Using SBAS to Enhance GBAS User Availability: Results and Extensions

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EIWAC 2010 **Tokyo, Japan**

Paper EN-030

12 November 2010

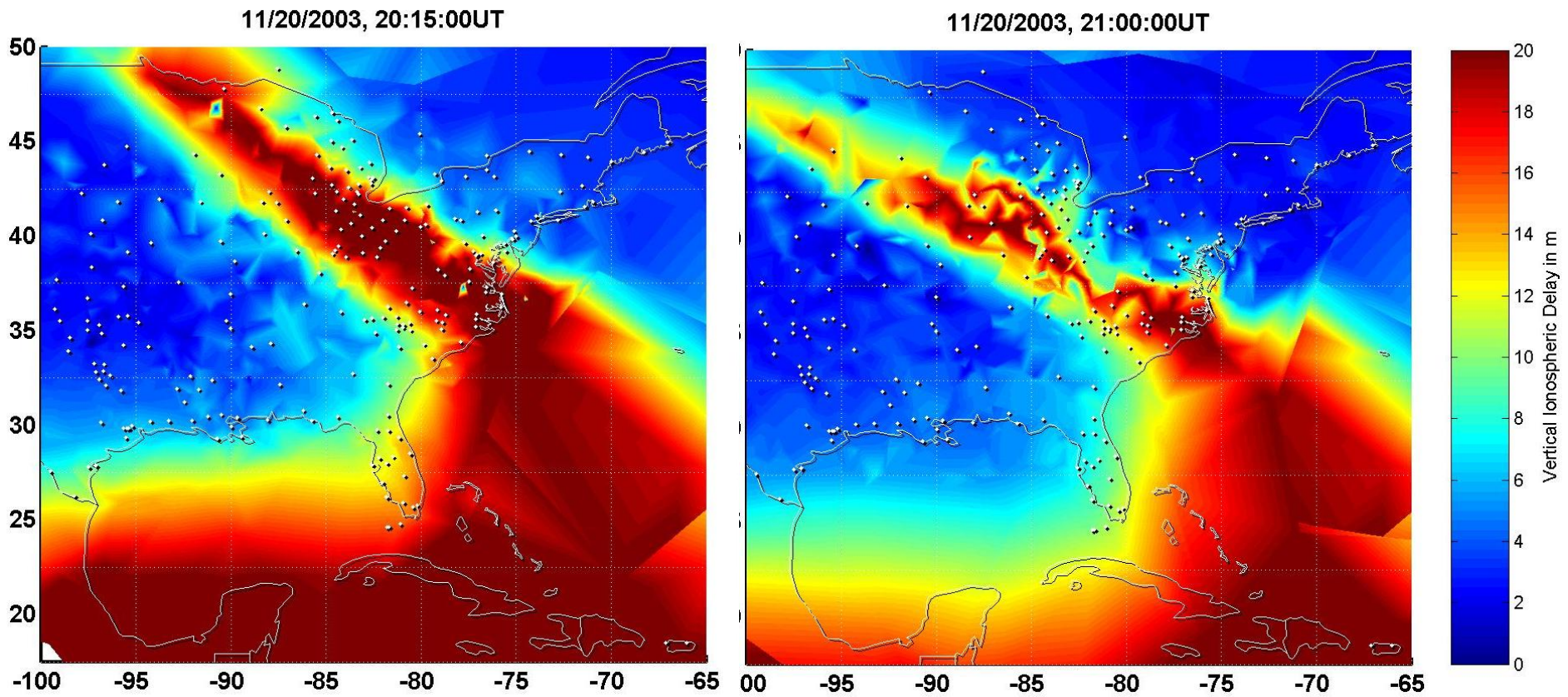
Motivation

- **GBAS availability is limited by the "geometry screening" implemented to mitigate hypothetical worst-case ionospheric anomalies.**
  - **Ground screening has severe impact on CAT I LAAS.**
  - **Airborne screening used in GAST-D (for CAT III) remains driven by ionospheric threats.**
- **External information is the key to removing this constraint.**
- **Three approaches have been envisioned:**
  1) **Use of certified SBAS where it now or will exist**
  2) **Use of uncertified "COTS" monitoring networks**
  3) **Use of space weather forecasts and "nowcasts"**

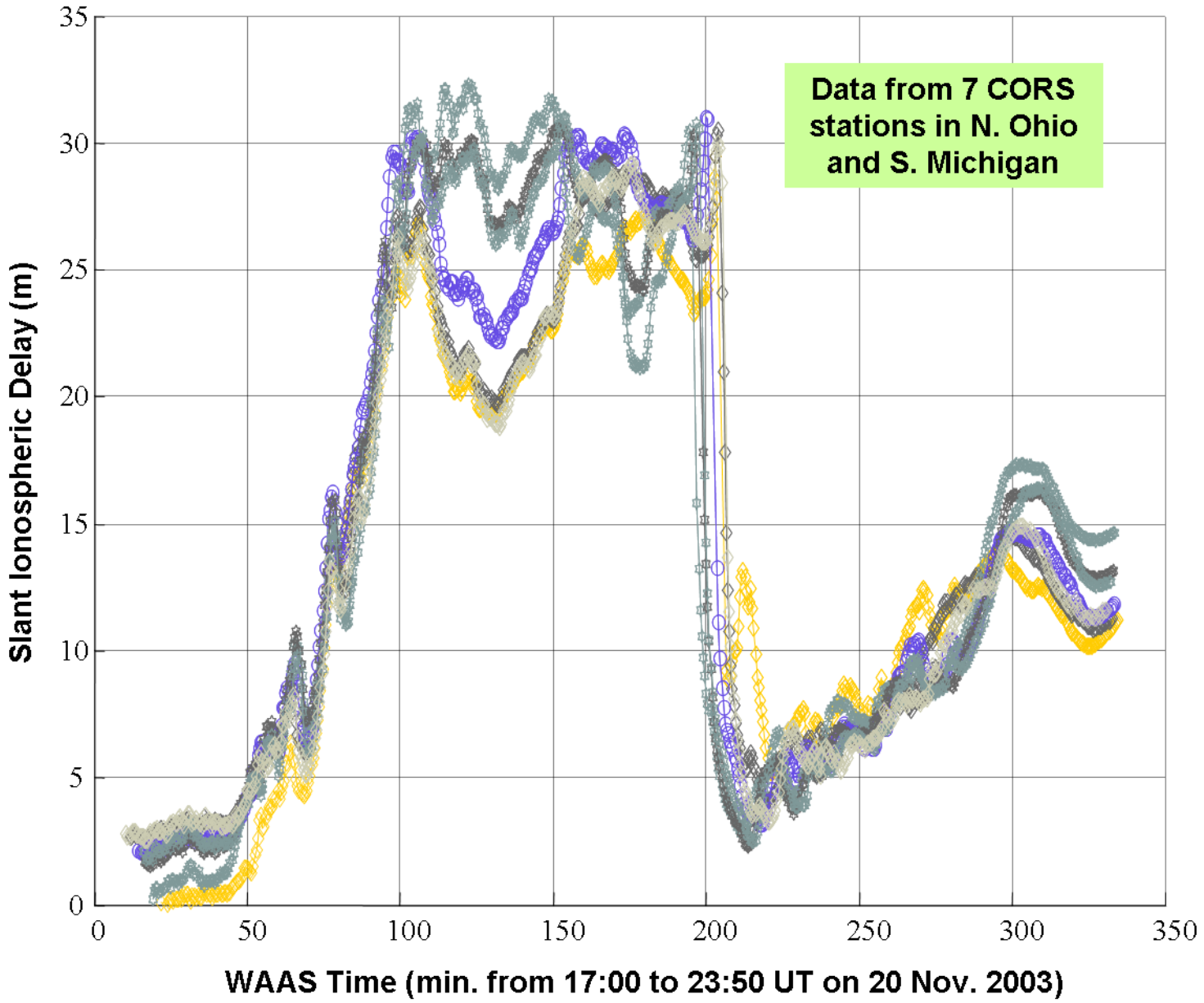
Severe Ionospheric Anomaly in CONUS on 20 November 2003

