SBAS SOLUTION FOR CAR SAM REGION

TWENTY-FIRST MEETING OF THE CARIBBEAN AND SOUTH AMERICAN REGIONS PLANNING AND IMPLEMENTATION GROUP (GREPECAS/21)

NOVEMBER 15TH-17TH 2023

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AGENDA

/// SBAS implementation status over the World

/// SBAS performances depending on ionosphere activity

/// Equatorial region ionosphere activity

/// Thales studies in Africa

/// Thales SBAS feasibility assessment in SAM region

/// Conclusion – Way Forward

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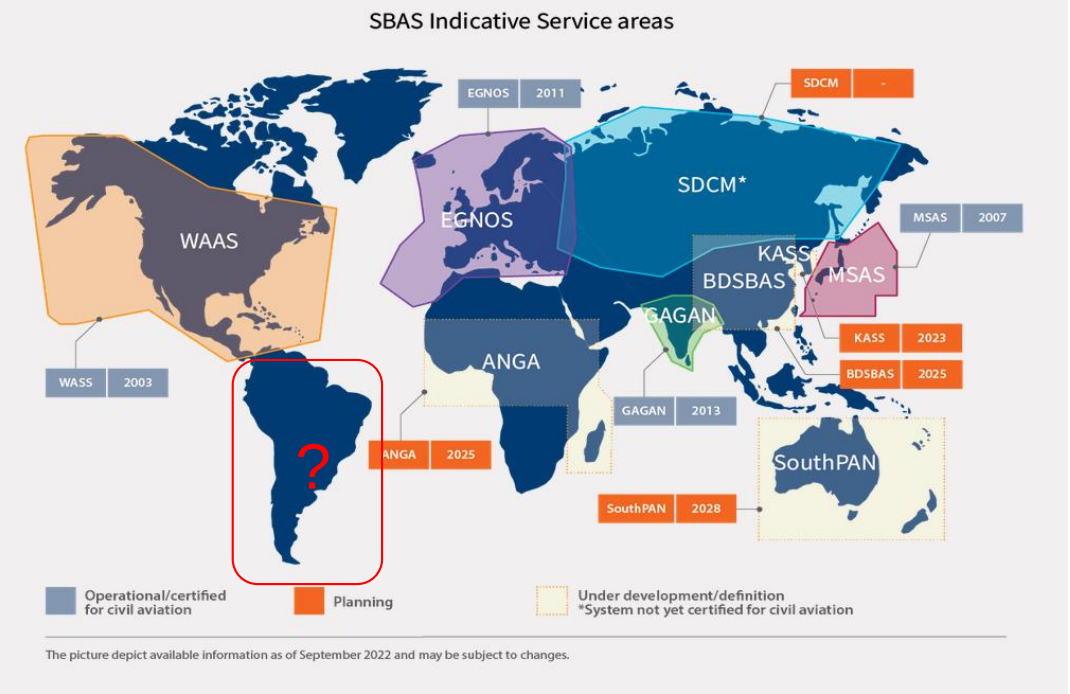
SBAS OVER THE WORLD

/// A SBAS system are being deployed worldwide to augment GNSS systems for Safety Critical Applications.

/// THALES is a world leader in SBAS development

- **EGNOS Development (phase E)**
- **KASS Development (Phase C/D)**
- **ANGA Development (Phase C0)**
- **EGNOS Evolutions (Phase A)**

/// South America is currently the only region without planned SBAS development



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SBAS PERFORMANCES DEPENDING ON IONOSPHERE ACTIVITY

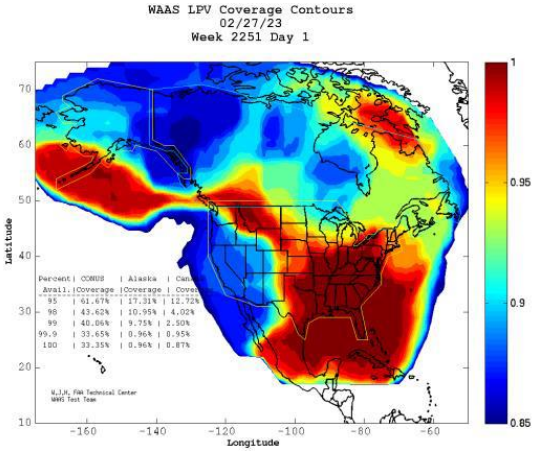
/// Current GNSS single frequency augmentation systems performance are dependent in particular on ionosphere activity.

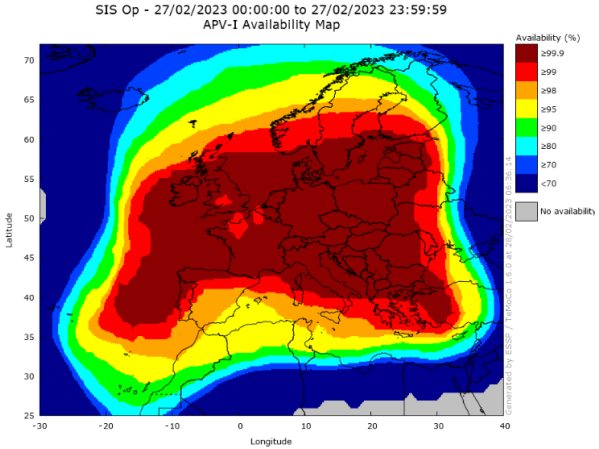
/// In particular, SBAS and GBAS are affected by strong ionosphere activity:

- Gradients → leading to degrade ionosphere corrections/bounds for SBAS and spatial degradation function for GBAS
- Scintillation → affecting SBAS ionosphere monitoring (mainly) and degrading GBAS overall satellites monitoring availability

/// Example of strong ionosphere activity on SBAS performances: February 27th 2023

