update of the *RT codes* theme

Jean-Luc Widlowski

IVOS theme on RT codes

"Focus is on activities that verify the quality of RT models or where validated RT models are used to assess the quality of retrieval algorithms and cal/val methodologies."

- atmosphere: I3RC (clouds – late 1990s)
- land: RAMI (vegetation – late 1990s)

so far RT models are physics-based

RAdiative transfer Model Intercomparison

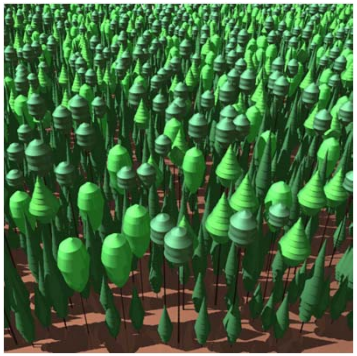
To assess the quality of the physics contained in RT models one must work under fully controlled experimental conditions:

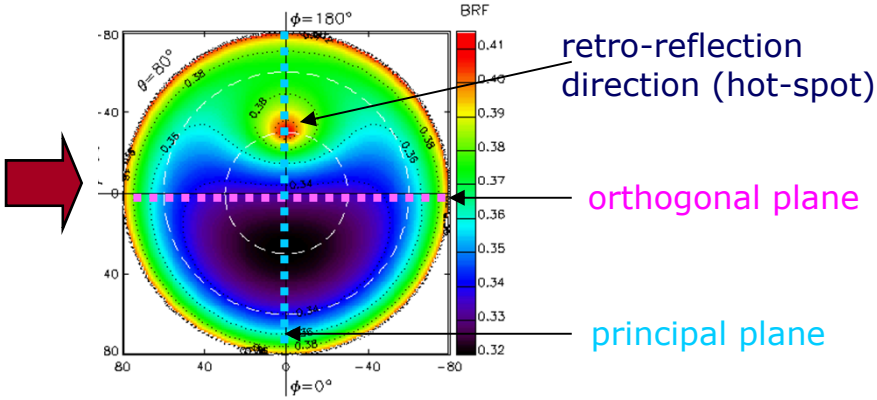
- plant & canopy architecture
- spectro-directional properties
- illumination conditions

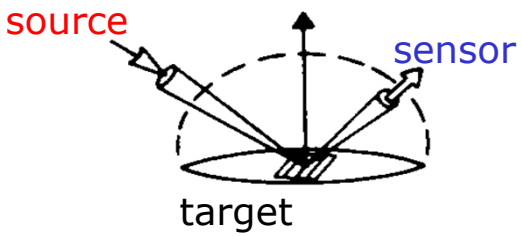
Must also verify sub-components of target RT quantities

RAMI evaluates RT models in forward mode (no atmosphere)

$$BRF_{\Omega_0,\Omega} = \frac{\Phi_{\Omega_0,\Omega}(target)}{\Phi_{\Omega_0,\Omega}(Lambertian)}$$







Pinty et al. (2001, 2004) JGR; Widlowski et al., (2007) JGR

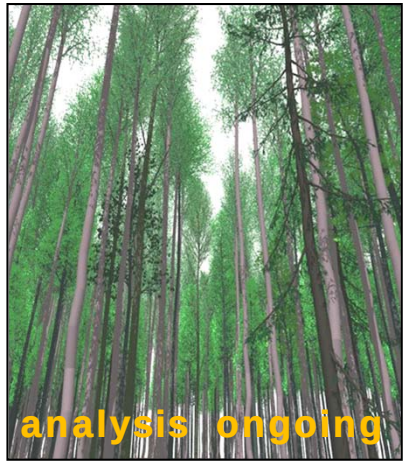
RAdiative transfer Model Intercomparison

community standard

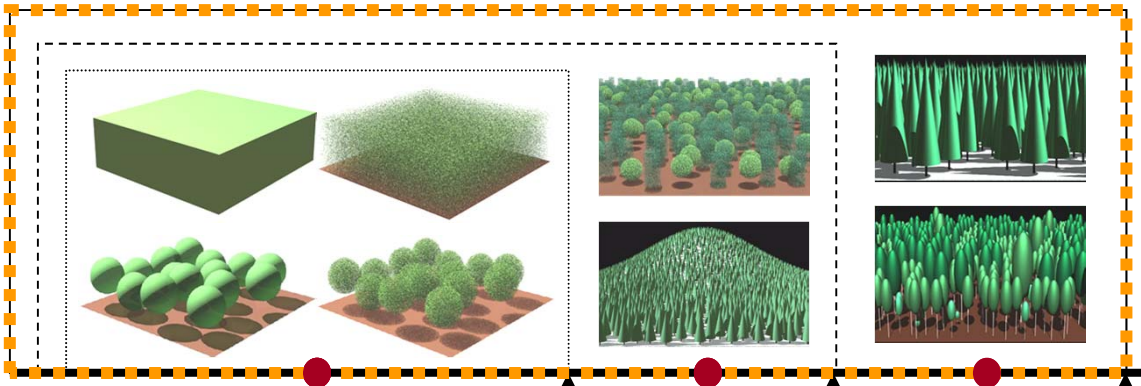
automate benchmarking process

increased realism

summer birch stand



RAMI On-Line Model Checker (ROMC)



reference data set

(2007)

RAMI-1 (1999)

RAMI-2 (2002)

RAMI-3 (2005)

RAMI-IV (2009/10)

8 models

substantial differences amid 1D and 3D models

13 models

still differences amid the 3D models

18 models

excellent agreement; especially for 3D MC models

Set of 6 'credible' 3-D Monte Carlo models (~1% deviation)

- satisfy energy conservation
- identical to analytical solutions
- versatile and few assumptions

Pinty et al. (2001, 2004) JGR; Widlowski et al., (2007) JGR, (2008) RSE, (2013) JGR – under review

RAMI On-line Model Checker

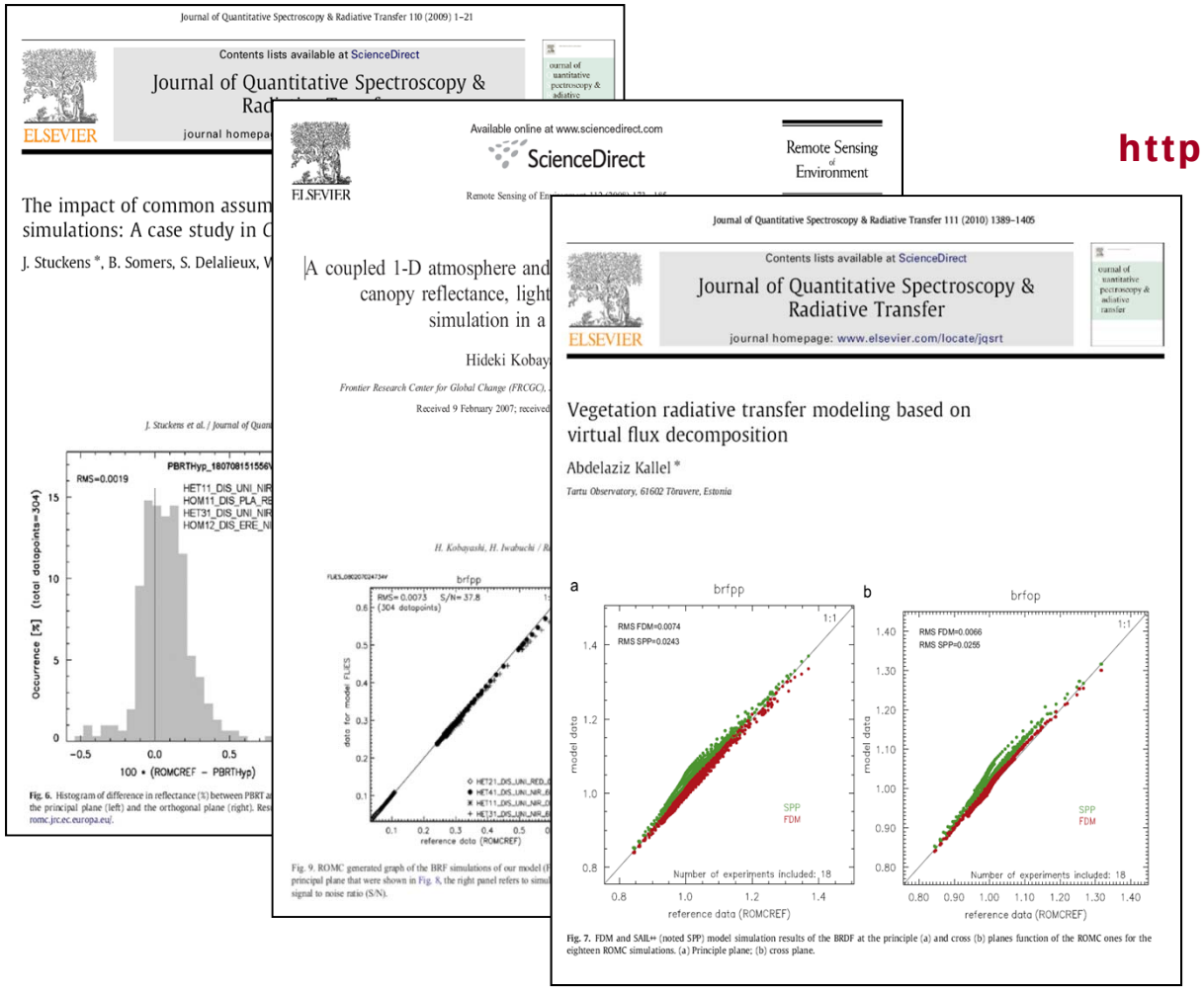


Fig. 6. Histogram of difference in reflectance (%) between PBRT a the principal plane (left) and the orthogonal plane (right). Res romc.jrc.ec.europa.eu[.

