Tropical Oceanic Cold Pools in a High-Resolution DYAMOND-ICON Simulation and Satellite Scatterometers

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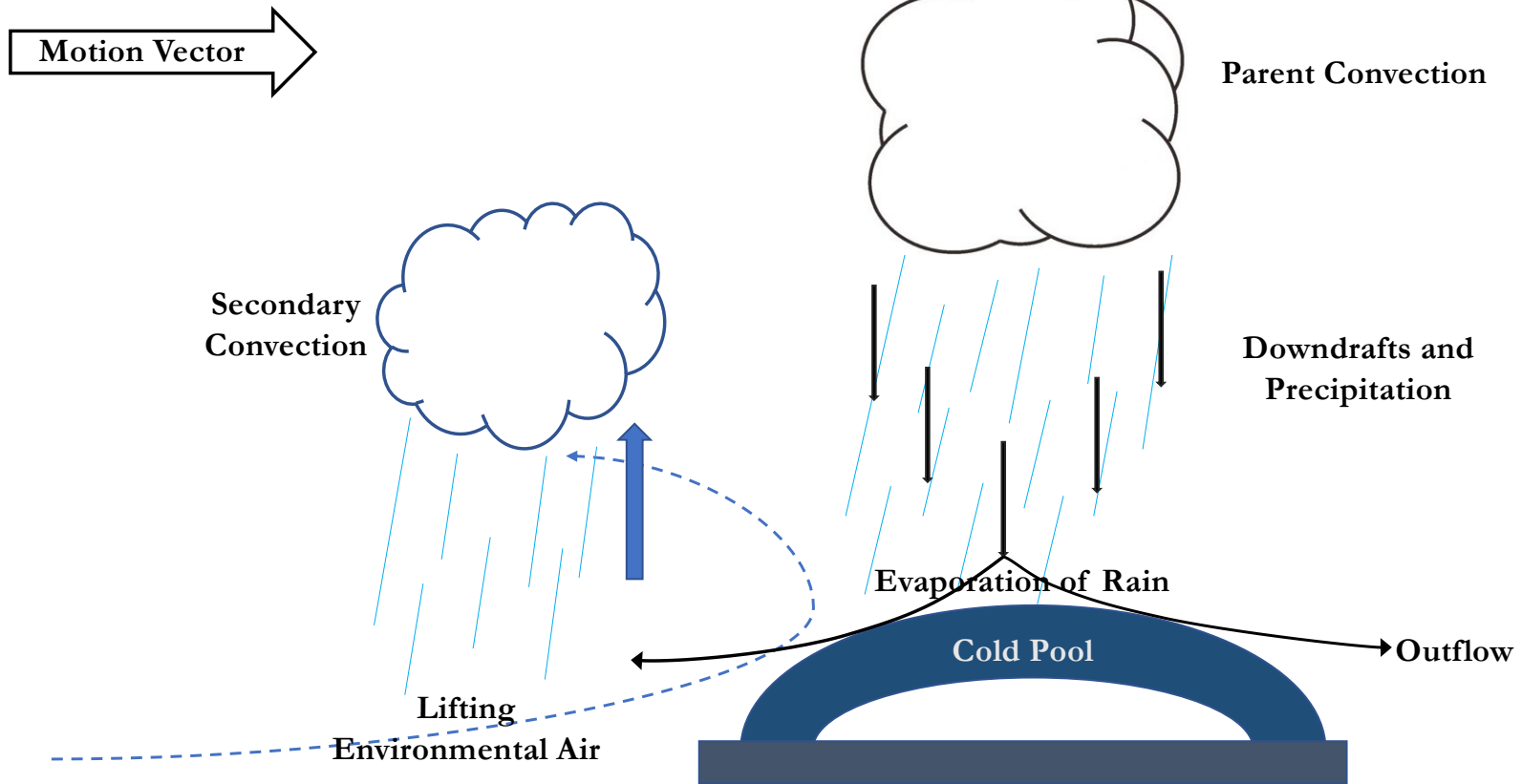
Structure of the Presentation

Review of Gradient Feature Algorithm

ICON-Scatterometer Cold Pool Comparison
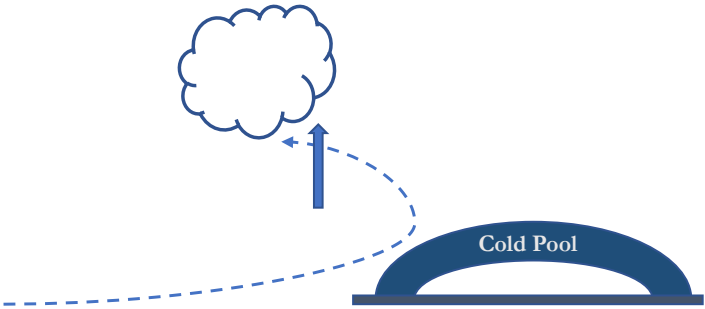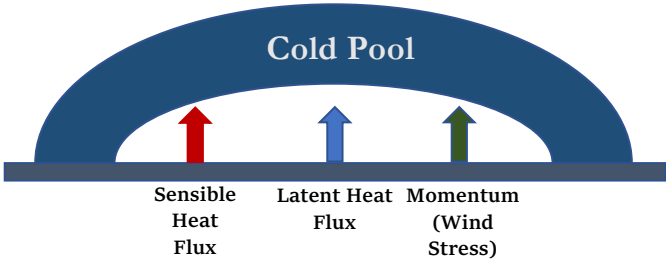
**Cold Pool-Environment Relationship using RF**

What are Cold Pools?

Motion Vector

Parent Convection

Secondary Convection

Downdrafts and Precipitation

Evaporation of Rain

Cold Pool

Outflow

Lifting Environmental Air

Why to better understand Cold Pools?

