The Absolute Geolocation Accuracy of DigitalGlobe's Satellites:

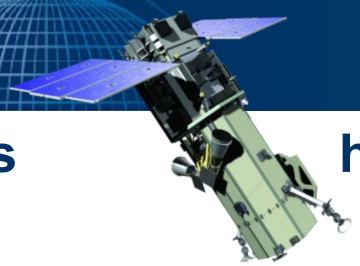
QB02, WV01, WV02

Dr. Byron Smiley
DigitalGlobe

outline

- quick review of the DG constellation
  - altitude
  - GSD, and a QB02, WV01, WV02 image of same gcp
- methods
  - gcps, latitude distribution
  - nadir projection
  - quiver plots, average error
  - CCAP metric of a group, 90th percentile
- absolute geolocation accuracy
  - 2D scatter plots
  - magnitude histogram, sample quiver plots from a few bins
  - time bin plots, stability

DigitalGlobe's high resolution constellation



WV02

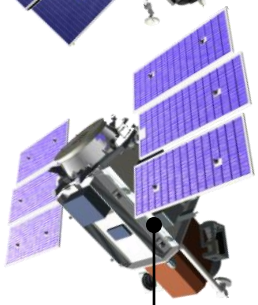
NEW!

770 km

WV01

496 km

QB02

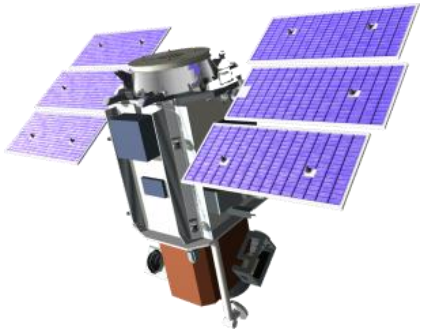


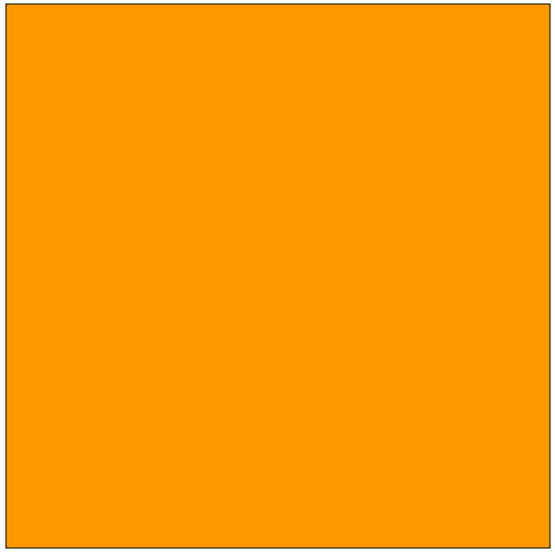
450 km

one gcp to demonstrate GSD of each satellite

this is gcp 9419 in Townsville, Australia

one gcp as imaged by QB02





QB02 = 61 cm

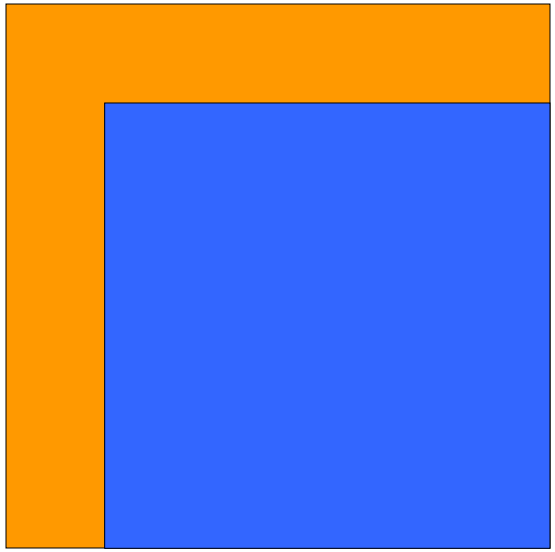
(at nadir)

catid: 1010010009F95E00
date: 23 Jul 2009
off nadir: ~18
effective GSD here: ~67 cm

Raw, 1A product

No radiometric or geometric corrections applied

one gcp as imaged by WV01



WV01 = 50 cm

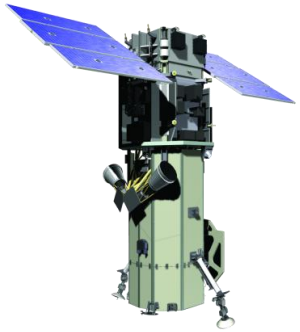
(at nadir)

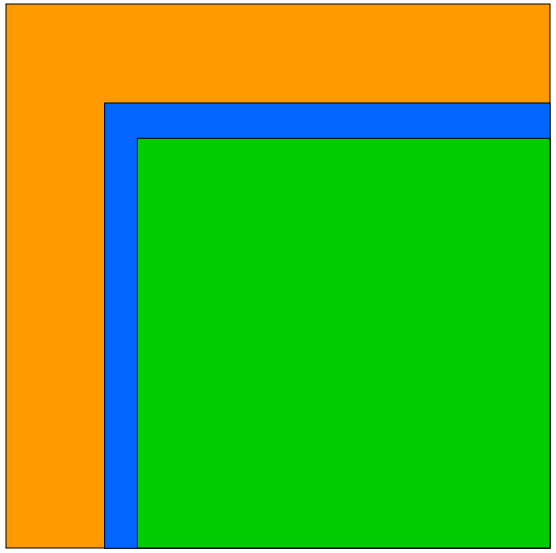
catid: 102001000AE22400
date: 12 Jan 2010
off nadir: ~20
effective GSD here: ~56 cm

Raw, 1A product

No radiometric or geometric corrections applied

one gcp as imaged by WV02





WV02 = 46 cm

(at nadir)

catid: 10300100037C5700
date: 18 Jan 2010
off nadir: ~16
effective GSD here: ~50 cm

Raw, 1A product

No radiometric or geometric corrections applied

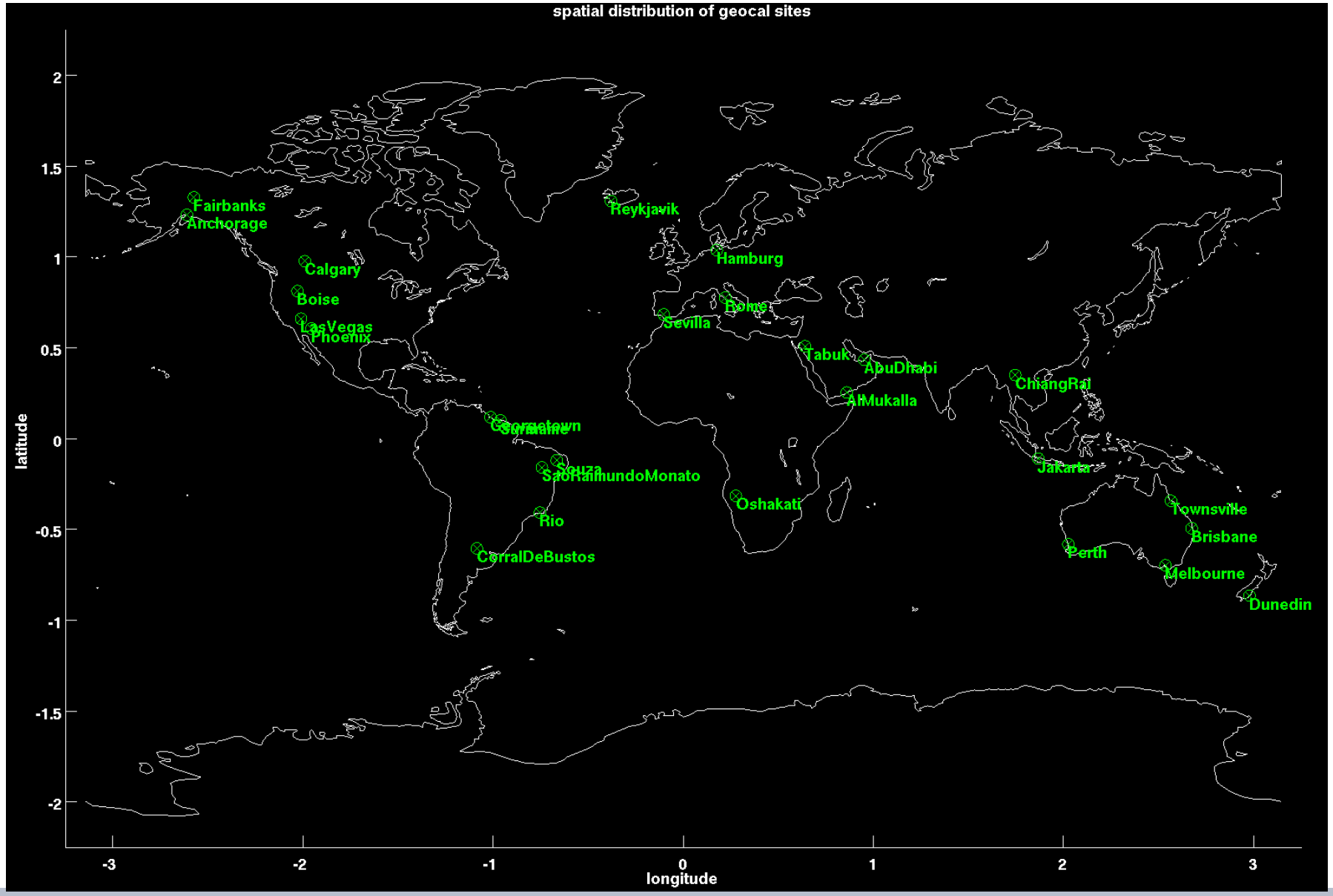
methods

gcps are used to assess absolute geolocation accuracy

- **each city/area has a set of GPS surveyed gcps, call it a *(geo)metric (cal)ibration site***
- **each geocal site has ngcps**
- **multiple geocal sites are used to assess accuracy**

abbreviation	site	ngcp
ABD	Abu Dhabi, United Arab Emirates	14
ACA	Acapulco, Mexcio	8
AMK	Al Mukalla, Yemen	10
ANC	Anchorage, Alaska	16
BOI	Boise, Idaho	14
BNE	Brisbane, Australia	13
CAL	Calgary, Alberta	10
CDB	Corral De Bustos, Argentina	13
DUN	Dunedin, New Zealand	9
FBK	Fairbanks, Alaska	24
GEO	Georgetown, Guyana	9
HAM	Hamburg, Germany	11
JAK	Jakarta, Indonesia	10
LVG	Las Vegas, Nevada	52
MEL	Melbourne, Australia	23
OSK	Oshakati, Namabia	14
PER	Perth, Australia	60
PHX	Phoenix, Arizona	95
REK	Reykjavik, Iceland	8
RIO	Rio de Janeiro, Brazil	26
ROM	Rome, Italy	10
SRM	Sao Raimundo Monato, Brazil	13
SVA	Sevilla, Spain	10
SZA	Souza, Brazil	13
SUR	Paramaribo, Suriname	13
TBK	Tabuk, Saudi Arabia	10
TNV	Townsville, Australia	19

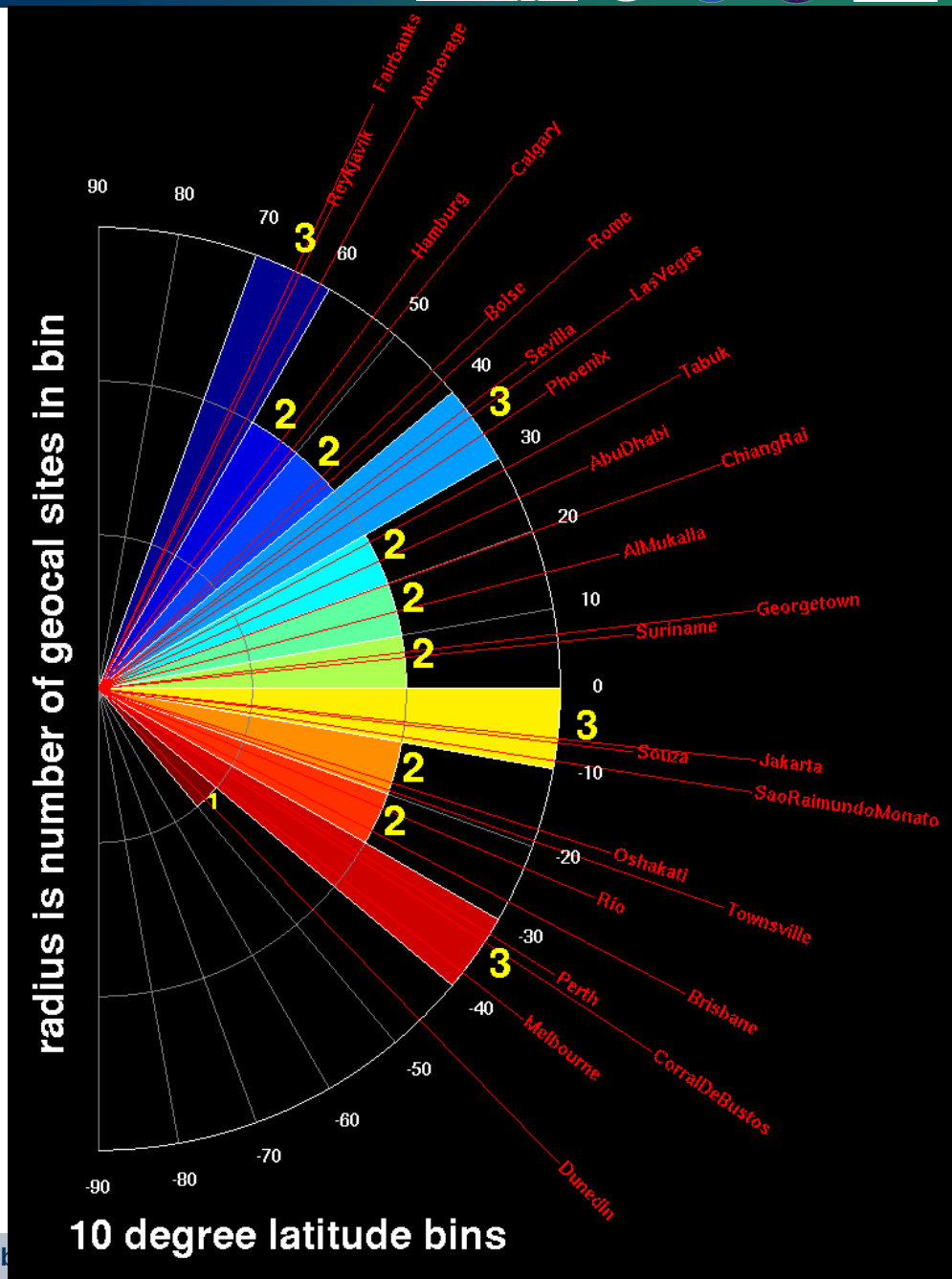
geocal sites in use as of March 2010



angular, latitude histogram of geocal sites as of March 2010

(almost) two sites every ten degrees of latitude

in the pursuit of good geolocation for all latitudes



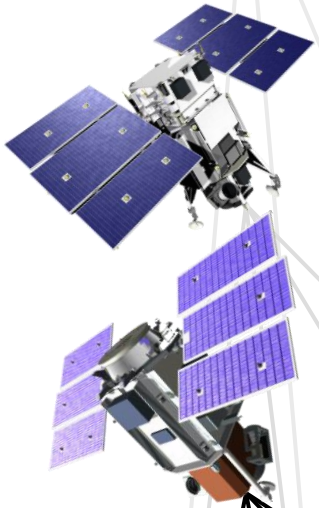
bad gcps, once identified, are excluded from use

