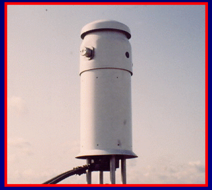
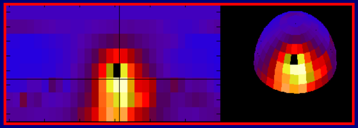
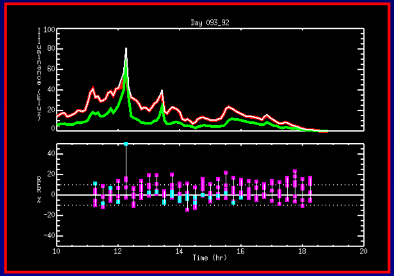
A 'GOLD STANDARD' DATASET FOR THE VALIDATION OF ILLUMINANCE PREDICTIONS

 +  →  → 

Dr. John Mardaljevic
jm@dmu.ac.uk

Institute of Energy and Sustainable Development
De Montfort University
Leicester, UK

Joint IEA 31 - CIE 3.33 Meeting NRC·CNRC Ottawa, October 2002

http://www.iesd.dmu.ac.uk/~jm

BACKGROUND

Physical modelling techniques predate all other methods to assess the provision of daylight illumination.

In principle, the quantity and distribution of daylight illuminance in a (perfect) scale model should be identical to that for the full-sized building under the same conditions.

Mirror-box artificial skies provide consistent - if somewhat idealised - luminous conditions to assess models, i.e. using the daylight factor approach.

Physical modelling is widely accepted as a ‘benchmark’ method, i.e. it provides the ‘truth model’ data against which the accuracy of other techniques is judged.

LEGACY

The accuracy of physical modelling is assumed - without question - by many researchers and practitioners.

Validation tests are invariably designed to use the CIE Standard Overcast sky pattern as the luminous source.

The (venerable) daylight factor approach, despite its manifest limitations, persists as the standard assessment method.

Dominated by decades-old ideas, perhaps daylighting research itself became somewhat moribund.

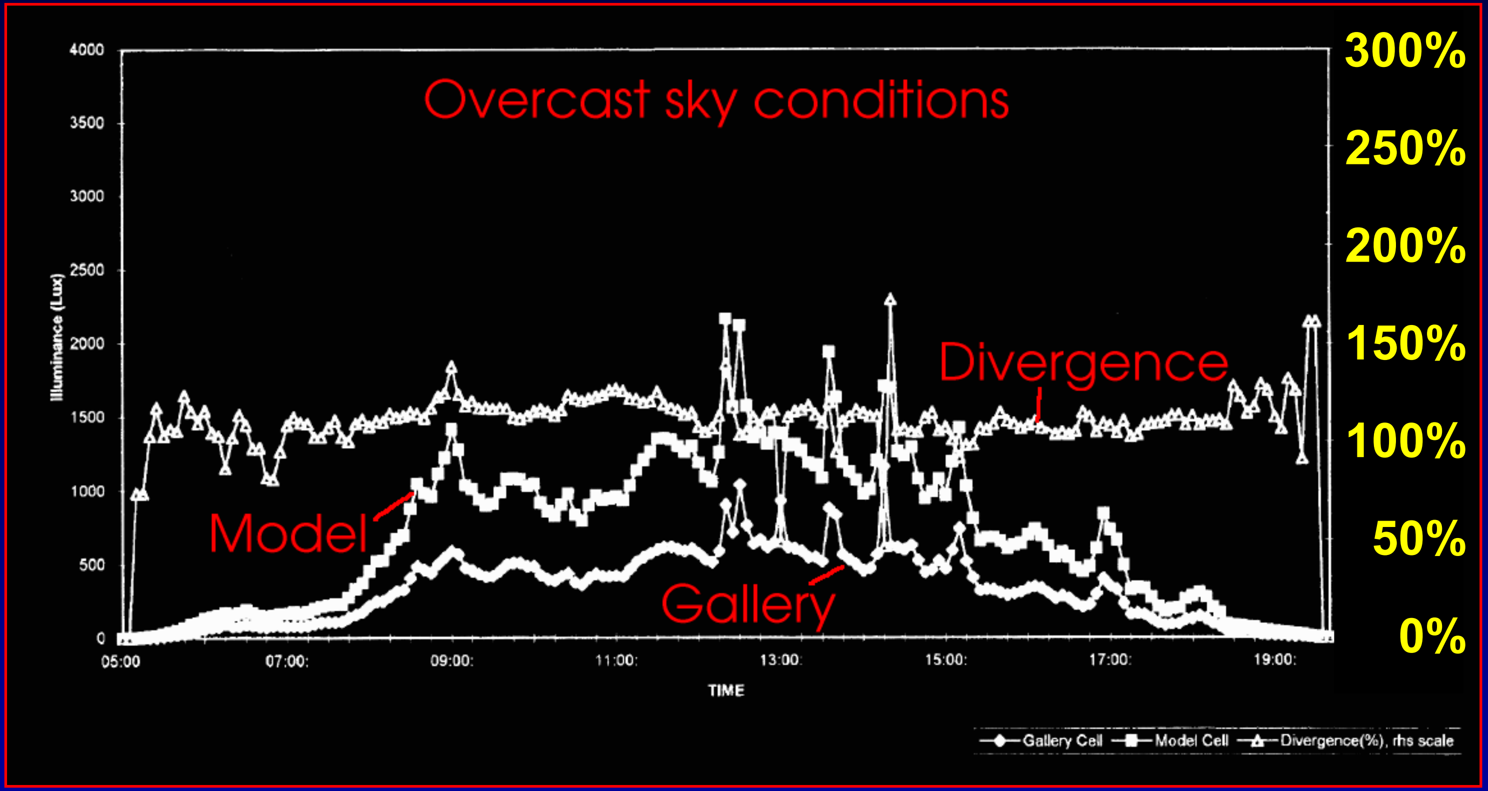
The role of daylighting in architectural design has never achieved the prominence that perhaps it should.

Cracks in the Edifice

Cannon-Brookes' definitive study (1997) revealed that imprecision in scale model construction can lead to large errors in measured illuminances.

