SCIENTIFIC AND PROCESS ORIENTED EVALUATION OF CLIMATE DATA

Jörg Schulz

EUMETSAT

A Quote That Has it All ...

GCOS-WCRP Letter, 12 May 2010 to many agencies:

"However, there is currently no systematic international approach to ensure transparency, traceability and sound scientific judgement in the generation of climate data records across all fields of climate science and related Earth observations, and there are no dedicated sustained resources in place to support such an objective. For example, there are currently eight sea-ice concentration products produced by different organizations globally that differ significantly in providing an estimate of sea-ice extent and concentrations, mostly due to differences in methodology and not the variability or dynamics of underlying phenomenon. It is very confusing and frustrating for the non experts as to which one of these products they can use in their research and analysis, and the necessary documents to describe their attributes in a comparative manner akin to the global model inter-comparisons do not exist."

User Perspective

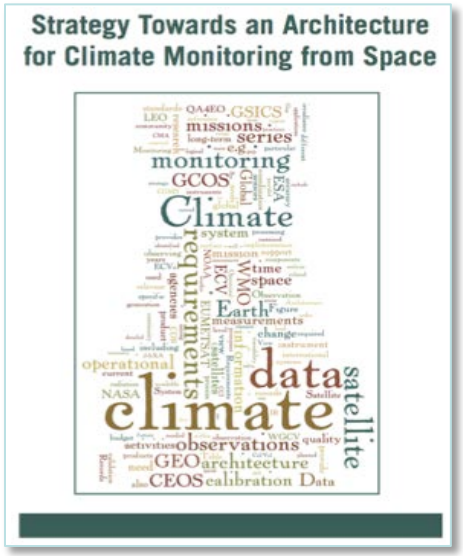
I need good new data … and quickly. A new data product could be very good, but if it is not being conveniently served and described, it is not good for me…
So I am going to use whatever I have and know already.

User

10/21/2011 Leptoukh QA4EO'11

Adapted form Folkert Boersma, KNMI

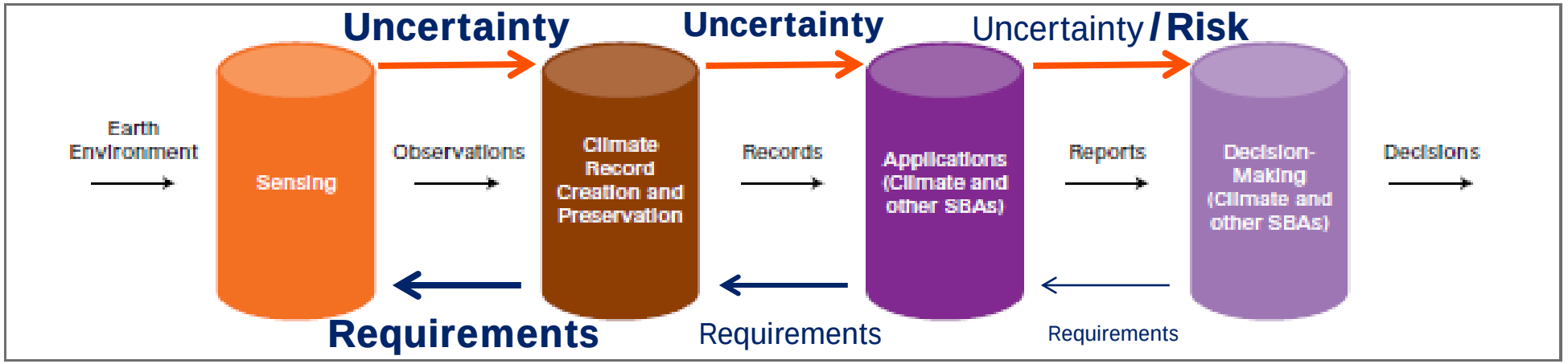
Value Adding Chain of Climate Data



CM SAF
NWP SAF
ROM SAF
H SAF
NWC SAF
OSI SAF
LSA SAF
O3M SAF

UERRA
CLIPC
EURO4M
ECLISE

Data users converting data into relevant information



Logical view from the Architecture for Space-based Climate Monitoring developed by space agencies.

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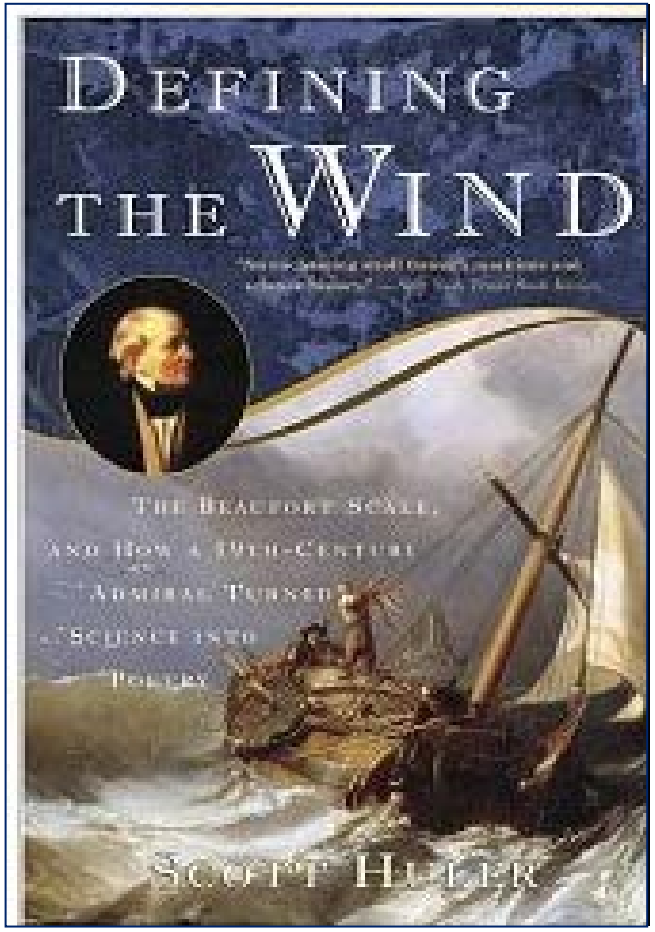
What is at Stake?

Slide: Courtesy of John Bates, NOAA NCDC, USA

- History shows that weather observations did not become useful for society until a lexicon was agreed to;
  - ✓ The Beaufort scale did this for wind climatology and maritime commerce in the 19th century.
- To benefit society, we must adopt a lexicon that sets expectations for quality, openness, process and transparency that are accessible to the public;
  - ✓ How might we define a climate record lexicon useful to the public in the 21st century?



