2.5 Intensity change: External influences

Marie-Dominique LEROUX

Laboratoire de l’Atmosphère et des Cyclones (LACy)
(CNRS – Météo-France – Université de La Réunion)
Saint Denis, La Réunion, France

1-10 December 2014, Jeju, Republic of Korea
OUTLOOK

1 Framework
   - Motive
   - IWTC-VII highlights

2 Impacts of environmental parameters on TC intensity
   - Surface impacts
   - Shear impacts
   - Relative humidity/aerosols impacts
   - PV / upper-level interactions

3 Rapid intensity changes
   - Rapid intensification (RI)
   - Rapid weakening (RW)

4 Predictability of RI

5 Forecasting TC intensity change

6 Summary & Brain-storming
OUTLOOK

1 Framework
   - Motive
     - IWTC-VII highlights

2 Impacts of environmental parameters on TC intensity
   - Surface impacts
   - Shear impacts
   - Relative humidity/aerosols impacts
   - PV / upper-level interactions

3 Rapid intensity changes
   - Rapid intensification (RI)
   - Rapid weakening (RW)

4 Predictability of RI

5 Forecasting TC intensity change

6 Summary & Brain-storming
Aim of the talk: report new advances and shortcomings in the matter of TC intensity change under external forcing (forecasting and research perspectives). Internal influences will be discussed in the next talk - structure changes in topic 4.1

Final objective: define suitable research routes to improve the prediction of TC intensity change.
OUTLOOK

1 Framework
   - Motive
   - IWTC-VII highlights

2 Impacts of environmental parameters on TC intensity
   - Surface impacts
   - Shear impacts
   - Relative humidity/aerosols impacts
   - PV / upper-level interactions

3 Rapid intensity changes
   - Rapid intensification (RI)
   - Rapid weakening (RW)

4 Predictability of RI

5 Forecasting TC intensity change

6 Summary & Brain-storming
Role of the SAL on intensity change (in the NATL basin)

Disagreement between studies
Role of the SAL on intensity change (in the NATL basin)

Disagreement between studies

A spectrum of shear values and TC intensities that permit continued intensification (contrary to conventional wisdom)

- Empirical MPI - observational research (Zeng et al., 2007): incorporates the negative effects of storm motion and vertical shear (dynamic + thermodynamic controls)
- Ventilation index - theoretical framework (Tang and Emanuel, 2010, 2012a)
Mechanisms for inner-core ventilation (entrainement of low-entropy air from the environment under vertical shear)

- (i) downdrafts outside the eyewall drying the inflowing BL and
- (ii) inward eddy fluxes (e.g., through VRWs) of low $\theta_e$ air

(Tang and Emanuel, 2010)
Mechanisms for inner-core ventilation (entrainement of low-entropy air from the environment under vertical shear)

- (i) downdrafts outside the eyewall drying the inflowing BL and
- (ii) inward eddy fluxes (e.g., through VRWs) of low $\theta_e$ air
  (Tang and Emanuel, 2010)

- pathway to vortex weakening (Riemer et al., 2010; Tang and Emanuel, 2012a):

Relative shear flow asymmetries import low $\theta_e$ air towards the TC core at mid levels where it excites downdrafts that flush the inflow layer with low $\theta_e$ air, which is then taken into downstream updrafts. Such processes reduce the eyewall buoyancy and convection and thus the storm intensity.
Rapid Intensification (RI)

- Composite study in the NATL and WNP (Hendricks et al., 2010): few significant differences between the LS environments of intensifying and RI TCs.
- RI predominantly influenced by internal dynamics?

