Sistema Internacional de Referência para Altitudes (IHRS)

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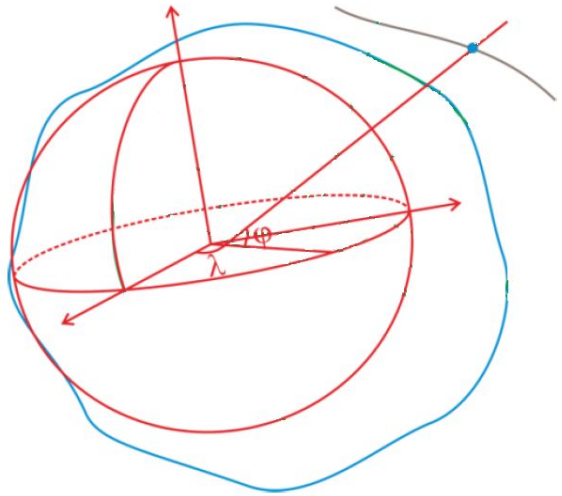
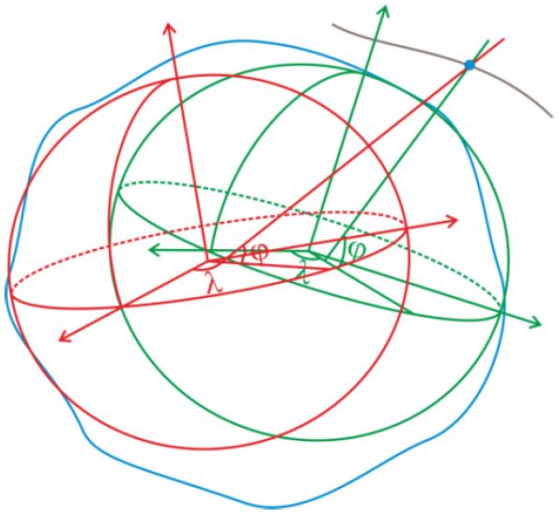
II Colóquio de Engenharia Cartográfica
UERJ, 08.05.2019

Unificação e refinamento de sistemas de referência



Sánchez, 2018 (http://www.sirgas.org/pt/sirgas-symposia/aguascalientes_2018/)

Unificação e refinamento de sistemas de referência



Sánchez, 2018 (http://www.sirgas.org/pt/sirgas-symposia/aguascalientes_2018/)

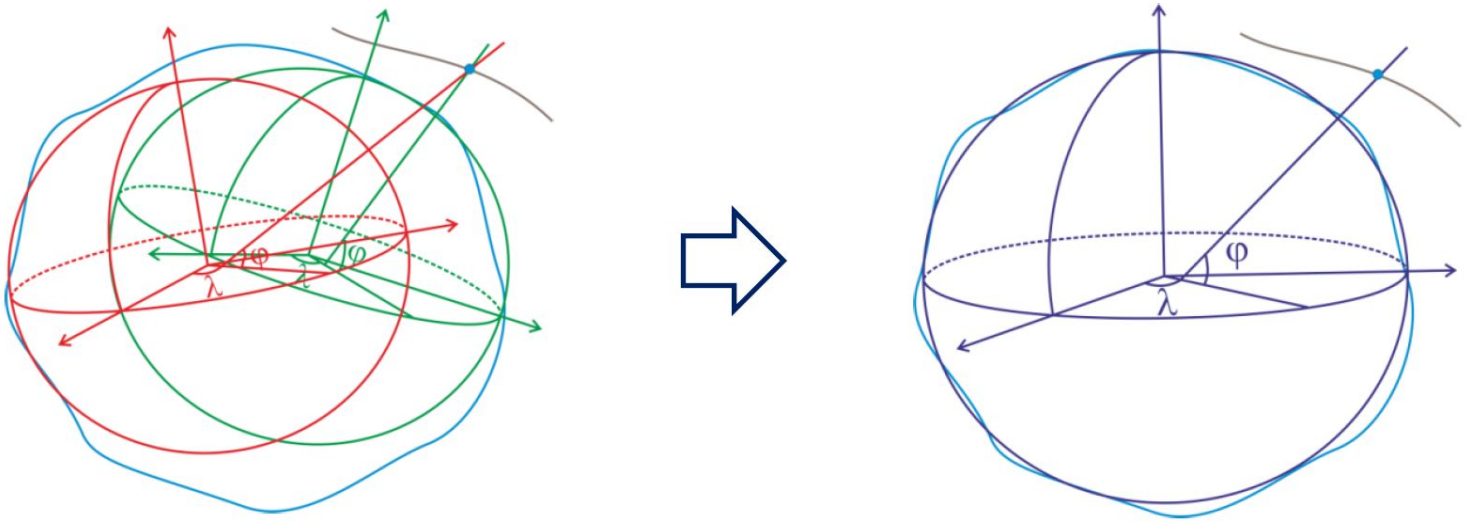
Unificação e refinamento de sistemas de referência

Geocentric Cartesian coordinates

IUGG IAG GGOS Global Geodetic Observing System TUM

refer to the International Terrestrial Reference System (ITRS) and Frame (ITRF)

- Standardized computation through the IERS (International Earth Rotation and Reference Systems' Service);
- Worldwide unified reference frame;
- Reliability at the cm-level.

