



# Aula prática 2

Avaliação do modelo geoidal calculado, transformação para modelo quase geoidal,  
referenciamento ao IHRF

Tiago Lima Rodrigues

2025

## 6. Avaliação estatística de valores de N para pontos de GPS/RN do SGB

LATITUDE (°) - tide free	LATITUDE GEOCÊTRICA (°) - tide free	LONGITUDE (°) - tide free	h (m) - mean tide	HN (m) - mean tide	Zeta SGB (m) - mean tide	N total interpolado (m) - zero tide	N total interpolado (m) - mean tide	Discrepância (m)	N total DVBI (m)	Discrepância (m) DVBI
-25.4521318	-25.3031088	-49.7136358	1149.6980	1145.2642	4.4338	3.9953	4.0403	-0.3935	4.4268	-0.0070
-24.7530239	-24.60700918	-51.7761673	894.8960	893.1957	1.7003	1.2393	1.2869	-0.4134	1.6735	-0.0268
-24.7249367	-24.57904461	-49.9863699	1041.7460	1037.6702	4.0758	3.3886	3.4364	-0.6394	3.8229	-0.2529
-24.0153659	-23.87261888	-51.0917001	1011.9770	1011.9916	-0.0146	-0.7505	-0.7000	-0.6854	-0.3135	-0.2989
-24.2556929	-24.11187081	-49.7132373	836.2620	834.7715	1.4905	1.0835	1.1331	-0.3574	1.5196	0.0291
-26.27023	-26.1177989	-49.9190782	849.8280	845.7893	4.0387	3.4624	3.5040	-0.5347	3.8906	-0.1481
-26.3139986	-26.16138855	-49.9099339	952.0200	947.9758	4.0442	3.4411	3.4825	-0.5617	3.8691	-0.1751
-23.6620747	-23.52092618	-51.6917918	604.3530	606.1806	-1.8276	-2.1531	-2.1012	-0.2736	-1.7147	0.1129
-24.0999335	-23.95680705	-51.6498157	537.7520	539.0504	-1.2984	-1.6181	-1.5679	-0.2695	-1.1814	0.1170
-23.6882243	-23.5469567	-49.8335201	622.3960	624.6169	-2.2209	-2.5491	-2.4973	-0.2764	-2.1108	0.1101
-23.8896361	-23.74745548	-50.2722059	683.9390	684.8542	-0.9152	-1.0735	-1.0225	-0.1073	-0.6360	0.2792
-24.1700992	-24.02665886	-49.7982672	940.4790	939.4021	1.0769	0.6409	0.6908	-0.3861	1.0773	0.0004
-24.4888138	-24.34395855	-52.8938454	514.5860	513.5290	1.0570	0.7538	0.8025	-0.2545	1.1890	0.1320
-24.0962411	-23.95313119	-52.6232107	590.2950	590.2758	0.0192	-0.4957	-0.4454	-0.4646	-0.0589	-0.0781
-25.109133	-24.96157506	-52.8558666	837.5650	835.1100	2.4550	2.1324	2.1787	-0.2763	2.5652	0.1102
-25.5220336	-25.37271465	-51.5398838	1068.6610	1064.1606	4.5004	4.0091	4.0538	-0.4466	4.4403	-0.0601
-25.1790674	-25.03120897	-50.656142	826.2310	822.5612	3.6698	3.2048	3.2508	-0.4190	3.6373	-0.0325
-25.2185833	-25.07055555	-50.0563493	827.9480	823.6970	4.2510	3.6949	3.7408	-0.5102	4.1273	-0.1237
-25.6342143	-25.4844222	-49.8312629	903.6170	899.3279	4.2891	3.8896	3.9338	-0.3553	4.3204	0.0313
-26.2173672	-26.06515261	-51.5172326	918.8100	912.5509	6.2591	5.7397	5.7815	-0.4776	6.1680	-0.0911
-24.6651829	-24.51955225	-50.6833077	935.8690	933.1940	2.6750	2.2354	2.2835	-0.3915	2.6700	-0.0050
-24.00364	-23.86094567	-50.4464865	868.0080	867.9588	0.0492	-0.3646	-0.3140	-0.3632	0.0725	0.0233
-23.5312014	-23.39065042	-50.1197177	484.1730	487.3743	-3.2013	-3.5518	-3.4994	-0.2981	-3.1129	0.0884
-25.2265814	-25.07851939	-50.5992965	879.1530	875.2503	3.9027	3.2618	3.3076	-0.5951	3.6941	-0.2086
-24.5665493	-24.4213516	-51.3375284	537.3330	536.5017	0.8313	0.3737	0.4221	-0.4092	0.8086	-0.0227
-23.7223914	-23.58096847	-52.180014	373.2190	375.0813	-1.8623	-1.9541	-1.9024	-0.0401	-1.5159	0.3464
-23.7893704	-23.64764348	-53.0603096	471.0500	471.0216	0.0284	-0.4821	-0.4307	-0.4591	-0.0442	-0.0726
-24.5570774	-24.41192134	-52.9985344	486.9500	485.7066	1.2434	1.0187	1.0671	-0.1763	1.4537	0.2103
-25.7498442	-25.5995668	-53.0535788	514.3000	511.5749	2.7251	2.4738	2.5175	-0.2076	2.9041	0.1790
-26.2665338	-26.11411777	-52.7826059	694.3880	689.7200	4.6680	4.1625	4.2042	-0.4638	4.5907	-0.0773
-25.4258255	-25.27691414	-52.0179865	773.5040	770.1935	3.3105	2.8027	2.8477	-0.4628	3.2343	-0.0762
-25.6969978	-25.54694193	-51.6599773	1056.8500	1052.0128	4.8372	4.3935	4.4374	-0.3998	4.8240	-0.0132

32 pontos de conexão RN/GPS do SGB econtrados na região do modelo

## 6. Avaliação estatística de valores de N para pontos de GPS/RN do SGB



LATITUDE (°) - tide free	LATITUDE GEOCÊTRICA (°) - tide free	LONGITUDE (°) - tide free	h (m) - mean tide	HN (m) - mean tide	Zeta SGB (m) - mean tide	N total interpolado (m) - zero tide	N total interpolado (m) - mean tide	Discrepância (m)	N total DVBI (m)	Discrepância (m) DVBI
-25.4521318	-25.3031088	-49.7136358	1149.6980	1145.2642	4.4338	3.9953	4.0403	-0.3935	4.4268	-0.0070
-24.7530239	-24.60700918	-51.7761673	894.8960	893.1957	1.7003	1.2393	1.2869	-0.4134	1.6735	-0.0268
-24.7249367	-24.57904461	-49.9863699	1041.7460	1037.6702	4.0758	3.3886	3.4364	-0.6394	3.8229	-0.2529
-24.0153659	-23.87261888	-51.0917001	1011.9770	1011.9916	-0.0146	-0.7505	-0.7000	-0.6854	-0.3135	-0.2989
-24.2556929	-24.11187081	-49.7132373	836.2620	834.7715	1.4905	1.0835	1.1331	-0.3574	1.5196	0.0291
-26.27023	-26.1177989	-49.9190782	849.8280	845.7893	4.0387	3.4624	3.5040	-0.5347	3.8906	-0.1481
-26.3139986	-26.16138855	-49.9099339	952.0200	947.9758	4.0442	3.4411	3.4825	-0.5617	3.8691	-0.1751
-23.6620747	-23.52092618	-51.6917918	604.3530	606.1806	-1.8276	-2.1531	-2.1012	-0.2736	-1.7147	0.1129
-24.0999335	-23.95680705	-51.6498157	537.7520	539.0504	-1.2984	-1.6181	-1.5679	-0.2695	-1.1814	0.1170

Extraído do Banco de Dados Geodésicos do IBGE

## 6. Avaliação estatística de valores de N para pontos de GPS/RN do SGB



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-26.3139986	-26.16138855	-49.9099339	952.0200	947.9758	4.0442	3.4411	3.4825	-0.5617	3.8691	-0.1751
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-24.0999335	-23.95680705	-51.6498157	537.7520	539.0504	-1.2984	-1.6181	-1.5679	-0.2695	-1.1814	0.1170

$$\tan \theta = (1 - e^2) \tan \varphi$$

## 6. Avaliação estatística de valores de N para pontos de GPS/RN do SGB



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-25.4521318	-25.3031088	-49.7136358	1149.6980	1145.2642	4.4338	3.9953	4.0403	-0.3935	4.4268	-0.0070
-24.7530239	-24.60700918	-51.7761673	894.8960	893.1957	1.7003	1.2393	1.2869	-0.4134	1.6735	-0.0268
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-24.2556929	-24.11187081	-49.7132373	836.2620	834.7715	1.4905	1.0835	1.1331	-0.3574	1.5196	0.0291
-26.27023	-26.1177989	-49.9190782	849.8280	845.7893	4.0387	3.4624	3.5040	-0.5347	3.8906	-0.1481
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-24.0999335	-23.95680705	-51.6498157	537.7520	539.0504	-1.2984	-1.6181	-1.5679	-0.2695	-1.1814	0.1170