QA4ECV Approach to E and QC

Users need clear info on validity of EO/climate data records

Climate Data Records available, but need info on strength/weakness and fitness for purpose

Need objective system

Need guidance

Maturity	SOFTWARE READINESS	METADATA	USER DOCUMENTATION	UNCERTAINTY CHARACTERISATION	F FE
1	Conceptual development	None	Limited scientific description of the methodology available from PI	None	Res
2	Research grade code	Research grade	Comprehensive scientific description of the methodology, report on limited validation, and limited product user guide available from PI; paper on methodology is sumitted for peer-review	Standard uncertainty nomenclature is identified or defined, limited validation done, limited information on uncertainty available	Data ava scientific
3	Research code with partially applied standards; code contains header and comments, and a README file; PI affirms portability, numerical reproducibility and no security problems	Standards defined or identified; sufficient to use and understand the data and extract discovery metadata	**Score 2 +** paper on methodology published; comprehensive validation report available from PI and a paper on validation is submitted; comprehensive user guide is available from PI; Limited description of operations concept available from PI	**Score 2 +** standard nomenclature applied; validation extended to full product data coverage, comprehensive information on uncertainty available; methods for automated monitoring defined	Data and c from PI, fe
4	**Score 3 +** draft software installation/user manual available; 3rd party affirms portability and numerical reproducibility; passes data providers security review	**Score 3 +** standards systematically applied; meets international standards for the data set; enhanced discovery metadata; limited location level metadata	**Score 3 +** comprehensive scientific description available from data provider; report on inter comparison available from PI; paper on validation published; user guide available from data provider; comprehensive description of operations concept available from PI	**Score 3 +** procedures to establish SI traceability are defined; (inter)comparison against corresponding CDRs (other methods, models, etc); quantitative estimates of uncertainty provided within the product characterising more or less uncertain data points; automated monitoring partially implemented	Data recor data pro version c feedback
5	**Score 4 +** operational code following standards, actions to achieve full compliance	**Score 4 +** fully compliant with standards; complete discovery	**Score 4 +** comprehensive scientific description maintained by data provider; report on data assessment results exists;	**Score 4 +** SI traceability partly established; data provider participated in one inter-national data assessment; comprehensive validation of	**Score 4** Provi

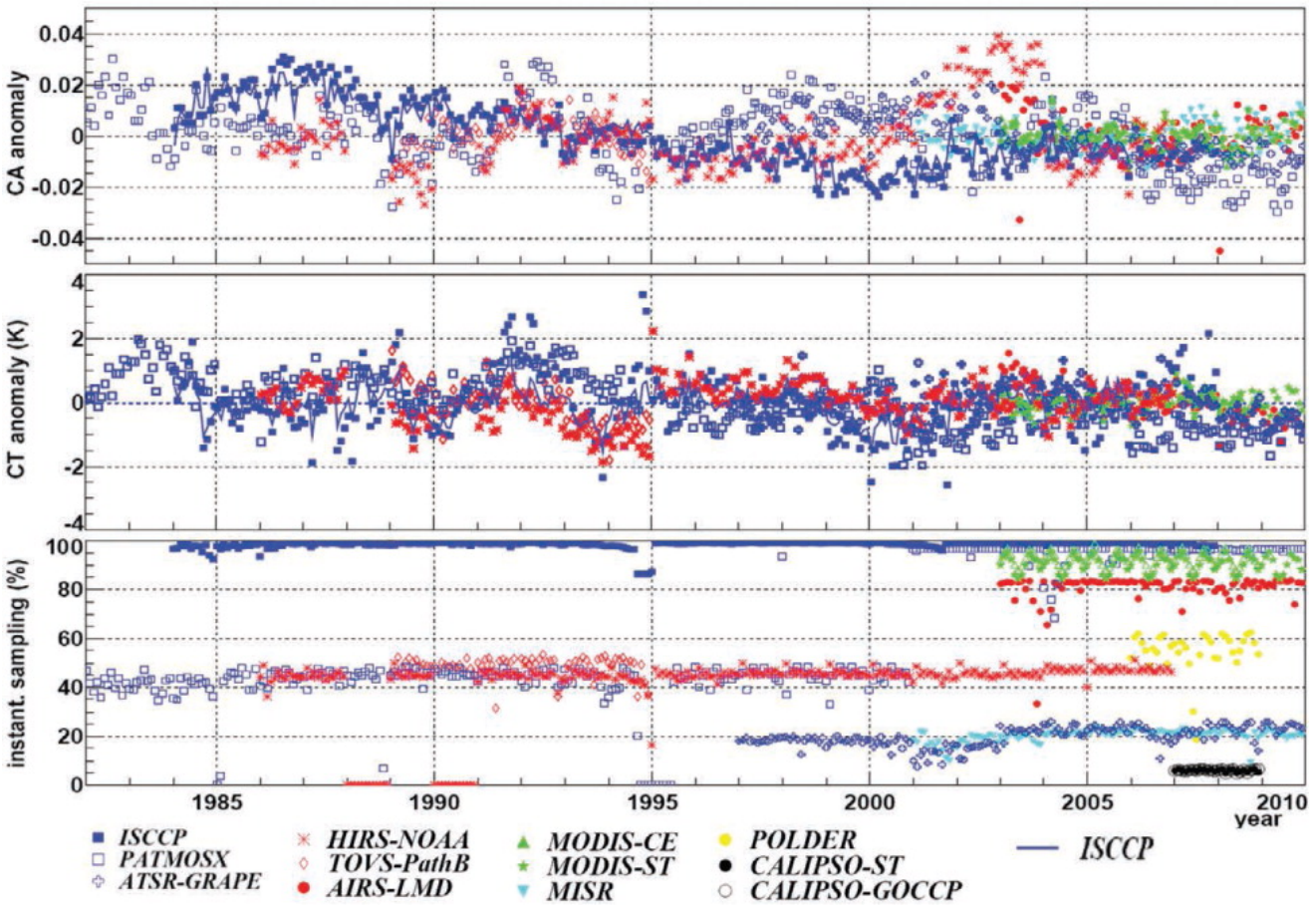
web portal

Quality Assurance System

- Provides traceable quality info on EO/climate data;
- Tied to international standards;
- QA processes and tools to support user community in tracing quality;

Quality assured multi-decadal Climate Data Records of GCOS ECVs (includes all inputs, such as FCDRs into it).

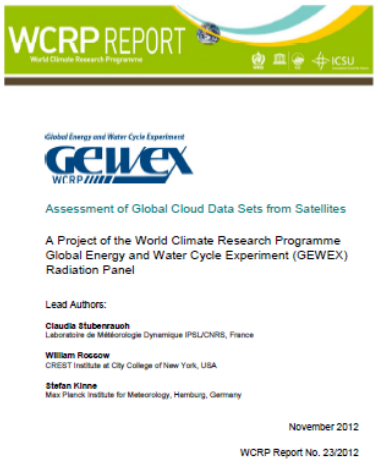
GEWEX Assessment of Cloud Data Records



Stubenrauch et al., BAMS, 2013

"An assessment of long-term variations in global-mean cloud amount from nine different satellite datasets by Stubenrauch et al. (2013) found differences between datasets were comparable in magnitude to the inter-annual variability. Such inconsistencies result from differences in sampling as well as changes in instrument calibration and inhibit an accurate assessment of global-scale cloud cover trends."

