Limiting uncertainties in SEBS estimated evapotranspiration in heterogeneous catchments

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Remote sensing and ET estimation

- In the last 15 years, much research into using remote sensing techniques for estimating ET

- Why use remote sensing?
  - Spatial coverage
  - Temporal coverage
  - Reduced costs
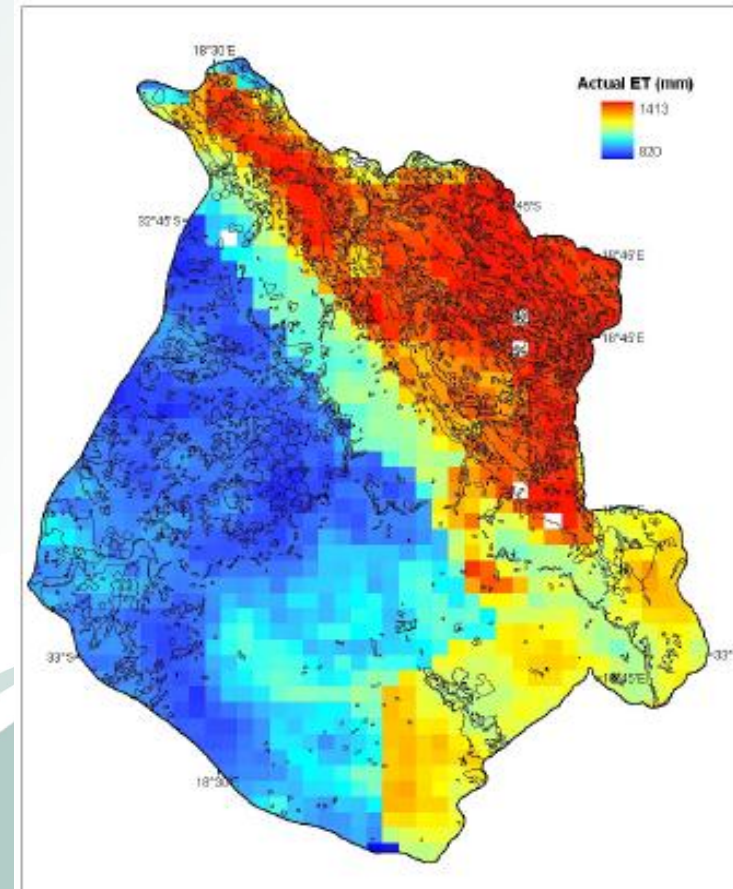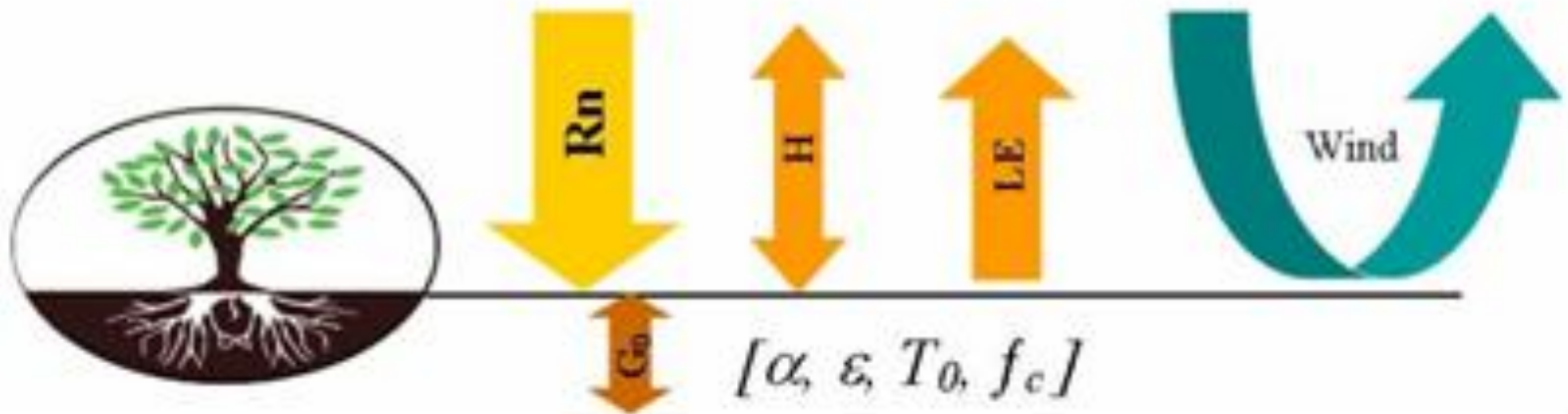
Evapotranspiration applications

