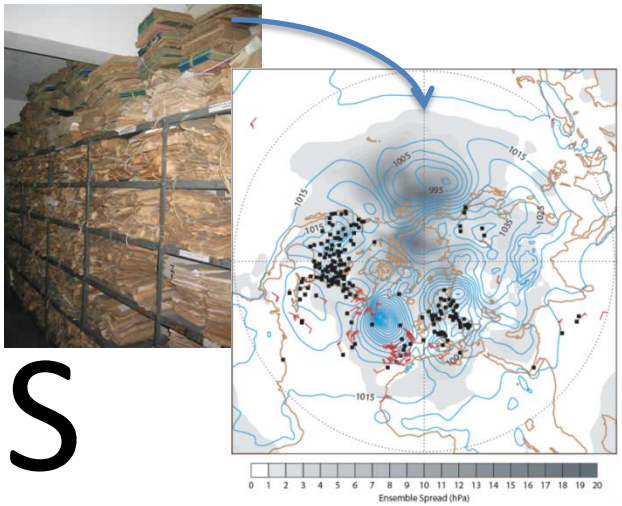


REANALYSIS UNCERTAINTIES

Considerations for Verification and Confidence

David Tan and colleagues

Reanalysis Section

European Centre for Medium-Range Weather Forecasts

Reading, UK

ERA CLIM Core Climax

ECMWF

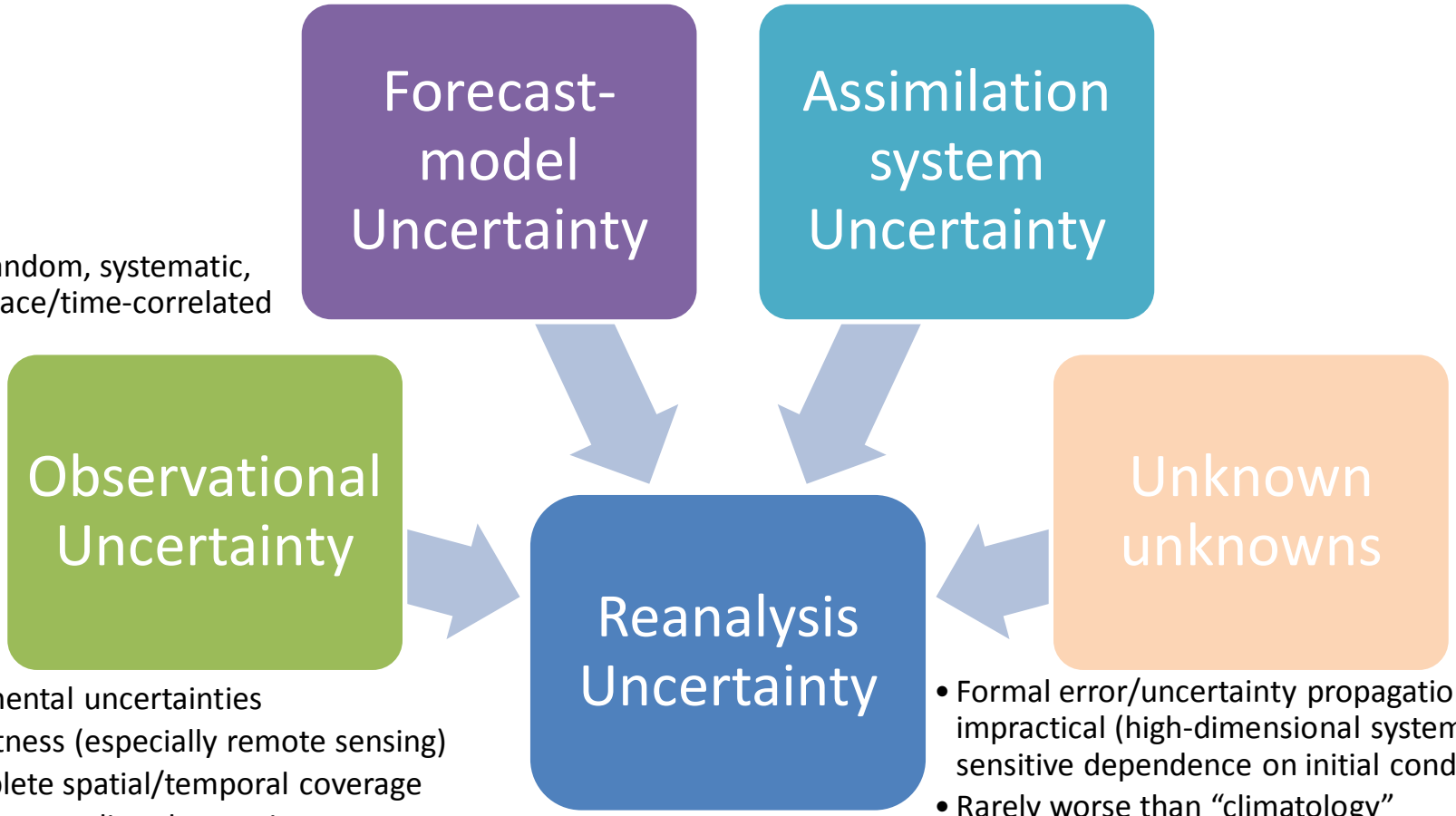
Reanalysis Uncertainties - Key Points

They exist	• For a variety of reasons
Comprehensive characterization	• Is a big challenge • Many geophysical parameters & spatio-temporal scales • Reference-quality observations are scarce
Expertise and information	• Is widespread and increasing • Often scattered amongst user community • Not always easy to access/interpret
Best-practice	• Is in a phase of significant change • Develop ways to use uncertain datasets *confidently* • Whether from reanalysis or other sources
Outlook	• Is positive • Needs community effort involving producers *& users* • Be open to new ideas on what to do (and how to do it)

Reanalysis Uncertainties – Major Sources

- Physical parametrizations - convection, GWD, …
- Boundary/forcing fields – SST, GHGs, …

- Estimates of bias corrections
- Estimates of error covariances

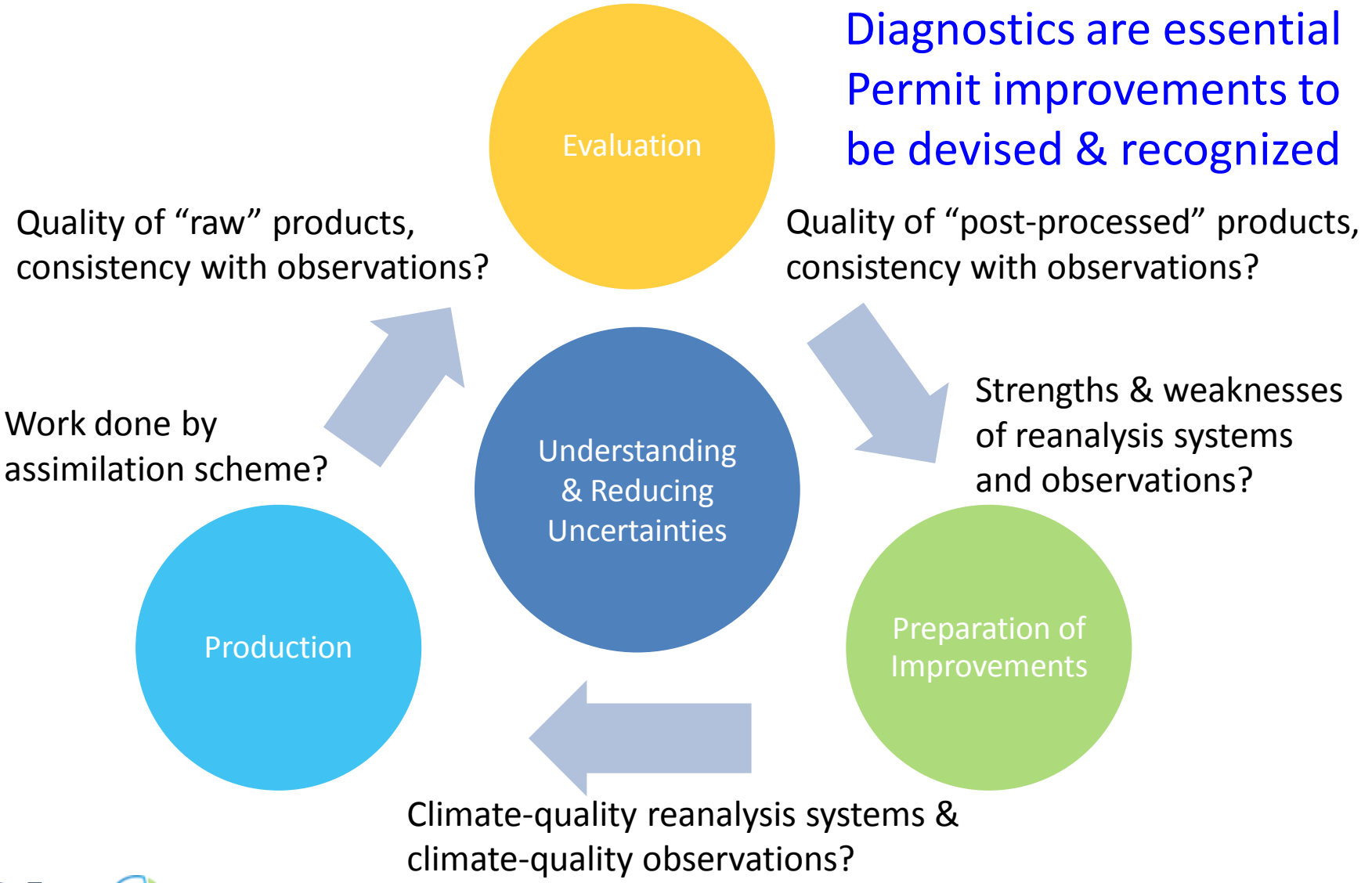


- Random, systematic, space/time-correlated

- Instrumental uncertainties
- Indirectness (especially remote sensing)
- Incomplete spatial/temporal coverage
- Reference-quality observations are scarce

- Formal error/uncertainty propagation is impractical (high-dimensional system, sensitive dependence on initial conditions)
- Rarely worse than "climatology"
- Can be reduced in successive reanalyses – a top-down/holistic life-cycle approach

Iterative progress: the reanalysis life-cycle

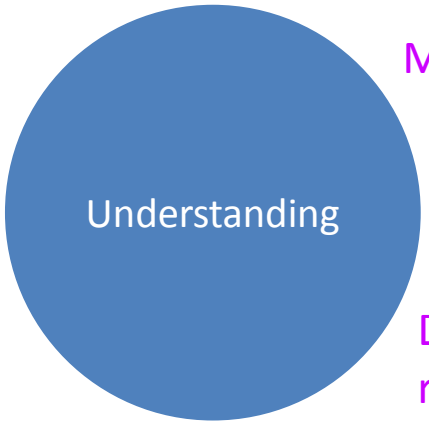


Diagnostics for Quality, Uncertainty & Confidence

INTERPRETATIVE METADATA
Abundant but much waiting to be discovered
Can be disjointed (grey-literature), not easy to synthesize

Quality of "raw" products, consistency with L1/L2 observations?

Quality of "post-processed" products, consistency with L2/L3/L4 observations?



Forecast scores
Bias corrections
Analysis departures
Analysis increments
Background departures
Cost function diagnostics

Monthly means
Trends & anomalies
Budgets, e.g. energy/water cycles
Ensemble statistics
Downstream data, e.g. hydrology, renewable energy, agriculture, health

Work done by assimilation scheme?