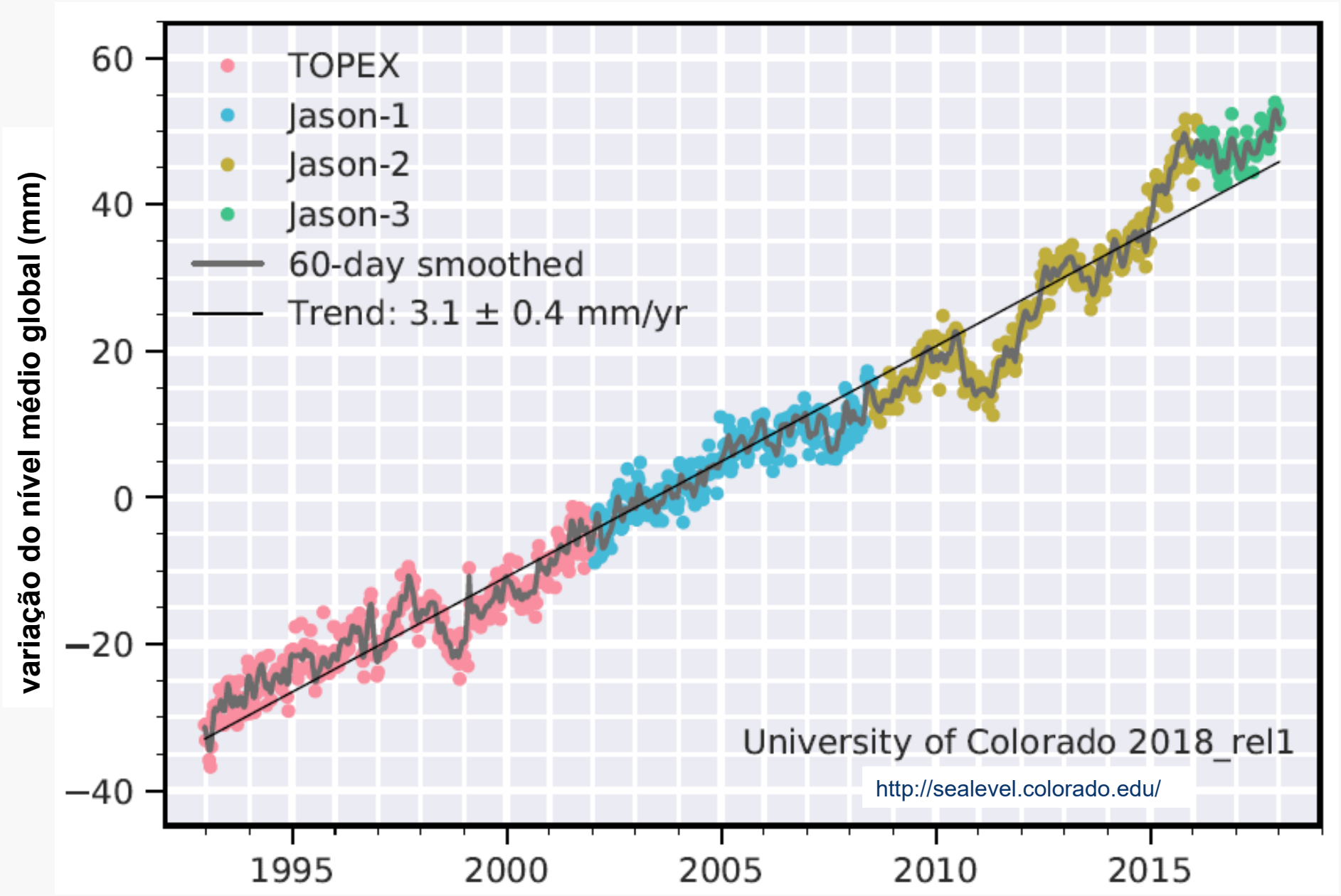


Before the ITRS/ITRF: many individual (local) horizontal reference systems

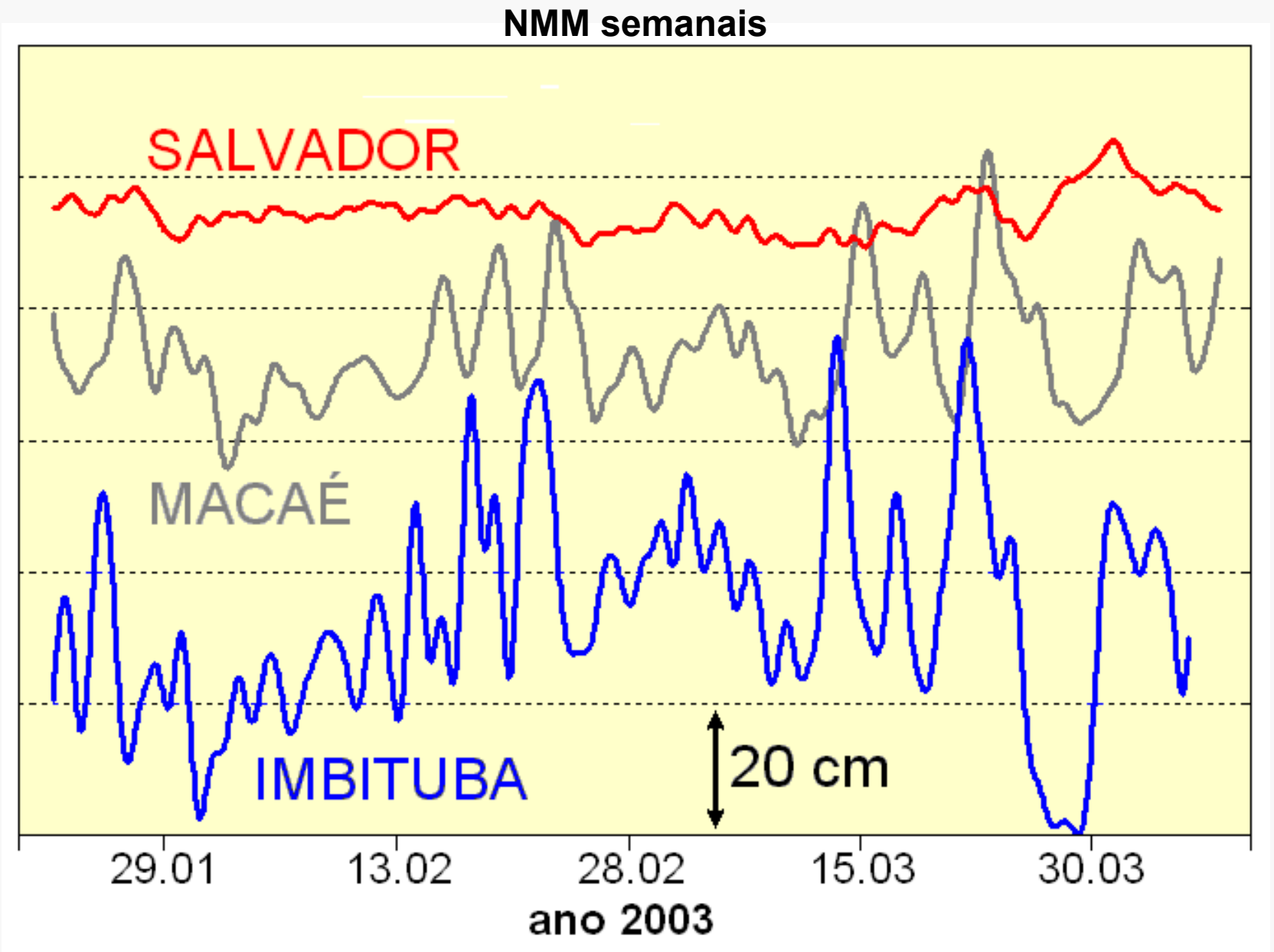
Today: one global unified geocentric reference system

Sánchez, 2018 (http://www.sirgas.org/pt/sirgas-symposia/aguascalientes_2018/)

Variações do NMM

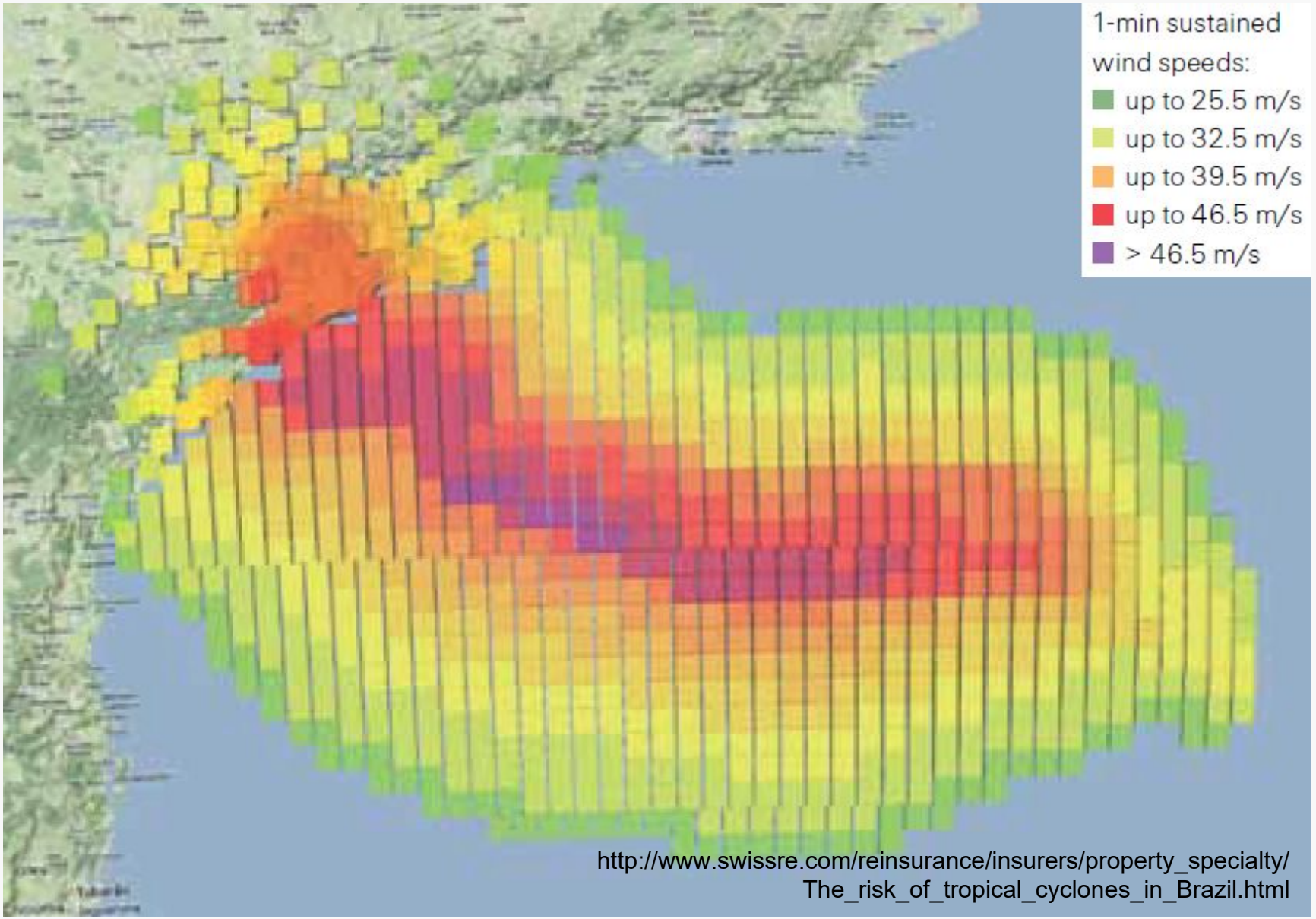


Variações do NMM



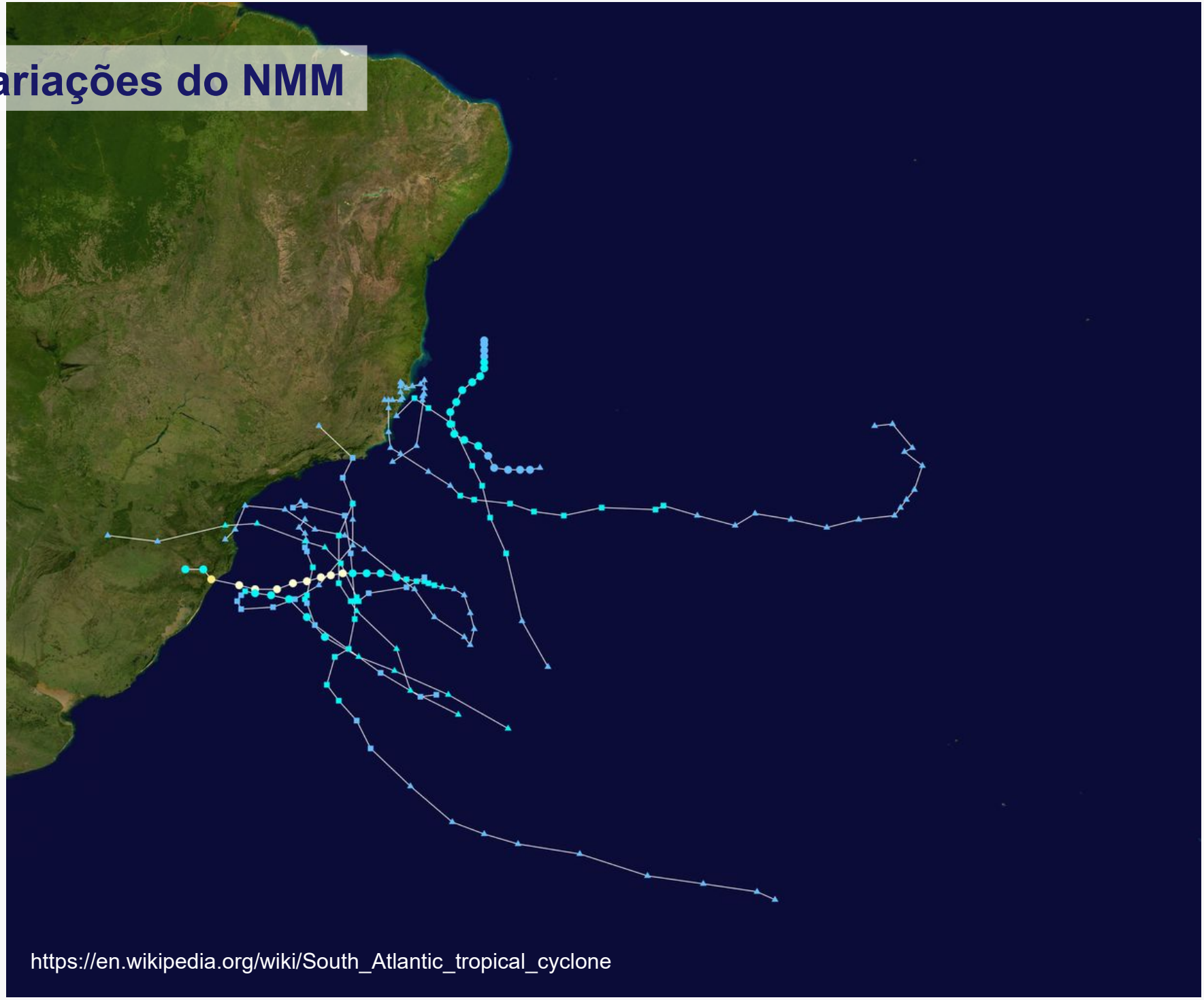
Luz, Guimarães, 2003 (ftp://geoftp.ibge.gov.br/metodos_e_outros_documentos_de_referencia/outros_documentos_tecnicos)