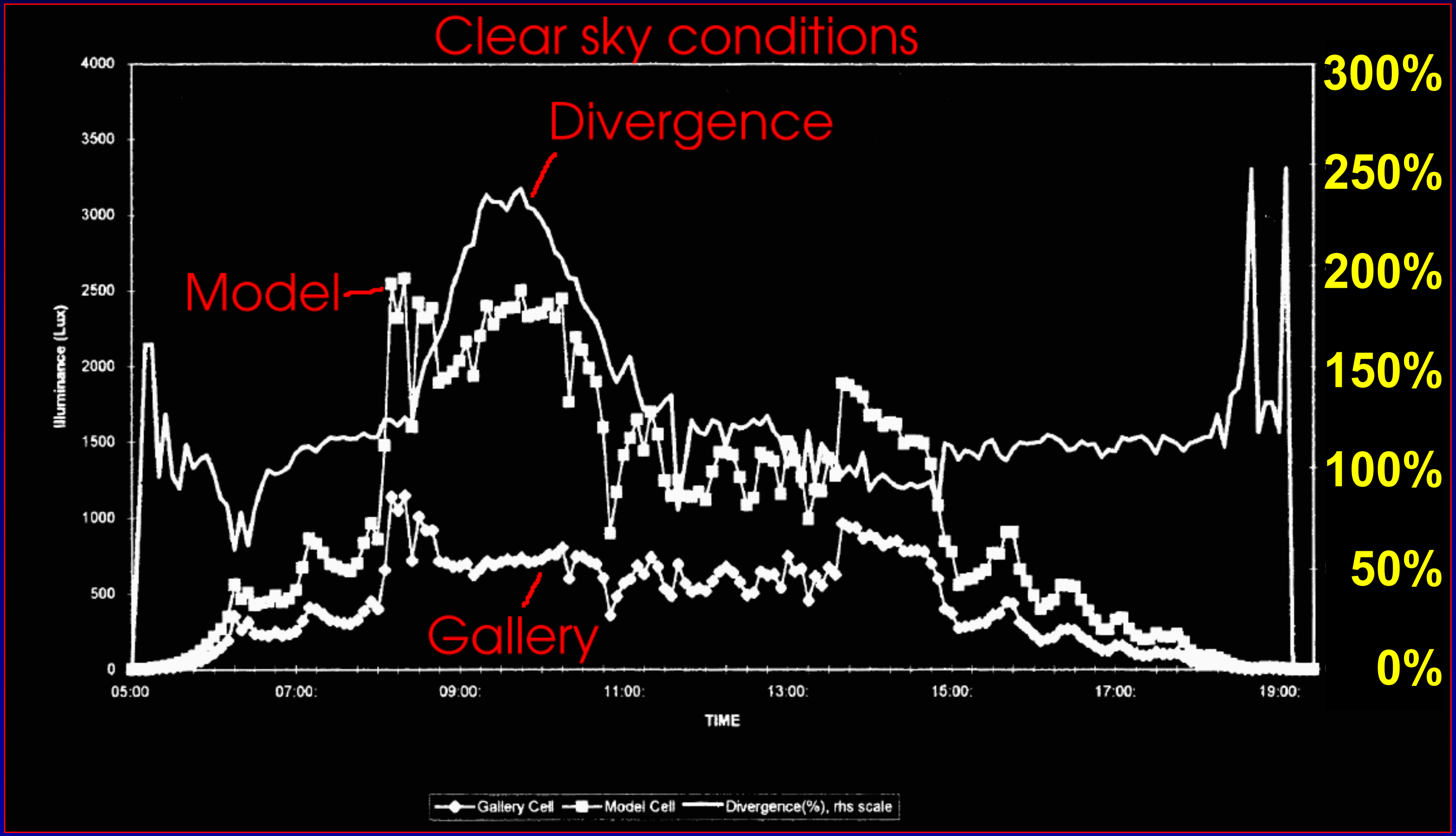
- Study compared scale model illuminances measured simultaneously with those in a full-sized building under a variety of real sky conditions.
- The physical model was constructed to a precision 'greater than that normally used' in lighting studies.
- For overcast skies, model illuminances were ~50% greater than for the real building.
- For clear skies, model illuminances were 100-250% greater than for the real building.

Plots From Cannon-Brookes' Study - Overcast



Divergence typically 80-100%

Plots From Cannon-Brookes' Study - Clear Sky



Divergence typically 100-250%

Possible Causes for the (Very) Large Errors

Cannon-Brookes' considers that the very large differences between actual and scale model illuminances were caused by one or more factors:

- Large illuminance gradients on the scale of the photometer diameter - reading sensitive to tiny displacements.
- For the scale model, glazing dimensions and surface reflectivities were greater than they should be.
- Correction factors for frame bars etc. are generally under-estimated.

He recommends that, in any future study, models should be built to larger scales using much greater precision.

MEANWHILE...

A lot was happening in many daylight-related fields of research - theoretical, computational, applied and metrology.

- Tregenza's daylight coefficient approach - a theoretical approach to efficiently predict time-varying illuminance.
- Physically-based lighting simulation packages, e.g. *Radiance* and Genelux.
- Manufacturers were developing various advanced glazing systems, e.g. mirrored louvre, prismatic film, electrochromic, etc.
- Sky luminance distributions were being measured at a number of sites around the world (IDMP).

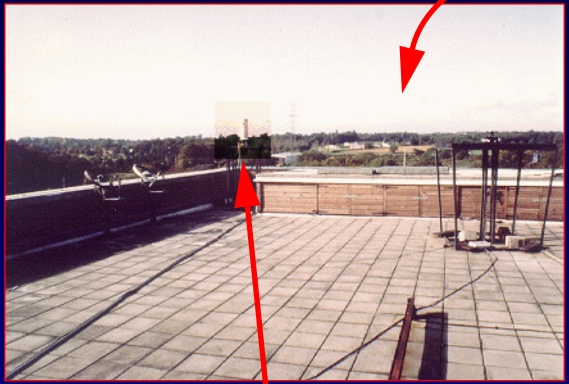
AT ONE OF THE IDMP SITES...

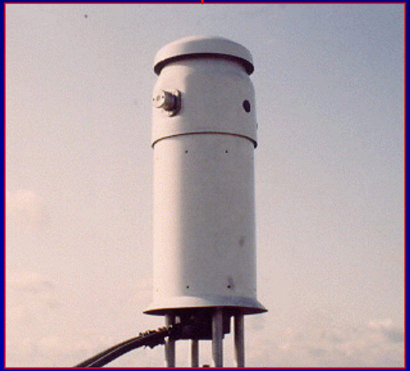
Namely the BRE (Garston, UK), internal illuminance in two full-sized offices was recorded simultaneous with measurements of the sky luminance distribution (and other parameters). This is the **BRE-IDMP Validation Dataset**.

