The WMO Vision for global observing systems in 2025: to what extent will it be met by space agencies' plans?

John Eyre Met Office, UK

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The WMO Vision for global observing systems in 2025: to what extent will it be met by space agencies' plans?

- WMO "Vision for the GOS in 2025"
- Comparison with space agencies' plans
- Summary and conclusions

... with focus on NWP

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WMO “Vision for the GOS in 2025”

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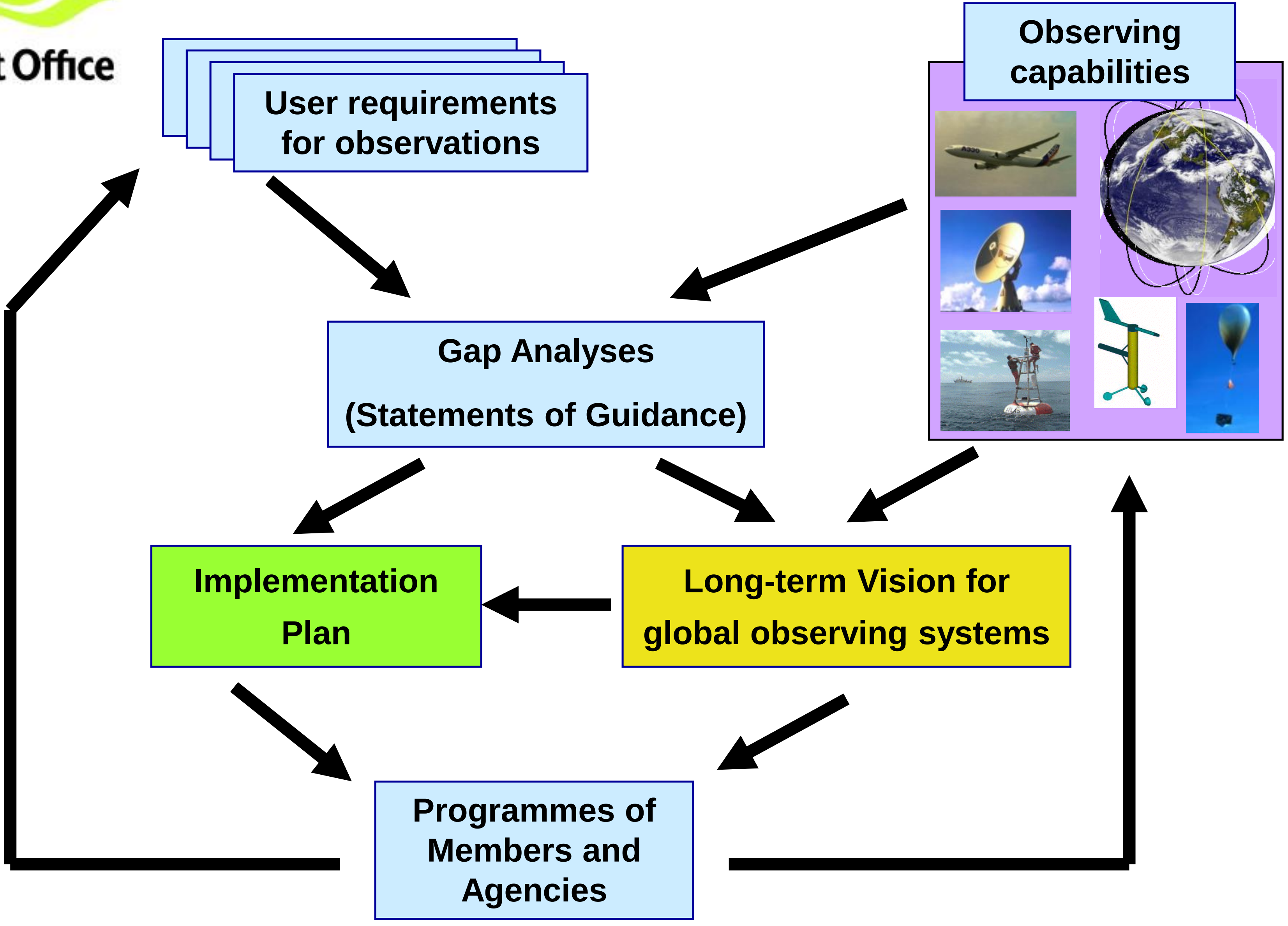
The WMO/CBS **RRR** process:
Rolling Review of Requirements



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RRR process: documentation

OSCAR (Observing Systems Capability Analysis and Review Tool)

User requirements: http://www.wmo-sat.info/oscar/requirements

Space-based capabilities: http://www.wmo-sat.info/oscar/spacecapabilities

Surface-based observing capabilities: to be constructed

Gap Analyses (Statements of Guidance, SoGs)

http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html#SOG

Vision: http://www.wmo.int/pages/prog/www/OSY/gos-vision.html

EGOS-IP: http://www.wmo.int/pages/prog/www/OSY/gos-vision.html#egos-ip

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RRR process: Application Areas

Global NWP

High-resolution NWP

Seasonal and Inter-Annual Forecasting (SIAF)

Nowcasting

Aeronautical Meteorology

Atmospheric Chemistry

Ocean Applications

Agricultural Meteorology

Hydrology

Climate Monitoring (GCOS)

Climate Applications

Space Weather

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Vision for the GOS in 2025

- General themes and issues
  - Response to user needs
  - Integration
  - Expansion
  - Automation
  - Consistency and homogeneity
- Space-based component
- Surface-based component
- System-specific trends and issues

(7 pages)

