Two decades of systematic RAdiation transfer Model Intercomparison (RAMI)

Jean-Luc Widlowski

&

the RAMI participants and contributors!

RAMI participants & contributors

Adams, J.
Allgöwer, B.
Andredakis, I.
Antunes, M.
Atzberger, C.
Belward, A.
Bacour, C.
Brennan, J.
Bruniquel-P., V.
Busetto, L
Buzica, D.
Cahalan, R. F.
Ceccherini, G.
Chelle, M.
Clerici, M.
Colombo, R.
Côté, J-F.
Dai, Y.
De Kauwe, M.
de Ridder, K.
Deussen, O.
Dickinson, R.

Disney, M.
Dobbertin, M.
Eenmäe, A.
Essery, R.
Fernandes, R.
Gascon, F.
Gastellu-E., J-P.
Gerboles, M.
Gerstl, S. A. W.
Gobron, N.
Goel, N.
Grau, E.
Haverd, V.
Homolová, L.
Huang, H.
Hunt, L. A.
Itten, K. I.,
Jacquemoud, S.
Jiang, L.
Kallel, A.
Kobayashi, H.
Kötz, B.

Kuusk, A.
Kuusk, J.
Lang, M.
Lavergne, T.
Leblanc, S.
Lewis, P.
Li, X.
Lopatka, M.
Lovell, J.
Lükk, T.
Malenovský, Z.
Martin, E.
Marshak, A.
McGuffy, K.
Meier, E.
Meroni, M.
Mio, C.
Morsdorf, F.
Mõttus, M.
Ni-Meister, W.
Nilson, T.
Nolin, A.

North, P.
Olchev, A.
Peltoniemi, J.
Perego, A.
Pinty, B.
Pisek, J.
Pitman, A.
Qin, W.
Quaife, T.
Raes, F.
Rautiainen, M.
Robustelli, M.
Rochdi, N.
Ruiloba, R.
Schlerf, M.
Seufert, G.
Soler, C.
Somers, B.
Stuckens, J.
Su, L.
Taberner, M.
Tang, S.

Teobaldelli, M.
Thompson, R.
Tognoli, P. V.
Tournier, A.
van den Hurk, B.
Várnai, T.
Verhoef, W.
Verstraete, M. M.
Wang, H.
Wang, J.
Wang, S.
Xie, D.
Yan, G.
Yang, W.
Yang, Y.
Yuan, H.
Zang, H.
Zeng, X.
Zenone, T.
Zhao, F.

IWMMM-2

first presentation of RAMI results

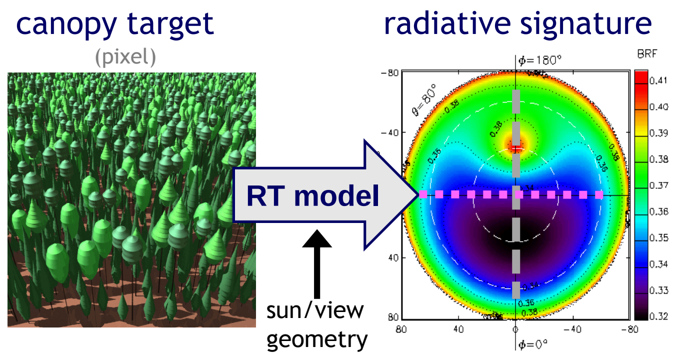
2nd International Workshop on Multiangular Measurements and Models, 15-17th Sept. 1999, JRC - Ispra

Juhan
Ross

RAMI

Launched in 1999:

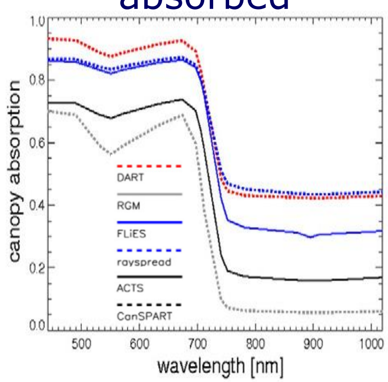
- enable systematic comparison
- establish evaluation protocols
- document quality impartially
- act as platform for community



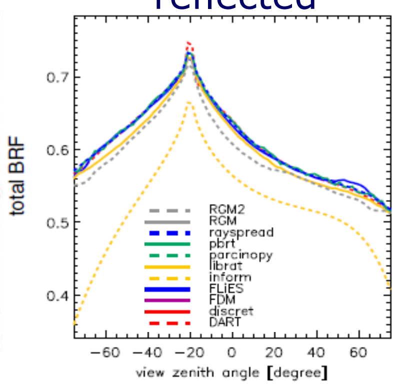
VIS/NIR, no atmosphere

Focus on:

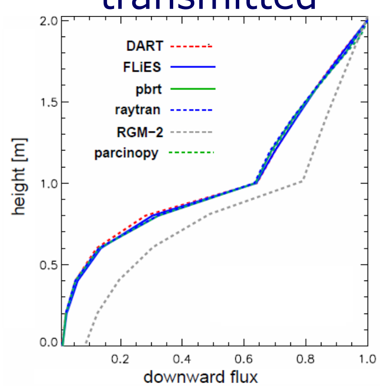
absorbed



reflected



transmitted



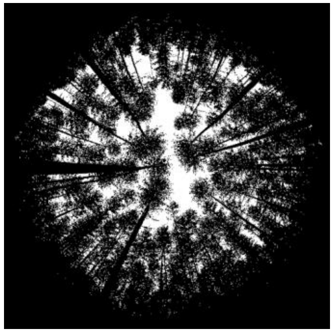
radiation quantities

directional / hemispherically integrated

above / within canopy volume

domain level / location specific

collected by sensors



binary DHP

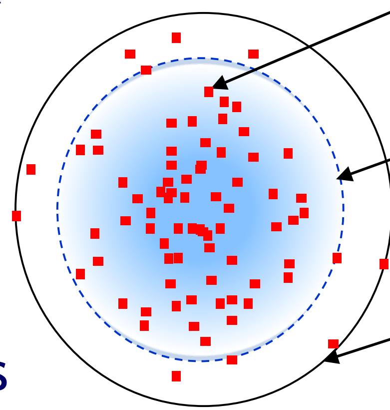
Widlowski et al., 2013 (JGR), 2015 (RSE)

RAMI strategy

- work under controlled experimental conditions:
  (i.e., no comparison with laboratory or *in situ* 'reference' data)
- verify sub-components of radiative target quantities:
  (i.e., evaluate quantities that cannot be measured in practice)
- test extreme but physically-meaningful situations:
  (i.e., test scenarios that cannot be encountered in the field)

Conformity with expectation is not proof of model validity!