The dataset contains:

- Sky luminance measured at 145 ‘patches’.
- Direct normal illuminance.
- Internal illuminance measured at six points for:
  - Office with clear glazing.
  - Office with various advanced glazings.
- Vertical N, E, S & W illuminance, temp., humidity, etc.

PHOTOGRAPHS OF THE BRE-IDMP SITE





Krochmann sky scanner

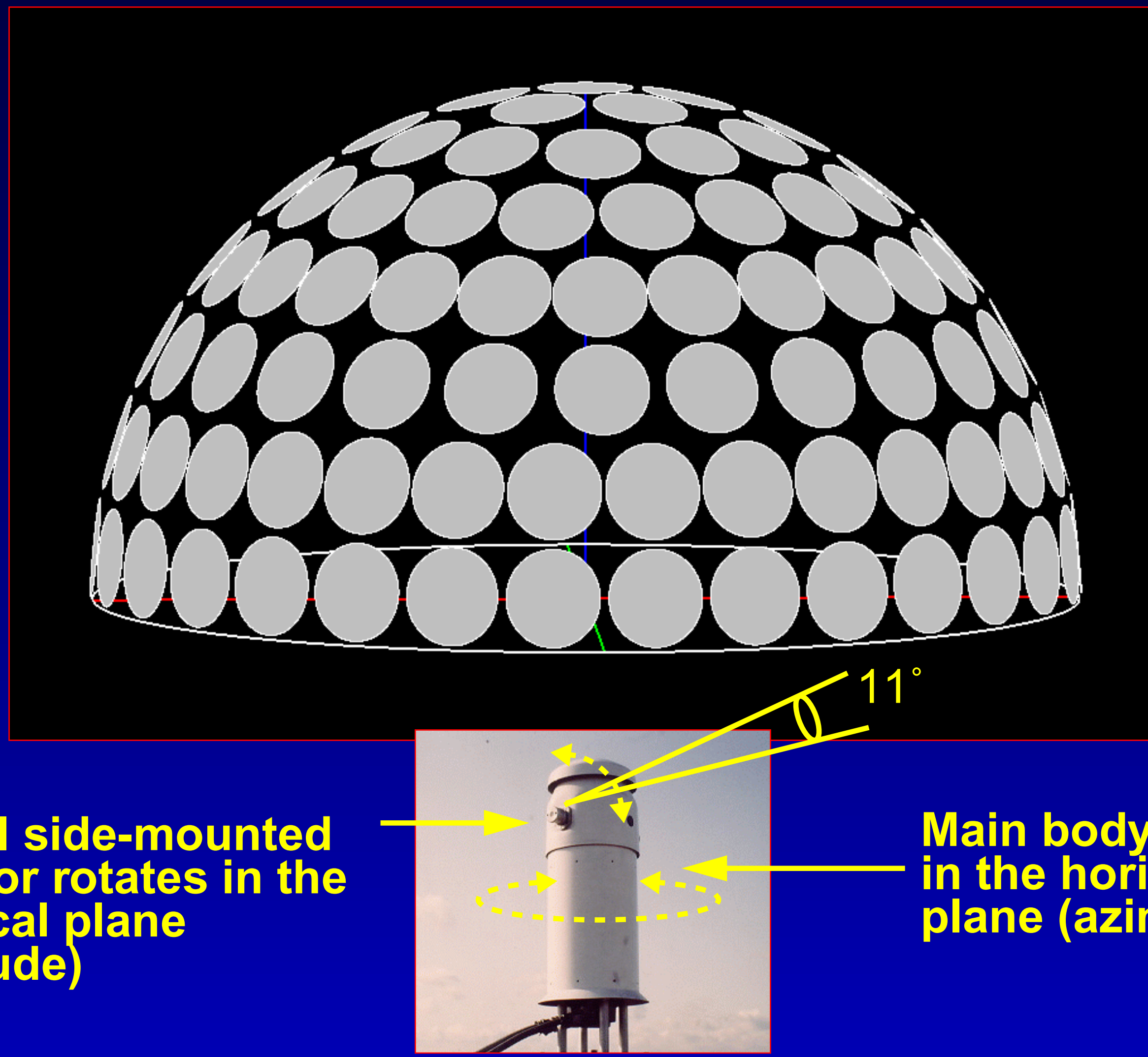
Building 9

Office with clear glazing

SCANNER MEASUREMENT PATTERN

145 patches

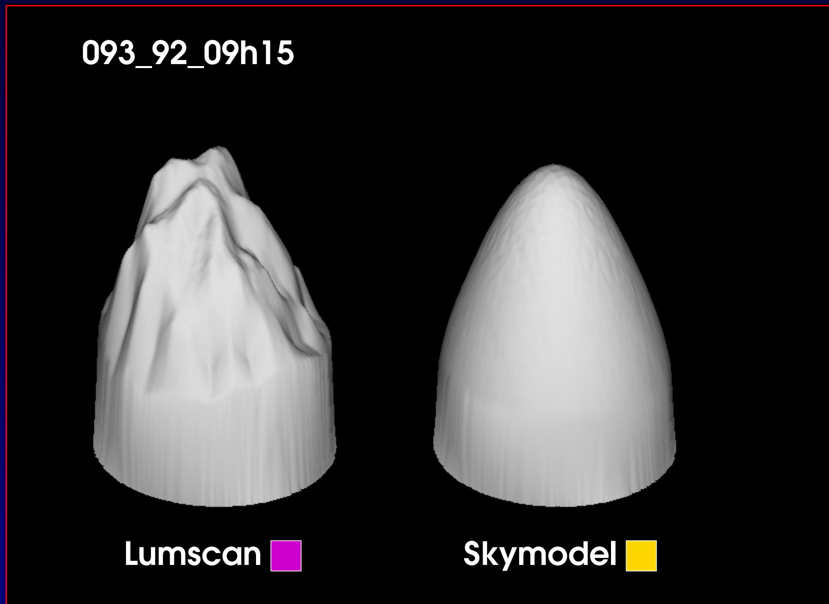
