A FORECAST WIND ERROR MODEL FOR USE WITH PSAS

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Abstract

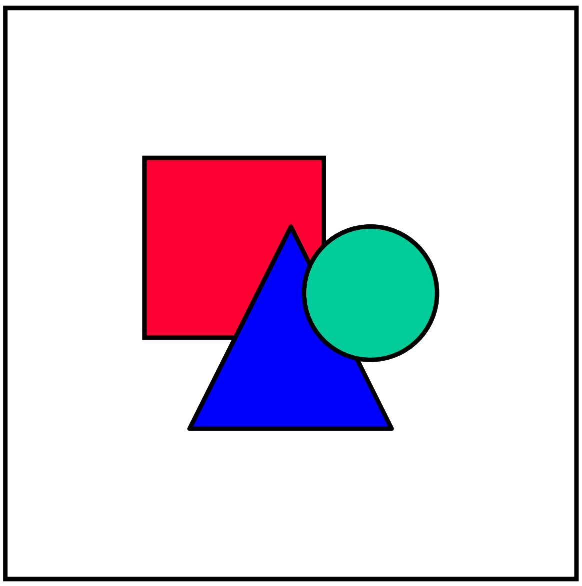
The PSAS forecast wind error covariance model, a component of the Eta based regional data assimilation system at CPTEC, is presented. A least-squares method is used to construct an empirical relation between height and wind errors. A maximum-likelihood approach is used to estimate the parameters of the model for uncoupled wind errors. The dependence of the uncoupled wind error covariance parameters on the height coupled wind error model is demonstrated.

Introduction

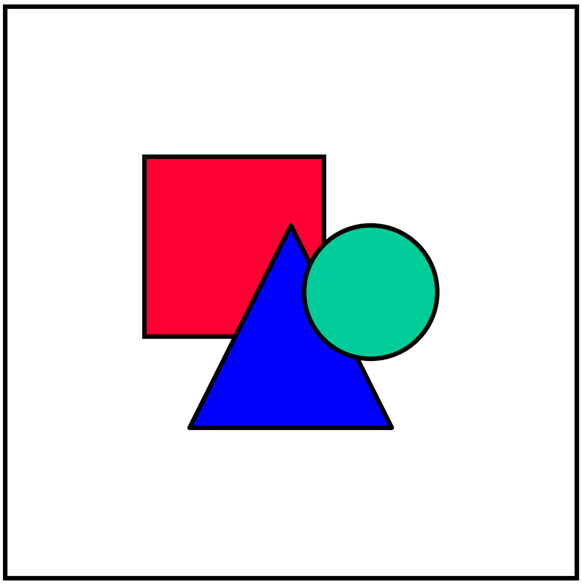
Modern data assimilation methods use information about forecast and observations errors to combine first-guess and observations so as to minimize analysis errors (Cohn, 1997). The forecast error covariance is impractical to calculate directly and must be approximated by models depending on a small number of adjustable parameters. Here the model for forecast wind errors used in the Physical-space Statistical Analysis System (PSAS) is presented. The parameters of the model are statically estimated using Eta model forecasts.

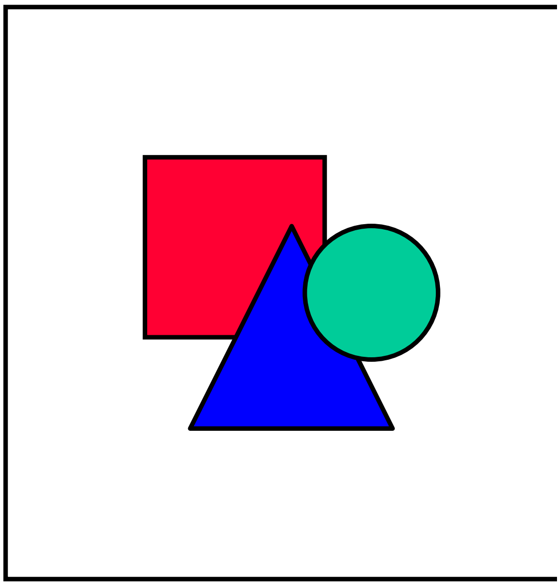
Wind forecast error model

The forecast wind errors are modeled in PSAS as the sum of a height-coupled component and a height de-coupled component (DAO, 1996). The height-coupled wind errors are modeled by assuming a linear relationship of the form



