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USO DE UMA INVERSÃO NUMÉRICA NA DETERMINAÇÃO DA PRESSÃO NO POÇO EM RESERVATÓRIOS DE GÁS NATURAL

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Uso de uma Inversão Numérica na Determinação da Pressão no Poço em Reservatórios de Gás Natural

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Resumo: Nas últimas décadas, o mercado de gás natural cresceu significativamente devido à produção a partir de novas reservas, à menor poluição gerada em comparação ao petróleo e à diversidade de aplicações. No que diz respeito às reservas petrolíferas, os avanços na recuperação do gás de xisto têm sido muito relevantes. Quando o gás flui nesses reservatórios, efeitos não descritos pela lei de Darcy podem ocorrer. Neste trabalho obtemos soluções analíticas para o escoamento de gás natural em reservatórios cilíndricos considerando o efeito de deslizamento. A metodologia emprega a pseudopressão, amplamente utilizada na indústria do petróleo, e uma inversão numérica de soluções no domínio de Laplace utilizando o algoritmo Stehfest. Desenvolvemos um código computacional em linguagem C para realizar as simulações. Os resultados mostraram a influência do escorregamento nos perfis de vazão de gás natural e na pressão de recuperação no poço produtor.

Palavras-chave: solução analítica, reservatório compartimentado, transformada de Laplace, algoritmo de Stehfest.

Abstract: In recent decades, the natural gas market has grown significantly due to production from new reserves, the lower pollution generated compared to oil, and the diversity of applications. Concerning petroleum reserves, the advances in recovering shale gas have been very relevant. When gas flows in these reservoirs, effects not described by Darcy's law may occur. In this work, we obtain analytical solutions for the flow of natural gas in cylindrical reservoirs considering the slippage effect. The methodology employs the pseudopressure, widely used in the oil industry, and a numerical inversion of solutions in the Laplace domain using the Stehfest algorithm. We developed a computational code in C language to carry out the simulations. The results showed the influence of slippage on the natural gas flow and recovery pressure profiles in the producing well.

Keywords: analytical solution, Laplace transform, natural gas reservoir, slippage, Stehfest's algorithm.

> cuperação do óleo e do gás armazenados na formações rochosas subterrâneas portadoras de hidrocarbonetos, de-

> nominadas reservatórios. Trata-se de uma indústria ca-

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1 Introdução

A indústria do petróleo tem como base a exploração, que é a busca por reservas, e a produção, que vem a ser a re-

racterizada pelo forte investimento tecnológico em áreas muito diversificadas, tais como a perfuração e a comple-CALIBRE - Revista Brasiliense de Engenharia e Física Aplitação de poços, o estudo das propriedades de fluido, a cada – Copyright ® 2023, Faculdades ICESP

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análise das propriedades de rocha, a escolha das técnicas de injeção de fluidos, a elevação dos fluidos presentes no poço, a caracterização do sistema poço-reservatório e a modelagem físico-matemática do escoamento no reservatório, entre outras.

Dentro do contexto exposto, o objetivo central da pesquisa e do desenvolvimento na indústria de Óleo & Gás é maximizar o fator de recuperação de hidrocarbonetos, dentro de um cenário técnico e econômico viáveis, levando em consideração que nas últimas décadas aumentou o interesse pelos reservatórios de gás natural. Isso ocorreu em função dos avanços ocorridos na descoberta de reservas e no transporte e armazenamento deste insumo, além do crescimento dos mercados consumidores de gás. Tais fatos levaram a um aumento dos estudos voltados para o aproveitamento de gás natural em diversas áreas.

1.1 Produção e consumo de gás natural

Historicamente [33], o gás natural foi descoberto na Pérsia entre 6000 e 2000 a.C. Na China, um manuscrito indica o ano de 347 a.C. como o da sua primeira utilização. Na Europa, se deu, segundo registros, em meados do século XVII, mas ainda sem a sua produção comercial. De acordo com a mesma fonte, apenas em 1885, com os estudos realizados por Robert Bunsen, para a queima de misturas de ar e gás natural, é que foi possível utilizar as potencialidades desse combustível.

No Brasil, as primeiras descobertas de gás natural de origem fóssil ocorreram em 1940, em poços no estado da Bahia, com a sua expansão posterior para o eixo Rio-São Paulo, a partir do início da produção na Bacia de Campos [18]. Em agosto de 1996, o Brasil firmou um contrato de importação de gás natural da Bolívia por intermédio das Jazidas Petrolíferas Fiscais Bolivianas (YPFB). Assim, em 1997, iniciaram as obras de construção do gasoduto GASBOL, interligando Santa Cruz de La Sierra à Guararema, município de São Paulo [24]. Ao longo de 20 anos, tem sido garantido um fornecimento de 30 milhões de metros cúbicos por dia para o país.

Ademais, o gás natural vem ganhando importância como fonte de energia, devido ao seu menor impacto ambiental em relação às outras fontes fósseis (óleo e carvão) e à diversidade de utilizações. Principalmente, quando usado na área de transporte. No Brasil, ele tem sido uma alternativa à gasolina e ao óleo diesel. Por esse motivo, o consumo de gás natural veicular (GNV) subiu de 1,35 para 6,71 milhões de metros cúbicos por dia, no período de 2001 a 2006 [27].

Define-se o gás natural fóssil como sendo um combustível não renovável, encontrado em jazidas subterrâneas [17]. Um reservatório típico (Figura [1]) é uma formação rochosa porosa, ou seja, composta por um arcabouço sólido que possui espaços, os poros, onde fluidos podem estar armazenados. O gás natural é uma mistura de hidrocarbonetos que, quando em condições de superfície se apresenta na forma gasosa, sendo preponderantes

o metano (CH₄), com cerca de mais de 80% da composição, e o etano (C₂H₆), alcançando mais de 10% da composição. Em menores quantidades aparecem o propano (C₃H₈) e o butano (C₄H₁₀), além de outros gases considerados como impurezas (por exemplo, N₂ e CO₂). Do ponto de vista da sua explotação, ele pode ser obtido a partir de reservatórios de gás: seco (há exclusivamente gás do reservatório até a superfície), úmido (algum líquido surge no poço e/ou nas instalações de superfície) ou de condensação retrógrada (condensação ocorre ainda no reservatório).

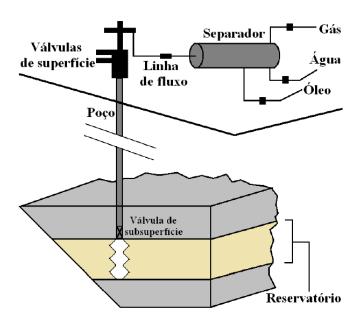


Figura 1: Sistema de produção de hidrocarbonetos. Fonte: os autores.

Por outro lado, uma outra classificação leva em conta a sua origem: gás livre nos poros da rocha, gás dissolvido no óleo e/ou na água e gás adsorvido. Segundo a Agência Nacional de Petróleo, Gás Natural e Biocombustíveis [5], ele pode se encontrar associado ou não associado, sendo o primeiro aquele originado em um processo no qual o óleo é o objetivo principal, predominante na produção brasileira. O segundo, é aquele oriundo somente do conteúdo de gás natural presente no reservatório (Figura [2]). Aqui, estuda-se somente a produção de gás que encontrase não associado, pois considera-se apenas a existência do gás natural.

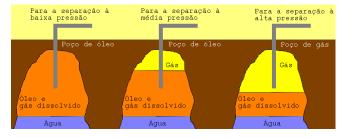


Figura 2: Gás associado e não-associado. Fonte: os autores.



1.2 Reservatórios do tipo shale gas

Os reservatórios portadores de hidrocarbonetos podem ser, em função da técnica de produção adotada, classificados em convencionais ou não-convencionais 17. Os convencionais são aqueles produzindo através de poços verticais. Eles são perfurados perpendicularmente ao acamadamento principal do reservatório. No caso dos não-convencionais, ao invés do uso de um poço vertical convencional é necessário o emprego de poços horizontais e/ou hidraulicamente fraturados, de modo a viabilizar economicamente a produção 2 4 32 34. Os poços horizontais são perfurados paralelamente ao acamadamento principal, sendo utilizados para ampliar a área de contato entre o poço e o reservatório. Já no fraturamento hidráulico, fluido é injetado a alta pressão no reservatório provocando o aparecimento de fissuras, fraturas, que atuam como canais que facilitam a passagem do fluido do meio poroso para o poço.

Desenvolvimentos industriais, principalmente nas últimas duas décadas, focados na perfuração de poços horizontais hidraulicamente fraturados permitiram a produção em reservatórios não-convencionais de gás natural, tais como os reservatórios do tipo shale gas [7, 23, 37], os quais tem se tornando cada vez mais importantes para a produção de gás no cenário mundial. O shale, ou folhelho, é uma rocha de estrutura laminar (em folhas), composta por argila de granulação muito fina. Apesar de apresentar um baixo armazenamento de fluidos e baixa capacidade de transporte, eles estão sendo explotados devido à sua extensão, à perfuração de poços horizontais hidraulicamente fraturados e à ocorrência de fenômenos físicos específicos, tais como o escorregamento [8, 12, 20] e a adsorção [3, 23, 31].

1.3 Análise de testes de pressão

Na análise de testes de pressão em poços (Well Testing Analisys) [16], realiza-se, por exemplo, a produção em um poço sob condições controladas de vazão, medindo-se a sua pressão ao longo do tempo. De posse dessa informação, de parte das características do sistema pocoreservatório e de um modelo físico-matemático para o escoamento, o objetivo dos estudos de análise de testes é o de determinar as propriedades do sistema poçoreservatório desconhecidas. A medida da capacidade de o meio poroso transportar fluidos, associada à permeabilidade absoluta, pode, por exemplo, ser estimada por essa análise [13], [19]. No entanto, nos reservatórios do tipo shale, é mais difícil realizar testes com esse intuito justamente pela demora com que o fluido se movimenta em meios com baixa permeabilidade 31. Nela, é possível, também, avaliar o potencial de produção das reservas de hidrocarbonetos, dentre outras propriedades, de forma a se realizar a chamada caracterização do sistema poço-reservatório, visando ao planejamento otimizado da produção comercial.

Um teste de pressão é, de fato, um experimento em escala de campo, sujeito ao aparecimento de "ruídos" 21. Dessa forma, os dados coletados passam por um pós-processamento, de modo a favorecer a sua interpretação acurada. De fato, a análise de testes é essencialmente a proposição de problemas de inversos, nos quais os modelos para o escoamento podem ser analíticos ou numéricos. Nesse sentido, torna-se relevante a modelagem físico-matemática do escoamento para que uma caracterização realística seja obtida. Por exemplo, se por meio da geofísica sabe-se da existência de uma falha selante (estrutura que causa um bloqueio ao escoamento) é necessário que o modelo de escoamento, analítico ou numérico, incorpore também tal ocorrência. Com o passar do tempo, diferentes testes foram desenvolvidos pela indústria para se avaliar diferentes propriedades das configurações de sistemas poço-reservatório [11] [19]:

3

- Flow-After-Flow (FAF), também conhecido por teste de quatro pontos, no qual o poço é submetido a uma sequência de períodos de vazão (fluxo) crescente, e ao fim, submetido a um período de poço fechado (estática);
- Isócrono, criado para diminuir o tempo do teste e a quantidade de gás produzido, inicia-se como o FAF, porém, é seguido por período de estática até atingir a pressão média do reservatório;
- Isócrono Modificado, que tem o intuito de melhorar o teste isócrono encurtando ainda mais o seu tempo, cuja diferença é a existência de intervalos de fluxo e de estática de mesma duração;
- 4. Testes de Fluxo, nos quais determina-se a produção no poço para uma taxa constante e conhecida, registrando-se a variação da pressão (medida no fundo do poço) ao longo do tempo;
- 5. Testes de Crescimento de Pressão, os quais consistem em usar os dados de pressão no poço, obtidos durante o período de estática, e aplicá-los após o mesmo ter sido submetido a um período de fluxo.

Essa área é tão relevante para a indústria de Óleo & Gás que existem empresas especializadas e dedicadas somente a esse campo de trabalho.

2 Escoamento monofásico de gás em meios porosos

Nesta seção, são apresentadas as correlações usadas na determinação das propriedades do fluido e da rocha, assim como é apresentada a Equação de Difusividade Hidráulica (EDH), para o escoamento de gás natural.

2.1 Propriedades da rocha

No reservatório, o fluido se encontra armazenado na rocha, nos poros, sendo a porosidade efetiva (ϕ) a propriedade que mede a capacidade do seu armazenamento. Ela



é definida como sendo a relação entre o volume de vazios da formação rochosa (considerando apenas os poros interconectados), V_p , e o volume total da mesma, V_t [26],

$$\phi = \frac{V_p}{V_t} \tag{1}$$

e, neste trabalho, considera-se que a formação rochosa possui uma porosidade constante.

Outra propriedade importante do reservatório é a permeabilidade, k. Conforme mencionado, ela fornece uma medida da resistência que o meio poroso impõe ao escoamento do fluido através do mesmo. Ela é chamada de absoluta quando medida no caso do escoamento monofásico de um líquido no interior dele, e trata-se de uma propriedade de rocha exclusivamente.

