Detection of overshooting convection using satellite imagery

Lorenzo Labrador and Pete Francis, Met Office

EUMETSAT's Working Group on Convection Workshop. Florence, April 2016

Outline

- Satellite detection of overshooting tops
- Detection of high ice-water content cloud regions: first steps

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Met Office's overshooting tops tool

1. Water Vapour – Infrared Window BrightnessTemperature Difference (Schmetz,1997, Aumann, 2009) WV-IRW BTD

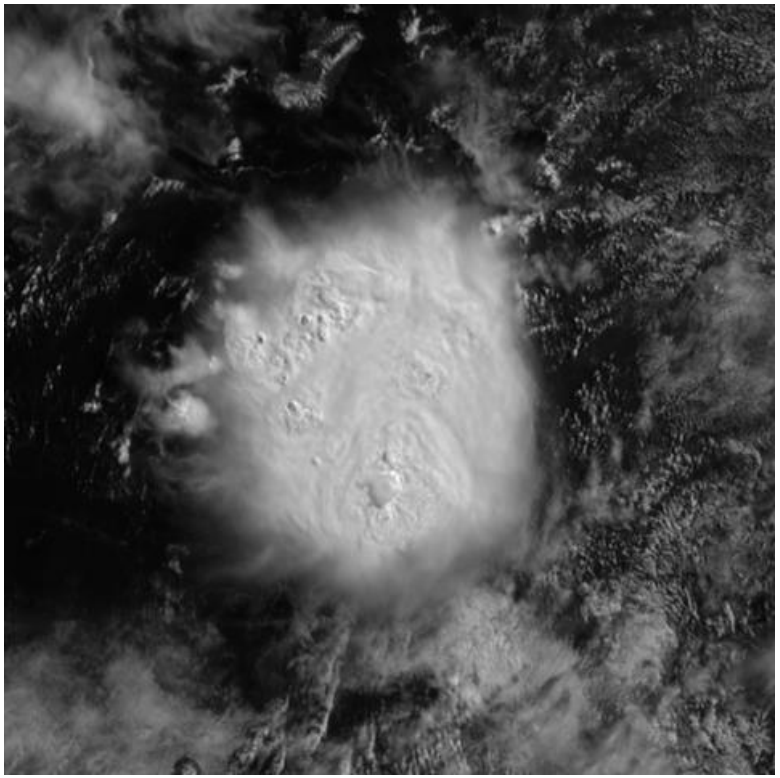
2. Infrared Window texture (Bedka *et al.*, 2010) IRW Texture

Water Vapour – Infrared Window Brightness Temperature Difference

WV-IRW BTD (Schmetz,1997; Aumann, 2009)

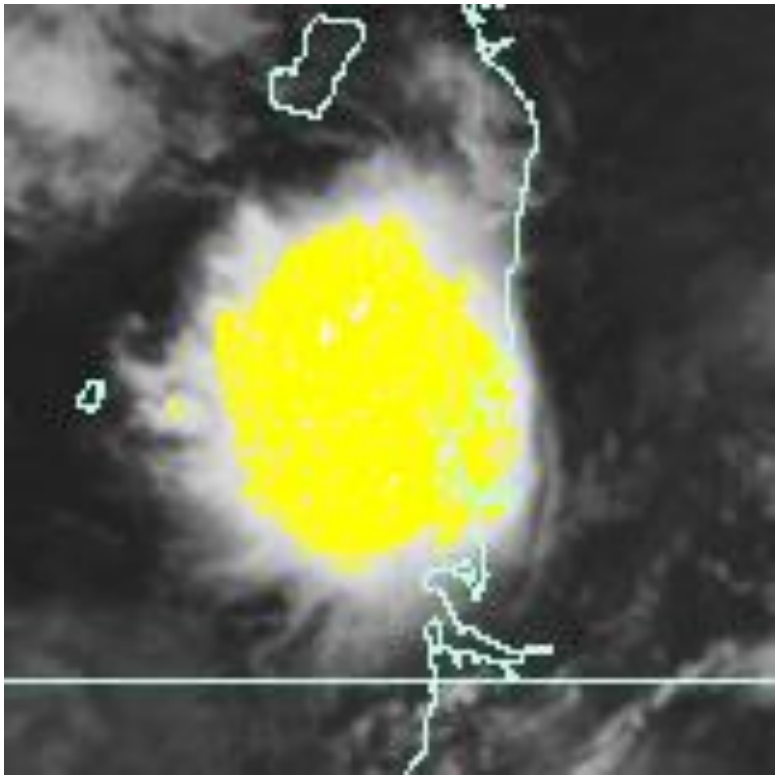
- Positive values imply emission from water vapour above *(i.e. warmer than)* a temperature inversion
- Often identifies OT regions with a spatial extent that is significantly larger than that of commonly observed OTs
- Often produces a significant number of false OT detections

WV-IRW BTD



SEVIRI HRV

9th May 2013, 0845 UTC

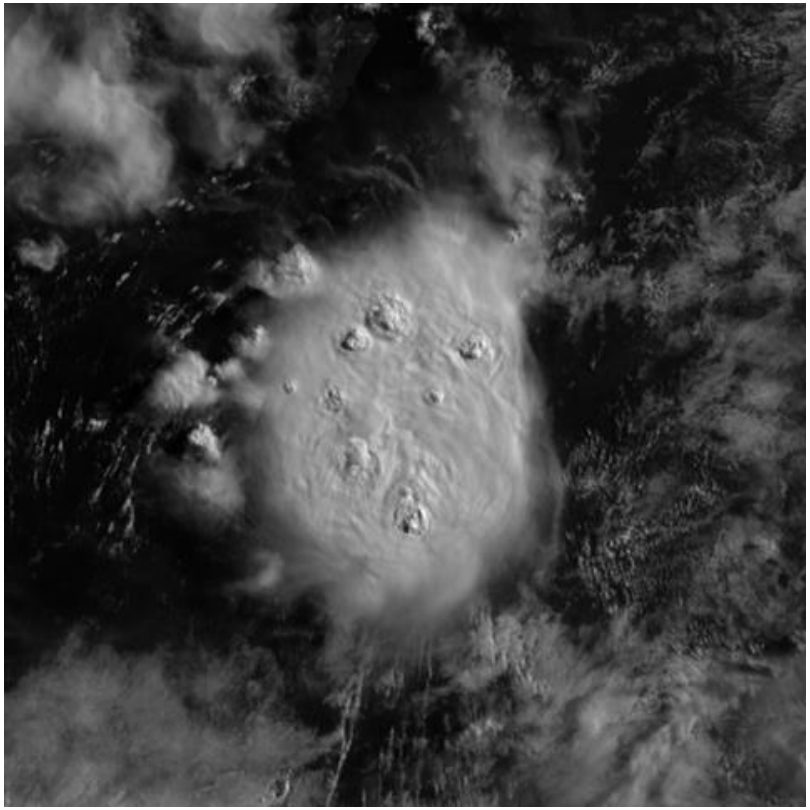


Infrared Window texture

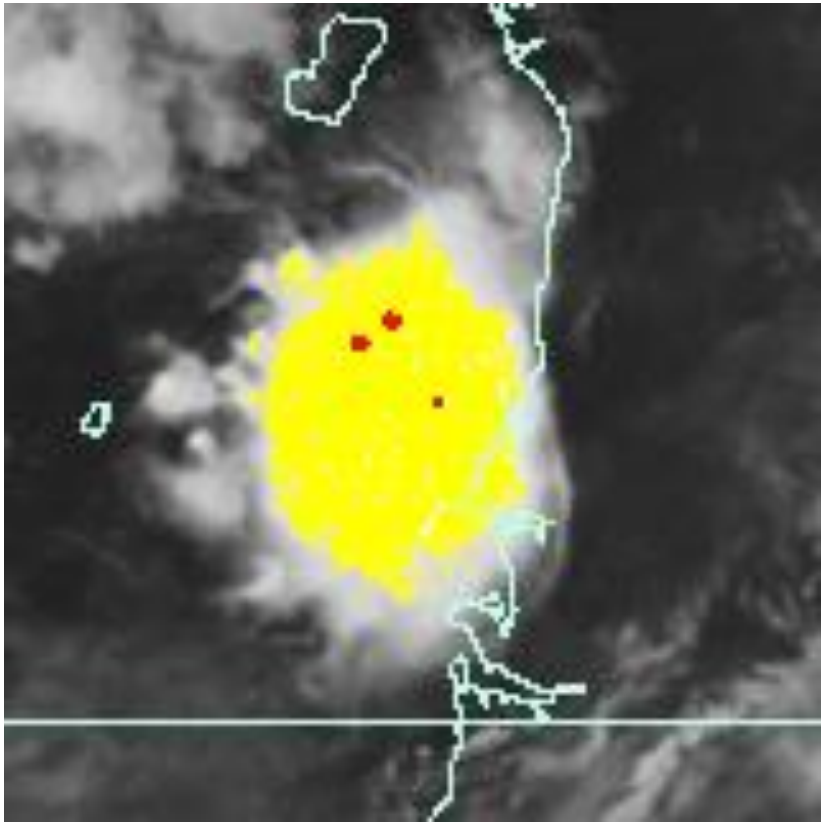
IRW Texture (Bedka *et al.*, 2010)

- Combination of 10.8 μm infrared window channel, an NWP model tropopause temperature forecast, OT horizontal size and brightness temperature criteria
- Looks for a characteristic infrared textural signature
- infrared brightness temperature minima < 215 K
- OT ≤ 15 km diameter

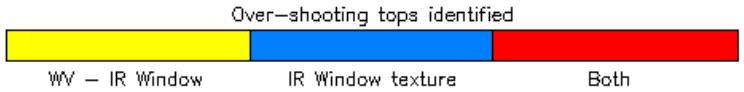
WV-IRW BTD + IRW Texture



SEVIRI HRV



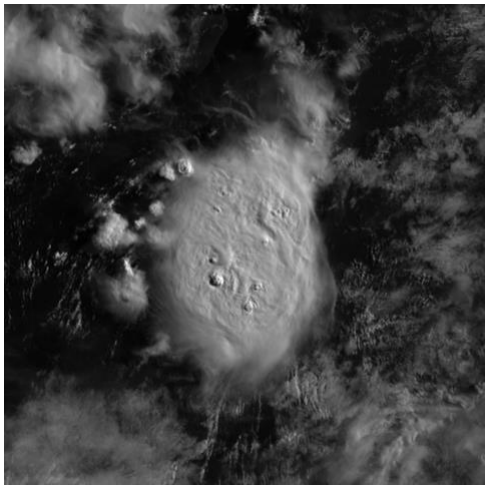
Detected OTs



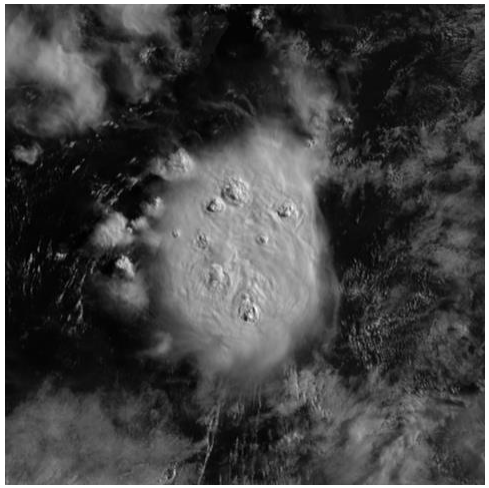
9th May 2013, 0800 UTC

9th May 2013

0745 UTC



0800 UTC



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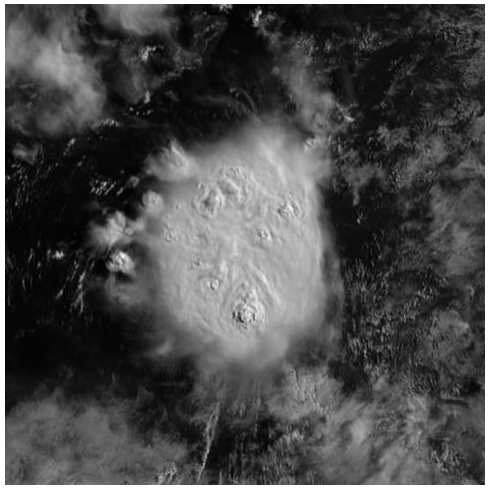
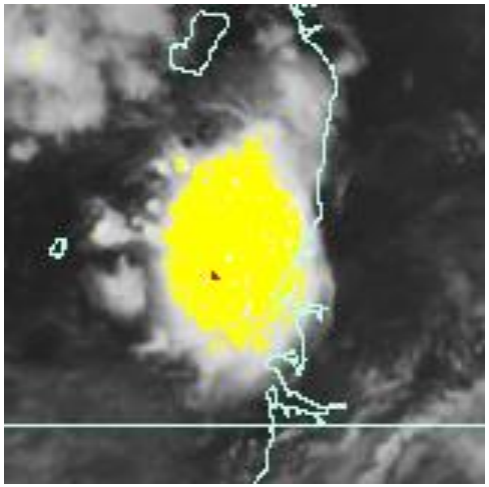
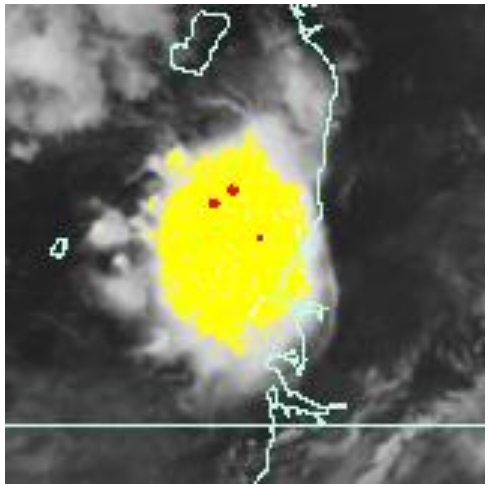
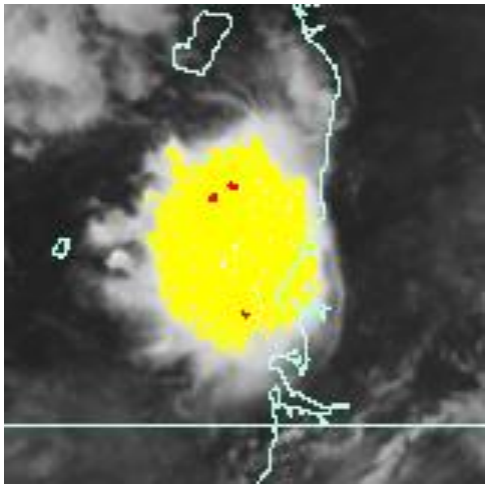
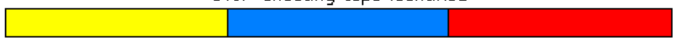