$$\zeta_{SGB} = h - H^N$$

LATITUDE (°) - tide free	LATITUDE GEOCÊTRICA (°) - tide free	LONGITUDE (°) - tide free	h (m) - mean tide	HN (m) - mean tide	Zeta SGB (m) - mean tide	N total interpolado (m) - zero tide	N total interpolado (m) - mean tide	Discrepância (m)	N total DVBI (m)	Discrepância (m) DVBI
-25.4521318	-25.3031088	-49.7136358	1149.6980	1145.2642	4.4338	3.9953	4.0403	-0.3935	4.4268	-0.0070
-24.7530239	-24.60700918	-51.7761673	894.8960	893.1957	1.7003	1.2393	1.2869	-0.4134	1.6735	-0.0268
-24.7249367	-24.57904461	-49.9863699	1041.7460	1037.6702	4.0758	3.3886	3.4364	-0.6394	3.8229	-0.2529
-24.0153659	-23.87261888	-51.0917001	1011.9770	1011.9916	-0.0146	-0.7505	-0.7000	-0.6854	-0.3135	-0.2989
-24.2556929	-24.11187081	-49.7132373	836.2620	834.7715	1.4905	1.0835	1.1331	-0.3574	1.5196	0.0291
-26.27023	-26.1177989	-49.9190782	849.8280	845.7893	4.0387	3.4624	3.5040	-0.5347	3.8906	-0.1481
-26.3139986	-26.16138855	-49.9099339	952.0200	947.9758	4.0442	3.4411	3.4825	-0.5617	3.8691	-0.1751
-23.6620747	-23.52092618	-51.6917918	604.3530	606.1806	-1.8276	-2.1531	-2.1012	-0.2736	-1.7147	0.1129
-24.0999335	-23.95680705	-51.6498157	537.7520	539.0504	-1.2984	-1.6181	-1.5679	-0.2695	-1.1814	0.1170

Arquivo .txt com os 32 pontos de conexão RN/GPS do SGB



%LATITUDE	LONGITUDE	h (m)	HN (m)
-25.4521317853	-49.7136358172	1149.6980	1145.2642
-24.7530239281	-51.7761672981	894.8960	893.1957
-24.7249366856	-49.9863698522	1041.7460	1037.6702
-24.0153658850	-51.0917000528	1011.9770	1011.9916
-24.2556928669	-49.7132372742	836.2620	834.7715
-26.2702300447	-49.9190781600	849.8280	845.7893
-26.3139985689	-49.9099338989	952.0200	947.9758
-23.6620747142	-51.6917918039	604.3530	606.1806

### % Importando as grades

```
Grade=double(imread('D:\AULAS MÉTODOS FÍSICOS\TRABALHO PRÁTICO 2025-1\RESTORE\Modelo_geoidal.tif'));
```

```
resolucao_graus=0.05;
```

Resolução espacial da grade em graus decimais em °

```
latN=-23.475-(resolucao_graus/2);
```

% latN

```
lonW=-53.525+(resolucao_graus/2);
```

% longW

```
Pontos_RN_GPS=readmatrix('Pontos_RN_GPS.txt');
```

Nome do Arquivo .txt com os 32 pontos de conexão RN/GPS do SGB



Nome do arquivo do modelo geoidal com extensão .tif

## 6. Avaliação estatística de valores de N para pontos de GPS/RN do SGB



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-24.0999335	-23.95680705	-51.6498157	537.7520	539.0504	-1.2984	-1.6181	-1.5679	-0.2695	-1.1814	0.1170

$$N_{\text{maré médio}} = N_{\text{maré zero}} + 9,9 - 29,6 \operatorname{sen}^2 \theta \quad [\text{cm}]$$

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-24.0999335	-23.95680705	-51.6498157	537.7520	539.0504	-1.2984	-1.6181	-1.5679	-0.2695	-1.1814	0.1170

$$\Delta\eta = N_{\text{maré média}} - \zeta_{SGB}$$

Não é diferença de anomalias de altura!

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-23.8896361	-23.74745548	-50.2722059	683.9390	684.8542	-0.9152	-1.0735	-1.0225	-0.1073
-24.1700992	-24.02665886	-49.7982672	940.4790	939.4021	1.0769	0.6409	0.6908	-0.3861
-24.4888138	-24.34395855	-52.8938454	514.5860	513.5290	1.0570	0.7538	0.8025	-0.2545
-24.0962411	-23.95313119	-52.6232107	590.2950	590.2758	0.0192	-0.4957	-0.4454	-0.4646
-25.109133	-24.96157506	-52.8558666	837.5650	835.1100	2.4550	2.1324	2.1787	-0.2763
-25.5220336	-25.37271465	-51.5398838	1068.6610	1064.1606	4.5004	4.0091	4.0538	-0.4466
-25.1790674	-25.03120897	-50.656142	826.2310	822.5612	3.6698	3.2048	3.2508	-0.4190
-25.2185833	-25.07055555	-50.0563493	827.9480	823.6970	4.2510	3.6949	3.7408	-0.5102
-25.6342143	-25.4844222	-49.8312629	903.6170	899.3279	4.2891	3.8896	3.9338	-0.3553
-26.2173672	-26.06515261	-51.5172326	918.8100	912.5509	6.2591	5.7397	5.7815	-0.4776
-24.6651829	-24.51955225	-50.6833077	935.8690	933.1940	2.6750	2.2354	2.2835	-0.3915
-24.00364	-23.86094567	-50.4464865	868.0080	867.9588	0.0492	-0.3646	-0.3140	-0.3632
-23.5312014	-23.39065042	-50.1197177	484.1730	487.3743	-3.2013	-3.5518	-3.4994	-0.2981
-25.2265814	-25.07851939	-50.5992965	879.1530	875.2503	3.9027	3.2618	3.3076	-0.5951
-24.5665493	-24.4213516	-51.3375284	537.3330	536.5017	0.8313	0.3737	0.4221	-0.4092
-23.7223914	-23.58096847	-52.180014	373.2190	375.0813	-1.8623	-1.9541	-1.9024	-0.0401
-23.7893704	-23.64764348	-53.0603096	471.0500	471.0216	0.0284	-0.4821	-0.4307	-0.4591
-24.5570774	-24.41192134	-52.9985344	486.9500	485.7066	1.2434	1.0187	1.0671	-0.1763
-25.7498442	-25.5995668	-53.0535788	514.3000	511.5749	2.7251	2.4738	2.5175	-0.2076
-26.2665338	-26.11411777	-52.7826059	694.3880	689.7200	4.6680	4.1625	4.2042	-0.4638
-25.4258255	-25.27691414	-52.0179865	773.5040	770.1935	3.3105	2.8027	2.8477	-0.4628
-25.6969978	-25.54694193	-51.6599773	1056.8500	1052.0128	4.8372	4.3935	4.4374	-0.3998
						<b>Média</b>		
						<b>Desvio padrão</b>		
						<b>Min</b>		
						<b>Max</b>		
						<b>REQM</b>		



Parâmetros estatísticos das discrepâncias

$$\Delta\eta = N_{\text{maré média}} - \zeta_{SGB}$$

$$\overline{\Delta\eta} = \frac{1}{P} \sum_{i=1}^P \Delta\eta_i$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^P (N_{\text{maré média}} - \overline{\Delta\eta})_i^2}{P}}$$

$$REQM = \sqrt{\frac{\sum_{i=1}^P \Delta\eta_i^2}{P}}$$

## 7. Transformação para o DVBI com modelagem local



LATITUDE (°) - tide free	LATITUDE GEOCÊTRICA (°) - tide free	LONGITUDE (°) - tide free	h (m) - mean tide	HN (m) - mean tide	Zeta SGB (m) - mean tide	N total interpolado (m) - zero tide	N total interpolado (m) - mean tide	Discrepância (m)	N total DVBI (m)	Discrepância (m) DVBI
-25.4521318	-25.3031088	-49.7136358	1149.6980	1145.2642	4.4338	3.9953	4.0403	-0.3935	4.4268	-0.0070
-24.7530239	-24.60700918	-51.7761673	894.8960	893.1957	1.7003	1.2393	1.2869	-0.4134	1.6735	-0.0268
-24.7249367	-24.57904461	-49.9863699	1041.7460	1037.6702	4.0758	3.3886	3.4364	-0.6394	3.8229	-0.2529
-24.0153659	-23.87261888	-51.0917001	1011.9770	1011.9916	-0.0146	-0.7505	-0.7000	-0.6854	-0.3135	-0.2989
-24.2556929	-24.11187081	-49.7132373	836.2620	834.7715	1.4905	1.0835	1.1331	-0.3574	1.5196	0.0291
-26.27023	-26.1177989	-49.9190782	849.8280	845.7893	4.0387	3.4624	3.5040	-0.5347	3.8906	-0.1481
-26.3139986	-26.16138855	-49.9099339	952.0200	947.9758	4.0442	3.4411	3.4825	-0.5617	3.8691	-0.1751
-23.6620747	-23.52092618	-51.6917918	604.3530	606.1806	-1.8276	-2.1531	-2.1012	-0.2736	-1.7147	0.1129
-24.0999335	-23.95680705	-51.6498157	537.7520	539.0504	-1.2984	-1.6181	-1.5679	-0.2695	-1.1814	0.1170