~68% coverage

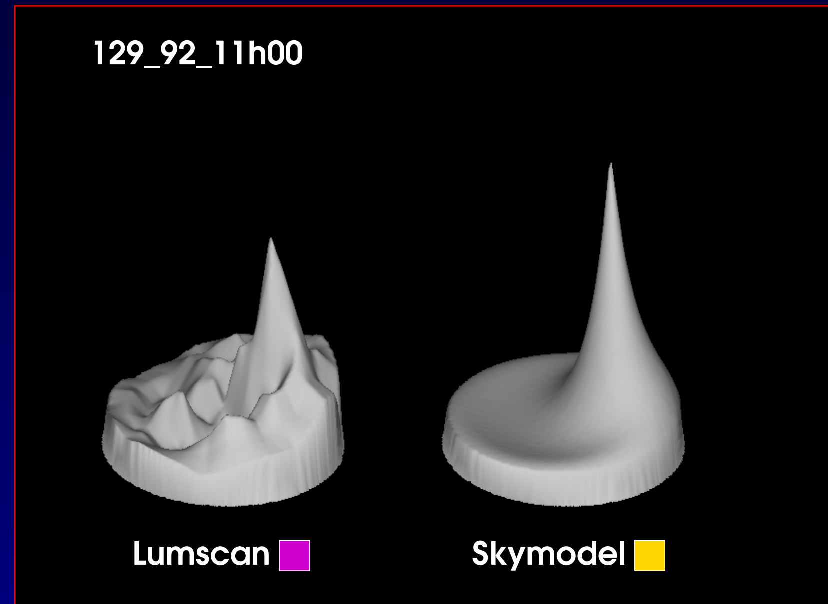


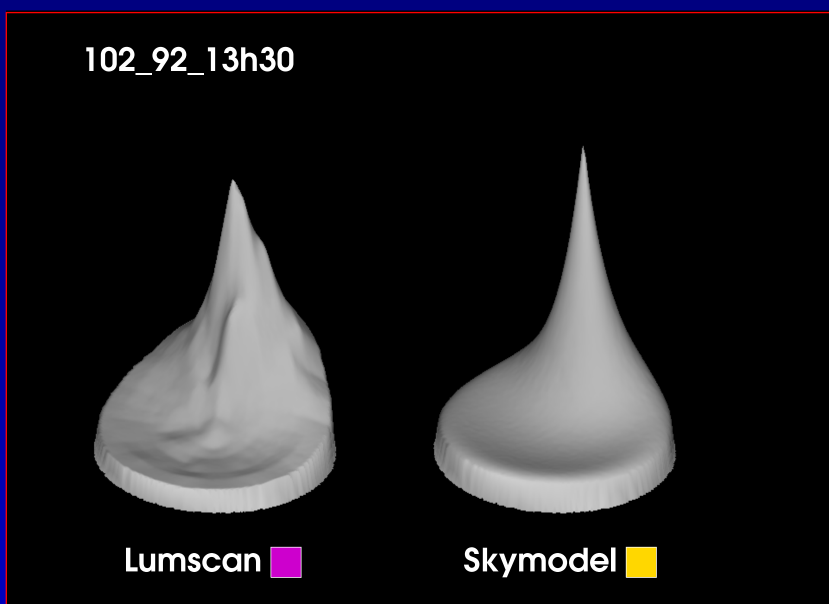
Small side-mounted sensor rotates in the vertical plane (altitude)

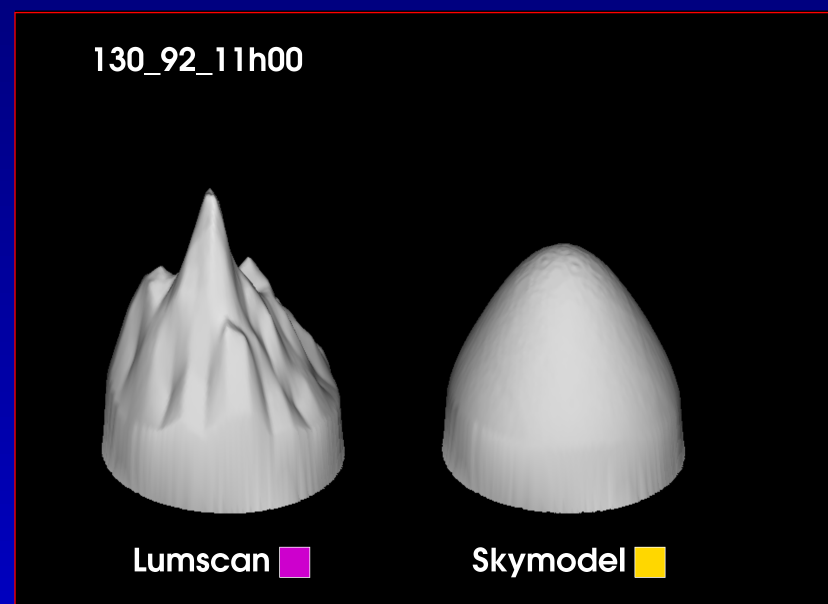
Main body rotates in the horizontal plane (azimuth)

Real and Modelled Sky Luminance Patterns









The BRE-IDMP Validation Dataset

It is a unique dataset - the only one with simultaneous measurements of internal illuminance in full-sized offices and sky luminance distributions.

