Tuning Hyperspectral Mission Specifications to the End-User Needs through End-to-End Simulations

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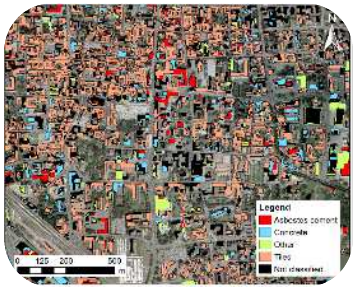
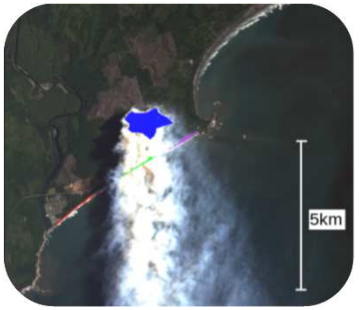
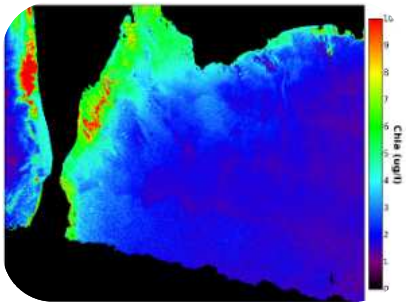
The starting point

- End-user needs
- First set of high-level mission requirements inherited from previous studies (HYPXIM, …) and User Requirements document
- Budget and time constraints
- Available technologies







Instrumental Design Challenge

- End-user needs
- First set of high-level mission requirements inherited from previous studies (HYPXIM, …) and User Requirements document
- Budget and time constraints
- Available technologies

➢ Finding the right balance was a complex task considering multiple constraints

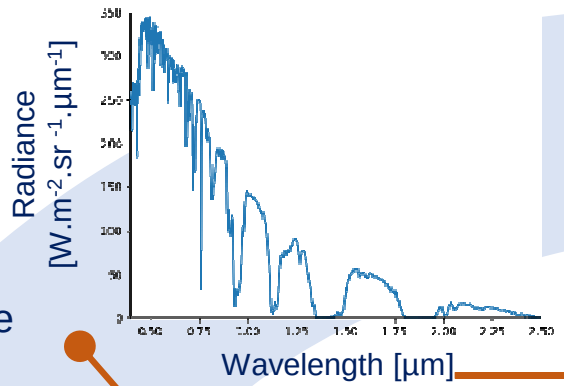
How to derive mission requirements from end-user needs?

- Use the CNES legacy on mission engineering and mission performances:
  - Inherit requirements from past and/or current optical missions (Sentinel3-OLCI, Sentinel2-MSI, VENµS, PLEIADES…)
  - Integrate results from past phase 0&A hyperspectral studies (HYPXIM, CHIMERE, HYSP, …)
- Include the end-user feedbacks on other airborne or spaceborne sensors
  - Rely on a Mission Advisory Group and its Principal Investigator (PI)
- Develop and run an End-to-End mission performance chain including end-user applications (E2ES)
  - Assess the mission requirements and concepts
  - Support generation of the system requirements
  - Develop and check L1 and L2 algorithms

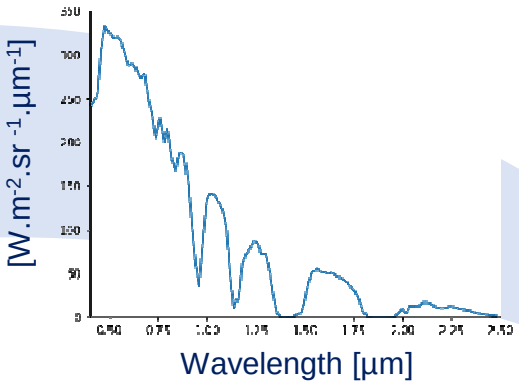
End-to-End mission performance simulation

The main effects of the whole imaging system are taken into account to simulate the final images of a given ground target (vegetation, minerals, etc.).

