Assessing uncertainties when estimating global-scale bulk turbulent air-sea fluxes

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Context

Bulk aerodynamic formulas are widely used to estimate the turbulent air-sea flux components of surface boundary conditions of most of state-of-the-art Ocean and Atmosphere GCMs and ESMs. These fluxes are wind stress, sensible heat flux, and evaporation (latent heat flux).

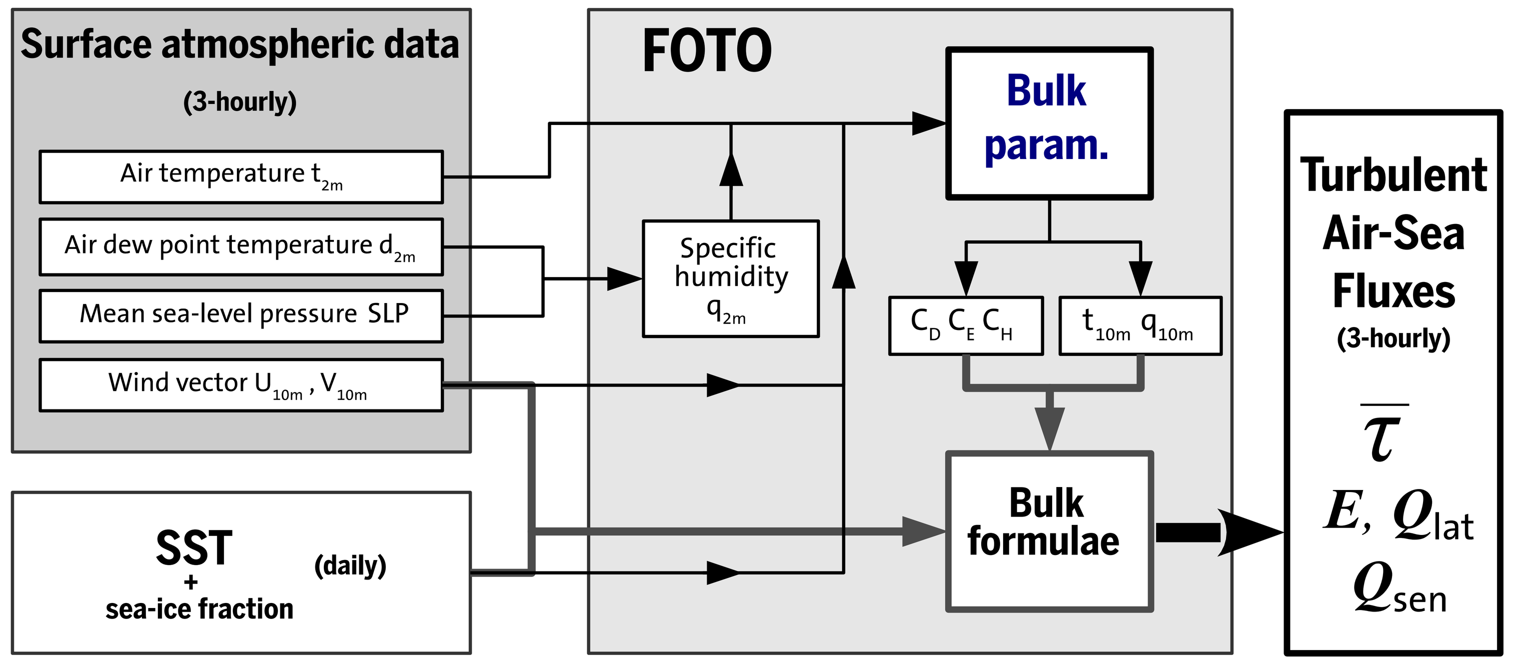
$$\left\{\begin{array}{rcl} \vec{\tau} & = & \rho_a \, C_D \left[\vec{U}_z - \vec{u}_0\right] \Delta U \\ Q_{sen} & = & \rho_a \, C_H \, C_p \left[\theta_z - SST\right] \Delta U \\ E & = & \rho_a \, C_E \left[q_z - 0.98 \, q_{sat}(SST)\right] \Delta U \\ Q_{lat} & = & L_{vap} \, E \end{array}\right. \qquad (\Delta U \equiv \|\vec{U}_z - \vec{u}_0\|)$$

In this study aims at assessing the errors and discrepancies, in terms of surface heat flux, wind stress and evaporation, caused by:

- the choice of the bulk algorithm (estimate of transfer coefficients)
- common assumptions and simplifications in the bulk approach
- biases in the input variables (surface atmospheric fields and SST)

Method

Using our tool FOTO, 3-hourly surface atmospheric fields and daily SST of the ERA-Interim reanalysis [Dee et al., 2011] are used to compute 3-hourly estimates of turbulent air-sea fluxes, during a period spanning 1979 to 2013.