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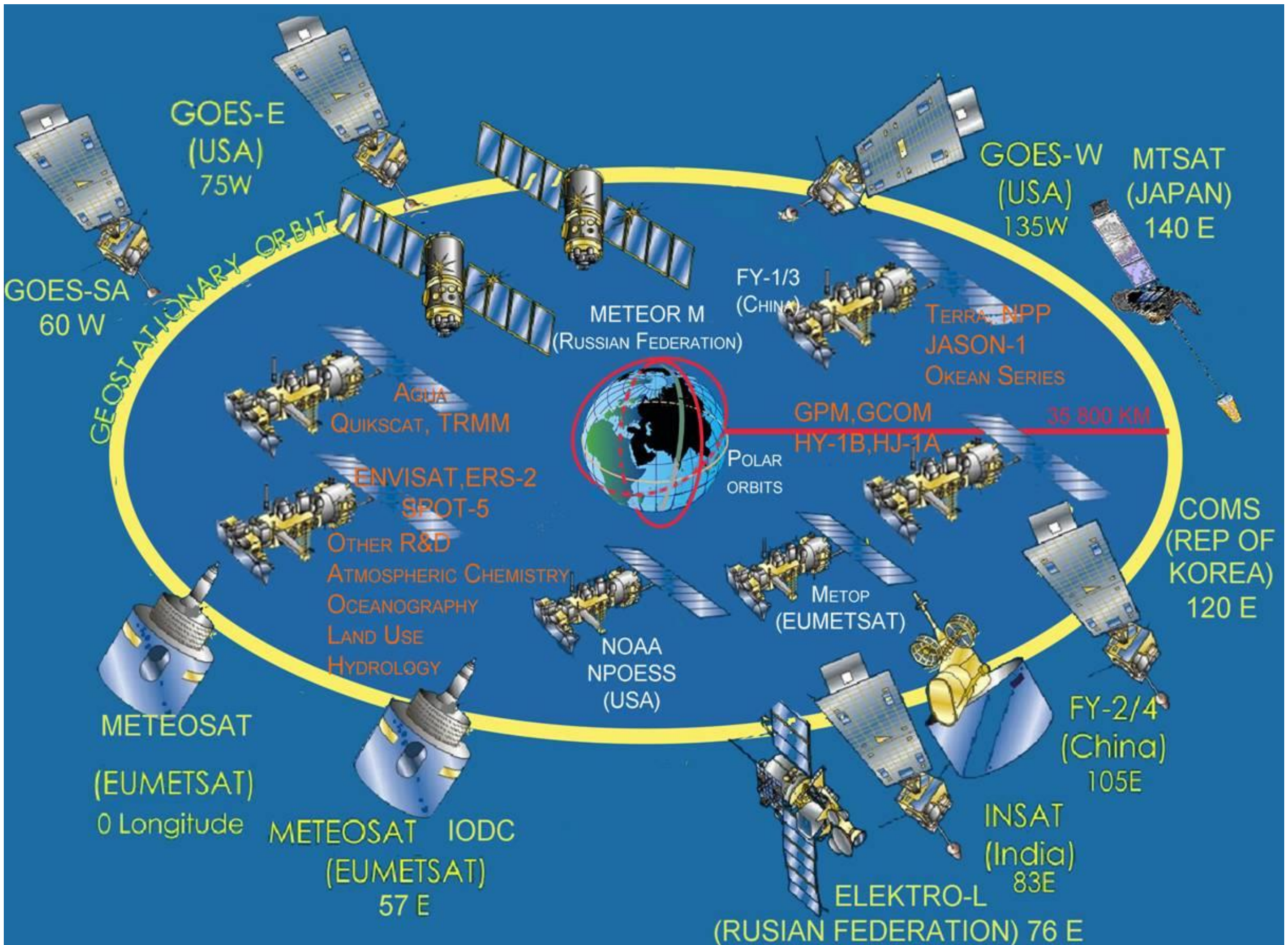
GOS - space-based component (1)



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GOS - space-based component (2)

Operational geostationary satellites

– at least 6 – each with:

- **Infra-red/visible multi-spectral imager**
- **Infra-red hyper-spectral sounder**
- Lightning imager

Operational polar-orbiting sun-synchronous satellites

- in 3 orbital planes – each with:

- **Infra-red/visible multi-spectral imager**
- **Microwave sounder**
- **Infra-red hyper-spectral sounder**

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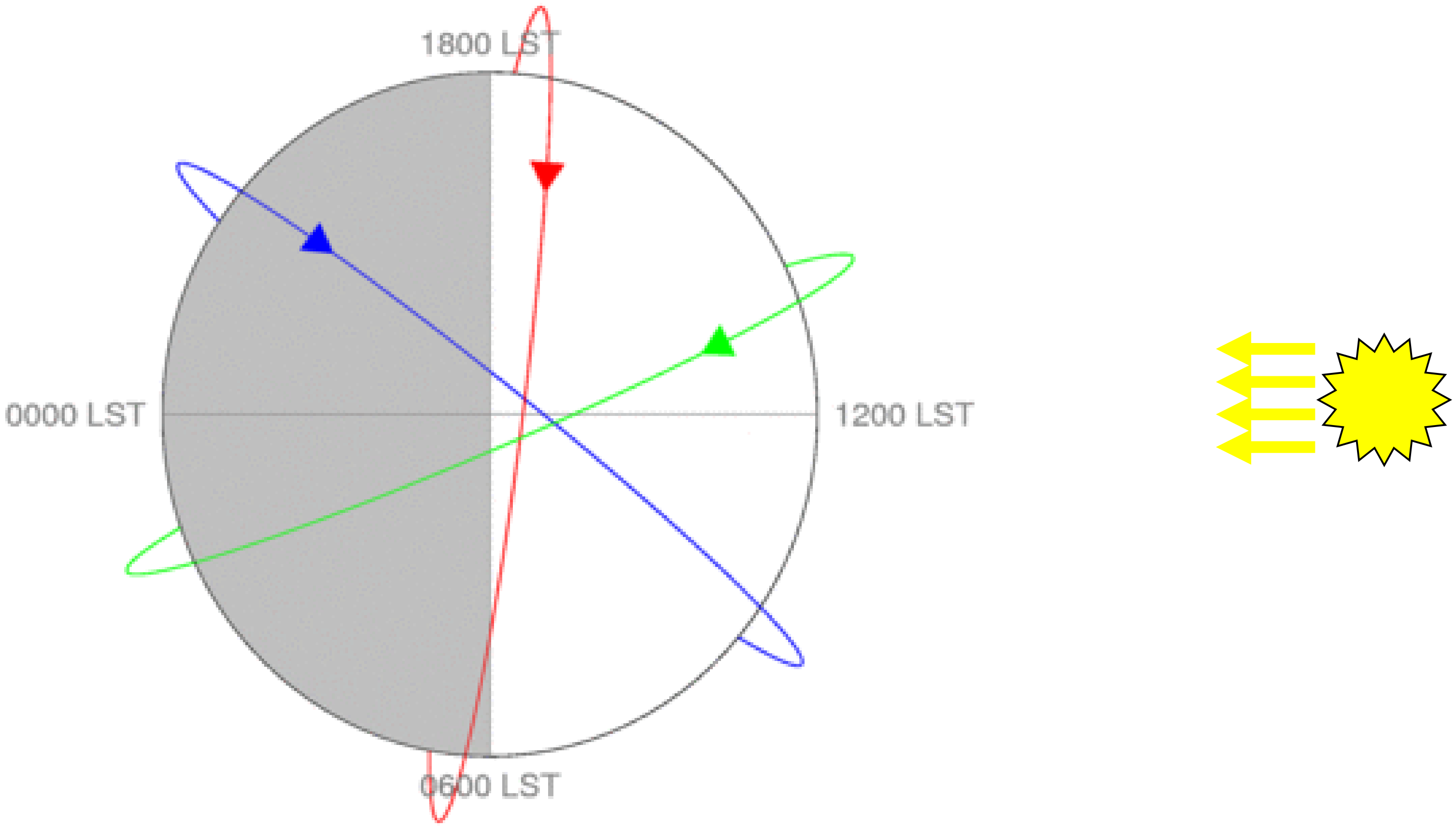
Vision for operational LEO satellites