Variações do NMM



http://www.swissre.com/reinsurance/insurers/property_specialty/The_risk_of_tropical_cyclones_in_Brazil.html

Variações do NMM

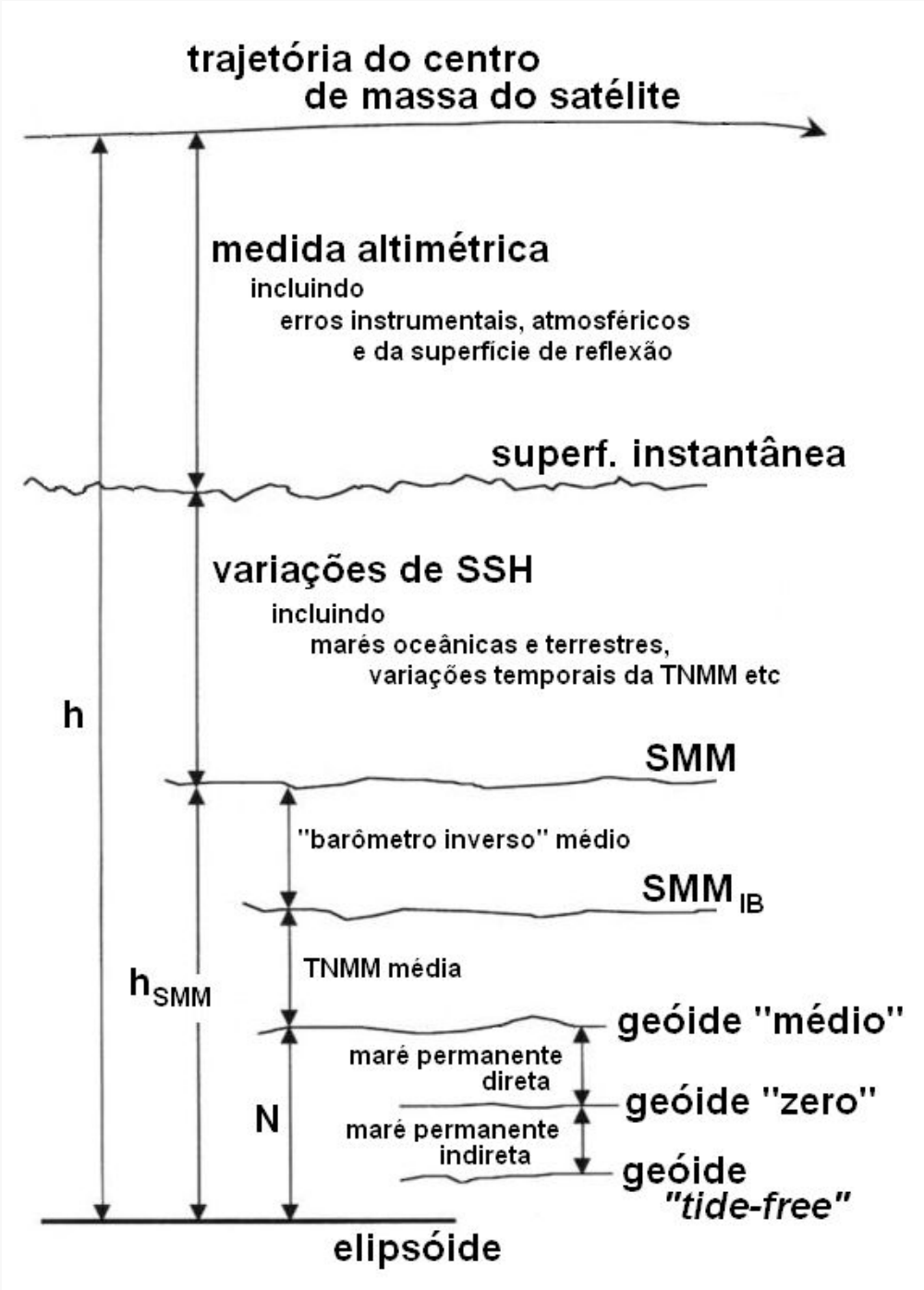


https://en.wikipedia.org/wiki/South_Atlantic_tropical_cyclone

Variações do NMM

$$R_{corr} = R_{altim} + \sum r_{instrum} + \sum r_{atmosf} + \sum r_{superf} + \sum r_{geof}$$

Integração de informações de múltiplas fontes!

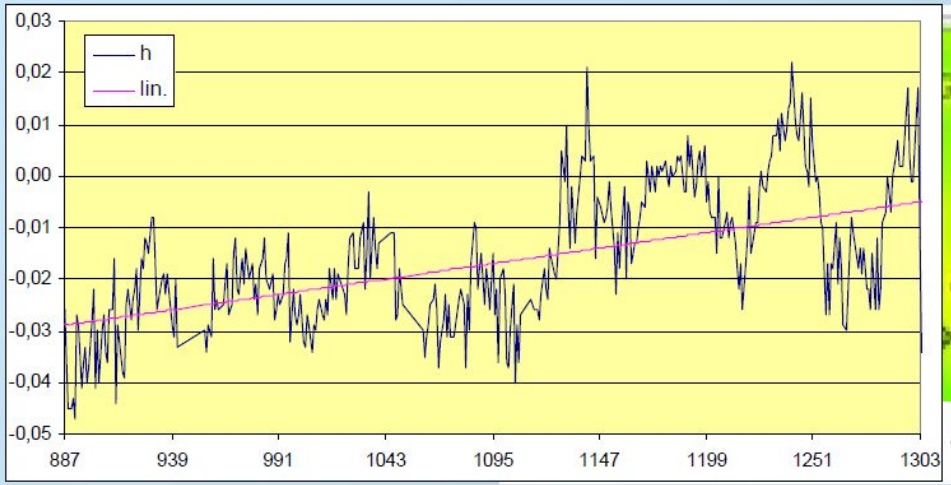


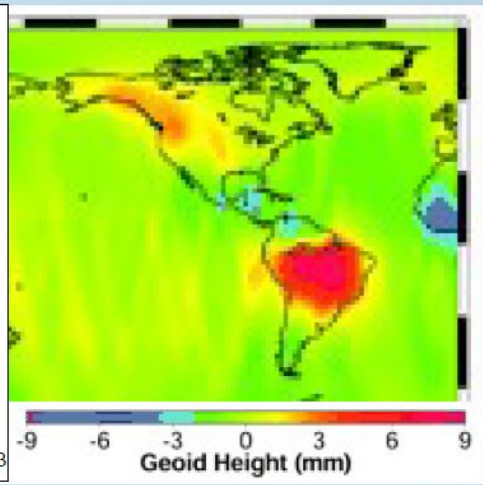
(adapt. de Tapley & Kim, 2001)

Variações do NMM

Consistent Parameters

Example: Non-modelled seasonal variations of a tracking station may enter into the orbit determination and affect other parameters (e.g., altimetry, gravity), and vice versa.





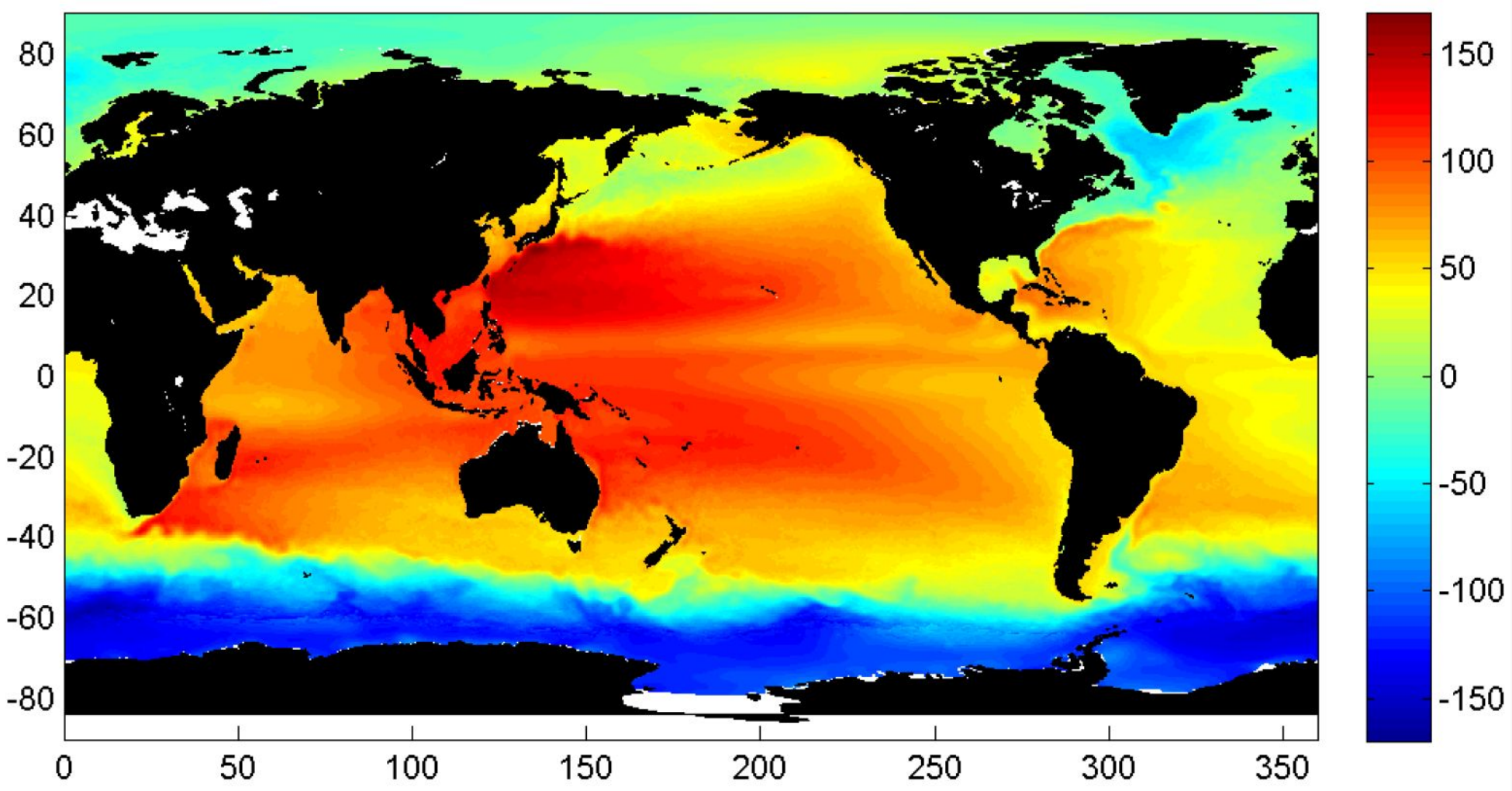
left: Height variation station BRAZ with 2 cm min. in spring;
right: Geoid variation from GRACE with 9 mm max. in spring