IWTC-VII recommendations

- improving the understanding of the impact of various environmental parameters
  - VWS, RH, SST and OHC, outflow-layer interactions with the environment
  - water vapor advection, dust, topography, and BL fluxes
- research into predictability limits for intensity forecasting
Outlook

1. Framework
   - Motive
   - IWTC-VII highlights

2. Impacts of environmental parameters on TC intensity
   - Surface impacts
   - Shear impacts
   - Relative humidity/aerosols impacts
   - PV / upper-level interactions

3. Rapid intensity changes
   - Rapid intensification (RI)
   - Rapid weakening (RW)

4. Predictability of RI

5. Forecasting TC intensity change

6. Summary & Brain-storming
OUTLOOK

1 Framework
- Motive
- IWTC-VII highlights

2 Impacts of environmental parameters on TC intensity
- Surface impacts
- Shear impacts
- Relative humidity/aerosols impacts
- PV / upper-level interactions

3 Rapid intensity changes
- Rapid intensification (RI)
- Rapid weakening (RW)

4 Predictability of RI

5 Forecasting TC intensity change

6 Summary & Brain-storming
OUTLOOK

1 Framework
   - Motive
   - IWTC-VII highlights

2 Impacts of environmental parameters on TC intensity
   - Surface impacts
   - Shear impacts
   - Relative humidity/aerosols impacts
   - PV / upper-level interactions

3 Rapid intensity changes
   - Rapid intensification (RI)
   - Rapid weakening (RW)

4 Predictability of RI

5 Forecasting TC intensity change

6 Summary & Brain-storming
Impacts of environmental parameters on TC intensity

Surface impacts

Oceanic impacts

Role of SSTs

Weakening TCs have lower SSTs than strengthening TCs in the WNP (Shu et al., 2014)
Oceanic impacts

Role of SSTs

Weakening TCs have lower SSTs than strengthening TCs in the WNP (Shu et al., 2014)

Changes in the SST field near the TC can be as important as the absolute value of SST

Upper-ocean stratification can modulate the sea surface cooling (induced by vertical mixing) by up to one order of magnitude (Vincent et al., 2014).

E.g.: In the Bay of Bengal, surface cooling is about 3 times larger during the pre-monsoon than during the post-monsoon season due to seasonal changes in oceanic stratification rather than to differences in TC wind energy input (Neetu et al., 2012).
Impacts of environmental parameters on TC intensity

Surface impacts

Oceanic impacts

Role of SSTs

Weakening TCs have lower SSTs than strengthening TCs in the WNP \cite{Shu et al., 2014}

Changes in the SST field near the TC can be as important as the absolute value of SST

**Upper-ocean stratification** can modulate the sea surface cooling (induced by vertical mixing) by up to one order of magnitude \cite{Vincent et al., 2014}.

E.g.: In the Bay of Bengal, surface cooling is about 3 times larger during the pre-monsoon than during the post-monsoon season due to seasonal changes in oceanic stratification rather than to differences in TC wind energy input \cite{Neetu et al., 2012}.

⇝ More oceanic influences: topic 4.4
OUTLOOK

1 Framework
   - Motive
   - IWTC-VII highlights

2 Impacts of environmental parameters on TC intensity
   - Surface impacts
   - Shear impacts
     - Relative humidity/aerosols impacts
     - PV / upper-level interactions

3 Rapid intensity changes
   - Rapid intensification (RI)
   - Rapid weakening (RW)

4 Predictability of RI

5 Forecasting TC intensity change

6 Summary & Brain-storming
Shear impacts

Robustness of the low-level ventilation process (Riemer et al., 2010)

- verified for different physics/physics parameters/vortex strengths (Riemer et al., 2013) - correlation between moist entropy depression underneath the eyewall and subsequent TC weakening.

\[ \Theta'_e(r, \lambda) = \Theta_e(r, \lambda) - \bar{\Theta}_e(r) \]

averaged over the lowest 1km and from 4-9h
Shear impacts

Robustness of the low-level ventilation process (Riemer et al., 2010)

- verified for different physics/physics parameters/vortex strengths (Riemer et al., 2013) - correlation between moist entropy depression underneath the eyewall and subsequent TC weakening.
- environmental air can be entrained into the inner core in the limit of strong shear and weak vortex intensity - sheared mature TCs are generally protected from environmental air intrusions (Riemer and Montgomery, 2011)
Shear impacts

