The Modernized National Spatial Reference System (NSRS)

A 2020 update to federal partners

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NOAA's National Geodetic Survey

Outline

- Refresher
- Summary of big changes
- Shift and Drift
- Alpha Products

Refresher

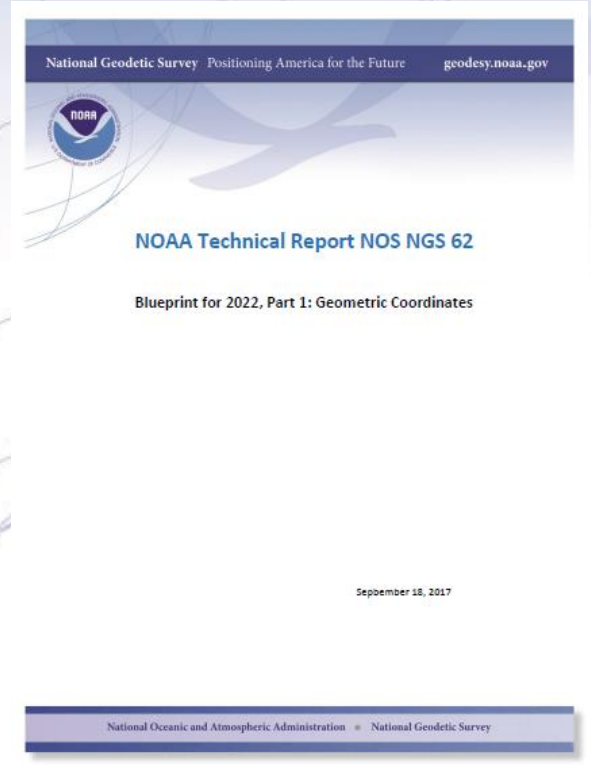
"Modernizing the NSRS" means…

- Replacing NAD 83 — Blueprint for 2022, Part 1
- Replacing NAVD 88 — Blueprint for 2022, Part 2
- Re-inventing Bluebooking
- Improving the Geodetic Toolkit
- Better Surveying Methodologies

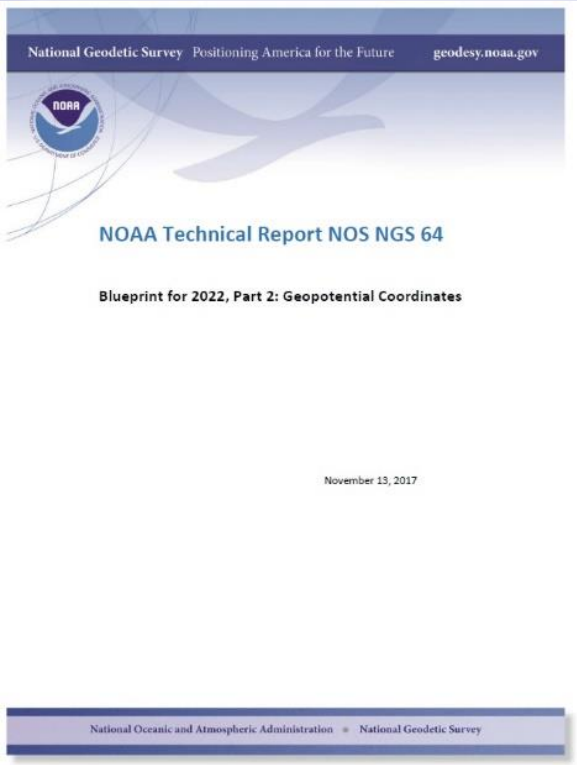
Re-inventing Bluebooking, Improving the Geodetic Toolkit, Better Surveying Methodologies — Blueprint for 2022, Part 3

Modernizing the NSRS

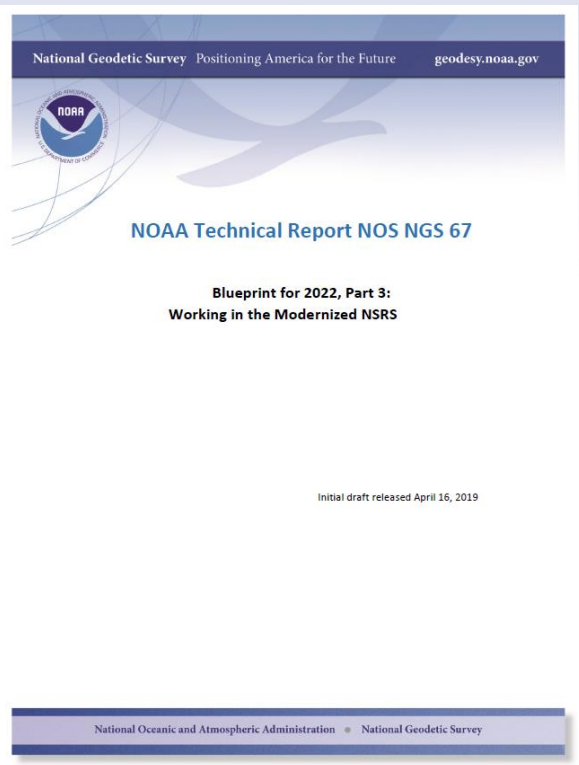
The "blueprint" documents: Your best source for information



Geometric:
Sep 2017
NOAA TR NOS NGS 62
32 pages



Geopotential:
Nov 2017
NOAA TR NOS NGS 64
41 pages



Working in the modernized NSRS:
April 2019
NOAA TR NOS NGS 67
77 pages

Summary list of "big changes"

(warning…lots of words on the next four slides)

Some of the biggest changes (1)

The old	The new

Some of the biggest changes (2)

The old	The new

Some of the biggest changes (3)

The old	The new

Some of the biggest changes (4)

The old	The new

Replacing NAD 83

The Old:

NAD 83(2011)

NAD 83(PA11)

NAD 83(MA11)

The New:

The North American Terrestrial Reference Frame of 2022 (NATRF2022)

The Caribbean Terrestrial Reference Frame of 2022 (CATRF2022)

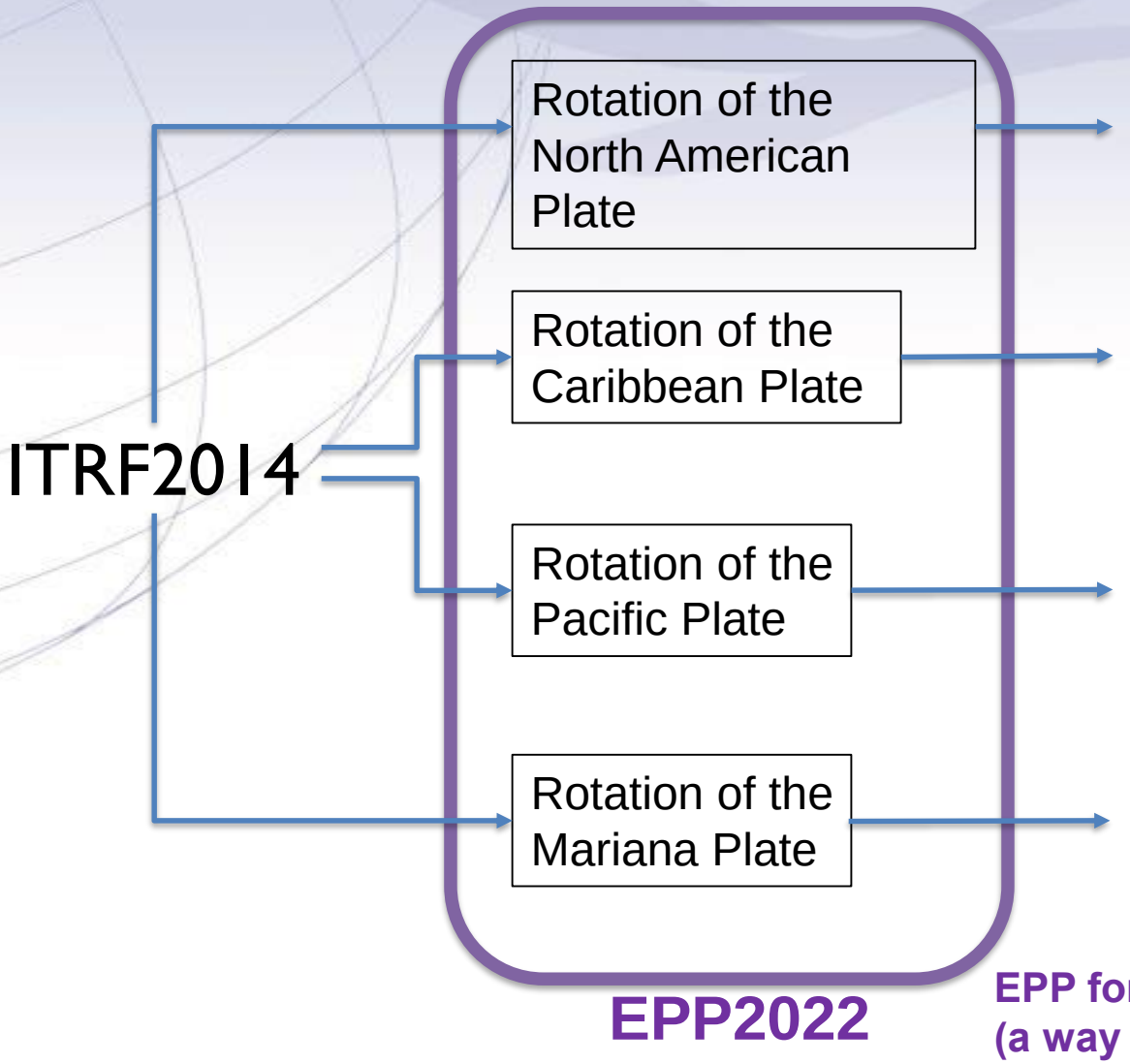
The Pacific Terrestrial Reference Frame of 2022 (PATRF2022)

The Mariana Terrestrial Reference Frame of 2022 (MATRF2022)

Replacing NAVD 88

	The Old:	The New:
Orthometric Heights	NAVD 88	The North American-Pacific ***Geopotential Datum*** of 2022 (NAPGD2022)
Normal Orthometric Heights	PRVD 02	
	VIVD09	
	ASVD02	Will include:
	NMVD03	– GEOID2022
	GUVD04	– DEFLEC2022
		– GRAV2022
Dynamic Heights	IGLD 85	– DEM2022
Gravity	IGSN71	– More
Geoid Undulations	GEOID12B	
Deflections of the Vertical	DEFLEC12B	

The preeminence of ITRF



The North American Terrestrial Reference Frame of 2022 (NATRF2022)

The Caribbean Terrestrial Reference Frame of 2022 (CATRF2022)

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The Mariana Terrestrial Reference Frame of 2022 (MATRF2022)

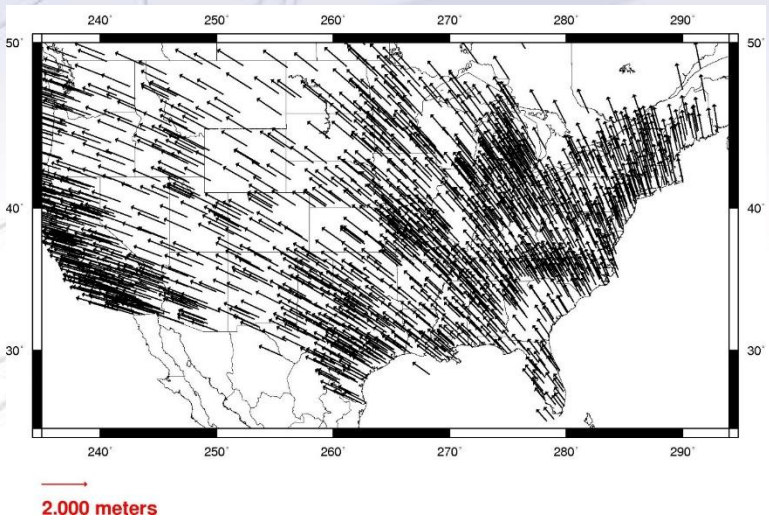
EPP for "Euler Pole Parameters"
(a way of describing a plate's rotation)

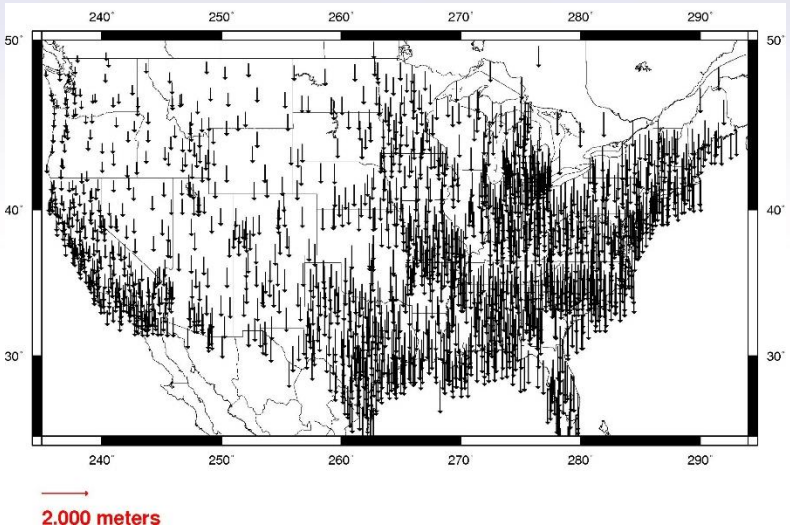
Shift and Drift

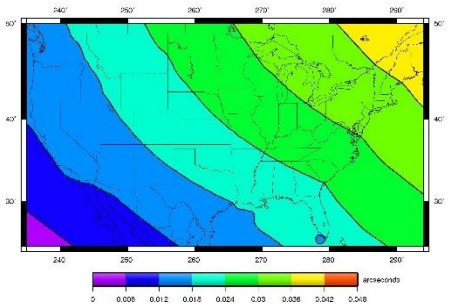
Shift

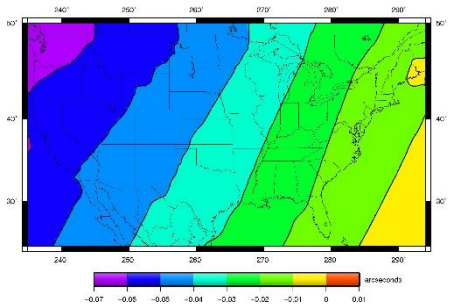
- One of the two major changes you'll see in 2022 is a ***shift*** in coordinates
  - Latitude, Longitude, Ellipsoid Height: -2 to +4 meters
    - Non-geocentricity of NAD 83
  - Orthometric Height: -0.5 to +2.0 meters
    - Bias and tilt in NAVD 88
  - Other shifts will occur in non-CONUS, non-Alaska regions of the USA
  - There will be outliers!
    - "Old" unsurveyed points might be off by meters if they've moved!

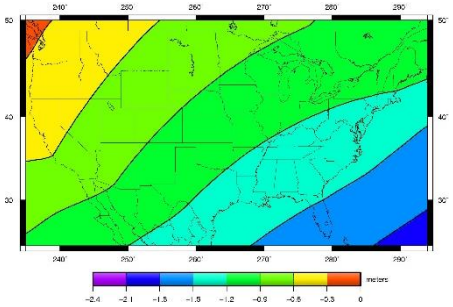
NAD 83(2011) epoch 2010.0 to NATRF2022 epoch 2020.00 (estimate)



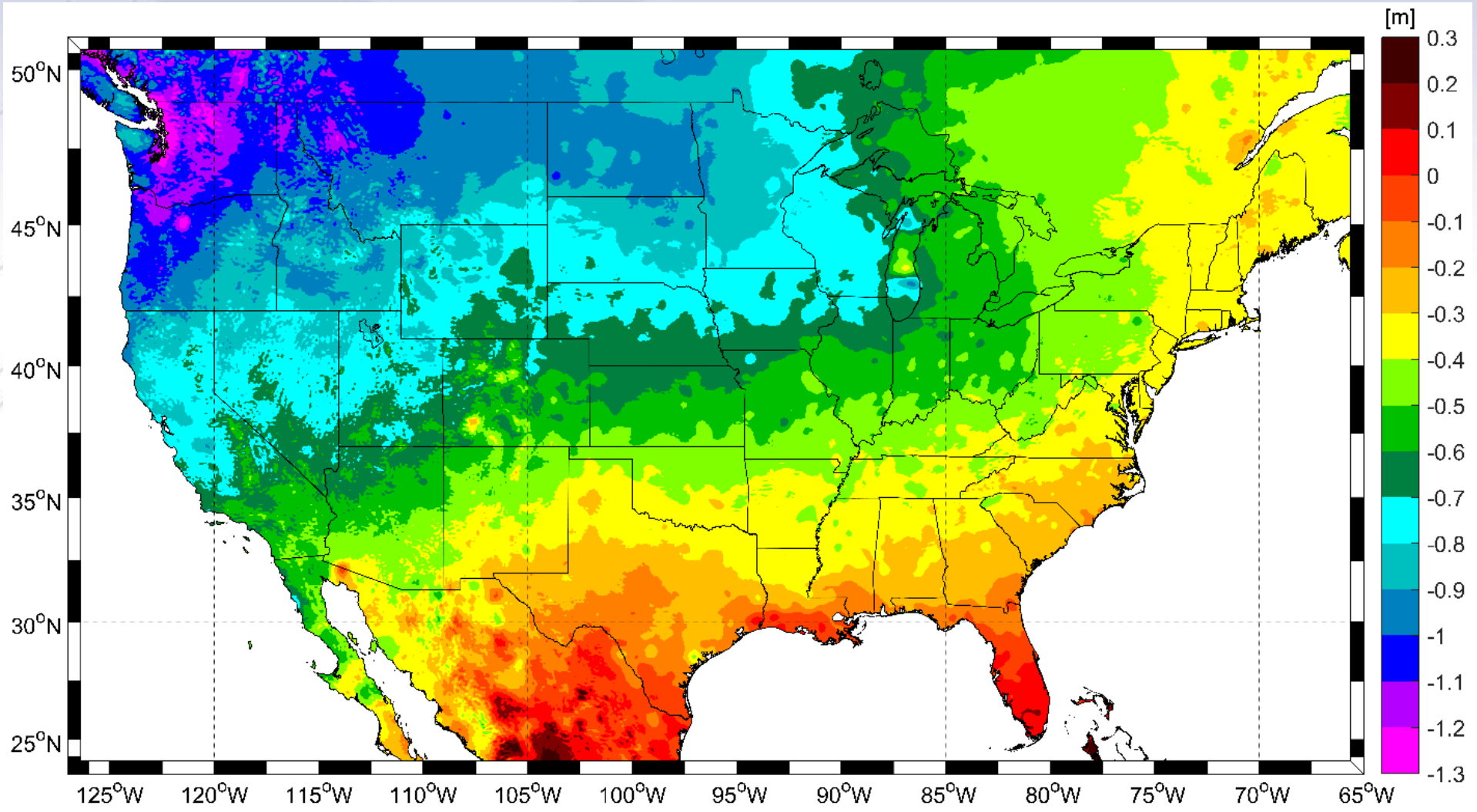








NAVD 88 to NAPGD2022 epoch 2020.00 (estimate)



Drift

- The second major change you'll see in 2022 is a ***drift*** in coordinates
  - Everything in the world moves
  - Coordinates will be associated with the actual date when the data was taken!

The wrong question, circa 2022:

"What is the latitude of that point?"

The right question, circa 2022:

"What is the latitude of that point, on some specific date?"

