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RADAR CHARACTERISTICS ASSOCIATED WITH THE STRAIGHT LINE WIND FROM WESTERN ROMANIA – SEPTEMBER 17th 2017 –

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ABSTRACT. Radar characteristics associated with the straight line wind from western Romania - September 17th 2017. The present paper is a radar analysis on **the mesoscale convective system** (MCS), which evolved as a straight line wind across western Romania in the afternoon of the September17th. This convective storm has developed in a SV-NE oriented baro-cline area, extending from the Italian Peninsula, over Serbia, Hungary, Poland and Ukraine. **The temperature gradient was over 15 degrees**, and **the tropospheric jet was parallel** to this baro-cline. Large wind velocities were present throughout the troposphere column, which means that the **shear force had high values throughout the tropospheric column**, **but concentrated to 500 hPa (approximately 5500 m)** and in the low layers **below 700 hPa (approximately 3000 m),** s**aturation deficit was high** on the western border of Romania. All these elements initiated and organized the thermo-dynamic convection towards a severe structure. The storm was initiated by the strong descending of the convective meso-scale system that evolved over the northwest of the Balkan Peninsula (Croatia and Bosnia).

Key words: radar analysis, drecho, severe wind storm

A. INTRODUCTION

On September 17th, 2017, several counties in the west and the center of the country were affected by a storm, which was organized as a linear convective meso-scale system (Fig. 1), which generated intensifications of wind speeds up to 90 ... 120 km / h and isolated over 140 km/h

Following these severe wind intensifications, 8 people died and more than a dozen people were injured as a result of the fall of trees or structures.

The severe phenomena were generated by the instability line (Fig. 1), which developed an arc echo radar structure (bow echo), associated with a **rear inflow jet** (RIJ). The strong descending associated with this convective meso-scale system has generated strong „derecho" winds. This term "derecho" was first used

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by Hinrichs (1888) to describe a long-life straight-line windstorms that generate wind speeds above 25 ... 30 m / s, concentrated on an area of over 400 km^2.

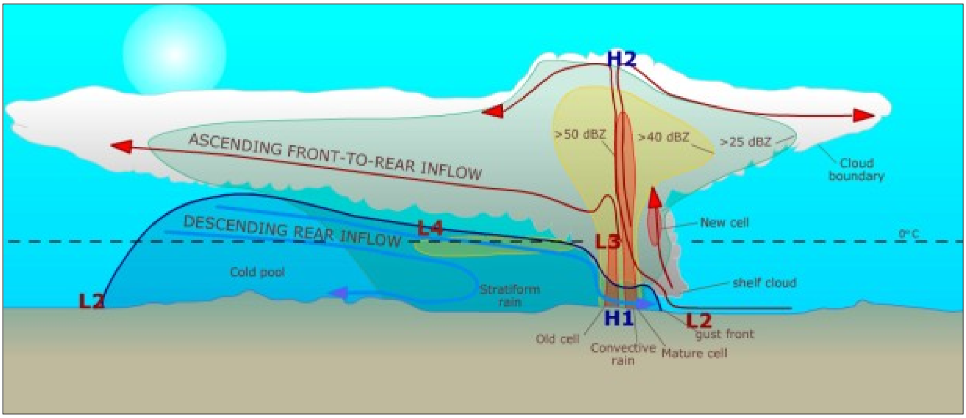

Fig. 1. A conceptual model of a mesoscale convective system (Smull and Houze, 1987).

According to the American Meteorological Agency (NNWS), a "derecho" has a distinctive appearance on the radar, known as a bow echo, with a number of unique features, such as areas with low reflection in the posterior, associated with a **rear inflow jet, mezo-vortexes**, and during the evolution with two or more major descending (macroburst) may occur.

Therefore, in this paper I aimed to make an analysis of this storm, especially the associated radar characteristics, from a theoretical perspective but also practical to be useful in the future in the operative meteorological activity.

The last similar event took place in 2011 when Bulgaria and the central part of the Romanian Plain were affected (Viorel Paraschiv et al. 2012, Iliana Gospodinov et al. 2013).

