PECORA22

Opening the Aperture to Innovation: Expanding Our Collective Understanding of a Changing Earth

What Next for Analysis Ready Data?

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Other info

Celebrating 50 YEARS Landsat 1972-2022

ASSOCIATION OF STATE FLOODPLAIN MANAGERS NASA USGS science for a changing world

Acknowledgements

- Analysis Ready Data is a fantastic team effort!

  You Know Who You Are! – Thanks!!

- Many colleagues have contributed to the ideas here, in particular the CEOS Land Surface Imaging team, colleagues from CEOS (USGS, Geoscience Australia, JAXA, ESA, NASA, the EC/JRC & etc) and others who have contributed to the development of the ideas and reality of CEOS analysis-ready data (CEOS-ARD)

- However, these are my own views

- Digital Earth Africa has funded my presence at Pecora-22

Key messages

1. **ARD is a major success but is not 'done'**. To continue the momentum the community needs to set an explicit goal such as:

   To enable sensor-agnostic characterisation of the Earth surface

2. **Uncertainty needs to be a priority**. 'Take it out of "the too hard basket"'.

3. **Aim to serve ARD to global grid systems** to bring a 'generic' user perspective.

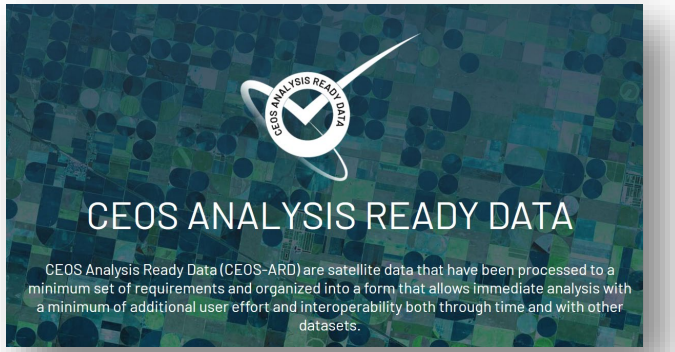
Leadership is needed (from the science community?) to guide technical implementations including specifying, harmonising and merging of sensor data.

The next key step in advancing Landsat is, counter-intuitively, to take a sensor-agnostic perspective!

ARD delivers value from EO

- Analysis ready data – is now a practical reality with global impacts
  - Due to the work of many people, the concept of Land surface data that are quantitative and ready to use has developed, realised, and is delivering global datasets.

- CEOS ‘standardisation’ of ARD has been a key achievement
  - CEOS Specifications provide detail and definition.
  - USGS / Landsat has been a global leader – coining the term ‘ARD’ and delivering the first comprehensive CEOS-ARD datasets.



- CEOS’ definition of ARD has served well:
  - ..satellite data that have been processed to a minimum set of requirements and organized into a form that allows immediate analysis with a minimum of additional user effort and interoperability both through time and with other datasets.

- CEOS-ARD is already enabling vastly greater usage of EO data
  - Empowering many more users and allowing EO providers to deliver the vastly increased quantities of data being produced in the last decade.
  - ARD datasets are some of the most popular products for users.
  - Digital Earth Africa (DE Africa) is an example, covering 54 countries and positioning Africa to leverage EO data at scale. Africa is the second largest continent.
  - NISAR will produce CEOS-ARD from day one!