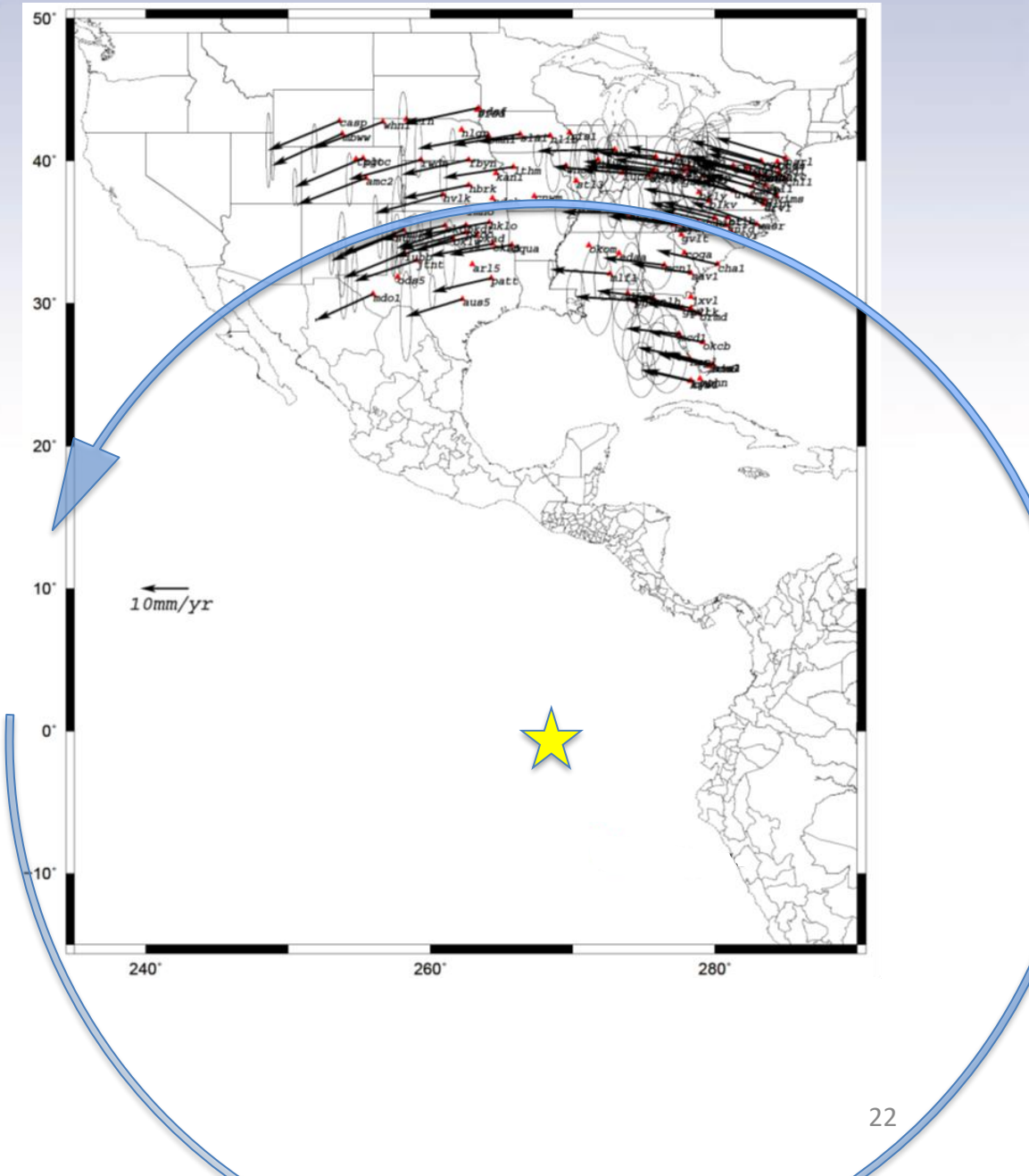
Drift

- The second major change you'll see in 2022 is a ***drift*** in coordinates
  - Everything in the world moves
  - Coordinates will be associated with the actual date when the data was taken!
  - Velocities at all marks can be estimated
    - Rarely, but most accurately: When a point is surveyed multiple times across years.
    - More commonly, but less accurately: Using a new tool, called the Intra-Frame Velocity Model (IFVM2022)

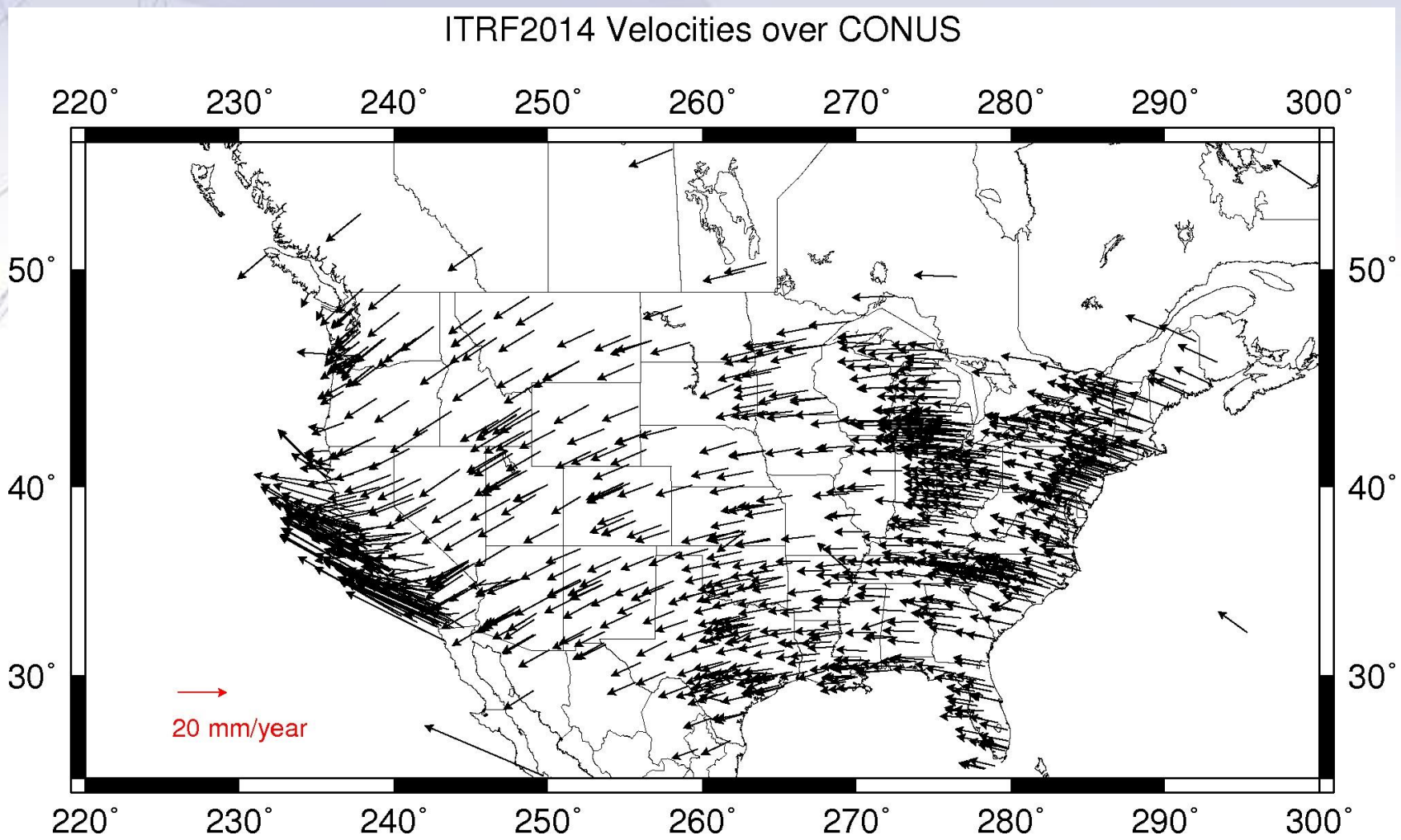
Drift

- Two things will mitigate the pain of time-dependent coordinates:
  - "Plate Fixed" frames
  - "Reference Epoch" coordinates

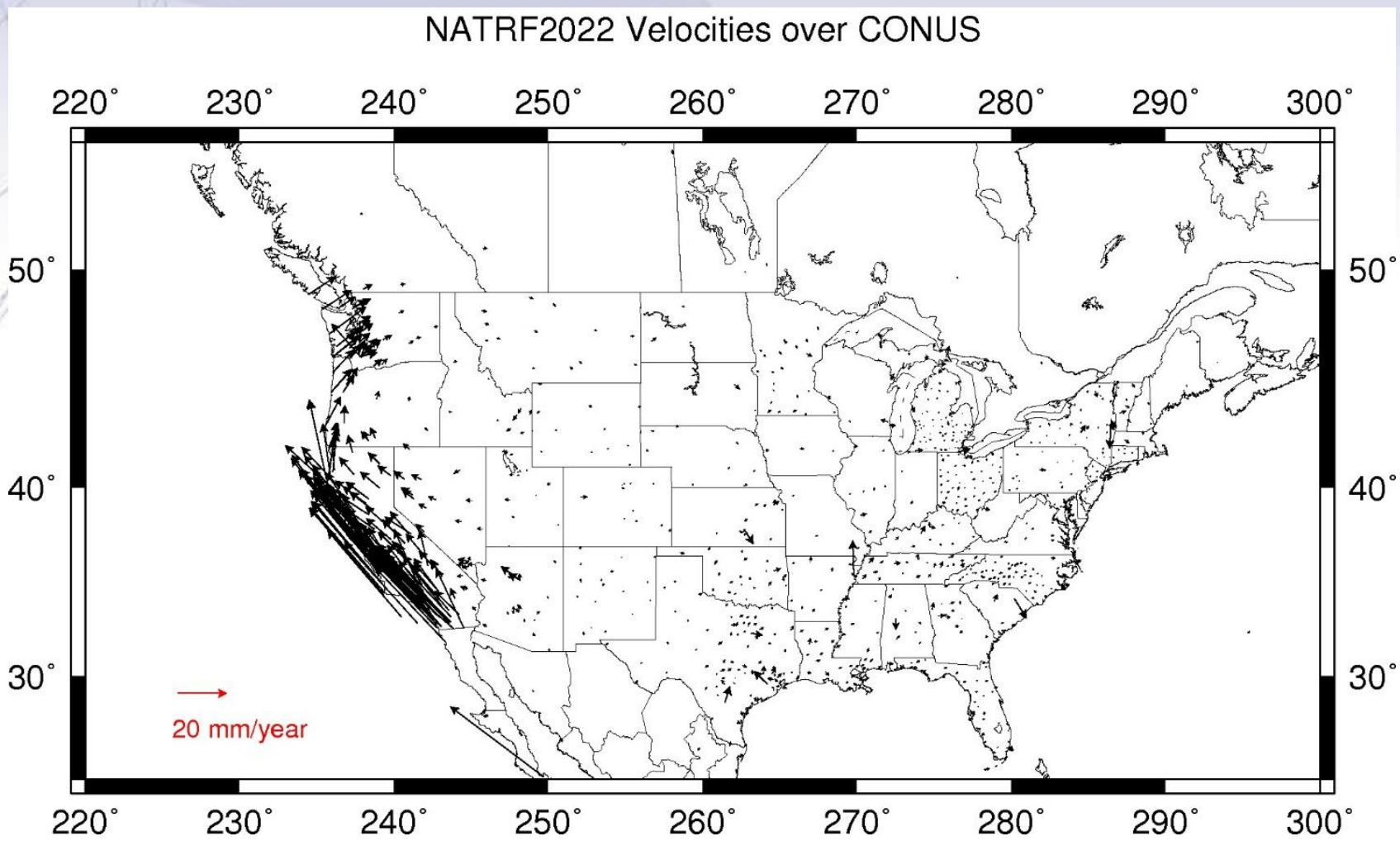
- # Euler Poles and "Plate Fixed"
  - In the ITRF, many tectonic plates have one *dominant* motion: rotation
    - Plus plenty of other motions
  - The point about which a continent rotates is called its "Euler Pole"
  - In summary:
    - Under ITRF
      - Frame = constant
      - N.A. Plate = rotating
  - It is a fairly simple matter to reverse this and define a rotating frame in which the plate is not rotating.
    - Under NATRF2022:
      - Frame = rotating (relative to ITRF)
      - N.A. Plate = constant (relative to NATRF2022 frame)
  - We say "NATRF2022" is "fixed" to the N.A. Plate, making it a "plate fixed" frame



CORS Velocities – ITRF2014



CORS Velocities – NATRF2022



Alpha Products

Alpha Products

- NGS set the goal of having an "alpha" version of every product/service of 2022 ready by the end of 2019.
  - Meaning bugs, limited availability in time/space, and generally not fully functional
    - But the intent is to show data formats, general direction and progress to the public
    - Information will be provided to industry partners so they can begin the process of ingesting the modernized NSRS into their software
  - Partial success, but still working toward a mid-2020 goal.

Thank you!

Questions?

Extra Slides

EPP2022 and IFVM2022:

The two tools that make time dependent geodetic control useable

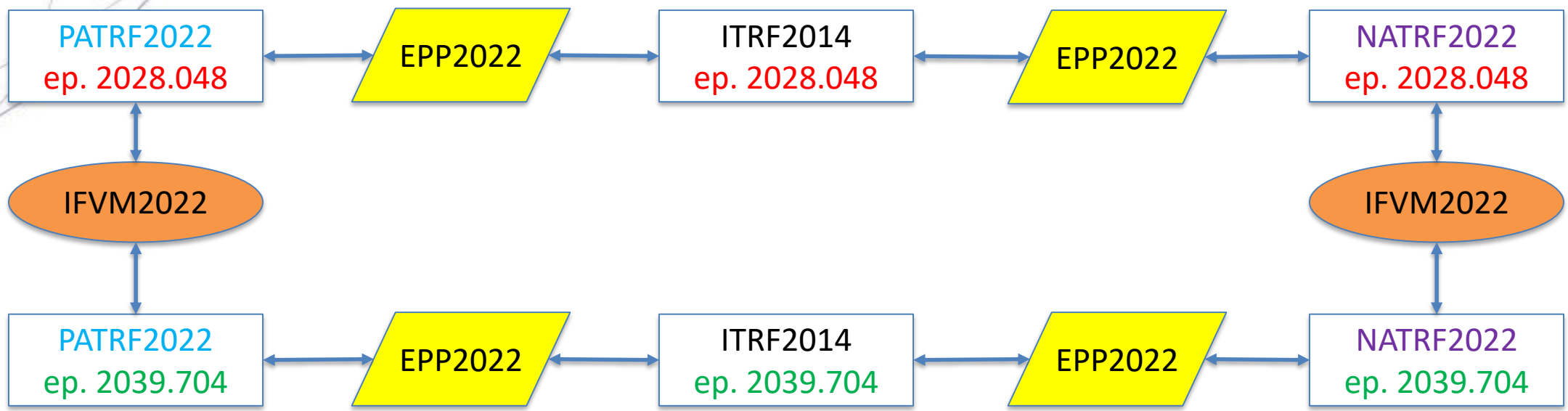
There's really *two* drifts

- The plate rotation is *simple* (3 parameters per plate)
  - Captured in EPP2022
  - Horizontal (latitude/longitude) *only*
  - Changes the *frame*
    - ITRF2014 to NATRF2022, PATRF2022, CATRF2022 & MATRF2022
  - Doesn't change the *epoch*
- The residual motions (after removing plate rotation) are *complex*
  - Captured in IFVM2022
  - *Residual* horizontal motion
  - *All* vertical motion
  - Changes the *epoch*
  - Doesn't change the *frame*
    - IFVM = "Intra-frame" velocity model

Example

- It's 2039 and you are working in San Diego using NATRF2022
- You need to compare your work against a competitor's survey
  - Done in 2028, using PATRF2022

Important: This slide only covers *geometric* coordinates.



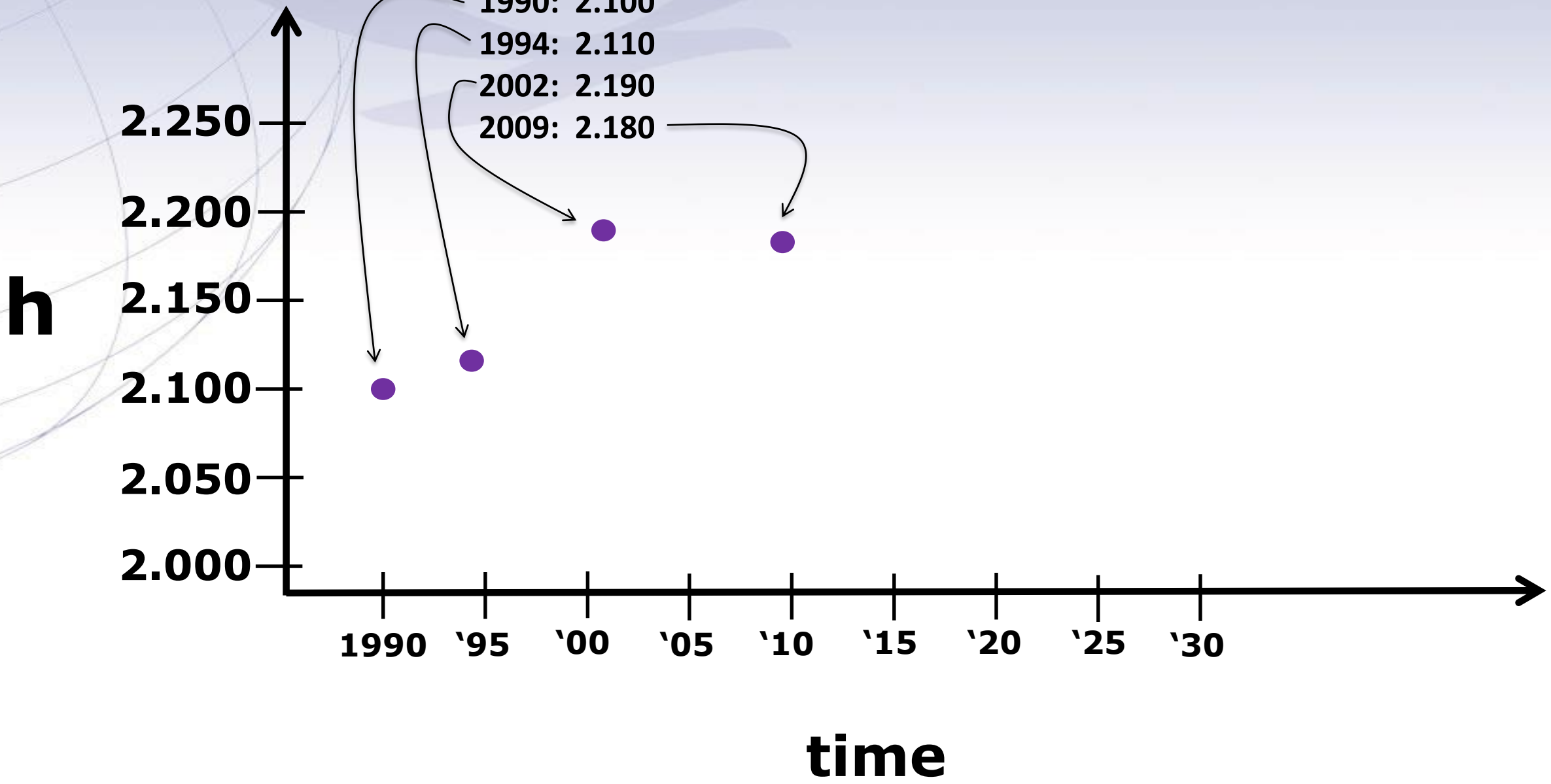
Reference Epochs

- It seems highly unlikely that surveyors will embrace coordinates with such diversity of epochs
- To mitigate that, NGS will issue "snapshots" of the NSRS every five years (called "Reference Epochs")
  - Estimates of coordinates at specific 5 year intervals, based on historic time-dependent coordinates and the IFVM2022
    - …and the Geoid Monitoring Service (GeMS), for non-geometric quantities
- Beginning with 2020.00
  - Each "snapshot" will be published 2-3 years after the reference epoch
    - Thus the 2020.00 Reference Epoch Coordinates get published by the end of calendar year 2022

