Uncertainty-weighted ensemble products for (Dust) AOD

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C3S_312b_Lot2, supported by ESA Aerosol_cci+

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Aerosol CDRs in the Climate Data Store

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C3S_312b_Lot2 satellite-based Aerosol Climate Data Records in the Climate Data Store			
Sensor(s) / algorithm(s)	Period	Partner	Planned extension / re-processing 11/2023 (1)
Dual view radiometer sensor line: AOD, Fine Mode AOD			
ATSR-2/ADV, AATSR/ADV, SLSTR-3A/SDV	06/1995-04/2003 05/2002-04/2012 07/2016-06/2020	FMI	-06/2023
ATSR-2/ORAC, AATSR/ORAC, SLSTR-3A/ORAC		RAL	
ATSR-2/OSURAC, AATSR/SU, SLSTR-3A/SU		SU	
ATSR-2/ENS, AATSR/ENS, SLSTR-3A/ENS		DLR	
Thermal spectrometer sensor line: Mineral Dust AOD, Dust Layer Height			
IASI-A/IMARS	10/2007-06/2020	DLR	-06/2023 (IASI-C)
IASI-A/MAPIR		BIRA	
IASI-A/LMD		LMD	
IASI-A/ULB		ULB	
IASI-A/ENS		DLR	
Nadir radiometer sensor line: AOD (overview)			
MERIS/XBAER, OLCI/XBAER	05/2002-04/2012 04/2016-06/2020	UBrem	-06/2023
MERIS/S4M, OLCI/S4O		DLR	
MERIS/ENS, OLCI-3A/ENS		DLR	
Multi-angle Polarimeter: AOD, Fine Mode AOD, Single Scattering Albedo, Aerosol Layer Height			
POLDER/GRASP	03/2005-10/2013	Lille	03/2005-10/2013
Star occultation spectrometer: Stratospheric Extinction Profile			
GOMOS/AERGOM	04/2002-04/2012	BIRA	04/2002-04/2012
https://cds.climate.copernicus.eu/cdsapp#!/dataset/satellite-aerosol-properties?tab=overview			

(1) C3S2_312a_LOT2 (11/2021 – 04/2024) kicked off 01/12/2021

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Ensemble approach (1)

- Developed in ESA Aerosol_cci
  - Round robin evaluation showed:
    - No single algorithm is always the best
- -> ensemble approach
- Goals
  - Combine the best of several algorithms for one sensor
  - Aim for improved coverage
  - Use pixel level uncertainties for weighting
  - Required minimum of valid results from 2 algorithms

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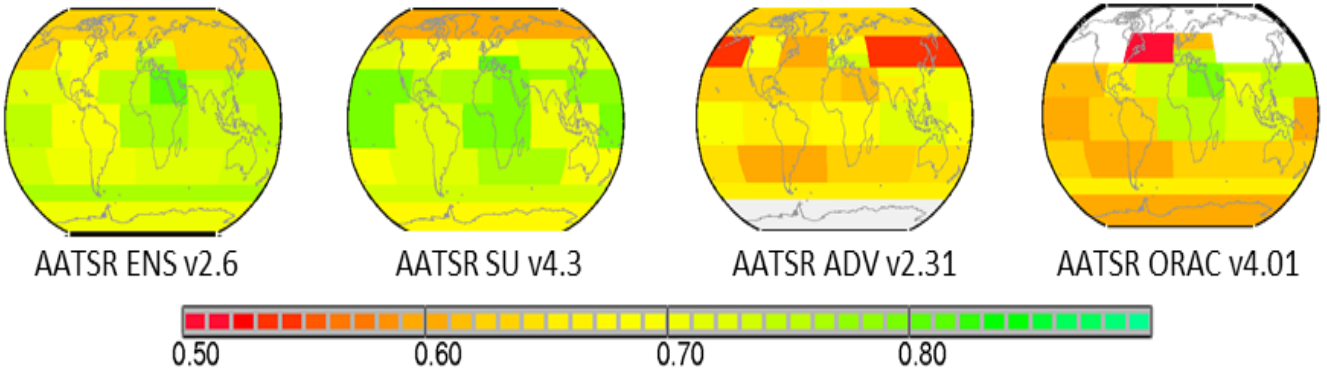
Ensemble approach (2)

