x-hour Outdoor Photometric Stereo

Yannick Hold-Geoffroy[1], Jinsong Zhang[1], Paulo F.U. Gotardo[2], and Jean-François Lalonde[1]

[1]Université Laval, Quebec City [2]Disney Research, Pittsburgh

http://vision.gel.ulaval.ca/~jflalonde/projects/xHourPS/

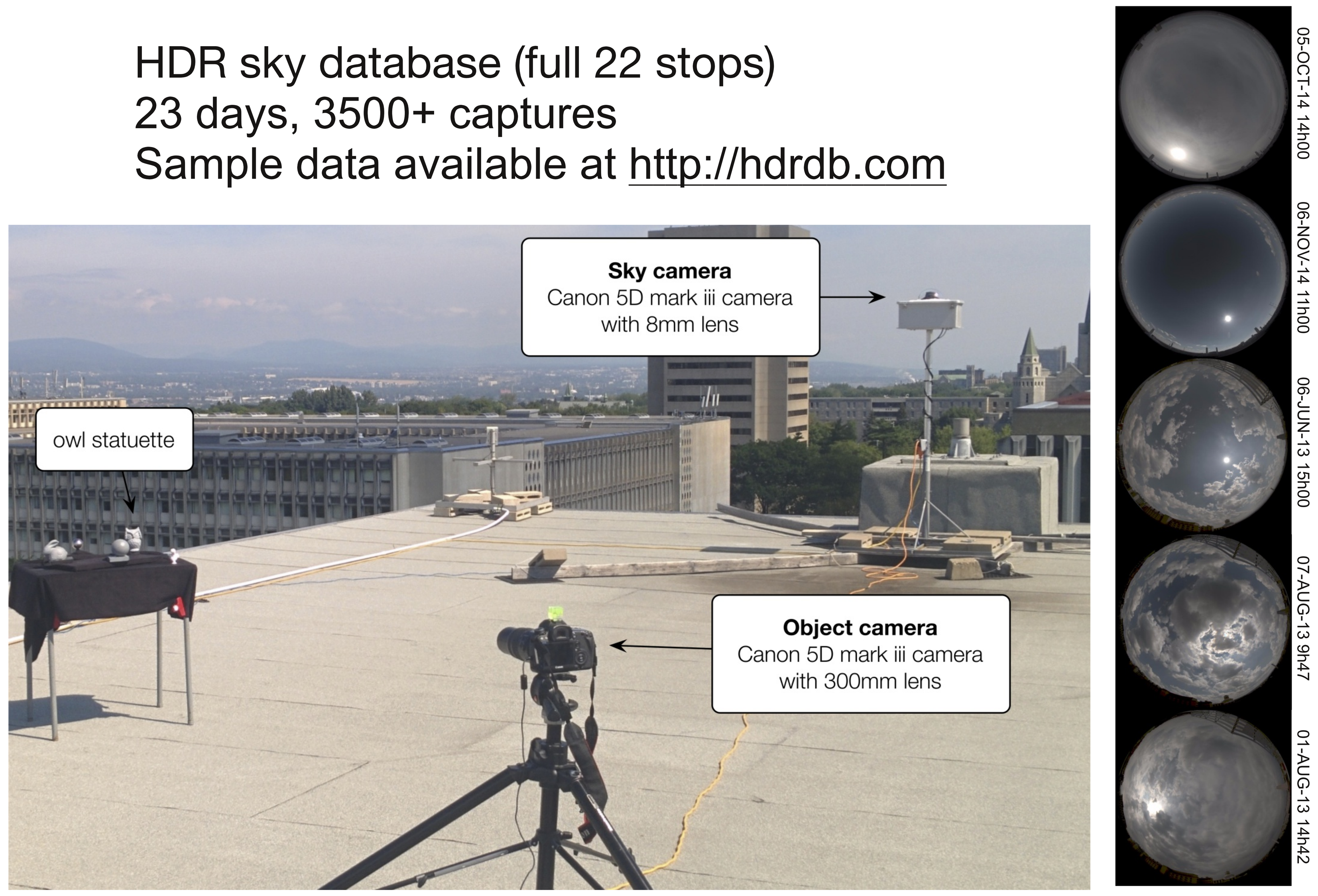
Motivation

Analyze the conditioning of outdoor Photometric Stereo (PS)

How does performance behave in very short intervals, in response to events in the sky?