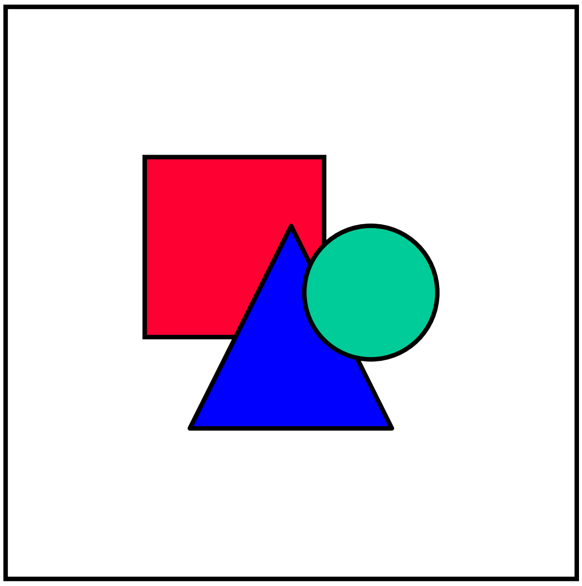
(1)

where  is a 2x2 matrix of wind-height coupling parameters; *x* and *y* are respectively the zonal and meridional coordinates. Uncoupled wind errors are modeled in terms of a streamfunction and a velocity potential by

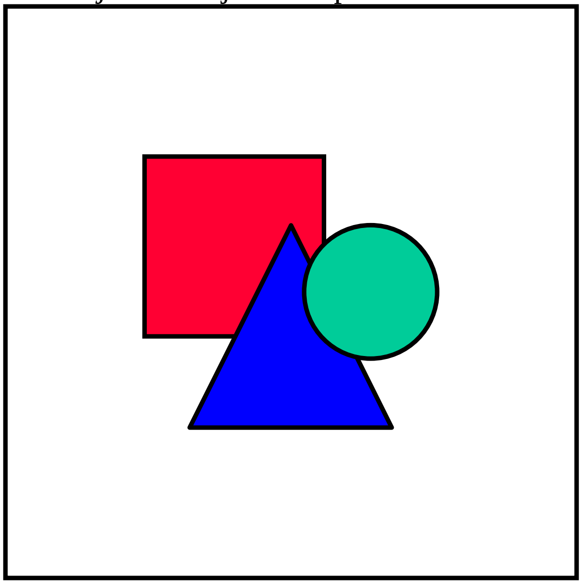
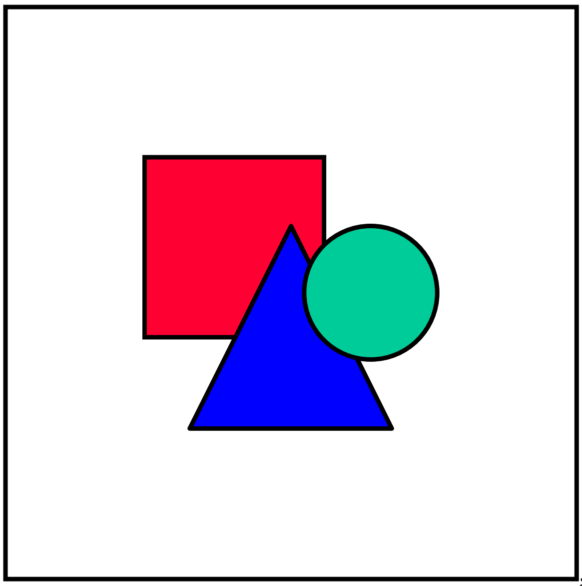
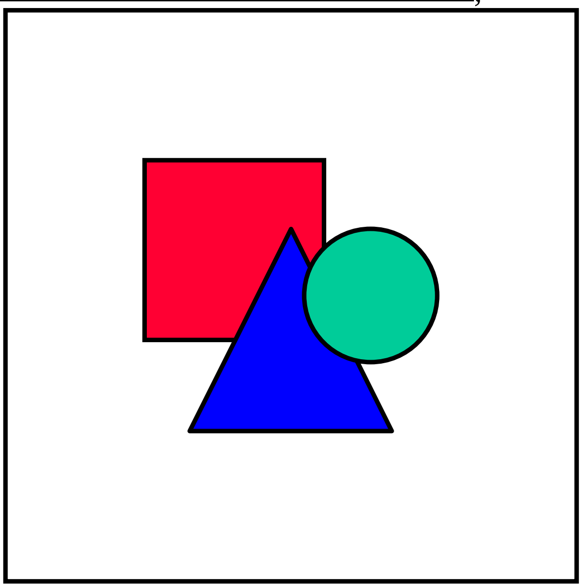