- Water use determination (water licenses)
- Water use efficiency
  - Agriculture "more crop per drop"
  - Ecosystem water use comparisons
- Drought forecasting
- Water footprinting
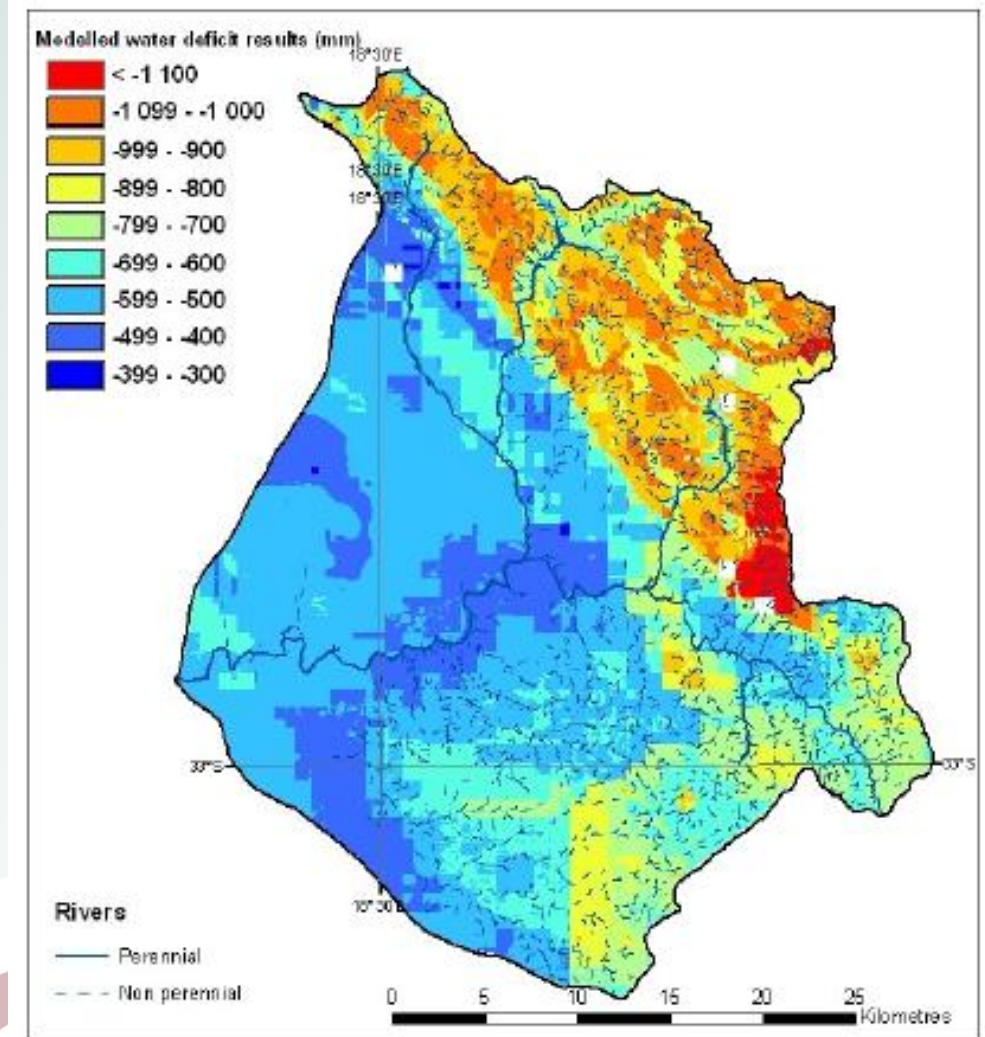- Water balance studies
- Hydrological modelling

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Remote sensing and ET estimation

- How?

