IVOS theme on:

Radiative Transfer codes

Jean-Luc Widlowski
(EC Joint Research Centre)

with contributions from
Tamás Várnai (GFCS)

Outline

Clouds:

- **I**ntercomparison of **3**D **R**adiative transfer **C**odes (http://i3rc.gsfc.nasa.gov/)

Vegetation:

- **RA**diative transfer **M**odel **I**ntercomparison (http://rami-benchmark.jrc.ec.europa.eu/)

I3RC: an ongoing project initiated in the late 1990s

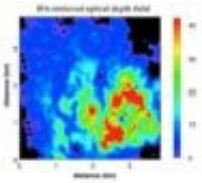
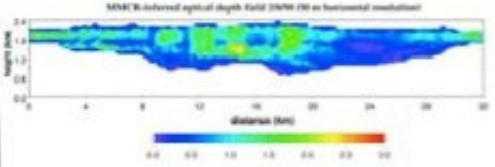
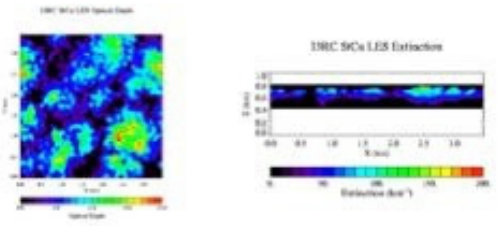
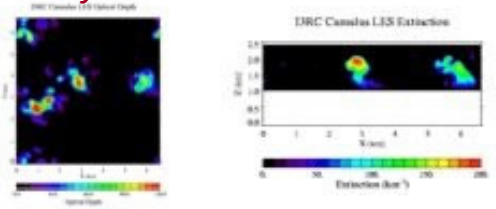
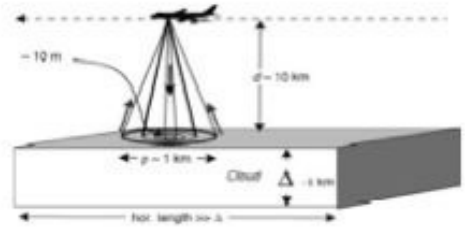
Objectives

- comparing methods available for 3D atmospheric RT calculations
- providing benchmark results for testing 3D RT codes
- publishing an open source toolkit (community 3D MC code)
- providing resources related to I3RC and 3DRT (codes, models, workshops, publications)

Model comparisons

- participants from 7 countries, using Monte Carlo and analytical models
- 3 phases of increasingly complex experiments
- experiments discussed at 3 workshops and at conferences (e.g., IRS 2008 in Brazil)
- results from Phases 1 & 2 published in BAMS article by Cahalan et al. (2005)
- results from Phase 3 published in extended abstract
  International Conference on Mathematics, Computational Methods & Reactor Physics (Saratoga Springs, NY, 2009)
- all results available at I3RC website: http://i3rc.gsfc.nasa.gov

I3RC test cases

Phase 1	step cloud 	Marine BL cloud 	ARM-radar reconstructed cloud 
Phase 2	 Large eddy simulated SC Cloud Field	Large eddy simulated Cumulus Cloud Field 	
Phase 3	Cumulus clouds in Brasil 	 3D spread of lidar pulse	

Consensus results for each case

- based on well-agreeing models
- have helped testing new models
- available at I3RC website: http://i3rc.gsfc.nasa.gov

I3RC community model for 3D radiative transfer

http://i3rc.gsfc.nasa.gov

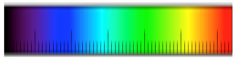
Publicly available model

- Publicly available source code (updated in June, 2010)
- Package also includes scripts for easy use and Mac executables
- Performance of the code is documented in JAS paper by Pincus and Evans (2009)
- Open Source Licensing to encourage further development and widest usage

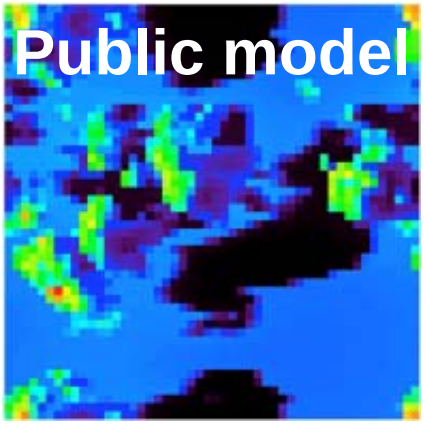
Online 3D radiative transfer calculator

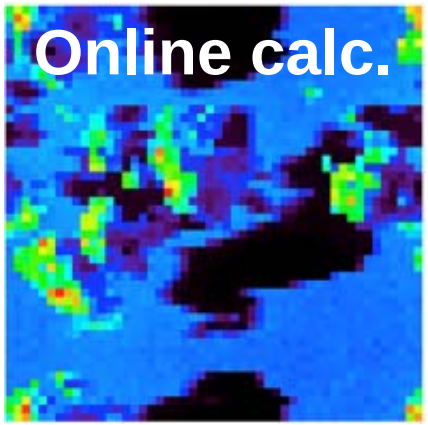
- Simple web interface based on I3RC community code
- Over 100 users since its release in January 2012
- Short 1D or 3D radiative transfer simulations (up to 5 min)
- Yields the spatial distribution and scene average value of radiances, fluxes, and absorption at selected wavelengths

Sample results
for I3RC Case 4



2.13 μm nadir refl.





Other I3RC activities and plans

Conference sessions on 3D radiative transfer
- Most recent: IUGG 2011 in Australia

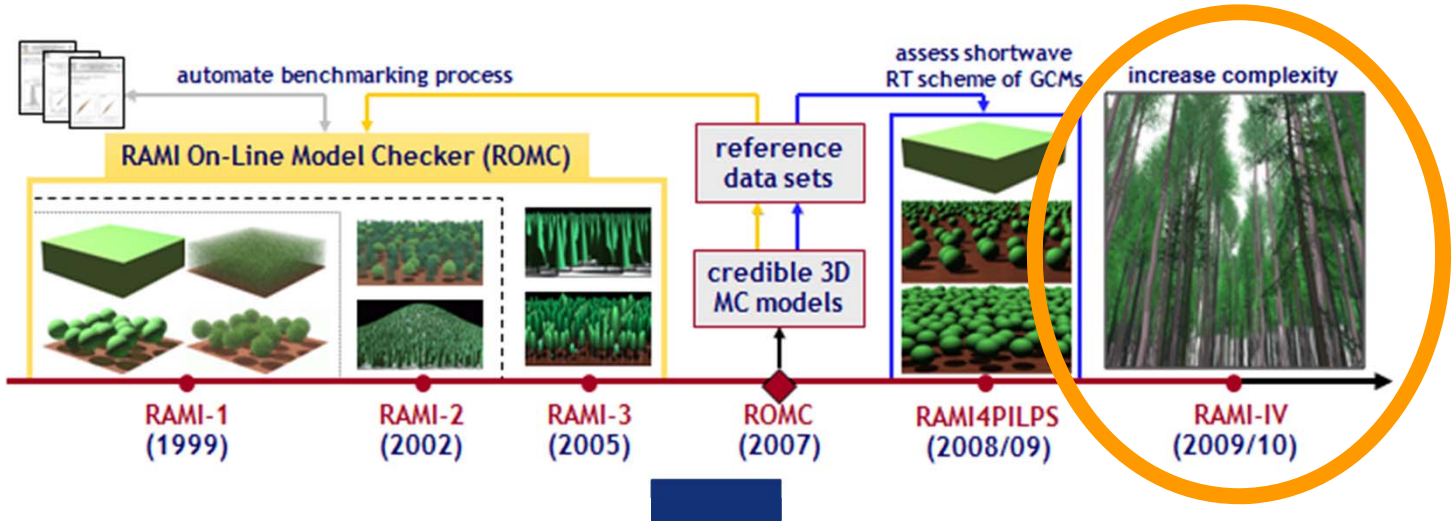
Website (http://i3rc.gsfc.nasa.gov)
- Publication database of over 400 papers on 3D radiative transfer
- Online image library for illustrating 3D radiative processes
- Links to publicly available models related to 3D clouds and radiation