Cold Pools Modulate Surface-Atmosphere Interactions

Cold Pool

Sensible Heat Flux

Latent Heat Flux

Momentum (Wind Stress)

Cold Pools are sub-grid scale processes and thus can alter model precipitation bias
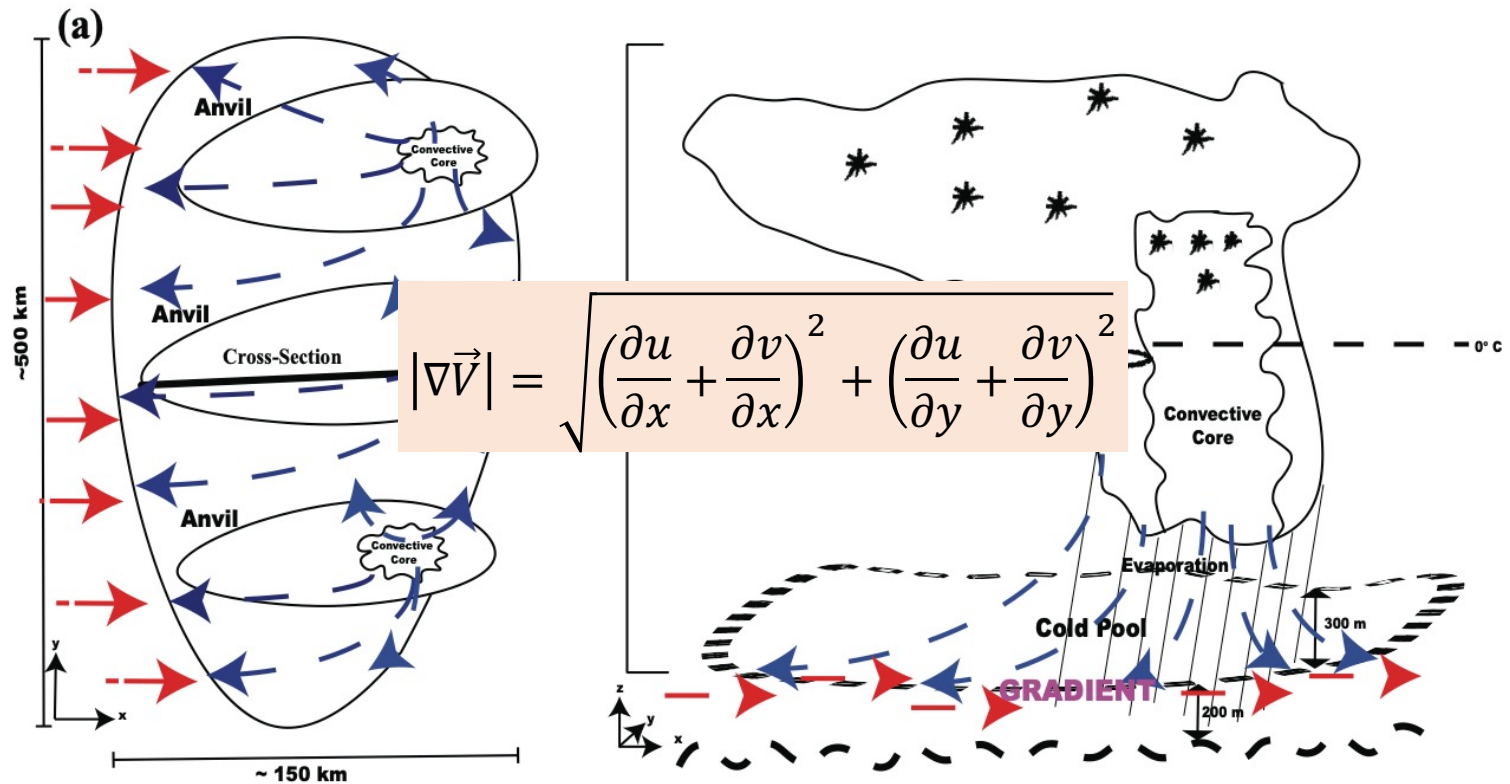
Cold Pool

Climate Model Gridbox

Cold Pool

Cold Pools Help Initiate and Sustain Secondary Convection (e.g., MCSs, precipitation extremes and cyclones)
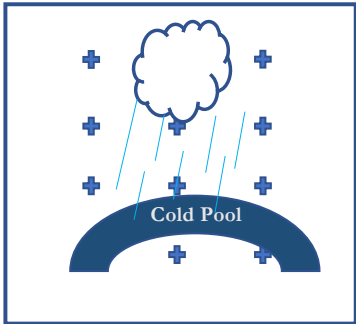
Hypothesis behind Cold Pool Identification

$$|\nabla \vec{V}| = \sqrt{\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial x}\right)^2 + \left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial y}\right)^2}$$
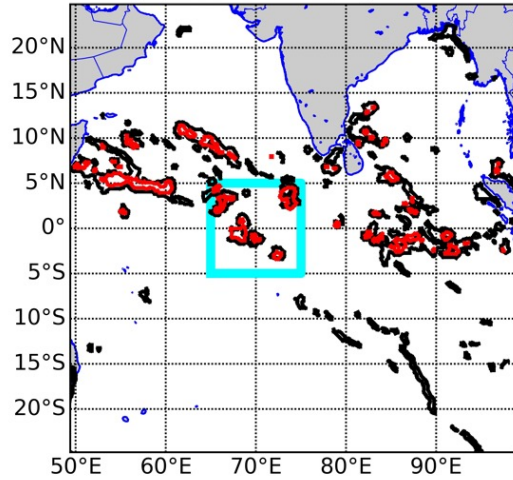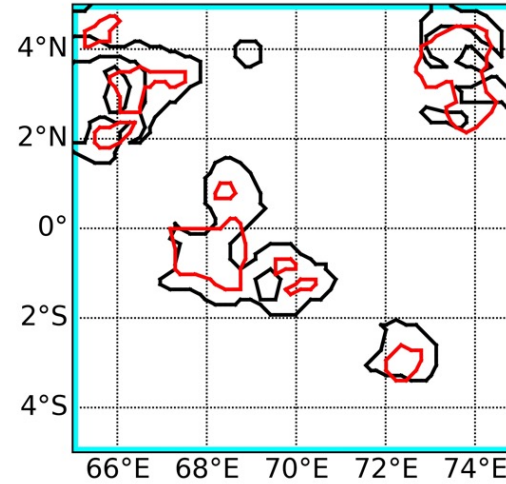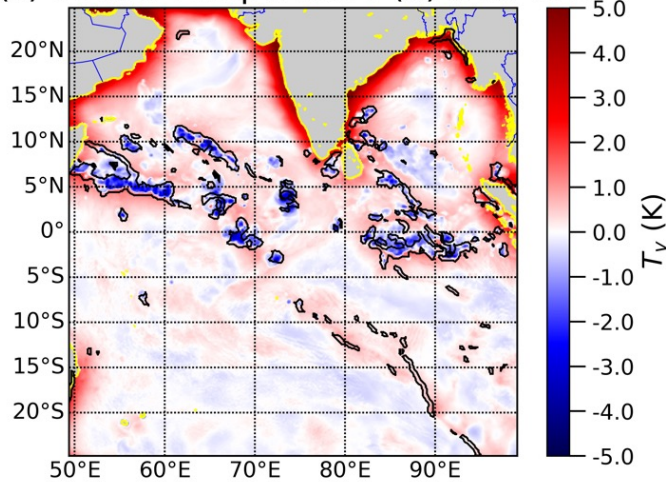
Garg et al. (2020)
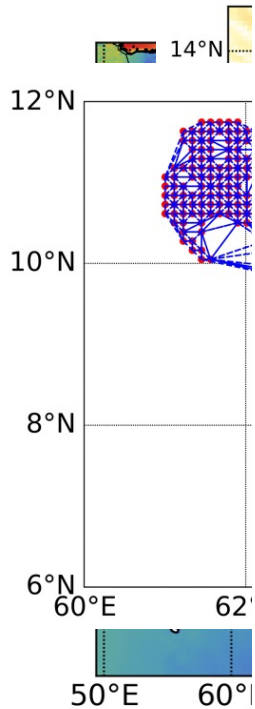
(a) GF - Black, T_v - Red
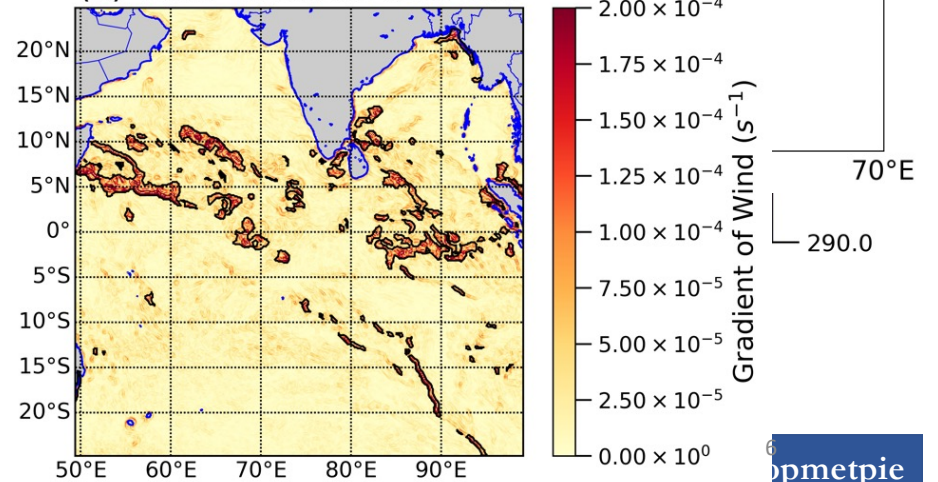
(b) GF - Black, T_v - Red

