National Geodetic Survey

Single Base (CORS) RTK in VT
A Case Study

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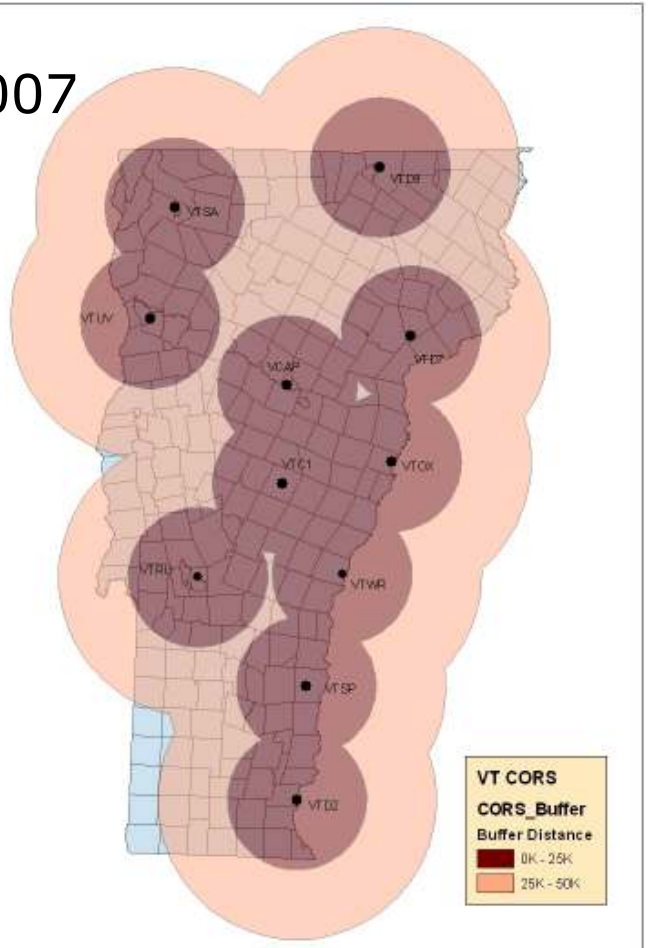
National Oceanic and Atmospheric Administration

CORS Network Background

- Existing network installed in 2007
- All but 2 are GNSS receivers
- Four additional CORS will be added in 2008
- 40km-50km network spacing after full build out
- RTK data stream available via NTRIP (Single Base)



Purpose of Study – 3 Primary Pursoses

- Develop/test field procedures (very little existing documentation) – new to VT
- Evaluate precision/accuracy limits within NGS guidelines
- Provide expectations to users in order to promote use of the technology and VT's network

Draft NGS Accuracy Classes

ACCURACY CLASS SUMMARY TABLE

	CLASS RT1	CLASS RT2	CLASS RT3	CLASS RT4
ACCURACY (TO BASE)	0.015 HORIZONTAL., 0.025 VERTICAL	0.025 HORIZONTAL., 0.04 VERTICAL	0.05 HORIZONTAL., 0.06 VERTICAL	0.15 HORIZONTAL., 0.25 VERTICAL
REDUNDANCY	≥ 2 LOCATIONS, 4-HOUR DIFFERENTIAL	≥ 2 LOCATIONS, 4-HOUR DIFFERENTIAL	NONE	NONE
BASE STATIONS	≥ 2 , IN CALIBRATION PROJECT CONTROL	RECOMMEND 2 IN CALIBRATION	≥ 1 , IN CALIBRATION	≥ 1 , IN CALIBRATION RECOMMENDED
PDOP	≤ 2.0	≤ 3.0	≤ 4.0	≤ 6.0
RMS	≤ 0.01 M	≤ 0.015 M	≤ 0.03 M	≤ 0.05 M
COLLECTION INTERVAL	1 SECOND FOR 3-MINUTES	5 SECONDS FOR 1-MINUTE	1 SECOND FOR 15 SECONDS	1 SECOND FOR 10 SECONDS
SATELLITES	≥ 7	≥ 6	≥5	≥ 5
BASELINE DISTANCE	≤ 10 KM	≤ 15 KM	≤ 20 KM	ANY WITH FIXED SOLUTION
TYPICAL APPLICATIONS	PROJECT CONTROL CONSTRUCTION CONTROL POINTS CHECK ON TRAVERSE, LEVELS SCIENTIFIC STUDIES PAVING STAKE OUT	DENSIFICATION CONTROL TOPOGRAPHIC CONTROL PHOTOPOINTS UTILITY STAKE OUT	TOPOGRAPHY CROSS SECTIONS AGRICULTURE ROAD GRADING SITE GRADING	SITE GRADING WETLANDS GIS POPULATION MAPPING ENVIRONMENTAL

Collection Procedures (3 Observers)