$$N_{\text{maré média DVBI}} = N_{\text{maré média}} - \bar{\Delta\eta}$$

→  $\bar{\Delta\eta}$  - Parâmetro de transformação vertical - translação

## 7. Transformação para o DVBI com modelagem local



LATITUDE (°) - tide free	LATITUDE GEOCÊNTRICA (°) - tide free	LONGITUDE (°) - tide free	h (m) - mean tide	HN (m) - mean tide	Zeta SGB (m) - mean tide	N total interpolado (m) - zero tide	N total interpolado (m) - mean tide	Discrepância (m)	N total DVBI (m)	Discrepância (m) DVBI
-25.4521318	-25.3031088	-49.7136358	1149.6980	1145.2642	4.4338	3.9953	4.0403	-0.3935	4.4268	-0.0070
-24.7530239	-24.60700918	-51.7761673	894.8960	893.1957	1.7003	1.2393	1.2869	-0.4134	1.6735	-0.0268
-24.7249367	-24.57904461	-49.9863699	1041.7460	1037.6702	4.0758	3.3886	3.4364	-0.6394	3.8229	-0.2529
-24.0153659	-23.87261888	-51.0917001	1011.9770	1011.9916	-0.0146	-0.7505	-0.7000	-0.6854	-0.3135	-0.2989
-24.2556929	-24.11187081	-49.7132373	836.2620	834.7715	1.4905	1.0835	1.1331	-0.3574	1.5196	0.0291
-26.27023	-26.1177989	-49.9190782	849.8280	845.7893	4.0387	3.4624	3.5040	-0.5347	3.8906	-0.1481
-26.3139986	-26.16138855	-49.9099339	952.0200	947.9758	4.0442	3.4411	3.4825	-0.5617	3.8691	-0.1751
-23.6620747	-23.52092618	-51.6917918	604.3530	606.1806	-1.8276	-2.1531	-2.1012	-0.2736	-1.7147	0.1129
-24.0999335	-23.95680705	-51.6498157	537.7520	539.0504	-1.2984	-1.6181	-1.5679	-0.2695	-1.1814	0.1170

$$\Delta\eta_{DVBI} = (N_{maré média} - \bar{\Delta\eta}) - \zeta_{SGB}$$

Não é diferença de anomalias de altura!

Zeta SGB (m) - mean tide	N total interpolado (m) - zero tide	N total interpolado (m) - mean tide	Discrepância (m)	N total DVBI (m)	Discrepância (m) DVBI
4.4338	3.9953	4.0403	-0.3935	4.4268	-0.0070
1.7003	1.2393	1.2869	-0.4134	1.6735	-0.0268
4.0758	3.3886	3.4364	-0.6394	3.8229	-0.2529
-0.0146	-0.7505	-0.7000	-0.6854	-0.3135	-0.2989
1.4905	1.0835	1.1331	-0.3574	1.5196	0.0291
4.0387	3.4624	3.5040	-0.5347	3.8906	-0.1481
4.0442	3.4411	3.4825	-0.5617	3.8691	-0.1751
-1.8276	-2.1531	-2.1012	-0.2736	-1.7147	0.1129
-1.2984	-1.6181	-1.5679	-0.2695	-1.1814	0.1170
-2.2209	-2.5491	-2.4973	-0.2764	-2.1108	0.1101
-0.9152	-1.0735	-1.0225	-0.1073	-0.6360	0.2792
1.0769	0.6409	0.6908	-0.3861	1.0773	0.0004
1.0570	0.7538	0.8025	-0.2545	1.1890	0.1320
0.0192	-0.4957	-0.4454	-0.4646	-0.0589	-0.0781
2.4550	2.1324	2.1787	-0.2763	2.5652	0.1102
4.5004	4.0091	4.0538	-0.4466	4.4403	-0.0601
3.6698	3.2048	3.2508	-0.4190	3.6373	-0.0325
4.2510	3.6949	3.7408	-0.5102	4.1273	-0.1237
4.2891	3.8896	3.9338	-0.3553	4.3204	0.0313
6.2591	5.7397	5.7815	-0.4776	6.1680	-0.0911
2.6750	2.2354	2.2835	-0.3915	2.6700	-0.0050
0.0492	-0.3646	-0.3140	-0.3632	0.0725	0.0233
-3.2013	-3.5518	-3.4994	-0.2981	-3.1129	0.0884
3.9027	3.2618	3.3076	-0.5951	3.6941	-0.2086
0.8313	0.3737	0.4221	-0.4092	0.8086	-0.0227
-1.8623	-1.9541	-1.9024	-0.0401	-1.5159	0.3464
0.0284	-0.4821	-0.4307	-0.4591	-0.0442	-0.0726
1.2434	1.0187	1.0671	-0.1763	1.4537	0.2103
2.7251	2.4738	2.5175	-0.2076	2.9041	0.1790
4.6680	4.1625	4.2042	-0.4638	4.5907	-0.0773
3.3105	2.8027	2.8477	-0.4628	3.2343	-0.0762
4.8372	4.3935	4.4374	-0.3998	4.8240	-0.0132
<b>Média</b>			-0.3865	<b>Média</b>	0.0000
<b>Desvio padrão</b>			0.1453	<b>Desvio padrão</b>	0.1453
<b>Min</b>			-0.6854	<b>Min</b>	-0.2989
<b>Max</b>			-0.0401	<b>Max</b>	0.3464
<b>REQM</b>			0.4122	<b>REQM</b>	0.1431

Parâmetros estatísticos das discrepâncias

$$\Delta\eta_{DVBI} = (N_{maré média} - \bar{\Delta\eta}) - \zeta_{SGB}$$

$$\bar{\Delta\eta}_{DVBI} = \frac{1}{p} \sum_{i=1}^P \Delta\eta_{DVBI} = 0$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^P [(N_{maré média} - \bar{\Delta\eta}) - \bar{\Delta\eta}_{DVBI}]_i^2}{P}}$$

$$REQM = \sqrt{\frac{\sum_{i=1}^P \Delta\eta_{DVBI_i}^2}{P}}$$

Média igual á zero indica que a tendência sistemática devido a diferença de referenciais verticais foi suprimida

Desvio-padrão igual indica que os erros aleatórios permanecem

REQM diminui porque a componente sistemática foi eliminada, e é próxima ao desvio-padrão pois os erros aleatórios permanecem

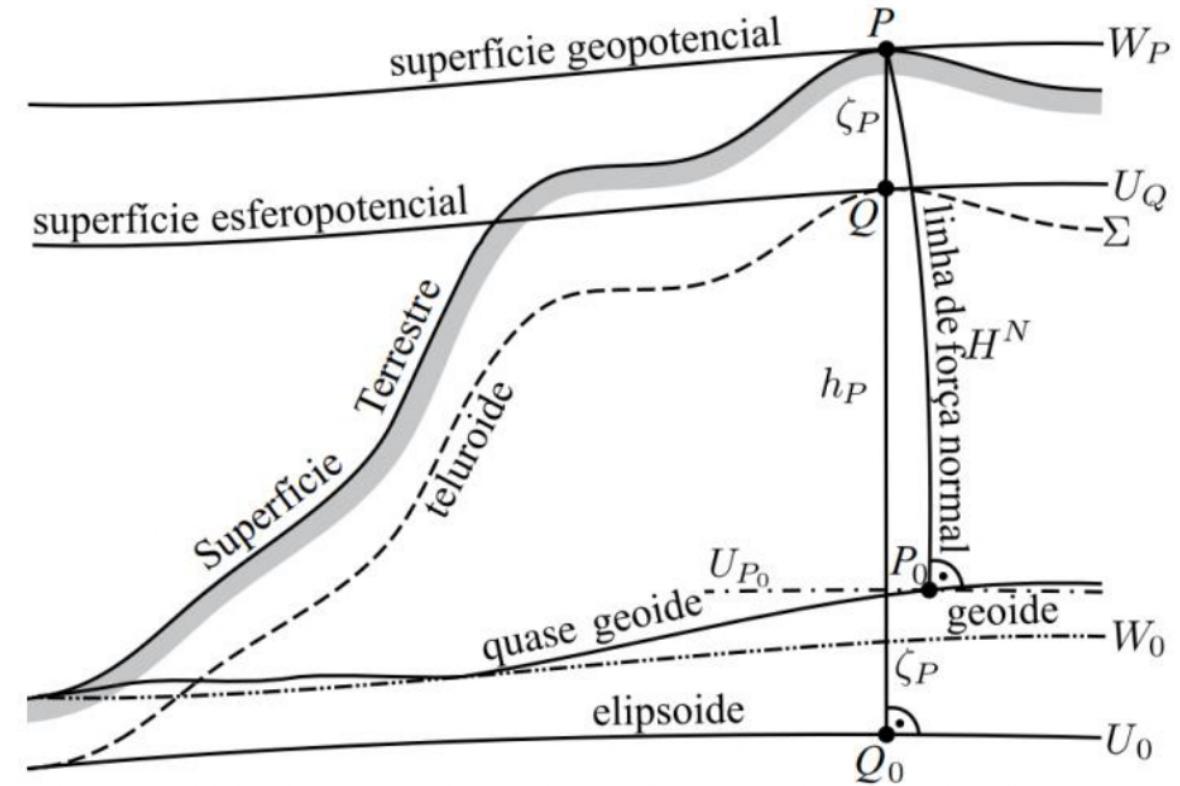
## 8. Transformação para quase geoide

$$N_P - \zeta_P \approx \left( \frac{\Delta g_{BP}}{\bar{\gamma}_P} \right)$$

$$\zeta_P \approx N_P - \left( \frac{\Delta g_{BP}}{\bar{\gamma}_P} \right)$$

Gravidade normal média ao longo da linha de força normal

$$\bar{\gamma}_P = \gamma_{Q_0} \left[ 1 - (1 + f + m - 2f \sin^2 \varphi_P) \frac{h_P}{a} + \left( \frac{h_P}{a} \right)^2 \right]$$



Ferreira (2011)