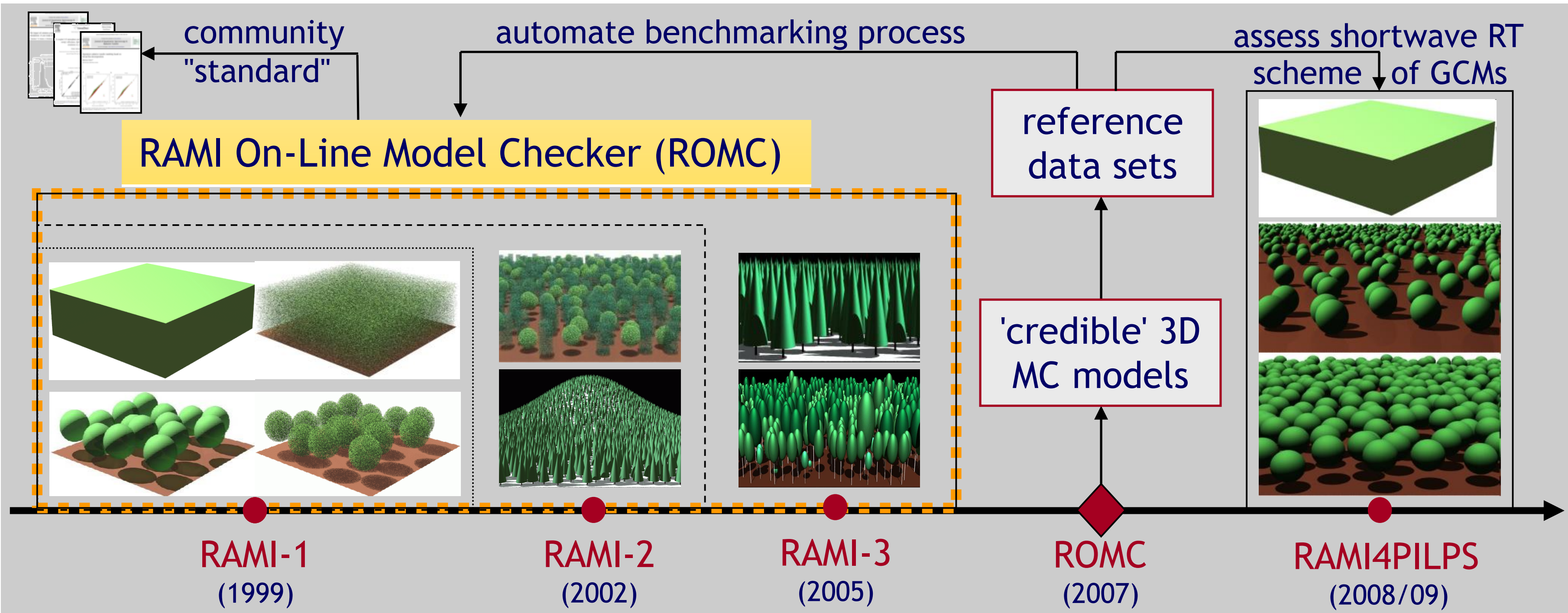
Verify if RT models handle the physics correctly over a continuously expanding number of RAMI test cases that span the complete range of parameter values



Oreskes et al. (1994) Science; Pinty et al. (2001, 2004) JGR; Widlowski et al., (2007, 2013) JGR

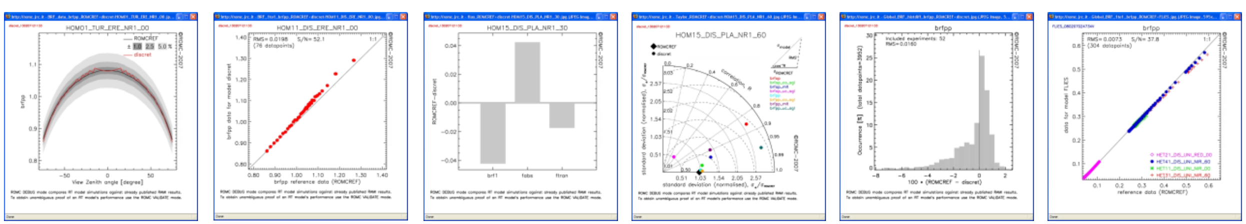
RAMI evolution

Systematic model comparison:



55 models in ROMC:

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



Pinty et al., 2001, 2004 (JGR); Widlowski et al., 2007, 2010 (JGR), 2008 (RSE)

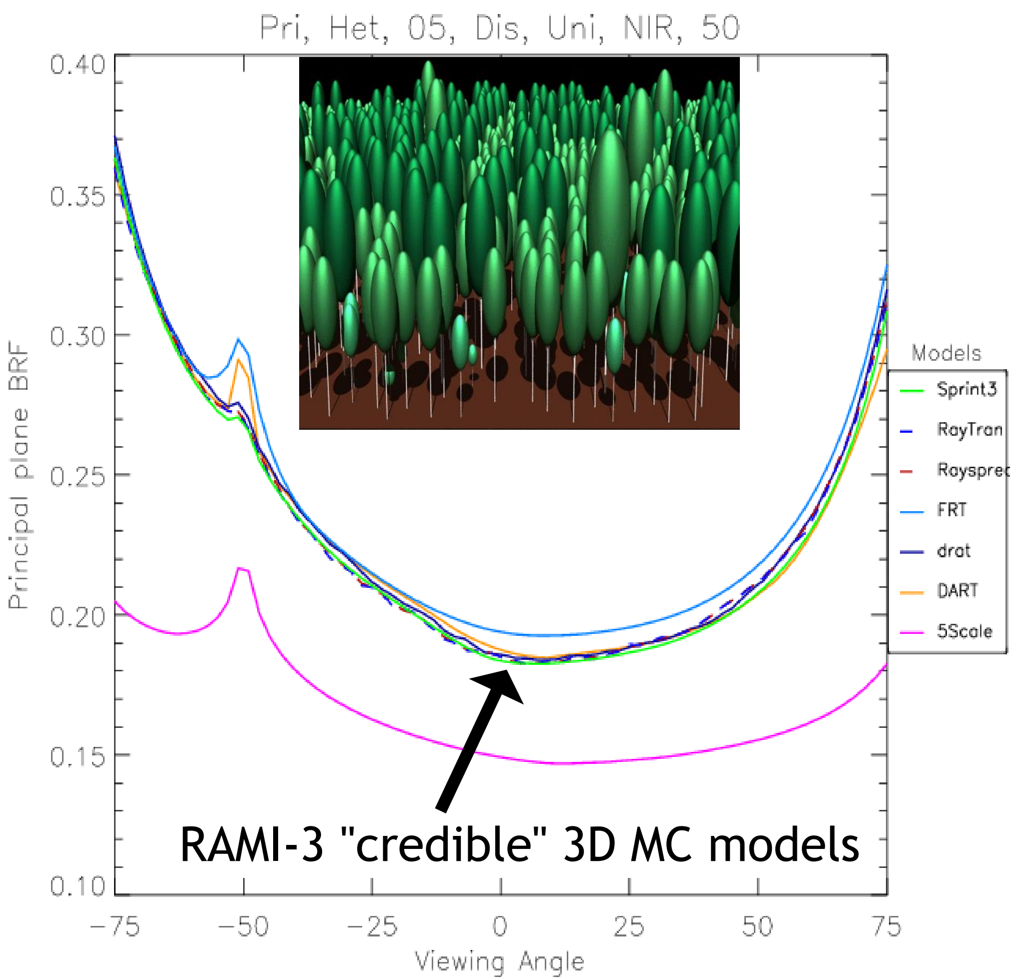
"credible" RT models

Requirements:

- versatile (1D + 3D),
- few assumptions,
- internally consistent,
- agree with analytical (exact) solutions.

