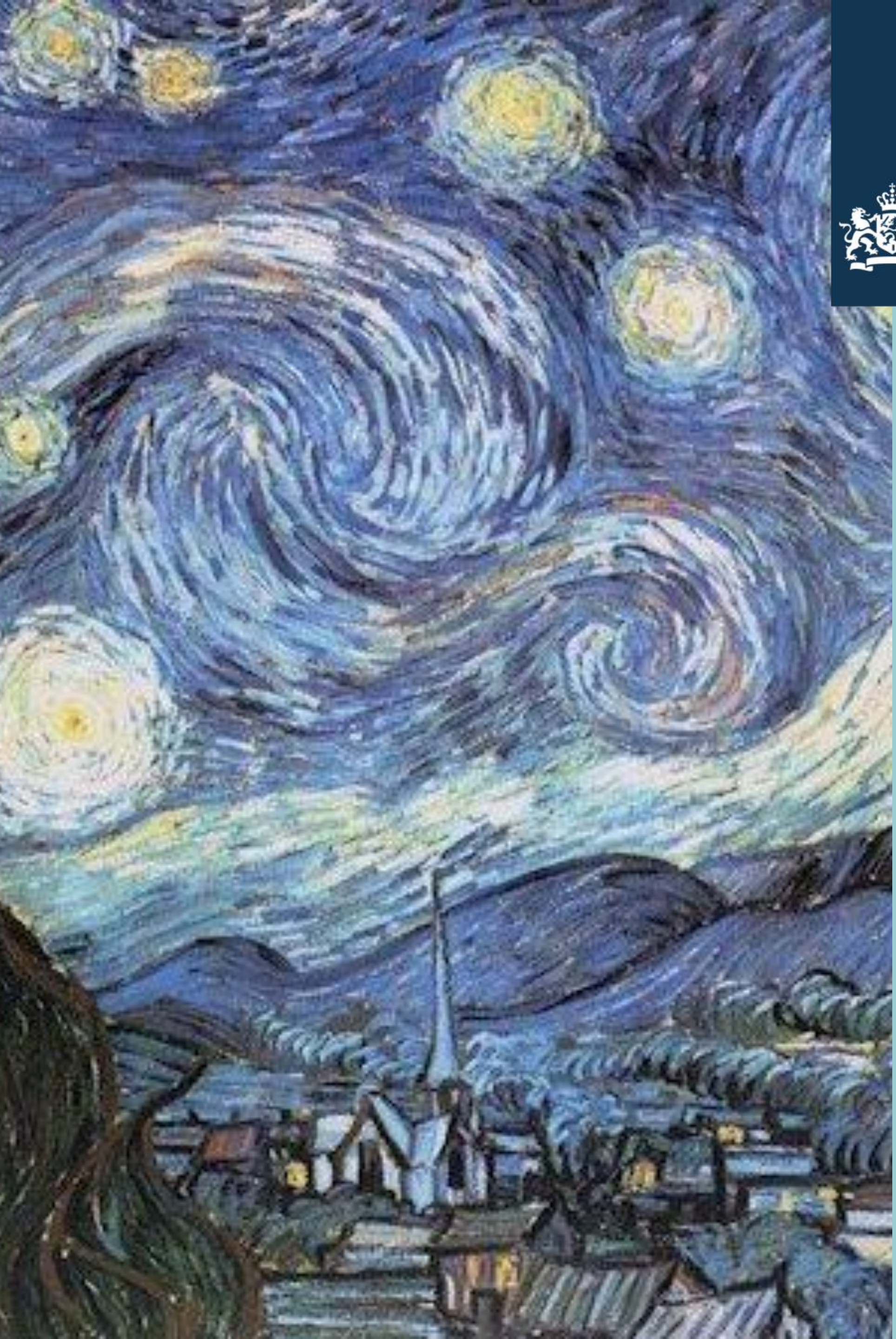

Royal Netherlands
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Signatures of upscale and downscale energy transfer in the near-surface winds over the Tropical Pacific

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IOVWST, May 2013

The EUMETSAT Network of Satellite Application Facilities

NWP SAF
Numerical Weather Prediction

Van Gogh first to depict $k^{-5/3}$

Two Mexican physicists, José Luis Aragón and Gerardo Naumis, have examined the patterns in Vincent van Gogh's

Starry Night

They found that the PDF of luminosity follows the -5/3 scaling law, as introduced later by Kolmogorov and as observed in the atmosphere < 500 km

See *Plus e-zine* for more information.

Why $k^{-5/3}$?

