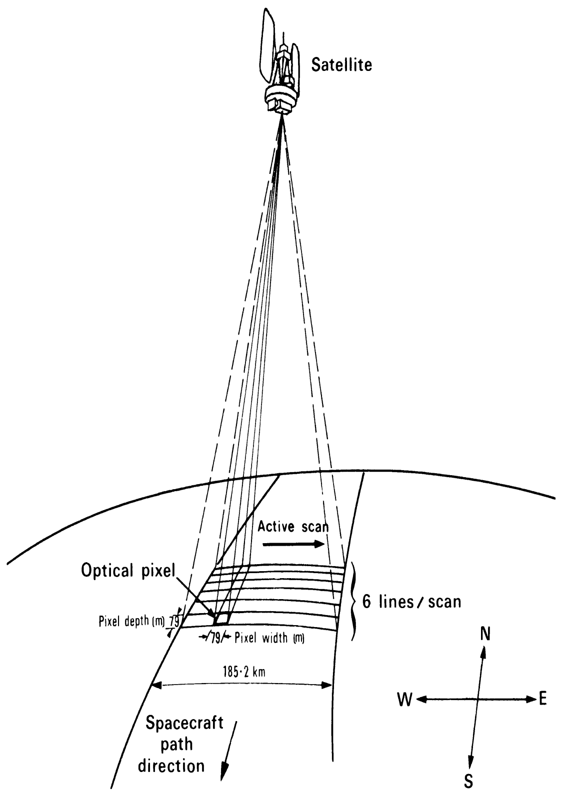
Potential and limitations of satellite remote sensing (& AusCover –TERN)

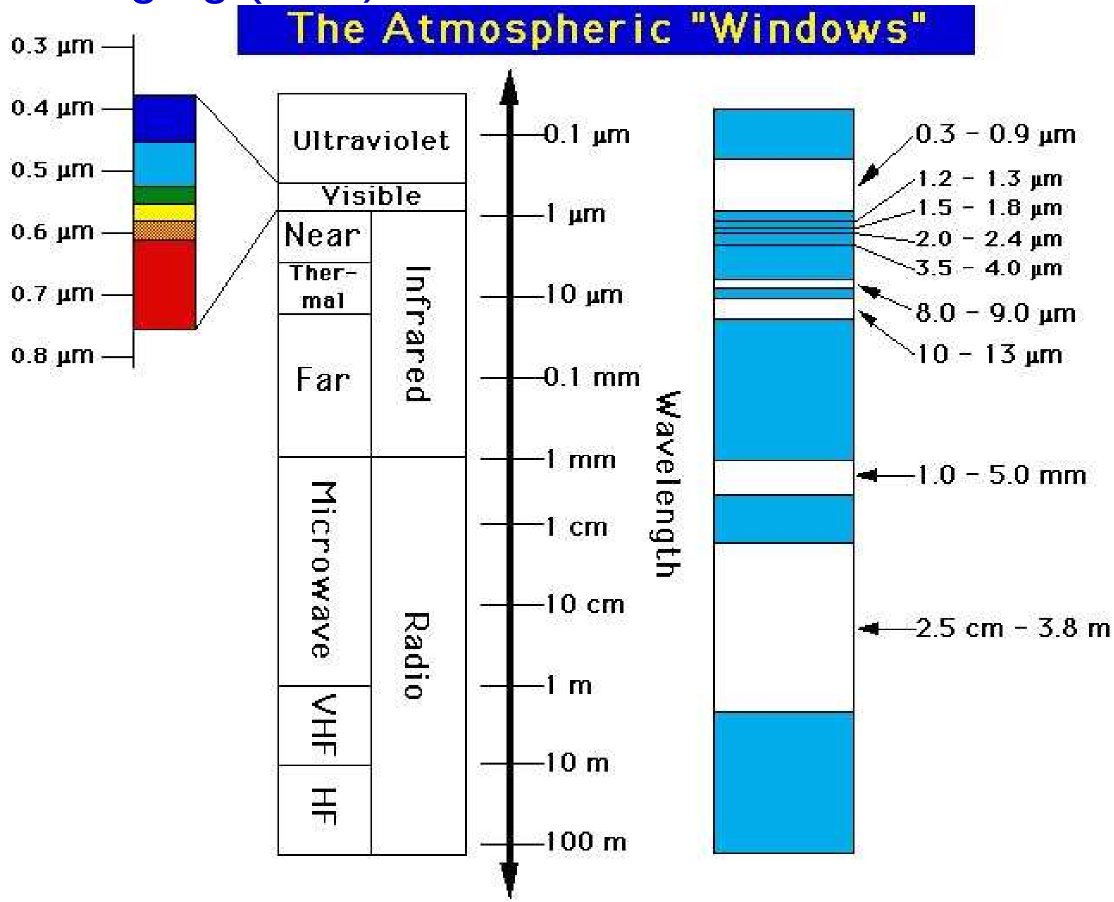
A. Held

AusCover Lead

Remote Sensing Basics

- Basis:
  - Optical spectroscopy
  - Radio detection and ranging (radar)
  - Light (laser) detection and ranging (lidar)

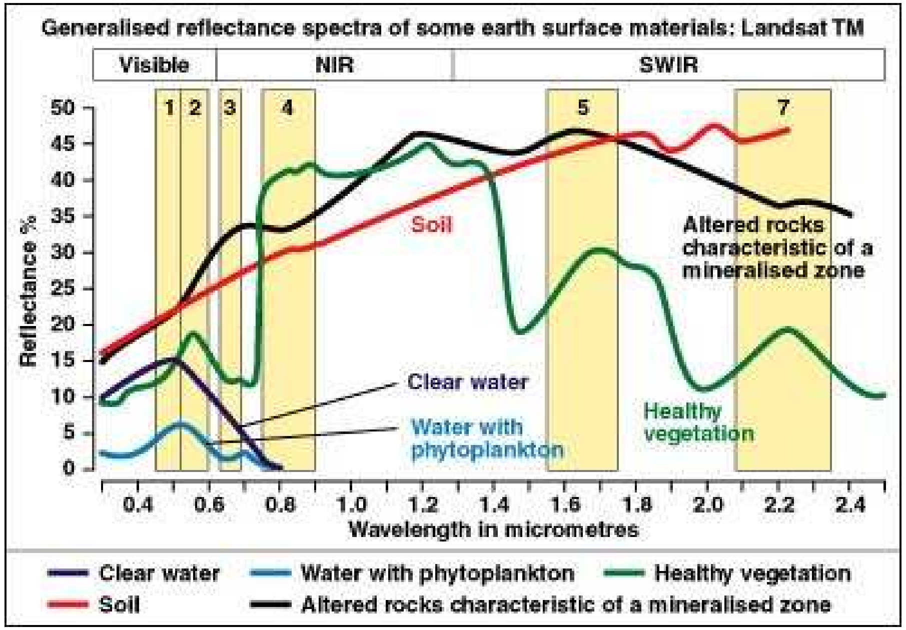




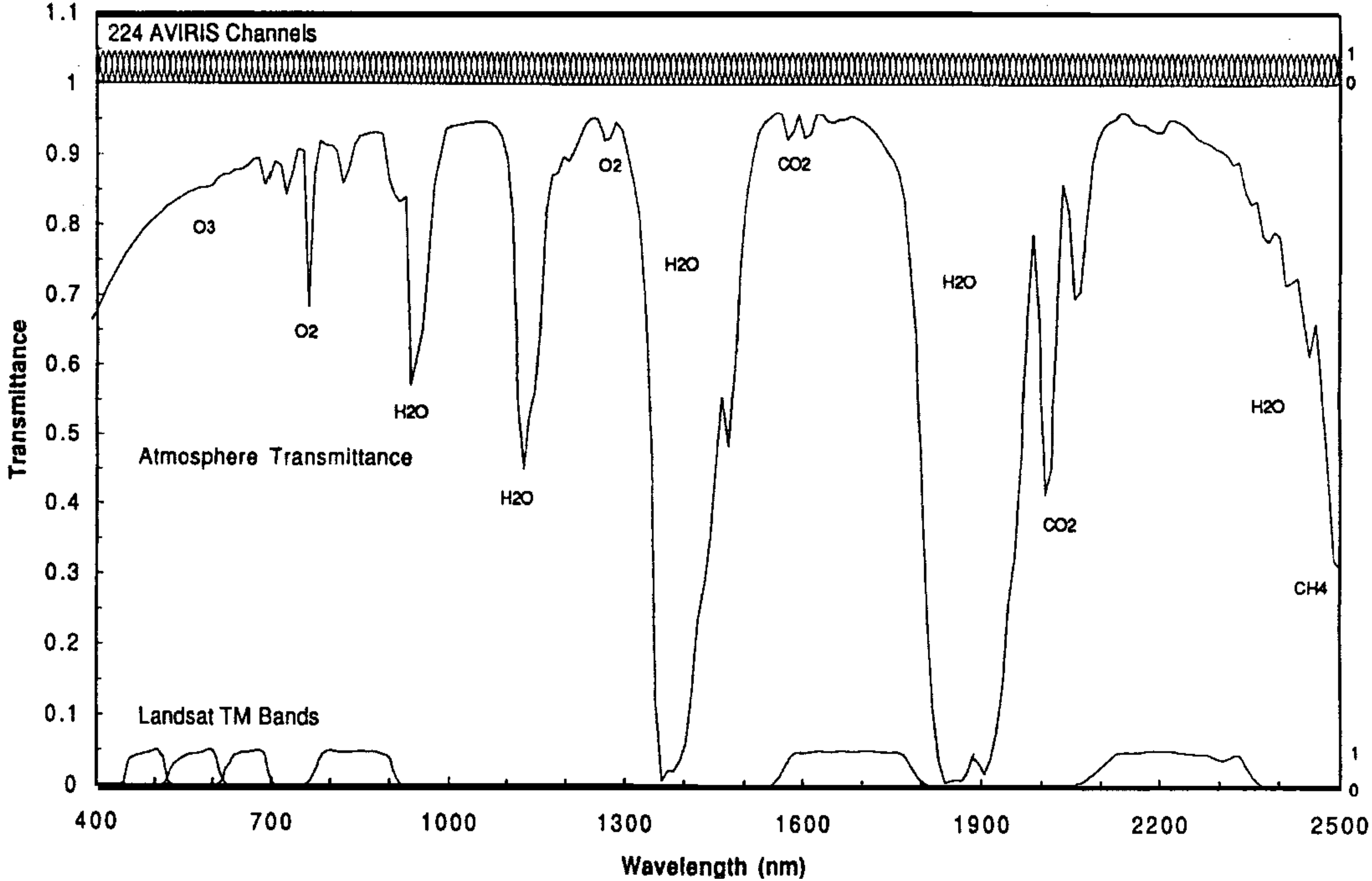
Panchromatic & Multispectral

Ikonos 1-m Resolution Pan

Landsat TM MX



Spectral Resolution and Signal-to-Noise Considerations



What is the Potential?