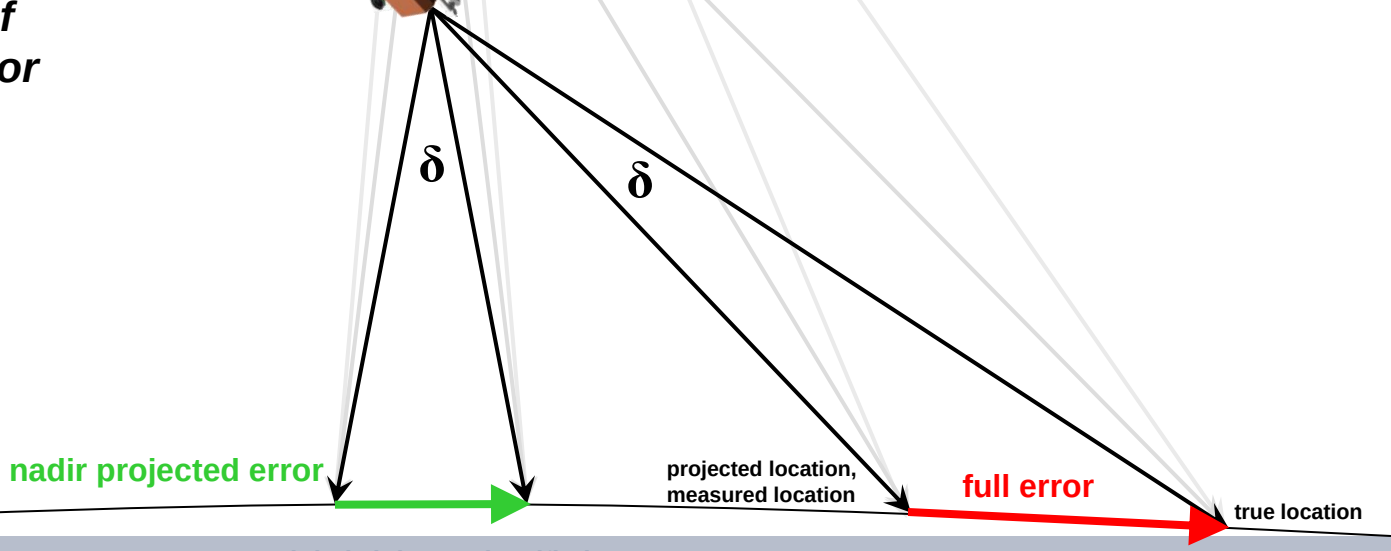
nadir projection facilitates comparison between satellites

nadir projection also helps compare images from different nadir angles

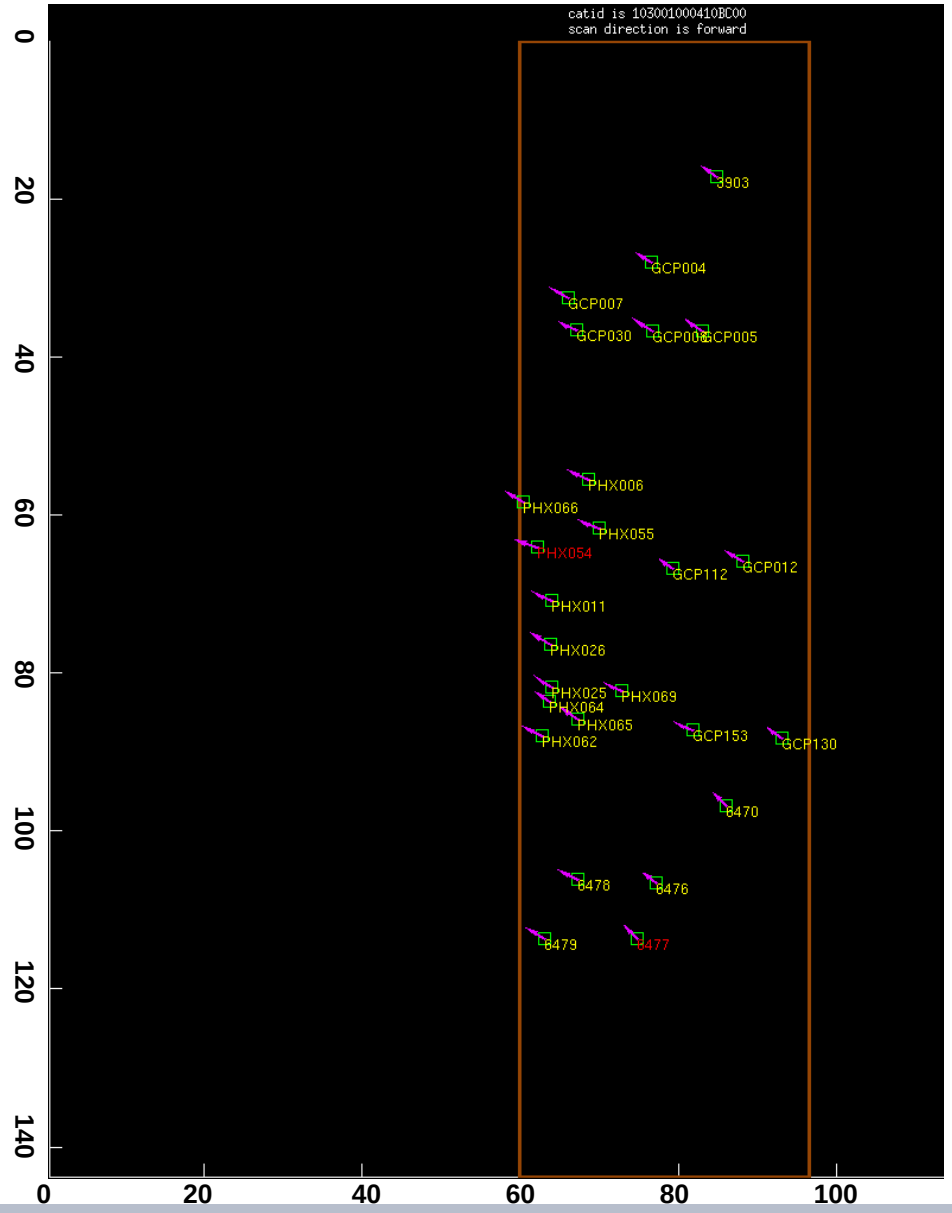
imagery from 0 to 35° off nadir checked

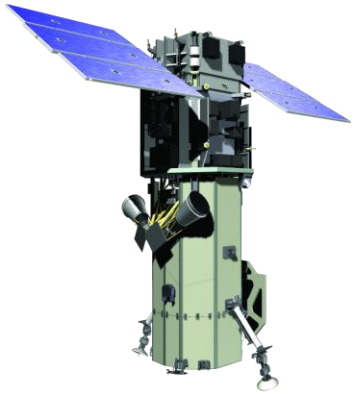
desired geolocation accuracy defined in terms of nadir projected error





nadir projected errors are assembled into quiver plots

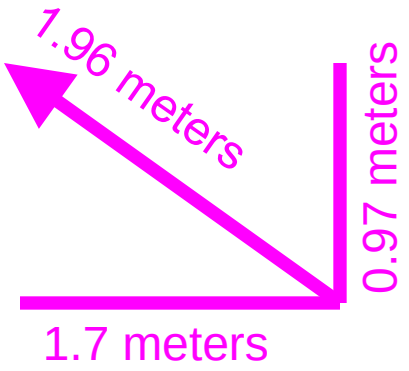




units are

kilometers for strip border

meters for error vectors



average error taken to following steps

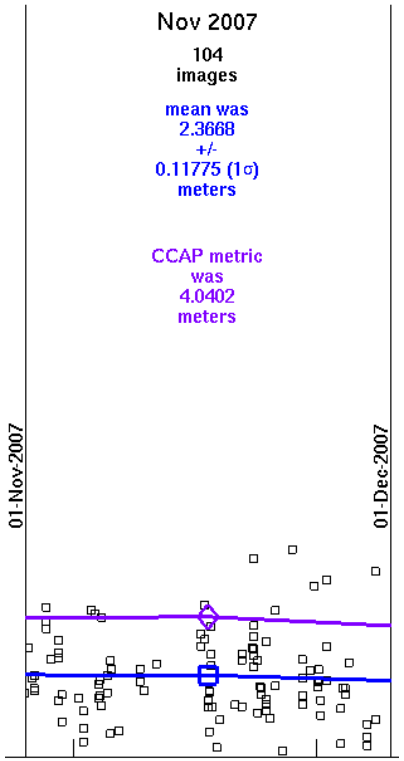
desired absolute geolocation accuracy

90th percentile of something, everything should be

23 meters (projected to nadir) for ***QB02***

6.5 meters (projected to nadir) for ***WV01, WV02***

this 90th percentile is used for evaluation



if you represent each strip by the magnitude of the average error,

then take the NGA 90th percentile of a bin,

that's the ***CCAP metric***.

- Say there are N errors, r_1 to r_N
- Multiply N by 0.9, express result as an integer plus a fraction:

$$N*0.9 + 0.5 = i + f$$

- Stand f of the way between r_i and r_{i+1}

$$CE90 = r_i + (r_{i+1} - r_i)*f$$

- I call it NGA percentile in this talk

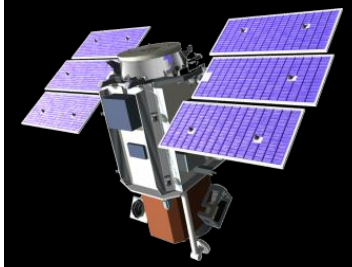
[1 2 3 4 5 6 7 8 9 10]

NGA percentile: if you have ten things, the 90th percentile is halfway between the ninth and tenth thing (it's unbiased, by construction through Monte Carlo studies)

scatter plots

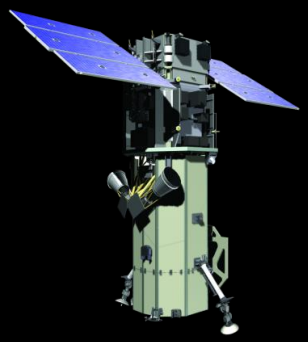
with percentiles

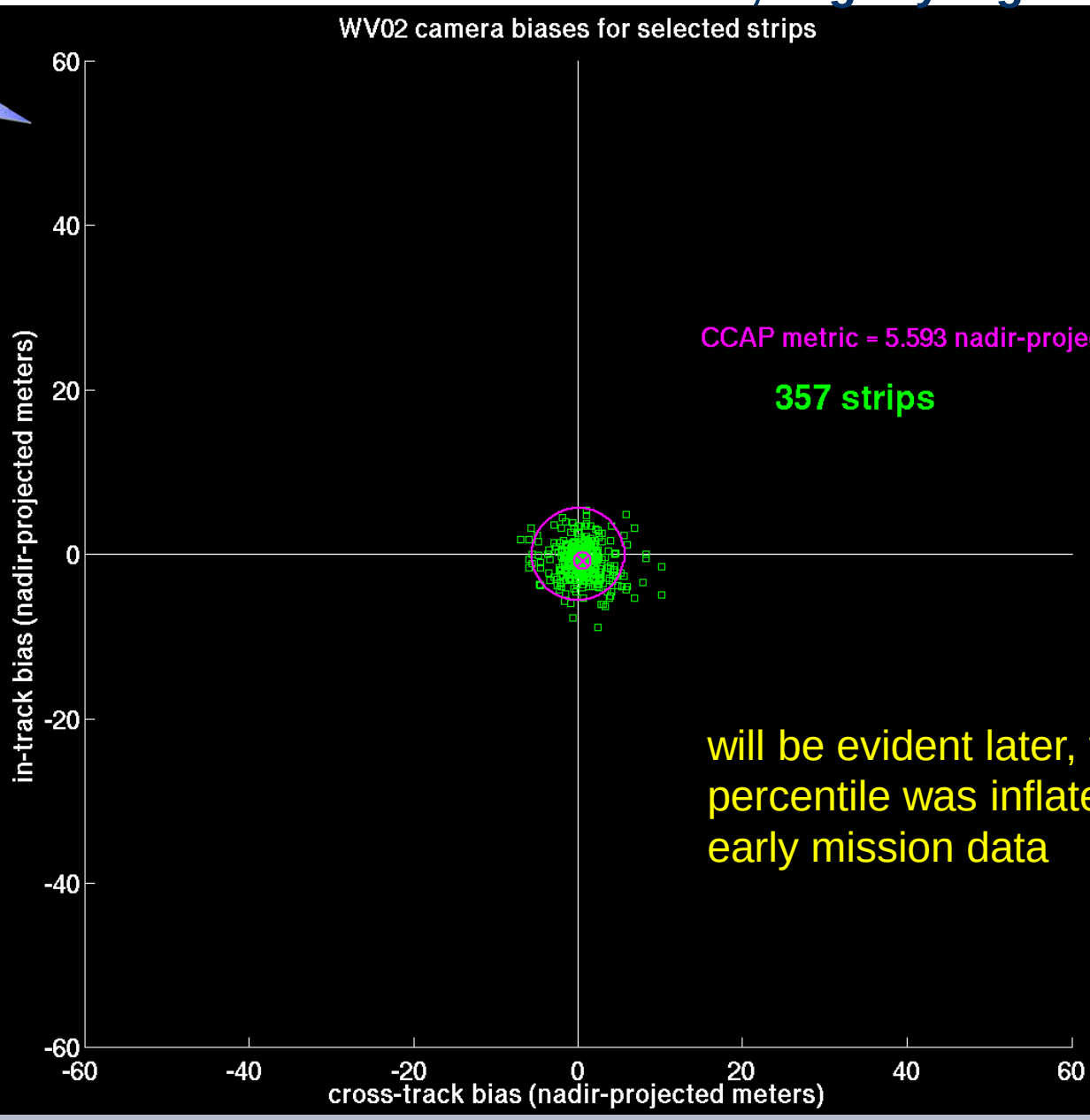
QB02 has a scatter plot with a wide spread



WV01 has a much tighter spread

WV02 about the same as WV01, slightly higher





CCAP metric = 5.593 nadir-projected meters

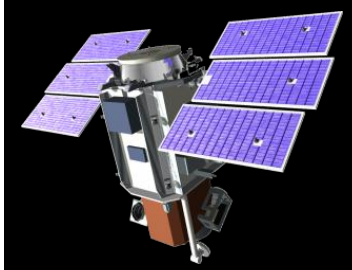
357 strips

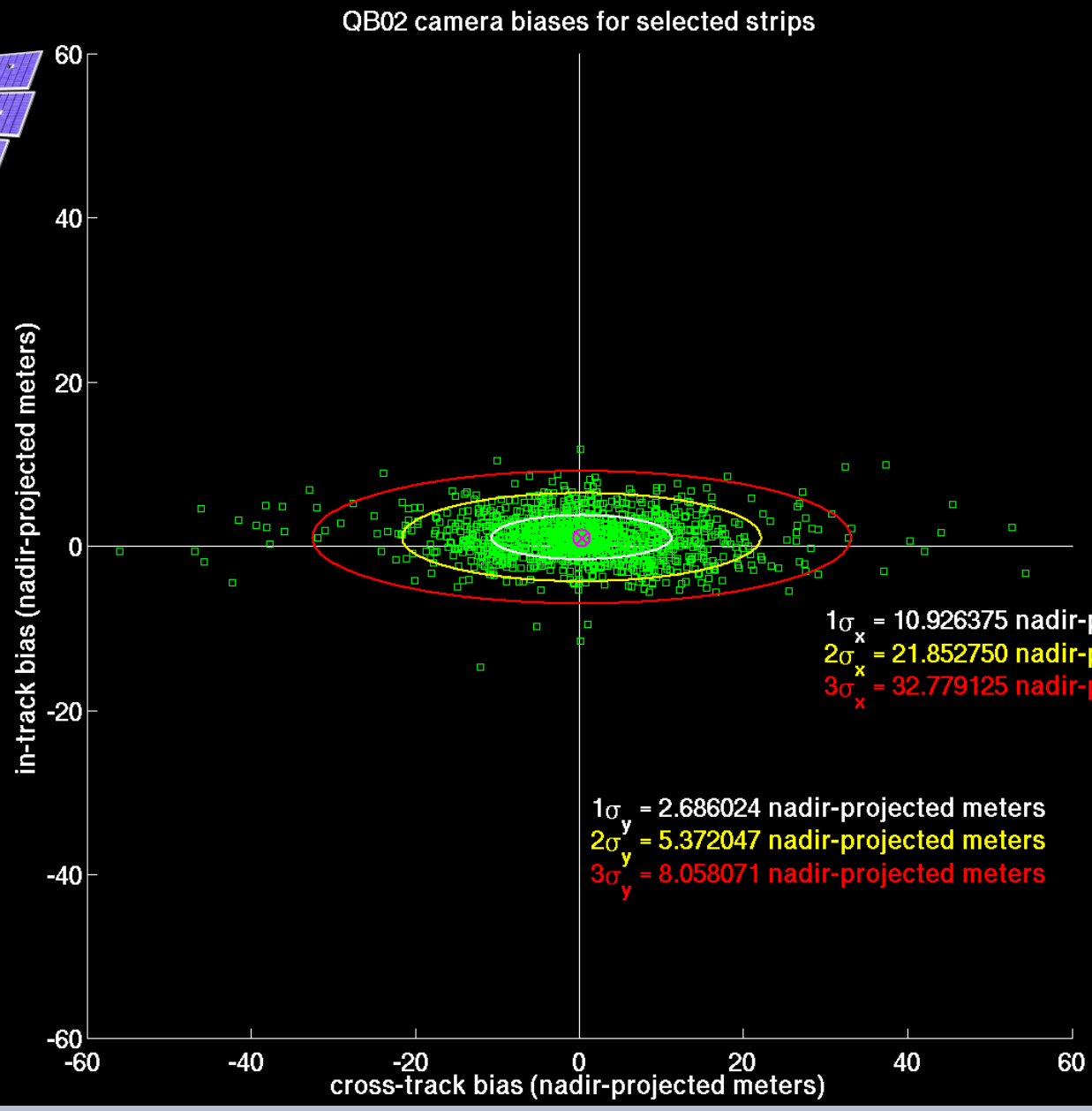
will be evident later, this 90th percentile was inflated by early mission data

