Ionospheric Modelling for WADGPS at Northern Latitudes - Initial Results

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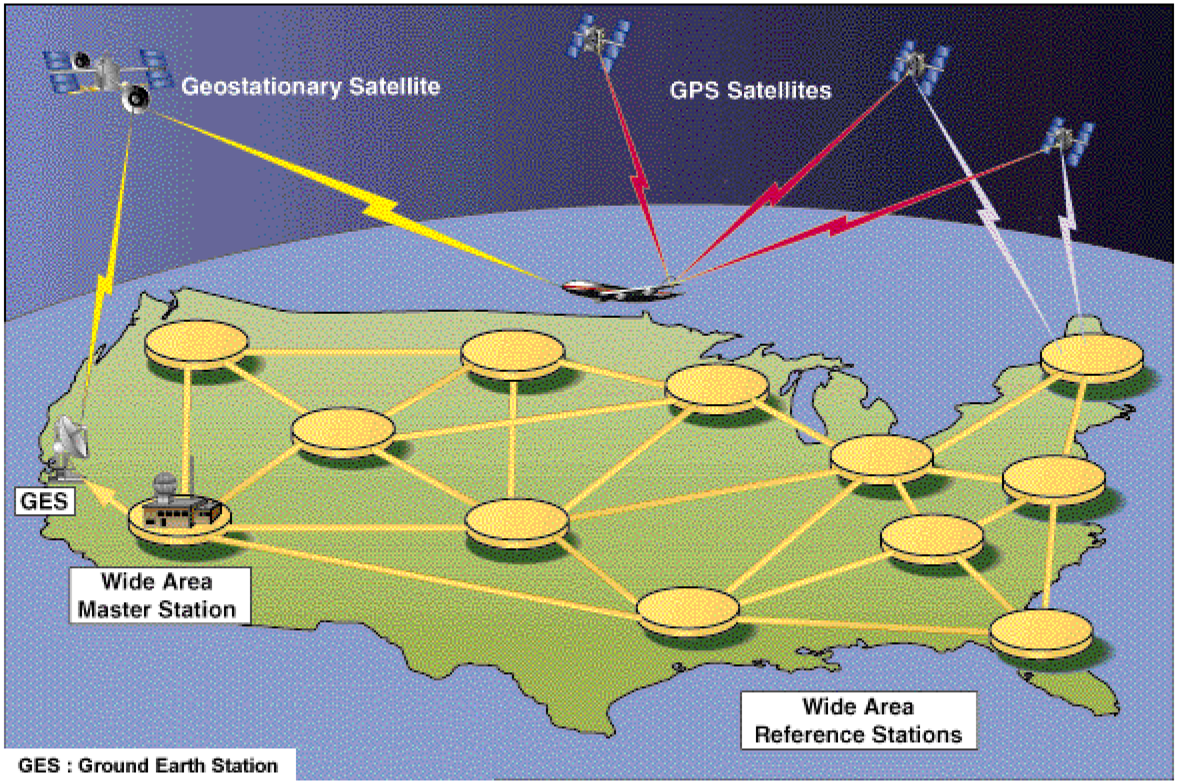
Introduction

- FAA sponsored Wide Area Augmentation System (WAAS) designed to provide en-route through precision approach navigation and integrity information to suitably equipped aircraft
- UNB is currently working with Nav Canada to investigate atmospheric effects on WAAS in Canadian airspace
- The airborne tropospheric model to be used in WAAS avionics was designed and tested at UNB
- As we approach solar maximum, so the potential effect of the ionosphere on GPS and WAAS intensifies; UNB have been charged with investigating ionospheric limitations on WAAS use in Canadian airspace
- CWAAS - Canadian WAAS

WAAS System Architecture



Source: Mitre Centre for Advanced Aviation System Development [www.caasd.org]