B. DATA AND METHODS

In this analysis, radar data from S-band radar from Timișoara, from the National Meteorological Administration network, were tracked and the basic products, namely the **Doppler radial velocities**, which indicated the movement of the convective system as **the sum of the wind produced of this storm** and **the speed of travel**, of course correlated with **reflectivity**. Relative speed data only indicated one of the components, that is **the movement inside the storm**, but they greatly underestimated the travel speed.

A series of radar signatures characteristic to the **bow echo** structure have been identified

MARC (mid altitude radial convergence) - medium-level radial convergence

RIJ (rear inflow jet) - the rear entrance jet

FRF (front to rear flow) - mesocalar ascent

WER (weak echo region) - weak echo region

A number of elements have been identified that indicate the dissipation of a convective system:

R (reflectivity) - high reflectivity only at first elevation

VIL (vertical integrated liquid) - rapidly decreasing

V (velocity) - RIJ and MARC

SRV (storm relative velocity) - MARC

These data are extremely important in today's operative work to understand and anticipate the subsequent evolution of thermal or thermodynamic convection. In the present case, dissipation of convective systems has occurred under conditions that would have suggested, at least theoretically, convection restoration.

Numerical forecasting models for the identification of synoptic scale elements were also analyzed.

Data were taken from meteorological stations within the National Meteorological Administration, on meteorological parameters evolution, as well as satellite imagery in the visible field.

3. RESULTS AND DISSCUSIONS

3.1. General aspects

Meteorological extremes marked the middle of September. In the afternoon of September 17, the instability line from the west of the country was accompanied by gusts of wind that surpassed 90 km/h, resulting in material damage and loss of human life. A series of atmospheric factors amplified these severe weather events, including the high temperature difference between the tropical air mass, which presented temperatures above 35ºC in southern Romania (38 ºC at Zimnicea) and the polar air mass from the center of Europe with temperatures of only 12 ... 14ºC in western Hungary (17ºC in Budapest).

3.2. General sinoptic context

In the middle of September, an atmospheric blockage of the "omega" type occurred over the North Atlantic’s mid-troposphere. As a result, a long wave talweg gradually developed over Western and Central Europe, which later evolved into a cut-off structure (Fig. 2 - right). Romania was on the morning of September 17, on the ascending part of this altitude structure, and the polar jet axis was on the western side.

Cold air of the mid-troposphere (within the altitude talweg) initiated cyclogenesis in the northern Mediterranean basin (Fig. 2 - left). Subsequently, on September 17, the atmospheric cyclone in the Mediterranean basin quickly evolved to the north-east, across Hungary, and later to Poland and the Baltic Republics.

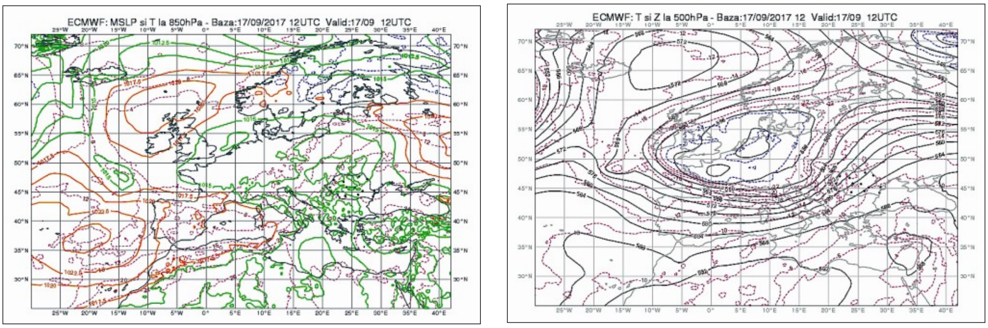

Fig. 2. ECMWF analysis – Ground pressure (left) and geopotential at 500 hPa, (approximate 5500 m in left) from September 17, 2017, 12 UTC.

On the southwest – northeast baro-clinic area, the cold front from the ground-based cyclone evolved, which influenced the afternoon of September 17 and the west of Romania. The polar jet (Fig. 3 - right) was kept parallel to this baro-clinic area in the low troposphere (with temperature gradients above 15ºC and consequently the shear force was raised on the whole tropospheric column, but especially in the low layers of the troposphere (Fig. 3 - left).

