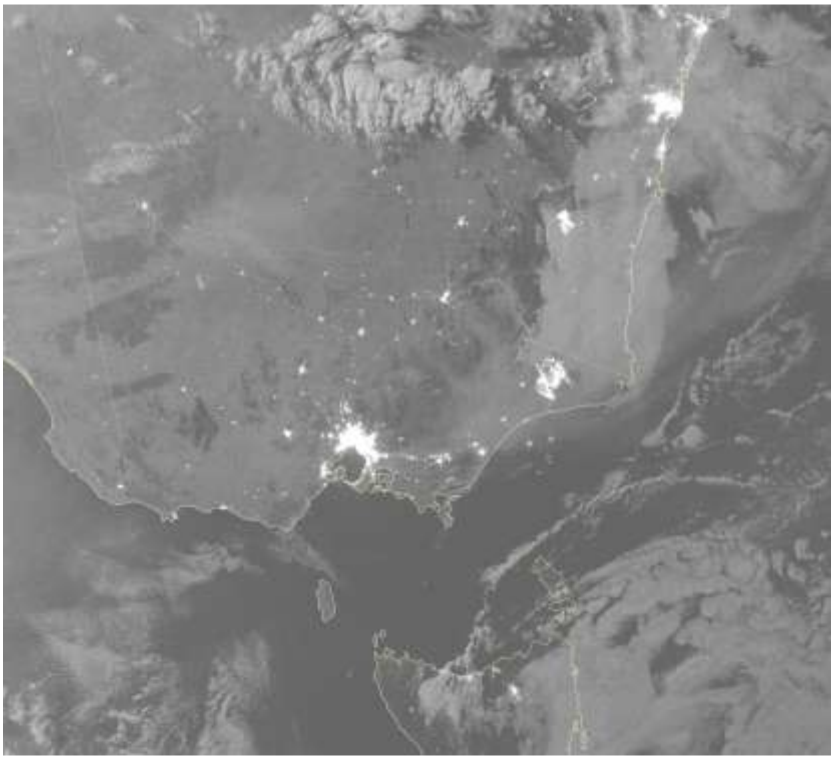
A GUIDE TO USING SATELLITE DATA IN EMERGENCY MANAGEMENT



VIIRS night-time image showing wildfires in East Gippsland, which can be compared with the lights of Sydney, Canberra and Melbourne.

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ACT Emergency Services Agency

September, 2015

Note: This document is continually evolving. Feedback and suggestions are welcome: rick.mcrae@act.gov.au

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INTRODUCTION

In 1978 the first weather satellite was launched. Its first images of the earth and its cloud systems were low resolution and grainy, but started a revolution that has changed the way society functions. Emergency management as we know it would be impossible without satellites. There would poor weather forecasts and bushfire preparedness would be a hit-and-miss affair (at least more than it is today). Severe storm warnings for electricity supply managers would not occur until the storms were overhead.

First Satellite Picture of Tropical Cyclone

Experimental weather satellite TIROS 1 launched April 1st, 1960, spotted a cyclone eight days later approximately 1,300 kilometres east of Brisbane. Picture of spiral-like clouds winding around the centre or "eye" of cyclone was taken from a height of 720 kilometres and transmitted to earth during satellite's 128th orbit. TIROS 1 was not earth-stabilized, making it difficult to determine where camera was pointing, however, subsequent weather satellites were earth-stabilized and this problem overcome.

From Wilkie, 1976.

Around the world there are groups of specialists who can access wide catalogues of imagery and data to assess emergency situations. Most of this information is readily accessible, and yet the vast majority of emergency managers lack awareness of it.

Most staff use some form of satellite imagery on routine basis, as with the hourly weather images from the Bureau of Meteorology (BoM). They may not realise, however, that at the same time the satellite took imagery that can directly show large wildfires or indicate the extent of floods.

Major improvements in satellites systems and data are scheduled for the not too distant future, and it is vital that we keep up with this technology and its benefits.

There is a global agreement - the International Charter 'Space and Major Disasters' - to make satellite data available in the event of a disaster. Activities under this are a Commonwealth matter. See www.disasterscharter.org

CONCEPTS

The following concepts need to be understood if the full value of satellite imagery is to be obtained. This is not a technical review.

Sensors

Almost all satellites used for emergency management use sensors that detect incoming electromagnetic radiation. This radiation is described by its wavelength and intensity.

They carry one or more sensors designed to measure the intensity of incoming radiation in one or more narrow bands of wavelength. Each part of the spectrum (for example visible light and infrared) requires different hardware, each in a separate sensor. The more ambitious a satellite is, the more sensors it carries and the heavier (and expensive) it is.

A solution to this has been achieved with the "A-Train" constellation of satellites. These satellites, each with different sensors for different jobs, follow the same orbit, but with some minutes of separation. There data can be combined to provide a unique insight into earth systems.

Satellites in the A-Train currently include:

- OCO-2, NASA's Orbiting Carbon Observatory.
- GCOM-W1, JAXA's Global Change Observation Mission.
- AQUA, a NASA earth observation satellite.
- CloudSat, a NASA cloud radar satellite.
- CALIPSO, a US-French cloud LIDAR satellite.
- AURA, a NASA air quality monitoring satellite.

Most detect incoming radiation only. This is either radiated by the Earth (for example thermal infra-red) or reflected (for example visible light).

A sub-set emit the radiation that is reflected by the Earth. These are LIDARs or RADARs, depending on the wavelengths used (laser or radio, respectively). Wavelengths are measured in micrometres (or microns, shown with the symbol "μ").

All of this is based on some key physical dynamics:

- All objects emit thermal radiation, and measuring this allows any objects temperature to be estimated.
- Any radiation leaving the Earth's surface passes through the atmosphere. Some bands pass through unaffected. Some bands are scattered, especially by dust or aerosols. Some bands are partially or completely absorbed.
- In some bands, the atmosphere emits its own radiation. This may provide information on water vapour or cloud composition.
- Some bands are strongly affected by the day-night cycle, while others are unaffected.

A camera takes an image at one instance, but cameras are rarely used on satellites these days. On satellites, a light sensing device (or similar) sweeps sideways across the orbit collecting data. Every repeat is at a different position on the orbit, and this allows an image to be built-up. However it is not instantaneous – there can be some minutes from beginning to end of the data collection.

A band is a block of the spectrum. Within any band, a satellite sensor may have one or more channels, picking up related but different information. For example in the visual band, red and green channels will clearly be different, but each will render clouds, waterbodies and forests.

Ownership

Satellites fall into a number of ownership classes, depending on who is able to finance them.

Private

These satellites serve a commercial need, mainly communications, but increasingly niches such as earth observation.

US Government

The US government has a special provision that if the taxpayer pays for a satellite, then its data may be accessed for no charge. They have funded many research-oriented satellites.

Other Government

Other Governments tend to charge for access to their data. The largest providers of relevance are the European Space Agency (ESA) and the Japanese Space Agency (JAXA).

Military

Major military bodies around the world have acquired or developed satellite technology. These tend to be classified and only available through special arrangements.

Orbits

For any height of orbit, a satellite must have a constant speed to maintain a stable orbit. Also its orbit may be on a plane that is inclined with respect to the Earth's equator. The greater the incline, the more of the Earth's surface may be covered by the satellite.

Based on this, satellites come in three primary groups: general, polar-orbiting and geostationary.

General

Satellites such as those used in GPS are designed to be on variously inclined orbits with short orbit cycles. To provide global coverage a large number of satellites are required. At any one time, at any point on the surface some number of satellites should be in the user's sky, giving the GPS fix. This constellation changes quickly.

Polar-Orbiting

Polar-orbiting satellites have steeply inclined orbits, almost passing over the poles. Their orbits are usually designed to ensure that they pass over any point on the ground at the same sun-time. This provides greater comparability of data obtained on different passes. Orbits may be designed to provide daily passes (such as the A-Train) or multi-day return times (such as LandSat).

Geostationary

If the speed of a satellite in an equatorial orbit equals the movement of the Earth's surface below, the satellite stays in the same part of the sky. This is of immense importance for communications satellites, but is also valuable for weather satellites. It must be remembered that higher latitudes are less well covered by geostationary platforms.

Data Acquisition

Satellite owners build ground-stations as the primary data download point for their system. Other users may, under licence, be able to build their own ground stations. The type of orbit determines ground station needs. A single primary station can serve a geostationary satellite, while polar orbits require multiple stations.

Some satellites are designed to store data until the next pass over a primary station, while others broadcast data continuously without regard to whether it is being received.

Ground stations pipe their data to processing centres.

Data Processing

The key steps in data processing are:

- Taking the raw data feed and turning it into usable formats.
- Correcting for orbit variations.
- Correcting for sensor variations.

Data processing centres tend to be the biggest source of disruption to data feeds.

The raw data from a satellite downlink requires considerable quality control and processing before it is fit for use for most users.

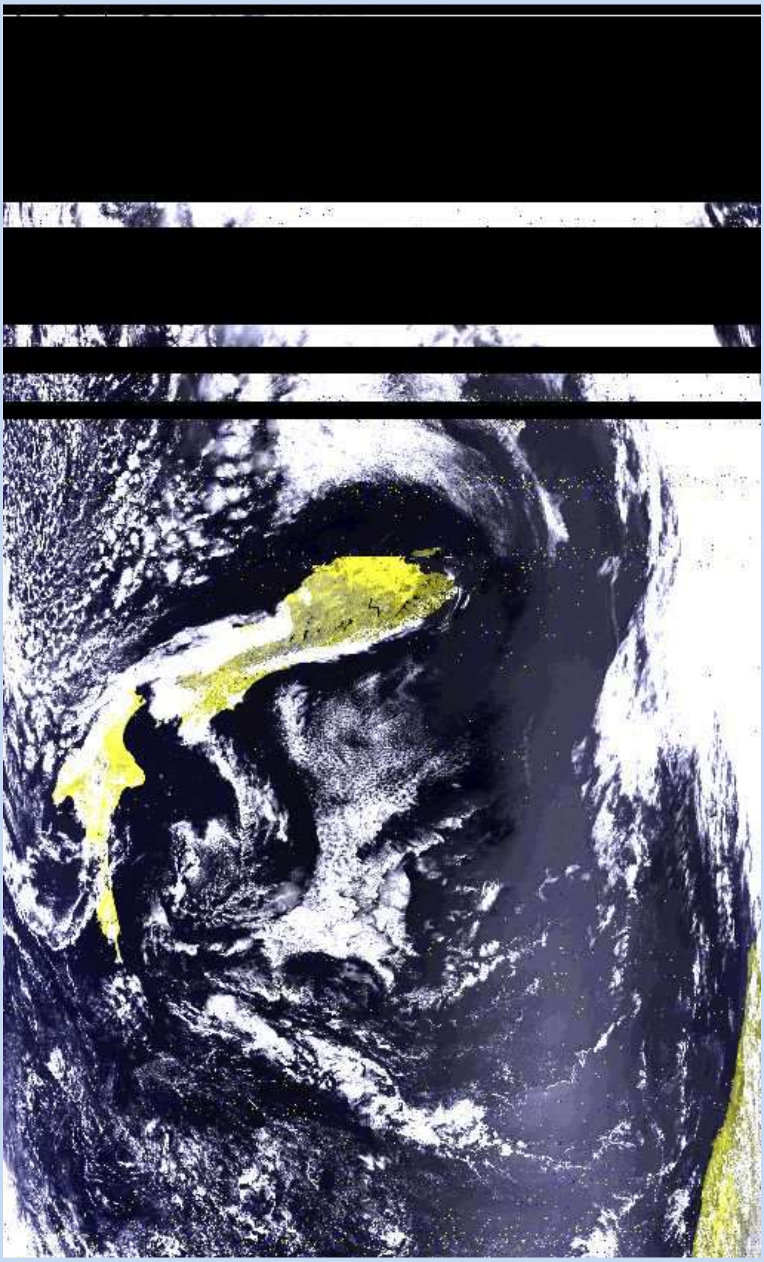


Figure 1. A raw image of the Tasman Sea from NOAA 19 AVHRR. This exhibits: (i) dropped data stripes (black); (ii) missing data bits (white flecks); (iii) cross-track geometric distortion and (iv) north-south reversal due to the satellite being on the "descending" part of its orbit; (v) false colours. Note also the sun glint on the sea. http://www.rss.dli.wa.gov.au/noaaql/2015/JAN/08/U19_30489ql.jpg

Data Access

There are a number of sites that provide near real-time access to satellite imagery. Many of these hold a short archive only, and outside of that window no retrospective access is possible. Some specialised research sites hold extended archives, especially for the US Government. Some end-users redistribute satellite imagery. There sites that require registration so that they know who is using their data. Yet more sites provide full commercial access, but require an account.

Data Use

Many sites allow full use of the data, but with acknowledgement of the source. Some place caveats on the use. Data for emergency management sometimes has a pre-arranged free-use agreement.

It is the responsibility of all users of satellite imagery to verify that it is what they believe it to be. Common issues centre on the time zone of the time stamp or assumptions about what band is depicted. For imagery, the spatial projection can be an issue and requires constant quality control. Orbit instability may affect this, especially for older satellites.

