Precipitation Structure Upshear and Its Role in Tropical Cyclone Intensification

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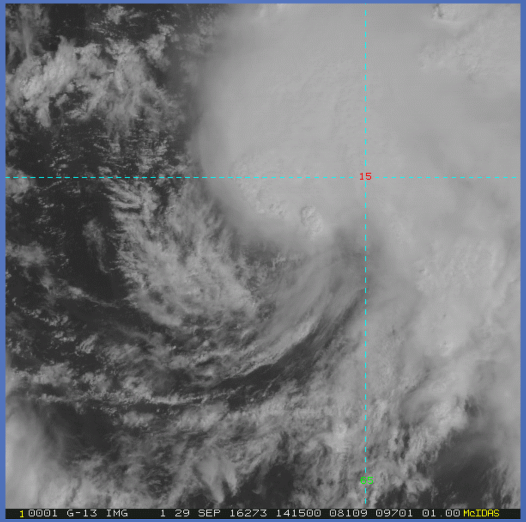
Motivation

- Well-known that tropical cyclone (TC) structure and intensity change highly sensitive to environmental vertical wind shear, with strong shear detrimental to intensification
- For moderate shear values (e.g., 10-20 kt) TC response is uncertain
  - Significant intensity forecast uncertainty lies in this range of shear

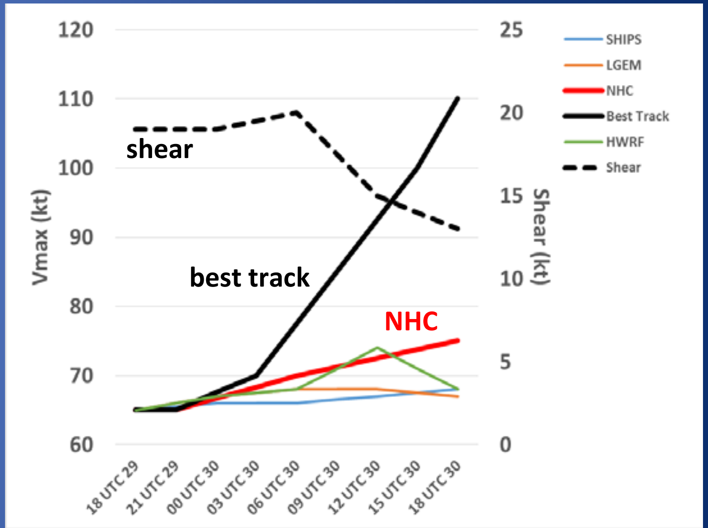
NHC advisory for Hurricane Matthew (2016)

"The center of Matthew is exposed to the southwest of the deep convection due to moderate southwesterly shear... Given the current shear and structure of Matthew, only slight strengthening is predicted during the next 24 hours..."
Storm in reality intensified 35 kt in 24 h subsequent to this advisory.

GOES-East visible image



24-h intensity and shear forecast



- Whether or not a TC intensifies in this shear environment is dependent on characteristics of the environment as well as the TC vortex
- Precipitation distribution, both in radial and azimuthal dimensions, one factor
  - Governs spatial distribution of diabatic heating and vortex response
  - Focus here is on azimuthal distribution of precipitation

Questions

1. What is the preferred azimuthal distribution of precipitation?
2. What governs that distribution?
3. Can this distribution, and potential for intensification, be predicted?

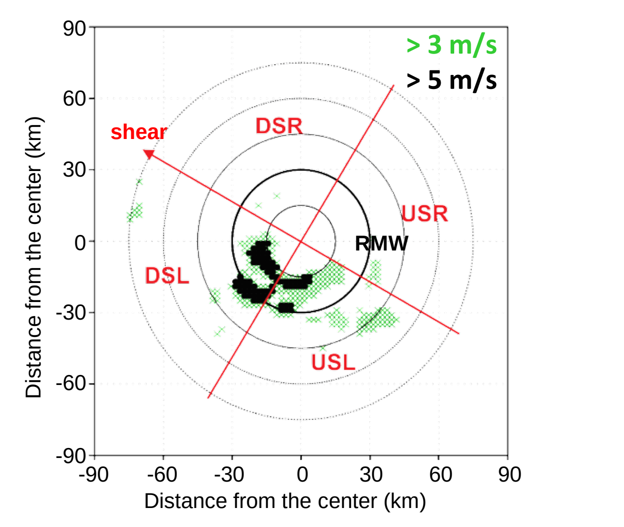
Address these questions through a series of studies using aircraft observations, examined in a shear-relative framework

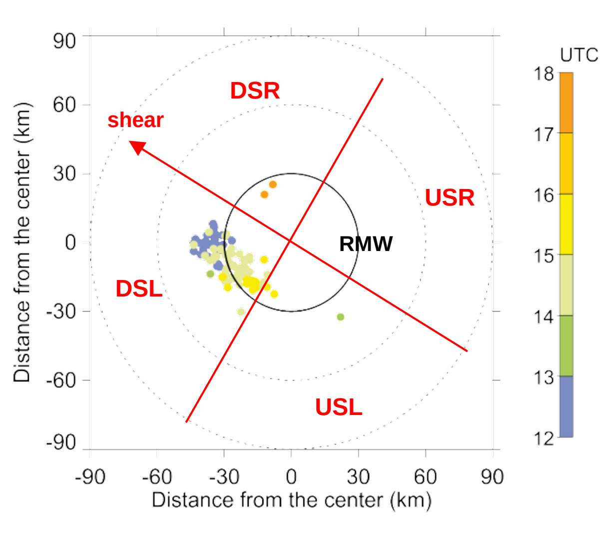
1. What is preferred azimuthal distribution?

