



A NEW TECHNIQUE FOR GPS-BASED ORBIT DETERMINATION OF GEOSCIENCE SPACECRAFT

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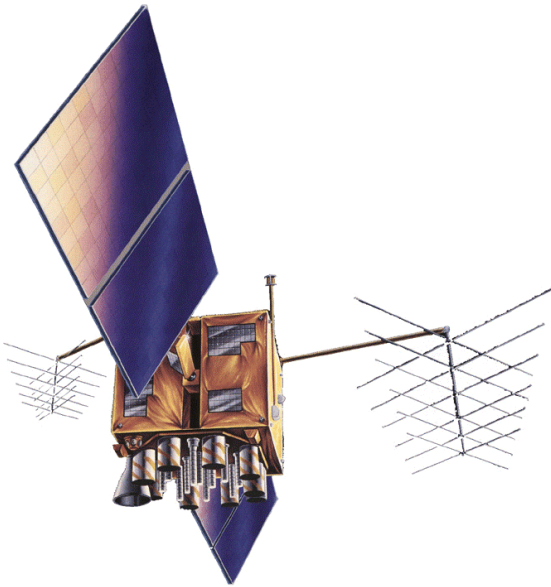
24-28 June 2001, Fredericton, New Brunswick



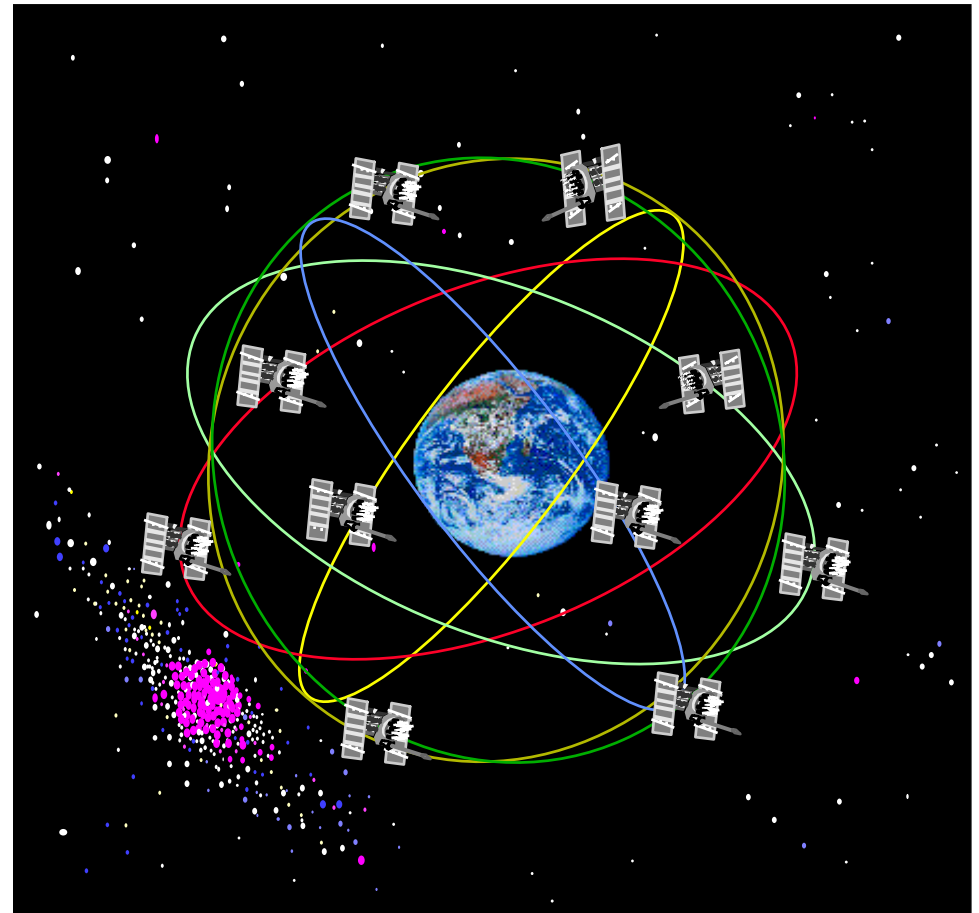
OVERVIEW



- Principles of the Global Positioning System.
- Uses of GPS data collected onboard geoscience spacecraft.
- Developed GPS data infrastructure.
- An implementation of the infrastructure:
The geometric orbit determination technique.
- Preliminary results.
- Conclusions.
- Acknowledgements.