IPCC, Chapter 2, AR5, 2013


WCRP REPORT

Global Energy and Water Cycle Experiment
GEWEX
WCRP

Assessment of Global Cloud Data Sets from Satellites

A Project of the World Climate Research Programme
Global Energy and Water Cycle Experiment (GEWEX)
Radiation Panel

Lead Authors:

Claudia Stubenrauch
Laboratoire de Météorologie Dynamique IPSL/CNRS, France

William Rossow
CREST Institute at City College of New York, USA

Stefan Kinne
Max Planck Institute for Meteorology, Hamburg, Germany

November 2012

WCRP Report No. 23/2012

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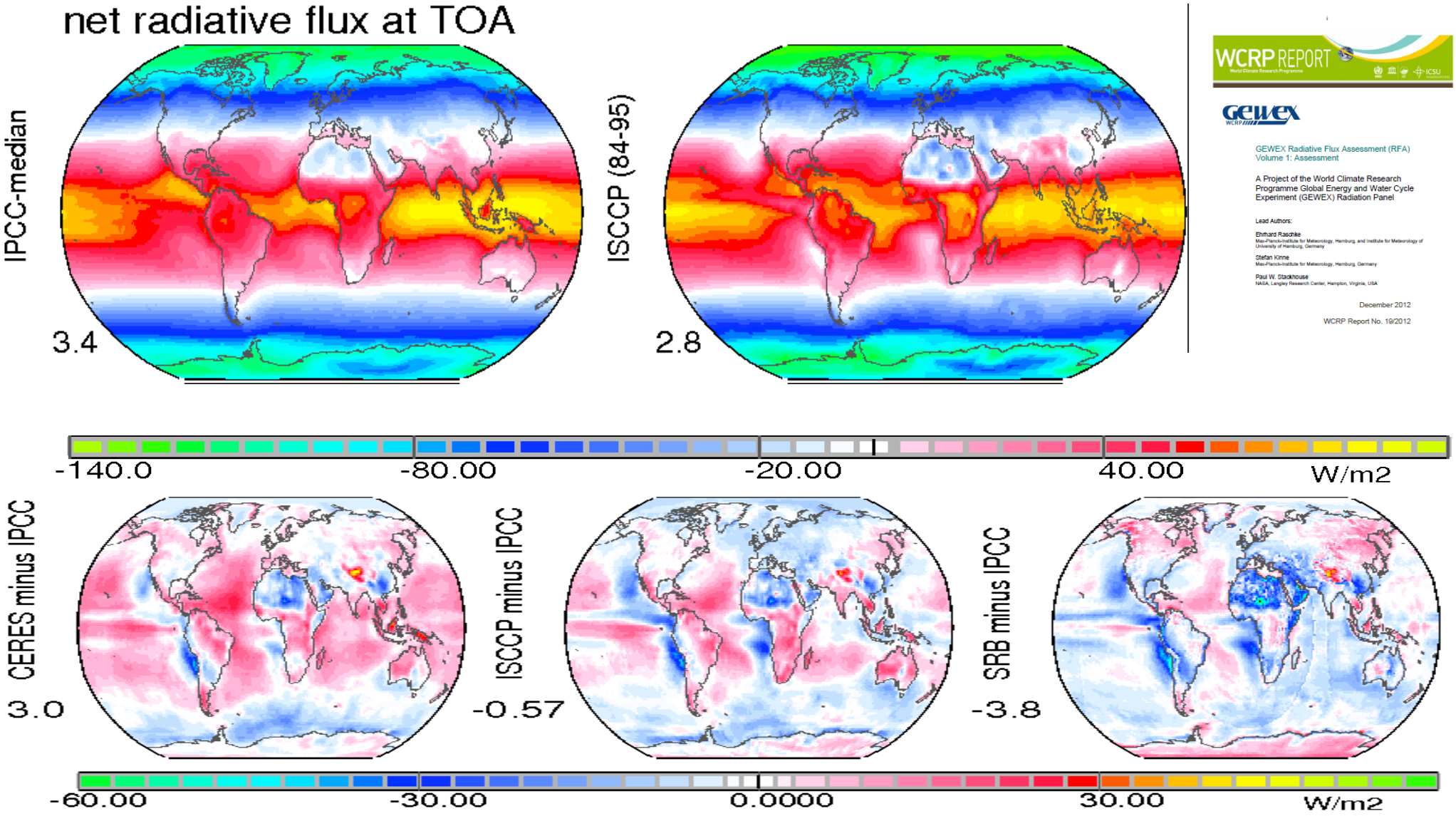
Annual averages of the net radiation at the TOA