Reference Epoch Coordinates from Time-Dependent Coordinates

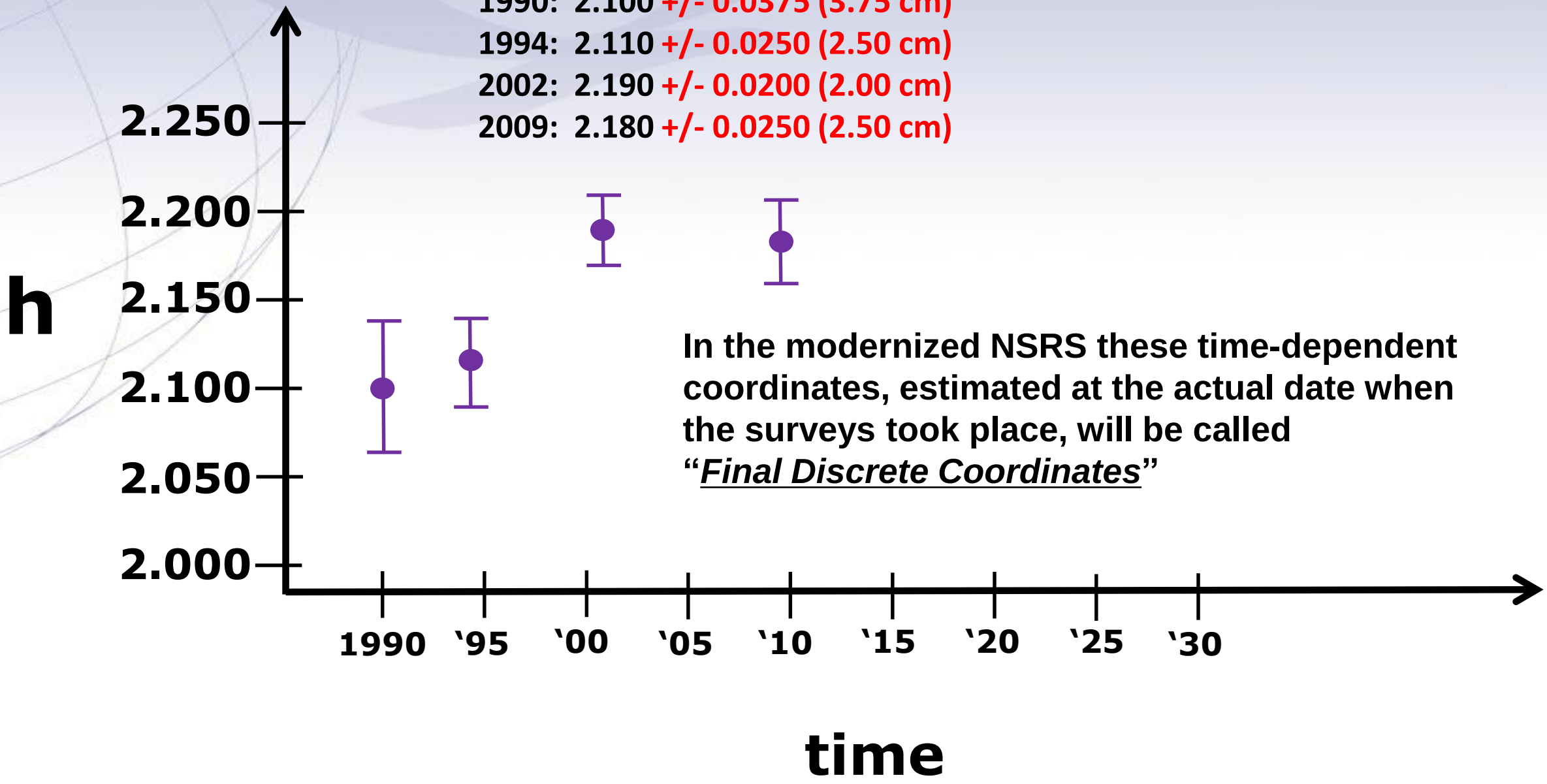
Assume "h" was determined four different times:

1990: 2.100
1994: 2.110
2002: 2.190
2009: 2.180



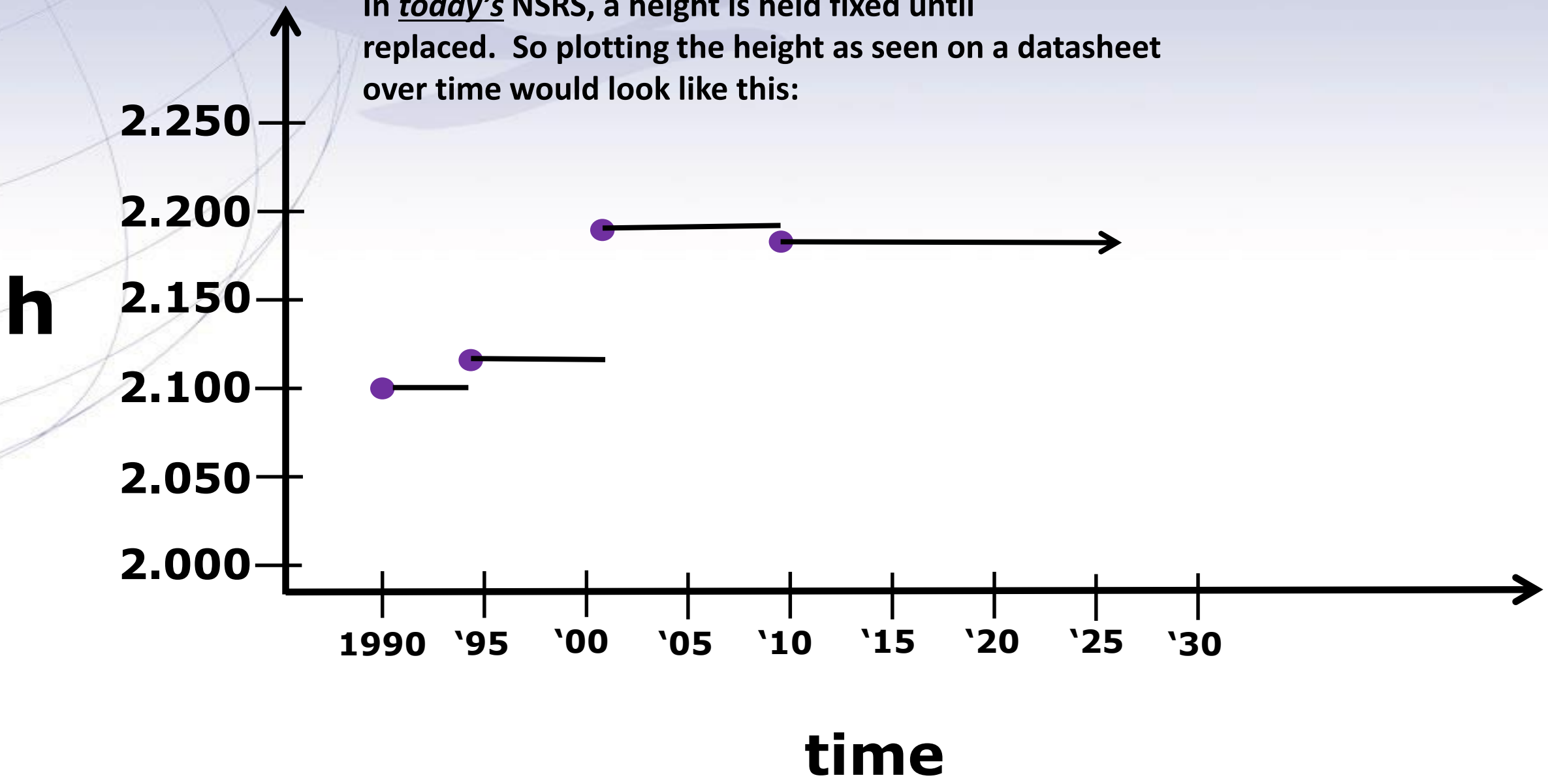
All measurements have error. Shown here are the same Values of "h", but with their error estimates.

1990: 2.100 +/- 0.0375 (3.75 cm)
1994: 2.110 +/- 0.0250 (2.50 cm)
2002: 2.190 +/- 0.0200 (2.00 cm)
2009: 2.180 +/- 0.0250 (2.50 cm)

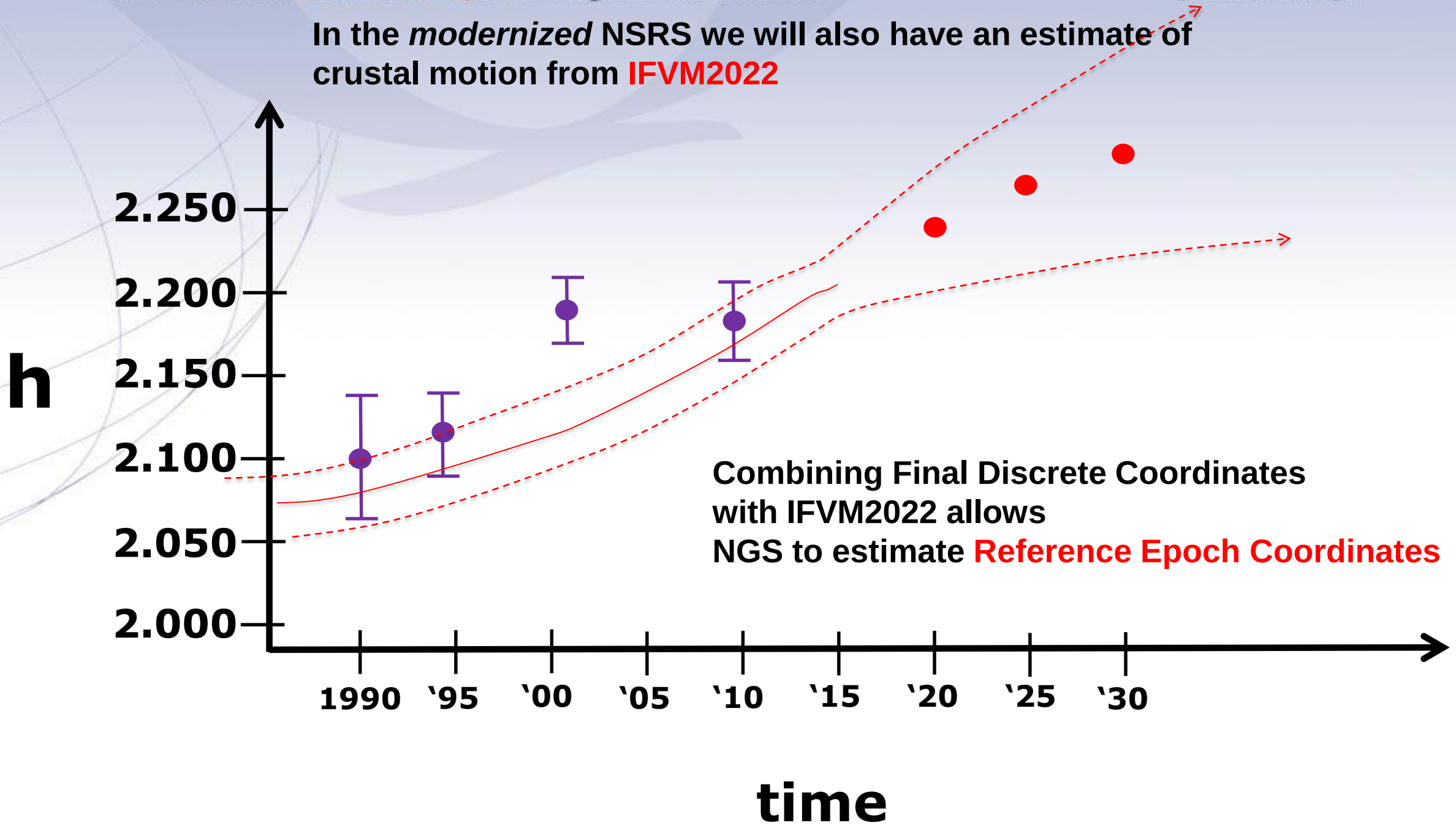


In the modernized NSRS these time-dependent coordinates, estimated at the actual date when the surveys took place, will be called "*Final Discrete Coordinates*"

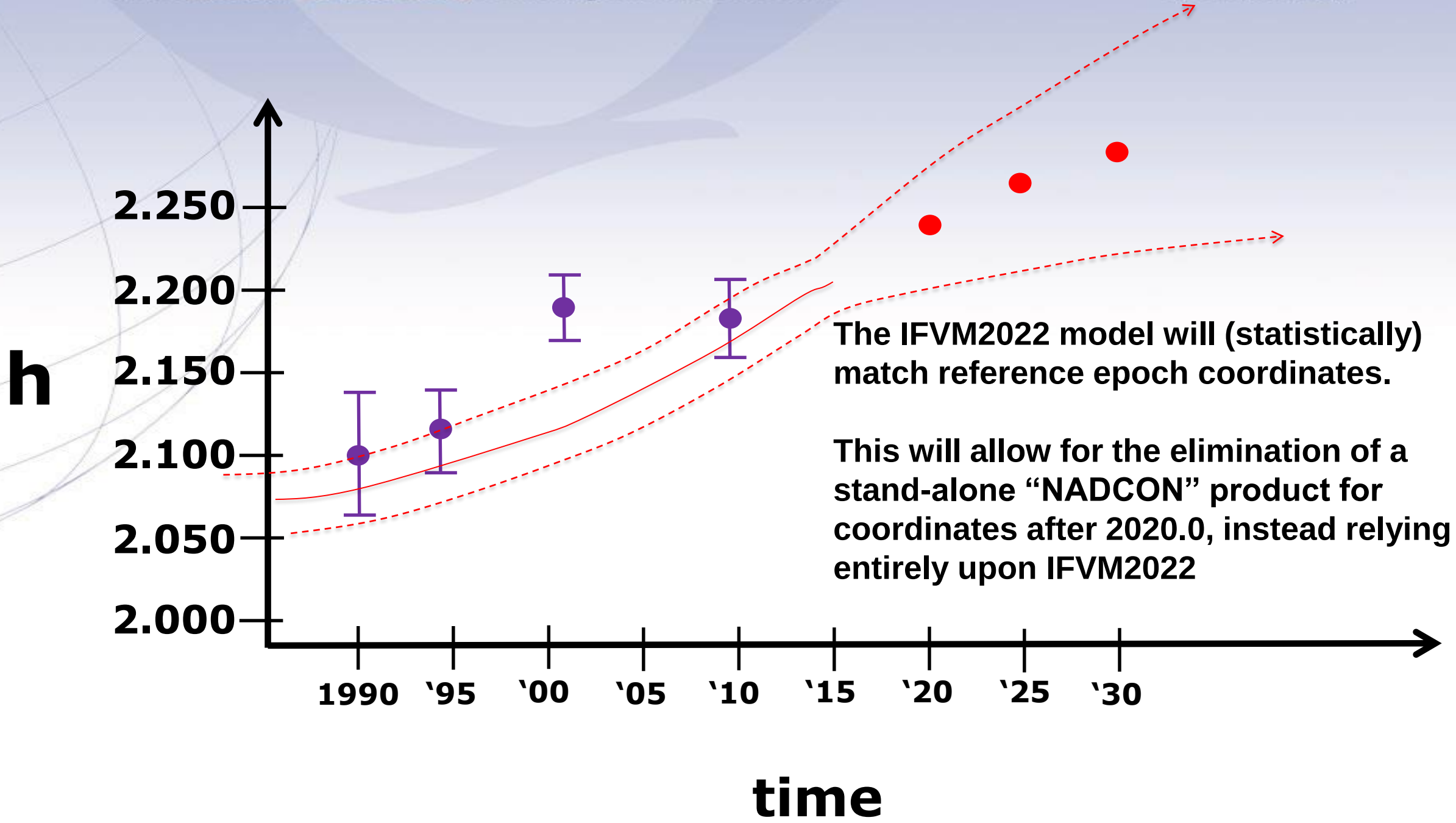
In *today's* NSRS, a height is held fixed until replaced. So plotting the height as seen on a datasheet over time would look like this:



In the *modernized* NSRS we will also have an estimate of crustal motion from IFVM2022

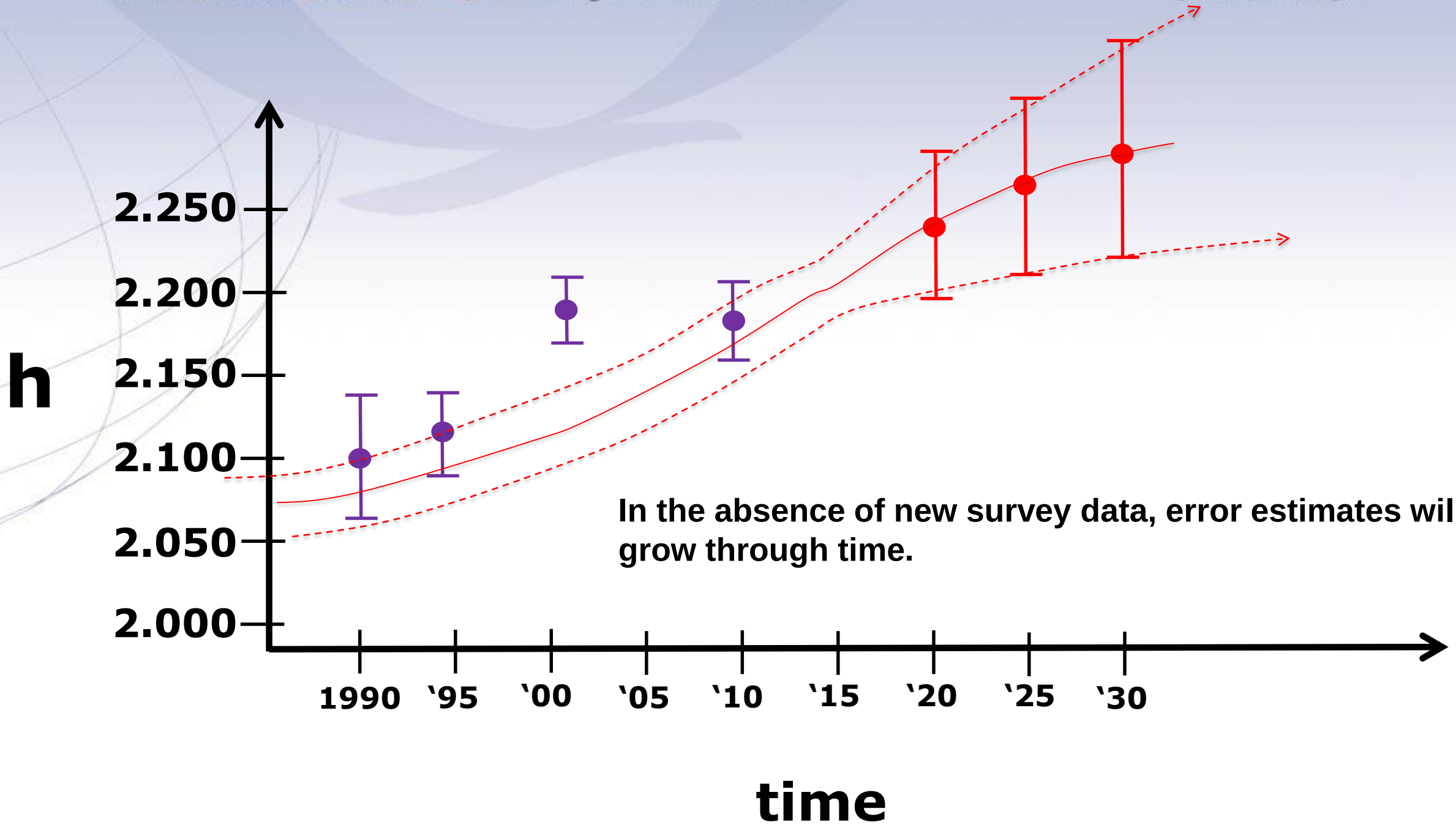


Combining Final Discrete Coordinates with IFVM2022 allows NGS to estimate Reference Epoch Coordinates

