

Storage of CO₂ at low temperature as liquid or solid gas hydrate

Application to the Biscay deep zone in the French EEZ

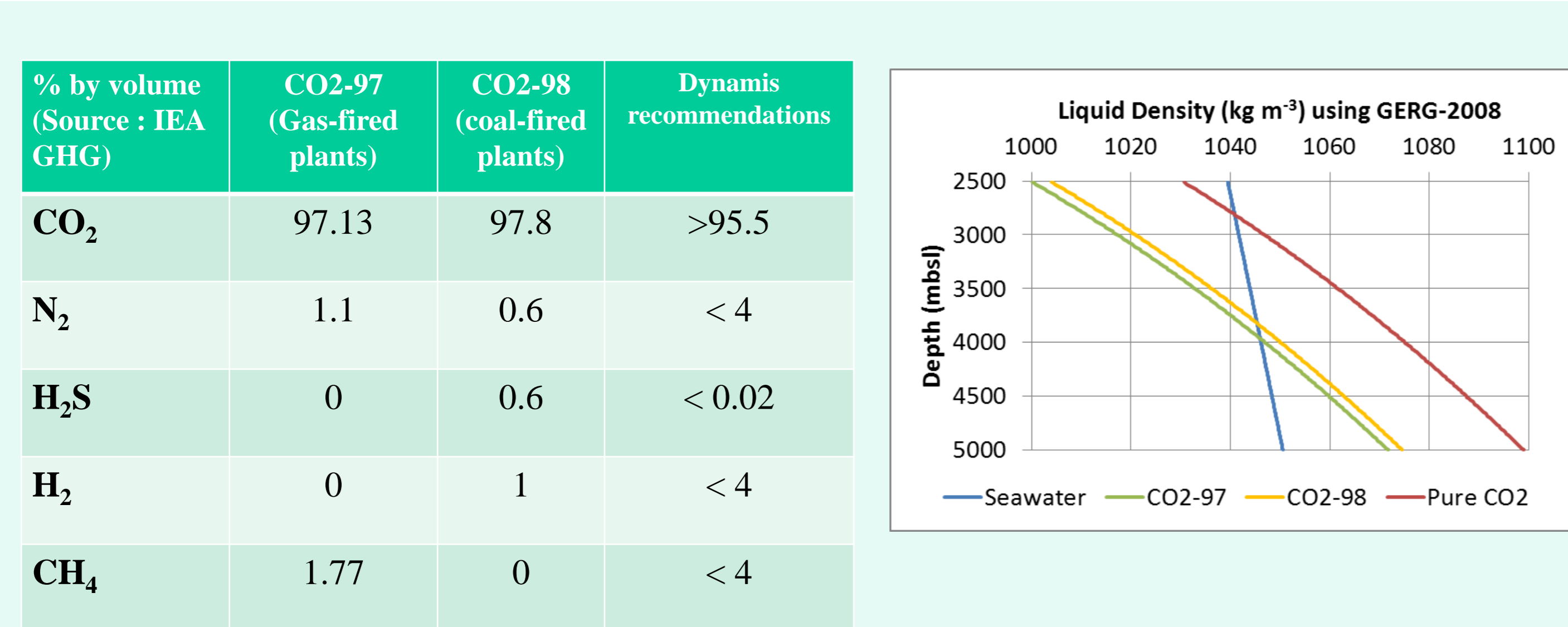
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