Estimating the Uncertainty of Satellite Microwave Ocean Surface Wind Observations and the Resulting Cross-Calibrated, Multi-Platform (CCMP) Ocean Surface Wind Analyses

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Introduction :: Desrozières diagnostics (DD)

- DD provide estimates of background (B), observation (O) and analysis (A) errors.
  - Desrozières et al., 2005, QJRMS, Oct, doi:10.1256/qj.05.108
  - (NB: There are two Desrozier et al. 2005 papers in that issue!)
- DD are exact provided the analysis system is optimal
- DD can help to iteratively refine the analysis system towards optimality
- DD are essentially a no-cost output of analysis procedures
  - (Do you already calculate rms increments of A-B, O-B, & O-A?)
Summary

• We examine B, O, A wind speed errors for the
  – Cross-Calibrated, Multi-Platform (CCMP) ocean surface wind data for 2004
  – CCMP is produced using a variational analysis method (VAM) and is hosted at JPL/PO.DAAC

• Error standard deviations vary with latitude for the
  – ECMWF operational surface wind speed error in the range 0.7-1.5 m/s
  – Cross-calibrated RSS wind speed retrievals in the range 0.5-0.8 m/s
  – CCMP analysis wind speed in the range 0.2-0.4 m/s

• DD will help address two VAM issues:
  – Specification of observation errors and the weights used in the VAM cost function
  – Assignment of analysis uncertainty for the CCMP products
Global variation of background errors

- Plotted at each $\frac{1}{4}^\circ$ grid box for all observations in a centered $5 \times 5$ grid box stencil

$\langle C_B \rangle^{\frac{1}{2}}$ (m/s)

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Desroziers diagnostics (DD)

- The contribution (C) to the estimated covariances from any two observations, i and j are
  - \( C_B = (A_i - B_i)(O_j - B_j) \)
  - \( C_O = (O_i - A_i)(O_j - B_j) \)
  - \( C_A = (A_i - B_i)(O_j - A_j) \)

- The estimated covariance is the sample mean of the \( C_x \) \((x=A,B,O)\)

- Everything is in observation space

- Generally \( O_i \) and \( O_j \) may be at different locations and different times

- Any sensible sample can be used for averaging
Quality control

• The $C_x$ are very noisy
  – QC the observations based on the values of $C_x$
  – We call this VC-QC (variance contribution QC)

• VC-QC is a gross QC
  – Observations are QC'd when at least one of the $C_x$ is more than 6 std. dev. from the mean

• VC-QC greatly reduces uncertainty in error estimates, with little effect on those estimates
  – One exception noted later
• For observed wind speed bins < 16 m/s, \(<C_x>_{1/2}\) is nearly constant
• For higher wind speeds \(<C_x>_{1/2}\) increase very rapidly
Variation with time difference

- No trends for A or B errors, linear trend for O errors
- $\sqrt{C_x}$ increases from 0.53 (at $|\delta t|=0$) to 0.70 m/s (at $|\delta t|=3$ h)
• Rewrite the basic DD equations specialized for variance (i=j) in terms of $Y = (O-B)/(A-B)$
  - $C_B = Y (A-B)^2$
  - $C_O = Y (Y-1)(A-B)^2$
  - $C_A = (Y-1)(A-B)^2$
    • (Similar relationships can be obtained in terms of $1/Y$ and $(O-B)$)
• Parameterizing $<C_x>$ in terms of $(A-B)^2$ is potentially very useful in estimating the analysis errors of the VAM for each synoptic time and for each grid cell
Large increments $\rightarrow$ large errors

\[ <C_x> \quad (m^2/s^2) \]

\[ (A-B)^2 \quad (m^2/s^2) \]

- w/o VC-QC
- w VC-QC

Mean values
- B = 1.94
- O = 0.69
- A = 0.17

Mean values
- B = 1.27
- O = 0.39
- A = 0.07
Conclusions

• Applied DD to the VAM outputs of the CCMP project for 2004
• Globally wind speed error standard deviations vary with latitude for the
  – ECMWF operational surface wind speed error in the range 0.7-1.5 m/s
  – Cross-calibrated RSS wind speed retrievals in the range 0.5-0.8 m/s
  – CCMP analysis wind speed in the range 0.2-0.4 m/s
• Errors are fairly constant for observed wind speed up to 16 m/s and are much higher for higher wind speeds
• Observational errors increase with time relative to the analysis time, and vary with platform and the number of observations
• The error variances depend linearly on \((A-B)^2\) and on \((O-B)^2\)
Lessons learned :: DD inconsistencies

• If there are no DD inconsistencies then the data assimilation system (DAS) is internally consistent

• By refining and specializing the samples, inconsistencies are likely to be observed
  – This approach presents opportunities to discover and then mitigate errors in the formulation of the DAS

• Possible sources of inconsistencies
  – Incorrect B or O error covariances in the DAS
  – Unaccounted for biases in the DAS or DD
  – Improper QC in the DAS
  – Non-Gaussian errors
  – Small sample sizes
  – Applying DD in non-observation space (QuikSCAT wind speeds)
Future work

- Tune the VAM and iterate the process
- Apply to wind vectors from QuikSCAT
- Estimate CCMP analysis errors
- Apply to correlations of errors
  - Earth relative geometry
  - Satellite swath geometries
Thank you

- doi:10.1256/qj.05.108
  » Desroziers et al., 2005, QJRMS, Oct
- doi:10.1175/2010BAMS2946.1
  » Atlas et al., 2011, BAMS, Feb
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