Plans
- I3RC poster at IRS 2012 in Berlin
- 3DRT/I3RC involvement in a model verification subgroup of WGCV
- Enhance capabilities of community model and online calculator
  e.g., polarization, broadband
- Expand resources at website

RAMI

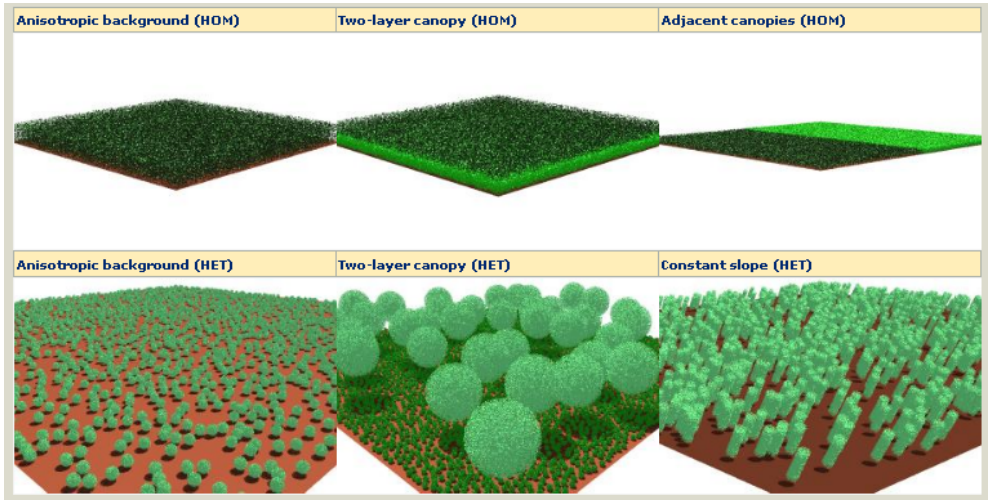
European Commission

- Platform for the systematic verification of RT models dealing with shortwave radiation & vegetated surfaces (launch 1999)
- Evaluation is primarily in 'forward' mode, i.e., to simulate an instrument's output using a detailed scene description
- Early phases, using simple canopy targets, managed:
  - to identify '**credible**' RT models (3-D Monte Carlo ray-tracing)
  - to develop reference datasets (**community standards**)
  - to **automate** the verification process (RAMI On-Line Model Checker)



RAMI-IV status

- Analysis of results from 4th phase on-going:
- Current focus is on 'abstract' canopy scenarios



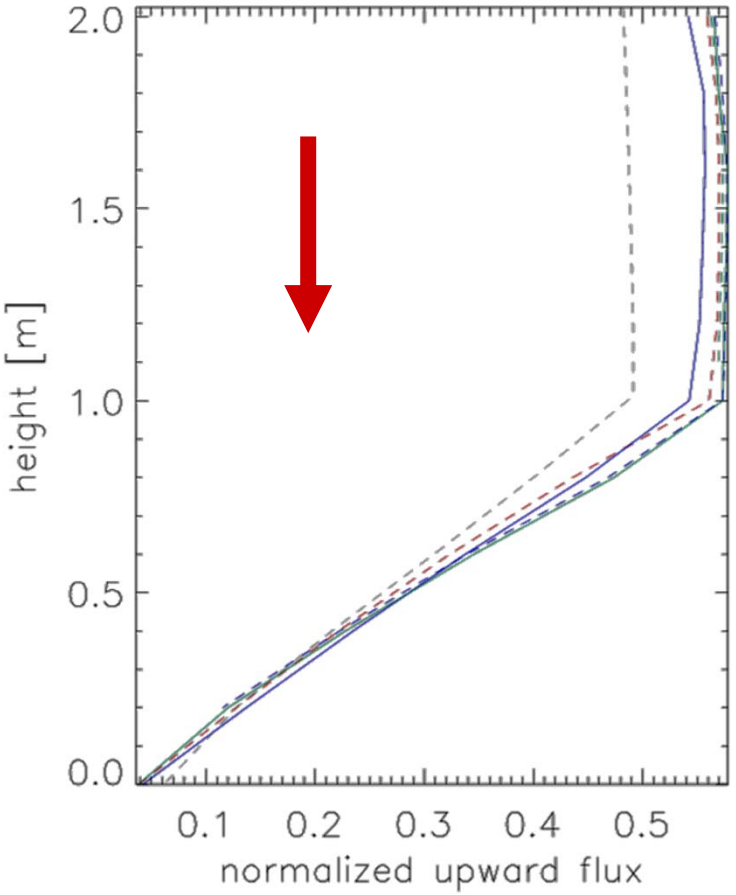
- Some stats:
  - Received files: 95,443 (BRF: 58,356; fluxes 31,218; vprof: 5869)
  - Number of unique BRF simulations: 1,628,148 (21,423 files)
  - Number of unique vprof simulations: 66,759 (2,023 files)
  - Number of email exchanges (25 April 2012): 1,270