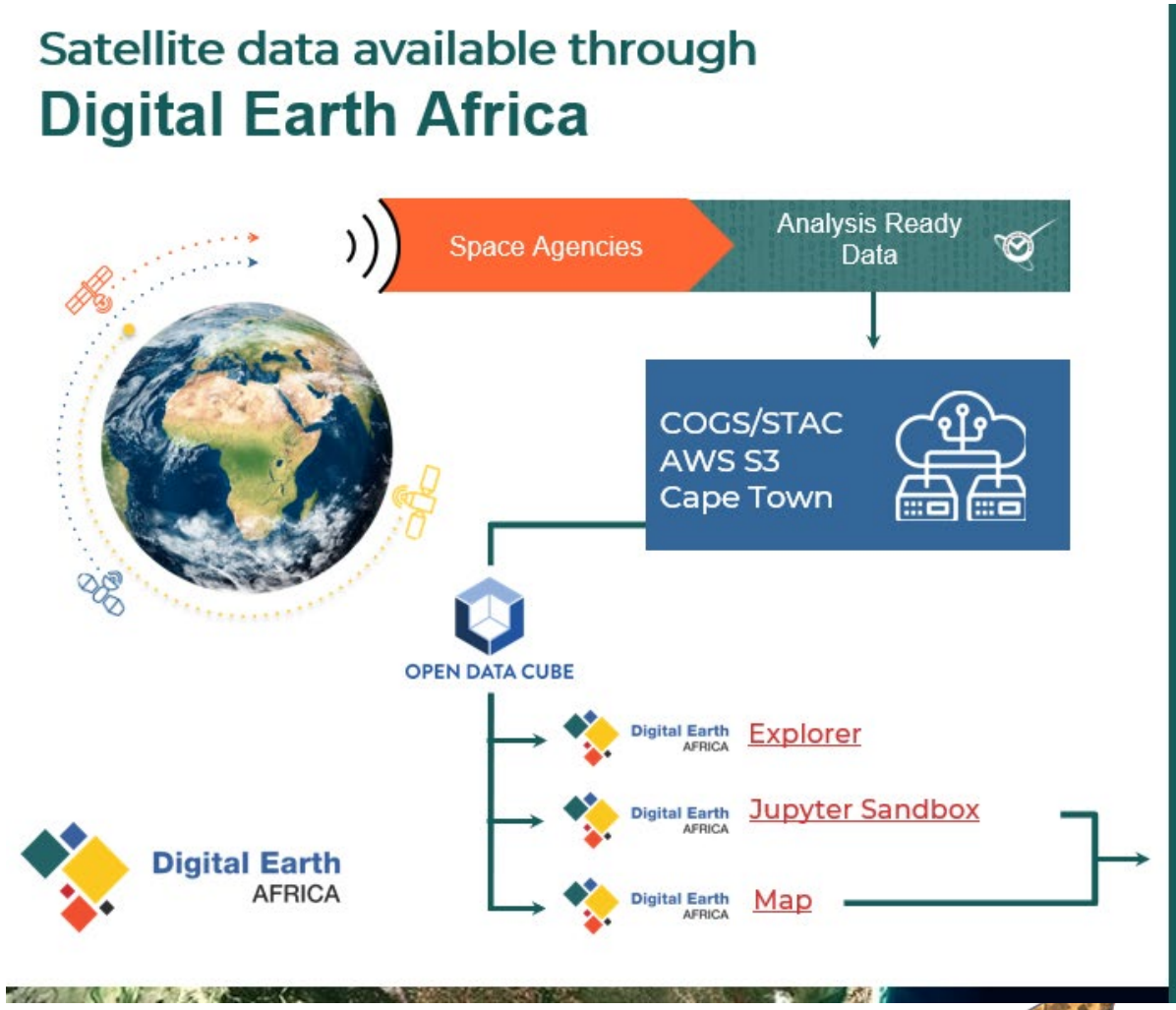
CEOS ARD

Datasets in production

Product	CEOS-ARD Type	PFS Version	Agency	Mission(s)	Threshold Specification	Target Specification	Access (DOI)	Info	Self Assessment	Peer Review	Sample Products
EnMAP	Surface Reflectance	v5.0	DLR	EnMAP	100%	Not assessed	TBA	Link	PDF	PDF	Link
Landsat Collection 2	Surface Reflectance	v5.0	USGS	Landsat 4, 5, 7, 8, 9	100%	81%	Landsat 4-5, 7, 8-9	Link	PDF	PDF	Link
Landsat Collection 2	Surface Temperature	v5.0	USGS	Landsat 4, 5, 7, 8, 9	100%	83%	Landsat 4-5, 7, 8-9	Link	PDF	PDF	Link
Landsat Collection 2 U.S. ARD	Surface Reflectance	v5.0	USGS	Landsat 4, 5, 7, 8, 9	100%	Not assessed	Link	Link	PDF	PDF	Link
Landsat Collection 2 U.S. ARD	Surface Temperature	v5.0	USGS	Landsat 4, 5, 7, 8, 9	100%	Not assessed	Link	Link	PDF	PDF	Link
Sentinel-1 RTC	Normalised Radar Backscatter	v5.5	Sinergise & Digital Earth Africa	Sentinel-1 (A, B)	100%	Not assessed	Link	Link	PDF	PDF	Link
Sentinel-2 Level-2A	Surface Reflectance	v5.0	ESA	Sentinel-2A, 2B	100%	Not assessed	Link	Link	PDF	PDF	Link