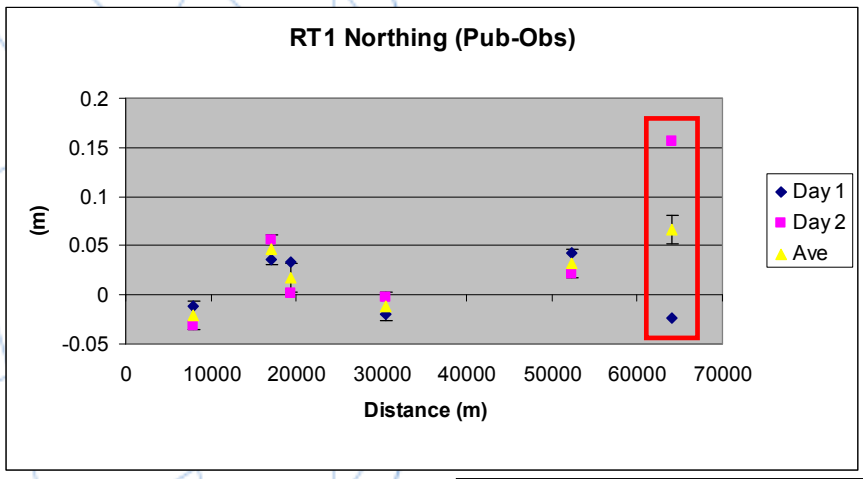
1. Setup bipod/antenna and start survey
2. Initialize to nearest CORS
3. Collect observation using the duration criteria for RT1, RT2, RT3 and RT4 in rapid succession (regardless of field conditions)
4. End survey
5. Start new survey
6. Initialize to a different CORS
7. Repeat steps 3-6 using a number of CORS stations
8. End Survey
9. Move to different test locations and repeat steps 1-8
10. Repeat procedure steps 1-9 four or more hours later (preferably the next day)

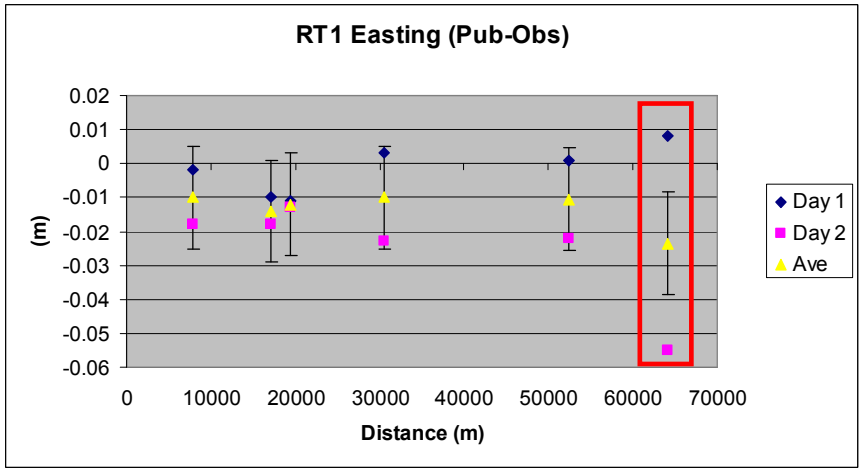
Test Stations and Vector Lengths

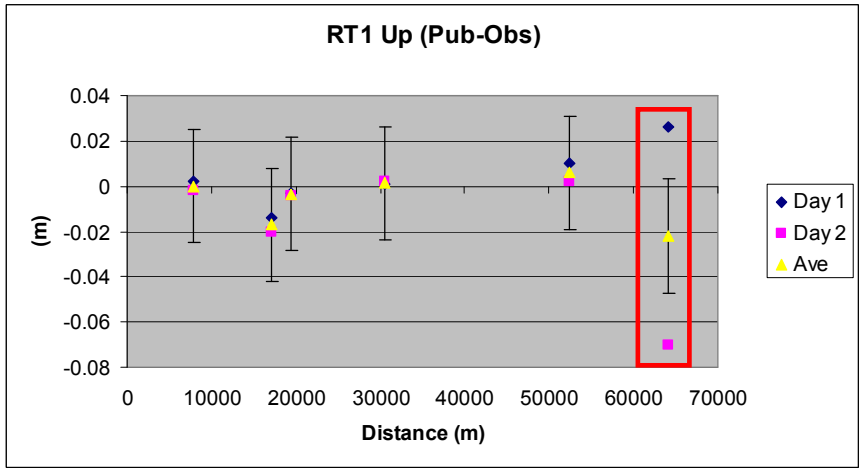
CORS	Field Station	Distance (m)
VCAP	SKYL	7888
VCAP	SOBA	11263
VTC1	LLCZ	17140
VCAP	LLCZ	19400
VTC1	SOBA	27097
VTC1	SKYL	30536
VTWR	LLCZ	52358
VTWR	SOBA	60397
VTUV	SOBA	63773
VTWR	SKYL	64112

