Demonstration Project Results of GPS•C: A Canadian Real-Time GPS Correction Service in a Marine Environment.

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ABSTRACT

The Geodetic Survey Division of Natural Resources Canada (NRCan) has implemented a real-time, wide-area GPS correction service called GPS•C. The GPS corrections are computed from a Canada wide network of continuously operating GPS receivers. This tracking network data is used at a central computing facility to compute GPS satellite clock and ephemeris corrections, in real-time. For this demonstration project, correction information was broadcast to users via satellite communication every 2 seconds.

A joint Canadian Coast Guard (CCG), Canadian Hydrographic Service (CHS), Geographic Data B.C., TMI Communications, Cygnus Satellite Systems Corp. and NRCan GPS•C demonstration project was conducted in July 1998. The data collection phase of the project took place on board the CCG vessel "CCGS GRIFFON" on a voyage from Prescott, Ontario to Churchill, Manitoba via the St. Lawrence River, Gulf of St. Lawrence, Labrador Coast, Davis Strait, Hudson Strait and Hudson Bay. The first half of this 4700 km route was within coverage of the CCG DGPS Navigation Service. The GPS•C corrections were delivered to the vessel for the entire voyage by the MSAT mobile satellite service and received by antenna/receiver radios of special design. An onboard computer system permitted RTCM-104 corrections to be applied to GPS observations and provided continuous real-time comparisons of GPS•C and CCG DGPS positions.

The Canadian Hydrographic Service used the GPS•C system operationally to support their hydrographic survey program in Hudson Bay and Bathurst Inlet area in the Canadian Arctic for the period of July to October, 1998. Real-time corrections were employed up to 70 degrees North latitude.

This paper briefly describes the GPS•C concept and its current implementation. Applicability of GPS•C in a marine environment is discussed. Real-time position comparisons of GPS•C and the CCG DGPS Navigation Service will also be presented.

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1. INTRODUCTION

A shipborne project was conducted in July 1998 to demonstrate the capabilities of the GPS•C real-time correction service in a marine environment for positioning and navigation applications. Real-time position comparisons were computed between GPS•C corrected positions and the CCG DGPS system corrected positions for the voyage of the CCGS GRIFFON, down the St. Lawrence River enroute to Hudson Bay. CCG beacon coverage was achieved along the St. Lawrence River and half way up the Labrador Coast of Eastern Canada. A description of the GPS•C system, the CCG system, the equipment configuration aboard the GRIFFON, and results of the real-time position comparisons will be discussed.

2. GPS•C: THE REAL-TIME GPS CORRECTION COMPONENT OF THE CANADIAN ACTIVE CONTROL SYSTEM

2.1 Canadian Active Control System (CACS)

The Canadian Active Control System (CACS) is a fundamental component of the Canadian Spatial Reference System (CSRS). The CSRS is defined as a foundation for all Canadian geospatial referencing and supports such reference system standards as the North American Datum 1983 (NAD83). The Geodetic Survey Division (GSD) maintains, continuously improves and facilitates efficient access to the CSRS through the CACS and provides improved positioning capability to the Canadian surveying and positioning community.

The CACS includes unattended tracking stations, referred to as Active Control Points, which continuously record carrier phase and pseudorange measurements for all satellites of the Global Positioning System (GPS) within station view (Figure 1). Some CACS products are precise ephemerides, precise satellite clock corrections and observational data, derived from the Active Control Points. These products offer significant benefits for Canadian users carrying out GPS positioning by making it possible to position any point in Canada with a precision ranging from centimetres to a few meters in relation to the national spatial reference frame.

2.2 GPS•C

The real-time component of the CACS utilizes a sub-set of tracking stations shown in Figure 1. Real-time tracking data is sent, utilizing various communication technologies, to a central site for processing and computation of wide-area GPS corrections. Corrections are currently made available every 2 seconds. Some of the benefits of the GPS•C system are; real-time connection to the CSRS, corrections applicable to a large geographic area, sparse network of reference station configuration required, independent of user distance to reference stations and flexible architecture (adding or deleting reference stations).