WAAS





EGNOS

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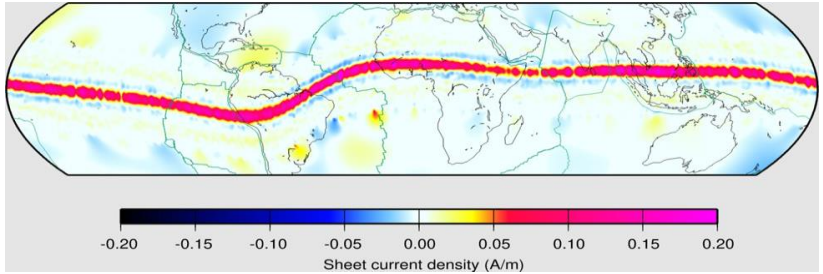
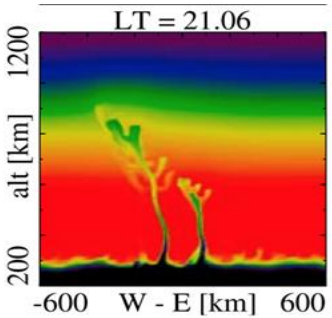
EQUATORIAL REGIONS IONOSPHERE ACTIVITY

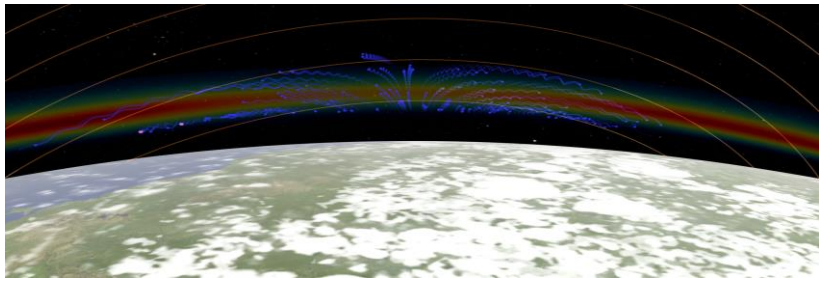
/// Such severe ionosphere events observed in WAAS and EGNOS latitudes are in fact more common in equatorial regions

/// Equatorial regions undergo the worst ionosphere activity. This is due to the specific geometry of the Earth geomagnetic field lines leading to generated different physical effects:

- A strong electric current: the equatorial electrojet
- The equatorial fountains
- Plasma bubbles







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EQUATORIAL REGIONS IONOSPHERE ACTIVITY

/// SBAS development in equatorial regions requires a better knowledge of ionosphere characteristics:

- Spatial and temporal gradients
- Bubbles size / amplitude
- Scintillation phenomenon

/// Usual SBAS algorithms cannot be easily adapted to such conditions and offer poor performances, this has been observed in South America:

- SACCSA project using adapted EGNOS CPF Processing Set SBAS algorithms
- WAAS like solutions (ref: “Reexamining Low-Latitude Ionospheric Error Bounds: An SBAS Approach for Brazil”)

/// **Dedicated SBAS algorithms managing both severe ionosphere gradients and scintillation effects are mandatory**

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EQUATORIAL REGIONS IONOSPHERE ACTIVITY

/// Several years of in depth studies of equatorial ionosphere new SBAS algorithm designed has been developed by Thales allowing to offer:

- A better capability to follow ionosphere dynamics
- Detection of plasma bubbles
- Ionosphere monitoring resilience to scintillation conditions

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THALES STUDIES IN AFRICA

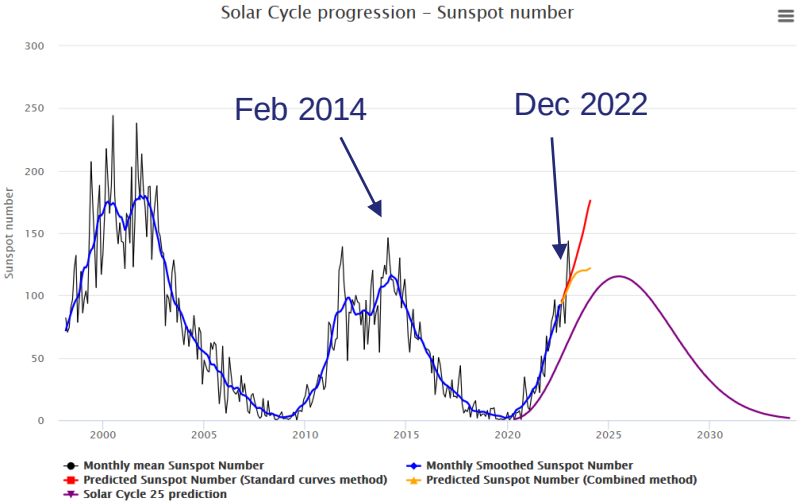
/// All these SBAS algorithms improvements allowed to demonstrate feasibility of LPV (APV-I) service in Middle Africa.

/// A complementary study phase reaching of Preliminary Design Review level has been successfully executed in 2020-2021

/// During this phase, 5 real SBAS precision approaches have been successfully performed in Togo (January 27th 2021), complemented by helicopter SBAS approach in June 2021

/// **A test bed has been set up providing results since November 2022, including real signal in space broadcast**

→ **These results confirm that a reliable APV-I service is achieved while ionosphere activity since October 2022 is increasing; already reaching similar levels as in previous solar cycle peak in 2014**