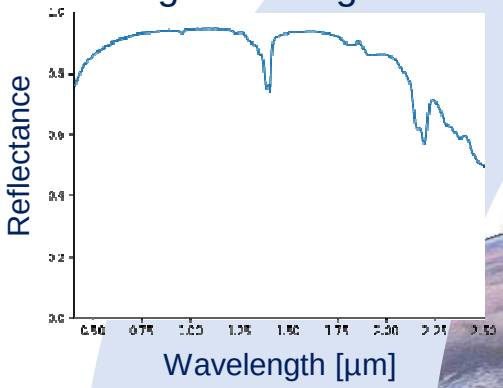
Top of atmosphere spectrum



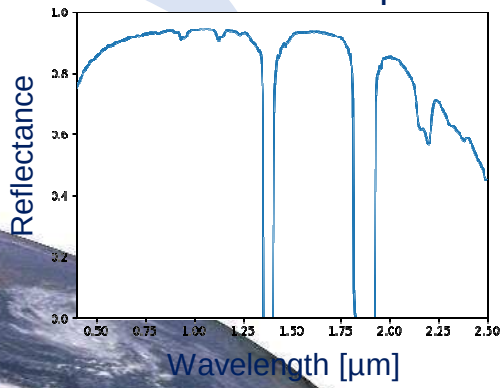
Out of instrument spectrum



Spectrum of the ground target



Spectrum of the target, estimated from space



2 Instrument

Spectral resolution 10 nm
Absolute calibration 0 % - 3%
Inter-band calibration 0% - 1%
Noise SNR 250 – 50
Spectral shift 1nm

1 Lighting and atmosphere

3 Atmospheric corrections

Simulate typical AOT and water vapour estimation errors

End-user application simulation chain

- The applications are selected to cover the mission targets expressed by users and to challenge the instrument characteristics on application performance, assuming state-of-the-art algorithm, not to challenge the end-user algorithms themselves.
- To overcome the limitation of the implemented scenarios, all performance results are analysed by comparison to the ones obtained with the initial set of requirements.

Vegetation

Biochemical parameters
- Leaf Area Index
- Chlorophyll A and B
- Carotenoid
- Equivalent Water Thickness

