FIG/IAG/UN-GGIM-AP/ICG/GSI/JFS
Technical Seminar
Reference Frame in Practice
Kobe, Japan, 29-30 July 2017

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VERTICAL REFERENCE FRAME AND GIS

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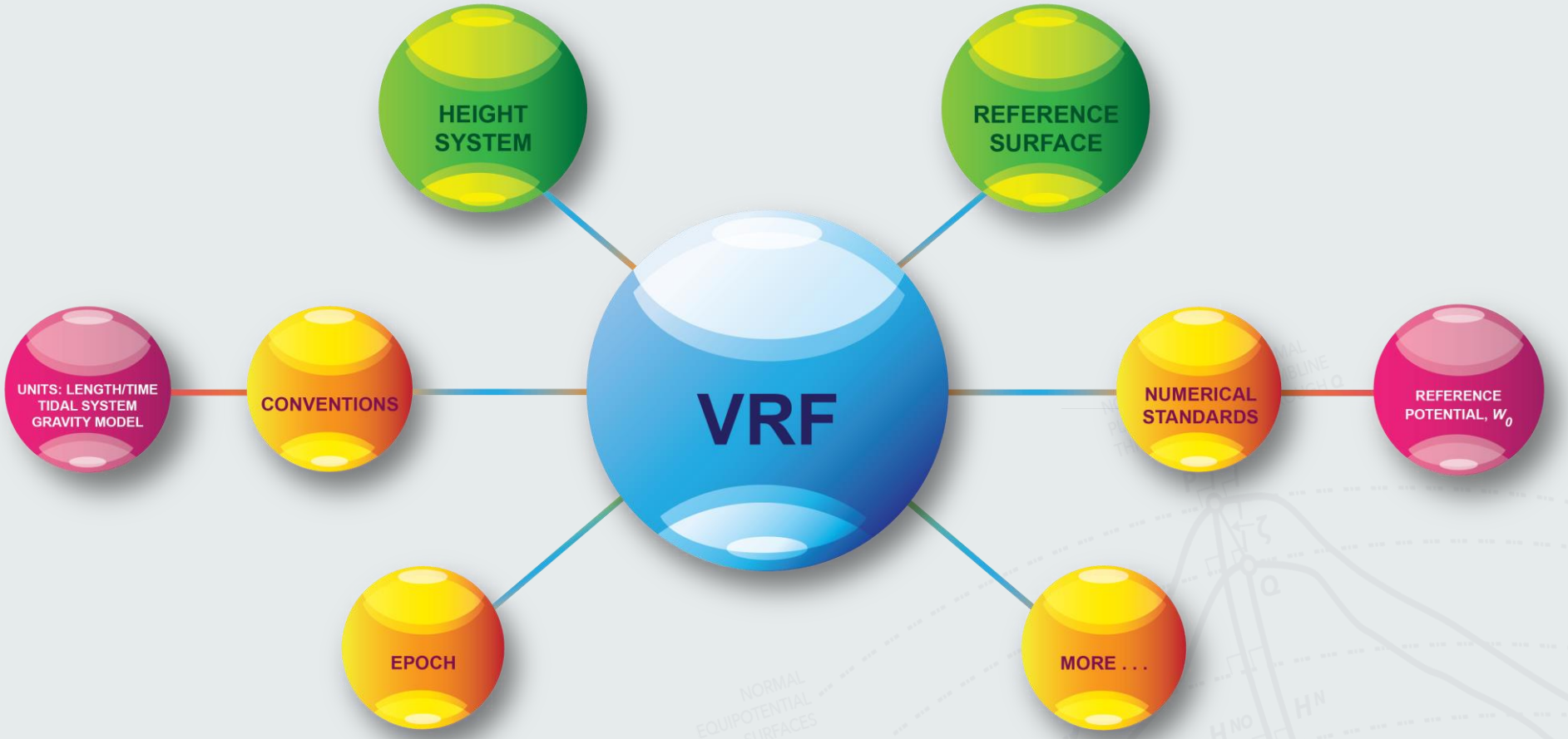
Key Points

- Basic components of VRF
- Data consistency in GIS
- VRF transformations in GIS
- Transformation models
- VRF transformations Demo

