X-Band EOS System

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Affordable, high performance, end-to-end solution for receiving and processing X-Band data from Terra, Aqua, Suomi-NPP and FengYun-3 Earth Observation Satellites

▲ *Suomi-NPP VIIRS 750m resolution true colour reprojected images showing southern Europe and northern Africa*

▲ *Dartcom X-Band EOS System antenna*

X-band EOS data is essential for accurate monitoring of global weather and climate patterns. It is also invaluable for remote sensing work, such as detecting forest fires, monitoring ocean currents and mapping land use.

However, X-Band reception systems have always tended to be very expensive to purchase and maintain. They also normally require specialised installation procedures and building works.

The Dartcom X-Band EOS System changes that, bringing X-Band within reach of universities, research institutions and other organisations with limited budgets and restricted installation sites.

It was developed from the outset as a lower cost X-Band system which still offers performance and features competitive with much more expensive products. Dartcom has achieved this with a smaller antenna, state-of-the-art RF components, tight tolerances and advanced software.

DARTCOM

X-Band EOS System Overview

▲ *Dartcom X-Band EOS System at the University of Valladolid, Spain, with the antenna system (circled) installed on top of a lift shaft*

▲ *Dartcom 1.5m X-Band antenna system at the University of Valladolid, Spain*

▲ *Radome removed to show 1.5m parabolic dish antenna, scalar feed horn, LNA and BDC*

Overview

The Dartcom X-Band EOS System comprises the following main components:

- **Outdoor equipment** – parabolic dish antenna, rotator, controller, RF components, GPS antenna, optional environmental control unit or heater, all housed in a radome (except GPS antenna).
- **Indoor equipment** – modular receiver rack, demodulator, UPS, ingest PC, processor PC, optional visualisation PC, all rack-mountable, and can be supplied in an optional floor-standing cabinet for a complete rack-mounted system.

Features

- Automatic data reception from X-Band Earth Observation Satellites including Terra, Aqua, Suomi-NPP and FengYun-3A/B/C (FY-3).
- Complete end-to-end solution with automatic data processing to level 0, 1 and 2 *(currently level 0 and 1 only for FY-3)*.
- Affordable to meet the limited budgets available for X-Band systems in universities and research institutions.
- Simple installation with minimal civil engineering works.
- 1.5m high-speed antenna system enclosed in a radome to allow normal operation at wind speeds up to 185km/h (115mph).
- All external components designed and treated to survive tropical and marine environments, with a water ingress protection rating of at least IP65.
- State-of-the-art RF components, allowing good data reception from 15° satellite elevation with a 1.5m antenna. In practice good quality data can be received from Terra and Suomi-NPP at 7° elevation and from Aqua and FY-3 at 5°.
- Automatic daily prediction data update from the internet ensures accurate tracking of all satellites.
- Modular construction for easy maintenance and future upgrades.
- Comprehensive hardware and software diagnostics at all levels.
- Cost-effective migration path from existing L-Band systems to X-Band for the next generation of weather and Earth observation satellites.
- Combined X/L-Band option allowing reception and processing of data from both X-Band and L-Band satellites using the same antenna system.

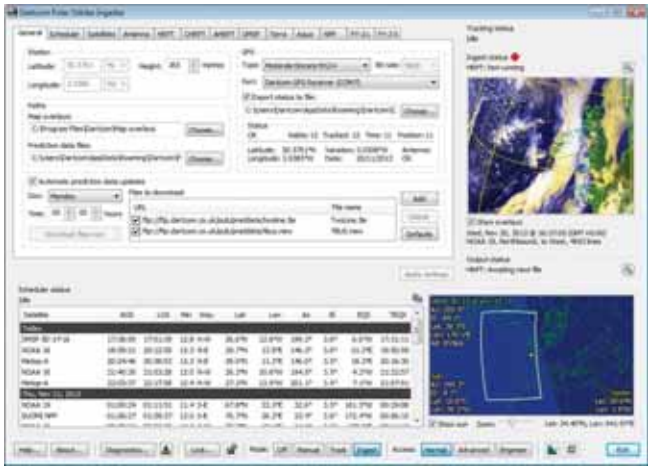
Outdoor equipment

- 2m diameter radome with hydrophobic coating to minimise signal loss caused by standing water during rainfall.
- 1.5m prime focus aluminium parabolic dish antenna.
- High-speed dual-axis antenna rotator (elevation over azimuth).
- Dual-axis rotator controller with closed-loop feedback control system for excellent pointing accuracy and smooth tracking.
- X-Band scalar feed horn, low-noise amplifier (LNA) and block downconverter (BDC).
- Rugged, weatherproof GPS antenna (mounted outside radome).
- Optional radome environmental control unit for hot climates.
- Optional radome heater for very cold climates.