Fig. 9. ROMC generated graph of the BRF simulations of our model (F principal plane that were shown in Fig. 8, the right panel refers to simu signal to noise ratio (S/N).

Fig. 7. FDM and SAIL++ (noted SPP) model simulation results of the BRDF at the principle (a) and cross (b) planes function of the ROMC ones for the eighteen ROMC simulations. (a) Principle plane; (b) cross plane.

http://romc.jrc.ec.europa.eu/

Currently 33 models registered in ROMC

Plan: 2013 – 2014

New test cases:
- RAMI4PILPS
- RAMI-IV
- MetEOC

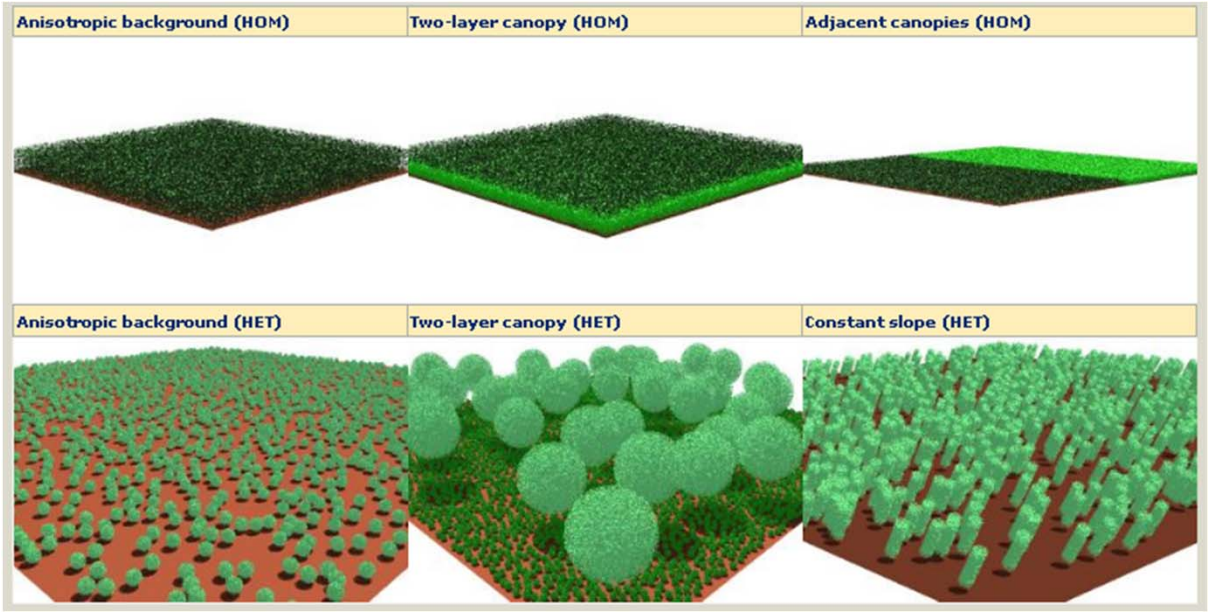
New functionalities:
- more graph types
- better interface
- user vs modeler

The ROMC enables users to autonomously assess the quality of RT models in quasi real time against the reference data from RAMI-3.

Widlowski et al., 2008 (RSE);

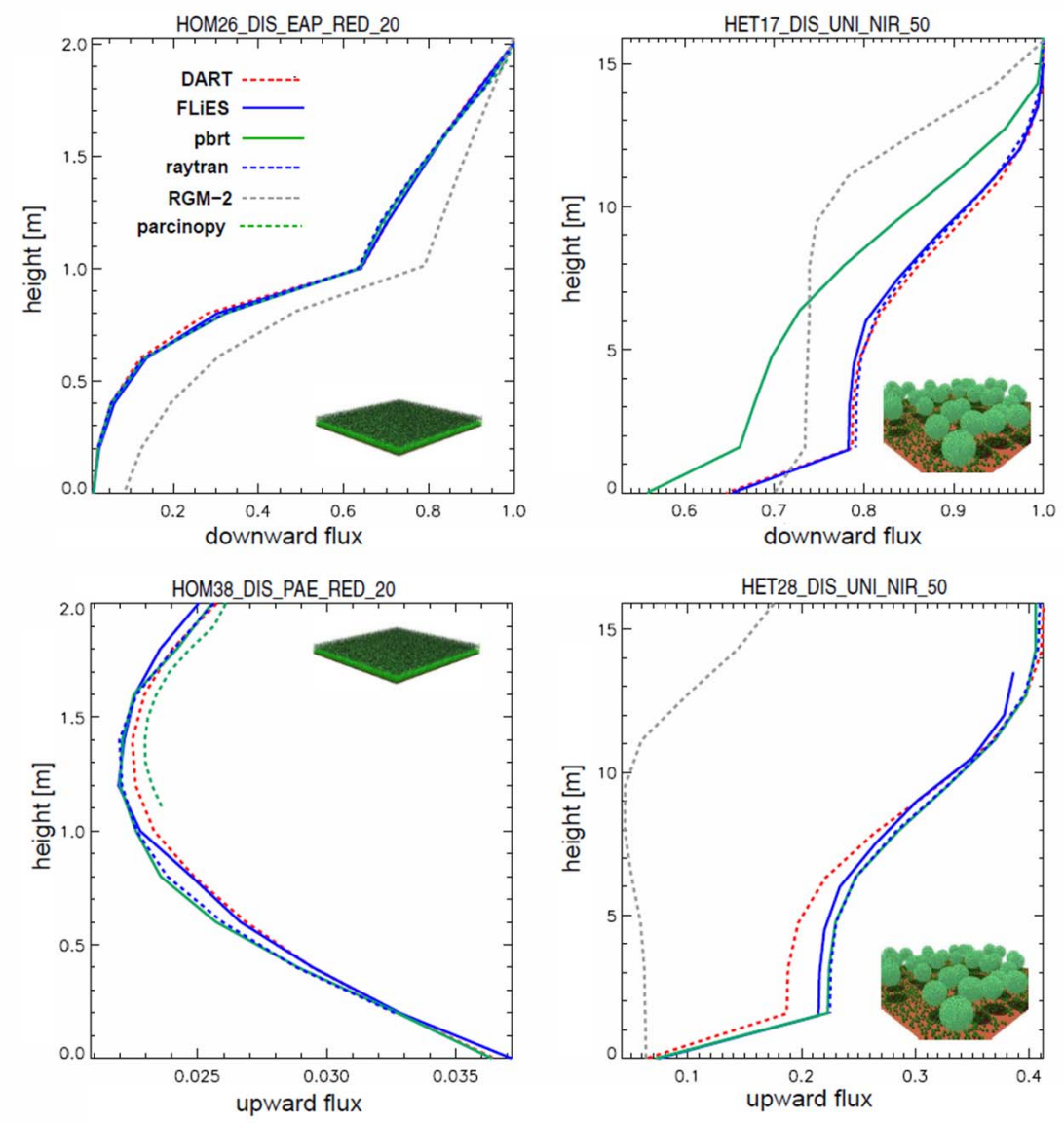
RAMI-IV

- Manuscript with results from 4th phase submitted
- Focus is on 'abstract' test cases & use of ISO-13528

