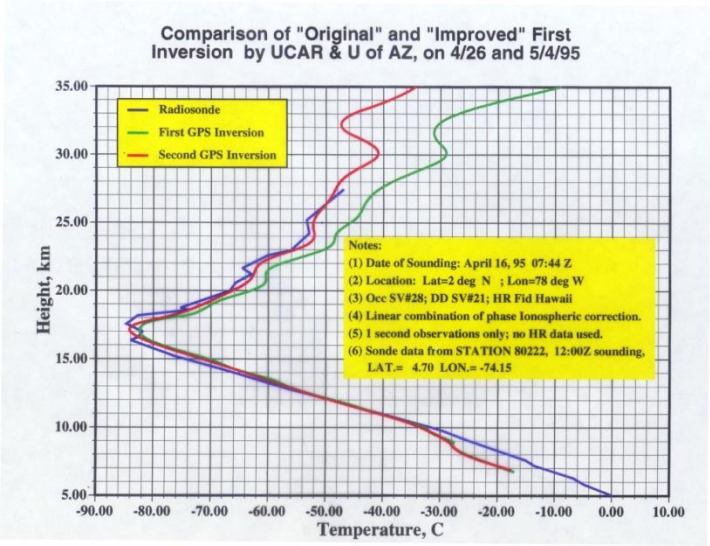
Atmospheric Sounding from Space Present and Future



Rick Anthes

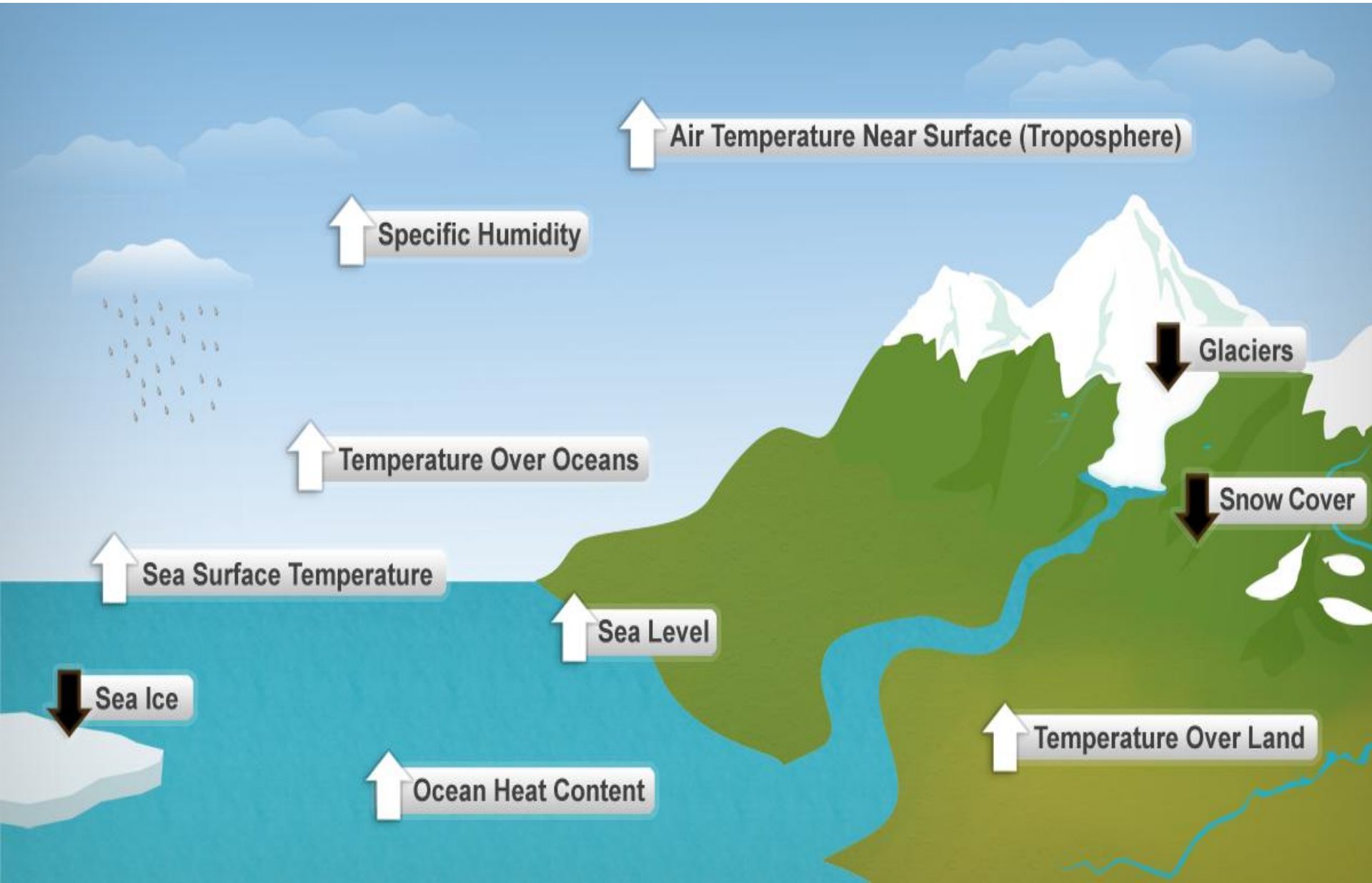
IROWG Workshop

28 March 2012

Why a talk on sounders?

Infrared, microwave, and radio occultation (RO) sounders contribute most of all observing systems to medium-range weather forecasting skill and have many applications in meteorology, and climate. RO also contributes to ionospheric research and space weather.

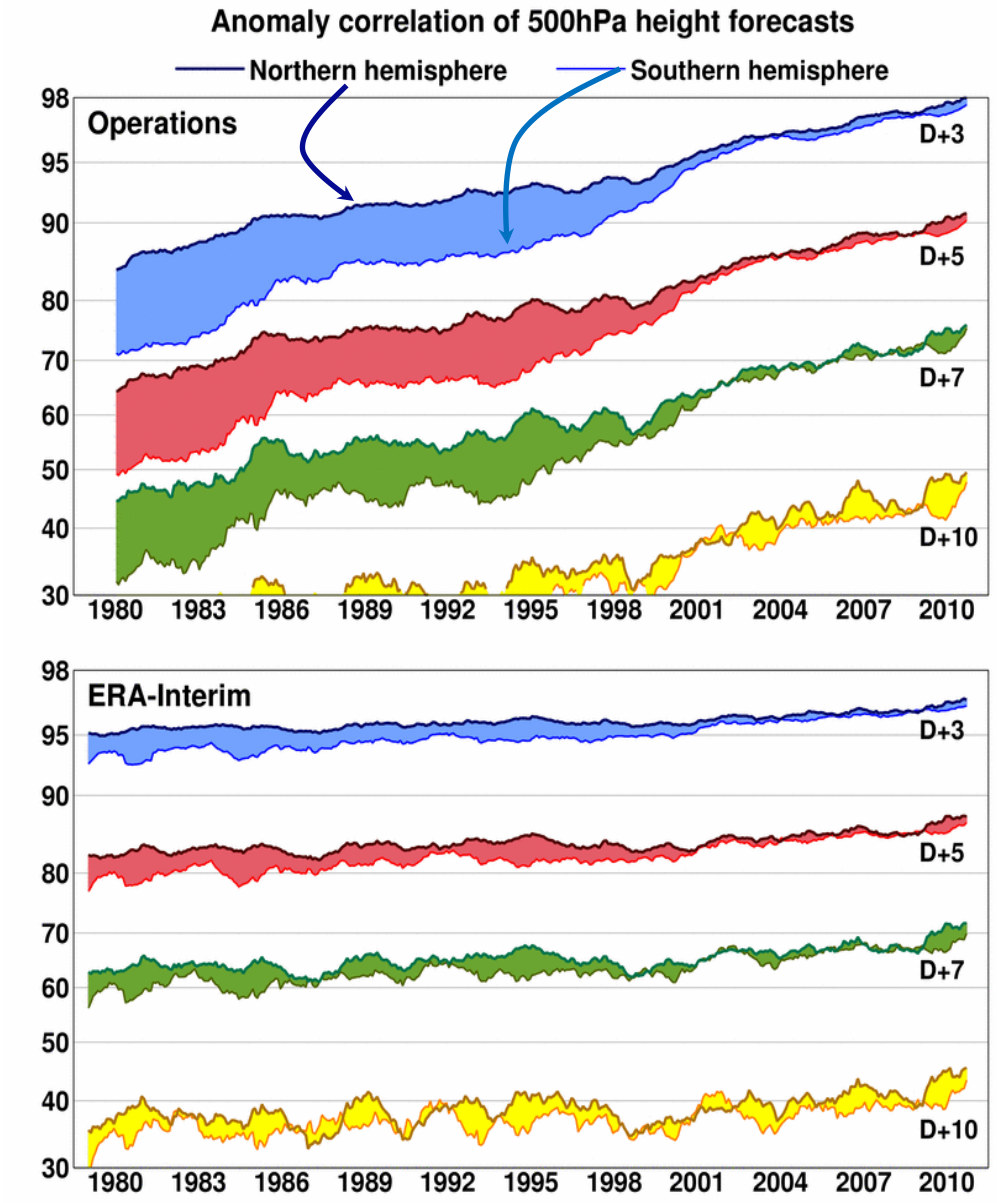
Sounders observe 3 out of 10 Essential Climate Variable Indicators



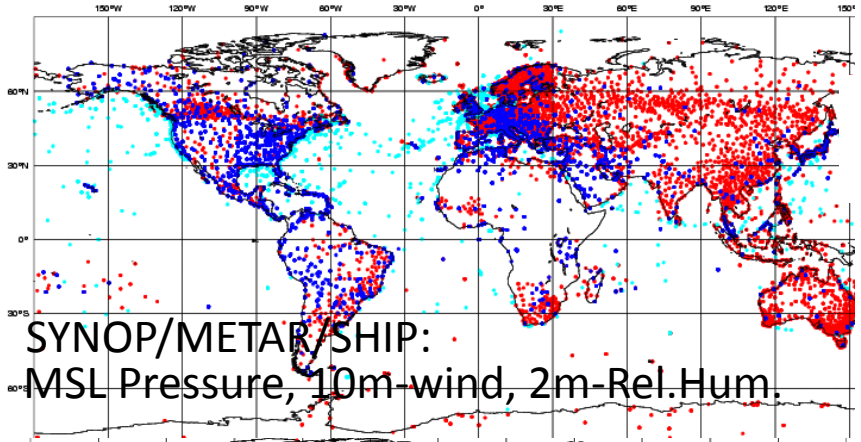
Improved forecasts only recently come from improvements in observations

From 1980 to 2000 forecast Improvements come mostly from improvement to forecasting system

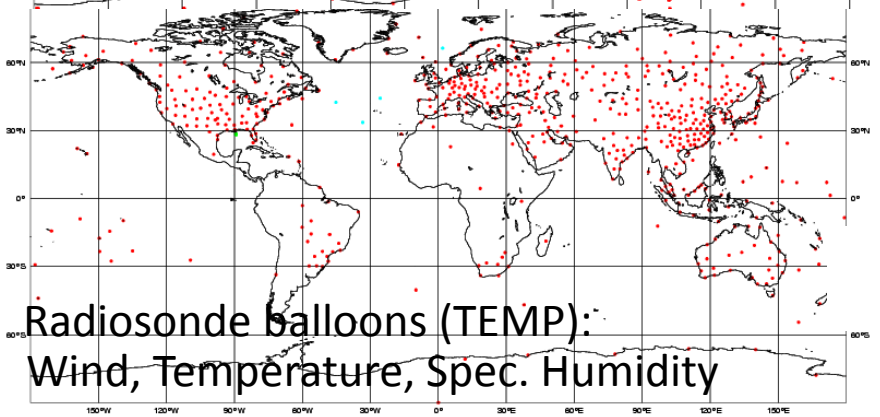
Reanalysis Improvement since 2000 comes from both forecasting system and observations



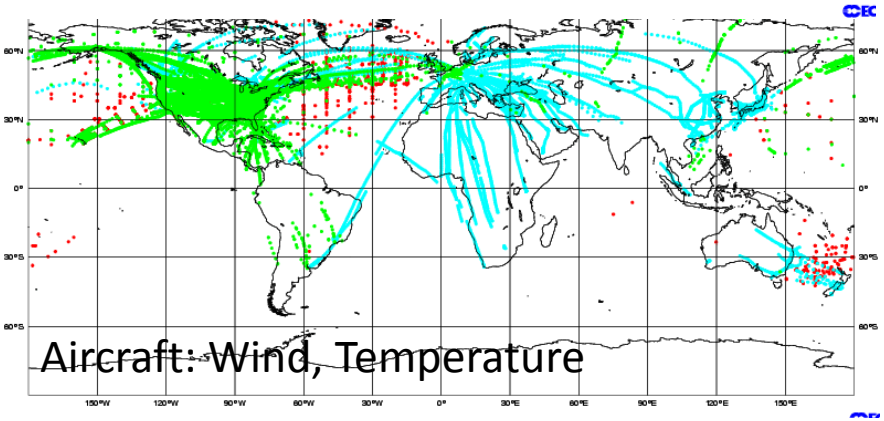
Conventional observations used by ECMWF's analysis



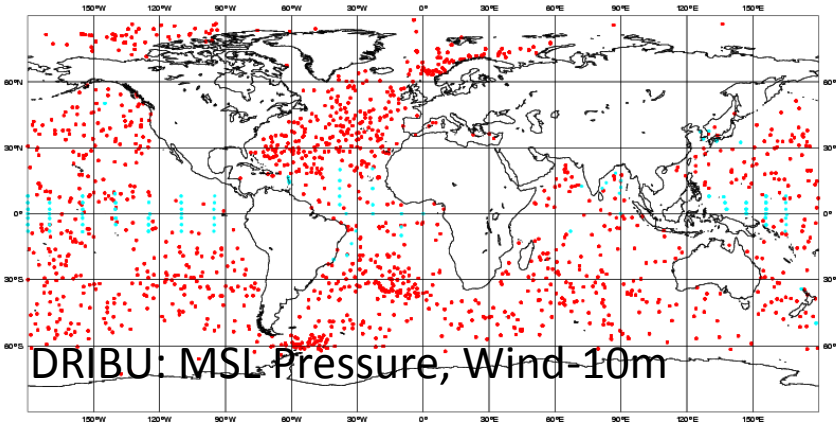
SYNOP/METAR/SHIP:
MSL Pressure, 10m-wind, 2m-Rel.Hum.



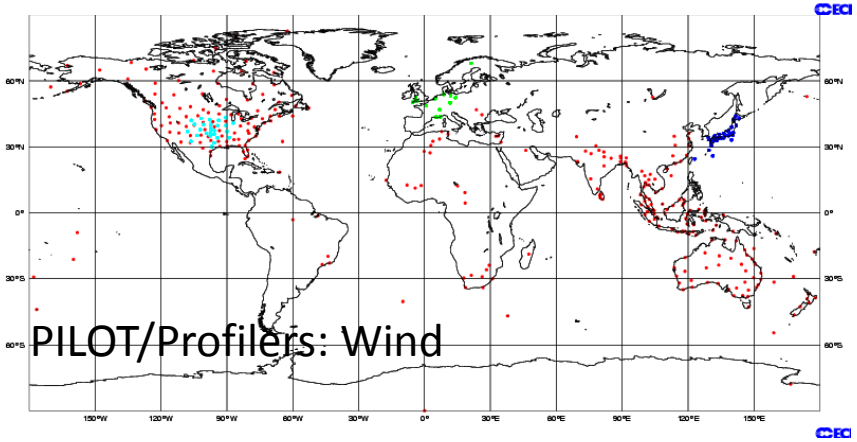
Radiosonde balloons (TEMP):
Wind, Temperature, Spec. Humidity



Aircraft: Wind, Temperature



DRIBU: MSL Pressure, Wind-10m



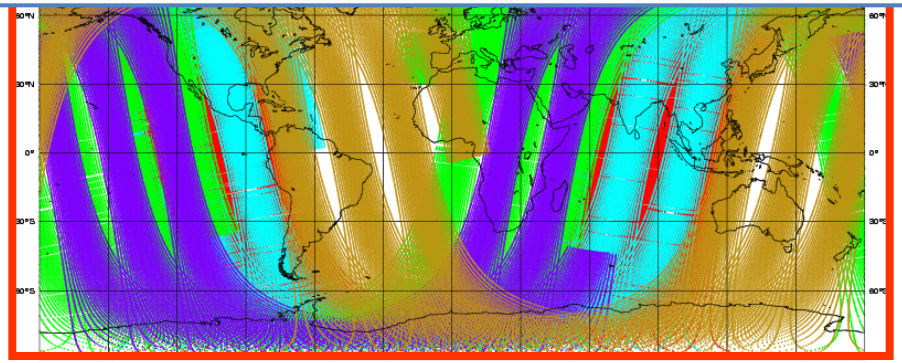
PILOT/Profilers: Wind

Note: We only use a limited number of the observed variables; especially over land.

