Removing cloud from moderate resolution imagery

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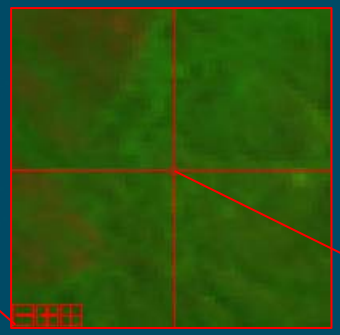
NEO cloud removal methodology

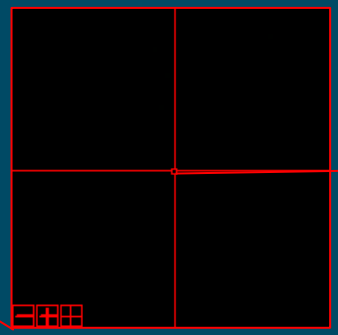
Horizon 1 goal: Generate cloud free annual composite image (IFCI deliverable)

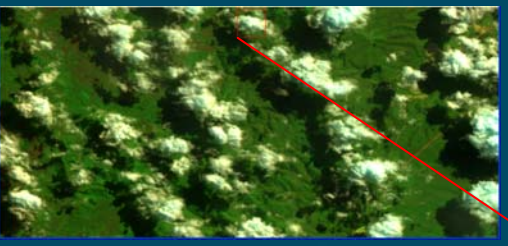
Horizon 2 goal: Remove every cloud affected pixel from every moderate resolution scene

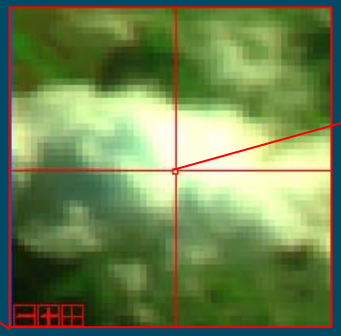
Generating cloud free composites in heavily cloud effected environments

- Step 1. Create a stack of georeferenced scenes
- Step 2. Sort each pixel from brightest to darkest using blue band reflectance
- Step 3. Retrieve non-cloud effected pixels from the sorted stack







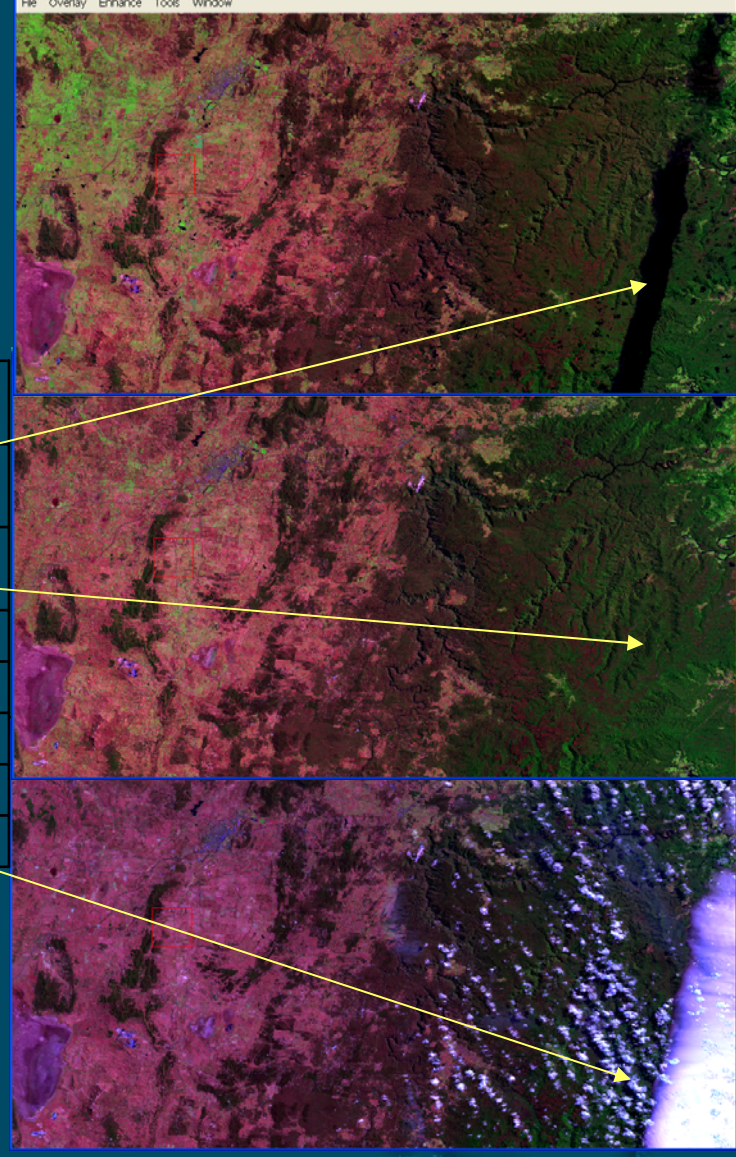


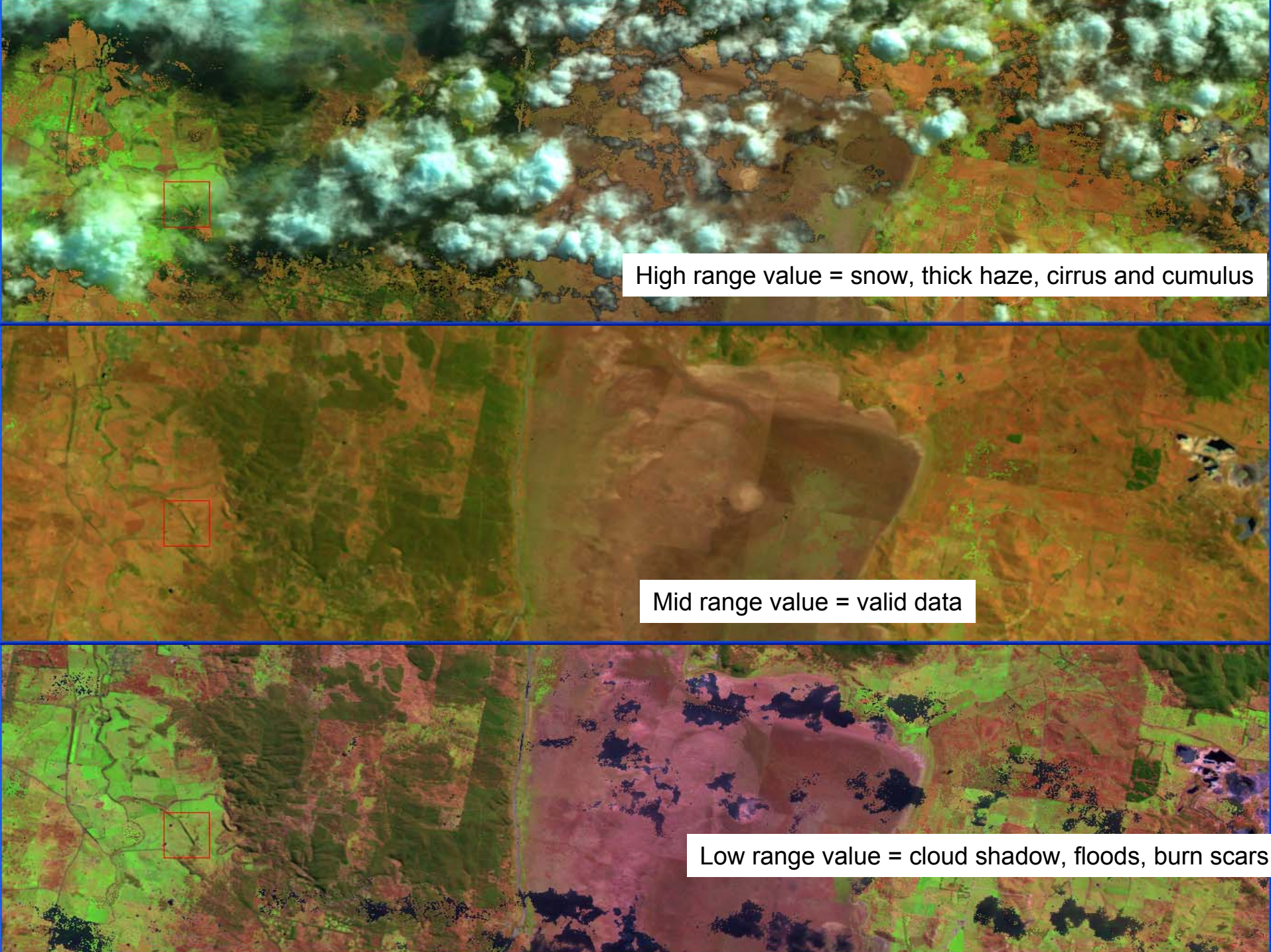
Blue band values for a single pixel sorted by date

Date	Blue Band Reflectance	Quality Flag
27/09/2009	501	Valid data
17/01/2009	15	Cloud shadow
06/03/2009	508	Valid data
07/04/2009	4300	Cloud
29/08/2009	520	Valid data
14/09/2009	555	Valid data
30/09/2009	3500	Cloud