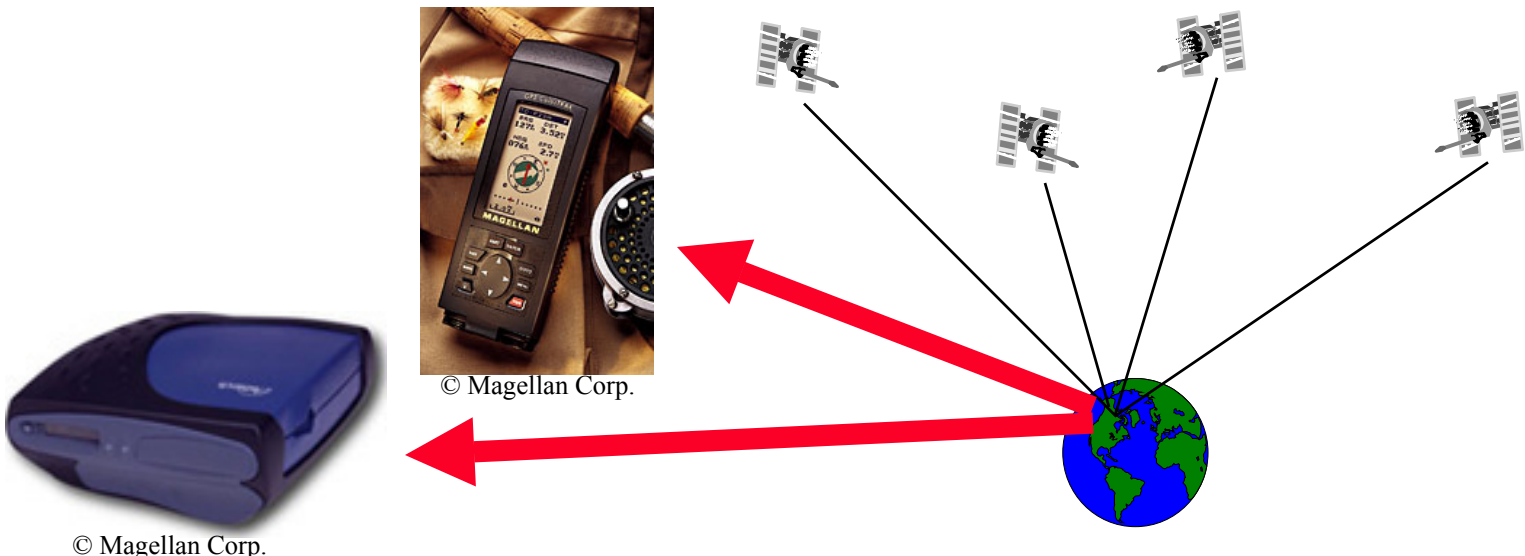


Block II-R satellite



Schematic of the GPS constellation

- GPS is possible for many reasons, the most important of which is precise, accurate timing.
- Atomic clocks on the GPS satellites and crystal clocks in GPS receivers are used to compute the travel time of electromagnetic waves, hence range.
- The combination of range measurements in a mathematical filter allows for receiver position and time to be estimated.



**GPS
measurement**

**low precision (10s of cm),
unambiguous
*pseudoranges***

**high precision (sub-mm),
ambiguous
*carrier phases***

**measurement
constituents
which must be
estimated or
eliminated**

- satellite position error
- satellite clock
- receiver clock
- troposphere
- ionosphere
- multipath
- receiver noise
- ...

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PSEUDORANGE POINT POSITIONING



**GPS
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few-metre accuracy

**measurement
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- **satellite position error** ×
- **satellite clock** ×
- **receiver clock** ×
- **troposphere** ×
- **ionosphere** ×
- **multipath**
- **receiver noise**
- ...

× partially addressed

×× fully addressed



**GPS
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centimetre accuracy

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- **troposphere** × ×
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- **receiver noise**
- **carrier-phase ambiguity** × ×
- ...
- ...

× partially addressed

× × fully addressed



- The following data can be collected by placing a GPS receiver modified for spaceflight (a *spaceborne* GPS receiver) aboard a Low Earth Orbiter (LEO) spacecraft:
 - **Orbit determination** (position and velocity).
 - Real-time [few-metre-level].
 - Post-processed [decimetre-level].
 - **Attitude determination** [sub-degree-level].
 - **Timing** [sub-microsecond-level].
 - **Ranging information** between spacecraft and GPS satellites for GPS signals transiting the atmosphere.