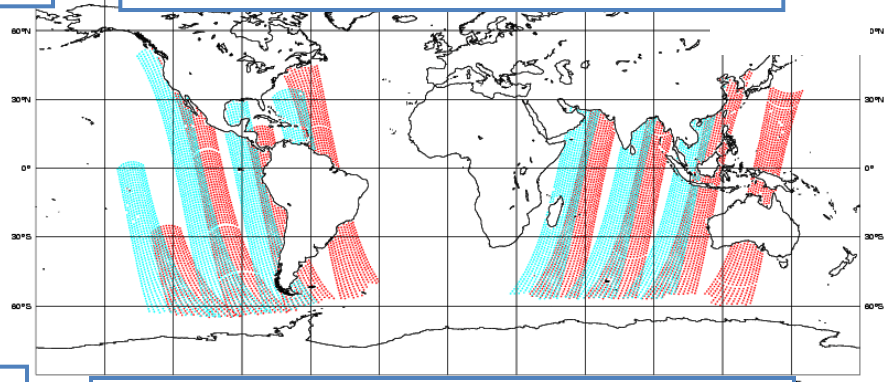
Lars Isaksen, ECMWF

Satellite data sources used in the operational ECMWF analysis

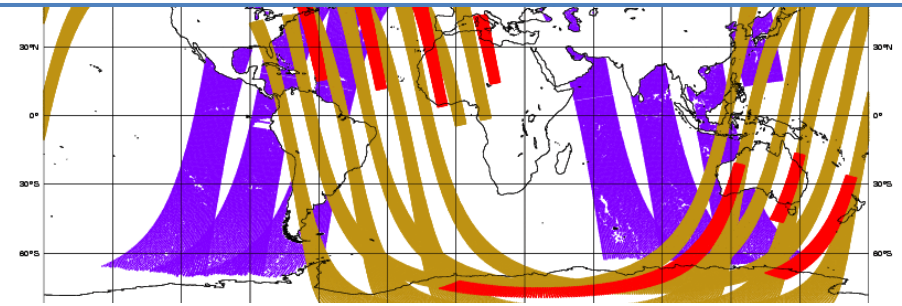
13 Sounders: NOAA AMSU-A/B, HIRS, AIRS, IASI, MHS



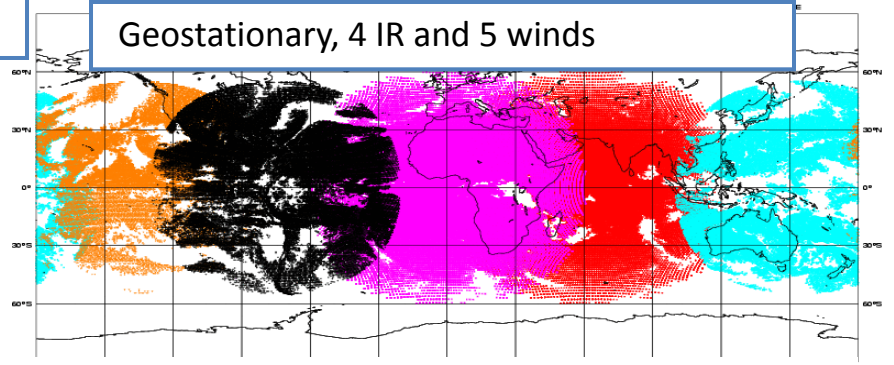
5 imagers: 3xSSM/I, AMSR-E, TMI

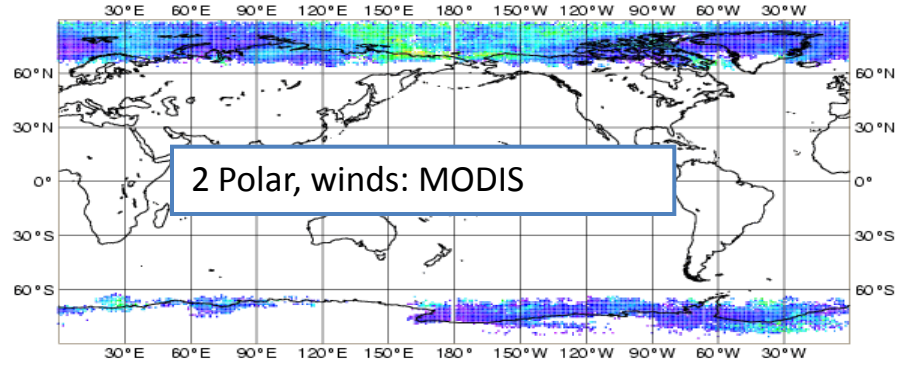


3 Scatterometer sea winds: ERS, ASCAT, QuikSCAT



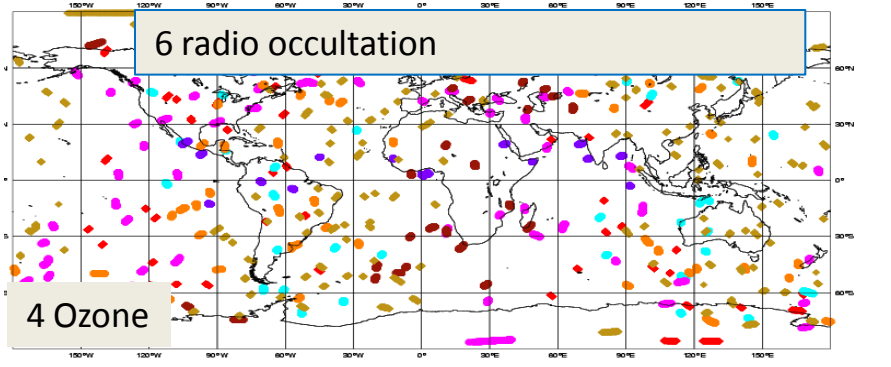
Geostationary, 4 IR and 5 winds





2 Polar, winds: MODIS

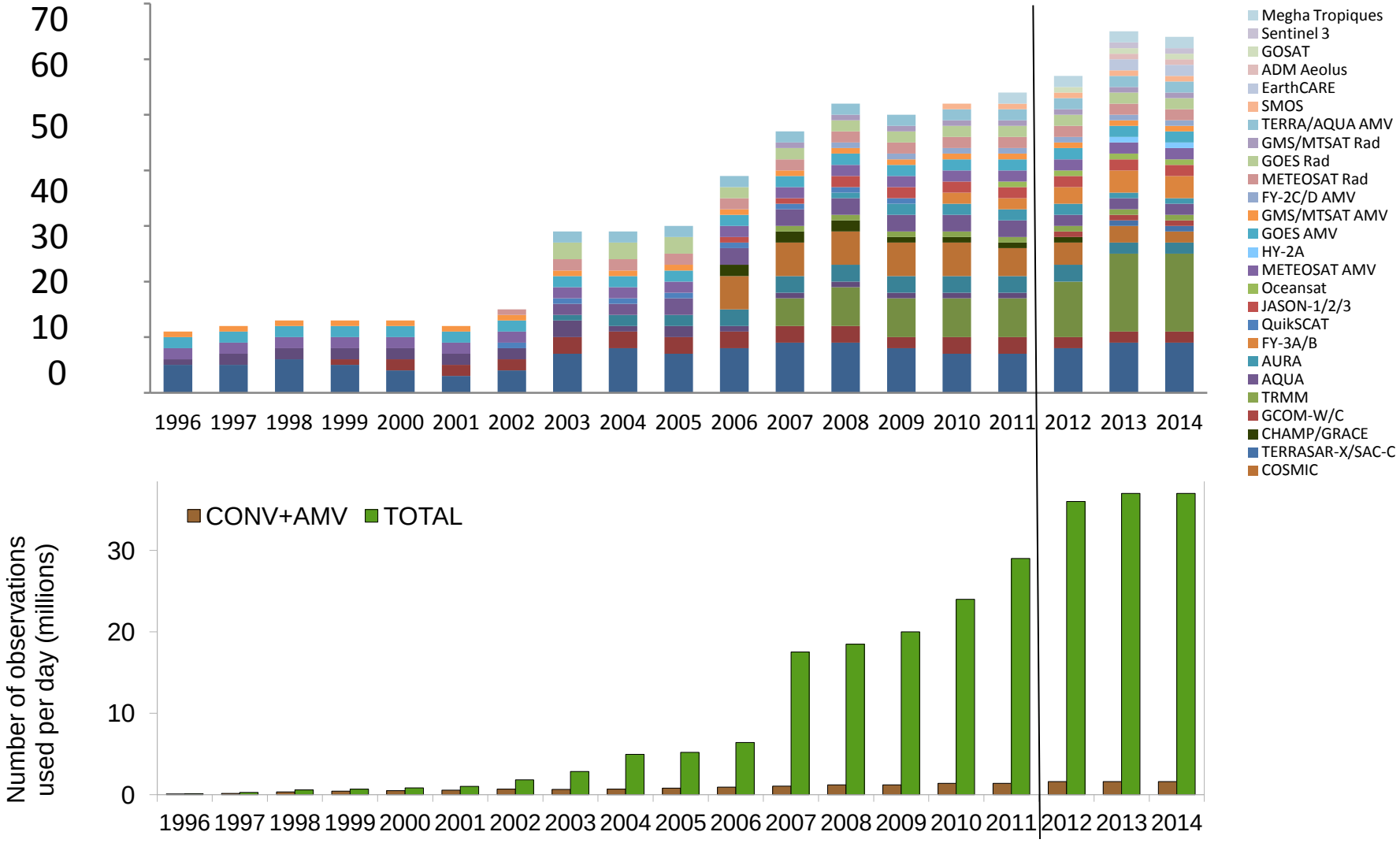
6 radio occultation



4 Ozone

Lars Isaksen, ECMWF

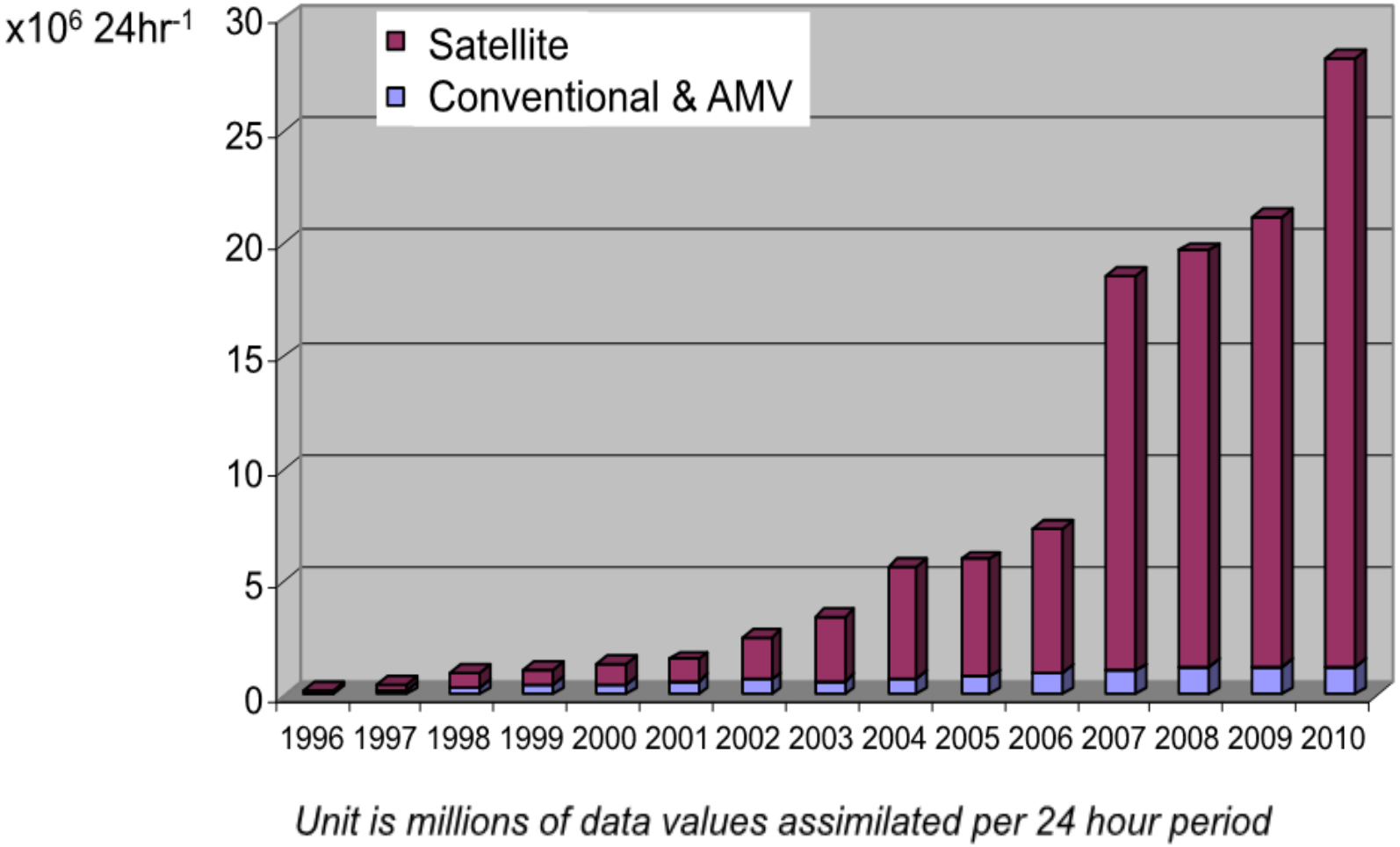
Used satellite instruments and data volume 1996-2014



Lars Isaksen, ECMWF

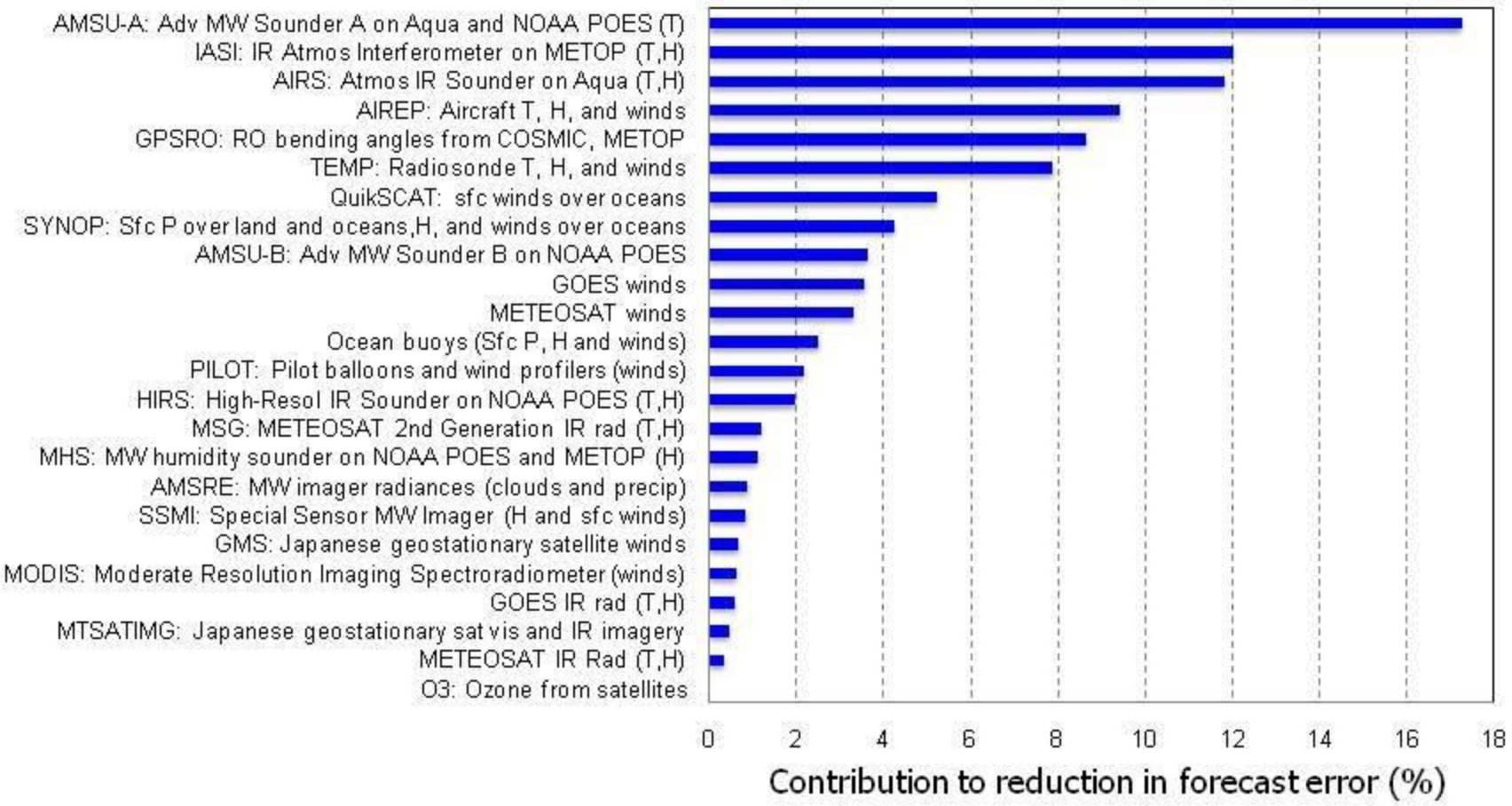
Significant increase in number of observations assimilated

Conventional and satellite data assimilated at ECMWF 1996-2010



Lars Isaksen, ECMWF

Operational ECMWF system September to December 2008. Averaged over all model layers and entire global atmosphere. % contribution of different observations to reduction in forecast error.