$$Rn = G_0 + H + LE + \Delta S$$

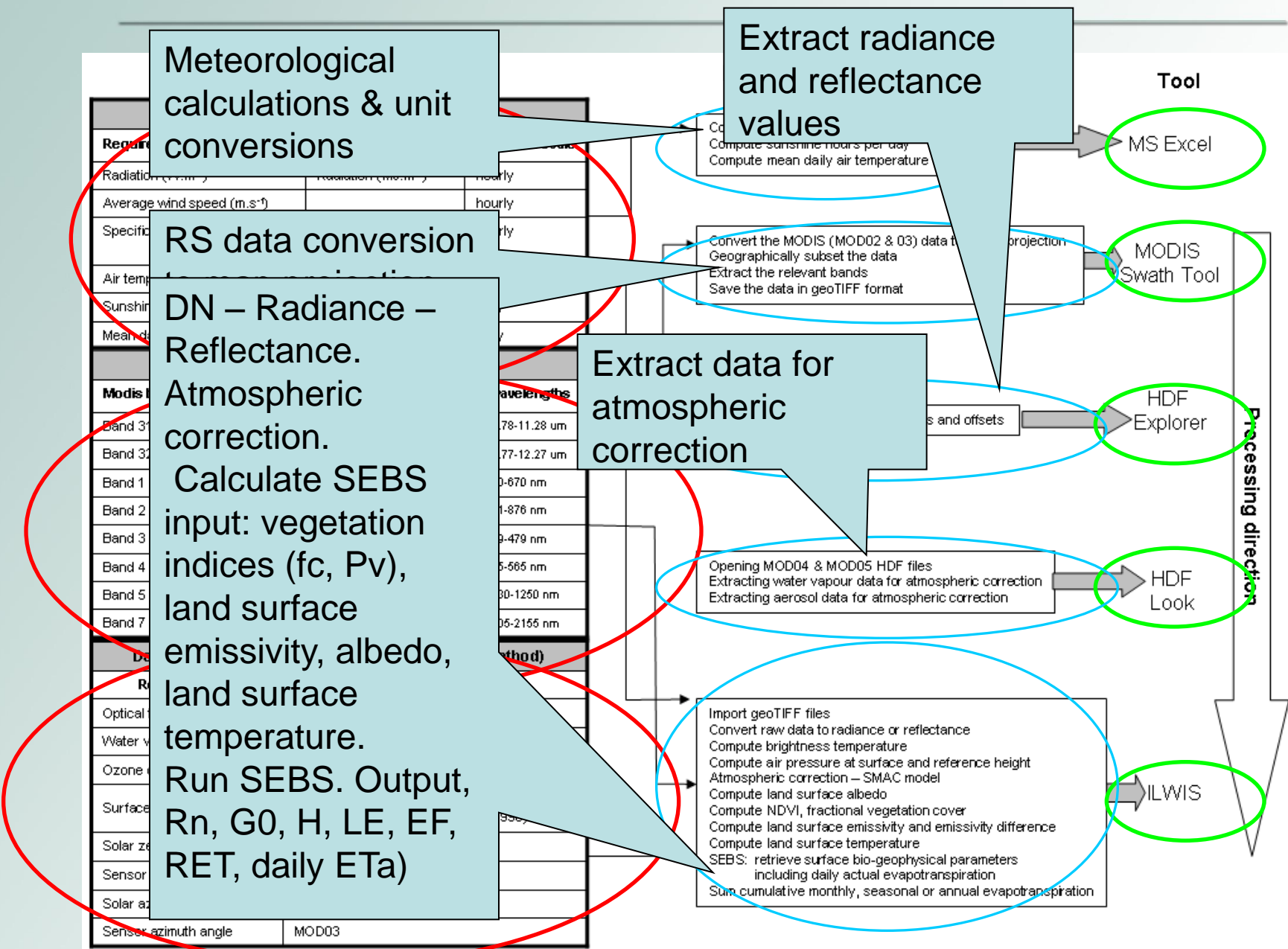$$\Delta S \approx 0$$

$$[\alpha, \varepsilon, T_0, f_c]$$

How we came to understand the limitations in SEBS

- Water balance study in Piket-Bo-Berg

- Significantly more ET than rainfall during a "wet" year

- What were we doing wrong?

Modelled water deficit results (mm)

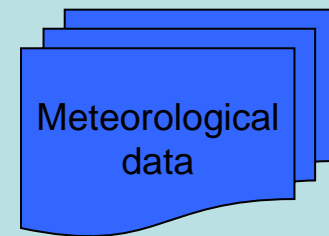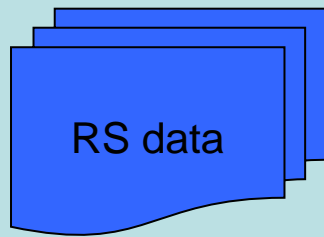|	
■	< -1 100
■	-1 099 - -1 000
■	-999 - -900
■	-899 - -800
■	-799 - -700
■	-699 - -600
■	-599 - -500
■	-499 - -400
■	-399 - -300

Rivers

— Perennial

- - - Non perennial

0 5 10 15 20 25 Kilometres

Let's look at the SEBS model

Meteorological calculations & unit conversions

Extract radiance and reflectance values

RS data conversion to map projection

DN – Radiance – Reflectance. Atmospheric correction. Calculate SEBS input: vegetation indices (fc, Pv), land surface emissivity, albedo, land surface temperature. Run SEBS. Output, Rn, G0, H, LE, EF, RET, daily ETa)

Extract data for atmospheric correction

Tool

MS Excel

MODIS Swath Tool

HDF Explorer

HDF Look

ILWIS

Processing direction

Require...		...ook
Radiation (W.m⁻²)	Radiation (Mo.m⁻²)	hourly
Average wind speed (m.s⁻¹)		hourly
Specific...		...rly
Air temp...		
Sunshin...		
Mean d...		