- recommended baseline, with in-orbit redundancy

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GOS - space-based component (3)

Met Office

Additional **operational** missions in appropriate orbits:

- **Microwave imagers**
- **Scatterometers**
- **Radio occultation constellation**
- Altimeter constellation
- Infra-red dual-view imager – sea surface temperature
- Advanced visible/NIR imagers – ocean colour, vegetation
- Visible/infra-red imager constellation – land-surface
- **Precipitation radars**
- Broad-band visible/IR radiometers – radiation budget
- Atmospheric composition monitoring instruments
- Synthetic aperture radar

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GOS - space-based component (4)

Met Office

Operational pathfinders and technology demonstrators:

- **Doppler wind lidar**
- **Low-frequency microwave radiometer** – salinity, soil moisture
- Microwave imager/sounder on geos - precipitation
- Advanced imagers on geos
- **Imagers on satellites in high-inclination, elliptical orbits**
- Gravimetric sensors – water: lakes, rivers, ground

Polar and geo platforms/instruments for space weather

- for solar imagery, particle detection, electron density

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GOS - surface-based component

Implementation of the Vision

- Vision
  - a realistic aspiration and target for 2025
  - endorsed by WMO/CBS in 2009

- Implementation Plan
  - … for the Evolution of Global Observing Systems, EGOS-IP
  - responds to the Vision
  - provides guidance for Members and partner consortia
  - proposes roles for fulfilling the new Vision
  - sets out “road-map” for achieving it
  - ~120 pages, 115 Actions
  - endorsed by WMO/CBS in 2012

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Comparison of “Vision” with space agencies’ plans

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Comparing “Vision” and capabilities

Sources of information:

OSCAR/Space: http://www.wmo-sat.info/oscar/spacecapabilities

- programmes
- satellites
- instruments
- capability review – assessment of instruments by type
- gap analysis by variable

WMO satellite status list:

http://www.wmo.int/pages/prog/sat/satellitestatus.php

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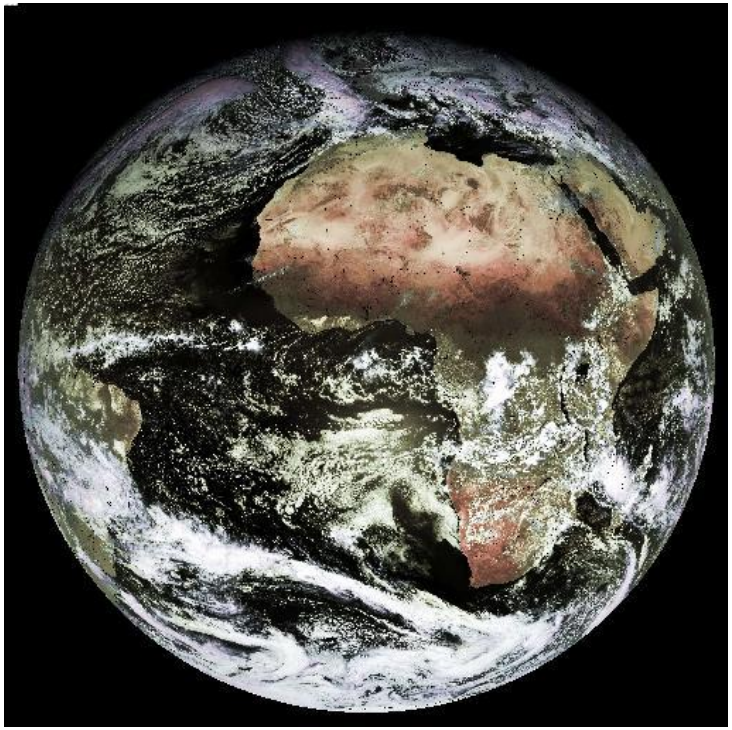
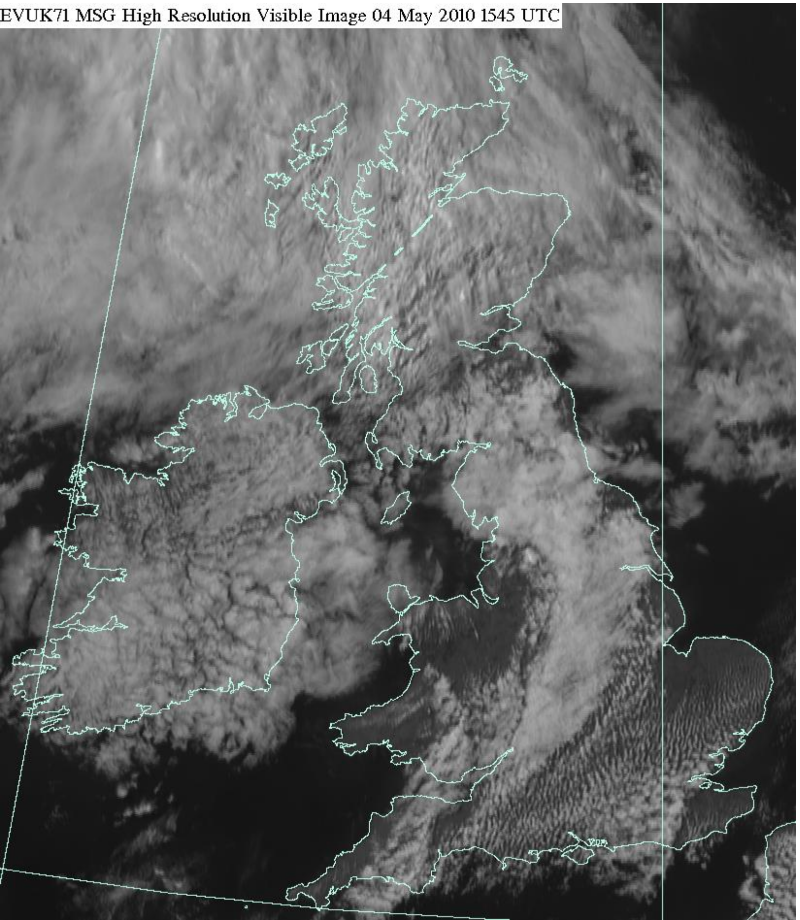
Operational geostationary satellites