2.2 Propriedades do fluido

No caso do fluido, inicia-se pela densidade, γ , que é a razão entre a massa molecular do gás e a massa molecular do ar,

$$\gamma = \frac{M}{M_{ar}} = \frac{M}{28,96}.\tag{2}$$

A partir dela e das condições de pressão e de temperatura pode-se definir outras propriedades do gás natural.

No caso de misturas, como é o caso do gás natural, a pressão (p_{pc}) e a temperatura (T_{pc}) pseudo-críticas podem ser obtidas via as seguintes correlações 30

$$p_{pc} = 756, 8 - 131\gamma - 3, 6\gamma^2 \tag{3}$$

е

$$T_{pc} = 169, 2 - 349, 5\gamma - 74\gamma^2, \tag{4}$$

onde as unidades de pressão e temperatura estão em psi e Rankine, respectivamente.

A seguir, introduz-se a pressão pseudo-reduzida

$$p_{pr} = \frac{p}{p_{pc}} \tag{5}$$

e a temperatura pseudo-reduzida

$$T_{pr} = \frac{T}{T_{nc}},\tag{6}$$

que são utilizadas na determinação do fator de compressibilidade do gás, também chamado de fator de desvio de gás real, Z, um número adimensional.

Dranchuk e Abou-Kassem (1975) [14] propuseram uma equação de estado a 11 coeficientes, a partir dos dados de Standing e Katz (1942) [28], e a extrapolaram para o uso com maiores pressões reduzidas. Ela foi ajustada usando 1.500 pontos e possui um valor médio do erro de 0,486%. O fator de desvio calculado é acurado para as faixas: $0,2 \le p_r < 30$ e $1,0 < T_r \le 3,0$; $p_r < 1,0$ e $0,7 < T_r \le 1,0$. Entretanto, ela leva a resultados inadequados para $T_r = 1,0$ e $p_r > 1,0$. A sua expressão é dada por [26]

$$Z = 1 + \left(A_1 + \frac{A_2}{T_{pr}} + \frac{A_3}{T_{pr}^3} + \frac{A_4}{T_{pr}^4} + \frac{A_5}{T_{pr}^5}\right) \rho_{pr}$$

$$+ \left(A_6 + \frac{A_7}{T_{pr}} + \frac{A_8}{T_{pr}^2} \right) \rho_{pr}^2 + -A_9 \left(\frac{A_7}{T_{pr}} + \frac{A_8}{T_{pr}^2} \right) \rho_{pr}^5$$

+
$$A_{10} \left(1 + A_{11} \rho_{pr}^2\right) \frac{\rho_{pr}^2}{T_{pr}^3} \exp\left(-A_{11} \rho_{pr}^2\right),$$
 (7)

onde os valores dos coeficientes A podem ser encontrados na Tabela $\boxed{1}$ e

$$\rho_{pr} = \frac{0.27p_{pr}}{ZT_{nr}}. (8)$$

Tabela 1 Coeficientes A_i para a Eq. (7)

A_i	Valor
A_1	$0,\!3265$
A_2	-1,0700
A_3	-0,5339
A_4	0,01569
A_5	-0,05165
A_6	0,5475
A_7	-0,7361
A_8	0,1844
A_9	$0,\!1056$
A_{10}	0,6134
A_{11}	0,7210

Aqui, a Eq. (7) é resolvida iterativamente usando o método de Newton-Raphson [10]. Conhecido Z, é possível computar a compressibilidade isotérmica do gás, c_q ,

$$c_g = \frac{1}{p} - \frac{1}{Z} \frac{dZ}{dp}. (9)$$

Quanto à avaliação da massa específica, ρ , utiliza-se uma equação de estado para gases reais,

$$\rho = \frac{pM}{ZRT},\tag{10}$$

onde R é a constante universal dos gases.

Finalmente, para a viscosidade (μ) optou-se por uma das correlações de uso mais difundido [22],

$$\mu = B \ 10^{-4} \exp\left(C\rho_{\mu}^{D}\right),\tag{11}$$

onde a viscosidade é dada em centipoise e

$$B = \frac{(9,4+0,02M)T^{1,5}}{209+19M+T},$$
(12)

$$C = 3.5 + \frac{986}{T} + 0.01M, (13)$$

$$D = 2, 4 - 0, 2X, (14)$$

onde

$$\rho_{\mu} = \left(\frac{T^{1,5}}{23,132}\right) \frac{p\gamma}{ZT}.\tag{15}$$



Uso de uma inversão numérica

2.3 A lei de Darcy modificada

A conhecida lei de Darcy clássica foi obtida experimentalmente [26], contudo, atualmente a sua derivação teórica pode ser obtida por métodos matemático rigorosos [35]. Na sua forma diferencial [15],

$$\mathbf{v} = -\frac{\mathbf{k}}{\mu}(\nabla p - \rho g \nabla D),\tag{16}$$

onde ${\bf v}$ é a velocidade de Darcy, g é a magnitude da aceleração da gravidade, D é a profundidade e ${\bf k}$ é o tensor de permeabilidade absoluta do meio poroso. A lei de Darcy é válida estritamente para um conjunto de hipóteses [6], que inclui, por exemplo, escoamento a baixas velocidades. Na literatura, usa-se a denominação de escoamento não-Darcy quando a lei clássica não descreve mais adequadamente o escoamento. Em geral, ela é substituída pela sua versão modificada como, por exemplo,

$$\mathbf{v} = -\frac{\mathbf{k}_a}{\mu} (\nabla p - \rho g \nabla D), \tag{17}$$

na qual foi introduzido o tensor de permeabilidade aparente, \mathbf{k}_a . Nele, neste trabalho, são incorporados os efeitos não-Darcy.

Klinkenberg (1941) [20], para incorporar o efeito do escorregamento do gás (deslizamento) em um meio poroso, observou que a permeabilidade aparente poderia ser correlacionada com a pressão,

$$\mathbf{k}_a = \left(1 + \frac{b}{p}\right)\mathbf{k},\tag{18}$$

onde b é o fator de Klinkenberg.

2.4 Equação da Difusividade Hidráulica

O princípio da conservação da massa aplicada ao escoamento em um meio poroso resulta na equação diferencial parcial [15]

$$-\nabla \cdot (\rho \mathbf{v}) + \frac{q_m}{V_b} = \frac{\partial}{\partial t} \left(\rho \phi \right), \tag{19}$$

onde q_m é um termo fonte que contabiliza a retirada/injeção de massa no reservatório e V_b é o volume total.

A equação que governa o escoamento de gases através de meios porosos, denominada Equação da Difusividade Hidráulica (EDH), resulta da combinação da equação do balanço de massa, da lei de Darcy modificada e da equação de estado para gases reais [26]. Neste estudo, assume-se as seguintes hipóteses:

- meio poroso homogêneo em termos da permeabilidade absoluta;
- 2. escoamento unidirecional horizontal;
- 3. escoamento isotérmico;
- 4. pequenos gradientes de pressão;

- 5. forças gravitacionais negligenciadas;
- 6. fluidos e rocha não reagentes entre si;
- 7. não há estocagem no poço;
- 8. não há dano à formação;
- 9. ausência de termo fonte/sorvedouro.

Portanto, da lei de Darcy modificada e do balanço de massa tem-se, para o escoamento unidimensional na direção do eixo x,

5

$$\frac{\partial}{\partial x} \left(\rho \frac{k_a}{\mu} \frac{\partial p}{\partial x} \right) = \frac{\partial}{\partial t} (\phi \rho). \tag{20}$$

Logo, de forma similar, obtém-se no caso do fluxo radial horizontal:

$$\frac{1}{r}\frac{\partial}{\partial r}\left(\rho\frac{k_a}{\mu}r\frac{\partial p}{\partial r}\right) = \frac{\partial}{\partial t}(\phi\rho). \tag{21}$$

Neste trabalho, obtém-se a solução da Eq. (21) utilizando o conceito de pseudo-pressão [1] para o escoamento de gás natural na presença do efeito de escorregamento. Desta forma, seguindo Wang (2013) [31], ela é dada na forma

$$m(p) = 2 \int_{p_b}^p \frac{p'}{\mu Z} \left(1 + \frac{b}{p} \right) dp', \tag{22}$$

onde p_b é uma pressão de referência arbitrária.

Assim, a partir da introdução da pseudo-pressão e considerando-se a porosidade constante, pode-se reescrever a Eq. (21) na forma [31]

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial m}{\partial r}\right) = \left(\frac{\phi\mu c_g}{k}\right)\frac{\partial m}{\partial t} = \frac{1}{\eta}\frac{\partial m}{\partial t}.$$
 (23)

No cálculo de η , Wang (2013) [31] introduziu uma pressão média ponderada pelo volume V_i , associado à pressão p_i , que deve ser utilizada no cômputo da permeabilidade aparente,

$$\overline{p} \approx \frac{\sum_{i} (V_i p_i)}{\sum_{i} V_i},\tag{24}$$

sendo que inicialmente $\overline{p} \approx P_i$ [36], a pressão inicial do sistema. Contudo, Wang (1993) [31] e Wu et al. (1998) [36] não detalharam como deve ser a distribuição dos pontos quando do cálculo dela. Tratar-se-á desse tópico mais adiante.

2.5 Determinação da variação da pseudo-pressão

Prossegue-se com a introdução da definição da variação da pseudo-pressão

$$\Delta m(r,t) = m(P_i) - m(r,t), \tag{25}$$

de modo que é possível reescrever a equação governante na forma.

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial\Delta m}{\partial r}\right) = \frac{1}{\eta}\frac{\partial}{\partial t}\Delta m,\tag{26}$$



que deve ser resolvida considerando-se a seguinte condição inicial:

$$\Delta m \left(r, t = 0 \right) = 0, \tag{27}$$

sendo a pseudo-pressão, inicialmente, uniforme em todo o reservatório [26].

Aplicando-se a transformada de Laplace [25] à Eq. ([26]) obtém-se

$$\frac{1}{r}\frac{d\Delta\overline{m}}{dr} + \frac{d^2\Delta\overline{m}}{dr^2} - \frac{s}{\eta}\Delta\overline{m} = 0, \tag{28}$$

que está na forma da equação modificada de Bessel, cuja solução é dada por **25**

$$\Delta \overline{m}(s) = C_1 I_0 \left(r \sqrt{s/\eta} \right) + C_2 K_0 \left(r \sqrt{s/\eta} \right), \qquad (29)$$

onde I_0 e K_0 são as funções modificadas de Bessel [25].

Devido à definição da transformada de Laplace 25, para pequenos valores de s têm-se a solução para tempos longos, no domínio real, e para valores altos obtém-se o comportamento para tempos curtos. Deste modo, para o estudo do comportamento da pressão no poço, nos instantes iniciais da produção, uma das metas na análise dos testes de pressão, torna-se necessária a determinação das funções de Bessel para valores altos de s.

2.6 Condições de contorno e solução no espaço de Laplace

Busca-se encontrar a solução para o escoamento radial em um reservatório cilíndrico fechado, de raio r_e , cuja pressão inicial é uniforme. O escoamento se dá em regime transiente, o poço vertical produtor penetra totalmente na formação e a vazão de produção é constante. Portanto, a condição de contorno na sua fronteira externa é dada por

$$\left(\frac{\partial \Delta m}{\partial r}\right)_{r=r_s} = 0,
\tag{30}$$

ou ainda, aplicando-se a transformada de Laplace,

$$\left(\frac{\partial \Delta \overline{m}}{\partial r}\right)_{r=r_e} = 0.$$
(31)

Portanto, da solução (29) e da condição de contorno (31),

$$\left(\frac{\partial \Delta \overline{m}}{\partial r}\right)_{r=r_e} = C_1 \sqrt{s/\eta} I_1 \left(r_e \sqrt{s/\eta}\right)$$

$$-C_2\sqrt{s/\eta}K_1\left(r_e\sqrt{s/\eta}\right) = 0, \quad (32)$$

onde $I_1 = I_0'(z)$ e $K_1 = K_0'(z)$, ou ainda, reescrevendo-a em função de C_2 ,

$$C_2 = C_1 \left[\frac{I_1 \left(r_e \sqrt{s/\eta} \right)}{K_1 \left(r_e \sqrt{s/\eta} \right)} \right], \tag{33}$$

que, após substituição na Eq. (29), resulta em

$$\Delta \overline{m}(s) = C_1 I_0 \left(r \sqrt{s/\eta} \right)$$

$$+ C_1 \left[\frac{K_0 \left(r \sqrt{s/\eta} \right) I_1 \left(r_e \sqrt{s/\eta} \right)}{K_1 \left(r_e \sqrt{s/\eta} \right)} \right]. \tag{34}$$

Na sequência, utiliza-se a condição de contorno interna [19],

$$\left(r\frac{\partial\Delta\overline{m}}{\partial r}\right)_{r=r,\dots} = -\frac{q_w p_w}{Z_w \pi k h s},$$
(35)

onde q_w , p_w e Z_w são, respectivamente, a vazão, a pressão e o fator de compressibilidade do gás no poço, de modo a se determinar a constante C_1

$$C_{1} = \left(\frac{q_{w}p_{w}}{Z_{w}\pi kh}\right) \left[\frac{K_{r_{e}}}{sr_{w}\sqrt{s/\eta}\left(I_{r_{e}}K_{r_{w}} - I_{r_{w}}K_{r_{e}}\right)}\right],(36)$$

onde

$$K_{r_e} = K_1 \left(r_e \sqrt{s/\eta} \right), \tag{37}$$

$$I_{r_e} = I_1 \left(r_e \sqrt{s/\eta} \right), \tag{38}$$

$$K_{r_w} = K_1 \left(r_w \sqrt{s/\eta} \right), \tag{39}$$

$$I_{r_w} = I_1 \left(r_w \sqrt{s/\eta} \right) \tag{40}$$

e, então, introduz-se o valor obtido para C_1 na Eq. (33),

$$C_{2} = \left(\frac{q_{w}p_{w}}{Z_{w}\pi kh}\right) \left[\frac{I_{r_{e}}}{s \, r_{w}\sqrt{s/\eta} \left(I_{r_{e}}K_{r_{w}} - I_{r_{w}}K_{r_{e}}\right)}\right].(41)$$

Por último, substitui-se as Eqs. (36) e (41) na Eq. (29) e leva-se em consideração a equação de estado para um gás real,

$$\Delta \overline{m}(s) = \left(\frac{q_0 p_0 T}{T_0 \pi k h}\right) \left[\frac{I_0 \left(r \sqrt{s/\eta}\right) K_{r_e} + I_{r_e} K_0 \left(r \sqrt{s/\eta}\right)}{s \, r_w \sqrt{s/\eta} \left(I_{r_e} K_{r_w} - I_{r_w} K_{r_e}\right)}\right],\tag{42}$$

onde p_0 e T_0 são a pressão e temperatura de referência e a solução no domínio do tempo será obtida mediante uma inversão numérica.