(2)

The covariances of the stream function and of the velocity potential are assumed to have the form



(3)

i and j are horizontal location indices and m and n are vertical level indices; the correlation function depends on the horizontal distance r_{ij} between locations i and j. The adjustable parameters are the horizontal variances  and , the vertical correlations  and the horizontal correlation lengths $L^{(m)}$ and $L^{(n)}$.

Data

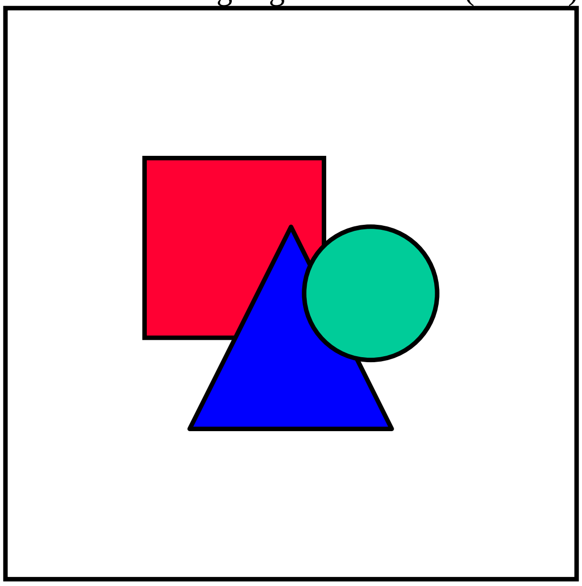
The data consists of differences of 24-hour and 48-hour Eta forecasts from the period June-July-August 1997, interpolated onto a 0.4x0.4 lat-lon grid with vertical pressure levels at 200, 300, 500, 700, 850 and 1000 mb. For the estimation of wind-height coupling coefficients, 75 days of gridded data east of -65 was used. The maximum-likelihood estimation used data from 64 locations per level with longitudes (-60.0, -57.2, -54.4, -51.6, -48.8, -46.0, -43.2, -40.4) and latitudes (-37.0, -34.2, -31.4, -28.6, -25.8, -23.0, -20.2, -17.4).

Table 1: Wind/height coupling coefficients.