20:15 UT

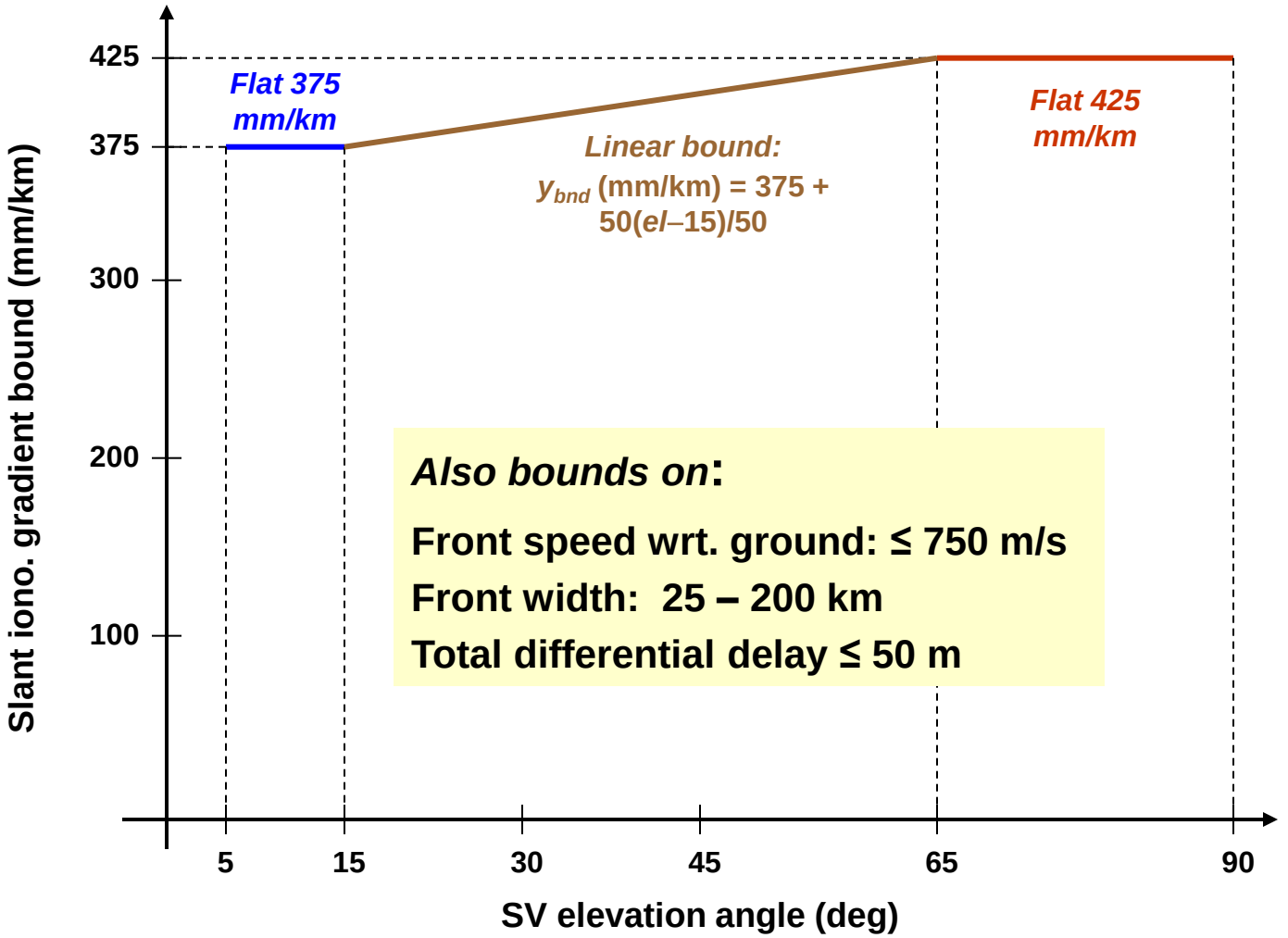
21:00 UT



Time Variation of Ionospheric Delay on 20 November 2003



Resulting Ionospheric Anomaly Threat Model for CONUS



(note: plot not precisely to scale)