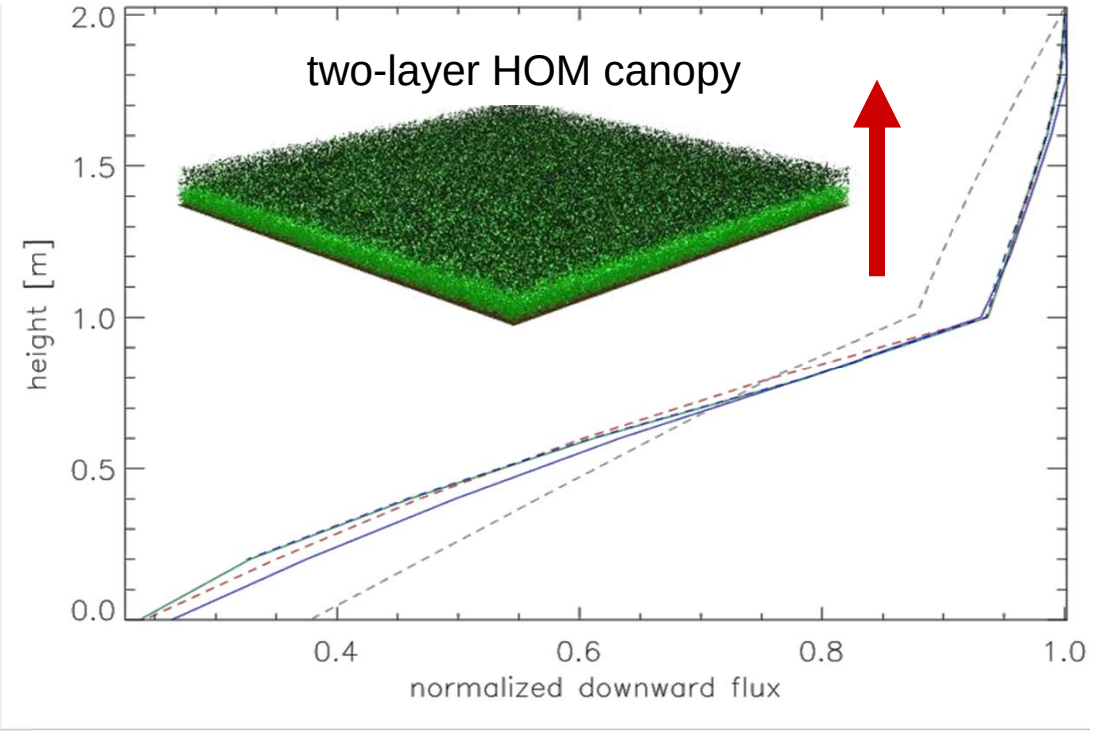
RAMI-IV abstract cases

Measurements

European Commission

Profiles of upward & downward radiation fluxes

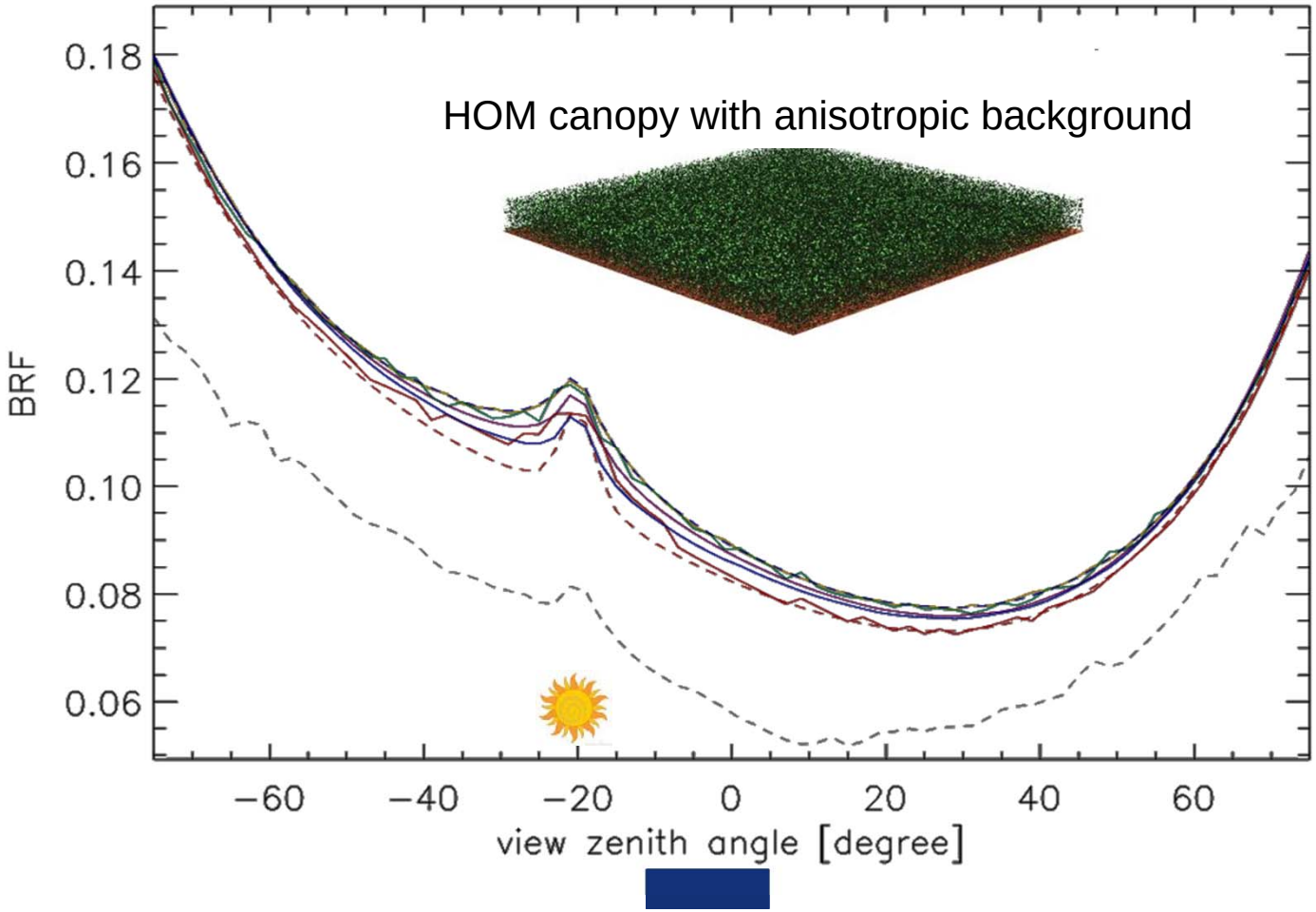




RAMI-IV abstract cases

Measurements

Bi-directional reflectance factors (total, single collided, multiple collided, single un-collided by vegetation)

