Camada equivalente aplicada ao processamento e interpretação de dados de campos potenciais

Vanderlei C. Oliveira Jr.

2016

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PINGA
Grupo de problemas inversos em geofísica

Distúrbio de gravidade (parte B)

Vanderlei C. Oliveira Jr.

2016

Observatório Nacional

SBGf

$$\boldsymbol{\delta}\mathbf{g}_P = \mathbf{g}_P - \boldsymbol{\gamma}_P$$

Vetor distúrbio de gravidade

$$\boldsymbol{\Delta}\mathbf{g}_P = \mathbf{g}_0 - \boldsymbol{\gamma}_Q$$

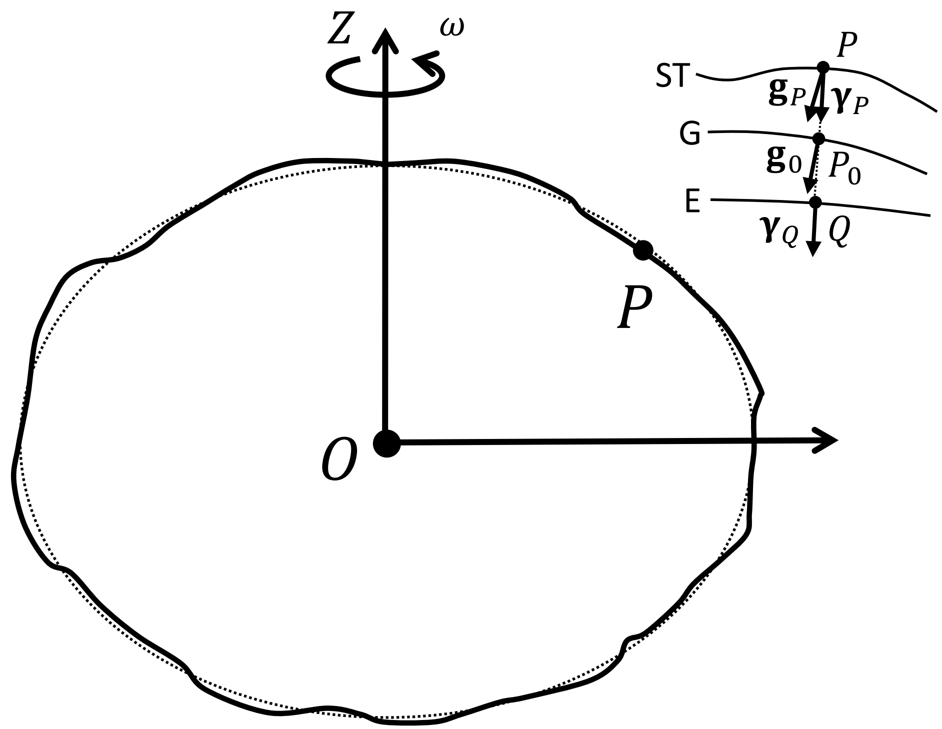
Vetor anomalia de gravidade

$$\delta g_P = g_P - \gamma_P$$

Distúrbio de gravidade

$$\Delta g_P = g_0 - \gamma_Q$$

Anomalia de gravidade



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Vetor gravidade normal

$$\begin{aligned}\boldsymbol{\gamma}_P &= \nabla \widetilde{W}_P \\ &= \nabla U_P + \nabla \Phi_P\end{aligned}$$

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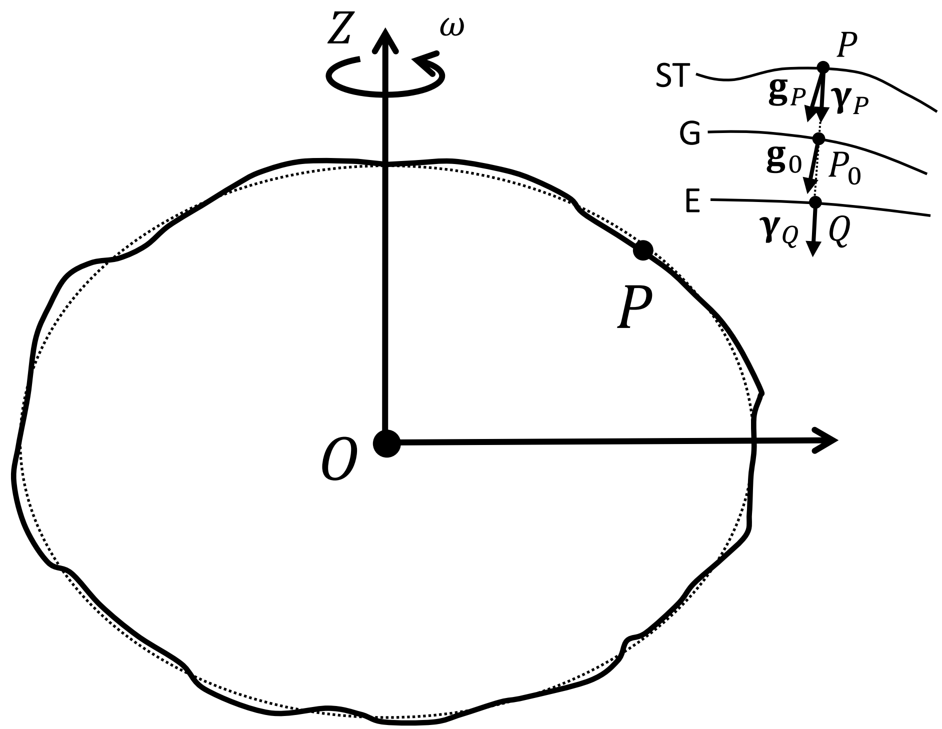

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$$W_P = V_P + \Phi_P$$

Potencial centrífugo

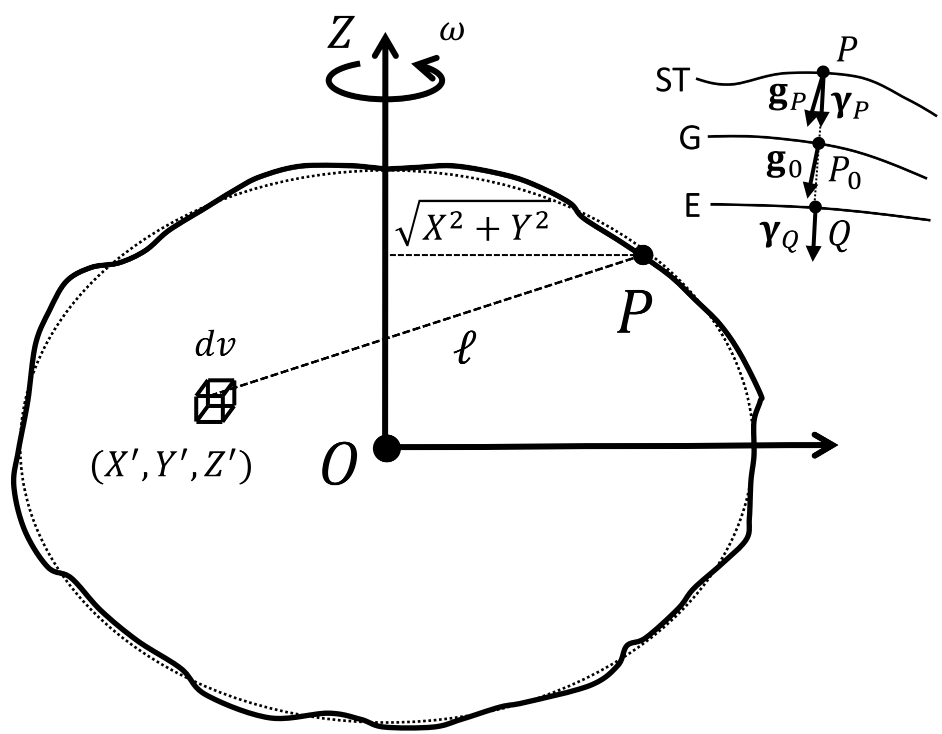
$$\Phi_P = \frac{1}{2}\omega^2(X^2 + Y^2)$$