Objectives

- weather in motion - nowcasting
- cloud cover and cloud height
- **winds (from moving clouds)**
- other cloud properties
- aerosols
- vegetation, snow, fire
- sea/land surface temperature

Operational geostationary satellites

	2014	→ 2025
E.Pacific		
	GOES-13,-14,-15	GOES-R,-S,-T,-U
W.Atlantic		
		Electro-M
E.Atlantic	MSG: M-8,-9,-10	MTG/I+S
Indian	M-7 INSAT-3C Kalpana-1	MSG? INSAT-3
Ocean	Electro-L N1 INSAT-3D	Electro-M
	FY-2D INSAT-3A FY-2E	FY-4
W.Pacific	FY-2F COMS-1	GEO-KOMSAT-2
	Himawari-6,-7 (MTSAT-1R,-2)	Himawari-8,-9
		Electro-M

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Operational geostationary satellites in 2025 (1)

satellite series	Vis/IR imager	Hyperspectral IR sounder	Lighting imager
MSG	**SEVIRI (12 ch)**	**no**	**no**
MTG	**FCI (16 ch)**	**IRS**	**LI**
GOES-R	**ABI (16 ch)**	**no**	**GLM**
Himawari	**AHI (16 ch)**	**no**	**no**
FY-4	**AGRI (14 ch)**	**GIIRS**	**LMI**
INSAT-3DS	**IMAGER (6 ch)**	**no (low-res SOUNDER)**	**no**
GEO-KOMSAT-2	**AMI (16 ch)**	**no**	**no**
Electro-M	**MSU-GSM (20 ch)**	**IRFS-GS**	**LM**

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Operational geostationary satellites in 2025 (2)

	Vis/IR imager	Hyperspectral IR sounder	Lighting imager
E.Pacific	**YES**	**?**	**YES**
W.Atlantic	**YES**	**?**	**YES**
E.Atlantic	**YES**	**YES**	**YES**
Indian Ocean	**YES**	**YES**	**YES**
W.Pacific	**YES**	**?**	**?**

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Operational geostationary satellites in 2025 (3)

Issues:

- Quality of AMVs
- IR sounder maturity / back up
- Use of LI in NWP?
- Others ??

