Jet Propulsion Laboratory
California Institute of Technology

Multi-sensor Worldwide Ocean Winds (MWOW): Enabling Diurnal Variability Studies, Advancing NASA PBL Investigations, and Supporting Synergistic Product Development with INCUS

Svetla Hristova-Veleva, *Bryan Stiles, Federica Polverari, Alex Fore, Alex Wineteer, Hector Torres*
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with special thanks to
Ad Stoffelen and Anton Verhoef,
Koninklijk Nederlands Meteorologisch Instituut,
for providing NRT ASCAT-B/C and HY-2B/C winds

MWOW is an NSITE (**N**ASA's **S**NWG **I**mplementation **Te**am) **project**

SNWG 2022-05

Multisensor Worldwide Ocean Winds (MWOW) Product

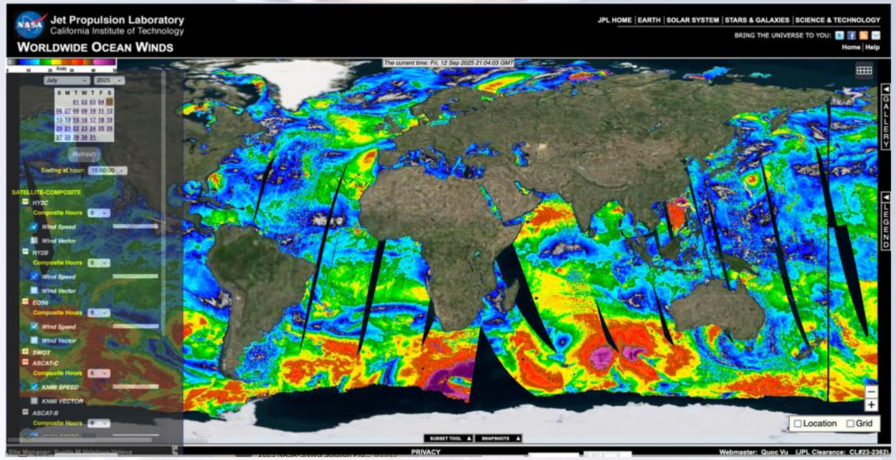
- A new product that will provide **gridded data for wind speed every 6 hours, combining wind retrievals from a variety of different instruments:** scatterometers, SAR instruments, altimeters and passive microwave radiometers. Wind direction will be provided when available (scatterometers, polarimetric radiometers).
  - Scatterometers: ASCAT-B/C, EOS-6, HY-2B, HY-2C,SCA
  - SARs : Sentinel 1, RadarSat 2, RadarSat Constellation Mission(from NOAA; Canadian SARs), NISAR, ALOS 4, commercial SARs, SWOT
  - Radiometers: GMI, AMSR2, AMSR3, SMAP, WFM-6 etc.

Product Utility

- ***analysis-ready data : a single source, a common format , on a common grid;***
- ***greatly increased global coverage and higher temporal resolution***
- ***collocated observations from multiple instruments enabling development of:***
  - ***a unified set of wind estimates with:***
    - ***harmonized retrievals from different instruments with;***
    - ***precise uncertainty estimates;***
    - ***unified quality indicators – user-transparent depiction of instrument-specific uncertainties***
  - ***development of synergistic products;***
  - ***ML/AI-based future improvements;***
- ***wind stress - more directly related to air/sea fluxes than the winds***
- ***derivatives of wind and wind stress - more directly related to: the dynamical forcing of the atmosphere (divergence/convergence of the winds); the ocean forcing (surface stress curl).***
- ***flexibility to add new instruments in the future***

Task manager: Bryan Stiles,
Task Scientist: Svetla Hristova-Veleva

https://wow.jpl.nasa.gov/data-portal



A single 6-hour MWOW Version 0.1 preliminary data global map with observations from 7 instruments including ASCAT-B/C, HY-2B/C, ScatSat3, SMAP and SWOT

Thematic Areas

SNWG 2024: 13 Needs across 4 Agencies	
(red)	Disaster Response
(gray)	Ocean and Cryosphere
(cyan)	Weather and Atmospheric Dynamics

Overview Link

Multisensor Worldwide Ocean Winds Product

MWOW:

Facilitating Science Investigations

Diurnal Variability

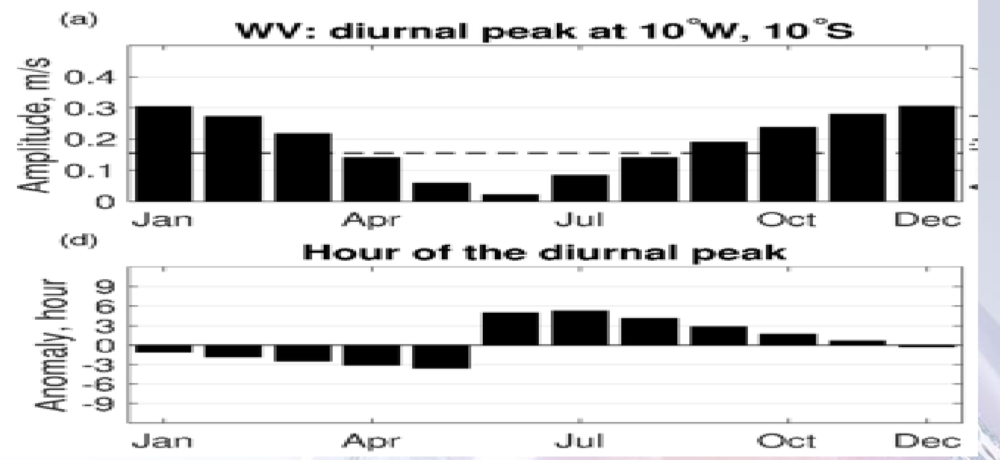
a. Goal: long-term efforts by the IOVWST to provide stable and well-intercalibrated records of the ocean surface winds
b. Motivation: existing difference in operational estimates from different wind missions and different institutions

Main Sources of Uncertainty

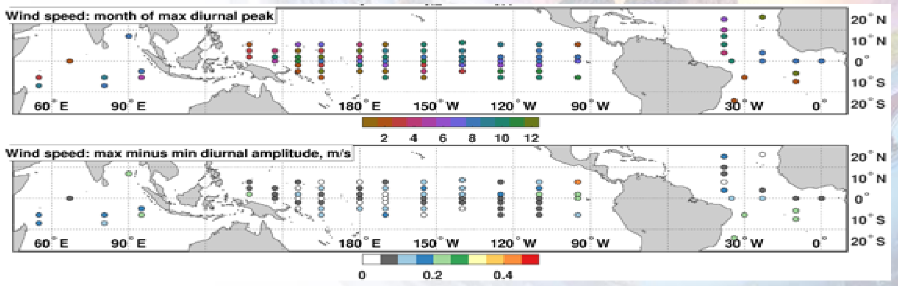
- **Diurnal variability of the winds**
  - **Not well-known magnitude and geographic variability of the diurnal signal, to allow properly isolating its contribution to the differences in the wind estimates from missions observing at different Local Times of Day.**
- **Differences in the observing systems**
  - **Active/passive signals**
  - **instrument frequency, design and geometry**
  - **Retrieval algorithms and assumptions -**

Challenge: Diurnal and seasonal variability of the winds

Donata Giglio, Sarah Gille et al



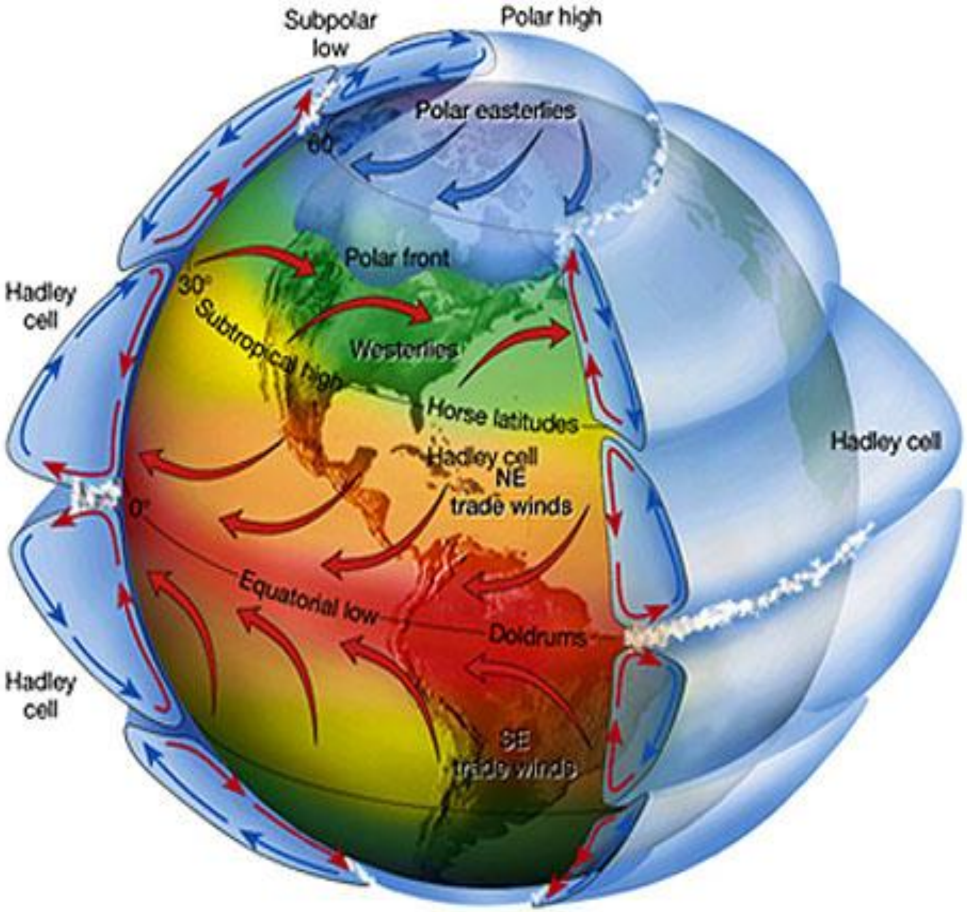
- Strength and timing of diurnal wind cycles vary seasonally.
- Patterns vary geographically.