Potencial gravitacional normal

$$U_P = G \iiint \frac{\tilde{\rho}}{\ell} dv$$

Potencial gravitacional

$$V_P = G \iiint \frac{\rho}{\ell} dv$$



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Anomalia de gravidade

$$U_P = G \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} \frac{\tilde{\rho}}{\ell}\, dv$$

Considere que $\tilde{\rho}$ se anula fora do volume da Terra Normal

Considere que ρ se anula fora do volume da Terra

$$V_P = G \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} \frac{\rho}{\ell}\, dv$$

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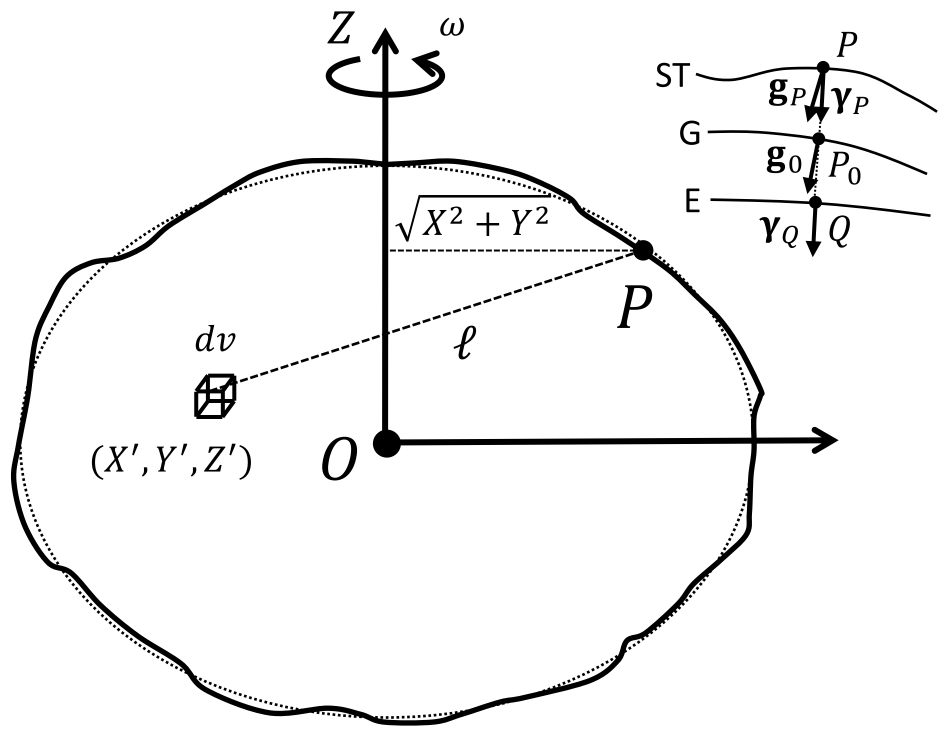

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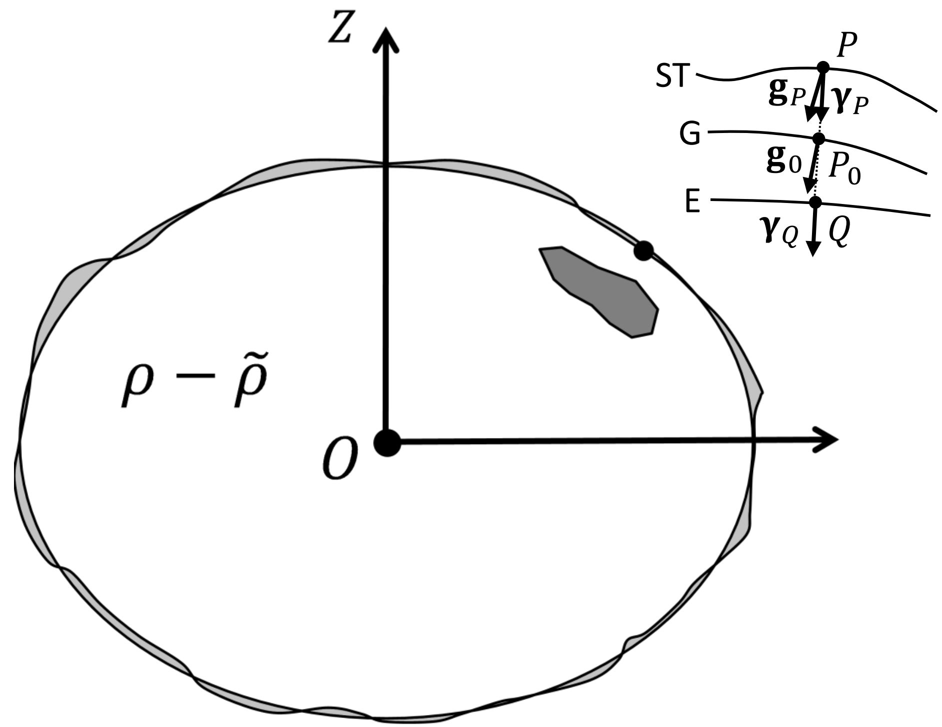
$$\boldsymbol{\delta}\mathbf{g}_P = G \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} (\rho - \tilde{\rho}) \nabla \frac{1}{\ell} dv$$

Representa a atração gravitacional exercida pelas **massas anômalas** ou **fontes gravimétricas**!



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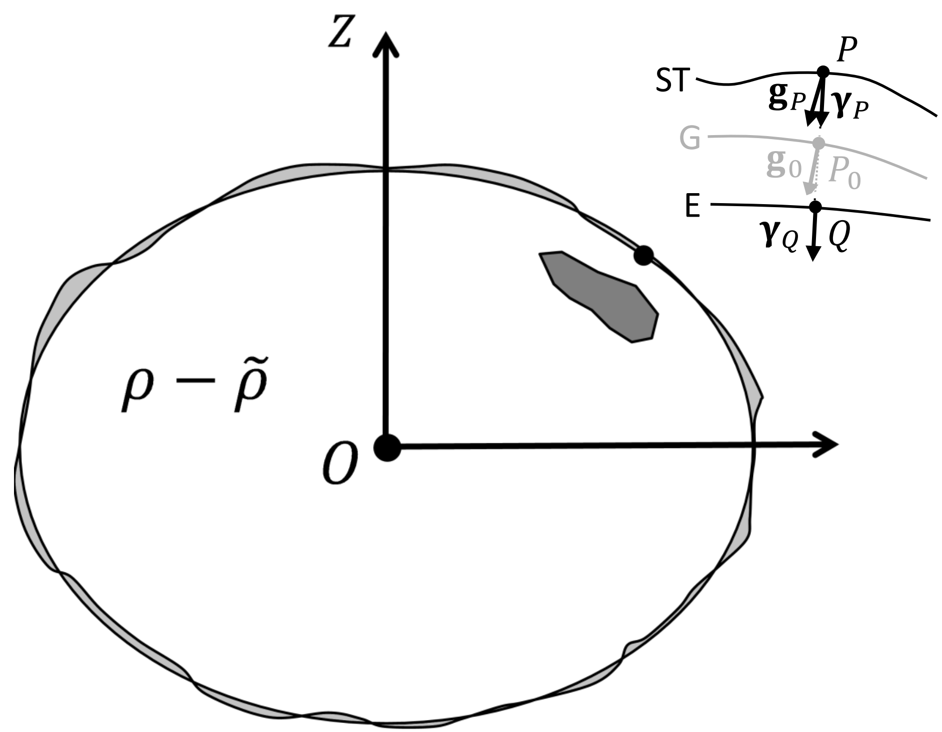

$$\boldsymbol{\delta}\mathbf{g}_P = \mathbf{g}_P - \boldsymbol{\gamma}_P$$

Vetor distúrbio de gravidade

$$\mathbf{g}_P = \boldsymbol{\gamma}_P + \boldsymbol{\delta}\mathbf{g}_P$$

$$\delta g_P = g_P - \gamma_P$$

Distúrbio de gravidade

$$\gamma_P \gg \|\boldsymbol{\delta}\mathbf{g}_P\|$$

Condição observada na prática

$$\boldsymbol{\delta}\mathbf{g}_P = G \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} (\rho - \tilde{\rho}) \nabla \frac{1}{\ell} dv$$