Observer 1 – Example of BAD Initialization

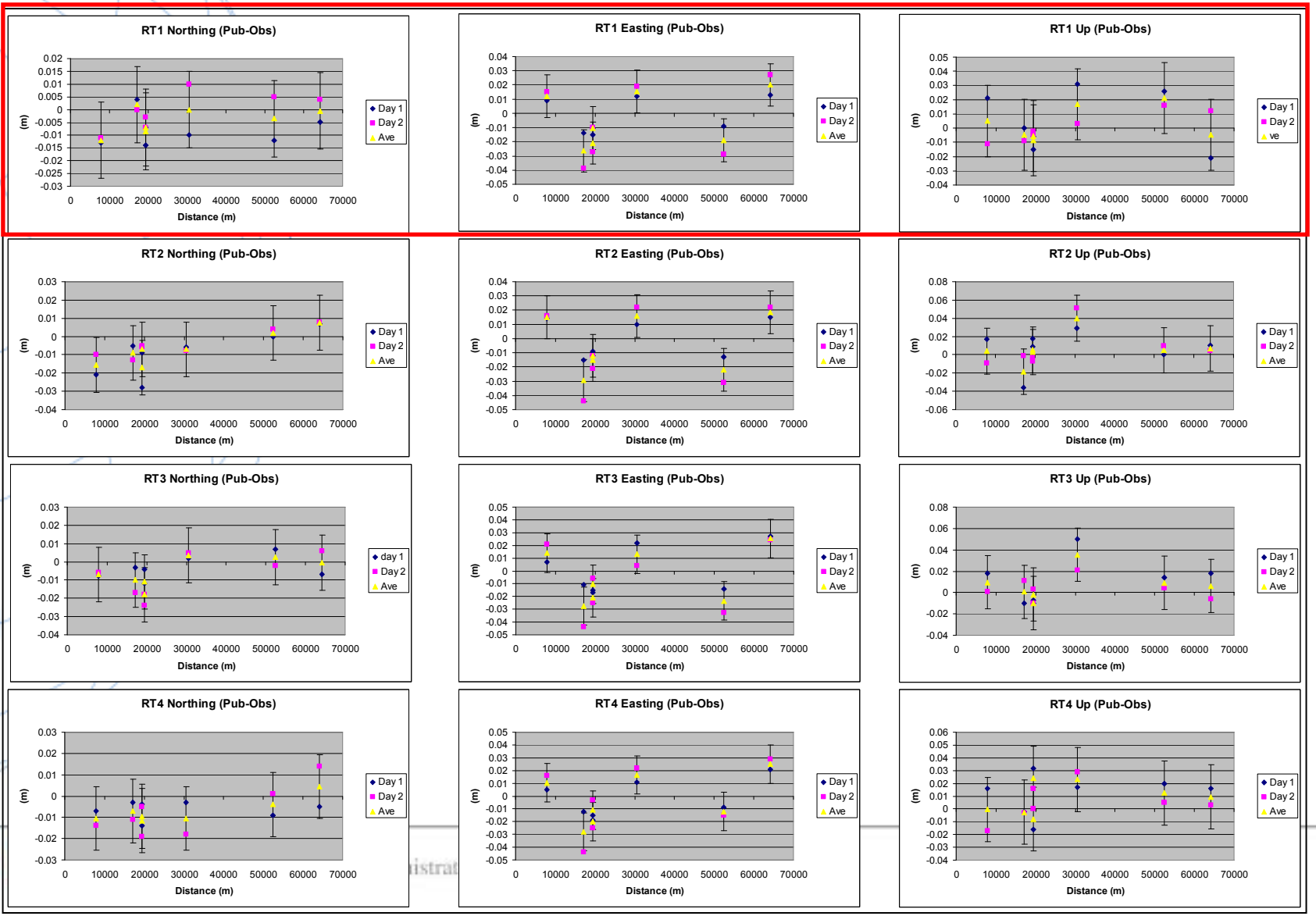
Y Error bars indicate RT1 accuracy cutoff



