

Large-scale Clustering of Natural Snowfall: Collective Precipitation Dynamics in Three Dimensions

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Session HS7.1

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Vienna



Imaging Snowfall over a 1000 Cubic Meters

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Experiments at Instrumented Field-site

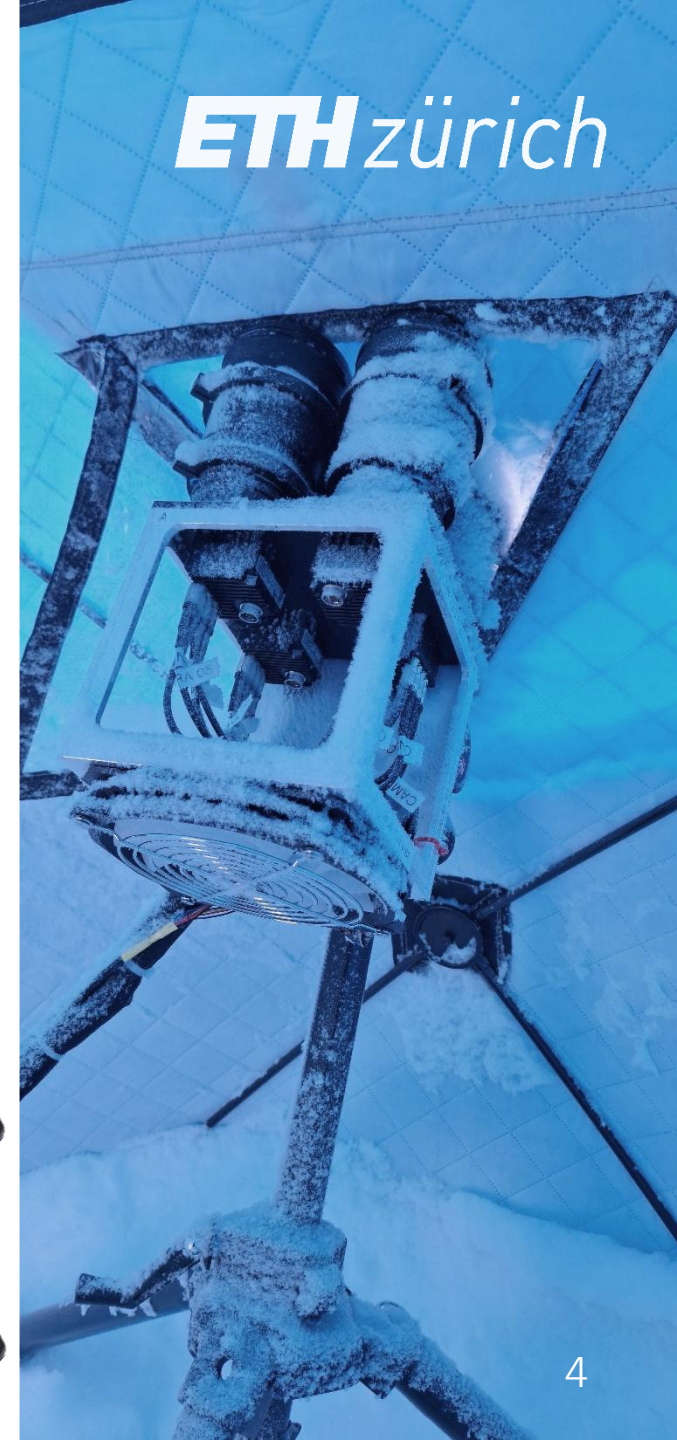
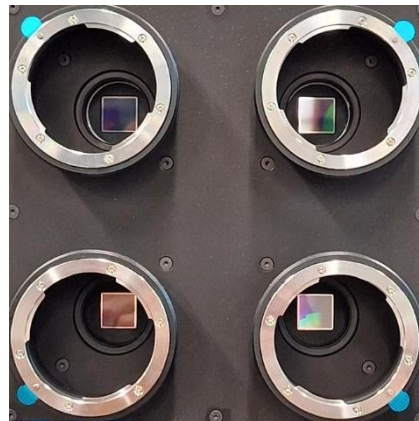
Snow Tracking Cameras on Arrays

Goal: Tracking snowflakes.

Realization: Cameras on arrays.

- Large 20x20m² field(s) of view
- Volumetric 26m depth of field
- 2mm Diffraction Limit
- 2x2 Kaya IRON0505 25MP Monochrome
- 2x2 Samyang 1:1.4 24mm UMC Nikon Lens
- 2x2 Shifted Lens Configuration