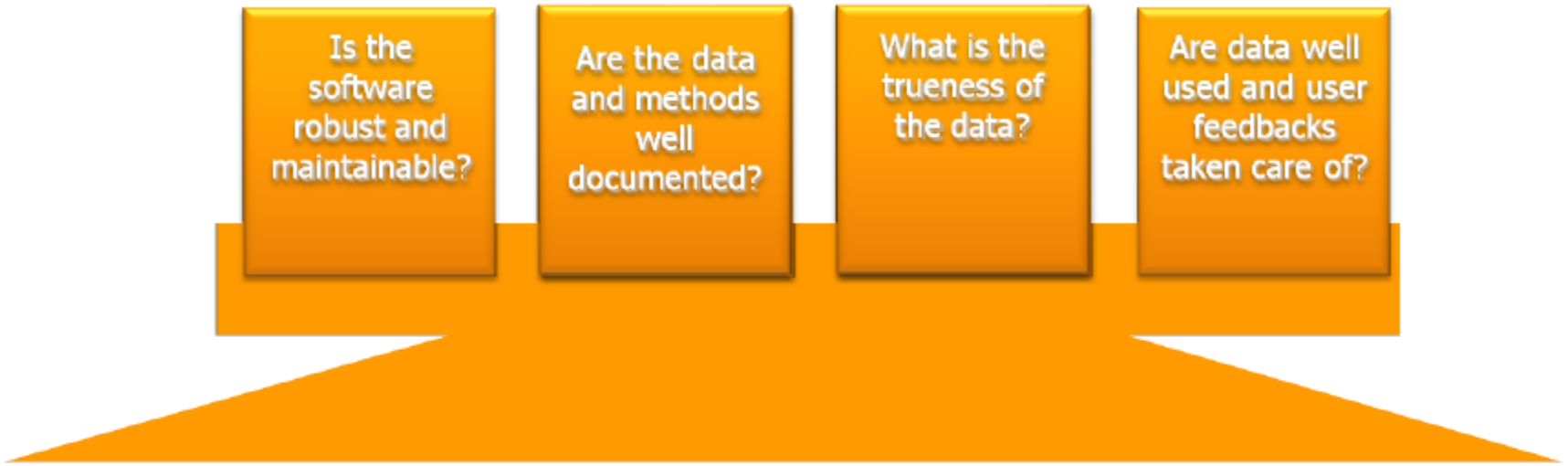
Climate-quality reanalysis systems & climate-quality observations?

Strengths & weaknesses of reanalysis systems and observations?
Intercomparison projects, e.g. S-RIP

Info on Reanalysis Uncertainties

Peer-reviewed literature	• Good public access • Unlikely to become fully comprehensive • Supplemented by Maturity Matrices? See next slides
Grey literature	• Technical reports • Private sector, e.g. wind/renewable energy industry • More sharing of data and insight?
Websites	• E.g. reanalysis.org (see later slide) • Discussion forums, preferably moderated
DIY	• Application-specific investigations • Customized diagnostics, sensitivity studies • More sharing of techniques, community toolboxes?
Consultancy advice?	• Could be part of an Environmental Service? • Needs a larger "expert community" – capacity-building • Interpretation of Maturity Matrices?

CORE-CLIMAX System Maturity Matrix



Software readiness	Metadata	User documentation	Uncertainty Characterization	Public Access, Feedback and Update	Usage
Are the codes compliant with standards, stable, portable and reproducible?	Do the metadata meets international standards, and allows 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?

- Evolved from Bates approach (NOAA) by Eumetsat (Joerg Schulz) and DWD (Andrea Kaiser-Weiss)
- Does the Dataset Production follow best-practice in Science and Software Engineering?
- Coupled with Application Performance Matrices/Indices

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 identified or defined; limited validation done; limited information on uncertainty available	Data available 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 scientific 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 + soure 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

- Maturity can increase (or decrease) after dataset is released
- Originally for Satellite-based Climate Data Records
- Currently being extended to Reanalyses and In-situ Datasets
- Not to be applied in “beauty contests” !!

ERA-Interim Top-level maturity (Jan 2014)

ECMWF Interim Reanalysis (ERA-Interim)

maturity level as of Jan/14/2014

CORE-CLIMAX System Maturity Matrix

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2	Research grade code	Research grade	methodology, report on limited validation, and limited product user guide available from PI; paper on methodology is sumitted for peer-review	limited validation done; limited information on uncertainty available	Data available from PI, feedback through scientific exchange, regular 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 cocept 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
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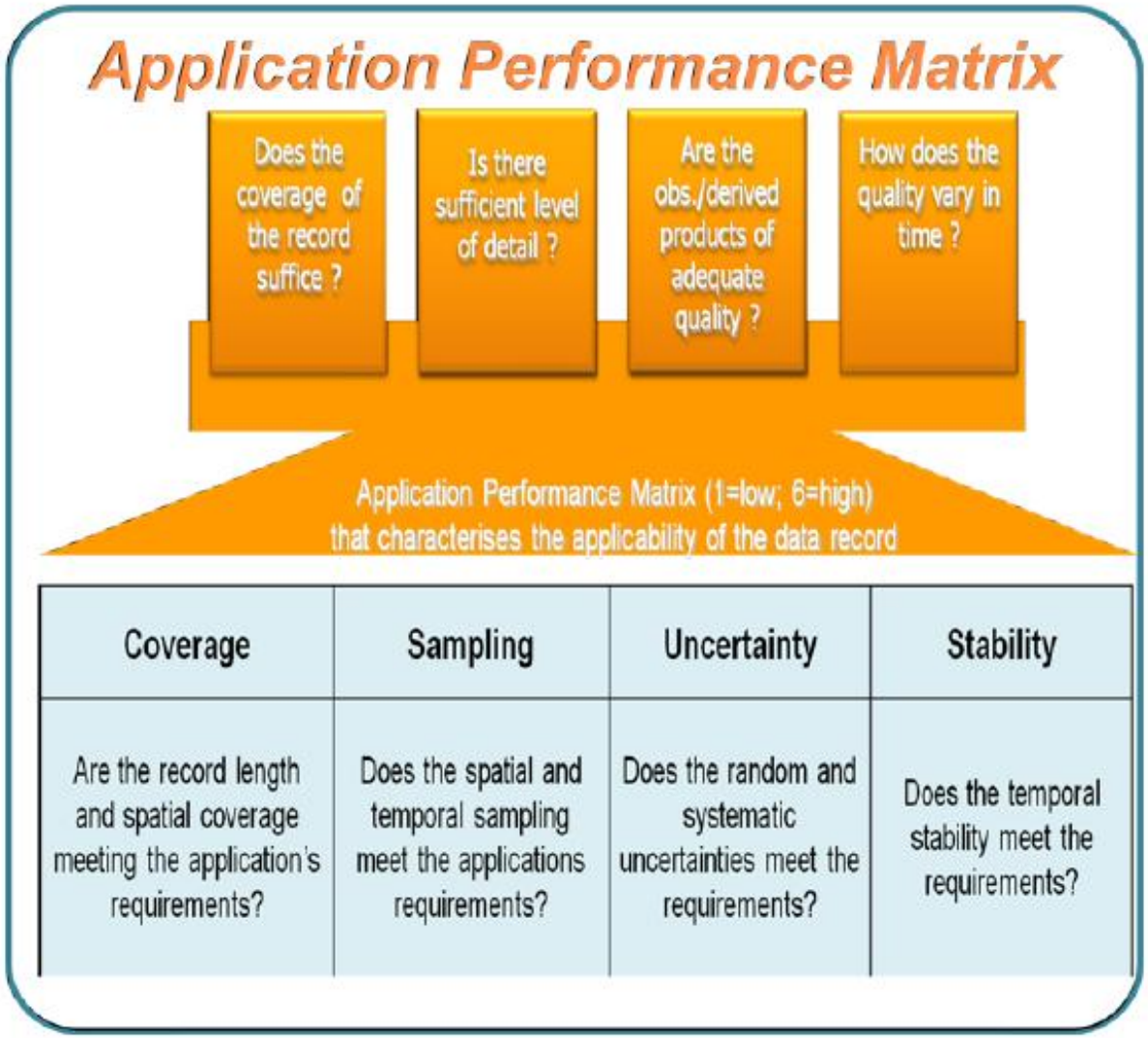
- Mix of research-capability and initial-operations (see sub-categories)
- Mature on usage (including decision-making)
- Feasible to improve (given enough resources)

Uncertainty characterization

Maturity	UNCERTAINTY CHARACTERISATION	Standards[1]	Validation	Uncertainty quantification	Automated Quality Monitoring
1	None	None	None	None	None
2	Standard uncertainty nomenclature is idenitified or defined; limited validation done; limited information on uncertainty available	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 nomenclature applied; validation extended to full product data coverage, comprehensive information on uncertainty available; methods for automated monitoring defined	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; (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	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; 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 + 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; 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 + 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

- Feasible to improve – easier for some ECVs than others
- Some aspects linked to improvements in reference/baseline observations

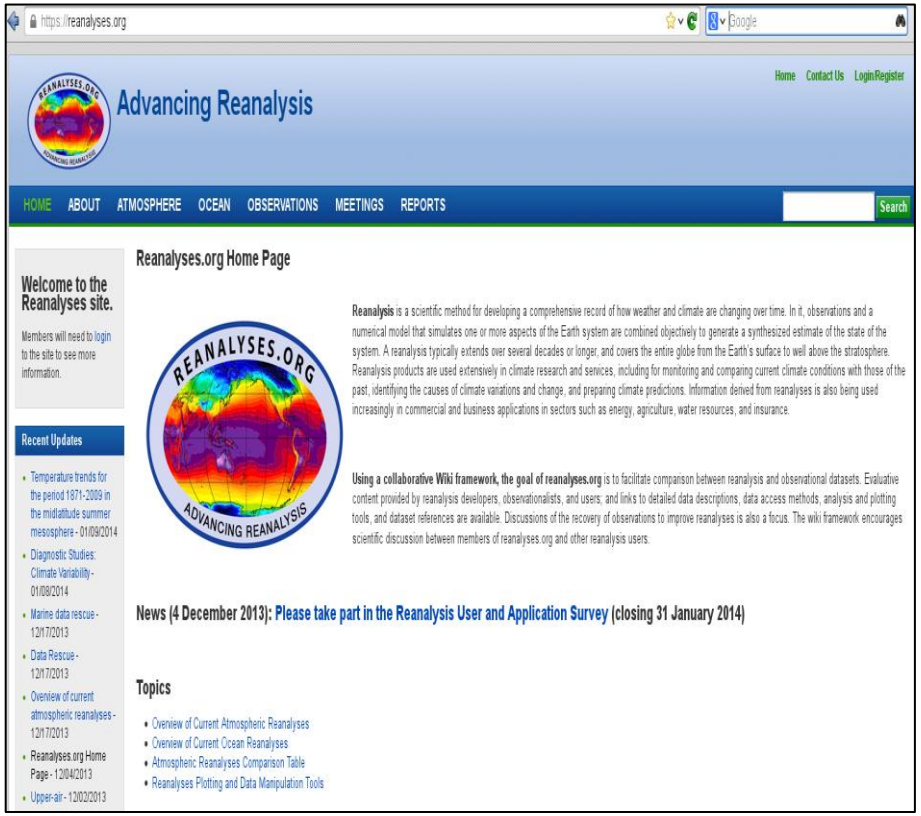
Core-Climax Application Performance Matrix



