The Origin of SAR Calibration Requirements

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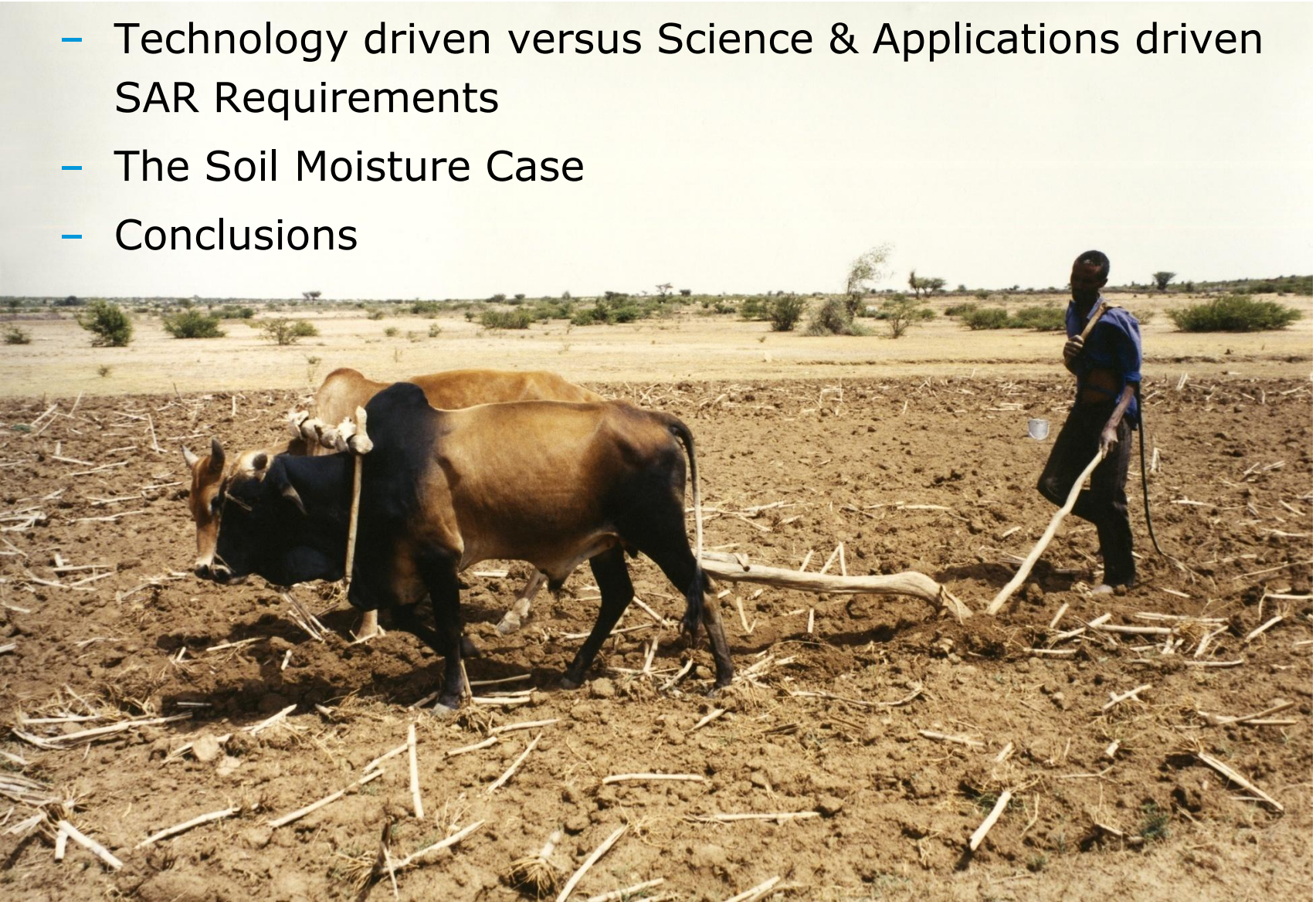
Outline

- Technology driven versus Science & Applications driven SAR Requirements
- The Soil Moisture Case
- Conclusions



Technology driven versus Science & Applications driven SAR Requirements

- Technology Driven SAR Requirements
  - Technically Challenging
  - Up-to-date Specifications
  - Best Possible Performance
  - Not Worse than Predecessors (SEASAT)
- Science & Application Driven SAR Requirements
  - Data Availability
  - Coverage and Revisit
  - Timeliness
  - Characteristics of Data Products
  - Error Budget associated with Uncertainty of User Service Information Product

