The impact of Solar Cycle 24 on Network RTK in Australia

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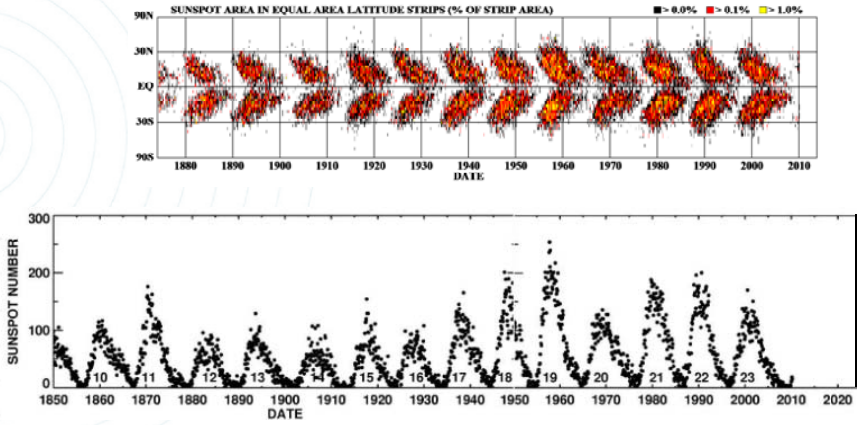
The Solar Cycle

- Discovered by Samuel Heinrich Schwabe in 1843 after 17 years of sun spot observations
- Rudolf Wolf re-constructed the cycle back to 1745
  - And then further back to the first observations by Galileo (17th century)
- … is defined by the observation of sun spot max and min numbers and placement on the suns surface (Butterfly diagram)
- Sun spots can result in *solar flares* and *coronal mass ejections - (NOAA Alerts)*

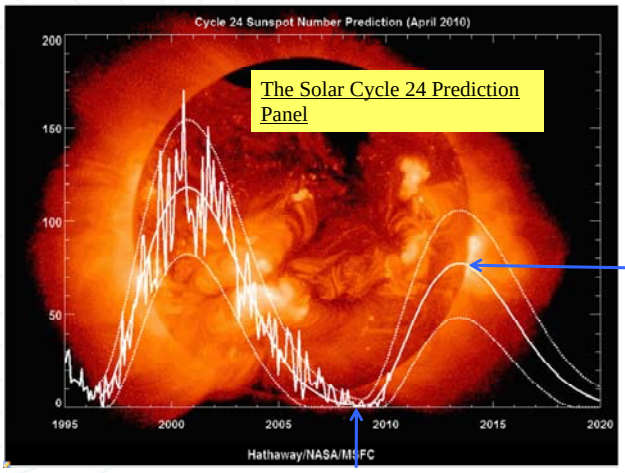
The Solar Cycle

Butterfly Diagram – Greenwich Observatory (1880 – 2010)



Solar Cycle 24

May 8, 2009 – (NOAA) Solar Cycle 24 Prediction Update
http://www.swpc.noaa.gov/SolarCycle/SC24/index.html



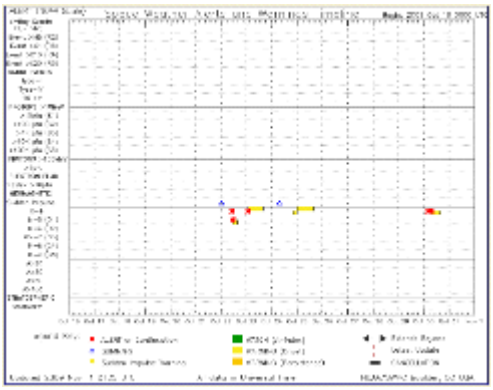
The Solar Cycle 24 Prediction Panel

- **Below Average Intensity**
- **Maximum Sun Spot number of 90**
- **Maximum predicted for May, 2013**

Solar Minimum
December, 2008

Ionospheric Disturbances from Solar Flares

1. Geomagnetic storms, - disturbances in the geomagnetic field caused by gusts in the solar wind that blows by Earth
2. Solar radiation storms, - elevated levels of radiation that occur when the numbers of energetic particles increase
3. Radio blackouts - disturbances of the ionosphere caused by X-ray emissions from the Sun



NOAA Space weather alert archives -
http://www.swpc.noaa.gov/alerts/archive.html

Medium Scale Travelling Ionospheric Disturbances (MSTID's)

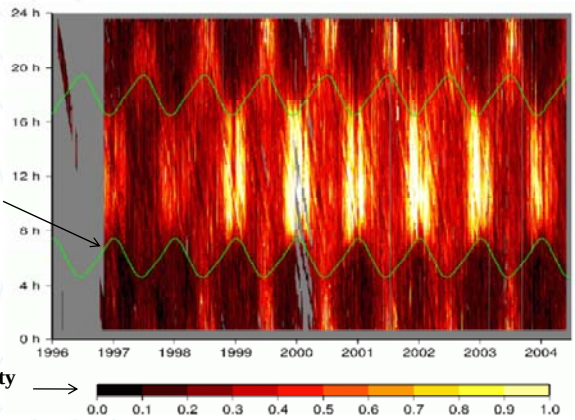
• TID's originate from Solar terminator – Suns grey area

•MSTID's have a wavelength between 100 – 300kms and amplitude of several TECUs (approx 1m)

• These disturbances have the biggest effect on Network RTK performance due mainly to their wavelength and amplitude.

