**4B.2** SPURIOUS DIVERGENCE WITHIN OBJECTIVE ANALYSES WITH APPLICATION TO TOGA COARE HEAT AND MOISTURE BUDGETS

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## 1. Introduction

This paper discusses a limitation of using gridded objective analyses to calculate heat and moisture budgets. Such analyses can contain divergence of the horizontal wind field that is spuriously generated by the analysis technique. The existence of spurious divergence can lead to errors in the calculation of vertical velocity, a variable to which budgets are quite sensitive. While the examples of spurious divergence discussed here are limited to gridded analyses constructed using multiquadric interpolation (Nuss and Titley 1994), it is likely that most if not all objective analysis techniques can generate spurious divergence.

## 2. Data

The data presented in this paper were collected during the Intensive Operating Period (IOP, 1 November 1992 through 28 February 1993) of the Tropical Ocean Global Atmosphere Coupled Ocean Atmosphere Response Experiment (TOGA COARE, Webster and Lukas 1992). Rawinsonde and profiler data were merged (Ciesielski et al. 1997) and then objectively analyzed to a grid using multiquadric interpolation.

## 3. Evidence of Spurious Divergence

The time- and vertically-averaged gridded tropospheric winds are weak to the south of the equator and progressively more easterly to the north of the equator (Fig. 1a). There are dipoles in the divergence of the mean tropospheric winds centered on a number of the sounding stations (e.g. on the vertices of the sounding arrays, Fig. 1b). The dipoles are the strongest to the north and south of the shear zone between the equator and 5 N, and those lying north of the shear zone have an opposite sign to those lying south of the shear zone (Fig. 1b). It is highly unlikely that these dipoles occurred in nature; they equate to unrealistic vertical motions at the tropopause, and it is hard to imagine a mechanism that would force them over an ocean with isolated small islands. The fact that their geometry follows the pattern of the sounding stations makes the dipoles especially suspect.

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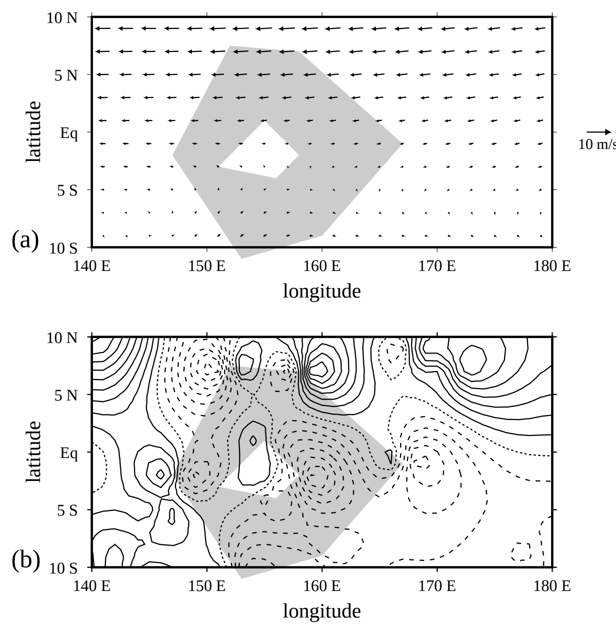


Fig. 1. The mean tropospheric winds (a) and divergence (b) during the IOP. Outer and inner sounding arrays are shaded dark and light respectively. The zero contour is dotted, negative contours are dashed, and the contour interval is 0.02/day.