2.7 Inversão Numérica

Na resolução da equação governante, a sua solução foi obtida no domínio de Laplace em termos da variação da pseudo-pressão. Portanto, se faz necessária a utilização de uma técnica de inversão numérica para que ela possa ser determinada no domínio do tempo. Aqui, optou-se



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pela aplicação do algoritmo de Stehfest, o qual é muito utilizado na indústria de Óleo & Gás. Ele é dado por [29]

$$\Delta m(t) = \frac{\ln 2}{t} \sum_{i=1}^{N} \alpha_i \ \Delta \overline{m} \left(\frac{\ln 2}{t} i \right), \tag{43}$$

sendo N a quantidade de termos no somatório e, para problemas de escoamento, utiliza-se os números pares no intervalo dado por $6 \le N \le 18$. Os valores de α_i variam em função da quantidade de termos, e são calculados via

$$\alpha_i = (-1)^{[(N/2)+i]}$$

$$\cdot \sum_{j=(i+1)/2}^{\min(i,N/2)} \frac{j^{N/2} (2j)!}{[(N/2)-j]!j! (j-1)! (i-j)! (2j-i)!}.$$
(44)

No código desenvolvido neste trabalho é possível se trabalhar com $N=8,\,10,\,12,\,14$ e 16.

3 Resultados Numéricos

Nesta seção, são apresentados os resultados obtidos para o caso do escoamento radial em um reservatório cilíndrico finito, ou seja, para uma jazida na qual a fronteira externa encontra-se fechada.

As variações de pressão no poço mostradas são obtidas em um processo que começa, para uma pressão inicial uniforme, mediante a conversão da pressão em pseudo-pressão usando uma tabela construída previamente via integração numérica. Em seguida, a partir dos valores iniciais de η , obtém-se a solução da equação governante no domínio de Laplace. Finalmente, após a inversão numérica, via o algoritmo de Stehfest, determinase as pseudo-pressões no domínio real e na sequência, via interpolação, as pressões. A partir delas são calculadas as pressões médias necessárias para o cômputo de η . Findo o processo, todo os procedimentos são repetidos para um novo tempo, até que seja alcançado o tempo máximo de simulação (t_{max}) .

3.1 Determinação de η

Para se determinar η , ao longo dos cálculos, é necessário o conhecimento prévio da pressão média, segundo a estratégia proposta por [36] e [31]. Contudo, os autores não indicam o critério que deve ser empregado na distribuição dos pontos para o cálculo da pressão no domínio. Neste trabalho, adotou-se um arranjo comumente utilizado na área de simulação de reservatórios [15] para problemas em geometria cilíndrica, elaborado com base em estudos analíticos para escoamentos em meios porosos. Dessa forma, usa-se as seguintes regras de cálculo, onde nr é o número total de pontos no interior do domínio cilíndrico,

$$\beta_{lg} = \left(\frac{r_e}{r_w}\right)^{nr-1},\tag{45}$$

com os pontos espaçados de acordo com

$$r_{i+1} = \beta_{la} r_i, \tag{46}$$

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onde i=1,2,3,...,nr-1 e, para a determinação dos volumes, os valores dos raios são elevados ao quadrado

$$r_{i+1/2}^2 = \frac{r_{i+1}^2 - r_i^2}{\log_e(r_{i+1}^2/r_i^2)}. (47)$$

Dessa forma, é garantido que o fluxo através das células, calculados empregando as equações discretas, seja igual àquele determinado pela forma contínua da lei de Darcy 15.

3.2 Derivada de Bourdet

A derivada de Bourdet [9], presente no gráfico diagnóstico, favorece a identificação dos regimes de escoamento no sistema poço-reservatório ao destacar as variações no comportamento da pressão no poço. Na implementação desta derivada, adota-se um esquema a três pontos

$$\left(\frac{d\Delta p}{d\ln\Delta t}\right)_{j} = \frac{\Delta p_{j} - \Delta p_{L}}{\ln\left(\Delta t_{j}/\Delta t_{L}\right)} \frac{\ln\left(\Delta t_{R}/\Delta t_{j}\right)}{\ln\left(\Delta t_{R}/\Delta t_{L}\right)} + \frac{\Delta p_{R} - \Delta p_{j}}{\ln\left(\Delta t_{R}/\Delta t_{j}\right)} \frac{\ln\left(\Delta t_{j}/\Delta t_{L}\right)}{\ln\left(\Delta t_{R}/\Delta t_{L}\right)}, \quad j \geq 2,$$
(48)

onde L=j-1, e R=j+1. Assim, no primeiro e no último tempo de registro da pressão não calcula-se a derivada. Aqui, utiliza-se a variação de pressão no poço (Δp_{wf}) para a construção da derivada de Bourdet.

3.3 Resultados para a variação de pressão no poço

Para os casos estudados, os diferentes parâmetros e propriedades especificados podem ser encontrados na Tabela 2. Ressalta-se que trabalha-se com um sistema poçoreservatório que possui um limite externo definido (limitação na quantidade de fluido). Os resultados são gerados com um passo de tempo inicial (Δt_i) que é multiplicado por uma razão de crescimento (F_t) até que o número total de passos, $N_{\Delta t}$, seja alcançado, sendo mantido constante daí em diante.

A Figura $\ 3$ traz os resultados para a variação de r_e , o raio externo. No gráfico diagnóstico, nota-se as mudanças da derivada que surgem devido à percepção dos efeitos de fronteira (usadas, na prática, em nos testes de pressão para a estimativa do tamanho da jazida, e identificados quando do início da região com uma curva crescente). Quanto maior o r_e , maior será o tempo necessário para se perceber os seus efeitos. A curvas da derivada de Bourdet e da variação da pressão, para r_e =50 m, convergindo após o aparecimento do efeito de fronteira, trata-se de um comportamento reportado na literatura. Para que ele aparecesse para os demais casos deveria se realizar os cálculos por mais tempo para os reservatórios de raio externo mais longo.



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Tabela 2 Parâmetros e propriedades

Parâmetro	Valor
\overline{b}	$6.8 \ 10^4 \ Pa$
F_t	1,1
h	20,00 m
k	$1,00 \ 10^{-13} \ \mathrm{m}^2$
nr	10
N	10
$N_{\Delta t}$	100
p_0	$101,35 \ 10^3 \ Pa$
P_i	$2,00 \ 10^7 \ Pa$
q_0	$1,00 \ 10^{-3} \ \mathrm{std} \ \mathrm{m}^3/\mathrm{s}$
r_e	100 m
r_w	$0,10 \mathrm{\ m}$
T	344,44 K
T_0	288,71 K
γ_g	0,6
ϕ	$0,\!15$
Δt_i	10 s

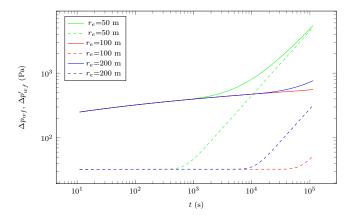


Figura 3: Queda de pressão no poço (linha contínua) e a sua derivada (linha tracejada) em função do tempo, variando o raio externo (r_e) .

Por outro lado, na Figura (gráfico diagnóstico) mostra a influência da variação da porosidade na percepção do efeito de fronteira. Como os valores de η são inversamente proporcionais a ϕ , quanto maiores forem os seus valores, mais tardiamente serão percebidas as mudanças de pressão na fronteira externa do reservatório. Até que os efeitos de fronteira sejam percebidos, as curvas para as derivadas são coincidentes, sendo que para menor porosidade a pressão muda mais cedo em relação ao valor inicial, quando comparado aos demais valores de porosidade.

Prossegue-se com a apresentação dos resultados correspondentes a diferentes valores da permeabilidade absoluta do reservatório, no gráfico diagnóstico da Figura Nesse caso, os seus valores influenciam diretamente nos de η , ou seja, quanto maiores forem as permeabilidades, maiores também serão os valores de η . Como consequência, o aparecimento dos efeitos de fronteira se dará precocemente em comparação ao caso anterior. Quanto maiores forem os valores de η , mais cedo ocorrerão os

efeitos de fronteira. Além disso, após o seu aparecimento, para os diferentes valores de k, as derivadas tendem a colapsar.

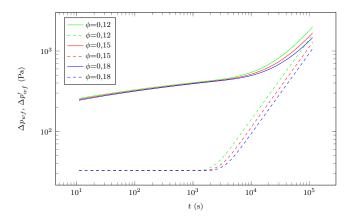


Figura 4: Queda de pressão no poço (linha contínua) e a sua derivada (linha tracejada) em função do tempo, variando a porosidade (ϕ) .

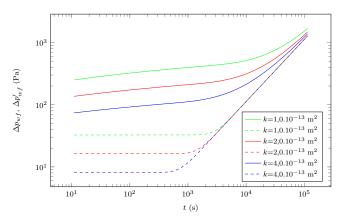


Figura 5: Queda de pressão no poço (linha contínua) e a sua derivada (linha tracejada) em função do tempo, variando a permeabilidade absoluta (k).

Por fim, variou-se os valores prescritos da vazão de produção, sendo que as curvas correspondentes podem ser vistas na Figura [6], no gráfico do tipo diagnóstico. Diferentemente dos casos anteriores, não há nenhuma região de concordância entre as curvas das derivadas. Para os maiores valores da vazão, o efeito de fronteira surge ligeiramente antes, quando comparado aos demais casos. Deve-se recordar que η é calculado a partir de um valor médio da pressão no reservatório, que é uma função da vazão de produção. Desta forma, diferentes valores de vazão implicam diferentes valores de η e na correção do efeito do escorregamento (que depende da pressão), influenciando, assim, o momento no qual se dá o surgimento do efeito de fronteira (de forma distinta do caso de óleo com η constante).



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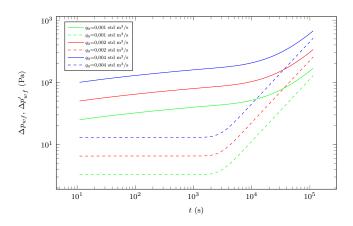


Figura 6: Queda de pressão no poço (linha contínua) e a sua derivada (linha tracejada) em função do tempo, variando a vazão de produção (q_0) .

4 Conclusões

A finalidade principal deste trabalho foi a obtenção de soluções analíticas, no contexto da análise dos Testes de Pressão de Poços em poços produtores de gás. Além disso, o código computacional implementado pode ser utilizado na verificação dos resultados obtidos com outros simuladores numéricos, desenvolvidos voltados para a resolução problemas de escoamentos complexos que não possuem solução analítica conhecida, quando testados sob as mesmas hipóteses que as aqui definidas.

Ademais, considerou-se na simulação a noção de pseudo-pressão e o efeito do escorregamento do gás. Os comportamentos qualitativos obtidos estão de acordo com a física dos escoamentos, tendo ocorrido variações consistentes também do ponto de vista qualitativo na análise de sensibilidade. Os gráficos diagnósticos, por exemplo, recuperaram os comportamentos previstos para os regimes de escoamento. Isso pôde ser observado, e.g., quando os intervalos nos quais as curvas da derivada de Bourdet coincidem ou se separam e quando da variação das propriedades (trechos iniciais e finais coincidentes para diferentes valores da porosidade e da permeabilidade absoluta, respectivamente).

Um contribuição relevante que pode ser citada foi a própria estratégia de solução, já que nem todas as etapas de cálculo estão disponíveis na literatura, tais como a distribuição dos pontos para a determinação da pressão média.

Como perspectivas para trabalhos futuros, propõe-se que sejam contemplados os casos de escoamentos na presença de poços hidraulicamente fraturados e a produção usando poços horizontais. Ademais, sugere-se a implementação de outras técnicas de inversão numérica e a incorporação dos efeitos inerciais ou de adsorção. Outras formas de incorporar o efeito de escorregamento podem ser adotadas, como aquela na qual o fator de Klinkenberg não é considerado constante [3].



