EUMeTrain WV event week, 12-16 December 2022

SYNOPTIC- TO MESO-SCALE DIAGNOSIS OF DYNAMICAL PROCESSES, WHICH GOVERN THE INTENSIFICATION OF WILDFIRE ACTIVITY

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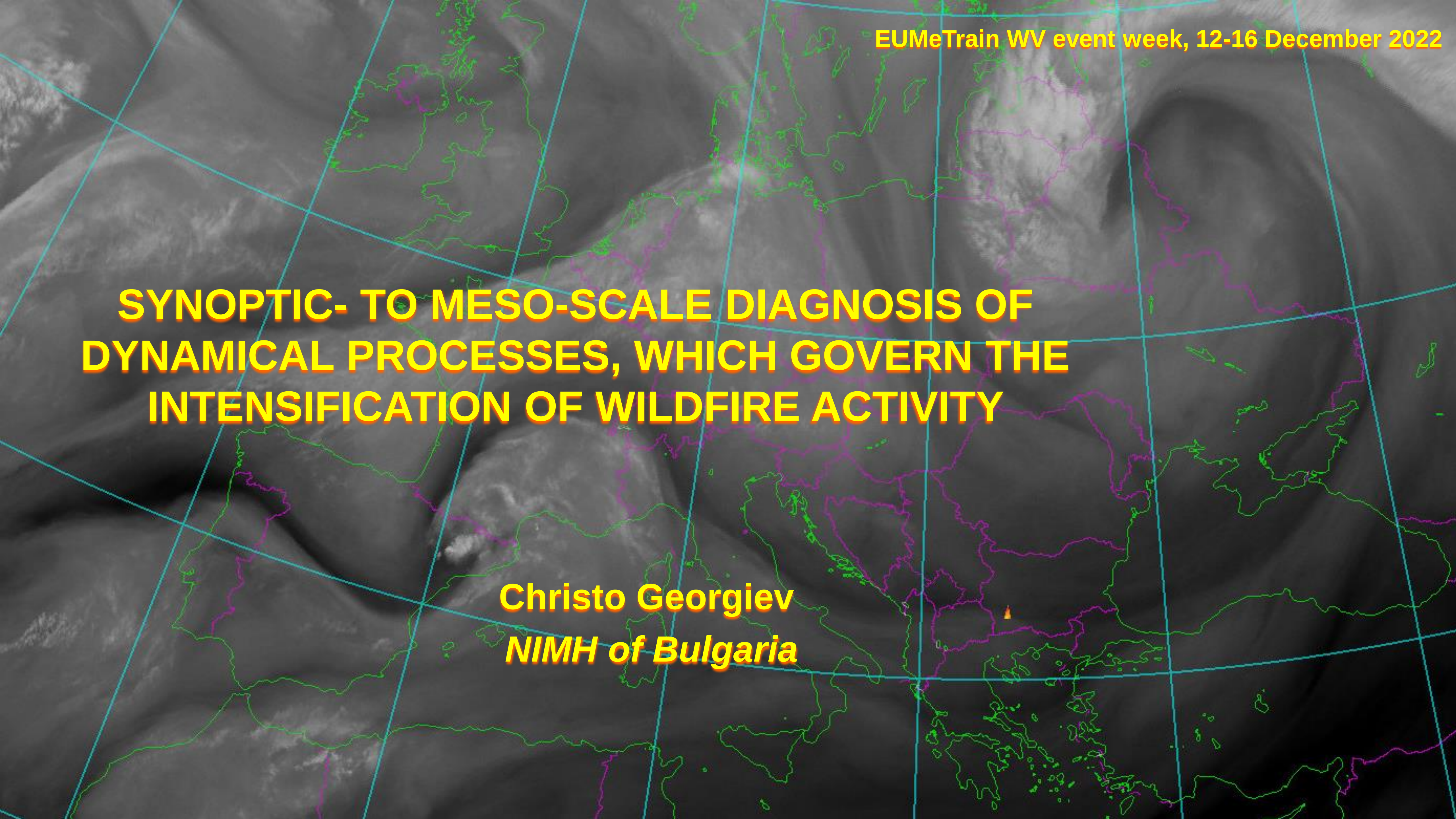
NIMH of Bulgaria



Outline

- Findings of different authors about the link between dry air intrusions seen in the satellite Water Vapour (WV) imagery and fire developments.
- Mechanisms, which can contribute to the vertical transport of dry stratospheric air down to the low levels.
- Use of IASI WV profiles to confirm the intrusion of stratospheric and upper-tropospheric air to lower levels
- Jet-like features in the eastern Mediterranean seen on the WV imagery that give rise to strong surface wind fluctuations and the intensification of wildfires.

Introduction

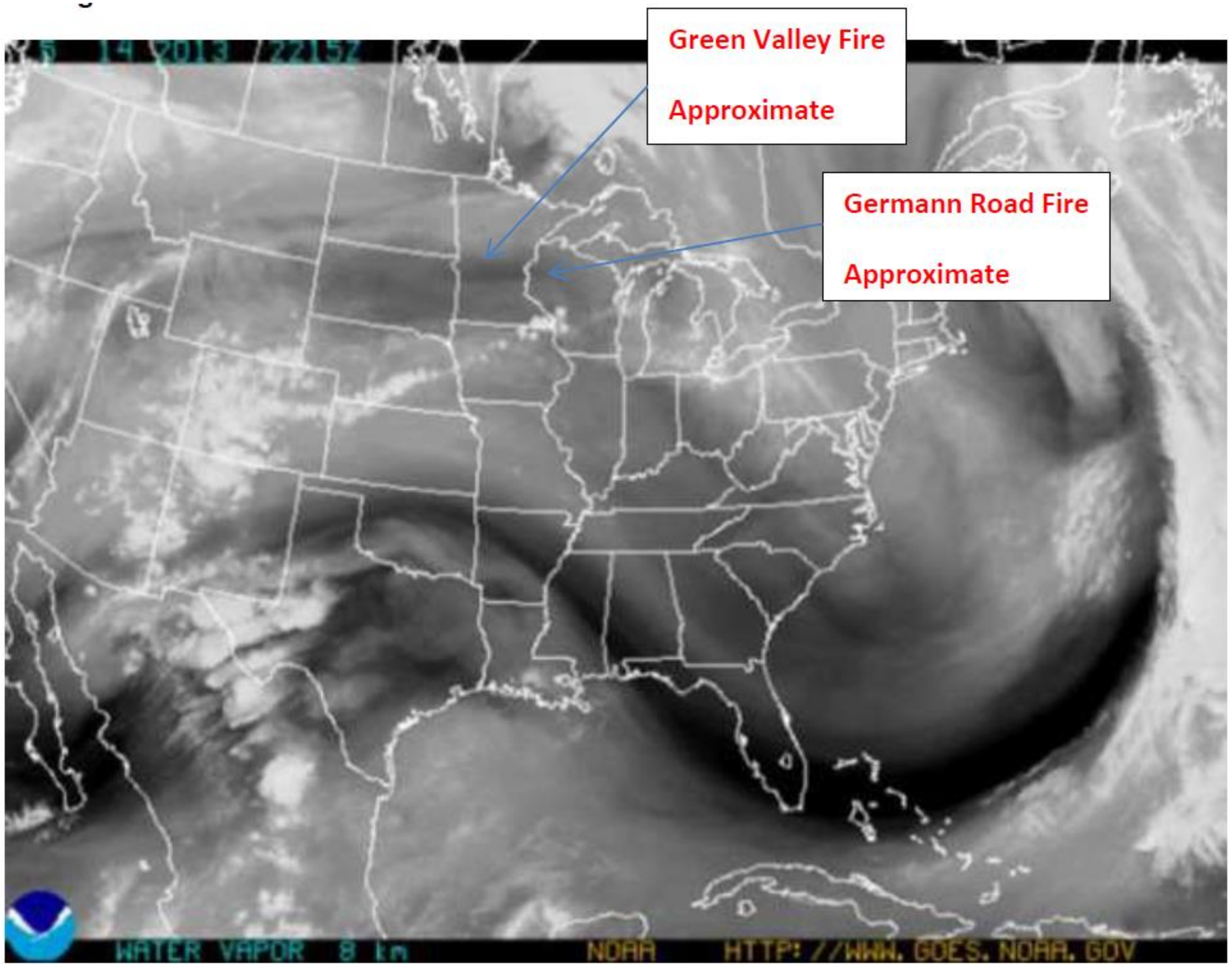
Findings of other authors have shown the link between dry air intrusions seen in the satellite Water Vapour (WV) imagery and fire developments over **Australia, USA** (**Mills, 2008; Zimet et al., 2007; Schoeffler Fred J., 2011, 2012; Fox-Hughes, 2015**).

The importance of this mechanism for **Southern Europe** has been recently demonstrated in

Georgiev, C.G.; Tjemkes, S.A.; Karagiannidis, A.; Prieto, J.; Lagouvardos, K. Observational Analyses of Dry Intrusions and Increased Ozone Concentrations in the Environment of Wildfires. Atmosphere 2022, 13, 597, 27 pp. https://doi.org/10.3390/atmos13040597.

When a dynamic dry feature seen in the WV imagery passes over a fire risky area, a usual result is rapid surface and/or near-surface drying, increasing wind speed that influence the fire development and can markedly increase fire activity.

USA, Schoeffler, F., J



The 14 May 2013,

GOES WV Image depicting dry intrusions advecting throughout the United States that day. In the northeastern United States (U.S) these mechanisms influenced at least two large wildfires in Minnesota (Green Valley Fire) and Wisconsin (Germann Road Fire). The Germann Road Fire was classified as one of the largest wildfires since 1980 (InciWeb 2013).

https://ams.confex.com/ams/10Fire/webprogram/Paper225272.html

Large USA Wildland Fires Influenced by Dry Intrusions and Dry Slots Visible in WVI

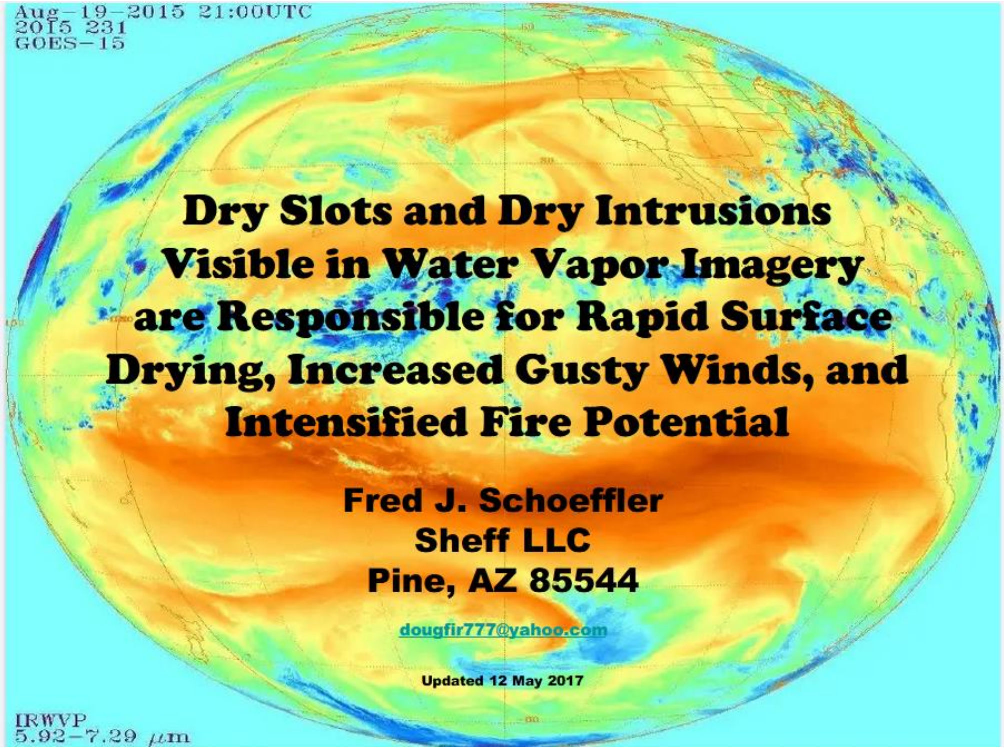
- **Mann Gulch Fire** - 5 August 1949 - MT
- **Rattlesnake Fire** - 9 July 1953 - CA
- **Decker Fire** - 8 August 1959 - CA
- **Mack Lake Fire** - 5 May 1980 - MI
- Lake Mountain Fire - 4 July 1985 - ID
- Butte Fire - 29 August 1985 - ID
- Willis Gulch Fire - 26 July 1988 - ID
- **Dude Fire** - 26 June 1990 - AZ
- Painted Cave Fire - 27 June 1990 – CA
- Awbrey Hall Fire - 5 August 1990 – OR
- **Midway Fire** - 26 August 1990 - Utah
- Marre Fire - 2 October 1993 - CA
- Coffee Pot Fire - 19 June 1994 - NM
- **South Canyon Fire** - 6 July 1994 - CO
- **Point Fire** - 28 July 1995 - ID
- Shepard Mountain Fire - 4 September 1996 - MT
- Tanner/Railroad Fire - 2 July 1999 - NV
- Wagonbox Fire - 22 July 1999 - NV
- **Sadler Fire** - 9 August 1999 - NV
- Cree Fire - 7 May 2000 - NM
- Cerro Grande/Los Alamos Escaped RX Fire and Outlet Escaped RX Fire - 10 May 2000 - NM/AZ
- Scott Able Fire - 11 May 2000 - NM
- Bobcat Gulch Fire - 13 June 2000 - CO
- Jasper Fire -24 August 2000 - SD
- **30- Mile Fire** - 10 July 2001 - WA
- Fish Fire - 10 August 2001 - NV
- Double Trouble State Park Fire - 2 June 2002 - NJ
- Price Canyon Fire - 6 June 2002 - Utah
- Hayman Fire - 8 June 2002 - CO
- Missionary Ridge Fire - 9 June 2002 - CO
- Rodeo-Chediski Fire - 23 June 2002 - AZ
- Toolbox Fire - 24 July 2002 – OR
- Thomas Fire – 13 June 2003 - AZ
- **Cramer Fire** - 22 July 2003 - ID
- **Cedar Fire** - 29 October 2003 - CA
- Nuttal Fire - 2 July 2004 – AZ
- Waterfall Fire - 14 July 2004 - NV
- Willow Fire - 24 August 2004 - AZ
- I-90 Complex - 10 August 2005 - MT

WFF / Citizen Fatalities - Burn Injuries and/or Shelter Deployments

Large USA Wildland Fires Influenced by Dry Intrusions and Dry Slots Visible in WVI

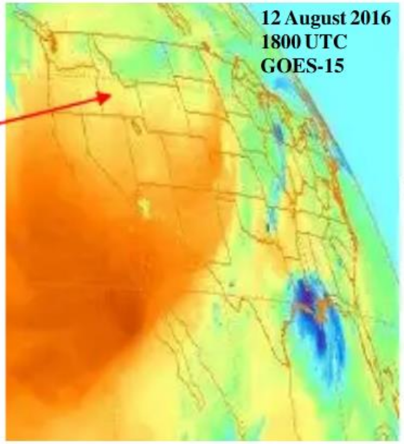
- **Southern Plains Wildfire Outbreak** - 1 January 2006 - TX / OK
- Warm Fire - 26 June 2006 - AZ
- Cavity Lake Fire - 14 July 2006 - Minnesota
- **Little Venus Fire** - 18 July 2006 - WY
- New York Peak Fire - 25 July 2006 - NV
- **Devils Den Fire** - 17 August 2006 - UT
- **Esperanza Fire** - 26 October 2006 - CA
- Ham Fire - 5 May 2007 – Minnesota
- Angora Fire - 26 June 2007 - CA
- **North Neola Fire** - 29 June 2007 - Utah
- Alabaugh Fire - 8 July 2007 - SD
- Fletcher Fire - 16 July 2007 - CA / OR
- Murphy Complex – 21 June 2007 - NV / ID
- Indians Fire - 11 June 2008 - California
- Panther Fire - 27 July 2008 - CA
- Jesusita Fire - 6 May 2009 - CA
- Black River Falls and Pinery Fires - 20 May 2009 - Wisconsin
- Station Fire - 30 August 2009 - California
- Last Chance Fire - 24 April 2011 - NM
- Wallow Fire - 29 May 2011 - AZ
- Monument - Horseshoe Fire - 19 June 2011 - AZ
- Conchas Fire - 26 June 2011- NM
- **Coal Canyon Fire** - 11 August 2011 – SD
- Salt Fire - 29 August 2011 - Idaho
- Pagami Fire - 12 September 2011 – MN
- **Lower North Fork Escaped RX Fire** - 26 March 2012 - CO
- Whitewater Baldy Fire - 24 May 2012 - NM
- Little Bear Fire - 8 June 2012 - NM
- High Park Fire - 9 June 2012 - CO
- Waldo Canyon Fire - 26 June 2012 - CO
- Holloway Fire - 10 August 2012 - NV/OR
- Barry Point Fire - 14 August 2012 - OR/CA
- Lagunas and Thompson Ridge Fires 8 June 2013 - New Mexico
- Black Forest Fire - 11 June 2013 - CO
- West Fork Complex (Papoose, Windy, West Fork Fires) - 20 June 2013 - CO
- **Yarnell Hill Fire** - 30 June 2013 - AZ
- Mountain Fire - 17 July 2013 - CA
- Rim Fire - 22 August 2013 - CA

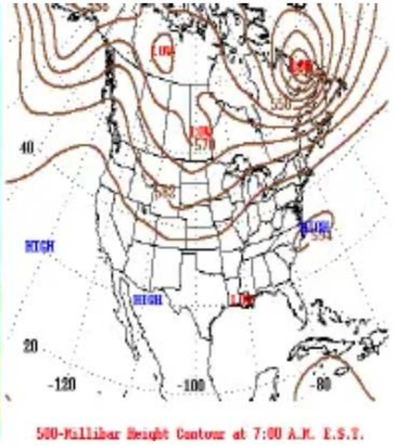
https://www.academia.edu/33046921/Dry_Slots_and_Dry_Intrusions_Visible_in_Water_Vapor_Imagery_are_Responsible_for_Rapid_Surface_Drying_Increased_Gusty_Winds_and_Intensified_Fire_Potential



Pioneer Fire

12 August 2016 - Idaho





Mary Wistner – NOAA NWS – Pendleton, OR

Large USA Wildland Fires Influenced by Dry Intrusions and Dry Slots Visible in WVI

- Beaver Fire - 11 August 2014 - CA
- King Fire - 17 September 2014 - CA
- Lowell Fire - 26 July 2015 - CA
- **Frog Fire** - 30 July 2015 - CA
- Stickpin Fire - 14 August 2015 - WA
- **Twisp River Fire** - 19 August 2015 - WA
- Valley Fire - 12 September 2015 - CA
- Cedar Fire - 28 June 2016 - AZ
- Blue Cut Fire - 8 August 2016 - CA
- Pioneer Fire - 12 August 2016 - ID
- Little Valley Fire Escaped RX - 14 October 2016 - NV
- **Chimney Tops 2 Fire** - 28 November 2016 – TN
- **Southern / Northern Plains Wildfires** 6-7 March 2017 - CO, TX, OK, KS

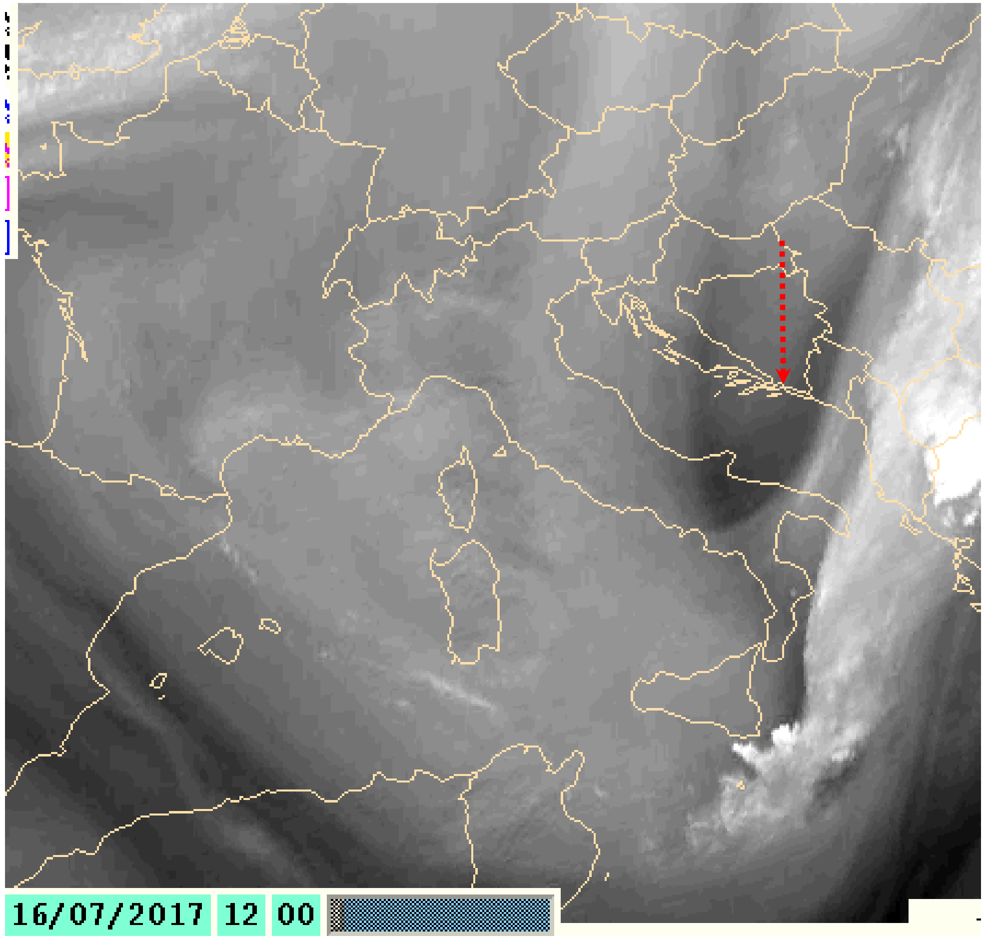
Wildfires across Southern Apennines and Western Balkans
16 – 17 July 2017

http://www.express.co.uk/news/world/829844/wildfire-deadly-fire-Europe-tourist-hotspot-Croatia-Italy

Croatia and Italy were in the grip of wires which are spreading, forcing people to flee and seeing hundreds of firefighters battling multiple blazes.

