<tr>
<td>descending</td>
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<td>both</td>
<td>6</td>
<td>6</td>
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Simulated Constellation (SC): RC + RSCAT
Scatterometer Sampling Errors
Assessment Of The Maximum Global Daily Coverage

MAXIMUM NUMBER OF SATELLITE PASSES FOR A DAY.
ERA-INTERIM ON SCATTEROMETER SAMPLED ORBITS (0.25X0.25 GRID)

- Substantial increase in the spatial coverage for a day
- Sampling density variations with time and latitude
- More than 5 passes at mid-latitudes
- Better coverage in the tropics and (notably) at mid-latitudes for the SC
Scatterometer Sampling Errors
Non-uniform Time Mean Vs. Uniform Time Mean

THE COLOR MAP DEPICTS THE WIND SPEED DIFFERENCES BETWEEN A DAY OF THESE SCATTEROMETER-SAMPLED ECMWF WINDS AND UNIFORMELY SAMPLED ECMWF WINDS.

- The real constellation has the lowest bias and std
- Larger errors in areas of high wind variability
High Resolution Ocean Wind Forcing

STRESS EQ. WINDS (U10S) 2012: OSI SAF ASCAT-A 12.5 KM PRODUCT (COASTAL) [25 KM]
ERA-INTERIM CLIMATOLOGY [200 KM SPATIAL RESOLUTION]

Persistent Features at daily scale

- Areas of high wind variability (e.g., the storm track regions)
- Large scale circulation will be better represented by the model
High Resolution Ocean Wind Forcing
Correction of ERA interim surface winds ($U_{10S^*}$)

The ocean modelling community would widely benefit from a wind stress forcing data set with high spatial and temporal resolution.

**CORRECTION**

$$U_{10S^*}(t) = U_{10S}(t) + \text{smallscale variability}$$

$$\text{ScatterometerCorrection} = (U_{10S_{scatt}} - U_{10S_{ERAs}})(t)$$

Scatterometer data will provide information on the smaller scales.

This “noise” contains information on the eddy scale for the ocean currents, moist convection, coastal interaction and stability parameterization of surface fluxes.
HOW LONG SHOULD THE WIND CORRECTIONS BE ACCUMULATED?

• The correction is computed on and applied to the wind vector components (u,v)
• The length of the accumulation should be weighted according to the physical phenomenon one intends to resolve
• A 5-day accumulation should still account for the eddy scale persistent features on the western boundary current systems like the Gulf Stream, the Agulhas or the Kuroshio currents (stationary)
This systematic correction is seasonally dependent.
High Resolution Ocean Wind Forcing
ERA* vs. ERA
DEC 1st at 03 UTC

More structure is present in ERA*
High Resolution Ocean Wind Forcing
ERA* details

STRESS EQUIVALENT V-COMPONENT JUNE 1ST

• v-wind component ERA* (bottom) shows a clear meridional wind effect south of the African coast and south of the equator

• Moist convection?

• Needs further spatial and temporal analysis

• Test implications for curl and divergence
High Resolution Ocean Wind Forcing
ERA* vs. ERA

GLOBAL: 2-DIMENSIONAL HISTOGRAM OF ERA* vs. ERA FOR THE 1ST DAY OF JJA 2012

```
cor_xy  =0.99
m(y–x)  =–0.11
s(y–x)  =0.77
N      =99532800
```

```
cor_xy  =0.99
m(y–x)  =–0.02
s(y–x)  =0.80
N      =99532800
```
High Resolution Ocean Wind Forcing
ERA* vs. ERA
SEASONAL EFFECTS: GLOBAL MAP OF WIND SPEED BIAS [ERA*-ERA]

The wind speed bias between ERA* and ERA is seasonally dependent (for instance at the ITCZ)
High Resolution Ocean Wind Forcing
ERA* vs. ERA

SEASONAL EFFECTS: GLOBAL MAP OF SD OF WIND SPEED DIFFERENCES [ERA*-ERA]

The SD of [ERA*-ERA] is seasonally dependent, generally larger in the summer months.
High Resolution Ocean Wind Forcing
ERA* vs. ERA

