Georeferencing and Orthoimage Generation from Long Strips of ALOS Imagery

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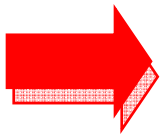
Outline

- Motivation
- Sensor model and strip adjustment
- Automatic determination of Ground Control Points (GCPs)
- Evaluation of Strip Adjustment
- Conclusion

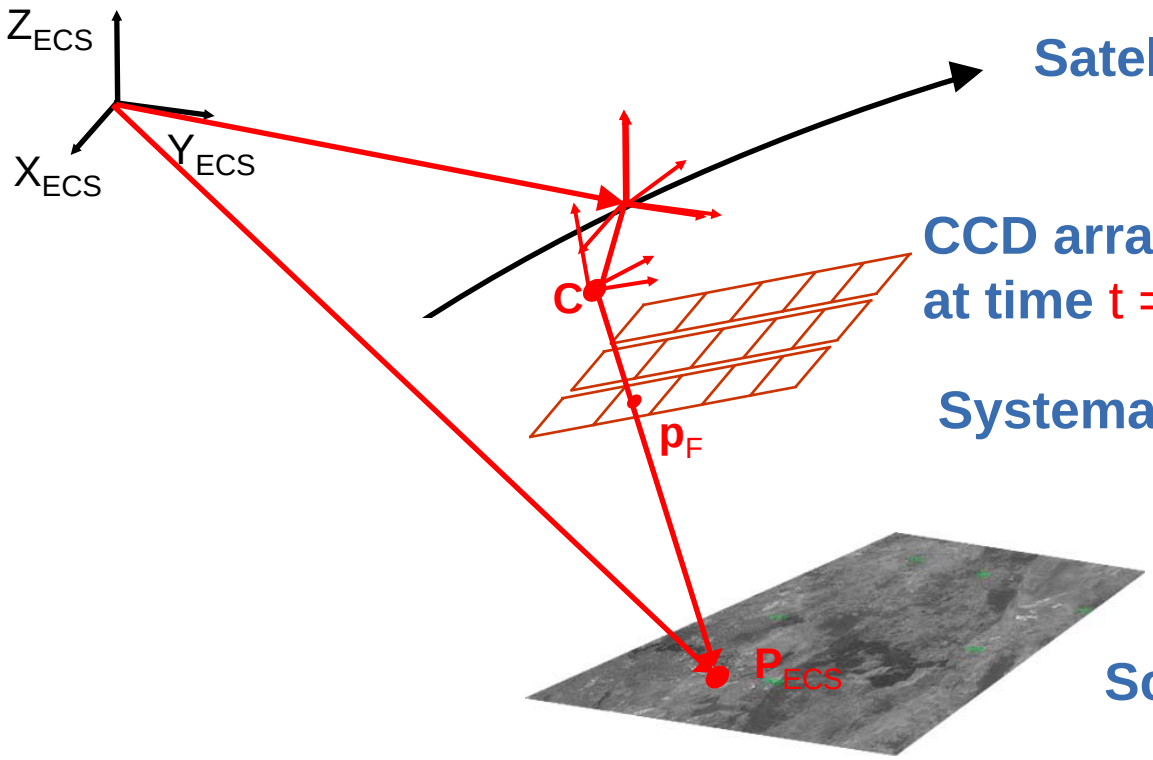
Motivation

- **Geoscience Australia (GA):** Data node for Oceania
- GA want to distribute ortho-rectified ALOS scenes
- Huge demand, e.g. all Western Australia (2.5 million km^2)
- **Existing solution:** processing of individual scenes
- Main bottleneck in the production line: Determination of GCPs
- In order to cope with the huge demand, the output rate has to be increased