Figure 2. Partially processed MODIS image showing cross-track geometric distortion. Note the latitude and longitude graticule.

Viewing Geometry

Some satellites, such as LIDAR platforms, always view straight down to the earth. This means that there is no geometric distortion. Others, especially those with cross-track scanners, may at times be looking almost side-on. This changes the way that vegetation is rendered. Most significantly large clouds may be interpreted as being some distance away from their plan position. This is further exacerbated by their shadows being in yet another position.

The sun's relative position is also important. While some satellites always pass over at the same time of day, others do not. Thus shadows change between passes. Also sun reflection may at times be significant. It is important to note that the sun's effect (e.g. hot ground) may not be in the same place as its reflection. All downwards looking sensors suffer from a "hotspot" – a change if the characteristics of the surface below the sensor.

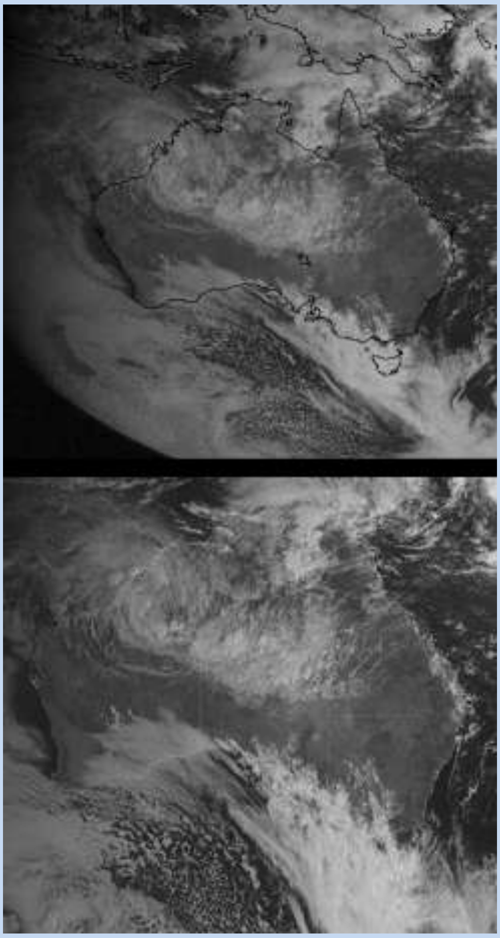


Figure 3. MT-SAT visual image showing part of the full-disc view from the satellite and, above, a rectified view of the same image.

Image Projection

Satellites are looking down on the surface of a [bumpy] sphere. Raw data can be accessed, but it will difficult to make sense of it, especially on a map. An image processing systems or a GIS will allow the map to be re-projected into a coordinate system that is user-friendly. These are typically a longitude-latitude system (i.e. the global WGS 84 or the Australia GDA 94 spheroids) or less frequently Mercator projections, where part of the spherical surface is flattened to allow a map grid to be overlaid.

With sensors such as MODIS, the data far-from track move over the earth's surface at very different rate to that below the track. When the image is re-projected this can create a stuttering effect, as seen in Figure 3.

Value-adding

Post-processing of the imagery takes it from being a data product to being an information product. This is required for efficient intelligence development and decision making under AIIMS 4 doctrine. It is too easy to be distracted by the sheer volume of data from satellites and - oh, wait look at that – I haven't seen that before. Ah, where was I?

Value adding can be done by:

- Government systems. The LandGate FIREWATCH web site is an example.
- Commercial providers, often under contract, sometimes for cost.
- In-house spatial teams, using GIS technology
- IMT units from diverse backgrounds working for Planning, Intelligence of Public Information units.
- Researcher or collaborators, who may come together on-line in real-time to develop a global picture of hazard dynamics (such as pyroCbs).

TIME

As satellite systems are inherently global or multinational, they operate in Universal Coordinated Time (UTC, from the French for this), also known as Greenwich Mean Time or Z-time.
The difference between local time and UTC are show in Table 1.

Where	When	Difference
SE Australia (NSW, Vic, ACT, Tas)	Normal time (AEST)	UTC+10:00
	Summer time (AEDT)	UTC+11:00
Qld	All year (AEST)	UTC+10:00
SA	Normal time (ACST)	UTC+9:30
	Summer time (ACDT)	UTC+10:30
NT	All year (ACST)	UTC+9:30
WA	All year (AWST)	UTC+8:00

Table 1. Australian Time Zones.

Raw imagery will have a UTC timestamp on it.

For a near-real-time image, that has just become available, the time delay in getting (also known as the latency) is the sum of the orbital time used in acquiring it, the downlink time, the processing time, and the time taken in posting it onto a web-server.

SENSORS

In some instances, the sensor is used on a number of satellites, and is the key focus.

AVHRR

The Advanced Very High Resolution Radiometer (AVHRR) sensors have been installed on a long-running series of satellites, starting with TIROS-N in 1978, and currently still in use on 4 NOAA satellites and MetOp-A&-B. For many years these were the preferred sources of data, partially replaced in that status by MODIS. They have 1km ground resolution.

MODIS

The Moderate Resolution Imaging Radiometer (MODIS) has been deployed on the TERRA and AQUA satellites, and is a widely used source of raw imagery and value-added products, most notably fire hotspots. It covers: VIS (at 250m resolution); NIR; SWIR, MWIR & LWIR (at 500m resolution).

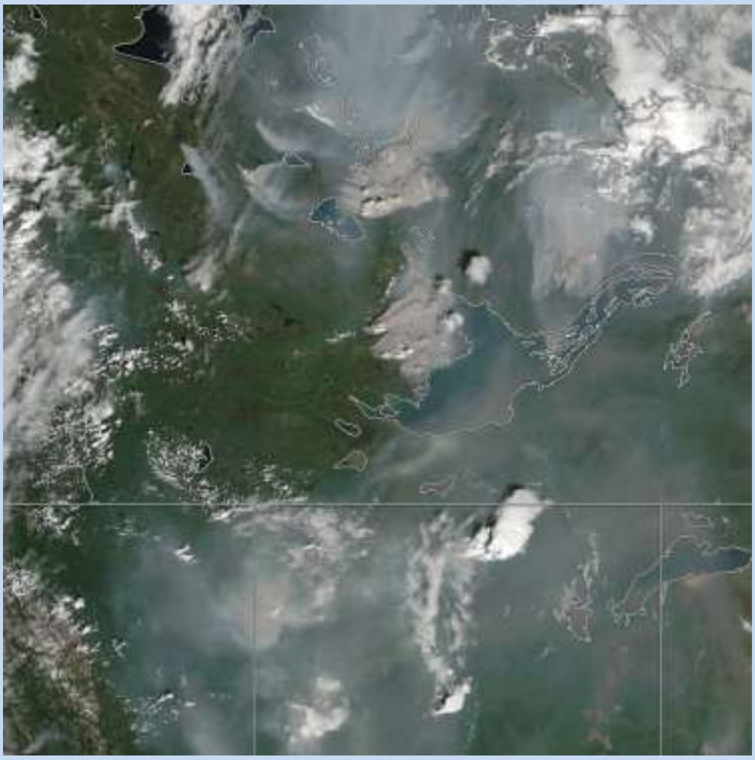


Figure 4. VIIRS visible band image of extensive wildfires burning around Great Slave Lake in Canada, July 2014.

VIIRS

The Visible Infrared Imaging Radiometer Suite (VIIRS) is the next generation platform after MODIS. While VIIRS has had a big impact on science, it has had less uptake in sectors such as emergency management.

SATELLITES

Weather Satellites

Weather satellites are geostationary. They tend to use some or all of the same bands:

- Visible, around 0.5 to 0.7μ, in one band (monochrome) or multiple bands.
- Long-wave infra-red, or thermal IR, around 10 μ.
- Mid-wave IR, water vapour imagery, around 9 μ.
- Mid-wave IR, around 4 μ.

Their resolution and repeat time is improving steadily.

Key satellites are:

- MT-SAT and HIMAWARI series from JMA. BoM licences data from these are the primary Australian weather satellites.
- The GOES series from the US NOAA (GOES West is over the Pacific Ocean).

Earth Observation Satellites

There are a number of series of Earth Observation Satellites (EOSs).

NOAA-15, NOAA-16, NOAA-18, NOAA-19

These satellites all carry the AVHRR, and have long been the workhorses for arrange of earth observation applications, including fire detection and grassland curing assessment. NOAA has a rolling replacement program.

TERRA & AQUA

These two satellites were designed to be an advance on the NOAA series. The MODIS data is generally better for most applications than the AVHRR data. However these two satellites are past their use-by-date and are not to be replaced.

SUOMI NPP

The SUOMI satellite is the first of the series to replaces TERRA and AQUA. Its sensor set, VIIRS, has different capabilities. SUOMI data is not generally used yet.

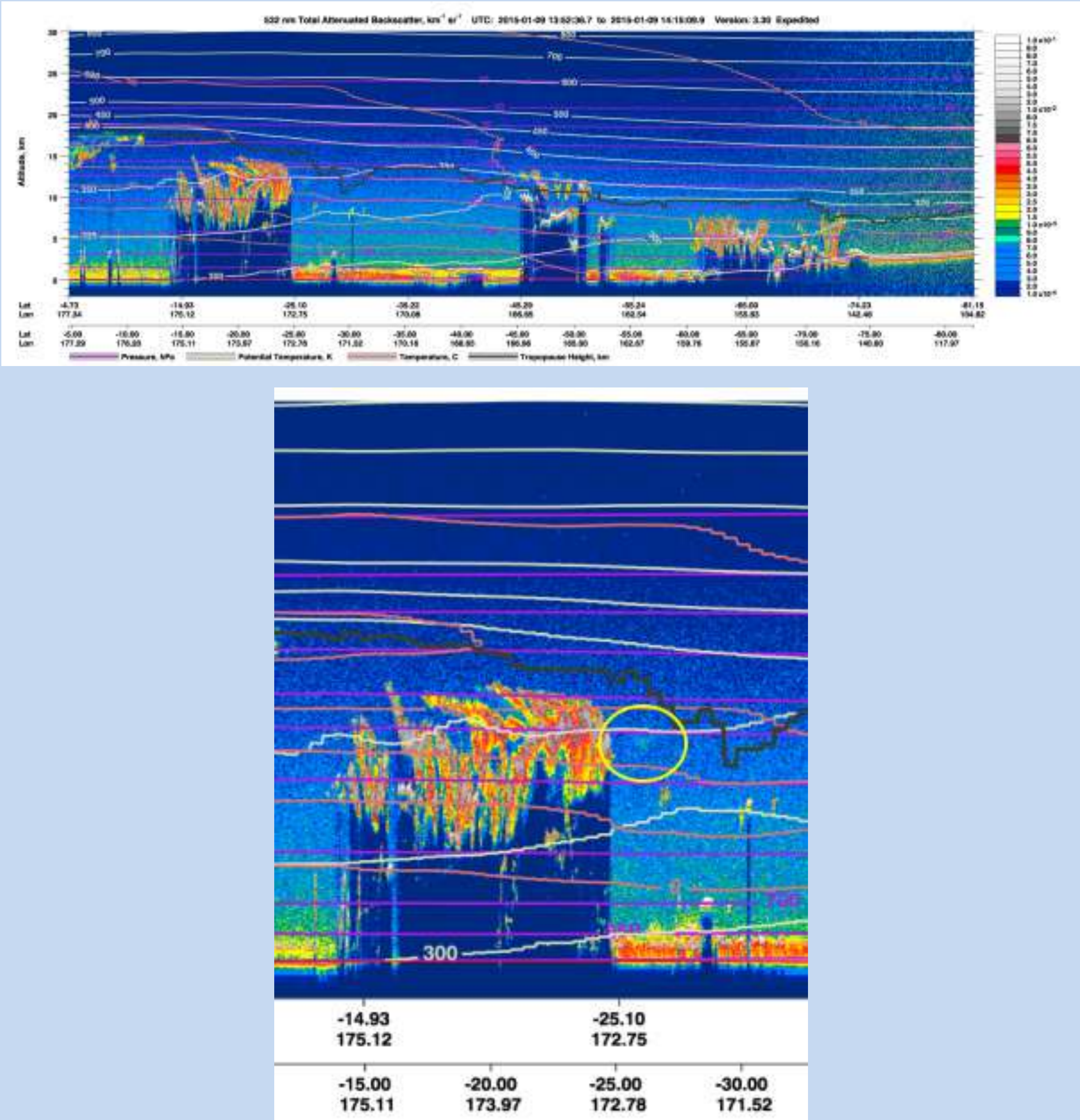


Figure 5. An example of a LIDAR profile of the atmosphere from the CALIPSO research satellite. The top image is an overview of a quarter of an orbit. Below is a close-up of part of it, showing data from a fire west of the Grampians in Victoria. The feature outlines in yellow is smoke injected to a height of 12 km by the fire.

Research Satellites

Research satellites are unashamedly designed to produce highly technical output. Understanding this requires considerable technical skill, and is not to be undertaken by those without it. It is too easy to draw incorrect conclusions. For example the highlighted feature in Figure 5 was possibly misclassified by the NASA system.