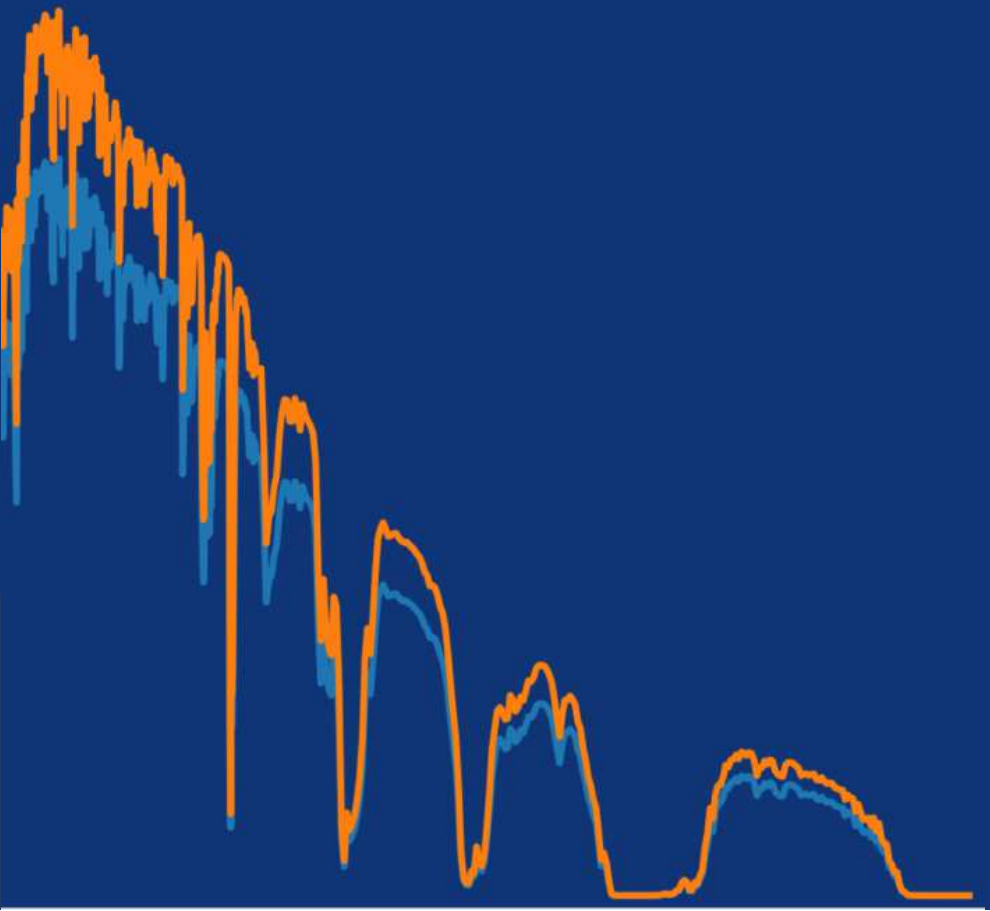
Bathymetry

Water column parameters
- phytoplankton
- colored dissolved organic matter
- non-algal particles
- water depth
- nature of the sea bed

Mineralogy (trafficability)

