MSAS System Development

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Outline

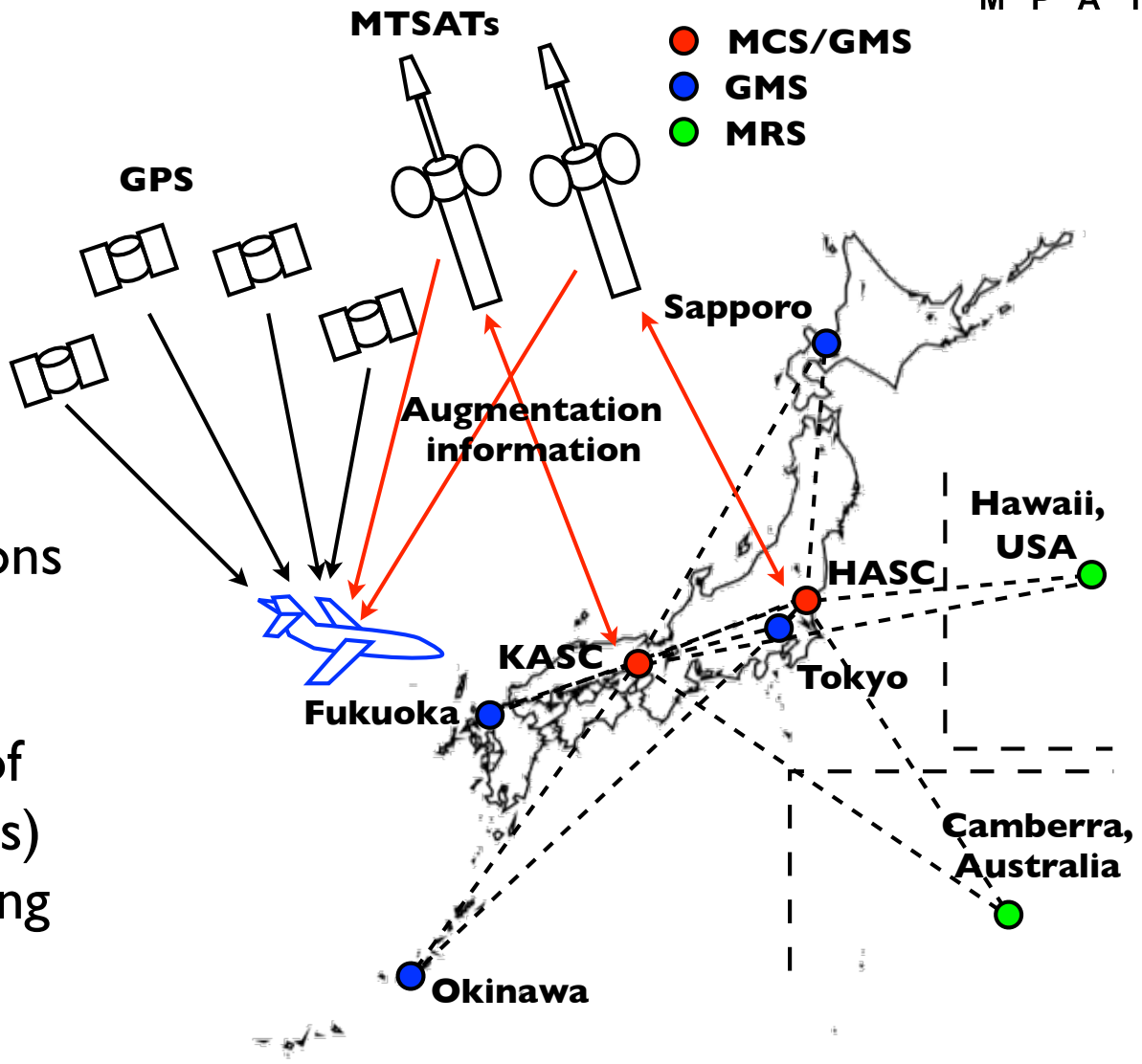
* MSAS development
  - MSAS history
  - MSAS configuration
  - Ionosphere threat mitigation
* MSAS upgrade
  - MTSAT to Michibiki (QZSS)
  - Further upgrade plan

MSAS History

* Japan Civil Aviation Bureau (JCAB) decided implementation of its own SBAS in 1993, aiming at commissioning in 2000.
  - Named as MSAS (MTSAT (Multi-functional Satellite) Satellite-based Augmentation System)
* Ground facility (MSAS-96 System)
  - Completed in 1996.
* GEOs
  - MTSAT-1 failed in 1999.
  - MTSAT-1R launched in 2005, MTSAT-2 in 2006.
* Operation
  - Test signal broadcast from summer 2005
  - Certification activities for 2 years
  - Operation started from September 2007