## 8. Transformação para quase geoide

Todos os pontos da grade do modelo geoidal



Latitude - tide free (°)	LATITUDE GEOCÊNTRICA (°) - tide free	Longitude - tide free (°)	N total (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsoide (mGal) - mean tide	gravidade normal média ao longo da plumb line (mGal) - mean tide	gravidade normal média ao longo da plumb line (mGal) - zero tide	Anomalia de gravidade refinada de Bouguer interpolada (mGal) - zero tide	Zeta (m) - zero tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978793.5394	978793.5555	-59.1034	-0.3438
-23.5500	-23.4094	-53.5000	-0.2606	330.5070	978857.4887	978806.4775	978806.4935	-58.4765	-0.2605
-23.6000	-23.4591	-53.5000	-0.1531	372.8014	978860.7967	978803.2580	978803.2739	-59.4977	-0.1530
-23.6500	-23.5089	-53.5000	-0.0256	384.8910	978864.1099	978804.7055	978804.7214	-60.2549	-0.0255

% Importando as grades

Grade=double(imread('MDS\_MERIT\_SRTM15PLUS\_900m\_fill.tif'));

Nome do arquivo de MDS com extensão .tif

resolucao\_graus=0.0083333333;

Resolução espacial do MDS em graus decimais

latN=-21.2504166667-(resolucao\_graus/2); % latN

lonW=-55.7495833333+(resolucao\_graus/2); % longW

Pontos\_grade=readmatrix('Pontos\_calculo\_grade.txt');

Nome do arquivo com as coordenadas dos pontos da grade do modelo geoidal

## 8. Transformação para quase geoide



Latitude - tide free (°)	LATITUDE GEOCÊTRICA (°) - tide free	Longitude - tide free (°)	N total (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsoide (mGal) - mean tide	gravidade normal média ao longo da plumb line (mGal) - mean tide	gravidade normal média ao longo da plumb line (mGal) - zero tide	Anomalia de gravidade refinada de Bouguer interpolada (mGal) - zero tide	Zeta (m) - zero tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978793.5394	978793.5555	-59.1034	-0.3438
-23.5500	-23.4094	-53.5000	-0.2606	330.5070	978857.4887	978806.4775	978806.4935	-58.4765	-0.2605
-23.6000	-23.4591	-53.5000	-0.1531	372.8014	978860.7967	978803.2580	978803.2739	-59.4977	-0.1530
-23.6500	-23.5089	-53.5000	-0.0256	384.8910	978864.1099	978804.7055	978804.7214	-60.2549	-0.0255

$$\gamma_{Q_0 \text{ GRS80}} = 9,780327(1 + 0,0052790414 \operatorname{sen}^2\varphi + 0,0000232718 \operatorname{sen}^4\varphi + 0,0000001262 \operatorname{sen}^6\varphi + 0,0000000007 \operatorname{sen}^8\varphi) \text{ [m/s}^2\text{]}$$

## 8. Transformação para quase geoide



Latitude - tide free (°)	LATITUDE GEOCÊTRICA (°) - tide free	Longitude - tide free (°)	N total (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsoide (mGal) - mean tide	gravidade normal média ao longo da plumb line (mGal) - mean tide	gravidade normal média ao longo da plumb line (mGal) - zero tide	Anomalia de gravidade refinada de Bouguer interpolada (mGal) - zero tide	Zeta (m) - zero tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978793.5394	978793.5555	-59.1034	-0.3438
-23.5500	-23.4094	-53.5000	-0.2606	330.5070	978857.4887	978806.4775	978806.4935	-58.4765	-0.2605
-23.6000	-23.4591	-53.5000	-0.1531	372.8014	978860.7967	978803.2580	978803.2739	-59.4977	-0.1530
-23.6500	-23.5089	-53.5000	-0.0256	384.8910	978864.1099	978804.7055	978804.7214	-60.2549	-0.0255

$$\bar{\gamma}_P = \gamma_{Q_0} \left[ 1 - (1 + f + m - 2f \sin^2 \varphi_P) \frac{H_P}{a} + \left( \frac{H_P}{a} \right)^2 \right]$$

## 8. Transformação para quase geoide



Latitude - tide free (°)	LATITUDE GEOCÊNTRICA (°) - tide free	Longitude - tide free (°)	N total (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsoide (mGal) - mean tide	gravidade normal média ao longo da plumb line (mGal) - mean tide	gravidade normal média ao longo da plumb line (mGal) - zero tide	Anomalia de gravidade refinada de Bouguer interpolada (mGal) - zero tide	Zeta (m) - zero tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978793.5394	978793.5555	-59.1034	-0.3438
-23.5500	-23.4094	-53.5000	-0.2606	330.5070	978857.4887	978806.4775	978806.4935	-58.4765	-0.2605
-23.6000	-23.4591	-53.5000	-0.1531	372.8014	978860.7967	978803.2580	978803.2739	-59.4977	-0.1530
-23.6500	-23.5089	-53.5000	-0.0256	384.8910	978864.1099	978804.7055	978804.7214	-60.2549	-0.0255

$$\gamma_{\text{maré zero}} = \gamma_{\text{maré médio}} + 30,4 - 91,2 \operatorname{sen}^2 \theta \text{ } [\mu\text{Gal}]$$

## 8. Transformação para quase geoide



Latitude - tide free (°)	LATITUDE GEOCÊTRICA (°) - tide free	Longitude - tide free (°)	N total (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsoide (mGal) - mean tide	gravidade normal média ao longo da plumb line (mGal) - mean tide	gravidade normal média ao longo da plumb line (mGal) - zero tide	Anomalia de gravidade refinada de Bouguer interpolada (mGal) - zero tide	Zeta (m) - zero tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978793.5394	978793.5555	-59.1034	-0.3438
-23.5500	-23.4094	-53.5000	-0.2606	330.5070	978857.4887	978806.4775	978806.4935	-58.4765	-0.2605
-23.6000	-23.4591	-53.5000	-0.1531	372.8014	978860.7967	978803.2580	978803.2739	-59.4977	-0.1530
-23.6500	-23.5089	-53.5000	-0.0256	384.8910	978864.1099	978804.7055	978804.7214	-60.2549	-0.0255

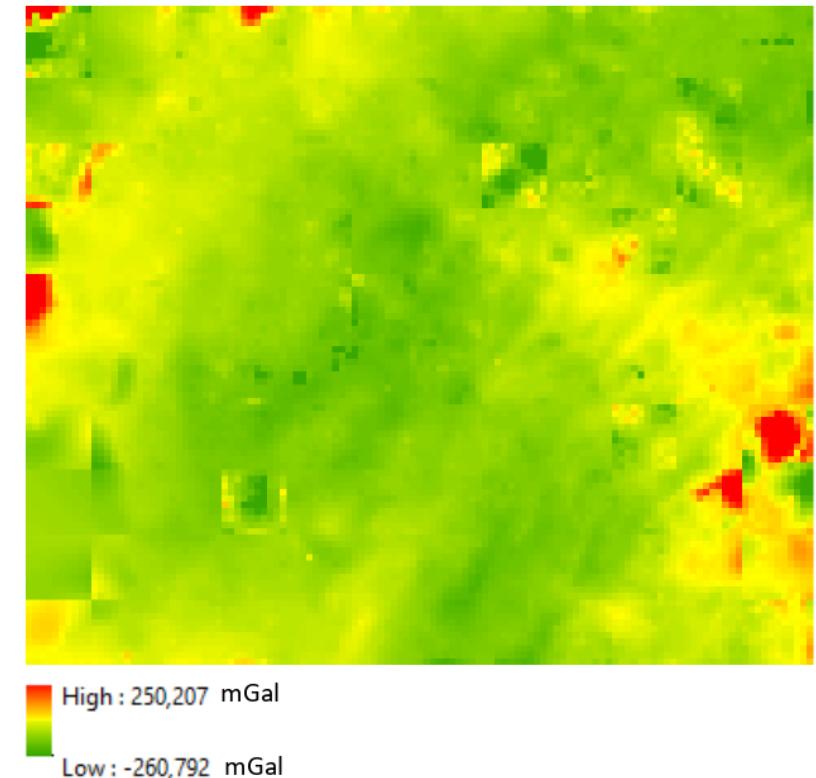
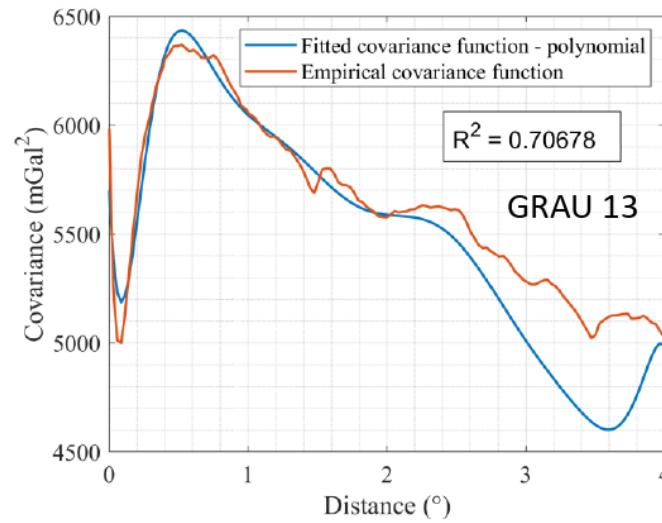
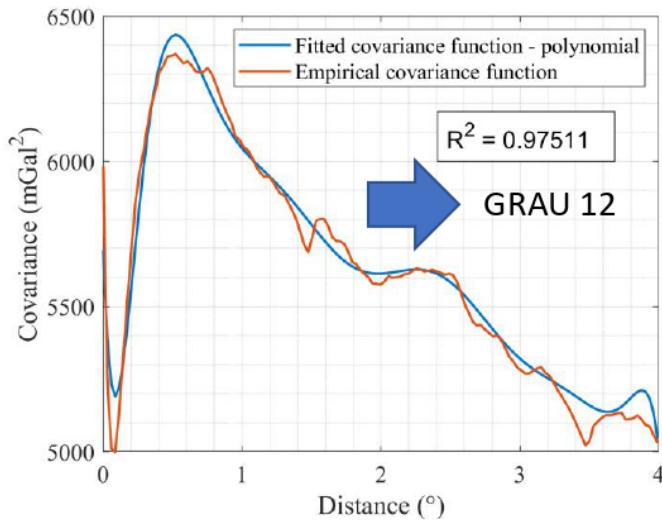