Indoor equipment

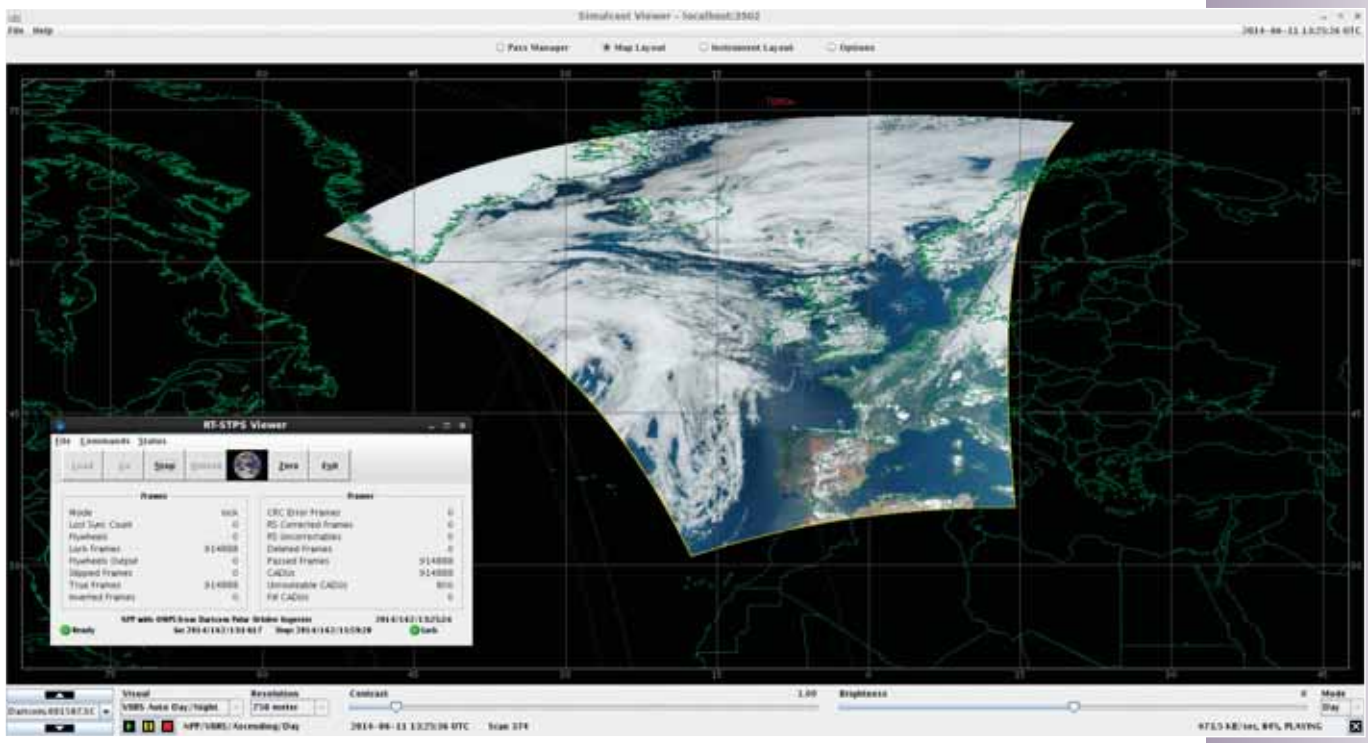
- Modular receiver rack (4U rack mount) containing LNB power supply, XDC programmable downconverter, USB hub and serial adapters, GPS receiver, switch mode power supply and optional USB interfaces for reception of L-Band services.
- High-rate demodulator (1U rack mount).
- 2kVA UPS (tower or 2U rack mount).
- Ingest PC (midi-tower or 4U rack mount) running 64-bit Windows with Dartcom Polar Orbiter Ingester software.
- Processor PC (midi-tower or 4U rack mount) running NASA RT-STPS, Simulcast, IPOPP and CMA FY3L0pp/FY3L1pp software.
- Optional visualisation PC (midi-tower or 4U rack mount).
- 6U desktop or optional 22U floor-standing cabinet for complete rack-mounted system.

▲ *Receiver rack, high-rate demodulator and ingest PC running 64-bit Windows with Dartcom Polar Orbiter Ingester software*



▲ *Dartcom Polar Orbiter Ingester software*

▲ *Processor PC running RT-STPS, Simulcast, IPOPP and FY3L0pp/FY3L1pp software*



▲ *RT-STPS and Simulcast software running on the processor PC showing Suomi-NPP pass being ingested*

X-Band EOS System Technical summary

Technical summary

The antenna system automatically tracks X-Band satellites and receives direct broadcast RF transmissions which are focused into the scalar feed horn by the parabolic dish, amplified by the low-noise amplifier, then fed to the block down-converter. This converts the signal to a lower frequency to minimise cable loss and feeds it to the XDC programmable downconverter in the receiver rack, where it is converted to a common frequency and fed to the high-rate demodulator.

The demodulator converts the RF signal back to a binary data stream which is then Viterbi decoded, byte-aligned and transferred via USB to the Polar Orbiter Ingester software running on the ingest PC. This detects the attached synchronisation markers (ASMs) in the data stream and extracts the CCSDS frames, which are then derandomised, Reed-Solomon decoded and demultiplexed into virtual channel data units (VCDUs).

In the case of Terra, Aqua and Suomi-NPP, the VCDUs are automatically transferred via a TCP socket to the RT-STPS software running on the processor PC, which processes them live and displays a preview in the Simulcast software. The IPOPP software automatically processes the resulting data sets into level 0, 1 and 2 data and products.

FengYun-3 data is assembled into a file which is automatically transferred via a LAN connection to the FY3L0pp and FY3L1pp software running on the processor PC, which automatically produces level 0 and 1 data and products.

