Radiation Transfer Model Intercomparison: Overview

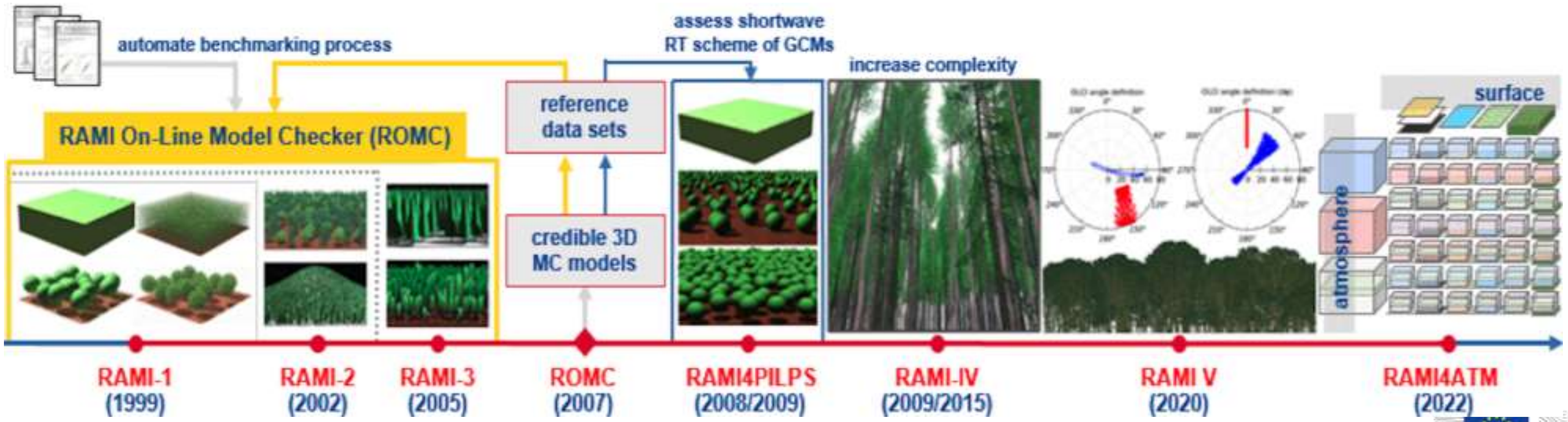
Nadine Gobron on behalf RAMI Team

RAMI Workshop 2023

European Commission

Radiation Transfer Model Intercomparison exercise

- (1D)-3D Radiative Transfer model **independent** assessment
- 20+ years activities (**five phases**, ROMC and RAMI4PILS)
- **Blind concept**
- Increased complexity of scenarios and experiments
- Oriented to vegetated surfaces
- Oriented to satellite and in situ observations
- RAMI4ATM: towards coupled atmosphere-surface scenes.



https://rami-benchmark.jrc.ec.europa.eu/

April 2022 — **RAMI4ATM**

Launch of the RAMI4ATM phase

October 2020 — **RAMI V**

Launch of the 5th RAMI phase

2009/2015 — **RAMI IV**

2008/2009 — **RAMI4PILPS**

2007 — **ROMC**

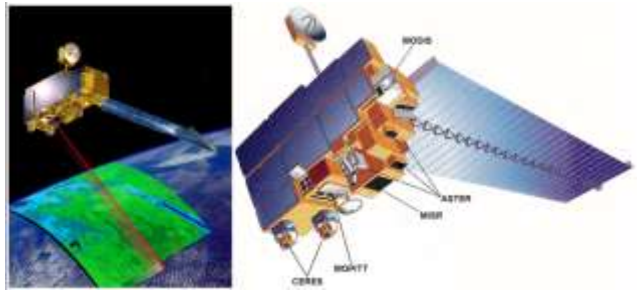
The RAMI On-line Model Checker

2005 — **RAMI 3**

2002 — **RAMI 2**

1999 — **RAMI 1**

EnviSat (Image credit: ESA)



Terra (Image credit: NASA)

European Commission

April 2022 **RAMI4ATM**

[Launch of the RAMI4ATM phase]

October 2020 **RAMI V**

[Launch of the 5th RAMI phase]

