Level 3 (gridded) scatterometer products: making the case for and designing them

Svetla Hristova-Veleva[1], Ernesto Rodriguez[1], Bryan Stiles[1], F. Joseph Turk[1], Ziad Haddad[1]

Larry 0'Neill[2], Mark Bourassa[3], Doug Vandemark[4]

[1] - Jet Propulsion Laboratory, California Institute of Technology
[2] - Oregon State University
[3] - Florida State University
[4] - University of New Hampshire, Durham

What and Why and Why now …

- Goal
  - to rekindle an old conversation, to bring back the points that were discussed
  - and to start again the conversation on what we would like to do as a community
- We are at a special place in time:
  - together, we now have a long-term record of scatterometer observations
  - the community, lead by RSS, has made a significant progress in understanding the Ku-band response to winds
  - similarly, the KNMI efforts have lead to much better understanding of the C-band observations
  - for the first time we now have an extended set of collocated Ku/C band observations that would allow us to create a coherent set of long-term observations
  - the combined efforts of the OVWST has lead to a **much better understanding of the wind-stress relationship**
  - many studies by the OVWST members have **highlighted the importance of the dynamically important derivatives**
  - several very important efforts **(Level 3 and Level 4) have greatly facilitated the use, and the ease of use, of the scatterometer observations**
- **So - what is still missing and what do we need to do ?**

What is still missing

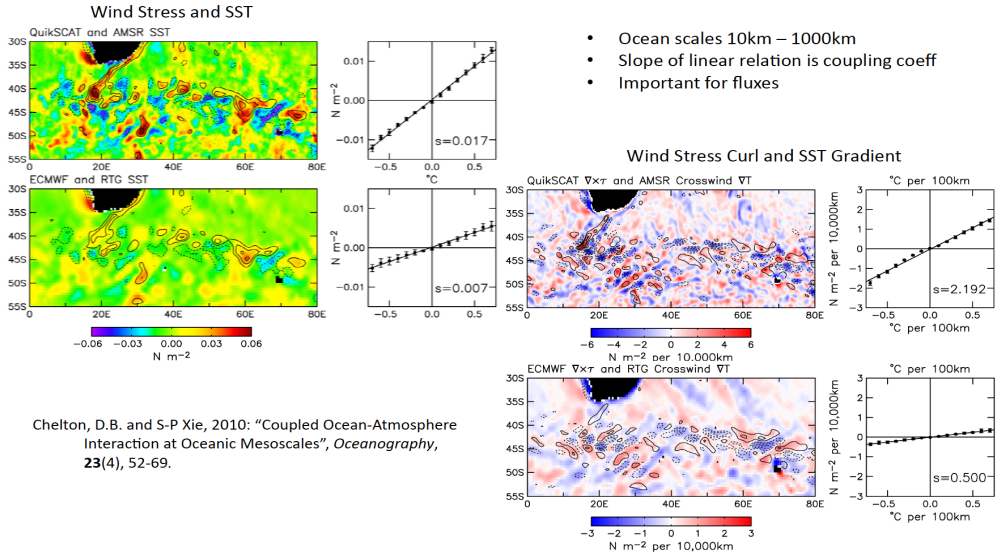
- **Measurement-specific gridded derived products from scatterometers**
  - **Stress, Curl and divergence of the wind Stress**
    - Upper oceanic circulation is driven by the curl of the wind stress
  - **Divergence and curl of the wind**
    - the atmospheric circulation is strongly affected by the wind convergence

IOVWST 2011

Ralph F. Milliff; NWRA/CoRA
Mark Bourassa; COAPS, Florida State Univ.
Dudley Chelton; COAS, Oregon State Univ.
Ernesto Rodriguez JPL, CalTech

Air-Sea Coupling Amplitude:

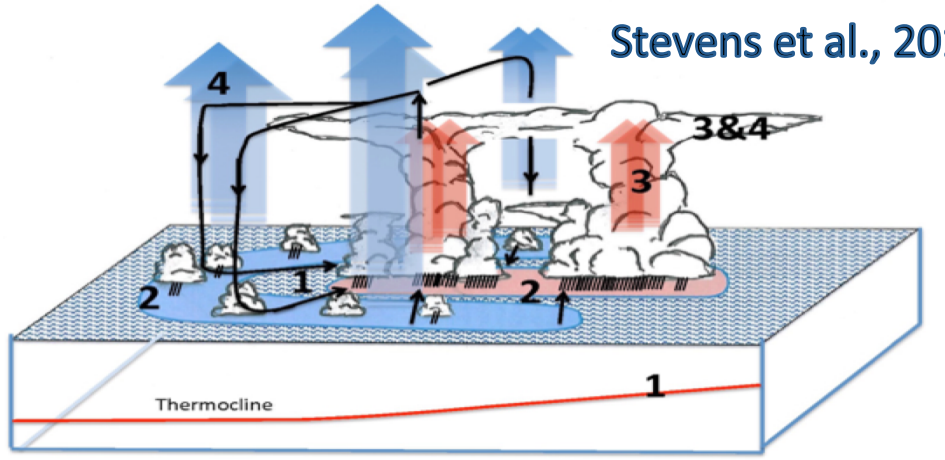
Satellite-to-Satellite comparisons yield Strongest Coupling Coefficients



- Ocean scales 10km – 1000km
- Slope of linear relation is coupling coeff
- Important for fluxes

Chelton, D.B. and S-P Xie, 2010: "Coupled Ocean-Atmosphere Interaction at Oceanic Mesoscales", *Oceanography*, **23**(4), 52-69.

Stevens et al., 2017



Swath-based products: advantages and disadvantages

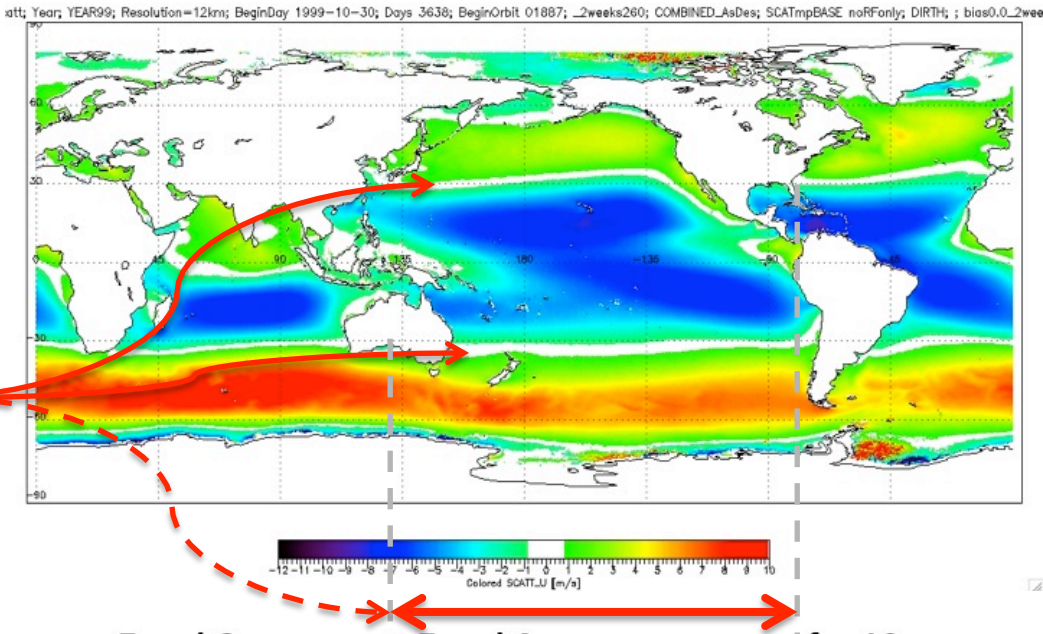
- **Advantages:**
  - the **most flexibility for use in in-depth scientific analyses**,
    - allowing each researcher to pre-screen
    - and aggregate the data based on the specific objectives of their studies.
- **Disadvantages**
    - **significant time and effort investment** on the part of each individual scientist
    - the **need to build very good understanding of the specifics of the measurements, the instrument capabilities and limitations**. This knowledge is needed to guide them in the proper use of the data (flags).
    - Additional difficulty in using swath-based data comes from the **need to develop user (case)-specific data discovery capabilities** when doing analysis over specific region or time of interest.

