International boundaries on a dynamic planet – issues relating to plate tectonics and reference frame changes

D Grant (RMIT University, Australia)
W Robertson (New Zealand)
V Belgrave (New Zealand)
Overview

- Methods of defining international boundaries by survey
- Plate tectonics
- Impacts of plate tectonics
- Changing reference frames
- Long term maintenance of boundary reference frames
- Case study: Iraq-Kuwait boundary
- Conclusions
- Commission 1 Working Group 1.3 International boundary settlement & demarcation
International boundaries defined by survey

- Physical monuments placed and surveyed
  - Monument define the boundary
  - Survey provides documentation
  - Survey assists with maintenance, repair, re-instatement
- Coordinates
  - Coordinates define the boundary
  - Monuments may be placed to make the boundary clearly visible
  - The geodetic datum defining the coordinate reference frame becomes critical
Boundaries defined by coordinates

- Historically the reference frame was not always specified (ambiguous)
- If not specified, ambiguity can be hundreds of metres
- If specified, the frame is likely to become obsolete over time
- Reference frames no longer in active use (except for the boundary) will need to be maintained in the long term
Plate tectonics

- Theory developed over 20th Century
- Validated by geodetic measurements in late 20th Century
- Movements are several cm/year = several metres/century
ITRF2008 Velocity Field

Major plate boundaries are shown in green

2 cm/y

Zuheir Altamimi
Impacts of plate tectonics

• Modern international reference frames
  – have no fixed points on earth
• Meridians & Parallels
  – if defined in terms of global frames, they slowly move across the Earth’s surface
• Directions
  – Plates slowly rotating which can affect long times
• Straight lines
  – These may become bent where they cross the plate boundary or major fault lines
• Median lines
  – Will move if land either side of the line are moving differently
Changing reference frames

- Global frames (WGS84 & ITRFs) are periodically updated
- National frames are changed from time to time
  - Updated for new technology & plate tectonics
- Some national or regional frames moving to a “dynamic” model
  - Coordinates continuously change as the Earth moves
Long term maintenance of boundary reference frames

- If defined by ITRF at an epoch, then maintained through transformations.
- If defined in terms of the coordinates of a specified origin mark – then maintenance of mark becomes crucial for both countries.
  - May be an issue if the mark is located in only one country.
- If defined by coordinates of a set of marks then maintenance of the set of marks becomes crucial.
  - Ideally some marks will be located in each country.
- Even if defined by marks, transformations can back up the definition.
  - Over long periods, a sequence of accurate transformations back to the original reference frame will be required.
Case Study – Iraq-Kuwait Boundary

• Coordinates are definitive
  – Monuments (pillars) placed on correct coordinates
• Independent plate fixed datum – Iraq Kuwait Boundary Datum 1992
  – Not precisely related to ITRF ± few metres
• Boundary moves with the plate – and with the pillars
  – Datum at risk (only 1 or 2 of definitive datum stations still available)
  – Dependency on primary control stations to “reverse-engineer” the datum
  – Some primary control stations also lost
• Maintenance necessary to protect the boundary in the long term
31mm/year  
43mm/year
Approx. 4 m / century

In this case the plate-fixed datum & boundary move with the land
Potential changes

- The Iraq Kuwait boundary coordinates defined in terms of a plate fixed datum
- **Therefore no change over time in sovereignty of land or resources**
- However if the boundary had been defined by fixed ITRF coordinates
  - Survey accuracy standard for boundary pillar placement of 200mm would have been exceeded by tectonic movement in just 5 years
  - Since 1992 survey (25 years), land and resources would have moved 1m relative to the boundary
  - Value of oil in Rumaila field is approximately US$10M per metre in the north-south direction
Datum stations still available?

Several primary stations also since lost
Conclusions

• Geodetic survey often used to define & maintain international boundaries
  – Boundary is then dependent on maintenance of the geodetic datum
• Geodetic datums also require maintenance
  – Affected by tectonic plate motion
  – Datums are updated more frequently than international boundaries
• Boundary negotiations should consider:
  – Definition of geodetic datum
  – Impact of changes in geodetic datum
  – Impact on the boundary of tectonic movement
• Does the boundary moves with the land or with the coordinates?
Working Group 1.3
International boundary settlement & demarcation

- Propose a supplement to FIG Publication 59 International Boundary Making
- Focus on geodetic and tectonic issues impacting on boundaries in the long term