Soil composition
- Sand
- Silt
- Kaolinite
- Montmorillonite
- Illite

} Clay types



SNR requirement

Influence on the end-user applications

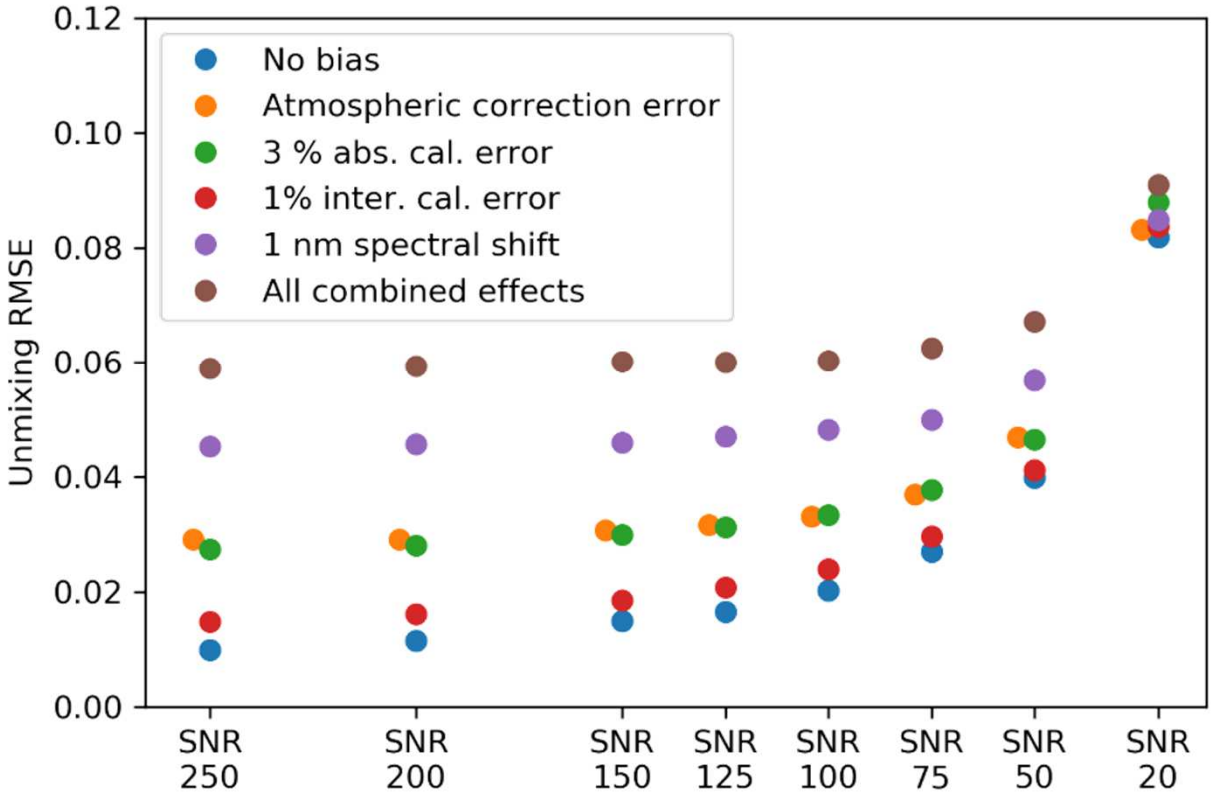
SNR

- SNR initial req. seems very challenging
- Potentially over-constrained

➢ Assess the impact of combined errors on the end-users application performances

SNR: resume & combined effects

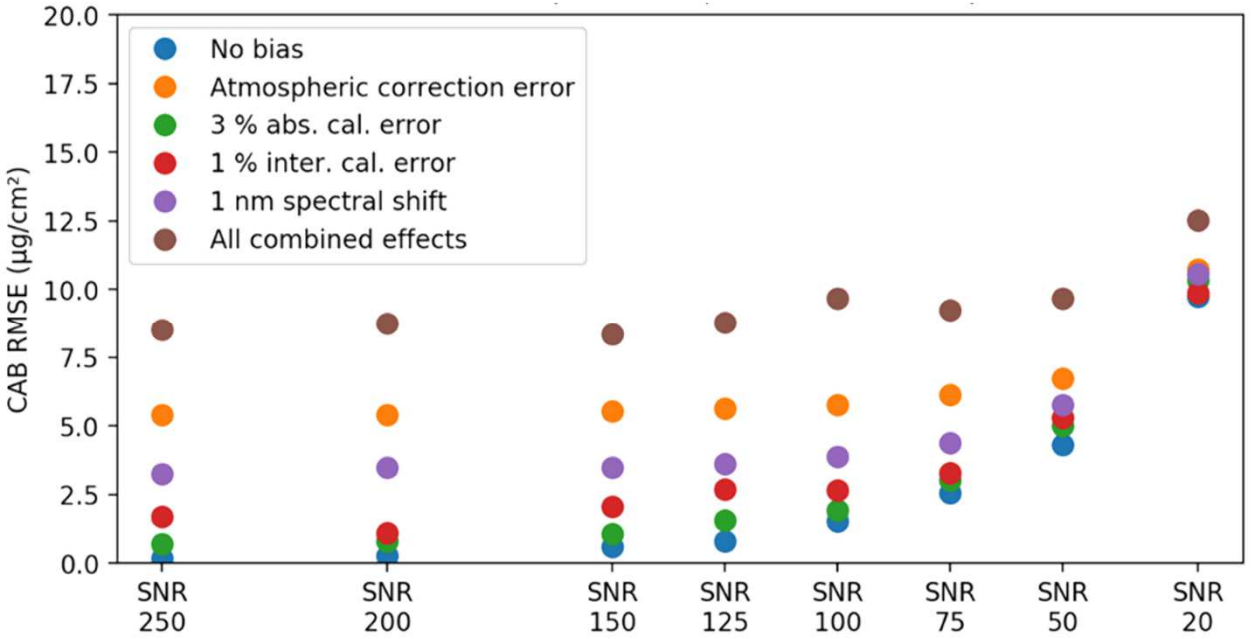
Mineralogy for trafficability



- SNR 100 and 250 models give same performance for this app. with instrumental & atmospheric correction combined errors
- Spectral shift errors is the major source of errors for this app. then absolute calibration & atmospheric correction errors