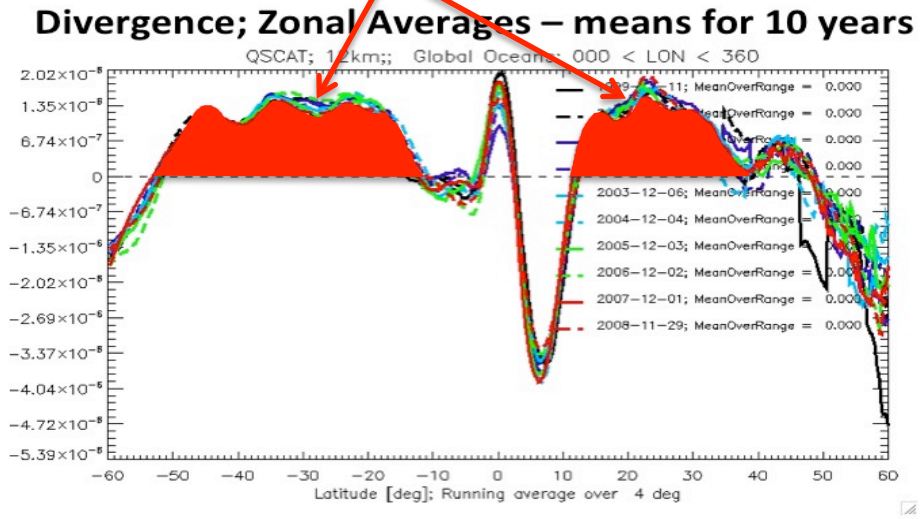
Need of gridded products

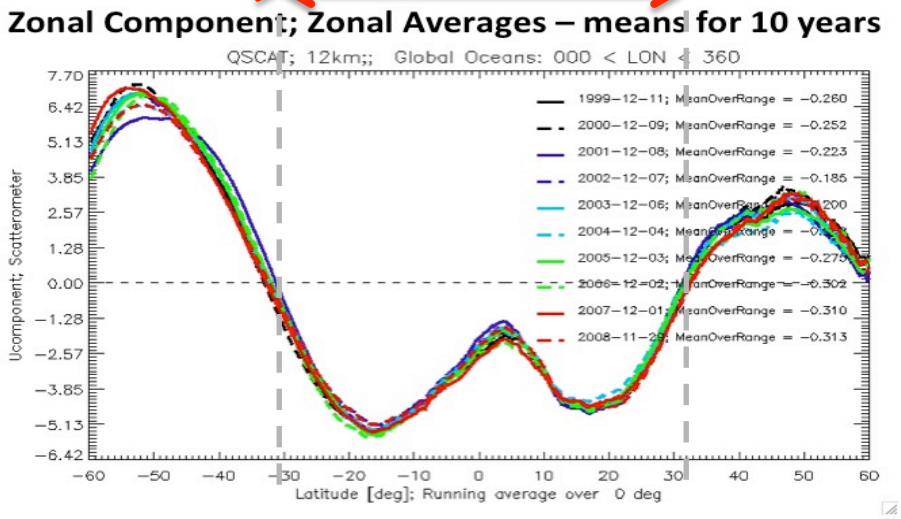
- On the other hand, **regularly gridded products have proven very valuable in advancing the broader science goals of a mission**. Their advantages include:
  - by the nature of their design these data provide observations in a format that **allows very easy integration in space and time**;
  - **collocation with observations of other parameters** that are also gridded (e.g. precipitation);
  - **consistent screening for data quality that incorporates best practices**.
  - Such pre-processing greatly facilitates
    - the generation of global and regional climatology,
    - the studying of trends,
    - the determination of correlations between parameters,
    - the comparisons between instruments;
    - the analysis of the diurnal cycle (??)

Climatology and trends in the Global Fields

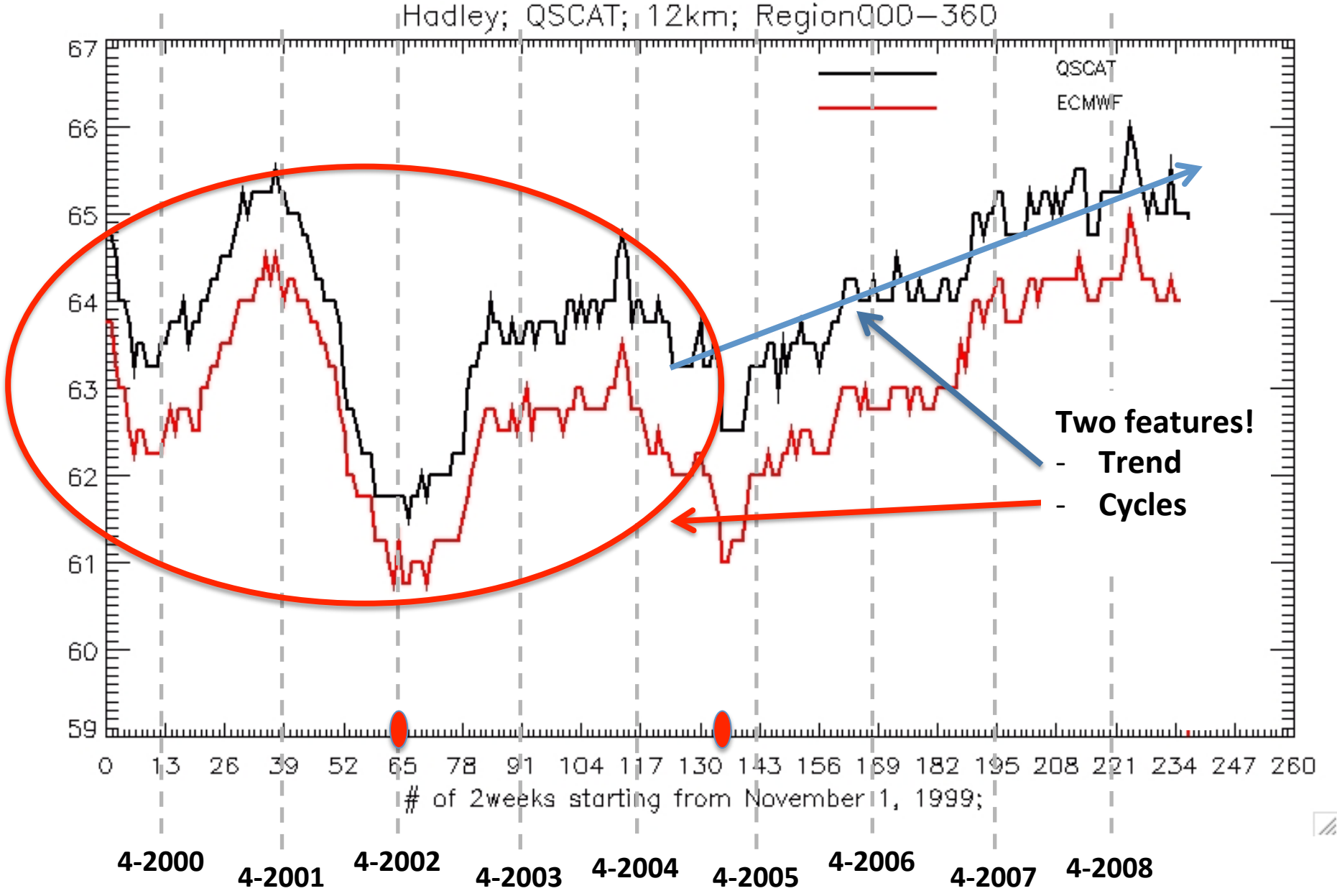
- Use the observations from QuikSCAT and ASCAT. **Compute statistics from time composites (1-year and 3-month running averages, offset by 2 weeks**.)
- Determine the **extent of the Hadley cell** as defined by the subtropical zero-crossing of the zonally-averaged zonal wind component (the separation between the midlatitude westerlies and the easterly winds in the tropics).
- Determine the **circulation strength** as defined by the area of divergence.







Trends in the Width of Hadley as determined from: Global data; 1-year averages; The zero-crossing of U



Data Processing Levels – Definitions (and confusion ?)

https://science.nasa.gov/earth-science/earth-science-data/data-processing-levels-for-eosdis-data-products

Level 3: Variables mapped on uniform space-*time(?)* grid scales, usually with some completeness and consistency.

Further interpretation:

- Do not have to be "uniform time grid".
  - Instead define as daily maps of
    - "local time morning observations, and local time evening observations"
    - **interpolated to regular spatial grid, within each swath**
    - **but not interpolated between swaths**.
- Swaths are mapped into two daily grids. Maps of observation time are also included.
- **The idea for Level 3 is**
  - **to present the measurements in a convenient spatial grid,**
  - **but not to do any averaging or extrapolation from the measurements**.

Level 4 : Model output or results from analyses of lower-level data (e.g., variables derived from multiple measurements).

Further interpretation:

- Regularly spaced in time
- No spatial gaps - Can included quantities that have been averaged from multiple observations.