(c) Virtual Temperature (K) with GFs

(d) Wind Gradient with GFs

ASCAT-Identified GFs
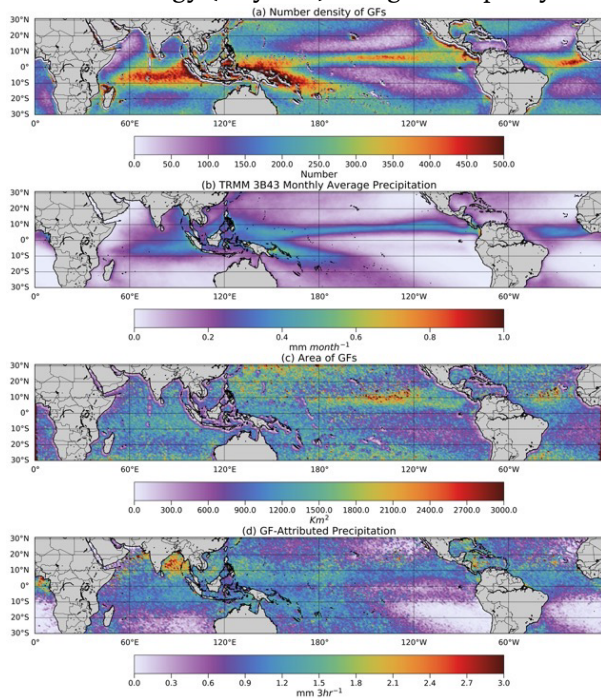

(a) Gradient of Wind (s^{-1}) 5 m/s

(b) Divergence of Wind (s^{-1})

(c) Horizontal Vorticity (s^{-1})

(d) IMERG Precipitation ($mm(30min)^{-1}$)

(e) GOES-16 Enhanced IR with ASCAT GFs (cyan)
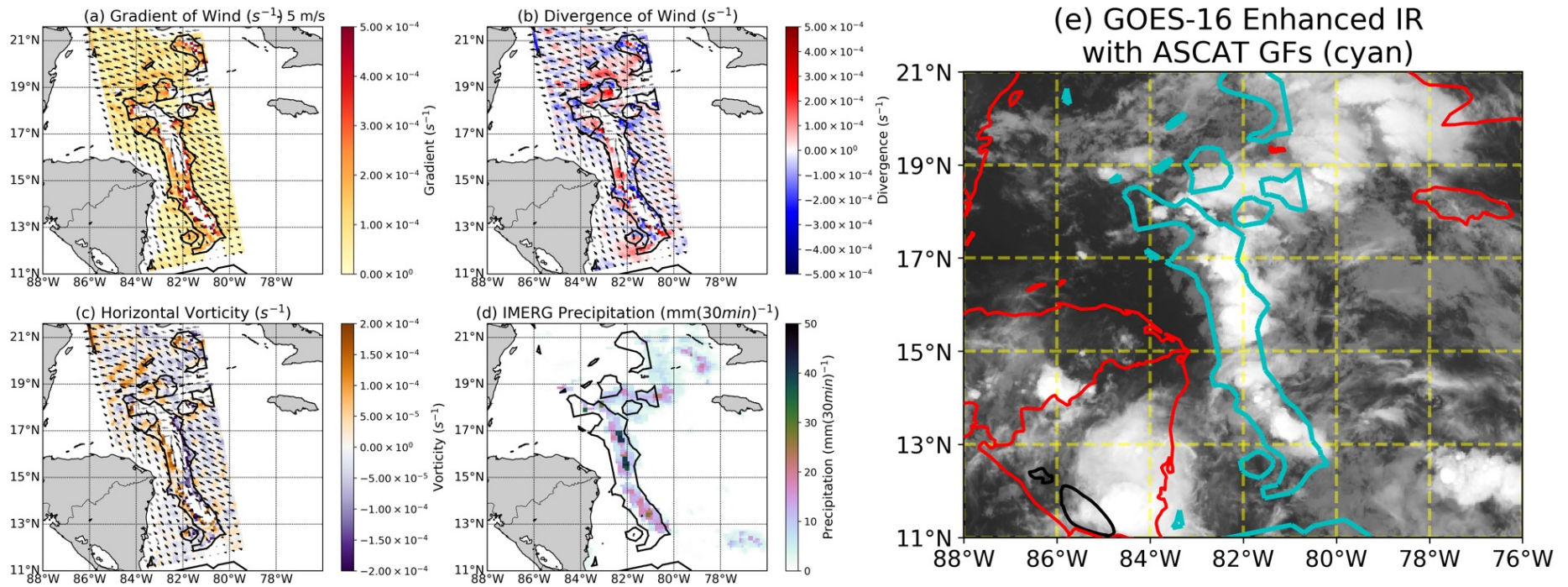
Scatterometer-Observed Gradient Features

First-ever global tropical oceanic cold pool climatology (12 years) using GF as proxy

Garg et al. (2020) JGR-Atmospheres

Diurnal Cycle of tropical oceanic cold pools was derived using RapidScat (2-years) derived GFs for the first time

Garg et al. (2021) Journal of Climate

Science Questions

How are the cold pool-attributed environmental properties across global tropics?

