CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT (CAASD)

Availability of GPS and MSAS with Standard and Degraded Constellations

Presentation for GIT/10

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GPS Standard Positioning Service (SPS)

- US government has committed to support worldwide peaceful use of GPS navigation without direct user fees for civil, commercial and scientific uses
  - Including GPS augmentations operated by the US (e.g., WAAS and NDGPS)
- Support for the nominal 24 satellite constellation has been excellent
  - Since Initial Operating Capability the system has operated with at least 24 satellites, and often significantly more

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Receiver Autonomous Integrity Monitoring (RAIM)/ Aircraft-Based Augmentation System (ABAS)

- Civil aviation aircraft flying under instrument flight rules must monitor integrity
  - Includes use of GPS position for ADS-A/C and ADS-B
- GPS navigation solution requires at least 4 satellites
  - Aircraft use additional satellites to verify integrity (RAIM/ABAS)
    - Some aircraft installations allow the use of the barometric altimeter to assist in RAIM/ABAS calculations
- RAIM/ABAS is not used with GPS augmentations such as SBAS, GBAS, and GRAS
  - Except as a backup in case of the loss of the augmentation signal

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GPS SPS Performance Standard

- **Although the USG has operated GPS with 24 or more satellites, the USG commitment for GPS is:**

  "In support of the service availability standard, 24 operational satellites must be available on orbit with 0.95 probability (averaged over any day). At least 21 satellites in the 24 nominal plane/slot positions must be set healthy and transmitting a navigation signal with 0.98 probability (yearly averaged)."*

- **Many current GPS satellites have operated beyond their design lifetimes**
  - **Excellent reliability**
  - **A number satellites are "single string," e.g., currently using their last bus or atomic clock**

- **New IIR-M satellite just launched**
  - **A number of new satellites are awaiting launch**

*** GPS SPS Performance Standard, October 2001**

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Future GPS

- **Although the US will maintain GPS at high levels of performance, the numbers of operating GPS satellites may not continue at the level experienced in the last few years**
- **Civil users and navigation service providers should plan conservatively with respect to performance of GPS**
- **What performance levels can be expected if the number of operating satellites drop to 24 or fewer?**
  - **Following slides show estimates of performance**

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Assumptions

- 24 GPS standard constellation
- Single-frequency receiver (URA=6m)
- 5º mask angle (2º for RNP results)
- Average availability of n-satellite failure (n = 0→3)
  - No failures on remaining 24 - n satellites
- MTSATs located at 140ºE and 145ºE
  - 8 GMS/MRS
  - No MTSAT failures
  - No MSAS ground equipment failures
- 24 hours with samples at 5 minute intervals