$$x = \frac{\sum_{j=1}^{N} w_j x_j}{\sum_{j=1}^{N} w_j} \qquad w_j = \left(\frac{1}{u_j}\right)^2$$



scoring by S. Kinne

- Applied now in C3S for ATSR-2, AATSR, SLSTR, IASI, MERIS, OLCI

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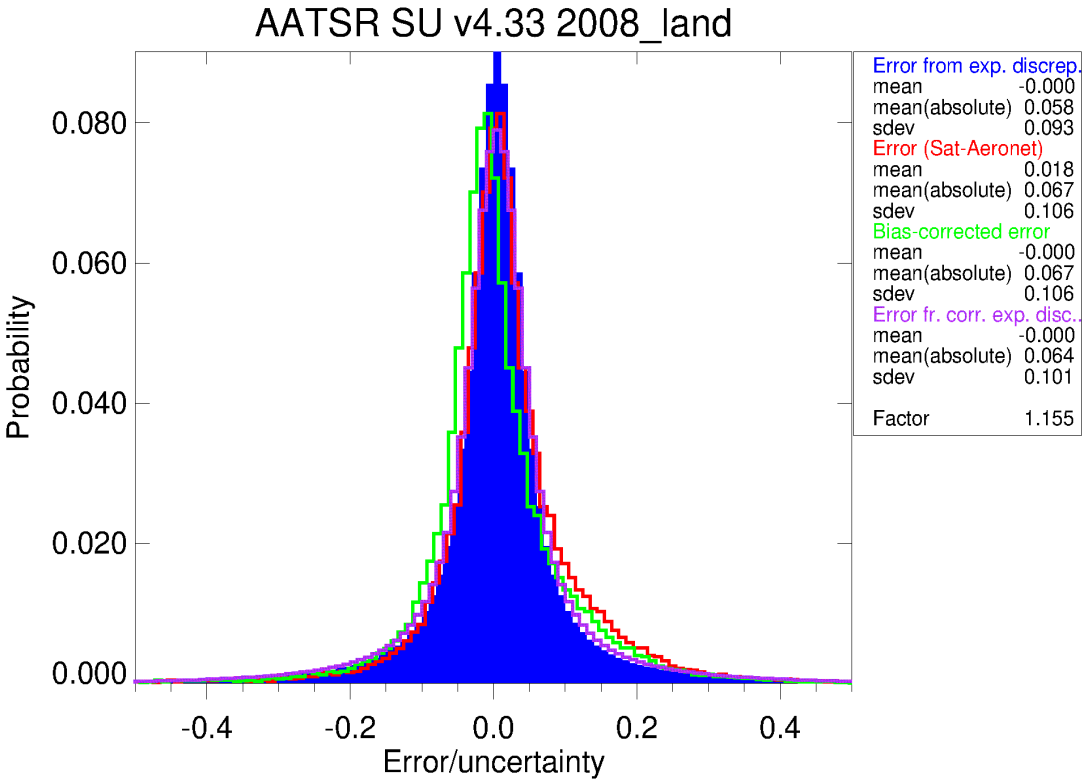
Pixel-level uncertainty evaluation (1)

- Pixel-level uncertainties must quantitatively represent true error distributions



