GAIA-CLIM H2020 project overview

Characterizing satellite measurements using in-situ, ground-based and sub-orbital capabilities

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With thanks to Anna Mikalsen, Fabio Madonna, Karin Kreher, Jean-Christopher Lambert, Bill Bell, Joerg Schulz, Martine de Maziere, Martin Burgdorf

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NERSC

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National University of Ireland Maynooth

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Ministry of Infrastructure and the Environment

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Toy example

A lidar – red points

A satellite – black line

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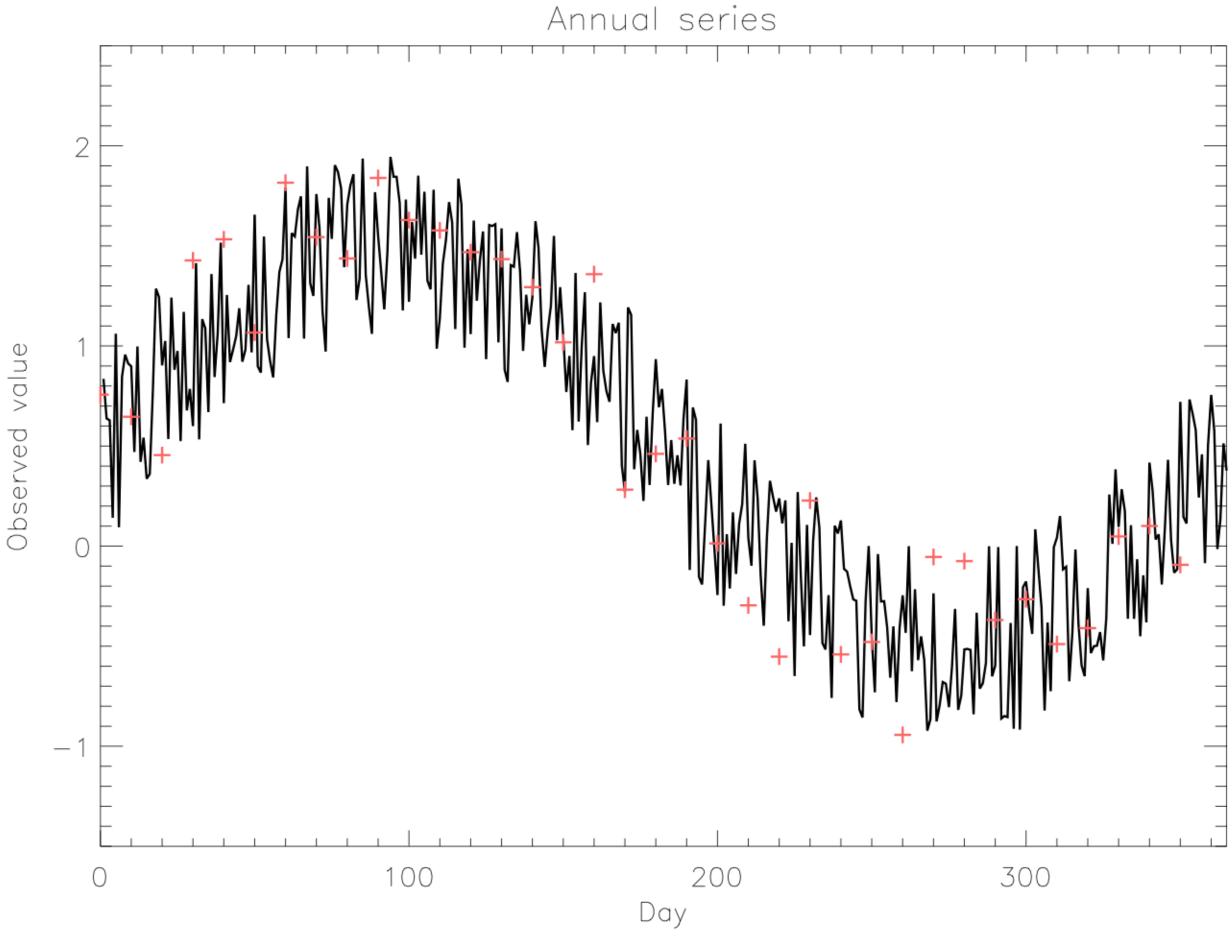
Toy example series



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Measurement A /= Measurement B

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Project rationale

- To date satellite to in-situ comparisons have been ill-posed if we desire definitive answers.
  - Comparing two imperfect measures of a non-coincident snapshot of a fluid dynamical system they will always differ.
  - Q. Does that difference matter?
- To answer that need to fully understand at least one of the two measurements and the expected geophysical difference arising from non-coincidence.