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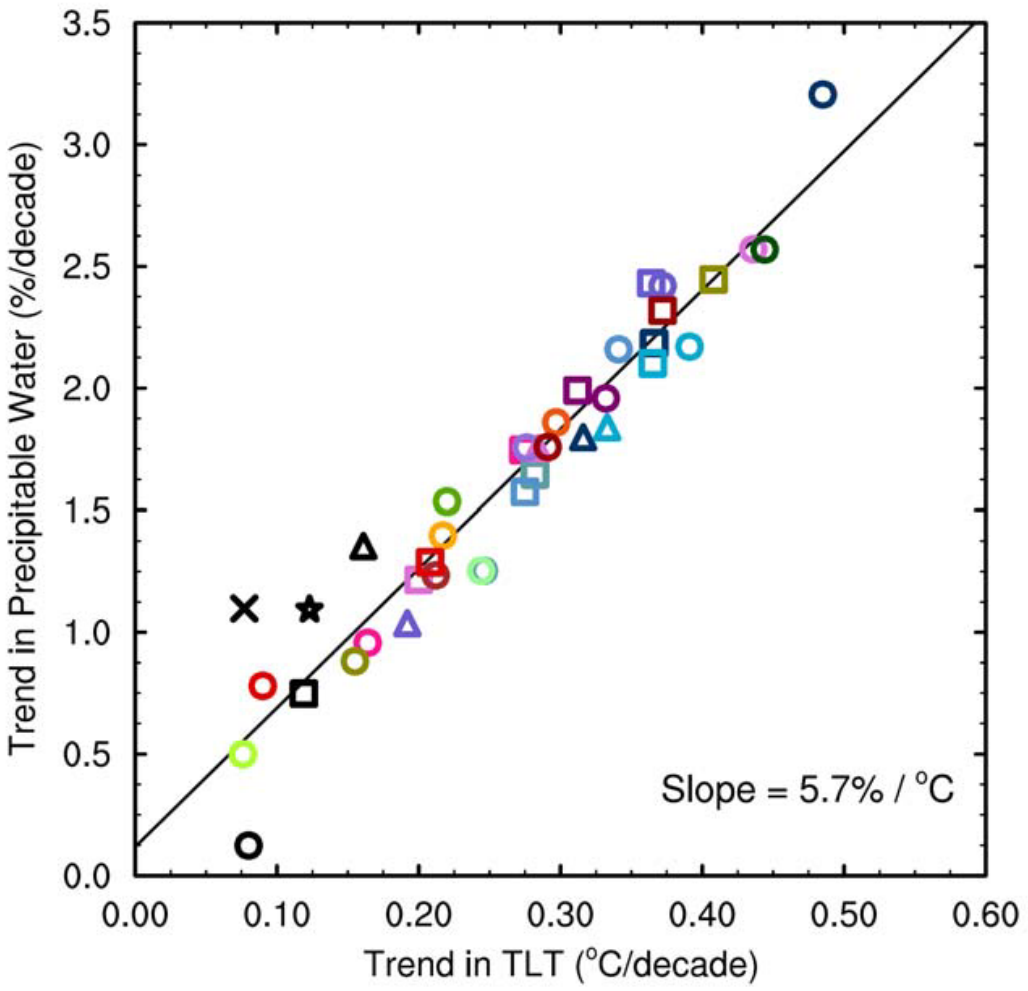
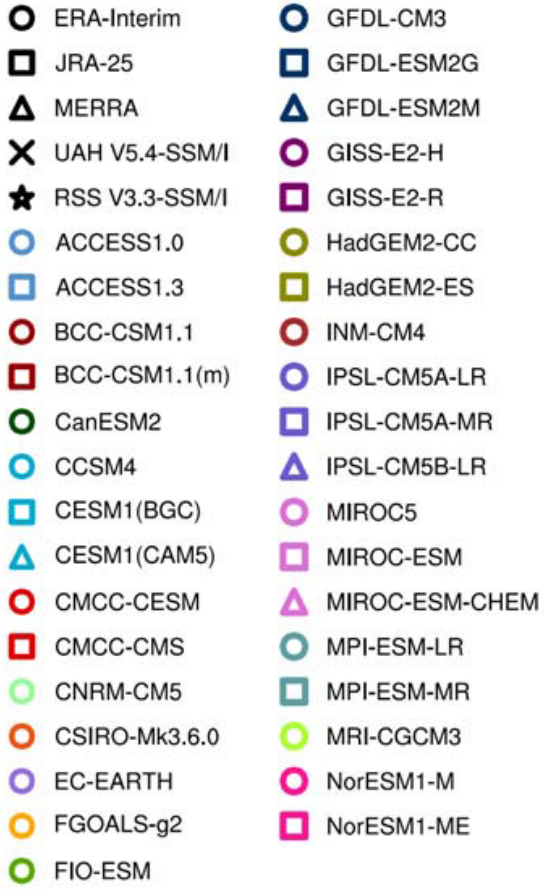
Trends in Tropical Precipitable Water and TLT





"It is not known whether these discrepancies are due to remaining inhomogeneity in the observational data and/or reanalysis results, or due to problems with the climate simulations. All of the observational and reanalysis points lie at the lower end of the model distribution, consistent with the findings of (Santer et al., 2013)."

IPCC, Chapter 9, AR5, 2013, Updated from (Mears et al., 2007)