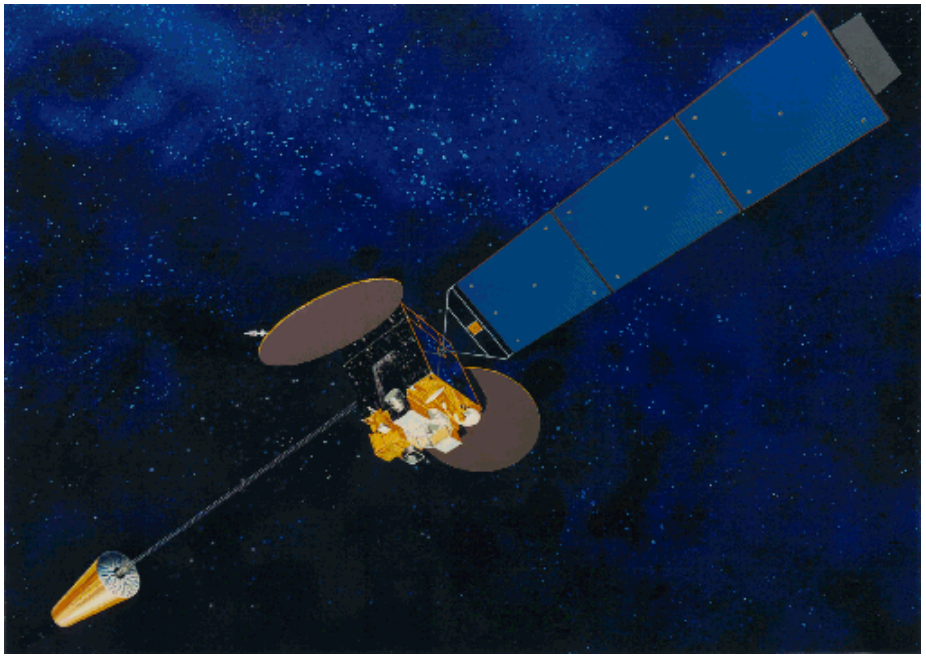
MSAS original configuration - overview

- Augments GPS L1 signals
- Two GEOs
  - MTSAT-1R (PRN129)*
  - MTSAT-2 (PRN137)
- Ground Facility
  - 2 Master Control Stations (MCSs)
  - 6 Ground Monitoring Stations (GMSs) (Two of them are with the MCSs)
  - 2 Monitoring and Ranging Stations (MRSs)**



*MTSAT-1R has been decommissioned in December 2015
**MRSs have been decommissioned.

MSAS original configuration - GEO



MTSAT-1R

* 3-axis stabilized spacecraft
* Together with instruments for weather monitoring missions
* L-band transponder with 2.2 MHz bandwidth
  - Uplink in Ku-band (13 GHz)

MSAS original configuration - MCS

KASC (Kobe Aeronautical Satellite Center)

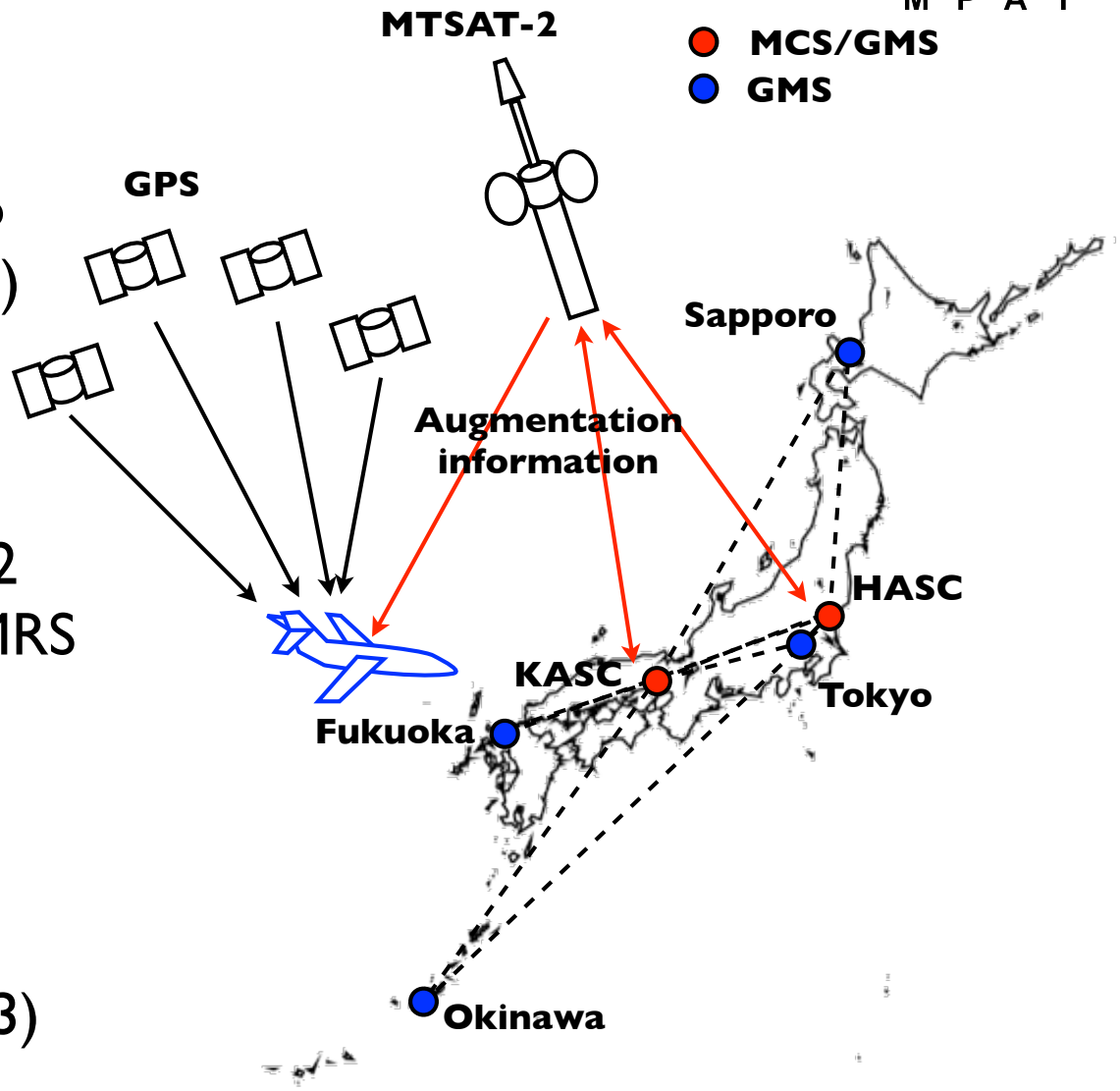
* Nominally for MTSAT-1R
  - Backup for MTSAT-2
* 3 dish antennas (2 for GEOs and one for emergency)