Implications for Calibration Requirements; the Recommended Approach

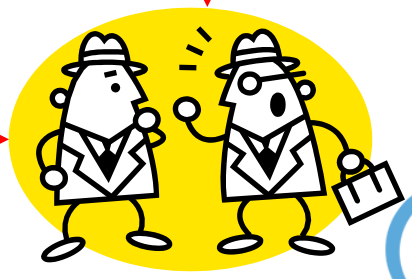
1. Obtain Information Product Accuracy Requirements
   - Marine: wind/waves, ice type, ship & pollution detection
   - Land: land surface motion, soil moisture, land cover
   - Cryosphere: ice type classification, ice edge, ice motion
2. Apply Retrieval Models to relate to
   - Radiometric Accuracy & Stability
   - Phase Error
   - Polarisation Purity
   - Doppler Stability
3. Define Technical Specification

Difficulty associated with the recommended approach: Communication Problem

Service Provider

Scientist

Systems Engineer



Frustration of System Engineer

- Service Provider "doesn't know what he wants"
  - End-User Requirements not in technical units e.g.
    - Accuracy [dB]
    - Phase Error [Deg.]
- Scientist "doesn't have robust retrieval algorithm"
- CEOS does not (yet) provide (application dependent) internationally accepted standards
  - Radiometric Accuracy (1 dB)
  - Phase Error (5 Deg.)
  - Sensitivity (NESZ -20....-30 dB)
  - Polarisation Purity (30 dB)
  - Ambiguity Ratio (25 dB)
  - Doppler Error (10 Hz)
  - Etc.