Strip adjustment using a generic sensor model

Generic Pushbroom Sensor Model I



Satellite path

CCD array records lines at time $t = t_0 + \Delta t \cdot y_F$

Systematic error correction: δx

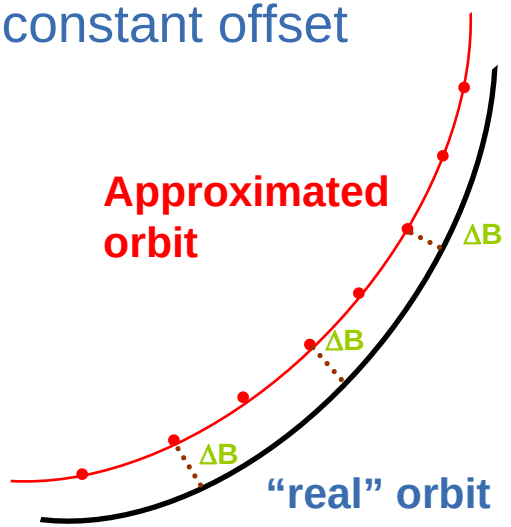
Scene on ground

$$P_{ECS} = f(p_F, x)$$

$$P_{ECS} = S(t) + R_O \cdot R_P(t) \cdot [C_M + R_M] R_M \cdot (p_F - c_F + \delta x)]$$

Generic Pushbroom Sensor Model II

- Orbit observations for path **S**(t) and attitudes $\mathbf{R}_P(t)$, affected by systematic errors
- Correction of systematic errors in path and attitudes
  - **S**(t) and attitudes $\mathbf{R}_P(t)$ modelled by **cubic splines**
  - **Image observations** relate to "real" orbit path and attitudes
  - **Observed orbit points** are direct observations for **S**(t) and $\mathbf{R}_P(t)$
  - Unknown bias correction **ΔB** modelled as time-constant offset (for path and attitudes)
- **Bundle adjustment** using ground control points and orbit observations to determine the orbit parameters and the bias corrections

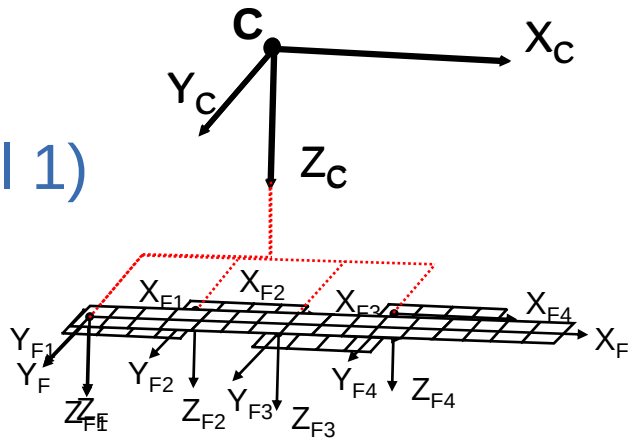


Generic Pushbroom Sensor Model III

- Systematic error correction in image space ($\delta\mathbf{x}$):

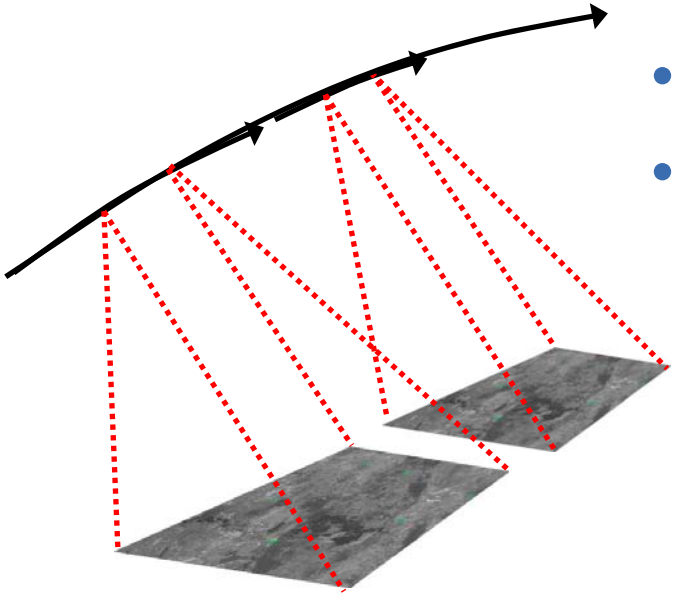
$$\delta x = a_0 + a_1 \cdot x_F + a_2 \cdot x_F^2$$
$$\delta y = b_0 + b_1 \cdot x_F + b_2 \cdot x_F^2$$