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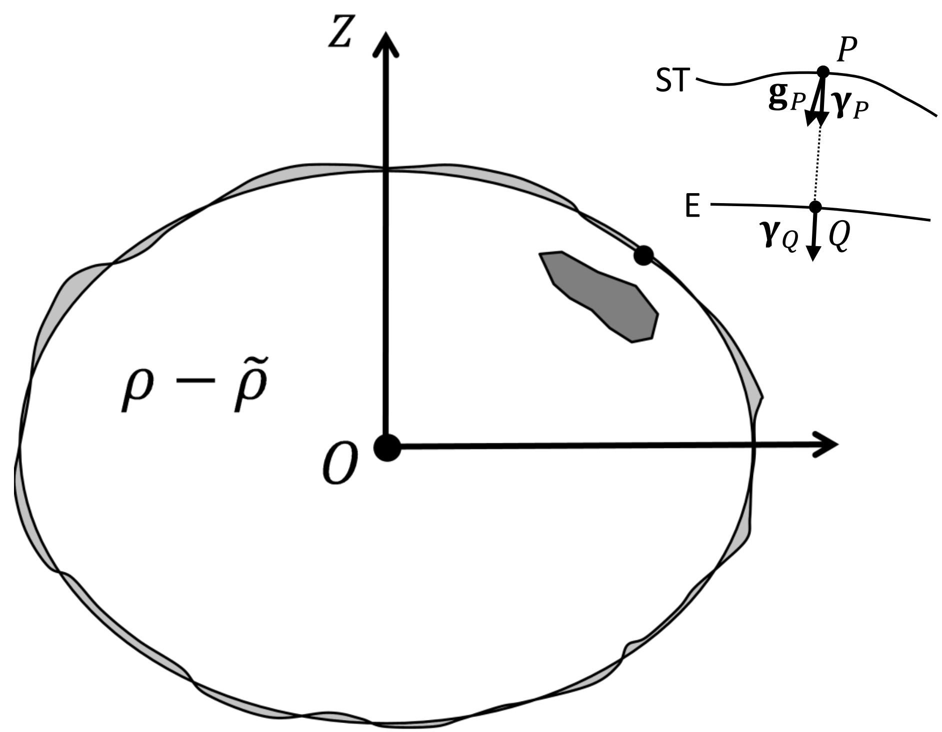

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Distúrbio de gravidade

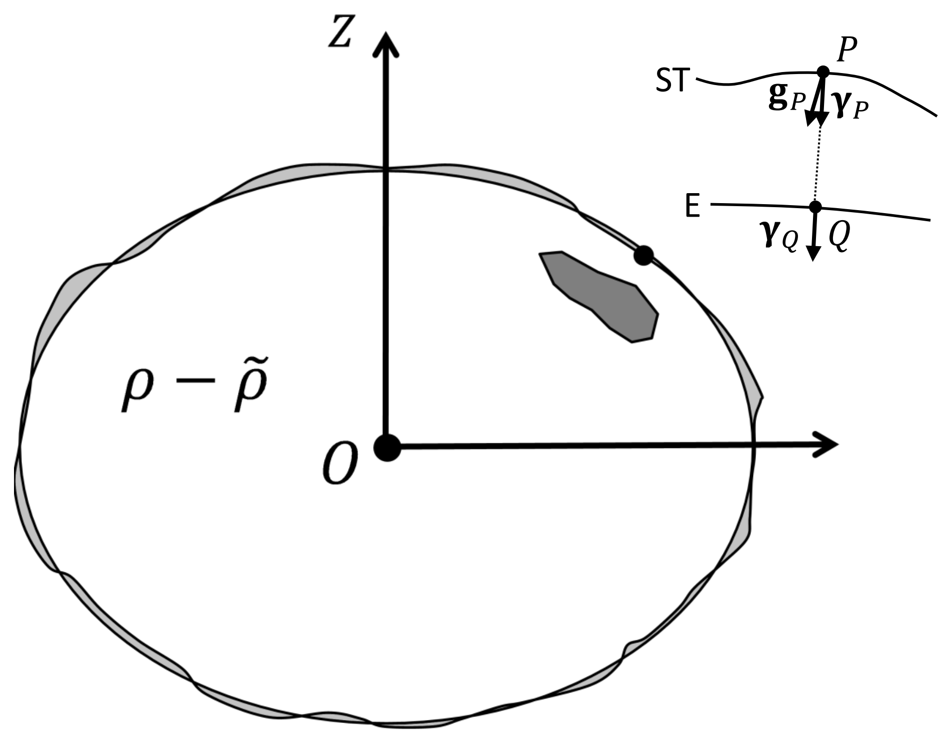
$$\gamma_P \gg \|\boldsymbol{\delta}\mathbf{g}_P\|$$

Condição observada na prática

Esta integral pode ser reescrita de tal forma que represente o efeito de cada fonte, separadamente

$$\boldsymbol{\delta}\mathbf{g}_P = G \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} (\rho - \tilde{\rho}) \nabla \frac{1}{\ell} dv$$

Representa a atração gravitacional exercida pelas **massas anômalas** ou **fontes gravimétricas**!



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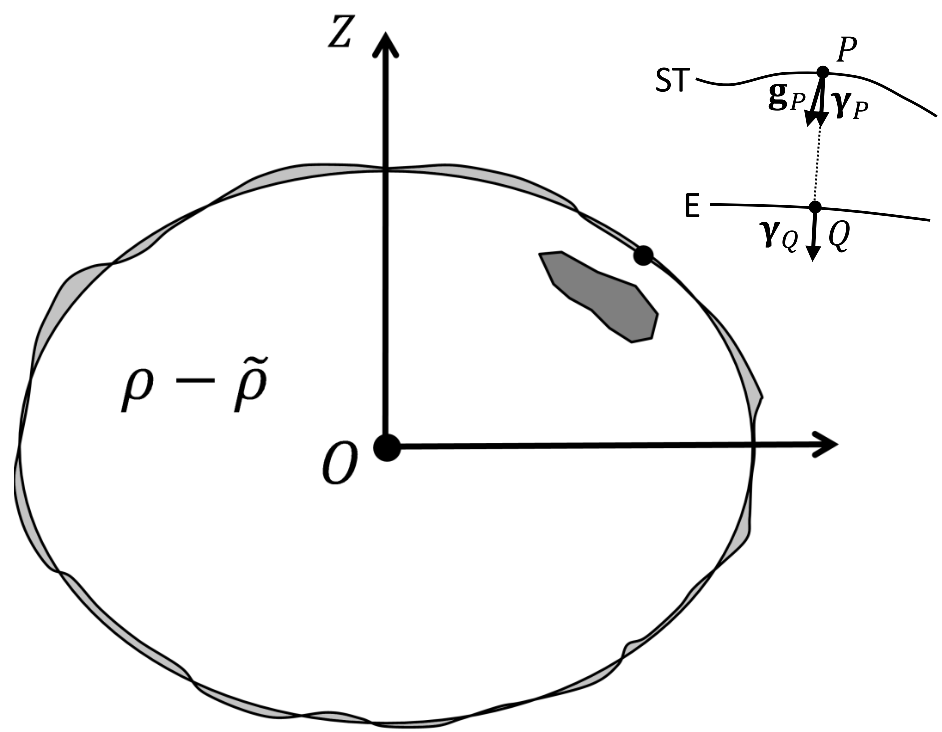
Distúrbio de gravidade

$$\gamma_P \gg \|\boldsymbol{\delta}\mathbf{g}_P\|$$

Condição observada na prática

Neste expressão, considerou-se que cada fonte possui um contraste de densidade $\Delta\rho = \rho - \tilde{\rho}$ constante

$$\boldsymbol{\delta}\mathbf{g}_P = G \sum_j \Delta\rho_j \iiint_{v_j} \nabla \frac{1}{\ell} dv$$



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Condição observada na prática