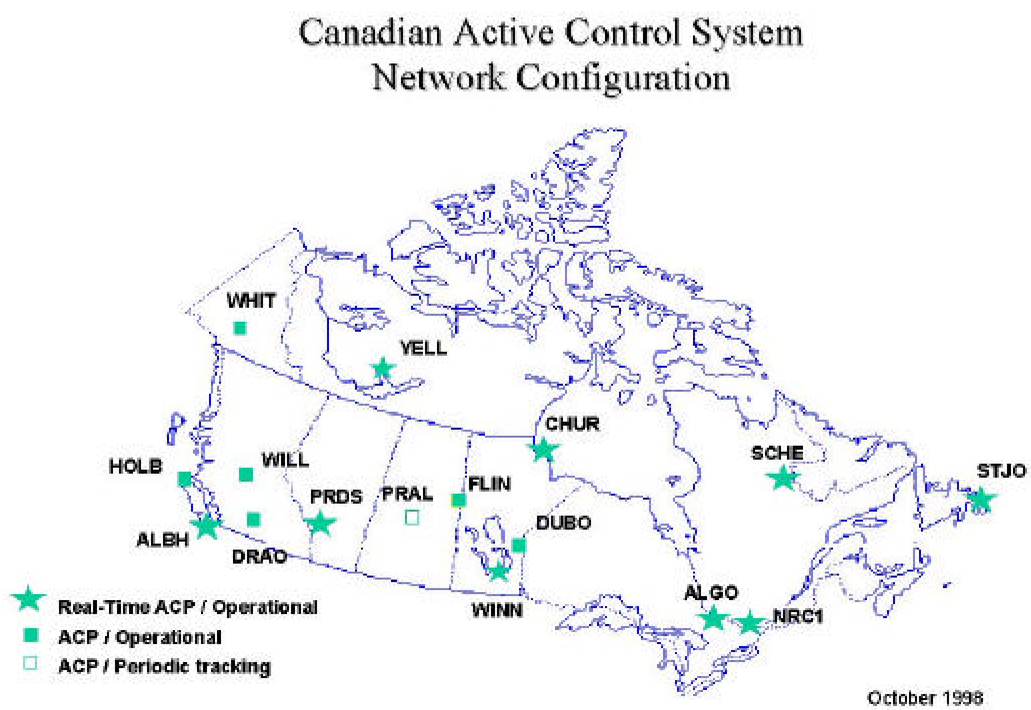

Figure 1: The CACS network configuration

GPS•C mitigates effects of the satellite clock errors, broadcast ephemeris errors and atmospheric effects. GPS•C provides estimates of satellite orbit corrections derived by comparing broadcast to predicted orbits over several days. Estimates of satellite clock errors are also computed based on the real-time collection of data from precise GPS receivers connected to precise atomic time standards. Estimates of ionospheric delay corrections are generated based on a grid derived from the network of dual-frequency GPS receivers. [1, 2 ,3]

3. THE CANADIAN COAST GUARD DGPS NAVIGATION SERVICE

The Canadian Coast Guard has implemented a marine differential GPS Navigation Service in southern Canadian waters specifically the Canadian West Coast, the Great Lakes, the St. Lawrence River and the Canadian East Coast. This differential GPS solution provides local users with GPS correction information derived at a reference station transmitting these corrections. Currently there are 18 DGPS stations linked to centralised control monitors. Medium frequency (MF) coast guard beacons, at the reference sites, are used to transmit corrections in RTCM 104 format, to users equipped with an appropriate beacon receiver.

This operational system has been designed to provide reliable GPS corrections by operating autonomously, tolerate faults without failure and ensure broadcast integrity. [4] The system is compatible with the United States Coast Guard DGPS system to ensure seamless coverage (ex: Great Lakes area). Figure 2 shows the Coast Guard beacon locations and coverage in the St. Lawrence River and East Coast areas.

