Modern Uses of 3-D Digital Spatial Data

Featuring:
2nd Edition – The 3-D Global Spatial Data Model: Principles & Applications

Monthly Meeting of
High-Tech Consortium of Southern New Mexico
4:30 – 6:00 p.m. NMSU Arrowhead Center
Genesis Center, Bldg. C, Las Cruces, NM

October 25, 2017

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HTC of Southern New Mexico – October 25, 2017
Featuring 3-D Spatial Data & 2nd Edition of 3-D Book by Burkholder

Presenter: Earl F. Burkholder, PS, PE, F.ASCE

- **Fellow and Life Member of ASCE.**
- **Retired from NMSU Surveying Engineering faculty - July ‘10.**
- **Wrote “The 3-D Global Spatial Data Model (GSDM)” - 2008.**
- **Second Edition – copyright is 2018 (but it is here now).**

- **Aspirations:**
  1. **That various disciplines share common experiences when working with 3-D digital spatial data.**
  2. **That Surveying Engineering and Geomatics be recognized for valuable contribution to spatial data user community.**

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Why did you come? What is the take-away?

- **Not really about the presenter.**
  - **But, thank you for coming!**
- **Includes exposure to 2nd Edition of 3-D book.**
  - **Yes, buy the book. . .**
  - **Information on "better" way to handle spatial data.**
  - **Includes algorithms and 12 "local" example projects.**
- **Take-away is realizing a different way to look at spatial data.**
  - **Digital data are 3-dimensional (efficient use in data bases)**
  - **Concepts applicable for spatial data disciplines worldwide.**
  - **"Sea change" of the century - Bigger than "going metric"?**
  - **How big? GIS market over $10 billion annually by 2023.**

http://www.marketsandmarkets.com/Market-Reports/geographic-information-system-market-55818039.html

Digital revolution impacts everything – including location:

- Traditional surveying – plats, topo maps, construction, etc.
- Modern surveying – ground based instruments, on-screen maps.
- Current – electronic sensors on many platforms collect 3-D data:
  - Total station surveying instruments and electronic recording.
  - Remote sensing and photogrammetric mapping.
  - GPS and LiDAR
  - Satellite imagery
  - Cell phones (3-D?)
- BIG DATA - NOAA request for information – silos of digital data!
  (see http://www.globalcogo.com/BIGDATA.pdf)

Traditional models for handling geospatial data include:

- **Flat Earth:**
  - x/y (or n/e) coordinates, third dimension is z or elevation.
- **Geodesy uses ellipsoid for precise "curved Earth" computations:**
  - Mixed units, curvilinear (lat/lon) and length (m) for height.
- **Cartography uses map projections to "flatten the Earth":**
  - Recover simplicity of plane 2-D but distortion is unavoidable.
  - Near global coverage with UTM maps (military origin/use).
  - State plane coordinate zones cover states in the USA.
  - Low distortion projections serve "small" area very well.
    - i.) Suffer from lack of standardization and only 2-D.
    - ii.) Numerous projections needed in each state or area.

The 3-D Global Spatial Data Model (GSDM):

- Based on Earth-centered, Earth-Fixed (ECEF) by U.S. DoD:
- X/Y is in plane of equator – Z nearly coincides with spin axis.
- Rules of solid geometry, vectors, matrices, & linear algebra.
- GSDM includes:
  - Functional model of geometry and equations.
  - Stochastic model to describe spatial data accuracy.
- X/Y/Z points are unique and stored in 3-D data base (cloud).
- Difference computations are from origin selected by user.
- Uses local coordinate differences – easy to understand.
- Model provides local direction and distance to any point.

