

An Active Subspace Study of Offshore Turbine Fatigue with FAST

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activesubspaces.org

Joint with:

Peter Graf (NREL)

Adam Short, Andrew Davey, &
Andrew Glaws (School of Mines)



WARNING: These slides are meant to complement the oral presentation. Use out of context at your own risk.

**There are more applications
than I have time for.**

ACTIVE COLLABORATIONS

- High-fidelity scramjet safety (Stanford PSAAP Center)
- Photovoltaic solar cell modeling (Mark Campanelli, NREL)
- Aerospace shape optimization (Juan Alonso, Stanford)
- Combustion stability analysis (Franck Nicoud, University Montpellier 2)
- Evapotranspiration in hydrology (Reed Maxwell, School of Mines)
- In-situ combustion reservoir simulation (Margot Gerritsen, Stanford)
- Combustion LES calibration (Guilhem Lacaze, Mohammad Khalil, SNL)
- Atmospheric re-entry (Nagi Mansour, NASA Ames; Thierry Magin, VKI)
- Subsurface sensitivity and inversion (Reed Maxwell, School of Mines)
- **Wind turbine modeling (Peter Graf, NREL)**

(And I'm open to others that might make me rich, famous, and/or **tenured**.)

$$f(\mathbf{x})$$

Doing things in high dimensions is hard, in general.

APPROXIMATION

$$\tilde{f}(\mathbf{x}) \approx f(\mathbf{x})$$

OPTIMIZATION

$$\underset{\mathbf{x}}{\text{minimize}} \quad f(\mathbf{x})$$

INTEGRATION

$$\int f(\mathbf{x}) \rho d\mathbf{x}$$

INVERSION

$$\mathbf{x} = f^{-1}(\mathbf{y})$$

You must first **discover** and then **exploit** some low-dimensional structure to make these problems tractable.

FAST-calculated turbine component fatigue is one such function.

X

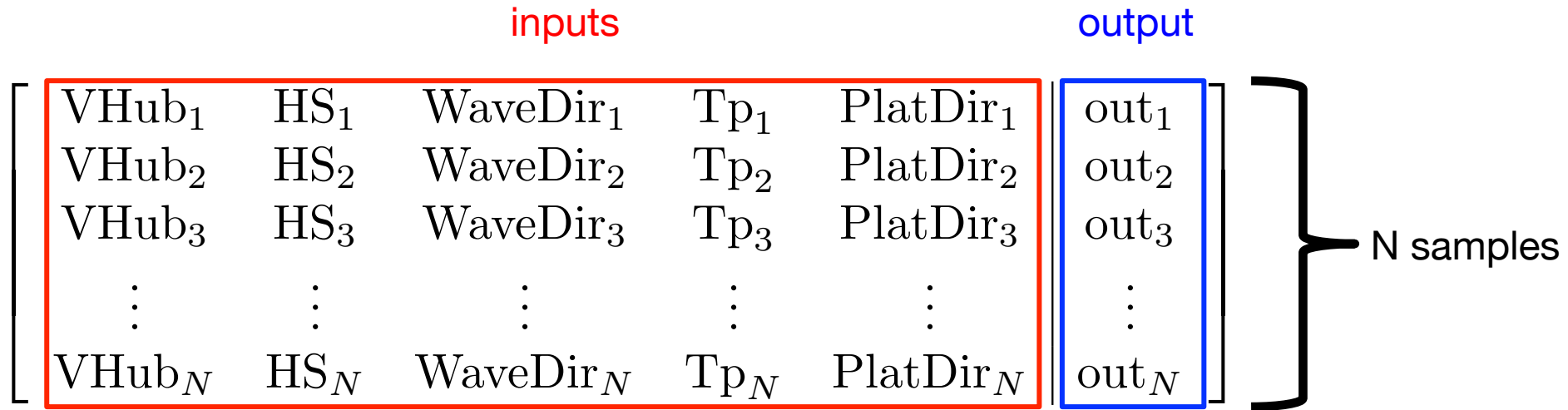
Input	Description	Distribution
V_{hub}	wind speed	Weibull
θ_w	wave direction	von Mises conditioned on V_{hub}
H_s	wave height	Gamma conditioned on V_{hub} and θ_w
T_p	wave period	Gamma conditioned on V_{hub} and H_s
θ_p	wind-pltf. direction	von Mises conditioned on V_{hub}

$f(\mathbf{x})$

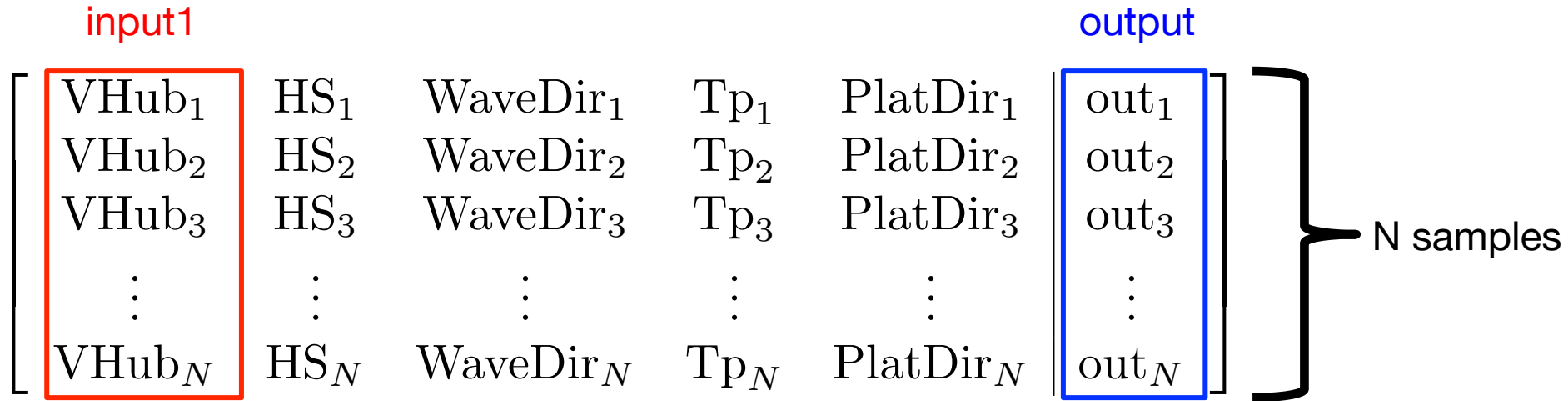
Group	Description	# of Outputs
Anchor	Tension of 3 anchor cables	6
Root	Blade moments in and out of plane at blade root	4
Tower Base	The roll and pitching moments of the tower base	4

