Mesoscale Cyclogenesis over the Western North Pacific Ocean during T-PARC

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T-PARC mesoscale cyclones

2 systems arose from the remnants of the non-developing depression TCS-025 that formed on the flank of a tropical upper tropospheric trough (TUTT) cell (T-PARC)

→ Explanation why the remnants of TCS-025 intensified but without either a tropical cyclone structure (C1) or a tropical cyclone intensity (C2)

→ Gain knowledge about development and persistence of marine mesoscale cyclones

→ Understanding the rapid spin-up process for surface vorticity – important aspect of tropical cyclones
Data and methods

- Analyses and forecasts from ECMWF IFS (version 33r1, implemented in June, 2008)
- Horizontal grid: 25 km, vertical grid: 25 hPa in pressure coordinates
- Additional tendency fields provided as part of the Year of Tropical Convection (YOTC) extensive archive

→ 3 hourly data allow the computation of area mean tendencies of physical processes in the model (temperature and moisture tendencies due to parametrized convection, grid-resolved condensation, 3-dim advection, short- and long-wave radiation, turbulent diffusion and fluxes)

→ vorticity budgets computed (method of Davis & Galarneau, 2009)

- Data from two flights of the DLR Falcon are used in the analysis, incorporating dropsondes and water vapor lidar measurements
- Observations from the seaWinds scatterometer (NASA QuikSCAT) and from the Advanced Scatterometer (ASCAT, EUMETSAT) are used
Separation of TCS-025 into C1 and C2

ECMWF analyses: Relative vorticity (shaded), streamlines (red) at 850 hPa
Formation of C1

QUICKSCAT derived surface winds (left); IR temperatures from GOES (right)

Location of mesoscale cyclone center

Dry notch

0810 UTC
30 Aug

1831 UTC
30 Aug

0734 UTC
31 Aug
Formation of C2

QUICKSCAT derived surface winds (left); IR temperatures from GOES (right)
Important role of upper-level troughs → mesoscale lifting

ECMWF analyses: Potential temperature (shaded) and wind on the 2 PVU surface mean sea level pressure (contours)

Lifecycle and environmental conditions of C1 and C2

🌟 C1
❌ C2
Rather strong wind shear during intensification

31 August 00 UTC

02 September 00 UTC

850 – 500 hPa shear

Magnitude of vector wind difference. Winds associated with the vorticity and the divergence have been removed following Davis et al. (2008)
C1 intensifies in a baroclinic environment

31 August 00 UTC

Lifecycle and environmental conditions of C1 and C2

02 September 00 UTC

Analysis: Sea surface temperatures

Ascent up the isentropic slope
Tropical moisture plume responsible for initiation of deep convection in C1

Proximity of dry air detrimental for C2

ECMWF analyses: 850 hPa relative humidity (shaded), 850 hPa relative vorticity > |9e-5|/s (contours, ci: 5e-5/s)
Tropical moisture plume $\rightarrow$ C1 in destabilized environment

30 August 00 UTC

High equivalent potential temperature in southeasterly winds $\rightarrow$ destabilization

Cross section of equivalent potential temperature (ci: 5 K), wind and water mixing ratio from DIAL aboard the DLR Falcon (g/kg)

Skew-t depiction of sounding 10 (red arrow)

Conditional instability
Formation of a distinct PV column under the influence of condensation heating

12 h ECMWF fcst valid on 31 August 00 UTC

Potential vorticity at 850 (contours) and 500 (shaded) (left). Cross section of PV (ci: 1 PVU) (right).
Significant vorticity in the boundary layer prior to convection important for intensifying surface circulation

Average of 81 member ensemble budget in which the location of the box was varied

Summarized sensitivity

Vorticities changes from 12 UTC 30 Aug to 00 UTC 31 Aug (left). Standard deviation (right).
Separation of TCS-025 into C1 and C2

Convection in TCS025 stays minimal until 1 September when lower tropospheric vorticity center approaches the upper tropospheric cold low
Formation of a distinct PV column
→ Condensation heating important for strong vertical motions and vortex stretching in lower/mid troposphere

12 h ECMWF fcst valid on 02 September 00 UTC

Potential vorticity at 850 (contours) and 500 (shaded) (left). Cross section of PV (ci: 1 PVU) (right).
Importance of diabatic processes for the formation of the PV column: Temperature tendencies

12 h ECMWF fcst valid on

C1: 00 UTC 31 August

C2: 00 UTC 02 September

- dynamics
- grid-scale cloud scheme
- cumulus scheme

- turbulent diffusion and fluxes
- radiation
- total change

Depth of PV column

Cooling by evaporation on grid scale
Importance of horizontal advection of dry air in decay of C2: Mixing ration

12 h ECMWF fcst valid on

C1: 00 UTC 31 August
C2: 00 UTC 02 September

Moisture fluxes from the ocean

Moistening by evaporation of fluxes from ocean

Horizontal advection of dry air

g/kg

- dynamics
- grid-scale cloud scheme
- cumulus scheme

- turbulent diffusion and fluxes
- radiation
- total change
Summary

- C1 and C2 are best classified as subtropical cyclones based on the importance of vertical wind shear and deep convection (organized by shear).
- Primary burst of convection was organized as the moisture laden, high vorticity remnant of a tropical disturbance encountered mesoscale lifting in conjunction with a TUTT cell.
- Mesoscale ascent of lower tropospheric flow polewards up the isentropic slope → destabilization and organizational mechanism for convection.
- However, with time in each case the thermodynamic environment becomes hostile for sustaining deep convection.
  - C1 affected by traversal over cooler water, encounter with strong vertical shear and deformation.
  - C2 dry air invades the lower troposphere around the cyclone, vertical shear promotes the decay.
- Cyclone intensification was favored by transient mechanisms → short period of intensification and subsequent weakening or extratropical transition.
Question of predictability of mesoscale developments is raised

ECMWF EPS:

48 h fcst has good signal for C1
24 h fcst has good signal for C2

Ensemble mean vorticity (colours), vorticity occuring in at least 75 % of the ensemble members (shaded)

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Significant vorticity in the boundary layer prior to convection important for intensifying surface circulation

Average of 81 member ensemble budget in which the location of the box was varied

Summarized sensitivity

Vorticity changes from 12 UTC 01 Sep to 00 UTC 02 Sep (left). Standard deviation (right).