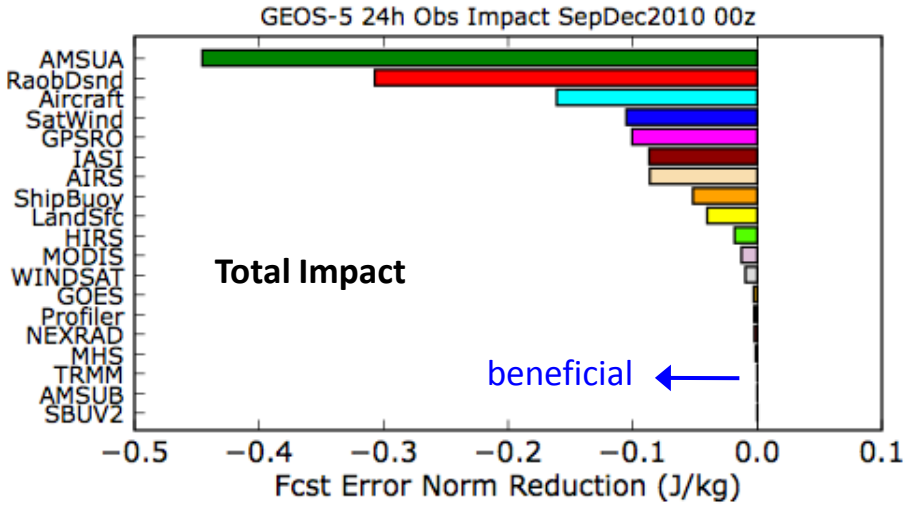
Importance of thermodynamic sounders-4 of top 5 observing systems are sounders

Impact of Various Observing Systems in GEOS-5

01 Sep – 31 Dec 2010 00z

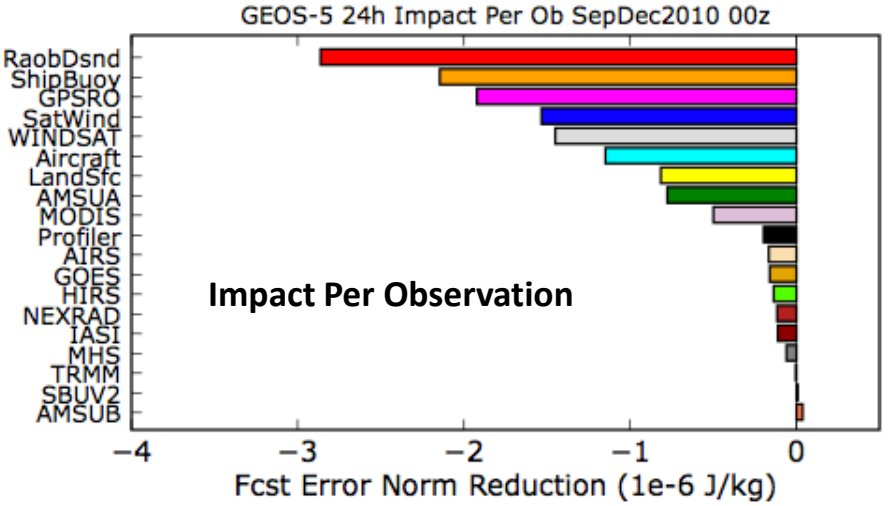
Total Impact

AMSU-A radiances have the largest impact globally, but conventional data (raob, aircraft) still very important. GPSRO now a significant contributor.



Impact Per Observation

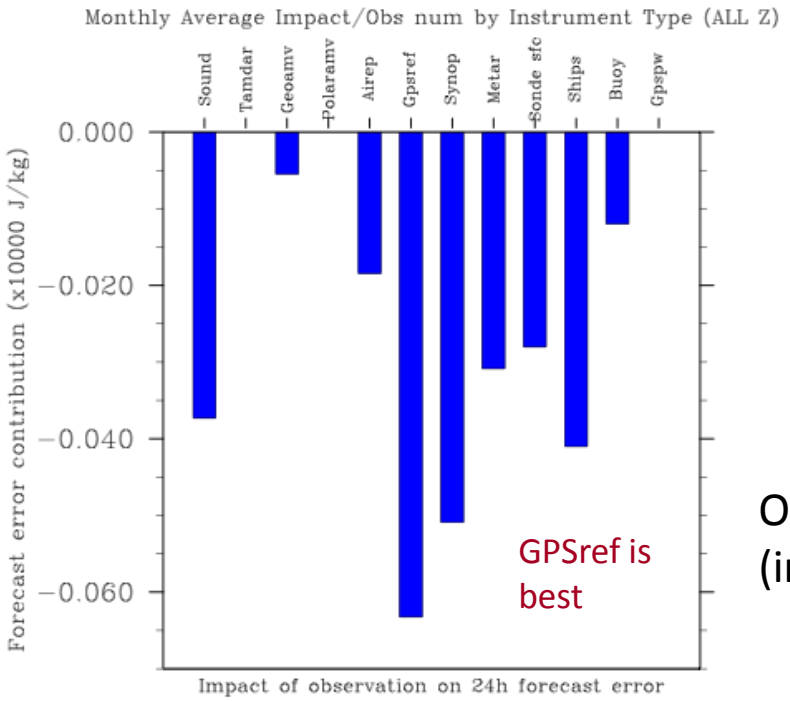
GPSRO third-most effective sounder from space



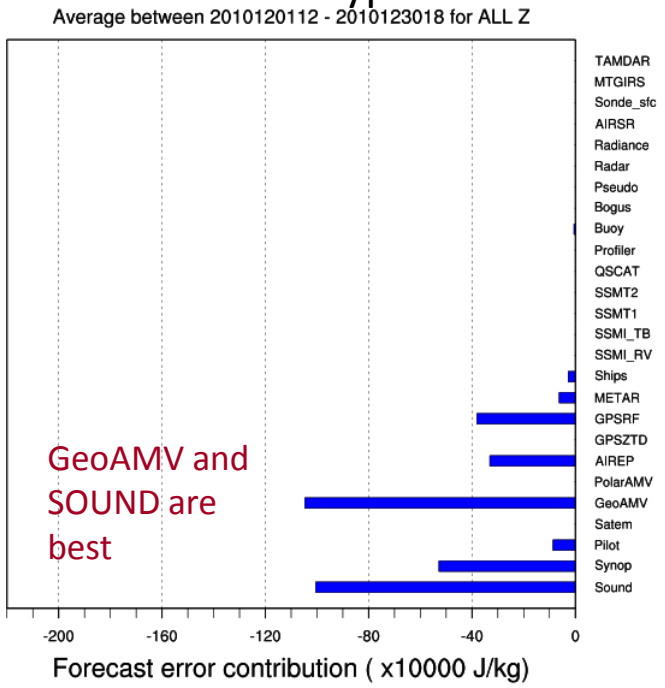
NCEP study (Gelaro): 4 out of top 7 observing systems are sounders

FSO results for CWB domain-two of top Five systems are sounders

Verified against ECMWF. Forecast errors calculated over domain 2 using dry energy norm.



Observation efficiency (impact / number of obs)



For the month of Dec 2010

IR, Microwave and RO sounders
Present and Future

From: THE SPACE-BASED GLOBAL OBSERVING SYSTEM IN 2012 (GOS-2012)

LIST OF EARTH OBSERVATION SATELLITES IR only

Satellite	Launch	Expected EOL	Height	ECT/incl.	Status	Instruments (see tables)
CLARREO	TBD	TBD	609 km	90°	Re-considered	GNSS-RO, IR spectrometer, SW spectrometer
Electro-M N1	≥ 2016	≥ 2023	GEO,	76°E	Being defined	ERBR, GGAK-E/M, HIS, LM, MSU-GSM
Electro-M N2	≥ 2017	≥ 2024	GEO,	14.5°W	Being defined	ERBR, GGAK-E/M, HIS, LM, MSU-GSM
EOS-Aqua	4 May 2002	≥ 2012	705 km	13:30 a	Operational	AIRS, AMSR-E, AMSU-A, CERES, HSB, MODIS
FY-3A	27 May 2008	≥ 2012	836 km	10:15 d	Operational	ERM-1, IRAS, MERSI-1, MWHS-1, MWRI, MWTS-1, SBUS, SEM, SIM-1, TOU, VIRR
FY-3B	4 Nov 2010	≥ 2013	836 km	13.40 a	Operational	ERM-1, IRAS, MERSI-1, MWHS-1, MWRI, MWTS-1, SBUS, SEM, SIM-1, TOU, VIRR
FY-3C	≥ 2013	≥ 2016	836 km	10.00 d	In integration	ERM-1, IRAS, MERSI-2, MWHS-2, MWRI, MWTS-2, SBUS, SES, SIM-2, TOU, VIRR
FY-3D	≥ 2015	≥ 2018	836 km	14.00 a	Planned	ASI, GAMI, GNOS, MERSI-2, MWHS-2, MWRI, MWTS-2, SES
FY-3E	≥ 2017	≥ 2020	836 km	10.00 d	Planned	ASI, ERM-2, GNOS, MERSI-2, MWHS-2, MWTS-2, OMS, SES, SIM-2, WindRAD
FY-3F	≥ 2019	≥ 2022	836 km	14.00 a	Planned	ASI, GAMI, GNOS, MERSI-2, MWHS-2, MWRI, MWTS-2, SES
FY-3G	≥ 2021	≥ 2024	836 km	10.00 d	Planned	ASI, ERM-2, GNOS, MERSI-2, MWHS-2, MWTS-2, OMS, SES, SIM-2, WindRAD
FY-4A	≥ 2015	≥ 2020	GEO,	86.5°E	Approved	AGRI, GIIRS, LMI, SEM, SXEUV
FY-4B	≥ 2017	≥ 2023	GEO,	105°E	Approved	AGRI, GIIRS, LMI, SEM, SXEUV
FY-4C	≥ 2019	≥ 2025	GEO,	86.5°E	Planned	AGRI, GIIRS, LMI, SEM, SXEUV
FY-4D	≥ 2021	≥ 2026	GEO,	105°E	Planned	AGRI, GIIRS, LMI, SEM, SXEUV
FY-4E	≥ 2025	≥ 2031	GEO,	86.5°E	Planned	AGRI, GIIRS, LMI, SEM, SXEUV
FY-4F	≥ 2028	≥ 2034	GEO,	105°E	Planned	AGRI, GIIRS, LMI, SEM, SXEUV
FY-4G	≥ 2031	≥ 2037	GEO,	86.5°E	Planned	AGRI, GIIRS, LMI, SEM, SXEUV
GOES-12	23 Jul 2001	≥ 2012	GEO,	60°W	Operational	IMAGER, SEM, SOUNDER, SXI
GOES-13	24 May 2006	≥ 2015	GEO,	75°W	Operational	IMAGER, SEM, SOUNDER, SXI
GOES-14	27 Jun 2009	≥ 2016	GEO,	105°W	Hot standby	IMAGER, SEM, SOUNDER, SXI
GOES-15	4 Mar 2010	≥ 2020	GEO,	135°W	Operational	IMAGER, SEM, SOUNDER, SXI
INSAT-3D	≥ 2012	≥ 2019	GEO,	83°E	Close to launch	IMAGER, SOUNDER
INSAT-3D-prime	≥ 2014	≥ 2021	GEO,	74°E	In development	IMAGER, SOUNDER
JPSS-1	≥ 2016	≥ 2023	833 km	13.30 a	Approved	ATMS, CERES, CrIS, OMPS-nadir, SEM-N, TSIS, VIIRS
JPSS-2	≥ 2021	≥ 2028	833 km	13.30 a	Approved	ATMS, CrIS, OMPS-nadir, SEM-N, VIIRS
MTG-S1	≥ 2019	≥ 2027	GEO,	0°	Planned	IRS, UVN
MTG-S2	≥ 2027	≥ 2035	GEO,	0°	Planned	IRS, UVN
MetOp-A	19 Oct 2006	≥ 2012	817 km	09.30 d	Operational	AMSU-A, ASCAT, AVHRR/3, GOME-2, GRAS, HIRS/4, IASI, MHS, SEM/2
MetOp-B	≥ 2012	≥ 2017	817 km	09.30 d	Close to launch	AMSU-A, ASCAT, AVHRR/3, GOME-2, GRAS, HIRS/4, IASI, MHS, SEM/2
MetOp-C	≥ 2016	≥ 2021	817 km	09.30 d	Approved	AMSU-A, ASCAT, AVHRR/3, GOME-2, GRAS, IASI, MHS
MetOp-SG-A1	≥ 2020	≥ 2026	817 km	09:30 d	Being defined	3MI, ATMS, IASI-NG, MetImage, RER, RO, UVNS
MetOp-SG-A2	≥ 2025	≥ 2031	817 km	09:30 d	Being defined	3MI, ATMS, IASI-NG, MetImage, RER, RO, UVNS
MetOp-SG-A3	≥ 2030	≥ 2036	817 km	09:30 d	Being defined	3MI, ATMS, IASI-NG, MetImage, RER, RO, UVNS
MetOp-SG-B1	≥ 2021	≥ 2027	817 km	09:30 d	Being defined	ICI, MWI, RO, SCA, SEM-N
MetOp-SG-B2	≥ 2026	≥ 2032	817 km	09:30 d	Being defined	ICI, MWI, RO, SCA, SEM-N
MetOp-SG-B3	≥ 2031	≥ 2037	817 km	09:30 d	Being defined	ICI, MWI, RO, SCA, SEM-N
NOAA-15	13 May 1998	≥ 2012	807 km	04:40 d	Degraded	AMSU-A, AMSU-B, AVHRR/3, HIRS/3, SEM/2
NOAA-16	21 Sep 2000	≥ 2012	849 km	07:55 d	Degraded	AMSU-A, AMSU-B, AVHRR/3, HIRS/3, SBUV/2, SEM/2
NOAA-17	24 Jun 2002	≥ 2012	810 km	07:50 d	Degraded	AMSU-A, AMSU-B, AVHRR/3, HIRS/3, SBUV/2, SEM/2
NOAA-18	20 May 2005	≥ 2012	854 km	14:25 a	Operational	AMSU-A, AVHRR/3, HIRS/4, MHS, SBUV/2, SEM/2
NOAA-19	6 Feb 2009	≥ 2014	870 km	13:30 a	Operational	AMSU-A, AVHRR/3, HIRS/4, MHS, SBUV/2, SEM/2
NPP	28 Oct 2011	≥ 2016	834 km	13.25 a	Operational	ATMS, CERES, CrIS, OMPS-limb, OMPS-nadir, VIIRS

ECMWF

LIST OF EARTH OBSERVATION SATELLITES IR only

Satellite	Launch	Expected EOL	Height	ECT/incl.	Status	Instruments (see tables)
CLARREO	TBD	TBD	609 km	90°	Re-considered	GNSS-RO, IR spectrometer, SW spectrometer
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FY-3C	≥ 2013	≥ 2016	836 km	10.00 d	In integration	ERM-1, IRAS, MERSI-2, MWHS-2, MWRI, MWTS-2, SBUS, SES, SIM-2, TOU, VIRR
FY-3D	≥ 2015	≥ 2018	836 km	14.00 a	Planned	ASI, GAMI, GNOS, MERSI-2, MWHS-2, MWRI, MWTS-2, SES
FY-3E	≥ 2017	≥ 2020	836 km	10.00 d	Planned	ASI, ERM-2, GNOS, MERSI-2, MWHS-2, MWTS-2, OMS, SES, SIM-2, WindRAD
FY-3F	≥ 2019	≥ 2022	836 km	14.00 a	Planned	ASI, GAMI, GNOS, MERSI-2, MWHS-2, MWRI, MWTS-2, SES
FY-3G	≥ 2021	≥ 2024	836 km	10.00 d	Planned	ASI, ERM-2, GNOS, MERSI-2, MWHS-2, MWTS-2, OMS, SES, SIM-2, WindRAD
FY-4A	≥ 2015	≥ 2020	GEO,	86.5°E	Approved	AGRI, GIIRS, LMI, SEM, SXEUV
FY-4B	≥ 2017	≥ 2023	GEO,	105°E	Approved	AGRI, GIIRS, LMI, SEM, SXEUV
FY-4C	≥ 2019	≥ 2025	GEO,	86.5°E	Planned	AGRI, GIIRS, LMI, SEM, SXEUV
FY-4D	≥ 2021	≥ 2026	GEO,	105°E	Planned	AGRI, GIIRS, LMI, SEM, SXEUV
FY-4E	≥ 2025	≥ 2031	GEO,	86.5°E	Planned	AGRI, GIIRS, LMI, SEM, SXEUV
FY-4F	≥ 2028	≥ 2034	GEO,	105°E	Planned	AGRI, GIIRS, LMI, SEM, SXEUV
FY-4G	≥ 2031	≥ 2037	GEO,	86.5°E	Planned	AGRI, GIIRS, LMI, SEM, SXEUV
GOES-12	23 Jul 2001	≥ 2012	GEO,	60°W	Operational	IMAGER, SEM, SOUNDER, SXI
GOES-13	24 May 2006	≥ 2015	GEO,	75°W	Operational	IMAGER, SEM, SOUNDER, SXI
GOES-14	27 Jun 2009	≥ 2016	GEO,	105°W	Hot standby	IMAGER, SEM, SOUNDER, SXI
GOES-15	4 Mar 2010	≥ 2020	GEO,	135°W	Operational	IMAGER, SEM, SOUNDER, SXI
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MTG-S1	≥ 2019	≥ 2027	GEO,	0°	Planned	IRS, UVN
MTG-S2	≥ 2027	≥ 2035	GEO,	0°	Planned	IRS, UVN
MetOp-A	19 Oct 2006	≥ 2012	817 km	09.30 d	Operational	AMSU-A, ASCAT, AVHRR/3, GOME-2, GRAS, HIRS/4, IASI, MHS, SEM/2
MetOp-B	≥ 2012	≥ 2017	817 km	09.30 d	Close to launch	AMSU-A, ASCAT, AVHRR/3, GOME-2, GRAS, HIRS/4, IASI, MHS, SEM/2
MetOp-C	≥ 2016	≥ 2021	817 km	09.30 d	Approved	AMSU-A, ASCAT, AVHRR/3, GOME-2, GRAS, IASI, MHS
MetOp-SG-A1	≥ 2020	≥ 2026	817 km	09:30 d	Being defined	3MI, ATMS, IASI-NG, MetImage, RER, RO, UVNS
MetOp-SG-A2	≥ 2025	≥ 2031	817 km	09:30 d	Being defined	3MI, ATMS, IASI-NG, MetImage, RER, RO, UVNS
MetOp-SG-A3	≥ 2030	≥ 2036	817 km	09:30 d	Being defined	3MI, ATMS, IASI-NG, MetImage, RER, RO, UVNS
MetOp-SG-B1	≥ 2021	≥ 2027	817 km	09:30 d	Being defined	ICI, MWI, RO, SCA, SEM-N
MetOp-SG-B2	≥ 2026	≥ 2032	817 km	09:30 d	Being defined	ICI, MWI, RO, SCA, SEM-N
MetOp-SG-B3	≥ 2031	≥ 2037	817 km	09:30 d	Being defined	ICI, MWI, RO, SCA, SEM-N
NOAA-15	13 May 1998	≥ 2012	807 km	04:40 d	Degraded	AMSU-A, AMSU-B, AVHRR/3, HIRS/3, SEM/2
NOAA-16	21 Sep 2000	≥ 2012	849 km	07:55 d	Degraded	AMSU-A, AMSU-B, AVHRR/3, HIRS/3, SBUV/2, SEM/2
NOAA-17	24 Jun 2002	≥ 2012	810 km	07:50 d	Degraded	AMSU-A, AMSU-B, AVHRR/3, HIRS/3, SBUV/2, SEM/2
NOAA-18	20 May 2005	≥ 2012	854 km	14:25 a	Operational	AMSU-A, AVHRR/3, HIRS/4, MHS, SBUV/2, SEM/2
NOAA-19	6 Feb 2009	≥ 2014	870 km	13:30 a	Operational	AMSU-A, AVHRR/3, HIRS/4, MHS, SBUV/2, SEM/2
NPP	28 Oct 2011	≥ 2016	834 km	13.25 a	Operational	ATMS, CERES, CrIS, OMPS-limb, OMPS-nadir, VIIRS

