Gaussian process (GP) models have become the de facto choice for response surface modeling of computer simulation data. The covariance functions that are most often used for this purpose – Gaussian, power exponential, and Matérn – are localized in the sense that the covariance at two input locations decays to zero as the locations move further apart. We contend that such covariance models are inherently poor choices for most real physical systems because they imply a what-goes-up-must-come-down GP behavior and tend to result in bumpy fitted response surfaces, whereas most physical systems may be better represented by a GP model that exhibits what-goes-up-may-stay-up behavior. To achieve the latter behavior, we propose a class of covariance models that can be viewed as incorporating an integrator into any standard stationary GP model, analogous to the integrator in an ARIMA time series model. More specifically, in the white noise integral representation of a fractional Brownian field (FBF), we replace the white noise by any stationary GP model and refer to the result as a Brownian-integrated GP. We show that this generalization inherits the desirable what-goes-up-may-stay-up behavior of FBFs without inheriting the undesirable, overly rough behavior that makes FBFs unsuitable for most deterministic response surfaces. We also discuss fundamental differences between Brownian-integrated covariance models and their standard stationary counterparts, such as sigmoidal versus localized basis function representations. Remarkably, for every real physical system that we have considered so far, the Brownian-integrated GP model performed better than the standard GP model.

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