How do CRM-Simulated Cold Pool Properties Compare with observed GFs?

Can we statistically identify environmental features important for cold pool activity?
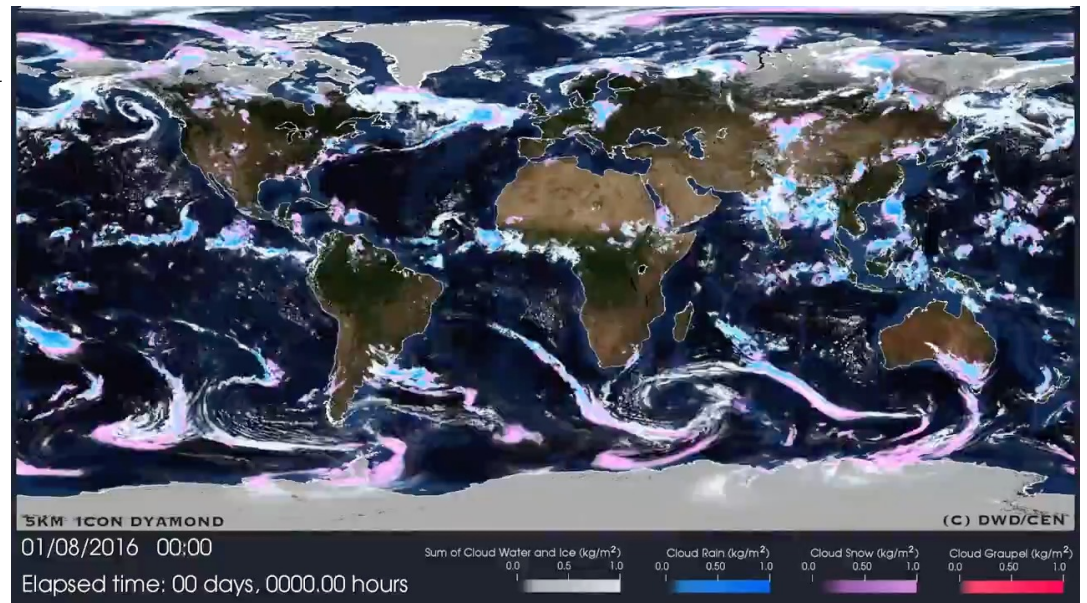
DYAMOND Project

- The **DY**namics of the **A**tmospheric general circulation **M**odeled **O**n **N**on-hydrostatic **D**omains or DYAMOND.

- Nine models simulated global atmospheric state for 40-days (1 Aug – 10 Sep 2016) at storm-resolving resolutions less than 5km without a cumulus scheme.

- These models were able to simulate atmospheric general circulation close to observations with certain biases.
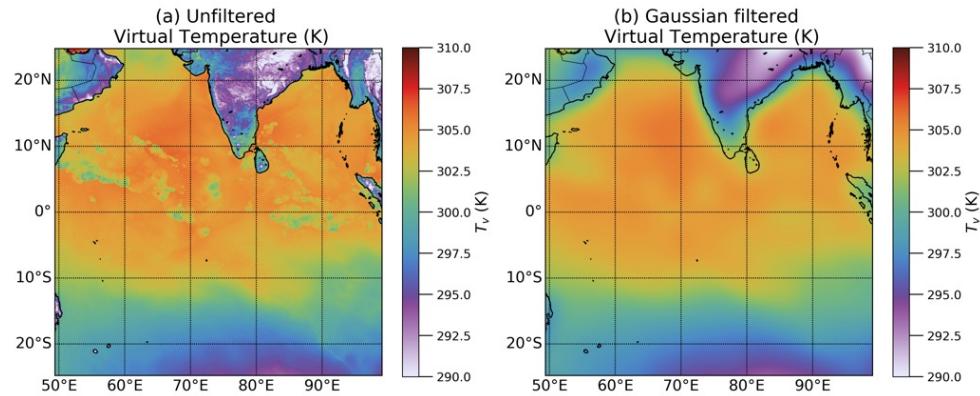

Courtesy: Stevens et al., 2019
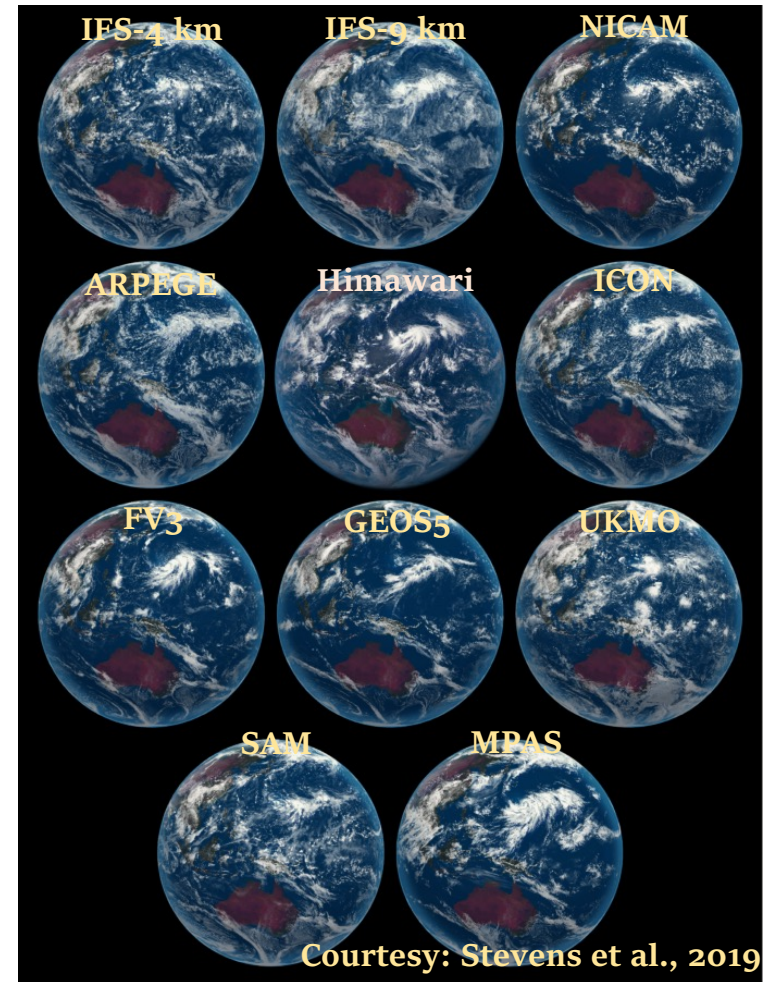
ICOsahedral Nonhydrostatic (ICON) Model
01 August – 10 September 2016
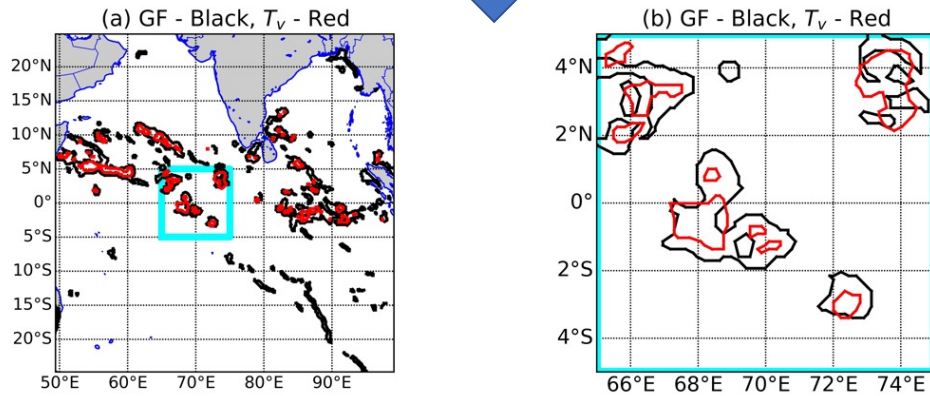
- 2.5 km global icosahedral grid