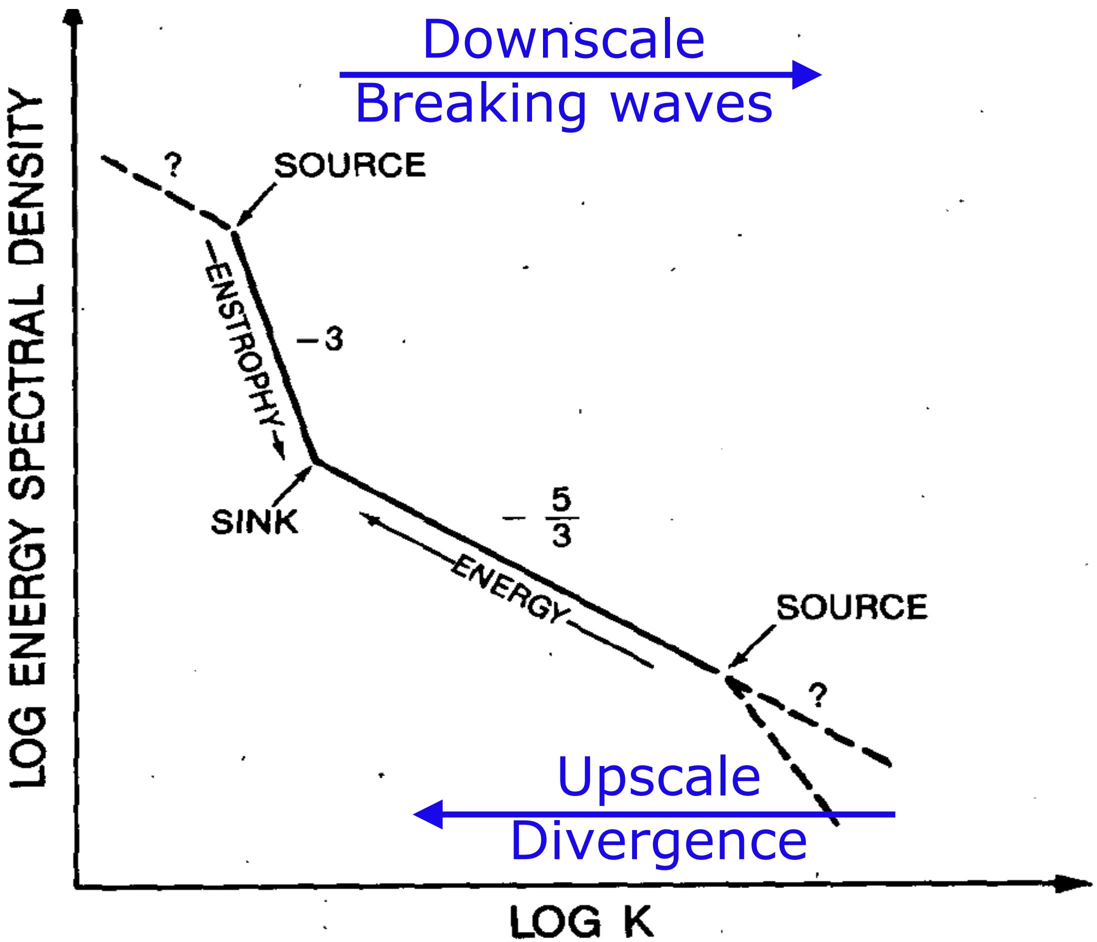


FIG. 1. Schematic representation of spectral ranges in quasi two-dimensional turbulence (after Larsen et al., 1982).

- 2D Turbulence
  - Energy & Enstrophy conserved
  - No vortex stretching
- 3D Turbulence
  - Enstrophy not conserved
  - Vortex stretching present
- QG Turbulence
  - Energy & Enstrophy conserved (like 2D)
  - Vortex stretching present (like 3D)
- Role of convection / downbursts ?

Current Picture

Below about 500 km, the downscale energy cascade begins to dominate the energy spectrum.

The $k^{-5/3}$ slope is evident at scales smaller than this.

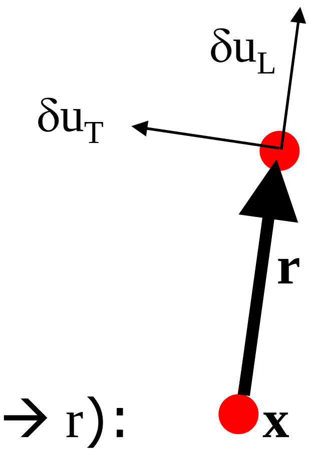
The $k^{-5/3}$ slope is probably augmented by an inverse energy cascade from convective scales.

- 3rd order structure functions are relatively insensitive to scatterometer instrument and processing effects, but reveal meteorological characteristics, in particular distinguish upscale and downscale processes

- Compute 3rd order structure functions from surface wind data

Structure functions - definitions

Velocity increments:



$$\delta u_L(\mathbf{x},\mathbf{r}) = u_L(\mathbf{x}+\mathbf{r}) - u_L(\mathbf{x})$$
$$\delta u_T(\mathbf{x},\mathbf{r}) = u_T(\mathbf{x}+\mathbf{r}) - u_T(\mathbf{x})$$

2nd order structure functions (assuming isotropy: $\mathbf{r} \rightarrow r$):

$$D_{AB}(r) = \langle \delta u_A \delta u_B \rangle, \quad A,B = L,T$$

$$D_2(r) = D_{LL}(r) + (d-1) D_{TT}(r), \quad d = 2,3$$

3rd order structure functions analogous to 2nd ord

$$D_3(r) = D_{LLL}(r) + (d-1) D_{LLT}(r), \quad d = 2,3$$

$$S = \frac{D_3}{D_2^{3/2}} \quad \text{Skewness}$$

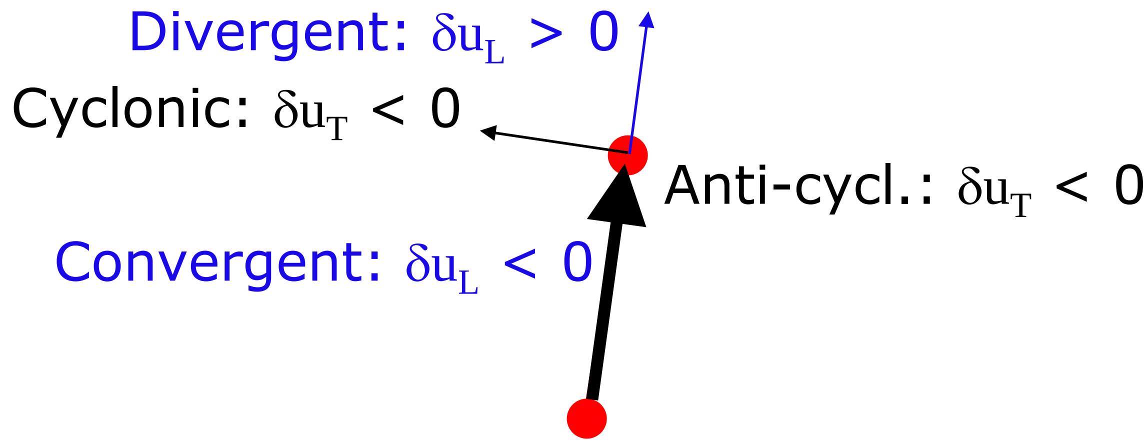
Kolmogorov 1941:

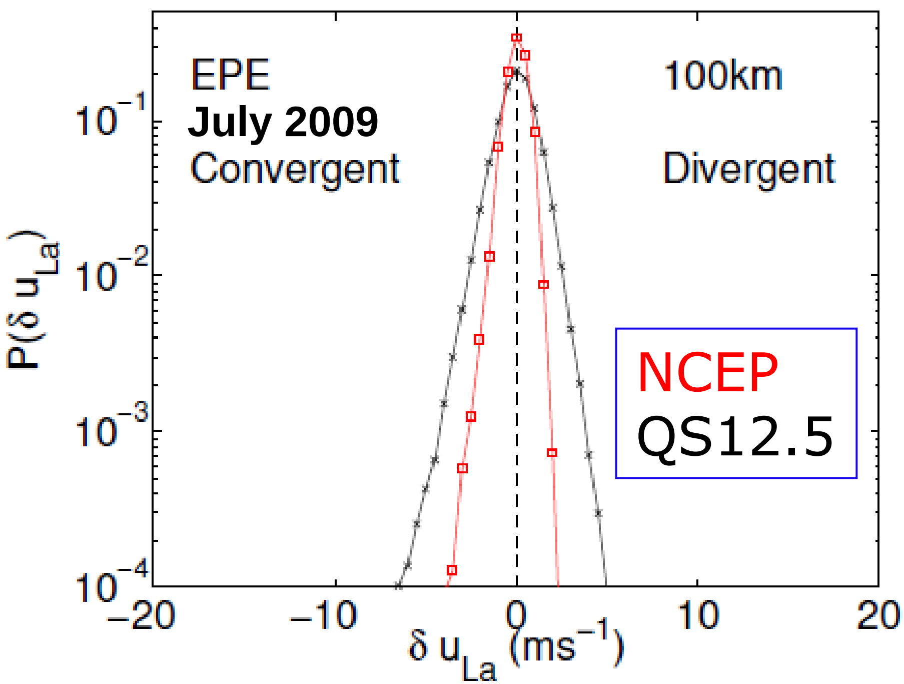
$$D_{LLL}(r) = -\frac{4}{5}\varepsilon r$$

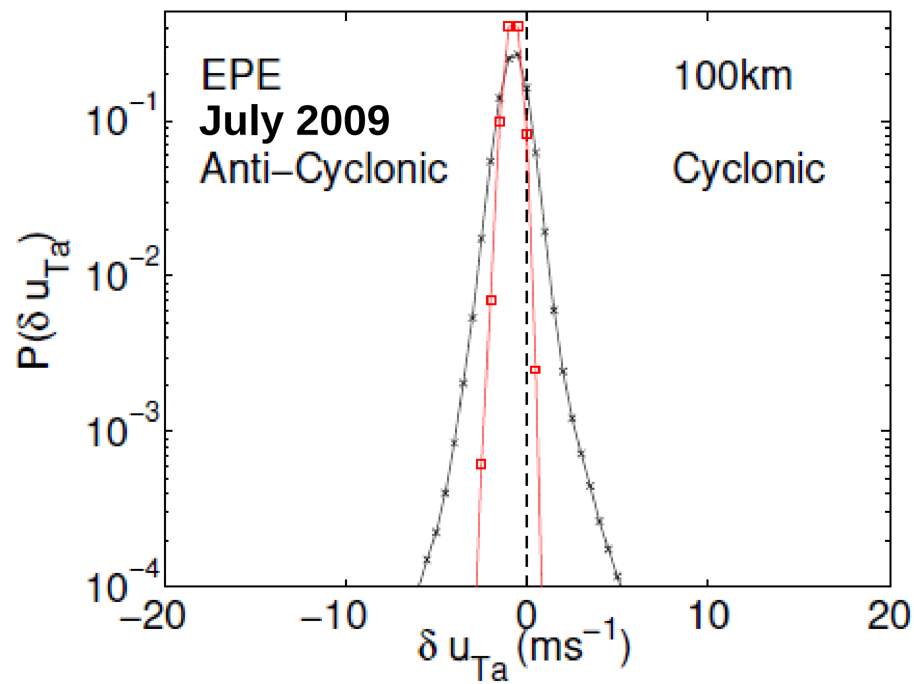
(3D turbulence)