Sort blue band values by reflectance

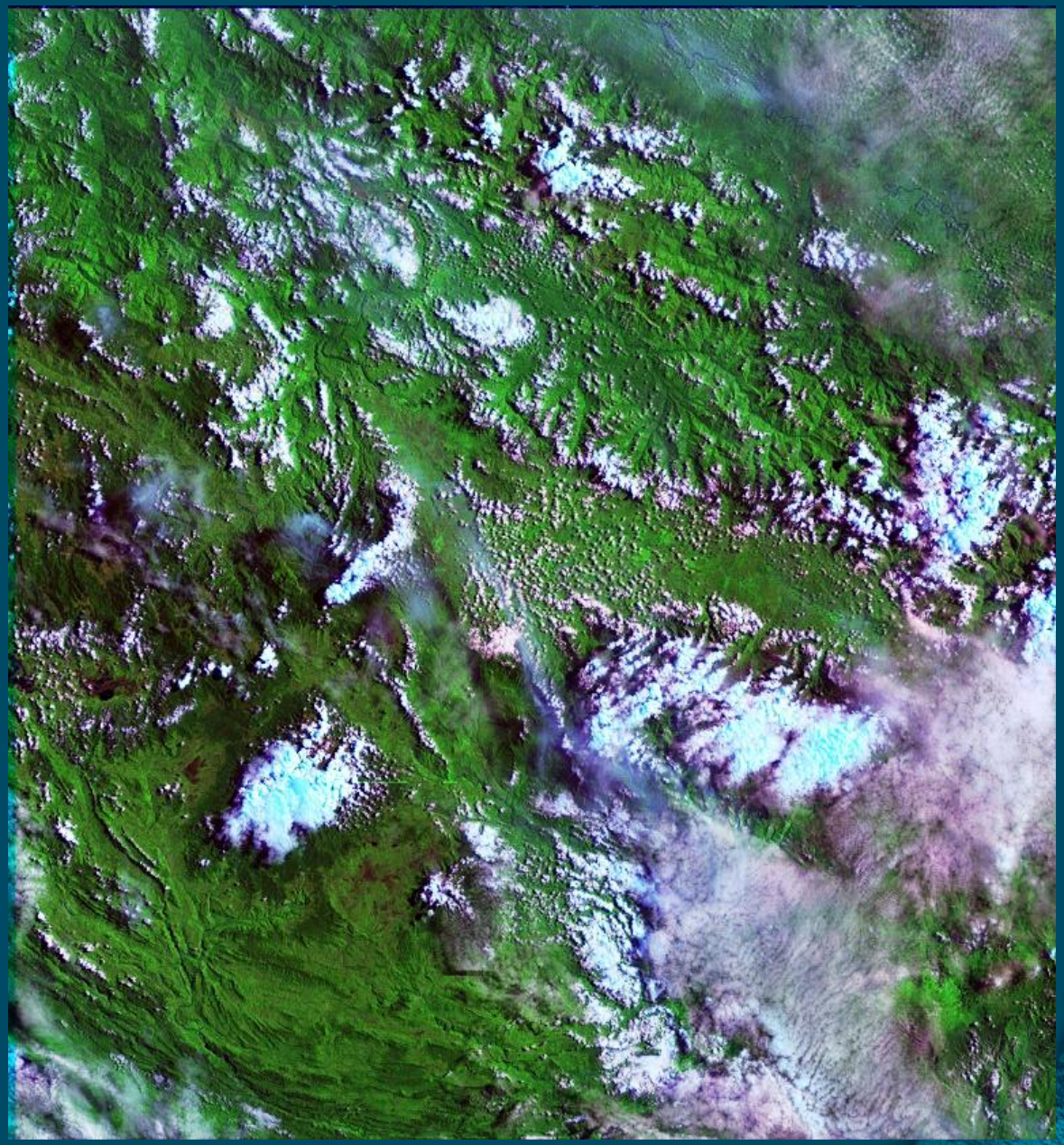
Date	Blue Band Reflectance	Quality Flag		Date	Blue Band Reflectance	Quality Flag
27/09/2009	501	Valid data		17/01/2009	15	Cloud shadow
17/01/2009	15	Cloud shadow		27/09/2009	501	Valid data
06/03/2009	508	Valid data		06/03/2009	508	Valid data
07/04/2009	4300	Cloud		29/08/2009	520	Valid data
29/08/2009	520	Valid data		14/09/2009	555	Valid data
14/09/2009	555	Valid data		30/09/2009	3500	Cloud
30/09/2009	3500	Cloud		07/04/2009	4300	Cloud

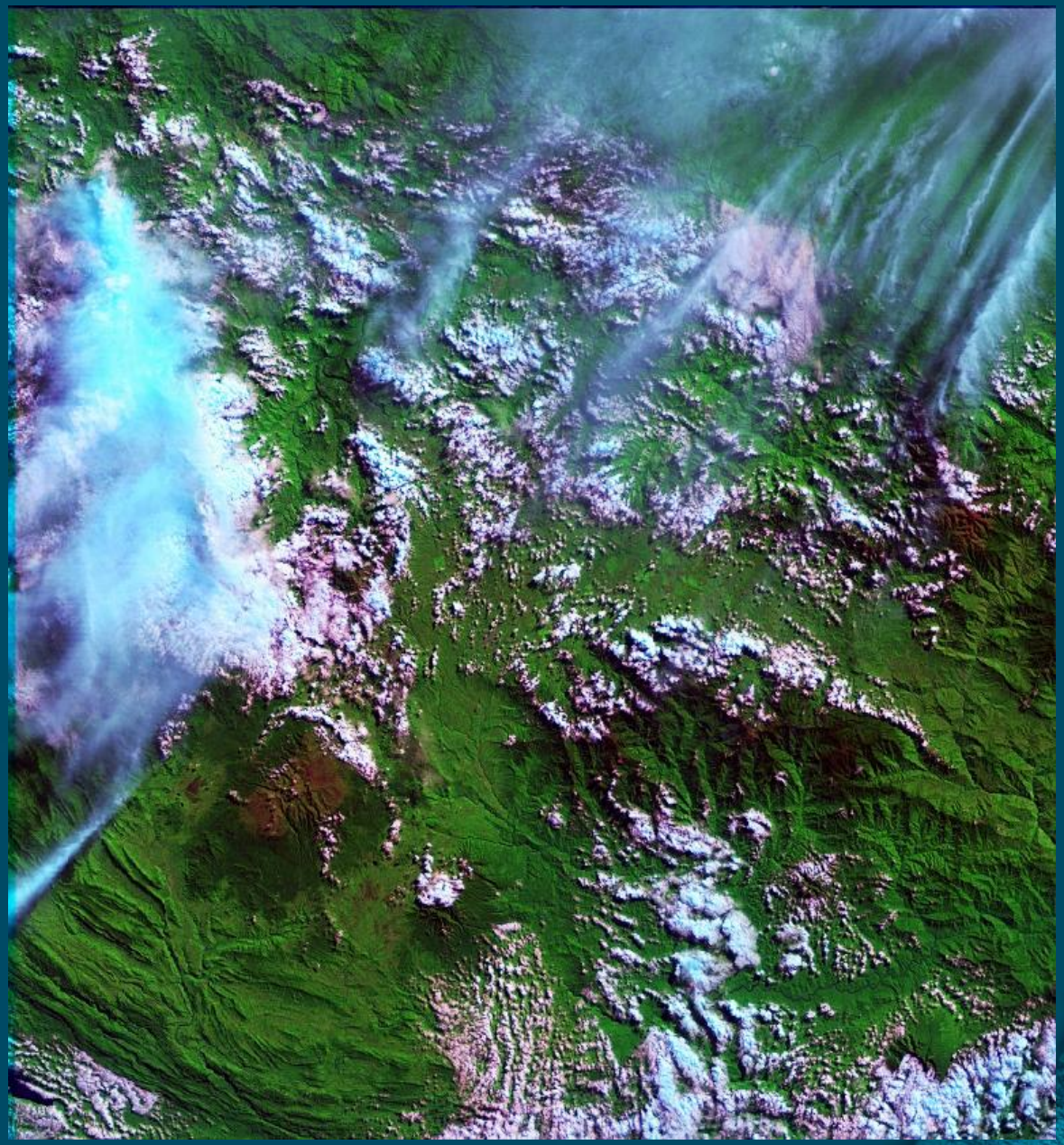


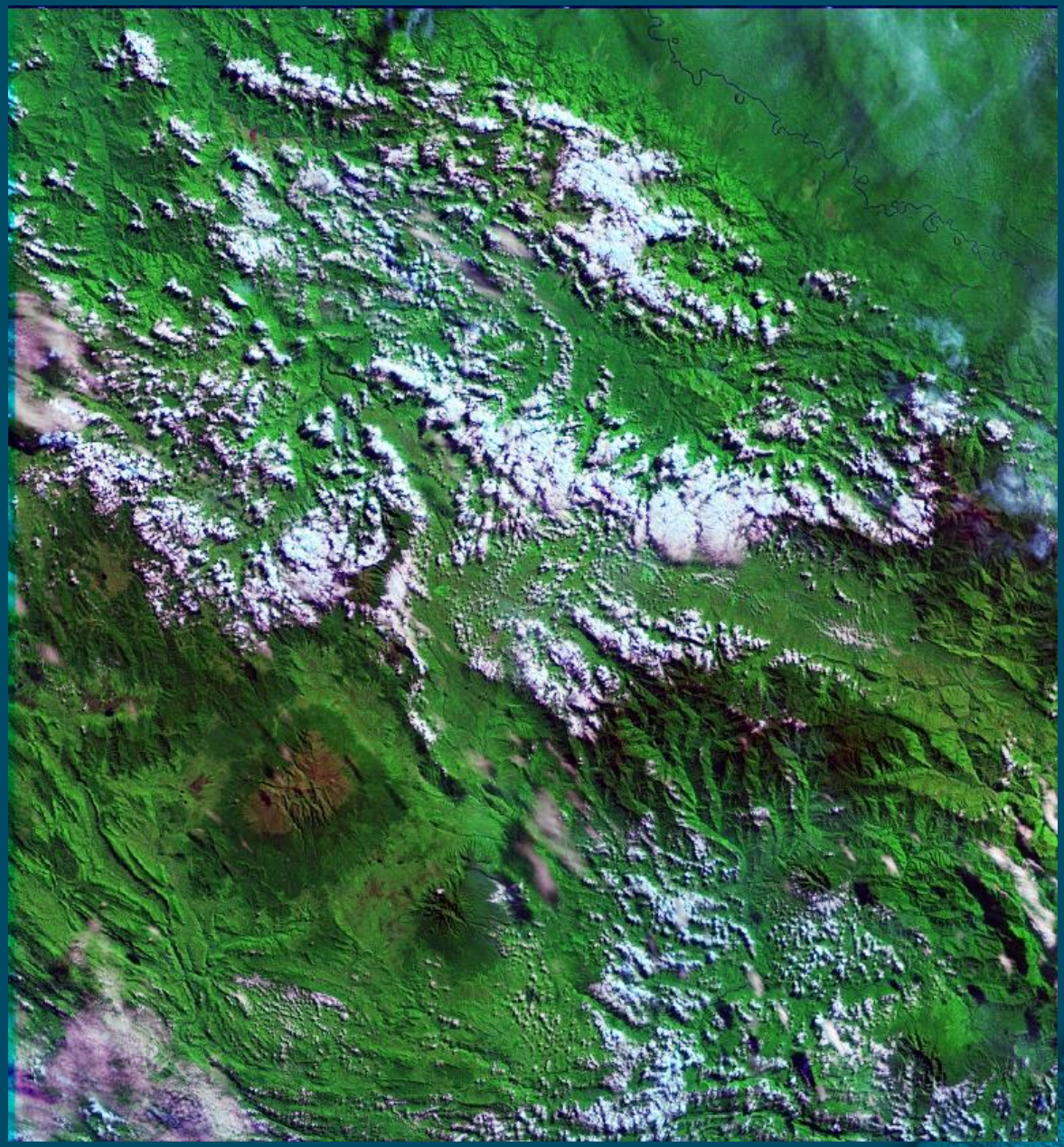

High range value = snow, thick haze, cirrus and cumulus
Mid range value = valid data
Low range value = cloud shadow, floods, burn scars

