Mathematical model for nowcasting the potential tornadogenesis: baseline for tornado cases in South Africa

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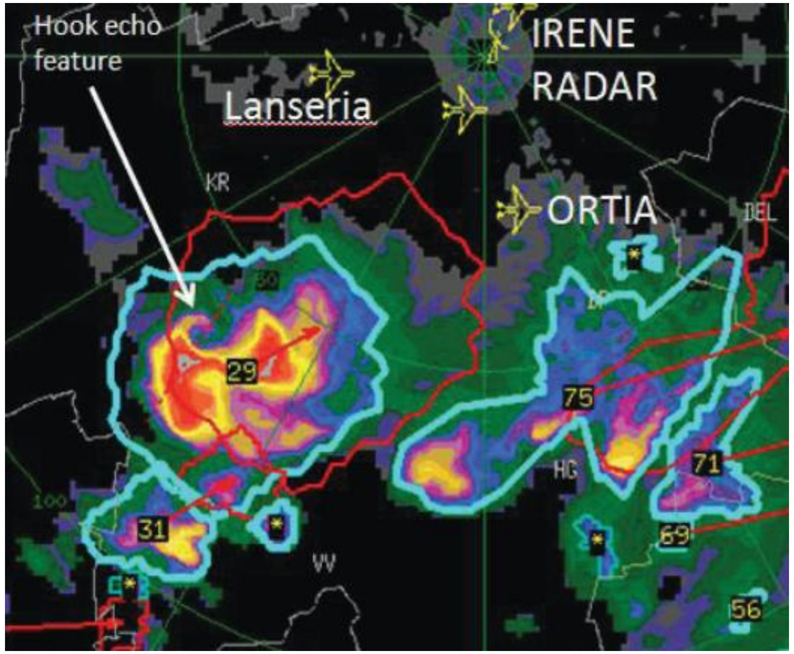
LOOKING BACK… OVER 8 YEARS AGO



SA Weather Service
@SAWeatherServic

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Warning:30/12/2017 17h00 TO:30/12/2017 19h00 Severe Thunderstorms- are observed over southern Westonaria and southern parts of City of Johannesburg (Grasmere area) as well as extreme eastern parts of Merafong District with possible tornado and large hail.

4:41 PM · Dec 30, 2017 · Twitter Web Client

Caller from first destructed house in Protea Glen, Soweto

30 Dec 16:46
Outgoing call, 15 secs

28 Dec 22:04
Outgoing call, 1 min 24 secs

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- ❑ Suggested solution
- ❑ Mathematical tools to consider
- ❑ Concluding remarks

PROBLEM STATEMENT AND OBJECTIVES

PROBLEM STATEMENT FOR TORNADO PREDICTION

- ✓ Population of South Africa was recently estimated to about 64 million,
- ✓ However, each tornado develops suddenly across the localised area
- ✓ So, tornado prediction (forecast/nowcast) is difficult,

OBECTIVES

- ✓ To isolate the subregion across which tornadogenesis is eminent,
- ✓ To develop the baseline mathematical model for tornadoes