▼ *Antenna and rotator specifications*

Radome	2m diameter, low-loss composite, hydrophobic coating
Antenna type	Parabolic dish, solid spun aluminium
Diameter	1.5m
F/D ratio	0.364
Gain @ 8200MHz	39.3dBiC including 0.4dB radome loss
Feed	Scalar horn
Frequency range	7200–8500MHz
Axial ratio	2dB max
Polarisation	RHC/LHC, software remote-controlled
Control	By ingest PC via MAD XPA controller
Movement	0–360˚ azimuth, 0–180˚ elevation
Speed	48˚/sec azimuth, 10˚/sec elevation
Mech. tolerance	±0.15˚
Tracking accuracy	±0.1˚

▼ *Low-noise amplifier (LNA) specifications*

Noise figure	0.5dB (35K) typical, 0.691dB (50K) max
Input frequency	7700–8500MHz
Gain	50dB min
Gain flatness	±1dB max

▼ *Block downconverter (BDC) specifications*

Noise figure	16dB typical
Input frequency	7750–8400MHz
LO frequency	6950.00MHz
IF output frequency	800–1450MHz
Gain variation within 30MHz	±0.4dB max
Gain variation over band	±3dB max
Conversion gain	0dB typical
Image rejection	>60dB
LO stability	±2.5ppm (–40 to +60˚C)
LO oscillator type	Internal PLL locked to TCXO
Phase noise	–90dBc/Hz @ 10kHz typical
	–95dBc/Hz @ 100kHz

▼ *XDC programmable downconverter specifications*

Noise figure	3dB max
Input frequency	800–1450MHz
Output frequency	720MHz
Output bandwidth	3dB @ 120MHz
Frequency step size	100kHz
LO stability	±5ppm
Oscillator phase noise	–100dBc/Hz @ 10kHz typical
IF filter	SAW
IF filter bandwidth	120MHz
Conversion gain	20dB typical
Output 1dB compression point	>+19dBm
Control interface	RS-232 serial

▼ *High-rate demodulator specifications*

Input frequency	720MHz (from XDC programmable downconverter)
RF input bandwidth	75MHz
Demodulator modes	BPSK, QPSK, SQPSK, OQPSK
Demodulator implementation loss	<0.2dB typical
Supported symbol rates	1–40Msps
Baseband filter	Root raised cosine (RRC) with variable alpha
Convolution decoding	Viterbi, K=7, rate ½, dual-channel, G1=171, G2=133
Coding gain	5.2dB @ 1:10^5 BER
Control/data interface	USB 2.0
Supported modes	Terra Direct Broadcast
	Aqua Direct Broadcast
	Suomi-NPP Direct Broadcast
	JPSS (NPOESS) Direct Broadcast
	FengYun-3 Direct Broadcast
Typical system G/T performance	19.4dB/K @ 8200MHz

Combined X/L-Band option

If reception of NOAA HRPT, Metop AHRPT or FengYun-3 AHRPT data is also required using the same antenna system, additional RF components and receiver rack modules can be supplied to allow that.

The X/L-Band feed has 4 dipoles spaced 90˚ apart around the outside of the X-band scalar feed, and a quad hybrid combiner. The L-Band signal is fed to a pre-LNA 3-pole cavity filter followed by a single stage LNA, 4-pole combline bandpass filter and block downconverter. An additional RF cable feeds the L-Band signal from the antenna system to the second RF input on the receiver rack, where a low-rate demodulator converts the RF signal back to a binary data stream which is byte-aligned and transferred via USB to the Polar Orbiter Ingester software running on the ingest PC.

Two versions of the low-rate demodulator are available. The LRD-100 provides reception of NOAA HRPT and Metop AHRPT data. The LRD-200B additionally provides reception of FengYun-3 L-Band data. Both have built-in Viterbi decoding for next generation downlinks, selectable RF inputs and IF bandwidths for multi-mode flexibility, RS-232 serial control for setup, tuning, mode selection and status, and an LCD display for status and signal level readout.

▼ *L-Band Pre-LNA filter specifications*

Type	3-pole cavity filter
Passband	1680–1710MHz
Passband loss	0.15dB
Bandwidth	–3dB ±86MHz centred on 1705MHz
Stopband loss	300MHz: –80dB
	1200MHz: –35dB
	1570MHz: –10dB
	1866MHz: –10dB

▼ *L-Band LNA specifications*

Type	Single stage advanced E-PHEMT technology
Noise figure	0.65dB typical
Gain	14dB min
IP3	33.5dBm typical
Operating temperature	–40 to +85˚C