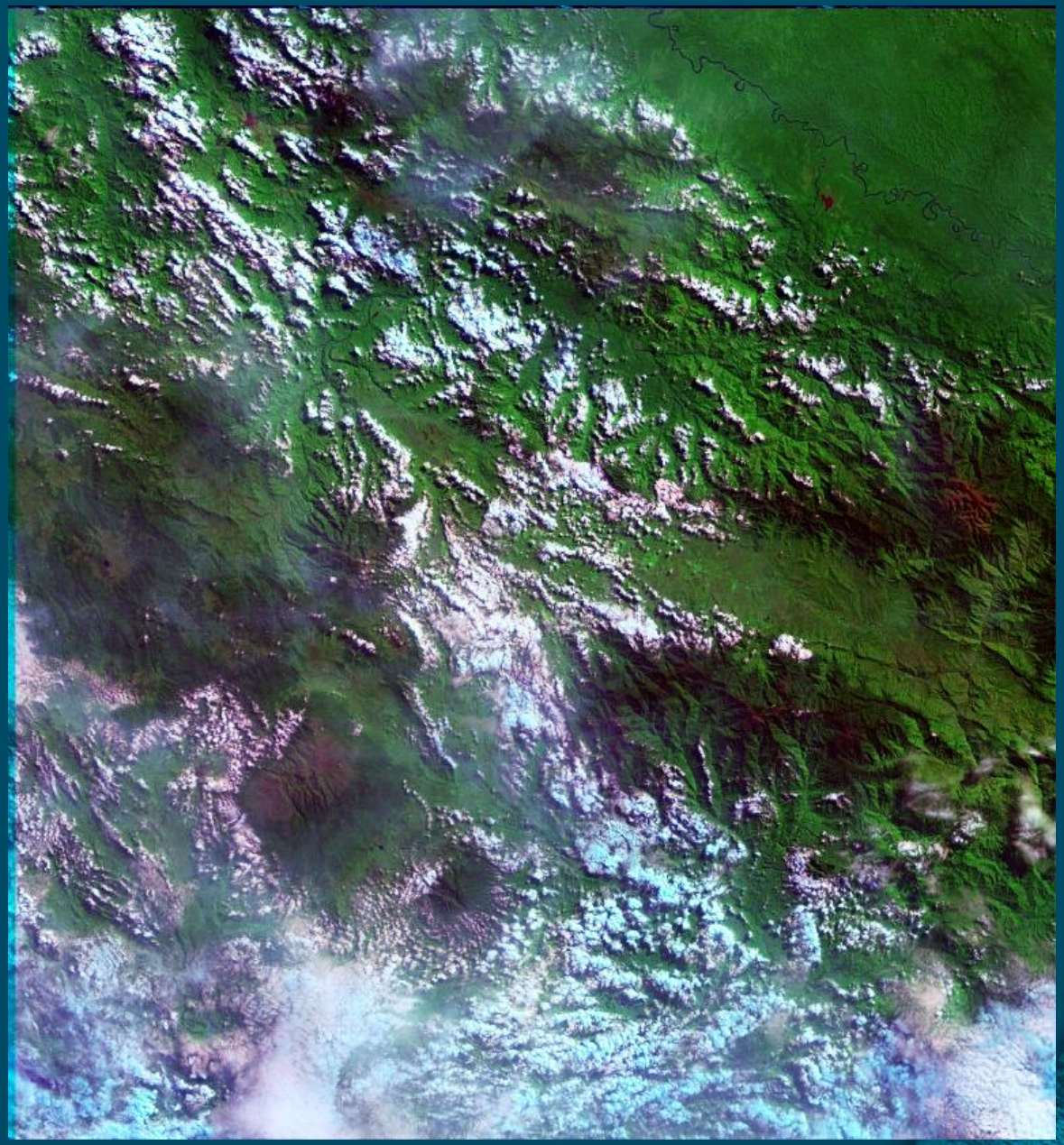
Works nicely in less cloudy environments like SE Aust…

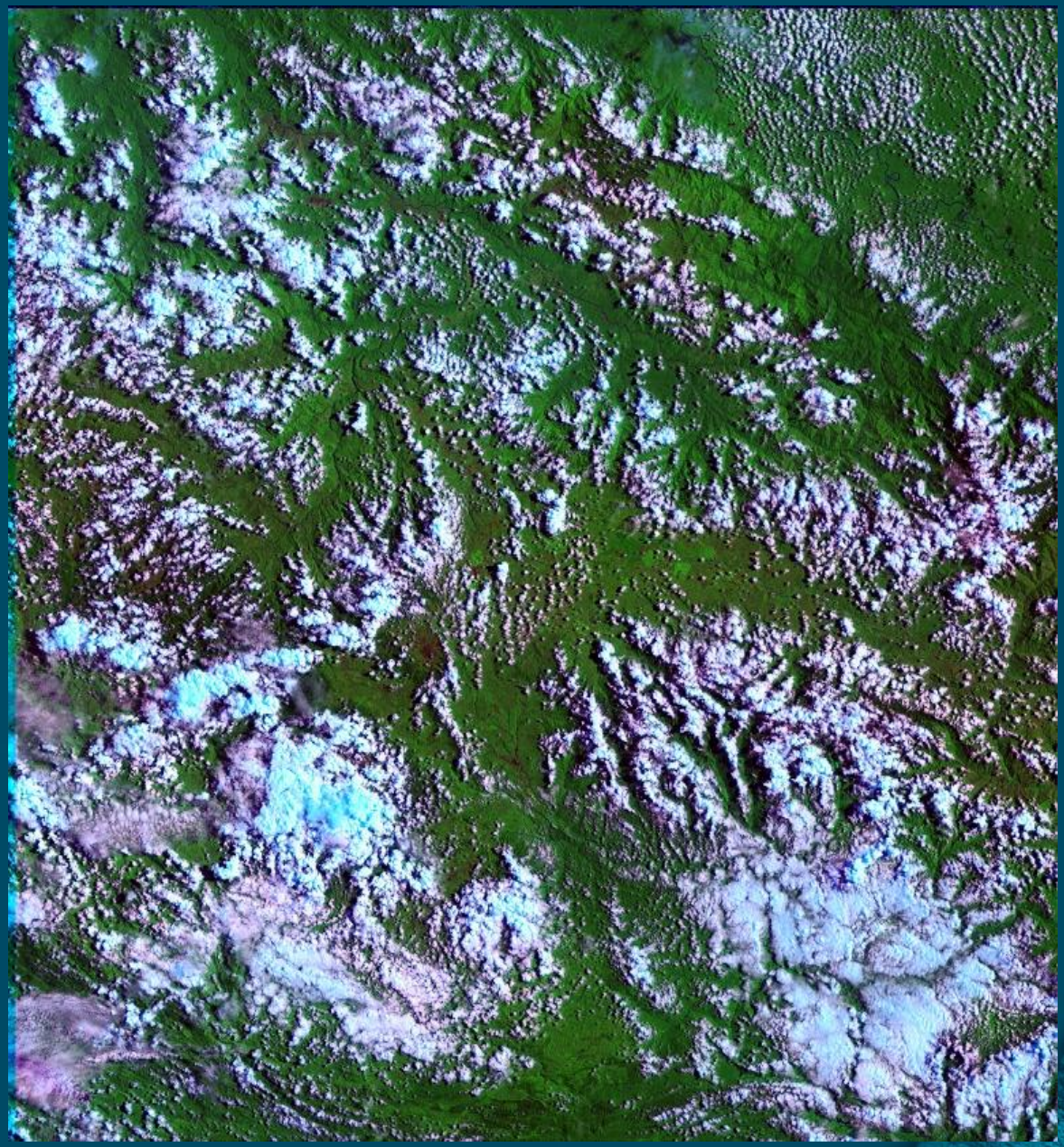
- But what about heavily cloud effected environments like Mt Hagen in PNG?