Vertical Reference Frame

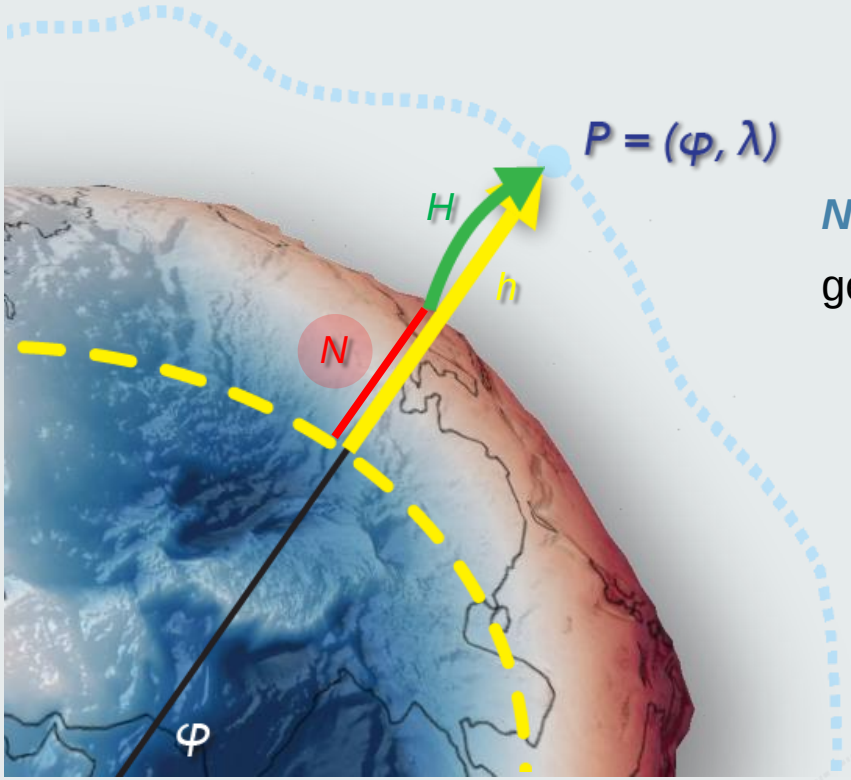


What is Height

Concept

- **Height** and **gravity** are intricately linked.
- Water (fluids) flows from higher to lower places.
- But it is actually the **force** of **gravity** that governs this flow – not height.
- Only **gravity–based** height systems provide heights that can predict the flow of fluids.
- Metric values provide a convenient means of expressing heights.

