Contrasts in Objective Analysis Philosophy: Comments on "The Theoretical, Discrete, and Actual Response of the Barnes Objective Analysis Scheme for One- and Two-Dimensional Fields"

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Pauley and Wu's (1990, hereafter PW90) thorough analysis of the widely used objective analysis scheme developed by Barnes (1964, 1973) is, in my opinion, a significant contribution to understanding how the scheme responds to the analysis of discretely spaced data distributed in two dimensions. Because the PW90 paper should be frequently cited by students of objective analysis, I wish to clarify a reference to the derivation of response theory in Achtemeier (1987, 1989; hereafter A87, A89) that appears in PW90 because it could be misleading to readers. At the end of the second paragraph on page 1151 of PW90 there appears the following statement: "The response curve for $\gamma = 1$ is also included in Fig. 3 for comparison. This is the curve that results after one iteration of the Barnes (1964) scheme and is the value Achtemeier (1987, 1989) advocates as optimal, although he uses it in a three-pass version of the scheme."

The curve labeled $\gamma = 1$ that appears in PW90 Fig. 3 (PW90 Fig. 3 is reproduced in Fig. 1) is not the response curve derived by A87 or A89 for comparable objective analyses. The reason is that A87 used a fundamentally different approach to analysis with the Barnes method. I suspect the reason for PW90's misconception is that I failed to adequately describe my methodology in A87. Therefore, in the paragraphs that follow, I attempt to describe more clearly the differences between the approach of A87 and A89 and that of Barnes and others.

The Barnes method allows two degrees of freedom in the selection of weight function parameters, namely, $4k_0$ (λ_0 in PW90) and γ. There exist an infinite number of combinations of these two parameters that analysts can choose to do an objective analysis. (Many of these combinations, however, are not advised.) Barnes (1973) made the problem tractable by fixing $4k_0$ to produce a smooth initial pass and deriving the final response for each wavelength as a function of γ. Other investigators (Koch et al. 1983; Smith and Leslie 1984; Smith et al. 1986; PW90) followed the same approach (PW90 normalized by λ_0 effectively removing the degree of freedom).

A87 restored the two degrees of freedom in the Barnes method by making both $4k_0$ and γ variable. Then to make the problem tractable—and still allow for two degrees of freedom—A87 compared sets of analyses for which the final responses at a reference wavelength were always the same. (See Tables 1–4 and Fig. 2 of A87.) To keep the final responses at the reference wavelength equal to a constant, it was necessary to reduce $4k_0$ while increasing γ or to increase $4k_0$ while decreasing γ. (This approach contrasts with that of Barnes, PW90, and others who hold $4k_0$ constant while varying γ.)

A87 found that if optimal is defined as the combination of weight function parameters that best restore desired wavelengths and best filter undesired wavelengths, the optimal choice for the weight function parameter γ is 1. Then, once optimality for short but resolvable wavelengths had been determined, A87 removed a degree of freedom by specifying $\gamma = 1$. Therefore, A87 fixed γ and allowed $4k_0$ to vary, whereas Barnes and others removed the degree of freedom by fixing $4k_0$ and allowing γ to vary.

However, there was a trade-off when A87 was tested with regularly and irregularly spaced data. By using $\gamma = 1$, A87 had to reduce $4k_0$ to produce at the reference wavelength the same final response obtained by the two-pass Barnes method with smaller γ. This costs the analysis the benefit of the smooth initial pass of the two-pass method. A87 analyses with regularly and irregularly spaced samples of monochromatic waves, though showing significant improvement at shorter wavelengths, were slightly degraded for longer wavelengths. The disparities were small, ranging from 0.5% to 1.7% of the amplitude of the wave, and depended upon the irregularity of the data distribution.

A89 combined the best of the two-pass Barnes method with the best of A87 into a three-pass objective

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analysis. The three-pass method follows a very smooth initial pass with two passes with $\gamma = 1$ to optimize resolvable short wavelengths. A89 showed that the three-pass version indeed produces the desired improvements. In addition, there was found marked improvement in derivatives calculated from fields of data obtained by the three-pass version. PW90's reference, "although he uses it in a three-pass version of the scheme," is to this three-pass method.