DGFI

GGOS

(Drewes, Dynamic Planet 2005)

Variações do NMM



Maximenko et al., 2014 (http://apdrc.soest.hawaii.edu/projects/DOT/)

IHRS

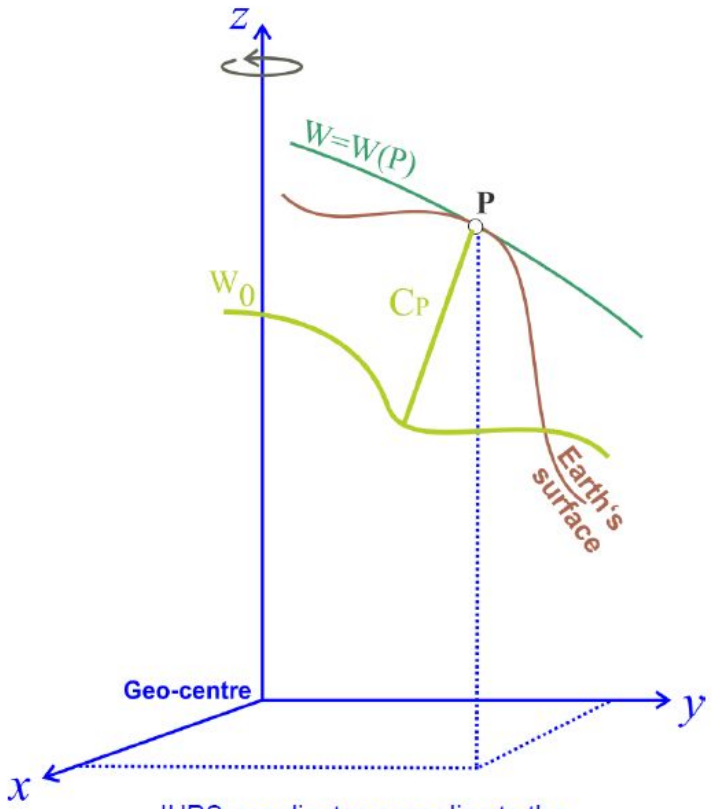
International Height Reference System (IHRS)
IAG Resolution No. 1, Prague, July 2015

IUGG

1) Vertical coordinates are potential differences with respect to a conventionally fixed W_0 value:

$$C_P = C(P) = W_0 - W(P) = -\Delta W(P)$$

$$W_0 = const. = 62\ 636\ 853.4\ m^2s^{-2}$$



IHRS coordinates according to the IAG Resolution No. 1, 2015

Sánchez, 2018 (http://www.sirgas.org/pt/sirgas-symposia/aguascalientes_2018/)

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IUGG IAG GGOS Global Geodetic Observing System

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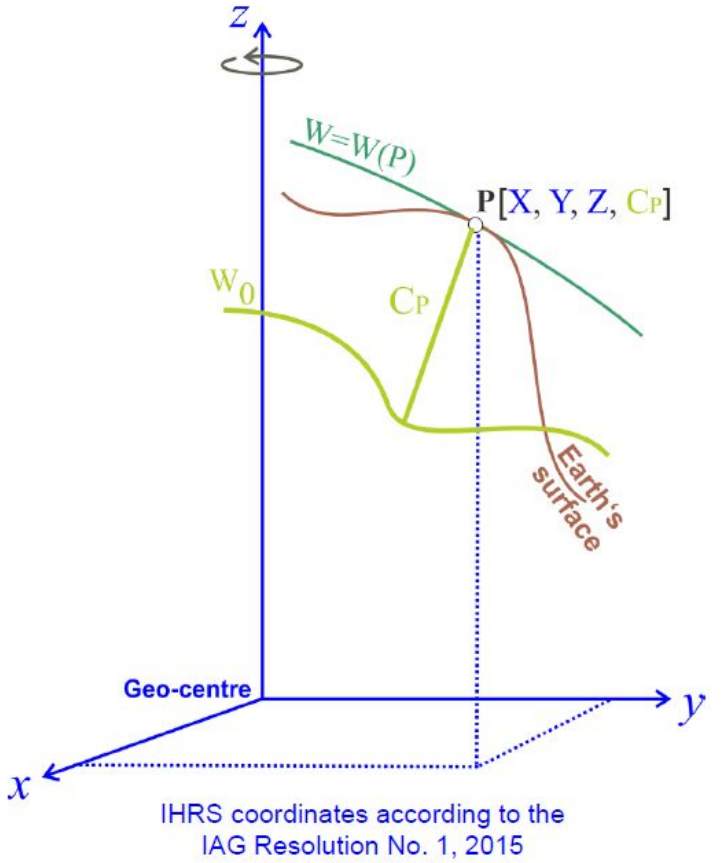
$$C_P = C(P) = W_0 - W(P) = -\Delta W(P)$$

$$W_0 = const. = 62\ 636\ 853.4\ m^2s^{-2}$$

2) The position P is given in the ITRF

$\mathbf{X}_P\ (X_P, Y_P, Z_P)$; i.e., $W(P) = W(\mathbf{X}_P)$

3) The estimation of $\mathbf{X}(P)$, $W(P)$ (or $C(P)$) includes their variation with time; i.e., $\dot{\mathbf{X}}(P)$, $\dot{W}(P)$ (or $\dot{C}(P)$).



IHRS coordinates according to the IAG Resolution No. 1, 2015

See: Ihde J. et al.: *Definition and proposed realization of the International Height Reference System (IHRS)*. Surv Geophy 38(3), 549-570, 10.1007/s10712-017-9409-3, 2017

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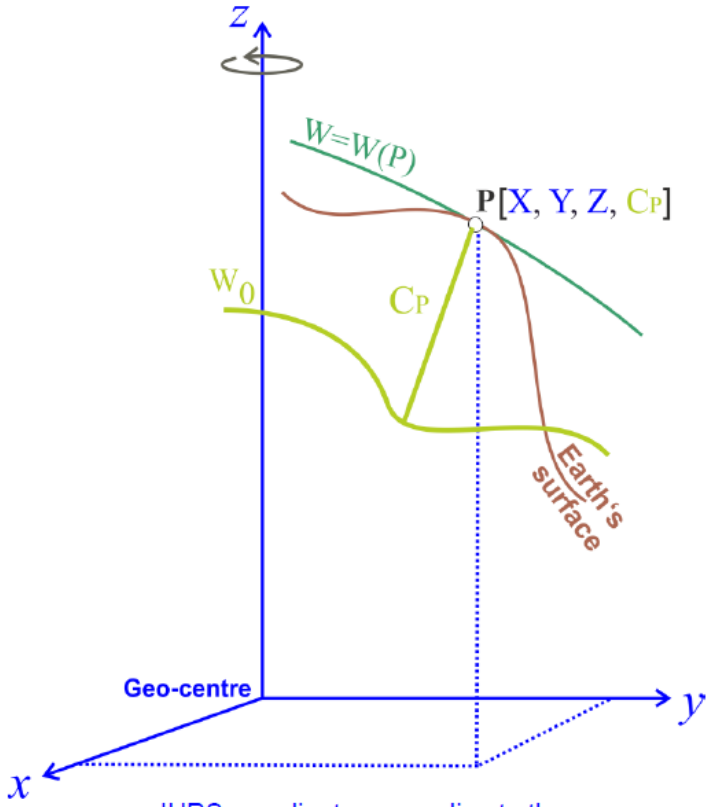
4) Coordinates are given in mean-tide system / mean (zero) crust.

5) The unit of length is the meter and the unit of time is the second (SI).