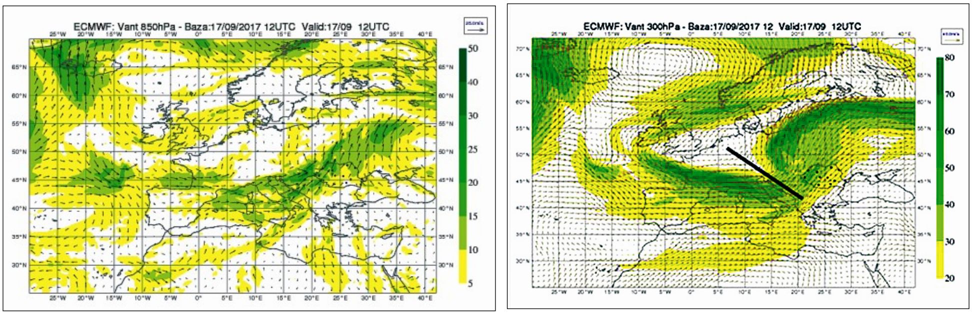

Fig. 3. ECMWF analysis – Wind at 850 hPa level (approximate 1500 m in right) and at 300 hPa (approximate 9000 m in left) from September 17, 2017, 12 UTC.

Since 1993 (Johns, 1993) there have been identified two classic synoptic patterns associated with long-lasting convective systems that develop radar-like structures on the radar, and derecho-type ground-level winds. The present one in the dynamics of the phenomenon was modulated by a cyclonic perturbation from medium latitudes (Fig. 4). In such synoptic situations, often in the hot season, linear convective structures develop, but not all of them become severe. Other elements, including instability and shear force of the environment, as well as the presence or absence of a dry air layer in the low troposphere, must be identified.

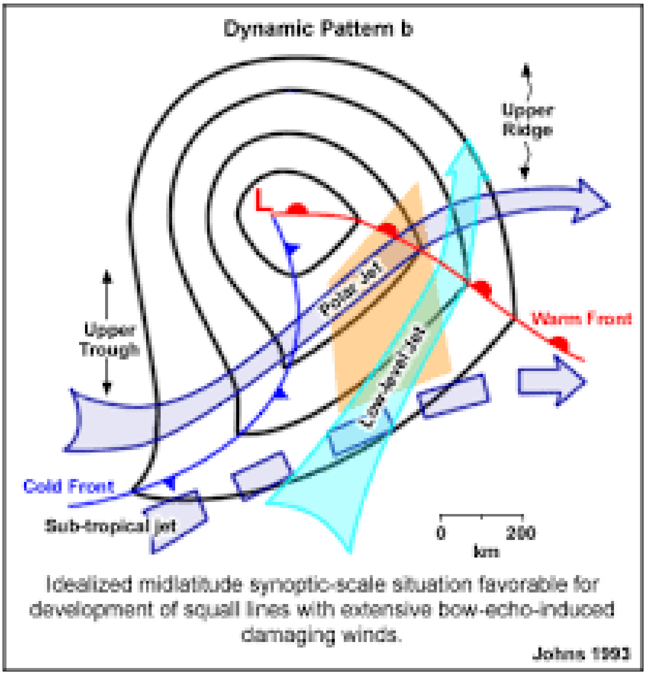

Fig. 4. Conceptual model at synoptic scale favorable to linear convective systems' development, with radar characteristics such as bow echo.
(after Johns, 1993)

3.3. Mezo-scale analysis

Aerospace data from Serbia (Belgrade) showed an intense flow from the south-western sector to almost the entire tropospheric column, except at low levels from the south-eastern sector. Also in the low troposphere layers, below 700 hPa (about 3000 m), the saturation deficit was very high that a dry air layer was present (Fig. 5).

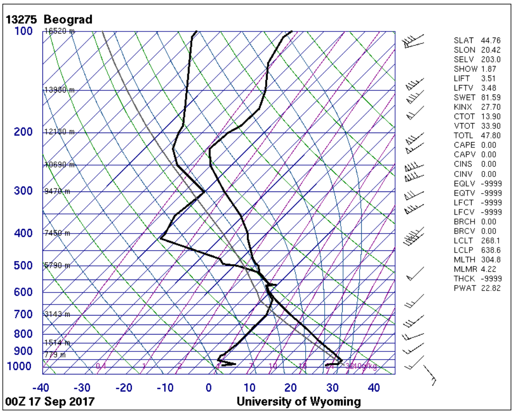

Fig. 5. Aerologic diagram, Belgrade, 17.09., 12 UTC
(Source: Wyoming University)

3.4. Event's description using radar data

All these elements have initiated and organized the thermo-dynamic convection towards a severe structure. The storm was initiated by the strong descending of the convective mezzo-scale system that evolved over the northwest of the Balkan Peninsula (Fig. 6 - left).

