41 ár við GPS – menning og avbjóðingar á høgum breiddarstigum

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FRÓÐSKAPARSETUR FØROYA

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Global Navigation Satellite Systems (GNSS)

GPS (USA)

GLONASS (RUSSIA)

BeiDou (CHINA)

GALILEO (EUROPE)

AÐRAR ØKISSKIPANIR

GPS

- Owned and operated by USA – *USA eigur og rekur*
- First satellite launched February 1978 – *Fyrsti fylgisveinur útsendur í februar 1978*
- Initially a military system with some civilian functionality (100m civilian accuracy) – *í fyrstani ein hernaðarskipan, sum í ávísan mun kundi brúkast av almenninginum (100 m neyvleiki)*
- Civilian growth in applications is dramatic – *umfatandi øking av vanligari nýtslu*
- New signals and architecture to be more civilian friendly – *nýggj signal og bygnaður fyri at gera skipanina meira brúkaravinarliga*
- Possible to obtain mm precision using specialist equipment – *gjørligt at røkka mm-neyvleika við serútgerð*

Originally - *upprunaliga*

24 GPS-FYLGISVEINAR

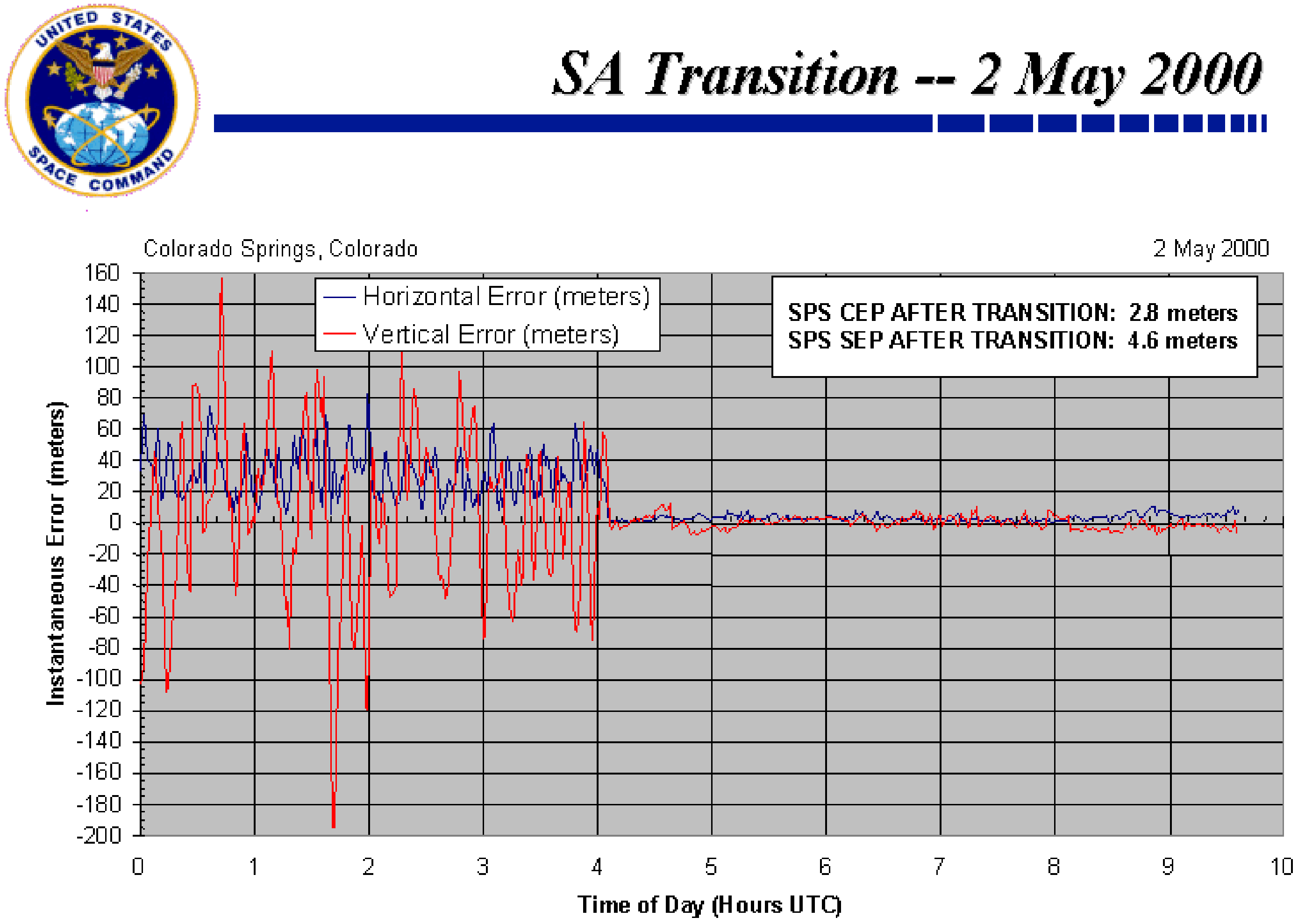
100M NEYVLEIKI FYRI VANLIGA BRÚKARAN OG 10M FYRI AMERIKANSKA HERIN

VERRI SIGNAL OG NEYVLEIKI FYRI VANLIGA BRÚKARAN

MENT LUTFALSLIG STØÐUSETING-TØKNI

Source: gps.gov

Selective Availability switched off



Current and Future GPS Satellite Generations

LEGACY SATELLITES		MODERNIZED SATELLITES		
BLOCK IIA	BLOCK IIR	BLOCK IIR-M	BLOCK IIF	GPS III/IIIF
1 operational	11 operational	7 operational	12 operational	1 in checkout