scatter plots

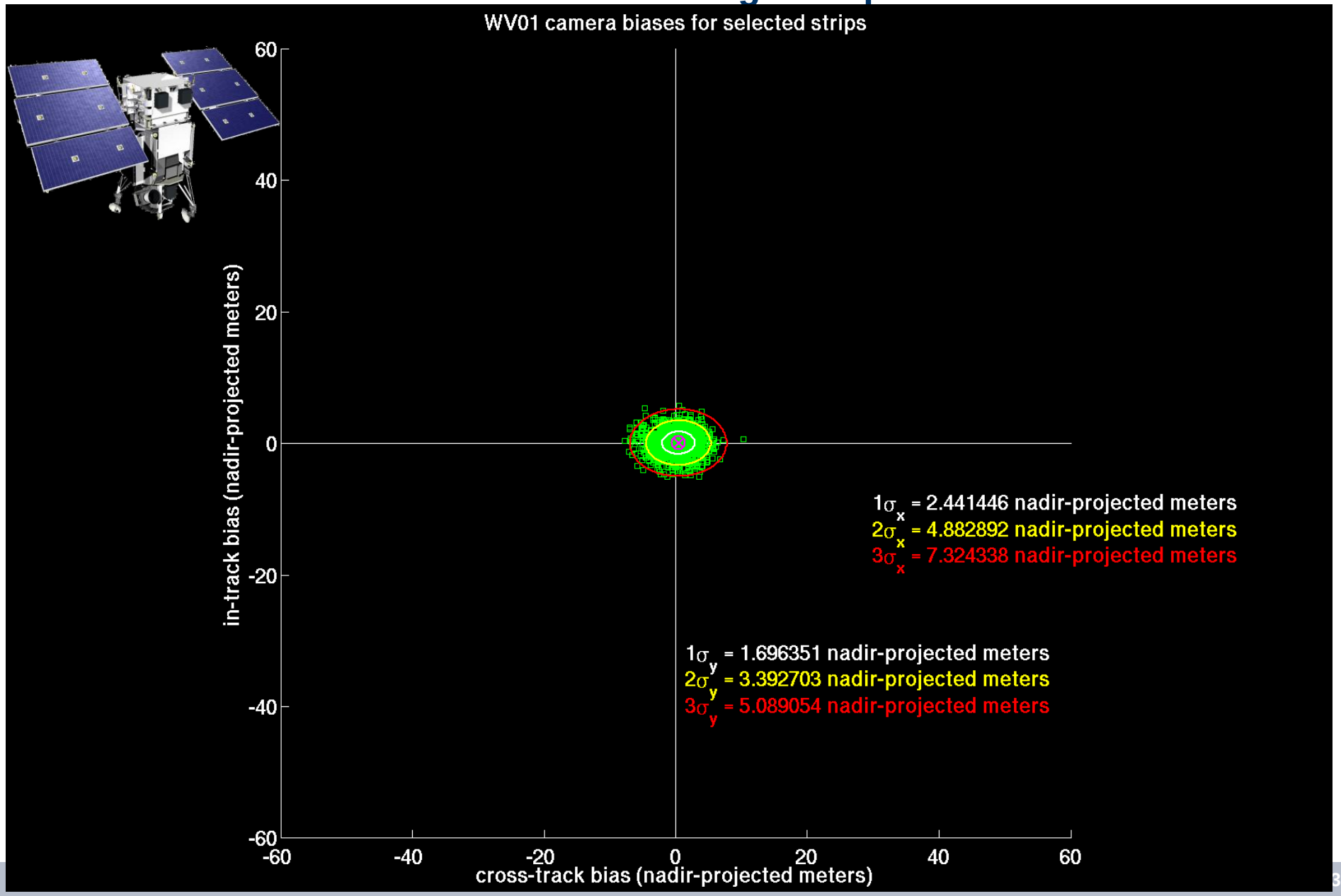
with standard deviations

QB02 has a scatter plot with a wide spread

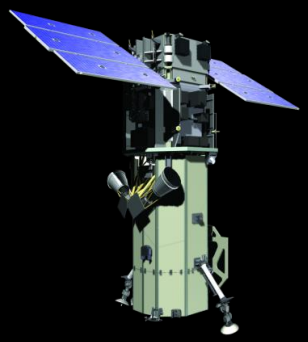


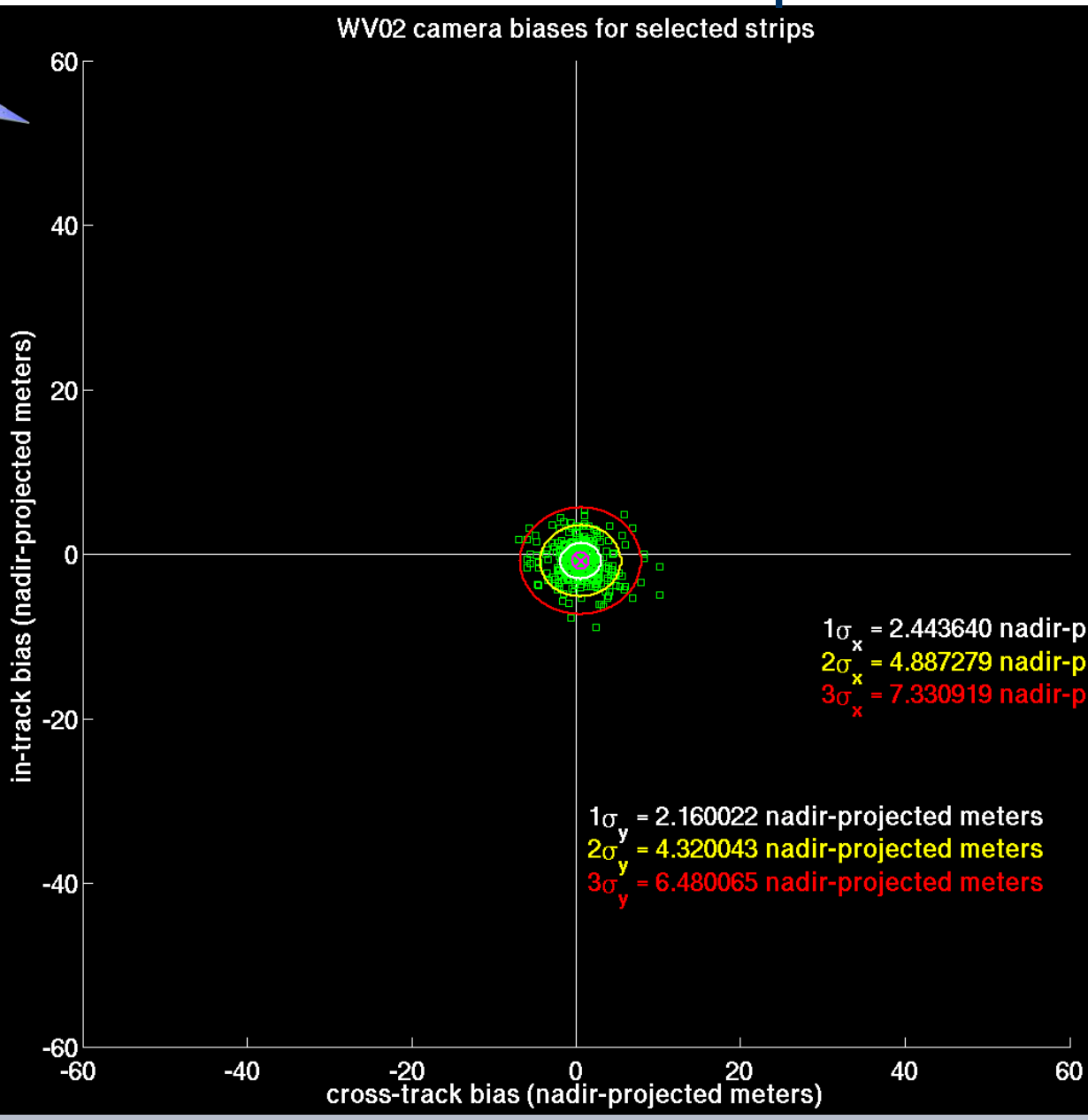


WV01 has a much tighter spread



WV02 has identical cross track spread as WV01

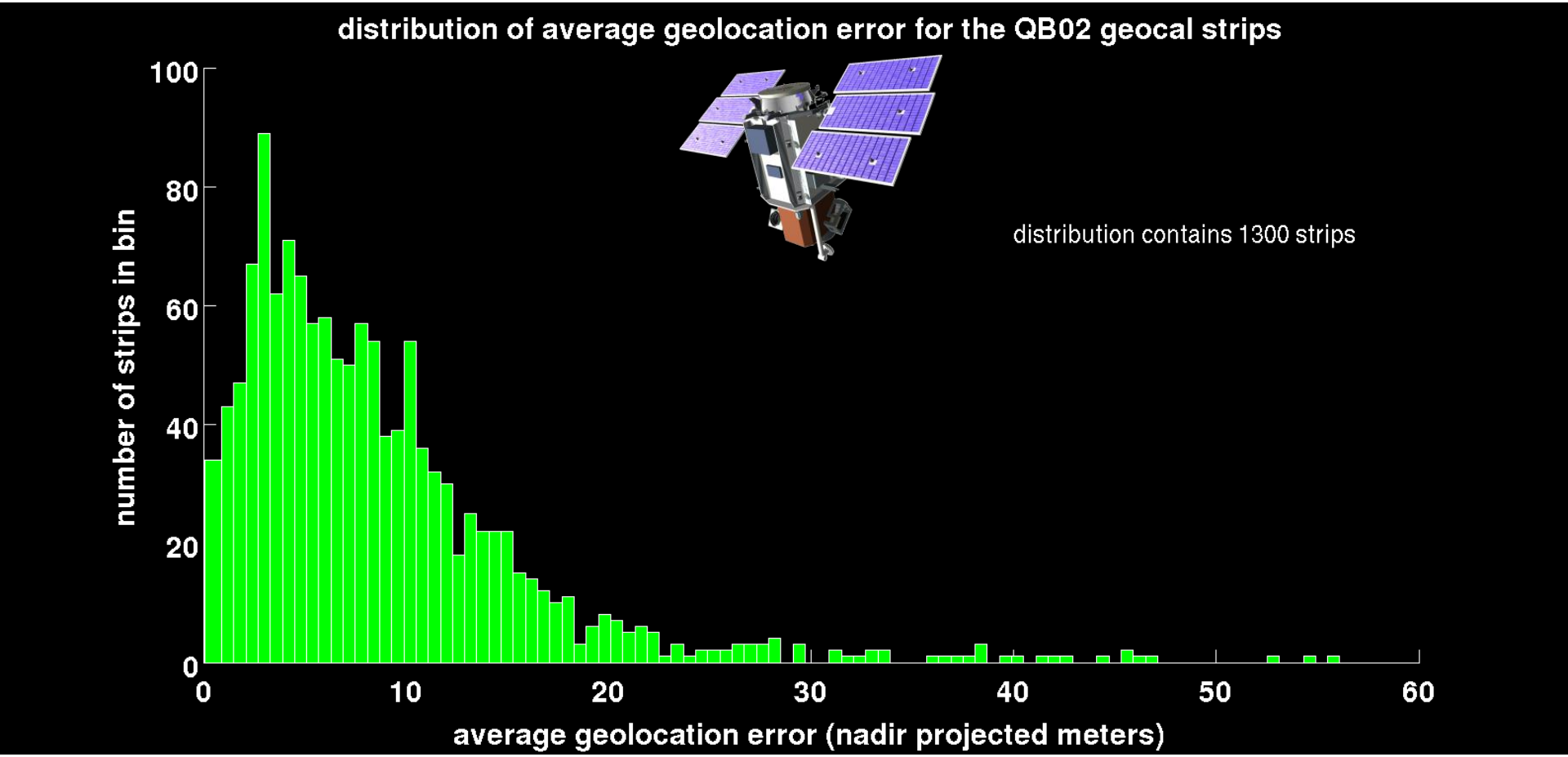




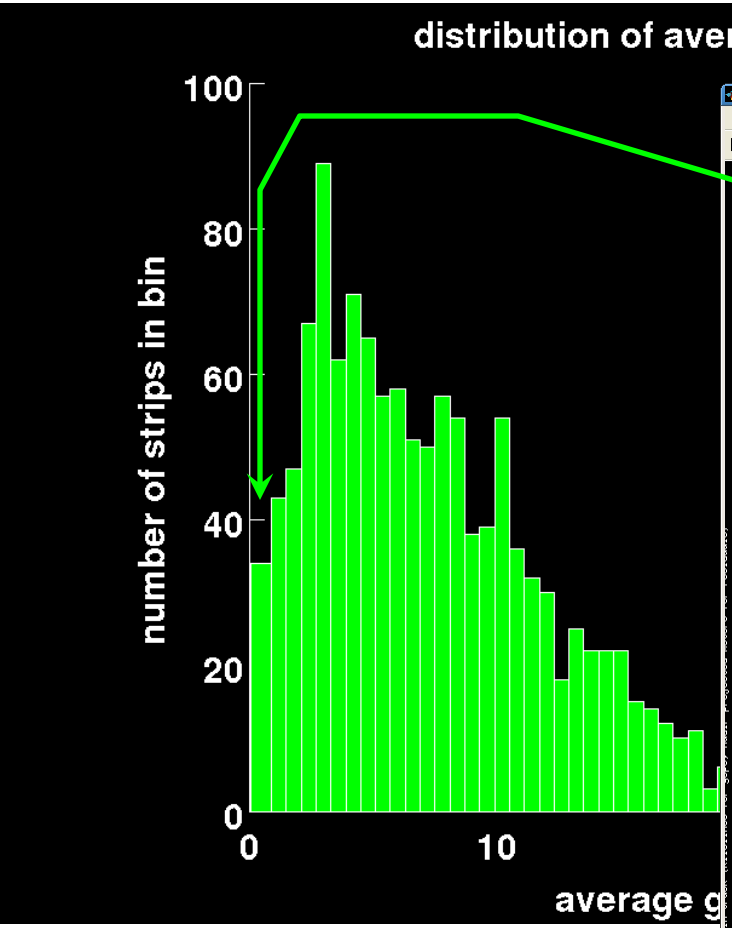
histograms

of average geolocation error,
with sample quiver plots

samples from the distribution

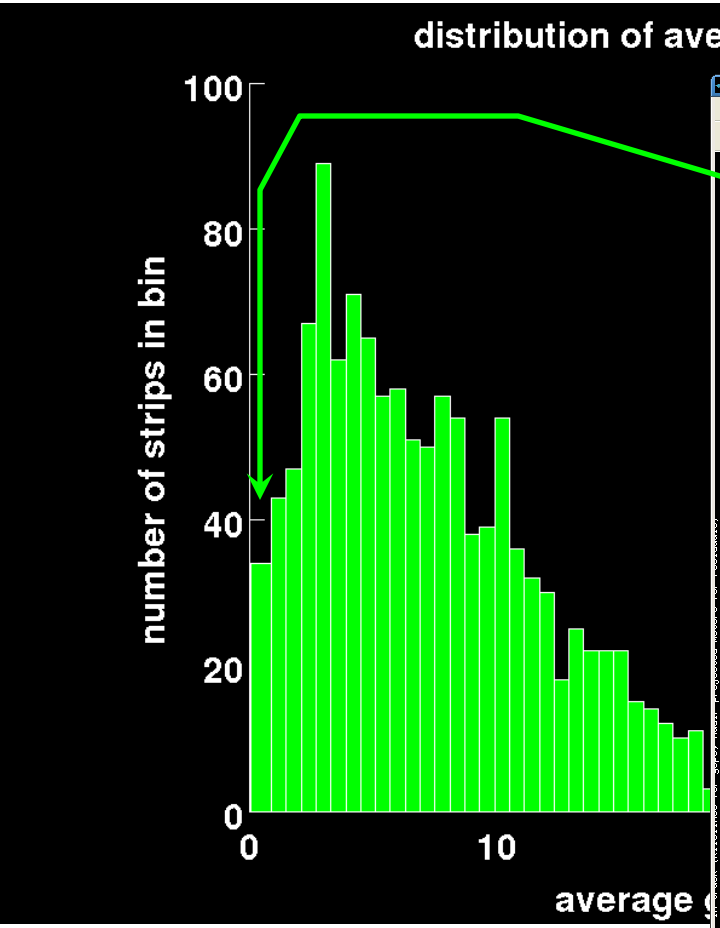


