MECHANISMS THAT FAVORED THE GENERATION OF THUNDERSTORMS IN IQUITOS, PERU DURING FEBRUARY 2015

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INTRODUCTION

Summer thunderstorms in the northern rainforests of Peru are frequent. This phenomena affects activities in Iquitos including flight delays. Forecasting thunderstorms in Iquitos is of great importance for the planification of flight schedules.

OBJECTIVE

Determine the mechanisms that favored the occurrence of thunderstorms in Iquitos during February 2015, with the ultimate goal os improving their forecasting.

GEOGRAPHIC LOCATION

Weather Station SPQT: "Coronel FAP Francisco SecadaVigneta", Iquitos Airport.

Coordinates:
Latitude: 03^{o}45' S
Longitude: 73^{o} 15' W
Elevation: 125 m

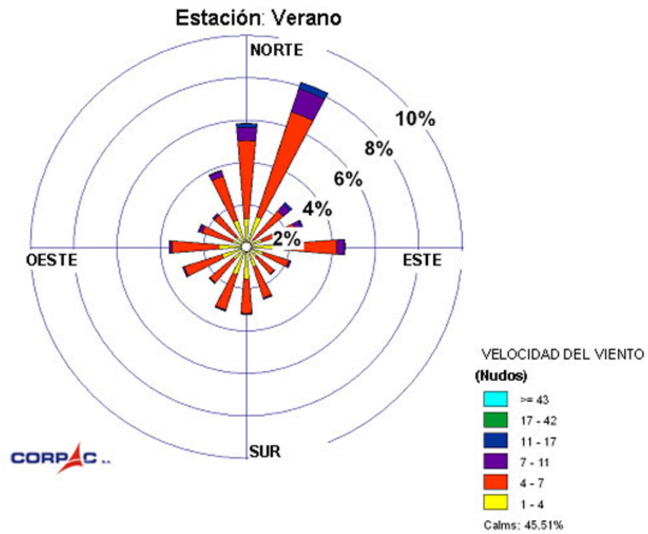
SPQT

Photo showing a thunderstorm and heavy rain in the SPQT airport.

FEBRUARY CLIMATOLOGY

- Highest frequency of thunderstorms during the summer.

- Temperatures: Max= 32º C Min=22º C
- Average wind: 2.5kt from the NNE
- Max winds: 15kt from the N
- Rainfall: 220 mm or ~9 in



Dirección predominante: del Nor-NorEste (**NNE**).

The February (summer) climatology shows temperatures between 22 and 32°C, average winds from the north-northeast at 2.5kt, máximum winds from the N at 15kt and rainfall in the order of 220 mm or 9 inches. Note that the percentage of calm winds conditions reaches 45.51% of the time. The prevalence of northerly winds responds to the low-level presusre gradient. During February the North Atlantic High intensifies while lower pressures organize over central South America and along the Eastern foothills of the Andes.

MATERIALS

METAR reports from the Iquitos (SPQT) from February 2015

CPTEC satellite imagery

GFS 1° data

Software: WINGRIDDS

ANALYSIS

Three (3) cases of thunderstorms were selected using METAR data.
Dates: 13/14; 15/16 and 27/28 during February 2015.

Satellite imagery analysis ←Spatial and temporal distribution of convection

Upper level winds (250-200 hPa)
Upper divergence (250-200 hPa)
Low-level winds (850-925 hPa)
Low-level convergence (850-925 hPa)
} Dynamic forcing/vertical motion enhancement

Mean flow (850-200 hPa) ←Cb movement
Relative humidity (850-200 hPa) ←Column saturation/clouds
Precipitable wáter ←Available moisture
Stability (GDI) ←Readiness for convective overturning

Three cases were selected when thunderstorms affected the SPQT airport. The cases were selected using METAR data only. The analysis was then complemented by the listed ítems .

RESULTADOS

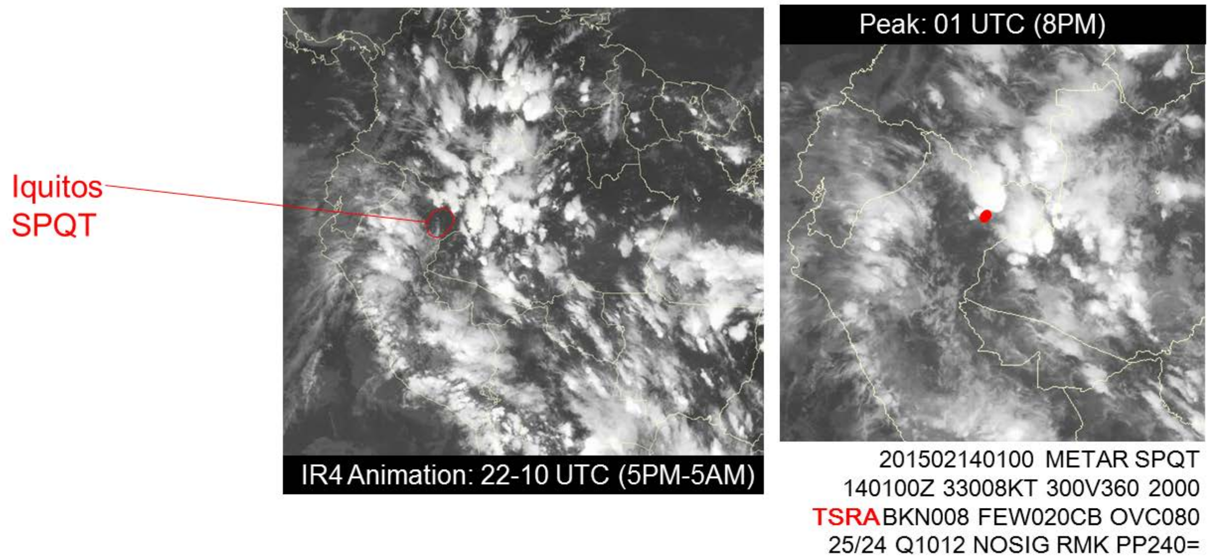
Case 1 Feb 13-14 2015 (Trough in the trades)