- Identify chemical nature of materials & their temporal dynamics (minerals, water bodies, vegetation composition/physiology, etc.)
- Map the 3-Dimensional structure and location of vegetation features –
- Quantitative Remote Sensing:
  - Measurement of the composition and the relative abundance of materials visible in the imagery
  - Spatial distribution of materials
  - Aerodynamics and canopy ‘light climate’
  - Monitoring changes over time

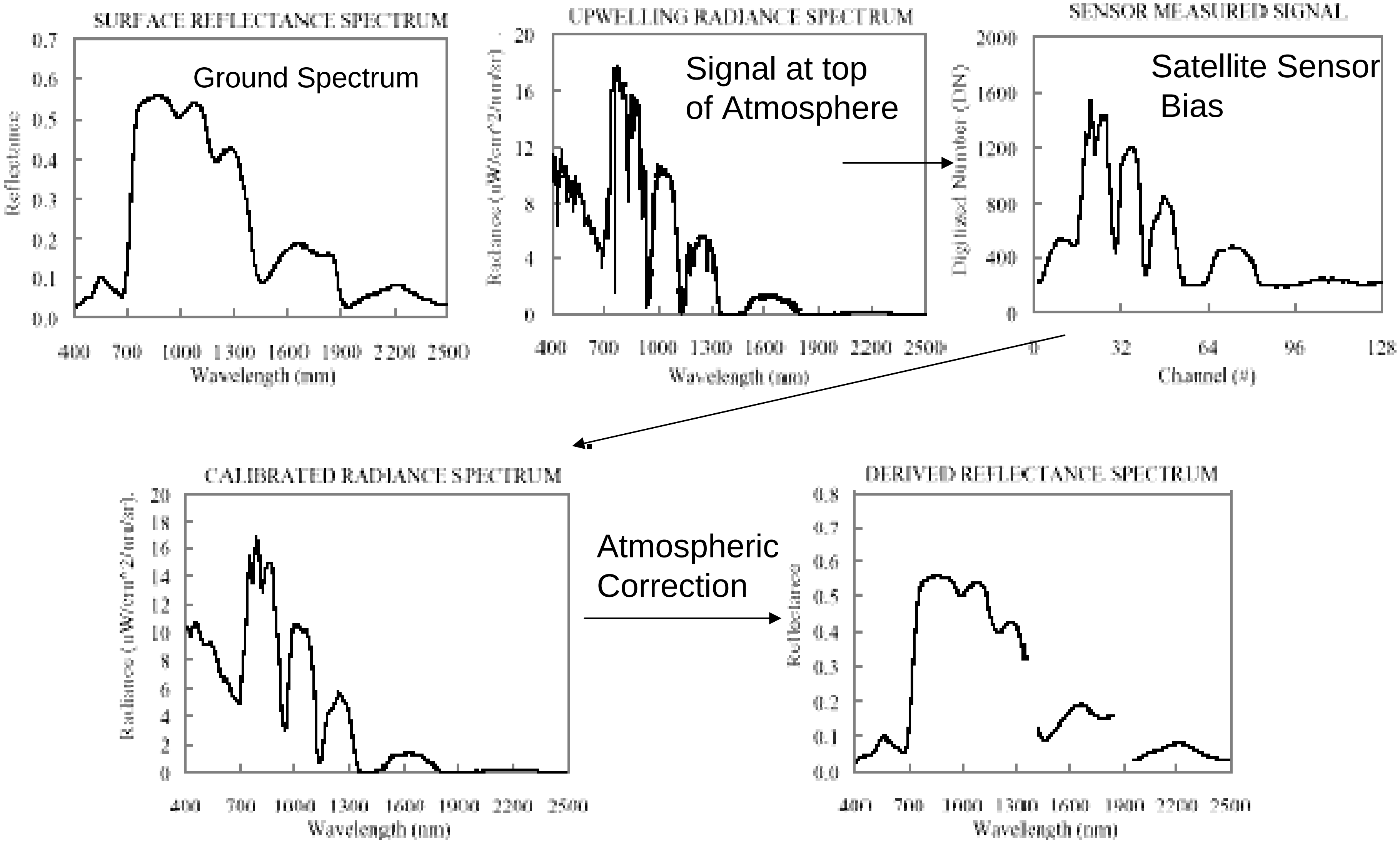
Basic Concept

- Imaging Spectroscopy: the measurement and analysis of spectra acquired as images
- Imaging Spectroscopy
  - Identifies based on resolved molecular absorptions
  - Identifies more than one material per spectrum (mixtures)
  - Assesses concentration through spectroscopic analysis of expressed absorption and scattering

General Hyperspectral Mapping Approaches

1. Use of full reflectance spectrum and spectral libraries to identify and/or quantify target material.
   - ‘Traditional’ spectroscopy
     - Spectra can be used for atmospheric correction
     - ‘Unmixing’ of mixed pixels
2. Reduce 220+ narrow bands to fewer, higher S/N bands, which are key for discrimination of target materials
   - Reduces data volume
   - Allows for smaller pixels
   - Avoids most large absorption features

Quality Control and Rigorous Image Corrections are critical! (Digital Numbers to Reflectance)



Spatial vs. Spectral Resolution

Tradeoffs

- Target size
- Swath width
- Data rate
- Data storage
- Data analysis time
- SNR
- Platform altitude
- Natural scales
- Topography

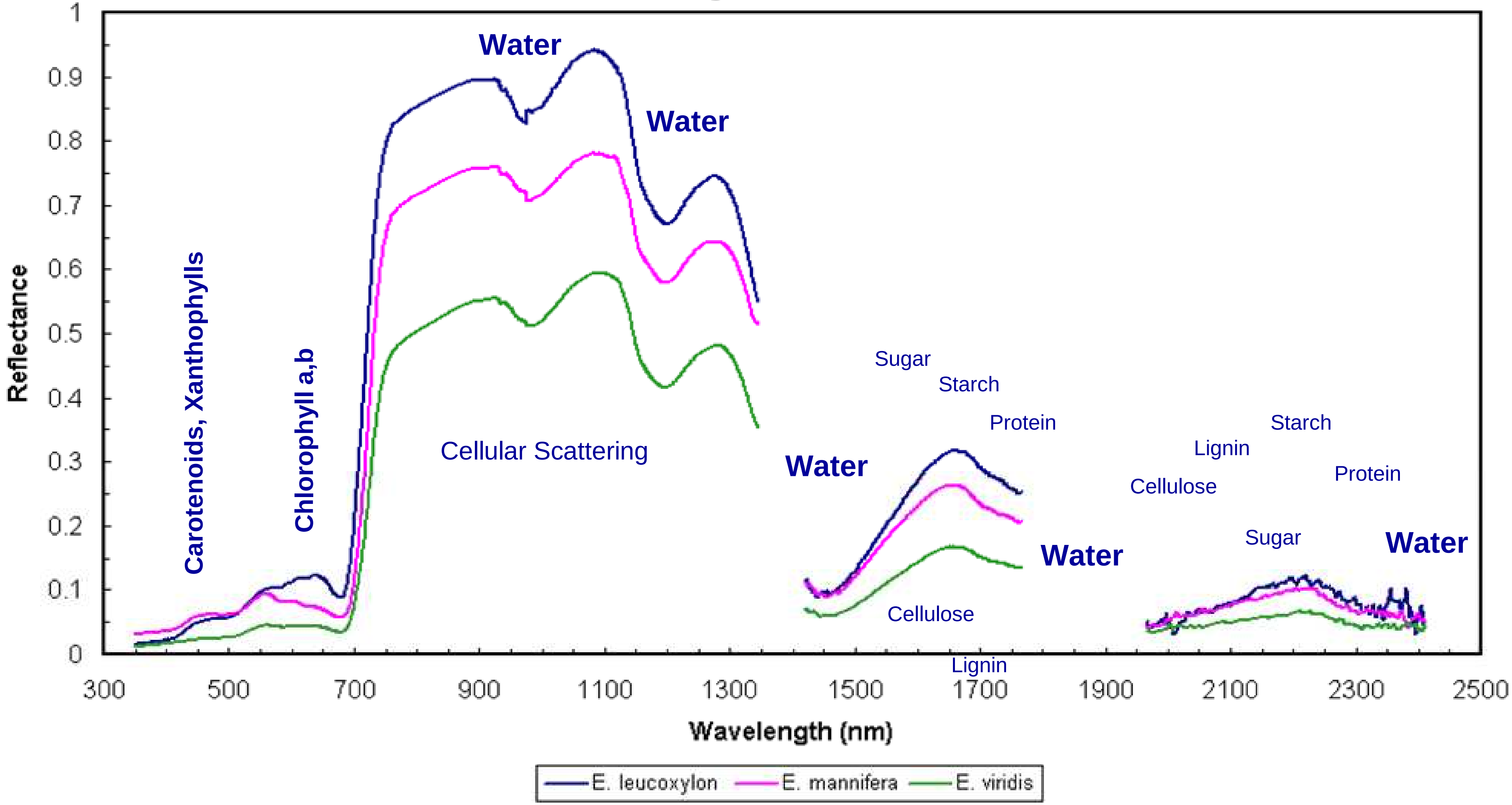
Field Spectrometry

- Use equivalent light source for sample and reference
- Take into account light scattered onto the sample or reference panel from the surroundings (trees, vehicles, field assistant, you...)
- Keep away from objects that are not part of the natural landscape (e.g.vehicles)
- The geometry between the objects in the area surrounding the sample or reference panel should be kept constant
- Wear clothing that have no sharp absorption features