▪ Coarse Acquisition (C/A) code on L1 frequency for civil users ▪ Precise P(Y) code on L1 & L2 frequencies for military users ▪ 7.5-year design lifespan ▪ Launched in 1990-1997	▪ C/A code on L1 ▪ P(Y) code on L1 & L2 ▪ On-board clock monitoring ▪ 7.5-year design lifespan ▪ Launched in 1997-2004 LEARN MORE ABOUT GPS IIR AT AF.MIL	▪ All legacy signals ▪ 2nd civil signal on L2 (L2C) LEARN MORE ▪ New military M code signals for enhanced jam resistance ▪ Flexible power levels for military signals ▪ 7.5-year design lifespan ▪ Launched in 2005-2009 LEARN MORE ABOUT GPS IIR-M AT AF.MIL	▪ All Block IIR-M signals ▪ 3rd civil signal on L5 frequency (L5) LEARN MORE ▪ Advanced atomic clocks ▪ Improved accuracy, signal strength, and quality ▪ 12-year design lifespan ▪ Launched in 2010-2016 LEARN MORE ABOUT GPS IIF AT AF.MIL	▪ All Block IIF signals ▪ 4th civil signal on L1 (L1C) LEARN MORE ▪ Enhanced signal reliability, accuracy, and integrity ▪ No Selective Availability LEARN MORE ▪ 15-year design lifespan ▪ IIIF: laser reflectors; search & rescue payload ▪ First launch in 2018 LEARN MORE ABOUT GPS III AT AF.MIL

Source: gps.gov

Today – *Nú*

- Over 100 GNSS satellites in operation, typically 30-40 at any time *– fleiri enn 100 GNSS-fylgisveinar virknir, vanliga 30-40 í senn*
- Numerous frequencies being transmitted upon *– verður sent á fleiri frekvensum*
- Improved accuracies *– betri neyvleiki*
- Interoperable GNSS *– samvirkandi GNSS*
- More and more positioning and timing applications *– fleiri og fleiri nýtsluskipanir í mun til støðu- og tíðarseting*
- 10m to 1mm accuracies possible *– 10m til 1mm neyvleiki møguligur*
- 3D positioning, up to 100Hz data rates *– 3D-støðuseting, upp til 100Hz dátu-ferð*
- But all rely on low powered radio signals travelling 20,000km through space and the atmosphere *– men alt er treytað av, at veik radiosignal ferðast ígjøgnum rúmdina og lofthavið*