Peter A. Graf, Gordon Stewart, Matthew Lackner, Katherine Dykes, and Paul Veers.
High throughput computation and the applicability of Monte Carlo integration in fatigue load estimation of floating offshore wind turbines. Submitted to Wind Energy (2014)

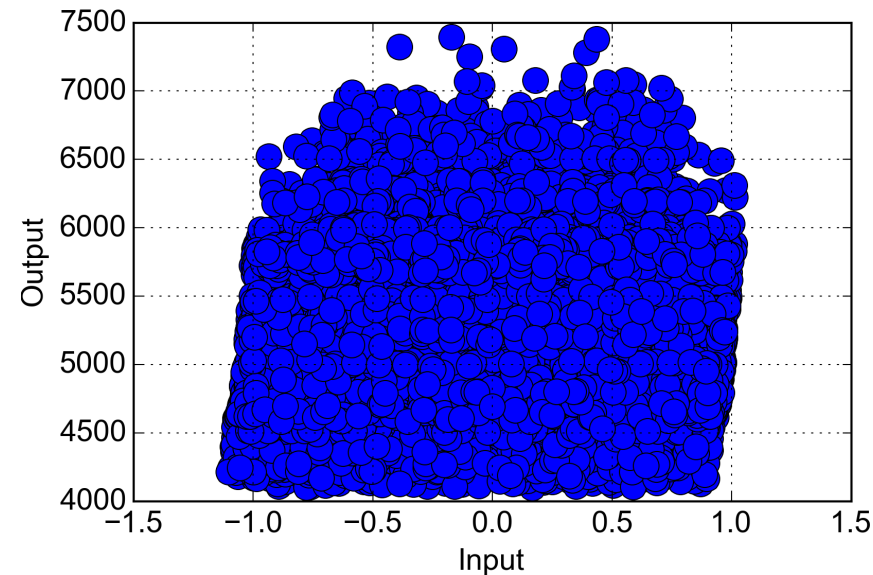
How do you plot a function of five variables?



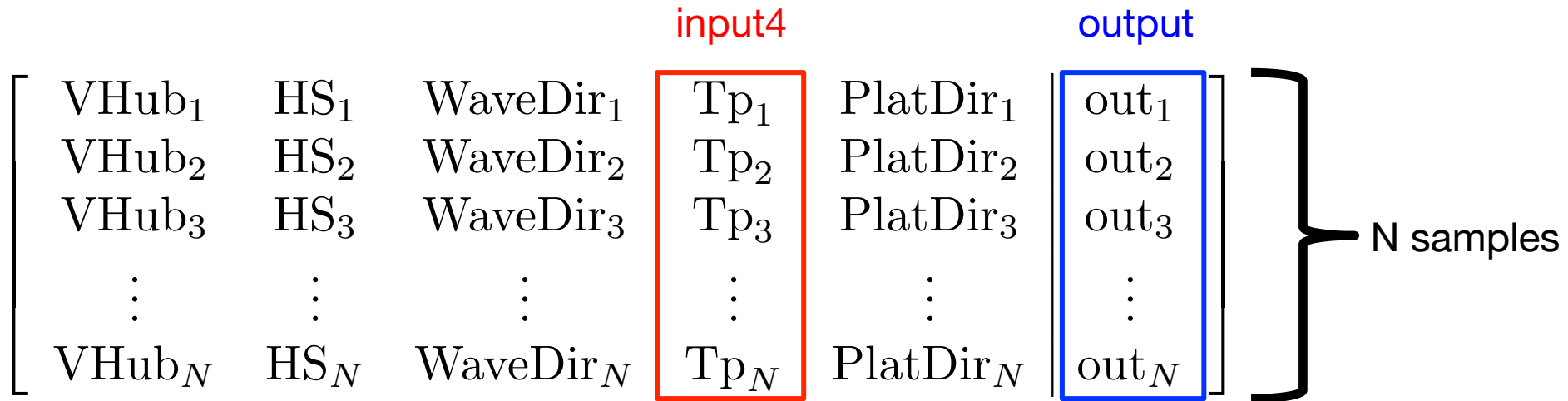
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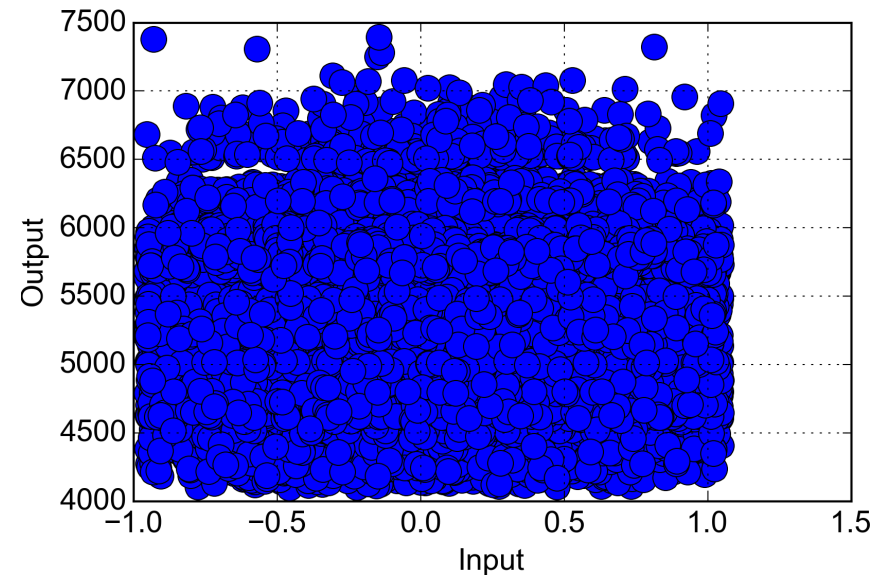
(1) Univariate scatter plots