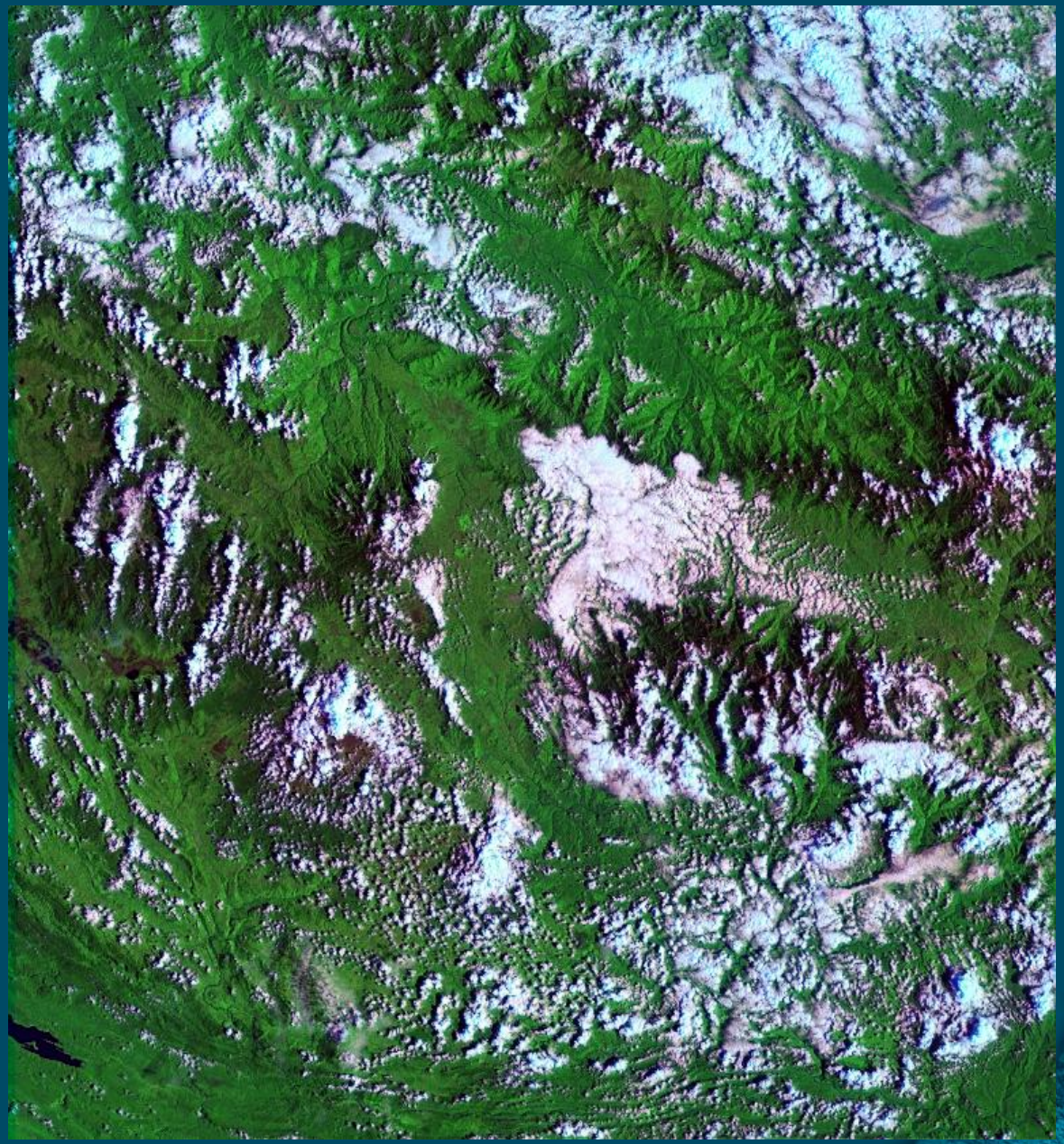




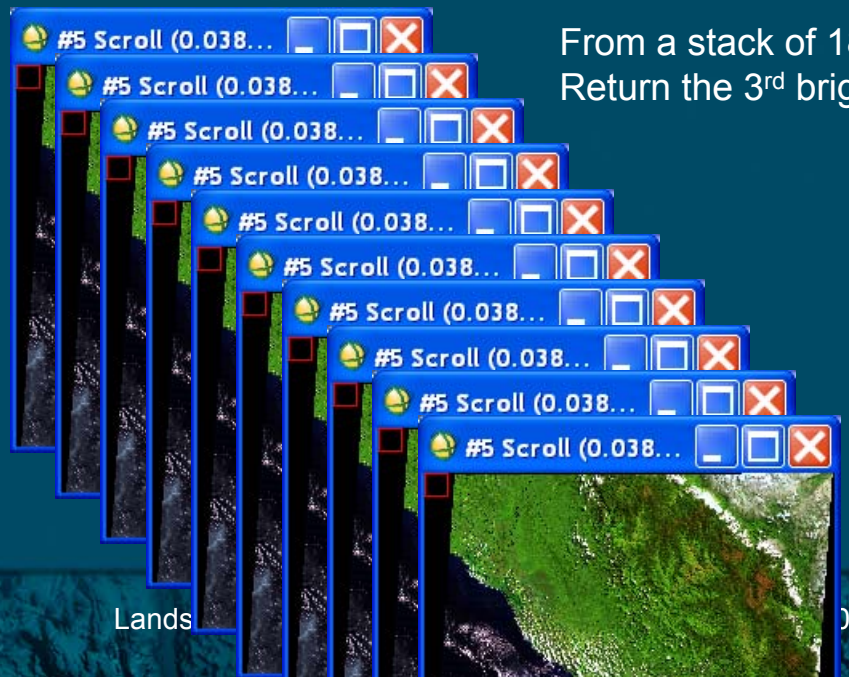






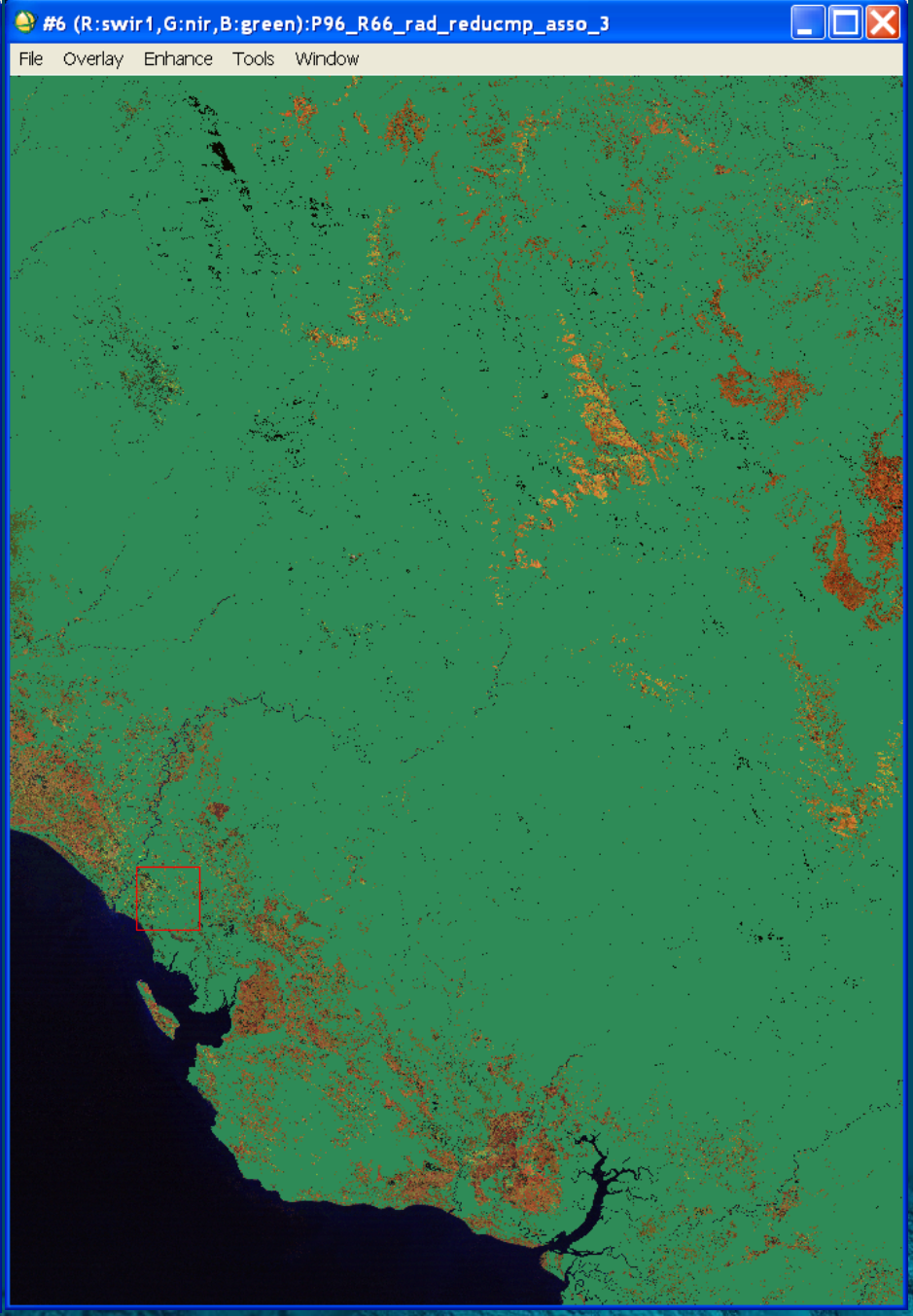


Or path 96 Row 66



From a stack of 18 images
Return the 3rd brightest value

#6 (R:swir1,G:nir,B:green):P96_R66_rad_reducmp_asso_3
File Overlay Enhance Tools Window


#6 (R:swir1,G:nir,B:green):P96_R66_rad_reducmp_asso_3
File Overlay Enhance Tools Window

Next steps

Sort blue band values by reflectance

Date	Blue Band Reflectance	Quality Flag		Date	Blue Band Reflectance	Quality Flag
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17/01/2009	15	Cloud shadow		27/09/2009	501	Valid data
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07/04/2009	4300	Cloud		29/08/2009	520	Valid data
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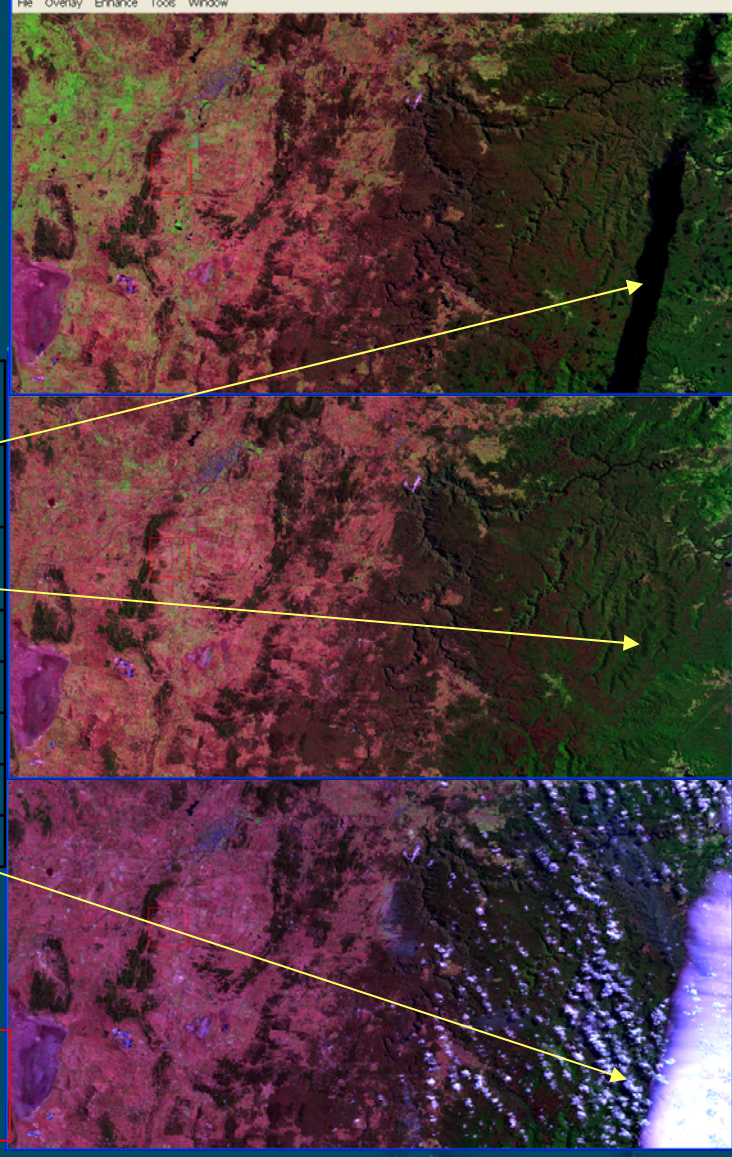

Define range of cloud free values to provide a more sensitive Cloud detection capability

Challenges in defining range

- The range of valid cloud free data varies from pixel to pixel depending on land cover
- Classic chicken and egg problem
- Solution: a statistically based approach
- Use the SD of pixel blue band values to identify if cloud present at any point in time
- Assumption: if cloud is present at any point the SD of the blue band will be high

To Define range

- If clouds are present in the stack:
  - Defined as Std Dev of blue band values > low threshold, then
    - If pixel blue value < mean blue value for that pixel through the stack
    - AND the pixel NIR value > (mean NIR - Std Dev NIR) then the pixel is cloud and shadow free.
- If clouds are not present in the stack:
  - Defined as Std Dev of blue band values < low threshold, then
    - If pixel NIR value > (mean NIR - Std Dev NIR) then the pixel is cloud and shadow free.

