Copernicus Sentinel-5:

Long-Term Global Monitoring of Atmospheric Composition

J. Langen ([1]), P. Ingmann ([1]), Y. Meijer ([1]), R. Munro ([2]), C. Retscher ([2]), B. Veihelmann ([1])

([1]) ESA-ESTEC, Noordwijk, The Netherlands
([2]) Eumetsat, Darmstadt, Germany

The Copernicus Atmospheric Mission: Sentinels -4, -5p and -5

Environmental Themes

- air quality
- climate
- stratospheric ozone and surface UV

Missions and Services

Sentinel-4

regional AQ at 1h temporal res.

- emission and abundance monitoring
- forecast

- first AQ mission approved for geostationary orbit (embarked on MTG-S)
- diurnal variation, e.g. NO_2, aerosol
- part of CEOS virtual constellation

Sentinel-5p

global AQ at 1d temporal res.

- emission and abundance monitoring
- forecast

climate

- GHG emission monitoring
- aerosol

ozone total column

- long term total O_3 evolution
- surface UV (health)

- bridging between OMI and S-5
- CO and CH_4
- x6 step in 2-D spatial resolution vs. OMI
- some diurnal information (with GOME-2)

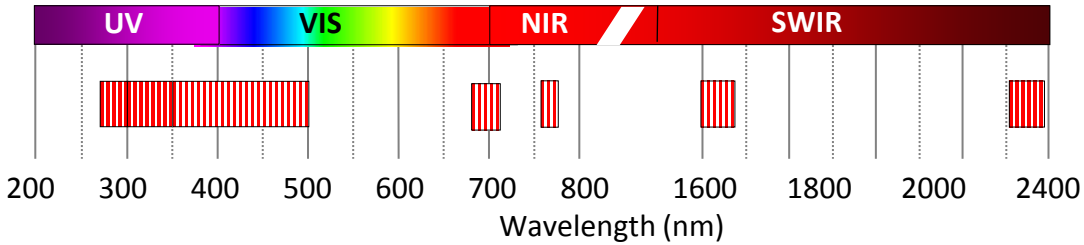
Sentinel-5

- continuity and long-term datasets
- synergies with meteo payloads (embarked on Metop-SG)
- CH_4 from 2 bands
- Some CO_2 (quality not sufficient for operational monitoring)

overview on S-4 S-5p S-5 system: see poster no. 55 by P. Ingmann et al.

S-5 instrument characteristics

- Nadir-viewing push-broom UVNS spectrometer, 2 telescopes
- spectral ranges between 270 and 2385 nm



- spectral resolution 0.25 – 1.0 nm, oversampling factor 2.5 – 3
- daily coverage at latitudes > 12 deg
- spatial resolution 7.5 km @ nadir (45 km at λ < 300 nm)
- high signal/noise
- demanding requirements on radiometric accuracy, spectral calibration and spatial co-registration

Main performance issues (1)

- **effective spectral radiometric accuracy (ESRA) for HCHO** (spectrally varying radiometric errors)
  - high sensitivity to errors due to small HCHO spectral signatures. Will require mitigation scheme in or after retrieval.

- **radiometric offset in SWIR**
  - requirement 0.1% of maximum radiance in high latitude dark scene
  - accuracy limited by thermal sensitivity of dark current and thermal background radiation. A serious non-compliance is expected affecting the CH_4 retrieval.

- **spectral stability ground-to-orbit and on-orbit**
  - requirements are 0.5/0.1 spectral sampling interval ground-to-orbit/on orbit
  - opto-mechanical stability insufficient. Significant non-compliance expected.
  - intention: mitigate situation by spectral calibration using radiance data. Computationally affordable ?