RAMI-3 'credible' models:

FLIGHT (North, 1996)
raytran (Govaerts & Verstraete, 1998)
dart (Gastellu-Etchegorry et al., 2004)
drat (Lewis, 1999; Saich et al., 2001)
rayspread (Widlowski et al., 2006)
sprint3 (Thompson & Goel, 1998)



Model agreement ~1%

Widlowski et al., (2007) JGR

"credible" RT models

Requirements:

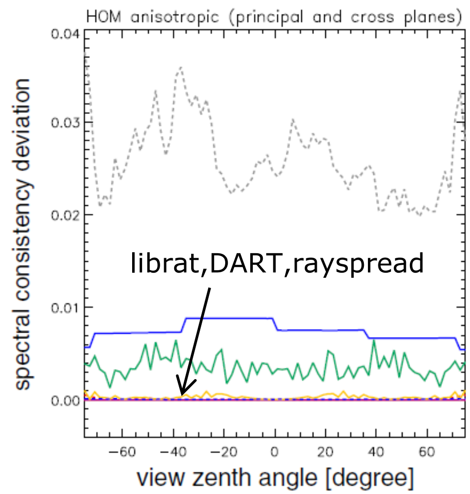
- versatile (1D + 3D),
- few assumptions,
- internally consistent,
- agree with analytical (exact) solutions.

Energy conservation:

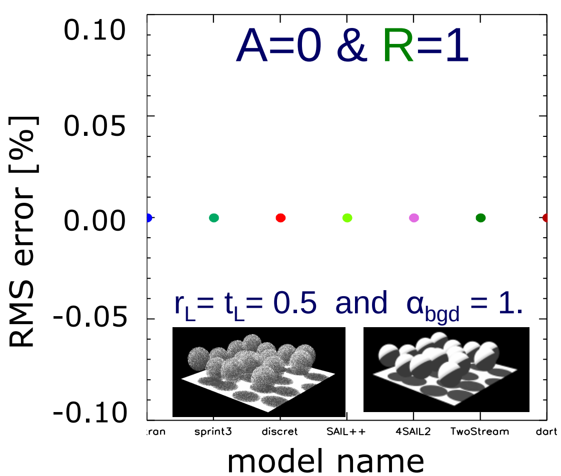
- BRFs: total=uc+co+mlt
- Fluxes: 1=A+R+T-αT

Spectral ratio:

- $T^0_{\lambda 1} / T^0_{\lambda 2} = 1$
- $(uc_{\lambda 1}/uc_{\lambda 2}) - (\alpha_{\lambda 1}/\alpha_{\lambda 2})=0$

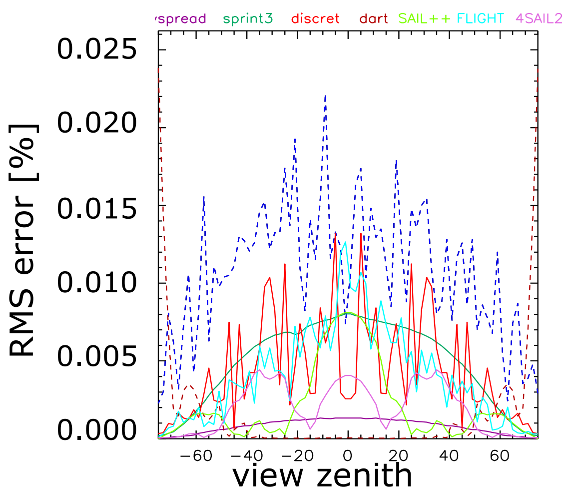


Purist corner fluxes:

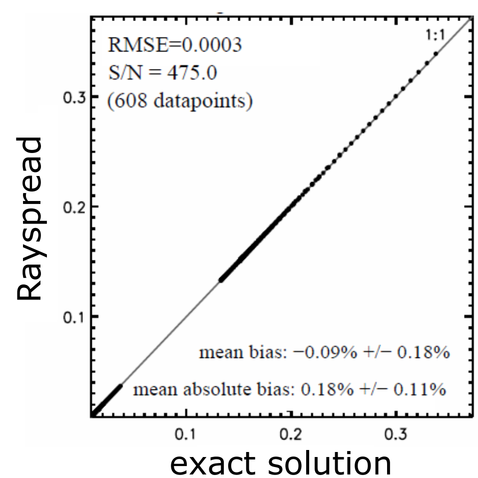


Widlowski et al., (2007) JGR

uc for HOM TUR UNI



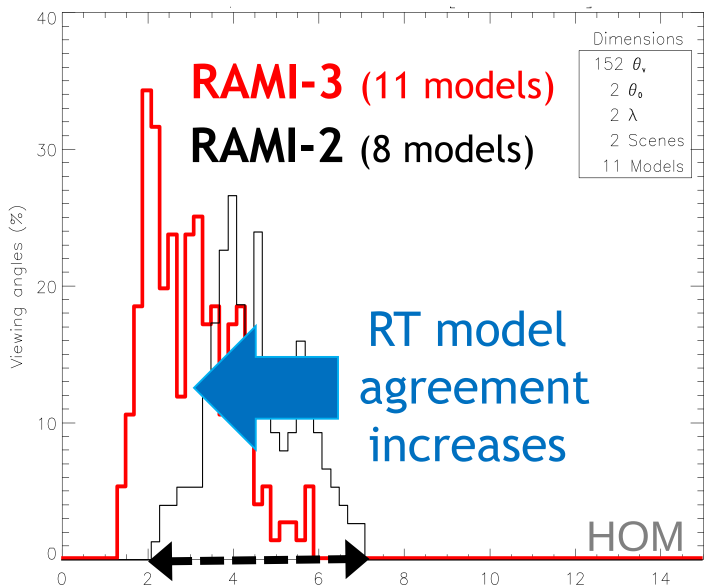
co for HOM TUR UNI



Widlowski et al., (2013) JGR

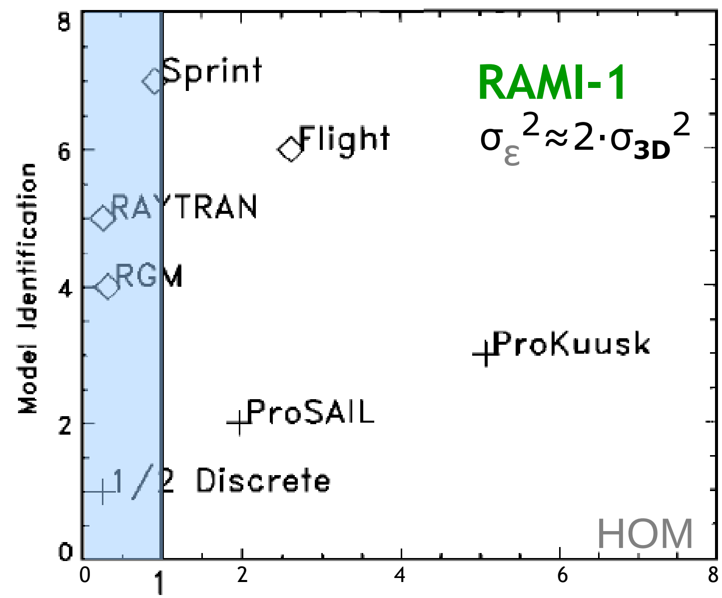
Model Evaluation

histogram of deviations

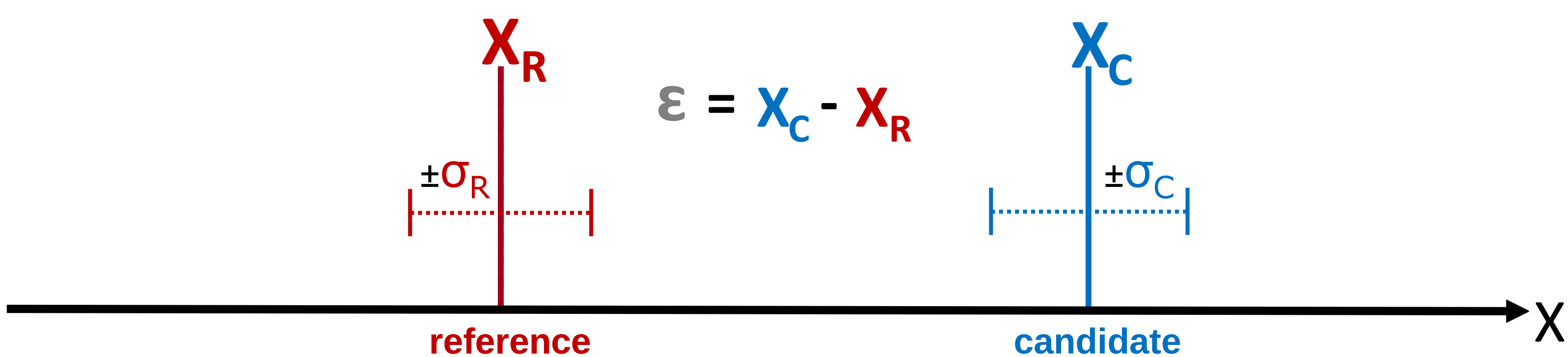


$\delta = |\varepsilon| / X_R$ [%]

discernability from reference



$\chi^2 = {}^1/_N \sum \varepsilon^2/\sigma_\varepsilon^2$



Widlowski et al., 2007 (JGR)

Pinty et al., 2001 (JGR)

Model Evaluation (2)

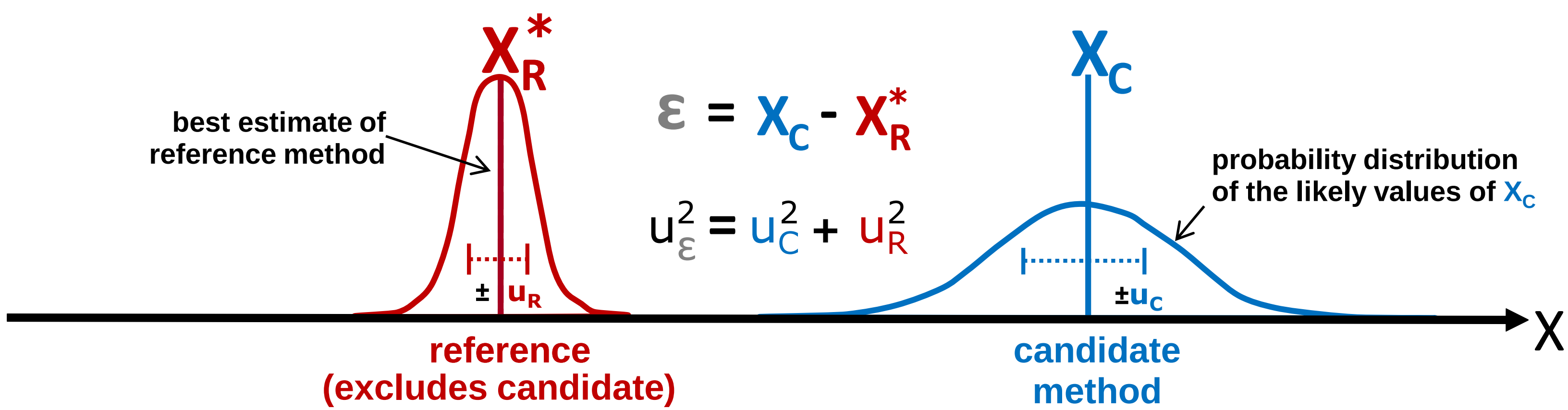
In RAMI-IV:

1) candidate models no longer contribute to own reference:
   - model-specific references X_R^*

2) both operator and RT issues cause 'method' uncertainty:
   - combined standard uncertainty

$$u_C = \sqrt{u_{op}^2 + u_{mod}^2}$$

3) the fitness-for-purpose of RT models is assessed.

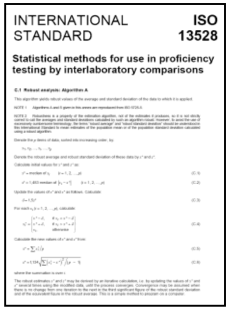


Widlowski et al., 2013 (JGR)

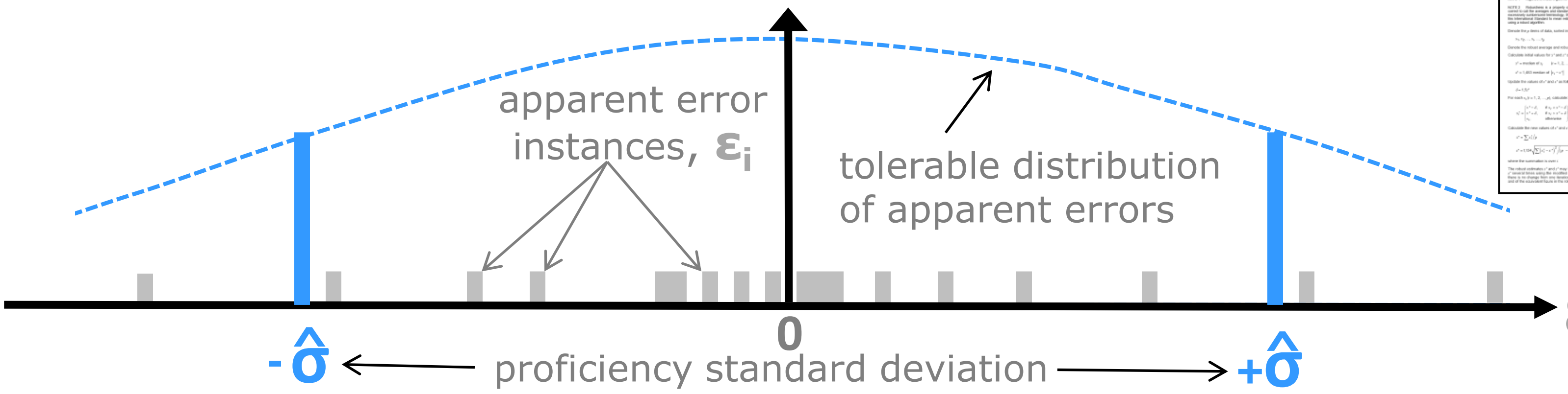
Widlowski et al., 2015 (RSE)

