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NADCON 5.01

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Versions

Date	Changes
July 30, 2019	Original Release

1 Introduction

In 2017, the National Geodetic Survey (NGS) completed the NADCON 5.0 project, whose purpose was to update and/or replace all previous versions of NGS's NADCON, GEOCON and GEOCON11 products. These earlier products were a combination of transformation data (grids) and software to apply the transformations to coordinate data. Although the NADCON 5.0 project generated the transformation grids, it did not produce a stand-alone computer program to *apply* the transformations to coordinate data. Rather, all of the horizontal datum transformations computed by the NADCON 5.0 project were incorporated into NGS's two primary coordinate transformation and conversion tools: NCAT (in late 2017) and VDatum (scheduled for late 2019.)

1.1 Terminology

This change in approach necessitates a subtle but critical change in terminology, which will be described and adopted below.

1) NADCON 5.0 is the name of a ***project***, whose goal was to create transformation grids, error grids and choose the interpolation method used on those grids.
2) NADCON 5.0 is *also* the name of ***the build software***, developed within said project and which created the aforementioned transformation and error grids.
3) A ***build*** is the use of ***build software*** to create transformation (and error estimate) grids for one or more specific combinations of "old datum", "new datum" and "region" on a specific date, called the ***build date***. A ***build date*** is always provided in YYYYMMDD format. Builds are not necessarily released to the public. A ***build*** name always contains both the version of the ***build software*** and the ***build date*** (example: "NADCON 5.0 build 20160901")
4) A ***release*** is one or more of the grids from a ***build*** that NGS has determined are the official NSRS transformations, and which have been released to the public. For completeness, a ***release*** will also contain the ***build software*** used to make the ***build***. Like the build name, the ***release*** name always contains both the version of the ***build software*** and the ***build date*** (example: "NADCON 5.0 release 20160901").

Using this terminology, NADCON 5.0, by itself, is *not* the name of the set of grids which went into NCAT and VDatum. Instead it is valid to say "the most current official latitude, longitude and ellipsoid height transformation grids of the NSRS are contained in NCAT and VDatum, using NADCON 5.0 release 20160901."

Because all existing NADCON, GEOCON and GEOCON11 grids and transformation functionality were superseded on September 1, 2016, NGS has (for now) identified *all* official NSRS transformation grids in latitude, longitude and ellipsoid heights as coming from NADCON 5.0 release 20160901.

Although NADCON 5.0 release 20160901 superseded existing transformation grids, it will be NGS policy going forward that *existing* official NSRS transformation grids will not be superseded, with two exceptions:

1) The currently underway VERTCON 3.0 project is planning to supersede the existing NGVD29/NAVD88/CONUS grid from NADCON 2.1.
2) If a blunder were found in an existing transformation grid which was so egregious that failing to correct it would be a dereliction of duty, then the existing grid would be replaced

However, as new combinations of "old datum", "new datum" and "region" need to be supported (such as with the roll-out of NATRF2022, et al), they will be provided to the public as a new release. That release name will consist of both the version of the build software, and the build date.

1.2 Rationale

As part of the completion of the NADCON 5.0 project, a comprehensive report (Smith and Bilich, 2017) was also written and issued at the same time. At that time, NGS supported two primary computing platforms: Solaris and Microsoft Windows. The NADCON 5.0 release 20160901 grids were entirely developed on a Solaris platform. Additionally, at that time, all of the gridding and most of the plot creation was performed by the Generic Mapping Tools (GMT) version 4.

In 2018, two major changes occurred at NGS, both of which necessitated an entire re-construction of the NADCON build software. The two major changes were:

1) Solaris platforms were phased out in favor of Red Hat Linux
2) Support for GMT inside NGS was transitioned from version 4 to version 5

These changes meant that the NADCON 5.0 build software was about to be functionally inoperable. Such a situation required correction, since part of the planned modernization of the NSRS calls for future transformation tools to be rolled out as well. The NADCON 5.0 build software could no longer be expected to support the NSRS modernization.