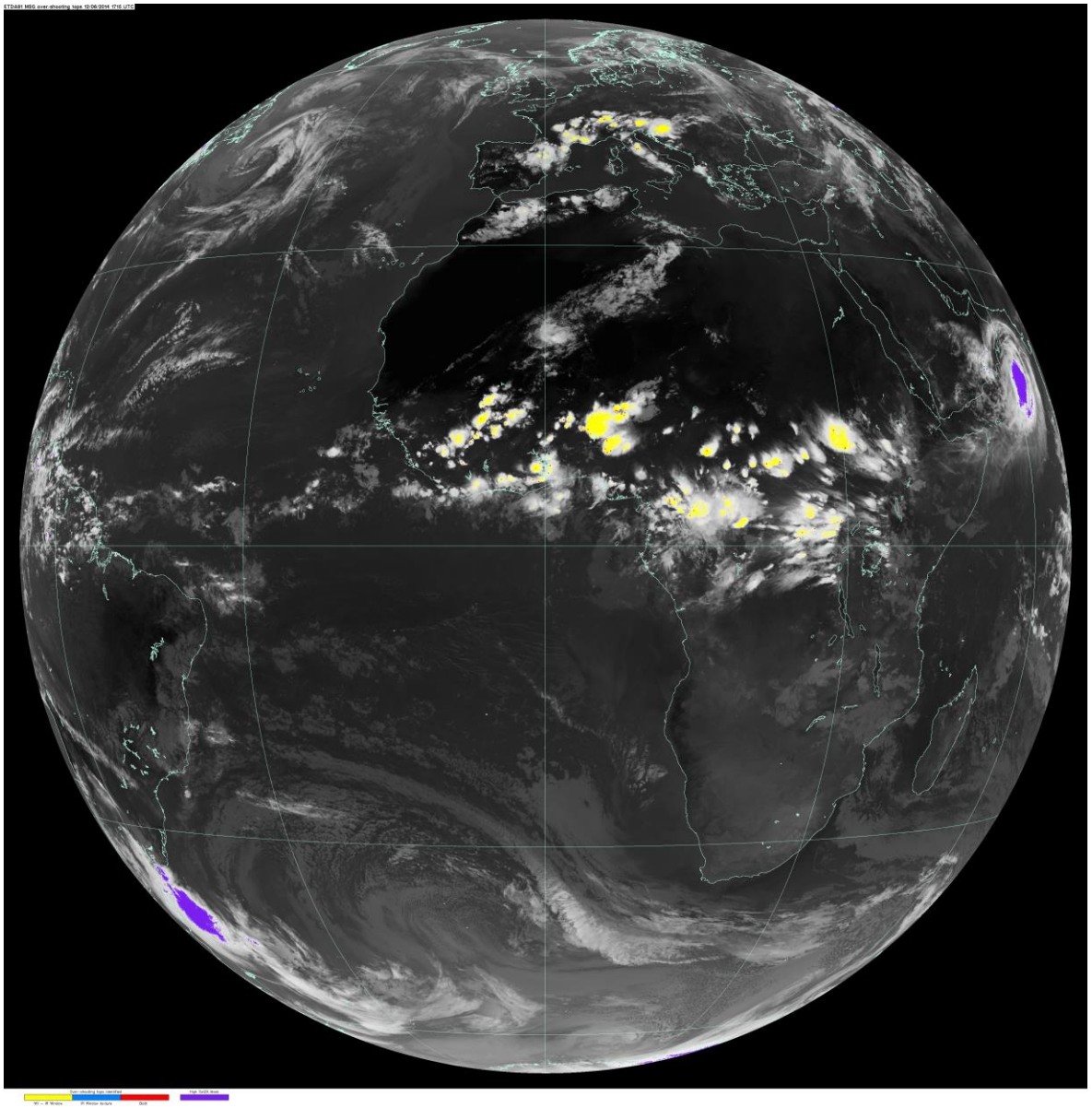




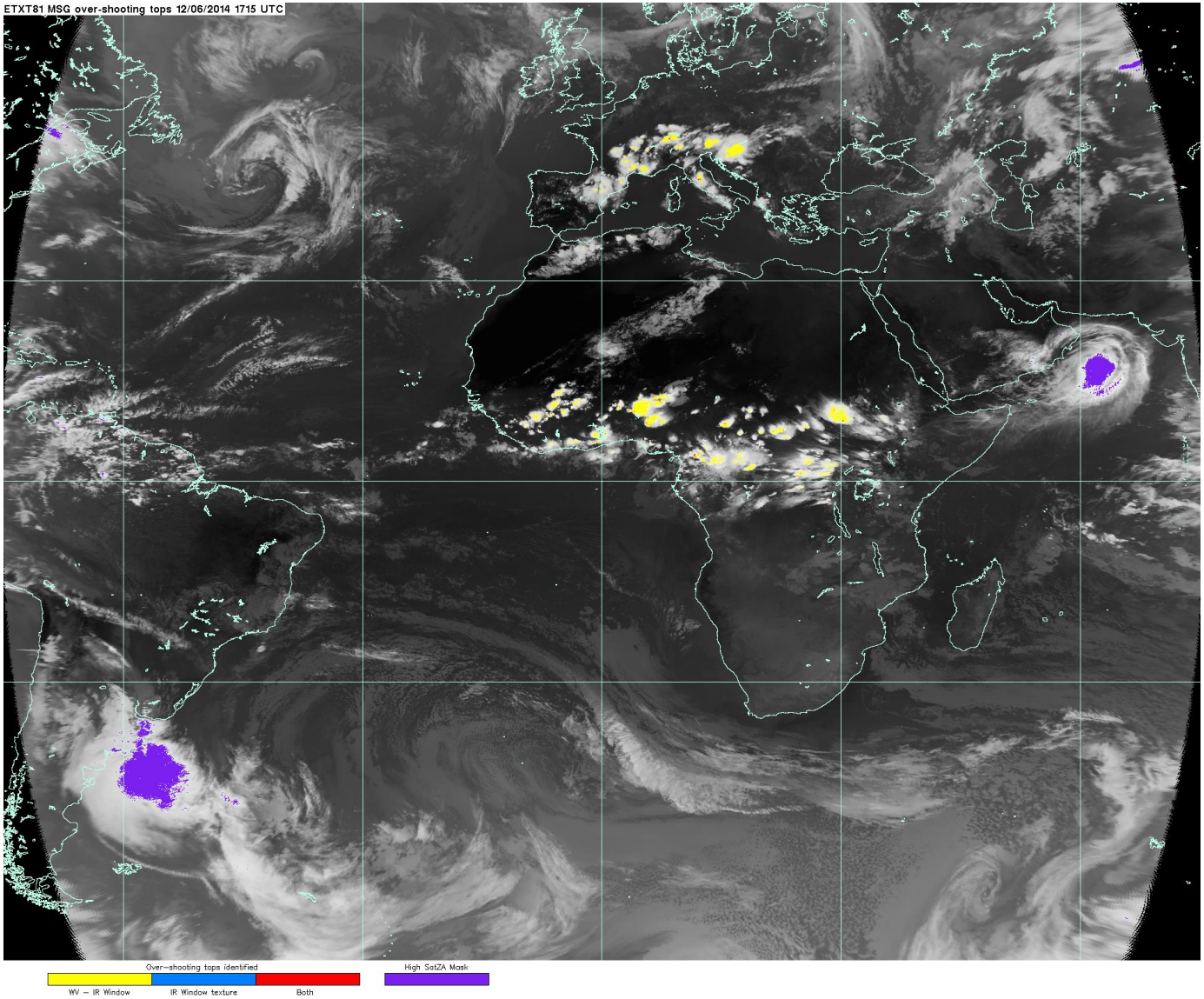
Over–shooting tops identified



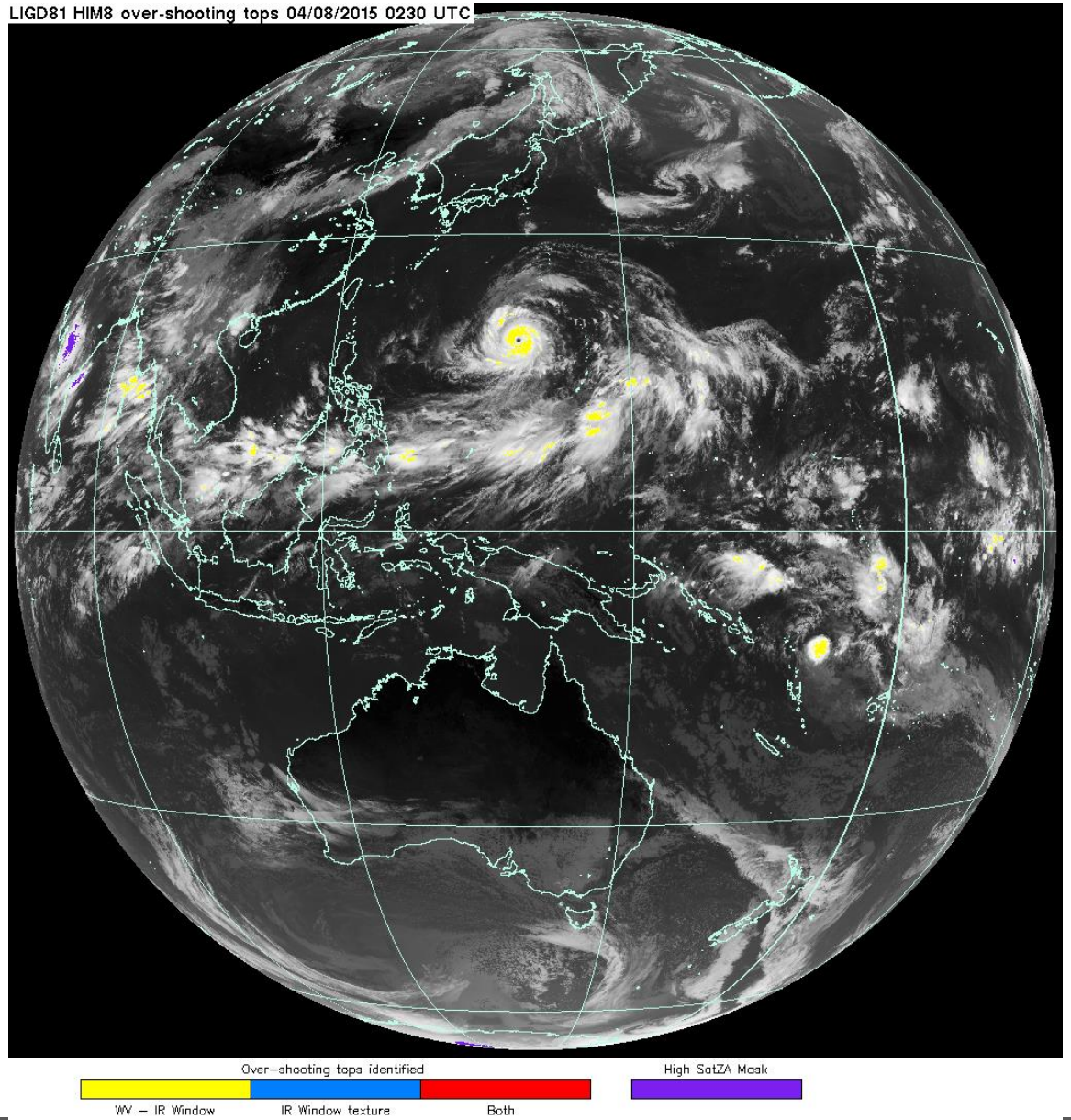
Satellite zenith angle mask



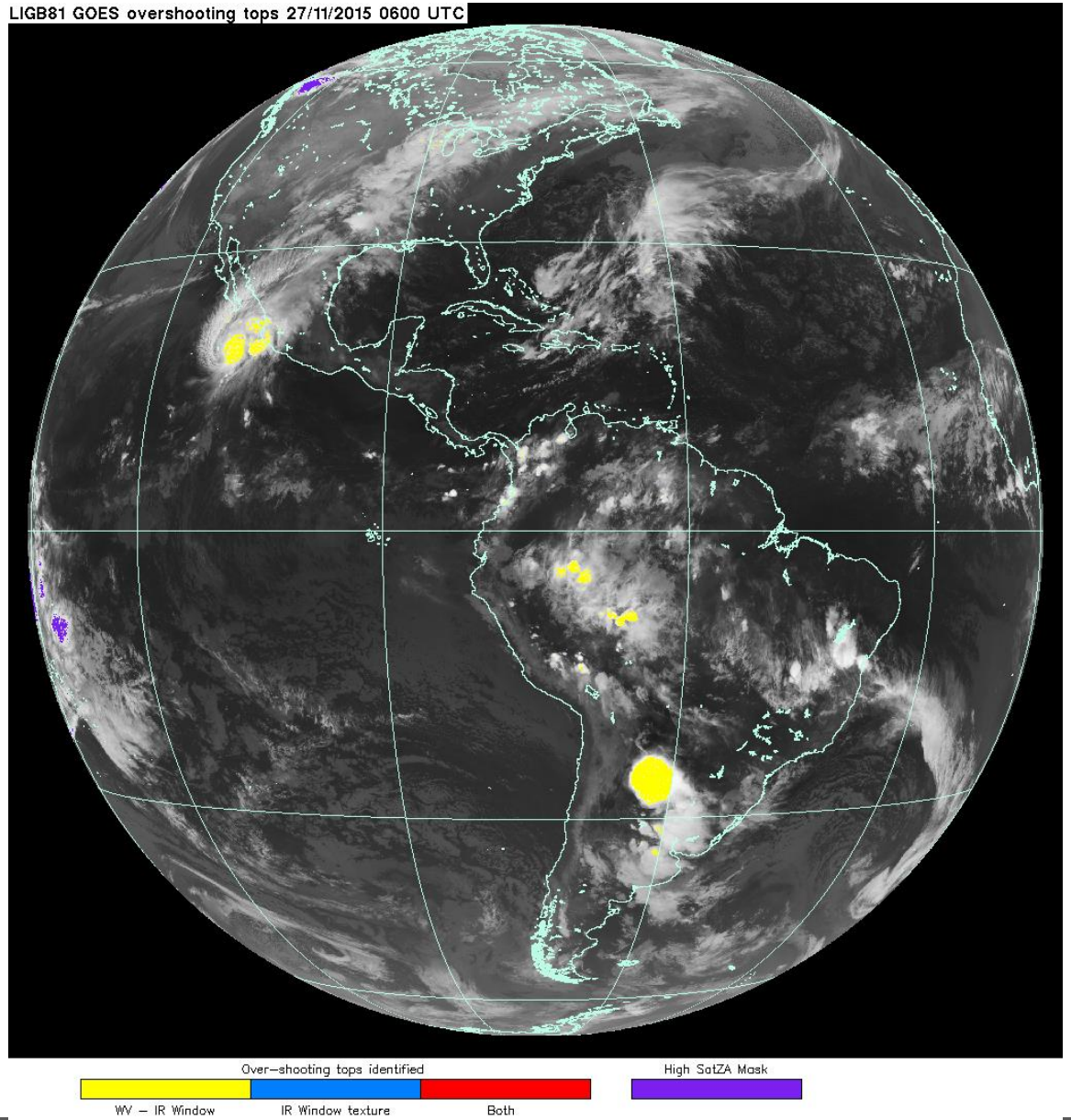
Satellite zenith angle mask



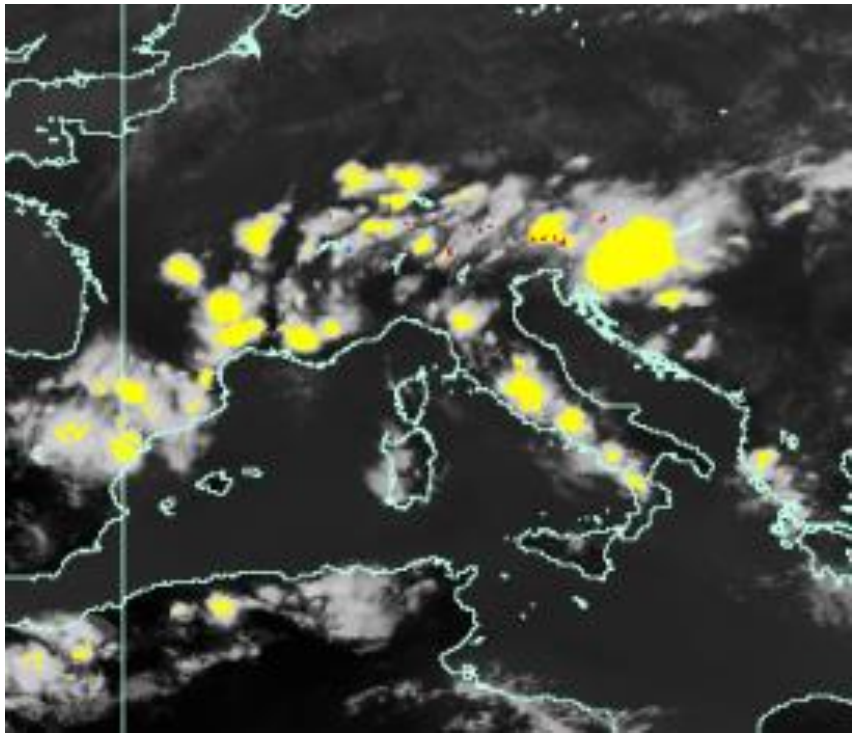
Overshooting tops Himawari 8



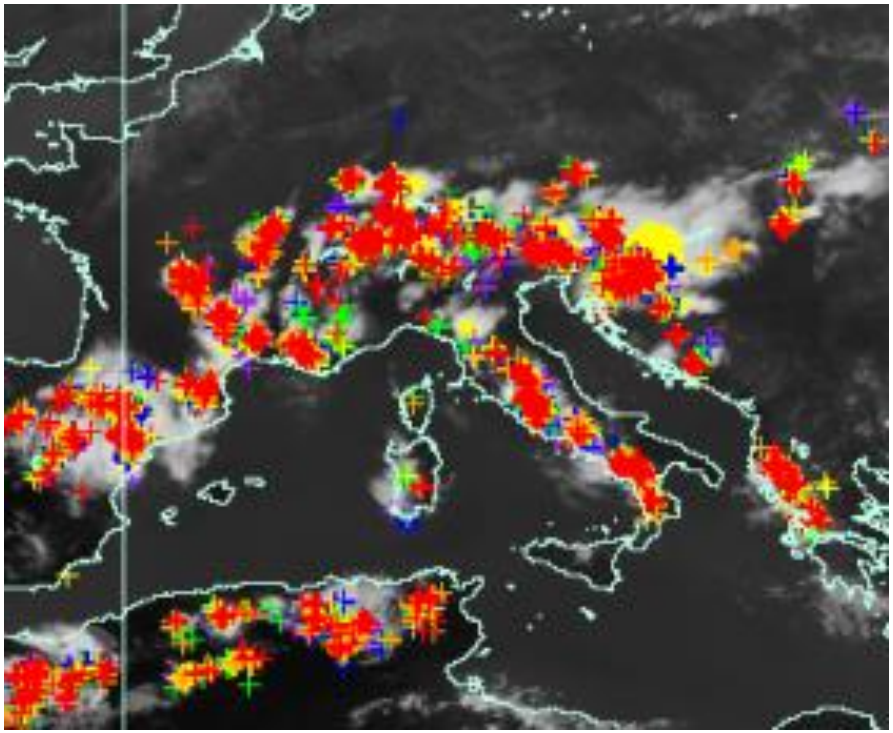
Overshooting tops GOES



Overshooting tops + Met Office's ATDnet lightning strokes



MSG overshooting tops
12/06/2014 @ 1600 UTC



MSG overshooting tops + ATDnet strokes
12/06/2014 @ 1600 UTC

Outline

- Satellite detection of overshooting tops
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High Ice-Water content cloud regions as a threat to aviation

- Thought to be responsible for high altitude ice-crystal icing events

- Icing affects engines, not airframe.

Hypothesis: aircraft flying in regions of high mass concentrations of ice crystals (HIWC). These ice crystals are in a size range that is not detectable to onboard weather radar