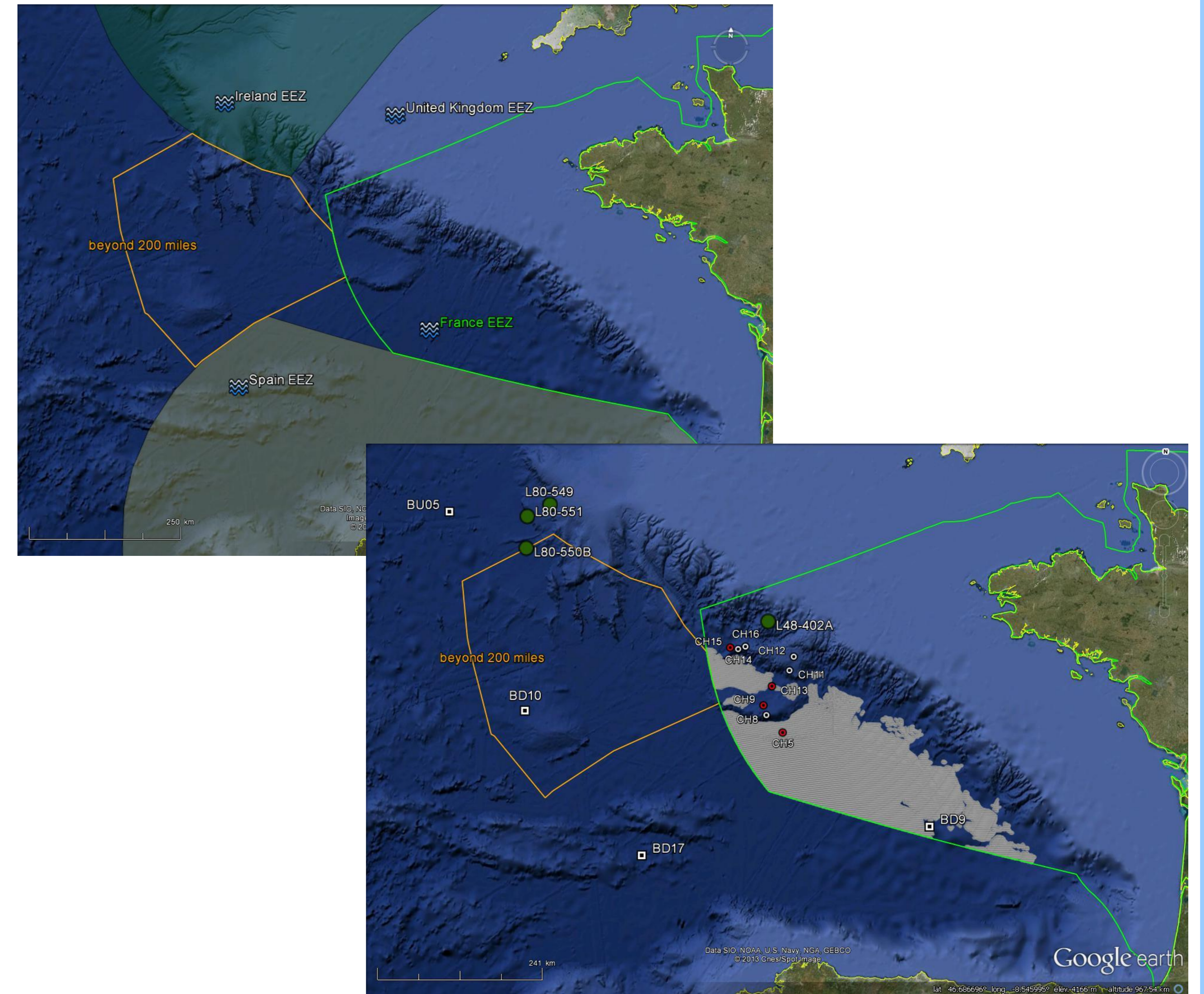
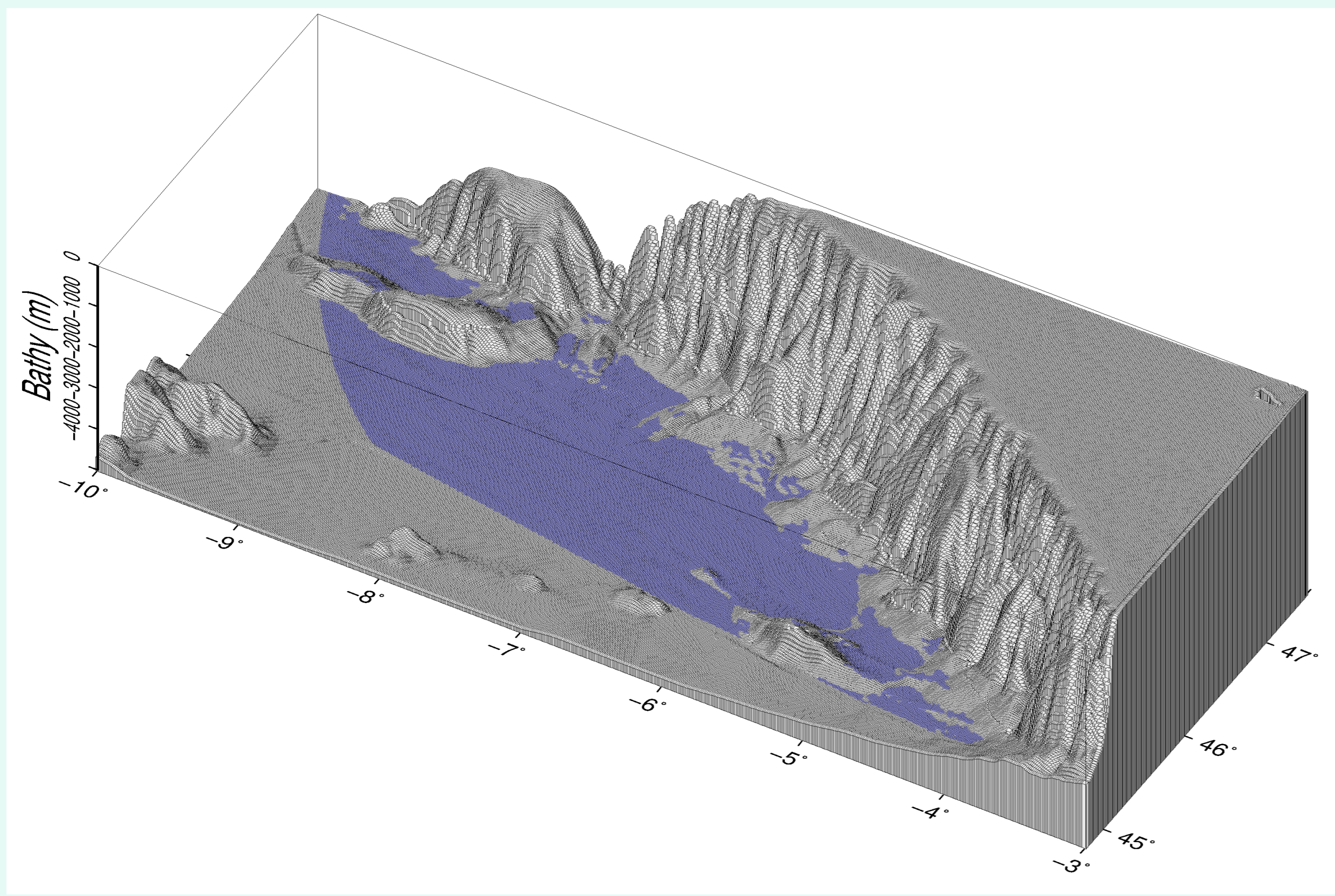
Main objectives:

- (1) Estimation of the CO₂ theoretical storage volume in the French EEZ in the area of the Bay of Biscay and the Celtic Sea
- (2) Comparison to the onshore CO₂ storage capacity in deep saline aquifers (Dogger and Trias layers in the Paris Basin)



CO₂ Storage Zone (in blue) defined by two criteria applied to the 1000m grid spacing bathymetry (Ifremer) using GMT (Wessel, 1998):

- 1) Sea Floor Depth > 4000 m => Density (CO₂+impurities) > (Sea Water)
- 2) Slope < 1 % => Safety criterium to avoid slumps on the continental slope

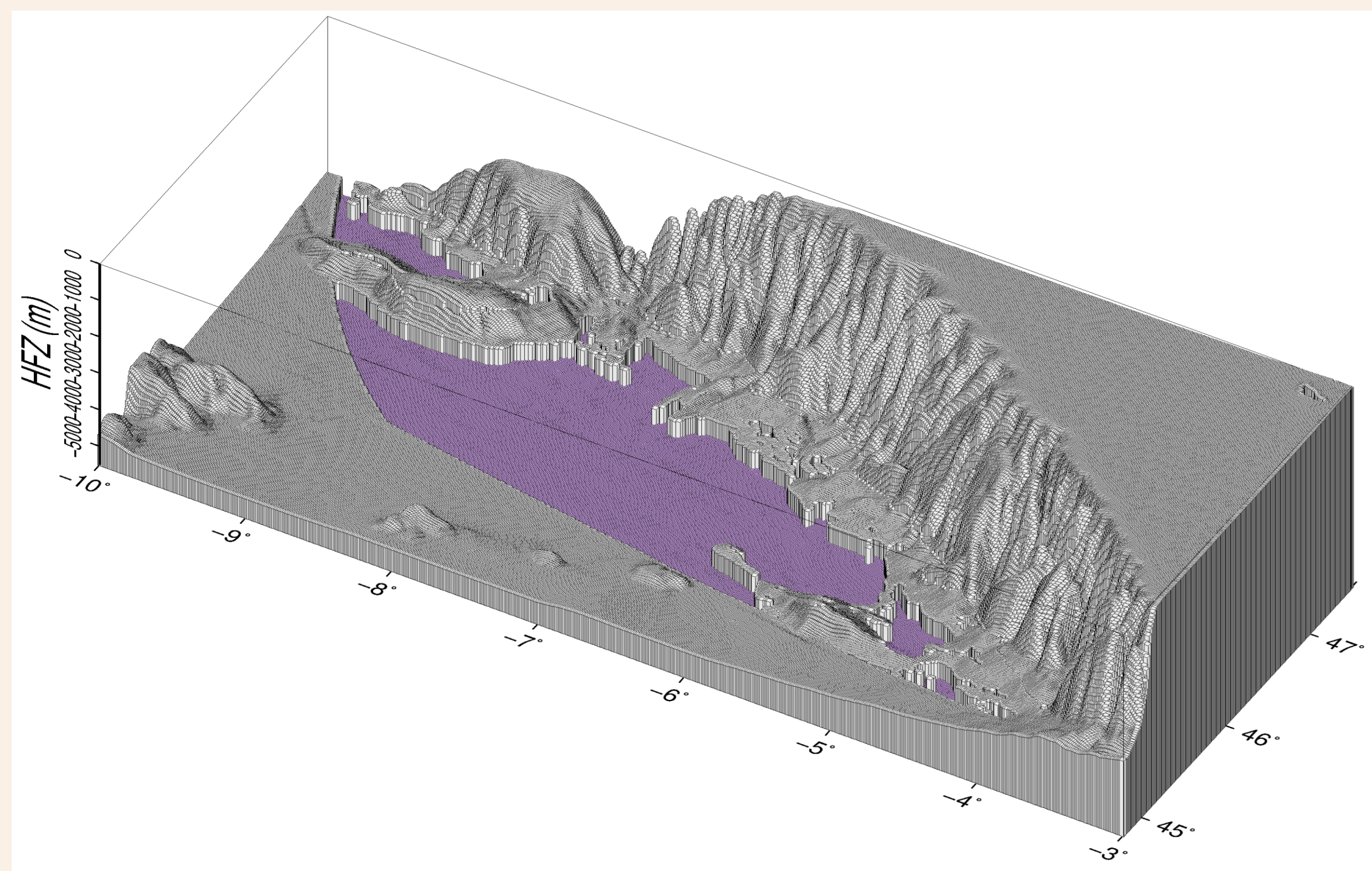


Source: GHFD09 (re-calculated)	H402	H550	H549	CH5	CH9	CH13	CH15	BD17	BD9	BD10	BU5
Surface Thermal Conductivity Wm ⁻¹ K ⁻¹	1.26 (1.25)	1.48 (1.1)	1.52 (1.21)	1.17	1.05	1.06	1.14	0.913	0.946	0.913	1.11
Surface Heat Flow mW m ⁻²	46 (43.2)	59 (60.1)	36 (37)	33 (33)	40 (46.3)	50 (52.4)	46 (45.5)	58.2 (58.05)	31.4 (32.64)	45.6 (50.2)	50.2

Thermal Conductivity of surface sediments is almost constant: TC = 1.1 Wm⁻¹K⁻¹

Surface Heat Flow in the French EEZ varies between two extreme values: Low HF = 33 mW/m², High HF = 60 mW/m²

CO₂ Hydrate Formation Zone (HFZ in purple) using CSMGem software (Sloan, 2007) supposing a homogeneous low Heat Flow (33 mW/m²)