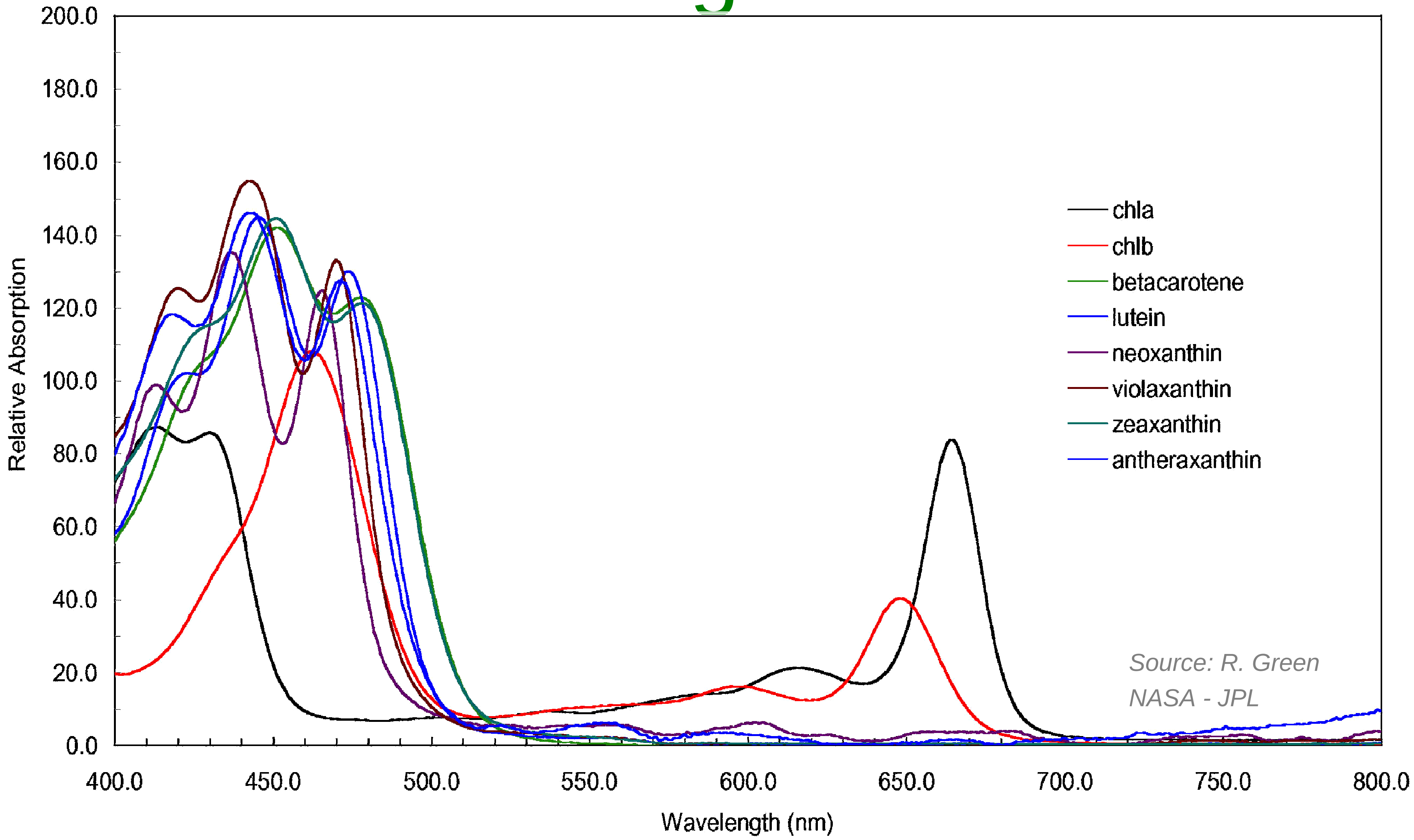
Data Processing & Software

- Advanced Processing
  - Spectral Un-Mixing
  - Spectral Modelling and Quantification
    - Radiative transfer through water & plants
    - Dynamic Bio-optical models
    - Mechanistic models ….
  - Texture & Spectral Processing
  - Data integration
    - Multi sensor: e.g. Thermal – Hyperspectral
    - GIS outputs

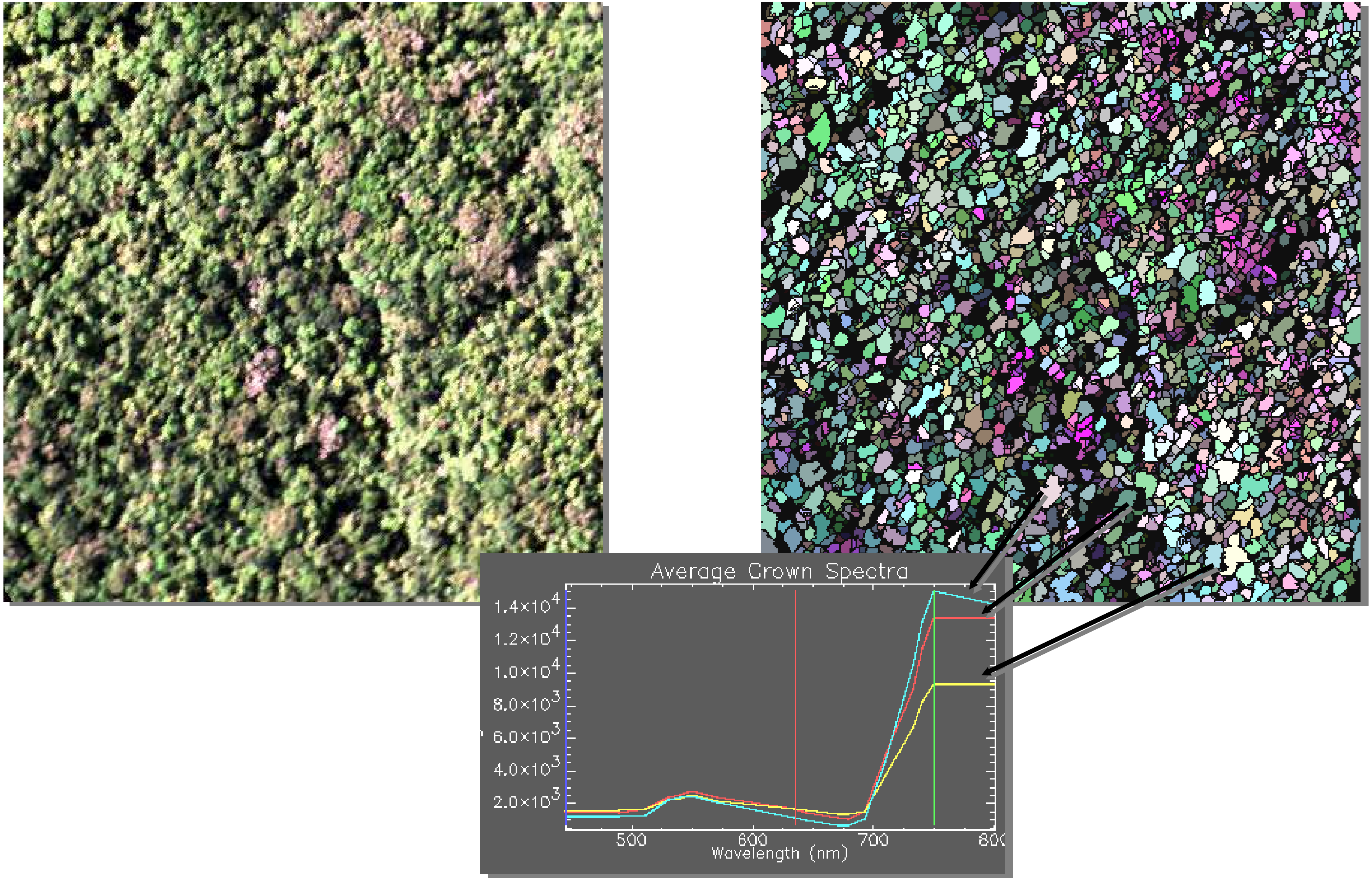
Foliar Chemistry and Reflectance



Leaf Pigments

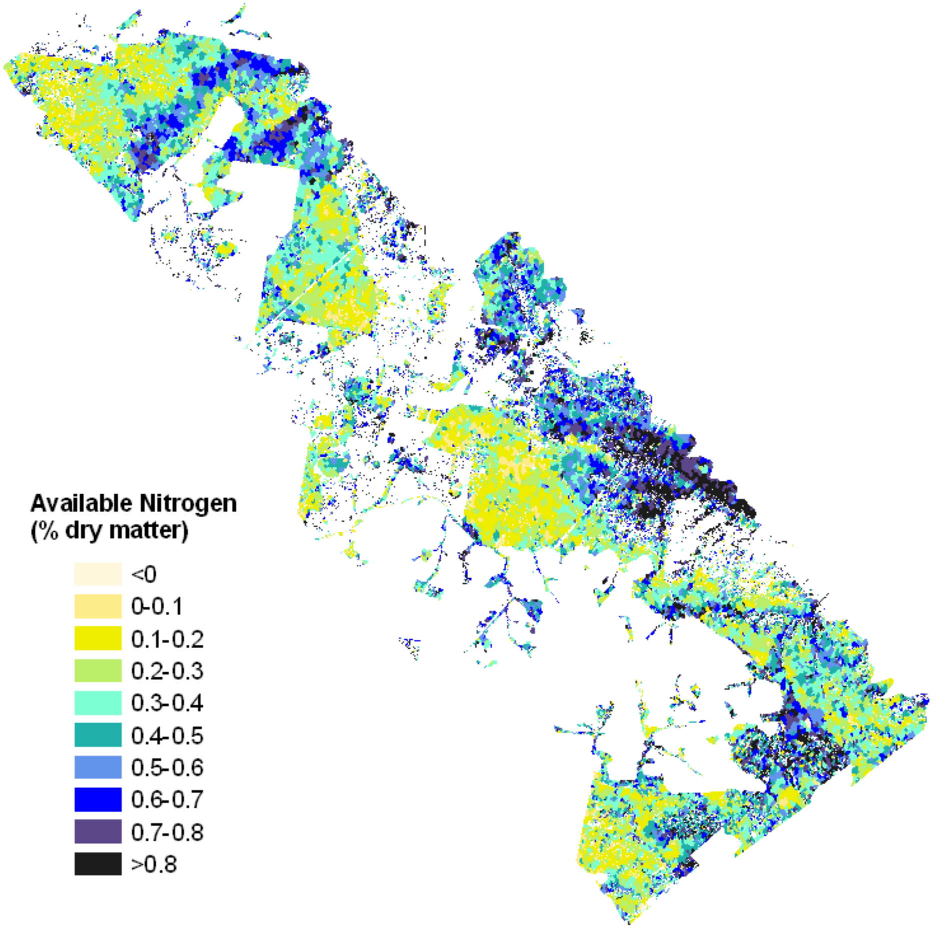


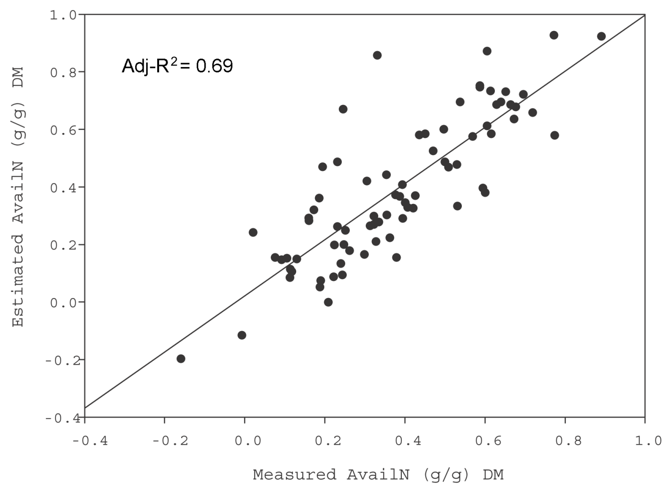
Examples: Precision Mapping of Tropical Rainforests



Habitat mapping—foliage chemistry

Available nitrogen across a eucalypt forest canopy





e.g., measured available nitrogen (AvailN) vs estimated AvailN from an airborne imaging spectrophotometer. The degree of correlation between the measured and estimated values is provided by R^2.