- Over 100 recorded events of jet-engine power loss while flying in the vicinity of deep convection

- Events occur from tropics to mid-latitudes

- Events associated with isolated convection up to tropical storm scales (both oceanic and continental convection)

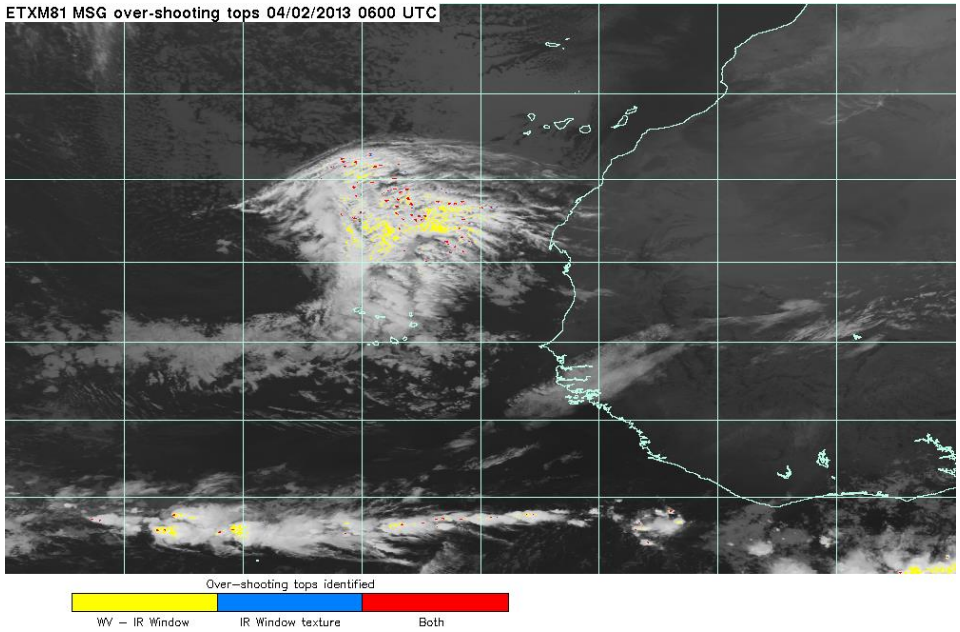
- Low flight-level radar reflectivity on on-board weather radar at location and altitude of engine event (no warning to aircrews)

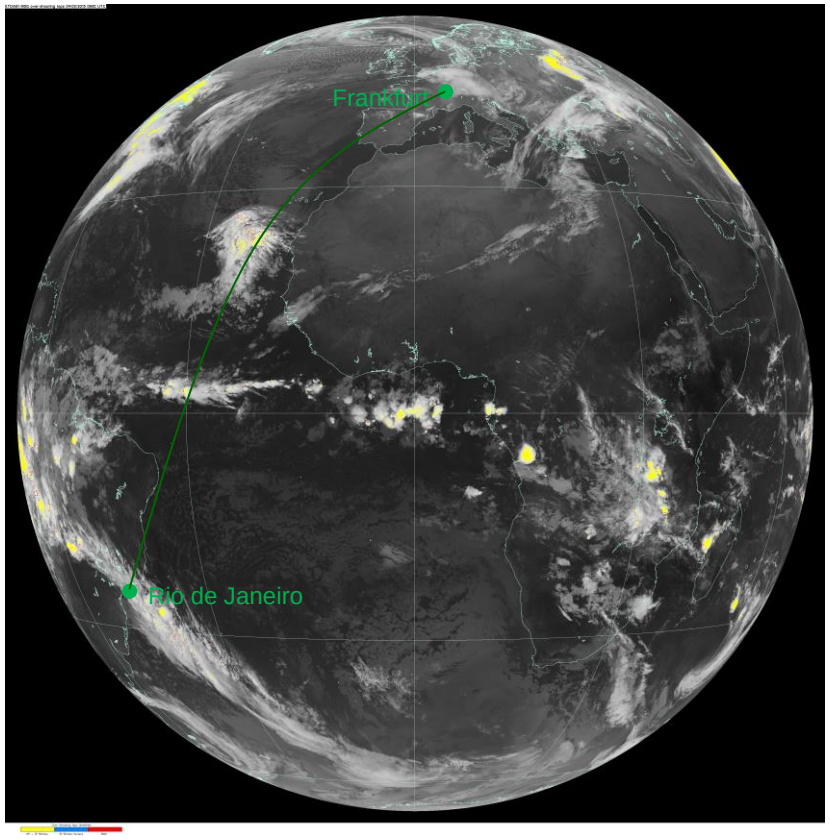
In-service Aircraft for a Global Observing System

www.iagos.org

Using Commercial Passenger Aircraft as a Network of Sensors

BCP2013020323583403: Rio – Frankfurt 0600 UTC, 2013/02/04



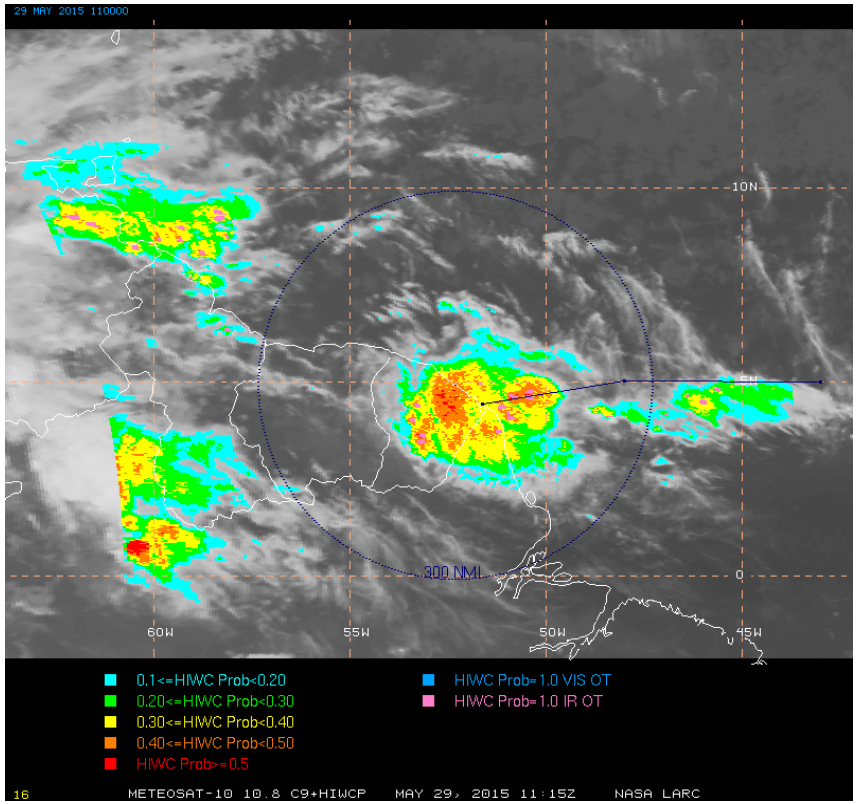


BCP004	BCP2013020323583403	v3	03/02/13	23:59	04/02/13	11:35	11:36	#REF!	Rio de Janeiro	Frankfurt	C: deep ascent profile; Canaries-Cape Verde; big event central Atlantic - major avoidance manoeuvre. Lufthansa also trialling NRT forecasting	4	4	4	Yes	2	1	4	3	7	Yes