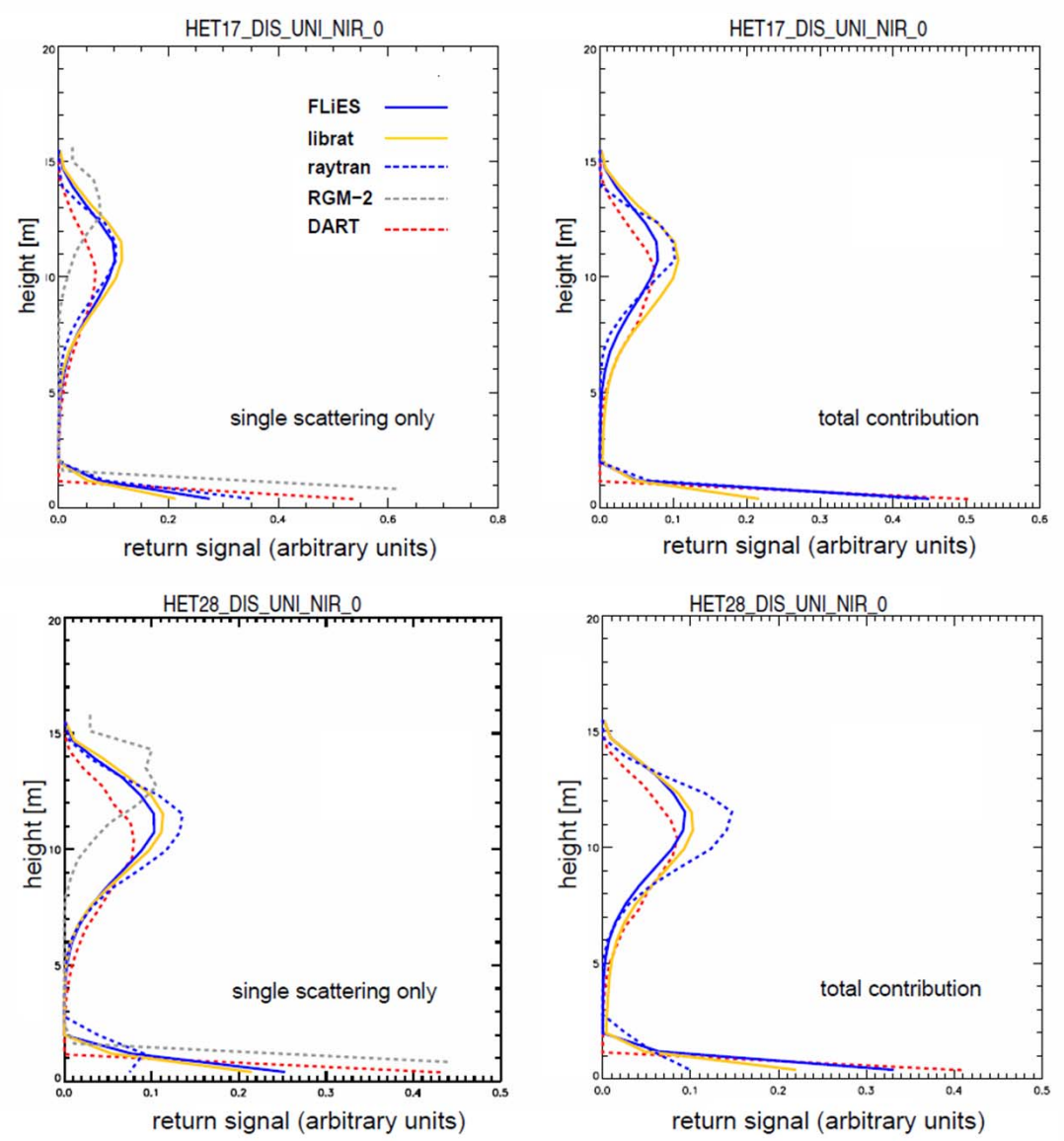


- Some stats:
  - Received files: 95,443 (BRF: 58,356; fluxes 31,218; vprof: 5869)
  - Number of unique BRF simulations: 1,628,148 (21,423 files)
  - Number of unique vprof simulations: 66,759 (2,023 files)

vertical transmission profiles

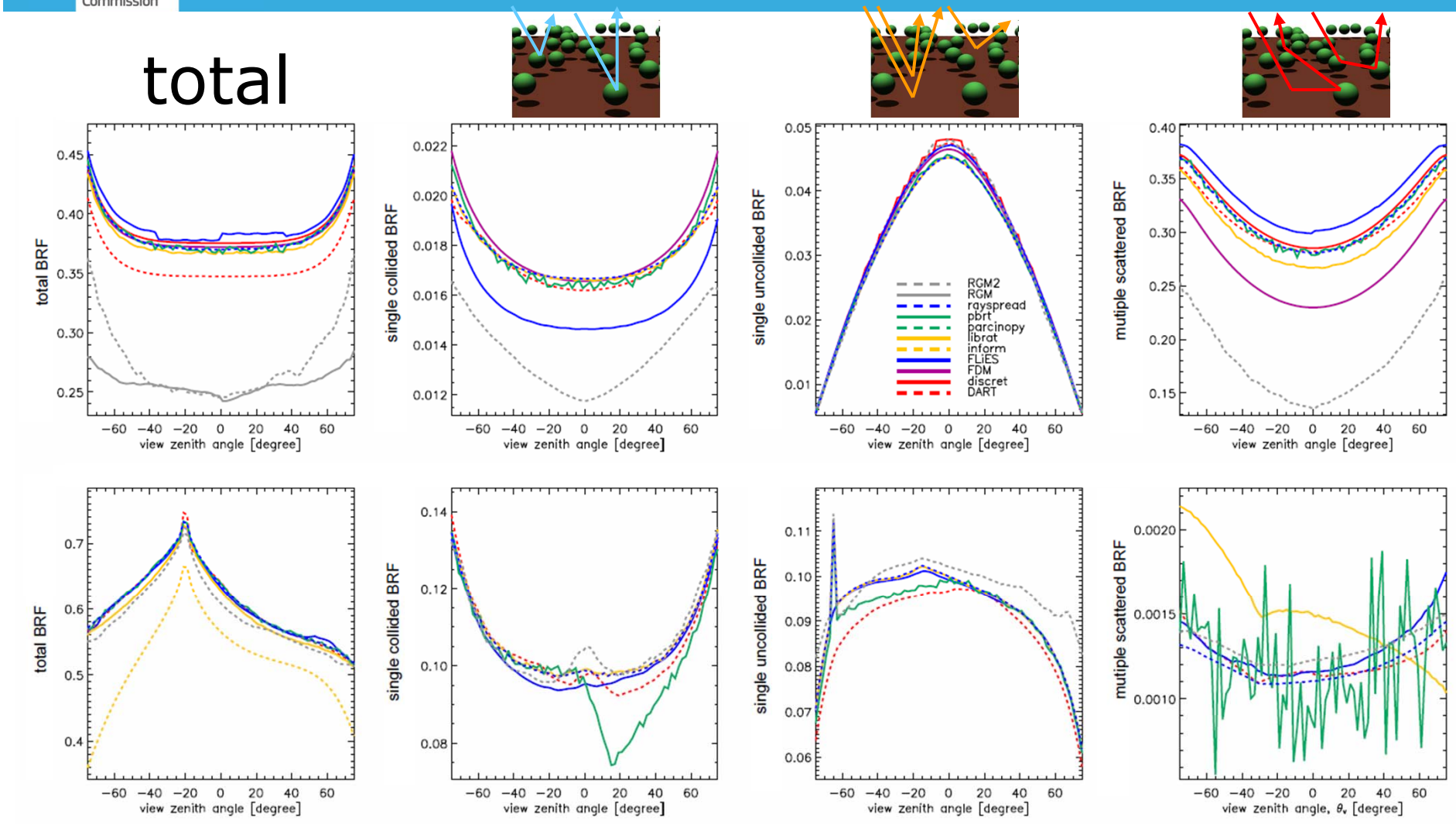


lidar return profiles



Example BRF simulation results

total



Many 'outliers' detected amid the RAMI-IV simulations: from different models, for different geometries & BRF components.

ISO-13528 focuses on methods

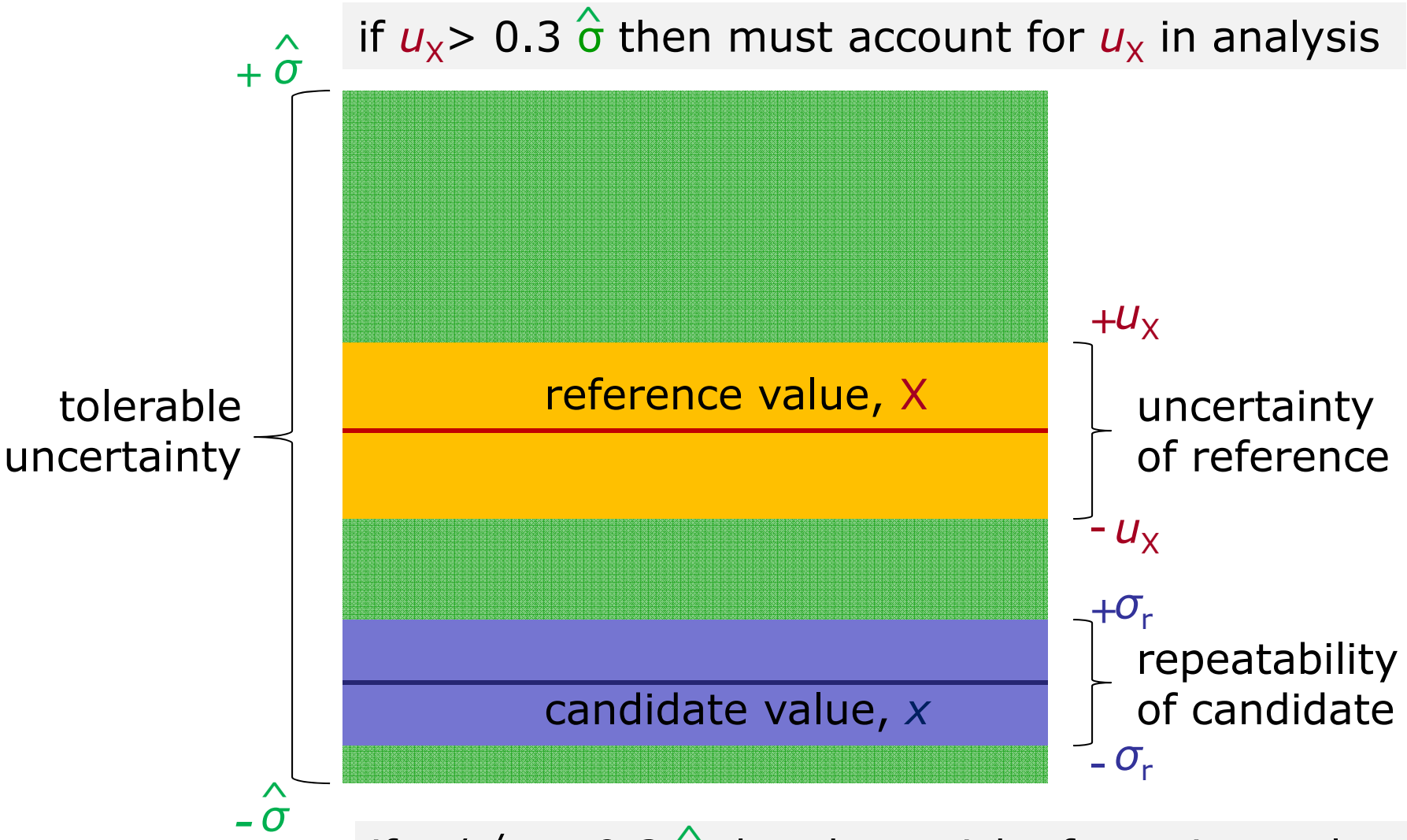
MEASUREMENT: output of an instrument in response to external stimuli

Accuracy of measurement method depends on: 1) the acquisition/ preparation of the sample, 2) the appropriateness of the instrument's technology to deliver accurate results irrespective of the condition under which the sample was acquired and subsequently analysed, 3) the choices/expertise of the operator carrying out the work (in a particular laboratory/outdoor environment).