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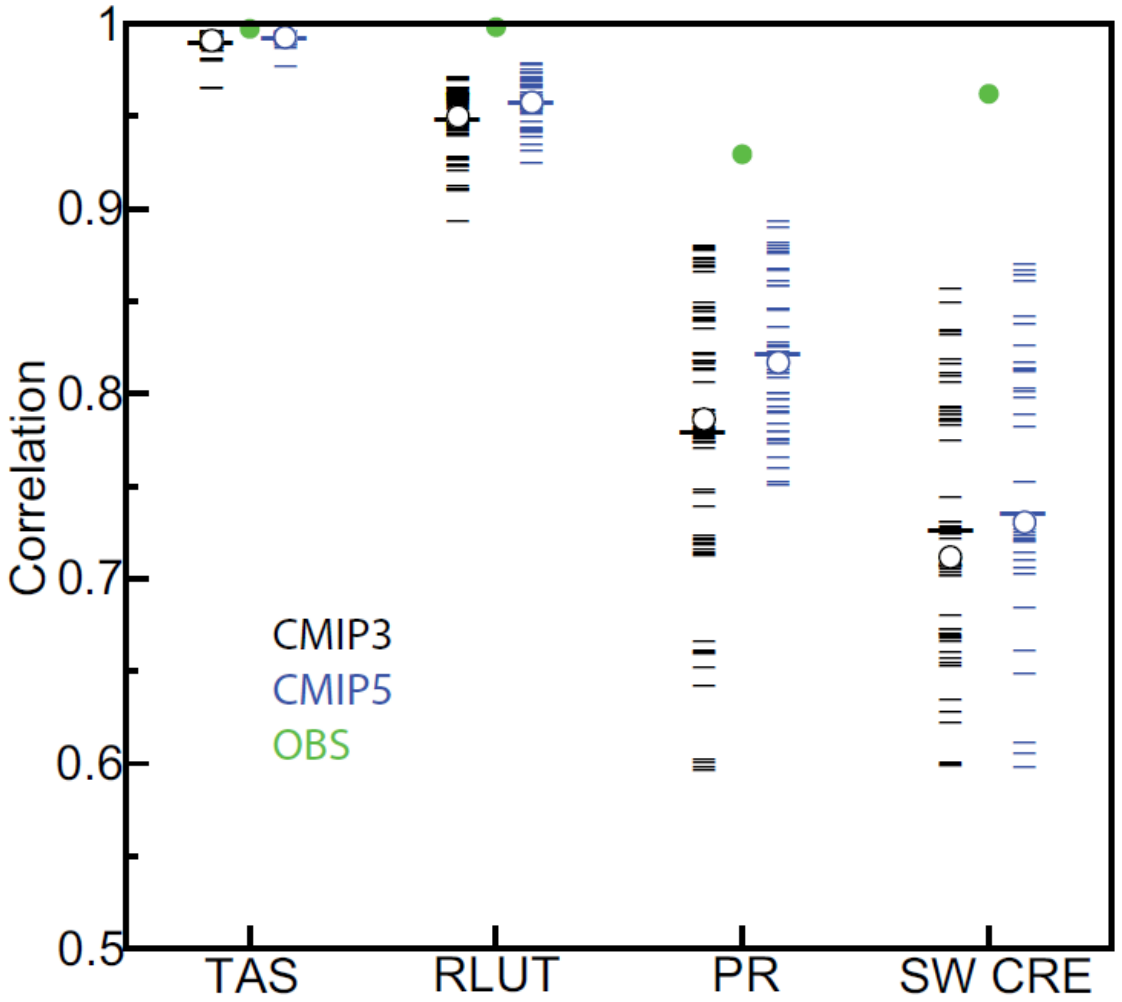
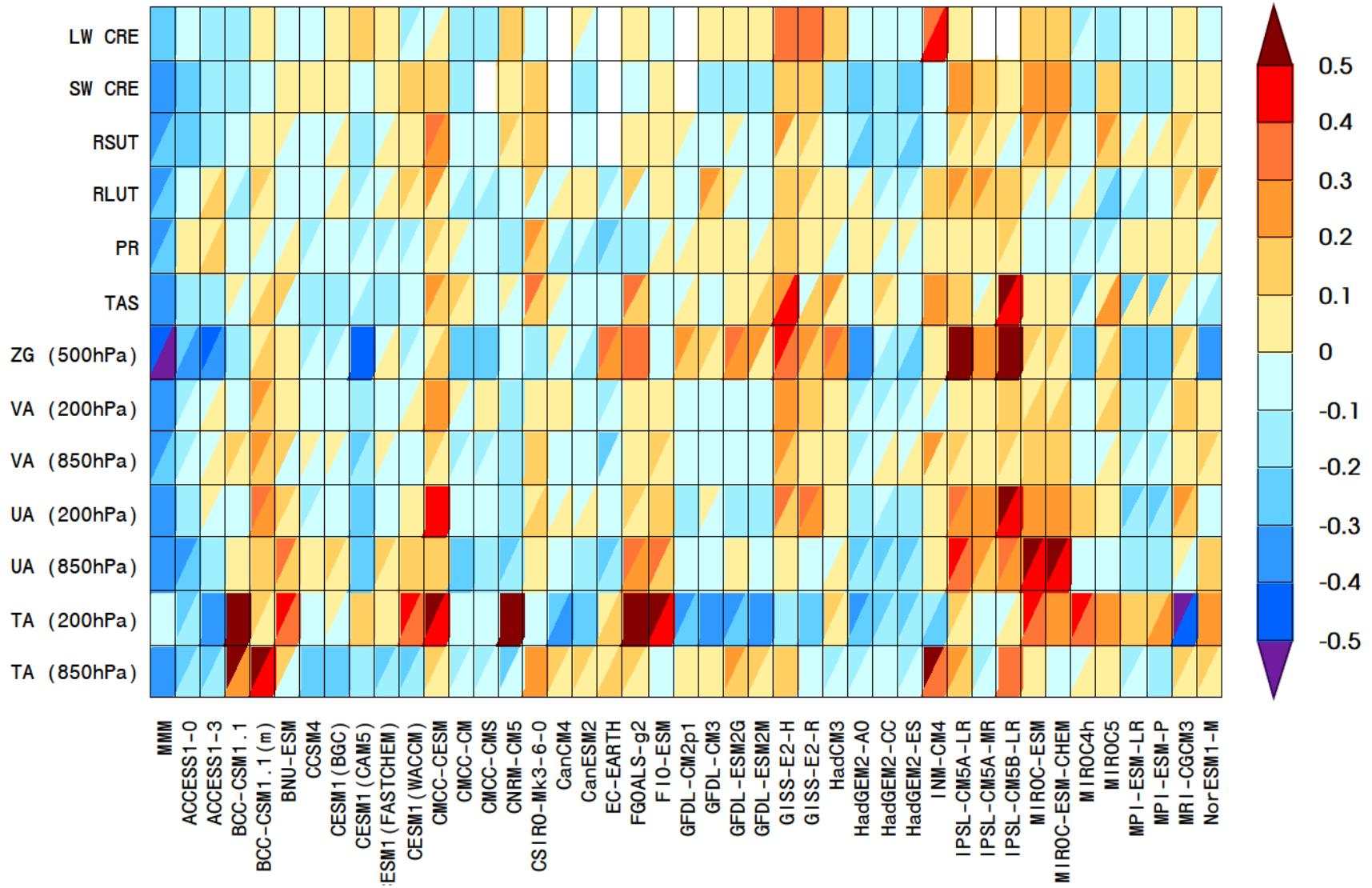
Annual Mean Pattern Correlation (Models vs. Obs)



IPCC, Chapter 9, AR5, 2013

Relative CMIP-5 Model Performance



IPCC, Chapter 9, AR5, 2013

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Motivation for Process QC

- Climate Change is a highly applied scientific field with major aspects related to regulation and societal wellbeing;
- Increasingly complex observing systems require more process control to ensure quality, access, and preservation;
- Software Engineering is also increasingly complex and process management is required to optimize cost, schedule, productivity and quality;
- The stakes in climate change are too high to assume a standard research approach to the creation of CDRs. Society is demanding more documentation, openness, and transparency;
- It is imperative that the CCCS responds with quantifiable metrics that inform society of both the scientific quality and process maturity of CDRs.

ECV Inventory @ http://www.ecvinventory.com

Home | View ECV Records | Editor LOGIN | Administrator LOGIN

Search Category: Show All

ECV Record Id	CDR_ECV04_7
Responder name	Rainer Hollmann
Responder email	rainer.hollmann@dwd.de
Data Set Identifier	Yes, new release of CM SAF (CM-05)
Responsible organization	EUMETSAT
International Coordination	yes SCOPE-CM
Assessment body	no
Quality control organization	no
Climate applications	cloud feedback, radiation budget
Essential Climate Variable (ECV)	Cloud amount
Collection organization	NOAA *EUMETSAT*
Calibration organization	NOAA
Intercalibration organization	NOAA
FCDR organization	NOAA
TCDR organization	EUMETSAT *CM SAF (DWD, KNMI, SMHI)*
GCOS Requirements Assessments organization	EUMETSAT *CM SAF*
Independent peer review organization	EUMETSAT *Secretariat*

ECV Records

Atmosphere

CDR_ECV01_10
CDR_ECV01_11
CDR_ECV01_12
CDR_ECV01_13
CDR_ECV01_14
CDR_ECV01_15
CDR_ECV01_16
CDR_ECV01_17
CDR_ECV01_18
CDR_ECV01_19
CDR_ECV01_20
CDR_ECV01_21
CDR_ECV01_3
CDR_ECV01_4
CDR_ECV01_5
CDR_ECV01_6
CDR_ECV01_7
CDR_ECV01_8
CDR_ECV01_9
CDR_ECV02_1
CDR_ECV02_2
CDR_ECV02_3
CDR_ECV02_4