- **Annual signal can be aliased by sampling (ISS)**
- **Multiple satellites, or well-coordinated orbits are needed to distinguish diurnal signal from other variability**

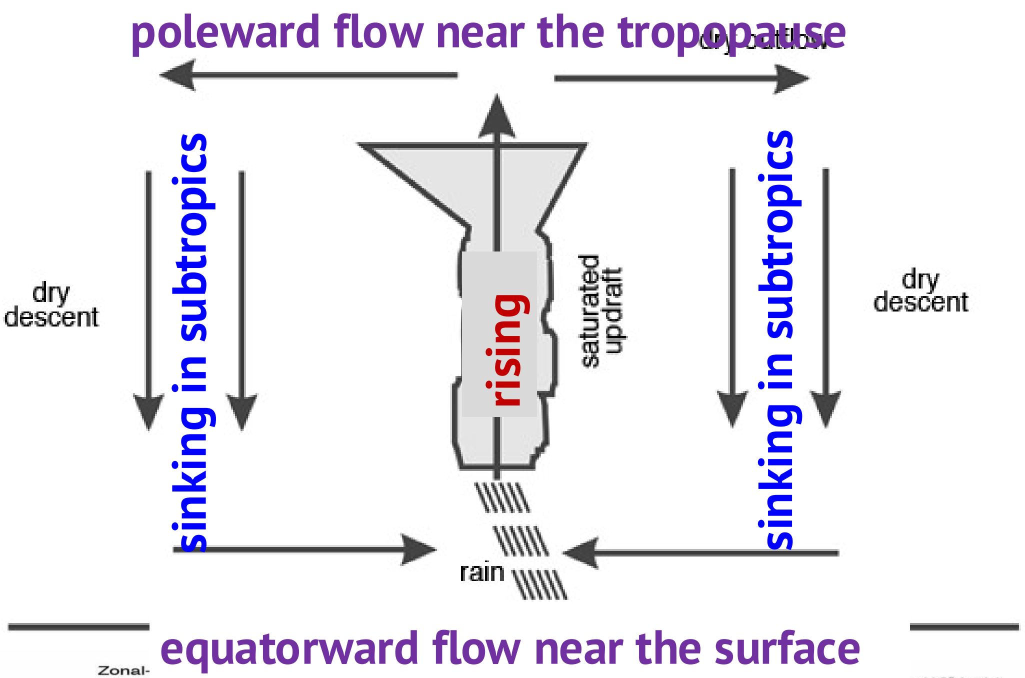
The Global Circulation and the Hadley Cell

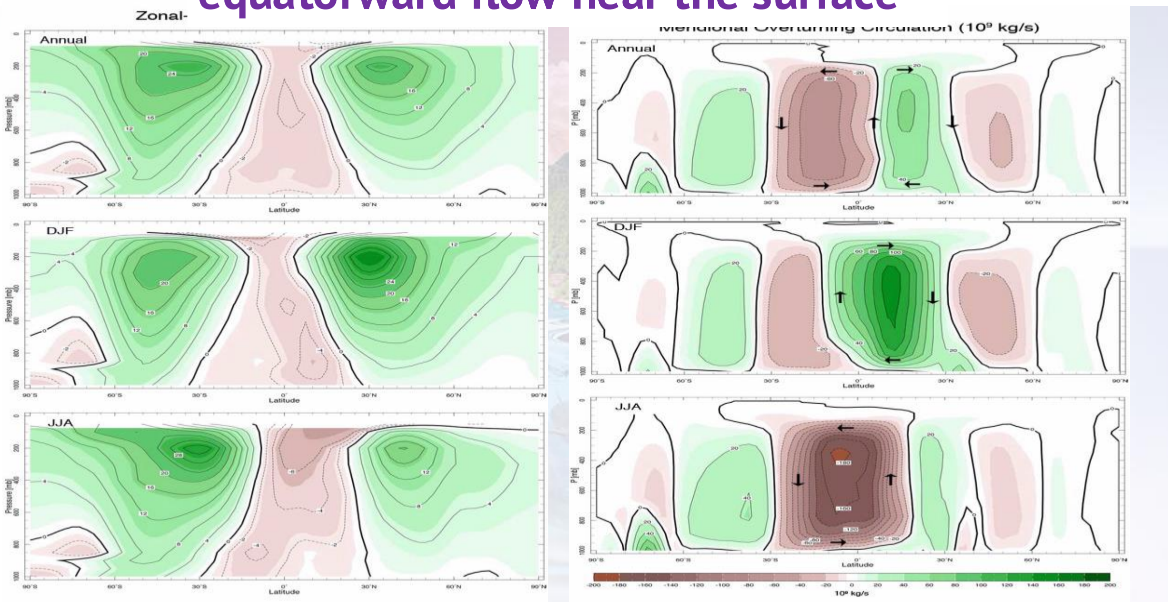
Originally uploaded in EarthLabs:Hurricanes.



- 3D view of the global wind circulation

- Due to unequal heating at the equator and the poles.





The Hadley cell :

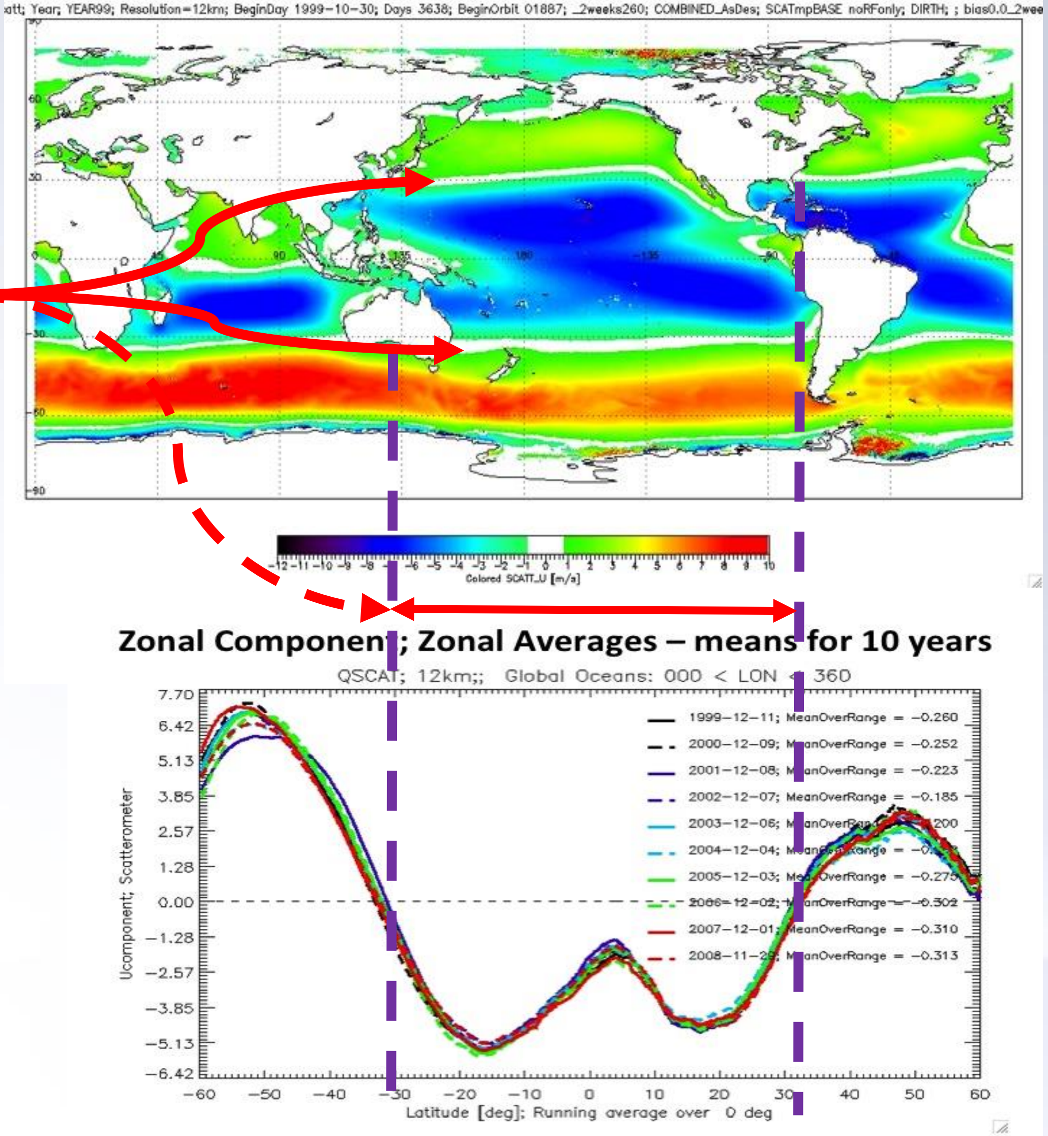
- depicts the equator-to-pole heat exchange
- is a global-scale tropical atmospheric circulation
- impacts the global circulation on a variety of different time scales

Approach: A new way of Haddley cell definition

- **Use QuikSCAT and ASCAT observations.**
  - Compute mean statistics from 1-year time composites .
  - Create a time - series, by offsetting the 1-year averages by 2 weeks

- Determine **extent of the double-Hadley cells**
  - Use as a measure the **width of the double-Hadley cell**
  - **Width defined as the latitudinal separation between the northern and southern subtropical zero-crossing of the zonally-averaged zonal wind component**
    - (the se

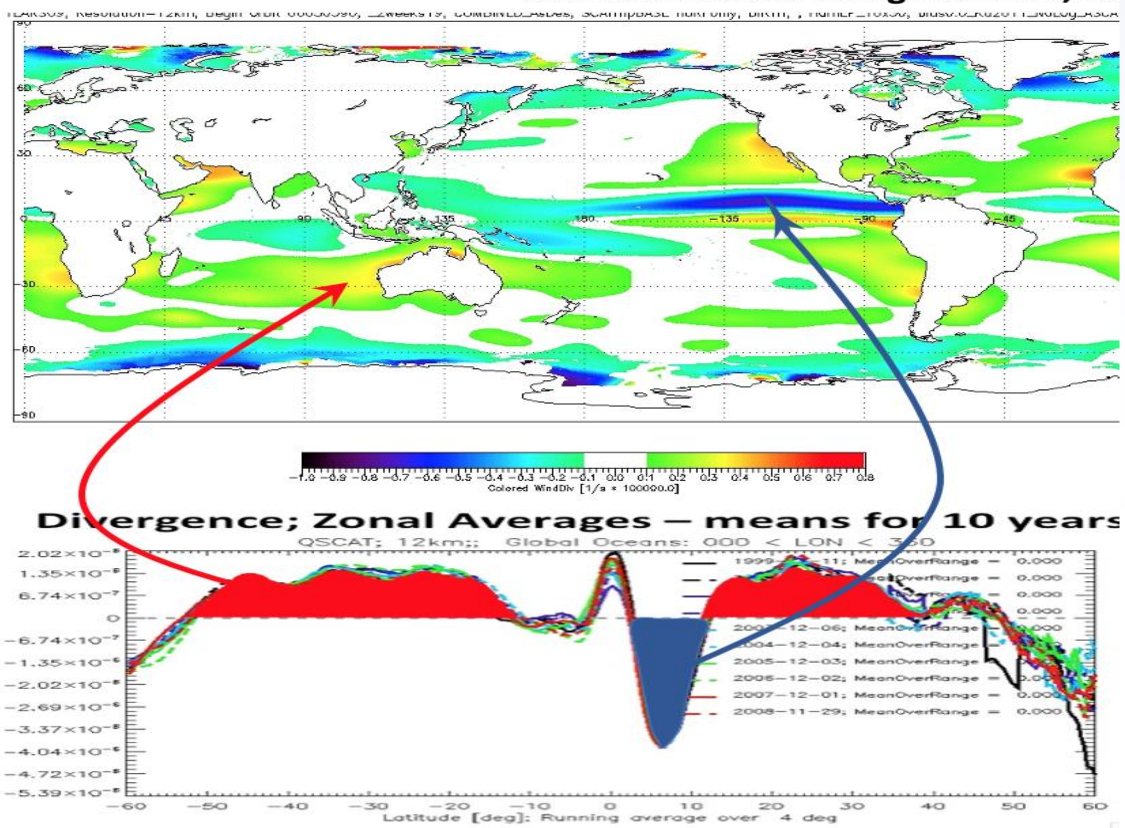
Zonal Component - 10 year mean



- the separation between the midlatitude westerlies and the easterly winds in the tropics.