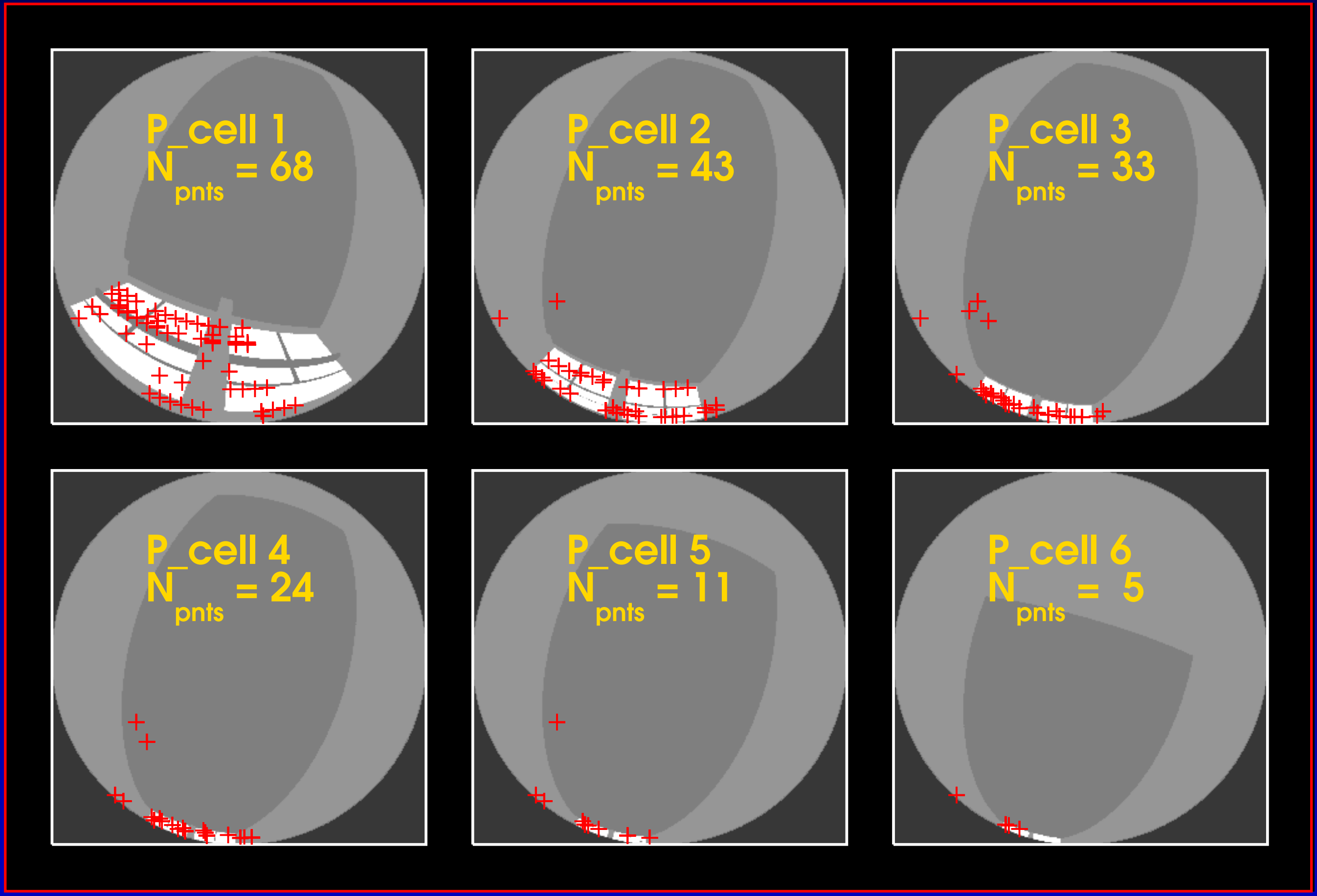
With this dataset it is possible to specify to an unprecedented degree of precision the conditions at the time of measurement.

A set of 754 skies, covering a wide range of naturally occurring sky conditions, have been used to validate the *Radiance* lighting simulation program.

The dataset is complex - potentially unreliable entries need to be identified and filtered out. This work has been done, the datasets' characteristics are fully understood and documented. It is ready for wider application.

Source Visibility Related Errors (SVRE)

Routine application of the dataset (validation of *Radiance*) revealed that high relative error predictions (|RER| > 50%) were associated with visibility of the circumsolar region.



Causes of the Source Visibility Related Errors

They could be due to any one or more of the following:

- The finite resolution of the sky luminance data, i.e. average luminance in 11° 'cone'. Also, the scanner did not measure the sky luminance at the sun position.
- Imprecision in the geometrical specification of the office. A photocell actually in shade could be predicted to be in sun, or vice-versa.
- Single ray light source sampling of the sun - solar penumbra not computed in the simulation.
- Photocell modelled as a point - partial shading (i.e. partial response) not modelled.

Note these are distinct in origin, but similar in effect.

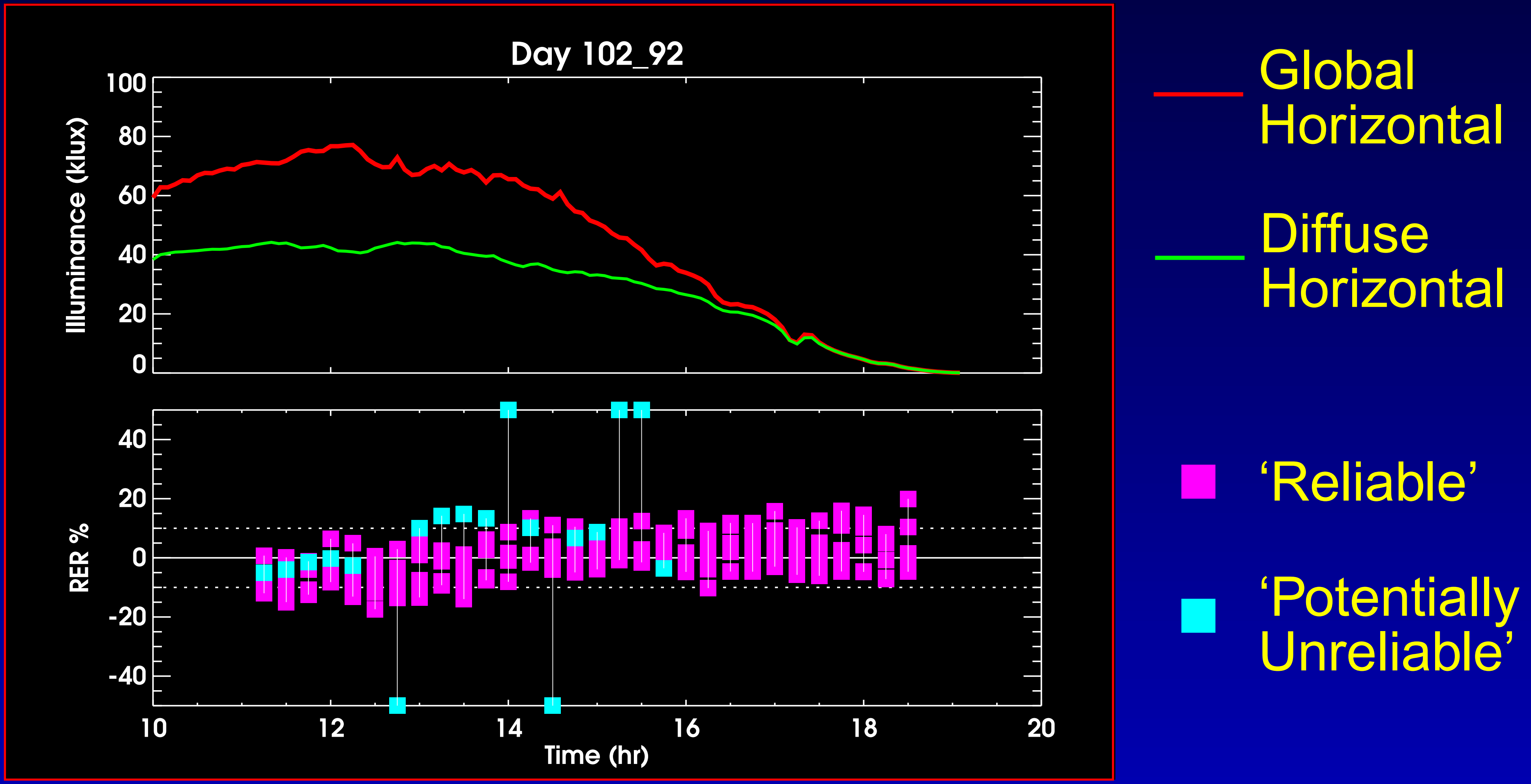
Filtering of the BRE-IDMP Validation Dataset

