Monitoring the effects of CO_2 sequestration on ground deformation using a combined InSAR-GNSS approach

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Scenario

Various human activities such as burning of fossil fuels and deforestation have led to increasing concentrations of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere. This accumulation can lead to global warming, with consequent rise in sea level and other serious ecological hazards in the coming decades.

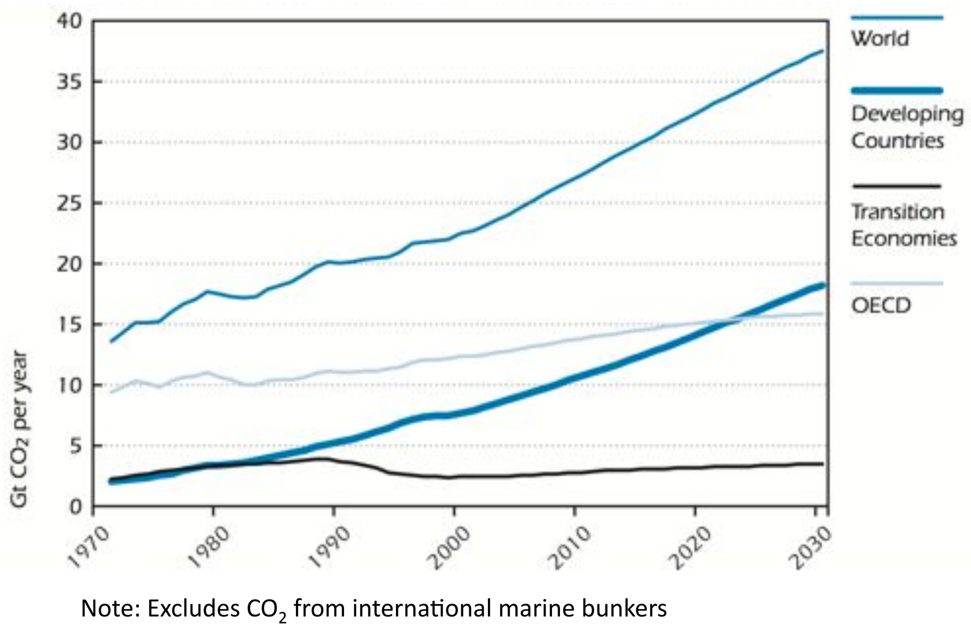

Figure 1: Energy-related CO_2 emissions, globally and by region (1973 – 2030) [1].

A possible way towards reducing this buildup is to capture CO_2 at stationary sources and inject it into underground geologic formations such as depleted oil or gas reservoirs for long-term storage (**geologic sequestration**).