***Also bounds on*:**

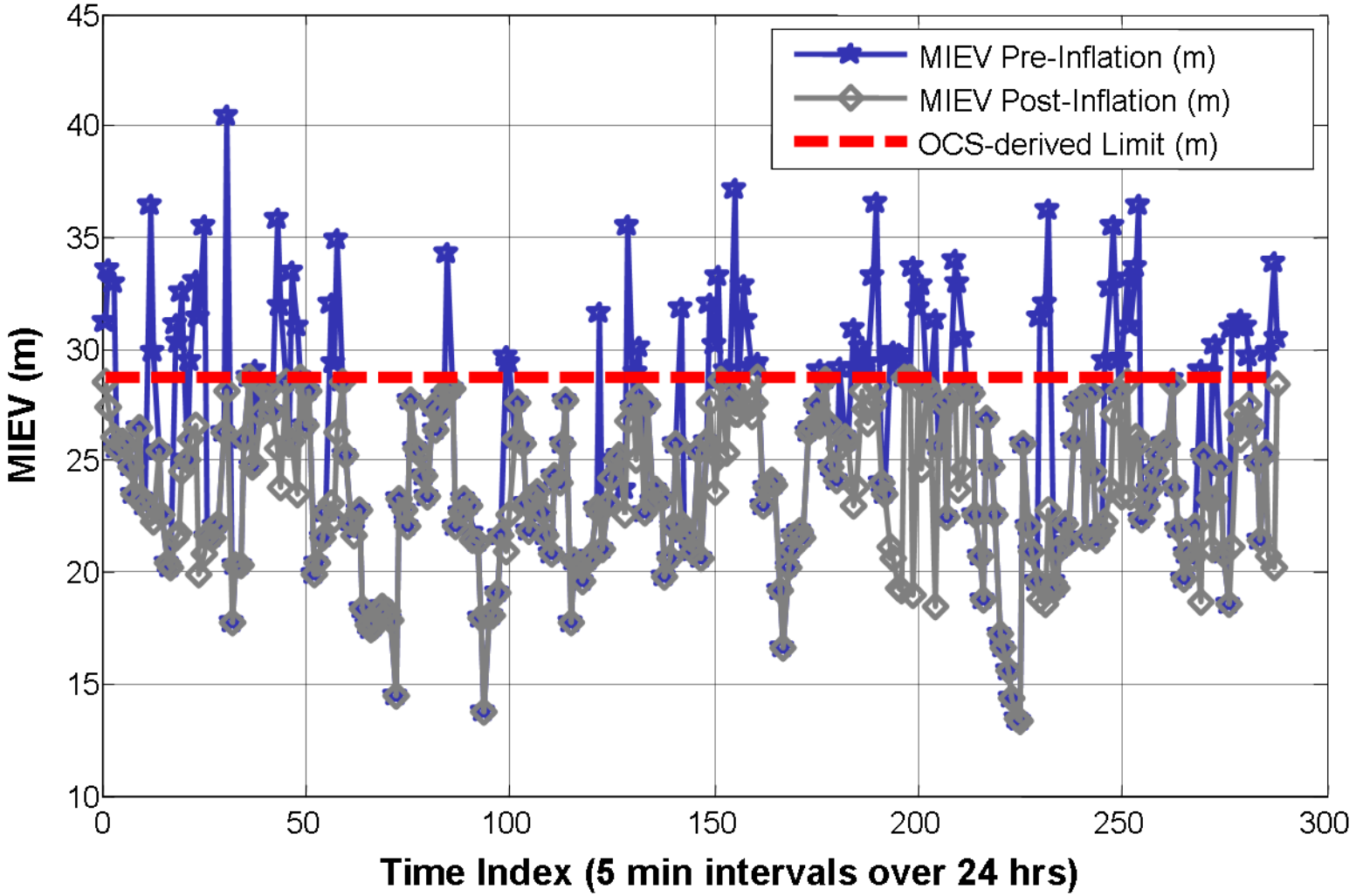
Front speed wrt. ground: ≤ 750 m/s

Front width: 25 – 200 km

Total differential delay ≤ 50 m

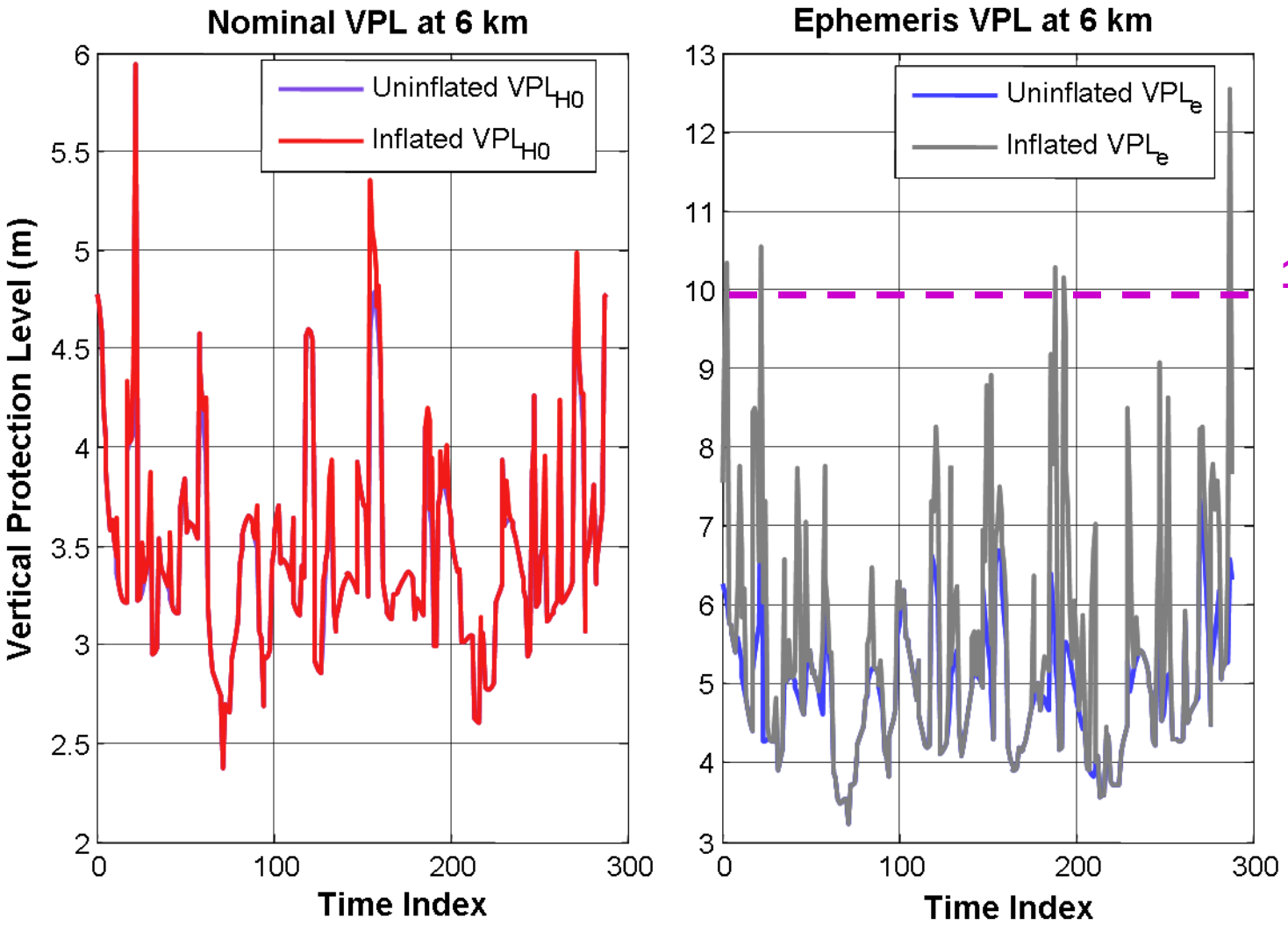
Worst-Case Impact on CAT I GBAS

Maximum Ionospheric Error in Vertical (MIEV) at Memphis
(24-Satellite SPS-Standard GPS Constellation)



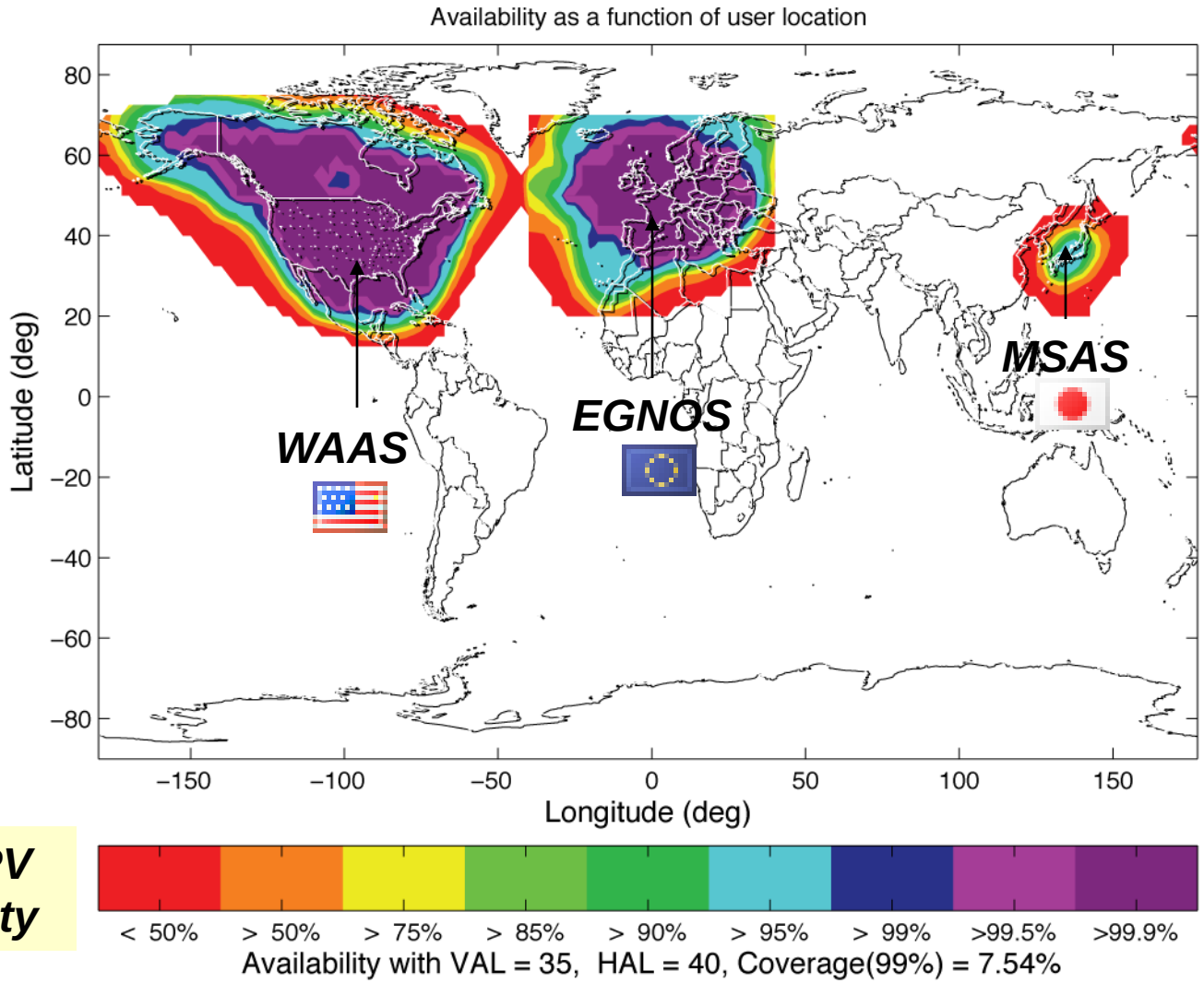
Parameter Inflation Required to Remove Unsafe Subset Geometries