SEASONAL EFFECTS: GLOBAL MAP OF VRMS [ERA*-ERA]

The VRMS is generally larger for the summer months.
High Resolution Ocean Wind Forcing Validation against Buoys

ECMARS Buoy Dataset: RAMA, JAMSTEC-TRITON-TAO, PIRATA ODAS and NDBC (binned 1 m/s)

2-DIMENSIONAL HISTOGRAM OF WIND VECTOR COMPONENTS (u,v) FOR JUNE 2012

- ERA v-component is positively biased w.r.t. buoys
- Same correlation is obtained for both ERA and ERA* w.r.t. buoys, with smaller wind component biases for ERA*
High Resolution Ocean Wind Forcing Validation against Buoys

ECMARS Buoy Dataset: RAMA, JAMSTEC-TRITON-TAO, PIRATA ODAS and NDBC (binned 1 m/s)

2-DIMENSIONAL HISTOGRAM OF WIND SPEED AND DIRECTION FOR JUNE 2012

- ERA* mean bias w.r.t. buoys is smaller for both wind speed and direction

\[
\begin{align*}
\text{ERA\* bias w.r.t. buoys is smaller for both} \\
\text{wind speed and direction}
\end{align*}
\]
High Resolution Ocean Wind Forcing
Validation against Buoys

ECMARS Buoy Dataset: RAMA, PIRATA and NDBC (temporally averaged over 5d window)

GLOBAL MAP OF THE $|\text{ERA}^*_{\text{bias}}|$ $|\text{ERA}_{\text{bias}}|$, $\text{ERA}^*_{\text{bias}}$ and $\text{ERA}_{\text{bias}}$ w.r.t. BUOYS

- Differences between ERA* and ERA are larger for the NDBC coastal buoys
  - Wind variability new the coast? Scatt. gridding near the coast?
High Resolution Ocean Wind Forcing
Validation against Buoys

ECMARS Buoy Dataset: RAMA, JAMSTEC-TRITON-TAO, PIRATA ODAS and NDBC (binned 1 m/s)

GLOBAL MAP OF THE $\text{ERA}^*_{\text{SD}} - \text{ERA}_{\text{SD}}$, $\text{ERA}^*_{\text{SD}}$ and $\text{ERA}_{\text{SD}}$ w.r.t. BUOYS

- Larger discrepancies in $\text{ERA}^*$ and ERA for the NDBC coastal buoys
- Larger SD for $\text{ERA}^*$ data sets w.r.t. buoys
High Resolution Ocean Wind Forcing
Validation against Buoys

ECMARS Buoy Dataset: RAMA, JAMSTEC-TRITON-TAO, PIRATA ODAS and NDBC (binned 1 m/s)

JUNE 2012:
• Solid lines for ERA* collocated with Buoys
• Dashed-dotted lines for ERA collocated with Buoys

- Wind speed bias slightly decreases for longer forecast ranges
- ERA* has smaller wind speed bias and SD at buoy locations w.r.t. ERA
- The VRMS and MVD are very similar
High Resolution Ocean Wind Forcing
Scatterometer correction skill

Monte Carlo Simulation: ERA-interim data collocated to ASCAT sampling

Dec. 2012:
• Temporal windows: 1, 5 and 7 days
• Bias: 1 m/s

- Unbiased "ASCAT" winds are simulated with component errors of 0.7 m/s (according to Vogelzang et al. 2011);
- "NWP" winds simulated with sd=1.5 m/s and 1m/s bias;
- Impact of the sampling errors over a 5-d centered window although reduced is still present
- Distribution with differences ("NWP"-"ASCAT") centered at the bias 1 m/s
High Resolution Ocean Wind Forcing
Scatterometer correction skill

Monte Carlo Simulation: ERA-interim data collocated to ASCAT sampling

- Impact of the sampling errors over a 5-d window although reduced is still present
High Resolution Ocean Wind Forcing Scatterometer correction skill

Monte Carlo Simulation: ERA-interim data collocated to ASCAT sampling

- Globally

\[
\begin{align*}
\text{cor}_{xy} &= 0.948 \\
\text{m}(y-x) &= 1.114 \\
\text{s}(y-x) &= 0.904 \\
\text{Num} &= 2232831
\end{align*}
\]