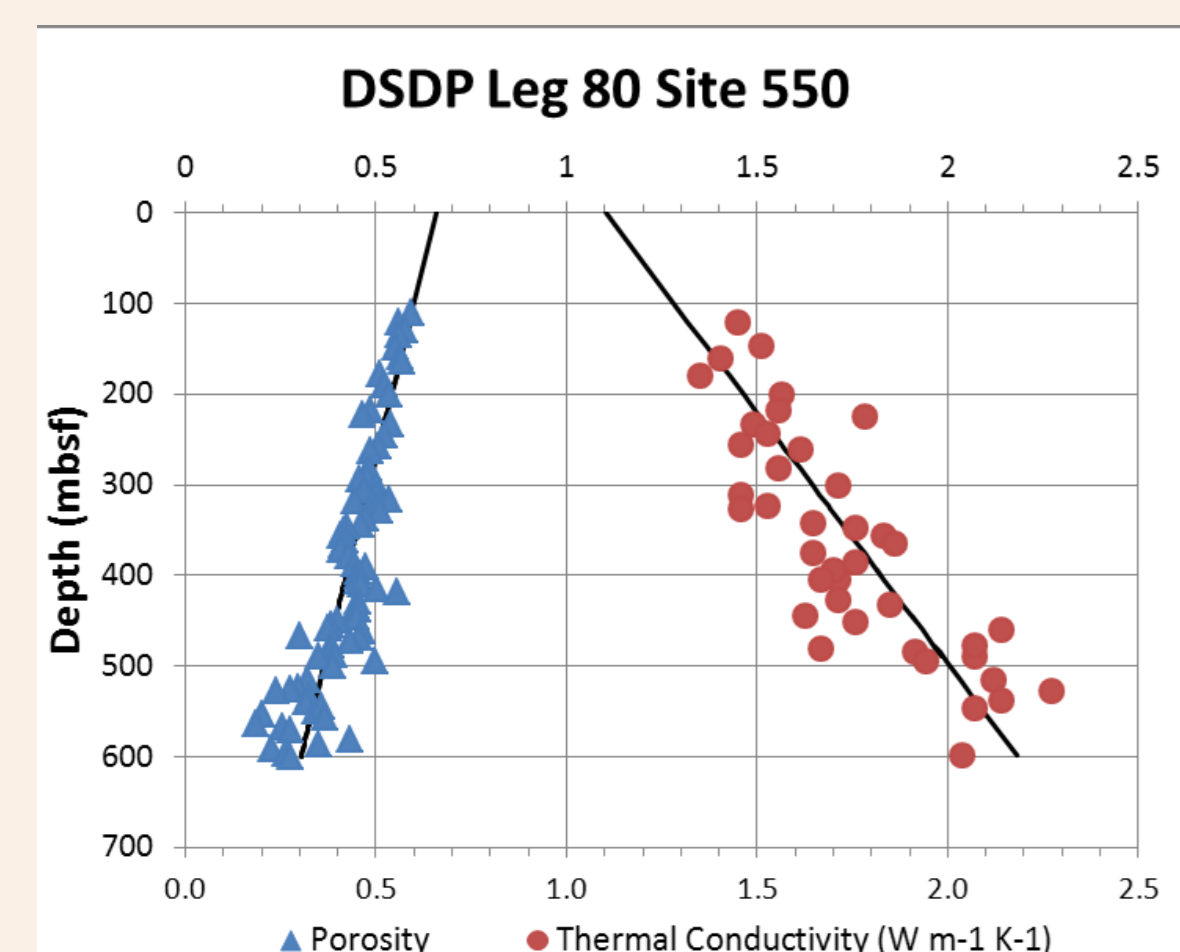
	Surface (km ²)	Mean thickness (m)	Total Volume (km ³)	Mean Porosity (%)	Theoretical Storage Volume (km ³)	Density (g/cm ³)
Low Heat Flow (CO2-97)	33 834 ^a	120 ^a	4415 ^a	46	2030	
High Heat Flow (CO2-97)	42 120 ^a	77 ^a	3846 ^a	55	2121	
Deep Offshore (French EEZ)			~4130	~50	~2075	~0.3
Paris Basin (Dogger layer)	15 000 ^b	~100		10	150 ^b	0.48
Paris Basin (Trias layer)	48 584 ^b	25 – 200		10 - 15	525 ^b	0.70
Onshore (Paris Basin)				~12	~675	0.48–0.7

^a calculated using GMT (Wessel, 1998)

^b from FP7 GeoCapacity project (2009)