Height Systems & Reference Surfaces

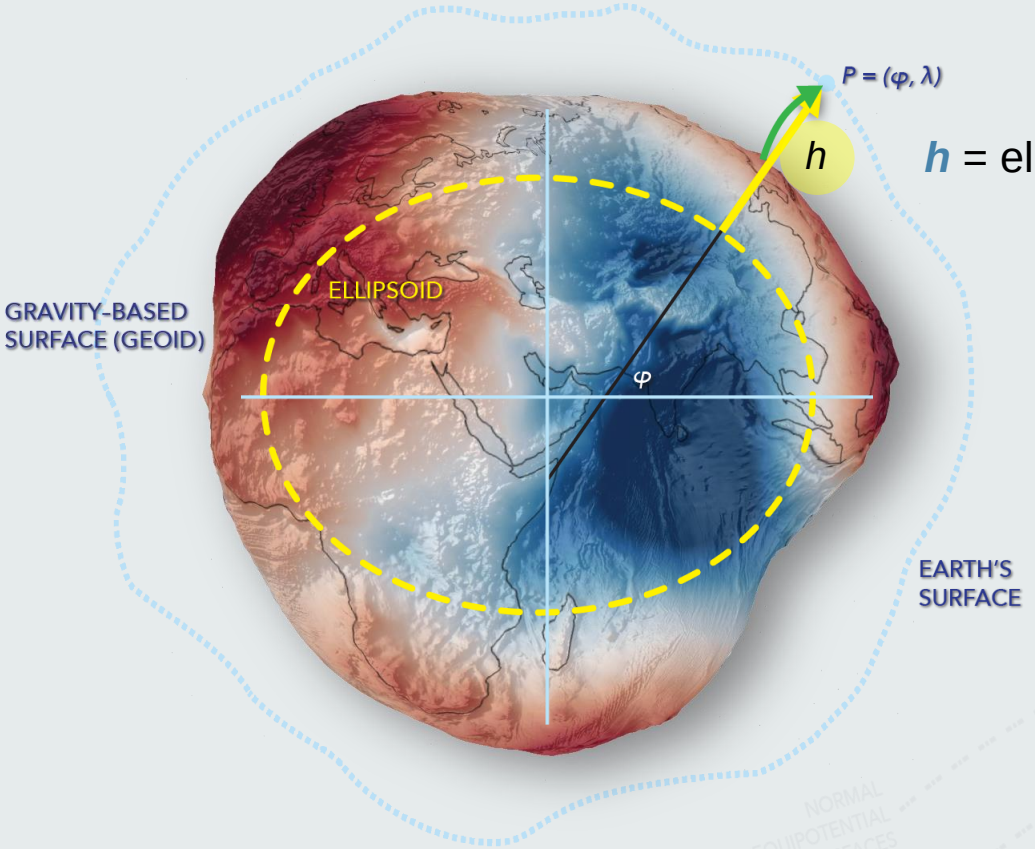


N – geoid undulation, **geoid height** or geoid-ellipsoid separation

$$H \approx h - N$$

GNSS-Heighting Equation

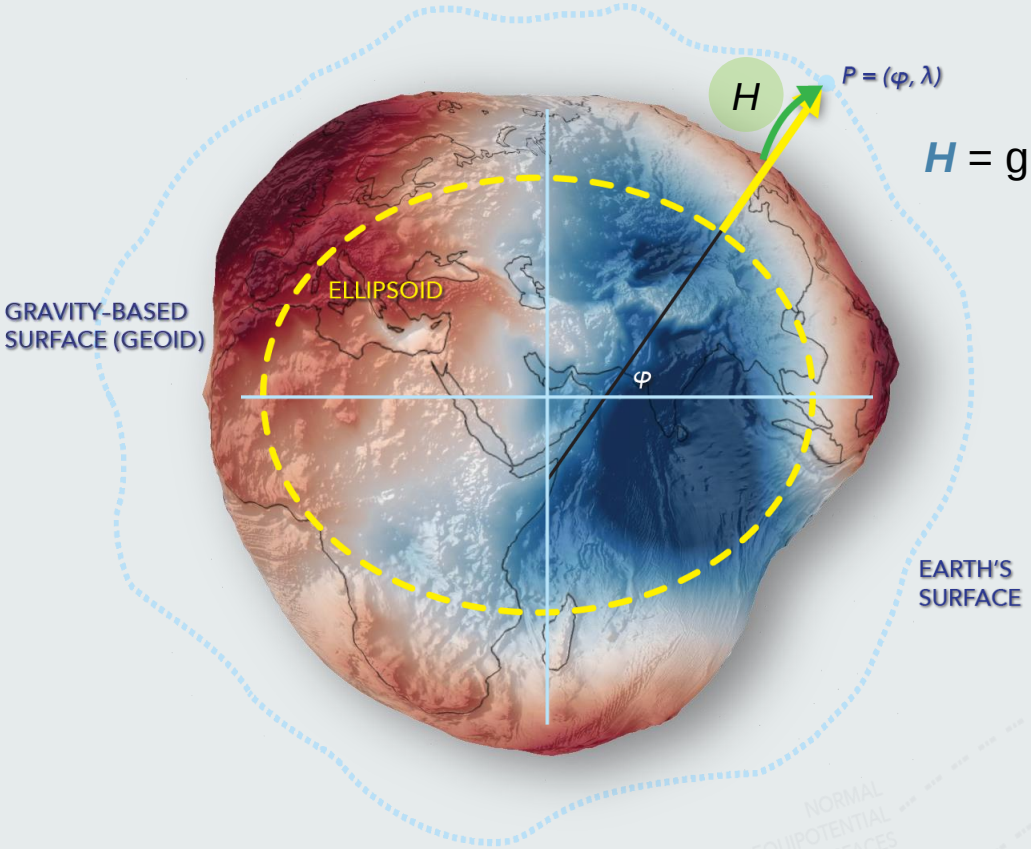
Height Systems & Reference Surfaces



h = ellipsoid height

Independent of
Earth's gravity field

Height Systems & Reference Surfaces

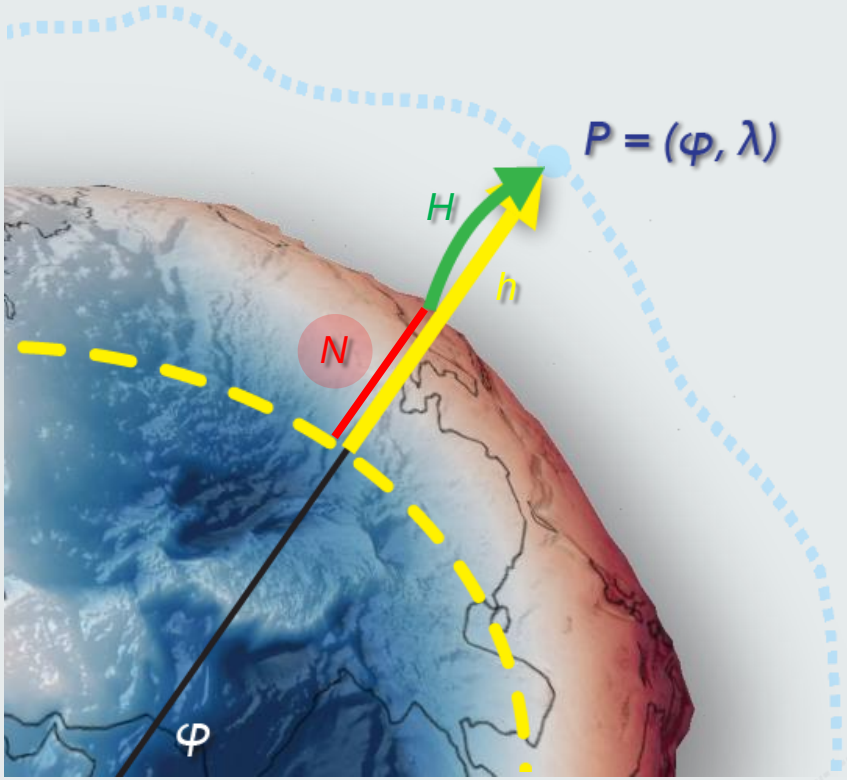


H = gravimetric height

Dependent on
Earth's gravity field

