Radiative forcing trade-offs in the thicket: carbon sequestration versus albedo

Kathleen G. Smart

Animal Plant and Environmental Sciences, University of the Witwatersrand, Johannesburg

R. J. Scholes

Natural Resources and Environment, CSIR, Pretoria

10th Annual Thicket Forum
03 September 2013

The earth has an albedo of 0.3

30% of the incident solar radiation is reflected into space

70% is absorbed by the Earth and reradiated as longwave infrared radiation

The earth has an albedo of 0.3

30% of the incident solar radiation is reflected into space

70% is absorbed by the Earth and reradiated as longwave infrared radiation

Thermal equilibrium

The earth has an albedo of 0.3

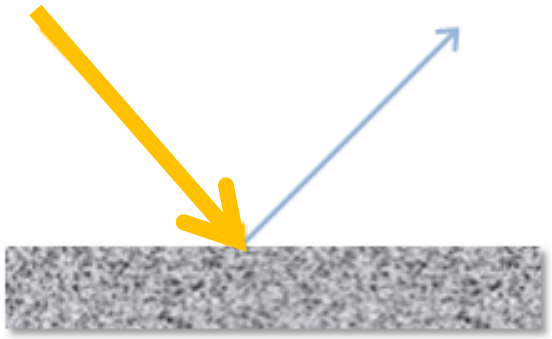
30% of the incident solar radiation is reflected into space

70% is absorbed by the Earth and reradiated as longwave infrared

Thermal equilibrium

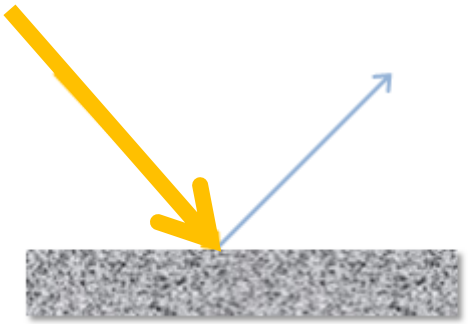
reflection coefficient:

Albedo?

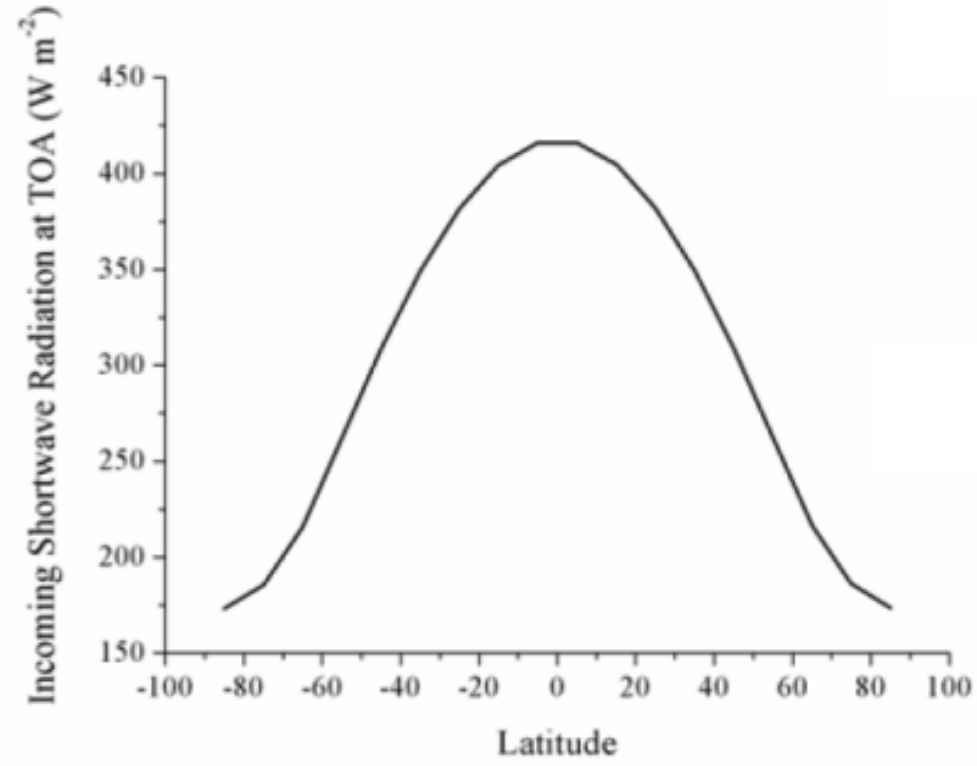


$$\frac{\text{reflected radiation}}{\text{incident radiation}}$$

reflection coefficient:



$$\frac{\text{reflected radiation}}{\text{incident radiation}}$$

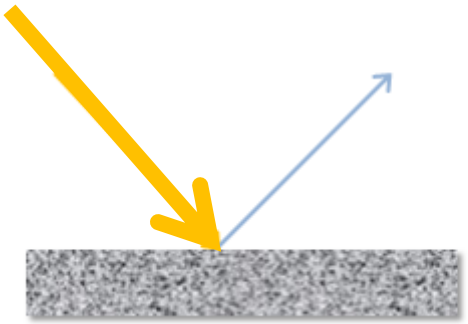


Latitudinal variation

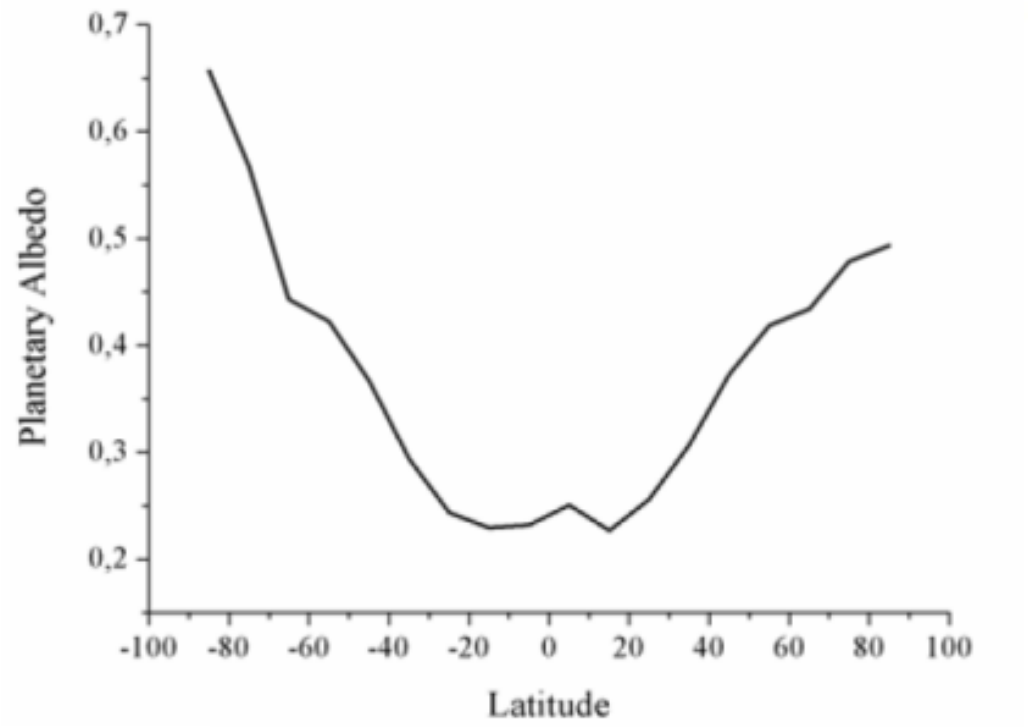
The long-term annual global average is around 342 W m^{-2}

Hatzianastassiou,2004

reflection coefficient:



reflected radiation
incident radiation

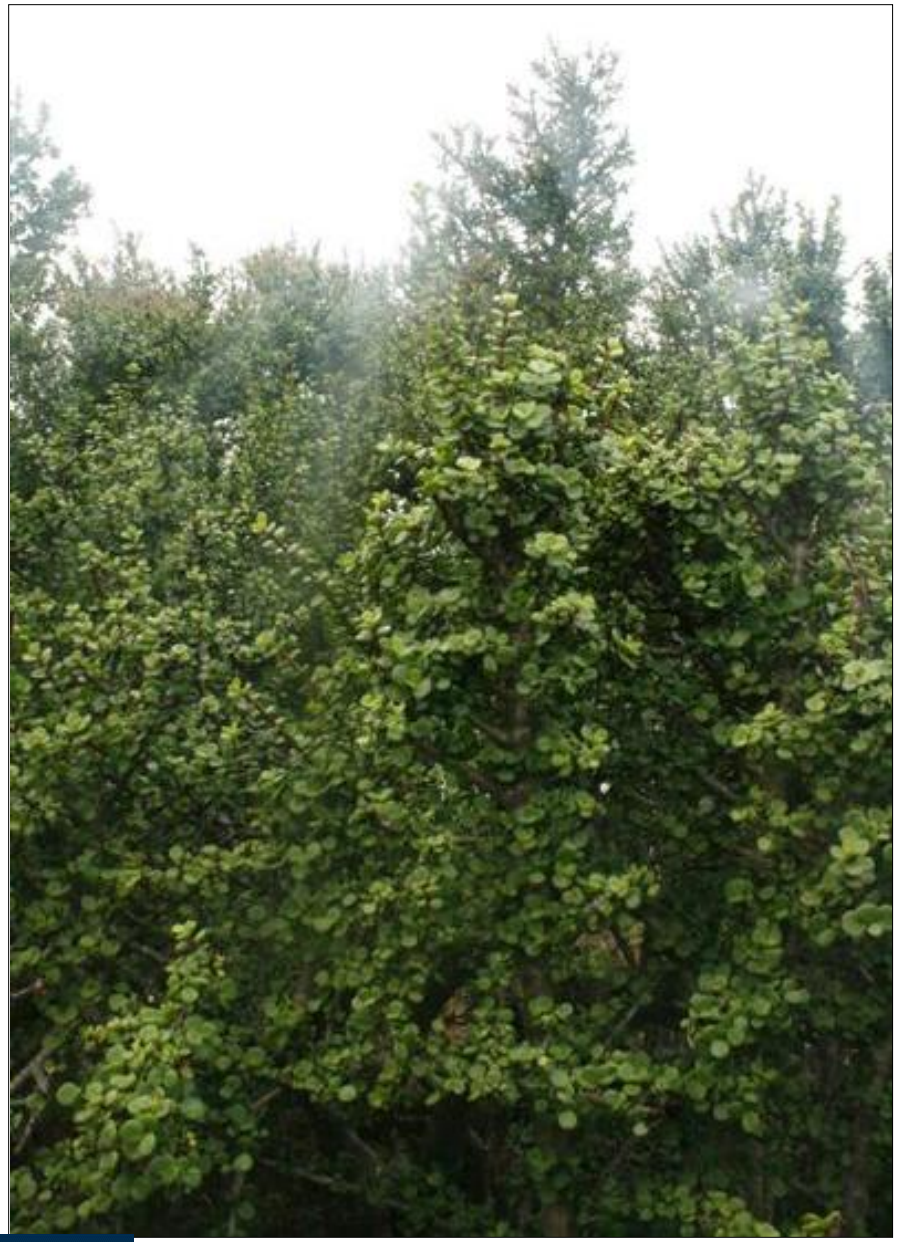


Latitudinal variation

Hatzianastassiou,2004

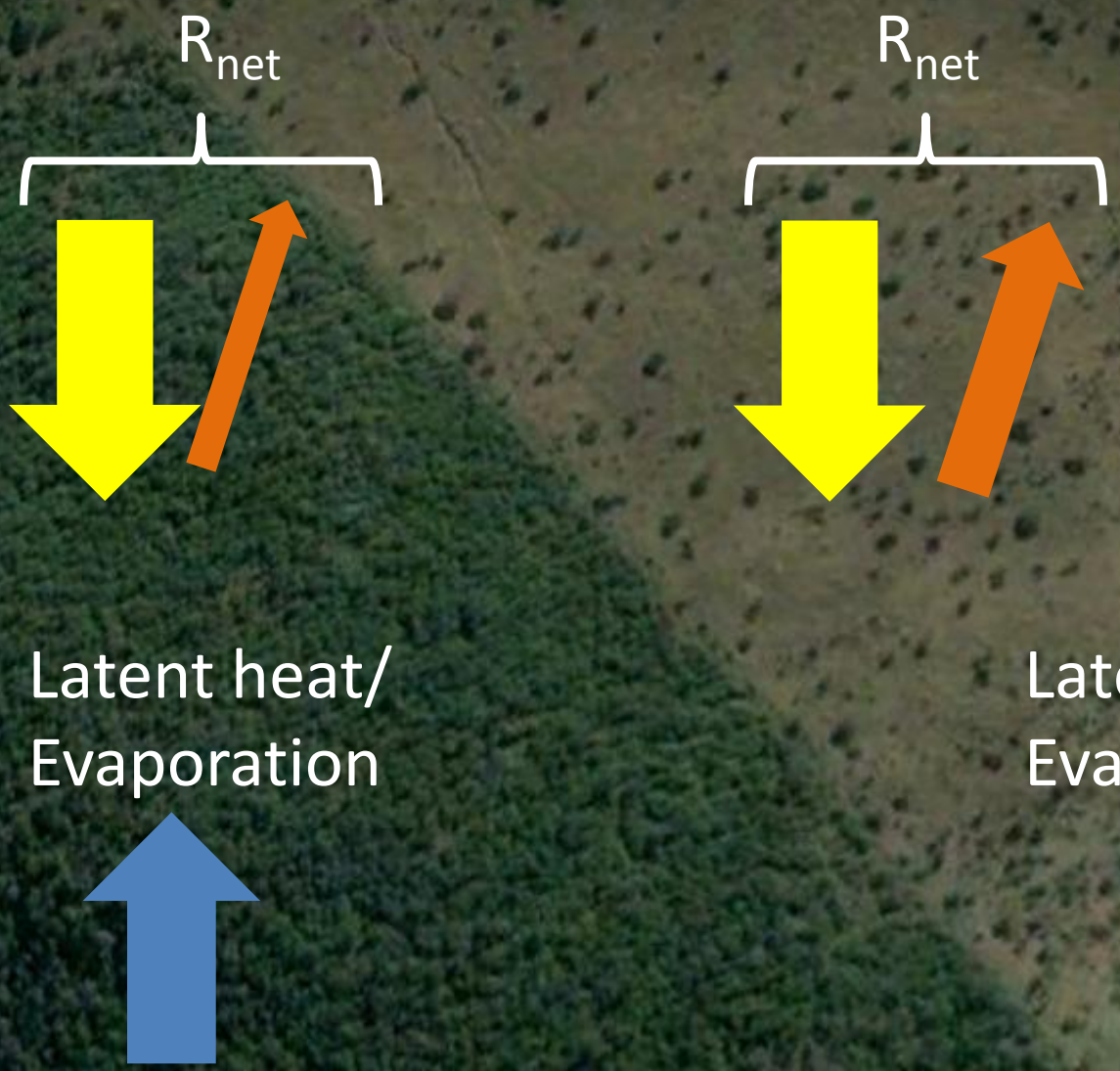
Albedo

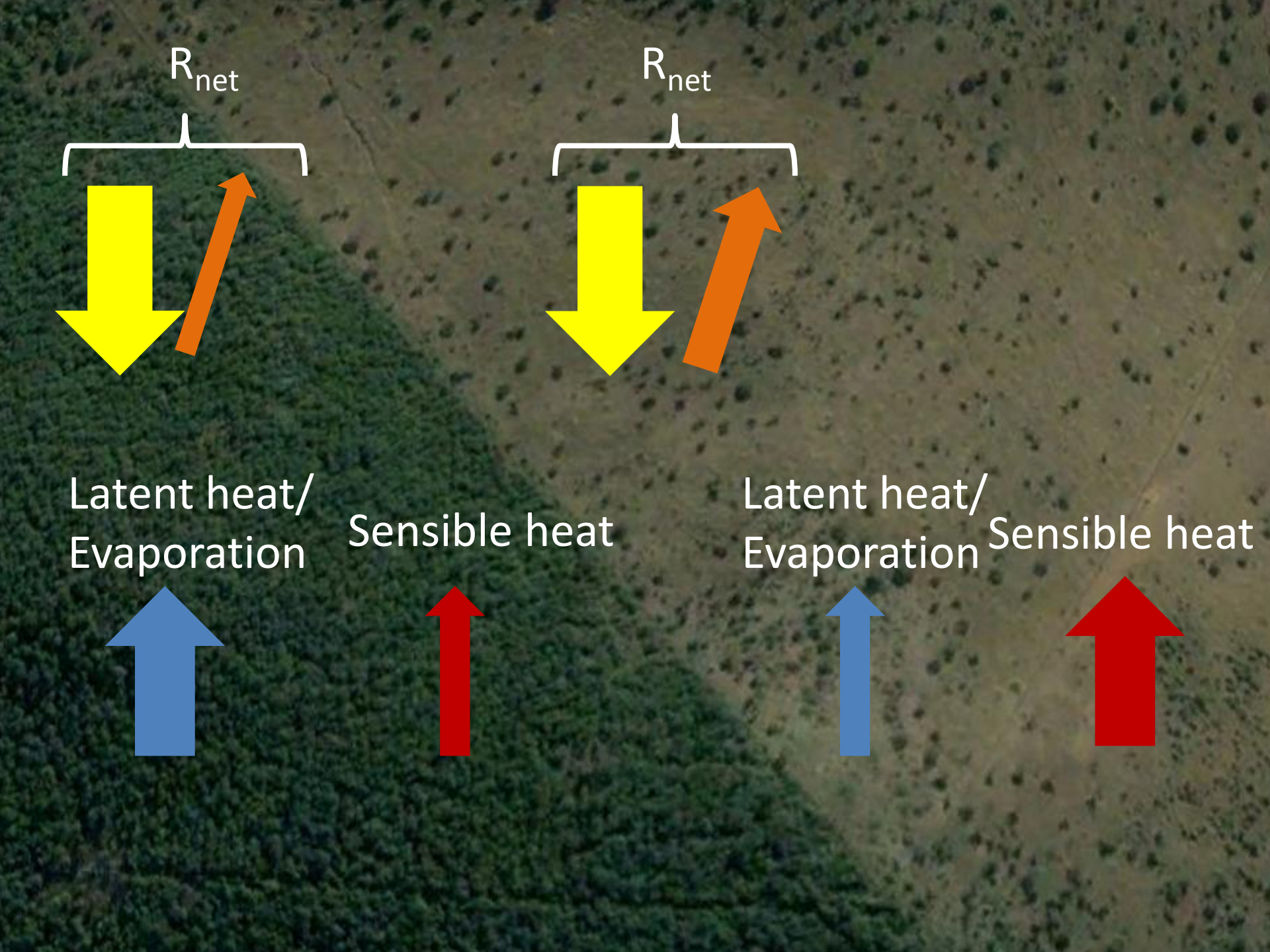
1 0

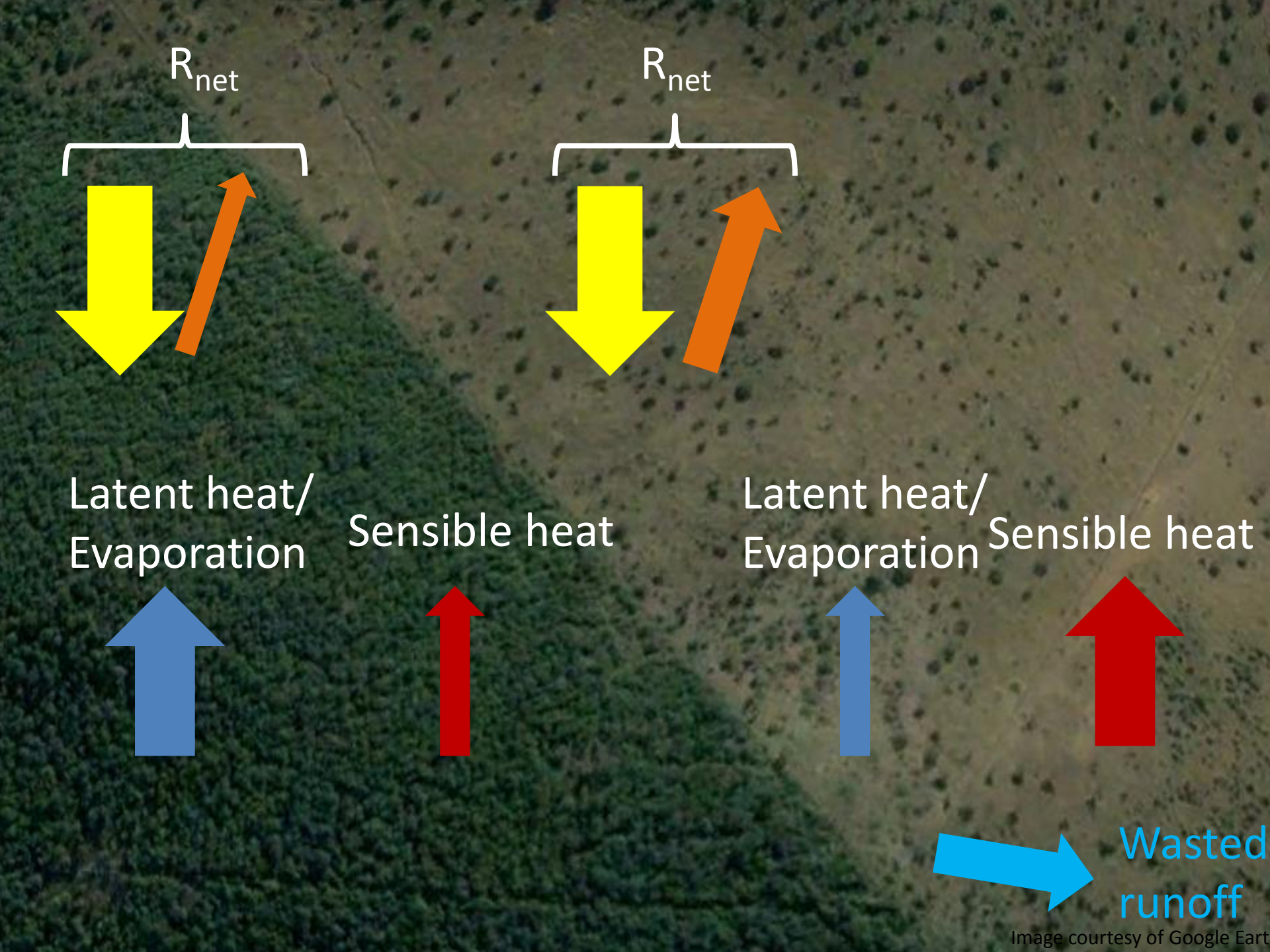


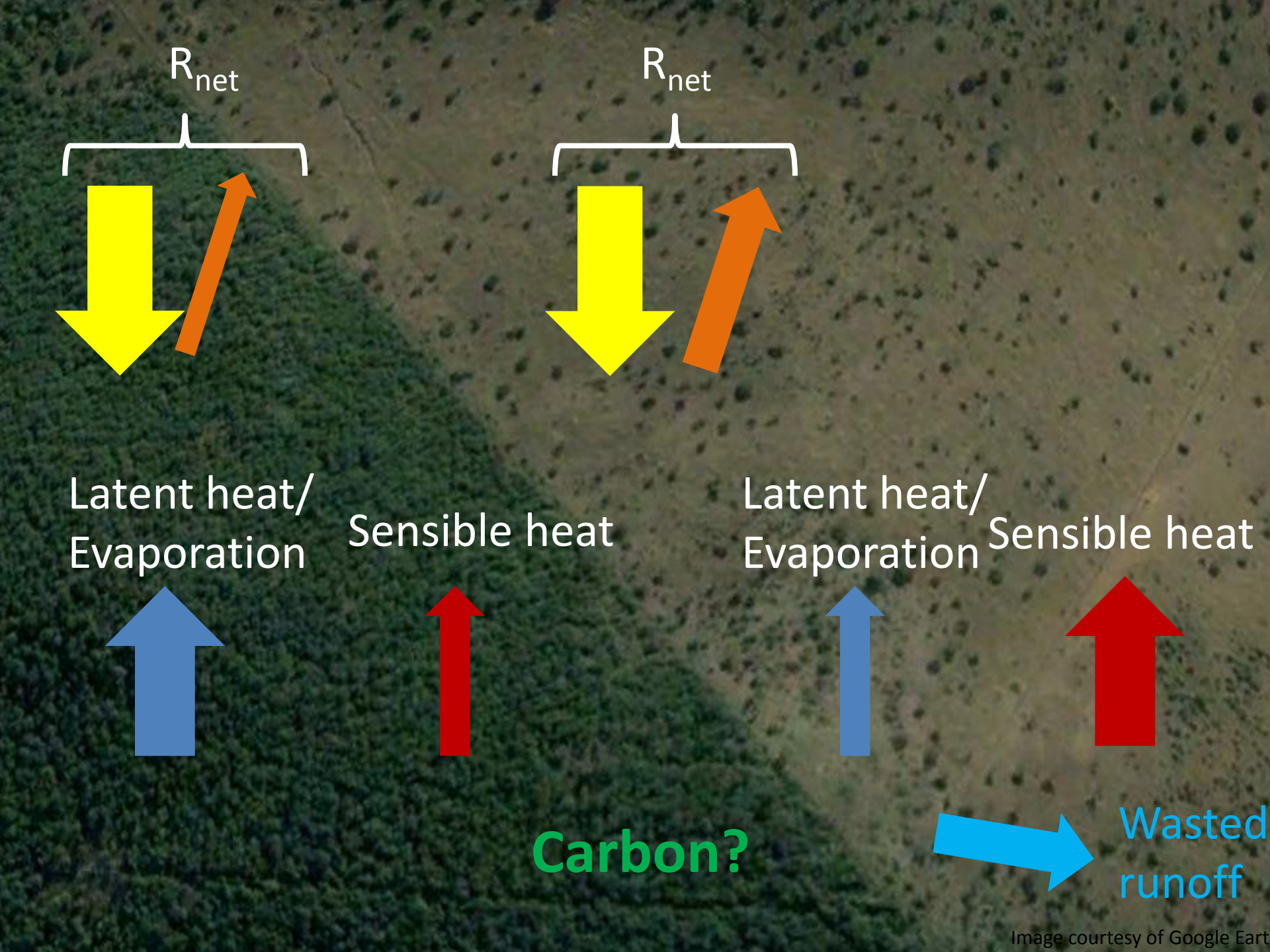
Portulacaria afra
'spekboom' or pork bush


R_{net}
R_{net}


R_{net}
R_{net}
Latent heat/
Evaporation
Latent heat/
Evaporation


R_{net}
R_{net}
Latent heat/
Evaporation
Sensible heat
Latent heat/
Evaporation
Sensible heat


R_{net}
R_{net}
Latent heat/
Evaporation
Sensible heat
Latent heat/
Evaporation
Sensible heat
Wasted
runoff
Image courtesy of Google Eart


R_{net}
R_{net}
Latent heat/
Evaporation
Sensible heat
Latent heat/
Evaporation
Sensible heat
Carbon?
Wasted
runoff
Image courtesy of Google Eart

Measuring albedo

- The first satellites started measuring reflected solar radiation in the late 1970's
  - Reflected solar radiation is one of the more challenging measurements to make
  - The main reason for this is reflected solar radiation takes place over all angles

Hatzianastassiou,2004

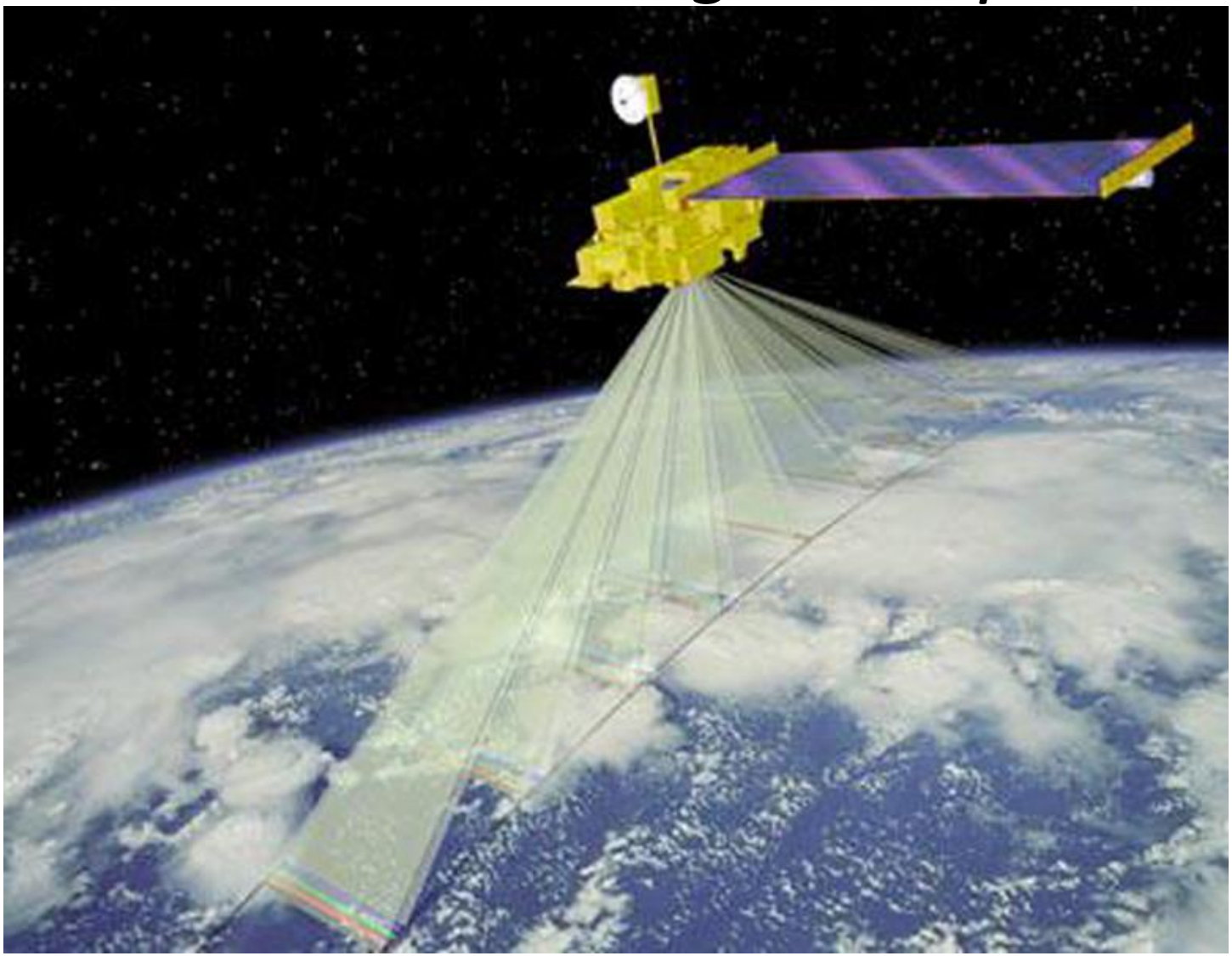
Measuring albedo

- Reflected solar radiation is one of the major elements in the earth's radiation budget
  - If the global albedo reduced by 1% this would produce an increase in radiative forcing (prior to any feedbacks) of 3.4W m^{-2}
  - This is a similar magnitude to the calculated effects from GHG