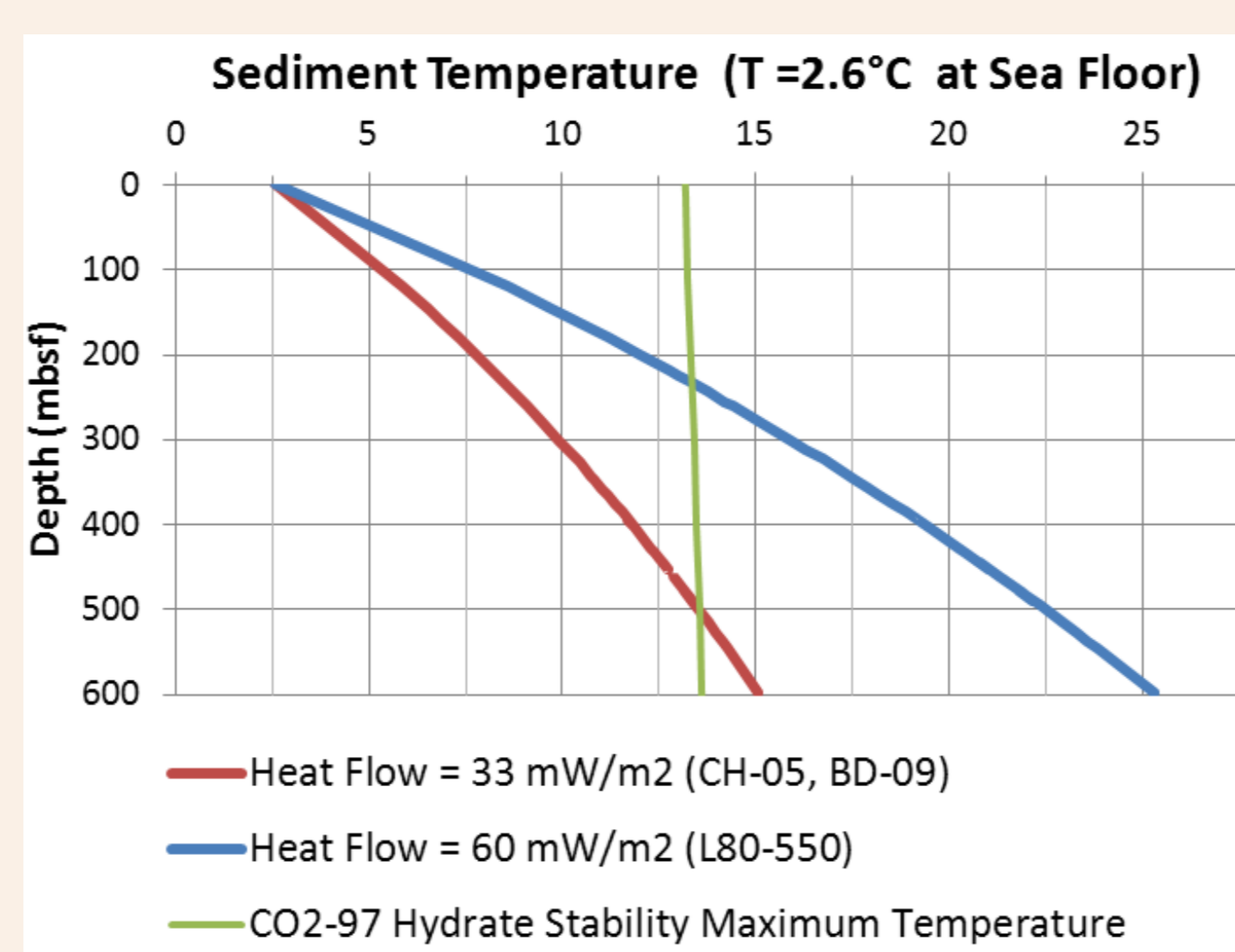
Conclusions

- Physical conditions (P,T) in French EEZ are favorable for a CO₂ storage within a surface close to the potential Paris Basin surface (~40 000 km²).
- Negative Buoyancy Zone (NBZ) and CO₂ Hydrate Formation Zone (HFZ) are calculated using GERG-2008 for liquid CO₂ and CSMGem code for CO₂ Hydrate: available porous volume for CO₂ hydrate formation lies between NBZ and HFZ surface (after CO₂ injection below HFZ).
- Theoretical storage volume for CO₂ Hydrate is almost the same in the Low Heat Flow or High Heat Flow case due to porosity variation with depth
- Theoretical storage volume in French EEZ is three times higher than the available volume in Paris Basin saline aquifers (Dogger + Trias)
- As CO₂ Hydrate density is only two times lower than SC CO₂, deep offshore storage capacity should be a priori higher than onshore capacity in France



$$\text{PORO} = 0.66 - 0.0006 \cdot Z$$

$$\text{TC} = 1.1 + 0.0018 \cdot Z$$



$$\text{TEMP} = 2.6 + \text{HF} / 1.8 \cdot \ln(\text{TC}/1.1)$$

References

- Sloan Jr, E. D., & Koh, C., 2007, Clathrate hydrates of natural gases. CRC (CSMGem software included)
- Wessel P, Smith WHF, 1998, New, improved version of Generic Mapping Tools released. EOS Trans Am Geophys Union 79(47):579
- Kunz, O. and Wagner, W., 2012, The GERG-2008 Wide-Range Equation of State for Natural Gases and Other Mixtures: An Expansion of GERG-2004, J CHEM ENG DATA 57 (11), 3032-3091