Locations of strong updrafts and lightning for Edouard (2014)

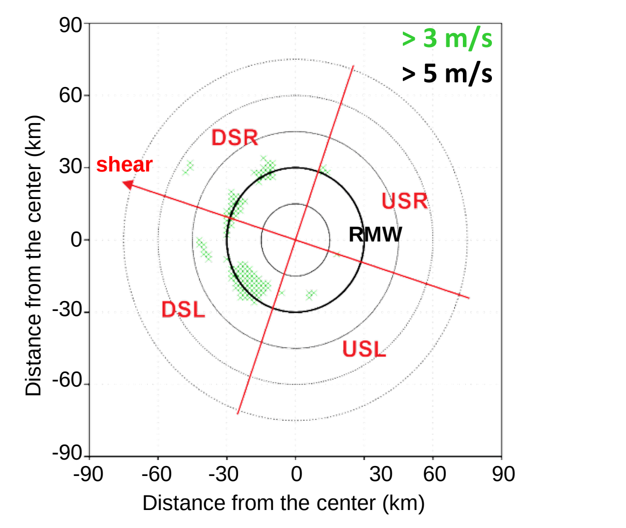
Strong 8-16 km updrafts | *Lightning flashes from WWLLN*

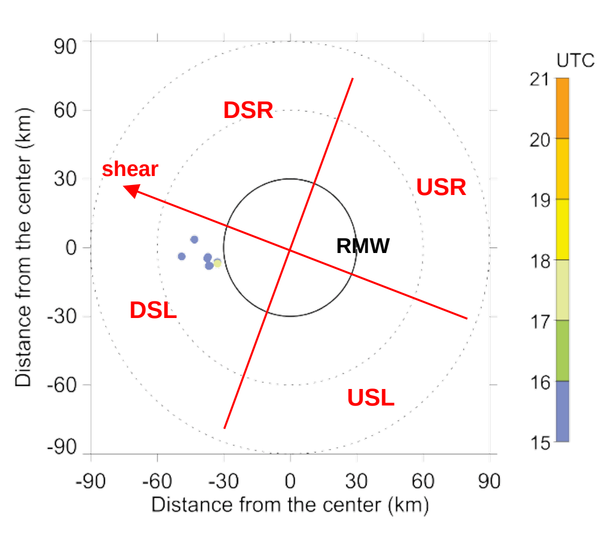
14 September (RI)
Shear: 10 kt





16 September (SS)
Shear: 12 kt





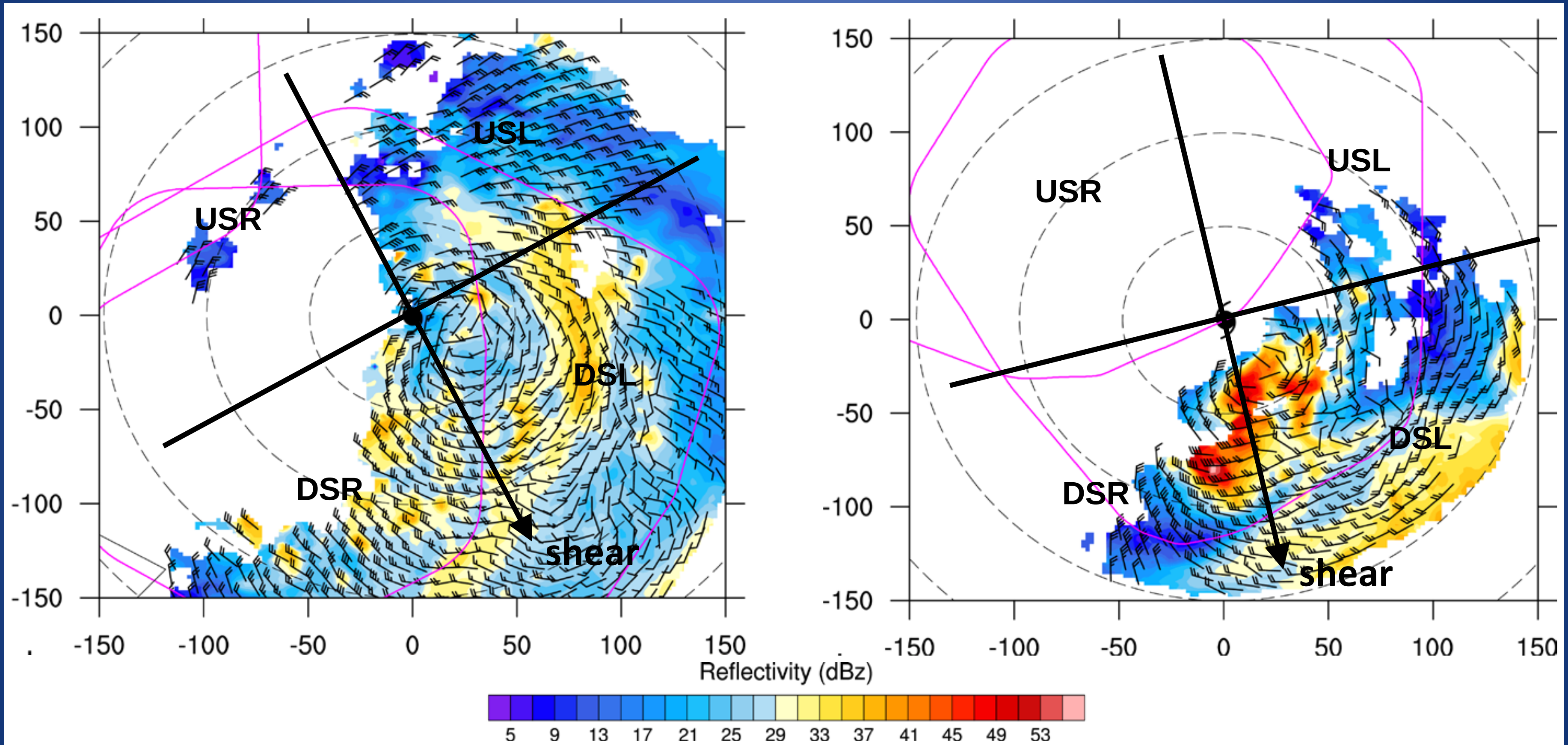
(Rogers et al. 2016)

- 14 Sept (RI): Strongest updrafts DSL, USL; Lightning flashes begin DSL, rotate toward USL and inside RMW
- 16 Sept (SS): Limited strong updrafts and lightning mostly DSL

1. What is preferred azimuthal distribution?

Winds and reflectivity at 6 km altitude from airborne Doppler for Bertha (RI) and Cristobal (SS) of 2014