However, if you do not know that something can be done, you will ask for it to be done.

The key thing to remember is that science-quality data takes a lot longer to process, and cannot be considered near-real time. There are expedited services (such as for CALIPSO data), but this is still not really timely enough for emergency management. It is valuable for post-analysis and lessons-learnt work.

Other Satellites

A range of other satellites may, from time-to-time, provide valuable imagery.

The International Space Station and, in the past, Space Shuttle astronauts have taken valuable photos out of viewing ports. These are posted on the web (official archives or social media) even before their mission ends.

Satellites run by countries such as India, China or Brazil may occasional post useful imagery.

Figure 6. Photograph taken by an astronaut on the Space Shuttle Mission STS-107 of fire activity near Khancoban, from over Mildura. January 2003. (The photographer died during re-entry.)
http://eol.jsc.nasa.gov/

BANDS

The bands that are commonly encountered in satellite systems are listed below. Not all of these are used in emergency management.

Band	Wavelength (µ)	Uses & typical wavelengths used
Visible	0.4 = Blue 0.65 = green 0.7 = red	Actual appearance imagery. Note that blue (0.4 µ) is heavily scattered by the atmosphere, and is sometimes a near IR band is used instead in a pseudo-colour image.
INFRARED Near IR (NIR or IR-A)	0.7 - 1000 07 – 1.4	Reflected IR. Not relevant The atmosphere is largely transparent.
Short-wave IR (SWIR or IR-B)	1.4 - 3	Reflected IR. Not relevant. The atmosphere has transparency windows.
Medium-wave IR (MWIR or IR-C)	3 - 8	Thermal IR. 3.9 µ = fire detection, major temperature anomalies. The atmosphere is transparent. 6.7 – 7.3 µ = water vapour imagery. Mainly emissions by water vapour in the mid-levels of the atmosphere. Dry air is transparent.
Long-wave IR (LWIR or, also, IR-C)	8 - 15	Thermal IR. The atmosphere is largely transparent. 10.7 µ = thermal IR imagery
Far IR (FIR)	Over 15	Not relevant

Table 2. Common bands.

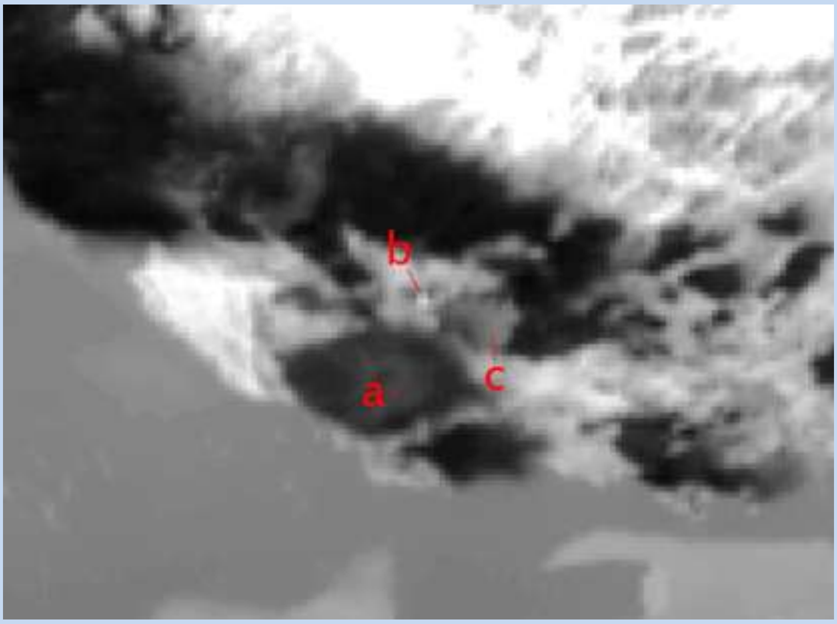


Figure 7. 3.9 µ image of an extreme wildfire, western Victoria, 8 Jan 2014. Note: a = normal thunderstorm with cold (dark) top; b = fire shown by white (hot) pixel; c = grey (warm) cloudtop indicating pyroCb.

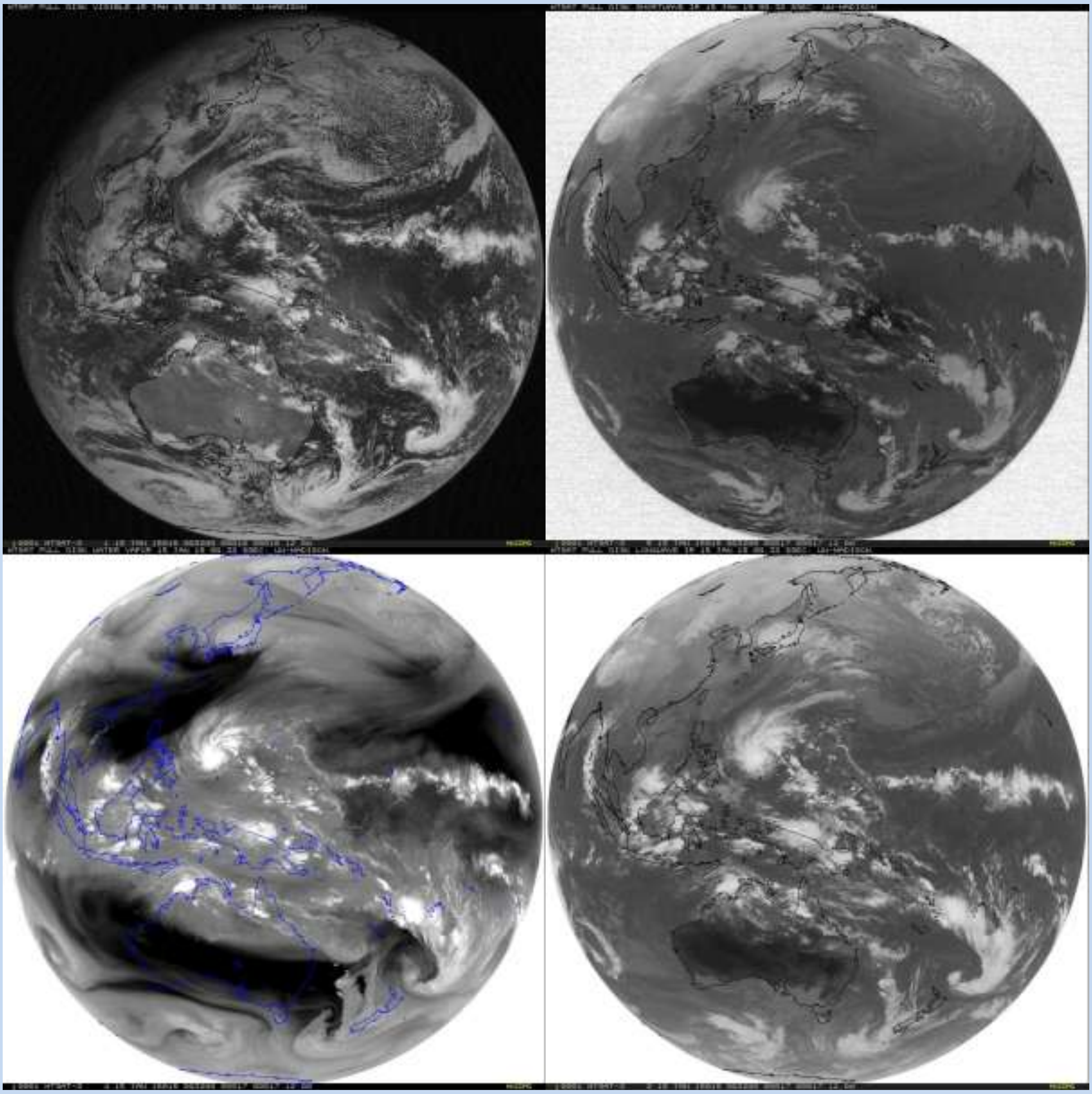


Figure 8. Sample bands from MTSAT, 15 Jan 2015 at 00:32 UTC. Top Left: Visible (0.73 μ); Top Right: MWIR (3.75 μ); Lower Left: Water vapour (6.75 μ); Lower Right: LWIR (10.8 μ).

Temperature:

In technical satellite products you may see temperature expressed in Kelvin (K), which has a similar scale to degrees Celsius (˚C), but
0 K = -273.15 ˚C.
Thus a nice summer day might be 303.15 K,
while high cloud tops might be at 233 K.

APPLICATIONS

Vegetation

Vegetation is principally green – it absorbs red and blue light strongly and reflects green. Detecting it is a straightforward application of visual imagery. However, it is difficult to infer properties of the vegetation, due to:

- Variations in the appearance of vegetation with viewing angle for cross-track scanners.
- Variations in the vigour of vegetation growth
- Scattering of blue light in the atmosphere

Thus applications like the assessment of grassland curing require more technical processing of the images. It has been found that vegetation vigour can be assessed using the ratio of bands, and the Normalised Difference Vegetation Index, and related indices, are widely used.

In terms of fire impact assessment, there are usually distinct differences in spectral signatures of unburnt vegetation, recently burnt vegetation and vegetation that lost burnt material (such as shedding of burnt foliage in a forest).

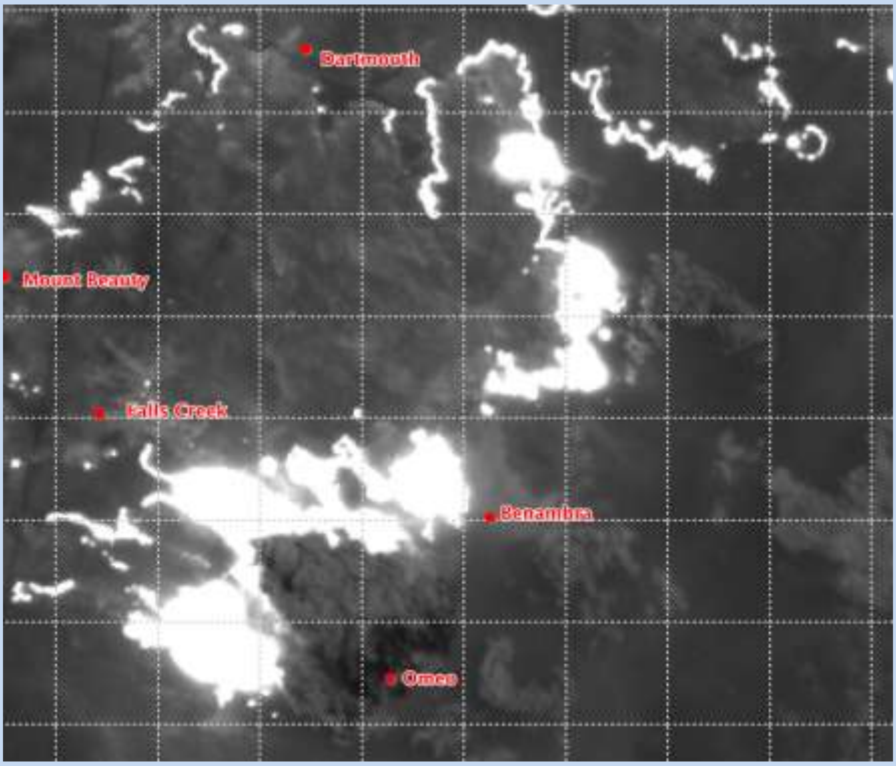


Figure 9. 3.9 μ BIRD image of fire activity (white) in the Victorian high country, 26th Jan 2003. The grid spacing is 10 km. BIRD was an experimental hotspot satellite launched by the German Space Agency, DLR.

Wildfire

There are four uses of satellite data for wildfire management.

Detection

Wildfire detection is by means of a hotspot – an image pixel that has been classified as having a spectral signature likely to be caused by a fire.

The standard wildfire hotspots products examine the difference between the 3.9 μ channel and the 10.7 μ channel. Cloud filtering and averaging are also involved. While most users simply look at where hotspots are assessed as occurring, there is data on the intensity available as well.

A number of sources provide hotspot data. Geoscience Australia runs the Sentinel website. Northern Australia is covered by the North Australian Fire Information (NAFI) site. LandGate in WA runs the Fire Watch site, which has national coverage. NASA's Earth Observing System Data and Information system (EOSDIS) runs the Fire Information for Resources Management system (FIRMS) site, which provides images, GIS data and Web Mapping Service (WMS) feeds of hotspots.

Burnt area mapping

Immediate burnt area detection (i.e. of the order of a day or so after a fire) is done through detection of anomalously hot ground in a thermal channel. After a month or so, any scorched forest canopy is shed, and burnt areas can be detected in standard earth observation imagery, such as that from LandSat.