▼ *L-Band post-LNA bandpass filter specifications*

Type	4-pole, Combline
Insertion loss	1.5dB max
Bandwidth	1690–1710MHz

▼ *L-Band feed specifications*

Type	4 dipoles with quad hybrid combiner
Polarisation	RHC

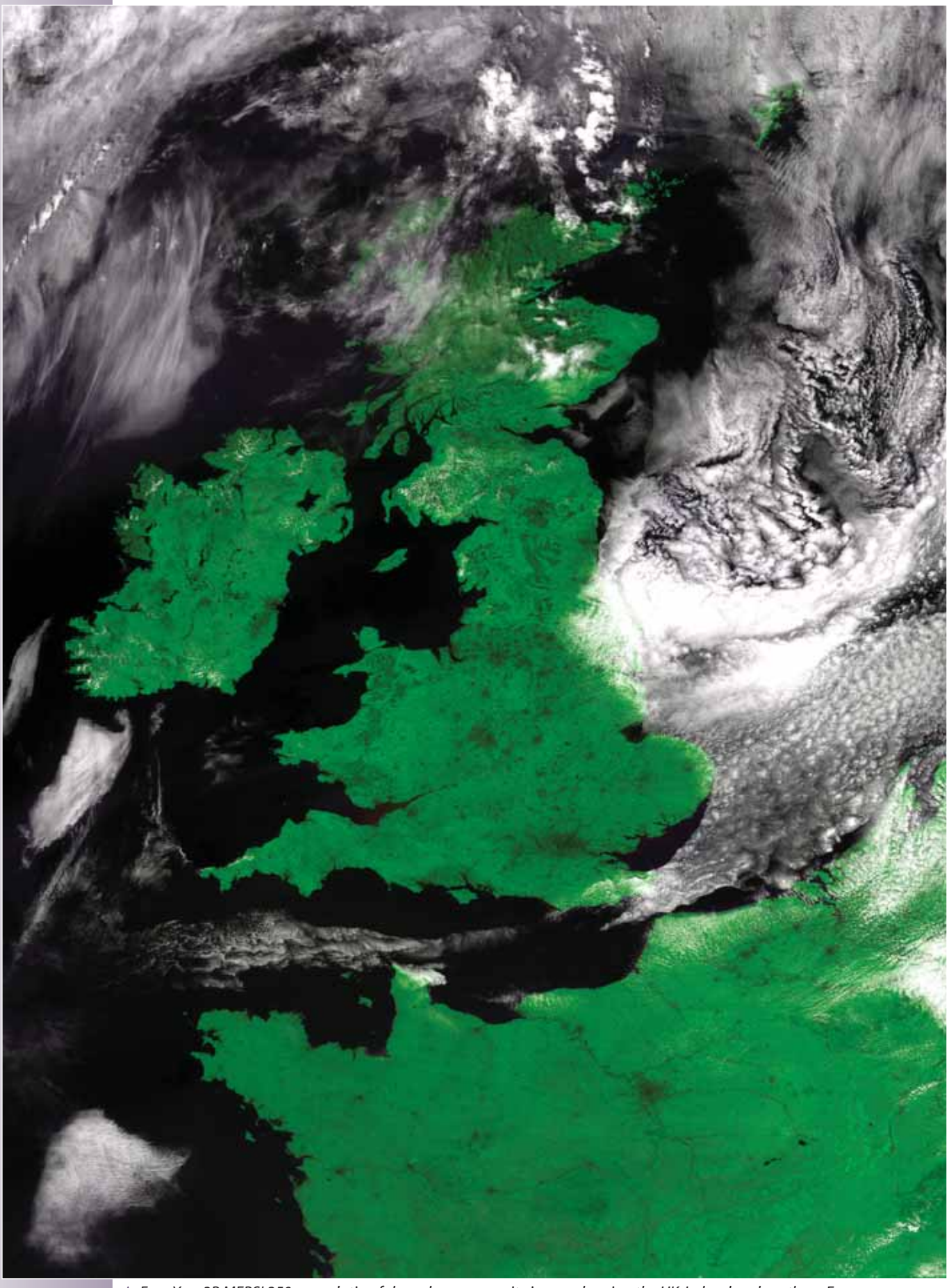
▼ *L-Band block downconverter specifications*

Noise figure	0.75dB typical
Input frequency	1682–1710MHz
LO frequency	1553.500MHz
Output frequency	126.5–154.5MHz
Converted bandwidth	50MHz @ 3dB typical
Conversion gain	>50dB, 55dB typical
Image rejection	>60dB
Input/output impedance	50Ω
Output 1dB comp. point	>+14dBm
LO stability	±2.5ppm (–30 to +60˚C)
LO type	Internal PLL locked to TCXO
Phase noise	–103dBc/Hz @ 10Hz typical
	–130dBc @ 100kHz
Input voltage	10–15V DC @ 350mA typical powered via IF output cable
Operating temperature	–40 to +60˚C
Operating humidity	100%

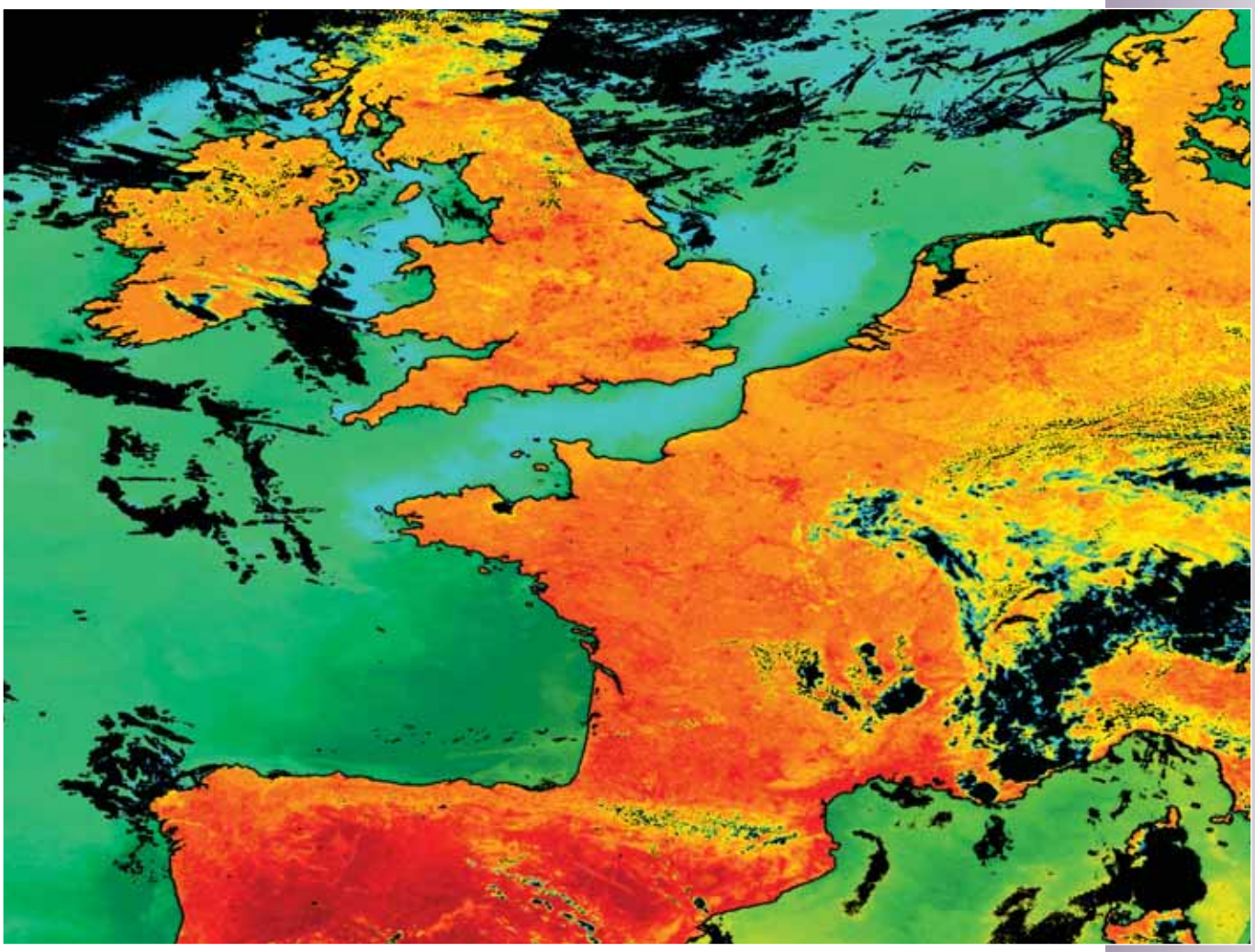
▼ *L-Band low-rate demodulator specifications*