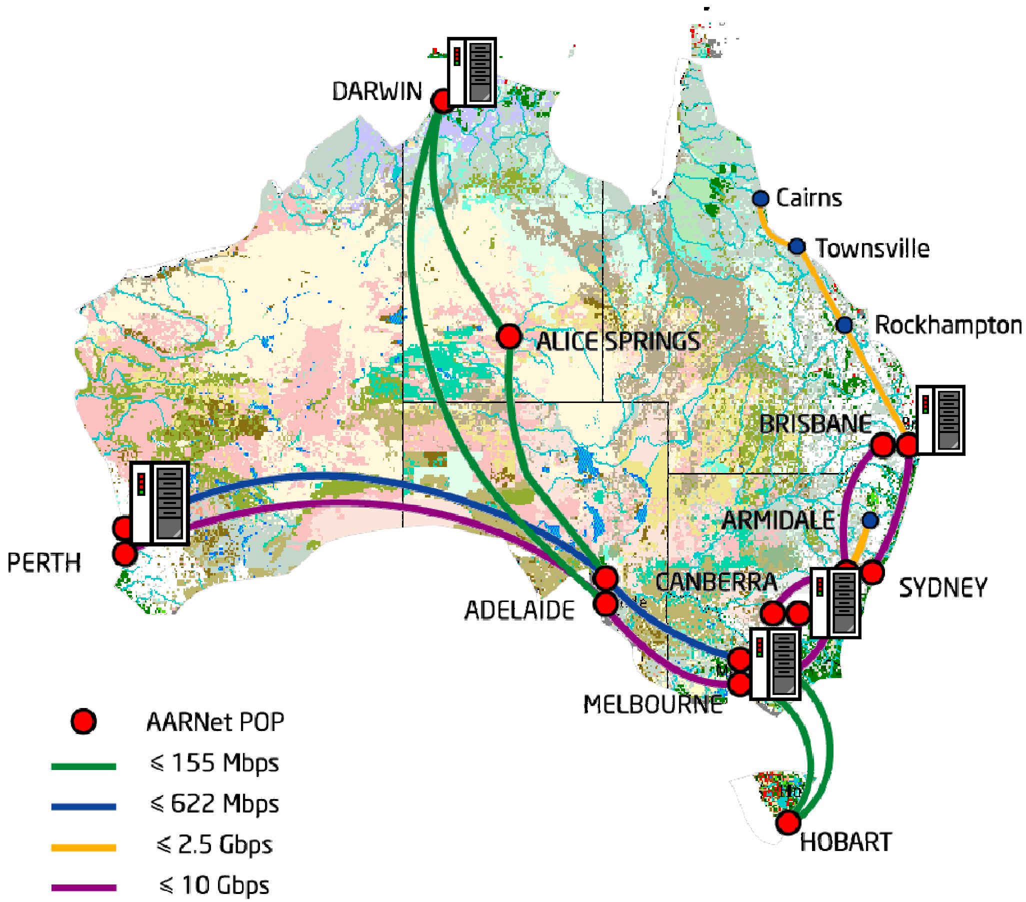
Source: K. Youngenob PhD Thesis (submitted)

Satellite Data: Key Considerations

- What is to be quantified?
  - Greenness dynamics, nitrogen concentration, 3D structure, etc.
- Spatial Resolution?
  - “Best Possible” often is not necessary (too much data, don’t often need to see individual trees, etc. – spectral, temporal & radiometric tradeoffs)
- How frequently: AVHRR-MODIS 1-5 km pixels, multiple times per day; but only few spectral channels (bands) for detailed analysis. Good for Greeness dynamics (NDVI, EVI, FPAR dynamics) – 25+ year history for Australia.
- What pre-processing is done by data suppliers? Spatial accuracy, derived products ‘ global algorithms or local validation?

"AusCover":

A Distributed National Landcover Remote Sensing Data Facility

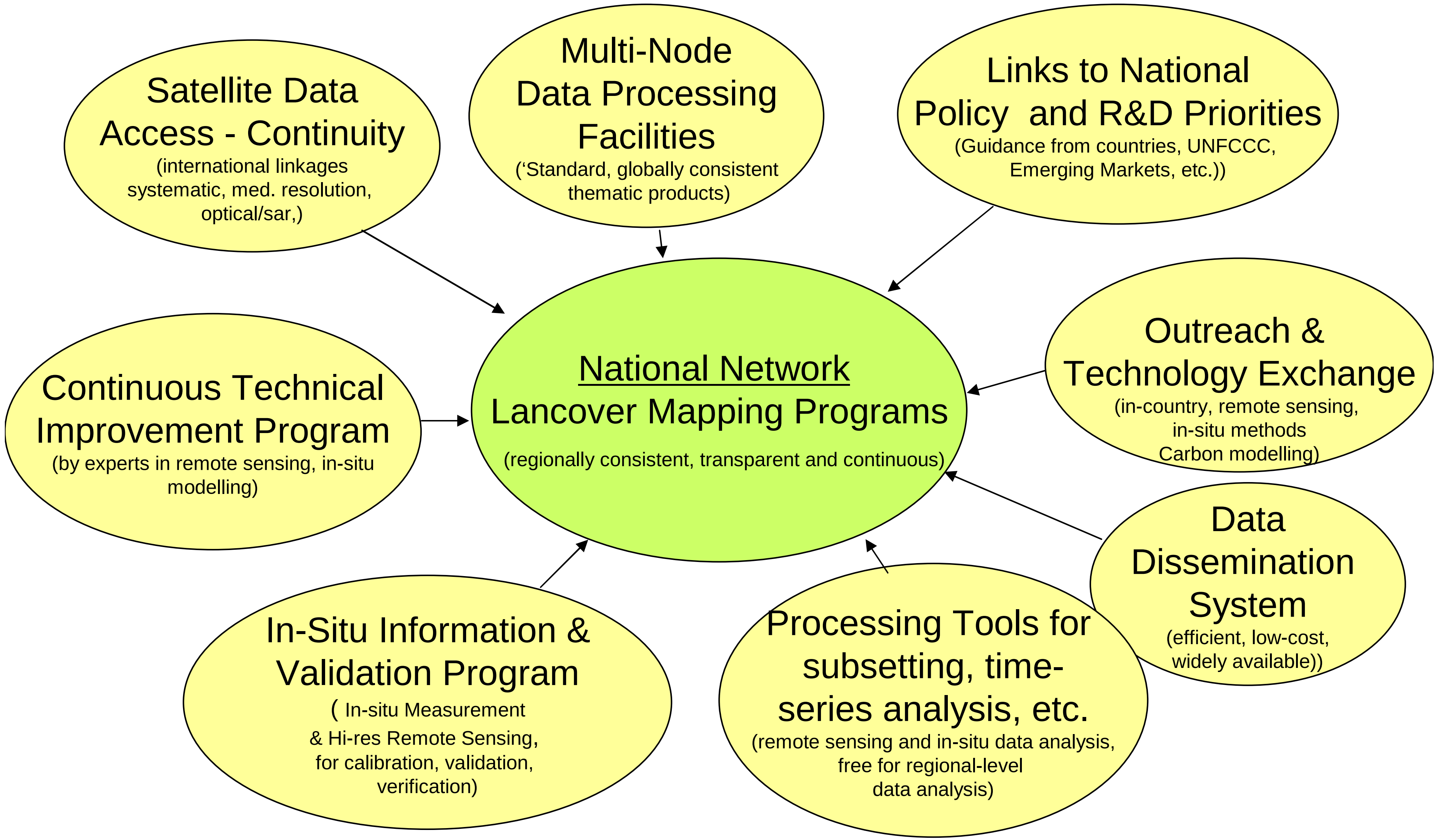


The AusCover Facility

- A **Distributed Archive and Access Capability** for Australian Biophysical Remote Sensing Products and Associated Data (known as "**AusCover DAAC"**) – Nodes in Darwin, Brisbane, Canberra, Melbourne, Perth.
- A nationally consistent approach to the delivery and validation of key historical and future satellite-derived datasets;
- Biophysical remote sensing data products designed specifically for Australian conditions.
- Supporting ecosystem science and natural resource management in Australia

AusCover –TERN

Components of an Operational Landcover Monitoring System



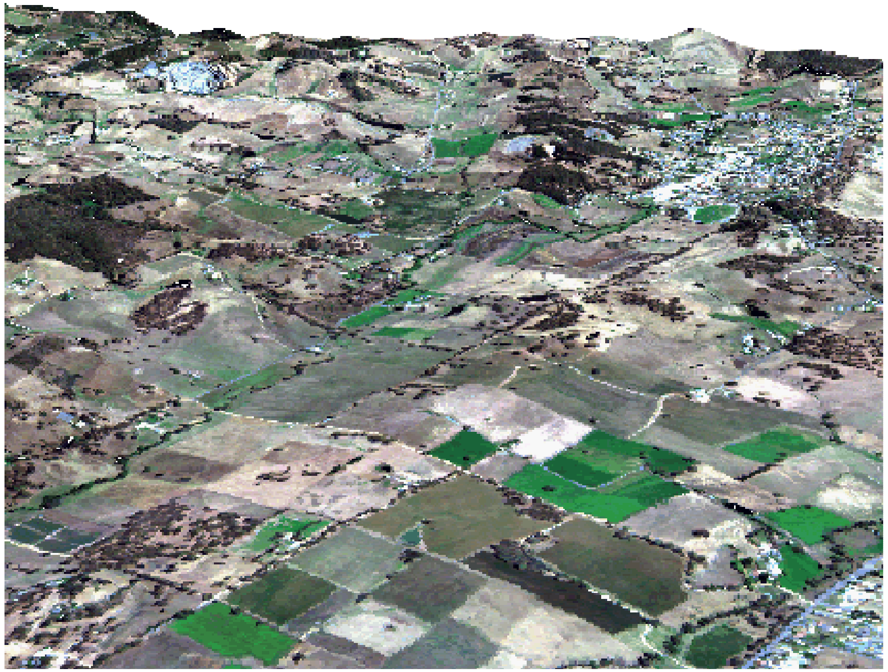
Implementation Priorities

- Set up distributed data delivery platform + network – January 2010 – December 2010
  - Nodes: Perth, Darwin, Brisbane, Canberra, Melbourne, +…)
- Establish Cal/VAL Program from January 2010
  - Protocols & Standards
  - Ground Instrumentation
  - Field Site network
- 'Data Portal" for "Core" Databases, Metadata – from about June 2010

