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Developing EO mission concepts to fly in convoy with the ESA Sentinel series

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The EO-Convoy Land study team

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Introduction

- ESA are undertaking three studies investigating possible synergistic satellite missions flying in formation with the operational Copernicus and METOP satellites: *EO-Convoy studies*
- These three studies are focused on:-
  - Ocean and Ice
  - Land
  - Atmosphere
- The EO-Convoy studies comprise two parts:-
  - Identification of science and operational objectives that need addressing via future missions
  - Definition and development of small cost-effective missions that meet these objectives (see also poster #48 by Rachel Bird, SSTL)

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Outline

- Current and planned EO capabilities for land surface science
- Definition of science needs: what observations do the land surface science community require?
- Summary of capabilities and gaps: are these requirements met by planned EO capabilities?
- Preliminary list of mission concepts to fly in convoy with the Sentinels
- Shortlist selected for further study based on assessment by ESA scientists

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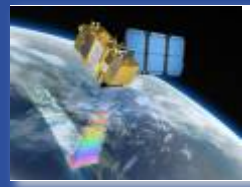
Current and planned missions: Sentinels

Sentinel 1 – C-band SAR imaging
All weather, day/night applications, interferometry
x 2 satellites, 693 km, Dawn dusk orbit

S-1A launched April 2014



Sentinel 2 – Multi-spectral high resolution imaging
Land applications: Land cover mapping, LAI, chlorophyll
Continuity of Landsat, SPOT missions
x 2 satellites, 786 km, LTDN 10:30 am

2015

Sentinel 3 – Global ocean and land monitoring
Wide-swath ocean color, vegetation, sea/land
surface temperature, altimetry
x 2 satellites, 814 km, LTDN 10:00 am

2015

Sentinel 4 – Geostationary atmospheric
Atmospheric composition monitoring, trans-
boundary pollution

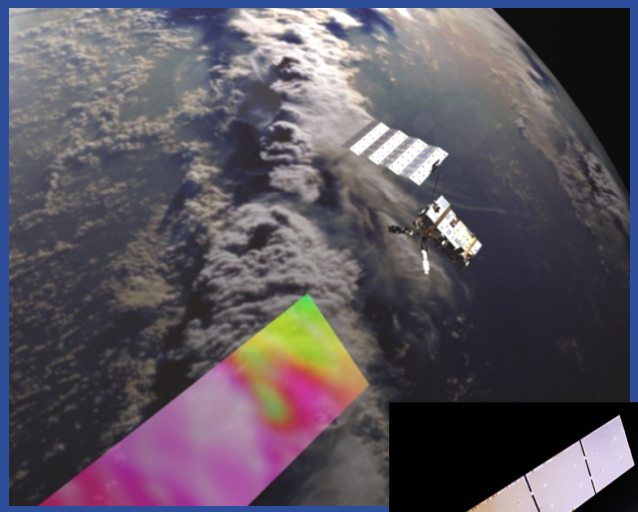
2019

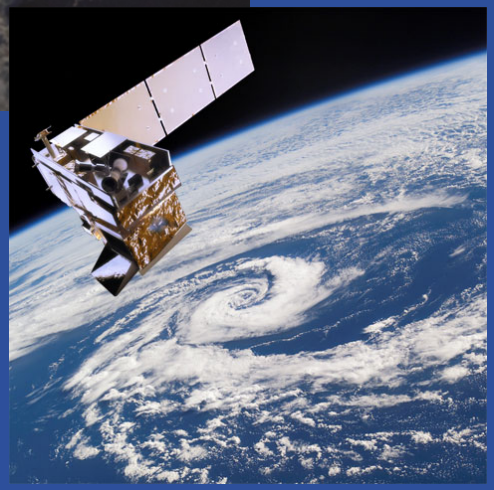
Sentinel 5 – Low-orbit atmospheric
Atmospheric composition monitoring
(S5 Precursor launch in 2015)

2020

Current and planned missions

- Operational missions:
  - ESA MetOp
    - AVHRR: surface albedo, vegetation (NDVI), land surface temperature, fire area
    - ASCAT: soil moisture
  - Suomi-NPP
    - VIIRS: surface albedo, vegetation (NDVI, LAI, land cover), land surface temperature, fire area and temperature, soil moisture
    - ATMS: land surface temperature
- Science missions (from ESA, NASA and other national space agencies) also considered