Main performance issues (2)

- **combination of radiometric and spatial requirements in [300, 310] nm**
  - UV1 non-compliant to spatial requirements. Sample size 45 km, sub-sample 7.5 km but not compliant to geolocation knowledge and spatial PSF requirements.
  - UV2 partially non-compliant to SNR and radiometric accuracy (straylight)
  - UV2 signal might be re-calibrated, using spectrally overlapping UV1 data in homogeneous scenes

- **radiometric stability**
  - requirement is 0.5% over one orbit
  - serious non-compliance expected in UV1 (detector)

- **radiometric accuracy variation across track**
  - requirement is 0.25%
  - significant non-compliance expected.
  - measurement accuracy (on-ground) insufficient.

Project status

- EPS-SG programme to be endorsed by Eumetsat Council in summer 2015
- Sentinel-5 subscription 100% after ESA Council Dec 2014
- ITTs for S-5 sub-contracts well underway
- Preliminary Design Review on-going
- Level 1b prototype processor development to start soon
- list of L2 products being discussed between ESA and Eumetsat

S-5 UVNS priority 1 data products

species	characteristics	wavelength range [nm]	applications	L2 requirement	S-5p (expected accuracy)	S-4	S-5
O_3	vertical profile	270 – 335	SO, AQ, CL	20% (strat. profile), 25% (trop. column), vert. res. reqt. in strat. TBD	10-30 % (strat. profile @6km vert. res.), TBD (trop. col.)	trop. column [3)]	priority 1
	total column	325 – 337	SO, CL	3%	3.5 – 5 %	x	priority 1
NO_2	total column and trop. column	405 – 500	AQ, AW	max {1.3 10^{15} molec cm^{-2}, 20%} (both)	strat. < 10% trop. 25-50 %	x	priority 1
SO_2	total column and height	308 – 325	AQ, AW	max {1.3 10^{15} molec cm^{-2}, 30%}, height reqt. TBD	30 – 50 %	x	priority 1
HCHO	total column	337 – 360	AQ	max {1.3 10^{15} molec cm^{-2}, 30%}	40 – 80 %	x	priority 1
CHOCHO	total column (averages)	430 – 460	AQ	max {1.5 10^{14} molec cm^{-2}, 30%}	x [2)]	x	priority 1
CH_4	total column	1590 – 1675 2305 – 2385	CL	precision (G/T): max {0.5/1.0%, 10/18ppbv} regional bias (G/T): max {0.5/1.0%, 10/18ppbv}	1.5 % (2305 – 2385 nm)	-	priority 1
CO	total column	2305 – 2385	AQ, CL	25%	< 15 %	-	priority 1
Cloud	effective optical depth, effective cloud fraction, effective height	360 – 400 460 – 490 685 – 710 755 – 773	auxiliary	(auxiliary only)	<20 % (fraction, optical depth, pressure)	x [1)]	priority 1
Aerosol	UV absorption index	336 – 340 360 – 400	AQ, CL, AW, auxiliary	TBD	~1 AAI	x	priority 1
	layer height	755 – 773	AQ, CL, AW	TBD	< 100 hPa	x	priority 1
Surface	effective reflectance	310 – 773 1590 – 1675 2305 – 2385	auxiliary	(auxiliary only)	x	daily map	priority 1
UV	spectrally resolved irradiance at surface, UV index	300 – 380	health	TBD	collaborative ground segment (FMI)	-	priority 1

[1)] optional products use also FCI Level 1c data.
[2)] funding not yet secured.
[3)] optional synergy with IRS for enhanced sensitivity to lower troposphere
G/T: Goal / Threshold