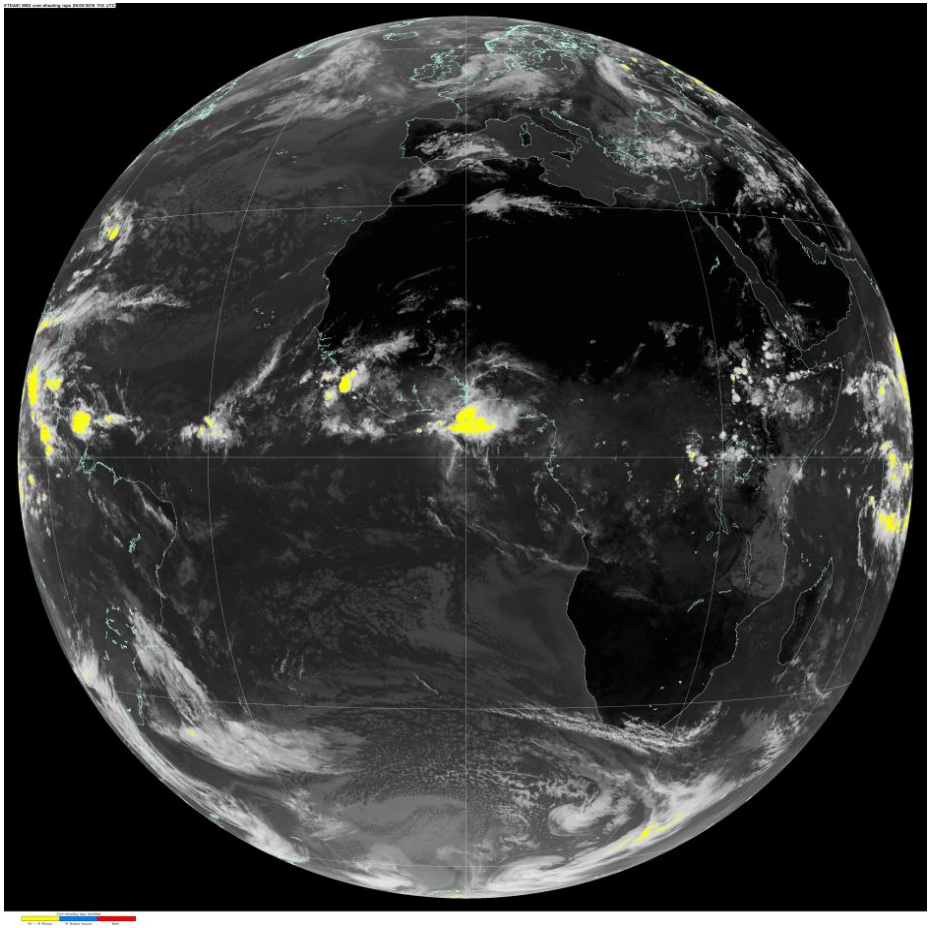
NASA Langley's HIWC Probability tool

- Uses data from in-situ measurements of ice water content in deep convective clouds from field campaigns to calibrate satellite tool.
- Measurements matched in space and time to satellite observed IR window (TIR), WV (TWV) brightness temperature channels.
- Algorithm uses fractional occurrence of HIWC as a function of TIR and TWV to compute probability of IWC > 1.0 g m^{-3}

NASA Langley's HIWC Probability tool

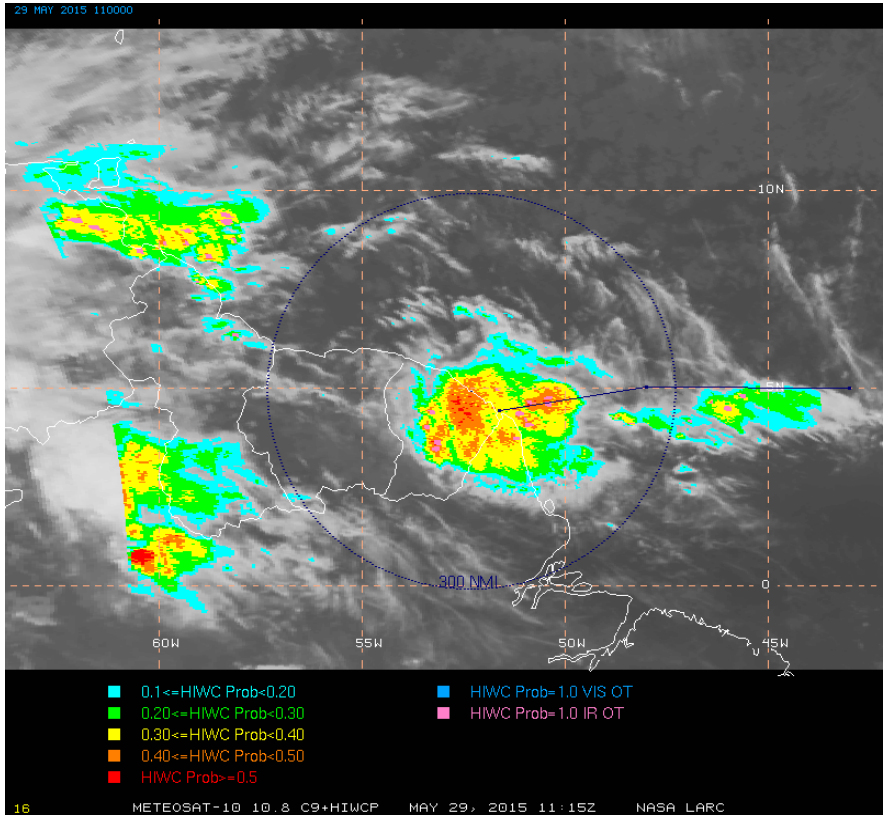


Pat Minnis product



Met Office, OT product

NASA Langley's, MetO's HIWC tool



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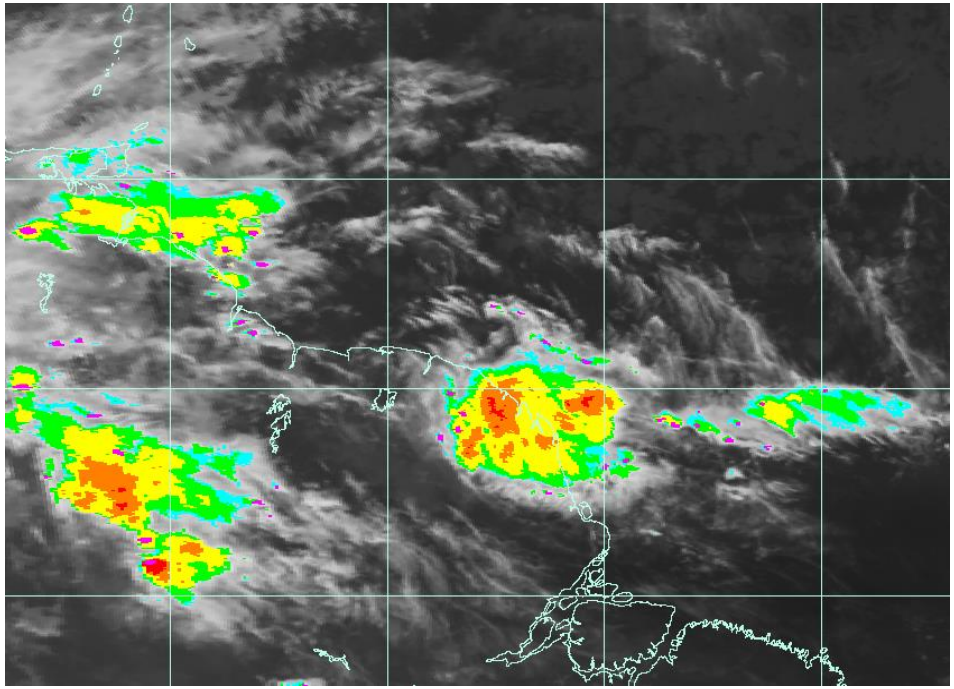


MetO's, Minnis-like product

Conclusions

•MO's overshooting tops detection tool useful. Work in progress.

•Addition of ATDnet lightning stroke information potentially valuable.

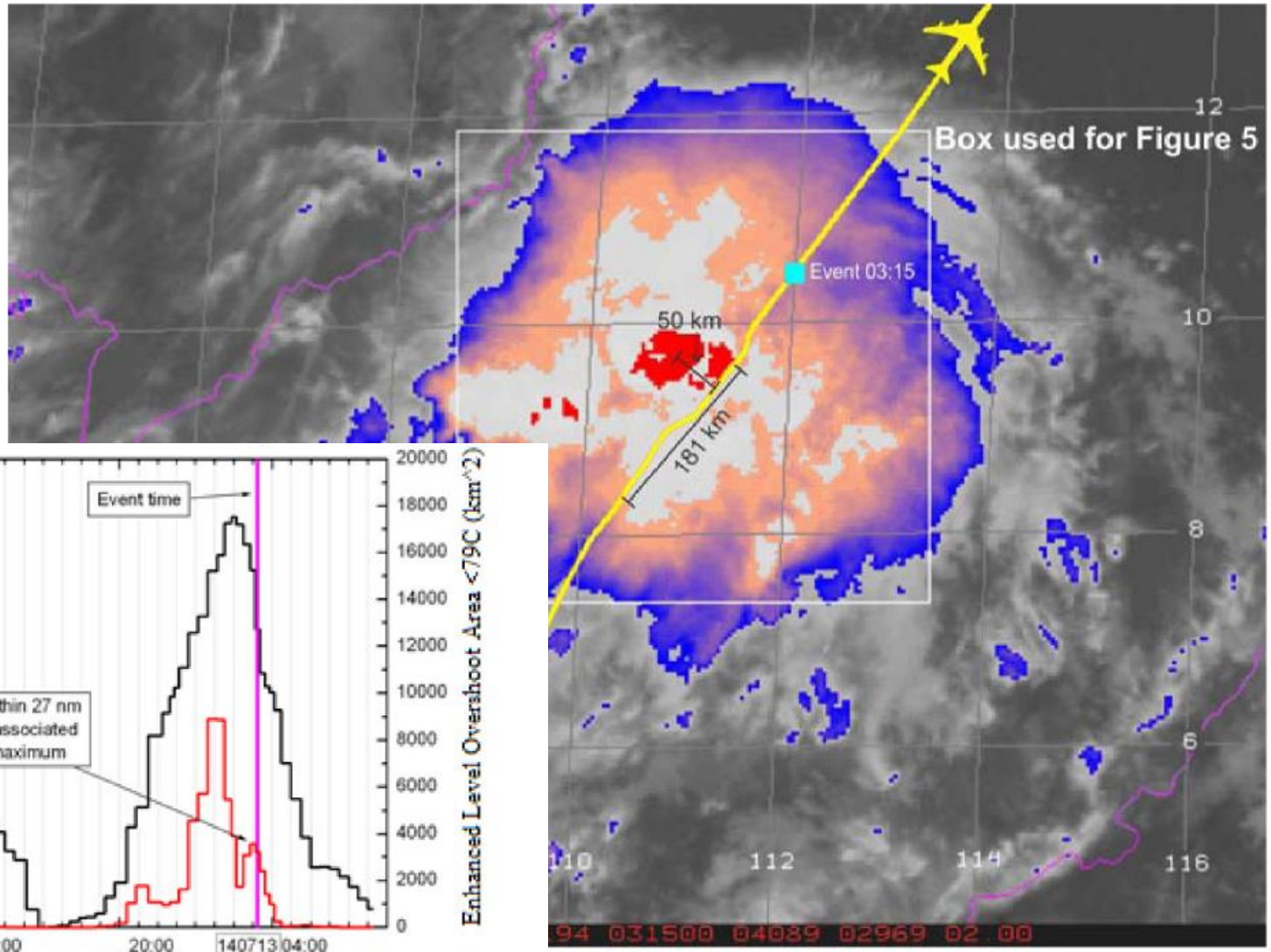
•High altitude ice-crystal icing, high ice-water content regions: many unanswered questions, work on satellite-based detection still in early stages

