FSU FLUXES
Center for Ocean-Atmospheric Prediction Studies

Spatial Variability of Random Error and Biases in the FSU3 Winds

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1. Introduction

Fields of surface winds and fluxes are used in a wide range of applications including El-Niño Southern Oscillation (ENSO) forecasts and impacts, as well as studies of ocean and atmospheric variability on a wide range of spatial and temporal scales. In-situ observations have been used to develop many surface wind products (e.g., Hellerman and Rosenstien 1983; daSilva et al. 1994; Servain et al. 1996; Stricherz et al. 1997). For more recent time periods, surface winds have also been determined from satellite observations: Special Sensor Microwave/Imager, altimeters, and scatterometers (Pegion et al. 2000). Surface flux fields are usually developed from atmospheric general circulation models such as the National Centers for Environmental Prediction – National Center for Atmospheric Research (NCEP–NCAR) reanalysis. The advantages of the GCM fields are greater temporal resolution than in-situ fields, longer time series than satellite derived fields, and the addition of upper-air fields. However, reanalysis data are noted to have a poor handling of the wind field in equatorial regions (Putman et al. 2000), as well as large biases in heat fluxes (Smith et al. 2001). For applications that require accurate surface fluxes and/or winds, and do not require better than monthly temporal resolution, a research quality climatology based on in-situ observations is preferred.

An objective technique (adapted from Bourassa et al. 2005) is used to create a new monthly climatology for surface fluxes and related fields. **But how good is this in situ based product?** Objectively derived uncertainties (random errors) are used to answer this question.

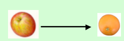
2. Bias Correction and Uncertainty in Observations

Biases Adjustments of the input observations

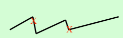
- Beaufort winds are adjusted with Lindau's correction.
- Ship winds are height adjusted to 10m.
- Biases in VOS temperatures are removed following Berry and Kent.

Uncertainties in observational estimates (of monthly averages) include

- Observational uncertainty (i.e., error in the observation)
- Representation error
  - Due to differences in location and time, and
  - Differences in sampling volume



- Sampling error
  - How well are fluctuating fields sampled in time?



Observational errors and representativeness for winds have been determined through various studies. Sampling Error has been estimated from variability in the NCEP/NCAR Reanalysis, and the number of observations in a grid cell per month. This number is often small: in areas of large sampling variability, the sampling error often dominates (see Fig. 1).

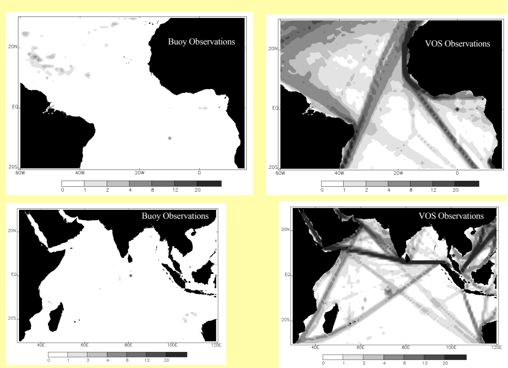


Figure 1. Example VOS and Buoy Observations density for December, averaged from 1988-1997.

3. Considerations in Creating Gridded Analyses

Three key issues are non-uniform observational coverage, observational errors, and highly non-uniform uncertainty. Furthermore, observational tracks from different times intersect, often with substantial changes in the wind pattern occurring between the observations. Simple averaging would result in spurious wind curl and divergence, which generates spurious Rossby and Kelvin waves when these fields are used to force ocean models.

There are several problems that must be overcome

- **Filling the gaps**
  - A good approximation (climatological averages are sometimes very poor guesses)
  - Must have realistic spatial trends
- **Removing the edge effects** due to overlapping ship tracks (or buoy chains)
  - Poor techniques will introduce too much spurious divergence/curl
  - Ocean models are highly sensitive to divergence/curl
- Avoid excessive **smoothing**
- **Remove bad (or unrepresentative) data** prior to the analyses

4. Comparison Data

- The validation data are from one scatterometer:
  - SeaWinds on QSCAT (53 months)
  - The QSCAT data are gridded on a half degree grid.
    - A similar objective method is applied (Pegion et al. 2003 MWR)
- Advantages of scatterometer data
  - Much better temporal sampling
  - Spatial sampling is much more uniform
    - ~92% of the ice free oceans covered each day.
    - The daily number of SeaWinds observations is approximately equal to the annual number of ship and buoy observations that enter the GTS data stream.
  - QSCAT winds are very accurate (Bourassa et al. 2003 *JGR*)
- Differences from in situ winds (Bourassa et al. 2005 JCLIM)
  - Equivalent neutral winds - stability influences
  - Current relative winds
  - Wave modifications to stress are at least partially accounted for

5. Estimation of the Biases

- The biases are estimated by taking the mean of the 53 monthly differences (FSU3 - scatterometer).

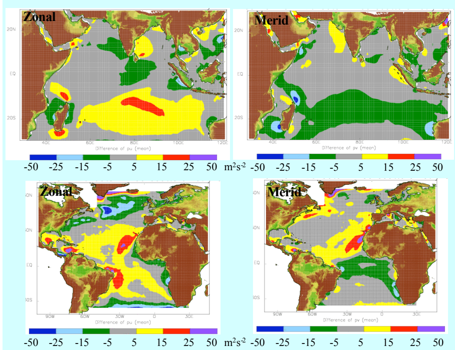


Figure 2. Biases in the FSU3 pseudostress components (right zonal; left meridional), relative to scatterometer winds gridded on a half degree grid.