RAMI-IV evaluation schemes

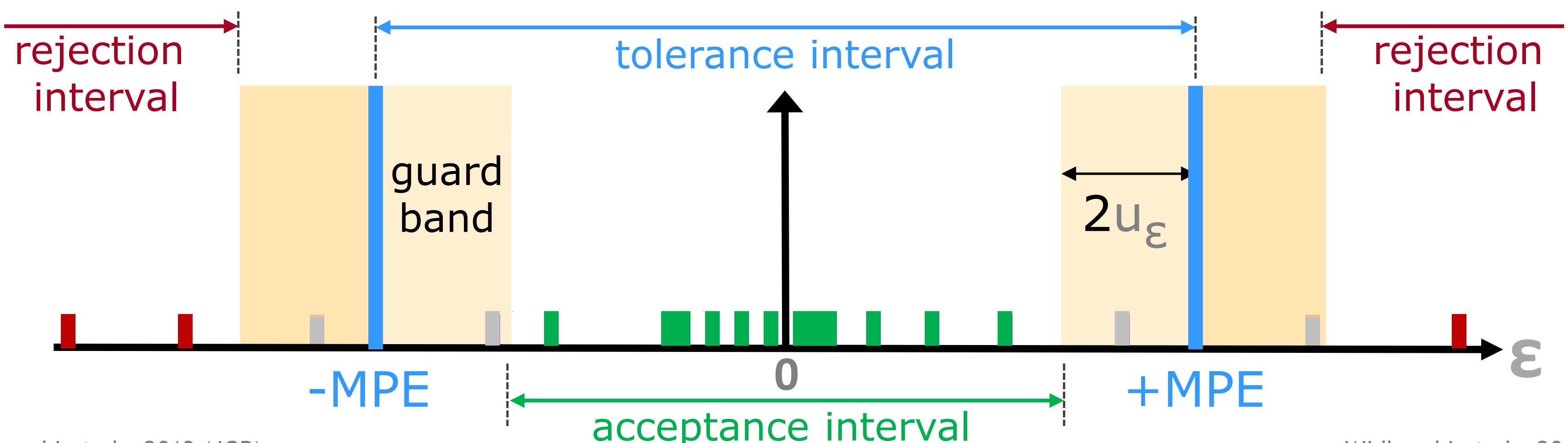
Proficiency testing:


INTERNATIONAL STANDARD ISO 13528

Statistical methods for use in proficiency testing by interlaboratory comparisons

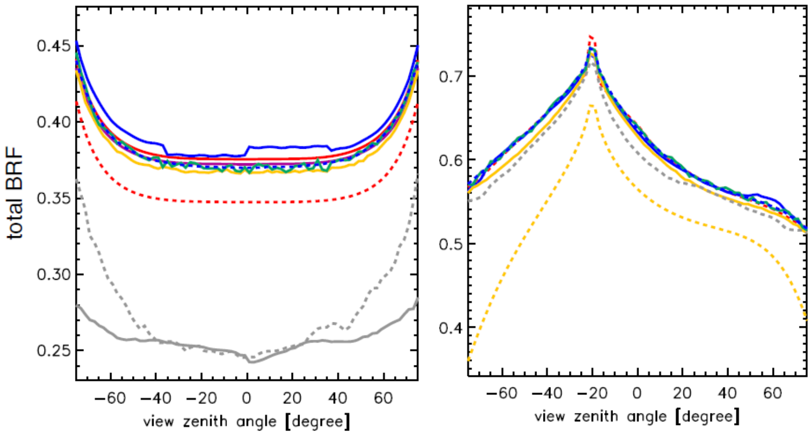


Conformity testing:



RAMI-IV

'abstract' canopies

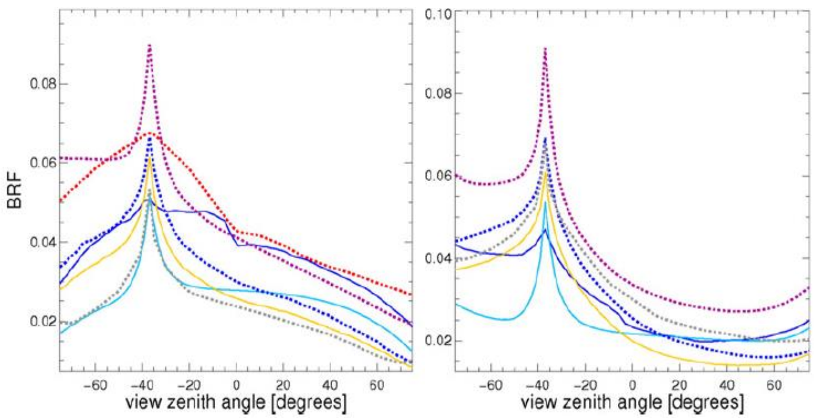


- ➢ Analysis using ISO-13528 *proficiency testing* method
- ➢ 12 participating models
- ➢ 'Good' performances
  - easy to spot BRF outliers
  - each BRF file ~3x submitted

$$\mathbf{u_C} = \sqrt{u_{op}^2 + u_{mod}^2} \approx \mathbf{u_{mod}}$$

Widlowski et al., 2013 (JGR)

'actual' canopies



- ➢ Analysis using BIPM/JCGM *conformity testing* method
- ➢ 12 participating models
- ➢ 'Poor' performances
  - 90-895 · 10^6 objects /scene
  - all BRFs differ (no cluster)

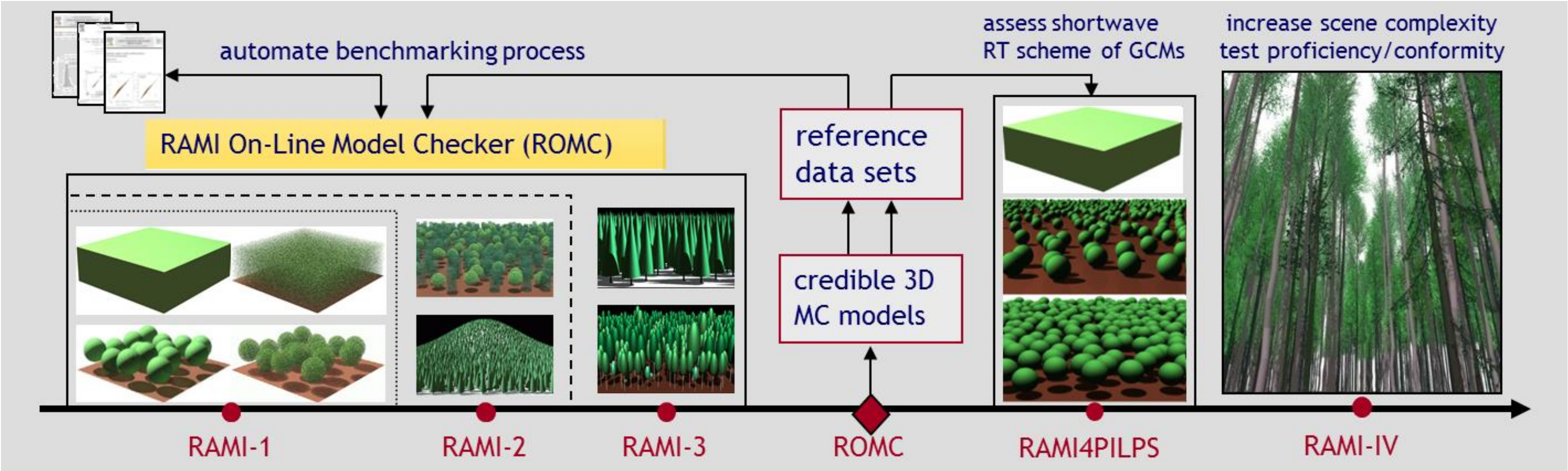
$$\mathbf{u_C} = \sqrt{u_{op}^2 + u_{mod}^2} \approx \mathbf{u_{op}}$$

Widlowski et al., 2015 (RSE)

RAMI achievements

Proficiency (ISO-13528) and *conformity* testing allows to assess RT model performance with respect to predefined tolerance criteria.

ROMC allows independent quasi-real-time RT model benchmarking using RAMI-3 test cases and reference datasets.