	LRD-100	**LRD-200B**
Signal input range	–90dBm to –20dBm	–90dBm to –20dBm
IF conversion	Direct 70MHz, up to 50Msps, 10-bit resolution	Direct 70MHz, up to 50Msps, 10-bit resolution
IF bandwidth	Programmable	Programmable
Supported symbol rates	0.1–3.5Msps	0.1–3.5Msps
Demodulator modes	BPSK, QPSK, PSK	BPSK, QPSK, PSK, 8PSK, 16QAM
BPSK/QPSK performance	BPSK/QPSK within 1dB of theoretical, 0.5dB typical	BPSK/QPSK within 0.4dB of theoretical, 0.2dB typical
Convolution decoding	Viterbi, rate ¾	Viterbi, rates ½ and ¾
RF inputs	Simulator or signal, selectable	Simulator or signal, selectable
Outputs	50Ω TTL clock and NRZ data	50Ω TTL clock and NRZ data
Display	LCD, 16-character × 2 line	LCD, 16-character × 2 line
Control interface	RS-232 serial via USB serial adaptor	RS-232 serial via USB serial adaptor

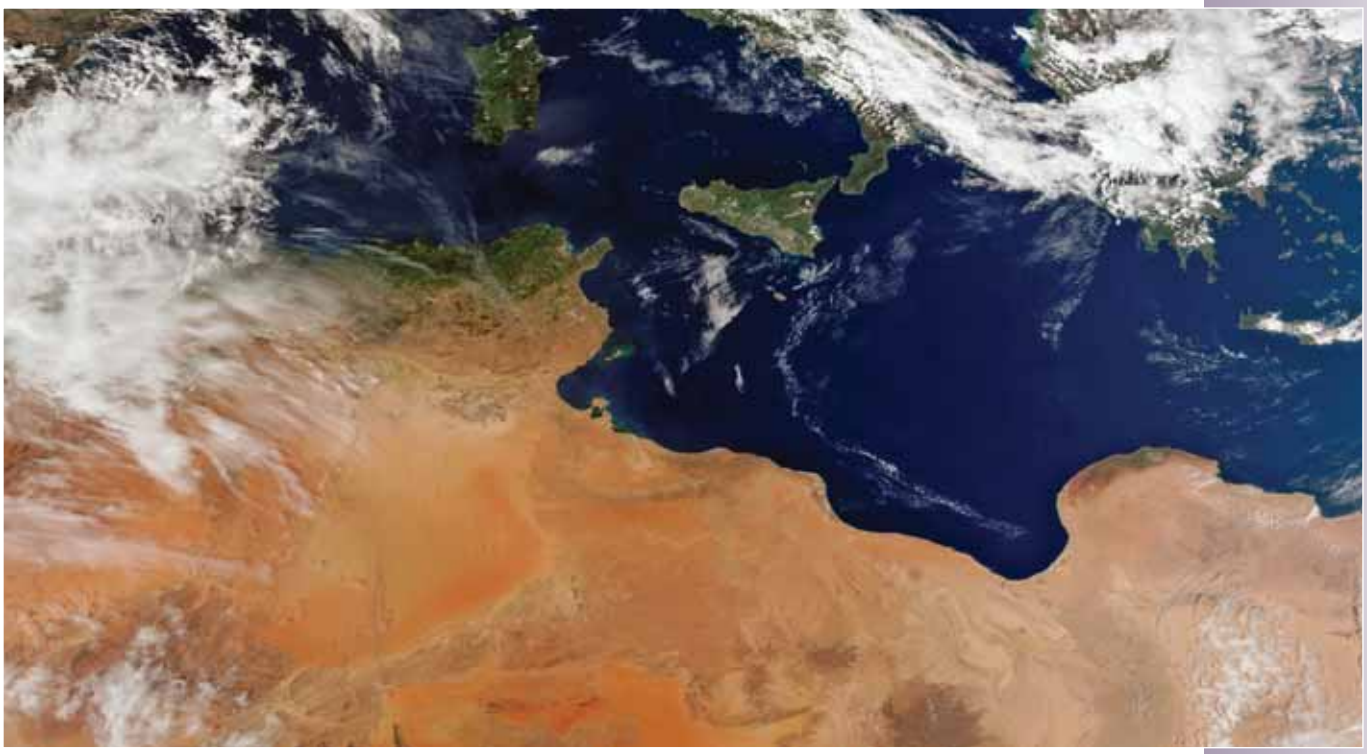
X-Band EOS System Sample images



▲ *FengYun-3B MERSI 250m resolution false colour composite image showing the UK, Ireland and northern Europe*