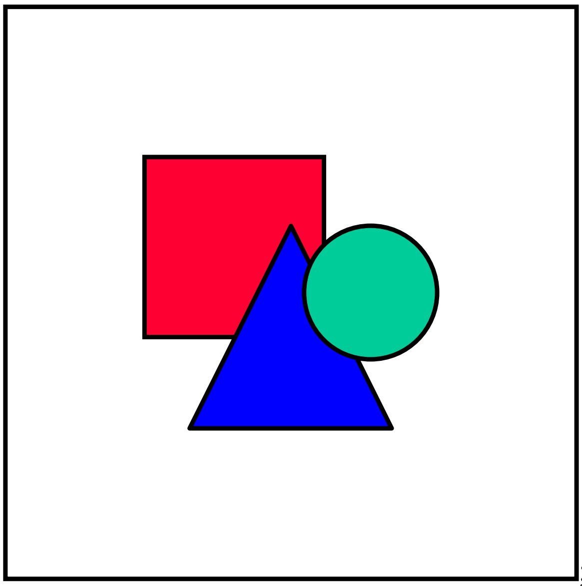
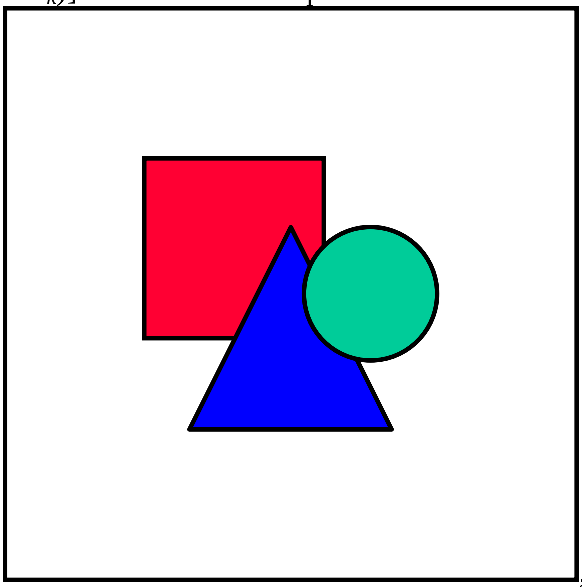
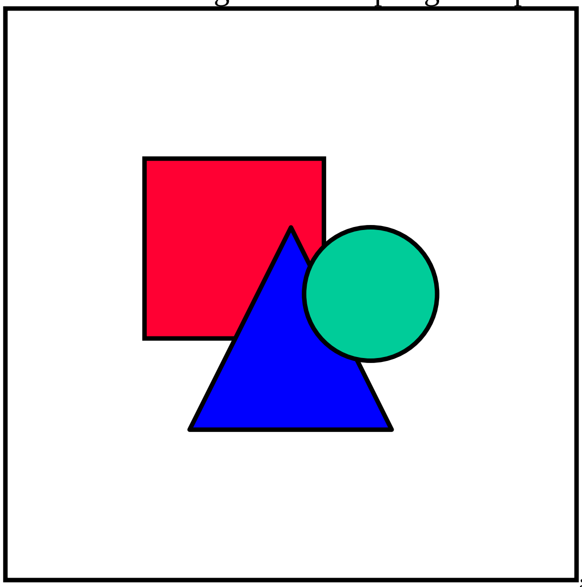
level	c_0	c_1	c_2
200 mb	0.6630	0.6988	0.9187
300 mb	0.4554	0.5219	0.4302
500 mb	0.2162	0.4176	0.4482
700 mb	0.0930	0.3793	0.4933
850 mb	0.0630	0.4483	0.2980
1000 mb	0.1252	0.5096	0.3203

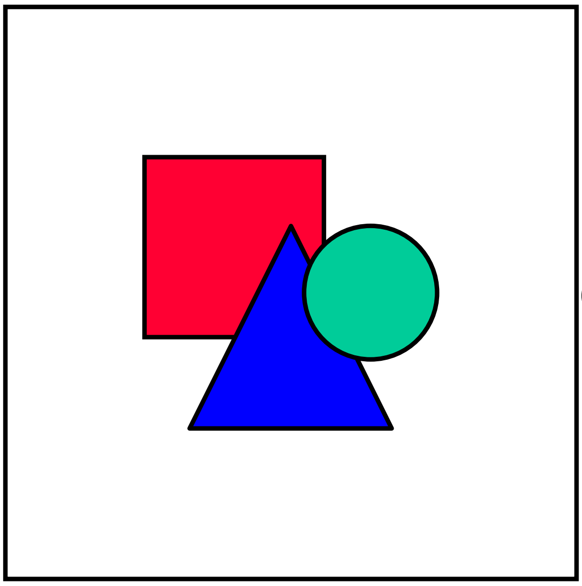
Estimation of wind-height coupling parameters

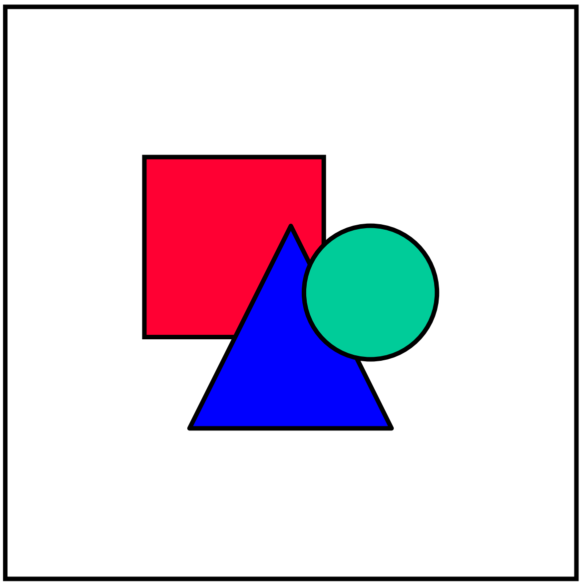
The wind-height coupling parameters are estimating by applying least-squares to the bias-removed time-series data. The coupling parameters are assumed to depend only on the latitude and the pressure level. For a given latitude and pressure level, the design matrix G of height gradients is a (mn x 2)