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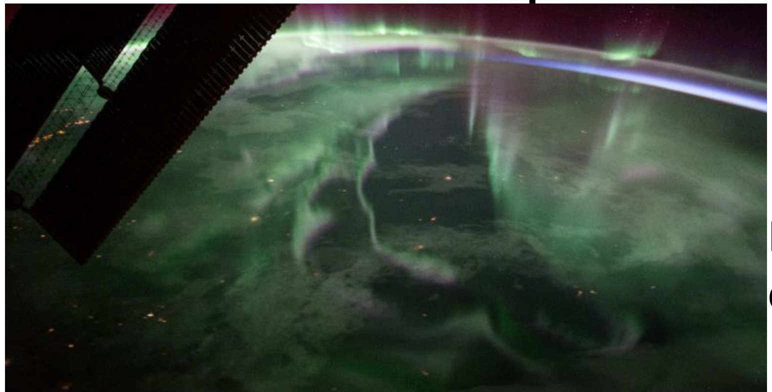
Ionospheric Scintillation over the Faroe Islands – *Glitran í ionosferuni yvir Føroyum*

- 7 October 2018: aurora borealis event witnessed for 30 mins –

  7. oktober 2018: norðlýsi yvir Føroyum í 30 min.
- GNSS data analysed from Umhvøvisstovan – *GNSS-dátur frá Umhvørvisstovuni verða greinaðar*
- Data gathered at 1Hz on all GNSS – *dátur innsavnaðar á 1Hz fyri alt GNSS*
- Results compared for 6, 7, 8 October - *úrslitini samanborin*