201502141100 METAR SPQT 141100Z 01006KT 340V040 8000 -DZ BKN008 OVC080 24/23 Q1014 RMK CB SE PP008=
201502141000 METAR SPQT 141000Z 00000KT 8000 -RA BKN010 OVC080 24/23 Q1013 RMK CB E PP008=
201502140900 METAR SPQT 140900Z 00000KT 8000 -DZ BKN006 OVC080 24/23 Q1012 RMK PP004=
201502140800 METAR SPQT 140800Z 00000KT 8000 -DZ BKN006 OVC080 24/23 Q1013 RMK CB N PP004=
201502140700 METAR SPQT 140700Z VRB01KT 8000 -RA BKN006 FEW020CB OVC080 24/23 Q1013 RMK PP028=
201502140600 METAR SPQT 140600Z 26003KT 240V300 8000 -TSRA BKN006 FEW020CB OVC080 24/23 Q1013 RMK PP024=
201502140500 METAR SPQT 140500Z 05007KT 360V080 7000 -TSRA BKN008 FEW020CB OVC080 24/23 Q1013 RMK PP064=
201502140400 METAR SPQT 140400Z 27003KT 8000 -DZ BKN015 OVC080 24/23 Q1014 NOSIG RMK CB S PP008=
201502140300 METAR SPQT 140300Z 16003KT 1300V190 7000 -TSRA BKN015 FEW020CB OVC080 24/23 Q1013 NOSIG RMK PP008=
201502140200 METAR SPQT 140200Z 24005KT 8000 -DZ BKN015 OVC080 25/23 Q1013 NOSIG RMK PP032=
201502140100 METAR SPQT 140100Z 33008KT 300V360 2000 TSRA BKN008 FEW020CB OVC080 25/24 Q1012 NOSIG RMK PP240=
201502140000 METAR SPQT 140000Z 29006KT 250V340 8000 VCSH BKN020 FEW025TCU OVC080 27/25 Q1010 TEMPO -RA RMK PP000=
201502132300 METAR SPQT 132300Z 19003KT 170V230 9999 SCT035 FEW040TCU 28/25 Q1009 NOSIG RMK BIRD HAZARD PP000=
201502132200 METAR SPQT 132200Z 26009KT 240V300 9999 BKN030 FEW035TCU 30/24 Q1009 TEMPO SHRA RMK BIRD HAZARD PP000=
201502132100 METAR SPQT 132100Z 31005KT 270V340 9999 BKN030 FEW035TCU 30/24 Q1009 NOSIG RMK BIRD HAZARD PP000=
201502132000 METAR SPQT 132000Z VRB02KT 9999 SCT030 BKN100 30/23 Q1010 NOSIG RMK BIRD HAZARD PP000=

} **TS**

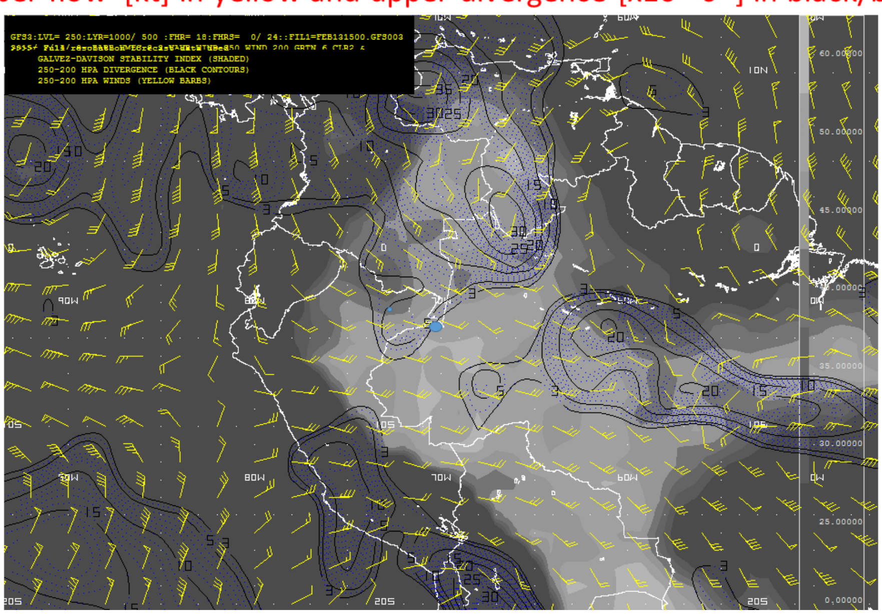
Storms occurred between 01 and 06 UTC, or during the evening/early night. The visibility was reduced to 2000m. *[Las horas de ocurrencia de las tormentas se dan entre las 01 y 06 UTC del día 14 de Febrero y las 01UTC. La tormenta disminuyo la visibilidad horizontal a 2000 m]*

Case 1 Feb 13-14 2015 (Trough in the trades)



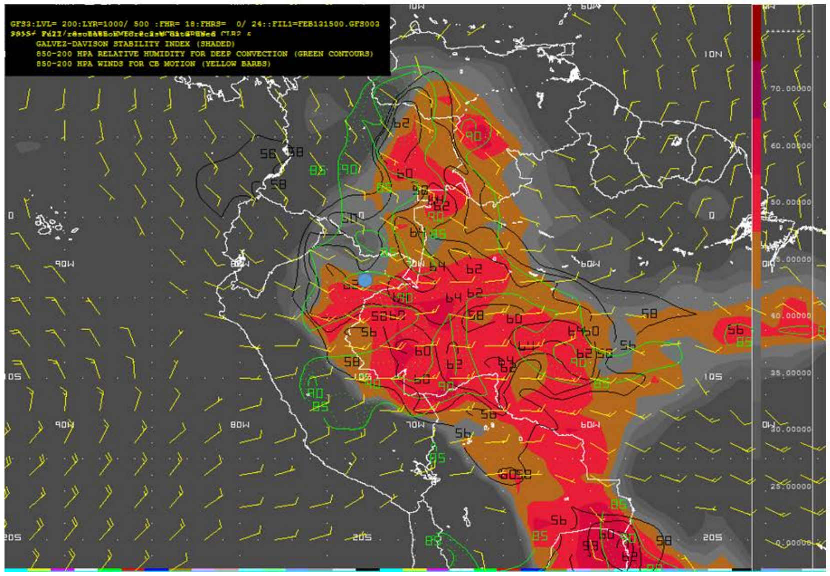
The satellite animation shows a wide region with convection affecting areas just to the east of Iquitos and moving into the region. The image to the right is a snapshot of the peak of the event. *[Se muestran a continuación de la animación de las imágenes de satélite IR desde las 22 UTC del día 13 hasta las UTC del día 14 se muestra además la Imagen de las 01 UTC donde se registro la tormenta en SPQT]*