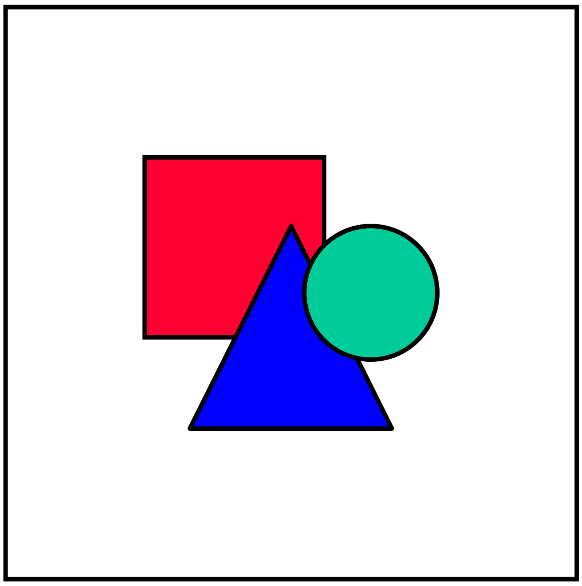


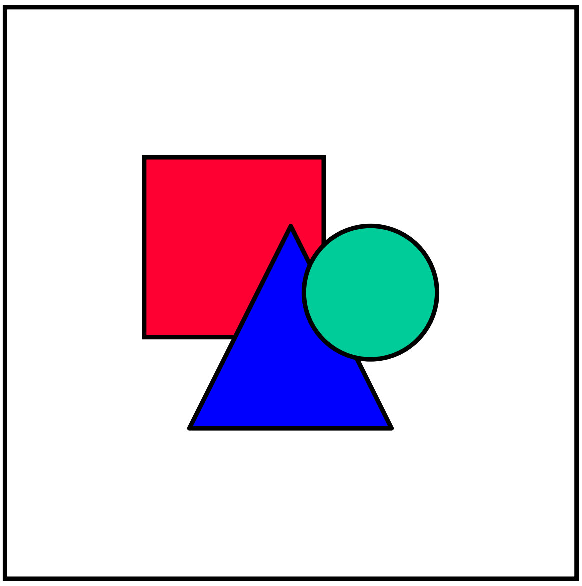
matrix with rows $(h_x(x_i,t_k)$, $h_y(x_i,t_k)]$,

, ; *m* is number of grid-points in the zonal direction and *n* the number of time intervals. Likewise, the wind data matrix *w* is a *(mn x* 2*)* matrix with rows [$u(x_i,t_k)$, $v(x_i, t_k)$]. The equation for the wind-height coupling parameter matrix , , is over determined. The least-squares estimate is

 (4)

The characterization of the zonal dependence of the matrix  is further simplifies with the use of the following parameterization

 (5)