Thus, at around 15:00 local time (12 UTC), the instability line has developed a bow echo structure (Fig. 6 - right) associated with a descending **rear inflow jet** (RIJ). The strong downfall associated with this convective mezzo-scale system has generated strong winds of the "derecho" type, with speeds above 25 ... 30 m/s, concentrated on an area of over 400 km^2, starting from Timiș County and up to Maramureș County.

After 14:00 local time (11 UTC), more exactly between **14:18 - 14:43,** the convective storm approaching the western extremity of Romania (west of Sânnicolau Mare) was dissipated. The radar data showed the presence of rear inflow jet (**RIJ**), the mid altitude radial convergence (**MARC**), as well as a decrease in **VIL**, higher reflectivity only at first elevation, and last but not least decreasing electric activity. These data indicated the dissipation of the initial convective cells **in a dry environment** as indicated by aerosounding data (see Fig. 5), but **dynamic, moderately unstable** and with **a strong shear force in low layers**, which suggested, at least from a theoretical point of view, the rapid restoration of convection. In meteorological forecasting, these elements indicating the dissipation of a storm, in a moderately unstable environment but with high shear force, are extremely important in order to understand and anticipate the subsequent evolution of the thermo-dynamic convection.

At 14:43 (11:43 UTC), the rear inflow jet (RIJ) was visible in the radial gear (elevation angle 0.5) at 110 km west of Timișoara at an altitude of over 2 km (speeds around 26 m/s) (Fig. 7).

The Medium Radial Convergence Area (MARC) is identified at elevation 1.5 in the Doppler Radial Speed Range, but especially at relative speeds (Fig. 8, left) at altitudes between 3.5 and 6 km. The speeds to / from the radar are not large (10 ... 20 m/s), but certainly underestimated in the relative speed range because of the high speed the convective system is moving.

This radar signature from medium storm levels (MARC) indicates a high probability that the convective system evolves into a bow echo and theoretic radar structure, and it is signaled 15 ... 20 minutes before the first violent gusts of wind to appear on the ground.

In about 20 minutes, at 15:01 AM (12:01 UTC) in the radial gear, the radar signature of a **rear inflow jet (RIJ)** is increasingly evident. At the first elevation (0.5) this downward current is visible in the Doppler Radial Speed Range at 65 km west of Timisoara (Fig. 9) at an altitude of approximately 0.9 km (radar speeds between 26 and 33 m/s). And in the reflection field at 12:19 UTC, there can be noticed a decrease (Fig. 9 - right) in the back of the bow echo, suggesting the rear inflow jet (RIJ).

At the next radar elevations, between 2 and 3 km in the Doppler radial speed range, radar speeds (around 10 m/s) were identified, which can be associated with turbulence of the upward mezzo-scale current (Fig. 10 - left) entering the storm or mezo-vortex, and the mid altitude radial convergence (MARC) is again identified at 3.5 km (Fig. 10 - right).

The development of arc convective systems (bow echo) and of strong winds on the surface are usually associated with the development of these rear inflow jet (RIJ). **The downward descending flow jet** develops due to the vortex generation caused by the buoyancy difference between **the ascending unstable air** and **the relatively stable air associated with the downward cold stream**. The strength and orientation of the rear jet are modulated by the downward cold current intensity, the degree of instability of the ascending air over the cold air layer and the shear of the environment. The downward trend was intensified in the present case and the presence of a dry air layer of considerable thickness, favoring **evaporative cooling** (from the ground up to 700 hPa).

Observation data and numerical simulations show that this downward input jet of the convective systems may vary in intensity from 5 to 10 m/s for low convective systems at 10 ... 15 m/s for those moderate and 25 ... 30 m/s for the severe ones (Weisman, 1992), such as those encountered in the present situation. But not in all situations, its identification in the radial Doppler velocities also determines high surface velocities.