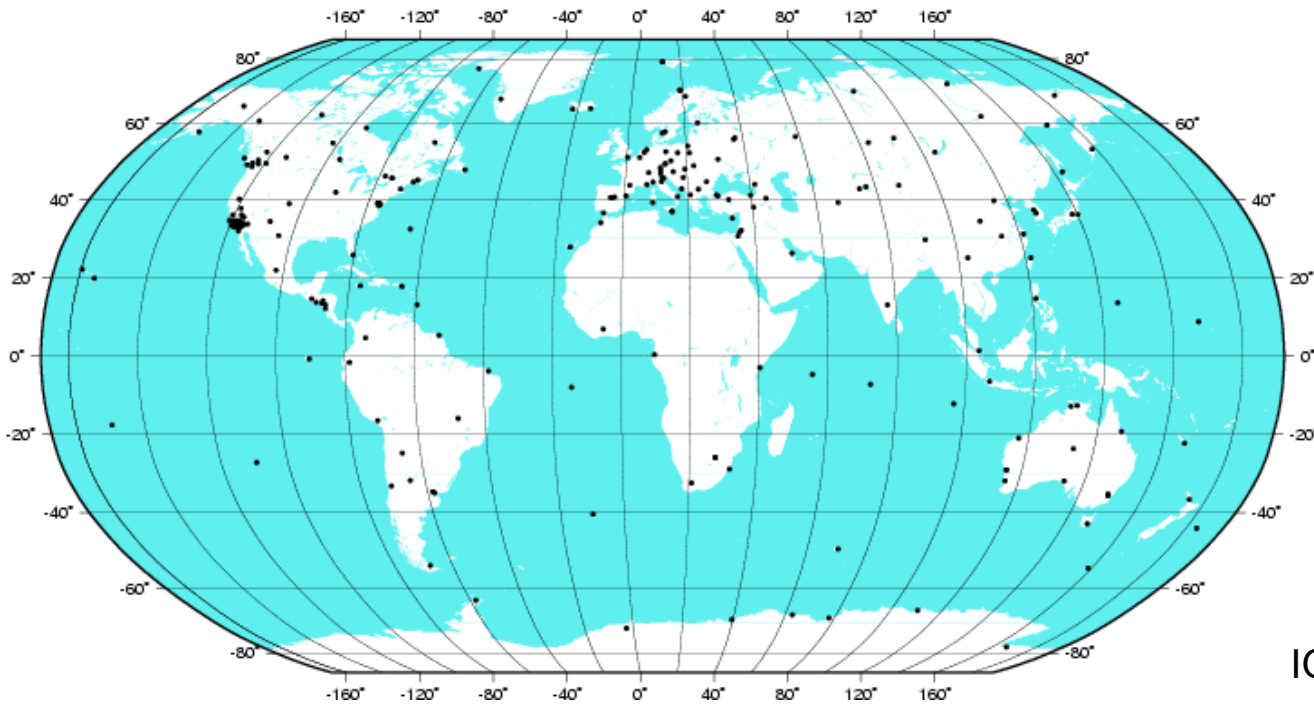
- Gravity field recovery and geoid determination.
- Radar and laser altimetry.
- Interferometric Synthetic Aperture Radar positioning.
- Other remote sensing instrumentation positioning.
- Time-tagging and synchronization of scientific sensor measurements.
- Ionospheric limb sounding.
- Tropospheric limb sounding.
- Sea-surface profiling.



SPATIAL DATA INFRASTRUCTURE PROVIDED BY THE INTERNATIONAL GPS SERVICE (IGS)



- The IGS is an association of worldwide scientific organisations:
 - Promoting:
 - International standards for GPS data acquisition and analysis.
 - Deployment and operation of a common, comprehensive global tracking system.
 - Providing:
 - GPS orbits.
 - Tracking data.
 - Other high-quality GPS data and data products on-line, in near-real-time.



IGS tracking network

- IGS data products of interest:
 - Precise GPS satellite orbits.
 - Precise GPS satellite clock corrections.



- Purely *geometrical*, GPS-based solution.
- Simultaneously:
 - Utilize *code* data to compute LEO *position*,
 - and *carrier* data to compute LEO *position change*,
 - in a kinematic sequential least squares filter/smoothing.
- Inputs (all *readily available* aside from LEO data):
 - Dual-frequency code and carrier measurements from LEO receiver.
 - Precise GPS constellation ephemerides.
 - Precise GPS constellation satellite clock offsets from GPST.
- Interpolate GPS-determined positions for LEO state throughout orbit.



