NEON Coordinate Systems Specification

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See configuration management system for approval history.

The National Ecological Observatory Network is a project solely funded by the National Science Foundation and managed under cooperative agreement by Battelle. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	11/15/2018	ECO-05825	Initial Release

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1 DESCRIPTION

1.1 Purpose

This document describes the specification of coordinate systems used in the design, construction and initial operation of the National Ecological Observatory Network. Due to the heterogeneity and geographical breadth of NEON instrumentation and observation, establishment of a unified and consistent coordinate frame is essential to the integrative scientific, engineering, and management goals of the Observatory. The goal of this document is not to specify exact locations for all NEON activities, but rather to ensure uniformity across those activities by ensuring a common and complete set of coordinate systems in which they are performed.

A secondary, but equally important, purpose of this document is to establish a format and precision for documenting the locations of activities occurring therein.

1.2 Scope

This document describes the rationale and design for the coordinate systems used, including both local (e.g., site- or plot-based) frames and global frames, referencing a geographical standard. Thus, the specification presented here is relevant to all NEON subsystems, installations, measurements, and maintenance activities. It ***does not*** disclose the transformation algorithms necessary to relate one NEON activity or location to another, nor does it proscribe the establishment of coordinates of any measurement process relative to another.

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Reference Documents

Reference documents contain information complementing, explaining, detailing, or otherwise supporting the information included in the current document.

RD [01]	NEON.DOC.000008 NEON Acronym List
RD [02]	NEON.DOC.000243 NEON Glossary of Terms
RD [03]	NEON.DOC.001025 TOS Protocol and Procedure: Plot Establishment
RD [04]	NEON.DOC.002453 TIS As-Built Report: D01C HARV

2.2 External References

External references contain information pertinent to this document, but are not NEON configuration-controlled. Examples include manuals, brochures, technical notes, and external websites.

ER [01]	NIMA Technical Report TR8350.2, "Department of Defense World Geodetic System 1984"
ER [02]	Addendum to NIMA TR8350.2, "Implementation of the World Geodetic System 1984 (WGS 84) Reference Frame G1150)
ER [03]	National Geodetic Survey Geoid12A Geospatial Model - https://www.ngs.noaa.gov/GEOID/GEOID12A/

2.3 Acronyms

EGM	Earth Gravitational Model
GCS	Geographic Coordinate System
GNSS	Global Navigation Satellite System
ITRF	International Terrestrial Reference Frame
LCS	Local Coordinate System
LCO	Local Common Origin
MSL	Mean Sea Level
NAVD	North American Vertical Datum
PCS	Projected Coordinate System
WGS	World Geodetic System
UTM	Universal Transverse Mercator

3 INTRODUCTION

The specification of a NEON-wide coordinate system enforces continuity of geospatial reference on both local and national scales. On local scales:

- Civil construction and site permitting require precise, unambiguous reference to geospatial coordinates to facilitate accurate characterization of site activities;
- Installation and maintenance activities must accurately document the locations and orientations of all fixtures, sensors, and infrastructure;
- Ground-based scientific activities must ensure consistency of design, adherence to site characterization requirements, and measurement replicability over time; and
- Scientific activities require accurate reference data for mission planning, flight design, sample collection, and data analysis.

On national scales, the collection of consistently georeferenced data are essential to:

- Ensuring the applicability of the domain sampling strategy;
- Assimilation of model-produced estimates of ecological variables with NEON data;
- Integration of data collected by external agencies into NEON's data products;
- Providing informed, integrative data products for policymakers, educators, and scientists;
- Ensuring feasible resource planning and allocation; and
- Provide compatibility among NEON subsystems of multi-spatial/temporal data collections.

This document describes a uniform set of geographic and projected coordinate systems used to determine the position of science, engineering, and management activities of the Observatory, and specifies the systems structure and accuracy.

4 STANDARDS

All coordinate systems shall conform to the basic rules for the arrangement of axes, direction of rotation, and labeling set forth in this document, and are referred to as standard coordinate systems. Other types of coordinate systems are referred to as non-standard coordinate systems, and additional documentation should be provided to justify the use of a non-standard coordinate system. If data are taken in a non-standard coordinate system, data shall be converted to a standard coordinate system prior to ingestion into the NEON database, and/or documented appropriately in NEON technical documents.

4.1 Right-handed Cartesian convention

All coordinate systems shall be orthonormal Cartesian and use a right-hand convention (unless otherwise determined and documented) for the arrangement of axes, as shown in Figure 1. The right-hand convention is such that the cross-product **x** x **y** = **z**, where boldface denotes unit vectors along each axis.

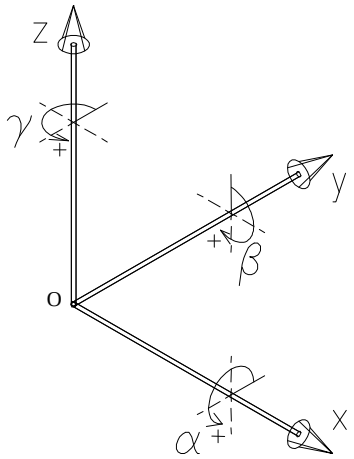

Figure 1: Axes and rotational angles

All axis labels shall be assigned an alphabetic label using a cyclic sequence consistent with the right-hand axis convention, as (x, y, z).