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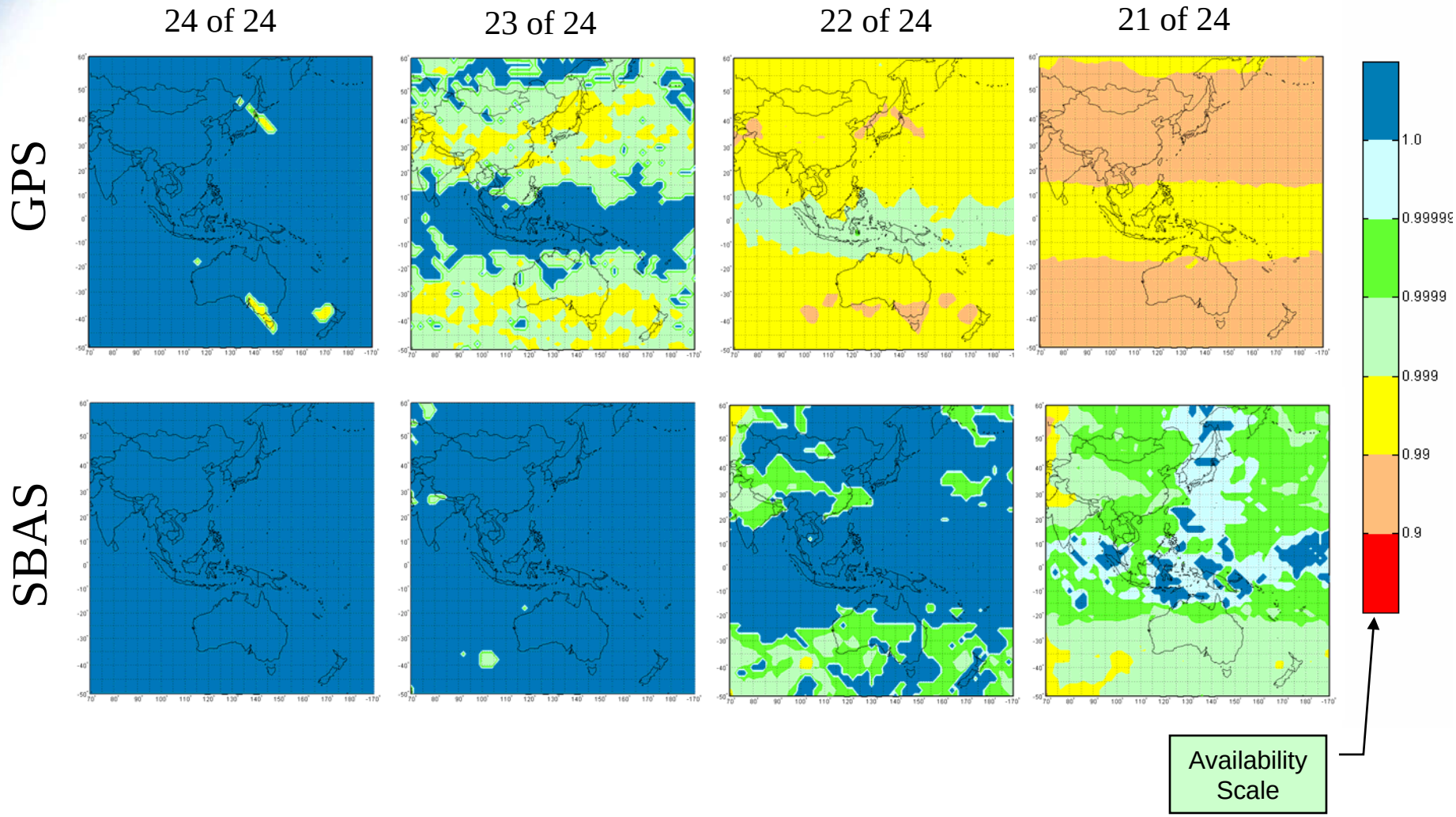
Predicted En Route Availability (HAL = 2 NM) for Standard and Degraded GPS Constellations