RACING AGAINST TIME FOR TORNADO PREDICTION

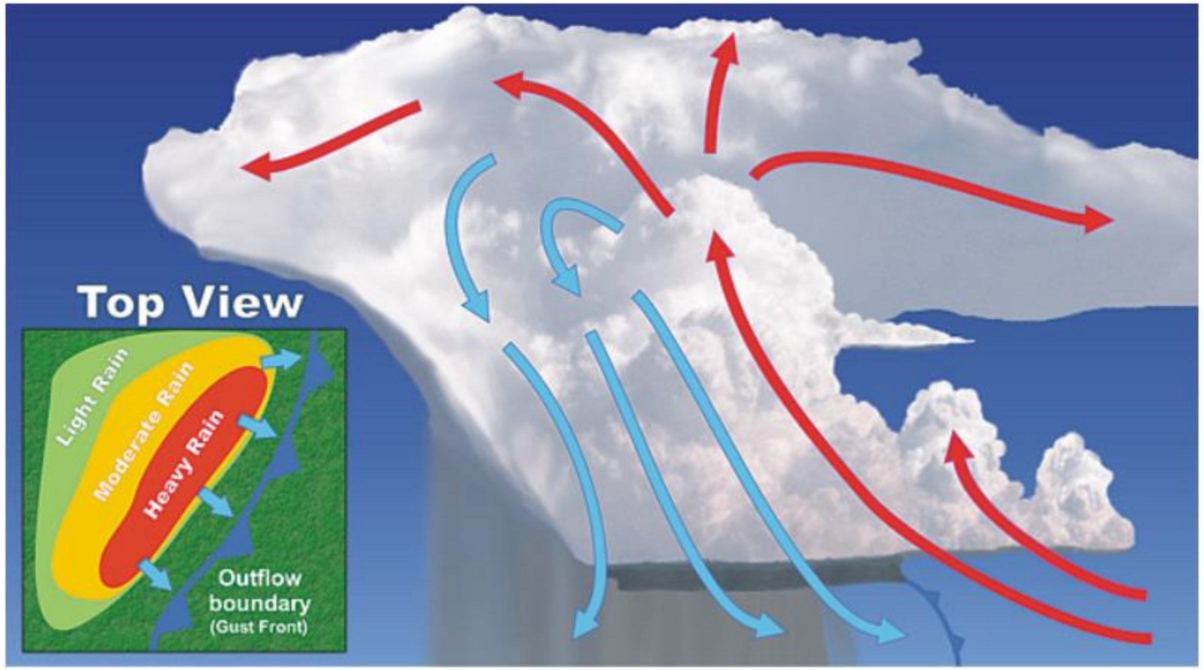
Early Warnings for All

Likelihood	Minimal	Minor	Significant	Severe
High		2	6	10
Medium		1	5	9
Low			4	8
Very Low			3	7
	Impact			

Warning Matrix showing the combination of Impact with the Likelihood of the Impact occuring.