- Determine **circulation strength** defined by the area and intensity of divergence/conv.

Low Pass filtered Divergence field; 20



Understanding trends/variability: Need of Long-term record

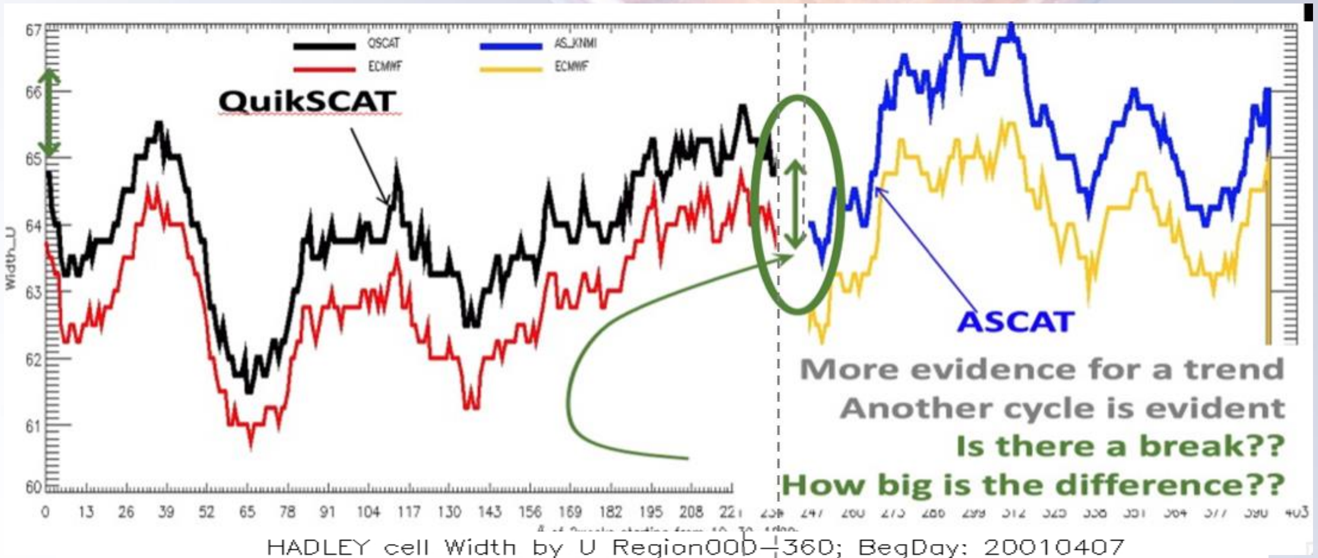
- Performed analysis of the Hadley cell using observations from two observing systems – with very little overlap in time:
- First used:
  - **OSW estimates from QuikSCAT's <u>JPL product</u>: period 2000-2010**
  - **OSW estimates from ASCAT's <u>KNMI product</u>: period 2009-2014 (available in 2015)**

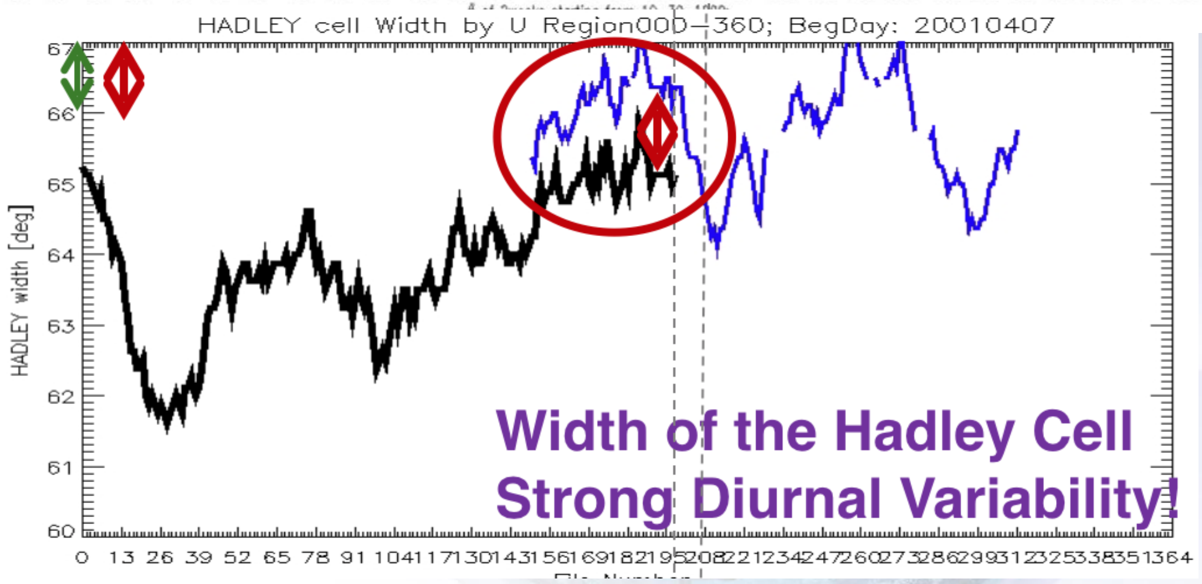
- **New input:**
  - **the MEaSUREs's consistent CDR of the OSW from QuikSCAT and ASCAT**

Results: Did we resolve the discontinuity using the CDR

- **made the "apparent" discontinuity smaller**
- **did not resolve it completely**
  - **diurnal variability ???**
  - **Yes: different LTD observations**
- **Hadley cell is wider during ASCAT times**

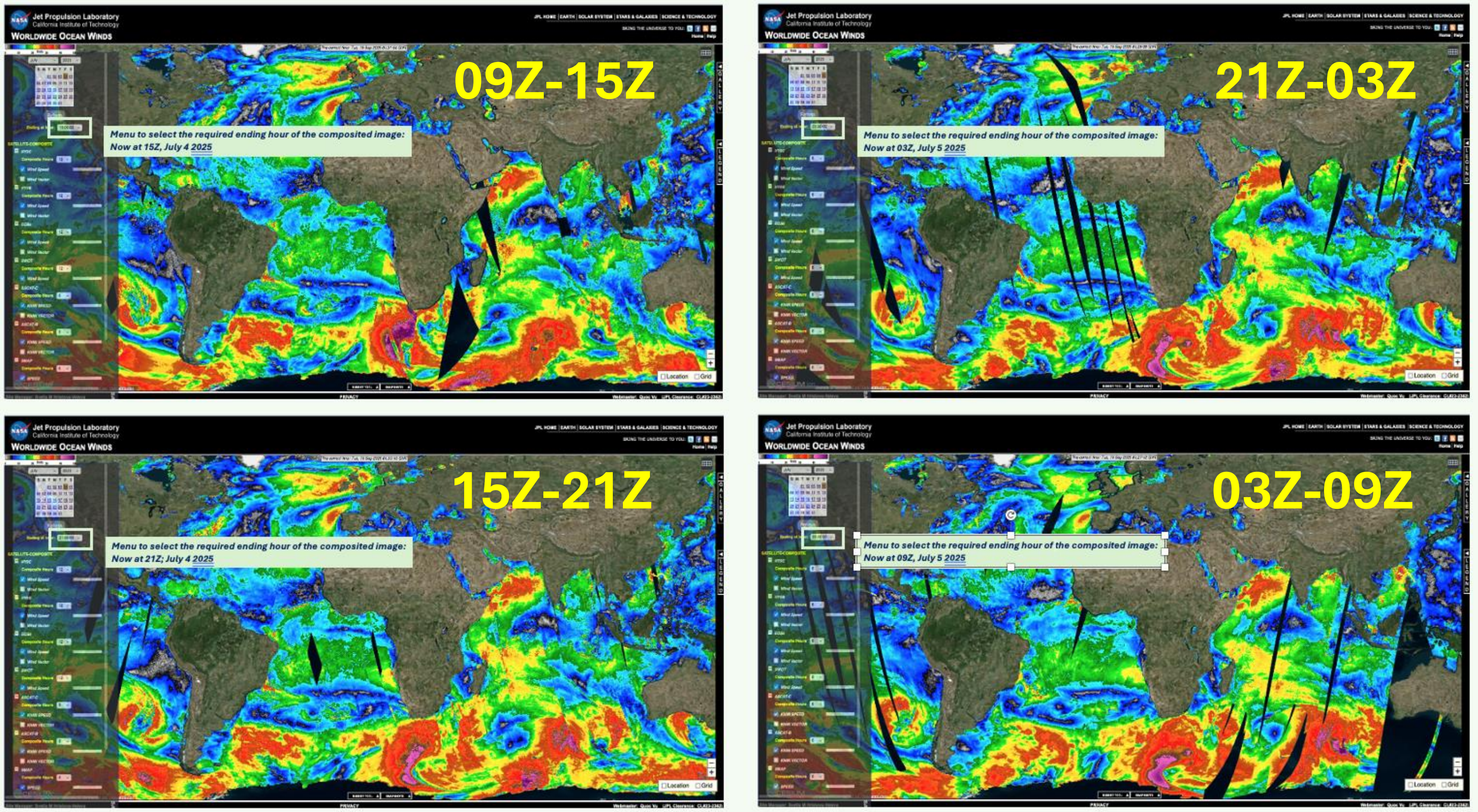
Time-series of the Width of the double Hadley cell - using 1-year running averages, offset by 2 weeks