In order to see if these dipoles can be spuriously generated by multiquadric interpolation, we apply such interpolation to pseudo observations of a non-divergent approximation of the mean tropospheric wind field (Fig. 2a). The non-divergent wind field is zonally symmetric, and is obtained by zonally averaging the original analysis of zonal wind. One pseudo observation is included at the position of each sounding station. The pseudo-analysis contains dipoles similar to those found in the actual data (Fig. 2b), and since the pseudo-observations are of a non-divergent wind field, these dipoles are entirely spurious. We conclude that multiquadric interpolation can generate spurious divergence, and, based on the similarity of the divergence fields depicted in Figs. 1b and 2b, that spurious

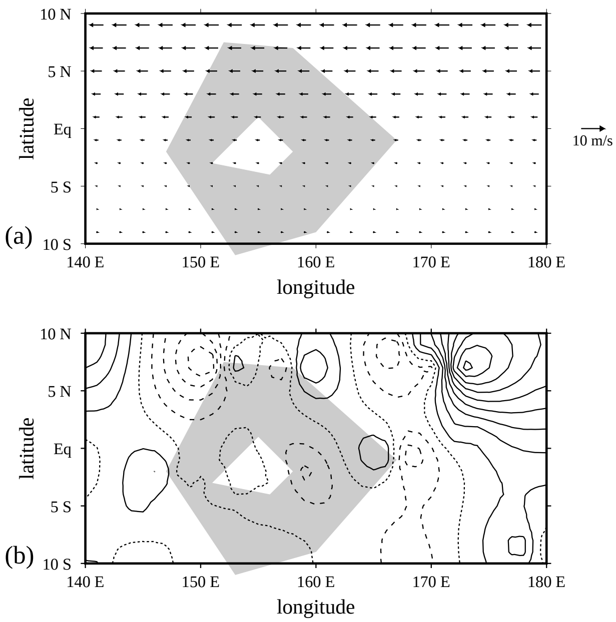


Fig. 2. (a) a non-divergent approximation of the mean tropospheric wind field. (b) the divergence of a multiquadric analysis of pseudo observations of the non-divergent wind field (contoured as in Fig. 1b).

divergence is most likely present in the original analysis.

## 4. Impact on Budgets

Gridded TOGA COARE data created using multiquadric interpolation were previously used to calculate heat and moisture budgets (Johnson and Ciesielski 2000). In order to estimate the impact of spurious divergence on these budgets we construct a non-divergent approximation of the IOP mean wind for each pressure level (using the same technique as above), apply multiquadric interpolation to pseudo observations of the non-divergent wind field, and then calculate a precipitation-minus-evaporation (PME) budget using the resulting wind field. Following Johnson and Ciesielski we mass-balance the analyzed divergence field by applying a correction that is independent of height. The pseudo wind field is non-divergent with no vertical velocity, so the correct PME budget is zero everywhere (horizontal advection and storage terms are neglected). However, the PME budget created from the gridded analysis has dipoles with magnitudes of several mm/day (Fig. 3), so we conclude that spurious divergence can generate errors of approximately this magnitude.

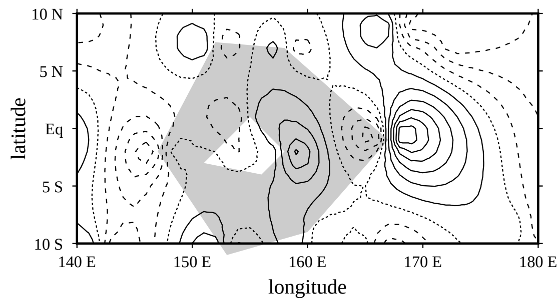


Fig. 3. Precipitation minus evaporation (1 mm/day contours, zero contour dotted) as calclated from a gridded analysis of pseudo observations of an idealized, non-divergent tropical atmosphere.

## 5. Correcting for Spurious Divergence

Spurious divergence depends on flow patterns and therefore can be a complex function of height, so standard techniques for mass-balancing divergence profiles (e.g. O'Brian 1970) do not properly correct for it. There is hope, however, that one can correct for spurious divergence in a gridded analysis by doing the following: (1) creating a non-divergent aproximation of the analyzed wind field; (2) constructing a pseudo-analysis of the non-divergent wind field; (3) subtracting the pseudo-analyzed divergence field from the original divergence field. Preliminary results suggest that this technique can reduce the variance of spurious divergence by more than a factor of two.

## 6. References

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