Furthermore, NGS made the decision to begin the VERTCON 3.0 project in 2018. It was (originally) the intent of the VERTCON 3.0 team to modify the NADCON 5.0 build software into VERTCON 3.0 build software. However, as VERTCON 3.0 had to be built on a Linux platform, using GMT 5, this necessitated a complete re-writing and testing of the NADCON 5.0 build software on Linux using GMT 5 first, and only then could the modified NADCON build software be transformed into VERTCON build software.

2 NADCON 5.01

In order to compartmentalize efforts, a new project, called "NADCON 5.01" was begun at NGS with the express intent of creating new NADCON build software with version number 5.01. This meant:

1) Porting the NADCON 5.0 build software onto Linux
2) Transitioning from GMT 4 to GMT 5
3) Correcting minor bugs which mostly affected the plots, and

4) Evaluating the final grids coming out of the NADCON 5.01 build software with the NADCON 5.0 release 20160901 grids.

No changes were made to *scientific choices* during the creation of the NADCON 5.01 build software. The transition from Solaris to Linux took place across years at NGS, though the NADCON team members (Dru Smith, Andria Bilich) transitioned their own systems around November 2017.

The NADCON 5.01 project took place between November 2017 and June 2019, resulting in ***NADCON 5.01 build software***. (This effort was done in parallel with the VERTCON 3.0 project as well, with lessons learned in NADCON 5.01 being applied to VERTCON 3.0).

2.1 Overview of the re-write of the NADCON build software

Complete details on all of the individual programs in the NADCON 5.0 build software are found in Smith and Bilich (2017), Section 5.2. It is not necessary to go into those details here. Suffice it to say that no program names changed, nor did the names of any input or output files. However, the complete NADCON 5.01 project was kept separate from NADCON 5.0 by building it in a separate directory[1], with a parallel set of sub-directories identical to those in which NADCON 5.0 build software was written and run to create the NADCON 5.0 release 20160901 grids.

The re-write began by copying input files from the NADCON 5.0 directory[2] over to their parallel locations in the NADCON 5.01 directories. Then, each program was tested in order to see if it compiled. Any calls to GMT 4 scripts were updated to their new GMT 5 scripts.

The switch from GMT 4 to GMT 5 also gave the team an opportunity to correct something in the NADCON 5.0 build software. Specifically, the vector plots which showed changes in latitude, longitude and ellipsoid height were somewhat difficult to understand, as they were black and white plots with vectors pointing always up/down (for latitude and ellipsoid height) or left/right (for longitude). A new scheme, one using colored dots rather than vectors, was introduced.

To exemplify this change, the NADCON 5.0 and NADCON 5.01 versions of plot **vsacdlat.nad83_2007.nad83_2011.conus.entire.jpg** are shown below. Those plots show the coordinate differences for points, in latitude, when going from NAD 83(NSRS2007) to NAD 83(2011) epoch 2010.00 in arcseconds. Note that, for NADCON 5.0, when the point density grows too large, the vectors overlap so that it is difficult to both determine the size of a vector and even whether it is pointing up or down. However with the NADCON 5.01 approach, the individual vectors are replaced with colored dots, so that both the direction (up or down) and magnitude of each vector can be discerned from its neighbors.

[1] NADCON 5.01 software was built and tested on NGS Linux machine ngs-vsu-rheldev, in directory /home/dru/NADCON/NADCON5.01