SIMULATION: output of a model in response to external inputs

Accuracy of a simulation method depends on 1) the abstraction/ representation of the target, 2) the appropriateness of the model's mathematics to deliver accurate results irrespective of the nature of the target and its external forcings, and 3) the choices/expertise of the operator carrying out the work (eg computing language/ environment).

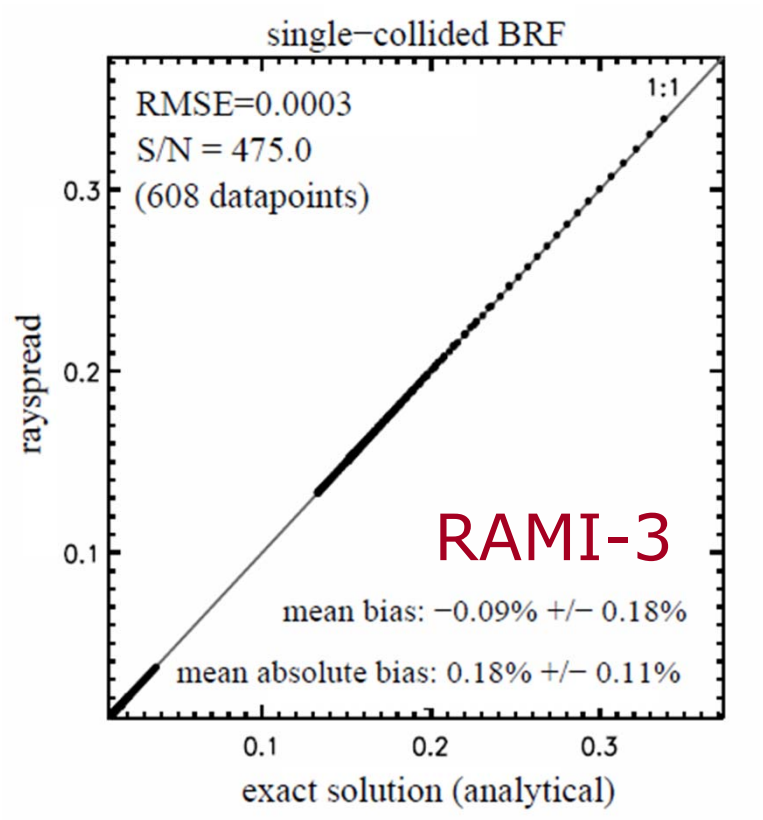
ISO-13528 in a nutshell

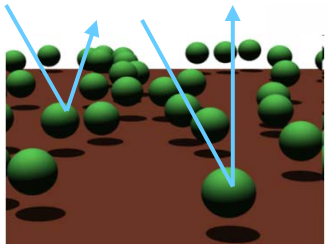


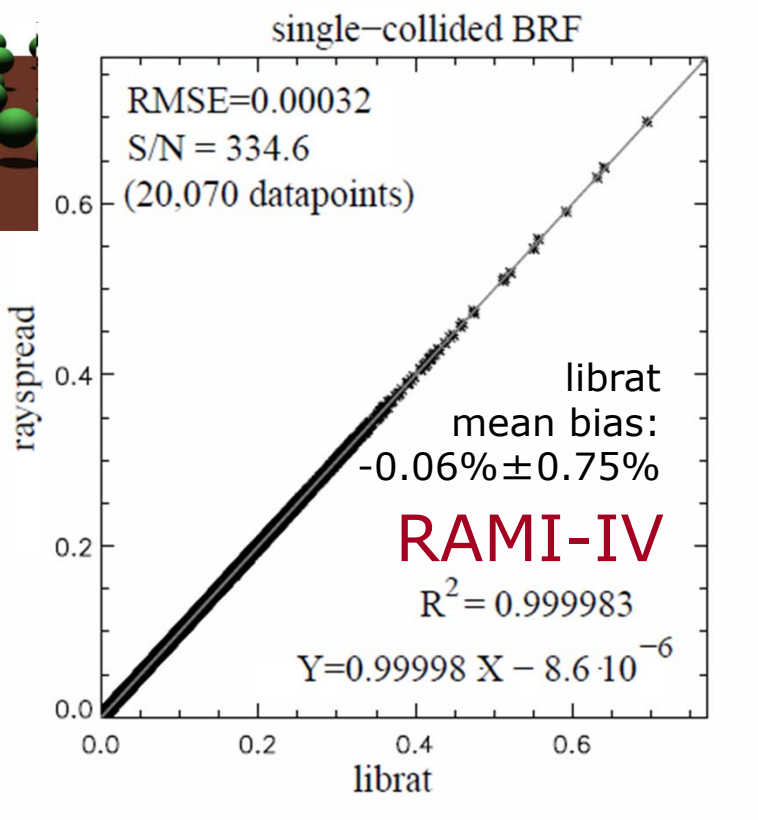
Assigning a reference value

ISO-13528 proposes to get "consensus values" from:

1) simulations of selected expert models
(RAMI-3: DART, **librat**, FLIGHT, **rayspread**, ***raytran***, sprint3)







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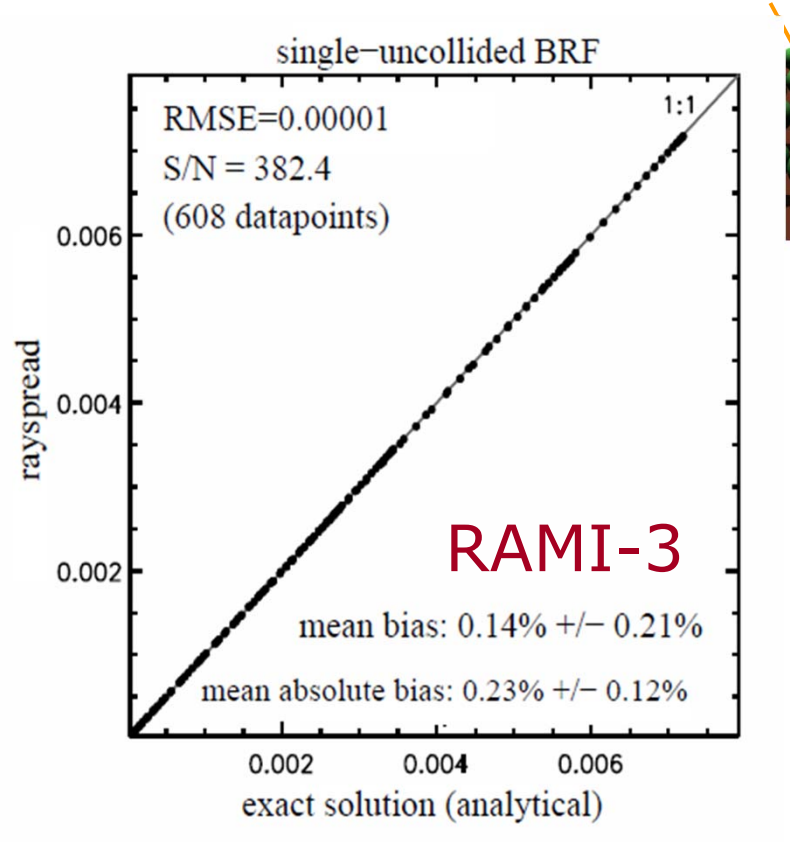
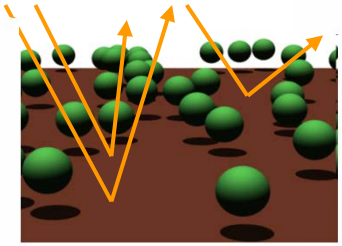
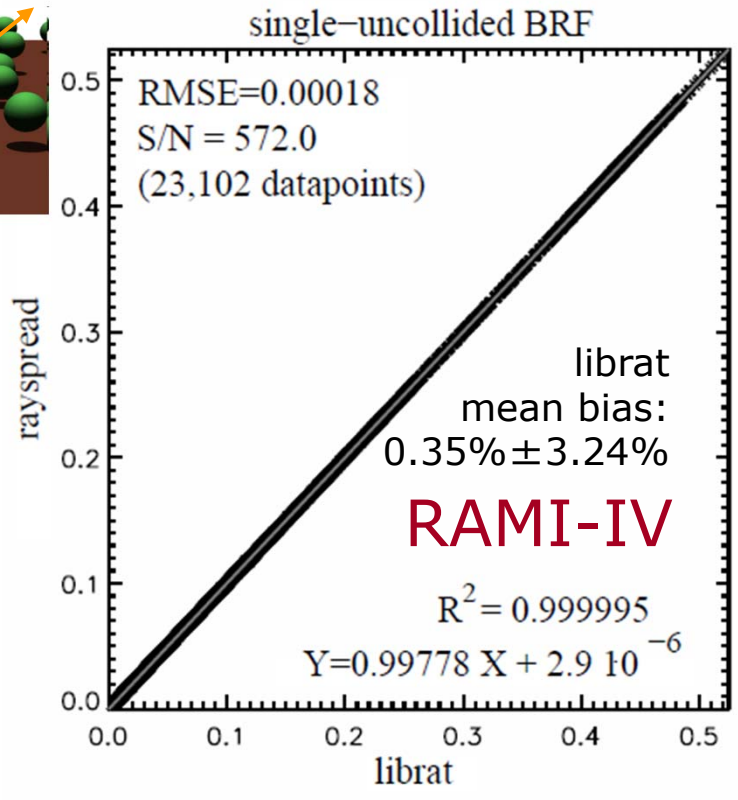