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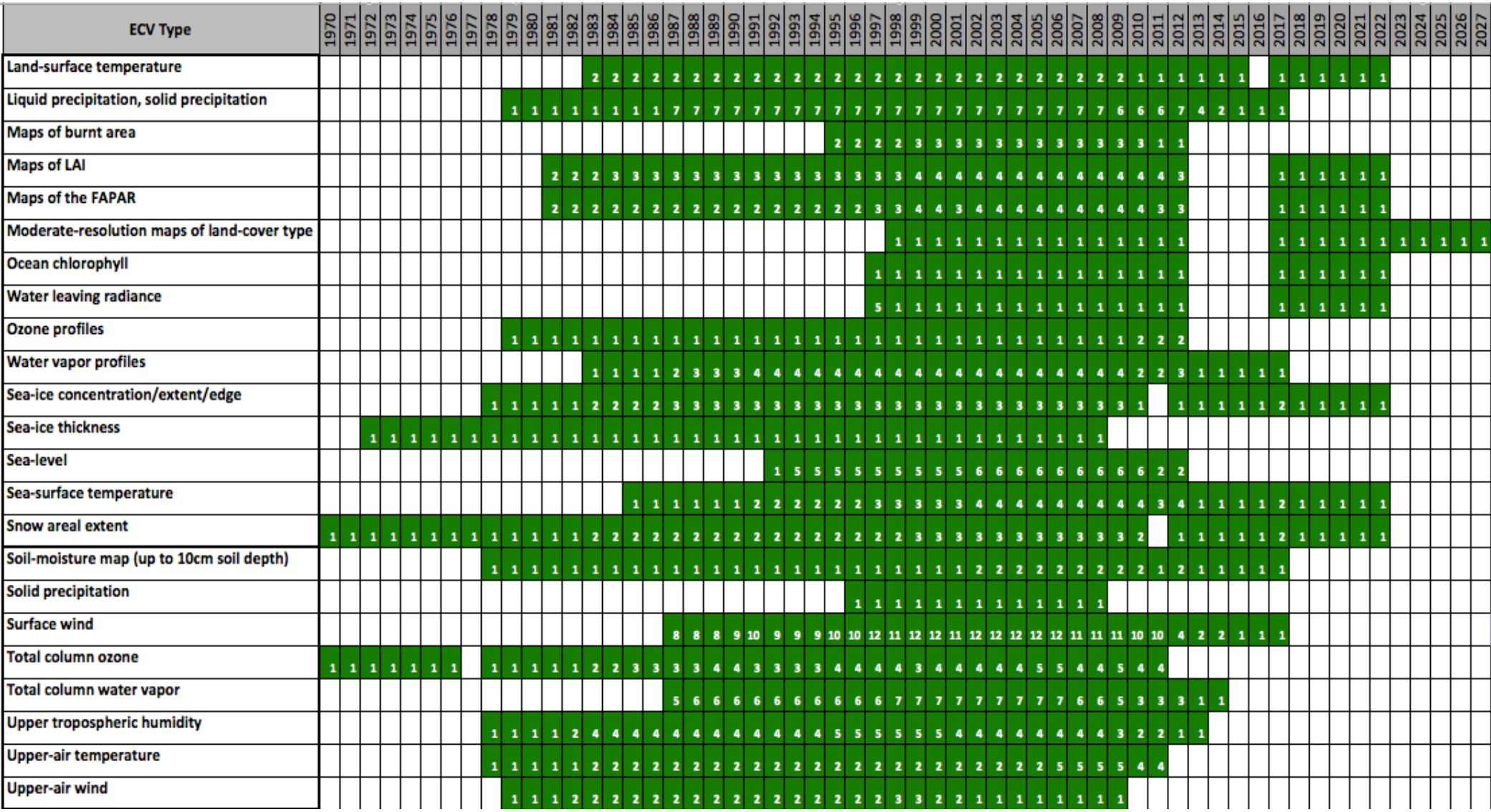
ECV Inventory Statistics – TCDR Timelines



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User Perspective

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10/21/2011 Leptoukh QA4EO'11

Adapted form Folkert Boersma, KNMI

EU FP7 CORE-CLIMAX

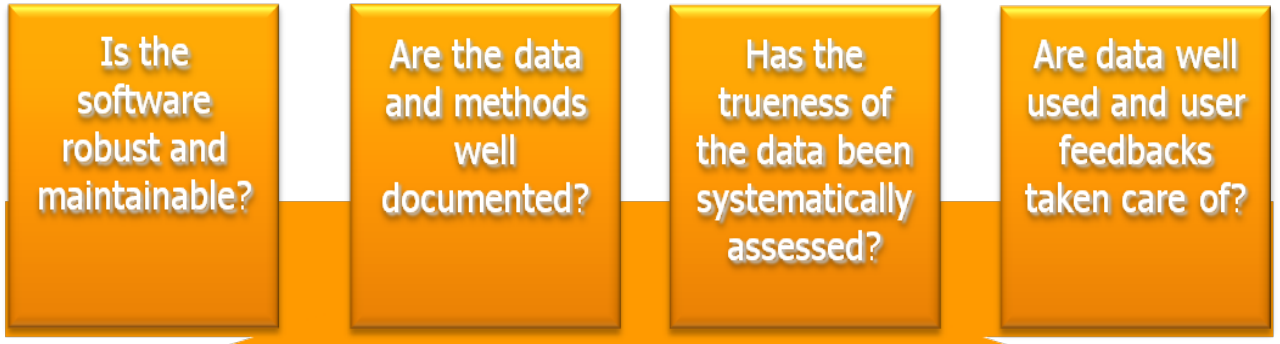
Establishing Common Practices for Climate Observations

Recent CORE-CLIMAX capacity assessment workshop studied 30+ data records established from satellite and in-situ data as well as reanalysis;

The capacity was assessed using three support tools developed by the project:

- **Data Record Inventories (DRI)**
  Contain technical specifications and also links to documented information on quality (serves as input to next obs4mips);
- **System Maturity Matrix (SMM)**
  Evaluates if the production of a CDR follows best practices for science and engineering and is assessing if data records are used and feedback mechanisms are implemented;
- **Application Performance Metric (APM)**
  Evaluates the performance of a CDR with respect to a specific application. Could be implemented as an interactive App that convolves user requirements with product specification information in a database.

Maturity Matrix Concept



Software readiness	Metadata	User documentation	Uncertainty Characterisation	Public Access, Feedback and Update	Usage
Are the codes compliant with standards, stable, portable and reproducible?	Do the metadata meet international standards, and allow provenance tracking?	Are the formal documents and peer-reviewed papers up-to-date and public?	Are the uncertainties assessed systematically in a standard manner?	Are the data, source code, and documents publicly available and regularly updated?	Are the data widely used in the scientific, and decision and policy making communities?