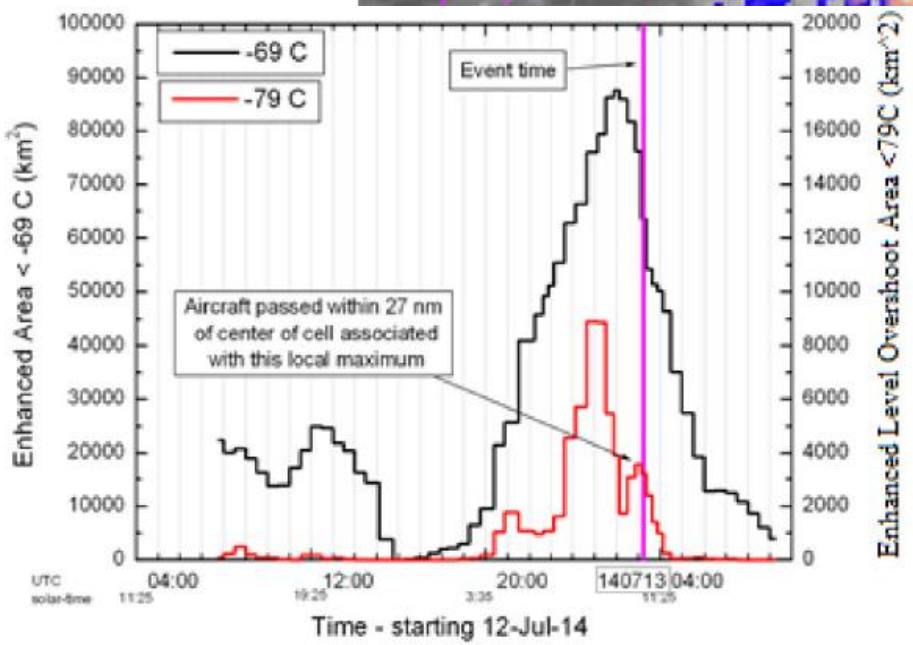
•Need "truth" to validate satellite derived-products

•IAGOS database of potential events underway

•Plans to start developing short-lead (0-1 hour) nowcasting tool

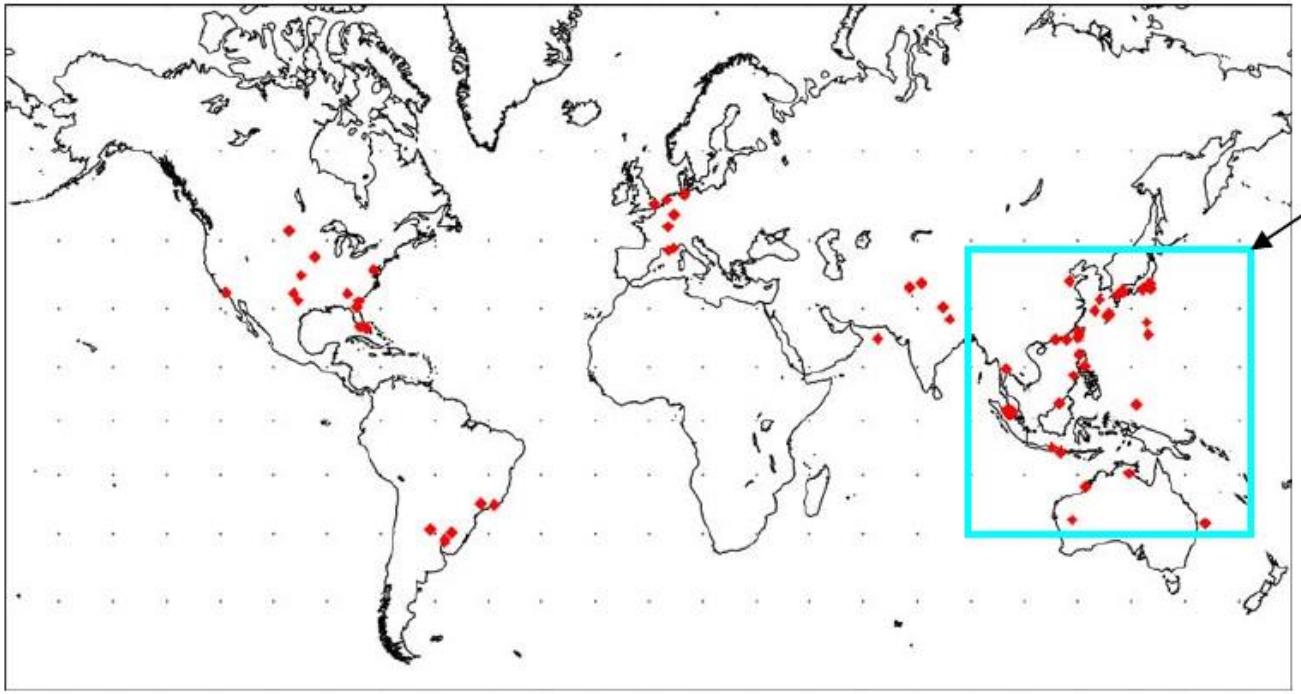
HIWC encounter: 13 July 2014





Figures from Bravin *et al*, 2015

HIWC as a threat to aviation: location



Reported events prevalent in southeast Asia/ Australasia

The way forward

•Develop a sa shooting tops Tool + existin + in-situ meas

•Keep abreas mote sensing) in other instit A)

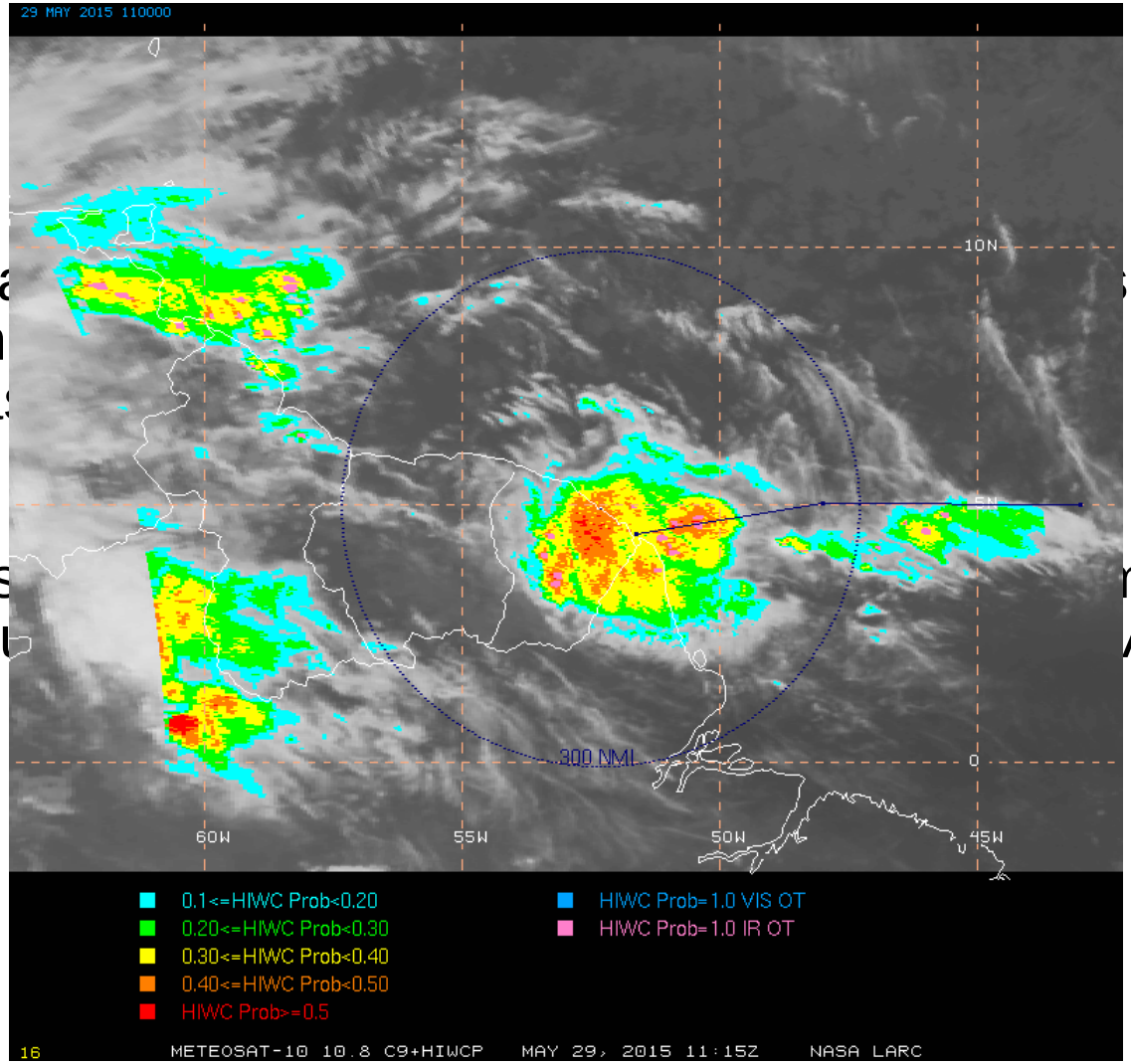
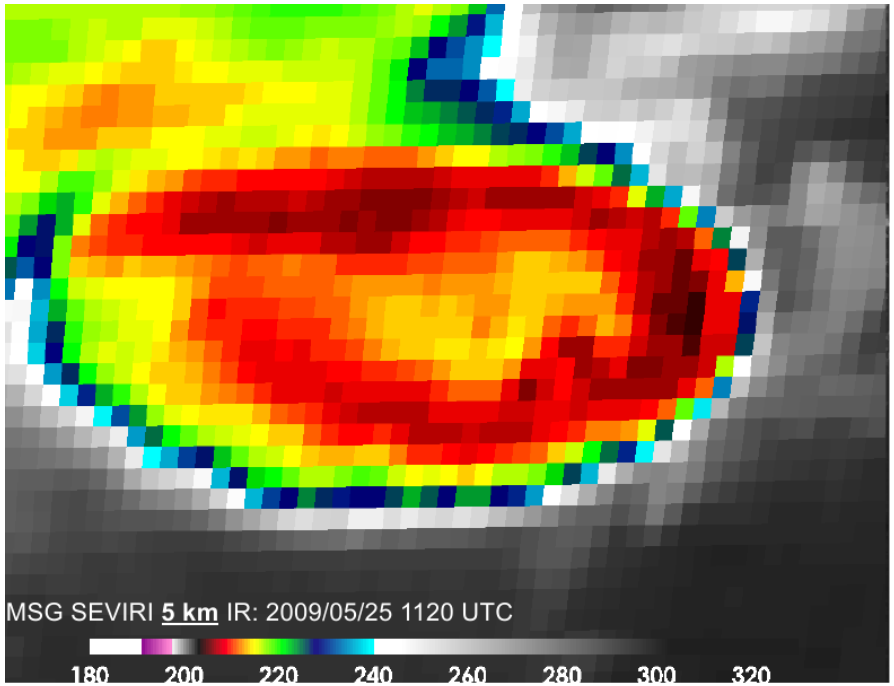
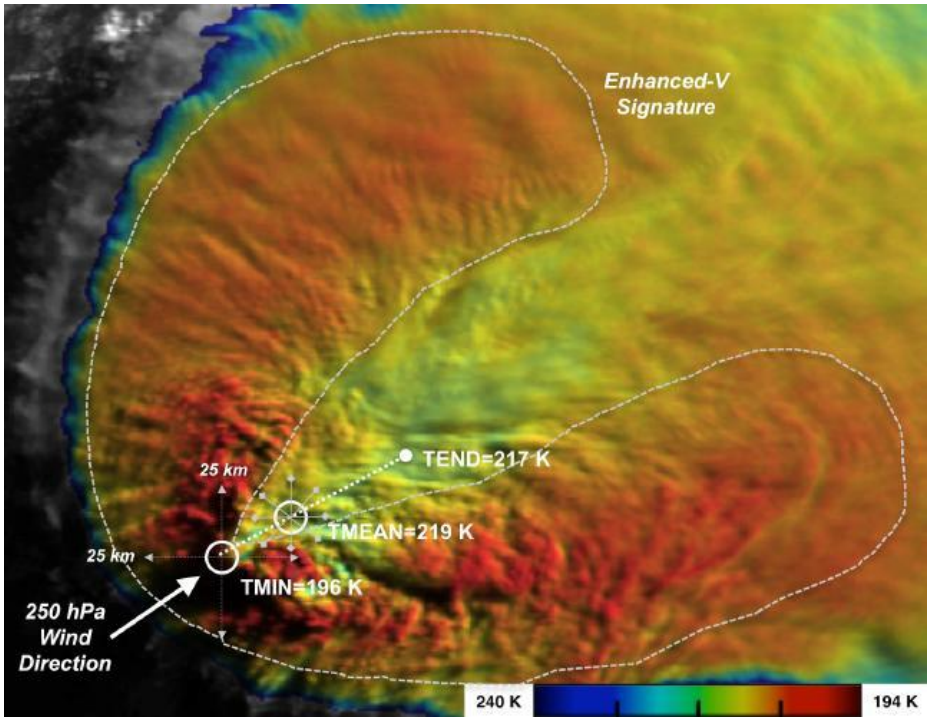