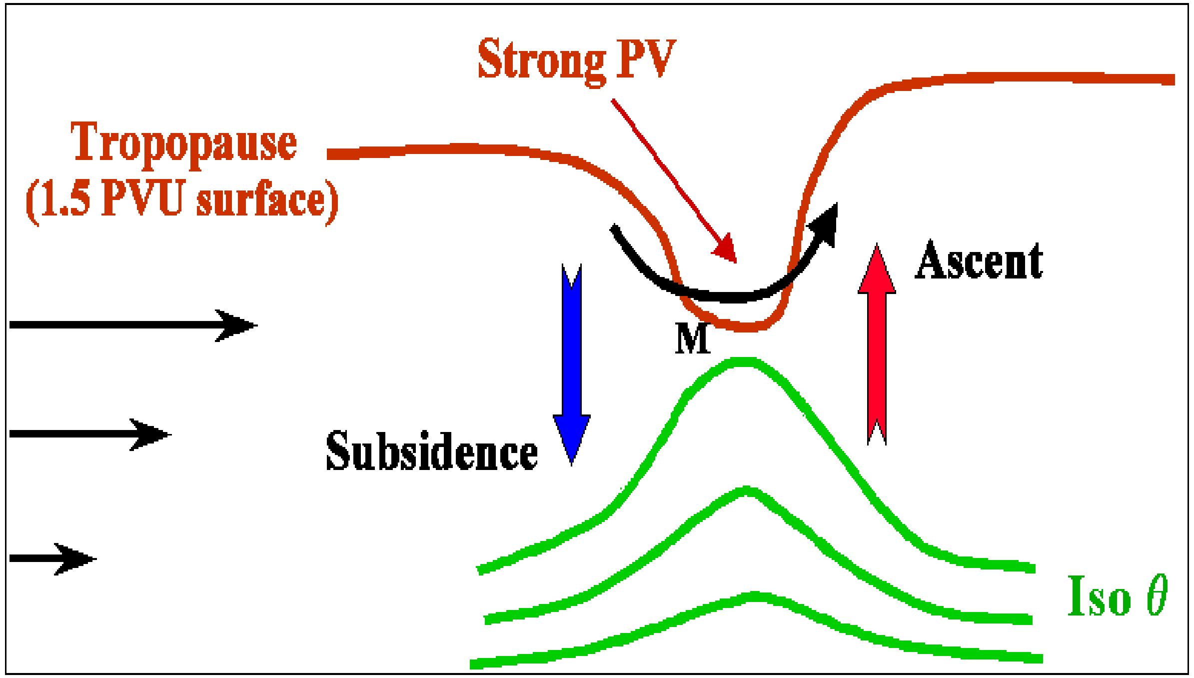
Dry stratospheric intrusion as a forcing mechanism seen in WV imagery

Meteosat WV image 6.2 μm



VORTICITY ADVECTION AND TROPOPAUSE FOLDING

The strong wild fire activity over the Mediterranean on **16 – 17 July 2017** was a result of a fire weather situation due to a polar advection of strong vorticity.



Mechanisms, which can contribute to the vertical transport of stratospheric air to the low levels are dry convective turbulence in deep daytime mixed layers, vertical circulations associated with frontal circulations, and topographically-induced flows on the downstream side of topographic barriers (Mills, 2008a).

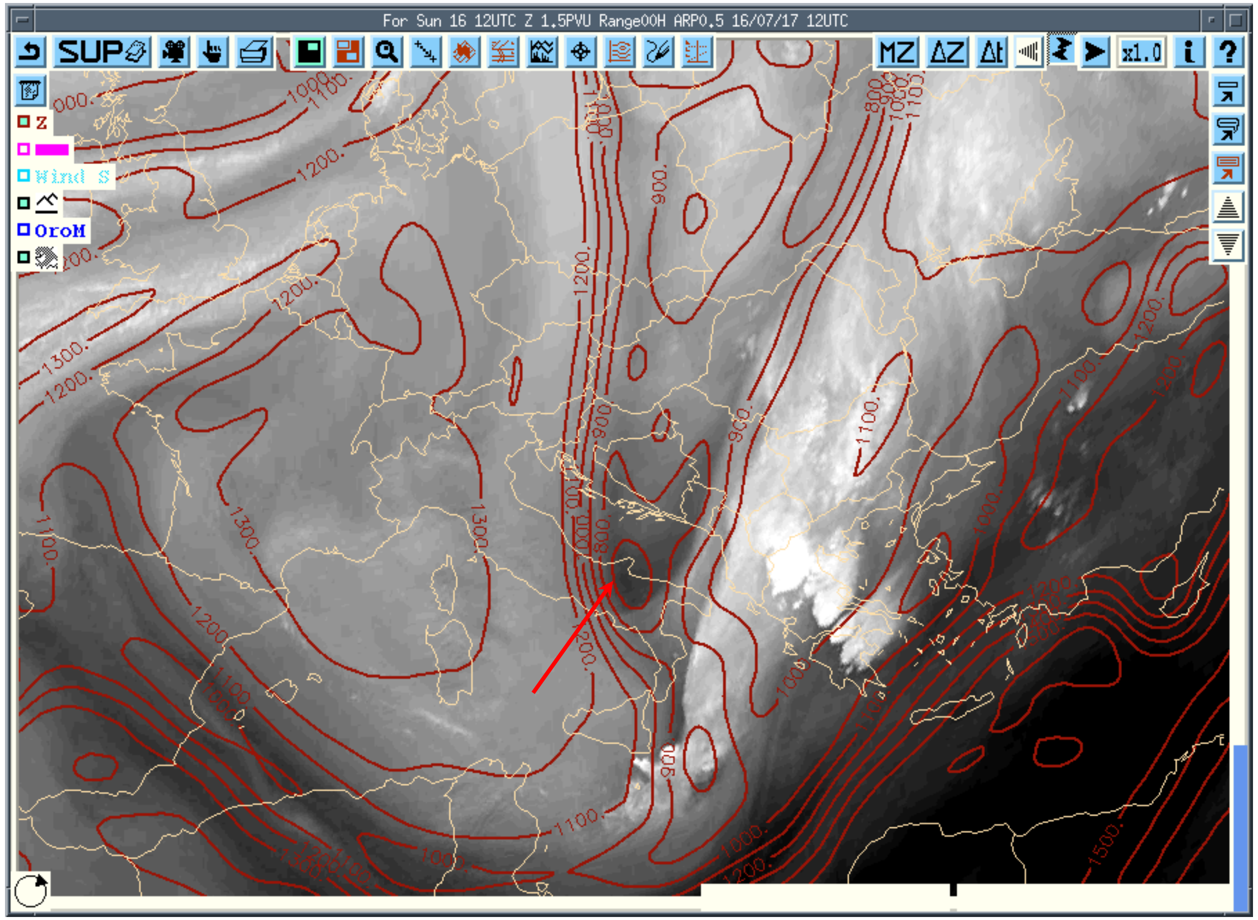
In terms of the PV concept, the tropopause in mid-latitudes may be represented by the surface of constant PV = 1.5 PVU, and considered as the “dynamical tropopause” (see Georgiev et al., 2016).

A folding of the tropopopause is associated with vorticity advection, subsidence and a stratospheric intrusion of very dry and O_3–rich air down into the troposphere.

Dry stratospheric intrusion seen in WV imagery and folding of the tropopause down to middle troposphere

Meteosat WV image (6.2 μm), overlaid by the heights of the Dynamical Tropopause (constant surface of PV= 1.5 PVU

16 July 2017 12 UTC

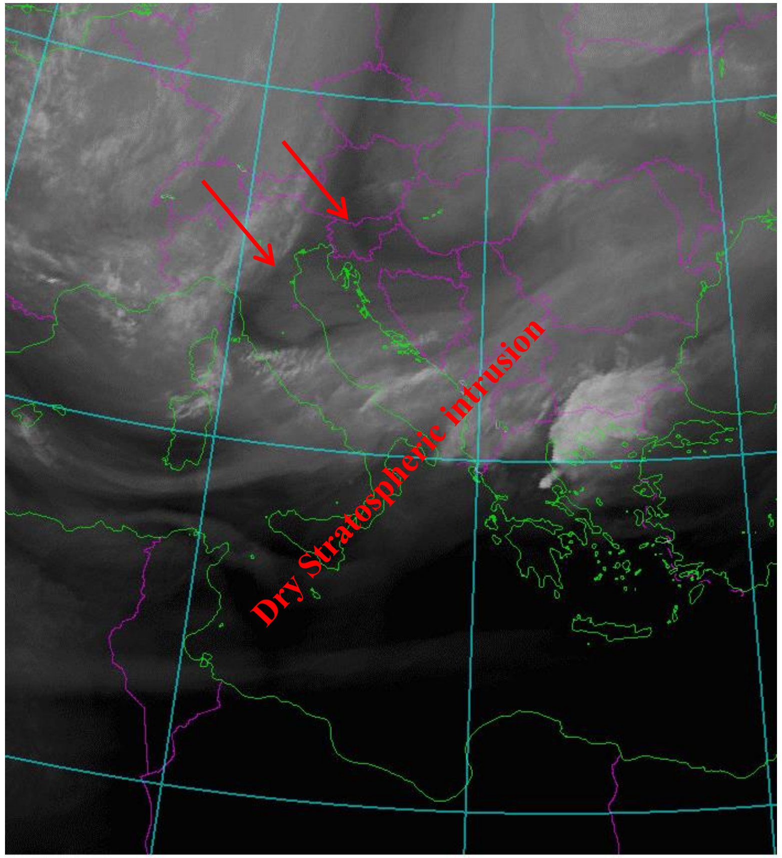


The tropopause folding is seen as dry slot in the WV imagery.

For Diagnosis, synoptic scale analysis of upper-level dynamics is performed by WV imagery and potential Vorticity (PV) fields (Georgiev et al., 2016).

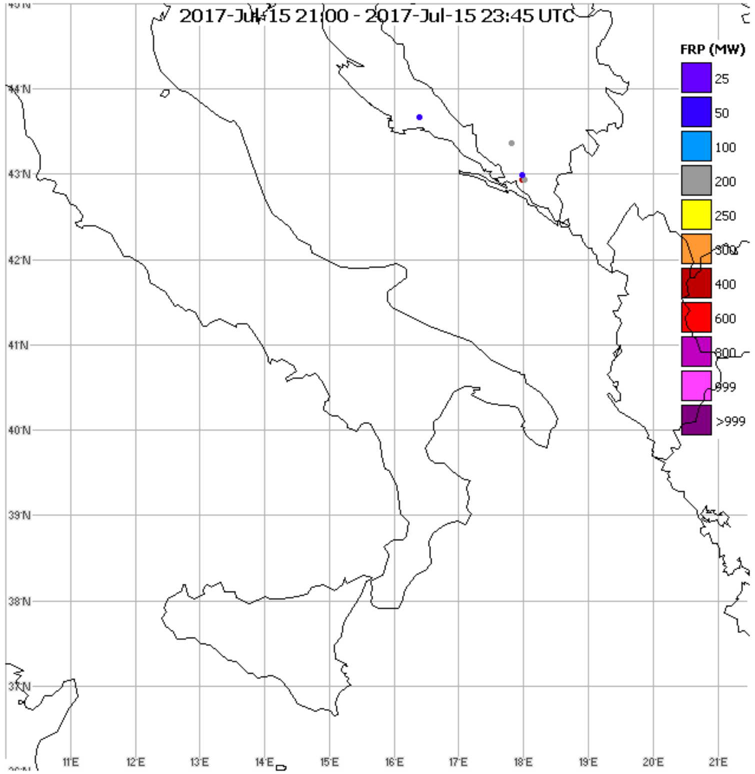
Appearance of a distinct dry slot on the satellite WV image is related to persistent folding of the tropopopause, subsidence of very dry air down in a deep layer of the troposphere.

Dry stratospheric intrusion seen in WV imagery and increased fire activity



MSG WV 6.2 20170715 2100 UTC

Surging dry slot in the WV imagery

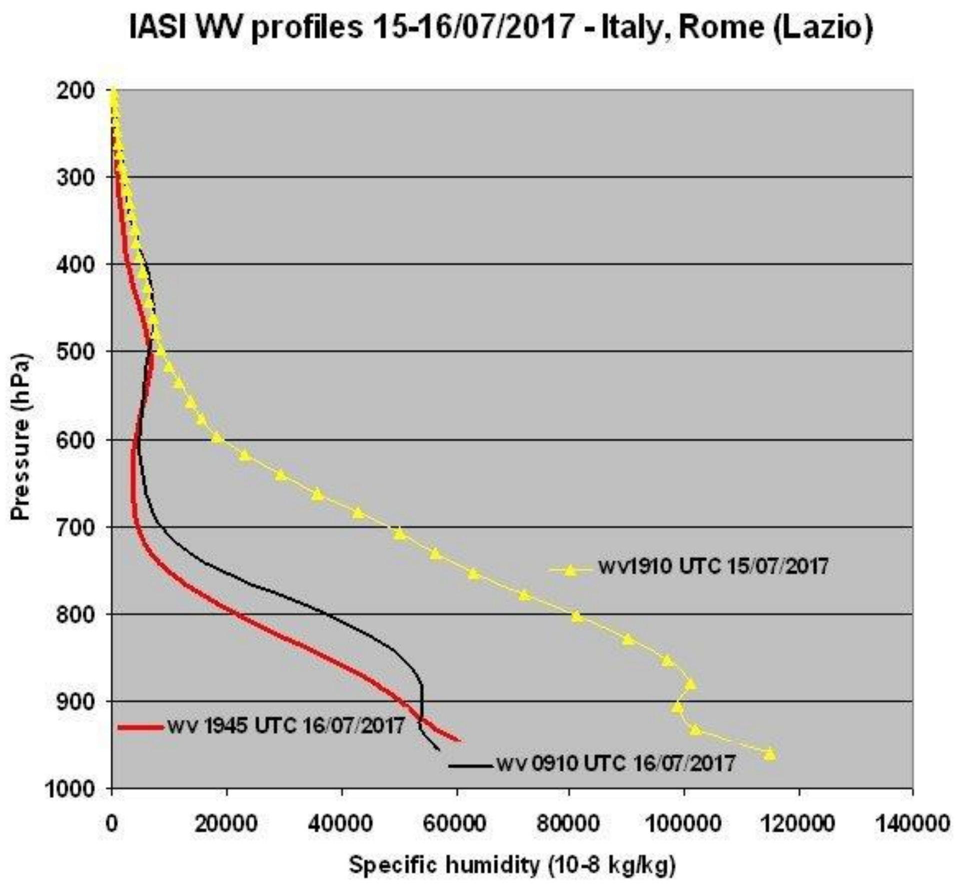


FIRE DETECTIONS by LSA SAF FRP PRODUCT **15 - 16 July 2017**

This stratospheric dry intrusion affects surface drying and intensifying the winds, thus can accelerate fire developments (Mills 2008; Zimet et al. 2007; Fox-Hughes, 2015).