Range definition approach

- Tested across 4 years of 15 different land cover types
- Accurate separation of cloud/shade from non-cloud 85%
- Cloud free pixel flagged as cloud/shade (omission) 11%
  - Flood and fire scars
- Cloud pixel included in the composite (commission) 4%
- Tightening of thresholds -> more omission and no commission)

New challenges presented by the range definition approach

- Which criteria to use when selecting pixels from multiple scenes
  - Use a moving window to
    - minimise variance in reflectance
    - minimise variance in date (julian day)
    - Some weighted combination of the above
- Criteria are different for
  - Annual average values for forest ID
  - Most recent cloud free pixel *i.e.* WELD
  - Weighting is different depending on phenomena of interest
    - Rapidly varying phenomena *i.e.* cropping reduced variance in date is paramount
    - Slowly varying phenomena *i.e.* forest clearing reduced variance in reflectance is paramount

Broader context within Australia

- Terrestrial Ecological Research Network (TERN)
  - Part of a national collaborative framework
  - Forum for selecting and approving nationally consistent algorithms for
    - Image radiometric calibration (atcor, BRDF, terrain etc)
    - Cloud/shadow removal
    - Compositing/mosaicking
- Queensland Department of Environment and Resource Management
  - Object oriented approach to cloud removal
    - Effective for cumulus and cumulus/cirrus mixtures
    - Currently ineffective for cirrus only
    - Collaborators within the TERN framework

Australian Government

Geoscience Australia

A PROCESSING SYSTEM FOR GENERATING STANDARD NADIR BRDF ADJUSTED SURFACE REFLECTANCE (NBAR) PRODUCTS FOR LANDSAT

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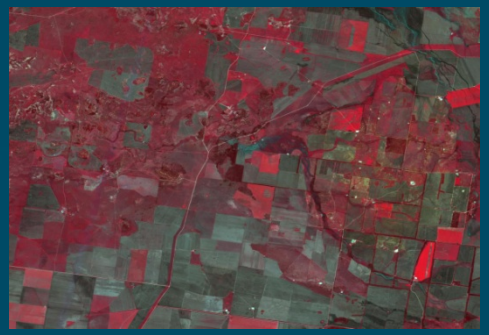
National Earth Observation Group

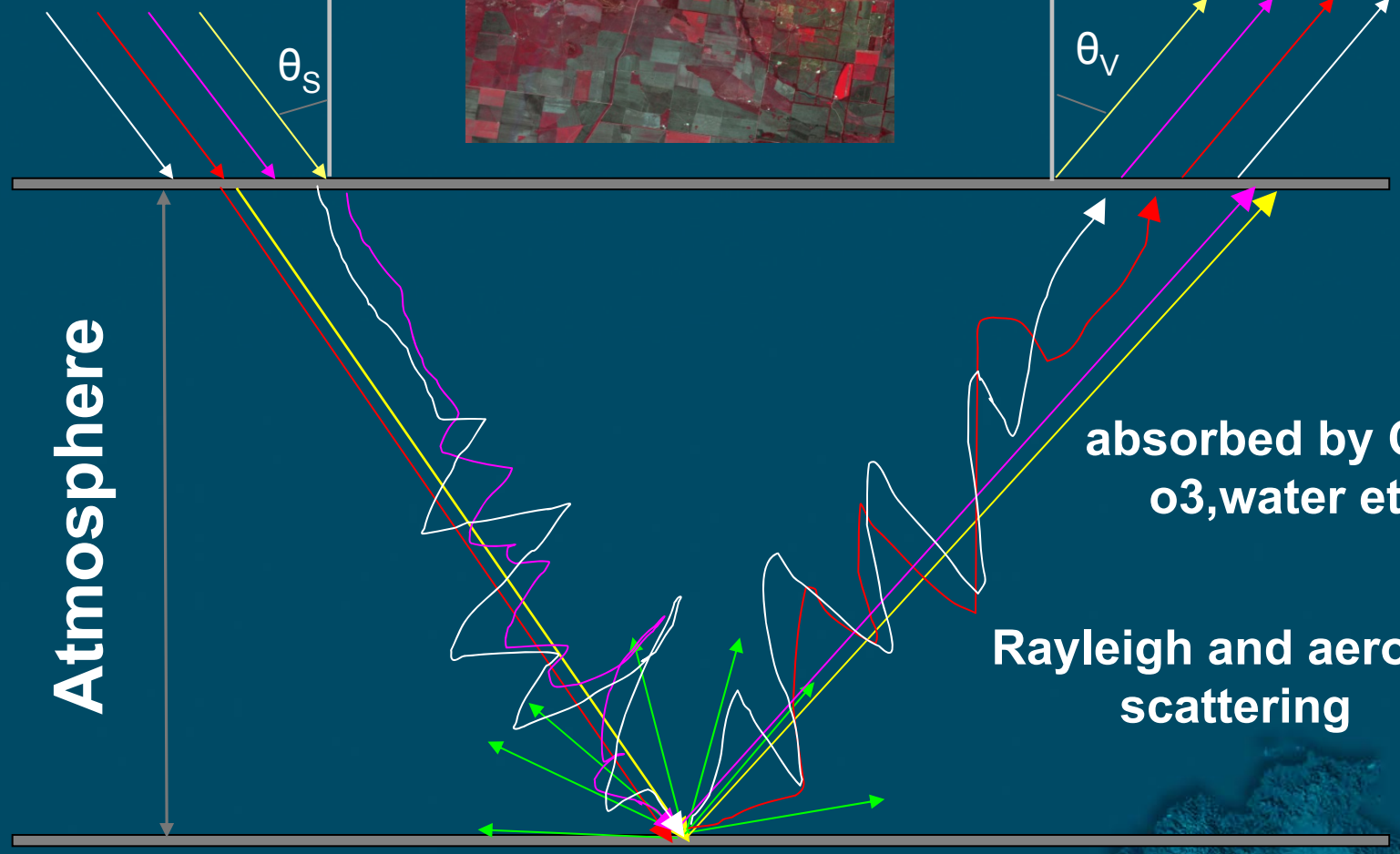
David L B Jupp
CSIRO, Marine and Atmospheric Research

Satellite data process needed

- Radiometric correction
- Geometric correction
- Atmospheric correction for thermal, visible and shortwave bands
- BRDF correction for visible and shortwave bands
- Terrain illumination correction for mountainous areas
- Preferably in units of spectral reflectance and surface temperature
- Changes in the data should represent changes on the earth surface
- The processing needs to be to an internationally acceptable standard

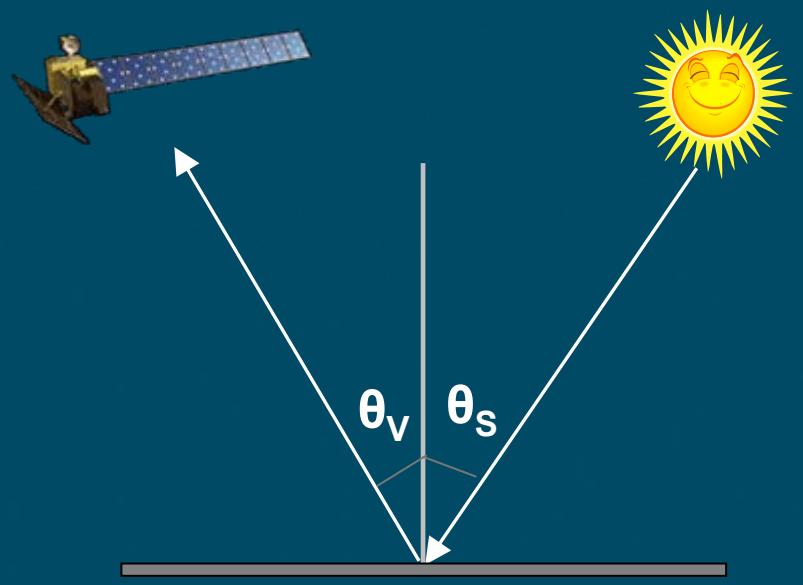
Landsat 5 false colour image



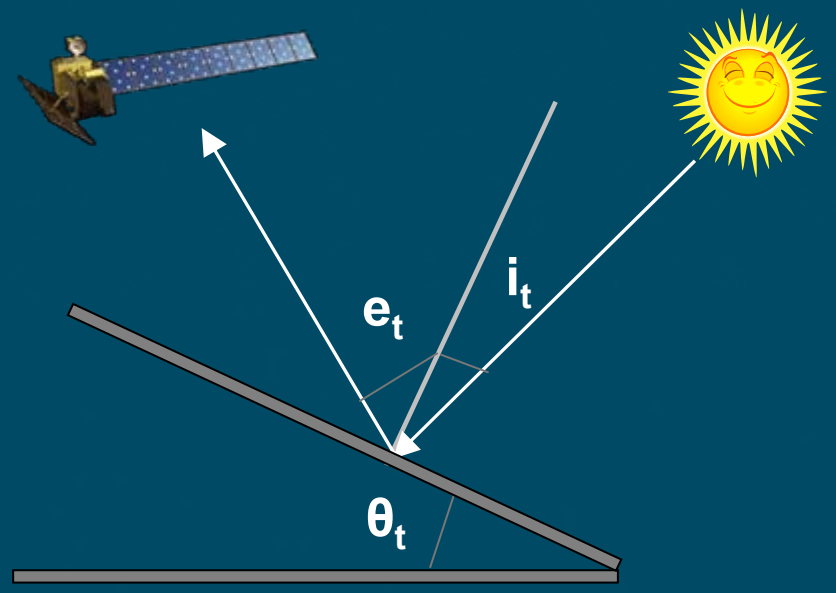


Bidirectional reflectance distribution function (BRDF)