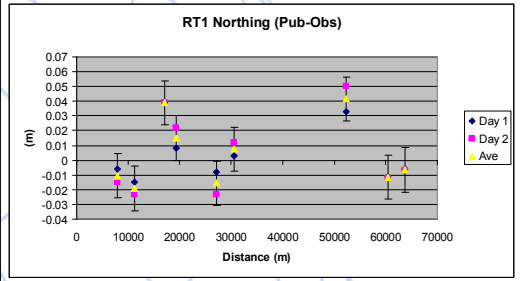


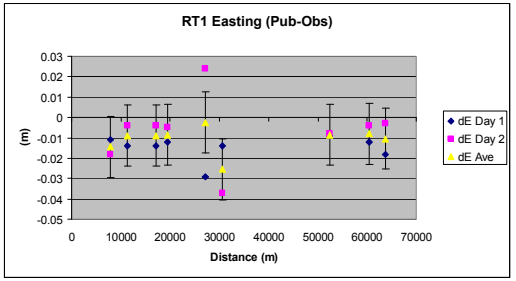


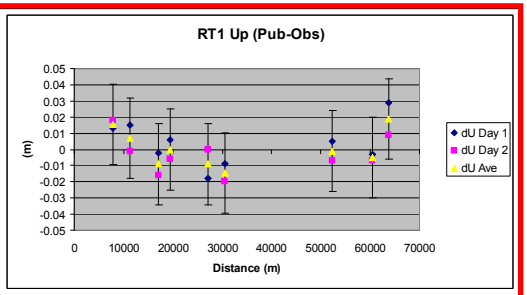
Observer 2 Data

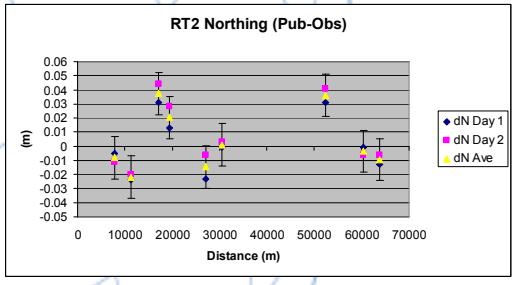


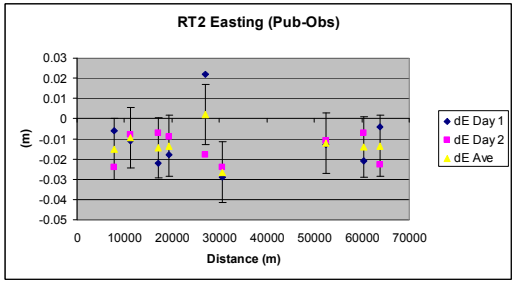
Observer 3 Data

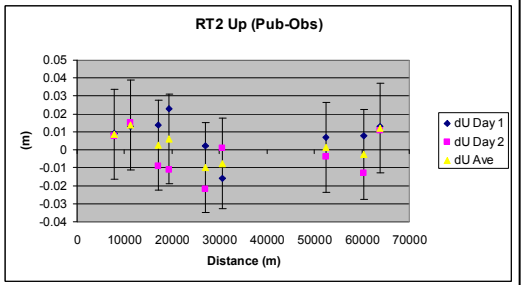


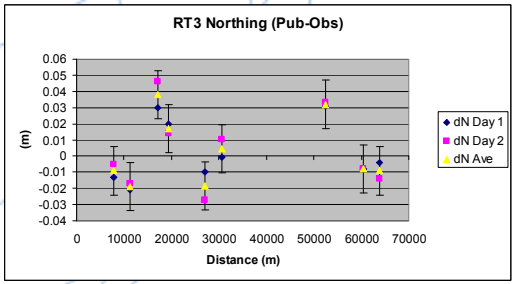