2009/2015 **[RAMI IV]**

2008/2009 **[RAMI4PILPS]**

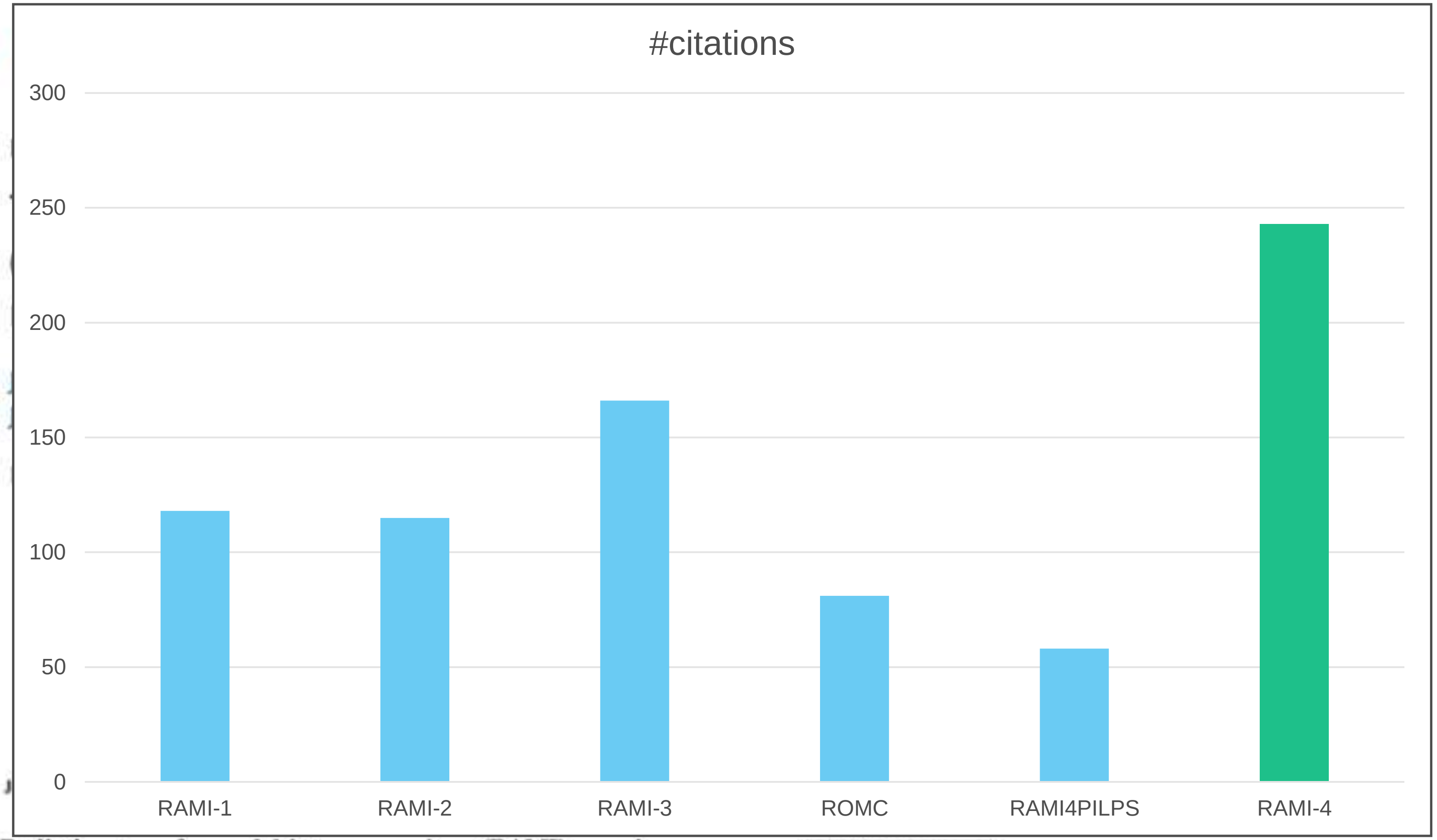
2007 **ROMC**

[The RAMI On-line Model Checker]

2005 **[RAMI 3]**

2002 **[RAMI 2]**

1999 **[RAMI 1]**



Radiation transfer model intercomparison (RAMI) exercise

Bernard Pinty,[1] Nadine Gobron,[1] Jean-Luc Widlowski,[1] Sigfried A. W. Gerstl,[1] Michel M. Verstraete,[1] Mauro Antunes,[2] Cédric Bacour,[3] Ferran Gascon,[4] Jean-Philippe Gastellu,[4] Narendra Goel,[5] Stéphane Jacquemoud,[3] Peter North,[6] Wenhan Qin,[7] and Richard Thompson[8]

Abstract. The community involved in modeling radiation transfer over terrestrial surfaces designed and implemented the first phase of a radiation transfer model intercomparison (RAMI) exercise. This paper discusses the rationale and motivation for this endeavor, presents the intercomparison protocol as well as the evaluation procedures, and describes the principal results. Participants were asked to simulate the transfer of radiation for a variety of precisely defined terrestrial environments and illumination conditions. These were abstractions of typical terrestrial systems and included both homogeneous and heterogeneous scenes. The differences between the results generated by eight different models, including both one-dimensional and three-dimensional approaches, were then documented and analyzed. RAMI proposed a protocol to quantitatively assess the consequences of the model discrepancies with respect to application, such as those motivating the development of physically based inversion procedures. This first phase of model intercomparison has already proved useful in assessing the ability of the modeling community to generate similar radiation fields despite the large panoply of models that

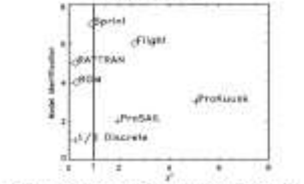


Figure 4. Plots of the χ^2 values estimated using equation for each of the RAMI models in the case of the homogeneous scenes. The cross and diamond signs identify the σ

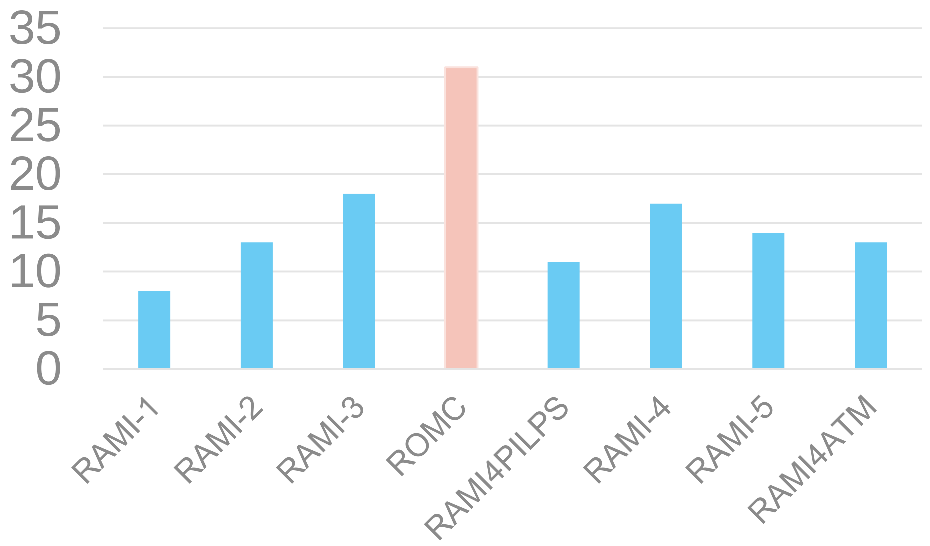
$$\rho^{\text{Credible}}(i, j, s, \lambda) = \langle \rho^{3D}(i, j, s, \lambda) \rangle,$$

$$\sigma^2_{3D}(\lambda) = \frac{1}{N_B - 1} \sum_{m=1}^{N_{3D}} \sum_{i=1}^{N_{\theta_i}} \sum_{j=1}^{N_{\theta_v}} \sum_{s=1}^{N_{\text{scenes}}} [\rho^{3D}(i, j, s, \lambda) - \rho^{\text{Credible}}(i, j, s, \lambda)]^2.$$

$$\chi^2 = \frac{1}{N} \sum_{i=1}^{N_{\theta_i}} \sum_{j=1}^{N_{\theta_v}} \sum_{s=1}^{N_{\text{scenes}}} \sum_{\lambda=1}^{N_\lambda} \frac{[\rho(i, j, s, \lambda) - \rho^{\text{Credible}}(i, j, s, \lambda)]^2}{\sigma^2(\lambda)}$$

European Commission

RT Models



RAMI-V: 14 models – 8 new in RAMI

Model	Participants	Reference
dart	Yingjie Wang	Gastellu-Etchegorry et al. (1996)
dirsig5	Adam Goodenough	Goodenough & Brown (2017)
Discret	Nadine Gobron	Gobron et al. (1997)
eradiate	Sebastian Schunke	Eradiate.eu (Copernicus Community Model - 2021)
flies	Hideki Kobayashi	Kobayashi & Iwabuchi (2008)
frt13 (*)	Andres Kuusk	Kuusk & Nilson (2000), Kuusk et al. (2010, 2014)
less	Jianbo Qi	Qi et al. (2019)
librat	Nial Oregon	Disney et al. (2009)
randerjay	Martin van Leeuwen	van Leeuwen M. et al. (2021)
rapid	Huaguo Huang	Huang et al. (2018a, 2018b)
raytran	Christian Lanconelli	Govaerts & Verstraete (1998)
spartacus	Robin Hogan	Hogan et al. (2018)
starter1	Zeng Yelu	Zeng et al. (2018) and Wu et al. (2021)
wps	Feng Zhao	Zhao et al. (2015, 2016)