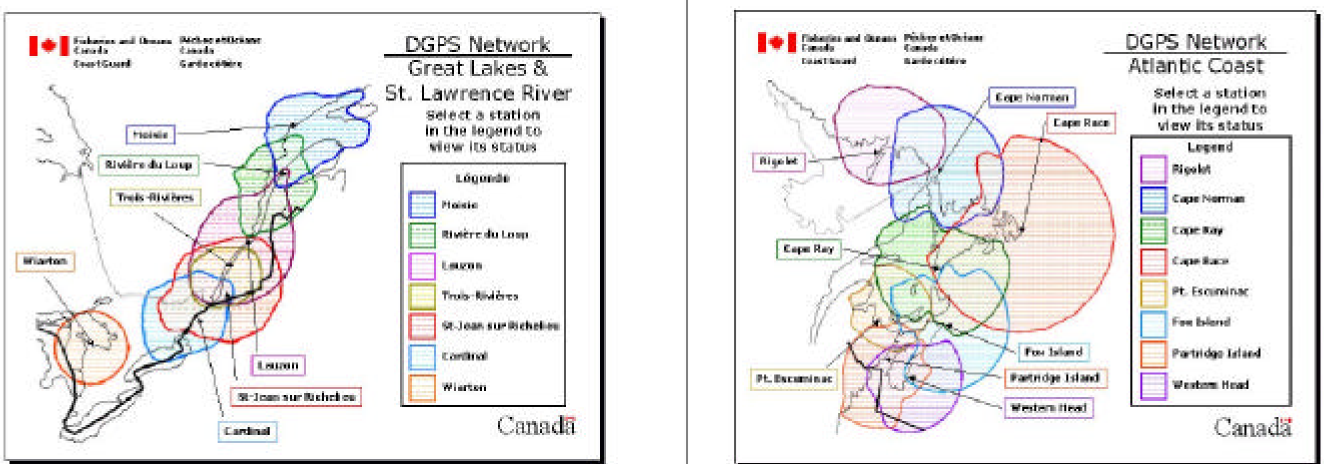

Figure 2 Canadian Coast Guard DGPS Navigation Service Coverage

4. THE DEMONSTRATION PROJECT

The purpose of the project was to demonstrate the GPS•C wide-area correction technology for marine positioning/navigation/hydrographic applications. The project included real-time comparisons of the GPS•C derived positions to the Canadian Coast Guard (CCG) DGPS navigation system derived positions, where CCG DGPS coverage was available (July 15th to July 21st)(Figure 3).

The data collection configuration consisted of 3 dual frequency GPS receivers connected to the same antenna mounted on a temporary tower structure above the ship's bridge. One GPS receiver supplied the GPS observations to a PC which then applied the GPS•C corrections and the CCG DGPS corrections in real-time. Real-time position comparisons were possible using identical GPS observables. The GPS•C correction information was received by a special MSAT radio supplied by Geographic Data BC and manufactured by