•Although they are a seasonal effect, they are modulated by the solar cycle. (see next slide)

MSTID's



Hernández-Pajares, M - *Real time MSTIDs modelling and application to improve the precise GPS and GALILEO navigation*

Network RTK in Australia

- Since 2000, Ad-Hoc development of a network of CORS stations across Australia, which are aligned with the GDA94 national coordinate framework.

- These networks will eventually provide a Network RTK solution:
  - VRS (Virtual Reference station)
  - MAC (Master Auxiliary concept)

- Greater need for modeled ionosphere (Network RTK)
  - Modeled ionospheric correction at a location near to the rover receiver.

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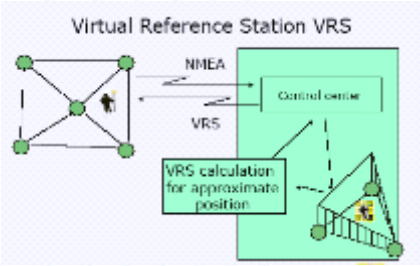
CORS Framework for Australia

Planned Geoscience Australia sites

VRS (Virtual Reference Station)



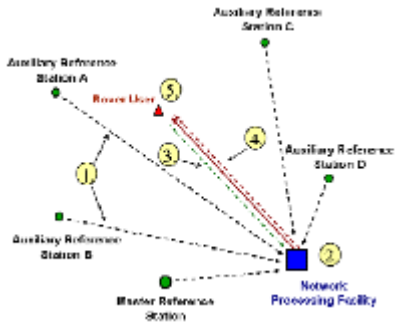
1) Determine atmospheric and orbit errors with cm-accuracy by fixing the ambiguities of the baselines within the network,

2) Simulate the position of the VRS by geometrically displacing the data of the reference station closest to the rover,

3) Interpolate the network errors at the VRS location using linear or more sophisticated models, and

4) Transmit the corrections to the rover in real-time. [Volker Janssen 2009]

MAC (Master Auxiliary Concept)



1. Transmission of raw observation data from the reference stations to the network processing facility.
2. Network estimation process including AR to reduce stations to the common ambiguity level
3. (optional) NMEA position received from the rover at the network processing facility. The most appropriate reference stations are chosen for the rover based on its location
4. Formation and transmission of RTCM 3.1 message. Corrections for master station and relative corrections for auxiliary stations
5. Computation of high accuracy rover position using the full information from the reference network [Volker Janssen 2009]

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Affect of MSTID's on Network RTK in Northern Mid- Latitudes (Germany)

The Performance of Virtual Reference Stations in Active Geodetic GPS-networks under Solar Maximum Conditions – *[Wanninger 99]*

Aim - Compare the performance of VRS's during periods of Medium-Scale Travelling Ionospheric Disturbances (MSTIDs) with periods of no Ionospheric disturbance

Relevant conclusions –

1. The quality of the ionospheric corrections decreases with increasing network size and increasing ionospheric activity
2. With networks over 100km during high ionospheric activity, the short VRS baseline will be adversely affected.

This study was carried out in the mid latitudes of Europe in Germany and highlights the need for similar studies to be carried out in Australia!

Conclusions

1. Opportunity to study VRS/MAC performance in an environment of peak solar activity
2. MSTID's will be the major cause of disruption to a Network RTK solution with isolated solar events causing random temporary degradation in performance.
3. Draw some conclusions about the maximum inter-reference station distances in a CORS network in Australia

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References

- Janssen, V. (2010) *FIG2010,* CORSnet-NSW: Towards State-wide CORS Infrastructure for New South Wales, Australia
- *Wanninger, L. (2004) ION GNSS 2004,* Ionospheric Disturbance Indices for RTK and Network RTK Positioning, *Dresden University of Technology, Germany*
- Hernández-Pajares, M. (2008) *Física de la Tierra,* MSTID Detection, Characterization and Modelling: A Key Point to Improve the Precise GNSS Navigation, Spain
- Rizos, C. (2005) New Global Navigation Satellite System Developments and Their Impact on Survey Service Providers and Surveyors1
- Janssen, V. (2009) IGNSS Symposium 2009, A Comparison of the VRS and MAC principles for Network RTK, Queensland, Australia

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