# SnowStorm Status

## Diffuse Workshop on Global Fit

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# SnowStorm Motivations

- Moving into a regime where uncertainties become less statistically, and more systematically, limited
  - the 'discrete ice model' is starting to become insufficient to deal with ice uncertainties within statistical precision
- Motivates a continuous and complete description of ice systematics
- SnowStorm: a method for the treatment of systematic uncertainties depending on a large number of nuisance parameters

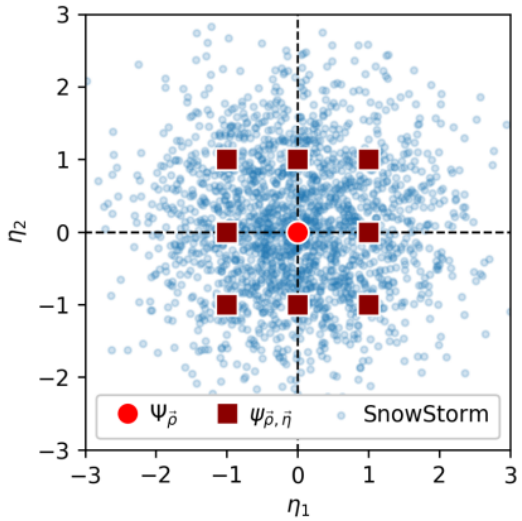
The paper is out!

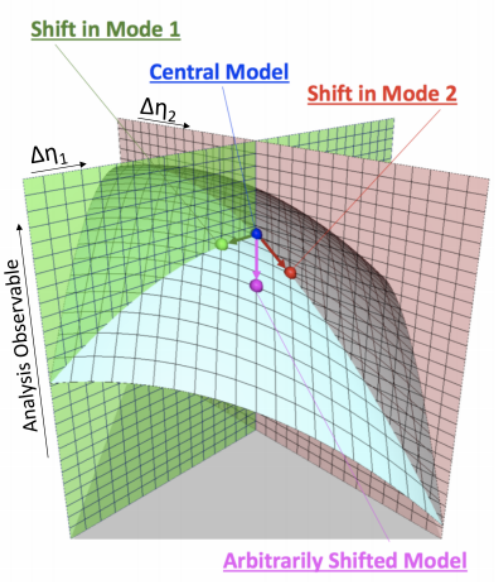
$\rightarrow$ https://arxiv.org/abs/1909.01530 $\leftarrow$

# SnowStorm Basics

MC systematic nuisance parameters are sampled continuously around a central model

$\rightarrow$ one MC set covers all systematics using this approach.



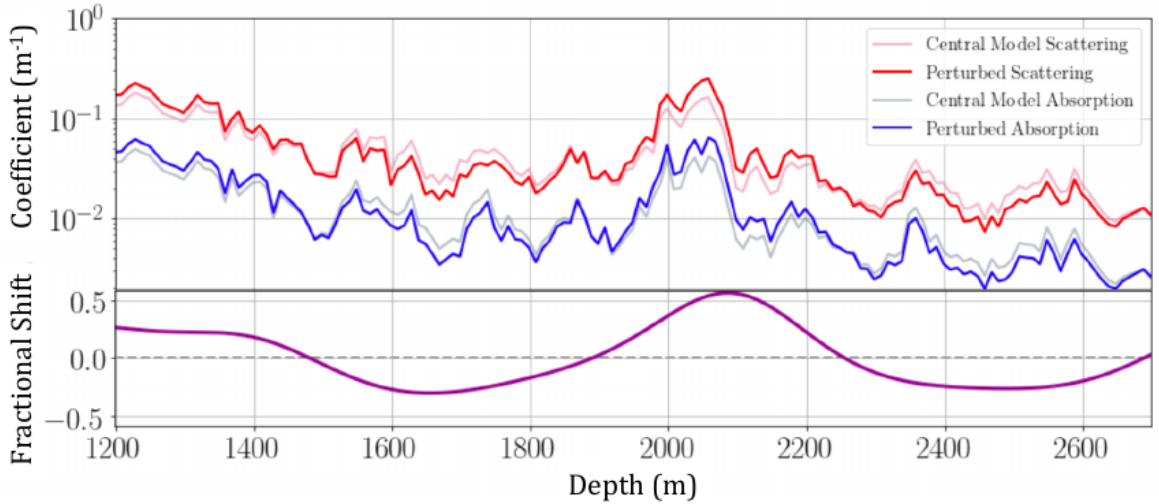




Does it work? Yes.

