GAIA-CLIM: Gap Identification Template[1])

Date: 30 April 2015

Guidance: Please adhere to this template and keep the inputs concise. Please provide longer explanatory remarks not in the summary table but in a separate document as input to the GAID with reference to the Gap Identifier (G<workpackage origin>.<gap number>) [Gap6.99, G2.40, G2.41 are examples. These are hypothetical gap as could be identified e.g. through the WP6 user survey, external documents as well as WP deliverables)]

Gap Identifier G<wp>.<no>	Gap Type [2])	Keywords [3]) [Up to 10 (max)]	ECV(s) [Specify if not generic]	Gap Description (<100 characters)	Trace (both underlying WP deliverable(s) as well as external papers, reports etc)	Gap Impacts (Bulleted summary)	Envisaged Remedy (including timescale and cost estimate if possible)	Remedy addressed in GAIA-CLIM (Yes/No)
G4.1	**Measurement uncertainty and traceability**	**Microwave radiometry, Infrared radiometry, Temperature sounding, NWP, Data assimilation, Validation.**	**Atmospheric temperature (0-50 km)**	**Lack of traceable uncertainty estimates for NWP and reanalysis fields & equivalent TOA radiances.**	**D4.2, D4.4, D4.5 Bell et al (2008), Lu et al (2011), Bormann et al (2013), Doherty (2015), Smith (2015), Geer (2011)**	• **Lack of robust uncertainties associated with model fields and related TOA radiances precludes the use of this data for a *complete* validation of satellite EO data.** • **Agencies and instrument teams sometimes slow to react to the findings of NWP based analyses of satellite data, due to lack of traceable uncertainties.**	**Remedy:** • **Assess uncertainties in NWP & reanalysis fields through systematic monitoring using GRUAN data.** • **Timescale: GAIA-CLIM** • **Cost estimate: 48 m.months**	**Yes**
G4.2	**Measurement uncertainty and traceability**	**Microwave radiometry, Infrared radiometry, humidity sounding, NWP, Data assimilation, Validation.**	**Atmospheric humidity (0-12km)**	**Lack of traceable uncertainty estimates for NWP and reanalysis fields & equivalent TOA radiances**	**D4.2, D4.4, D4.5 References as for G4.1**	• **Lack of robust uncertainties associated with model fields and related TOA radiances precludes the use of this data for a *complete* validation of satellite EO data.** • **Agencies and instrument teams sometimes slow to react to the findings of NWP based analyses of satellite data, due to lack of traceable uncertainties.**	**Remedy:** • **Assess uncertainties in NWP & reanalysis fields through systematic monitoring using GRUAN data.** • **Timescale: GAIA-CLIM** • **Cost estimate: 48 m.months**	**Yes**
G1.1 & G4.3	**Limited availability of traceable uncertainty estimates for**			**Where traceable uncertainty estimates exist for a model or reanalysis quantity, it is often**		**Limited availability of traceable uncertainty estimates propagates to applications that use model or reanalysis fields.**	**Mix of** • **operational improvements in observing systems (G4.4)**	

	most model-based and reanalysis-based parameters & locations			**limited to a few locations and parameters where reference datasets are available. Comprehensiveness is lacking for extension to locations and parameters where reference datasets are not available.**		**Progress here is critical for establishing the scientific basis for using such fields as a transfer standard in satellite dataset characterization and other activities, and for assessing the cost-effectiveness of potential observing system enhancements.**	• **better characterization of model-based & assimilation-based uncertainty (G4.5)**	
G4.4	**Operational improvements in observing systems**			**Datasets from baseline and comprehensive networks provide valuable spatio-temporal coverage, but often lack the characteristics needed to facilitate traceable uncertainty estimates.**		**Essential contribution to make progress on G4.3.**	**Identify scope for baseline and comprehensive networks leverage expertise from reference networks, including adopting elements of best practice from reference networks, and/or facilitating reprocessing that iteratively improves dataset quality.**	**WPs 1,2 & 3.**
G4.5	**Better characterization of model-based & assimilation-based uncertainty**			**Limited knowledge about how to propagate uncertainty from well-characterized locations and parameters to other locations and parameters.**		**Essential contribution to make progress on G4.3.**	**Modelling studies to characterize propagation of uncertainty in models and assimilation systems.**	**Would be nice linkup if Task 1.5 and Task 1.4 could be shown to address these issues.**
G4.6	**Well-characterized locations may still fall short of full traceability**			**Interpretation of model-observation comparisons often hampered by missing features in the “observation operator”, often linked to unknown/unmonitored aspects of instrument behaviour**		**Prevents full traceability of both the model/assimilation quantity and also the observational dataset**	**Research to characterize model-observation differences with focus on enhancing representation of “observation operators”**	**WP4 but again Task 1.5 and 1.4 could potentially link.**