Bertha (RI case) *Cristobal (SS case)*

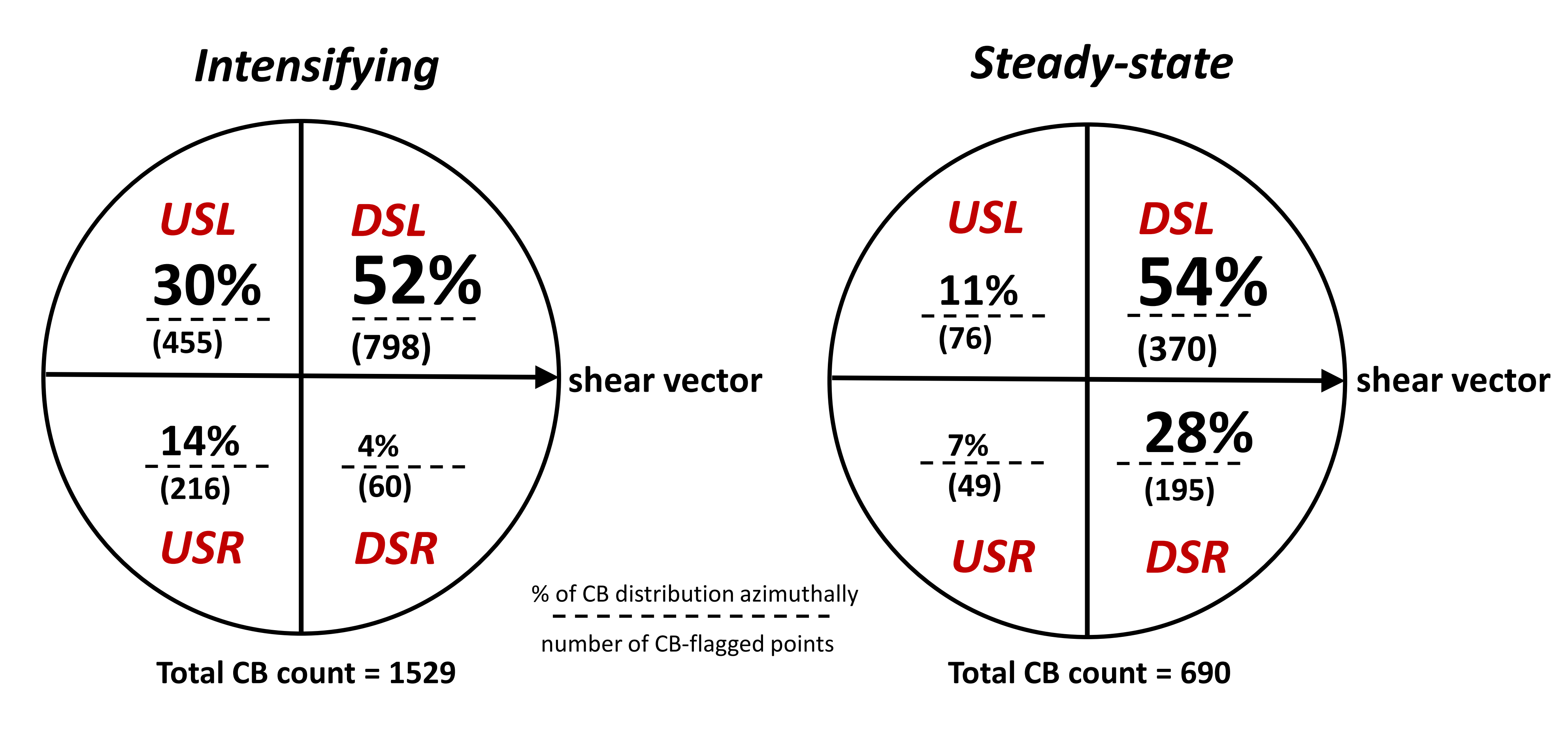


(Nguyen et al. 2017, in review)

- Both cases had similar shear values, ~20 kt from northwest, similar tilt toward southeast
- Bertha (RI case) has greater coverage of precipitation on upshear side
- Cristobal (SS case) had areas of heavy precipitation and strong convection downshear, little upshear

1. What is preferred azimuthal distribution?

Shear-relative azimuthal locations of convective bursts (CBs) from airborne Doppler composite of 28 P-3 missions



(Adapted from Wadler et al. 2017, in prep)

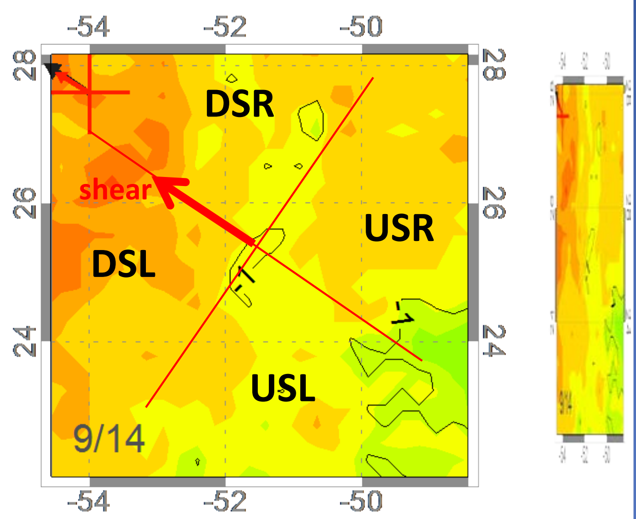
- Intensifying TCs have more CBs than steady-state, significant proportion (~45%) on upshear side
- Steady-state TCs have much fewer CBs (<20%) on upshear side

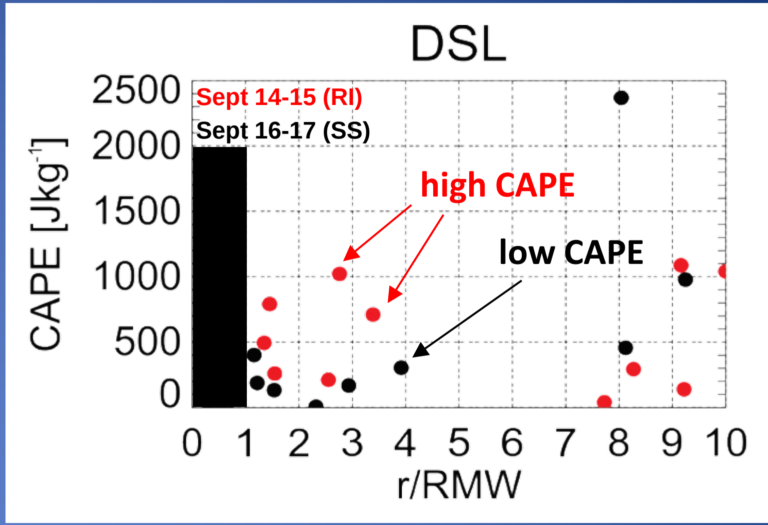
2. What governs that distribution? SST and PBL recovery