SUGGESTED SOLUTION / NEW APPROACH

SUGGESTED PARTIAL SOLUTION: A SCHEMATIC DIAGRAM

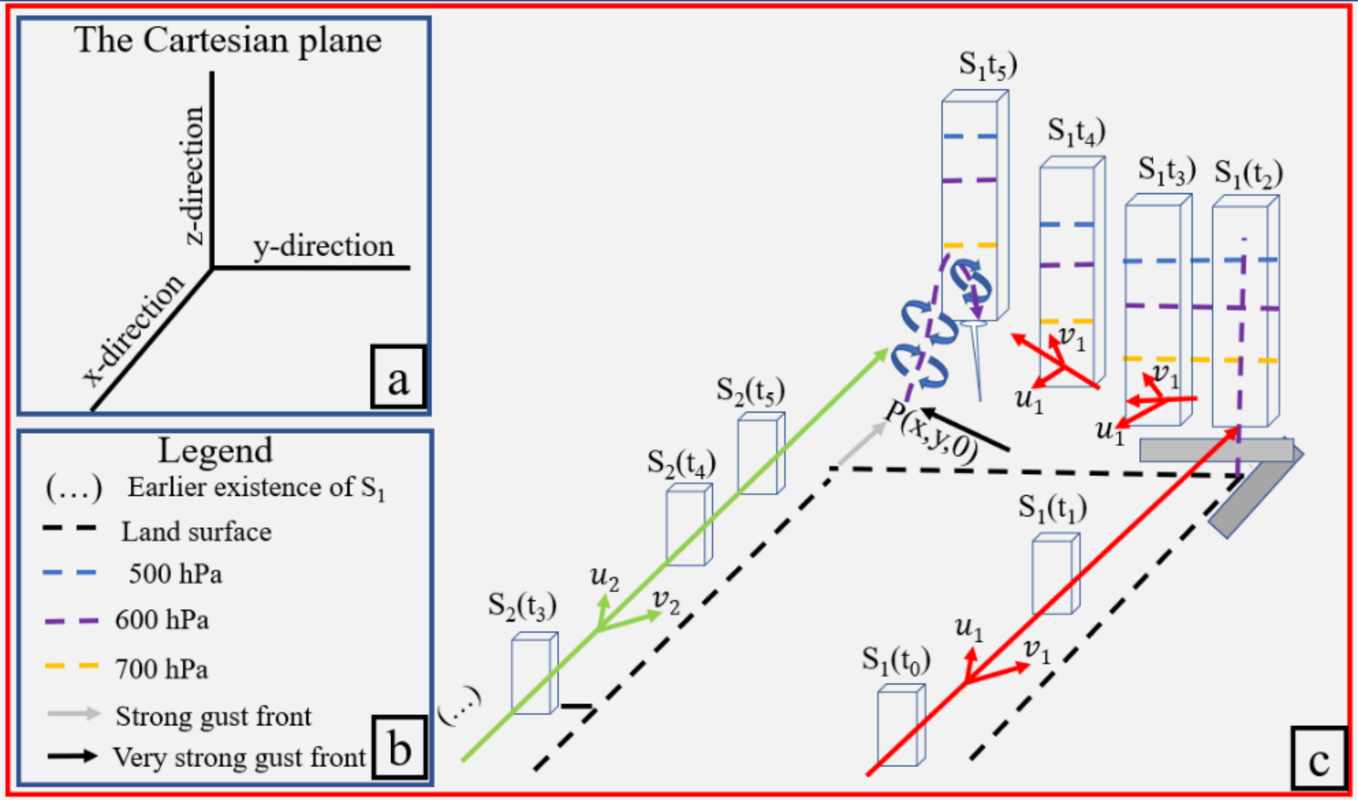


Thunderstorm outflow typically occurs beneath its base,

Its gust front usually form an arc-shaped structure ahead of the thunderstorm,

Some intense gust fronts could travel well beyond 10 km ahead of the thunderstorm,

SUGGESTED PARTIAL SOLUTION: A SCHEMATIC DIAGRAM



The Cartesian plane showing x-, y- and z-directions in solid black lines in Figure 1a, as from Holtan (1972). Figure 1b represent the legend for critical marks in Figure 1c. Idealised thunderstorms (downwind S_1 storm associated with elongated red vector and upwind S_2 storm along the elongated green vector) are shown at a given time t in Figure 1c. The grey shapes underneath the intensified S_1 at time (t_2) represent significant topography that has the tendency to deform near surface low with occurrence of strong convection and storm intensification. On some occasions, S_1 deviates onto y-direction but later moves diagonally from time t_4 in response to the initial mid-tropospheric (MTS) steering wind. The interaction and unequal strengthening of the gust fronts of S_1 and S_2 at P(x,y,0) at time t_5 initiate and increase localized rotational tendency with respect to height (z-direction). Sustained lifting of rotational flow with heavier density of air often at time t5 drops the base of S_1 with potential for tornadogenesis

BRIEF FINDINGS ON TORNADOES

Of tornadoes that were studied between June 2016 and June 2021, over 75% occurred where the discrete thunderstorms were individually deviated onto the assumed strong gust front,

The leading storm could also produce a tornado when the trailing storm is in parallel but at close range (short diagonal),

Such mechanisms were represented by each of the two tornadoes that hit Mpumalanga on 1 January 2026, near Middelburg and Carolina,