CARRIER-PHASE-CONNECTED, PSEUDORANGE POINT POSITIONING



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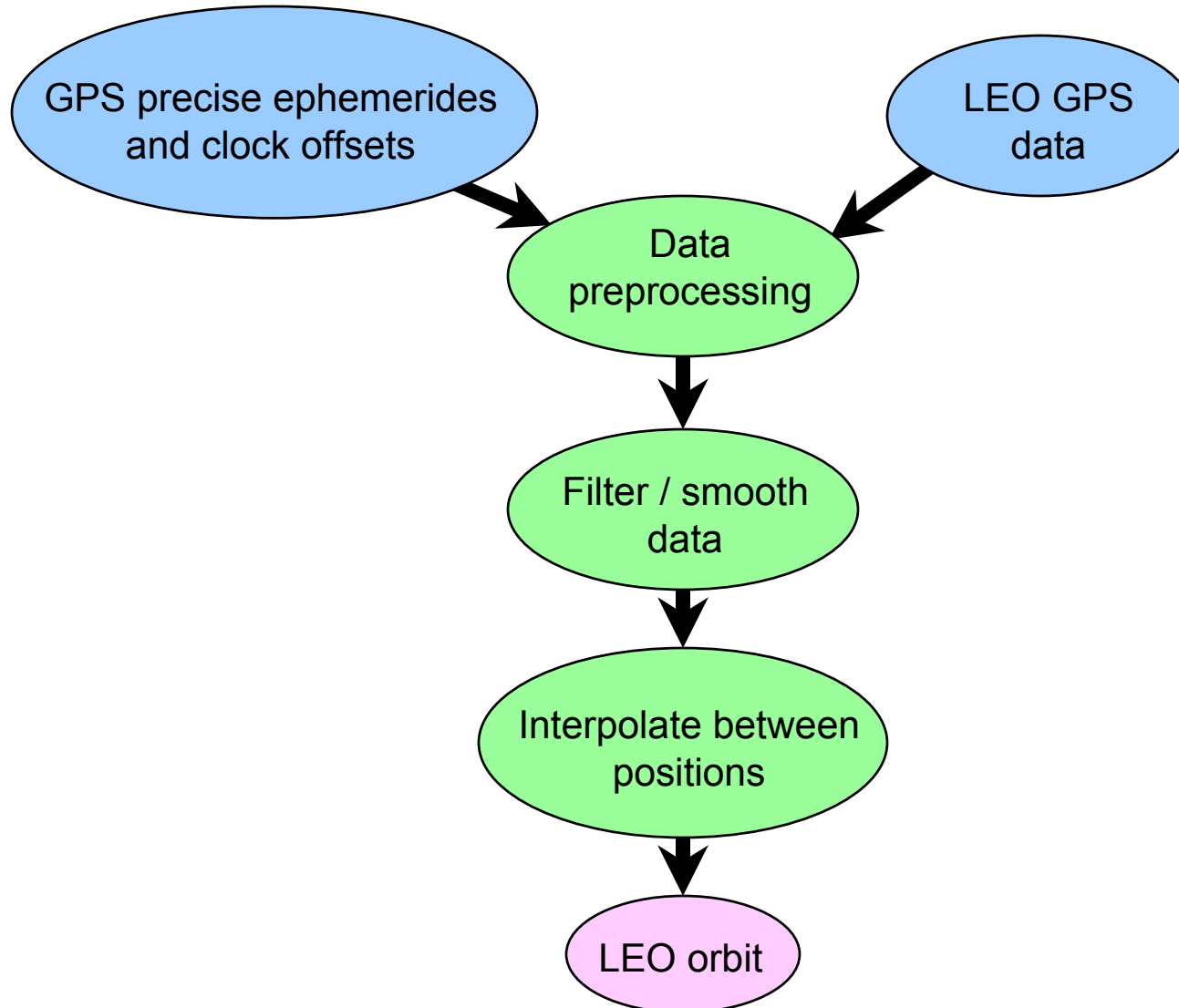
decimetre accuracy