Case Study: Sentinel-1 Soil Moisture Product

1. End-User Requirements
2. Soil Moisture Retrieval
3. Sentinel-1 Performance
4. Soil Moisture Accuracy

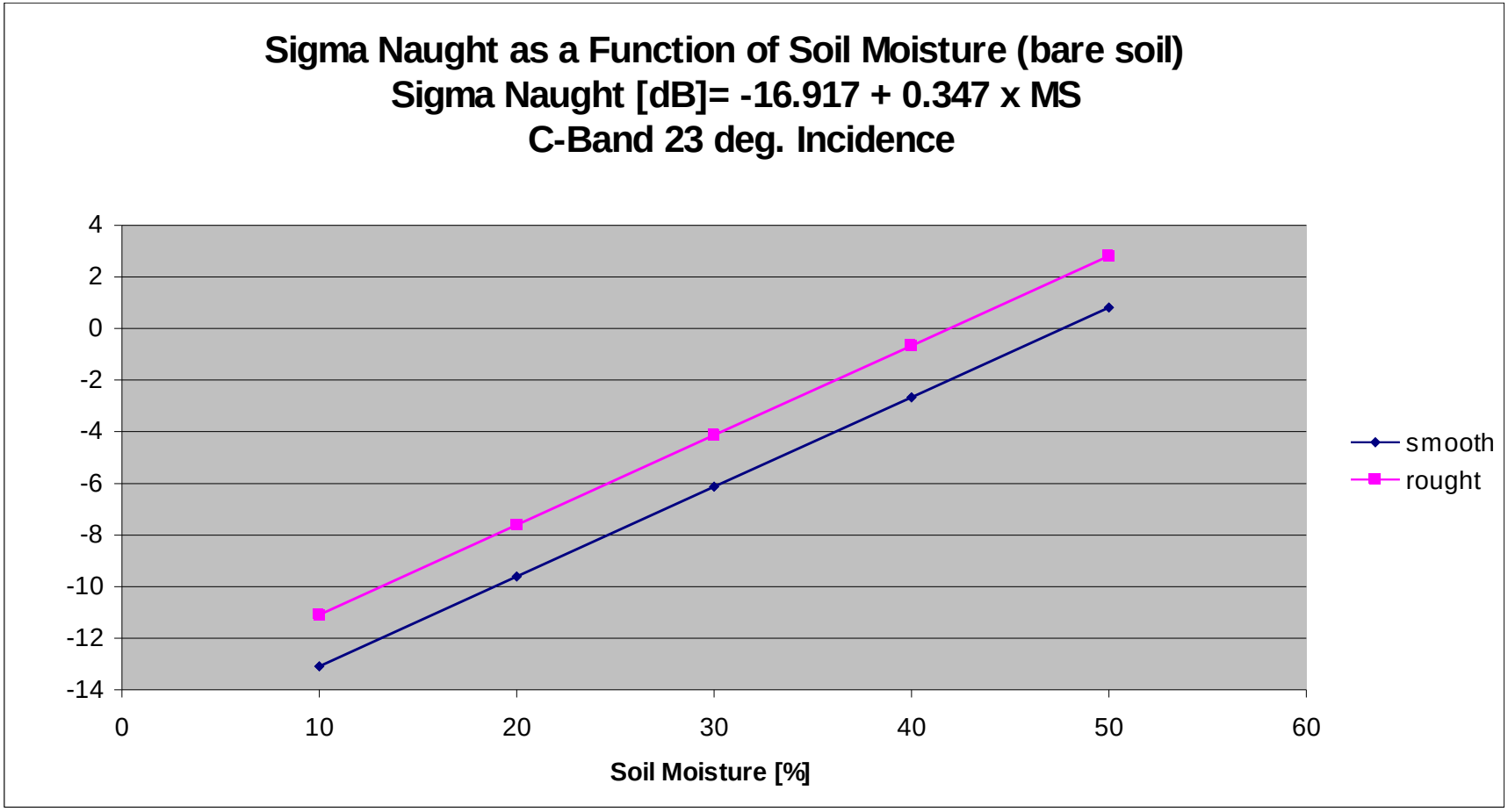
End-User Requirements

- For typical Western Europe mid-latitude conditions volumetric soil moisture varies roughly between 20 and 40 volume %
- A widely accepted uncertainty for satellite soil moisture estimation is 5 % uncertainty which means that 4 classes could be identified (dry, medium dry, medium wet, wet)
- Tighter specifications would be difficult to achieve and hard to validate
- Spatial Resolution 100 to 1000 m

Simplified Soil Moisture Retrieval Model (Bare Soil)

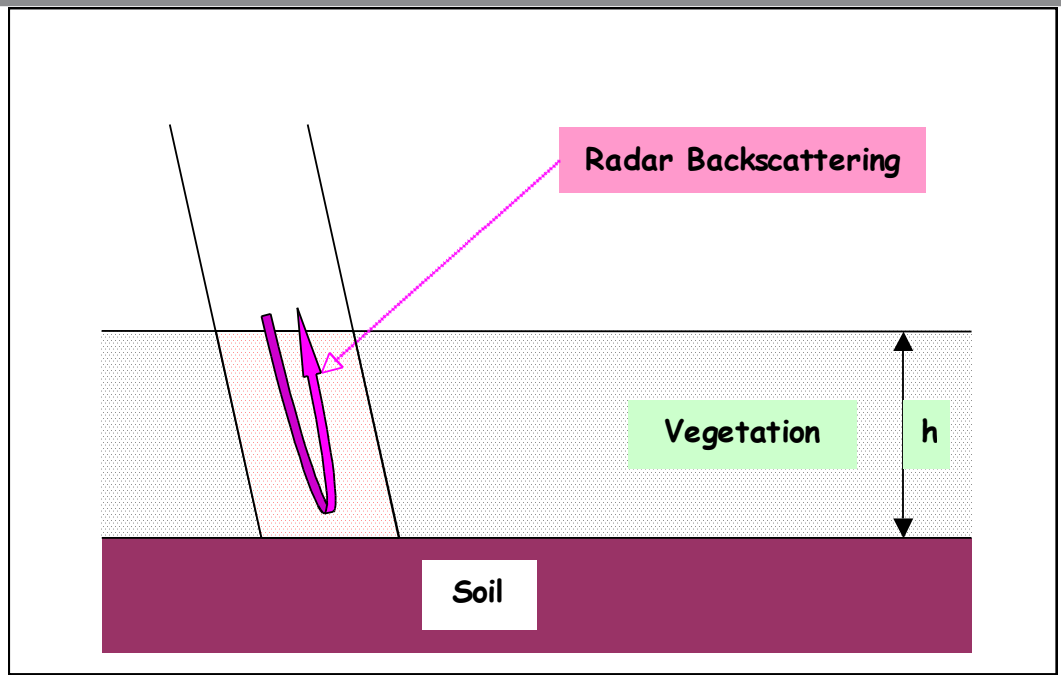
$$\sigma^0 = \{Ce^{Dm_s}\}\cos\theta$$

θ		Incidence Angle
m_s		Soil moisture



Canopy Effects on the Soil Moisture Retrieval Model

$$\sigma^0 = \left\{ A\left(1 - e^{-\frac{m_b B}{\cos\theta}}\right) + Ce^{-\frac{m_b B}{\cos\theta} + Dm_s} \right\} \cos\theta$$