SST

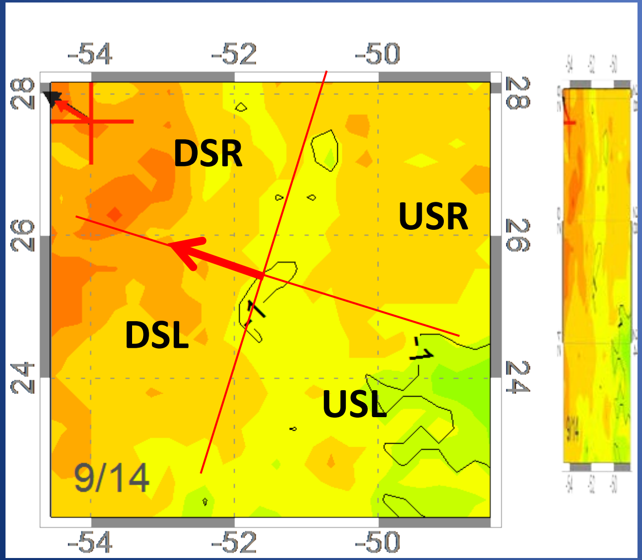
CAPE from Global Hawk sondes

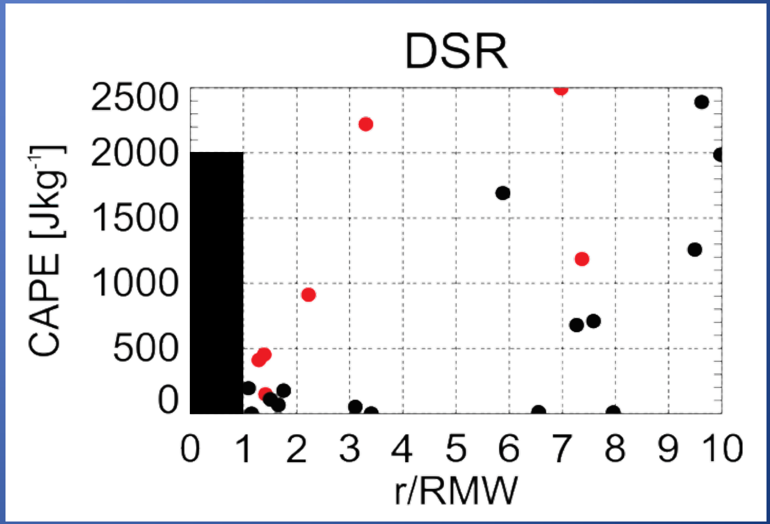
14 September (RI)





16 September (SS)





(Zawislak et al. 2016)

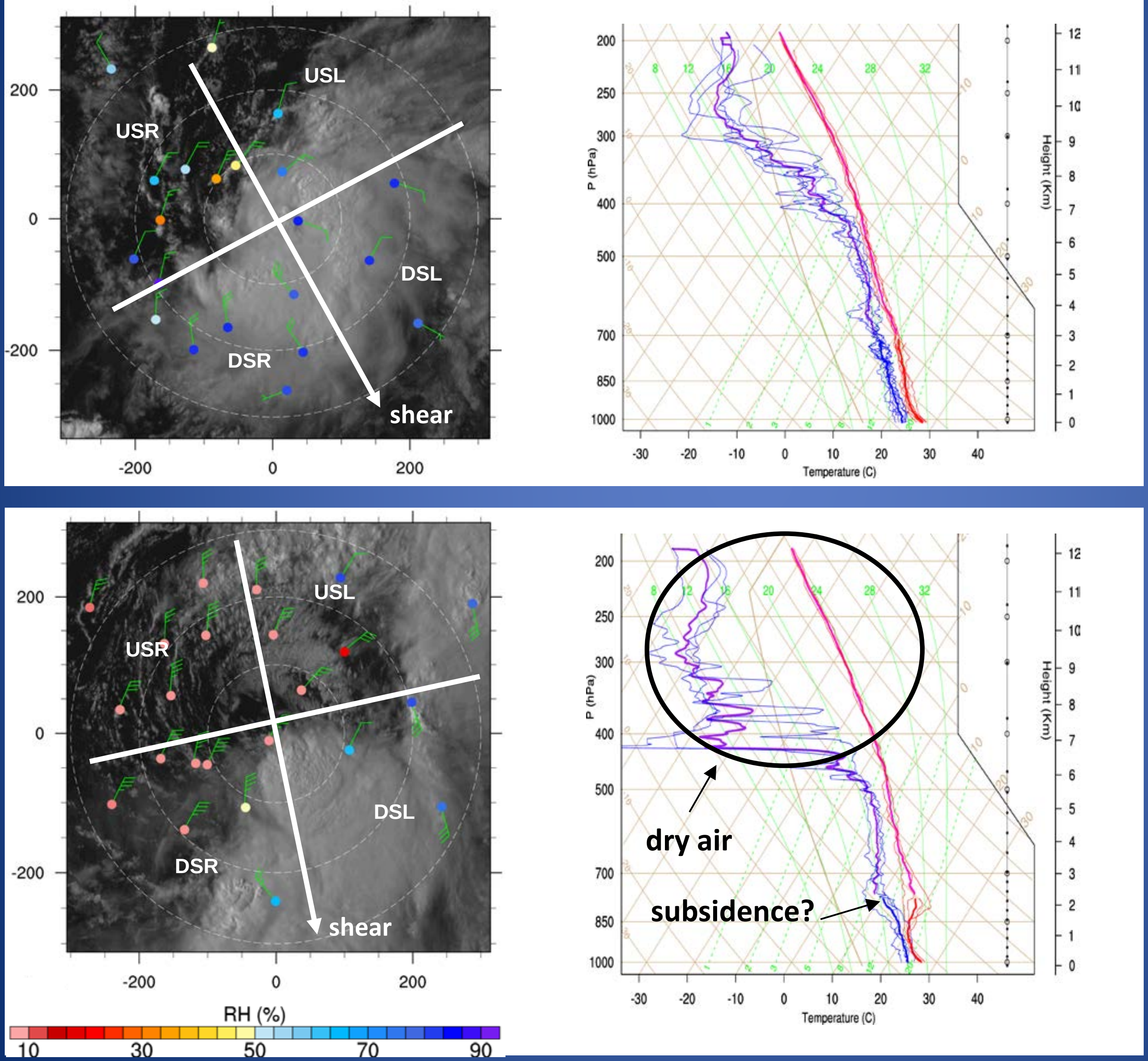
- 14 Sept (RI): High SST downshear, around storm, high CAPE downshear
- 16 Sept (SS): Pronounced SST cooling USL, USR, reduced CAPE values downshear

2. What governs that distribution? Dry air, subsidence upshear

Winds and RH at 8 km | **Skew-T, log P diagrams from USR**

Bertha (RI case)