Robustness of the low-level ventilation process (Riemer et al., 2010)

- verified for different physics/physics parameters/vortex strengths (Riemer et al., 2013) - correlation between moist entropy depression underneath the eyewall and subsequent TC weakening.
- environmental air can be entrained into the inner core in the limit of strong shear and weak vortex intensity - sheared mature TCs are generally protected from environmental air intrusions (Riemer and Montgomery, 2011)

Other path for VWS effect on TC intensity: upward flux of high-entropy air (Gu et al., 2014)

Fluxes associated with shear-induced updraft, outside the eyewall, from the boundary layer into mid levels, can weaken the radial gradient of moist entropy across the eyewall, and thus weaken the storm.
Shear impacts

Sensitivity to the vertical location of ventilation

- greatest impact when ventilation placed at middle to lower levels (Tang and Emanuel, 2012b) - ventilation at upper levels has little impact on intensity

\[ \Lambda = \frac{u_{\text{shear}} \chi_m}{u_{p1}} \]

- 850hPa-10m shear has more impact on TC intensification over the WNP in the 2000-2006 period (Shu et al., 2013)

- 700-1000hPa or 850-1000hPa shear averaged in a 5-9 degree annulus: highest correlation with the 24-h lagged TC intensity over the WNP in the 1981-2010 period (Wang et al., 2014)
Impacts of environmental parameters on TC intensity

Shear impacts

Sensitivity to the vertical location of ventilation

- greatest impact when ventilation placed at middle to lower levels (Tang and Emanuel, 2012b) - ventilation at upper levels has little impact on intensity
- 850hPa-10m shear has more impact on TC intensification over the WNP in the 2000-2006 period (Shu et al., 2013)
- 700-1000hPa or 850-1000hPa shear averaged in a 5-9 degree annulus: highest correlation with the 24-h lagged TC intensity over the WNP in the 1981-2010 period (Wang et al., 2014)

Is the VWS effect basin-dependent?

The low-level shear is no longer important when a similar analysis is conducted over the NATL basin (Wang, pers. comm.)
→ Differences in other environmental conditions need to be investigated in future studies
Impacts of environmental parameters on TC intensity

Shear impacts

Methodology to compute the VWS

- fact: traditional two-level approach oversimplified to account for the effect of VWS on TC intensity change
- Velden and Sears (2014) derives the VWS from two mass-weighted layer-mean wind fields; one upper-tropospheric and one lower-tropospheric (CIMSS)
- correlation coefficient of lagged TC intensity change with shear explains 30% the variance for NATL TCs
Shear impacts

Methodology to compute the VWS
- fact: traditional two-level approach oversimplified to account for the effect of VWS on TC intensity change
- Velden and Sears (2014) derives the VWS from two mass-weighted layer-mean wind fields; one upper-tropospheric and one lower-tropospheric (CIMSS)
- correlation coefficient of lagged TC intensity change with shear explains 30% the variance for NATL TCs

Need for a comprehensive VWS diagnostic?
- take into account the total vertical profile of the ambient wind: to include both the dynamic and thermodynamic effects of shear on TC intensity change
Impacts of environmental parameters on TC intensity

Shear impacts

### Sensitivity to the direction of shear

**Easterly shear has weaker effects** than westerly shear:

- Part of the easterly shear could be offset by the beta-induced northwesterly shear (Zeng et al., 2010)

- Westerly shear appears to promote the intrusion of dry environmental air in weakening TCs over the WNP (Shu et al., 2014)

- NCEP reanalysis data from 41 NATL storms exhibited stronger westerly winds (and VWS) above weakening storms (Braun, 2010)
Impacts of environmental parameters on TC intensity

Shear impacts

Sensitivity to the direction of shear

**Easterly shear has weaker effects** than westerly shear:

- part of the easterly shear could be offset by the beta-induced northwesterly shear (Zeng et al., 2010)
- westerly shear appears to promote the intrusion of dry environmental air in weakening TCs over the WNP (Shu et al., 2014)
- NCEP reanalysis data from 41 NATL storms exhibited stronger westerly winds (and VWS) above weakening storms (Braun, 2010)