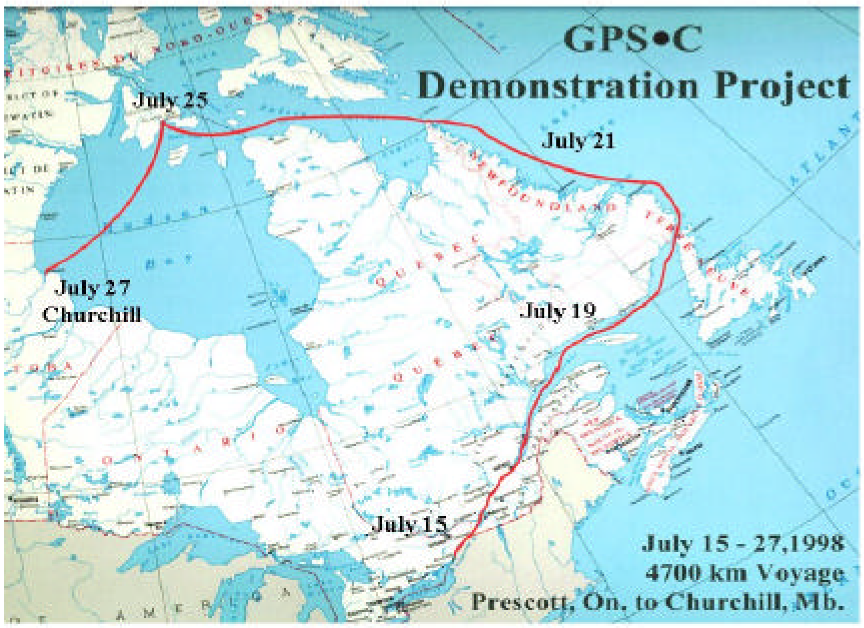

Figure 3: Demonstration Project Route

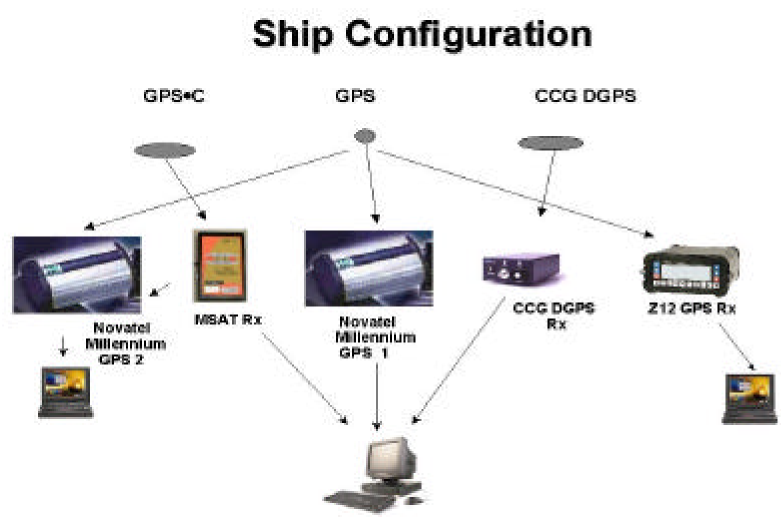

Figure 4: Data Collection Configuration

Cygnus Satellite Systems. Cygnus also provided an MSAT antenna optimized to improve high latitude performance. Data from the other GPS receivers was logged for backup and post-processing for independent position computations.

5. DEMONSTRATION PROJECT RESULTS

Horizontal position comparisons are presented in this section. A "static" test was performed on July 15 while the GRIFFON was docked at Prescott, Ontario. A precise GPS post processed position was computed using a permanent CACS station as a reference (NRC1). This position was used as "truth" system for the results shown in Figure 5 and 6.

Differences in latitude and longitude are shown (Figure 5) between the "truth" position and the Coast Guard DGPS real-time corrected position for the entire 24 hour period on July 15, 1998. The mean latitude and longitude differences were
–0.48 m and –0.34 m respectively with RMS errors at the 0.8 to 0.9 m range.

Differences in latitude and longitude are shown (Figure 6) between the "truth" position and the GPS•C real-time corrected position for the entire 24 hour period on July 15, 1998. The mean latitude and longitude differences were -0.10 m and -0.31 m respectively with RMS errors at the 0.7 to 0.8 m range.