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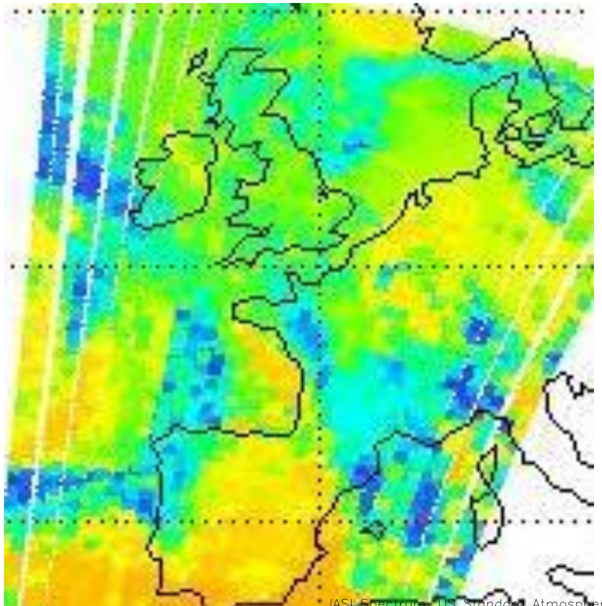
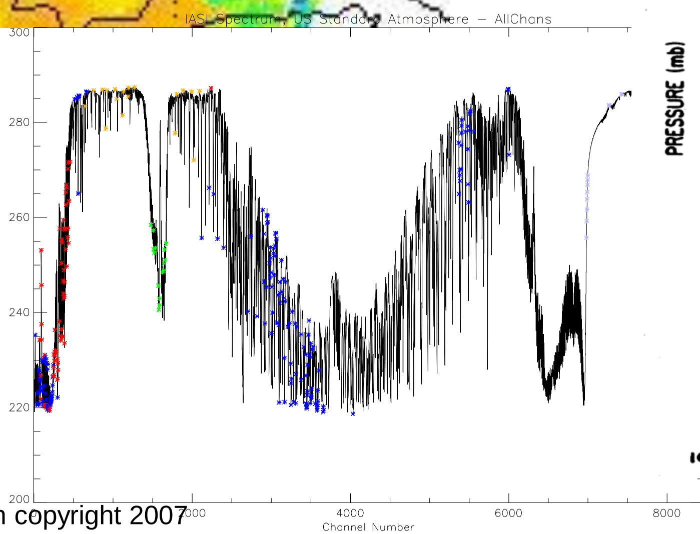
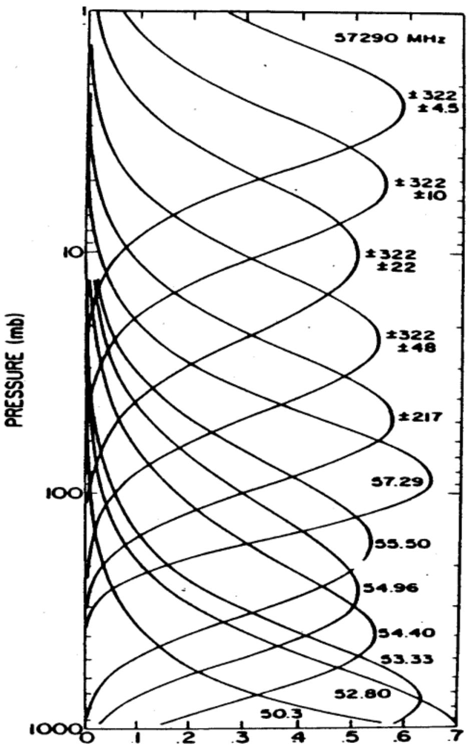
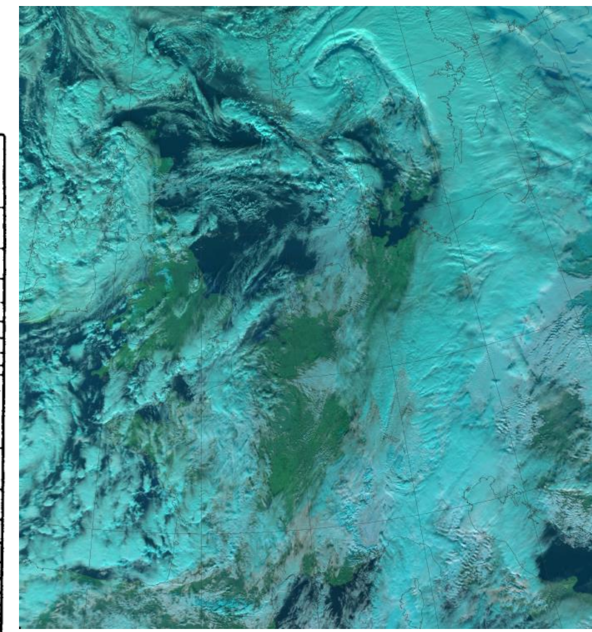
Operational polar-orbiting sun-synchronous satellites

- hyperspectral IR sounding
- MW sounding
- vis/IR imagery









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Operational polar-orbiting sun-synchronous satellites

	2014	→ 2025
Early morning (LECT ~1730)	**DMSP F-16,-17,-19**	**DMSP F20** **FY-3E,-3G**
Morning (LECT ~0930)	**Metop-A,-B** **DMSP-18** **FY-3C** **Meteor-M N1,-N2**	**Metop-C** **Metop-SG** **Meteor-M N2**
Afternoon (LECT ~1330)	**NOAA-15,-18,-19** **Suomi-NPP** **FY-3B**	**JPSS-1,-2** **FY-3F**
(LECT ~1530)		**Meteor-M N2, -MP**

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Operational polar-orbiting sun-synchronous satellites in 2025 (1)

satellite series	Hyperspectral IR sounder	MW sounder	Vis/IR imager
Metop-SG	**IASI-NG**	**MWS**	**METimage**
JPSS	**CrIS**	**ATMS**	**VIIRS**
FY-3, FY-3M	**HIRAS**	**MWTS-2, MWHS-2**	**MERSI-2**
Meteor-3M	**IKFS-2**	**MTVZA-GY**	**MSU-MR**
Metop	**IASI**	**AMSU-A, MHS**	**AVHRR**
DMSP	**no**	**SSMIS**	**OLS**

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Operational polar-orbiting sun-synchronous satellites in 2025 (2)

	Vis/IR imager	Hyperspectral IR sounder	MW sounder
Early morning	**YES**	**YES**	**YES**
Morning	**YES**	**YES**	**YES**
Afternoon	**YES**	**YES**	**YES**

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Operational polar-orbiting sun-synchronous satellites in 2025 (3)

Issues:

- Continuity – vulnerability to early failure
- Operational back-up – preparations?
- MW sounders – NEdT marginal
- Others??

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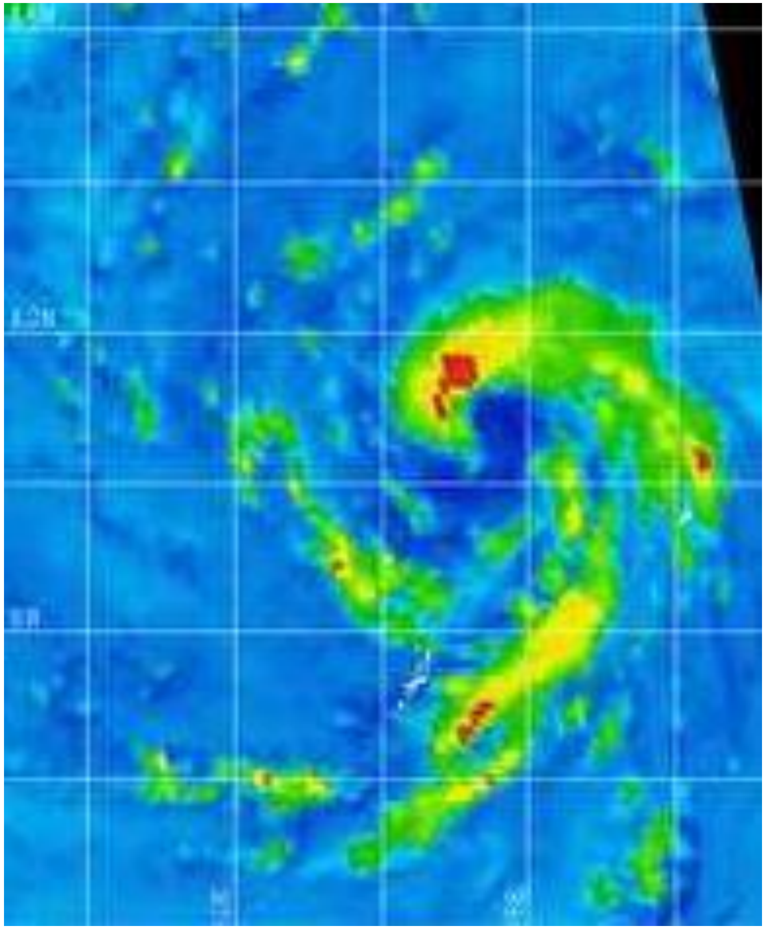
Microwave Imagery