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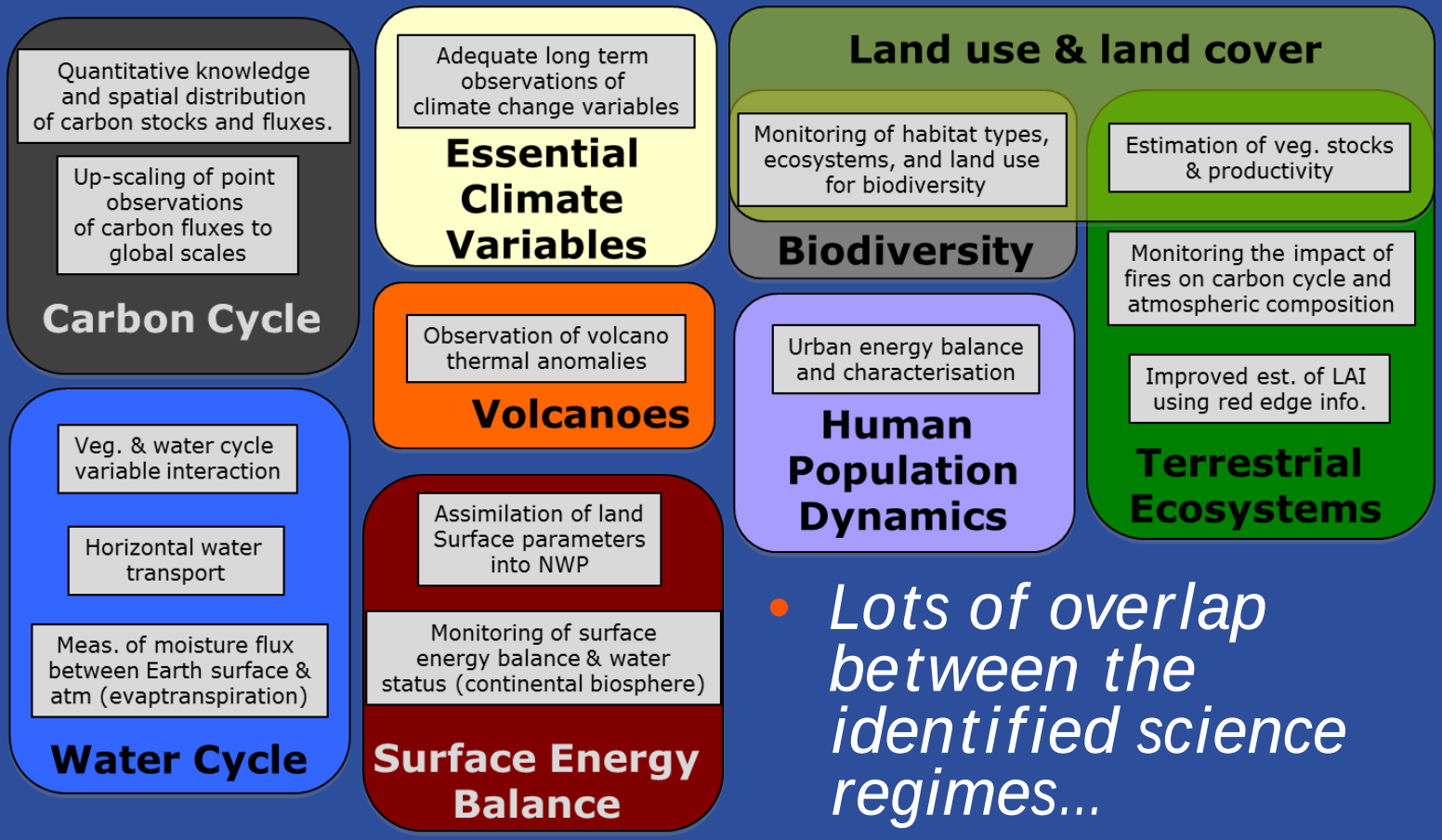
Science needs: overview