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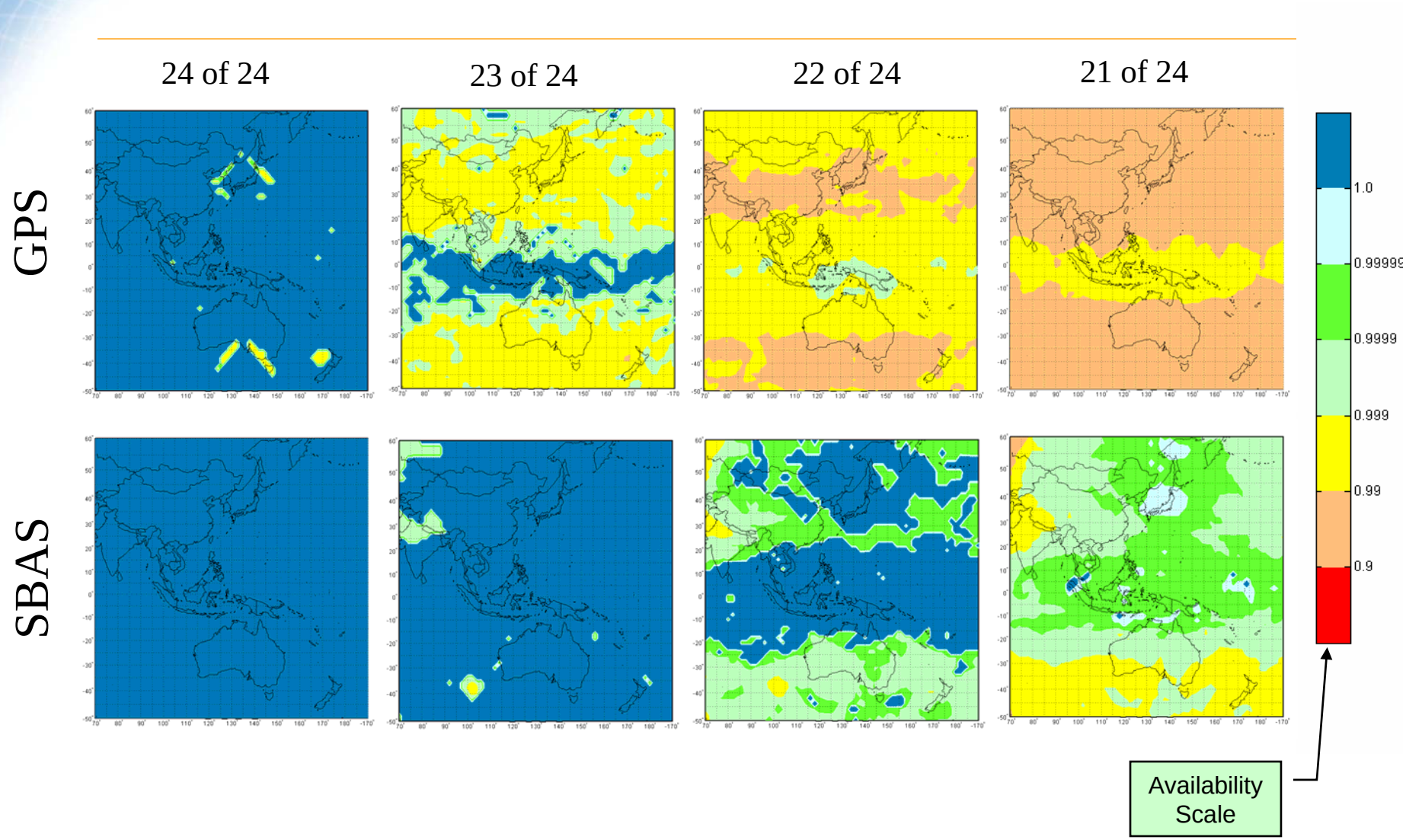
Predicted Terminal Availability (HAL = 1 NM) for Standard and Degraded GPS Constellations