SO: stratospheric ozone
AQ: air quality
CL: climate
AW: alert warning

S-5 UVNS priority 2 / 3 data products

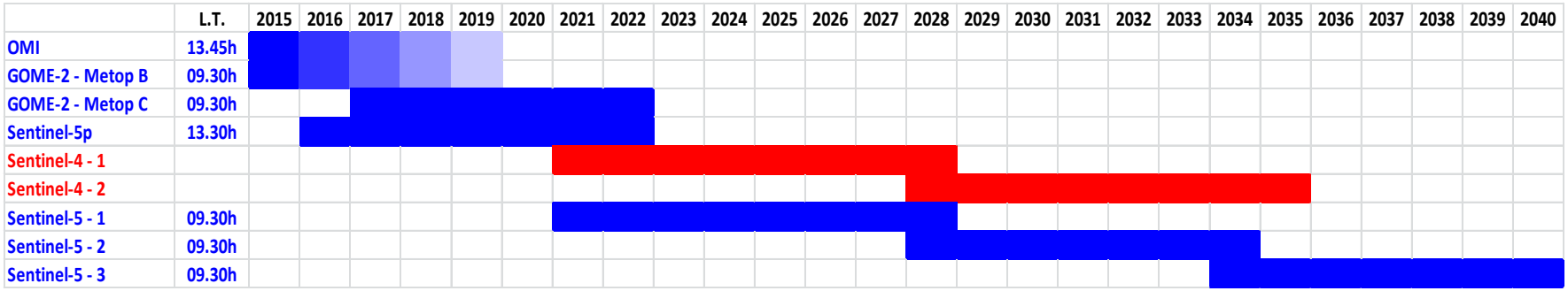
species	characteristics	wavelength range [nm]	applications	L2 requirement	S-5p (expected accuracy)	S-4	S-5
H_2O	total column	685 – 710 2305 – 2385	AQ, CL	10%	x [2])	-	priority 2
CO_2	total column	1590 – 1675	CL	0.75%	-	-	priority 2
BrO	total column	345 – 360	SO	TBD	x [2])	-	priority 2
OClO	total column	363 - 391	SO	TBD	x [2])	-	priority 2
IO	total column	415 – 430	science	TBD	x [2])	-	priority 3
HDO	total column	2305 – 2385	science	TBD	x [2])	-	priority 3
Aerosol	optical depth at ≥ 2 wavelengths	336 – 340 360 – 400 400 – 430 440 – 460 755 – 773 1590 – 1675 2305 – 2385	AQ, CL	0.05		x [1])	priority 2
	absorption optical depth		AQ, CL	TBD		-	
	fine mode optical depth		AQ, CL	TBD	x	-	

S-5 relevant products of other MetOp-SG instruments

IASI-NG			3MI	MetImage
priority 1	priority 2	priority 3		
O_3 profile	CH_3OH	C_2H_2	multispectral AOD	cloud flag
CO profile	HCOOH	HCN	multispectral SSA	snow/ice flag
SO_2 (incl. height)	CFC-11	C_2H_4	bimodal size distribution	cloud optical depth, phase, height
NH_3	CFC-12	C_2H_6	effective radius (total, fine, and coarse modes)	Level 1b products
CH_4	N_2O		multispectral refractive index	
H_2O	HONO		aerosol type	
HNO_3	CO_2		AAI	
PAN			aerosol height	
			surface BRDF	

Schedule + Long-Term Perspective

- GOME-2 (Metop B/C at 9.30h) and OMI on Aura /TROPOMI on S-5p (~13.30h) provide partial diurnal information, before S-4 takes over with hourly data
- S-4 and S-5, together with IR sounders and 3MI, will be Europe's long-term contribution to operational nadir-viewing atmospheric composition sounding



- Guaranteed provision of long-term datasets in synergy with meteorological payloads is based on identical instruments, however this implies

  → no innovation until 2035/40

- Update of geophysical requirements for future successors is under EU responsibility:
  - GMES-PURE contract (2013/14)
  - Requirements Framework for the next generation of the Copernicus Space Component (2015–18) ("small scale exercise" for atmosphere complementing PURE)

The Limb Gap

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air quality

climate

stratospheric ozone and surface UV

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climate

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climate

- forcing
- NWP contribution

stratospheric ozone

- long-term 3-D evolution
- climate and NWP impact

(limb-sounder)

programmatically not covered → limb gap
see presentation by M. v. Weele, Tue 17.00h