- 90 vertical levels

- Bulk microphysics scheme

- T_v anomaly ($\leq$-1.5K)
  to identify Cold Pools

5KM ICON DYAMOND
01/08/2016 00:00
Elapsed time: 00 days, 0000.00 hours
Sum of Cloud Water and Ice (kg/m²) 0.0 0.5 1.0
Cloud Rain (kg/m²) 0.0 0.50 1.0
Cloud Snow (kg/m²) 0.0 0.50 1.0
Cloud Graupel (kg/m²) 0.0 0.50 1.0
(C) DWD/CEN

Courtesy: DWD/CEN

(a) Unfiltered
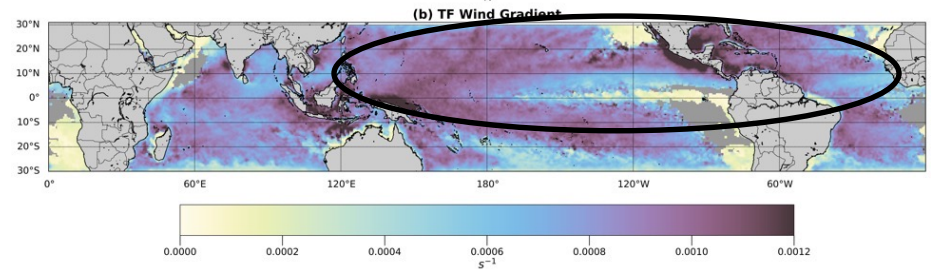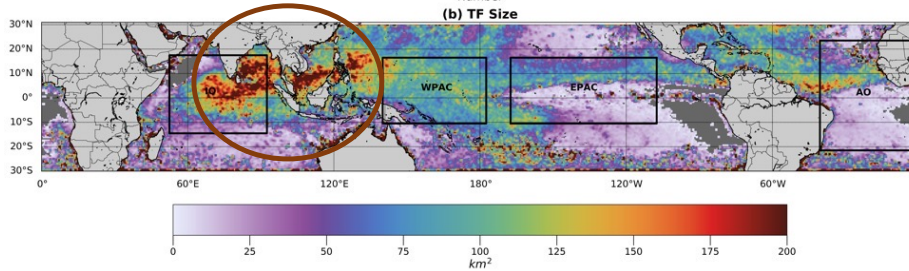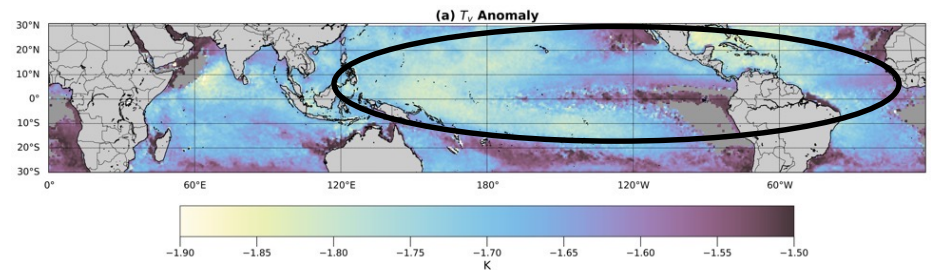Virtual Temperature (K)

(b) Gaussian filtered
Virtual Temperature (K)
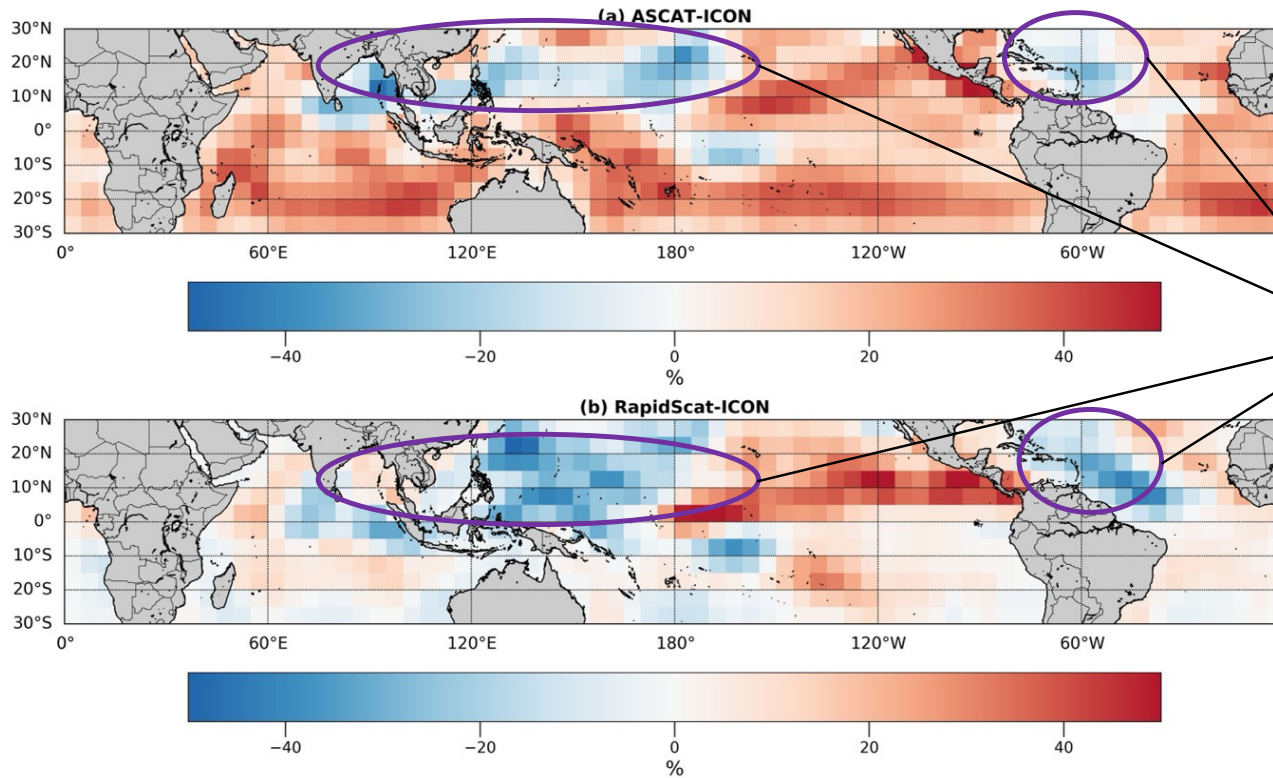
Gradient Feature/Temperature Feature
Algorithm (Garg et al., 2020)