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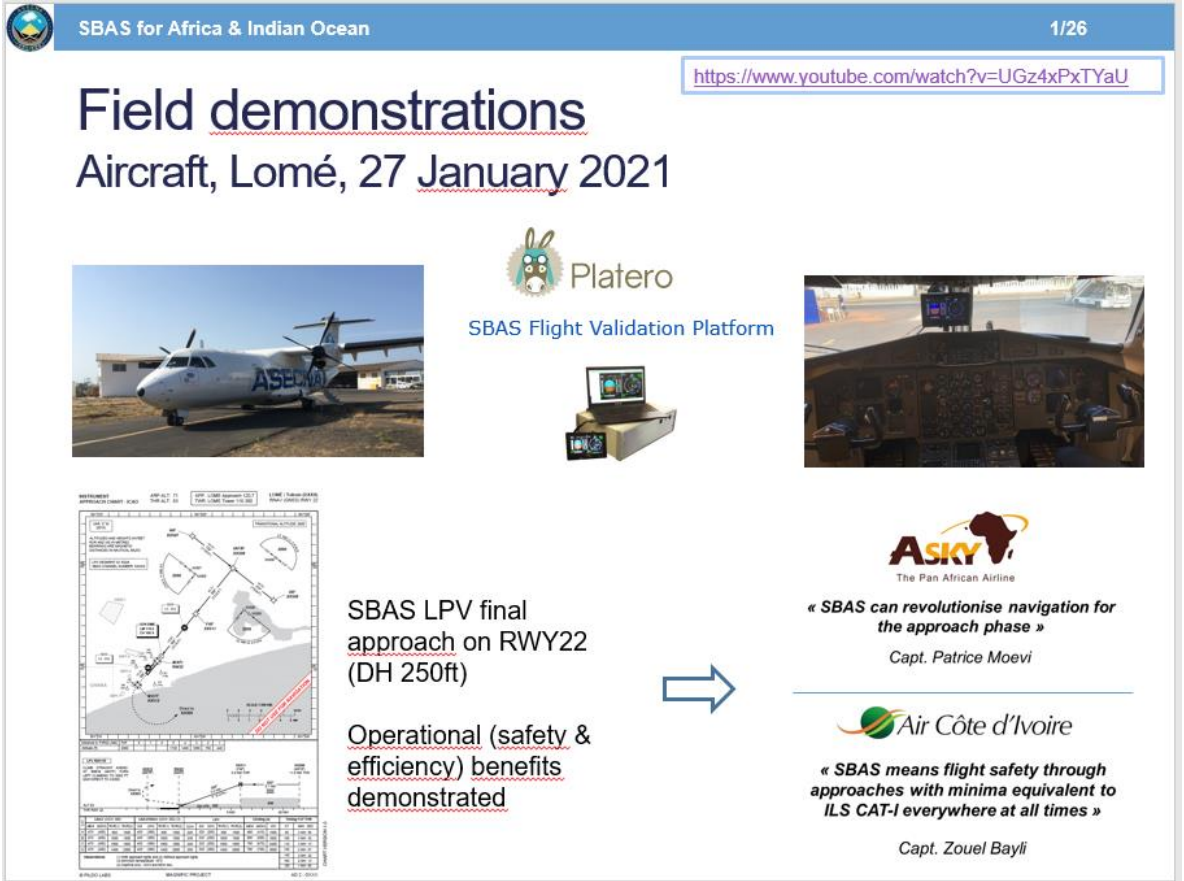
THALES STUDIES IN AFRICA- AIRCRAFT DEMONSTRATION

/// Reference demonstration is the one performed in Lomé (Togo) for ASECNA in 01/2021

/// ASECNA aircraft demonstration video : https://www.youtube.com/watch?v=UGz4xPxTYaU



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THALES STUDIES IN AFRICA – HELICOPTER DEMONSTRATION

/// Another reference SBAS demonstration is the one performed in Douala (Cameroun) for ASECNA in 06/2021 with rotorcraft

/// Link to the press release:

https://www.thalesgroup.com/en/worldwide/space/press-release/asecna-teams-nigcomsat-and-thales-alenia-space-continue-developing

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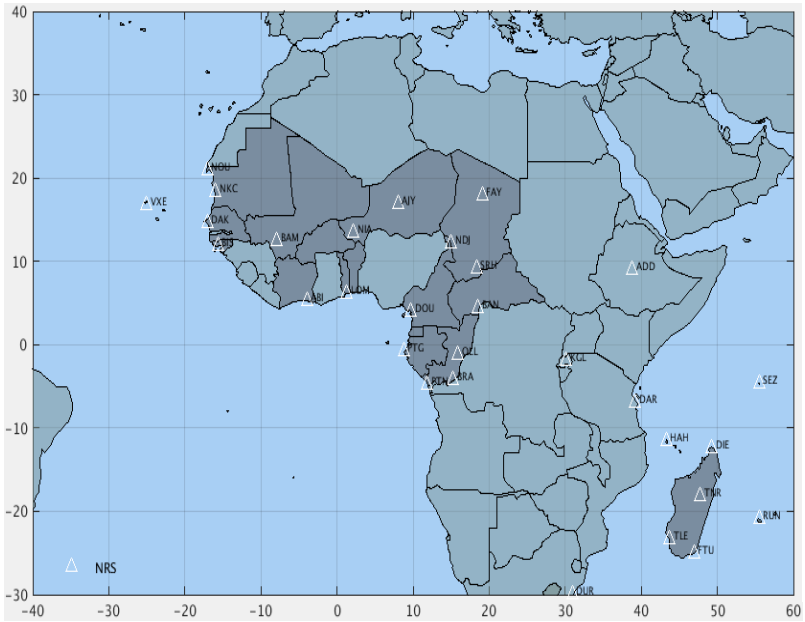
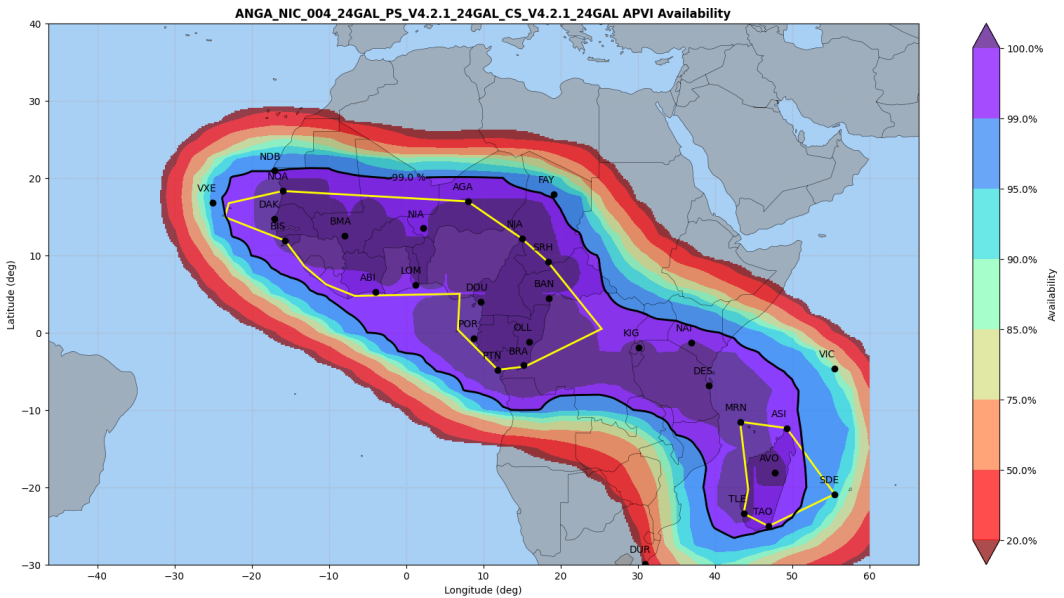
THALES STUDIES IN AFRICA