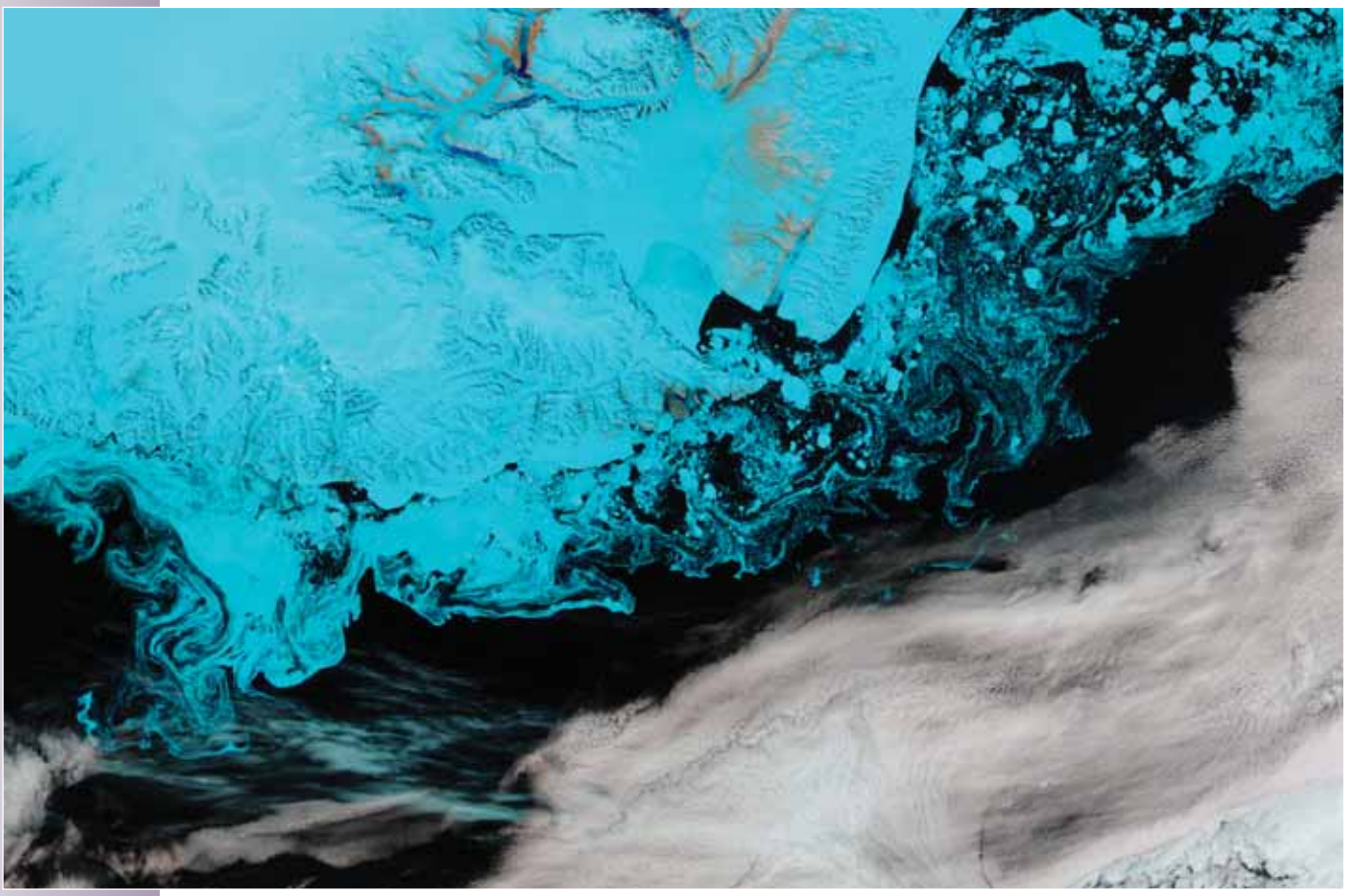


▲ *Terra MODIS Land Surface Temperature (LST) and Sea Surface Temperature (SST) products reprojected and combined*