References

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Large, W. G., and S. G. Yeager, Diurnal to decadal global forcing for ocean and sea-ice models, *NCAR technical note*, pp. 22 pp, 2004

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Experiments

Control setup

- Bulk parametrization: COARE v3 of Fairall et al. [2003] with wind-dependent *Charnock* parameter and no skin temperature parametrization.
- Surface current taken into account: use of climatology from Lumpkin and Garraffo [2005].
- Accurate estimate of density of air and specific humidity at saturation using air temperature and SLP from ERA-Interim.

Tested setups (difference with control)

- NCAR bulk parametrization of Large and Yeager [2004] (→ Fig. 1)
- Constant *Charnock* parameter
- Constant air density
- Constant SLP (affects both air density and specific humidity)
- Constant air density + constant SLP
- No lapse-rate adjustment (t_{2m} and q_{2m} are not adjusted to 10m)
- Less accurate empirical formula to estimate q_{sat}(SST)
- Constant air density + less accurate q_{sat}(SST)
- No surface current
- Positive and negative biases applied to t_{2m}, q_{2m}, U_{10m} and SST (→ Fig. 2)

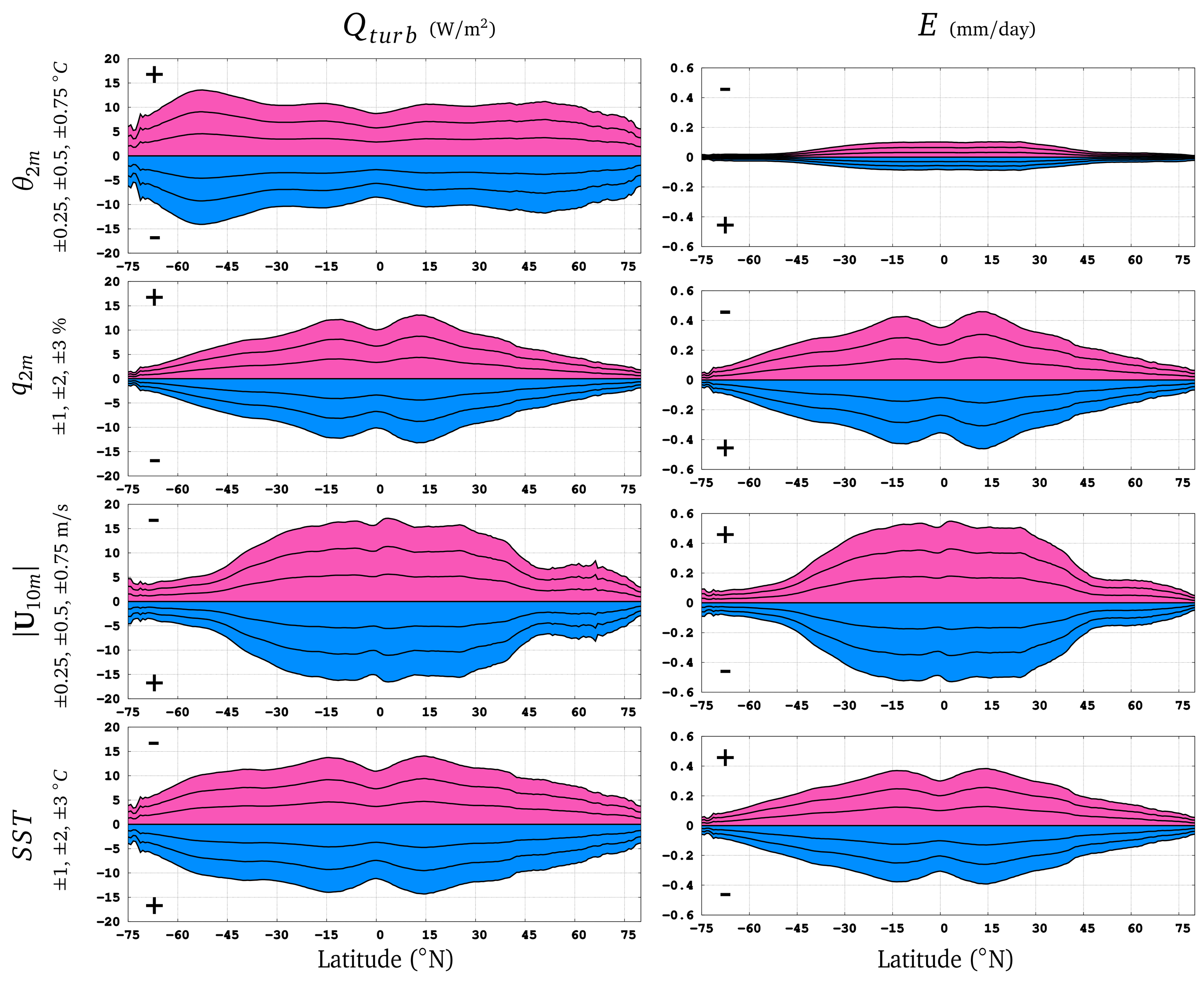

Figure 2: Zonally-averaged differences in turbulent heat flux (Qturb = Qlat + Qsens) and evaporation (E) between the biased-variable case and the control experiment (case - control) for the period 1979-2013.