Existing gridded products

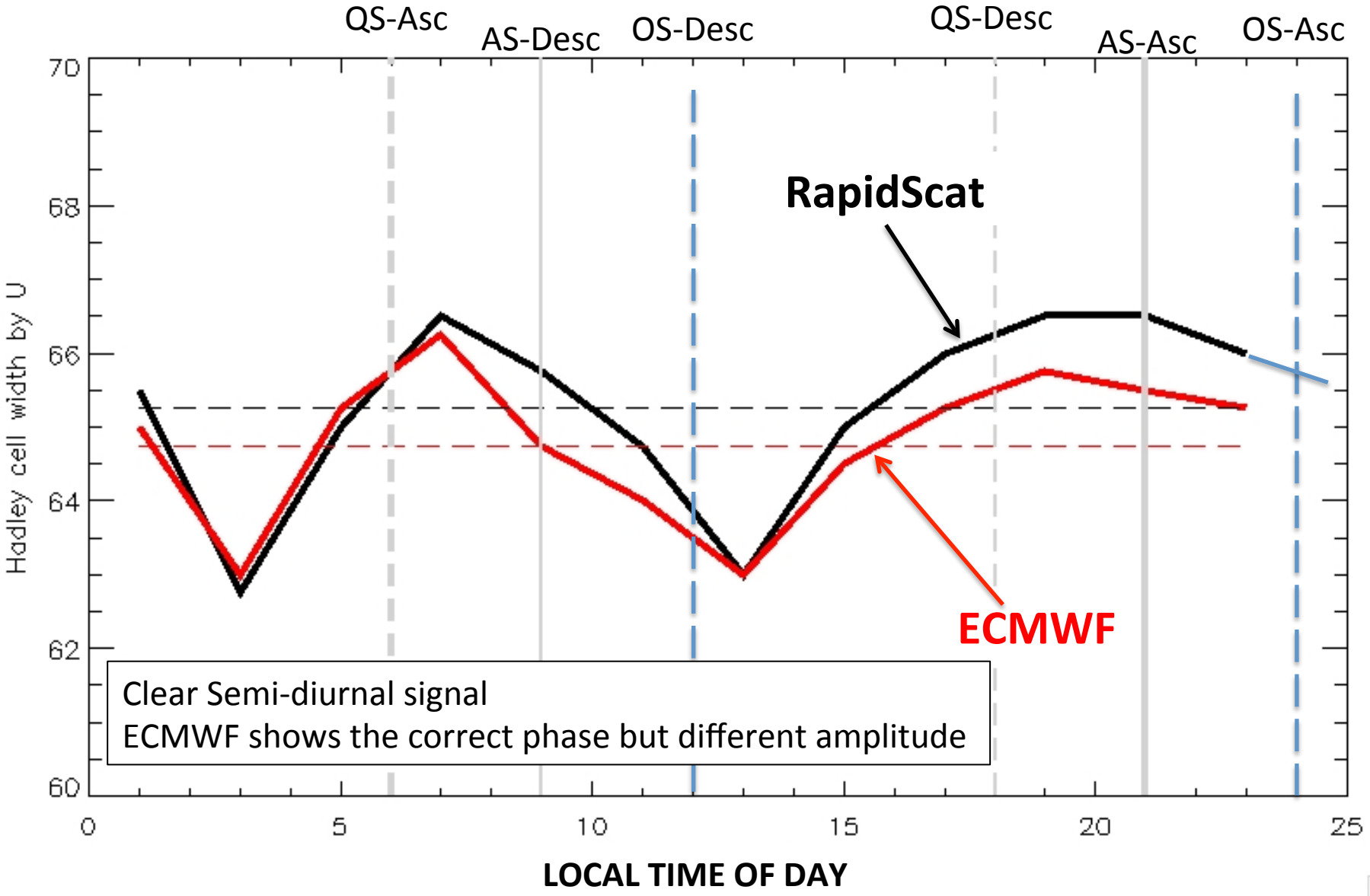
- **Level 3**
  - **RSS's daily** (ascending/descending) **wind products**
  - very significant level of use
- **Level 4**
  - Types:
    - **CCMP, DASCAT, Others??? – wind products**
    - **OAFLUX, Others ??? – wind, stress, curl/divergence**
  - What do the current level 4 products provide:
    - Products that can be easily used for Data Assimilation in NWP
    - Forcing of the ocean models
    - General analysis

Existing Level 4 products

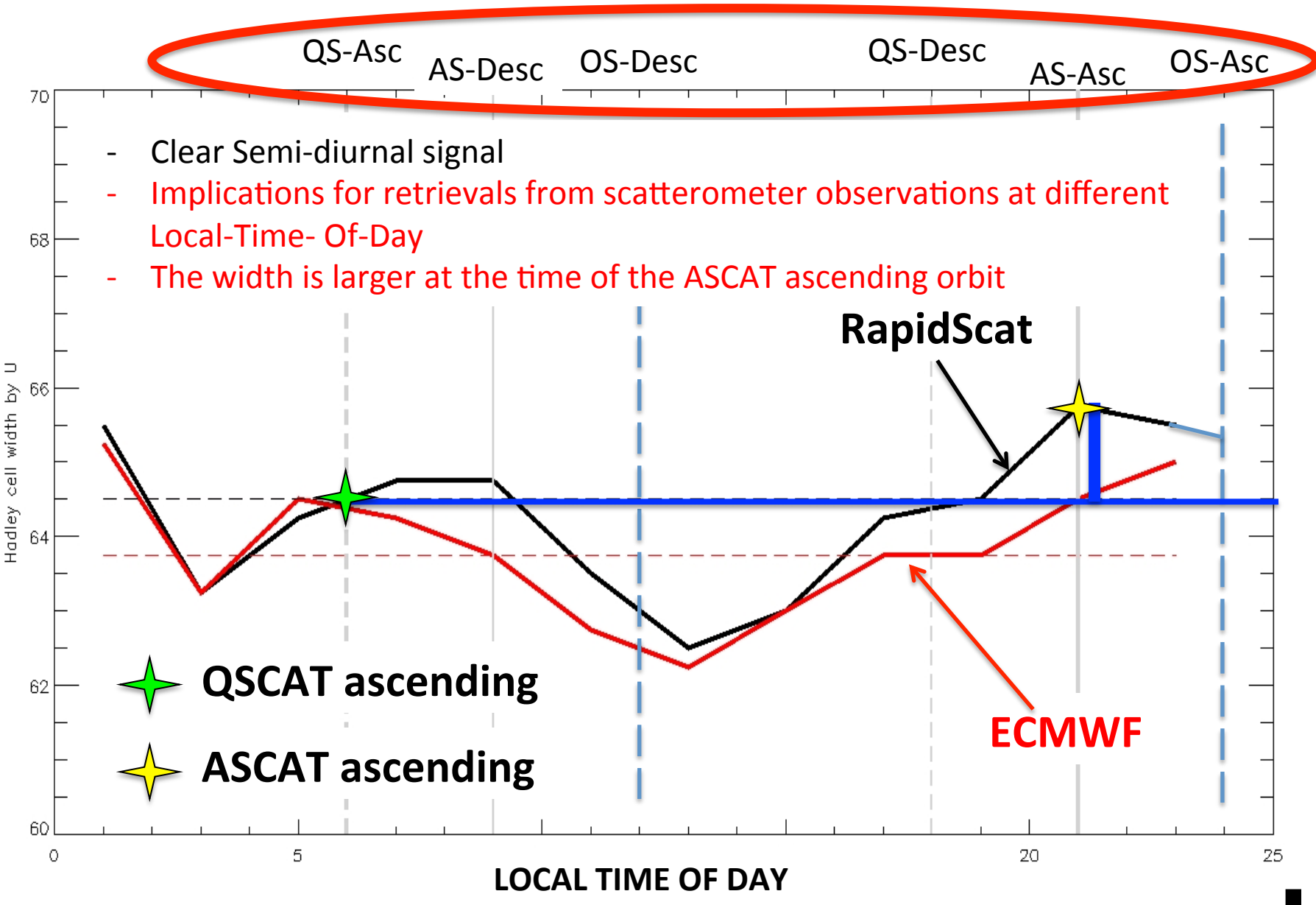
- **Any interpolation in time requires the use of models**
  - only because we have insufficient temporal resolution of the wind field.
- **Any procedure to fill the space gaps between orbits can benefit from using model data and other observations (e.g. radiometers)**
- **Because of that the L4 products might not be providing**
  - **An accurate depiction if the diurnal cycle and of long-term variability and trends** (El Nino and Hadley)
  - **An accurate representation of the measurement-specific characteristics of the wind**

Is ECMWF capturing the diurnal signal correctly ?

RapidScat: Hadley Width by the Zonal Wind U



RapidScat (308 days)
Hadley Width by the Zonal Wind U

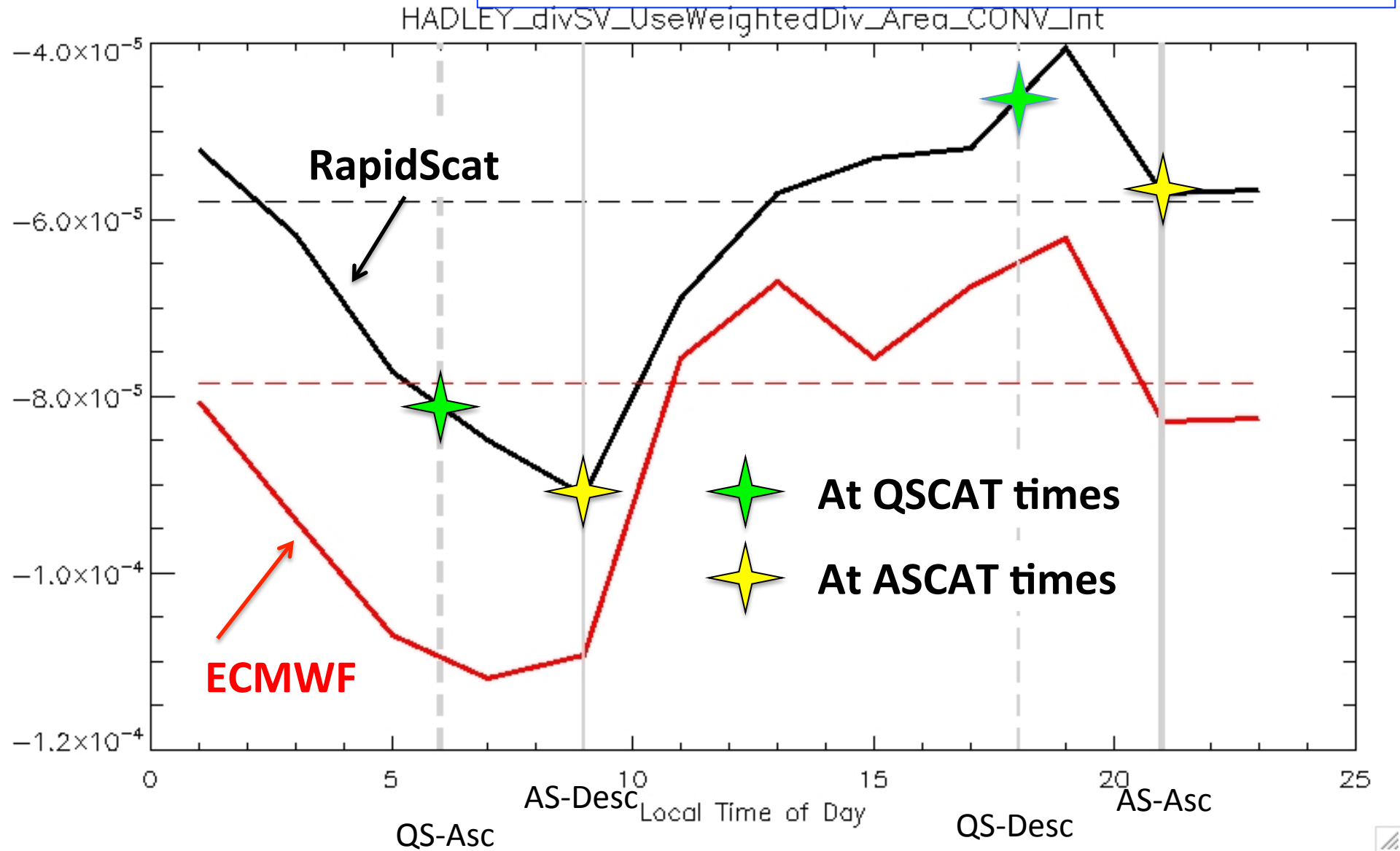


Is ECMWF capturing the diurnal signal correctly ?