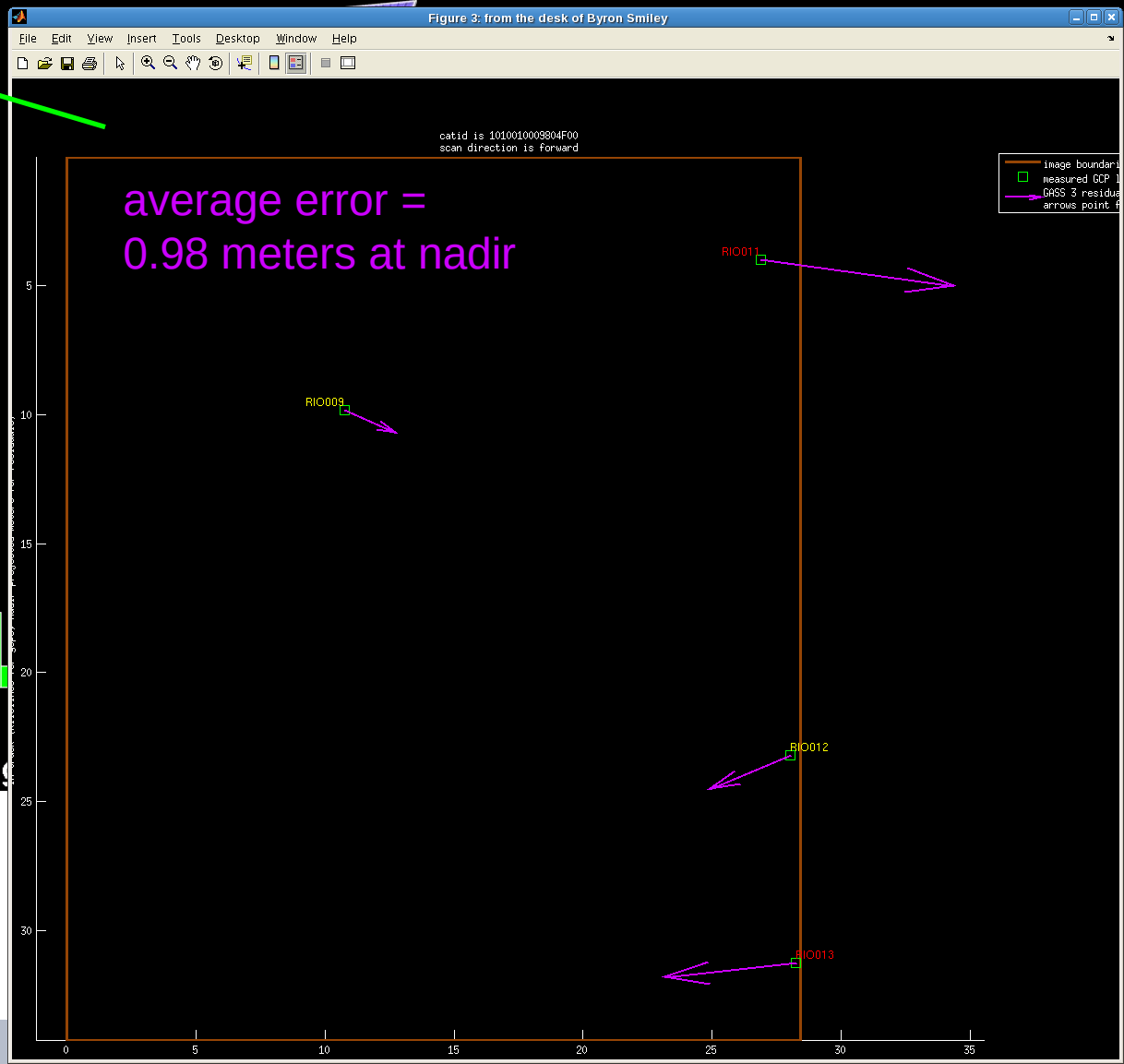
samples from the distribution



QB02 is capable of genuine submeter average error, where all gcps are submeter.

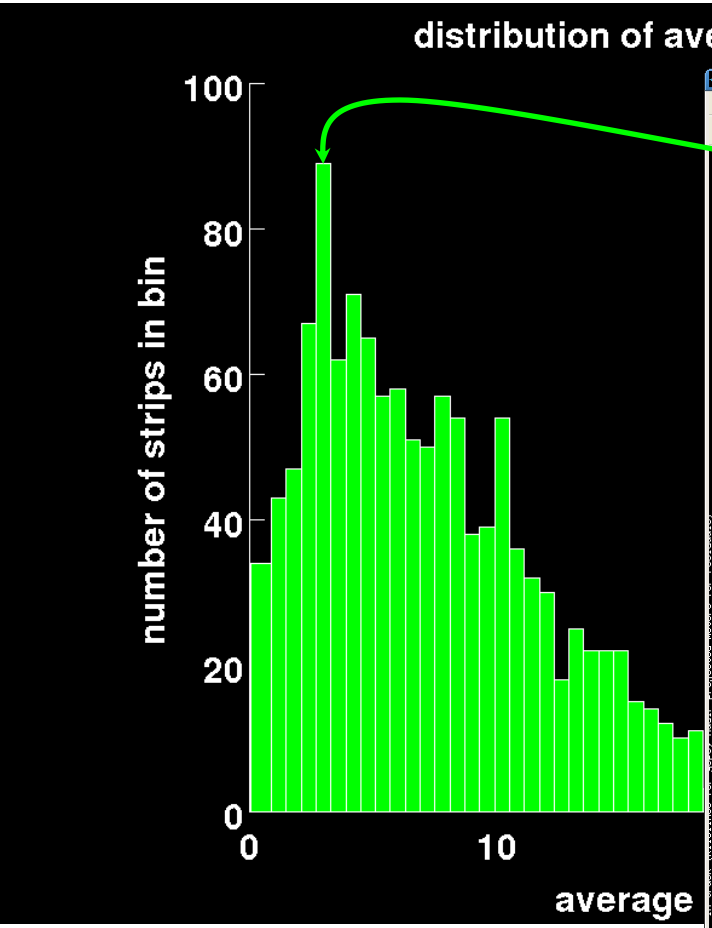
samples from the distribution

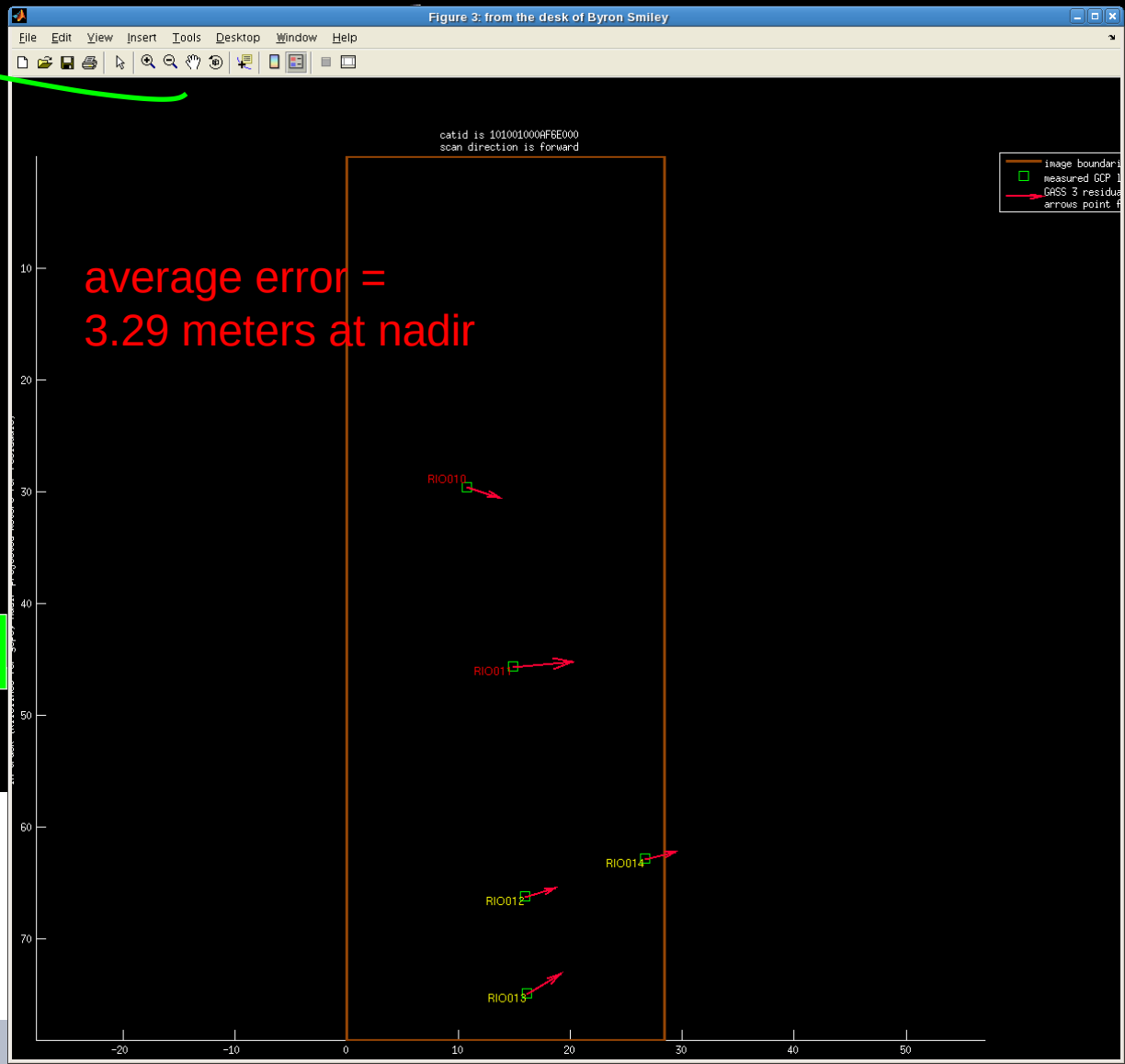




Sometimes, however, QB02 submeter average error comes from vector cancellation instead.

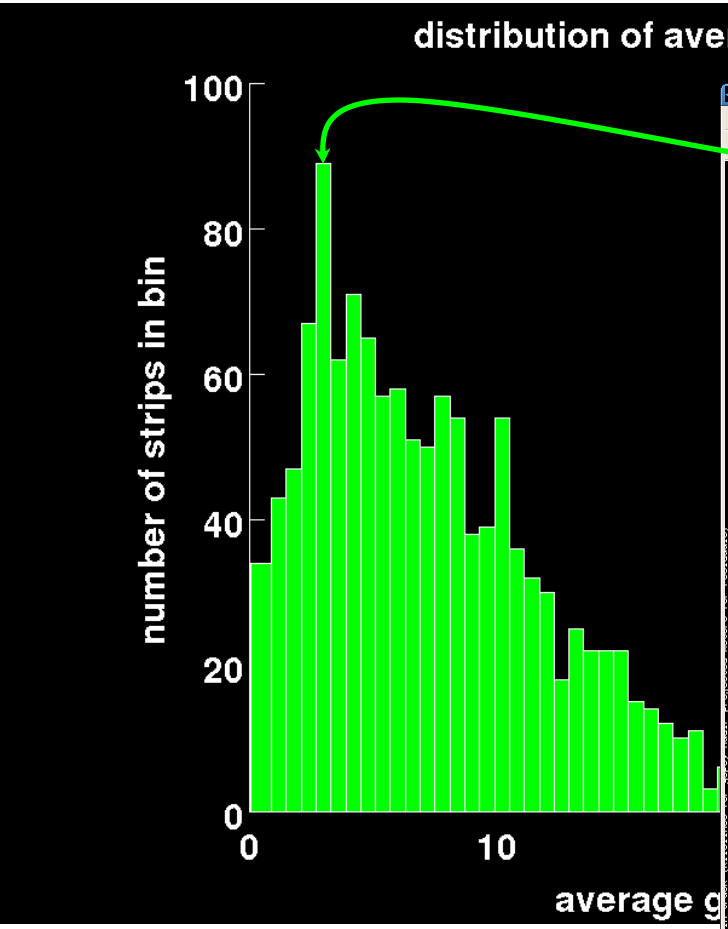
samples from the distribution

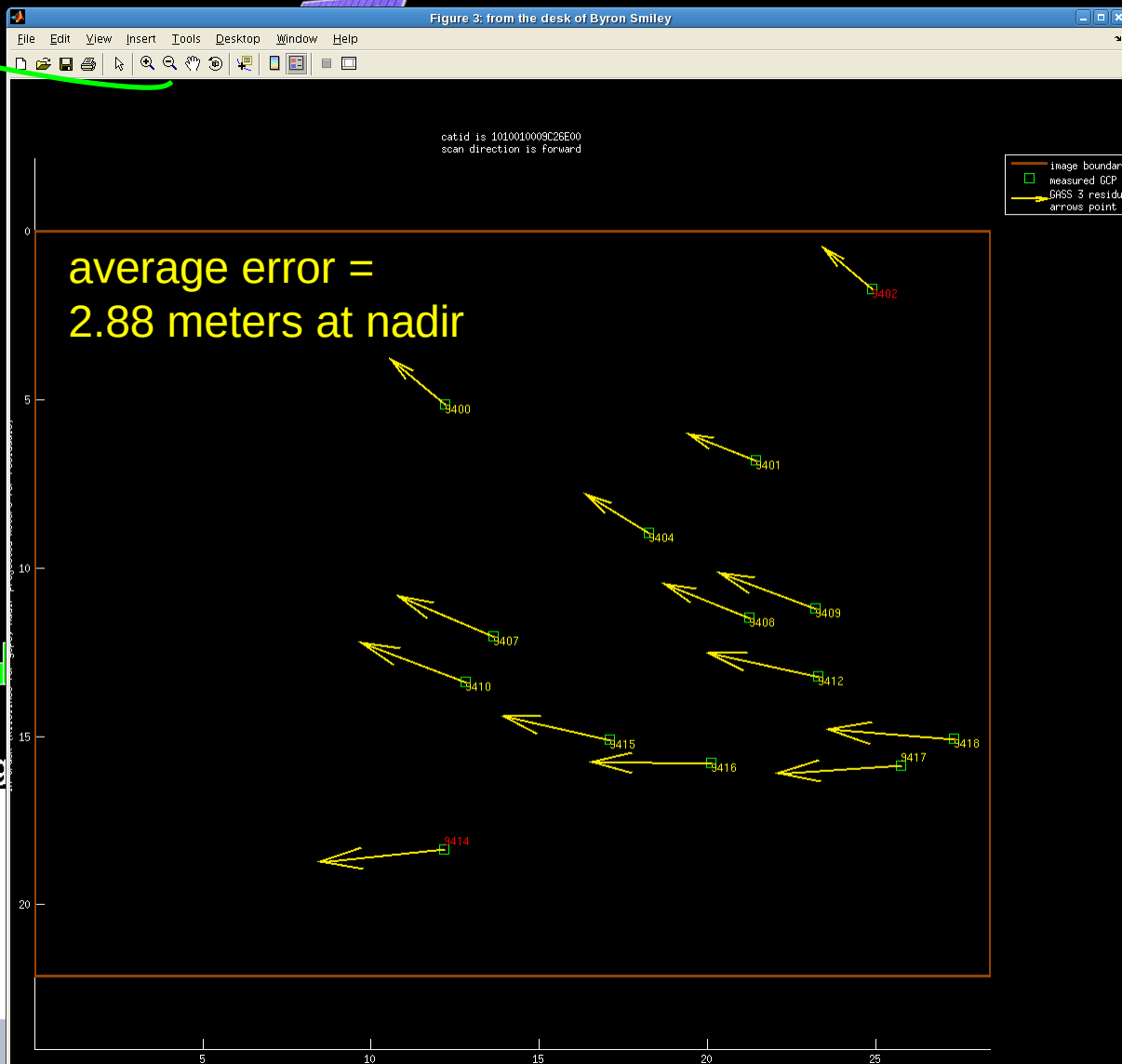




Most probable bin has strips with “shear”, i.e. error changes with line.