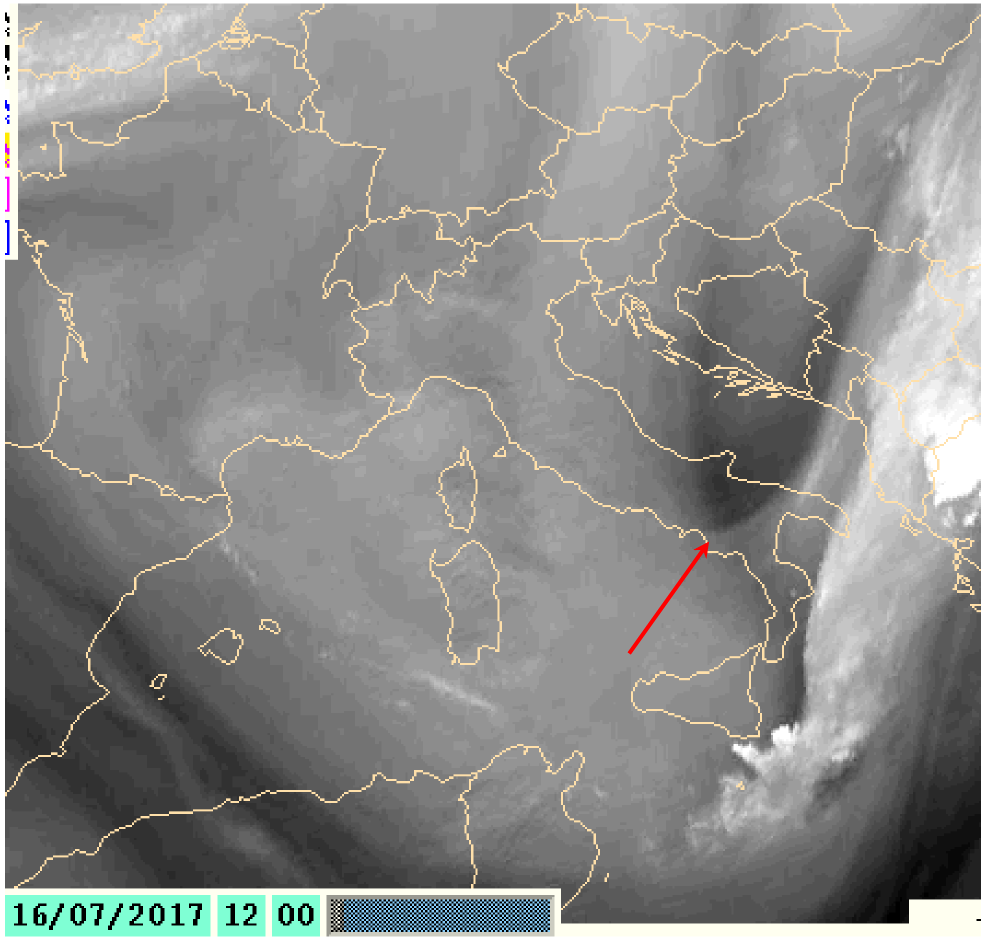
Much stronger fire activity on 16 July associated with the dry intrusion seen in the WV imagery

Dry stratospheric intrusion seen in WV imagery and retrieved by IASI measurements moisture profiles



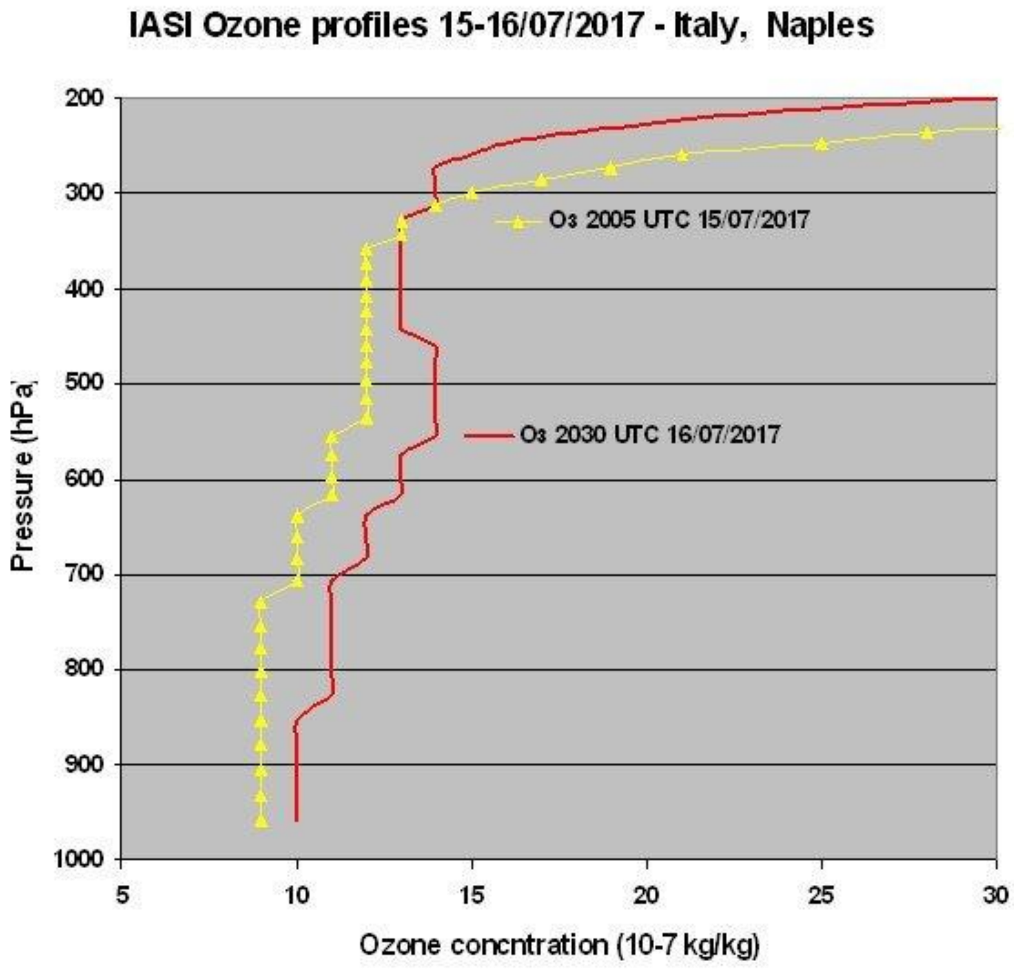
Deep stratospheric dry intrusions may cause significant near-surface air drying.

IASI profiles retrieved by Jose Prieto



Strong subsidence seen as a distinct dry slot on the WV imagery is a sign for decreased moisture in a deep layer of the troposphere down to the surface.

Deep stratospheric intrusion and related increase ozone concentration down to the low troposphere



Such a deep stratospheric intrusion is associated with increasing O_3 concentration from 300 hPa down to the surface.

The increased ozone due to deep stratospheric intrusions in the environment of wild fires could contribute to fire propagation as well.

According to findings of other authors,

- **Ozone has shown the capability to accelerate ignition and control ignition timing, enhance flame propagation, improve flame stabilization,** https://www.sciencedirect.com/science/article/abs/pii/S0360128518300935
- **Ozone is a form of oxygen. Oxygen is not flammable, though it acts as an oxidizer and can intensify fires.**
  https://firefighterinsider.com/ozone-flammable/
- **Ozone is among the most powerful oxidizing agents known, far stronger than O_2.**
  https://www.quora.com/Will-fire-burn-faster-in-ozone-than-regular-oxygen

IASI profiles retrieved by Jose Prieto

Dry stratospheric intrusion seen in WV imagery and Wild fire over Australia

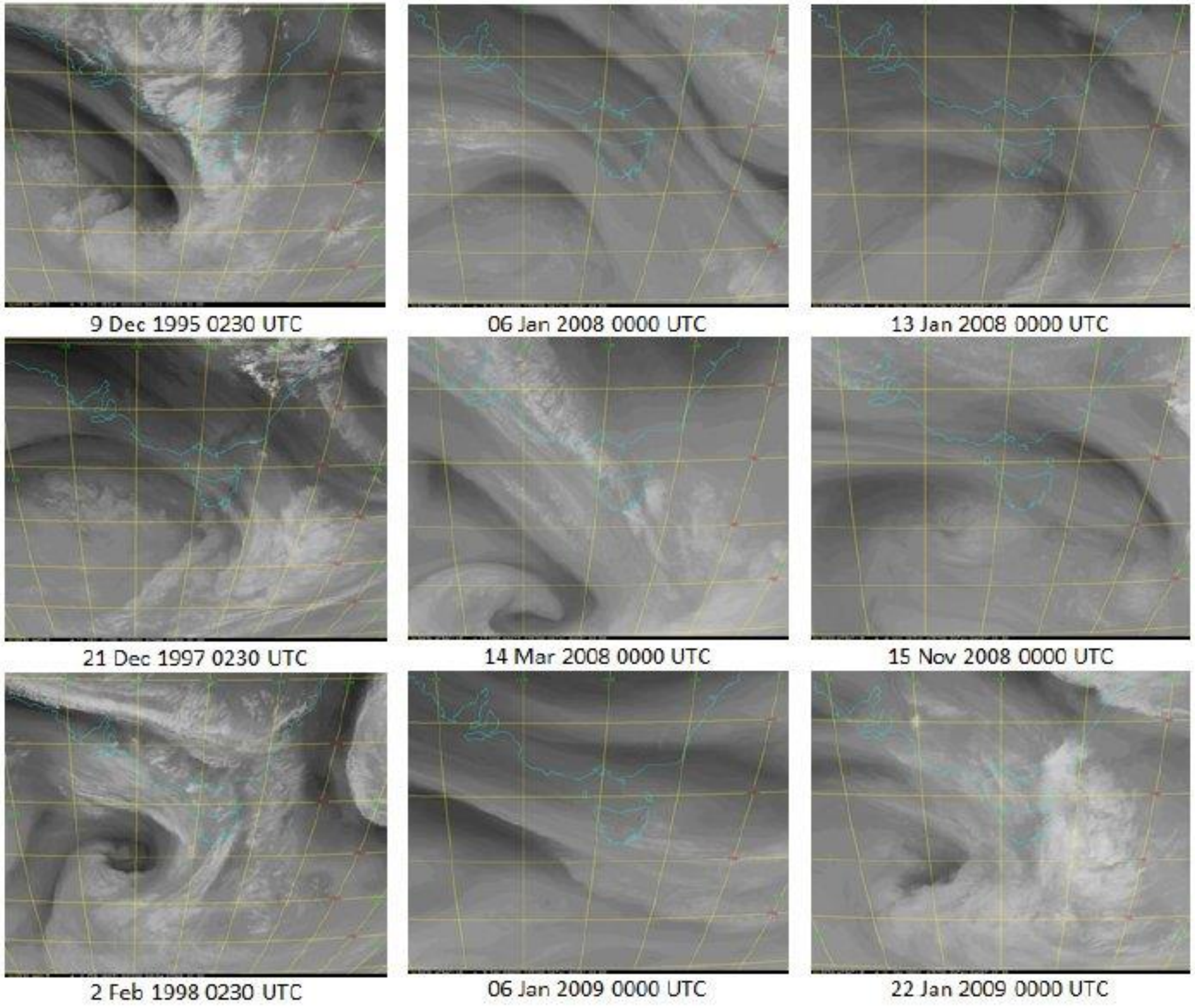


Figure 5S.3: Satellite WV imagery of spike events. Imagery courtesy of NOAA and JMA.

UNIVERSITY of TASMANIA

A Meteorological Investigation of the 'Springtime Bump'

An Early Season Peak in the Fire Danger Experienced in Tasmania

Paul Fox-Hughes

Submitted in fulfilment of the requirements

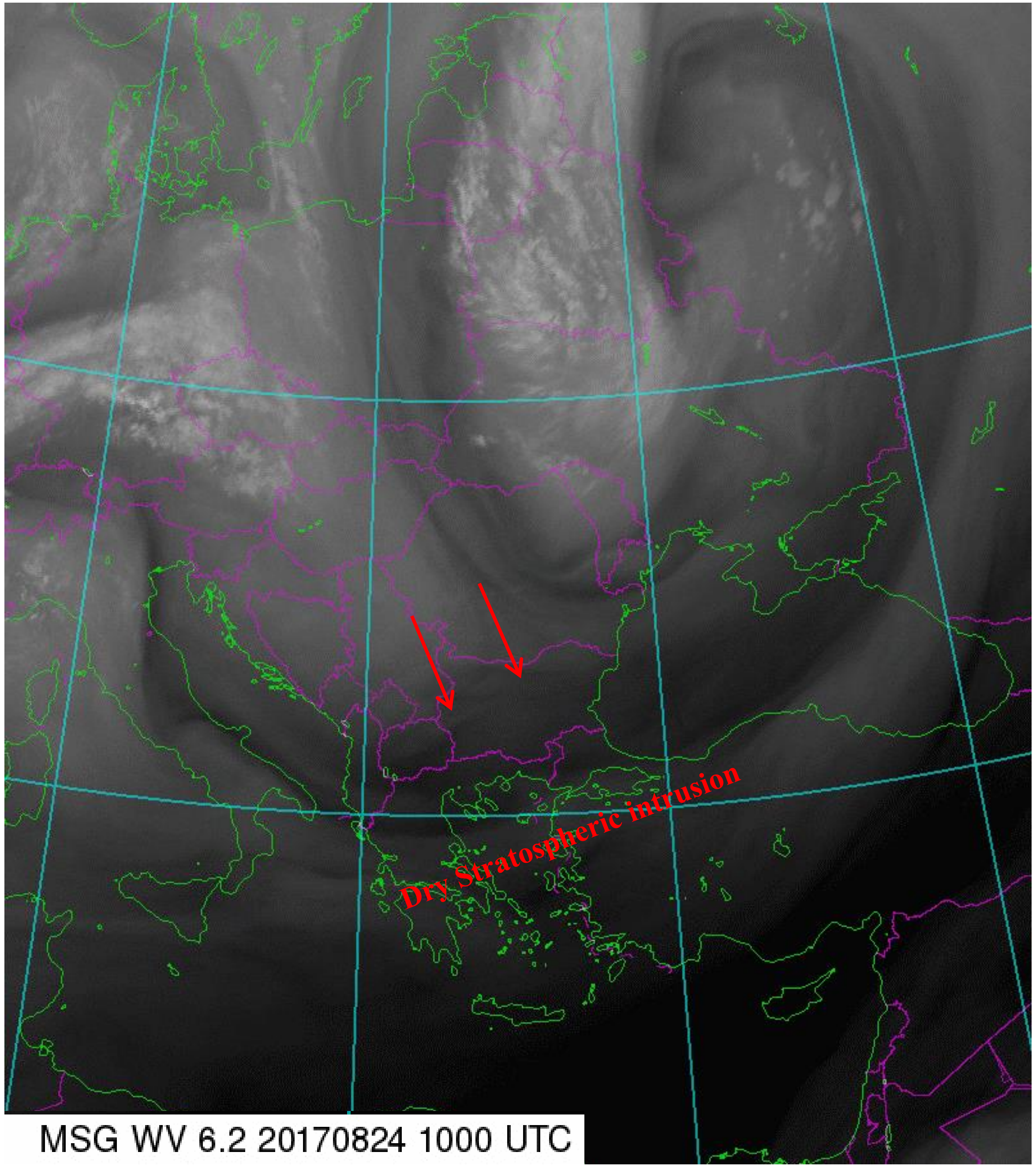
for the degree of Doctor of Philosophy

December 2014

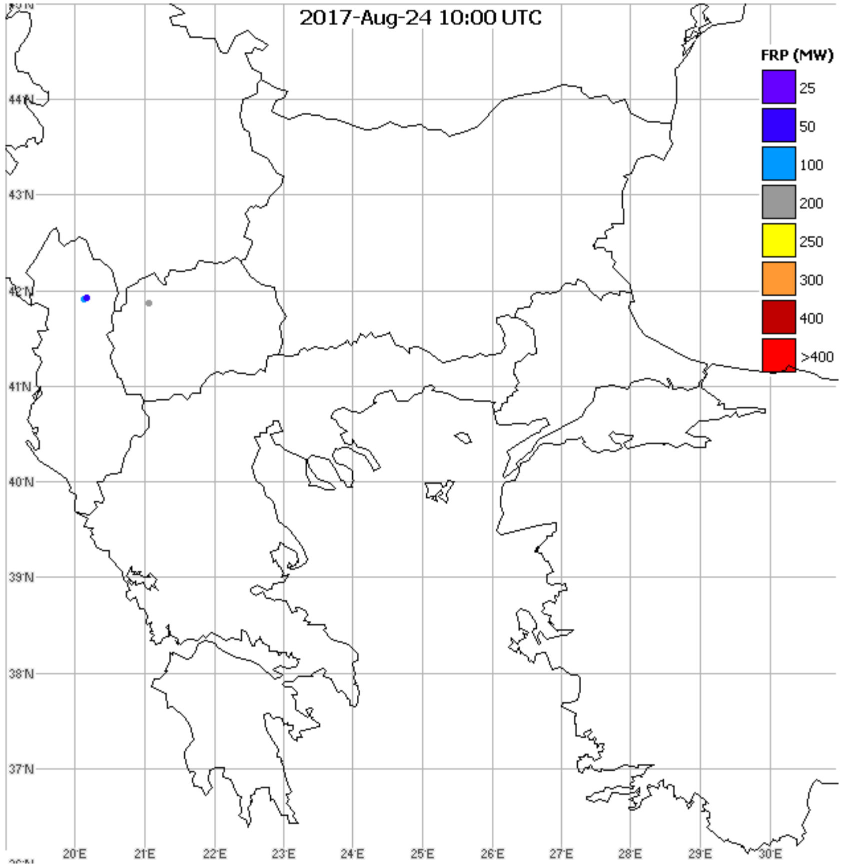
WV satellite imagery from 1995 onward, available for 31 (of 37) spike events and 15 (of 25) non-spike events.
The imagery in the hours leading to peak on spike and non-spike days was examined for features indicating dry conditions in the upper troposphere.

The study by Fox-Hughes (2015) of Tasmania wildfire events showed that for 63 % of the investigated cases the rapid increase of fire activity was accompanied by a dry band in the WV imagery, indicative of pronounced descent of upper-tropospheric or stratospheric air.

Dry stratospheric intrusion and Wild fire over South-Eastern Europe



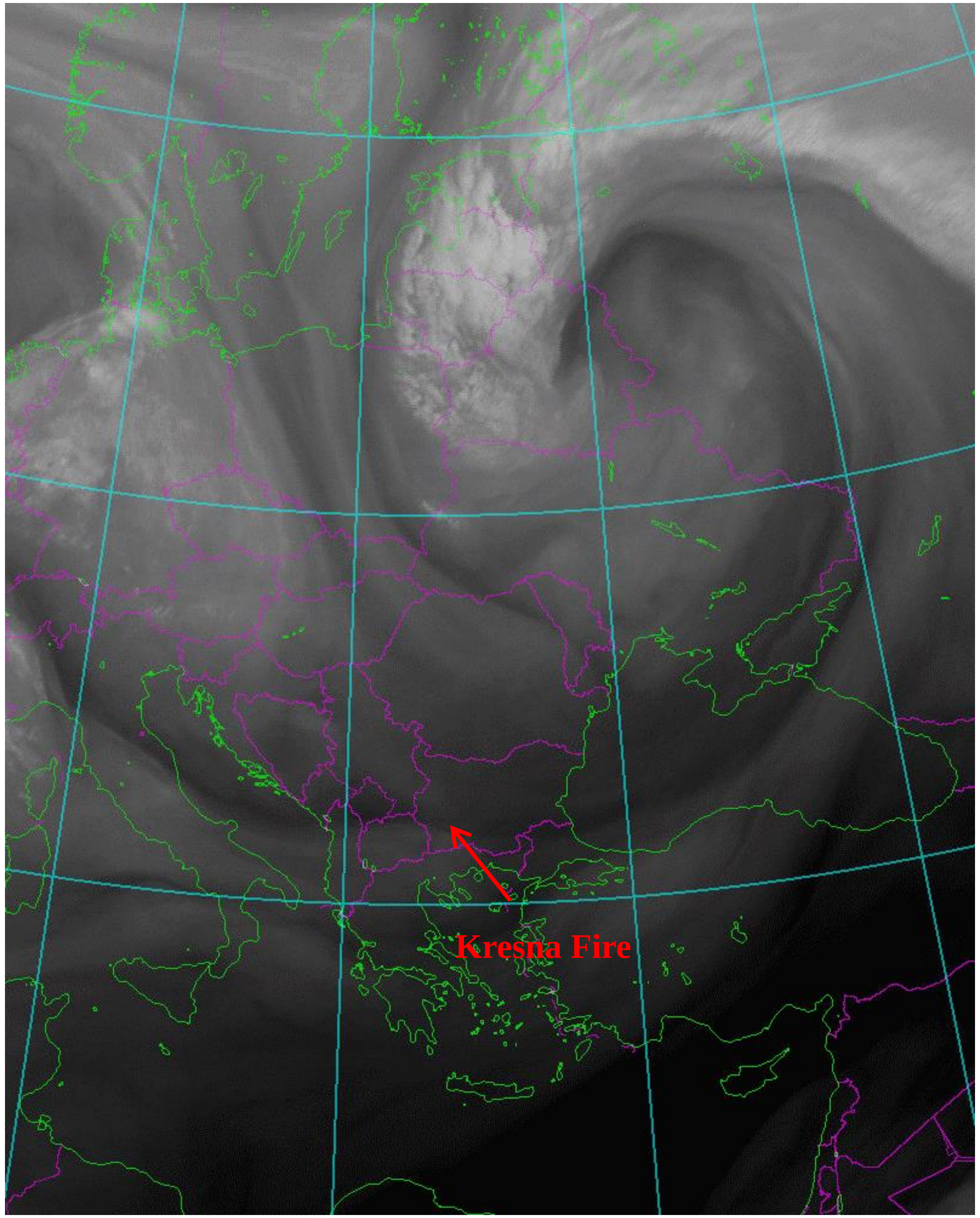
LSASAF FRP



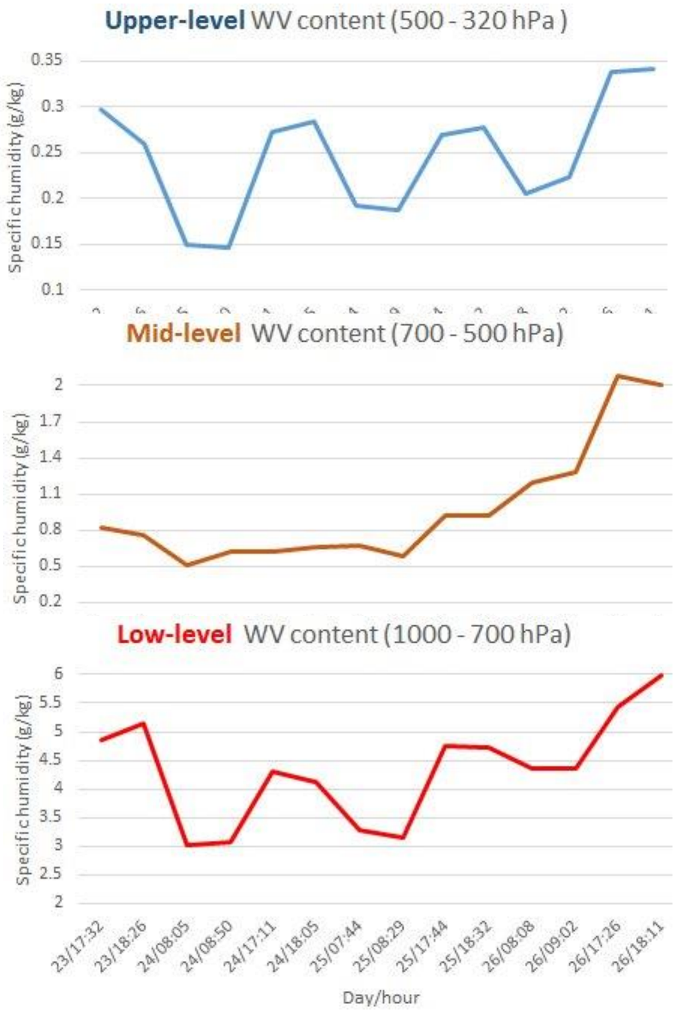
Most of the fires detections occurred over the areas affected by the **dry intrusion** in Bulgaria, North Macedonia and Albania, seen in the WV imagery.