WAAS Accuracy Requirements

- Accuracy requirements for WAAS are expressed in terms of the navigation system error (NSE)
- In an operational system, the airborne GPS/WAAS receiver calculates horizontal and vertical protection levels (HPL_{WAAS} and VPL_{WAAS}), which must be less than the allowed NSE with a probability of 99.999% to ensure integrity
  - The HPL and VPL values describe a region, centred on the true position, which is assured to include the indicated horizontal and vertical positions respectively
  - The HPL and VPL values are computed as the sum of the variances of the ionospheric, tropospheric, airborne receiver, clock and orbit errors

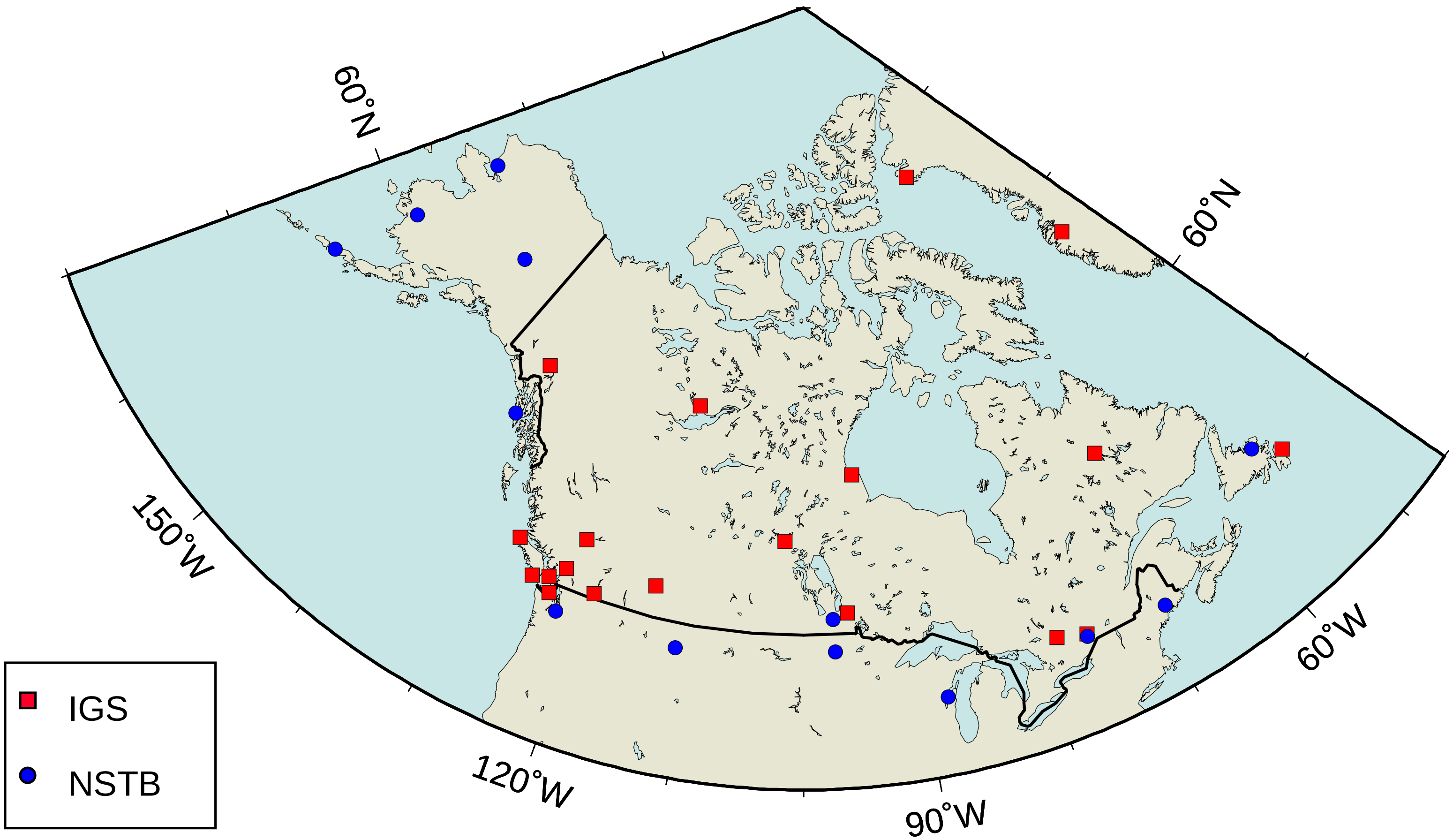
Ionospheric Delay Mitigation Techniques in WAAS