Modis...		...avelengths
Band 31		.78-11.28 um
Band 32		.77-12.27 um
Band 1		.0-670 nm
Band 2		.1-876 nm
Band 3		.9-479 nm
Band 4		.5-565 nm
Band 5		.30-1250 nm
Band 7		.05-2155 nm

De...		...thod)
R...		
Optical...		
Water v...		
Ozone...		
Surface...		
Solar ze...		
Sensor...		
Solar az...		
Sensor azimuth angle	MOD03	

Compute sunshine hours per day
Compute mean daily air temperature

Convert the MODIS (MOD02 & 03) data t... projection
Geographically subset the data
Extract the relevant bands
Save the data in geoTIFF format

...s and offsets

Opening MOD04 & MOD05 HDF files
Extracting water vapour data for atmospheric correction
Extracting aerosol data for atmospheric correction

Import geoTIFF files
Convert raw data to radiance or reflectance
Compute brightness temperature
Compute air pressure at surface and reference height
Atmospheric correction – SMAC model
Compute land surface albedo
Compute NDVI, fractional vegetation cover
Compute land surface emissivity and emissivity difference
Compute land surface temperature
SEBS: retrieve surface bio-geophysical parameters
          including daily actual evapotranspiration
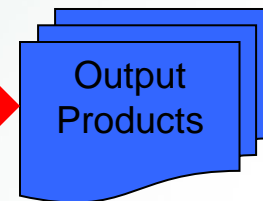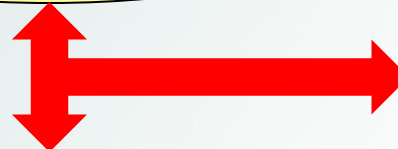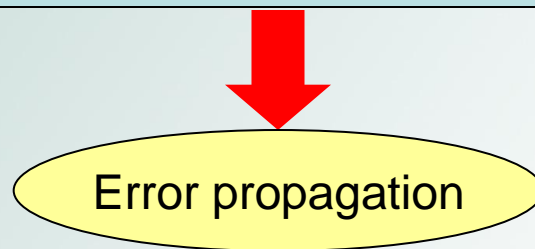Sum cumulative monthly, seasonal or annual evapotranspiration

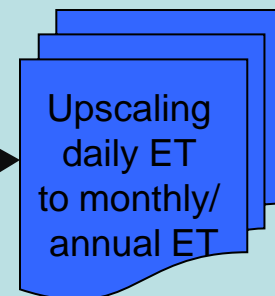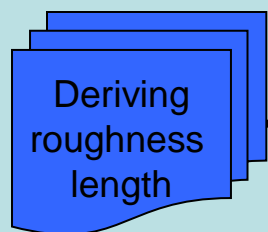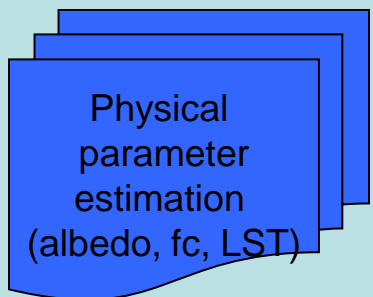# Uncertainties in using complex models

Possible error sources….

Error propagation
errors in input data
passed through
processing sequences
errors accumulate in
output products

Error production
errors produced
in output products
no errors in input data

Atmospheric correction

RS data

Meteorological data

Errors in input data

Error propagation

Output Products

Error production

Possible processing errors

Physical parameter estimation (albedo, fc, LST)

Deriving roughness length

Energy balance partitioning

Upscaling daily ET to monthly/ annual ET

Identified source of uncertainties

Sensitivity analysis to determine the input parameters to which SEBS is most sensitive and what the impact of possible uncertainty ranges are on estimated daily ETa

Simultaneous multiple parameter sensitivity analysis of SEBS is required to determine the interaction of all parameters however, single parameter sensitivity analysis has uncovered some interesting findings

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Identified source of uncertainties

1. Temperature gradient (LST minus air temperature)

2. Choice of fractional vegetation cover formula

3. Height at which wind speed is measured (in relation to maximum canopy height)

Landscape heterogeneity

Temperature

- LST – limitations where:
    - High sensor zenith angle
    - Topographically rough areas