In the case of the face, this rear inflow jet (RIJ) had a high stratification (Weisman, 1992), (Fig. 11) vertically, being identified in the Doppler radial velocities at different levels, so it remained very close to the initiation zone of the convection and was forced to descend to the surface by increasing the descendancy in the dry air layer.

Thus, at approximately 12:30 UTC, the blow front associated with the convective system, which generated wind intensities at 25 m/s at Sânnicolau Mare, exceeded by about 20 minutes (Fig. 12 - right) the intense precipitation line by the large gradient in the field of reflectivity (Fig. 12 - left) and causes a sudden increase of the wind speed in the Timioara municipality at 30 m/s.

5. CONCLUSIONS

In conclusion, in order to explain the high wind speeds recorded in the afternoon of September 17 in western Romania, in addition to the synoptic context, a number of elements that were identified with the Doppler radar were important. The rea inflow jet (**RIJ**) was supplemented by mid altitude radial convergence (**MARC**), so that **the descendant was assured and amplified by these two elements**.

To these elements was added **the dry air layer** in the low troposphere, which amplified the air descendancy by evaporating cooling, which differentiated from the point of view of the violence of manifestation, compared to other similar structures, the phenomenon of September 17.

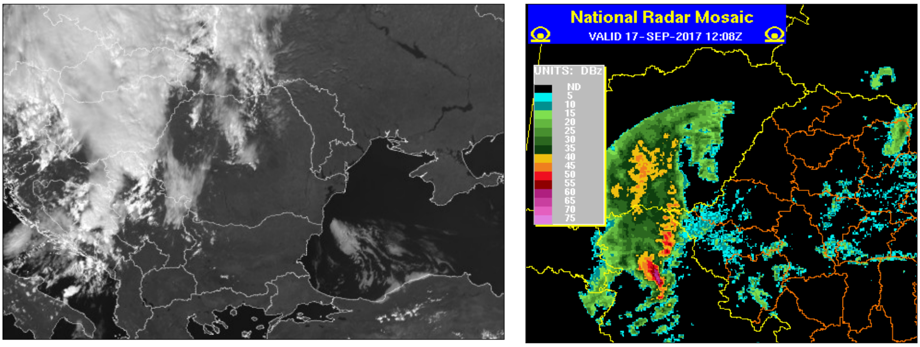

Fig. 6. High resolution satellite image – METEOSAT 9 (left) and radar image from the national radar mosaic radar national of the National Meteorological Administration (right) from September 17, 2017, 12 UTC.

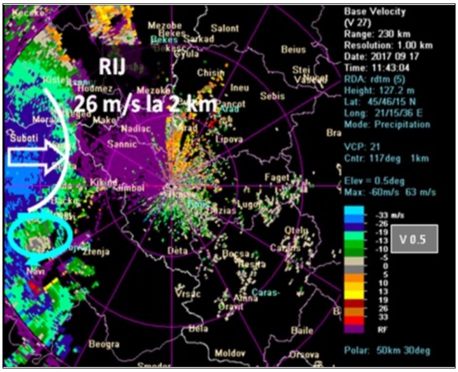

Fig. 7. Doppler radial speed range at 0.5 elevation. Doppler Radar WSR – 98D from Timișoara (11:43 UTC)

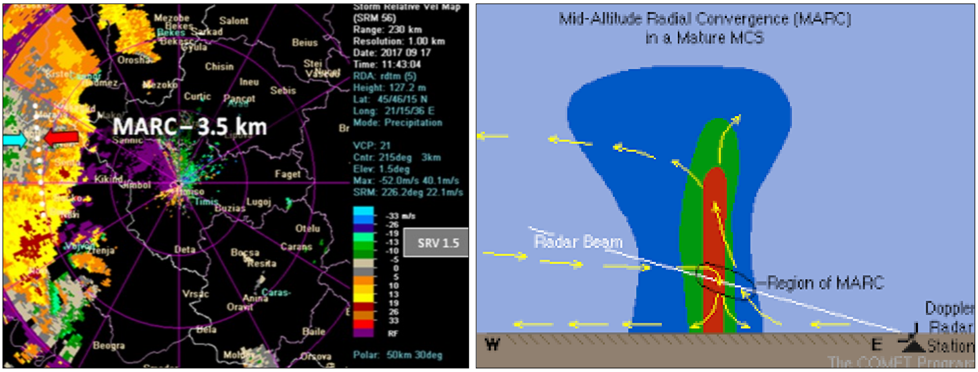

Fig. 8. Relative speed range at 1.5 elevation (left) from the Doppler Radar WSR – 98D of Timișoara (11:43 UTC) and the conceptual model concerning radial convergence area at mid-level in a convective cell