- A network of continuously operating reference receivers provides dual frequency carrier phase and pseudorange measurements
- Line-of-sight ionospheric delay values estimated from each receiver to each satellite
  - This involves estimating and removing the satellite and receiver hardware biases
- Vertical ionospheric delay values at each of a series of ionospheric grid points (IGPs) are estimated along with an error bounding value (GIVE)
  - The surface described by these discrete grid points is at a height of 350km
  - The spacing of these IGPs is latitude dependant, with a 5x5 degree grid at latitudes less than 55N and S, a ten by ten degree grid spacing between 55 and 75N and S, and 10 degrees of latitude by 90 degrees of longitude spacing above 75N and S
- Corrections for user line-of-sight delays, and a user error bounding value (UIVE) can then be created

The Concept of GIVE

- The Grid Ionospheric Vertical Error (GIVE) is designed to put a bound on the postcorrection ionospheric vertical error at each of the grid nodes
- The GIVE value should be less than 2m 99.9 % (3.29σ) of the time
- This corresponds to a requirement of ~60cm rms accuracy at each of the grid points

NSTB and IGS Station Locations



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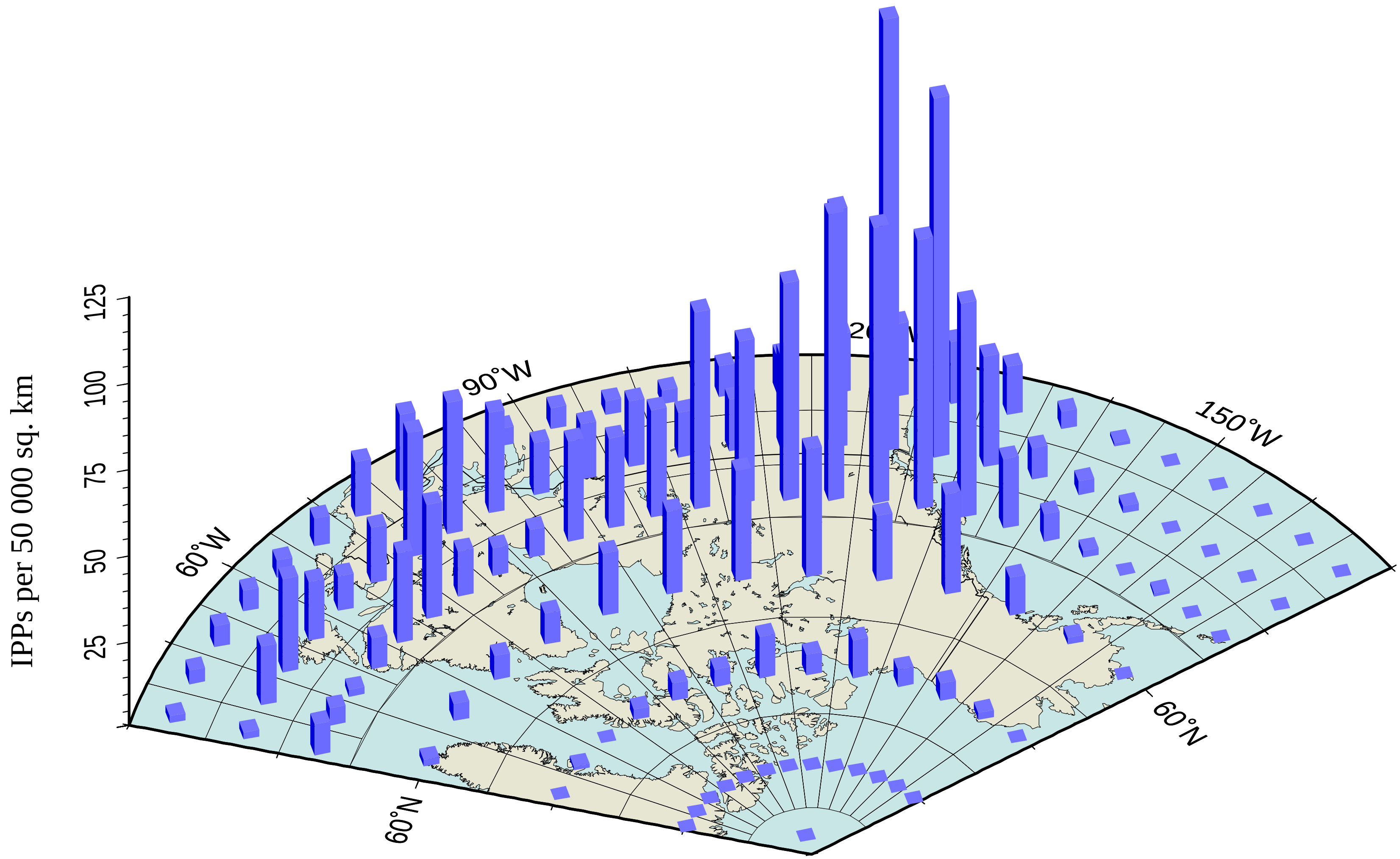
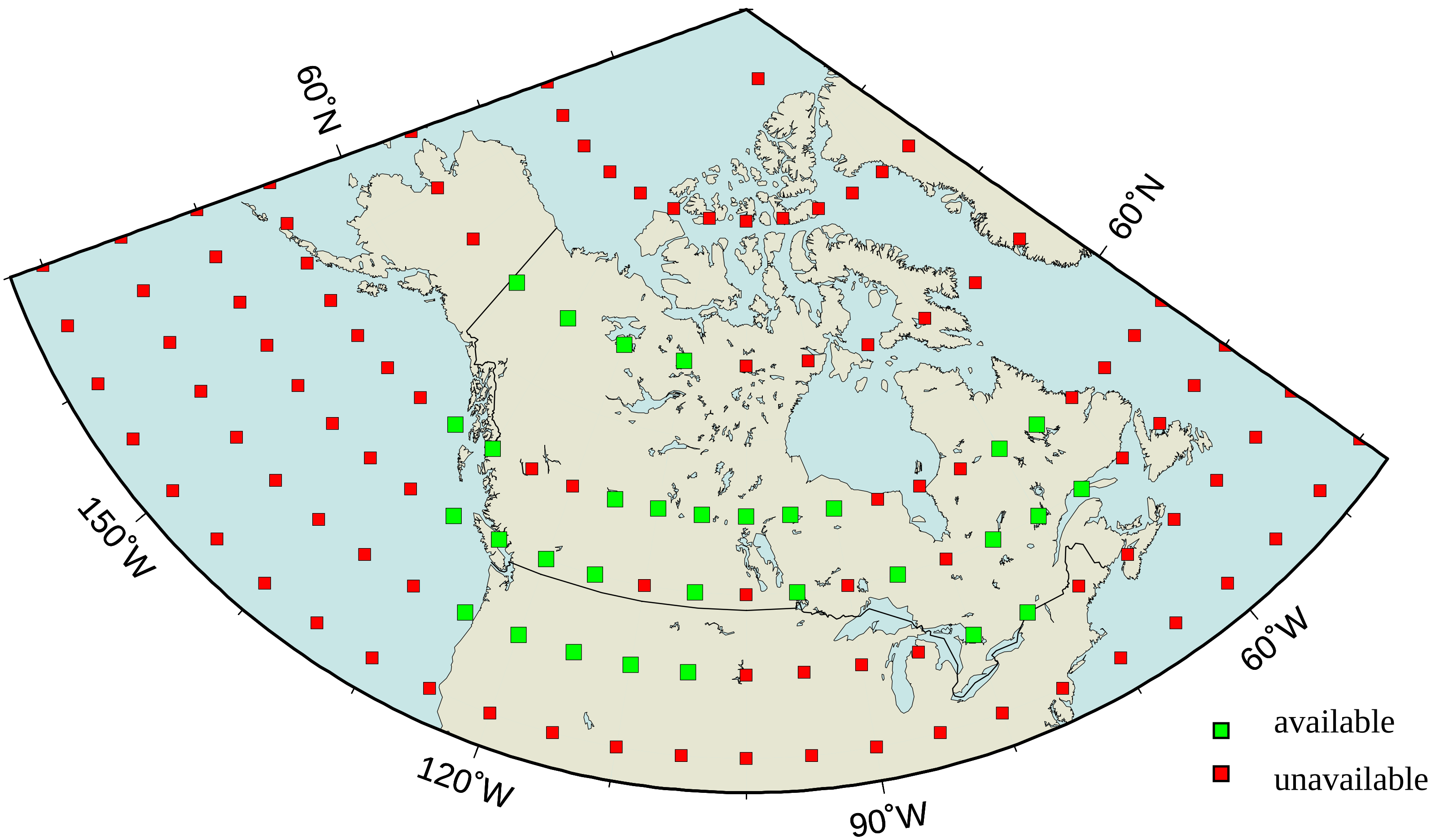
Research - Past, Present and Future

