Affordable Differential GPS

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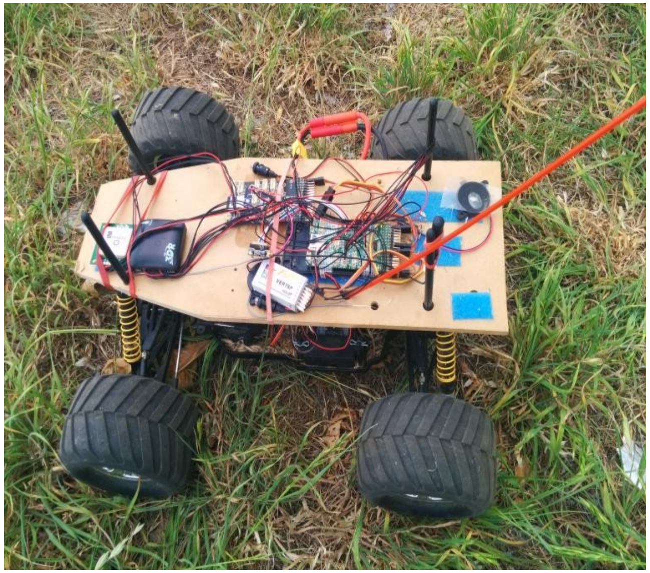
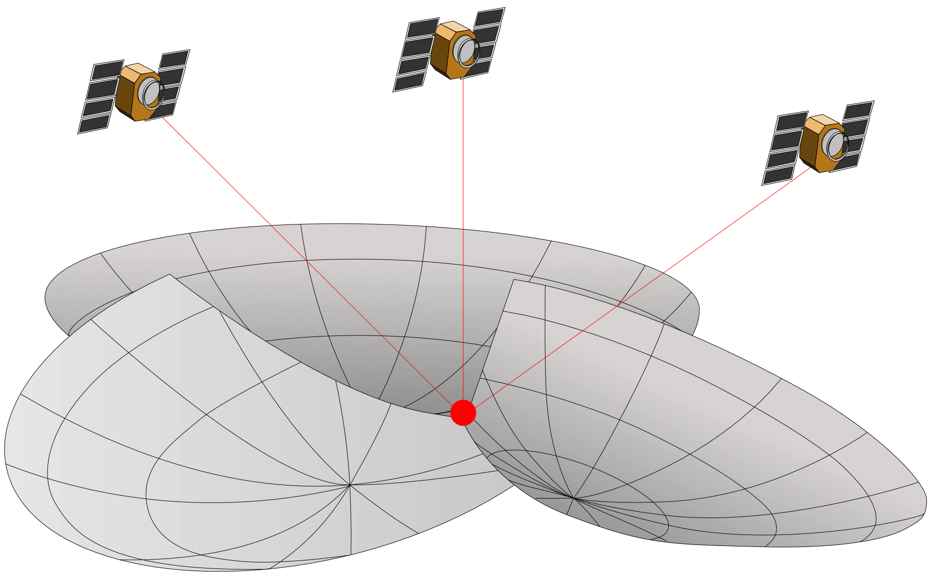
Better positioning – cheaply!

- Very accurate GPS systems are possible, but expensive
- Can we build one cheaply?
- Needed for:
    - accurate UAV flight
    - swarming quadcopters
    - accurate ground rovers



How does GPS work?

- “Clocks in the sky”
  - each satellite broadcasts a time signal, plus orbit information
  - receivers calculate 'pseudoranges' to visible satellites
  - receivers triangulate their position
  - least-squares solution in 4 dimensions (position+time)
- Phase information
  - more accuracy by tracking 'carrier phase'
  - need to disambiguate solution as multiple of 19cm wavelength



How accurate is GPS?

- It depends on how much you spend!
  - 'base' GPS in Australia is around 10m error horizontally (for around $50)
  - in US, Europe and Japan SBAS (Satellite Based Augmentation System) can reduce error to around 3m
  - dual frequency GPS receivers can do a lot better, but cost more than $2k for a cheap one
  - with a source of corrections and dual-frequency 10cm accuracy is common
  - with great corrections and a $10k receiver you can get better than 1cm
- Or how much CPU you have
  - Possible to run open source RTK solutions (like RTKlib) if you have enough CPU power in on a ground station and on the rover.