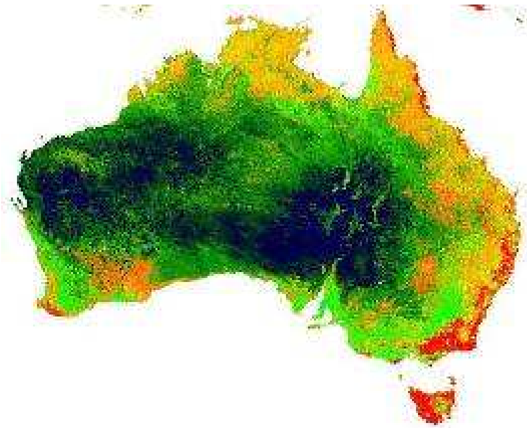
Scales of Observation

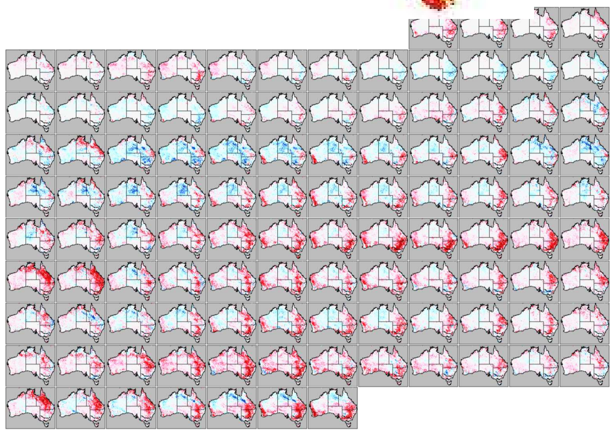
Sub-paddock

(e.g. SuperSites, and selected flux-towers)

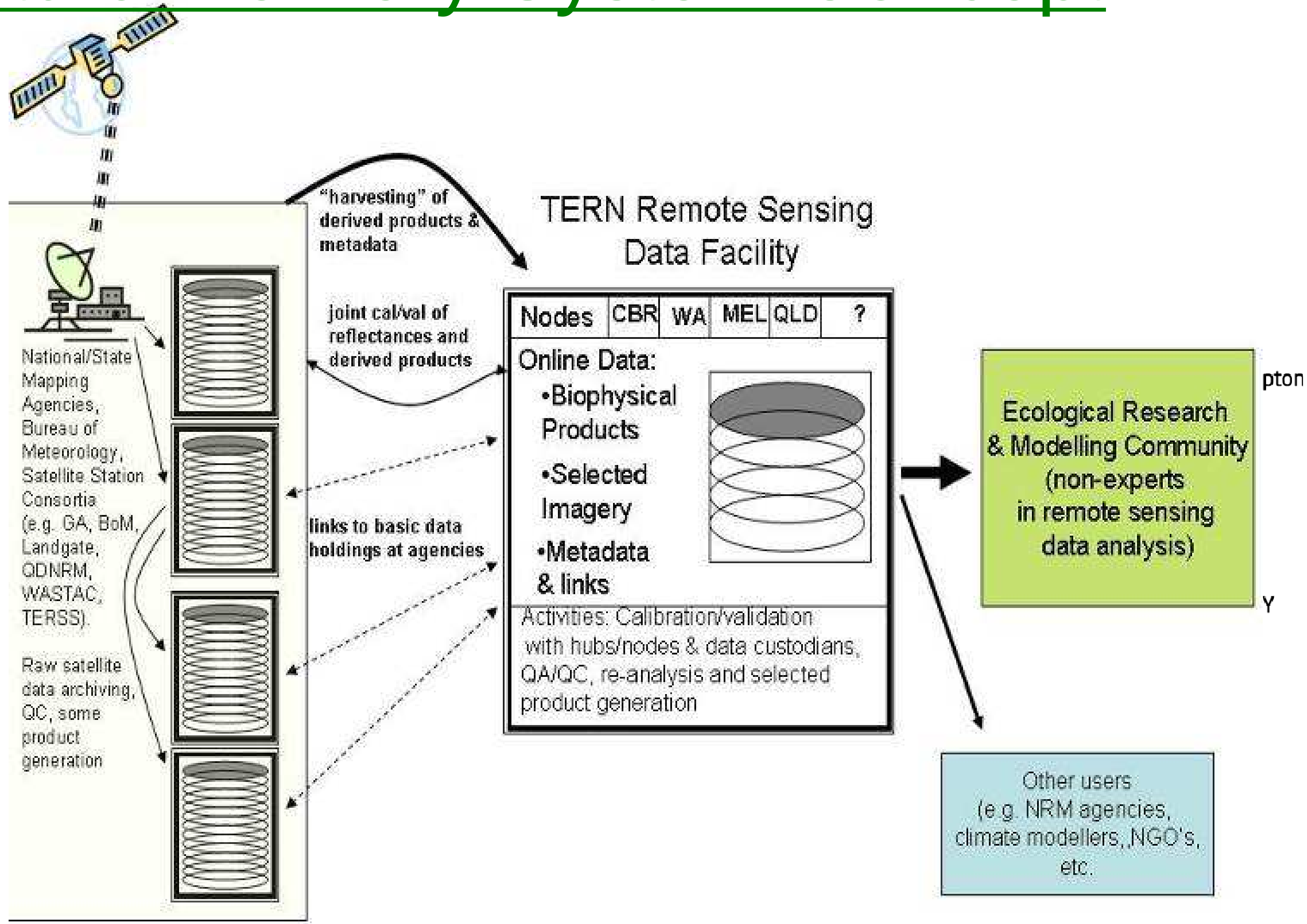


Continental & Multi-Decadal





Data & Delivery System Concept



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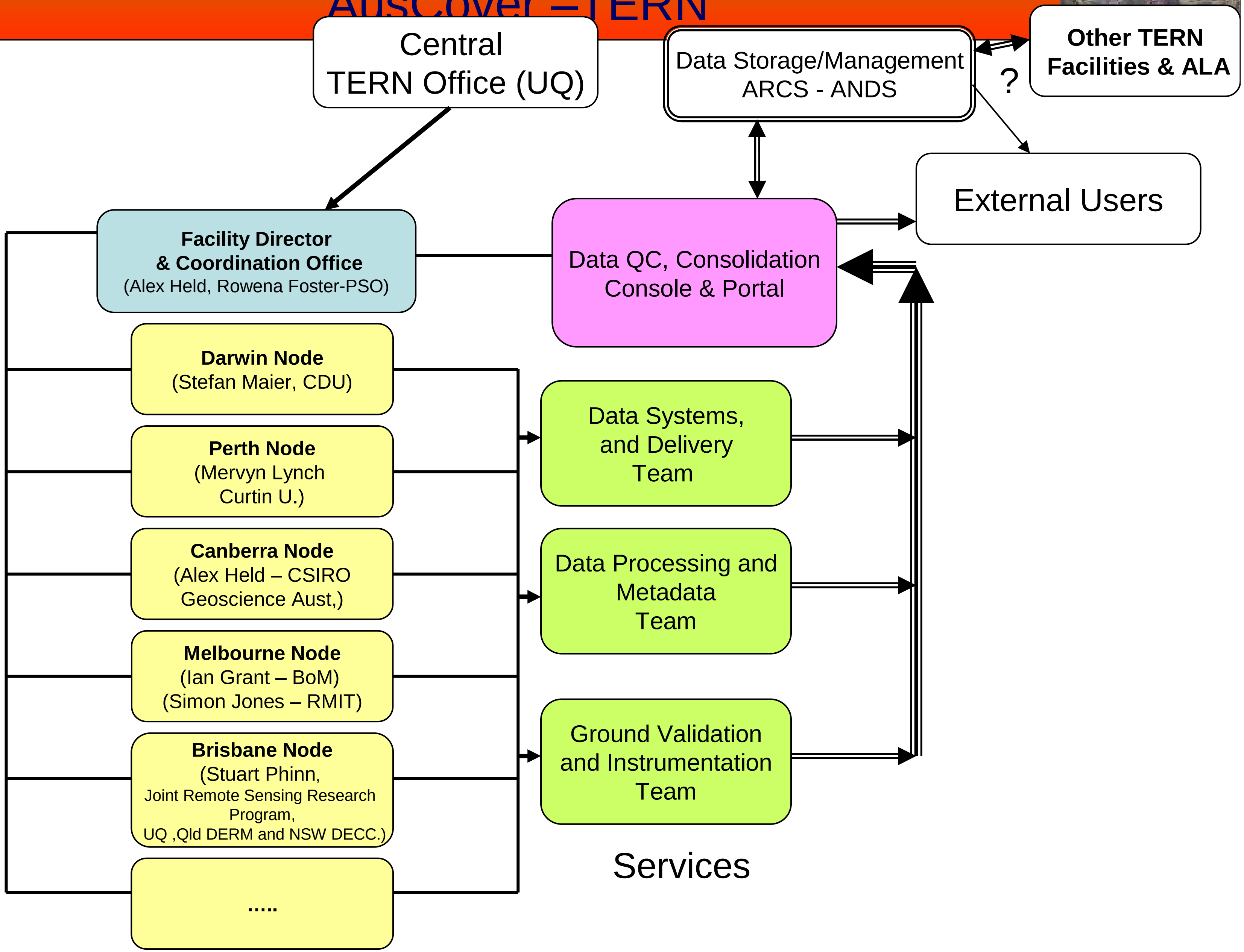
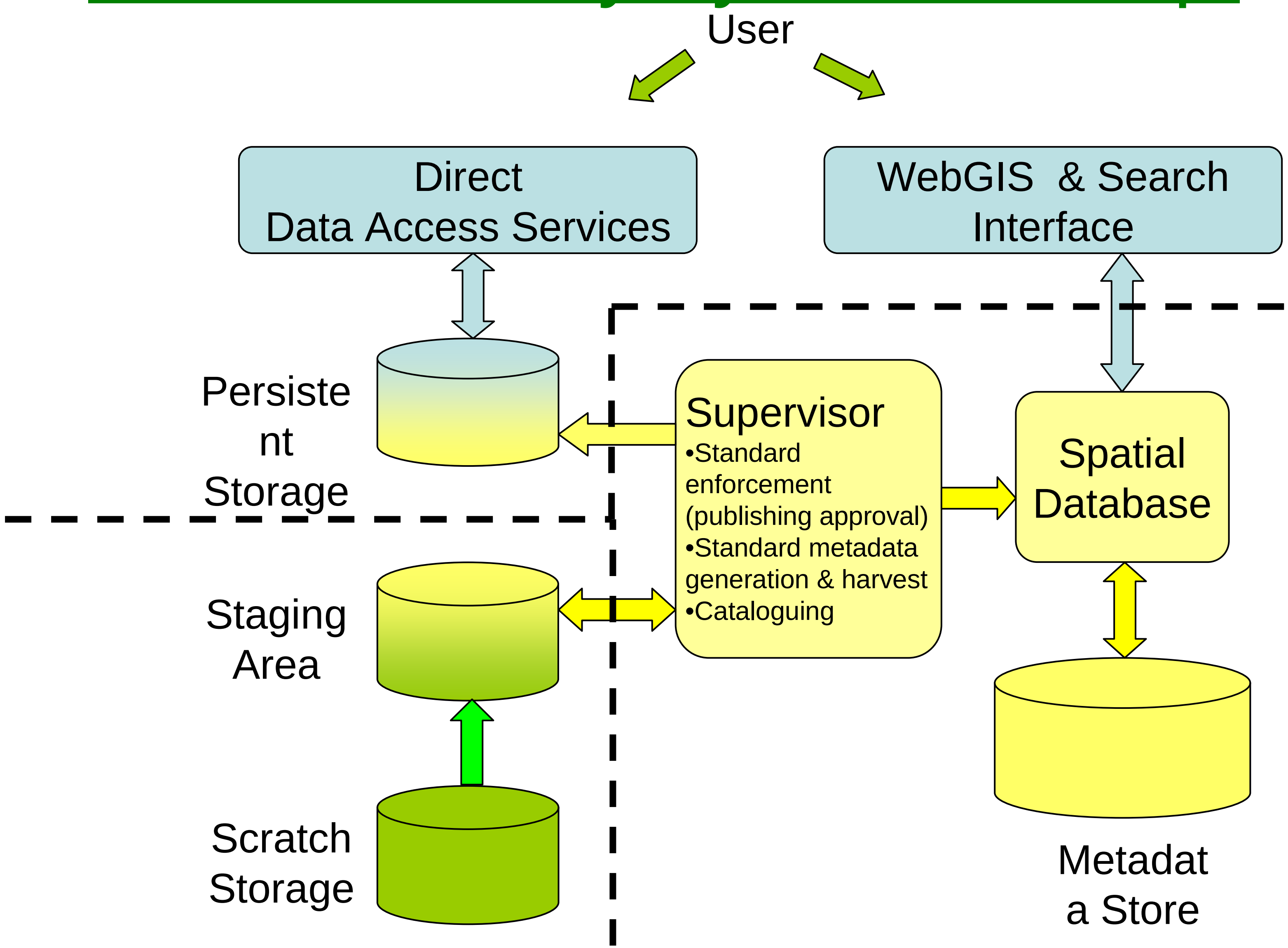