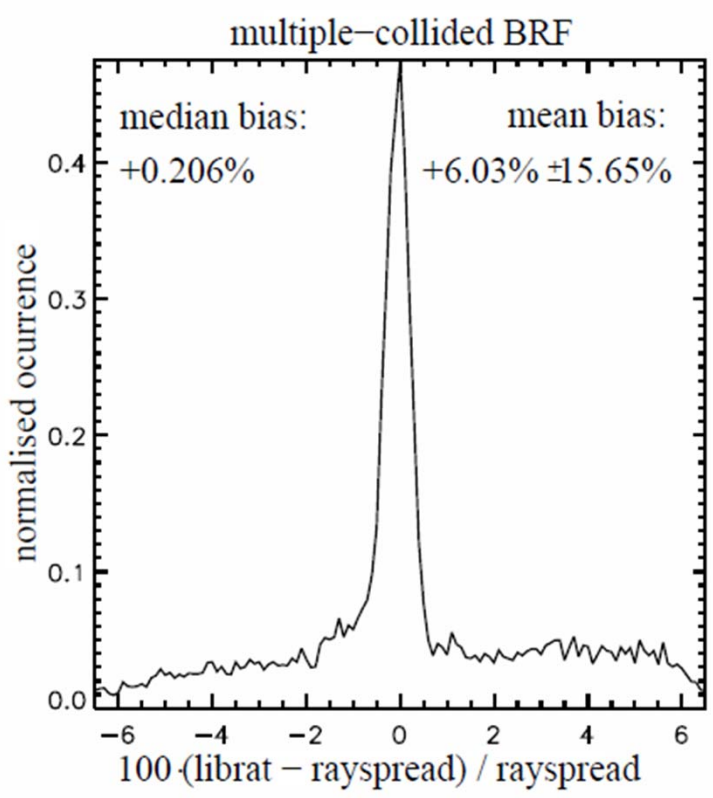


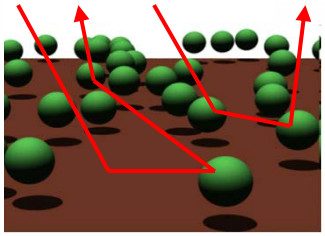


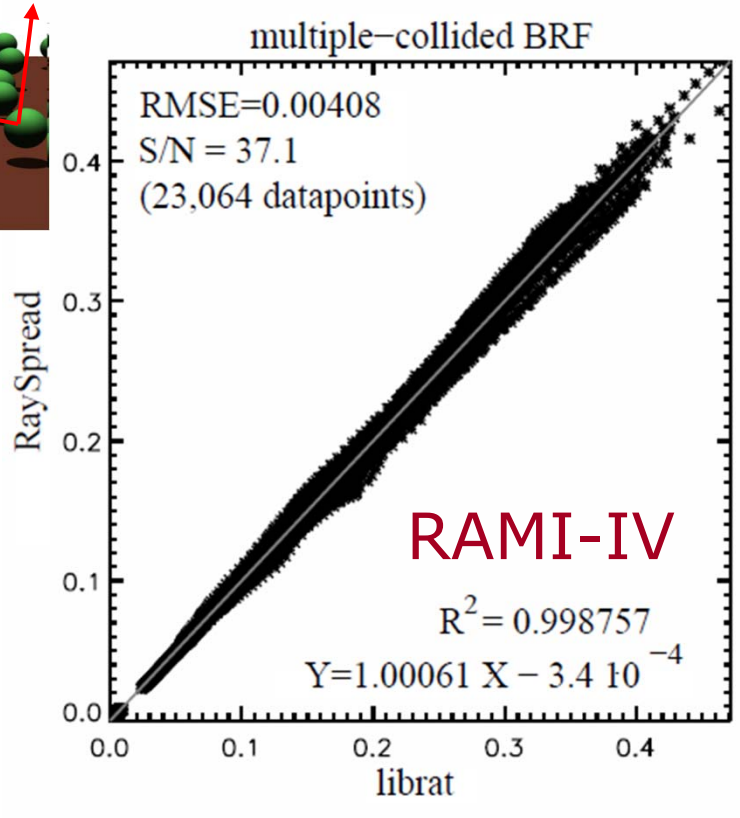
Assigning a reference value

ISO-13528 proposes to get "consensus values" from:

1) simulations of selected expert models
(RAMI-3: DART, **librat**, FLIGHT, **rayspread**, ***raytran***, sprint2)







Assigning a reference value

ISO-13528 proposes to get "consensus values" from:

2) simulations of all *consistent* participants of the proficiency test.

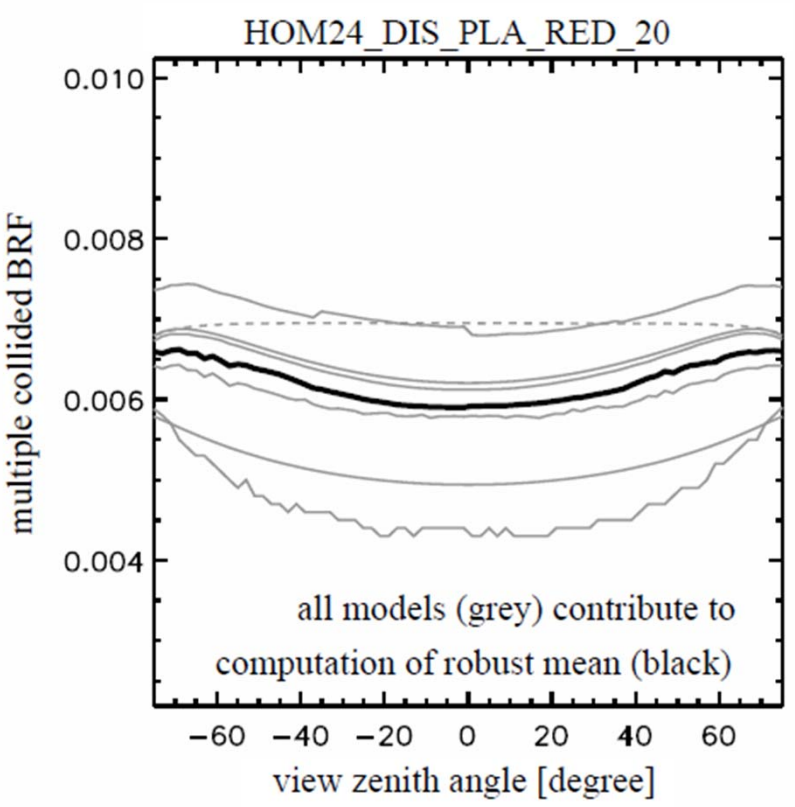
Assigned reference value is computed as 'robust mean' from annex C of ISO-13528

Models do not contribute to their own reference values!

Apply to all simulations:

- BRF components
- fluxes (A, R, T)

BRF_{tot} = uc + co + mlt



Specify a tolerance criterion

For BRF simulations (ρ) the tolerance criterion ($\hat{\sigma}$) was set to 3% and 5% of the reference (X) as is often seen in VC efforts:

$$\hat{\sigma}_{\rho*} = f \cdot X_{\rho*}$$

For hemispherical flux simulations (A, R, T) the tolerance criterion was set in accordance with the GCOS accuracy criteria:

$$\begin{aligned} \hat{\sigma}_{\mathrm{R}} &= 0.05 \cdot X_{\mathrm{R}}/\sqrt{3} && \text{if } 0.05 \cdot X_{\mathrm{R}} > 0.0025 \\ &= 0.0025/\sqrt{3} && \text{otherwise} \end{aligned}$$

$$\begin{aligned} \hat{\sigma}_{\mathrm{A}} &= 0.10 \cdot X_{\mathrm{A}}/\sqrt{3} && \text{if } 0.10 \cdot X_{\mathrm{A}} > 0.05 \\ &= 0.05/\sqrt{3} && \text{otherwise} \end{aligned}$$