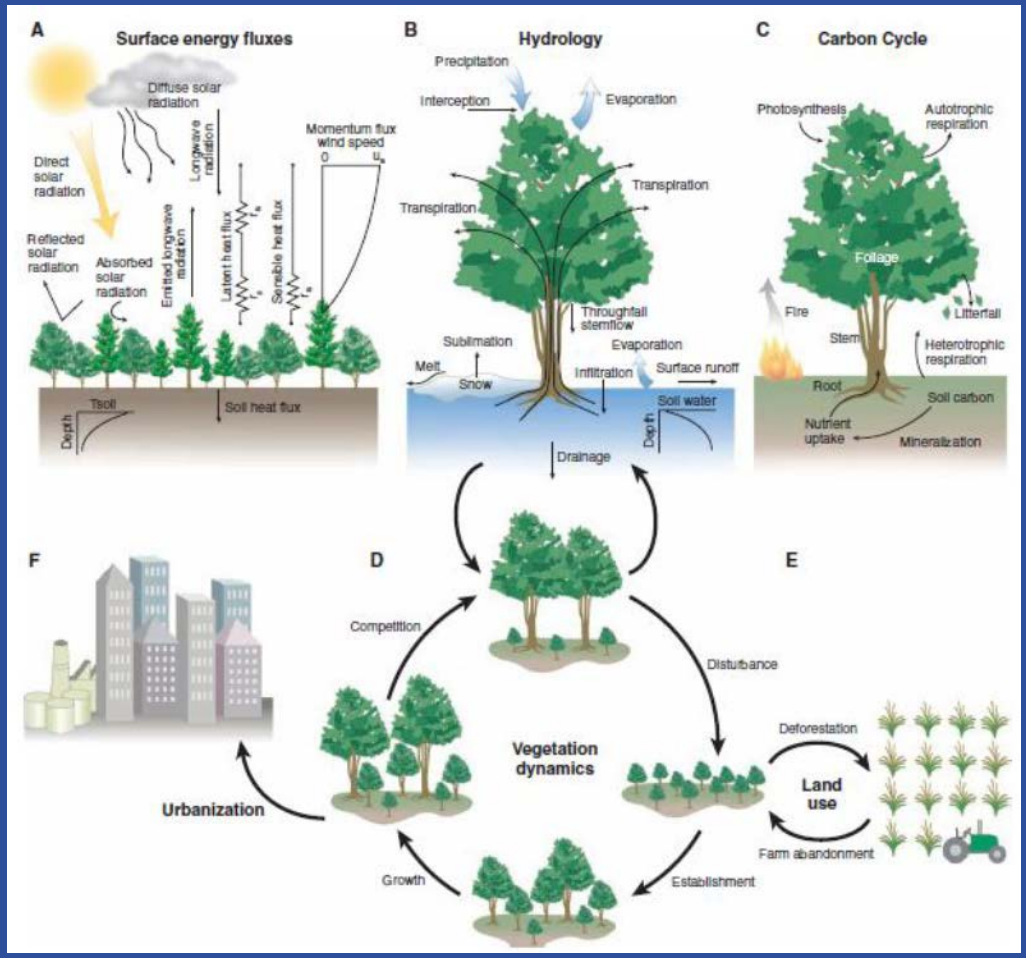
- Science areas (loosely) defined to provide a starting point for the study and workshop discussion



- *Lots of overlap between the identified science regimes…*

Science needs: overview

- *Lots of overlap between the identified science regimes…*



Bonan (2008)

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Science needs: surface energy balance

- Within each science regime, we identify science needs with associated EO variables: through a ***workshop***, literature review and trace-down of science to EO parameters
- Gap analysis relates identified needs with current and planned EO capabilities
- Surface energy balance shown here as an example

Science ref no.	Science need	Variable ref no.	Relevant EO variables	Comments
S-SE-01	Assimilation of land surface parameters into numerical weather prediction models	**V-WC-01**	- Soil moisture	Higher spatial resolution required for soil moisture; Snow line definition and change with time is important
		V-WC-02	- Snow cover	
		V-WC-03	- Snow water equivalent	
		V-CC-03	- LAI	
		V-CC-08	- Fire radiative power	
S-SE-02	Monitoring of surface energy balance and water status of continental biosphere	**V-WC-01**	- Soil moisture	High spatial resolution and frequent revisit needed; Emissivity required in addition to LST
		V-HD-04	- Land use	
		V-SE-03	- Albedo	
		V-SE-02	- LST	
		V-CC-04	- NDVI	
		V-SE-04	- Thermal emissivity	

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Gap analysis results: surface energy balance

I.D.	Variable	Gap	Identified User Needs
G-SE-01	Surface albedo and BRDF	- Higher spatial resolution and multi-angle BRDF measurement to provide improved info on vegetation structure.	- 10 m to 50 m spatial resolution - < 1-30 days temporal resolution - < 5-10% accuracy - BRDF (multi-angle) capability
G-SE-02	Land surface temperature (LST)	- Higher spatial resolution, < 100 m - Improved emissivity observations with more TIR spectral channels to take into account spectral variations.	- 50 m to 100 m spatial resolution - 5 day revisit - < 0.5 K accuracy - NeDT < 0.2 - > 1 TIR channel
G-WC-02	Land surface temperature (LST)	- Higher spatial resolution (< 100 m) to avoid anomalies in LST/emissivity which can be mistaken for soil moisture anomalies. - More TIR spectral channels to take into account spectral variations in emissivity.	- 50 m to 100 m spatial resolution - 5 day revisit - < 0.5 K accuracy - NeDT < 0.2