LIST OF INSTRUMENTS (IR Sounders Only)

Acronym	Full name	Satellites	Utilisation
AIRS	Atmospheric Infra-Red Sounder	EOS-Aqua	2002-2012
ASI	Atmospheric Sounding Interferometer	FY-3 D to G	2015-2024
CrIS	Cross-track Infrared Sounder	NPP, JPSS-1, JPSS-2	2011-2028
GIIRS	Geostationary Interferometric Infrared Sounder	FY-4 A to G	2015-2037
HIRS/3	High-resolution Infra Red Sounder / 3	NOAA 15 to 17	1998-2012
HIRS/4	High-resolution Infra Red Sounder / 3	NOAA 18 & 19	2005-2014
HIRS/4	High-resolution Infra Red Sounder / 4	Metop A&B	2006-2017
HIS	Hyperspectral Infrared Sounder	Electro-M N1, N2	2016-2024
IASI	Infrared Atmospheric Sounding Interferometer	MetOp A to C	2006-2021
IASI-NG	Infrared Atmospheric Sounding Interferometer - New Generation	MetOp-SG-A 1, 2, 3	2020-2036
IRAS	Infra Red Atmospheric Sounder	FY-3 A to C	2008-2016
IRMSS	Infrared Multispectral Scanner	CBERS 1 and 2, CBERS 3 and 4	1999-2019
IRS	Infra Red Sounder	MTG-S1, MTG-S2	2019-2035
SOUNDER	GOES Sounder IR	GOES 8 to 15	1994-2020
SOUNDER	INSAT Sounder IR	INSAT-3D, INSAT-3D-prime	2012-2021

LIST OF EARTH OBSERVATION SATELLITES (microwave sounders only)

Satellite	Launch	Expected EOL	Height	ECT/incl.	Status	Instruments (see tables)
DMSP-F13	24 Mar 1995	≥ 2012	849 km	06:05 d	Tactical operations	OLS, SEM, SSM/I, SSM/T
DMSP-F14	4 Apr 1997	≥ 2012	849 km	03:35 d	Tactical operations	OLS, SEM, SSM/I, SSM/T, SSM/T-2
DMSP-F15	12 Dec 1999	≥ 2012	845 km	04:30 d	Secondary operations	OLS, SEM, SSM/I, SSM/T, SSM/T-2
DMSP-F16	18 Oct 2003	≥ 2012	855 km	06:25 d	Secondary operations	OLS, SEM+, SSMIS
DMSP-F17	4 Nov 2006	≥ 2013	855 km	05:35 d	Primary operations	OLS, SEM+, SSMIS
DMSP-F18	18 Oct 2009	≥ 2014	857 km	08:10 d	Primary operations	OLS, SEM+, SSMIS
DMSP-S19	≥ 2012	≥ 2018	848 km	05.30 d	Close to launch	OLS, SEM+, SSMIS
DMSP-S20	≥ 2014	≥ 2020	848 km	07.30 d	In storage	OLS, SEM+, SSMIS
DWSS-2 DWSS CANCELED ?	≥ 2022	≥ 2028	833 km	5.30 d	Being defined	MIS, SEM-N, VIIRS
EOS-Aqua	4 May 2002	≥ 2012	705 km	13:30 a	Operational	AIRS, AMSR-E, AMSU-A, CERES, HSB, MODIS
FY-3A	27 May 2008	≥ 2012	836 km	10:15 d	Operational	ERM-1, IRAS, MERSI-1, MWHS-1, MWRI, MWTS-1, SBUS, SEM, SIM-1, TOU, VIRR
FY-3B	4 Nov 2010	≥ 2013	836 km	13.40 a	Operational	ERM-1, IRAS, MERSI-1, MWHS-1, MWRI, MWTS-1, SBUS, SEM, SIM-1, TOU, VIRR
FY-3C	≥ 2013	≥ 2016	836 km	10.00 d	In integration	ERM-1, IRAS, MERSI-2, MWHS-2, MWRI, MWTS-2, SBUS, SES, SIM-2, TOU, VIRR
FY-3D	≥ 2015	≥ 2018	836 km	14.00 a	Planned	ASI, GAMI, GNOS, MERSI-2, MWHS-2, MWRI, MWTS-2, SES
FY-3E	≥ 2017	≥ 2020	836 km	10.00 d	Planned	ASI, ERM-2, GNOS, MERSI-2, MWHS-2, MWTS-2, OMS, SES, SIM-2, WindRAD
FY-3F	≥ 2019	≥ 2022	836 km	14.00 a	Planned	ASI, GAMI, GNOS, MERSI-2, MWHS-2, MWRI, MWTS-2, SES
FY-3G	≥ 2021	≥ 2024	836 km	10.00 d	Planned	ASI, ERM-2, GNOS, MERSI-2, MWHS-2, MWTS-2, OMS, SES, SIM-2, WindRAD
JPSS-1	≥ 2016	≥ 2023	833 km	13.30 a	Approved	ATMS, CERES, CrIS, OMPS-nadir, SEM-N, TSIS, VIIRS
JPSS-2	≥ 2021	≥ 2028	833 km	13.30 a	Approved	ATMS, CrIS, OMPS-nadir, SEM-N, VIIRS
Meteor-M N1	17 Sep 2009	≥ 2014	830 km	09:10 d	Operational	GMSC, KMSS, MSU-MR, MTVZA-GY, Severjanin-M
Meteor-M N2	≥ 2012	≥ 2017	830 km	09:30 d	Close to launch	GMSC, IKFS, KMSS, MSU-MR, MTVZA-GY, Severjanin-M
Meteor-M N2-1	≥ 2014	≥ 2019	830 km	15:30 a	In development	GMSC, IKFS, KMSS, MSU-MR, MTVZA-GY, Severjanin-M
Meteor-M N2-2	≥ 2015	≥ 2020	830 km	09:30 d	Approved	GMSC, IKFS, KMSS, MSU-MR, MTVZA-GY, Severjanin-M
Meteor-MP N2	≥ 2018	≥ 2023	830 km	09:30 d	Planned	ACS, BRLK "Briz", GGAK-M, IKFS-2, MSU-MR-MP, MTVZA-GY-MP, Radiomet
Meteor-MP N3	≥ 2019	≥ 2024	TBD	TBD	Planned	MMIS, OCS, SAR-X, SCAT, SZS
MetOp-A	19 Oct 2006	≥ 2012	817 km	09.30 d	Operational	AMSU-A, ASCAT, AVHRR/3, GOME-2, GRAS, HIRS/4, IASI, MHS, SEM/2
MetOp-B	≥ 2012	≥ 2017	817 km	09.30 d	Close to launch	AMSU-A, ASCAT, AVHRR/3, GOME-2, GRAS, HIRS/4, IASI, MHS, SEM/2
MetOp-C	≥ 2016	≥ 2021	817 km	09.30 d	Approved	AMSU-A, ASCAT, AVHRR/3, GOME-2, GRAS, IASI, MHS
MetOp-SG-A1	≥ 2020	≥ 2026	817 km	09:30 d	Being defined	3MI, ATMS, IASI-NG, MetImage, RER, RO, UVNS
MetOp-SG-A2	≥ 2025	≥ 2031	817 km	09:30 d	Being defined	3MI, ATMS, IASI-NG, MetImage, RER, RO, UVNS
MetOp-SG-A3	≥ 2030	≥ 2036	817 km	09:30 d	Being defined	3MI, ATMS, IASI-NG, MetImage, RER, RO, UVNS
NOAA-15	13 May 1998	≥ 2012	807 km	04:40 d	Degraded	AMSU-A, AMSU-B, AVHRR/3, HIRS/3, SEM/2
NOAA-16	21 Sep 2000	≥ 2012	849 km	07:55 d	Degraded	AMSU-A, AMSU-B, AVHRR/3, HIRS/3, SBUV/2, SEM/2
NOAA-17	24 Jun 2002	≥ 2012	810 km	07:50 d	Degraded	AMSU-A, AMSU-B, AVHRR/3, HIRS/3, SBUV/2, SEM/2
NOAA-18	20 May 2005	≥ 2012	854 km	14:25 a	Operational	AMSU-A, AVHRR/3, HIRS/4, MHS, SBUV/2, SEM/2
NOAA-19	6 Feb 2009	≥ 2014	870 km	13:30 a	Operational	AMSU-A, AVHRR/3, HIRS/4, MHS, SBUV/2, SEM/2
NPP	28 Oct 2011	≥ 2016	834 km	13.25 a	Operational	ATMS, CERES, CrIS, OMPS-limb, OMPS-nadir, VIIRS

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LIST OF EARTH OBSERVATION SATELLITES (microwave sounders only)

Satellite	Launch	Expected EOL	Height	ECT/incl.	Status	Instruments (see tables)
DMSP-F13	24 Mar 1995	≥ 2012	849 km	06:05 d	Tactical operations	OLS, SEM, SSM/I, SSM/T
DMSP-F14	4 Apr 1997	≥ 2012	849 km	03:35 d	Tactical operations	OLS, SEM, SSM/I, SSM/T, SSM/T-2
DMSP-F15	12 Dec 1999	≥ 2012	845 km	04:30 d	Secondary operations	OLS, SEM, SSM/I, SSM/T, SSM/T-2
DMSP-F16	18 Oct 2003	≥ 2012	855 km	06:25 d	Secondary operations	OLS, SEM+, SSMIS
DMSP-F17	4 Nov 2006	≥ 2013	855 km	05:35 d	Primary operations	OLS, SEM+, SSMIS
DMSP-F18	18 Oct 2009	≥ 2014	857 km	08:10 d	Primary operations	OLS, SEM+, SSMIS
DMSP-S19	≥ 2012	≥ 2018	848 km	05.30 d	Close to launch	OLS, SEM+, SSMIS
DMSP-S20	≥ 2014	≥ 2020	848 km	07.30 d	In storage	OLS, SEM+, SSMIS
DWSS-2 DWSS CANCELED ?	≥ 2022	≥ 2028	833 km	5.30 d	Being defined	MIS, SEM-N, VIIRS
EOS-Aqua	4 May 2002	≥ 2012	705 km	13:30 a	Operational	AIRS, AMSR-E, AMSU-A, CERES, HSB, MODIS
FY-3A	27 May 2008	≥ 2012	836 km	10:15 d	Operational	ERM-1, IRAS, MERSI-1, MWHS-1, MWRI, MWTS-1, SBUS, SEM, SIM-1, TOU, VIRR
FY-3B	4 Nov 2010	≥ 2013	836 km	13.40 a	Operational	ERM-1, IRAS, MERSI-1, MWHS-1, MWRI, MWTS-1, SBUS, SEM, SIM-1, TOU, VIRR
FY-3C	≥ 2013	≥ 2016	836 km	10.00 d	In integration	ERM-1, IRAS, MERSI-2, MWHS-2, MWRI, MWTS-2, SBUS, SES, SIM-2, TOU, VIRR
FY-3D	≥ 2015	≥ 2018	836 km	14.00 a	Planned	ASI, GAMI, GNOS, MERSI-2, MWHS-2, MWRI, MWTS-2, SES
FY-3E	≥ 2017	≥ 2020	836 km	10.00 d	Planned	ASI, ERM-2, GNOS, MERSI-2, MWHS-2, MWTS-2, OMS, SES, SIM-2, WindRAD
FY-3F	≥ 2019	≥ 2022	836 km	14.00 a	Planned	ASI, GAMI, GNOS, MERSI-2, MWHS-2, MWRI, MWTS-2, SES
FY-3G	≥ 2021	≥ 2024	836 km	10.00 d	Planned	ASI, ERM-2, GNOS, MERSI-2, MWHS-2, MWTS-2, OMS, SES, SIM-2, WindRAD
JPSS-1	≥ 2016	≥ 2023	833 km	13.30 a	Approved	ATMS, CERES, CrIS, OMPS-nadir, SEM-N, TSIS, VIIRS
JPSS-2	≥ 2021	≥ 2028	833 km	13.30 a	Approved	ATMS, CrIS, OMPS-nadir, SEM-N, VIIRS
Meteor-M N1	17 Sep 2009	≥ 2014	830 km	09:10 d	Operational	GMSC, KMSS, MSU-MR, MTVZA-GY, Severjanin-M
Meteor-M N2	≥ 2012	≥ 2017	830 km	09:30 d	Close to launch	GMSC, IKFS, KMSS, MSU-MR, MTVZA-GY, Severjanin-M
Meteor-M N2-1	≥ 2014	≥ 2019	830 km	15:30 a	In development	GMSC, IKFS, KMSS, MSU-MR, MTVZA-GY, Severjanin-M
Meteor-M N2-2	≥ 2015	≥ 2020	830 km	09:30 d	Approved	GMSC, IKFS, KMSS, MSU-MR, MTVZA-GY, Severjanin-M
Meteor-MP N2	≥ 2018	≥ 2023	830 km	09:30 d	Planned	ACS, BRLK "Briz", GGAK-M, IKFS-2, MSU-MR-MP, MTVZA-GY-MP, Radiomet
Meteor-MP N3	≥ 2019	≥ 2024	TBD	TBD	Planned	MMIS, OCS, SAR-X, SCAT, SZS
MetOp-A	19 Oct 2006	≥ 2012	817 km	09.30 d	Operational	AMSU-A, ASCAT, AVHRR/3, GOME-2, GRAS, HIRS/4, IASI, MHS, SEM/2
MetOp-B	≥ 2012	≥ 2017	817 km	09.30 d	Close to launch	AMSU-A, ASCAT, AVHRR/3, GOME-2, GRAS, HIRS/4, IASI, MHS, SEM/2
MetOp-C	≥ 2016	≥ 2021	817 km	09.30 d	Approved	AMSU-A, ASCAT, AVHRR/3, GOME-2, GRAS, IASI, MHS
MetOp-SG-A1	≥ 2020	≥ 2026	817 km	09:30 d	Being defined	3MI, ATMS, IASI-NG, MetImage, RER, RO, UVNS
MetOp-SG-A2	≥ 2025	≥ 2031	817 km	09:30 d	Being defined	3MI, ATMS, IASI-NG, MetImage, RER, RO, UVNS
MetOp-SG-A3	≥ 2030	≥ 2036	817 km	09:30 d	Being defined	3MI, ATMS, IASI-NG, MetImage, RER, RO, UVNS
NOAA-15	13 May 1998	≥ 2012	807 km	04:40 d	Degraded	AMSU-A, AMSU-B, AVHRR/3, HIRS/3, SEM/2
NOAA-16	21 Sep 2000	≥ 2012	849 km	07:55 d	Degraded	AMSU-A, AMSU-B, AVHRR/3, HIRS/3, SBUV/2, SEM/2
NOAA-17	24 Jun 2002	≥ 2012	810 km	07:50 d	Degraded	AMSU-A, AMSU-B, AVHRR/3, HIRS/3, SBUV/2, SEM/2
NOAA-18	20 May 2005	≥ 2012	854 km	14:25 a	Operational	AMSU-A, AVHRR/3, HIRS/4, MHS, SBUV/2, SEM/2
NOAA-19	6 Feb 2009	≥ 2014	870 km	13:30 a	Operational	AMSU-A, AVHRR/3, HIRS/4, MHS, SBUV/2, SEM/2
NPP	28 Oct 2011	≥ 2016	834 km	13.25 a	Operational	ATMS, CERES, CrIS, OMPS-limb, OMPS-nadir, VIIRS

LIST OF INSTRUMENTS (microwave sounders only)