Hatzianastassiou,2004

Characterizing surface anisotropy

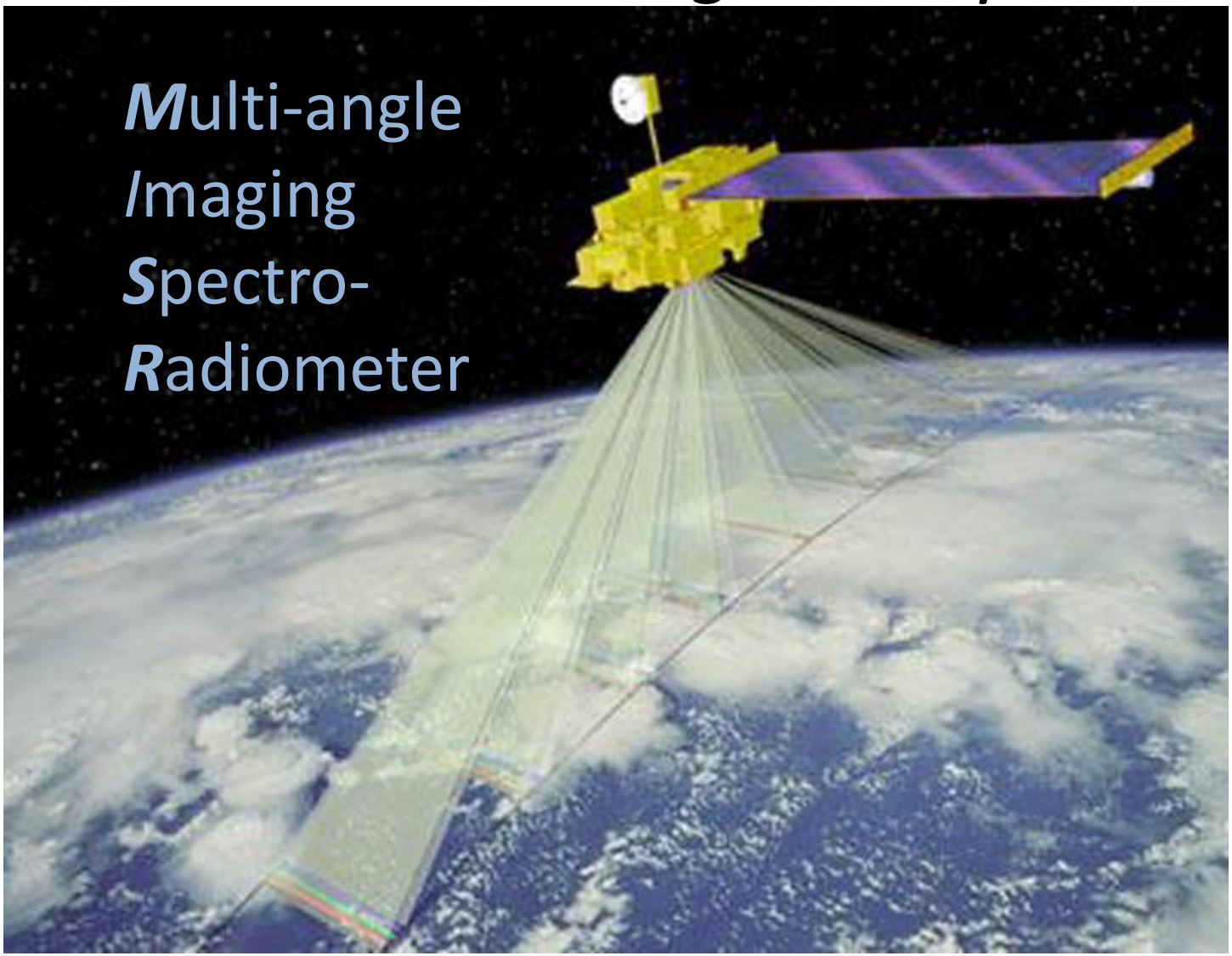
MISR Observing Concept



www-misr.jpl.nasa.gov , image courtesy of S. Suzuki and E. M. De Jong

Characterizing surface anisotropy

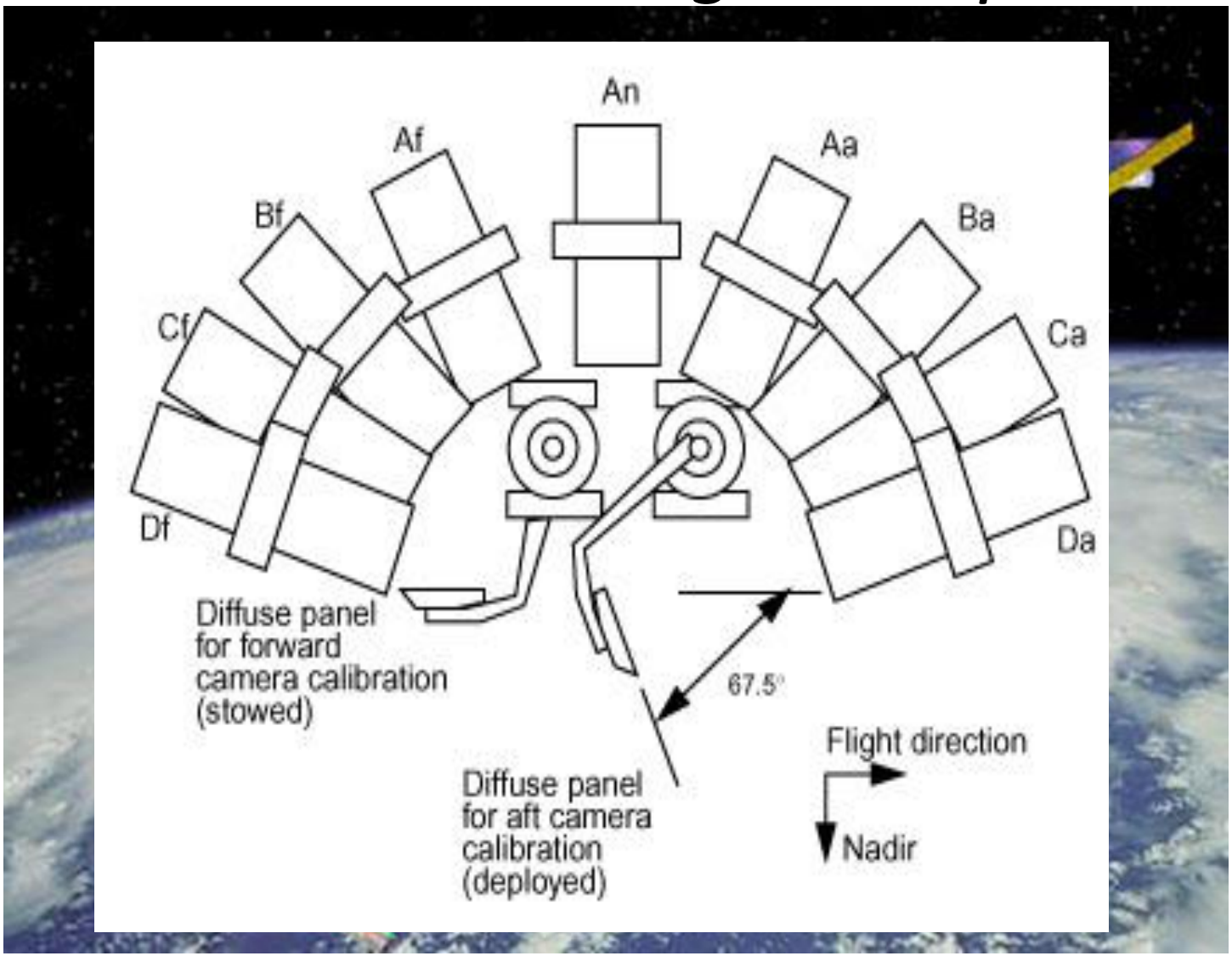
MISR Observing Concept



www-misr.jpl.nasa.gov , image courtesy of S. Suzuki and E. M. De Jong

Characterizing surface anisotropy

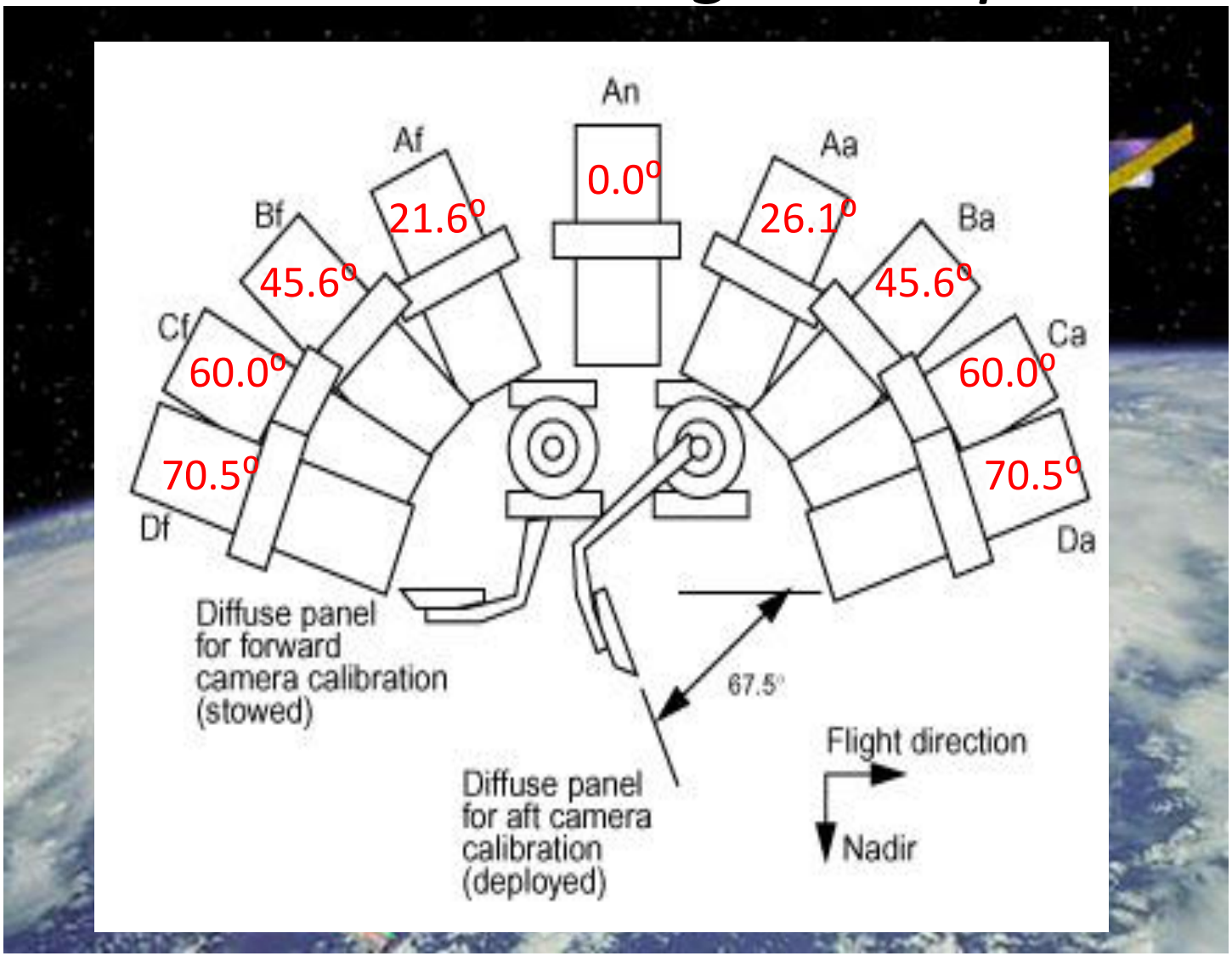
MISR Observing Concept



www-misr.jpl.nasa.gov , image courtesy of S. Suzuki and E. M. De Jong

Characterizing surface anisotropy

MISR Observing Concept



www-misr.jpl.nasa.gov , image courtesy of S. Suzuki and E. M. De Jong

- Sensitivity to vegetation structure, owing to effects of shadowing
- Ability to distinguish canopy and understory reflectance due to contrast differences between nadir and oblique views
- Accuracy improvements in vegetation community and land cover classifications