δu_L and δu_T

- r=100km
  - Scatterometer more variable than NWP
  - Skewness in PDFs



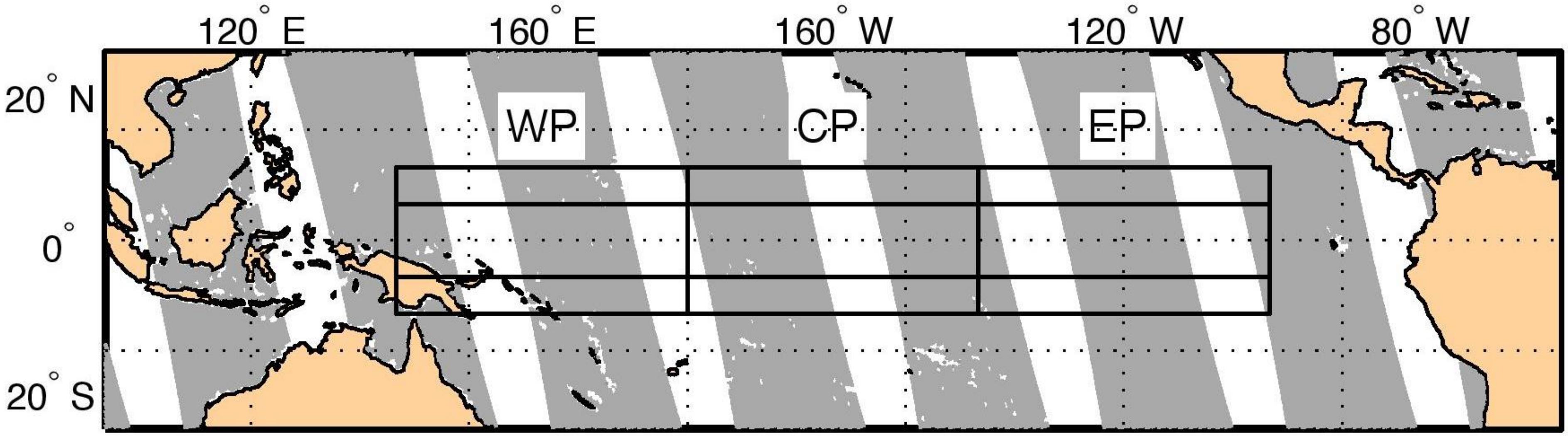




Study area

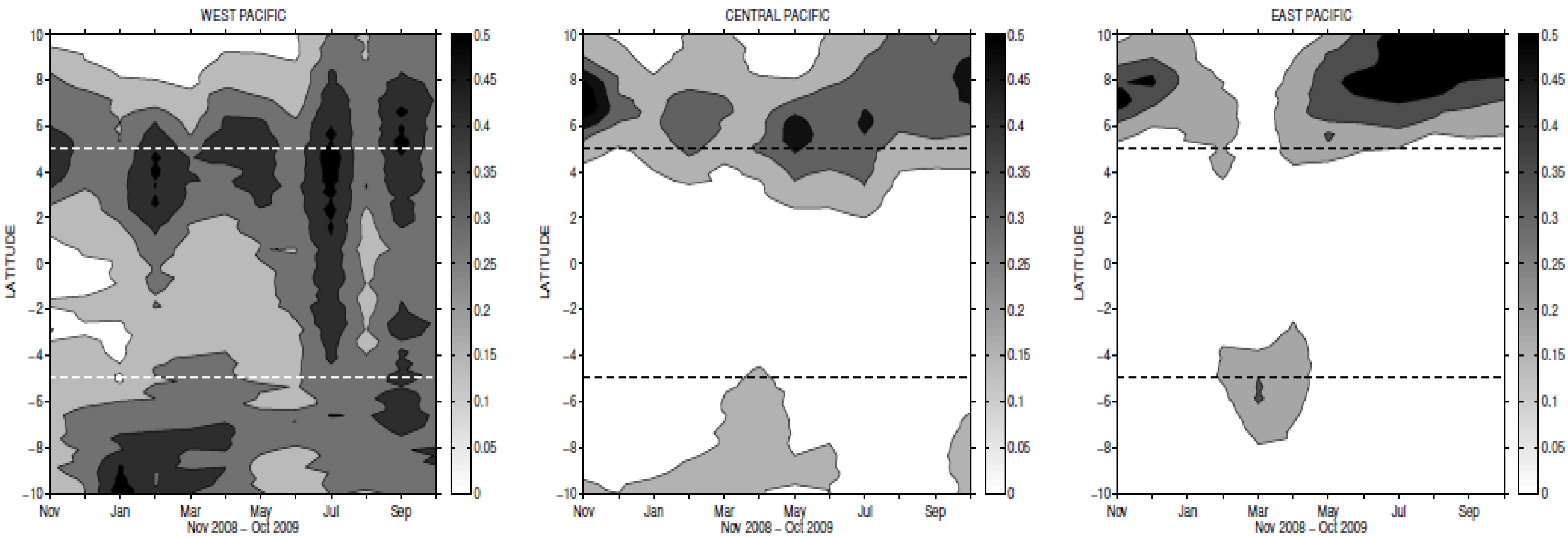
Tropical Pacific between 140 E and 100 W

- Three longitude bands (WP,CP,EP)
- Three latitude bands (N,E,S)
- Study period Nov 2008 – Oct 2009 (QuikSCAT and ASCAT)