5 REFERENCE SYSTEMS

Because the Observatory is geographically distributed over several thousand kilometers, the coordinate frame covering its extent must reference a datum, a geoid model, and a gridded surface location system (a projection). The datum provides raw altitude data, the gravitational model (geoid) provides nominal sea level, and the projection, a grid applied to the earth surface, provides geodetic references for surface locations.

5.1 Datum

NEON shall employ the World Geodetic System 1984 (WGS84) for its fundamental horizontal reference datum. The WGS84 coordinate system is a right-handed, Earth-centered, Earth-fixed, orthogonal coordinate system, employed worldwide for practical applications of mapping, charting, geopositioning and navigation (ER [01]). It must be noted that as positioning technology has progressed, periodic modifications have been applied to the WGS84 datum parameters. Each modification is identified with

an epoch designation. The G1150 epoch of the WGS84 datum has been selected as the NEON reference. This epoch can also be considered identical to the International Terrestrial Reference Frame of 2000 (ITRF00) (ER [02]). The epoch identification eliminates ambiguity in the intended WGS84 datum parameters, and provides a temporal reference for reconciling positions collected over extended time periods. The conventional notation for identifying the datum and epoch is 'WGS84 (G1150)'.

5.2 Geoid model

NEON shall use the Geoid12A/B models developed by the National Oceanic Atmospheric Administration's National Geodetic Survey to convert ellipsoidal height obtained from the Global Navigation Satellite System (GNSS) to the orthometric height of a specific vertical datum (ER [03]), the North American Vertical Datum of 1988 (NAVD88). The Geoid12A/B models currently provide the highest accuracy for vertical reference across our project area. It should be noted that the Geoid12A/B models could experience periodic updates within the lifespan of NEON, therefore, NEON Science will determine if model updates meet a change criteria threshold and will determine feasibility for applying future updates.

5.3 Surface projection

NEON shall use the Universal Transverse Mercator (UTM) projected coordinate system. UTM is a 2-dimensional Cartesian coordinate system based on the projection of location on the Earth onto a cylindrical surface. UTM zones are divided into 6 degree of longitude east to west running from the equator to the North Pole (N) in the northern hemisphere and the equator to the South Pole (S) in the southern hemisphere with a central meridian running through each zone. The NEON project domains span UTM Zones 3N to 20N.

5.4 Local coordinate system

A local coordinate system (LCS) is a localized instance of a NEON standard coordinate system, a right-handed, orthonormal Cartesian coordinate system, which uses a local common origin (LCO) as the referential datum to derive all subsequent local measurements. The TIS subsystem defined a LCO and uses a LCS to derive asbuilt locations of TIS instrumentation on the tower and soil array plots near the tower. TIS asbuilt positions are reported as geodetic coordinates and measurements in the LCS are captured as a distance of x, y, z, meters relative to the LCO. The TIS LCO is located at the center of the top of the flange on the CD leg of the tower installation (where the C Face and D Face of the tower meet) (RD [04]).

6 PRECISION, STYLE, AND FORMAT

6.1 Geodetic coordinates

A location specified via geodetic coordinates shall be denoted by Latitude-Longitude in decimal degree notation to six decimal places. Longitudinal positions shall be written using the convention where coordinates are measured *positive* east of the Greenwich Meridian. Thus, all NEON locations will have positive geodetic latitude and negative geodetic longitude, for example 40.016281, -105.245842.

6.2 Universal Transverse Mercator system

If the UTM system is used, then all locations shall specify a zone (3-20), a northern hemisphere designator (N), and a Northing-Easting pair in metric units. The northing value specifies the distance in meters a point is located north of the equator. Northing values will be represented as a 7 digit number followed by 3 decimal places. The easting value of a point is the measured distance in meters from the central meridian of the UTM Zone where the central meridian is assigned a “false” easting value of 500,000 meters east. The easting value either increases east of the meridian or decrease west of the meridian. Easting values will be represented as a 6 digit number followed by 3 decimal places.

6.3 Vertical scale

Vertical measurements should be captured in metric units with notation taken to the third decimal place. Where applicable, vertical measurements should reference NADV88 vertical control datum and elevation above mean sea level (MSL).

7 NEON USE OF OTHER GEOID MODELS

During NEON prototype, construction and initial operations, the use of Geoid 93, Earth Gravitational Model 1996 (EGM96), and Geoid09 were utilized for some initial data collection, construction design drawings, and to establish terrestrial observation plots (RD [03]). Some sites were constructed prior to the release of the Geoid12A model. To maintain as-built consistency, these sites were subsequently resurveyed and/or re-processed, and TIS and AIS as-built documents were released using Geoid12A or 12B. AOS monument locations were reprocessed and rereleased in Geoid12a. TOS plot establishment locations remain in Geoid09 with an average difference in geoid resolution of 0.015m compared to Geoid12A across the contiguous U.S. NEON Science staff evaluated transforming TOS location data to Geoid12A and found that the amount of increased precision offered by moving from Geoid09 to Geoid12A did not justify the cost.