Open Geospatial Consortium

semantics and architecture in ARD

The 128th OGC Member Meeting

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P. Strobl, EC-JRC, CEOS-LSI-VC
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What is CEOS 'Analysis Ready Data'

- Provision of analysis-ready geophysical measurements
- Reduce pre-processing burden for users
  - Facilitate analysis in the cloud
  - Reduce egress and processing
- Foster **interoperability**
  - Develop an open, transparent, consistent framework for ARD
  - Achieve a first important milestone on the 'interoperability scale'
- Promote clear documentation of processing steps
- Increase data uptake and foster new user communities
- Capitalise on space agency expertise and experience
  - Best available science and high-quality processes

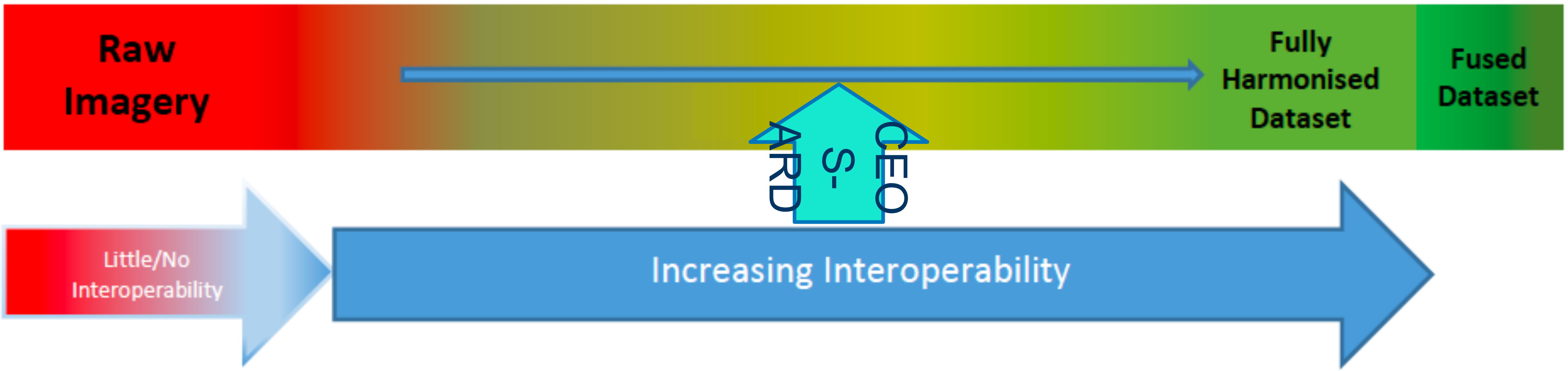
CEOS-ARD Interoperability

’Analysis Readiness’ is first and foremost a promise of interoperability within the scope

1) of a specific instrument
2) of related sensor types
3) across observation methods
4) across disciplines

CEOS-ARD

And along what CEOS called the ‘interoperability spectrum’:



Move CEOS agency and other data providers' land surface imaging datasets along the interoperability spectrum, with a view to a future of sensor agnostic land surface data from all missions.

CEOS Interoperability approach

- At its 2023 plenary CEOS adopted an “Interoperability Framework”
- Intention is to advance Interoperability in a more holistic and coordinated manner
- 4 ‘Interoperability Factors’ have been identified
- All factors are considered essential to Earth Observation data interoperability
- Probably the framework applies to geospatial data in general

CEOS Interoperability Framework

CEOS Interoperability Factors

Semantics

Naming and meaning of terms and data elements, includes developing, harmonising, and maintaining vocabularies and schemata

Architecture

Organisational structure of concepts, processes, and assets, including data and workflows

Interfacing

Data exchange protocols, and application interfaces necessary to access and exchange data and workflows

Quality

Performance against references which are data and schemes that are used as benchmarks for comparison or analysis

Policy

Legal frameworks, policies and strategies regulating the relation between the different stakeholders

OGC ARD SWG current issues

- **How to structure ARD overall?**
  - by sensor technology? (optical, SAR, hyperspectral, LiDAR, etc.)
  - by (geophysical) variable? (Surface reflectance, LST, Elevation, etc.)
  - by processing level? (L1, L2, L3, …)
  - by application domain (atmosphere, clima, agriculture, …)

- **How to group metadata?**
  - per data sample/observation/pixel
  - per data (sub-)set/file/scene
  - per data collection/mission

All these touch (at least) on ‘Architecture’ and ‘Semantics’!

Semantics

© Dilbert

Open semantic questions regarding ‘ARD’:

- Definition of unambiguous terminology: What is Earth ‘Observation’, ‘Data’, ‘Products’, ‘Information’
- Delineation and naming of spectral ranges
- Delineation and naming of sensor types
- Delineation and naming of spatial granularity categories
- Delineation and naming of processing levels (see following slides)
- …

Why is Terminology important?

Earth Observation ≠ Remote Sensing ≠ Satellite Imaging

- Harmonised use of a term
- Clear outline of a technical concept
- Facilitation of targeted discussions
- Avoiding misunderstandings

remote vs. in-situ

observation ≠ simulation

upscaling or downscaling?

forest vs. tree cover

'Level 2A'

Data?