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Establishing Uncertainty

- Official BIPM terminology (VIM/GUM) is applied, e.g., uncertainty is used instead of often misused error and accuracy
  - Important to distinguish contributions from systematic and random effects in the measurement

- A measurement is described by a range of values
  - m is corrected for known and quantified systematic effects
  - u is random uncertainty (generally assumed gaussian but does not need to be)
  - generally expressed by $m \pm u$

Literature:

- Guide to the expression of uncertainty in measurement (GUM, 1980)
- Guide to Meteorological Instruments and Methods of Observation, WMO 2006, (CIMO Guide)
- Reference Quality Upper-Air Measurements: Guidance for developing GRUAN data products, Immler et al. (2010), Atmos. Meas. Techn.

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Focus on *reference* in-situ observations

In GAIA-CLIM it is proposed (following GRUAN) that a reference observation is defined as having the following charactersistics:

- ✓ Is traceable to an SI unit or an accepted standard
- ✓ Provides a comprehensive uncertainty analysis
- ✓ Is documented in accessible literature
- ✓ Is validated (e.g. by inter-comparison or redundant observations)
- ✓ Includes complete meta data description

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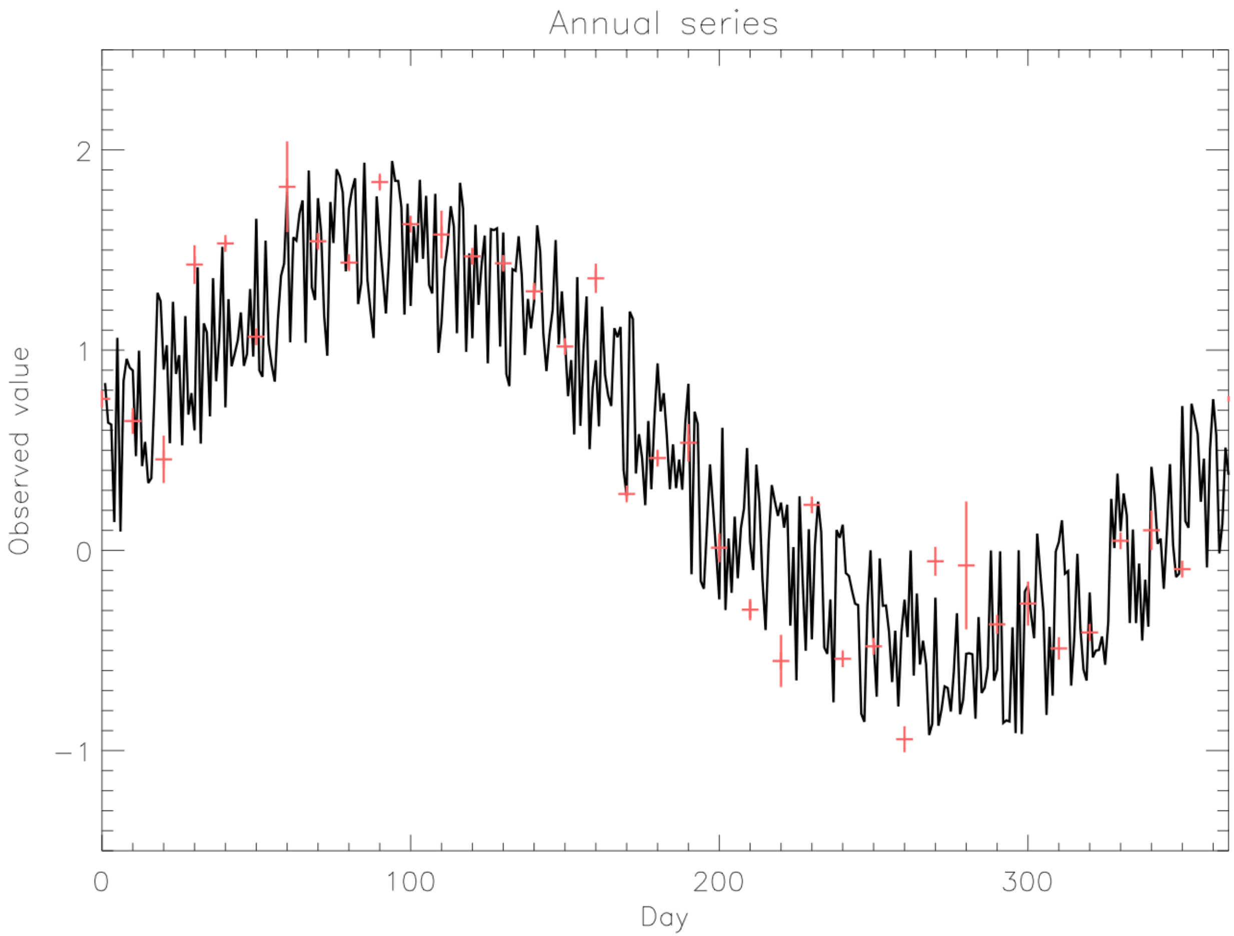
Lidar measurements with uncertainties



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But what about the satellite?