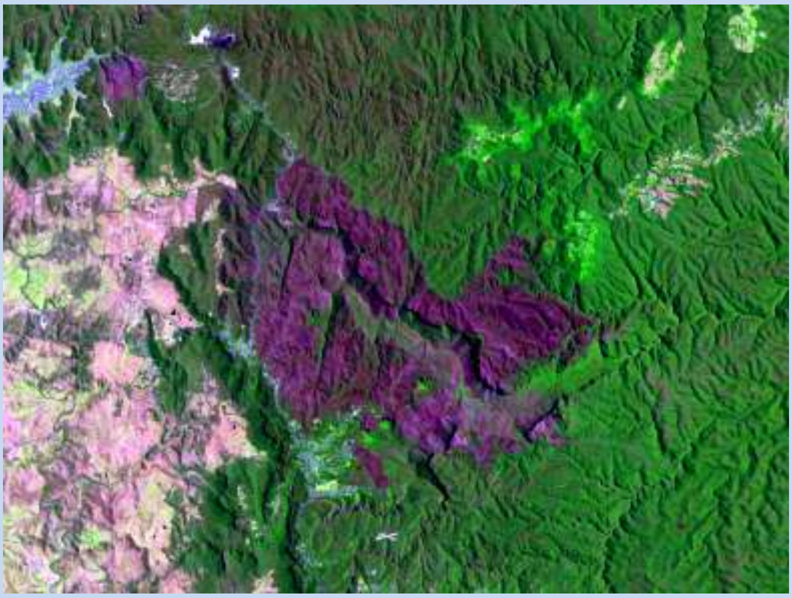


Figure 10. LandSat image of burnt area from a fire in the Grose Valley, NSW, November 2006.

Plume detection

In visual imagery of sufficient resolution, it is possible to see the plume directly. This will not work at night or under stratiform clouds. Plumes, especially those from extreme wildfires, many be detected from the brightness temperature of the cloud-tops within them. PyroCbs are often colder on top than surrounding clouds.

Conditions conducive to fire escalation

Dry slot detection in water vapour imagery is a standard technique. A dry slot passing over an established wildfire indicates some potential for blow-up conditions.

Smoke

As discussed above the smoke plume may be directly detected using satellite imagery. With time the smoke is carried downwind and may cause new problems with visibility and air quality. Again this may be picked up in visible imagery, and again cloud and night may prevent that. Sometimes smoke can be inferred through discolouration of cloudtops.

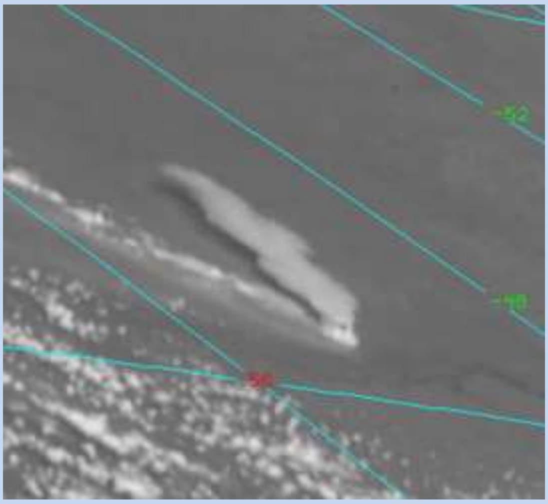


Figure 11. Almost side-on MeteoSat-9 view of a spectacular pyroCb formation east of Moscow, July 2010.

If smoke is injected to high levels it may be detected using as a thermal anomaly. Often this can be distinguished from adjacent clouds.

LIDAR satellites, such as CALIPSO, can detect smoke though the amount of radiation backscattered off it, and its polarisation. This may work even when the smoke is mixed with light cloud.

Volcanos & Ash

There is a strong similarity between detection of volcanic activity and detecting extreme wildfires. Both may emit strong heat signatures. Both may produce plumes that are easily visible in visual band images. Both may inject large quantities of aerosol into the atmosphere, which may be detected in LIDAR or other data.

Considerable research is underway into the differences, as only the former affects civil aviation.

Flood

A number of techniques have been developed to detect floodwaters. Obviously a cloud-free visual image will do this. Radar satellites (often developed to detect ice and icebergs) have been used to detect the difference in reflection patterns between a smooth water surface and a rough rock or vegetation covered surface. A cloud-free thermal band image may show the distinct temperature of a wet surface if adjacent dry surfaces are quite hot or cold. This difference may vary significantly through the diurnal cycle. For instance floodwaters in Lake Eyre will appear warmer at night and cooler in the day. They may be "swamped" by the "glow" of adjacent hot ground in mid-afternoon.

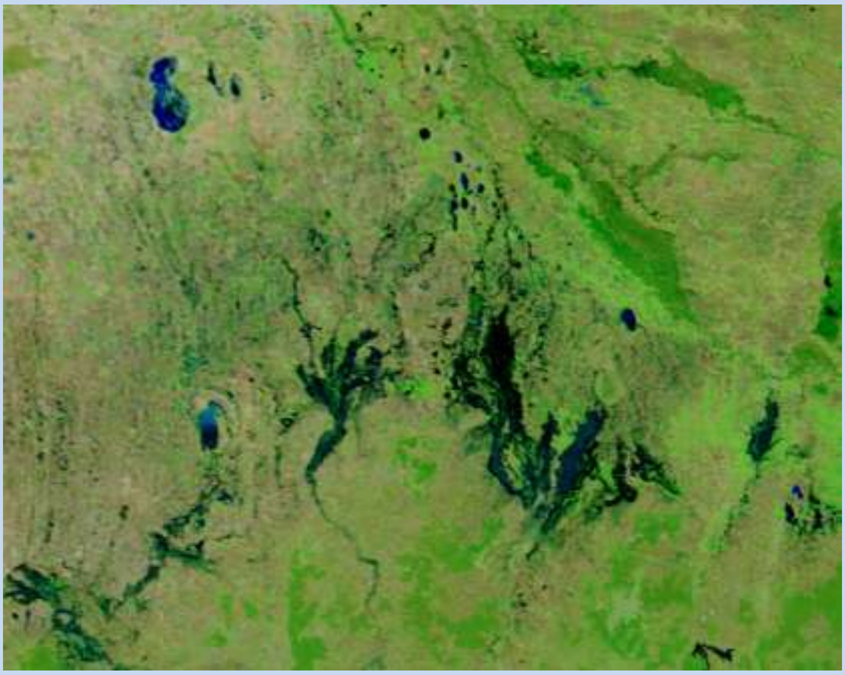


Figure 12. MODIS visual imagery of floods in NW Victoria, January 2011.

Storms

Thunderstorms may be easily seen in visible imagery. This is the best way to assess large-scale bands of convective activity, which may be partially missed by radar coverage. If the sky is cloudy already, it may be difficult to distinguish storm cells. As their anvils punch through other cloud layers, their tops are colder and readily picked in thermal IR images.

Water vapour imagery may show accumulations of water that have not yet formed into storms.

Animations of six to eight hours of geostationary imagery are valuable for assessing the dynamics of storm formation.

Care must be taken when using side-on looking imagery, as the cloud-tops are rectified onto a ground position quite distance from the cloud.

Other

Satellite imagery is useful for detecting and assessing dust storms. These brew up in the inland, where observations site are sparse at best. As dust absorbs thermal IR (where air does not), a storm heats up and expands. This produces a cap of fractocumulus cloud that can be seen in the imagery.

Figure 13. A dust storm moving offshore from the Hunter Valley, October 2009. AQUA Terra image.

OUTLOOK

JMA has recently commissioned its next generation weather satellite, HIMAWARI 8. This has more bands, better resolution and ten-minute repeat time. This has opened many new possibilities for Australian emergency management.

WEB SITES

It is worth keeping a list of web sites bookmarked.

SITE	**BoM Recent Satellite images**
URL	http://reg.bom.gov.au/australia/satellite/?ref=ftr
CONTENTS	IR image draped over a standard LandSat base image. Allows animation and selection of timezone.
USES	Designed from tracking cloud mass evolution and thus rainfall potential.
ISSUES	Basic design,

SITE	**Uni of Wisconsin at Madison** **Space Systems Engineering Center Geostationary RealEarth**
URL	http://realearth.ssec.wisc.edu/
CONTENTS	This is a very powerful satellite image viewer, including Himawari-8 data.
USES	With access to all bands and full global zoom and pan capabilities, this supports a wide range of uses.
ISSUES	The user interface is complex and requires familiarisation.

SITE	**Uni of Wisconsin at Madison** **Space Systems Engineering Center Geostationary Image Viewer**
URL	http://www.ssec.wisc.edu/data/geo/
CONTENTS	Single and animated multiple band imagery from all geostationary weather satellites. Currently using MT-SAT2 data.
USES	Useful for tracking weather systems, especially tropical cyclones.
ISSUES	No Himawari-8 data yet,

SITE	**WORLDVIEW (NASA EOSDIS)**
URL	https://earthdata.nasa.gov/labs/worldview/
CONTENTS	A wide range of imagery and value-added products, using a global web map interface with a timeline slider. Includes wildfire hotspots.
USES	Widlfires, floods, storms, dust, vegetation assessment, drought and air quality. Imagery capture.
ISSUES	---

SITE	**LandSatLook Viewer (USGS)**
URL	http://landsatlook.usgs.gov/viewer.html
CONTENTS	Access to the entire archive of LandSat imagery (back to 1972) using a global webmap interface. Imagery download.
USES	Post impact assessment. Long time-frame land-use changes.
ISSUES	Care is needed to filter the image search to manageable quantities.

SITE	**GIBBS (NOAA)**
URL	http://www.ncdc.noaa.gov/gibbs/
CONTENTS	A global archive of satellite imagery from a range of platforms covering a range of bands (mainly Vis, IR & WV), selectable by date back to 1974.
USES	Post impact assessment. Long time-frame land-use changes.
ISSUES	The archive is not complete, but who are we to complain…

SITE	**LANCE (NASA)**
URL	https://earthdata.nasa.gov/data/near-real-time-data/rapid-response
CONTENTS	Near-real time data from a range of NASA platforms. A wide range of products is indexed.
USES	Very wide range.
ISSUES	Requires familiarisation if not system development to gain full benefit.

SITE	**TC-WEB**
URL	https://www.fnmoc.navy.mil/tcweb/cgi-bin/tc_home.cgi
CONTENTS	The US Navy's global monitoring system for tropical storms. This relies heavily on accessing the latest imagery from a wide range of platforms and channels.
USES	Good for assessing cyclone dynamics and flood potential.
ISSUES	There are frequent Security Certificate problems with this site.

SITE	**BRISBANE STORM CHASERS**
URL	http://realtime2.bsch.com.au/vis_sat2.html?region=aus&loop=no&images=&allday=&start=&stop=#nav
CONTENTS	The best source of zoomed-in MTSAT imagery for Australia. Their data is processed by the US Navy in Japan. Provides VIS, IR and WV imagery.
USES	All weather satellite applications.
ISSUES	Processing outages (in Japan) are common. No Himawari-8 data yet.

SITE	**Landgate FireWatch**
URL	http://firewatch.landgate.wa.gov.au/home.php
CONTENTS	This site (based in WA) provides excellent access to imagery and value-added products from MODIS, AVHRR & VIIRS in near-real time.
USES	Used for fire detection and monitoring.
ISSUES	---

SITE	**GEOSTATIONARY IMAGERY LOOPS**
URL	http://rammb.cira.colostate.edu/dev/lindsey/loops/
CONTENTS	Sets of the last 20 images for a specific set of geographic areas, including mainland Australia. Uses a range of channels.
USES	Designed for wildfire detection and monitoring.
ISSUES	Restricted geographic extents and not rectified.

SITE	**NAFI**
URL	http://www.firenorth.org.au/nafi2/
CONTENTS	Provides hotspots, fire scar maps, maps and data download.
USES	Designed for wildfire detection and monitoring.
ISSUES	Not designed for southern parts of Australia.

SITE	**HighFireRisk**
URL	http://www.highfirerisk.com.au/imr/ACT_H8_03.htm
CONTENTS	Regional subset viewer for all Himawari-8 bands. Uses SSEC WMS feeds.
USES	Designed for Australian emergency management support.
ISSUES	Simplified user interface.