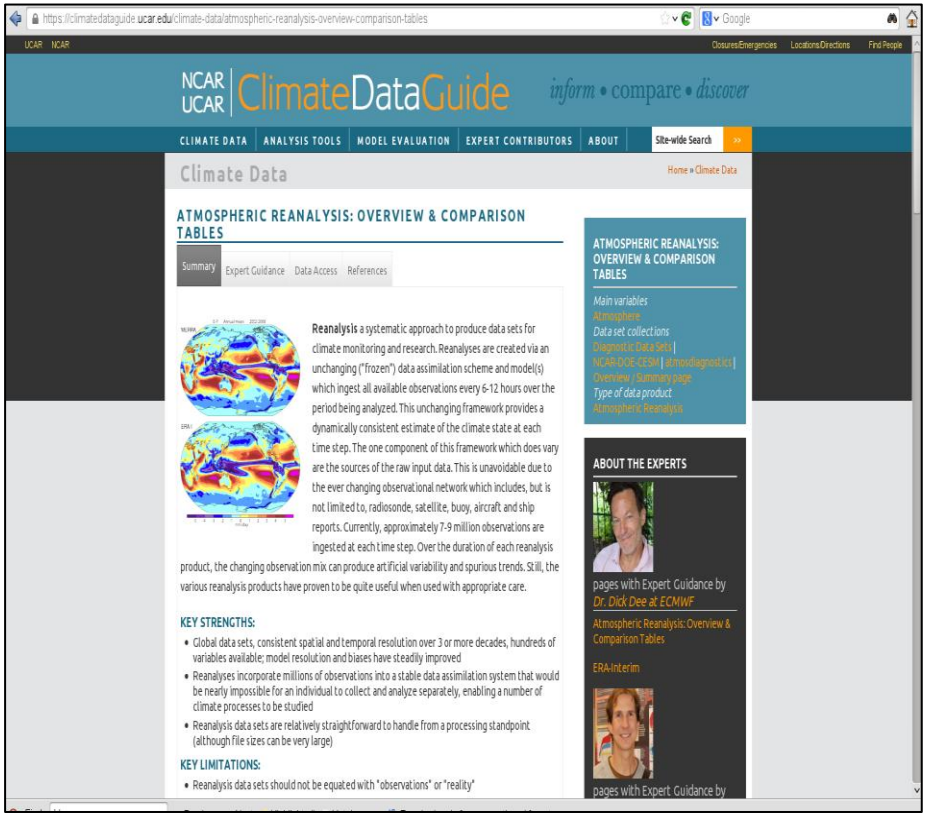
Coverage	Sampling	Uncertainty	Stability
Are the record length and spatial coverage meeting the application's requirements?	Does the spatial and temporal sampling meet the applications requirements?	Does the random and systematic uncertainties meet the requirements?	Does the temporal stability meet the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

Reanalysis resources on the Web

reanalysis.org



UCAR/NCAR Climate Data Guide



Some replies to questions about accuracy/reliability

- "Well, the answer to your question isn't so straightforward …"
- "There is no easy answer to your question …"

UCAR/NCAR Climate Data Guide

Assessing the quality of reanalysis data

Please visit http://www.ecmwf.int/research/era for up-to-date information about ERA-Interim production, data availability, quality issues, documentation, etc.

Reanalysis data are often used to represent the "true state of the atmosphere according to observations." In actual fact, reanalysis combines inaccurate and incomplete observations with imperfect models, using methods and procedures that are technically and scientifically complex. Limitations and caveats of reanalysis data mainly result from:

- Lack of observations. The atmosphere is not now, nor ever has been, fully observed.
- Errors in the observations, and lack of information about those errors.
- Shortcomings in the assimilating model, and lack of information about model errors.
- Shortcomings in data assimilation methodology.
- Technical errors and mistakes.
- Computational limitations (e.g. limitations in spatial and temporal resolution)

Several of these items have to do with a lack of information. They represent fundamental limitations that are not restricted to reanalysis but play a role in any observational data set. (Note: replacing a skillfull forecast model by straightforward spatial interpolation does not solve anything - it is tantamount to removing, not adding, information).

To assess uncertainties in specific variables produced by reanalysis requires answering the following questions:

- How strongly is the variable constrained by observations? Is it directly or indirectly observed?
- What is the spatial and temporal distribution of the observations? How does this change in time?
- How accurately can the model represent the variable? Does the model have skill in extrapolating and/or predicting it?

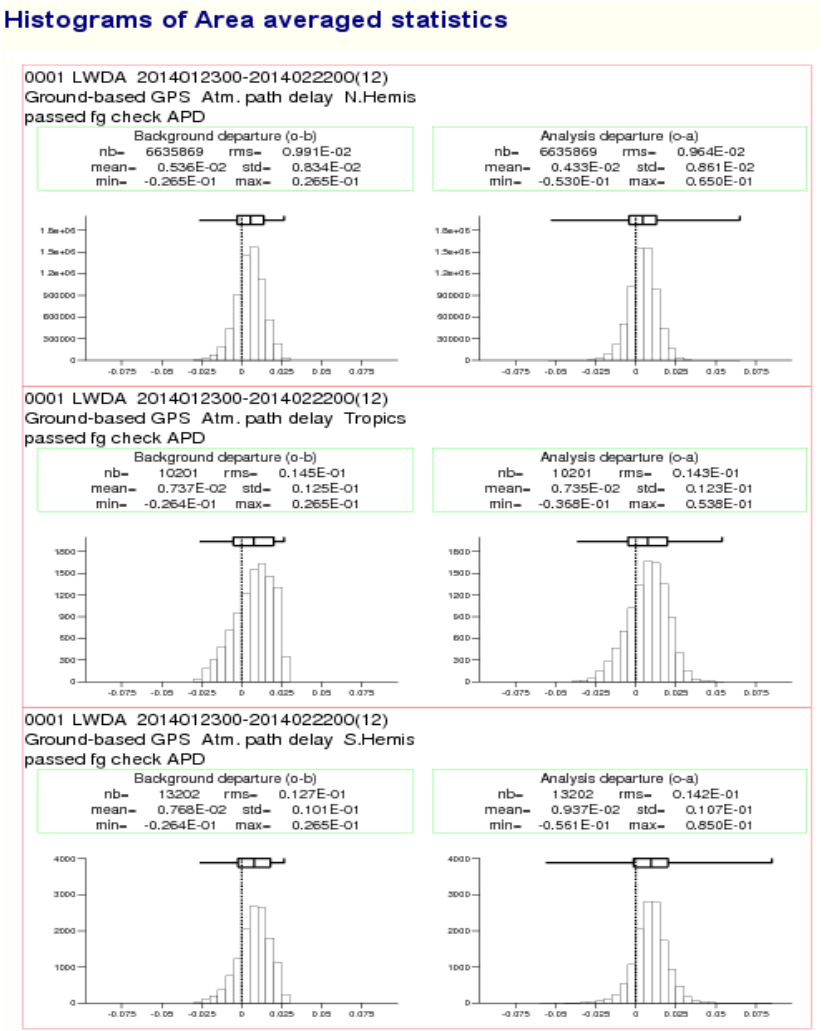
Users interested in the quality of low-frequency variability and/or trend estimates need to consider these aspects throughout the time period in question. Temporal variation in the observational constraint can produce artificial shifts in the reanalysis time series, especially if the assimilating model has systematic errors. See Section 8 in Dee and Uppala (2008) for a stratospheric example of this problem.

Given the continuous changes in the observing system, and the fact that all models have some systematic errors, users should be cautious when using reanalysis data for climate studies. It is necessary (but not always possible) to verify trend estimates by comparing with independent data sets, e.g. as in Simmons et al (2010).

Most users do not have access to the information needed to answer the difficult questions listed above. On the other hand, producers of reanalysis data do not have the resources (nor the application-specific knowledge) to answer them either. The challenge is to provide better tools and information to support users in making their own uncertainty assessments. In particular, it should be made much easier for a user to get detailed information about the observations used in reanalysis, including the quality assessment and bias adjustments produced by the reanalysis process itself.#

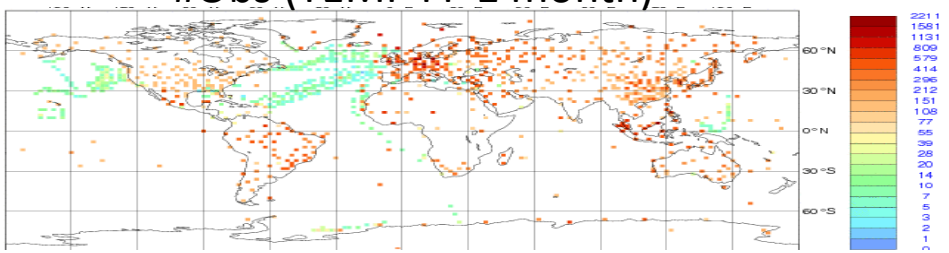
E.g. 1a: Compare with co-located observations

1. OBS-BG at the obs locations
   - Combined observation and reanalysis uncertainty
   - Typically better agreement than climatology
   - Remember to account for effects of *representativity*
2. Limitations
   - Incompleteness - confined to observed parameters and locations
3. Trade-off between assimilating the observations and keeping them as reference

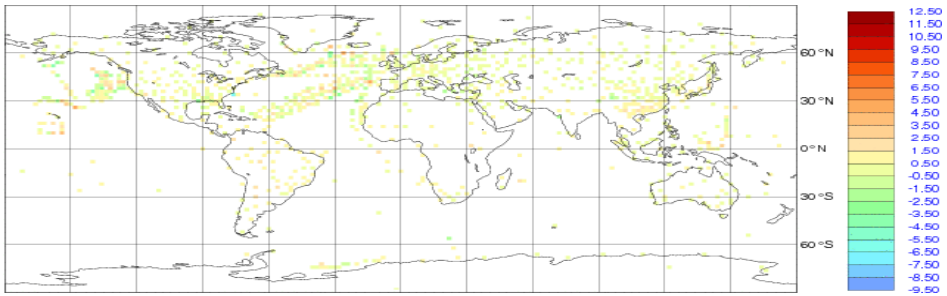


E.g. 1b: the spatial variation

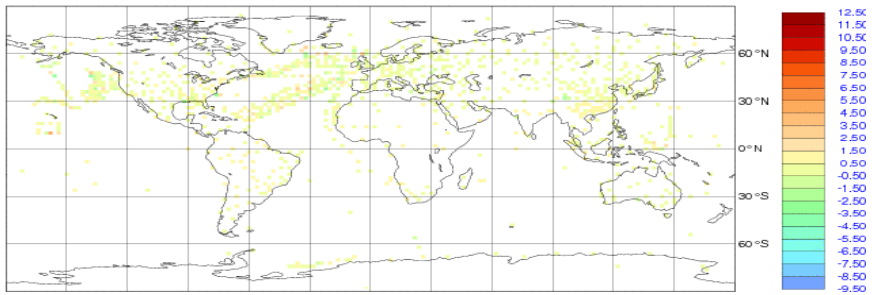
#Obs (TEMP FF 1 month)



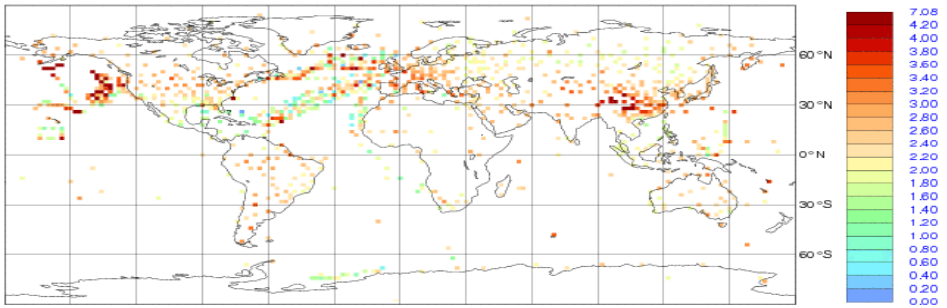
mean(obs-bg)