- Built upon a strong mathematical framework
- Integrated SnowStorm ensemble approaches the central model as number of perturbations grows

# Visualization with IceCube Ice

Below, depth dependence of scattering/absorption lengths perturbed by tweaking modes in their Fourier decomposition (perturbation widths from flasher fit data)



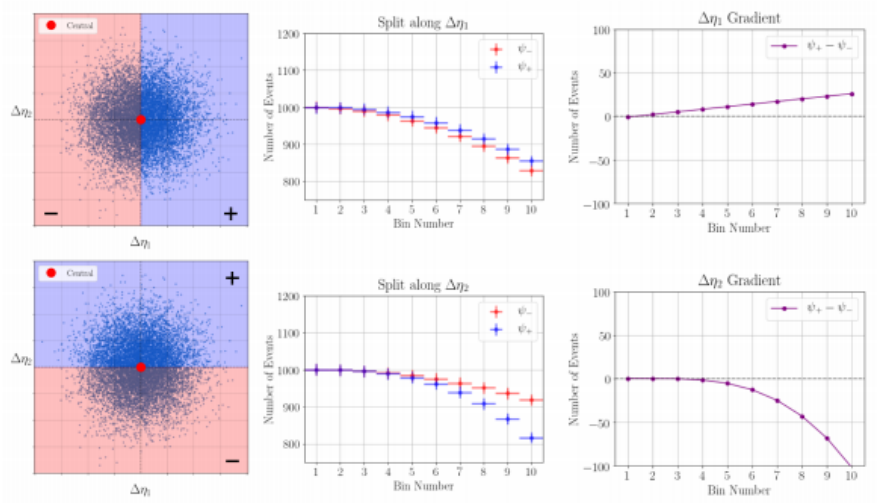

From the SnowStorm Paper, pg 8

For rigorous mathematical overview, see the Snowstorm paper.

# Gradient Extraction

How to understand effects of nuisance parameters in your analysis?

- Divide Sample into two sub-samples along a nuisance parameter



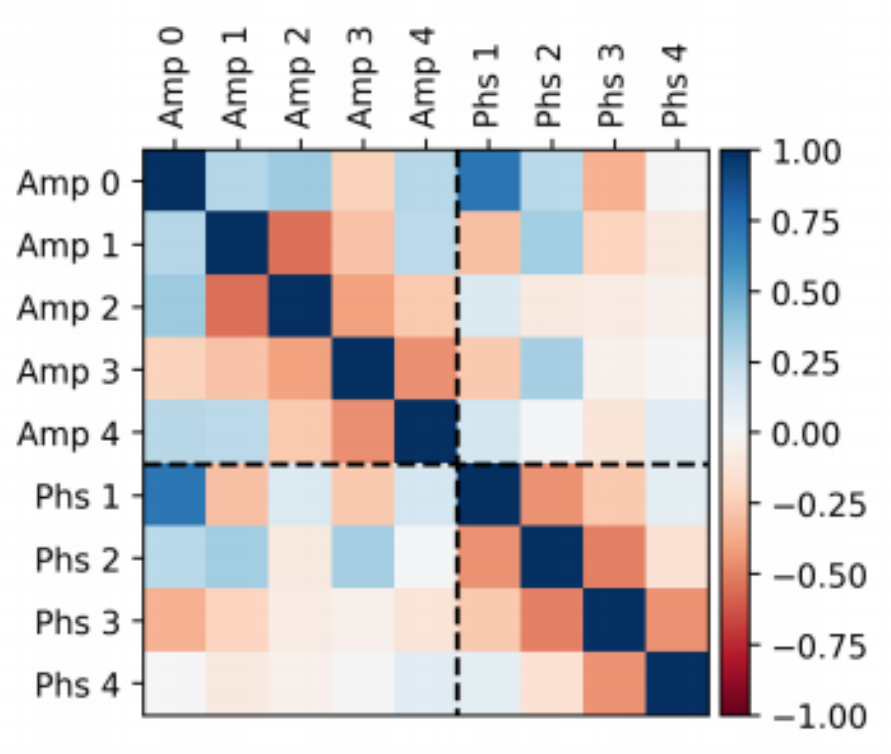

- Bin the events in analysis space
- Related 'Nuisance Gradient' element proportional to the difference in bin occupation

- Repeat for each nuisance parameter $i$, analysis space quantity $\alpha$, yielding nuisance gradient $G_{i,\alpha}$

# Covariance Matrix in Analysis Space

Ideally...