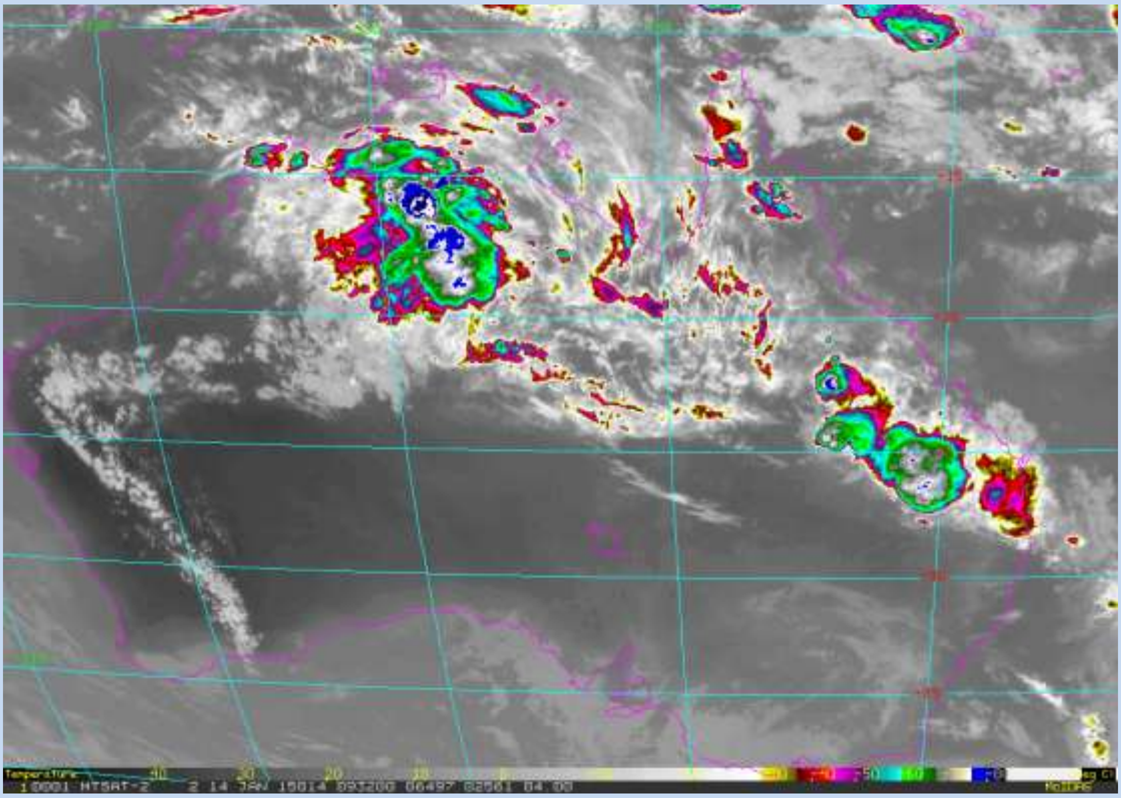


Figure 14. False-coloured IR MTSAT image. Note the temperature-based colour legend along the bottom edge. The cooling effect of a sea breeze around Albany is easily seen.

Figure 15. A composite RGB image using the three Himawari-8 Water Vapour channels

APPENDIX 1. GEOSTATIONARY WEATHER SATELLITES

Satellite	Longitude	Owner
Meteosat-10	0˚	EUMETSAT, ESA
Meteosat-9	9.5˚ E	EUMETSAT, ESA
Meteosat-7	57.5˚ E	EUMETSAT, ESA
INSAT-3D	82˚ E	ISRO
FY-2E	86.5˚ E	CMA, NRSCC
FY-2G	105˚ E	China
COMS-1	128.2˚ E	KMA, KARI, ME, MLTM (S. Korea)
Himawari-8	140.7˚ E	JMA
MTSAT-2	145˚ E	JMA
GOES-11	135˚ W	NOAA, NASA
GOES-14	105˚ W	NOAA, NASA

AVHRR Spectral Channels

http://noaasis.noaa.gov/NOAASIS/ml/avhrr.html

Channel	Resolution at nadir	Wavelength (μ)	Typical Use
1	1.09 km	0.58 - 0.68	Daytime cloud and surface mapping
2	1.09 km	0.725 - 1.00	Land-water boundaries
3A	1.09 km	1.58 - 1.64	Snow and ice detection
3B	1.09 km	3.55 - 3.93	Night cloud mapping, sea surface temperature
4	1.09 km	10.30 - 11.30	Night cloud mapping, sea surface temperature
5	1.09 km	11.50 - 12.50	Sea surface temperature

HIMAWARI-8 Spectral Channels

http://www.data.jma.go.jp/mscweb/en/himawari89/index.

Channel	Resolution at nadir	Wavelength (μ)	Key Use
1	1 km	0.47	Visible – Blue
2	1 km	0.51	Visible – Green
3	0.5 km	0.64	Visible – Red
4	1 km	0.86	NIR
5	2 km	1.6	NIR
6	2 km	2.3	NIR
7	2 km	3.9	MWIR – fire detection
8	2 km	6.2	MWIR – water vapour
9	2 km	6.9	MWIR – water vapour
10	2 km	7.3	MWIR – water vapour
11	2 km	8.6	LWIR
12	2 km	9.6	LWIR
13	2 km	10.4	LWIR – thermal infrared
14	2 km	11.2	LWIR
15	2 km	12.4	LWIR
16	2 km	13.3	LWIR

MTSAT Spectral Channels

http://space.skyrocket.de/doc_sdat/mtsat-2.htm

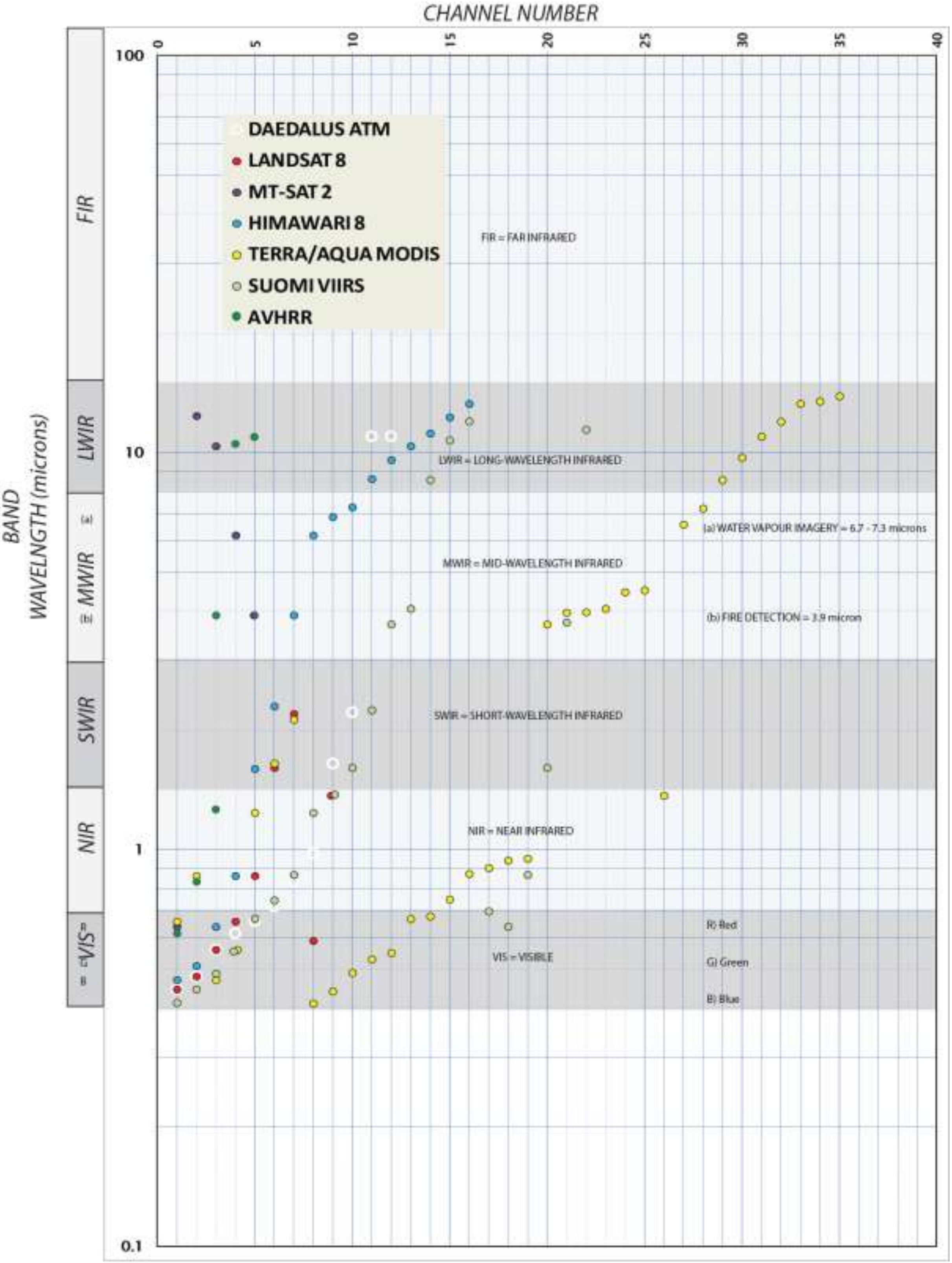
Channel	Resolution at nadir	Wavelength (μ)	Key Use
1	1 km	0.55-0.80	Visible channel (monochrome)
2	4 km	10.3-11.3	IR1 channel
3	4 km	11.5-12.5	IR2 channel
4	4 km	6.5-7.0	water vapour channel (IR3)
5	4 km	3.5-4.0	near-infrared channel

MODIS Spectral Channels

https://lpdaac.usgs.gov/products/modis_products_table/modis_overview

Channel	Range		Key Use
	Reflected (nm)	Emitted (μ)	
1	620-670		Absolute Land Cover Transformation, Vegetation Chlorophyll
2	841-876		Cloud Amount, Vegetation Land Cover Transformation
3	459-479		Soil/Vegetation Differences
4	545-565		Green Vegetation
5	1230-1250		Leaf/Canopy Differences
6	1628-1652		Snow/Cloud Differences
7	2105-2155		Cloud Properties, Land Properties
8	405-420		Chlorophyll
9	438-448		Chlorophyll
10	483-493		Chlorophyll
11	526-536		Chlorophyll
12	546-556		Sediments
13h	662-672		Atmosphere, Sediments
13l	662-672		Atmosphere, Sediments
14h	673-683		Chlorophyll Fluorescence
14l	673-683		Chlorophyll Fluorescence
15	743-753		Aerosol Properties
16	862-877		Aerosol Properties, Atmospheric Properties
17	890-920		Atmospheric Properties, Cloud Properties
18	931-941		Atmospheric Properties, Cloud Properties
19	915-965		Atmospheric Properties, Cloud Properties
20		3.660-3.840	Sea Surface Temperature
21		3.929-3.989	Forest Fires & Volcanoes
22		3.929-3.989	Cloud Temperature, Surface Temperature
23		4.020-4.080	Cloud Temperature, Surface Temperature
24		4.433-4.498	Cloud Fraction, Troposphere Temperature
25		4.482-4.549	Cloud Fraction, Troposphere Temperature
26	1360-1390		Cloud Fraction (Thin Cirrus), Troposphere Temperature
27		6.535-6.895	Mid Troposphere Humidity
28		7.175-7.475	Upper Troposphere Humidity
29		8.400-8.700	Surface Temperature
30		9.580-9.880	Total Ozone
31		10.780-11.280	Cloud Temperature, Forest Fires & Volcanoes, Surface Temp.
32		11.770-12.270	Cloud Height, Forest Fires & Volcanoes, Surface Temperature
33		13.185-13.485	Cloud Fraction, Cloud Height
34		13.485-13.785	Cloud Fraction, Cloud Height
35		13.785-14.085	Cloud Fraction, Cloud Height
36		14.085-14.385	Cloud Fraction, Cloud Height

Note: Reflections are described using nanometres (nm). 1000 nm – 1 μ.


CHANNEL NUMBER
0
5
10
15
20
25
30
35
40
BAND
WAVELNGTH (microns)
100
10
1
0.1
FIR
LWIR
(a)
MWIR
(b)
SWIR
NIR
"VIS"
DAEDALUS ATM
LANDSAT 8
MT-SAT 2
HIMAWARI 8
TERRA/AQUA MODIS
SUOMI VIIRS
AVHRR
FIR = FAR INFRARED
LWIR = LONG-WAVELENGTH INFRARED
(a) WATER VAPOUR IMAGERY = 6.7 - 7.3 microns
MWIR = MID-WAVELENGTH INFRARED
(b) FIRE DETECTION = 3.9 micron
SWIR = SHORT-WAVELENGTH INFRARED
NIR = NEAR INFRARED
R) Red
VIS = VISIBLE
G) Green
B) Blue

APPENDIX 2. INTERPRETATION OF RGB COMPOSITE IMAGERY.

Interpretation of satellite imagery can be difficult. Analysts have collaboratively developed a setoff Red-Green-Blue composite images that make interpretation much easier.

Any coloured image is built up of three bands – red, blue and green. When these bands' varying levels are combined they may form any of the possible colours.

Bringing together bands that show different aspects of a meteorological phenomenon allows us to use visual skills to rapidly and efficiently pick out specific colours.