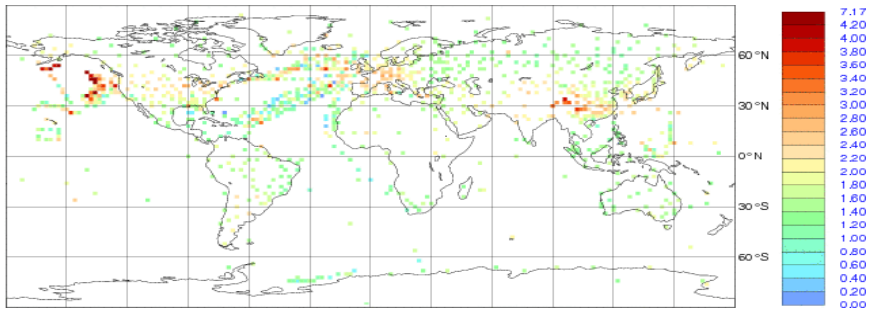
mean(obs-an)



stdev(obs-bg)

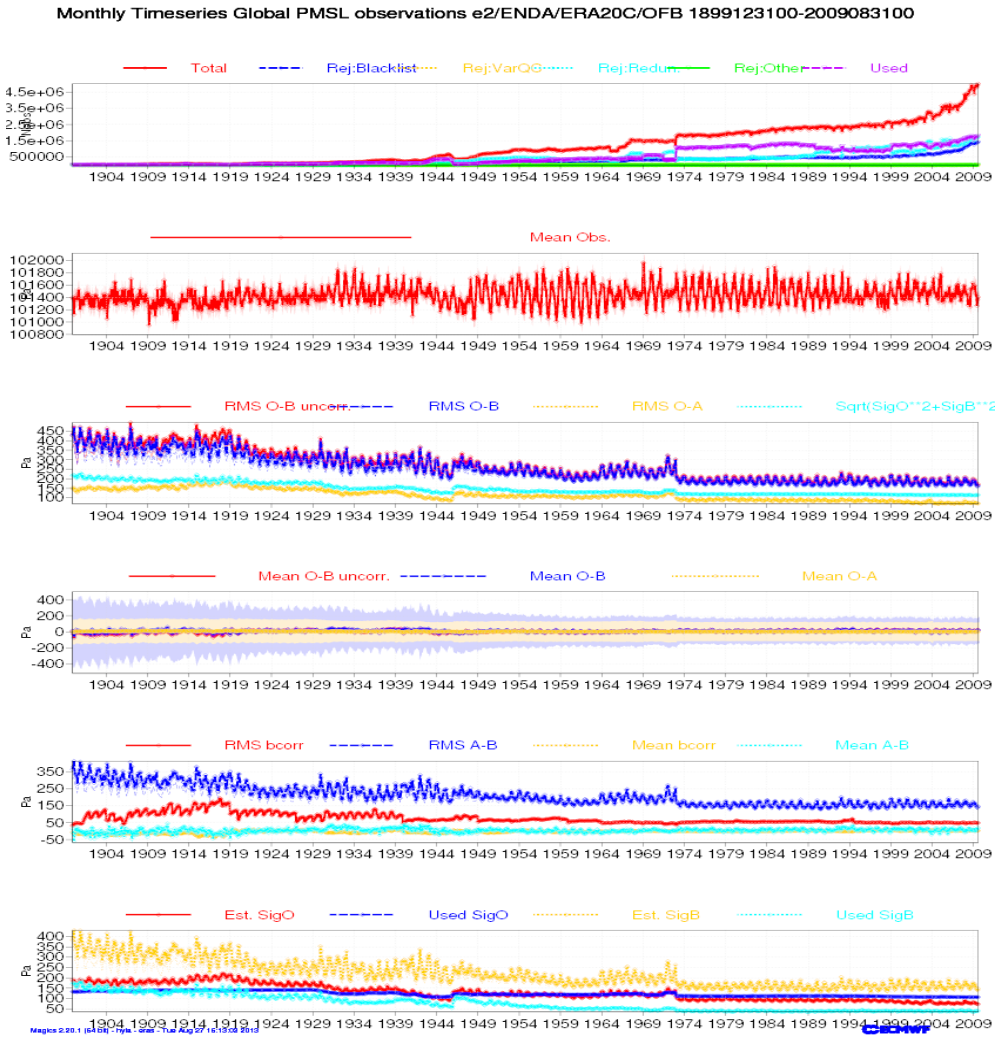


stdev(obs-an)



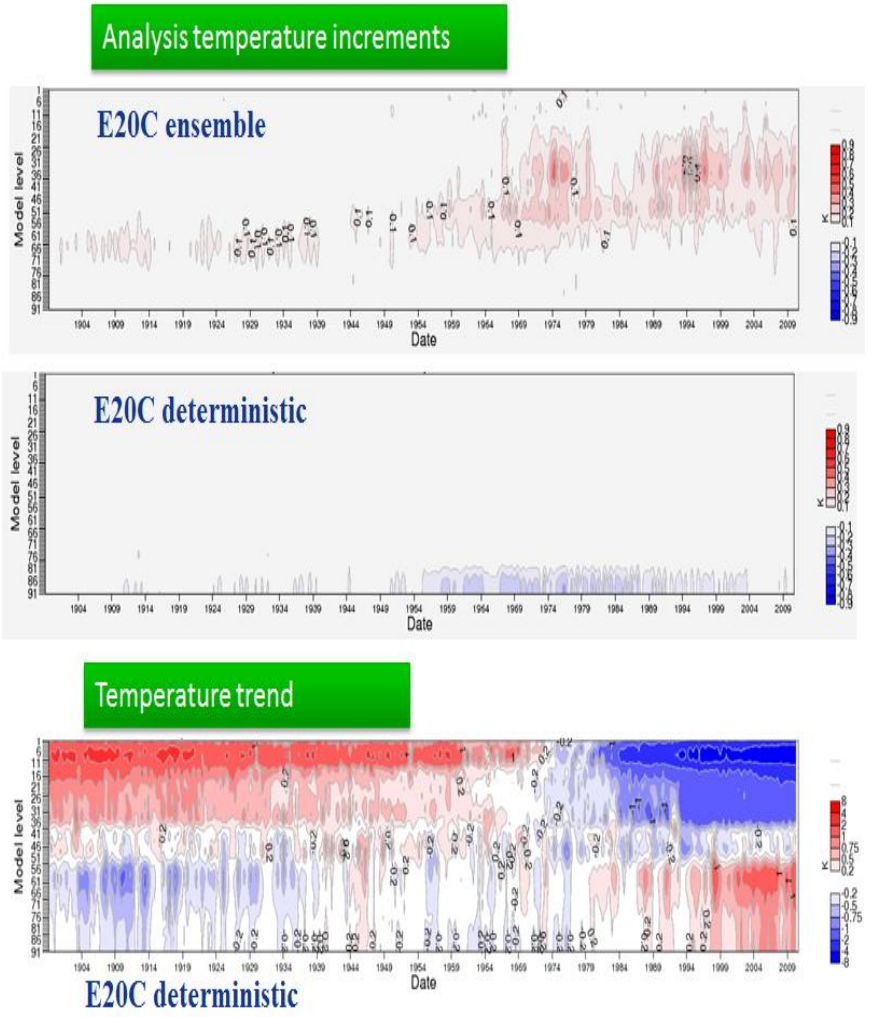
Eg 1c: the time-dimension

1. Time-series OBS-BG
   - Random, systematic, correlated in time?
2. Lessons
   - Reveal uncertainties in the underlying observations
   - Some insight into how these propagate to reanalysis
3. Further work
   - Feedback loop to data providers
   - Improve historical datasets via reprocessing



Example 2: Analysis increments

1. Convolution of the departures with gain matrix
   - From observation space to model space
2. Lessons
   - Need careful interpretation
   - Influenced by uncertainties in the underlying observations
   - And details of how these propagate to reanalysis via the data assimilation system
3. Further work
   - Encourage community to integrate both perspectives, i.e. observation- *and* model-space

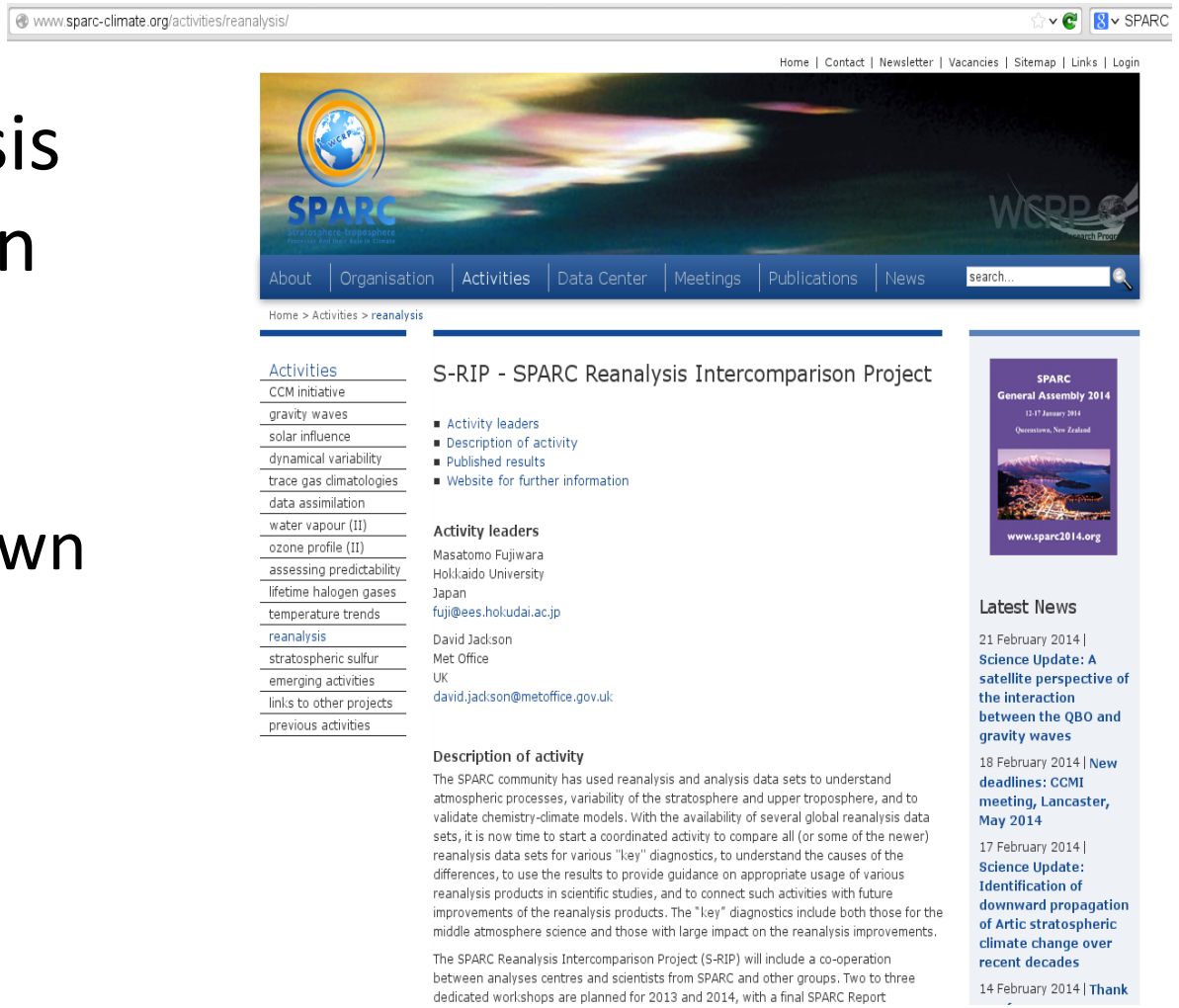


Example 3: Use of ensembles

1. Relatively new
   - EnKF, EDA, sample sizes are still small
2. Lessons
   - Need careful interpretation
   - Simple standard deviation may be insufficient
3. Further work
   - Develop community understanding and best-practice for this approach

Example 4: Inter-comparisons

1. SPARC Reanalysis Intercomparison Project
   - Emphasis on stratosphere down to UTLS
2. Further work
   - Extension to full troposphere?