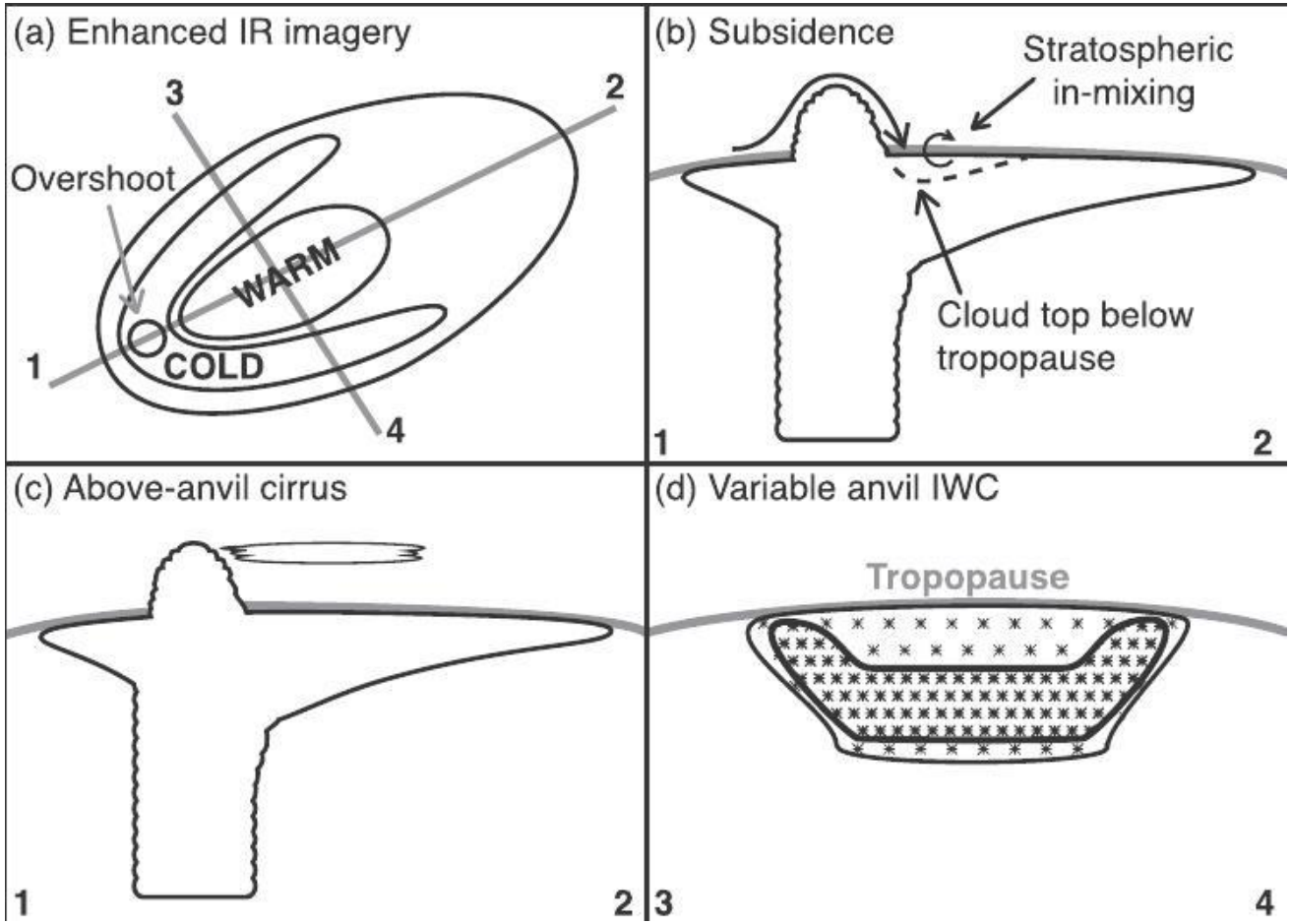
Image:NASA (http://cloudsgate2.larc.nasa.gov/cgi-bin/site/showdoc?docid=22&lkdomain=Y&domain=FEXP_HIWC_2015_IMG_OTP_MSG)

HIWC regions, cold cloud rings, enhanced “V” features





HIWC regions, hypothesis



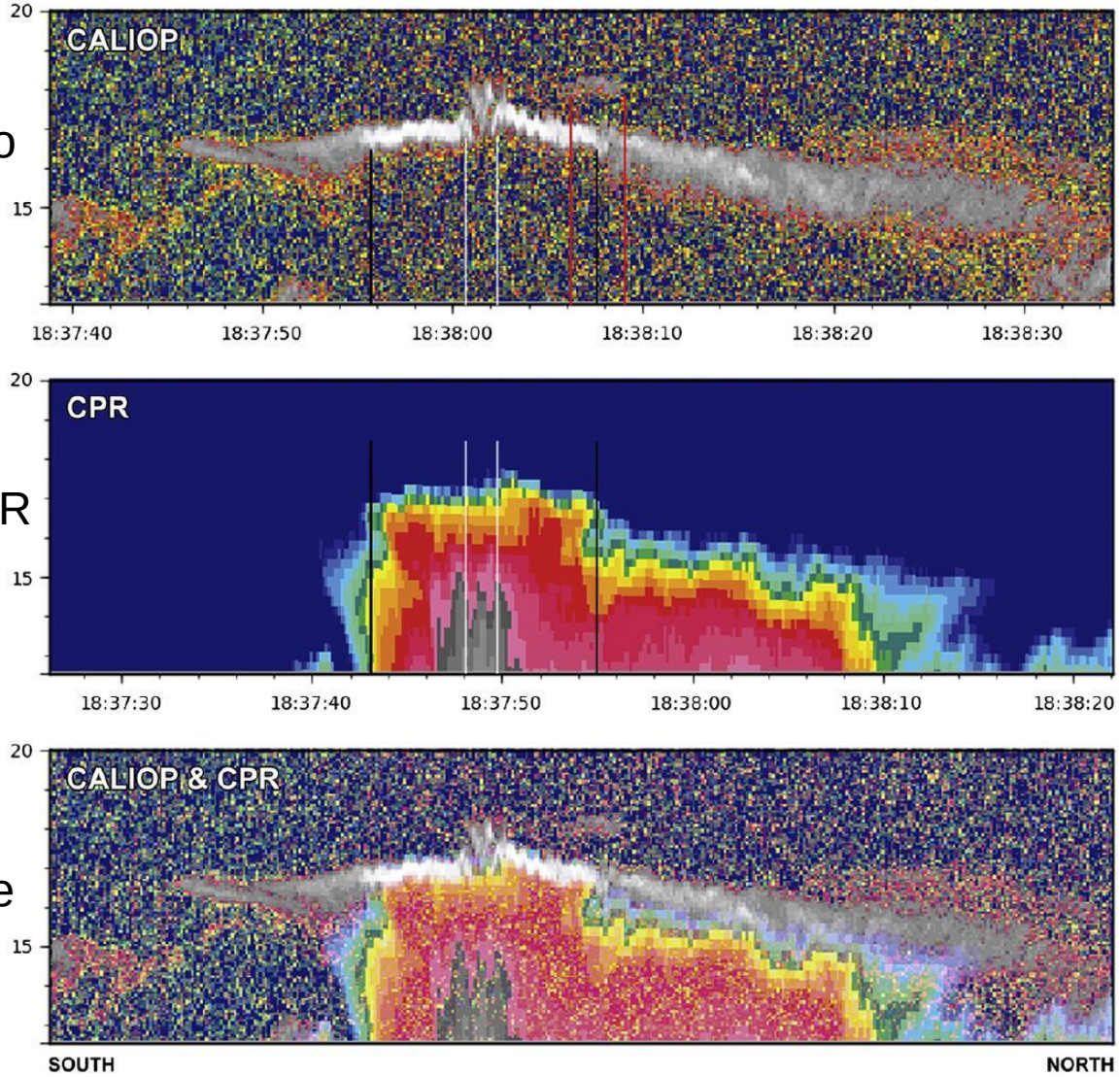
From Homeyer, 2013

HIWC, satellite observations. Brazil 22/12/2007

Calipso

CloudSat CPR reflectivity

composite

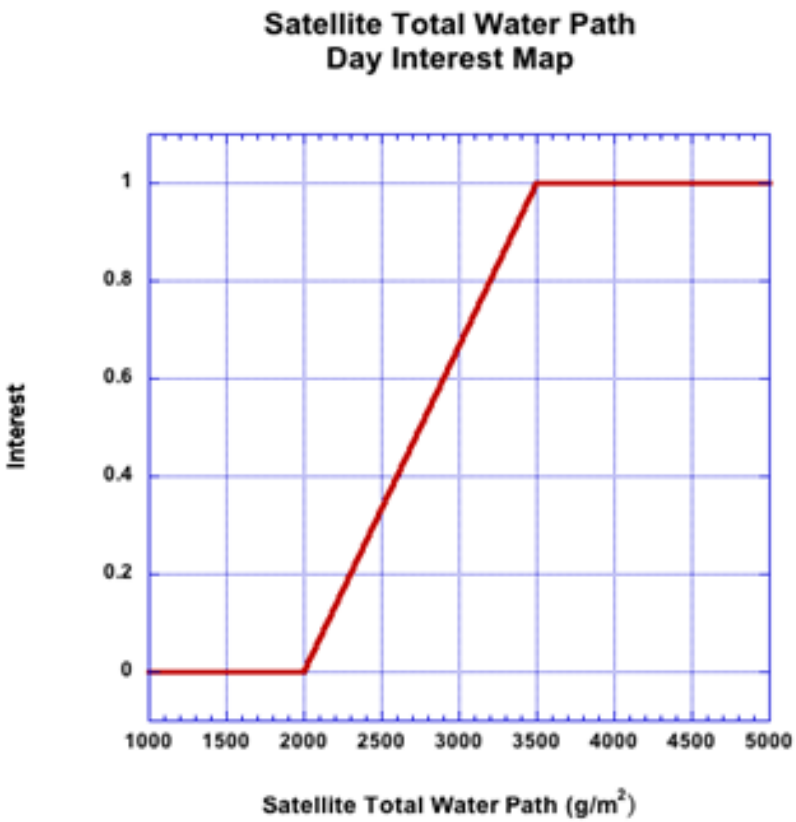


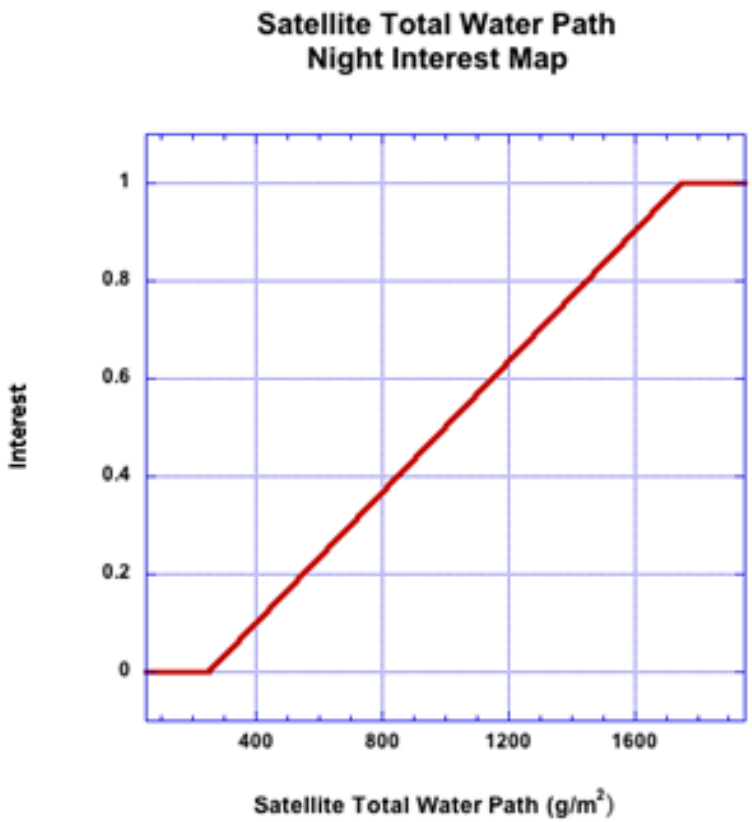
From Setvack et al, 2013

NCAR's Algorithm for the Prediction of HIWC Areas (ALPHA)

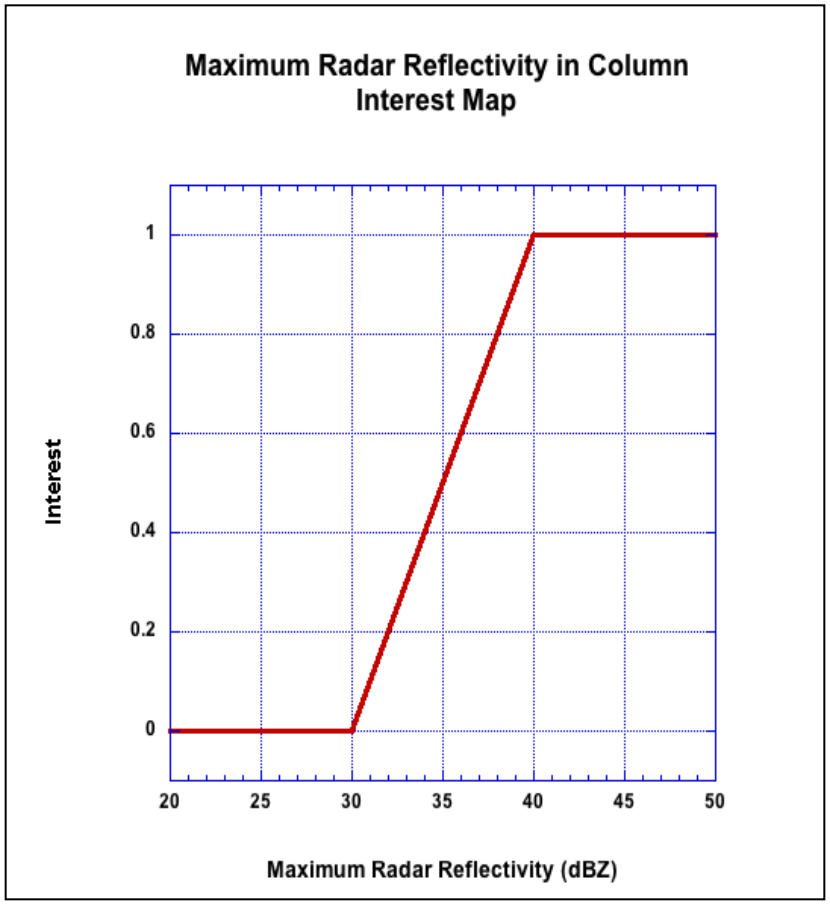
- Uses existing knowledge of high ice water content regions (HIWC) to estimate the likelihood of these conditions occurring for a given location
- Existing knowledge originally derived from (few) engine events and statistics published by Mason and Grzych
- Applies fuzzy logic to blend input data to maximize strengths and minimize weaknesses of each data set
  - Membership functions characterize the relationship of each variable to the possibility of HIWC conditions