- The vast majority of regions have small biases.
- The analogous biases in speeds are usually <0.75 ms^{-1}.
- The problem areas are usually areas that are very poorly sampled
- However, on the main ship track from the Mediterranean Sea to South America, off the coast of Africa, there is a bias of ~2ms^{-1}, which requires further investigation.
- The biases around the tips of Madagascar are due to the differences in resolution of the products being compared.

Key References

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6. Random Error in the Objectively Derived Pseudostress

Random errors in the output are propagated from two sources: random errors in the observation field (section 8), and random errors in the background field (section 9).

7. Random Errors in Observations

- Two types of errors contribute: observational errors and sampling errors
- For the spatial distances considered, representation errors are small compared to observational errors (Kent et al. 1998).

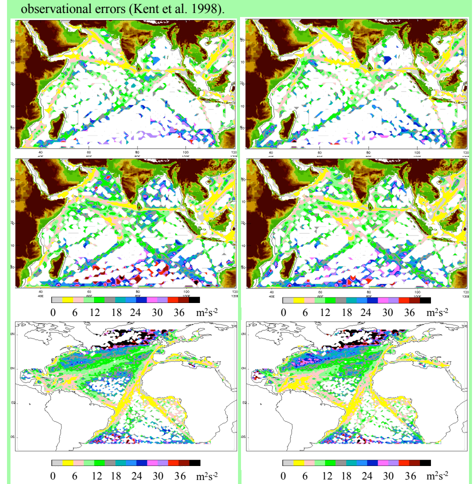

Figure 3. Random errors in the observational terms (pseudostress) used in the objective method. The left panels are zonal pseudostress, and the right panels are meridional pseudostress. Examples are for Sept. 1992 (top), July 1985 (middle), and March 1983 (bottom).

- Areas with good sampling have very low observational errors.
- Areas with no sampling have an undefined uncertainty, but do not contribute to the output fields, and therefore do not contribute to uncertainty in the output fields.
- Future studies will investigate if the error in the output fields can be reduced by ignoring areas with very few observations.

8. Random Errors in the Background Fields

- The background fields are overly smoothed fields of the same data that is used to construct the fields of observations.
  - Observations from widely different regions can be binned together, particularly so in data sparse areas.
- All three types of errors contribute: observational errors, representation errors, and sampling errors
- Representation errors are based on the estimates of Kent et al. (1998).
  - The errors are assumed to be isotropic.
  - Observational uncertainty is also treated as independent of direction, therefore uncertainty in velocity components are identical prior to the consideration of sampling error.
- The spatial pattern (Fig. 4) of uncertainty is closely related to natural variability and the observation density.
  - The large uncertainties in the southern Indian Ocean indicate a large area of poor sampling.
  - The arctic Atlantic Ocean also has poor sampling, and has very large natural variability in the winds, resulting in extremely high uncertainty.

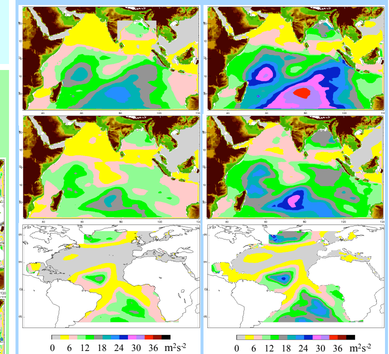

Figure 4. Examples of uncertainty in the background field, due to (left) observation and representation errors and (right) observation, representation, and sampling errors in the zonal pseudostress. The examples are from July 1985 (top) and Sept. 1982 (middle).

- The uncertainties on the right will dominate uncertainties shown on on the right will dominate the uncertainties in the final product.

9. Estimate of Random Error Relative to QuikSCAT

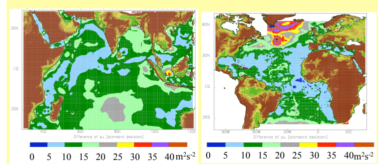

Figure 5. Standard deviations of monthly differences (FSU3-QSCAT) for 53 months. If the QSCAT fields are assumed to have very small errors in comparison to the FSU3 fields, then these standard deviations are an approximation for the mean error field (including error propagation).

- The general pattern and magnitude of the fields in Fig. 5 are similar to those in the left column of Fig. 4.
- Therefore the objective technique for estimating error is producing estimates with reasonable patterns and magnitudes.

10. Future Work

- Improved bias adjustments will be investigated.
- The propagation of error will be considered in uncertainties.
  - This will combine the error estimate from the observational and background parts of the objective method.
- The uncertainty calculation will be extended to apply to all output fields: air temperature, atmospheric humidity, scalar wind speed, vector stress components, sensible heat flux, and latent heat flux.
- Representation error will be considered in satellite observations.
  - The satellite version of the code allows the grid size to be specified. The random errors can be examined as functions of spatial and temporal averaging scales.
- Improved physical assumptions could be used to reduce representation error.

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