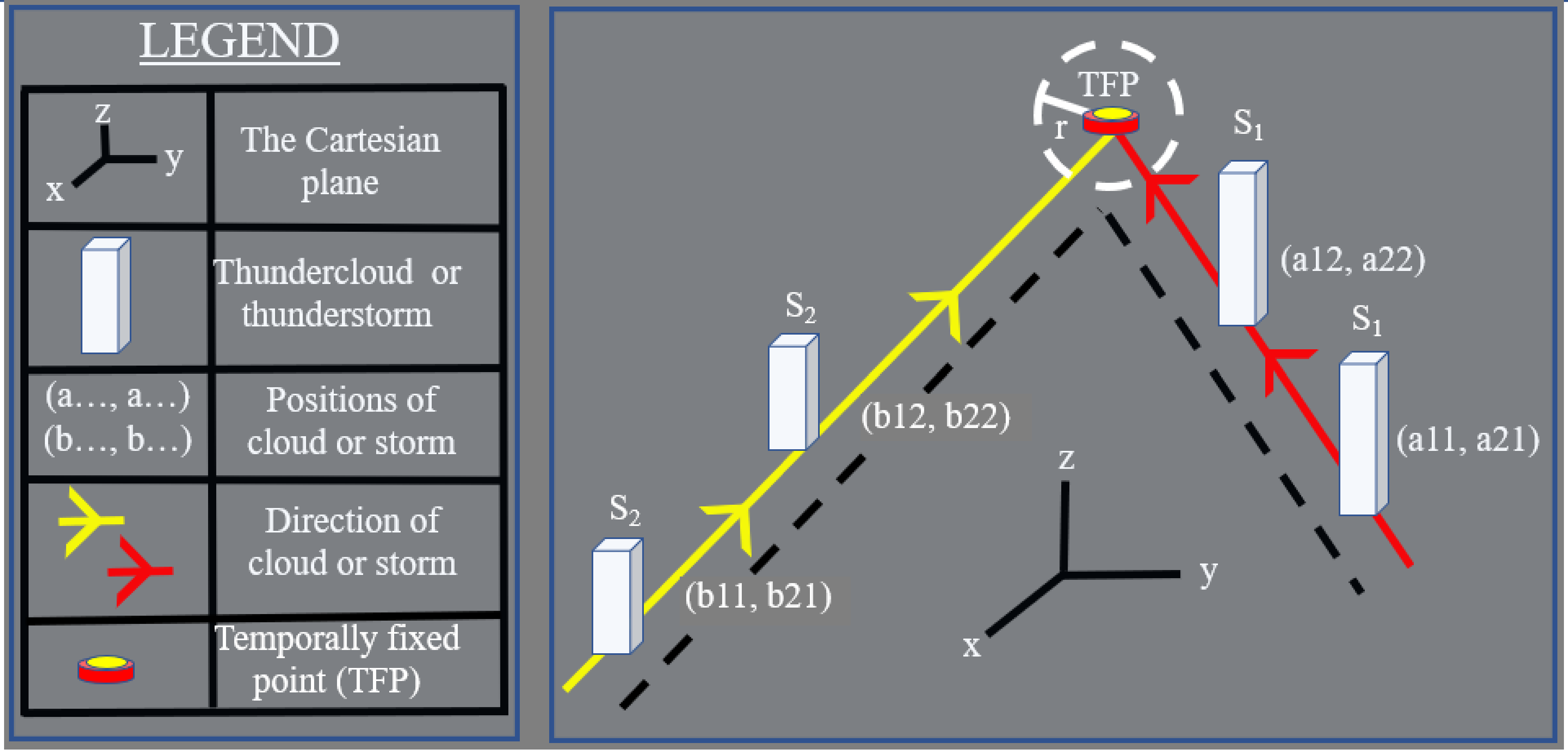
Tornadoes typically occur at higher frequencies directly when El-Ninos end.

A STANDING CHALLENGE TOWARDS MATHEMATIC SOLUTION

"…when you cannot express what you are talking about in numbers, your knowledge is of meagre and unsatisfactory kind. It may be the beginning of knowledge, but you have scarcely advanced to science.