θ = incidence angle

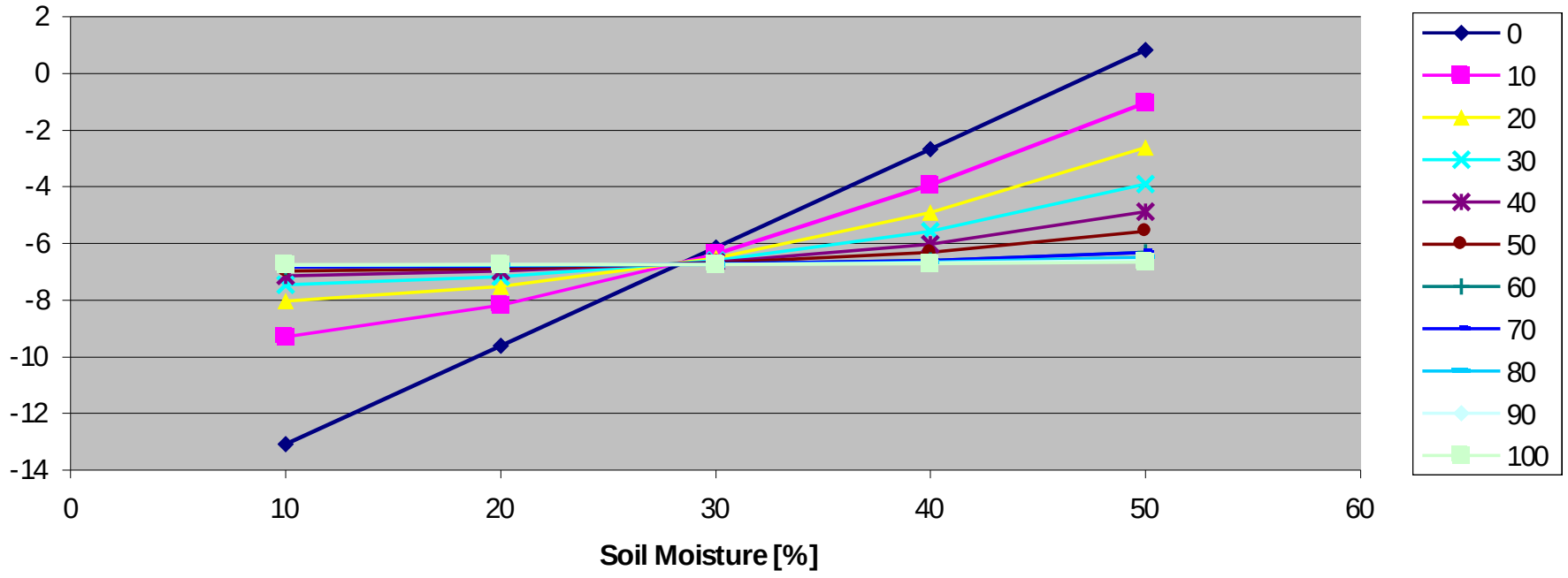
m_s = soil moisture

m_b = total vegetation water content (biomass) per unit area
This could be expressed as $m_b = W/h$
where