/// Based on real data, APVI >99% availability is achieved in Middle Africa despite the very limited number of stations (APVI performances are met in the correct reference station density area)

/// Expected SBAS APVI performances for SBAS ANGA equipped with 30 reference stations:





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THALES STUDIES IN AFRICA

/// **Maturity of Thales solution in Africa has been demonstrated during long duration testing.**

/// For Middle Africa SBAS now named « ANGA », critical design phase is about to start targeting safety of life services declaration in FY2028/2029

→ **Gathering all our experience in SBAS and more precisely in equatorial region, Thales will be pleased to support a South America initiative allowing to test and deploy such solution as soon as possible.**

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THALES SBAS SOLUTION FEASIBILITY ASSESSMENT IN SAM REGION

/// To properly assess Thales SBAS solution and its feasibility over CAR/SAM region specific test cases have been executed under real ionosphere conditions

/// In order to better understand those results comparison with a Brazilian paper has been made:

- "Reexamining Low-Latitude Ionospheric Error Bounds: An SBAS Approach for Brazil" (Marini et al, 2021) – ICEA Brazil

/// For each condition assessed in this paper, comparison is provided

/// Thales study contains quiet, active and severe ionosphere conditions

/// The reference station network (34) used is composed with a mix of IGS and IBGE stations providing 1Hz data (better to properly manage ionosphere scintillation effects, compared to about 100 stations in the above paper)

/// 3 sets of scenario:

- For ionosphere quiet condition, August 16th 2021 (occurrence probability of such conditions bigger than 75%-80% of time)
- For active ionosphere condition, January 9th 2023 (occurrence probability of such conditions about 15% of time)
- For severe ionosphere condition, February 11th 2023 (occurrence probability lower than 5% of time)

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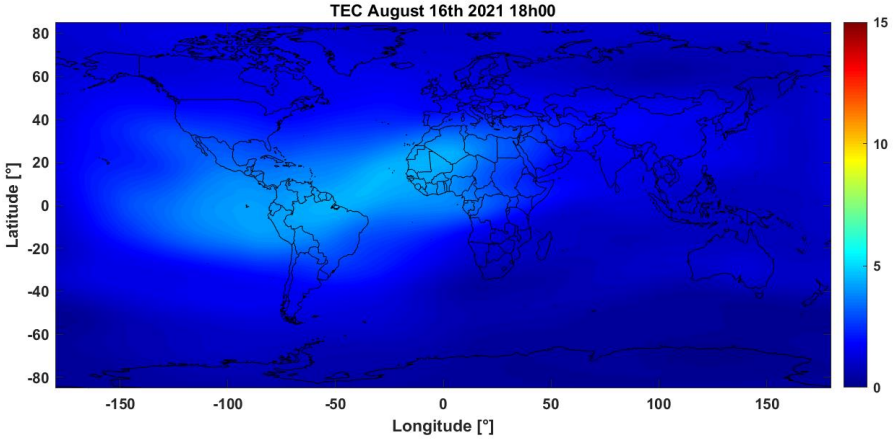
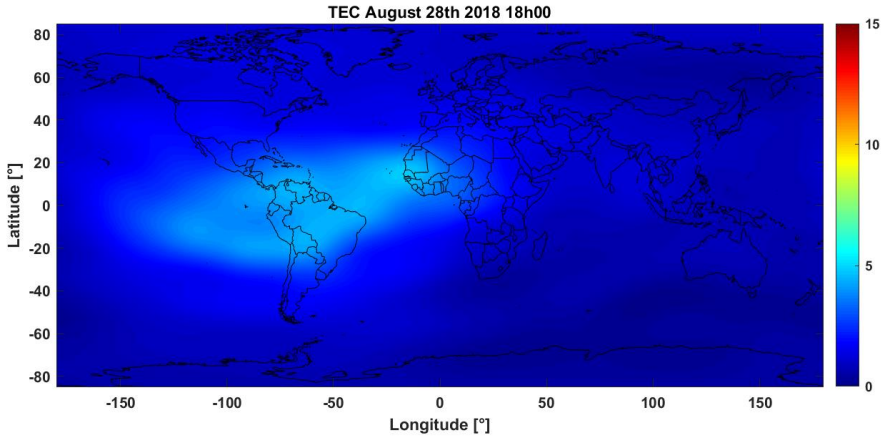
SBAS PERFORMANCES IN SOUTH AMERICA: QUIET DAY

/// August 16th 2021 ionosphere conditions compared to August 28th 2018



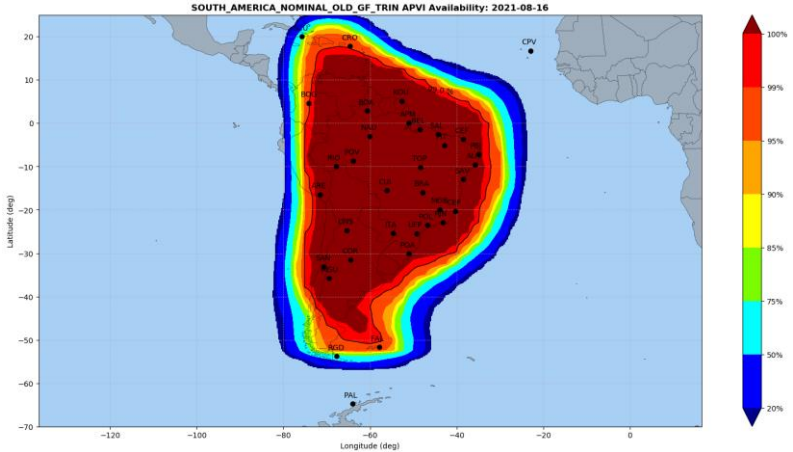


→ Similar conditions to those selected in ICEA paper for the quiet day (2018-08-28)

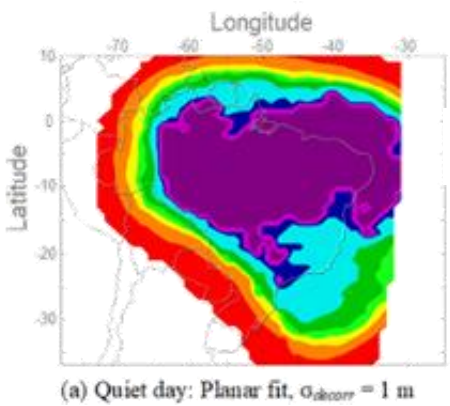
SBAS PERFORMANCES : QUIET DAY (2021-08-16)

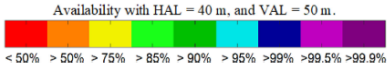
/// CONCLUSION:

- **Under quiet ionosphere activity conditions, Thales SBAS algorithms performances allow to achieve ICAO SARPS APV-I service performances with margins**
- **Availability performance can be compared as extracted from ICEA 2021 paper:**



Thales SBAS algorithms





ICEA 2021 paper using WAAS-like algorithms

→ Under fully similar ionosphere conditions (with less reference stations compared to ICEA paper), Thales SBAS solution offers a full APV-I service capability contrary to WAAS-like solution which is not adapted to equatorial regions.