Data

HDR sky database (full 22 stops)
23 days, 3500+ captures
Sample data available at http://hdrdb.com



Performance measure

Given the stack of light vectors $\bar{\mathbf{l}}_t$ associated with images b_t of a surface patch, and assuming Lambertian reflectance, the PS constraints on normal $\mathbf{n}$ are:

$$\mathbf{b} = \begin{bmatrix} b_1 \\ b_2 \\ \dots \\ b_m \end{bmatrix} = \begin{bmatrix} \bar{\mathbf{l}}_1^T \\ \bar{\mathbf{l}}_2^T \\ \dots \\ \bar{\mathbf{l}}_m^T \end{bmatrix} \mathbf{n} = \mathbf{L}\mathbf{n}$$

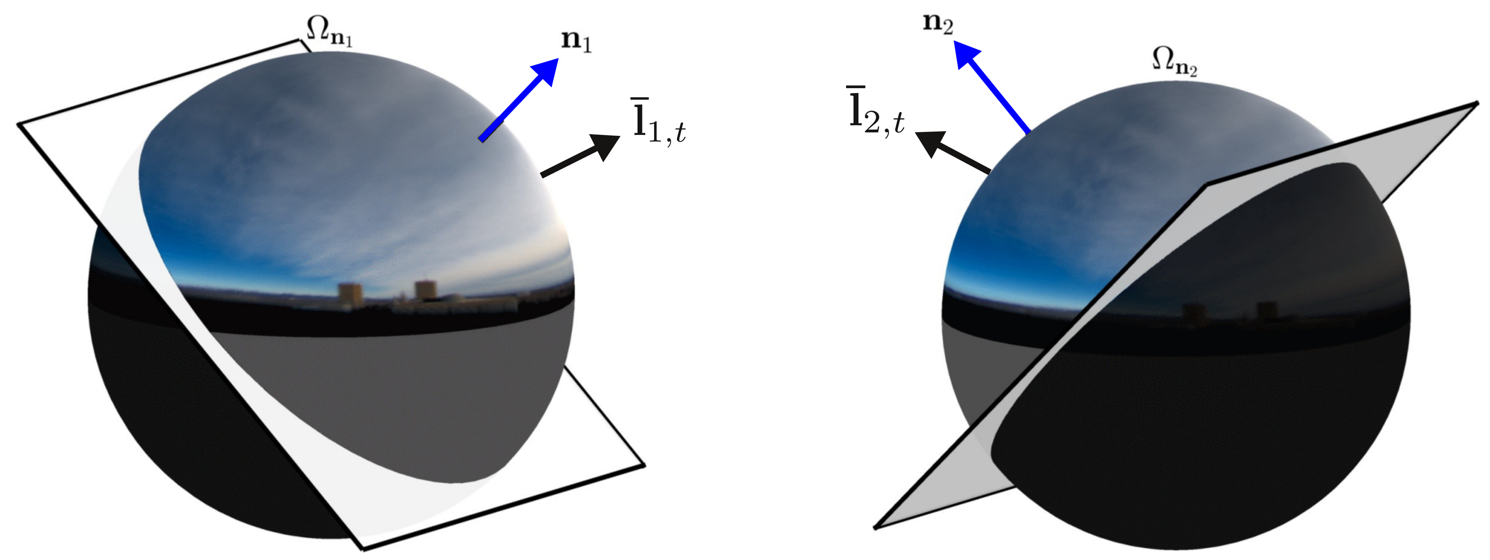
We define an uncertainty measure (noise gain) that is akin to the condition number of $\mathbf{L}$ (smaller is better).