150 fps: 64 – 128 Gb/s image data in 8-bit, *i.e.*, ~terabit per second

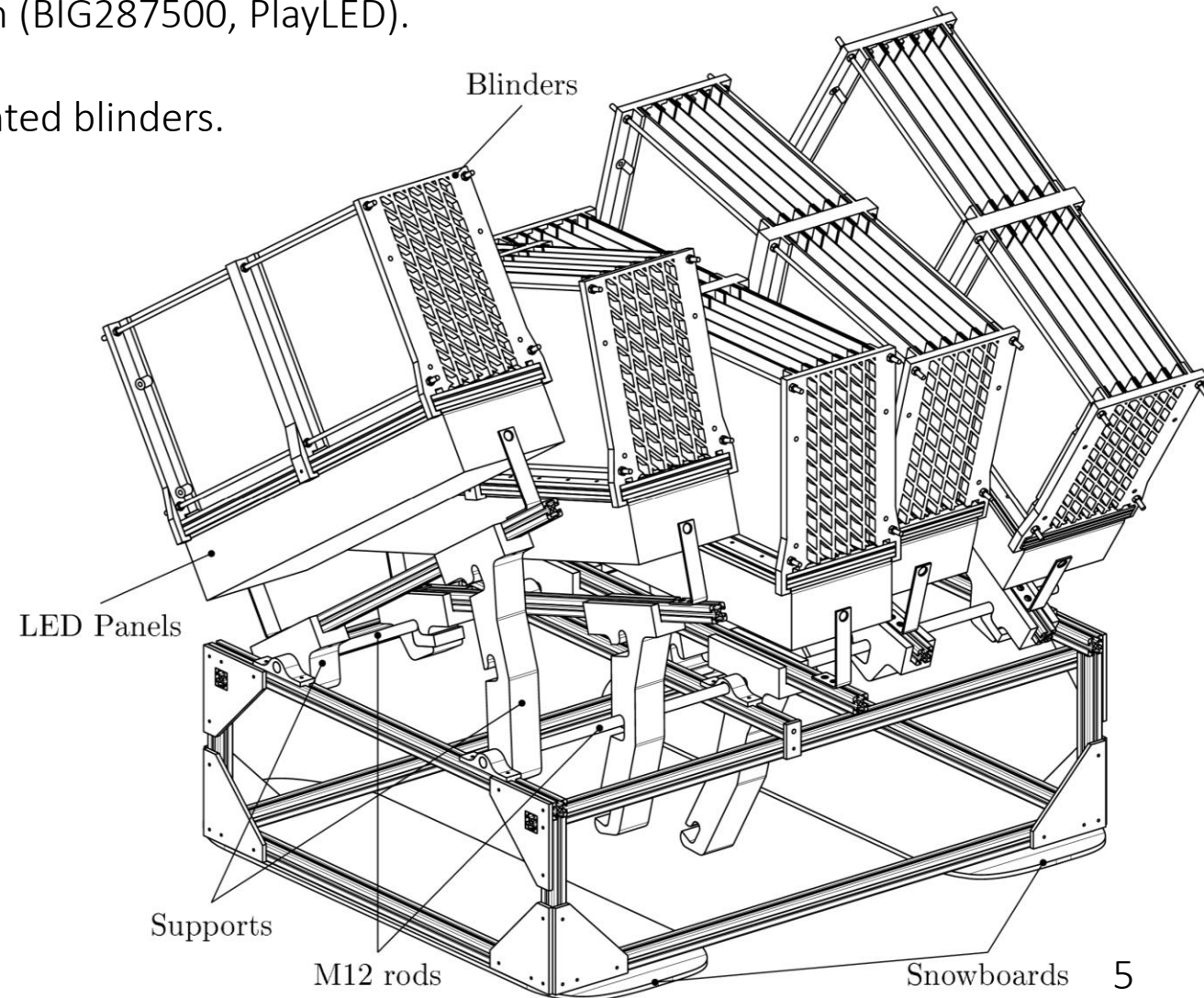
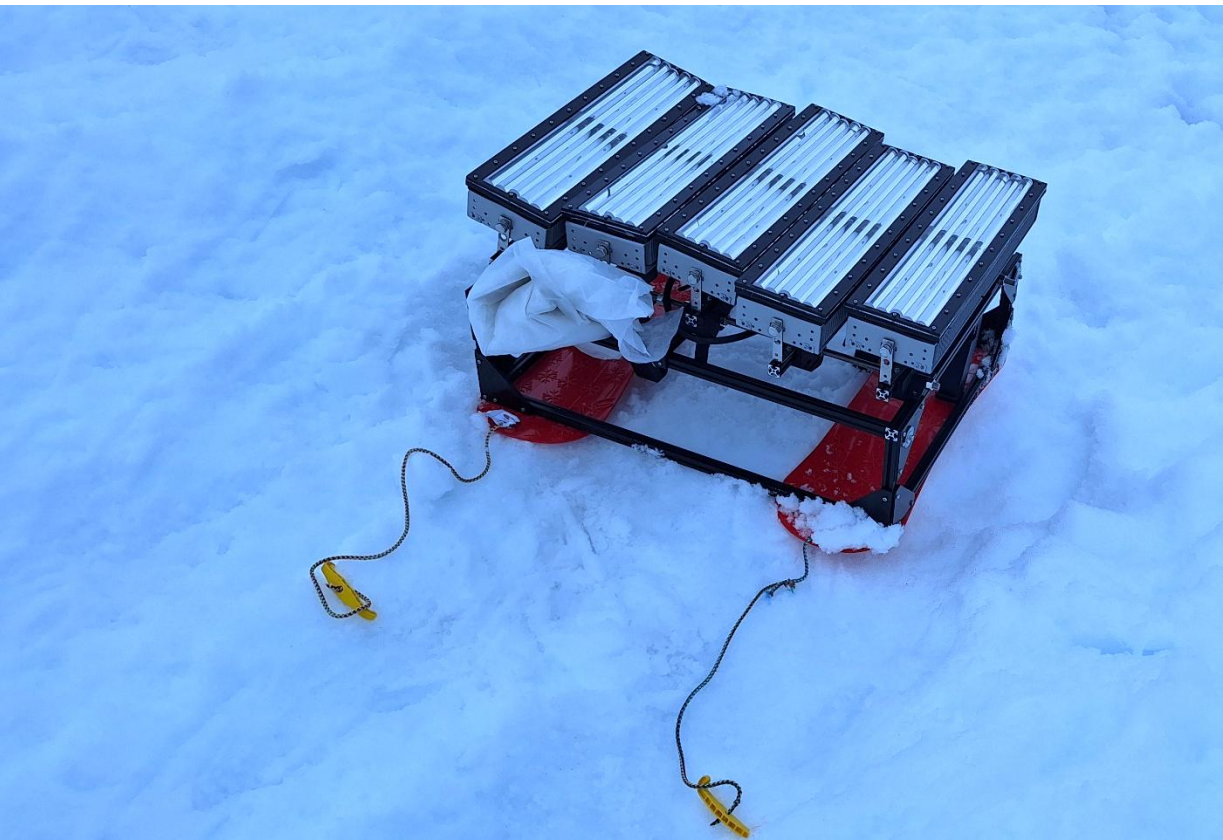


Stadium Illumination on Snowboards

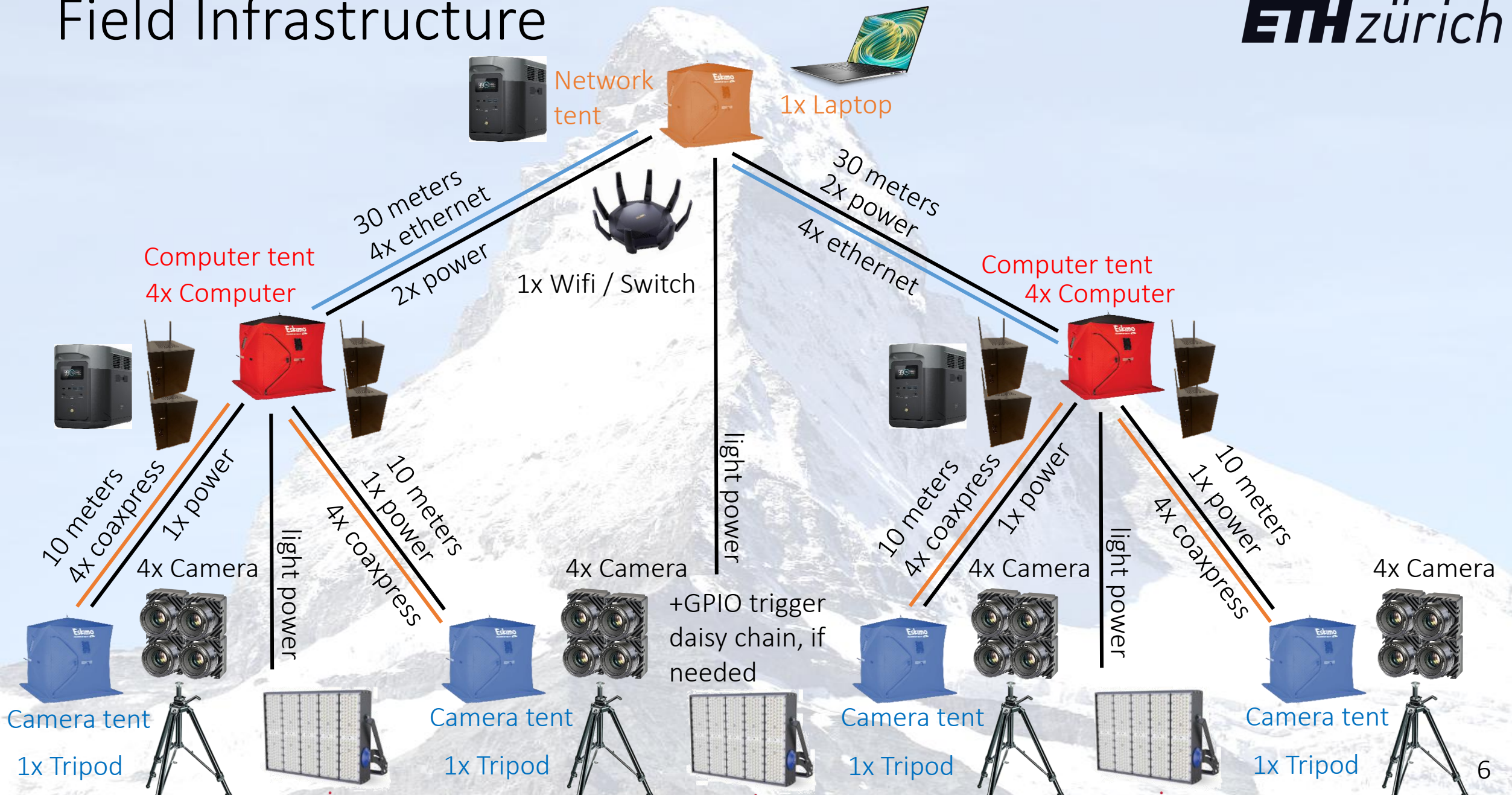
Stadium LED Floodlights: 1575Watt / ~250'000 lumens each (BIG287500, PlayLED).