HASC (Hitachi-Ota Aeronautical Satellite Center)

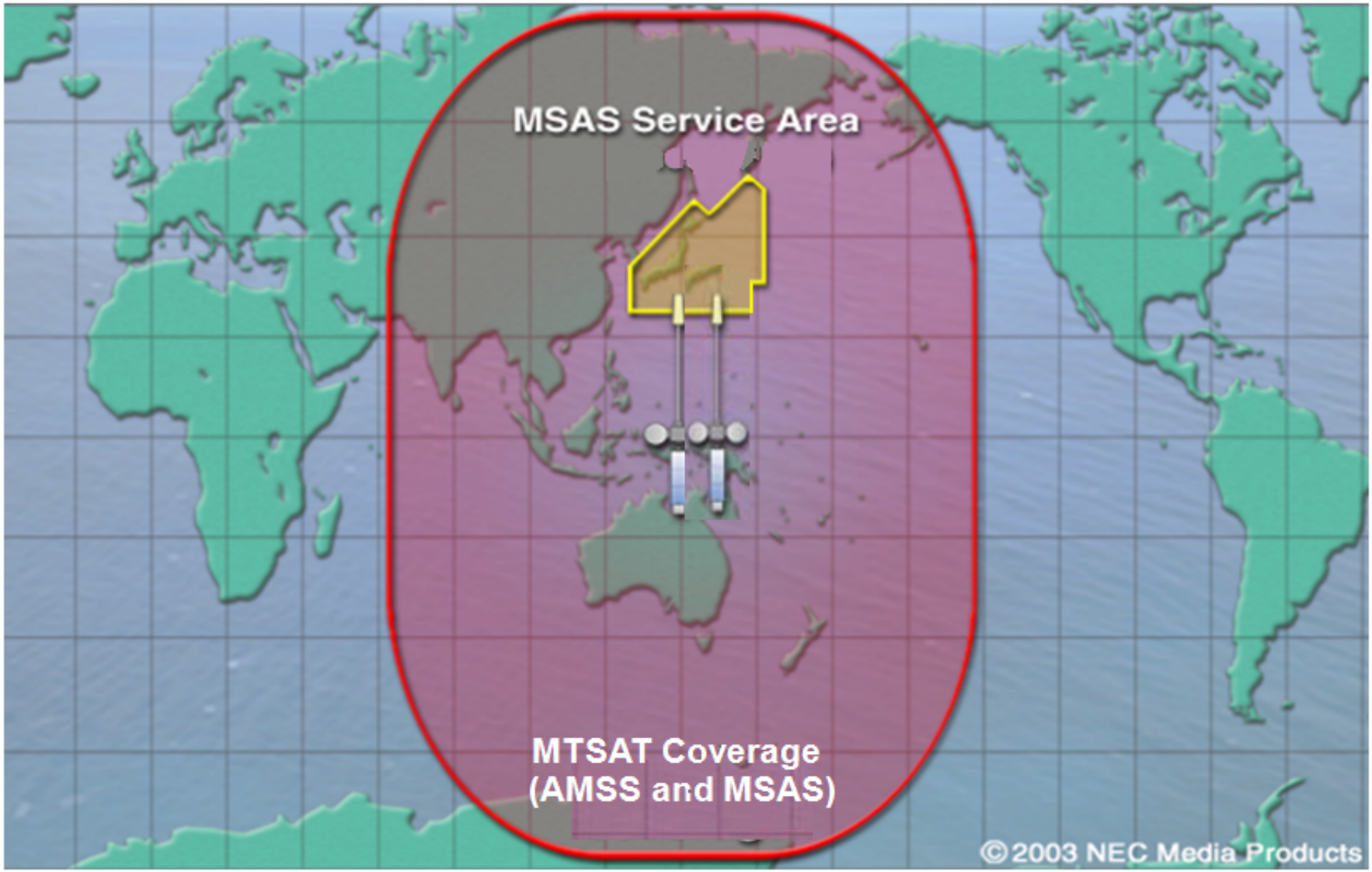
* Nominally for MTSAT-2
  - Backup for MTSAT-1R
* 3 dish antennas (2 for GEOs and one for emergency)