VWS affects the timing and rate of TC intensification

- influences the spatial distribution of convection and the positive feedback between diabatic heating and the TC vortex primary circulation.
- the larger the vertical wind shear, the farther and weaker the convection from the TC center, which leads to a weakening TC vortex circulation and more time for the onset of RI (Tao and Zhang, 2014a,b) - [convection-permitting ensemble simulations]
Shear impacts

Intensification cases under strong shear forcing

- What governs the radial distribution of convection in sheared storms remains an active area of research.

- Downshear redevelopment of a new circulation: preceded the RI of TS Gabrielle (2001) and Hurricane Irene (1999) (Molinari and Vollaro, 2010; Nguyen and Molinari, 2012). The shear and motion induced convective asymmetry focused radially inside the max winds, where heating can most effectively intensify the vortex (Nolan et al., 2007; Vigh and Schubert, 2009; Rogers et al., 2007).

- Competition between the weakening influence of ventilation through downward transport of low-entropy air into the BL by convective downdrafts (Riemer et al., 2010, 2013) and the intensifying role of enhanced heat and moisture fluxes from the ocean (Molinari et al., 2013).
Shear impacts

Testing the hypotheses for shear-induced intensity change

The TC in shear Experiment is part of the overarching Intensity Forecasting Experiment IFEX (Rogers and coauthors, 2013):

Purpose: sample the TC during distinct phases of its interaction with VWS; measure kinematic and thermodynamic fields with the azimuthal and radial coverage necessary to test the hypotheses.
OUTLOOK

1. Framework
   - Motive
   - IWTC-VII highlights

2. Impacts of environmental parameters on TC intensity
   - Surface impacts
   - Shear impacts
   - Relative humidity/aerosols impacts
   - PV / upper-level interactions

3. Rapid intensity changes
   - Rapid intensification (RI)
   - Rapid weakening (RW)

4. Predictability of RI

5. Forecasting TC intensity change

6. Summary & Brain-storming
Impacts of environmental parameters on TC intensity

Relative humidity/aerosols impacts

Dry air impacts

Dry air intrusion into the storm core

- **A tilted TC is more vulnerable to dry air** (Tao and Zhang, 2014a,b)
- In moderate-sheared environments, dry air is able to penetrate the TC core
- In low-sheared environments, **dry air may slow intensification only when it is located very close to the vortex core at early times** (Braun et al., 2012) - [idealized simulations with no mean flow]
- When a moist envelope is present in the inner-core, the surrounding dry air has no deleterious impact on storm intensity
- (in the NH) **Dry air located to the right of the VWS direction is detrimental** to TC development because it is subsequently advected by the vortex primary circulation to the downshear side and taken into the forced updrafts (Ge et al., 2013) - [idealized experiments]

⇒ **whether dry air can be taken into the updrafts seems the most important process for the dry air intrusion mechanism**
Dry air impacts

SAL influence

The SAL has an inhibiting effect (Dunion and Velden, 2004)

- during the pre-depression to depression stages only (Braun)
- the SAL is not a primary determinant of storm intensity following formation (Braun, 2010; Braun et al., 2013; Braun and coauthors, 2013) - verified in three cases with different methodology. In mesoscale ensemble forecasts of TS Debby (2006), sensitivity to the dry air depended on cyclone strength and became insignificant once a TS formed (Sippel et al., 2011).
Dust, or the indirect effects of aerosols

Role of dust or aerosols on TC intensity and dynamics

- The modification of cloud properties via aerosols injected into idealized TCs is hypothesized to initiate interactions between cloud microphysics and storm dynamics (Carrio and Cotton, 2011; Rosenfeld et al., 2011, 2012; Cotton et al., 2012; Herbener et al., 2014)