Landsat 9

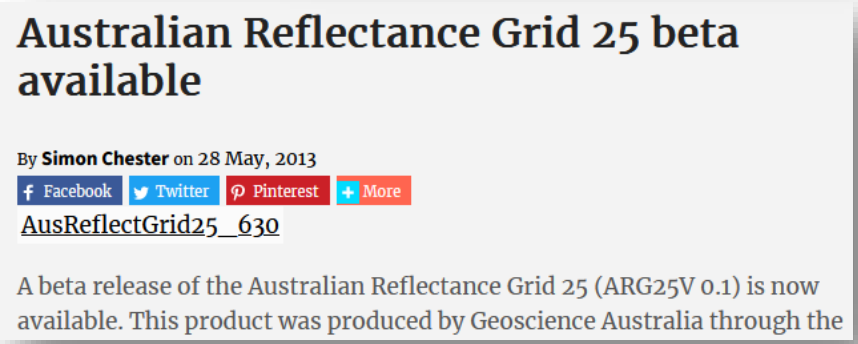
- Data was available on Digital Earth Africa hours (minutes?) of the data being released.



ARD development needs ambition

- ARD development has, in some ways, stalled
  - Information produced from EO is still tied to a specific sensor type, and often to a specific model of that sensor.
  - ‘Sensor-agnostic’ concepts have been not progressed. For example the Australian Surface Reflectance Grid (May 2013) did not progress beyond a beta version.
  - Harmonisation is often ‘to make one look like another’. This is akin to ‘image-to-image’ rectification methods used in the 1990s.
  - Data cubes are still (mis-)characterised as ‘Landsat data cube’ or ‘Sentinel data cube’ and are regarded as ways of organising imagery, rather than representing the environment (‘digital Earths’) and producing information. (with exceptions, such as the Brazilian Data Cube).
- Ambition is needed to *agree on, and to operationalize,* the best science
  - Is this a role for the **Landsat Science Team** ?

Ghana Coastal change, Landsat only. (maps.digitalearthafrica.org)



Australian Reflectance Grid 25 beta available

By **Simon Chester** on 28 May, 2013

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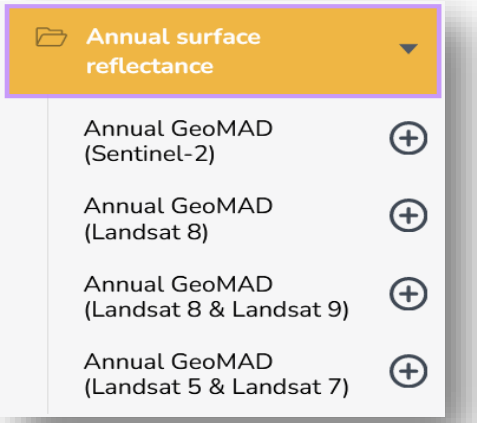
AusReflectGrid25_630

A beta release of the Australian Reflectance Grid 25 (ARG25V 0.1) is now available. This product was produced by Geoscience Australia through the



Digital Earth Africa has **four different** annual surface reflectance products

CEOS ARD

Datasets in 'in the ARD pipeline'.

How does a user apply 6-10 different 'surface reflectance' EO datasets?

These data streams need to *combine, not compete*

Agreed concepts and methods to harmonise and merge data are missing.

Under Development / Assessment

Product	CEOS-ARD Type	PFS Version	Agency	Mission(s)	Access (DOI)	Info	Self Assessment	Peer Review	Sample Products
DESIS L2A	Surface Reflectance	v5.0	DLR	DESIS-on-ISS	TBA	TBA	TBA	TBA	TBA
Envisat ASAR	Normalised Radar Backscatter	v5.5	ESA	Envisat	TBA	TBA	TBA	TBA	TBA
Envisat MERIS	Surface Reflectance	v5.0	ESA	Envisat	TBA	TBA	TBA	TBA	TBA
ERS ATSR	Surface Reflectance	v5.0	ESA	ERS-1,-2	TBA	TBA	TBA	TBA	TBA
ERS SAR	Normalised Radar Backscatter	v5.5	ESA	ERS-1,-2	TBA	TBA	TBA	TBA	TBA
Fused S-2 & L-8/9 (Level-2F)	Surface Reflectance	v5.0	ESA	Sentinel-2A, 2B; Landsat 8, 9	TBA	TBA	TBA	TBA	TBA
Gaofen-1 SR	Surface Reflectance	v5.0	AIR (China)	Gaofen-1	TBA	TBA	TBA	TBA	TBA
Harmonised S-2 & L-8/9 (Level-2H)	Surface Reflectance	v5.0	ESA	Sentinel-2A, 2B; Landsat 8, 9	TBA	TBA	TBA	TBA	TBA
L8 SR (Aerospace Information Research Institute)	Surface Reflectance	v5.0	AIR (China)	Landsat 8	TBA	TBA	TBA	TBA	TBA

Solutions?