[2] /home/dru/NADCON/Research/NADCON5

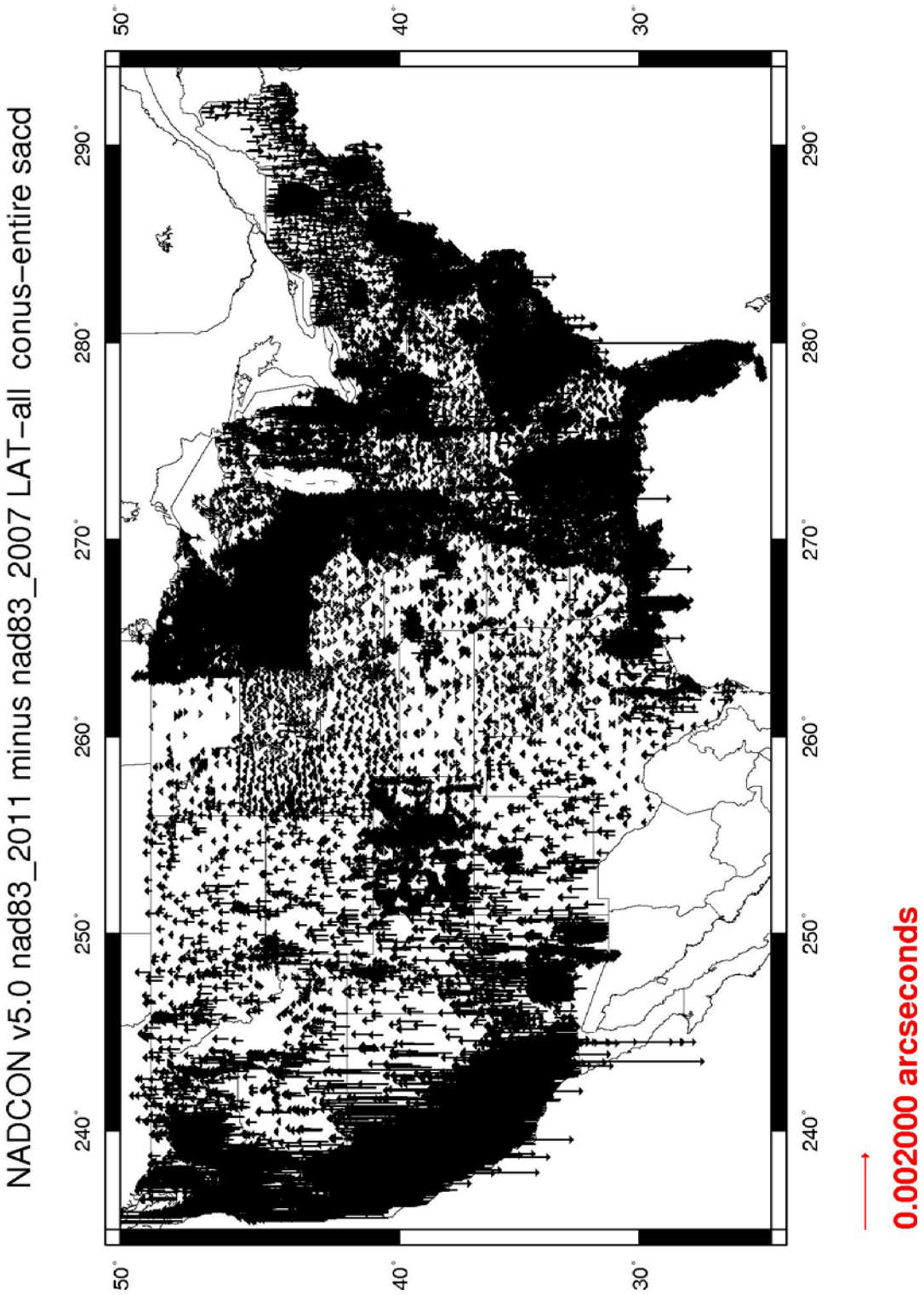

Figure 1: Latitude Vectors as represented in the NADCON 5.0 build software

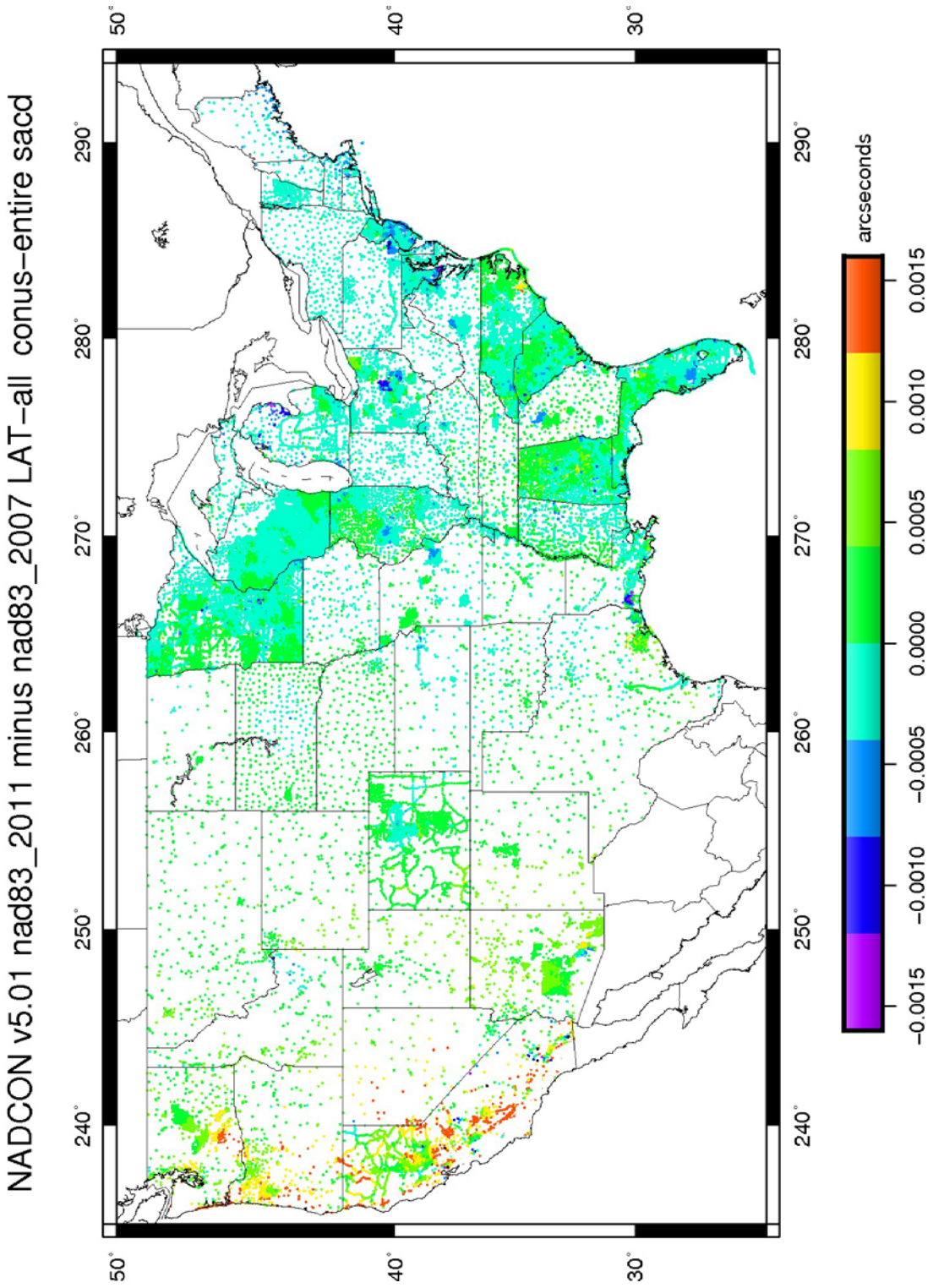

Figure 2: Latitude Vectors as represented in the NADCON 5.01 build software

As was the case for NADCON 5.0, the NADCON 5.01 project was documented in laboratory notebooks kept by Dru Smith[3]. Specifically notebook DRU-12 (pages 140-143) and DRU-13 (pages 4-6) document this re-write of the build software.

Additional changes made as the part of the NADCON 5.01 build software include:

- Dropping the use of "coverage" plots beyond those first generated, as both coverage and magnitude were available in the new "color dot plots" (see above) which replaced the black and white vector plots (see above)
- Correcting a bug that skipped creating some plots
- Labeling "method noise", "data noise" and "total error" in the titles of their respective plots

2.2 The NADCON 5.01 build 20190531 grids

Once the new build software was available, it was run in order to create transformation and error estimate grids. At first blush, one might expect that the output grids would match the NADCON 5.0 release 20160901 grids, but there are many reasons why this should *not* happen:

1) The actual gridding process is performed by a program called ***surface*** which is contained within GMT. With the switch from GMT 4 to GMT 5, it is possible that this function was modified slightly.
2) The ***surface*** routine only works in 4-byte floating point real numbers, so some numerical accuracy is lost by not using 8-byte reals, especially if one changes hardware.
3) There are hardware and software differences between Solaris (NADCON 5.0) and Red Hat Linux (NADCON 5.01) which could cause small changes in computed values. Such changes include:
    a. Big Endian versus Little Endian storage
    b. Different FORTRAN compilers
    c. Different chipsets (hardware)
4) The use of ***surface*** across data gaps and/or extrapolating outside of known data edges can take any of the small changes from #1, #2 or #3 above and magnify them across such gaps.