- In short time period uncertainty of 10 K was found

- Impact on results? (ET mm/day)

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Impact of uncertainties – RS derived LST or air temp
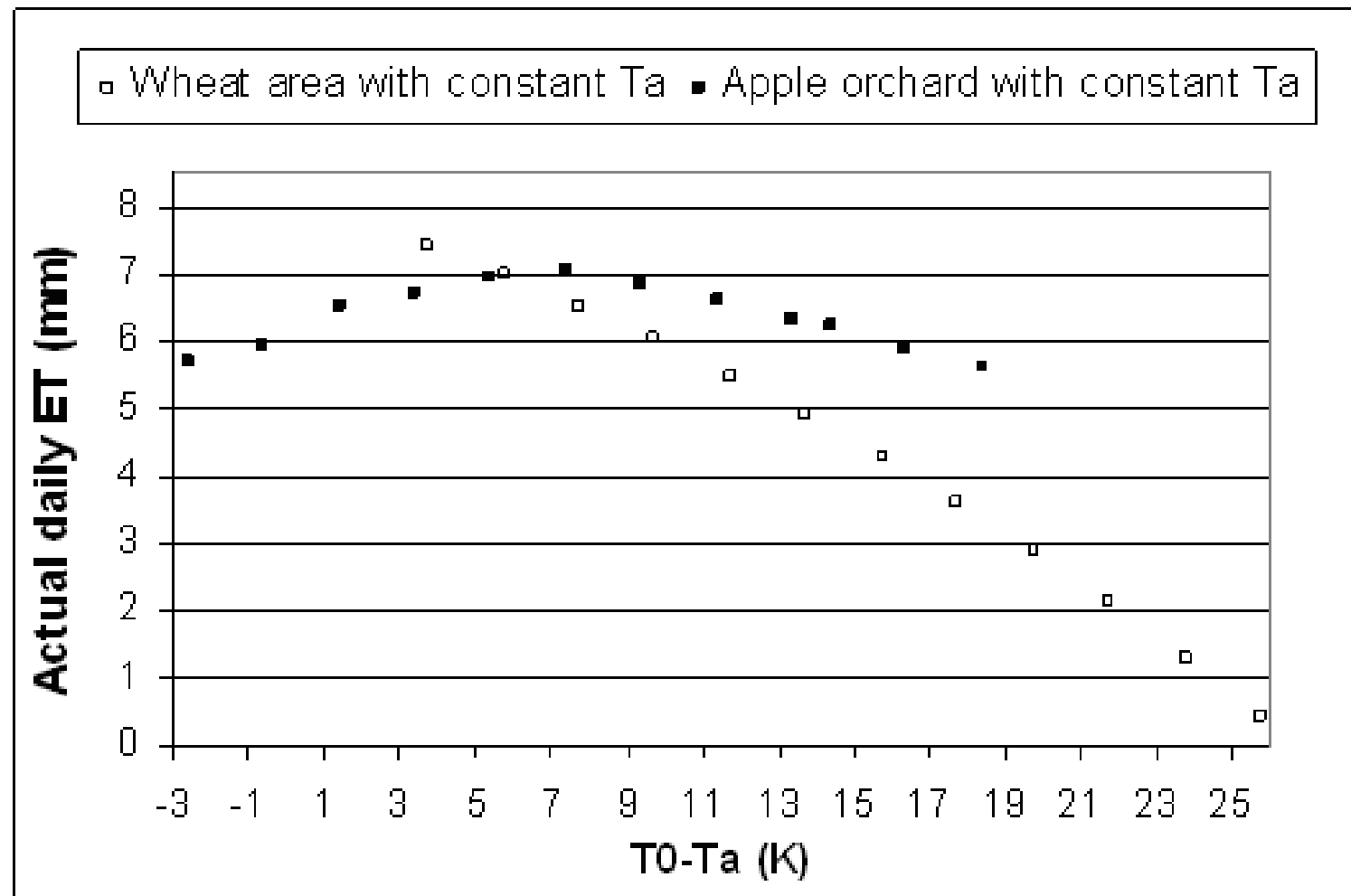
Uncertainties in the derivation of ET using SEBS