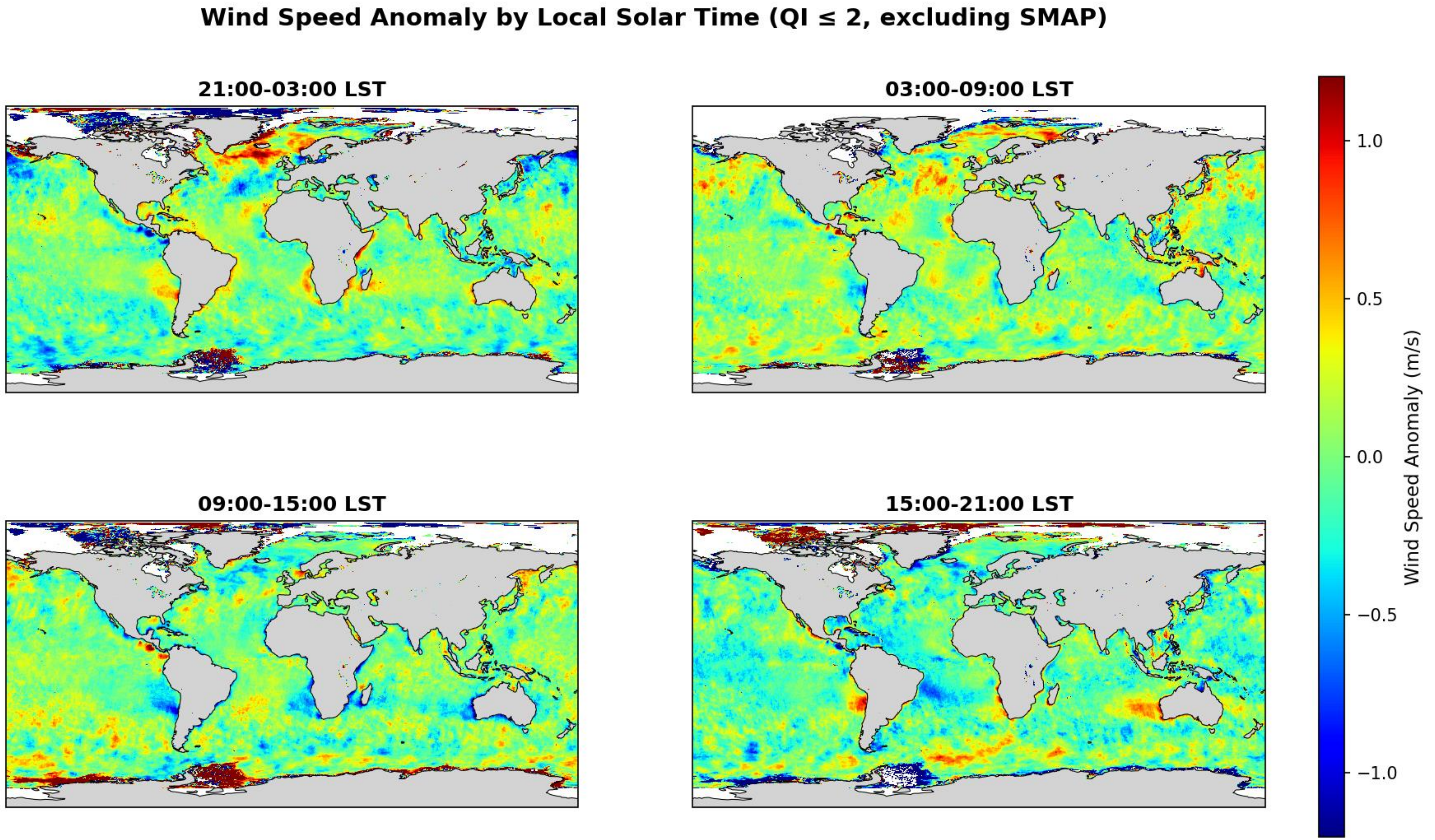
MWOW – a new look at the diurnal signal

Exploring coverage, instrument characters, mission contribution,
Through the interactive portal for visualization - the MWOW portal - https://wow.jpl.nasa.gov/data-portal

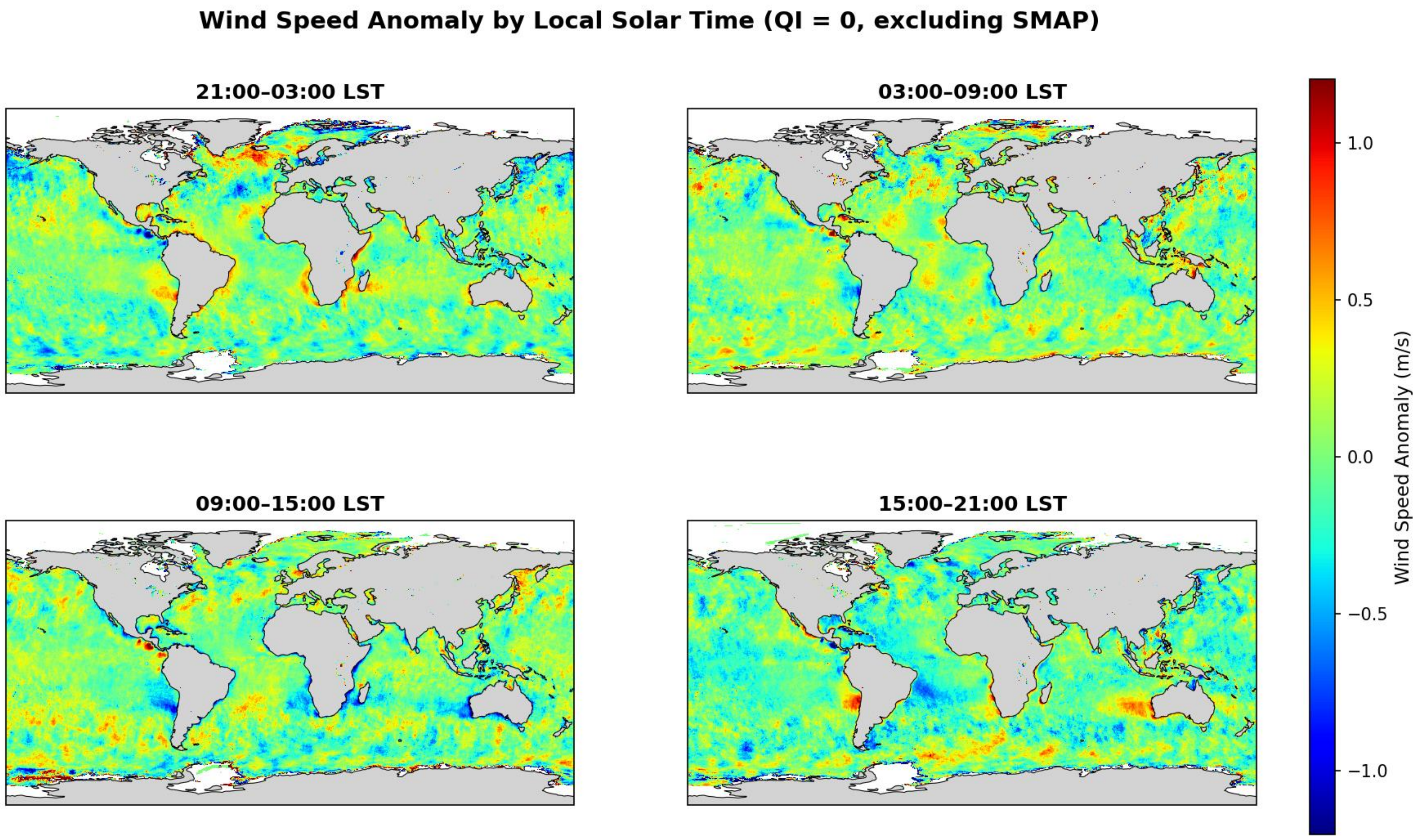


- Diurnal Variability

Diurnal variability: anomalies from the daily mean



Diurnal variability: anomalies from the daily mean



MWOW:

Facilitating Science Investigations

Enhancing PBL Science

The NASA PBL Incubation Study: PBL goals

From the Study team Report

- *A global Planetary Boundary Layer (PBL) observing system is urgently needed to address fundamental PBL science questions and societal applications related to weather, climate and air quality.*

- *This PBL observing system should optimally combine:*
  - *new space-based observations of the PBL thermodynamic structure*
  - *with complementary surface-based and suborbital assets,*
  - *while taking advantage of, and helping improve, modeling and data assimilation systems*

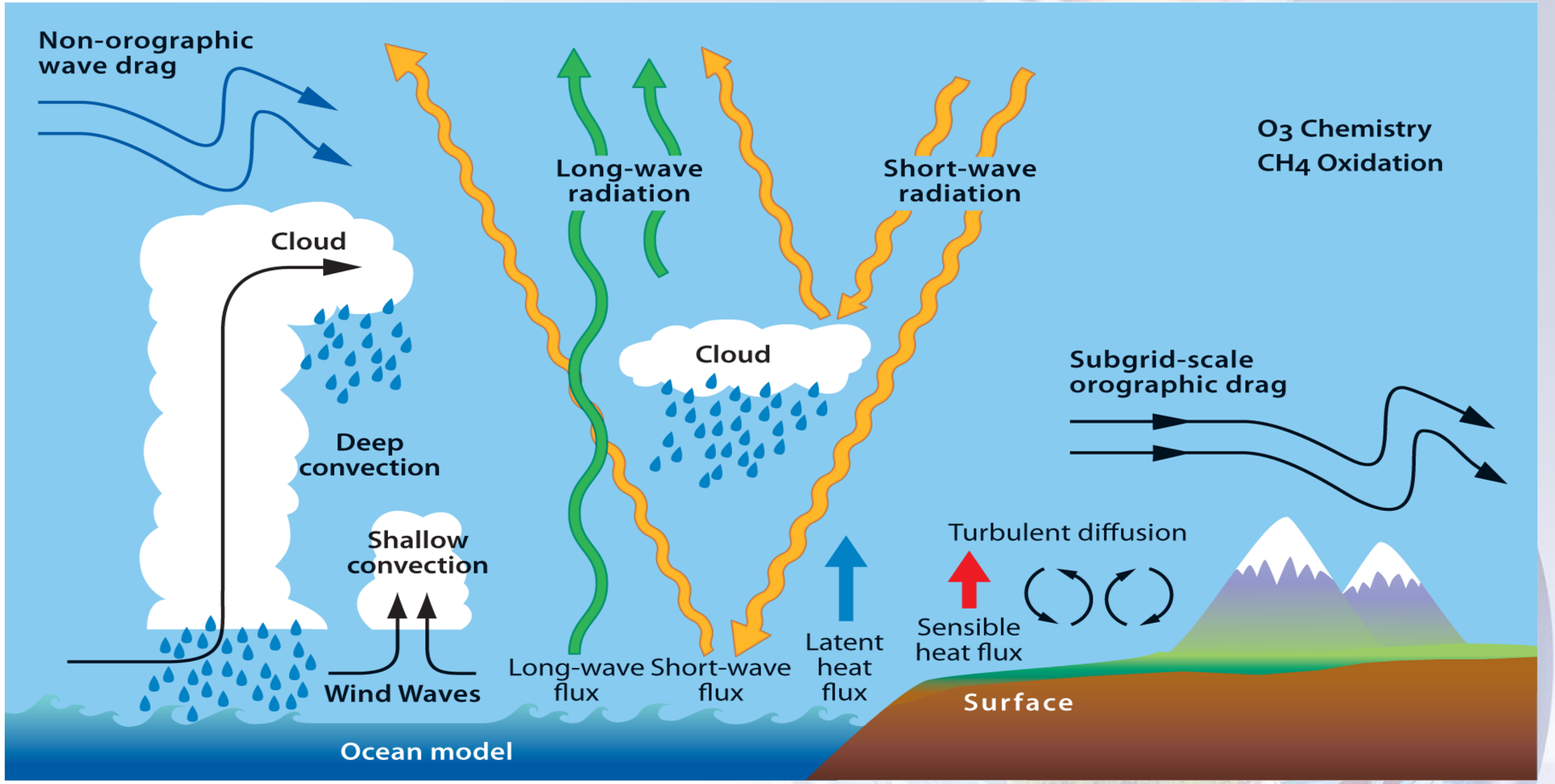
The PBL is of critical importance as it connects the atmosphere to the other components of the Earth system (oceans, land, and ice) and is essential to a number of Earth science priorities

Table 1-1. Summarized SATM highlighting the key PBL science goals and topics.

Overarching PBL Vision	Science Goal	Science Topics (summarized questions)
Globally characterize the thermodynamic structure of the PBL	**G1. PBL, Convection and Extreme Weather**	**Q1.1:** PBL, Convection and Mesoscale **Q1.2:** Shallow and Deep Convection **Q1.3:** PBL, Surface processes and Precipitation
	G2. Cloudy PBL	**Q2.1:** PBL Thermodynamics and Clouds **Q2.2:** PBL Clouds, Surface Fluxes and Free Troposphere **Q2.3:** PBL, Clouds and Mesoscale
	G3. PBL and Surface Interaction	**Q3.1:** PBL Thermodynamics and Surface Fluxes **Q3.2:** Water Vapor Near the Surface **Q3.3:** Surface Heterogeneity, PBL and Convection **Q3.4:** PBL Thermodynamics and Extremes
	G4. PBL Modeling, Mixing and Air Quality	**Q4.1:** PBL Mixing and Transport **Q4.2:** PBL Parameterizations and Models

Ocean Surface Winds (OSW) observations represent a unique measurement at the interface of two fluids, reflecting their interactions, modifying their boundary layers and the vertical circulations in each.