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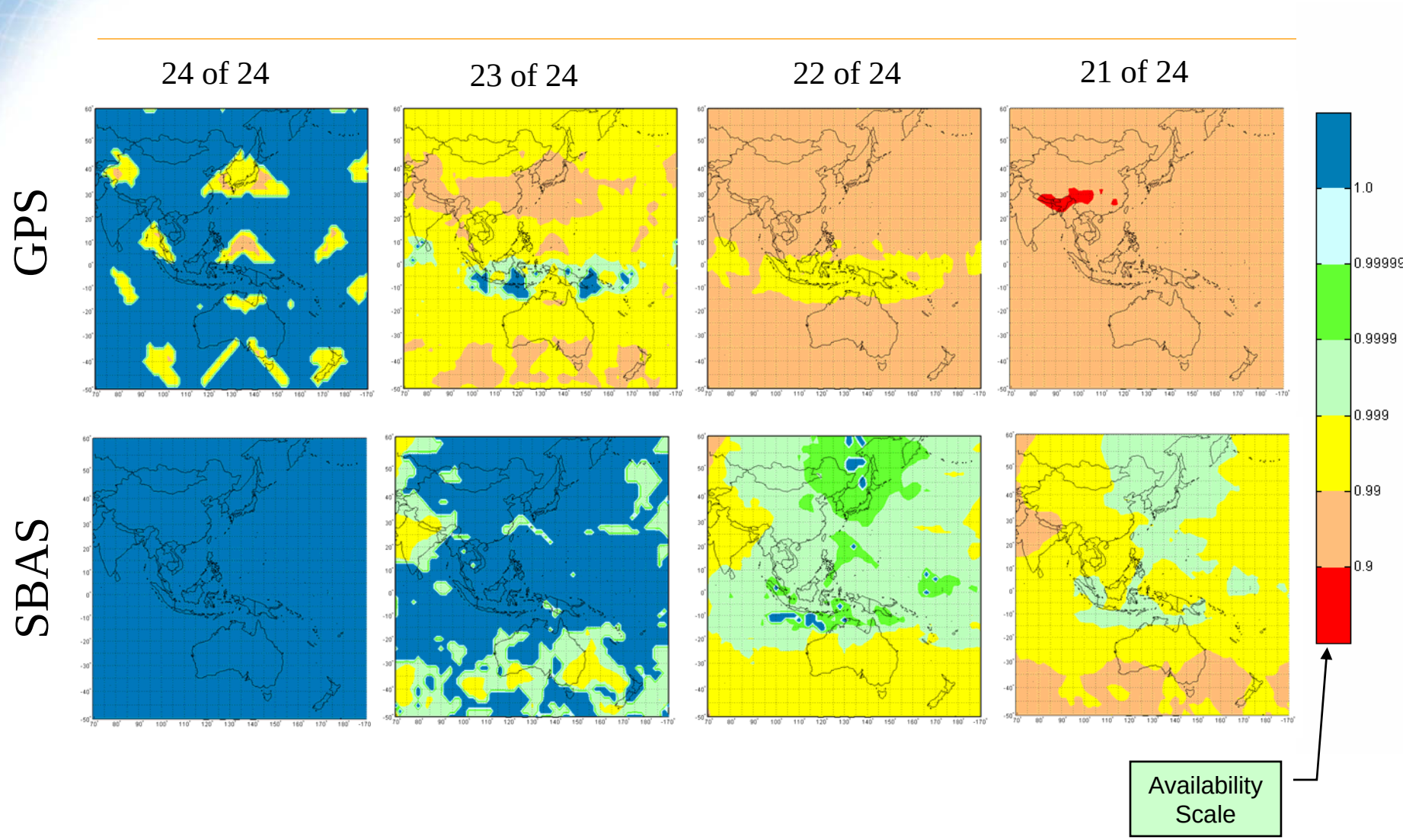
Predicted NPA-BARO/VNAV Availability (HAL = 0.3 NM) for Standard and Degraded GPS Constellations