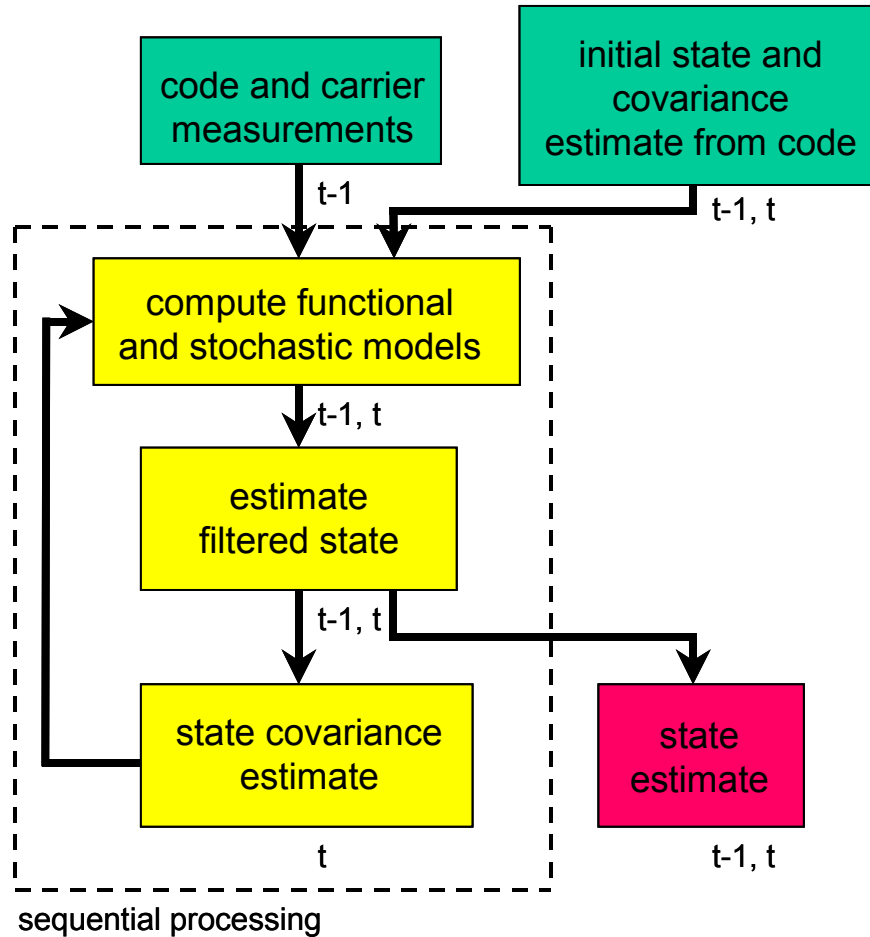
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- satellite position error × ×
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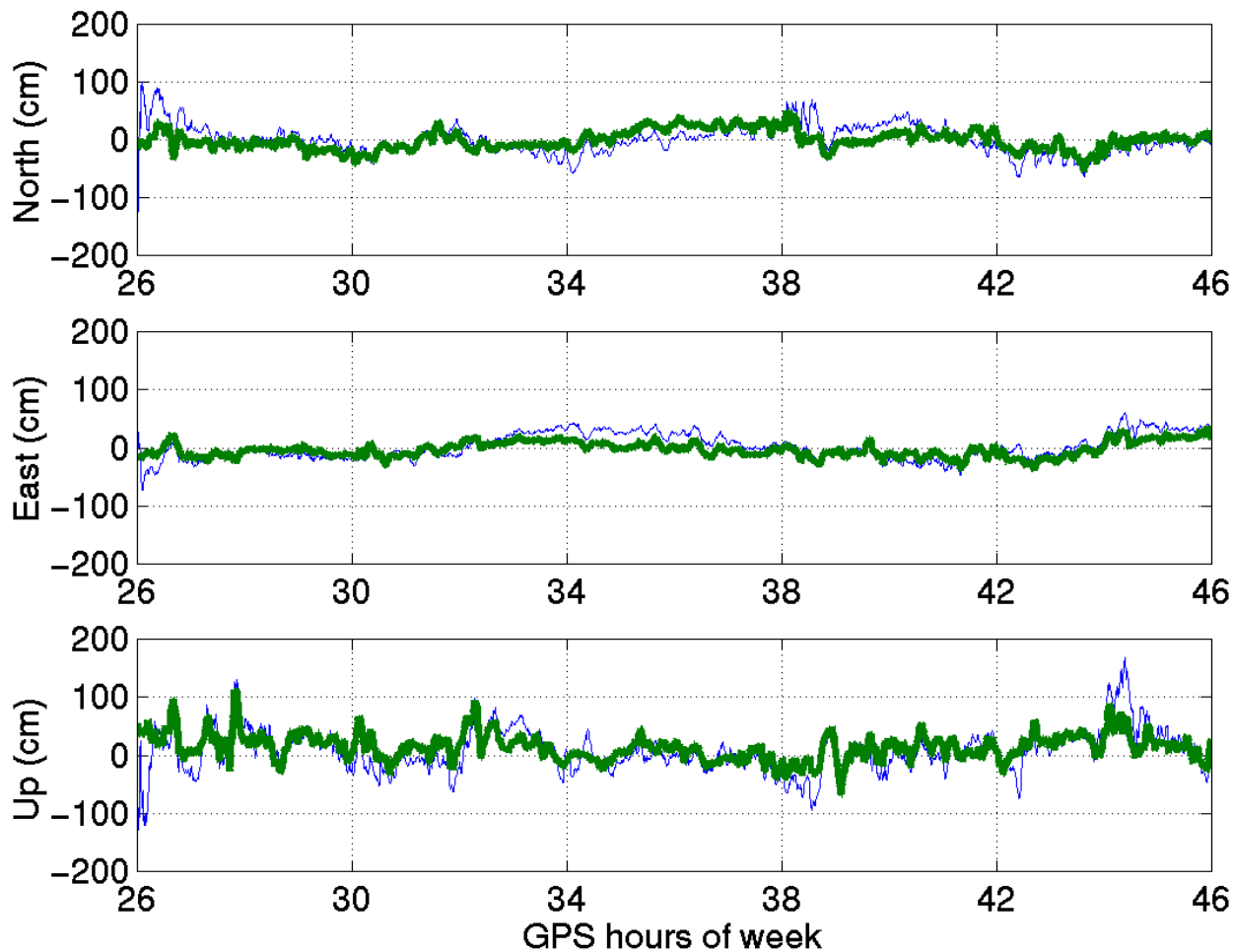
- × partially addressed
- × × fully addressed