The data entries that are likely to be affected by source visibility related errors are those where the (BRE office) photocell can ‘see’ the circumsolar region. The solution is to identify and exclude them from the validation.

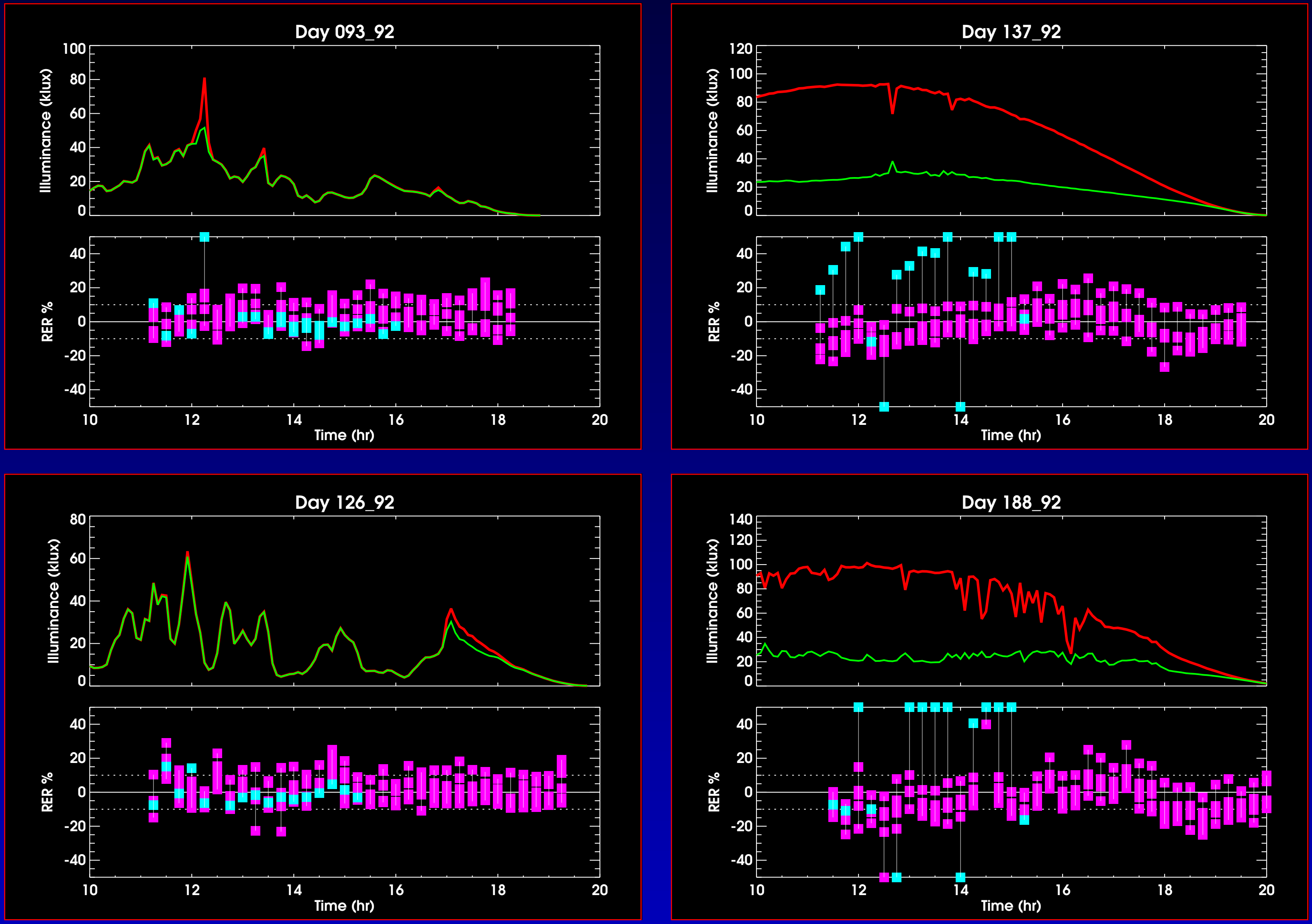
Note that this does not in any way weaken the validation. The direct component of illuminance is relatively trivial to compute. However, to compute it accurately (where the photocell ‘sees’ the circumsolar region) the luminance distribution around the sun must be known to an unattainable degree of accuracy. And the 3D office model must be an exact representation of the actual office.

In fact, filtering biases the data to those instances where (difficult to compute) inter-reflection dominates.