Reanalysis Uncertainties - Key Points

They exist	• For a variety of reasons
Comprehensive characterization	• Is a big challenge • Many geophysical parameters & spatio-temporal scales • Reference-quality observations are scarce
Expertise and information	• Is widespread and increasing • Often scattered amongst user community • Not always easy to access
Best-practice	• Is in a phase of significant change • Develop ways to use uncertain datasets *confidently* • Whether from reanalysis or other sources
Outlook	• Is positive • Needs community effort involving producers *& users* • Welcome new ideas on what to do (and how to do it)

Reanalysis uncertainty: way forward

Improve observations	• Better and more comprehensive observing networks • Reference-quality, traceable to SI standards (GRUAN) • Reprocess observational datasets to reduce uncertainties
Improve forecast models and assimilation systems	• Synergies with NWP • Reanalysis adds emphasis on consistency over time
Build confidence in use of uncertain products	• Accept uncertainty as a part of life • Communicate it and manage it responsibly
Uncover and report uncertainties	• Help others to understand the implications in user-specific applications
Co-operate as a community	• Share knowledge and approaches • Always remember that quantitative measures need careful interpretation. Make methods & data transparent

Additional slides

ECMWF's OFA
(Observation Feedback Archive)

Overview

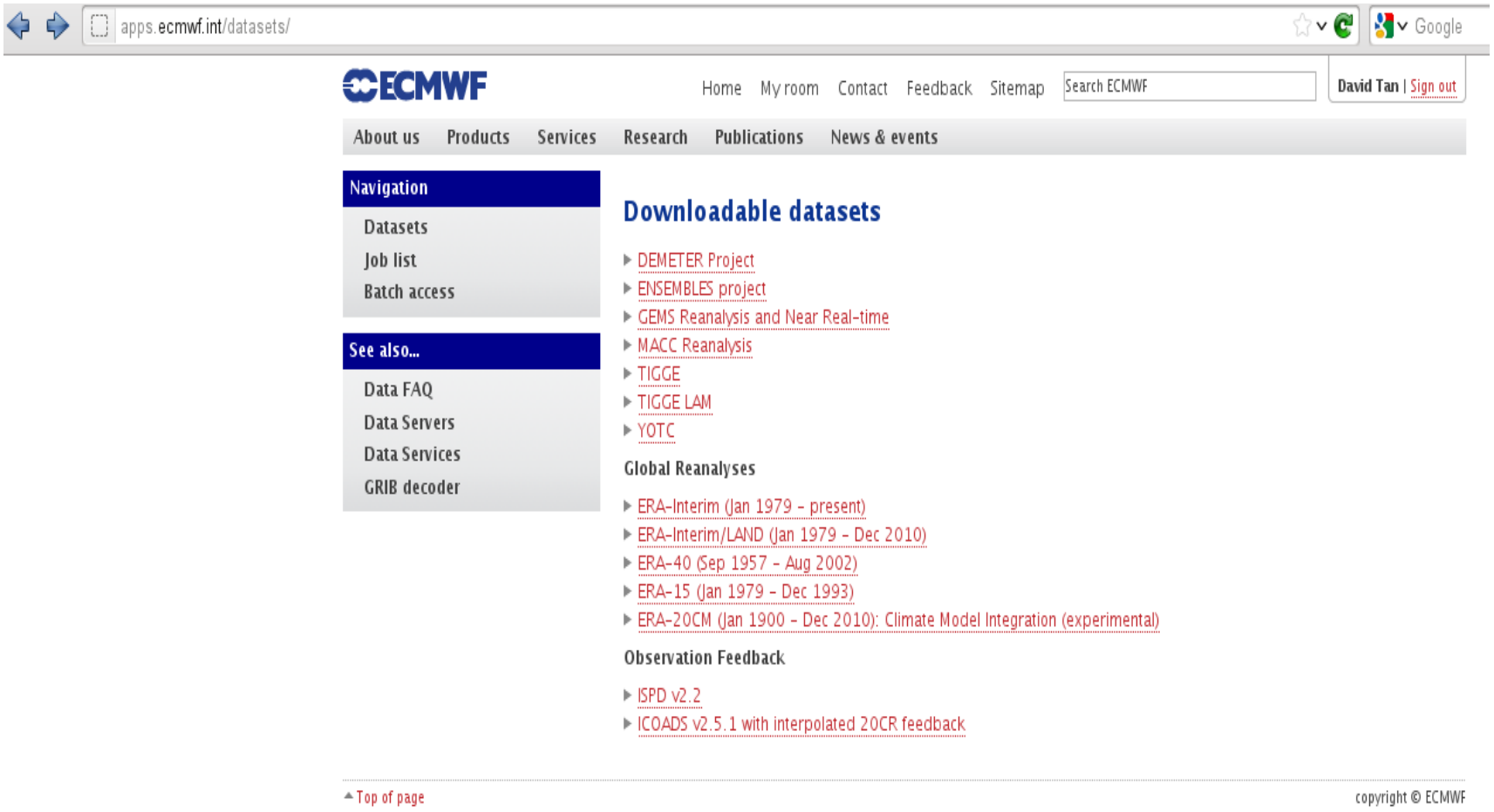
- Key vehicle for providing information about observation quality
- Quantitative components
  - departures, observation-model
  - bias corrections, typically derived during the assimilation process
- Qualitative components
  - Flags, e.g. indicating reasons for rejection by the assimilation system
- User-friendly tools
  - For access and manipulation

Observation Feedback Archive: Current Status

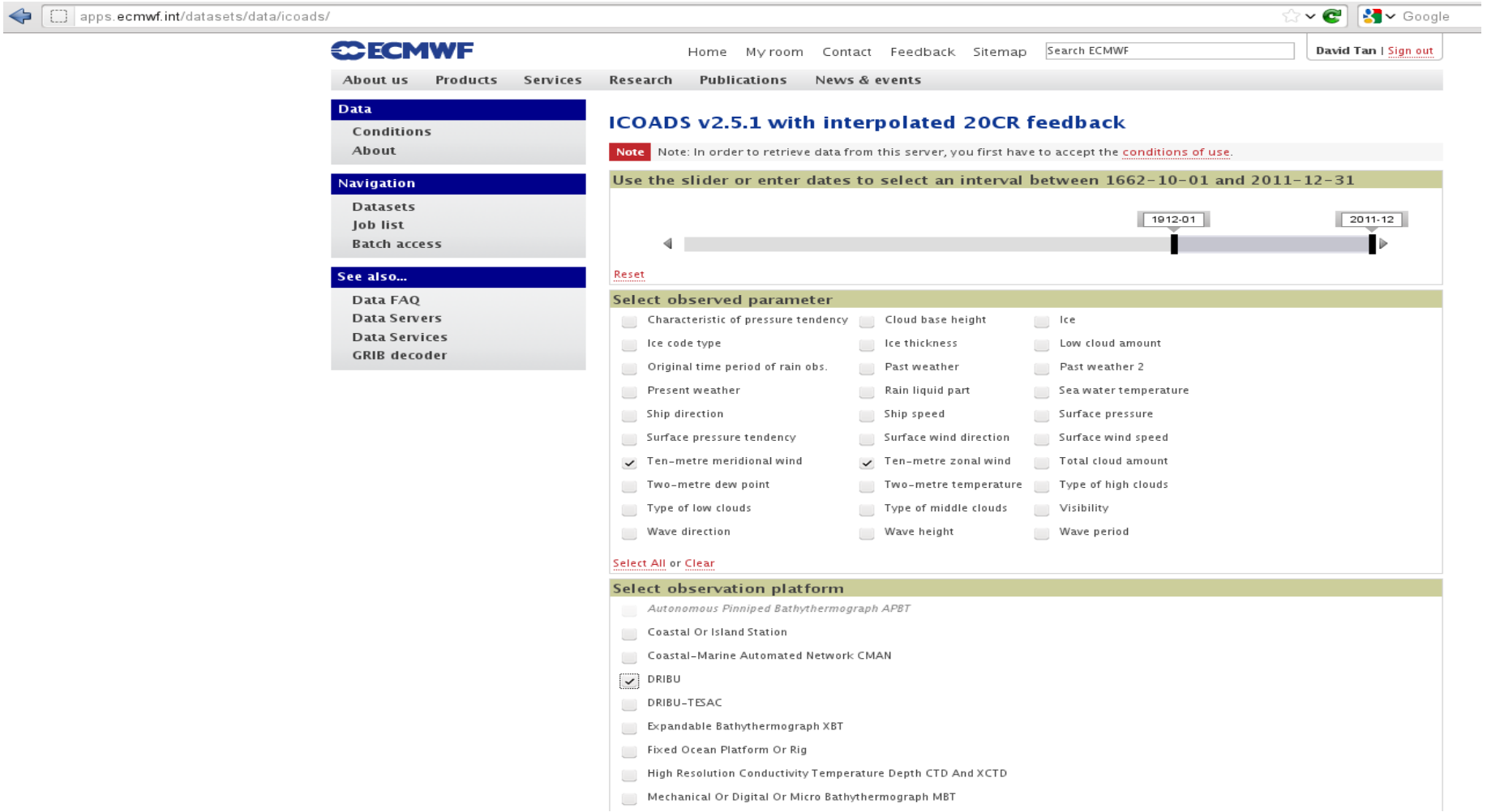
- Different elements in place (see following slides)
  - Archiving/retrieval from MARS, interactive web-based user-interface(s)
  - Manipulation and visualization, e.g. with Metview4
  - Selected observational datasets + model datasets
    - Ops + Ops
    - ICOADS + 20CR
- Some gaps to be filled
  - Model = ERA-Interim