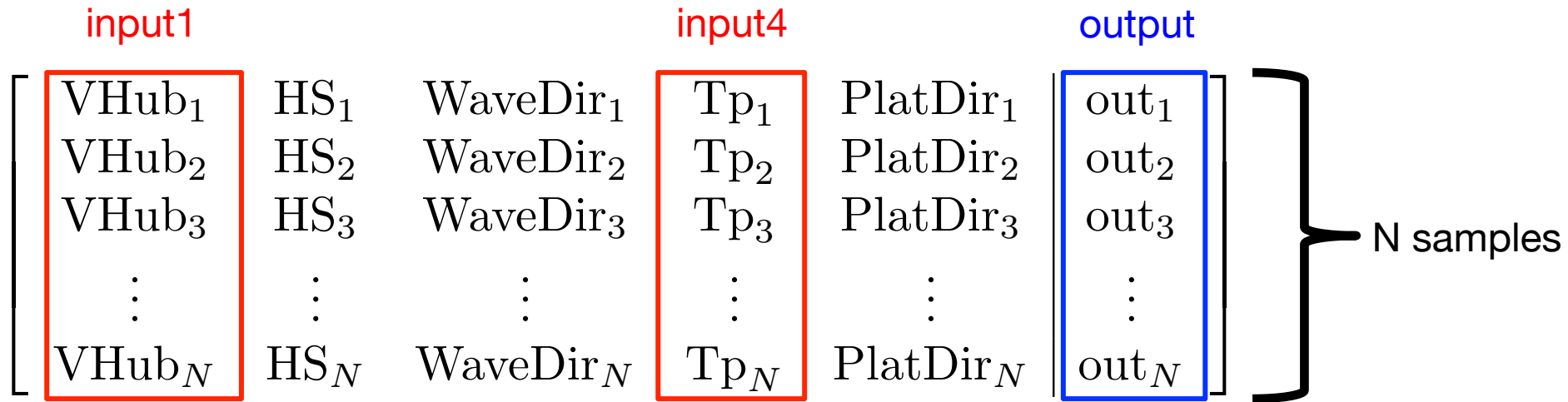
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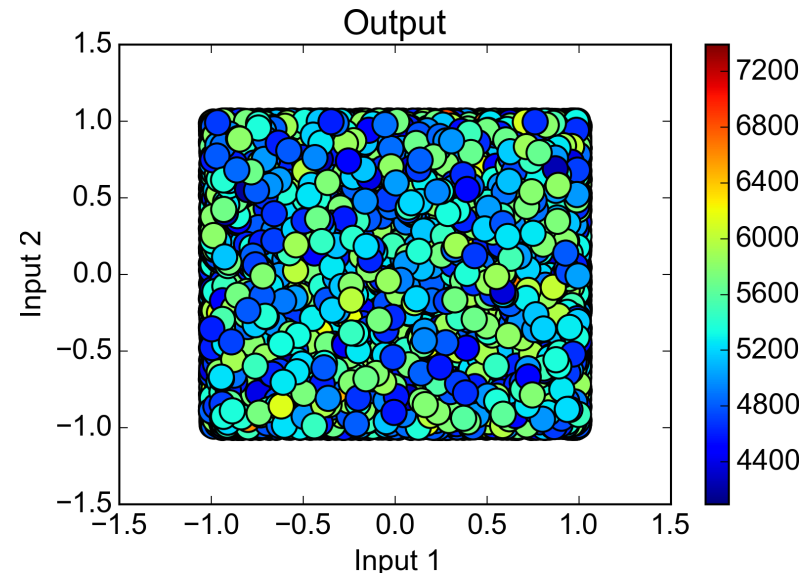
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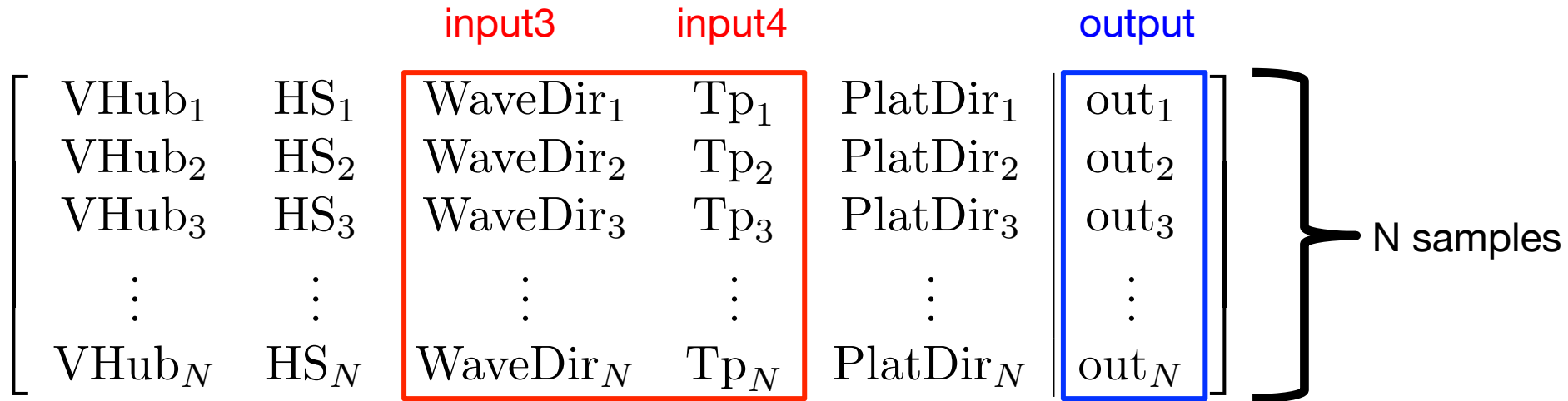
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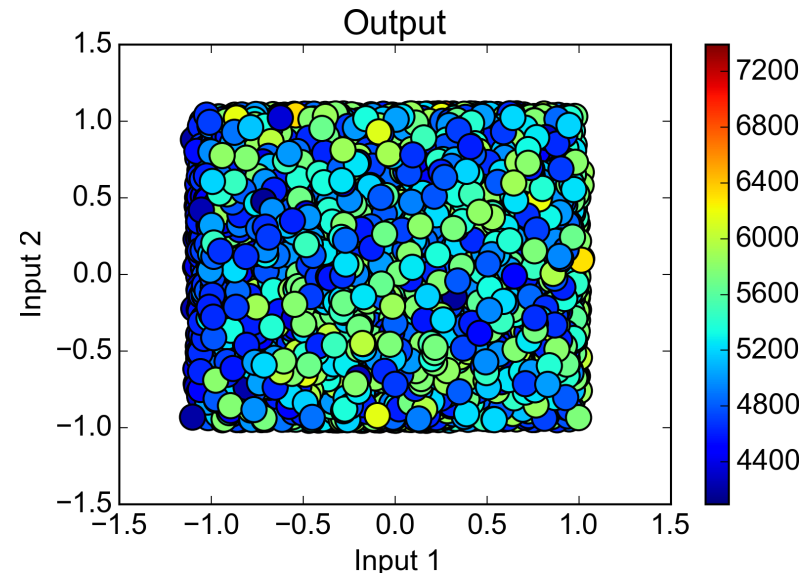
- (1) Univariate scatter plots
- (2) Bivariate scatter plots



How do you plot a function of five variables?