However, when you can measure what you are speaking about and express it in numbers, you know what you are speaking about." – Lord Kelvin

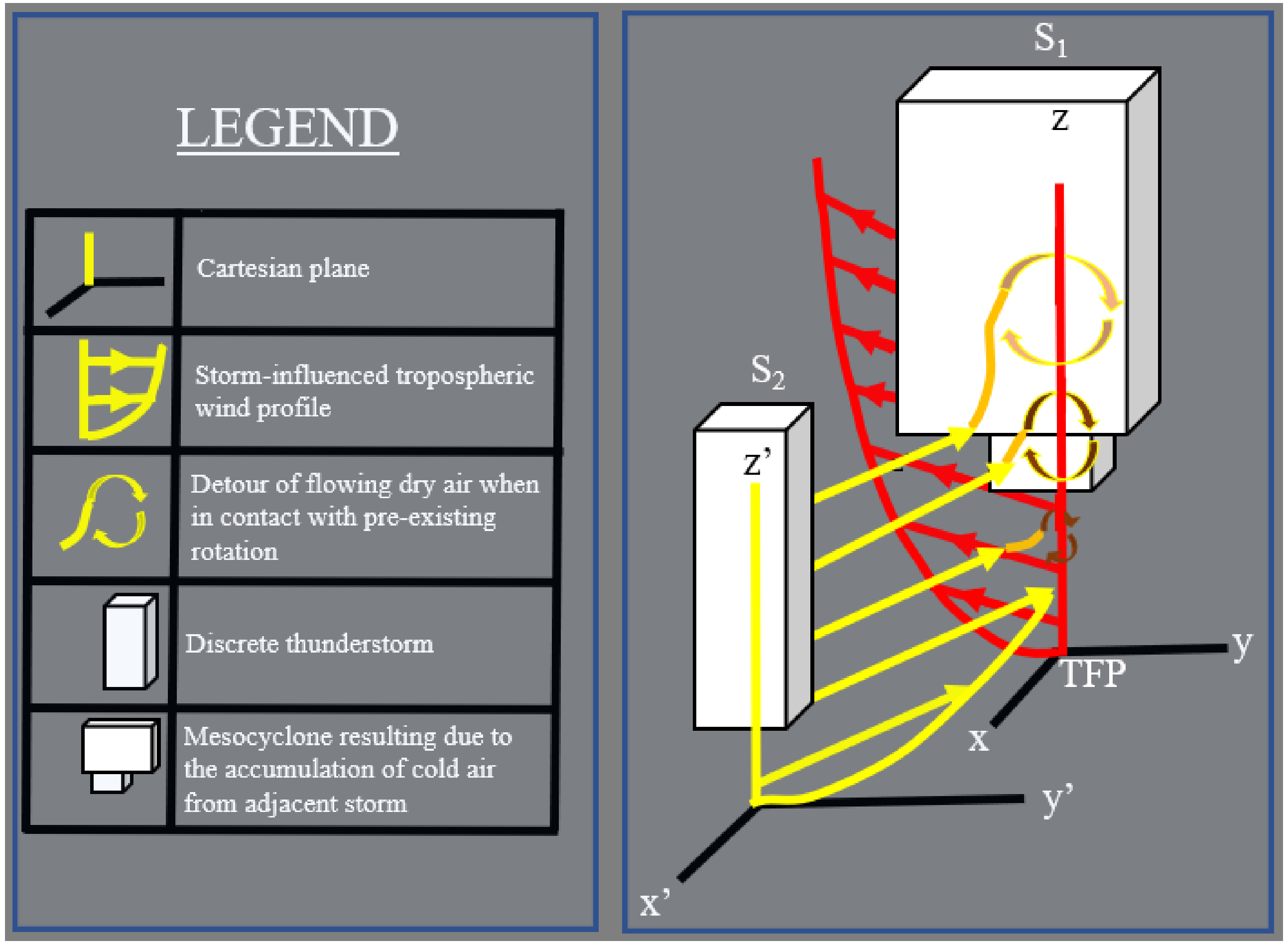
SUGGESTED PARTIAL SOLUTION: A SCHEMATIC DIAGRAM



Two positions for each of the two active thunderclouds / thunderstorms could be used to determine a temporally fixed point (TFP) or common geographic position,

The theoretical TFP is important for isolating the subregion across which tornadogenesis is possible.