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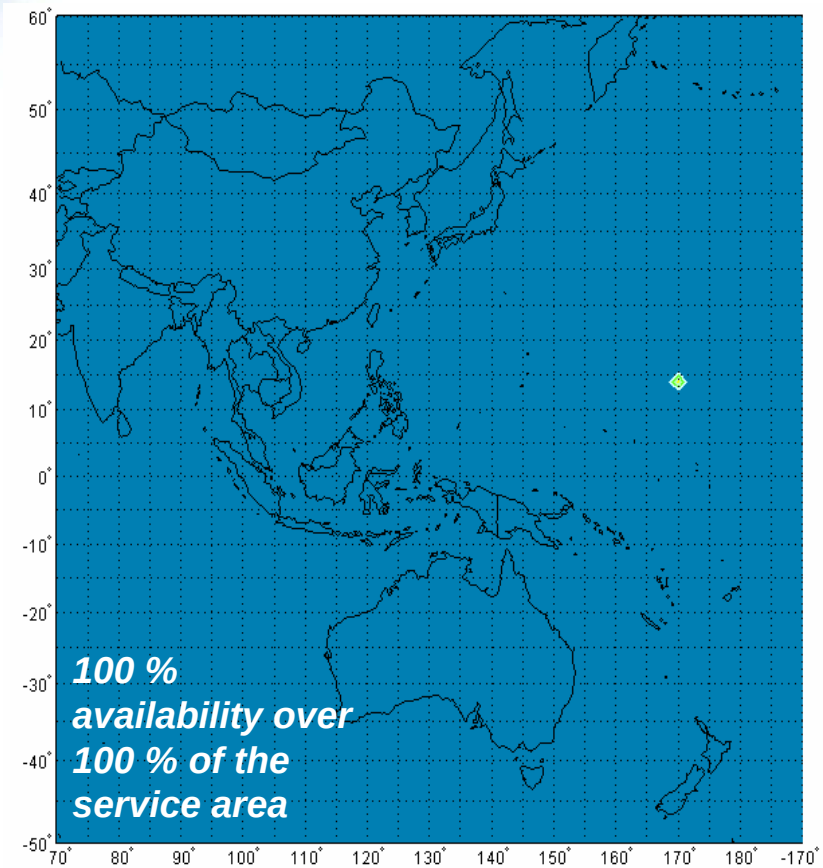
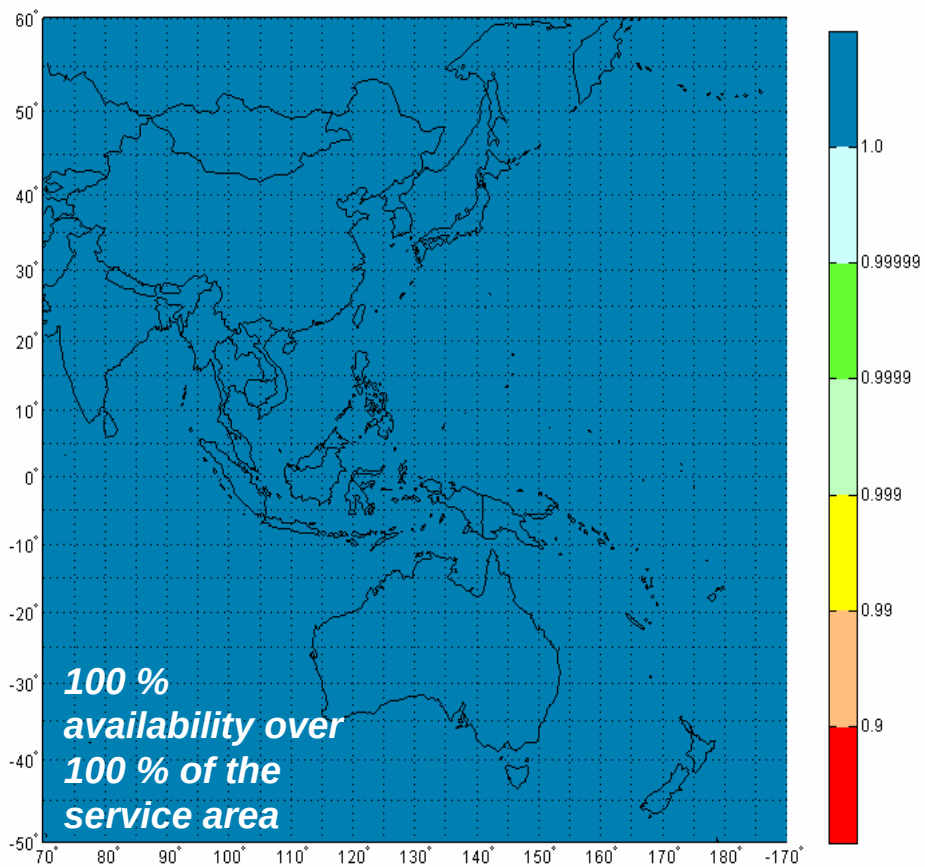
Predicted Availability of RNP 0.1 (29 Satellite GPS Constellation)