- The choice of fractional vegetation cover formula

- The selection of minimum and maximum NDVI values
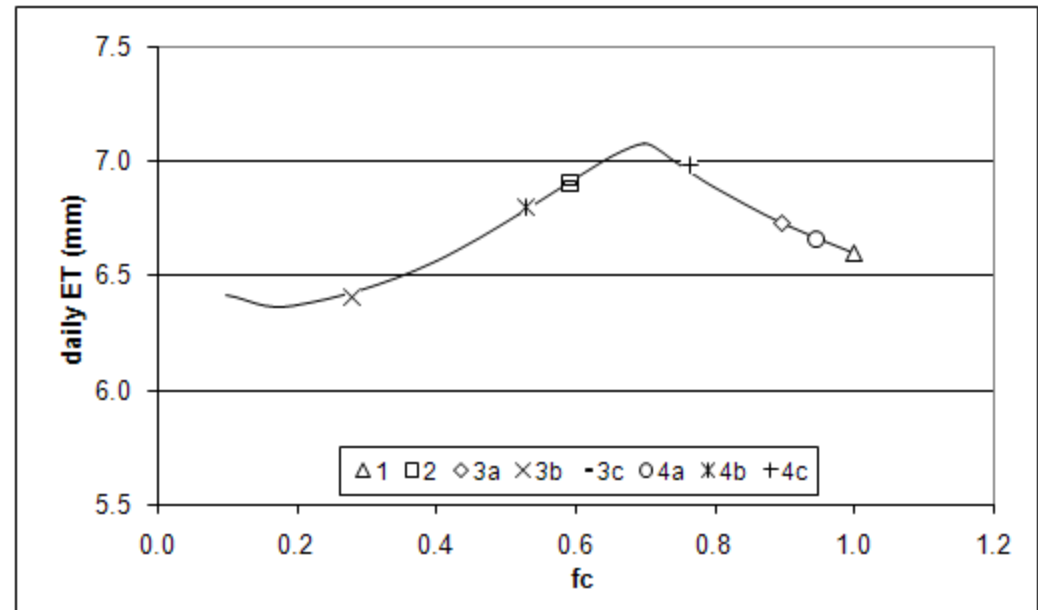
| 1 | Fixed NDVI max (0.5) and min (0.2) (Sobrino & El Kharraz, 2003)) |
2	LAI dependent (Choudhury, 1987, cited in French et al., 2003)
3a	Scene dependent NDVI max (0.563) and min (0.207) (Carlson & Ripley, 1997)
3b	Time series derived NDVI max (0.863) and min (0.184) (Carlson & Ripley, 1997)
3c	Study area derived NDVI max (0.65) and min (0.2) (Carlson & Ripley, 1997)
4a	Scene dependent NDVI max (0.563) and min (0.207) (Gutman & Ignatov, 1998)
4b	Time series derived NDVI max (0.863) and min (0.184) (Gutman & Ignatov, 1998)
4c	Study area derived NDVI max (0.65) and min (0.2) (Gutman & Ignatov, 1998)

Note: where fc is calculated to be greater than 1, then fc is taken to be equal to 1

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Uncertainties in the derivation of ET using SEBS

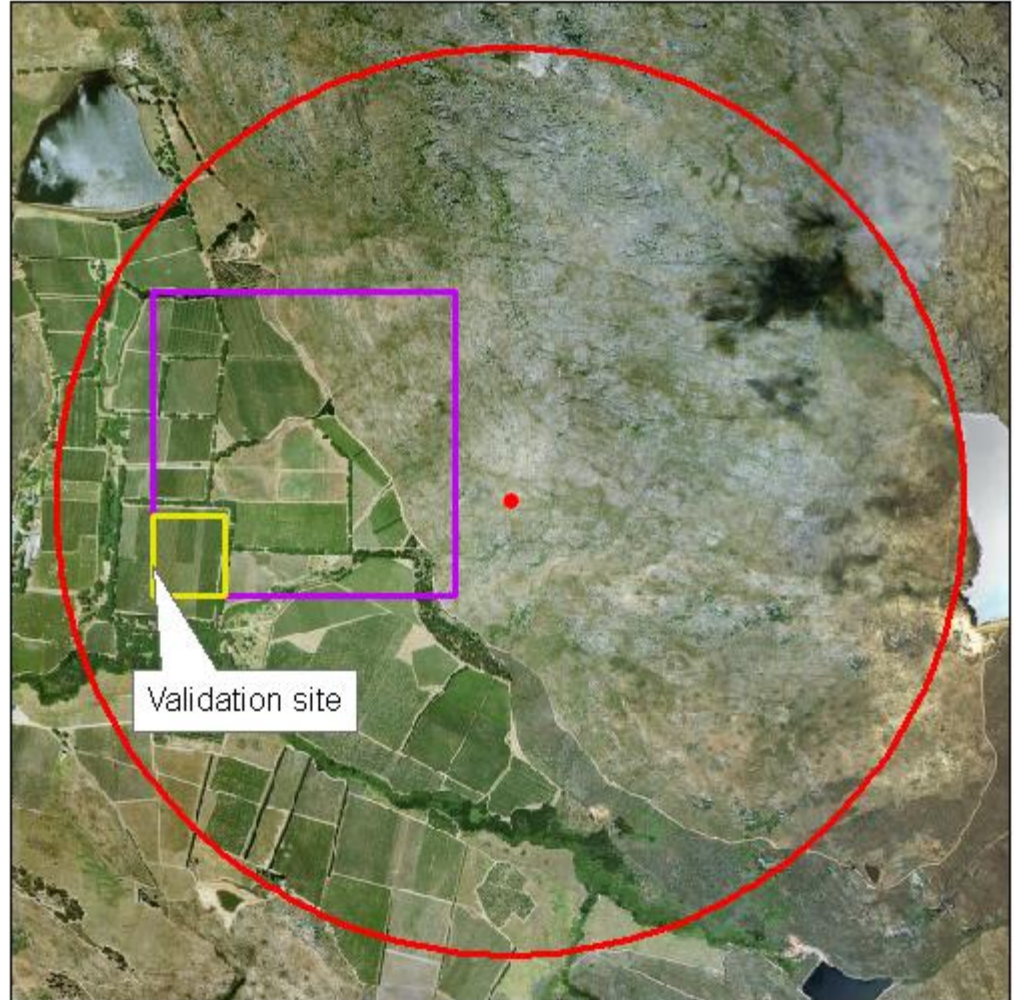- The height of wind speed measurement in relation to canopy height