(a) GF - Black, T_v - Red

(b) GF - Black, T_v - Red
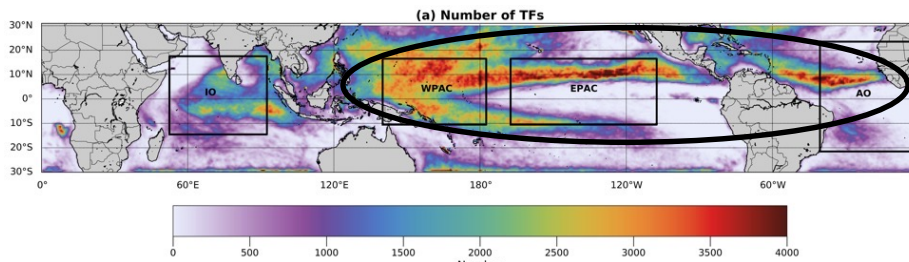
ICON-Observed TFs

# Percentage difference in ICON TF and ASCAT/RapidScat GF Frequency

ICON observed relatively more number of cold pools than ASCAT and RapidScat with RapidScat showing relatively less difference than ASCAT

How do CRM-Simulated Cold Pool Properties Compare with observed GFs?

Diurnal Cycle of Cold Pools and IMERG Precipitation

IMERG Precipitation only depict dominant morning peak
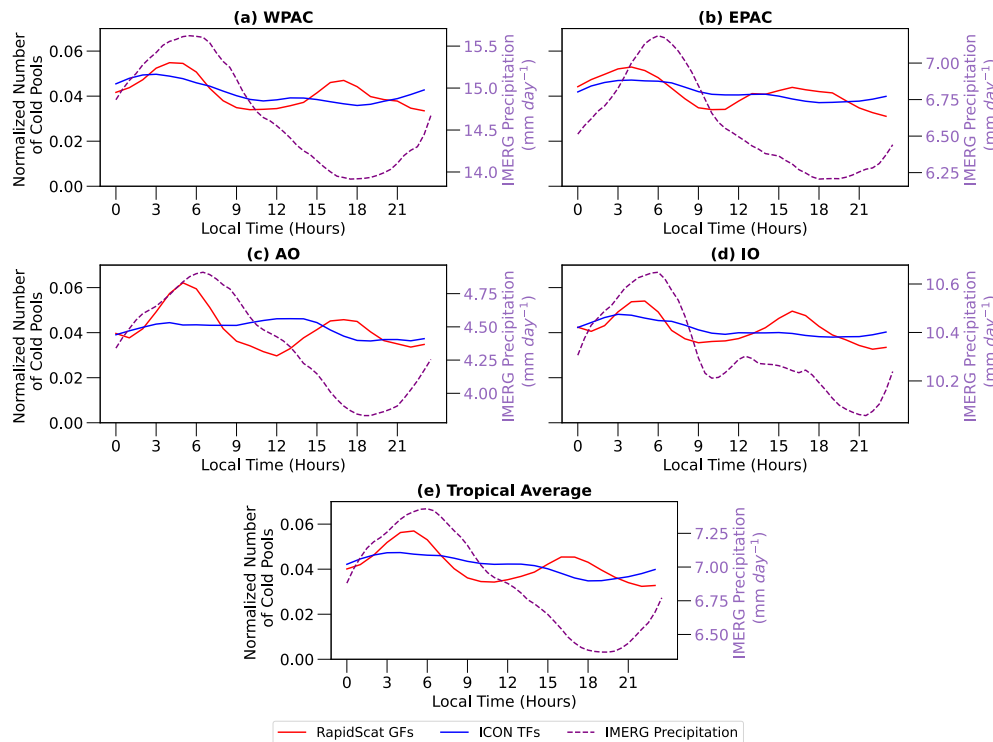
RapidScat GFs show dominant nocturnal and secondary afternoon peak

ICON TFs show dominant nocturnal but no secondary afternoon peak

Can we statistically identify environmental features important for cold pool activity?

Random Forest Regression

Randomized Search Cross-Validation

- Ran RF on a random combination of hyperparameter space

Grid Search Cross-Validation

- Once a hyperparameter configuration with low RMSE is achieved, a narrow combination was given to RF.

Hyperparameter space with high R^2 score and low RMSE

- N_estimators = 400
- Min_Samples_Split = 2
- Min_Samples_Leaf = 1
- Max_Features = 3
- Max_Depth = 80
- Bootstrap = False

Can we statistically identify environmental features important for cold pool activity?