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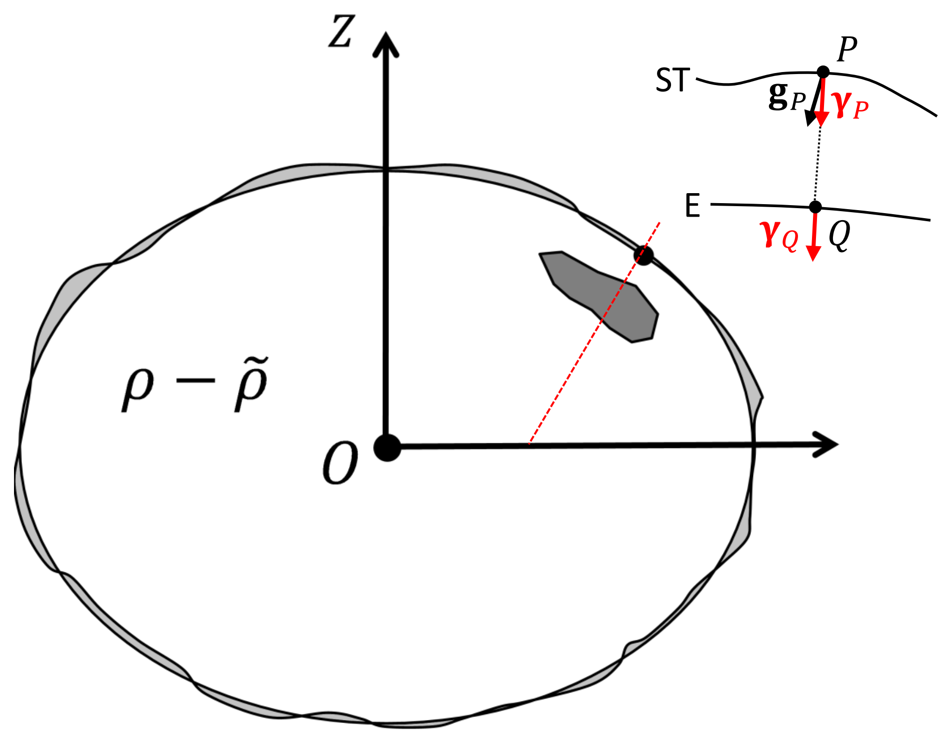

Em geral, considera-se que a direção do vetor gravidade normal no ponto P é igual a direção do vetor gravidade normal no ponto Q. No sistema de coordenadas geodésicas, esta direção é constante ao longo da normal ao elipsoide

$$\boldsymbol{\delta}\mathbf{g}_P = \mathbf{g}_P - \boldsymbol{\gamma}_P$$

Vetor distúrbio de gravidade

$$\mathbf{g}_P = \boldsymbol{\gamma}_P + \boldsymbol{\delta}\mathbf{g}_P$$

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Distúrbio de gravidade

$$\gamma_P \gg \|\boldsymbol{\delta}\mathbf{g}_P\|$$

Condição observada na prática

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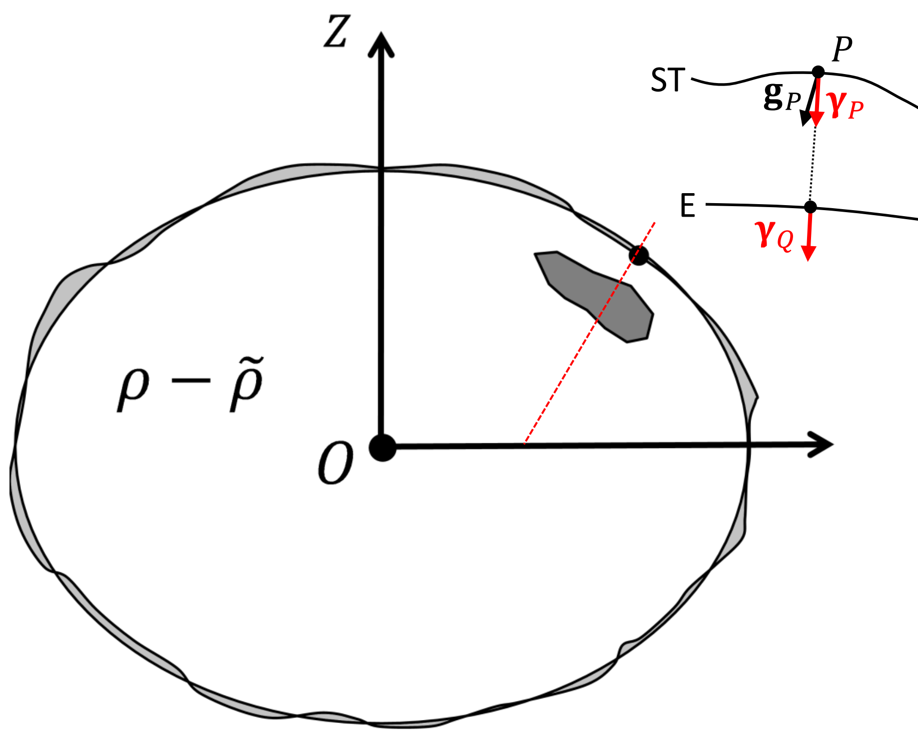
Direção constante normal ao elipsoide



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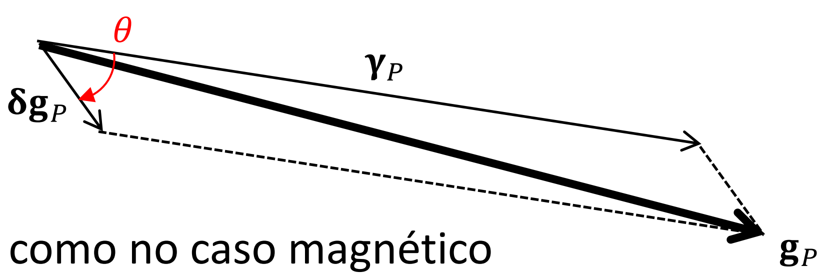
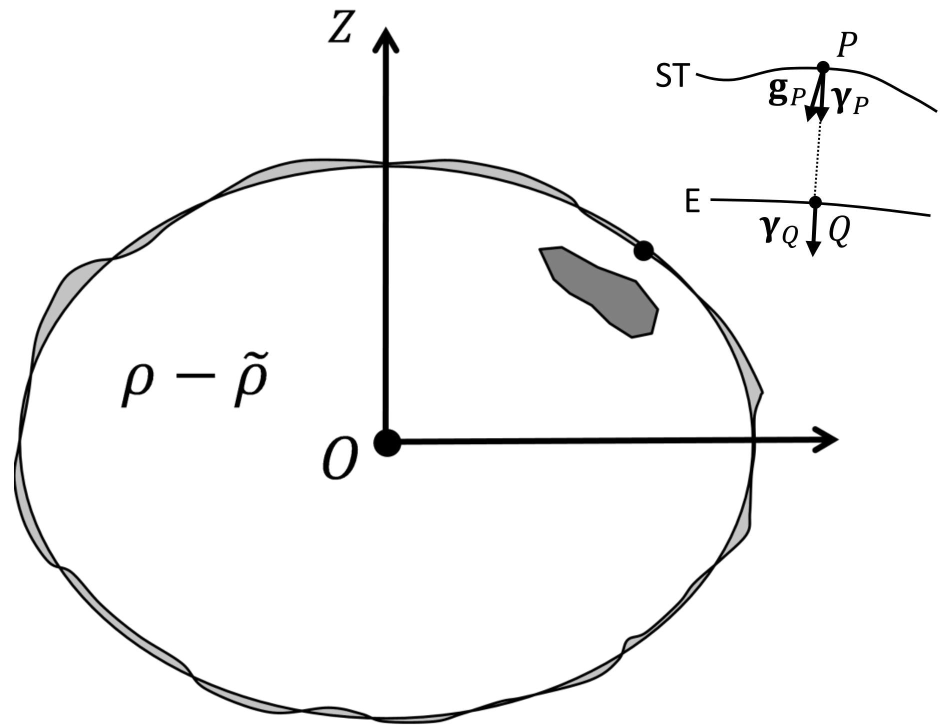