* **frt13** *is an updated version of the model* **frt** (RAMI-IV)

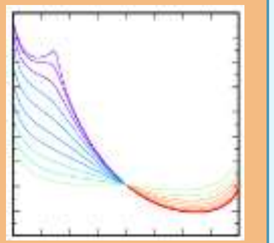
European Commission

Canopies

ABSTRACT

Homogeneous

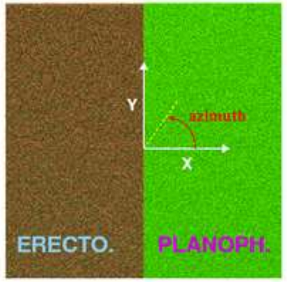
Anisotropic Background (HOM23,24,25/HOM33,34,35)

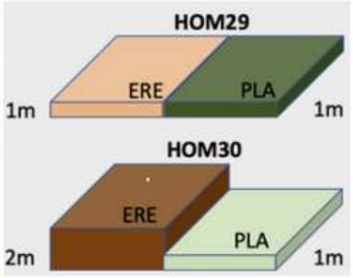



Two-layer canopy (HOM26,27,28/HOM36,37,38)

Lambertian

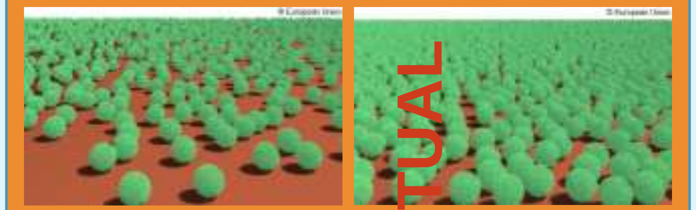
Adjacent canopies (HOM29,HOM30)





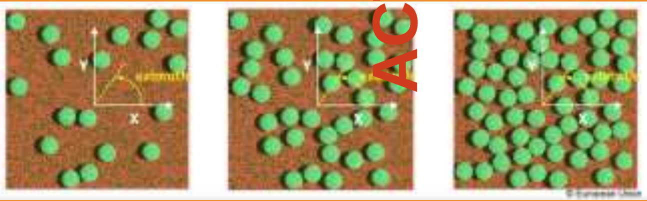
Heterogeneous

Anisotropic background (HET10,11,12/HET20,21,22)



ACTUAL

Two-layer canopy (HET16,17,18/HET26,27,28)



Constant Slope (HET23,24/HET33,34)

Järvselja Pine Stand (Summer) (HET07_JPS_SUM)

Järvselja Birch Stand (Summer) (HET09_JBS_SUM)

Ofenpass Pine Stand (Winter) (HET08_OPS_WIN)

Järvselja Birch Stand (Winter) (HET15_JBS_WIN)

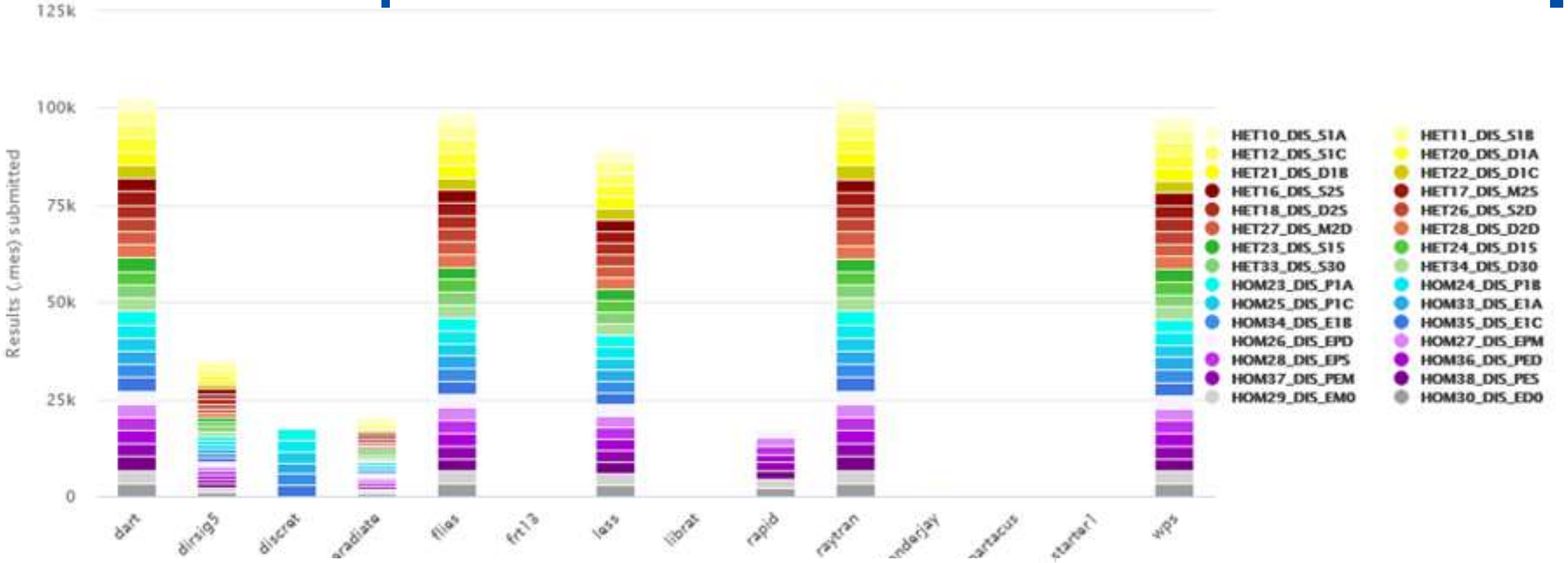
Wellington Citrus Orchard (HET14_WCO_UND)

Agricultural crops: Short Rotation Forest (HET16_SRF_UND)

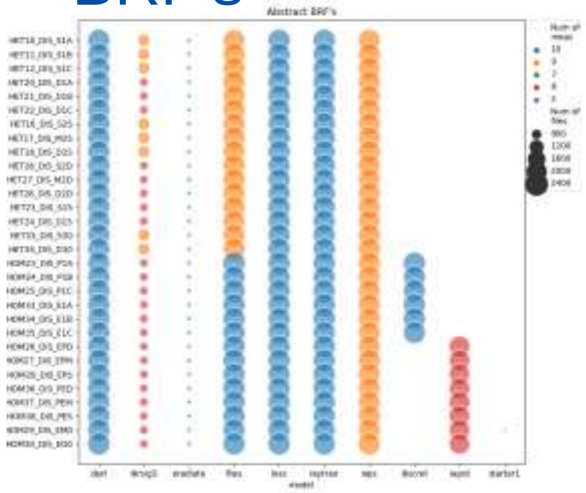
Savanna pre-fire (HET50_SAV_PRE)