Objectives

- cloud and precipitation
- total column water vapour
- sea-ice, snow, sea surface wind
- SST, soil moisture



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Microwave imagers - 2014

satellites	instrument	channels (GHz)
DMSP F15	**SSM/I**	19-85
DMSP F16,F18,F19	**SSMIS**	19-183, incl.50-60
TRMM	**TMI**	10-85
Coriolis	**Windsat**	6.8-37
GCOM-W1	**AMSR-2**	6.9-89
FY-3B,-3C	**MWRI**	10-89
Megha-Tropiques	**MADRAS**	18-157
GPM Core	**GMI**	10-183
Meteor-M N1, N2	**MTVZA-GY**	10-183, incl.50-60
HY-2A	**MWI**	6.6-37

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Microwave imagers - 2025

Met Office

satellite series	instrument	channels (GHz)	
DMSP	**SSMIS**	19-183, incl.50-60	→ 2025
GCOM-W	**AMSR-2**	6.9-89	→ 2025
GPM-Core, -Braz	**GMI**	10-183	→2021+
HY-2	**MWI**	6.6-37	→ 2025
FY-3, FY-3M	**MWRI**	10-89	→ 2028
Metop-SG	**MWI**	18-183, incl.50-54,118	2022→
Metop-SG	**ICI**	183-664	2022→
DWSS	**MIS**	6.3-183, incl.50-60	??
Meteor-M	**MTVZA-GY**	10-183, incl.50-60	→ 2025
Meteor-MP	**MTVZA-GY-MP**	6.9-183, incl.50-60	2024-2031

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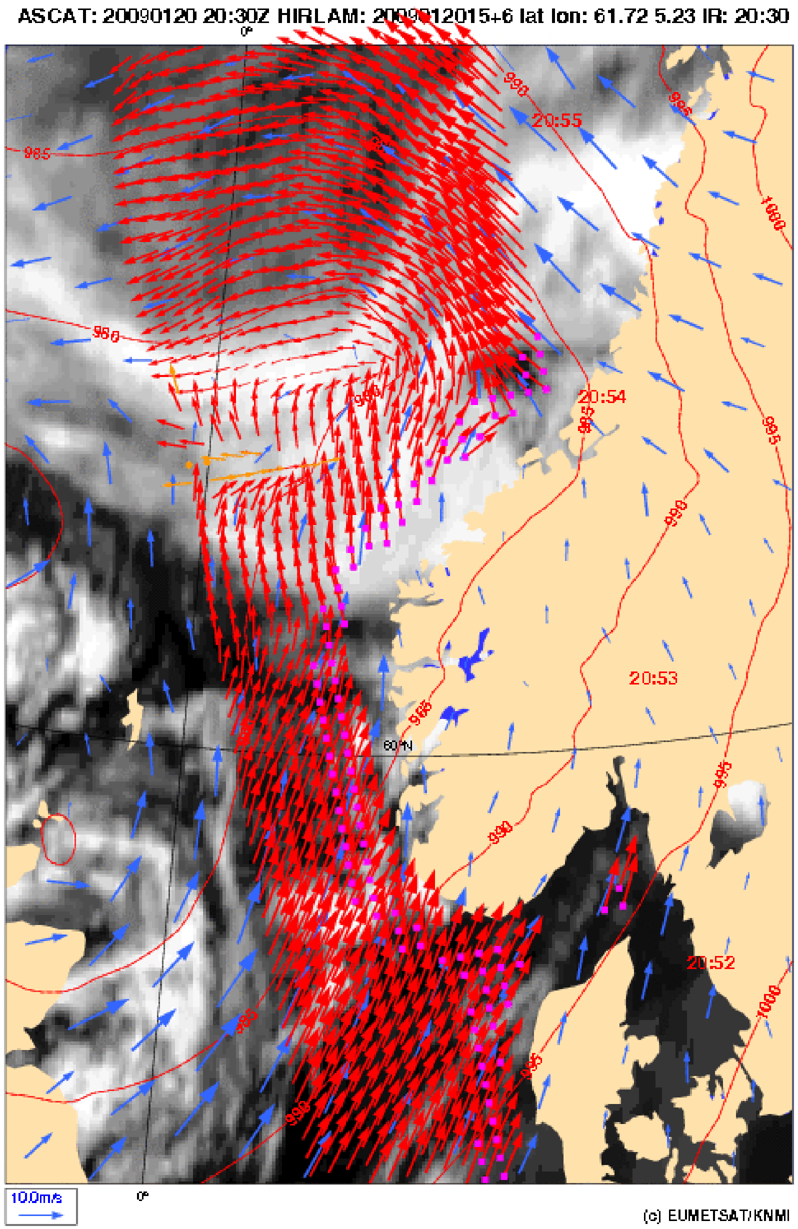
Scatterometry

Objectives

- ocean surface wind speed and direction
- soil moisture
- snow equivalent water
- sea-ice type



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Scatterometers - 2014

satellites	instrument	
Metop-A,-B	**ASCAT**	C-band
Oceansat-2	**OSCAT**	Ku-band
HY-2A	**SCAT**	Ku-band