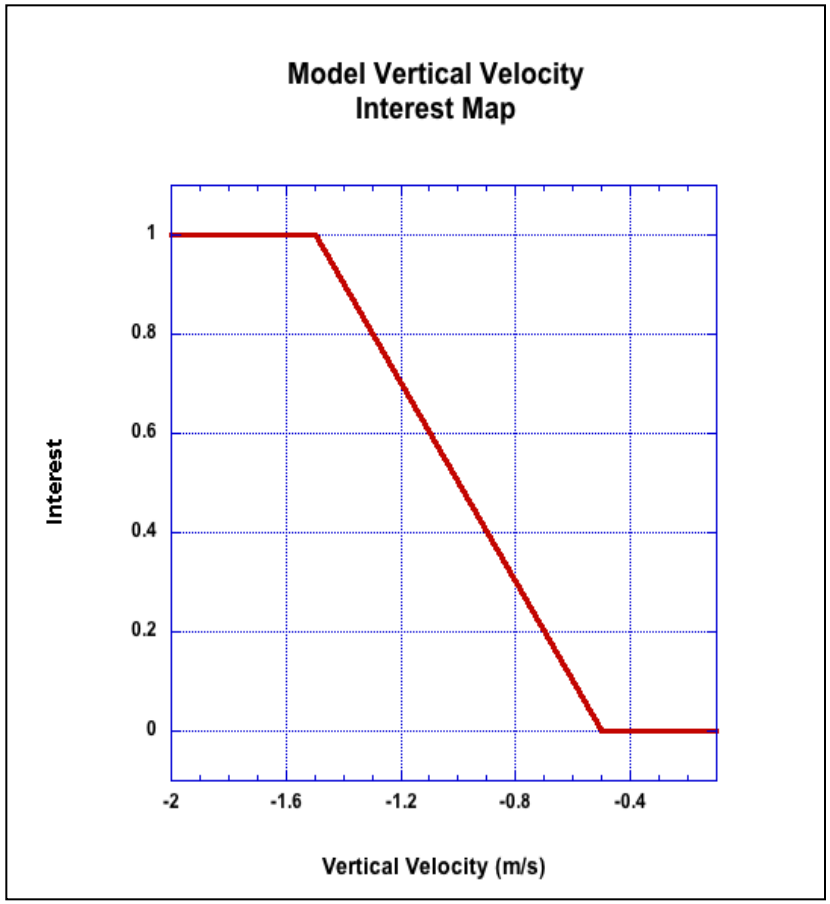
ALPHA membership function, satellite total water path



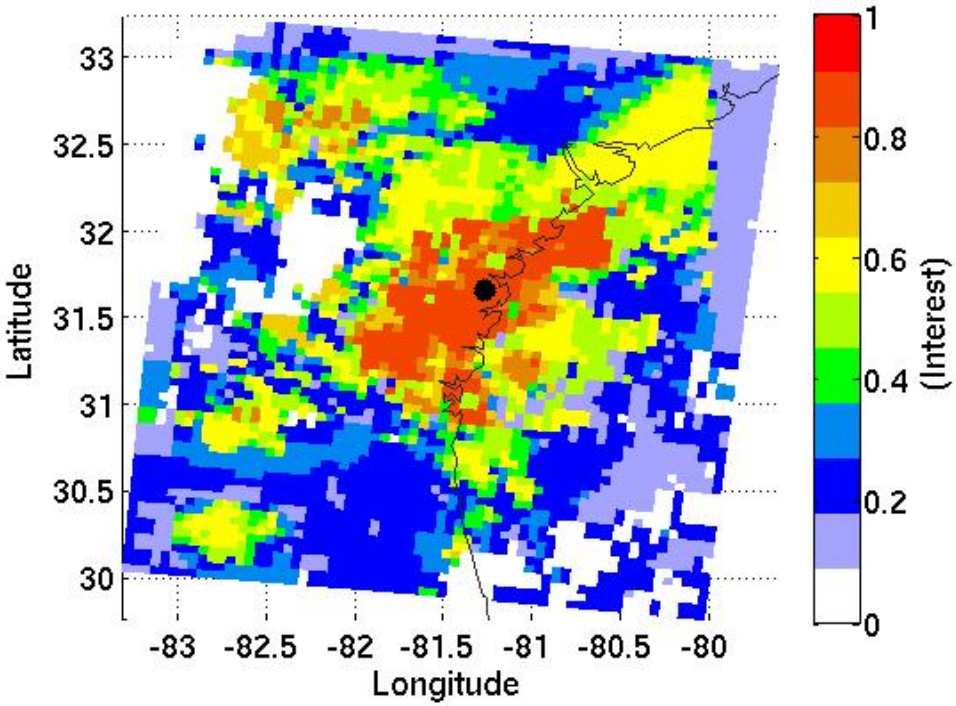


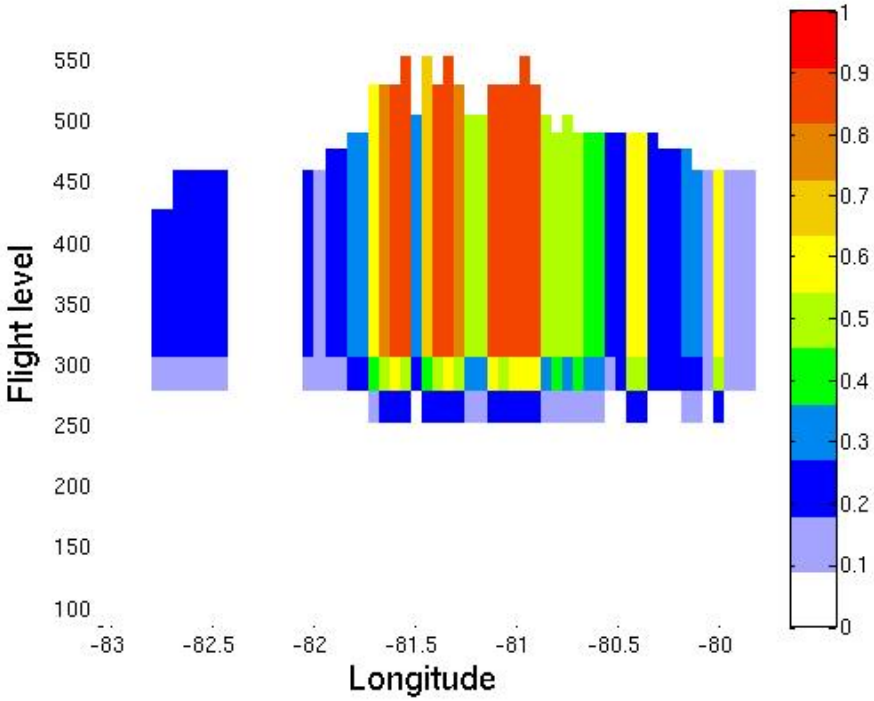
ALPHA Membership Function, radar reflectivity, model vertical velocity



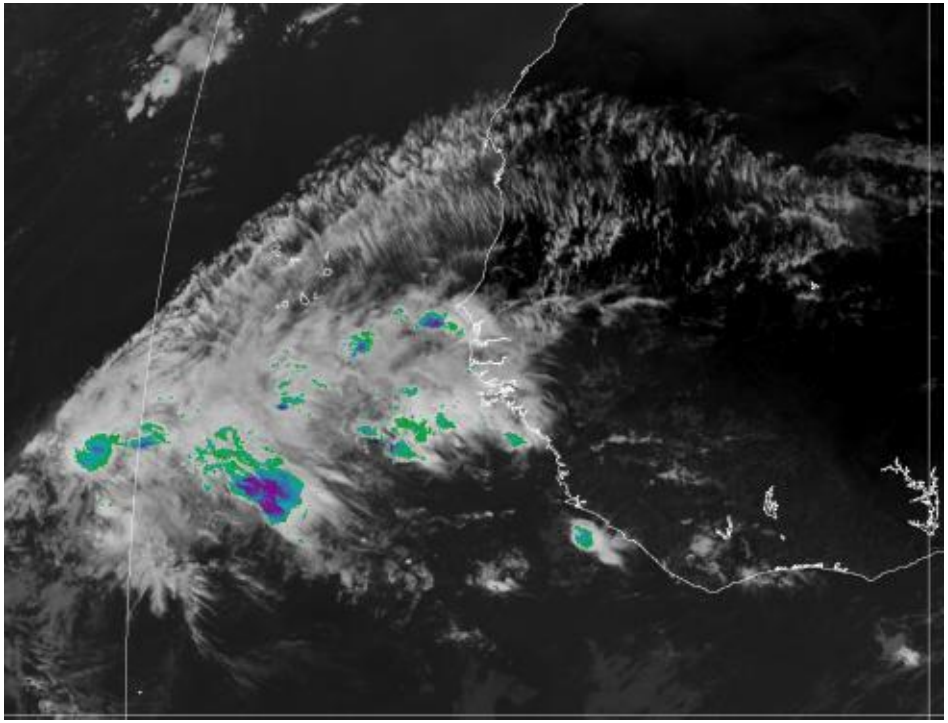


ALPHA experimental product

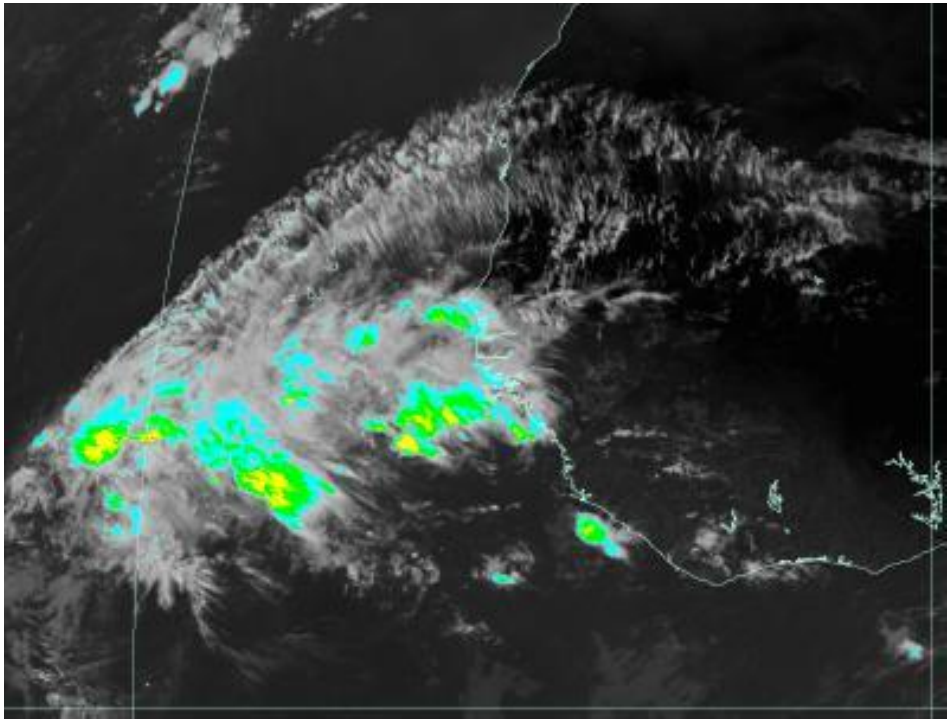




M.O.’s ALPHA-based method



MetO’s ALPHA-like product



MetO’s Minnis-like product

Detection challenges

- No obvious way to detect HIWC/low weather radar reflectivity areas with current remote sensing

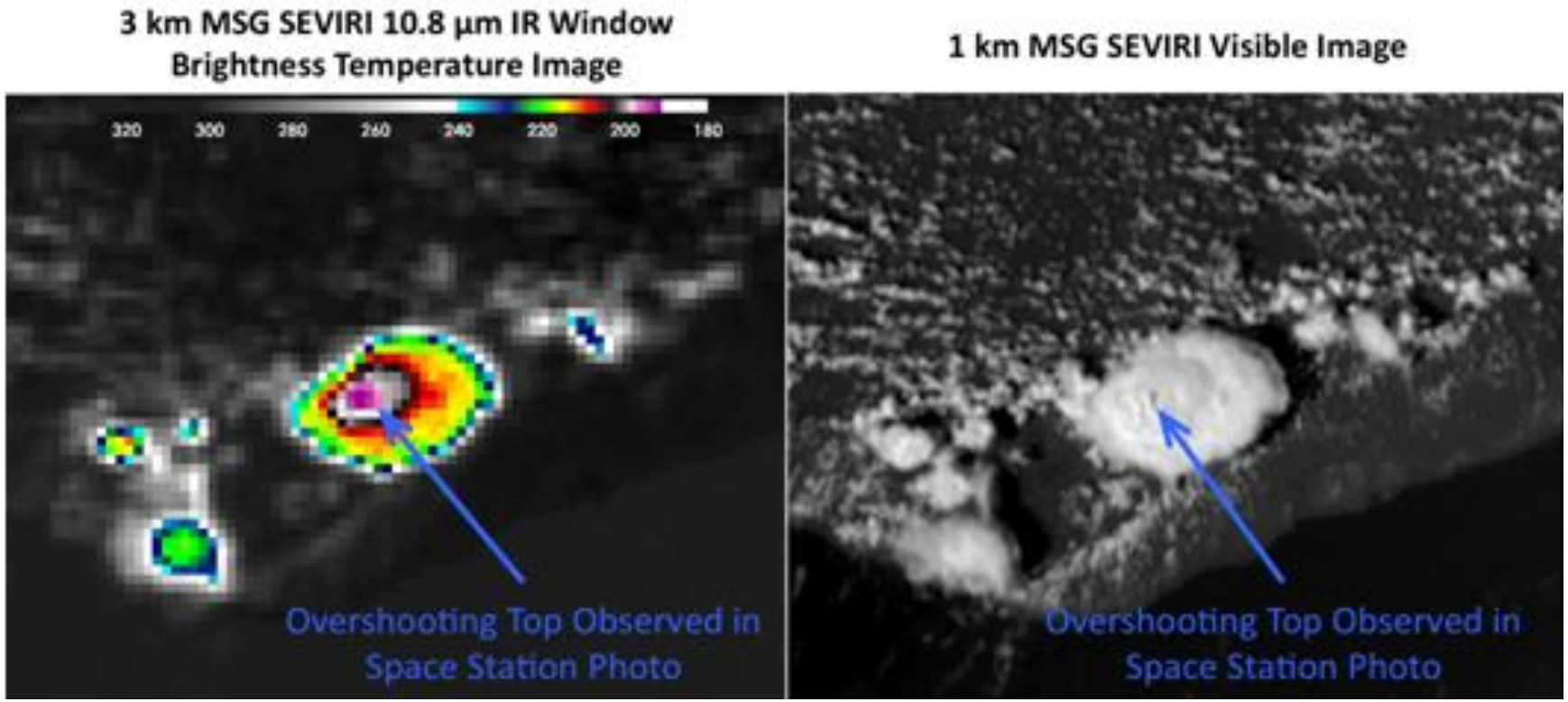
- Areas of deep convection responsible for events can have relatively short time scales. Cannot be precisely predicted by models