Wytham Wood (HET51_WWO_TLS)

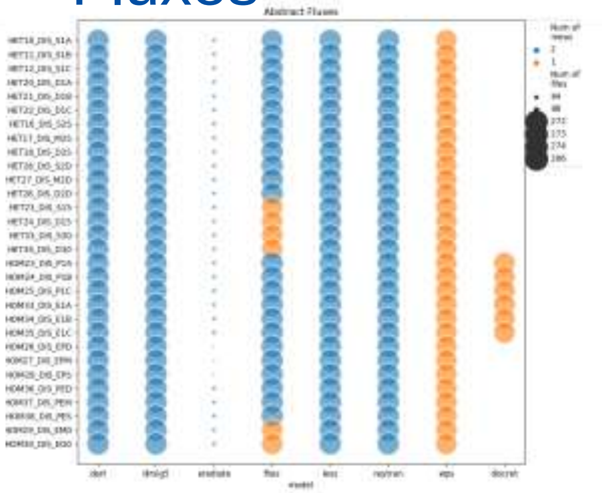
Scenes per Models: **Abstract canopies**



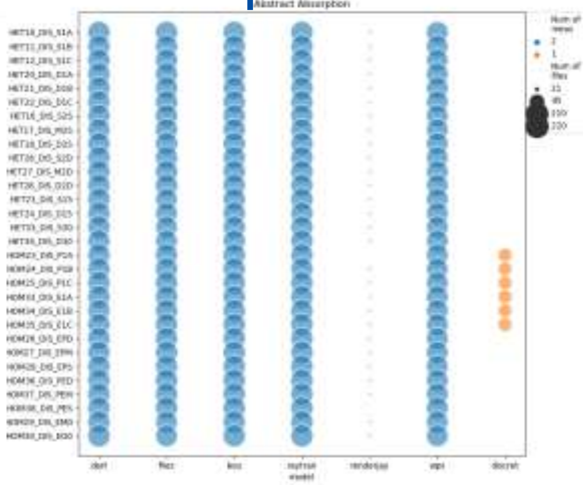
BRF's



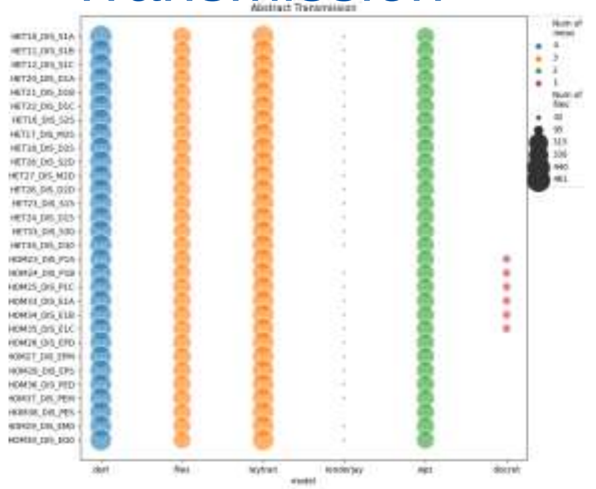
Fluxes



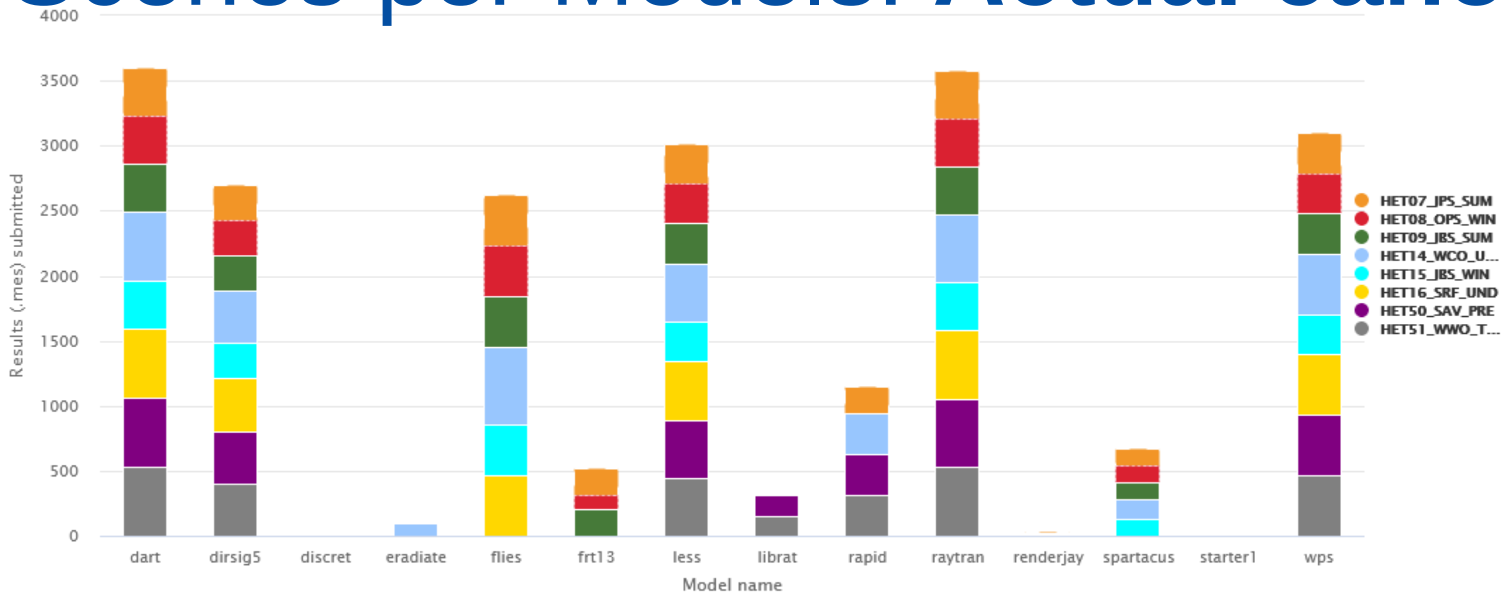
Absorption



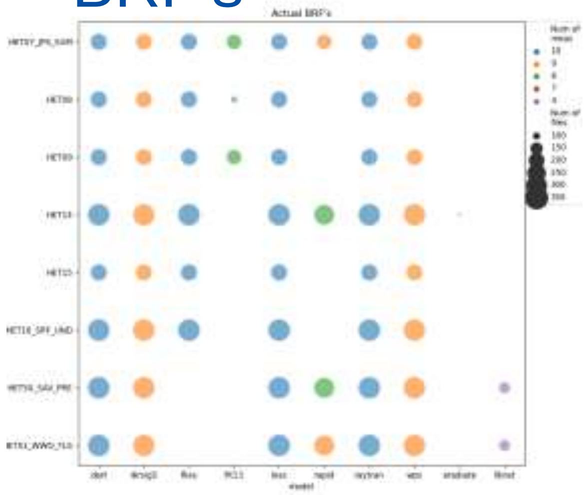
Transmission



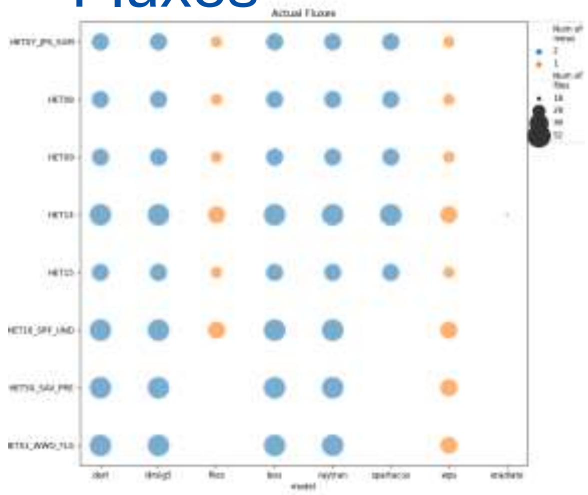
Scenes per Models: **Actual canopies**



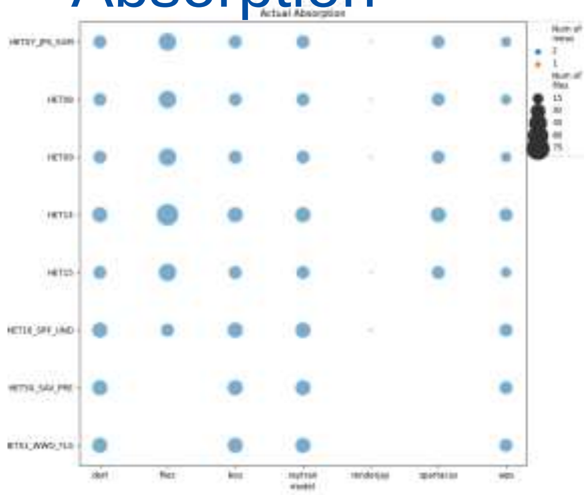
BRF's