Current MSAS operations

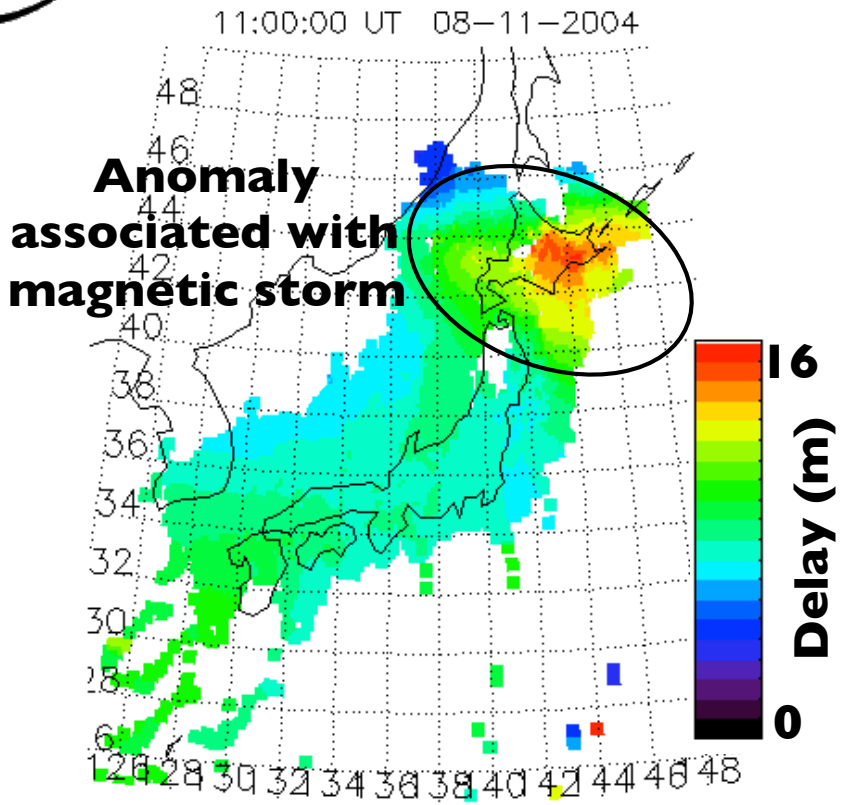
- Augments GPS L1 signals
- System configuration
  - 1 GEO (MTSAT-2) with two signals (dual-PRN operation)
    - MTSAT-1R was decommissioned in December 2015.
  - 2 MCSs, 6 GMSs (including 2 GMSs with MCSs) and no MRS
    - 2 MRSs were decommissioned in February 2015.
- Service level
  - RNAV (en-route to RNP-0.3) in Fukuoka FIR
  - Horizontal guidance only due to ionospheric activities