ISO/IEC

reinterpretable representation of information (3.2.1) in a formalized manner suitable for communication, interpretation, or processing [SOURCE: ISO/IEC 8000:-2.2022(en)]

CEOS-WGISS

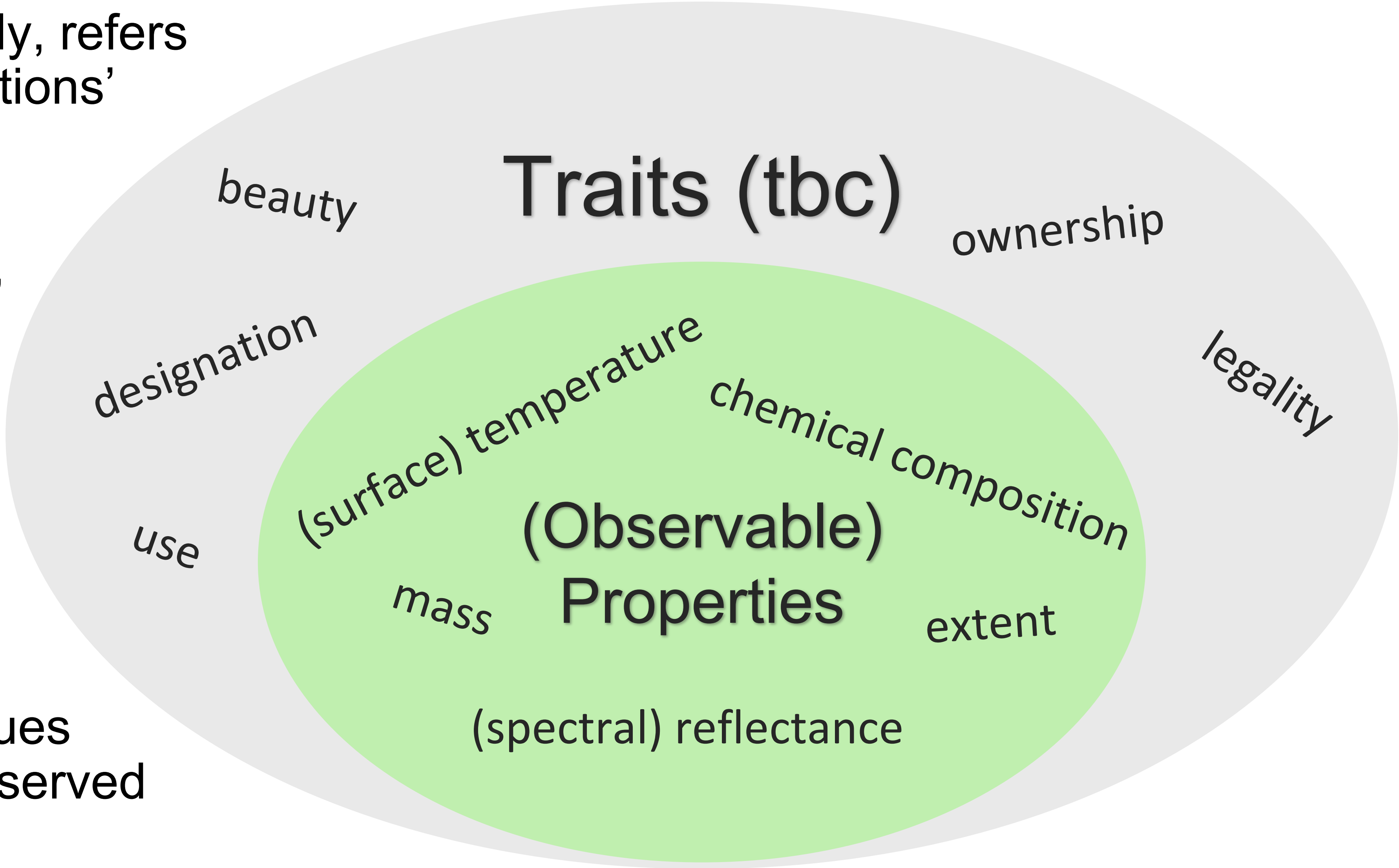
Scientific or technical measurements, values calculated therefrom, observations, or facts that can be represented by numbers, tables, graphs, models, text, or symbols which are used as a basis for reasoning and further calculation.

Data in ARD

Value and (preferably) *uncertainty* of a *trait* of a specific *entity*.

… and what they describe

- 'ARD', at least initially, refers primarily to 'observations'
- Distinction between 'observable' and ultimately 'observed' properties is essential
- Proposal is to reserve 'properties' to traits which are 'observable' and 'observations' to values which have been observed



Categories as proposed in 19176

- Current 19176 draft suggests to distinguish 'products' as:
  - sensor
    - optical
    - microwave
      - SAR
      - active
    - thermal
    - sound
  - thematic
    - numerical
    - categorical
  - earth system sciences
  - and 'ARD services'

In EM spectrum 'Optical' is including 'thermal'!