Notes

1) Gaps are assumed to be supported by **full text entries in the underlying WP deliverables** indicated in the column 'Trace' (a suggested full text format is provided below)
2) **Proposed Gap Types** (either scientific, technical, organizational), please complete the following list of gap types if necessary. Note: Gap type will be used to help organizing the table with collected gaps: coverage(horizontal); coverage (vertical); coverage (temporal) or 'missing data'; resolution (vertical); uncertainty large (systematic); uncertainty large (random); uncertainty unknown (systematic); uncertainty unknown (random); …
3) **Proposed Keywords**, please complete the following list of keywords if necessary. Keywords will facilitate search tools for the gaps related to e.g. any networks, techniques: [measurement technique(s)], [network(s)], relative uncertainty, absolute uncertainty, error budget, smoothing error, retrieval, calibration, representativity, etc.

G4.1 Lack of traceable uncertainty estimates for NWP and reanalysis fields & equivalent TOA radiances

Gap Type: *Measurement uncertainty*
Gap Keywords: *Microwave radiometry, Infrared radiometry, Temperature sounding, NWP, Data assimilation,*

ECV(s): *Atmospheric Temperature*
Trace (external refs): *(see 'References' below)*

Gap Description

In the last decade numerical weather prediction (NWP) and reanalysis fields have been used as a very effective means of validating satellite radiance observations from operational microwave and infrared sounding and imaging missions [Bell (2008), Bormann (2013), Geer (2010) ,Lu (2011), Doherty (2015), Smith (2015)]. The high accuracy of NWP and reanalysis fields means that the TOA radiances computed from these fields, coincident in space and time with the target satellite observations to be validated, provide a useful *proxy* for the true TOA radiances. The most rigorous approach to this type of validation is to map the geophysical state represented by the model to the observation space of the satellite, through the use of an accurate radiative transfer model. The complete global coverage enables the detection, quantitative analysis and parameterization of the underlying physical mechanisms which give rise to complex, state dependent biases. Despite the success of these approaches, a remaining deficiency is our current inability to quantify the uncertainty budget associated with NWP model fields, and the associated TOA radiances.

Gap Impacts

The current lack of a traceable estimate of the uncertainty in NWP model fields (in temperature and humidity) undermines confidence in the findings of such validation efforts. In some cases this has led to delays in implementing suggested design improvements, or improvements to pre-launch characterization or ground processing systems for future satellite missions.

The lack of such uncertainty estimates precludes the possibility of completing a comprehensive and complete validation, *i.e*. one in which both validation data (in this case NWP fields and radiative transfer modeling) and satellite observations have *independent traceability chains* and associated uncertainty estimates.

Gap Remedy

In the longer term, the aim is to establish traceability for both validation data (NWP and reanalysis fields, and associated radiative transfer modeling) and satellite radiances. In the case of NWP/Reanalysis this will be achieved through the integration of reference quality data into data assimilation systems, allowing the passive monitoring of traceable reference data and therefore and estimation of uncertainties in model fields. In the case of satellite radiances, the eventual aim is to develop technologies to enable the on-orbit traceable calibration of satellite radiances.

Within the GAIA-CLIM project the aim is to demonstrate how reference quality data, from the GRUAN network, can be passively monitored in NWP DA systems to enable the estimation of traceable uncertainty estimates for model fields and TOA radiance computed from them.

References

W. Bell, S. English, B. Candy, N. Atkinson, F. Hilton,S. Swadley, W. Campbell, N. Bormann, G. Kelly and M. Kazumori,The Assimilation of SSMIS Radiances in Numerical Weather Prediction Models, *IEEE Transactions on Geoscience and Remote Sensing, Vol 45, April 2008.*

Bormann, N., et al, 2013, Evaluation and assimilation of ATMS data in the ECMWF system, Journal of Geophysical Research: Atmospheres, Volume 118, Issue 23, pages 12,970–12,980, 16 December 2013.