Sub-Matrix for Uncertainty

SOFTWARE READINESS	METADATA	USER DOCUMENTATION	**UNCERTAINTY CHARATERISATION**	PUBLIC ACCESS, FEEDBACK, UPDATE	USAGE

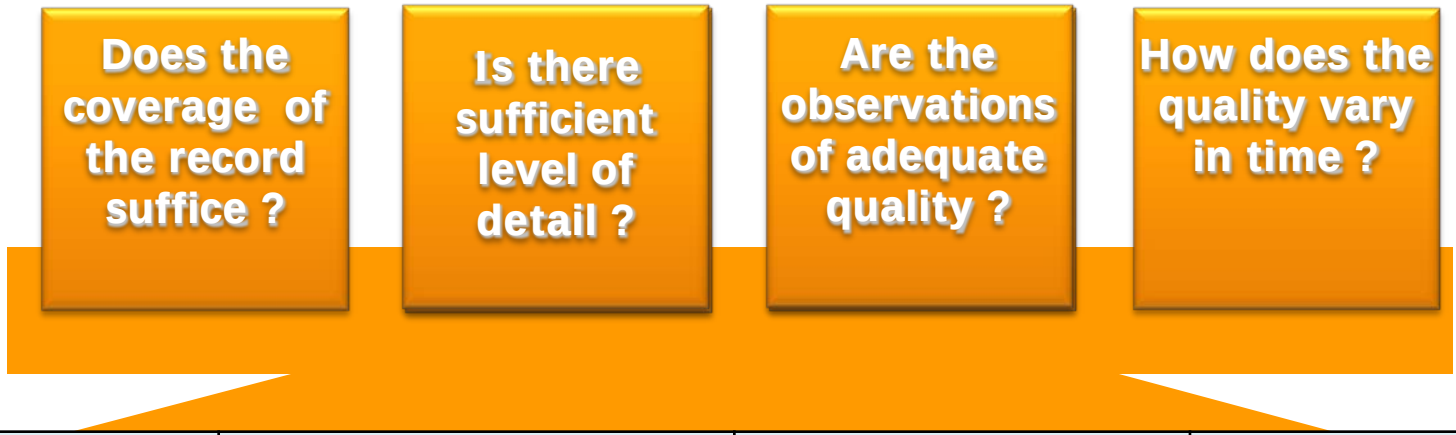
	Standards	Validation	Uncertainty quantification	Automated Quality Monitoring
1	None	None	None	None
2	Standard uncertainty nomenclature is identified or defined	Validation using external reference data done for limited locations and times	Limited information on uncertainty arising from systematic and random effects in the measurement	None
3	Score 2 + Standard uncertainty nomenclature is applied	Validation using external reference data done for global and temporal representative locations and times	Comprehensive information on uncertainty arising from systematic and random effects in the measurement	Methods for automated quality monitoring defined
4	Score 3 + Procedures to establish SI traceability are defined	Score 3 + (Inter)comparison against corresponding CDRs (other methods, models, etc)	Score 3 + quantitative estimates of uncertainty provided within the product characterising more or less uncertain data points	Score 3 + automated monitoring partially implemented
5	Score 4 + SI traceability partly established	Score 4 + data provider participated in one inter-national data assessment	Score 4 + temporal and spatial error covariance quantified	Score 3 + monitoring fully implemented (all production levels)
6	Score 5 + SI traceability established	Score 4 + data provider participated in multiple inter-national data assessment and incorporating feedbacks into the product development cycle	Score 5 + comprehensive validation of the quantitative uncertainty estimates and error covariance	Score 5 + automated monitoring in place with results fed back to other accessible information, e.g. meta data or documentation

European Capacity Assessment

- Workshop held at EUMETSAT in January 2014 endorsed assessment concept and tools and assessed 30+ data records;
- Assessment:
  - Provides consistent view on strengths and weaknesses of the process to generate, preserve and improve CDRs to each individual CDR producer, agencies and EC;
  - Provides information to the user community on:
    - Status of individual records;
    - Collective state of all records;
  - Provides this information for the first time across different observing systems (satellite, in situ and reanalysis);
  - Increases transparency and openness towards the user;
  - Supports selection of CDRs for services and applications;
  - Supports Europe's contribution to the next Obs4Mips activity by providing consistent information on CDRs produced in Europe.

Support User's to Select Data

- User requirements collection exercises show a large variability in the stated requirements of users with nominally similar applications;
- But a core set of typical questions may always be isolated:



Coverage	Sampling	Uncertainty	Stability
Are the record length and spatial coverage meeting the application's requirements?	Do the spatial and temporal sampling meet the applications requirements?	Do the random and systematic uncertainties meet the specifications?	Do the temporal and spatial stability meet the specifications?

Conclusions

- EQC for Copernicus Climate Change Service (CCCS) needs to consider both scientific quality and process maturity;
- CCCS should support development of metrics for both;
- CCCS should support international data quality assessments collaborating with research organisations such as WCRP and Future Earth;
- CCCS should periodically assess process maturity for European data producers.

SPARE SLIDES

European Potential to Provide GCOS ECVs from Satellite

Atmosphere	Ocean	Terrestrial
Composition	Surface	
Aerosol Properties	Sea Surface Temperature	Land Cover
Methan & Long Lived GHGs	Sea Level	Fire Disturbance
Ozone	Sea Ice	Soil Moisture
Carbon Dioxide	Ocean Colour	Glacier and Ice Caps
Precursors (for Aerosol & O3)	Sea State	Ice Sheets
Upper Air	Current	Snow Cover
Cloud Properties	Sea Surface Salinity	Albedo
Temperature	Carbon Dioxide Partial Pressure	Leaf Area Index
Water Vapour	Phytoplankton	FAPAR
Wind Speed and Direction	Ocean Acidity	Lakes
Earth Radiation Budget	Sub Surface	Above Ground Biomass
Surface	Carbon	Permafrost
Surface Air Pressure	Current	Ground Water
Surface Air Temperature	Nutrients	River Discharge
Surface Precipitation	Ocean Acidity	Soil Carbon
Surface Radiation Budget	Oxygen	Land Surface Temperature
Water Vapour (Surface Humidity)	Salinity	
Near-surface Wind Speed	Temperature	
	Tracers	
	Global Ocean Heat Content	

EUMETSAT | CCI Started | CCI Scope

SAT

Climate Model Evaluation Employing "Metrics"

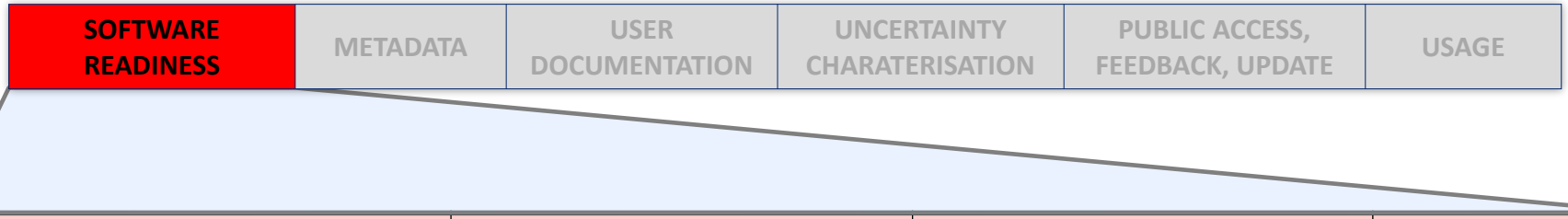
- Questions motivating routine benchmarks for climate models
  - Are models improving?
  - Do some models consistently agree with observations better than others?
  - What do models simulate robustly, and what not?
- Related research drivers
  - How does skill in simulating observed climate relate to projection credibility?
  - Can we justify weighting model projections based on metrics of skill?
- Metrics
  - Metrics, as used in IPCC, are succinct and objective measures of the quality of a model simulation – usually a scalar quantity;
  - Quantify errors, usually *not* designed to diagnose reasons for model errors;
  - Skill in simulating things we have observed: "performance metrics;
  - Model reliability for application (e.g., "projection reliability metrics") - How accurate are model projections of climate change?