Height Systems & Reference Surfaces

A Remarkable Relationship



Physical – gravity dependent

Physical – geometric relationship

$$H \approx h - N$$

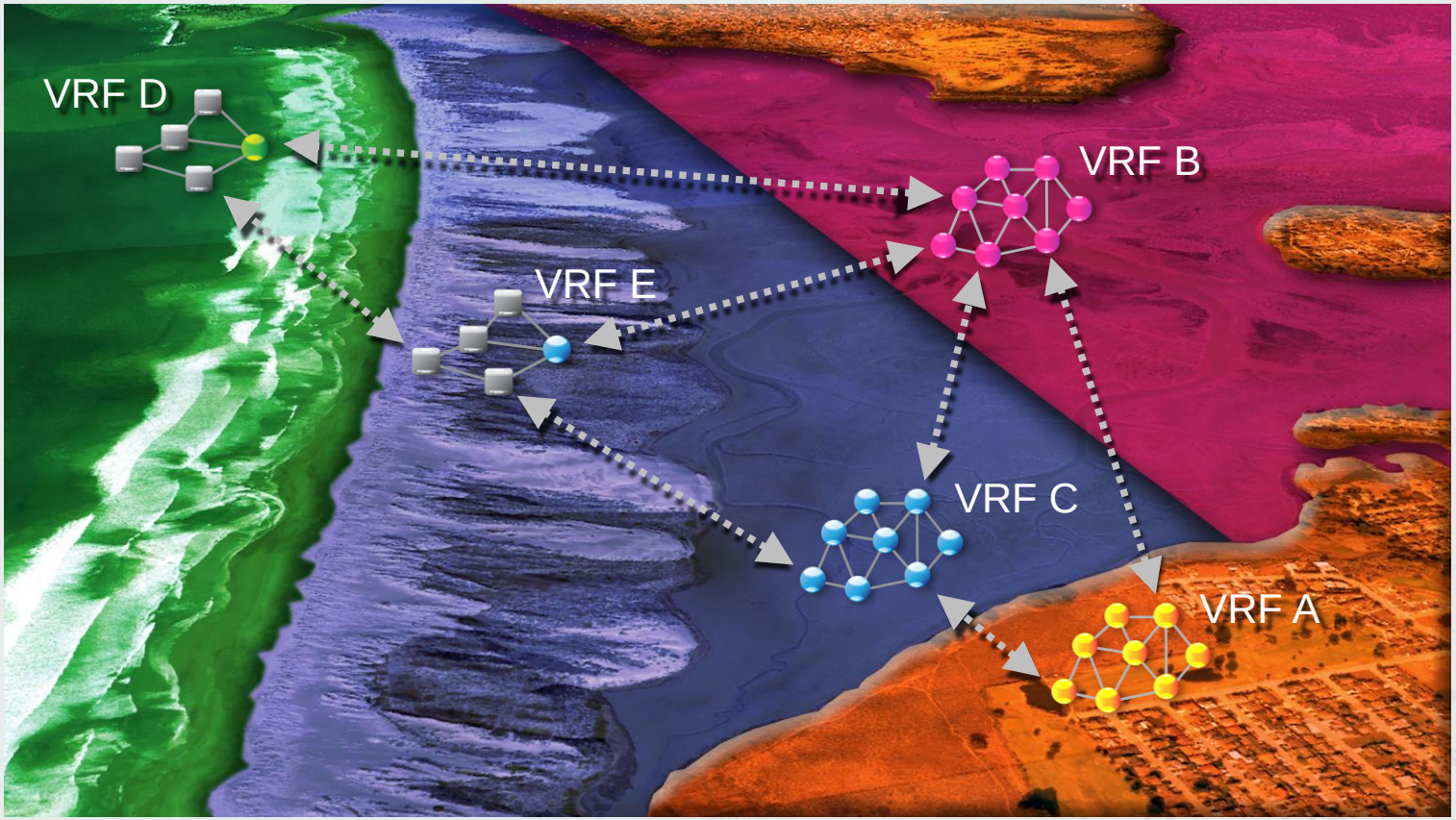
Geometric – gravity independent

Data Consistency

Concept

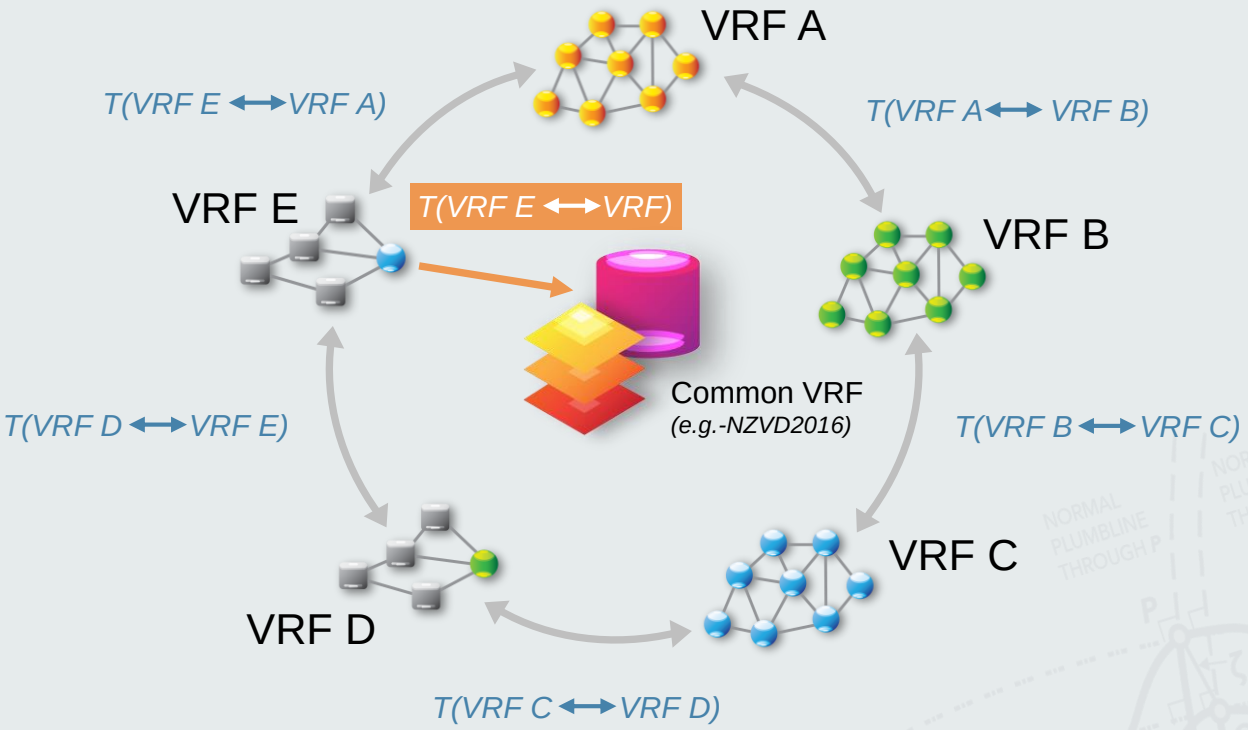
In order to **combine** different height datasets **consistently**, the datasets need to refer to a **common datum**, or, the **relationship** between different vertical datums needs to be known.