Without SBAS

With SBAS

Availability Scale

RNP .1/HAL=333m/No Inertial

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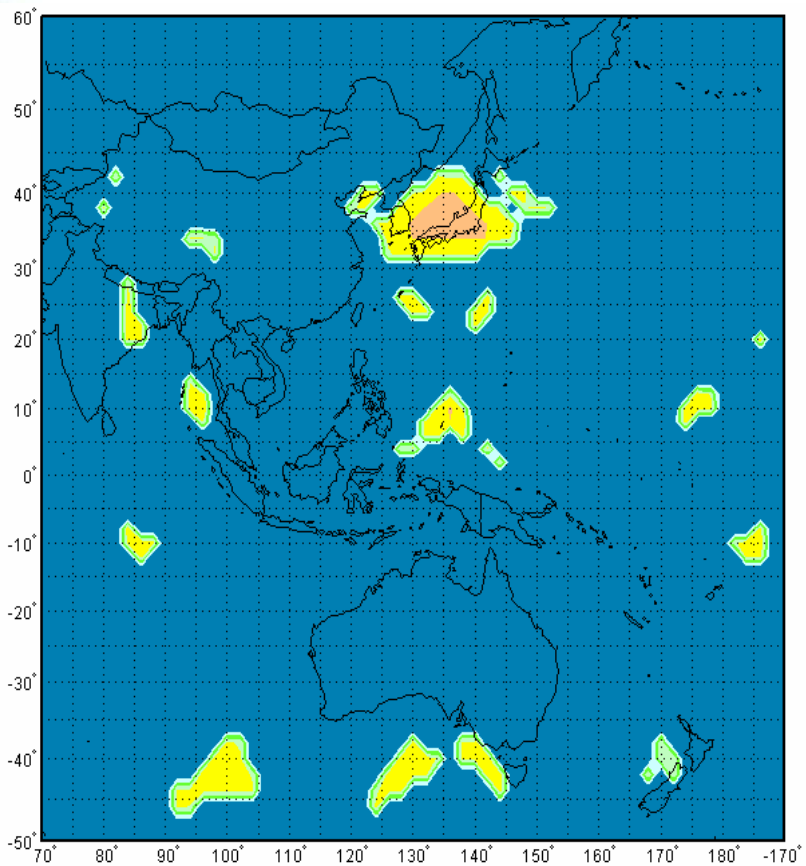
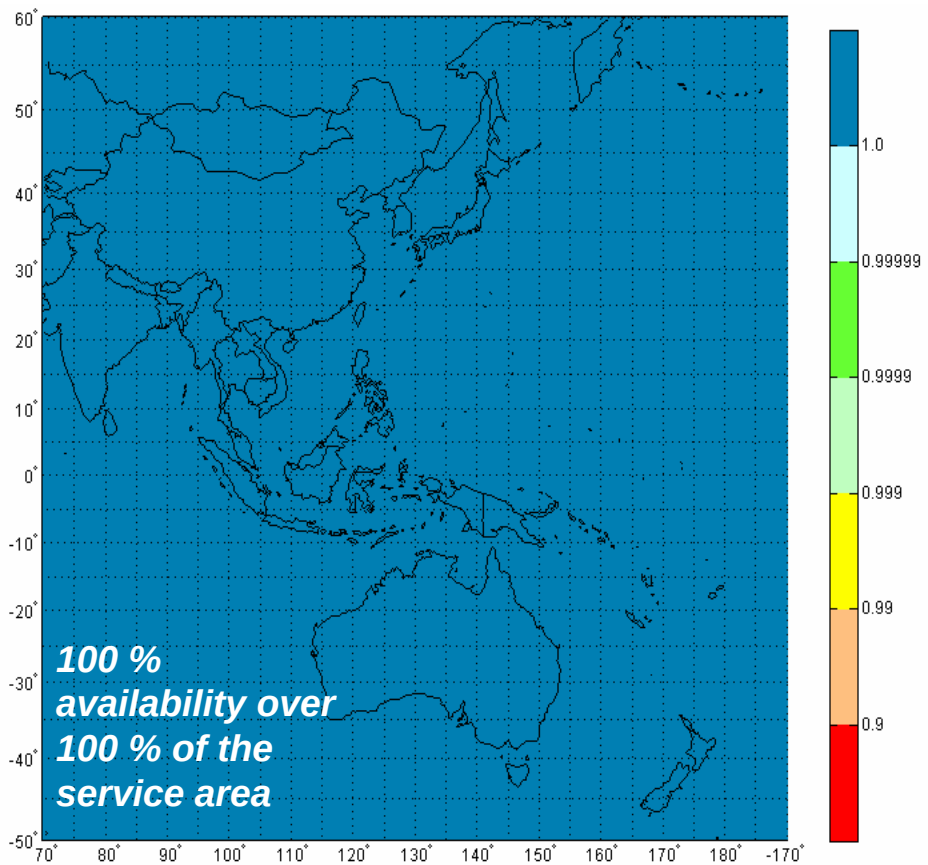
Predicted Availability of RNP 0.1 (24 Satellite GPS Constellation)