Upper flow [kt] in yellow and upper divergence [$x10^{-6}$ s^{-1}] in black/blue



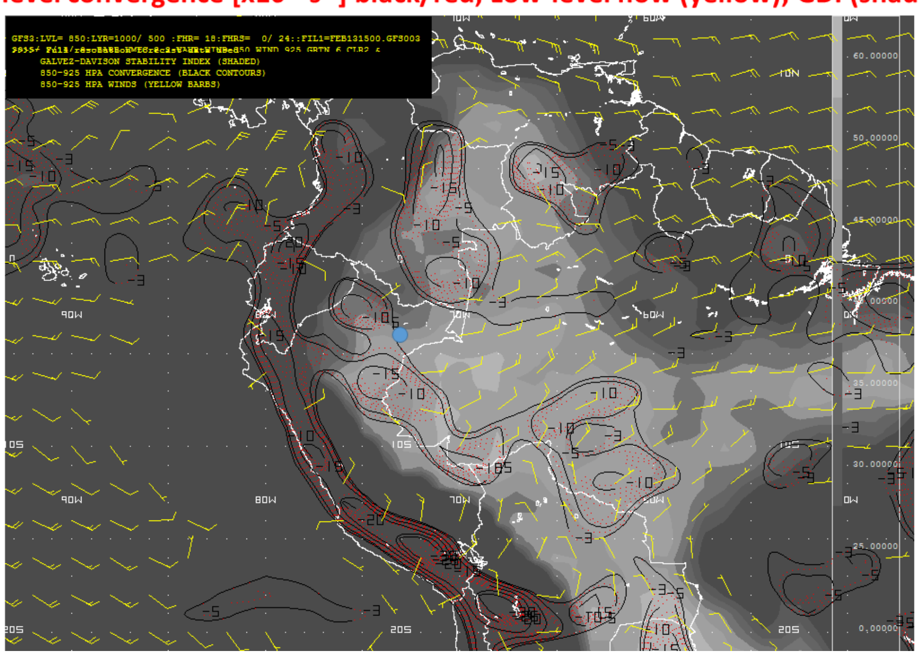
The upper tropospheric analysis shows east-southeasterlies with speeds of 20-30kt in the northern periphery of the subtropical high. This is associated with enhanced upper divergence with values of 3 to $8x10^{-6}$ s^{-1} and GDI values between 45 and 60, which suggests a high potential for deep convection. *[Se presentas las animaciones del día 13 a las 18UT y del día 14 de 00UTC y 06 UTC en el cual se observan el flujo de nivel alto predomina del este con velocidades entre 20 y 30 nudos y la divergencia entre 3 a 8 $x10^{-6}$ s^{-1} y los valores del GDI entre 45 y 60 lo cual es un valor que nos indica alta convección y ocurrencia de tormentas]*

850-200 Relative Humidity [%] in green, 850-200 mean flow, precipitable water [mm] in black, GDI shaded and



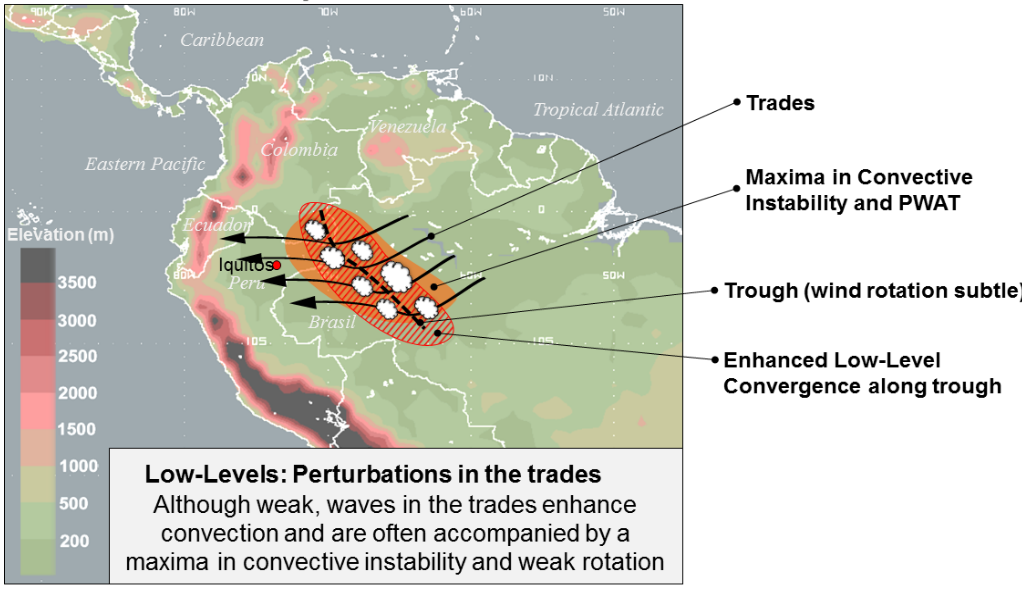
Relative humidity fluctuates between 85 and 90% showing a nearly-saturated layer. The averaged wind is from the east with speeds of 10-15kt which is related to the storm motion. Precipitable water fluctuates between 60 and 62mm and the GDI between 45 and 60. *[Se presentan el comportamiento de la humedad relativa que fluctúa entre85 y 90% y el viento promedio de dirección Este con velocidades de 10 a 15 nudos y el agua precipitable fluctua entre 60 a 62 mm y el GDI entre 45 y 60]*

Low-level convergence [x10^{-6} s^{-1}] black/red; Low-level flow (yellow); GDI (shaded)



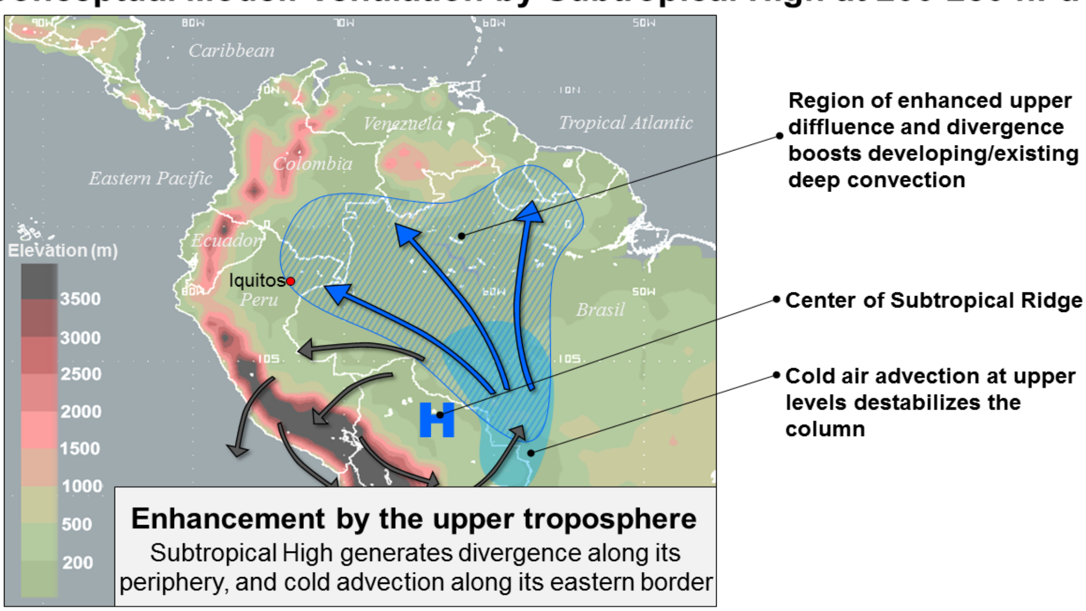
The low-level analysis shows winds at 850 hPa and the presence of a trough along Iquitos (light blue dot) and to the south into Acre/Madre de Dios; and enhanced low-level convergence near and ahead of the trough axis. *[Se presenta la convergencia en nivel bajo y su valor entre 3 a 8 x 10^{-6} s^{-1} y el viento de nivel bajo del NE con 10 nudos]*