- In the absence of other information a useful test is whether the satellite is performing within design build specification …
- But I'd rather be using FIduceo
- More on this later

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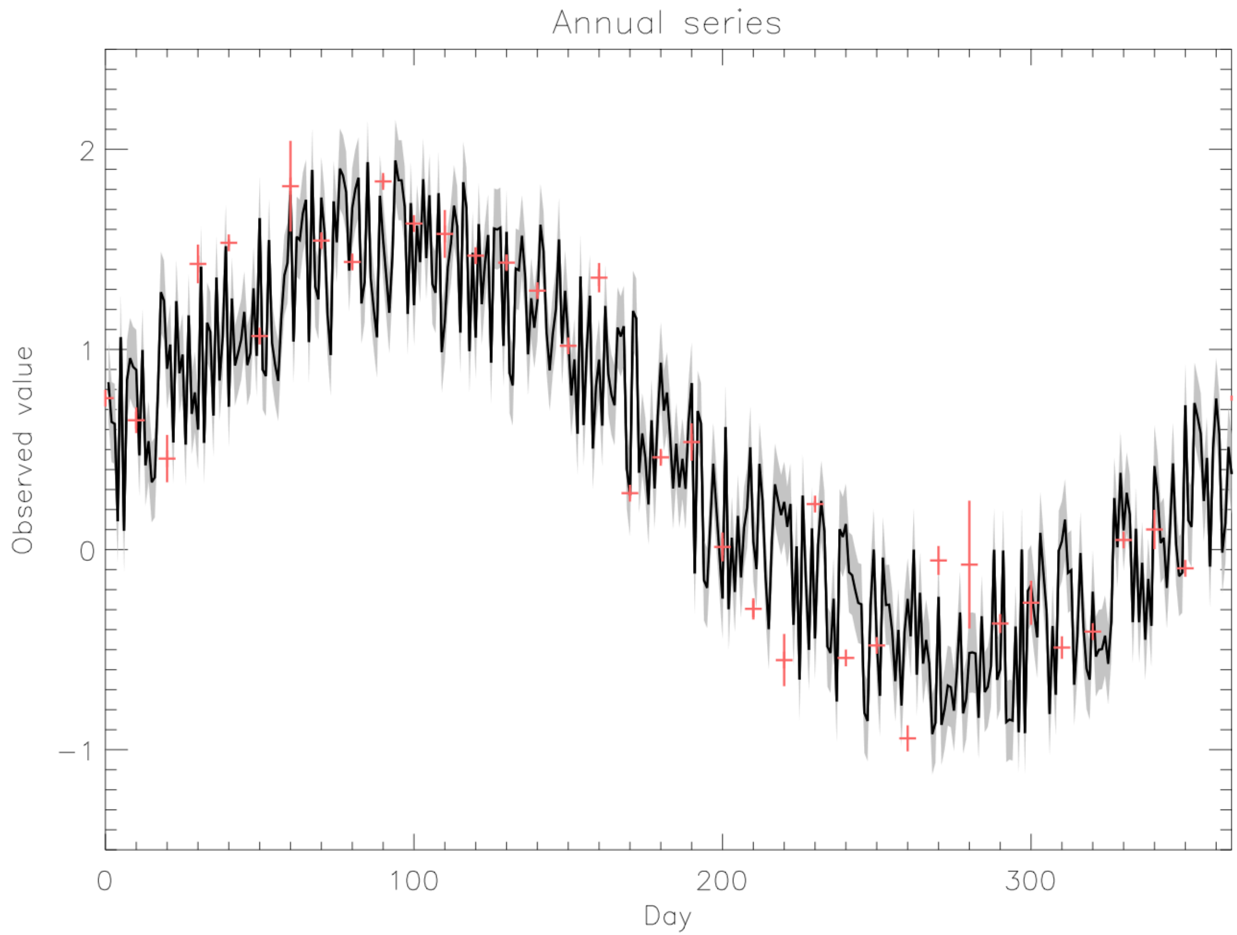
Satellite measurements with design specification ranges



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Consistency for perfectly co-located measures

- Reference quality in-situ (m1) and satellite measurements (m2) should be consistent:

$$|m_1 - m_2| < k\sqrt{u_1^2 + u_2^2}$$

  - ✓ No meaningful consistency analysis possible without uncertainties
  - ✓ if m_2 has no uncertainties use u_2 = satellite instrument specification

$\|m_1 - m_2\| < k\sqrt{u_1^2 + u_2^2}$	TRUE	FALSE	significance level
k=1	consistent	suspicious	32%
k=2	in agreement	significantly different	4.5%
k=3	-	inconsistent	0.27%