Use σ_{pr_gnd} / P-value inflation algorithm described in {Ramakrishnan, *et al*, ION NTM 2008}



SBAS to Augment GBAS (1): *Today's SBAS Coverage*

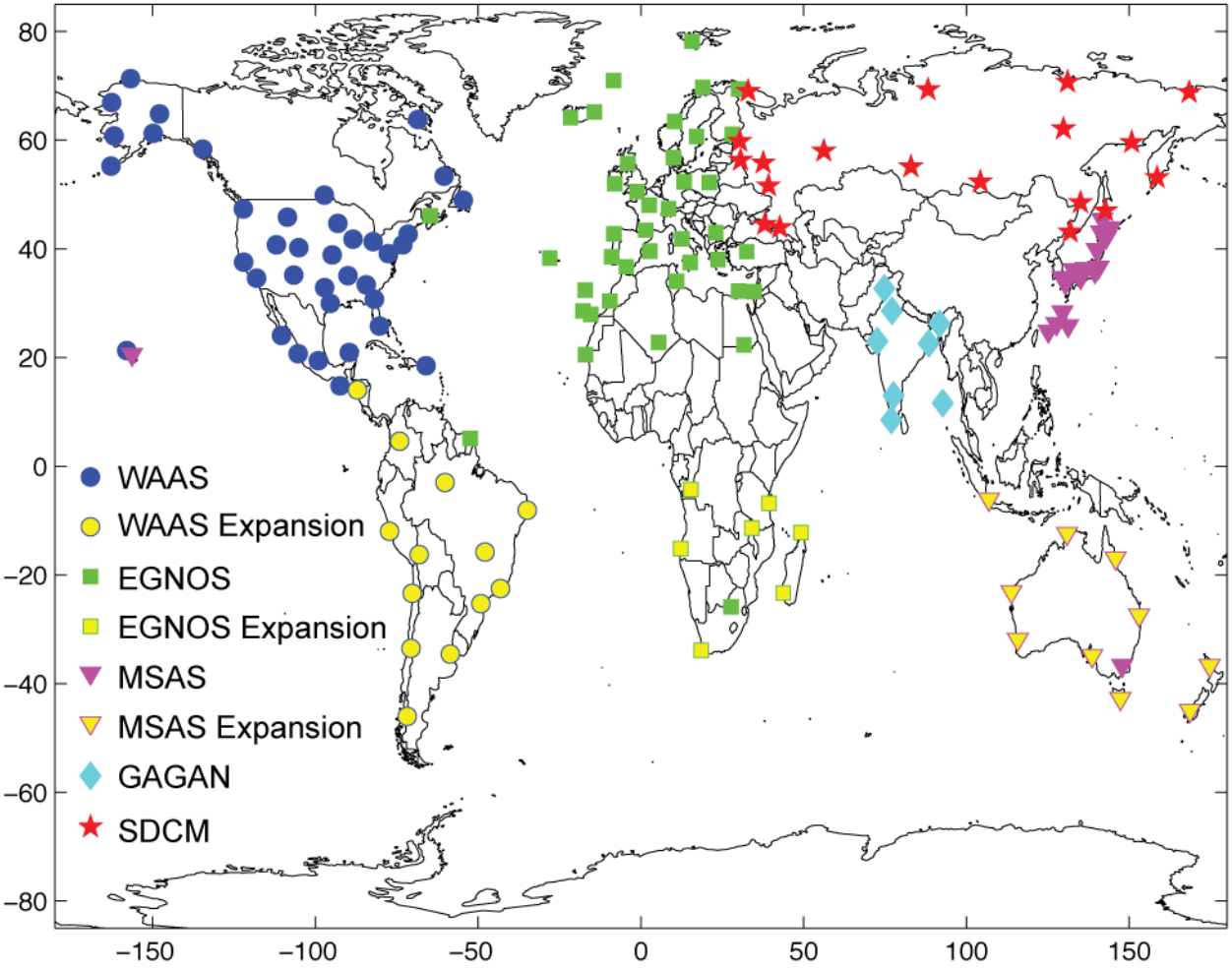
***Source*: T. Walter, *et al*, ION ITM 2010**