Sources of GPS error

- Major error sources
  - mismatch between ionospheric model and actual conditions
    - 'space weather' - largely solar activity
  - multi-pathing
  - dynamic model mismatch to real movement
  - bugs in code and standards (can be arbitrarily large!)
  - tropospheric errors
  - antenna errors
  - clock errors
  - orbital errors

Differential GPS

- Major errors are spatially correlated
  - two receivers that are close to each other see the same ionospheric errors
  - This is the basis for how DGPS works
- Steps in DGPS
  - Use a reference station to measure error
    - assumes you know the true position of the reference
  - Send measured errors to 'rover'
  - Rover subtracts errors from its pseudoranges
  - Rover performs normal triangulation with corrected ranges
- How much can it help?
  - Expected improvement is roughly 50% to 70% reduction in horizontal errors

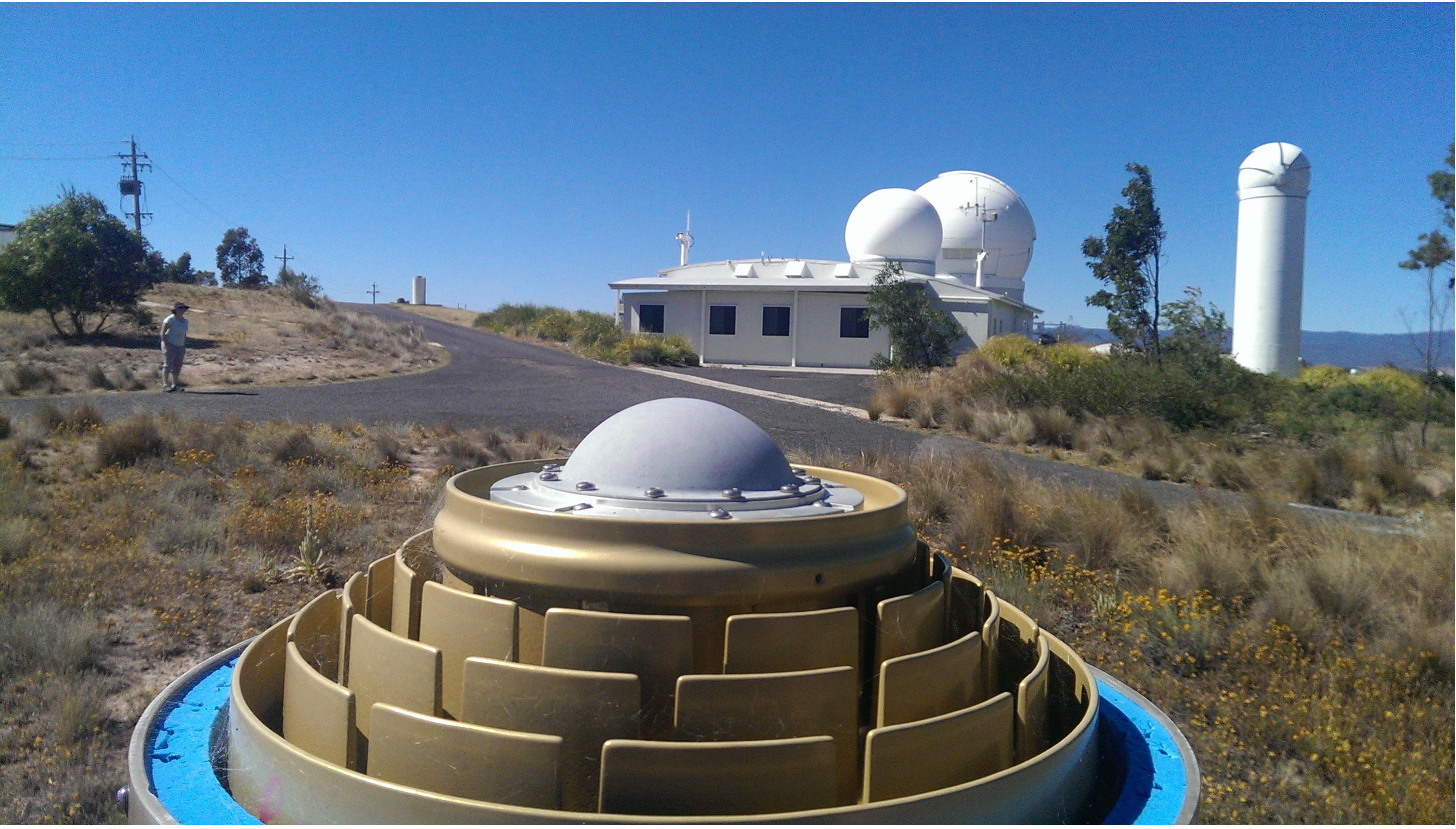
Raw receivers

- For DGPS we need a 'raw capable' receiver
  - A 'raw capable' receiver gives the pseudoranges and carrier phase in the local protocol
  - These pseudoranges are combined with reference position to calculate the per-satellite corrections
- Raw capable receivers are more expensive
  - cheapest is around $80 for a uBlox-6T
  - much cheaper than commercial DGPS reference stations, which cost many thousands