+ + > + +

Hadley Convergence (Integral)

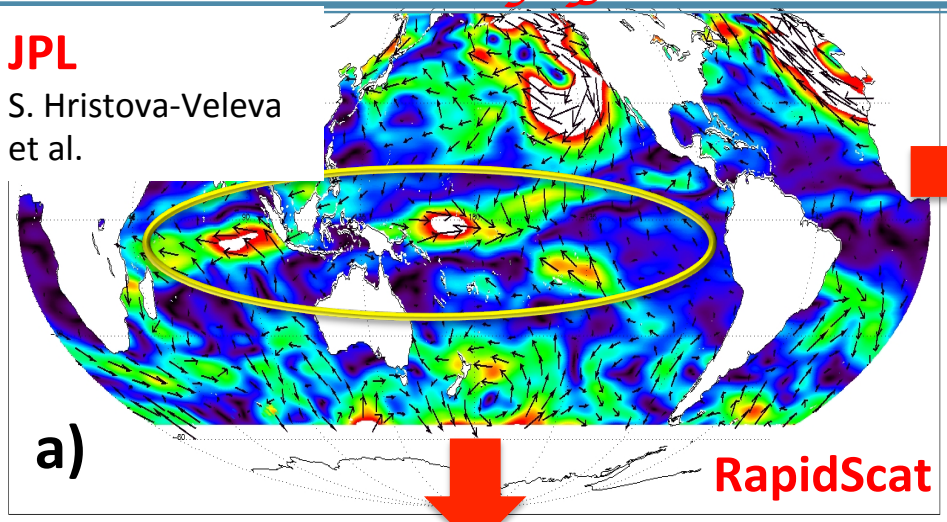
Stronger ITCZ convergence in the ASCAT observations
(The Integral over the area of Convergence is more negative)

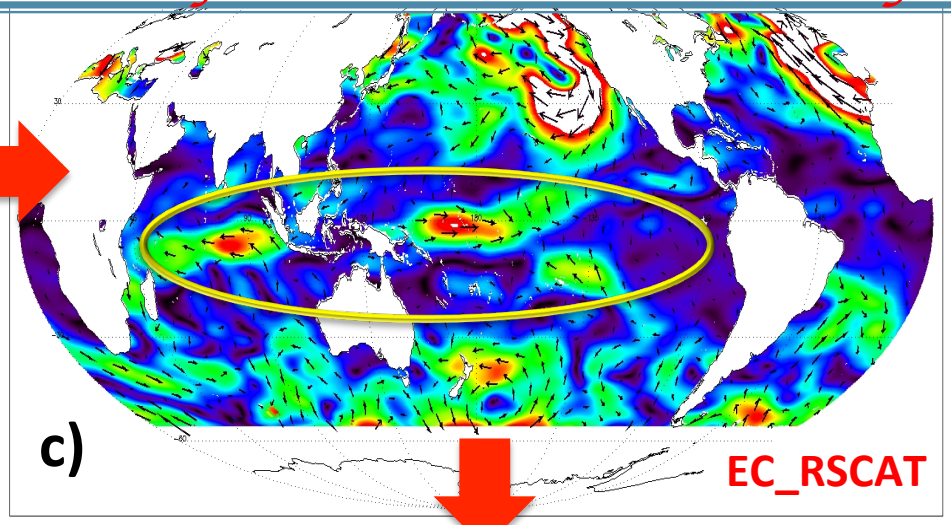


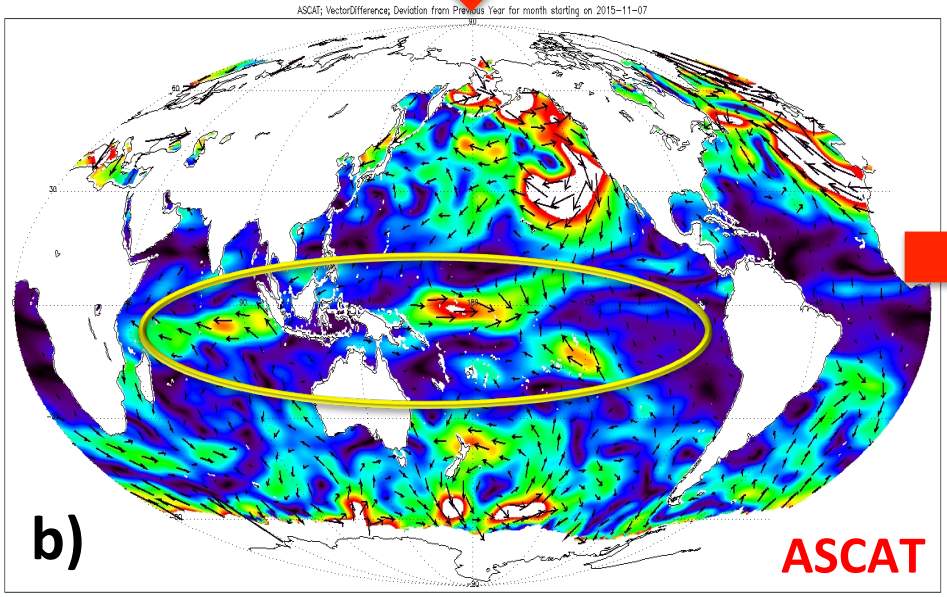
The 2015-16 El Niño evolution and teleconnections inferred from RapidScat, ASCAT and ECMWF winds: does diurnal variability affect the characterization of El Nino-related wind anomaly?

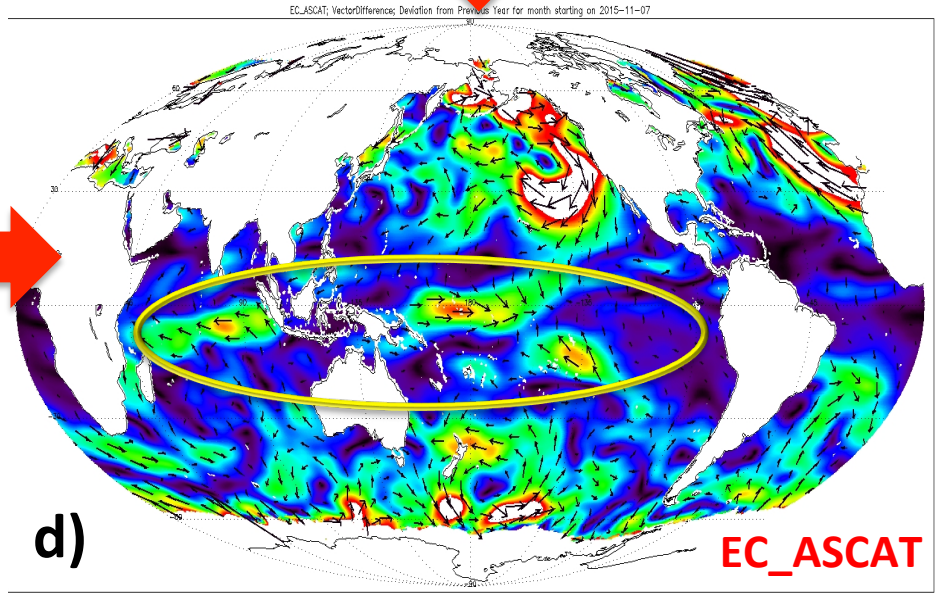
JPL

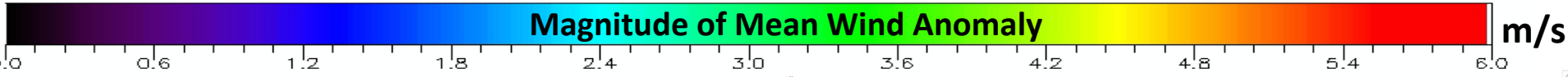
S. Hristova-Veleva et al.



