Contribution of tropical cyclones to global deep convection with overshooting tops

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Objective

- To quantify the contribution of tropical cyclones (TCs) to overshooting convections
- To compare the overshooting properties and convective intensity proxies of overshooting convections associated with TCs and non-TCs

Data and Methodology

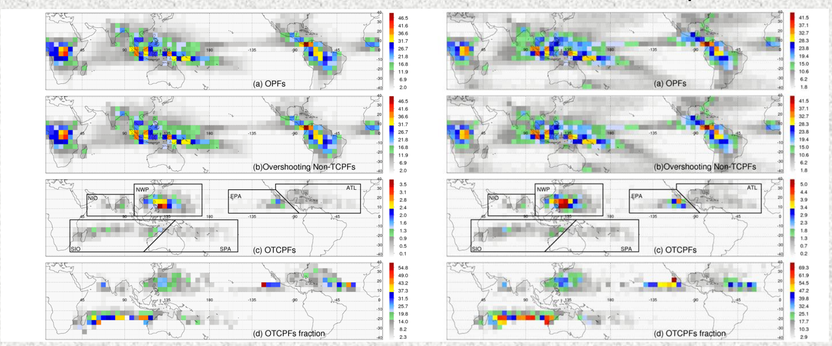
- 12-yr (1998-2009) TRMM Tropical Cyclone Precipitation Feature (TCPF) database, contains over 16677 TRMM overpasses of 1022 TCs
- Precipitation Feature (PF): (1) contiguous pixels (≥ 4 pixels) with PR 2A25 near surface rain rate > 0; (2) area ≥ 1000 km^2 ; (3) minimum 85-GHz PCT < 225K
- TCPF: PF within 500-km from the TC center
- Overshooting PF (OPF): PF with PR 20 dBZ radar echo height ≥ 14 km ***or*** 10.8μm IR brightness temperature ≤ the NCEP reanalysis derived tropopause temperature

Definition	OPFs defined with 14 km				Minimum $T_{IR} \le T_{trop}$			
Size ≥ 1000 km^2 & PCT_{85} < 225K	TCPFs	Non-TCPFs (land)	Non-TCPFs (ocean)	Total	TCPFs	Non-TCPFs (land)	Non-TCPFs (ocean)	Total
Population of OPFs[#]	3323	72333	61677	137333	6037	66704	104078	176819
Population of PFs[#]	17088	274729	539760	831577	17088	274729	539760	831577
Contribution to OPFs[%]	2.42	52.67	44.91	100	3.41	37.72	58.86	100
Contribution to PFs[%]	2.05	33.04	64.91	100	2.05	33.04	64.91	100
Percentage of OPFs[%]	19.45	26.33	11.43	16.86	35.33	24.28	19.28	21.26
Percentage of OPFs with lightning[%]	40.81	92.68	47.27	71.03	24.91	89.45	38.83	57.45

Result

Global Distribution of Number Density

Max. Z_{20dBZ} ≥ 14 km | **Min. $T_{IR} \le T_{trop}$**

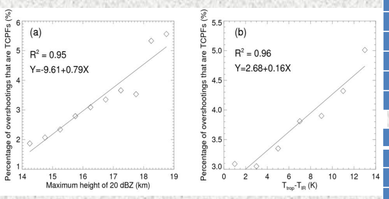


* Number density: total number of overshootings (98-09) in each 5ºx5º bin divided by TRMM 3A25 total pixel numbers to remove sampling bias. Units are parts per million.

Basin	Total OPFs [#]		Overshooting Non-TCPFs[#]		OTCPFs [#]		OTCPFs fraction [%]	
	14 km	T_{IR}	14 km	T_{IR}	14 km	T_{IR}	14 km	T_{IR}
ATL	14655	24327	14134	23309	521	1018	3.56	4.18
EPA	5573	8738	5277	7993	296	745	5.31	8.53
NWP	21518	25619	20199	23281	1319	2338	6.13	9.13
NIO	8254	8319	8041	8039	213	280	2.58	3.37
SIO	15219	17249	14537	16134	682	1115	4.48	6.46
SPA	15655	23428	15363	22887	292	541	1.87	2.31

Population and Fraction of Overshootings that are TCPFs

14 km | **T_{IR}**



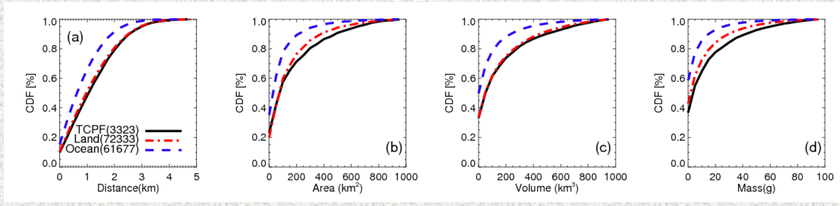
* Statistically significant at the 99% level

Z_{20dBZ} [km]	14.0-14.5	14.5-15.0	15.0-15.5	15.5-16.0	16.0-16.5
# OTCPFs	649	644	596	532	398
# OPFs	34664	31137	25417	19092	12864
%OTCPFs	1.87	2.07	2.34	2.79	3.09
# OTCPFs	16.5-17.0	17.0-17.5	17.5-18.0	18.0-18.5	18.5-19.0
# OPFs	260	145	58	31	9
%OTCPFs	7763	3959	1644	582	162