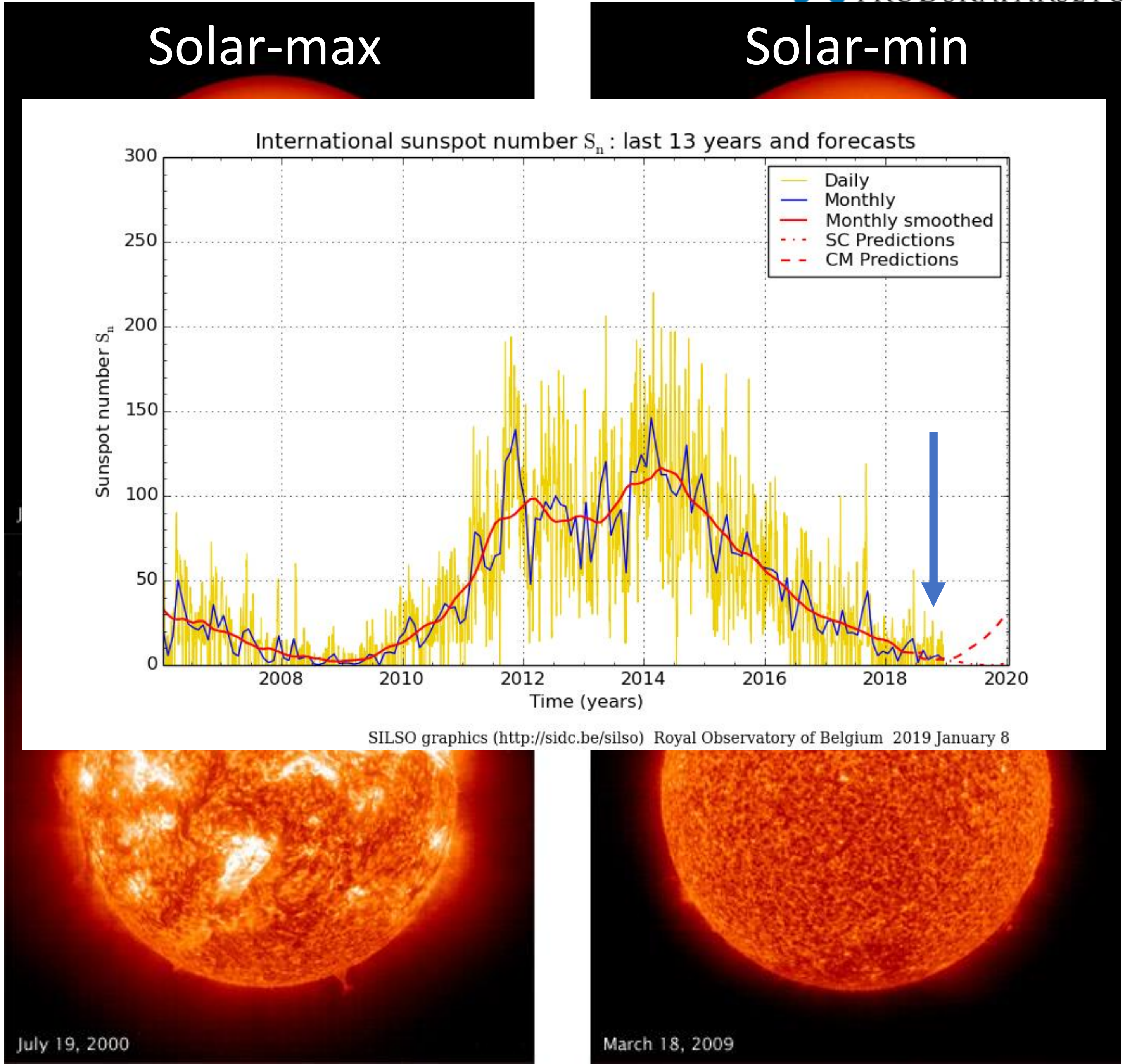


Northern lights over Canada courtesy NASA.gov

Sunspot cycle – *sólblettaringrás*

- 11 year cycle – *11 ára-ringrás*
- Solar-max & solar-min
- Currently in a solar-min – *í løtuni á solar-min*
- Solar-max will affect the ionsphere – *solar-max ávirkar ionosferuna*
- Introduce more noise – *hevur við sær meira órógv*

Sun images Courtesy NASA
earthobservatory.nasa.gov



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GPS data noise – *GPS dátu-órógv*

- Clean data before and after – *reinar dátur áðrenn og aftaná*
- Noise around the aurora borealis event – *órógv rundan um norðlýsi*
- Offset from each other – *órógvið er forskotið*
- Noise not present on all satellites – *órógv er ikki á øllum fylgisveinum*
- Similar results for all GNSS – *líknandi úrslit fyri alt GNSS*