Tal como no caso magnético



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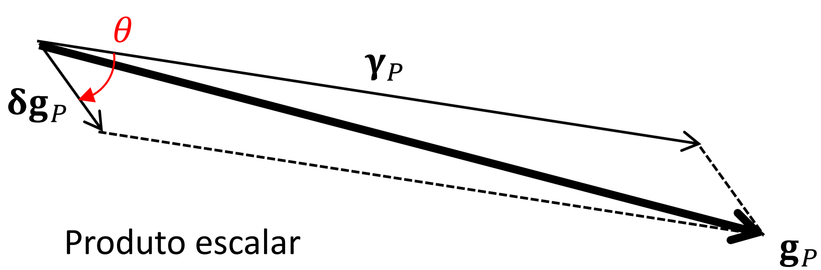
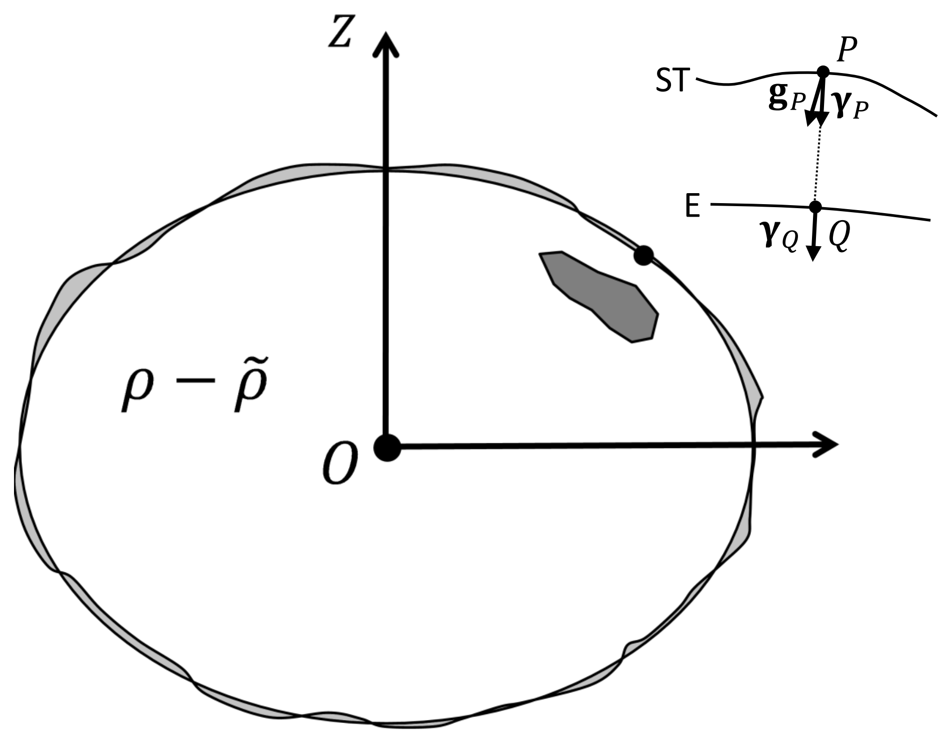


Produto escalar

$$\boxed{\begin{aligned} \mathbf{v}^{\mathrm{T}}\mathbf{w} &= v_x w_x + v_y w_y + v_z w_z \\ &= v\, w\, cos\theta \end{aligned}}$$

$$g_P \approx \gamma_P + \hat{\boldsymbol{\gamma}}_0^{\mathrm{T}} \boldsymbol{\delta}\mathbf{g}_P$$

$$\delta g_P \approx \hat{\boldsymbol{\gamma}}_0^{\mathrm{T}} \boldsymbol{\delta}\mathbf{g}_P$$



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Distúrbio de gravidade

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Condição observada na prática

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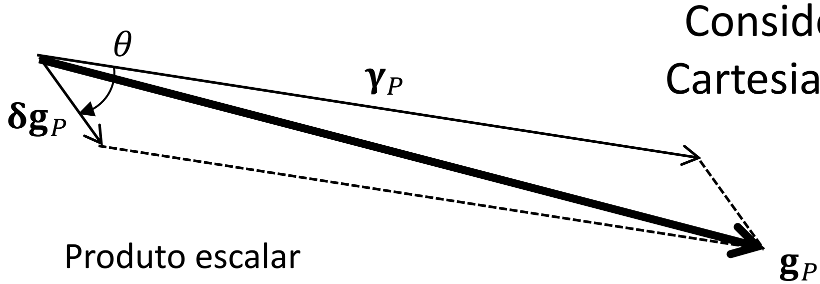
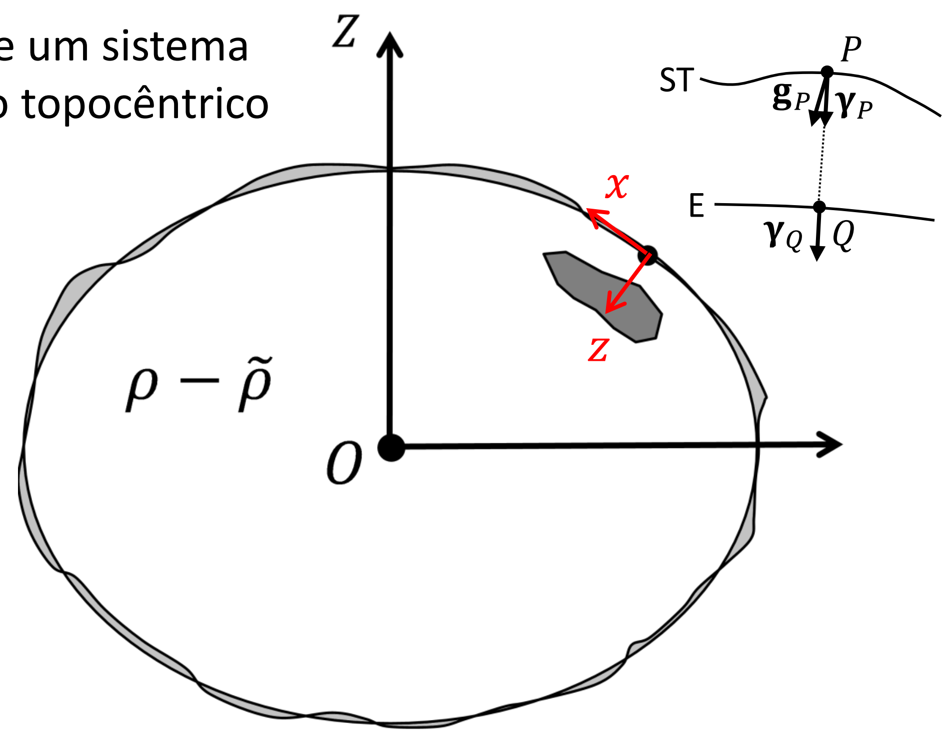


Considere um sistema Cartesiano topocêntrico



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$$\boldsymbol{\delta}\mathbf{g}_P = \mathbf{g}_P - \boldsymbol{\gamma}_P$$

Vetor distúrbio de gravidade

$$\mathbf{g}_P = \boldsymbol{\gamma}_P + \boldsymbol{\delta}\mathbf{g}_P$$

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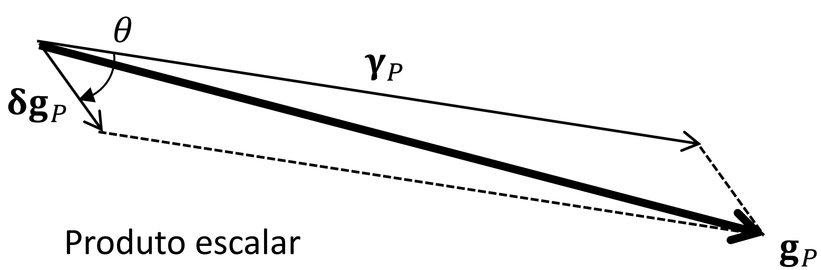