Cristobal (SS case)

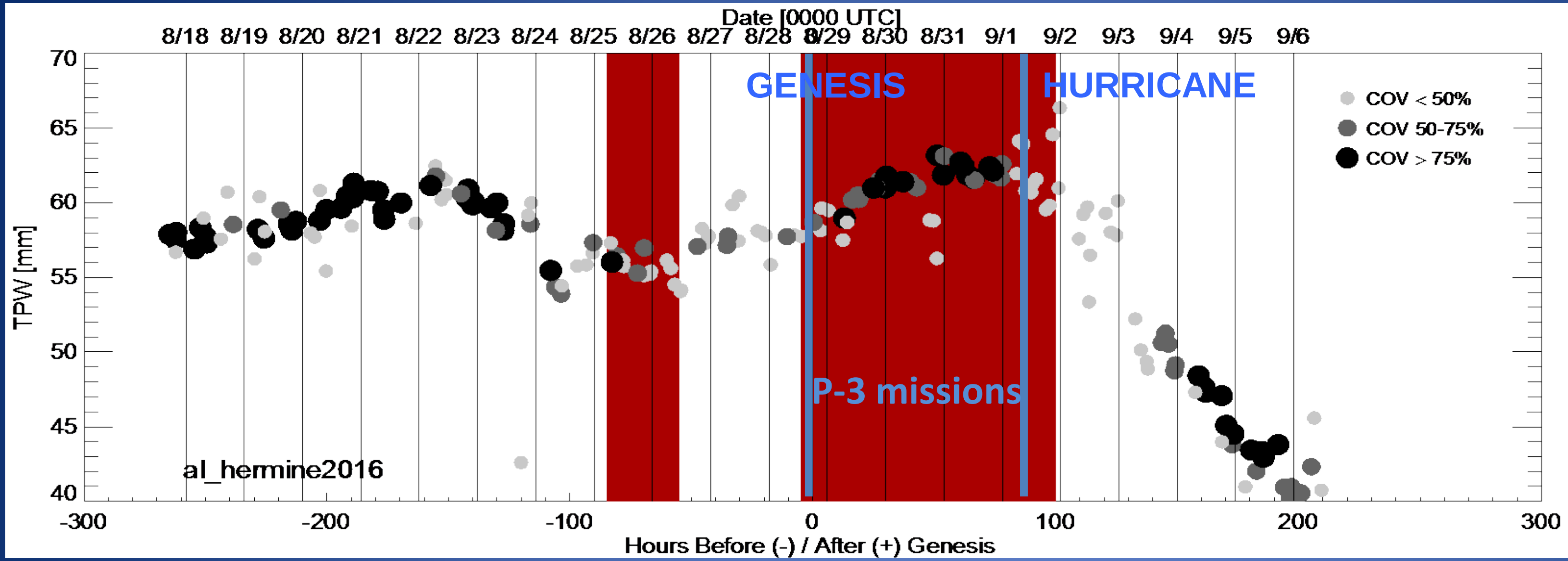


- Bertha (RI): higher RH upshear, more cloud coverage
- Cristobal (SS): less cloud coverage upshear, much drier air above 400 hPa, potential layer of subsidence around 700 hPa

(adapted from Nguyen et al. 2017, in review)

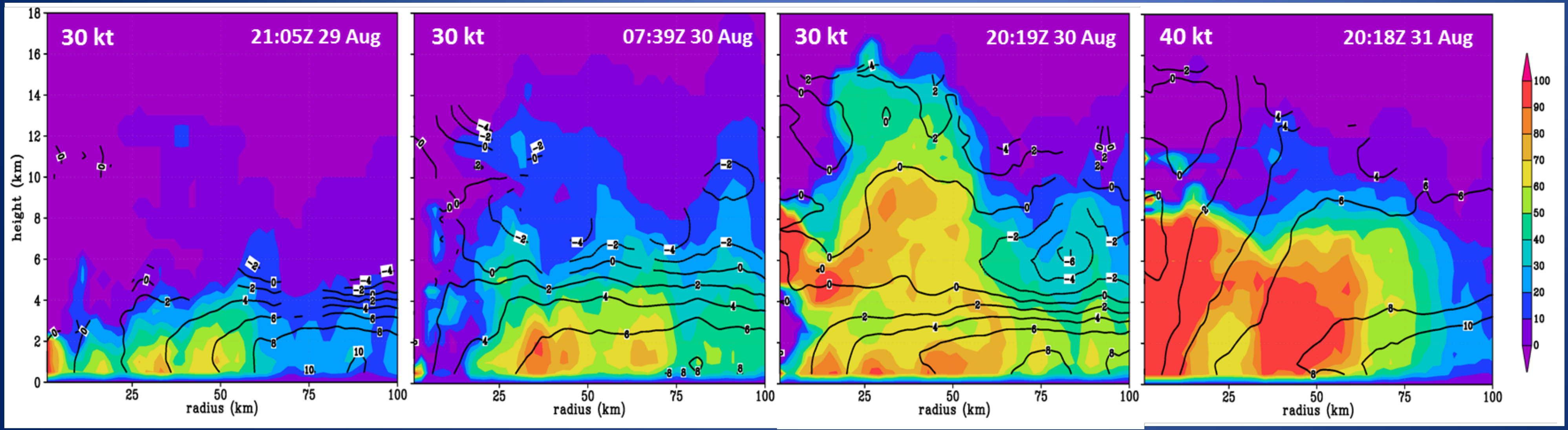
2. What governs that distribution? Dry air upshear