Constructing the corrections

- We know the reference station position exactly, but not time
  - From the pseudoranges and reference position, we solve for the receiver's clock error
  - What's left can be directly compared to the geometric range between the receiver and satellite
  - The difference is the error
- Cheap receivers can accept corrections in RTCMv2 format
  - Modelled after the GPS satellite format, very hard to work with!
  - Contains pseudorange corrections, rates, estimated satellite qualities

Infrastructure references - NTRIP



NTRIP to RTCMv2

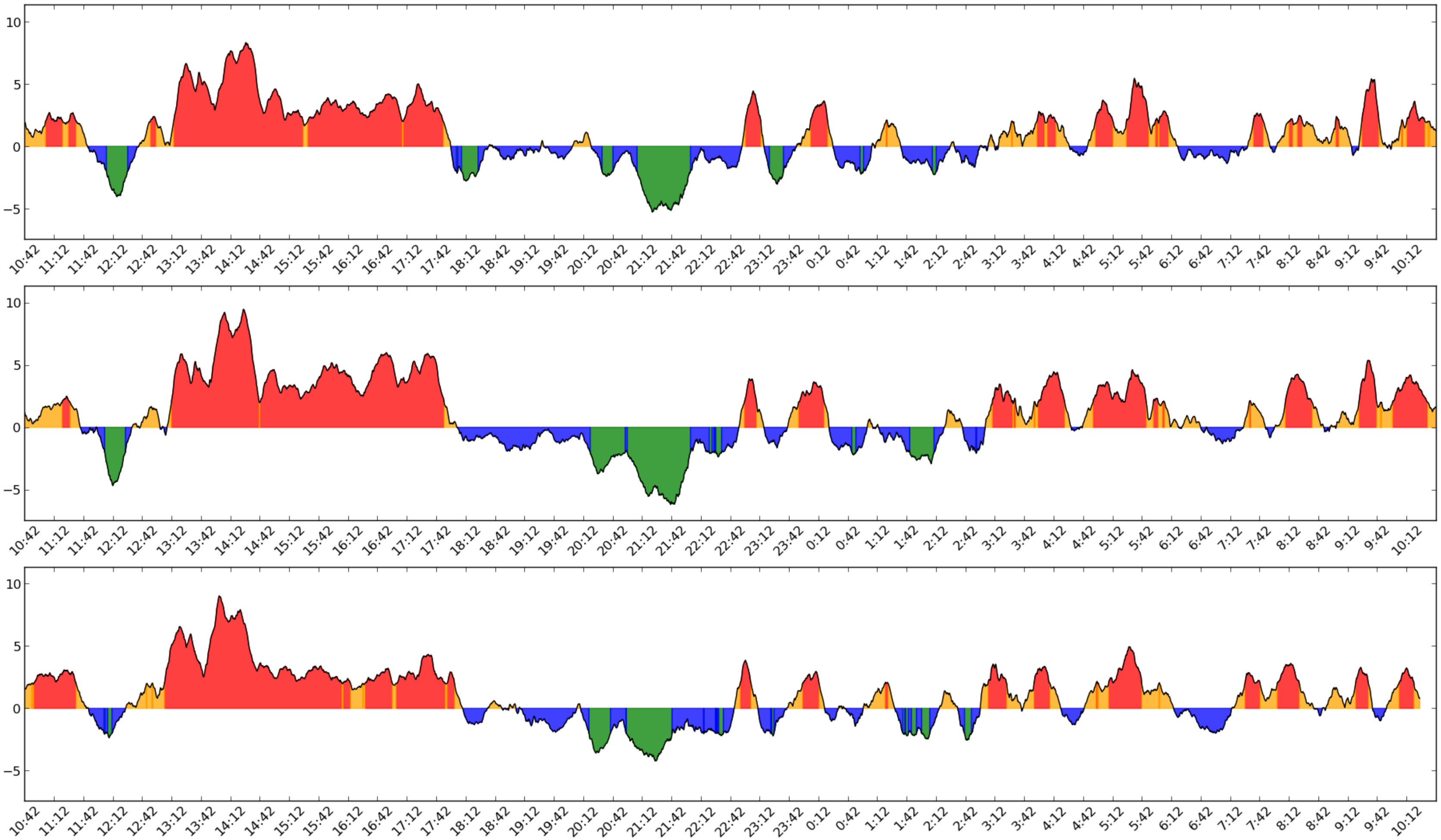
- Geoscience Australia also generates corrections
  - Some stations require a fee, some are free to use for non-commercial purposes (if you ask nicely!)
  - Available in NTRIP (encapsulated RTCMv3)
  - Need to convert between v3 from GA and v2 for the receivers
- RTCMv3 doesn't provide corrections directly
  - Provides observations at reference point
  - Similar to raw receiver outputs but corrected for receiver clock error
  - We know both where the reference is and *when* it is
  - Can then difference the geometric ranges and observed pseudoranges