- you know what the nuisance parameters are
- can calculate nuisance parameter covariance ($\Xi_{i,j}$) from calibration data

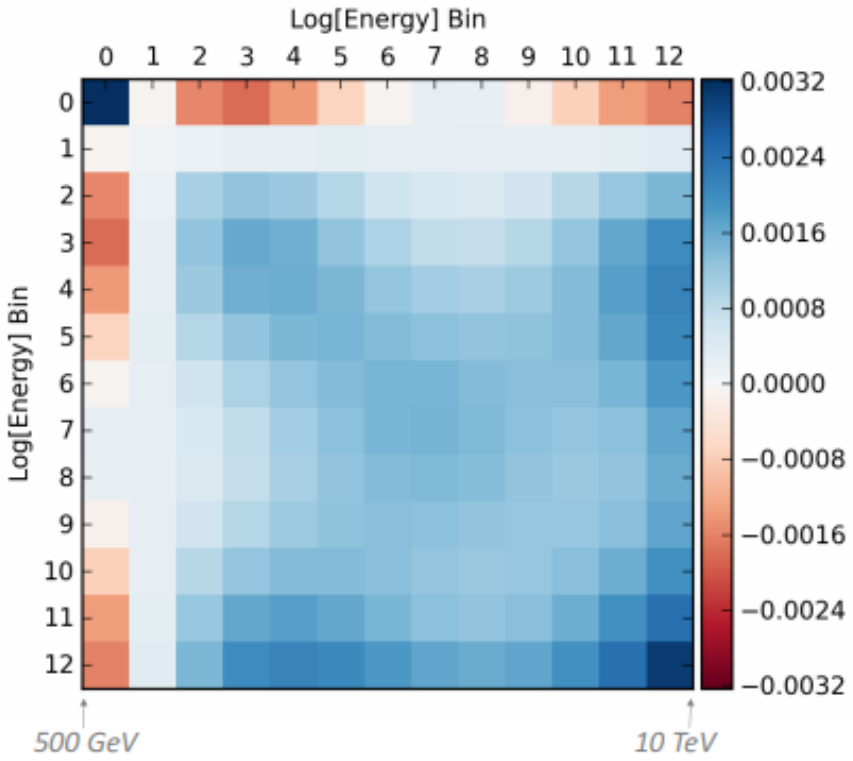



# Covariance Matrix in Analysis Space

Can be combined with Nuisance Gradient ($G$) to calculate covariance matrix $\Sigma$ in analysis space:

$$\Sigma_{\alpha,\beta} = G_{i,\alpha}\Xi_{i,j}G_{j,\beta}$$

$\rightarrow$ can get uncertainty in analysis space




# SnowStorm in IceCube

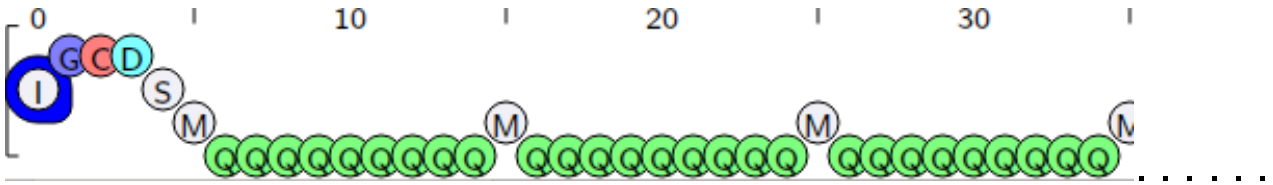
- SnowStorm is applicable to most any experimental setup with confounding and complicated nuisance parameters
- IceCube Systematic targets:
  - Depth dependence of dust
  - Ice anisotropy
  - Hole Ice
  - DOM Efficiency
  - DOM Angular/Wavelength acceptance
- Individual, or groups of, frames will use uniquely perturbed set of nuisance parameters
- Analysis space would be reconstructed event energy, direction

# SnowStorm in IceCube

How are perturbations currently stored in the sample?