SNR: resume & combined effects

Vegetation – Chlorophyll estimation



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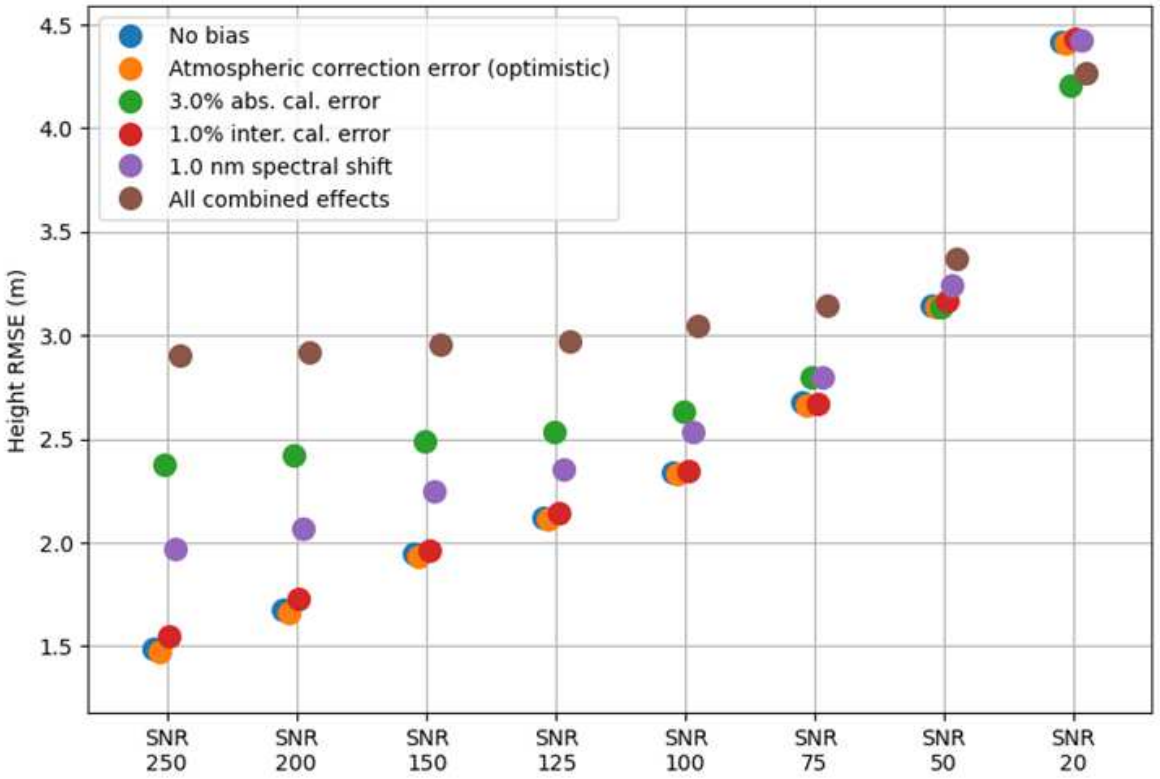
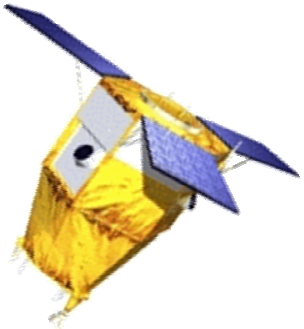
SNR: resume & combined effects

Bathymetry – Water depth



- SNR 125 and 250 models give similar performance for this app. with instrumental & atmospheric correction combined errors
- The performance continues to increase with the SNR increase
- Absolute calibration error is the major error for this app. then spectral shift error
- Impact of atmospheric correction errors is most likely underestimated

Conclusion



- Develop an End-to-End Simulator (E2ES) including 3 representative end-user scenarios
  - ➢ Built to assess mission requirements
  - ➢ Paves the way for a massive evaluation of various instrumental configurations
  - ➢ To speed up the instrumental design process and focus end-user expertise on the main challenges

- Emphasize that atmospheric correction has to be considered of major importance for end-user applications
  - ➢ Evaluate the instrument performance at Level-2 in addition to Level-1

- Balance the SNR against all other contributors to the image quality, for every studied end-users applications

- Find a SWIR spectral sampling compromise based to the MAG studies (cf. Xavier Briottet presentation)