SBAS LPV Availability

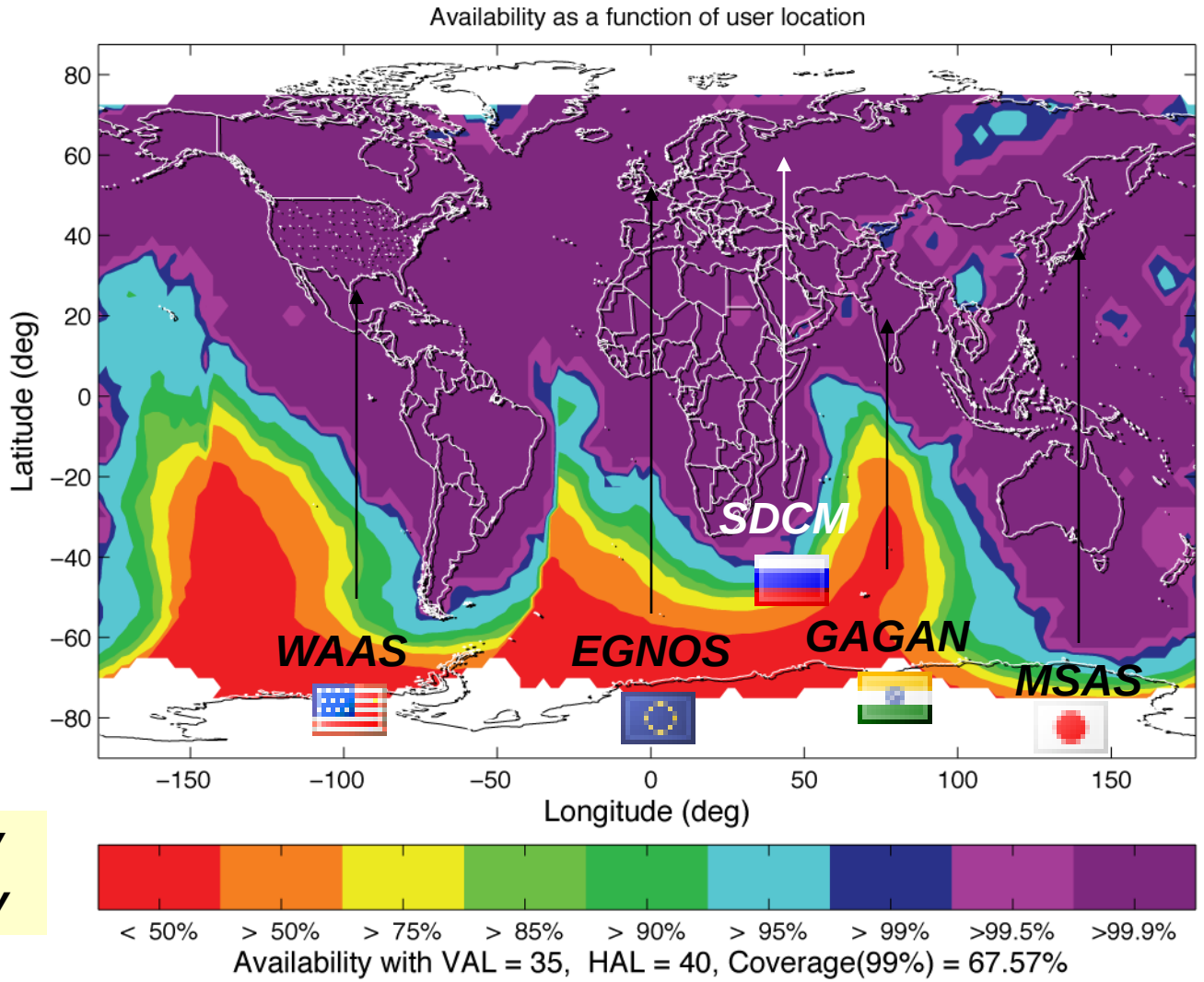
SBAS to Augment GBAS (2): *Future SBAS Network Expansion*