(a) Number of TFs

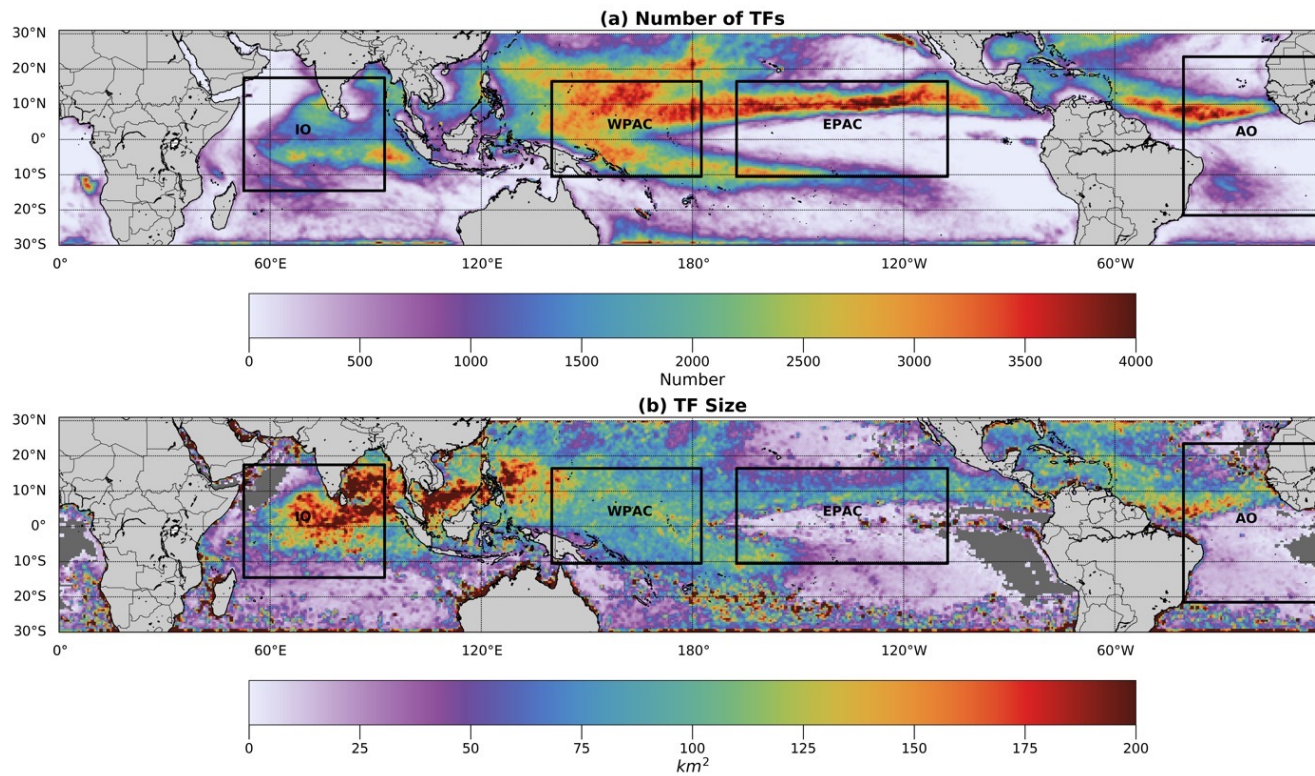**(b) TF Size**

(c) T_v Anomaly
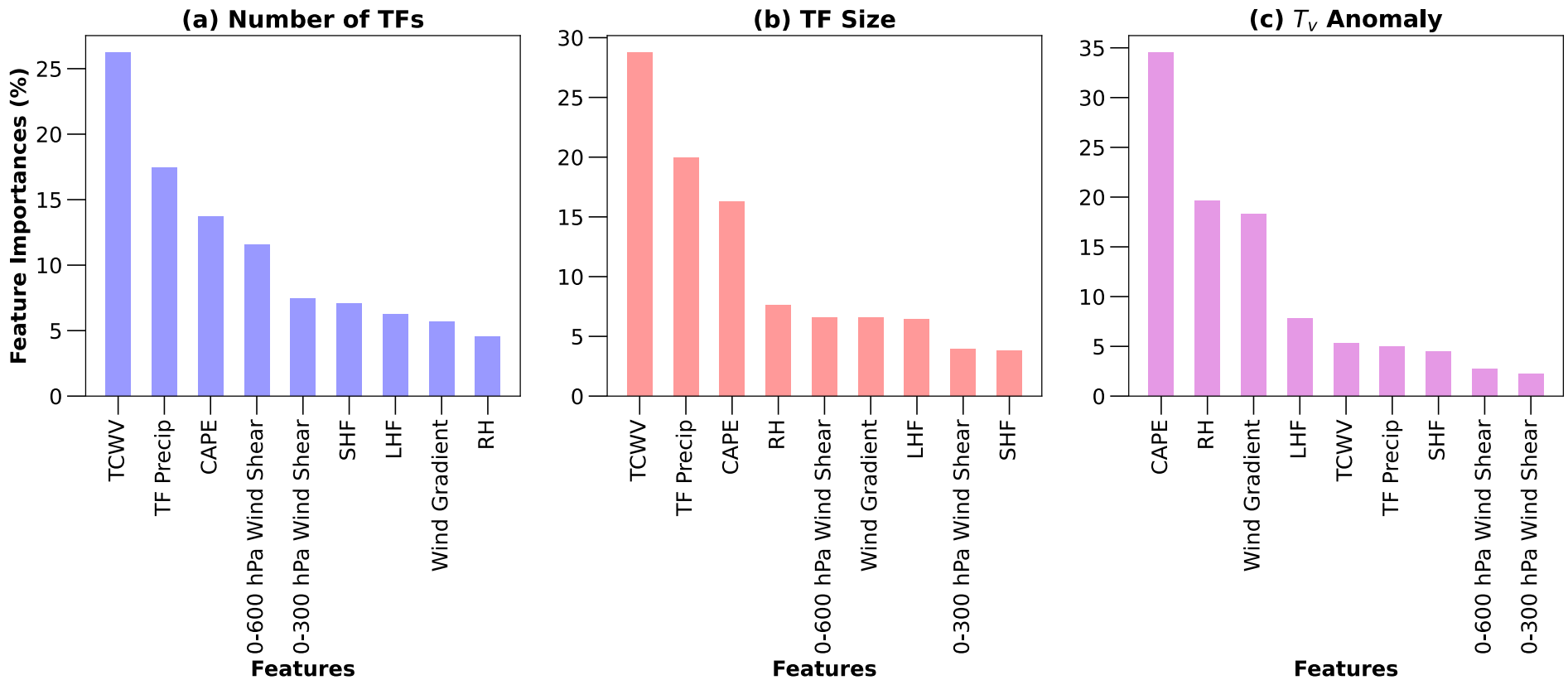
Can we statistically identify environmental features important for cold pool activity?
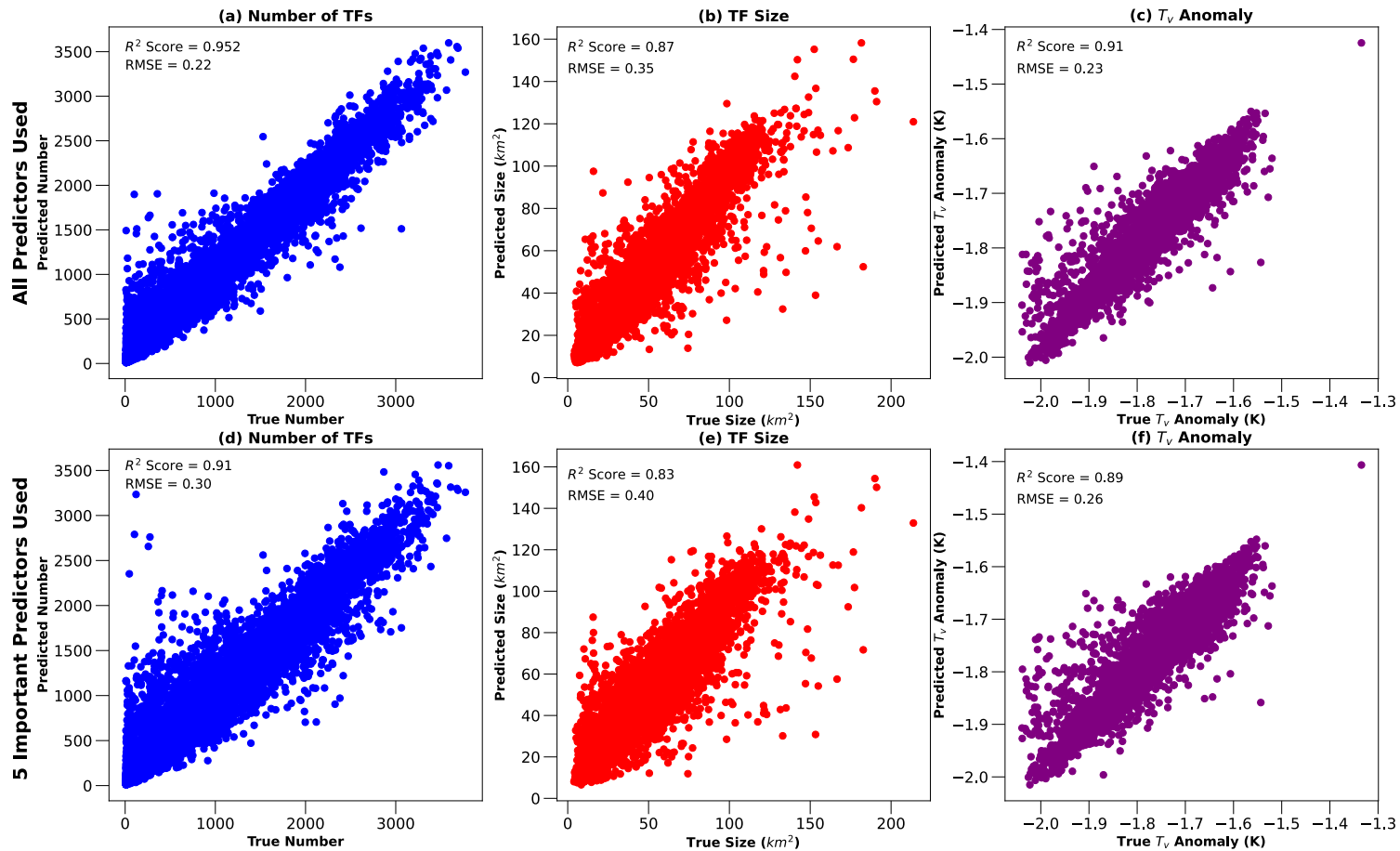
Summary