On May 31, 2019 a set of new grids were created using the NADCON 5.01 build software. Those grids will be known as ***NADCON 5.01 build 20190531***. A comparison of the values in those grids against ***NADCON 5.0 release 20160901*** grids was performed using MATLAB's built in ability to read big endian and little endian values. As expected, some variations were found in both transformation grids and error grids, primarily in areas of data gaps (either on land in actual void areas, or offshore). Because of this, a table of statistical differences, grid by grid, would be misleading, as the most interesting comparison is only over the land areas, where the transformation grids are supported by actual data. However, it is fairly accurate to say that, *statistically most of the differences form extraordinarily boring histograms, with a spike at 0.0,*

[3] See Smith and Bilich (2017), page xvii, "*Author's Note regarding Scientific Notebook Documentation*"

and nearly imperceptible tails. But this is *not always* the case. One single example is presented below, and from that example, conclusions will be drawn.

2.3 NAD 83(1986) / NAD 83(1993) / Hawaii – NADCON 5.0 vs 5.01

The differences between the ***NADCON 5.0 release 20160901*** and ***NADCON 5.01 build 20190531*** grids were computed and plotted using MATLAB, and are displayed below.

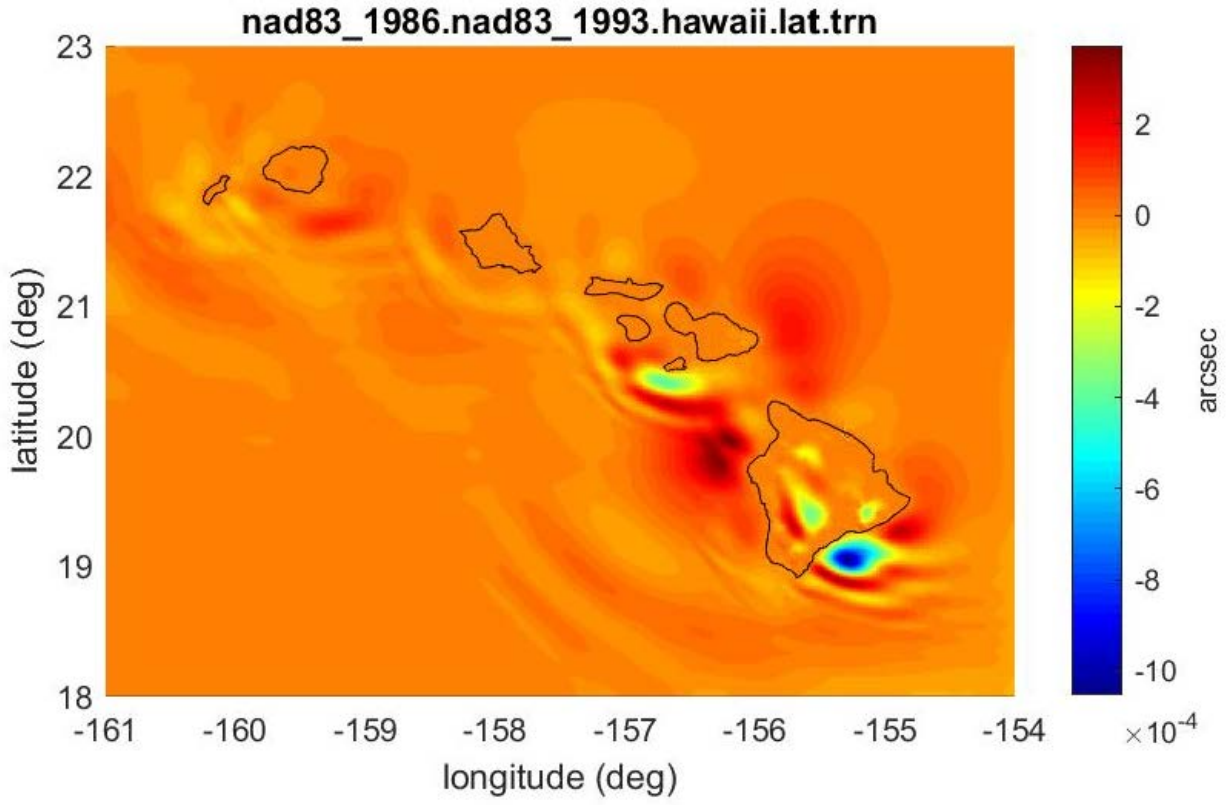

Figure 3: Differences between the *NADCON 5.01 build 20190531* and *NADCON 5.0 release 20160901* grids for the NAD 83(1986) to NAD 83(1993) latitude transformation in Hawaii, in units of arcseconds. Notice the 10^{-4} label on the colorbar.

Of particular note is the large green/yellow feature just southwest of the center of the big island. Although the scale bar is in arcseconds, a simple conversion shows that this approximately 0.0004 arcsecond feature has a 9 mm maximum. An examination of the data coverage on Hawaii for this area shows it to be a data gap. See the horizontal vector plot below for both an idea of coverage as well as the signal being mapped.