***Source*: T. Walter, *et al*, ION ITM 2010**



SBAS to Augment GBAS (3): *SBAS by 2025 (GPS L1-L5 w/Expansion)*

***Source*: T. Walter, *et al*, ION ITM 2010**

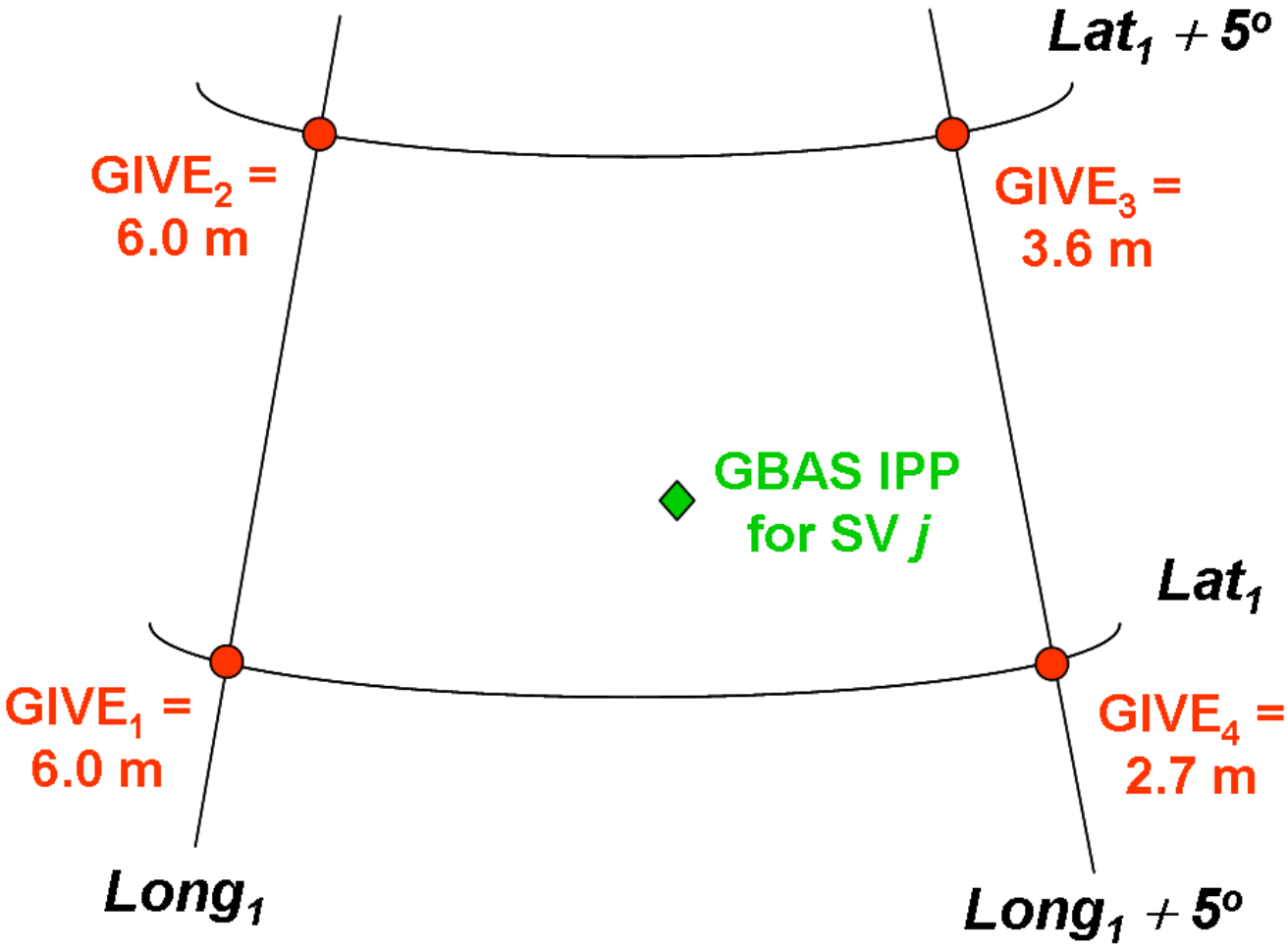


SBAS LPV Availability

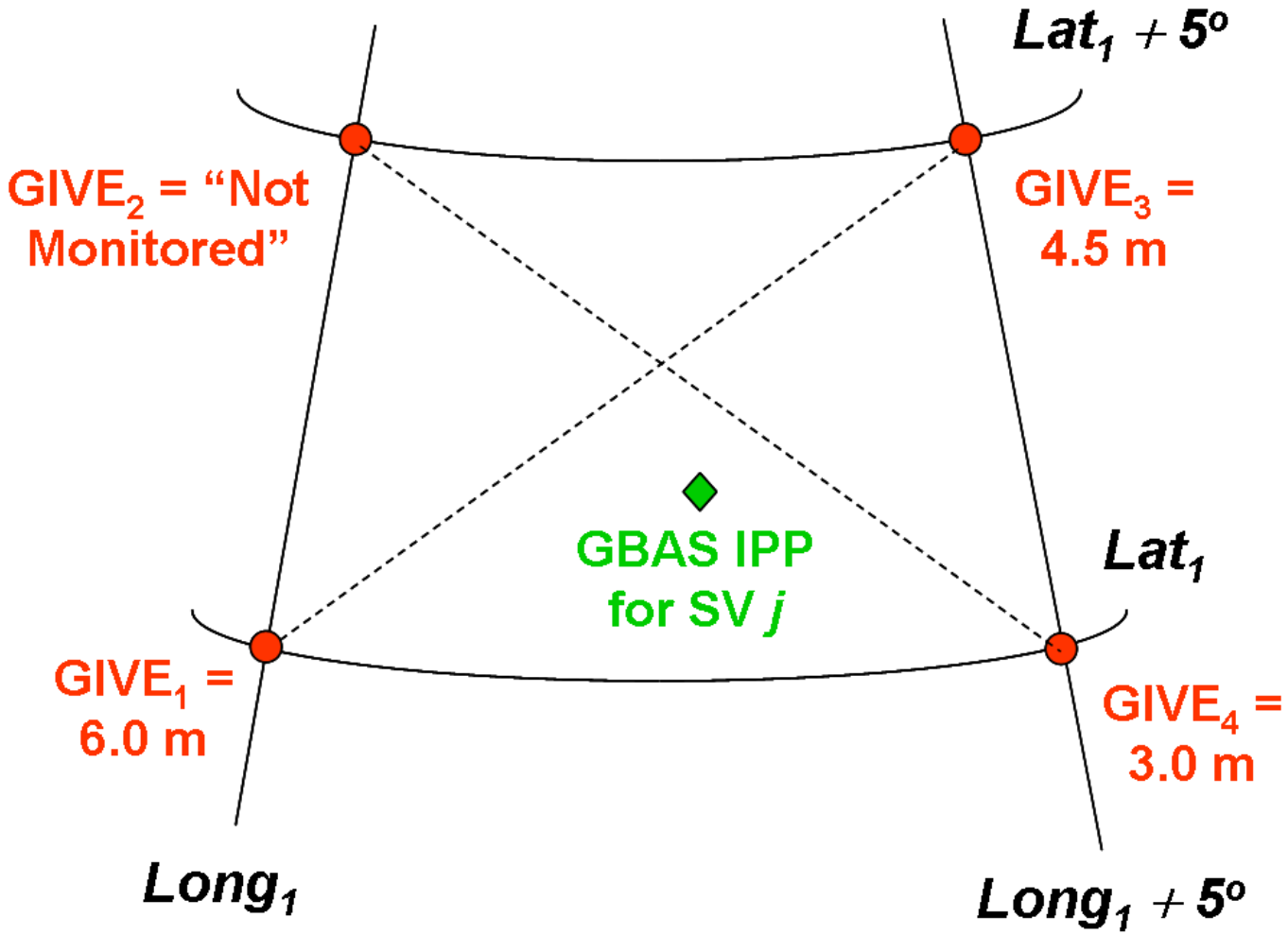
GBAS Use of WAAS GIVE Values

GIVE Value	GIVE Integer	GBAS Class.	*Notes*
≤ 6.0 m	0 – 12	Good	*WAAS verifies that no threat is present here.*
15.0 m	13	Not Observed	*WAAS observations are too limited to confirm that no threat exists.*
45.0 m	14	Bad	*WAAS detects a nearby ionosphere storm – possible threat.*
Not Monitored	15	Not Observed	*WAAS observations are too limited to provide any iono. assurance.*

GIVE Method Case 1: All IGP's are "Good"

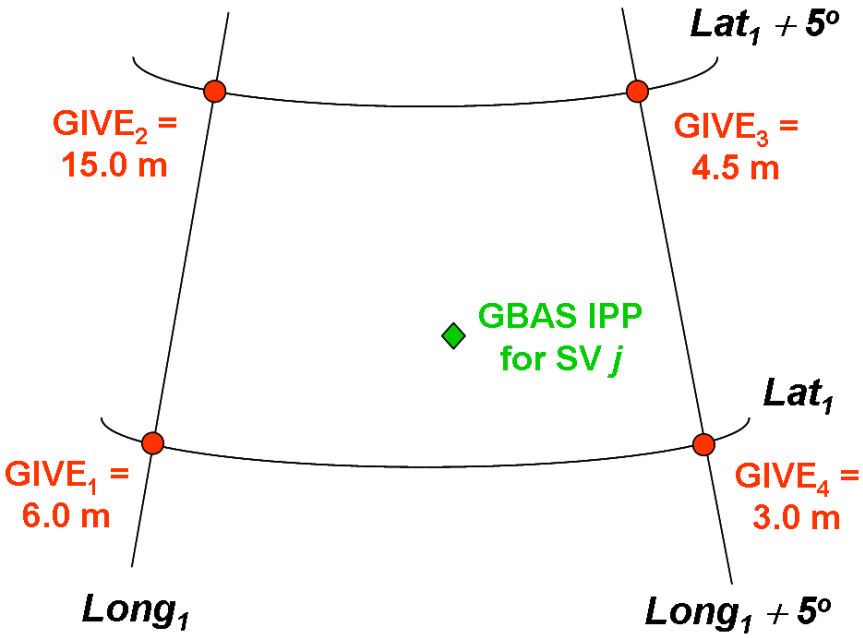


GIVE Method Case 2: One IGP is "Not Observed"

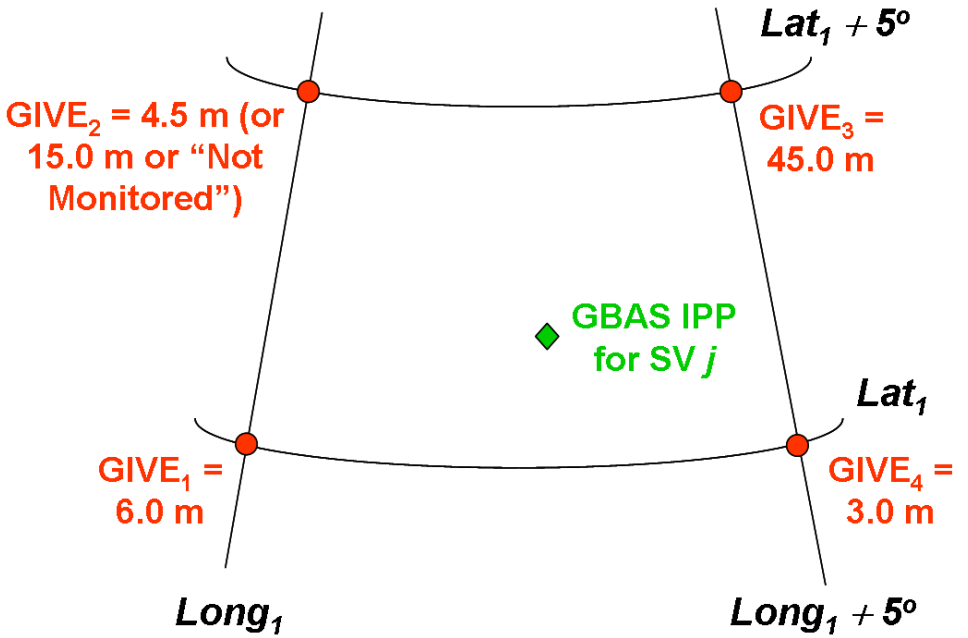


GIVE Method Cases 3 and 4: One IGP is Either "Neutral" or "Bad"