SUGGESTED PARTIAL SOLUTION: A SCHEMATIC DIAGRAM

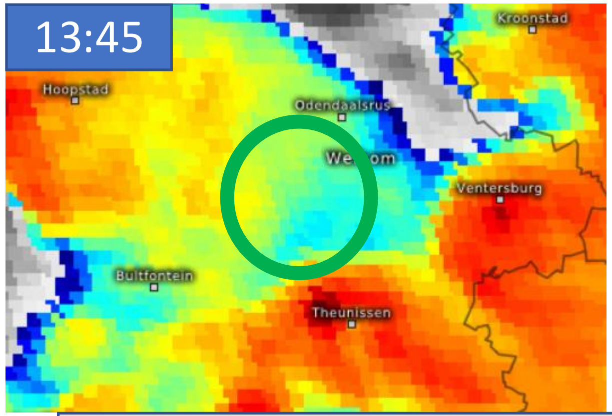


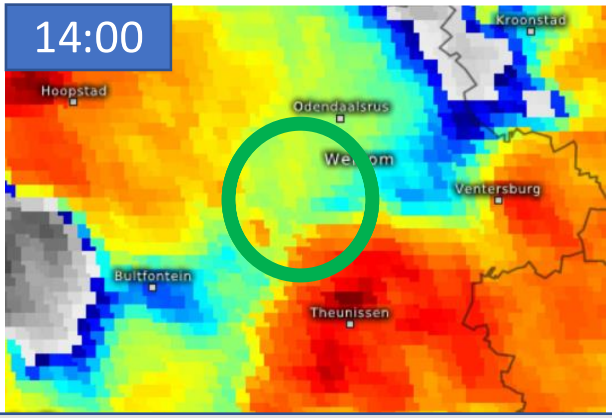
Sometimes, a discrete thunderstorm is deviated (e.g., S1) onto strong winds (yellow vector fields) from another storm (e.g., S2),

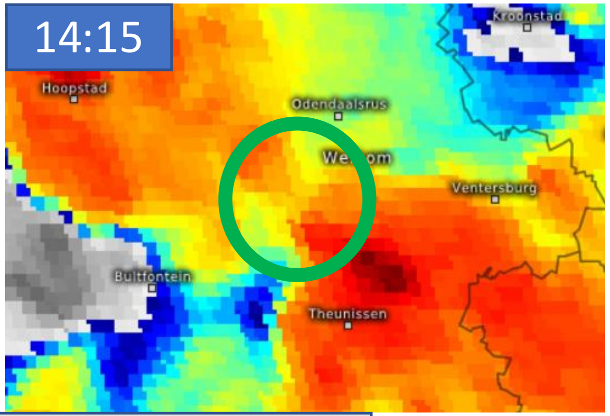
In such situations, the cross-intersection with vertical rotational flow occur,

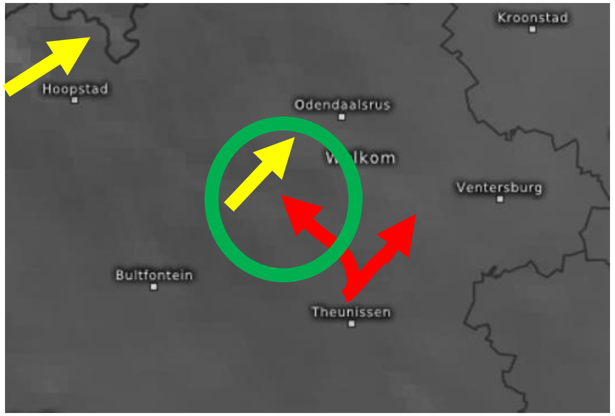
When optimally sustained, vertical rotation flows lead to the development of tornadoes.