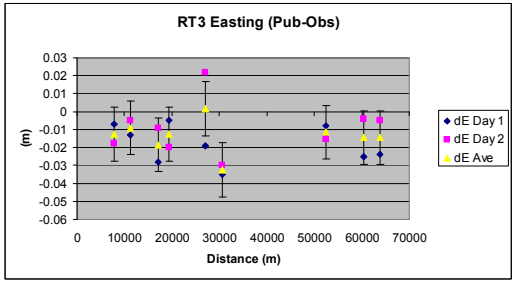


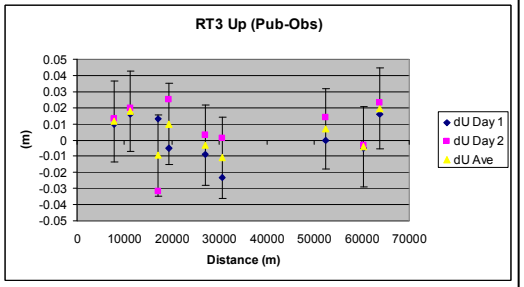


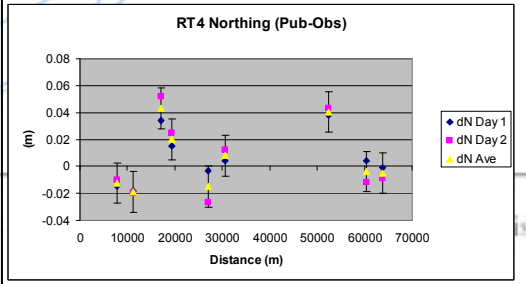


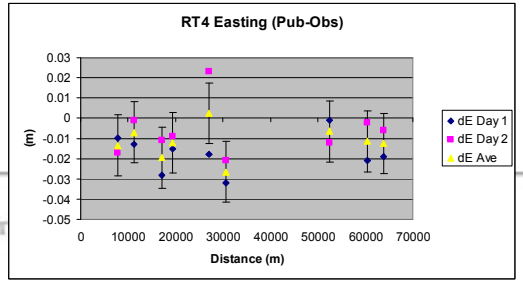


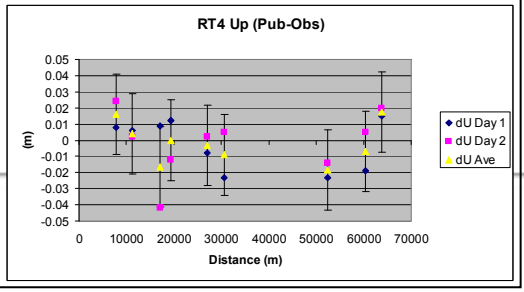




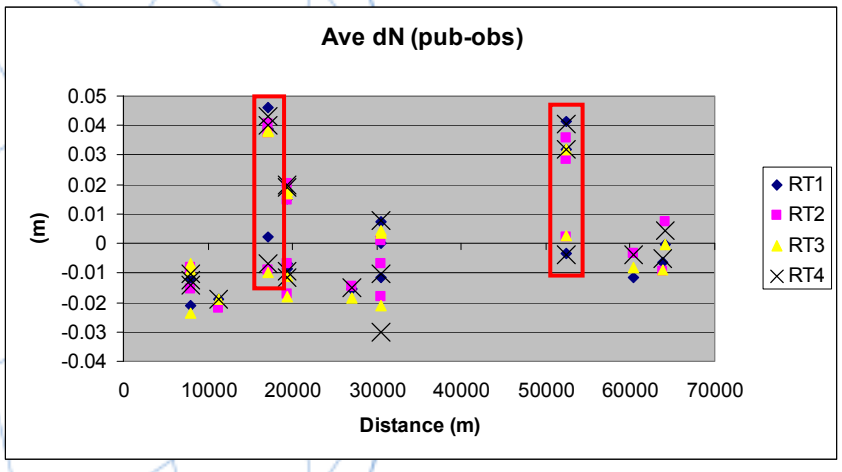


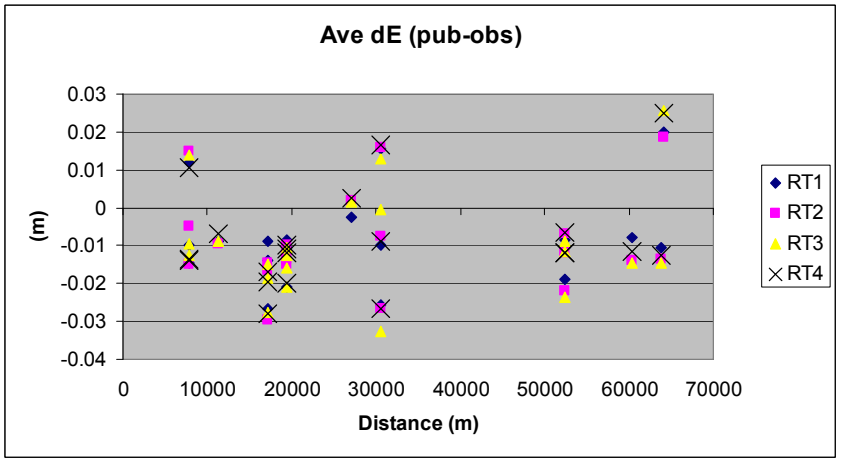