AusCover Components

1. Data Systems and Delivery
2. Processing and Metadata
3. Ground Validation and Instrumentation

Data & Delivery System Concept



Biophysical RS Data Products

“Mature & Operational”
-Standardised,
-Quality checked,
-Validated
-Wide User Base
-peer-reviewed,
- documented (ATBD)
-Operationally produced

“Pre-Operational”
-Partly Validated
-key users interested
-peer-reviewed,
- documented (ATBD)?

“Experimental”
-locally developed
-Potential users identified
-peer-reviewed?

Continuous Evaluation by Users & Reference Group and AusCover Team

Quality Assurance & Complementary Datasets
Spectral library data, satellite calibration files, in-situ validation data, online protocols, climatology, topography, soils, etc. (tbd)

Interim “Core” Land-Products (1)

(locally maintained and accessible via each AusCover node)

Initial focus will be on existing **national** datasets, with some level of QA/QC already available, and underpinned with well documented algorithm development & validation data.

Year 1

National Scale - Coarse Resolution:

- 25+ year NDVI (AVHRR) (’92-present 1km) (+2 band TOR) –netCDF/HDF +(documented)
- MODIS Land Products (Land Cover, NBAR, albedo, NDVI, EVI, LAI, FPAR; LST, BURNED AREA etc.) for Australia (from year 2000 onwards)
- MODIS Land reflectance (NBAR) composites for Australia (historical data from 2000 onwards)
- ESA-produced Globcover
- MERIS/AATSR – fPAR data

National Scale - Medium-resolution (<50):

- Medium-resolution data layers of land-cover types
- Vegetation-cover trends (from CSIRO ‘VegMachine?)
- Time-series of forest, non-forest cover.
- National control point chip library, topography
- Climate Data: Met. Data: Rainfall, Air temp, RH, wind, Solar exposure
- Atmospheric Characteristics eg optical thickness for atmospheric correction, Pressure, column Water vapor, ozone

Local Scale – Medium + High Resolution:

- Time-series Landsat reflectance for key validation & demonstration sites
- Spectral libraries (vegetation, soils)
- Radiance from vicarious calibration targets.
- Available airborne imagery over key validation & demo sites

Interim "Core" Land-Products (2)

(locally maintained and accessible via each AusCover node)

Years 2-3

- Time-series Landsat nadir-reflectance for key validation and demonstrator sites)
- Annual (2) mosiac of Landsat data time-series (nadir-reflectance at bottom of atmosphere) corrected using standardised and agreed best-practice methods (when available)
- Validated leaf area index (LAI) and fraction of absorbed photosynthetically active radiation (fPAR) products (MODIS, MERIS-AATSR) (for validation sites)
- Vegetation structure product separating woody, herbaceous, grass and bare ground .(from MODIS)
- Bare ground/wood/litter fractions and additional vegetation structure/function metrics, all calibrated against field point/transect-measurement sites across Australia.
- Environmental 'geofabric' datasets of value in ecosystem modeling would also be available via this TERN facility. These would include spatial datasets on topography, soil chemistry, structure, soil moisture, soil carbon content, mineralogy, climate variables, etc.
- <u>Site-based, High Resolution (<1m – 5 m)</u>:
- \- Where available, geo-, orthorectified and radiometrically corrected optical, radar and Lidar satellite and airborne imagery where available (e.g. Ikonos, Quickbird, Hymap, CAO, Casi, Lidar, etc.).
- \- Repository for targeted remote sensing data (airborne/satellite) collected in support of validation campaigns for TERN, as well as continental and regional TERN Hub data collection activities (campaigns might include Hymap, CAO, soil moisture instrument LIEF, etc.) building on existing supersites, such as NATT, Injune (Queensland), Tumbarumba (ACT),,…

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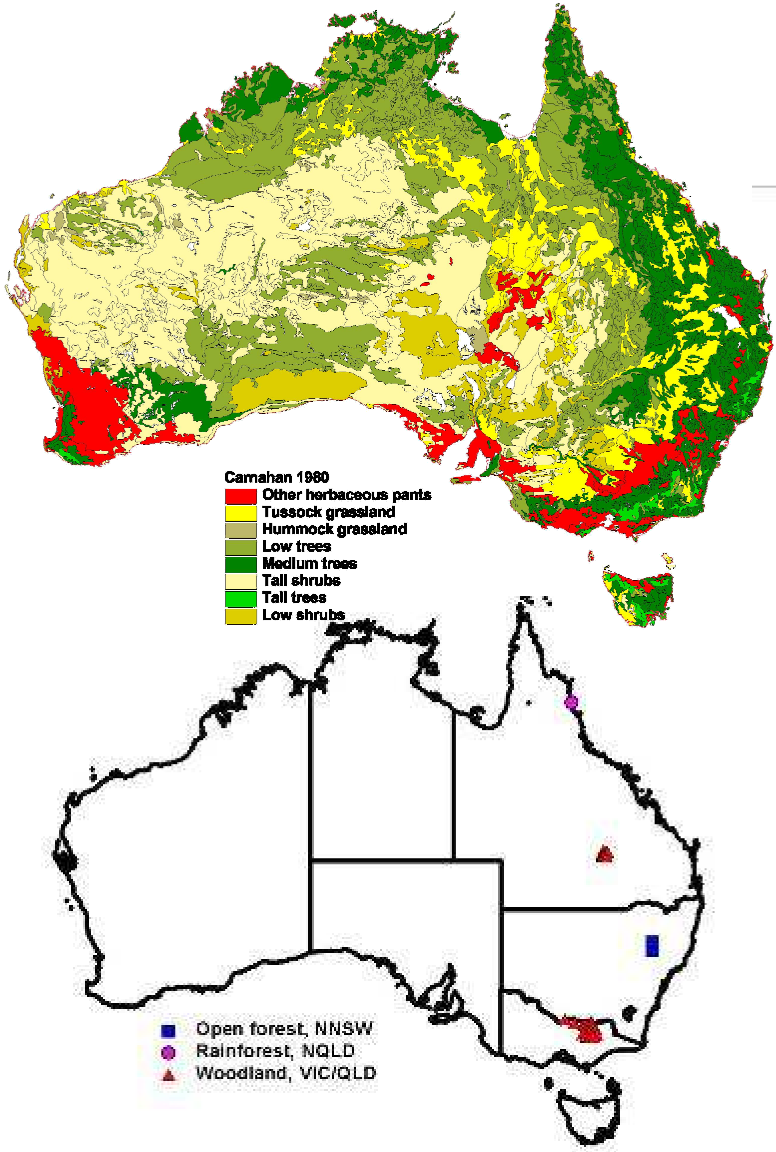
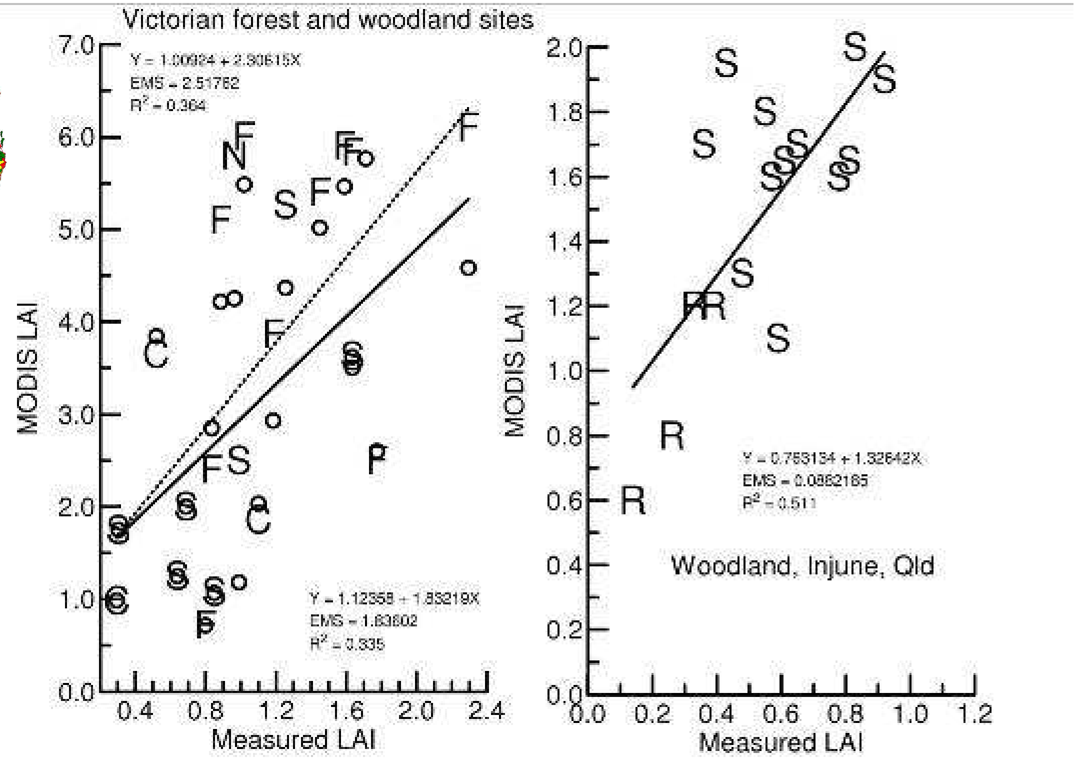
Land-Product Validation Program - a key TERN Activity