Lechmere Ortel, 2005

Mills & Fey 2004

My approach

Site selection

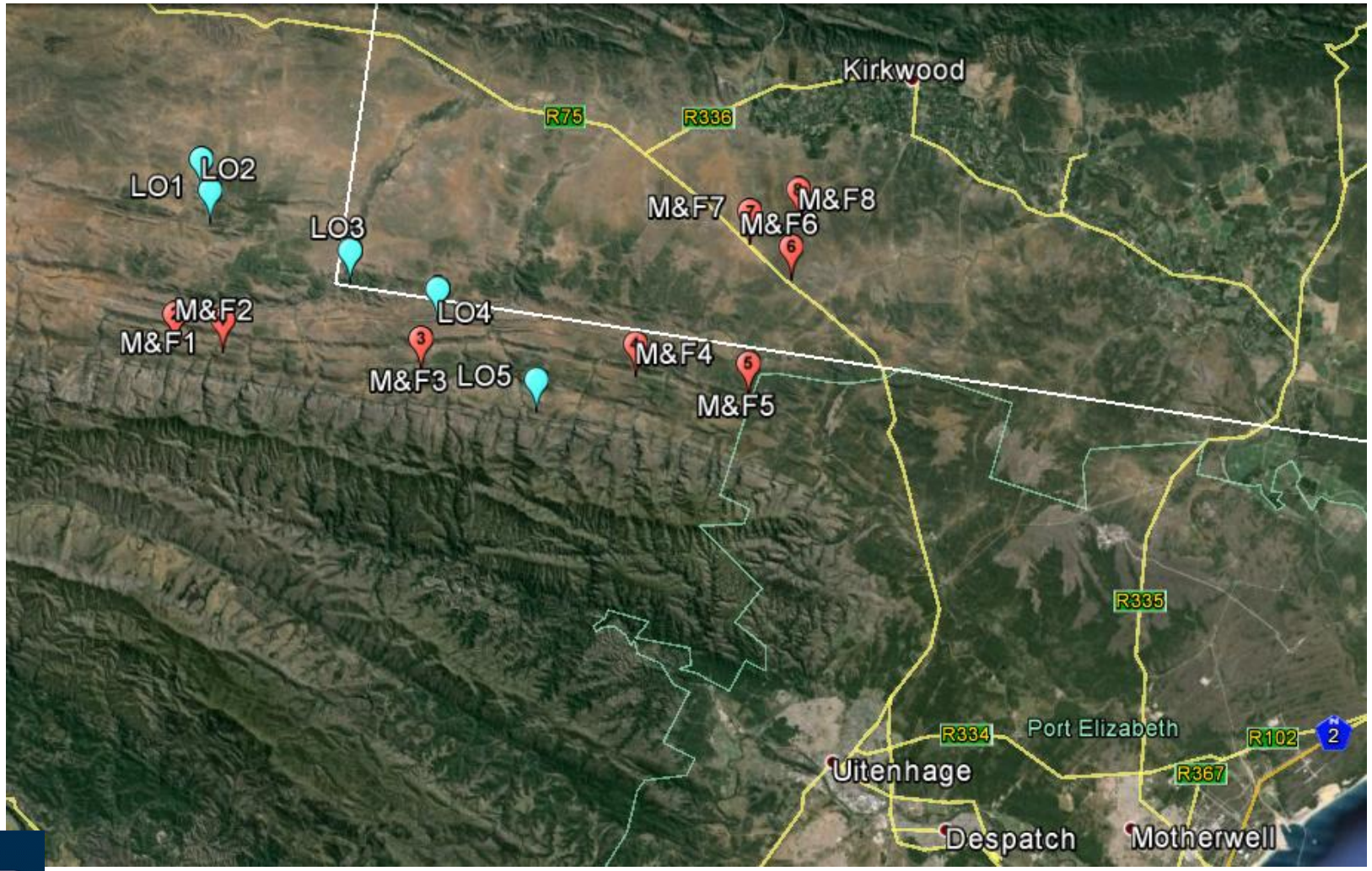


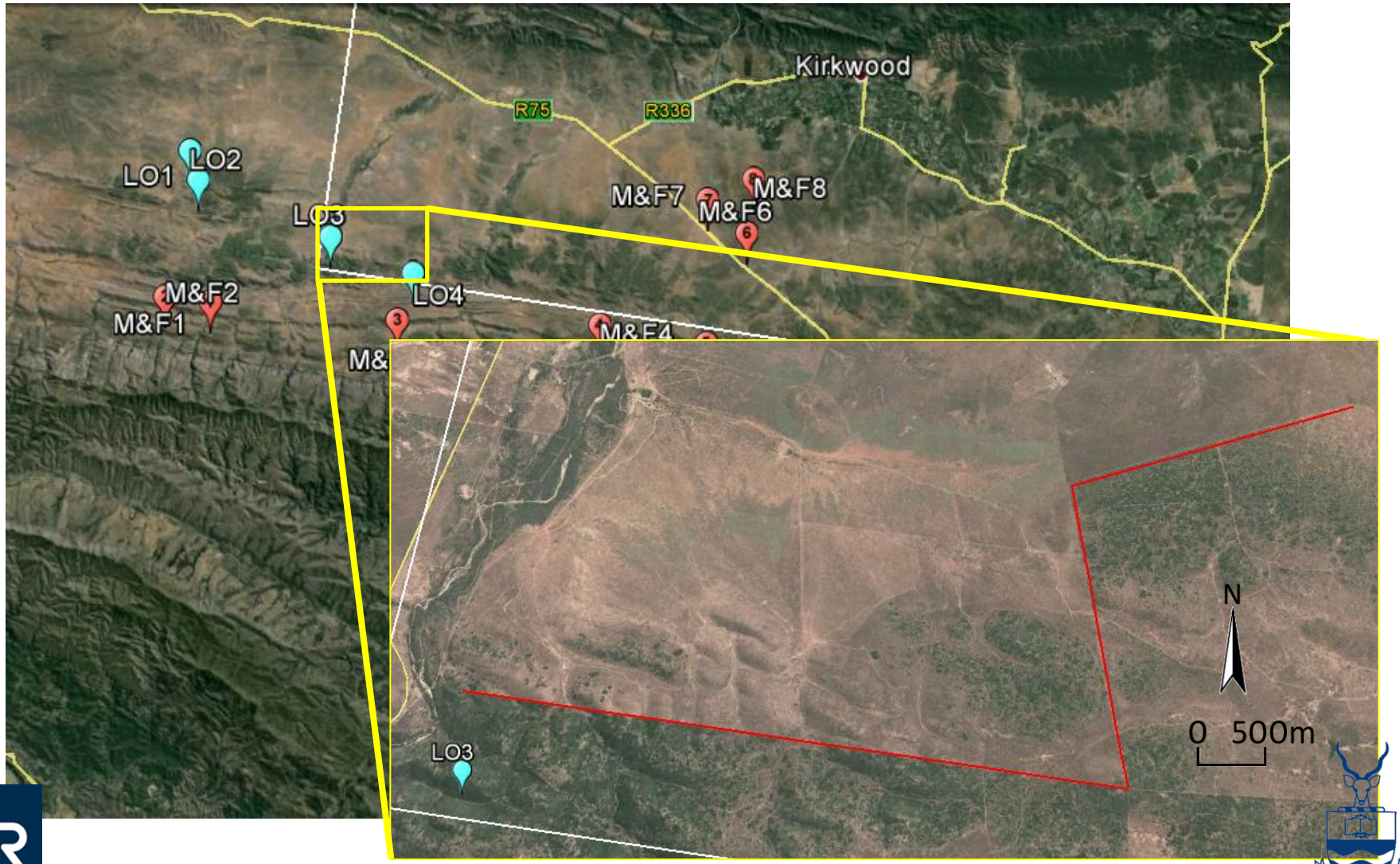
Image courtesy of Google Earth

Lechmere Ortel, 2005

Mills & Fey 2004

My approach

Site selection



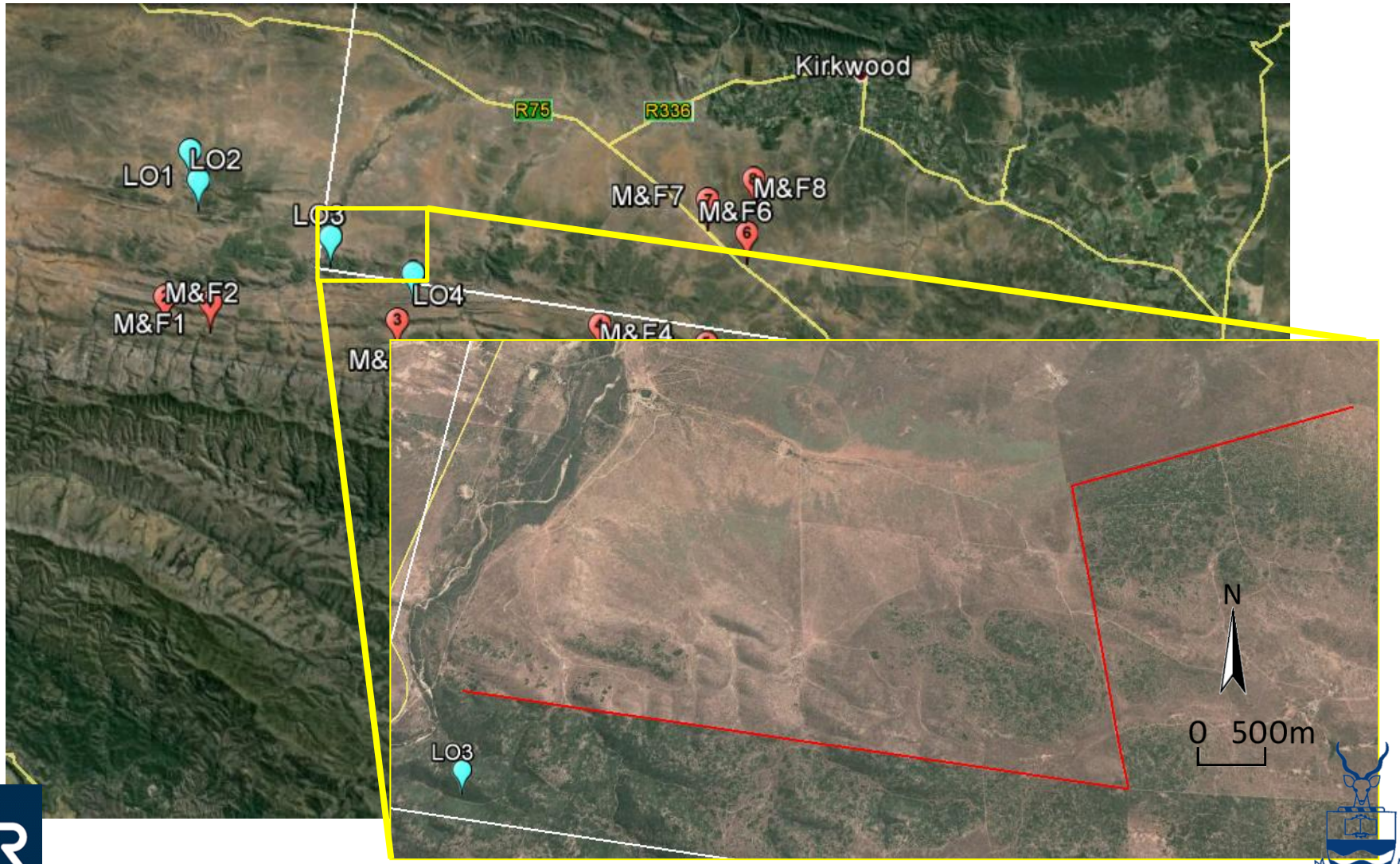
Images courtesy of Google Earth

Lechmere Ortel, 2005

Mills & Fey 2004

My approach

Site selection



Images courtesy of Google Earth

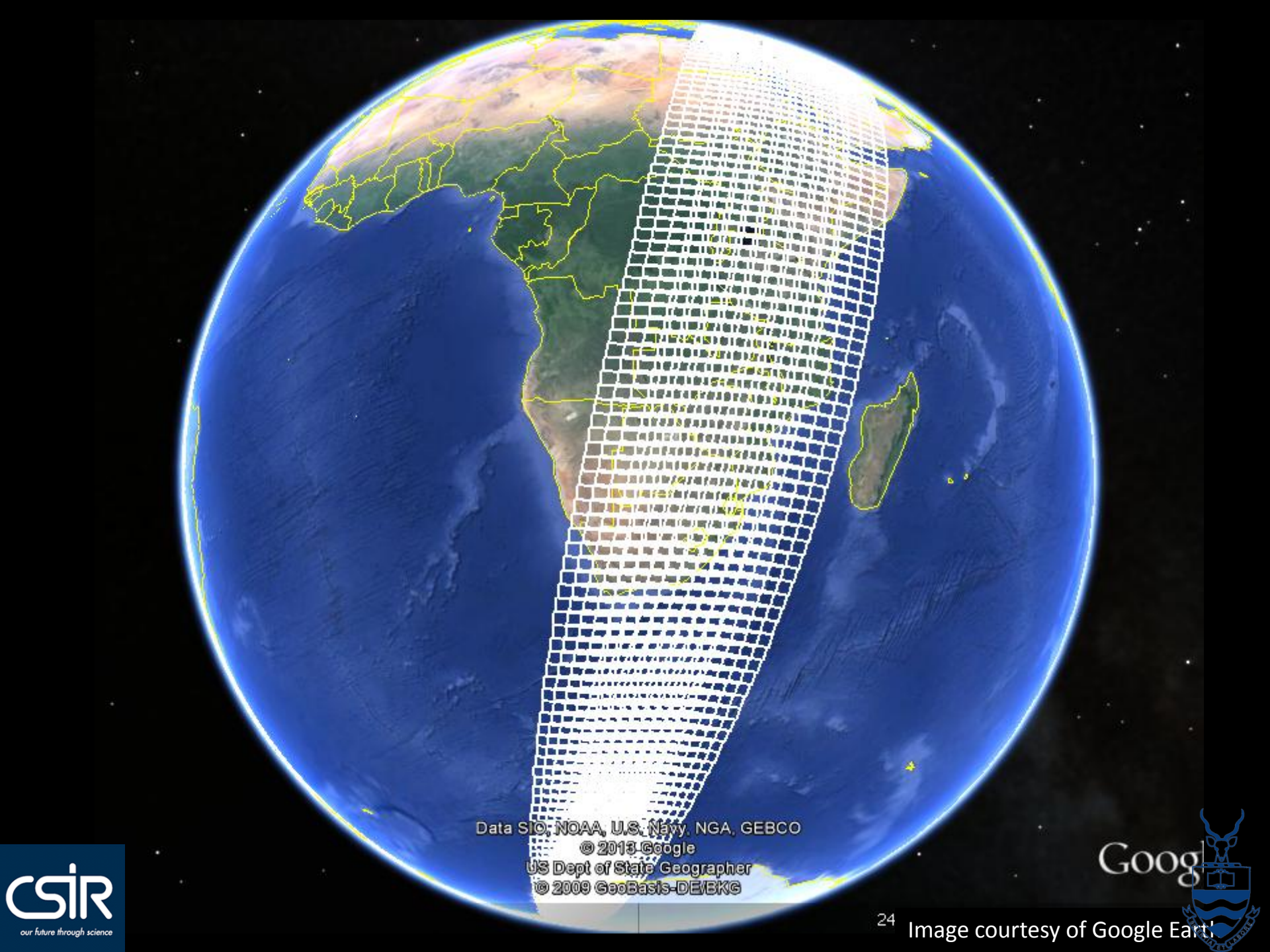
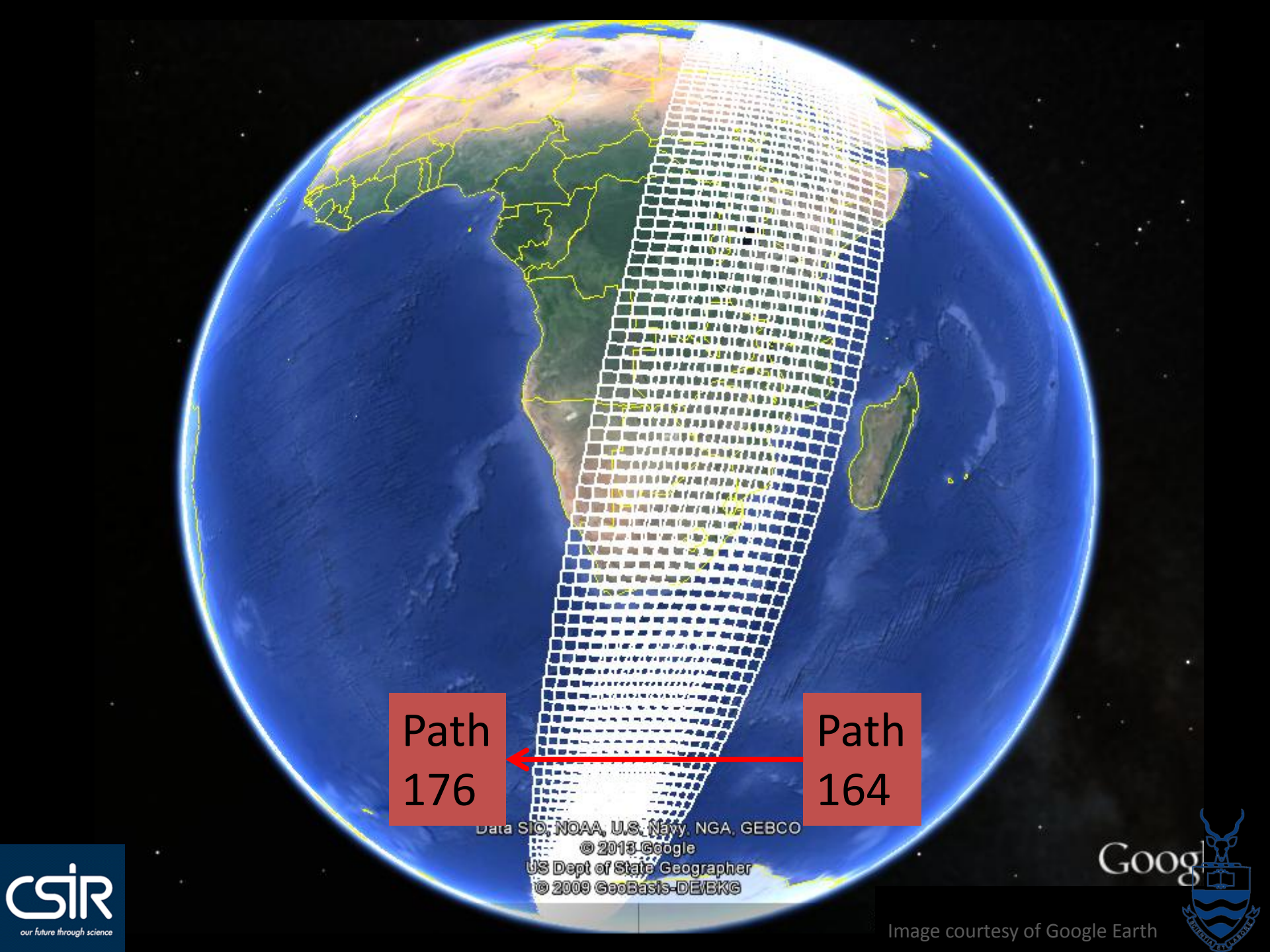
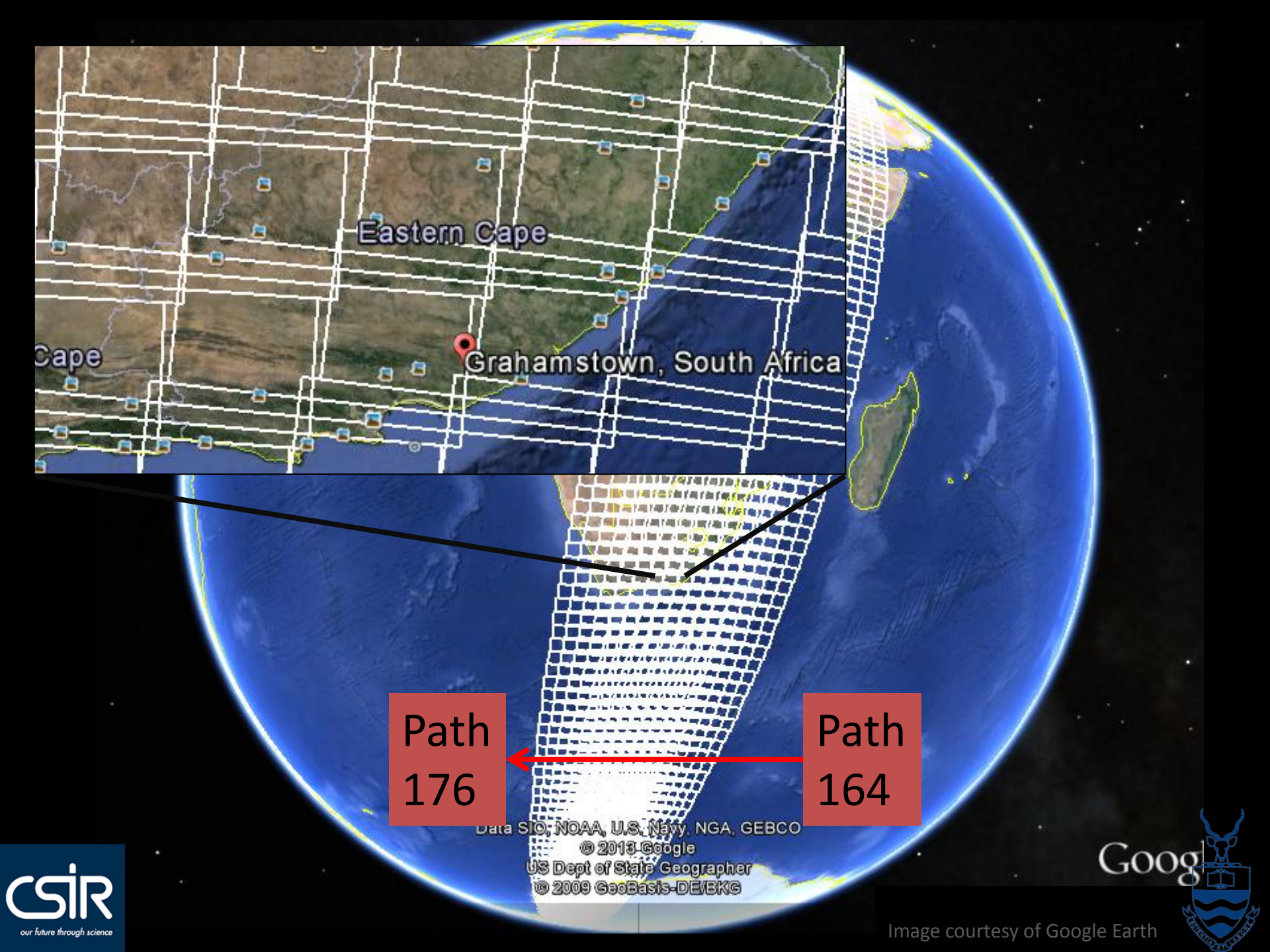


Image courtesy of Google Earth


Path
176
Path
164
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2013 Google
US Dept of State Geographer
© 2009 GeoBasis-DE/BKG
Google
Image courtesy of Google Earth

Single MISR path


Eastern Cape
Cape
Grahamstown, South Africa
Path 176
Path 164
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2013 Google
US Dept of State Geographer
© 2009 GeoBasis-DE/BKG
Google
Image courtesy of Google Earth