Total Precipitable Water averaged within 3 degrees



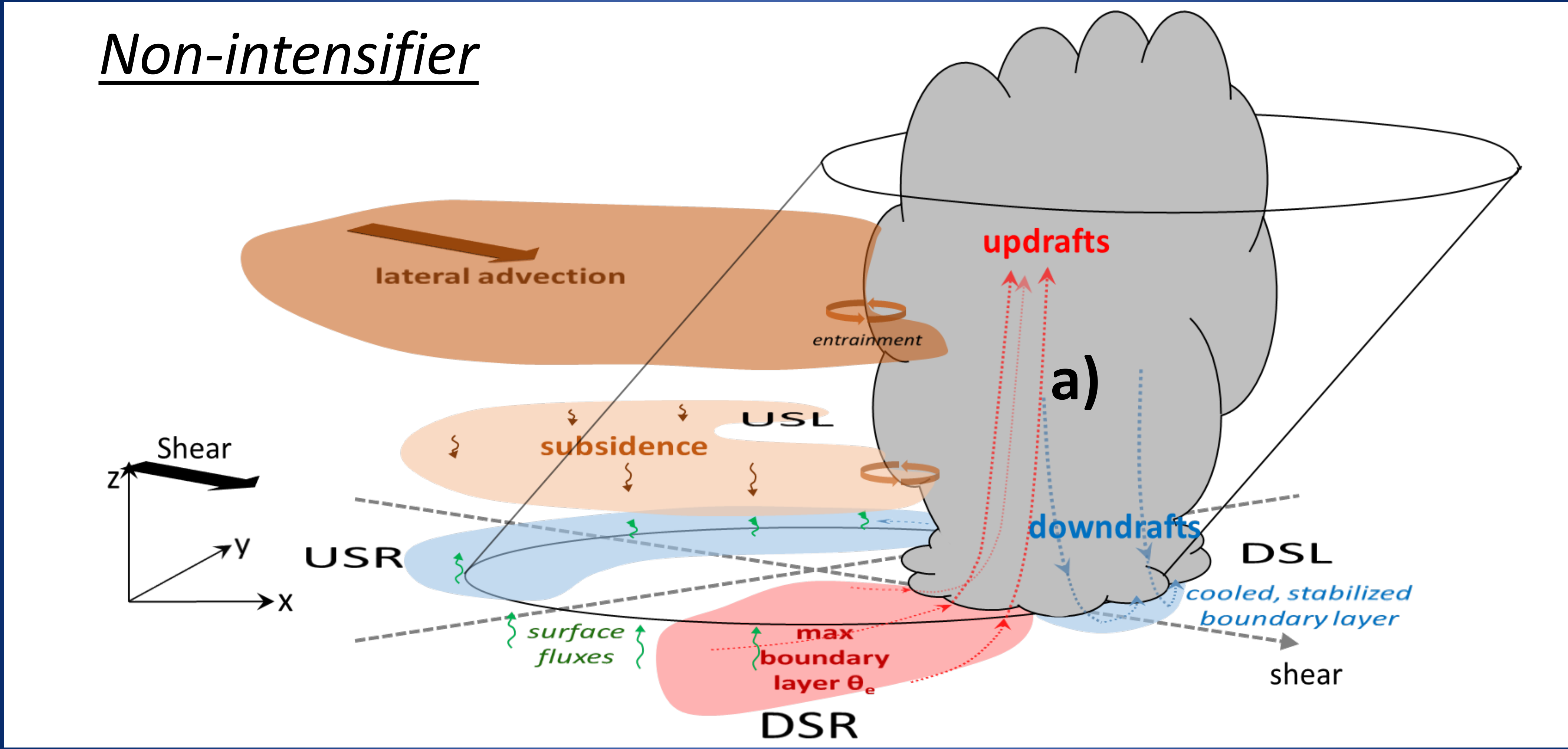
- Moistening in near environment during early intensification
- Greater coverage of reflectivity upshear – preconditioning from moistening by detrainment?

Fractional azimuthal coverage of reflectivity > 15 dBZ on upshear side



2. What governs that distribution?

Schematic of vortex and precipitation structures associated with non-intensifying TCs



a) **Main precipitation/convection downshear left, little to no precipitation upshear**
b) Significant dry air upshear
c) Subsidence signatures upshear
d) Broad area of PBL cooling upshear, limited recovery of PBL entropy downshear

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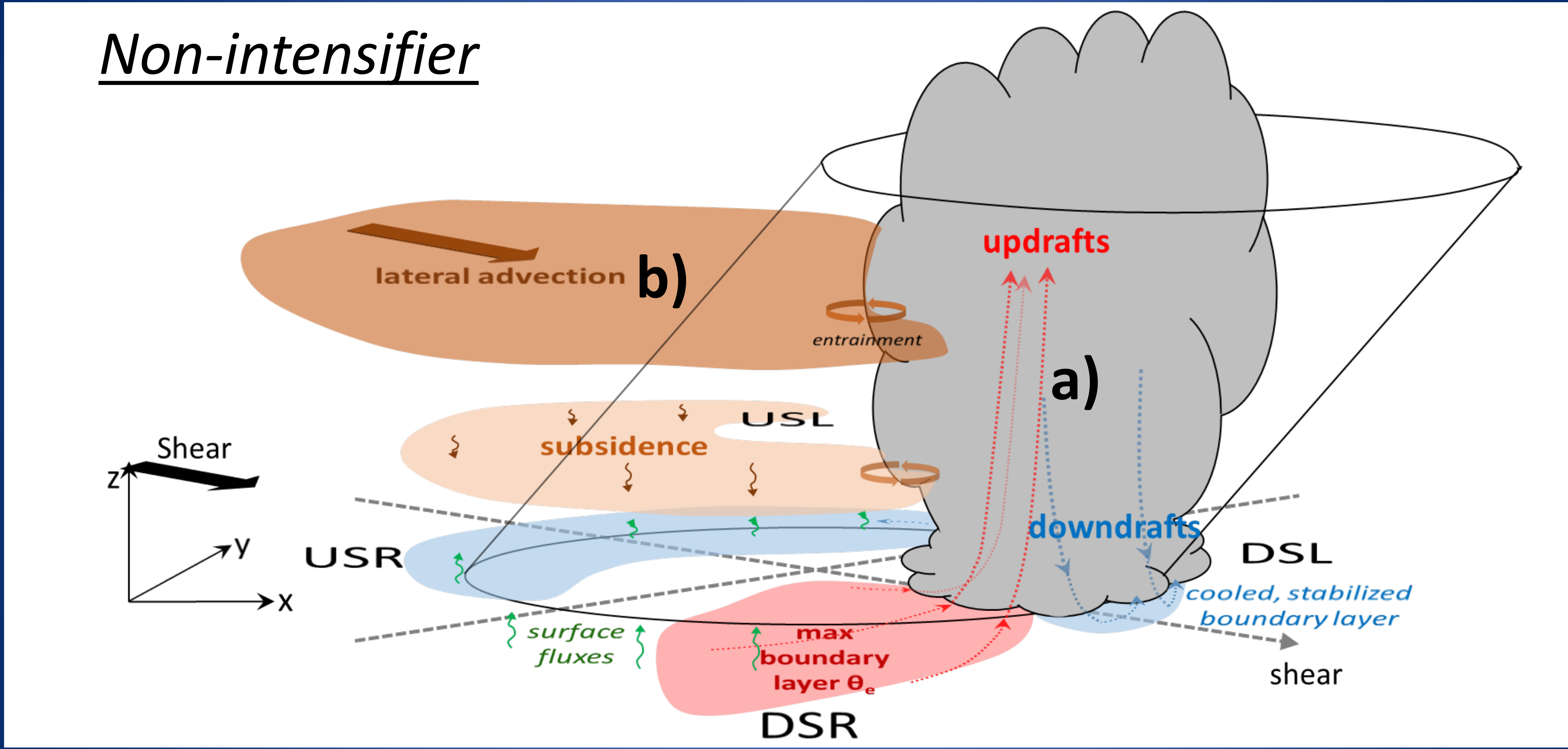