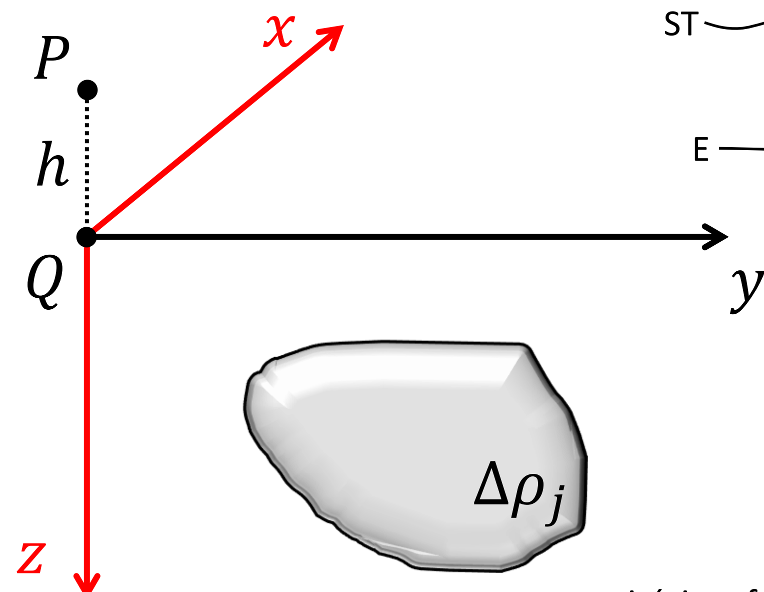

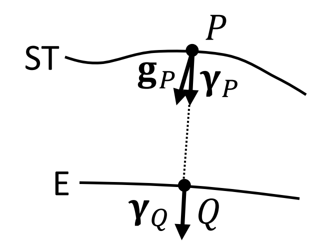

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j-ésima fonte gravimétrica

$$\delta g_P \approx \hat{\boldsymbol{\gamma}}_0^{\mathrm{T}} \boldsymbol{\delta}\mathbf{g}_P$$

$$\boldsymbol{\delta}\mathbf{g}_i = \mathbf{g}_i - \boldsymbol{\gamma}_i$$

Vetor distúrbio de gravidade

$$\mathbf{g}_i = \boldsymbol{\gamma}_i + \boldsymbol{\delta}\mathbf{g}_i$$

$$\delta g_i = g_i - \gamma_i$$

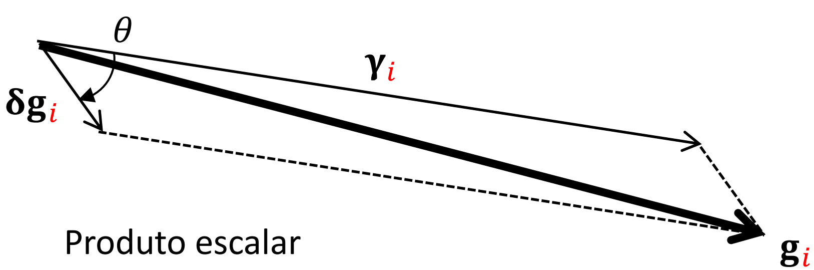
Distúrbio de gravidade

$$\gamma_i \gg \|\boldsymbol{\delta}\mathbf{g}_i\|$$

Condição observada na prática

$$\boldsymbol{\delta}\mathbf{g}_i = G \sum_j \Delta\rho_j \iiint_{v_j} \nabla \frac{1}{r_{ij}} dv$$

$$\boldsymbol{\gamma}_i = \gamma_i \hat{\boldsymbol{\gamma}}_0$$



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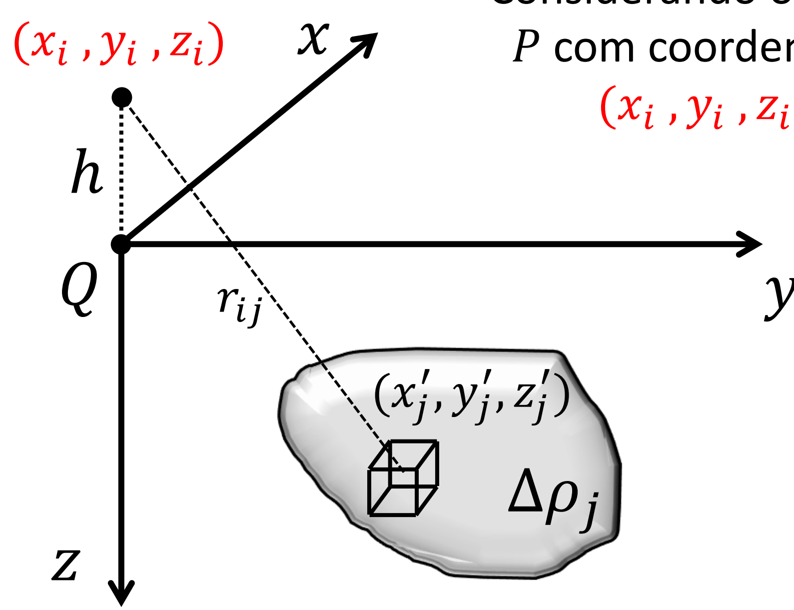
Considerando o ponto P com coordenadas (x_i, y_i, z_i)



$$r = \sqrt{(x - x')^2 + (y - y')^2 + (z - z')^2}$$

$$\boldsymbol{\delta}\mathbf{g}_i = \mathbf{g}_i - \boldsymbol{\gamma}_i$$

Vetor distúrbio de gravidade

$$\mathbf{g}_i = \boldsymbol{\gamma}_i + \boldsymbol{\delta}\mathbf{g}_i$$

Embora tudo esteja calculado na posição $(x_i\,, y_i\,, z_i)$, as equações também podem ser avaliadas em outros pontos próximos referidos a este mesmo sistema de coordenadas

$$\delta g_i = g_i - \gamma_i$$

Distúrbio de gravidade

$$\gamma_i \gg \|\boldsymbol{\delta}\mathbf{g}_i\|$$

Condição observada na prática

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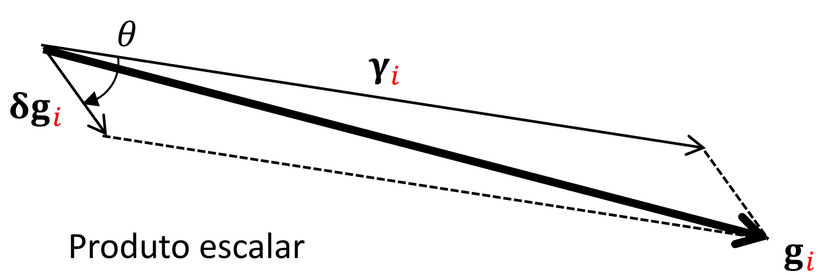

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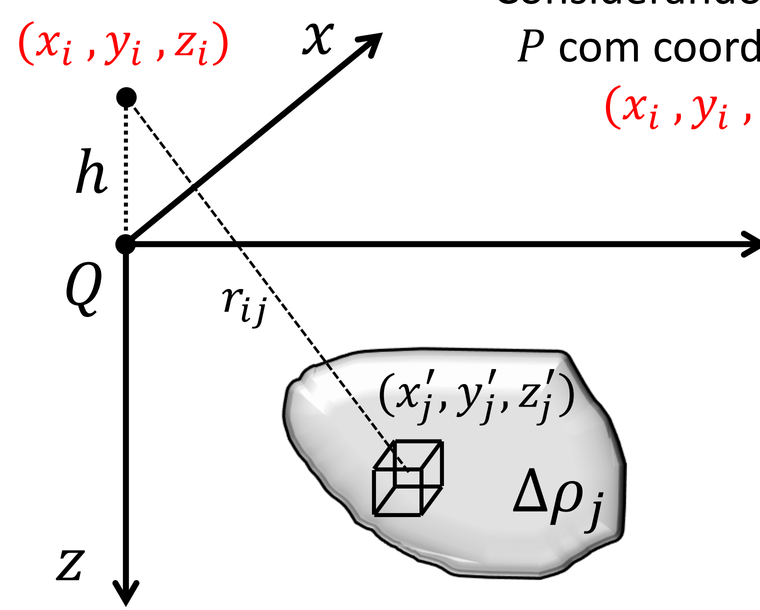