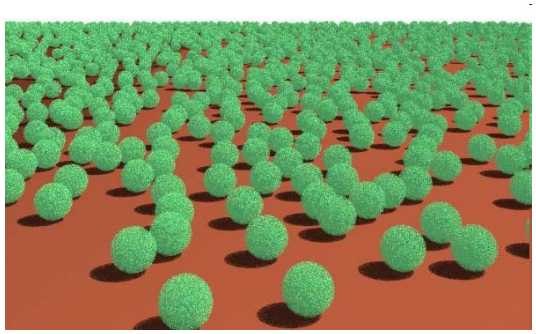


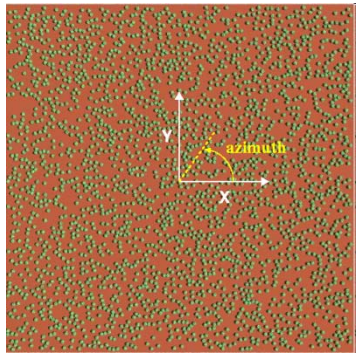
RAMI-IV abstract cases

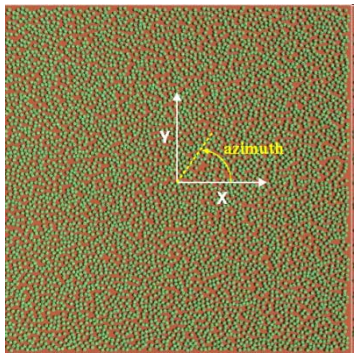
Canopy scenarios

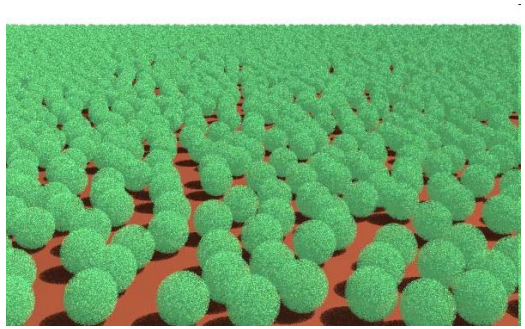
European Commission

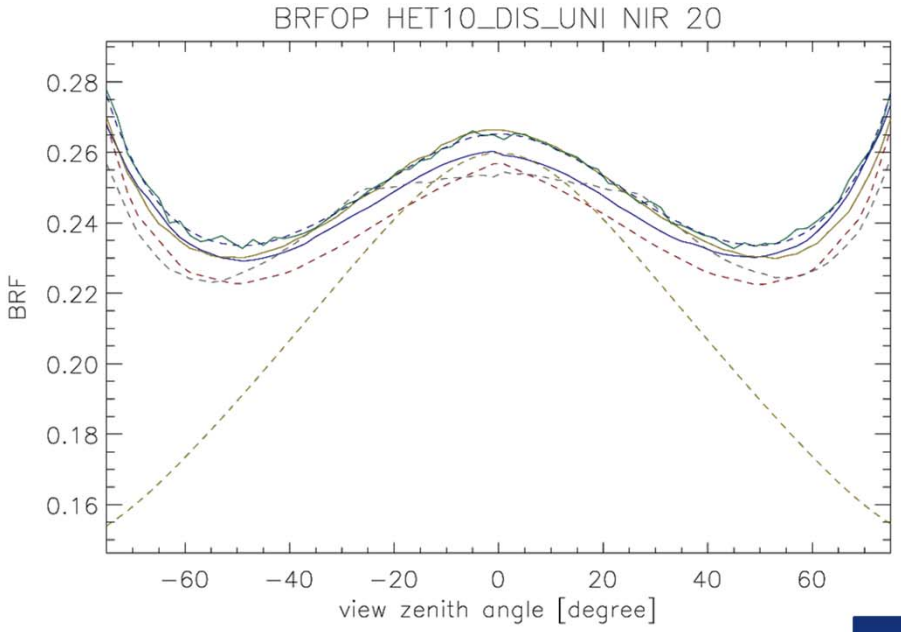
Heterogeneous canopies with anisotropic background