SAR is part of passive but there are also other passive MW techniques!

Thermal is usually a 'passive' optical technique!

Where are the 'active' optical techniques (LiDAR)?

'sound' is a tiny range out of mechanical waves, where's the rest?

Categorical might also be 'numerical' is what is meant 'continuous'? Define!

Categorisation/Discretisation best practise

- **assessable**: all characteristics used for distinguishing categories must be identified, and objective/measurable
- **unambiguous**: categories mutually exclude each other
- **gap free**: each item can be assigned to a specific category
- **intrinsic**: assignment of an item to a category is independent of other, not previously agreed characteristics
- **instantaneous:** assignment of an item to an category is independent of that of other items
- **hierarchical:** different granularity in categorisation is achieved by a hierarchical
- **nested:** lower level categories have exactly on parent at higher level

Categorisation prerequisites

- **What:**
  a clearly defined and limited range or feature space, what it is that should be discretised (or categorised)

- **Why:**
  information or data base about characteristics (or traits?) that are available to distinguish items within that range

- **How:**
  rules and schemes how the different items according to their characteristics can be assigned to categories

Categories of sensors and sensing

- Domain of ‘signal’ sensed: ’optical’, ‘microwave’, can be built e.g. on ISO 21348:2007 and ISO 20473:2007
- Source of signal: active vs. passive
- Relation to measured phenomenom: remote vs. “in-situ” (probably not as defined by ISO!)
- Sensor platform: ground-based, airborne, satellite, …
- …
  - ➢ important to group metadata into meaningful blocks!
  - ➢ mainly relevant for Level 1&2, for higher Levels can be reduced

electromagnetic spectrum - optical

ISO:

range or continuum of electromagnetic radiation, characterized in terms of frequency or wavelength, and energy

https://www.iso.org/obp/ui/en/#iso:std:iso-iec:19762:ed-1:v1:en:term:06.01.05

TABLE 1-3. The primary spectral regions used in earth remote sensing. The boundaries of some atmospheric windows are not distinct and one will find small variations in these values in different references.

Source: R. A. Schowengerdt, https://doi.org/10.1016/B978-012369407-2/50004-8

name	wavelength range	radiation source	surface property of interest
Visible (V)	0.4–0.7µm	solar	reflectance
Near InfraRed (NIR)	0.7–1.1µm	solar	reflectance
Short Wave InfraRed (SWIR)	1.1–1.35µm 1.4–1.8µm 2–2.5µm	solar	reflectance
MidWave InfraRed (MWIR)	3–4µm 4.5–5µm	solar, thermal	reflectance, temperature
Thermal or LongWave InfraRed (TIR or LWIR)	8–9.5µm 10–14µm	thermal	temperature
microwave, radar	1mm–1m	thermal (passive), artificial (active)	temperature (passive), roughness (active)

Class			Wave-length λ	Freq-uency f	Energy per photon E
Ionizing radiation	γ	Gamma rays	10 pm	30 EHz	124 keV
	HX	Hard X-rays	100 pm	3 EHz	12.4 keV
	SX	Soft X-rays	10 nm	30 PHz	124 eV
	EUV	Extreme ultraviolet	121 nm	3 PHz	10.2 eV
	NUV	Near ultraviolet	400 nm	750 THz	
		Visible spectrum	700 nm	480 THz	
Infrared	NIR	Near infrared	1 μm	300 THz	1.24 eV
	MIR	Mid infrared	10 μm	30 THz	124 meV
	FIR	Far infrared	100 μm	3 THz	12.4 meV
Micro-waves	EHF	Extremely high frequency	1 mm	300 GHz	1.24 meV
	SHF	Super high frequency	1 cm	30 GHz	124 μeV
	UHF	Ultra high frequency	1 dm	3 GHz	12.4 μeV
Radio waves	VHF	Very high frequency	1 m	300 MHz	1.24 μeV
	HF	High frequency	10 m	30 MHz	124 neV
	MF	Medium frequency	100 m	3 MHz	12.4 neV
	LF	Low frequency	1 km	300 kHz	1.24 neV
	VLF	Very low frequency	10 km	30 kHz	124 peV
	ULF	Ultra low frequency	100 km	3 kHz	12.4 peV
	SLF	Super low frequency	1 Mm	300 Hz	1.24 peV
	ELF	Extremely low frequency	10 Mm	30 Hz	124 feV
			100 Mm	3 Hz	12.4 feV

Sources: File:Light spectrum.svg[12][13][14] Table shows the lower limits for the specified class

- IEC 60050-845:1987
- "optical radiation for which the wavelengths are longer than those for visible radiation
- Note 1 to entry: For infrared radiation, the range between 780 nm and 1 mm is commonly subdivided into:
- — IR-A: 780 nm to 1 400 nm;
- — IR-B: 1,4 µm to 3 µm;
- — IR-C: 3 µm to 1 mm."

➢ Make sure a unique set of named ranges is defined in the ARD standard!

electromagnetic spectrum - microwave

- Similar situation for microwave (SAR)
- Informed and well documented choices to be made!