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IHRS

Computation of potential values $W(P)$

1) Global gravity models of high-degree (with RTM)

$$W_P = f(X_P, GGM)$$

2) High-resolution gravity field modelling:

$$W_P = W_{P,satellite-only} + W_{P,high-resolution}$$

Satellite-only gravity field modelling:
Satellite orbits and gradiometry analysis
Satellite tracking from ground stations (SLR)
Satellite-to-satellite tracking (CHAMP, GRACE)
Satellite gravity gradiometry (GOCE)
Satellite altimetry (oceans only)

+

High-resolution gravity field modelling:
Stokes or Molodenskii approach
Satellite altimetry (oceans only)
Gravimetry, astro-geodetic methods, levelling, etc.
Terrain effects

3) Potential values recovered from existing (quasi)-geoid models:

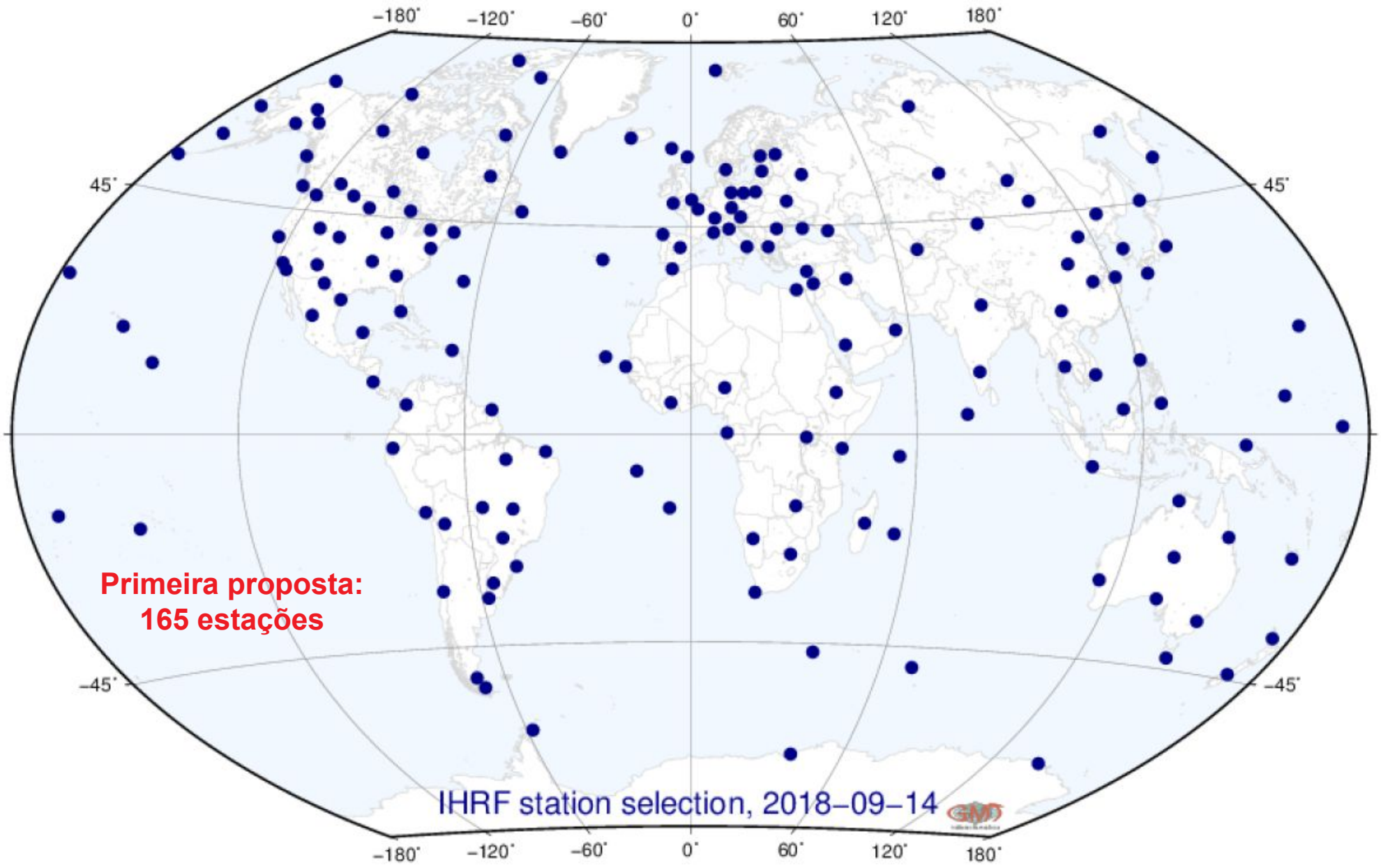
$$W_P = U_P + \gamma\,\zeta_P + (W_0 - U_0)$$

4) Levelling + gravimetry (after vertical datum unification):

$$W_P = (W_0^{local} + \delta W) - C_P; \quad \delta W = W_0^{IHRF} - W_0^{local}$$

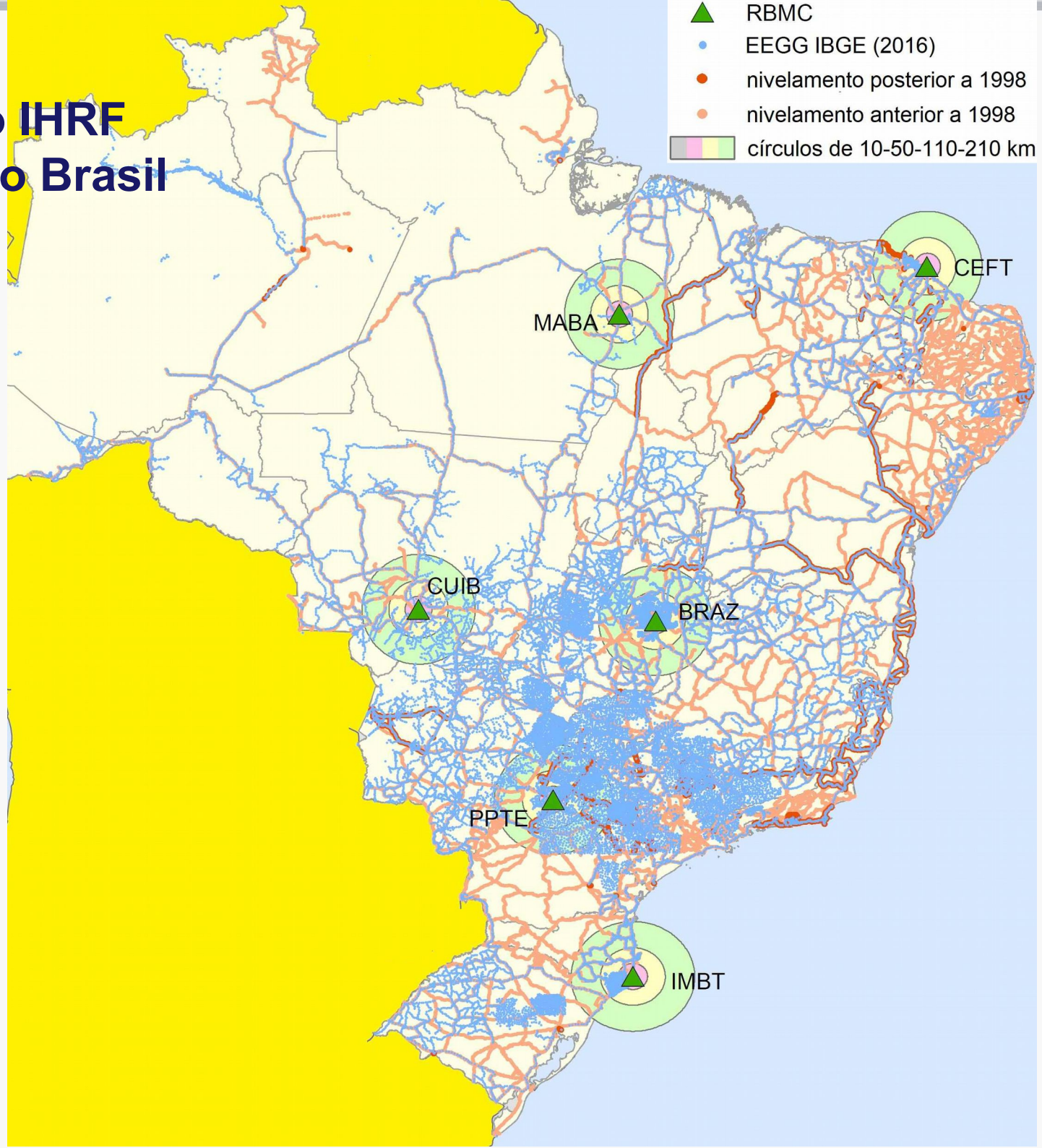
Sánchez, 2018 (http://www.sirgas.org/pt/sirgas-symposia/aguascalientes_2018/)

Materialização (realização) do IHRS :: IHRF (… Frame)



Sánchez, 2018 (http://www.sirgas.org/pt/sirgas-symposia/aguascalientes_2018/)

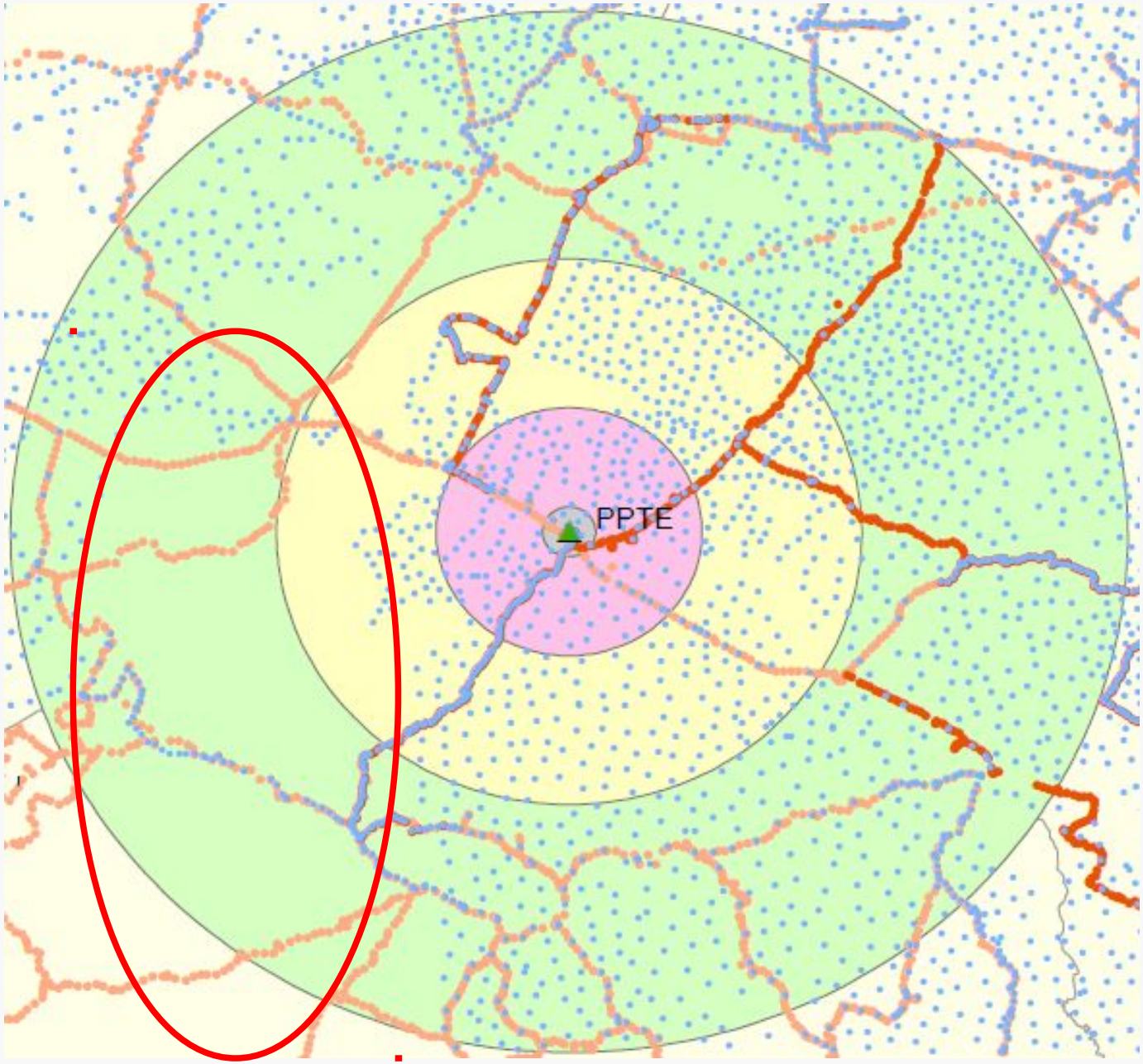
Estações do IHRF preliminar no Brasil



IBGE | DGC Diretoria de Geociências

Departamento de Engenharia Cartográfica (CARTO)