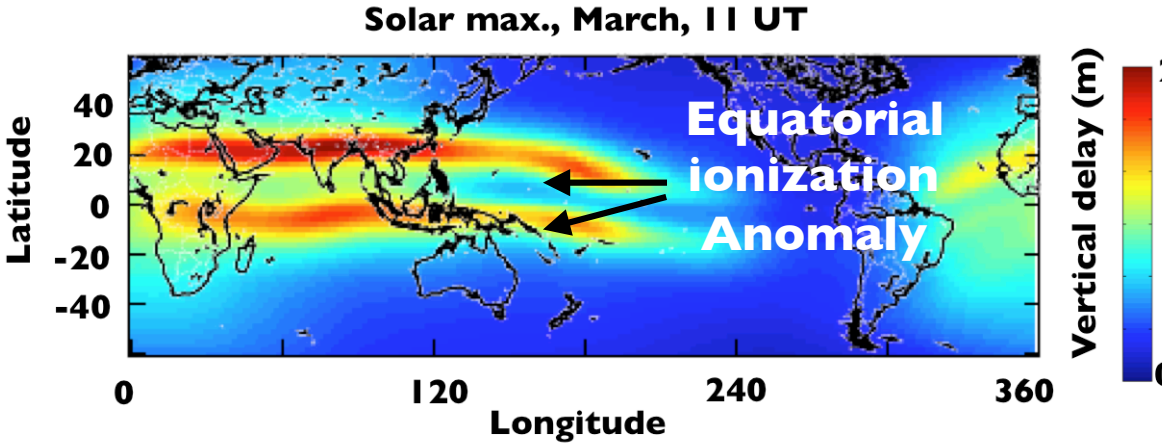


MSAS Coverage

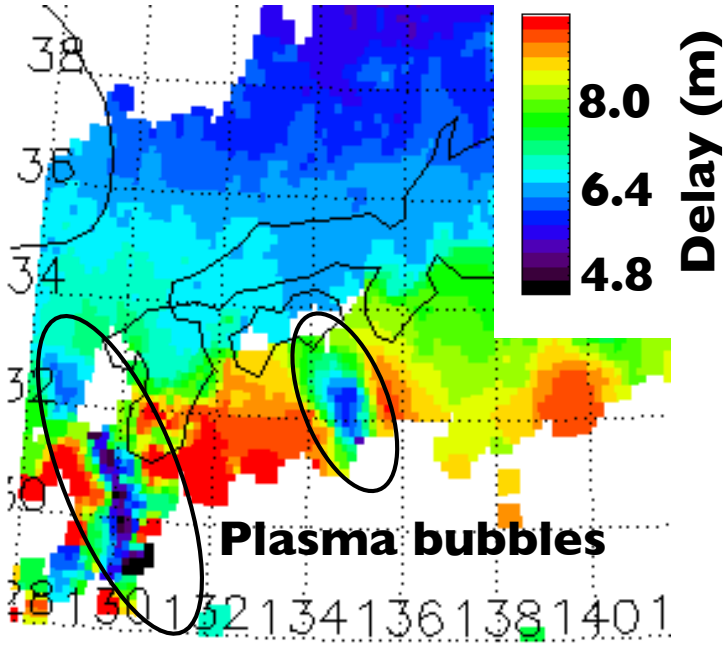


Ionospheric Conditions in Japan



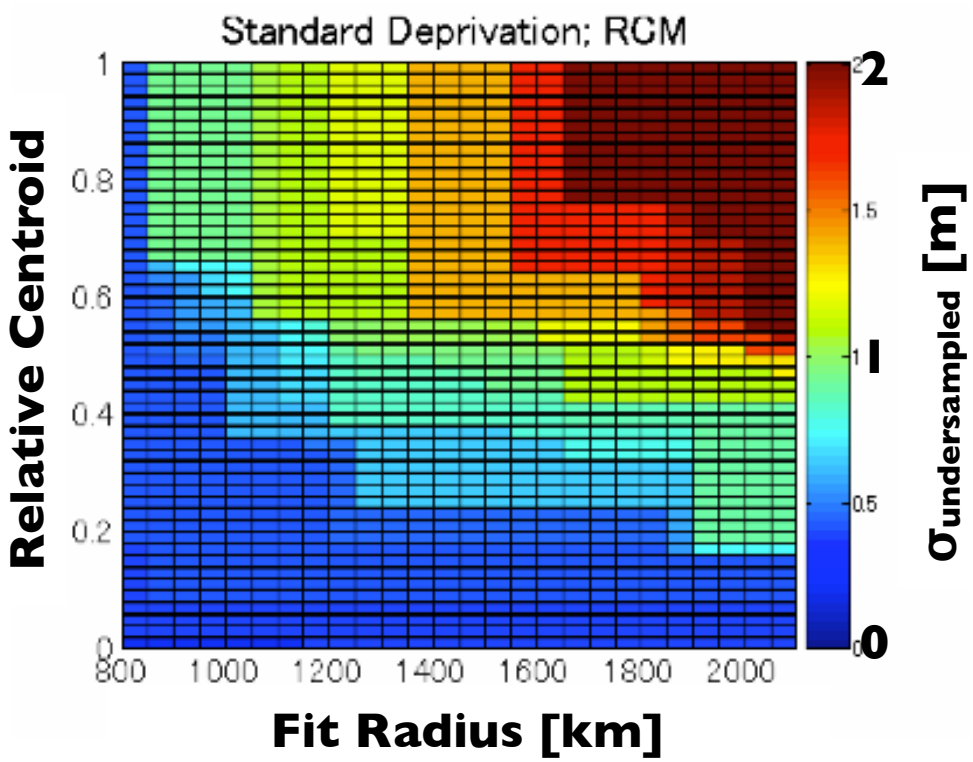


* Japan is located at mid- to low magnetic latitude region (~15-41° in magnetic latitude).
  - Subject to both mid-latitude type and low latitude type ionospheric anomalies

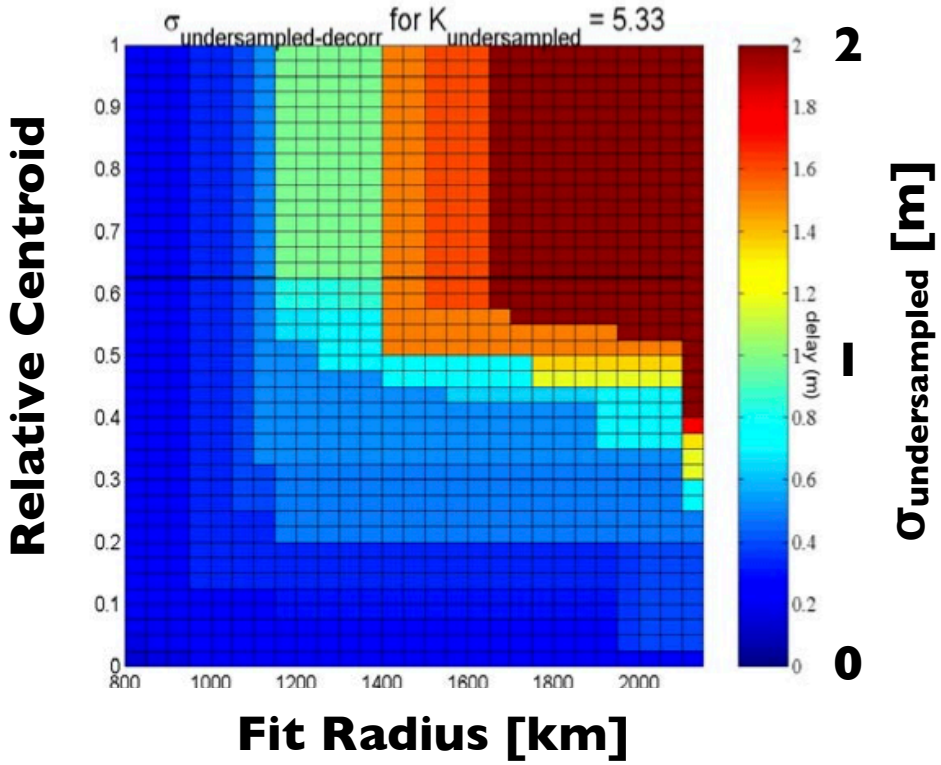


Ionospheric Threat Model

MSAS [Sakai et al., 2008]



WAAS [Anshuler et al., 2002]