- Aerosols introduced at the periphery of a TC with increasing concentration ranging from 100 to 2000 cm$^{-3}$ can impact both storm intensity (up to 17% increase) and size (up to 16% decrease) (Herbener et al., 2014)
OUTLOOK

1 Framework
   - Motive
   - IWTC-VII highlights

2 Impacts of environmental parameters on TC intensity
   - Surface impacts
   - Shear impacts
   - Relative humidity/aerosols impacts
   - PV / upper-level interactions

3 Rapid intensity changes
   - Rapid intensification (RI)
   - Rapid weakening (RW)

4 Predictability of RI

5 Forecasting TC intensity change

6 Summary & Brain-storming
Impacts of environmental parameters on TC intensity

PV / upper-level interactions

TC-trough interactions

- primary pathway for TC-environment interaction known to be the outflow layer, region of weak inertial stability (Rappin et al., 2011)

- the interaction can occur below the outflow layer: Rossby wave breaking events spawn cyclonic PV coherent structures that are advected towards TCs via the imposed asymmetric radial circulation. Can cause large intensity forecast errors.

- cyclonic PV injection in the mid-upper TC circulation = a potential contributor to TC intensification/structure (Leroux et al., 2013; Davidson et al., 2014)
Impacts of environmental parameters on TC intensity

PV / upper-level interactions

ex-TC Oswald (2013) - PV injection

3-day back trajectories from ERA-Interim analyses, from points scattered through the mid levels of the Oswald circulation
Impacts of environmental parameters on TC intensity
PV / upper-level interactions

ex-TC Oswald (2013) - PV injection

3-day back trajectories from ERA-Interim analyses, from points scattered through the mid levels of the Oswald circulation

transition from an isolated vortex → a circulation interacting strongly with its environment
Impacts of environmental parameters on TC intensity

PV / upper-level interactions

ex-TC Oswald (2013) - PV injection

3-day back trajectories from ERA-Interim analyses, from points scattered through the mid levels of the Oswald circulation

direct spin up of the mid-level circulation + favorable conditions for enhanced ascent, convection and rainfall within the circulation

transition from an isolated vortex → a circulation interacting strongly with its environment
Impacts of environmental parameters on TC intensity

PV / upper-level interactions

TC Dora (2007) - PV injection

Numerical model able to reproduce the main features of the RI and ERC observed for TC Dora
Impacts of environmental parameters on TC intensity

PV / upper-level interactions

TC Dora (2007) - PV injection

Mechanisms for vortex intensification (Leroux et al., 2013)

1. PV superposition (associated with $M_a$ convergence) in a [200-500] hPa layer
2. SEF induced by eddy angular momentum ($M_a$) convergence, eddy PV (or $\zeta_a$) fluxes, and dynamically forced upward motion

Numerical model able to reproduce the main features of the RI and ERC observed for TC Dora
Impacts of environmental parameters on TC intensity
PV / upper-level interactions

TC Dora (2007) - PV injection

Mechanisms for vortex intensification (Leroux et al., 2013)

1. PV superposition (associated with $M_a$ convergence) in a [200-500] hPa layer
2. SEF induced by eddy angular momentum ($M_a$) convergence, eddy PV (or $\zeta_a$) fluxes, and dynamically forced upward motion

External forcing may excite internal processes within 200 km of the hurricane core, as speculated by Molinari and Vollaro (1989) and supported by Nong and Emanuel (2003) in an idealized framework.
Impacts of environmental parameters on TC intensity

TC Dora (2007) - PV injection

Mechanisms for vortex intensification (Leroux et al., 2013)

1. PV superposition (associated with $M_a$ convergence) in a [200-500] hPa layer
2. SEF induced by eddy angular momentum ($M_a$) convergence, eddy PV (or $\zeta_a$) fluxes, and dynamically forced upward motion

A conceptual model for TC-trough interaction?