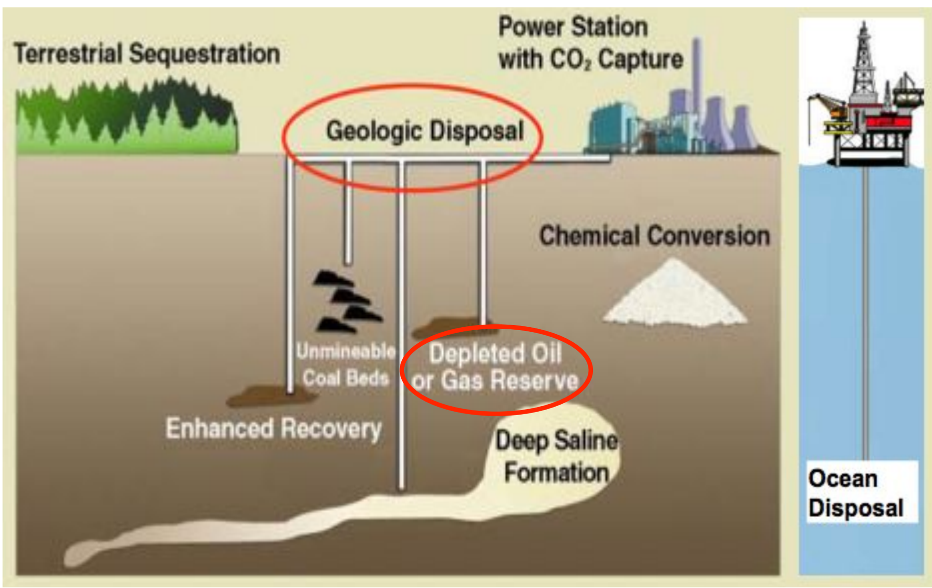

Figure 2: Geologic CO_2 sequestration [2].

However, owing to the high degree of urbanisation in some of the proposed sequestration sites, it is imperative to accurately **monitor the risks** associated with geologic sequestration. This entails continuous and precise measurement of ground deformation and analysis of subsidence effects, if any, in order to assess the propagation (and possible leakage) of CO_2 in the storage reservoirs. For this purpose, the application of an integrated InSAR-GNSS approach is proposed.

Integrating InSAR and GPS

Example area: Friesland in the Netherlands (Figure 3)

Gas and salt extraction in this region have resulted in a cumulative subsidence of up to 320 mm (1988 – 2006), confirmed by periodic levelling campaigns [3] and **Persistent Scatterer Interferometry (PSI)** performed on this area (Figure 4). Utilisation of the PSI approach requires the presence of adequate **Persistent Scatterers (PS)**. These temporally coherent radar scatterers, however, are not always present in rural and agricultural areas.

Figure 3: Northwestern Friesland.