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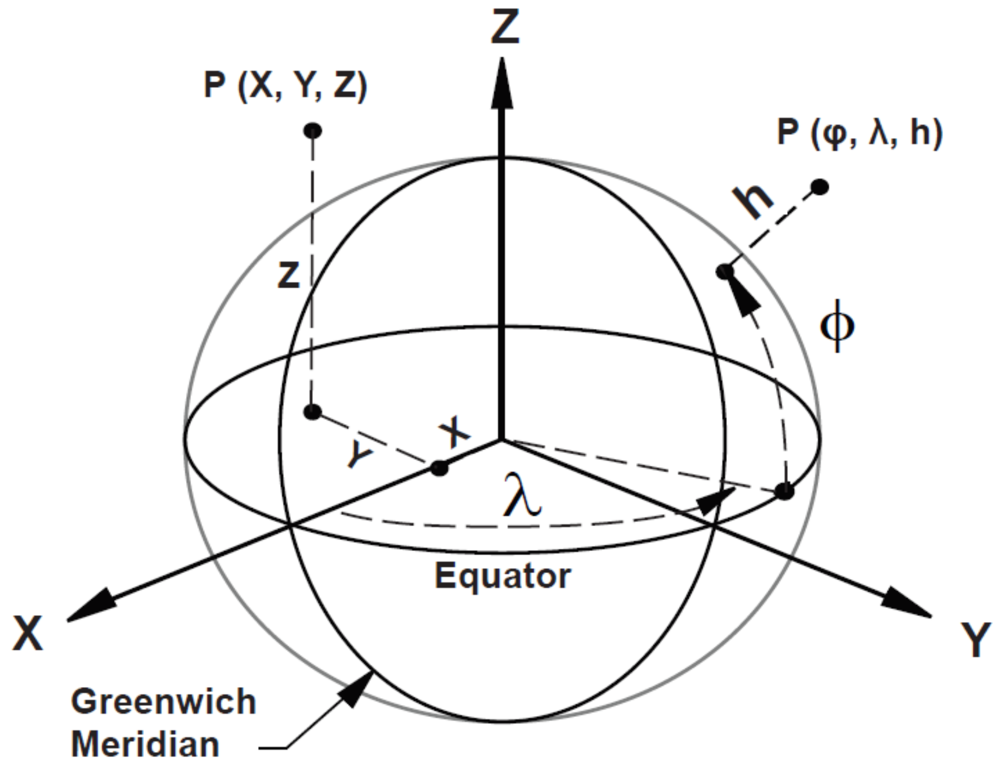

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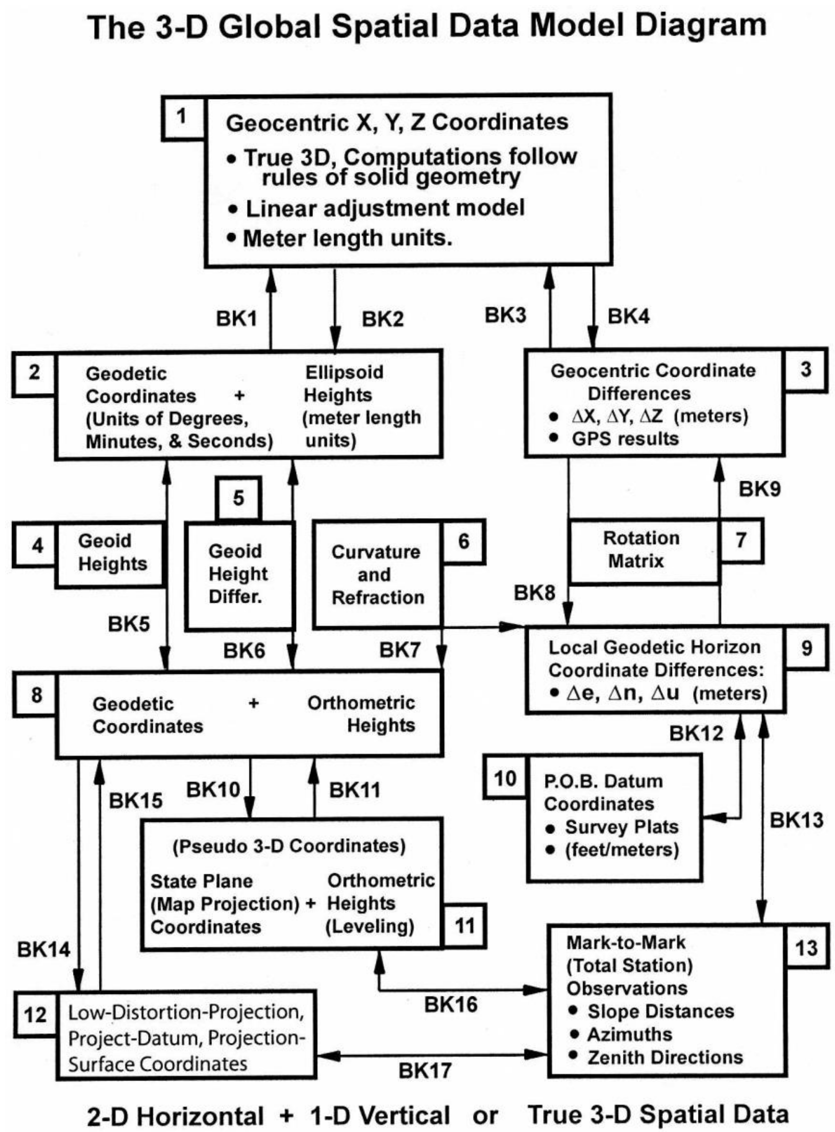

As described in Chapter 1 of the 3-D book, equations 1.34 thru 1.36, the stochastic model portion of the GSDM uses the error propagation procedure shown below along with the matrix inverse between two points defined by their ECEF coordinates. The model accommodates the full covariance matrix associated with those two points. That includes both the covariance matrix for each point as well as the correlation between points as contained in the off-diagonal 3 x 3 submatrices. Various accuracies are obtained depending on which elements of the covariance matrix actually exist and/or which of the covariance matrix values are used in the computation.