Thanks to Geoscience Australia for access to their NTRIP service!

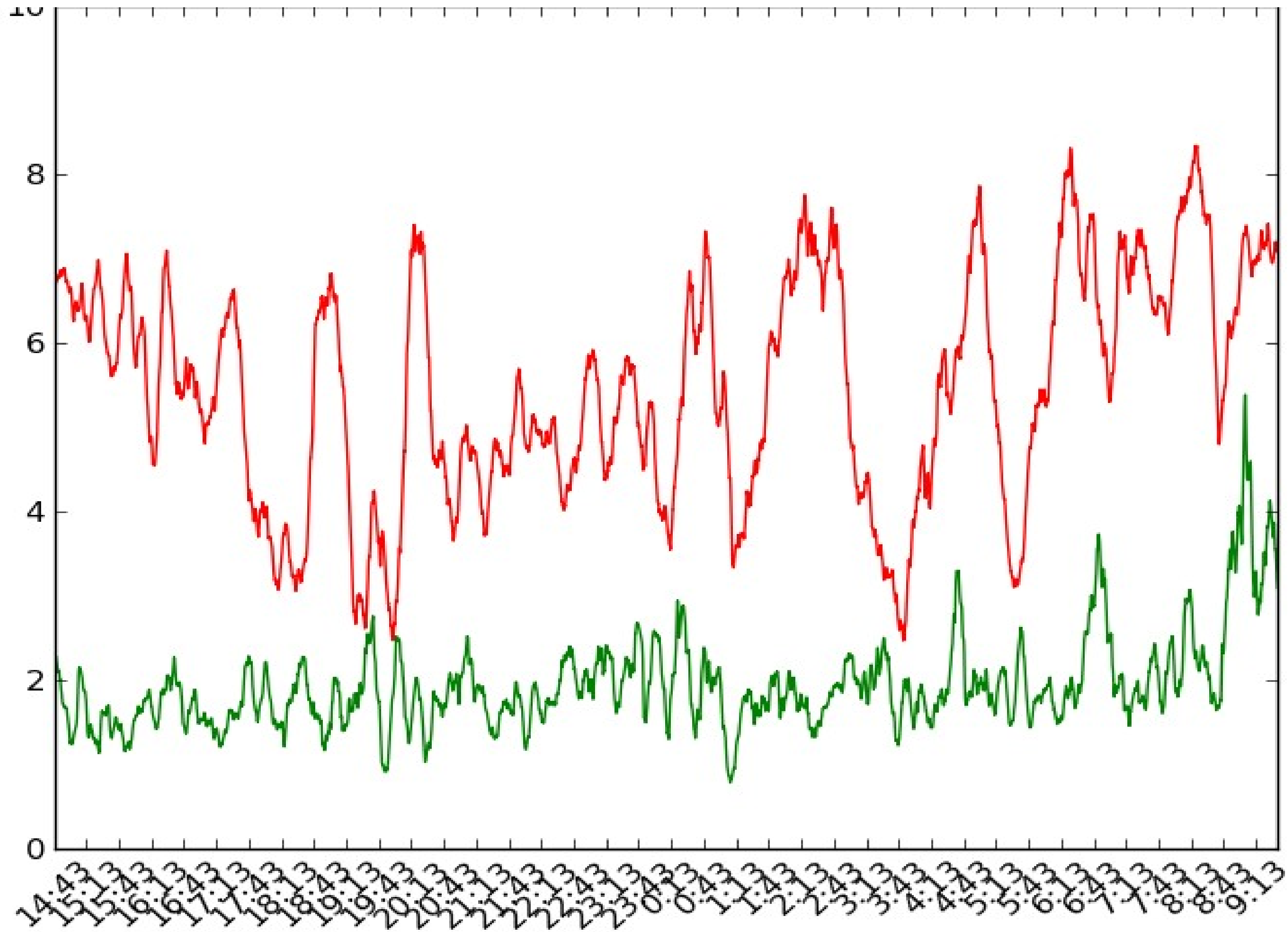
Test setups

- Rooftop system
  - 3 receivers on Canberra roof
  - one raw capable uBlox 6P, two low cost uBlox modules
- Spring Valley farm
  - 3 uBlox 6T modules
  - much clearer view of sky