MISR paths 169-172

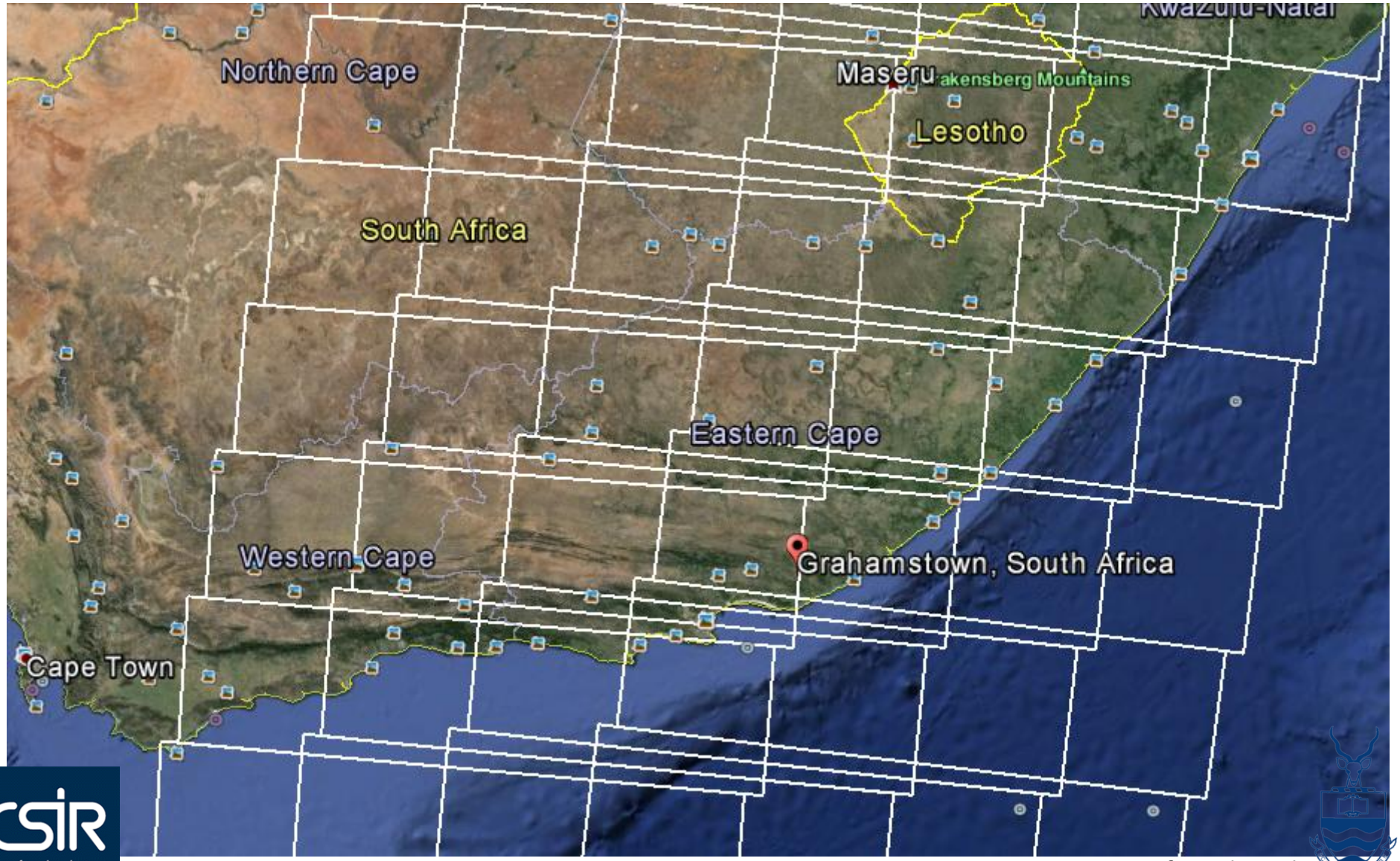


Image courtesy of Google Earth

MISR paths 169-172

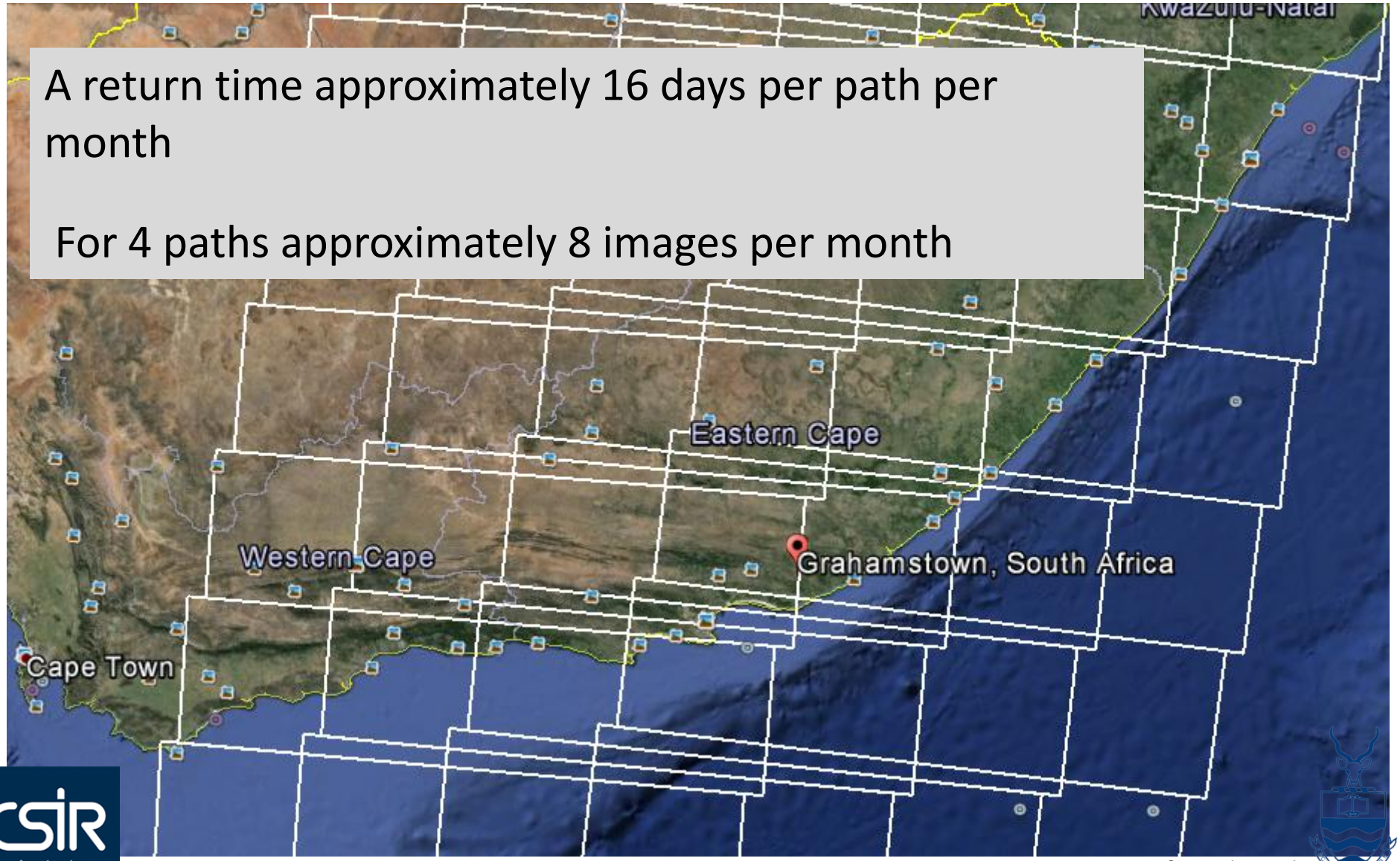
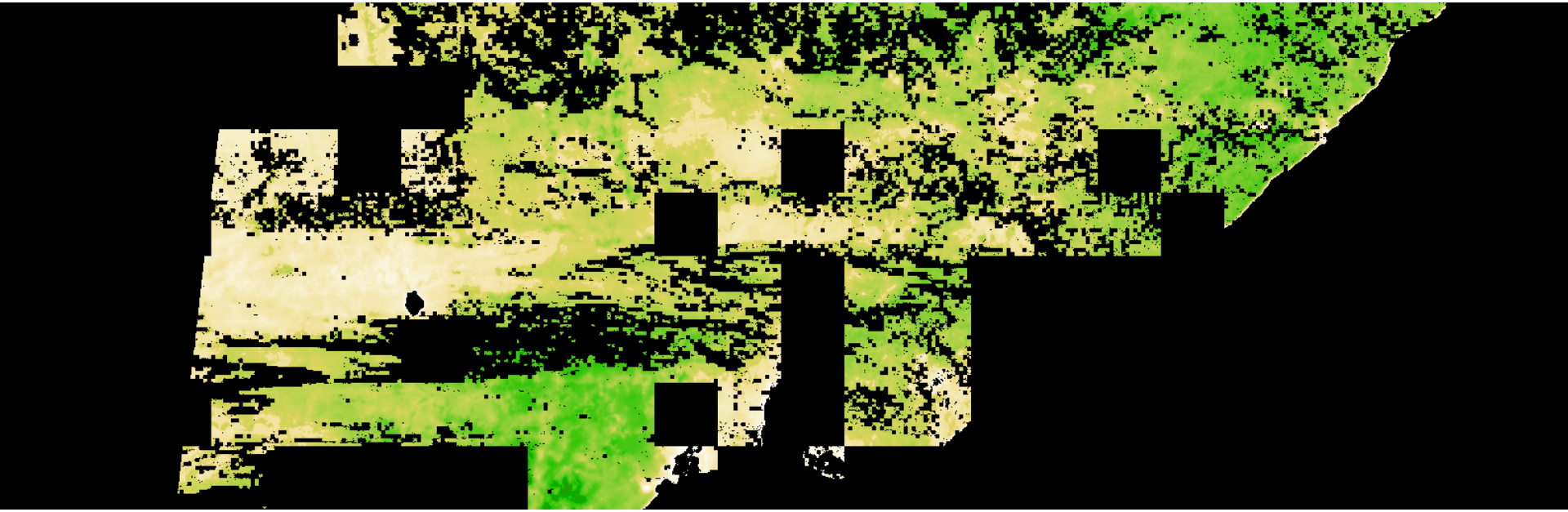


Image courtesy of Google Earth

What does the data look like?

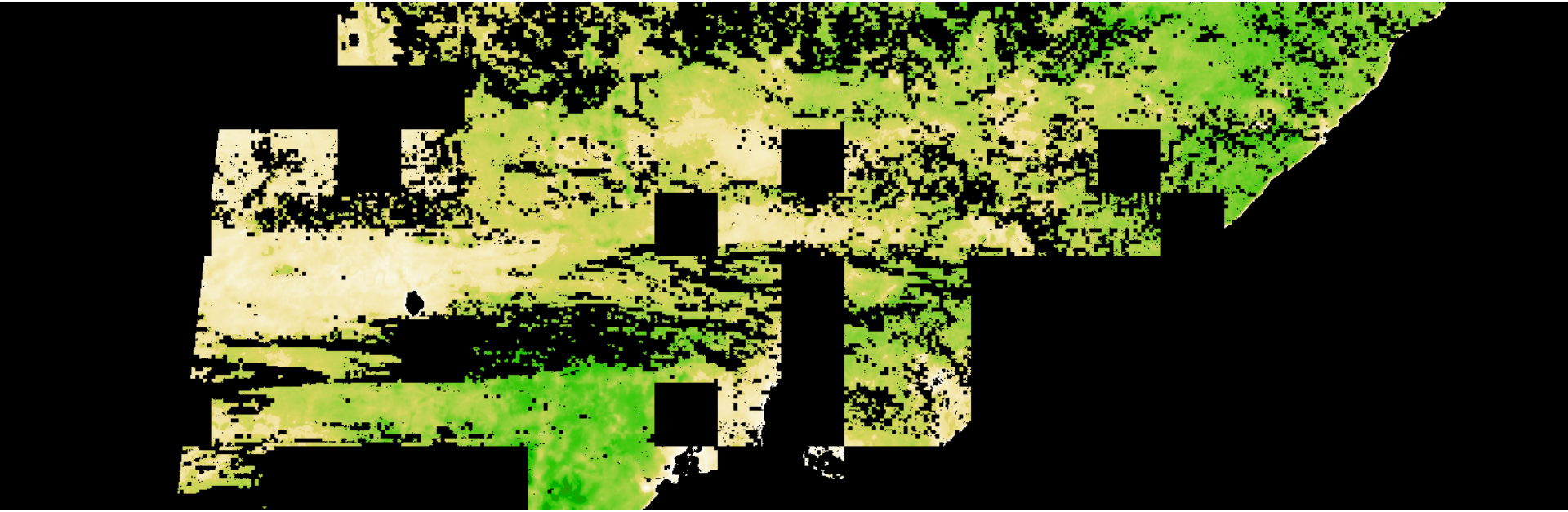
FAPAR path 170, block 117



12 August 2000

What does the data look like?

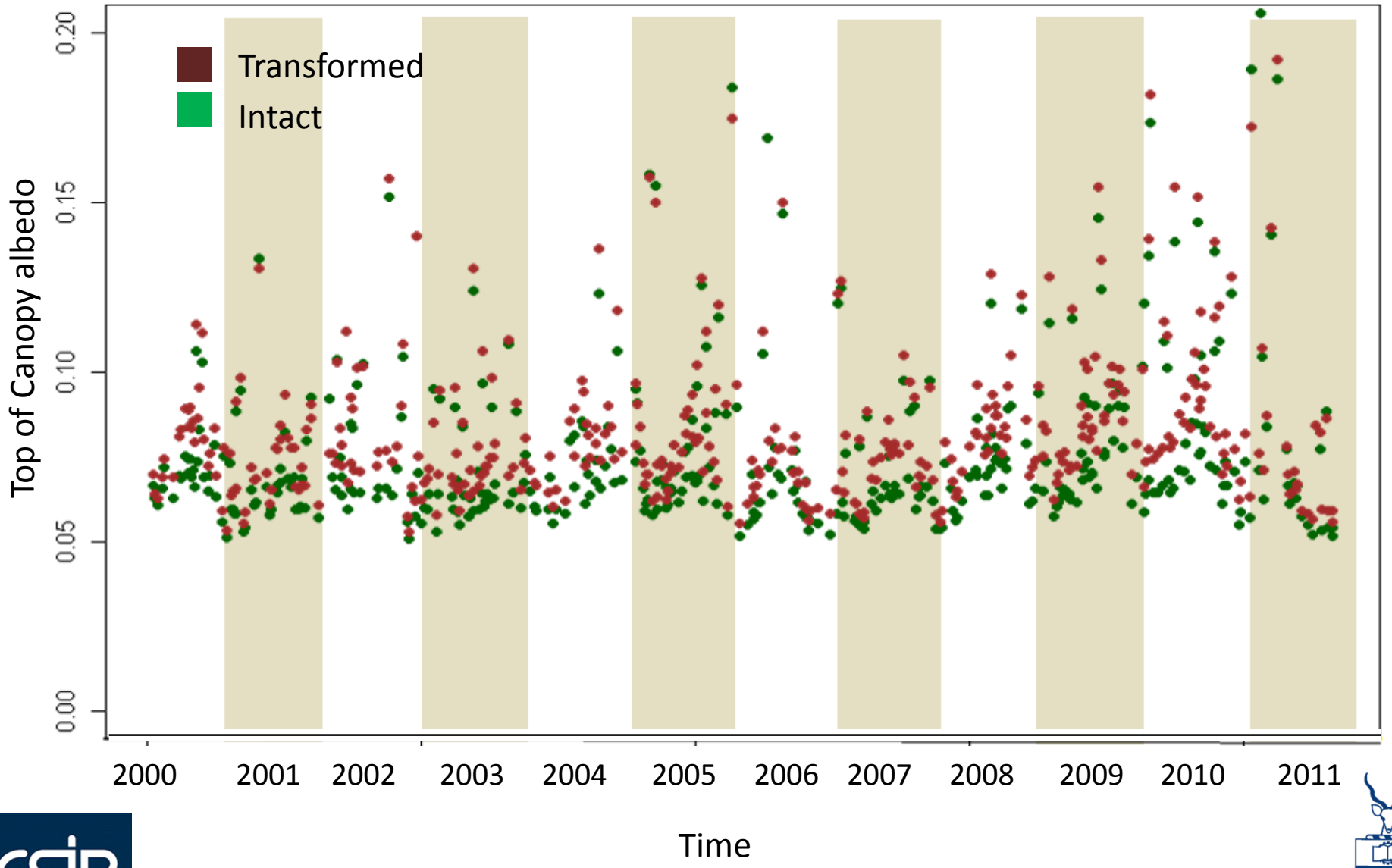
FAPAR path 170, block 117

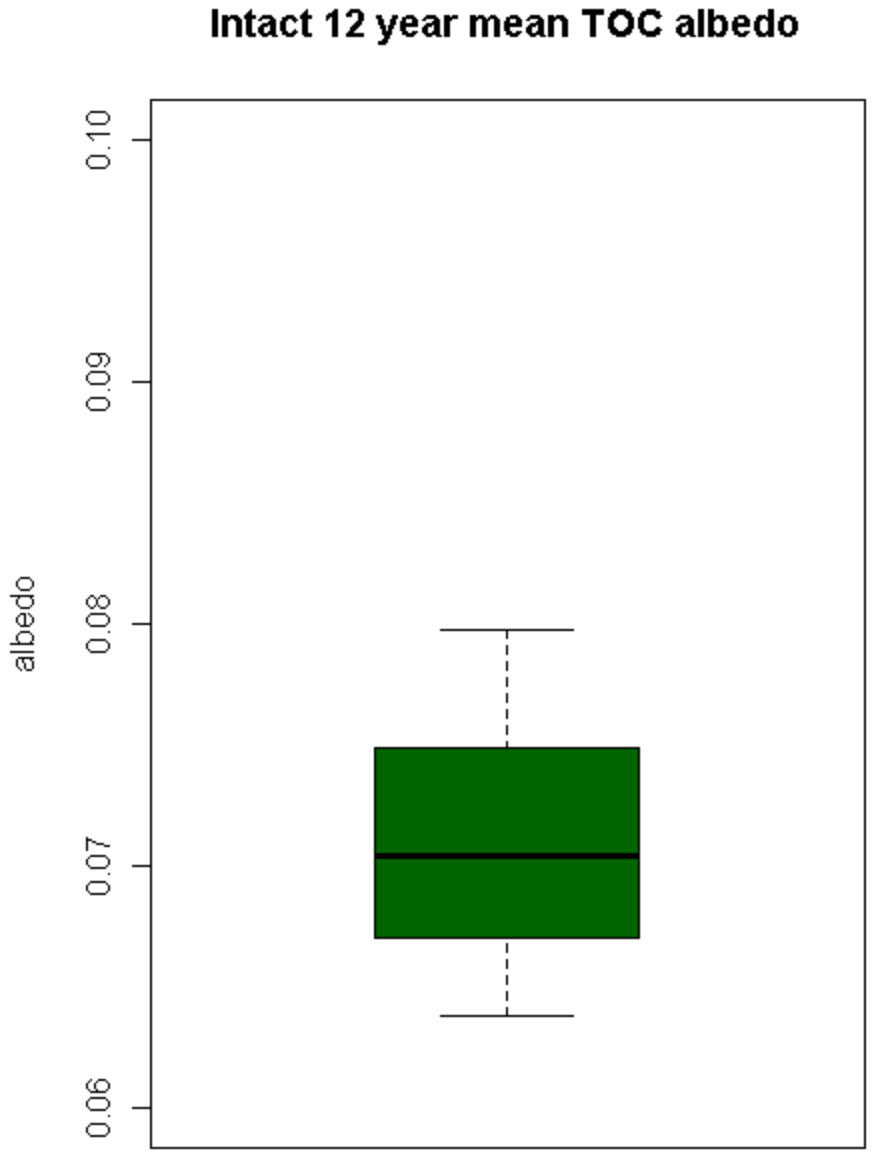


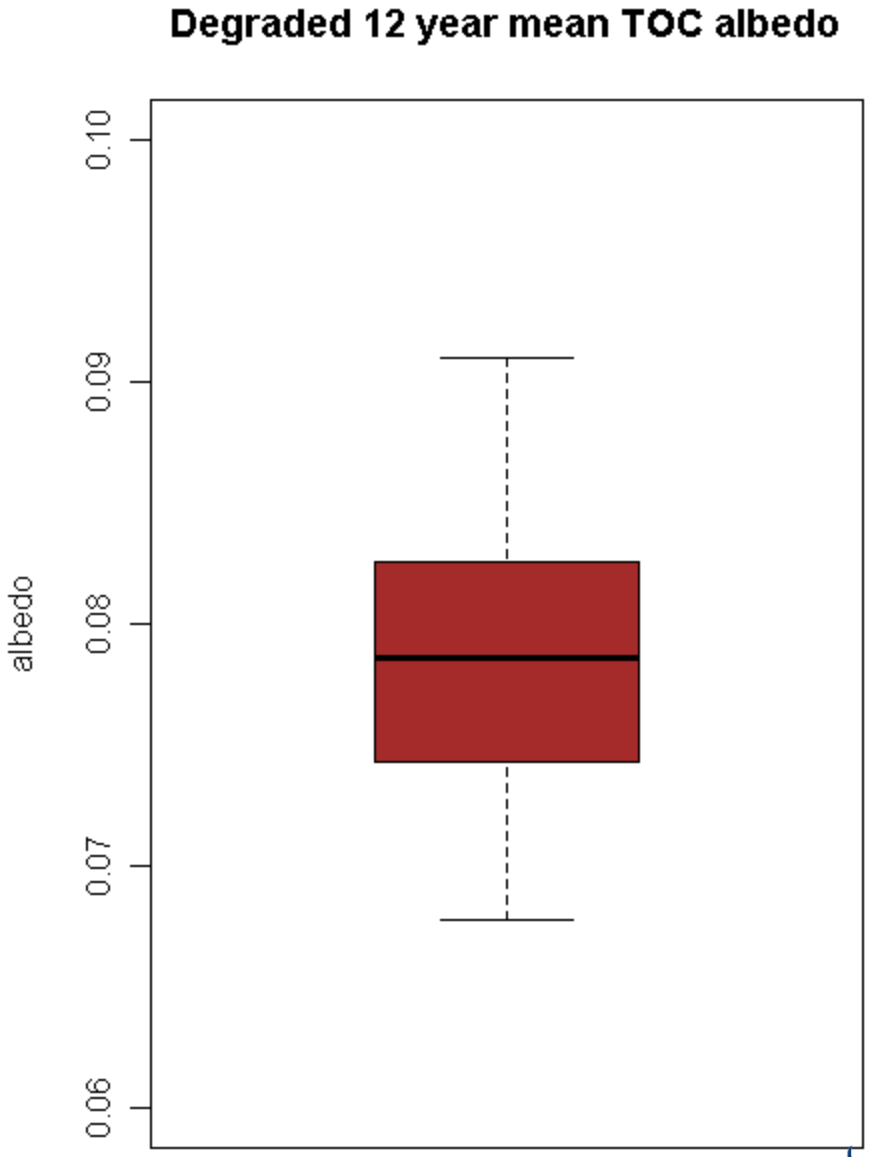
12 August 2000

The current algorithms which produce the MISR-HR products produce ‘No Data’ when any one of the nine cameras has insufficiently accurate or no data