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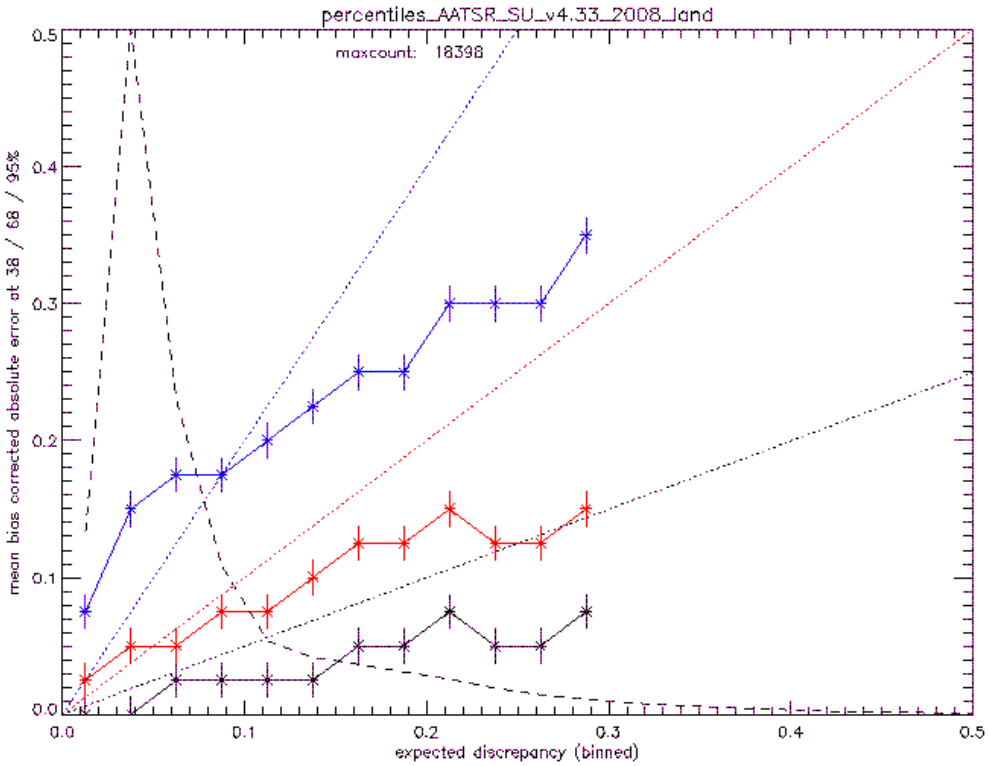
Pixel-level uncertainty evaluation (2)

- Pixel-level uncertainties must separate “good” and “weak” pixels



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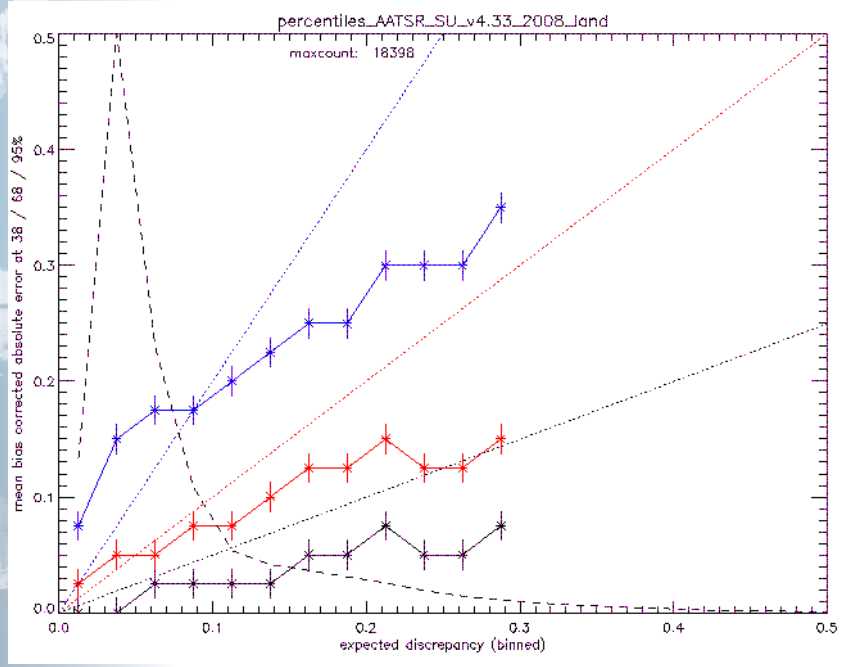
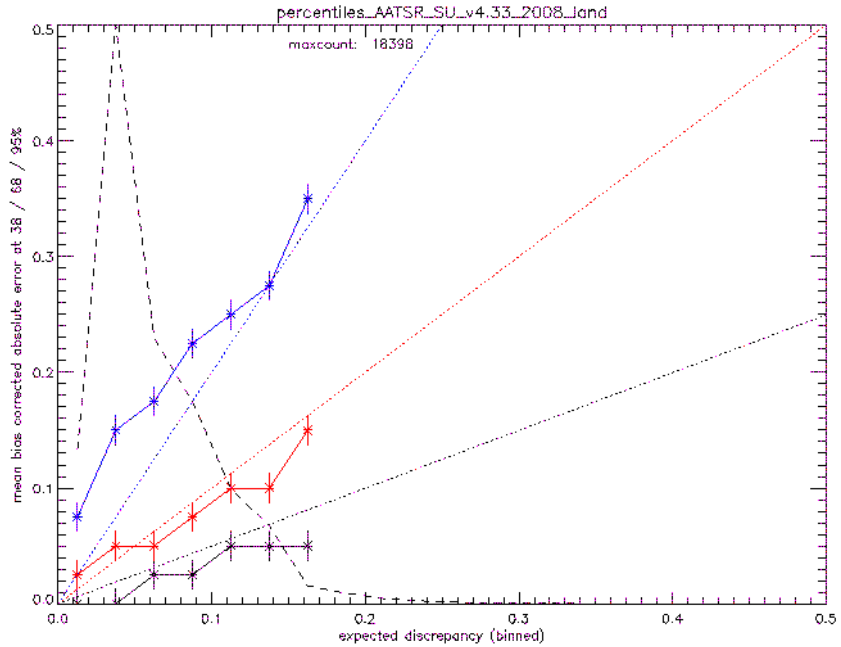
Uncertainty correction