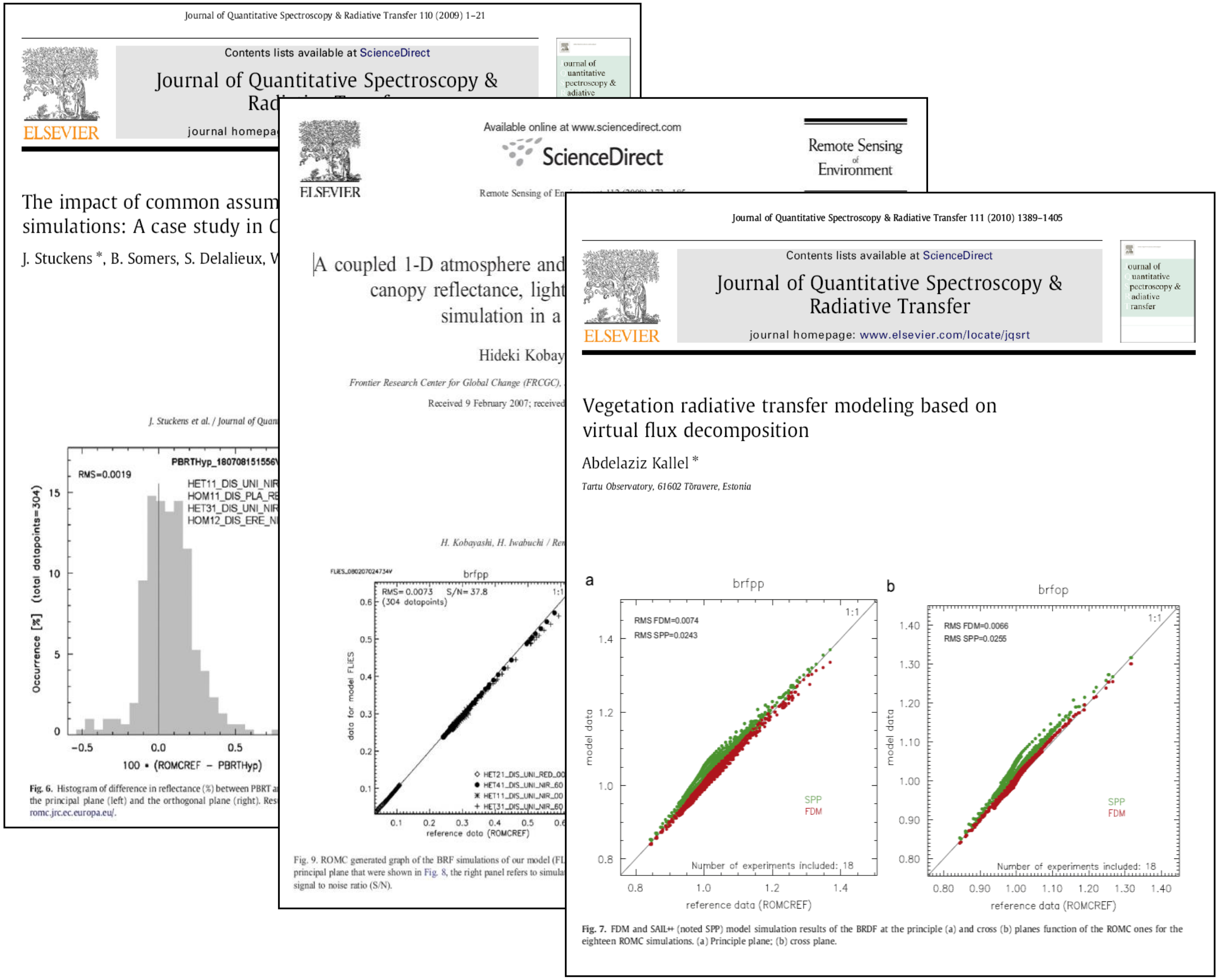
Systematic comparison of models is essential to document progress, identify 'credible' models and to build reference datasets.

Pinty et al., 2001, 2004 (JGR); Widlowski et al., 2007, 2010, 2013 (JGR); Widlowski et al, 2008, 2015 (RSE)

European Commission

Thank you

ROMC usage



Availability of ROMC allows to *automate* the RT model benchmarking process using the test cases from RAMI-3.

New in 2016/2017:

- GOSAILT
- oneDCI
- dirsig5
- RTEC
- Canray
- Luxrender
- dofin2

So far 55 unique models registered in ROMC: http://romc.jrc.ec.europa.eu/

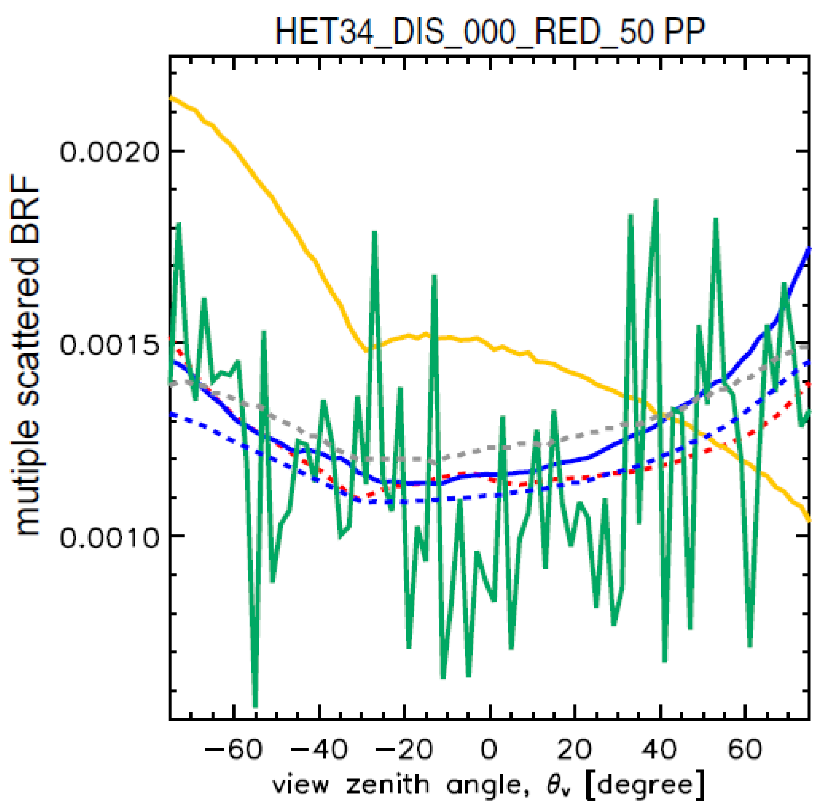
Widlowski et al., 2008 (RSE);