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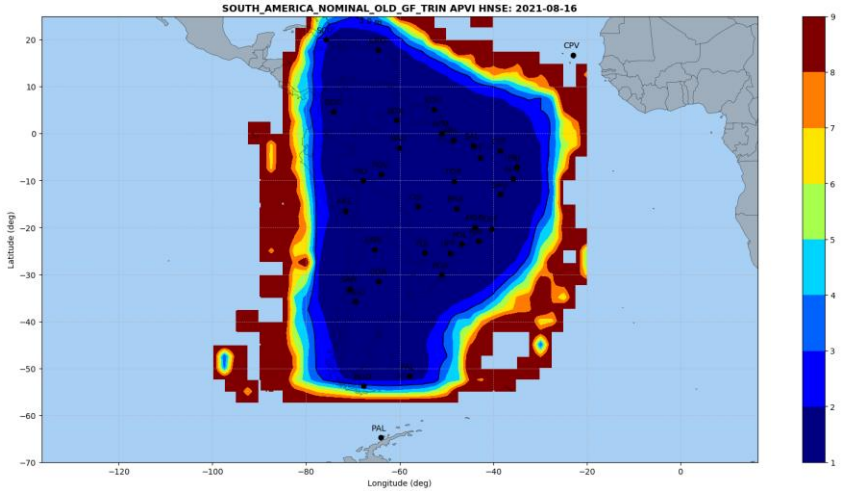
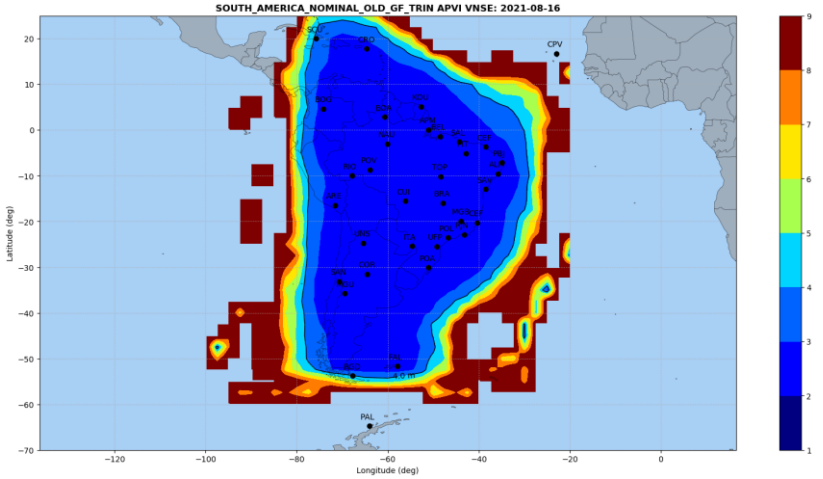
THALES SBAS PERFORMANCES : QUIET DAY (2021-08-16)

/// APV-I PERFORMANCES (HAL=50m VAL=40m)



HNSE 95%
(<16m → ICAO SARPS)



VNSE 95%
(<20m → ICAO SARPS)

→ICAO SARPS required accuracy performances for APV-I are achieved with huge margins (HNSE<2m , VNSE<3m) – compatible with CAT-I approach

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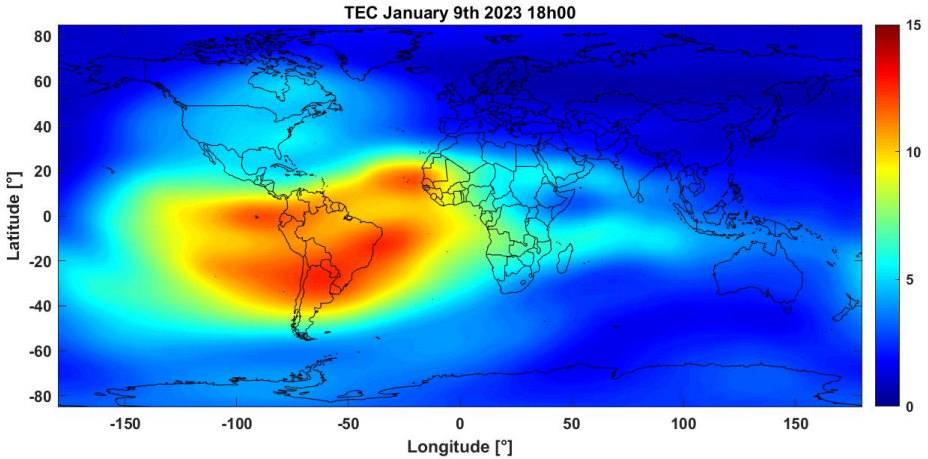
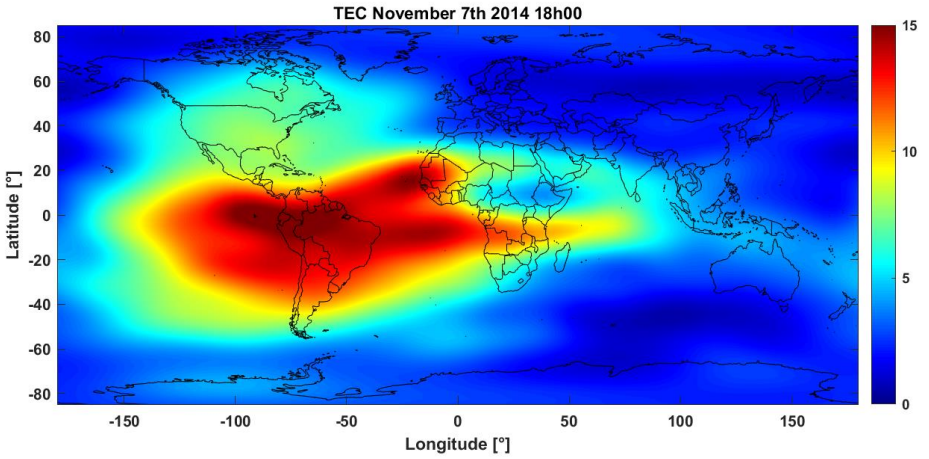
SBAS PERFORMANCES IN SOUTH AMERICA: ACTIVE DAY