Upper-level Dynamics and WV Content

Kresna Fire, Bulgaria



MSG WV 6.2 20170824 0300 UTC



Averaged WV content 60 km around Kresna Fire location for three tropospheric layers: All clear sky IASI soundings of Metop-A and Metop-B satellites in the target areas were considered (Georgiev et al., 2022).

Only some of the dry WV imagery patterns are related to stratospheric intrusions.

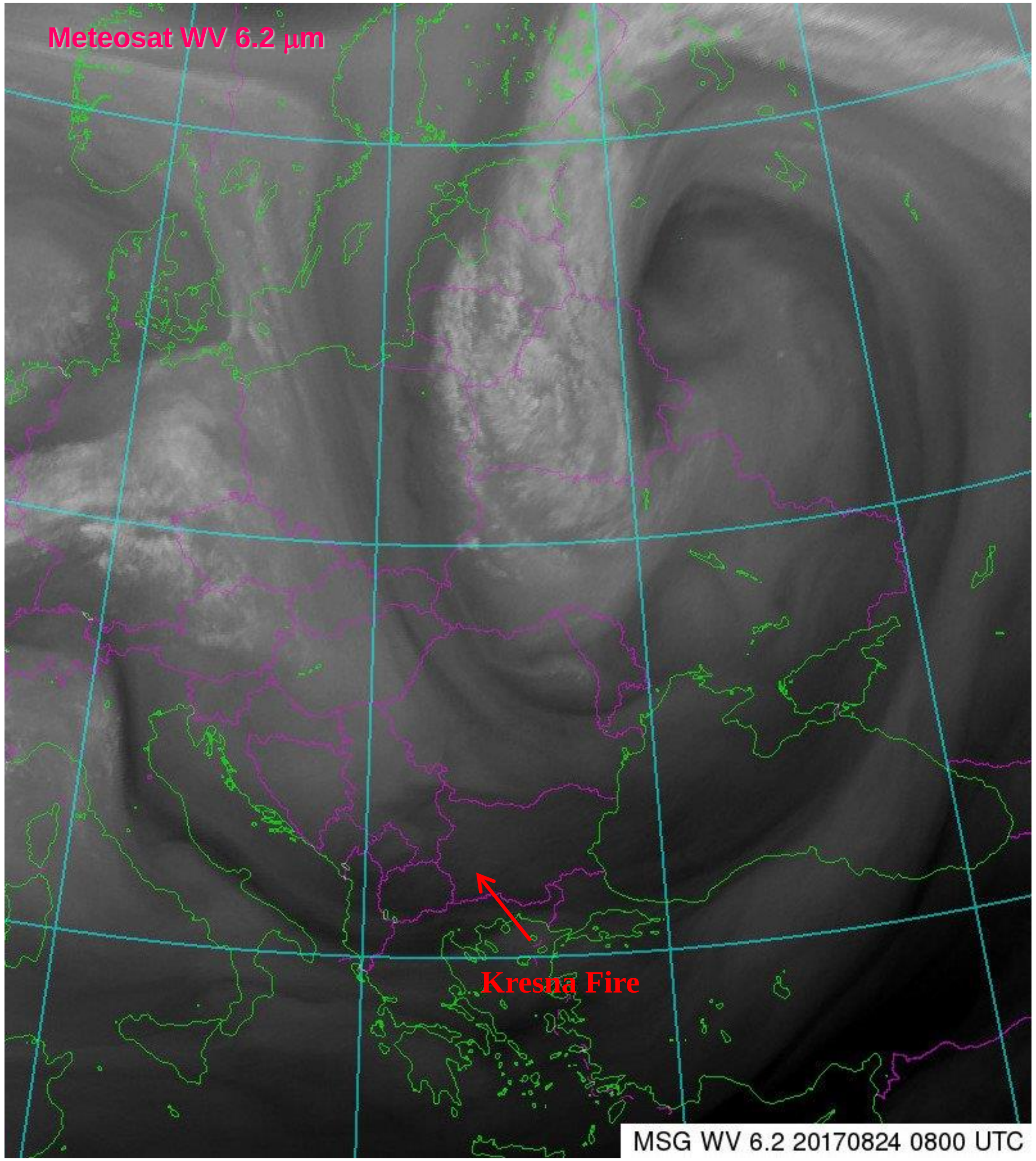
24 Aug 0800 UTC: Tropopause folding, Dynamic Dry zone, **Subsidence.**

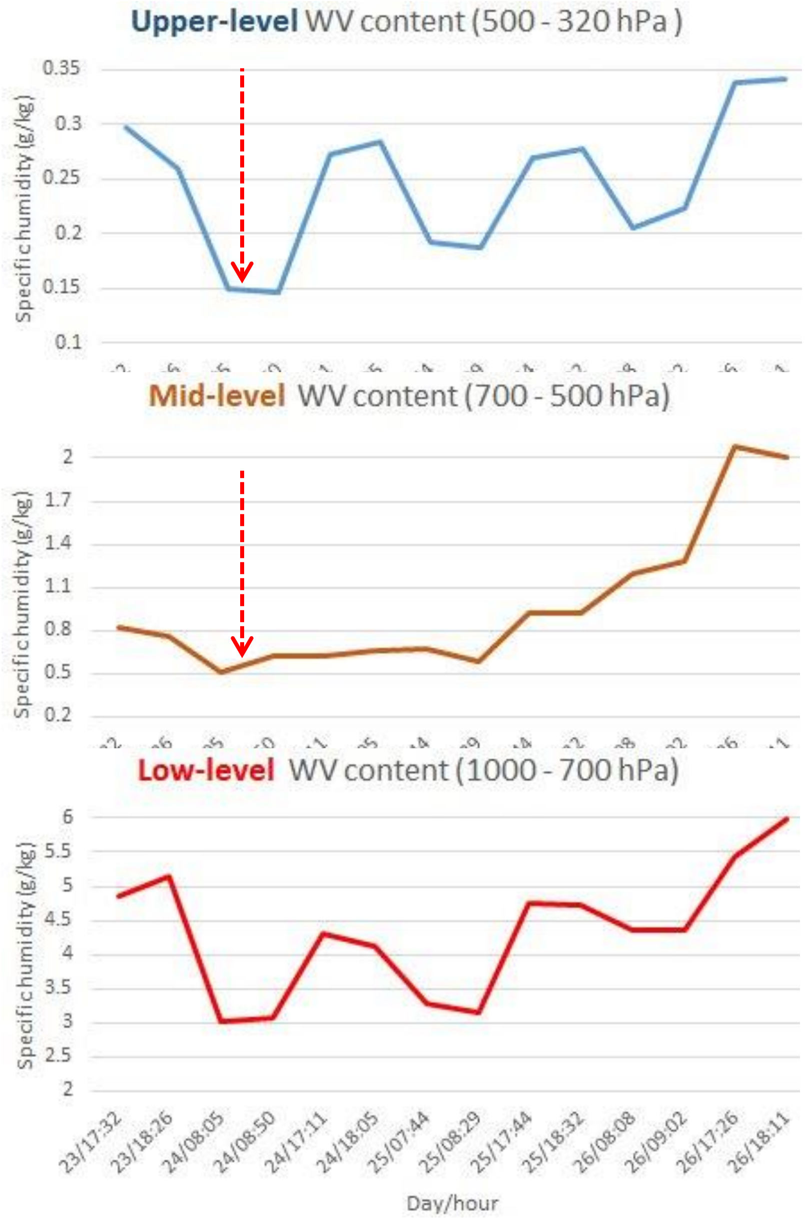
25 Aug 0800 UTC: Upper-level vorticity advection, **Subsidence.**

26 Aug 0800 UTC: Upper-level dry air advection. **No subsidence**

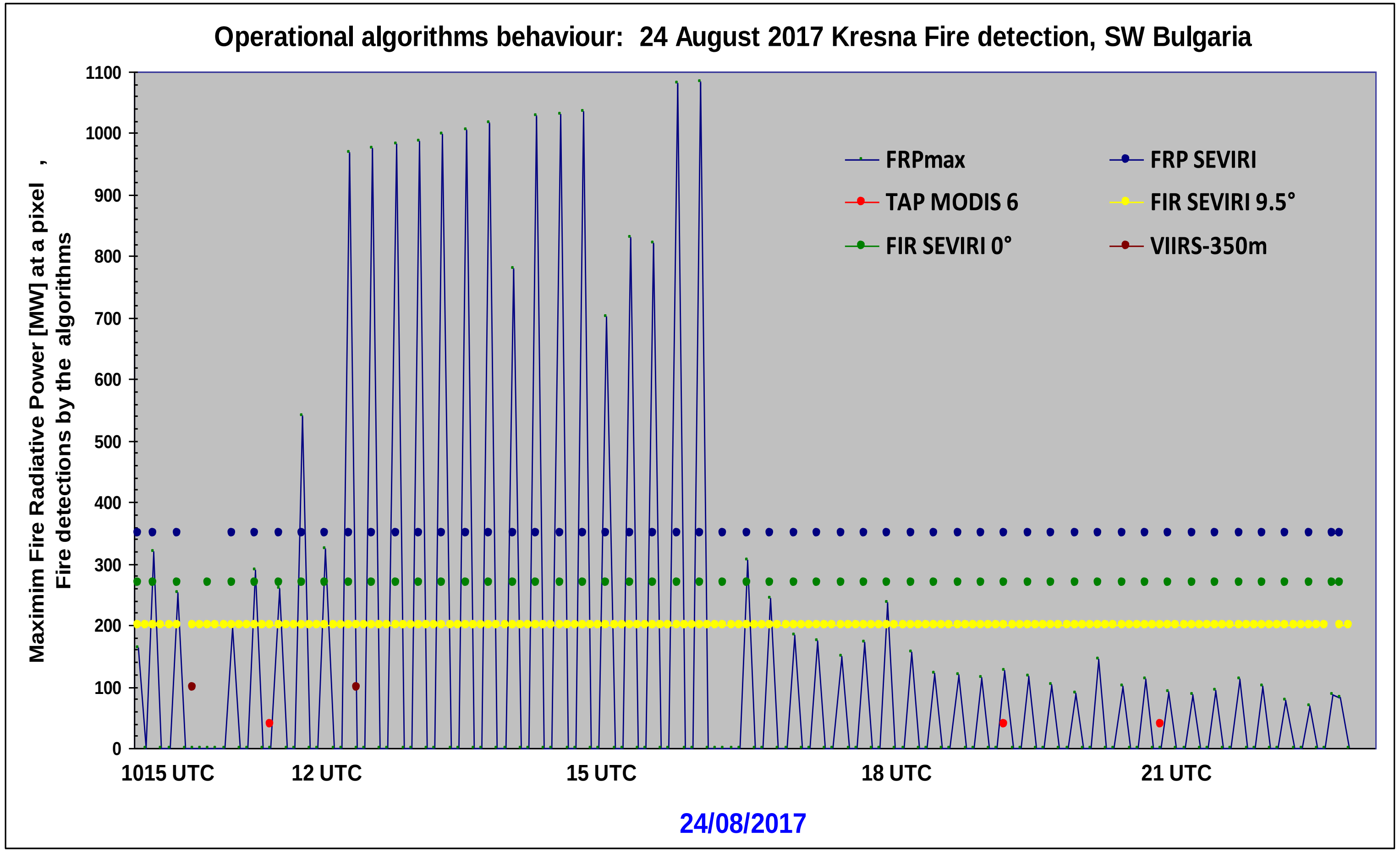
Dry stratospheric intrusion and airmass drying mechanisms

Kresna fire, Bulgaria, 24 August 2017





Satellite detection of Kresna fire, Bulgaria on 24 August 2017

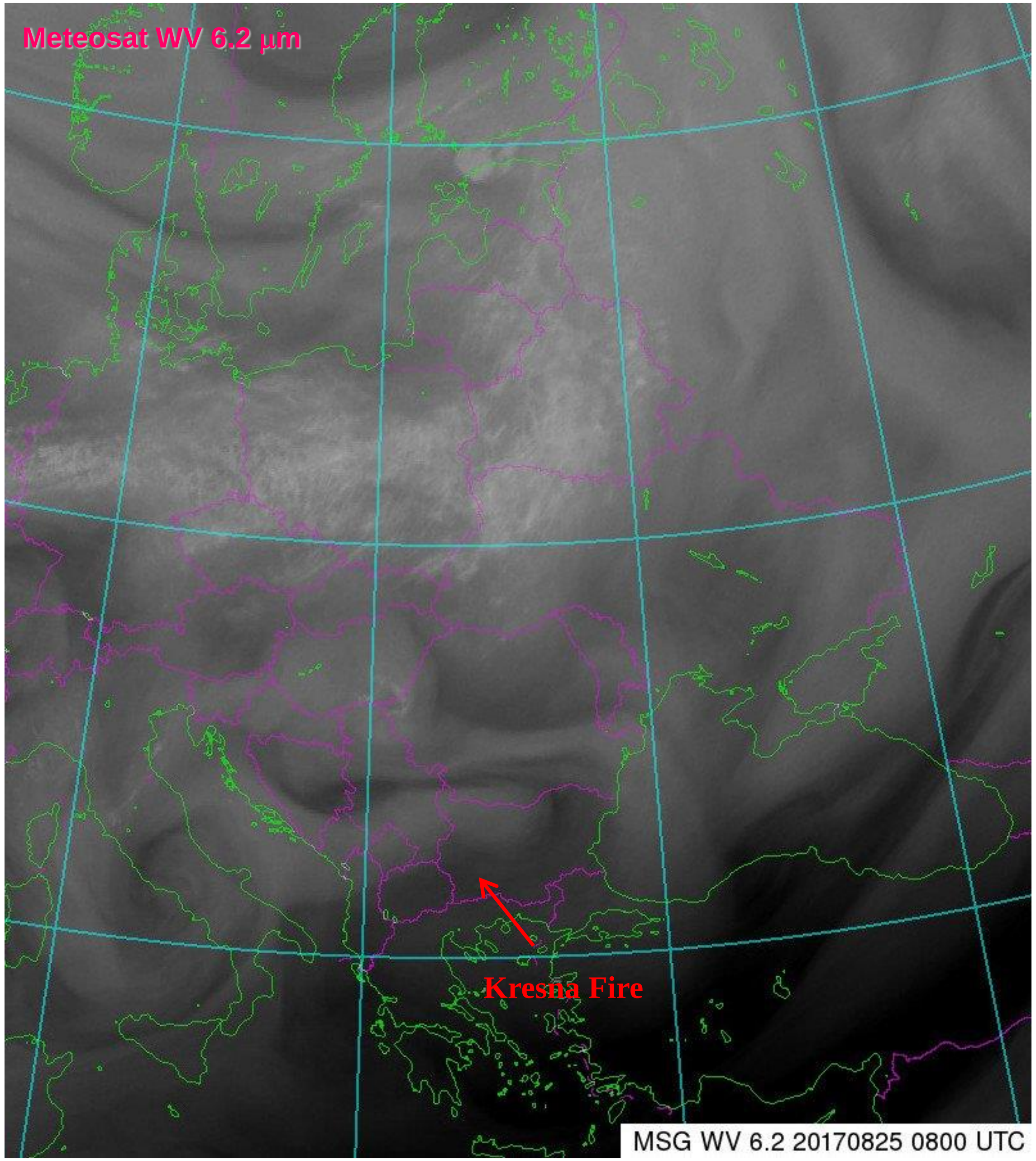


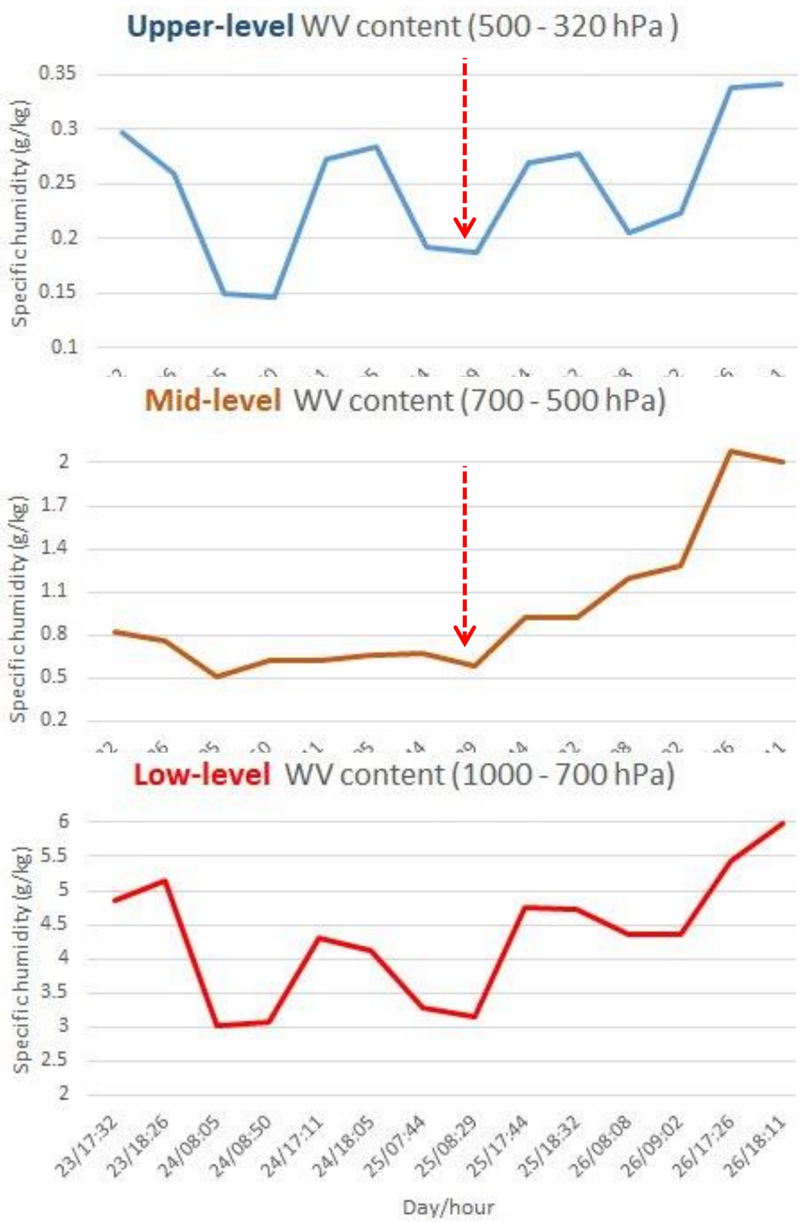
Ozone production from the wildfire seems to be the main contributing mechanism for enhanced low-level O_3 that is confirm by satellite measurements:

- ***FIR Rss: 1015 – 2315 UTC each 15 minutes detections and***
- ***FIR Fss: 1015 – 2330 UTC each 5 minutes (159 time slots) detections***
- ***LSASAF FRP: 1015 – 2315 UTC each 15 minutes detections with 61,586.7 MW radiant energy released and 9,525,640 kg carbon emissions.***
- **MODIS 6 and S-VIIRS also detect the fire**

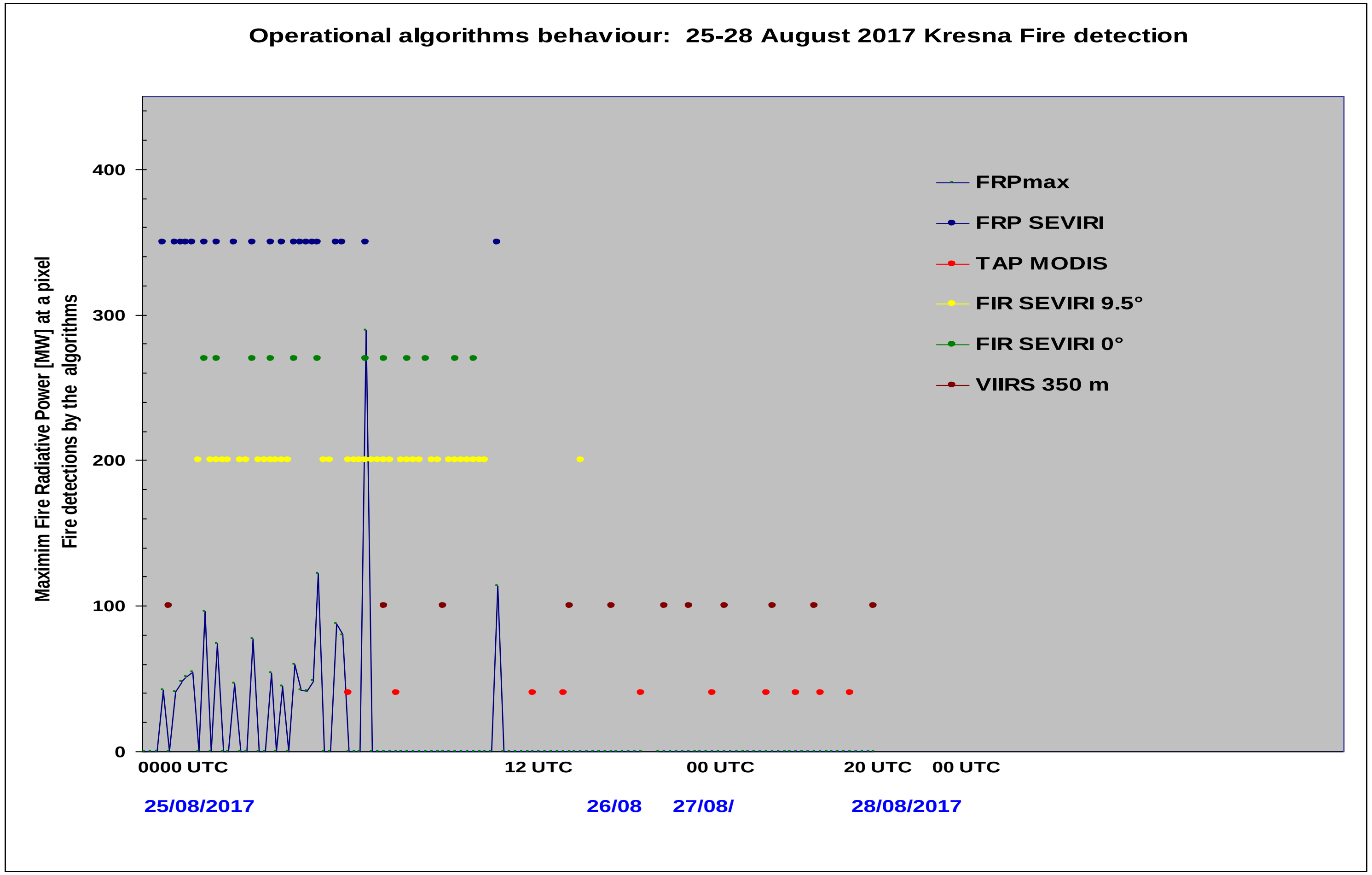
Dry stratospheric intrusion seen in WV imagery and airmass drying

Kresna fire, Bulgaria, 25 August 2017





Satellite detection of Kresna fire, Bulgaria



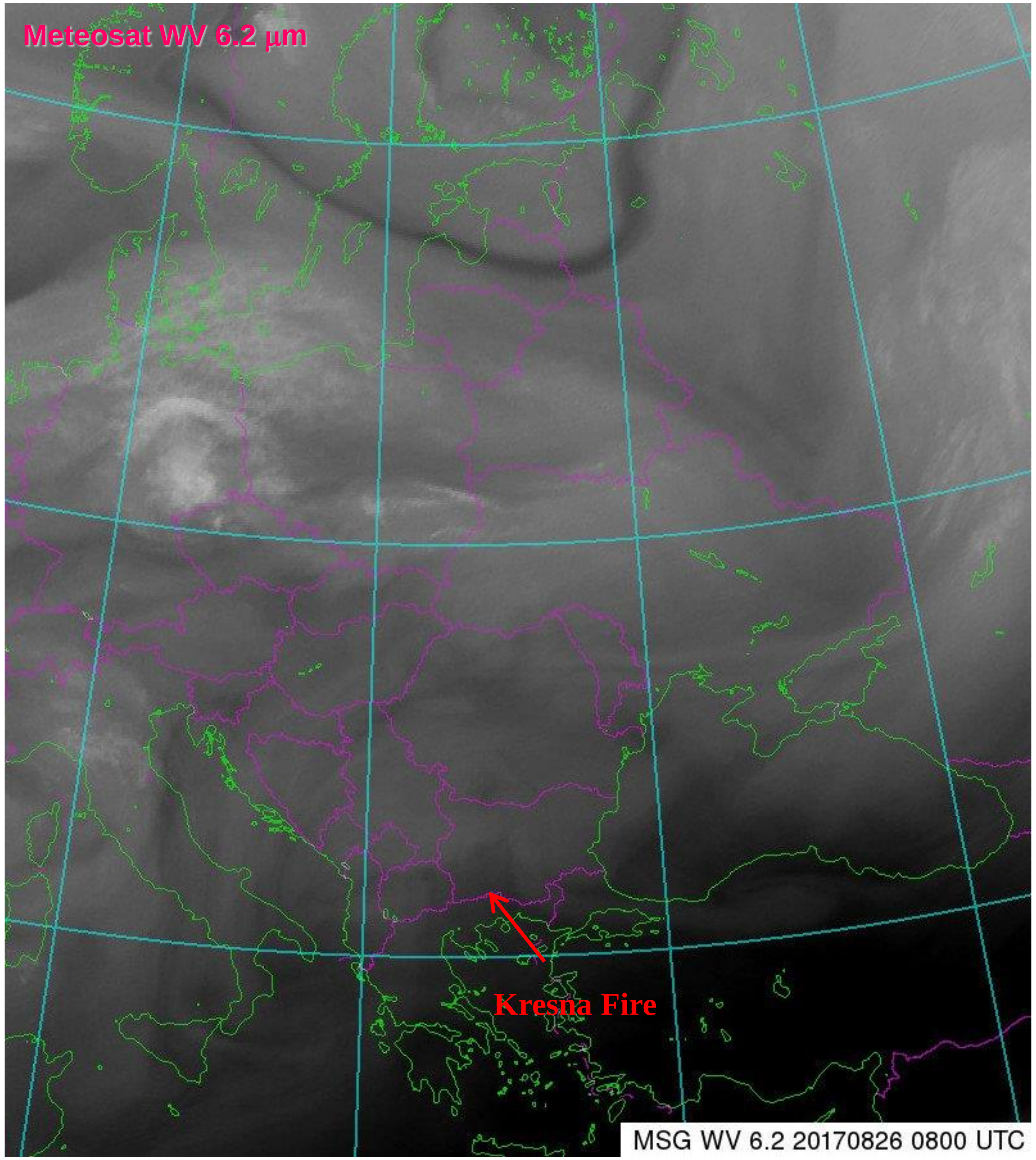
25 Aug:

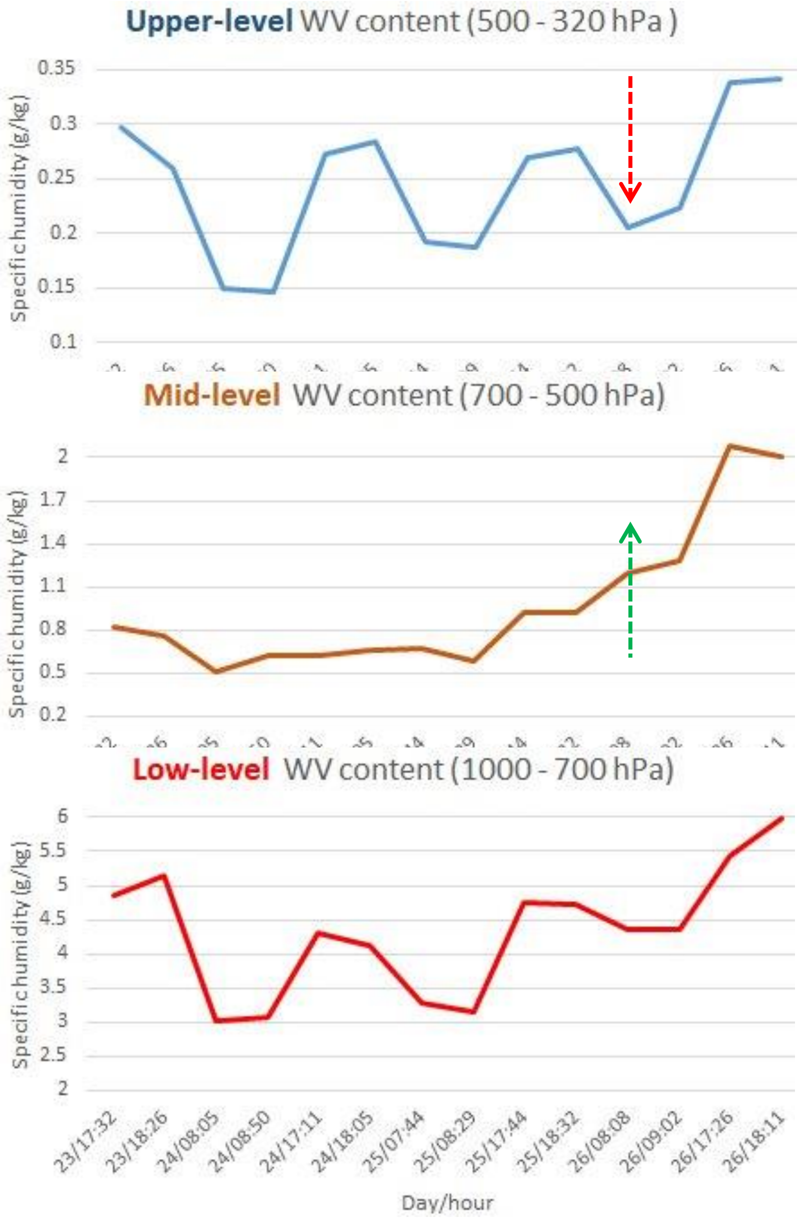
- ***FIR Fss: 1015 – 1030 UTC each 15 minutes; FIR Rss: 0210 – 1340 UTC each 5 minutes***
- ***LSASAF FRP: 0045 – 1430 UTC; 2,255.7 MW radiant energy released and 348,890 kg carbon emissions.***
- **MODIS 6 and S-VIIRS 750 m with several hot spots identified**

- ***26 Aug: Among the SEVIRI algorithms only FIR Rss has single detection at 0310***
- ***26, 27, 28 Aug*: only MODIS 6 and S-VIIRS proceed to detect the fire (in addition to 25 Aug)**