GPS data

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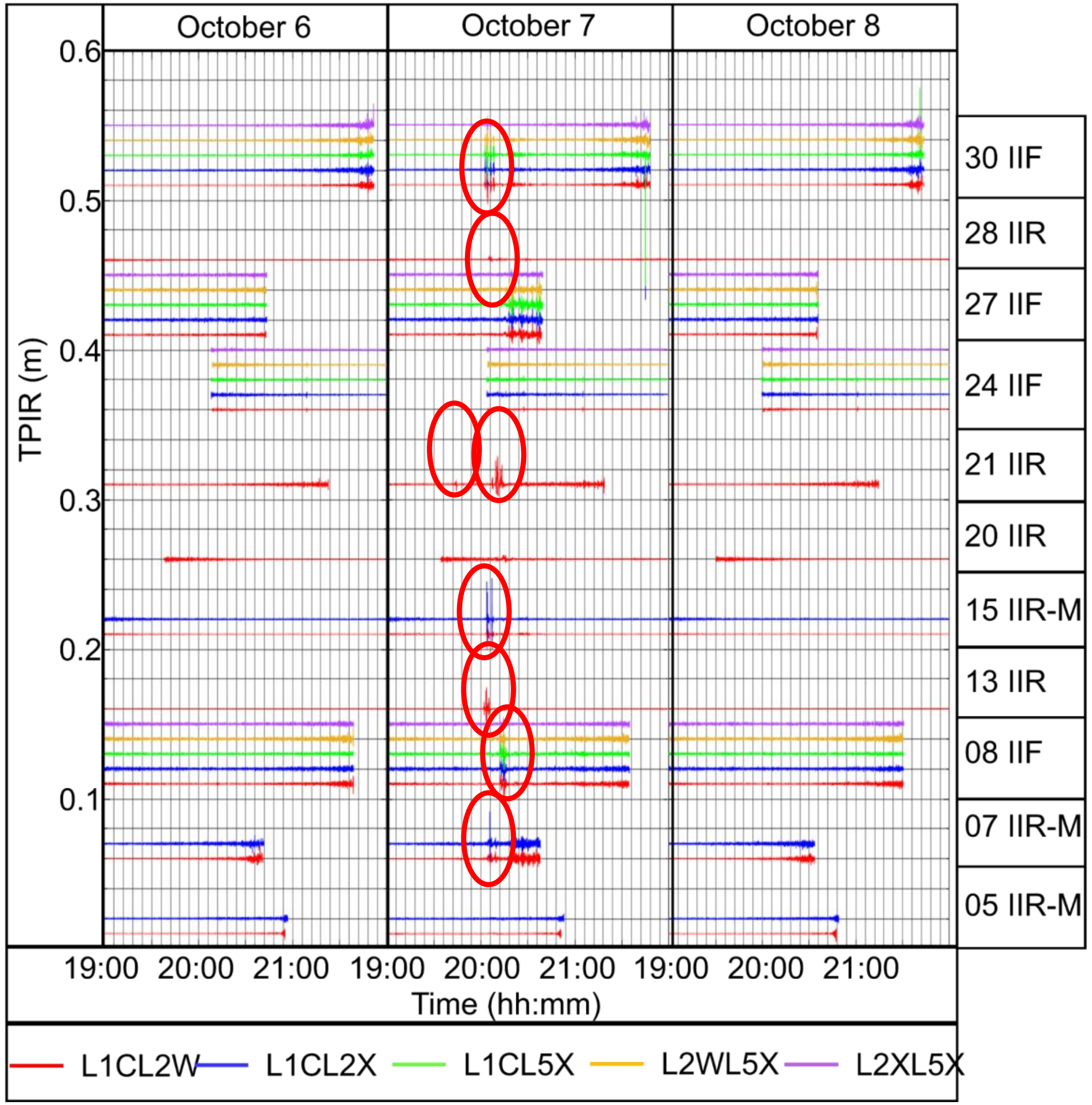
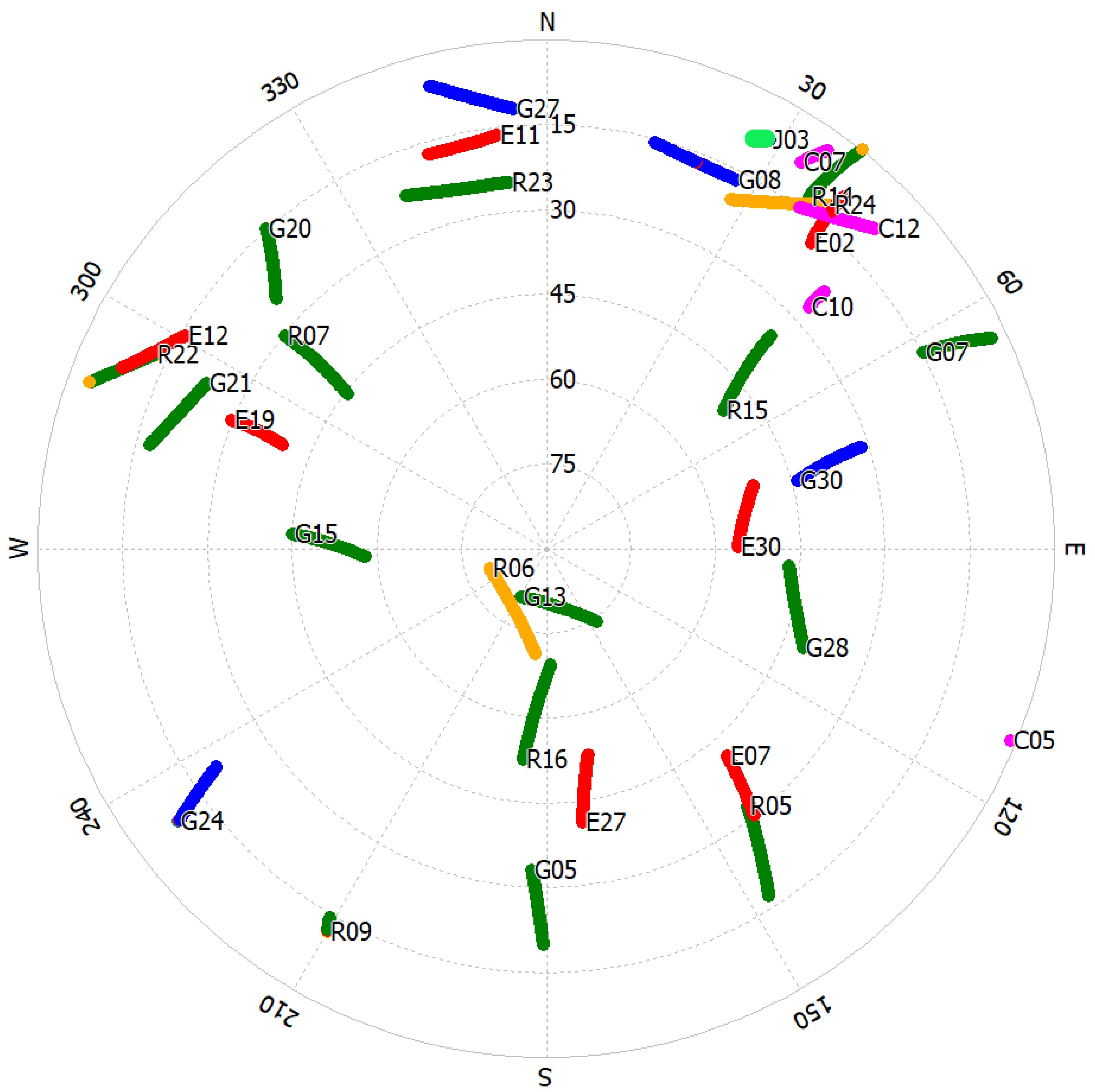
Time Differenced Phase Ionospheric Residual