/// January 9th 2023 ionosphere conditions compared to November 7th 2014



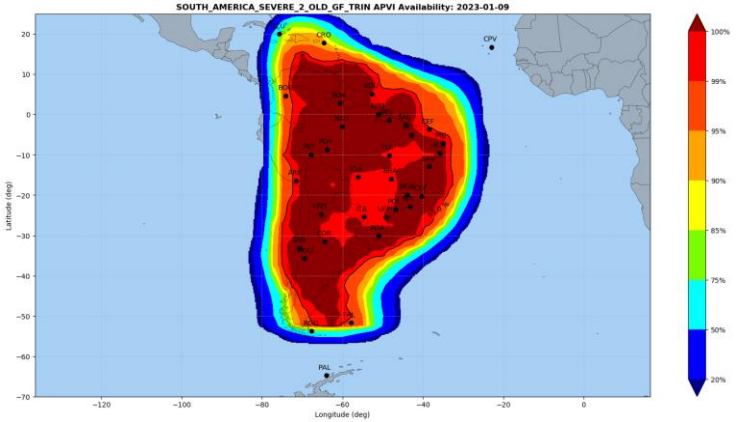


→ **This selected day is not as degraded as the scenario selected by ICEA paper for the « active day » however another scenario has been executed in a much more degraded situation compared to November 2014**

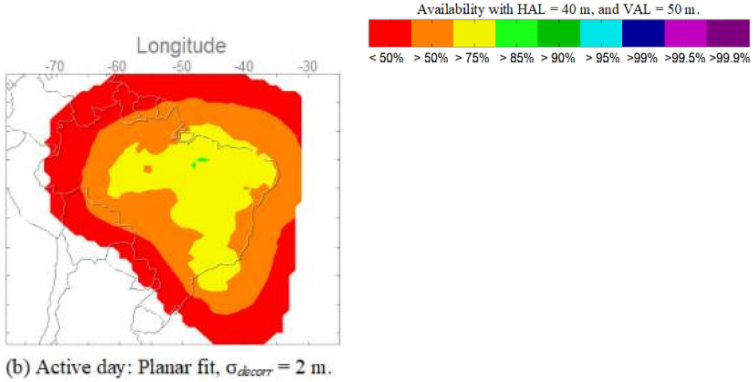
THALES SBAS PERFORMANCES : ACTIVE DAY (2023-01-09)

/// CONCLUSION:

- **Under active ionosphere activity conditions, Thales SBAS algorithms performances allow to achieve APV-I service with enough margin to allow SBAS operations (always ensuring the required integrity level)**
- **Availability performance can be compared as extracted from ICEA 2021 paper:**



Thales SBAS algorithms



ICEA 2021 paper using WAAS-like algorithms

→ **Under slightly less active conditions, Thales SBAS algorithms offer a huge improvement compared to WAAS like solution. Under same conditions, it is expected to get at least 95% APV-I availability performances..**

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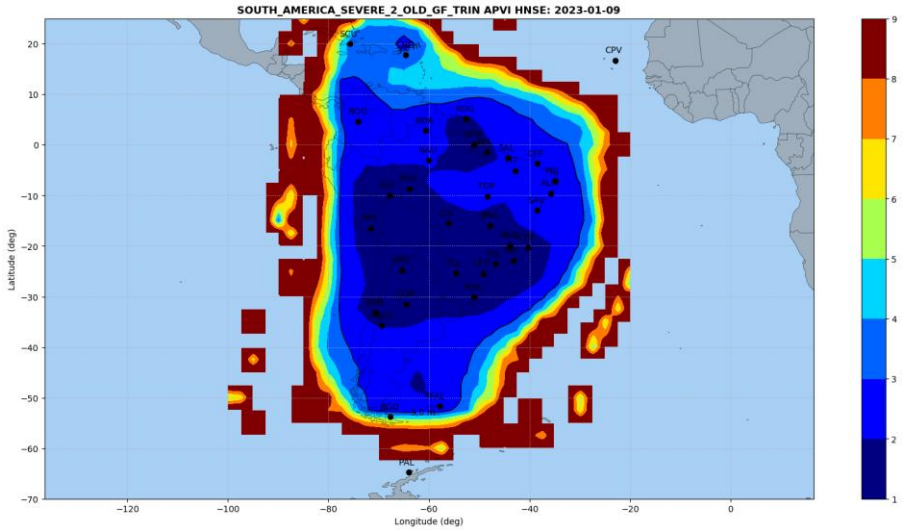
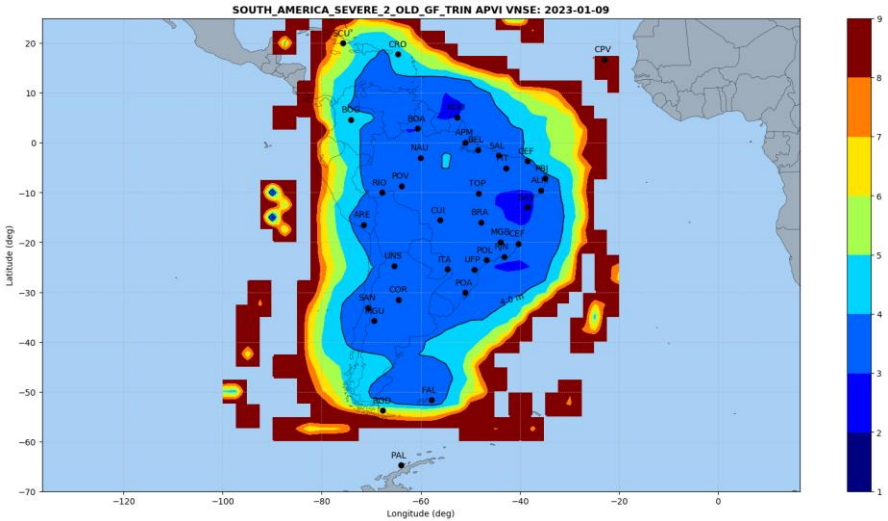
THALES SBAS PERFORMANCES : ACTIVE DAY (2023-01-09)