- Need for a unified theory for TC-trough interaction to help forecasters in the context of the “good trough/bad trough” issue
- Clarify the dynamics and quantify the potential effects on TC intensity change
- First TC-TUTT cell interaction conceptual model in the WNP, designed for operational track guidance only (Patla et al., 2009)
- Sensitivity experiments to modify the initial TC strength and relative TC-trough position to see if and how quickly the TC intensifies (Leroux et al., 2014)
OUTLOOK

1 Framework
   - Motive
   - IWTC-VII highlights

2 Impacts of environmental parameters on TC intensity
   - Surface impacts
   - Shear impacts
   - Relative humidity/aerosols impacts
   - PV / upper-level interactions

3 Rapid intensity changes
   - Rapid intensification (RI)
   - Rapid weakening (RW)

4 Predictability of RI

5 Forecasting TC intensity change

6 Summary & Brain-storming
OUTLOOK

1 Framework
   - Motive
   - IWTC-VII highlights

2 Impacts of environmental parameters on TC intensity
   - Surface impacts
   - Shear impacts
   - Relative humidity/aerosols impacts
   - PV / upper-level interactions

3 Rapid intensity changes
   - Rapid intensification (RI)
   - Rapid weakening (RW)

4 Predictability of RI

5 Forecasting TC intensity change

6 Summary & Brain-storming
Rapid intensification (RI)

Thermodynamics aspects for RI

- greater intensification rates associated with stronger radial gradients of RH at upper levels (300 to 400 hPa) in the front-right quadrant relative to TC motion (Wu et al., 2012).

- upper-level inertial stability increases & static stability decreases sharply 2-3 h prior to RI (Chen and Zhang, 2013) - Cloud-permitting predictions of Hurricane Wilma (2005) down to 1-km resolution.

- the formation of an upper-level warm core, from the subsidence of stratospheric air associated with the detrainment of convective bursts, coincides with the onset of RI (Chen and Zhang, 2013).
Rapid intensification (RI)

Thermodynamics aspects for RI

- greater intensification rates associated with stronger radial gradients of RH at upper levels (300 to 400 hPa) in the front-right quadrant relative to TC motion (Wu et al., 2012).
- upper-level inertial stability increases & static stability decreases sharply 2-3 h prior to RI (Chen and Zhang, 2013) - Cloud-permitting predictions of Hurricane Wilma (2005) down to 1-km resolution
- the formation of an upper-level warm core, from the subsidence of stratospheric air associated with the detrainment of convective bursts, coincides with the onset of RI (Chen and Zhang, 2013).

RI over the WNP (Wang et al., 2014)

- relatively higher probability for TCs drifting between 3 \( ms^{-1} \) and 8 \( ms^{-1} \), under low shear (e.g. VWS300-850 < 11 \( ms^{-1} \) and VWS700-1000 < 5 \( ms^{-1} \)): weaker negative ocean feedback.
- deep-layer shear \( \leq 7 \ ms^{-1} \) or low-level shear \( \leq 3.5 \ ms^{-1} \) favorable for RI.
OUTLOOK

1 Framework
   • Motive
   • IWTC-VII highlights

2 Impacts of environmental parameters on TC intensity
   • Surface impacts
   • Shear impacts
   • Relative humidity/aerosols impacts
   • PV / upper-level interactions

3 Rapid intensity changes
   • Rapid intensification (RI)
   • Rapid weakening (RW)

4 Predictability of RI

5 Forecasting TC intensity change

6 Summary & Brain-storming
Rapid weakening (RW)

Conditions conducive to RW over the ENP (1979-2012)

- RW is much more common in the ENP (33%) than in the NATL (11%) in part due to the lower areal extent of SSTs \( \geq 26^\circ C \) (Wood and Ritchie, 2014)
- Strongest contributor to accelerated TC decay = decreasing [400-700] hPa RH in the southern part of TCs
OUTLOOK

1 Framework
   - Motive
   - IWTC-VII highlights

2 Impacts of environmental parameters on TC intensity
   - Surface impacts
   - Shear impacts
   - Relative humidity/aerosols impacts
   - PV / upper-level interactions

3 Rapid intensity changes
   - Rapid intensification (RI)
   - Rapid weakening (RW)

4 Predictability of RI

5 Forecasting TC intensity change

6 Summary & Brain-storming
Predictability of RI

Inherent predictability of TC intensity

- SST and VWS have a greater impact on intensity forecast errors than other thermodynamic environmental parameters (Zhang et al., 2014) - 5-yr forecasts in the ATL basin.