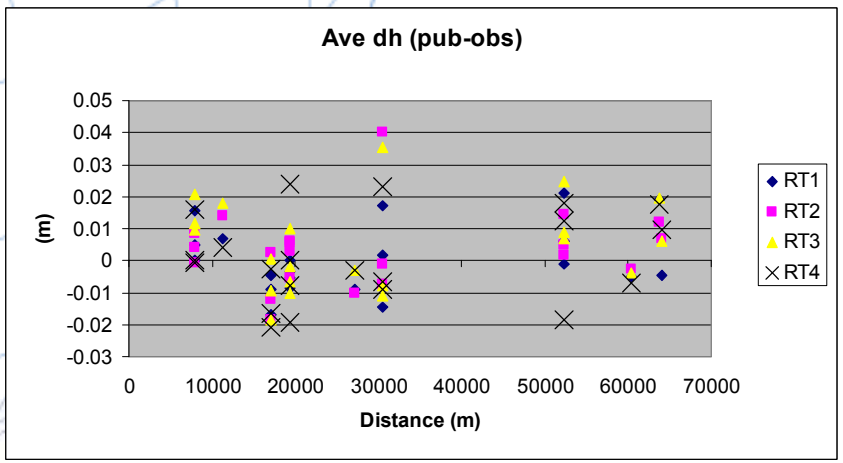




Combined Data - Average of each observers Day1 and Day2 observations

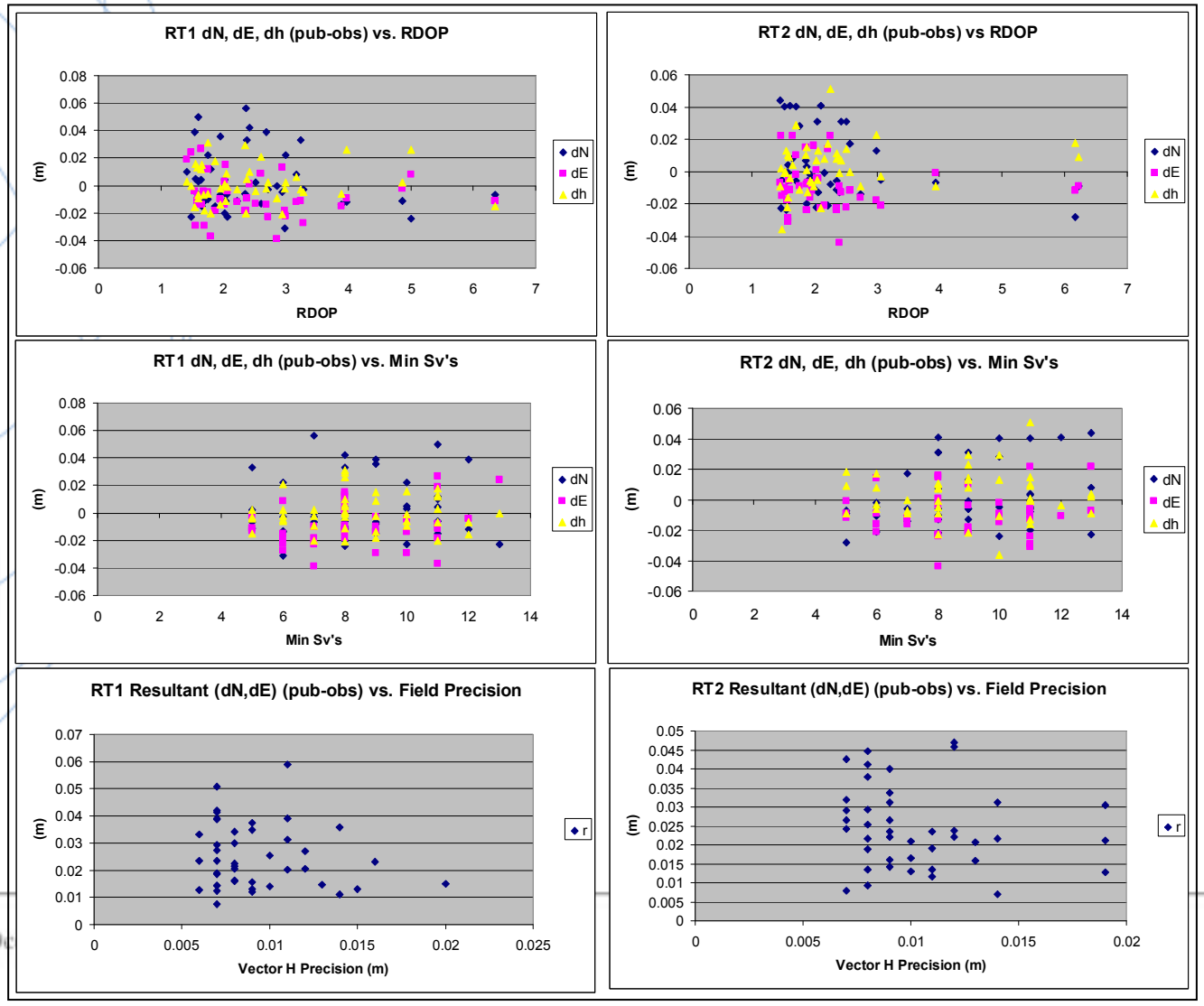




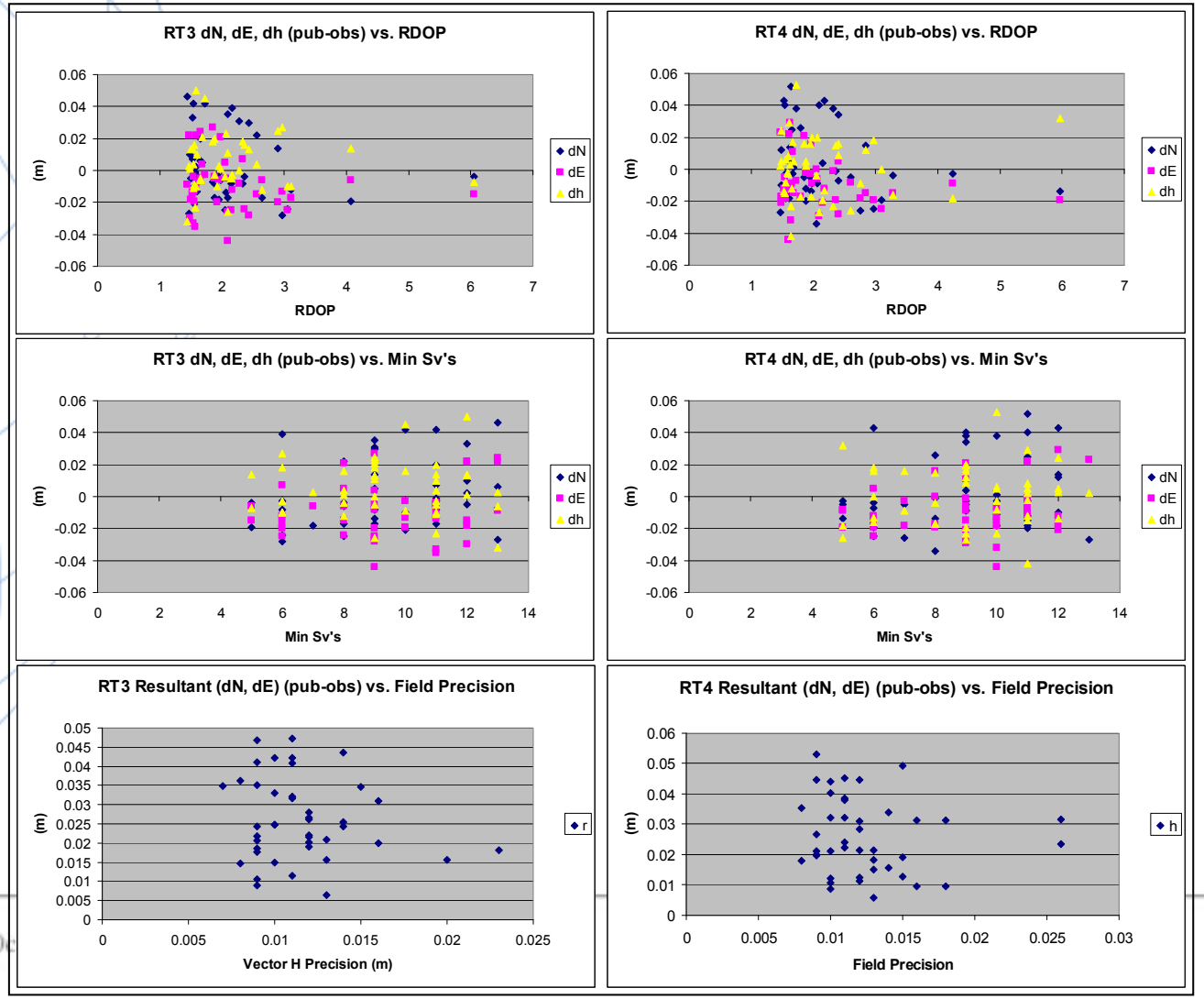


	σ N (m)	σ E (m)	σ h (m)
RT1	0.021	0.012	0.011
RT2	0.020	0.013	0.012
RT3	0.020	0.014	0.014
RT4	0.021	0.013	0.014