Slide: Courtesy of Peter Gleckler, LLNL, USA

Core-Climax: System Maturity Matrix

Maturity	SOFTWARE READINESS	METADATA	USER DOCUMENTATION	UNCERTAINTY CHARACTERISATION	PUBLIC ACCESS, FEEDBACK, UPDATE	USAGE
1	Conceptual development	None	Limited scientific description of the methodology available from PI	None	Restricted availability from PI	None
2	Research grade code	Research grade	Comprehensive scientific description of the methodology, report on limited validation, and limited product user guide available from PI; paper on methodology is sumitted for peer-review	Standard uncertainty nomenclature is idenitified or defined; limited validation done; limited information on uncertainty available	Data avaliable from PI, feedback through scientific exchange, irregular updates by PI	Research: Benefits for applications identified DSS: Potential benefits identified
3	Research code with partially applied standards; code contains header and comments, and a README file; PI affirms portability, numerical reproducibility and no security problems	Standards defined or identified; sufficient to use and understand the data and extract discovery metadata	**Score 2 +** paper on methodology published; comprehensive validation report available from PI and a paper on validation is submitted; comprehensive user guide is available from PI; Limited description of operations concept available from PI	**Score 2 +** standard nomenclature applied; validation extended to full product data coverage, comprehensive information on uncertainty available; methods for automated monitoring defined	Data and documentation publically available from PI, feedback through scientifc exchange, irregular updates by PI	Research: Benefits for applications demonstrated. DSS: Use occuring and benefits emerging
4	**Score 3 +** draft software installation/user manual available; 3rd party affirms portability and numerical reproducibility; passes data providers security review	**Score 3 +** standards systematically applied; meets international standards for the data set; enhanced discovery metadata; limited location level metadata	**Score 3 +** comprehensive scientific description available from data provider; report on inter comparison available from PI; paper on validation published; user guide available from data provider; comprehensive description of operations concept available from PI	**Score 3 +** procedures to establish SI traceability are defined; (inter)comparison against corresponding CDRs (other methods, models, etc); quantitative estimates of uncertainty provided within the product characterising more or less uncertain data points; automated monitoring partially implemented	Data record and documentation available from data provider and under data provider's version control; Data provider establishes feedback mechanism; regular updates by PI	**Score 3 +** Research: Citations on product usage in occurring DSS: societal and economical benefits discussed
5	**Score 4 +** operational code following standards, actions to achieve full compliance are defined; software installation/user manual complete; 3rd party installs the code operationally	**Score 4+** fully compliant with standards; complete discovery metadata; complete location level metadata	**Score 4 +** comprehensive scientific description maintained by data provider; report on data assessment results exists; user guide is regularly updated with updates on product and validation; description on practical implementation is available from data provider	**Score 4 +** SI traceability partly established; data provider participated in one inter-national data assessment; comprehensive validation of the quantitative uncertainty estimates; automated quality monitoring fully implemented (all production levels)	**Score 4 +** source code archived by Data Provider; feedback mechanism and international data quality assessment are considered in periodic data record updates by Data Provider	**Score 4+** Research: product becomes reference for certain applications DSS: Societal and economic benefits are demonstrated
6	**Score 5 +** fully compliant with standards; Turnkey System	**Score 5 +** regularly updated	**Score 5 +** journal papers on product updates are and more comprehensive validation and validation of quantitative uncertainty estimates are published; operations concept regularly updated	**Score 5 +** SI traceability established; data provider participated in multiple inter-national data assessment and incorporating feedbacks into the product development cycle; temporal and spatial error covariance quantified; Automated monitoring in place with results fed back to other accessible information, e.g. meta data or documentation	**Score 5 +** source code available to the public and capability for continuous data provisions established (ICDR)	**Score 5 +** Research: Product and its applications becomes references in multiple research field DSS: Influence on decision and policy making demonstrated

Sub Matrix – Software Readiness



	Coding standards	Software Documentation	Numerical Reproducibility and Portability	Security
1	No coding standard or guidance identified or defined	No documentation	Not evaluated	Not evaluated
2	Coding standard or guidance is identified or defined, but not applied	Minimal documentation	PI affirms reproducibility under identical conditions	PI affirms no security problems
3	Score 2 + standards are partially applied and some compliance results are available	Header and process description (comments) in the code, README complete	PI affirms reproducibility and portability	Submitted for data provider's security review
4	Score 3 + compliance is systematically checked in all code, but not yet compliant to the standards.	Score 3 + a draft Software Installation/User Manual	3rd party affirms reproducibility and portability	Passes data provider's security review
5	Score 4 + standards are systematically applied in all code and compliance is systematically checked in all code. Code is not fully compliant to the standards. Improvement actions to achieve full compliance are defined.	Score 4 + enhanced process descriptions throughout the code; software installation/user manual complete	Score 4 + 3rd party can install the code operationally	Continues to pass the data provider's review
6	Score 5 + code is fully compliant with standards.	As in score 5	Score 5 + Turnkey system	As in score 5

Sub Matrix - Meta Data

SOFTWARE READINESS	METADATA	USER DOCUMENTATION	UNCERTAINTY CHARATERISATION	PUBLIC ACCESS, FEEDBACK, UPDATE	USAGE

	Standards	Collection level	File level
1	No standard considered	None	None
2	No standard considered	Limited	Limited
3	Metadata standards identified and/or defined but not systematically applied	Sufficient to use and understand the data independent of external assistance; Sufficient for data provider to extract discovery metadata from meta data repositories	Sufficient to use and understand the data independent of external assistance
4	Score 3 + standards systematically applied at file level and collection level by data provider. Meets international standards for the dataset	Score 3 + Enhanced discovery metadata	Score 3 + Limited location (pixel, station, grid-point, etc.) level metadata
5	Score 4 + meta data standard compliance systematically checked by the data provider	Score 4 + Complete discovery metadata meets international standards	Score 4 + Complete location (pixel, station, grid-point, etc.) level metadata
6	Score 5	Score 5 + Regularly updated	Score 5

Climate Data Record App

- User looking for data …
  - Selects the ECV of interest
  - Selects the product features relevant to them
  - Can adjust their requirements (around guided sensible ranges) for themselves
- App then convolves requirements with product specification information in database
- User is presented with (say) 3 suggested datasets to consider, and their scores across their product feature requirements
- App also points to data, documentation, “product reviews” uploaded by earlier app users, and is further linked via CHARMe metadata