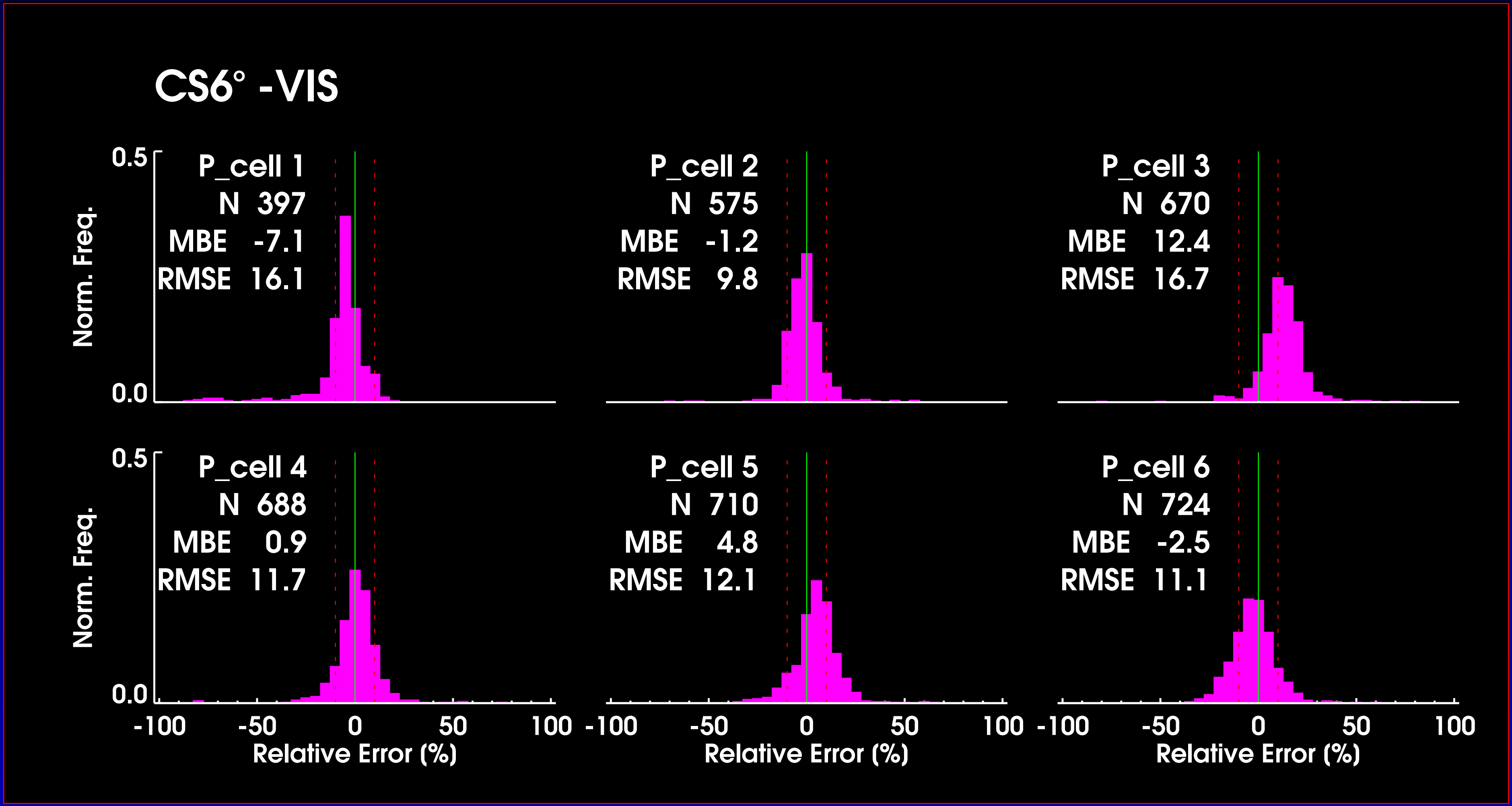
RESULTS FROM THE *RADIANCE* VALIDATION



RESULTS (CONTINUED)



HISTOGRAM PLOT - 'RELIABLE'



NOTES ON THE *RADIANCE* VALIDATION

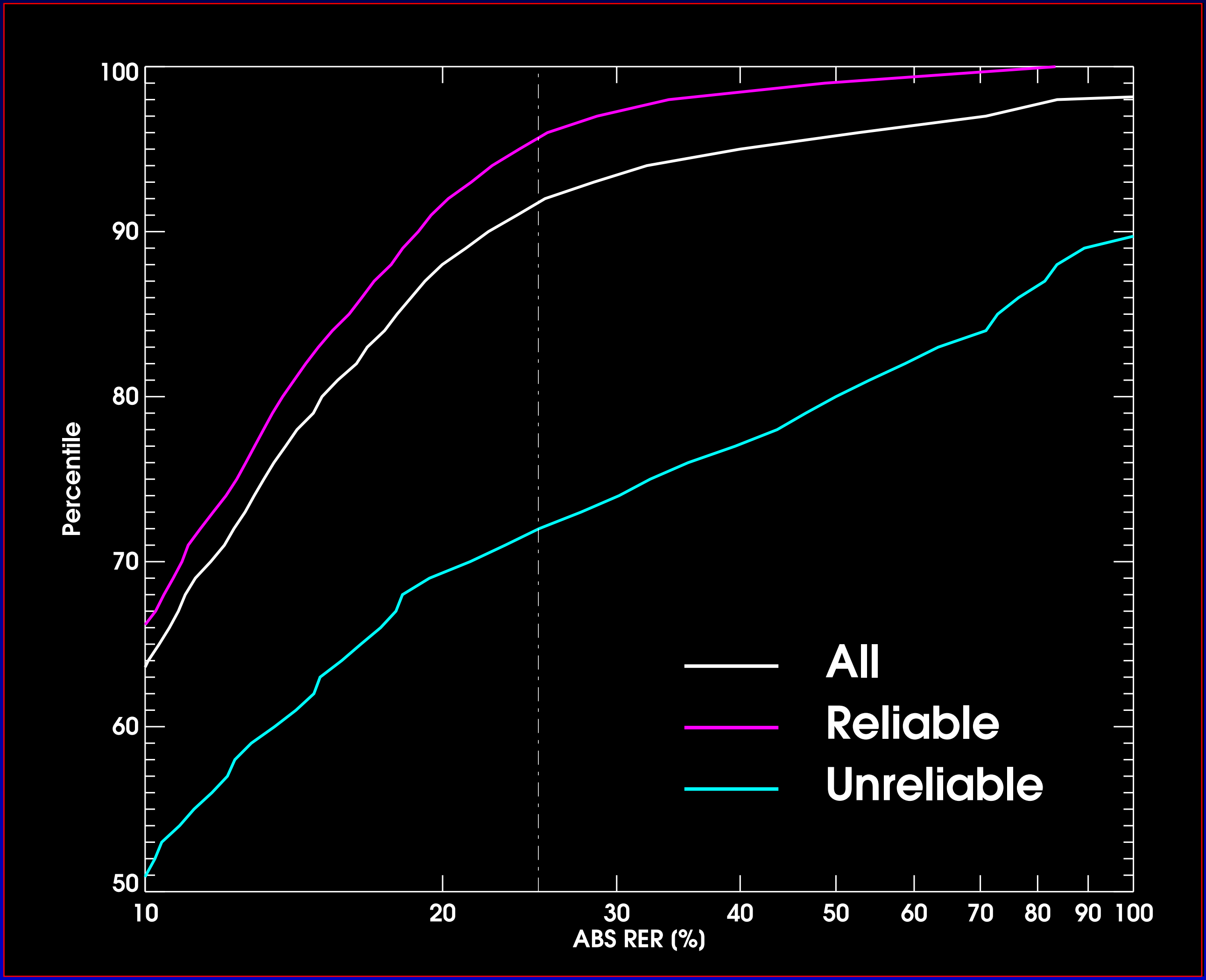
The parameters for the office model were either directly measured (surface reflectivities & dimensions) or based on product data (glazing transmittance). The original values were used throughout the validation - no ‘tweaking’ of values to ‘hunt’ for accurate predictions was carried out.