/// APV-I PERFORMANCES (HAL=50m VAL=40m)



HNSE 95%
(<16m → ICAO SARPS)



VNSE 95%
(<20m → ICAO SARPS)

→ICAO SARPS required accuracy performances for APV-I are achieved with huge margins (HNSE<3m , VNSE<5m)

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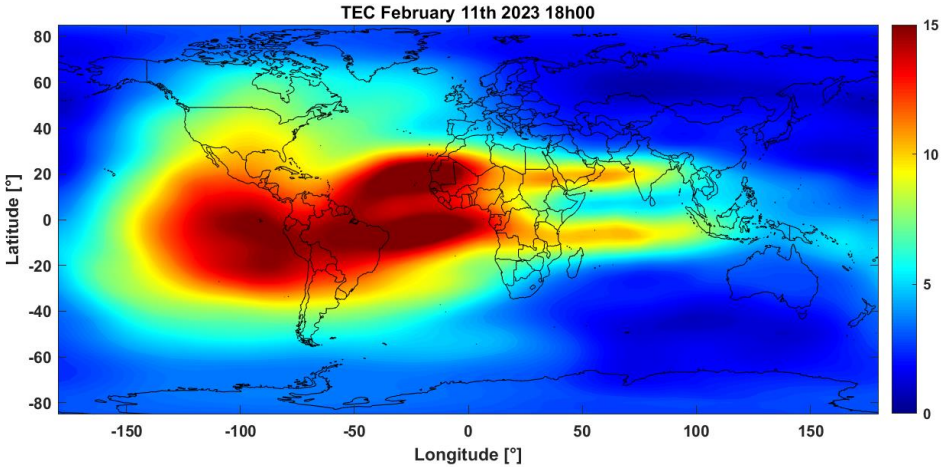
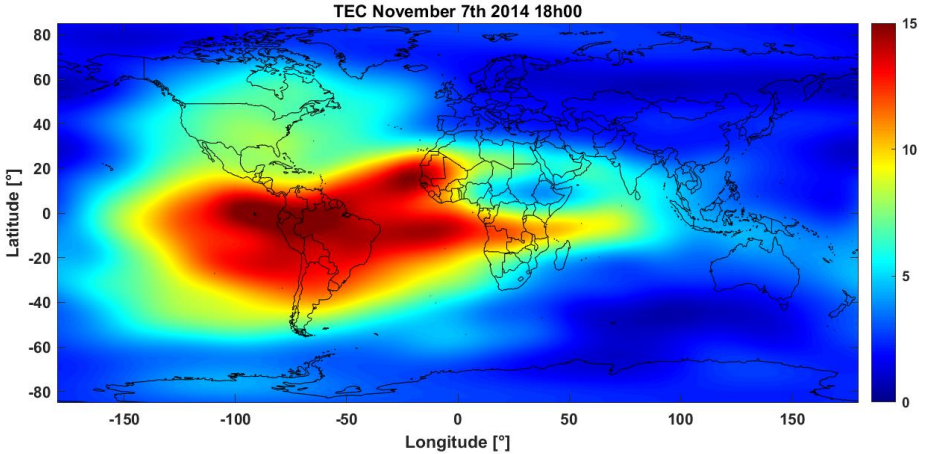
SBAS PERFORMANCES IN SOUTH AMERICA: SEVERE DAY

/// February 11th 2023 ionosphere conditions compared to November 7th 2014

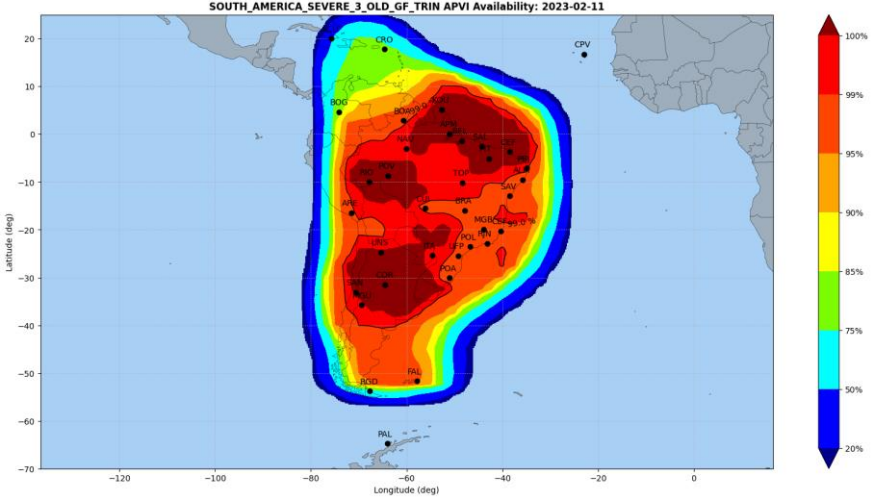




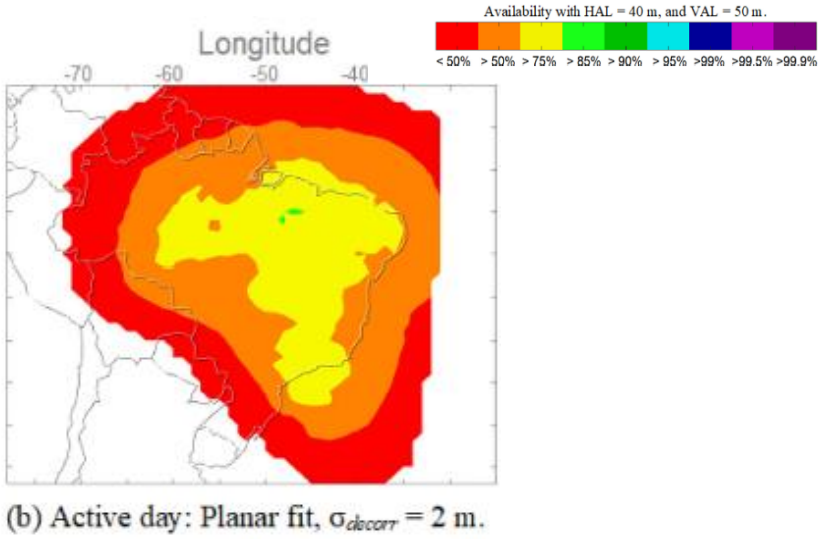
→ This selected day is much more degraded than the scenario selected by ICEA paper for the « active day » both concerning ionosphere dynamics but also scintillation amplitude.