Amy Doherty, Nigel Atkinson, William Bell, and Andrew Smith, An Assessment of Data from the Advanced Technology Microwave Sounder at the Met Office , Advances in Meteorology, In press, May 2015.

Geer, A. J., P. Bauer and N. Bormann , Solar Biases in Microwave Imager Observations Assimilated at ECMWF, IEEE Transactions on Geoscience and Remote Sensing - IEEE TRANS GEOSCI REMOT SEN , vol. 48, no. 6, pp. 2660-2669, 2010DOI: 10.1109/TGRS.2010.2040186

Qifeng Lu, W. Bell, P. Bauer, N. Bormann and C. Peubey, Characterising the FY-3A Microwave Temperature Sounder Using the ECMWF Model, Accepted by *Journal of Oceanic and Atmospheric Technology*, March 2011, doi: 10.1175/JTECH-D-10-05008.1.

Andrew Smith, Nigel Atkinson, William Bell and Amy Doherty, An initial assessment of observations from the Suomi-NPP satellite: data from the Cross-track Infrared Sounder (CrIS) Atmospheric Science Letters, 5 JAN 2015, DOI: 10.1002/asl2.551

G4.2 Lack of traceable uncertainty estimates for NWP and reanalysis fields & equivalent TOA radiances

Gap Type: *Measurement uncertainty*
Gap Keywords: *Microwave radiometry, Infrared radiometry, Temperature sounding, NWP, Data assimilation,*

ECV(s): *Atmospheric Humidity*
Trace (external refs): *(see 'References' in G4.1)*

Gap Description

In the last decade numerical weather prediction (NWP) and reanalysis fields have been used as a very effective means of validating satellite radiance observations from operational microwave and infrared sounding missions [Bell (2008), Bormann (2013), Geer (2010) ,Lu (2011), Doherty (2015), Smith (2015)]. The high accuracy of NWP and reanalysis fields means that the TOA radiances computed from these fields, coincident in space and time with the satellite observations to be validated, provide a useful *proxy* for the true atmospheric state. The most rigorous approach to this type of validation is to map the geophysical state represented by the model to the observation space of the satellite, through the use of an accurate radiative transfer model. The complete global coverage enables the detection, quantitative analysis and parametrisation of the underlying physical mechanisms which give rise to complex, state dependent biases. Despite the success of these approaches, a remaining deficiency in this approach is our current inability to quantify the uncertainty budget associated with NWP model fields, and the associated TOA radiances.

Furthermore, most of the satellite sensors targeted to date have been temperature sounding instruments where the accuracy of NWP and reanalysis fields, integrated over the broad vertical layers sampled by sounding instruments, is known to be very high. For example, for temperature sounding channels free of cloud effects and peaking in the mid-troposphere model fields, expressed in observation space, are accurate to better than 0.1K. For satellite observations sensitive to humidity, the equivalent figure is in the range 1 - 1.5K. The effectiveness of NWP fields in validating this type of observation is an active topic of research.

Gap Impacts

The current lack of a traceable estimate of the uncertainty in NWP model fields (in temperature and humidity) undermines confidence in the findings of such validation efforts. In some cases this has led to delays in implementing suggested design improvements, or improvements to pre-launch characterization or ground processing systems for future satellite missions.

The lack of such uncertainty estimates precludes the possibility of completing a comprehensive and complete validation, *i.e*. one in which both validation data (in this case NWP fields and radiative transfer modeling) and satellite observations have independent traceability chains and associated uncertainty estimates.

Gap Remedy

In the longer term, the aim is to establish traceability for both validation data (NWP and reanalysis fields, and associated radiative transfer modeling) and satellite radiances. In the case of NWP/Reanalysis this will be achieved through the integration of reference quality data into data assimilation systems, allowing the passive monitoring of traceable reference data and therefore and estimation of uncertainties in model fields. In the case of satellite radiances, the eventual aim is to develop technologies to enable the on-orbit traceable calibration of satellite radiances.

In the GAIA-CLIM project the aim is to demonstrate how reference quality data, from the GRUAN network, can be passively monitored in NWP DA systems to enable the estimation of traceable uncertainty estimates, and to include these estimates in a number of validation studies of current operational missions targeting atmospheric temperature. An innovation of the GAIA-CLIM project is to perform a quantitative analysis of the accuracies achievable, using NWP and reanalysis fields, in the validation of radiance observations which are primarily sensitive to atmospheric humidity.