- Size of ice crystals in HIWC events not ascertained as of yet

Signature of idealised OT in infrared imagery

ISS photograph,
West Africa

5 February 2008



K. Bedka (CIMSS)

Deep convection, threats to aviation

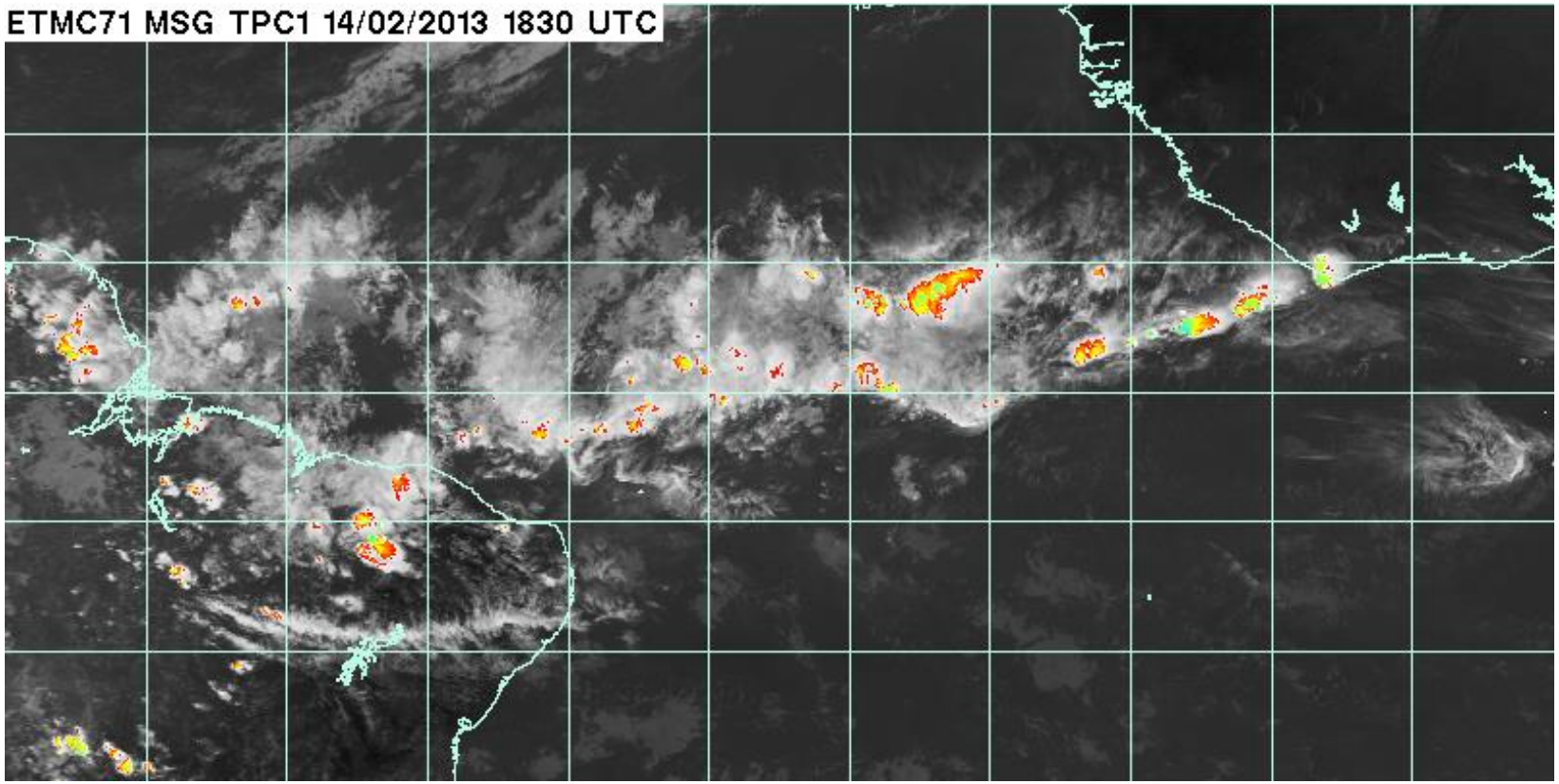
Phenomena:

- Microbursts
- Overshooting tops
- Cold cloud rings, enhanced-V features
- High ice-water content (HIWC) clouds

Threats:

- Severe turbulence
(vertical air motions of ~15-20 m s^{-1})
- Airframe, engine icing
- Poor visibility
- Loss of control

WV-IRW BTD



14th February 2013, 1830 UTC

(all coloured pixels have a positive BTD)

Satellite-imagery based methods for detection of overshooting tops

SEVIRI(*) Brightness Temperature Difference method:

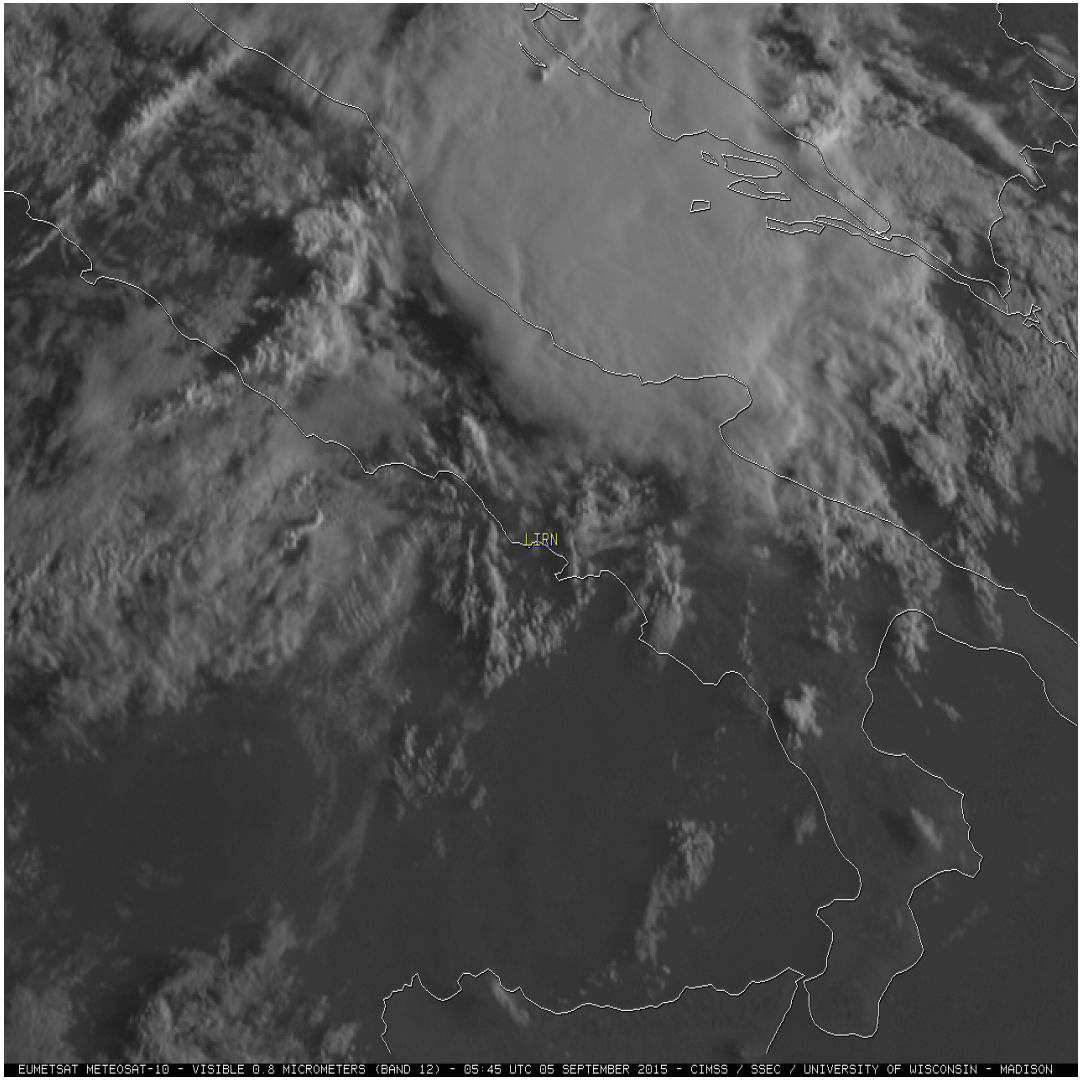
•Look for signatures where very cold cloud tops yield radiances are warmer in a WV absorption band than in an IR Window (IRW) channel: WV - IRW BTD

• SEVIRI channels: 6.2 μm (WV), 10.8 μm (IRW)

(*)Spinning Enhanced Visible and InfraRed Imager on Meteosat Second Generation (MSG) satellite

Overshooting tops

Single-storm cell over central Italy, 9 September 2015



Over-shooting tops

A dome-like protrusion above a cumulonimbus anvil – often with a lumpy ("cauliflower") texture

Forms when a Cb's updraft protrudes above its level of neutral buoyancy

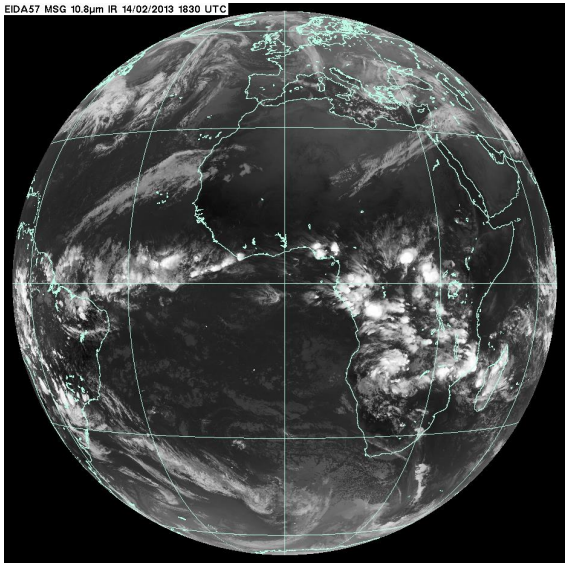
Generally exists for less than 30 minutes, and has a maximum diameter of ~15km

Facilitate the transport of various chemical species (especially water vapour) from the troposphere into the stratosphere

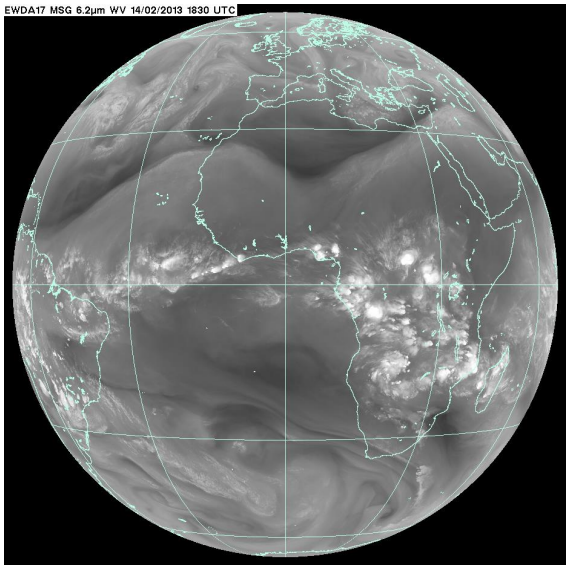
Generates gravity waves which can produce significant turbulence (Lane *et al.* 2003)

Image credit: NASA

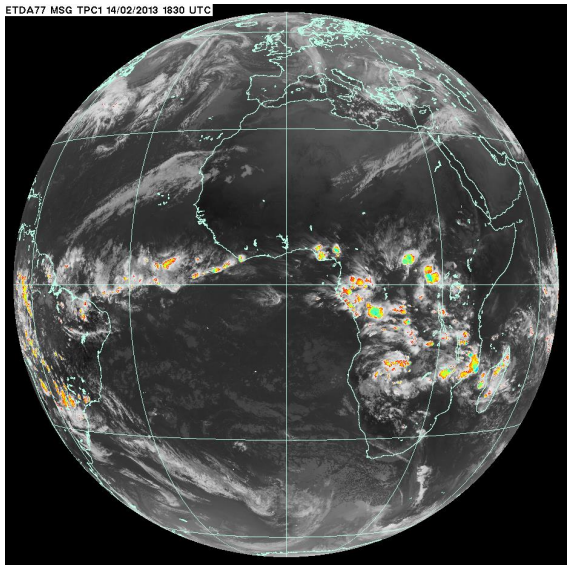
WV-IRW BTD



10.8 µm infrared window



6.2 µm water vapour



WV-IRW BTD

14th February 2013, 1830 UTC