"Neutral" Case

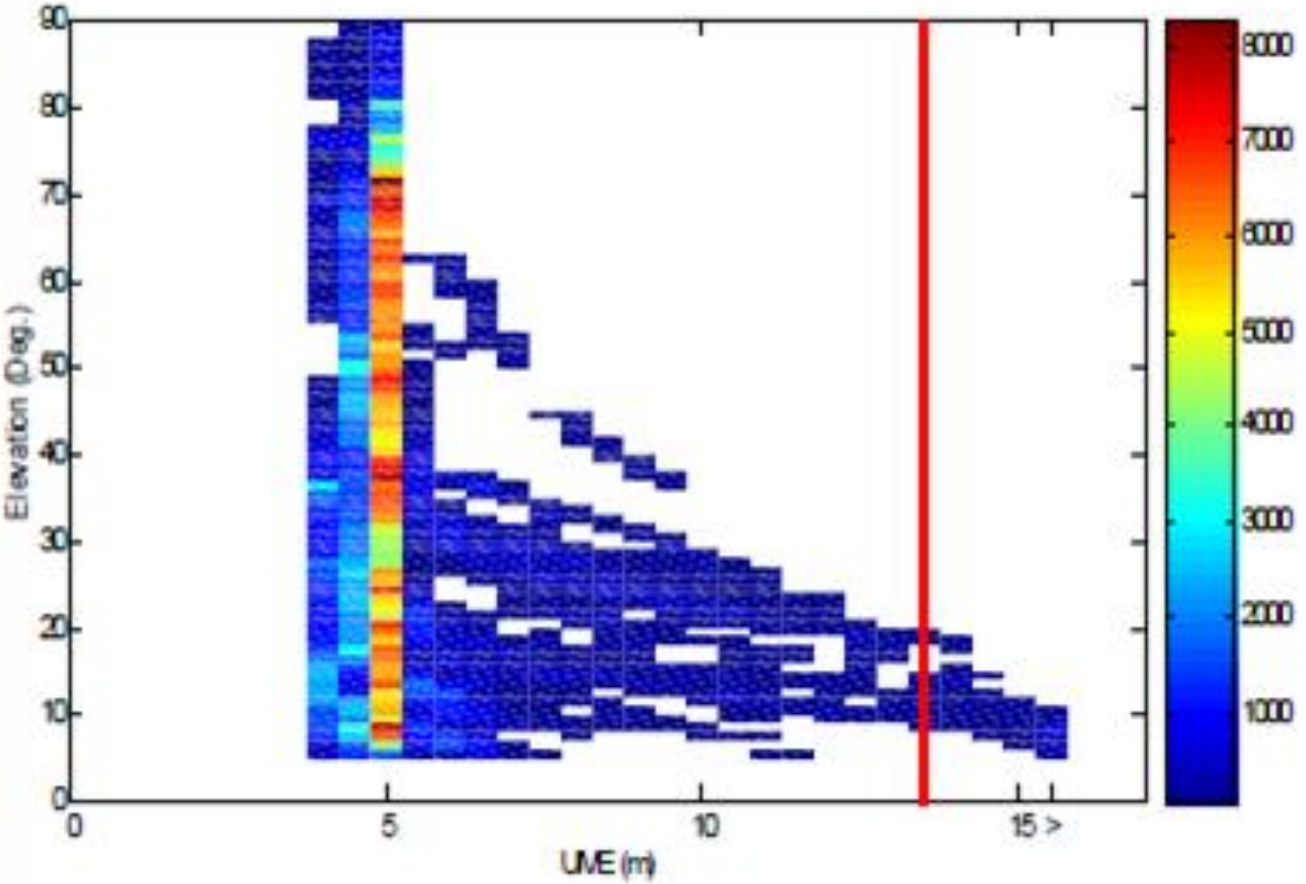


"Bad" Case



Validation via UIVE at Local Area Monitor (LAM) Site

***Source*: J. Rife, *et al*, IEEE PLANS 2006**



- **UIVE > 13 m threshold violated (briefly) ≈ 0.6 % of the time**
- **Proposed rules for GBAS are somewhat stricter**
- ➢ ***Need to retain geometry screening as a backup mode***

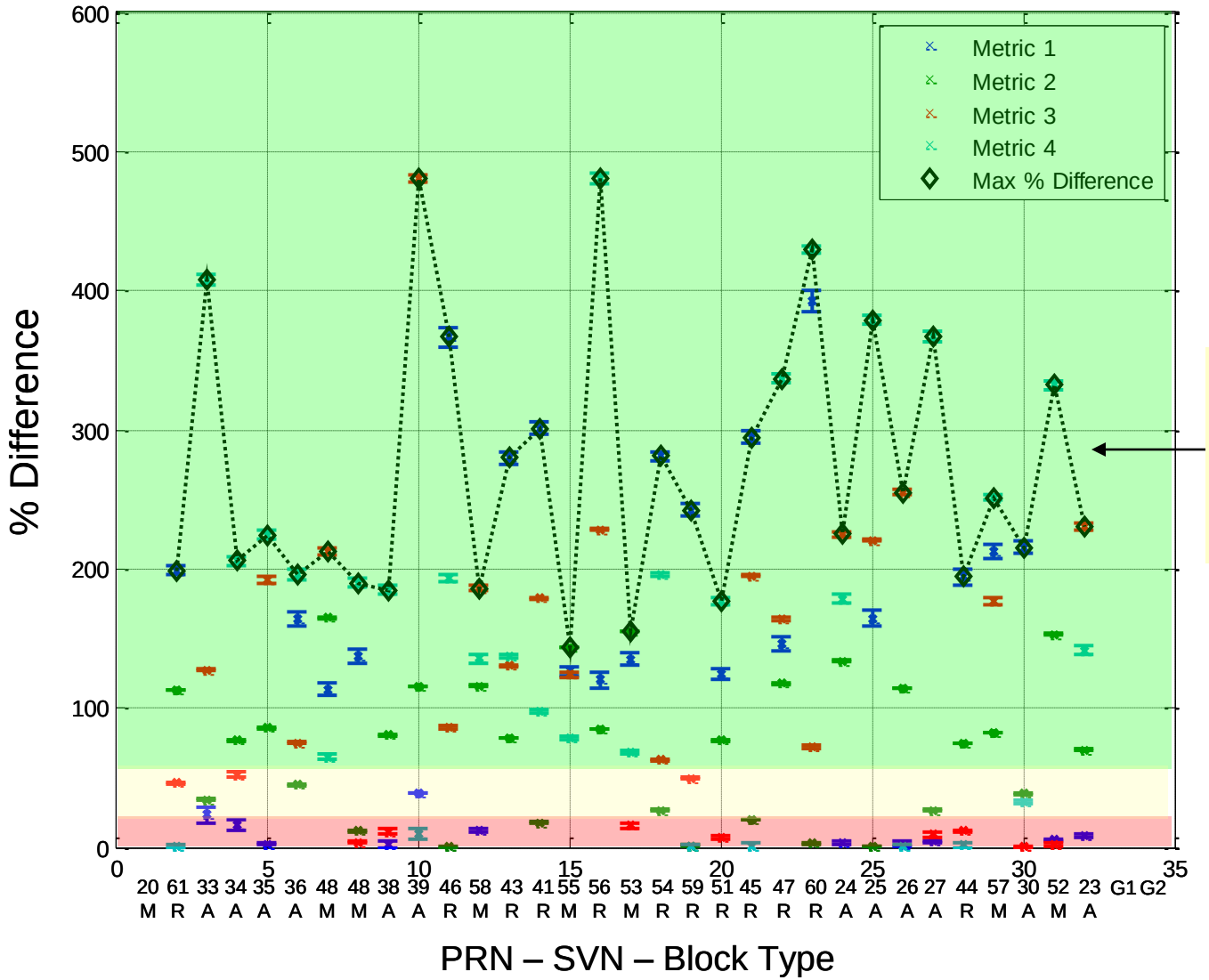
SBAS UDRE for Clock/Ephemeris Monitoring