- The larger the shear magnitude, the less predictable the onset time of RI (impact of high-frequency transients such as moist convection) and the larger the uncertainty in the intensity forecast (Zhang and Tao, 2013), until the shear magnitude is large enough to prevent TC formation.

(a) Uncertainty in RI onset time for sheared experiments
Predictability of RI

(a) Uncertainty in RI onset time for sheared experiments

Non Developer

<table>
<thead>
<tr>
<th>SST27</th>
<th>SST29</th>
<th>SST27Dry50</th>
<th>SST29Dry50</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Predictability $\alpha \{\text{environment hostility} + \text{vortex vulnerability}\}$

- Under moderate to large VWS, environmental **dry air** may have a negative impact on TC predictability (Tao and Zhang, 2014a,b).
- Higher **SSTs** also increase the predictability of RI onset (Tao and Zhang, 2014a,b; McGauley and Nolan, 2011) by shortening the onset time of RI & increasing the VWS magnitude threshold for vortex development.
OUTLOOK

1 Framework
   - Motive
   - IWTC-VII highlights

2 Impacts of environmental parameters on TC intensity
   - Surface impacts
   - Shear impacts
   - Relative humidity/aerosols impacts
   - PV / upper-level interactions

3 Rapid intensity changes
   - Rapid intensification (RI)
   - Rapid weakening (RW)

4 Predictability of RI

5 Forecasting TC intensity change

6 Summary & Brain-storming
Forecasting TC intensity change

External influences contribution to the forecast (Courtney, Kucas)

- **Primary driver of intensity change**
  - during formation or demise: external influences
  - at tropical storm intensities (34-64 knots): intensity estimates due to external factors adjusted based on the analysis of internal dynamics.

- **Short-term (to +24h or +36h):** combination of persistence + subjective assessment of external influences (including SST/OHC, VWS, RH and potential dry air intrusion, low-level inflow, upper-level DIV and interaction with upper-level circulations like the TUTT)

- **After +24h or +36h:** combination of objective guidance and subjective interpretation of changes in dynamical model depiction of those external factors
Assessing external influences (Courtney, Kucas)

- Valuable standard output of environmental predictors: STIPS (Knaff et al., 2005) + SHIPS (DeMaria et al., 2005) + LGEM (DeMaria, 2009)
- Over the WNP: consider using the low-level shear in statistical intensity prediction schemes, since it provides a better representation of the VWS effect on TC intensity change? (Shu et al., 2013; Wang et al., 2014)
Intensity forecast challenges (Courtney, Kucas)

- Diagnosed dominant external factors $\leadsto$ intensity change forecast
  - Models can have differing responses with similar representations of external factors such as the wind shear (timing of peak intensity and change to weakening).

- Interpreting environmental VWS: What is the effective shear on the circulation?

- Situations when some factors may favor development and others may oppose them.
  - TC-trough interactions: shortcomings in model forecasts cause large intensity prediction errors - e.g., Typhoon Vicente (2012) - Shieh et al. (2013).
  - How quickly may a TC intensify or weaken as it interacts with TUTTs/TUTT cells of various magnitudes and storm-relative positions?
OUTLOOK

1 Framework
   - Motive
   - IWTC-VII highlights

2 Impacts of environmental parameters on TC intensity
   - Surface impacts
   - Shear impacts
   - Relative humidity/aerosols impacts
   - PV / upper-level interactions

3 Rapid intensity changes
   - Rapid intensification (RI)
   - Rapid weakening (RW)

4 Predictability of RI

5 Forecasting TC intensity change

6 Summary & Brain-storming
Summary & Brain-storming