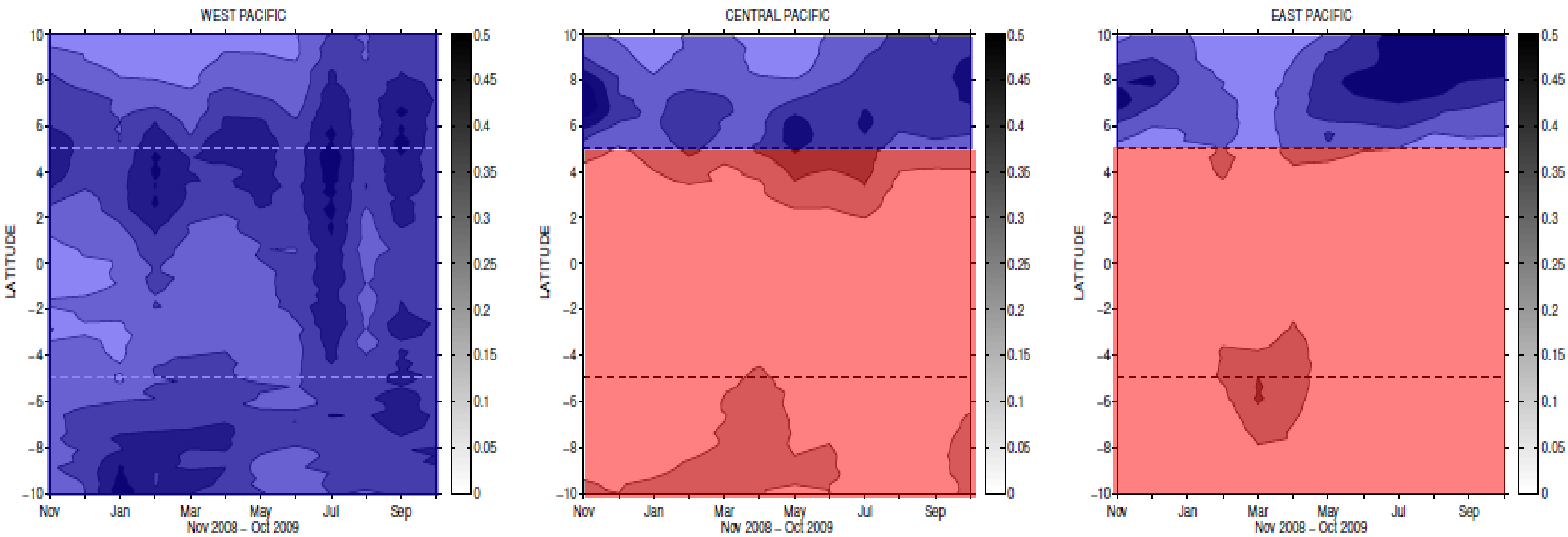
Rain

SRAD rain rates (monthly averaged)



Rain

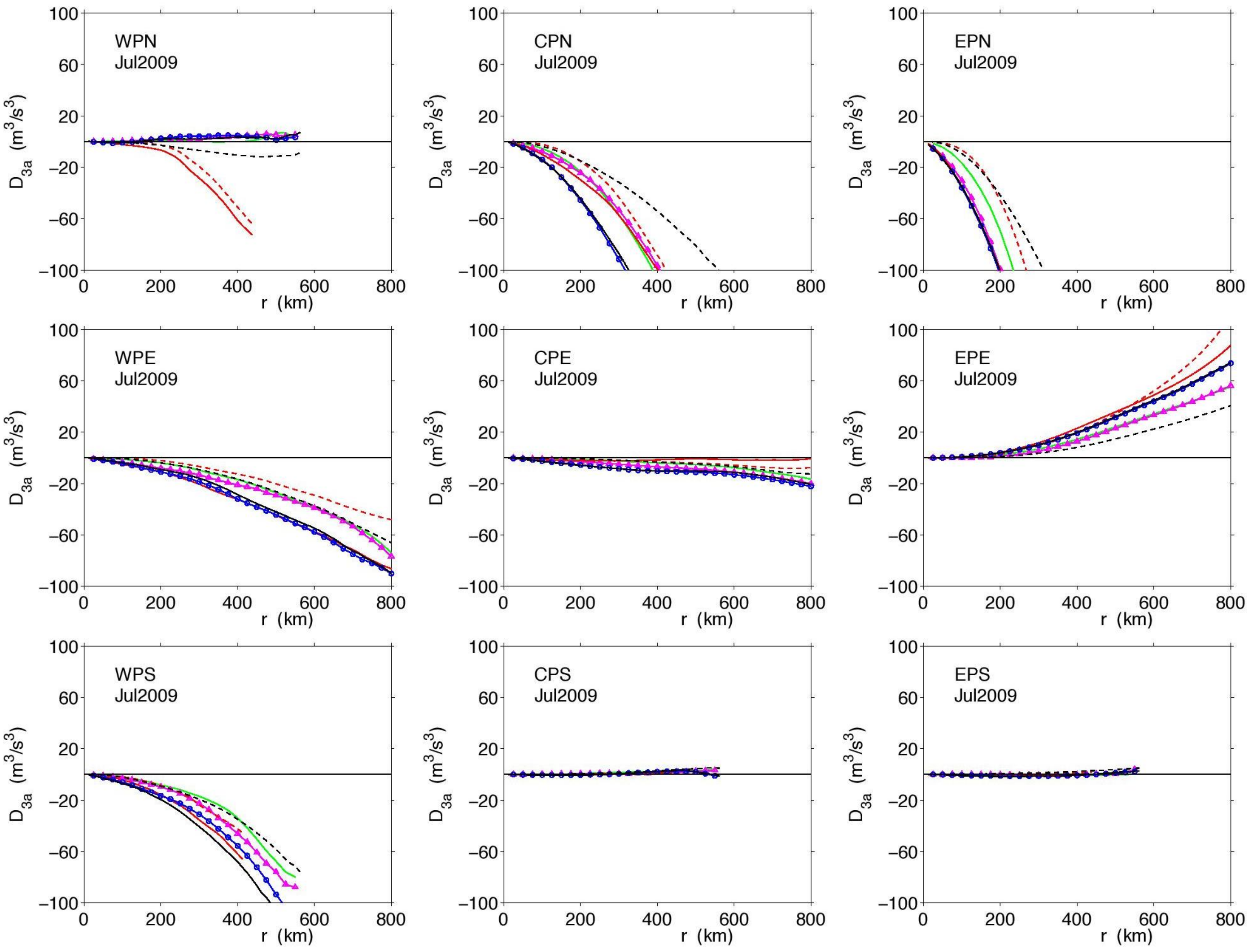
SRAD rain rates (monthly averaged)