BRDF on flat and sloping surface



Flat surface

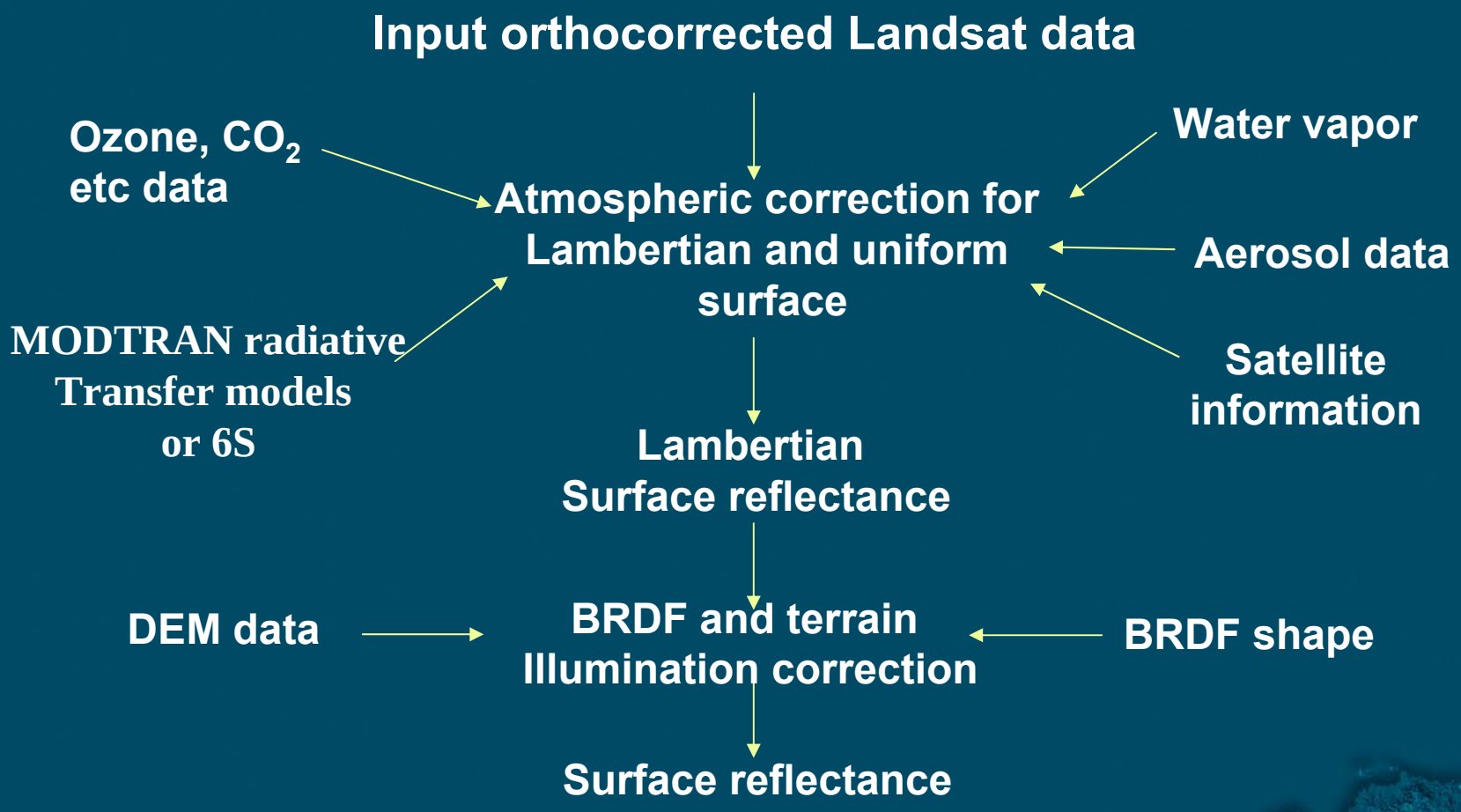


Sloping surface
slope angle θt

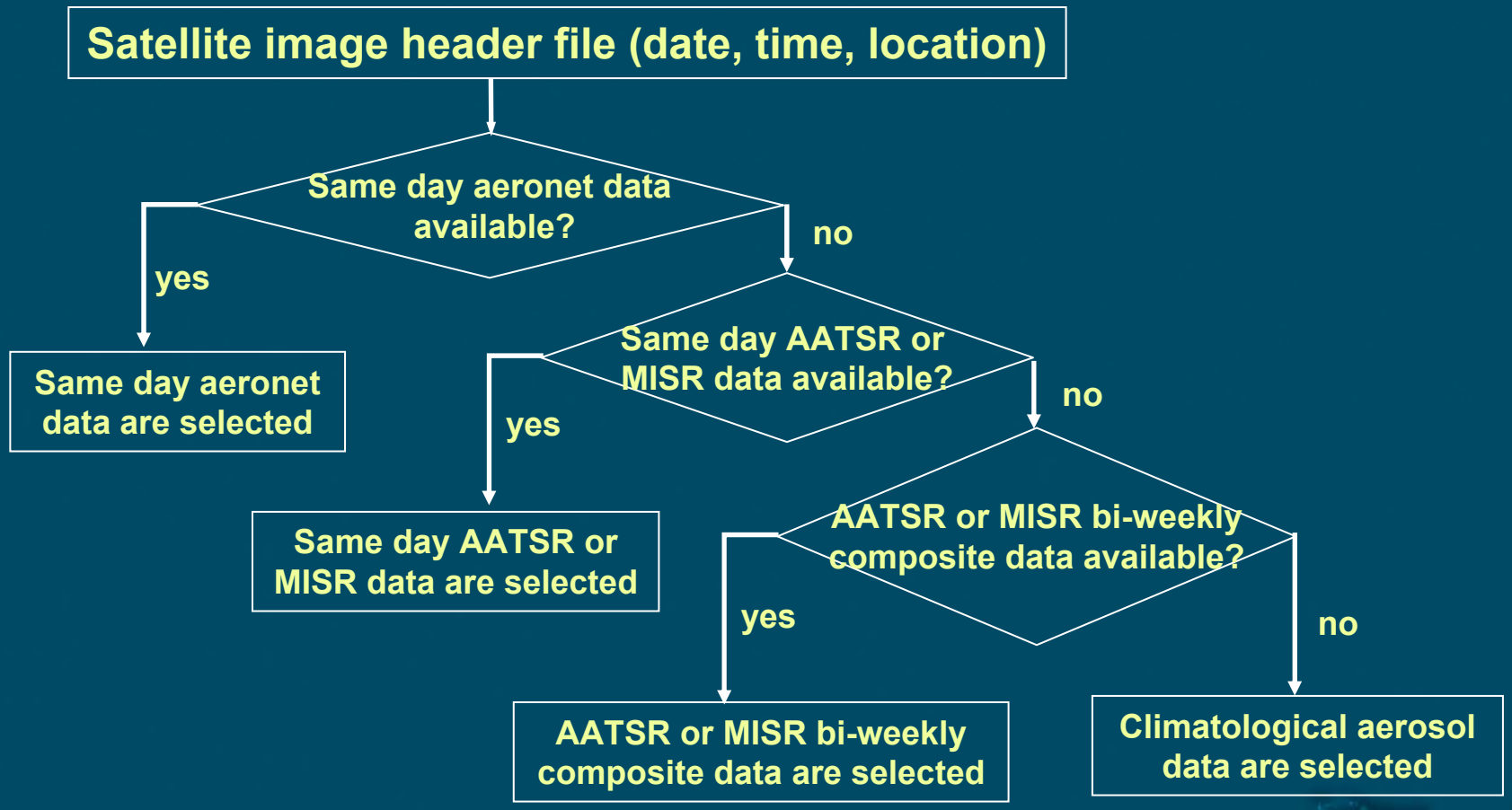
The GA Landsat NBAR product

- Set up as an add-on to GA Landsat products
- Uses physically based processing
- Independent of the image data
- Processing to surface reflectance
- Allowance for MSVA atmospheric effects
- Allowance for surface BRDF effects
- Allowance for terrain illumination correction
- Standard choices of atmospheric parameters
- Aerosol from a decision tree
- Supported by parallel Cal/Val effort

Algorithm


Input orthocorrected Landsat data
Ozone, CO_2 etc data
Water vapor
Atmospheric correction for Lambertian and uniform surface
Aerosol data
MODTRAN radiative Transfer models or 6S
Satellite information
Lambertian Surface reflectance
DEM data
BRDF and terrain Illumination correction
BRDF shape
Surface reflectance

Implementation - Aerosol Inputs



Implementation – Ozone, BRDF parameters, DEM and Water Vapour Inputs

- Water vapour data from NOAA NCEP (total water vapour) 2.5 x 2.5 degree grid data (every 6 hours)
- BRDF shape function is from MODIS BRDF parameters.
- Ozone database is monthly average from Canadian ozone maps.
- DEM data from 1sec SRTM data from GA and CSIRO

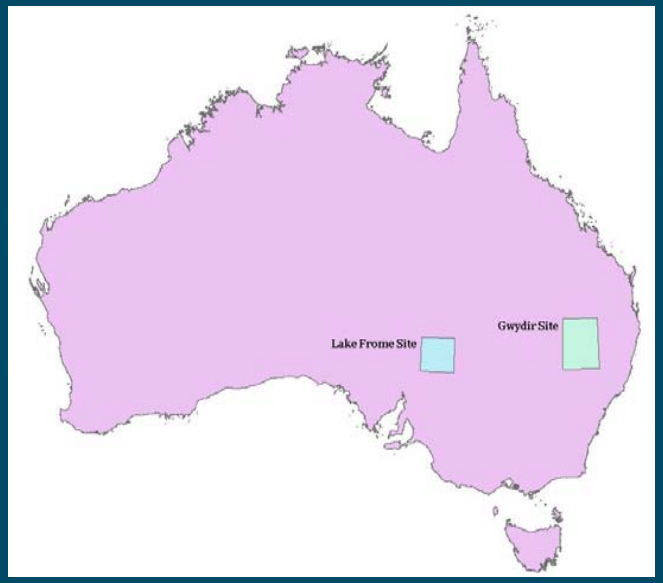
Implementation – Computational Requirements

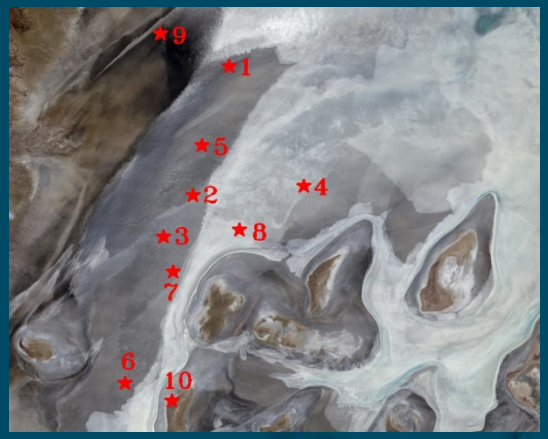
- Code and scripts have been written to automate processing of the images
- Speed 65-80 minutes/per scene implemented on a Linux platform (can be speeded up)
- Space – 1 GB for surface reflectance output, need 10 GB for ancillary input files
- The system could be located at GA or the NCI facility at ANU could be used

How was the algorithm validated?