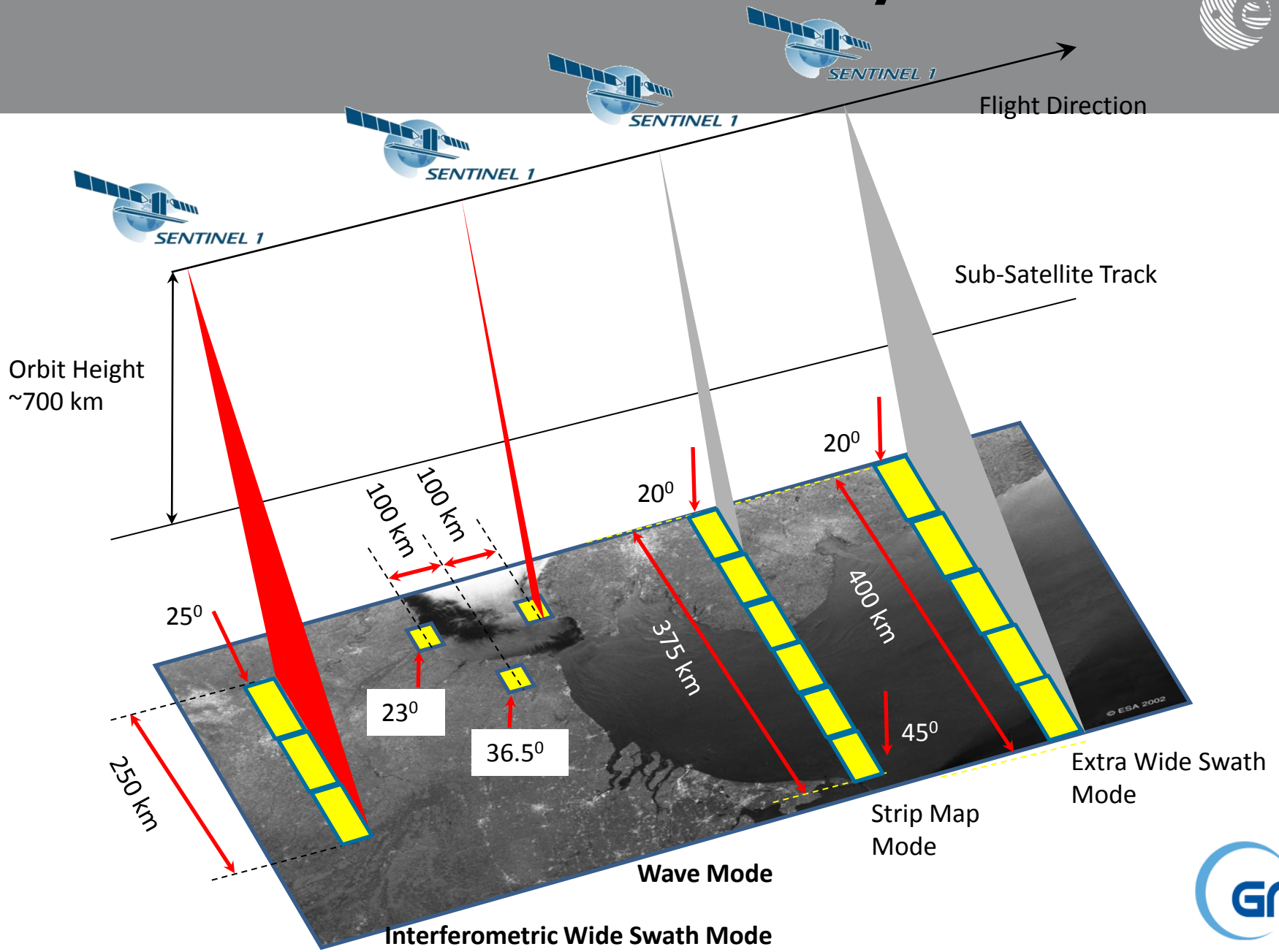
W = volumetric water content (biomass) of the vegetation per unit volume