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Specimen Quaestionum Philosophicarum ex Scientia

Physica Collectarum: Revisiting Leibniz in

Physics with the Sharp-Product

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Abstract: This article shows the importance of semiological considerations in the writing of physics equations, in the sense of showing that certain multiplication operations must be indicated at first hand as main descriptors of the process represented by the equation, characterizing its nature. Only in this way will it be possible to interpret equations in their symbolic totality an correctness. Bringing some of Leibniz's ideas to the argumentative construction of the logical foundation of the central thesis, multiplication is discussed as an essential operation for the description of evolutionary processes, such as

one thing $\underbrace{[in-the-mode-of]}_{ imes}$ another [equals] new thing,

representing the necessary interactions for these processes. The notion of "sharp-product" is introduced to denote the multiplications that perform those interactions. It is hoped that, as a result of the discussion raised, the analysis of the mathematical formalizations of contemporary physics will be returned to their own ambit instead of getting lost in an abstractionism that does little to contribute to the formation of world representations.

Key words: semiology, multiplication, sharp-product, interaction, complex number.

Resumo: Este artigo mostra a importância das considerações semiológicas na escrita das equações da física, no sentido de evidenciar que certas operações de multiplicação devem ser indicadas como principais descritores do processo representado pela equação. Só assim será possível interpretá-las corretamente em suas totalidades simbólicas. Trazendo algumas ideias de Leibniz para a construção argumentativa da fundamentação lógica da tese central, discute-se a multiplicação como operação essencial para a descrição dos processos evolutivos, algo como

one thing $\underbrace{[in-the-mode-of]}_{\times}$ another [equals] new thing,

representando as interações necessárias a estes processos. A noção de "sharp-product" é introduzida para denotar as multiplicações que desempenham aquelas interações. Esperase que, como resultado da discussão levantada, a análise das formalizações matemáticas da física contemporânea seja gradualmente devolvida ao seu próprio âmbito ao invés de perder-se em um abstracionismo pouco contributivo para a formação das representações do mundo.

Palavras-chave: semiologia, multiplicação, sharp-product, interação, número complexo.

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Prologue

The mind, once stretched by a new idea, never returns to its original dimensions.

R. W. Emerson

There is a fundamental difference between a researcher and a scientist. Not every researcher is scientist, although every scientist is a researcher. The difference is that the scientist does the research to establish the background of a new theory, a new system of hypotheses that answers an open question. The pure and simple researcher is usually content with citing and restating known results, sometimes applying alternative corroboration techniques. This is certainly an important work insofar as its results can reinforce or weaken a given theory or hypothesis, helping science to advance. But, a researcher would probably not be interested in something like the reconsideration of number theory or fundamental arithmetic, perhaps judging that there is nothing new to be learned in these matters. A scientist, on the contrary, would think of anything else to be said about the use of numbers and their basic operations as symbolic instruments for representing natural or anthropic processes. He is willing to deal philosophically with relatively simple things, however, with great syntagmatic¹ potential for the construction of new models and for a better in-

Some of my first thoughts surfaced much later on matured theories in cosmology and thermodynamics. Long ago, when a young student, I had an inspiration and established a physical interpretation of the product operation between fields coupled by a constant. Shortly afterwards, I became aware of a Leibniz model as simple as mine, whilst in a wider purpose. Obviously, the title of this article pays tribute to Leibniz, placing him at the beginning of everything. Leibniz, as is known, was a true genius, an exuberant and incredibly creative mind [1, 18] to whom is credited the introduction of the dot as a multiplication sign. Although he invented calculus without knowing that Newton — another admirable genius — had already done it, we owe him the notation used today.

terpretation of the ones that already exist.

He advanced to the creation of calculating machines and a binary numerical system. His concern with symbology promoted unprecedented formal progress. Now, going a step further, I return to the question of symbology, however, with the extra meaning that it can accumulate to build and represent a fundamental physical process in the writing of an equation.

In essence, the model Leibniz illustrated had the same semantic intention of the proposition I discuss: animal \times rational = man; the "mode" operation as I named it at the time. Generalizing, lastly, an attribute with a given level of complexity times another at any level of complexity is equivalent to an attribute of a higher level of complexity than the original two. By higher level I mean a certain circumstance such that an object or event would not arise or occur without the interactions between the primordial objects.

From a purely arithmetic point of view, multiplying is nothing more than adding successively. The theoryladenness of my proposition is that, in physics, if two functions, φ_1 and φ_2 , are multiplied with each other, this means that φ_1 evolves "in the mode of" φ_2 , and vice-versa with the same result if the context is Abelian. This is what I called "sharp-multiplication" or "sharpproduct", i.e., $\varphi_1 \sharp \varphi_2 = \varphi_{1,2}$. A sharp-product — P- \sharp (Psharp) — originates a new physical object, not the result of a simple successive sum. Thus, all multiplications between variables or functions in physics are sharpproducts, as well as geometric operations with real magnitudes (ex: width \sharp length = area). It seems obvious, but notice that, when writing an equation representing a physical process, it is important to know which properties, which magnitudes must combine, inflecting each other and determining the paramount features of the process. Of course, equation terms are naturally identified by their roles: "this term does this...that term does that...", and so on. But what does each term actually summarize? Why introduce representations in complex numbers and their conjugates? Furthermore, how intuitive-deductive guidelines take part in the intellectual constructive process of an equation? And how does all this conspire for the success of a model? I think that dealing with equations of physical significance requires much more than simple mathematical manipulations. The meaning of what we are doing and the result we want

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¹A linguistic critique of the symbolic forms we use and the definition of *syntagma* as a metaphysical element whose meaning depends on their relationships with other elements is available in reference 14.

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to obtain depends on correct answers to those questions. When we say that two fields are coupled, we mean that one is inflected by the other, the intervening coupling constant being mainly a convenient dimensional adjustment factor. This P-\pm is in fact the representation of an interaction between two objects that gives another object. But what is the true content of such an operation and what we want with that?

The essentials

For simplists, science is all about finding ways to fit theories to empirical facts. This is certainly the route of least effort, for which we pay the price of superficiality and obscurantism. As Zinkernagel pointed out,

"[...]science is often concerned with what the studied theories implies for our deeper understanding of the world. This involves the philosophical activity of interpreting the theories in question, and philosophy thus continues to be an integral part of scientific, including cosmological, thought." [17].

An example of dim ideas in physics proceeds from the fact that underdetermination in cosmology is often about solutions of general relativity, and, with regard to the expansion of the universe, the complication arises precisely because it is treated in terms of finding a natural way to superpose solutions in general relativity, something that does not exist, rather than assuming expansion — independently of mass — as a primigenous feature of the space-time continuum and not an aspect depending on solutions of equations².

From this, as Ellis well emphasized with the scientific seriousness that is peculiar to him, cosmology as the territory of a philosophy about our existence and our place in the cosmos leads to questions far beyond the simplistic view, involving the emergence of complexity, meaning, purpose and ultimate causation [5]. In view of my complete agreement with this position, I can say that the physics I advocate — referring in particular to cosmology — starts from two basic philosophical principles (Leibniz influence!):

- The sufficient reason, i. e., "there must be sufficient reason for something to exist, for an event to occur, for a truth to be obtained" (It is important to remember that among the great priest cosmologists of the 20th century, God certainly appears as the sufficient reason for the greatness and harmony of the Universe). From the point of view of science, I evoke this principle in the foundations of contemporary cosmology in the following way: "The sufficient reason to assume the continuity of space-time is that it expands without sufficient reason to consider it discontinuous". This principle, arguably, poses serious objections to the idea of quantizing gravity.
- natura non saltum facit, a principle that is established as a corollary of the previous principle: the continuity of space-time in all things.

Besides, as defended by Leibniz, symbols are important for human understanding. Semiology is fundamental for the representations of physical processes to be elegant, clear and informative. So, good notations combining characters for simpler thoughts are the "encaustic tiles" to form complex thoughts.



Therefore, in physics, a product between two quantities is indeed a P-#. Using a singular metaphor, it

measurements from nearby stars — continue to yield different values after decades of persistent work, and the problem was alarmingly worsened with new more accurate data from the Webb, which makes us suspect of a flaw in the current model. Faced with the fact that something may be really wrong, the standard model is now in check, forcing us to reevaluate our own ideas about the ultimate structure of the universe, something I have been trying to do.



 $[\]overline{^2}$ Recently, a local periodical published a small article (names don't matter here) in which the author, possibly delighted with so much data coming from all over, seemed to adopt a generalized position against the way theoretical work has been carried out in cosmology. In his partially pertinent criticism, he asks why we don't use the available data in our models, instead of spending time with mathematical exercises in directions that have already been rejected by observational science. On the whole, I agree, especially considering the time wasted looking for new solutions to Einstein's equation that suggest alternative universes. But the discourse conducted makes us believe that we are "swimming armfuls" in evidences, when in fact there is much controversy about critical points for the survival of the currently accepted model of the universe. Yes, the standard model remains the basis for essentially all research in cosmology, being the best we have so far, which does not exempt it from carrying serious problems that may oblige us to review our ideas from the beginning. If we take the issue of how fast the universe is expanding, the results have been found to be appallingly inconsistent. The two methods to measure Hubble constant — one based on early universe measurements, the other on

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comes to "tuning an equation a semitone up"!, indicating the multiplications critical to the overall meaning of the described process; that is, indicating in the equation who commands the process and who stabilizes it under specific conditions. Thus, when analyzing the content of the expressions, depending on the immanent complexity, we can rewrite them in a more instructive way, "tuning" them in P-#. Firstly, my aim is to discuss the particular situation of conjugate products between classical fields represented in the complex numerical system. In this particular case, defining restrictively as sharp-applications the products between complex fields and their conjugated temporal derivatives seems sufficient from the semantic-ontological perspective in view of the nature of the fields in question, the fields of thermal energy I called "caloric fields". It would take a lot of time and a lot of useless discussion to decide to change the symbol for multiplication in physics, but it would be worthwhile to write the equations using the symbol "#" (sharp) to indicate the applications between the fields leading to essential results that occupy a prominent place for the understanding of the theory. The sharp-application is the trigger of a creation; we therefore want to know what happens when one thing evolves in the manner of another thing in evolution:

one thing $\underbrace{[in-the-mode-of]}_{\times}$ another [equals] new thing.

Of course, if powers were assigned to the product factors, we are symbolizing the weight each factor contributes to the final result.



II: NEW INSIGHTS ON MORPHOLOGY OF THE PHYSICAL REPRESENTATION

P-# in caloric field theory

It is not my purpose here to discuss thermodynamics, something I have already done extensively in previous

works. From the vast literature on thermodynamics, I highlight the references [2, 3, 4, 6, 8, 10, 15, 16]. I bring my own example along with other from cosmology, also discussed earlier, to consolidate the defended semiology.

From a macroscopic-cosmological point of view, thermodynamics stands out in the conception of a relativistic space-time woof in accelerated expansion as an ingredient theory, provided that it is considered in a new consistent perspective of the Second Law and, consequently, of the very concept of entropy. As Bejan pointed out, and here very much with regard to cosmology,

"The universal principle of evolution belongs in thermodynamics because thermodynamics is a universal science and evolution is a universal phenomenon." 3 4.

My studies on contemporary thermodynamics and its broad application, including cosmology, leaded to the so-called "caloric field theory", comprising, within the scope of the work, approaches on the shape of the caloric field (the function that characterizes thermal energy itself) and the physical law of its propagation with the entropic trail left by the diffusion process. From a deep revision of the Second Law, in caloric field theory I defined entropy acceleration³ as

$$\frac{\partial^2 S}{\partial \tau^2} = -2\gamma^2 \frac{\partial^2}{\partial \tau^2} \int |\xi|^2 \ln |\xi| \, dq$$

 3 Despite the insistence on adopting a Boltzmannian interpretation of the field entropy in generalized coordinates q given by

$$S = \int -2\gamma^2 |\xi|^2 \ln |\xi| dq, \tag{1}$$

associating it with state probabilities (I myself have already been subject to this interpretation), there is no sufficient reason for such an association, since entropy is a perfectly defined quantity in thermodynamics, without any stochastic connotation, as I have repeatedly stated in recent works. Since entropy irrevocably advances with time in our universe, much more consistent with the temporal arrow is to associate it with an evolutionary variable, a cosmic temporal marker in the continuous interval [0,1]. It is noteworthy that the differential equation of caloric fields,

$$\partial_q \partial^q \xi + \left(1 - \gamma^2\right) \xi - \gamma^2 \xi \ln|\xi|^2 = 0, \tag{2}$$

with γ as an environmental constant, includes a field entropy term because the physical intuition is that the evolution of the field should expose the trace of its own entropy, since this magnitude accompanies the action of the field throughout its existence. Note that the meaning of an equation in physics transcends pure mathematical form; the expression (2) tells us that the evolution of the caloric field is concomitant with the entropy trail left by the field in action (1), and the environment imposes inflections to this evolution.