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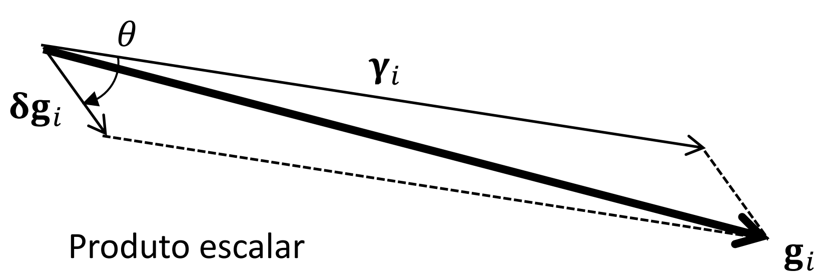
$$\gamma_i \gg \|\boldsymbol{\delta}\mathbf{g}_i\|$$

Condição observada na prática

$$\boldsymbol{\delta}\mathbf{g}_i = G \sum_j \Delta\rho_j \iiint_{v_j} \nabla \frac{1}{r_{ij}} dv$$

$$\boldsymbol{\gamma}_i = \gamma_i \hat{\boldsymbol{\gamma}}_0$$



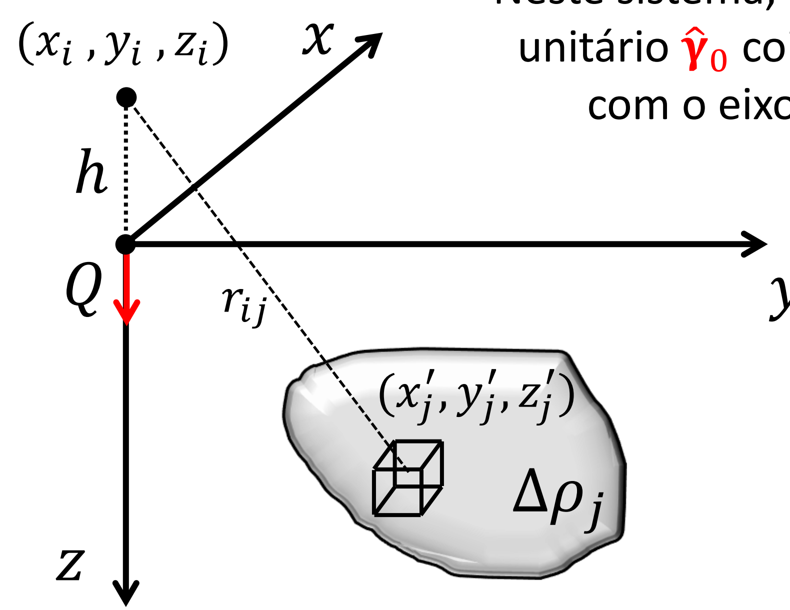
Produto escalar

$$\boxed{\begin{aligned} \mathbf{v}^{\mathrm{T}}\mathbf{w} &= v_x w_x + v_y w_y + v_z w_z \\ &= v\, w \cos\theta \end{aligned}}$$

$$g_i \approx \gamma_i + \hat{\boldsymbol{\gamma}}_0^{\mathrm{T}} \boldsymbol{\delta}\mathbf{g}_i$$

$$\delta g_i \approx \hat{\boldsymbol{\gamma}}_0^{\mathrm{T}} \boldsymbol{\delta}\mathbf{g}_i$$

Neste sistema, o vetor unitário $\hat{\boldsymbol{\gamma}}_0$ coincide com o eixo z



$$r = \sqrt{(x - x')^2 + (y - y')^2 + (z - z')^2}$$

$$\boldsymbol{\delta}\mathbf{g}_i = \mathbf{g}_i - \boldsymbol{\gamma}_i$$

Vetor distúrbio de gravidade

$$\mathbf{g}_i = \boldsymbol{\gamma}_i + \boldsymbol{\delta}\mathbf{g}_i$$

$$\delta g_i = g_i - \gamma_i$$

Distúrbio de gravidade

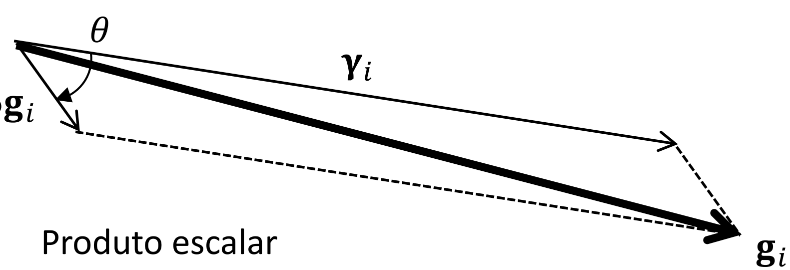
$$\gamma_i \gg \|\boldsymbol{\delta}\mathbf{g}_i\|$$

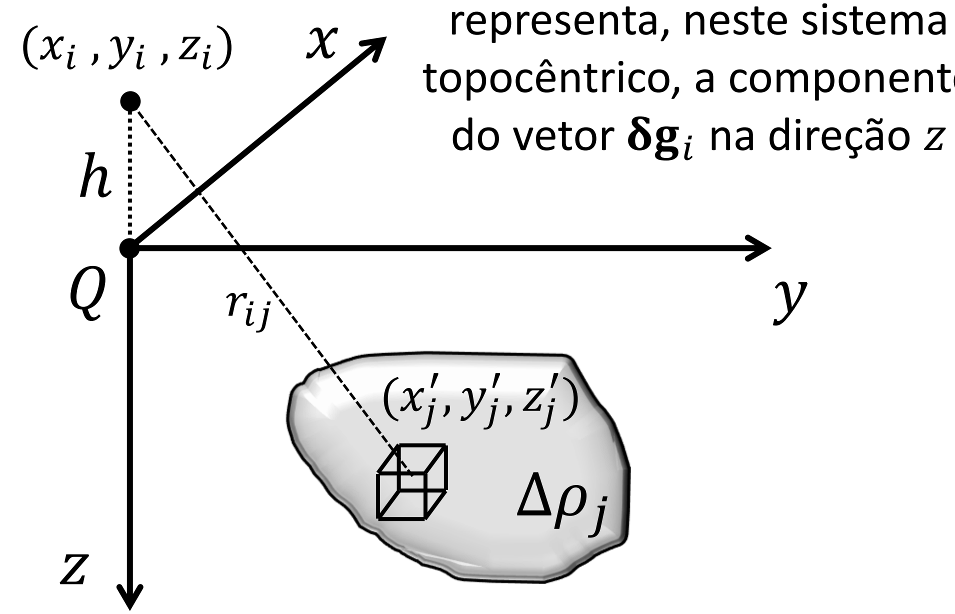
Condição observada na prática

$$\boldsymbol{\delta}\mathbf{g}_i = G \sum_j \Delta\rho_j \iiint_{v_j} \nabla \frac{1}{r_{ij}} dv$$

$$\boldsymbol{\gamma}_i = \gamma_i \hat{\boldsymbol{\gamma}}_0$$

Consequentemente, o distúrbio de gravidade representa, neste sistema topocêntrico, a componente do vetor $\boldsymbol{\delta}\mathbf{g}_i$ na direção z