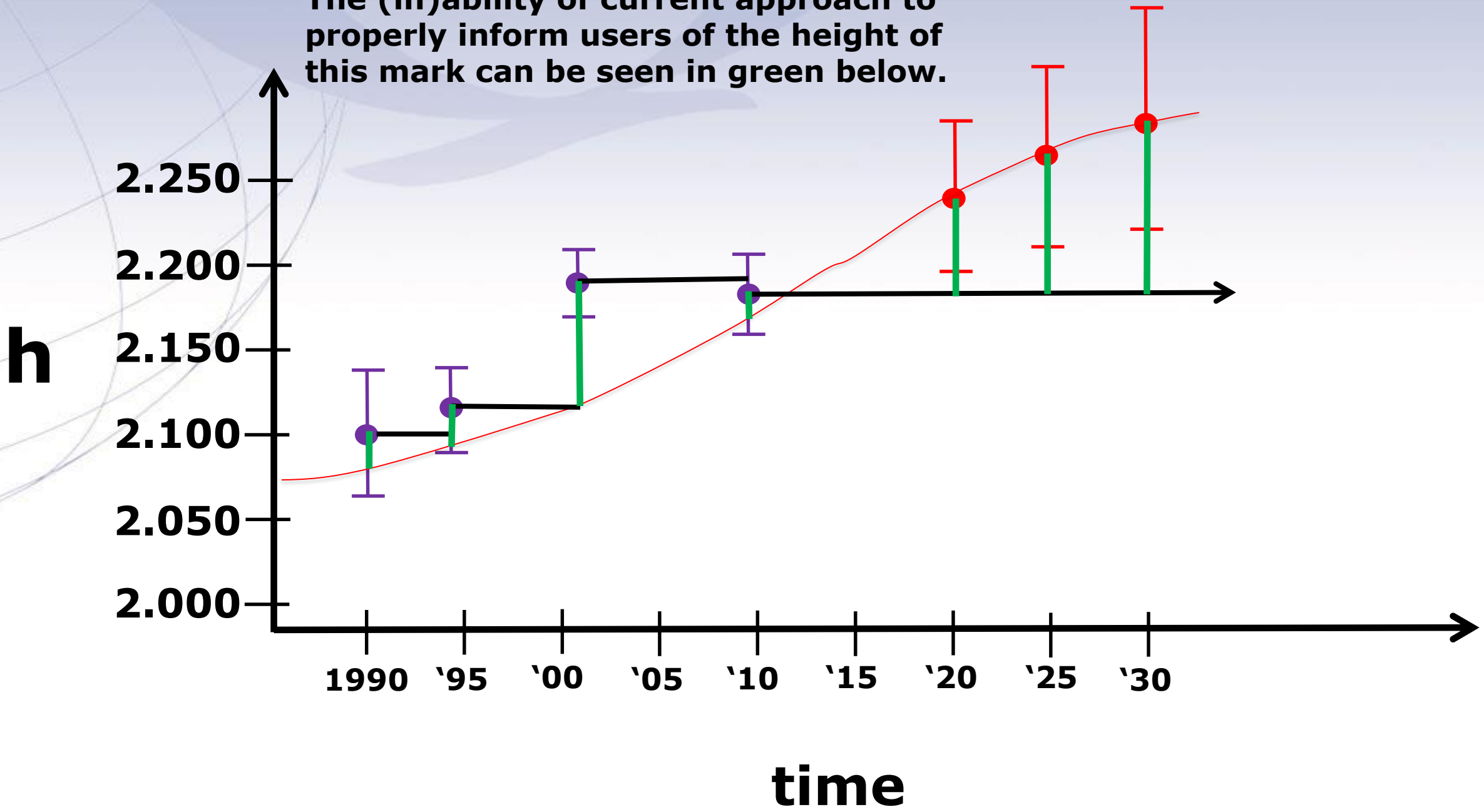


The IFVM2022 model will (statistically) match reference epoch coordinates.

This will allow for the elimination of a stand-alone "NADCON" product for coordinates after 2020.0, instead relying entirely upon IFVM2022

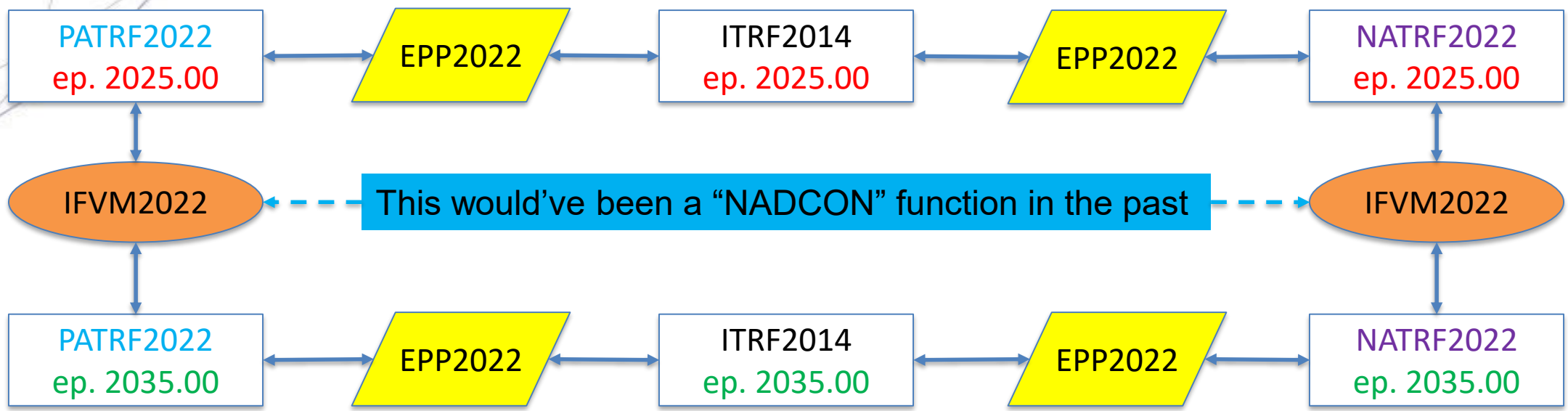

h
2.250
2.200
2.150
2.100
2.050
2.000
1990
'95
'00
'05
'10
'15
'20
'25
'30
time
In the absence of new survey data, error estimates will grow through time.

The (in)ability of current approach to properly inform users of the height of this mark can be seen in green below.



Example (v2)

- It's 2039 and you are working in San Diego using NATRF2022 (**epoch 2035.00**)
- You need to compare your work against a competitor's survey
  - Done in 2028, using PATRF2022 (**epoch 2025.00**)



Terminology

Terminology

- The following terms (and more) are defined meticulously in BP3 in a coordinated effort within NGS and with the IERS:
  - Point, Mark, Station, Site, ARP, GRP, Site Marker, CORS, the NOAA CORS Network
    - GRP = Geometric Reference Point – the official point on a station to which all coordinates refer
- As a direct fallout: NGS will no longer provide CORS coordinates at an *ARP*, only to a *GRP*
  - An ***antenna*** has an ARP.
    - A CORS only ***sometimes*** has an antenna.
      - Therefore a CORS only ***sometimes*** has an ARP.
      - But it ***always*** has a GRP.
        - » The ARP and GRP are only ***sometimes*** coincident in space when the antenna is mounted at a CORS
  - The GRP gets a Permanent Identifier (PID)

ARP vs GRP

- The purpose of a CORS can be debated
  - But at NGS: the continuous collection of GNSS data for the express purpose of determining the continuous coordinates of ***a unique, permanent, physical point on each CORS***
    - Such a point is called the Geometric Reference Point, or GRP
    - Not to be confused with the Antenna Reference Point, or ARP
      - Which is part of each ***antenna***, not a permanent, unique physical part of a CORS
  - Identification of GRPs has begun
    - Coordinates on a CORS will eventually be fully transitioned to be "coordinates of the GRP of the CORS". Right now they are…unclear.

Terminology

- "CORS" is an acronym
  - It is *singular* (S means "Station", not "Stations")
  - It will no longer be used to describe the *network* of all such stations
    - That will, for now, be called **the NOAA CORS Network, or NCN**
      - Which has a subset of stations called **the NOAA Foundation CORS Network, or NFCN**
  - Its plural form is **CORSs**
    - **No apostrophe, No "es" and no skipping the "s"**
    - GODE is a CORS
      - Not "a CORS site"
        - » And ***definitely*** NOT "a CORS Station"
          - That's like "an ATM machine"
    - GODE and 1LSU are CORSs
    - GODE and 1LSU belong to the NOAA CORS Network
    - TMG2 is a NOAA Foundation CORS
    - TMG2 and FLF1 are NOAA Foundation CORSs
    - TMG2 and FLF1 belong to the NOAA Foundation CORS Network

The NOAA CORS Network (NCN)

- As of 2019, this is the official name of the network managed at NGS
  - Historically referred to as "CORS" or "the CORS"

GPS Month

- A span of four consecutive GPS weeks, where the first GPS week in the GPS month is an integer multiple of 4
  - GPS Month 0 = GPS weeks 0, 1, 2 and 3
  - GPS Month 1 = GPS weeks 4, 5, 6 and 7
  - Etc.

New Types of Coordinates

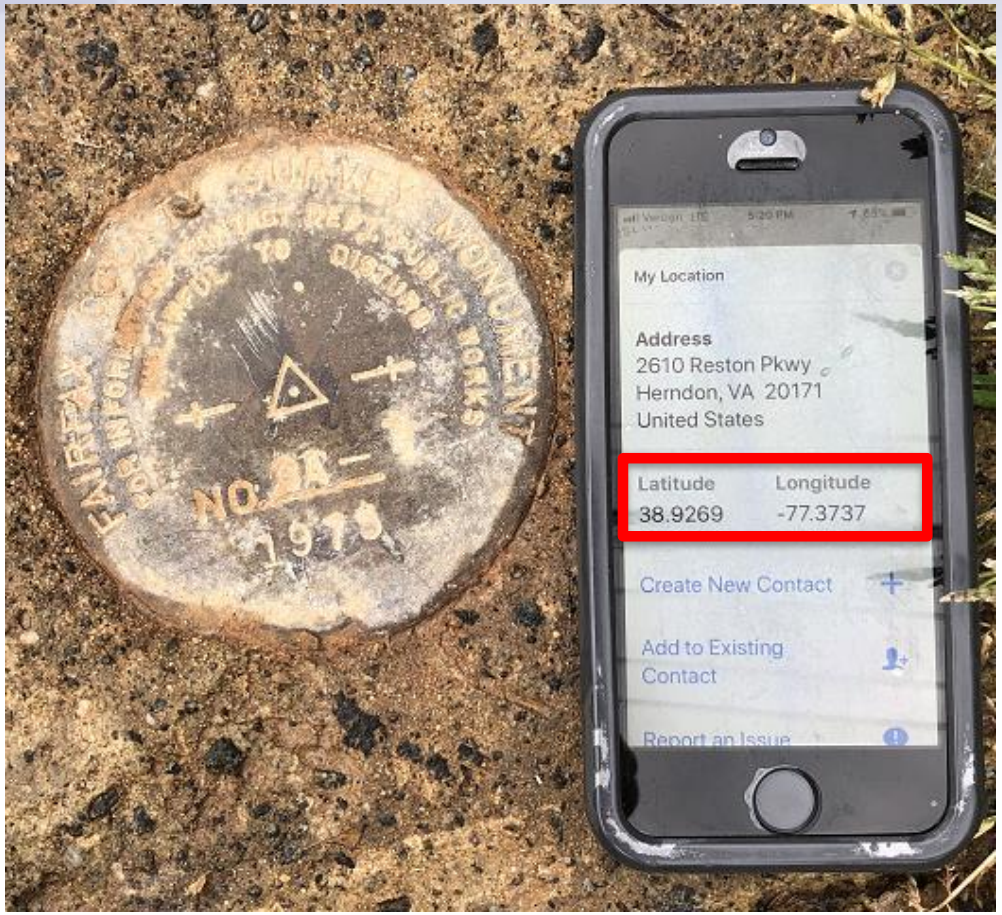
Five types of coordinates

Name	Generally on…	Description

New Types of Coordinates

- **Reported**
  - *"These are from any source where the coordinate is directly reported to NGS without the data necessary for NGS to replicate the coordinate."*
    - Scaled
    - From NCAT or Vdatum
      - NGS Coordinate Conversion and Transformation Tool (NCAT)
    - Hand Held / Smartphone
    - Reported directly from an RTK rover without data files

Reported Coordinates



New Types of Coordinates

- **Preliminary**
  - *"These are coordinates at survey epoch that have been computed from OPUS, but not yet quality checked and loaded into the National Spatial Reference System Database (NSRS DB)."*
    - *User-computed* values, such as they might get today from either OPUS-S or OPUS-Projects
    - "Preliminary" coordinates are the ***only*** coordinates a user will get directly from OPUS

New Types of Coordinates

- **Reference Epoch**
  - *"These are coordinates which have been estimated by NGS, from time-dependent (final discrete and final running) coordinates, at an Official NSRS Reference Epoch (ONRE)"*
    - NAD 83(2011) epoch 2010.00 (sort of) would've fallen under this category
    - These will be computed by NGS every 5 years
      - On a schedule 2-3 years past ONRE
        - » 2020.00 coordinates will be computed in CY 2022
        - » 2025.00 coordinates will be computed in CY 2027

New Types of Coordinates

- **Final Discrete**
  - *"These are coordinates computed by NGS using submitted data and metadata, checked and adjusted and referenced to a single survey epoch."*
    - These represent the best estimates NGS has of the time-dependent coordinates at any mark
    - Survey epochs:
      - GNSS: Each GPS Month
        - » Stand-alone occupations, RTK/RTN, Campaigns, etc
      - Leveling: Annually
        - » Orthometric heights: Leveling adjusted to GNSS-based orthometric heights

New Types of Coordinates

- **Final Running**
  - *"Of all types of coordinates on a mark, these are the only ones which will have a coordinate at any time."*
    - Generally will only be available at each CORS
      - Also being called the coordinate function
      - Which will be generated by a "fit" to daily processed data

Using the modernized NSRS

- OPUS
  - Will include stand-alone GNSS (like "OPUS-S" and "OPUS-RS")
  - Will include mark discovery, recovery and reporting
  - Will include project management and analysis for:
    - GNSS (including RTK and RTN!)
    - Leveling
    - Classical
    - Gravity
    - All in one project!
  - Will have a "submit to NGS" button which replaces "bluebooking"

Using the modernized NSRS

- OPUS
  - ***Guidance*** (such as pre-selected CORSs and assistance in locating marks in project areas)
  - ***Users will decide*** what control to hold fixed and what epochs they wish to set for the adjustment
    - "Preliminary coordinates"
  - If submitted to NGS, we will harvest your raw data and use it to compute Final Discrete coordinates

Using the modernized NSRS

- GNSS is your only entry (for now)
  - Leveling and Classical surveys will need some GNSS if you wish to submit your survey to NGS for inclusion in the NSRS database
    - Some GNSS = RTK or RTN is fine
    - No decision yet on whether OPUS will operate if projects have no GNSS
      - If it does, this tends to encourage reliance upon passive control
        - » which is "so 90's"
          - (1890s!)

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Terminology

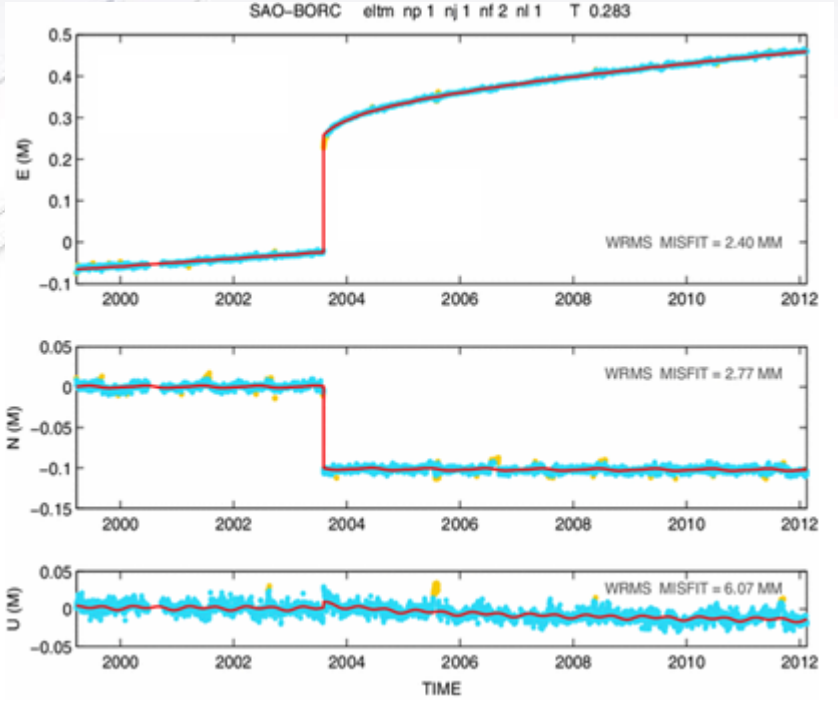
- "OPUS"
  - Online Positioning User Service
  - Adopted as the general term for all of our online positioning software
    - Rather than "-Projects" , "-S" , etc
    - Basically "**do it with OPUS**" should be applicable to a wide variety of tasks
      - Recon, Mark Recovery, GPS, Leveling, Gravity, Classical

