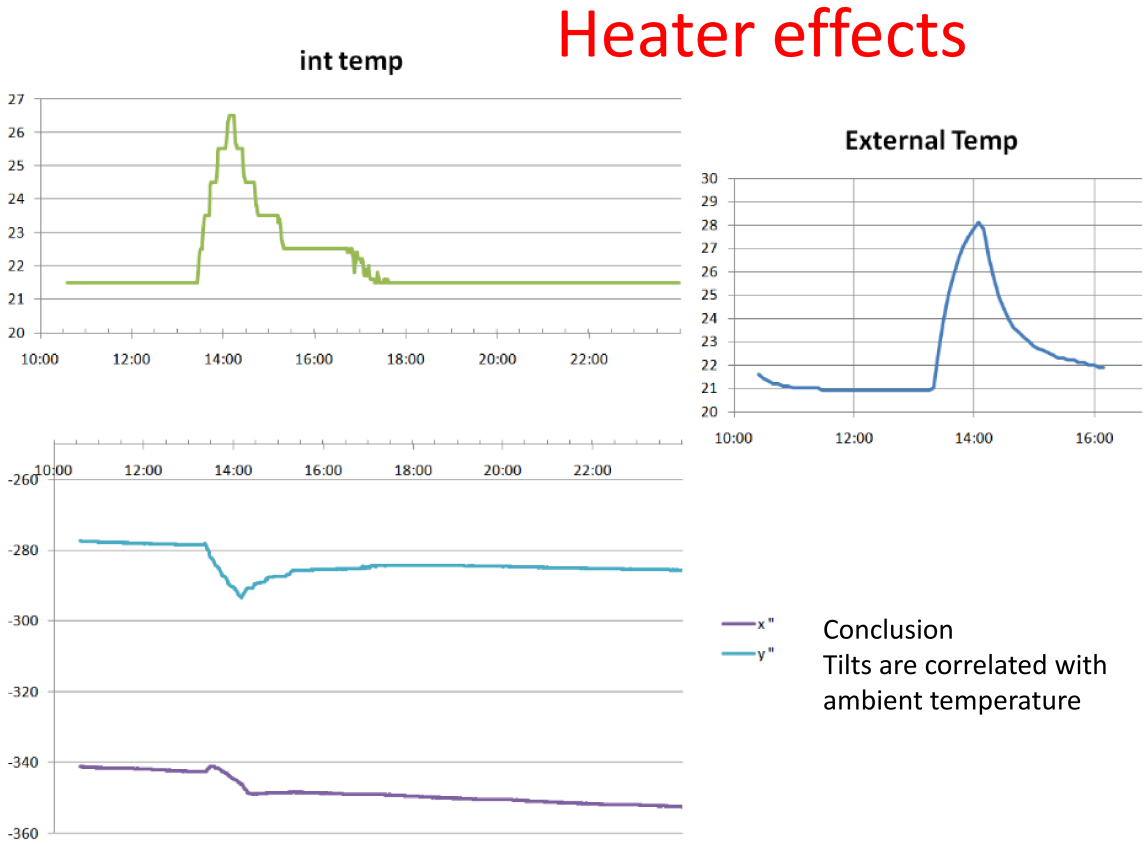
deformation surveying

- What are the effects of temperature on Nivel tiltmeters?
  - Both x and y tilt correlated with temperature.
    - 0.9" per ˚C in x and 2.6" per ˚C in y for over 5˚C