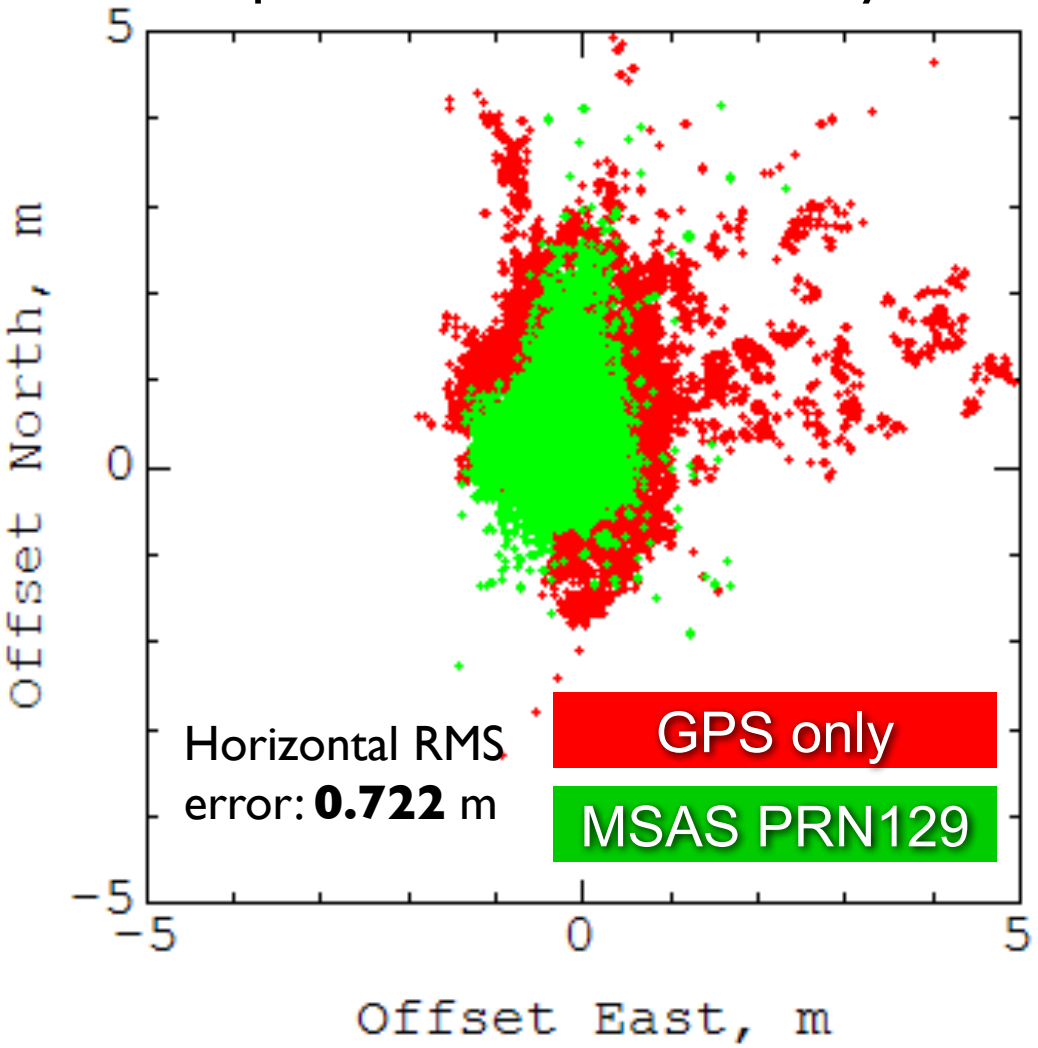


- Threat space is wider for MSAS than WAAS.
  - Severer ionospheric conditions
  - Limited distribution of GMSs

➡ Currently only horizontal guidance can be provided.