where  is the latitude and

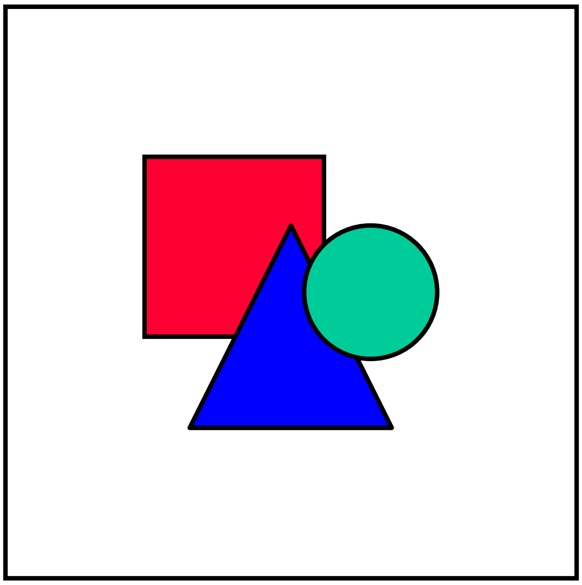
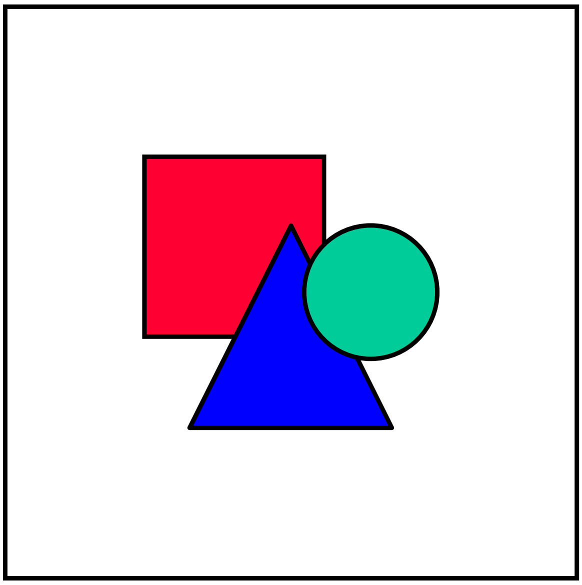
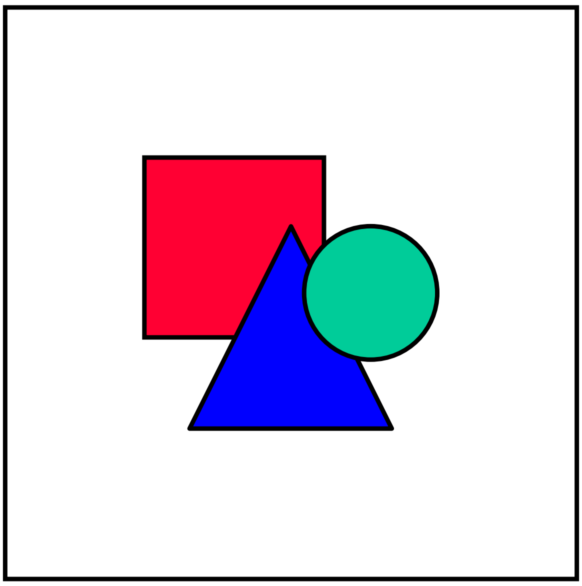
 (6)

Figure 1 shows the least-squares fitted values of  using all 75 days of data, the first 38 days, the last 38 days and the parameterization (5) using c_i given in Table 1.

In this model the residual  is accounted for by the uncoupled part of the forecast wind error. Figure 2 shows the kinetic energy ($u^2/2+v^2/2$) of the residual as a function of location. In principle, the uncoupled wind errors depend on latitude but it appears not unreasonable to use the latitude independent formulation of (3).

Estimation of covariance parameters

The parameters that appear in the uncoupled wind error covariance model (3) are estimated from the data using the maximum-likelihood method described in Dee & da Silva (1998) and are shown in Table 2. The uncoupled wind error parameters depend on the height coupled part of the wind error model. Table 3 shows the results of estimating the uncoupled wind error parameters using level independent parameters from (DAO, 1996). The largest difference is seen at the 300 mb level.

Table 2: Unbalanced wind error covariance model parameters using level dependent coefficients c_i.

	200 mb	300 mb	500 mb	700 mb	850 mb	1000 mb
	79.1527	44.6658	29.4452	23.7813	16.7111	26.4628
	0.9492	0.6265	0.5912	0.6175	0.5134	0.5733

	32.9882	27.1685	12.1226	9.9196	24.2803	31.9592
	0.7062	0.7623	0.5358	0.3960	0.7581	0.8219

Table 3: As in Table 2 but using level independent c_i.

	200 mb	300 mb	500 mb	700 mb	850 mb	1000 mb
	53.0862	31.9758	22.4544	21.1386	17.4539	23.4015

	0.8378	0.5150	0.5624	0.5827	0.5080	0.5473
	37.2173	62.8714	12.9767	9.3782	27.1557	39.7342
	0.8319	1.3161	0.5508	0.3883	0.7535	0.9128

Summary

Here the model for forecast wind errors used in the Physical-space Statistical Analysis System (PSAS) was presented. Wind errors are modeled as the sum of a height-coupled component and a height uncoupled component. The latitude and pressure level dependent height-wind coupling parameters are estimated using least-square analysis. The parameters in the height uncoupled wind error modal are estimated using a maximum-likelihood method.