- Coefficients can be determined in adjustment ⇒ self-calibration
- **ALOS PRISM:**
  - One set of coefficients per CCD (level 1)
  - Calibration data from JAXA
  - Preprocessing: merge sub-images

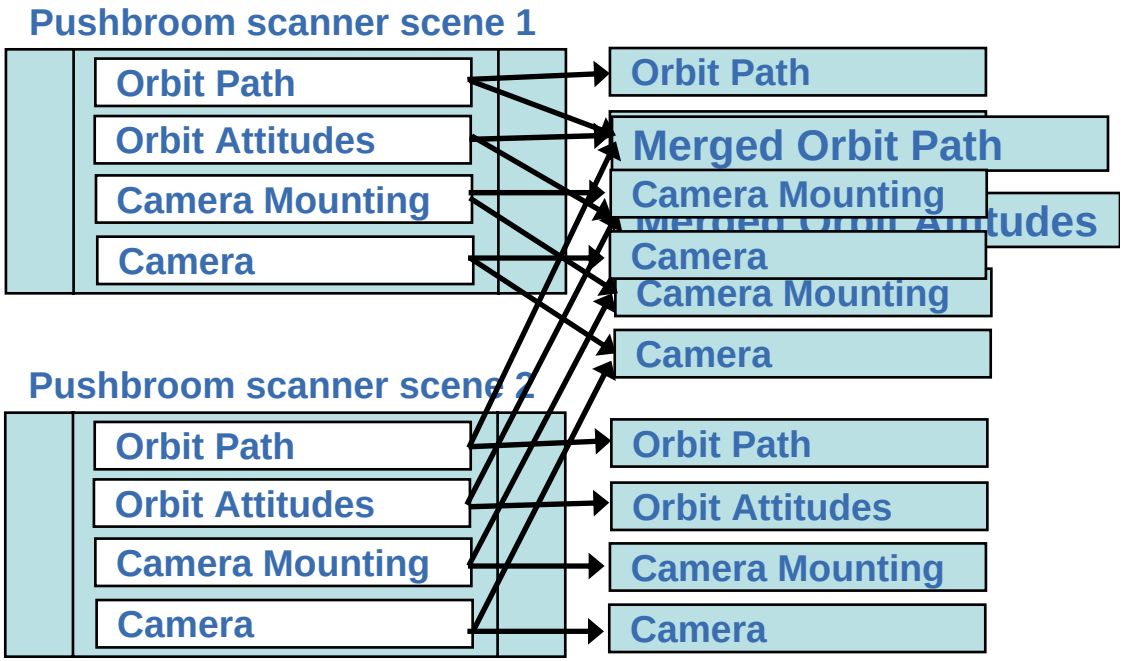


- **ALOS AVNIR-2:**
  - Only one set of coefficients
  - Preprocessing of level 1 images to get multi-spectral image

Strip Adjustment



- Modularised sensor model
- Individual scenes can share components
  - Internal camera parameters
  - Exterior orientation ⇒ Strip adjustment



- One set of EO parameters
- One set of bias correction parameters per strip
- Bridging of scenes without ground control

Automatic Generation of GCPs

- **Input data:** Existing digital orthophoto + DEM
- **Work flow:**

  1) Extraction of points from digital orthophoto (Foerstner interest operator), interpolation of heights in DEM
  ⇒ **3D GCP candidates**

  2) Automatic measurement of GCP candidates in images

     a) Extraction of image patches from digital orthophoto

     b) Maximum cross correlation coefficient (CCC)