Goal

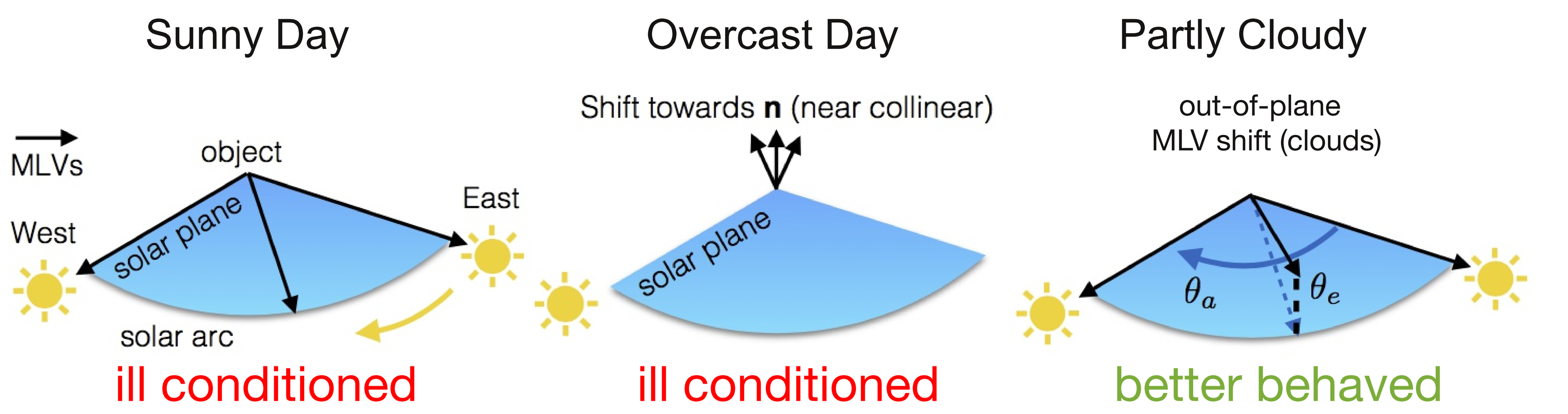
Why does outdoor Photometric Stereo work?
Can it work in x hours?

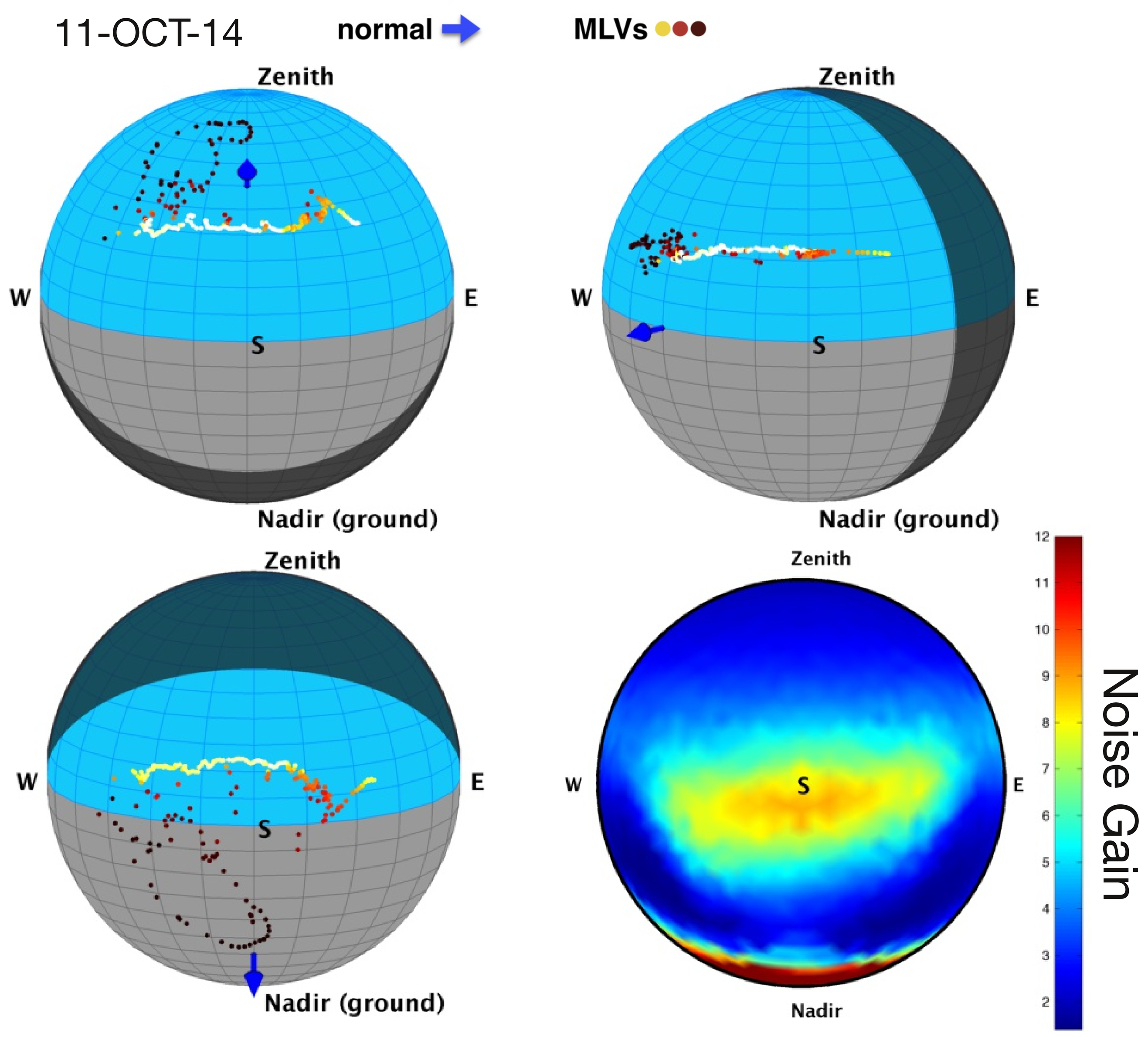
Mean Light Vectors (MLVs)