STORM DEVIATION LEADING TO THE SPIRAL CLOUD: 2 DEC 2025









SUMMARY OF STORM ACTIVITIES: 2 DECEMBER 2025

- The mean wind flow often steer thunderstorms in one directions,
- Sometimes, however, storms deviate due to significant topography or when the mean flow is altered by the adjacent storm,
- The lifted outflow of the deviated storm have the tendency to take another detour during the cross-intersection with another thunderstorm,
- The localised wind detour and its counter-detour typically lead to downward spiral of convective cloud with reduced radii,
- Tornadoes typically develop due to the persistence of cross-intersection

Sias sent (14:17) this amazing photo from Welkom in the Free State as the storm approached (Storm Report, 2025)

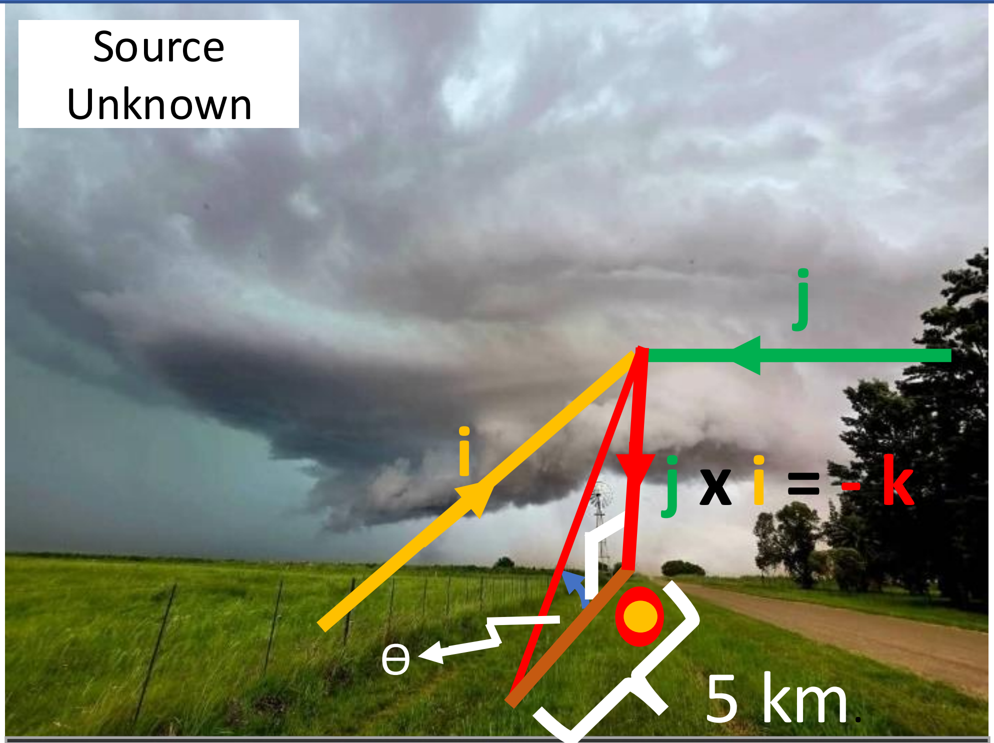
DOWNWARD INCREASING SPEED OF A TORNADO

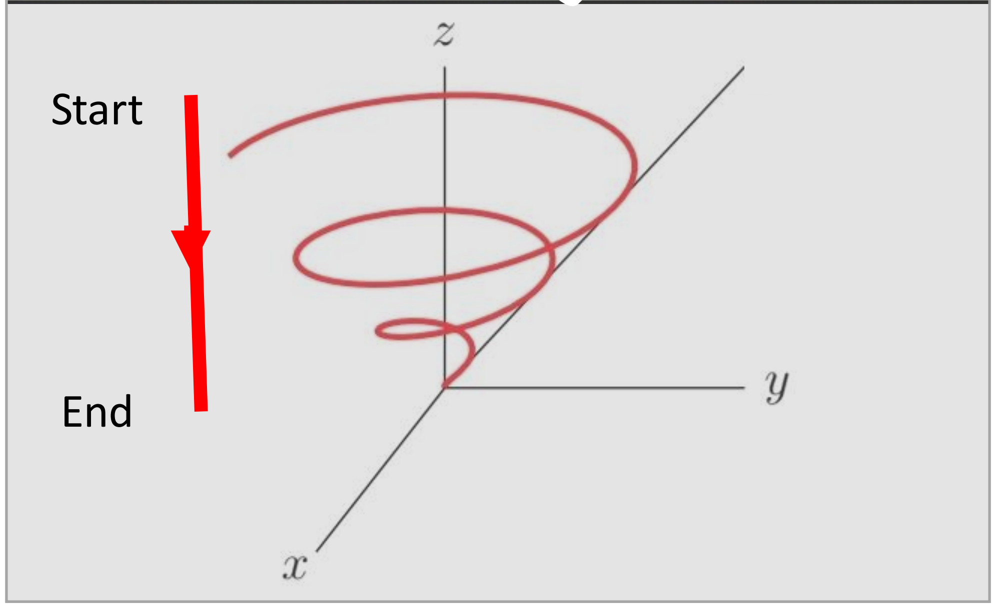
Formative State: Mathematical Tornado Model

$$\zeta_{-k} \cong \frac{h(\sin\theta + \cos\theta + k)}{\sigma^{-t}}$$

Cross-intersection ( ) of convective cloud with the persistent increase of strong lifted wind velocity ( ) often leads to the lingering of funnel cloud beneath the cloud base ( ). The height (*h*) between the cloud base and idealised land surface ( ) could be estimated by individually averaging both the air and dew-point temperatures within 100 km. Persistence and further increase of the lifted wind velocities would probably lead to the spiralling of near the cloud base around the inverted z-component, pinned on temporally-fixed point. The radius of the downward spiral "of cloud" should decrease with the height, the