Radio Frequency Bands

name	ITU[1] number	frequency	wavelength
extremely low frequency (ELF)*	1 (~10^{1} Hz)	3 - 30 Hz	100,000 - 10,000 km
super low frequency (SLF)*	2 (~10^{2} Hz)	30 - 300 Hz	10,000 - 1,000 km
ultra low frequency (ULF)*	3 (~10^{3} Hz)	300 - 3000 Hz	1000 - 100 km
very low frequency (VLF)	4 (~10^{4} Hz)	3 - 30 kHz	100 - 10 km
low frequency (LF)†	5 (~10^{5} Hz)	30 - 300 kHz	10 - 1 km
medium frequency (MF)†	6 (~10^{6} Hz)	300 - 3000 kHz	1000 - 100 m
high frequency (HF)†	7 (~10^{7} Hz)	3 - 30 MHz	100 - 10 m
very high frequency (VHF)	8 (~10^{8} Hz)	30 - 300 MHz	10 - 1 m
ultra high frequency (UHF)	9 (~10^{9} Hz)	300 - 3000 MHz	1000 - 100 mm
super high frequency (SHF)	10 (~10^{10} Hz)	3 - 30 GHz	100 - 10 mm
extremely high frequency (EHF)	11 (~10^{11} Hz)	30 - 300 GHz	10 - 1 mm
tremendously high frequency (THF)‡	12 (~10^{12} Hz)	0.3 - 3 THz	1 - 0.1 mm

Radar frequency bands

band		frequency range (GHz)		
		IEEE[1]	ITU[2]	ISO[3]
P	previous			0.225 – 0.39
L	long	1 – 2	1.215 – 1.400 1.525 – 1.710*	0.39 – 1.55
S	short	2 – 4	2.300 – 2.500 2.500 – 2.690* 2.700 – 3.400	1.55 – 5.20
C	compromise	4 – 8	3.400 – 4.200* 4.500 – 4.800* 5.250 – 5.850 5.850 – 7.075*	3.90 – 6.20
X	crosshair	8 – 12	8.500 – 10.50	5.20 – 10.9
K_u	*kurze* under	12 – 18	10.70 – 13.25* 13.40 – 14.00 14.00 – 14.50* 15.30 – 17.30	
K	*kurze*‡	18 – 27	17.70 – 20.20* 24.05 – 24.25 24.65 – 24.75†	10.9 – 36
K_a	*kurze* above	27 – 40	27.50 – 30.00* 33.40 – 36.00	
Q				36 – 46
V		40 – 75	37.50 – 42.50* 47.20 – 50.20* 59.00 – 64.00†	46 – 56
W		75 – 110	76.00 – 81.00† 92.00 – 100.0†	56 – 100
mm	millimeter	110 – 310	126.0 – 142.0† 144.0 – 149.0† 231.0 – 235.0† 238.0 – 248.0†	

TABLE 1-4. Microwave wavelengths and frequencies used in remote sensing. Compiled from Sabins, 1987, Hollinger et al., 1990, Way and Smith, 1991, and Curlander and McDonough, 1991.

band	frequency (GHz)	wavelength (cm)	examples (frequency in GHz)
Ka	26.5–40	0.8–1.1	SSM/I (37.0)
K	18–26.5	1.1–1.7	SSM/I (19.35, 22.235)
Ku	12.5–18	1.7–2.4	Cassini (13.8)
X	8–12.5	2.4–3.8	X-SAR (9.6)
C	4–8	3.8–7.5	SIR-C (5.3), ERS-1 (5.25), RADARSAT (5.3)
S	2–4	7.5–15	Magellan (2.385)
L	1–2	15–30	Seasat (1.275), SIR-A (1.278), SIR-B (1.282), SIR-C (1.25), JERS-1 (1.275)
P	0.3–1	30–100	NASA/JPL DC-8 (0.44)