Observation Feedback Archive: Web-MARS

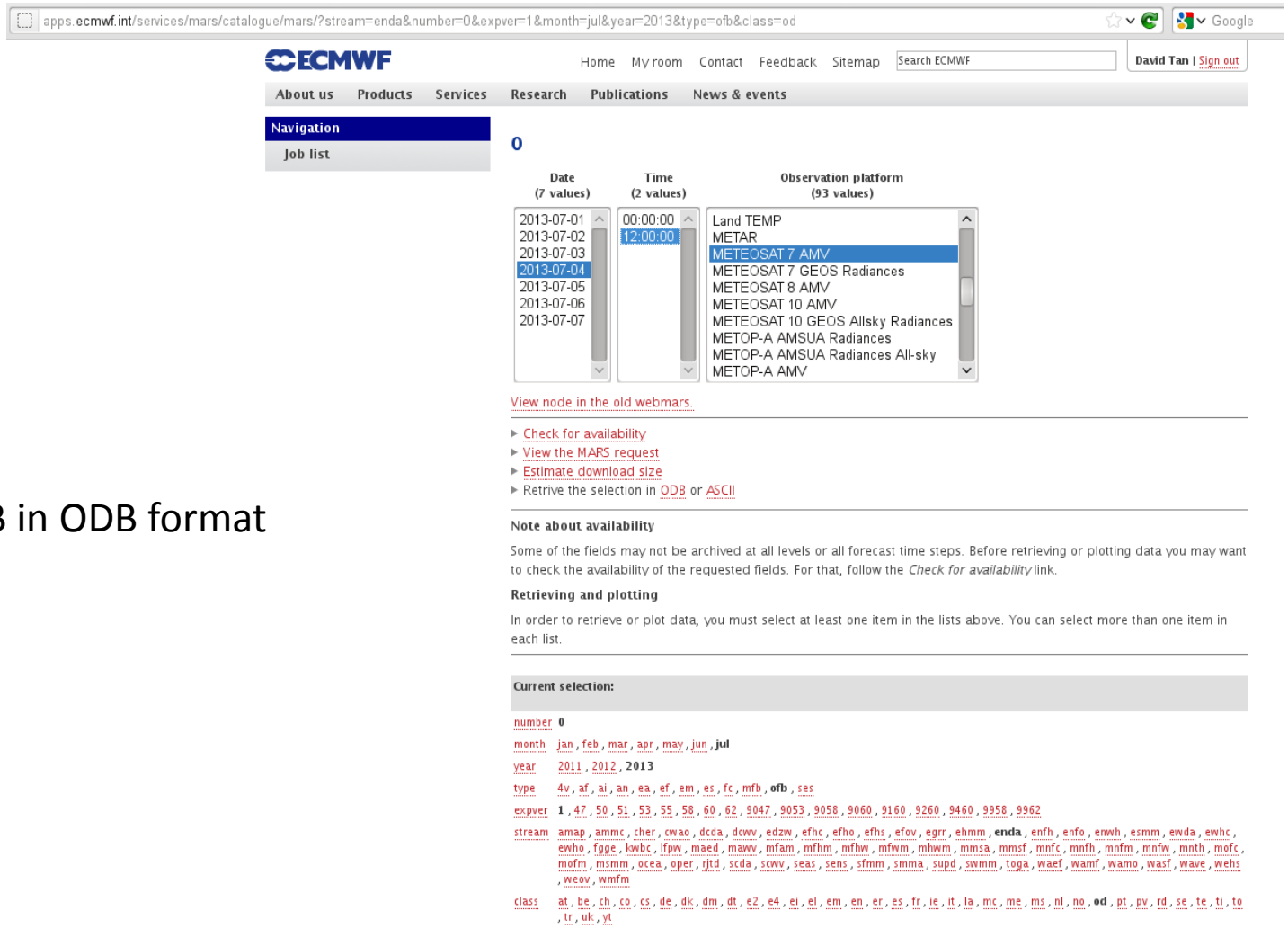
apps.ecmwf.int/datasets



Observation Feedback Archive: Selection by Parameter/Platform

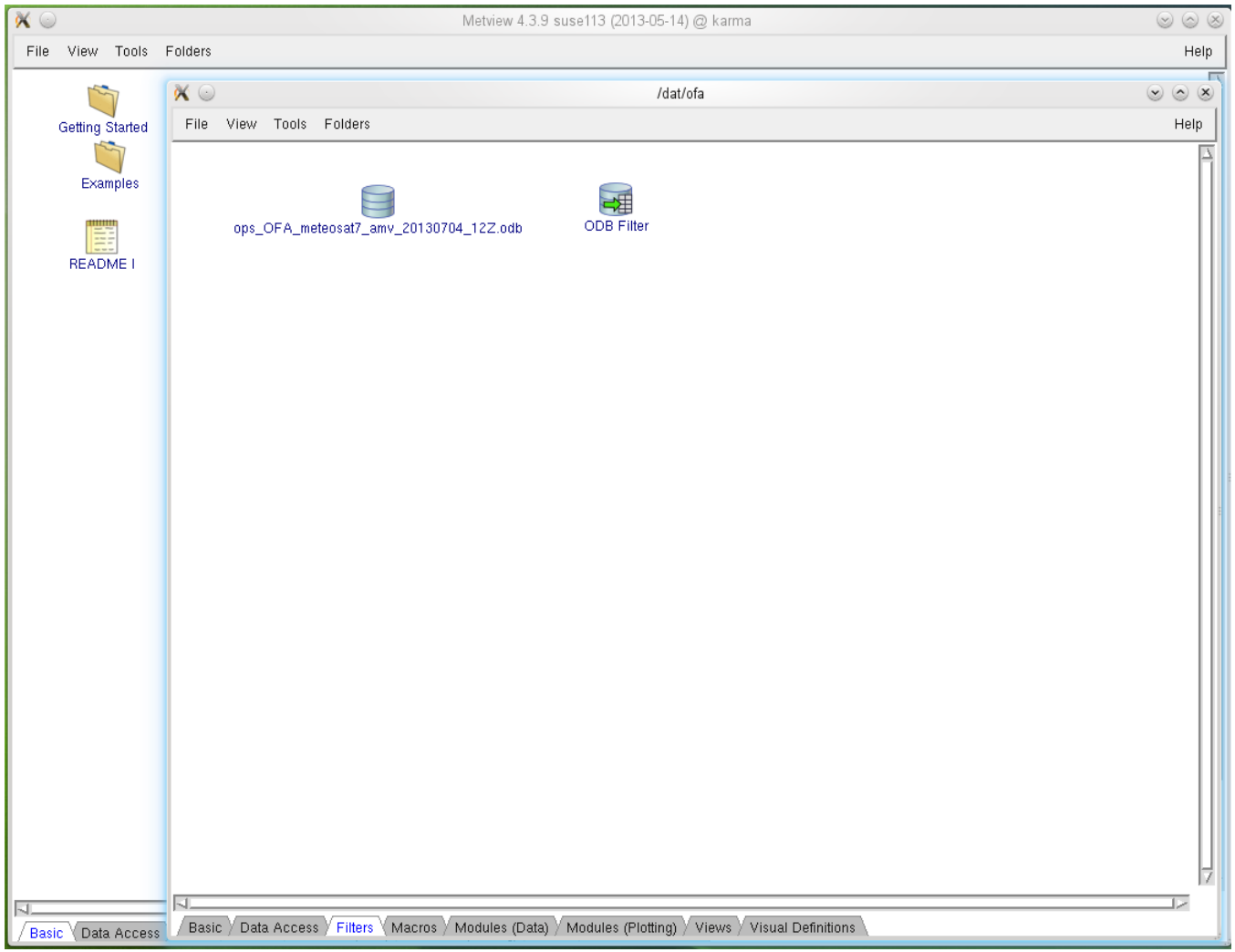


Observation Feedback Archive: Meteosat7 vs Operational Model

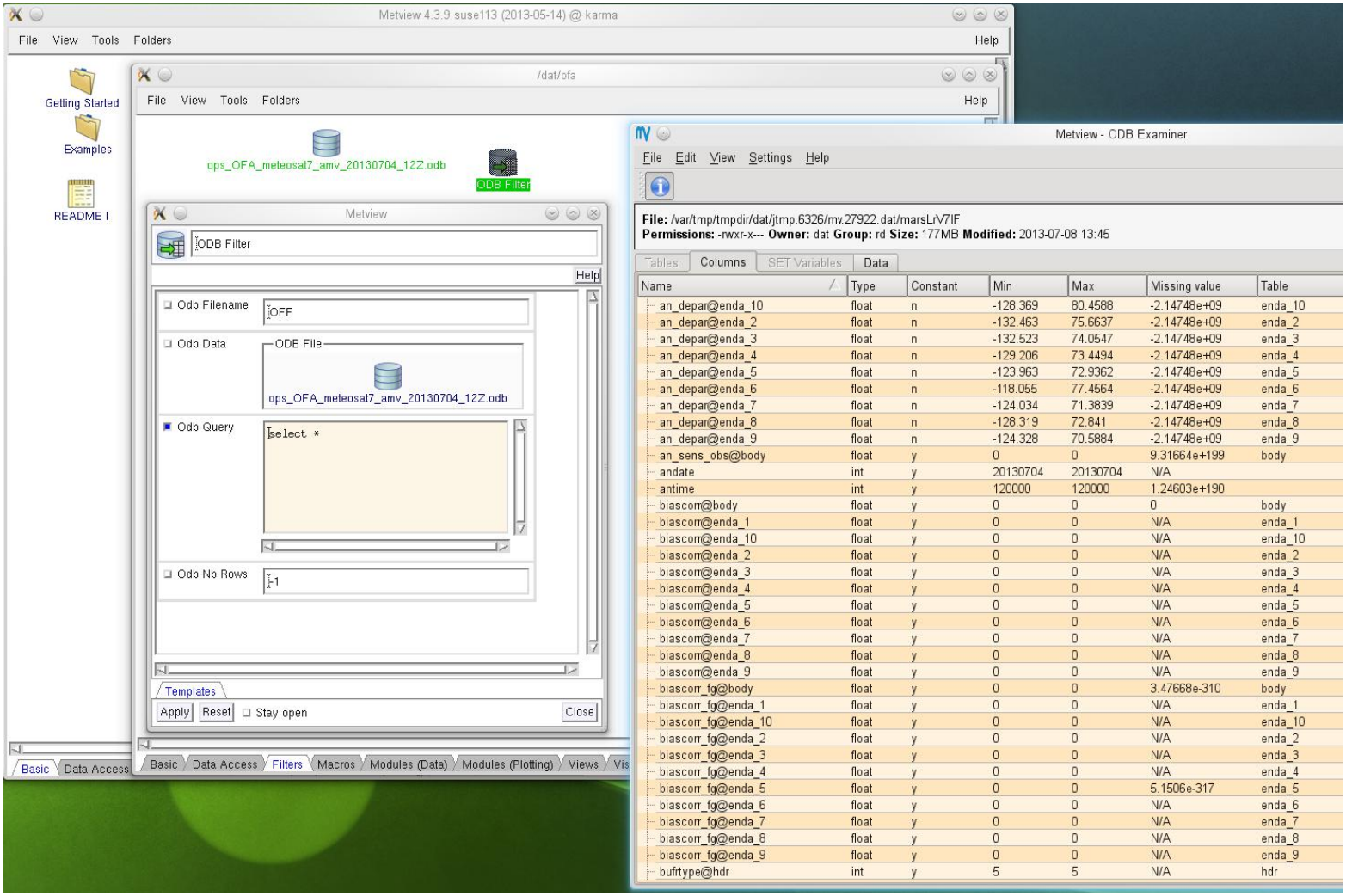


185 MB in ODB format

Observation Feedback Archive: Visualization with Metview4

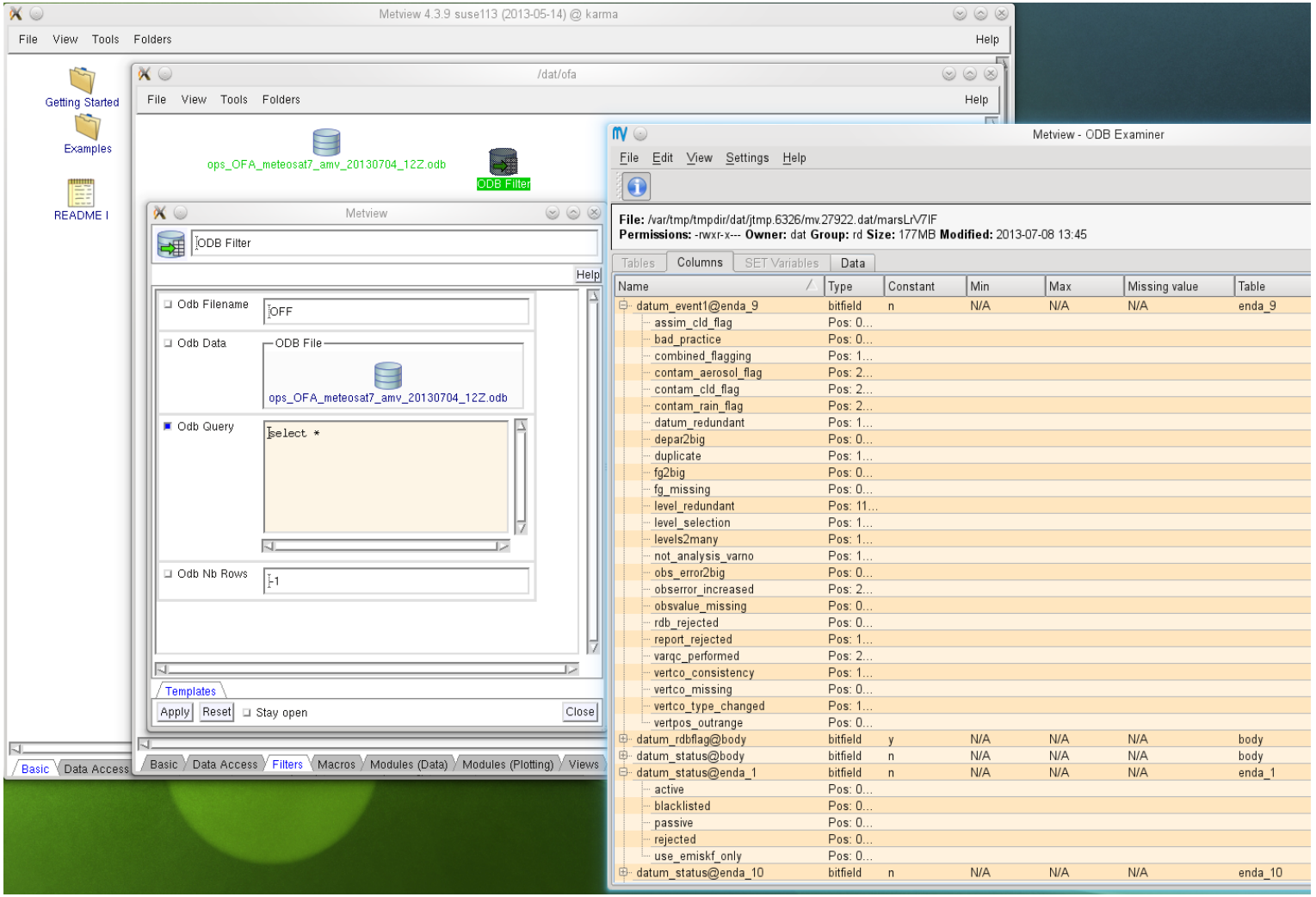


Observation Feedback Archive: Information about the “columns”

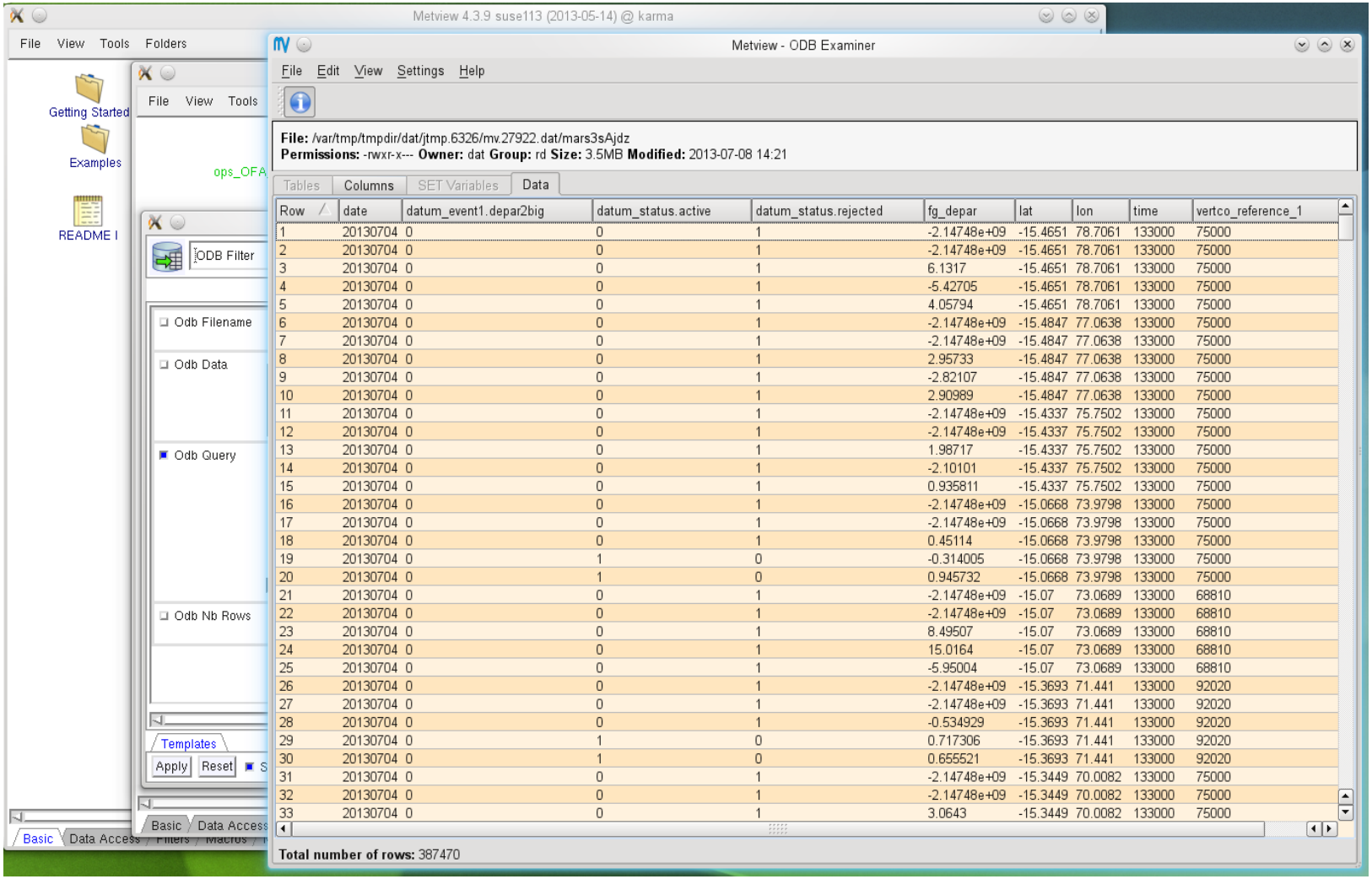


Name	Type	Constant	Min	Max	Missing value	Table
an_depar@enda_10	float	n	-128.369	80.4588	-2.14748e+09	enda_10
an_depar@enda_2	float	n	-132.463	75.6637	-2.14748e+09	enda_2
an_depar@enda_3	float	n	-132.523	74.0547	-2.14748e+09	enda_3
an_depar@enda_4	float	n	-129.206	73.4494	-2.14748e+09	enda_4
an_depar@enda_5	float	n	-123.963	72.9362	-2.14748e+09	enda_5
an_depar@enda_6	float	n	-118.055	77.4564	-2.14748e+09	enda_6
an_depar@enda_7	float	n	-124.034	71.3839	-2.14748e+09	enda_7
an_depar@enda_8	float	n	-128.319	72.841	-2.14748e+09	enda_8