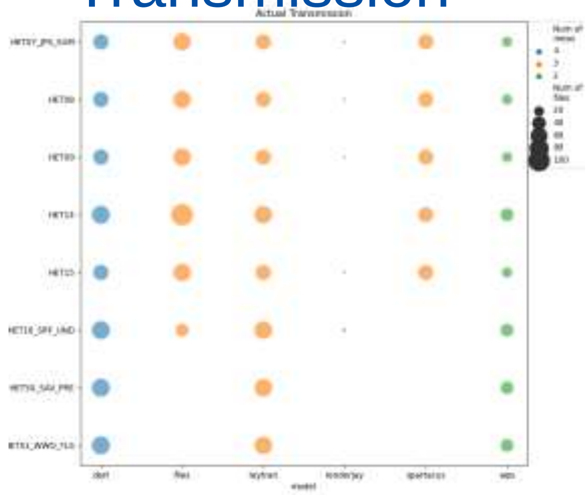
Fluxes



Absorption



Transmission



RAMI X Cal/Val

Open Access Review

European Space Agency (ESA) Calibration/Validation Strategy for Optical Land-Imaging Satellites and Pathway towards Interoperability

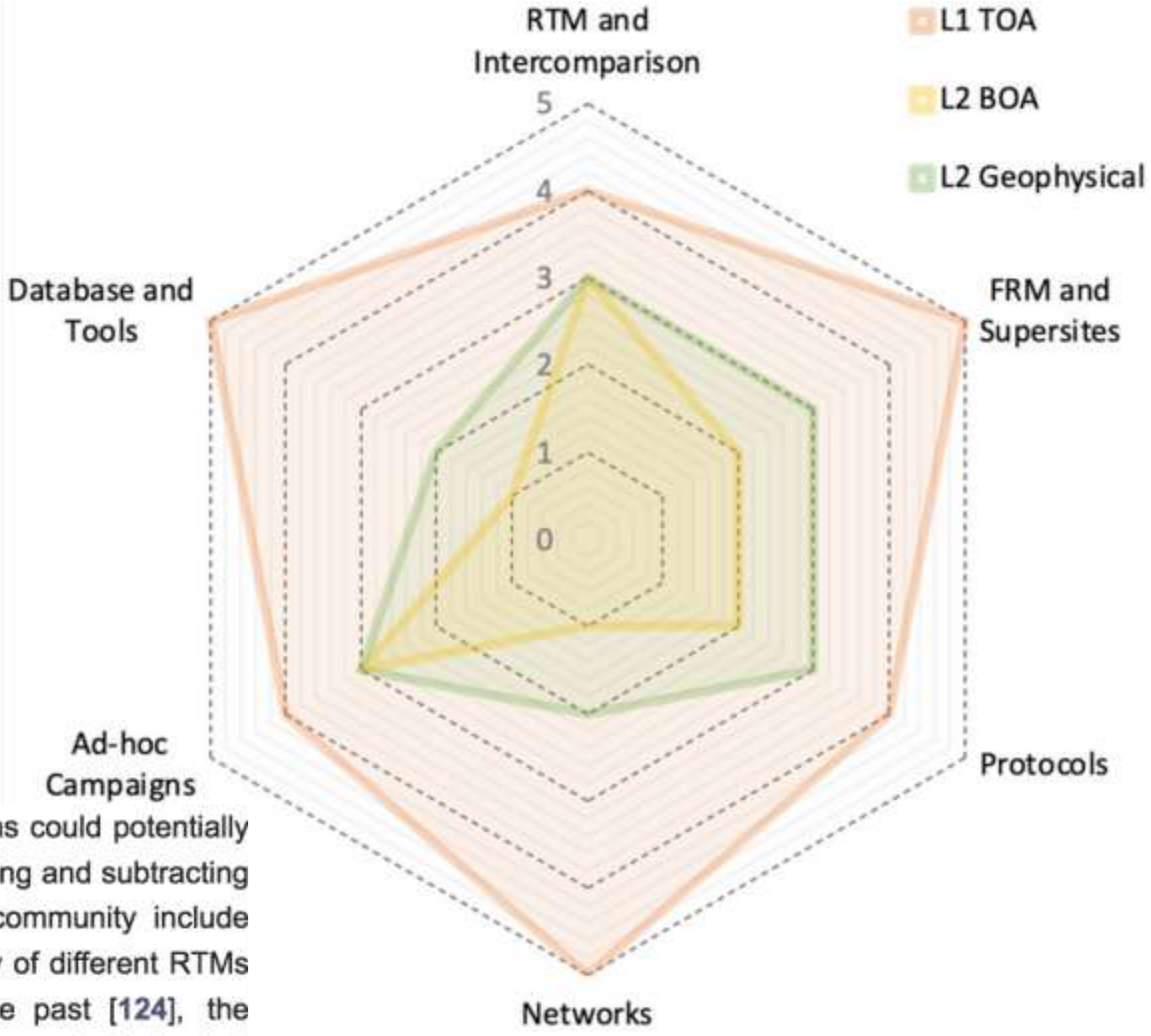
by Fabrizio Niro [1,*], Philippe Goryl [2], Steffen Dransfeld [2], Valentina Boccia [2], Ferran Gascon [2], Jennifer Adams [3], Britta Themann [2], Silvia Scifoni [1] and Georgia Doxani [1]