Conceptual Model: Perturbation in the trades



This conceptual models shows the usual signature of a wave in the trades visible near 850 hPa. It is accompanied by a maxima in low-level convergence (red lines) and convective instability (orange). Diurnal convection is usually enhanced near the trough axis or where the maxima in convergence, precipitable water and instability intercept. *[Este modelo conceptual representa las condiciones para la ocurrencia de la tormenta del 13/14 de Febrero]*

Conceptual Model: Ventilation by Subtropical High at 200-250 hPa



This conceptual models of the upper levels show the importance of the subtropical ridge at upper levels in the ventilation of convection along its periphery. If upper divergence is present it will boost any deep convection that develops or already exists. *[Este modelo conceptual nos explica la importancia de la alta subtropical entre 250-200 hPa la cual garantiza la divergencia en altura, adveccion de aire frio].*

Case 2 Feb 15-16 2015 (Low-level jet from the north)

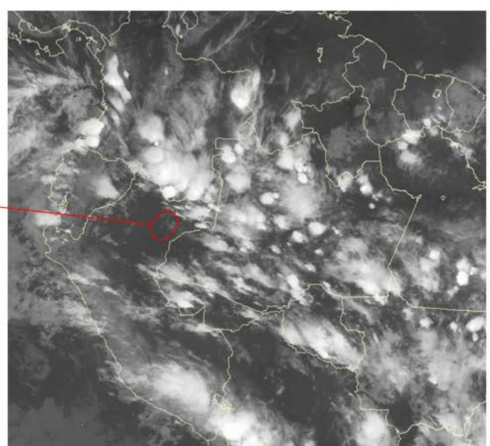
201502161000 METAR SPQT 161000Z 00000KT 9999 SCT007 OVC100 23/22 Q1011 RMK BIRD HAZARD PP000=
201502160900 METAR SPQT 160900Z 13003KT 9999 SCT007 OVC100 23/22 Q1010 RMK PP000=
201502160800 METAR SPQT 160800Z 19004KT 9999 SCT020 OVC100 23/22 Q1010 RMK PP008=
201502160700 METAR SPQT 160700Z 22003KT 8000 -RA BKN020 OVC100 23/22 Q1011 RMK PP022=
201502160600 METAR SPQT 160600Z 25004KT 6000 -TSRA BKN020 FEW030CB OVC100 23/23 Q1012 RMK PP060=
201502160511 METAR SPQT 160511Z 01010KT 3000 TSRA BKN020 FEW030CB BKN100 25/23 Q1012=
201502160500 METAR SPQT 160500Z 23003KT 9999 -TSRA BKN020 FEW030CB 25/23 Q1012 RMK PPTRZ=
201502160400 METAR SPQT 160400Z 28004KT 9999 VCTS BKN030 25/23 Q1012 NOSIG RMK CB N PP000=
201502160300 METAR SPQT 160300Z 26004KT 9999 SCT030 25/23 Q1011 NOSIG RMK CB NE PP000=
201502160200 METAR SPQT 160200Z 24005KT CAVOK 26/23 Q1011 NOSIG RMK PP000=
201502160100 METAR SPQT 160100Z 25005KT 9999 SCT040 27/24 Q1010 NOSIG MK PP000=
201502160000 METAR SPQT 160000Z 28004KT 9999 SCT030 SCT100 28/24 Q1008 NOSIG RMK PP000=
201502152300 METAR SPQT 152300Z 27004KT 9999 SCT030 31/23 Q1007 NOSIG RMK PP000=
201502152200 METAR SPQT 152200Z 27005KT 230V310 9999 SCT030 32/23 Q1007 NOSIG RMK PP000=
201502152100 METAR SPQT 152100Z 23004KT 160V280 9999 SCT020 SCT100 32/24 Q1008 NOSIG RMK PP000=

TS

The second case study is that of February 15-16 2015. Thunderstorms started arounf 04Z or 11pm peaking at midnight. This case was associated with the generation of convection along a lee trough that forms to the southwest of the mountain range in Central Venezuela under northeasterly trades. A weak northerly low-level jet also intensified during the evening along the Colombian lowlands which enhanced low-level shear and convergence ahead of the storms in northern Peru. *[Se presenta el segundo caso: Día 15/16 los reportes de tormenta es desde las 04 a 06 UTC del día 16 de Febrero del 2015 t al 0511].*

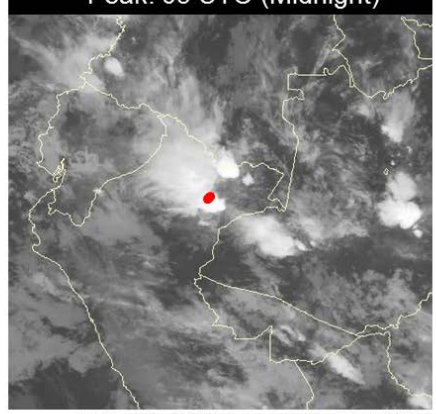
Case 2 Feb 15-16 2015 (Low-level jet from the north)

Iquitos
SPQT



Animation: 00-09 UTC (7PM-4AM)

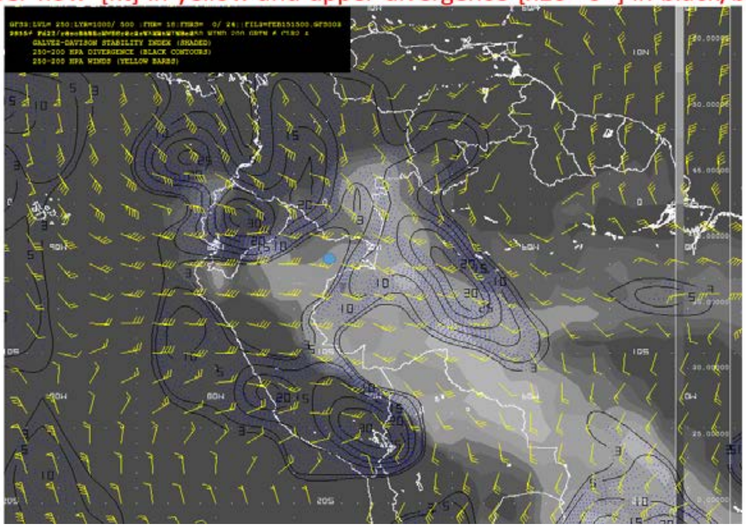
Peak: 05 UTC (Midnight)