Generally wet

Generally dry

Regional variability

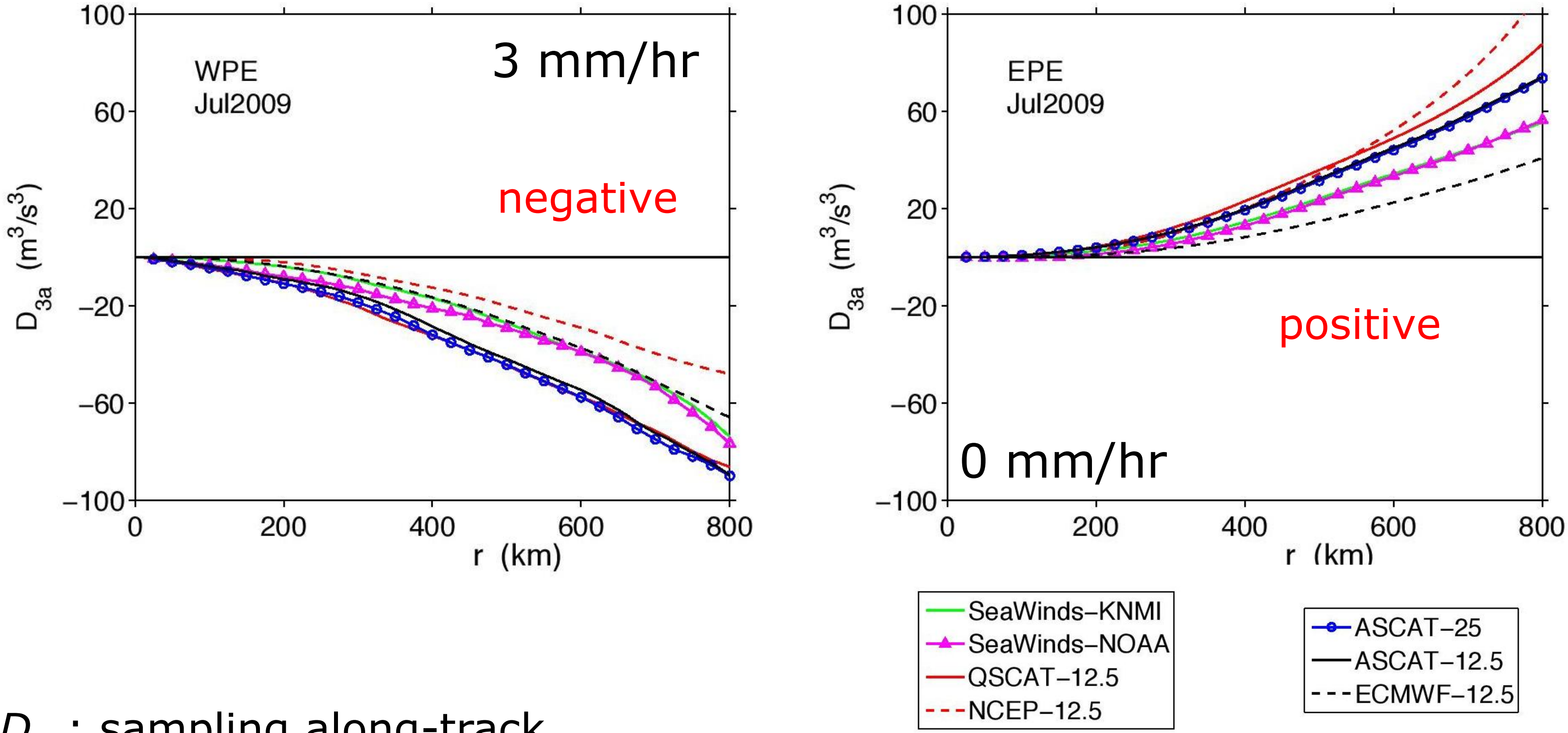


D_{3a} vs r

July 2009

- All wind products show generally similar basin values
- Each basin has rather different values