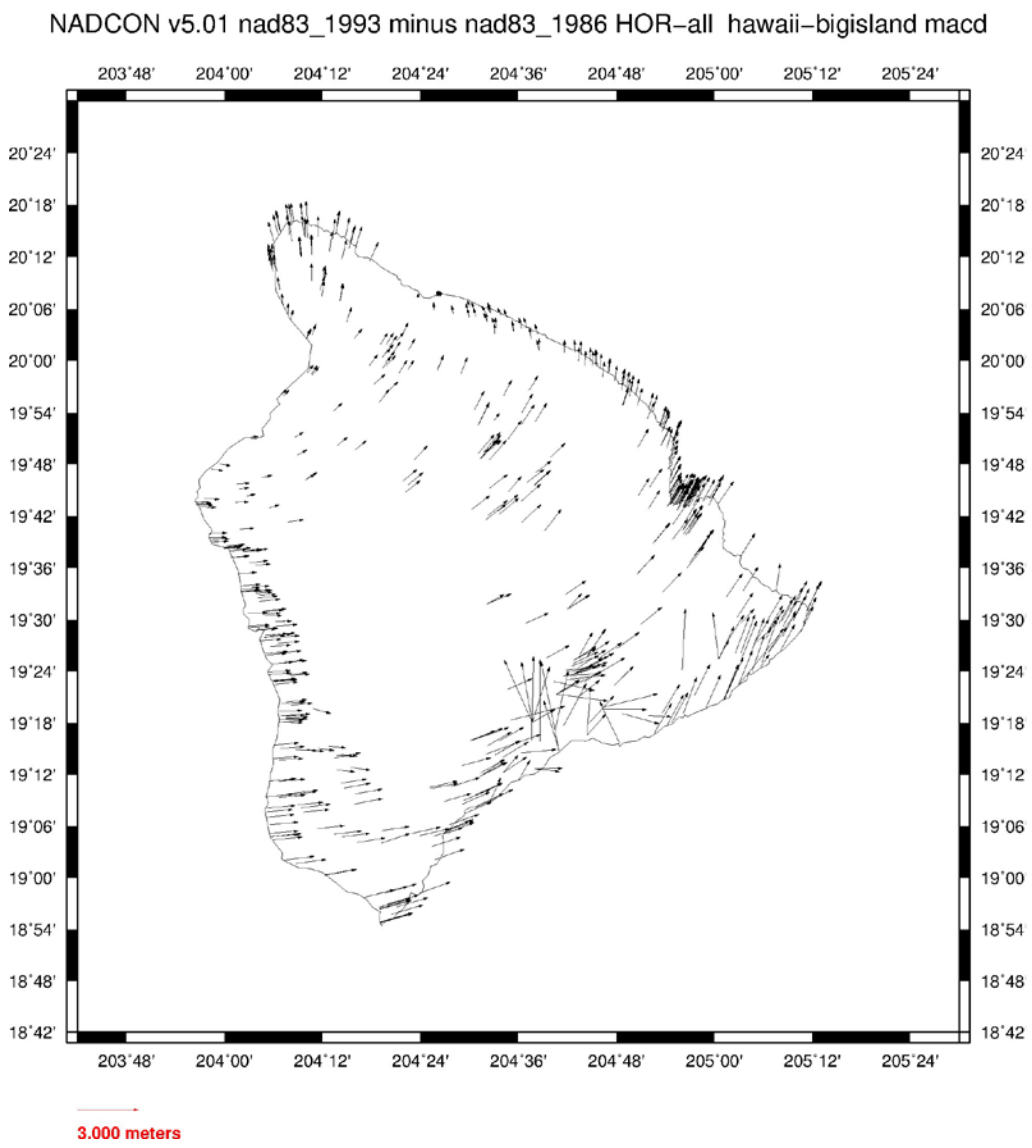

Figure 4: Horizontal vectors reflecting latitude/longitude changes in Hawaii going from NAD 83(1986) to NAD 83(1993). Note the substantial data gap in the southwest-central part of the island.

This example alone is sufficient to show why the ***NADCON 5.01 build 20190531*** grids ***will not replace*** the ***NADCON 5.0 release 20160901*** grids in NCAT and VDatum.

However, going forward, any *new* horizontal transformation grids (either fixing blunders from NADCON 5.0 release 20160901 or else with a new combination of "old datum", "new datum", and "region", not currently in ***NADCON 5.0 release 20160901***) will be generated by the NADCON 5.01 build software (or possibly even a later version, depending on when the work is done). No future grids will come from the NADCON 5.0 build software.

Therefore, for the purposes of customer satisfaction and continuity, NGS products and services like NCAT and VDatum will continue to use the transformation and error grids from

NADCON 5.0 release 20190901. For all future transformations, the actual build software will be documented, and official releases will occur. As of right now, that means that, should the 2022 modernization happen say on December 31, 2022 without any further updates to the NADCON build software, the official source of horizontal transformation grids in the NSRS as implemented in NCAT and VDatum for the last three chronologically adjacent transformations in CONUS would look like this:

From	To	Region	Release
NAD 83(FBN)	NAD 83(NSRS2007)	CONUS	NADCON 5.0 release 20160901