ID	LATITUDE (°) - tide free	LATITUDE GEOCÊTRICA (°) - tide free	LONGITUDE (°) - tide free	h (m) - tide free	H (m) - zero tide	g (mGal) - mean tide	Correção atmosférica (mGal) - mean tide	g com correção atmosférica (mGal) - mean tide	g com correção atmosférica (Mgal) - zero tide	gravidade normal no elipsoide (mGal) - mean tide	gravidade normal no elipsoide (mGal) - zero tide	Anomalia de gravidade ar livre (mGal) - zero tide	Ct (mGal)	Anomalia de gravidade de Helmert (mGal) - zero tide	Anomalia refinada de Bouguer (mGal) - zero tide	INSTITUICAO	FONTE
1	-25.5167556	-25.3674589	-49.1198662	904.4351	901.0751	978777.1525	0.7877	978777.9402	978777.9539	978991.5587	978991.5724	64.3944	0.12276	64.5171588	-36.25427065	DGEOM_TIAGO LIMA RODRIGUES	Gravímetro
2	-25.5470783	-25.3976535	-49.0490649	922.4376	919.3276	978776.6075	0.7860	978777.3935	978777.4071	978993.6876	978993.7012	67.3491	0.03879	67.38789258	-35.42358312	DGEOM_TIAGO LIMA RODRIGUES	Gravímetro
3	-25.4913997	-25.3422103	-48.9967520	963.8742	961.0942	978767.1830	0.7822	978767.9652	978767.9788	978989.7799	978989.7936	74.712	0.06228	74.77428383	-32.70522987	DGEOM_TIAGO LIMA RODRIGUES	Gravímetro
4	-25.4382415	-25.2892774	-49.0141729	938.4872	935.6272	978764.7232	0.7845	978765.5077	978765.5215	978986.0548	978986.0686	68.124	0.06026	68.18426383	-36.44898764	DGEOM_TIAGO LIMA RODRIGUES	Gravímetro
5	-25.4395725	-25.2906028	-49.0990577	886.2281	882.9281	978781.1751	0.7894	978781.9645	978781.9782	978986.1480	978986.1618	68.2315	0.07293	68.30442608	-30.43866591	DGEOM_TIAGO LIMA RODRIGUES	Gravímetro

$$Ag_B = g + 0,1967 H + C_t - \gamma_0$$

Geração da grade de anomalias de gravidade refinada de Bouguer pelo Método da Colocação por Mínimos Quadrados

## 8. Transformação para quase geoide



## 8. Transformação para quase geoide

Todos os pontos da grade do modelo geoidal



Latitude - tide free (°)	LATITUDE GEOCÊNTRICA (°) - tide free	Longitude - tide free (°)	N total (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsoide (mGal) - mean tide	gravidade normal média ao longo da plumb line (mGal) - mean tide	gravidade normal média ao longo da plumb line (mGal) - zero tide	Anomalia de gravidade refinada de Bouguer interpolada (mGal) - zero tide	Zeta (m) - zero tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978793.5394	978793.5555	-59.1034	-0.3438
-23.5500	-23.4094	-53.5000	-0.2606	330.5070	978857.4887	978806.4775	978806.4935	-58.4765	-0.2605
-23.6000	-23.4591	-53.5000	-0.1531	372.8014	978860.7967	978803.2580	978803.2739	-59.4977	-0.1530
-23.6500	-23.5089	-53.5000	-0.0256	384.8910	978864.1099	978804.7055	978804.7214	-60.2549	-0.0255

% Importando as grades

```
Grade=double(imread('.\GERAÇÃO DA GRADE ANOMALIAS REFINADAS DE BOUGUER\Grade_AG_Bouguer_Poly12.tif'));
```

resolucao\_graus=0.05;  Resolução espacial da grade do modelo geoidal em graus decimais

 Nome do arquivo da grade do modelo geoidal com extensão .tif

```
latN=-22.475-(resolucao_graus/2); % latN  
lonW=-54.525+(resolucao_graus/2); % longW
```

Pontos\_grade=readmatrix('Pontos\_calculo\_grade.txt');  Nome do arquivo com as coordenadas dos pontos da grade do modelo geoidal

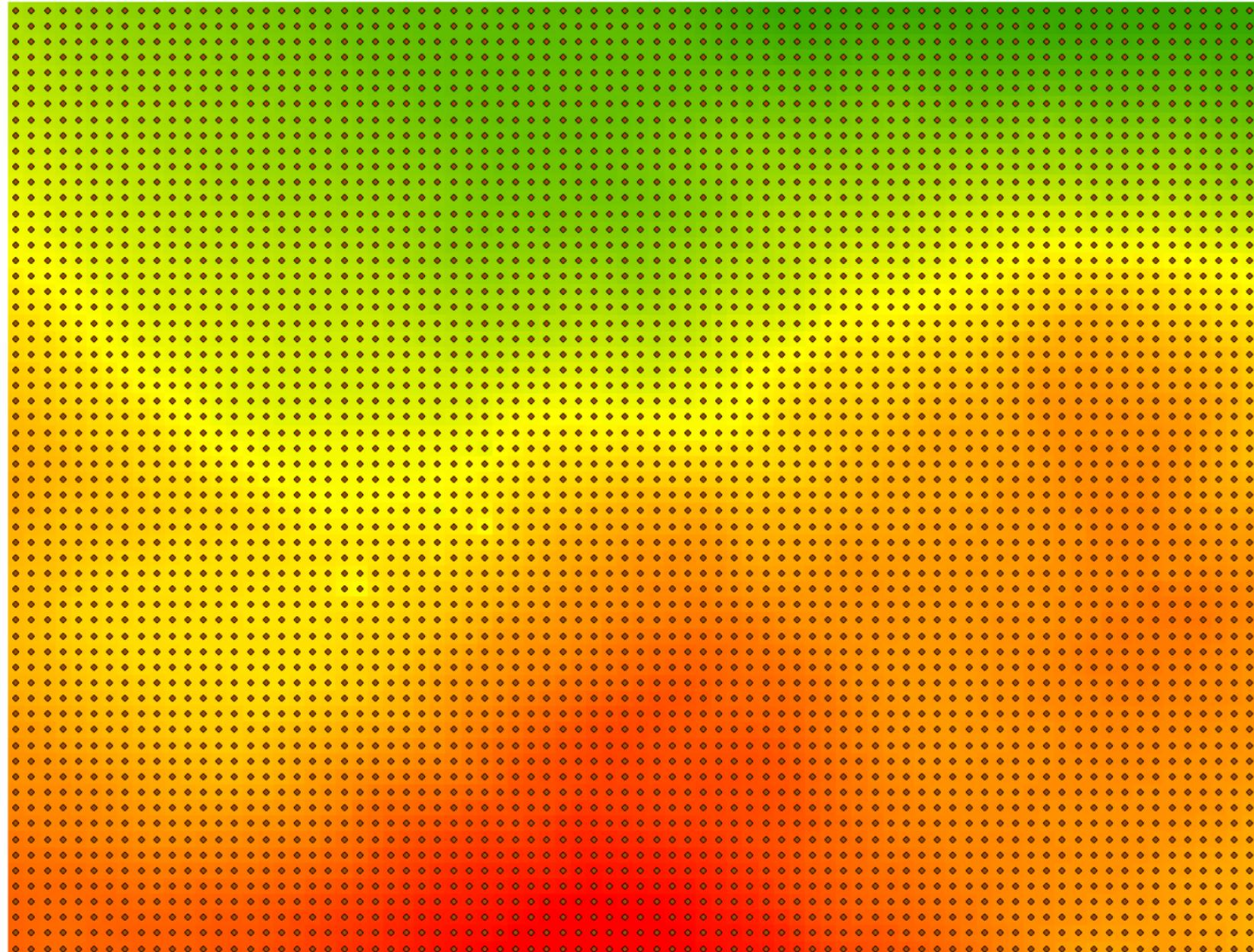
## 8. Transformação para quase geoide



Latitude - tide free (°)	LATITUDE GEOCÊTRICA (°) - tide free	Longitude - tide free (°)	N total (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsoide (mGal) - mean tide	gravidade normal média ao longo da plumb line (mGal) - mean tide	gravidade normal média ao longo da plumb line (mGal) - zero tide	Anomalia de gravidade refinada de Bouguer interpolada (mGal) - zero tide	Zeta (m) - zero tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978793.5394	978793.5555	-59.1034	-0.3438
-23.5500	-23.4094	-53.5000	-0.2606	330.5070	978857.4887	978806.4775	978806.4935	-58.4765	-0.2605
-23.6000	-23.4591	-53.5000	-0.1531	372.8014	978860.7967	978803.2580	978803.2739	-59.4977	-0.1530
-23.6500	-23.5089	-53.5000	-0.0256	384.8910	978864.1099	978804.7055	978804.7214	-60.2549	-0.0255

$$\zeta_P \approx N_P - \left( \frac{\Delta g_{BP}}{\bar{Y}_P} \right)$$

## Ponto para raster – Modelo quase geoidal referenciado ao $U_0$ do GRS80



Somente o termo de grau zero referente á diferença de GM entre GRS80 e XGM2019 foi aplicado no próprio ICEGM (~-0,93 m)