Wet and dry



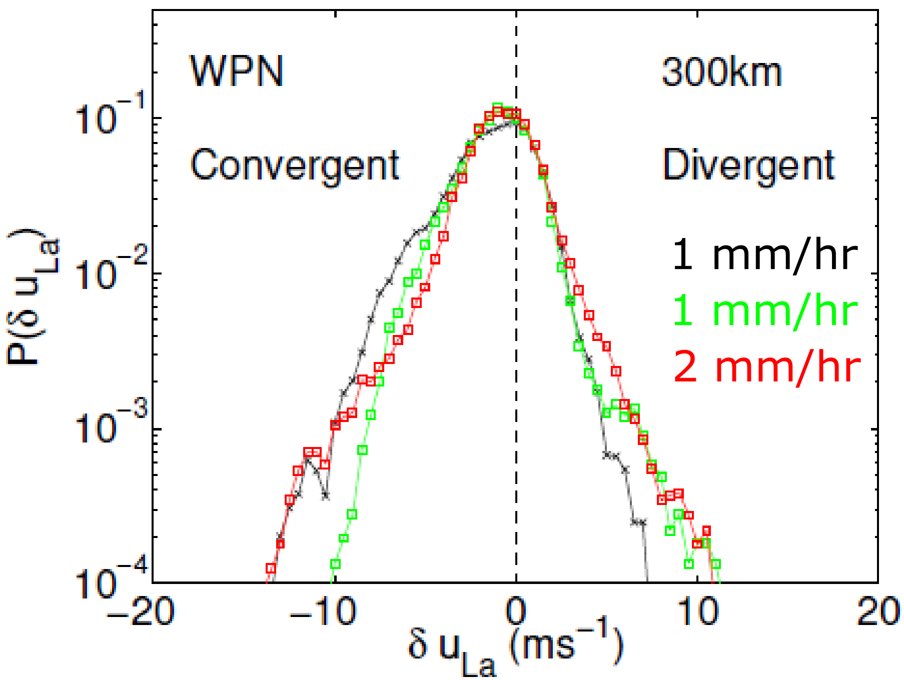
D_{3a}: sampling along-track

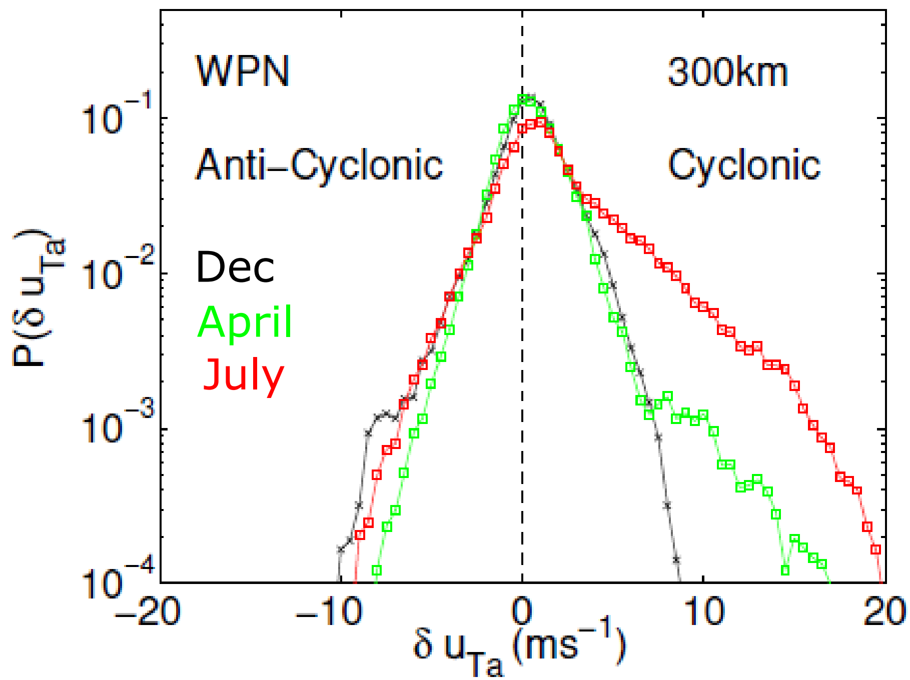
WPE : West Pacific (140E-180E), Equatorial (5S- 5N)