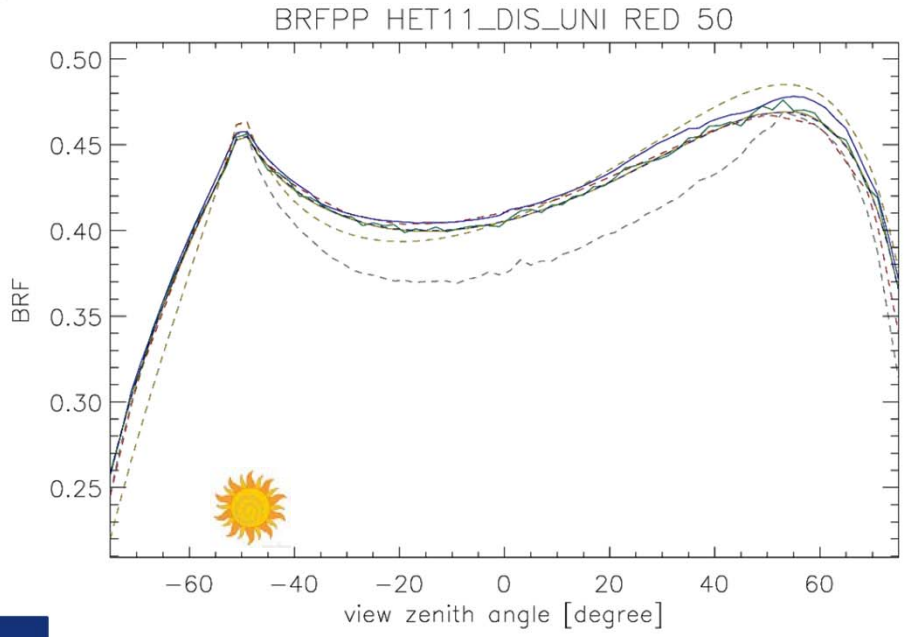










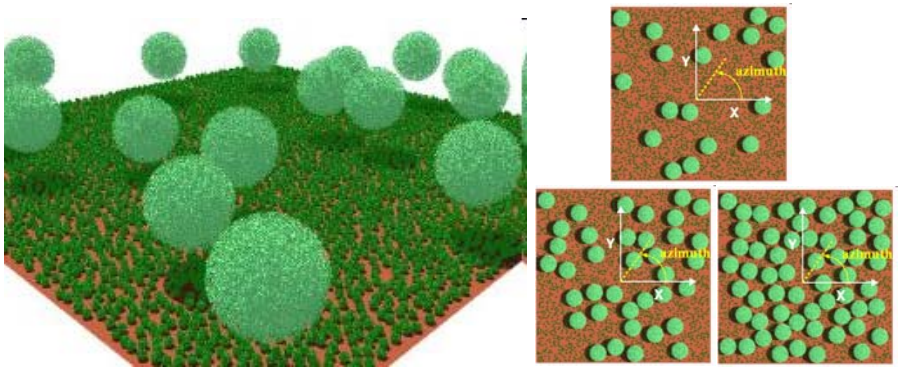


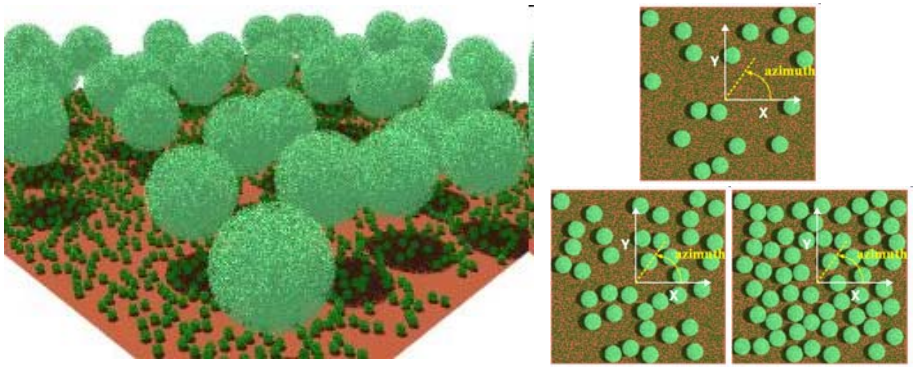
RAMI-IV abstract cases

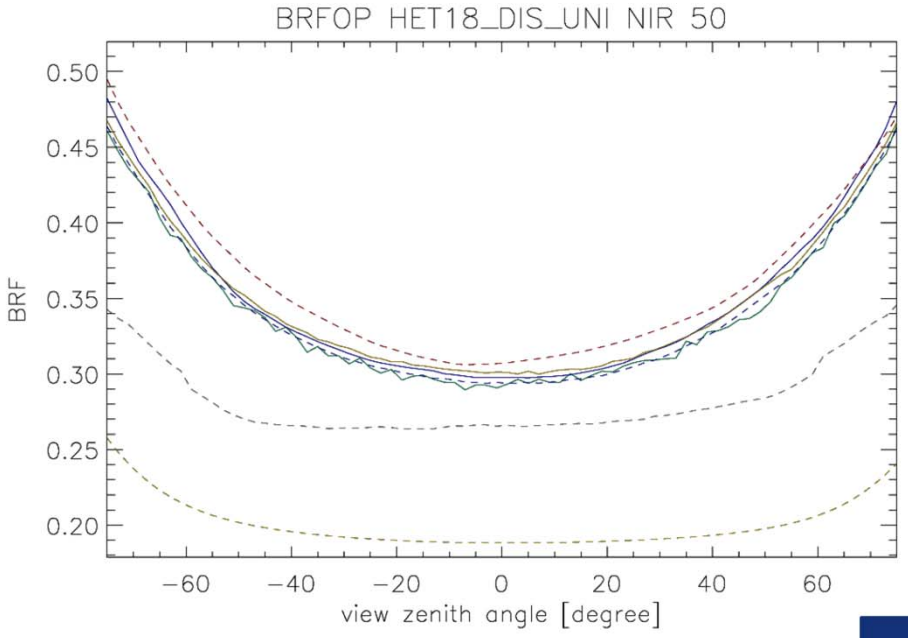
Canopy scenarios

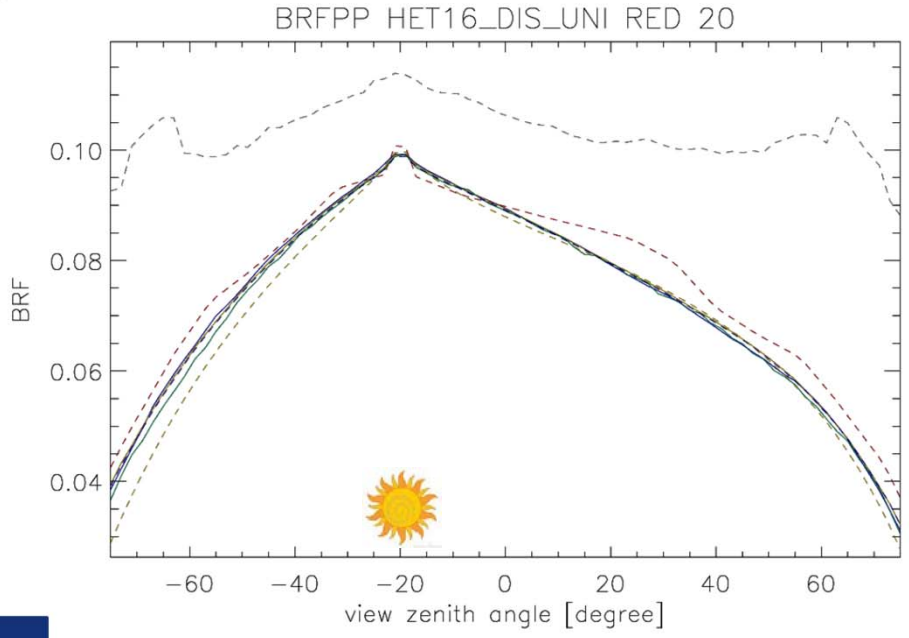
European Commission

Heterogeneous two-layer canopies







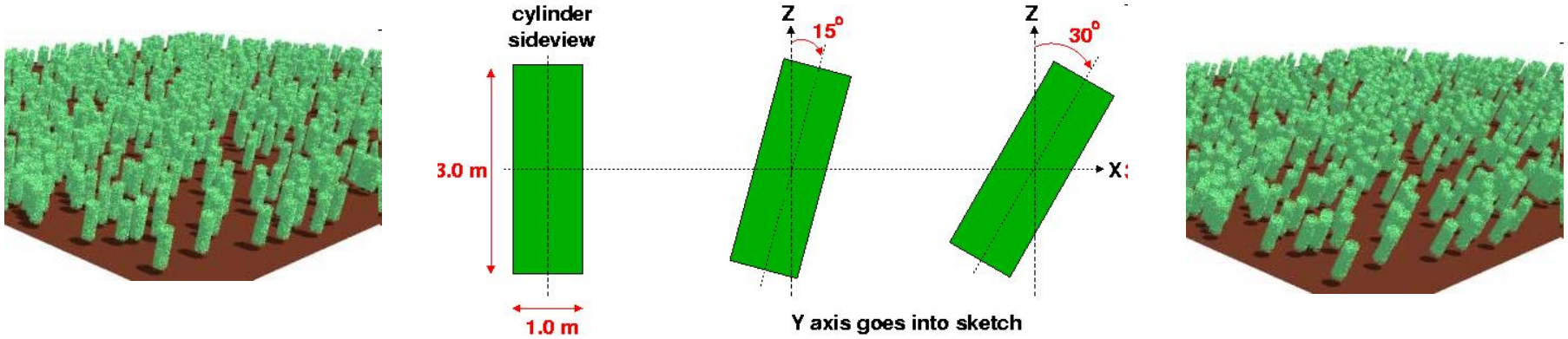


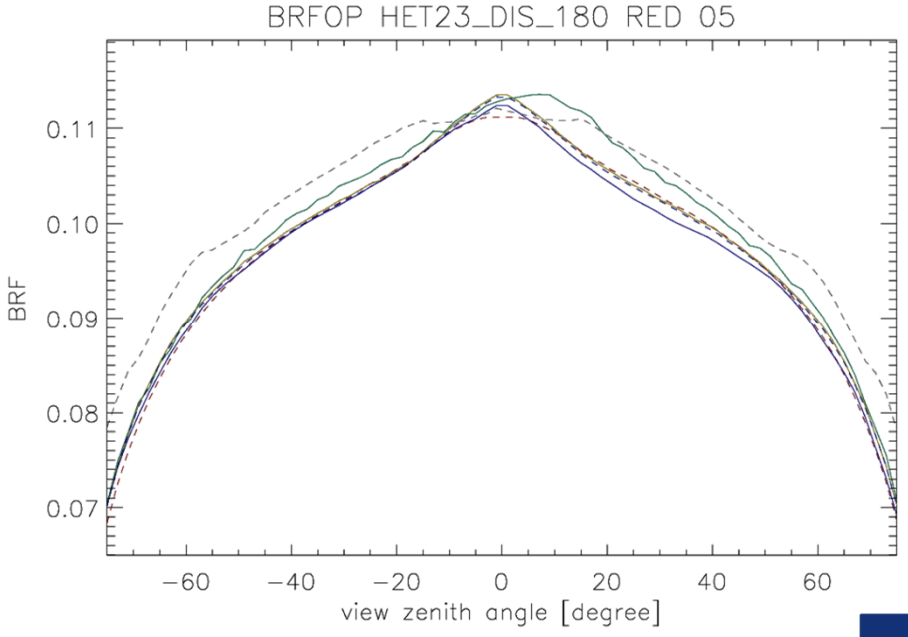
RAMI-IV abstract cases

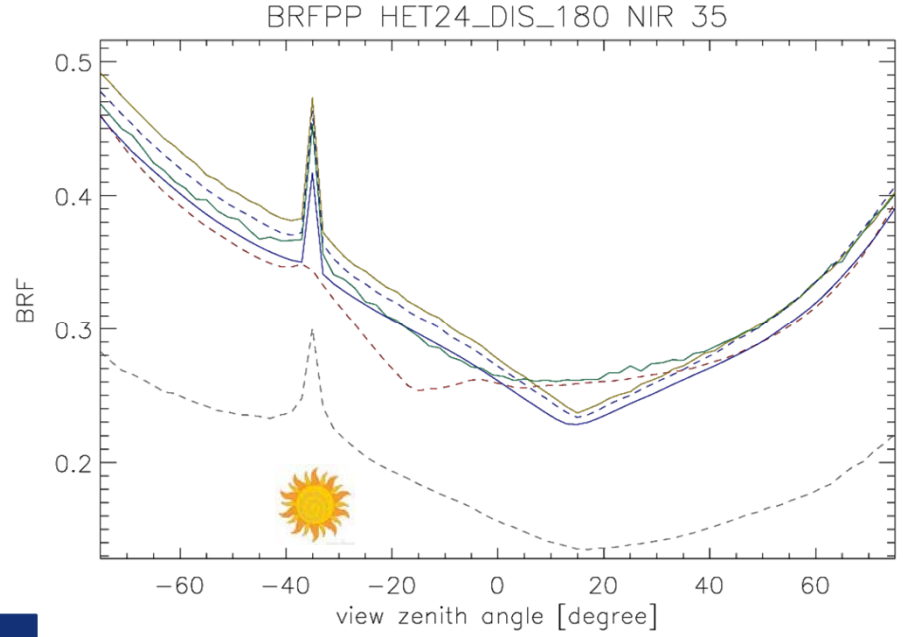
Canopy scenarios