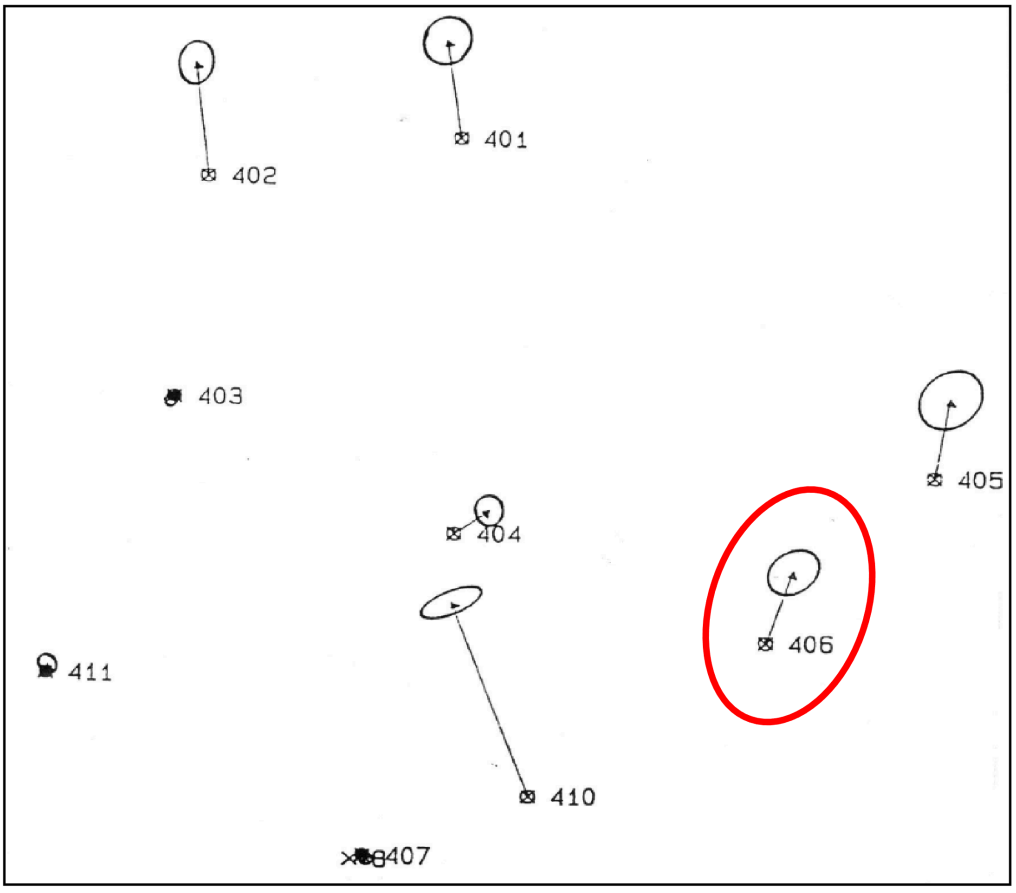


  - Hard to measure absolute tilt, but relative tilt (changes in tilt from one instant to another) is possible.
- What are deformation surveys typically conducted on?
  - Bridge surveys (e.g Sea Cliff Bridge, Nepean River bridges, Bruce Harvey's case study)
  - Sinking buildings
  - Mine deformation -- links to utilising Local Scale Parameter method.
  - Volcano monitoring
- How is a deformation survey conducted?
  1. Determine the appropriate method.
     - Levelling
     - Total stations: used in mine monitoring to marks, and calculate the movements.
       - Can be computed to generate alerts when thresholds have been passed, based on displacement of coordinates/change in slope distance.
       - Cadia Hill Mine.
     - Laser scanning
     - GNSS
     - Radar, DinSAR + satellite Radar: used in mine monitoring to high accuracy
     - Tilt-meters (ensure they aren't affected by atmospheric conditions, like temperature)
  2. Determine the survey design

- Appropriate measurements should have a precision less than the deformation.
  - Ensure the instrument is calibrated
  - The required σ accuracy is 1/5 of the expected smallest deformation
    - e.g $\pm$ 1 mm survey to detect 5mm changes.
  - The basic **statistical** test of displacement is:
    - If $$\frac{\text{distance moved}}{s_{dis}} < 2$$
      - Then movement is NOT statistically significant
    - NOTE s_{dis} is the standard deviation of the distance moved from one epoch to the next, NOT between measurements in the same epoch, or of the coords.
- Conduct multiple baselines (two or more, before movement) at high frequency (/year,/day,etc), also called **Zero Epoch Test**.
  - Conduct multiple epochs where there is no movement expected, or before movement begins.
  - Do the same measurements and analysis for normal deformation. If any deformation is detected, the method is not reliable.
  - This zero epoch test (baseline) aims to distinguish real motions from apparent motions due to random, systematic, or gross errors in the data
    - Baseline should be better than the type of magnitude movement expected.
    - Essentially, the control variable.
- Ensure the **cancellation of systematic errors**
  - If a systematic error is constant and affects two epochs similarly, the deformation vector essentially free of systematic error (e.g similar idea to relative error ellipses).
- Stable reference points as well as targets on the moving objects
  - should be stable, not moving, and location should be outside of zone of influence
  - Ensure that there are a large number of targets for redundancy.

3. Conduct deformation monitoring.
   - This can be done in two ways:
     - Calculate the difference in a point's coordinates from one epoch to the next
     - OR through observation differencing, which observes changes in the **measurements** between epochs (direct measurement)
       - This requires identical network configurations with equivalent instrument types.
   - Take independent measurements to detect and eliminate blunders.
   - Consider for atmospheric conditions (temperature, line of sights)
4. Data Processing
   - Reference points given the same value. Object points are given a different number in each epoch. Adjust each epoch separately.
   - Then, conduct a LS analysis

- If the deformation vector is **inside** the relative confidence ellipse of the **JOINS** between the two epochs (std dev of the join between epochs or use the statistical test), no deformation has occurred and vice versa.
  - Choice of constraints (datum, what is held fixed) is important as it can effect the error ellipses.
    - Not the point error ellipses of the coordinates.



5. Decision-Making
   - Results near thresholds should be scrutinised further. False alarms could occur, causing a large ethical dillema. Judgements have to be made:
     - Possible error (sighting to targets that were moved during operations)
     - Rate of movement possible? Part of an existing trend?
     - e.g Bingham Canyong mine slide.