samples from the distribution

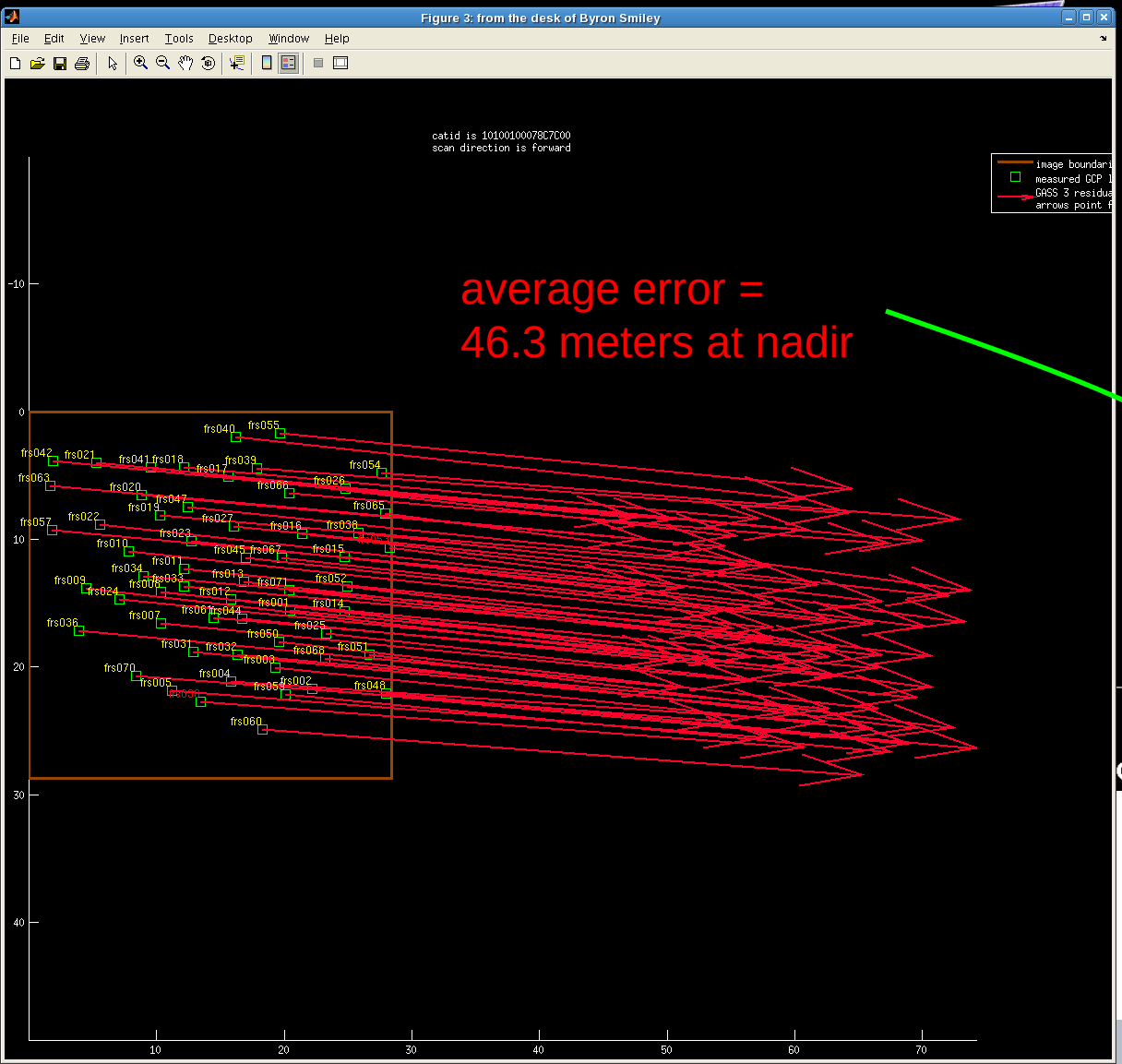


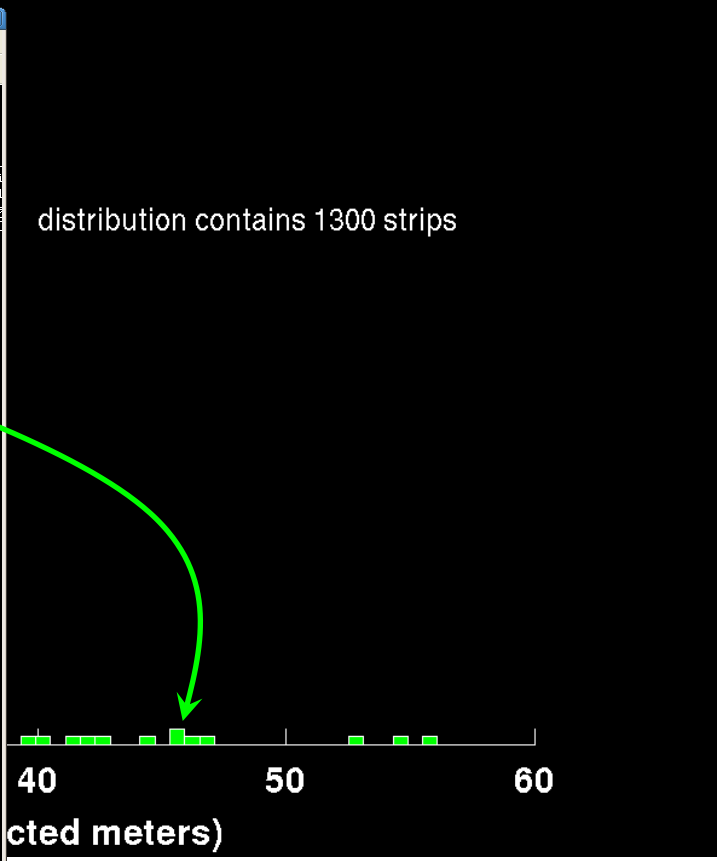


Most probable bin has strips with “shear”, i.e. error changes with line.

samples from the distribution

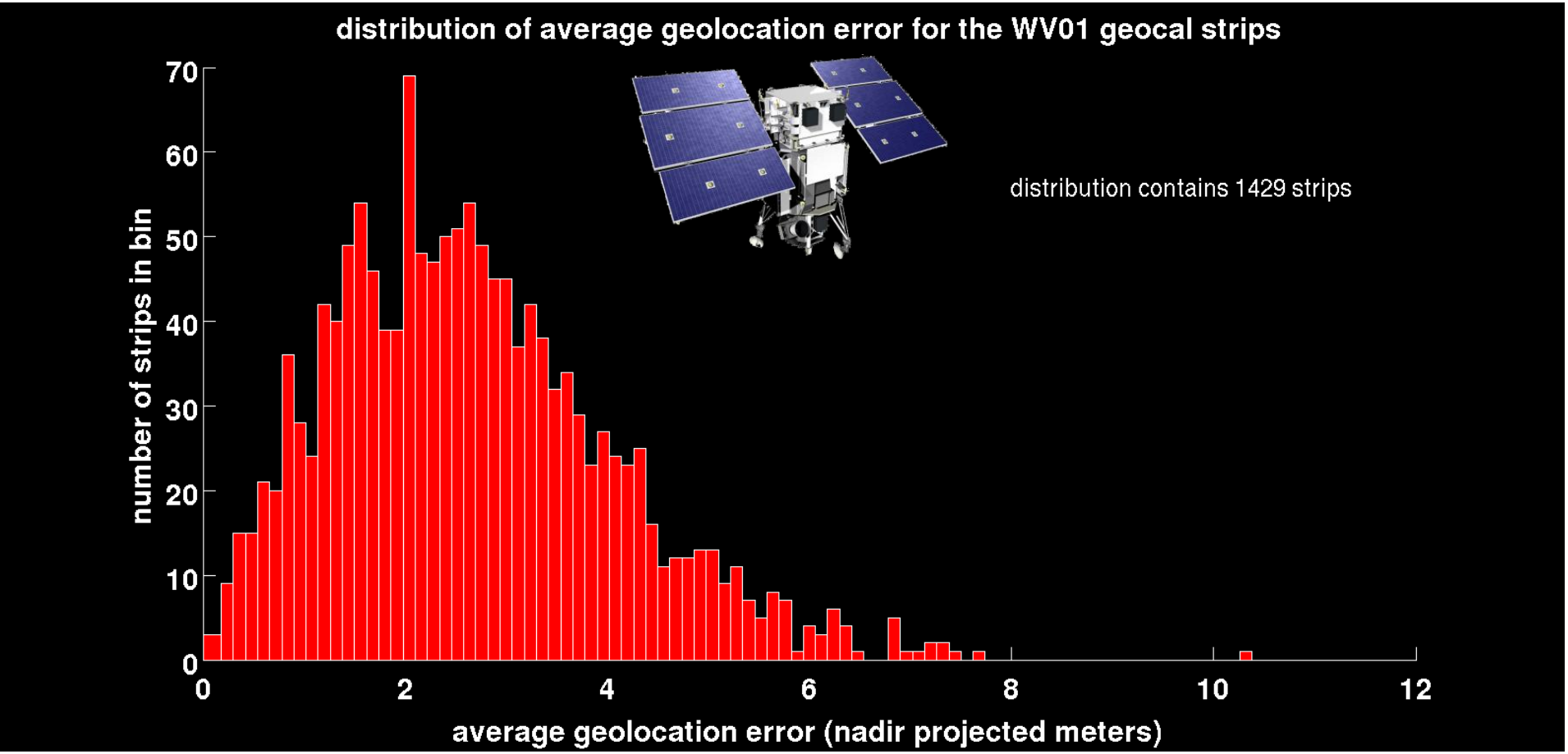
distribution of average geolocation error for the QB02 geocal strips



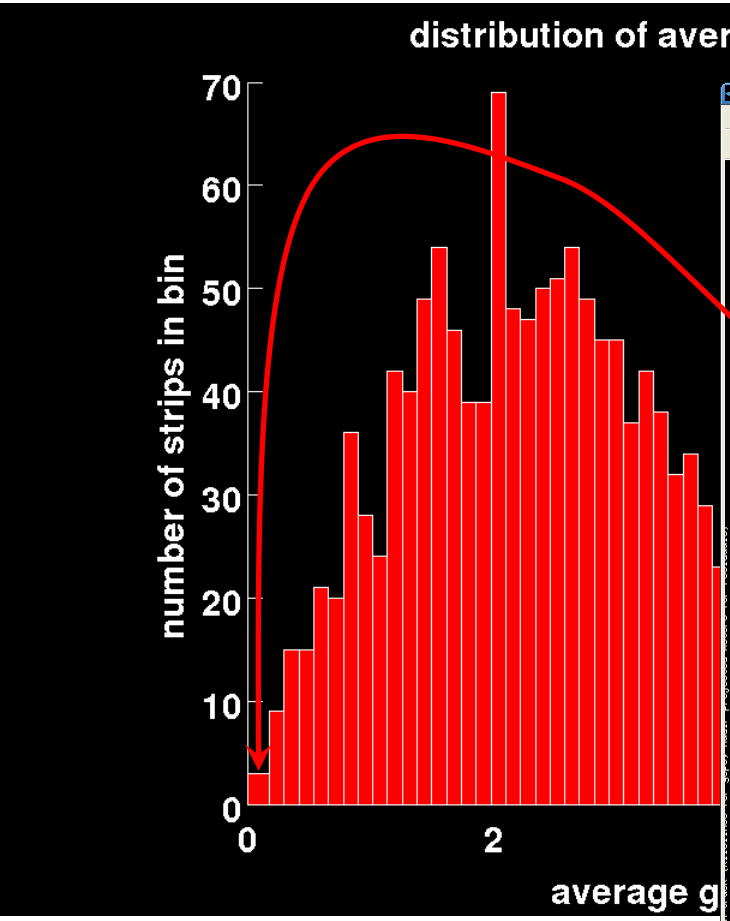


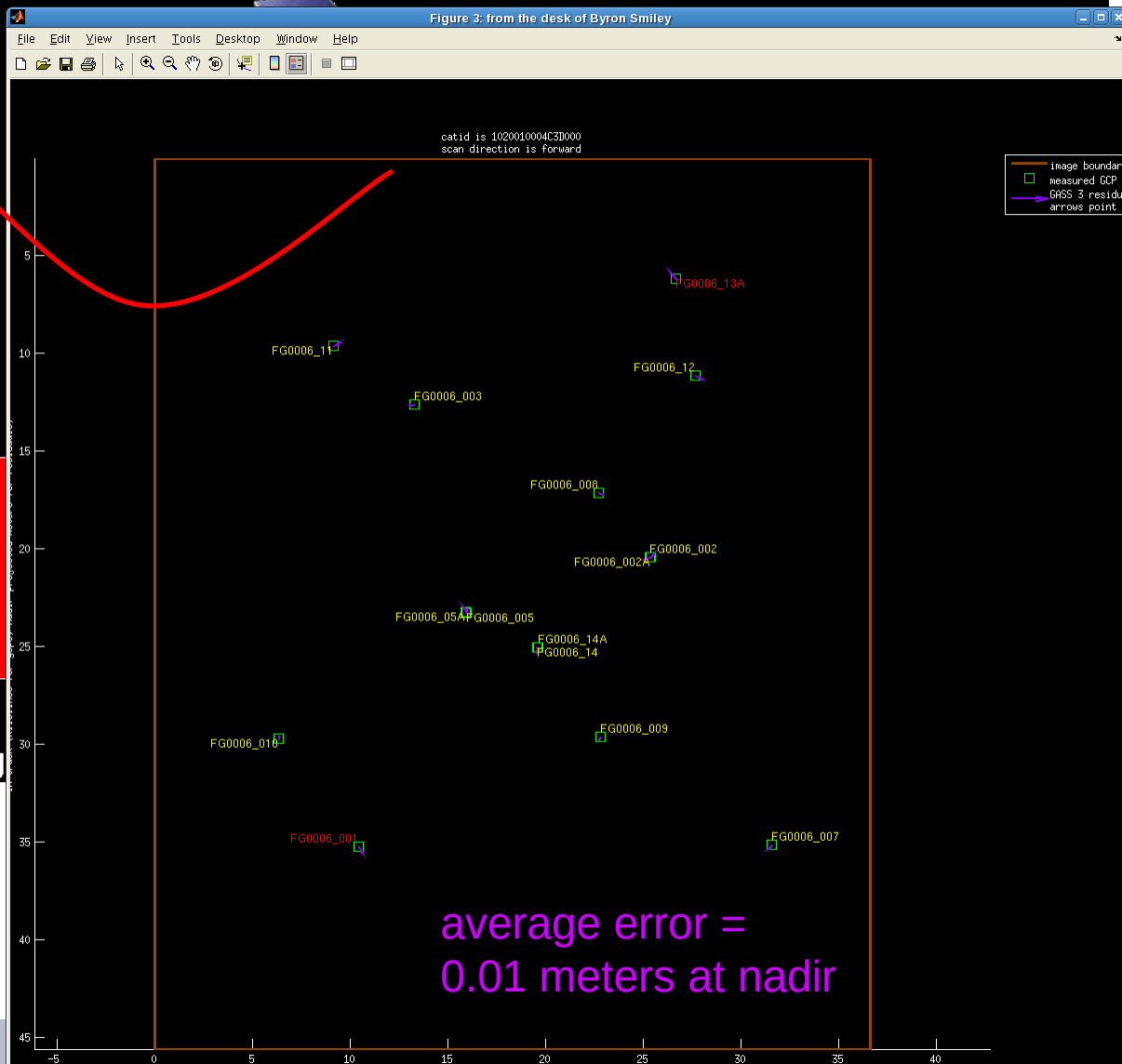
High average error is almost always a large, plain bias.