1. Agree to a shared goal for ARD

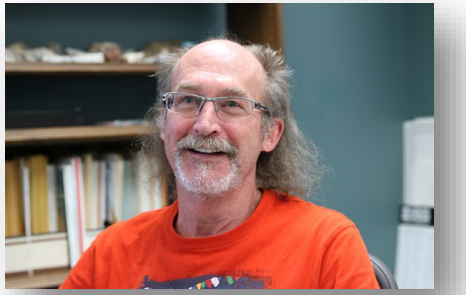
- The CEOS definition for ARD still stands, but a statement of purpose is also needed such as:

> "The goal of ARD is to allow Sensor-Agnostic Characterization of the Land/Earth Surface"*

- An explicit goal would:
  - Articulate a purpose / outcome – the activity is not an end in itself
  - Support the CEOS definition of ARD
  - Set ambitions for the future
  - Guide the prioritization of activity

- This is one for the CEOS community to lead!

*Peter Strobl, CEOS Land Surface Imaging Chair (LSI-VC-12, September 2022)

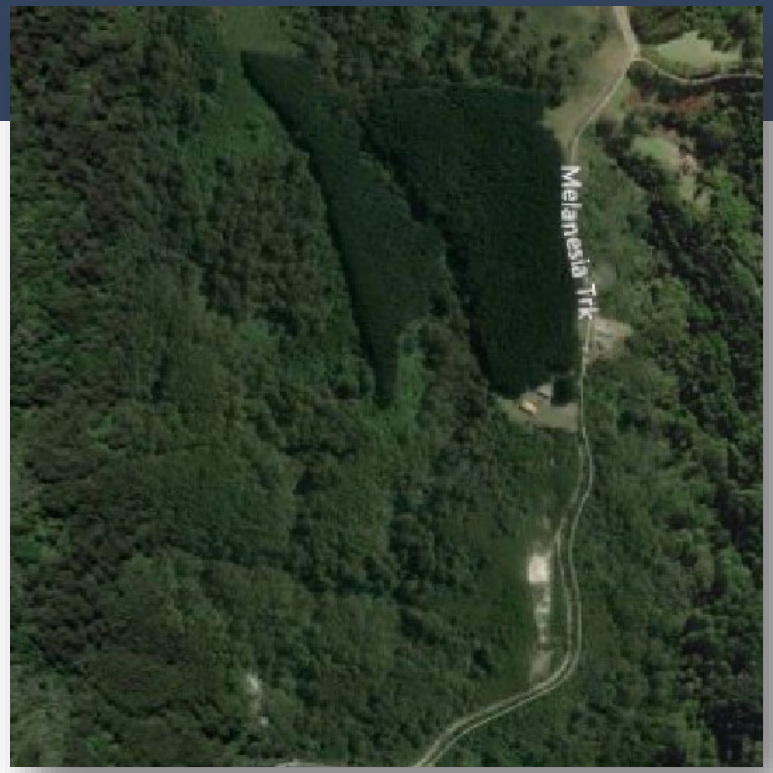


I hope this idea would make John happy!