- Work completed to Date
  - Analysis software written to produce graphical representations of pierce point density and grid point status
  - Software written to produce grid ionospheric vertical delays (GIVD) and associated GIVE values.
    - Input data is RINEX format dual frequency GPS from IGS and NSTB sites
- Work in Progress
  - Evaluation of the model accuracy is done via a WAAS user simulation, receiving the “broadcast” delays and GIVEs and applying these to the users pseudorange values
  - How far north will the current network of WAAS reference sites provide reliable ionospheric corrections?

Ionospheric Pierce Point Density



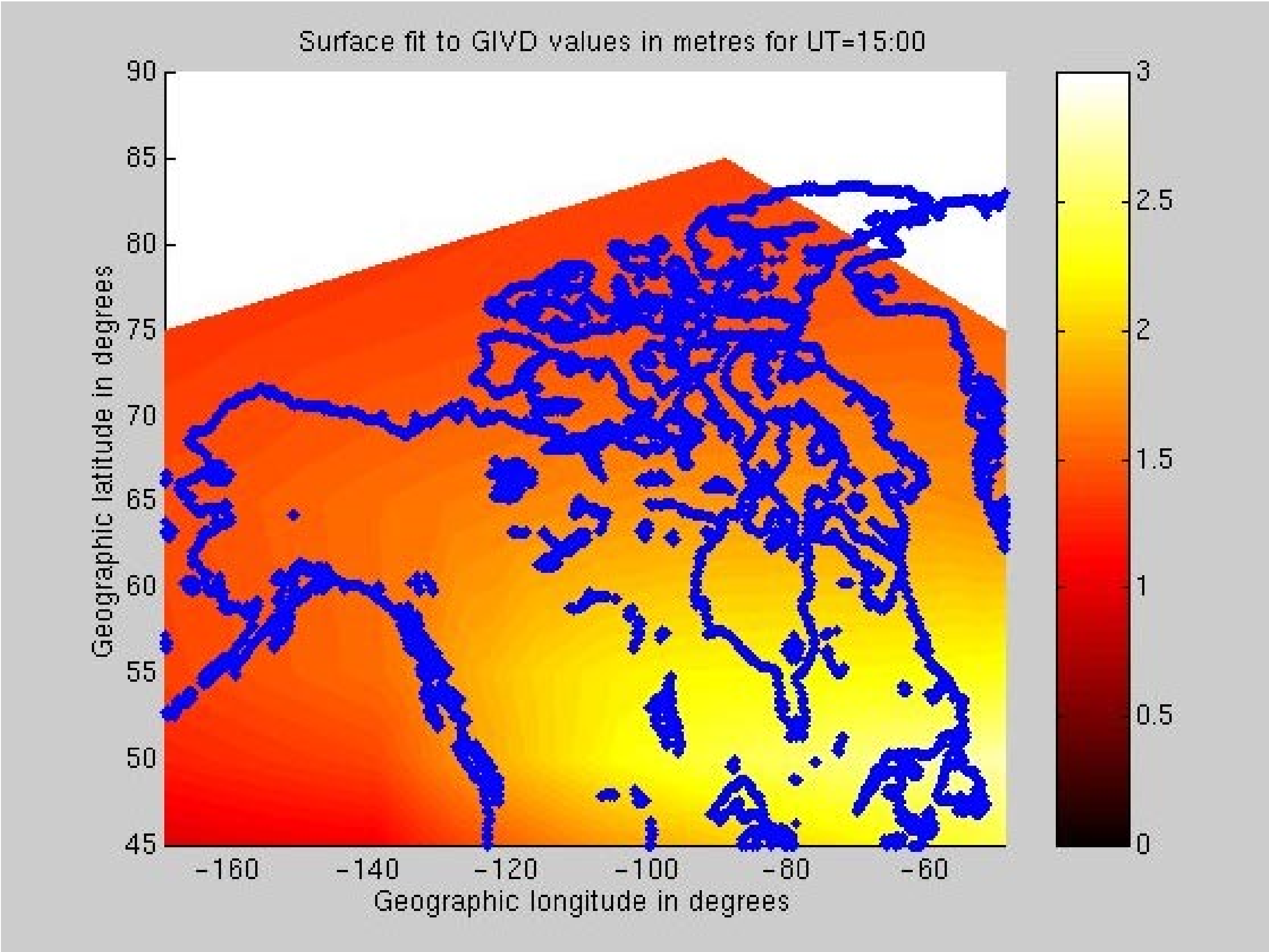
Ionospheric Grid Point Status



Representing a Continuous Ionosphere with a Discrete Grid

- In order to minimise the WAAS link bandwidth and avionics computation requirements, a discrete set of IGP delays and error bounds are broadcast to the user
- In prevailing conditions at mid latitudes, this grid system has been shown to adequately represent the ionosphere
- During ionospheric storms, the occurrence of which will increase with solar activity, temporal and spatial gradients, especially in the equatorial, auroral and polar zones will require significant degradation of the broadcast IGP accuracy, typical forecasts being an increase of 2-3 times for mid latitudes

Surface Interpolated from a Grid of Ionospheric Delay Values on September 16th 1998



Issues

- Potential ionospheric limitations on WAAS use over the Canadian landmass
  - Range error:
    - anecdotal evidence suggests increases in range delays of up to 10 metres within a time interval of 2-3 minutes, and return within about the same time at auroral and polar latitudes during disturbed conditions at solar maximum
  - Scintillation:
    - magnitude and frequency of occurrence of “significant” scintillations in the auroral and sub-auroral zone
    - identification of potentially problematic periods for tracking of GPS and/or WAAS signals both by user and reference receivers
    - prediction of effects of increasing solar activity

Summary and Future Work

- Implementation of WAAS in Canada requires careful consideration of ionospheric effects
- Validation of WAAS ionospheric grid model a primary task
- Outline system and methodology to monitor operational WAAS/CWAAS ionospheric modelling performance
- Contingency plan if current WAAS model proves to be insufficient