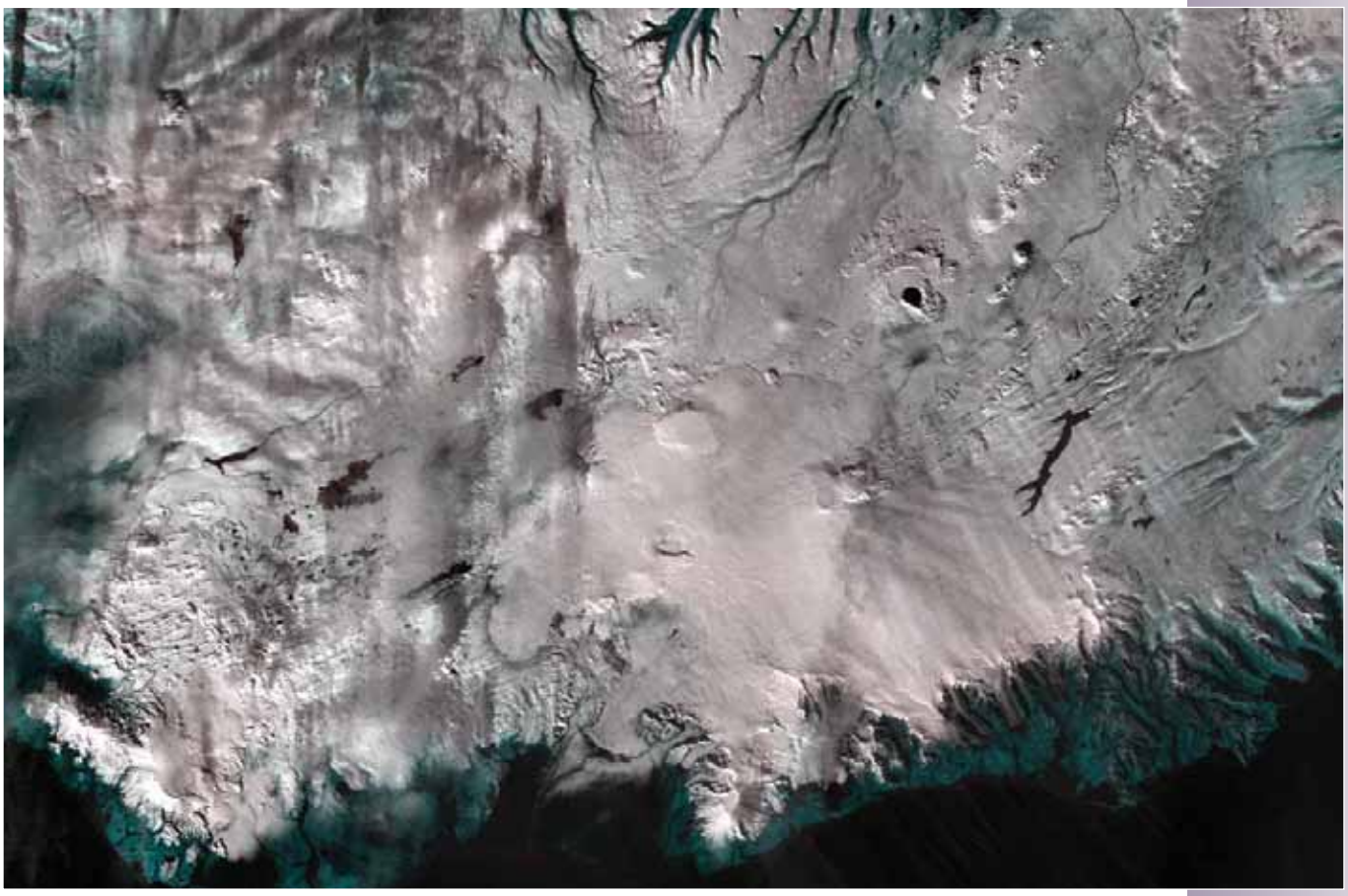
▲ *Suomi-NPP VIIRS 750m resolution true colour image showing northern Africa and the Mediterranean Sea*