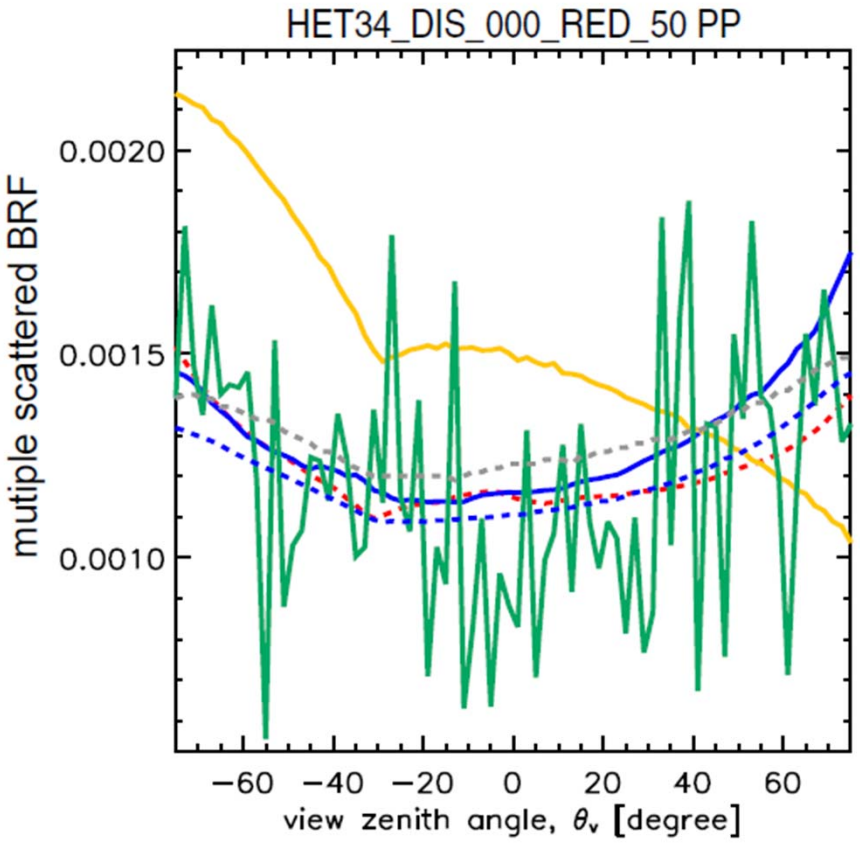
$$\hat{\sigma}_{\mathrm{T}} \approx \sqrt{\frac{\hat{\sigma}_{\mathrm{R}}^2 + \hat{\sigma}_{\mathrm{A}}^2}{(1 - R_{bgd})^2}}$$

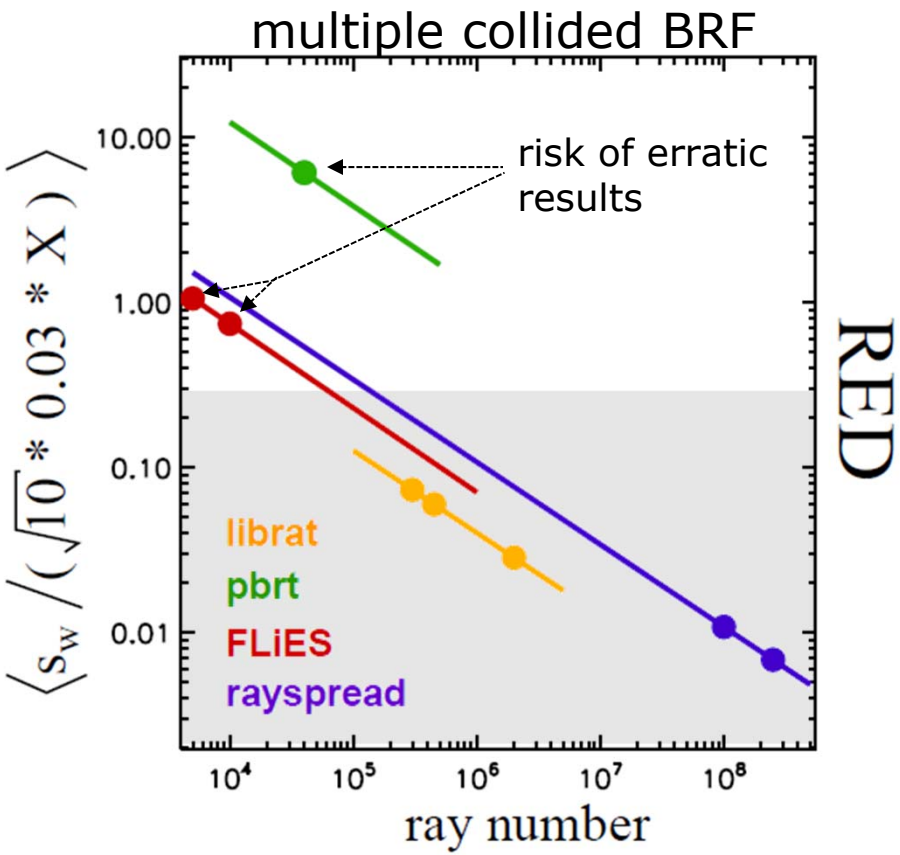
Assess repeatability standard dev.

For analytic or parametric models $\sigma_r = 0$

MC models estimate σ_r as s_w from 10 runs with different seeds.

ISO criteria re-written as: $0.3 \geq \sigma_r/(\hat{\sigma} \cdot\sqrt{n}) \approx s_w/(f \cdot X \cdot\sqrt{n})$





Assess reference uncertainty

Robust analysis in Annex C of ISO-13528 yields also reference uncertainty (u_X):

Test cases compliant with $u_X < 0.3\ \hat{\sigma}$

$\hat{\sigma}_{\rho_*} = f \cdot X_{\rho_*}$

	f=0.03	f=0.05
ρ_{tot}	71%	87%
ρ_{uc}	88%	91%
ρ_{co}	99%	100%
ρ_{mlt}	11%	27%

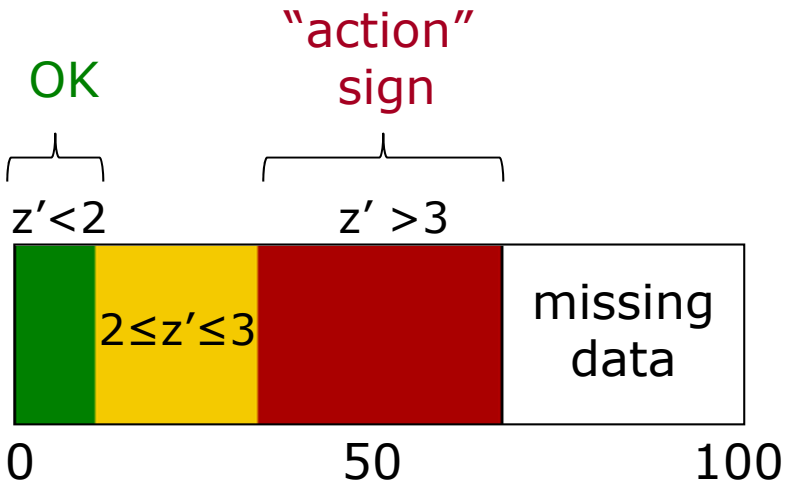
$\hat{\sigma}_T \quad \hat{\sigma}_R \quad \hat{\sigma}_A$

	GCOS
A	79%
R	60%
T	78%

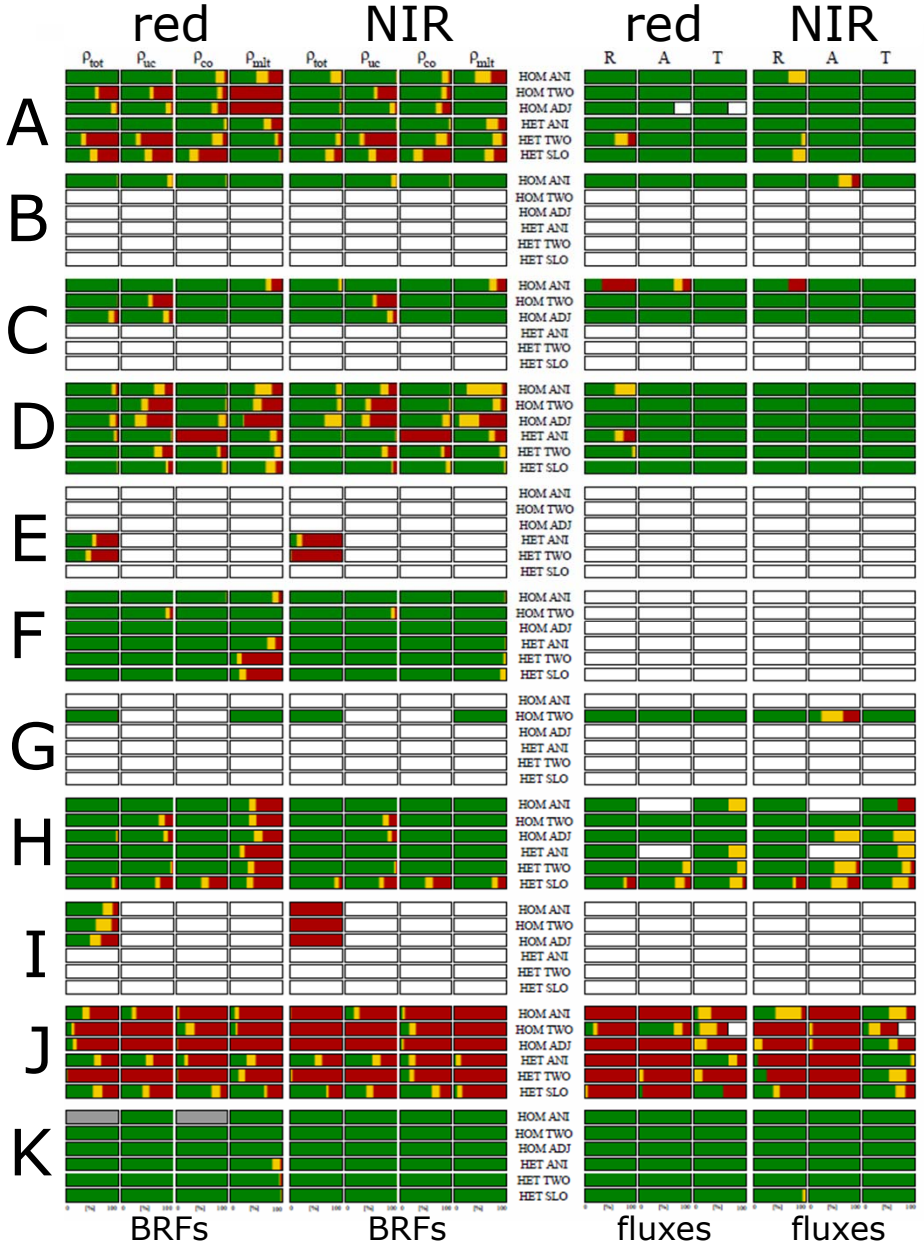
Use $z' = \dfrac{x^m - X}{\sqrt{\hat{\sigma}^2 + u_X^2}}$ and $E_n = \dfrac{x^m - X}{\sqrt{U_{x^m}^2 + U_X^2}}$ metrics

z' scores

Summarise z' scores for all BRF or flux data of a given canopy type.

