Precise GPS Orbit Determination at National Geodetic Survey: How and Why

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(Total 20 Slides)

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Outline

- Precise GPS ephemeris at NGS
  - What is it?
  - How is it done?
  - Why is it done?
  - What is coming?

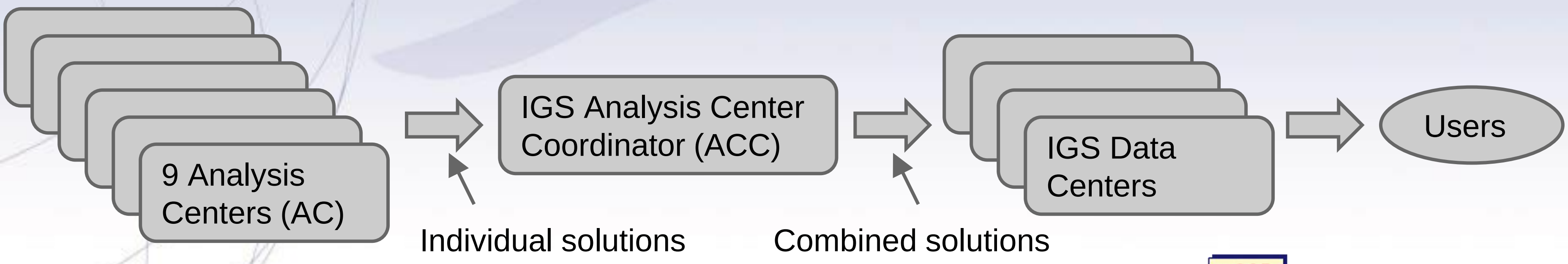
Precise GPS ephemeris at NGS

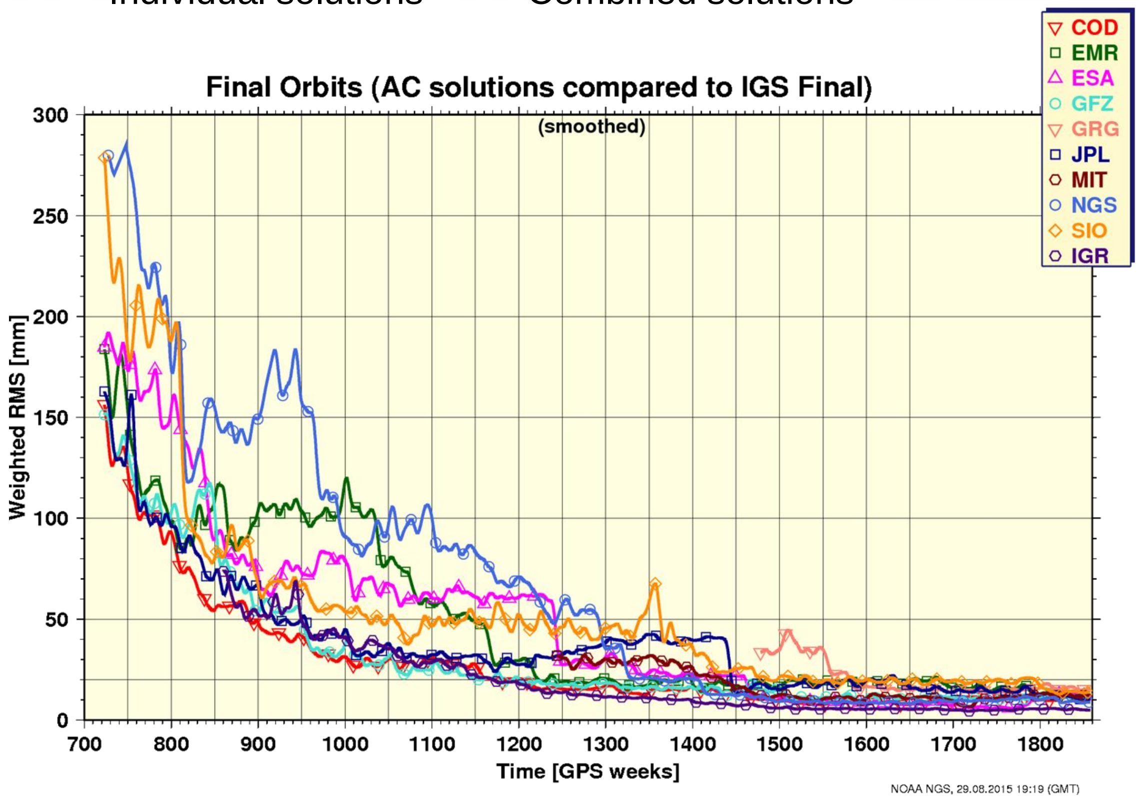
IGS Precise GPS ephemeris

- International GNSS Service (IGS) publishes precise GPS ephemeris

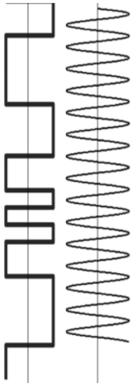
Products	Accuracy	Latency
Ultra-Rapid (predicted half)	~ 5 cm	real time
Ultra-Rapid (observed half)	~ 3 cm	3 ~ 9 hours
Rapid	~ 2.5 cm	17 ~ 41 hours
Final	~ 2.5 cm	12 ~ 18 days

Analysis Center at NGS





How is it done?