samples from the distribution



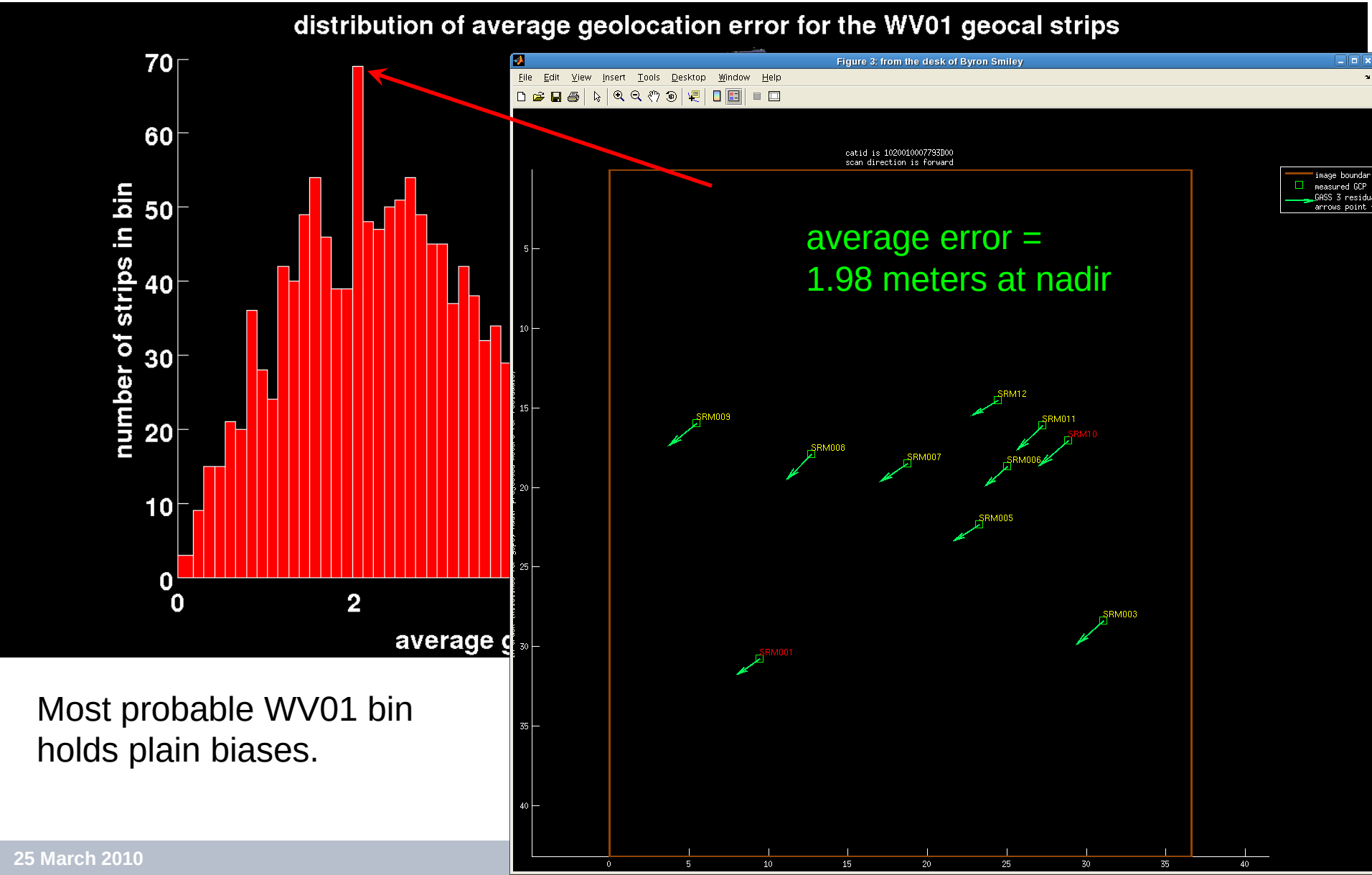
samples from the distribution





Nearly all WV01 low error strips are genuinely low error, no vector cancellation.

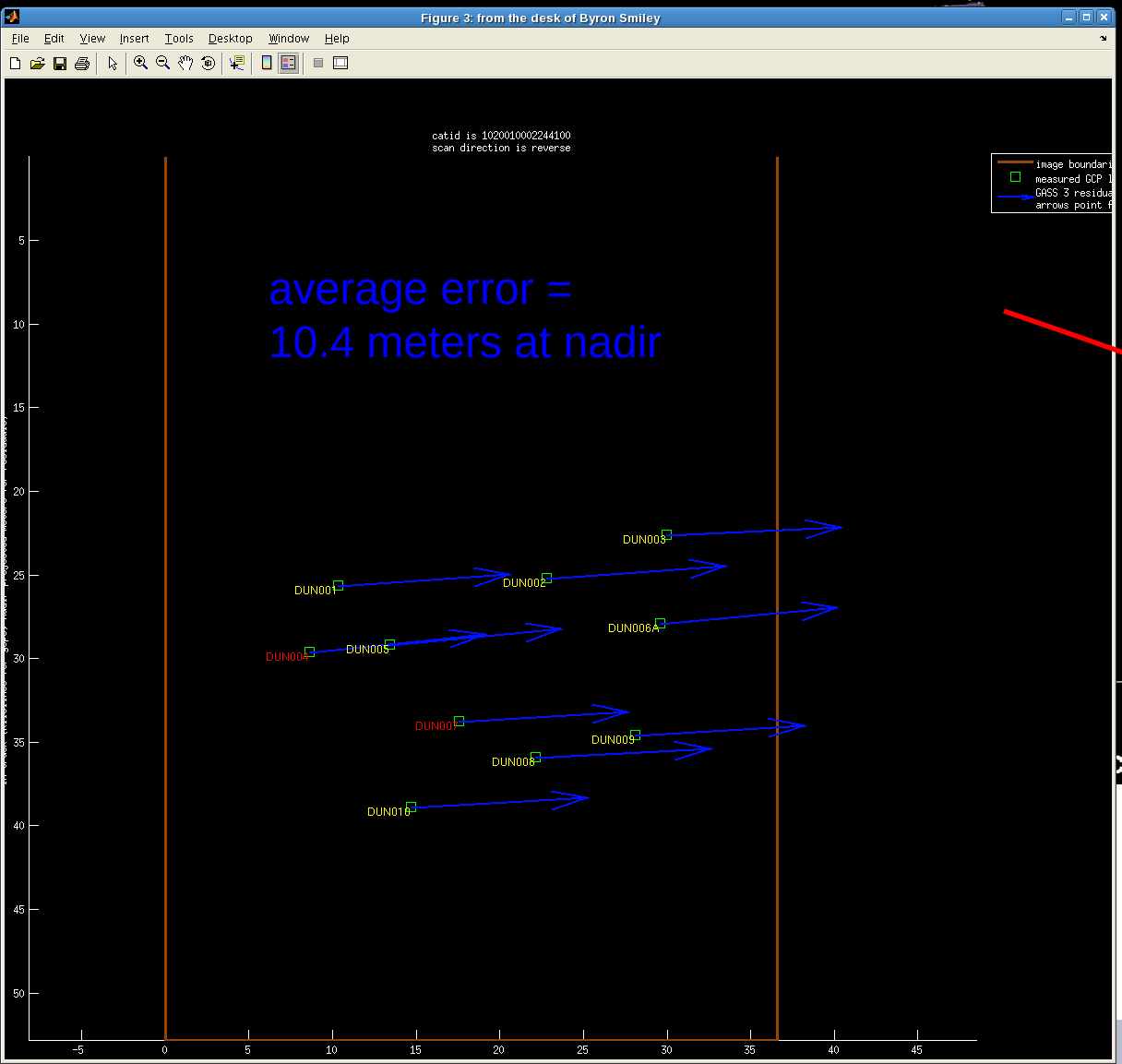
samples from the distribution



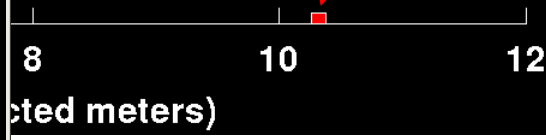
Most probable WV01 bin holds plain biases.

samples from the distribution

distribution of average geolocation error for the WV01 geocal strips

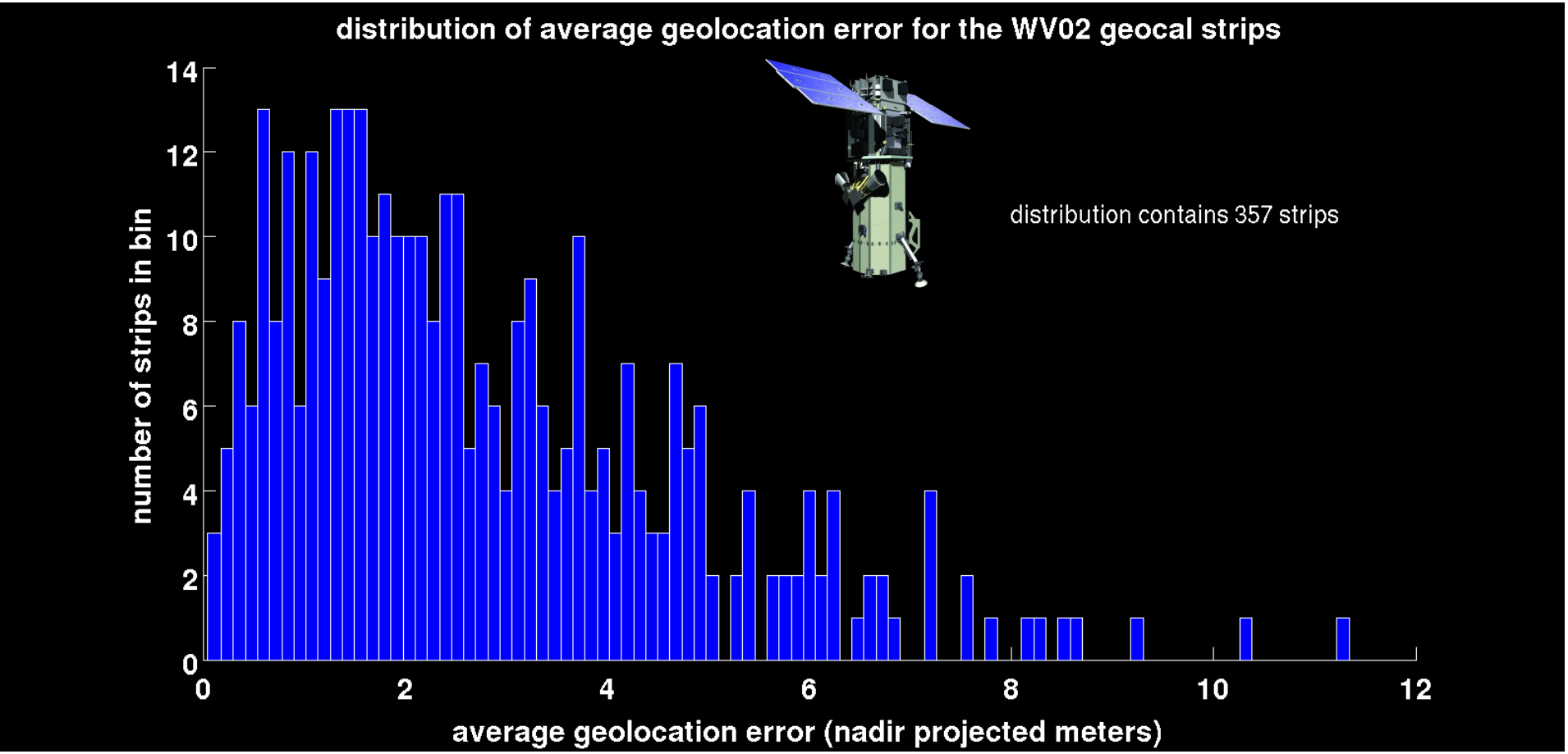


distribution contains 1429 strips

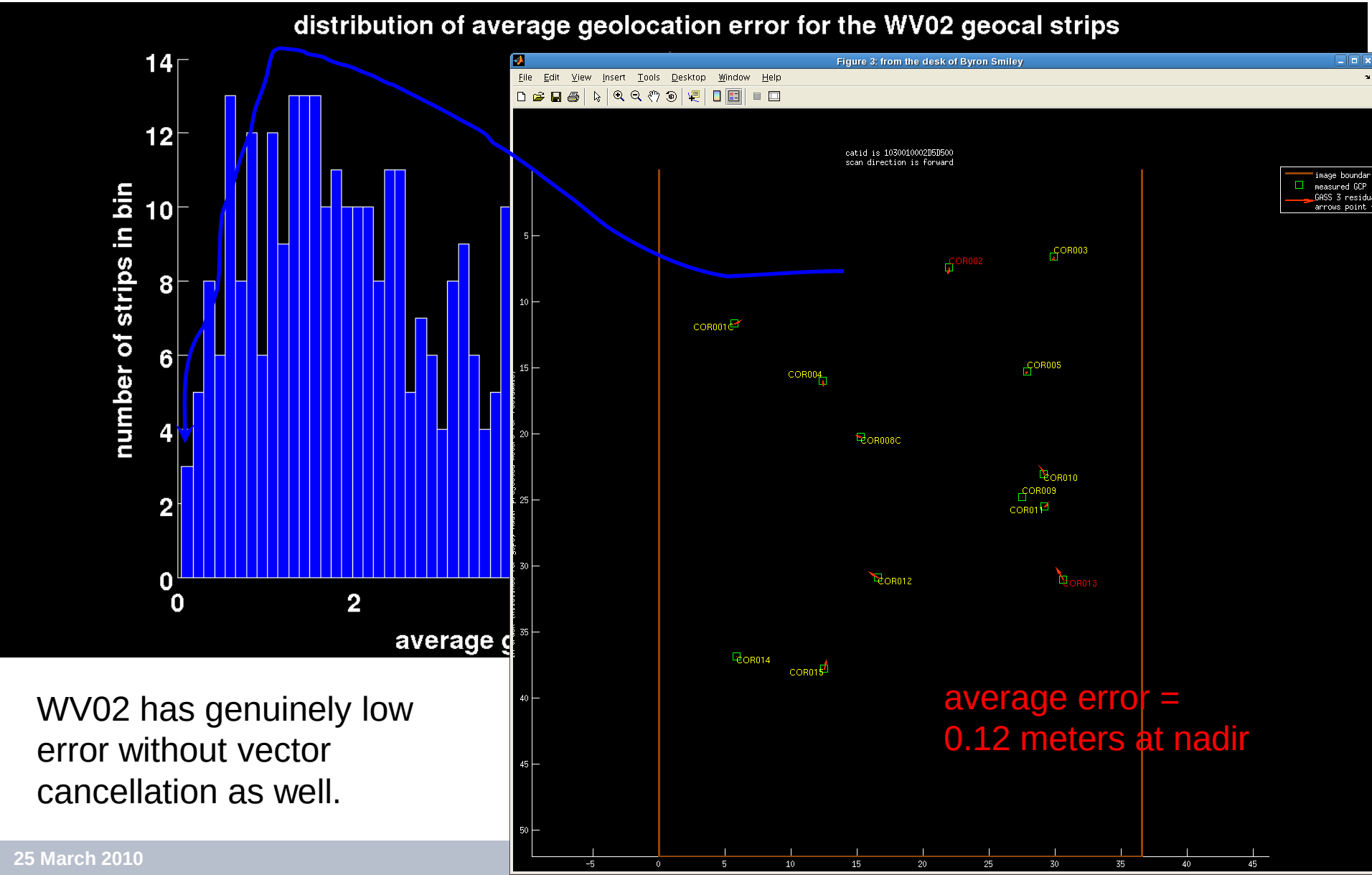


WV01's idea of an outlier is a 10 meter strip.... good!

