Design of Experiments for the 2015 CLOUD Run

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CLOUD Experiment

- We would like to know Earth’s climate sensitivity, but the effect of clouds is highly uncertain
- The CLOUD chamber simulates cloud formation

\[ J \text{ rate} = \text{rate of nucleation} \]

Source: JasperKirkby, CERN colloquium, 2011
Design of Experiments

- How do several parameters affect nucleation rate?
  - Affected by sulfuric acid concentration, ammonia concentration, organic molecules, amines, temperature, ionization (from GCR and Proton Synchrotron)
- Maximin Latin Hypercube Sampling
- Kriging Model emulator

A simple Latin Square

2D Kriging Model Interpolation
The height of the red dot is interpolated from the surrounding points

Testing the Emulator in 4D

Values internal to CERN CLOUD experiment

Emulated Value of Log(J) from Kriging Model
Adding Organics, the Fifth Parameter

\[ J(H_2SO_4, NH_3, C, Q, T) = f(H_2SO_4, T) + f(H_2SO_4, NH_3, T) + f(H_2SO_4, Q, T) + f(H_2SO_4, NH_3, Q, T) + f(H_2SO_4, C, T) + f(H_2SO_4, C, Q, T) + f(C, T) + f(C, Q, T) \]

\[
\begin{align*}
\text{log10}(J) &\quad \text{log10}(C10) \\
\text{H2SO4 = 1e5} &\quad \text{H2SO4 < 1e6} \\
\text{H2SO4 = 1e6} &\quad \text{1e6 < H2SO4 < 1e7} \\
\text{H2SO4 = 1e7} &\quad \text{H2SO4 > 1e7} \\
\text{H2SO4 = 1e9} &\quad \text{N = 2ppt} \\
\text{Q < 1, N = 2ppt} &\quad \text{Q < 10, NH3 = 2ppt} \\
\text{Q > 10, NH3 = 2ppt} &\quad \text{Q < 1, N = .5 ppt} \\
\text{1 < Q < 10, NH3 = .5 ppt} &\quad \text{Q > 10, NH3 = .5 ppt} \\
\end{align*}
\]
Design of Model: 100-point Latin Hypercube

Values internal to CERN CLOUD experiment
Design of Model: 30-point Latin Hypercube with 95 Experimental Points

Values internal to CERN CLOUD experiment
Open Questions

- Emulator does not predict as well outside of the range of experimental data
- Constraints of experimental runs still need to be taken into account
Conclusion

• The predictive capability of a Kriging Model emulator based on a Maximin Latin Hypercube is comparable to that of a parameterization within the range of experimental values

• The emulator is more efficient at interpolating with less input than a parameterization
Thank you! Questions?