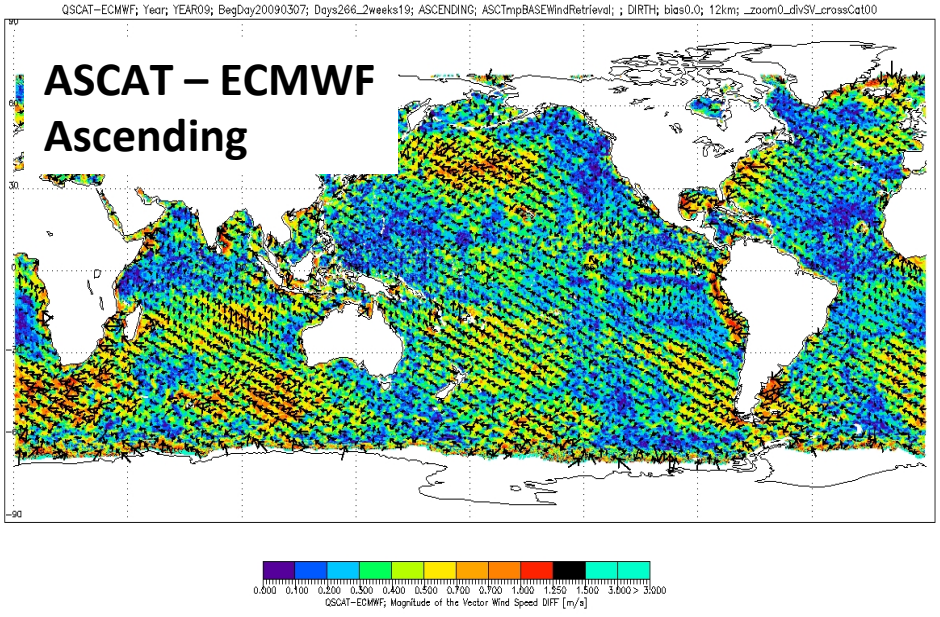


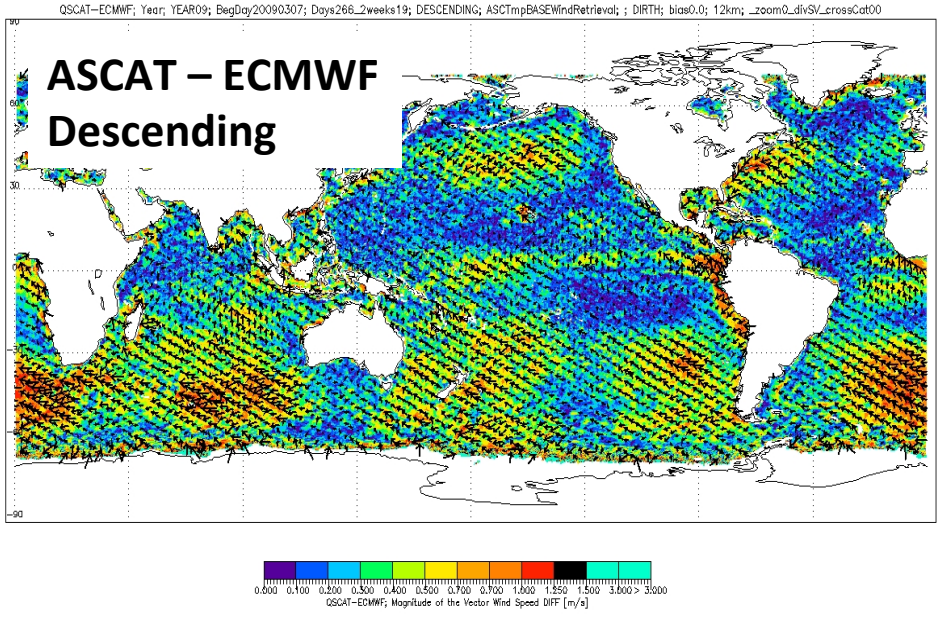




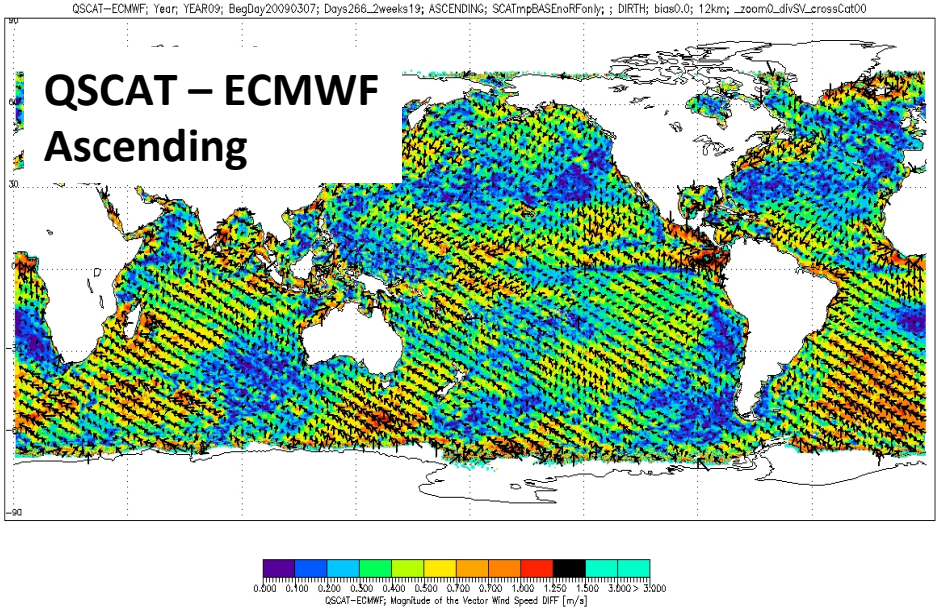


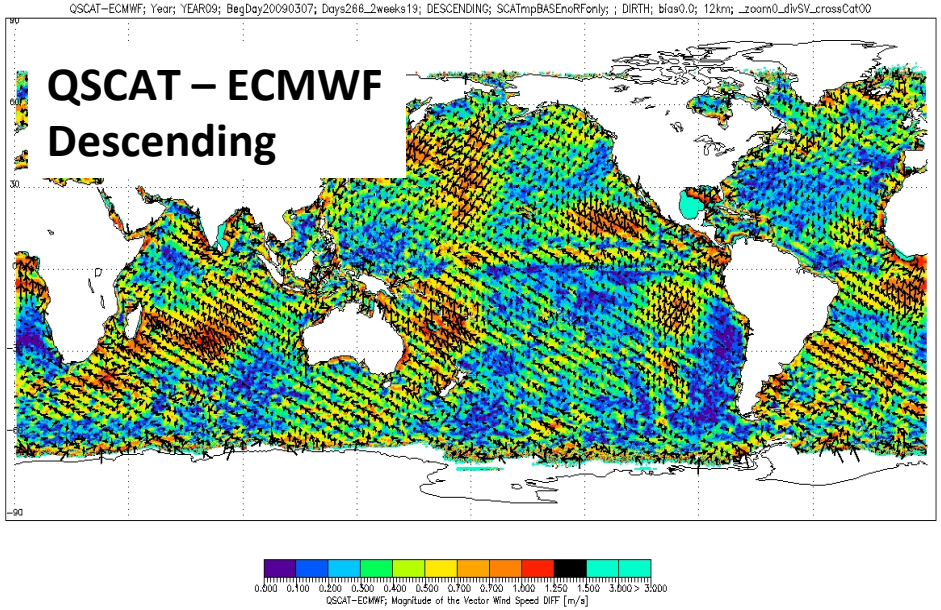
Is ECMWF capturing the wind signal correctly ?