Produto escalar

$$\boxed{\begin{aligned} \mathbf{v}^{\mathrm{T}}\mathbf{w} &= v_x w_x + v_y w_y + v_z w_z \\ &= v\ w\ cos\theta \end{aligned}}$$

$$g_i \approx \gamma_i + \hat{\boldsymbol{\gamma}}_0^{\mathrm{T}} \boldsymbol{\delta}\boldsymbol{g}_i$$

$$\delta g_i \approx \hat{\boldsymbol{\gamma}}_0^{\mathrm{T}} \boldsymbol{\delta}\mathbf{g}_i$$

$$r = \sqrt{(x - x')^2 + (y - y')^2 + (z - z')^2}$$

$$\boldsymbol{\delta}\mathbf{g}_i = \mathbf{g}_i - \boldsymbol{\gamma}_i$$

Vetor distúrbio de gravidade

$$\mathbf{g}_i = \boldsymbol{\gamma}_i + \boldsymbol{\delta}\mathbf{g}_i$$

$$\delta g_i = g_i - \gamma_i$$

Distúrbio de gravidade

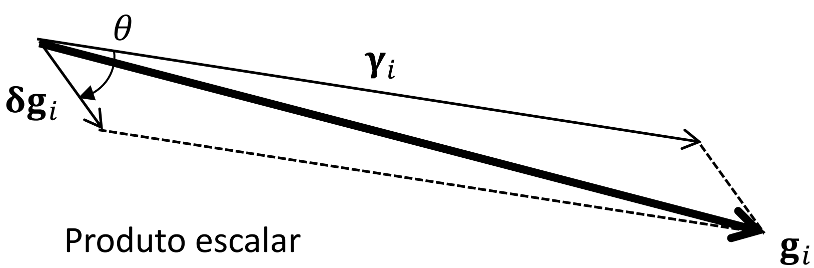
$$\gamma_i \gg \|\boldsymbol{\delta}\mathbf{g}_i\|$$

Condição observada na prática

$$\boldsymbol{\delta}\mathbf{g}_i = G \sum_j \Delta\rho_j \iiint_{v_j} \nabla \frac{1}{r_{ij}} dv$$

$$\boldsymbol{\gamma}_i = \gamma_i \hat{\boldsymbol{\gamma}}_0$$

Ou, analogamente, o distúrbio de gravidade representa a componente vertical da atração gravitacional exercida pelas fontes gravimétricas



Produto escalar

$$\boxed{\begin{aligned}\mathbf{v}^{\mathrm{T}}\mathbf{w} &= v_x w_x + v_y w_y + v_z w_z \\ &= v\, w\, cos\theta\end{aligned}}$$

$$g_i \approx \gamma_i + \hat{\boldsymbol{\gamma}}_0^{\mathrm{T}} \boldsymbol{\delta}\boldsymbol{g}_i$$

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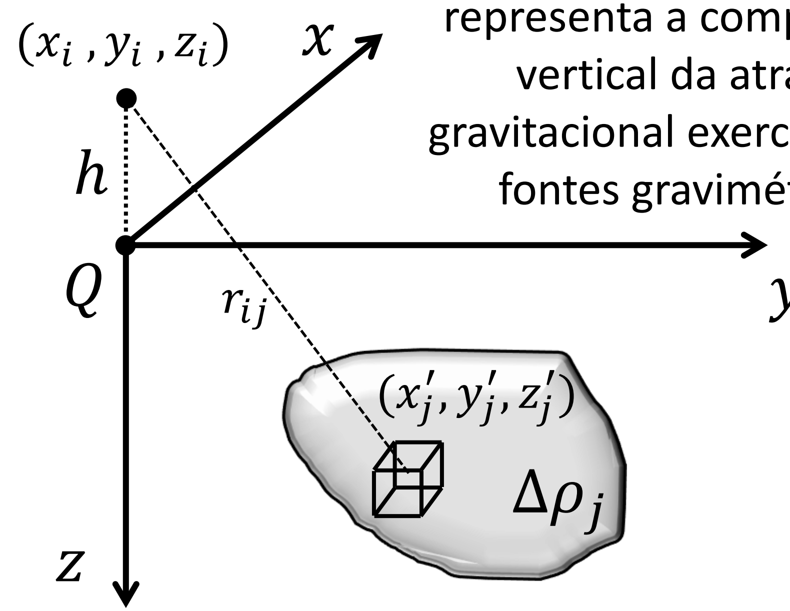


$$r = \sqrt{(x - x')^2 + (y - y')^2 + (z - z')^2}$$

$$\boldsymbol{\delta}\mathbf{g}_i = \mathbf{g}_i - \boldsymbol{\gamma}_i$$

Vetor distúrbio de gravidade

$$\mathbf{g}_i = \boldsymbol{\gamma}_i + \boldsymbol{\delta}\mathbf{g}_i$$

$$\delta g_i \approx G \sum_j \Delta\rho_j \iiint_{v_j} \frac{\partial}{\partial z} \frac{1}{r_{ij}} dv$$

$$\delta g_i = g_i - \gamma_i$$

Distúrbio de gravidade

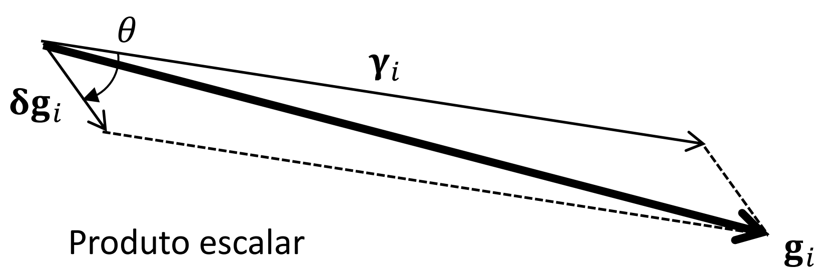
$$\gamma_i \gg \|\boldsymbol{\delta}\mathbf{g}_i\|$$

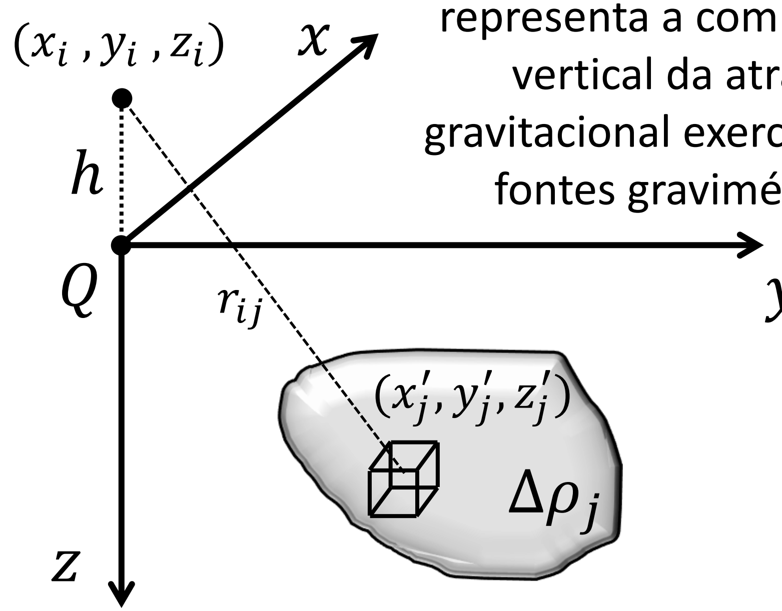
Condição observada na prática

$$\boldsymbol{\delta}\mathbf{g}_i = G \sum_j \Delta\rho_j \iiint_{v_j} \nabla \frac{1}{r_{ij}} dv$$

$$\boldsymbol{\gamma}_i = \gamma_i \hat{\boldsymbol{\gamma}}_0$$

Ou, analogamente, o distúrbio de gravidade representa a componente vertical da atração gravitacional exercida pelas fontes gravimétricas





Produto escalar

$$\boxed{\begin{aligned}\mathbf{v}^{\mathrm{T}}\mathbf{w} &= v_x w_x + v_y w_y + v_z w_z \\ &= v\, w\, cos\theta\end{aligned}}$$

$$g_i \approx \gamma_i + \hat{\boldsymbol{\gamma}}_0^{\mathrm{T}} \boldsymbol{\delta}\boldsymbol{g}_i$$

$$\delta g_i \approx \hat{\boldsymbol{\gamma}}_0^{\mathrm{T}} \boldsymbol{\delta}\mathbf{g}_i$$

$$r = \sqrt{(x - x')^2 + (y - y')^2 + (z - z')^2}$$

Referências

- Blakely, R. J., 1996, Potential theory in gravity and magnetic applications: Cambridge University Press.