A surface patch sees a hemisphere of incoming light vectors.
We compute an MLV ($\bar{\mathbf{l}}_t$) for each patch (normal) and time t.



Over a time interval, the surface is lit by a sequence of MLVs, equivalent to virtual point light sources.





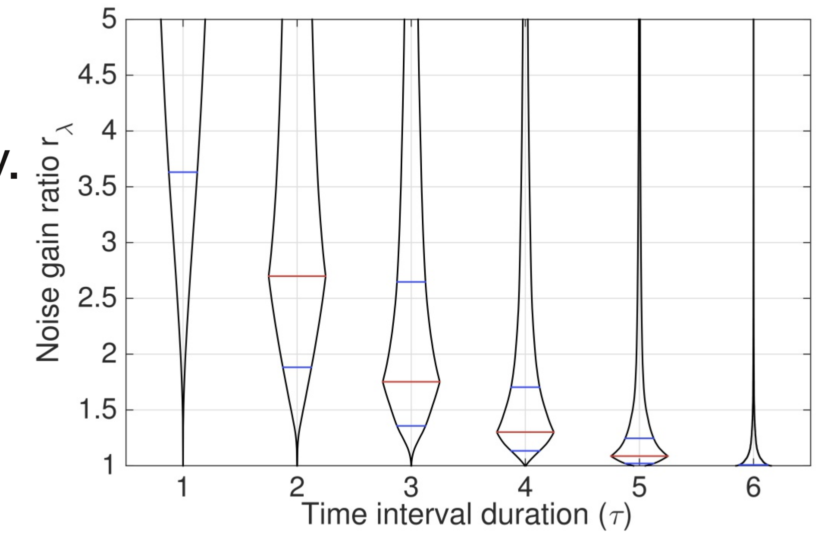
Zero-crossing region where MLV shifts are predominantly along the sun trajectory.

Nearly horizontal normals present the least shifting.