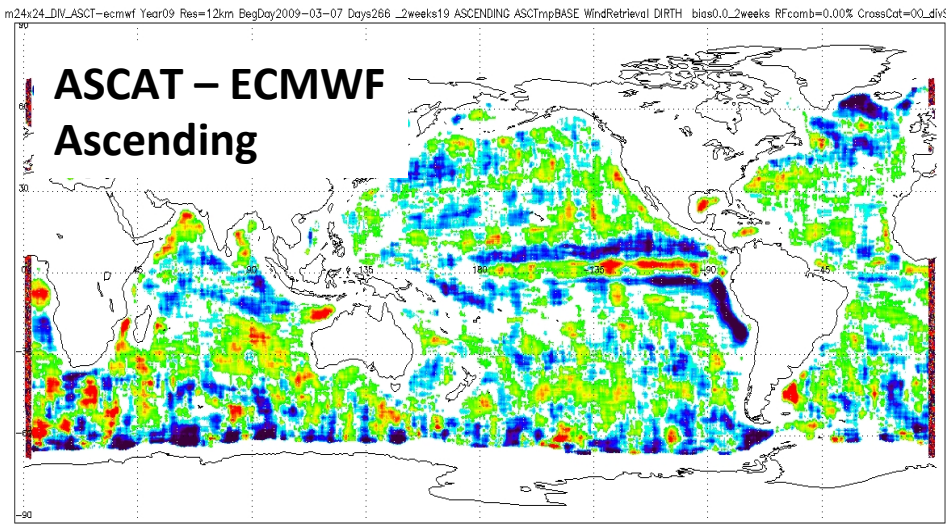


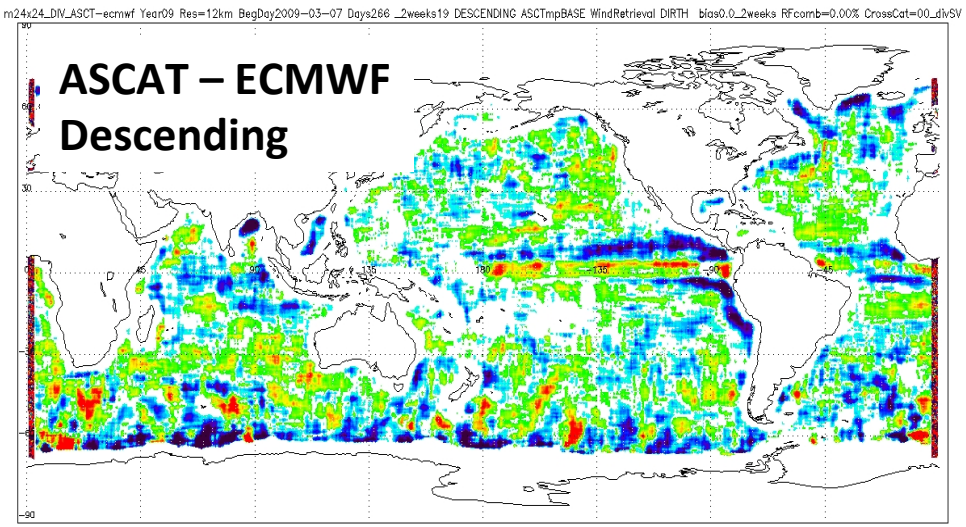
Vector of the mean component difference



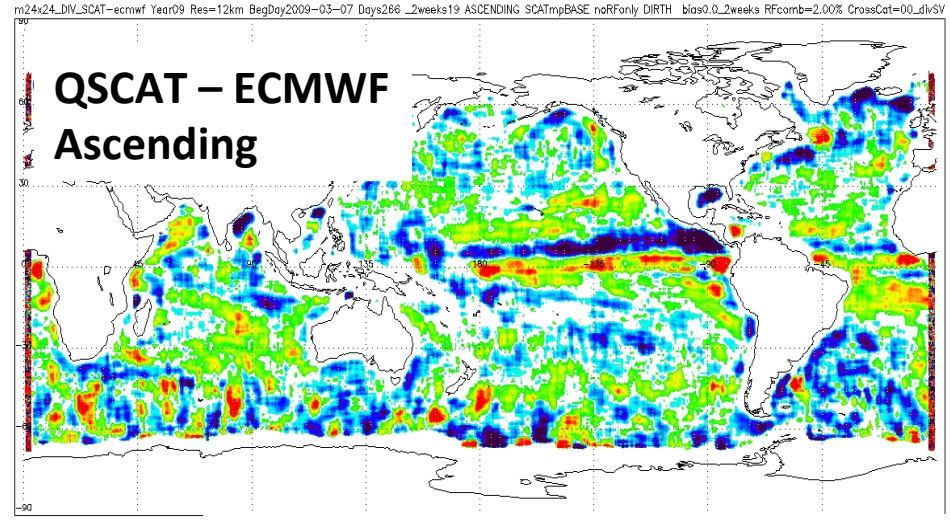


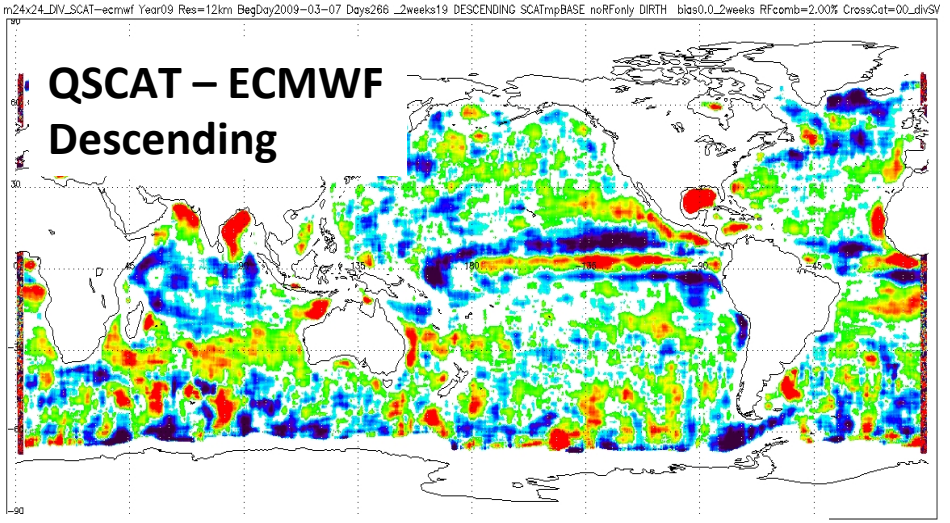
Is ECMWF capturing the wind signal correctly ?





"Divergence" of the residual winds (SCATT – ECMWF)





Why do we need instrument-specific L3 products

- **to create a long- term unbiased record of winds**
  - **To describe, and understand their variability on a variety of temporal and spatial scales**
    - **Diurnal**
    - **Intraseasonal**
    - **Decadal**
  - **To help evaluate models**
- **to present an accurate record of stress and the spatial derivatives of stress and wind**
  - **To provide observational constraints (observed stress) in forcing the ocean models**;
  - **To study the relationships to other parameters**
    - e.g. surface convergence and precipitation
    - SST fronts and wind coupling,
    - fluxes, etc.

Designing the L3 products

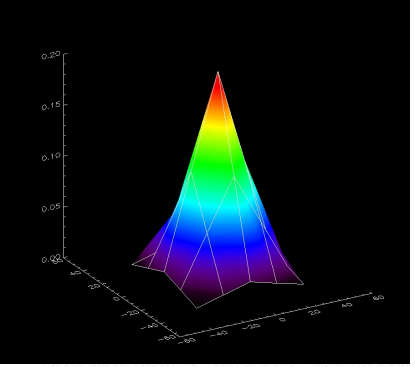
- Probably the main limitation of Level 3 products is that they do not allow untangling the data when multiple observations are present.
- The decisions to be made in the design of L3 scatterometer products include:
  - Defining the optimal grid size (minimum averaging)
  - When multiple observations are found in the same grid cell
    - Defining the representative observations
    - Flagging for rain/ice/land
  - Determining the optimum set of information that should be kept (keep the time of the observation)
  - The development of derived products (curl/divergence/stress)

Stress/ Curl/ Divergence – computing on the swath versus from averaged data

- **When computing from time/space averaged fields**:
  - **Stress**
    - will be biased because of the non-linear relationship to wind
  - **Spatial derivatives**
    - Specifics:
      - Rain-flagged data should be included in order to preserve/capture the dynamic range of the derivatives and to reflect the dynamically-significant winds/derivatives near convective systems. (Larry O'Neill – IOVWST 2014)
      - level of smoothing is not an issue – they have been significantly smoothed
    - **The disadvantage of this approach is:**
      - **Smearing of the small-scale and transient features** such as extra-tropical fronts and mesoscale convective systems.
      - **Miss-representation of curl and divergence** – neighboring grid values include observations from multiple times

Stress/ Curl/ Divergence – computing on the swath versus from averaged data

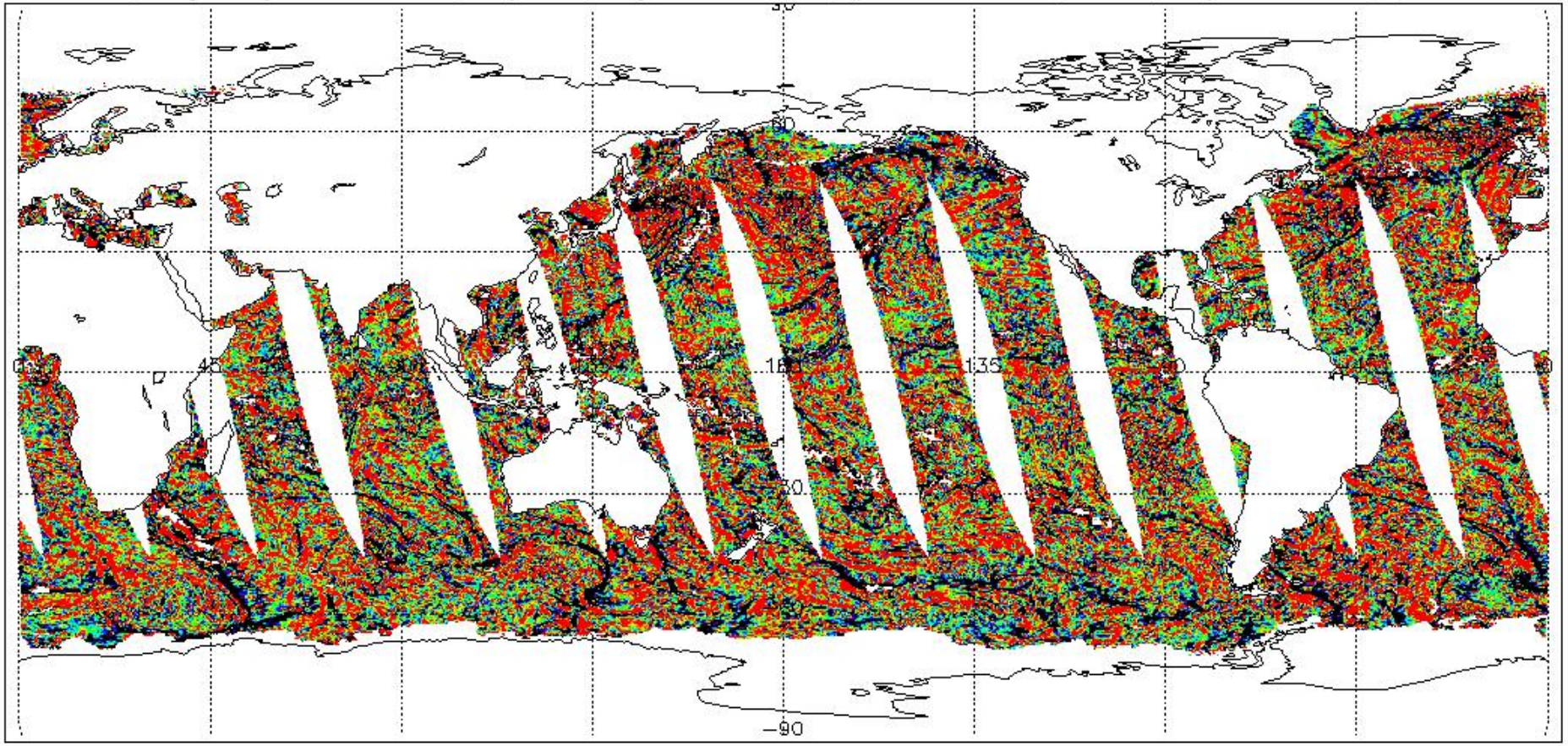
- **When computing from instantaneous (swath) fields**:
  - **Stress** will be properly represented
  - **Spatial derivatives**
    - Stronger Sensitivity to the choices to be made
      - the rain-flagging philosophy
      - the selected degree of smoothing.
    - **The big advantage of this approach is the ability to preserve and properly reflect the intensity of the small-scale and transient features (e.g. the frontal convergence**).