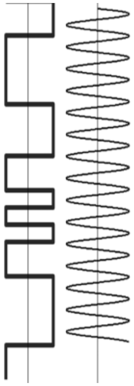


Precise modeling of GPS satellites (1/4)

- Geopotential model
  - EGM2008 12x12
- Solar radiation pressure model
  - Modified CODE model
- Transmission antenna phase center model
  - Absolute phase center variation model from IGS
- Eclipsing satellites
  - Observations from eclipsing satellites are deleted

Precise modeling of GPS signal (2/4)

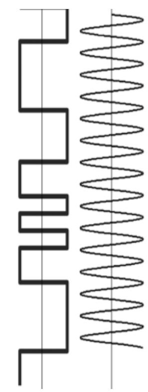
- Tropospheric path delay
  - Saastamoinen model
  - Vienna Mapping Function (VMF1)
- Ionospheric path delay
  - First-order effect is removed using linear combination of dual-frequency phase
  - Higher-order effect is ignored



- Relativistic effect
- Carrier-phase wind-up effect

Precise modeling of GPS antenna (3/4)

- Metadata book-keeping
  - Antenna type
- Receiver antenna phase center model
  - Absolute phase center variation model from IGS

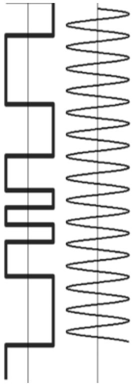


- Tidal displacements
  - Solid Earth tide
  - Permanent tide
  - Solid Earth pole tide
  - Ocean pole tide
  - Ocean tide loading
  - Ocean tide geocenter

- Data from ~230 globally distributed IGS stations are processed daily

Algorithms (4/4)

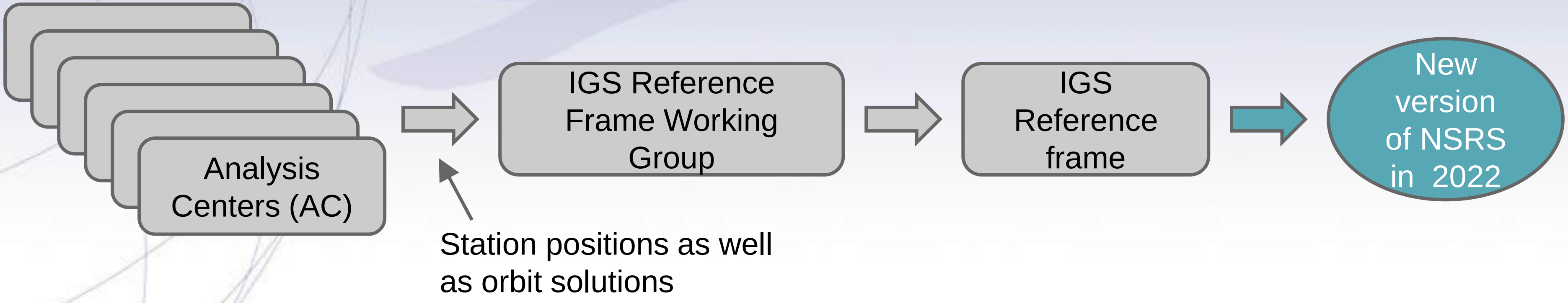
- Basic observables
  - Double-differenced ionosphere-free carrier phase
- Ambiguity resolution
  - Melbourne-Wübbena widelane method



- Adjusted parameters
  - GPS orbit
  - Station coordinates
  - Earth rotation parameters
  - Tropospheric correction parameters
  - Real-valued ambiguities for any ambiguities not fixed
  - Solar radiation pressure model parameters

Why is it done?

Defining Reference Frame (1/3)



- The Mission of NGS is "to define, maintain and provide access to the **National Spatial Reference System**".
- NGS is working toward new geometric and geopotential reference frame in 2022 and they will be closely tied to IGS reference frame.
- NGS is an active participant of IGS

Understanding Space Segment (2/3)

- GPS infrastructure
  - User segment
  - Control segment
  - Space segment
- As nation's permier geodetic agency, we seek to have complete understanding of space segment.
- GPS orbit determination works as test bed for new models