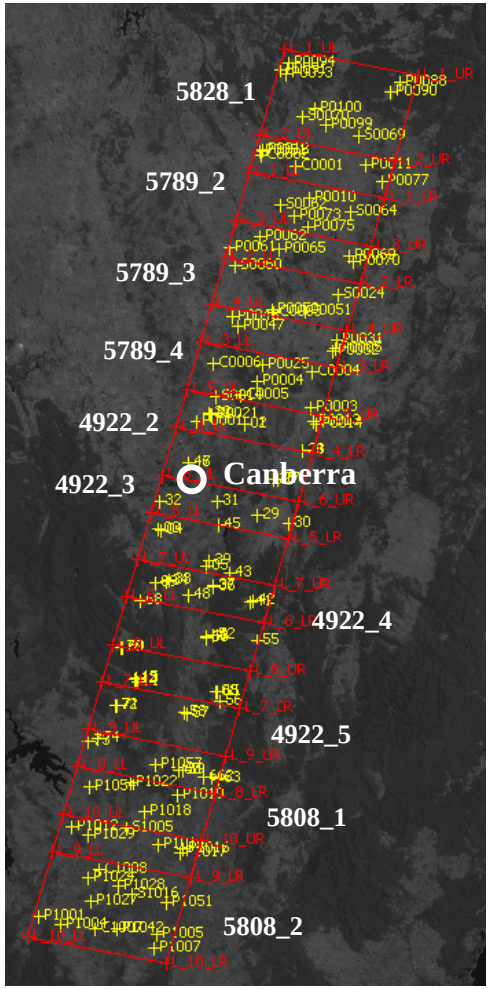
     c) Least squares matching

     d) Eliminate GCP candidates with CCC < threshold

  3) Bundle adjustment with robust estimation

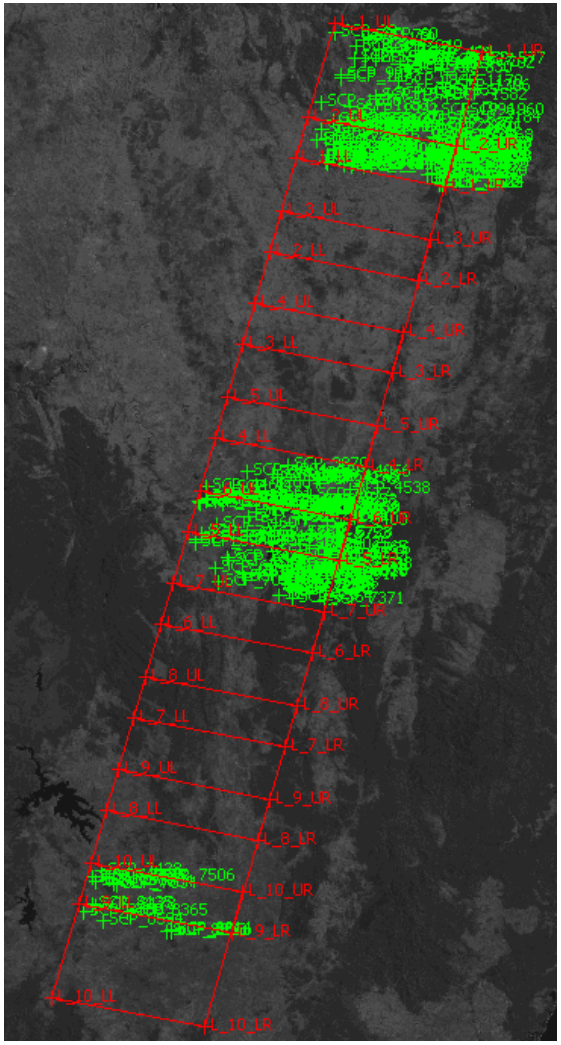
Strip Adjustment – PRISM: Test setup

- Strip consisting of 10 level 1B1 nadir scenes
- Strip length: 293 km
- 123 GPS points (accuracy < 1m)
- Digital orthophoto from Landsat 7
- DEM from Dept. of Lands NSW
- Four different scenarios for adjustment:
  1) Individual orientation (4 GCPs / scene)
  2) Strip adjustment (8 GCPs)
  3) Strip adjustment (4 GCPs)
  4) Strip adjustment (automatic definition of GCPs)