- (1) Univariate scatter plots
- (2) Bivariate scatter plots



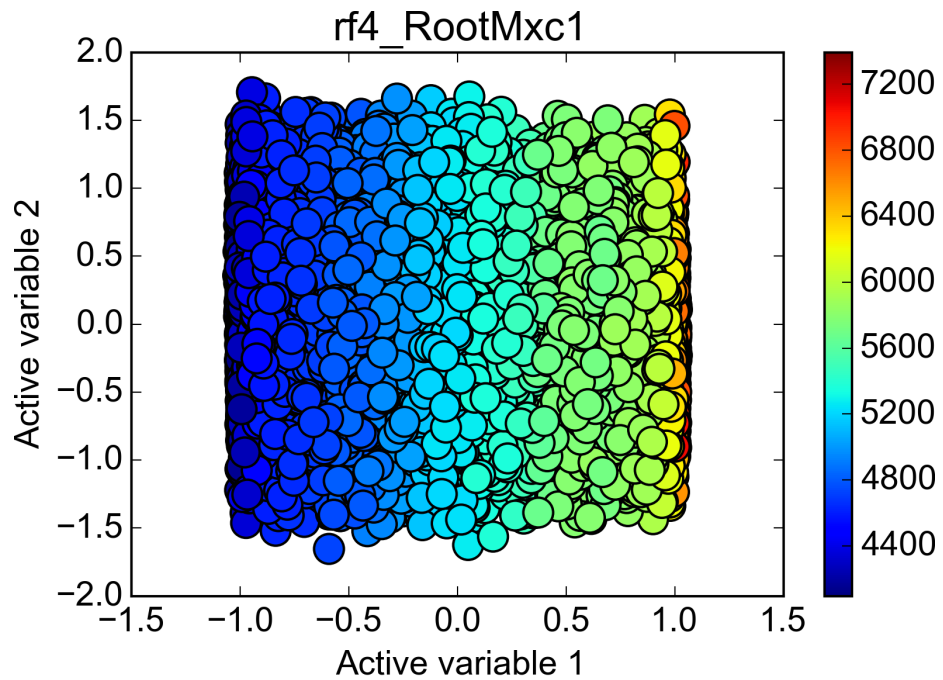
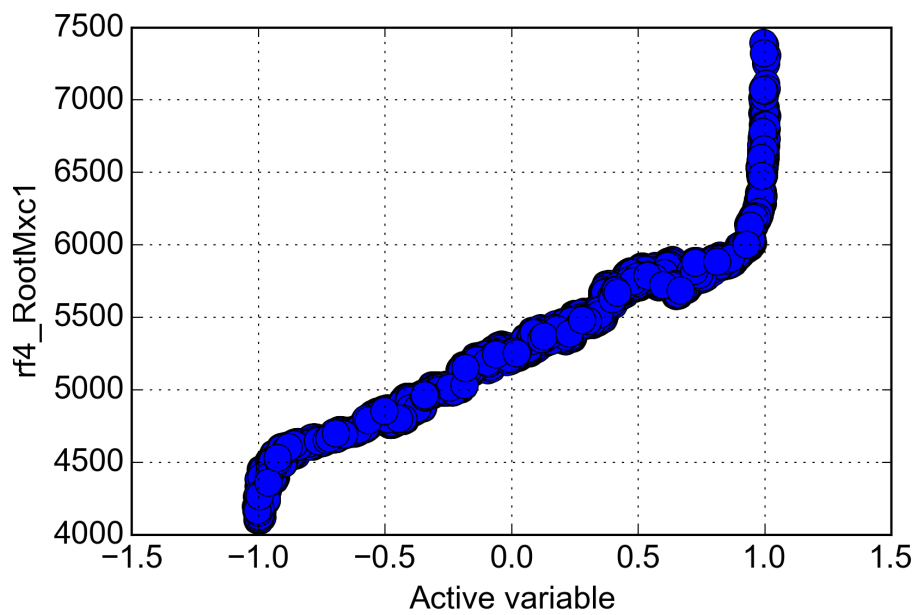
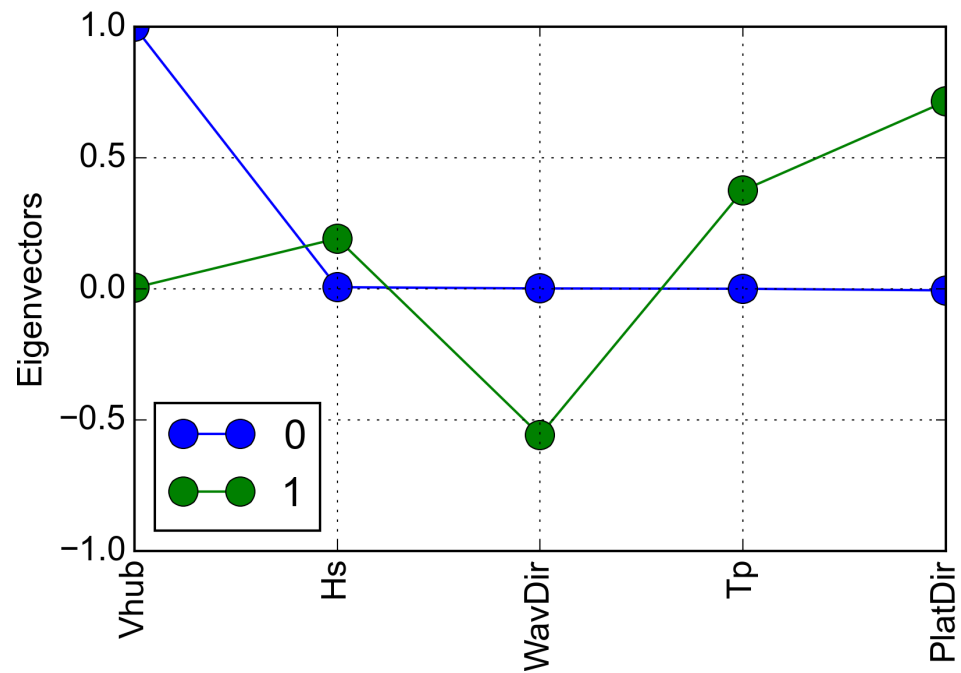
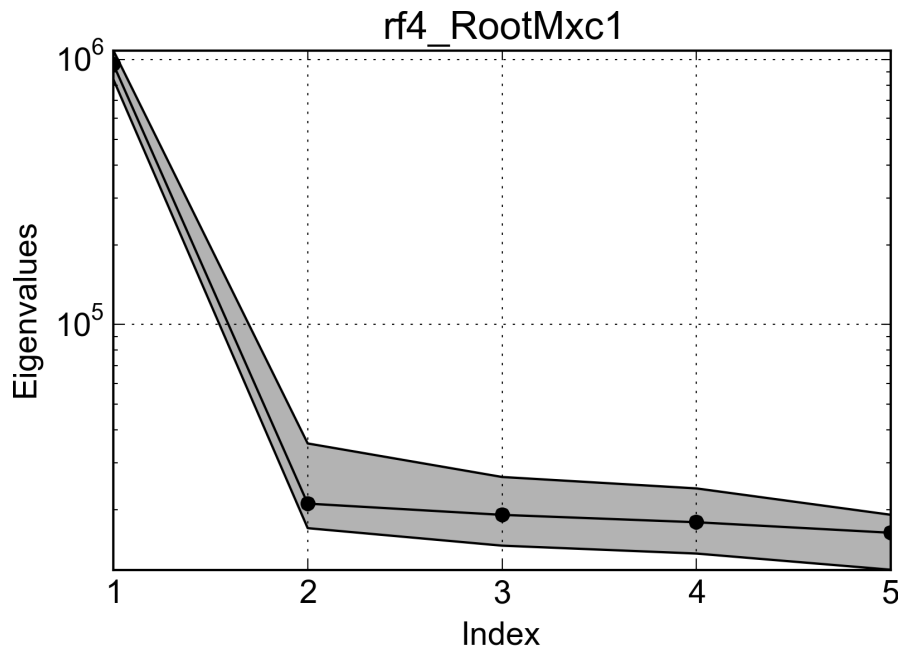
How do you plot a function of five variables?