## 9. Referenciamento ao ITRS



Latitude - tide free (°)	LATITUDE GEOCENTRICA (°) - tide free	Longitude - tide free (°)	Zeta (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsóide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - zero tide	T (m²/s²) - zero tide	Termo de grau zero ITRS (m²/s²)	T prov (m²/s²) - zero tide	U (m²/s²) - mean tide	Wprov (m²/s²)	Delta W ITRF	W (m²/s²) - zero tide	Wto	W (m²/s²) - mean tide	Wo ITRS (m²/s²)	CP (m²/s²) - mean tide	Zeta IHRF (m) - mean tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978732.8964	978732.9125	-3.3645	7.4500	4.0855	62633017.9076	62633021.9931	-0.3116	62633021.6816	0.5131	62633022.1947	62636853.4000	3831.2053	0.4380
-23.5500	-23.4094	-53.5000	-0.2605	330.5070	978857.4887	978755.4688	978755.4848	-2.5497	7.4500	4.9003	62633628.2079	62633633.1082	-0.3104	62633632.7977	0.5113	62633633.3090	62636853.4000	3220.0910	0.5212
-23.6000	-23.4591	-53.5000	-0.1530	372.8014	978860.7967	978745.7227	978745.7386	-1.4975	7.4500	5.9525	62633213.1412	62633219.0937	-0.3093	62633218.7844	0.5094	62633219.2938	62636853.4000	3634.1062	0.6286
-23.6500	-23.5089	-53.5000	-0.0255	384.8910	978864.1099	978745.3046	978745.3205	-0.2495	7.4500	7.2005	62633093.5393	62633100.7398	-0.3082	62633100.4317	0.5076	62633100.9392	62636853.4000	3752.4608	0.7561
-23.7000	-23.5587	-53.5000	0.0847	407.3288	978867.4286	978741.6981	978741.7139	0.8290	7.4500	8.2790	62632872.8121	62632881.0912	-0.3071	62632880.7841	0.5057	62632881.2899	62636853.4000	3972.1101	0.8662

$$\gamma_Q = \gamma_{Q_0} \left[ 1 - 2(1 + f + m - 2f \sin^2 \varphi_P) \frac{H_P}{a} + 3 \left( \frac{H_P}{a} \right)^2 \right]$$

## 9. Referenciamento ao ITRS



Latitude - tide free (°)	LATITUDE GEOCENTRICA (°) - tide free	Longitude - tide free (°)	Zeta (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsóide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - zero tide	T (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Termo de grau zero ITRS (m <sup>2</sup> /s <sup>2</sup> )	T prov (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	U (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wprov (m <sup>2</sup> /s <sup>2</sup> )	Delta W ITRF	W (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Wto	W (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wo ITRS (m <sup>2</sup> /s <sup>2</sup> )	CP (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Zeta IHRF (m) - mean tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978732.8964	978732.9125	-3.3645	7.4500	4.0855	62633017.9076	62633021.9931	-0.3116	62633021.6816	0.5131	62633022.1947	62636853.4000	3831.2053	0.4380
-23.5500	-23.4094	-53.5000	-0.2605	330.5070	978857.4887	978755.4688	978755.4848	-2.5497	7.4500	4.9003	62633628.2079	62633633.1082	-0.3104	62633632.7977	0.5113	62633633.3090	62636853.4000	3220.0910	0.5212
-23.6000	-23.4591	-53.5000	-0.1530	372.8014	978860.7967	978745.7227	978745.7386	-1.4975	7.4500	5.9525	62633213.1412	62633219.0937	-0.3093	62633218.7844	0.5094	62633219.2938	62636853.4000	3634.1062	0.6286
-23.6500	-23.5089	-53.5000	-0.0255	384.8910	978864.1099	978745.3046	978745.3205	-0.2495	7.4500	7.2005	62633093.5393	62633100.7398	-0.3082	62633100.4317	0.5076	62633100.9392	62636853.4000	3752.4608	0.7561
-23.7000	-23.5587	-53.5000	0.0847	407.3288	978867.4286	978741.6981	978741.7139	0.8290	7.4500	8.2790	62632872.8121	62632881.0912	-0.3071	62632880.7841	0.5057	62632881.2899	62636853.4000	3972.1101	0.8662

$$\gamma_{\text{maré zero}} = \gamma_{\text{maré médio}} + 30,4 - 91,2 \operatorname{sen}^2 \theta \text{ } [\mu\text{Gal}]$$

## 9. Referenciamento ao ITRS



Latitude - tide free (°)	LATITUDE GEOCENTRICA (°) - tide free	Longitude - tide free (°)	Zeta (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsóide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - zero tide	T (m2/s2) - zero tide	Termo de grau zero ITRS (m2/s2)	T prov (m2/s2) - zero tide	U (m2/s2) - mean tide	Wprov (m2/s2)	Delta W ITRF	W (m2/s2) - zero tide	Wto	W (m2/s2) - mean tide	Wo ITRS (m2/s2)	CP (m2/s2) - mean tide	Zeta IHRF (m) - mean tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978732.8964	978732.9125	-3.3645	7.4500	4.0855	62633017.9076	62633021.9931	-0.3116	62633021.6816	0.5131	62633022.1947	62636853.4000	3831.2053	0.4380
-23.5500	-23.4094	-53.5000	-0.2605	330.5070	978857.4887	978755.4688	978755.4848	-2.5497	7.4500	4.9003	62633628.2079	62633633.1082	-0.3104	62633632.7977	0.5113	62633633.3090	62636853.4000	3220.0910	0.5212
-23.6000	-23.4591	-53.5000	-0.1530	372.8014	978860.7967	978745.7227	978745.7386	-1.4975	7.4500	5.9525	62633213.1412	62633219.0937	-0.3093	62633218.7844	0.5094	62633219.2938	62636853.4000	3634.1062	0.6286
-23.6500	-23.5089	-53.5000	-0.0255	384.8910	978864.1099	978745.3046	978745.3205	-0.2495	7.4500	7.2005	62633093.5393	62633100.7398	-0.3082	62633100.4317	0.5076	62633100.9392	62636853.4000	3752.4608	0.7561
-23.7000	-23.5587	-53.5000	0.0847	407.3288	978867.4286	978741.6981	978741.7139	0.8290	7.4500	8.2790	62632872.8121	62632881.0912	-0.3071	62632880.7841	0.5057	62632881.2899	62636853.4000	3972.1101	0.8662

$$T_P = \zeta_P \cdot \gamma_Q$$

## 9. Referenciamento ao ITRS

Latitude - tide free (°)	LATITUDE GEOCENTRICA (°) - tide free	Longitude - tide free (°)	Zeta (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsóide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - zero tide	T (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Termo de grau zero ITRS (m <sup>2</sup> /s <sup>2</sup> )	T prov (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	U (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wprov (m <sup>2</sup> /s <sup>2</sup> )	Delta W ITRF	W (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Wto	W (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wo ITRS (m <sup>2</sup> /s <sup>2</sup> )	CP (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Zeta IHRF (m) - mean tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978732.8964	978732.9125	-3.3645	7.4500	4.0855	62633017.9076	62633021.9931	-0.3116	62633021.6816	0.5131	62633022.1947	62636853.4000	3831.2053	0.4380
-23.5500	-23.4094	-53.5000	-0.2605	330.5070	978857.4887	978755.4688	978755.4848	-2.5497	7.4500	4.9003	62633628.2079	62633633.1082	-0.3104	62633632.7977	0.5113	62633633.3090	62636853.4000	3220.0910	0.5212
-23.6000	-23.4591	-53.5000	-0.1530	372.8014	978860.7967	978745.7227	978745.7386	-1.4975	7.4500	5.9525	62633213.1412	62633219.0937	-0.3093	62633218.7844	0.5094	62633219.2938	62636853.4000	3634.1062	0.6286
-23.6500	-23.5089	-53.5000	-0.0255	384.8910	978864.1099	978745.3046	978745.3205	-0.2495	7.4500	7.2005	62633093.5393	62633100.7398	-0.3082	62633100.4317	0.5076	62633100.9392	62636853.4000	3752.4608	0.7561
-23.7000	-23.5587	-53.5000	0.0847	407.3288	978867.4286	978741.6981	978741.7139	0.8290	7.4500	8.2790	62632872.8121	62632881.0912	-0.3071	62632880.7841	0.5057	62632881.2899	62636853.4000	3972.1101	0.8662