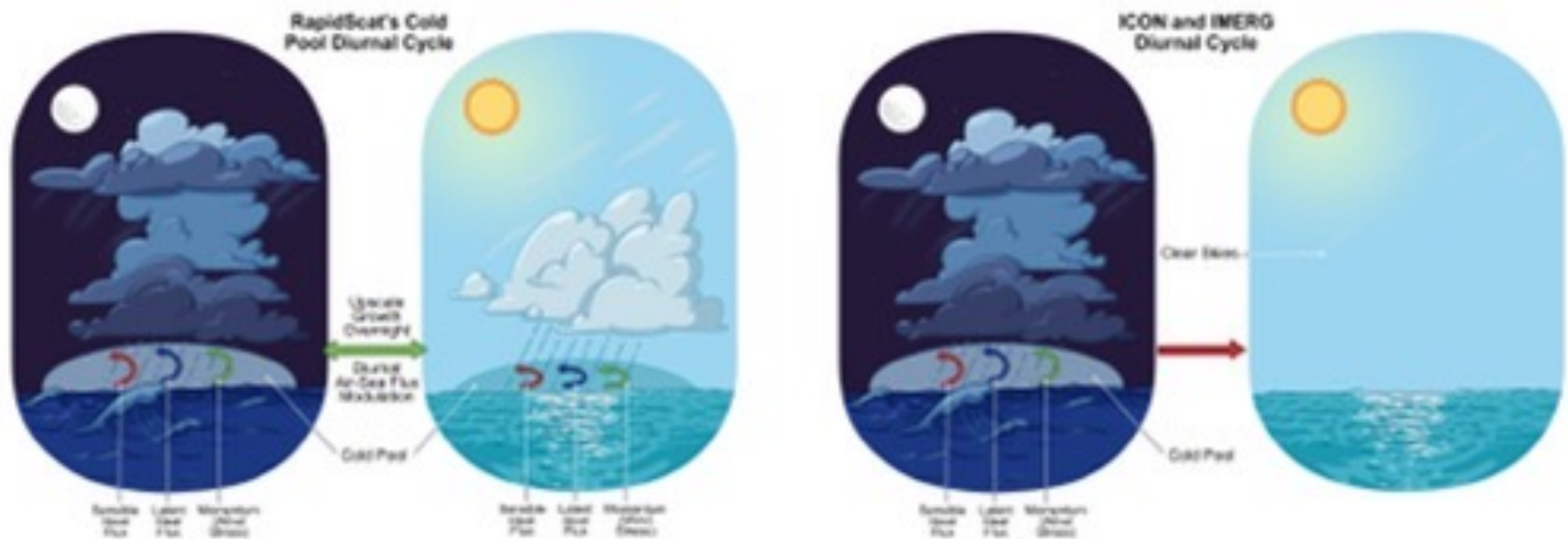ICON-Simulated Cold pools depict realistic depiction over the global tropical oceans

(a) Number of TFs

(b) TF Size

Summary

ICON-Simulated Cold pools depict similar nocturnal peak as RapidScat-Observed GFs but miss the afternoon peak related to congestus cluster type of convection

Summary

ICON-Simulated Cold pool properties have strong controls through TCWV, Precipitation, CAPE, wind shear and RH

(a) Number of TFs (b) TF Size (c) T_v Anomaly