samples from the distribution

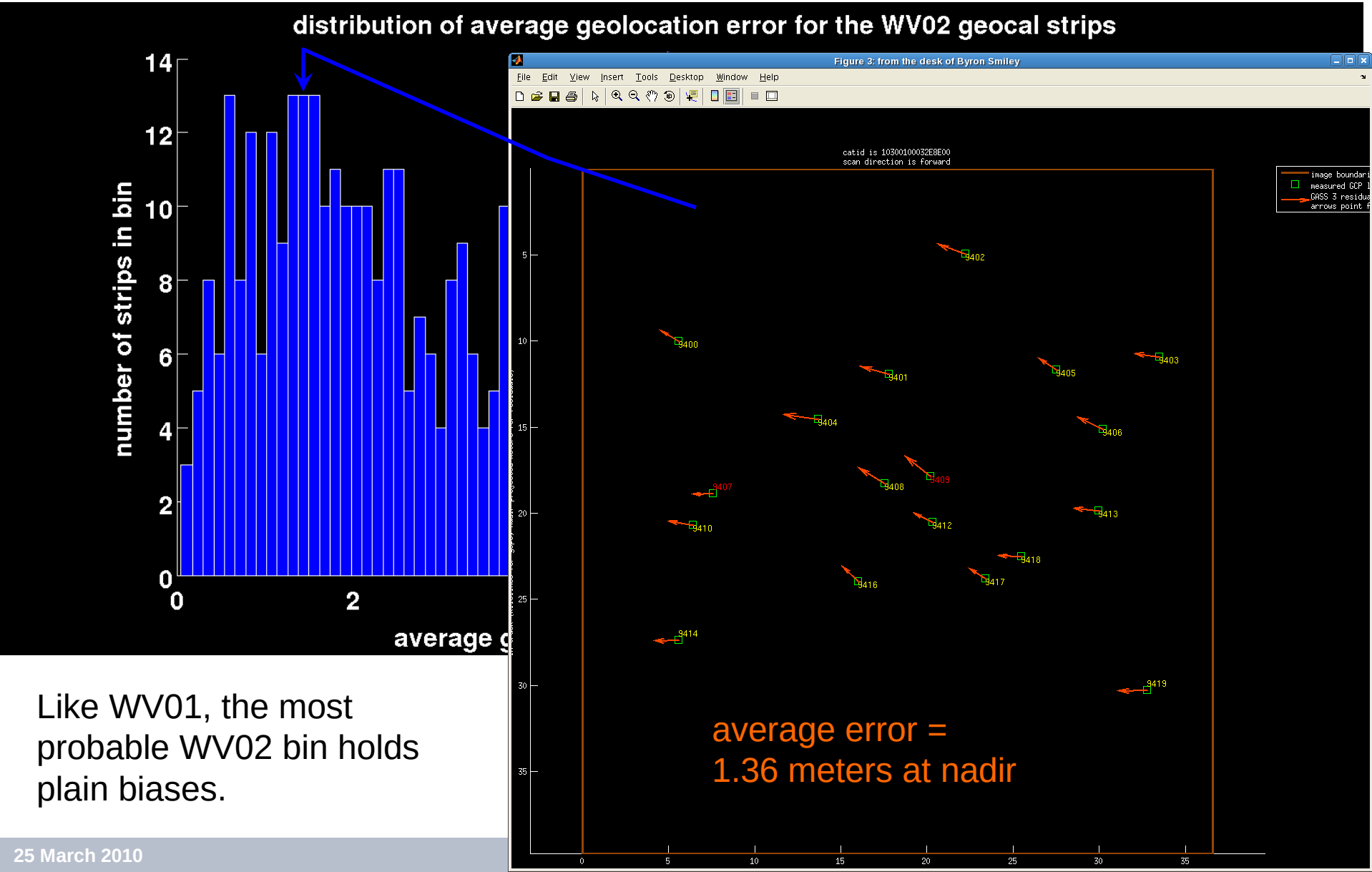


samples from the distribution



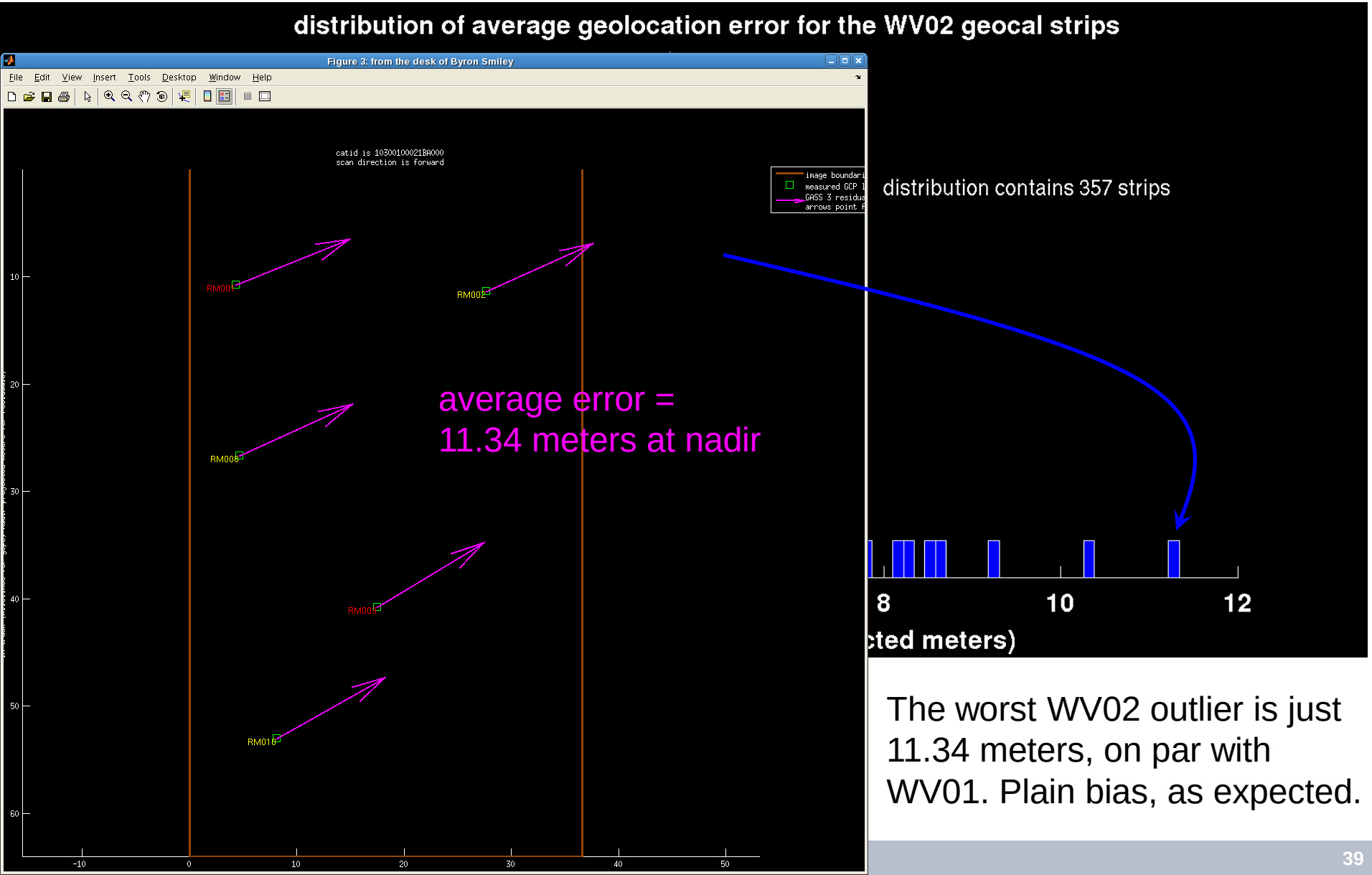
WV02 has genuinely low error without vector cancellation as well.

samples from the distribution



Like WV01, the most probable WV02 bin holds plain biases.

samples from the distribution

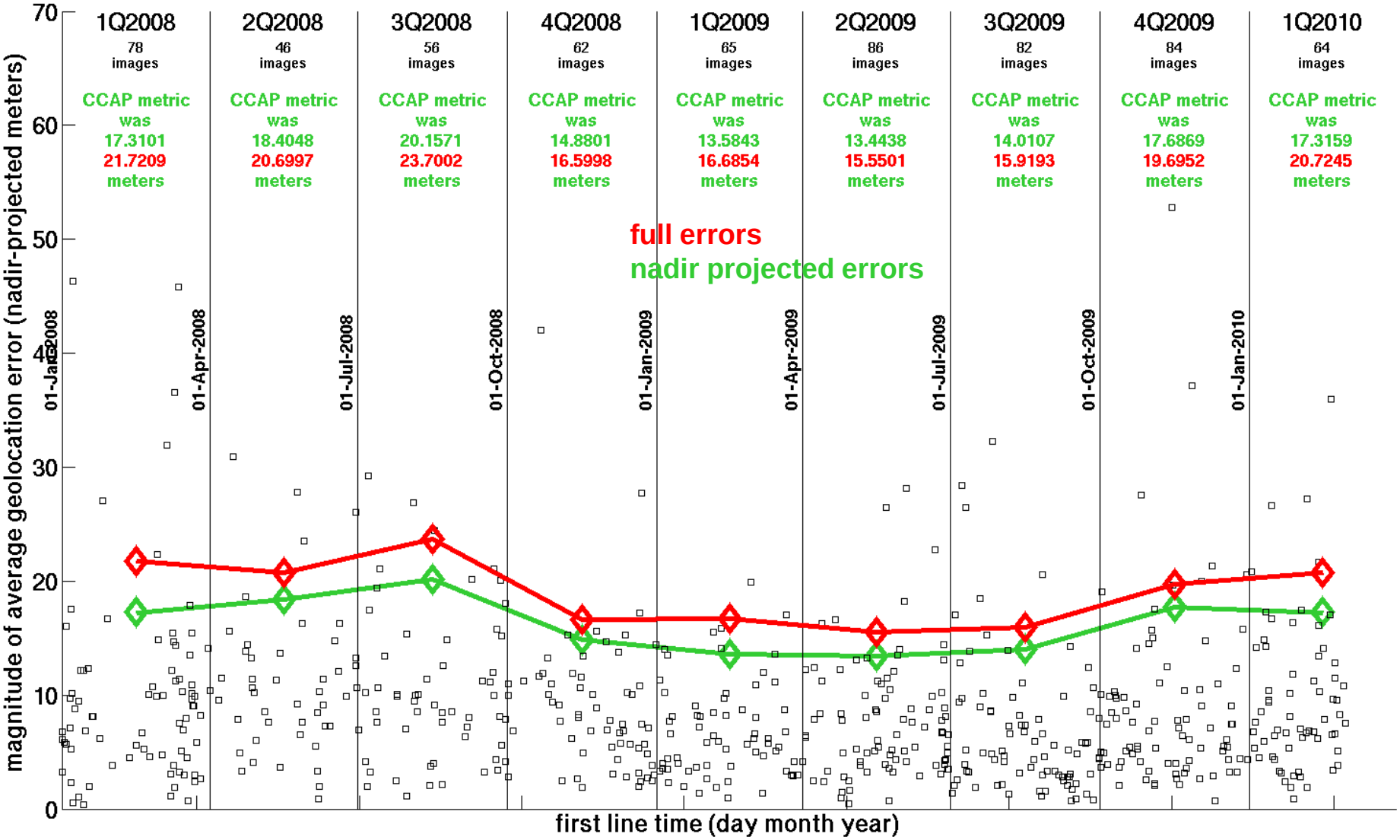


The worst WV02 outlier is just 11.34 meters, on par with WV01. Plain bias, as expected.

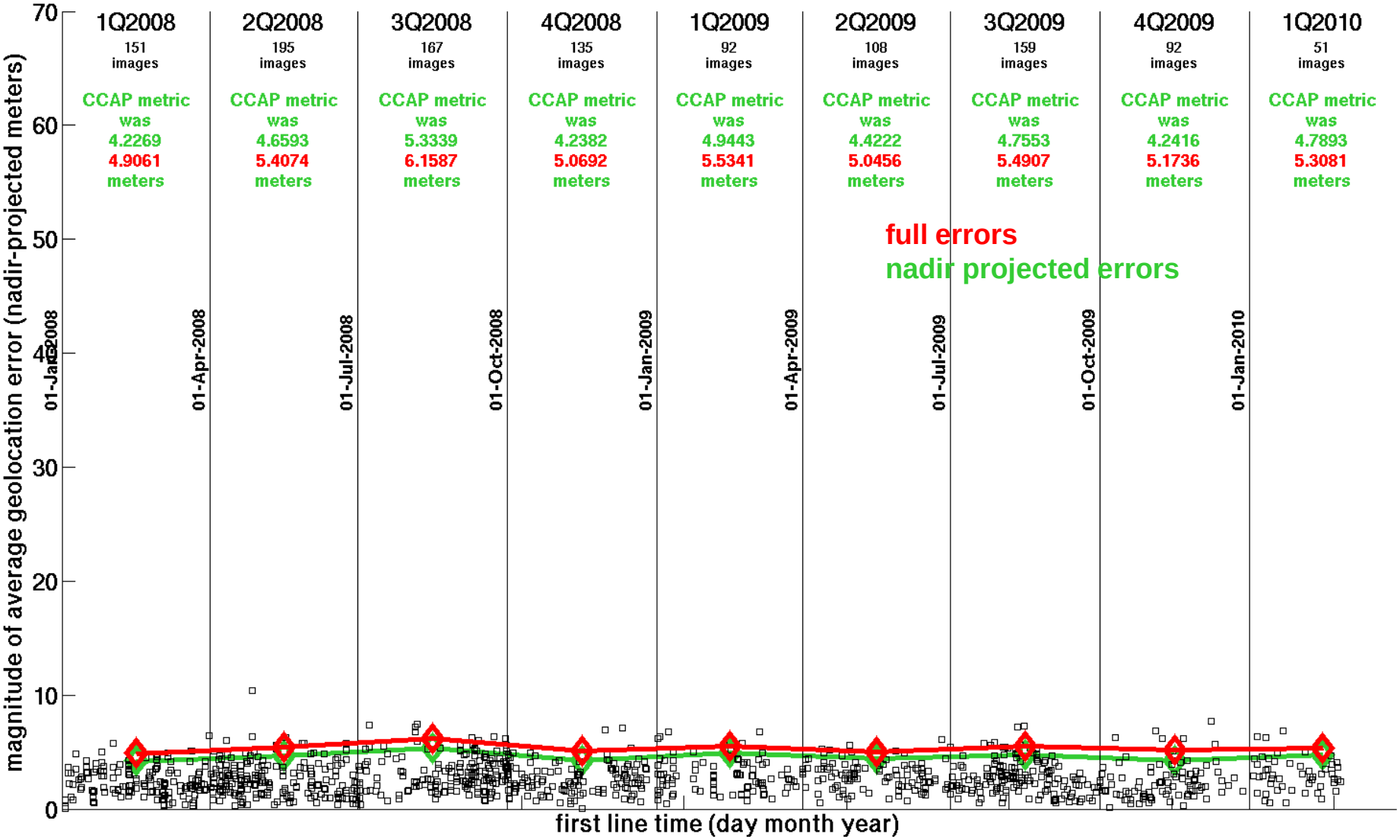
quarterly time plots

for the last 2 years, when available

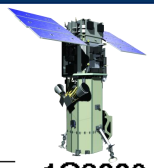
QB02 quarterly CCAP metric for the last 2 years