There is a tutorial on this online at:

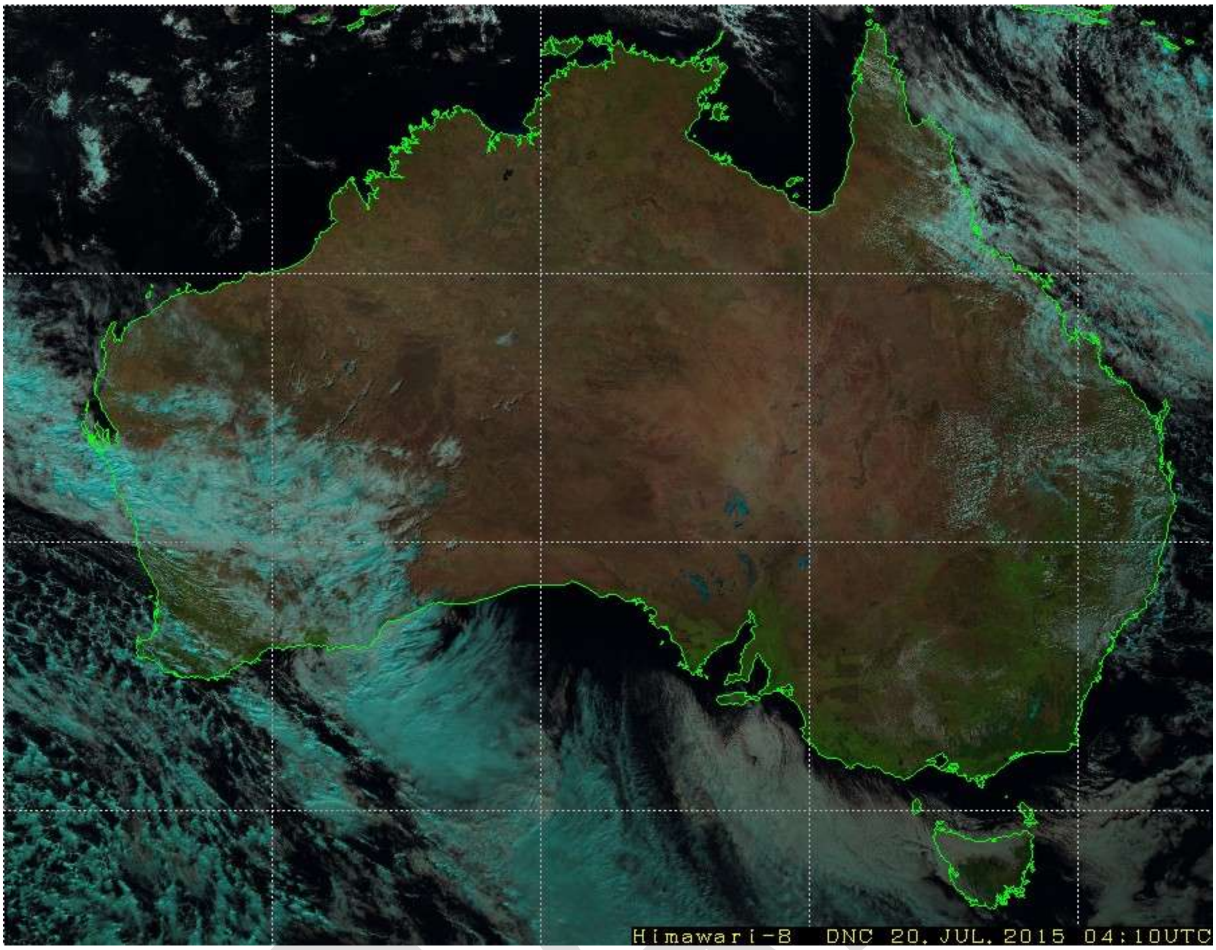
http://www.data.jma.go.jp/mscweb/en/VRL/VLab_RGB/RGBimage.html

(JMA; Eumetsat)

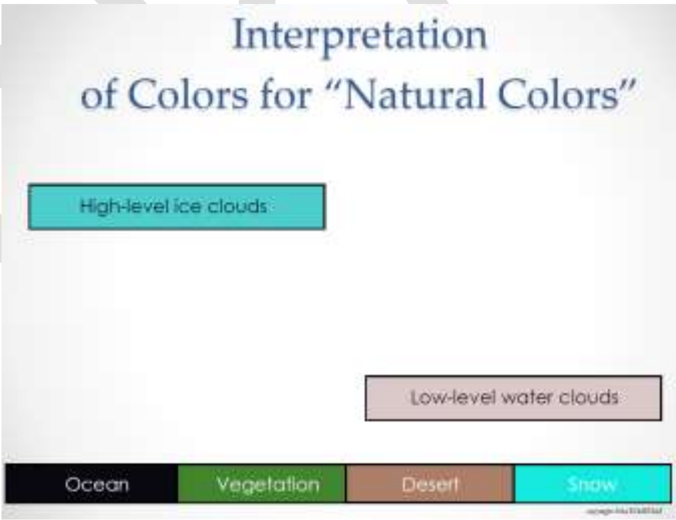
The Himawari-8 products can be accessed on-line at:

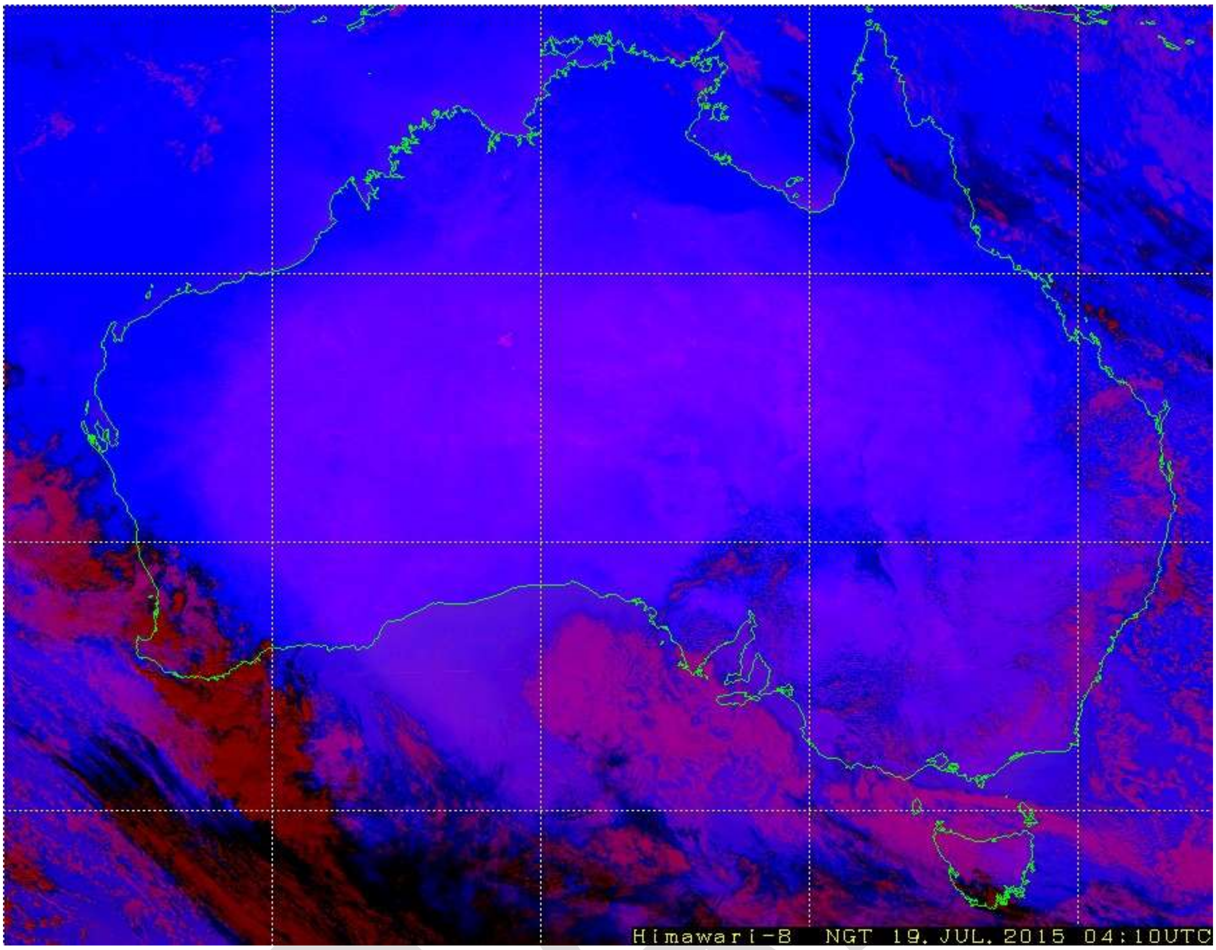
http://www.data.jma.go.jp/mscweb/data/himawari/sat_img.php

This allows you to explore the way these RGB composite products work and what they can show you.

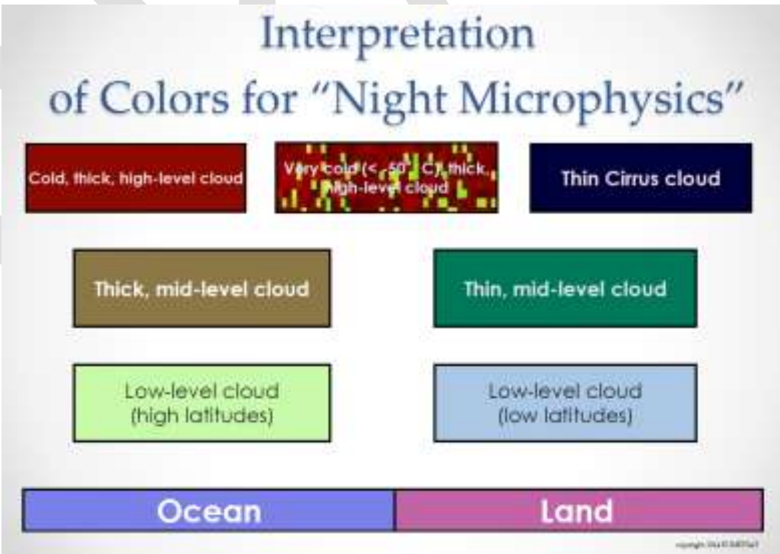


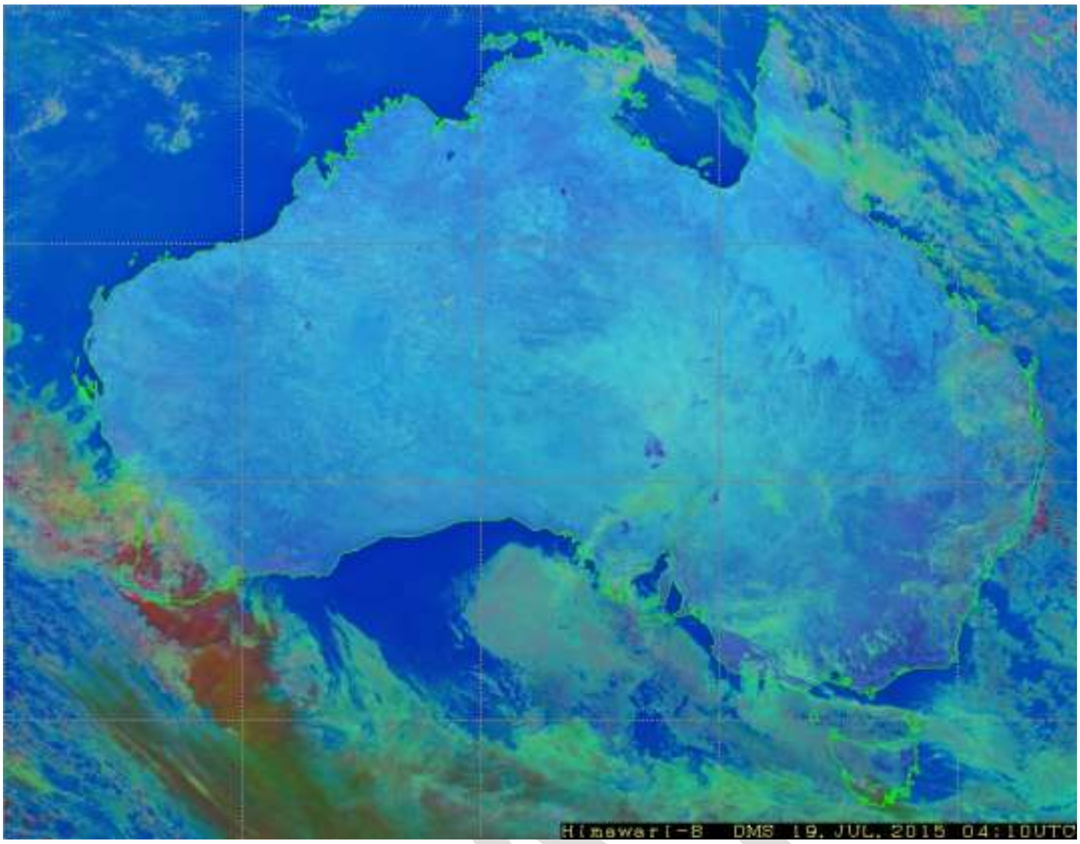
RED = [7 IR]; GREEN = [3 VIS]; BLUE = [2 VIS]