(J = matrix of partial derivatives & Σ_{XYZ} is covariance matrix.)

$$\begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} = \begin{bmatrix} -1 & 0 & 0 & 1 & 0 & 0 \\ 0 & -1 & 0 & 0 & 1 & 0 \\ 0 & 0 & -1 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_1 \\ Y_1 \\ Z_1 \\ X_2 \\ Y_2 \\ Z_2 \end{bmatrix} \qquad and \quad \Sigma_\Delta = J \, \Sigma_{XYZ} \, J^t$$

$$\Sigma_{XYZ} = \begin{bmatrix} \begin{bmatrix} \sigma_{X_1}^2 & \sigma_{X_1Y_1} & \sigma_{X_1Z_1} \\ \sigma_{X_1Y_1} & \sigma_{Y_1}^2 & \sigma_{Y_1Z_1} \\ \sigma_{X_1Z_1} & \sigma_{Y_1Z_1} & \sigma_{Z_1}^2 \end{bmatrix} & \begin{bmatrix} \sigma_{X_1X_2} & \sigma_{X_1Y_2} & \sigma_{X_1Z_2} \\ \sigma_{Y_1X_2} & \sigma_{Y_1Y_2} & \sigma_{Y_1Z_2} \\ \sigma_{Z_1X_2} & \sigma_{Z_1Y_2} & \sigma_{Z_1Z_2} \end{bmatrix} \\ \begin{bmatrix} \sigma_{X_1X_2} & \sigma_{Y_1X_2} & \sigma_{Z_1X_2} \\ \sigma_{X_1Y_2} & \sigma_{Y_1Y_2} & \sigma_{Z_1Y_2} \\ \sigma_{X_1Z_2} & \sigma_{Y_1Z_2} & \sigma_{Z_1Z_2} \end{bmatrix} & \begin{bmatrix} \sigma_{X_2}^2 & \sigma_{X_2Y_2} & \sigma_{X_2Z_2} \\ \sigma_{X_2Y_2} & \sigma_{Y_2}^2 & \sigma_{Y_2Z_2} \\ \sigma_{X_2Z_2} & \sigma_{Y_2Z_2} & \sigma_{Z_2}^2 \end{bmatrix} \end{bmatrix}$$

Local accuracy uses the full X/Y/Z covariance matrix. Network accuracy uses only the diagonal 3 x 3 submatrices of each station.

Applications are worldwide in many disciplines:

- **Surveying, engineering, planning, transportation, mapping, geography, navigation, facilities management, GIS, & other.**

- **GSDM answers question – accuracy with respect to what?**
  - **This issue looms enormous and begs for an answer!**
  - **This question is addressed in the 2nd Edition.**
  - **Links on subsequent page lead to deeper considerations.**

- **Is there a "high tech" role for NMSU in the larger picture of spatial data applications?**

Transition will not occur instantaneously but . . . .

- **Many knowledgeable professionals are already using 3-D.**
- **Standardization/operational efficiencies will drive the transition.**
- **Educational efforts can provide huge opportunities/benefits.**
- **Known obstacles include:**
  - **Proprietary considerations.**
  - **Gate-keeper attitudes.**
  - **Investments in the status quo.**
  - **Reluctance to have users "think for themselves."**
  - **Temptation to "buy" solutions rather than to "own" them.**

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- **Thank you for opportunity to participate!**

- **A pdf file of this presentation can be accessed at:**

  www.globalcogo.com/HTC-October-2017.pdf

- **The power point presentation file is posted at:**

  www.globalcogo.com/HTC-October-2017.pptx

- **2nd Edition ordering information – www.globalcogo.com**
  (or Google "global spatial data model 2nd Ed.")

The following links lead to "deeper" considerations:

- **Formal definition/description of the GSDM**

  http://www.globalcogo.com/gsdmdefn.pdf

- **High-level article in EOS**

  http://www.globalcogo.com/gsdm-eos.pdf

- **Abstract view of 3-D spatial data (Award winner!)**

  http://www.globalcogo.com/setepaper.pdf

- **Peer reviewed article on spatial data accuracy**

  http://www.globalcogo.com/accuracy.pdf

- **Network/local accuracy comparison in Wisconsin**

  http://www.globalcogo.com/WisGPSNet.html

Additional investigation is warranted in following areas:

The GSDM. . .

- **Is an "umbrella" for other spatial models.**
- **Supports efficient algorithms for location computations.**
- **Will provide undistorted values of horizontal distance.**
- **Efficiently defines local and network accuracies.**
- **Ideally suited for real-time computations involving:**
  - **Intelligent vehicle navigation.**
  - **Monitoring instantaneous location of any/all drones.**
- **Other . . .**