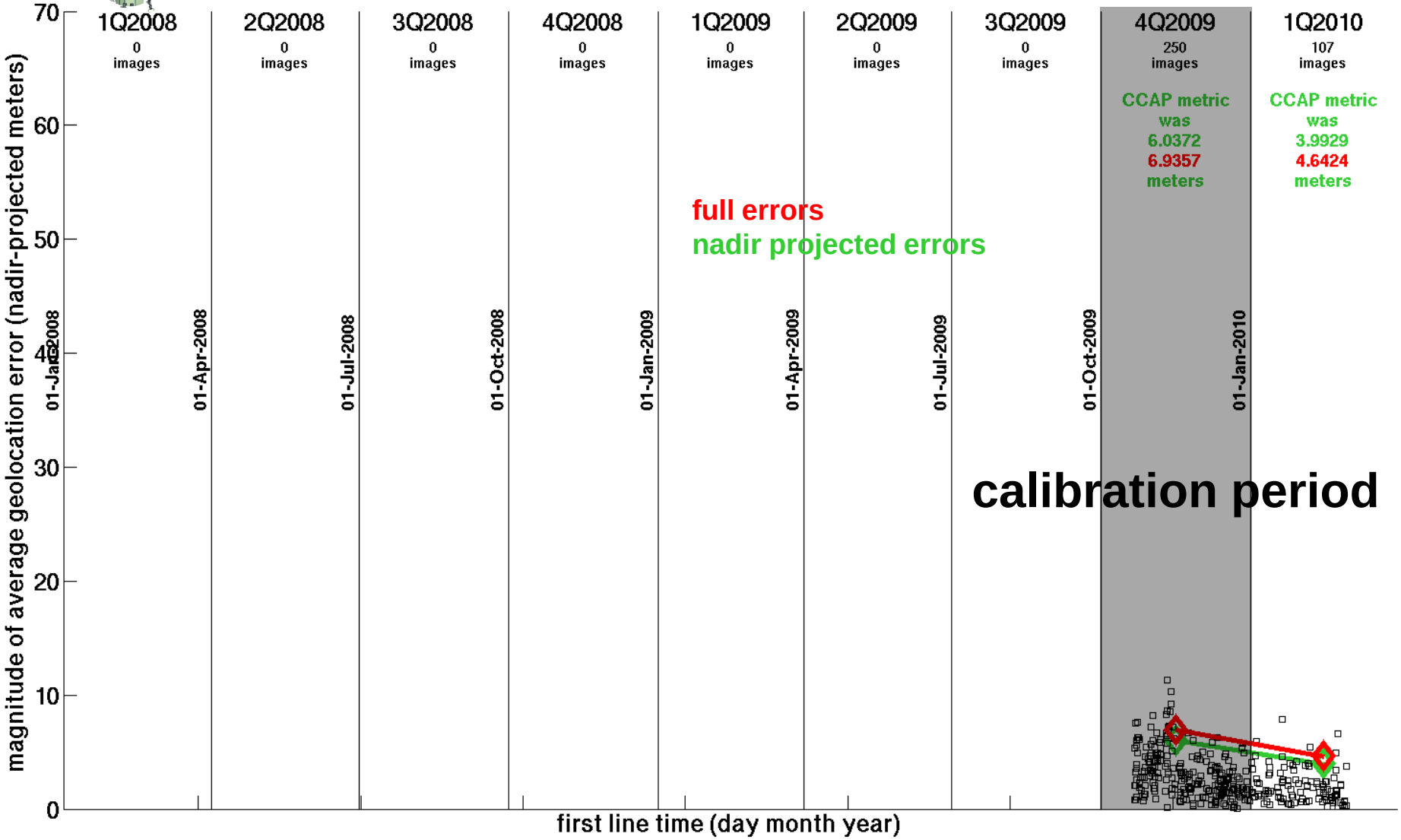


WV01 quarterly CCAP metric for the last 2 years



WV02 quarterly CCAP metric beats WV01 in 1Q2010



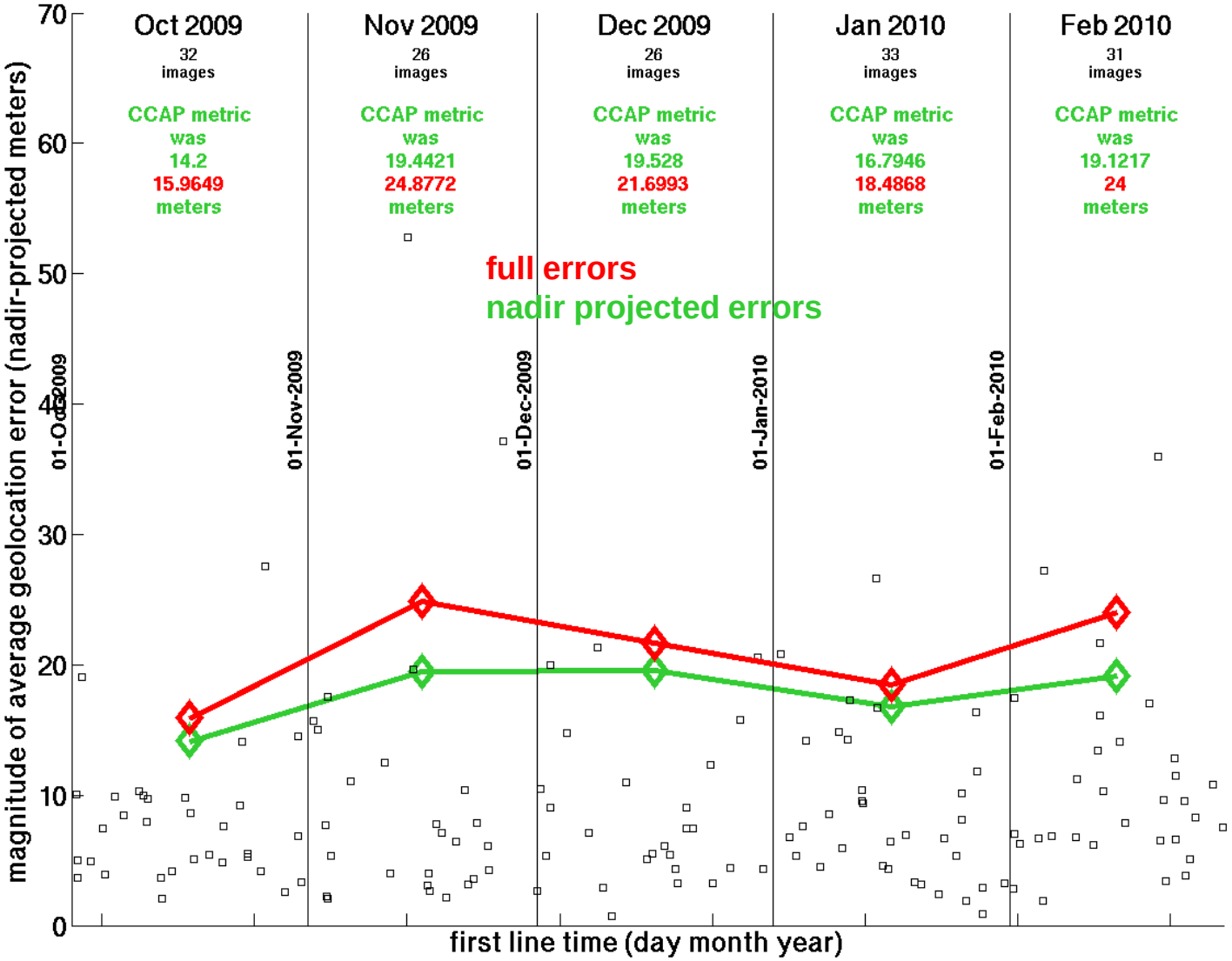


quarterly time plots

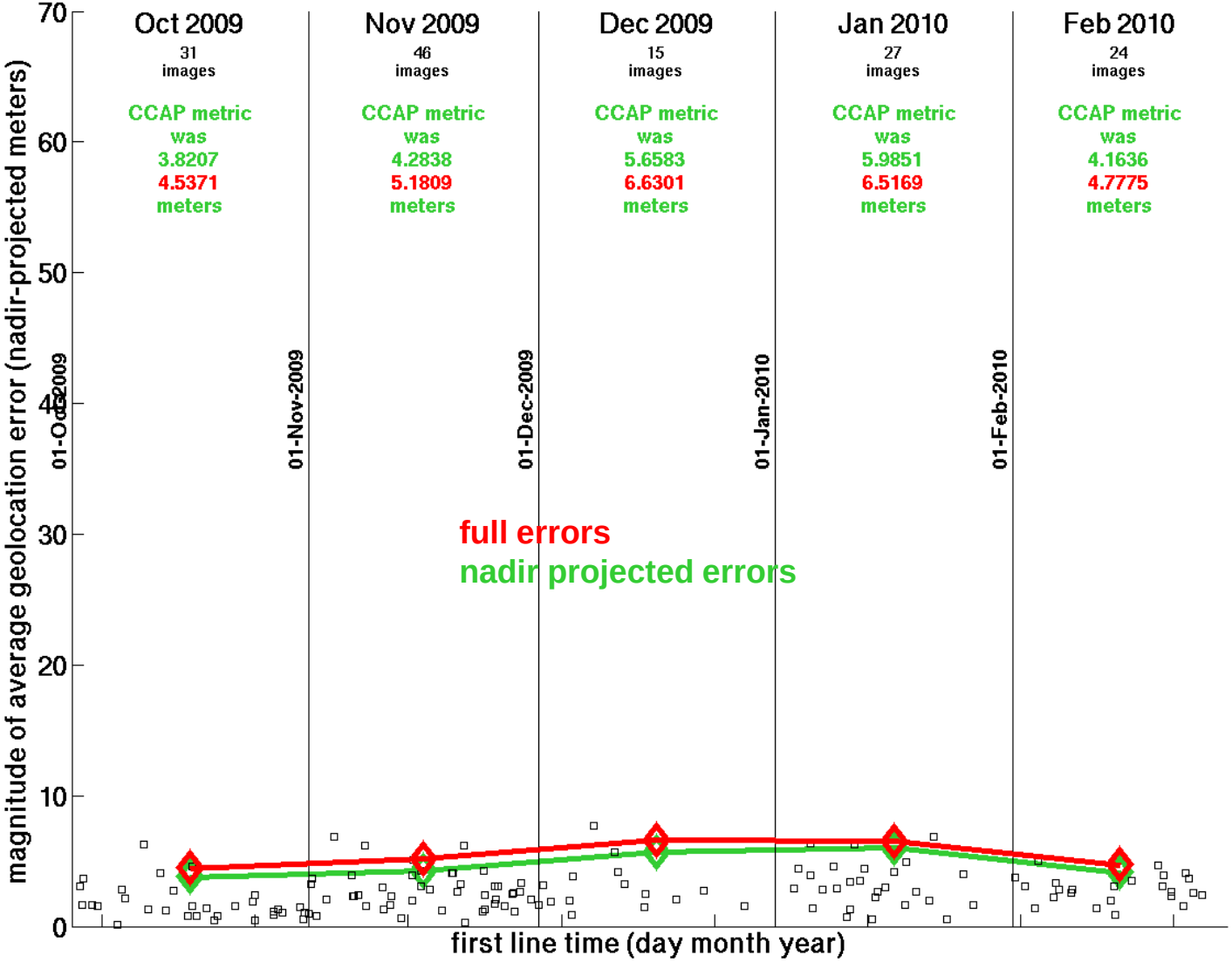
for the last 5 months,

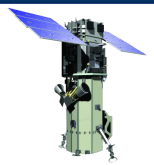
because just 2 quarters for WV02 is unsatisfying

QB02 monthly CCAP metric for the last 5 months

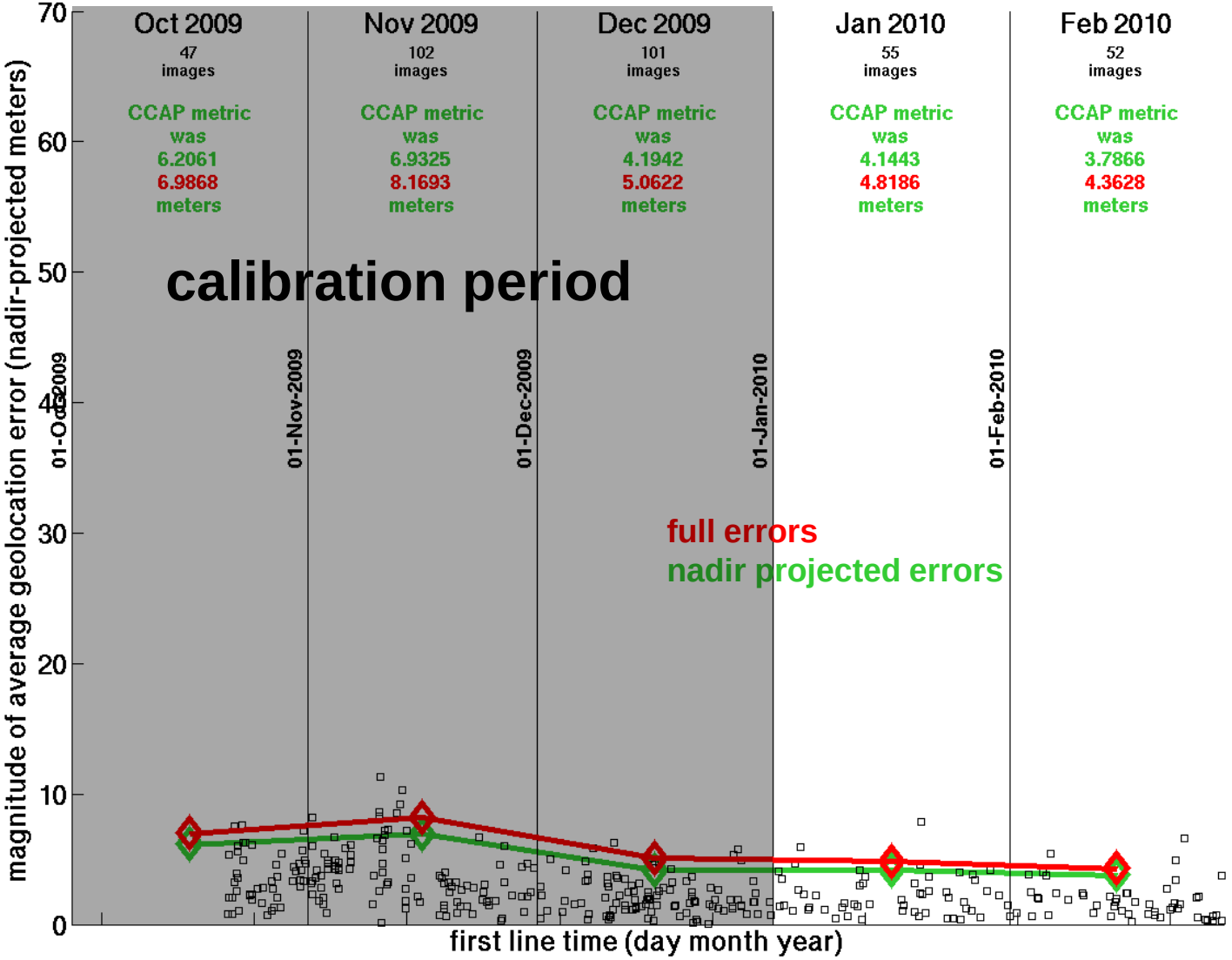


WV01 monthly CCAP metric for the last 5 months





WV02 beats WV01 since Dec 2009



conclusions

- All satellites meet absolute accuracy goals for all past time periods, and especially those shown today:
  - QB02 beat 23 meters at nadir for last 5 months, 2 years
  - WV01 beat 6.5 meters at nadir for last 5 months, 2 years
  - WV02 beat 6.5 meters at nadir for last 5 months

- Each satellite has a characteristic range of CCAP metrics over time, implies stability
  - QB02 fluctuates between 13 and 20 meters at nadir
  - WV01 fluctuates between 4.2 and 5.3 meters at nadir
  - outside of calibration period, WV02 fluctuates between 3.8 and 4.1 meters at nadir, with future performance expected near 4.0 meters