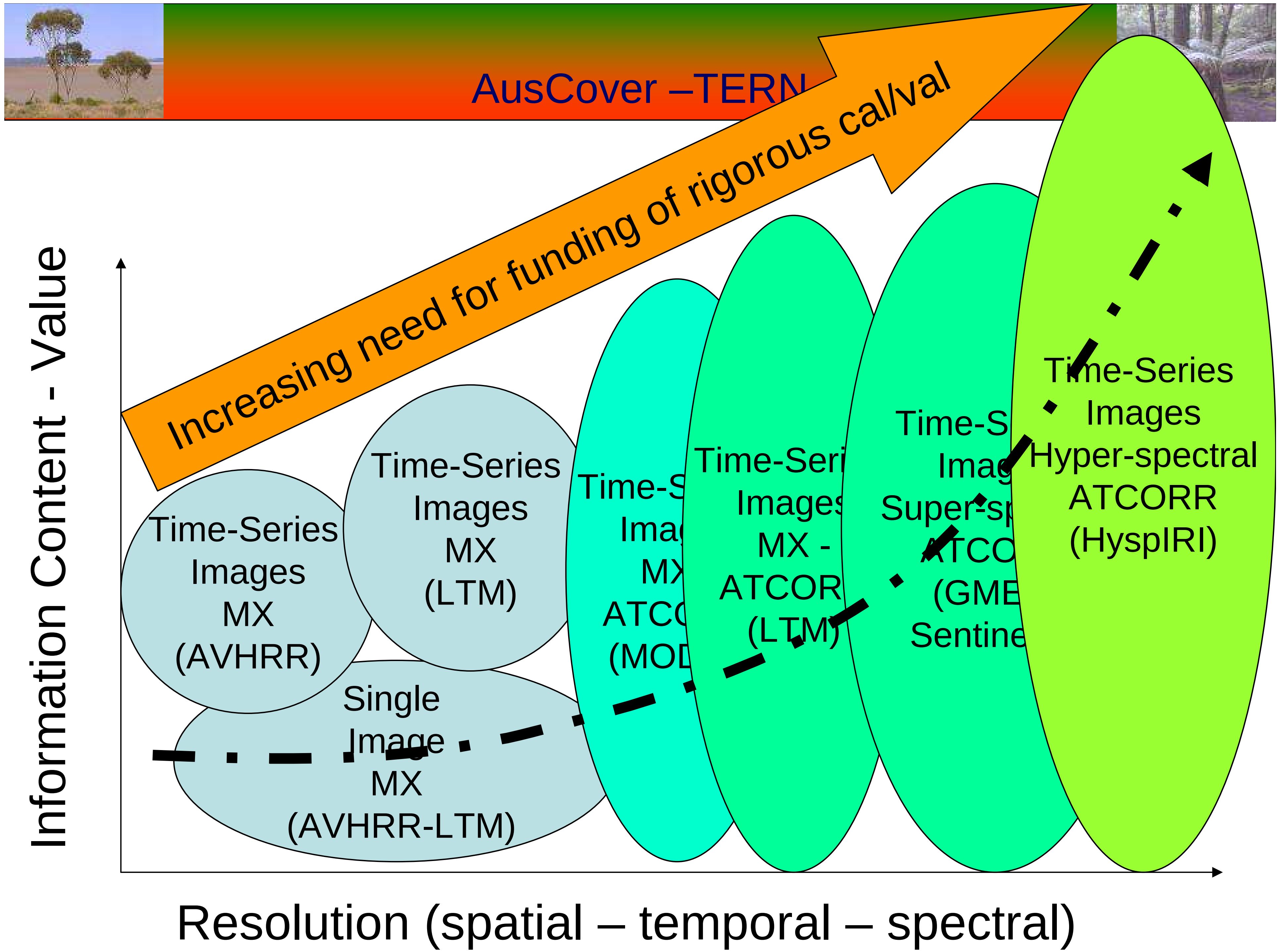


Collection 4

From Hill et al., 2005.

Validation Program – Scope (interim)

1. Establish validation framework, data needs and work plan
2. Develop & document nationally consistent validation protocols and standards
3. Establish network of validation sites with AusCover nodes
4. Linkages to other national/international programs, and TERN activities (eg EconInformatics + Fluxnet)
5. Assemble validation database (historical + new field campaigns)
6. Technical input to land-product re-processing activities by AusCover Data and Processing Team
7. Deliver data & results via AusCover portal.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Increasing need for funding of rigorous cal/val
Information Content - Value
Time-Series
Images
MX
(AVHRR)
Time-Series
Images
MX
(LTM)
Single
Image
MX
(AVHRR-LTM)
Time-S
Imag
MX
ATCO
(MOD
Time-Seri
Images
MX -
ATCOR
(LTM)
Time-S
Imag
Super-sp
ATCO
(GME
Sentine
Time-Series
Images
Hyper-spectral
ATCORR
(HyspIRI)
Resolution (spatial – temporal – spectral)

Calibration & Validation

- AusCover working definitions:
  - Calibration: Sensor radiometric & geometric performance & stability
  - Land Product Validation: Comparison and scaling of r.s.-derived biophysical products vs. in-situ measurements
  - Verification: Independent authority checks on model & r.s. high-level products- eg. cabon stocks (not in scope for AusCover)

Validation – Scope (interim)

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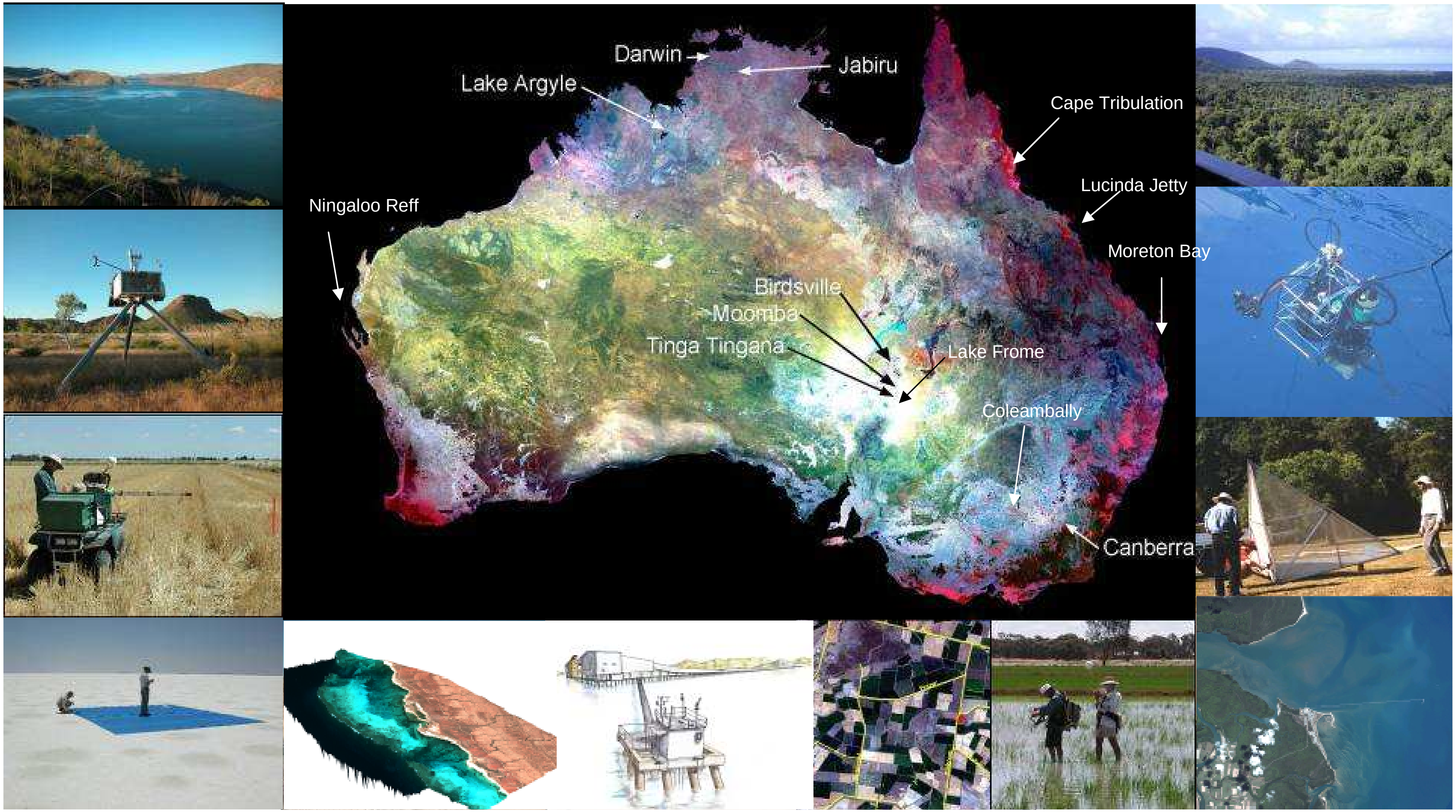
Surface types for use in **Vicarious Radiometric Calibration** and for Biophysical Land Surface **Product Validation**