an_depar@enda_9	float	n	-124.328	70.5884	-2.14748e+09	enda_9
an_sens_obs@body	float	y	0	0	9.31664e+199	body
andate	int	y	20130704	20130704	N/A	
antime	int	y	120000	120000	1.24603e+190	
biascorr@body	float	y	0	0	0	body
biascorr@enda_1	float	y	0	0	N/A	enda_1
biascorr@enda_10	float	y	0	0	N/A	enda_10
biascorr@enda_2	float	y	0	0	N/A	enda_2
biascorr@enda_3	float	y	0	0	N/A	enda_3
biascorr@enda_4	float	y	0	0	N/A	enda_4
biascorr@enda_5	float	y	0	0	N/A	enda_5
biascorr@enda_6	float	y	0	0	N/A	enda_6
biascorr@enda_7	float	y	0	0	N/A	enda_7
biascorr@enda_8	float	y	0	0	N/A	enda_8
biascorr@enda_9	float	y	0	0	N/A	enda_9
biascorr_fg@body	float	y	0	0	3.47668e-310	body
biascorr_fg@enda_1	float	y	0	0	N/A	enda_1
biascorr_fg@enda_10	float	y	0	0	N/A	enda_10
biascorr_fg@enda_2	float	y	0	0	N/A	enda_2
biascorr_fg@enda_3	float	y	0	0	N/A	enda_3
biascorr_fg@enda_4	float	y	0	0	N/A	enda_4
biascorr_fg@enda_5	float	y	0	0	5.1506e-317	enda_5
biascorr_fg@enda_6	float	y	0	0	N/A	enda_6
biascorr_fg@enda_7	float	y	0	0	N/A	enda_7
biascorr_fg@enda_8	float	y	0	0	N/A	enda_8
biascorr_fg@enda_9	float	y	0	0	N/A	enda_9
bufrtype@hdr	int	y	5	5	N/A	hdr