Estações do IHRF preliminar no Brasil



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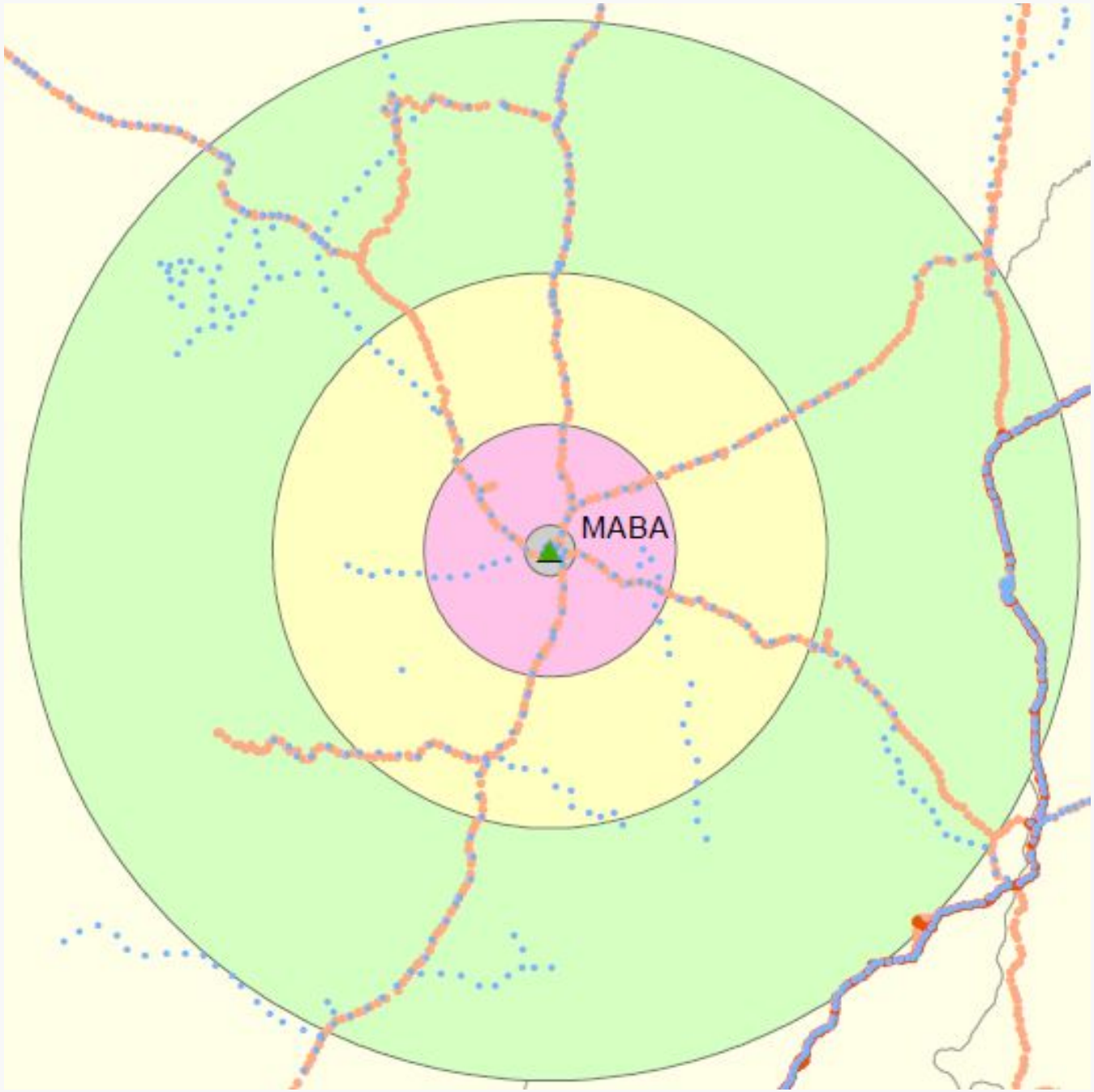

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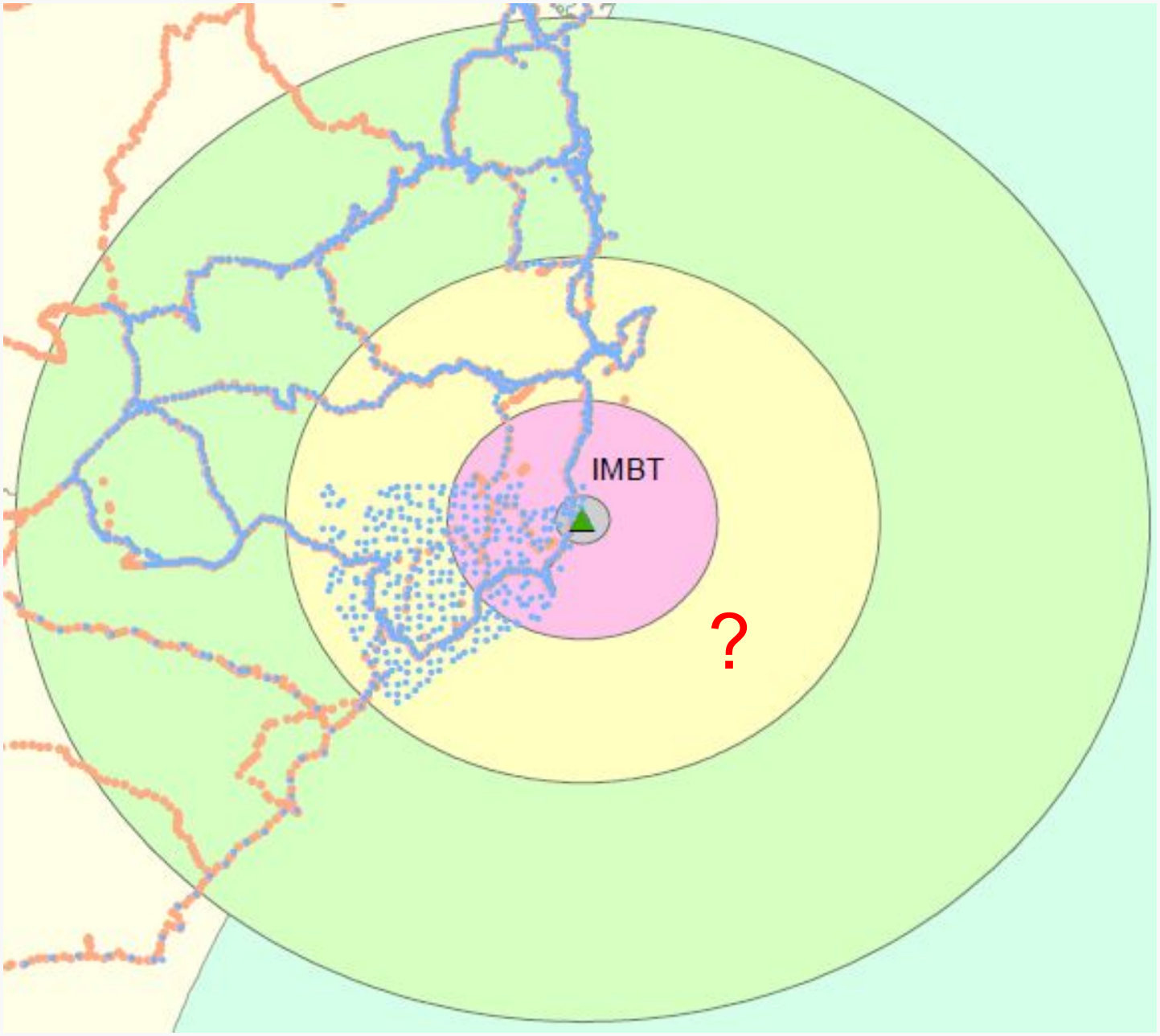
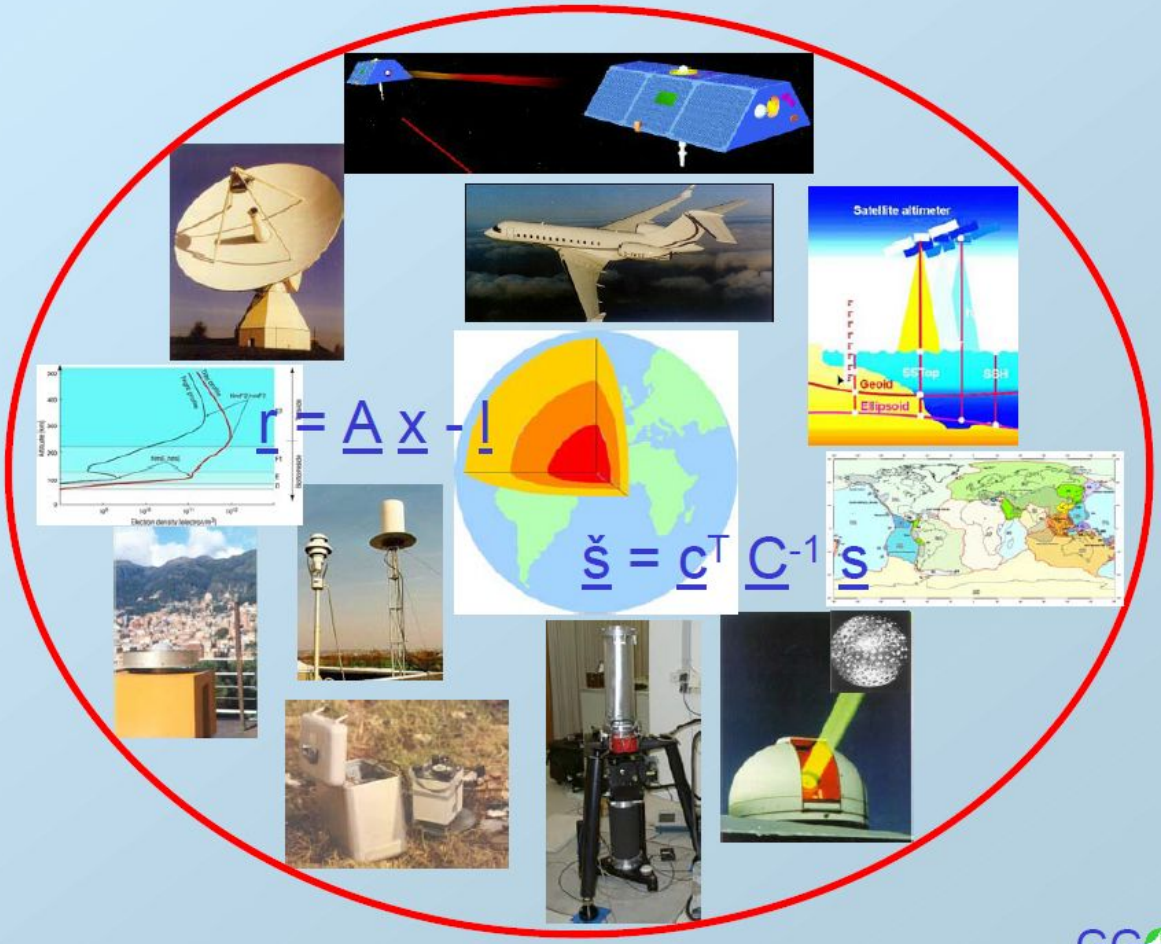