Data Consistency



Data Consistency

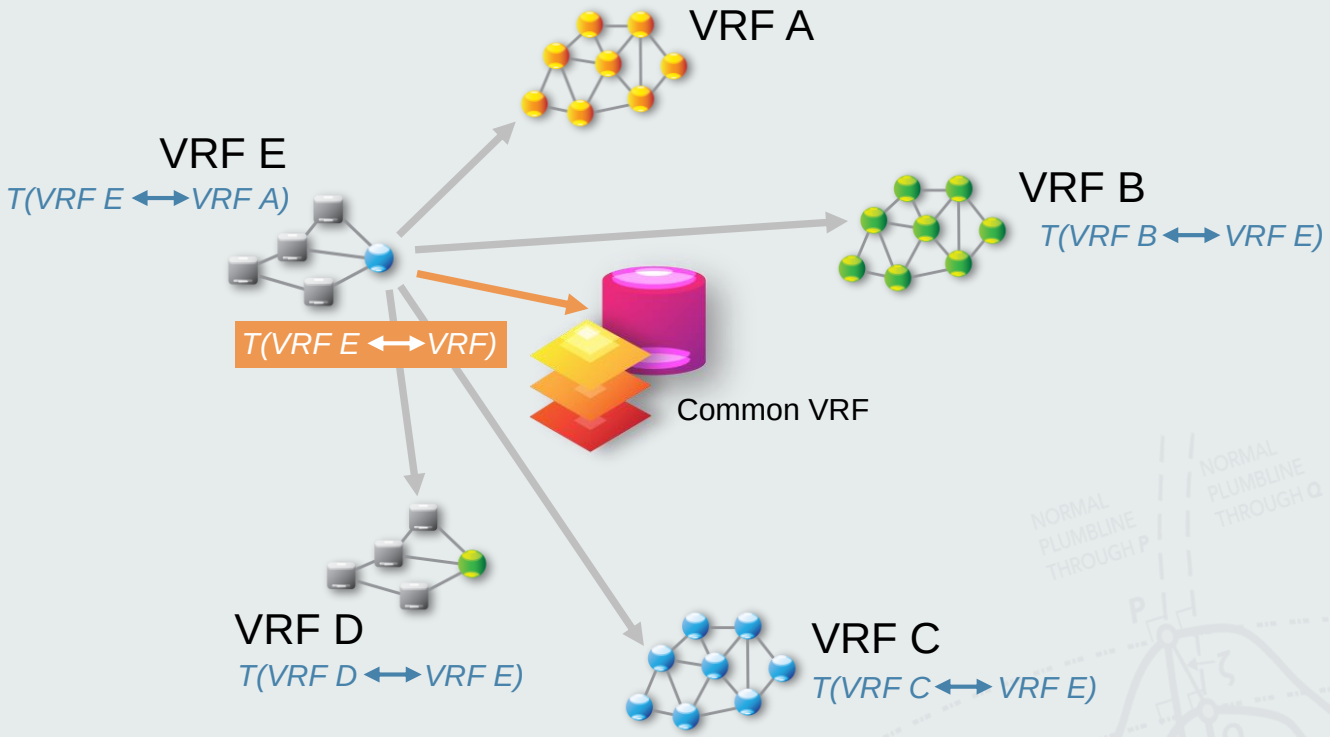
Least Desirable…Maximizes Error Propagation



A **vertical transformation** allows a change of coordinates from one VRF to another.

Data Consistency

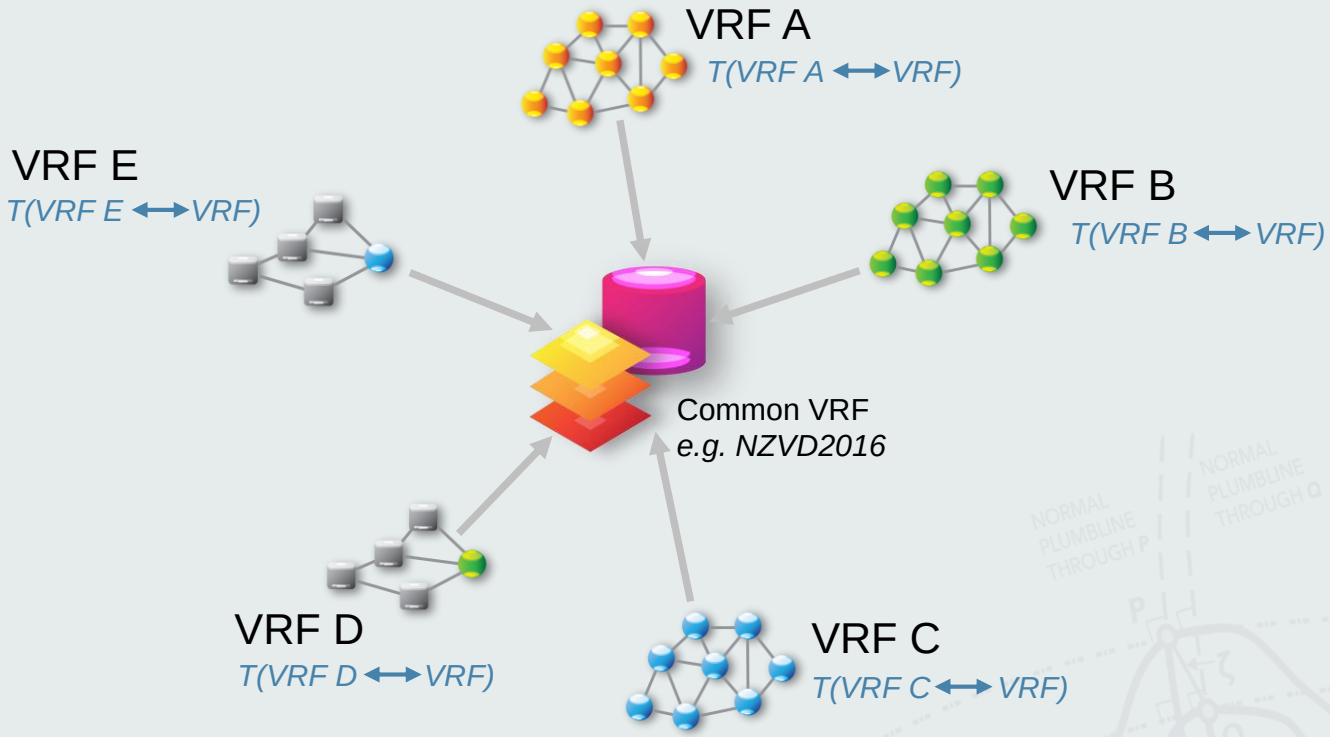
Common Approach



In general, a VT is not unique because it is empirically defined.