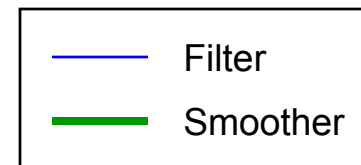


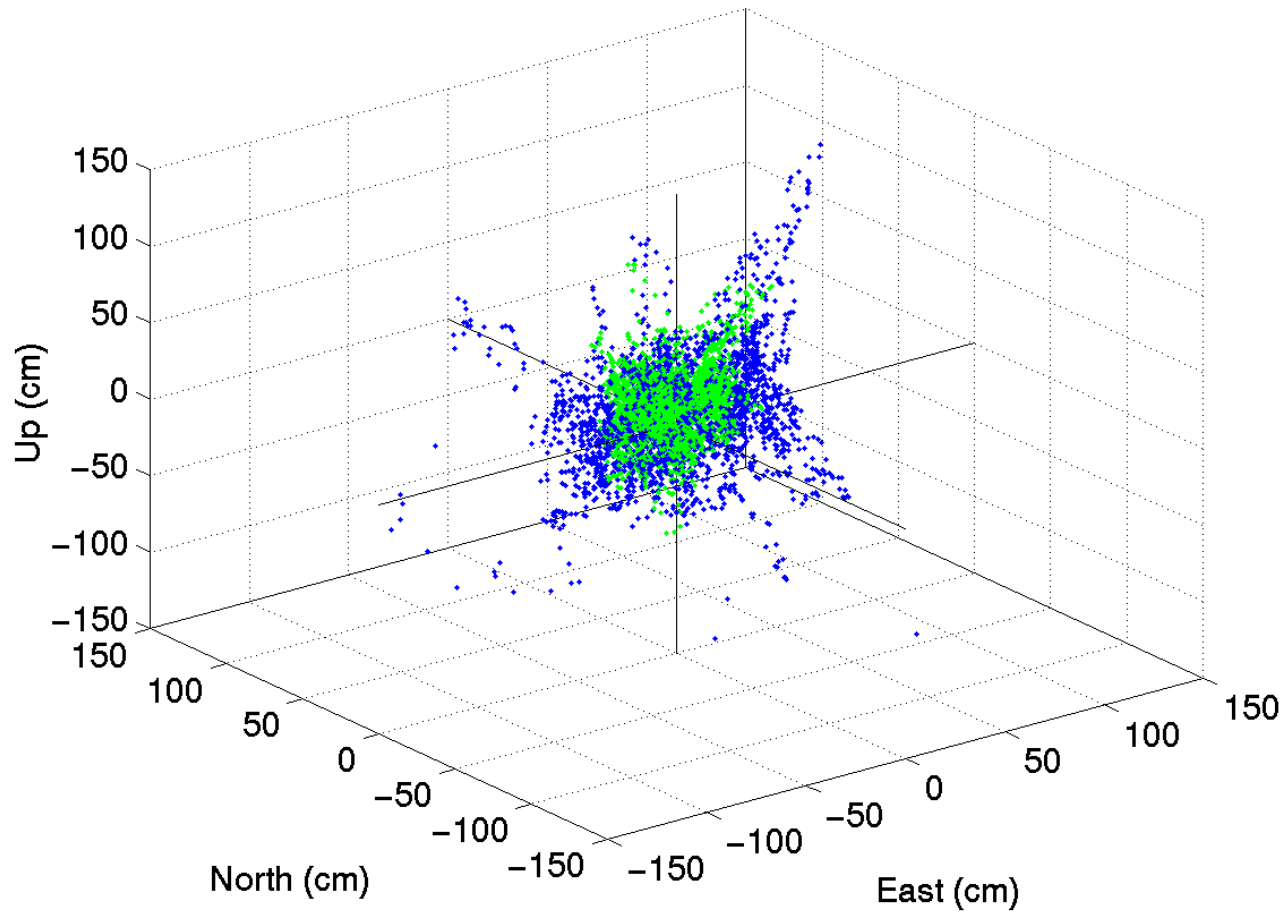


- Data description:
 - One day of dual-frequency data from station Algonquin (ALGO) located at 45.96° N, 78.07° W in central Ontario, Canada.
 - 7 August 2000.
 - 30 second data interval.
 - 5° elevation angle mask.
 - IGS precise GPS satellite orbits and clock offsets.
- Processing:
 - Use of UNB3 tropospheric prediction model; residual delay not estimated.
 - Investigate repeatability of position computations.
 - Test performance of technique against most accurate geodetic techniques.