Acronym	Full name	Satellites	Utilisation
AMSU-A	Advanced Microwave Sounding Unit - A	NOAA 15 to 19	1998-2014
AMSU-A	Advanced Microwave Sounding Unit - A	Metop A to C	2006-2021
AMSU-A	Advanced Microwave Sounding Unit - A	EOS-Aqua	2002-2012
AMSU-B	Advanced Microwave Sounding Unit - B	NOAA-15/16/17	1998-2012
ATMS	Advanced Technology Microwave Sounder	NPP, JPSS-1, JPSS-2	2011-2028
ATMS	Advanced Technology Microwave Sounder	MetOp-SG-A 1, 2, 3	2020-2036
MHS	Microwave Humidity Sounder	NOAA-18/19	2005-2014
MHS	Microwave Humidity Sounder	MetOp A to C	2006-2021
MIS	Microwave Imager/Sounder	DWSS 1 and 2 DWSS CANCELED	2018-2028
MTVZA-GY	Imaging/Sounding Microwave Radiometer - improved	Meteor-M N1, N2, N2-1, N2-2	2009-2020
MTVZA-GY-MP	Imaging/Sounding Microwave Radiometer for Meteor-MP	Meteor-MP N1 & N2	2017-2023
MWHS-1	Micro-Wave Humidity Sounder -1	FY-3 A and B	2008-2013
MWHS-2	Micro-Wave Humidity Sounder -2	FY-3 C to G	2013-2024
MWTS-1	Micro-Wave Temperature Sounder -1	FY-3 A and B	2008-2013
MWTS-2	Micro-Wave Temperature Sounder -2	FY-3 C to G	2013-2024
SSMIS	Special Sensor Microwave - Imager/Sounder	DMSP F16 to S20	2003-2020

LIST OF EARTH OBSERVATION SATELLITES (RO only)

Satellite	Launch	Expected EOL	Height	ECT/incl.	Status	Instruments (see tables)
C/NOFS	16 April 2008		400-850 km	13°	Operational	CORISS
CLARREO	TBD	TBD	609 km	90°	Re-considered	GNSS-RO, IR spectrometer, SW spectrometer
COSMIC (6 sats)	14 Apr 2006	≥ 2012	800 km	71°	Operational	IGOR
COSMIC-2 (1-6)	≥ 2015	≥ 2020	520 km	24°	Being defined	Tri-G
COSMIC-2 (7-12)	≥ 2017	≥ 2022	800 km	72°	Being defined	Tri-G
FY-3D	≥ 2015	≥ 2018	836 km	14.00 a	Planned	ASI, GAMI, GNOS, MERSI-2, MWHS-2, MWRI, MWTS-2, SES
FY-3E	≥ 2017	≥ 2020	836 km	10.00 d	Planned	ASI, ERM-2, GNOS, MERSI-2, MWHS-2, MWTS-2, OMS, SES, SIM-2, WindRAD
FY-3F	≥ 2019	≥ 2022	836 km	14.00 a	Planned	ASI, GAMI, GNOS, MERSI-2, MWHS-2, MWRI, MWTS-2, SES
FY-3G	≥ 2021	≥ 2024	836 km	10.00 d	Planned	ASI, ERM-2, GNOS, MERSI-2, MWHS-2, MWTS-2, OMS, SES, SIM-2, WindRAD
GRACE-2 (2 sats)	≥ 2016	≥ 2021	485 km	89°	Approved	HAIRS, LRA, SCA, SuperSTAR, Tri-G
KOMPSAT-5	≥ 2012	≥ 2017	550 km	06:00 a	Close to launch	AOPOD, COSI
GRACE (2 sats)	17 Mar 2002	≥ 2012	485 km	89°	Operational	BlackJack, HAIRS, LRA, SCA, SuperSTAR
Megha-Tropiques	12 Oct 2011	≥ 2016	865 km	20°	Operational	MADRAS, SAPHIR, ScaRaB, ROSA
MetOp-A	19 Oct 2006	≥ 2012	817 km	09.30 d	Operational	AMSU-A, ASCAT, AVHRR/3, GOME-2, GRAS, HIRS/4, IASI, MHS, SEM/2
MetOp-B	≥ 2012	≥ 2017	817 km	09.30 d	Close to launch	AMSU-A, ASCAT, AVHRR/3, GOME-2, GRAS, HIRS/4, IASI, MHS, SEM/2
MetOp-C	≥ 2016	≥ 2021	817 km	09.30 d	Approved	AMSU-A, ASCAT, AVHRR/3, GOME-2, GRAS, IASI, MHS
MetOp-SG-A1	≥ 2020	≥ 2026	817 km	09:30 d	Being defined	3MI, ATMS, IASI-NG, MetImage, RER, RO, UVNS
MetOp-SG-A2	≥ 2025	≥ 2031	817 km	09:30 d	Being defined	3MI, ATMS, IASI-NG, MetImage, RER, RO, UVNS
MetOp-SG-A3	≥ 2030	≥ 2036	817 km	09:30 d	Being defined	3MI, ATMS, IASI-NG, MetImage, RER, RO, UVNS
MetOp-SG-B1	≥ 2021	≥ 2027	817 km	09:30 d	Being defined	ICI, MWI, RO, SCA, SEM-N
MetOp-SG-B2	≥ 2026	≥ 2032	817 km	09:30 d	Being defined	ICI, MWI, RO, SCA, SEM-N
MetOp-SG-B3	≥ 2031	≥ 2037	817 km	09:30 d	Being defined	ICI, MWI, RO, SCA, SEM-N
OceanSat-2	23 Sep 2009	≥ 2014	723 km	12:00 d	Operational	OCM, ROSA, SCAT
Ørsted	23 Feb 1999	≥ 2012	750 km	96.5°	Operational	ASC, CPD, FVM, OVM, TRSR
Paz (SEOSAR)	≥ 2012	≥ 2017	514 km	06:00 d	Close to launch	IGOR, SAR-X
SAC-C	21 Nov 2000	≥ 2012	705 km	10:20 d	Operational	GOLPE, HRTC, HSTC, IST, MMC/Ørsted-2, MMRS
SAC-D	10 Jun 2011	≥ 2016	657 km	06:00 d	Operational	Aquarius, HSC, MWR, NIRST, ROSA
TanDEM-X	21 Jun 2010	≥ 2015	515 km	06:00 d	Operational	IGOR, SAR-X
TerraSAR-X	15 Jun 2007	≥ 2013	515 km	06:00 d	Operational	IGOR, SAR-X
TerraSAR-X2	≥ 2015	≥ 2022	515 km	06:00 d	Approved	IGOR, SAR-X
Meteor-M N3	≥ 2015	≥ 2020	TBD	TBD	Approved	OCS, Radiomet, SAR-X, SCAT, SZS
Meteor-MP N1	≥ 2017	≥ 2022	830 km	15:30 a	Planned	ACS, BRLK "Briz", GGAK-M, IKFS-2, MSU-MR-MP, MTVZA-GY-MP, Radiomet
Meteor-MP N2	≥ 2018	≥ 2023	830 km	09:30 d	Planned	ACS, BRLK "Briz", GGAK-M, IKFS-2, MSU-MR-MP, MTVZA-GY-MP, Radiomet

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LIST OF EARTH OBSERVATION SATELLITES (RO only)

Satellite	Launch	Expected EOL	Height	ECT/incl.	Status	Instruments (see tables)
C/NOFS	16 April 2008		400-850 km	13°	Operational	CORISS
CLARREO	TBD	TBD	609 km	90°	Re-considered	GNSS-RO, IR spectrometer, SW spectrometer
COSMIC (6 sats)	14 Apr 2006	≥ 2012	800 km	71°	Operational	IGOR
COSMIC-2 (1-6)	≥ 2015	≥ 2020	520 km	24°	Being defined	Tri-G
COSMIC-2 (7-12)	≥ 2017	≥ 2022	800 km	72°	Being defined	Tri-G
FY-3D	≥ 2015	≥ 2018	836 km	14.00 a	Planned	ASI, GAMI, GNOS, MERSI-2, MWHS-2, MWRI, MWTS-2, SES
FY-3E	≥ 2017	≥ 2020	836 km	10.00 d	Planned	ASI, ERM-2, GNOS, MERSI-2, MWHS-2, MWTS-2, OMS, SES, SIM-2, WindRAD
FY-3F	≥ 2019	≥ 2022	836 km	14.00 a	Planned	ASI, GAMI, GNOS, MERSI-2, MWHS-2, MWRI, MWTS-2, SES
FY-3G	≥ 2021	≥ 2024	836 km	10.00 d	Planned	ASI, ERM-2, GNOS, MERSI-2, MWHS-2, MWTS-2, OMS, SES, SIM-2, WindRAD
GRACE-2 (2 sats)	≥ 2016	≥ 2021	485 km	89°	Approved	HAIRS, LRA, SCA, SuperSTAR, Tri-G
KOMPSAT-5	≥ 2012	≥ 2017	550 km	06:00 a	Close to launch	AOPOD, COSI
GRACE (2 sats)	17 Mar 2002	≥ 2012	485 km	89°	Operational	BlackJack, HAIRS, LRA, SCA, SuperSTAR
Megha-Tropiques	12 Oct 2011	≥ 2016	865 km	20°	Operational	MADRAS, SAPHIR, ScaRaB, ROSA
MetOp-A	19 Oct 2006	≥ 2012	817 km	09.30 d	Operational	AMSU-A, ASCAT, AVHRR/3, GOME-2, GRAS, HIRS/4, IASI, MHS, SEM/2
MetOp-B	≥ 2012	≥ 2017	817 km	09.30 d	Close to launch	AMSU-A, ASCAT, AVHRR/3, GOME-2, GRAS, HIRS/4, IASI, MHS, SEM/2
MetOp-C	≥ 2016	≥ 2021	817 km	09.30 d	Approved	AMSU-A, ASCAT, AVHRR/3, GOME-2, GRAS, IASI, MHS
MetOp-SG-A1	≥ 2020	≥ 2026	817 km	09:30 d	Being defined	3MI, ATMS, IASI-NG, MetImage, RER, RO, UVNS
MetOp-SG-A2	≥ 2025	≥ 2031	817 km	09:30 d	Being defined	3MI, ATMS, IASI-NG, MetImage, RER, RO, UVNS
MetOp-SG-A3	≥ 2030	≥ 2036	817 km	09:30 d	Being defined	3MI, ATMS, IASI-NG, MetImage, RER, RO, UVNS
MetOp-SG-B1	≥ 2021	≥ 2027	817 km	09:30 d	Being defined	ICI, MWI, RO, SCA, SEM-N
MetOp-SG-B2	≥ 2026	≥ 2032	817 km	09:30 d	Being defined	ICI, MWI, RO, SCA, SEM-N
MetOp-SG-B3	≥ 2031	≥ 2037	817 km	09:30 d	Being defined	ICI, MWI, RO, SCA, SEM-N
OceanSat-2	23 Sep 2009	≥ 2014	723 km	12:00 d	Operational	OCM, ROSA, SCAT
Ørsted	23 Feb 1999	≥ 2012	750 km	96.5°	Operational	ASC, CPD, FVM, OVM, TRSR
Paz (SEOSAR)	≥ 2012	≥ 2017	514 km	06:00 d	Close to launch	IGOR, SAR-X
SAC-C	21 Nov 2000	≥ 2012	705 km	10:20 d	Operational	GOLPE, HRTC, HSTC, IST, MMC/Ørsted-2, MMRS
SAC-D	10 Jun 2011	≥ 2016	657 km	06:00 d	Operational	Aquarius, HSC, MWR, NIRST, ROSA
TanDEM-X	21 Jun 2010	≥ 2015	515 km	06:00 d	Operational	IGOR, SAR-X
TerraSAR-X	15 Jun 2007	≥ 2013	515 km	06:00 d	Operational	IGOR, SAR-X
TerraSAR-X2	≥ 2015	≥ 2022	515 km	06:00 d	Approved	IGOR, SAR-X
Meteor-M N3	≥ 2015	≥ 2020	TBD	TBD	Approved	OCS, Radiomet, SAR-X, SCAT, SZS
Meteor-MP N1	≥ 2017	≥ 2022	830 km	15:30 a	Planned	ACS, BRLK "Briz", GGAK-M, IKFS-2, MSU-MR-MP, MTVZA-GY-MP, Radiomet
Meteor-MP N2	≥ 2018	≥ 2023	830 km	09:30 d	Planned	ACS, BRLK "Briz", GGAK-M, IKFS-2, MSU-MR-MP, MTVZA-GY-MP, Radiomet

LIST OF INSTRUMENTS (RO only)

Acronym	Full name	Satellites	Utilisation
AOPOD	Atmosphere Occultation and Precision Orbit Determination	KOMPSAT-5	2012-2017
BlackJack	BlackJack	CHAMP	2000-2010
BlackJack	BlackJack	GRACE (2 sats)	2002-2012
CORISS	C/NOFS Occultation Receiver for Ionospheric Sensing and Specification	C/NOFS	2008-
GNOS	GNSS Occultation Sounder	FY-3 D to G	2015-2024
GNSS-RO	Global Navigation Satellite System - Radio Occultation	CLARREO	TBD
GOLPE	GPS Occultation and Passive reflection Experiment	SAC-C	2000-2012
GRAS	GNSS Receiver for Atmospheric Sounding	MetOp A to C	2006-2021
IGOR	Integrated GPS Occultation Receiver	COSMIC (6 satellites)	2006-2012
IGOR	Integrated GPS Occultation Receiver	TerraSAR X & X2	2007-2022
IGOR	Integrated GPS Occultation Receiver	TanDEM-X	2010-2015
IGOR	Integrated GPS Occultation Receiver	Paz (SEOSAR)	2012-2017
Radiomet	Radio-occultation sounder	Meteor-M N3, Meteor-MP N1, N2	2015-2023
RO	Radio Occultation sounder	MetOp-SG A 1, 2, 3 and B 1. 2. 3	2020-2037
ROSA	Radio Occultation Sounder of the Atmosphere	OceanSat-2	2009-2014
ROSA	Radio Occultation Sounder of the Atmosphere	Megha-Tropiques	2011-2016
ROSA	Radio Occultation Sounder of the Atmosphere	SAC-D	2011-2016
Tri-G	Triple G (GPS, GLONASS, Galileo)	COSMIC-2 (1-6), COSMIC-2 (7-12)	2015-2022
Tri-G	Triple G (GPS, GLONASS, Galileo)	GRACE-2 (2 sats)	2016-2021
TRSR	TurboRogue Space Receiver	Ørsted	1999-2012

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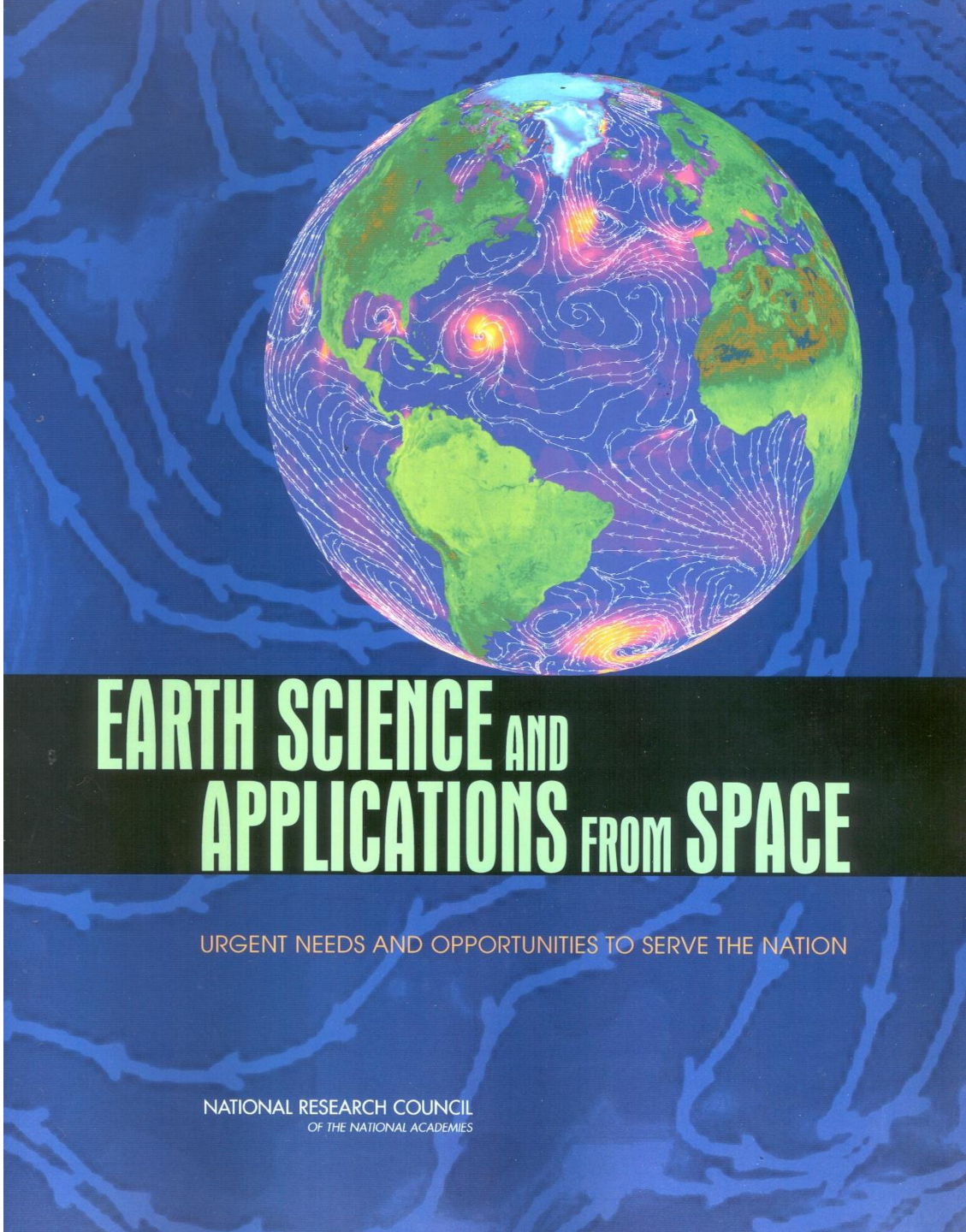
NRC (April 2005)