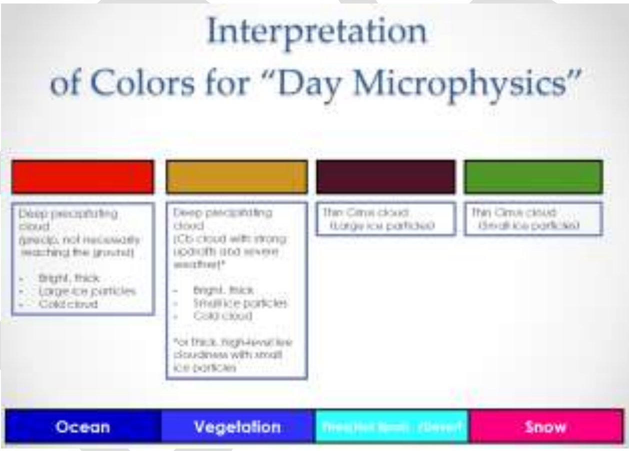


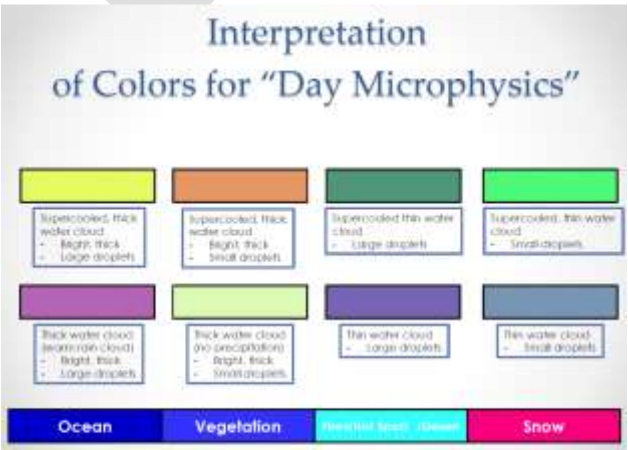
RED = [15 IR]-[13 IR]; GREEN = [13 IR]-[7 IR]; BLUE = [13 IR]

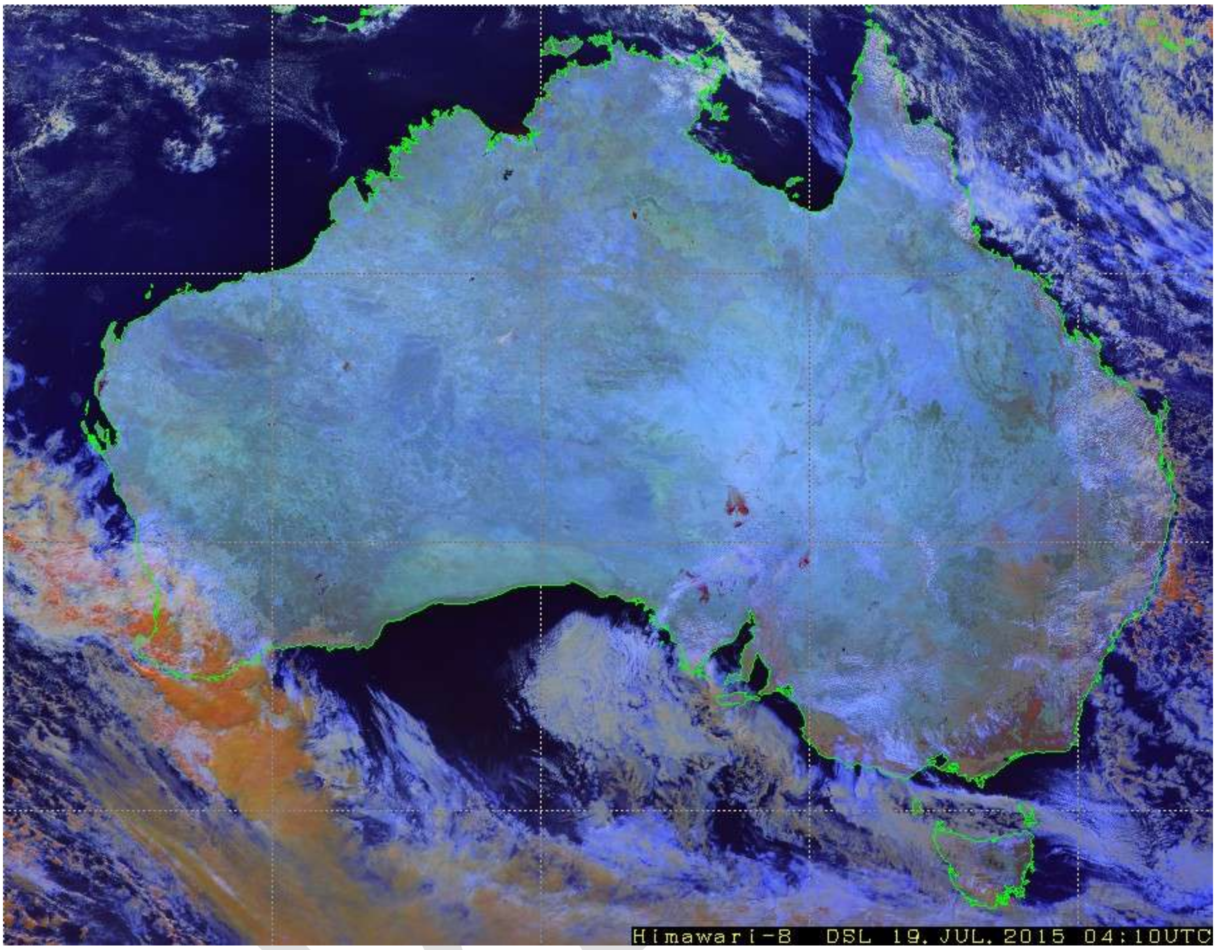




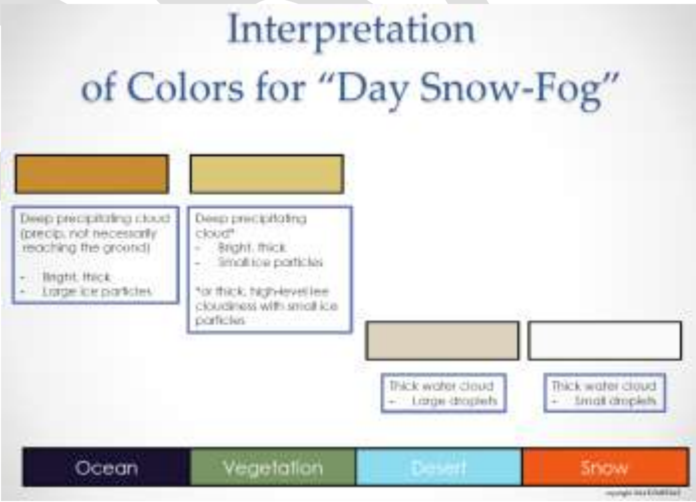
RED = [3 VIS]; GREEN = [7 IR]; BLUE = [13 IR]

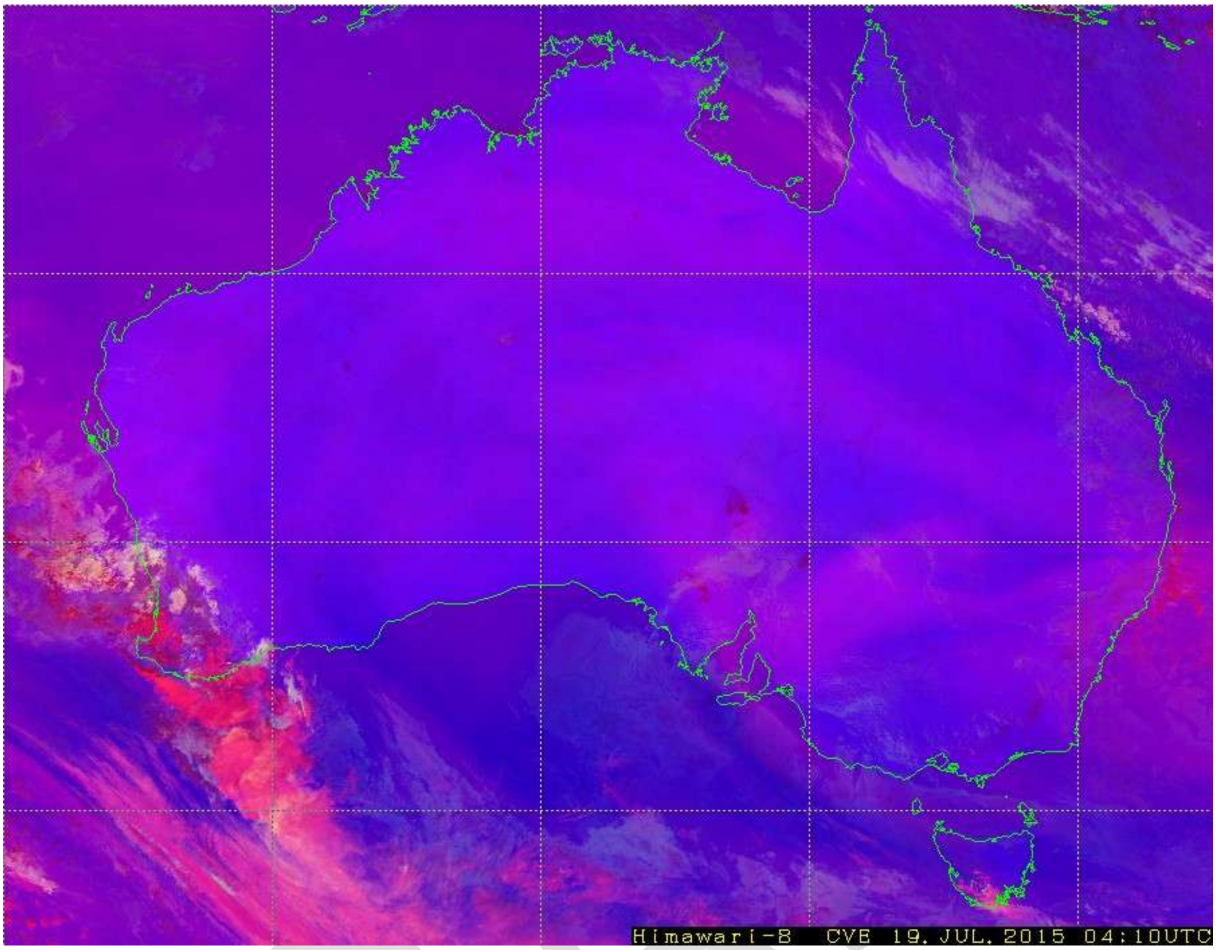




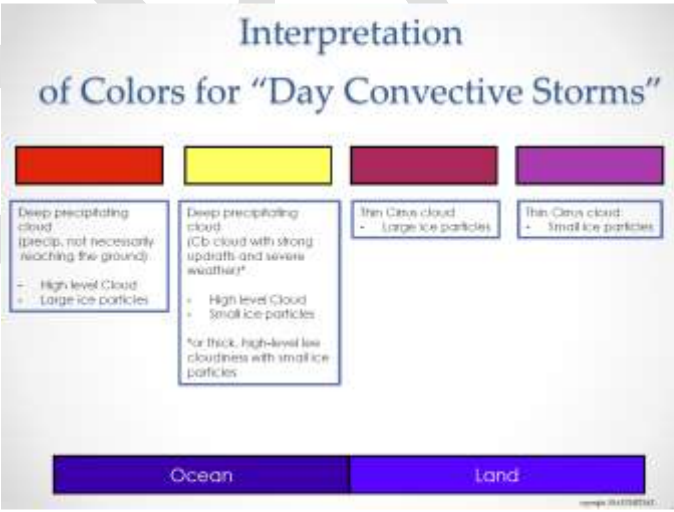


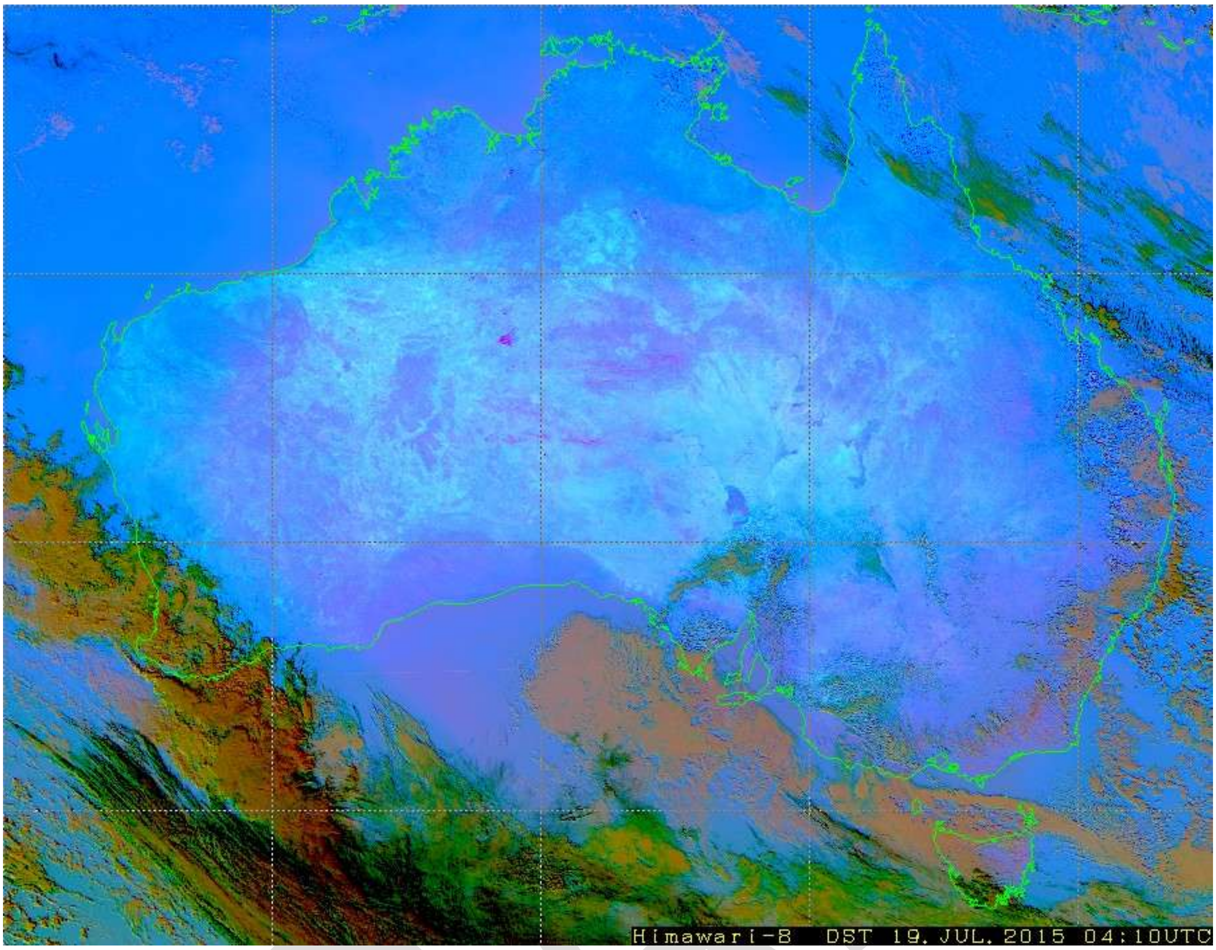
RED = [3 VIS]; GREEN = [5 NIR]; BLUE = [7 IR]