- modulate air–sea exchanges of heat and momentum,
- shaping temperature and humidity variability within the Planetary Boundary Layer (PBL) and
- driving vertical mixing.

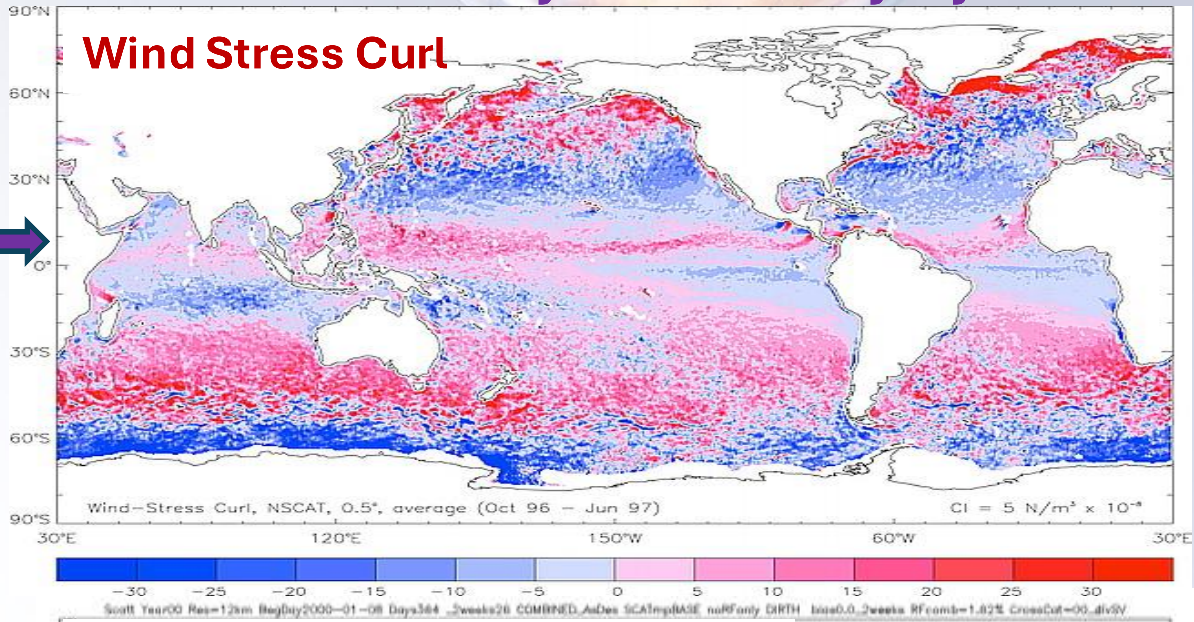


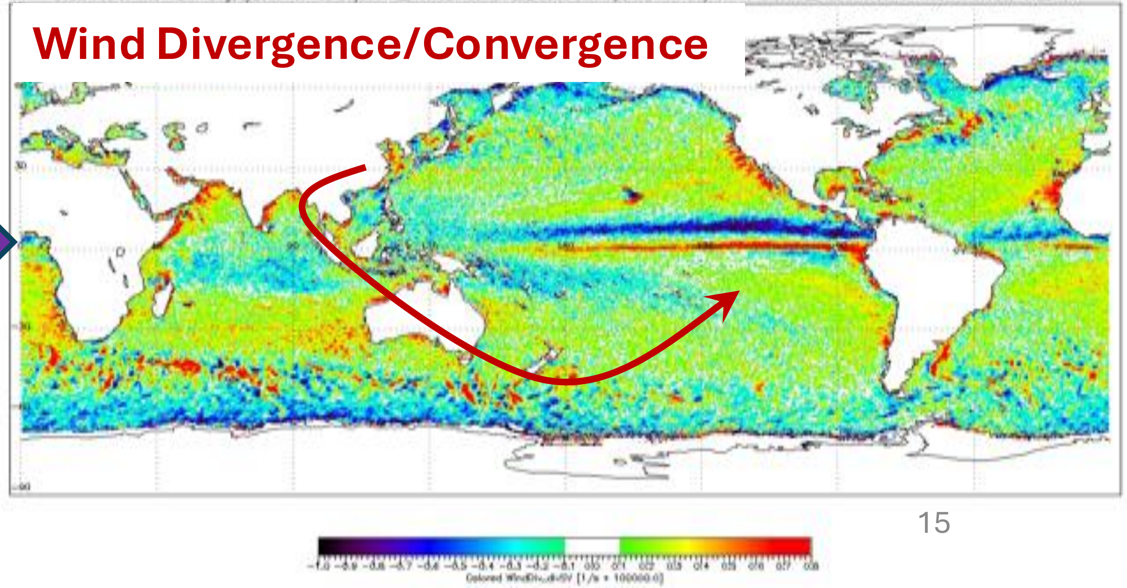
OBSERVING OSW is NOT part of the planned mission

This is where Program of Record (PoR) will contribute

- **Ocean surface winds (OSW) are one of the key components of the Earth system**.
- They represent a **unique measurement at the interface of two fluids – the ocean and the atmosphere**. As such, they reflect the interactions at this interface and **modify the boundary layers in each one of them.**

- **They are a major driver of**
  - **the ocean circulation through the surface stress curl**
  - **affect the air-sea interactions**
    - provide fuel to the weather systems by modulating the sensible and latent heat fluxes.
    - modify the turbulent mixing in the upper levels of the ocean
  - **drive the atmospheric convection by providing dynamical forcing through the convergence of the near-surface winds**
- **Understanding these interactions is critical for improving ocean modeling and weather forecasting on a variety of spatial and temporal scales.**





MWOW:

Facilitating Science Investigations

Understanding Convection

Svetla Hristova-Veleva[1], Z. Haddad[1], B. W. Stiles[1], D. S. Jones[2], G. Liu[2], S. Prasanth[3], B. W. Knosp[1]

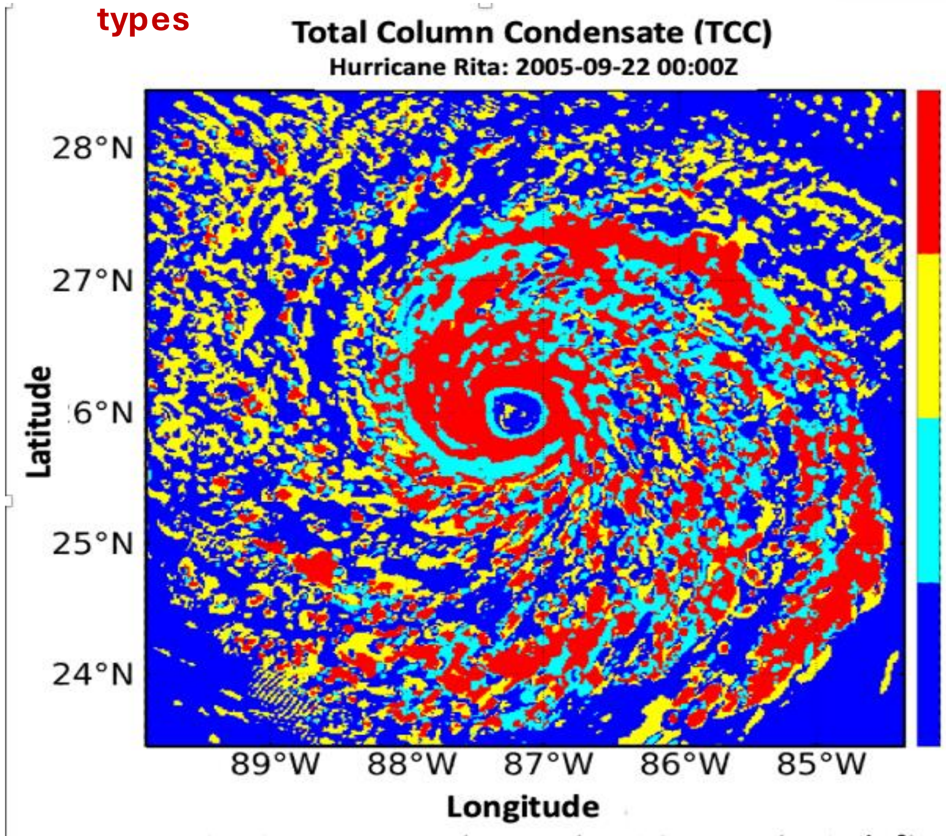
A novel method to quantify the relations between surface convergence and convective vertical transport and identify how they relate to hurricane evolution

Jones et al., 2026 – QJRMS accepted with small revisions

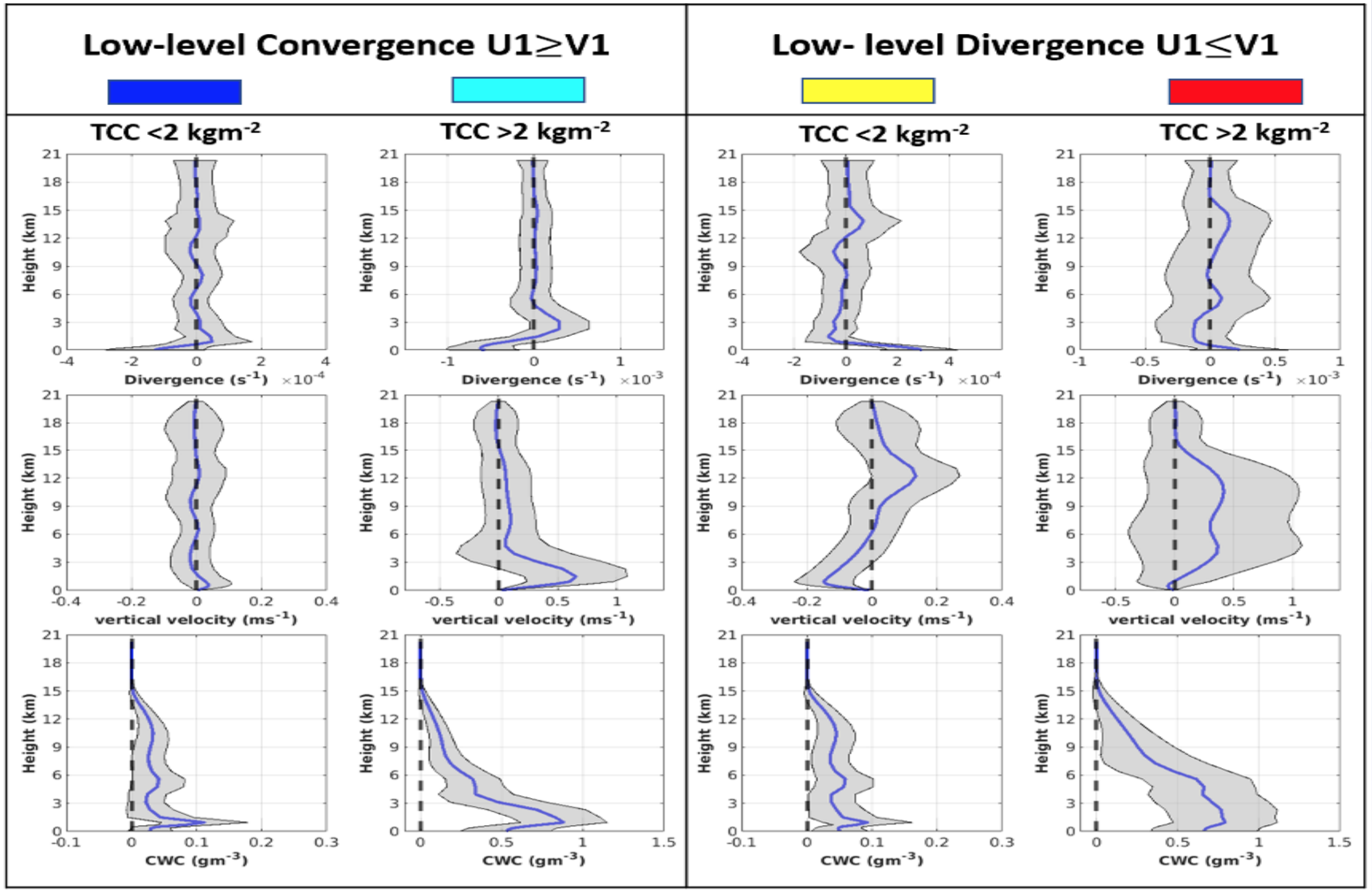
Using Model Simulations, developed a relationship between:

- maximum vertical velocity
- low-level divergence
- and total column condensate (TCC)

- Resulted in the identification of 4 precipitation types



- What convective structures are represented by the four regions?
  - computed, separately for each type, the mean vertical profiles of divergence, vertical velocity, and condensate water content (CWC).



- **Closer inspection revealed that the classification resulted in the identification of 4 well-known precipitation types**

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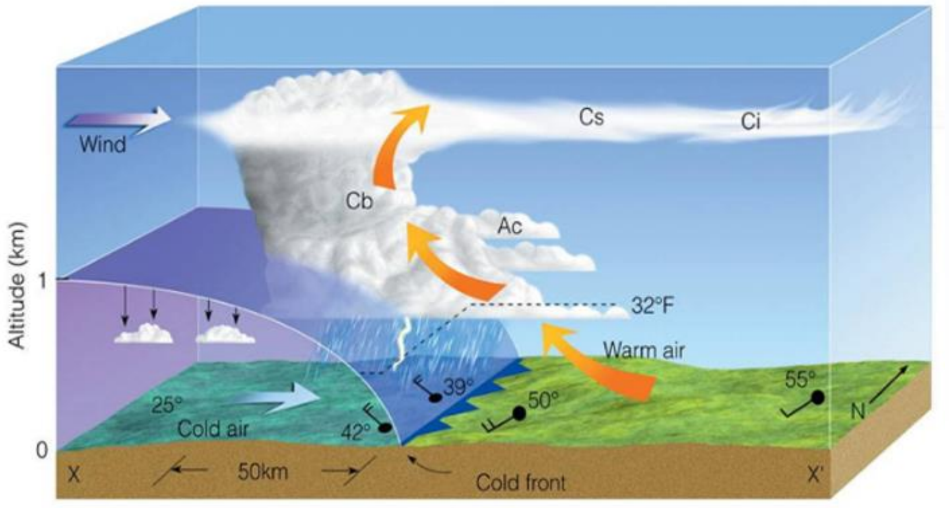
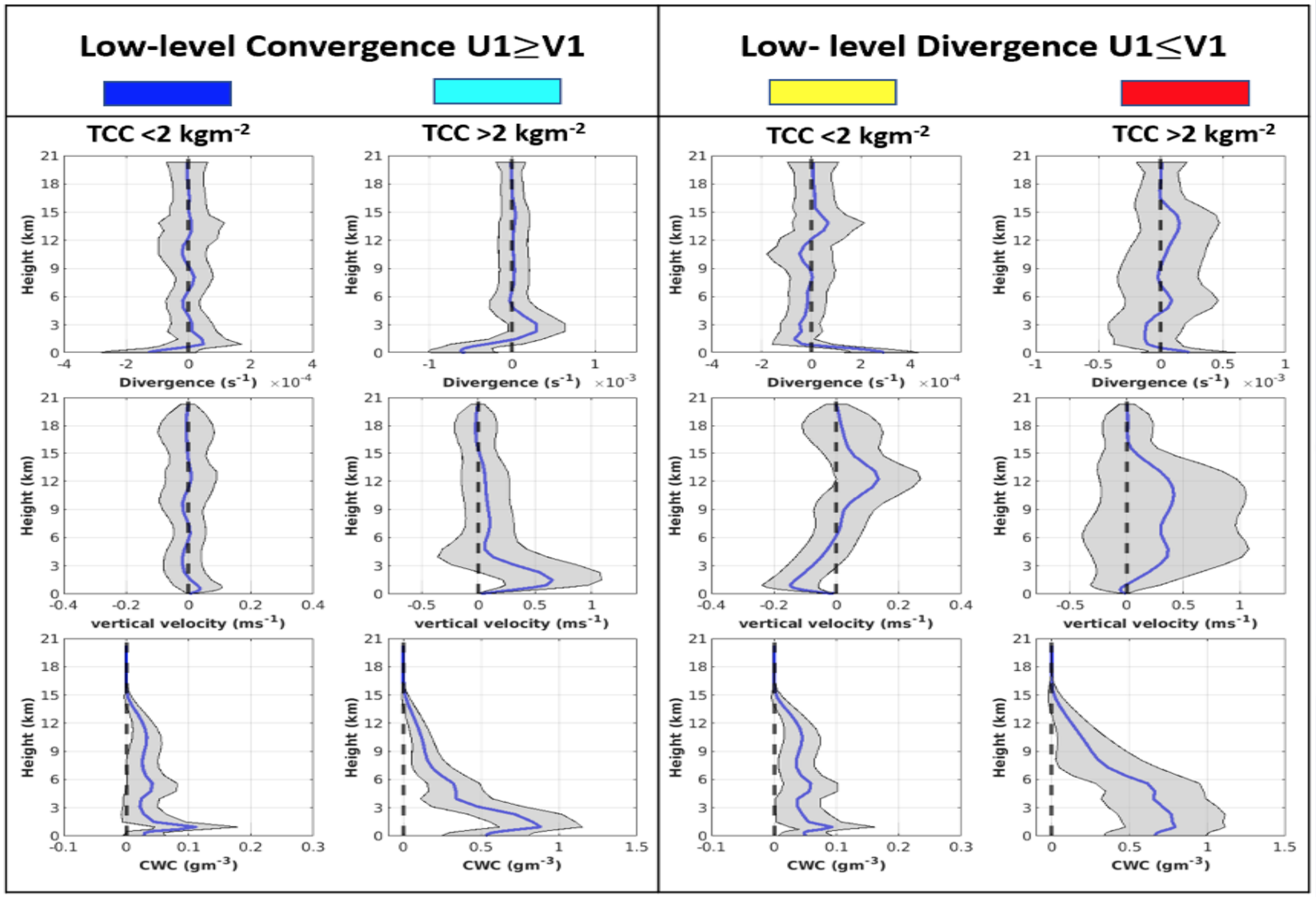
A novel method to quantify the relations between surface convergence and convective vertical transport and identify how they relate to hurricane evolution





Initial convection

Developing convection

Stratiform precipitation

Deep convection

- **This classification can be reproduced using satellite-like observables:**
  - **TCC from PMW observations**
    - **Separating the TCC into low and high ratio of IWP/TCC**
  - **Divergence of the near-surface winds !!!! (IOVWST and MWOW)**

Investigations of Convective Updrafts

INCUS

Beyond INCUS? Extending CMF Estimation Using Existing Observations

- Previous **TRMM/GPM** studies used convective–stratiform classification to estimate latent heating in precipitating systems.
- Here, **we propose extending this approach using TRMM/GPM + MWOW to produce an enhanced precipitation classification that distinguishes deep and shallow convection**, enabling improved estimation of **Convective Mass Flux (CMF)** into the upper troposphere—**a key objective of the upcoming INCUS** mission.
- **INCUS-derived CMF estimates** for tropical cyclones will serve as a benchmark for evaluating and validating the proposed methodology.
- Once validated, this approach can be applied to **Program-of-Record (PoR) satellite observations** to generate a **long-term, global record of TC CMF**. While less accurate than INCUS retrievals, these estimates would significantly extend CMF observations in time and space, supporting improved understanding of TC structure and evolution.