- Pixel-level uncertainties:
  - where needed apply piece-wise linear corrections





u' = 0.6 * u; if u > 0.15

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Uncertainty corrections (from ENS ATBD)

4. Table: Uncertainty correction functions for algorithms used in ensembles

algorithm	Correction over land	Correction over ocean
SLSTR SDV v2.10	u' = 4. * u; if u < 0.05 u' = 0.3 * u; if u > 0.15	
SLSTR ORAC v1.0	u' = 2. * u + 0.03	
SLSTR SU v1.12	u' = 0.6 * u; if u > 0.15	
IASI IMARS v7.0	u' = 0.5 * u - 0.05	
IASI MAPIR v4.1	u' = 7. * u	
IASI LMD v2.2	no correction needed	
IASI ULB v8	no correction needed	
OLCI XBAER v1.0	u' = 1.45 * u	u' = 2 * u
OLCI S4O v1.0	u' = u + 0.15; if u < 0.15	
ATSR-2 / AATSR SDV v4.0	u' = 1.5 * u + 0.1; if u < 0.1 u' = 0.15 * u; if u > 0.2	
ATSR-2 / AATSR ORAC v4.02	u' = 2. * u + 0.03	
ATSR-2 / AATSR SU v4.33	u' = 0.6 * u; if u > 0.15	
MERIS XBAER v2.3	u' = 1.45 * u	u' = 2 * u
MERIS S4M v7.0a	u' = u + 0.2; if u < 0.2	u' = u + 0.15; if u < 0.15

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Ensemble L3 example results (1)