- S Frames: 1 per sample, overall information about the perturbations
- M Frames: 1 per perturbed ice model in sample

| Frame | Frame Element Key | Description |
|---|---|---|
| S | SnowstormParameterRanges | overall |
| | SnowstormParametrizations | information about |
| | SnowstormProposalDistribution | perturbations |
| M | SnowstormParameters | Parameters for perturbation |




# How is this applied?

## SnowSuite

# SnowSuite

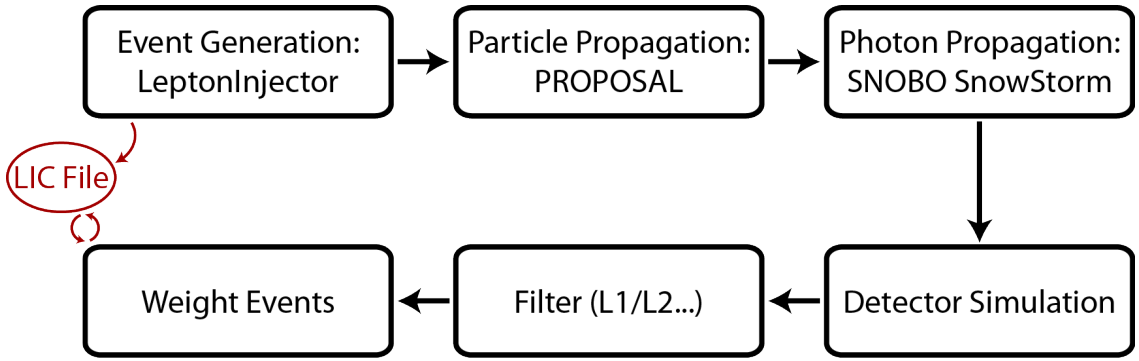
*Suite* of processors for *Snow*storm

`snobo/simprod-scripts/resources/scripts/SnowSuite`

- built in the snobo branch of combo metaproject
- Implemented for generation through detector simulation
- Ready for people to use!

# SnowSuite Details

- Based on Spencer Axani's SPE Templates
- Photon propagation uses implementation of Jakob van Santen's 'Hobo Multisim' $\rightarrow$ SNOBO Snowstorm




# SNOBO Snowstorm

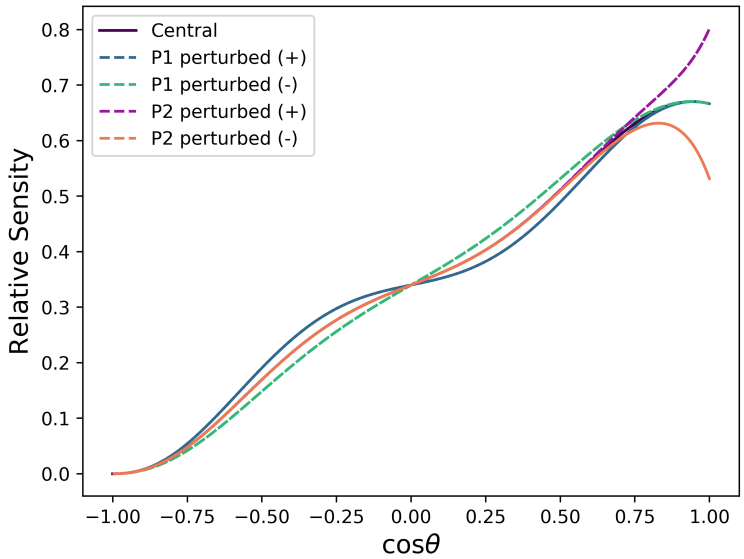
Photon Propagation - SNOBO SnowStorm

- Runs in slightly modified version of CLSim
- Runs several short I3 trays, each with a perturbed Ice/DOM model
- CLSim model configuration saved between mini-trays
- Perturbation applied after chosen number of frames

| Frame | Frame Element Key | Description |
|---|---|---|
| M | AngularAcceptance | MSU Hole Ice Model |
| | MediumProperties | scaled anisotropy strength |
| | WavelengthAcceptance | scaled overall |
| | SnowStormParameters | Depth Dependent Ice Params |