Precision Relative to Collection Criterion

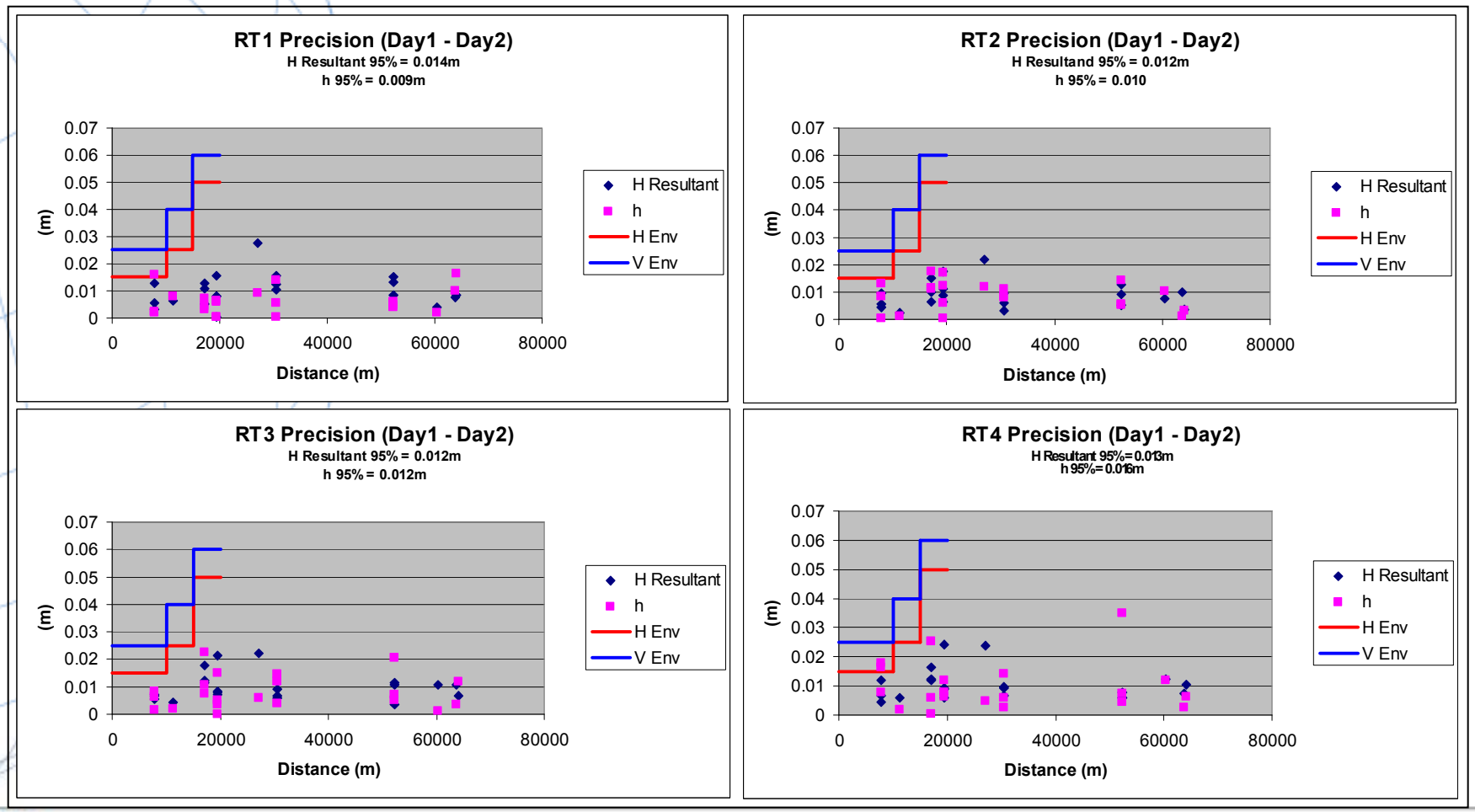


Precision Relative to Collection Criterion cont.



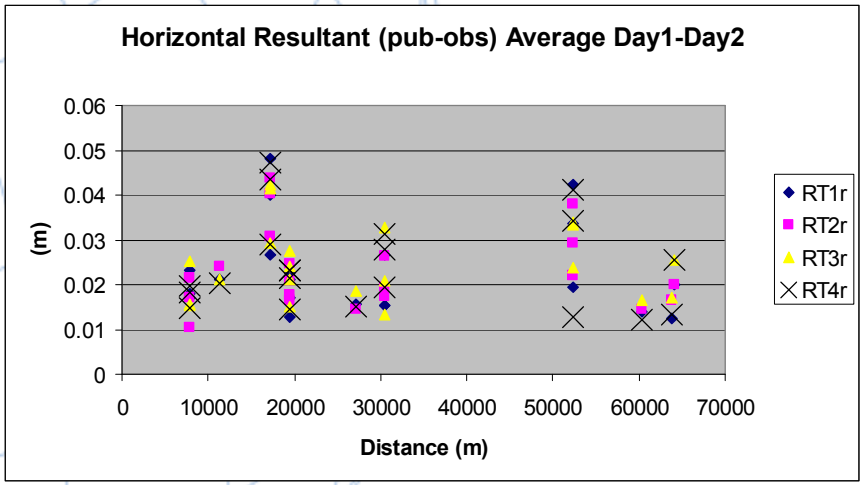
Day1-Day 2 Precisions (NGS Guidelines)

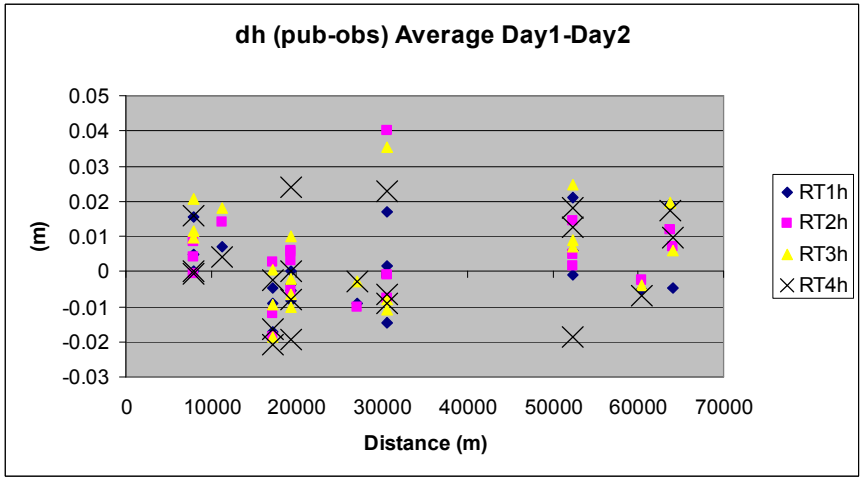
H Resultant = $\sqrt{\left(\frac{(dN_{d1} - dN_{d2})}{2}\right)^2 + \left(\frac{(dE_{d1} - dE_{d2})}{2}\right)^2}$