201502160511 METAR SPQT 160511Z 01010KT 3000 **TSRA** BKN020 FEW030CB BKN100 25/23 Q1012=

The IR4 satellite animation shows active convection moving into the región from the northeast. The area with convection is smaller than that of the previous case. *[Se muestran a continuación de la animación de las imágenes de satélite IR desde las 00 UTC hasta las 09 UTC del día 14 se muestra además la Imagen de las 0511 UTC donde se registro la tormenta en SPQT].*

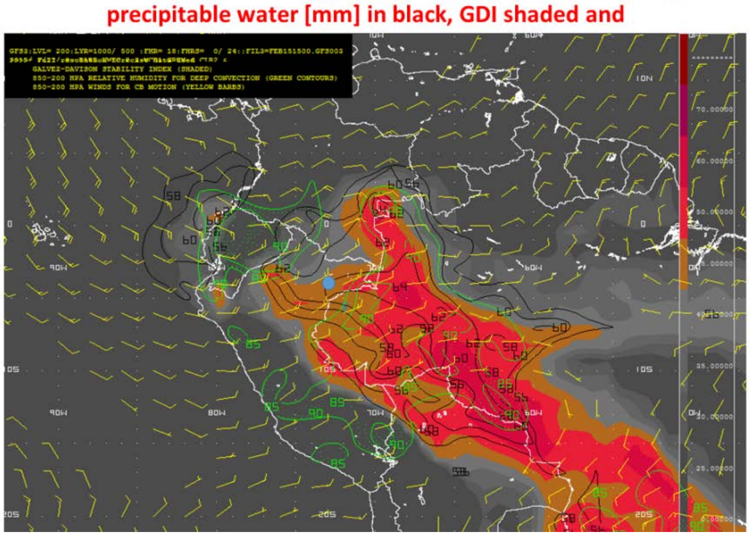
Upper flow [kt] in yellow and upper divergence [$x10^{-6}$ s^{-1}] in black/blue



This animation of the upper levels shows again an upper divergent pattern just to the east and northeast of Iquitos. This enhances the deep convection that developed in regions upstream of Iquitos. The convection often moves in from the east, thus the thunderstorms arrive to Iquitos already enhanced.

Se presentan las animaciones del día 15 a las 18UT y del día 16 de 00UTC y 06 UTC en el cual se observan el flujo de nivel alto predomina del Este con velocidades entre 25 y 35 nudos y una circulación anticiclónica al sur de Perú y Bolivia y la divergencia entre 5 a 15 $x10^{-6}$ s^{-1} que favorece a la convección en los niveles bajos de la zona de estudio y los valores del GDI entre 45 y 60 lo cual es un valor que nos indica alta convección y ocurrencia de tormentas

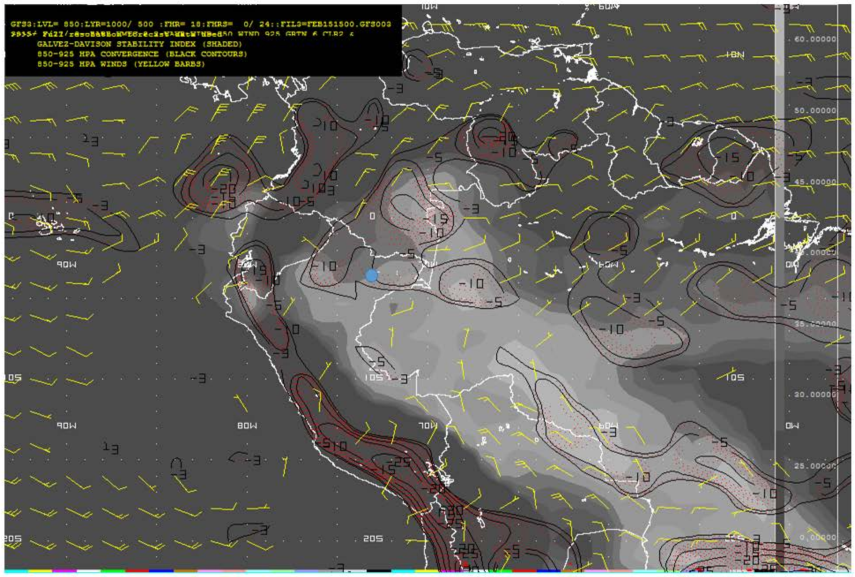
850-200 Relative Humidity [%] in green, 850-200 mean flow, precipitable water [mm] in black, GDI shaded and



This animation shows the mean flow from the east-northeast at 10-15kt, high convective instability with GDI>50 and precipitable water over 60mm.

Se presentan el comportamiento de la humedad relativa que fluctúa entre 85 y 90% y el viento promedio de dirección Nor-este conVelocidades de 10 a 15 nudos y el agua precipitable fluctúa entre 58 a 64 mm, lo cual garantiza la humedad disponible para la La ocurrencia de las tormentas en la zona de estudio y el GDI entre 45 y 60 valores que indican la convección y la ocurrencia de tormentas

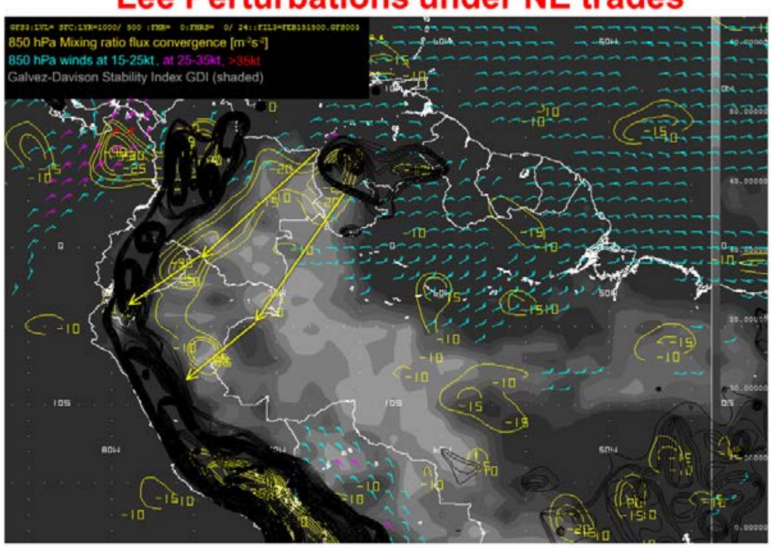
Low-level convergence [$x10^{-6}$ s^{-1}] black/red; Low-level flow (yellow); GDI (shaded)