# Angular Acceptance

Probability of DOM photon acceptance with respect to photon incident angle




Following MSU Forward Hole Ice Model parametrization

$$P_{p_1,p_2}(\theta) = 0.34\left(1 + 1.5\cos\theta - \cos^3\theta/2\right) + \ldots /$$
$$/\ldots + p_1\left(\cos\theta\right)\left(\cos^2\theta - 1\right)^3 p_2 \exp\left(10\left(\cos\theta - 1.2\right)\right)$$

# Four Test Samples

Four Test Samples

- Generated to provide small test sample for familiarization and practicing techniques
- Generation up through detector simulation
- Run through SnowSuite (though using simpleinjector for generation)

Sample is currently up on the cobalts at

`/data/user/bsmithers/runs/chiba_sample/`

See ‘notes’ file for specifics.

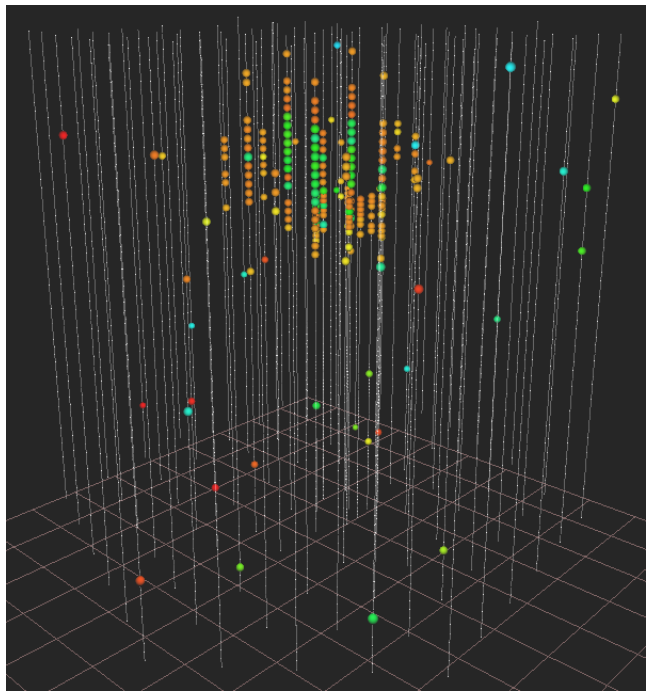
# Test Sample Generation

Generation Information

- 1000 events each
- 100 TeV $e^-$ cascades
- DOM Oversize of 5.0

Four different parts of IceCube

- Edge: 4-500m from IceCube center
- Deep Cube: >400m below IceCube Center
- Dust Layer
- Top Center



Steamshovel rendering of event in the 'top center'

# Larger Sample

Generated for the global fit effort

- $\sim 5 \times 10^5$ NC and CC events
- All Flavors, All neutrino
- 1TeV to 10PeV generated at $E^{-1}$

`/data/user/bsmithers/runs/snobo_large/`

- LeptonInjector, Snowstorm, SnowSuite

# Fun Sample Projects

Ideas

- Building Snobo metaproject and running SnowSuite scripts
  - Scripts are written for Python 3, may need small changes for Python 2
- Load i3 files in dataio-pyshovel, or steamshovel. Examine frame structure
- Run basic L1/L2 scripts on detector level files
- Perform some basic event reconstruction
- Extract one nuisance gradient element
  - But which?

# Summary Slide (1/2)

needpix.com

Snowstorm

- Read more about it https://arxiv.org/abs/1909.01530
- Treatment for systems with complicated sources of systematic uncertainties
- Continuous sampling of nuisance parameters
- Single MC sample can account for all systematics

# Summary Slide (2/2)

SnowSuite

- processor group for generation through detector sim
- Application of Snowstorm application of ice+dom systematics
- A few samples already available
- More to come!

needpix.com

`snobo/simprod-scripts/resources/scripts/SnowSuite`

# Thank you!