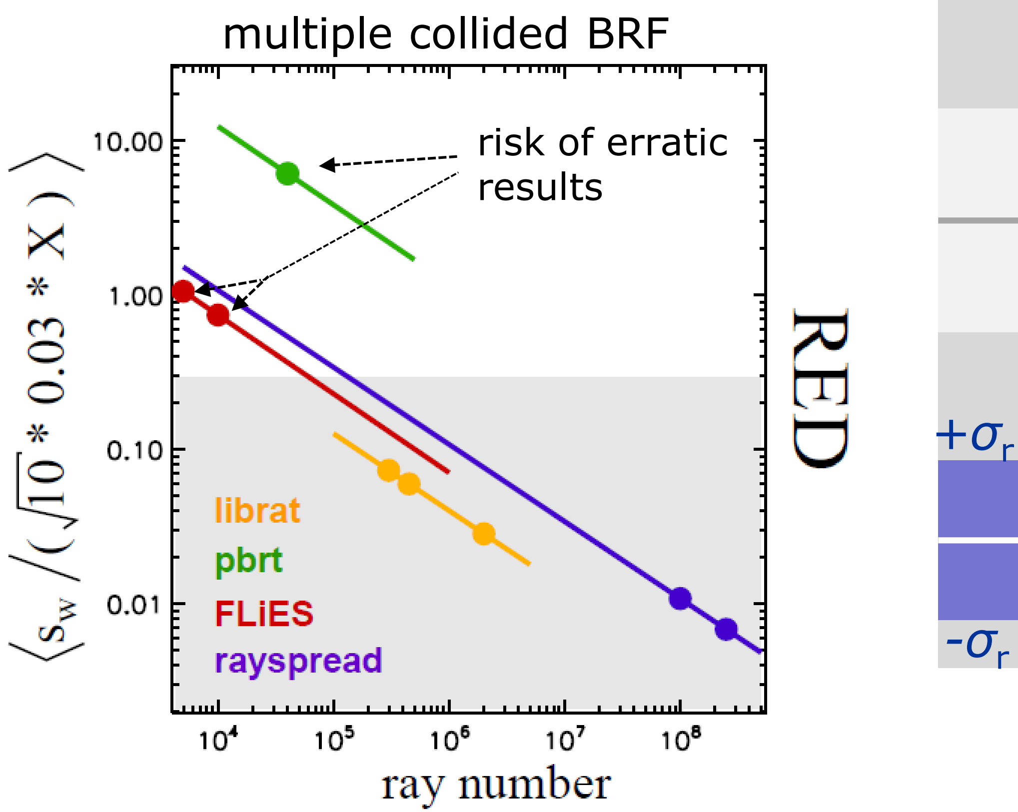
Assess repeatability standard dev.

For analytic or parametric models $\sigma_r = 0$

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

Rewrite ISO criteria $0.3\,\hat{\sigma} > \sigma_r/\sqrt{n}$ as: $0.3 \geq s_w / (f \cdot X \cdot \sqrt{n})$





Widlowski et al., (2012) JGR

European Commission

results relevance: surface radiative forcing

Comparison with 2 studies defining surface radiative forcing [W/m^2] as:

$\Delta F = I{\downarrow}(t_2)R(t_2) - I{\downarrow}(t_1)R(t_1)$

$$\chi^2 = \frac{1}{N}\sum_{i}^{N}(M_i - R_i)^2/\sigma^2$$

Some large ΔF deviations are found (3-D case)

Significance of ΔF deviations can only be assessed if uncertainty of retrieval is known

Widlowski et al., JGR, 2011

3-D woody savanna fire

(Jin and Roy, 2005, GRL)

pre-burn SW albedo = 0.151±0.008
postburn SW albedo = 0.130±0.007
$I{\downarrow}(t_1) = I{\downarrow}(t_2) = I{\downarrow}(\text{july}) = 203 \pm 6$ W/m^2

closest RAMI4PILPS case:
OFC, $\alpha_{soil(t1)}$=MED; $\alpha_{soil(t2)}$=BLK
LAI=2.5, θ_0=60°, $R=R_{VIS}+R_{NIR}$

	R(t_1)	R(t_2)	-ΔF [W/m^2]
JinRoy05	.151	.130	4.26±0.32
Ref. model	.151	.126	5.14±0.40
ACTS	-	-	11.5 (+123%)
CoLM	-	-	17.2 (+234%)
EALCO	-	-	6.26 (+21.8%)
FLiES	-	-	5.68 (+10.7%)
IAGL	-	-	2.07 (-59.7%)
JRCTIP	-	-	6.09 (+18.6%)

$\sigma_{\Delta F}$=1.158W/m^2 → χ^2=0.60

3-D forest snow melt

(Lyons et al., 2008, JGR)

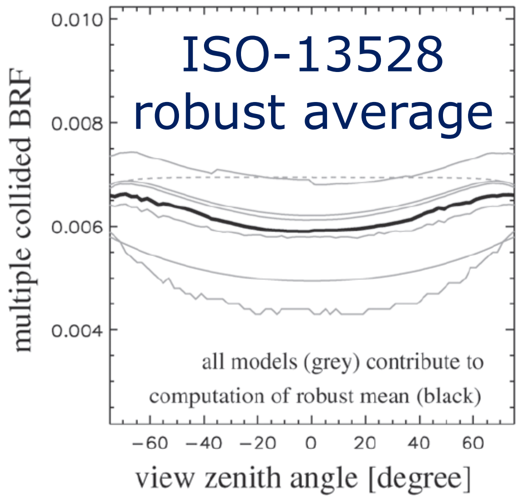
day 100 SW albedo ≈ 0.36
day 200 SW albedo ≈ 0.12
$I{\downarrow}(d100)=165.5$, $I{\downarrow}(d200)=206.7$ W/m^2

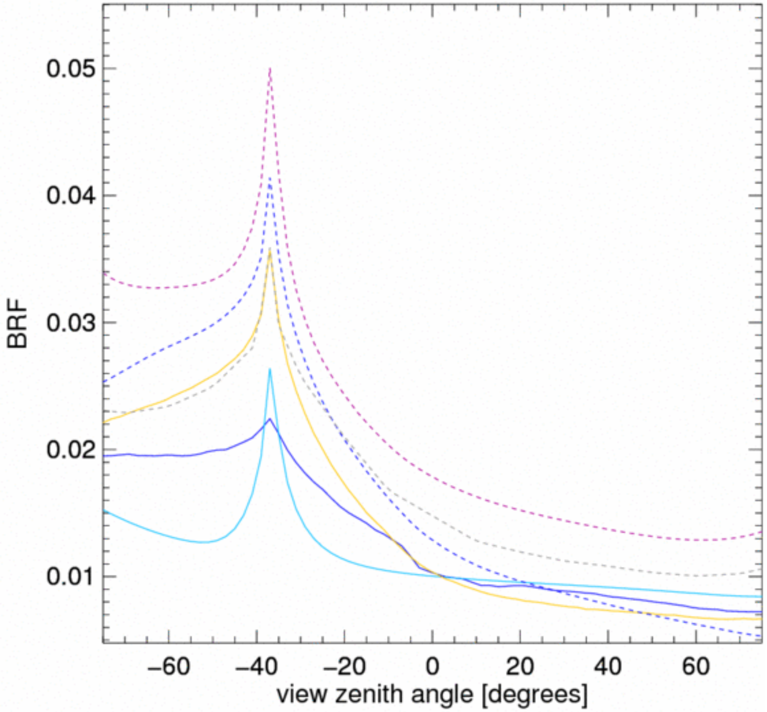
closest RAMI4PILPS case:
OFC, $\alpha_{soil(t1)}$=SNW; $\alpha_{soil(t2)}$=MED
LAI=1.5, θ_0=60°, $R=R_{VIS}+R_{NIR}$