UDRE Value	UDRE Integer	GBAS Class.	Ephemeris MDE
≤ 50.0 m	0 – 12	Good	500 m
150.0 m	13	OK	1500 m
Not Monitored	14	Neutral	GBAS value (≈ 2700 m)
Do Not Use	15	Do Not Use	Exclude from Use

Ensures that ephemeris threat never limits CAT I availability

SBAS SDM: Support of GBAS Approval of New Satellites

Recent Work of Dr. R. Eric Phelts at Stanford

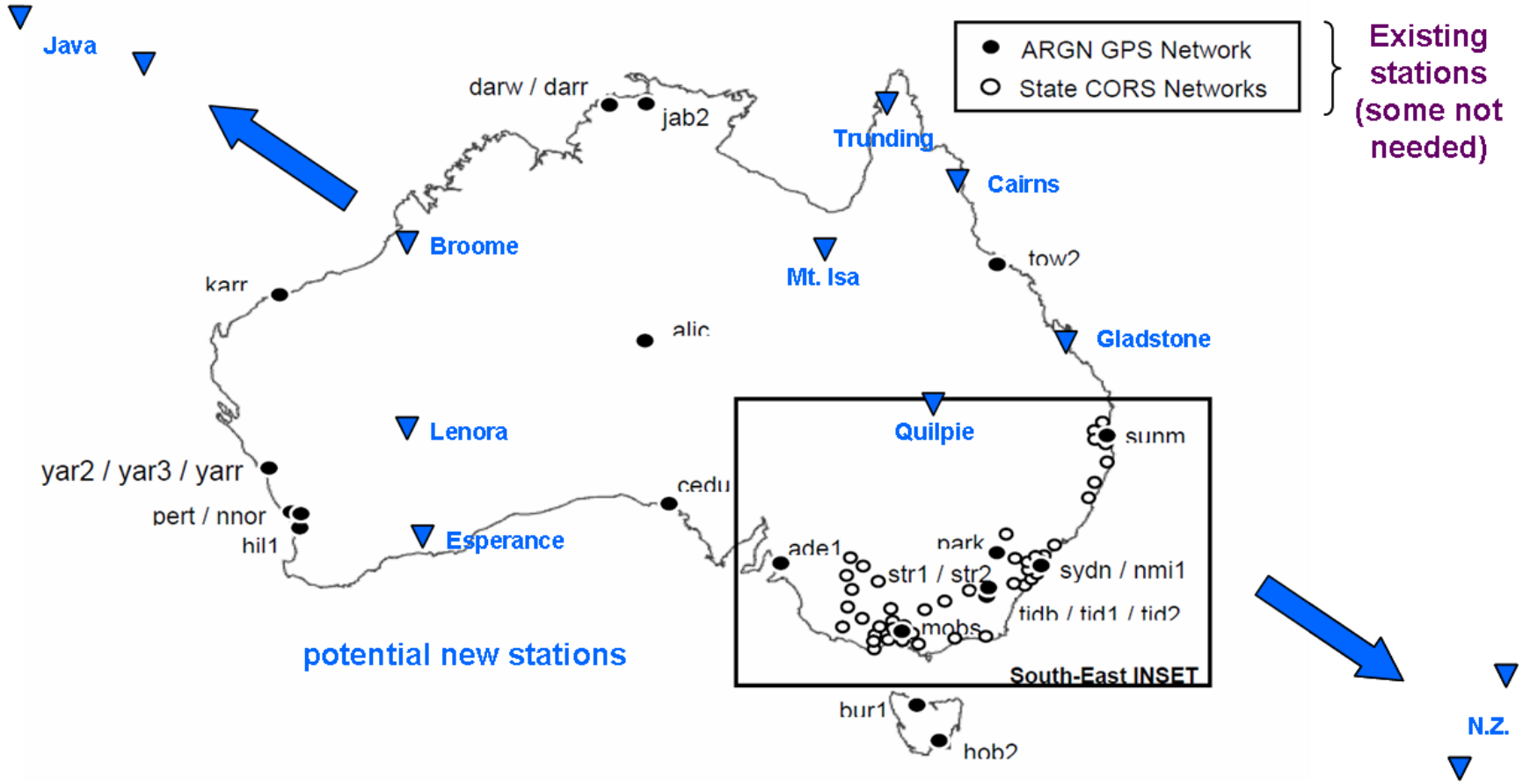


Maximum of 4 SDM metrics used to demonstrate lack of signal deformation

Alternatives to SBAS

- **Despite expected growth of SBAS, some GBAS sites will lie outside good SBAS coverage**
  - **Also, no assurance that all SBAS systems will satisfy GIVE and UDRE performance assumptions.**
- **Two alternatives are worth considering:**
  - **Running SBAS-like algorithms on outputs of existing, "uncertified" receiver networks**
  - **Using space weather products now being developed:**
    - » **"nowcasts" of the real-time situation**
    - » **3 – 6 hour (?) look-ahead forecasts**
- **Both of these alternatives require replacements for high-integrity SBAS processors and datalinks**

Use of Regional Networks: Australian Example



- **Enhancements of existing ground receiver networks can substitute for SBAS in specific regions.**

Concerns with Use of External Information (1)

- **The original "benefits case" for GBAS assumes that each site operates independently, as do ILS and MLS.**
  - **GBAS precision approaches are "ILS-lookalike".**
- **Therefore, GBAS cannot rely upon external information.**
  - **GBAS-only methods run in the background at all times.**
  - **For example, when SBAS cannot guarantee that no threat exists, existing GBAS algorithms still provide required integrity assurance, but with reduced availability.**
- **Even if GBAS can operate without external information, the FAA is hesitant to rely on it to meet advertised performance benchmarks.**

Concerns with Use of External Information (2)

- **Non-aviation substitutes for SBAS are technically feasible but require guarantees that information provided is "safe" to civil aviation standards.**
- **Existing receiver networks must be "certifiable" without requiring "SBAS" levels of coding and redundancy (otherwise, not cost-effective).**
- **Beyond network outputs, automated data-transfer mechanism to each GBAS site must also be certified.**
  - **NextGen mission statement highlights the future importance and data-sharing networks, but most ATM information has less direct safety impact (or does it?)**
  - **Understanding and providing this capability should be part of NextGen/SESAR/etc. and should not be limited to GNSS.**

Summary

- **The use of external information is the most cost-effective near-term way to enhance GBAS availability.**
  - **Guarantee absence of ionospheric anomalies**
    - » **Enhance precision approach availability**
    - » **Enable other uses of GBAS ("DCPS")**
  - **Monitor GNSS satellites to much tighter tolerances**
- **SBAS is the most convenient way to obtain this information**
  - **Algorithms and datalinks are already certified**
  - **Information delivered in timely manner on L1 frequency**
- **Where SBAS is not suitable, alternatives exist, but new safety certification is needed.**

Questions?

- Thank you for your attention。

  ご清聴は、ありがとうございました。

- Questions are welcome!

  質問だったら、遠慮しないで、英語にも日本語にも伺ってください。

Backup Slides follow…