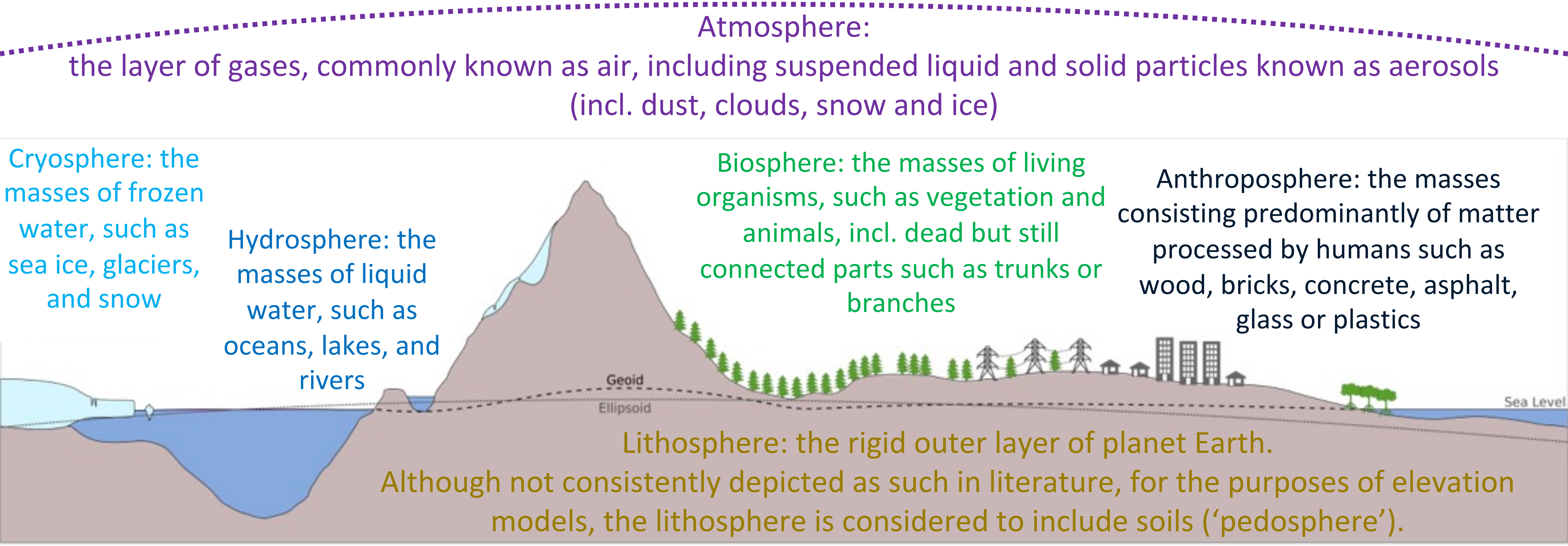
Categories of Applications

- Could use the 'spheres' concept (see next slide) also used e.g. by Radeloff, 2023 [1]
- Will often be non-exclusive (same parameter in several spheres, e.g. surface temperature)
- Distinguish directly measured from inferred parameters
- …
  - ➢ important to group metadata into meaningful blocks!
  - ➢ mainly relevant for Level 2 and higher

[1] Radeloff V. C. et al., Need and vision for global medium-resolution Landsat and Sentinel-2 data products, RSE(300), 2024, https://doi.org/10.1016/j.rse.2023.113918

The delineation of ‘spheres’

Our planetary environment can be categorized in a range of spheres which is characterized by matter which shares specific properties:



courtesy: Guth, P.L. et al.; Digital Elevation Models: Terminology and Definitions. Remote Sens. 2021, 13, 3581. https://doi.org/10.3390/rs13183581

Categories of spatial resolution

- The spatial resolution of sensors or data sets is also often categorised in to a number of discrete classes
- Several schemes exist in parallel (is Landsat HR or MR?). Standards?

Spatial resolution categories within Copernicus programme

The satellite data of Copernicus is categorised by the Ground sampling distance (GSD) with the current definition:

- For optical data : GSD of the visible and Near-Infrared bands except for VHR1 (pan-sharpen data included),
- For SAR data, GSD is the pixel spacing (distance between adjacent pixels in an image) using ground range and azimuth.

Spatial resolution categories are defined as:

	1m	4 m	10 m	30 m	100 m	300 m
VHR1	VHR2	HR1	HR2	MR1	MR2	LR

Architecture

- Example: How to structure the value chain?

Pertinent questions:

"My favourite slide of the entire week"
Scott Simmons, 125th OGC TCM, Frascati Feb 2023
https://portal.ogc.org/files/?artifact_id=104110

ANALYSIS

- What kind?
  visual interpretation, simple algebra, machine learning, physical modelling, AI, with same sensor, sensor fusion, data assimilation …

READY

- For whom?
  EO experts, EO users, analysts, decision makers, general public …

DATA

- Which types?
  "Remote Sensing", "in-situ", "Earth Observation", "gridded", "localised", "orthorectified", "spatiotemporal" …

The ‘value chain’

- Going from **raw data** acquired by a sensor to **information** meaningful to an end-user requires a series of interventions on the data, often referred to as **pre-processing** and **value-adding** along the **‘value chain’**
- The complexity and length of this chain calls for a break-down into smaller steps. These are often referred to as **processing ‘levels**’
- Structuring these steps is meant to assign **specific tasks** and **resulting qualities** to each level and inform the user about what to expect
- Different **applications** and **user** types will build on **different Levels**
- At each Level, data products should have certain **communalities** to help in establishing **harmonised metadata, formats,** and other **standards** that will render them ‘**analysis ready data (ARD)**’ for the intended usage

ARD and Processing Levels

- Raw measurements and model-based information are distinctively different product categories regarding how they are characterised and used.
- Structuring ARD according to different stages of value adding seems therefore not only useful but necessary to define e.g. relevant metadata and user needs
- Current CEOS ‘processing levels’ might not be fully applicable as not developed for this particular purpose