Retrofitted with custom made cylindrical lenses and 3D printed blinders.

Planar and volumetric configurations.



Field Infrastructure



Tetrahedron(e) Calibrator

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Camera Calibration Framework

Step 1: Compute Drone Position.

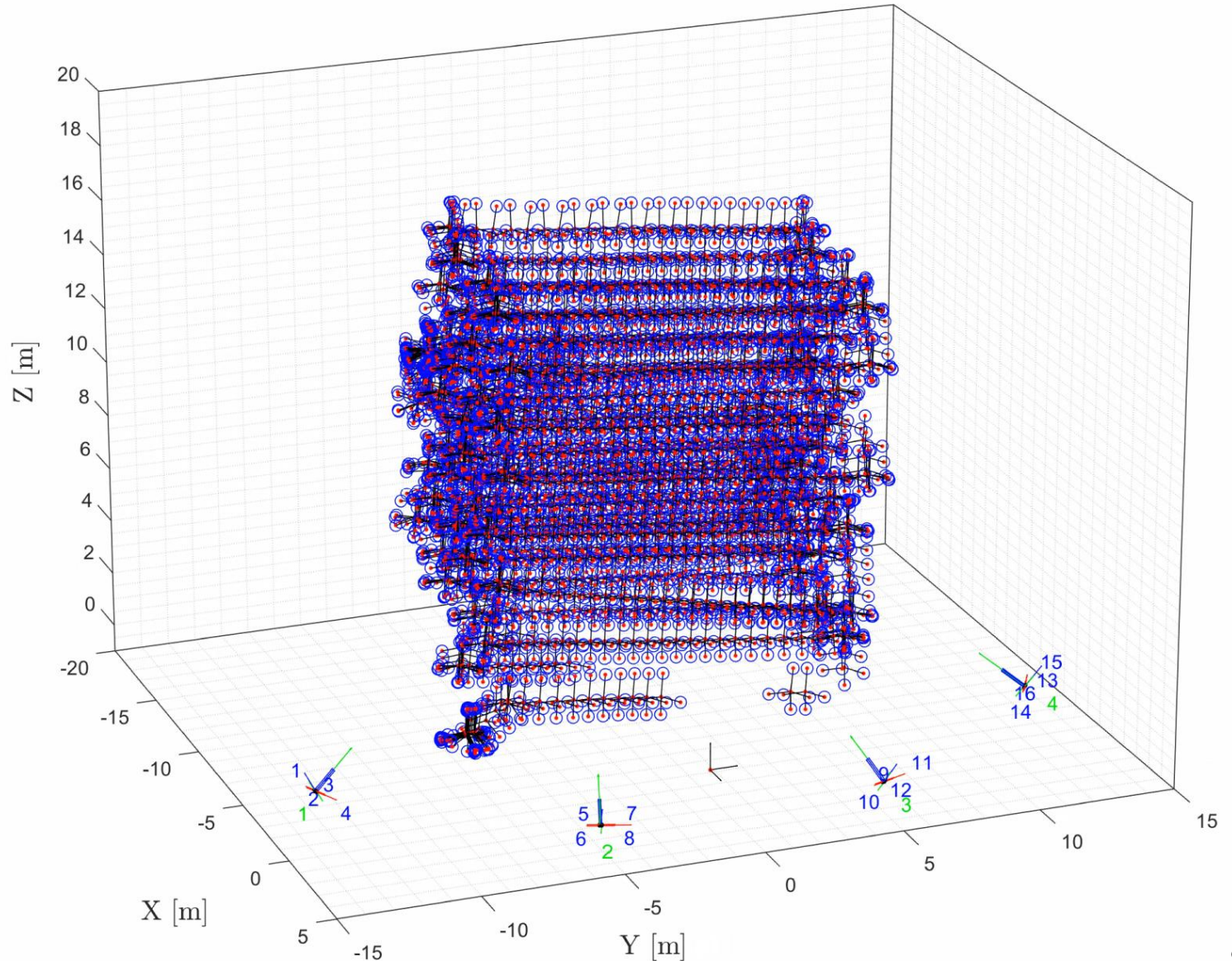
Step 2: Align multiple views.

Step 3: Drone flight tracking.

Track the drone position and orientation over its flight path, progressing over all 16 cameras, minimize the global residual in object space.

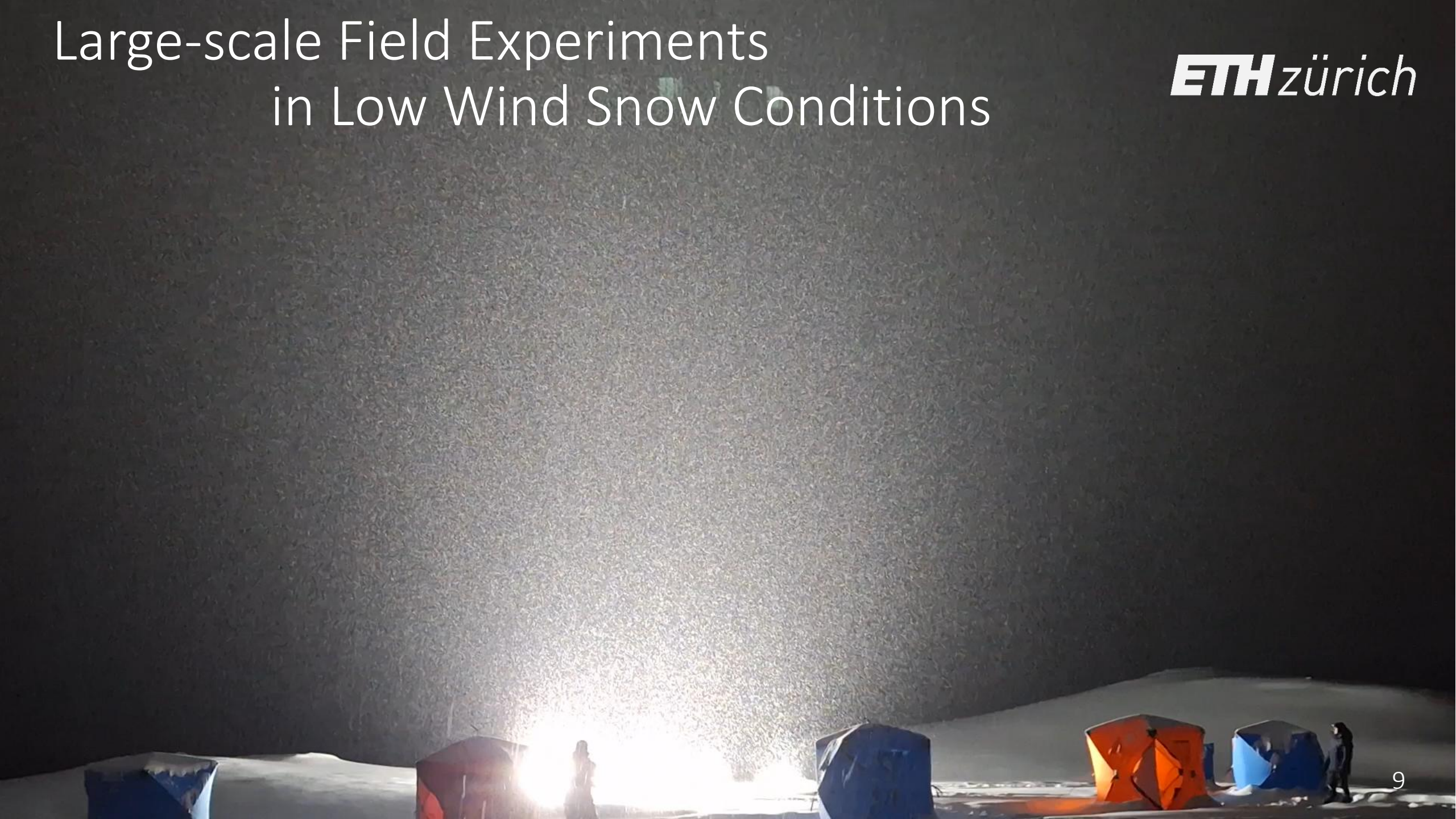
$$\min_{\{k_i^{c,n}, K^c, b_k^c, \theta^c, t^c, R^a, T^a\}} \sum_{i,n,c,a} \left\| d(K^c \setminus \tilde{x}_i^{c,n}; b_k^c) k_i^{c,n} - R_k(\theta^c) \begin{bmatrix} I^* \\ \mathbf{t}^c \\ 0 \end{bmatrix} \begin{bmatrix} R^a & \mathbf{T}^a \\ \mathbf{0}^T & 1 \end{bmatrix} \begin{bmatrix} R_d^n & \mathbf{T}_d^n \\ \mathbf{0}^T & 1 \end{bmatrix} \begin{bmatrix} \mathbf{X}_i \\ 1 \end{bmatrix} \right\|_2^2$$