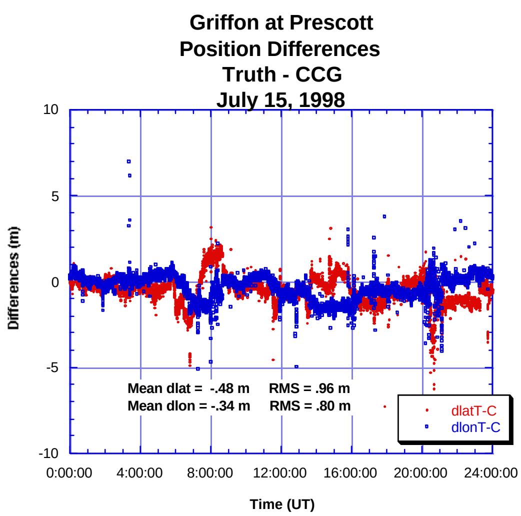

Figure 5: Position Differences: "truth" vs CCG DGPS

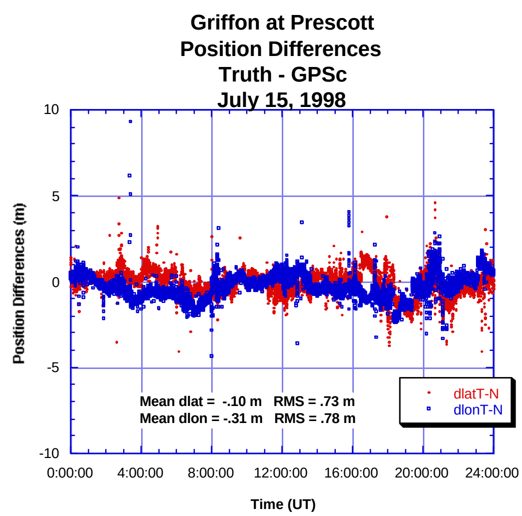

Figure 6: Position Differences: "truth" vs GPS•C

Comparing the "truth" results, slightly larger mean position differences and RMS numbers were found for the CCG DGPS system compared to the GPS•C derived position comparisons, however, these differences are small and well below the quoted specifications of the Coast Guard DGPS system of 10 m.

Real-time comparisons of the Coast Guard DGPS derived positions and the GPS•C derived positions were carried out for the same 24 hour period on July 15th. Figure 7 shows the latitude and longitude differences for July 15, 1998. Mean differences for the day were –0.40 and –0.03 metres for latitude and longitude respectively with one-sigma standard deviations of 1.1 and 0.8 metres.

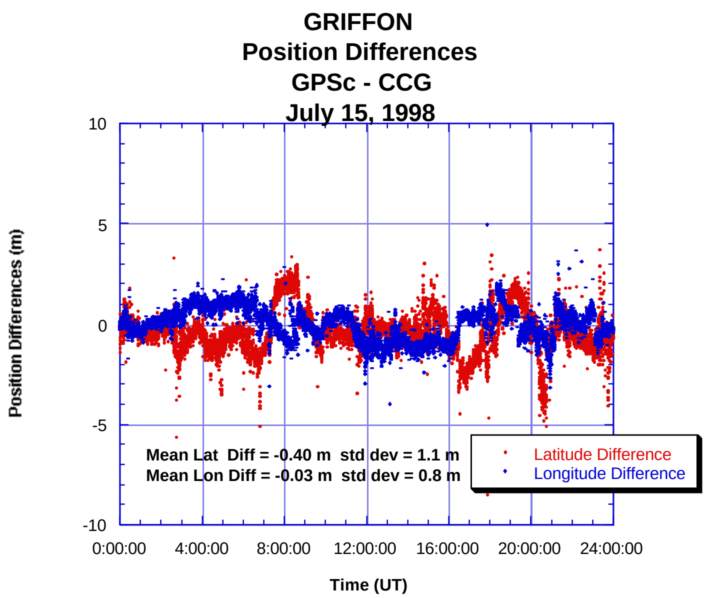

Figure 7: Real-Time Position Differences: GPS•C vs CCG DGPS July 15, 1998

Dynamic testing was carried out from July 16th to July 21st. Figure 8 and Figure 9 show horizontal position comparisons for the July 17th and July 21st 24 hour periods of the voyage. The July 21st plot (Figure 8) shows larger differences due to the distance limitations of the local differential method ie. the correction accuracy may diminish with distance from the reference station. By the end of the July 21st the GRIFFON was about 800 km from the Cape Norman Coast Guard DGPS reference station. The GPS•C system was constantly (daily) updating the vessel position to provide appropriate "localized" RTCM-104 corrections. Therefore no significant distance-to-reference-station (spatial decorrelation) related errors were present in the GPS•C results.