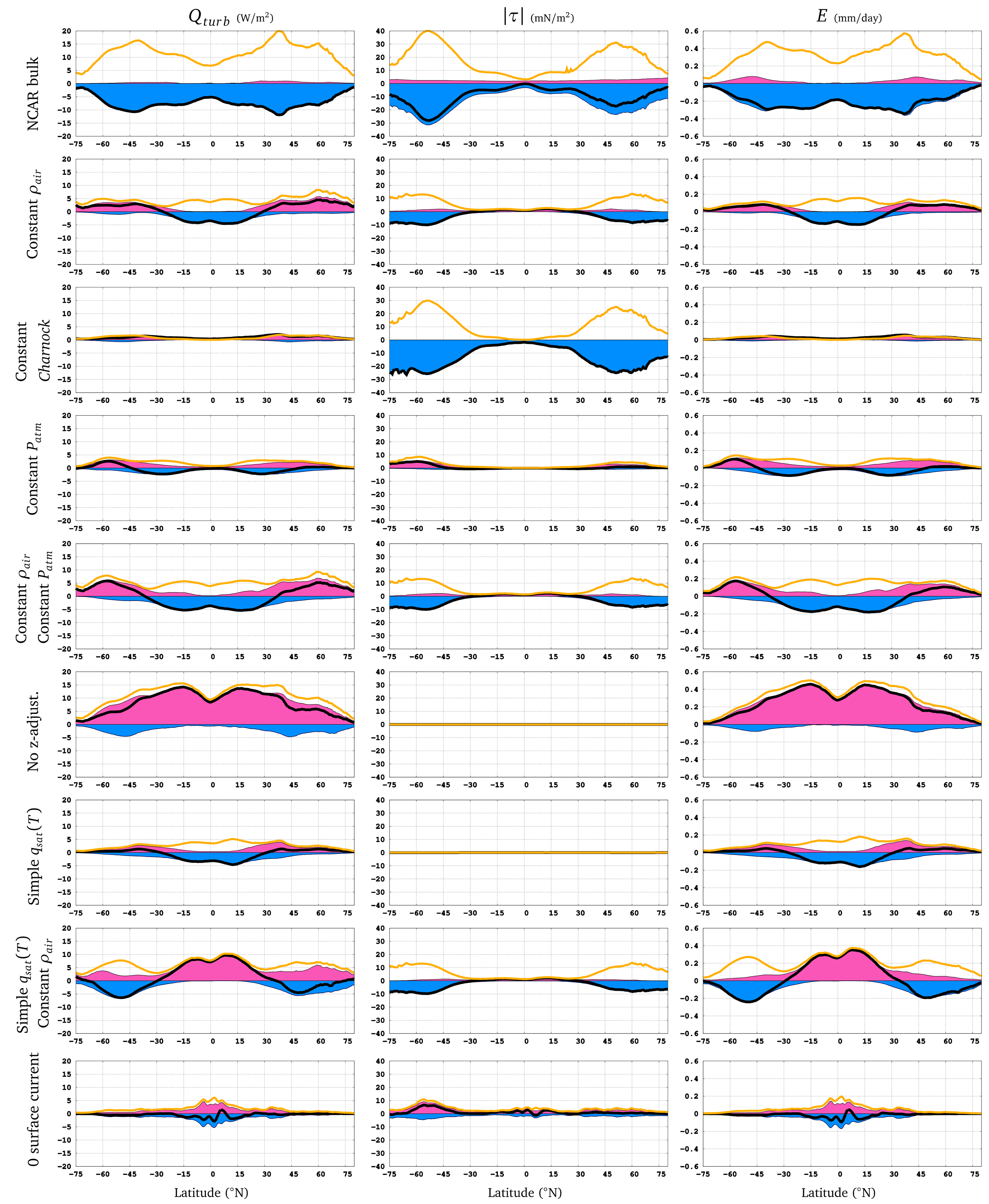

Figure 1: Zonal average (1979-2013) of the differences (black lines), positive- and negative-only differences (pink and blue shading) and 3-hourly RMS (orange lines) between the test and the control experiment, for the turbulent heat flux (Qturb = Qlat + Qsens), the wind stress module (|τ|) and evaporation (E). A positive difference means that the ocean is gaining more heat/momentum/freshwater in the test experiment than in the control experiment.

Main results

The largest source of flux uncertainties results from the choice of the bulk algorithm used to calculate bulk transfer coefficients (COARE vs NCAR). The disagreement, in terms of globally-averaged heat flux and evaporation, is of the order of 10 W/m² and 1 Sv. The same order of error is obtained when not adjusting temperature and humidity to wind height. In mid latitudes, the same heat flux disagreement could result from a bias of 0.75 m/s in surface wind speed, of 2-3° in SST, of 0.5° in surface air temperature, and from a change of 5% in the surface humidity. This stresses the need to improve and unify the parametrizations on which these algorithms are based. Our study also underlies the relative importance of the air density when combined to other simplifications such as the use of a simplistic formula for q_{sat}(SST) or a constant SLP.