Data Consistency

Most Desirable…Minimizes Error Propagation

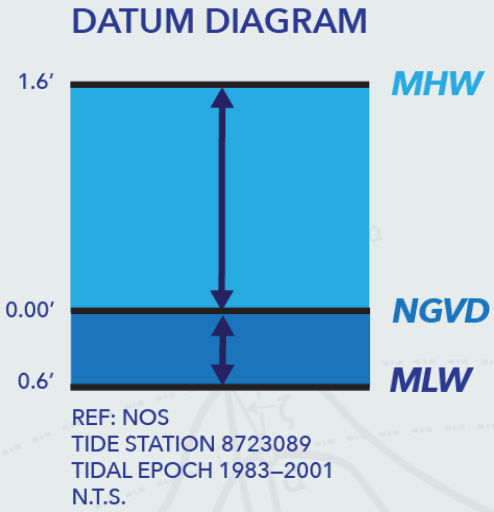


Registering GIS datasets to a common VRF can be accomplished using vertical transformations.

Types of Vertical Transformations

Vertical Offset

- Relationships between tidal datums *(e.g.-VDATUM)*



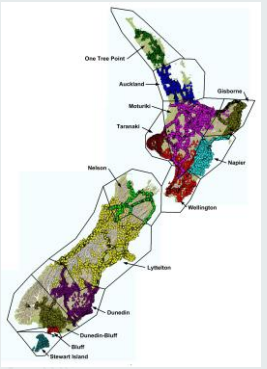
$$X_{VRF2} = X_{VRF1} + Offset$$

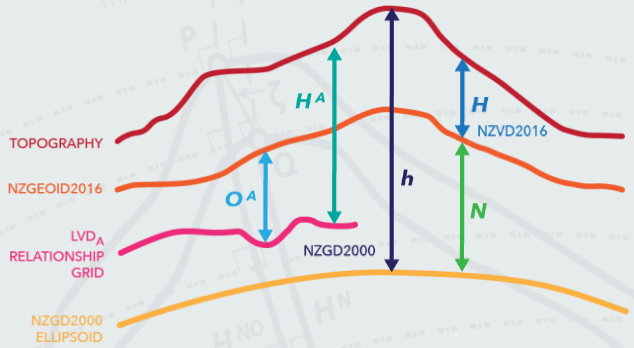
$$X_{VRF2} = X_{VRF1} + Offset(\phi, \lambda)$$