Background

Understanding trends/variability: Need of Long-term record

- To investigate the long-term trends and variability we performed analysis of the Hadley cell using observations from two observing systems – with very little overlap in time:
  - **Ocean Surface Wind estimates from QuikSCAT's JPL product: period 2000-2010**
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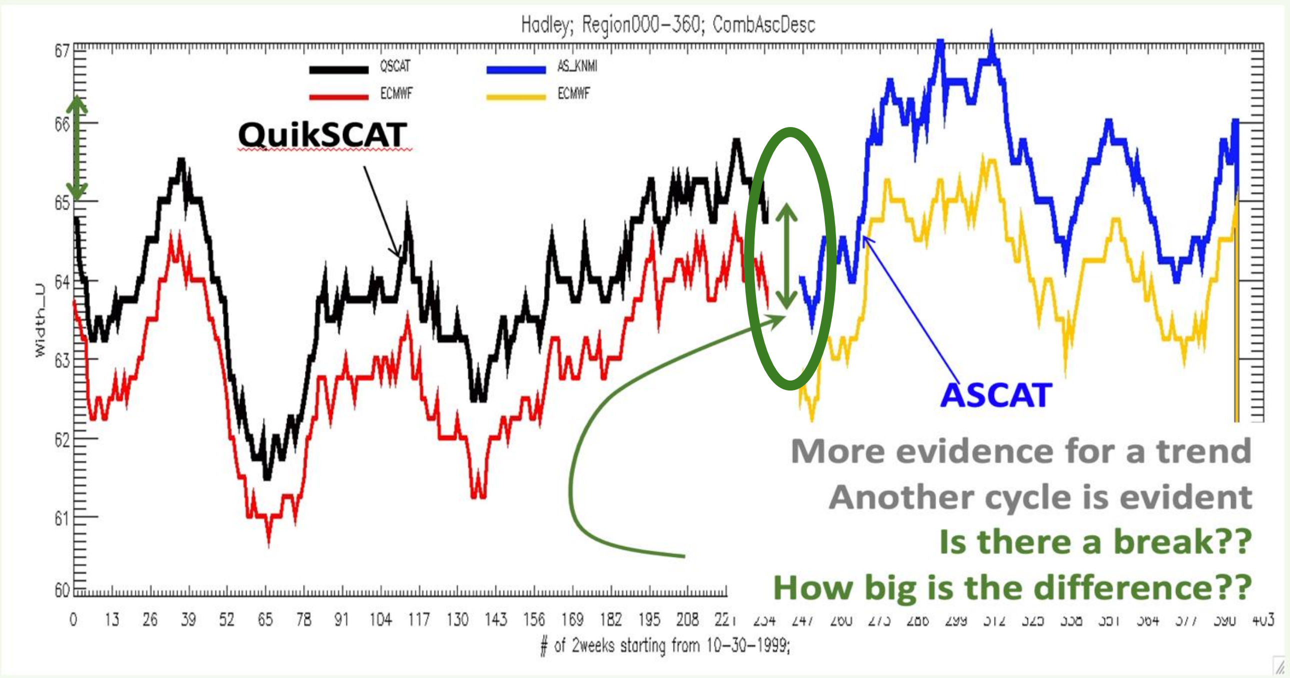
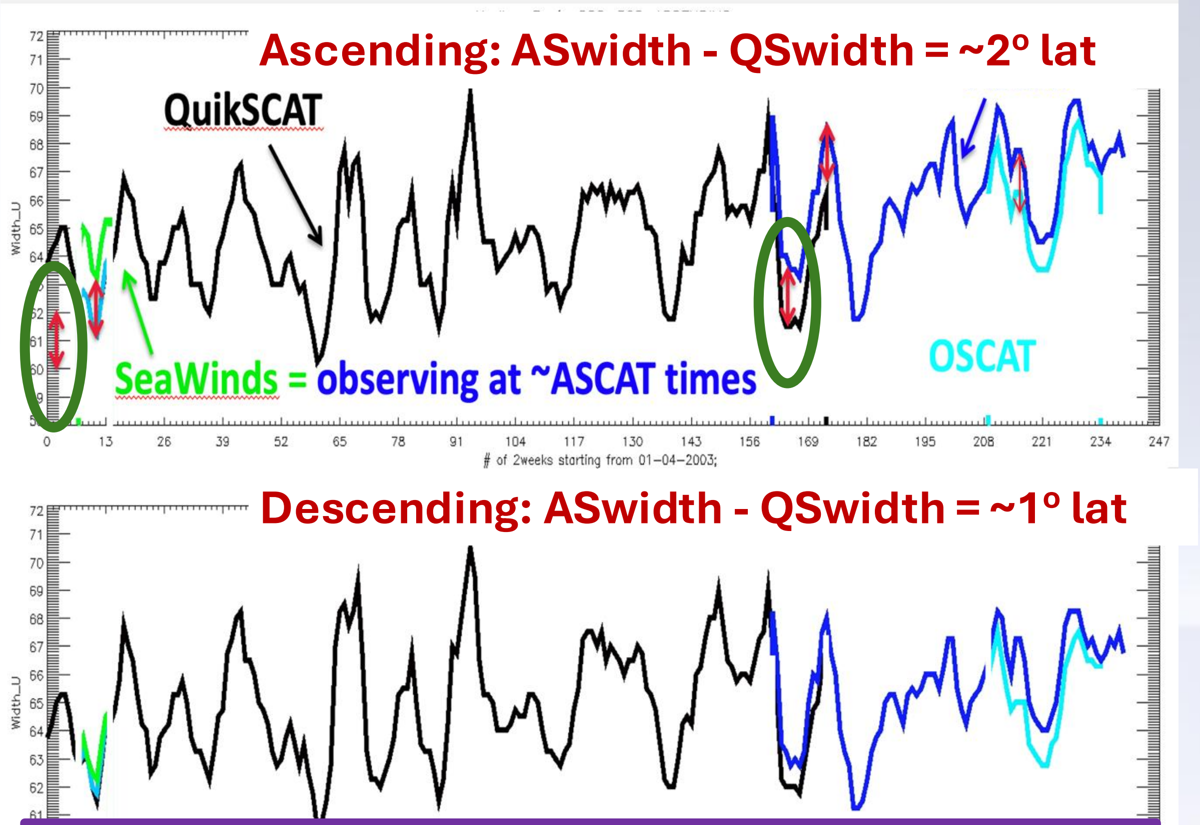
Time-series of the Width of the double Hadley cell - using 1-year running averages, offset by 2 weeks



Time evolution of the width of the combined Hadley cell as determined from the zero crossing of the mean zonal wind (from 1-year running averages)



3-month running averages: Note strong seasonal cycle

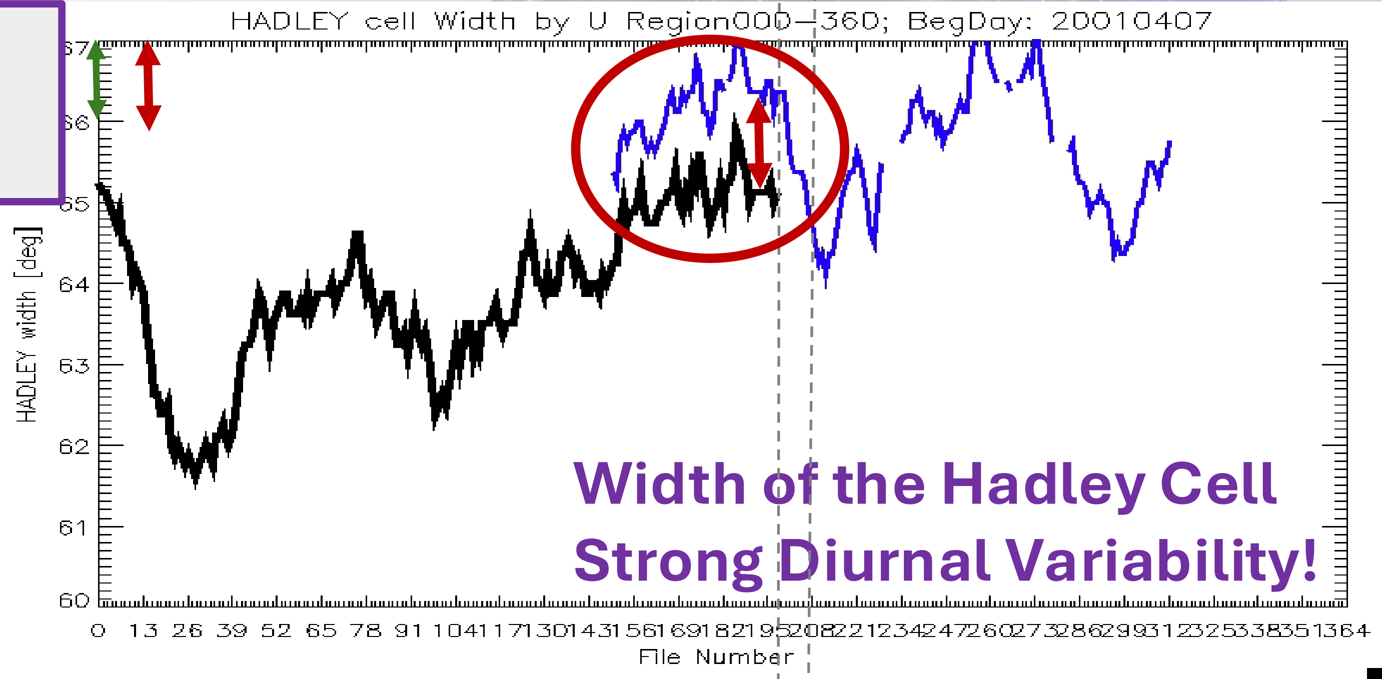
Using the MEaSUREs data - new CDR - and ERA-5 collocated in space and time

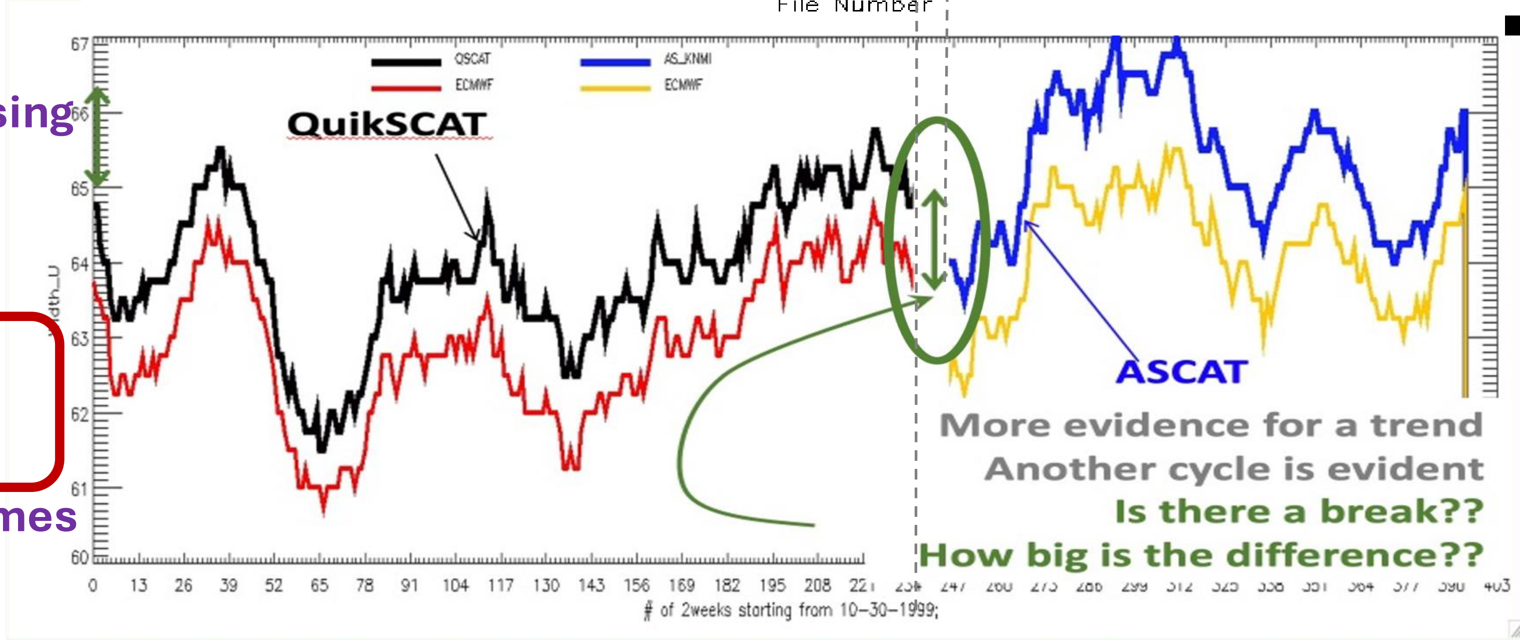
Computed Hadley cell width with the same methodology:

- time series of 1-year averages of the zonal mean winds, offset by 14 days between each entry
  - **New input:**
    - **the MEaSUREs's consistent CDR of the ocean surface winds**
    - **Compared to ERA5 (earlier comparison to ECMWF analyses)**

Results: Did we resolve the discontinuity using the CDR

- **made the "apparent" discontinuity smaller**
- **did not resolve it completely**
  - **diurnal variability ???**
  - **Yes: different LTD observations**
- **Hadley cell is wider during ASCAT times**