CEOS processing level implementations

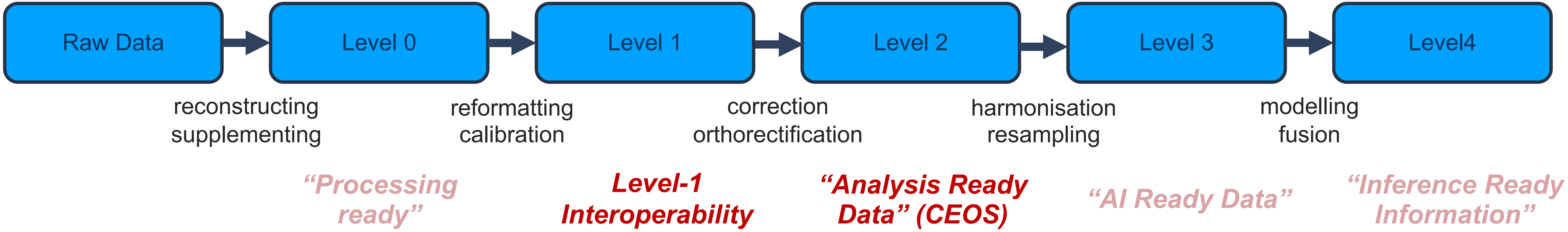
Over the years a number of Level definitions were developed, they are similar but not identical…

	CEOS 1996	LTDP Guidelines	NASA EOSDIS	ESA PDGS Glossary
Raw	Data in their original packets, as received from a satellite.	The physical telemetry payload data as received from the satellite, i.e. a serial data stream without de-multiplexing. These data are not computer compatible.	Missing	Missing
Level0	Reconstructed unprocessed instrument data at full space-time resolution with all available supplemental information to be used in subsequent processing (e.g., ephemeris, health and safety) appended.	Reconstructed unprocessed data at full space-time resolution with all available supplemental information to be used in subsequent processing (e.g. ephemeris, health and safety) appended.	Reconstructed, unprocessed instrument and payload data at full resolution, with any and all communications artifacts (e.g., synchronization frames, communications headers, duplicate data) removed. (In most cases, the EOS Data and Operations System (EDOS) provides these data to the data centers as production data sets for processing by the Science Data Processing Segment (SDPS) or by a SIPS to produce higher-level products.)	Reconstructed unprocessed data at full space-time resolution with all available supplemental information to be used in subsequent processing (e.g. ephemeris, health and safety) appended.
Level1	Unpacked, reformatted level 0 data, with all supplemental information to be used in subsequent processing appended. Optional radiometric and geometric correction applied to produce parameters in physical units. Data generally presented as full time/space resolution. A wide variety of sub-level products are possible.	Reconstructed unprocessed data at full resolution, time-referenced, and annotated with ancillary information, including radiometric and geometric calibration coefficients and geo-referencing parameters (e.g. ephemeris) computed and appended but not applied to the Level 0 data.	Reconstructed, unprocessed instrument data at full resolution, time-referenced, and annotated with ancillary information, including radiometric and geometric calibration coefficients and georeferencing parameters (e.g., platform ephemeris) computed and appended but not applied to Level 0 data.	Reconstructed unprocessed data at full resolution, time-referenced, and annotated with ancillary information, including radiometric and geometric calibration coefficients and geo-referencing parameters (e.g. ephemeris) computed and appended but not applied to the Level 0 data.
Level1A	Missing	Radiometrically corrected and calibrated data in physical units at full instrument resolution as acquired.	Level 1A data that have been processed to sensor units (not all instruments have Level 1B source data).	Radiometrically corrected and calibrated data in physical units at full instrument resolution as acquired.
Level1B	Missing	L1B data orthorectified, re-sampled to a specified grid.	Missing	L1B data orthorectified, re-sampled to a specified grid
Level2	Retrieved environmental variables (e.g., ocean wave height, soil moisture, ice concentration) at the same resolution and location as the level 1 source data.	Derived geophysical parameters (e.g. sea surface temperature, leaf area index) at the same resolution and location as Level 1 source data.	Derived geophysical variables at the same resolution and location as Level 1 source data.	Derived geophysical parameters (e.g. sea surface temperature, leaf area index) at the same resolution and location as Level 1 source data.
Level3	Data or retrieved environmental variables which have been spatially and/or temporally resampled (i.e., derived from level 1 or 2 products). Such resampling may include averaging and compositing.	Data or retrieved geophysical parameters which have been spatially and/or temporally re-sampled (i.e. derived from Level 1 or 2 products), usually with some completeness and consistency. Such re-sampling may include averaging and compositing.	Variables mapped on uniform space-time grid scales, usually with some completeness and consistency.	Data or retrieved geophysical parameters which have been spatially and/or temporally re-sampled (i.e. derived from Level 1 or 2 products), usually with some completeness and consistency. Such re-sampling may include averaging and compositing.
Level4	Model output or results from analyses of lower level data (i.e., variables that are not directly measured by the instruments, but are derived from these measurements).	Outputs or results from models using lower level data as inputs and, thus, not directly derived from the instruments.	Model output or results from analyses of lower-level data (e.g., variables derived from multiple measurements).	Missing