How does Precision translate to Accuracy

- NGS Accuracy Classes defined by 2d horizontal, 1d vertical precision (Repeatability) at 95% per redundant observation set





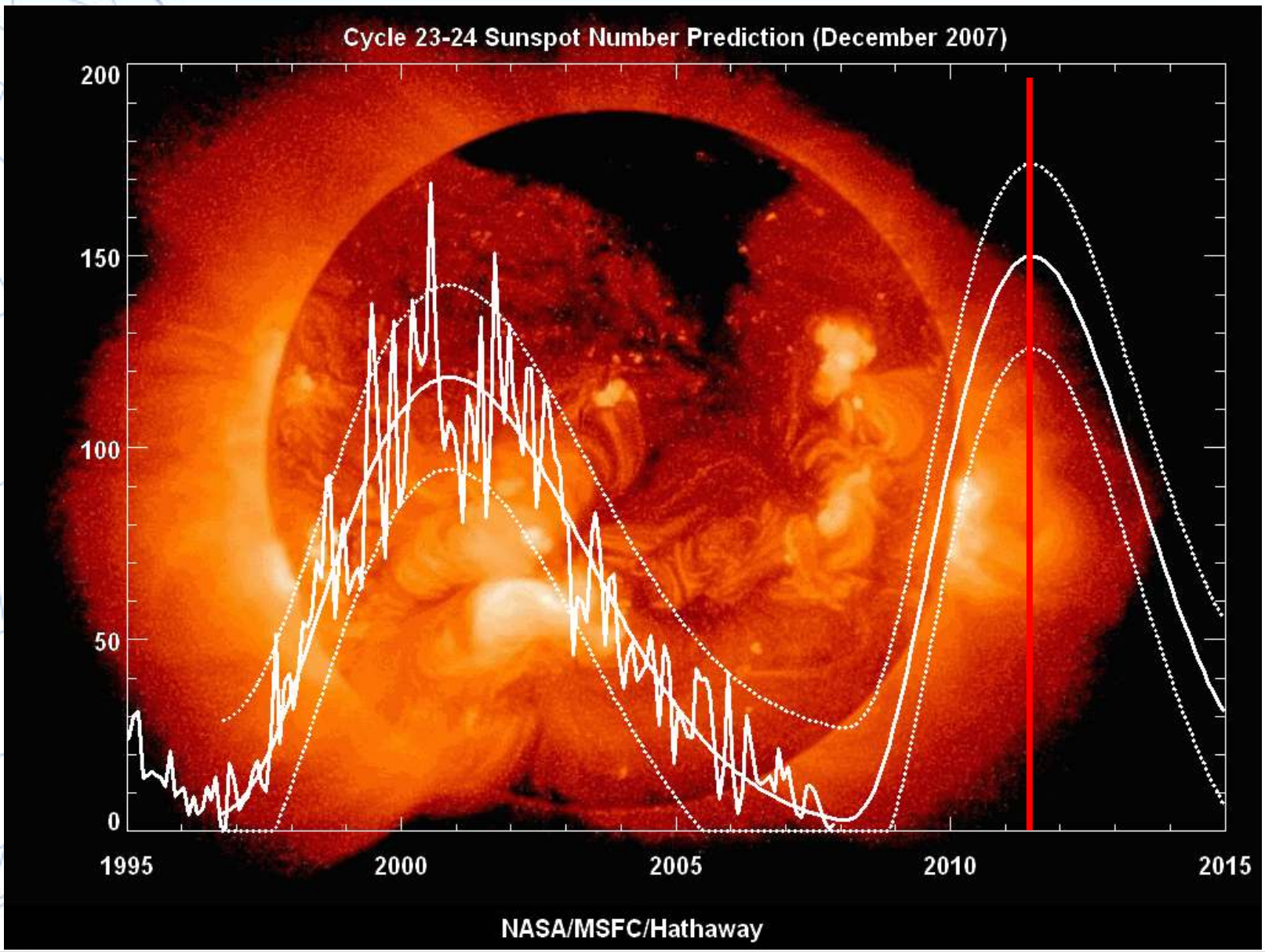
	2σ Horizontal	2σ Vertical
RT1	0.024663	0.020933
RT2	0.021754	0.023475
RT3	0.020684	0.027002
RT4	0.025223	0.027488

Conclusions (Based on this study only)

- Duration of observation only appears to improve field RMS – no apparent bearing on actual precision
- No apparent correlation between actual precision and:
  - Baseline Length
  - Number of SV's
  - RDOP
- Small increase in accuracy (vertical) with longer observations (based on 2σ error estimates of all observers' data)
- Horizontal and Vertical precisions are about the same
- Most important factor is achieving good initialization.
- Good accuracy and precision is possible even with short occupations on long vectors

Questions I have – More work to do

- Is this achievable everywhere? (TROPO)
  - Need more research from around the country under different TROPO conditions
  - Is there some way to know when/if TROPO will be an issue?
- Does the equipment new/old, GPS/GNSS make a difference?
  - Need more research using different equipment, different software
- Is this achievable in 2011 - 2012?


Cycle 23-24 Sunspot Number Prediction (December 2007)
200
150
100
50
0
1995
2000
2005
2010
2015
NASA/MSFC/Hathaway