NAD 83(NSRS2007)	NAD 83(2011) epoch 2010.0	CONUS	NADCON 5.0 release 20160901
NAD 83(2011) epoch 2010.0	NATRF2022 epoch 2020.0	CONUS	NADCON 5.01 release 20221231

2.4 Roll-out

Although a complete set of grids were created in house (***NADCON 5.01 build 20190531***) they will not be made publicly available as a release for the simple reason that they are not the official horizontal transformation grids of the NSRS. However, as the NADCON 5.01 project created build software capable of running on Linux, using GMT 5, and as that software was then used as the foundation for the VERTCON 3.0 build software, it introduces an "endian" issue to the end-users. Specifically, those users who wish to directly download and use the official NSRS transformation grid files (in ".b" format; see Smith and Bilich, 2017), the binary structure will be as follows:

Release	Platform	Endian Structure
NADCON 5.0 release 20160901	Solaris	Big Endian
VERTCON 3.0 release 20190531	Red hat Linux	Little Endian
NADCON 5.01 release TBD	Red hat Linux	Little Endian

The other changes which came with NADCON 5.01, specifically in the plots, are not being released publicly either. This is because, while clearer, these plots do not perfectly reflect the information in ***NADCON 5.0 release 20160901*** (see Hawaii example, above). As such, this report only documents the NADCON 5.01 project and the creation of the NADCON 5.01 build software but not any official release of NSRS transformation grids.

3 Bibliography

Smith, D.A and A. Bilich, 2017: NADCON 5.0: Geometric Transformation Tool for points in the National Spatial Reference System, NOAA Technical Report NOS NGS 63.