$$w1*input1 + w2*input2 + \dots + w5*input5$$

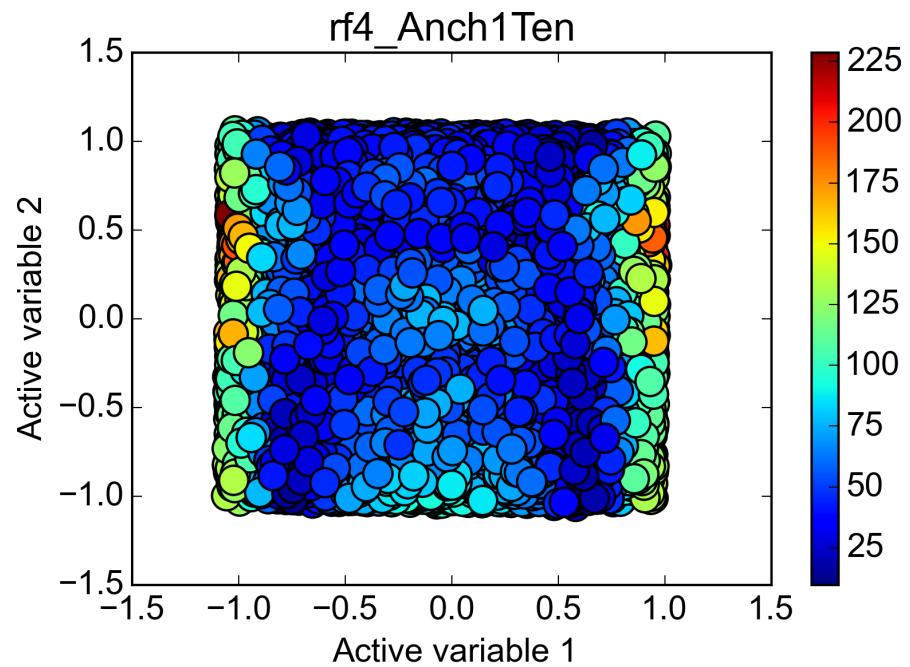
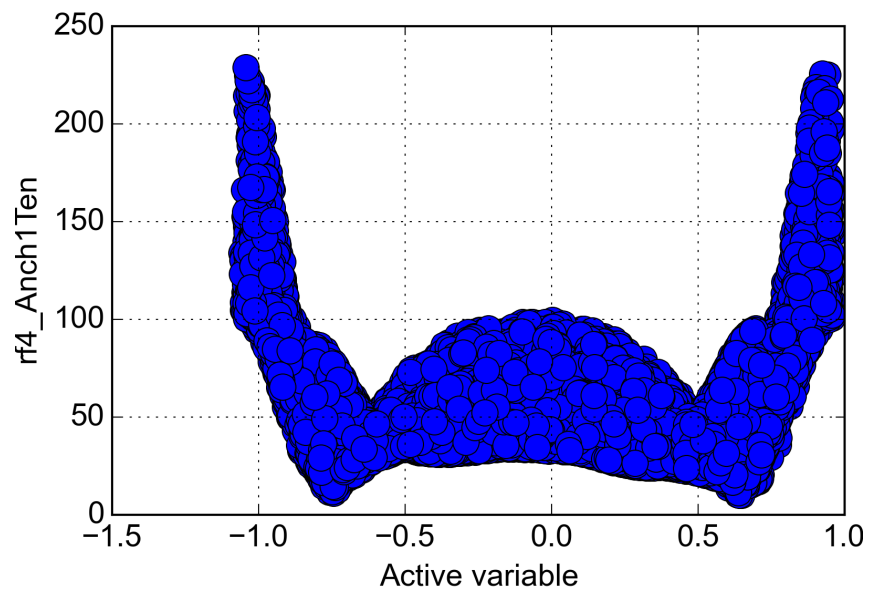
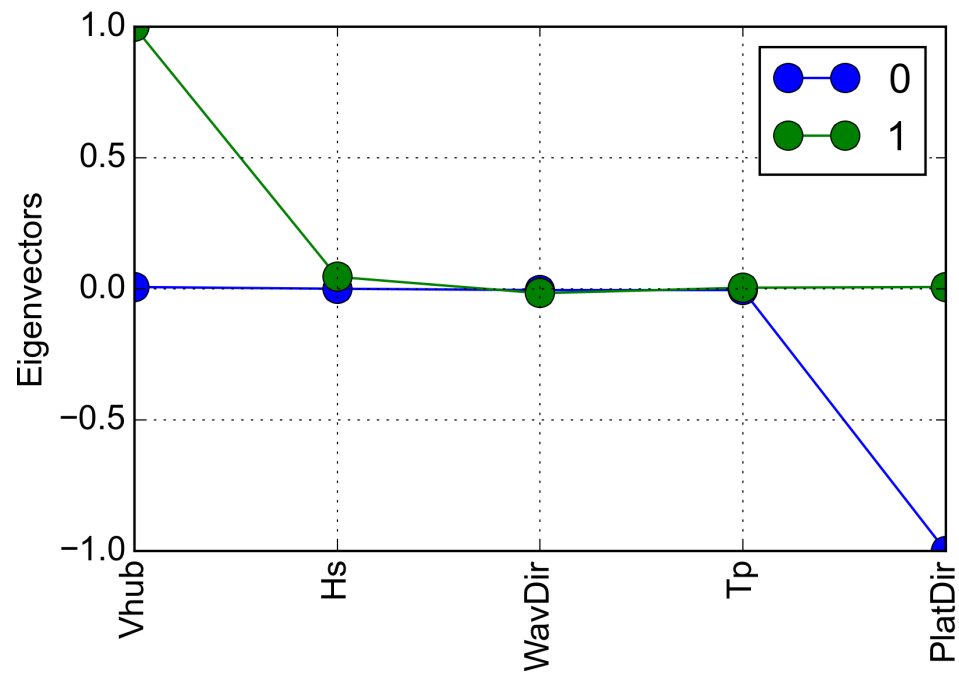
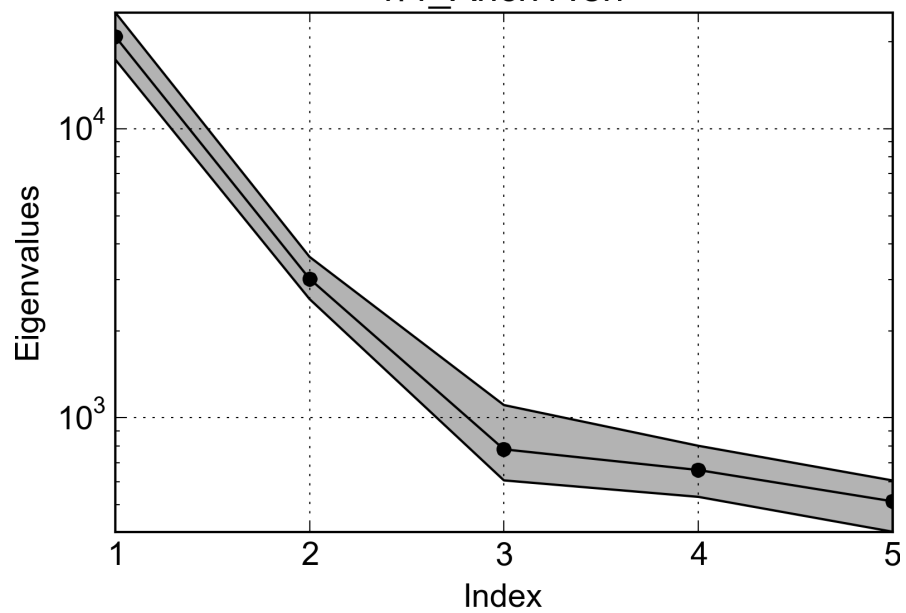
output