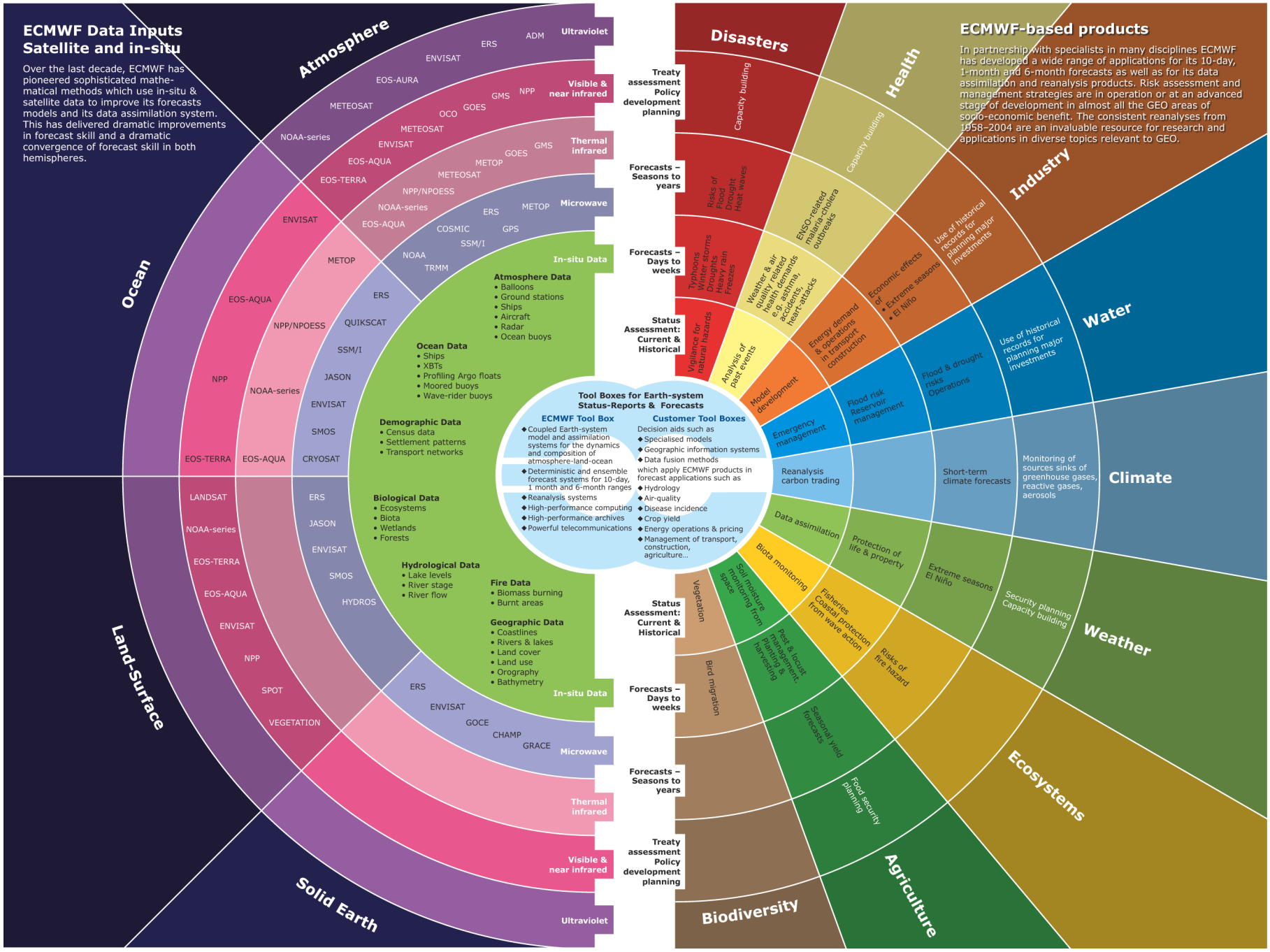
"Man must rise above the Earth - to the top of the atmosphere and beyond - for only thus will he fully understand the world in which he lives."

Socrates, ca 400 BC

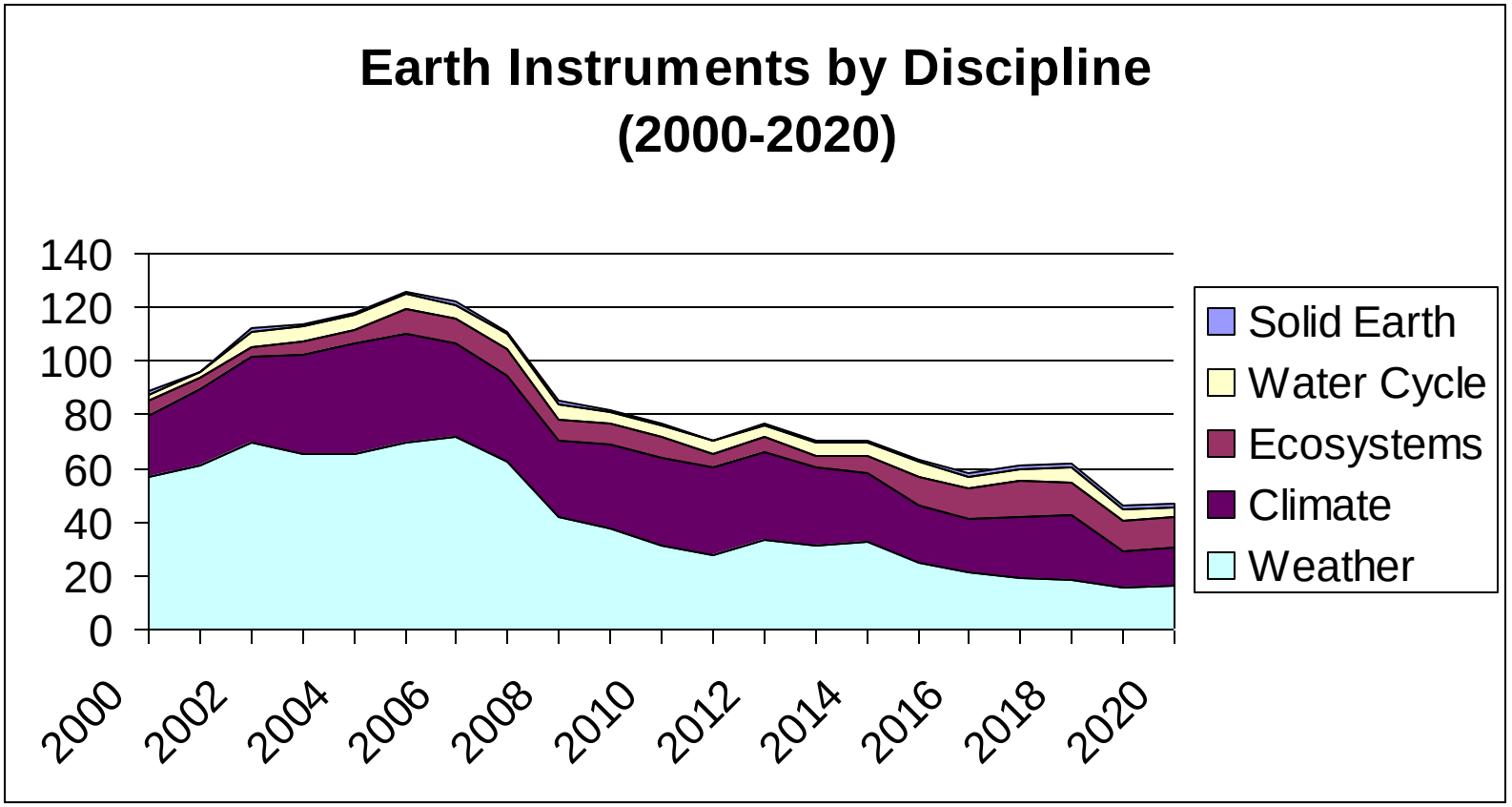
ECMWF Earth-System Deliverables for GEO

ECMWF Data Inputs Satellite and in-situ

Over the last decade, ECMWF has pioneered sophisticated mathematical methods which use in-situ & satellite data to improve its forecasts models and its data assimilation system. This has delivered dramatic improvements in forecast skill and a dramatic convergence of forecast skill in both hemispheres.



“Today, this system of environmental satellites is at risk of collapse”



ESAS Interim Report, 2005

MAIN RECOMMENDATION
(for next decade)

- NOAA and NASA should undertake a set of 17 recommended missions, phased over the next decade

MAIN RECOMMENDATION
(for next decade)

- NOAA research to operations
  - Vector ocean winds
  - GPS radio occultation temperature, water vapor and electron density profiles
  - Total solar irradiance/and Earth Radiation (NPP) and restored to NPOESS
- NASA
  - 15 missions in small, medium and large categories

17 Missions

(Red = <$900 M; Green = $300-$600 M; Blue = <$300 M)

Decadal Survey Mission	Mission Description	Orbit	Instruments	Rough Cost Estimate
Timeframe 2010 - 2013—Missions listed by cost				
CLARREO (NOAA portion)	Solar and Earth radiation characteristics for understanding climate forcing	LEO, SSO	Broadband radiometer	$65 M
GPSRO	High accuracy, all-weather temperature, water vapor, and electron density profiles for weather, climate, and space weather	LEO	GPS receiver	$150 M
Timeframe 2013 – 2016				
XOVWM	Sea surface wind vectors for weather and ocean ecosystems	MEO, SSO	Backscatter radar	$350 M

Climate Absolute Radiance and Refractivity Observatory

Operational GPS Radio Occultation

Extended Ocean Vector Winds Mission

Decadal Survey Mission	Mission Description	Orbit	Instruments	Rough Cost Estimate	
Timeframe 2010 – 2013, Missions listed by cost					
CLARREO (NASA portion)	Solar radiation: spectrally resolved forcing and response of the climate system. Each of 3 satellites also carries GPS RO receiver.	LEO, Precessing	Absolute, spectrally-resolved interferometer; GPS receiver	$200 M	Climate Absolute Radiance And Refractivity Observatory
SMAP	Soil moisture and freeze/thaw for weather and water cycle processes	LEO, SSO	L-band radar L-band radiometer	$300 M	Soil Moisture Active-Passive
ICESat-II	Ice sheet height changes for climate change diagnosis	LEO, Non-SSO	Laser altimeter	$300 M	Ice, Cloud, and land Elevation SATellite II
DESDynI	Surface and ice sheet deformation for understanding natural hazards and climate; vegetation structure for ecosystem health	LEO, SSO	L-band InSAR Laser altimeter	$700 M	Deformation, Ecosystem Structure and Dynamics of Ice
Timeframe: 2013 – 2016, Missions listed by cost					
HyspIRI	Land surface composition for agriculture and mineral characterization; vegetation types for ecosystem health	LEO, SSO	Hyperspectral spectrometer	$300 M	Hyperspectral Infrared Imager
ASCENDS	Day/night, all-latitude, all-season CO_2 column integrals for climate emissions	LEO, SSO	Multifrequency laser	$400 M	Active Sensing of CO2 Emissions Over Nights, Days and Seasons
SWOT	Ocean, lake, and river water levels for ocean and inland water dynamics	LEO, SSO	Ka-band wide swath radar C-band radar	$450 M	Surface Water and Ocean Topography
GEO-CAPE	Atmospheric gas columns for air quality forecasts; ocean color for coastal ecosystem health and climate emissions	GEO	High and low spatial resolution hyperspectral imagers	$550 M	Geostationary Coastal And Air Pollution Events
ACE	Aerosol and cloud profiles for climate and water cycle; ocean color for open ocean biogeochemistry	LEO, SSO	Backscatter lidar Multiangle polarimeter Doppler radar	$800 M	Aerosol-Cloud-Ecosystems

Timeframe: 2016 -2020, Missions listed by cost				
LIST	Very high resolution land surface topography for landslide hazards and water runoff	LEO, SSO	Laser altimeter	$300 M
PATH	High frequency, all-weather temperature and humidity soundings for weather forecasting and SST[a]	GEO	MW array spectrometer	$450 M
GRACE-II	High temporal resolution gravity fields for tracking large-scale water movement	LEO, SSO	Microwave or laser ranging system	$450 M
SCLP	Snow accumulation for fresh water availability	LEO, SSO	Ku and X-band radars K and Ka-band radiometers	$500 M
GACM	Ozone and related gases for intercontinental air quality and stratospheric ozone layer prediction	LEO, SSO	UV spectrometer IR spectrometer Microwave limb sounder	$600 M
3D-Winds (Demo)	Tropospheric winds for weather forecasting and pollution transport	LEO, SSO	Doppler lidar	$650 M

Lidar Surface Topography

Precipitation and All Weather Temperature And Humidity

Gravity Recovery and Climate Exp II

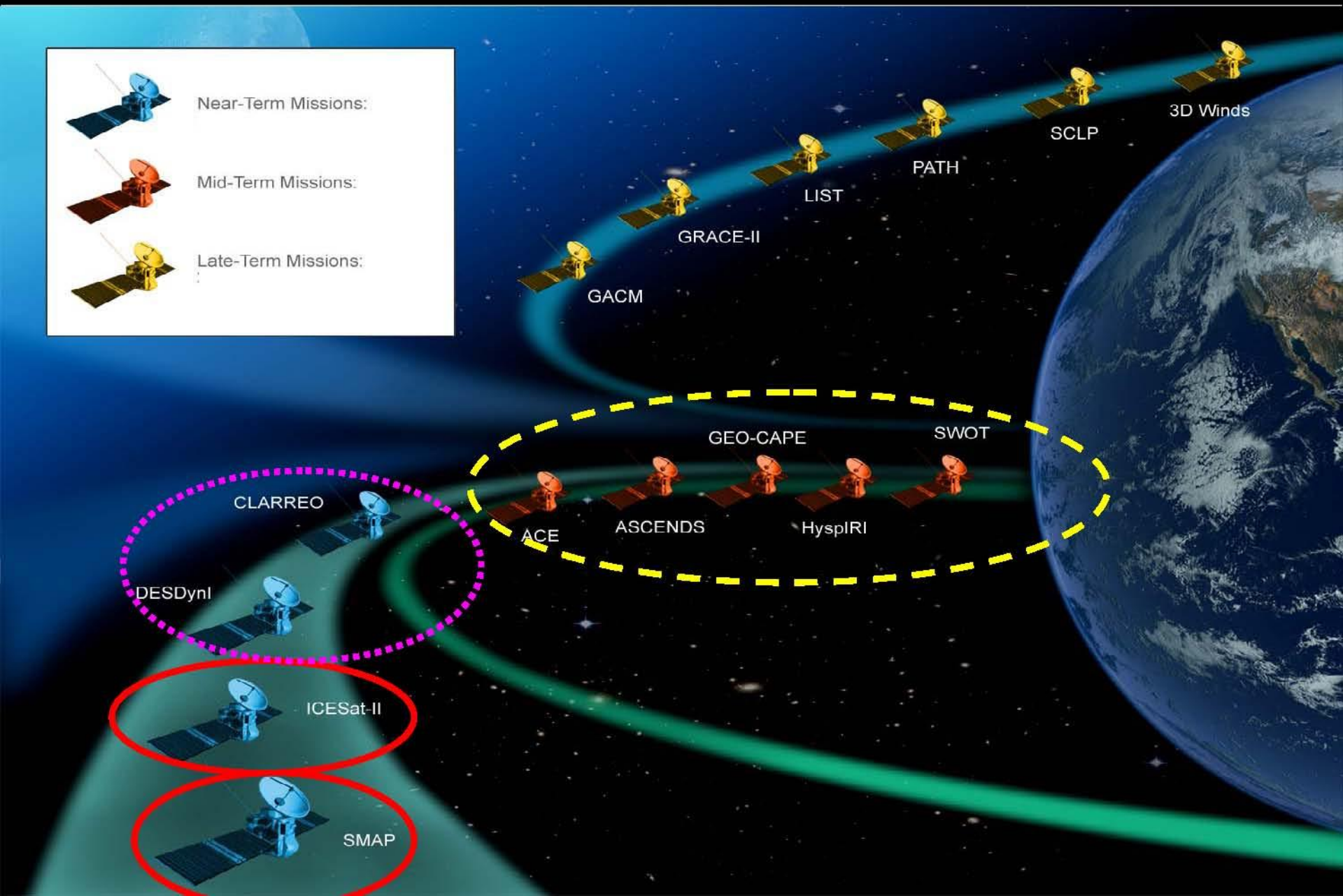
Snow and Cold Land Processes

Global Atmospheric Composition Mission

3D Tropospheric Winds

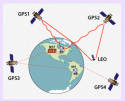
[1] Cloud-independent, high temporal resolution, lower accuracy SST to complement, not replace, global operational high-accuracy SST measurement

Decadal Survey Missions Next Generation



Changes in carbon storage in vegetation

DESDynI
Launch 2010-2013



Pressure/ temperature/ water vapor profiles

GPSRO
Launch 2010-2013

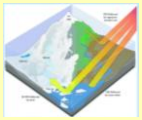
Estimate of flux of low-salinity ice out of Arctic basin