Without SBAS

With SBAS

Availability Scale

RNP .1/HAL=333m/No Inertial

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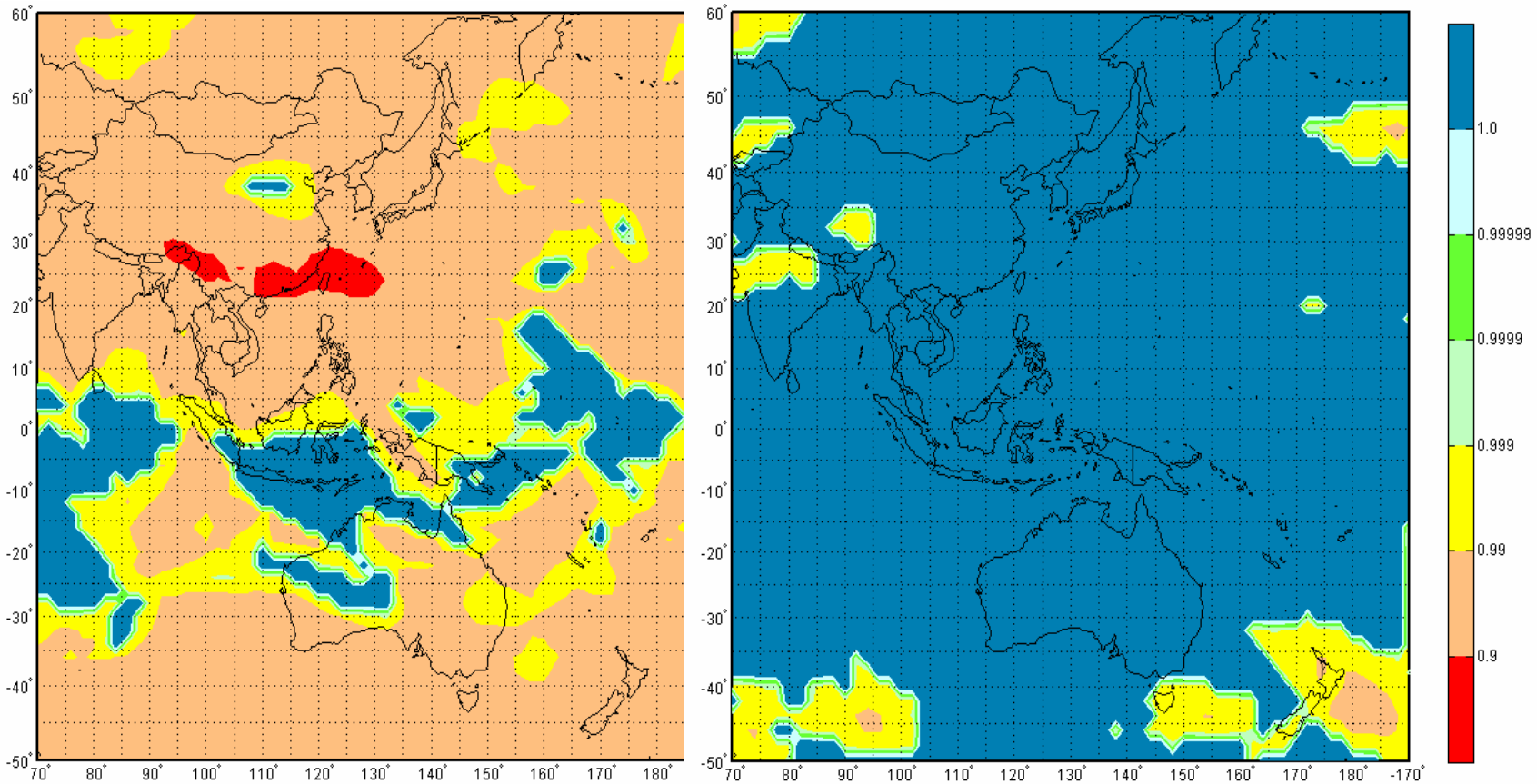
Predicted Availability of RNP 0.1 (22 Satellite GPS Constellation)



Without SBAS

With SBAS

Availability Scale

RNP .1/HAL=333m/No Inertial

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Observations and Additional Thoughts

- **Service availability tends to degrade with reduced numbers of GPS satellites without SBAS**
- **Service availability using SBAS is generally robust with reduced numbers of GPS satellites**
- **Possible launch of the Indian GAGAN system may further improve SBAS performance in Asia-Pacific**
- **Modernization of GPS, the development of Galileo, and effort with GLONASS should offer further improvements**

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Recommendations

- **Economies should plan to approve the use of SBAS in their airspace**
  - **Low cost to the Economy**
  - **Similar to the recommendations of Asia-Pacific Regional Navigation Feasibility Study**

- **Economies should monitor the development and modernization of GPS, Galileo, GLONASS and augmentations to these systems**
  - **GAGAN**
  - **GBAS**
  - **GRAS**

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