It is likely that photocell 3 suffered from a calibration error producing a positive offset in the MBE (12%).

A few outliers remain in the ‘reliable’ subset. These are most likely due to model representation (e.g. change in sky conditions during scan, spurious reflections from puddles or snow, etc.) rather than the underlying accuracy of the simulation program.

Assessment Criteria

A few outliers with large RERs skew the MBE and RMSE. Instead, use percentiles to assess program accuracy.



PROPOSAL I

It is proposed that the BRE-IDMP dataset should be considered the benchmark for the validation of daylight illuminance prediction techniques.

USE OF THE BRE-IDMP DATASET

The BRE give permission to use the data free of charge provided:

- The data are used for research purposes only; and
- The data are not given, transferred or sold, whether in original or modified form, to third parties without consent.

The BRE have authorised the IESD to distribute the dataset of 754 skies that were used for the *Radiance* validation in accordance with the conditions noted above.

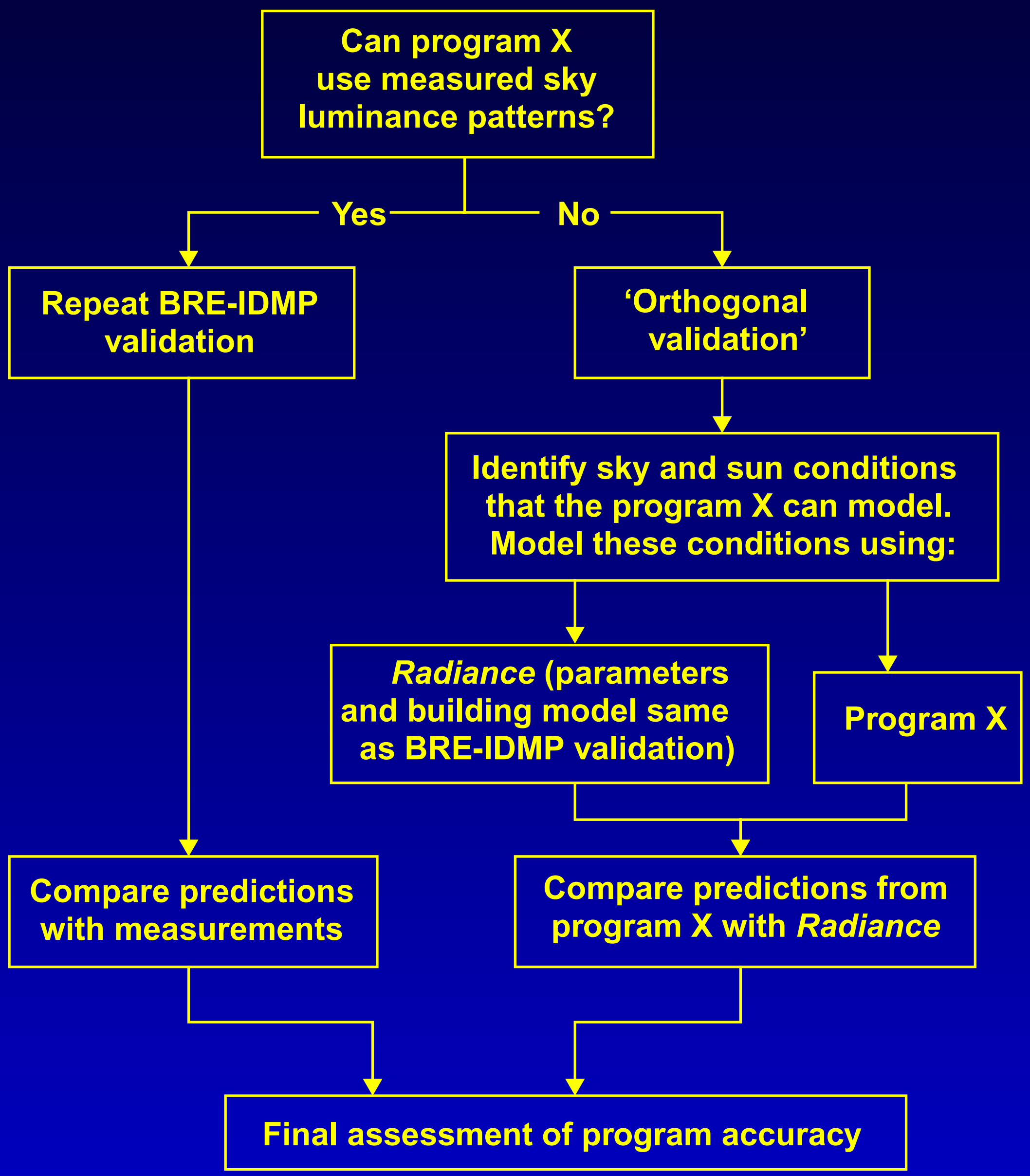
In addition, the IESD will make available the 3D model of the BRE office room.

PROPOSAL II

The *Radiance* program should be considered the benchmark lighting prediction technique - at least until greater accuracy has been proven for other methods/programs.

Orthogonal Validation

Procedure for when a program cannot use the BRE-IDMP dataset



SUMMARY

Validation under ‘realistic’ conditions is a commonplace activity in thermal modelling research. For daylighting however it is still relatively novel.

The BRE-IDMP dataset has been proven to be the most reliable dataset for the validation of illuminance predictions.

The IEA 31 and CIE TC 3.33 tasks provide the opportunity to define new benchmarks founded on the BRE-IDMP dataset.

Validation carried out using the BRE-IDMP dataset will enhance the credibility of computer programs that can be proven to accurately model real-world conditions.