Example of different gaps with similar user needs

- More science gaps listed on Rachel Bird's poster (#48)

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Preliminary concepts

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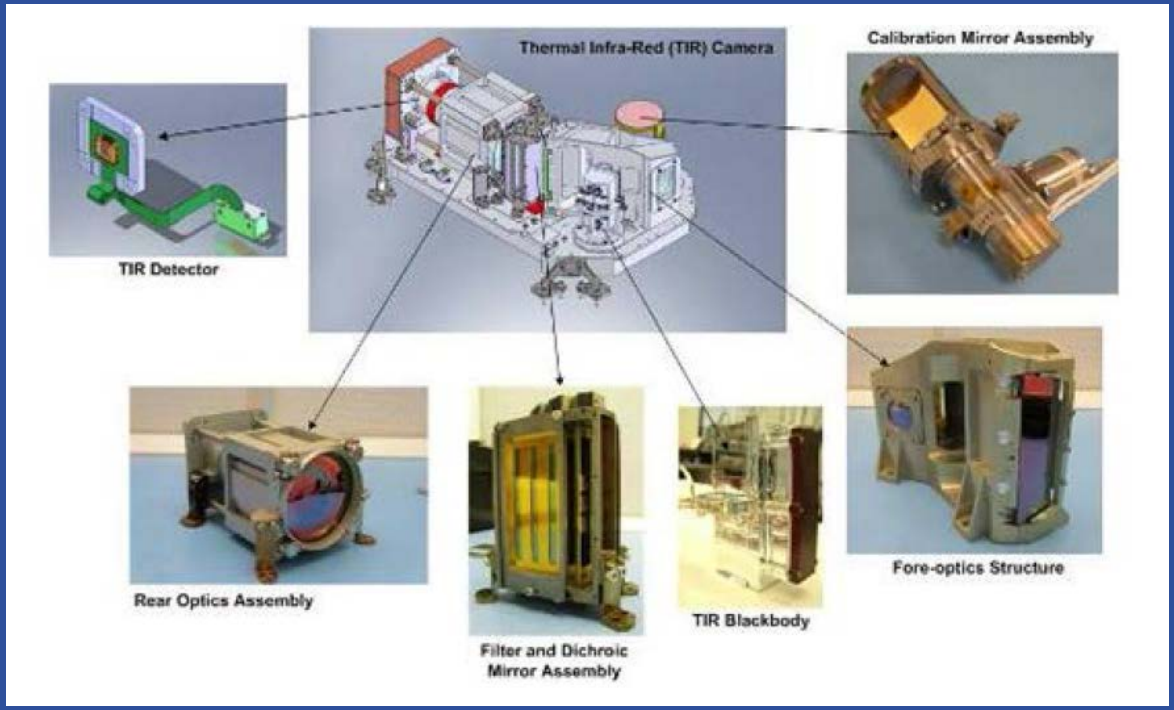
Mission Concept Number	Concept Name	Gaps Addressed	Concept Application and Focus
1	Passive C-band SAR	G-CC-01 G-CC-02	Improvement in observations of vegetation 3D structure, specifically canopy height above the ground
2	Conventional L-band SAR	G-CC-01	Improvement in observations of vegetation 3D structure
3	Wide swath LWIR/MWIR multispectral imager	G-SE-02	High spatial resolution LST observations needed to model surface energy balance and water cycle Both LST and emissivity are required both to provide complete variables and also to obtain accuracy of LST
4	L-band radar in sparse array configuration	G-CC-01	Improvement in observations of vegetation 3D structure
5	W-band conical scanner	G-CC-03	True retrieval of LAI requires multi-directional observations
6	IR fire thermal feature measurement concept (with higher spatial resolution than MODIS/GEOS etc)	G-CC-04 G-VO-01 G-VO-02	Fire sensing, volcanic fumaroles and lava temperatures. Higher spatial resolution (< 250m) to ensure that small fires are correctly sampled. Sensitivity to high temperatures up to 1500K to enable observations of volcanic thermal features.
7	Multi-angle imager	G-CC-03 G-SE-01	BRDF sampling to provide true retrieval of LAI
8	S-band SAR	S-CC-04	Interaction of vegetation with water cycle variables
9	Active C-band SAR interferometer	G-CC-01 G-CC-02	Improvement in observations of vegetation 3D structure, specifically canopy height above the ground