DATA SETS (19) ⊖ Remove All Colla

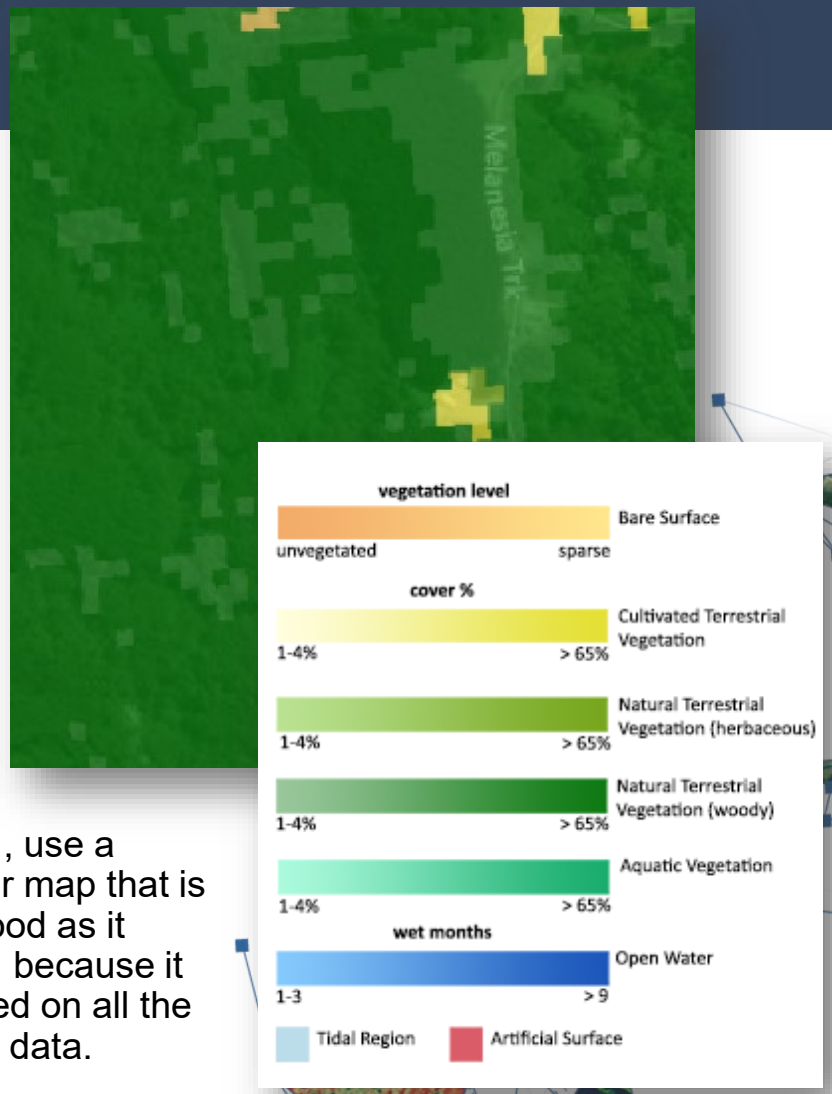
- ☐ DEA Surface Reflectance (Sentinel-2B MSI, Provisional)
- ☐ DEA Surface Reflectance (Sentinel-2A MSI, Provisional)
- ☐ DEA Surface Reflectance (Sentinel-2, Provisional)
- ☐ DEA Surface Reflectance (Sentinel-2B MSI)
- ☐ DEA Surface Reflectance (Sentinel-2A MSI)
- ☐ DEA Surface Reflectance (Sentinel-2B MSI Near Real-Time)

Option 1., work through many 'analysis-ready' datasets to figure it out.



When was this harvested?

The simple answer (which you can figure out if you are (used to be) an expert:
Eastern half: 2007-2009
Western part: 2016



Option 2., use a landcover map that is not as good as it could be, because it isn't based on all the available data.

pathways to multi-sensor services

Product	CEOS-ARD Type	V
EnMAP	Surface Reflectance	
Landsat Collection 2	Surface Reflectance	
Landsat Collection 2	Surface Temperature	
Landsat Collection 2 U.S. ARD	Surface Reflectance	
Landsat Collection 2 U.S. ARD	Surface Temperature	
Sentinel-1 RTC	Normalised Radar Backscatter	
Sentinel-2 Level-2A	Surface Reflectance	

'an algorithm for each product for each sensor'

Landcover EnMAP

Landcover Landsat C2

Landcover Sentinel 2

Landcover ☺ (*etc*)

Surface Reflectance

Surface Temperature

Surface backscatter

Landcover ☺ (*etc*)

'harmonise and merge at the measurement level'