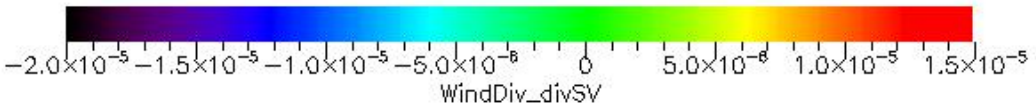


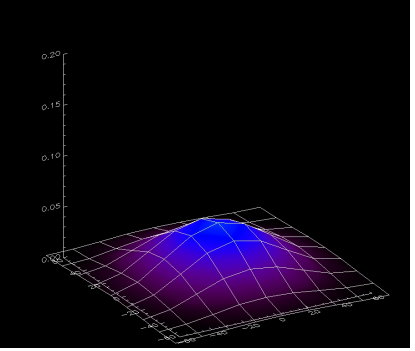
LatLonBiRes = 0.15; Smooth 5; weight>0.3

Computing Divergence in the Swath: Role of smoothing

ScatSCAT; Begin Day 2009-01-10; Days 01; Begin orbit 49791; # orbits = 0015; DIRTH; Only SST>-50.0; ;_crossCat00



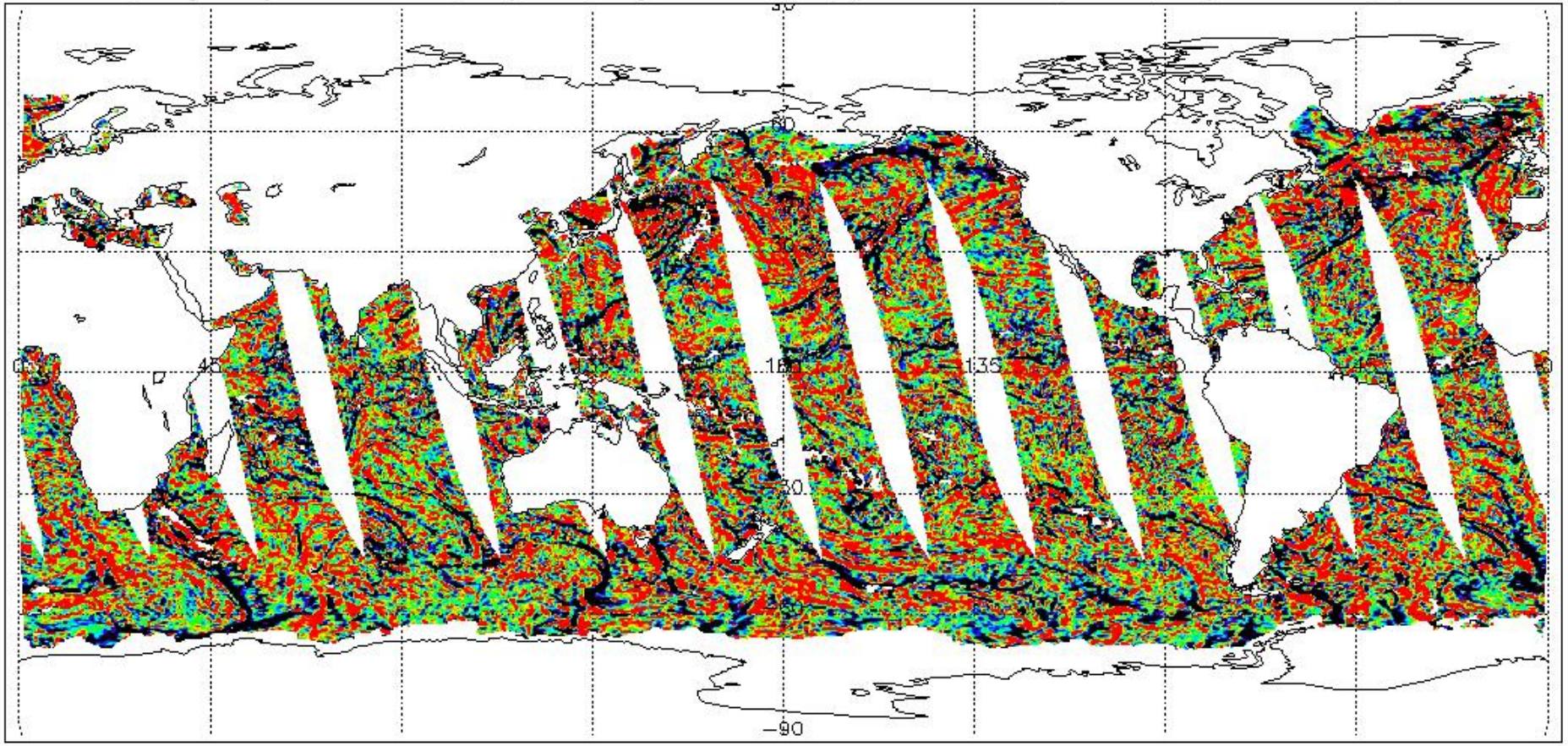


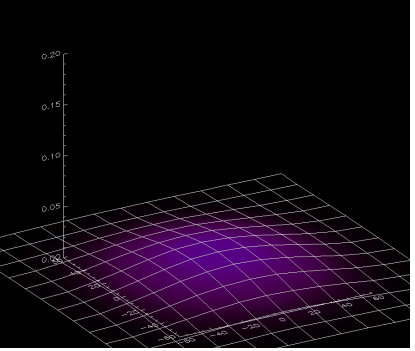


LatLonBiRes = 0.15; Smooth 9; weight>0.3

Computing Divergence in the Swath: Role of smoothing

ScatSCAT; Begin Day 2009-01-10; Days 01; Begin orbit 49791; # orbits = 0015; DIRTH; Only SST>-50.0; ;_crossCat00