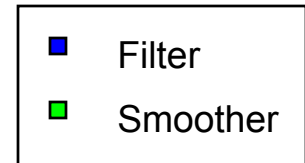


r.m.s. (cm)	Filter	Smoother
North	24.5	16.8
East	21.9	13.3
Up	37.2	26.7
Hor.	32.9	21.4
3-D	49.6	34.2





Bias (cm)	Filter	Smoother
North	0.8	-1.1
East	1.6	-3.5
Up	7.3	13.7
Hor.	1.8	3.7
3-D	7.5	14.2

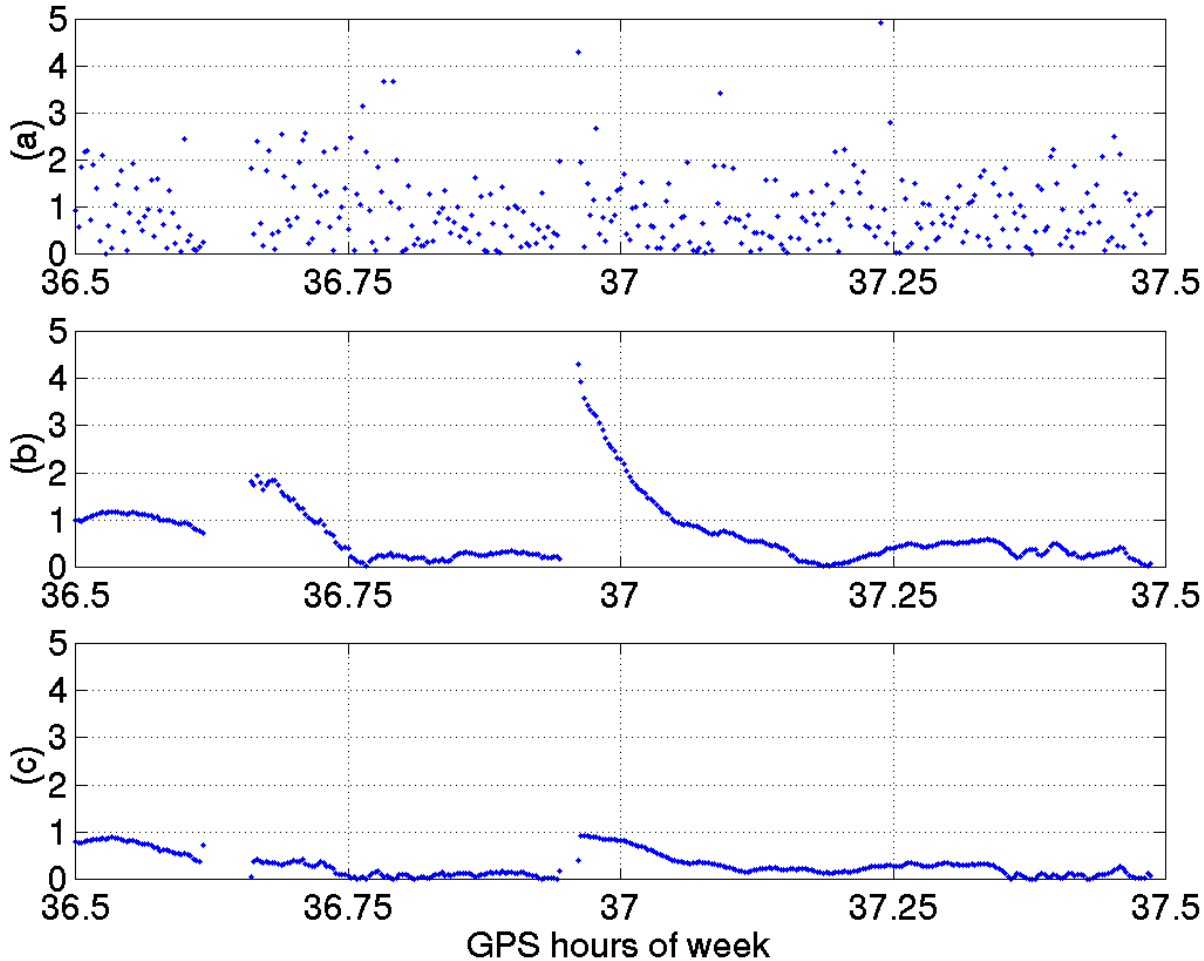




- Data description:
 - One day of single-frequency data from Topex/Poseidon (altitude 1335 km).
 - 13 November 2000.
 - 300 second data interval.
 - No elevation angle mask.
 - IGS precise GPS satellite orbits and clock offsets.
- Processing:
 - Investigate the geometric strength of measurements.
 - Test practicality and performance of technique against JPL high-quality orbit.