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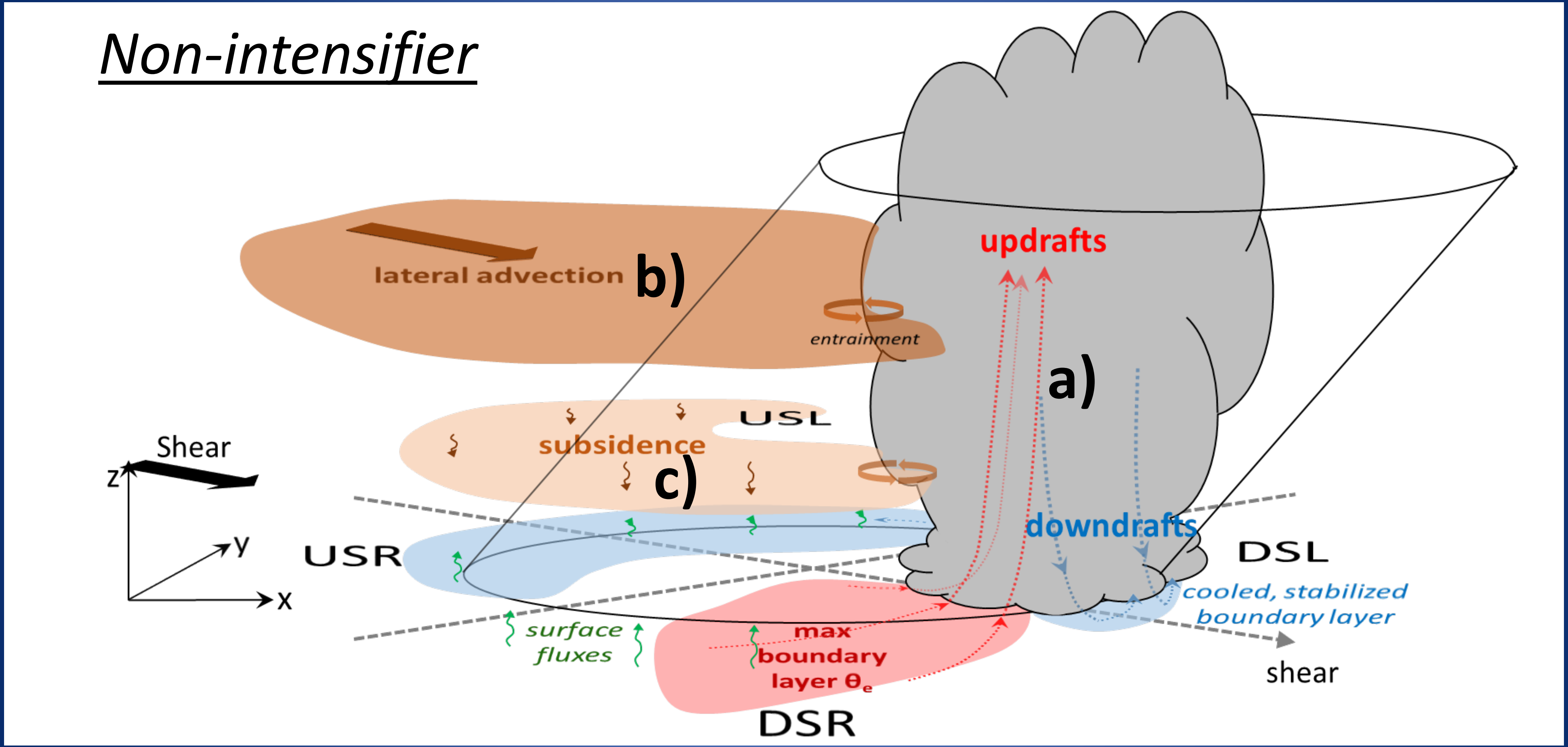

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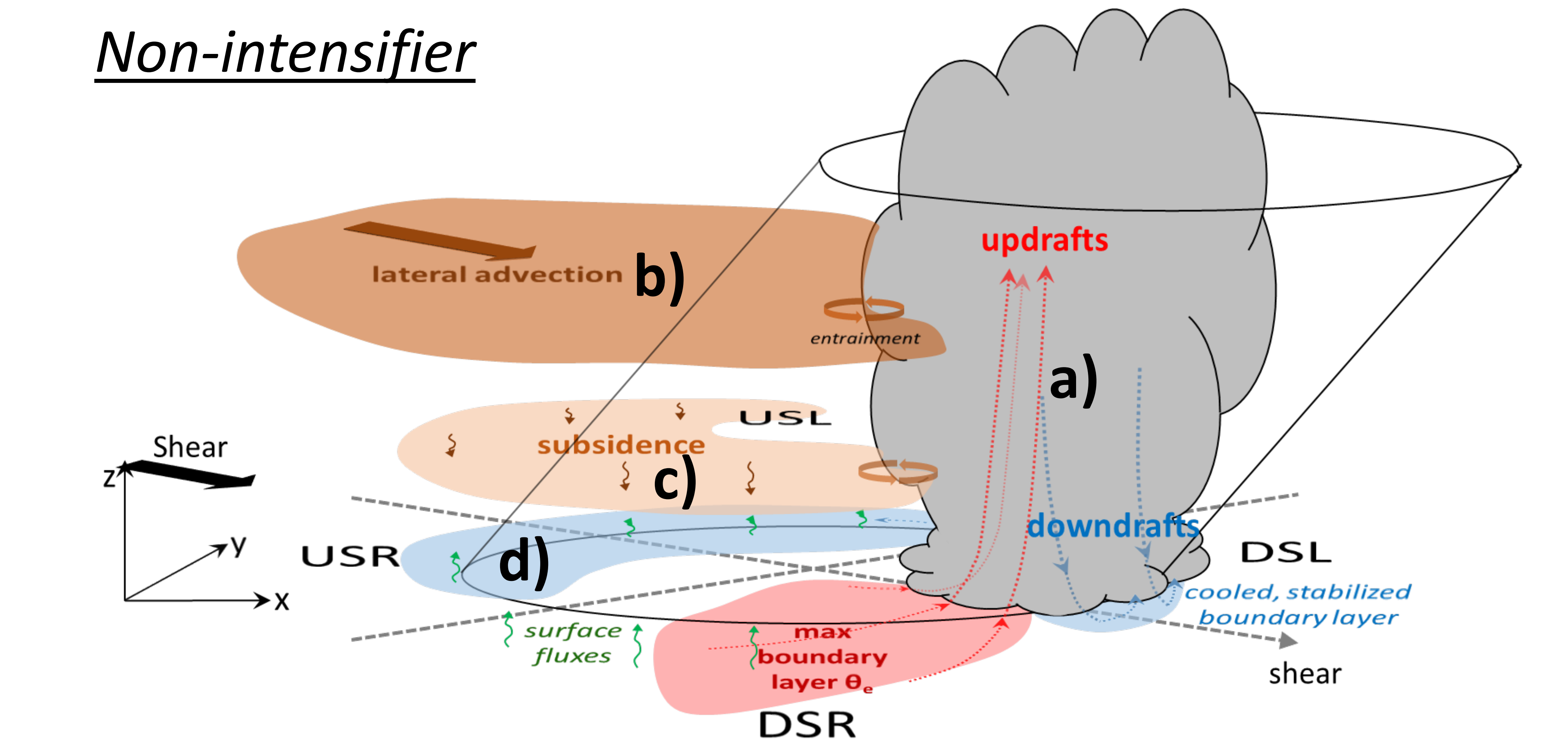