magnitude of which controls the sine and cosine functions. The decrease in height and radii should be proportional to exponential increase of rotational speed of vertical wind (e.g. tornado). Therefore, the tornado speed should increase exponentially towards the ground.

[Concept refinements are still in early research phase: extra-tropical transitions (ETT) to be considered]





MATHEMATICS TOOLS TO CONSIDER

TEST FOR ENVIRONMENTAL HELICITY USING ACTIVE THUNDERSTORMS

The environmental helicity of the two thundercloud / thunderstorm could be tested as:

$$\tau = |V_{S_1}||V_{S_2}| \sin \theta$$

NAVIER-STOKES EQUATION WITH CORIOLIS PARAMETER

$$\frac{\partial \boldsymbol{v}}{\partial t} + (\boldsymbol{v}.\nabla)\boldsymbol{v} = \nu\Delta\boldsymbol{v} - \nabla p + (F + f) \ \textit{where,}$$

$$\frac{\partial \boldsymbol{v}}{\partial t} = \textit{steady state term}$$

$$(\boldsymbol{v}.\nabla)\boldsymbol{v} = \textit{Convectional term}$$

$$\nu\Delta\boldsymbol{v} = \textit{diffusion term}$$

$$\nabla p = \textit{pressure term}$$

$$F = \textit{External force term}$$

$$f = \textit{Coriolis parameter } (=2\boldsymbol{\omega})$$

$$\nabla.\boldsymbol{v} = 0 \ (\textit{for incomprehensible fluids})$$

CONCLUDING REMARKS

CONCLUSIONS

Tornadogenesis seems to require the automatic determination of:

- ✓ the temporally fixed point, *once at least two discrete thunderstorms are projected to move towards each other,*
- ✓ its helical environment and potential strength
- ✓ vectors and their analysis
- ✓ Baseline or functional mathematical and machine learning models

Thank You for Attention

Dikgomo