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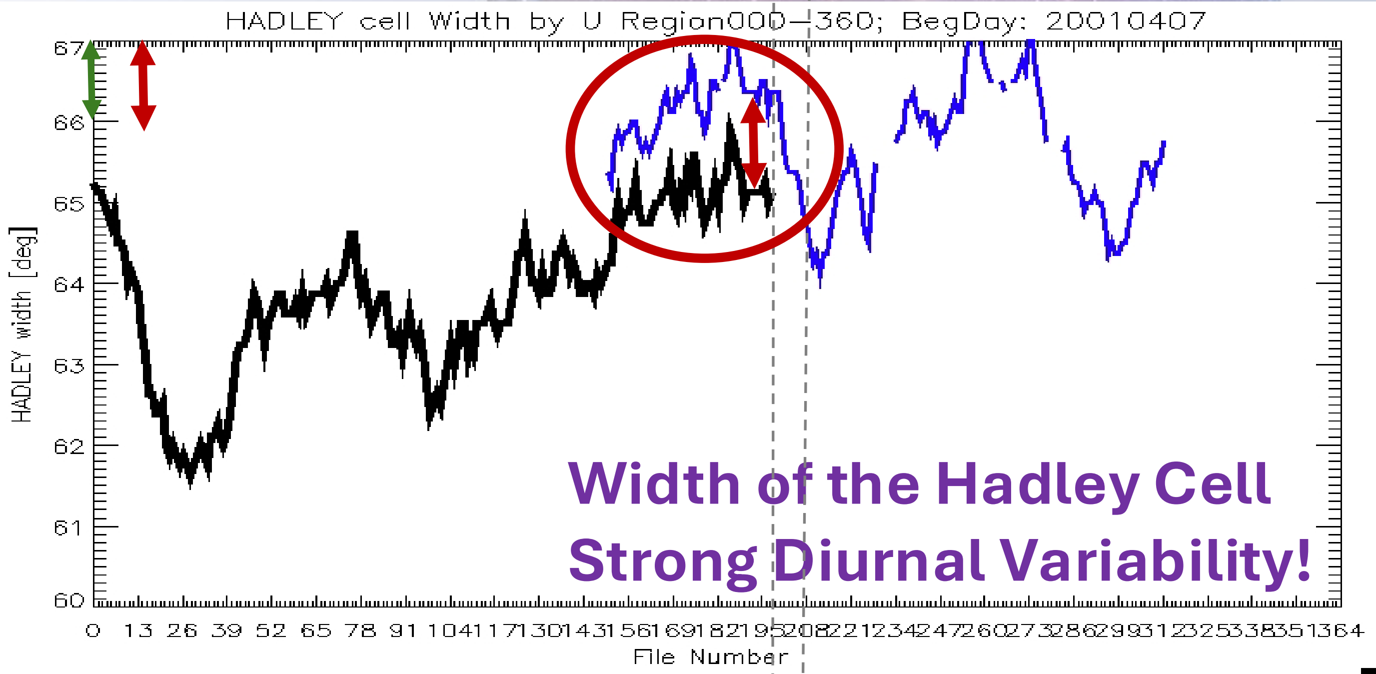

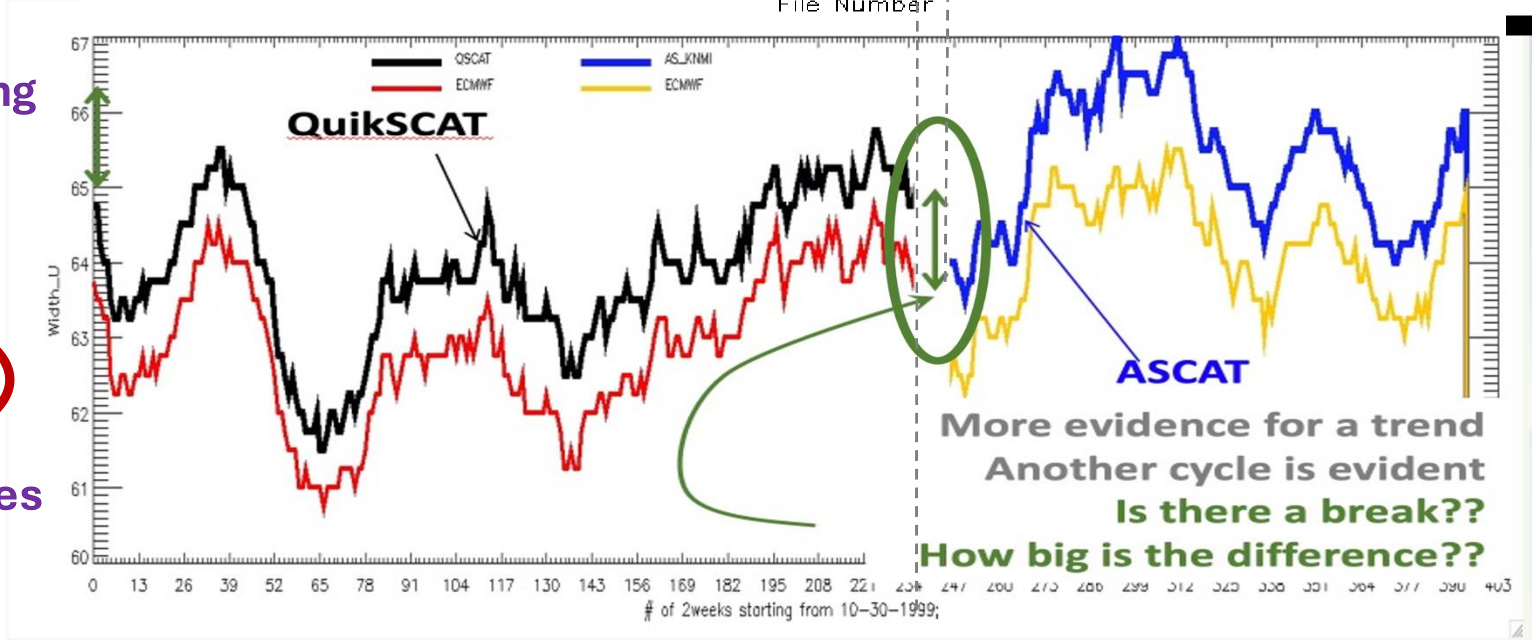

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Using Model Simulations, developed a relationship between:

- maximum vertical velocity
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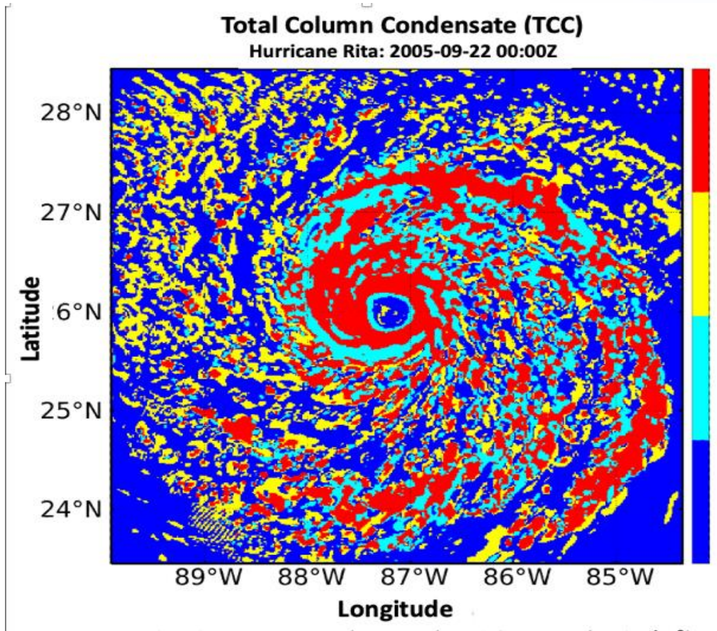
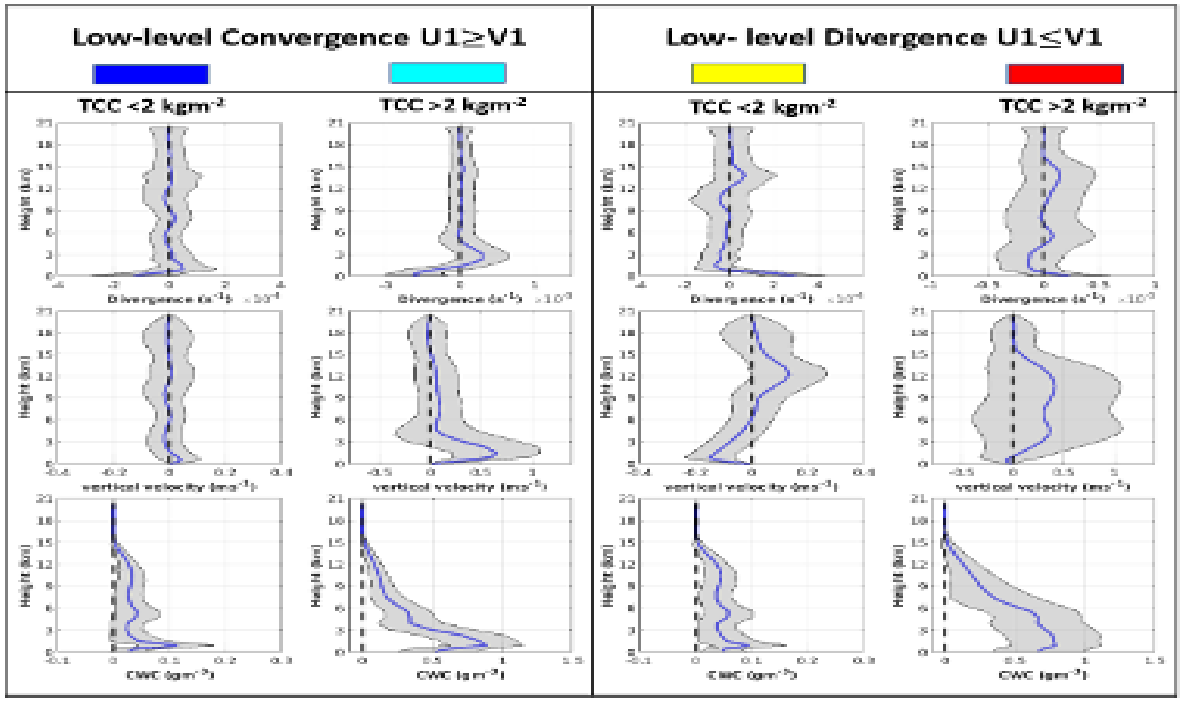
- and total column condensate (TCC)

- Resulted in the identification of 4 well-known convective types



Hurricane Rita of 2005



mostly clear air | *Developing convection* | *Stratiform convection* | *Deep convection*

- This classification can be reproduced using satellite-like observables:
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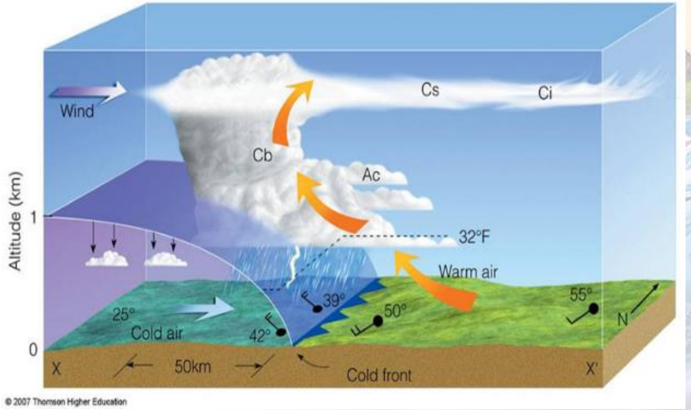
    - Separating the TCC into low and high ratio of IWP/TCC
  - Divergence of the near-surface winds



It is remarkable to note that each of these 4 groups represents a very well-known class of convective precipitation structures.

** IWP - Ice Water Path*