Dry stratospheric intrusion seen in WV imagery

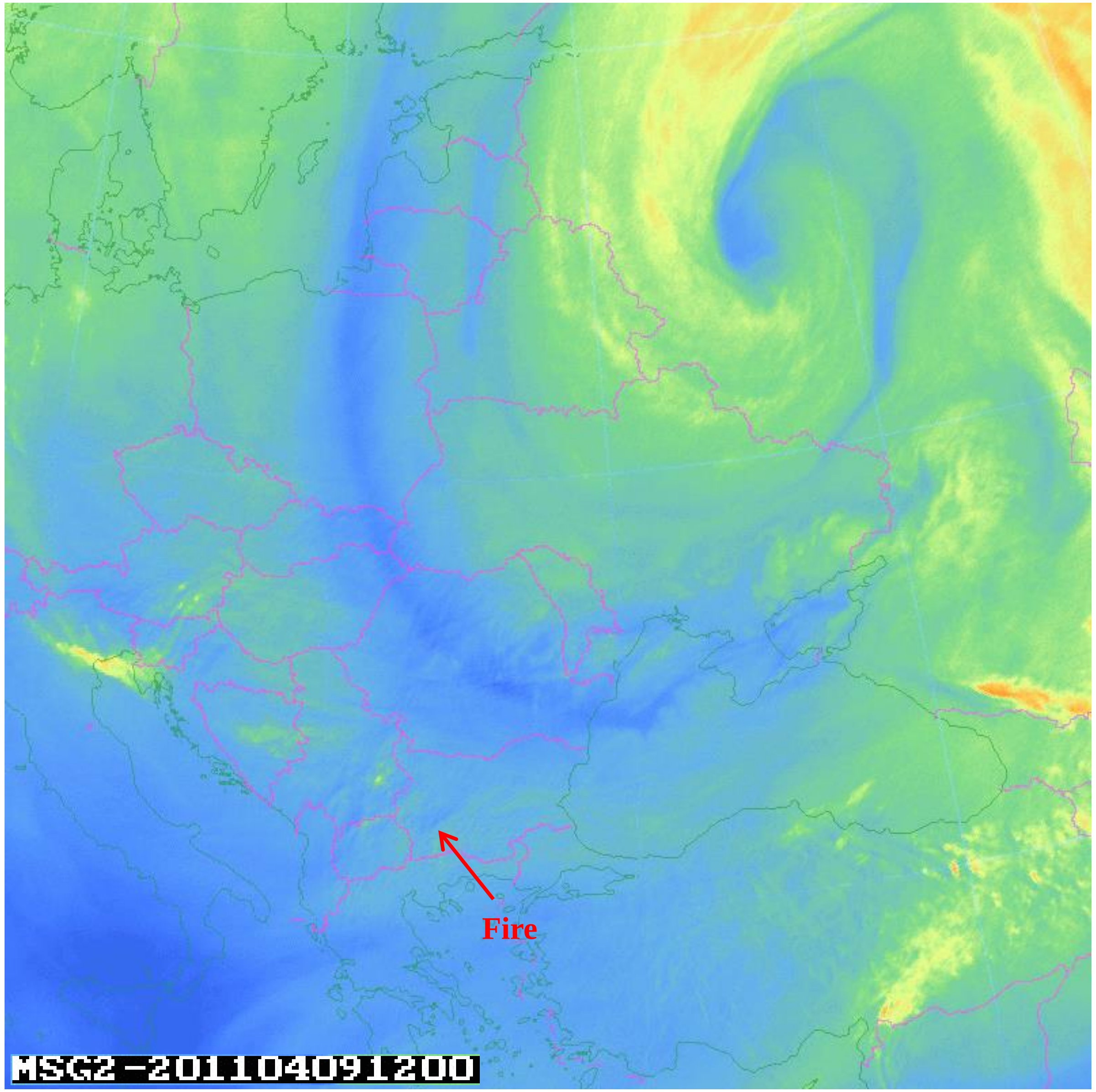
Kresna fire, Bulgaria, 26 August 2017





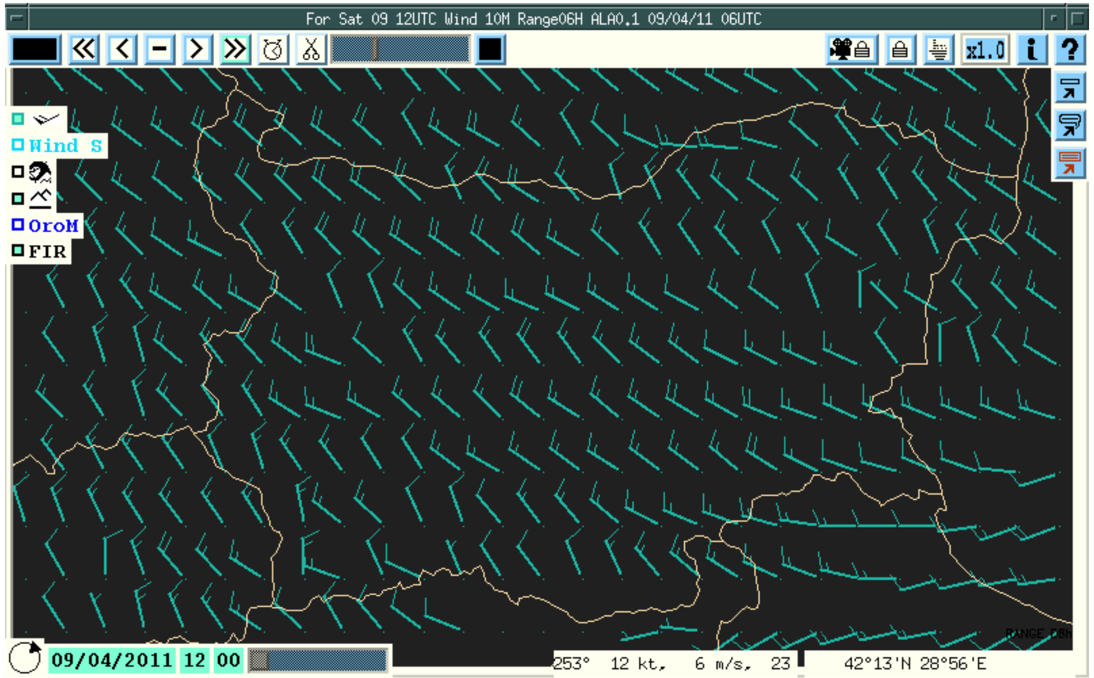
Vertical transport of dry air

Meteosat Colour Enhanced WV 6.2 µm



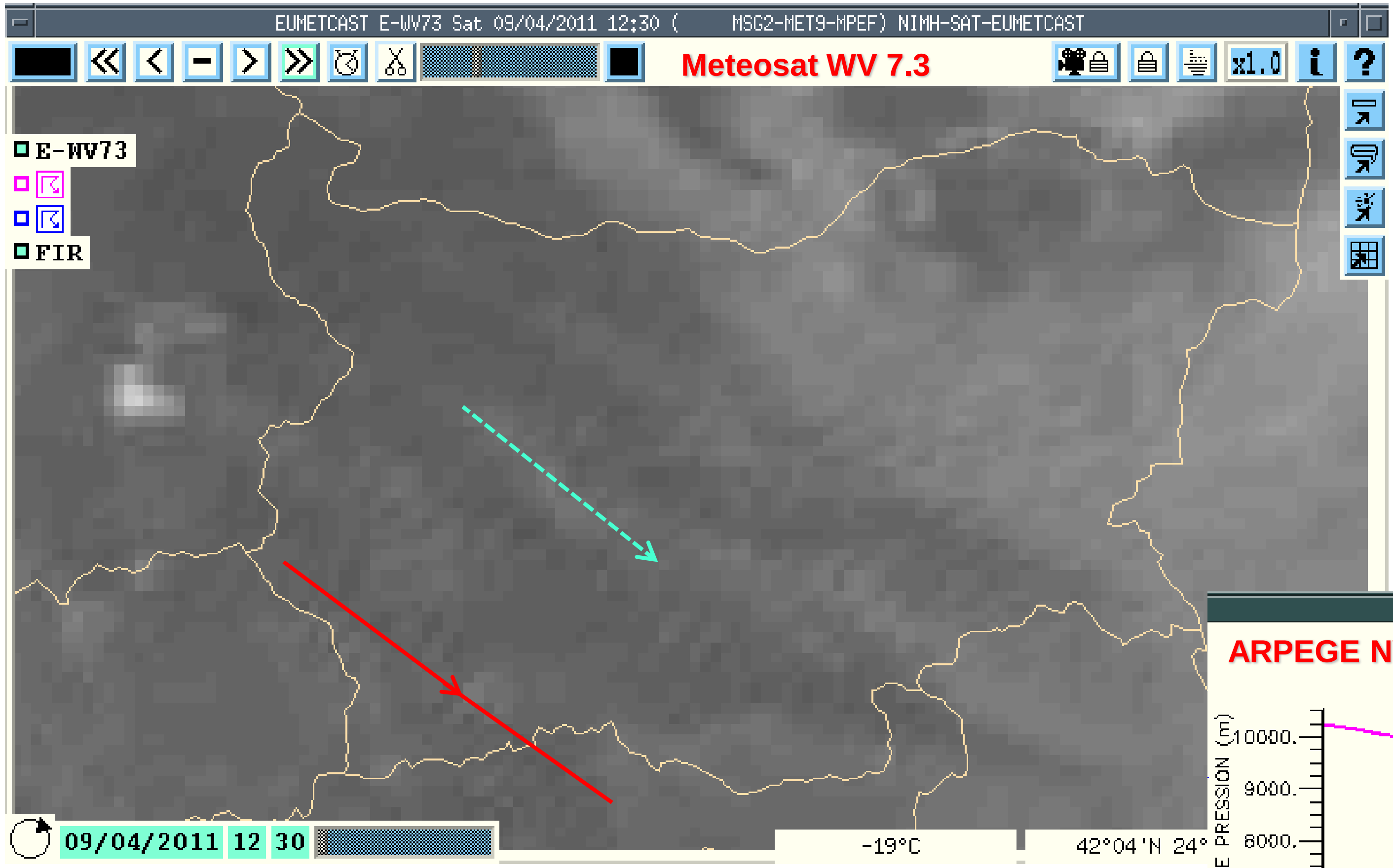
Wild fire, Bulgaria, 9 April 2011

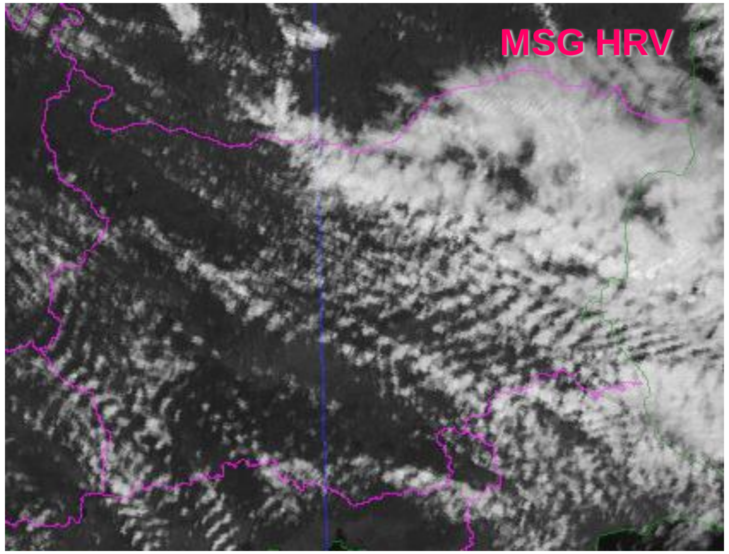
ALADIN NWP model Wind 10m

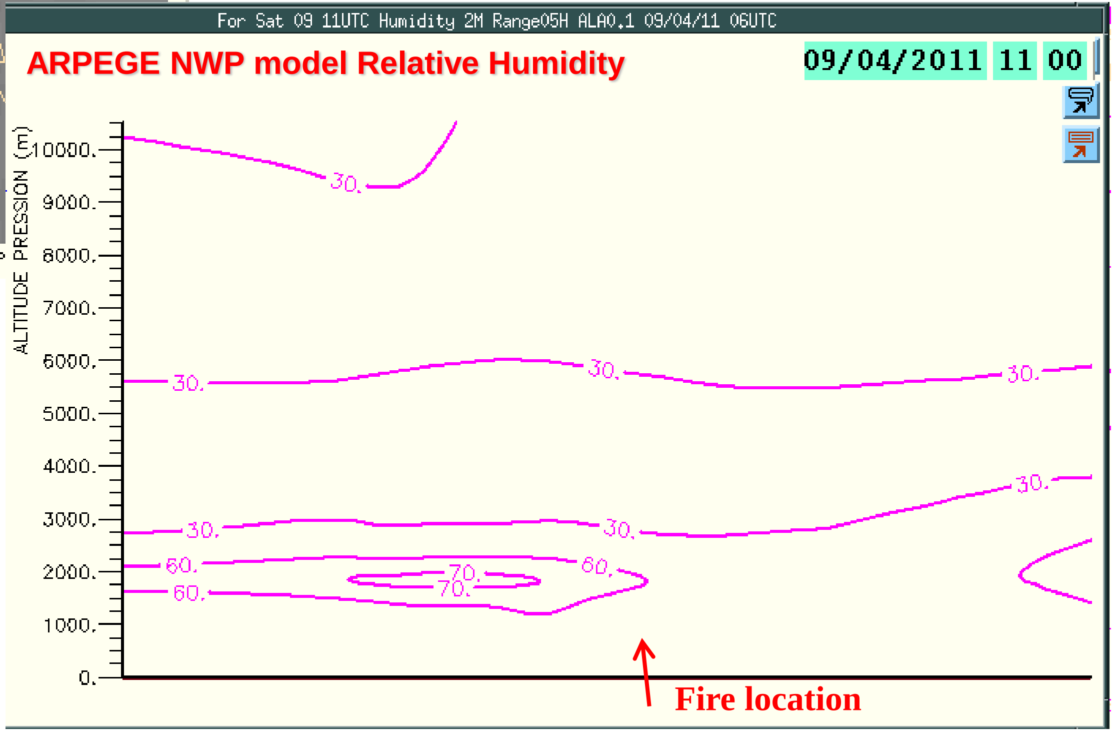


- **Wild Fire developed with 6-7 m/s sustain wind near the surface.**
- **The evolution of the wind field is govern by the upper-level circulation: Approach of upper-level trough in blocking regime.**

Low- / Mid-level airmass drying seen in WV images 7.3 µm







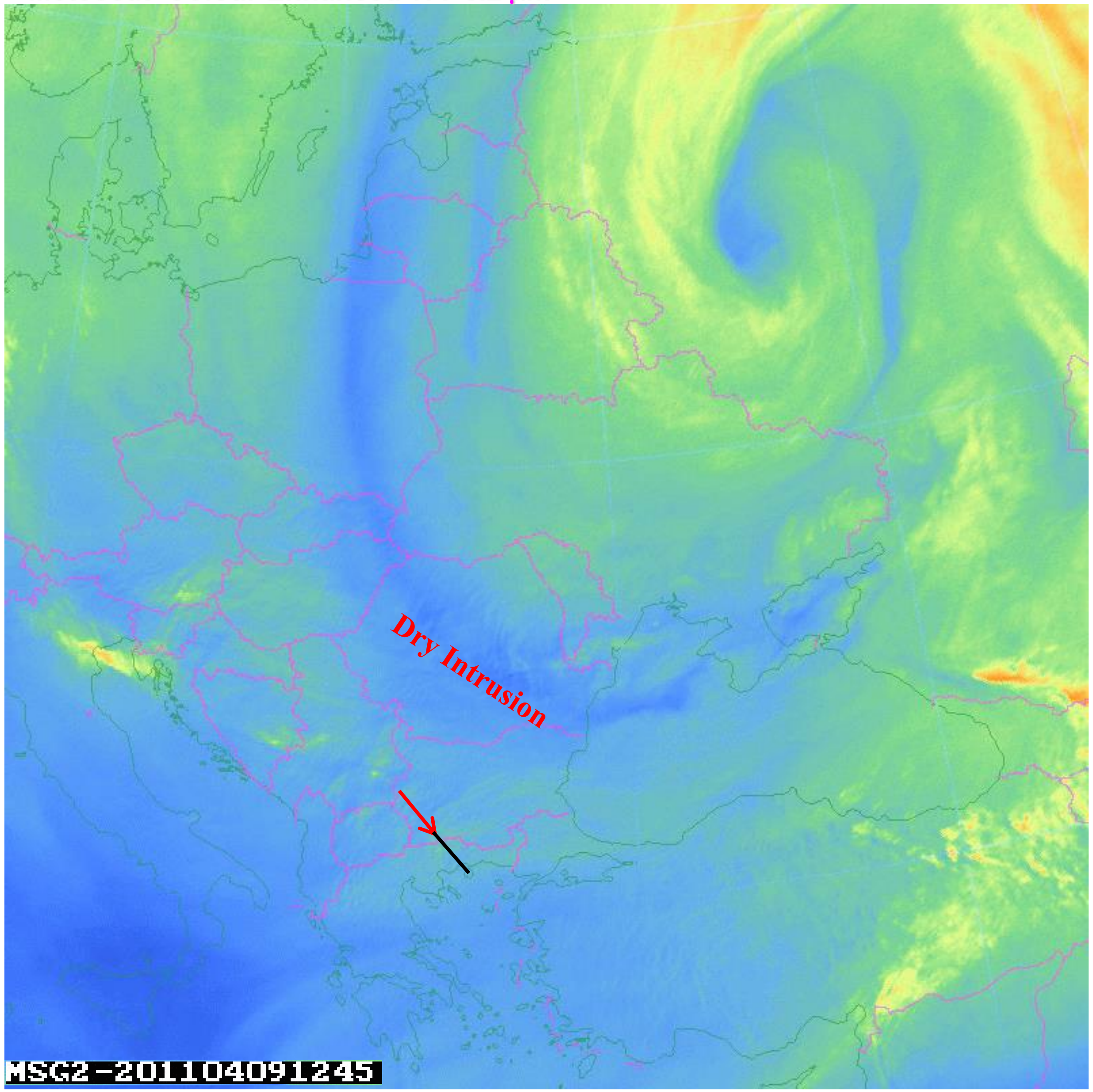
11 UTC: Gravity waves in the cloud field seen in the **7.3 µm imagery**:

- generated through **instability in jet streams, and the interactions of surface winds with topography**
- could be visible on satellite imagery through cloudiness or moisture as a tracer.
- Disappeared from the image with **decrease of low- and mid-level humidity**

15 UTC: Wild Fire ignition in the region of Drying low-level airmass

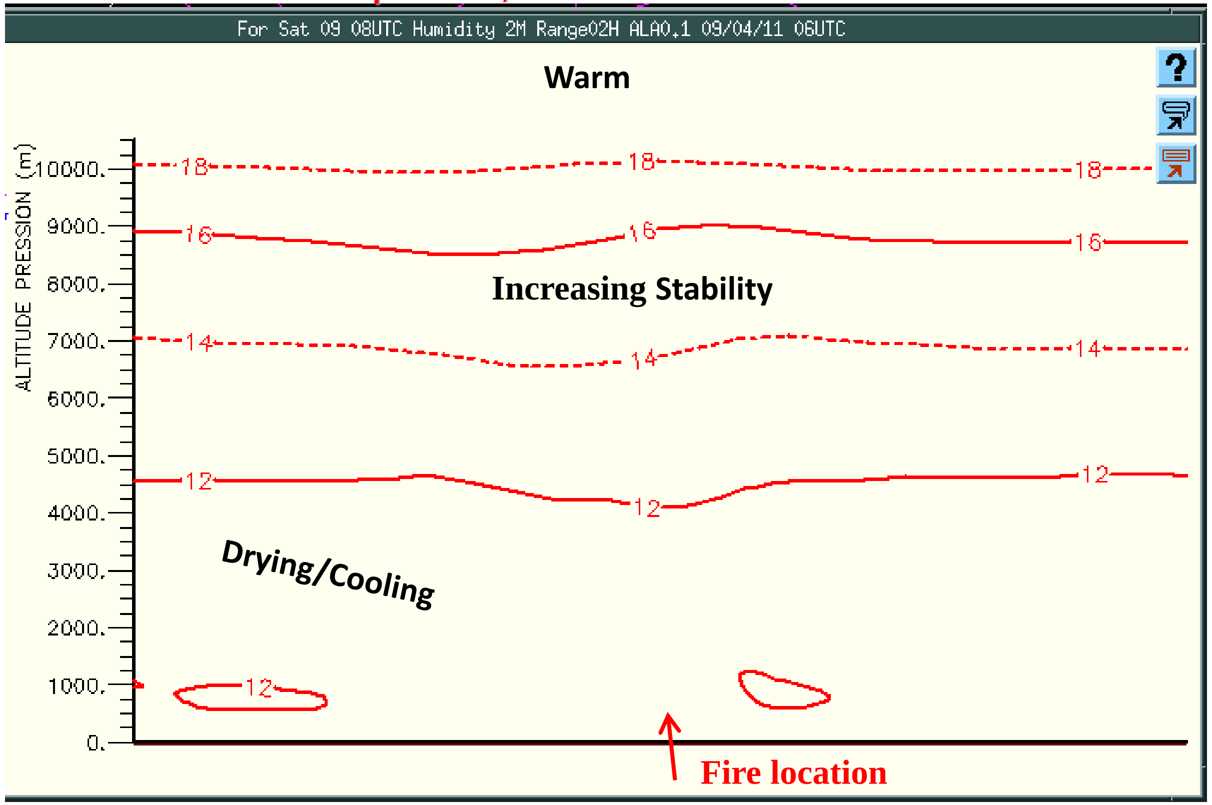
Vertical transport of dry air associated with frontal circulation

Meteosat Colour Enhanced WV 6.2 μm



Wild fire, Bulgaria, 9 April 2011

Wet-bulb Potential temperature, Vertical cross section Vertical cross section



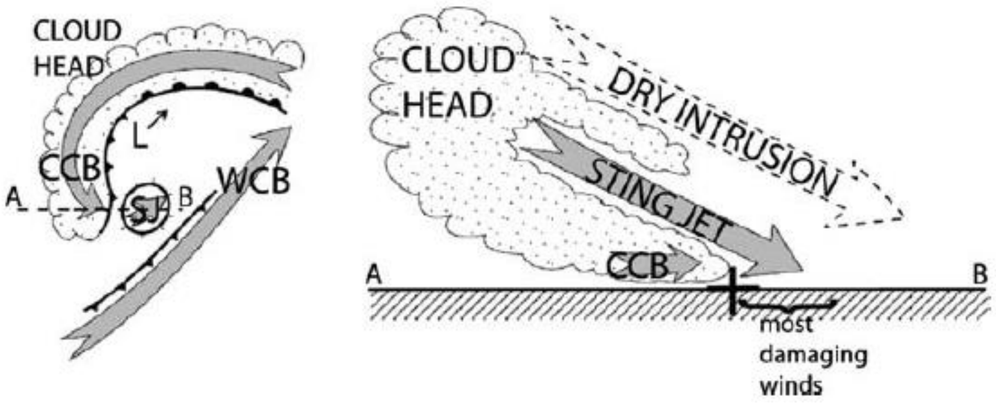
Approaching of upper-level trough in blocking regime:

- Subsidence of dry, cold air from upper troposphere down to the low-levels along the slope of the frontal zone.
- Increasing mid to upper-level stability
- The dry air subsidence is enabled by the vertical circulations associated with frontal systems

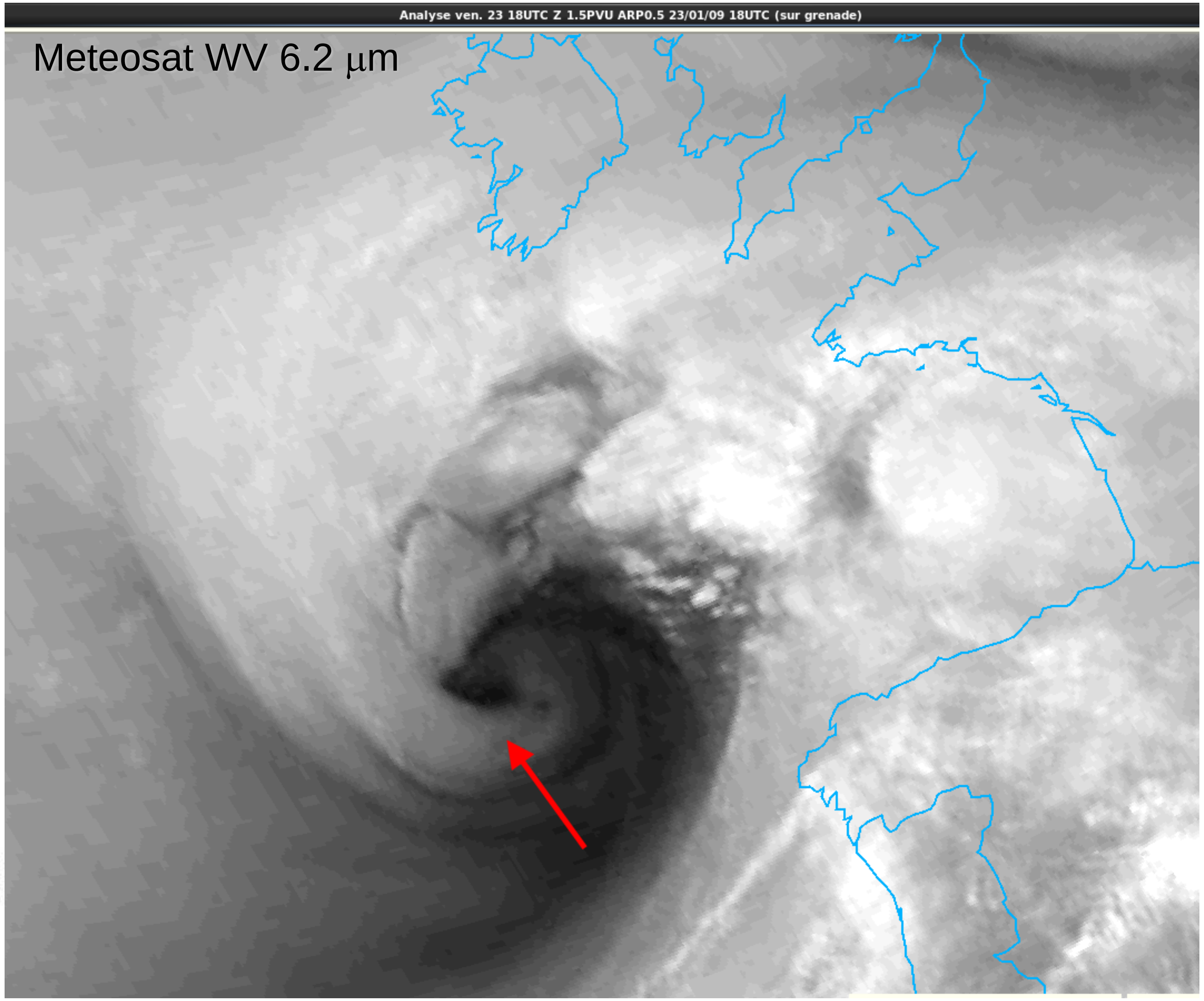
WV signatures of strong wind: Sting Jet, 23 January 2009 1800 UTC, SW of France

The **sting jet is a mesoscale descending air stream that can cause strong near-surface winds in the dry slot of the cyclone**, a region not usually associated with strong winds (Browning, 2004; Schultz and Sienkiewicz, 2013).