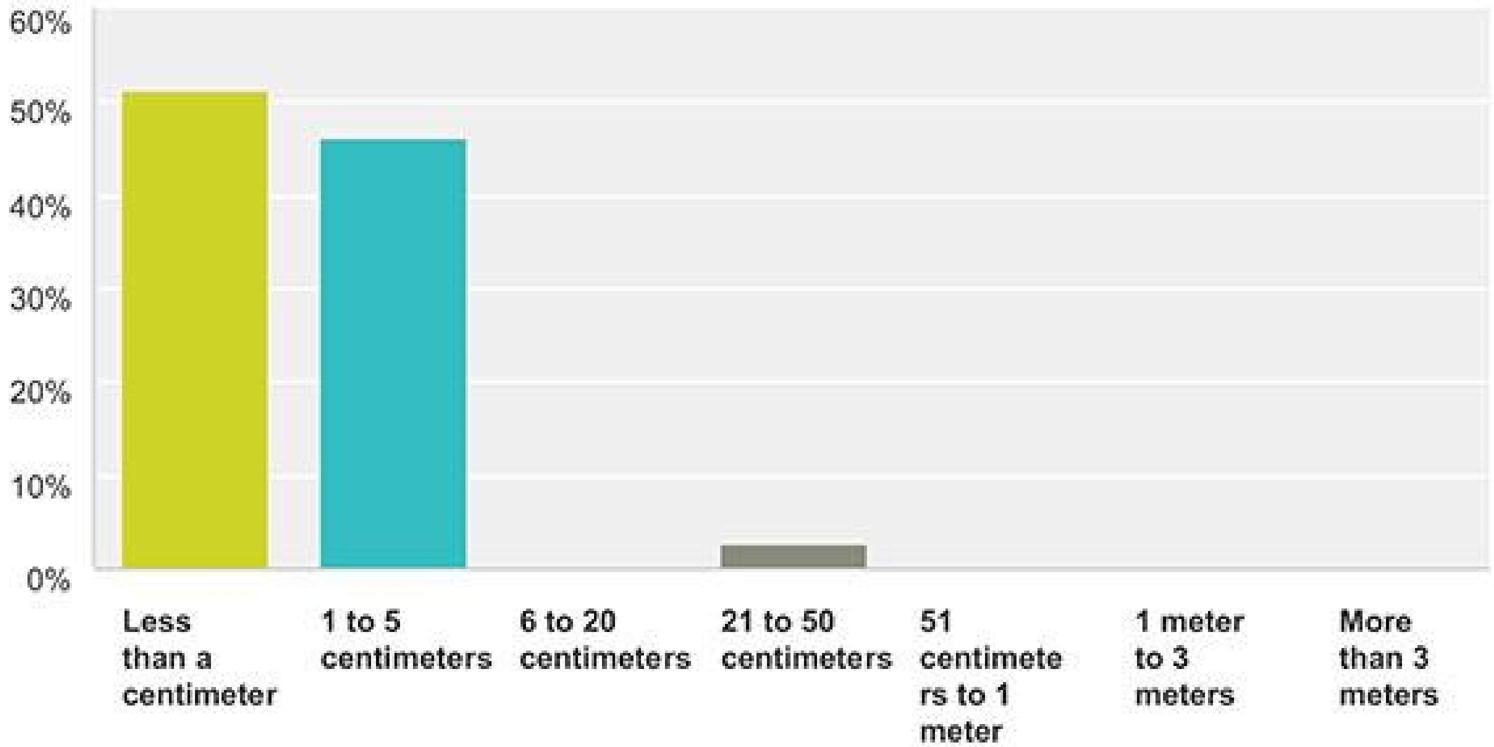
Importance of GPS Ephemeris (3/3)

- All positioning using GNSS signal starts from the location of the transmitter - which is the position of the GNSS satellites.
- Precise positioning requires precise GPS ephemeris.
- In RTK, position of the reference stations provide access to the reference frame. In PPP, GPS ephemeris provides access to the reference frame.
- NGS needs to keep the capability to produce and improve this crucial information.

What is coming?

GNSS User Expectation 1 - Survey Community

[Q] How accurate is good enough for the majority of "Survey and High Precision" sector? [from GPS World, September 2015]



GNSS User Expectation 2 - Science Community

- Positioning precision to meet current and future scientific requirements:

  1 mm post-processing (24 hour averaging)
  1 cm near real-time (a few second latency)

  [Quoted from "Precise Geodetic Infrastructure: National Requirements for a Shared Resource, page 72, National Research Council Report 2010]

Multi GNSS Constellation

- Global Navigation Satellite System (GNSS)
  - GPS (USA) - currently operational
  - GLONASS (Russia) - currently operational
  - Galileo (Europe) - fully operational by 2020
  - BeiDou (China) - fully operational by 2020

Future Activities at NGS

- Next generation GNSS processing engine

- Multi GNSS constellation processing capability
  - New models for GNSS constellations
  - Pseudorange biases among GNSS constellations
  - GNSS antenna calibration

Summary

- NGS has been generating precise GPS ephemeris since 1991.
- How → Precise modeling of GPS satellites, GPS signal, GPS antenna and geophysical effects with data from ~230 globally distributed IGS stations
- Why → To define reference frame, To understand GPS space segment and because precise positioning starts from precise GPS ephemeris.
- NGS is working hard to meet future demands.

References

William G. Kass, et al., **Global GPS data analysis at the National Geodetic Survey**, Journal of Geodesy, 2009

Alan Cemeron, **More, More, More. Accuracy, Accuracy, Accuracy.**, GPS World, September, 2015

National Research Council, **Precise Geodetic Infrastructure: National Requirements for a Shared Resource**, National Academies Press, 2010