The Vision of a Global Geodetic Observing System

A system which integrates different geodetic techniques, different models, and different approaches



DGFI

GGOS

(Drewes, Dynamic Planet 2005)

Agradecemos a oportunidade e a atenção!

(segue material adicional)

Scientific Requirements for Efficient Integration

The rigorous integration of observations requires:

- Consistent observations (stations, networks, missions);
- Consistent reference frames;
- Consistent constants, conventions, models;
- Consistent processing methodologies and algorithms;
- Consistent parameters;
- Consistent product generation;
- Consistent applications.

DGFI

GGOS

(Drewes, Dynamic Planet 2005)

IHRS

W(P) obtenido del modelado detallado del campo de gravedad

Es el único metodo que actualmente permite el mayor acercamiento possible a la precision necesaria para establecer el IHRS

$$W_P = W_{P,satellite-only} + W_{P,high-resolution}$$

Modelo global de gravedad basado en técnicas satelitales
Satellite tracking from ground stations (SLR)
Satellite-to-satellite tracking (CHAMP, GRACE)
Satellite gravity gradiometry (GOCE)
Altimetría satelital (solo en océános)

+

Modelado de alta resolución (Stokes o Molodensky)
Altimetría satelital (solo en océános)
Gravimetría terrestre (a´rea, marina), métodos astrogeodésicos, nivelación, etc.
Efectos topográficos.

$$W_P = U_P + T_P$$

$$T_P = T_{P,satellite-only} + T_{P,residual} + T_{P,terrain}$$

un GGM — Gravimetría terrestre (aérea) — un DTM

- Si el potencial de perturbación T_P se utiliza para el cálculo del (cuasi)geoide:

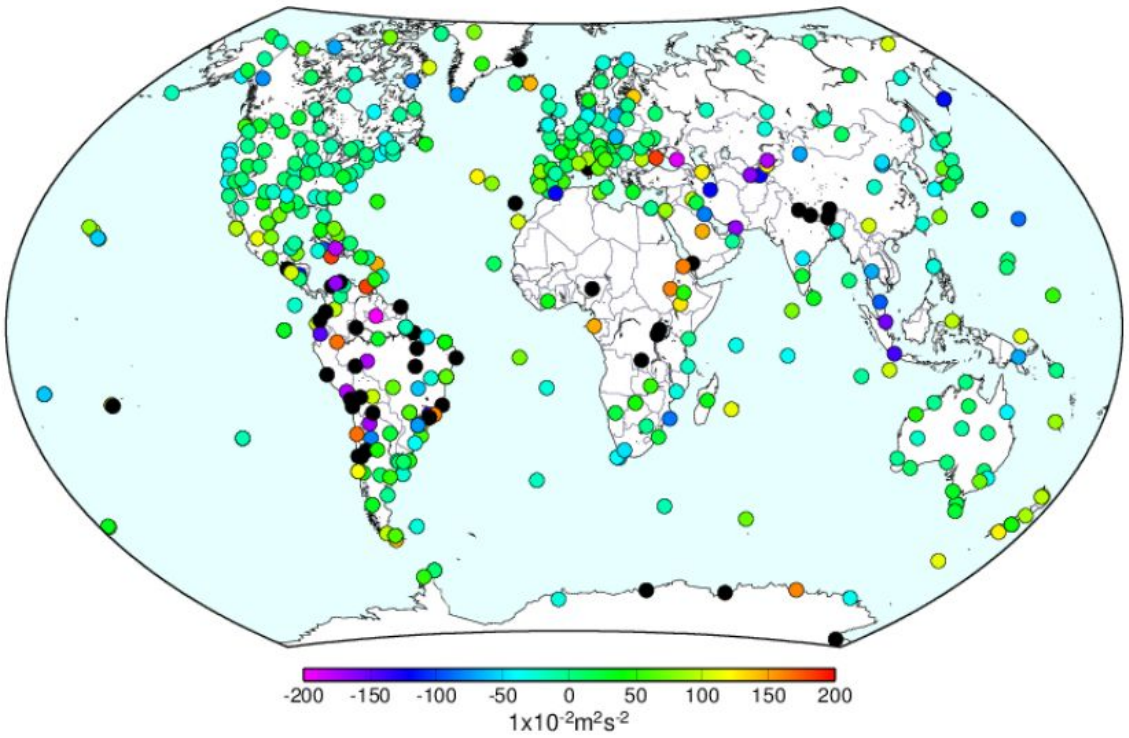
$$N_P \simeq \zeta_P = \frac{T_P}{\gamma_P}$$

se garantiza consitencia entre la realización „regional/nacional“ del geoide y el marco global IHRF.

IHRS

W(P) derivado de modelos globales de gravedad de alta resolución (n = 2190)

- Diferencias de valores de potencial W_P obtenidos del EGM2008 (Pavlis et al. 2008) y EIGEN6C4 (Förste et al. 2014), ambos con n=2190
- Discrepancias mayores que ±20 cm (algunos valores, especialmente en América del Sur, sobrepasan ± 2 m)



➢ Este método no puede utilizarse (aún) en la realización del IHRS.

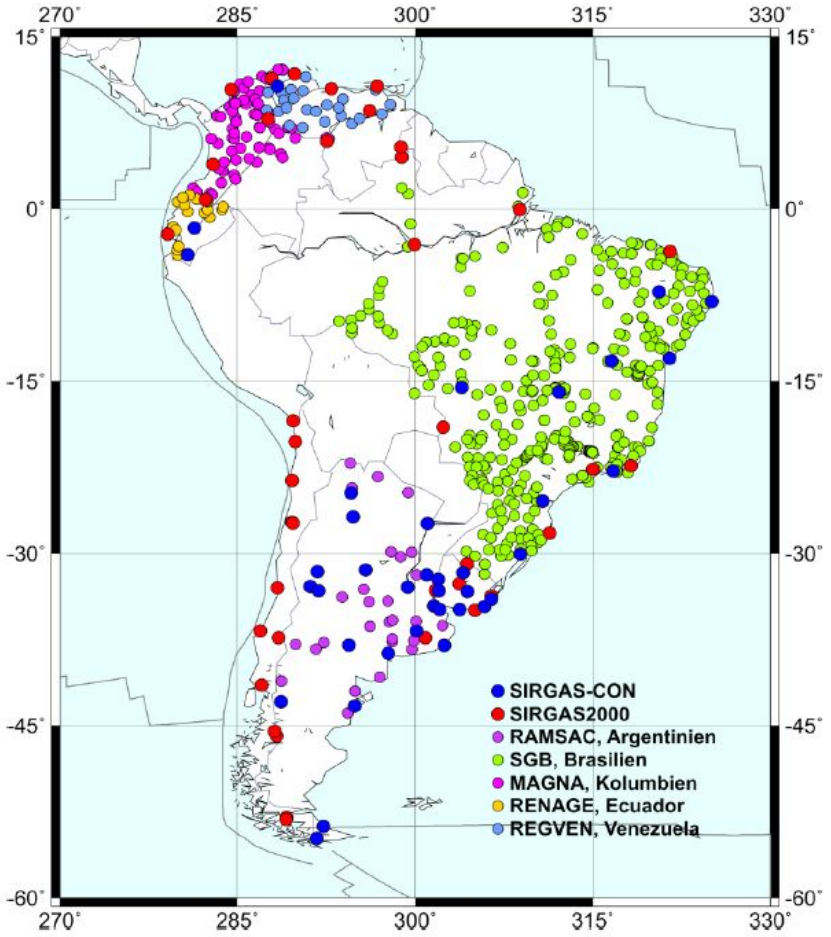
IHRS

W(P) obtenido de nivelación + gravimetría

Ejemplo: δW para los sistemas de alturas de América del Sur con respecto al valor W_0 del IHRS.