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Scatterometers - 2025

satellite series	instrument		
Metop	**ASCAT**	C-band	→2024+?
Metop-SG	**SCA**	C-band	2022→
FY-3	**WindRad**	C+Ku-band	2018-27
HY-2	**SCAT**	Ku-band	→ 2025
Meteor-M, -MP	**SCAT**	Ku-band	2020-30
ISS	**RapidScat**	Ku-band	2014-19
ScatSat-1	**OSCAT**	Ku-band	2016-19
CFOSAT	**SCAT**	Ku-band	2016-21
OceanSat-3	**OSCAT**	Ku-band	2017-22

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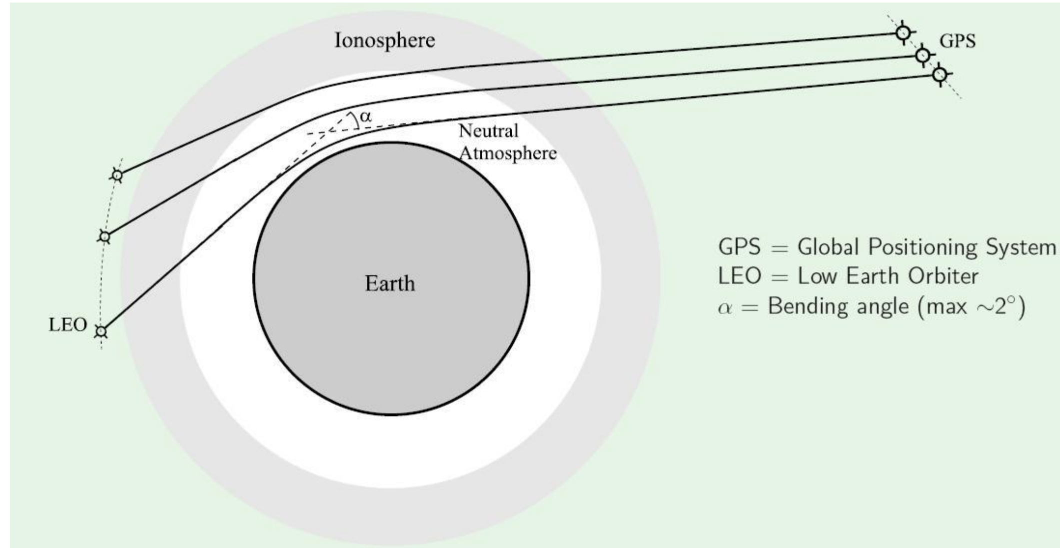
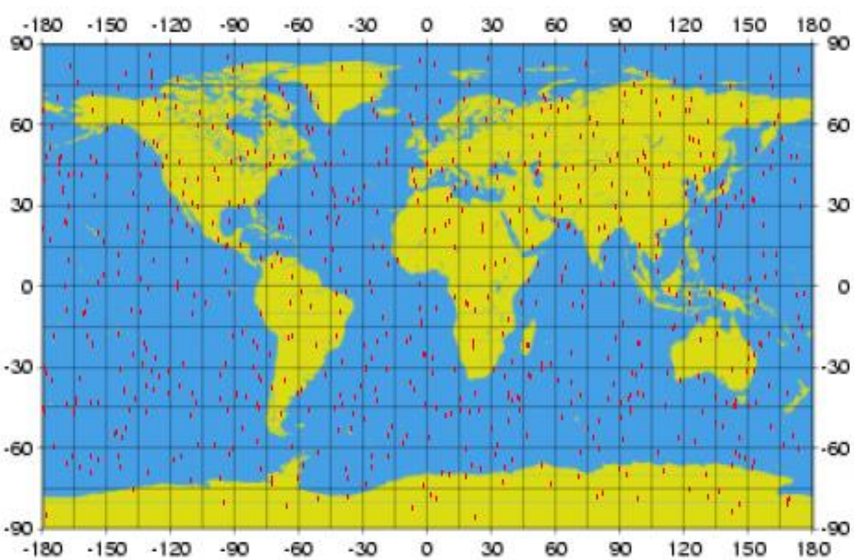
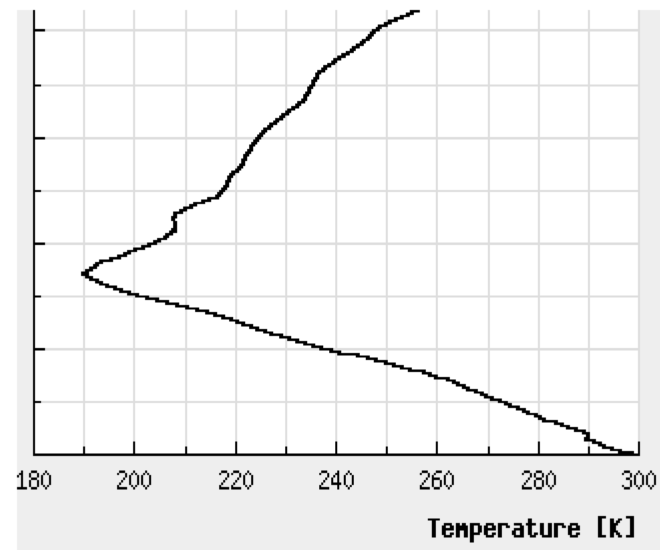
Radio occultation

Objectives

- refractivity profiles at high vertical resolution
    - temperature / humidity profiles
- ionospheric electron content







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Radio occultation - 2014

Total:

10 receivers

~2600 occultations per day

(July 2014)

satellites	instrument	
COSMIC	**IGOR**	5 satellites
Metop-A, -B	**GRAS**	
GRACE-A, -B	**Blackjack**	
TerraSAR-X	**IGOR**	
Tandem-X	**IGOR**	
FY-3C	**GNOS**	
SAC-D	**ROSA**	
Oceansat-2	**ROSA**	
Megha-tropiques	**ROSA**	
KOMPSAT-5	**AOPOD**	

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Radio occultation - 2025

WMO EGOS-IP says:

“ at least 10000 occultations per day”

satellite series	instrument		
COSMIC-2	**Tri-G**	12 sats	2016-25
Metop-C	**GRAS**		→ 2024+?
Metop-SG	**RO**	2 sats	2021→
FY-3	**GNOS**		→ 2027
Meteor-M N3, -MP	**Radiomet**		2020-30
JASON-CS	**Tri-G**		2018-31
SEOSAR/Paz	**ROHPP**		2014-19
GRACE-FO	**Tri-G**	2 sats	2017-22

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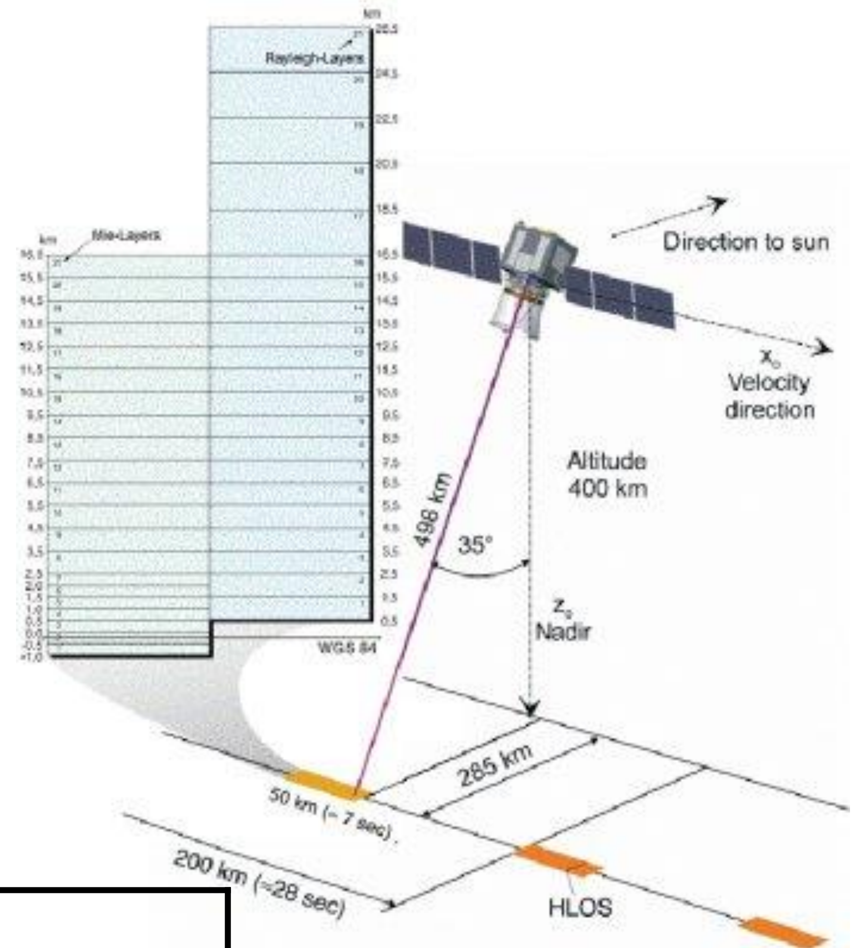
Doppler wind lidar

Objectives

- wind profiles (line-of-sight)
- profiles of cloud and aerosol
- aerosol properties
- boundary layer height



satellites	instrument	
ADM-Aeolus	**ALADIN**	2016-19
3D-Winds	**3D-Winds lidar**	?

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Low frequency microwave –
~1.4 GHz - soil moisture and salinity

satellites	instrument	
SMOS	**MIRAS**	2009-14+
SAC-D	**Aquarius**	2011-16
SMAP	**SMAP**	2014-17

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Cloud and precipitation radar

satellites	instrument	frequency (GHz)	
TRMM	**PR**	13.8	1997-2014+
Cloudsat	**CPR**	94	2006-14+
GPM-Core	**DR**	13.6 + 35.6	2014-17
EarthCARE	**CPR**	94	2017-20
FY-3RM-1, -2	**Ku/Ka-PR**	? 12-18 + 26-40 ?	2019-28

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Imagers on satellites in high-inclination elliptical orbits

satellites	instrument		
Arctica-M N1, N2	**MSU-GS/A**	10 channels	2015-21
PCW-1, -2	**ISR**	21 channels	2022-29

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Additional operational missions and operational pathfinders in 2025

SUMMARY

MW imagers	**7+**	needed for GPM concept
Scatterometers	**4+**	
RO	**15+**	EGOS-IP calls for >10,000 occs. per day
DWL	**?**	
Low-freq. MW	**?**	
Cloud+precip radar	**1**	FY-3RM/KuKaPR
Imagers in HEO	**2**	PCW/ISR

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Summary and Conclusions

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Observing System Network Design Principles for WIGOS

1. SERVING MANY APPLICATION AREAS
2. MEETING USER REQUIREMENTS
3. MEETING NATIONAL, REGIONAL AND GLOBAL REQTS.
4. DESIGNING APPROPRIATELY SPACED NETWORKS
5. DESIGNING COST-EFFECTIVE NETWORKS
6. ACHIEVING HOMOGENEITY IN OBSERVATIONAL DATA
7. DESIGNING THROUGH A TIERED APPROACH
8. DESIGNING RELIABLE AND STABLE NETWORKS
9. MAKING OBSERVATIONAL DATA AVAILABLE
10. PROVIDING INFO SO THAT THE OBS CAN BE INTERPRETED
11. ACHIEVING SUSTAINABLE NETWORKS
12. MANAGING CHANGE

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Issues

- Data availability!
- Keys gaps:
  - key variables for NWP – 3D wind
  - missions – DWL, low-freq.MW
  - several vulnerabilities to early failure
  - more gaps for climate monitoring and other applications
- Role of NWP centres in helping space agencies

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Conclusions

- Space agencies' plans provide a good response to the "WMO Vision for 2025"
- ... with some gaps for NWP
- ... and more gaps for climate monitoring + other applications

- Towards new "WMO Vision for 2040":
  - which gaps in Vision for 2025 remain unfilled?
  - which technology will be mature in 2040?

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Thank you! Questions?

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