72 Hours on rooftop system



18 hours at Spring Valley



Vehicle Testing

Testing at UWA in Perth

Testing in a SkyWalker aircraft

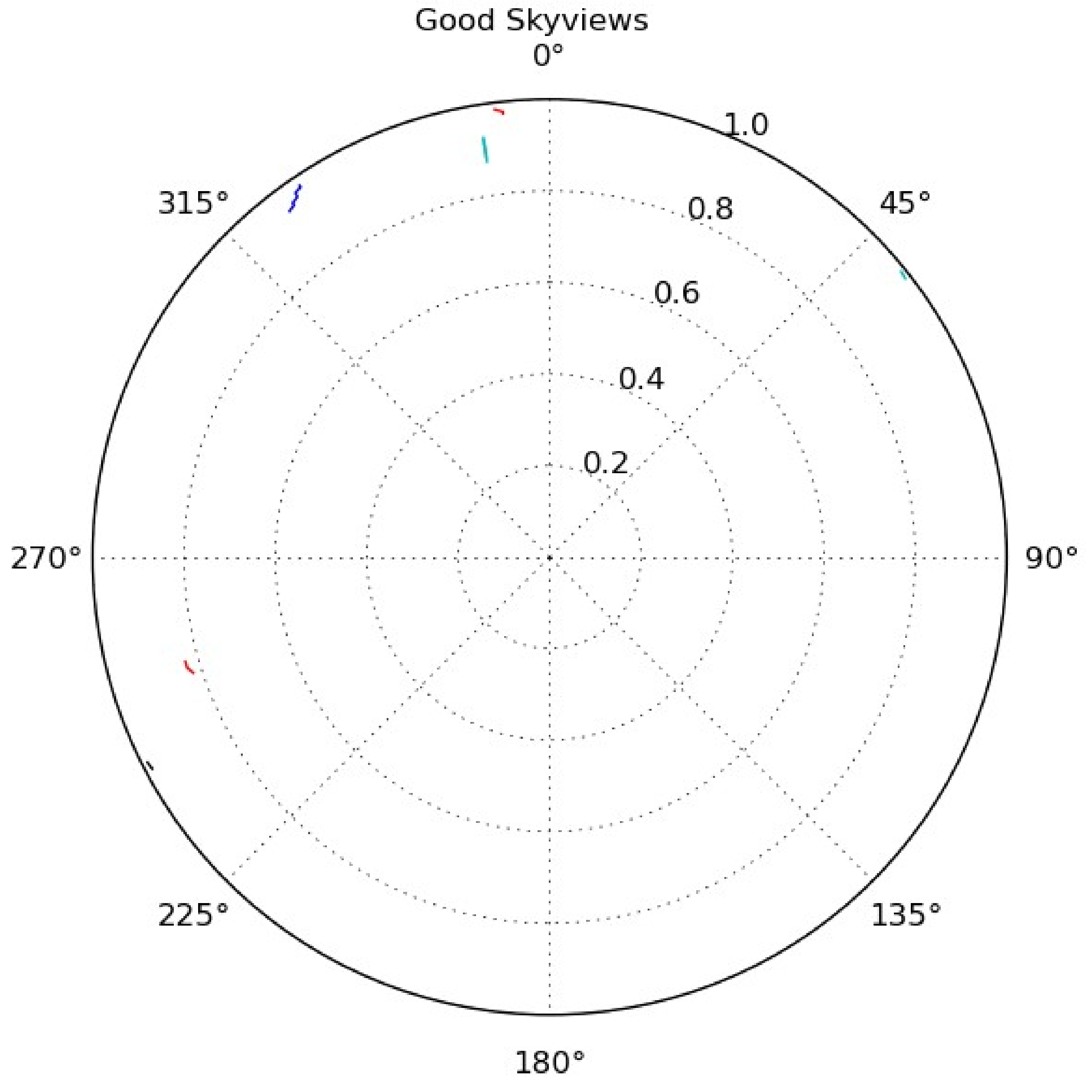
Other low cost options

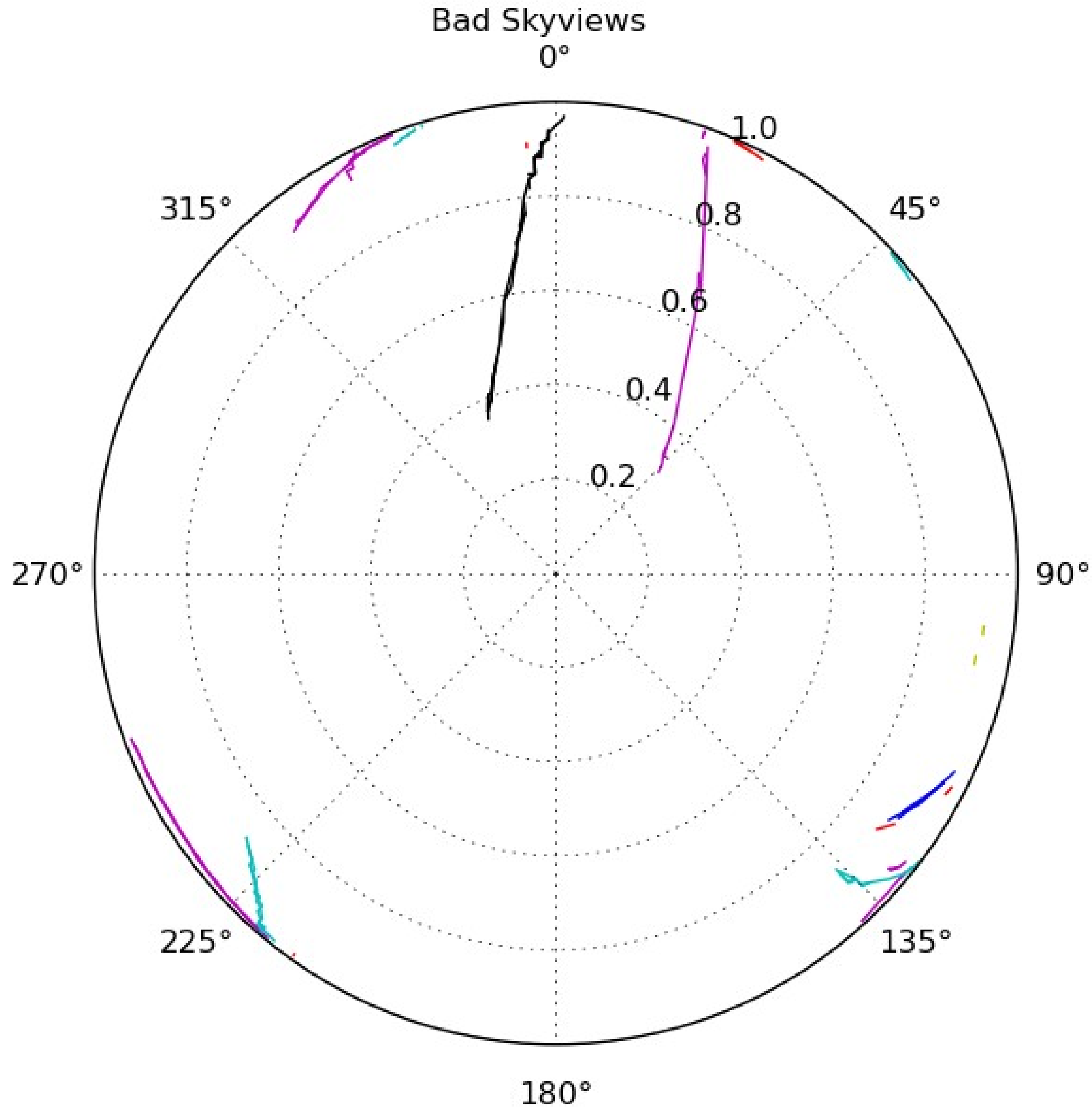
- SwiftNav 'Piksi' GPS
  - around $500 per module
  - built-in STM32 running RTK
  - may be able to get decimeter accuracy for $1000
- RTKLib
  - open source GPS library implementing RTK
  - combined with a RaspberryPi or BeagleBone may be able to get decimeter accuracy
  - requires substantial CPU resources in aircraft