Types of Vertical Transformations

Vertical Offset

- Relationships between tidal datums *(e.g.-VDATUM)*





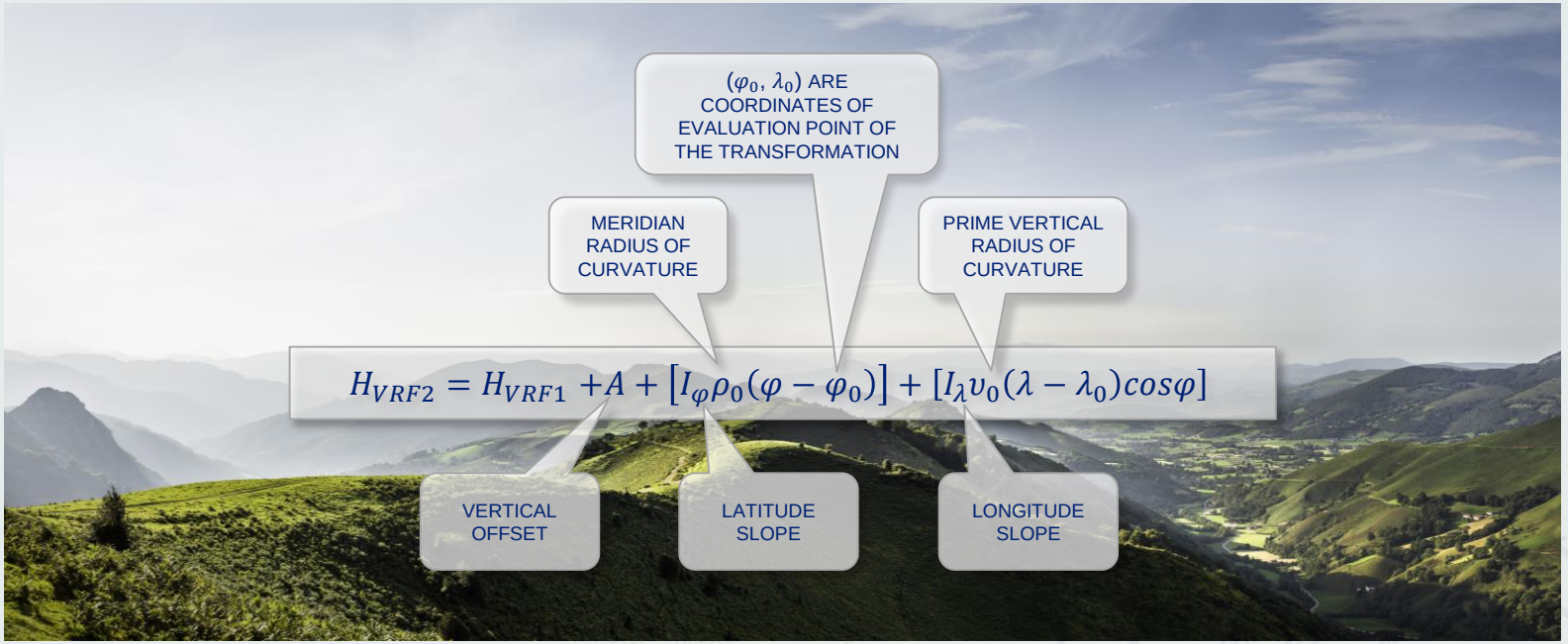
$$X_{VRF2} = X_{VRF1} + Offset$$

$$X_{VRF2} = X_{VRF1} + Offset(\phi, \lambda)$$

Types of Vertical Transformations

Vertical Offset and Slope (or 3–parameter)

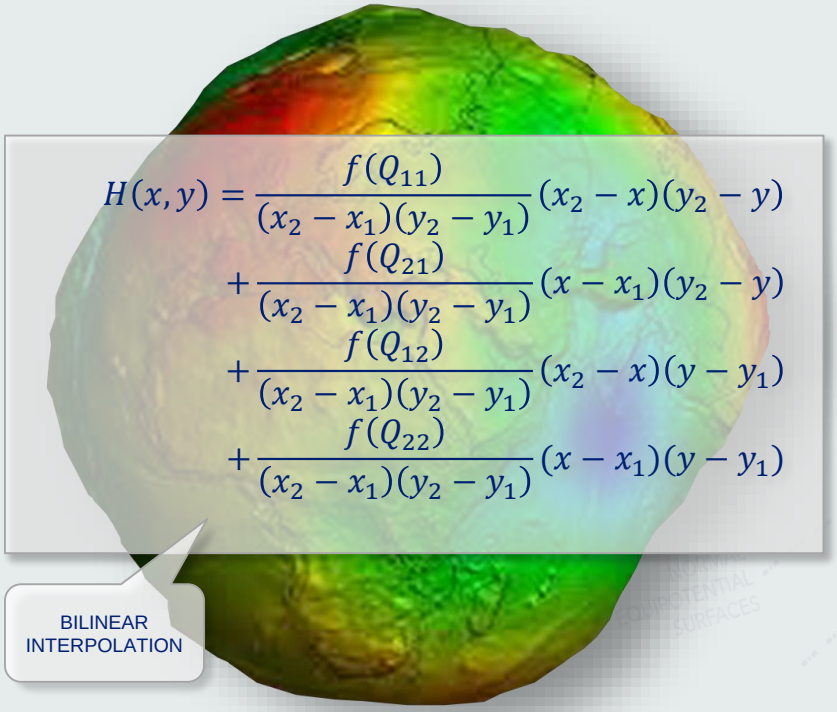
- Relationship between local and regional VRF's *(e.g.-Europe)*



Types of Vertical Transformations

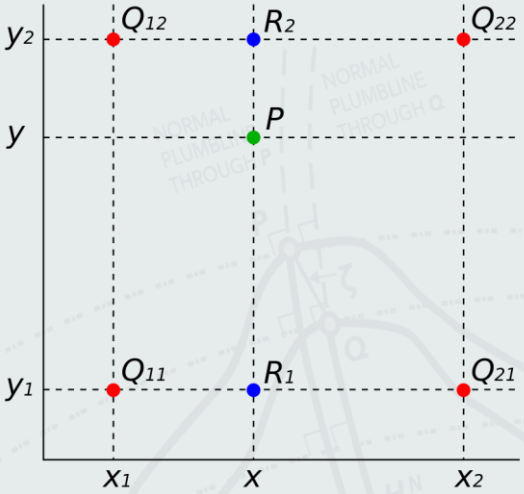
Interpolation of Gridded Shifts

- Gridded vertical datum shifts *(e.g.-NZ LVDs)*
- Application of geoid model *(e.g.-GSIGEO2011)*



$$H(x,y) = \frac{f(Q_{11})}{(x_2-x_1)(y_2-y_1)}(x_2-x)(y_2-y) + \frac{f(Q_{21})}{(x_2-x_1)(y_2-y_1)}(x-x_1)(y_2-y) + \frac{f(Q_{12})}{(x_2-x_1)(y_2-y_1)}(x_2-x)(y-y_1) + \frac{f(Q_{22})}{(x_2-x_1)(y_2-y_1)}(x-x_1)(y-y_1)$$