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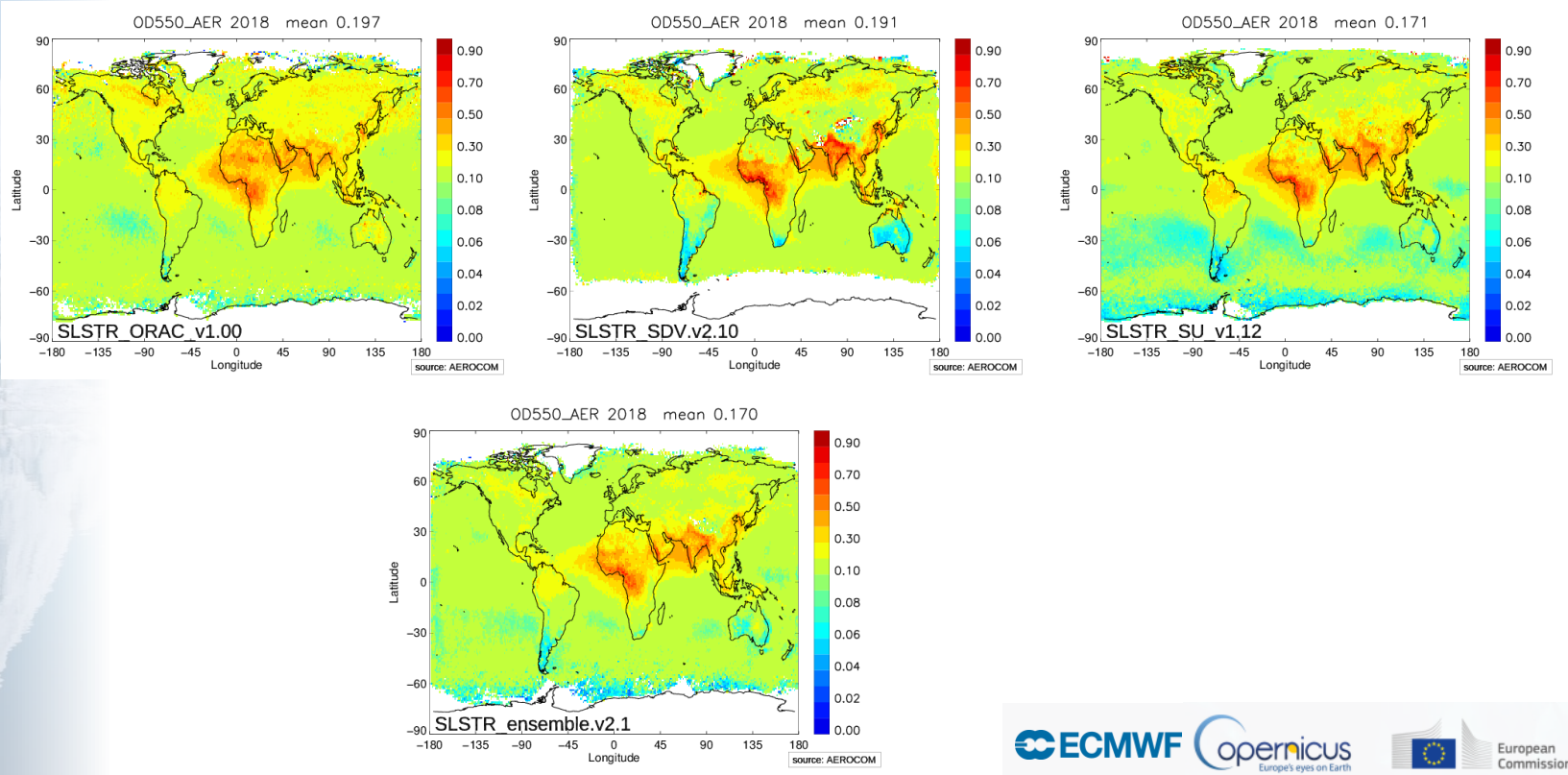
- AOD mean 2018



Ensemble L3 example results (2)