Strip Adjustment – PRISM

Distribution of automatically determined GCPs

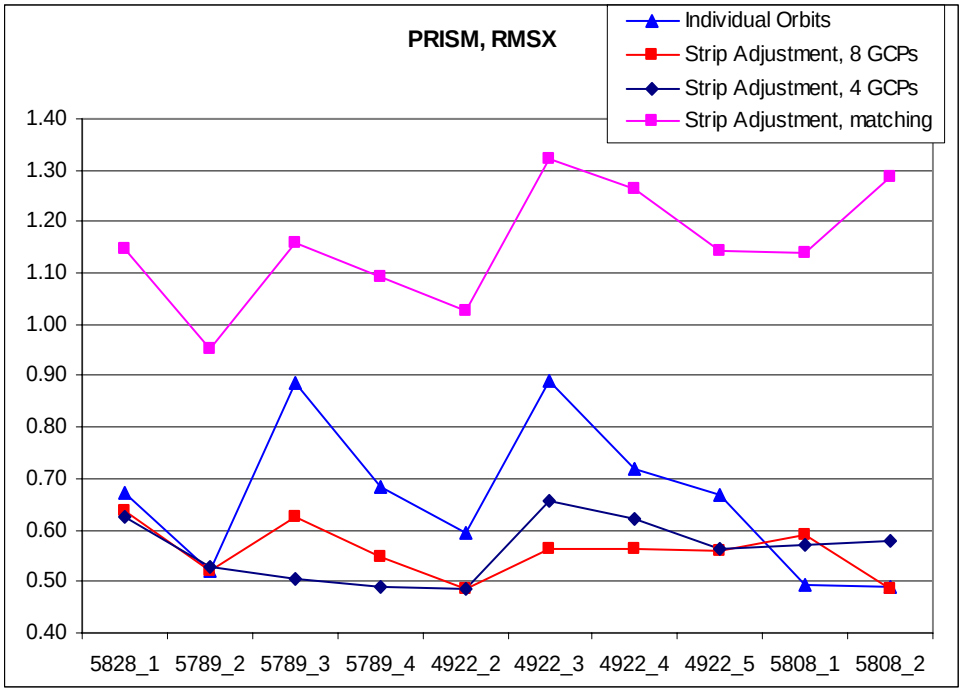


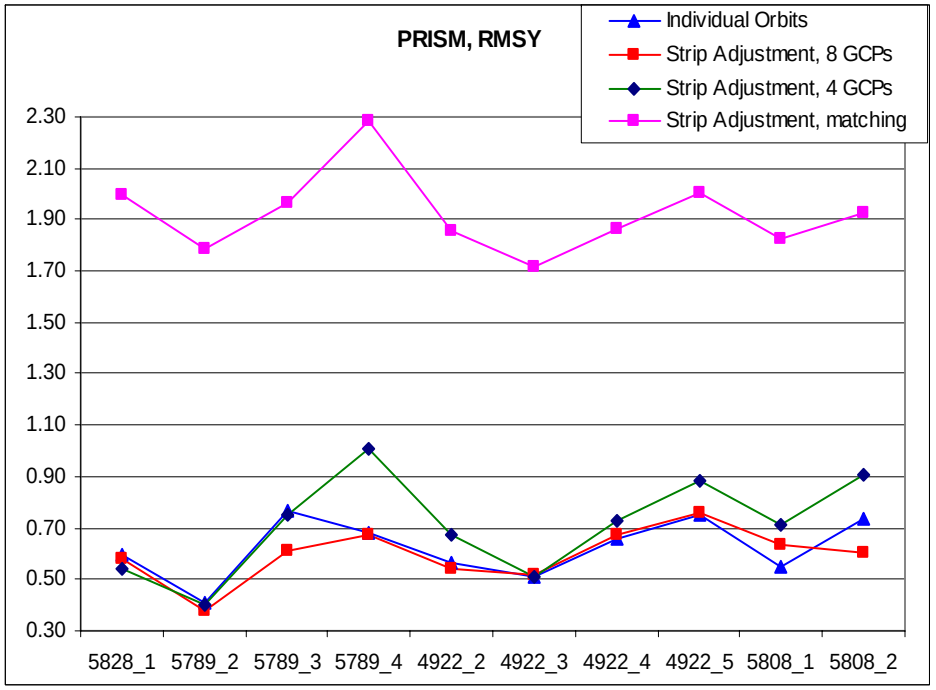
- Altogether 205 GCPs
- Computation time: 4:40 minutes