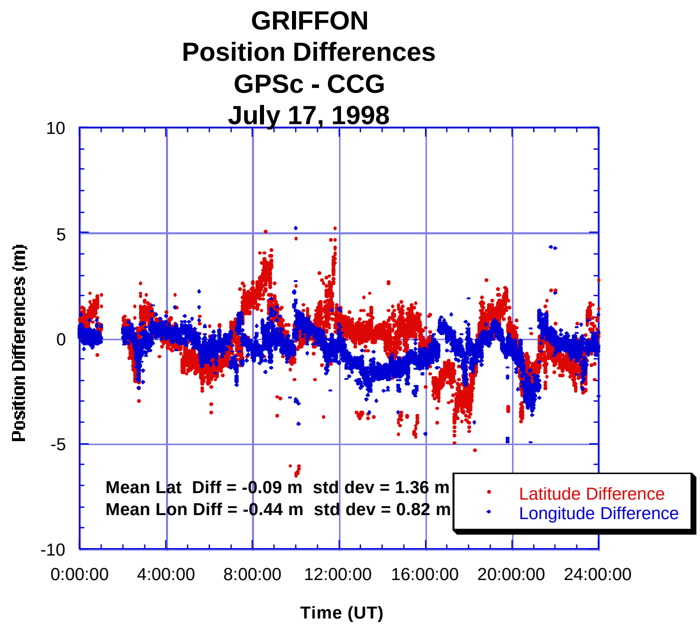

Figure 8: Real-Time Position Differences: GPS•C vs CCG DGPS July 17, 1998

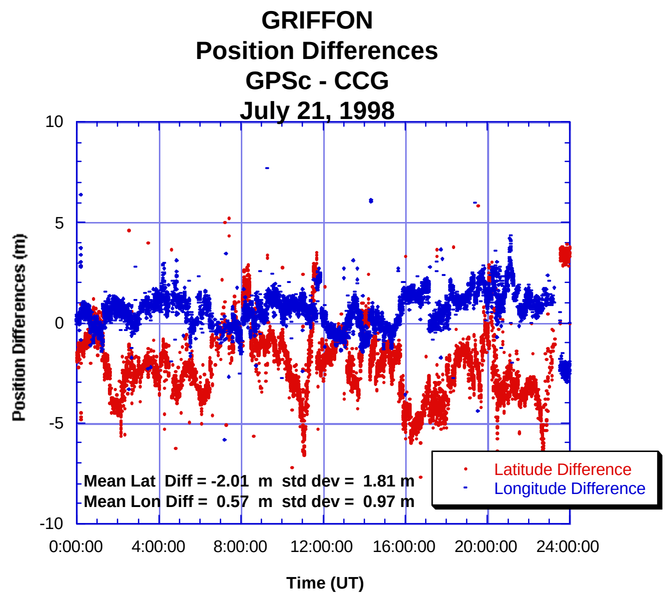

Figure 9: Real-Time Position Differences: GPS•C vs CCG DGPS July 21, 1998

Figure 10 summarizes the daily mean differences and standard deviations for each day of the trip within Coast Guard beacon coverage. Note the right hand Y axis shows the daily maximum distance from a Coast Guard reference station. The plot shows the well known effect of spatial decorrelation in local differential GPS. The overall comparison results illustrate the compatibility at the 2-5 meter range of each of these independent systems.

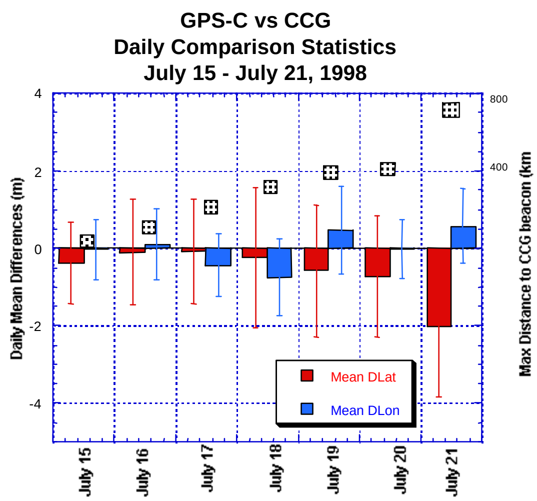

Figure 10: Daily Summary of Position Differences (GPS•C vs CCG DGPS) and Maximum Distance to CCG DGPS Beacon Station

6. SUMMARY

The results of this demonstration project has shown that the GPS•C system is compatible with the Canadian Coast Guard DGPS Navigation System. Since GPS•C is a wide-area system it is usable for areas beyond the current CCG DGPS Navigation System coverage. Experience from this past summer's work demonstrated that GPS•C was functional as far North as 70 degrees North latitude. The MSAT satellite delivery system performed reliably at MSAT satellite elevation angles approaching 10 degrees. [5]

Based on the GPS•C demonstration project, the Canadian Hydrographic Service then used GPS•C operationally for their Hudson Bay hydrographic surveys during the summer of 1998. It had the distinct advantage of reducing the number of shore reference stations required.

ACKNOWLEDGEMENTS

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