Site Selection

(we can't do them all in the first round)

1. Sampling / Stratification
   - Which biomes / ecosystems are we trying to characterise?
   - Supersites vs. many sites

(making the activities relevant to RS & ecological, envi management communities)

2. Compatibility / Synergy with existing CALVAL activities
   - CEOS / International sites (Bigfoot & VALERI)
   - Past / current Australian activities

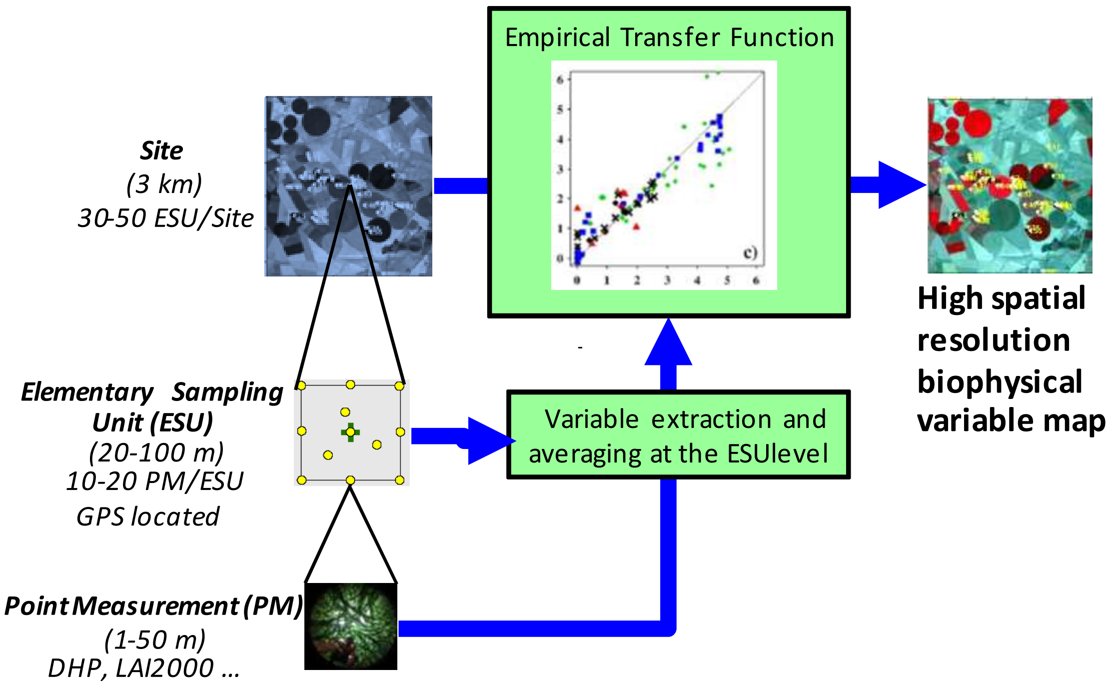
3. The measurements (& products validated)
   - *Absolute & Relative* Validation data / methods
   - Site hierarchy (benchmarking, QA and data quality)

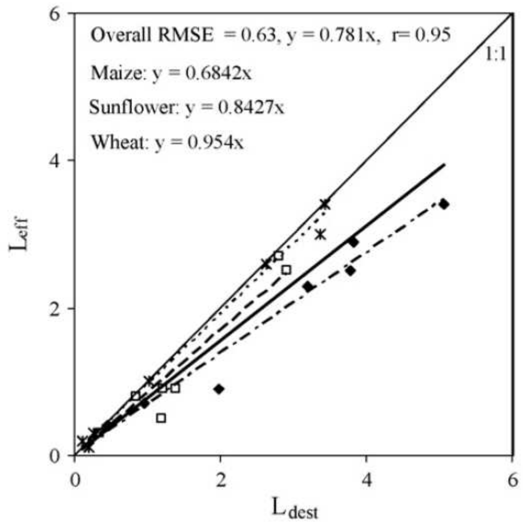
(not re-inventing the wheel)

Data sets for validation: measurement

Reference measurements

- interpretation by experts based on HSR images (land-cover, fire etc.)
  - definition of the variable measured
- quantitative measurements (albedo, LAI-fAPAR, LST&E , moisture)
  - footprint and scaling





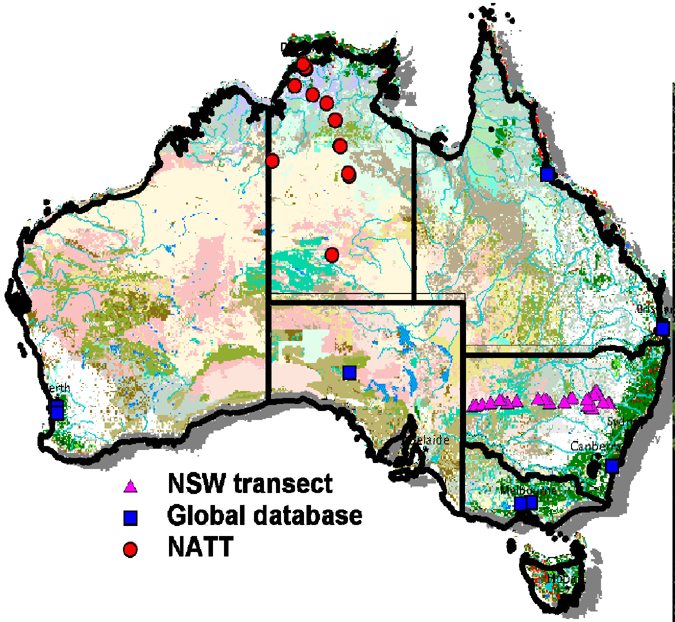
Need for high spatial resolution images (Landsat/SPOT)

Slide from F. Baret, J. Nightingale, S. Garrigues, J. Nickeson

Validation of MODIS Land Products

Product	Name	Stage	Accuracy
MOD09	Land Surface Reflectance	2 (3)	+/- (0.005 + 5 %)
MOD10/29	Snow / Sea Ice	2 / 2	92 %
MOD11	Land Surface Temperature	2	+/- 0.5-1.0 K
MOD12	Land Cover / Dynamics	2 / 1	> 75-80 %
MOD13	NDVI / EVI	2 / 2	+/- (0.002 + 2%)
MOD14 MCD 45	Active Fire Burned Area	2 1 (2)	100 m2 @ 800 K 75%
MOD15	LAI / ƒPAR	2 / 1	+/- 0.50-0.66 / +/- 0.12
MOD17	GPP / NPP	2	+/- 10%
MOD29	Sea Ice	2	92%, +/- 1.3 K
MCD43	BRDF / Albedo	1	+/- 5%
MOD44	VCF / VCC	1	+/- 11-16 %

Extensive vs. Intensive Validation



Establishing a National Protocol

- canopy multispectral reflectance (nadir or bidirectional)
- leaf spectra (reflectance and transmittance)
- background nadir spectral reflectance (soil + litter)
- fraction of areal vegetation cover
- vegetation crown allometry (height, width, gap)
- phenology (green-up, mature, and senescent stages)
- vegetation composition (either by species or structural type)
- moisture status
- fraction of non-photosynthesizing vegetation
- meteorological data

(Morisette 2001)

Moving forward / proposed protocol

- Sampling / Stratification
  - Based on IBRA –Australian bioregions
  - Incorporates Supersites & extensive sites in a hierarchy (3?) of validations

- To use the Bigfoot / VALERI (Supersite concept) as a base to promote international standards and protocols for:
    - Field sampling
    - Scaling techniques
    - Accuracy reporting
    - Data / information exchange
  - Incorporate relevant Past / current Australian activities
  - BE SENSOR NON-SPECIFIC

- Agree / prioritise which products need validation
  - *Determine both Direct* vs. *Indirect* methods applicable
  - Embed within Site hierarchy
  - Agree on QA / metadata and data quality standards (x-ref international peer reviewed standards)

Moving forward / proposed protocol (2)

Protocol should:

- Coordinate but be inclusive in terms of allowing different communities to compare & cross validate their field methods / protocols
  - (Embedded within Site hierarchy?)

- Encompass diverse *in situ* methods needed to capture biophysical information (across many biomes)
  - Too ambitious?

- Allow *continuous improvement* of LC products

- All validation data must conform to a base set of standards
  - (Agree on method and data quality standards)

- Taken as a whole the dataset must be comparable / form part of international CALVAL efforts

Site characterisation

- BRF and BDRF
- Spatial and temporal variability and stability

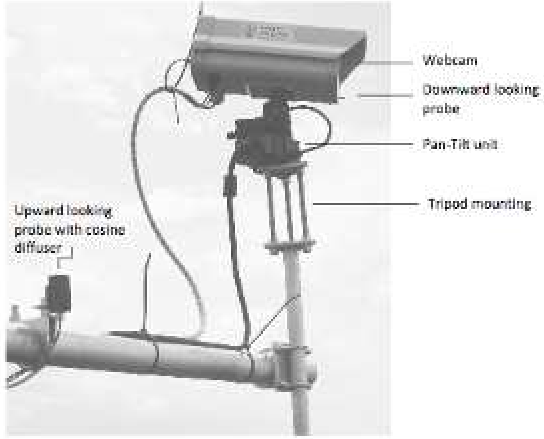
Need to support this with airborne data? – We probably should

NPL/FSF GRASS goniospectroradiometer

Autonomous Instrumentation

- Further research needed into this
- Smarter in situ devices, continuously monitoring
- Need environmentally robust spectral measurement devices

Meteorological stations



AMSPEC II system

AERONET site

L-Spec system