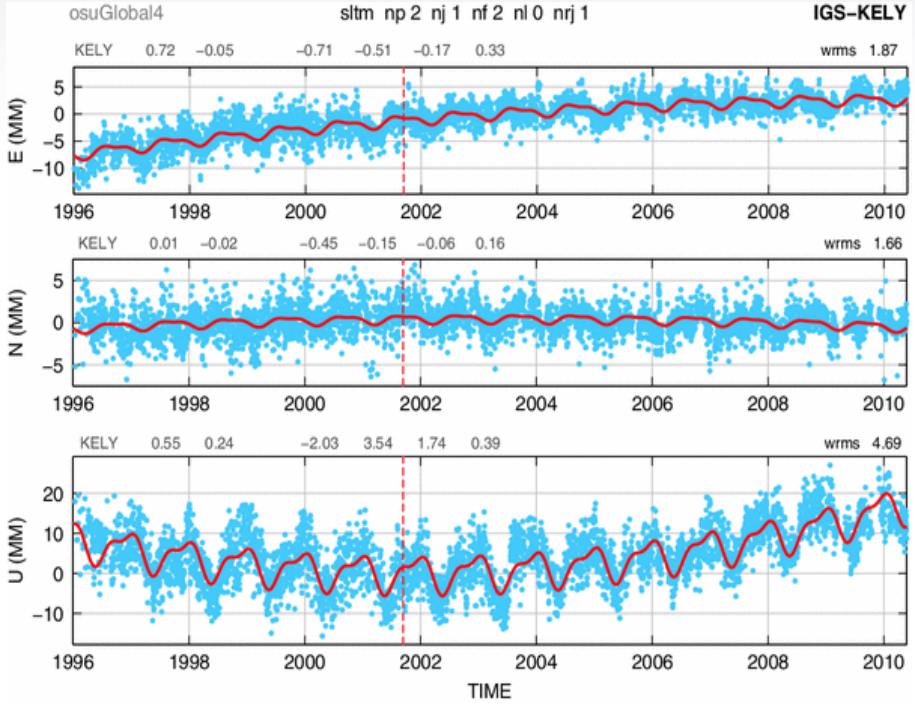
New Way of Operating the NOAA CORS Network (NCN)

New Way of Operating the NOAA CORS Network (NCN)

- Each CORS will get a coordinate function
  - Actually three functions, X(t), Y(t), Z(t), in the ITRF2014 frame
  - In the strict mathematical definition of "function"
    - For any given "t", there is one and only one X , Y and Z
    - We actually do this today, just that the functions are piecewise linear
  - We are NOT limiting our "modernized NSRS" discussions of CORS coordinate functions to linear functions only!
    - But have made no further decisions yet

Examples of what non-linear CORS coordinate functions look like





New Way of Operating the NOAA CORS Network (NCN)

- Philosophy:
  - The NOAA CORS Network (NCN) will be self-consistent, meaning:
    - The impact of a user's CORS choices within their project will not exceed a small, statistically acceptable value:
      - Horizontal < 5 mm, Vertical < 10 mm
  - On a daily basis NGS must be able to detect, and react to, *persistent disagreement* between daily solutions and the current "coordinate function" assigned to any CORS in the NOAA CORS Network (NCN)

Persistent Disagreement

- The point:
  - It's not enough to say "each CORS is good to 1 cm in ellipsoid height".
    - That phrase is vague, lacking what it means to be "good to 1 cm".
  - NGS will define and publish "persistent disagreement"
    - Possible component: A persistent non-zero average disagreement
    - Possible component: A persistently deviating disagreement
  - And NGS will define what happens when a CORS exhibits "persistent disagreement"

New Way for *USERS* to Process GNSS Projects

GNSS: Time Span…

- GNSS projects have no time limit.
  - (Leveling does. More on that later)
  - But they will be processed by NGS in GPS Months*

GNSS: Processing *by users* in OPUS

- GNSS projects, processed by users using OPUS, must always be processed by GPS month as a first step*
  - Multiple occupations on a point within a GPS month will be adjusted together
  - Coordinate functions from the IGS network or the NOAA CORS Network are the only allowable control
  - These are effectively the identical steps NGS will use in-house to compute Final Discrete Coordinates (FDCs) from your data
    - Except NGS will merge your data with all other data in the nation during each GPS month
  - This process will be built into OPUS as the default, making it easy for users to quickly perform the adjustment
  - Afterwards, users may move on to a second step…

GNSS: Processing by users in OPUS

- As a second step, a user may do many alternative things…
  - Adjust to some epoch that is convenient to them…
  - Hold any CORSs or passive control as constraints…
- This two-step approach is a form of sequential adjustments and allows a win-win:
  - NGS gets to see the user-computed time-dependent "preliminary" coordinates, which have been computed by GPS Month
    - Which will be checked against "final discrete" coordinates computed by NGS
  - The user gets whatever adjustment and/or coordinates fulfill their contractual needs
  - Redundancy checks can occur both *within* a GPS month (at step 1, if multiple occupations occur in 1 GPS month) and *across* GPS months (at step 2, if occupations occur in different GPS months)

New Way of Processing Leveling Projects

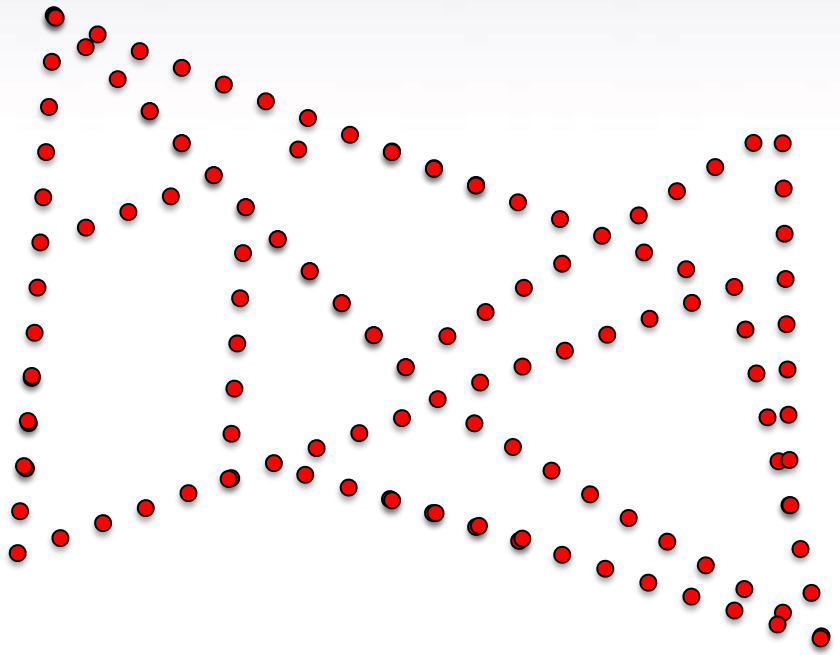
Leveling: Time Span…

- Leveling projects must not exceed 12 sequential months
  - Longer projects must be broken into sub-projects each spanning less than 12 sequential months
- A compromise between:
  - Treating "1 GPS Month" as "simultaneous" in the GNSS arena, and
  - Acknowledging that leveling surveys often take weeks to months to conduct
- Mixed with the reality that:
  - You can't solve for time-dependent orthometric heights in most leveling projects

Leveling: GNSS required

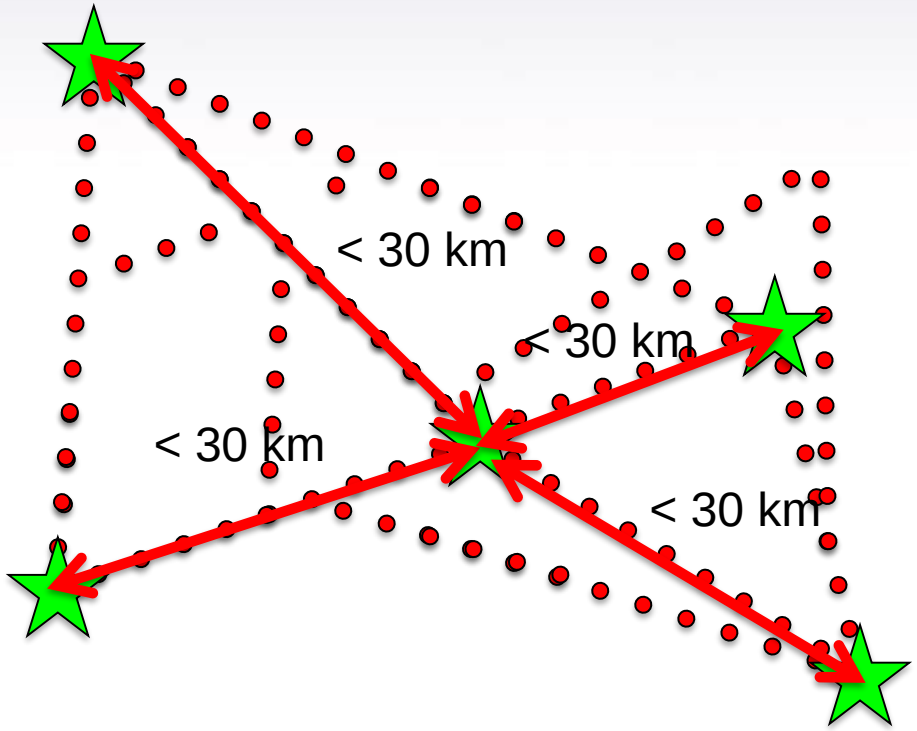
- For the immediate years following 2022, NGS will require that all leveling projects turned in have GNSS on primary control
  - Minimum of 3 points
  - Maximum spacing of 30 km
  - At least two occupations:
    - +/- 14 days of beginning of leveling
      - But also within the same GPS month
    - +/- 14 days of ending leveling
      - But also within the same GPS month
  - If leveling exceeds 6 months, must have a 3rd, middle occupation
- A GNSS "occupation" can mean "RTK/N"!

Leveling: Step 1
Identify project marks



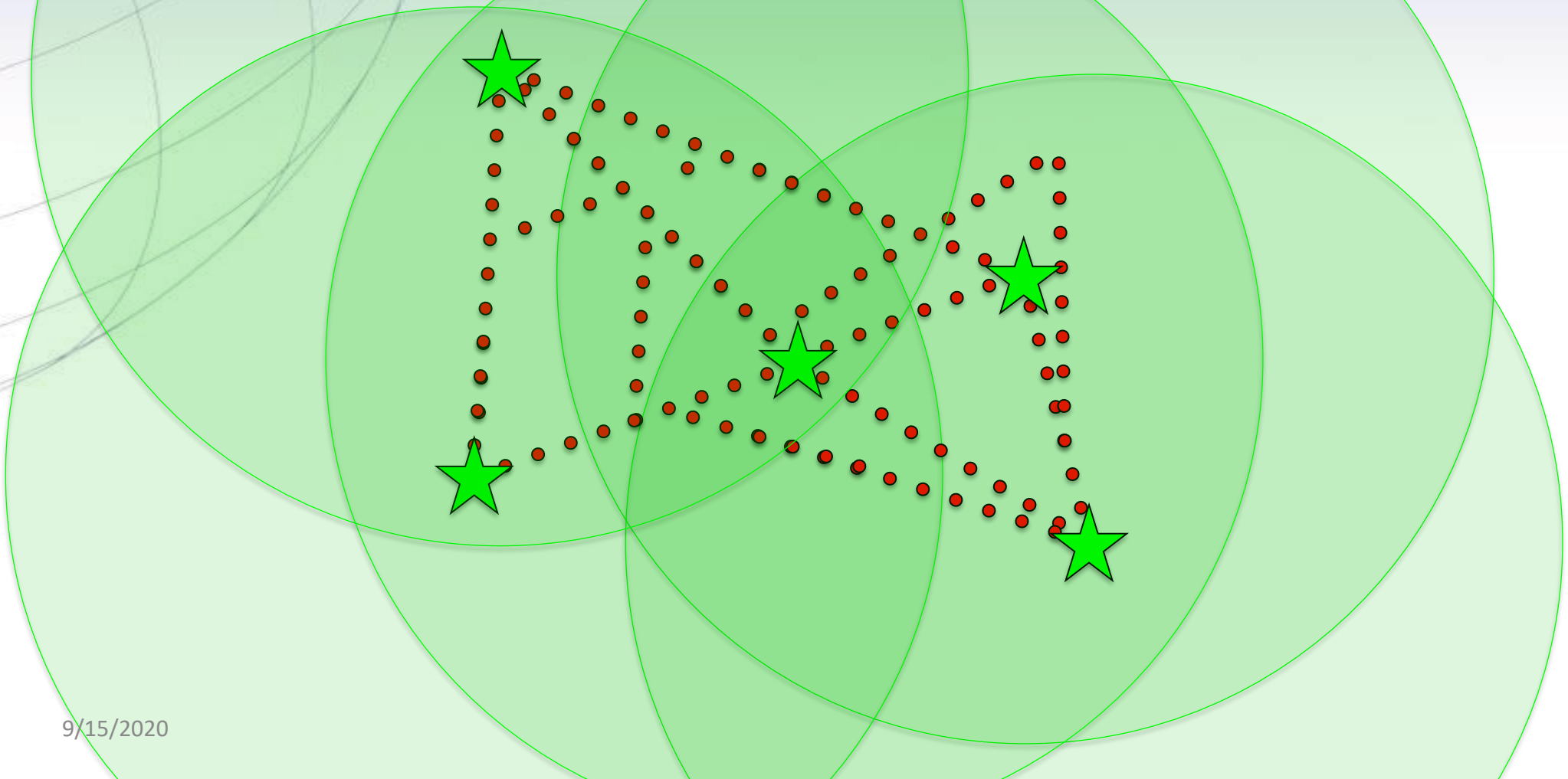
Leveling: Step 2
Identify primary control marks (PCM)

- Each PCM is within 30 km of at least one other PCM



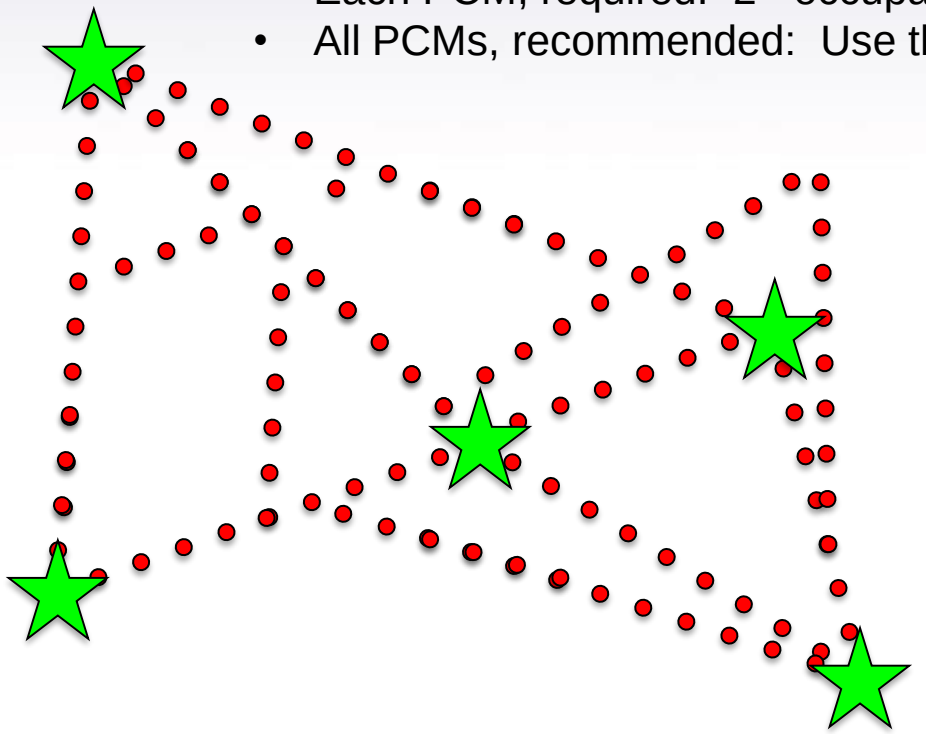
Leveling: Step 2
Identify primary control marks (PCM)

- No point over 30 km from a PCM



Leveling: Step 3
Initial GNSS on all PCMs

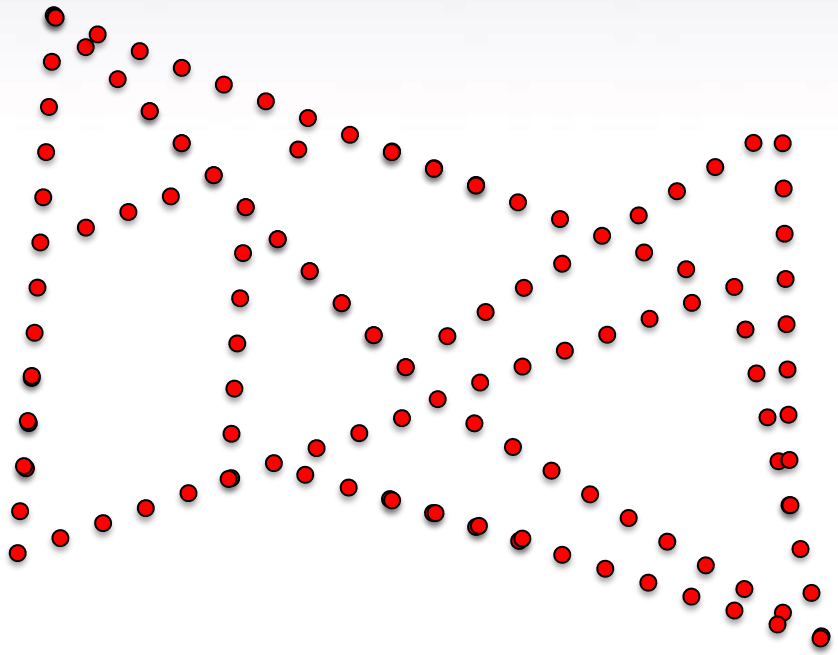
- All PCMs, required: within +/- 2 weeks of the start of leveling
- Each PCM, required: 2+ occupations within the same GPS month
- All PCMs, recommended: Use the same GPS month



Leveling: Step 4

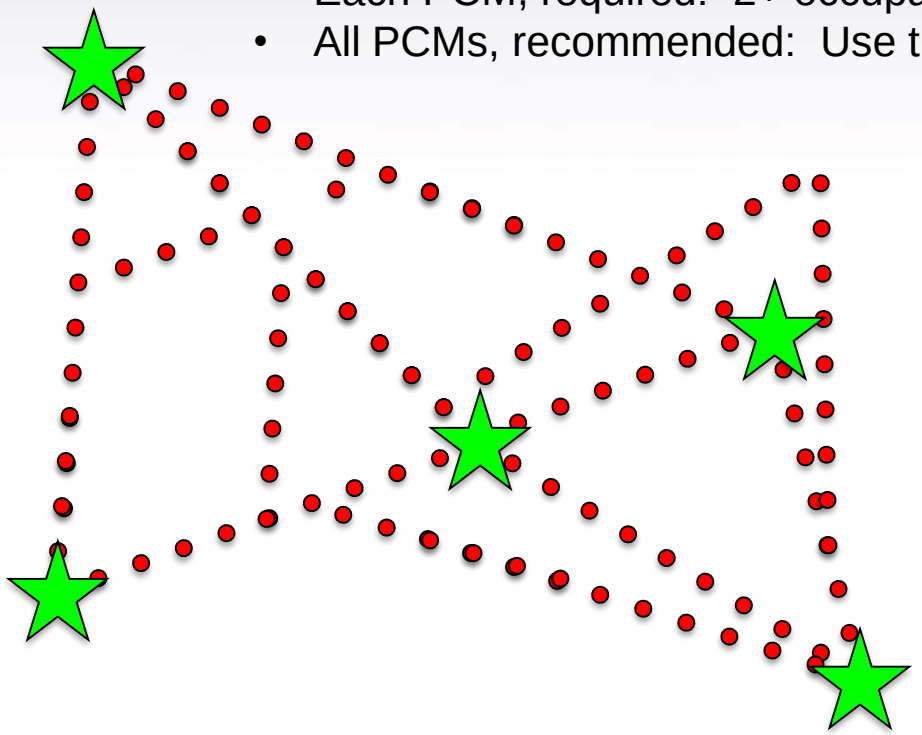
Leveling

- Finished in under 12 months
- If greater than 6 months, need a mid-project GNSS set on PCMs