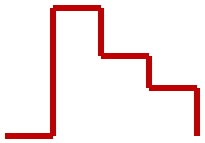


- many 'missing' test cases !
- most RT simulations are 'OK'
- some models (E,I,J) receive mostly "action" signs
- systematic (I,E) vs operator (A,C,D,F, J,?) errors



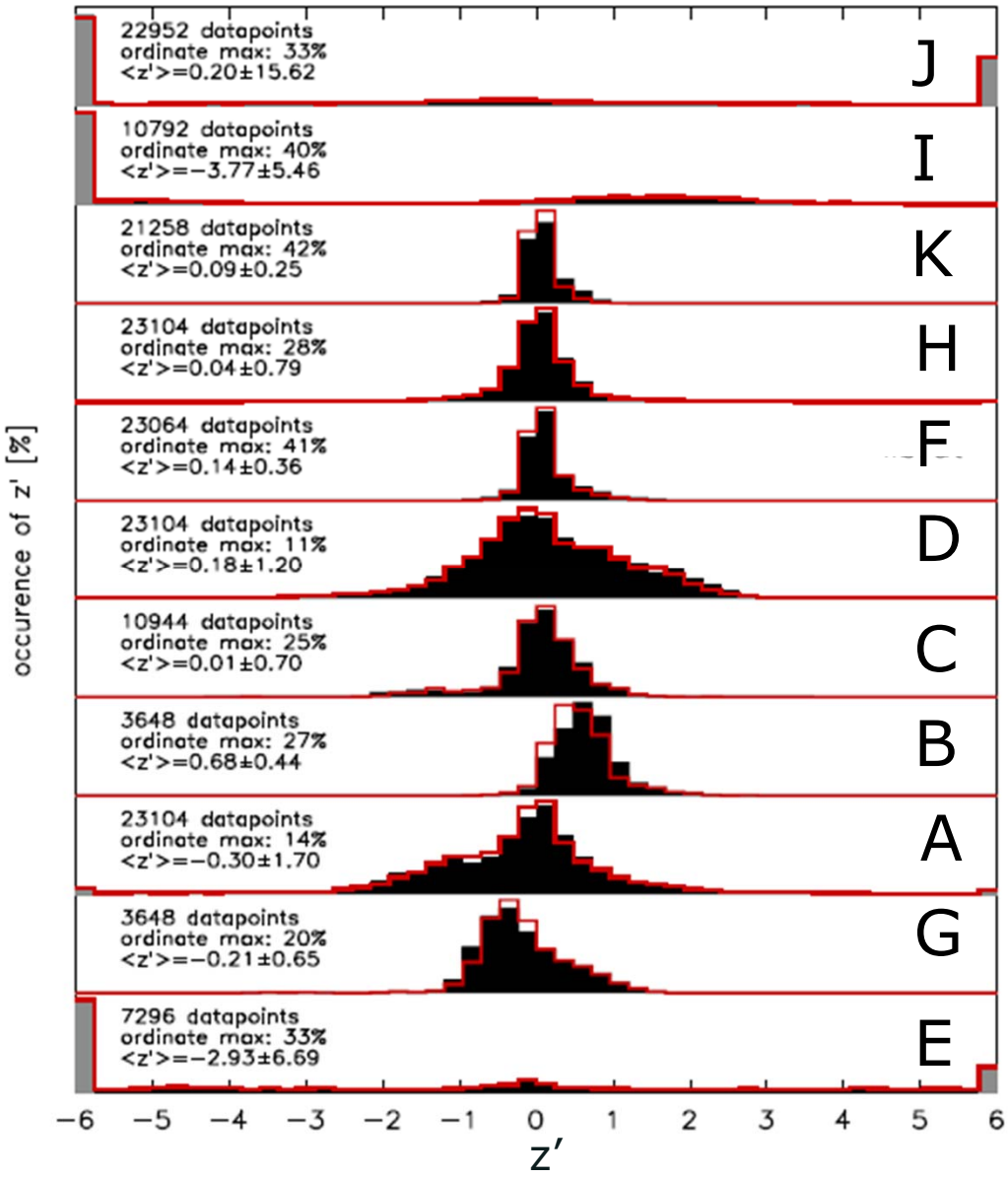
histograms of z' scores

model doesn't contribute to its reference solution



one single reference is applied to all models

- most histograms of z' are not Gaussian
  - operator choices/errors
  - insufficient sampling of structure space
- when models contribute to their reference then the histograms get narrower

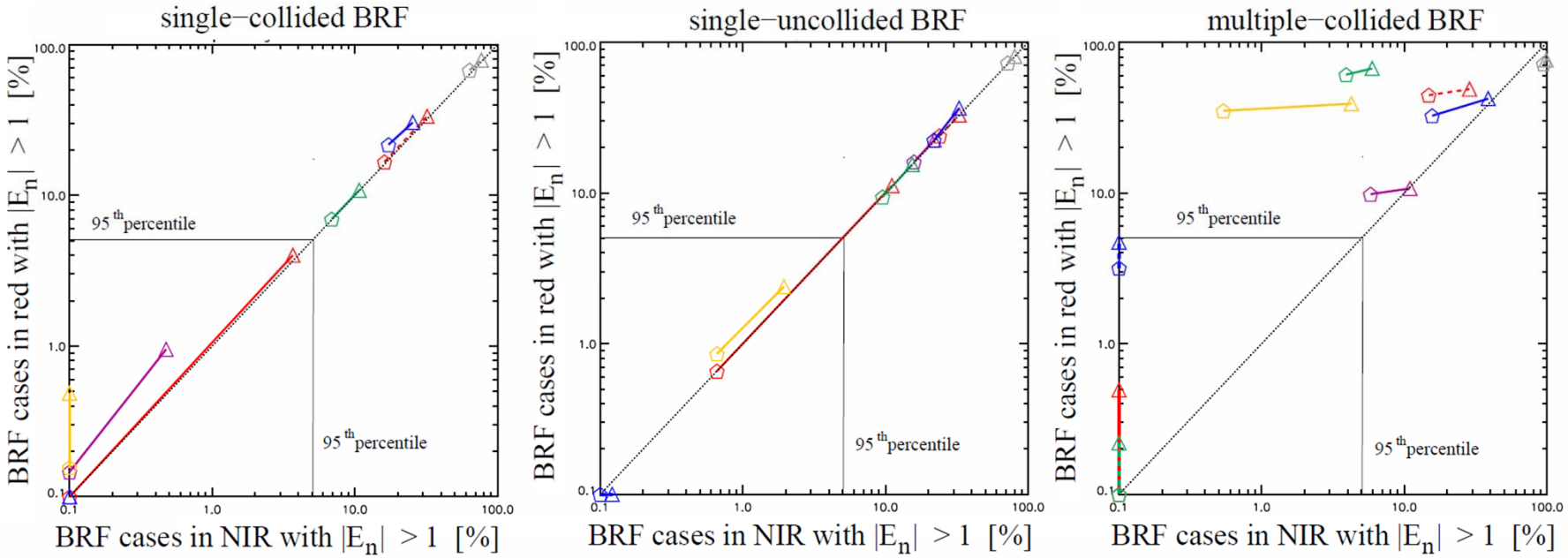


E_n number

Select the *largest tolerable* standard uncertainty $u_x^m = \hat{\sigma} = f \cdot X$ for the model simulations, i.e., $U_x^m = 2 \cdot f \cdot X$ with f=0.03 and 0.05

For each one of the ~10,000 BRFs compute $|E_n| = \dfrac{|x^m - X|}{\sqrt{U_{x^m}^2 + U_X^2}}$

Plot % of $|E_n| < 1$ in red against % in NIR.



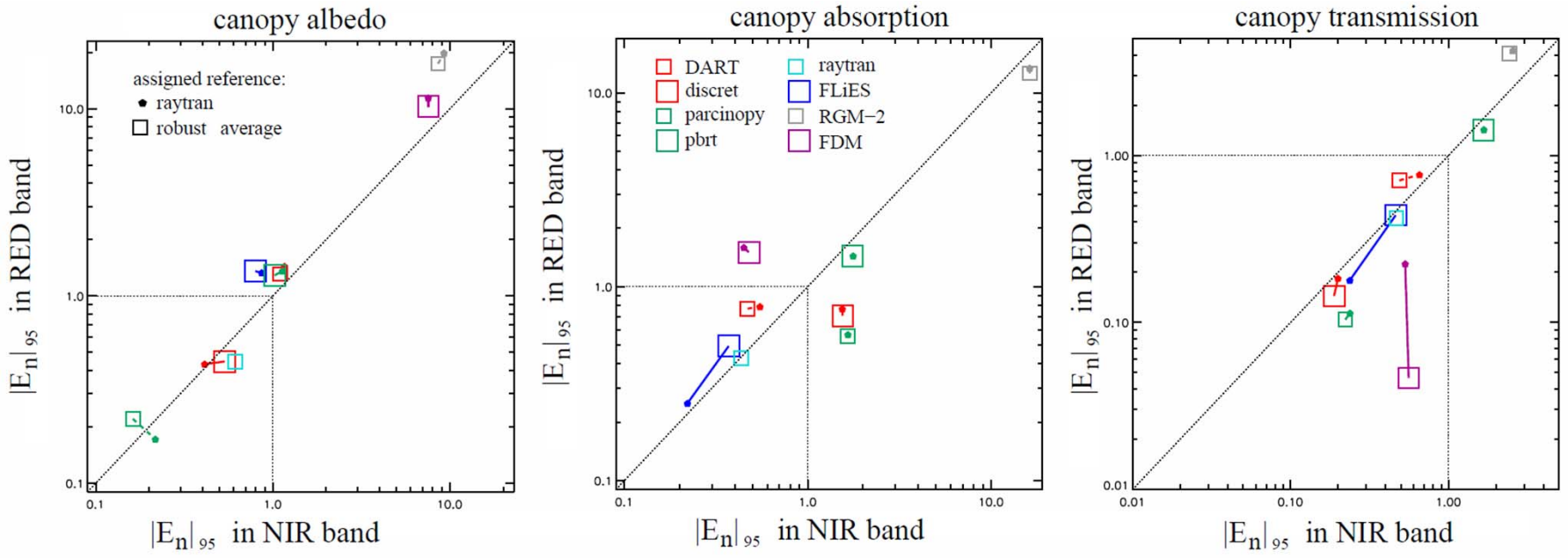
For f=0.03 only 1 (uc & co) or 0 (mlt) model have $|E_n|_{99.9\%} < 1$