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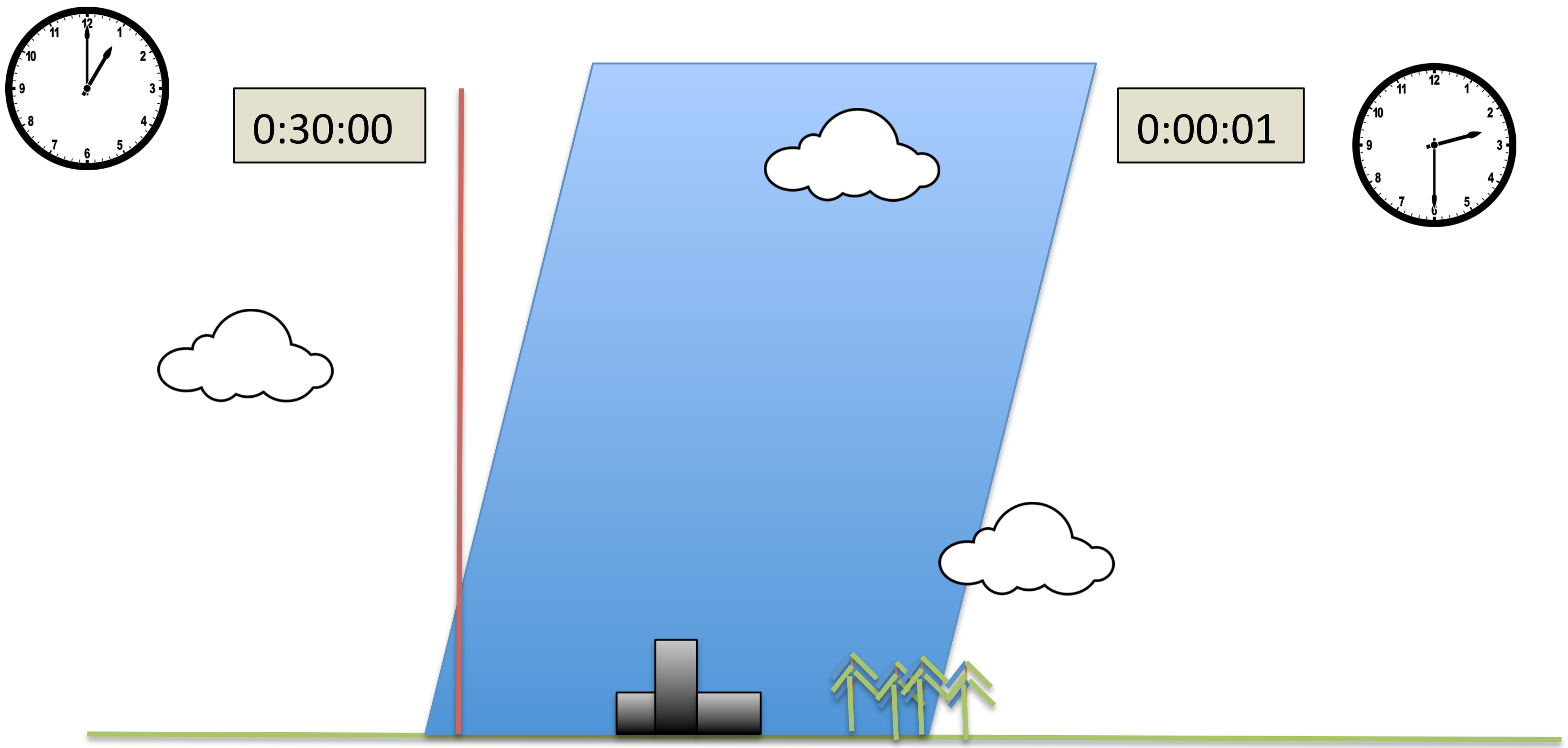
Co-location uncertainties



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Consistency in a finite atmospheric region

- Co-location / co-incidence matters and inflates the expected difference
- Determine the variability (σ) of a variable (m) in time and space from measurements or models
- Two observations on different platforms are consistent if

$$|m_1 - m_2| < k\sqrt{\sigma^2 + u_1^2 + u_2^2}$$

✓ This test is only meaningful, i.e. observations are co-located or co-incident if:

$$\sigma < \sqrt{u_1^2 + u_2^2}$$

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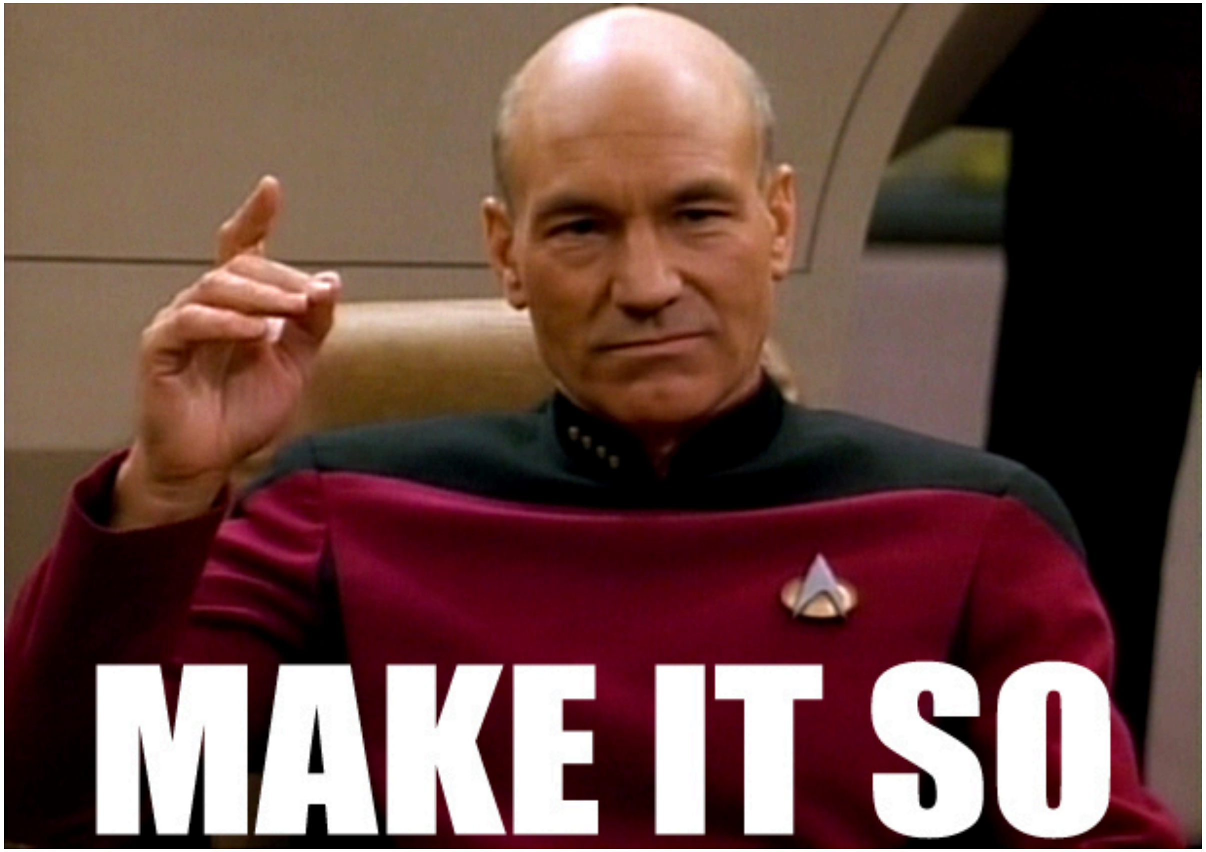
From theory to practice



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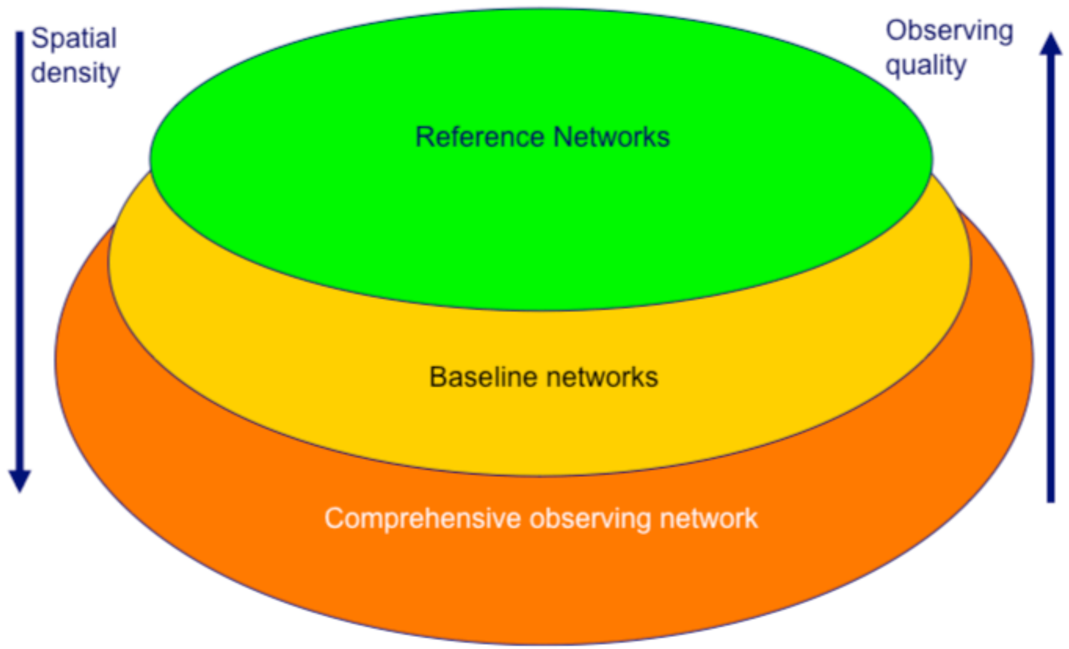
WP1: Mapping and A tiered system of systems approach