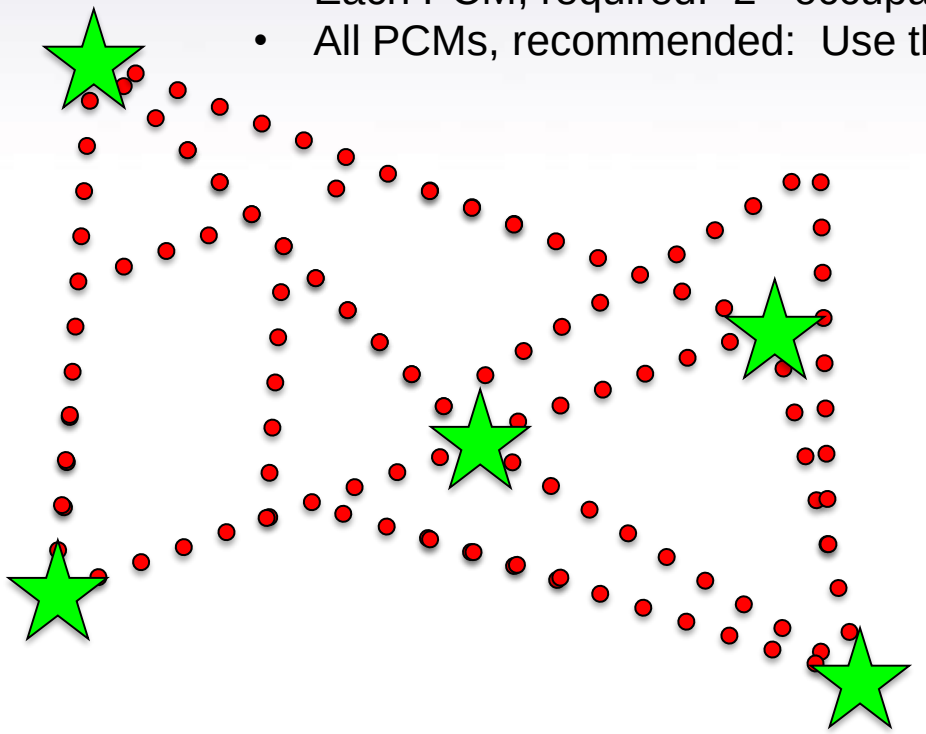
Leveling: Step 5 (if 6-12 months)
Mid-project GNSS on all PCMs

- All PCMs, recommended: Near midpoint of project
- Each PCM, required: 2+ occupations within the same GPS month
- All PCMs, recommended: Use the same GPS month



Leveling: Step 6
Final GNSS on all PCMs

- All PCMs, required: within +/- 2 weeks of the end of leveling
- Each PCM, required: 2+ occupations within the same GPS month
- All PCMs, recommended: Use the same GPS month



Leveling: Processing

- All GNSS data processed into GPS months, as per normal processing
- These are then adjusted to a mean epoch of the entire leveling survey to yield "representative" orthometric heights that serve as control over the entire leveling project
- Stochastic but no time dependency

Leveling: Processing

- The pre-computed GNSS-based orthometric heights are held as stochastic constraints in the adjustment of leveling data
- Use math model from NOAA TM NOS NGS 74
- Separates out errors in GNSS from Leveling:
  - *Absolute* heights will have standard deviations that are "at GNSS accuracy levels"
  - *Differential* heights will have standard deviations that are "at leveling accuracy levels"

Leveling: Absolute errors

- Consider this quote from a concerned user:
  - "In the old NSRS, I could pull the datasheet for a point in California and see that NGS trusted the NAVD 88 height to 1 millimeter. Now, you're telling me to use RTN to establish orthometric heights in the same area, and I'm getting heights with 4 cm standard deviations! Why are your heights less accurate today than in the past?"

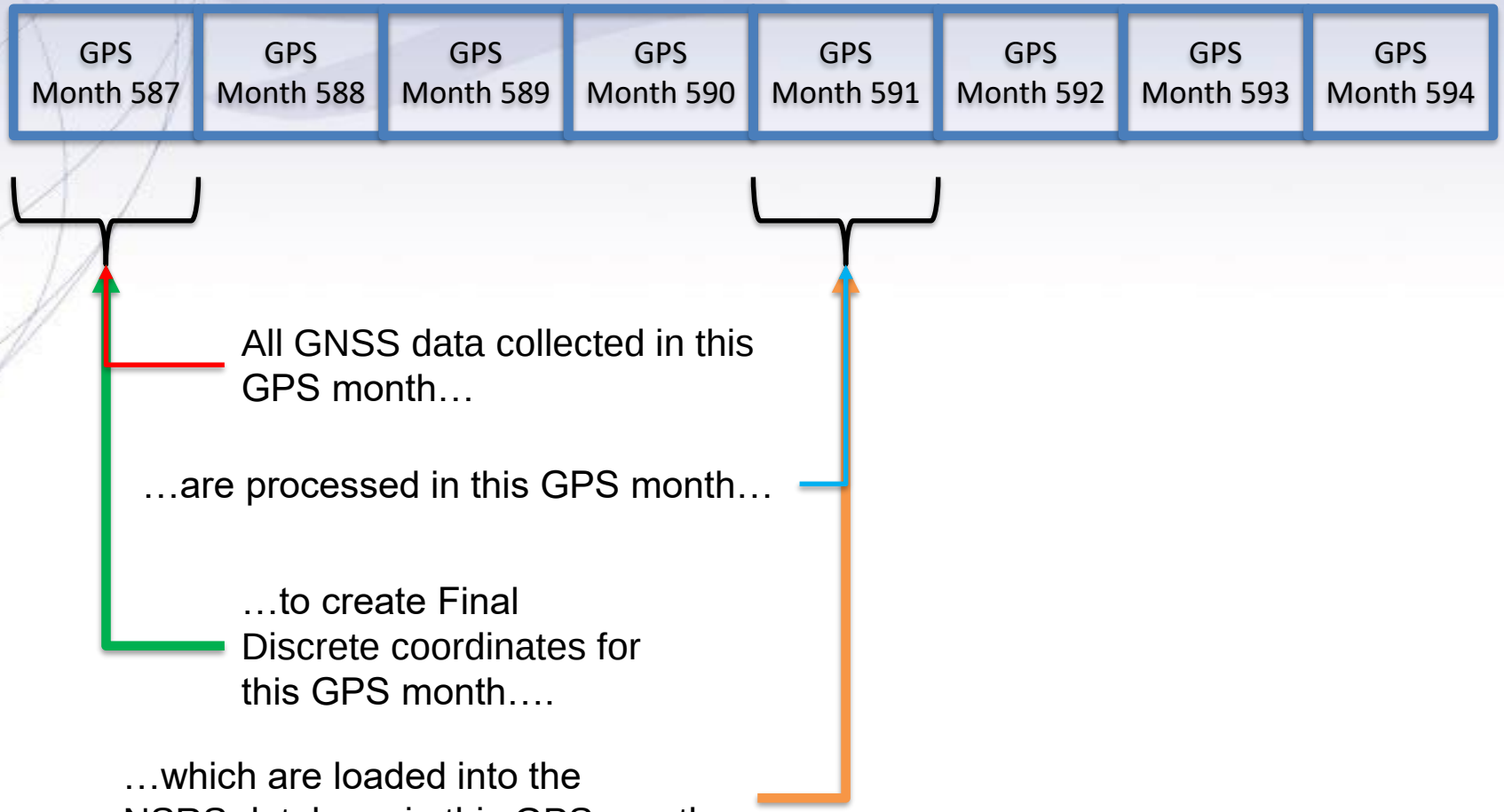
New Way for *NGS* to Process and store GNSS Data:

Final Discrete Coordinates (*FDCs*)

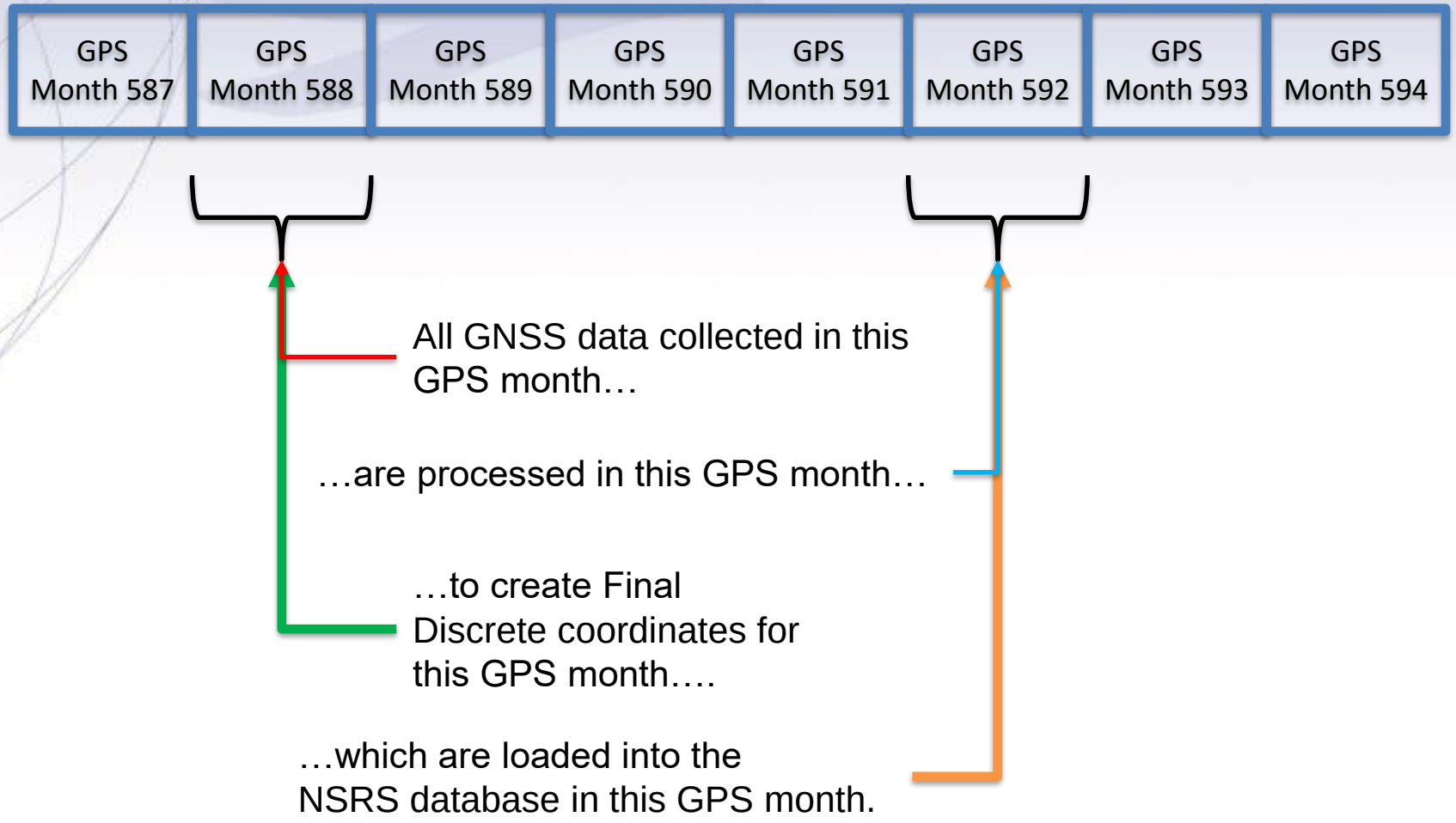
GNSS: Monthly workflow…

- Every **GPS month** (say the first Monday of that GPS month), NGS will "process the GPS month of 12-16 weeks ago" by doing the following:
  - Ensure that the "final" IGS orbits for the GPS month that spans 12-16 weeks prior are available
    - If not, hold off on this until they are
  - Create an in-house project named for that prior GPS month
  - Farm all data (collected during that GPS month) from all projects submitted to NGS, and put them all into the in-house project

Processing by GPS Month…



Processing by GPS Month…



GNSS: Monthly workflow…

- Adjust all that data together
- Take the results of this adjustment and load them into the NSRS database as "final discrete" coordinates

GNSS: Monthly workflow…

- Q: What about users' projects that span more than 12-16 weeks?

- A: NGS will provide a way for a user to "allow NGS to farm my data as it is loaded to my ongoing project"
  - Thus NGS needn't wait for them to finish their project and click "submit".
  - Will require some sort of metadata validity statement from the user for each data file uploaded

GNSS: Monthly workflow…

- Q: What if a user turns in data more than 12-16 weeks after it was collected?

- A: NGS will have a "holding bin" for such data. Occasionally, but not more than 1/year, NGS will sweep up all data in the holding bin, and put that data into the proper in-house GPS-month-based projects, depending on the GPS month of that data.
  - Since those in-house projects have already been adjusted once before using data that WAS submitted within the 12-16 week limit, and "final discrete" coordinates were computed on those early-submitted data, NGS will hold the "final discrete" coordinates on that early-submitted data as "fixed", and adjust the later-submitted data only.

New Way for *NGS* to Process and store GNSS Data:

Reference Epoch Coordinates (*RECs*)

GNSS: Every five years…

- Official NSRS Reference Epochs (*ONREs*) will happen every five years, beginning with 2020.00.
- Every ONRE will have a project associated with it
  - To estimate the Reference Epoch Coordinates (RECs) at each ONRE
  - That project will begin 2 years after the ONRE and will end 3 years after it
    - Thus the project to create 2020.00 RECs will run January 1-December 31, 2022
    - Using data collected through the end of 2021
- Error estimates in RECs will grow larger every five years for those points which are not regularly observed
- Once computed, the REC at an ONRE for a point will stand forever, unless corrected for a blunder

Miscellaneous

Miscellaneous

- **OPUS-RS** will be modified to work in the modernized NSRS online, but will not be used to populate the NSRS Database
  - To use the new terminology: it will provide preliminary coordinates
  - To acknowledge the problems with integrating this software with any other version of OPUS
  - In preparation for its eventual mothballing / replacement by the new multi-GNSS PAGES

Future Discussions/Decisions:

- What will be the nature of the coordinate functions at each CORS?

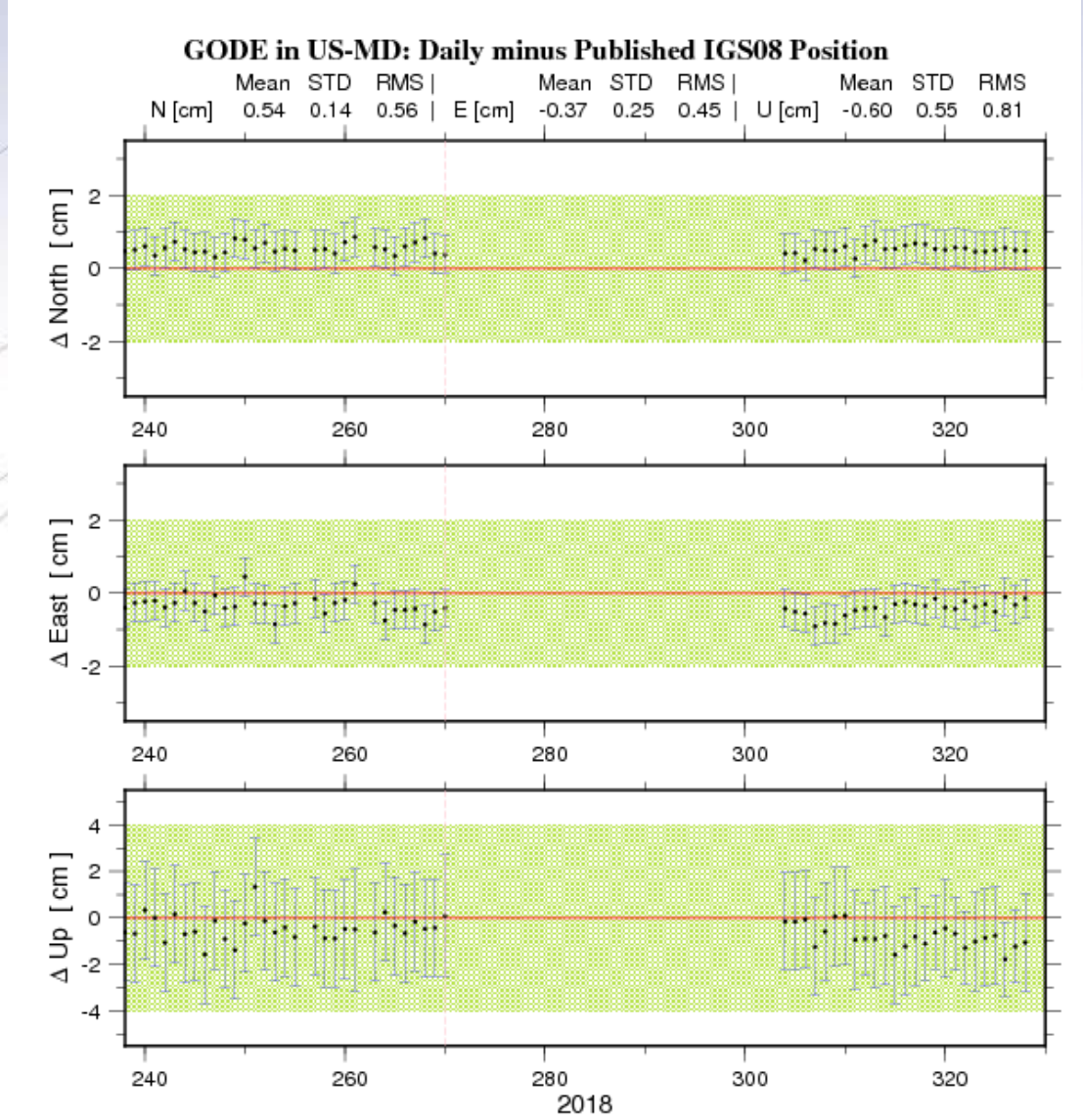
- How will those functions be used to detect, and correct, persistent disagreement between daily solutions and the coordinate functions?

Future discussions:

What will be the nature of the "coordinate functions" at each CORS?

How will those functions be used to detect, and correct, persistent disagreement between daily(?) final discrete coordinates and the coordinate functions?