- Field validation
- Overlap validation
- Comparison with MODIS NBAR product

Field measurements

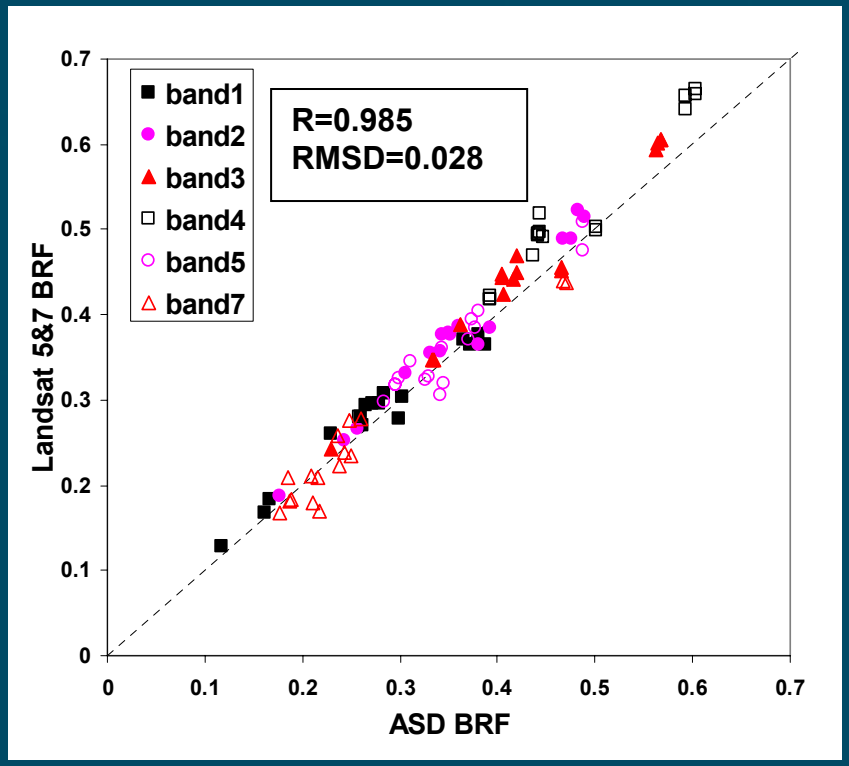


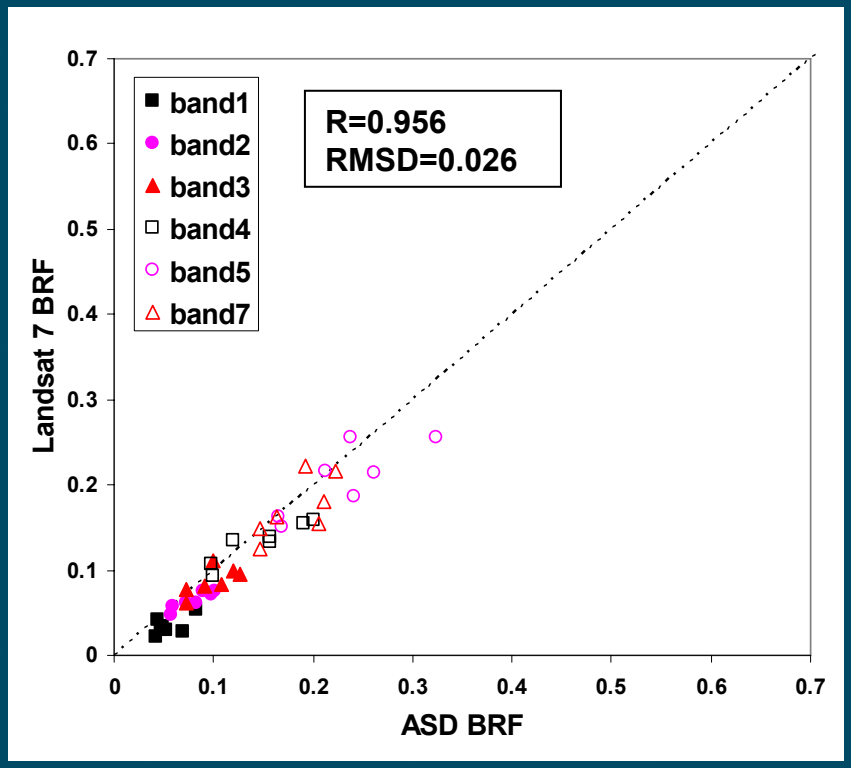


Gwydir field experiment
23/06/2008 to 25/06/2008
Northern New South Wales
bare soil and vegetation

Lake Frome field experiment
09/02/2009 to 13/02/2009
South Australia, Dry salty lake