VHub ₁	HS ₁	WaveDir ₁	Tp ₁	PlatDir ₁	out ₁	} N samples
VHub ₂	HS ₂	WaveDir ₂	Tp ₂	PlatDir ₂	out ₂	
VHub ₃	HS ₃	WaveDir ₃	Tp ₃	PlatDir ₃	out ₃	
⋮	⋮	⋮	⋮	⋮	⋮	
VHub _N	HS _N	WaveDir _N	Tp _N	PlatDir _N	out _N	

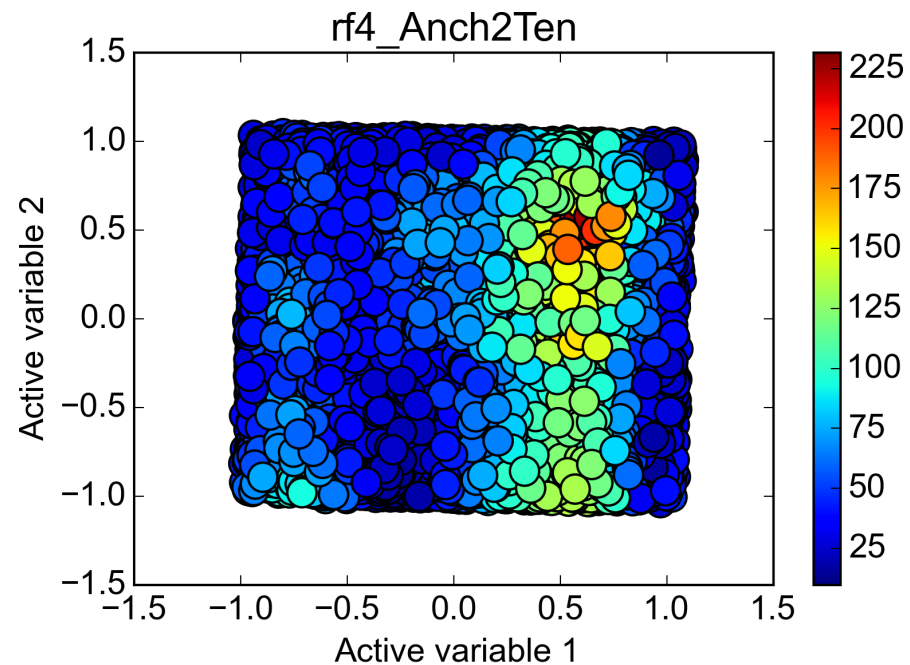
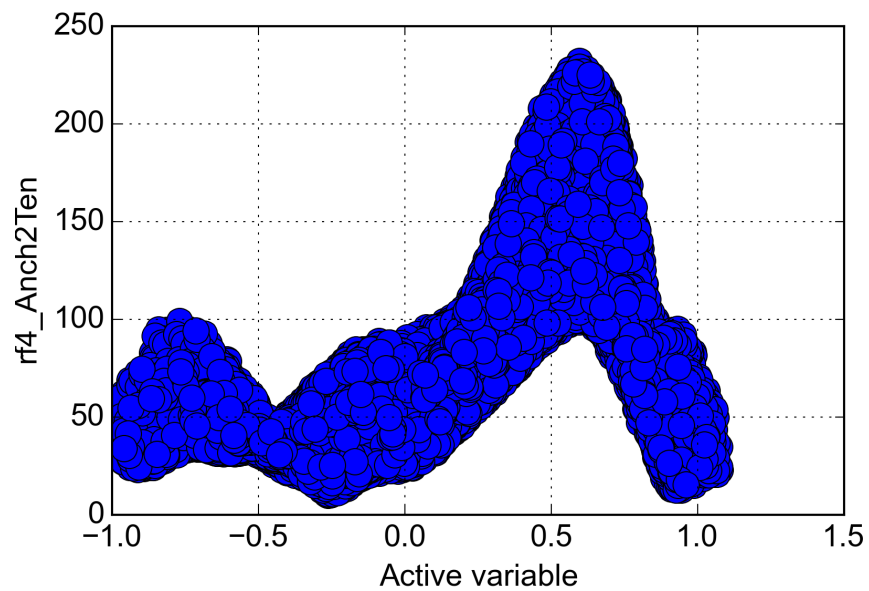
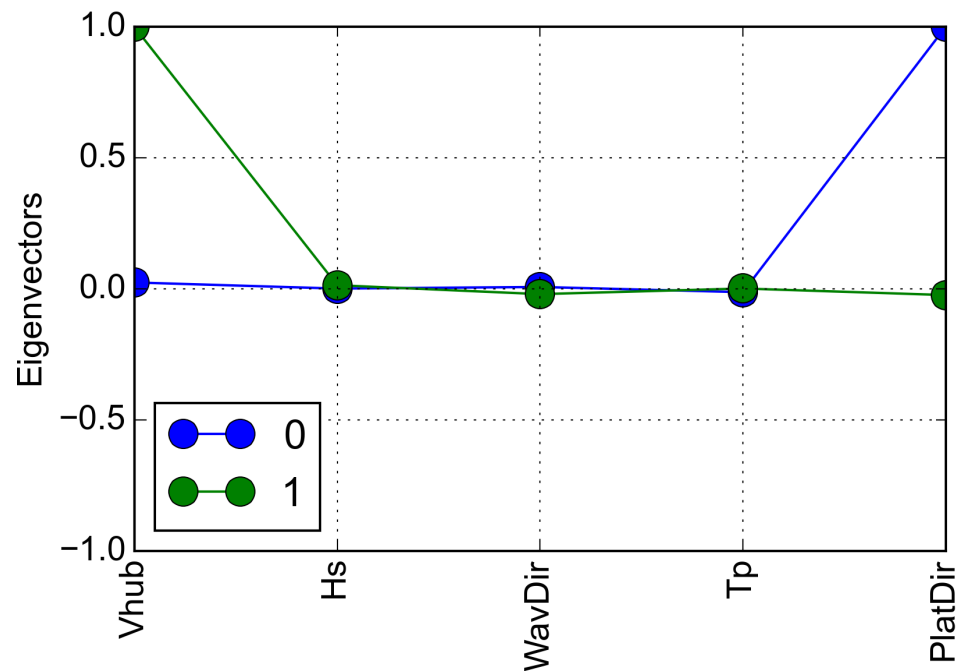
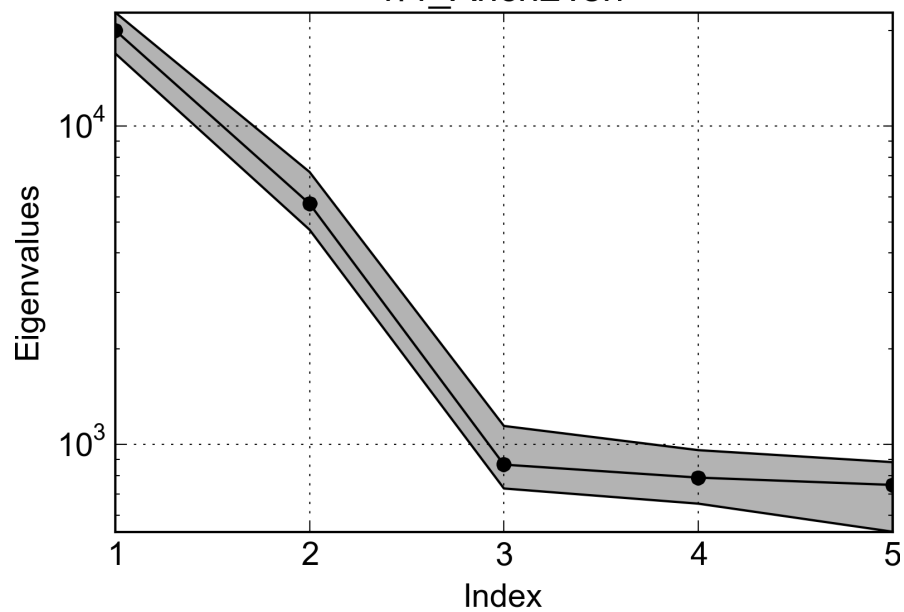
- (1) Univariate scatter plots
- (2) Bivariate scatter plots
- (3) Scatter plots with linear combinations