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$$= -2\gamma^2 \frac{\partial^2}{\partial \tau^2} \int \xi \xi^{\dagger} \ln \sqrt{\xi \xi^{\dagger}} dq.$$
 (3)

Some math manipulations involving partial derivatives led to

$$-2\gamma^2 \frac{\partial}{\partial \tau} \left[\left(\dot{\xi} \xi^{\dagger} + \xi \dot{\xi}^{\dagger} \right) \ln \left(\xi \xi^{\dagger} \right)^{1/2} + \right.$$

$$+\xi\xi^{\dagger} \frac{1}{2(\xi\xi^{\dagger})^{1/2}} (\xi\xi^{\dagger})^{-1/2} (\dot{\xi}\xi^{\dagger} + \xi\dot{\xi}^{\dagger}) \right]; \tag{4}$$

$$-2\gamma^2 \left[\left(\ddot{\xi} \xi^\dagger + 2 \dot{\xi} \dot{\xi}^\dagger + \xi \ddot{\xi}^\dagger \right) \ln \left(\xi \xi^\dagger \right)^{1/2} + \right.$$

$$+\left(\dot{\xi}\xi^{\dagger}+\xi\dot{\xi}^{\dagger}\right)\frac{1}{2(\xi\xi^{\dagger})^{1/2}}\frac{\left(\dot{\xi}\xi^{\dagger}+\xi\dot{\xi}^{\dagger}\right)}{\left(\xi\xi^{\dagger}\right)^{1/2}}+$$

$$+\frac{1}{2}\left(\ddot{\xi}\xi^{\dagger}+2\dot{\xi}\dot{\xi}^{\dagger}+\xi\ddot{\xi}^{\dagger}\right). \tag{5}$$

The reader can find the complete explanation in reference [10].

Now, of the ways a field in complex notation interacts with itself, perhaps the most significant is the interaction of the field with the time derivative of its complex conjugate. To take but one single example drawn from the formalism developed above, imagine a caloric field composed of two functions so susceptible to change over time that they are able to interact with their own rates of change (this type of interaction was called "calorergy", a kind of synergy between the propagation of heat and its own variation rate; indeed, I see this as a characteristic feature of complex systems). Furthermore, due to mutual interactions, each component function interacts equally with its partner's rate of change. Also, more than the thermal energy itself, it's the thermal energy differences that really make it all happen. Therefore, besides total calorergy, we are interested in expressing the difference between these later interactions, however separately, so that we can analyze in what proportion it reflects the evolution of the system as a whole. In a nutshell, all this is given by the P-#.

$$\mathcal{A}: \xi \to \dot{\xi}^{\dagger} = \xi \sharp \dot{\xi}^{\dagger} = \xi \dot{\xi}^{\dagger}. \tag{6}$$

For the sake of brevity, let us take the field and its conjugate as

$$\xi = \varphi_1(t) + i\varphi_2(t),$$

$$\xi^{\dagger} = \varphi_1(t) - i\varphi_2(t),$$

with the time derivative of the conjugate given by

$$\dot{\xi}^{\dagger} = \dot{\varphi}_1(t) - i\dot{\varphi}_2(t).$$

The P-# is a simple product but exactly expressing the semantic prescriptions explained above in the form

$$\begin{split} \xi \sharp \dot{\xi}^{\dagger} &= \left[\varphi_{1} \left(t \right) + i \varphi_{2} \left(t \right) \right] \left[\dot{\varphi}_{1} \left(t \right) - i \dot{\varphi}_{2} \left(t \right) \right] = \\ &= \varphi_{1} \left(t \right) \dot{\varphi}_{1} \left(t \right) - i \varphi_{1} \left(t \right) \dot{\varphi}_{2} \left(t \right) + i \varphi_{2} \left(t \right) \dot{\varphi}_{1} \left(t \right) + \\ &+ \varphi_{2} \left(t \right) \dot{\varphi}_{2} \left(t \right) = \varphi_{1} \left(t \right) \dot{\varphi}_{1} \left(t \right) + \varphi_{2} \left(t \right) \dot{\varphi}_{2} \left(t \right) + \\ &+ i \left[\varphi_{2} \left(t \right) \dot{\varphi}_{1} \left(t \right) - \varphi_{1} \left(t \right) \dot{\varphi}_{2} \left(t \right) \right]. \end{split}$$

In the last equality, the right-hand side shows the imaginary unit as nothing more than a separator, isolating the sum of the interactions between the field components and their respective rates of change, and the difference of the interactions between the field components and their respective partner's rate of change, as specified in natural language. Without the search for this understanding, all the effort of calculation is a simple mathematical exercise with no clear physical meaning.

If we consider that the first-order interactions are the most relevant for characterizing the sensibility of the functions that form the field, it is enough to rewrite equation (5) as

$$-2\gamma^{2} \left[\left(\ddot{\xi}\xi^{\dagger} + 2\dot{\xi}\dot{\xi}^{\dagger} + \xi\ddot{\xi}^{\dagger} \right) \ln \left(\xi\xi^{\dagger} \right)^{1/2} + \right.$$

$$+ \left(\dot{\xi}\sharp\xi^{\dagger} + \xi\sharp\dot{\xi}^{\dagger} \right) \frac{1}{2(\xi\xi^{\dagger})^{1/2}} \frac{\left(\dot{\xi}\sharp\xi^{\dagger} + \xi\sharp\dot{\xi}^{\dagger} \right)}{(\xi\xi^{\dagger})^{1/2}} +$$

$$+ \frac{1}{2} \left(\ddot{\xi}\xi^{\dagger} + 2\dot{\xi}\dot{\xi}^{\dagger} + \xi\ddot{\xi}^{\dagger} \right) \right]. \tag{7}$$



The general theory of caloric fields associates time, energy and entropy without any stochastic demand, from a perspective of permanent thermal evolution of the systems. As discussed earlier in cosmology [II], [I4], an interesting thing when thinking about this association is that an expanding sub-Planckian temporal interval can be understood as a reservoir of thermal energy in entropy flux, just as an expanding spatial interval can be assumed as a container of a certain amount of matter in dispersion. This way of describing the cosmic woof is a



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natural outcome of the presumed unity between space, time and gravitation, a concept that leaves no doubt about the physicality of time. As will be seen shortly, this has a decisive impact on understanding the structure of a space-time geodesic.

P-# in gravitational driving

Another example comes from the expression of the Euler-Lagrange modified sine-Gordon type equation of the geodesic line referring to the metric $ds^2 = -e^{2\phi(X^1,X^2,X^3)}dt^2 + \zeta_{ij}(X^1,X^2,X^3)dX^idX^j$, in which an arbitrary interval subject to expansion or contraction is warped by a soliton of acceleration, a solitary gravitational pulse, Π , say

$$\frac{d}{ds} \left(\zeta_{ij} \widetilde{\mathbf{X}}^{j} \right) + \frac{\partial \phi}{\partial \mathbf{X}^{i}} e^{2\phi} \widetilde{t}^{2} - \frac{\partial \zeta_{jk}}{\partial \mathbf{X}^{i}} \underbrace{\widetilde{\mathbf{X}}^{j} \widetilde{\mathbf{X}}^{k}}_{2} + + m^{2} \widetilde{t} E \sin \vartheta \frac{\partial \vartheta}{\partial \mathbf{Y}^{i}} = 0,$$
(8)

with the corresponding Lagrangian density

$$\mathcal{L} = \frac{1}{2} \left(-e^{2\phi} \tilde{t}^2 + \zeta_{ij} \widetilde{X}^i \widetilde{X}^j \right) - m^2 \tilde{t} E \left(1 - \cos \vartheta \right) \quad (9)$$

for

$$\frac{d}{ds} \left(\frac{\partial \mathcal{L}}{\partial \widetilde{\mathbf{X}}^i} \right) - \frac{\partial \mathcal{L}}{\partial \mathbf{X}^i} = 0.$$
 (10)

The arbitrary constant E matches the freedom of the null geodesics affine parameter and is interpreted as the expansion energy contained in the worldline intervals $[\Pi]$. In this case, with P- \sharp terms equation $[\Xi]$ is rewritten as

$$\frac{d}{ds}\left(\zeta_{ij}\sharp\widetilde{X}^{j}\right) + \frac{\partial\phi}{\partial X^{i}}e^{2\phi}\widetilde{t}^{2} - \frac{\partial\zeta_{jk}}{\partial X^{i}}\sharp\widetilde{X}^{j}\sharp\widetilde{X}^{k} + \frac{\partial\zeta_{jk}}{\partial X^{i}}\sharp\widetilde{X}^{k}$$

$$+m^2 \tilde{t} E \sin \vartheta \frac{\partial \vartheta}{\partial \mathbf{X}^i} = 0. \tag{11}$$

To exemplify the temporal structure of a geodesic, an expanding interval $X^0 = \langle \forall | \tau - \tau_0 \rangle$ (read "no matter the scale of $\tau - \tau_0$ ") is a finite time-like path that holds an intrinsic stretching thermal energy and remains continually swelling⁴. So, as the soliton warps the space-time, we may interpret the \widetilde{X}^j as the transformation components coupled to the metric. Therefore, the terms in

 \widetilde{X}^{J} are the ones that head the description of the phenomenon, providing information about the way in which the metric undergoes inflection caused by the solitary wave. Also, to include the proposed semiology, we may define an operator $\Delta\sharp$ such that

$$\Delta \sharp \left[\zeta_{ij}, \ \mathbf{X}^{j} \right] = \frac{d}{ds} \left(\zeta_{ij} \sharp \widetilde{\mathbf{X}}^{j} \right) - \frac{\partial \zeta_{jk}}{\partial \mathbf{X}^{i}} \sharp \widetilde{\mathbf{X}}^{j} \sharp \widetilde{\mathbf{X}}^{k}. \tag{12}$$

Lastly, equation 11 changes to

$$\Delta \sharp \left[\zeta_{ij}, \ \mathbf{X}^{j} \right] + \frac{\partial \phi}{\partial \mathbf{X}^{i}} e^{2\phi} \tilde{t}^{2} + m^{2} \tilde{t} E \sin \vartheta \frac{\partial \vartheta}{\partial \mathbf{X}^{i}} = 0, \quad (13)$$

and in the spatial infinity, assuming field ϕ asymptotically constant, $\lim_{r\to\infty} \phi = const.$, or even cancelled, and considering the limit of small ϑ , we can say that

$$\Delta \sharp \left[\zeta_{ij}, \ \mathbf{X}^{j} \right] + m^{2} \vartheta \tilde{t} E \frac{\partial \vartheta}{\partial \mathbf{X}^{i}} - \frac{1}{6} \vartheta^{3} \tilde{t} E \frac{\partial \vartheta}{\partial \mathbf{X}^{i}} + \dots = 0, (14)$$

with remaining terms $\mathcal{O}\left(\vartheta^{5}\right)$ and higher. Details on the components \widetilde{X}^{j} are explained in reference Π . Equation (13) is a synthetic and elegant way of displaying, on one hand, the bulk that shapes the phenomenon, on the other, the complements that stabilize it so that it is recognizable. Evidently, $\Delta\sharp$ is not a generic operator, but a deformation non-commutative operator of the metric under the conditions specified by the Lagrangian of the system.

Alcubierre metric and the shape function

A final example is illuminating (considerably more could be said but it is enough to the reader which will take examples in his own field of research). Inferring the shape function,

$$f_{(r_s)} = \frac{\sqrt{c^2 - e^{2\phi}}}{v_s},\tag{15}$$

at the junction of a type-Alcubierre warp bubble with the external space-time, I explained that the null-diagonal metric field matrix ζ_{ij} has components ζ_{i4} of the form $-4E^{-1}\sqrt{1-e^{2\phi}}$, where E is the energy of space-time expansion (please, see reference [12] for an explanation considering the static metric $ds^2 = -e^{2\phi}dt^2 + \zeta_{ij}dx^idx^j$). In this case, P- \sharp indicates a fundamental mode operation on the inverse of the energy E at the junction, i.e.,



 $^{^4{\}rm This}$ is the essence, the ontological foundation of the idea of continuity specifically in physics.

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 $-4E^{-1}\sharp\sqrt{1-e^{2\phi}}$. In other words, components ζ_{i4} of the metric field matrix,

$$\zeta_{lk} = \begin{bmatrix}
0 & 2E^{-1} & 2E^{-1} - 4E^{-1} \sharp \sqrt{1 - e^{2\phi}} \\
2E^{-1} & 0 & 2E^{-1} - 4E^{-1} \sharp \sqrt{1 - e^{2\phi}} \\
2E^{-1} & 2E^{-1} & 0 & -4E^{-1} \sharp \sqrt{1 - e^{2\phi}} \\
2E^{-1} & 2E^{-1} & 2E^{-1} & 0
\end{bmatrix}, (16)$$

show that the expansion energy at the junction inflects the shape function (and, of course, how this inflection occurs).

Then, we have a representation of the way in which expansion energy — the dark energy, as I understand it — acts on the shape function in the matching between Alcubierre and static metrics, and this is a basal process to be identified, since expansion is intrinsic to space-time nature.



I : OTHER DIRECTIONS, SAME UNIVERSE

On the scale of the cosmos, only the fantastic has conditions to be true.

Teilhard de Chardin

While a physics student many years ago I heard a cliche common to theoretical disciplines: "...this is very important", or "...this is also very important", said the teacher pointing to some terms of an equation without much concern with the "why" of the importance. This is how obscure ideas propagate through generations; it is enough that we accept them once.