(~2 cm residual error)



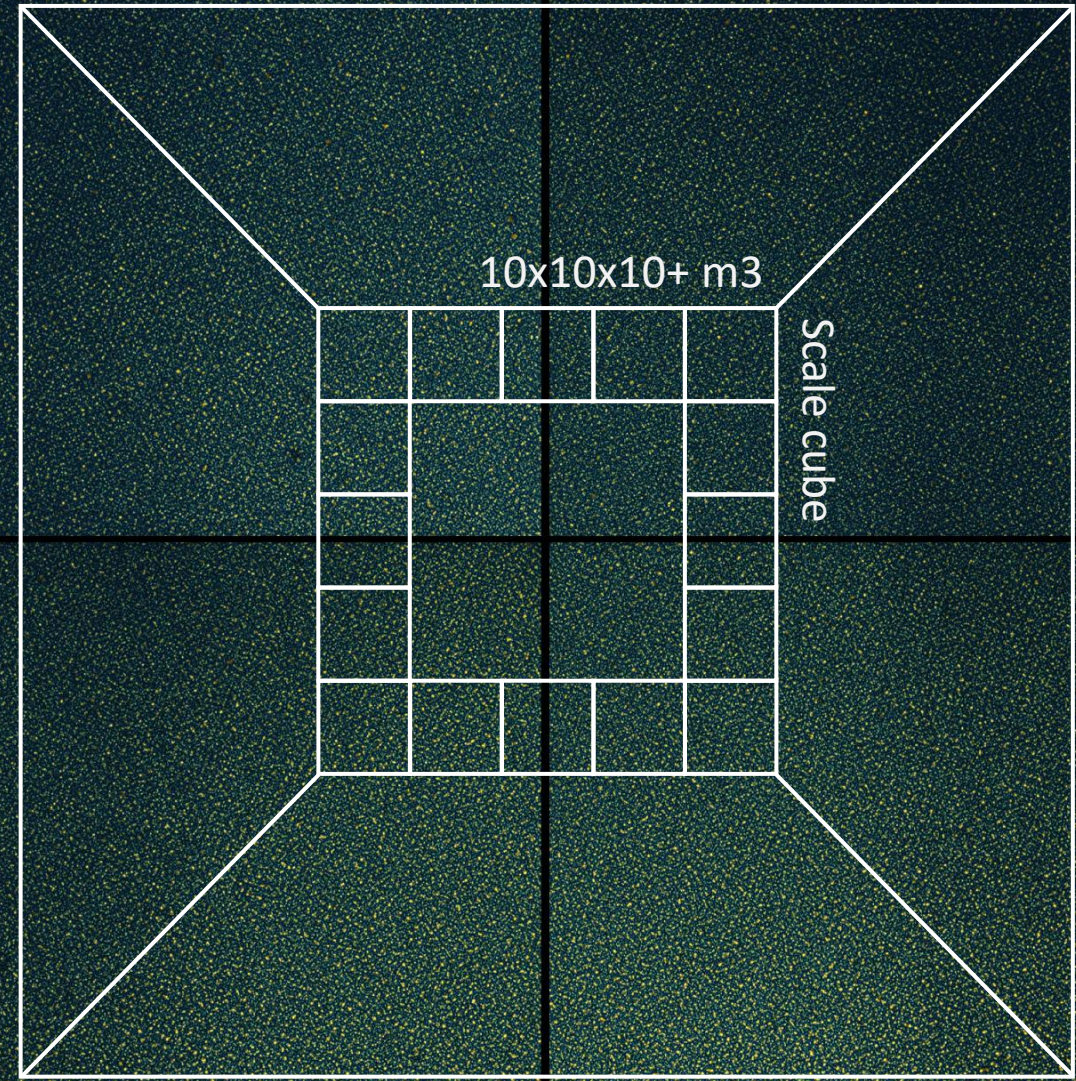
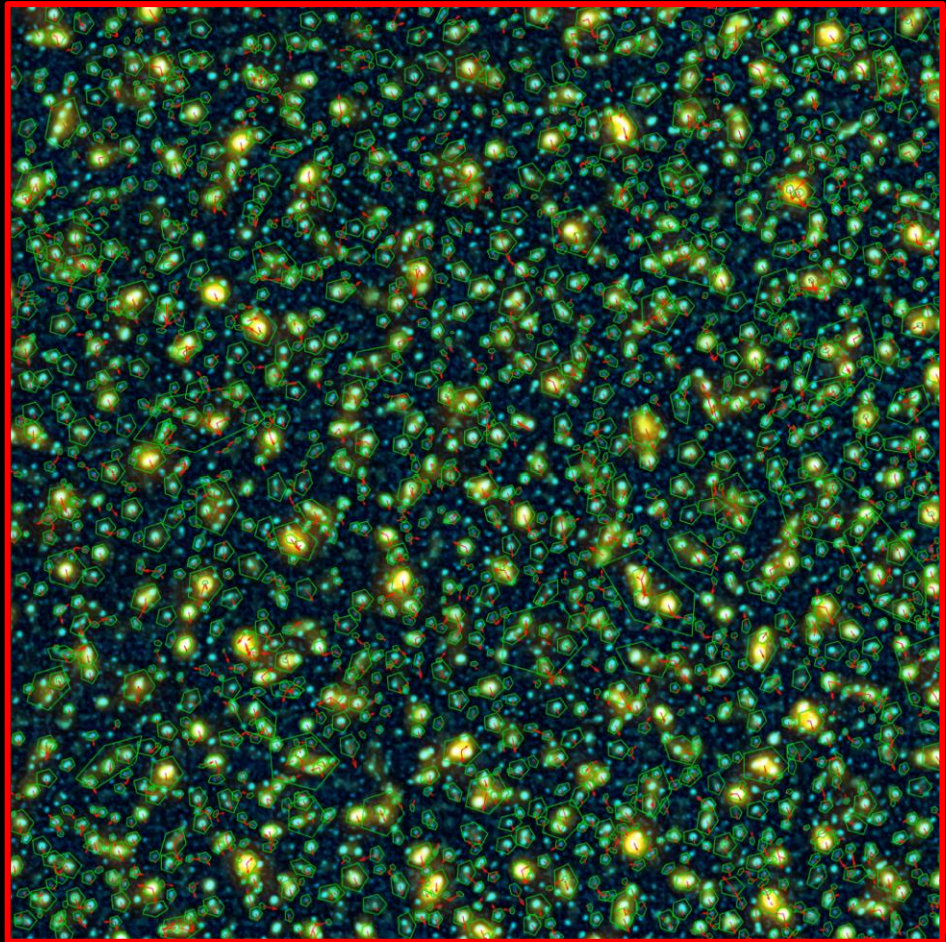
Large-scale Field Experiments in Low Wind Snow Conditions