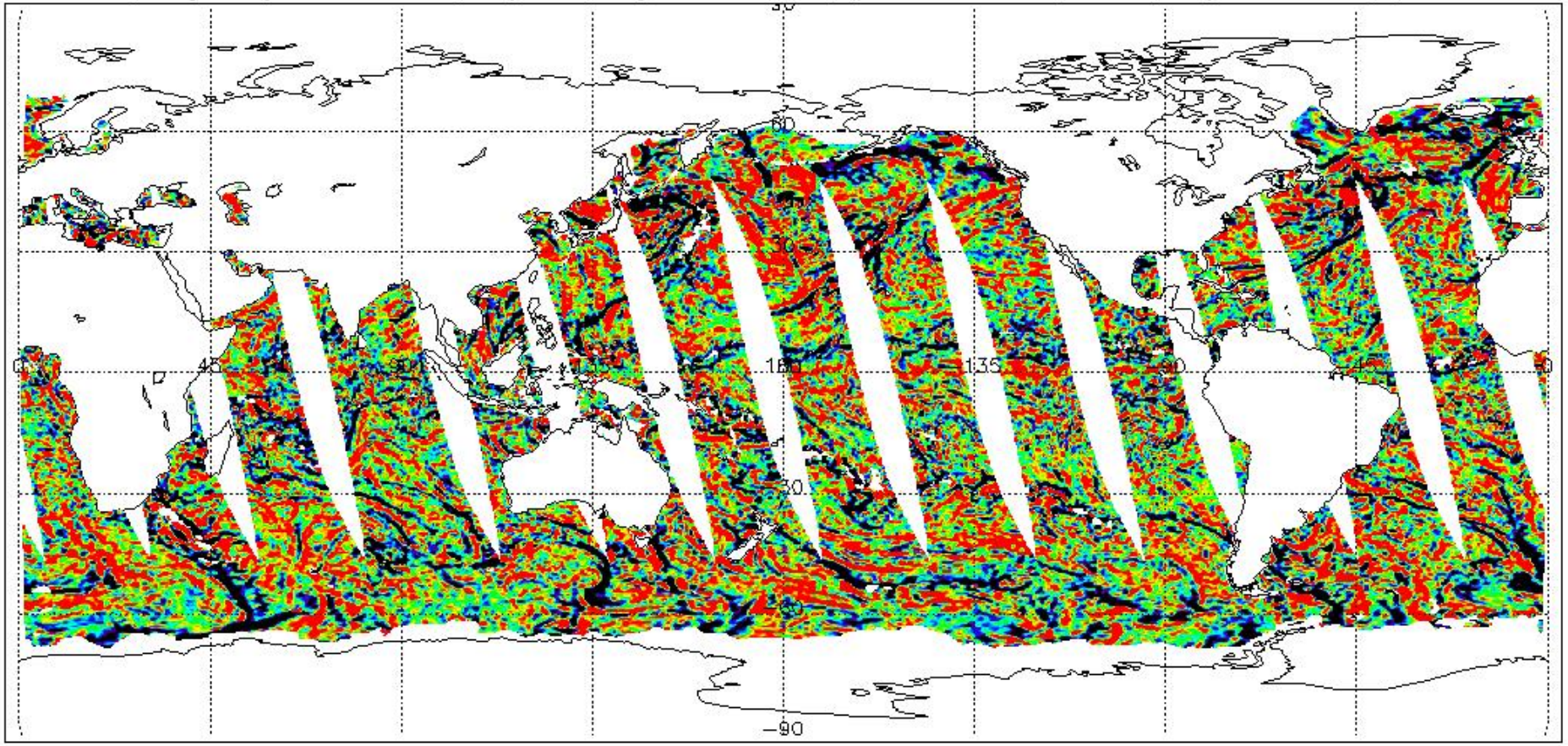




LatLonBiRes = 0.15; Smooth 13; weight>0.3

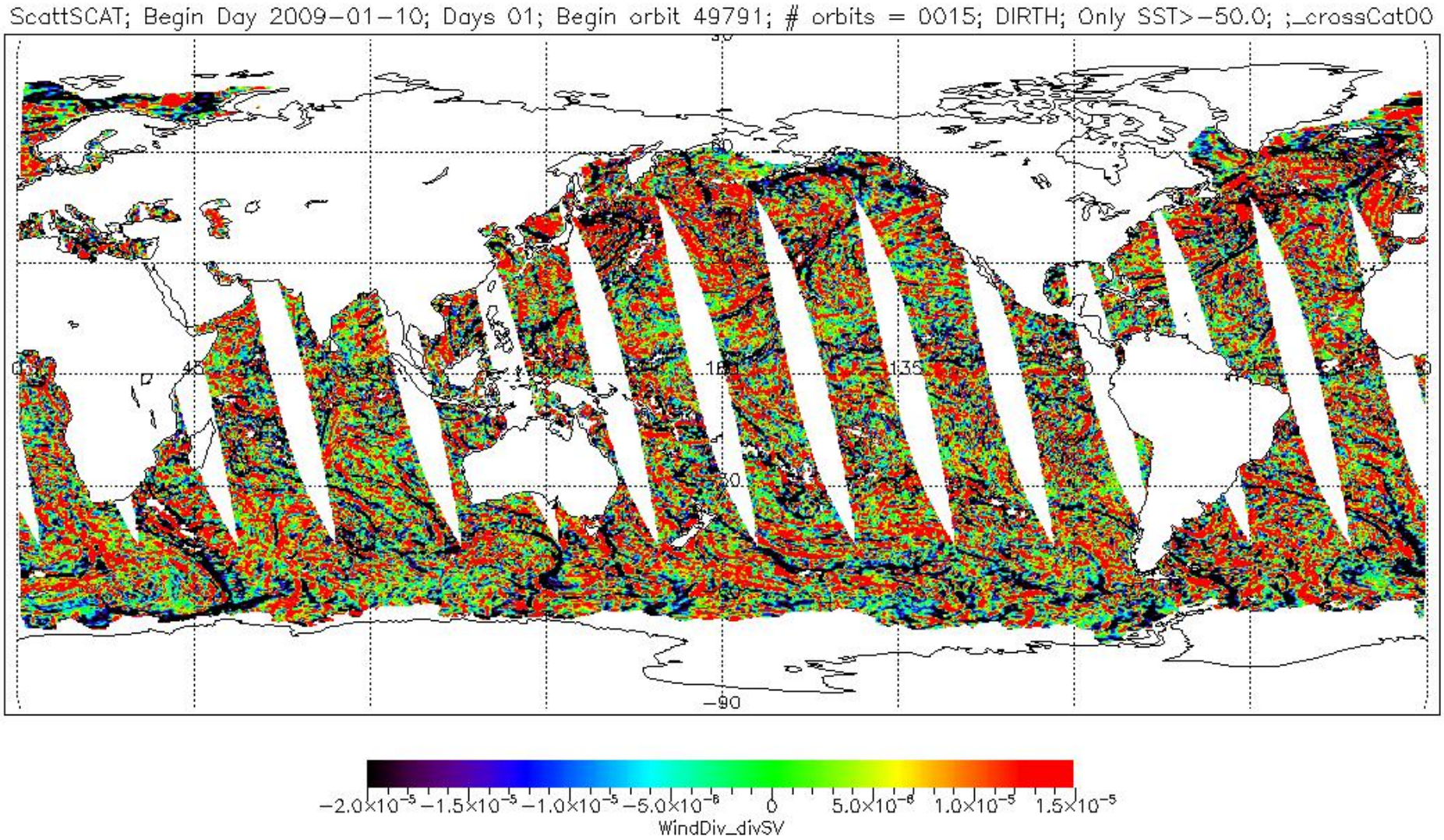
Computing Divergence in the Swath: Role of smoothing

ScatSCAT; Begin Day 2009-01-10; Days 01; Begin orbit 49791; # orbits = 0015; DIRTH; Only SST>-50.0; ;_crossCat00



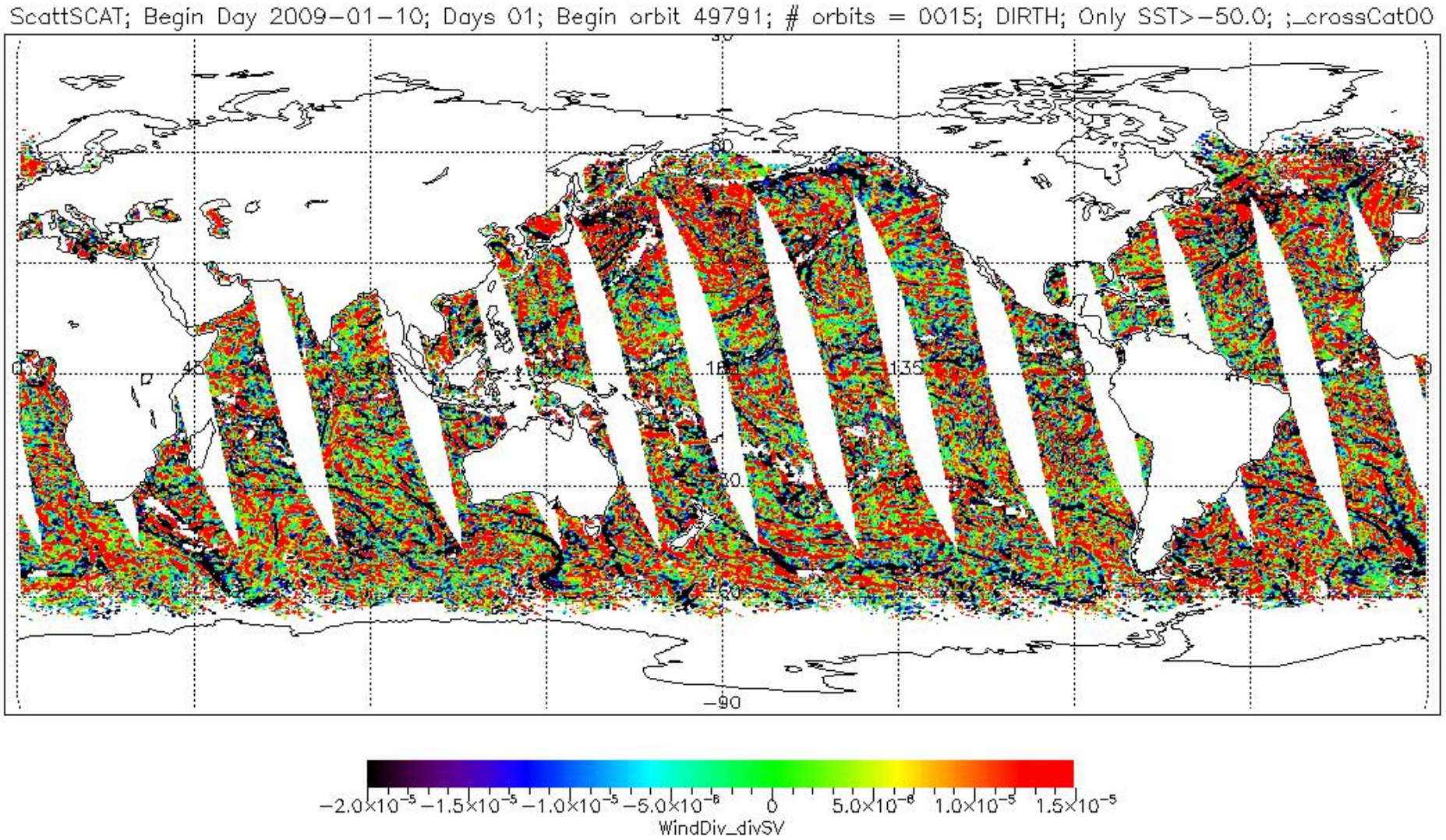
LatLonBiRes = 0.15; Smooth 5; weight>0.3

Computing Divergence in the Swath: Getting closer to the rain



LatLonBiRes = 0.15; Smooth 5; weight>0.75

Computing Divergence in the Swath: Getting closer to the rain



What we propose

- **Complete set of Level 3 scatterometer-specific products should be generated**
  - rules for aggregation
    - Select latest when swaths overlap (rare for daily maps separated by LTD)
  - rules for flagging
    - Use the ice/rain flag for selected data (e.g. latest)

- The L3 products **should include wind, stress and curl/divergence of wind & stress**
  - **Stress should be computed from the highest resolution swath data, then put on grid**
  - **The derivatives should be computed from the instantaneous/coincident swath data then put on grid**
    - there is need to smooth and need to fill out rainy holes
    - As a result: the need of some level of averaging; the need of some level of extrapolation
    - **Question: how much smoothing is not too much**
    - **Answer:**
      - **analyze spectra;**
      - **analyze mean zonal averages**
      - **relate to precipitation**