h = vegetation height

Impact on Soil Moisture Retrieval



Sentinel-1 Observation Geometry



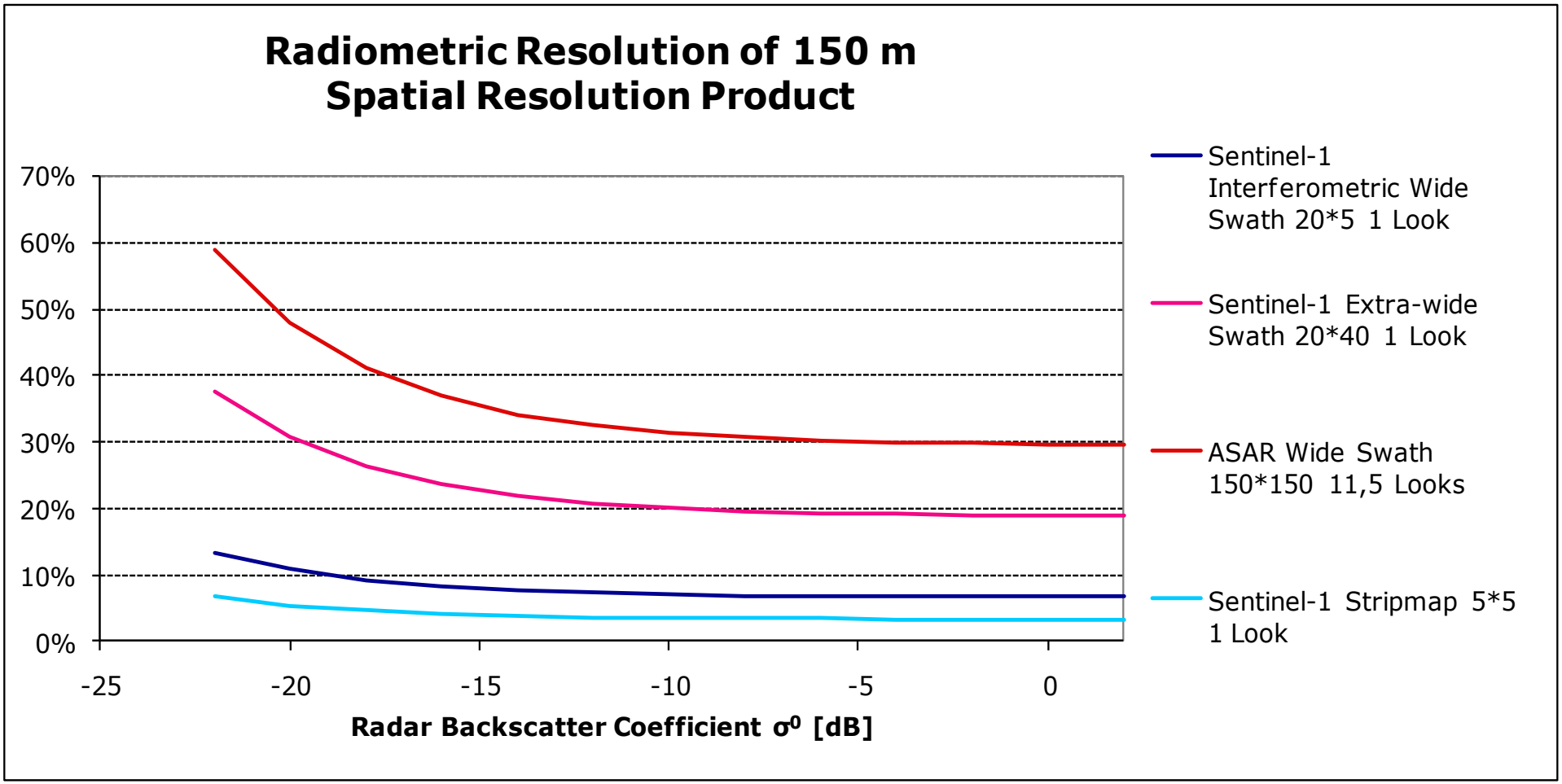
Sentinel-1 Performance Requirements

Mode	Access Angle	Single Look Resolution	Swath Width	Polarisation
Interferometric Wide Swath	**> 25 deg.**	**Range 5 m Azimuth 20 m**	**> 250 km**	**HH+HV or VV+VH**
Wave mode	**23 deg. and 36.5 deg.**	**Range 5 m Azimuth 5 m**	**> 20 x 20 km Vignettes at 100 km intervals**	**HH or VV**
Strip Map	20-45 deg.	Range 5 m Azimuth 5 m	> 80 km	HH+HV or VV+VH
Extra Wide Swath	> 20 deg.	Range 20 m Azimuth 40 m	> 400 km	HH+HV or VV+VH