FRÓÐSKAPARSETUR FØROYA

October 7, 2018

20:00:00 to 20:30:00

33 Satellites

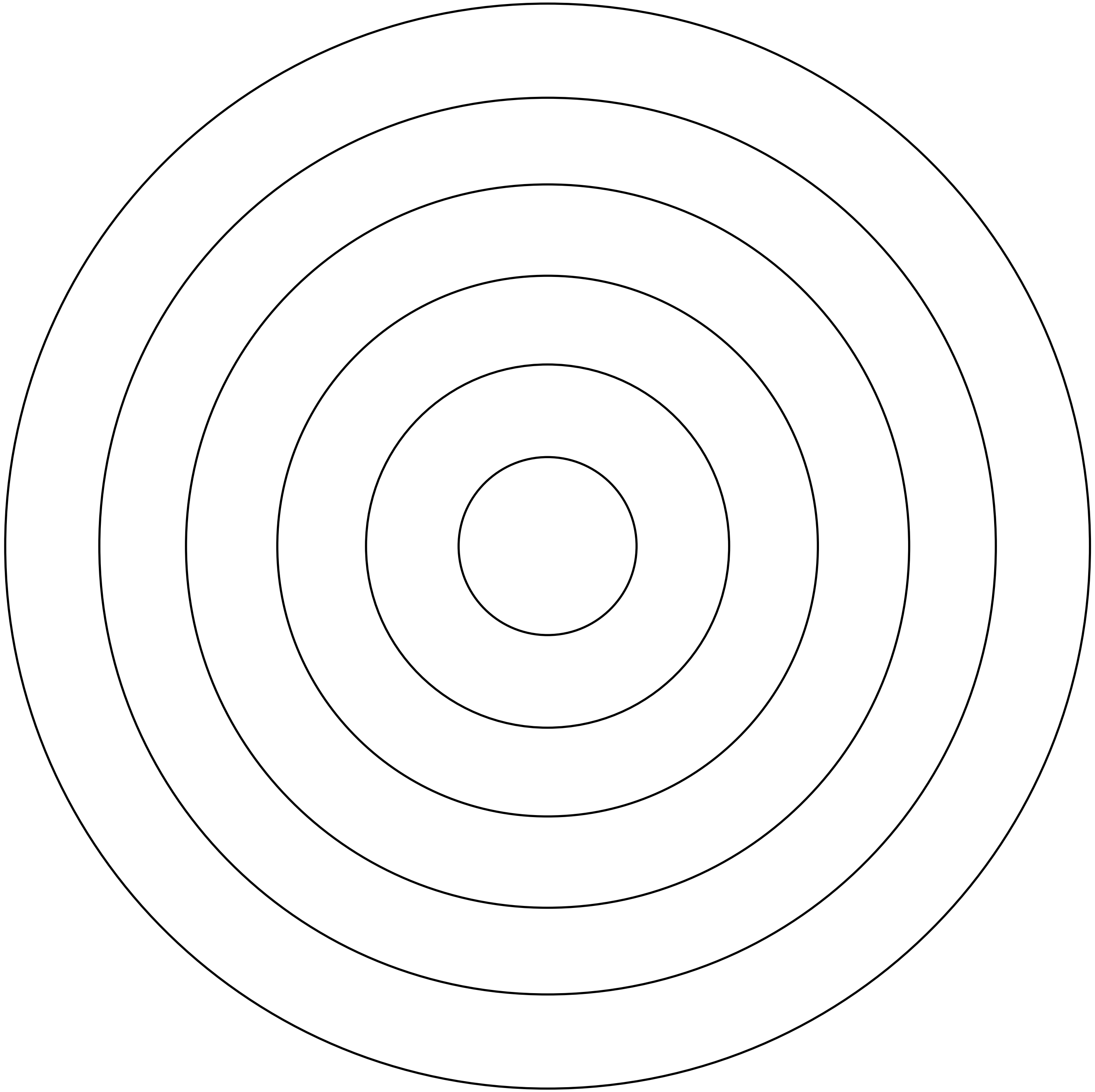
11 GPS (USA)