Vegetation albedo





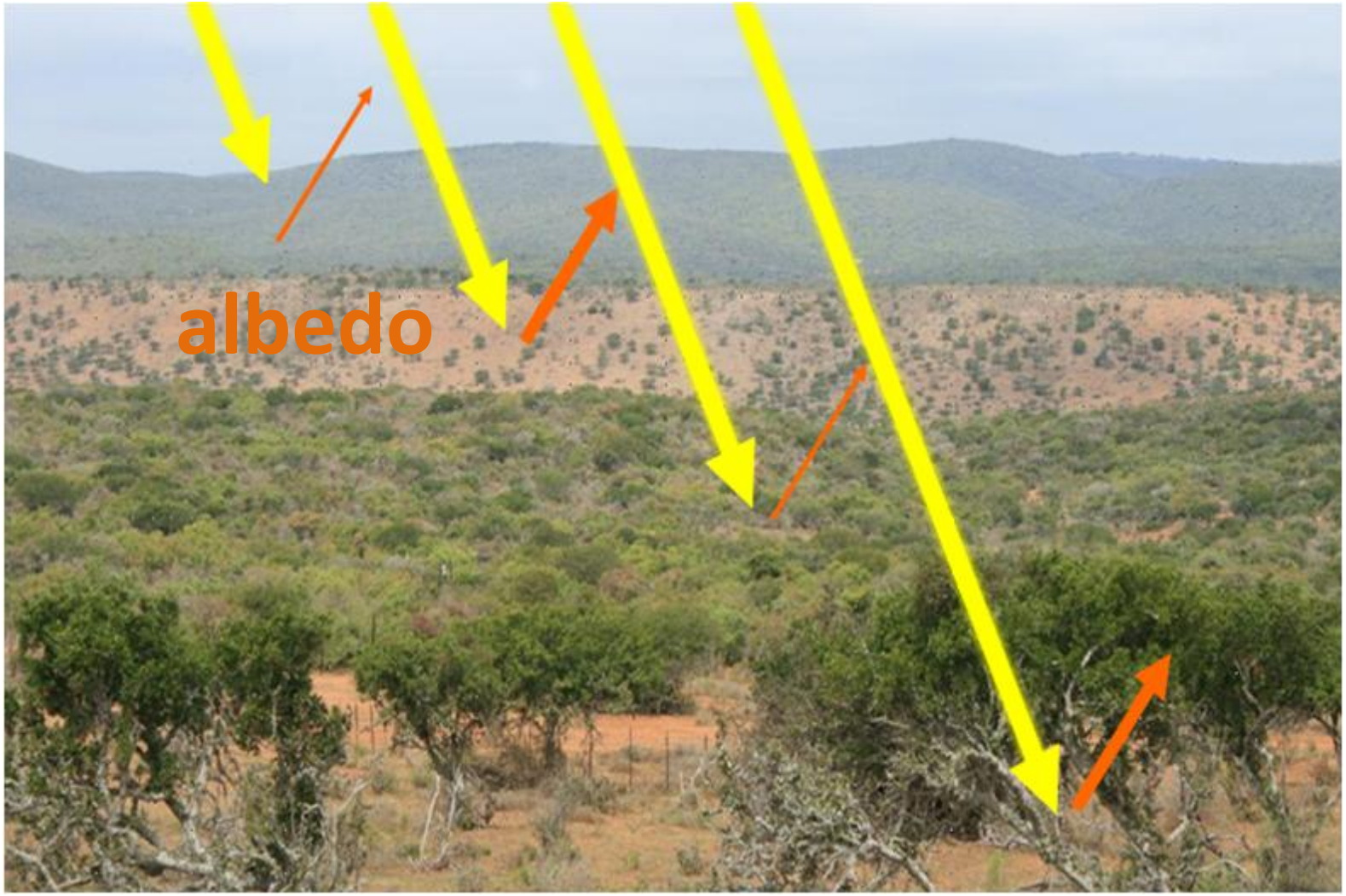


CSIR
our future through science

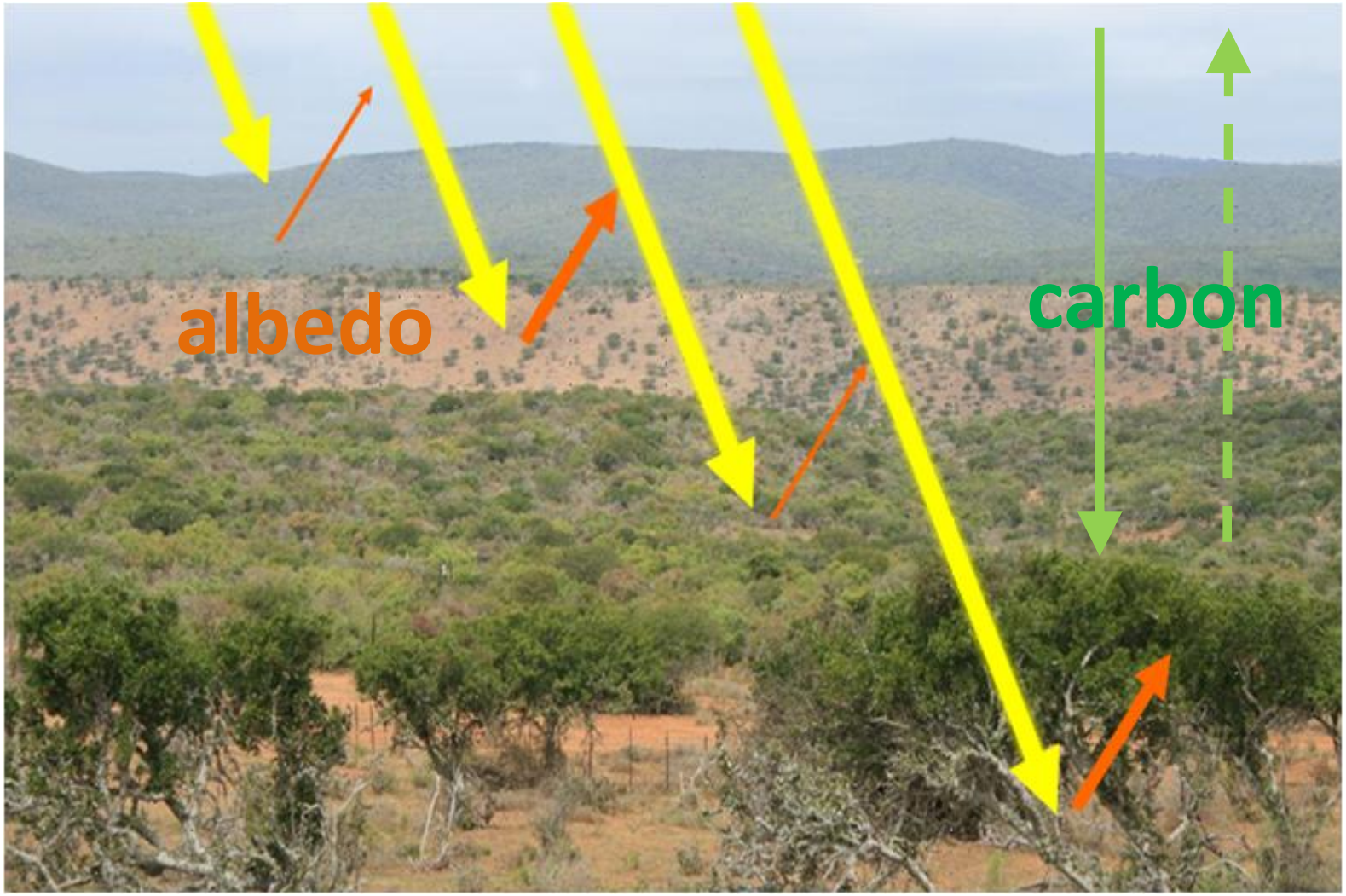
There is a difference in the albedo of transformed and intact vegetation

What does this mean?

Comparing carbon and albedo



Comparing carbon and albedo



Comparing carbon and albedo

- Average 27 year rate K27 block at Krompoort
- 0.42 ± 0.08 kgC m^{-2} yr^{-1}

- Mean of the mean albedo for each site
- Calculate the difference between the degraded and intact sites
- Use the average incoming solar radiation for Addo, Baviaanskloof, Bucklands, East London, Jansenville, Middleton and Patensie

Mills & Cowling 2005; modelling following Kirschbaum *et al*. 2011

Comparing carbon and albedo

- Average 27 year rate K27 block at Krompoort
- 0.42 ± 0.08 kgC m^{-2} yr^{-1}
- -436 GJ ha^{-1} yr^{-1} radiative forcing

- Mean of the mean albedo for each site
- Calculate the difference between the degraded and intact sites
- Use the average incoming solar radiation for Addo, Baviaanskloof, Bucklands, East London, Jansenville, Middleton and Patensie
- + 426 GJ ha^{-1} yr^{-1}

Mills & Cowling 2005; modelling following Kirschbaum *et al*. 2011

Comparing carbon and albedo

- Average 27 year rate K27 block at Krompoort
- 0.42 ± 0.08 kgC m^{-2} yr^{-1}
- -436 GJ ha^{-1} yr^{-1} radiative forcing

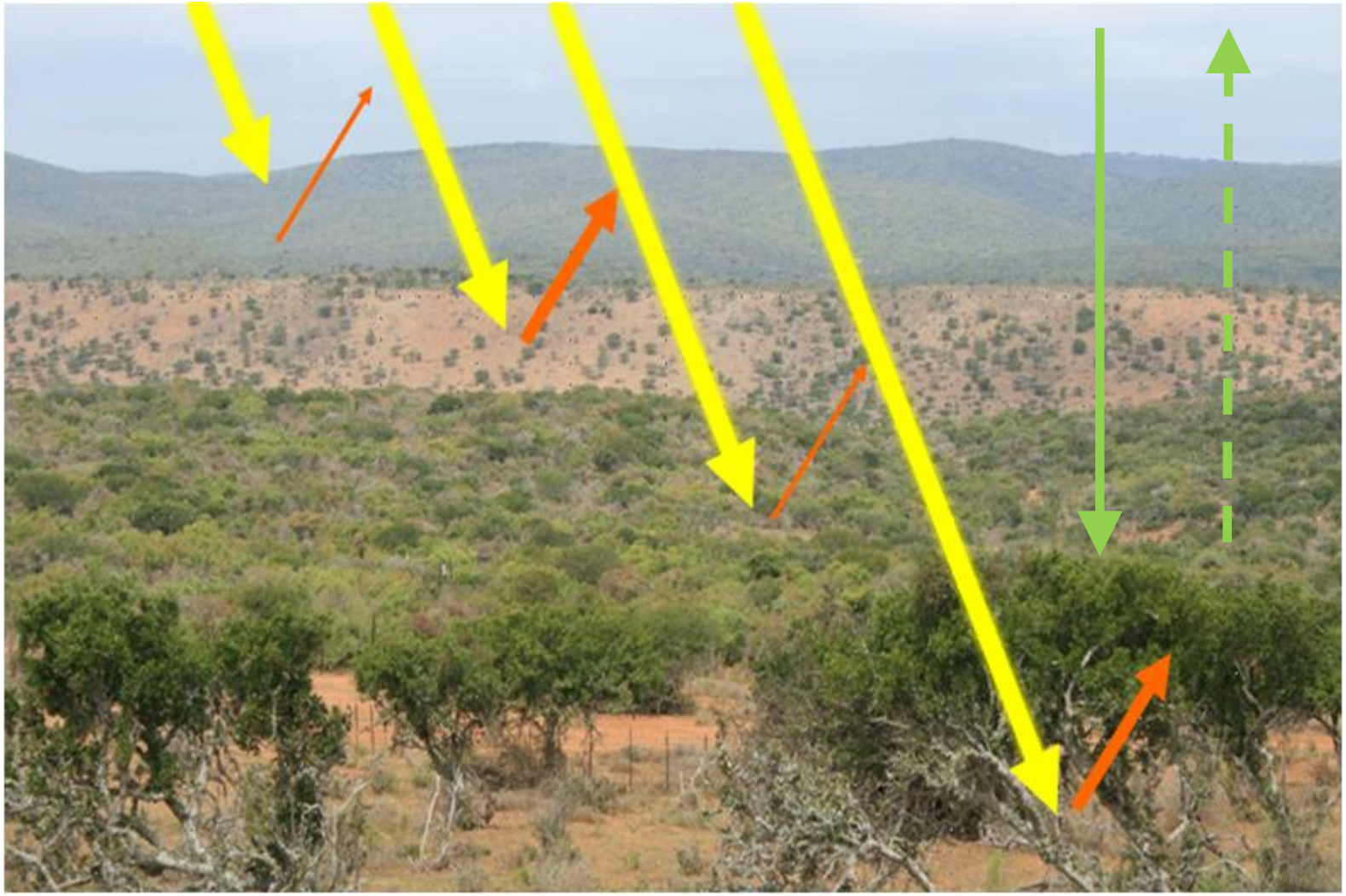
  Cooling effect

- Mean of the mean albedo for each site
- Calculate the difference between the degraded and intact sites
- Use the average incoming solar radiation for Addo, Baviaanskloof, Bucklands, East London, Jansenville, Middleton and Patensie
- + 426 GJ ha^{-1} yr^{-1} radiative forcing

  Warming effect

Mills & Cowling 2005; modelling following Kirschbaum *et al*. 2011

Comparing carbon and albedo



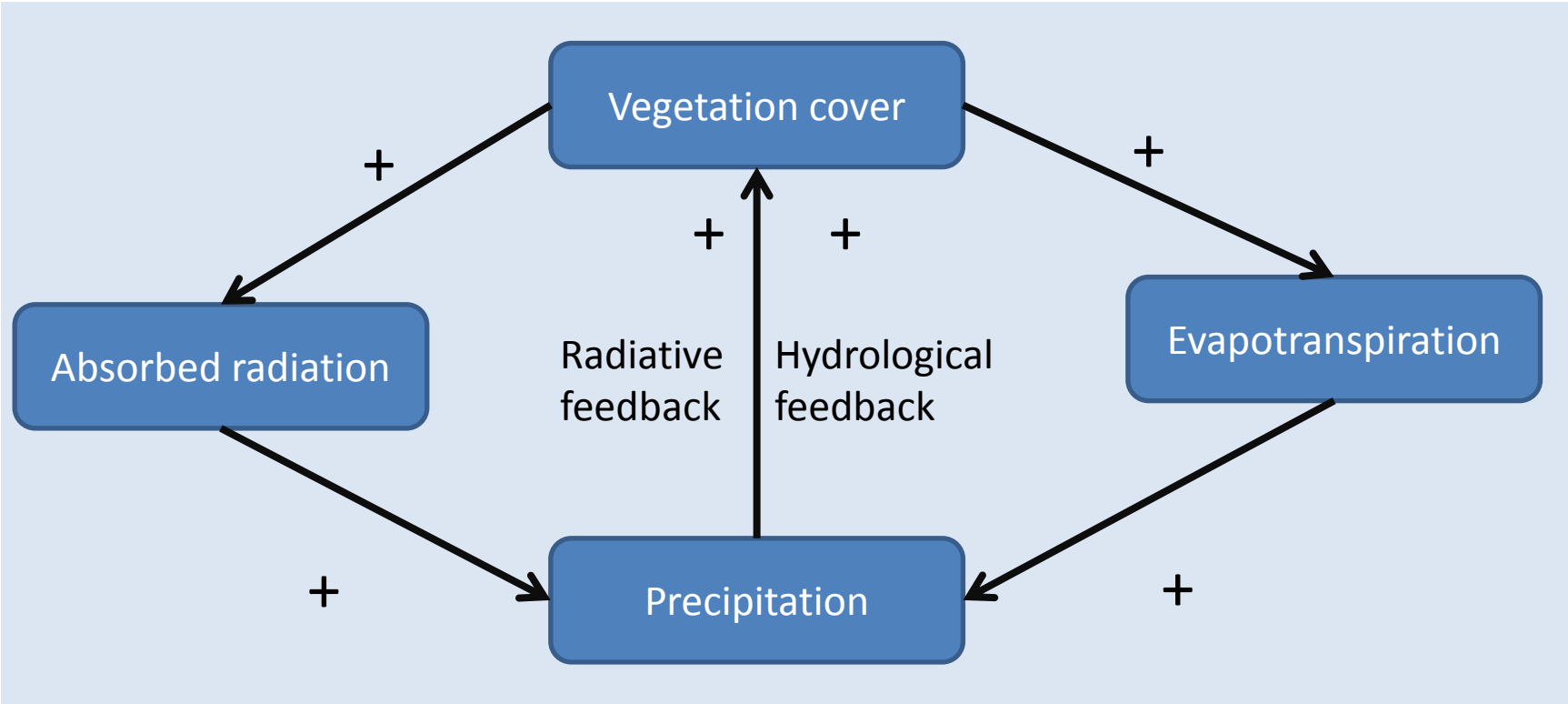
Comparing carbon and albedo

- Depending on colour and brightness, a land surface can have a positive (cooling) or negative (warming) effect on climate
- There is a real difference between the intact and transformed thicket landscapes
- This difference is important for heat and moisture budgets

Does this mean we stop restoration?