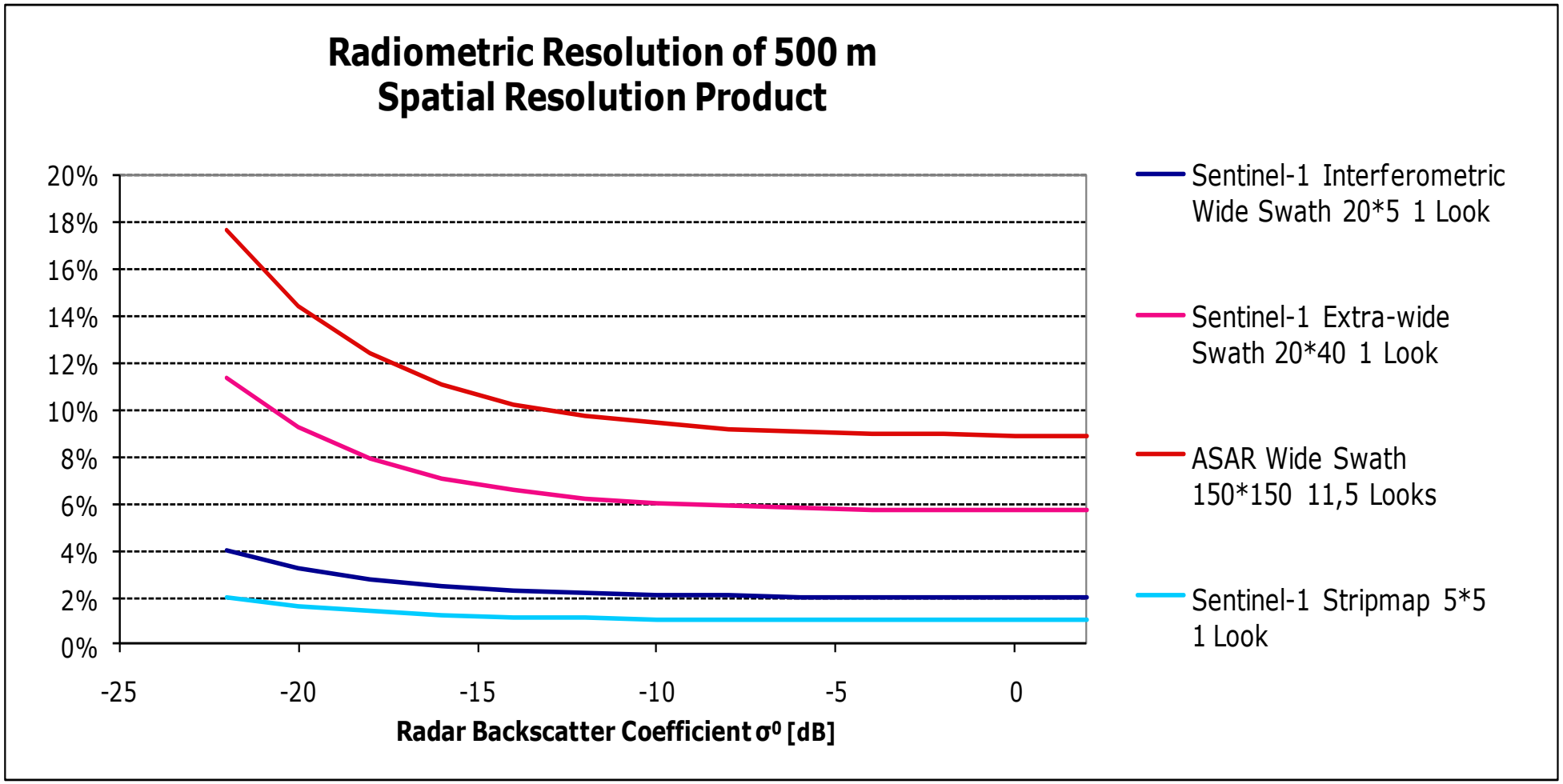
Main modes

For All Modes	
Radiometric accuracy (3 σ)	**1 dB**
Noise Equivalent Sigma Zero	**-22 dB**
Point Target Ambiguity Ratio	**-25 dB**
Distributed Target Ambiguity Ratio	**-22 dB**

Radiometric Resolution (Noise & Speckle) for 150 x 150 m Product



Radiometric Resolution (Noise & Speckle) for 500 x 500 m Product



End-to-End Performance of 150 * 150 m spatial resolution product

	Envisat	Sentinel-1			
	ASAR WS	EWS	IWS	Strip Map	Unit
Radiometric Resolution	1.16	0.79	0.29	0.15	dB
Radiometric Accuracy	0.33	0.33	0.33	0.33	dB
Soil Moisture Sensitivity	0.34	0.34	0.34	0.34	dB/Volume %
Soil Moisture Measurement Uncertainty (3 * standard deviation)	10.66	7.58	3.91	3.22	Volume %

Conclusion and Recommendation

- System calibration requirements can be related to the estimation uncertainty of SAR information products such as geophysical variables (soil moisture)
- To arrive at a balanced compliant system design the dialogue between service providers, scientists and system engineers is essential
- If there are generally accepted performance levels in terms of Radiometric Accuracy & Stability (1 dB), Phase Error (5 deg.), Polarisation Purity (30 dB), Doppler Uncertainty (10 Hz), CEOS should consider a recommendation