Performance of MSAS - Accuracy

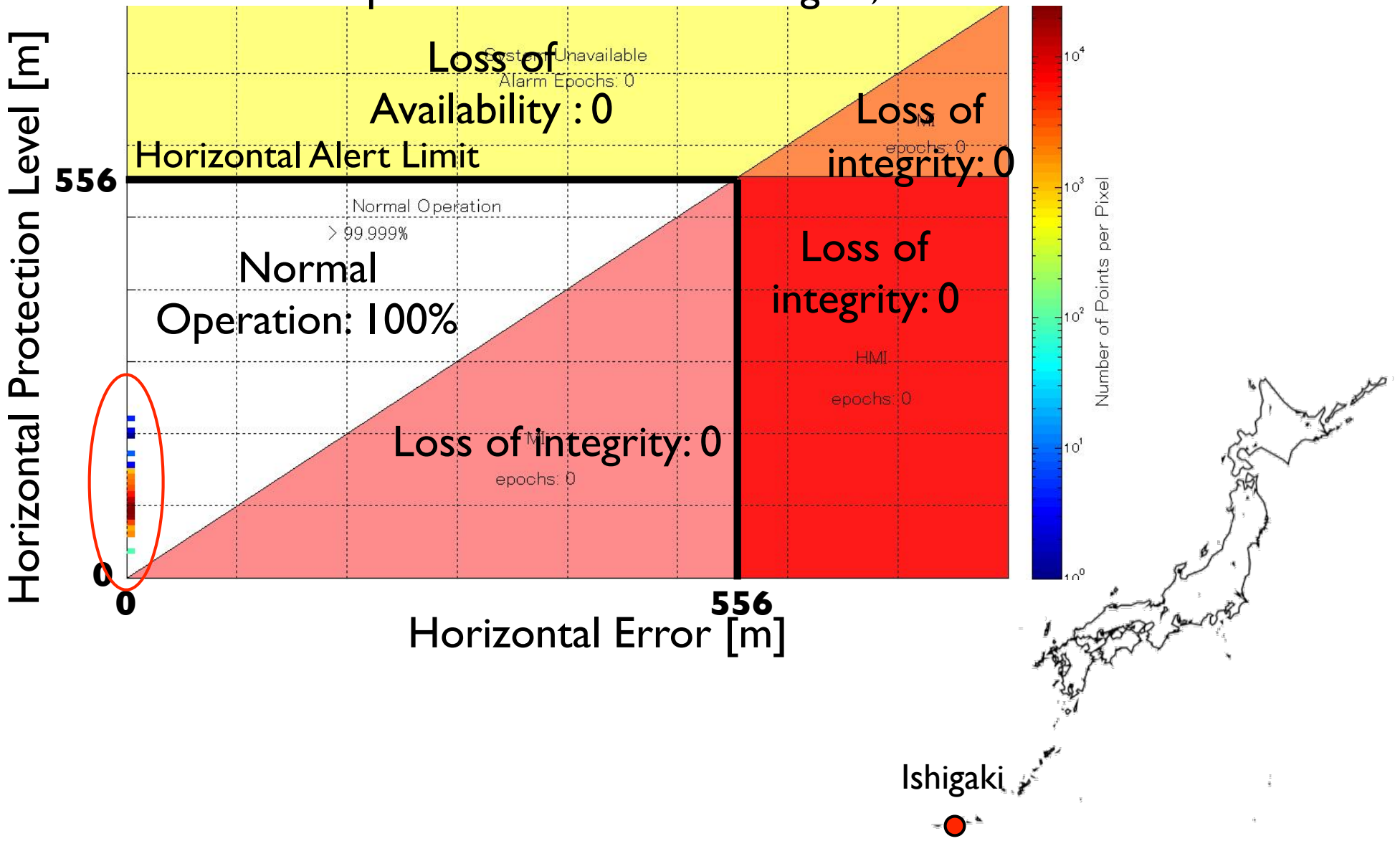
8-12 August 2016
Independent receiver at Takayama