The low-level analysis shows a región of enhanced low-level convergence between northern Peru and southern Venezuela, where the northeasterly Low-Level Jet in Colombia and the easterly trades over Brasil converge. Interactions between the flow and the southern Venezuela mountains produce perturbations that propagate southwestward into northern Peru when the trades are from the northeast. These perturbations propagate without weakening when the environment is favorable: enhanced convective instability and low-level convergence.\

Se presenta la convergencia en nivel bajo y su valor entre -5 a -15 x 10^{-6} s^{-1} condiciones favorables para la ocurrencia de tormentas en la zona de estudio. El viento de nivel bajo del NE con 10 nudos y el GDI 45 a 60 valores que son favorables para la convección y la ocurrencia de tormentas.

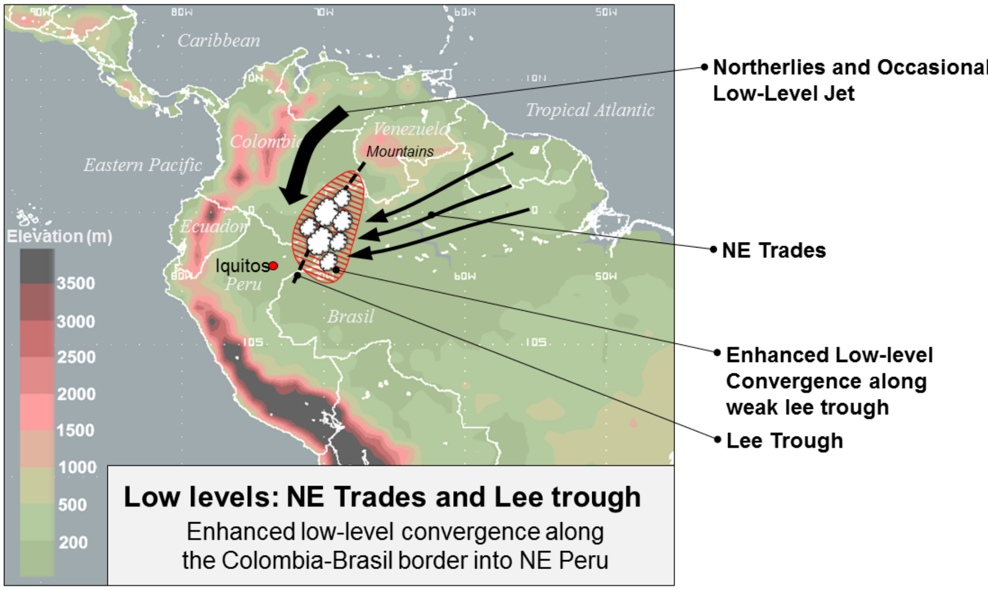
Lee Perturbations under NE trades



This animation shows the track that lee-side perturbations followed during this case. Note that convective is enhanced along the entire path, favoring storm maintenance.

Se presenta la animación de la convergencia a 850 hPa; Vientos entre 15 a 25 KT en nivel de 850 hPa y donde se observa la perturbación a sotavento de los alisios del Nor-Este , lo cual favorece la convección en la región de estudio.

Conceptual Model: Lee Perturbations under NE trades



This slide shows a conceptual model of the enhanced convergence and convection that form along the lee-side trough that forms southwest of southern Venezuela into extreme northeastern Peru.

Este modelo conceptual representa al Segundo caso de estudio. Los factores que dan lugar a esta tormenta son: Jet de bajo nivel; Alisios del NE,

Case 3 Feb 27-28 2015 (Trough/Weak Low-level Jet)

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201502281100 METAR SPQT 281100Z VRB02KT 8000 VCFG SCT005 SCT040 OVC100 23/22 Q1011 RMK PPTRZ=
201502281000 METAR SPQT 281000Z VRB01KT 8000 -DZ FEW010 BKN100 24/23 Q1011 RMK PPTRZ=
201502280900 METAR SPQT 280900Z 35005KT 300V030 8000 -DZ FEW010 BKN100 24/23 Q1010 RMK PP004=
201502280800 METAR SPQT 280800Z 00000KT 8000 -DZ SCT008 OVC100 23/22 Q1011 RMK PP020=
201502280700 METAR SPQT 280700Z VRB01KT 7000 -RA BKN008 OVC100 23/22 Q1011 RMK PP036=
201502280600 METAR SPQT 280600Z VRB01KT 5000 -RA BKN006 FEW025CB OVC100 23/22 Q1011 RMK PP052=
201502280500 METAR SPQT 280500Z 36005KT 5000 -TSRA BKN005 FEW025CB OVC100 23/22 Q1012 RMK PP040=
201502280400 METAR COR SPQT 280400Z 04005KT 010V090 5000 -TSRA BKN005
             FEW025CB OVC100 23/22 Q1013 TEMPO 8000 RMK PP165=
201502280300 METAR SPQT 280300Z 10007KT 060V140 3000 TSRA BKN005 FEW025CB BKN100 23/22 Q1012
             TEMPO 1000 RMK PP321=
201502280240 METAR SPQT 280240Z 13010KT 100V160 3000 TSRA BKN005 FEW025CB BKN100 23/22 Q1012=
201502280228 METAR SPQT 280228Z 14013KT 100V160 1000 +TSRA BKN010 FEW025CB BKN100 24/22 Q1012=
201502280225 METAR SPQT 280225Z 14013KT 110V170 3000 TSRA BKN010 FEW025CB BKN100 24/22 Q1012=
201502280219 METAR SPQT 280219Z 14012KT 110V170 7000 -TSRA BKN015 FEW030CB BKN100 25/22 Q1012=
201502280200 METAR SPQT 280200Z 14004KT 9999 TS BKN020 FEW030CB BKN100 27/25 Q1012 TEMPO SHRA RMK PP000=
201502280100 METAR SPQT 280100Z 35003KT 330V090 9999 TS SCT020 FEW030CB BKN100 27/25 Q1010 NOSIG RMK PP000=
201502280000 METAR SPQT 280000Z 31003KT 9999 SCT040 BKN100 27/25 Q1009 NOSIG RMK PP000=
201502272300 METAR SPQT 272300Z 29005KT 9999 FEW030 BKN100 28/24 Q1008 NOSIG RMK BIRD HAZARD PP000=
201502272200 METAR SPQT 272200Z 31006KT 9999 FEW030 BKN100 30/24 Q1007 NOSIG RMK BIRD HAZARD PP000=
201502272100 METAR SPQT 272100Z 35004KT 9999 FEW030 SCT100 32/24 Q1006 NOSIG RMK BIRD HAZARD PP000=
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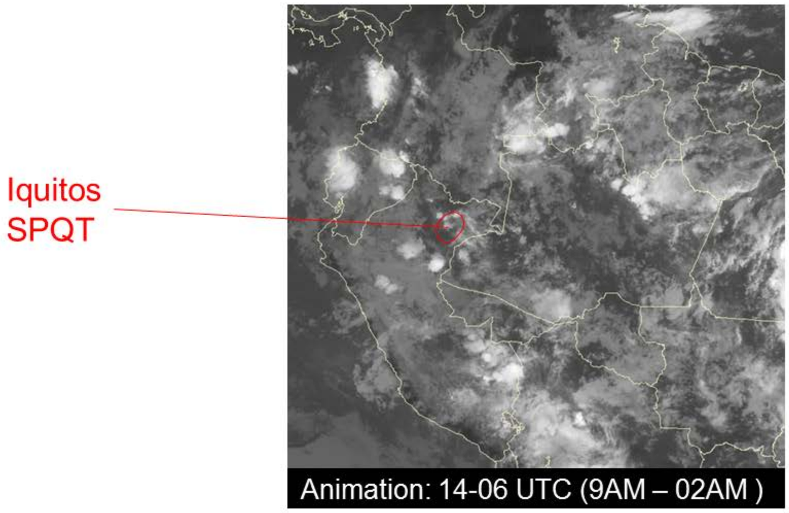
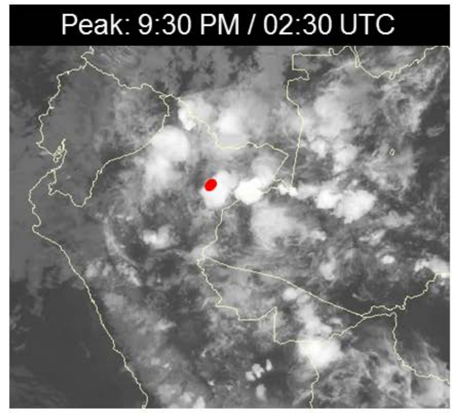
TS