CORS Processing

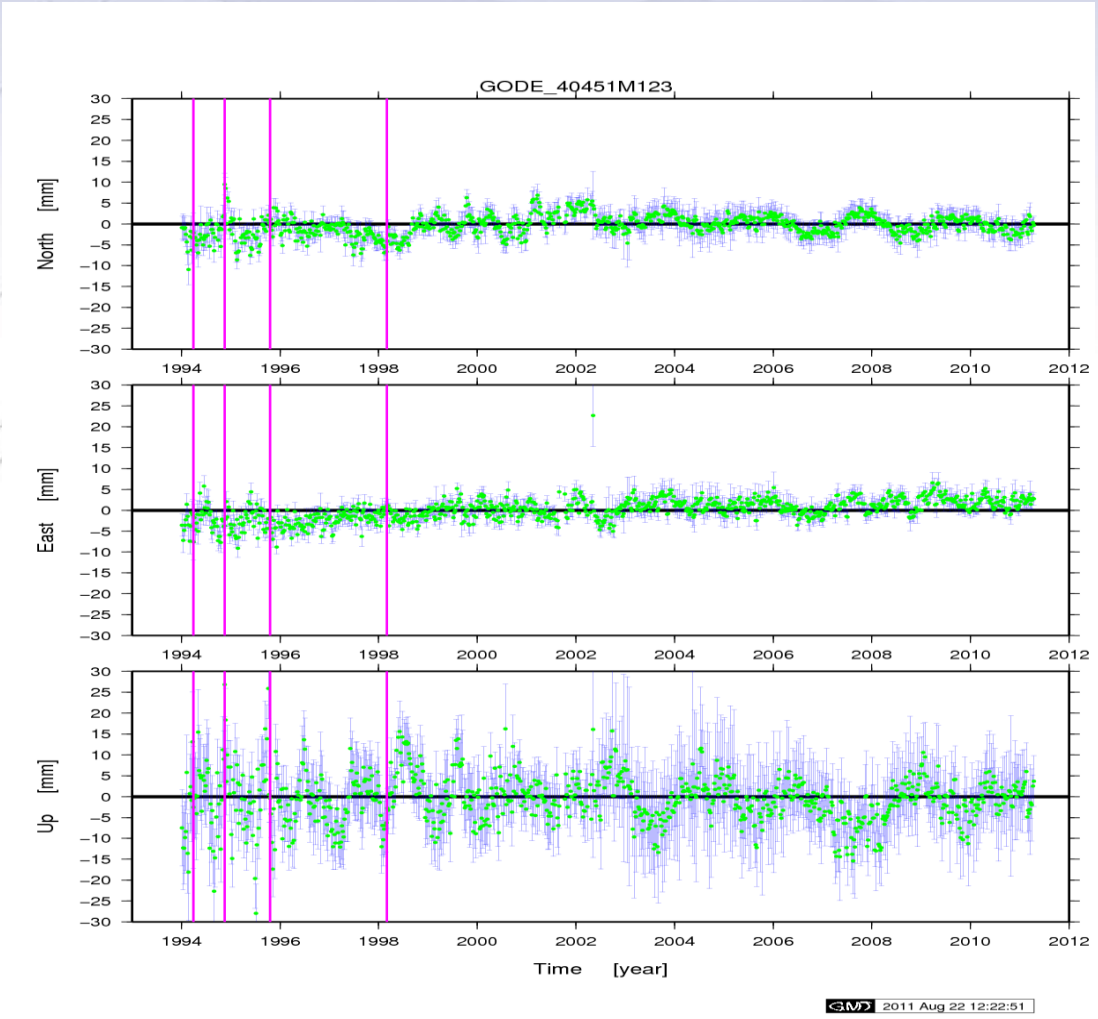


This is from the most recent "short term" plots of GODE

Note, what could be called a "persistent non-zero average disagreement" between daily solutions and the assigned coordinate function (about 5 mm in North, for example)

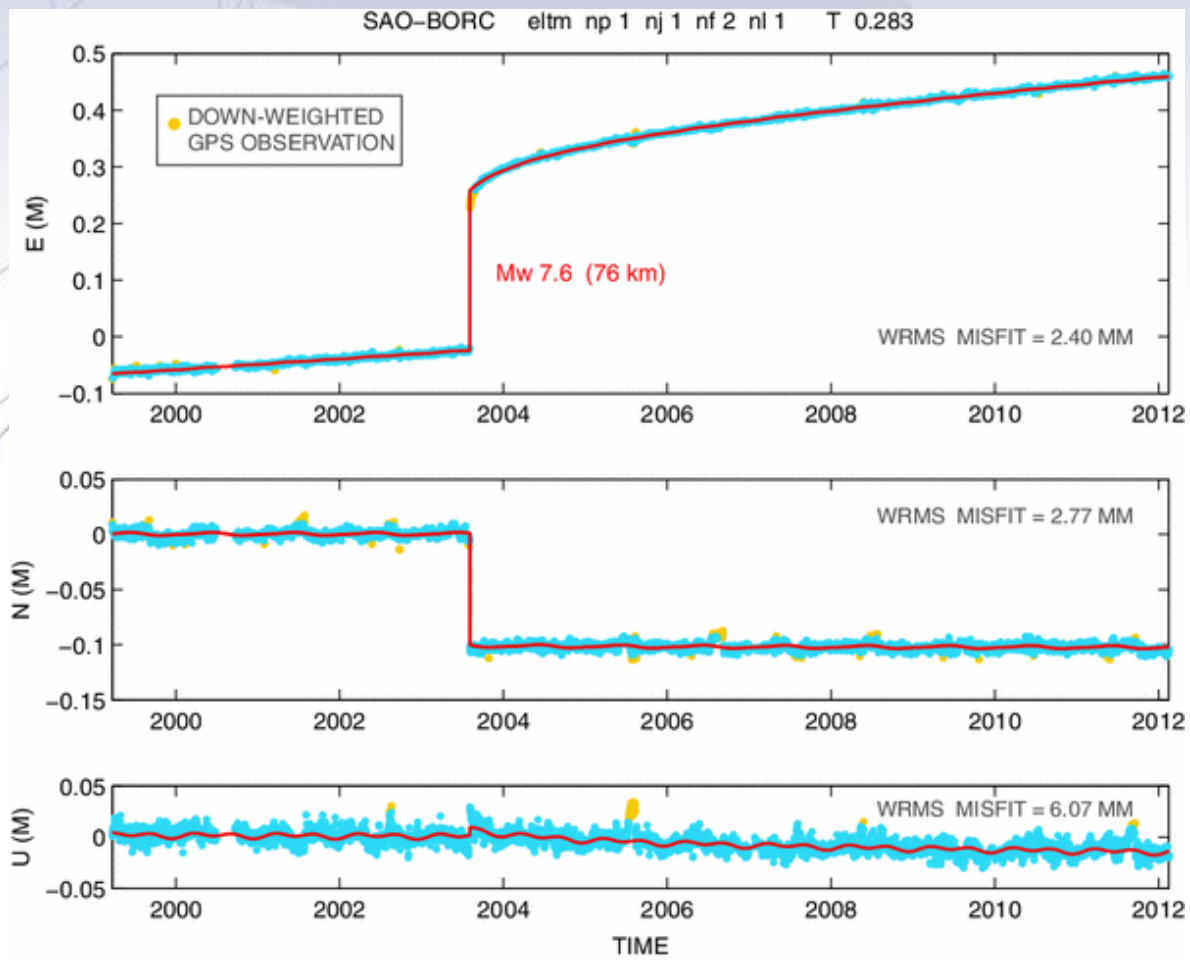
Not "persistently *growing* disagreement", as the average disagreement isn't getting worse.

CORS Processing



This is from the most recent "long term" plots of GODE

CORS Processing

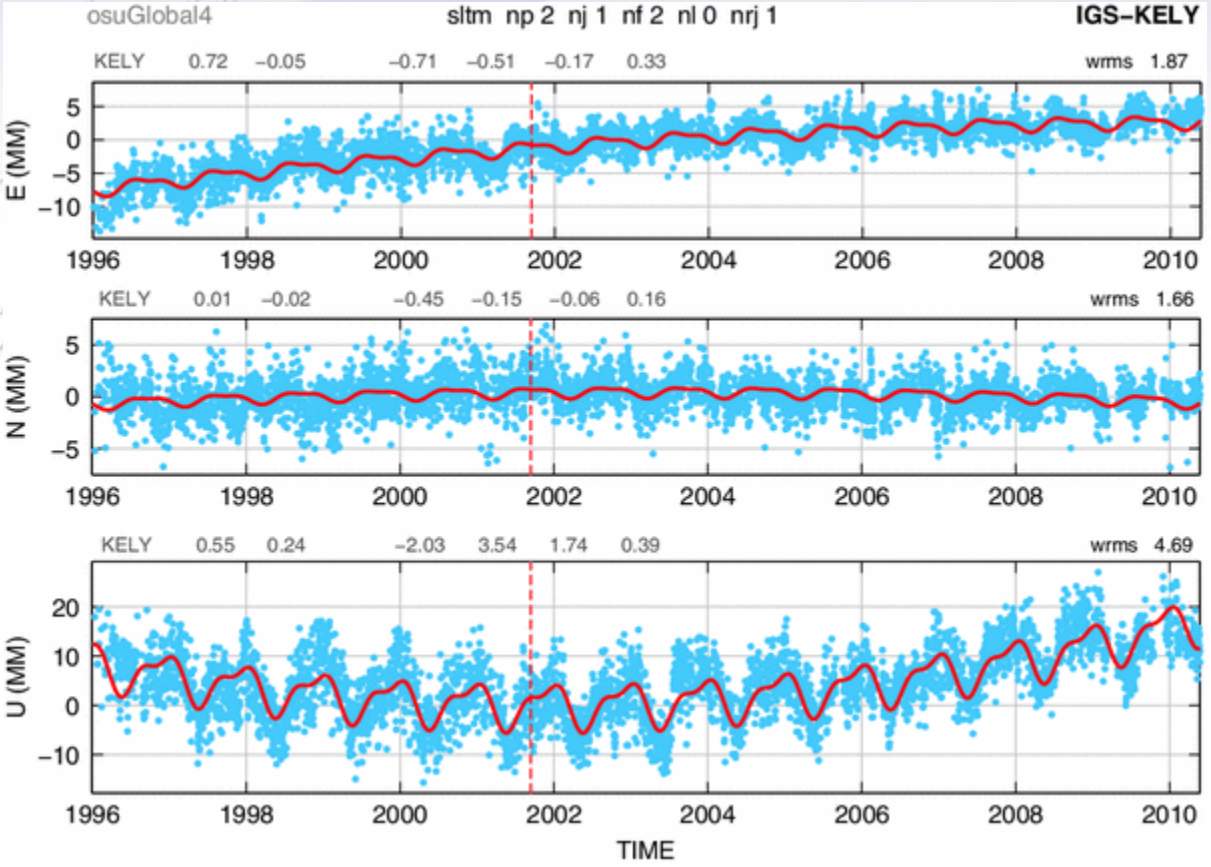


An example of how OSU processes daily data (blue) into "coordinate functions" (red).

Coordinate functions contain:

- Linear terms
- Polynomials (to 4)
- Annual/Semi-Annual
- Exponentials
- Discontinuities

CORS Processing



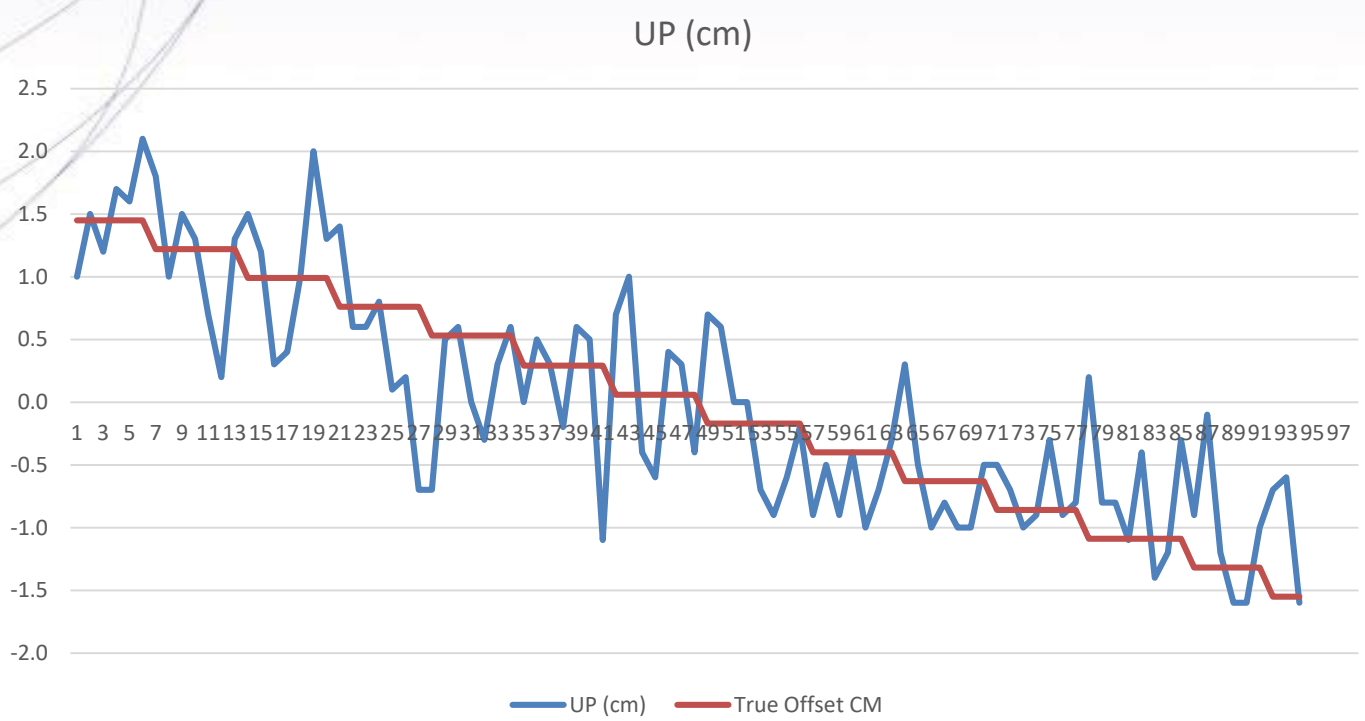
An example of how OSU processes daily data (blue) into "coordinate functions" (red).

Why "1 GPS Month"?

- The NSRS should be more accurate than everything built upon it
- Has everything to do with *systematic* movement of passive marks, not *random* error in GPS
- In order to properly adopt time-dependent coordinates, NGS must pick *some* time span that we call "simultaneous"
- During that time span, the mark must not move systematically (in the ITRF2014 frame) by more than some set threshold

Why "1 GPS Month"?

- What threshold to pick?
  - Do NOT confuse *random* errors with *systematic* movement



To the left is a daily set of GPS-derived heights (blue) collected from an antenna which was systematically lowered by 1 mm every week over 14 weeks.

Random error: +/- 0.5 cm (OP)

See that the "mm/week" trend is definitely manifest in the blue curve, despite the "half cm of noise"!

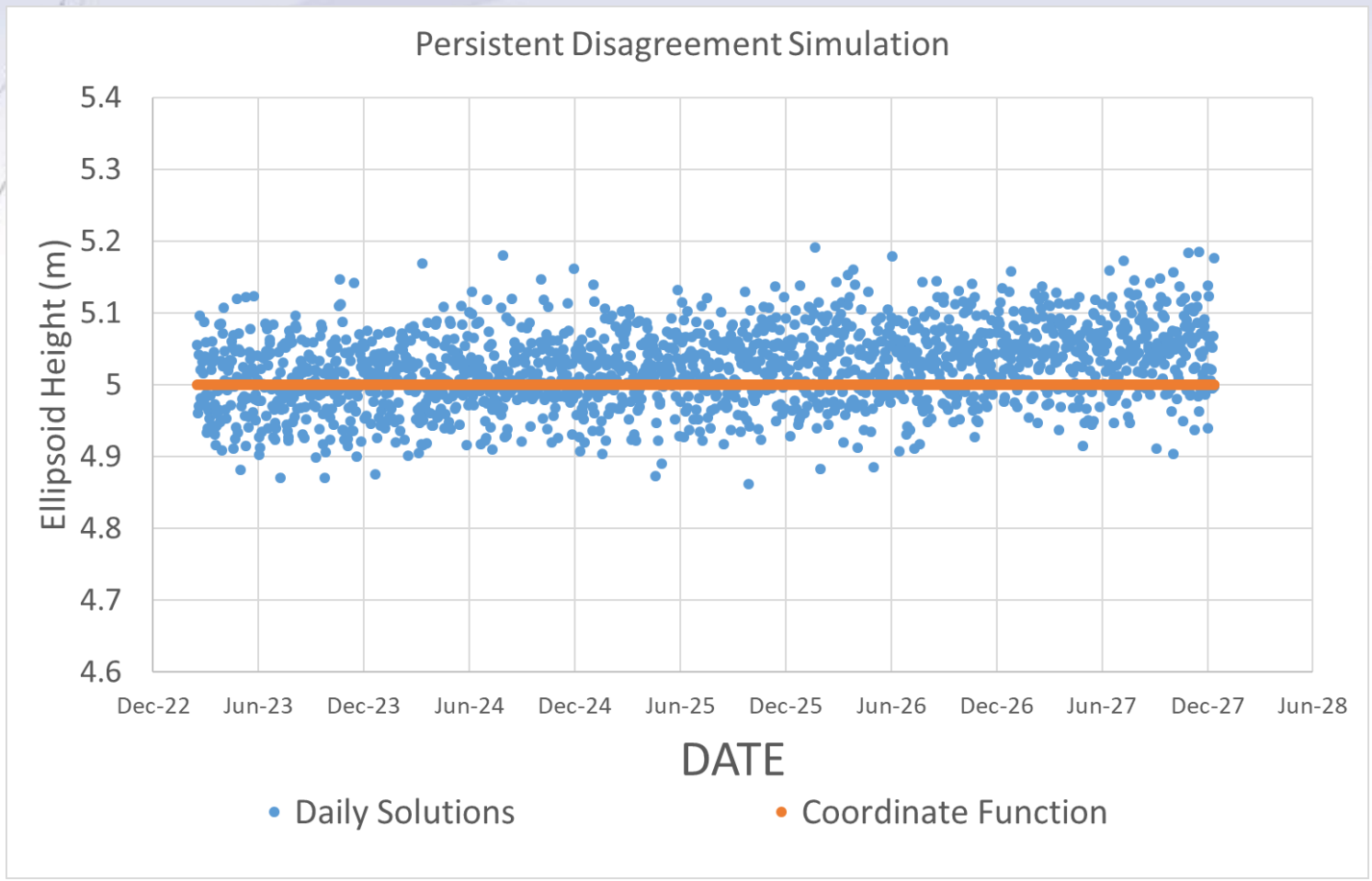
Why "1 GPS Month"?