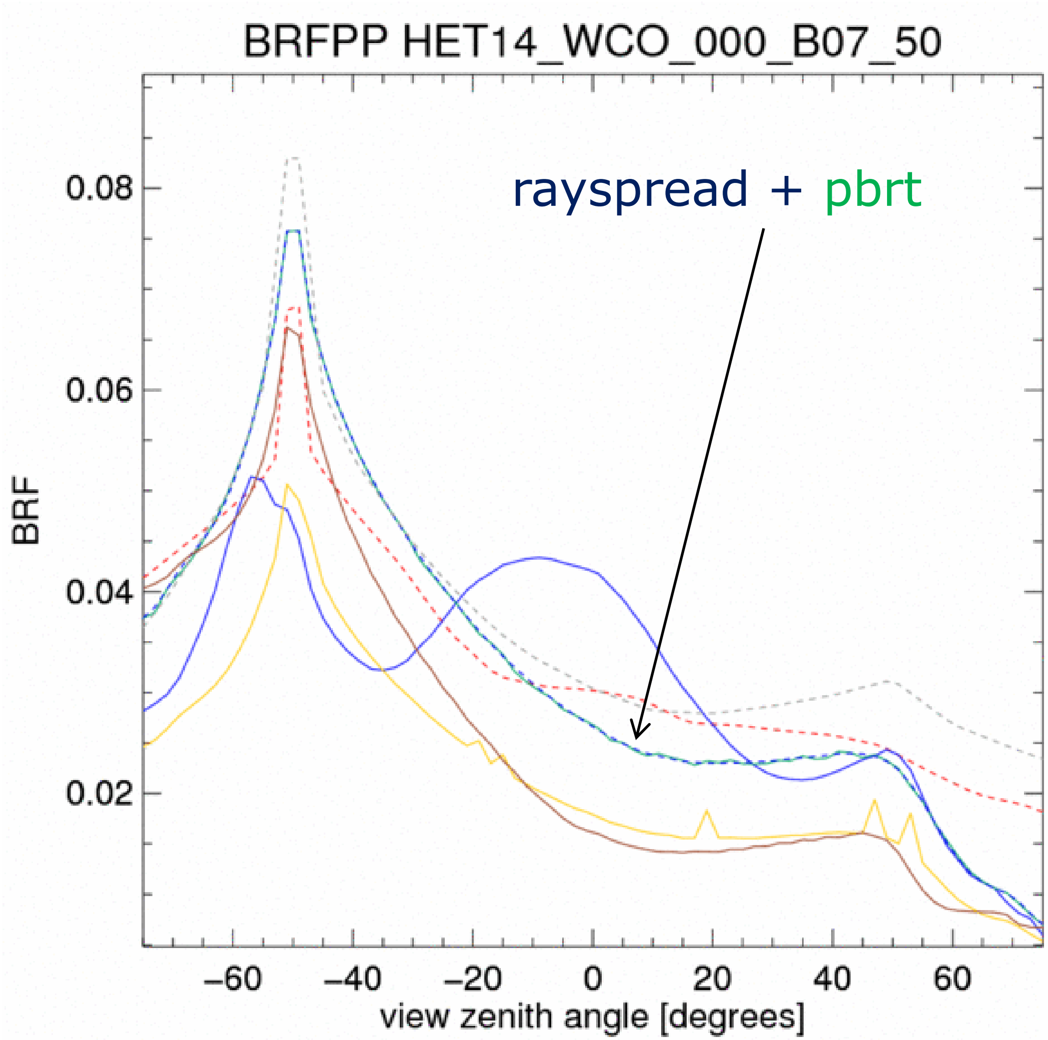
	R(t_1)	R(t_2)	-ΔF [W/m^2]
Lyons08	0.36	0.12	34.8
Ref. model	0.36	0.14	29.0±0.37
ACTS	-	-	38.0 (+31.0%)
CoLM	-	-	63.4 (+111%)
EALCO	-	-	29.9 (+2.9%)
FLiES	-	-	29.3 (+0.9%)
MixFor3D	-	-	25.9 (-10.8%)
JRCTIP	-	-	29.7 (+2.3%)

$\sigma_{\Delta F}$=1.140W/m^2 → χ^2=0.21

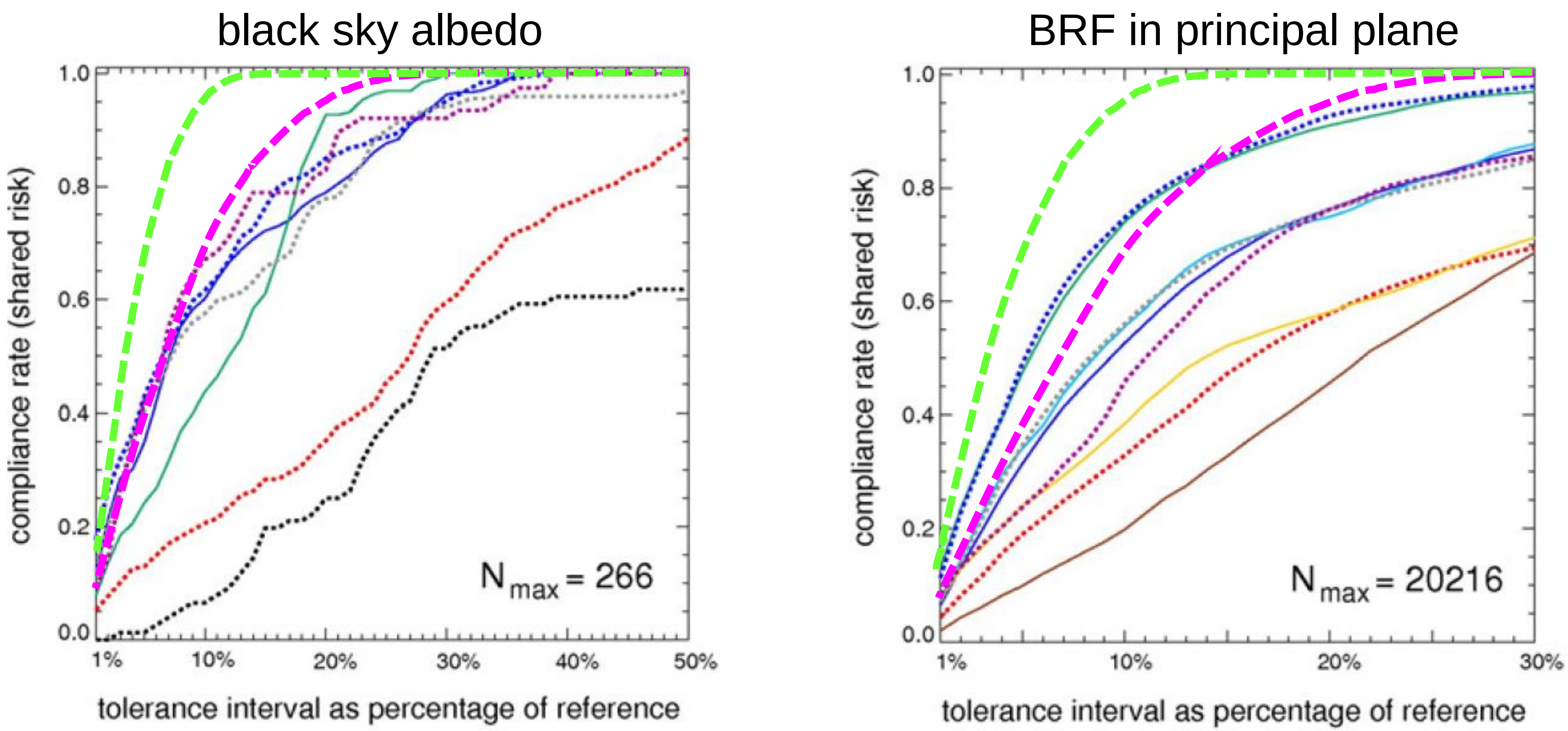
RAMI-IV reference







RAMI-IV: Shared Risk



MPE = $f \cdot X_R$ MPE = $f \cdot X_R$