Strip Adjustment – PRISM: Results

RMS errors at check points

- Strip adjustment, 8 GCPs: subpixel accuracy, 65% fewer GCPs
- Strip adjustment, 4 GCPs: pixel-level accuracy, 82% fewer GCPs
- Automated orientation: Systematic offset of 1/3-1/2 (LS 7) pixels



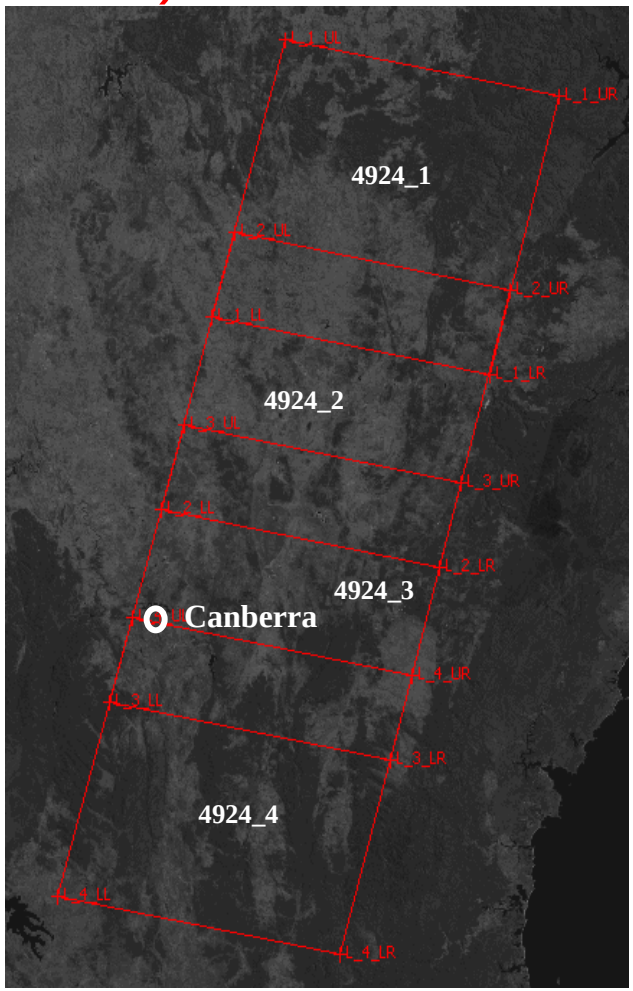


Strip Adjustment – PRISM: Long strip

- Strip from previous example expanded to 21 nadir scenes
- Strip length: 600 km
- Check points from previous example
- Adjustment with 8 GCPs:
  - RMS at check points: 0.6 pixels
  - Maximum RMS: 0.8 pixels
  - Reduction of GCPs: 81%
- Adjustment with 4 GCPs:
  - RMS at check points: 0.7 pixels
  - Maximum RMS: 0.9 pixels