Case 3 is a hybrid case in which both the influence of a trough in the trades, and to a lesser extent, the low-level jet were present. Heavy rainfall was present at the station in this case with accumulations of 53mm in 2 hours associated with a line of convection that developed after 02 UTC (9pm local time).

Case 3 Feb 27-28 2015 (Trough/Weak Low-level Jet)



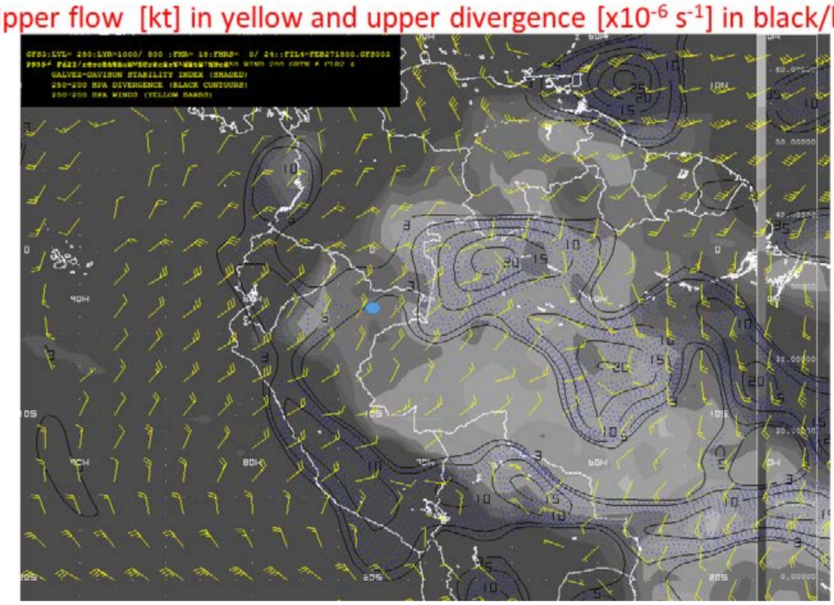


201502280228 METAR SPQT
280228Z 14013KT 100V160 1000
+TSRA BKN010 FEW025CB
BKN100 24/22 Q1012=

Case three consists of another trough in the trades in this case interacting with a weak nocturnal low-level jet that developed across Central Colombia. Areas of convection were more widespread than during previous cases and accumulations reached approached 60mm/day.

Se muestran a continuación de la animación de las imágenes de satélite IR desde las 14 UTC del día 27 hasta las 06UTC del día 28,en el cual se observa el desplazamiento de la convección hacia la zona de estudio SPQT. Se muestra además la Imagen de las 0230 UTC imagen cuando se presento la tormenta en SPQT

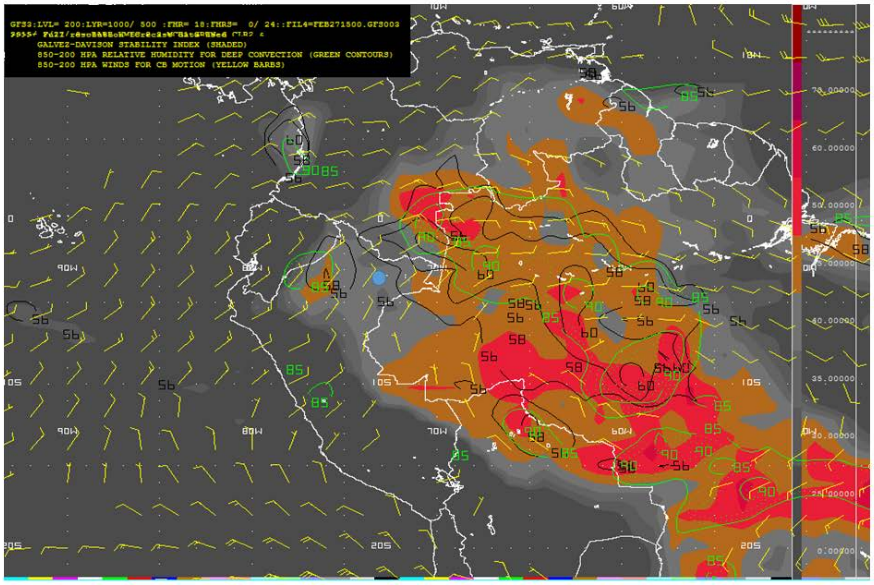
Upper flow [kt] in yellow and upper divergence [$x10^{-6}$ s^{-1}] in black/blue



In this case the subtropical ridge was located over Rondonia in Brasil with áreas of enhanced upper diffluence over northern Amazonas-Brasil into Southern Colombia, upstream from Iquitos.