ICESat-II
Launch 2010-2013

Aerosol and cloud types and properties

ACE
Launch 2013-2016

Absolute spectrally resolved IR radiance



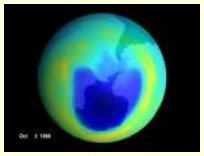
Incident solar and spectrally resolved reflected irradiance

CLARREO
Launch 2010-2013

CO_2 measurements: Day/night, all seasons, all latitudes

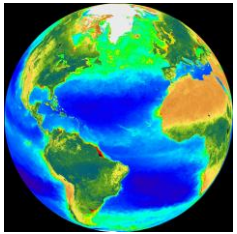
Connection between climate and CO_2 exchange

ASCENDS
Launch 2013-2016



Vertical profile of ozone and key ozone precursors

GACM
Launch 2016-2020

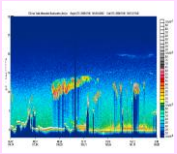


Societal Challenge: **Climate Prediction**

Robust estimates of primary climate forcings for improved climate forecasts, including local predictions of the effects of climate change

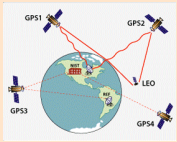
Linkage between terrestrial water, energy, and carbon cycle

SMAP
Launch 2010-2013



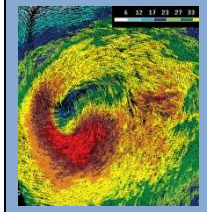
Cloud and aerosol height

ACE
Launch 2013-2016



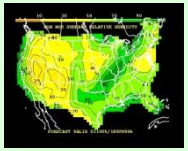
Pressure/ temperature/ water vapor profiles

GPSRO
Launch 2010-2013

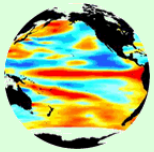


High resolution ocean vector winds

XOVWM
Launch 2013-2016



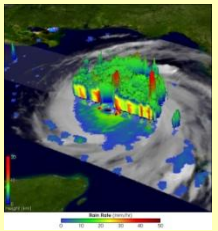
Temperature and humidity profiles



Sea surface temperature

PATH
Launch 2016-2020

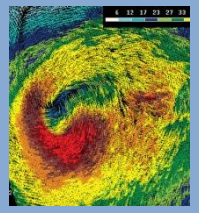
Three dimensional tropospheric wind profiles



Hurricane wind fields

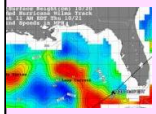
3D-Winds
Launch 2020+

Societal Challenge: **Improved Weather Prediction**
Longer-term, more reliable weather forecasts

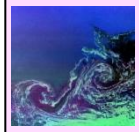


High resolution ocean vector winds

XOVWM
Launch 2013-2016

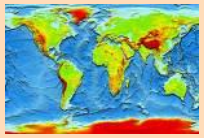


Sea level measurements extended into coastal zones



Ocean eddies and currents

SWOT
Launch 2013-2016



Global high resolution topography

Detection of active faults

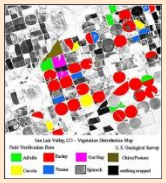
LIST
Launch 2016-2020

Snow pack accumulation and Snowmelt extent

SCLP
Launch 2016-2020

Changes in Earth's surface and movement of magma

DESDynI
Launch 2010-2013

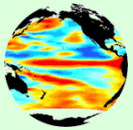


Nutrients and water status of vegetation, soil type and health

Processes indicating volcanic eruption

HyspIRI
Launch 2013-2016

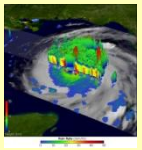
Temperature and humidity profiles



Sea surface temperature

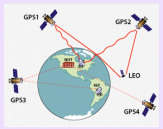
PATH
Launch 2016-2020

Three dimensional tropospheric wind profiles



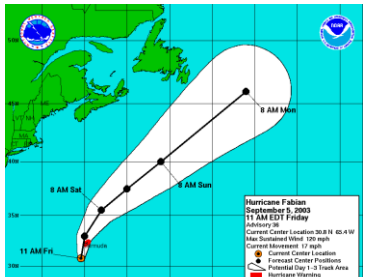
Hurricane wind fields

3D-Winds
Launch 2020+



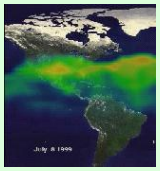
Pressure/ temperature/ water vapor profiles

GPSRO
Launch 2010-2013



***Societal Challenge:* Extreme Event Warnings**

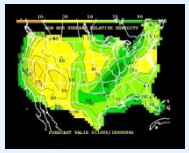
Longer-term, more reliable storm track forecasts and intensification predictions, volcanic eruption and landslide warnings to enable effective evacuation planning.



Identification of human vs. natural sources for aerosols and ozone precursors

Observation of air pollution transport in North, Central, and South America

GEO-CAPE
Launch 2013-2016

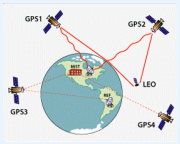


Temperature and humidity profiles

PATH
Launch 2016-2020

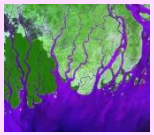
Three dimensional tropospheric wind profiles

3D-Winds
Launch 2020+



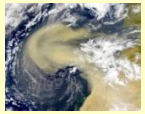
Pressure/ temperature/ water vapor profiles

GPSRO
Launch 2010-2013



River discharge estimates

SWOT
Launch 2013-2016



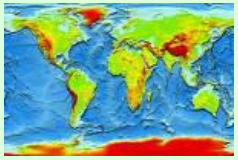
Global aerosol and air pollution transportation and processes

GACM
Launch 2016-2020

Societal Challenge: **Human Health**
More reliable forecasts of infectious and vector-borne disease outbreaks for disease control and response

Changes in Earth's surface

DESDynI
Launch 2010-2013



Global high resolution topography

Detection of active faults

LIST
Launch 2016-2020

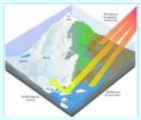
Societal Challenge: **Earthquake Early Warning**

Identify active faults and predict likelihood of earthquakes to enable effective investment in structural improvements, inform land use decisions, and provide early warning of impending earthquakes

Ice sheet deformation and dynamics

DESDynI
Launch 2010-2013

Absolute spectrally resolved IR radiance



Incident solar and spectrally resolved reflected irradiance

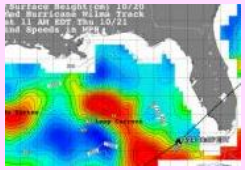
CLARREO
Launch 2010-2013

Ice sheet mass, volume, and distribution

GRACE-II
Launch 2016-2020

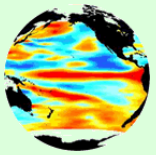
Ice sheet thickness and volume

ICESat-II
Launch 2010-2013



Sea level measurements extended into coastal zones

SWOT
Launch 2013-2016

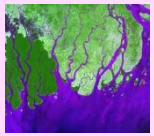


Sea surface temperature

PATH
Launch 2016-2020

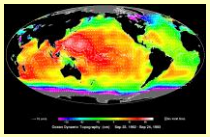
***Societal Challenge:* Sea Level Rise**

Climate predictions based on better understanding of ocean temperature and ice sheet volume changes and feedback to enable effective coastal community planning



River discharge estimates

SWOT
Launch 2013-2016

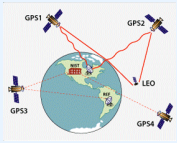


Changes in aquifers and deep ocean currents

GRACE-II
Launch 2016-2020

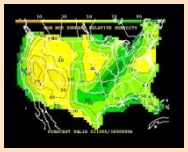
Snow pack accumulation and Snowmelt extent

Snow water equivalent, snow depth, and snow wetness



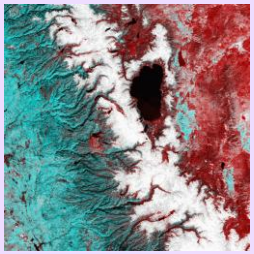
Pressure/ temperature/ water vapor profiles

GPSRO
Launch 2010-2013



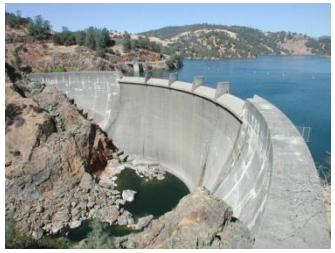
Temperature and humidity profiles

PATH
Launch 2016-2020

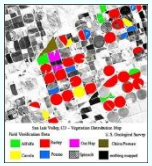


Dynamics of water storage in seasonal snow packs

SCLP
Launch 2016-2020

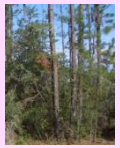


Societal Challenge: **Freshwater Availability**
Improved precipitation and drought forecasts to improve water resource management



Nutrients and water status of vegetation, soil type and health

HyspIRI
Launch 2013-2016



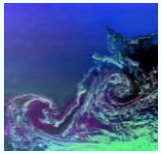
Height and structure of forests

DESDynI
Launch 2010-2013

Soil freeze/ thaw state

Soil moisture effect on vegetation

SMAP
Launch 2010-2013

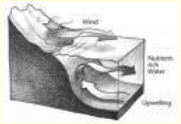


Ocean eddies and currents

SWOT
Launch 2013-2016

Dynamics of coastal ecosystems, river plumes, tidal fronts

GEO-CAPE
Launch 2013-2016



Improved estimates of coastal upwelling and nutrient availability

XOVWM
Launch 2013-2016

CO_2 measurements: Day/night, all seasons, all latitudes

Inventory of global CO_2 sources and sinks

ASCENDS
Launch 2013-2016

Organic material in surface ocean layers

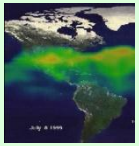
ACE
Launch 2013-2016

***Societal Challenge:* Ecosystem Services**

Improved land use, agricultural, and ocean productivity forecasts to improve planting and harvesting schedules and fisheries management

Three dimensional tropospheric wind profiles

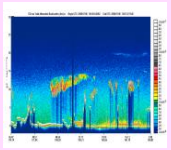
3D-Winds
Launch 2020+



Identification of human vs. natural sources for aerosols and ozone precursors

Observation of air pollution transport in North, Central, and South America

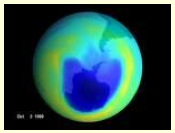
GEO-CAPE
Launch 2013-2016



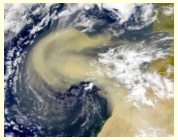
Cloud and aerosol height

Aerosol and cloud types and properties

ACE
Launch 2013-2016

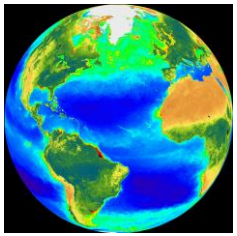


Vertical profile of ozone and key ozone precursors



Global aerosol and air pollution transportation and processes

GACM
Launch 2016-2020

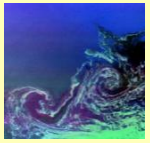


***Societal Challenge:* Air Quality**

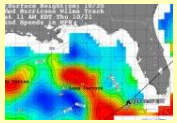
More reliable air quality forecasts to enable effective urban pollution management.

Linkage between terrestrial water, energy, and carbon cycle

SMAP
Launch 2010-2013

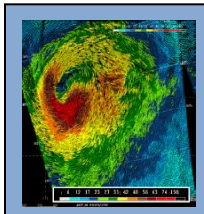


Ocean eddies and currents



Sea level measurements extended into coastal zones

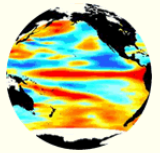
SWOT
Launch 2013-2016



High resolution ocean vector winds

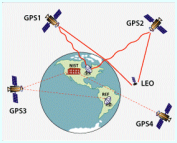
XOVWM
Launch 2013-2016

Temperature and humidity profiles



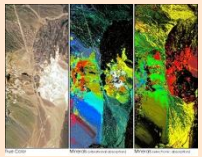
Sea surface temperature

PATH
Launch 2016-2020



Pressure/ temperature/ water vapor profiles

GPSRO
Launch 2010-2013



Spectra to identify locations of natural resources

HyspIRI
Launch 2013-2016

CO_2 measurements: Day/night, all seasons, all latitudes

Inventory of global CO_2 sources and sinks

ASCENDS
Launch 2013-2016

Three dimensional tropospheric wind profiles

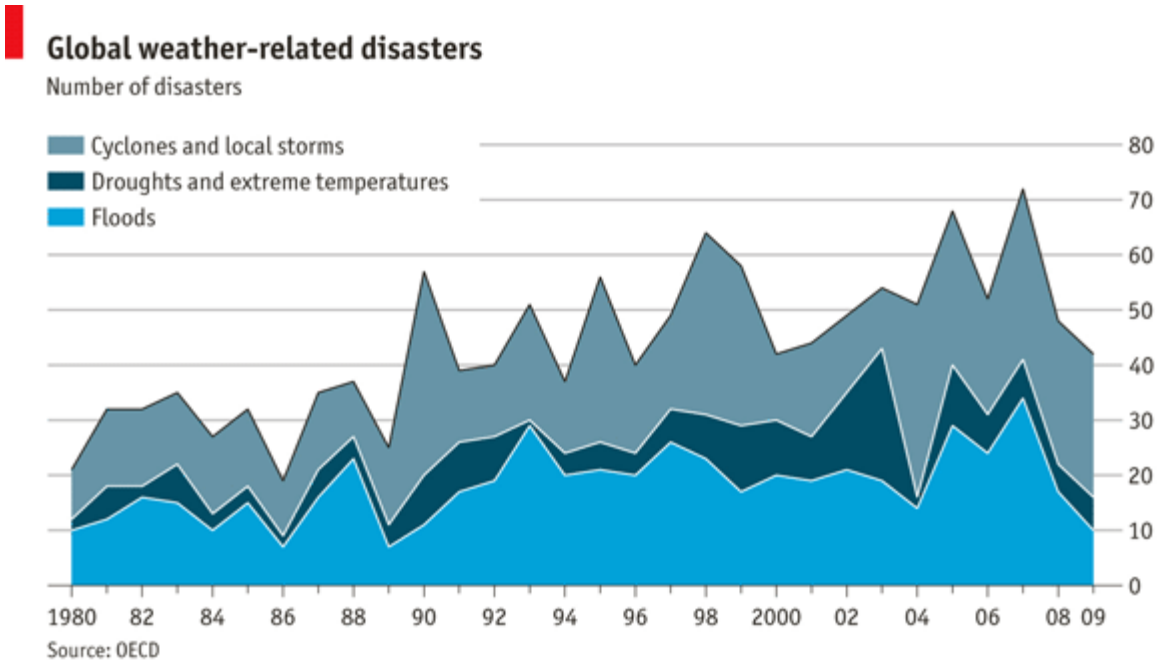
3D-Winds
Launch 2020+

***Societal Challenge:* Energy Security**

Improved energy security through more effective oil and gas exploration, safer extraction through improved marine forecasts, optimized placement of wind farms through measurement of global winds, better energy conservation through improved heating/cooling forecasts, and support of carbon trading and energy policy.

Since the Decadal Survey was released in 2007

The need for Earth observations is greater than ever



The number of severe floods, droughts and storms has increased worldwide over the past three decades, according to the OECD's Environmental Outlook To 2050. Data from the Centre for Research on the Epidemiology of Disasters show that from 1980 to 2009 floods accounted for over 40% of what it terms weather-related disasters, storms nearly 45% and droughts 15%. Between 100 million and 200 million people a year were affected, and economic losses amounted to between $50 billion and $100 billion annually. The report suggests that by 2050 more than 1.6 billion people (or nearly 20% of the world's population) and assets worth $45 trillion could be at risk from the impact of increased flooding. The cities most likely to be affected are largely in Asia. They include Dhaka, Kolkata, Shanghai, Mumbai, Jakarta, Bangkok, and Ho Chi Minh City.

The need for Earth observations is greater than ever

See also: *Predicting and managing extreme weather events*
Jane Lubchenco and Thomas R. Karl
Phys. Today 65(3), 31 (2012); doi: 10.1063/PT.3.1475
View online: http://dx.doi.org/10.1063/PT.3.1475

Last year (2010), new records were set in the US for tornadoes, drought, wind, floods, and wildfires. Heat records were set in every state. At one time last summer, nearly half of the country's population was under a heat advisory or heat warning. In late November, hurricane-force winds hit parts of Wyoming, Utah, Nevada, Arizona, New Mexico, and California, with winds reaching 97 mph in Pasadena.