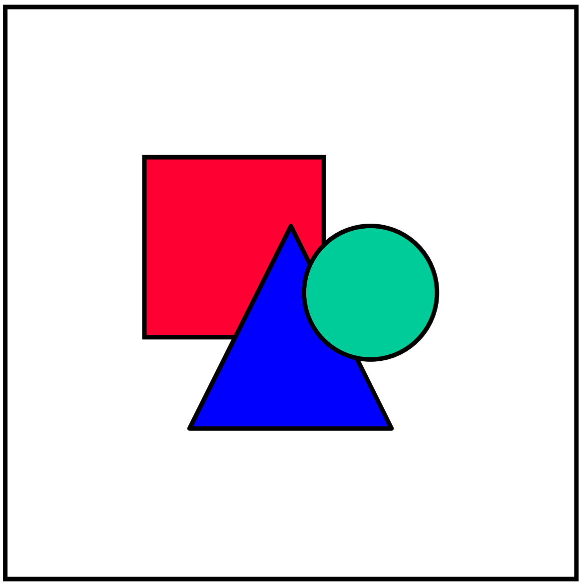
Acknowledgment. This work was supported by Conselho Nacional de Desenvolvimento Científico e Tecnológico Grant 381737/97-73.

References

Cohn, S. E. (1997). An Introduction to estimation theory, *J. Meteor. Soc. Japan* **75**(1B), 257-288.

DAO (1996), Algorithm Theoretical Basis Document Version 1.01, Technical report, Data Assimilation Office, NASA's Goddard Space Flight Center, Greenbelt, MD.

Dee, D. P. & da Silva, A. M. (1998). Maximum-likelihood estimation of forecast and observation error covariance parameters. Part I: Methodology., *Mon. Wea. Rev.* .



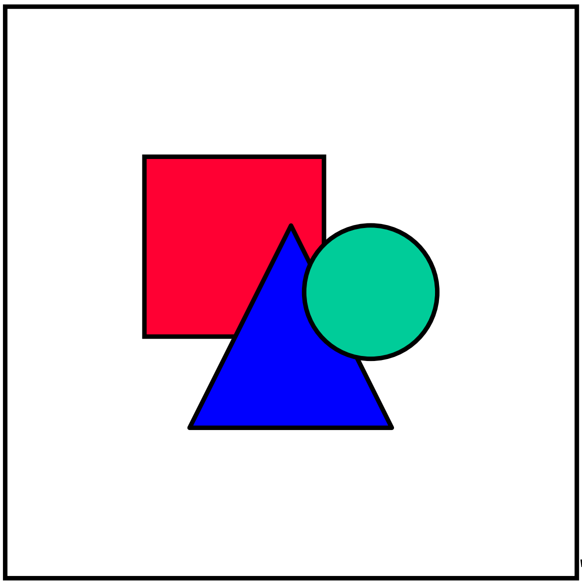


Figure 1: The least-squares fitted 's using 75 days of data (red), using the first 38 days (blue), and using the last 38 days (green). The c_i parameterization fit (dashed cyan).

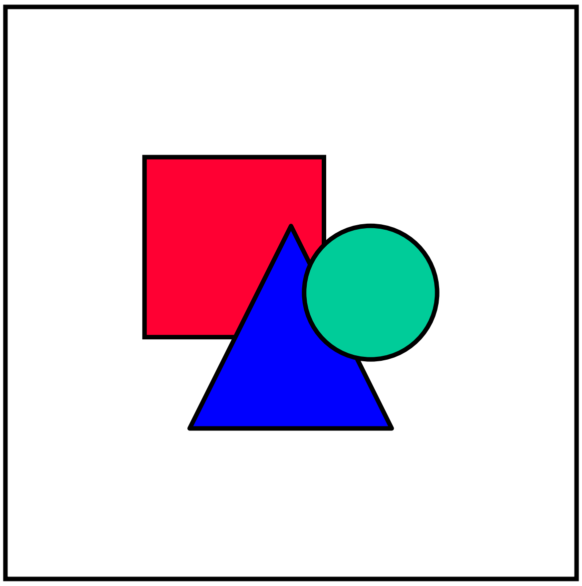


Figure 2: Contours plots of the bias-removed residual energy and its zonal average for the (a) 200 mb (b) 300 mb (c) 500 mb, (d) 700 mb, (e) 850 mb and (f) 1000 mb levels.