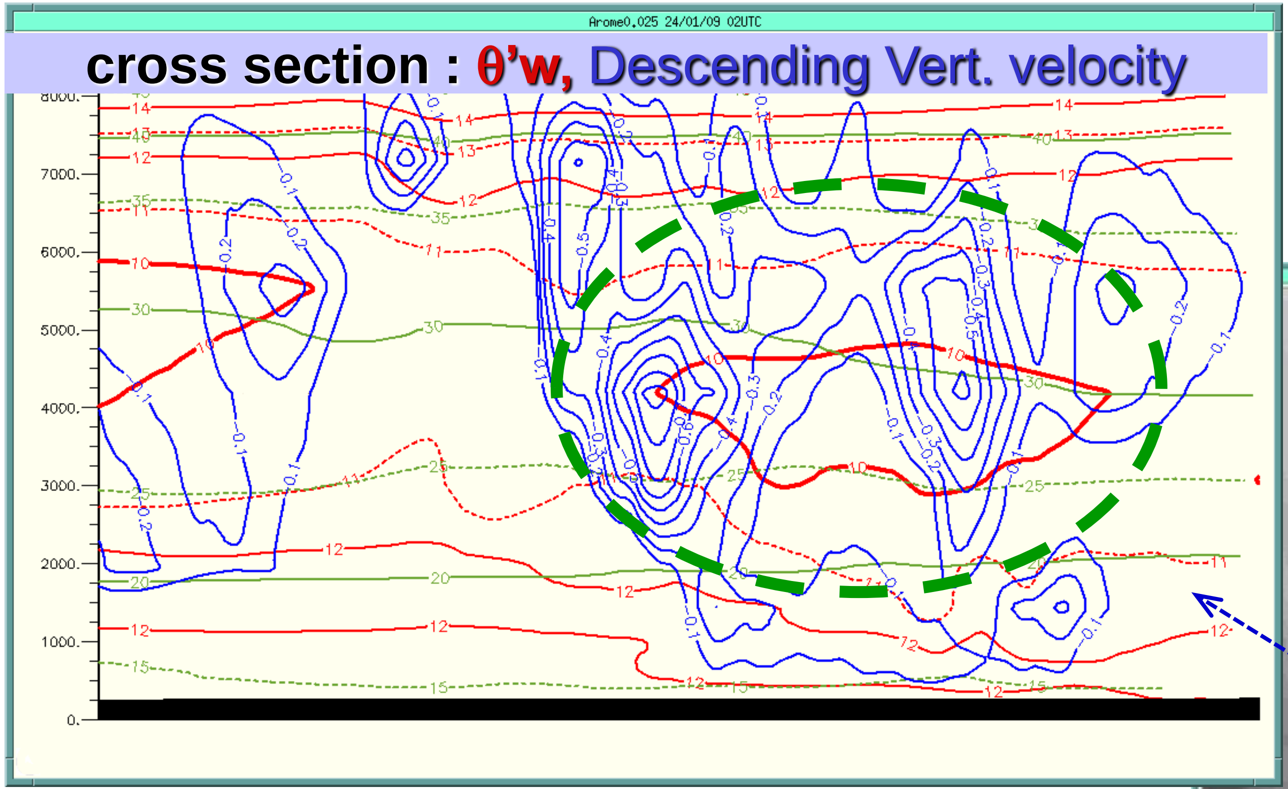
A sting jet is a flow of air that originates in the cloud head associated with a rapidly deepening area of low pressure (see Georgiev, C., Santurette, P., Maynard, K., 2016).



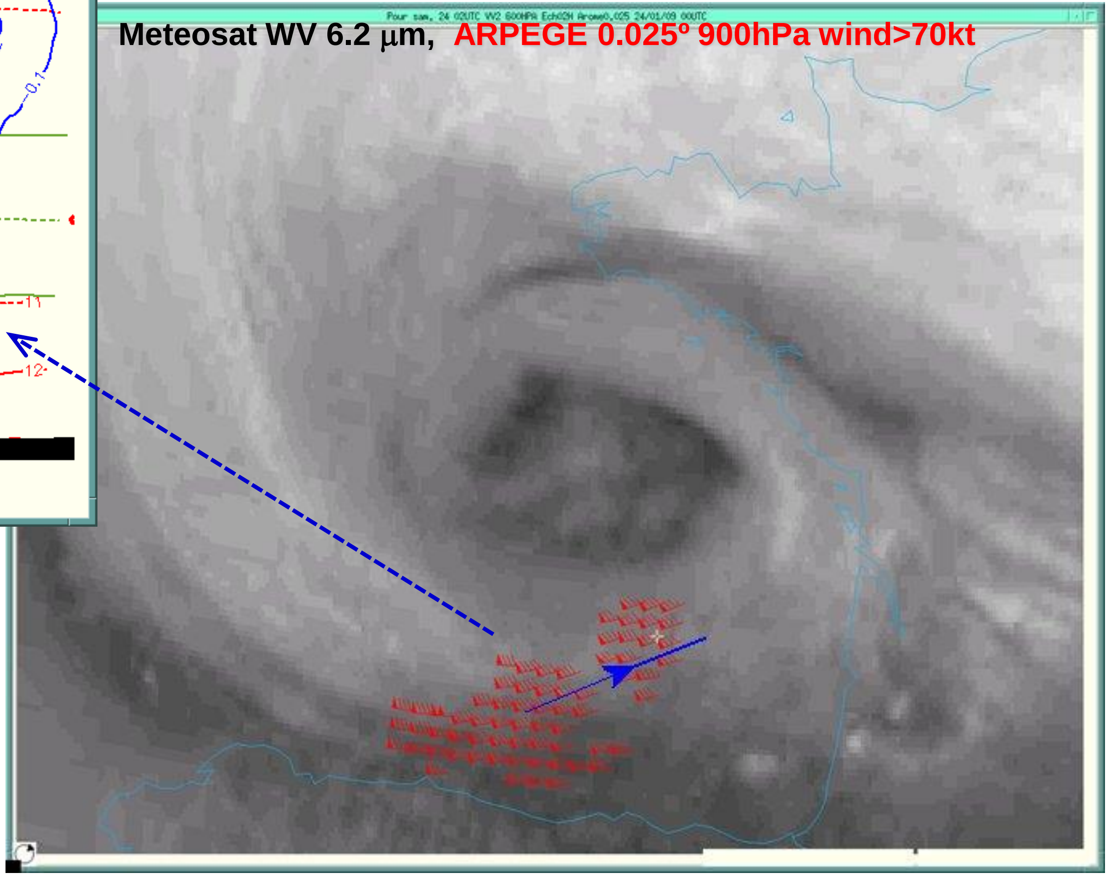
Conceptual scheme of the sting jet (SJ) beneath the descending dry intrusion and above the cold conveyor belt (CCB) (Clark et al., 2005).



Sting Jet, 24 January 2009 0200 UTC, SW of France



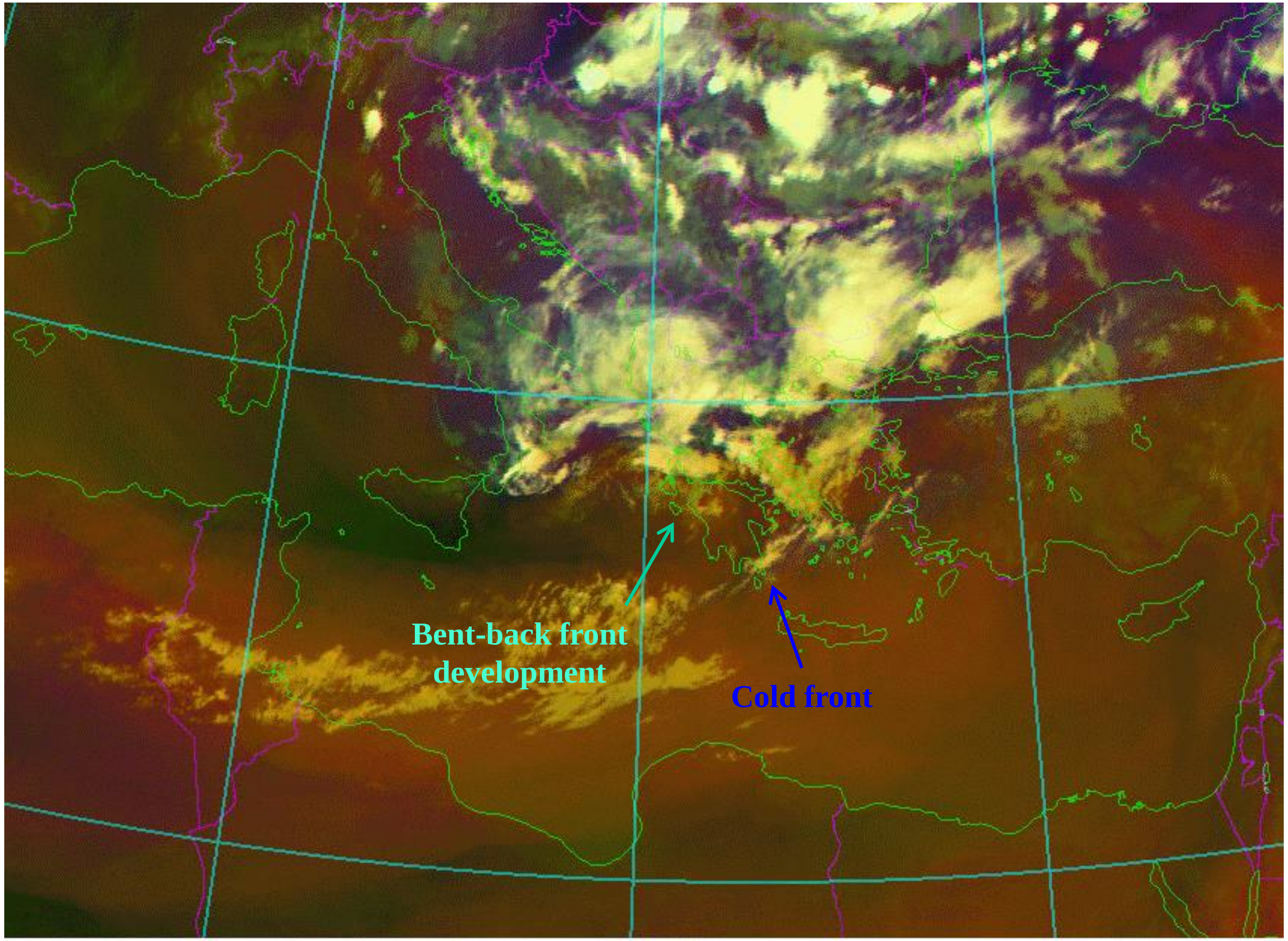
Srong subisdence of cold dry air



Strong wind at 900 hPa level

For the conceptual model, physical understanding and the effects, see also Herold (2022).

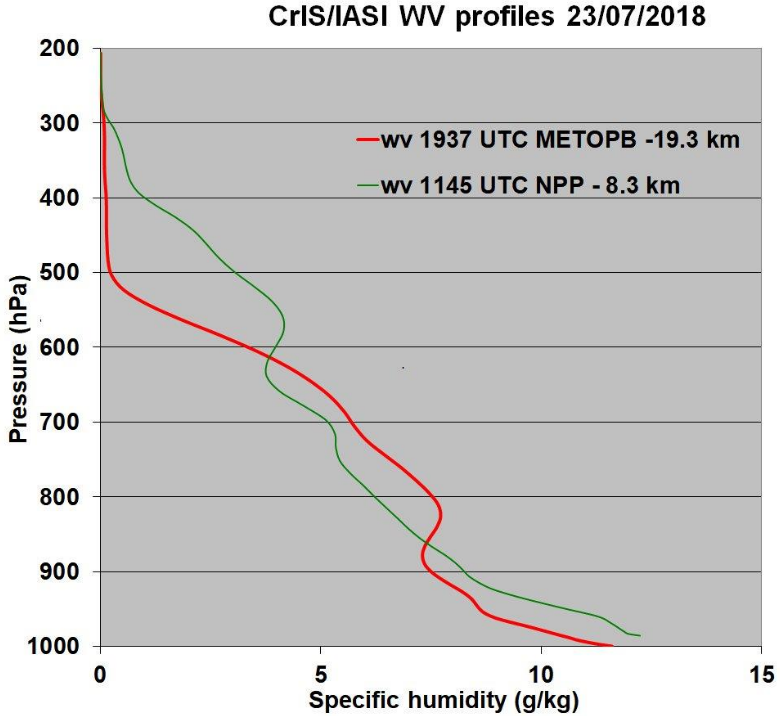
Vertical transport of dry air associated with frontal circulation,
Bent-back front and Sting like feature



rgb-AIRMASS 20180723 1700 UTC

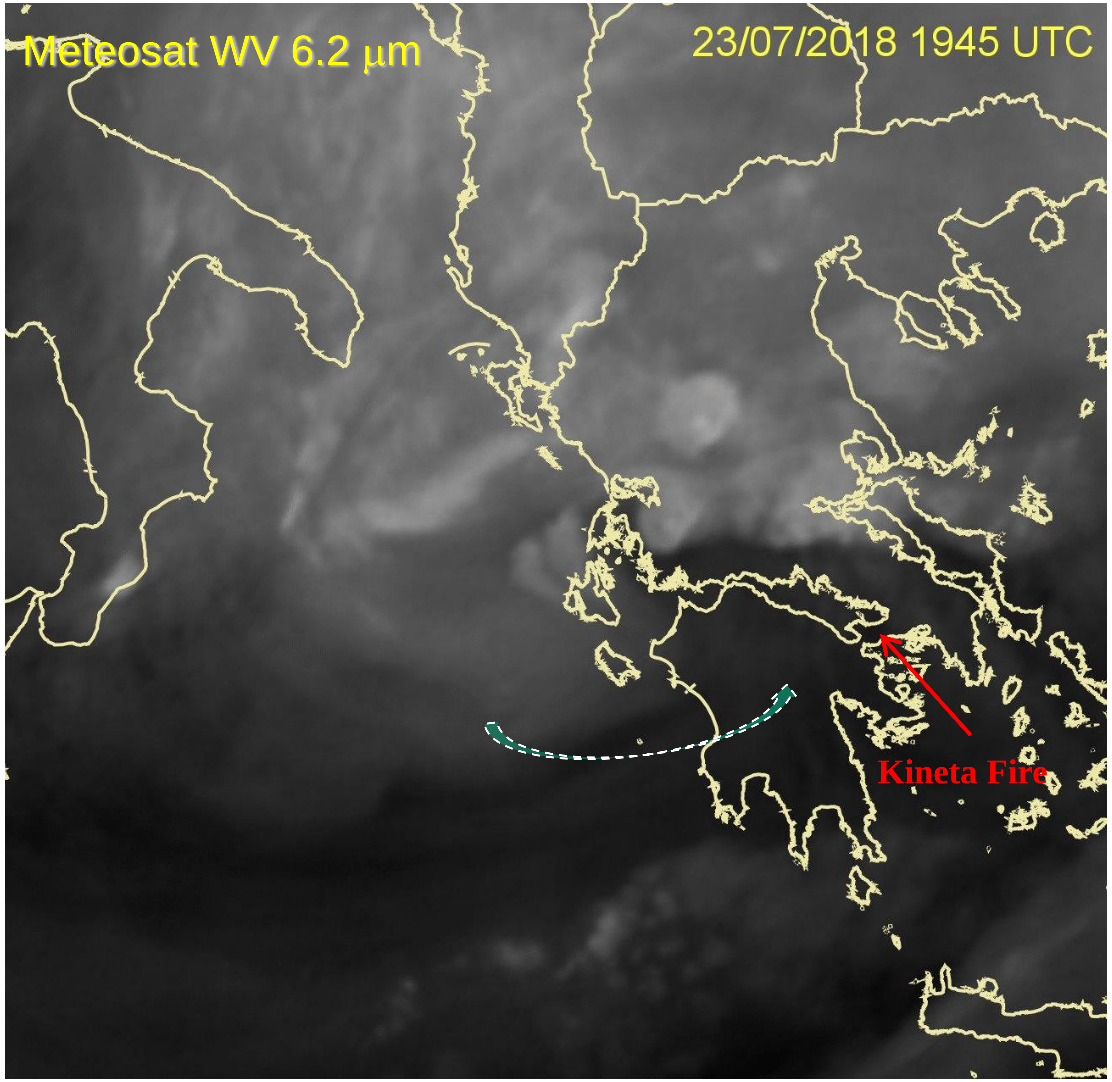
WV profiles by Stephen Tjemkes

Not a typical case of the sting-jet phenomenon which is usually associated to fast deepening mid-latitude cyclones.

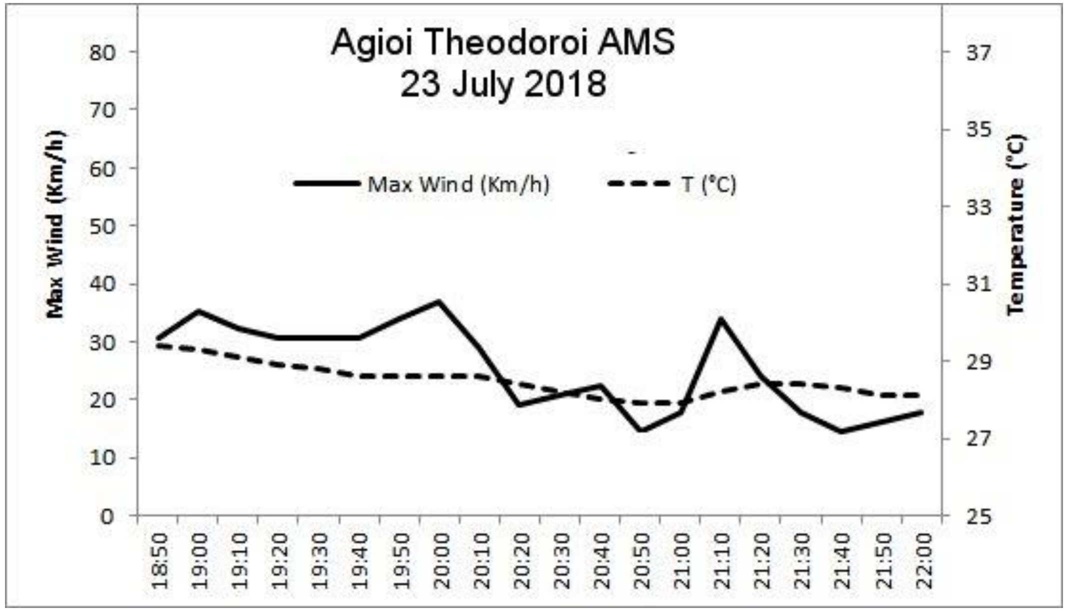


- Dry intrusion at upper-troposphere.
- Sharp decreasing of moisture content in a thin layer below 800 hPa level that may be due to evaporation of descending air.