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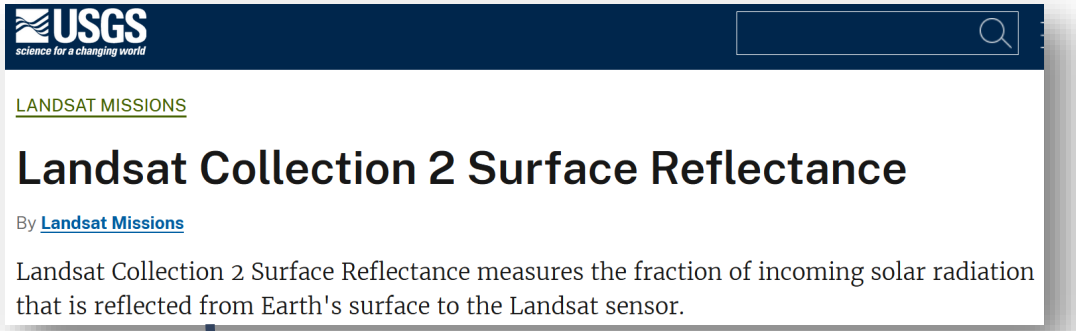
pathways to multi-sensor services



- What are the characteristics for a *sensor-agnostic*, *operational* surface reflectance grid?

2. Focus on Uncertainty

Uncertainty is the ‘Elephant in the Room’
Understanding the uncertainty in surface observations will:

- Put EO land data on a better scientific footing.
- Simplify ARD specifications. Specific preparation steps are *proxies for accuracy*. The need for these varies depending on the sensor.
- Help the community to converge on specification requirements by focusing on the preparation steps needed to reduce uncertainty.
- Reduce barriers to entry / make CEOS ARD more accessible to private sector providers.
- Highlight the areas of greatest importance to progress
- Accelerate interoperability and provide a basis to inform users of uncertainty in end products!

CEOS’ ARD specifications allow for statements of pixel accuracy but to date no data providers provide them.

Reducing uncertainty in ARD products should be an aim.

CEOS ARD favours processing over accuracy

Required

Overall
Geometric Correction (sub-pixel relative)
Directional Atmospheric Scattering
Water Vapour Corrections
Machine Readability
Data Collection Time
Geographical Area
Coordinate Reference System
Map Projection
Instrument
Spectral Bands
Algorithms used
Auxiliary Data
Data Access
Measurement type (units)
Per pixel
Metadata Machine Readability
No Data
Incomplete Testing
Saturation
Cloud
Cloud Shadow
Solar and Viewing Geometry

Desired

Overall
Geometric Correction (sub-pixel absolute)
Ozone Corrections
Traceability
Geometric Correction Methods
Geometric Accuracy of the Data
Sensor Calibration
Radiometric Accuracy
Processing Chain Provenance
Overall Data Quality
Per pixel
Measurement Uncertainty
Measurement Normalisation (BRDF)
Land/Water Mask
Snow/Ice Mask
Terrain Shadow Mask
Terrain Occlusion
Terrain Illumination Correction Parameters
Aerosol Optical Depth Parameters

The CEOS ARD requirements reflect established practice and processes, + ambition to improve.

No providers are providing ‘Measurement Uncertainty or Measurement Normalisation

If *minimising uncertainty* is set as an aim, improvements and efficiencies will follow.

Required	Desired
Overall **Geometric Correction** **(sub-pixel relative)**	Overall **Geometric Correction** **(sub-pixel absolute)**

Issues:

The specification requirement does not assure *"interoperability … with other datasets"* because absolute accuracy is not required, only relative accuracy

Geospatial accuracy is not binary. *Any* geospatial error will introduce variations into the results of spatial query. A time-series will always have some variance due to geometric uncertainty.

The importance of this effect *depends on the context / location*. E.g. :
One 10m pixel 'off' on a homogeneous area (such as a salt-pan) probably makes no difference
One 10m pixel 'off' in a built up area can lead to a building being missed – a big difference

Some high-resolution datasets may not be able to be corrected to sub-pixel accuracy.

Conclusion:

If we develop the specifications from an uncertainty point of view we may take a different approach, e.g., insisting first in the specification that the spatial error is characterised!

The outcome that we need is observations with quantified uncertainty.