There is the same problem in all languages, namely, the question of clarity and accurate interpretation. The "why" of the importance of a given mathematical term crucial to ensure the purpose of the equation has to reflect a relevant bringing-of-an-action of thought for the understanding and for the consistency of the theory behind; the "why" has to do with the ultimate meaning of the equation. This leads us to always keep in mind, with Kim et al., that

"[...]learning physics equations should go beyond understanding mathematical relationships of the equations. In this sense, it is necessary to distinguish the difference between mathematical and physical aspect when learning the meaning of a physics equation. The mathematical meaning of a physics equation involves quantitative relation and mathematical operation among the symbols included in the equation." [7].

In cosmology, I think we are living in an era of dispersive fascination with the colossal amount of data that we now have at our disposal (add to this the loss of precious time consuming intellect with the invention of other universes, if we still can't explain the only one we know!). However, it is necessary to know in which theoretical framework we will work and interpret them "to what", thus reaching more fundamental conclusions. It seems to me that the more data we have, the more confused we get. This feeling alerts us to a key questioning upon what we are actually discovering and studying about the structure of the cosmos, its evolution and its origins. There is a whole propaedeutics to be reviewed, and this includes the possibility of semiological improvements. At least we have the advantage that general relativity turns out to be a sufficiently robust theory to support some external contributions that leave it less overcharged by the load of being asked to account for everything. It is not, therefore, a question of just seeking solutions to Einstein's equations (with very few exceptions, this has served to increase the perception of underdetermination in cosmology), but also of seeking to apply them from a broader and more theoretically elaborate semantics; deep down, it is much more than simply mathematics.

The lack of interest in the points I discuss is fueled by idealism — with its multiverse and inaccessible dimensions — and by what we could call "scientific corporatism" driven on behalf of motivations other than those of open, full and inclusive science. It is a fact that we are going through controversial situations in the way physical science has been conducted today. There are strong indications that the simplistic route has dominated scientific production in this area in recent times, blocking original initiatives that could very well shed light on a



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series of open questions. Academic environments seem more and more concerned with citation numbers and impact factors than with science itself. Furthermore, it would be very naive to imagine that science is immune to human ills, such as envy, vanity and selfishness.

In my personal opinion, I think that the way of doing theoretical physics — mostly in cosmology — needs to be revised. The universe is such that it is possible to represent it reasonably well with the help of mathematical formalism. This does not mean, as some would like, that the universe is mathematical. Science is best conveyed in English, which is not to say that it is English. It is the thoughtless uses of language that give rise to confusion and end up leading to meaningless inferences. I even believe that the adequate symbology can help the selection of better theories and models for the understanding of the cosmic structures and, virtually, for the future development of new technologies, including some kind of gravitational navigation that may improve our prospects for interstellar transport, of course, within the constraints imposed by known physics.

In our methodological revision, Leibniz's classic works, whether philosophical, mathematical or theological, must always be under our sights (so it goes for Kant!). More than his precocious and brilliant dissertation "On Combinatorial Art" (1666-1668), which aimed to create a method by which all the truths of reason would be reducible to a type of calculation [9], Leibniz planted the seed of a true mathematical linguistics that, very unlike being static, now allows us to elaborate an entire improved symbology to create representations in physics with greater semantic precision.

From all this discussion it is easy to conclude that languages, scales, grammars, metrics, none of that exists; they are just the means at our disposal to bring the incommensurability of the universe to the remarkable finitude of human understanding (from the cosmological point of view, I believe that a first step towards the very dematerialization of languages — and their postulated connections with reality — was taken with the introduction of structural invariance under scale changes, especially when dealing with Planckian and sub-Planckian dimensions [13, 14]. That is why there is not much epistemological future in thinking that the universe is mathematical, since it takes tremendous mental effort to make

it fit our models. In particular, the scales we create are so that we can keep parts of the world within our cognizable purview in face of the true unfathomability of reality. So, for mathematics to play its role in the best possible way as a language for physics, it needs to be considered in ever-evolving symbolic characterization, adopting semantic and grammar enhancements whenever necessary. This can be done from simple and luminous ideas like Leibniz's.

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Abstract: On-land construction of most of the inexpensive elements of an impermeable durable "fabric" sea-dam separating the Mediterranean Sea from the North Atlantic Ocean will allow speedy installation and early finished facility first use. Despite the vast science-predicted geographical change, including climate change, within the existing Mediterranean Sea Basin we anticipate subsequent built sea-dam "close enough" near-maintenance of the regional environmental status quo; consider encouragement of in-Basin smaller adaptive macroprojects as well as an efficient and sparely organized International Caretaker Council operational authority to be established before 2050-2100 AD. With sea-locks and siphonic small-scale electric power generators allowing seawater inflows, the GSBB can match Basin evaporation with a compensating controlled seawater inflow from the North Atlantic Ocean, keeping most conditions as they are today. The Suez Canal's single sea-lock will work similarly and in tandem with the GSBB. The engineering challenge is to handle a salty fluid that is > 800 denser than air! Successful performance of the GSBB will come in time if the macroproject's planning, execution and handover are up to standard practice. If it judged a failure, the cost of its removal will not be financially onerous or prolonged in time.

Key words: Macro-engineering, artificially stabilized Mediterranean Sea, marine transgression, flexible sea-dam, future climate change, North Atlantic Ocean, navigational alterations, supportive macroproject components, GSBB.

Resumo: A construção em terra da maioria dos elementos baratos de uma barragem marítima de "tecido" impermeável e durável que separe o Mar Mediterrâneo do Oceano Atlântico Norte permitirá uma instalação rápida e uma utilização antecipada do sistema. Apesar da vasta mudança geográfica prevista pela ciência, incluindo as alterações climáticas, dentro da Bacia do Mar Mediterrâneo existente prevemos que a subsequente construção de barragens marítimas dará conta da quase manutenção do status quo ambiental regional; considere-se o incentivo a macroprojectos adaptativos menores na Bacia, bem como a autoridade operacional eficiente e organizada de um Conselho Interno Internacional, a ser estabelecido antes de 2050-2100 DC. Com eclusas marítimas e geradores de energia eléctrica sifónicos de pequena escala que permitam a entrada de água do mar, o GSBB pode combinar a evaporação da Bacia com uma entrada de água do mar controlada e compensatória do Oceano Atlântico Norte, mantendo a maioria das condições como são hoje. A eclusa marítima única do Canal de Suez funcionará de forma semelhante e em conjunto com a GSBB. O desafio da engenharia é lidar com um fluido salgado que seja > 800~% mais denso que o ar! O desempenho bem sucedido da GSBB chegará a tempo se o planeamento, a execução e a transferência do macroprojecto estiverem de acordo com a prática padrão. Se for considerado um fracasso, o custo da sua remoção não será financeiramente oneroso nem prolongado no tempo.

Palavras-chave: Macroengenharia, Mar Mediterrâneo estabilizado artificialmente, transgressão marinha, barragem marítima flexível, futuras alterações climáticas, Oceano Atlântico Norte, alterações de navegação, componentes de macroprojectos de apoio, GSBB.

Introduction

Ongoing and proposed climate change mitigations focused on Earth's air ought to be accompanied by parallel technically practical mitigation plans dealing with the world-ocean's seawater. Soon, society must adopt a new adaptive mindset that is based on predicted future sea-level rise and everyday management of a post-Ice Age marine transgression. That is, a viable human tactical adaptational vision is required which is perhaps one that is derived from past, present-day, and imagined Macro-engineering concepts. For example, it is essential the Mediterranean Sea Basin be apprehended geographically, both holistically and realistically, not as a mare nostrum of merely probable, separately threatened, coastline correctable protective construction or destruction mini-projects. Certainly, a global meter of sea-level rise will reshape the world's coastline, its

major cities (some already equipped with storm-surge barriers) and seaports (such as ancient and beloved Venice, Italy), and its vast uninhabited beaches, cliffs and wetland stretches as well. The total monetary cost of even haphazardly defending the Earth's coastlines by emplacement of protective dikes and seawalls is significantly less than that of avoiding seawater-inundation induced urban damage [1]. Yet, perhaps an even cheaper physical protection scheme may be available for population centers situated east of the Strait of Gibraltar. Taking the form of a seawater impenetrable "fabric" dam, with sea-locks there (also at the northern entrance to the Suez Canal. [erja[s with as safety backup at its southern entrance), spanning the shipping-route between Spain and Morocco, the proposed engineering structure is referred to as the Gibraltar Strait Bimarian Barrier (GSBB). Although truly unassessed yet, the question remains as to how do Mediterranean Sea Basin populations want their national coastlines [2] to appear during the remainder of the 21st Century?

People, lately advised by medical experts have learned about the normal functions of human physiology based on thousands of years of observation. In contradiction, the Earth has been scientifically studied for only a few hundred years. As remarked by Lynn Margulis (1938-2011) "Can you imagine yourself with the task of overseeing your body's physical processes?" [3]. Indeed, caretaking of such a living creation seems a ludicrous notion. Humans [4] appear to essentially constitute a kinetic state of matter as opposed to the thermodynamic states prevailing in the inanimate. Only during the first decade of the 21st Century have geoscientists used supercomputer models to consider the sphericity aspect of Planet Earth: "A mostly forgotten assumption in climate models is that of a flat Earth atmosphere. Spherical atmospheres intercept 2.5 W-m-2 more sunlight and heat the climate by an additional 1.5 W-m-2 globally" [5]. Critical also is the bioshell fact of Homo sapiens' existence for past millennia [6].

Since at least the mid-1960s AD and almost daily, normal human environmental concerns have been manipulated by elaborate but unperfected computer-projections for impending worldwide climate catastrophe. Numerous such publicized dire warnings have well served those of a certain pecuniary persuasion; that is, those individuals and groups with certain social connections and celebrity status who permit themselves to be intellectually overwhelmed by airy hyperhypotheses and mathematical gibberish. In fact, the impressive government and academia-housed electronic gadgetry, along with the conversationally impressive laboratory-coated modelers and broad-

cast institutional press-release penners, seems to thoroughly stunt normal human imaginations. This onslaught results from those who partake of this addictive certitude that is based on ignorance (nescience) and its drug-like miasma of mapped globalized future disasters. "Climate Science," massaged and emitted by excessively fictionalized electronic and print social-media pronouncements, remains ersatz "science" stultified and intellectually sullied, shifted to inconsequential status in terms of all impending actionable statements of proposed mega-programs of social coercion and public-taxations. With timely politically strategic and tactical duress boldly implied, not inferred, by socially hostile wannabe intellectual masters in government and academia, three-dimensional thinking is fortunately still accomplished by good people (possibly those surviving ostracized "Climate Deniers"?). This situation is due, probably not so extra-ordinarily, to self-control as well as morality, willfulness, and ethicalness. These researchers are thus uncorrupted by imprudent flat-Earth assumptions offered for broadscale consumption by pre-2019 AD so-called climate scientist modelers and their powerful political and monied financial directors.

One may wonder how may non-geoscientists really escape omniscient bureaucratic gazes that mold behavioral influence of these error-prone authorities' diktats? We suggest that possibly quite soon individuals will gain capabilities, with the help of just-dawning artificial intelligence RD (also known as "artificial responsibility"), for modeling personal daily weather forecasts. Additionally, it will be possible to model interesting future local, regional, and global climate regimes from the purview of situation-adjustable family entertainment. Such computer-assisted group fun could be enjoyed during familiar hot dry or humid summertime evenings to avoid sweltering "Hothouse Earth" and cold wintertime days but possibly not a hyper-chilly "New Ice Age Earth"! For instance, developed technology already allows monitoring and prediction of weather events by using TEMPEST, an AI-assisted personal meteorological eventreporting system nowadays sold by WeatherFlow. Such personal facilitation enables macro-imagination to bud. Thanks to the ramifying and amplifying World Wide Web virtual resources, the day will come when people will no longer need national weather service data inputs nor politicized modeled climate warning prognostications from various long-established international organizations. Because technology is improving, climate change alarm-doubters may achieve absolute liberty from the condemnable and unimaginative wannabe thought ghetto-fencers who seem strongly desirous of human civilization's inglorious just-over-the-horizon species doom! Indeed, this is a Business as Usual-1 Scenario proposed as the final limitation on Homo sapiens. This scenario features the economic twilight of all human-kind, dubbed the "crepuscular planet [Earth]" [7].

As a geopolitical issue, global and regional climate change entails vastly more ambiguity than is perceivable in the popular news media-constrained public discourse about geophysical futurity [8]. Only lately, for example, was the standard datum for the instrumental measurement of the world's oceanic sea level, the "mean sea-level (MSL)" substituted by an improved measurement. Frustratingly, MSL is still referred to and although flawed from its earliest conception, there never was a worldwide fixed international definition. Such an oversight can become financially costly if two or more different sets of national coordinates are employed by separately organized and funded planning and building teams on a mutually beneficial joint megaproject! The introduction of an internationally valid elevation/depth reference system [9] based on the known irregularities of Earth's gravity-field has become useful because the strength and direction of the planet's gravitational force is determined mainly by seawater distribution in a single world-ocean basin. For curious astronomers, the Universe is fully assembled for commerce-oriented professional macro-engineers. The Earth's open bioshell [10] is a place where applied force and planned function can be amalgamated by innovative technological design and modern-day AI-guided additive manufacture [11]. As octogenarians, we notice a depressing alteration in public perception of life, including the Universe and everything within it. As developed so far, Geoscience has instilled an almost disinterested, or sometimes overly passionate, uninformed public outlook that ranges from perception of the lifesustaining world-ocean as "the sea around us" to today's mechanistic "blue machine" driven by the saddening climate change leitmotif of contemporary existential geopolitics. Corrective Macro-engineering plans unavoidably fail when they are underpinned by a failure in the context of human imagination. Innovation, commonly defined as the ability to produce an object (or an idea) that is both original and adequate to a geographically-demarcated place, is a core component of Homo sapiens' ability to promote and cope with various aspects of inevitable Earth-bioshell change [12]. Expert imaginers use their instructive macro-imaginative capacities to impressive community-wide perceived effect as they "... to try to figure out how the world works, or at least, how some aspect of the world works" [13]. Unfortunately, there are numerous real-world regional planning failures that were initiated by groupthink lock-in of a once diverse RD team which became totally focused on promotion of a specific desired Earth-bioshell development, functioning as an interest group only [14].