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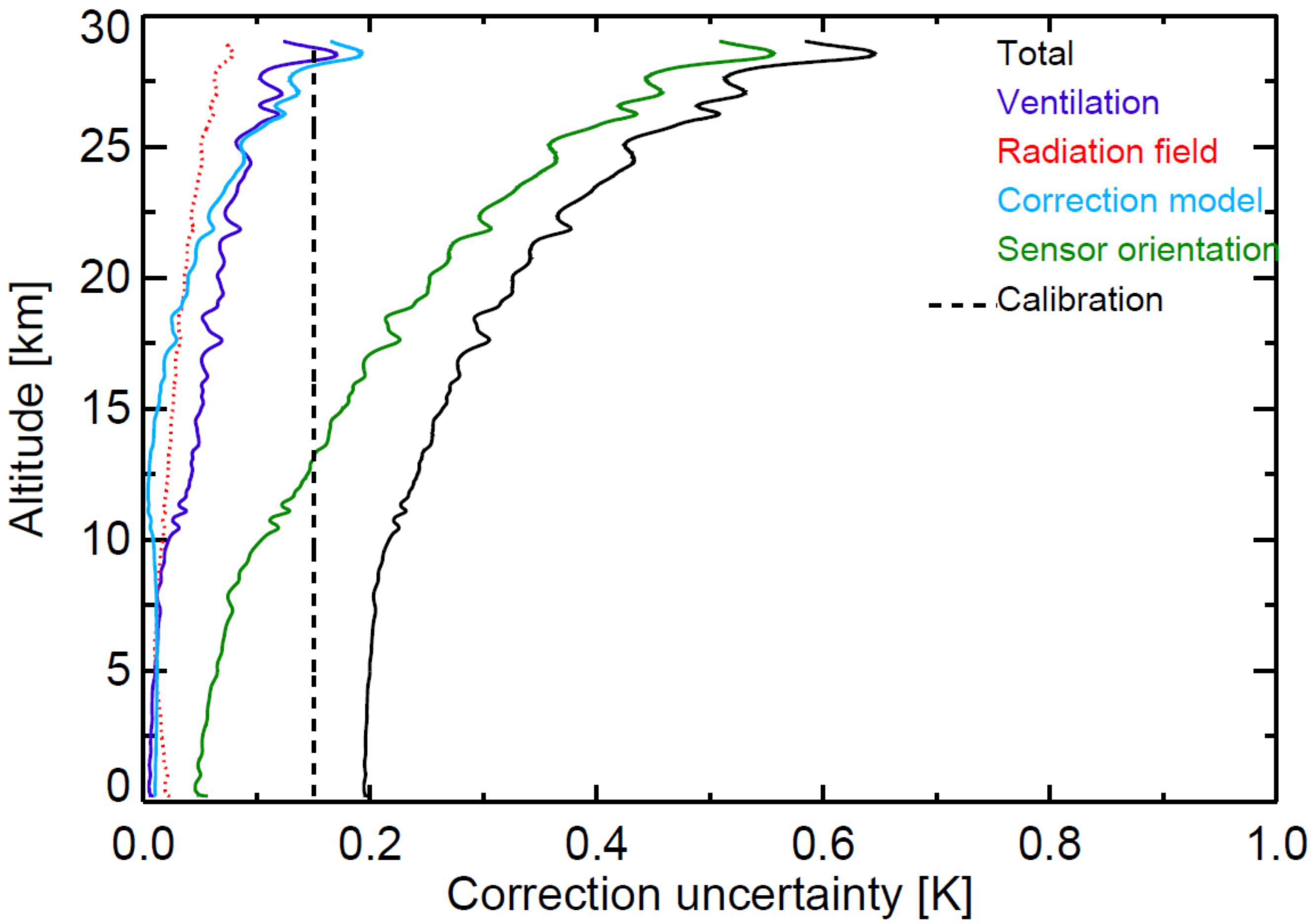
WP2: Quantifying measurement uncertainties



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WP3: Measurement mismatch uncertainties

- Satellites and other measures will never measure the exact same volume over the exact same interval.
  - Differences in time of observation
  - Differences in horizontal geolocation
  - Differences in vertical registration
  - Differences in vertical smoothing
  - Differences in horizontal smoothing
  - Vicarious data issues such as cloud impacts if comparing to radiances in the IR spectrum.