$\ln (z - d0)$

If wind speed measured at 2 m, the maximum canopy height be in the region of 2.8 m.

$d0$ = 2/3 x canopy height
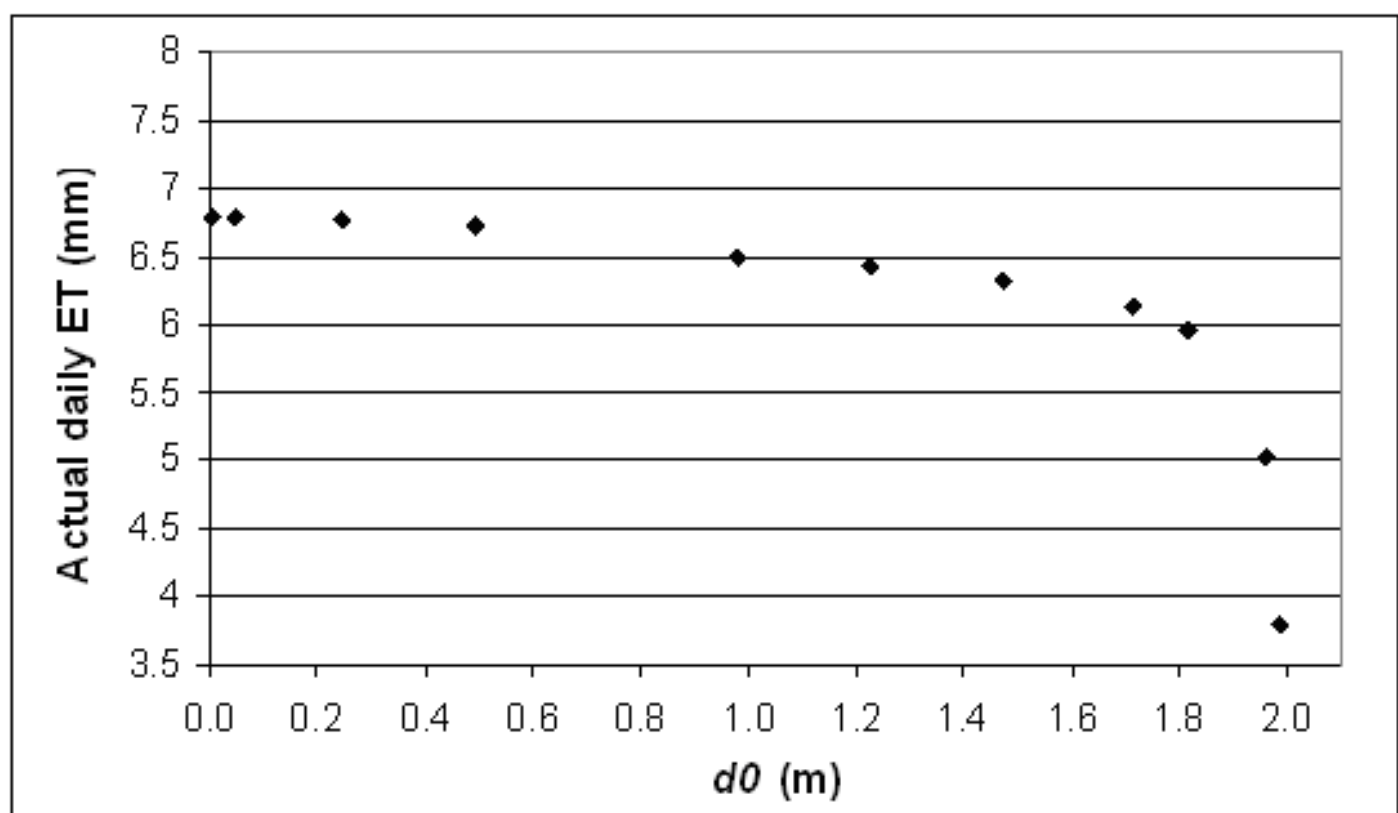
Identified source of uncertainties