- What threshold to pick?
  - Because we are an agency that has long cared about *millimeters*…
    - See, for example, leveling accuracy. See, for example, XYZ coordinates of all CORSs.
  - Because *one half millimeter* is the most systematic error one can absorb before rounding error could make you "off by a millimeter"…
  - Because GPS *noise* is not the same as systematic mark movement…
  - Because a SOP which works for the *worst* case will work for *all* cases…
  - Because the "worst case" (fastest horizontal movement) in the USA is in Hawaii at 0.5 mm in 3 days…
  - Because the "worst case" (fastest subsidence we've ever observed in the USA) is around 0.5 mm in 1 day…
  - The right answer should be "1 day", but instead…
  - NGS has proposed that we call "1 GPS Month" as "Simultaneous", which is worse than the "1 day" or even "3 days" we should use, but which is a round number, easy to work with and not too far outside of capturing 0.5 mm of movement everywhere in the USA.
    - Plus when we do the "GPS month" adjustments, we will ALSO introduce the IFVM, which will help account for any systematic movement over the four week time span
    - And four weeks is the median length of time of most projects turned in to NGS

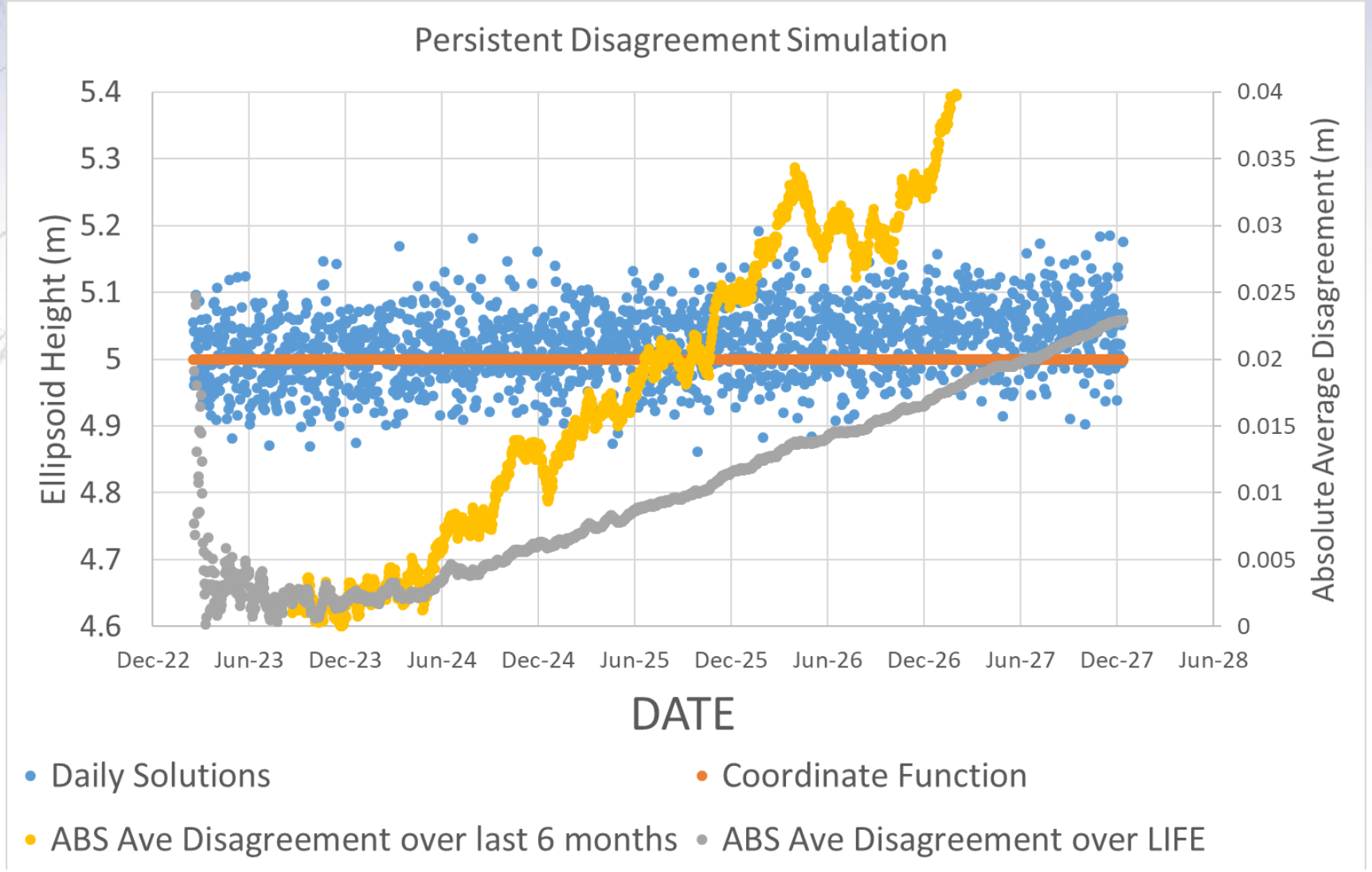
New Way of Operating The CORS Network

- 100% of CORS available to OPUS every day will pass a regular statistical test for ***persistent disagreement***
  - One ***possible*** definition of "persistent disagreement": *For 14 days in a row, the absolute value of the average of the difference between "daily solutions" and the "coordinate function" assigned to that CORS, since the last known discontinuity at that CORS, exceeds 5 mm in latitude or longitude or 10 mm in ellipsoid height*
    - *Just as reasonable, we **might** say "…since the last 6 months…" rather than "…since the last known discontinuity…" – More on that later.*
    - If the CORS fails this test ***pull CORS out of OPUS***
      - Watch, evaluate, update coordinate function and get the CORS back into OPUS as soon as the coordinate function has been updated so that the statistical test is passed
      - ***Likely***: Do NOT update function for any days BEFORE the failure, only AFTER. This may mean introducing a *derivative* discontinuity, but not a *functional* discontinuity
        - » This prevents users from having to continually respond to a changing historical function at each CORS

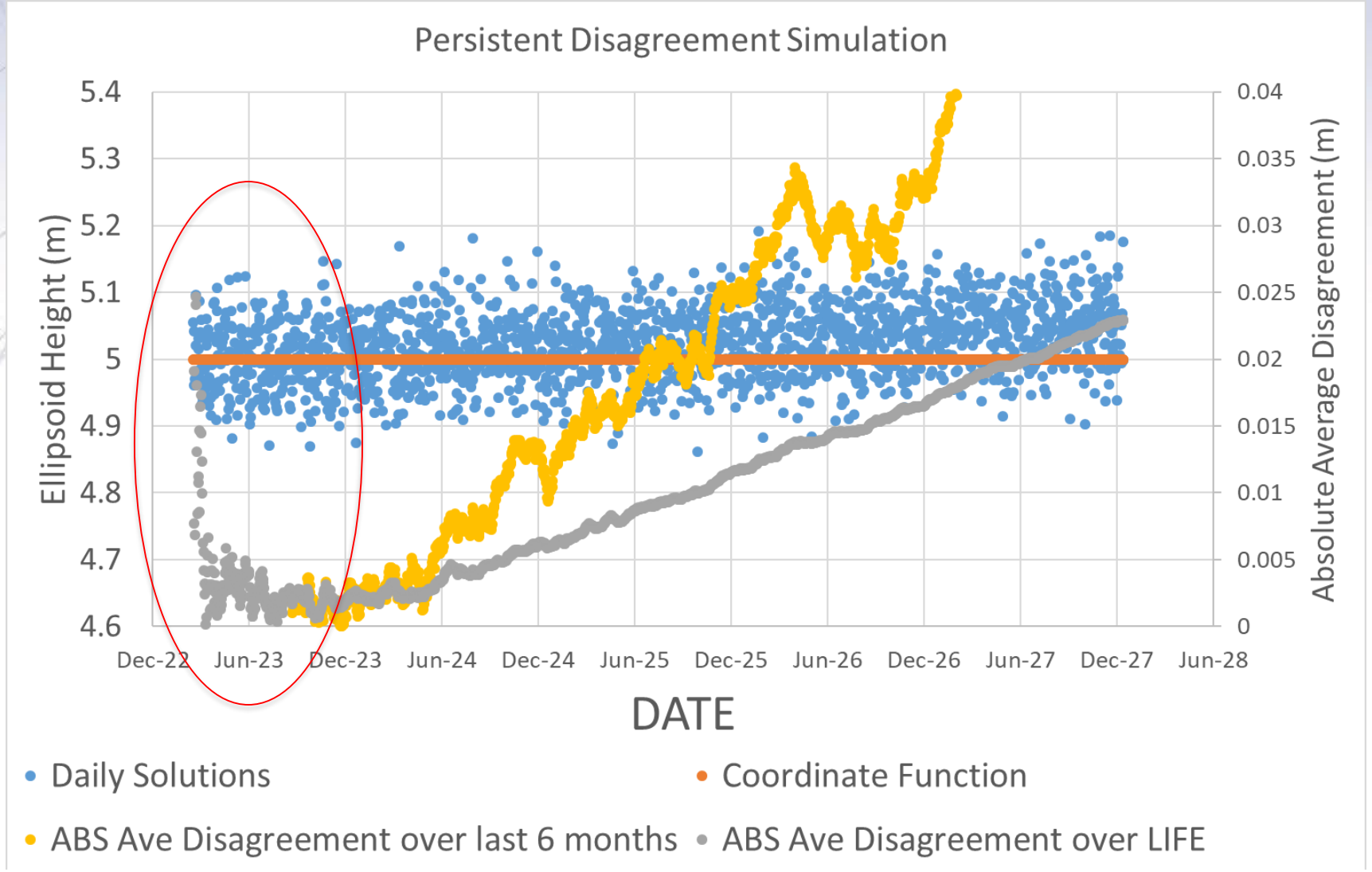
Persistent Disagreement



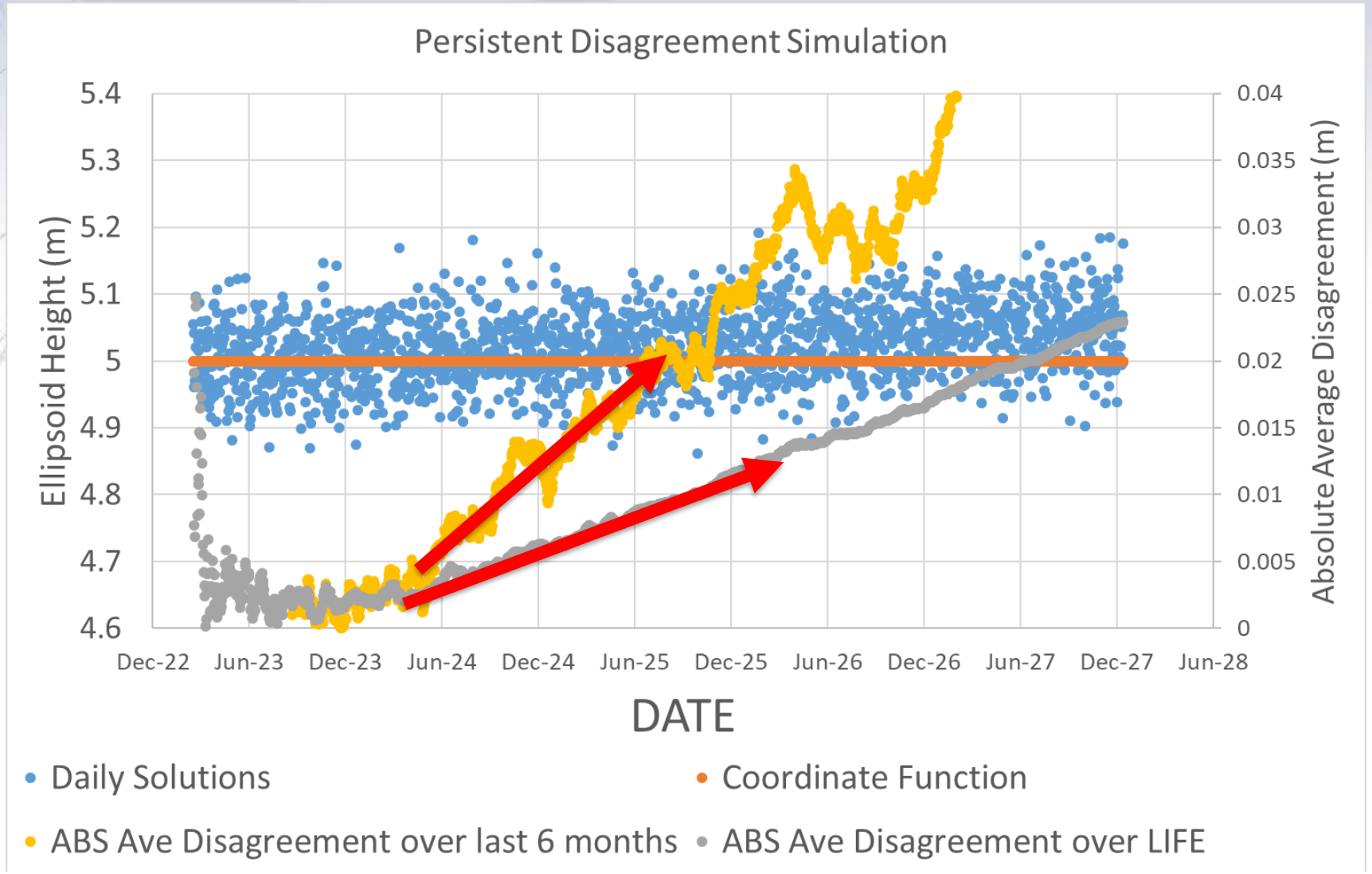
Persistent Disagreement…



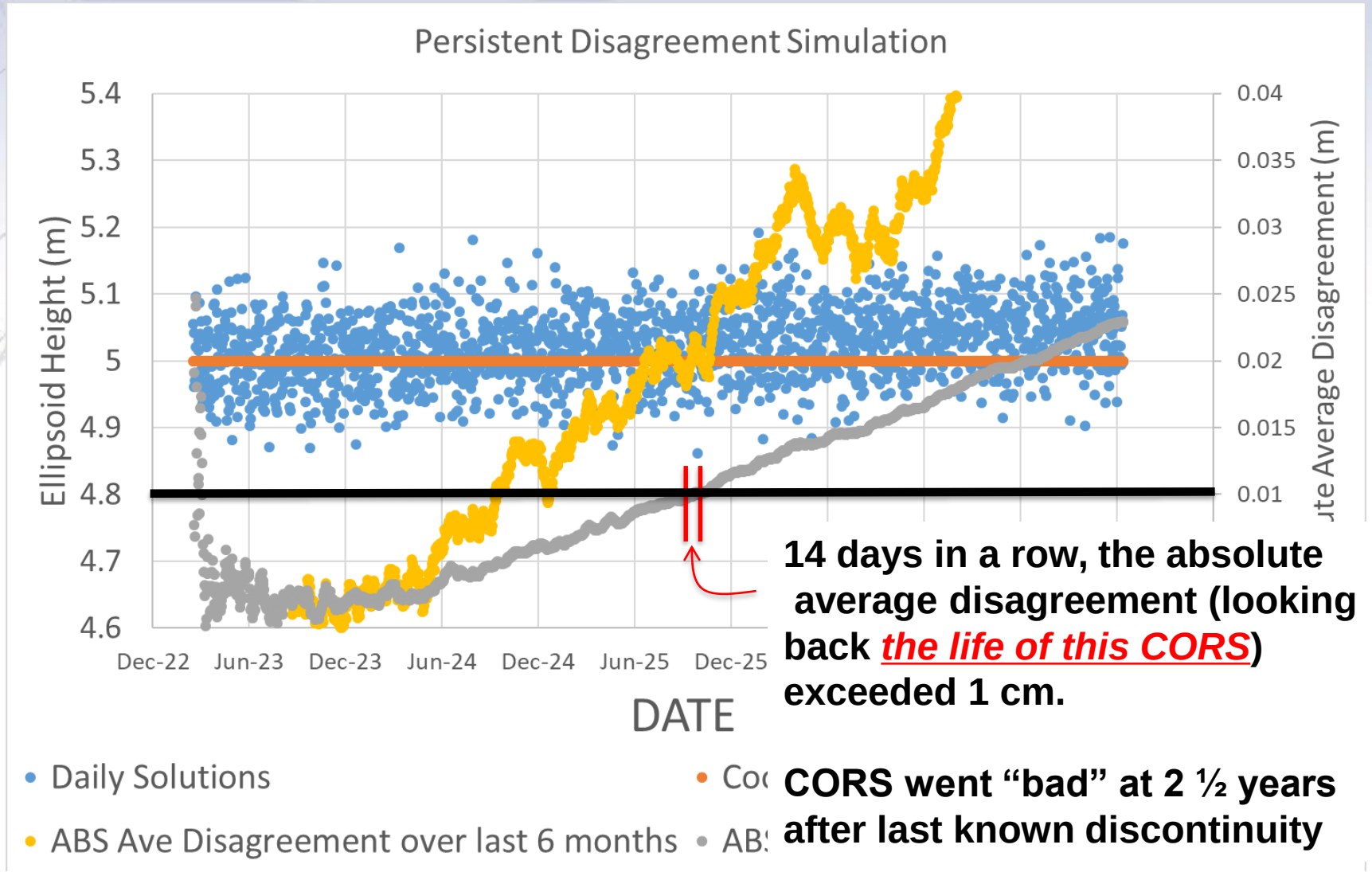
Persistent Disagreement…



Persistent Disagreement…



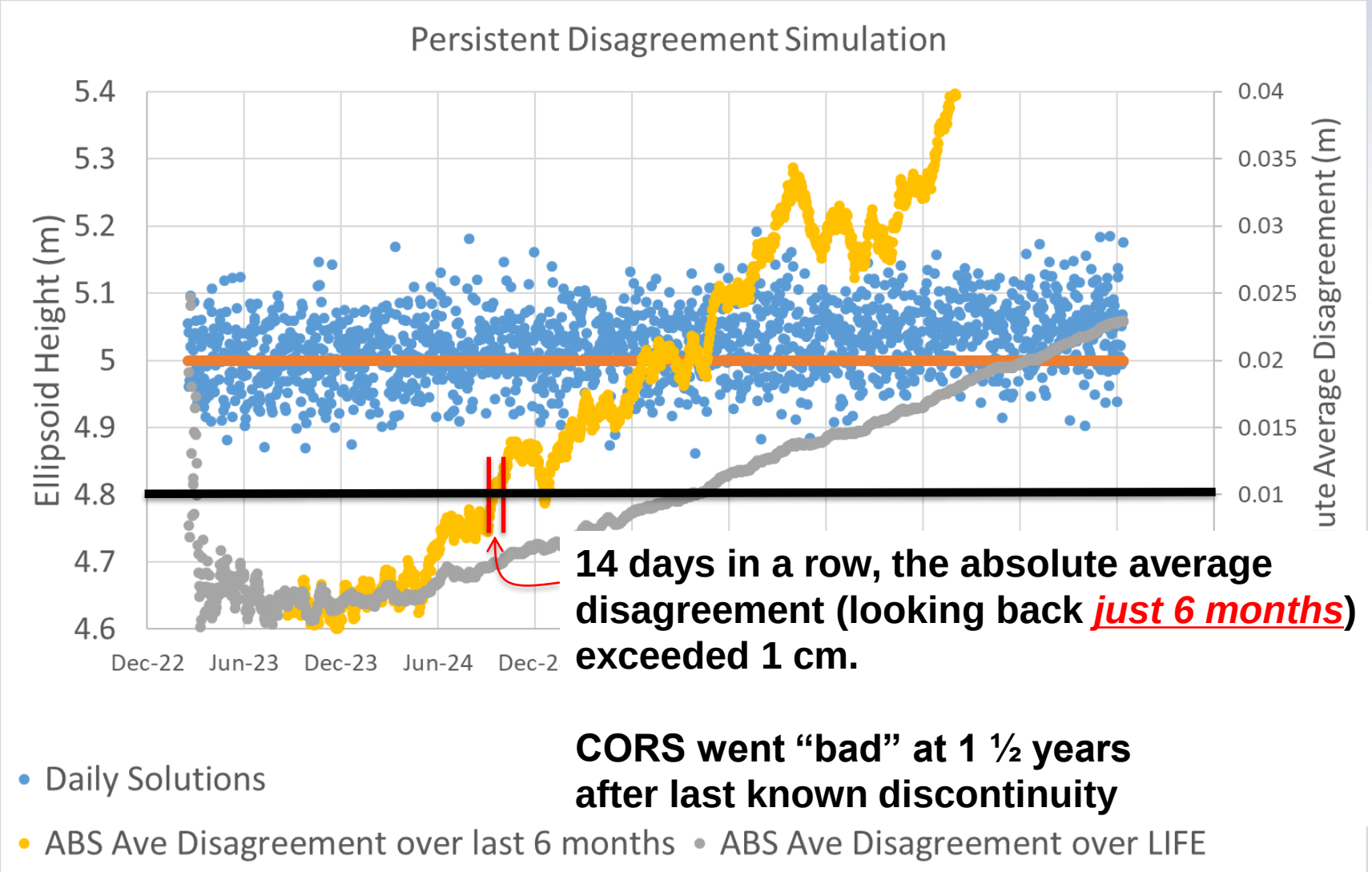
Persistent Disagreement…



14 days in a row, the absolute average disagreement (looking back *the life of this CORS*) exceeded 1 cm.

CORS went "bad" at 2 ½ years after last known discontinuity

Persistent Disagreement…



14 days in a row, the absolute average disagreement (looking back *just 6 months*) exceeded 1 cm.

CORS went "bad" at 1 ½ years after last known discontinuity