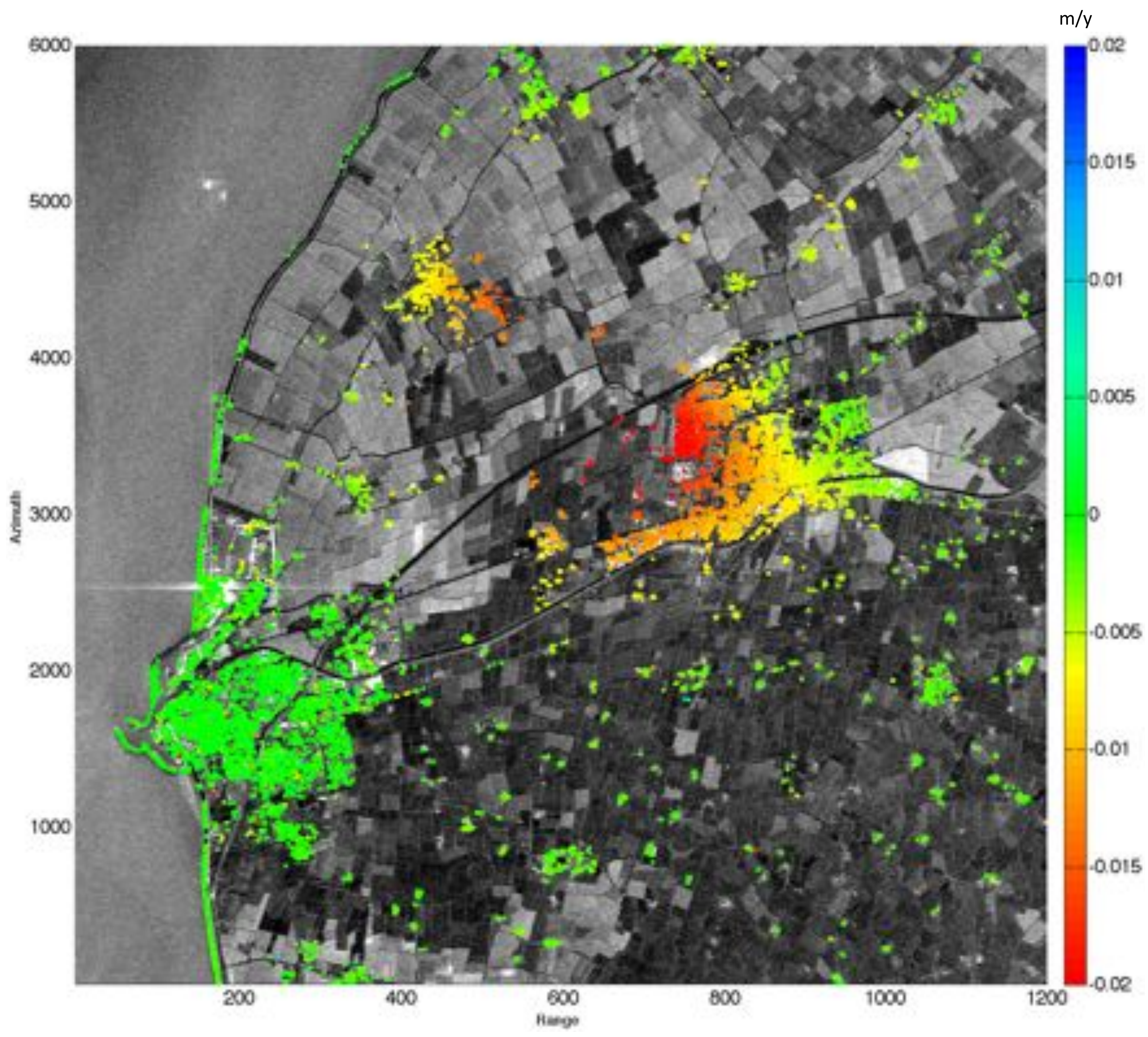

Figure 4: Ground deformation per year based on Envisat ASAR data during the period 2003-2009. PSI processing was performed using a standard set of assumptions.

Specific area of interest:

In the region between the salt mine and gas reservoir (Figure 5), using PSI alone to accurately measure ground deformation is difficult, owing to rural characteristics.

To ensure that the lack of PS points in this area is not due to a particular assumption made during PSI processing, the area in Friesland was processed with **15 different processing settings**. These settings differed in their *a priori* choice of deformation model, network method, atmosphere filter length and shape, noise filter length, and choice of detrending.

It can be seen in Figure 5 that there are large regions in this area of interest with **no PS point** detected by any setting, or **possibly unreliable PS points** detected by only one processing setting (red points).