1 Serco SpA for European Space Agency (ESA), European Space Research Institute (ESRIN), 00044 Frascati, Italy

2 European Space Agency (ESA), European Space Research Institute (ESRIN), 00044 Frascati, Italy

3 RHEA System SpA for European Space Agency (ESA), European Space Research Institute (ESRIN), 00044 Frascati, Italy

* Author to whom correspondence should be addressed.



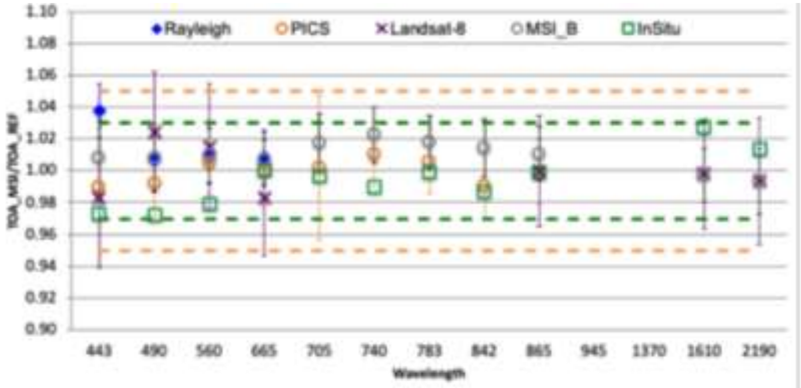
The adoption of the 6SV RTM [119] for generating the "ground-truth" over AERONET stations could potentially induce biases when assessing the accuracy of those codes, which use different RTMs for estimating and subtracting the atmospheric contribution from the TOA signal. Typical RTMs being used by the ACIX community include LibRadTran [122] and MODTRAN [123]. Overall, there is a need of inter-comparing the accuracy of different RTMs against a community-agreed benchmark algorithm. While similar exercises were done in the past [124], the benchmarking should now be repeated to assess how much RTM discrepancies propagate in the uncertainty budget of the output SR products, with focus on the current and future optical land imaging sensors. To this purpose, ESA in coordination with the EC, is currently supporting and promoting the RAdiation transfer Model Intercomparison for Atmosphere (RAMI4ATM) initiative [125]. The primary goal of RAMI4ATM will be to document the variability between coupled surface–atmosphere RTMs under well-controlled, but realistic, conditions. Within RAMI4ATM, the surface properties will be defined by the simple homogeneous scenes, as defined within the RAMI-V exercise [126].

European Commission

RAMI4ATM

Many radiative transfer models have been developed and are widely used in Earth Observation:

- **Calibration**



- **Atmospheric correction** or **sensitivity analyses**

- The uncertainties of these models have not been clearly assessed in **realistic usage conditions** when supporting typical Earth Observation applications by remote sensing scientists.

RAMI4ATM was dedicated to the benchmarking of **coupled surface-atmosphere** radiative transfer models.

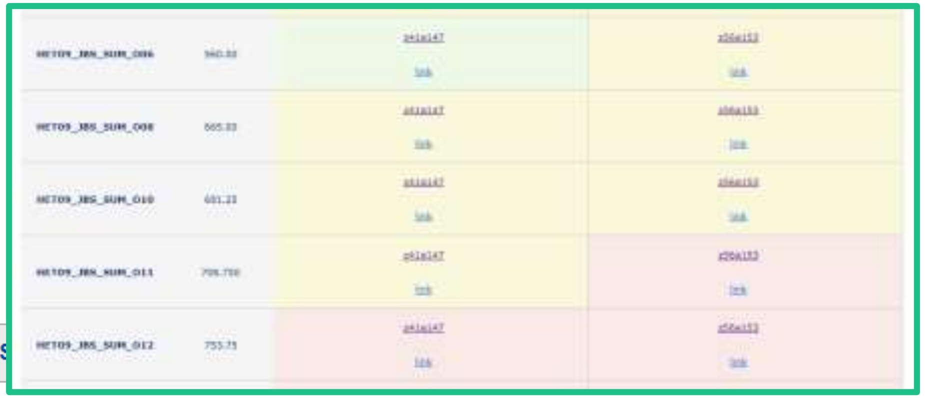
https://rami-benchmark.jrc.ec.europa.eu/