CEOS processing levels

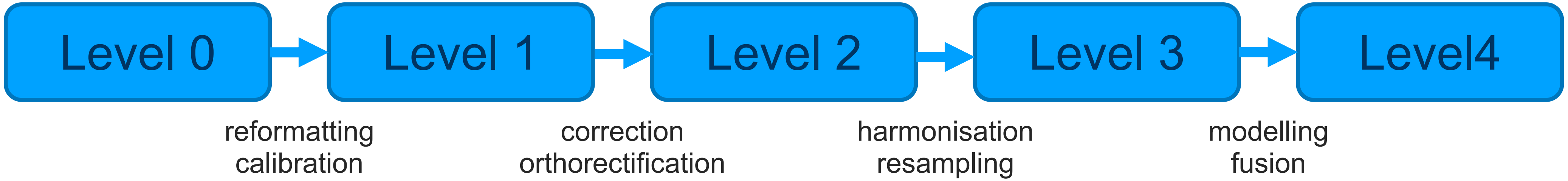
In a nutshell:

- linear sequence in which one level builds on the previous one
- rooted in ground segment technology of the 1990s
- somewhat biased towards spectroradiometric sensors
- never fully harmonised across sensor types and agencies



Disentangling the processing steps

Separate between interventions affecting the measurand and those affecting geometry



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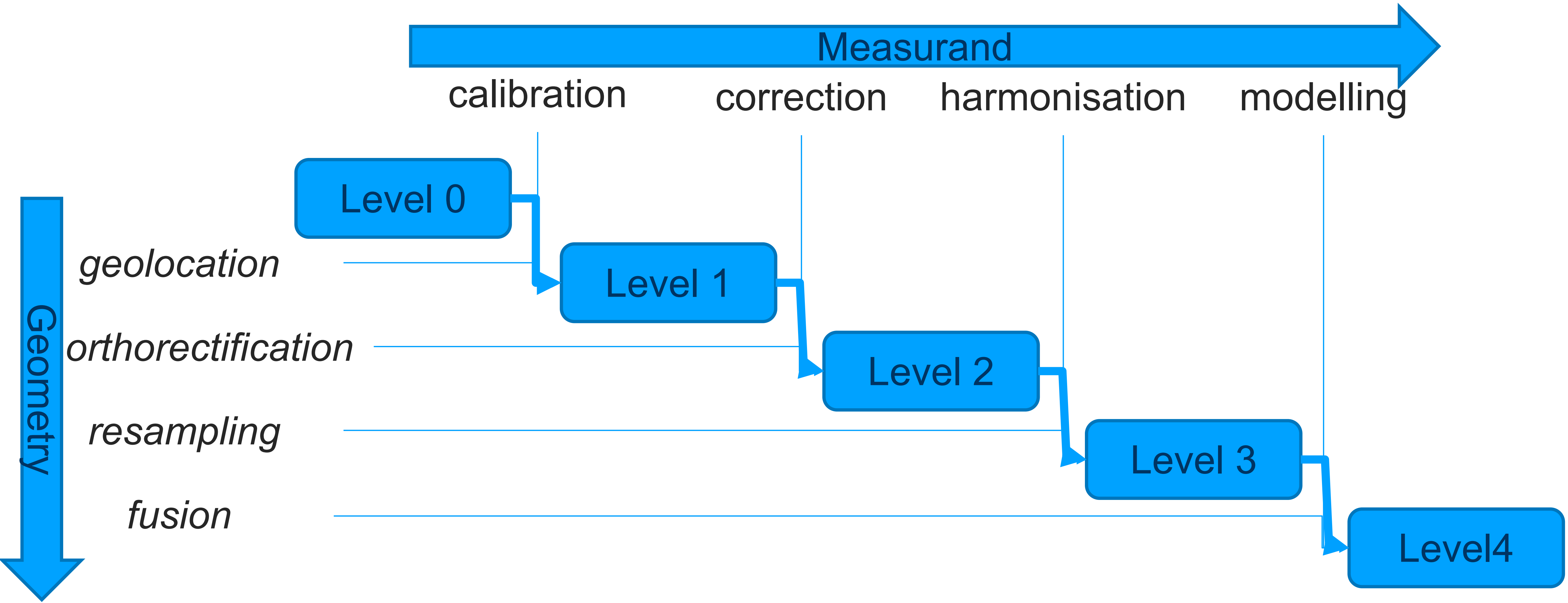