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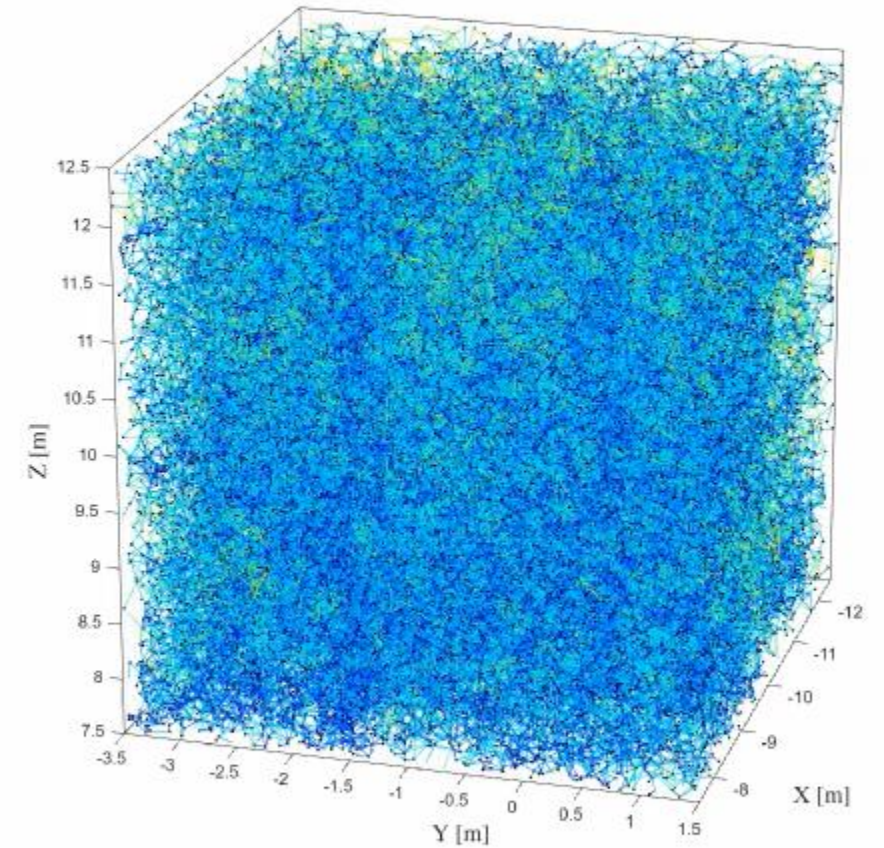
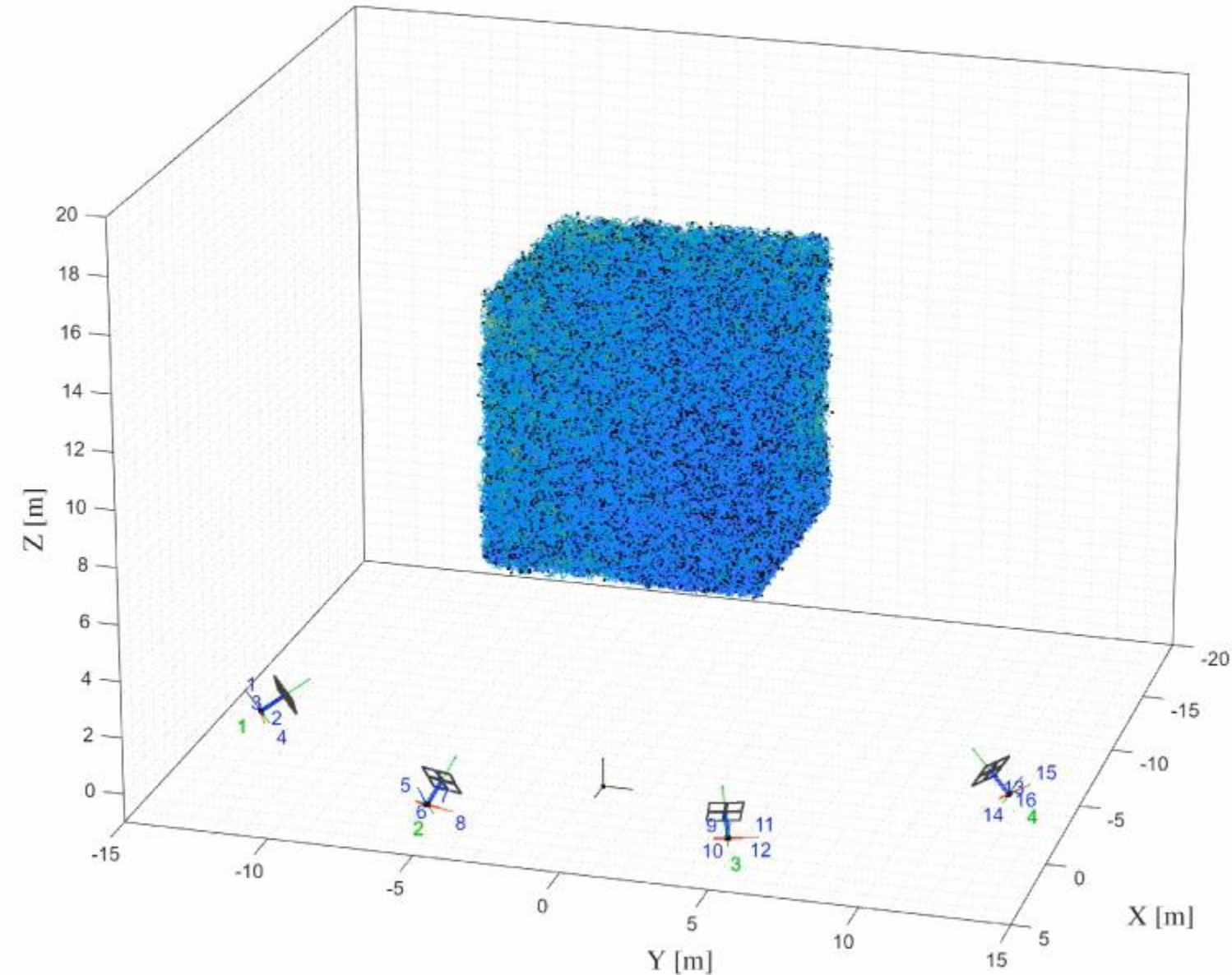