Figure 3 of PW90 is reproduced in Fig. 1. Note that the same $4k_0$ was used to calculate each curve. Only γ varies. Figure 2 reproduces the $\gamma = 0.2$ and $\gamma = 0.4$ curves from Fig. 1 and overlays them with comparable response curves calculated from A89 with $\gamma = 1$ (dashed lines). Note that these curves are not the same as the $\gamma = 1$ curve produced by PW90 and attributed to A87 and A89. The PW90 and A89 curves are comparable at the reference wavelength, $\lambda = 2$, where the responses are equal. Elsewhere, the A89 analyses restore more (less) of the wavelengths greater (less) than the reference wavelength.

PW90 represents a significant step in understanding the "real world" response of the Barnes objective analysis method. For two reasons, I encourage Pauley and Wu to do a similar analysis of the three-pass method of A89. First, A89 selected a first-pass weight function parameter to make the first-pass response small at the reference wavelength. This selection was not guided by theoretical considerations but was done so that the results of A87 could be directly transferred into A89. For example, if the first-pass response is D_1 and the second-pass response is D_2, then the two-pass final response using A87 with $\gamma = 1$ is

$$D_{f2} = 1 - (1 - D_1)^2. \qquad (1)$$

Similarly, the final response for the three-pass method of A89 is

$$D_{f3} = 1 - (1 - D_0)(1 - D_1)^2. \qquad (2)$$

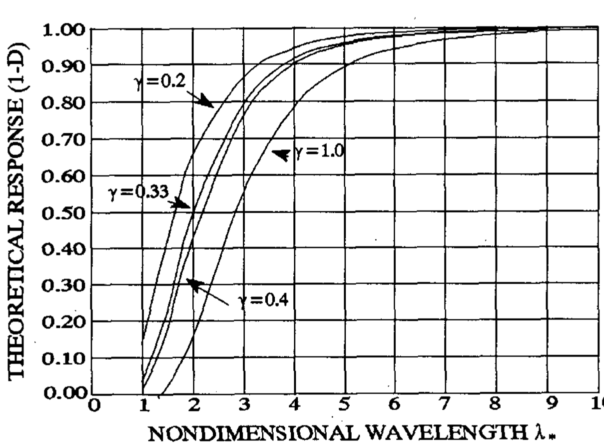

FIG. 1. The second-pass theoretical response R_t for 1D fields for the convergence parameter γ equal to 0.2, 0.33, 0.4, and 1.0 (reproduced from PW90, Fig. 3).

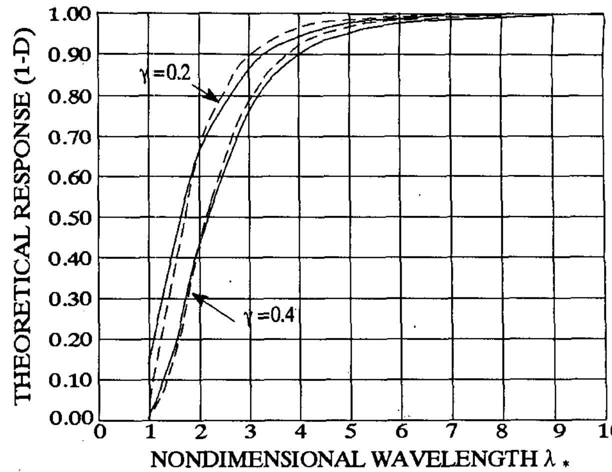

FIG. 2. Selected response curves from PW90 (solid lines) and comparable response curves for the three-pass method of A89 (dashed lines).

If the smooth initial pass, with response D_0, is large enough to restore long wavelengths yet small enough at the reference wavelength to be negligible relative to one, then the results of A87 may be directly transferred into A89. Still better analyses may be obtainable with weight function parameters set to produce nonnegligible first-pass response and the cumulative responses of the second and third passes reduced commensurately to yield the desired final response at the reference wavelength.

Second, although A89 verified the three-pass method with continuum response theory and confirmed it with analyses of real data, an analysis of A89 with PW90's methods would go far in showing how A89 responds to the analysis of discretely spaced data distributed in two dimensions.

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