European Commission

Heterogeneous canopies on an inclined slope





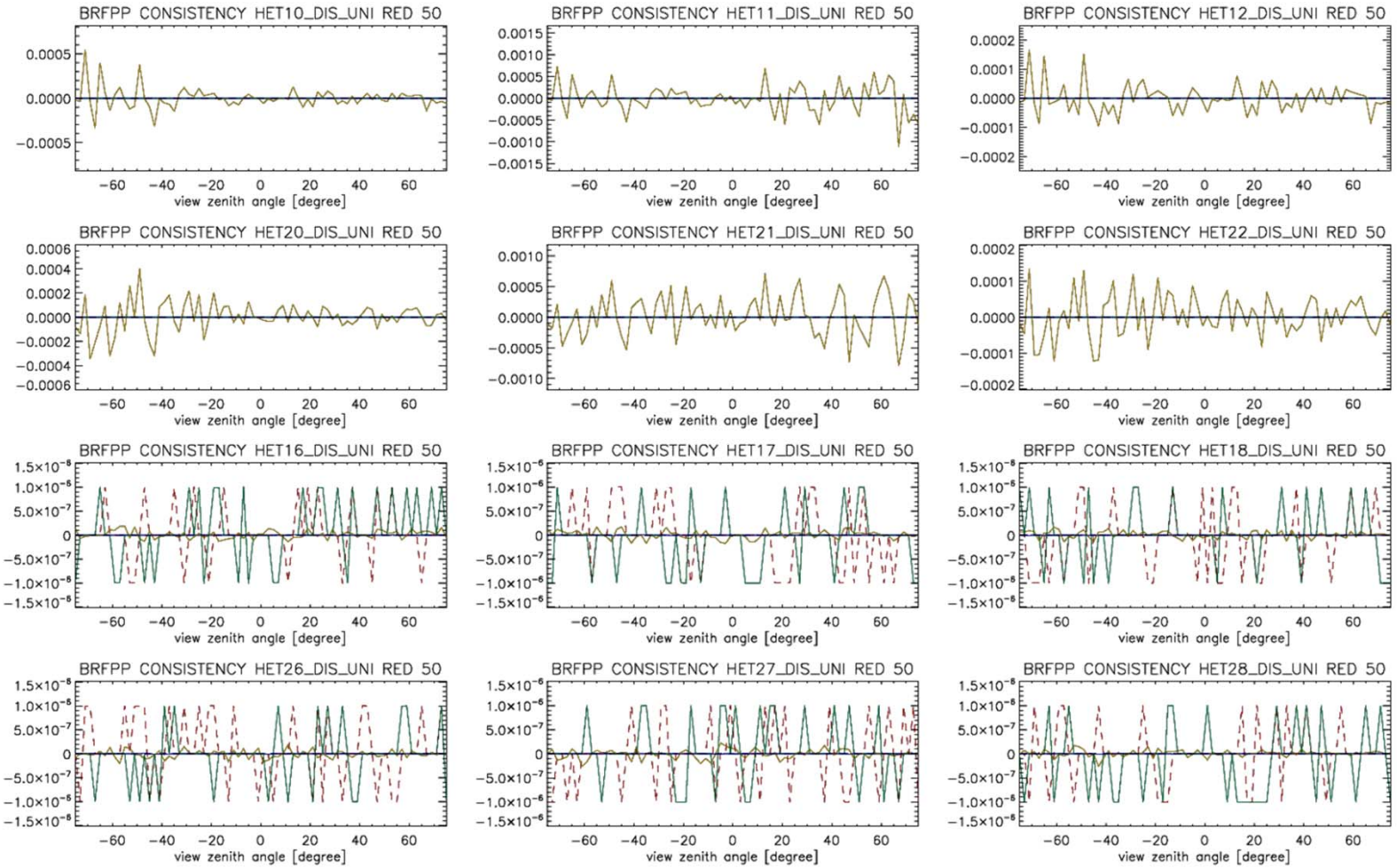


RAMI-IV abstract cases

Consistency

European Commission

$$BRF_{total} - (BRF_{mult} + BRF_{coll} + BRF_{uncoll}) = 0$$

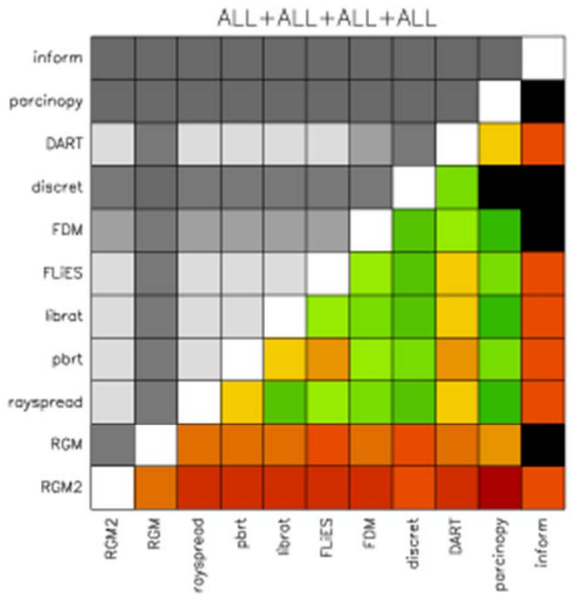


RAMI-IV abstract cases

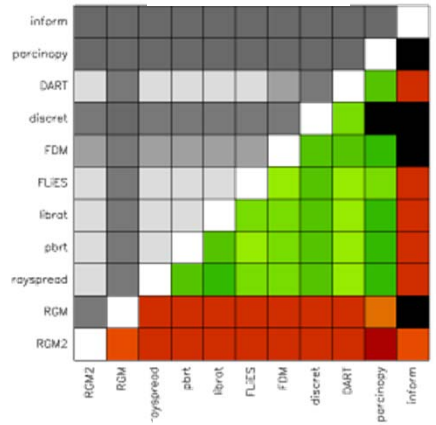
Results (draft)

European Commission

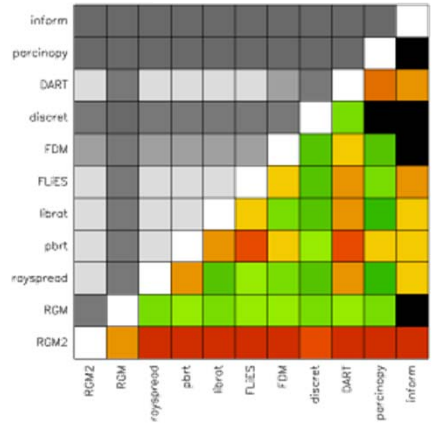
Model-to-model differences of all BRF simulations:



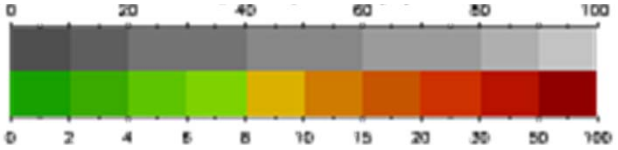
NIR only



Red only



percentage of cases run by both model (%)

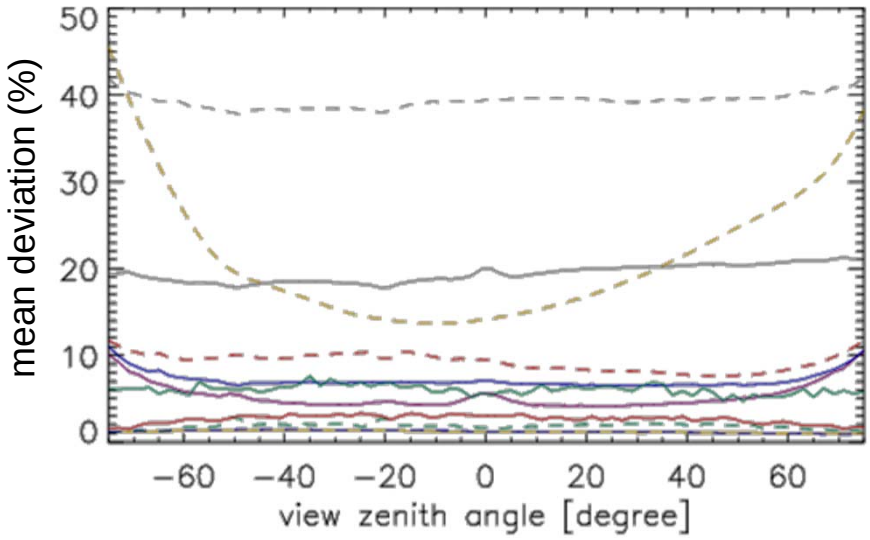


difference between models (%)

RAMI-IV abstract cases reference data

European Commission

- *Use simulations of 3-D Monte Carlo ray-tracing models that were identified as 'credible' models during RAMI-3*
- *Compute 'robust average' from their simulations using algorithm A proposed in Annex C of ISO-13528*
- *Compare against model simulations*



INTERNATIONAL STANDARD **ISO 13528**

Statistical methods for use in proficiency testing by interlaboratory comparisons

C.1 Robust analysis: Algorithm A

This algorithm yields robust values of the average and standard deviation of the data to which it is applied.

NOTE 1 Algorithms A and S given in this annex are reproduced from ISO 5725-5.

NOTE 2 Robustness is a property of the estimation algorithm, not of the estimates it produces, so it is not strictly correct to call the averages and standard deviations calculated by such an algorithm robust. However, to avoid the use of excessively cumbersome terminology, the terms "robust average" and "robust standard deviation" should be understood in this International Standard to mean estimates of the population mean or of the population standard deviation calculated using a robust algorithm.

Denote the p items of data, sorted into increasing order, by:

$$x_1, x_2, \ldots, x_i, \ldots, x_p$$

Denote the robust average and robust standard deviation of these data by x^* and s^*.

Calculate initial values for x^* and s^* as:

$$x^* = \text{median of } x_i \quad (i = 1, 2, \ldots, p) \tag{C.1}$$

$$s^* = 1{,}483 \text{ median of } |x_i - x^*| \quad (i = 1, 2, \ldots, p) \tag{C.2}$$

Update the values of x^* and s^* as follows. Calculate:

$$\delta = 1{,}5s^* \tag{C.3}$$

For each x_i ($i = 1, 2, \ldots, p$), calculate:

$$x_i^* = \begin{cases} x^* - \delta, & \text{if } x_i < x^* - \delta \\ x^* + \delta, & \text{if } x_i > x^* + \delta \\ x_i, & \text{otherwise} \end{cases} \tag{C.4}$$

Calculate the new values of x^* and s^* from:

$$x^* = \sum x_i^* / p \tag{C.5}$$

$$s^* = 1{,}134 \sqrt{\sum (x_i^* - x^*)^2 / (p - 1)} \tag{C.6}$$

where the summation is over i.

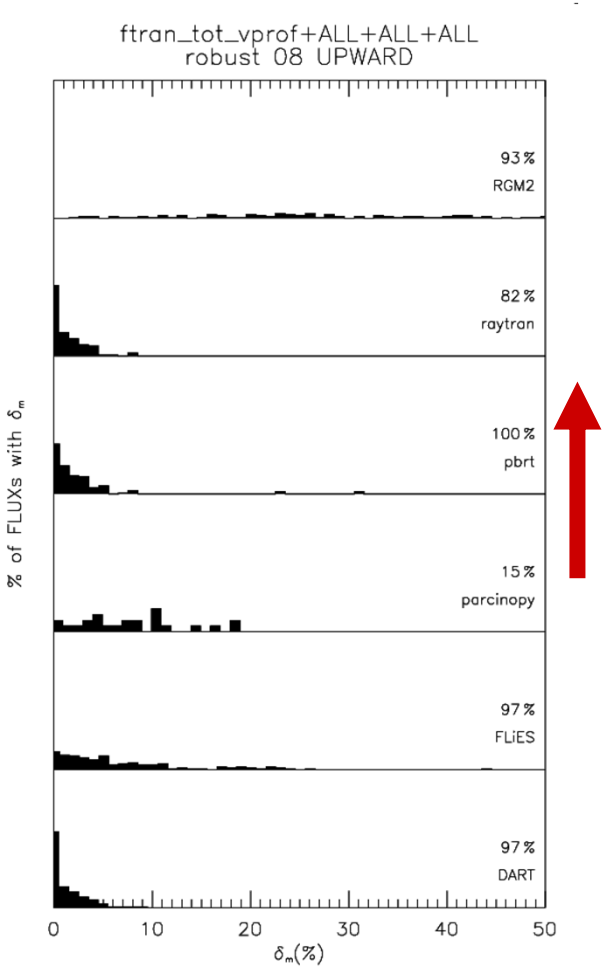
The robust estimates x^* and s^* may be derived by an iterative calculation, i.e. by updating the values of x^* and s^* several times using the modified data, until the process converges. Convergence may be assumed when there is no change from one iteration to the next in the third significant figure of the robust standard deviation and of the equivalent figure in the robust average. This is a simple method to program on a computer.