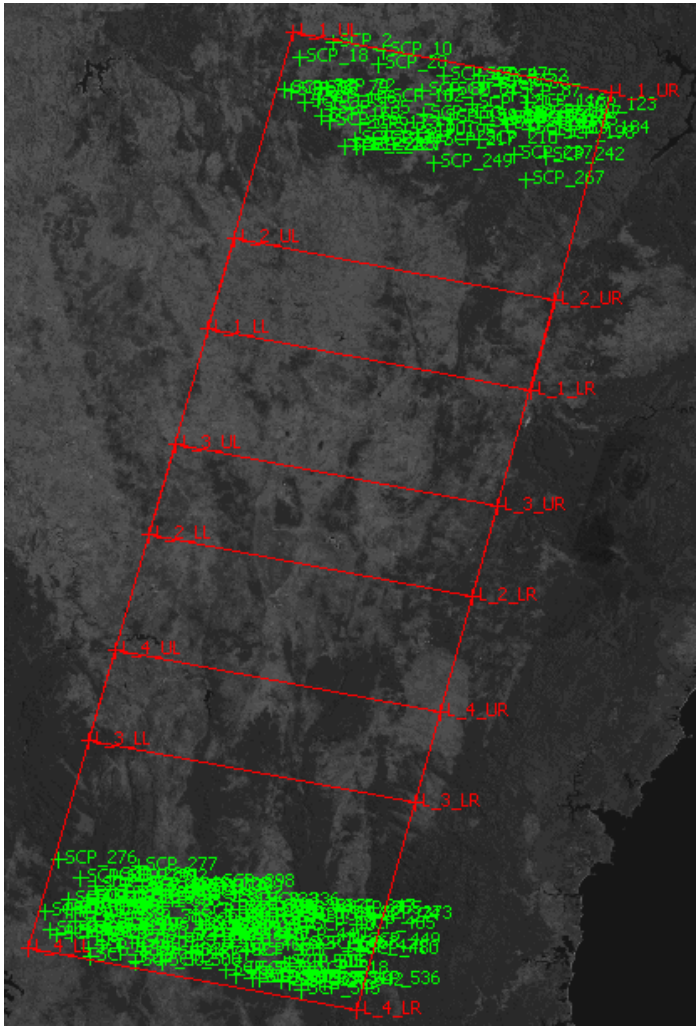
Strip Adjustment – AVNIR: Test setup

- Strip consisting of 4 AVNIR-2 scenes (level 1B1)
- Strip length: 250 km
- Same points as for PRISM
- Digital orthophoto from Landsat 7
- DEM from SRTM
- Calibration of camera parameters
- Three different scenarios for adjustment:
  1) Individual orientation (4 GCPs/scene)
  2) Strip adjustment (4 GCPs)
  3) Strip adjustment (automatic definition of GCPs)