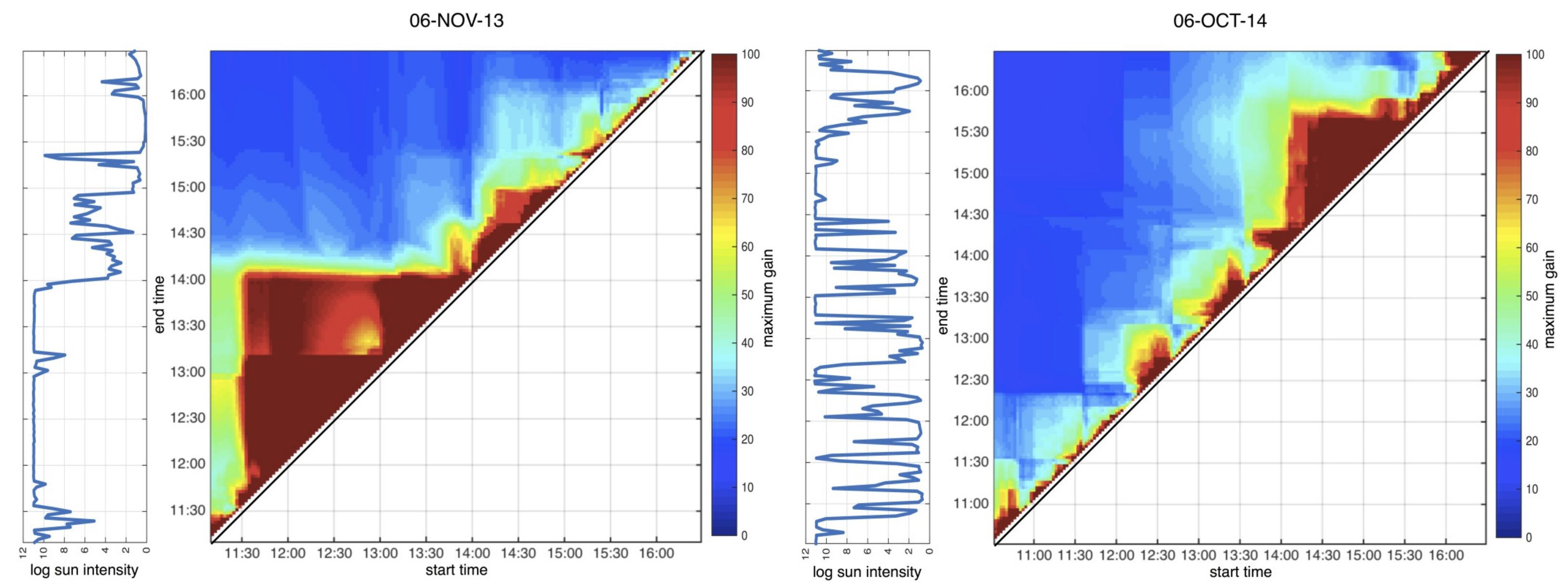
Full database analysis

Noise gains normalized by best (minimum) gain over all possible intervals on that day.

Suggests that short intervals often provide similar performance (under 2x gain).

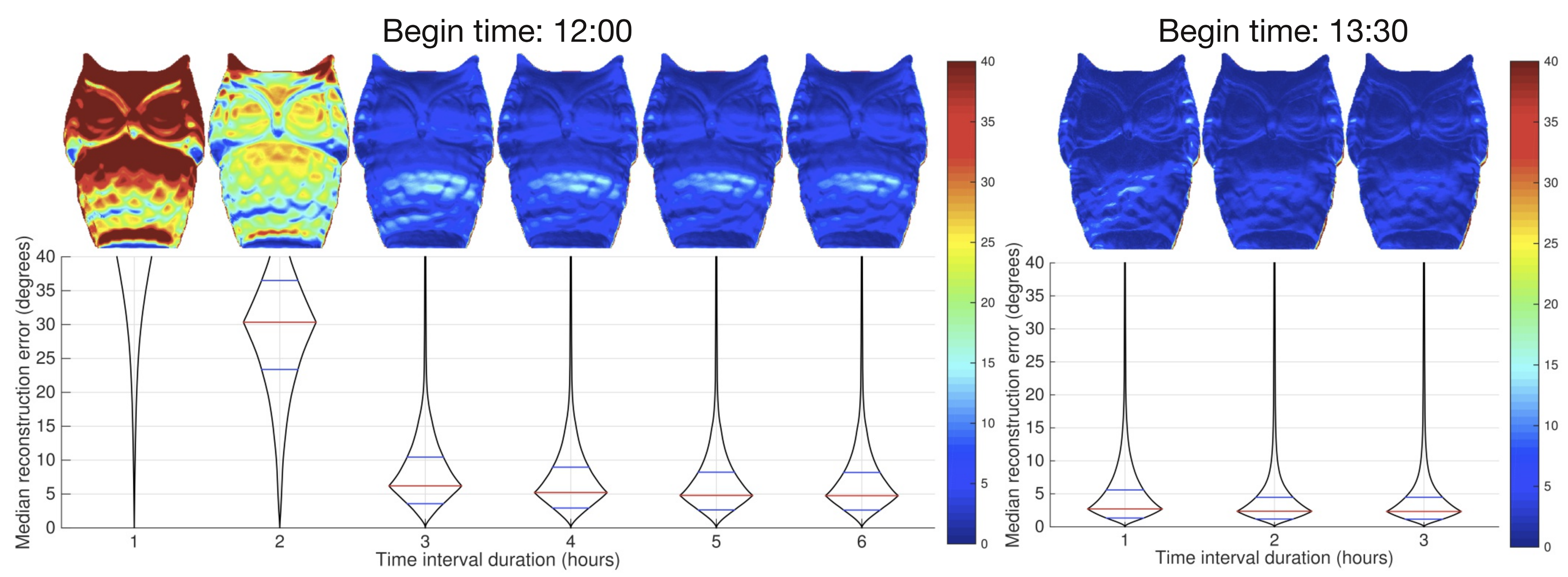


Fine-grained analysis



Results on synthetic data

Real sky probes, no inter-reflections, highlights or cast shadows.



Results on real data