3. Embrace Global Grids

- ‘Discrete global grid systems’ (DGGS) are developing:
  - Already quite well developed – mostly ‘in the back end’ / not user-visible.
  - Will replace map projections of data
  - **Have started to go ‘main-stream’ - e.g., what3words**

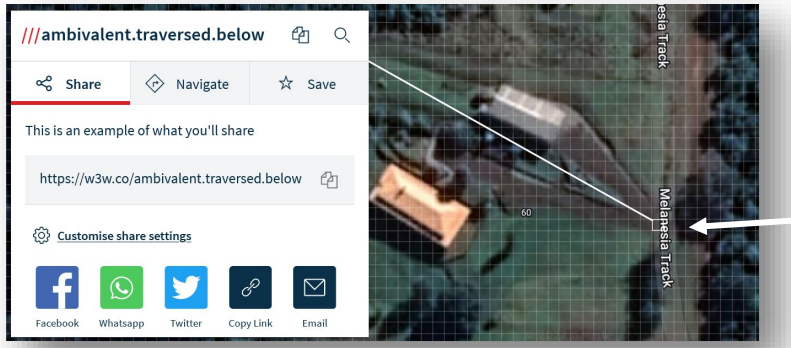
- DGGS could transform the application of EO data:
  - provide a window for mass-application of EO information; ‘democratising location’ / move beyond maps
  - bring a user/demand-driven perspective, from the general public to modellers (rather than an EO provider / EO specialist point of view)
  - be seeking localised information rather than images

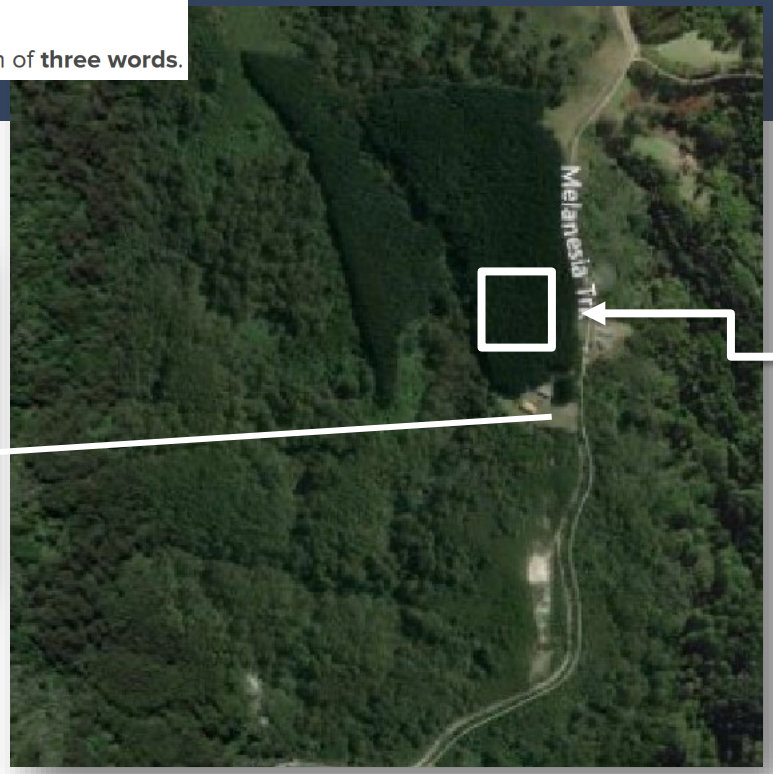
- The ARD community should ensure that EO data *can be served to* a *user’s grid system.*

https://what3words.com

what3words /// The simplest way to talk about location

Every 3 metre square of the world has been given a unique combination of **three words**.





- Data users don't care about provider's pixels
- Global grids will 'democratize location' anyone can speak authoritatively abut *place*.
- Users will ask for information *about their places* (through apps, or models, or other)
- Providers who can respond to this (at scale) will be prepared for all comers.

ARD Data Services

What … can you tell me about …. *this.place.here*?

- Surface reflectance time-series?
- Land cover changes?
- Distance from the coast?
- Frequency of flooding? & etc.

Request to service operator (possibly a data-cube)

Report the estimated data value and uncertainty

- Spatially aggregate or interpolate
- Temporally aggregate or interpolate
- Harmonise and merge sources
- Locate available data and meta-data

stuff to be done

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Key messages

1. **ARD is a major success but is not 'done'.** To continue the momentum the community needs to set an explicit goal such as:

   To enable sensor-agnostic characterisation of the Earth surface
   (and follow through with specifications for a sensor-agnostic, operational surface reflectance grid!)

2. **Uncertainty needs to be a priority.** 'Take it out of "the too hard basket"'.
   (and set an aim of reducing uncertainty in ARD products)

3. **Prepare to serve ARD to global grid systems** to bring a 'generic' user perspective.

Leadership is needed (LS science team?) to guide operational implementations including specifying, harmonising and merging of sensor data.