$$T_{GZ\_ITRS} = -(W_{0\_ITRS} - U_{0\_GRS80})$$



## 9. Referenciamento ao ITRS



Latitude - tide free (°)	LATITUDE GEOCENTRICA (°) - tide free	Longitude - tide free (°)	Zeta (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsóide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - zero tide	T (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Termo de grau zero ITRS (m <sup>2</sup> /s <sup>2</sup> )	T prov (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	U (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wprov (m <sup>2</sup> /s <sup>2</sup> )	Delta W ITRF	W (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Wto	W (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wo ITRS (m <sup>2</sup> /s <sup>2</sup> )	CP (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Zeta IHRF (m) - mean tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978732.8964	978732.9125	-3.3645	7.4500	4.0855	62633017.9076	62633021.9931	-0.3116	62633021.6816	0.5131	62633022.1947	62636853.4000	3831.2053	0.4380
-23.5500	-23.4094	-53.5000	-0.2605	330.5070	978857.4887	978755.4688	978755.4848	-2.5497	7.4500	4.9003	62633628.2079	62633633.1082	-0.3104	62633632.7977	0.5113	62633633.3090	62636853.4000	3220.0910	0.5212
-23.6000	-23.4591	-53.5000	-0.1530	372.8014	978860.7967	978745.7227	978745.7386	-1.4975	7.4500	5.9525	62633213.1412	62633219.0937	-0.3093	62633218.7844	0.5094	62633219.2938	62636853.4000	3634.1062	0.6286
-23.6500	-23.5089	-53.5000	-0.0255	384.8910	978864.1099	978745.3046	978745.3205	-0.2495	7.4500	7.2005	62633093.5393	62633100.7398	-0.3082	62633100.4317	0.5076	62633100.9392	62636853.4000	3752.4608	0.7561
-23.7000	-23.5587	-53.5000	0.0847	407.3288	978867.4286	978741.6981	978741.7139	0.8290	7.4500	8.2790	62632872.8121	62632881.0912	-0.3071	62632880.7841	0.5057	62632881.2899	62636853.4000	3972.1101	0.8662

$$T_{prov_P} = T_P + T_{GZ\_ITRS}$$

## 9. Referenciamento ao ITRS

Latitude - tide free (°)	LATITUDE GEOCÊNTRICA (°) - tide free	Longitude - tide free (°)	Zeta (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsóide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - zero tide	T (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Termo de grau zero ITRS (m <sup>2</sup> /s <sup>2</sup> )	T prov (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	U (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wprov (m <sup>2</sup> /s <sup>2</sup> )	Delta W ITRF	W (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Wto	W (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wo ITRS (m <sup>2</sup> /s <sup>2</sup> )	CP (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Zeta IHRF (m) - mean tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978732.8964	978732.9125	-3.3645	7.4500	4.0855	62633017.9076	62633021.9931	-0.3116	62633021.6816	0.5131	62633022.1947	62636853.4000	3831.2053	0.4380
-23.5500	-23.4094	-53.5000	-0.2605	330.5070	978857.4887	978755.4688	978755.4848	-2.5497	7.4500	4.9003	62633628.2079	62633633.1082	-0.3104	62633632.7977	0.5113	62633633.3090	62636853.4000	3220.0910	0.5212
-23.6000	-23.4591	-53.5000	-0.1530	372.8014	978860.7967	978745.7227	978745.7386	-1.4975	7.4500	5.9525	62633213.1412	62633219.0937	-0.3093	62633218.7844	0.5094	62633219.2938	62636853.4000	3634.1062	0.6286
-23.6500	-23.5089	-53.5000	-0.0255	384.8910	978864.1099	978745.3046	978745.3205	-0.2495	7.4500	7.2005	62633093.5393	62633100.7398	-0.3082	62633100.4317	0.5076	62633100.9392	62636853.4000	3752.4608	0.7561
-23.7000	-23.5587	-53.5000	0.0847	407.3288	978867.4286	978741.6981	978741.7139	0.8290	7.4500	8.2790	62632872.8121	62632881.0912	-0.3071	62632880.7841	0.5057	62632881.2899	62636853.4000	3972.1101	0.8662

$$U_P = U_{0GRS80} + \gamma_{Q_0} \cdot h_P = U_{0GRS80} + \gamma_{Q_0} (H + \zeta_P)$$

## 9. Referenciamento ao ITRS



Latitude - tide free (°)	LATITUDE GEOCENTRICA (°) - tide free	Longitude - tide free (°)	Zeta (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsóide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - zero tide	T (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Termo de grau zero ITRS (m <sup>2</sup> /s <sup>2</sup> )	T prov (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	U (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wprov (m <sup>2</sup> /s <sup>2</sup> )	Delta W ITRF	W (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Wto	W (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wo ITRS (m <sup>2</sup> /s <sup>2</sup> )	CP (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Zeta IHRF (m) - mean tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978732.8964	978732.9125	-3.3645	7.4500	4.0855	62633017.9076	62633021.9931	-0.3116	62633021.6816	0.5131	62633022.1947	62636853.4000	3831.2053	0.4380
-23.5500	-23.4094	-53.5000	-0.2605	330.5070	978857.4887	978755.4688	978755.4848	-2.5497	7.4500	4.9003	62633628.2079	62633633.1082	-0.3104	62633632.7977	0.5113	62633633.3090	62636853.4000	3220.0910	0.5212
-23.6000	-23.4591	-53.5000	-0.1530	372.8014	978860.7967	978745.7227	978745.7386	-1.4975	7.4500	5.9525	62633213.1412	62633219.0937	-0.3093	62633218.7844	0.5094	62633219.2938	62636853.4000	3634.1062	0.6286
-23.6500	-23.5089	-53.5000	-0.0255	384.8910	978864.1099	978745.3046	978745.3205	-0.2495	7.4500	7.2005	62633093.5393	62633100.7398	-0.3082	62633100.4317	0.5076	62633100.9392	62636853.4000	3752.4608	0.7561
-23.7000	-23.5587	-53.5000	0.0847	407.3288	978867.4286	978741.6981	978741.7139	0.8290	7.4500	8.2790	62632872.8121	62632881.0912	-0.3071	62632880.7841	0.5057	62632881.2899	62636853.4000	3972.1101	0.8662

$$W_{prov_P} = T_{prov_P} + U_P$$

## 9. Referenciamento ao ITRS



Latitude - tide free (°)	LATITUDE GEOCÊNTRICA (°) - tide free	Longitude - tide free (°)	Zeta (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsóide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - zero tide	T (m²/s²) - zero tide	Termo de grau zero ITRS (m²/s²)	T prov (m²/s²) - zero tide	U (m²/s²) - mean tide	Wprov (m²/s²)	Delta W ITRF	W (m²/s²) - zero tide	Wto	W (m²/s²) - mean tide	Wo ITRS (m²/s²)	CP (m²/s²) - mean tide	Zeta IHRF (m) - mean tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978732.8964	978732.9125	-3.3645	7.4500	4.0855	62633017.9076	62633021.9931	-0.3116	62633021.6816	0.5131	62633022.1947	62636853.4000	3831.2053	0.4380
-23.5500	-23.4094	-53.5000	-0.2605	330.5070	978857.4887	978755.4688	978755.4848	-2.5497	7.4500	4.9003	62633628.2079	62633633.1082	-0.3104	62633632.7977	0.5113	62633633.3090	62636853.4000	3220.0910	0.5212
-23.6000	-23.4591	-53.5000	-0.1530	372.8014	978860.7967	978745.7227	978745.7386	-1.4975	7.4500	5.9525	62633213.1412	62633219.0937	-0.3093	62633218.7844	0.5094	62633219.2938	62636853.4000	3634.1062	0.6286
-23.6500	-23.5089	-53.5000	-0.0255	384.8910	978864.1099	978745.3046	978745.3205	-0.2495	7.4500	7.2005	62633093.5393	62633100.7398	-0.3082	62633100.4317	0.5076	62633100.9392	62636853.4000	3752.4608	0.7561
-23.7000	-23.5587	-53.5000	0.0847	407.3288	978867.4286	978741.6981	978741.7139	0.8290	7.4500	8.2790	62632872.8121	62632881.0912	-0.3071	62632880.7841	0.5057	62632881.2899	62636853.4000	3972.1101	0.8662

$$\Delta W_P = -0,5901 + 1,7475 \operatorname{sen}^2 \varphi_P + 0,0273 \operatorname{sen}^4 \varphi_P$$