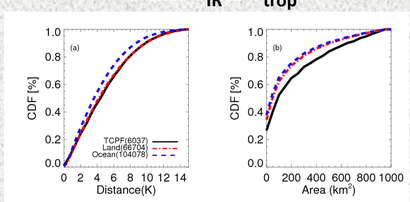
T_{trop}-T_{IR} [K]	0-2	2-4	4-6	6-8	8-10	10-12	12-14
#OTCPFs	1268	1386	1186	954	618	378	205
#TCPFs	41018	45460	35428	25069	15865	8748	4098
%OTCPFs	3.09	3.05	3.35	3.81	3.90	4.32	5.00

Overshooting Properties

Max. Z_{20dBZ} ≥ 14 km



Min. $T_{IR} \le T_{trop}$



Overshooting Distance
- OPFs defined with 14 km: $Z_{20dBZ} - 14$
- OPFs defined with IR brightness temperature: $T_{trop} - T_{IR}$

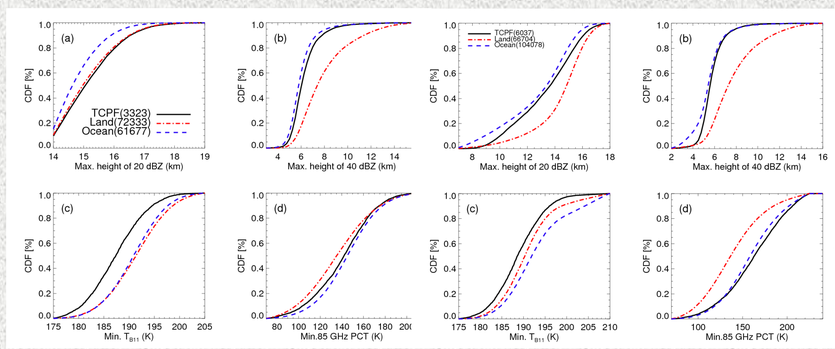
The Precipitating ice mass for each pixel:

$$M_{ice} = 1000\pi(\rho_{ice})N_0^{\frac{3}{7}}(5.28 \times \frac{10^{-18}}{720Z_{ice}})^{4/7} \times UnitVolume$$

* Statistically significant at the 99% level

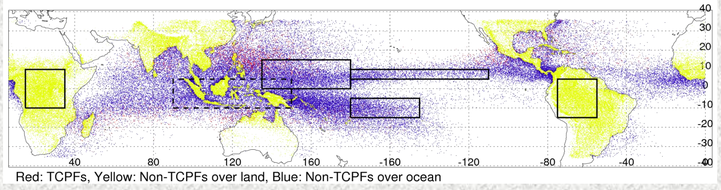
Convective Intensity Proxies

Max. Z_{20dBZ} ≥ 14 km | **Min. $T_{IR} \le T_{trop}$**



* Statistically significant at the 99% level

Location of Overshooting Non-TCPFs Defined with 14km

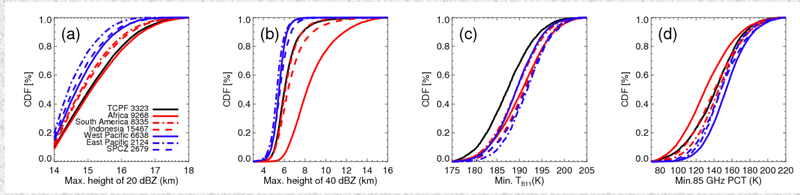


Red: TCPFs, Yellow: Non-TCPFs over land, Blue: Non-TCPFs over ocean

- Selected regions with frequent high clouds: Africa, Indonesia (dashed line box), West Pacific Ocean, East Pacific Ocean, SPCZ, and South America

Convective Intensity for OTCPFs and Overshootings in Selected Regions

Max. Z_{20dBZ} ≥ 14 km



Summary and Conclusions

- TCs contribute only 2.05% to total Precipitation Features (PFs), but account for about 2.42% of PFs penetrating 14 km and 3.41% of those with IR brightness temperature lower than the temperature of tropopause.
- The global distribution of number density of overshooting Precipitation Features (OPFs) defined with 14km is similar to that defined with IR brightness temperature.
- Although the majority of OPFs are contributed by Non-TCPFs, TCPFs do contribute a disproportionate amount of overshooting convection in some particulate areas: south Indian Ocean between 15ºS and 20ºS and south of Baja California between 15ºN and 25ºN.
- Distribution of OTCPFs is similar to the global distribution of TCPFs, and TC rainfall, i.e., higher concentration in northwest Pacific *(Jiang et al. 2009)*
- The fraction of overshootings contributed by TCs increases with Max. height of 20 dBZ and the differences between IR and tropopause temperature.
- OTCPFs have the greatest overshooting properties compared with non-TCPFs over land and over ocean.
- The Max. height of 20 dBZ is greatest for OTCPFs defined with 14km, while for non-TCPFs over land when using IR brightness temperature.
- OTCPFs appear to produce colder/taller cloud tops when compared with selected regions.

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