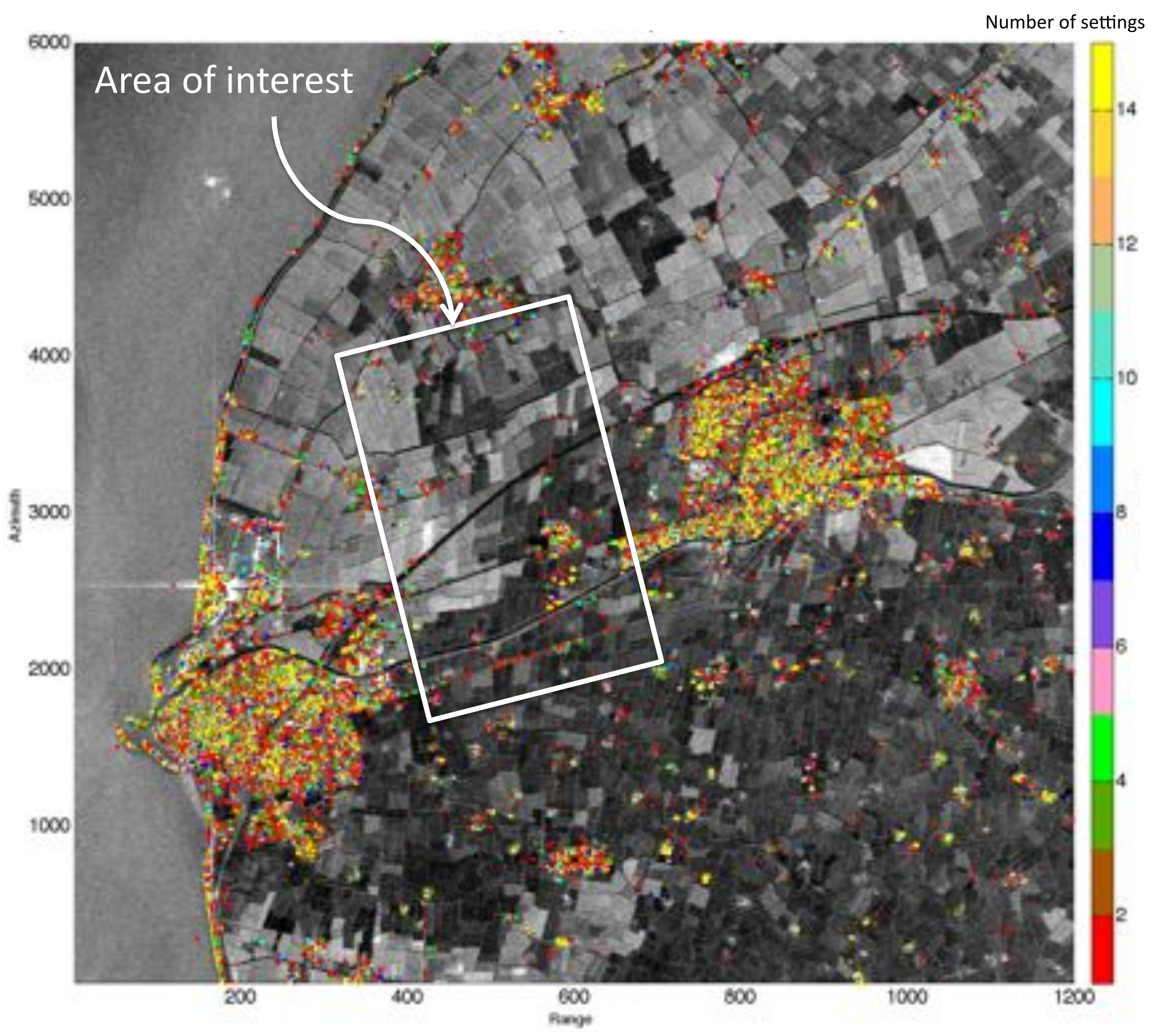

Figure 5: PS acceptance map. A PS point of a particular colour indicates the number of settings in which that point was detected.

In such an area of interest where PS are absent or unreliable, a suitably-designed **network of GPS receivers** can provide complementary deformation information (Table 1). To ensure millimetric co-registration and a coherent cross-reference between the two precision surveying techniques, a few corner reflectors equipped with GPS receivers may be used (Figure 6), which may be levelled for additional validation.

Table 1: Complementarity of PS-InSAR and GPS

PS-InSAR	GPS
Low temporal resolution (several days)	High temporal resolution (30 s)
High spatial resolution (a few metres)	Low spatial resolution (usually a few kilometres between receivers)
Wide area coverage	Area coverage is localised
Line-of-sight deformation measurement	3D deformation measurement
Measurement accuracy of a few millimetres	Measurement accuracy of a few millimetres
No hardware or maintenance cost	High hardware and maintenance cost
Relative reference system	'Absolute' reference system

Figure 6: Corner reflectors equipped with GPS receivers (Cabauw, the Netherlands).

References

[1] D. Gielen, J. Podkanski *et al*. Prospects for CO_2 Capture and Storage. *OECD/IEA*, 2004.

[2] B. Rabus, P. Ghuman, B. MacDonald. Monitoring CO_2 Sequestration with a Network Inversion InSAR Method. 2009.

[3] S. Samiei-Esfahany, R. Hanssen *et al*. On the Effect of Horizontal Deformation on InSAR Subsidence Estimates. *FRINGE*, 2009.