E_n number & fluxes

Select the *largest tolerable* standard uncertainty $u_x^m = \hat{\sigma}$ for the model simulations, i.e., $U_x^m = 2 \cdot \hat{\sigma}$

For each one of the ~76 fluxes compute $$|E_n| = \frac{|x^m - X|}{\sqrt{U_{x^m}^2 + U_X^2}}$$

Plot 95th percentile of $|E_n|$ in red against NIR.



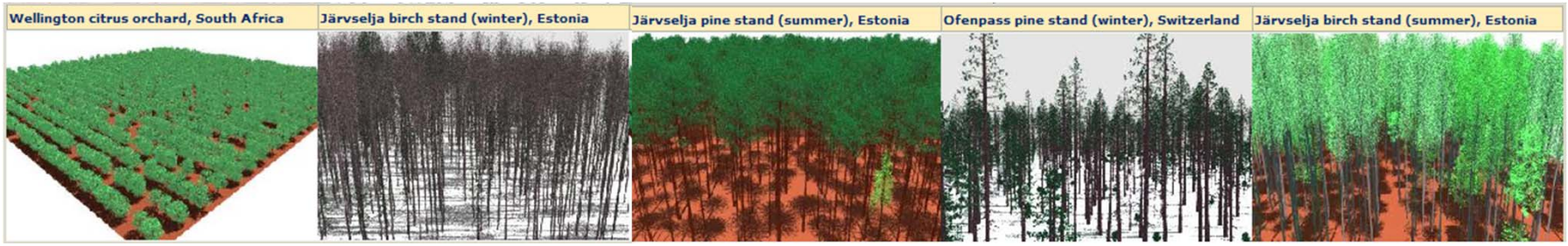
Not all models are compliant with the GCOS criteria at 95% level

RAMI-IV abstract canopy

- Successful application of ISO-13528 from original measurement context to RT model simulations
- RAMI-IV "abstract canopy" results heavily affected by choices and errors of model operators.
- Some models are not compliant with the GCOS accuracy criteria at the 95% level.
- Some models do not match reference BRFs within 3-5% levels typical of VC efforts.
- Few models provide more than 90% of prescribed RAMI-IV test cases

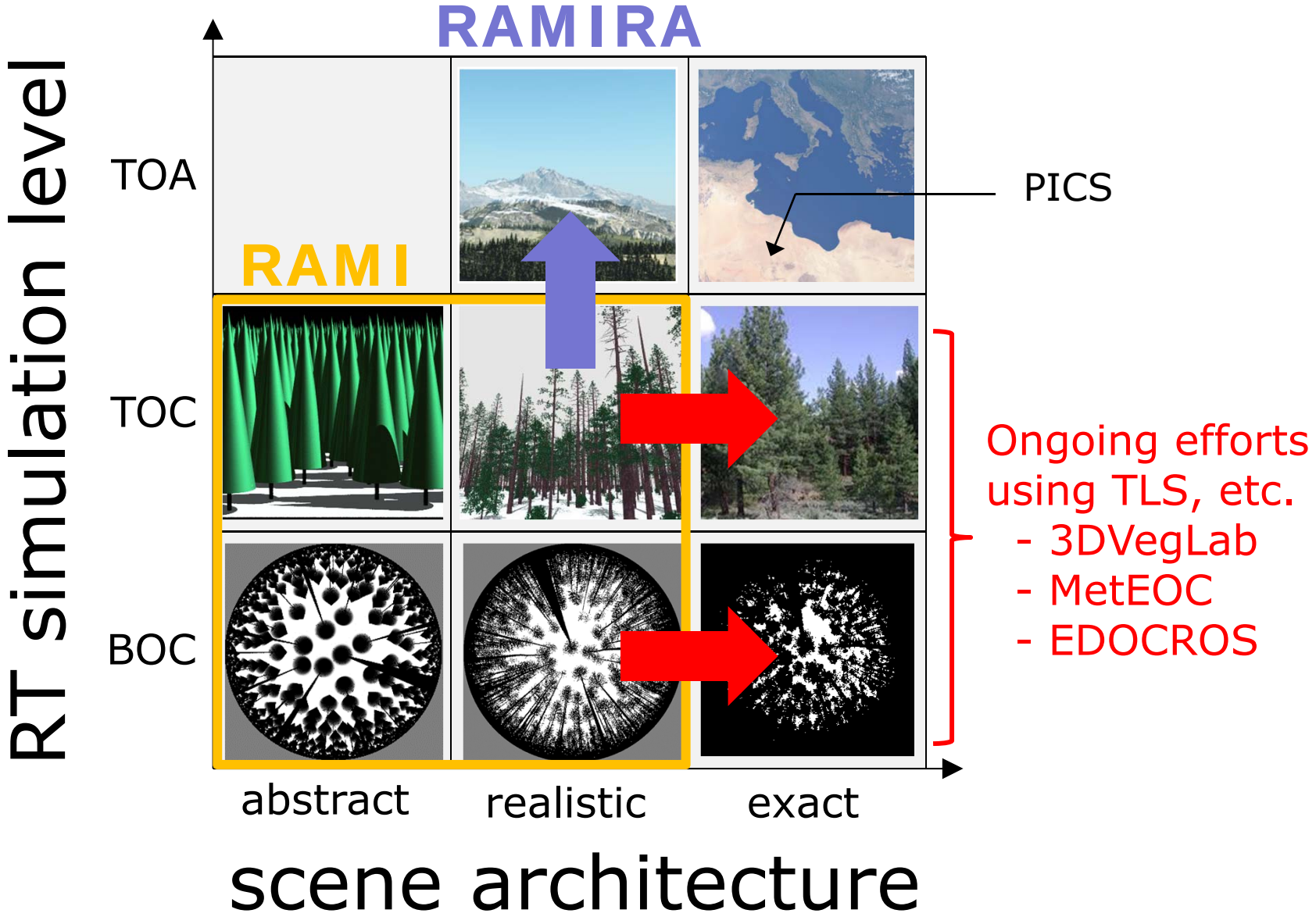
RAMI-IV outlook

- *Publish analysis of RAMI-IV abstract cases (2013)*
- *Complete analysis of RAMI-IV 'actual' canopies*



- *Expand RAMI OnLine Model Checker to larger set of experiments (RAMI4PILPS, MetEOC), add new graph types and improve user interface*
- *Compare model simulations of BRFs for 3D artifical targets against actual measurements acquired under controlled experimental conditions (MetEOC)*

next steps…


RAMIRA
RAMI
PICS
TOA
TOC
BOC
RT simulation level
abstract
realistic
exact
scene architecture
Ongoing efforts
using TLS, etc.
- 3DVegLab
- MetEOC
- EDOCROS

RAMIRA (LAI, FAPAR, albedo)

- *Generate large number of structurally & spectrally realistic canopies*
- *Use credible RAMI model to simulate TOC (and one/two atmospheric models) to get TOA BRFs/radiances for different:*
  - *sensors (spat. res., PSF, bands, etc.)*
  - *illumination & view geometries*
  - *atmospheric conditions*
- *If needed simulate multi-temporal data (under identical or varying conditions)*
- *Provide GS or PI's with simulated data as required by their retrieval algorithm*
- *Analyse returned results against truth.*

RAMIRA (LAI, FAPAR, albedo)

Benefits:

- *Allows to evaluate all retrieval algorithms under identical conditions.*
- *Allows to evaluate retrieval algorithms against own/ambient definition of ECV*
- *Reference not affected by unknown biases (as is the case for in situ ECV estimates)*
- *QA process is neutral (JRC not a space agency & bound by its mission statement)*
- *Cheaper than actual field campaigns*
- *Process apt for automation*
- *Test dataset can be gradually expanded*

RAMIRA

JRC cannot invest time and resources into the preparation of datasets for a given sensor without commitment from PI or GS to participate (within given timeframe).

- *JRC would welcome if IVOS were to ask WGCV to place a request to CEOS plenary to support such a task.*

PIs and GS are likely to ask for funding in order to commit resources to this.

- *Are space agencies willing to support the RAMIRA effort (possibly financially)?*

thank you

APPENDIX

Mission of the Joint Research Centre

… to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies.

As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union.

Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.