Focus on Concept 3: Wide swath LWIR multi-spectral imager

- Bolometer array imager operating several channels in 8-11 micron wavelength range
- Thermal data at GSD ~90m over 290km swath



Mike Cutter, SSTL

- Fly in convoy with S-2/3 with 1 to 2 minutes separation:
  - S-2: determined by cloud variability (use S-2 cloud information)
  - S-3: benefit in understanding finer spatial scale compared with S-3 resolution (1km)

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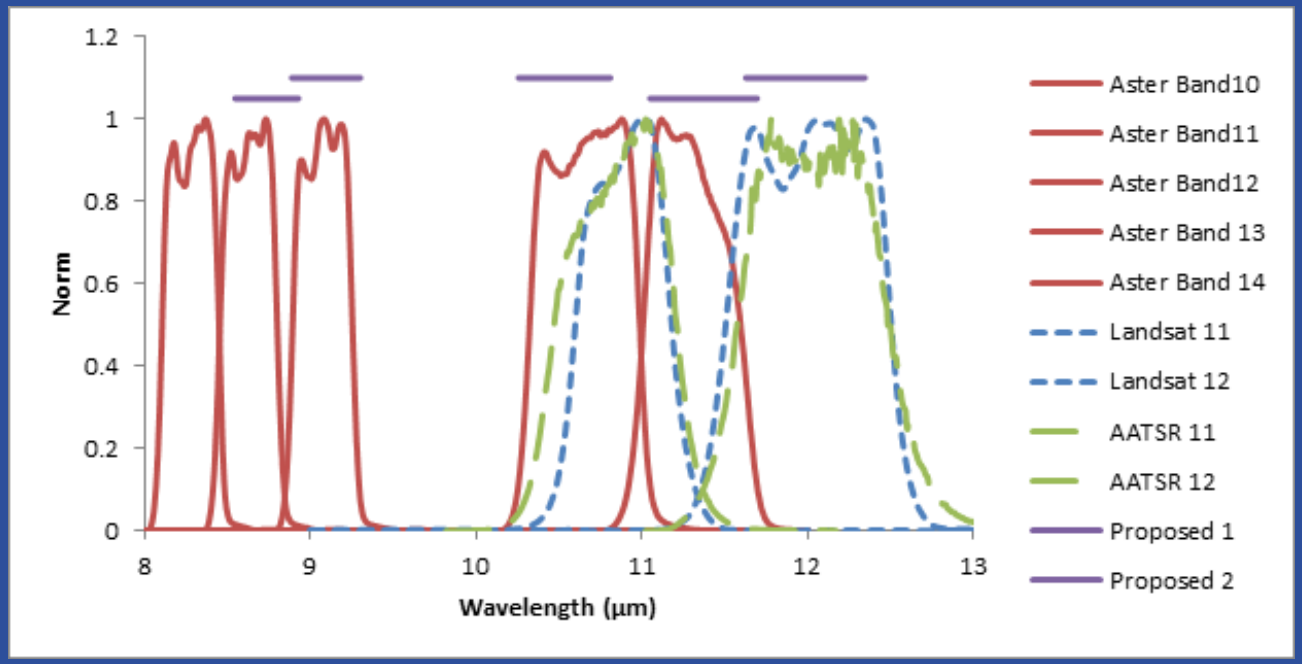
Further study of concept: spectral bands for multi-spectral LWIR imager



Michael Perry, University of Leicester

- Optimisation of spectral window ranges using radiative transfer simulations
- Maximise sensitivity to both emissivity ***and*** temperature
- Error analysis through optimal estimation retrieval of temperature and emissivity
- Previous high spatial resolution instruments have ***either*** had 8 and 11 ***or*** 11 and 12 micron channels. Our optimisation identifies channels in ***all*** 3 regions

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Summary

- Current and planned EO capabilities for land surface science have been assessed
- Science needs and observational requirements defined
- Gap analysis: identifying where science needs are not met by planned EO missions
- Preliminary list of concepts reduced to shortlist of three:
  - Passive SAR with S-1 for improved vegetation height
  - Thermal multi-spectral imager for joint LST and emissivity at high spatial resolution
  - Fire at improved spatial resolution (250m) for better estimation of emissions to atmosphere
- ***Result is novel developments which would benefit from convoy operation***

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Acknowledgements

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  - John Remedios, University of Leicester
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  - Martin Wooster, King's College London
  - Heiko Balzter, University of Leicester
  - Philip Lewis, University College London
- Participants in the Sentinel Convoy for Land Applications workshop
- Gap analysis document (including workshop report) available here: *http://congrexprojects.com/2013-events/13m12/measurement-gap-analysis*