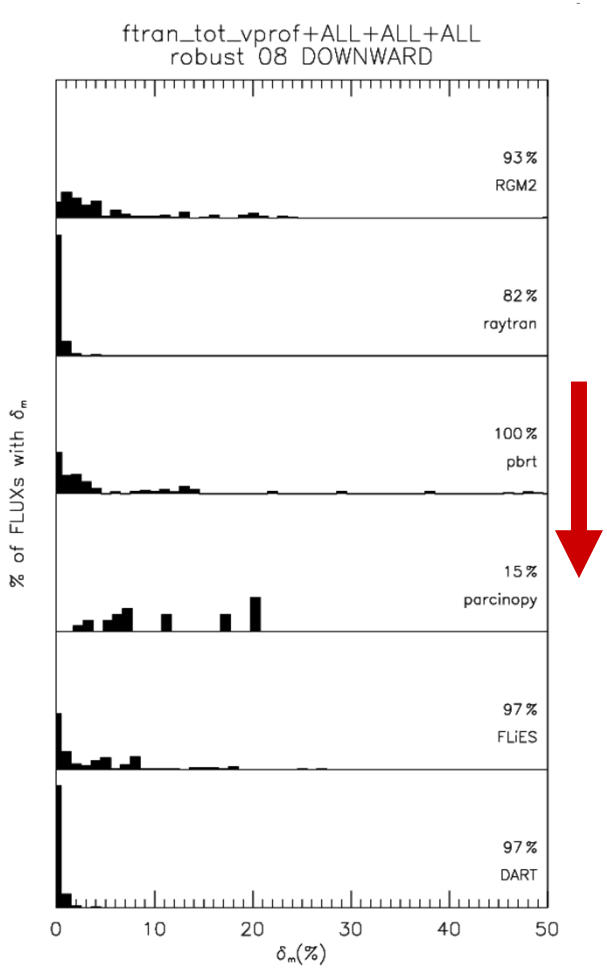
RAMI-IV abstract cases

Results (draft)

European Commission

Histograms of model-to-reference differences for flux profile simulations





RAMI-IV abstract cases

z′ score statistics

European Commission

$z' < 2$

$2 \leq z' \leq 3$

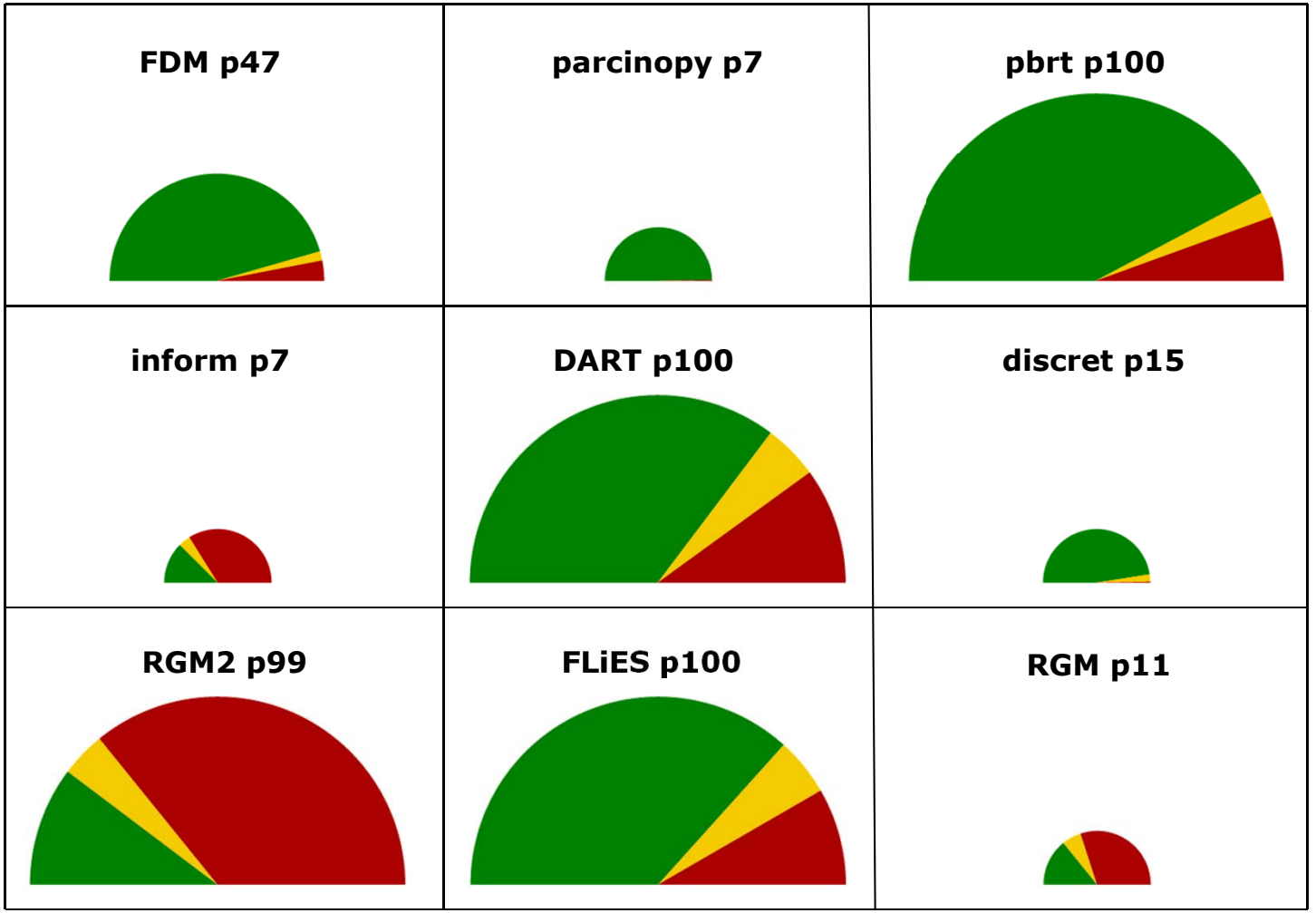
$z' > 3$

z′ score computed according to the ISO standard 13528

2 ≤ z′ ≤ 3 gives rise to warning signal

z′ > 3 gives rise to an action signal

p=percentage of test cases covered by model [%]



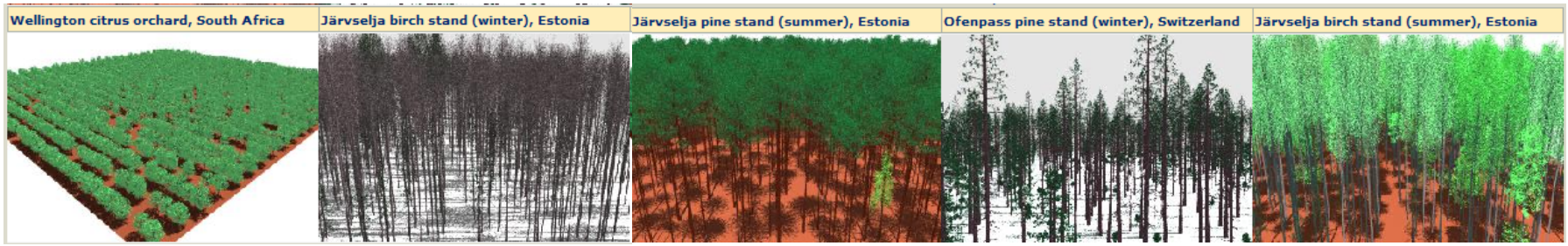
Stand. dev. for proficiency assessment = 3% of reference

RT models used to build reference are excluded here.

RAMI outlook

European Commission

- *Finish analysis of RAMI-IV abstract cases (end 2012)*
- *Achieve re-submission of faulty 'actual' canopy cases of RAMI-IV and start/complete analysis (2013)*



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

Thank you

Jean-Luc.Widlowski@jrc.ec.europa.eu