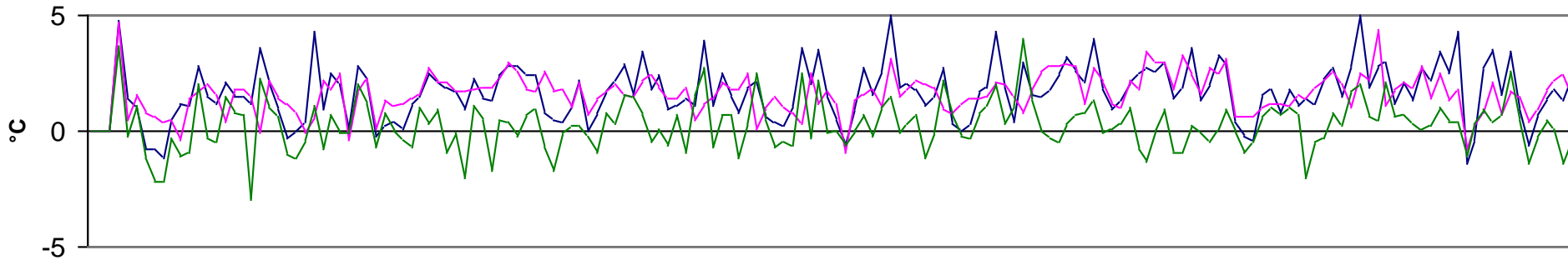- Study area heterogeneity

  – mixed-pixel effect

Validation site

MODIS 250m resolution pixel
MODIS 1 km resolution pixel
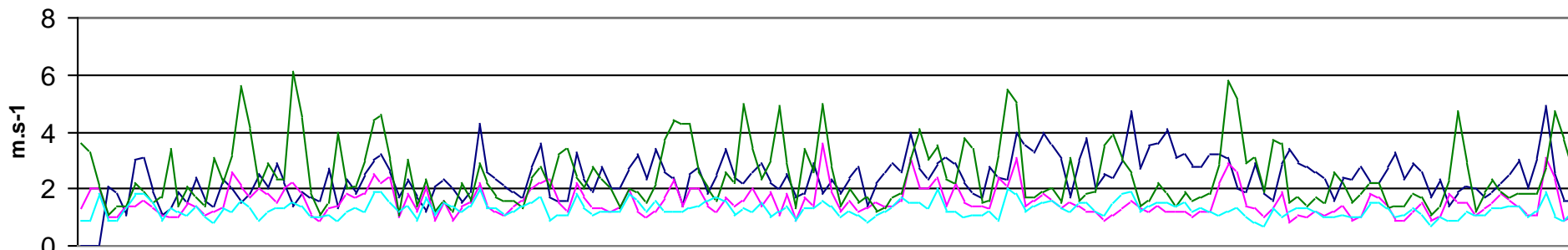SEVIRI centre point of pixel with 1.5km radius

Study area heterogeneity

The need for spatially distributed measurements of near-surface weather conditions due to the topographic heterogeneity

Air temperature - difference

wind variability

Limiting the uncertainties

- Expectations for results
  - Field-scale vs. catchment scale?
- Pixel resolution for study area
  - Heterogeneity analysis before you start
  - Choice of sensor and availability of images
- Source of Weather Station data
  - In relation to canopy height
- Critical choice of fractional vegetation cover
  - NDVI vs. LAI and min and max NDVI values
- Interpolation of meteorological inputs

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Concluding remarks

- Current project (WRC) to test SEBS taking cognisance of limitations and adjusting for these

- Further multi-parameter sensitivity analysis is required

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