

GlaDS simulation ensemble

Ensemble design: $\mathbf{X}$

- Training: 512 x Sobol' sequence
- Test: 100 x Latin hypercube
- Normalize log-parameters:
 $\log([k_s, k_c, h_b, r_b, A, l_c, \omega, e_v])$

GlaDS: $\mathbf{Y}$

Inputs:

- Synthetic bed, surface topography
- KAN_L air temperature + temperature-index melt model
- 60 random moulines

Outputs:

- Flotation fraction f_w
- Scalar characteristics $f_Q, \log T_s, L_c$

(ISSM v4.24; Larour et al., 2012)

GlaDS
ensemble

Principal
components

Emulator fitting

Model
selection

sensitivity
indices

Principal components

Compute principal components and truncated basis

- Standardize simulation outputs $\mathbf{Y}$
- Randomized low-rank singular-value decomposition (Halko et al., 2011)

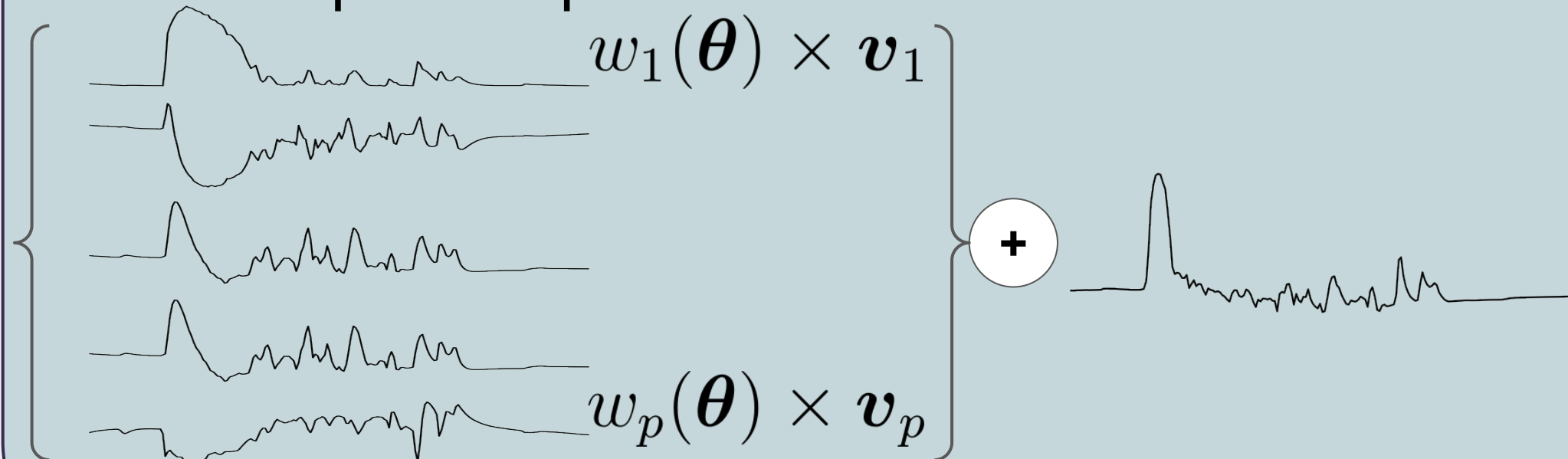
$$\mathbf{Y} \approx \sum_{j=1}^p w_{ij} \mathbf{v}_j$$

Emulator fitting

Sample GP hyperparameters θ using Metropolis-Hastings MCMC

Gaussian process emulator

Principal components



Record, update θ
Repeat 5000x

Likelihood
 $p(\theta|\mathbf{Y}) \propto p(\mathbf{Y}|\theta)p(\theta)$

Prior distribution
 $p(\theta)$

(SEPIA v1.1; Gattiker et al., 2020)

Model selection and evaluation

For each test parameter vector:

- Repeat for $i = [1, 2, \dots, 512]$:
 - Sample hyperparameters θ_i
 - Draw a GP realization
 - Sample error ϵ_i
- Compute prediction mean, percentiles
- Repeat for $p = [1, 2, \dots, 11]$ PCs
- Repeat for subsets of $m = [16, 32, \dots, 512]$ training simulations

Sensitivity indices

Estimate sensitivity indices:

First-order: $S_i = \frac{\text{Var}(\mathbb{E}_{\mathbf{X}_{\sim i}}(\mathbf{Y}|\mathbf{X}_i))}{\text{Var}(\mathbf{Y})},$

Total sensitivity: $S_{T_i} = 1 - \frac{\text{Var}(\mathbb{E}(\mathbf{Y}|\mathbf{X}_{\sim i}))}{\text{Var}(\mathbf{Y})},$