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WP4: Use of data assimilation as integrators

- Investigate the value of use of data assimilation and reference quality measurements
  - Constrain / better understand biases in data assimilation
  - Propagate information from point measures to more regionally / globally complete estimation
  - Use in both NWP and reanalyses to be investigated

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WP5: Virtual observatory

- Make the outcomes of previous WPs useable and actionable
  - Collocation database build
  - Availability of Level 1 (radiance) / 2 (geophys retrieval) satellite to in-situ data comparisons including uncertainties
  - Graphical display and user interface
  - Build with expectation of becoming a sustainable service

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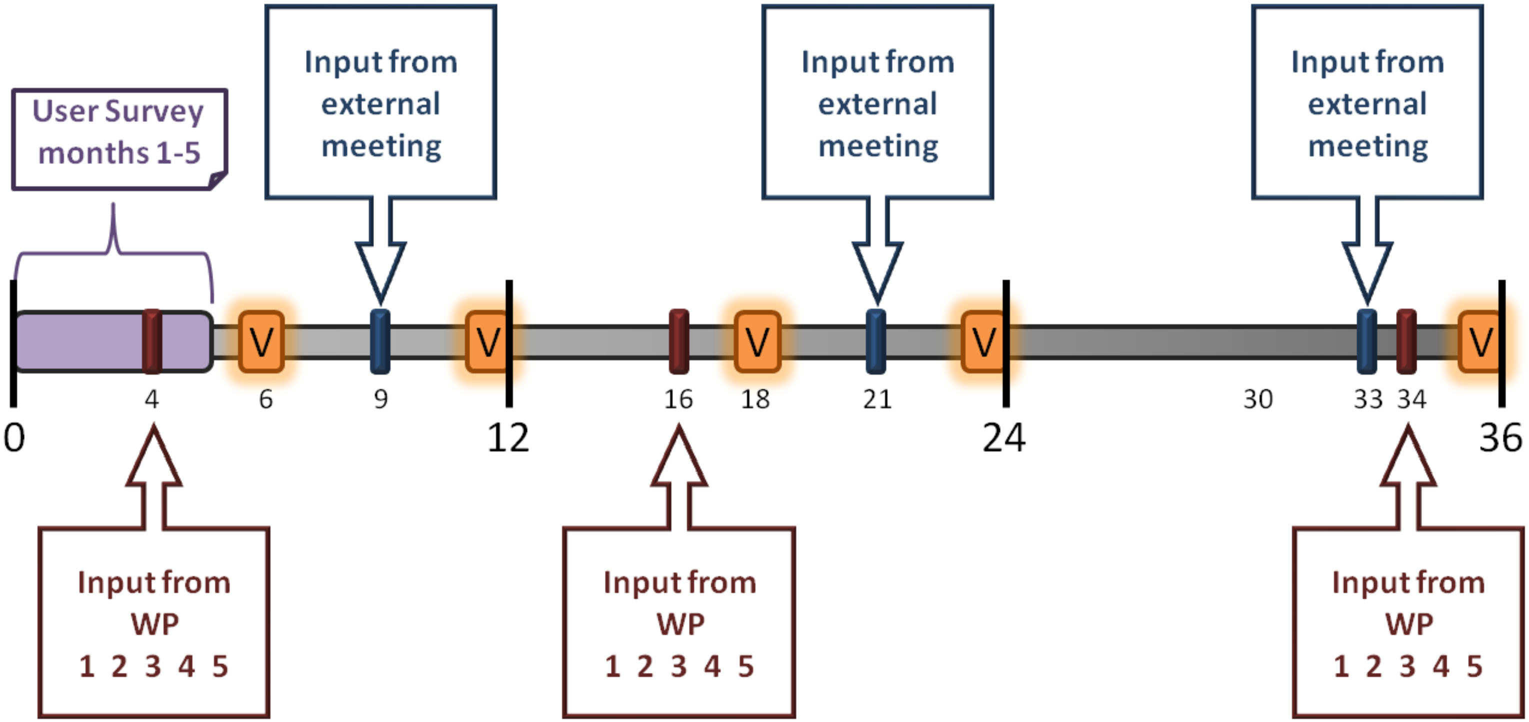
WP6: Gap assessment is iterative with community