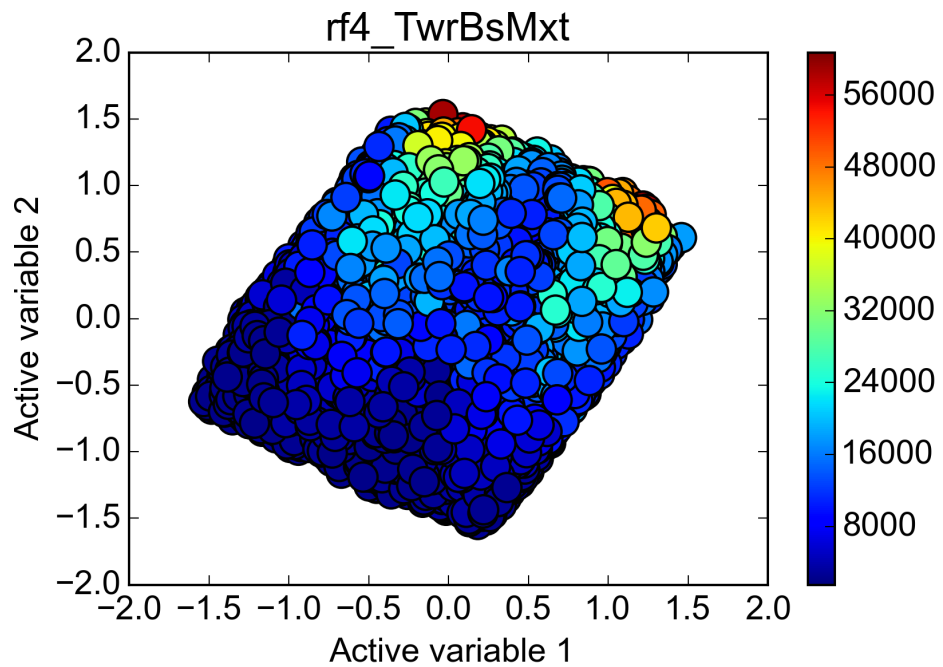
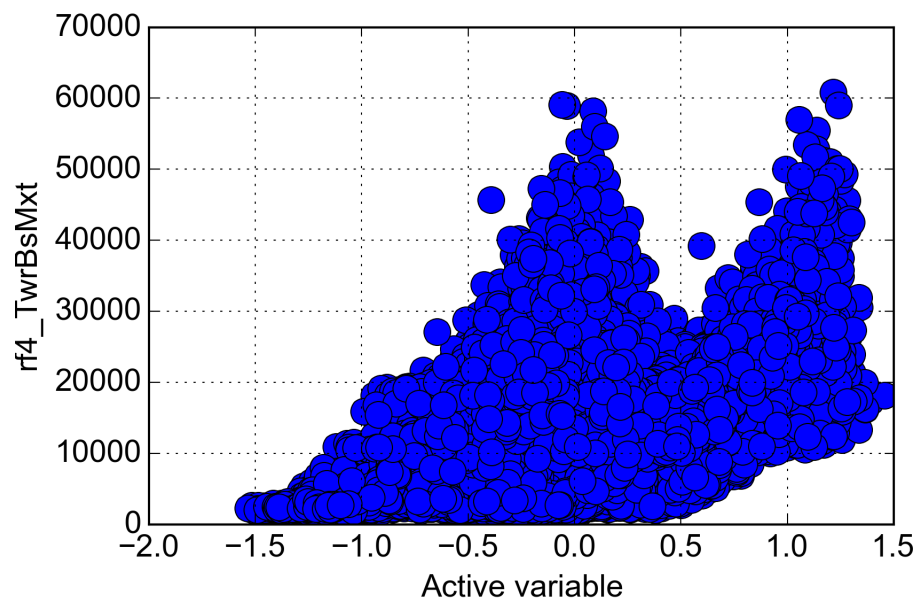
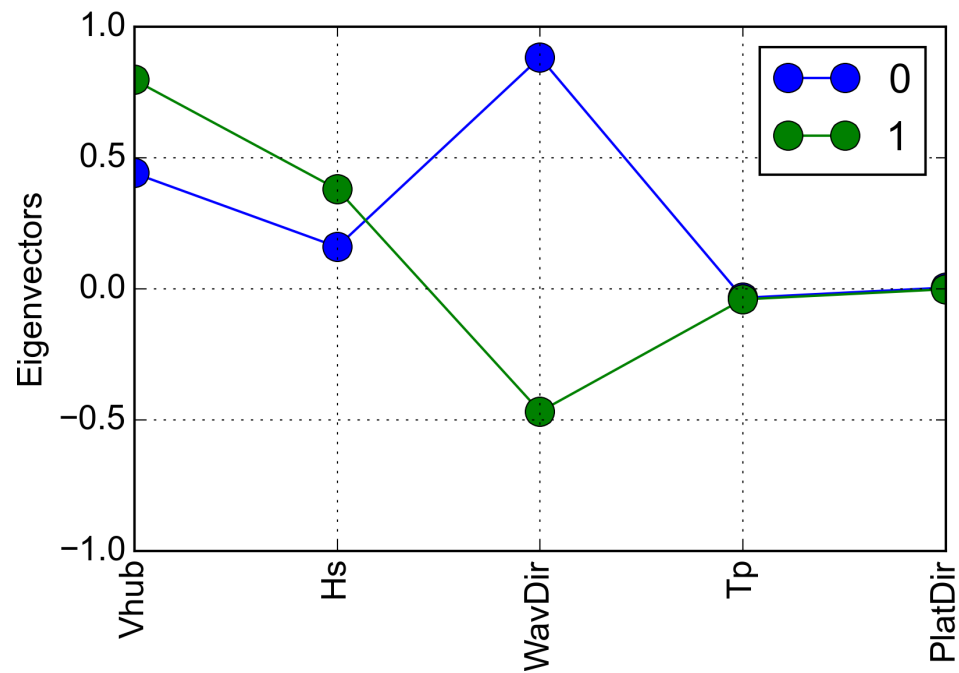
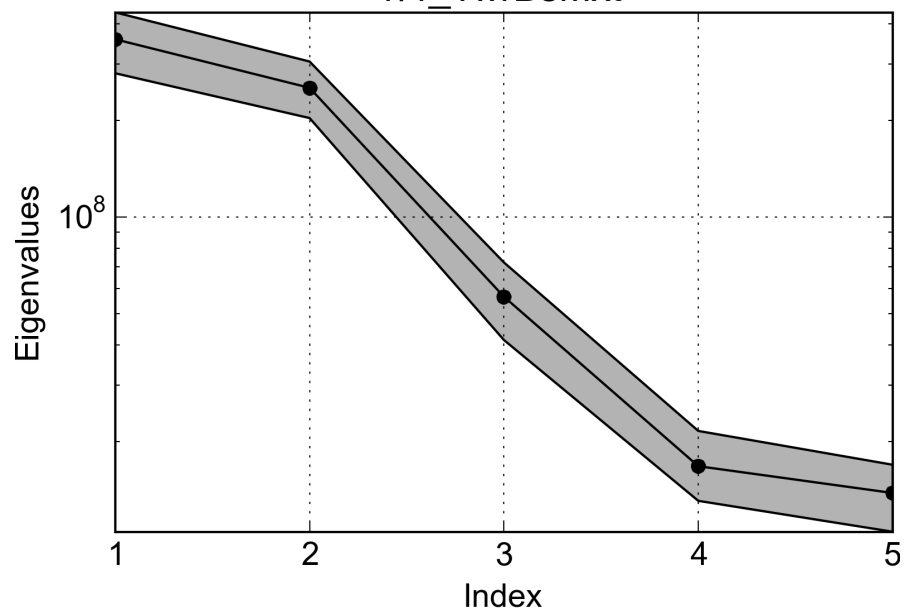
rf4_Anch1Ten