Tracking Millions of Snowflakes on Arrays

Discern small & large snowflakes by wavelets



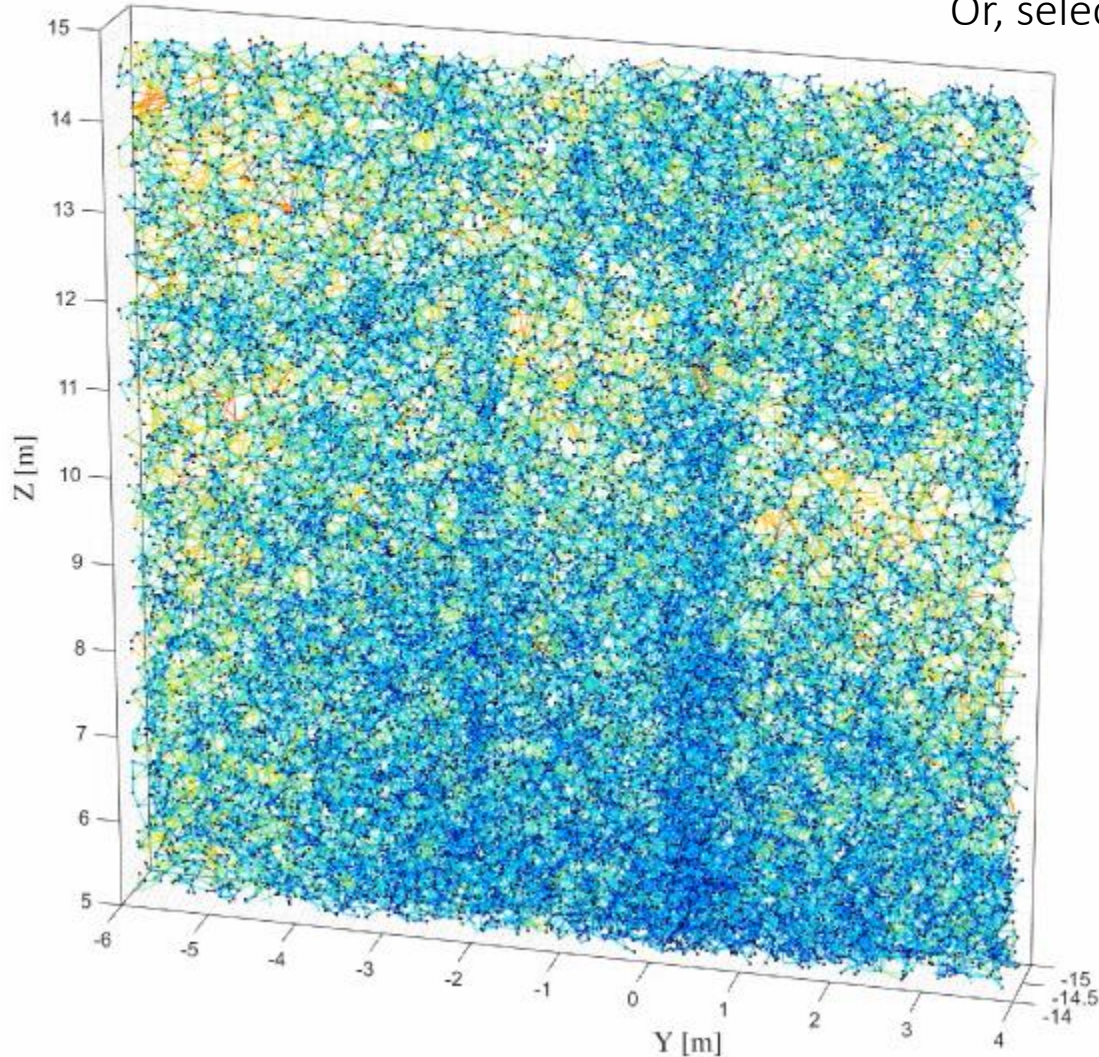
Volumetric Tracking Millions of Snowflakes



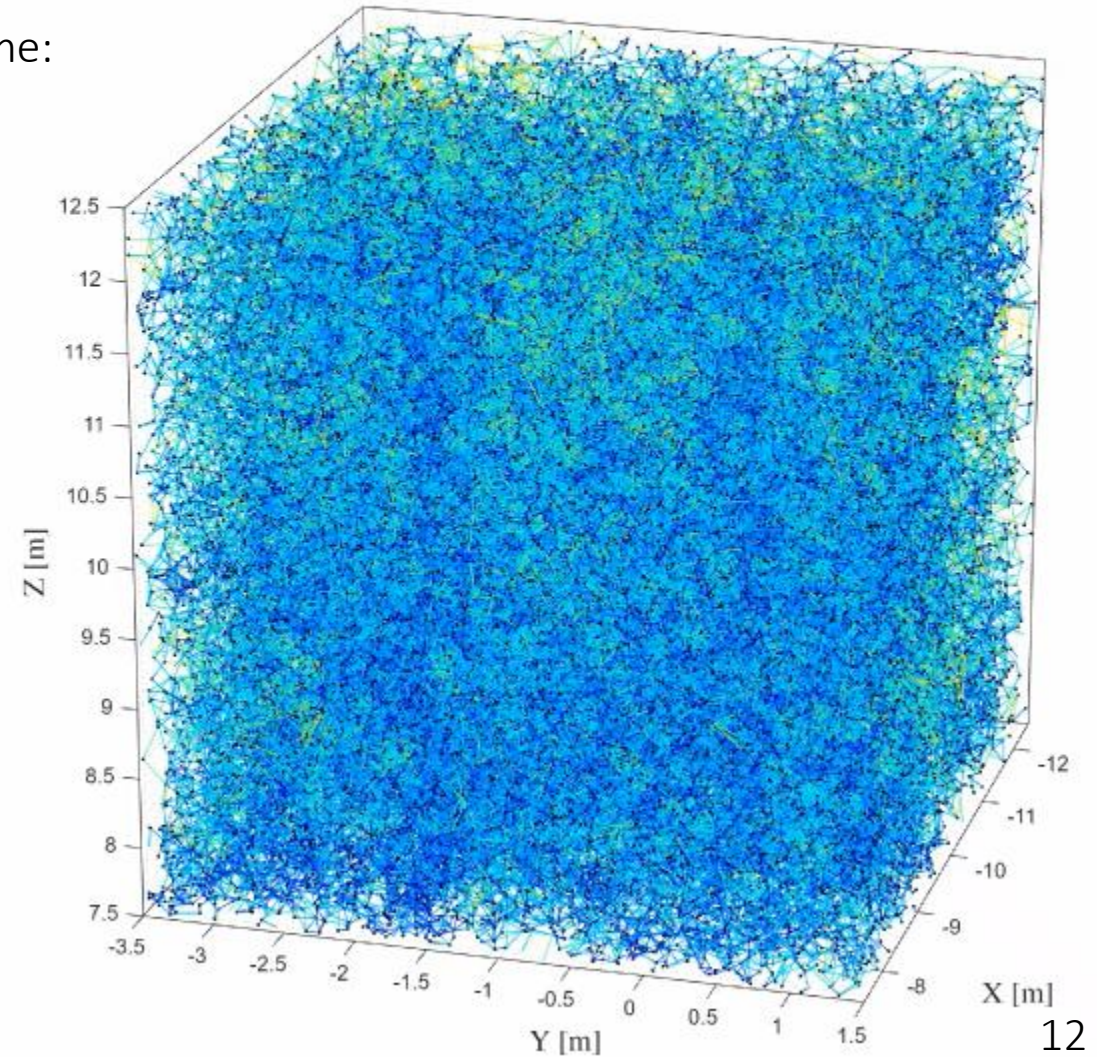
Vast volumes over a 10x10x10 cube
at one terabit of snow per second.

Interparticle Distance & Measurement Bias

Analyze a slab of snowfall:

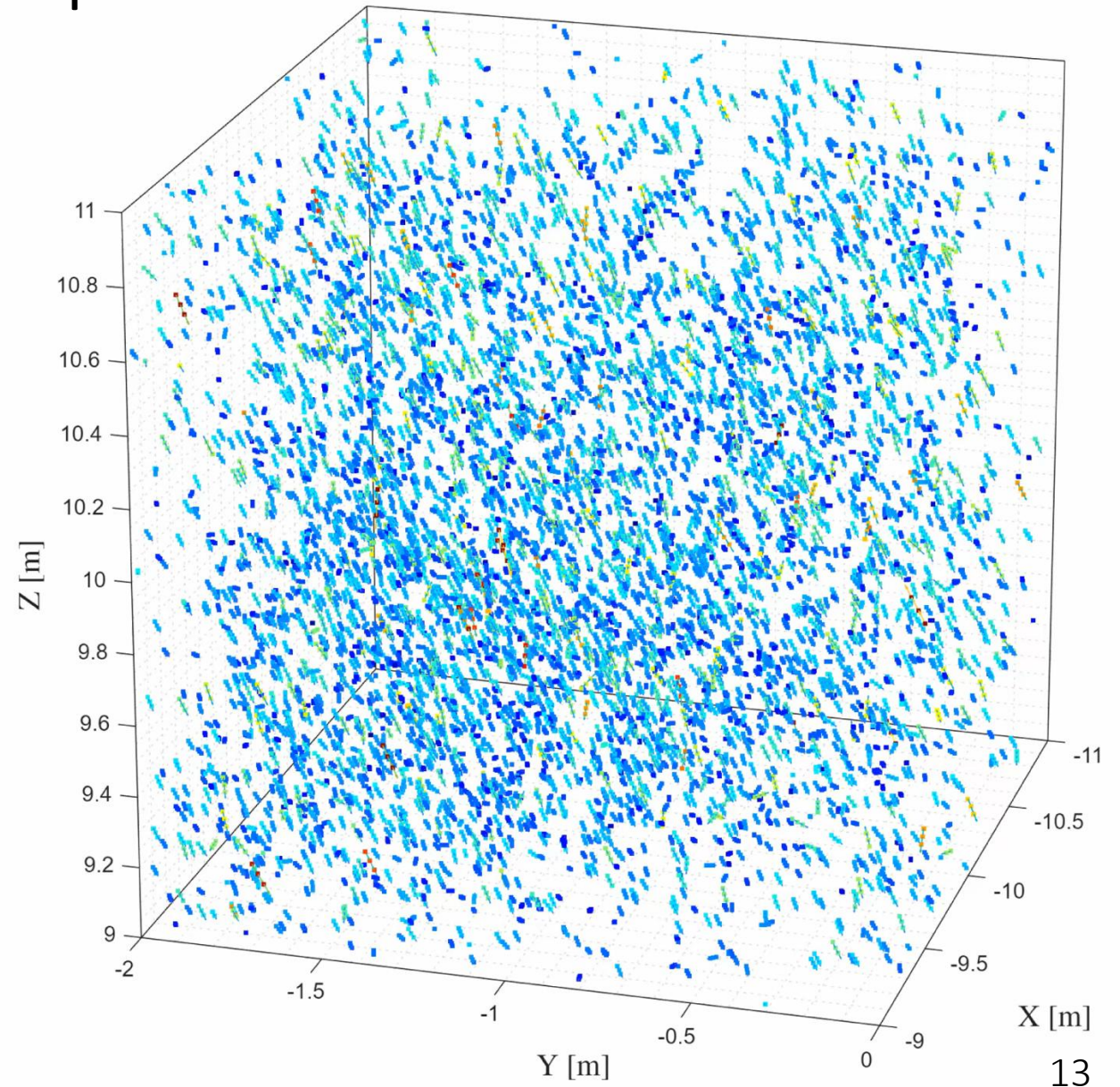
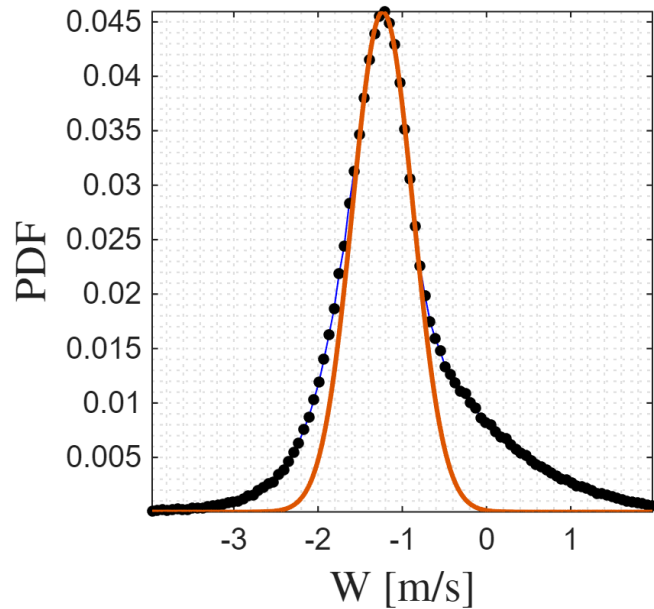
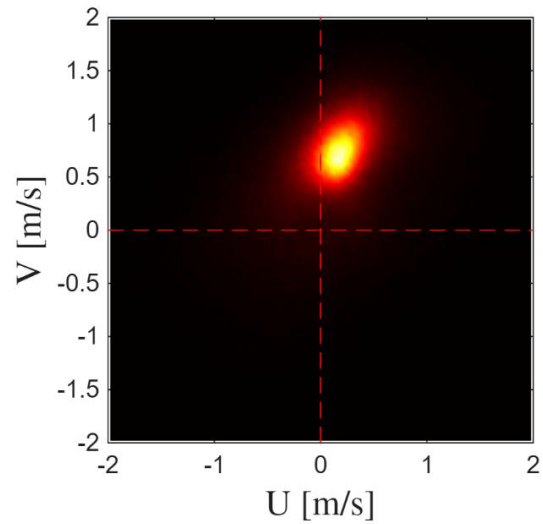


Or, select a subvolume:



Zooming into the Snow Fall Speed

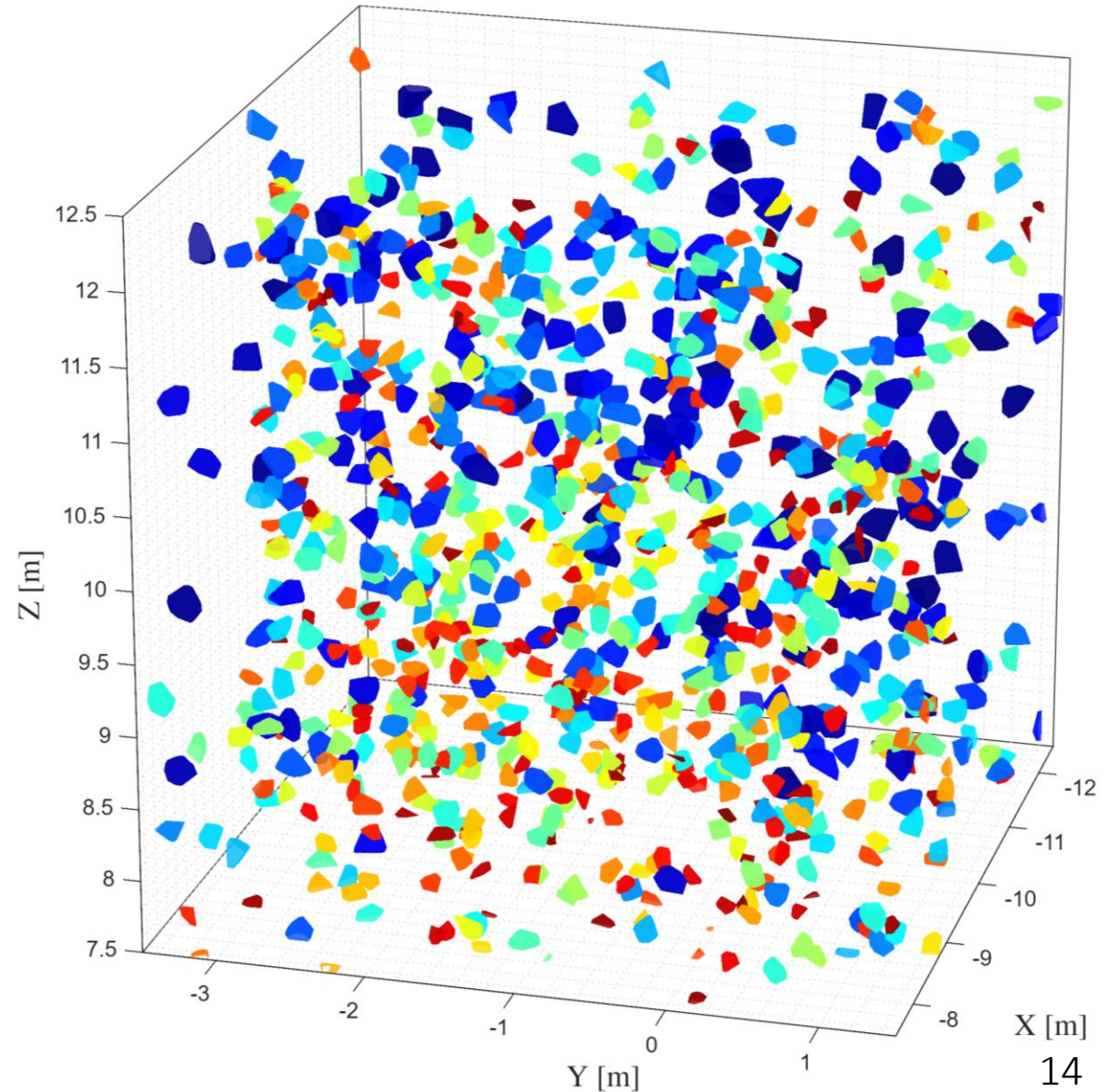
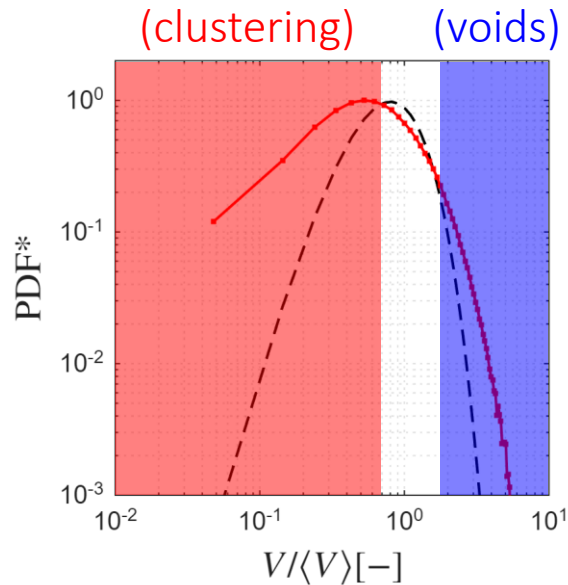
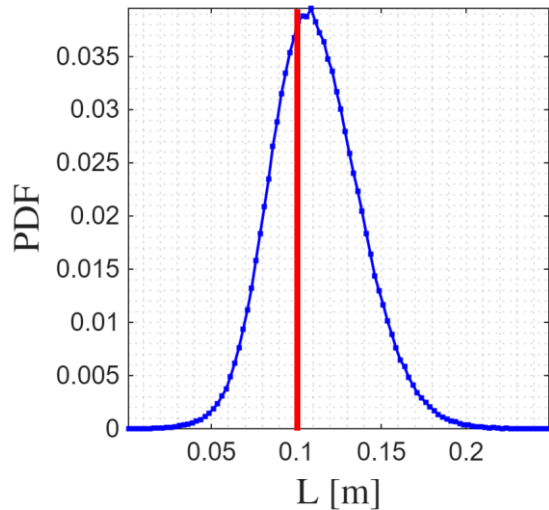
- 1\ Snowfall aligns with the weak wind vector of ~ 1 m/s.
- 2\ Apparent multimodality corroborated by strong deviation from Gaussian reference fit.



Sampling Voronoi Cells of Increasing Size

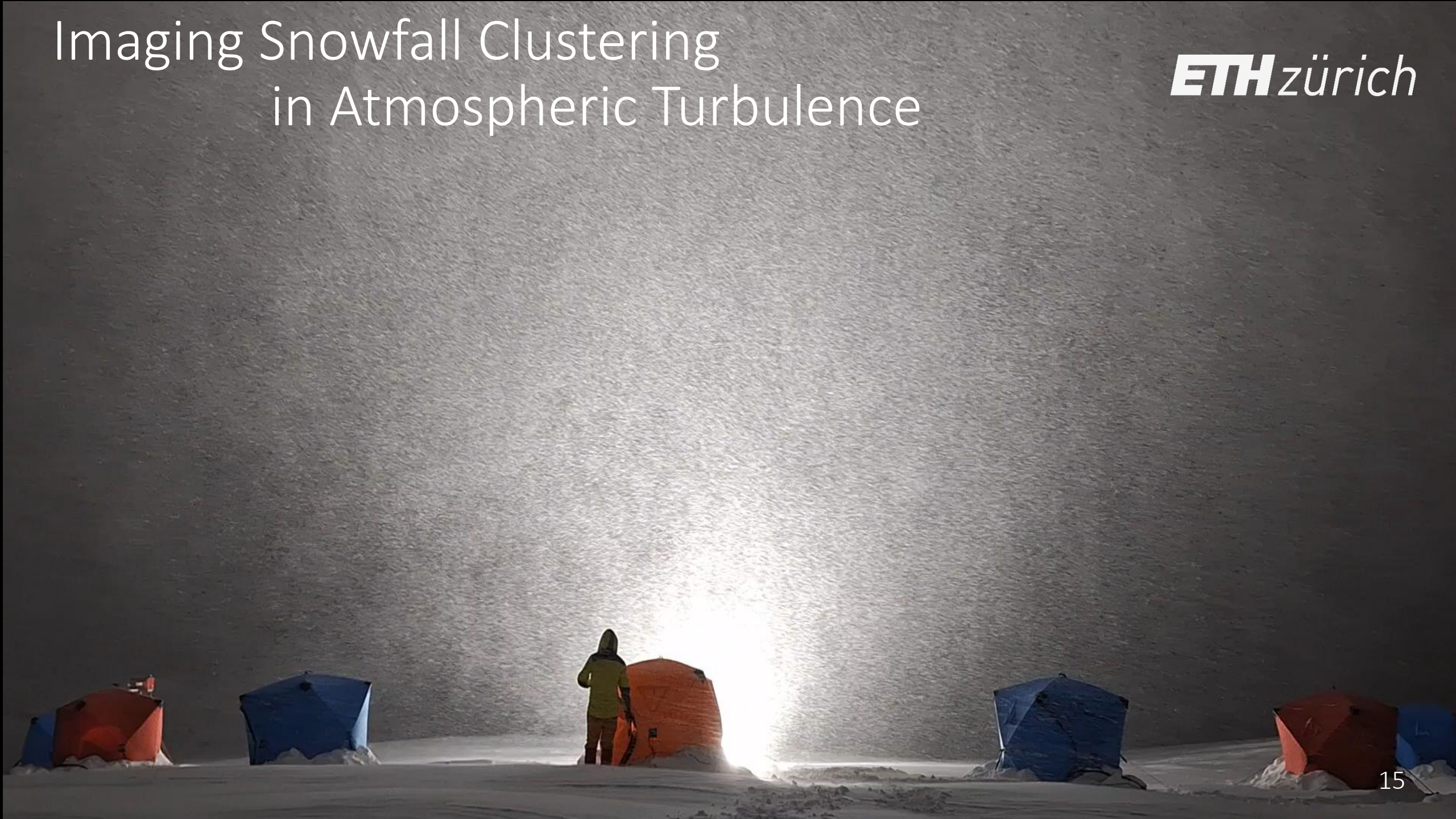
- 1\ Snowfall at an average 10cm spacing
- 2\ Strong predominance of clustering compared to a random Poisson in 3D:

$$f\left(\frac{V}{\langle V \rangle}\right) = \left(\frac{3125}{24}\right) \left(\frac{V}{\langle V \rangle}\right)^4 \exp\left(-5 \frac{V}{\langle V \rangle}\right)$$



Imaging Snowfall Clustering in Atmospheric Turbulence

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Unravelling Storming Blizzard Winds

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Atmospheric
Surface Layer



Blowing Snow

Saltation Layer

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