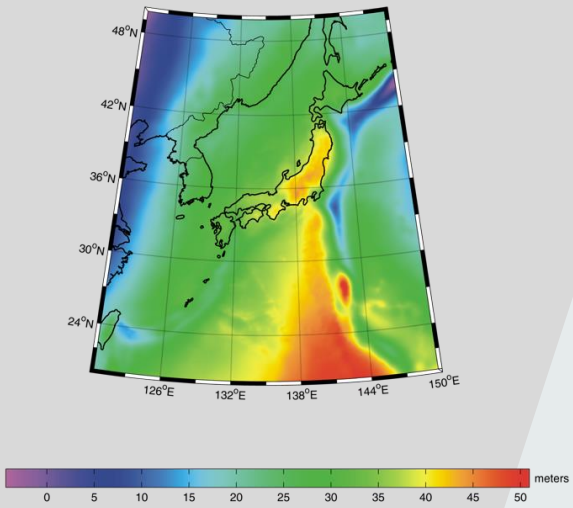
BILINEAR INTERPOLATION



Height System Conversions

Concept

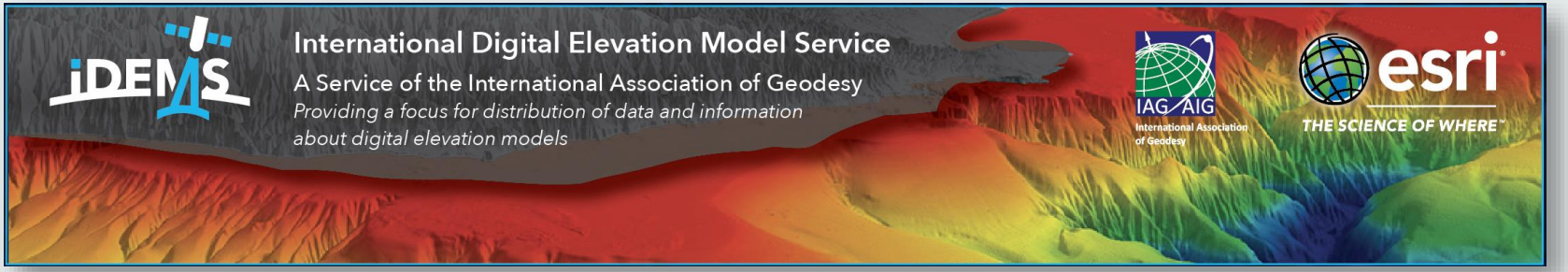
- Relate heights between different height systems
- Can be distinct from VRF transformations and may get quite complex
- Often involves complicated computations requiring surface gravity and/or DEM data.
  - For example, conversion between normal and orthometric heights.



VRF Transformations in GIS - Demo

- After the devastating 2011 earthquake in Japan a new geoid model is required.
- Terrain data – DEM – is required in Japan and surrounding region. The joint METI/NASA ASTER GDEM dataset is selected for the purpose.
- The GDEM data will be transformed into the current Japan vertical datum using GIS.

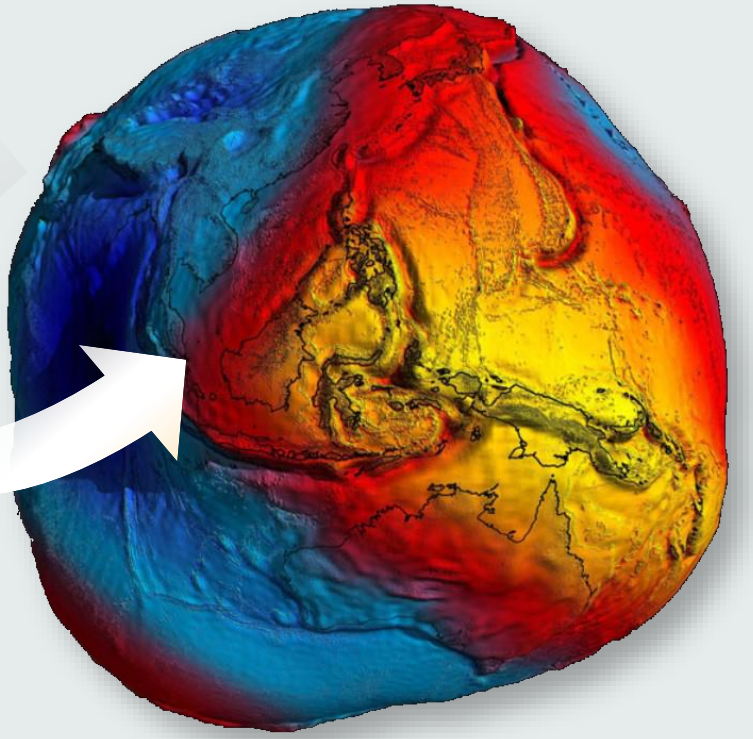
International Digital Elevation Model Service (IDEMS)



IDEMS provides a focus for distribution of data and information about digital elevation models, spherical-harmonic models of Earth's global topography, lunar and planetary DEM, relevant software and related datasets.

International Digital Elevation Model Service (IDEMS): A Revived IAG Service
Session G02-P, Static gravity field
Shisho Hall
15:30-16:30 Tuesday, August 1/ Wednesday, August 2, 2017

International Service for the Geoid (ISG)



Main tasks of ISG are:

- to collect geoid data on a worldwide scale (geoid repository)
- to collect and distribute software for geoid determination (software download)
- to conduct researches on procedure for geoid determination (projects)
- to organize Geoid schools
- to edit and distribute the Newton's Bulletin

Compound Vertical Transformations

Relate AsterV2 GDEM to Japan Geodetic Datum 2011 Orthometric Height (JGD2011 Vertical)

Input Frames
$TRF = WGS84, \quad VRF = EGM96\ Geoid$

Output Frames
$TRF = JGD2011, \quad VRF = JGD2011\ Vertical$

$EGM96(H) \overset{VT}{\Rightarrow} WGS84(h)$ → $WGS84(h) \overset{GT}{\Rightarrow} JGD2000(h)$ → $JGD2000(h) \overset{GT}{\Rightarrow} JGD2011(h)$ → $JGD2011(h) \overset{VT}{\Rightarrow} JGD2011(H)$

$EGM96\ Geoid\ Model$

$7-parameter\ Helmert\ null\ transformation$

$JGD2000 \leftrightarrow JGD2011\ Grid\ shifts\ \Delta\varphi, \Delta\lambda$

$GSIGEO2011\ Geoid\ Model$

$14-parameter\ time-based\ Helmert\ non-null\ transformation$

$JGD2000 \leftrightarrow JGD2011\ Grid\ shifts\ \Delta\varphi, \Delta\lambda, \Delta h$

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Thank you!

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