## 9. Referenciamento ao ITRS



Latitude - tide free (°)	LATITUDE GEOCENTRICA (°) - tide free	Longitude - tide free (°)	Zeta (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsóide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - zero tide	T (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Termo de grau zero ITRS (m <sup>2</sup> /s <sup>2</sup> )	T prov (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	U (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wprov (m <sup>2</sup> /s <sup>2</sup> )	Delta W ITRF	W (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Wto	W (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wo ITRS (m <sup>2</sup> /s <sup>2</sup> )	CP (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Zeta IHRF (m) - mean tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978732.8964	978732.9125	-3.3645	7.4500	4.0855	62633017.9076	62633021.9931	-0.3116	62633021.6816	0.5131	62633022.1947	62636853.4000	3831.2053	0.4380
-23.5500	-23.4094	-53.5000	-0.2605	330.5070	978857.4887	978755.4688	978755.4848	-2.5497	7.4500	4.9003	62633628.2079	62633633.1082	-0.3104	62633632.7977	0.5113	62633633.3090	62636853.4000	3220.0910	0.5212
-23.6000	-23.4591	-53.5000	-0.1530	372.8014	978860.7967	978745.7227	978745.7386	-1.4975	7.4500	5.9525	62633213.1412	62633219.0937	-0.3093	62633218.7844	0.5094	62633219.2938	62636853.4000	3634.1062	0.6286
-23.6500	-23.5089	-53.5000	-0.0255	384.8910	978864.1099	978745.3046	978745.3205	-0.2495	7.4500	7.2005	62633093.5393	62633100.7398	-0.3082	62633100.4317	0.5076	62633100.9392	62636853.4000	3752.4608	0.7561
-23.7000	-23.5587	-53.5000	0.0847	407.3288	978867.4286	978741.6981	978741.7139	0.8290	7.4500	8.2790	62632872.8121	62632881.0912	-0.3071	62632880.7841	0.5057	62632881.2899	62636853.4000	3972.1101	0.8662

$$W_{\text{zero tide}_P} = W_{\text{prov}_P} + \Delta W_P$$

## 9. Referenciamento ao ITRS



Latitude - tide free (°)	LATITUDE GEOCENTRICA (°) - tide free	Longitude - tide free (°)	Zeta (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsóide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - zero tide	T (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Termo de grau zero ITRS (m <sup>2</sup> /s <sup>2</sup> )	T prov (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	U (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wprov (m <sup>2</sup> /s <sup>2</sup> )	Delta W ITRF	W (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Wto	W (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wo ITRS (m <sup>2</sup> /s <sup>2</sup> )	CP (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Zeta IHRF (m) - mean tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978732.8964	978732.9125	-3.3645	7.4500	4.0855	62633017.9076	62633021.9931	-0.3116	62633021.6816	0.5131	62633022.1947	62636853.4000	3831.2053	0.4380
-23.5500	-23.4094	-53.5000	-0.2605	330.5070	978857.4887	978755.4688	978755.4848	-2.5497	7.4500	4.9003	62633628.2079	62633633.1082	-0.3104	62633632.7977	0.5113	62633633.3090	62636853.4000	3220.0910	0.5212
-23.6000	-23.4591	-53.5000	-0.1530	372.8014	978860.7967	978745.7227	978745.7386	-1.4975	7.4500	5.9525	62633213.1412	62633219.0937	-0.3093	62633218.7844	0.5094	62633219.2938	62636853.4000	3634.1062	0.6286
-23.6500	-23.5089	-53.5000	-0.0255	384.8910	978864.1099	978745.3046	978745.3205	-0.2495	7.4500	7.2005	62633093.5393	62633100.7398	-0.3082	62633100.4317	0.5076	62633100.9392	62636853.4000	3752.4608	0.7561
-23.7000	-23.5587	-53.5000	0.0847	407.3288	978867.4286	978741.6981	978741.7139	0.8290	7.4500	8.2790	62632872.8121	62632881.0912	-0.3071	62632880.7841	0.5057	62632881.2899	62636853.4000	3972.1101	0.8662

$$W_{t0P} = 0,9722 - 2,884 \operatorname{sen}^2 \varphi_P - 0,0195 \operatorname{sen}^4 \varphi_P$$

## 9. Referenciamento ao ITRS



Latitude - tide free (°)	LATITUDE GEOCENTRICA (°) - tide free	Longitude - tide free (°)	Zeta (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsóide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - zero tide	T (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Termo de grau zero ITRS (m <sup>2</sup> /s <sup>2</sup> )	T prov (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	U (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wprov (m <sup>2</sup> /s <sup>2</sup> )	Delta W ITRF	W (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Wto	W (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wo ITRS (m <sup>2</sup> /s <sup>2</sup> )	CP (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Zeta IHRF (m) - mean tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978732.8964	978732.9125	-3.3645	7.4500	4.0855	62633017.9076	62633021.9931	-0.3116	62633021.6816	0.5131	62633022.1947	62636853.4000	3831.2053	0.4380
-23.5500	-23.4094	-53.5000	-0.2605	330.5070	978857.4887	978755.4688	978755.4848	-2.5497	7.4500	4.9003	62633628.2079	62633633.1082	-0.3104	62633632.7977	0.5113	62633633.3090	62636853.4000	3220.0910	0.5212
-23.6000	-23.4591	-53.5000	-0.1530	372.8014	978860.7967	978745.7227	978745.7386	-1.4975	7.4500	5.9525	62633213.1412	62633219.0937	-0.3093	62633218.7844	0.5094	62633219.2938	62636853.4000	3634.1062	0.6286
-23.6500	-23.5089	-53.5000	-0.0255	384.8910	978864.1099	978745.3046	978745.3205	-0.2495	7.4500	7.2005	62633093.5393	62633100.7398	-0.3082	62633100.4317	0.5076	62633100.9392	62636853.4000	3752.4608	0.7561
-23.7000	-23.5587	-53.5000	0.0847	407.3288	978867.4286	978741.6981	978741.7139	0.8290	7.4500	8.2790	62632872.8121	62632881.0912	-0.3071	62632880.7841	0.5057	62632881.2899	62636853.4000	3972.1101	0.8662

$$W_{mean\ tide\ p} = W_{zero\ tide\ p} + W_{t0\ p}$$

## 9. Referenciamento ao ITRS



Latitude - tide free (°)	LATITUDE GEOCÊNTRICA (°) - tide free	Longitude - tide free (°)	Zeta (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsóide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - zero tide	T (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Termo de grau zero ITRS (m <sup>2</sup> /s <sup>2</sup> )	T prov (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	U (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wprov (m <sup>2</sup> /s <sup>2</sup> )	Delta W ITRF	W (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Wto	W (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wo ITRS (m <sup>2</sup> /s <sup>2</sup> )	CP (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Zeta IHRF (m) - mean tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978732.8964	978732.9125	-3.3645	7.4500	4.0855	62633017.9076	62633021.9931	-0.3116	62633021.6816	0.5131	62633022.1947	62636853.4000	3831.2053	0.4380
-23.5500	-23.4094	-53.5000	-0.2605	330.5070	978857.4887	978755.4688	978755.4848	-2.5497	7.4500	4.9003	62633628.2079	62633633.1082	-0.3104	62633632.7977	0.5113	62633633.3090	62636853.4000	3220.0910	0.5212
-23.6000	-23.4591	-53.5000	-0.1530	372.8014	978860.7967	978745.7227	978745.7386	-1.4975	7.4500	5.9525	62633213.1412	62633219.0937	-0.3093	62633218.7844	0.5094	62633219.2938	62636853.4000	3634.1062	0.6286
-23.6500	-23.5089	-53.5000	-0.0255	384.8910	978864.1099	978745.3046	978745.3205	-0.2495	7.4500	7.2005	62633093.5393	62633100.7398	-0.3082	62633100.4317	0.5076	62633100.9392	62636853.4000	3752.4608	0.7561
-23.7000	-23.5587	-53.5000	0.0847	407.3288	978867.4286	978741.6981	978741.7139	0.8290	7.4500	8.2790	62632872.8121	62632881.0912	-0.3071	62632880.7841	0.5057	62632881.2899	62636853.4000	3972.1101	0.8662

$$C_{P_{IHR}} = W_{0_{IHR}} - W_{mean\ tide\ p}$$

## 9. Referenciamento ao ITRS



Latitude - tide free (°)	LATITUDE GEOCÊNTRICA (°) - tide free	Longitude - tide free (°)	Zeta (m) - zero tide	H interpolada (m) - zero tide	gravidade normal no elipsóide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - mean tide	gravidade normal no Telúroide (mGal) - zero tide	T (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Termo de grau zero ITRS (m <sup>2</sup> /s <sup>2</sup> )	T prov (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	U (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wprov (m <sup>2</sup> /s <sup>2</sup> )	Delta W ITRF	W (m <sup>2</sup> /s <sup>2</sup> ) - zero tide	Wto	W (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Wo ITRS (m <sup>2</sup> /s <sup>2</sup> )	CP (m <sup>2</sup> /s <sup>2</sup> ) - mean tide	Zeta IHRF (m) - mean tide
-23.5000	-23.3596	-53.5000	-0.3438	392.9398	978854.1862	978732.8964	978732.9125	-3.3645	7.4500	4.0855	62633017.9076	62633021.9931	-0.3116	62633021.6816	0.5131	62633022.1947	62636853.4000	3831.2053	0.4380
-23.5500	-23.4094	-53.5000	-0.2605	330.5070	978857.4887	978755.4688	978755.4848	-2.5497	7.4500	4.9003	62633628.2079	62633633.1082	-0.3104	62633632.7977	0.5113	62633633.3090	62636853.4000	3220.0910	0.5212
-23.6000	-23.4591	-53.5000	-0.1530	372.8014	978860.7967	978745.7227	978745.7386	-1.4975	7.4500	5.9525	62633213.1412	62633219.0937	-0.3093	62633218.7844	0.5094	62633219.2938	62636853.4000	3634.1062	0.6286
-23.6500	-23.5089	-53.5000	-0.0255	384.8910	978864.1099	978745.3046	978745.3205	-0.2495	7.4500	7.2005	62633093.5393	62633100.7398	-0.3082	62633100.4317	0.5076	62633100.9392	62636853.4000	3752.4608	0.7561
-23.7000	-23.5587	-53.5000	0.0847	407.3288	978867.4286	978741.6981	978741.7139	0.8290	7.4500	8.2790	62632872.8121	62632881.0912	-0.3071	62632880.7841	0.5057	62632881.2899	62636853.4000	3972.1101	0.8662

$$\zeta_{P_{IHR}} = \frac{(W_{mean\ tide\ P} - U_P)}{\gamma_Q}$$

## Ponto para raster – Modelo quase geoidal referenciado ao ITRS