- No.
- Why not?
- Let’s look at another service, besides carbon squestration

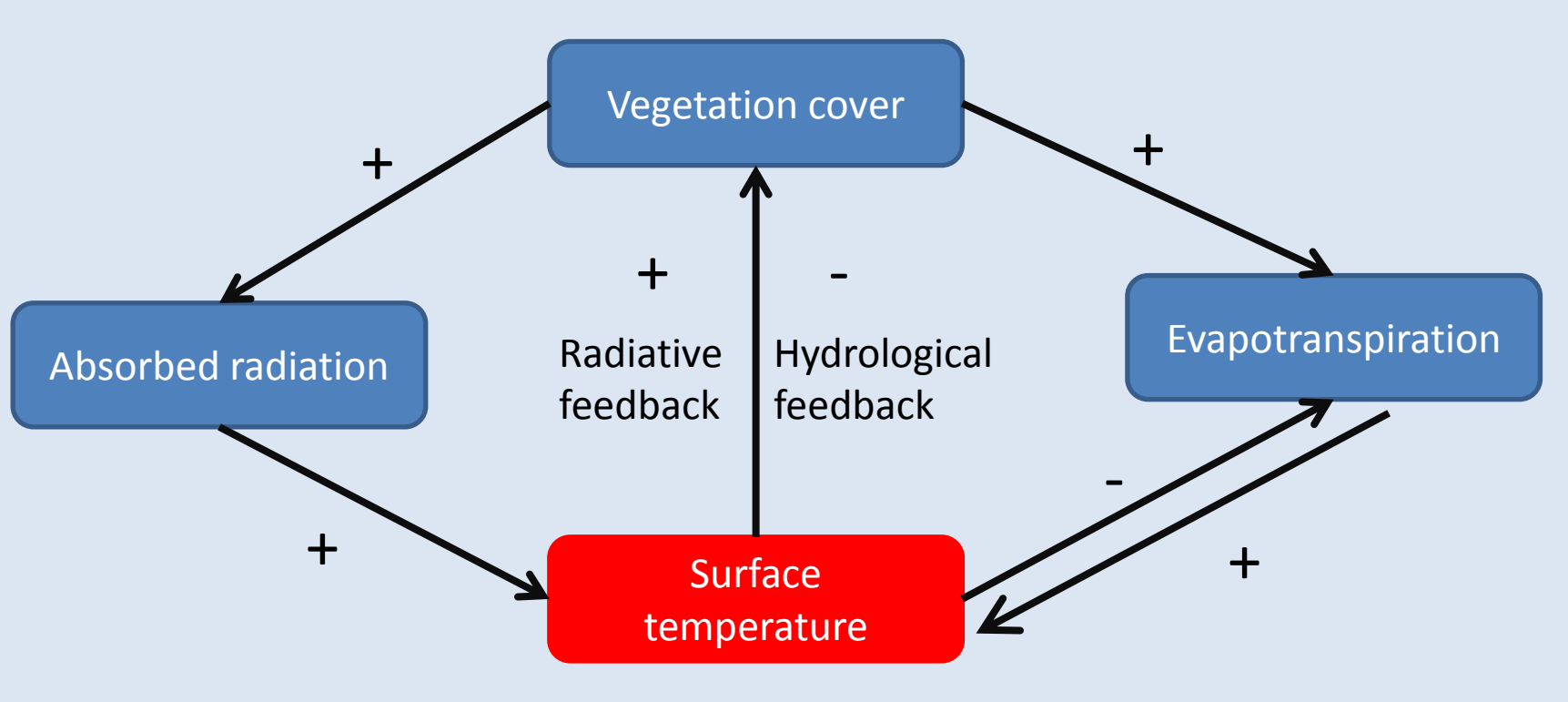
What does this mean?



Idealised sketch of land-atmosphere interactions. The signs indicate the effect of the outgoing box on the ingoing box.

Both radiative and hydrological feedbacks are + -> they amplify change

What does this mean?

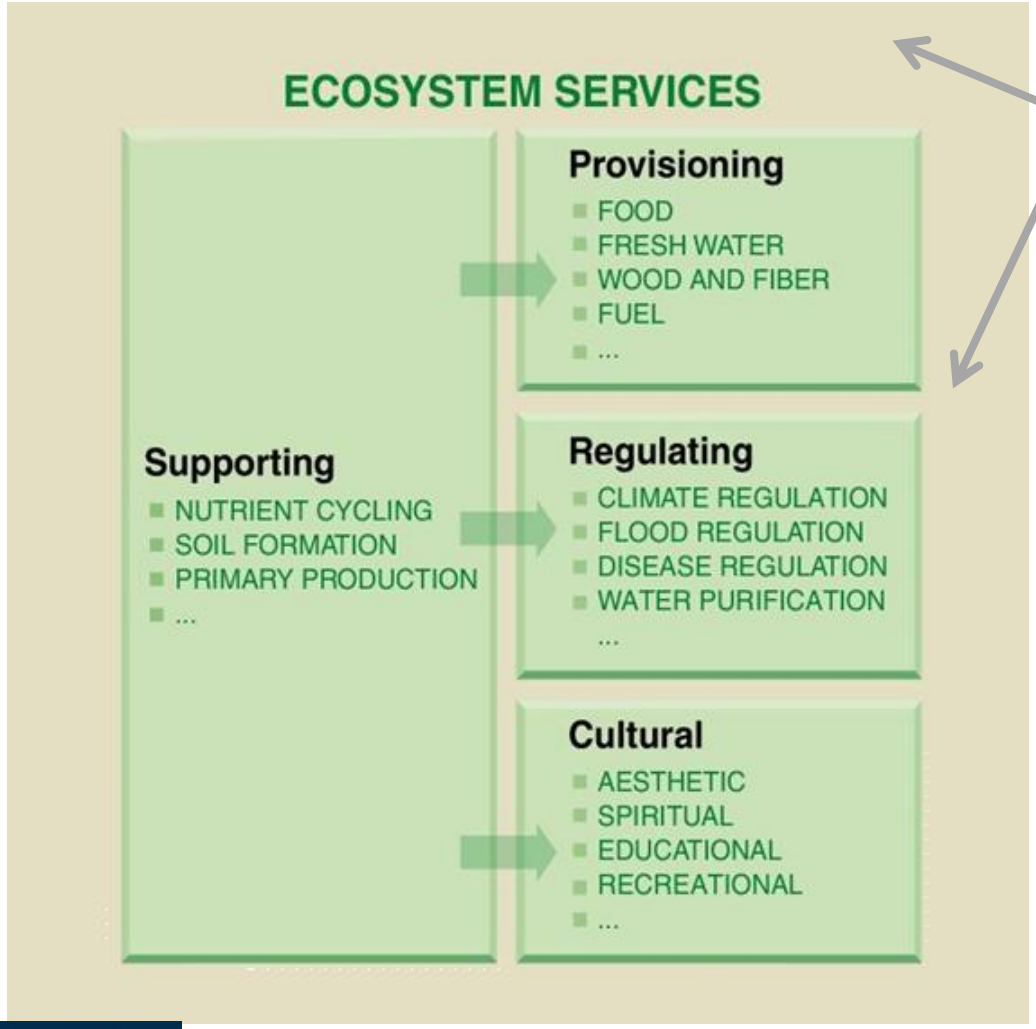


Idealised sketch of land-atmosphere interactions. The signs indicate the effect of the outgoing box on the ingoing box.

The radiative feedbacks are + -> they amplify change

The hydrological feedbacks are - -> they dampen change

Ecosystem services



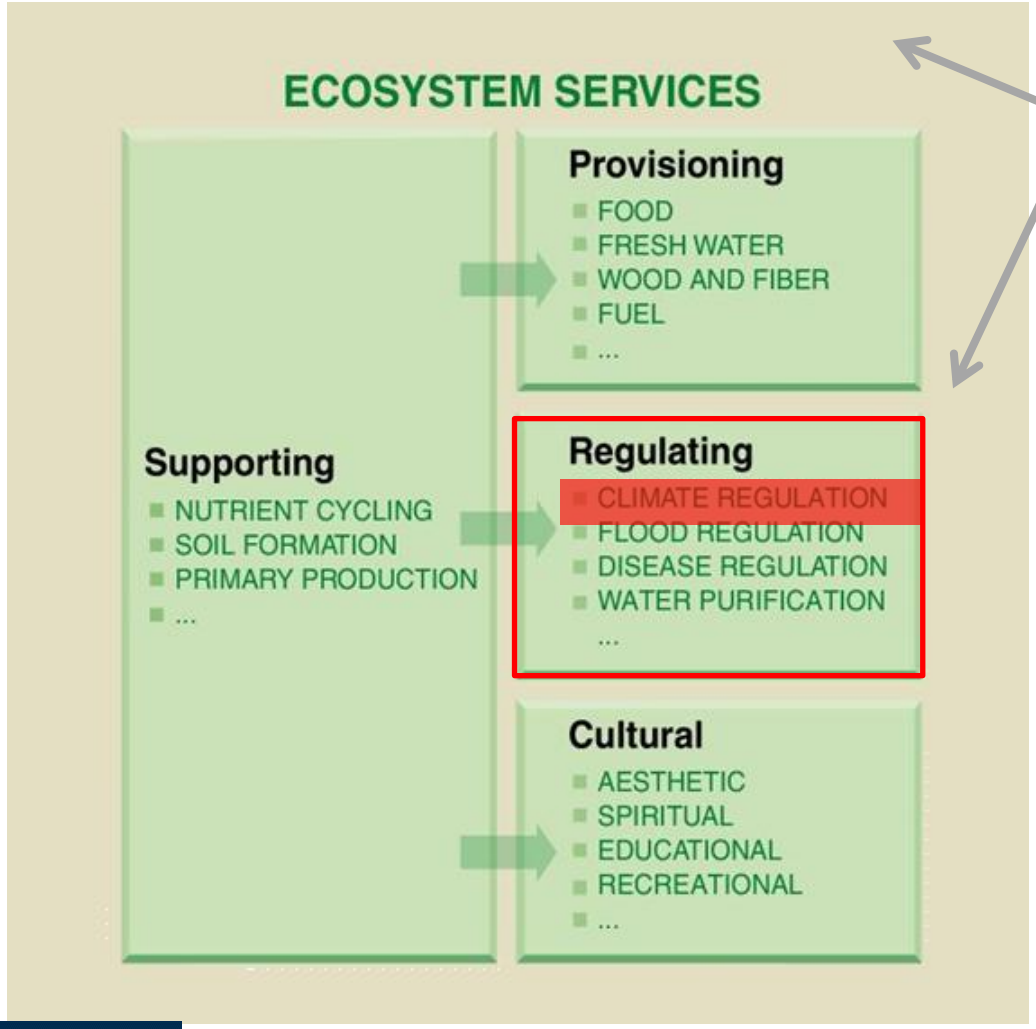
BIODIVERSITY

Restoring to an intact biodiversity-rich state will change the flow of services

- Carbon sequestration
- Other provisioning services

Millennium Ecosystem Assessment, 2005

Ecosystem services



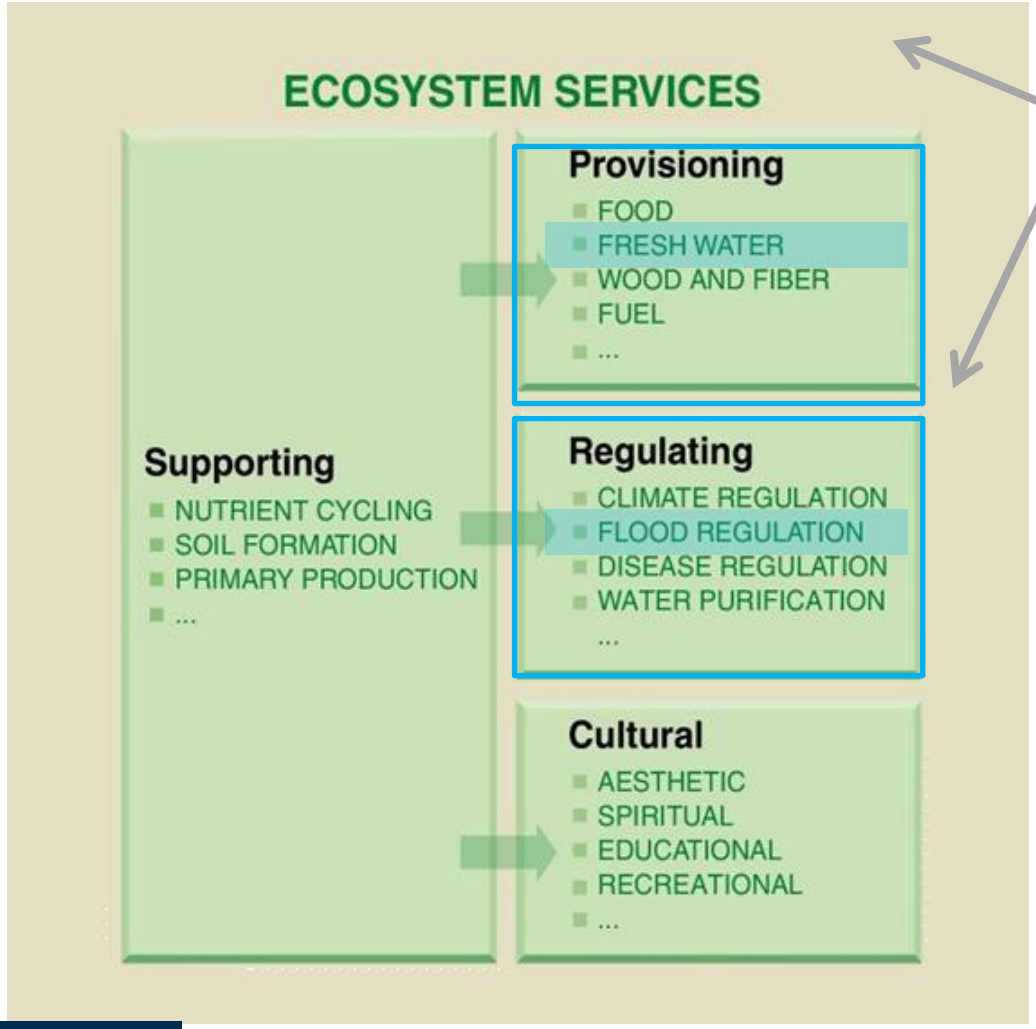
BIODIVERSITY

Restoring to an intact biodiversity-rich state will change the flow of services

- Carbon sequestration
- Other provisioning services

Millennium Ecosystem Assessment, 2005

Ecosystem services



BIODIVERSITY

Restoring to an intact biodiversity-rich state will change the flow of services

- Carbon sequestration
- Other provisioning services

Millennium Ecosystem Assessment, 2005

River flow characteristics
Catchment comparison

Compare these services in two contrasting land-cover states

Statistical analysis of river flow characteristics

- Flow Duration Curves to examine low flows
- Extreme Value Theory on peak flows
- Cumulative plots of discharge and rainfall

River flow characteristics

Catchment comparison

Intact thickets provide:

- Attenuation of flood peaks
- Decreased variability in low flows
- Decreased probability of low flow cessation

Concluding thoughts

- The same order of magnitude as the forcing exerted by a decrease in albedo associated with the successful reestablishment of spekboom
- Restoration would exert a positive radiative forcing through reduced albedo which could equal the negative forcing expected through carbon sequestration
- The albedo effect is large enough to warrant inclusion in assessments of the climate regulation potential of thicket restoration projects.