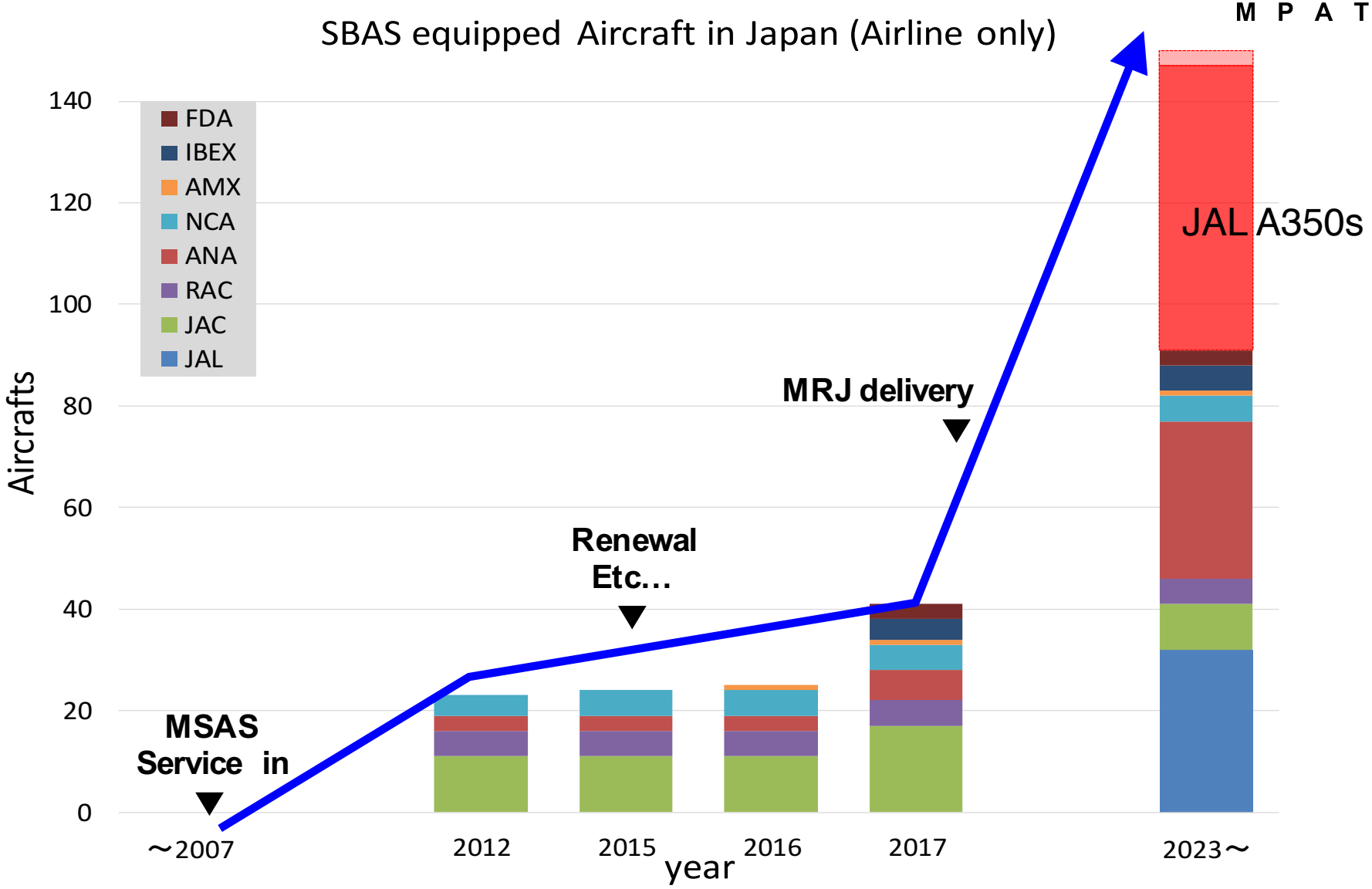
Performance of MSAS - Integrity

19 April 2016

Independent Receiver at Ishigaki,

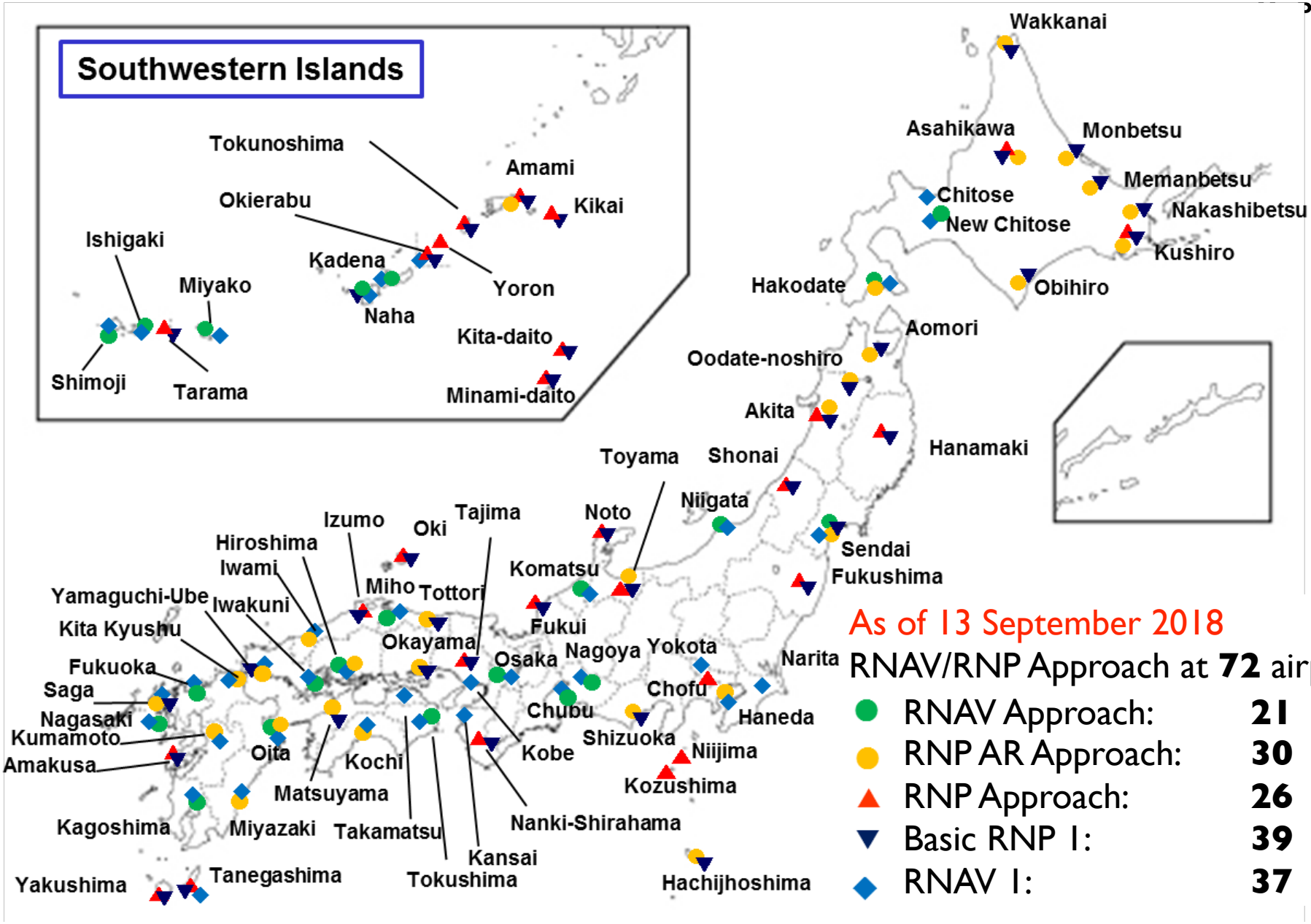


SBAS Equipage



* The number of SBAS equipped aircraft is increasing.

RNAV/RNP Implementation



As of 13 September 2018

RNAV/RNP Approach at **72** airports

RNAV Approach:	**21**
RNP AR Approach:	**30**
RNP Approach:	**26**
Basic RNP 1:	**39**
RNAV 1:	**37**

MSAS upgrade

* MSAS V2 (2020-)
  - System update with QZSS (Michibiki)
  - RNAV (en-route to RNP-0.3) in Fukuoka FIR (Same as current MSAS)
* MSAS V3 (2023(TBD)-)
  - Additional GEOs and GMSs
  - LPV implementation
* MSAS V4
  - DFMC (Dual-Frequency and Multi-Constellation) SBAS
  - Validation activities by ENRI (2017-)