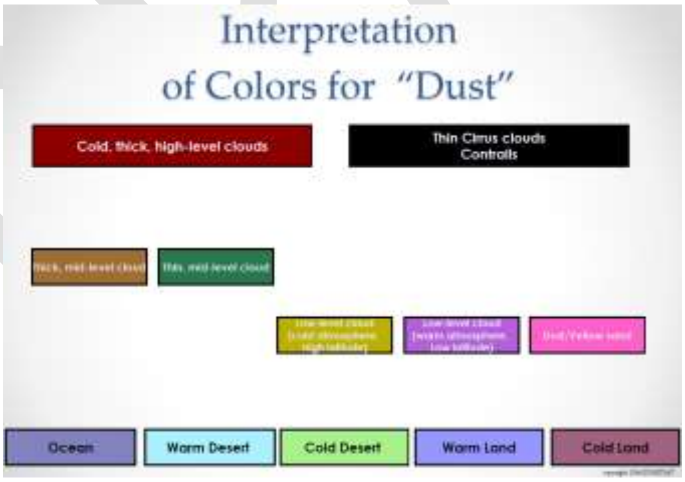


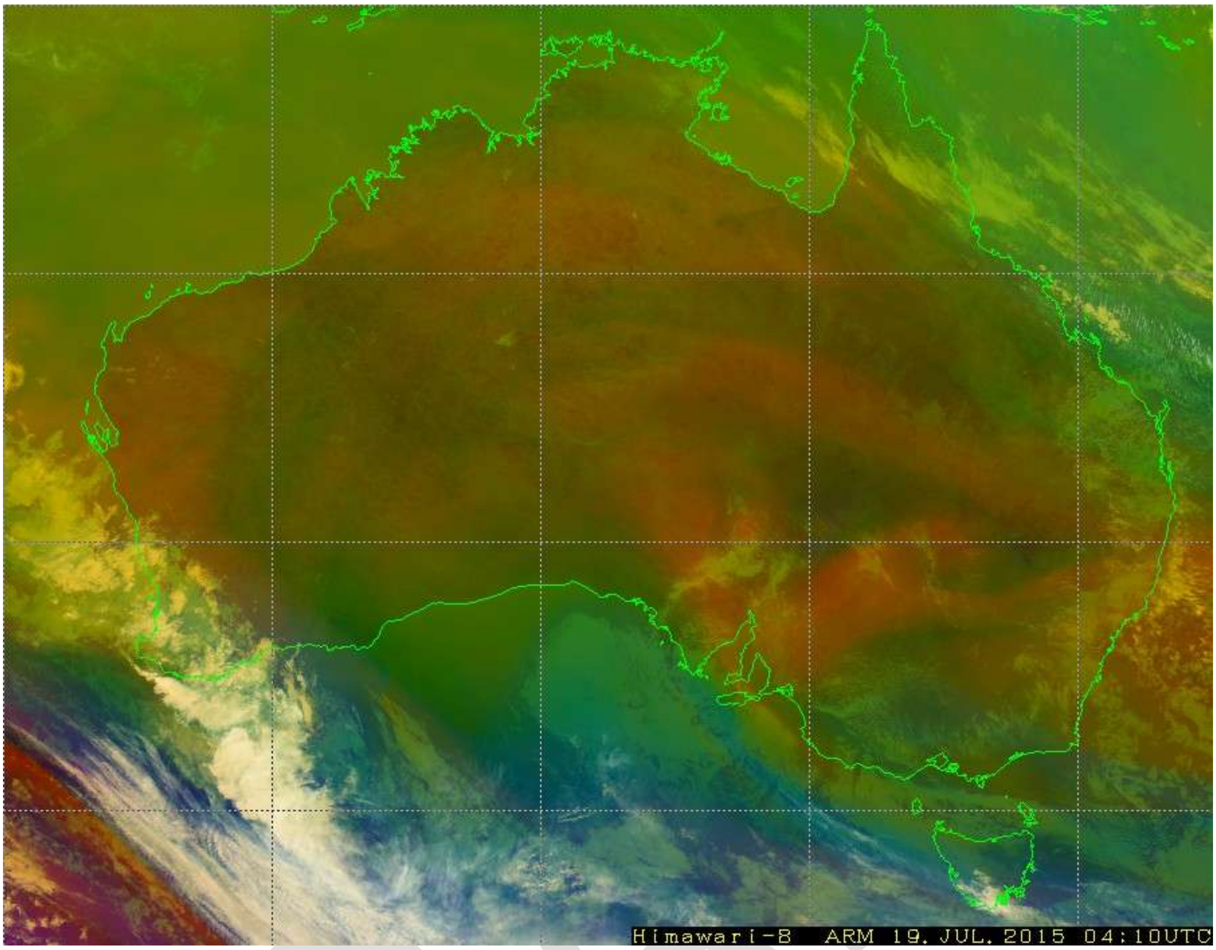
RED = [8 IR]–[10 IR]; GREEN = [7 IR]-[13 IR]; BLUE = [5 NIR]-[3 IR]



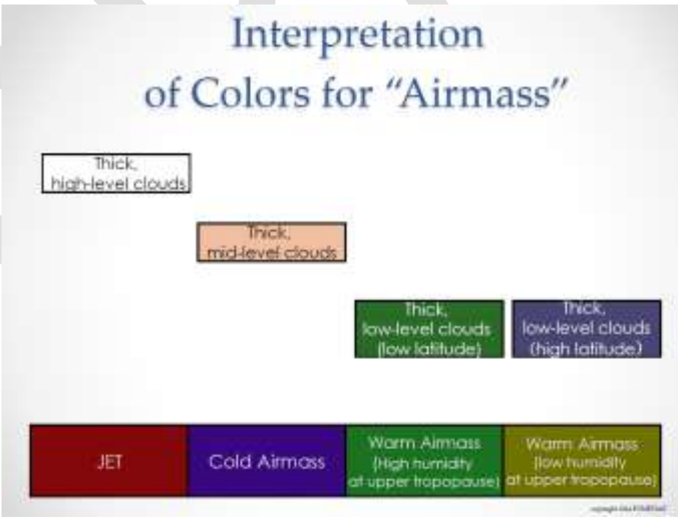


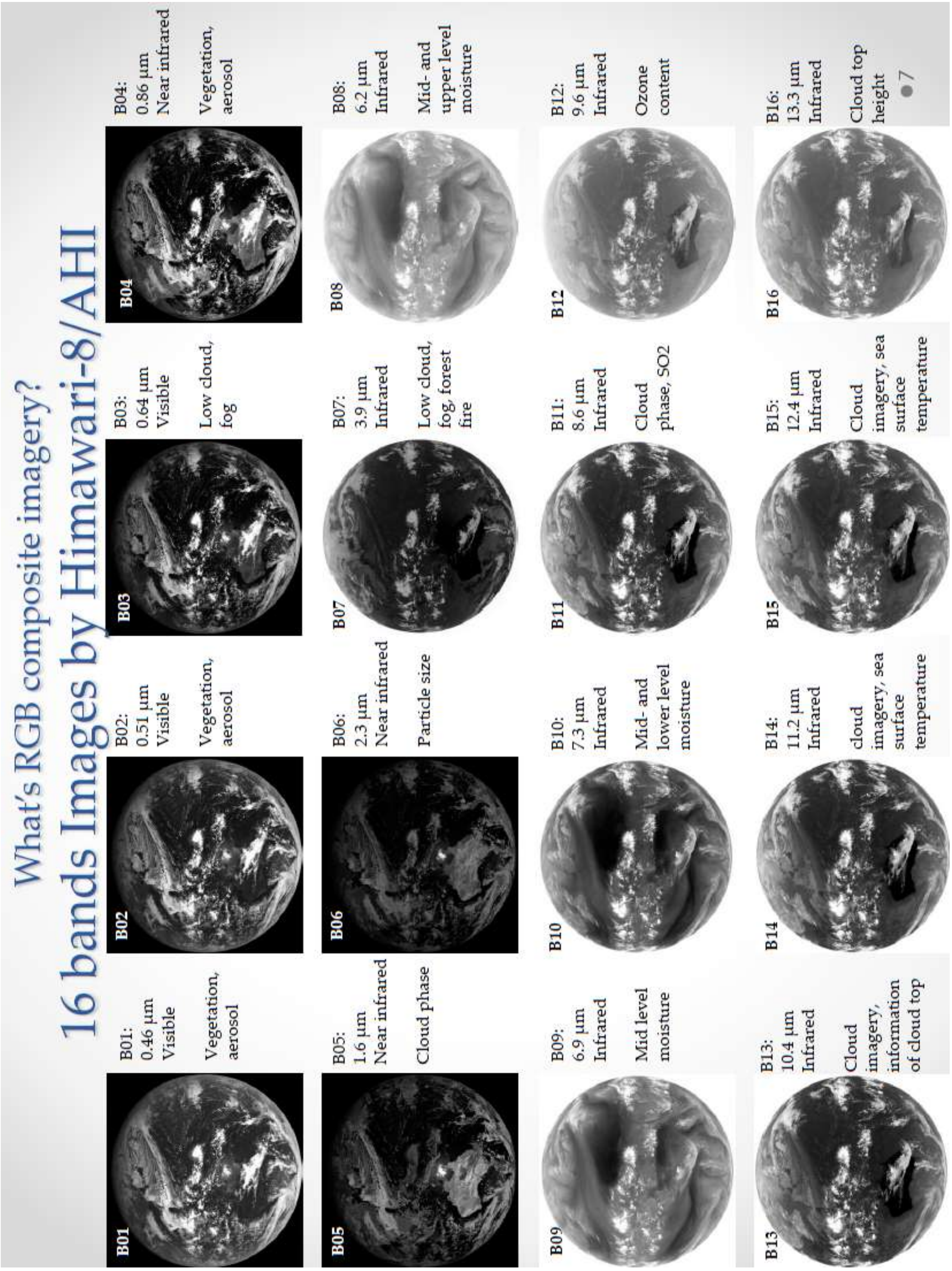
RED = [15 IR]-[13 IR]; GREEN = [13 IR]-[11 IR]; BLUE = [13 IR]





RED = [8 IR]-[10 IR]; GREEN = [12 IR]-[13 IR]; BLUE = [8 IR]




What's RGB composite imagery?
16 bands Images by Himawari-8/AHI
B01
B01: 0.46 µm Visible
Vegetation, aerosol
B02
B02: 0.51 µm Visible
Vegetation, aerosol
B03
B03: 0.64 µm Visible
Low cloud, fog
B04
B04: 0.86 µm Near infrared
Vegetation, aerosol
B05
B05: 1.6 µm Near infrared
Cloud phase
B06
B06: 2.3 µm Near infrared
Particle size
B07
B07: 3.9 µm Infrared
Low cloud, fog, forest fire
B08
B08: 6.2 µm Infrared
Mid- and upper level moisture
B09
B09: 6.9 µm Infrared
Mid level moisture
B10
B10: 7.3 µm Infrared
Mid- and lower level moisture
B11
B11: 8.6 µm Infrared
Cloud phase, SO2
B12
B12: 9.6 µm Infrared
Ozone content
B13
B13: 10.4 µm Infrared
Cloud imagery, information of cloud top
B14
B14: 11.2 µm Infrared
cloud imagery, sea surface temperature
B15
B15: 12.4 µm Infrared
Cloud imagery, sea surface temperature
B16
B16: 13.3 µm Infrared
Cloud top height
7