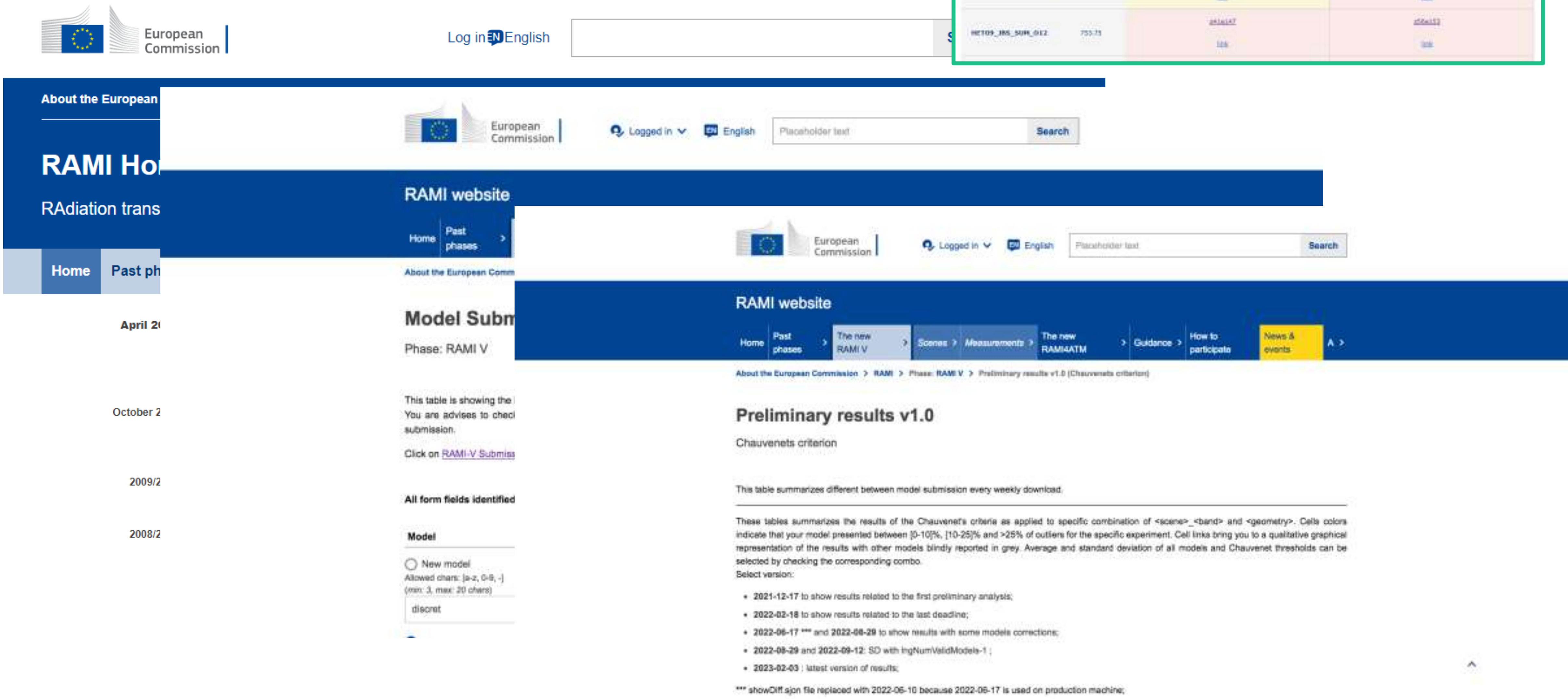
RAMI4ATM models/inst = 16

Model	#	Institution	Participants	Reference
6sv	*Second Simulation of the Satellite Signal in the Solar Spectrum v2.1*	Magellium	Jorge VICENT SERVERA	*S.Y. Kotchenova et al. (2008), J. Vicent et al. (2020)*
modtran6	*MODerate resolution atmospheric TRANsmission*			*A. Berk et al. (2014), L. Guanter et al. (2009)*
sbdart	*Santa Barbara DISORT Atmospheric Radiative Transfer*			*P. Ricchiazzi et al. (1998), J. Vicent et al. (2020)*
6sv2.1	*6SV v2.1 (2014)*	*EC-JRC*	Christian LANCONELLI	*S.Y. Kotchenova et al. (2008)*
sixsnad	*Modified 6SV, RT coupled model used for ESA*		Nadine GOBRON	*S.Y. Kotchenova et al. (2008); Gobron et al. (1997)*
eradiate	*A cal/val-oriented 3D radiative transfer model*	RAYFERENCE	Nicolas Misk	*Reference: https://www.eradiate.eu*
rtmom	***R**adiative **T**ransfer **M**atrix **O**perator **M**ethod*			*Y. Govaerts (2006)*
pnims	***P**olarized radiance **I**mproved **M**ultiple and **S**ingle scattering (PnIMS)*	GRASP	Masahiro Momoi	*Lenoble et al. (2007)* *Momoi et al. (2022)* *Nakajima and Tanaka (1988)*
waqh	*Waquet and Herman radiance correction*			*Lenoble et al. (2007), Waquet and Herman (2019)*
model-iao	*Model of V.E. Zuev Institute of Atmospheric Optics SB RAS*	IAO	Zhuravleva Tatiana	*T. Zhuravleva (2008), T. Zhuravleva and I. Nasrtdinov (2018)*
smartg	*Speed-Up Monte Carlo Advanced Radiative Transfer using GPU*	HYGEOS	Mustapha MOULANA	*Ramon et al. (2019)*
smartmom	*Simulated measurement of the atmosphere using radiative transfer based on the Matrix Operator Method*	JPL	Sanghavi Suniti	*Sanghavi, S., et al. (2013)*
vsmartmom	*Vectorized Simulated measurement of the atmosphere using radiative transfer based on the Matrix Operator Method*			*Sanghavi, S., et al. (2014)*
sos-abs	*Successive Orders of Scattering code including gas absorption*	CS Group	Stéphan Gwendoline	*J. Lenoble, et al. (2007)*
pydome	*python library for radiative transfer computations*	DLR	Dmitry Efremenko	*A. Doicu and T. Trautmann (2009)*
wps	*Weighted Photon Spread*	Beihang University	Feng Zhao	*Zhao et al. (2022, 2015)*

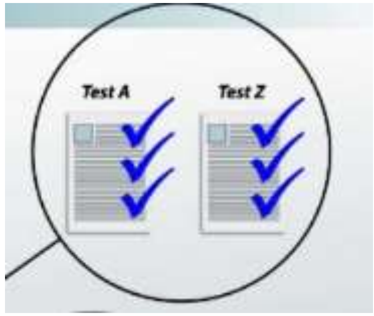
Web Site

https://rami-benchmark.jrc.ec.europa.eu/





Internal Consistencies



- Energy conservation (λ) $$\Delta F = 1 - T(1 - \alpha) - A - R$$
- BRF consistency (Λ) $$\Delta F_2(\zeta, \lambda, \Omega_i, \Omega_v) = \rho_{tot} - (\rho_{co} + \rho_{uc} + \rho_{mlt})$$
- BRF vs Albedo (***NEW***) (Λ) $$\rho_0, \Theta, k = f^{-1}(\rho_j(\theta_i, \theta_v, \phi))$$
    - The BRF simulations are used to optimize the RPV function to obtain the corresponding BRDF parameters. *DHR* and *BHR* are then recomputed by geometrical integration and compared with the submitted DHR, BHR.
- Albedo vs ($F^{\uparrow}/F^{\downarrow}$) Top-of-Canopy (λ)
- Spectral consistency (un-collided BRF vs Input surface properties)

European Commission

Applying ISO-13528 to Canopy RT Models

- *Ensure the homogeneity and stability of the samples that are to be analyzed by the participants*
- *Assign a reference value against which the bias of the participants can be determined* → ISO-13528 recommends to use **consensus values derived either from the simulations of selected expert models** or else from the **participants of the proficiency test itself**.
- *Specify a tolerance criteria allowing to determine whether deviations from the reference are significant*.