Acknowledgements and thanks go to

For project funding

For weather datasets

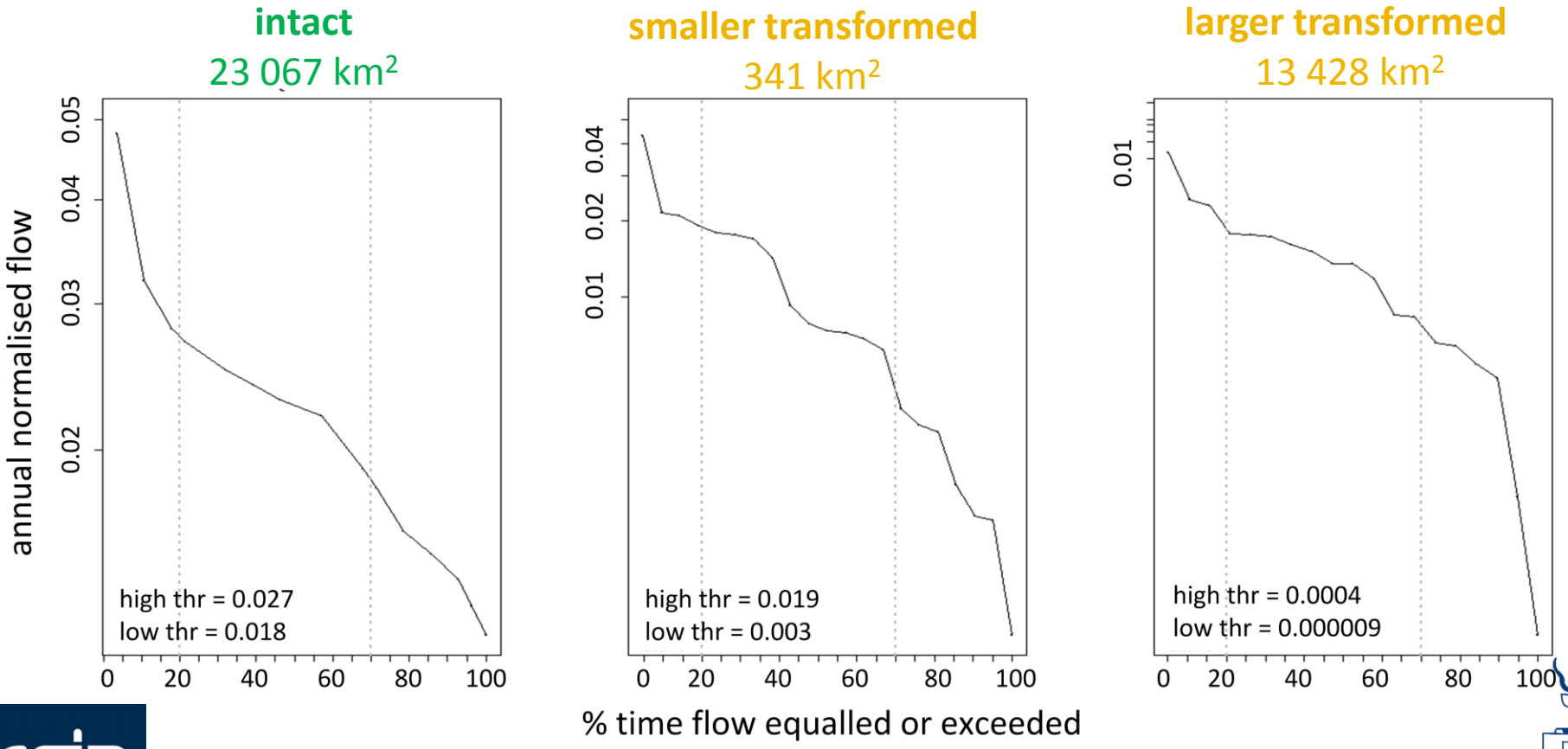
Michel Verstraete (*United Nations Joint Research Council, Ispra, Italy*) for theoretical and technical help

Linda Hunt (NASA Langley Research Centre (LaRC)) for her programming expertise

River flow characteristics

Catchment comparison

Flow Duration Curves (1981-2011)



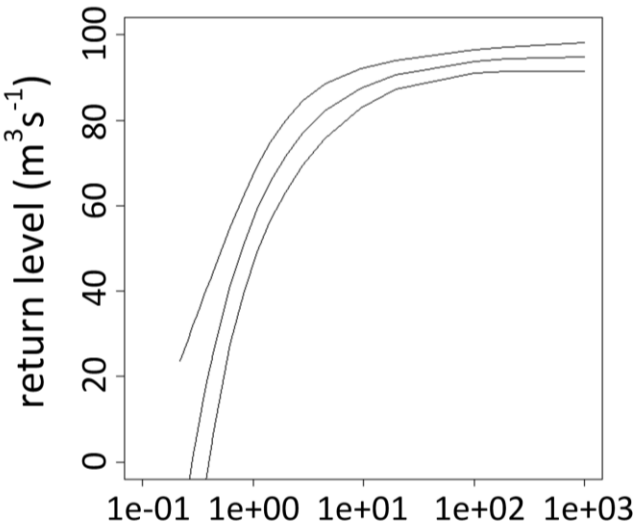
River flow characteristics

Catchment comparison

Extreme value analysis, return level plot (1981-2011)

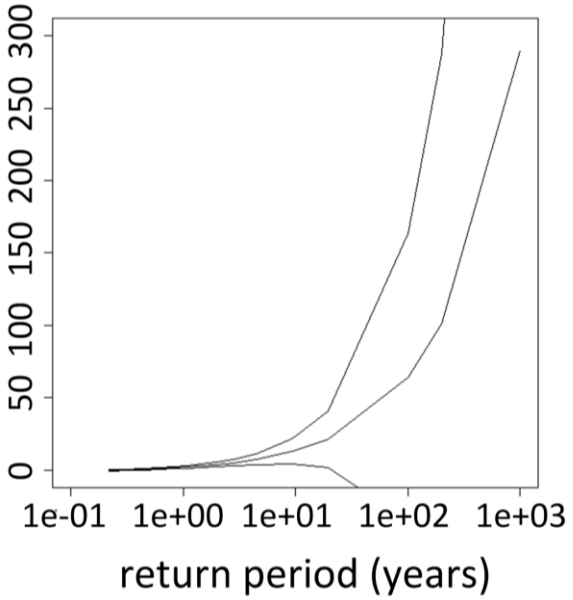
intact

23 067 km^2



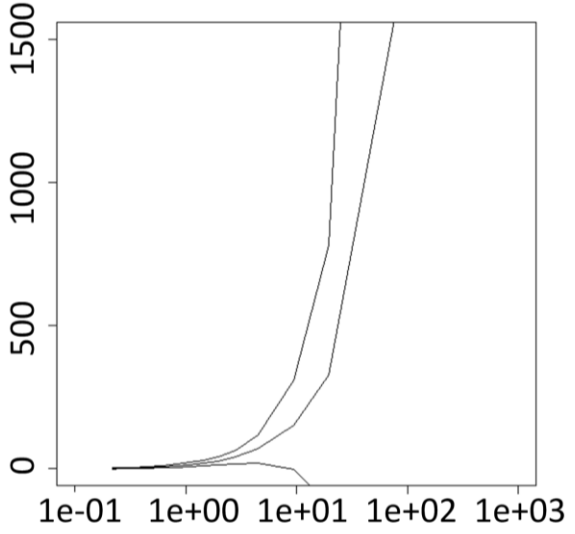
smaller transformed

341 km^2



larger transformed

13 428 km^2



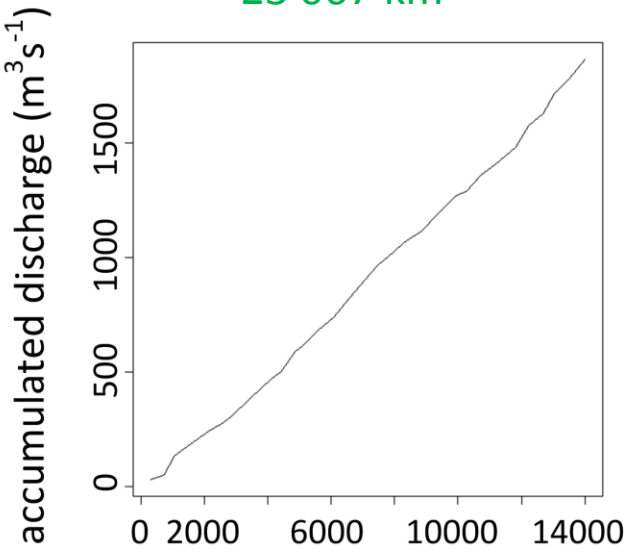
River flow characteristics

Catchment comparison

Cumulative plots(1981-2011)

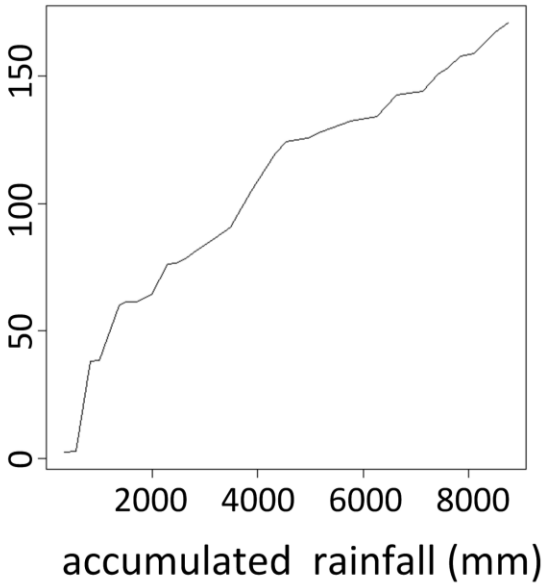
intact

23 067 km^2



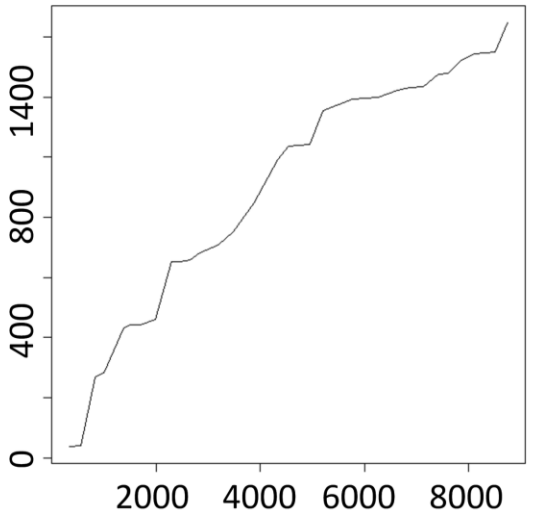
smaller transformed

341 km^2



larger transformed

13 428 km^2



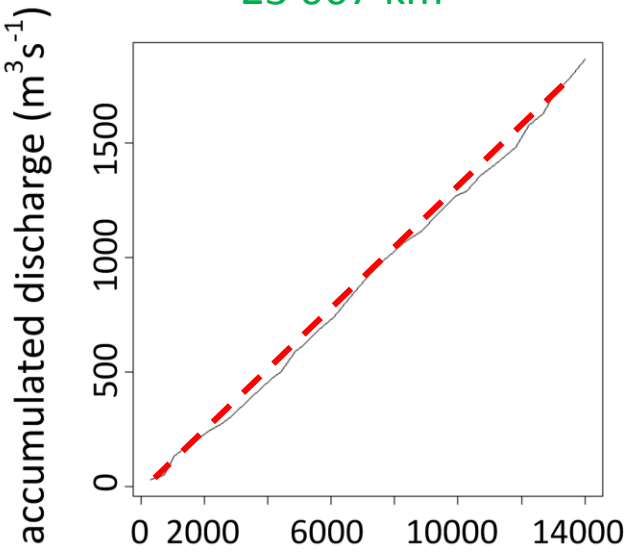
River flow characteristics

Catchment comparison

Cumulative plots(1981-2011)

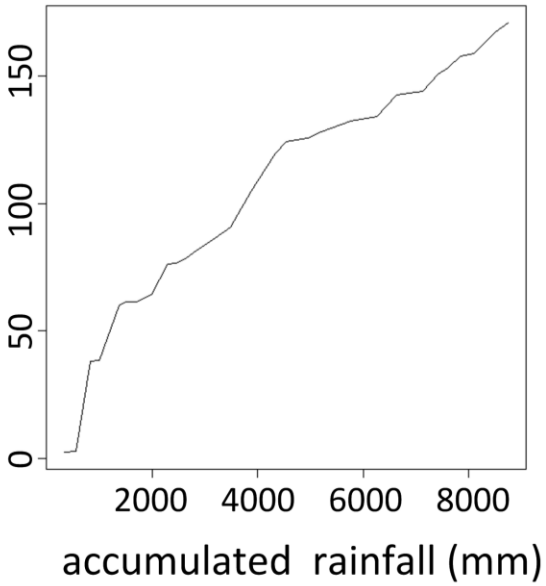
intact

23 067 km^2



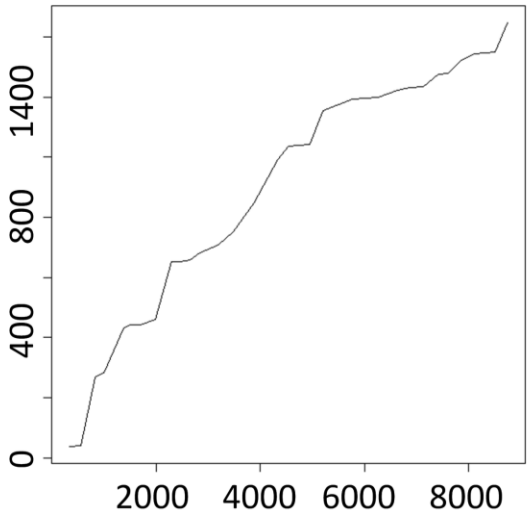
smaller transformed

341 km^2



larger transformed

13 428 km^2

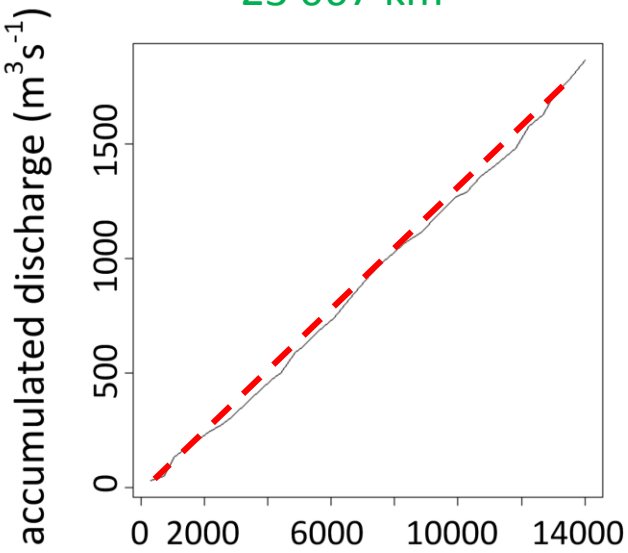


River flow characteristics

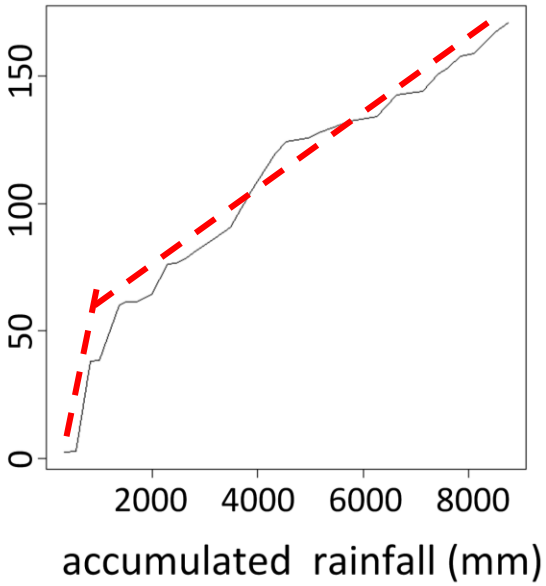
Catchment comparison

Cumulative plots(1981-2011)

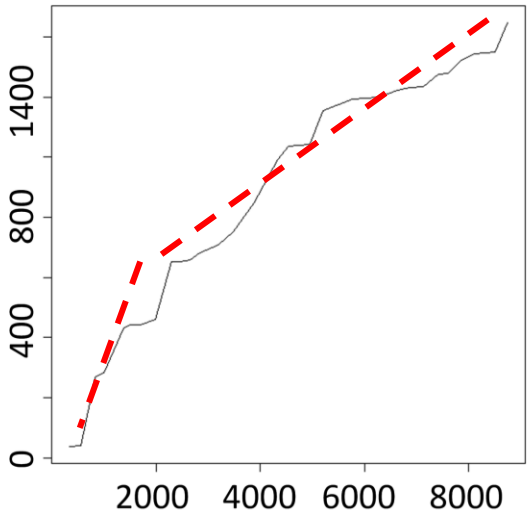
intact
23 067 km^2



smaller transformed
341 km^2



larger transformed
13 428 km^2

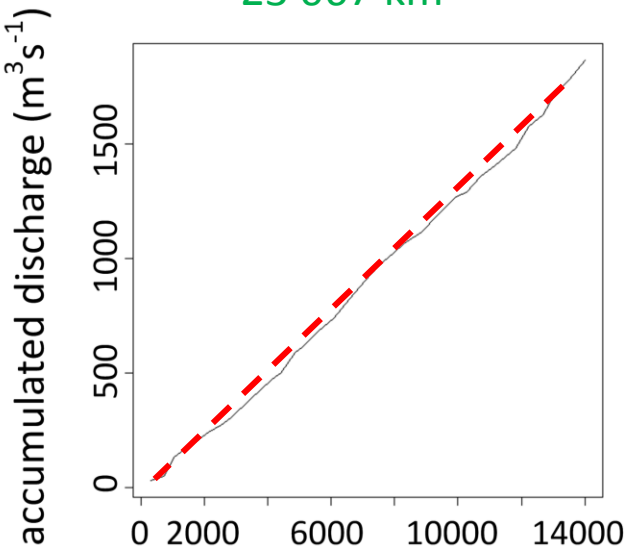


River flow characteristics

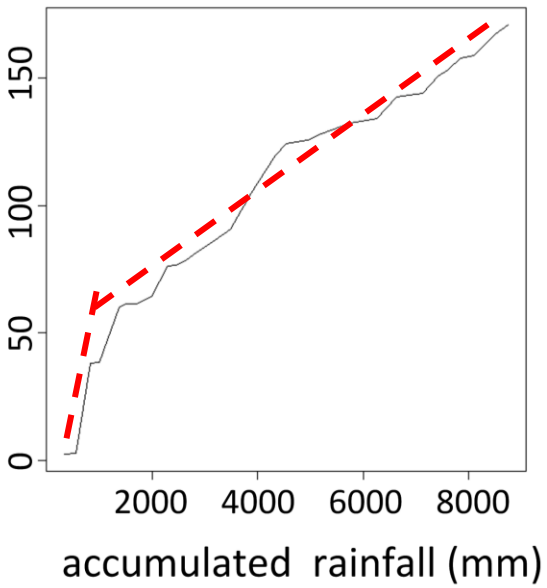
Catchment comparison

Cumulative plots(1981-2011)

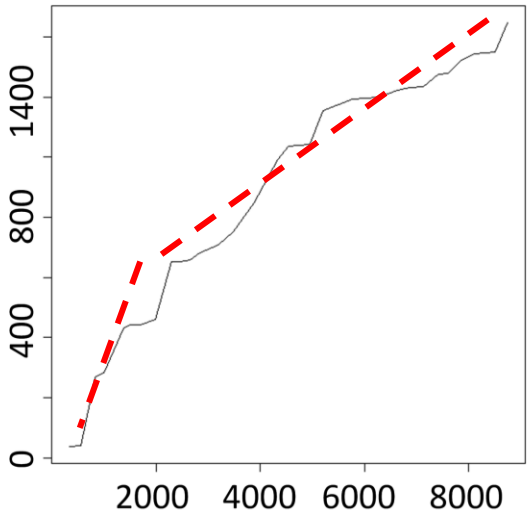
intact
23 067 km^2



smaller transformed
341 km^2



larger transformed
13 428 km^2



run-off yield has declined over time