As the world turns toward infrastructure gigantism

Human action within the Universe-imposed gravitational constraints of the Earth-bioshell, while still assumed by the world-public to be vigorous, is now systematically slowing [15]. William Lee Steffen (1947-2023) [16] first illustrated in a generalized diagram the ongoing deceleration of human-centered provoking facets of global bioshell change, including global climate change, yet he mostly ignored his own chart-line's important implications [17]. In other words, Steffen did not recognize potential eucatastrophe, the favorable future trend for Homo sapiens instead of an impending disaster. Instead, this concept expressed in more comprehendible terms would be called "salvation" when viewed as the preservation from ruin, deliverance from difficulty and imponderable danger! The canonical Section 27 statement from the 1987 Brundtland Commission report Our Common Future: Report of the World Commission on Environment and Development boldly asserts "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs". In a spirit of charity, we assume Steffen's continuous explanatory omission was deliberate, meant to induce hubristic macro-engineers to be truly humble about the limits of what they know, what they can know, and about the gap between what they plan and what they ultimately deliver to this planet's reality. The difference comes not from their own incapacity to deliver on the ballyhooed megaproject plans, but from inevitable unknowns or absent facts that cannot be efficaciously daisy-chained to form a reliable objective single factor. These factors are what often render such grandiose plans an inspiration for protesting comedy skits. (A Californian, the engineer William Henry Smyth (1855-1940) coined "technocracy" in AD 1919 while a UK sustainability authority neologized "avivocracy" as its first antonym almost a century later [18].) We care to believe that, perhaps, W.L. Steffen intentionally sought to forestall the usual dreary European dreams of cheap future electricity-powered decadence?

Bernard Gottschalk (1935-2021) mathematically speculated by an unusual newspaper-published graph that indicated a 0.10 C thermal spike of global air temperature co-incident with the Second World War [19]. Europe above ground level was somehow affected despite the massive shading aviation contrails [20] and daily large ground-impact explosive shockwaves that distorted the ionosphere above

[21]. The import of these collective findings is highlighted by the fact that predicted global climate change becomes financially too risky whenever the advancement of human-generated technologies is forgotten or underplayed by modelers! As of mid-2023 AD, most corporate and governmental climate change researchers worldwide do not support Green-style economic growth [22]. In fact, their preferred stance is civilizational "degrowth" or depopulation, a geopolitical position that is greatly out-of-step with the world-public's vociferously expressed desires for a common need for positivity, hope, and suitable rewards for appropriate behaviors [23]. Indeed, the model named International Futures suggests a human bioshell-confined living species that is anticipated to exhibit, or at least realistically characterized, as high-poverty and fast population increase, but with moderate energy demands and aerial carbon dioxide gas emissions [24]. As an understatement, let us indicate that we are somewhat bewildered by these contrasting announcements! Nevertheless, and despite these repressive purviews, we pursue our own course of macroproject proposals based on the facts at hand. That is, the known laws of the Universe help distinguish the impossible from the merely probable [25].

North Europe earth-fill sea-dams, the NEED

The American geographer Jerome E. Dobson bestowed the dualmedia designation "Aquaterra." This collective toponym identified landscapes that were cyclically inundated (flooded or drowned) by seawater and then again exposed to the ambient air. This repeated increase (rise) and decrease (fall) of sea level during multiple ice age cycles in the Late Pleistocene (130,000 -11,700 YBP, years before the present-day) took place after the first Earth-bioshell appearance of biologically modern Homo sapiens until "today" [26]. Aguaterra's dry-landscape area was approximately the size of South America, it was all coastal (shallows + "beaches"), flat (wind-wave suppressed gradient), and mostly located within the planet's Equatorial Zone. In other words, the human species has much long-term experience with naturally transforming coasts and strand dwelling survival macro-problems! The people of the Netherlands, since circa 1818 AD, have rightly boasted that "God created the world, but the Dutch created the Netherlands" [27]. In other words, Netherlanders, like others who elsewhere settled near vertically variable, tidal, and storm surge effected zones, studied perceptible climatic change. These sometimes-drastic regime changes compelled the projection of affordable region-specific actionable adaptation and mitigation plans [29]. The successful performance of durable megaprojects, however, always depends on what happens during planning, execution, and handover to operational staffers. Macroprojects are, off course, fully or partially imagined before they are materialized and utilized while many conceptualizations only ever exist as residual (un)recorded memories in the human mind! And yet, their prospective realization can have palpable effects on civilization's demeanor for decades. This situation obtains because this tentative state bestows a momentary investment in hardware, time, and manpower for examining and acquiring the precise knowledge (at the macroproject proposal stage of development) determines cost-effectiveness. Jesus' habit of bountiful excess whenever it came to meeting peoples expressed needs and literally anoints him as an historically notable macro-engineering specialist.

Complementing concepts of the "blue machine" are fashionable "blue humanities" narratives [30]. These discoveries focus on presentday world-ocean explanations that are partially founded on accumulating accurate geophysical and geopolitical facts concerning seafloor terrain, from shorelines to the deep trench depths as discovered by mobile humans during prior millennia [31]. Ever since anthropoids became Homo sapiens, humans have been beset by constant biological and psychological adaptational bioshell stresses, the so-called polycrises, which is a collective term for synchronous and interwoven species survival macro-problems [32]. Unfortunately, the widespread and indiscriminate use of "polycrises" as a pejorative buzzword inserts a thought-limiting fence that blocks debates regarding macroengineering's most exuberant innovational concepts that offer alternatives to the status quo. Climate change, caused by recognized and still to be determined factors, is a macro-problem of primary concern to humans viz. sublimation of the Polar Zone icecaps, marked shrinkage of mountain range glaciers almost everywhere presents humanity with ecological shifts of huge landscape scope [33] as well as unfamiliar coastline submergence. For all European nations, including western Russia, North Africa, and the Middle East, faltering of the North Atlantic Ocean Overturning Circulation translates to a worrisome and, possibly geopolitically bothersome, climate change that may result in an encompassing polycrisis of unprecedented geographical consequence [34].

In all probability, Earth's future climate, composed of many weather regime climate regions, will be unprecedented in the recorded history of humankind. Although highly mobile and physiologically-socially adaptable, the people of Earth's bioshell tend to avoid insalubrious places that might be 120 C and receive 25 cm/year of

precipitation [35]. Instead, many geoscientists mull chemical engineering concepts that might lead to industrialization of the Earth's air-shell, significantly reducing its gaseous carbon dioxide concentrations. On the other hand, potential future increases in atmospheric carbon dioxide content will stimulate biomass accumulation of annual plants whereas an artificial return to lower Pleistocene Ice Age carbon dioxide concentrations will reduce biomass approaching 90% [36]. Annuals include vital food crops for humans and ranched domesticated grazing beasts. Governments, commercial and even philanthropic organizations are increasingly directing available monies toward the development of techniques to change the gaseous and sometimes, too, the particulates (dust, nanoplastics [37]) content of the atmosphere. For our purposes here, and following its discoverer, Peter M. Saunders [38], the world-ocean's air-seawater interface is composed of a one-meter-thick assemblage of different seawater layers varying vertically and horizontally in temperature and salinity. Ignoring pollution from sewage outfalls [39], shipping mishaps and operations etc., humans have influenced the sheer bulk and flows of this topmost layer of the world-ocean through freshwater impoundments on landscape [40]! Hydropower facilities help to illuminate the world's huge expanse of cities [41]. However, new electricity production may be installed aboard floating PV power-stations, perhaps even spanning the entire length of the Earth's Equator like some gargantuan hula-hoop [42] which might also power sun-spectrum lamps strung above the tree canopy of the Tropic Zone rainforests (say, of the Amazon River and Congo River basins) to foster a massive uptake of aerial carbon dioxide by green plants 12 hours daily [43].

European ideas for sea-dams stem from intentions to recover some of the previously lost "Aquaterra" or to prevent future loss of extant landscapes to ongoing sea-level rise. One of these of recent elaborations, the Northern European Enclosure Dam (NEED) [44], Figure 1, supposedly was devised to showcase the macro-size of infrastructure that would be required for one region if global sea-level rise continued unabated. NEED is comprised by three earth-fill embankments. The first being a 161 km-long dam between Brittany, France, and Cornwall (England) followed by a 331 km-long barrier spanning the ocean gap between Norway and the Shetland Islands (Scotland) and finally completed by a constructed interruption of 145 km filling the north of Scotland to the Shetland Islands. Presumably NEED shields about 6,000 km of northwest European coastline and possibly reduce the influx of climate refugees. Totaling 637 km, with a stabilized volume of 36 cubic km (approximately one hundred times the AD 1932-completed Afsluitdijk barrier linking the provinces of

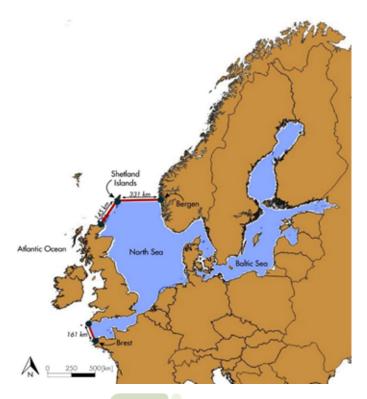


Figure 1: NEED, its three dams and the resulting controlled freshwater lake (Google image).



Figure 2: The debated ridiculous focus map of a European student contestation (U. Leiden image).

Noord-Holland and Fryslan, and converting saltwater of the Zuider Zee to a freshwater reservoir named Ijsselmeer) NEED would constitute a western European multilateral scheme that could potentially become a freshwater lake [44]. In effect, NEED is an enlargement of

an idea offered by Swedish oceanographer Stig H. Fonselius (1921-2003) a half-century earlier to isolate the Baltic Sea, making it a potable water reservoir serving all northern Europe [45]. However, during AD 2023, a public debate was organized by Universiteit Leiden, held 20 April 2023, on the topic "Should we build a European mega-dam?" Artistic license was prevalent since the debate focused on a misleading chart, without bathymetry, of an enclosure dam quite remarkably different from the more accurate straight-line NEED! Figure 2.

The planimetric chart offered to pro/con debaters by the contest's officiators appears to be an inverted interrogation point (?), without the dot beneath the curl and lobe. It is a cartographical travesty, invalid oceanographically, as well as a deliberate exhibition by the debate sponsor, the Kring of Coastal Engineers, that mocks the Macro-engineering idea of NEED. What might be Portugal's motive for associating itself with such a bathymetric blunder? Could NEED halt harm to western Europe's seashores from another Storegga tsunami like the one that terminated availability of onceinhabited "Doggerland" [46]? (Dutch planners seem to anticipate such a destructive sea-wave process-event by their determined investigation of mega-scale offshore sand extraction in one place of 20 billion cubic meters that results in a final rectangular trench in the seabed that is 224 km-long by 15 km wide of minimal depth 6 m that will affect the southern North Sea tidal range by several centimeters [47].) Oddly, on 17 August 2023, Sweden's government authorized, without controversy whatsoever, the expenditure of four million Krona (USD 364,000), administered by Dr. Celine Heuze, to examine the proposition: "Would the Northern European Enclosure Dam really protect Sweden from sea level rise?" The investigative group's Final Report is due for release during December 2024 AD. One may well wonder about the non-simultaneous same-year coincidence of these public macro-project representations. Fenno-Scandinavia is being elevated by post-Ice Age glacial unloading while the Netherlands, along with southern England, is known to be subsiding. Perhaps anticipating the fabulous financial costs of NEED, the Netherlands wishes to off-load further public NEED RD to other Europeans, the "we" (European Union) of the debate's title? Our query is answered by Hugo Kim Nota's Master of Science thesis, defended on 24 February 2022, that concluded: "For the Netherlands, it can be seen that it will have to bear a significant amount of the NEED costs due to its high exposure risk..." [48]. Unlike NEED, which can be implemented piecemeal, the grotesquely charted version debated must be rejected in toto as a worthless macro-engineering notion. Its purpose is to negatively nudge public opinion so that it will not to be built. Besides, the UN Environmental Programme, voiced its concern about the under-recognized stress on the Earth-bioshell's biodiversity of marine sand mining, amounting to six billion tonnes per annum at the present time (AD 2023).