TOPEX/POSEIDON SATELLITE ORBIT ERROR



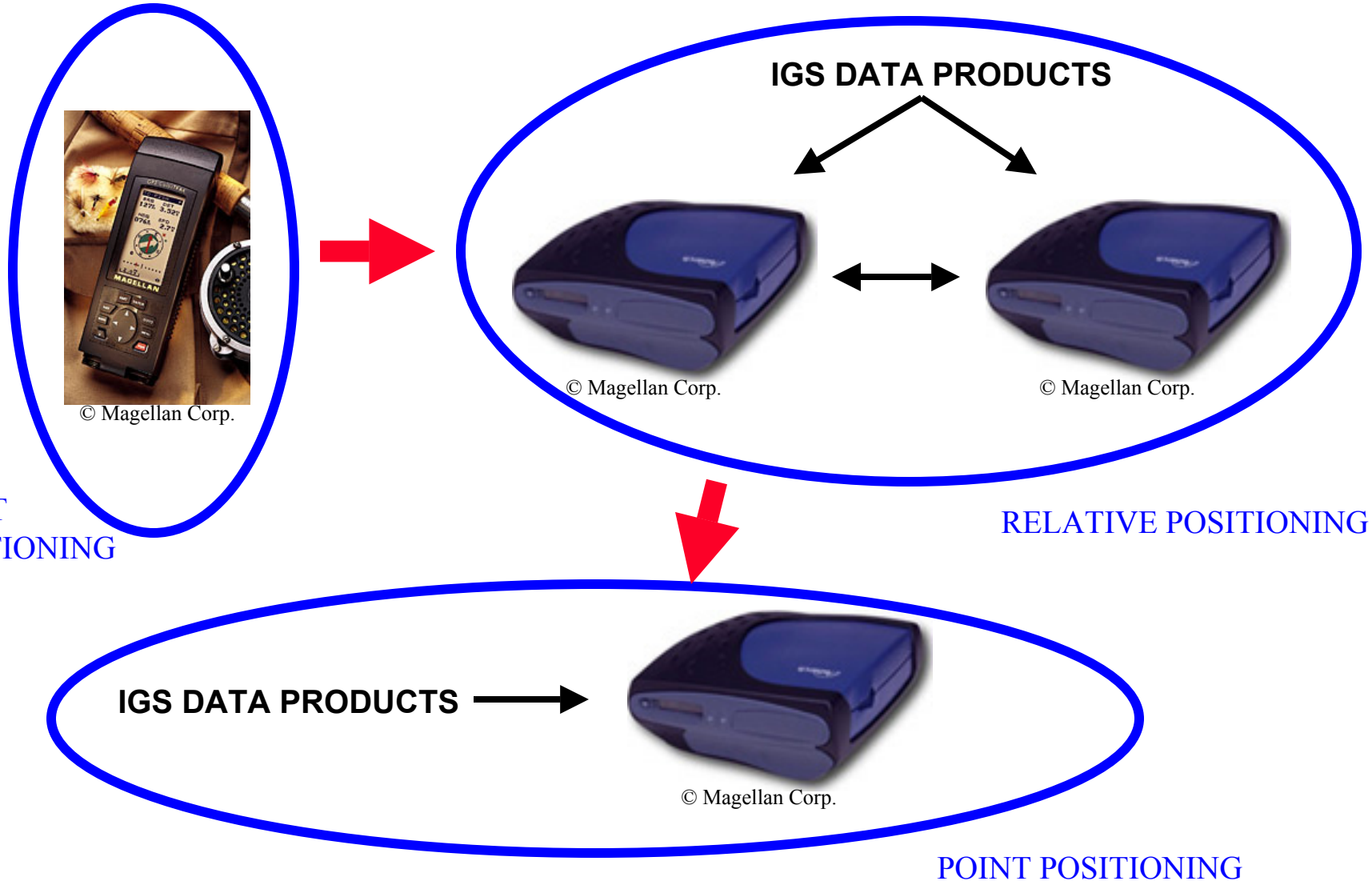
sol'n (cm)	3dr.m.s.
(a) code	154
(b) filter	43
(c) smoother	33



CONCLUSIONS



- Geometric orbit determination strategy proposed.
- Kinematic, sequential least-squares filter described.
- Static, terrestrial state testing indicates few-decimetre position component r.m.s. and few-centimetre overall position bias. Promising results.
- Preliminary spaceborne data testing indicates few-decimetre total displacement r.m.s. Envisage decimetre-level position component r.m.s.
- Dynamics-free nature of filter allows for application of technique to any platform.



POINT
POSITIONING

RELATIVE POSITIONING

POINT POSITIONING



ACKNOWLEDGEMENTS



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