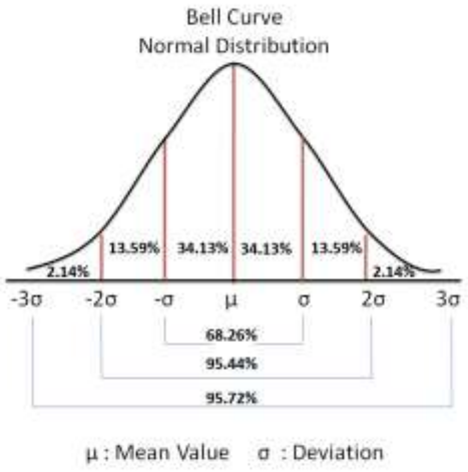
Widlowski J.-L., et. al. The fourth Radiation Transfer Model Intercomparison (RAMI-IV): Proficiency Testing of Canopy Reflectance Models with ISO-13528. (2013), Journal of Geophysical Research - Atmospheres, 118, D09111, 13, DOI: 10.1002/jgrd.50497.

Histograms of z' statistics

A priori reference (when possible)
Tolerance: 3 & 5 %

@Rapporteur:
Note to ask 'Which value do we really need?"

$$z'(m;\lambda,\zeta,\Omega_v,\Omega_i) = \frac{x_*^m(\lambda,\zeta,\Omega_v,\Omega_i) - X_*(\lambda,\zeta,\Omega_v,\Omega_i)}{\sqrt{\hat{\sigma}^2(\lambda,\zeta,\Omega_v,\Omega_i) + u_{X_*}^2(\lambda,\zeta,\Omega_v,\Omega_i)}}$$



x^m_* is the radiative quantity of interest simulated by model

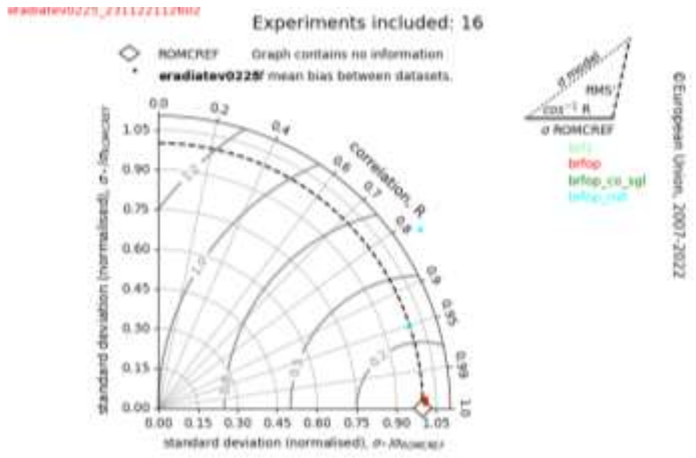
X_* is the "reference" value

u^2_{X*} standard uncertainty of the **assigned reference value**

σ proficiency criteria

Widlowski J.-L., et. al. The fourth Radiation Transfer Model Intercomparison (RAMI-IV): Proficiency Testing of Canopy Reflectance Models with ISO-13528. (2013), Journal of Geophysical Research - Atmospheres, 118, D09111, 13, DOI: 10.1002/jgrd.50497.

Rules for the reference – Custom



- 3D – Published – Used - **ROMC Validation 99% ?**
- Consistency check – depend on the measurements

BRF types

- **BRF consistency OK**
- **Spectral consistency OK**
- **Model-to-model : < 1-2% overall at least 2 models**
- **Participation : at least 80%**

DHR/BHR - FAPAR

- Energy conservation OK
- etc ….

@Rapporteur:
Note to ask 'Which rules do we agree?"

Do we have reference values ?

@Rapporteur:
Note to ask 'Which values do we agree for σ proficiency criteria ?"

Reference – Custom (Credible)

$\delta < 2\%$

Participation= 100%

$$z'(m;\lambda,\zeta,\Omega_v,\Omega_i) = \frac{x_*^m(\lambda,\zeta,\Omega_v,\Omega_i) - X_*(\lambda,\zeta,\Omega_v,\Omega_i)}{\sqrt{\hat{\sigma}^2(\lambda,\zeta,\Omega_v,\Omega_i) + u_{X_*}^2(\lambda,\zeta,\Omega_v,\Omega_i)}}$$

Reference Model Dependence (RMD)

u^2_{X*} standard uncertainty of the assigned reference values

model-specific reference values = {mod_p if n=76}-m

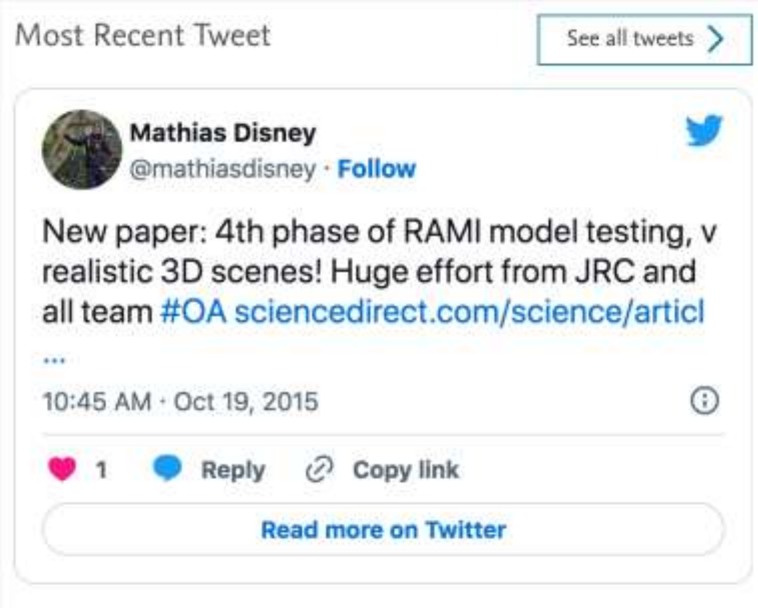
σ proficiency criteria for BRF = **3%** or 5 %

Canopy albedo (R) and Foliage Absorption (A) ← GCOS ECVs requirements

Others DHP → Gap Fraction → **LAI** ← GCOS ECVs requirements

Summary

- RAMI is linked to EO space life.
- From basic' experiences to **current sensors spectral bands and geometries**;
- Preparation of each phase's scenarios and deep dive analysis required huge work.



https://rami-benchmark.jrc.ec.europa.eu/

Thank to Copernicus as the sponsor of the workshop !

European
Commission

Keep in touch

EU Science Hub: ec.europa.eu/jrc

@EU_ScienceHub

EU Science Hub – Joint Research Centre

EU Science, Research and Innovation

Eu Science Hub

Thank you