Validation using field data

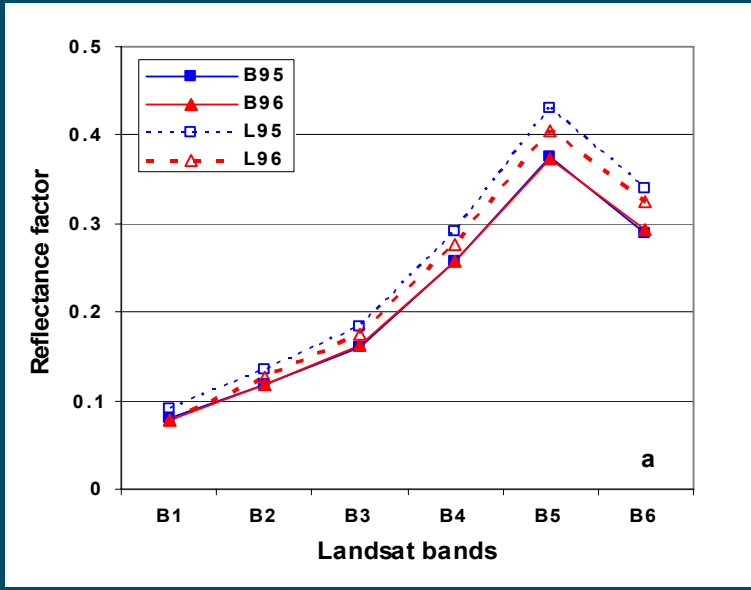


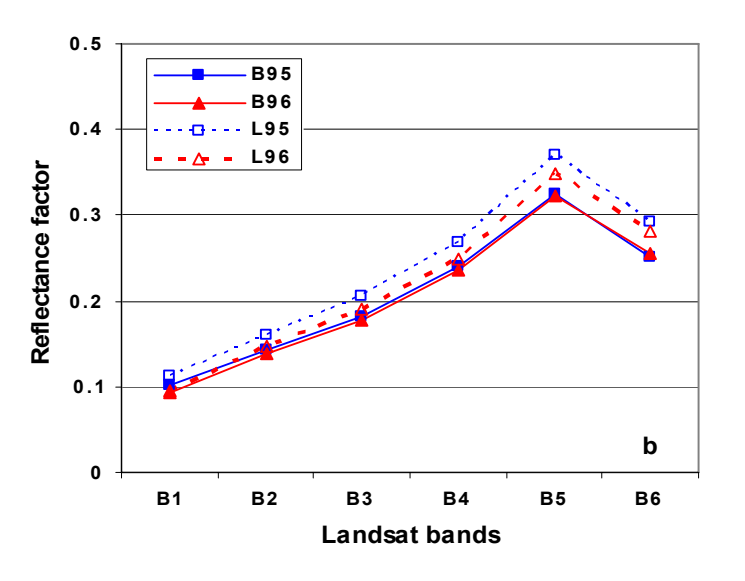


Lake Frome Field Measurement 09/02/2009-13/02/2009

Gwydir Field measurement 23/06/2008-24/06/2008

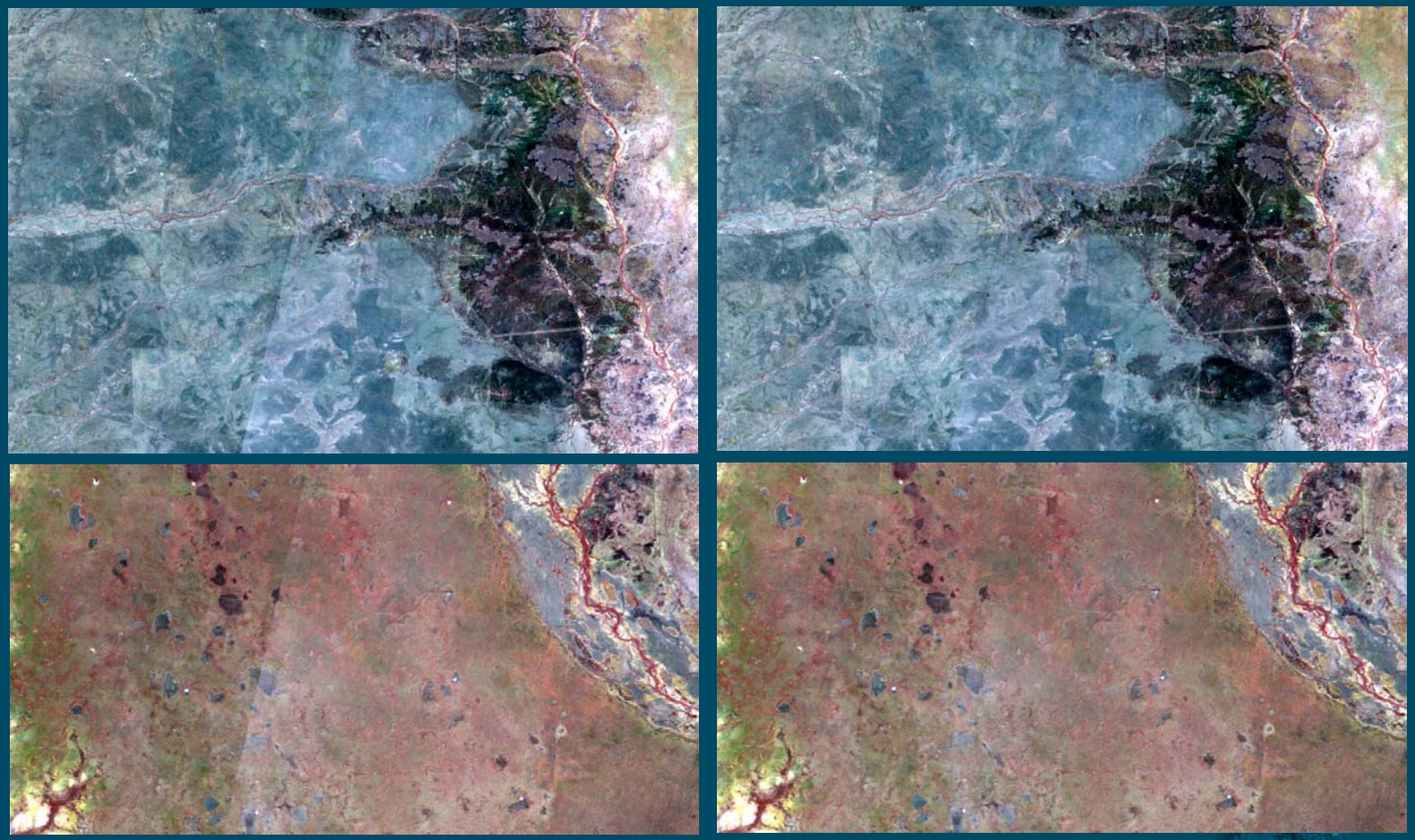
Overlap validation





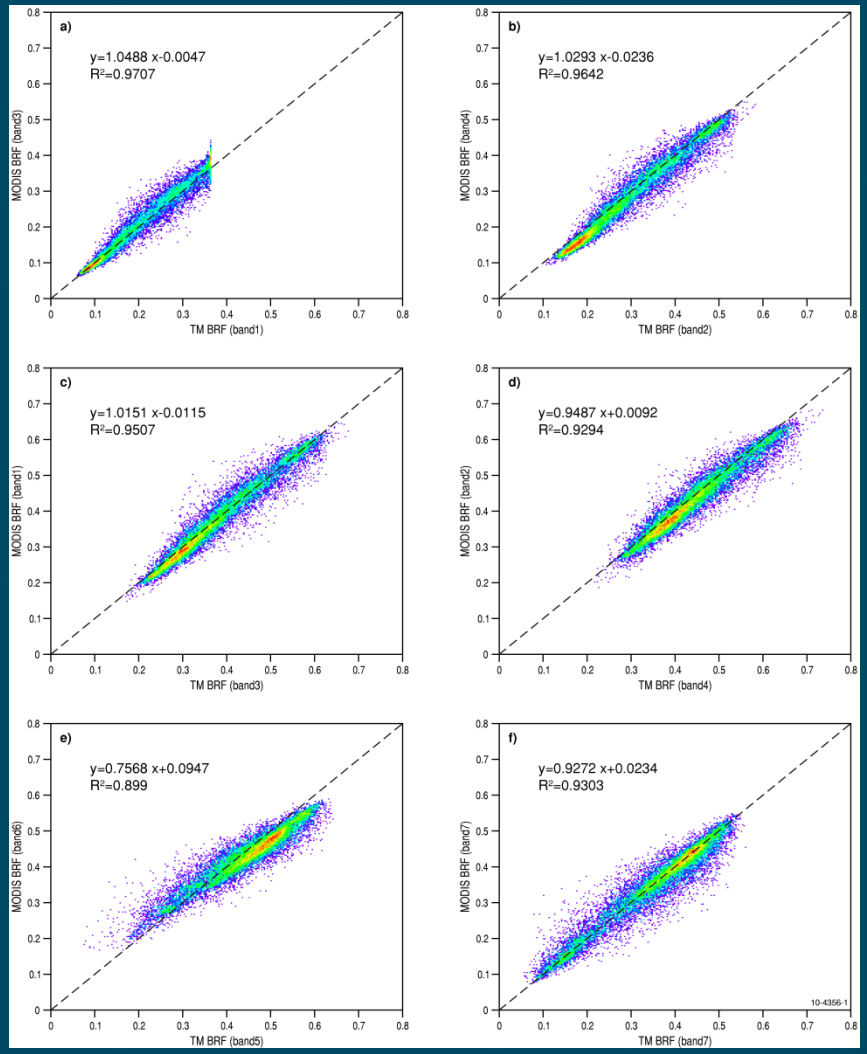
Reflectance factor products comparison computed from different processing methods for image overlap areas (a) target 1, (b) target 2. Symbols B95, B96 are reflectance factor with BRDF correction for paths 95 and 96, respectively, whereas L95, L96 is reflectance factor without BRDF correction for paths 95 and 96

Overlap validation

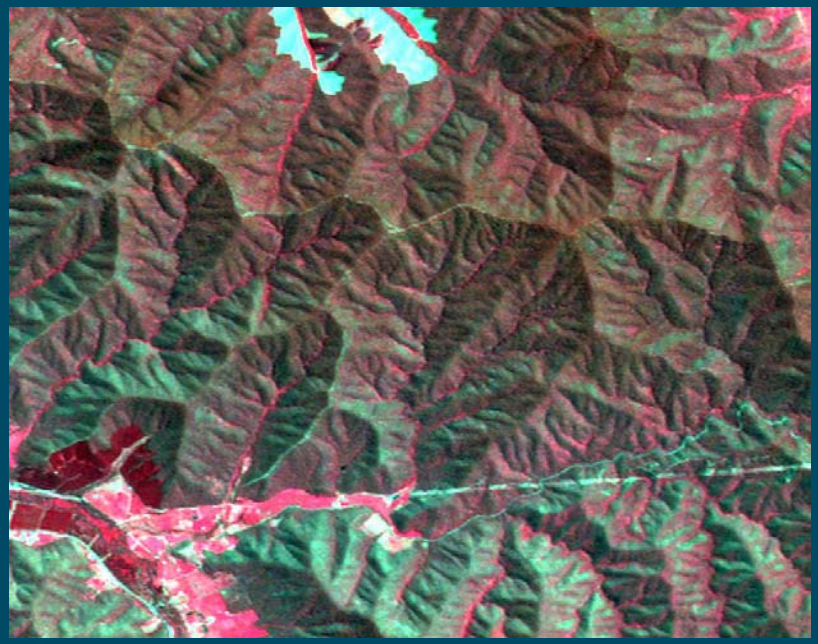


Before correction **After correction**

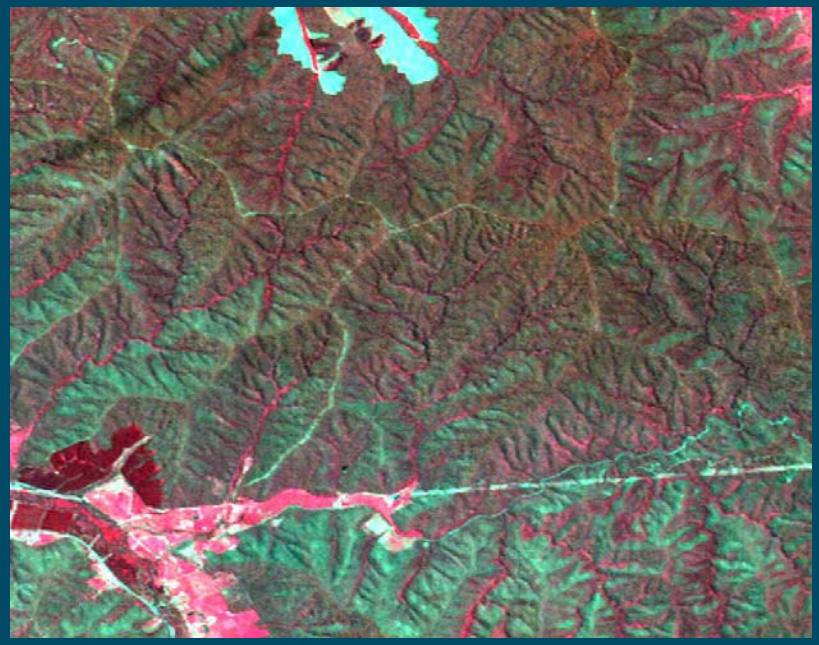
Comparison between MODIS and Landsat 5 4/02/2009 at Lake Frome, SA



Terrain illumination correction

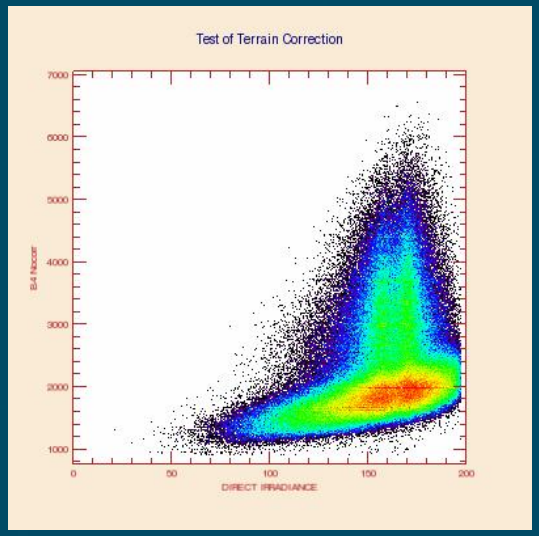


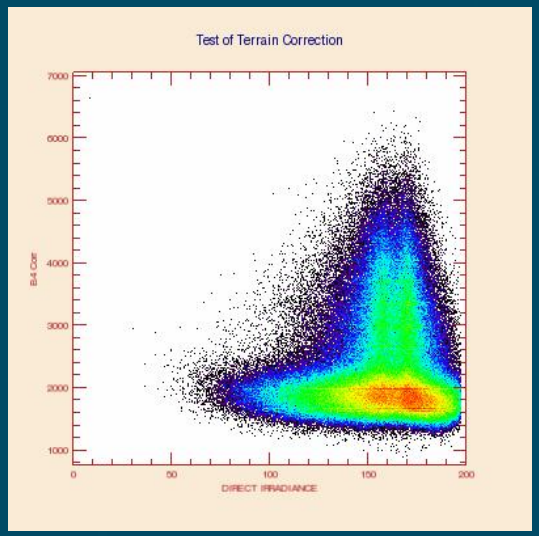
BRDF and atmospheric correction for Snowy Mountain, 2009



BRDF, atmospheric and terrain illumination correction for Snowy Mountain area, 2009

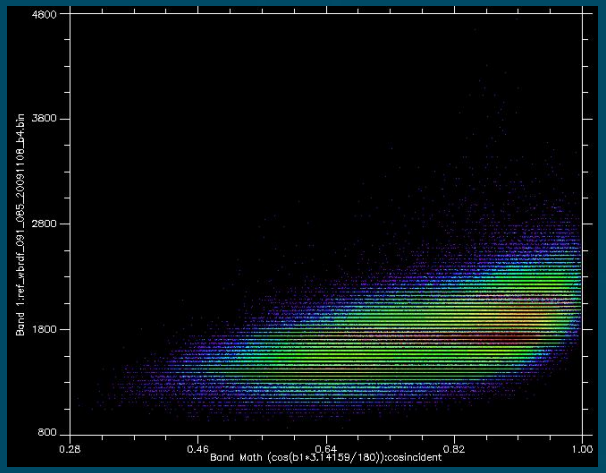
Terrain illumination correction



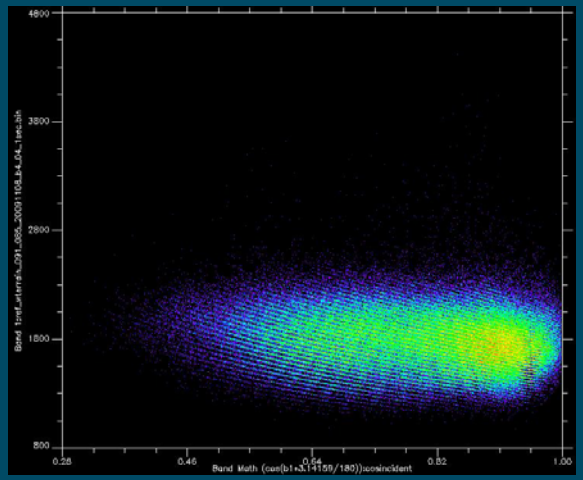


Correlation with slope

Band	before	after
1	0.268	0.010
3	0.288	0.058
4	0.322	0.072
5	0.410	0.107



BRDF and atmospheric correction for Snowy Mountain, 2009



BRDF, atmospheric and terrain illumination correction for Snowy Mountain area, 2009

Conclusions

- The coupled atmospheric and BRDF model can provide consistent surface reflectance products. The retrieved surface reflectance shows good agreement with ground based ASD measurements.
- The retrieved surface reflectance is free of BRDF effects and enables mosaicing at all latitudes without empirical adjustments.
- The coupled atmospheric and BRDF model can be used for both flat and sloping surfaces and enables physically based (not empirical) terrain illumination correction.
- There is a strong correlation between MODIS NBAR and Landsat NBAR products. This relationship can be used to cross-calibrate and validate with MODIS NBAR products / or products from other sensors.
- This method can be used for other satellite data with similar resolution and enable multi-sensors comparisons for climate change, water and environment monitoring through time series analysis.

Future work

- Implement land cover based BRDF algorithm
- Find surrogate estimators for MODIS BRDF data to process Landsat from the pre - MODIS era

Acknowledgements

- The Lake Frome field experiment crews collected and processed data to reflectance for the Lake Frome site
- Guy Byrne and Paul Daniels of CSIRO Land and Water provided expertise and support for data collection, processing and analysis for the Gwydir field measurements
- Aerosol data are being provided by Ross Mitchell's group at CSIRO
- Access to MODIS BRDF data has been facilitated by Edwards King's group at CSIRO
- The NEO System Development Team at GA wrote the scripts and code for the automating the workflow process