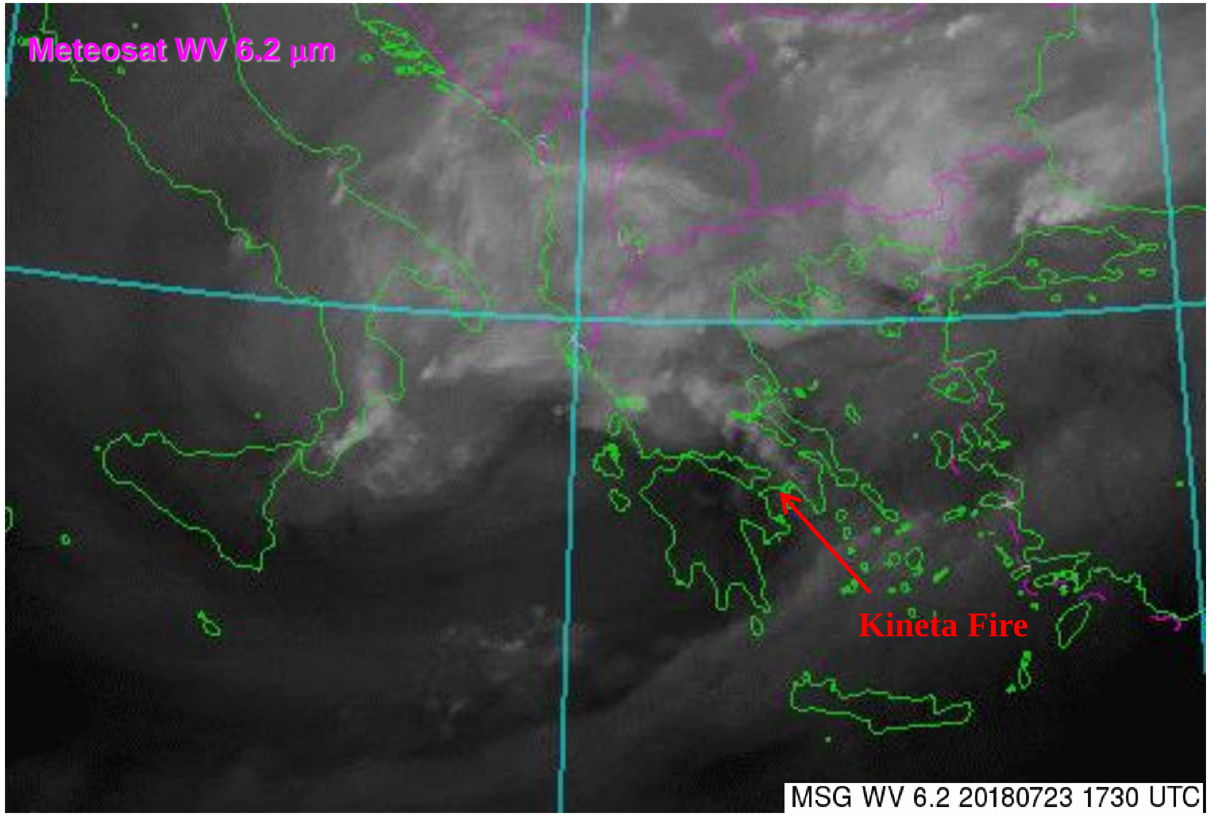
Vertical transport of dry air associated with frontal circulation, Sting Jet feature near Kineta Fire, Greece 23 July 2018

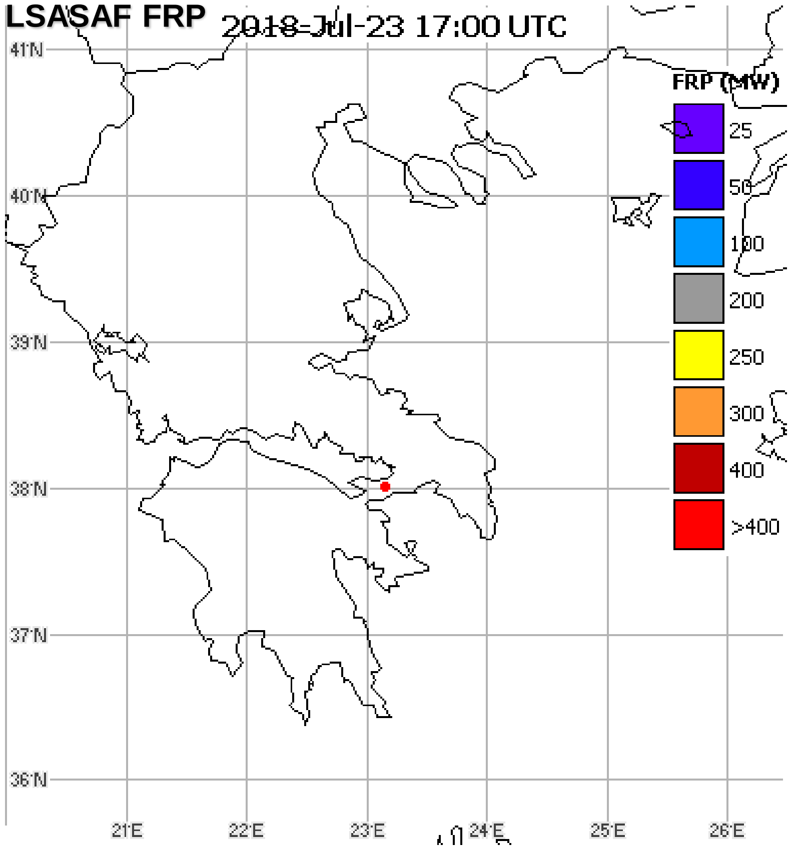


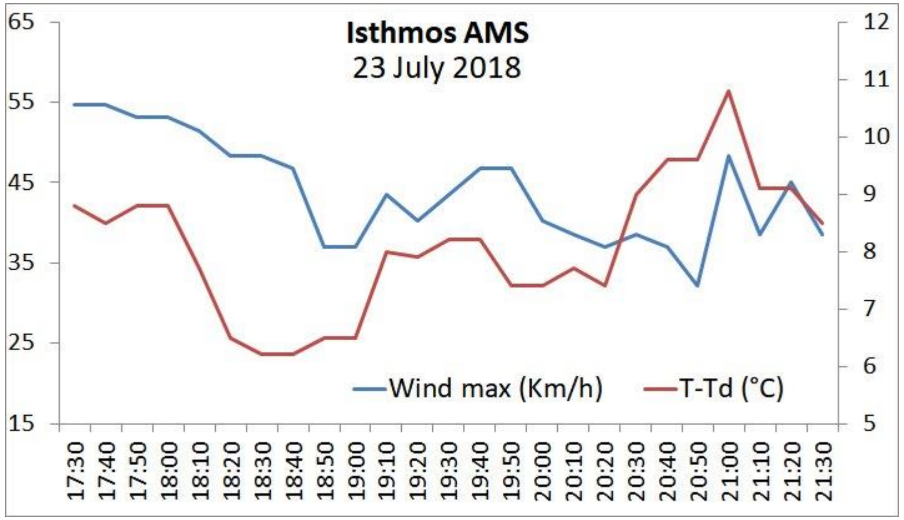
Wind speed fluctuations measured by Agio Theodoroi AMS, located approximately 3 km south of Kineta fire location, and 15 km from the sting-jet feature around 21 UTC.



AMS data provided by the National Observatory of Athens network (NOA).







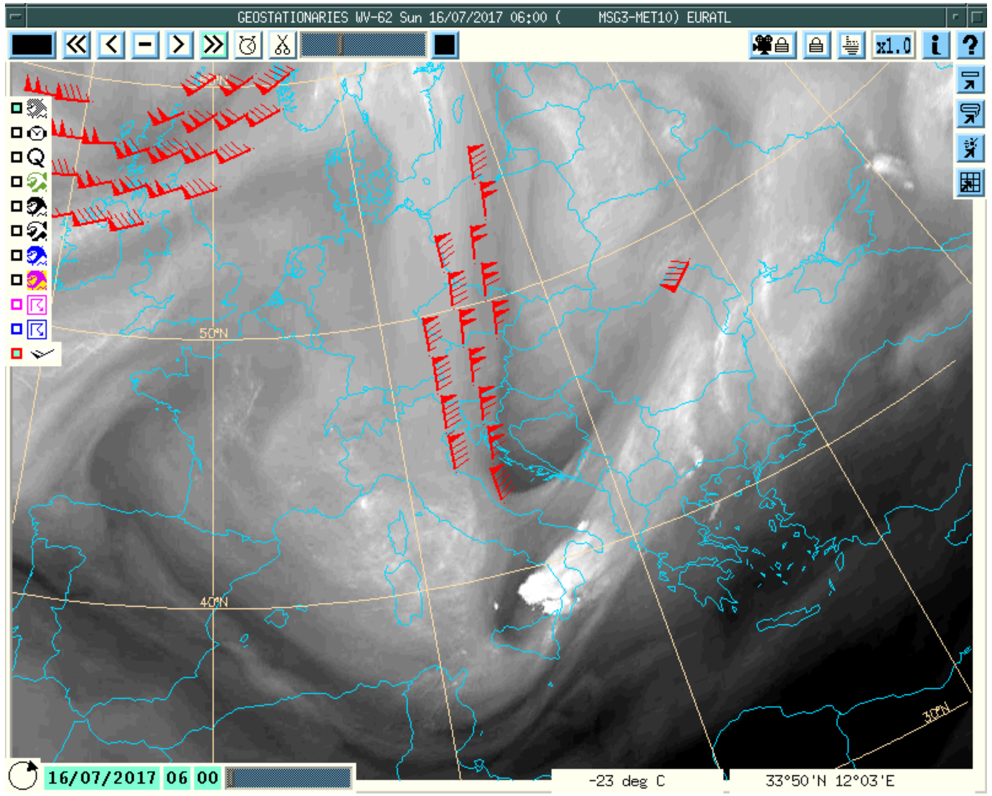
AMS measurements, 15 km west of the fire location, very close to the sting-jet feature around 21 UTC:

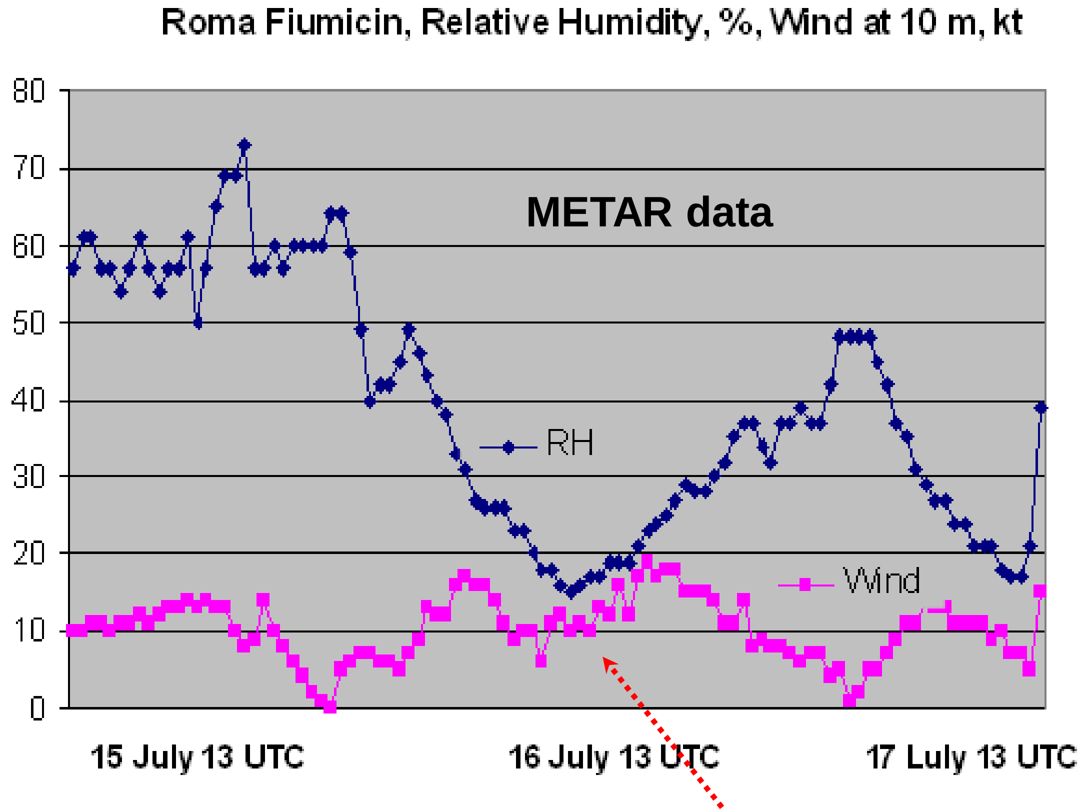
Wind gusts after 1830 UTC, closely related to the dry air intrusion, inferred by maximum of the T-Td difference.

Kineta Fire intensification especially after 1900 UTC Seen by the LSASAF FRP.

AMS data provided by the National Observatory of Athens network (NOA).

Conclusion





Satellite Water Vapour imagery provides information for the evolution of upper-level dynamical structures, which are associated with processes leading to

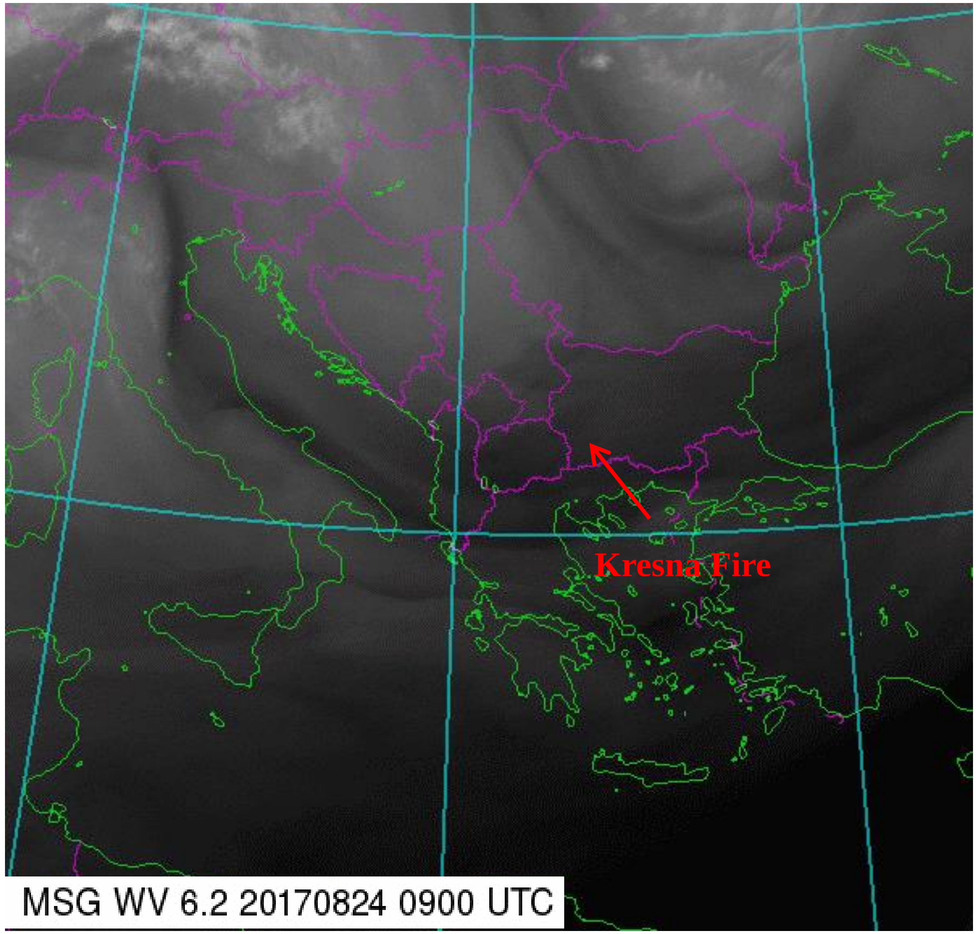
- **rapid drying of the low-level air and**
- **increasing wind speed**

that influence the fire development and can increase fire activity.

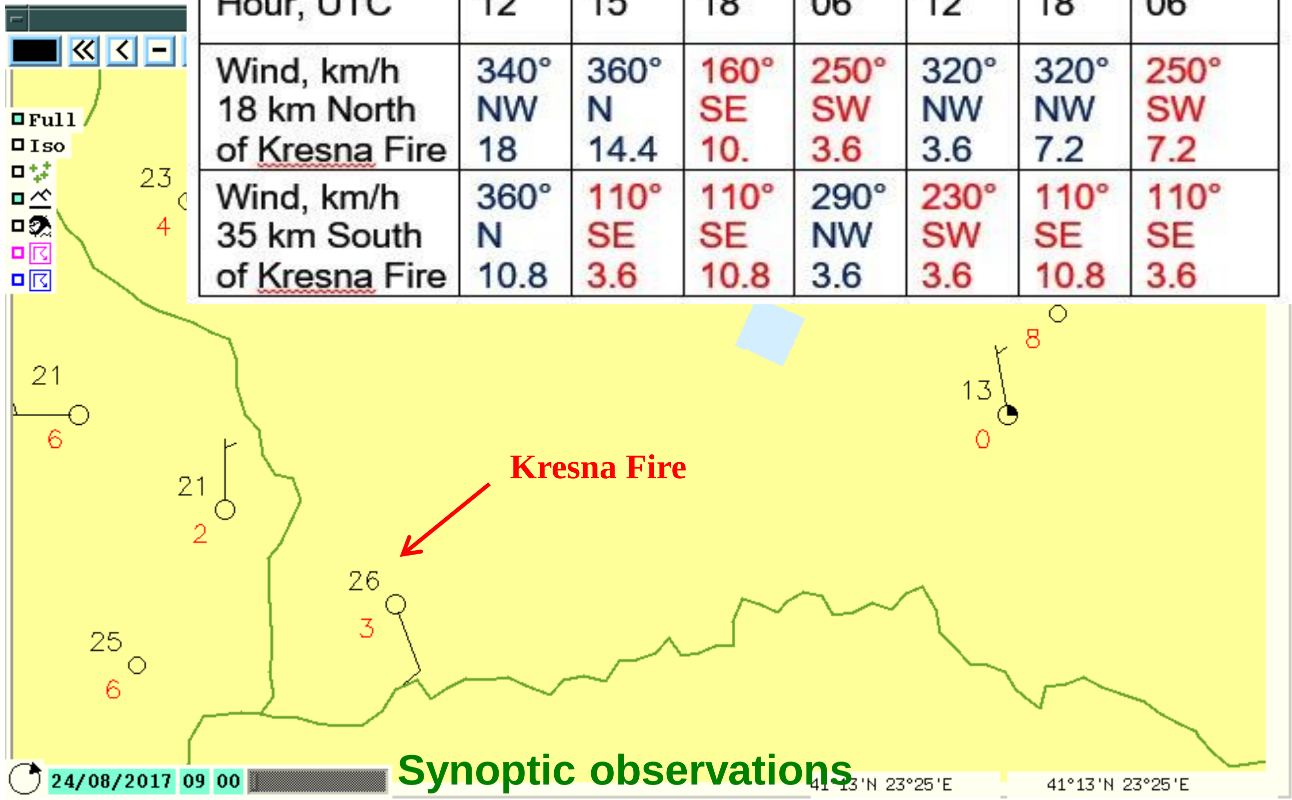
Data provided by Davide Melfi
Italian Air Force Meteorological Service

Conclusion

Fluctuations of the near ground wind increase a wildfire spread and make difficult the fire rescue operations.



Day	24 Aug			25 Aug			26 Aug
Hour, UTC	12	15	18	06	12	18	06
Wind, km/h 18 km North of Kresna Fire	340° NW 18	360° N 14.4	160° SE 10.	250° SW 3.6	320° NW 3.6	320° NW 7.2	250° SW 7.2
Wind, km/h 35 km South of Kresna Fire	360° N 10.8	110° SE 3.6	110° SE 10.8	290° NW 3.6	230° SW 3.6	110° SE 10.8	110° SE 3.6



The upper-level circulation governs the low-level flow.

Strong upper-troposphere dynamics seen in the evolution of dynamic patterns in the WV imagery enables mesoscale low-level features to set up through interaction with topography.

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