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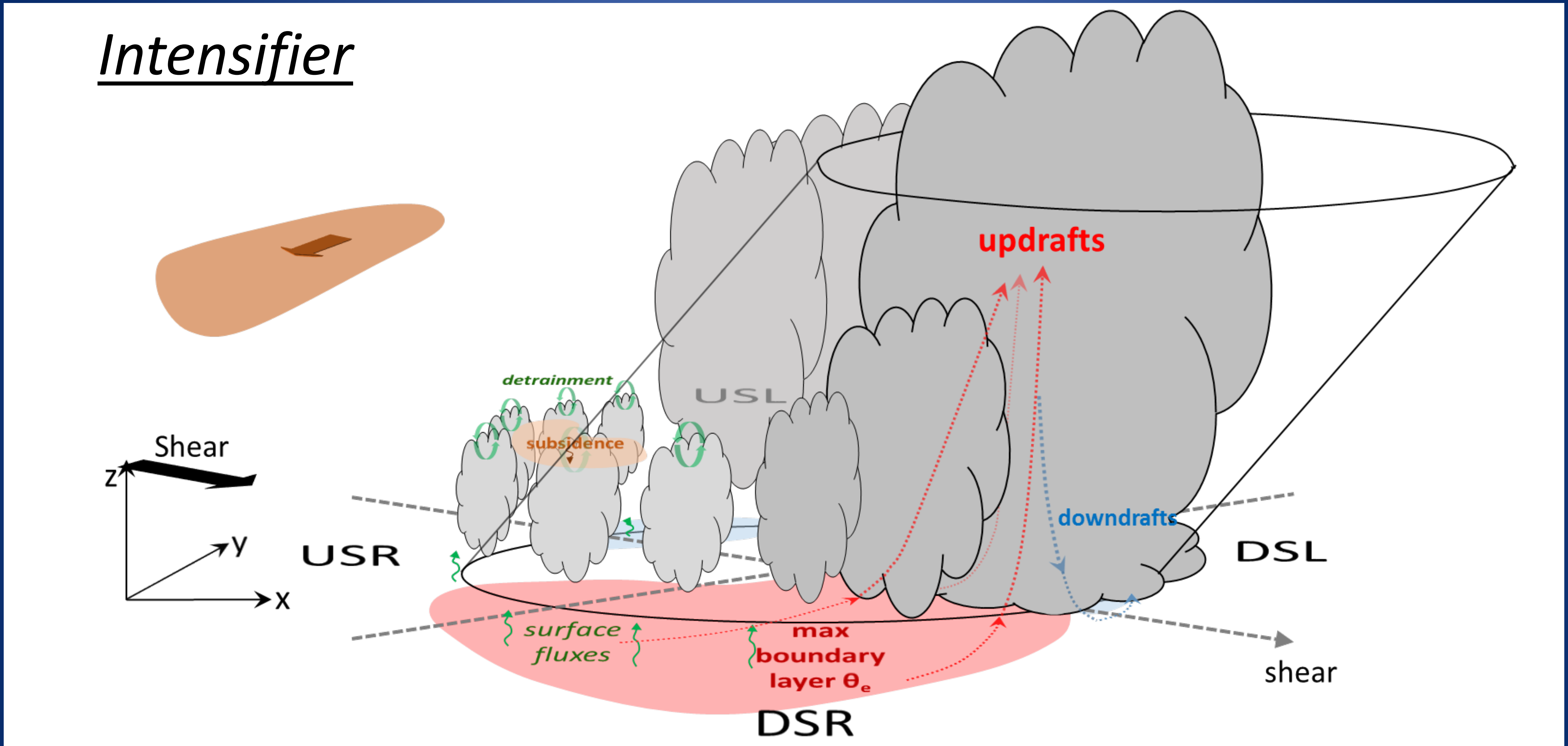
2. What governs that distribution?

Schematic of vortex and precipitation structures associated with intensifying TCs



a) Precipitation/convection downshear left, significant coverage of convection USL, shallow precipitation USR/USL
b) More moist environment upshear
c) Limited indication of subsidence upshear
d) Smaller area of PBL cooling upshear, greater area of PBL recovery downshear

3. Can this distribution be predicted?

- Predictability of precipitation is limited, but environmental and vortex structure (context for precipitation) less so
  - need information on precipitation and its local environment
- Aircraft provides that, but sampling is limited
- What about satellites?
  - GOES-16: Geostationary Lightning Mapper provides rapid updates on IC lightning distributions
  - TROPICS: 12 Cubesats will provide passive microwave imagery with rapid refresh rates, median revisit time ~20 minutes
- If this information is available:
  - can be used as predictors for statistical/dynamical prediction schemes (e.g., SHIPS RII)
  - can be used to evaluate numerical models, improve representation of structures and physical processes for improved numerical prediction of intensity change


Thank you!