Conclusions

- It is possible to get better relative positioning using cheap DGPS and RTCMv2 injection
- Getting a good reference position is hard!
- New options such as Piksi will open up some new low cost options
- Altitude is still poor even with DGPS, so landing by GPS is still not a good option

Code: http://github.com/tridge/pyUblox


Good Skyviews
0°
45°
90°
135°
180°
225°
270°
315°
0.2
0.4
0.6
0.8
1.0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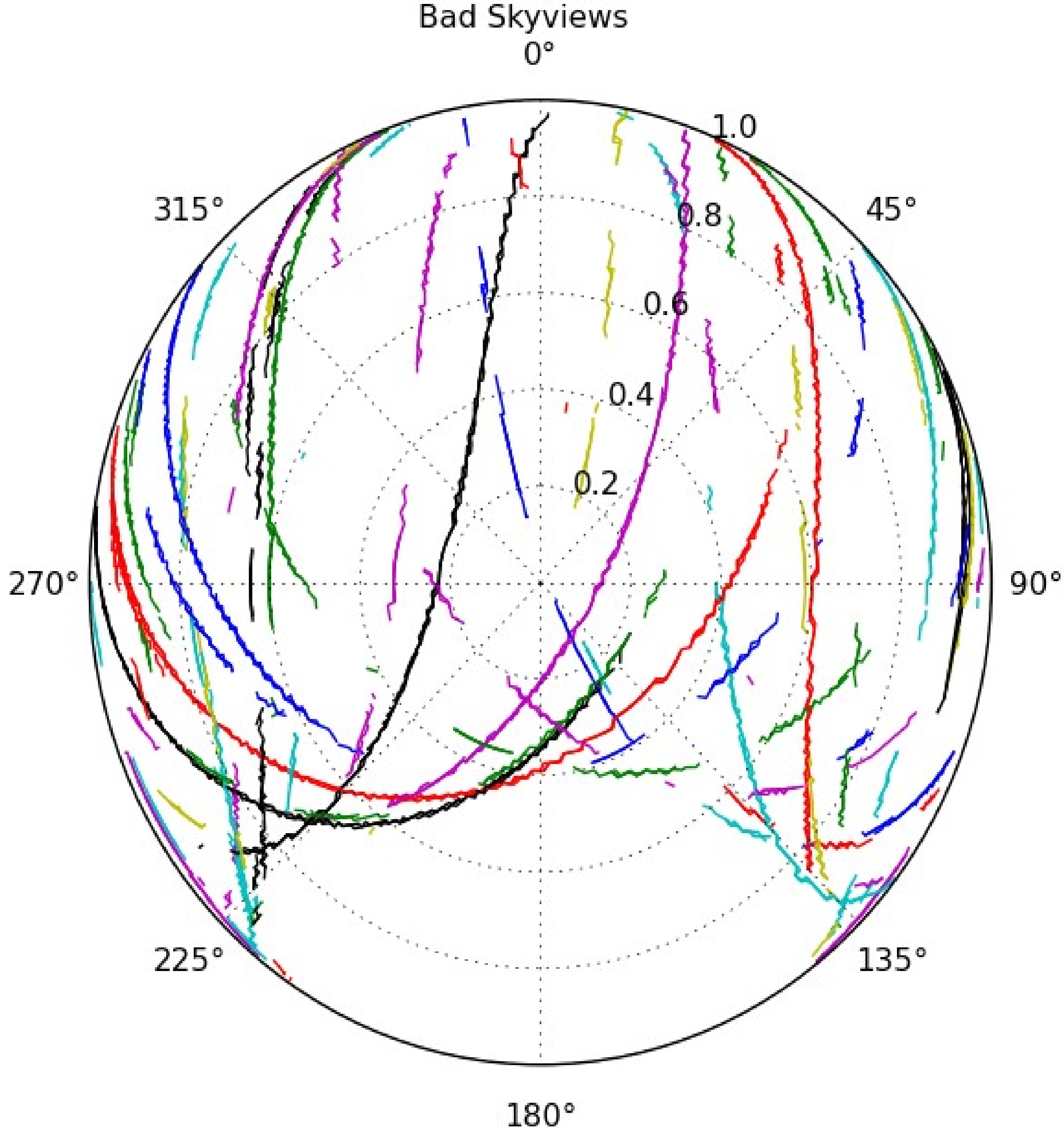
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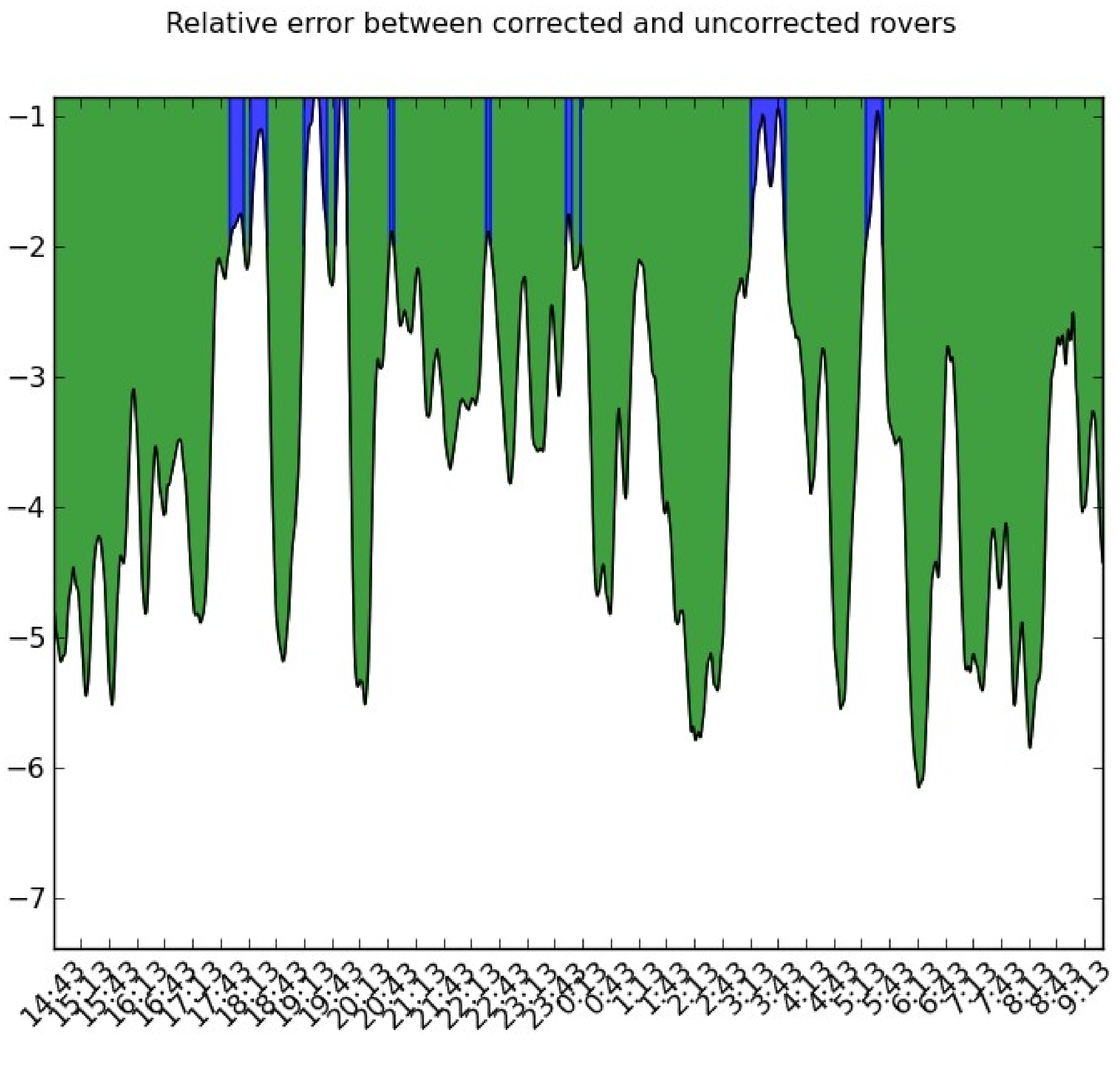
Relative error between corrected and uncorrected rovers
−1
−2
−3
−4
−5
−6
−7
14:43
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