Strip Adjustment – AVNIR

Distribution of automatically determined GCPs

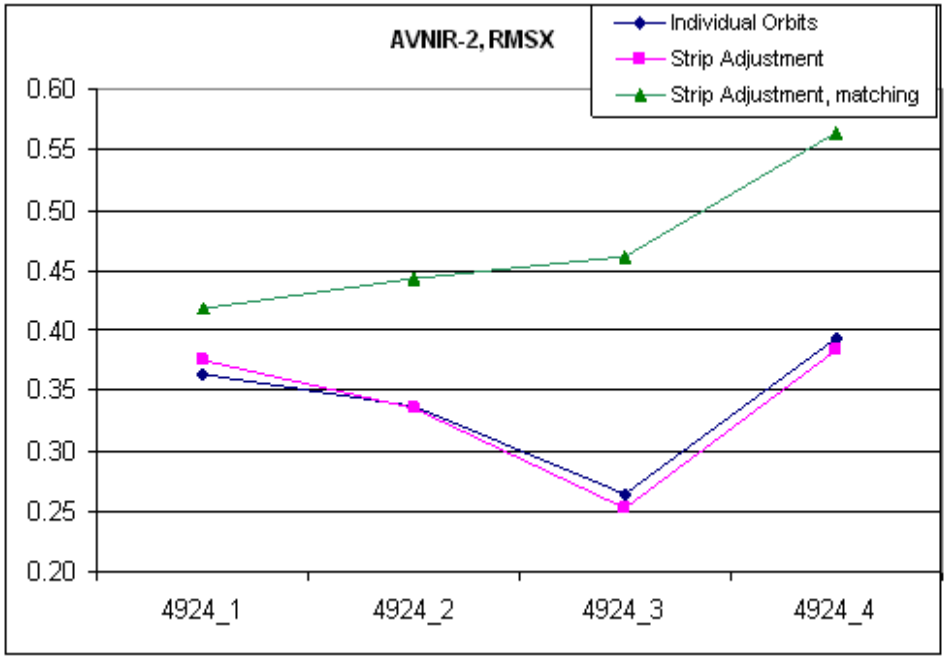


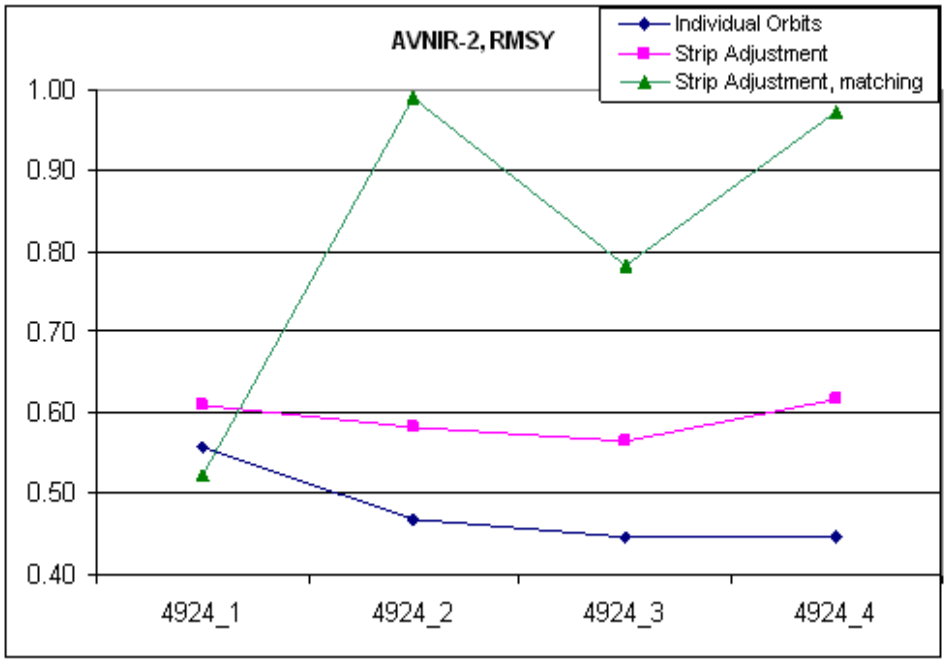
- Altogether 148 GCPs
- Computation time: 50 seconds

Strip Adjustment – AVNIR: Results

RMS errors at check points

- Strip adjustment, 4 GCPs: subpixel accuracy, 65% fewer GCPs
- Automated orientation: pixel-level accuracy
- Systematic offset relative to LS7 can also be observed





Conclusion

- Strip adjustment can achieve a reduction of the number of GCPs by up to 80% without loss of accuracy
- With PRISM, a 600 km strip could be georeferenced with sub-pixel accuracy using only 8 GCPs
- The accuracy of automated GCP measurement is limited by the quality of the original orthophoto
- Strip adjustment is used for production at Geoscience Australia
  $\Rightarrow$ Increase in productivity of 300%

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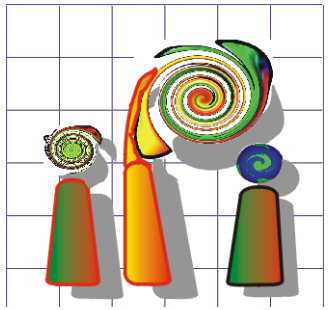

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