Observation Feedback Archive: Information about the flags

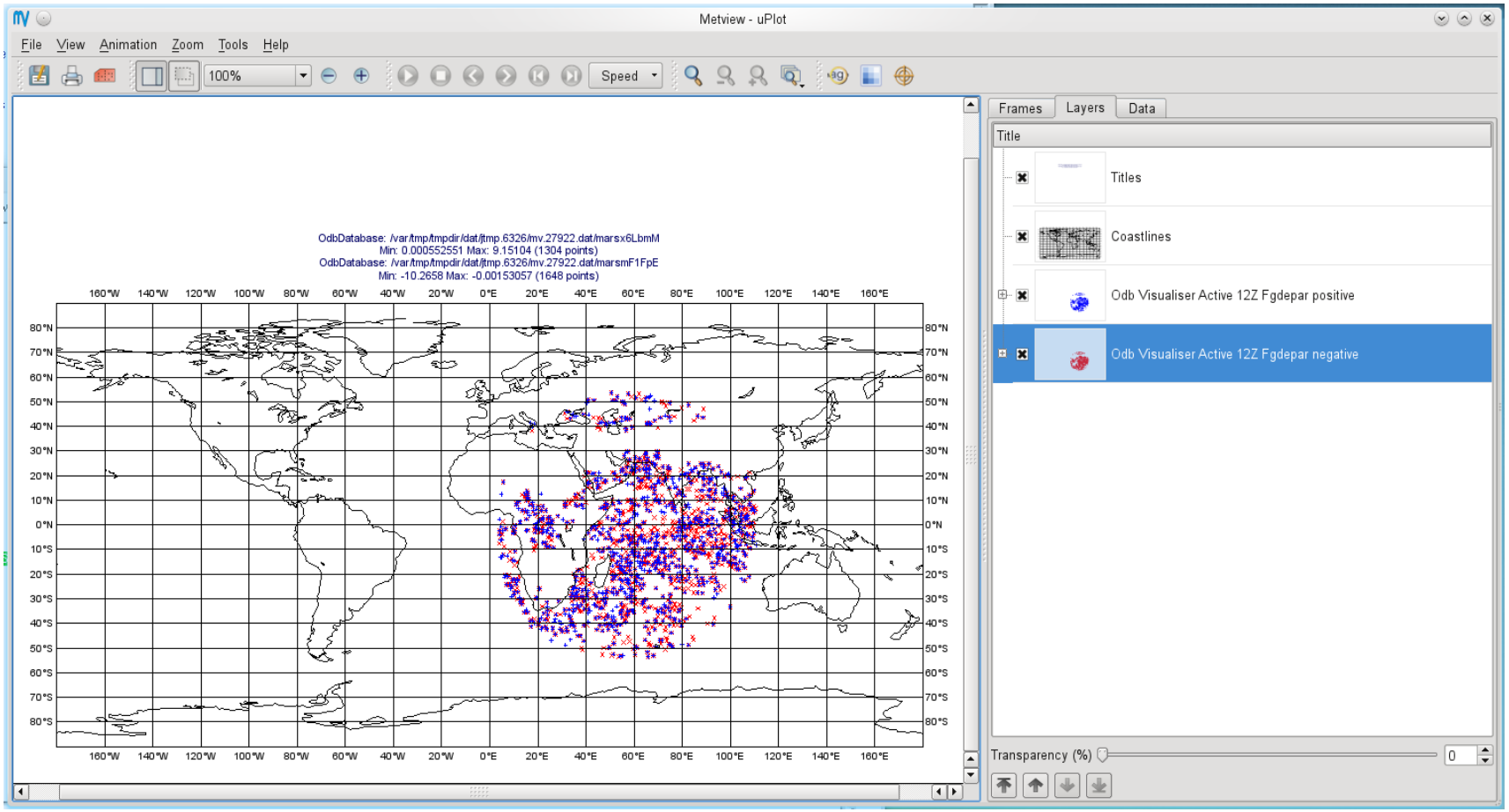


Observation Feedback Archive: Examining selected columns



Row	date	datum_event1.depar2big	datum_status.active	datum_status.rejected	fg_depar	lat	lon	time	vertco_reference_1
1	20130704	0	0	1	-2.14748e+09	-15.4651	78.7061	133000	75000
2	20130704	0	0	1	-2.14748e+09	-15.4651	78.7061	133000	75000
3	20130704	0	0	1	6.1317	-15.4651	78.7061	133000	75000
4	20130704	0	0	1	-5.42705	-15.4651	78.7061	133000	75000
5	20130704	0	0	1	4.05794	-15.4651	78.7061	133000	75000
6	20130704	0	0	1	-2.14748e+09	-15.4847	77.0638	133000	75000
7	20130704	0	0	1	-2.14748e+09	-15.4847	77.0638	133000	75000
8	20130704	0	0	1	2.95733	-15.4847	77.0638	133000	75000
9	20130704	0	0	1	-2.82107	-15.4847	77.0638	133000	75000
10	20130704	0	0	1	2.90989	-15.4847	77.0638	133000	75000
11	20130704	0	0	1	-2.14748e+09	-15.4337	75.7502	133000	75000
12	20130704	0	0	1	-2.14748e+09	-15.4337	75.7502	133000	75000
13	20130704	0	0	1	1.98717	-15.4337	75.7502	133000	75000
14	20130704	0	0	1	-2.10101	-15.4337	75.7502	133000	75000
15	20130704	0	0	1	0.935811	-15.4337	75.7502	133000	75000
16	20130704	0	0	1	-2.14748e+09	-15.0668	73.9798	133000	75000
17	20130704	0	0	1	-2.14748e+09	-15.0668	73.9798	133000	75000
18	20130704	0	0	1	0.45114	-15.0668	73.9798	133000	75000
19	20130704	0	1	0	-0.314005	-15.0668	73.9798	133000	75000
20	20130704	0	1	0	0.945732	-15.0668	73.9798	133000	75000
21	20130704	0	0	1	-2.14748e+09	-15.07	73.0689	133000	68810
22	20130704	0	0	1	-2.14748e+09	-15.07	73.0689	133000	68810
23	20130704	0	0	1	8.49507	-15.07	73.0689	133000	68810
24	20130704	0	0	1	15.0164	-15.07	73.0689	133000	68810
25	20130704	0	0	1	-5.95004	-15.07	73.0689	133000	68810
26	20130704	0	0	1	-2.14748e+09	-15.3693	71.441	133000	92020
27	20130704	0	0	1	-2.14748e+09	-15.3693	71.441	133000	92020
28	20130704	0	0	1	-0.534929	-15.3693	71.441	133000	92020
29	20130704	0	1	0	0.717306	-15.3693	71.441	133000	92020
30	20130704	0	1	0	0.655521	-15.3693	71.441	133000	92020
31	20130704	0	0	1	-2.14748e+09	-15.3449	70.0082	133000	75000
32	20130704	0	0	1	-2.14748e+09	-15.3449	70.0082	133000	75000
33	20130704	0	0	1	3.0643	-15.3449	70.0082	133000	75000

Observation Feedback Archive: Meteosat7 active data valid at 12Z



Observation Feedback Archive: Ongoing work

- Development and evolution
- OFA for Model = ERA-Interim
  - Largely a technical exercise, format conversions
  - Quality control during the conversion process
    - E.g. how to treat unrealistic values?
  - Some decision-making & problem-solving needed
- Feedback from users, e.g. data providers, is welcome
  - Subject to some restrictions, there is scope to evolve the content, e.g. add more “columns”

Climate Monitoring

External Website (current) …

- pre-defined plots
- various levels
- various parameters
- various regions
- several periods

Climate Monitoring

… becoming more interactive

Done

- Pre-defined data
- User-defined plots

Potential extensions

- More data, e.g. daily or 2D
- Overlay user data for plotting
- Toolkits, e.g trend/breakpoint analysis

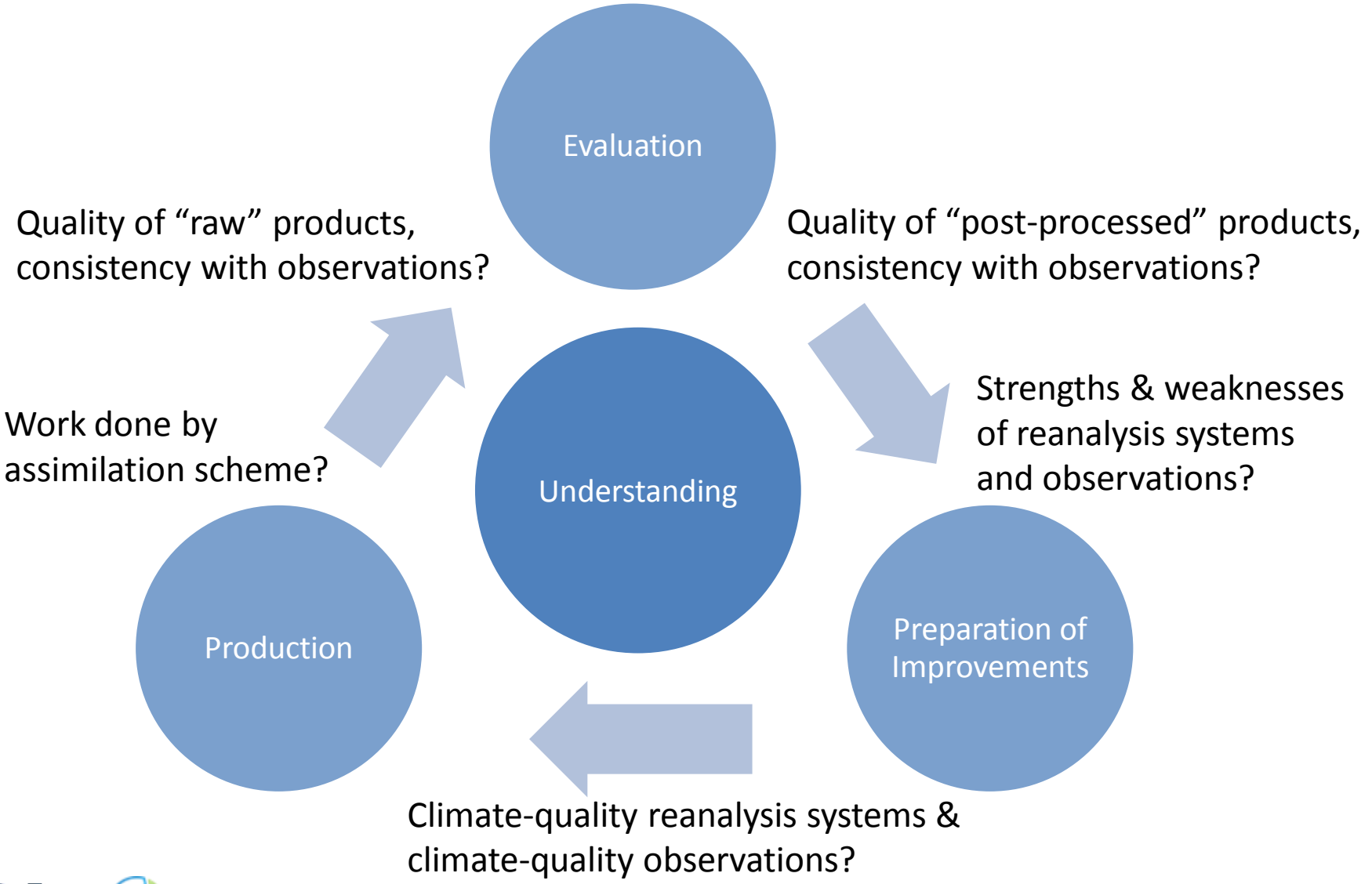
Opportunities & Challenges

1. Raw products, Diagnostics & Tools
   - Easy to access, development by the community
2. Collating and sharing Interpretative Metadata
   - Beyond peer-reviewed literature
   - Web-forums (e.g. reanalysis.org), meta-databases
   - Education and training
3. Widening participation
   - Bringing together expertise in Observations, Reanalyses, Earth-System Science, Downstream Applications
4. Climate-quality Observations & Renanalyses

Reanalysis Diagnostics - Key Points

1. Contribute to all stages of the Reanalysis Life-Cycle
   - Production, evaluation, feedback to inform preparation & improvement of future reanalyses
2. Cornerstones for assessing Quality & Uncertainty
   - Of both Reanalysis Products and Observational Record
3. Growing & dynamic activity
   - Ripe for new ideas on what to do (and how to do it)
   - Needs more collaboration to combine/extend insight on Observations, Reanalyses, Earth-System Science & Downstream Applications
   - Involve the whole community in its widest sense, producers and users all have something to offer

Diagnostics in the reanalysis life-cycle

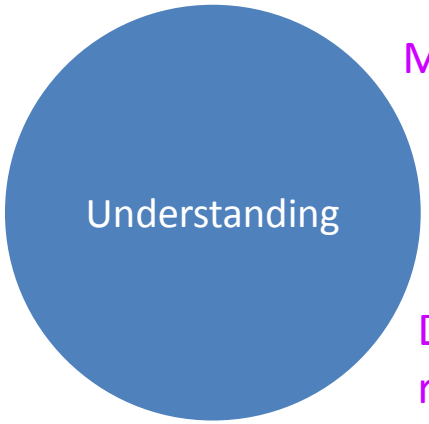


Diagnostics to assess Quality & Uncertainty

INTERPRETATIVE METADATA
Abundant but much waiting to be discovered
Can be disjointed (grey-literature), not easy to synthesize

Quality of "raw" products, consistency with L1/L2 observations?

Quality of "post-processed" products, consistency with L2/L3/L4 observations?



Forecast scores
Bias corrections
Analysis departures
Analysis increments
Background departures
Cost function diagnostics

Monthly means
Trends & anomalies
Budgets, e.g. energy/water cycles
Ensemble statistics
Downstream data, e.g. hydrology, renewable energy, agriculture, health

Work done by assimilation scheme?

Climate-quality reanalysis systems & climate-quality observations?

Strengths & weaknesses of reanalysis systems and observations?
Intercomparison projects, e.g. S-RIP