Se presentas las animaciones del día 27 a las 18UT y del día 28 de 00 UTC y 06 UTC en el cual se observan el flujo de nivel alto predomina del Este con velocidades entre 15 y 20 nudos; se observa una circulación anticiclónica de altura en Perú y Bolivia y la divergencia entre se varia entre 3 a 12 $x10^{-6}$ s^{-1} y los valores del GDI entre 45 y 60 lo cual es un valor que nos indica alta convección y ocurrencia de tormentas

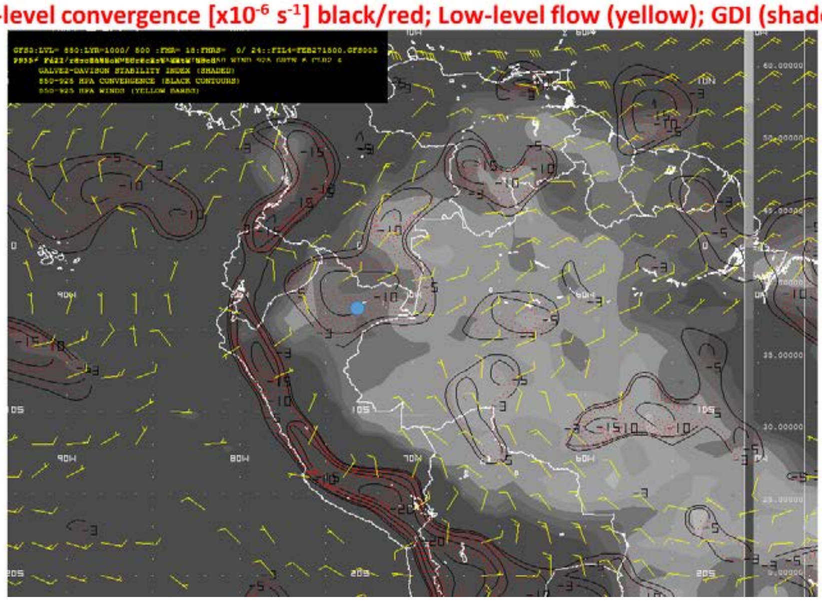
850-200 Relative Humidity [%] in green, 850-200 mean flow, precipitable water [mm] in black, GDI shaded and



Mean flow was from the northeast, once again transporting thunderstorms from the región with enhanced upper divergence into Iquitos. GDI values were also high between 45 and 55.

Se presentan el comportamiento de la humedad relativa que fluctúa entre 85 y 90% y el viento promedio de dirección Nor-Este con Velocidades de 10 nudos y el agua precipitable fluctúa entre 56 a 60 mm y el GDI entre 45 y 60 lo cual indica convección y tormentas en la región de estudio. El flujo del nor-este nos indica el movimiento de las tormentas

Low-level convergence [$x10^{-6}$ s^{-1}] black/red; Low-level flow (yellow); GDI (shaded)



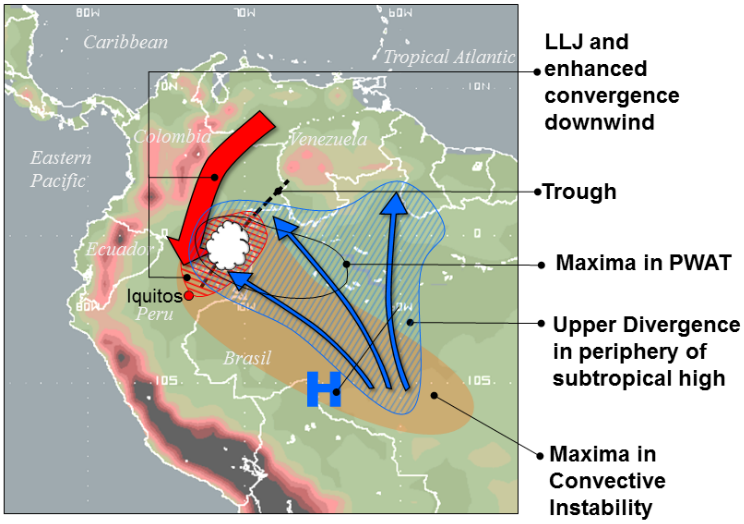
The figure shows low-level convergence in the order of -5 a -15 x 10^{-6} s^{-1} under flow from the northeast exceeding 10kt. This together with GDI values of 45-60 are favorable for the development of thunderstorms in the region.

Se presenta la convergencia en nivel bajo y su valor entre -5 a -15 x 10^{-6} s^{-1} condición favorable para la ocurrencia de la tormenta y el viento de nivel bajo del NE con 10 nudos y el GDI 45 a 60 el cual nos indica condicion favorable para la ocurrencia de la tormenta

Conclusions

1 Where might storms form?

Convective Initiation: Region most favorable is where factors interact



TRIGGERS

- **Solar radiation very important**
- **Perturbations from previous convection**
- **Diurnal circulations (e.g. river/lake breezes)**

2 How will storms move/propagate?

- **Mostly controlled by the mean flow (e.g. average of 850-200 hPa winds)**

3 Will storms persist/regenerate?

More likely if the environment is favorable:

- **LLJ exit: enhances low-level convergence and provides shear.**
- **Trough in the trades enhances low-level convergence as well as coverage and magnitude of the perturbations/triggers.**
- **Enhanced convective instability ahead of storm (GDI>45).**
  - Clear skies during daytime, maximum heating;
  - Deep moisture, usually from remnants of convection in the region.
- **Enhanced precipitable water (55mm+) ahead of the storm.**

CONCLUSIONS

PREDICTOR VALUES FOR EACH CASE

VARIABLES	CASE1: FEB 13/14	CASE2: FEB 15/16	CASE3: FEB 27/28
GDI	45 - 60	45 – 60	55 - 60
250-200 DIVERGENCE x 10^{-6} s^{-1}	3 - 10	5– 15	3 - 12
250-200 WIND kt	NE y 15 -30	NE Y 25 – 35	NE y 15 - 20
RELATIVE HUMIDITY%	85 - 90	85 – 90	85 - 90
PRECIPITABLE WATER mm	60 - 62	58 - 64	56 - 60
RAINFALL mm (SPQT)	37.6	6.0	52.6
850 -200 kt WINDS	E y 10 – 15	NE – E y 10	NE y 15
850-925 CONVERGENCE x$10^{-6}$$s^{-1}$	-3 - -10	-5 - -15	-5 - -15
850-925 WINDS kt	NE y 5 – 10	NE – E y 10	NE y 10