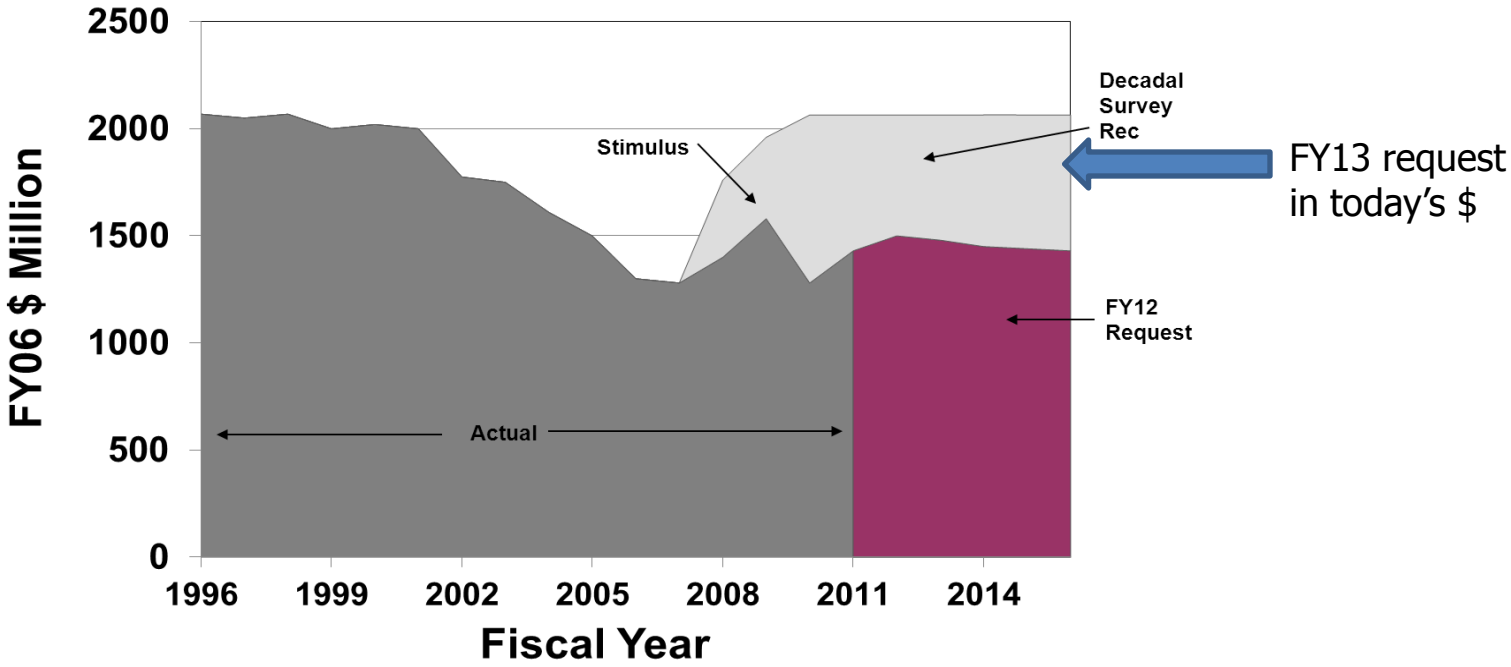
For statistics on damage caused by weather and climate disasters, see http://www.ncdc.noaa.gov/oa/reports/billionz.html

Status of Decadal Survey Missions (February 2012)

Mission	Recommended Launch Time Frame	Planned Launch Date	Status
CLARREO (NASA portion)	2010-2013	None	Formulation (Pre-Phase A)
CLARREO (NOAA portion)	2010-2013	None	Not in NOAA Budget or Plans
DESDynI	2010-2013	None	Formulation (Pre-Phase A)
GPSRO (NOAA)	2010-2013	None	Not in NOAA Budget
ICESat-II	2010-2013	10/2015	Implementation Phase (Phase A)
SMAP	2010-2013	11/2014	Implementation Phase (Phase B)
ACE	2013-2016	None	Formulation (Pre-Phase A)
ASCENDS	2013-2016	None	Formulation (Pre-Phase A)
GEO-CAPE	2013-2016	None	Formulation (Pre-Phase A)
HyspIRI	2013-2016	None	Formulation (Pre-Phase A)
SWOT	2013-2016	None	Formulation (Pre-Phase A)
XOVWM (NOAA)	2013-2016	None	Not in NOAA Budget or Plans
3D-WINDS (Demo)	2016-2020	None	Formulation (Pre-Phase A)
GACM	2016-2020	None	Formulation (Pre-Phase A)
GRACE-II	2016-2020	None	Formulation (Pre-Phase A)
LIST	2016-2020	None	Formulation (Pre-Phase A)
PATH	2016-2020	None	Formulation (Pre-Phase A)
SCLP	2016-2020	None	Formulation (Pre-Phase A)

Earth Science and Applications from Space: A Midterm Assessment of NASA's Implementation of the Decadal Survey

coming soon to a theatre near you….



NASA ESD budget in constant FY06 dollars

Learned during the Decadal Update Process

Launch failures, delays, changes in scope, and cost estimate growth have hampered the program.

NOAA has made significant reductions in scope to the nation's future operational environmental satellite series, omitting observational capabilities assumed by the Decadal Survey to be part of NOAA's future capability, and failing to implement the three new missions recommended for NOAA implementation by the Survey (GPS radio occultation, sea-surface vector winds, and the NOAA portion of CLARREO).

The nation's Earth observing system is beginning a rapid decline in capability as long running missions end and key new missions are delayed, lost, or cancelled.

NOAA Decadal Survey Related Update (January 2012)

NPOESS
Cancelled in 2010 and split into separate NOAA (JPSS) and Air Force (DWSS) programs. NOAA's JPSS program did not get anywhere near its requested funding in FY2011, so it is off to a slow start. The joint NASA/NOAA NPP mission was successfully launched on October 28, 2011.

Restore decoped climate sensors
No NPOESS Climate Sensors flown

Aerosol Polarimetry Sensor (APS)
Failed to reach orbit due to the Glory Launch Vehicle Failure.

Total Solar Irradiance Sensor (TSIS)
TIM instrument on Glory failed to reach orbit due to the Glory launch vehicle failure. TSIS (TIM + SIM) is currently the highest priority for flight of the cancelled NPOESS climate sensors.

Ozone Monitoring and Profiling Suite (OMPS) - Limb
On NPP, but not on JPSS-1. Planned to be included on JPSS-2 launching no earlier than 2019.

Earth Radiation Budget Sensor (ERBS)
Clouds and Earth's Radiant Energy System (CERES) instrument on NPP and JPSS-1 no earlier than 2017.

NOAA Decadal Survey Related Update (January 2012)

Altimeter

Cancelled altimeter on NPOESS essentially replaced by plans in place to fly Jason-3 no earlier than 2013, but NOAA's budget for Jason-3 was substantially reduced in FY2011, and is threatened for FY2012, thus also threatening this important partnership with Europe.

Ocean Vector Winds (aka XOVWM)

NOAA has recognized that it does not have the ability to fund this effort, so NOAA has requested NASA to assume this responsibility.

GOES-R/Hyperspectral Environmental Suite (HES)

Advanced atmospheric sounder requirement deleted from GOES-R program. As a result, U.S. GEO sounding capability will end after GOES-N/O/P,

COSMIC-2 (aka GPSRO)

Excellent plan in place with Taiwan and U.S. Air Force for a 12-satellite constellation. The President's budget for FY2011 and FY2012 included funds for COSMIC-2 in the NOAA budget. However no funds were provided to NOAA in FY2011 or FY2012 and the NOAA/Air Force/Taiwan partnership is clearly threatened.

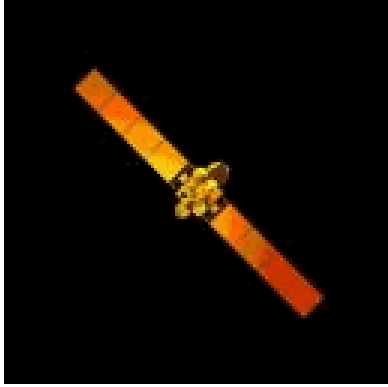
Deep Space Climate Observatory (DSCOVR)

Though not a Decadal Survey priority, using the DSCOVR spacecraft bus as a platform for space weather instruments at L1 was proposed in NOAA's FY2011 budget, but not funded. Zeroed in FY2012 as well, but Congress funded it anyway for FY12.

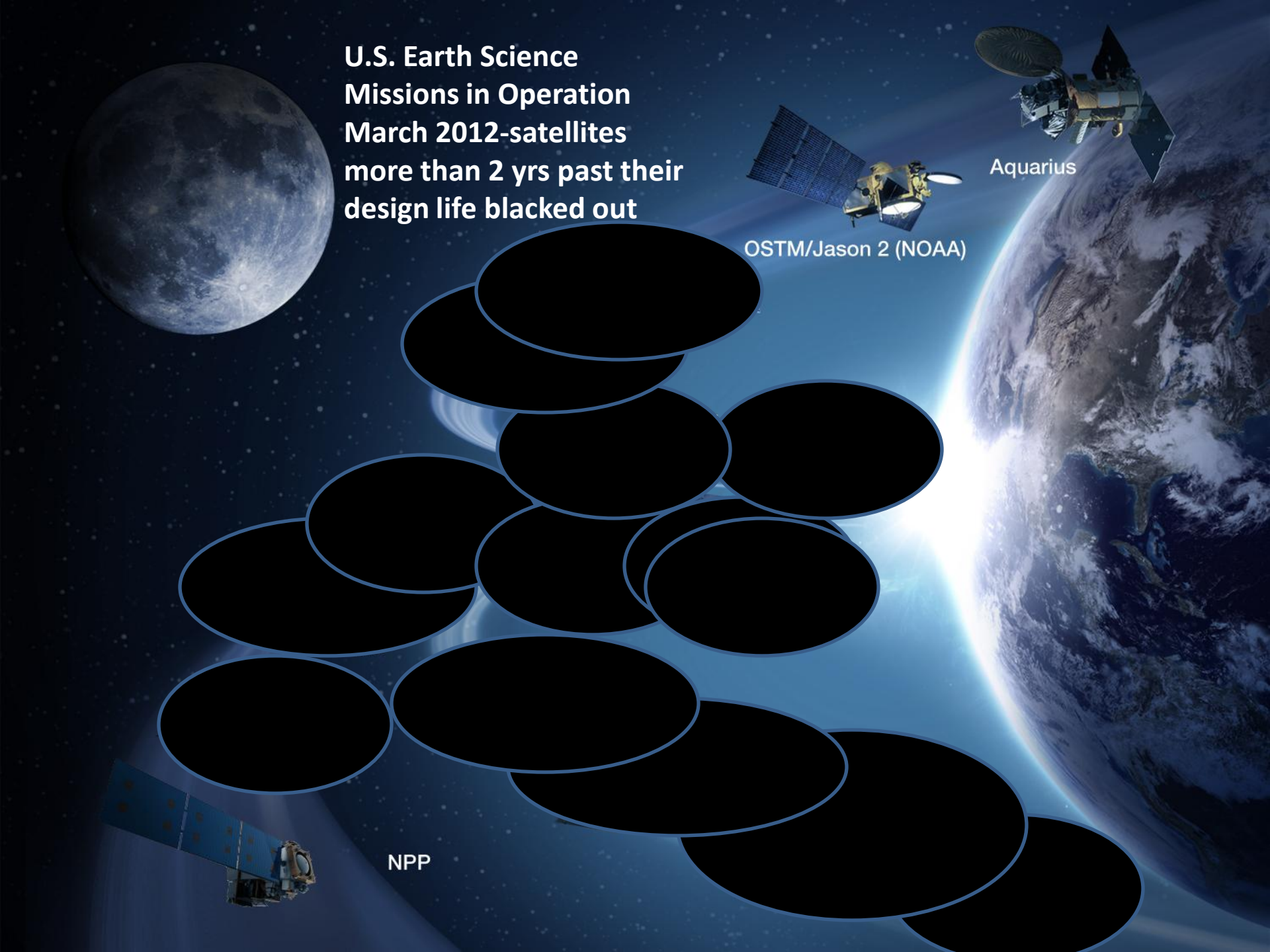
NPP Launched on Oct. 28!

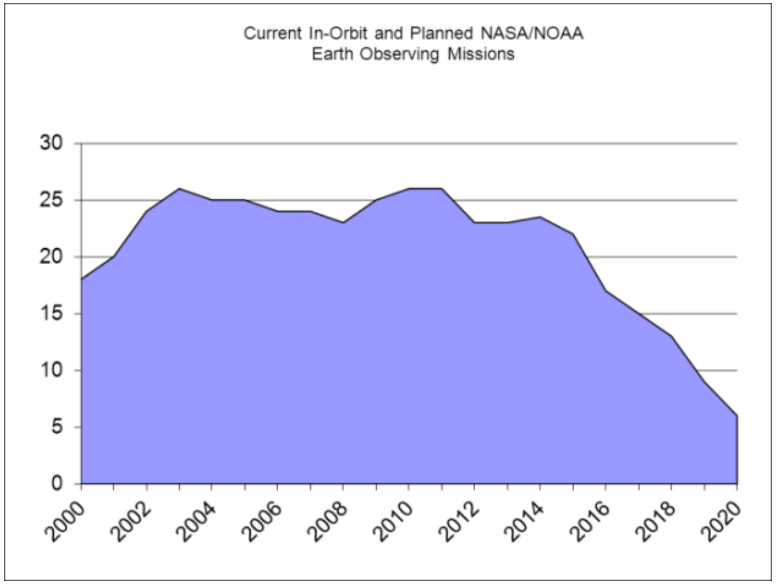
“Blue Marble” Suomi NPP composite Visible Infrared Imager Radiometer Suite (VIIRS)

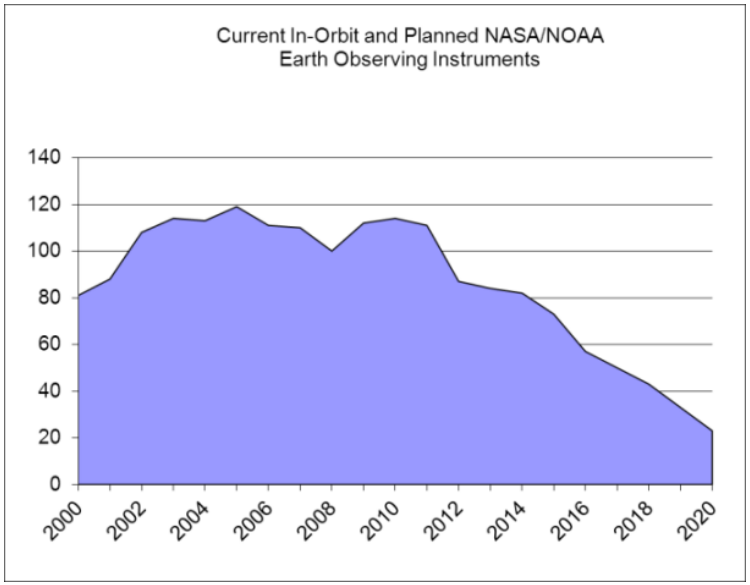
Orbiting (?) Carbon Observatory




U.S. Earth Science
Missions in Operation
March 2012
Aquarius
OSTM/Jason 2 (NOAA)
Jason
QuikSCAT*
TRMM
EO-1
Landsat-7 (USGS)
Aqua
ACRIMSAT
Terra
SORCE
GRACE (2)
Aura
CALIPSO
CloudSat
NPP


U.S. Earth Science Missions in Operation March 2012-satellites more than 2 yrs past their design life blacked out
Aquarius
OSTM/Jason 2 (NOAA)
NPP





Number of operating (2000-2011) and planned (2012-2020) NASA and NOAA Earth observing missions (left) and instruments (right). Estimated lifetimes for missions already in orbit taken from NASA and NOAA data supplied to the committee. Planned missions are only included when the missions are funded and have a specified launch date in NASA or NOAA budget submissions.

CHINA-12 meteorological satellites planned before 2020

Updated: 2012-03-03 15:21

(Xinhua)

BEIJING - China will launch 12 meteorological satellites before 2020 to further boost the country's weather monitoring capabilities, a senior meteorological official said Saturday. The orbiters are among 14 meteorological satellites that are scheduled to be launched as part of a 10-year plan created by the China Meteorological Administration, said Zheng Guoguang, director of the administration. "The launch of these satellites will dramatically boost China's weather monitoring capabilities, providing better services for a variety of industries," Zheng, a member of the National Committee of the Chinese People's Political Consultative Conference (CPPCC), the country's top political advisory body, said ahead of the body's upcoming annual session.

On January 13, China successfully launched meteorological satellite Fengyun-II 07 from its southwestern Xichang Satellite Launch Center. The Fengyun-II 07 is the 13th meteorological satellite launched by China since 1988, bringing its total number of meteorological satellites to seven. With improvements based on previously-launched satellites, the Fengyun-II 07 is particularly useful for monitoring emergent natural disasters, Zheng said.

The Fengyun 2F spacecraft lifted off at 0056 GMT Friday Jan. 13 2012 from the Xichang space base in southwestern China's Sichuan province, according to the Chinese defense ministry. Geostationary with visible and IR imagery.

Summary

- Satellite observations have become the dominant factor in improving NWP forecasts over the past 10 years
- U.S. Earth observations from space are almost certain to decrease over the next decade-the “risk of collapse” is becoming a reality
  - Funding issues (Congress and Administration)
  - Launch failures
  - Increasing costs of rockets and missions
- China is becoming a leader in producing Earth observations from space—but will the quality and real-time availability be issues?

Summary

- Atmospheric sounders are extremely important for science and applications, notably NWP
- RO sounders have been shown to have significant impact in their own right, and to improve the impact of IR and microwave sounders
- Only a relatively small set of sounders in space are used operationally-a successful launch is a necessary but not sufficient condition for value of a satellite mission!

SHERFFIUS
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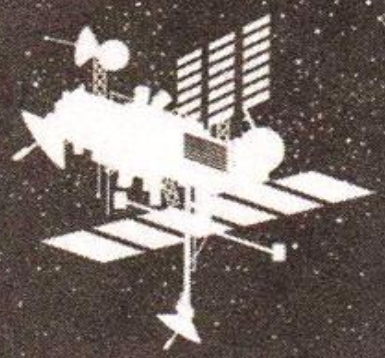
jsherffius@gmail.com
sherffius.com

America's most advanced weather tracking system with Congressional funding.



America's most advanced weather tracking system without Congressional funding.