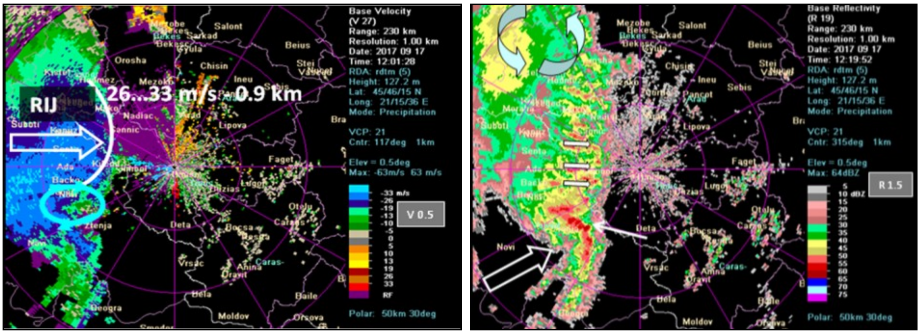

Fig. 9. Radial Doppler speed range at 0.5 elevation (left 12:01 UTC) and the reflectivity field at 1.5 elevation (right - 12:19 UTC). Doppler Radar WSR – 98D from Timișoara

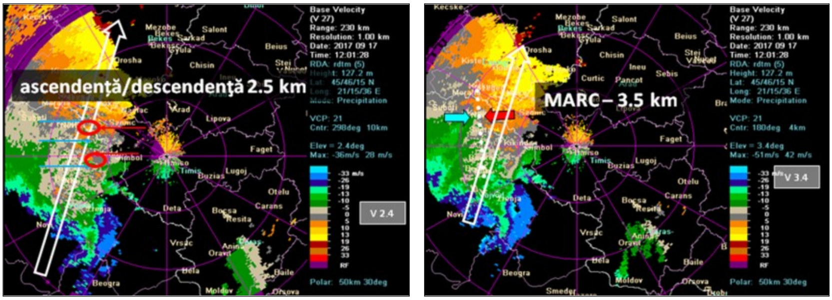

Fig. 10. Radial Doppler speed range (left) at 2.4 and 3.4 elevation (right). Doppler Radar WSR – 98D from Timișoara (12:01 UTC)

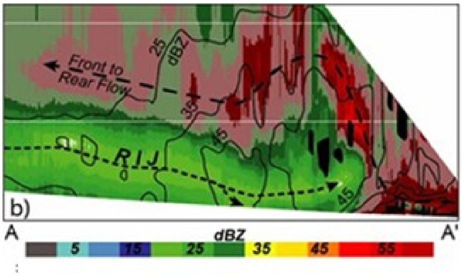

Fig. 11. Vertical section in radial Doppler speeds in a bow convective system, underlining the rear inflow jet (RIJ) and front to rear flow (FRF)

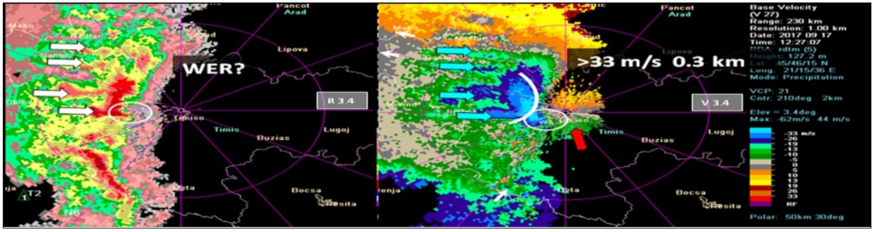

Fig. 12. Reflectivity range at 3.4 elevation (left) Doppler radial speed range at 3.4 elevation (right) on the Doppler Radar WSR – 98D from Timișoara, (12:27 UTC)

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