10 GLONASS (Russia)

7 Galileo (Europe)

4BeiDou (China)

1 QZSS (Japan)



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GPS Solutions (2019) 23:89
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ORIGINAL ARTICLE

Temporal characteristics of triple-frequency GNSS scintillation during a visible aurora borealis event over the Faroe Islands amid a period of very low solar activity

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Abstract
Ionospheric scintillation causes noise in GNSS measurements and hence affects the resulting coordinates or even the ability to track data. We investigate the characteristics of GNSS scintillation during a visible aurora borealis event over the Faroe Islands during October 7, 2018, which lasted for around 30 min. Data of 1 Hz rate from a typical geodetic GNSS receiver are analyzed during a 3-h window around the event, as well as during the same period the days before and after. Data from all four GNSS are analyzed, which consist of 31 satellites during the occurrence, resulting in a good overview of the temporal distribution of the scintillation. Two approaches are used, called the time difference code-minus-carrier and the time difference phase ionospheric residual. The results illustrate that there is little effect on the code measurements, but significant repercussion on the carrier phase observables, resulting in erroneous position solutions. The approaches we present can be used in GNSS processing software to detect scintillation noise in real time on individual satellites, allowing such noisy data to be rejected.

Keywords GNSS · Scintillation · Ionosphere

Introduction

Small-scale irregularities in the density and movement of free electrons in the ionosphere, called ionospheric scintillation, cause rapid and random fluctuations in the GNSS signals after propagating through these plasma inconsistencies. These perturbations can result in signal strength reduction, leading to the GNSS receiver not being able to acquire and track the signal, and causing cycle slips (Zhao et al. 2019) in the data due to the phase lock loop of the receiver being impinged (Luo et al. 2017). Scintillation occurrences depend on many factors including solar and magnetic activity, the time of year, the time of day, in addition to the geographic location and, in particular, due to solar storms (Skone 2001), and peaks in the 11-year sunspot cycle.

Studies have shown that the impact of scintillation on code measurements is small compared to the random and abrupt fluctuations in the carrier phase observables (Myer et al. 2017). Ionospheric scintillation is usually classified into amplitude scintillation and phase scintillation (Crane 1977), which are symbolized by indexes S_4 and σ_ϕ, respectively (Van Dierendonck et al. 1993; Guo et al. 2017; Mushini et al. 2012). S_4 is the standard deviation of the received power normalized by its mean power, and σ_ϕ is the standard deviation of the de-trended carrier phase.

Previous work has investigated techniques used to distinguish scintillation noise and local multipath noise (D'Angelo et al. 2015; Romano et al. 2013). Further work has focused on the effect of scintillation on different frequencies and signals, such as the L2 C-code (Marques et al. 2016). Research has shown that there are ionospheric scintillation events at polar regions during solar-min periods (Skone et al. 2001), concluding that phase scintillation occurrence levels are correlated with magnetic local time and that scintillation can be localized, such that two receivers 100 km apart may

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