Unbiased "ASCAT" wind speed (sd=0.7 m/s)

"NWP" wind speed (sd=1.5 m/s bias=1 m/s)

average "ASCAT" = 8.07
average "NWP" = 9.18
Conclusions

Wind scatterometer constellation increases temporal and spatial coverage (although remains latitude dependent)

Low global bias and SD between a non-uniform daily time mean and a uniform daily time mean, but significant local differences

Sampling errors prevail on regions of strong wind variability

ERA* corrected stress equivalent data set shows potential to resolve small scales
Future work

ERA U10S reprocessed with full ECMWF surface layer model
Thoroughly characterize sampling errors through simulation
Improve bias corrections in coastal areas
Include surface current information in the validation
Verification against other scatterometer data (e.g., OSCAT, RSCAT, HSCAT)
Addition of variance in areas of high wind variability (using ASCAT MLE and SE parameters)
Addition of other scatterometer data

Vacancy on scatterometer data processing and applications (to be issued in October 2016)!
High Resolution Ocean Wind Forcing

ERA* vs. ERA

GLOBAL: 2-DIMENSIONAL HISTOGRAM OF ERA* vs. ERA FOR THE 1\textsuperscript{ST} DAY OF JJA 2012

\begin{align*}
cor_{xy} &= 0.98 \\
m(y-x) &= -0.04 \\
s(y-x) &= 0.76 \\
N &= 99532800
\end{align*}
High Resolution Ocean Wind Forcing
MC Simulation extra plots
GLOBAL: “NWP” – “ASCAT” 5 days average

“NWP” – Input + 1m/s bias added to wind speed and 1.5 m/s error added to the wind components;

“ASCAT” – Unbiased wind speed with 0.7 error added to the wind components;
High Resolution Ocean Wind Forcing
MC Simulation extra plots
West Africa

cor_xy  =0.911
m(y−x)  =1.129
s(y−x)  =0.992
Num    =84362

average "ASCAT" =6.50
average "NWP"  =7.63
High Resolution Ocean Wind Forcing
MC Simulation extra plots

cor_xy = 0.775
m(y-x) = 1.121
s(y-x) = 1.002
Num = 67810

average "ASCAT" = 6.78
average "NWP" = 7.90
High Resolution Ocean Wind Forcing
MC Simulation NWP*

NWP* = “NWP” + (“ASCAT” - “NWP”) 

bias = 1 m/s
T': unbiased with sd of 0.7 m/s

\[ \text{cor}_{xy} = 0.931 \]
\[ m(y-x) = 1.238 \]
\[ s(y-x) = 1.455 \]
\[ \text{Num} = 4147200 \]

\[ \text{cor}_{xy} = 0.879 \]
\[ m(y-x) = 0.038 \]
\[ s(y-x) = 1.897 \]
\[ \text{Num} = 2232831 \]

average "INPUT" = 6.02 
average "NWP" = 7.26 
average "INPUT" = 8.09 
average "NWP*" = 8.13
High Resolution Ocean Wind Forcing Scatterometer correction skill

Monte Carlo Simulation: ERA-interim data collocated to ASCAT sampling

Impact of the sampling errors over a 5-d window although reduced is still present.
Monte Carlo Simulation: ERA-interim data collocated to ASCAT sampling

Dec. 2012:

- Temporal windows: 1, 5 and 7 days
- Bias: 0, 0.5 1 m/s

- Unbiased "ASCAT" winds are simulated with component errors of 0.7 m/s (according to Vogelzang et al. 2011);
- "NWP" winds simulated with sd=1.5 m/s and varying bias;
- Impact of the sampling errors over a 5-d centered window although reduced is still present
- Distribution with differences centered at the bias value
High Resolution Ocean Wind Forcing
MC Simulation extra plots
Tropical Atlantic

\[ \text{cor}_{xy} = 0.775 \]
\[ m(y-x) = 1.121 \]
\[ s(y-x) = 1.002 \]
\[ \text{Num} = 67810 \]

average "ASCAT" TA = 6.78
average "NWP" TA = 7.90