rf4_Anch2Ten



rf4_TwrBsMxt



Take some ideas home with you.

You must first **discover** and then **exploit** some low-dimensional structure to make high-dimensional problems tractable.

Active subspaces offer a new set of tools for working with functions that depends on several (tens to thousands of) variables.

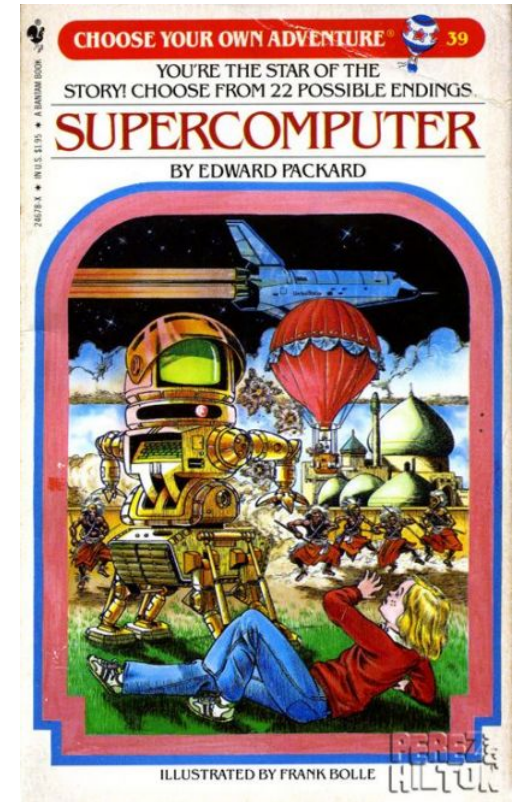
COMING IN MARCH!

Active Subspaces

Emerging Ideas for Dimension Reduction in Parameter Studies
SIAM, 2015

Questions?

- Can we talk about the trade-off between **discovering** and **exploiting**?
- Can you tell me more about [insert application]?
- How does this relate to other dimension reduction techniques?
- How “new” is all this?
- Can you show us the cool videos of the active subspace in the aerodynamic shape optimization?



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