Datos de entrada:

- Estaciones de referencia SIRGAS2000, SIRGAS-CON, densificaciones nacionales.
- Con alturas niveladas conocidas.
- Modelos de geoide nacionales o GGM.
- Datos proporcionados parcialmente por los países miembros de SIRGAS, otros datos obtenidos de los sitios web de los Institutos Geográficos, otros datos simulados.

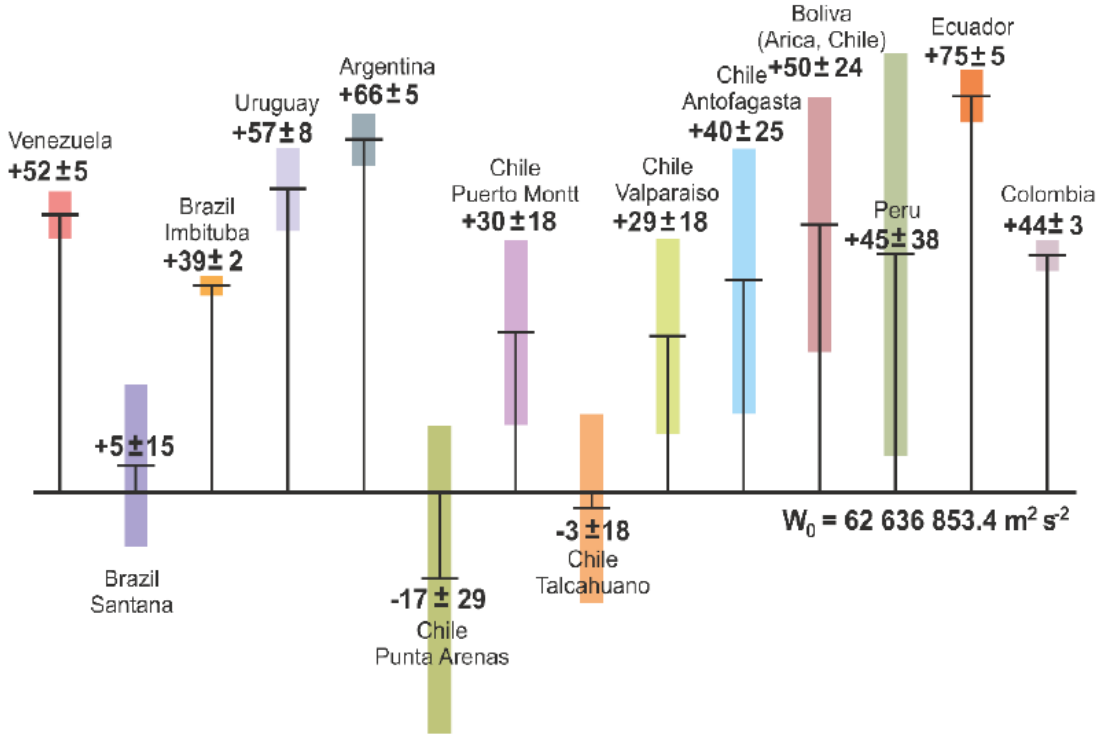


IHRS

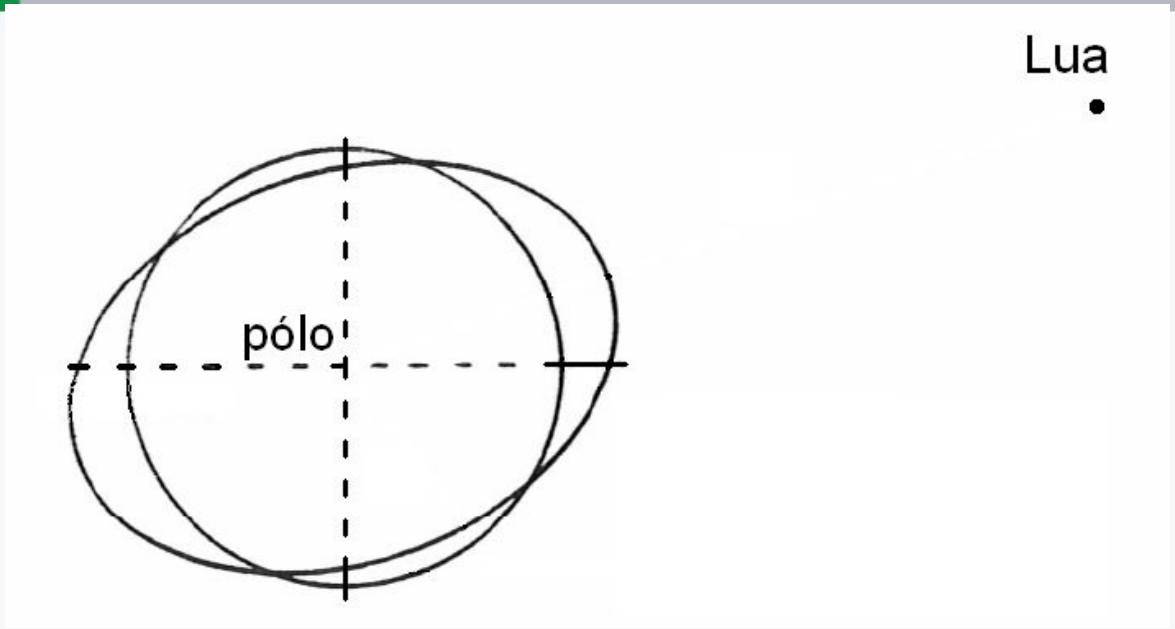
W(P) obtenido de nivelación + gravimetría

IUGG

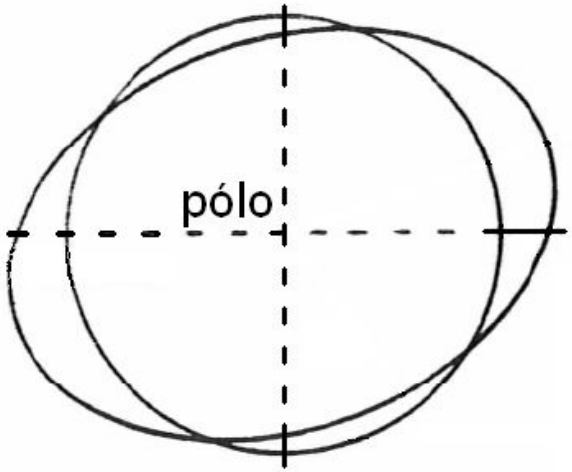
Ejemplo: δW (en cm) para los sistemas de alturas de América del Sur con respecto al valor W_0 del IHRS.

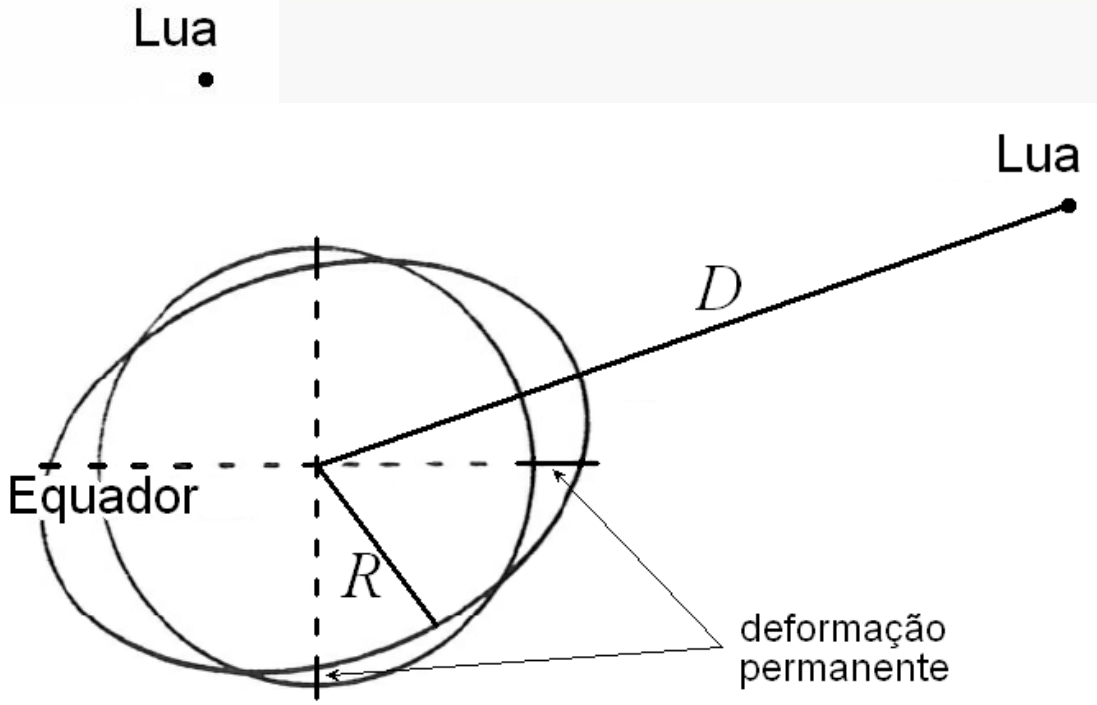


➢ Esta estrategía se puede utilizar para integrar al IHRS/IHRF los sistemas de alturas existentes, pero no es lo suficientemente precisa para establecer la red de referencia del IHRF.



O tratamento dos efeitos **periódicos**
da atração lunissolar (“maré”) não oferece
dificuldades, mas, para a componente “permanente” (não periódica):





O tratamento dos efeitos **periódicos** da atração lunissolar ("maré") não oferece dificuldades, mas, para a componente "permanente" (não periódica):

a. "livre da maré" ("*tide-free*" ou "*non-tidal*") : completa redução dos efeitos diretos (gravitação) e indiretos (deformação), incluindo M_0S_0 : : ITRF, SIRGAS, EGM96 ...

b. "maré média" ("*mean tide*") : são reduzidos apenas os termos periódicos, mantendo-se os efeitos de M_0S_0 : : IGSN-71, altimetria por satélites ...
   : : **Resolução da IAG n. 1 (2015) para IHRS / IHRF**

c. "maré zero" ("*zero tide*") : redução total dos efeitos diretos (incluindo M_0S_0) e somente das componentes periódicas do efeito indireto : : **Resoluções da IAG n. 9 e n. 16 (1983)**