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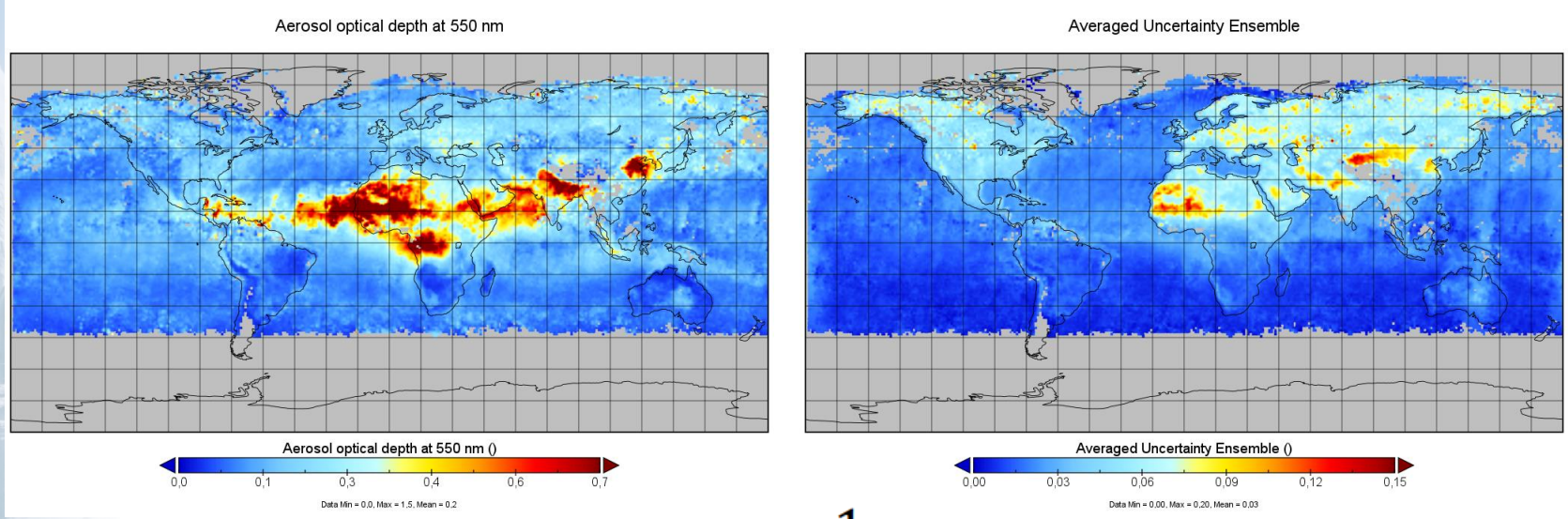
- Ensemble AOD / uncertainty June 2020



$$u_x = \frac{1}{\sqrt{\sum_{j=1}^{N} \frac{1}{u_j^2}}}$$

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Ensemble L3 evaluation SLSTR 2019 AOD

- In C3S done by J. Griesfeller / AEROOCM tools

(vs. Aeronet)	ORAC	SDV	SU	Ensemble 2.1
number of pairs	1631	1808	2023	2226
AERONET total AOD avg	.175	.187	.186	.184
retrieval total AOD average	.237	.264	.229	.214
normalized mean bias	35.6%	41.3%	23%	16.3%
mod. norm. mean bias	45.2%	36%	28%	26%
correlation coefficient	.728	.76	.82	.781
root-mean square error	.134	.156	.111	.114

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Ensemble L3 evaluation IASI 2019 AOD

- In C3S done by J. Griesfeller / AEROOCM tools

(vs. Aeronet SDA)	Ensemble 1.1	DLR 7.0	LMD 2.2	MAPIR 4.1	ULB v8
number of pairs	2721	2227	2582	2452	1443
AERONET coarse mode AOD average	.05	.048	.049	.051	.061
retrieval dust AOD average	.043	.045	.069	.033	.06
normalized mean bias	-14.5%	-6.4%	40.2%	-34.8%	-2.2%
mod. norm. mean bias	-12.6%	-34.2%	17%	-97.7%	-15%
correlation coefficient	.705	.451	.371	.837	.669
root-mean square error	.037	.055	.076	.039	.054

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Conclusions

- Ensemble approach to combine best of algorithms demonstrated
  - using (corrected) pixel-level uncertainties for weighting
  - requiring valid results from a minimum of 2 algorithms per pixel
- Best results for IASI: 4 algorithms, improved coverage, mean quality
- SLSTR and ATSR: 3 algorithms, smallest bias, best consistency (A)ATSR(-2)
- No benefit for OLCI: 2 algorithms only
- Regional reliability information

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