THALES SBAS PERFORMANCES : STRONG ACTIVE DAY (2023-02-11)

/// APV-I PERFORMANCES (HAL=50m VAL=40m)



Availability (over 24h)



ICEA 2021 paper using WAAS-like algorithms

→ Under these very severe conditions availability performance for APV-I is achieved in most of service area (Availability>95%) compared to ICEA paper with less than 50% availability

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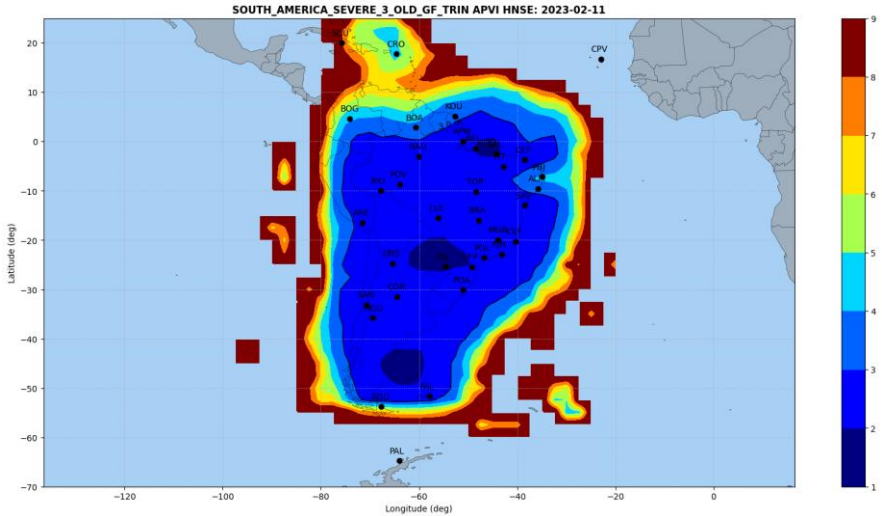
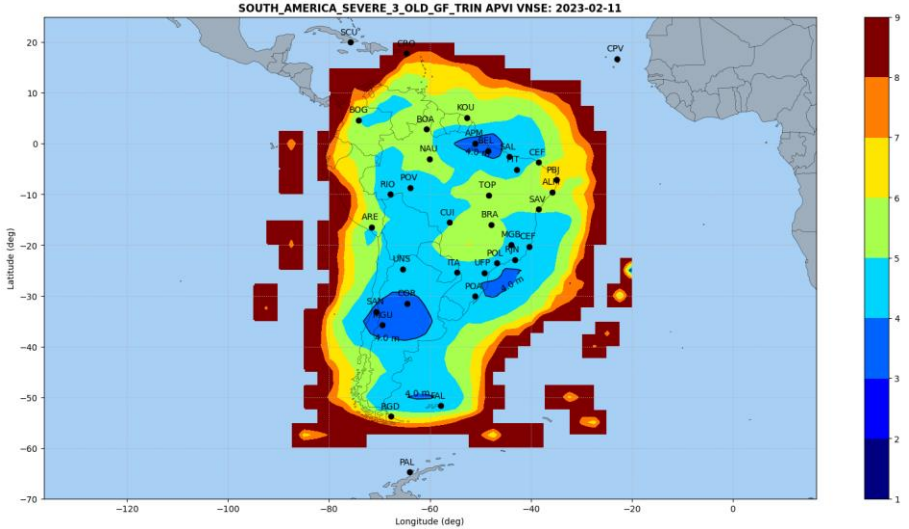
THALES SBAS PERFORMANCES : VERY ACTIVE DAY (2023-02-11)

/// APV-I PERFORMANCES (HAL=50m VAL=40m)





HNSE 95%
(<16m → ICAO SARPS)

VNSE 95%
(<20m → ICAO SARPS)

→ICAO SARPS required accuracy performances for APV-I are achieved with huge margins (HNSE<3m , VNSE<6m)

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THALES SBAS SOLUTION FEASIBILITY ASSESSMENT IN SAM REGION

/// What about integrity of the solution:

- All above presented performances have been analyzed using EGNOS qualified tools
- The SBAS algorithms tested are the « pre-industrialized » algorithms designed for ASECNA SBAS complying with DO-178B coding rules
- In depth analyses have been performed and all evidences have been collected
- Integrity of corrections allowing to reach the requested 10-7/150s for precision approaches is achieved with comfortable margins
  - Satellites clock and orbits corrections are nominal for all scenarios
  - Ionosphere corrections integrity have been controlled using real independent GNSS stations and IGS IONEX products when compatible

- **No issues have been observed as SBAS algorithms are fully adapted to low latitude ionosphere dynamics and scintillation effects**
- **Similar results as those obtained in future ASECNA (West/Central Africa) SBAS are obtained.**

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CONCLUSION – PROPOSED WAY FORWARD

/// SBAS L1 feasibility in equatorial region has been demonstrated using Thales solution in Middle Africa for which a CD phase SBAS is about to start

/// Thales is fully confident to deliver similar service capability in all CAR/SAM region

/// Waiting for DFMC SBAS capabilities would delay the availability of such services, because despite service availability around 2030, **aircrafts DFMC equipment will not be deployed before 2040's.**

/// **Thales is ready to support CARS/SAM in SBAS deployment**

/// **Such initiative could lead to benefit to all CAR/SAM region in various areas and not only civil aviation (agriculture, mining, drones, cars…)**

/// **A test bed could be deployed in CAR/SAM region allowing to demonstrate all SBAS added value in this region**

/// **At the end, it is worth mentioning that SBAS infrastructure can be spread around all CAR/SAM countries allowing them to benefit from RNP associated performances in most of airports while minimizing their cost impact in contrary to systems such as GBAS /ILS/DME requiring specific infrastructure for each airport.**

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THANK YOU!

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THALES SBAS SOLUTION DESIGN AUTHORITY

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