The measurand dimension M

- **Level - (raw):** The complete and unaltered/unprocessed set of *data* ..
- **Level M/0 (uncalibrated):** Unaltered/unprocessed Level 0 *(main) sensor data* annotated with ancilliary data …
- **Level M/1 (sensor-calibrated):** Level M/0 sensor data which have been calibrated (ideally traceable to SI) and spatially aligned (geo-located, eventually co-gridded) to represent **at-sensor measurements** (value and uncertainty) in sensor nominal spatiotemporal sampling, supplemented by appropriate ancillary and auxiliary data for further processing.
- **Level M/2 (target calibrated):** Level M/1 data processed to represent **geophysical properties (values and uncertainties) for a specified target** (object, feature of interest, e.g. surface reflectance, apparent temperature) derived (exclusively?) from M1 sensor data, as much as possible maintaining the sensors nominal spatial and temporal sampling (observation preserving).
- **Level M/3 (homogenised*):** Level M/1 or M/2 data which have been generalised and integrated across one or several sensors and acquisitions to achieve an increased, more regular or in any other form enhanced spatial or temporal coverage in which **values are agnostic of the originally acquiring sensor** and thus directly comparable. This homogenisation and fusion may include measurand re-calibration to external standards and references including use of modelling, aggregation and interpolation.
- **Level M/4 (derived/inferred):** Model output or results from analyses of Level M/3 (or lower level) data incl. attributes that might not be (directly?) observable by the sensor(s) but are **derived from observations in combination with other external incl. non-observational data** using techniques like modelling or machine learning (incl. AI).

*For a definition of ‘homogenisation’ and disambiguation with ‘harmonisation’ see: https://research.reading.ac.uk/fiduceo/glossary/

The geometry dimension G

- **Stage G/A (raw):** individual observations (samples) are not geolocated
- **Stage G/B (geolocated):** Each observation is geolocated with documented uncertainty in a (traceable) Reference System. At this stage the individual observations can be considered forming an irregular ‘point cloud’ which might also be pseudo-regularised to enhance storage efficiency (‘sensor grid’).
- **Stage G/C (georectified/gridded):** Observations have been spatially re-sampled to fall within a specified, usually regular, geodetic grid.
- **Stage G/D (regridded1):** Observations have been re-sampled from the original geodetic grid into another specified (geodetic) grid.
- **Stage G/E (regridded2):** Observations or derived values have been again re-sampled from the second geodetic grid into a third one. This should under no circumstances be equal to their Stage G/C geodetic grid

Old Levels in a new perspective

- Considering these two types of refinement strains separate, a matrix could be built in which classical Processing Levels would (roughly) appear as below:

Measurand / Geometry	M/0 - raw	M/1 - sensor calibrated	M/2 - target calibrated	M/3 - homogenised	M/4 - derived
G/A - raw	L0/L1A				
G/B - georeferenced		L1B			
G/C - georectified		L1C	L2(A)		
G/D - regridded1				L3	
G/E - regridded2					L4

A new Processing Level matrix

Preliminary labelling scheme:

- Numbers are used to identify Measurand steps
- Letters indicate spatio(temporal) Geometry steps

Labelling scheme could also be revised to clearly distinguish from classical CEOS Levels. Colour coding is only indicative to illustrate possible suitability e.g. for spectroscopic data.

Measurand / Geometry	M/0 - raw	M/1 - sensor calibrated	M/2 - target calibrated	M/3 - homogenised	M/4 - derived
G/A - raw	L0/L1A				
G/B - georeferenced		L1B	L2B	L3B	?
G/C - georectified		L1C	L2C	L3C	L4C
G/D - regridded1		L1D	L2D	L3D	L4D
G/E - regridded2				L3E	L4E

ideal	tolerable	critical

Future interoperability levels (tentative – for discussion!)

- L0 (raw data)
- L1A (calibration ready data)
- L1B (orthorectification ready data)
- L2B/C (conflation/combination/*analysis?* ready data)
- L3B/C (fusion ready data)
- L3C/D (application/model ready data)
- L4C/D (inference ready information)

Way forward

- Proposals and recommendations for developing an ARD standard

A new (better?) definition

Now:
Geospatial data that have been processed to meet a minimum set of requirements and organized into a form, allowing immediate analysis with a minimum of additional user effort and interoperability both through time and with other datasets.

Proposal:
“Analysis Ready Data” (ARD) in the context of Earth Observation are packages (sets?, collections?, assemblies?) of geo-spatio-temporal (observational?) data which meet all specifications according to the intended data type, usage, community, and level of interoperability.”

A new (clearer?) structure

- Processing levels
- Sensor categories
- Application domains
- Resolution classes
-

Proposed Partitioning of ISO 19176

- **Part 1**: **framework**, overall content requirements for ARD and division of (observational) geospatial data into subtypes
- **Part 2: sensor-calibrated data,** sensor data which have been calibrated and geo-located to representing at-sensor measurements (value and uncertainty)
- **Part 3: target-calibrated data**, geophysical properties (values and uncertainties) for a specified target (feature) as obtained with a specific sensor
- **Part 4: sensor agnostic data,** data which have been processed to represent geophysical properties independent of a specific sensor or according to (standard?) sensor specifications
- **(Part 5: derived/inferred data**: results from analyses of lower level data, model-based outputs, including non-observational data)
- …

Thank You

Community

500+ International Members
110+ Member Meetings
60+ Alliance and Liaison partners
50+ Standards Working Groups
45+ Domain Working Groups
25+ Years of Not for Profit Work
10+ Regional and Country Forums

Innovation

120+ Innovation Initiatives
380+ Technical reports
Quarterly Tech Trends monitoring

Standards

65+ Adopted Standards
300+ products with 1000+ certified implementations
1,700,000+ Operational Data Sets
Using OGC Standards