X-Band EOS System Sample images

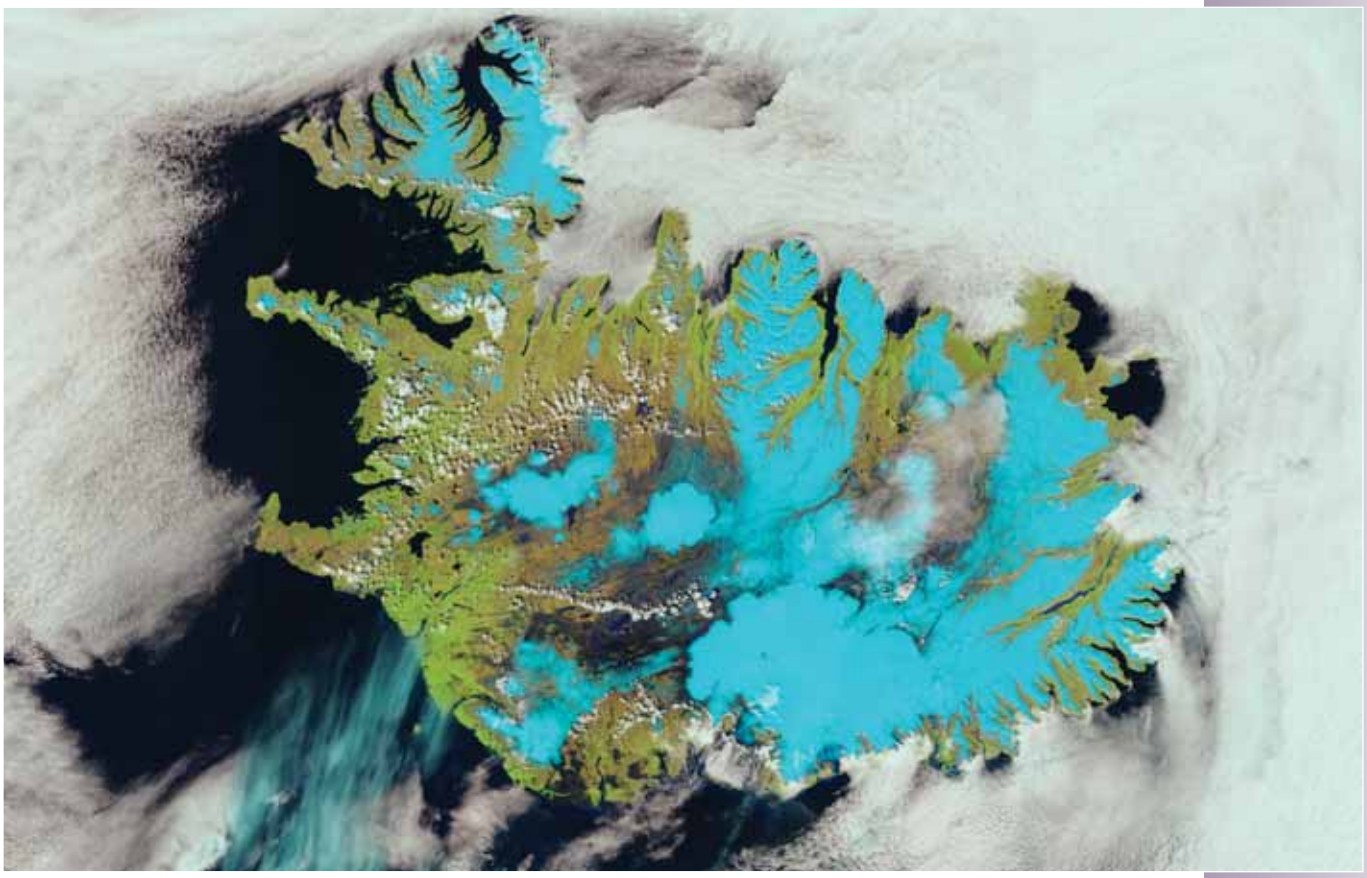


▲ *Suomi-NPP VIIRS 375m resolution false colour image showing icebergs, sea smoke and brackish ice off southern Greenland*

▲ *Suomi-NPP VIIRS 375m resolution false colour image showing the north African coast*



▲ *Aqua MODIS 250m resolution false colour image showing southern Iceland*



▲ *Suomi-NPP VIIRS 375m resolution false colour image showing Iceland with ice and snow appearing cyan*

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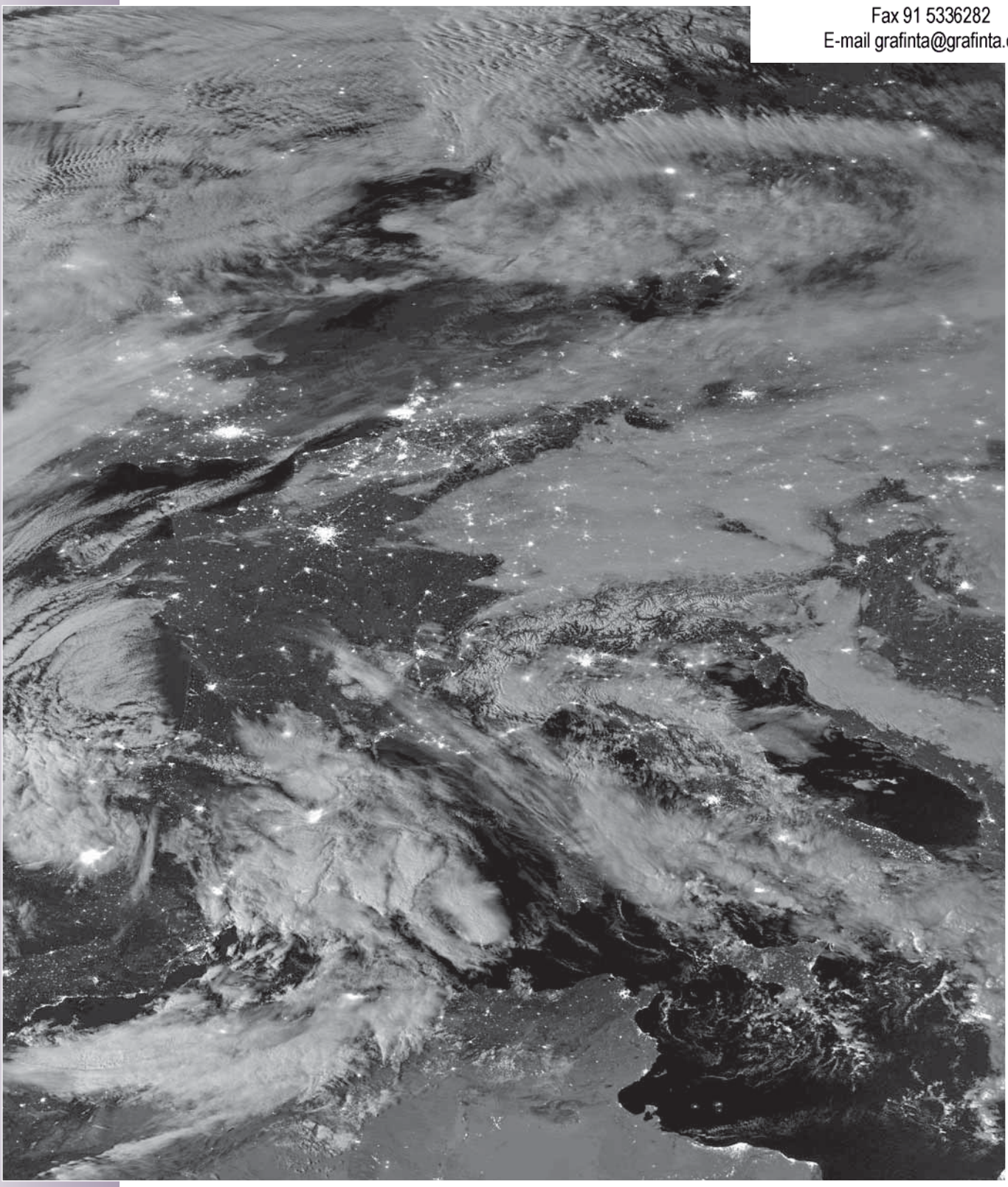

▲ *Suomi-NPP VIIRS 750m resolution day-night band reprojected night-time image showing the effect of lunar illumination and artificial lighting in urban areas over Europe and northern Africa*

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