South Europe fabric sea-dam, the GSBB

What is the motivation for thinking from a macro-engineering point of view? For us, such a procedure could reveal how much Homo sapiens might gain infrastructurally if people really wanted to progress past the level of major bioshell project technologies that are extant. Oftentimes, macroprojects are offered to funders with several alternatives as Plan A, Plan B, et cetera. No one ever alludes to a Plan Z (at the end of the alphabet) because such a presentation would likely be assumed as crackpottery! "Balmy" in the English-language is an adjective used to describe a prevailing weather regime that is pleasant, warm, and calm but the same word can also be utilized to describe someone, or the technically realizable idea of some physical thing, that is presenter-condemned as being foolish or irrational to undertake. Viewable on YouTube are a plethora of unserious videos about macroprojects, most of which feature the phrase "insane plan" in their titles, viz. "Atlantropa: The Insane Plan to Drain the Mediterranean" first offered by MEGAPROJECTS during January 2023. Possibly there exists a reverence for the Mediterranean Sea Basin that does not exist for the North Sea? Or, maybe, it is reverse commercial and geopolitical sales psychology? Whatever is the case, there is a pronounced renewal of public interest in macroprojects worldwide. And, the Strait of Gibraltar is one place of especial interest to many persons. Figure 3.

A sill is a seafloor barrier of relatively shallow depth restricting seawater movement between basins and such is the geomorphic status, for millions of years, of the Strait of Gibraltar. Since the mid-1960s, the professional ideology of macro-engineering has delegated those trained and skillful persons to be tasked with special responsibilities to undertake macroprojects that harness topographic features of the Earth-bioshell. These enormous technologies are designed for implementation to present beneficial and enlightening new geophysical situations to all wise people. Nevertheless, some macroproject plans were sometimes fiascos resulting from unreasonable mechanistic thought. That is, they were not germane to solving the macro-problem at hand and were possibly even utterly inchoate! For example, professional Italian architect Cristiana Penna's 2024 book,



Figure 3: International Space Station astronaut taken oblique photograph ISS069-E-3412, acquired on 14 April 2023, showing the 13 km-wide Strait of Gibraltar situated between the Iberian Peninsula (Spain) and northern Morocco in Africa, a unique seawater connection between the North Atlantic Ocean and the Mediterranean Sea which naturally throttles seawater exchanges between both saltwater bodies (NASA image).

Atlantropa 2.0: The Euro-African Continent, published in English by Letteraventure in Italy, recounts the sad lifetime story of notoriously idee fixe German architect-engineer Herman Sorgel (1885-1952), the primary butt for many of those silly "insane" macroproject histories outlined in sensational, brief YouTube videos. His monstrous Atlantropa concrete dam designed for emplacement within the Strait of Gibraltar was, by itself, unsafe, costly, and inappropriate. For example, modern concrete (but not ancient Roman concrete) once immersed in seawater deteriorates quickly and might have aged rapidly because of inadequacy of design, construction, or operation. Because the tsunamigenic tectonic plate boundary between Africa and the Iberian Peninsula is located beneath the Alboran Sea [49], Sorgel's design blueprint was undoubtedly structurally insufficient for the imposed tasks he optimistically imagined for it. The word "macroengineering" evidently had its first print appearance in the British weekly science news roundup magazine New Scientist, on 12 March 1964 at page 685. There, anonymous columnist "Geminus", in his article "It Seems to Me", elegantly alleged: "The real cause of our attachment to macro-engineering is at once more subtle and more profound". Yes, because the fantastic is fascinating! Many of macroengineering's productivity macro-problems are caused more by internal rather than external disruptors. Macroprojects can vary from

the molecular to the planetary and beyond, out to the farthest places of this Universe. Especially in formal schools there is much talk about investing in macroproject RD, but de facto most researchers invest in refining old ideas. This kind of situation obtains because the Earth-bioshell's reality remains theoretical. Curiosity-prompted RD is thus considered marginal, if not useless, because it is not immediately productive. Making a region of the bioshell world-ocean, namely the Mediterranean Sea Basin, into a managed compartment of Spaceship Earth" [50] is a kind of boldness that was rarely seen until technically detailed discussions of terraforming Mars commenced. Indeed, a night-lit NEED would be visible to humans equipped with small telescopes dwelling, temporarily or constantly, on Mars [51]. It is a well-known fact that sea level is affected by river dams on land [52]. Additionally, groundwater mining on land, echoing Archimedes old-time assertion, has shifted the trajectory of Earth's polar drift [53]. Contemplating the Earth's atmosphere 20 C warmer than today [54], as it seems to us, fosters among macro-engineers a tendency to launch more vigorous worldly speculations that possibly adopt some professional techniques used by future-minded persons [55].

Some supercomputer climate models suggest that widespread windand solar-power installations, if imagined as "farms" covering the Sahara and Sahel landscapes of northern Africa, would increase air temperature, rainfall, and vegetation. Following that projection, digital modelers assume that such well-spaced facilities affixed to >9 million square kilometers of desert and drylands would possibly generate 82 TW, about 4.4 times human civilization's AD 2023 energy production [56]. But it should be noted that at a conservative 2\% compounded annual growth rate, 18.5 TW cannot be doubled in less than 134 years! Thus, beneficial power-plant "farms" built in drylands might conceivably substitute for hydro-power. That is, it might be unnecessary to construct the trans-Gibraltar Strait Herman Sorgel-style concrete dam twin powerhouses because output would exceed actual human bioshell needs for electrical energy before 2100 AD. (Reportedly, by circa 2027 AD, the first phase construction will be completed by Xlinks Morocco-UK Power Project to transmit 10.5 GW via two 1.8 GW HVDC subsea cables 3,800 km, from a 1,500 square kilometer solar and wind farm in Morocco (Guelmim-Qued Noun region) to Alverdiscott, North Devon, England.) As macroengineers, we see this exuberant innovational landscape development as a potential extension of the geography of biological rewilding opportunities occurring concurrently with civilization's "Great Deceleration" [15]. Increases of precipitation are projected for western China and central Asia, hosting China's riskiest climate change stimulator called the Belt and Road Initiative [57]. Furthermore, Europe may become the main market for green hydrogen fuel manufactured and exported from northern Africa, especially Morocco and Egypt, before AD 2050.

Recent mathematical problem treatments have decisively shown that a hydrogen gas-methane blend can be transferred through former pure natural gas pipelines via land and submarine routes [58]. While electrical cables can be buoyant (for example, US Patent 3795759 issued to William A. Rhyne in March 1974), present trans-Mediterranean Sea underwater pipelines can perhaps be shut-down or abandoned with a change-over to green hydrogen or re-purposed to prevent the development of dead zones within a closed-off worldocean division. Hypoxia alleviation, a means to technically raise the dissolved oxygen concentration in a large volume of seawater by bubbling air from undersea pipelines, appears mandatory to us, the contemplators of a pendulous draped fabric GSBB. We propose a cure that uses in-place non-operational submarine natural gas pipelines to aerate an isolated Mediterranean Sea. Such a macroproject was previously suggested for the Baltic Sea [59] and it now appears that the currently non-functional 1,234 km-long Nord Stream-2 natural gas submarine tube offers an interesting re-dedicated use prospect for Macro-engineers. As the Mediterranean Sea waters warm, more marine species of life will migrate downward to reach cooler seawater [60].

The Gibraltar Strait Bimarian Barrier would be composed of an impermeable fabric, a complete physical interruption that precludes migration of Mediterranean Sea marine life or its seawater into the North Atlantic Ocean but the GSBB will have some fixable, even preventable, biofouling [61]. (Alien, or invasive, marine life species are spread throughout the Mediterranean Sea by recreational vessels, commercial and naval traffic, refugee rafts, and the lack of a truly effective brine-barrier in the lakes of the central part of the Suez Canal shipping route.) Bigger dead zones must result when the seawater column is warmed and acidification of seawater results from increased uptake of aerial carbon dioxide by absorption. A macro-project, involving the onerous annual discharge from tankers of millions of metric tons of slaked lime constantly, to achieve a yearly total alkalinization of the Mediterranean Sea has been computationally studied and found to be efficacious [62]. Artificial marine upwelling to lift nutrients from near the sea-bottom to overhead marine life (mostly living in the euphotic zone) has been proposed to sequester aerial carbon dioxide in seawater. We do not examine that technology's possibilities here. Construction materials and labor for the GSBB might be brought to Morocco's Tangier Med Port for storage and housing because it offers the greatest container capacity near the Strait of Gibraltar, but outside of the Basin proper. Tangier Med Port, unfortunately, is open to storm surges and tsunamis as proved by the storm surge of AD 1913 and the tsunami of AD 1755 that devastated Lisbon, Portugal as well as damaging major earthquakes such as that of AD 2023. Entirely artificial harbor constructions first appear in the Basin's archaeological record during the Iron Age, 1200-600 BC; more such maritime refuges for commercial shipping during storms may be built in the future because we are now equipped with massive earthmoving machines.

Discussion

We discard as completely infeasible, as well as useless, the spurious idea of filling the Gibraltar Strait with a dike-like rock-fill originally proposed in 1997 AD [63]. Similar structural control dams, also composed of mounded rocks as presented in 2015 AD [64] and 2022 AD [65], equally fail to result in cheaper blockade solutions. On the contrary, our hung fabric GSBB has been fully explicated. That is, its ultimate function on-land parts fabrication means of marine installation, its minimal siphonic hydropower plant output, and its final use by Mediterranean Sea Basin societies were previously described in an AD 2019 book chapter [66]. Our inspiration for the GSBB came from the flexible kinetic constraints used by highway and railway builders for the prevention and control of geological disasters on sloping and terraced landscapes, e.g., landslides. These roadway and town protections absorb the kinetic energy of falling material impacts, some have been tested >10,000 kJ by significant inelastic deformation. Basin members of an International Caretaker Council, in a sense an absorber of ongoing Basin geopolitical conflicts, would be responsible for maintaining the present-day level of the Mediterranean Sea. Artistically, but only when ship or boat-viewed from the North Atlantic Ocean side of the GSBB, the GSBB amounts to a watery version of Architecture's public garden and zoo "Ha-Ha" optical illusions designed to keep people apart from secured areas. There is no requirement for a grander-scale geopolitical organization because the stoppage of seawater flow that is outgoing from the Mediterranean Sea seems almost inconsequential considering the vastness of climate change, weather regimes occurring during the 21st Century [67-69] and because, too, only one major infrastructure refurbishment will be required. That is the addition of a sea-lock, or two for

safety, at the Suez Canal that is/are capable of safely restraining a one-meter seawater difference near Port Said [70] or Port Suez. A Mediterranean Sea kept one-meter lower in elevation than the rest of the world-ocean would cause the excluded seawater to rise 0.0005 meters from that single cause. Undoubtedly, a sea-lock situated in the Basin at Suez would help to mitigate any tsunami striking Egypt's coast at the Suez Canal's northern entrance [71]. The ICC might be established with a Memorandum of General Agreement on the Current Geographical Situation. Spain and Morocco would need to constantly confer, serving as the GSBB's guardians for all other Basin ecosystem-states. There can be, then, little question of "Neocolonialism" in international relationships within the Mediterranean Sea Basin.

Conclusions

We concur with Langdon Winner's astute assertion that all technical artifacts have political overtones [72]. The estimated volume of 1.27 cubic kilometers of piled rocks and dredged sand comprising barrier components for one sea-dam are too costly to consider as suitable for a world-ocean compartmentalization "wall" sited in the Strait of Gibraltar, even though this site is the best place to throttle inter-basin seawater flows. Of course, when the GSBB is operational there will be variations in sea level and continued crustal deformation of the Mediterranean Sea Basin. For instance, Venice, Italy, will still require its MoSE, which first successfully tested its lift-gates by simultaneous elevation on 3 October 2020, to ward off Adriatic Sea storm surges. Additionally, continued status quo sea levels offer saving little recalibration for the underwater ANTARES, ARCA and ORCA neutrino telescopes or the massive improvements necessary to maintain the functioning of coastal airports [73]. The polysemy of the word "model", as in supercomputer model of climate change, is the first obstacle to proper assessment of the GSBB's worthiness. Therefore, public dialogues should concern the risks of GSBB construction, operation, or even destruction. Cogent public discussions may theoretically display a macro-engineering approach that is fruitful and encouraged by relevant supervisory organizations that offer widely respected value concepts of the present-day world. Disparate societies that comprise human civilization are subject to unexpected exogenous inputs. Because these factors are so complex, it would be counter-productive to add any component of social engineering to the realization and operation of the GSBB. Would it not be foolish to cause the demise of a real-world 21st Century "Atlantis"? Paradoxically, some Earth-bioshell climate manipulators

who grandiosely dub themselves parasol-purveying "geo-engineers," offer to block incoming sunshine with transparent refractive surfaces composed of manufactured ultra-thin polymeric films and bunched nanotubes deployed in outer space between the Earth and Sun [74]. The boldness of this concept arouses curiosity as well as ordered contemplative faculties, resulting in a kinder and gentler re-assessment of the worth of NEED by recalling the early-18th Century satire penned by the wit Jonathan Swift, Thoughts for a Project for Draining the Irish Channel [75]. So, perhaps the NEED episode of public exposition was really a work of art? Re-reading Figure 2, possibly the organizers of the NEED debate intended to portray a human ear [76], meant to mimic the Vitruvian ideal of the human body! Like the Dutch, we, and others like us would enjoy being heard, our ideals and ideas at least rationally considered.



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