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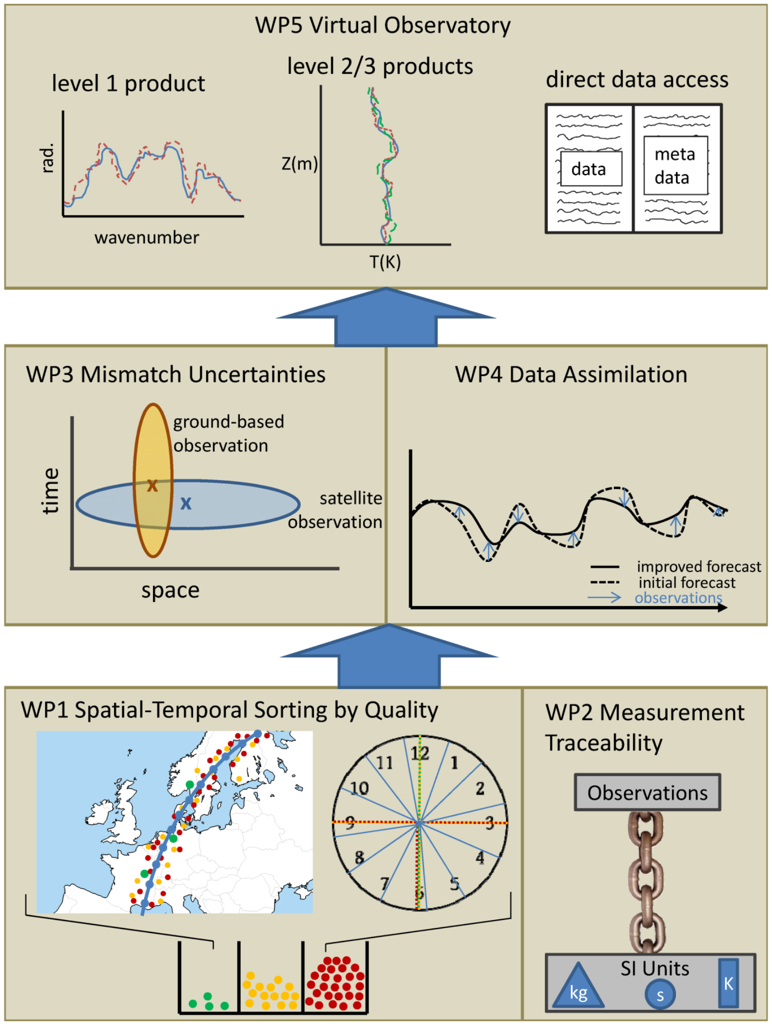

- Define data quality attributes and map by capabilities
- Improve metrological quantification of in-situ ground-based and sub-orbital measurements
- Robustly quantify the impacts of inevitable measurement mismatches
- Use Data Assimilation to improve the usefulness of high quality measurements
- Provide useable and actionable information to end users to improve the value of both satellite and non-satellite data

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Potential EU project synergies

Foreseen at outset

- QA4ECV (esp. WP2)
- CORE-CLIMAX (esp. task on measurement maturity)

Since arisen

- FIDUCEO
- ConnectinGEO

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Fiduceo Aims: Uncertainty-quantified FCDR

DATASET	NATURE	POSSIBLE USES
AVHRR FCDR	Harmonised infra-red radiances and best available reflectance radiances, 1982 - 2016	**SST, LSWT, aerosol,** LST, phenology, cloud properties, surface reflectance …
HIRS FCDR	Harmonised infra-red radiances, 1982 - 2016	**Atmospheric humidity,** NWP re-analysis, stratospheric aerosol …
MW Sounder FCDR	Harmonised microwave BTs for AMSU-B and equivalent channels, 1992 - 2016	**Atmospheric humidity,** NWP re-analysis …
Meteosat VIS FCDR	Improved visible spectral response functions and radiance 1982 to 2016	**Albedo, aerosol,** NWP re-analysis, cloud, wind motion vectors …

At all data set scales there is adequate quantification of error distributions to propagate uncertainty across all data transformations accounting for error correlation structures

Fiduceo Aims: Uncertainty-quantified CDRs

DATASET	NATURE	USE
Surface Temperature CDRs	Ensemble SST and lake surface water temperature	Most of climate science … model evaluation, re-analysis, derived/synthesis products …
UTH CDR	From HIRS and MW, 1992 - 2016	Sensitive climate change metric, re-analysis …
Albedo and aerosol CDRs	From M5 - 7, 1995 – 2006	Climate forcing and change, health …
Aerosol CDR	2002 – 2012 aerosol for Europe and Africa from AVHRR	Climate forcing and change, health …

Uncertainty information that (i) discriminates more and less certain data, (ii) is validated as being realistic in magnitude, (iii) is traceable back to the FCDR uncertainty information

Potential Synergies GAIA-CLIM / FIDUCEO

- WP2 (quantifying measurement uncertainties) / WP2 (metrological foundations)
- WP3 (measurement mismatch uncertainties) / WP2-T2.5 (assessing validity of uncertainty based on closeness of match to validation data)
- WP5 (make outcomes of previous WPs useable) / WP7 (communicate FICUCEO results and methods)
- WP6 (gaps assessment) / WP6-T6.2 (assess AATSR-to-SLSTR gap filling by comparisons to radiosondes)

Thanks for your attention

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