EPE : East Pacific (220E-260E), Equatorial

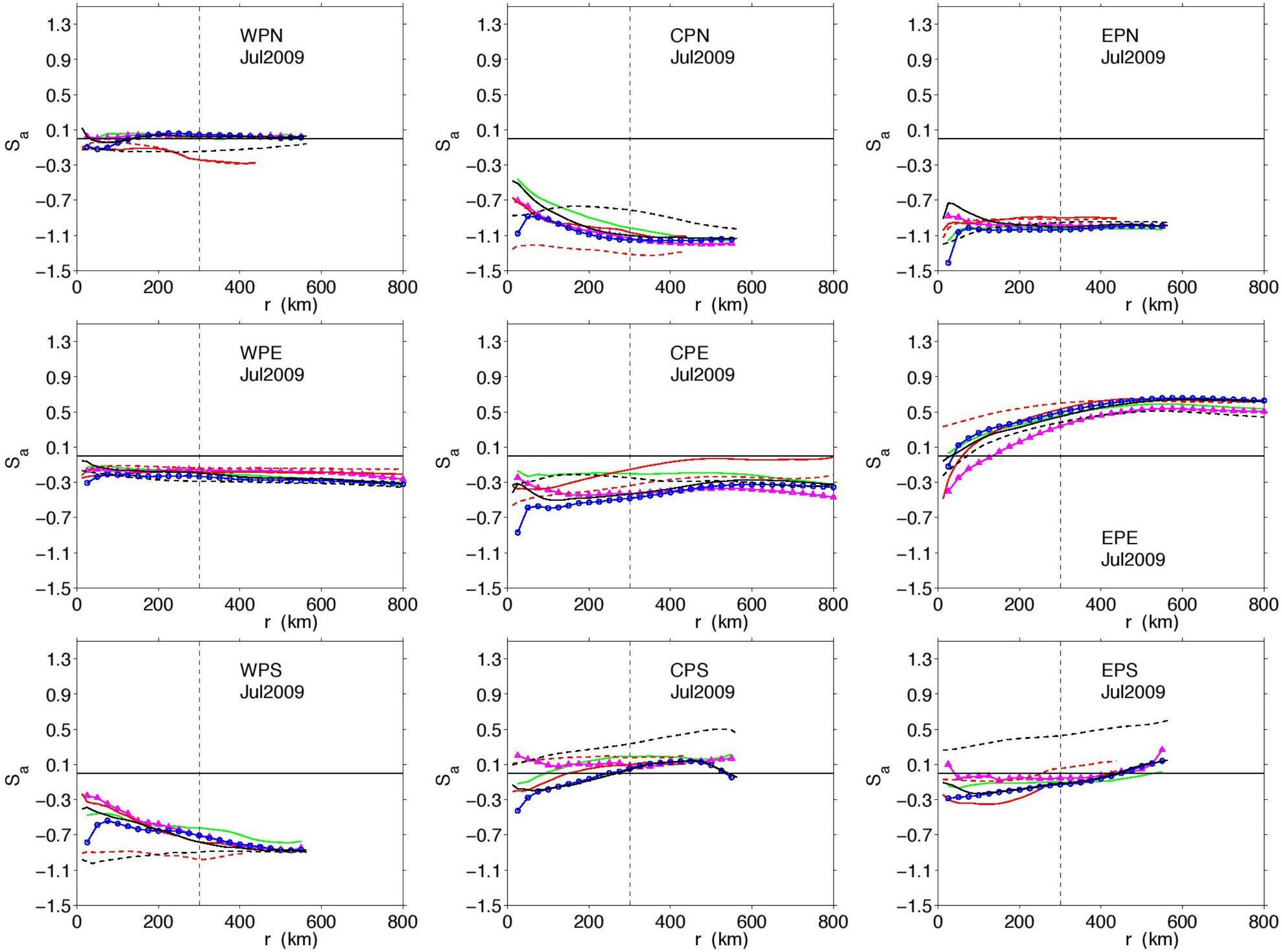
δu_L and δu_T PDFs

- Rain affects structure of δu_L and δu_T and therefore D_3 and S
- Cyclonic activity in WPN in wettest month
- Inversion errors?
  Due downburst variability or rain contamination ?





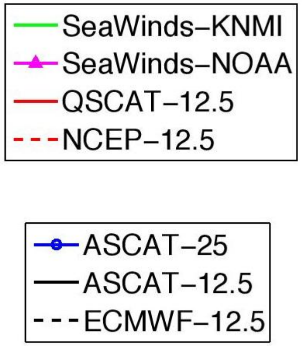
Regional variability Skewness



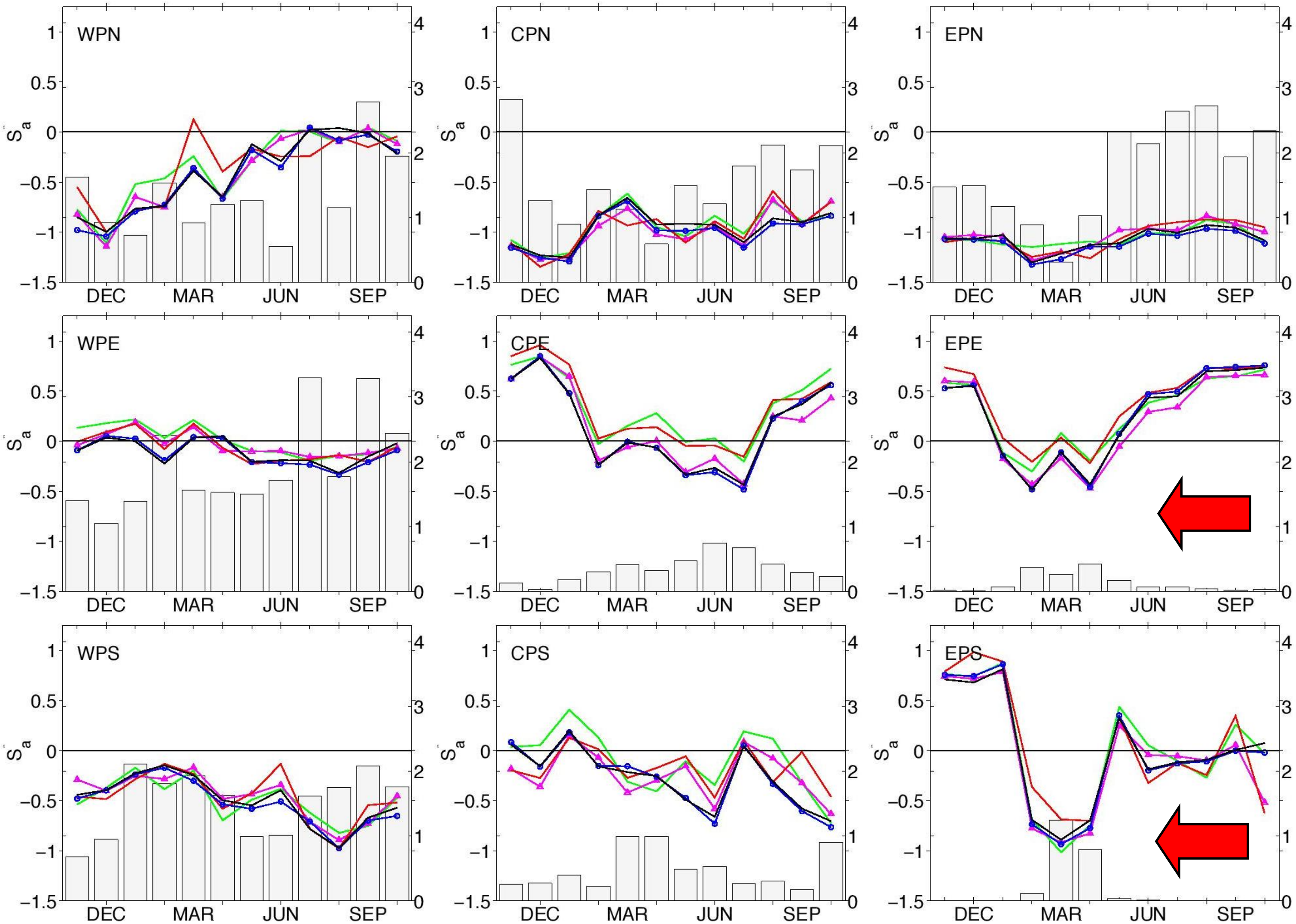
Skewness vs *r*

In general good agreement between various products

Take value at 300 km



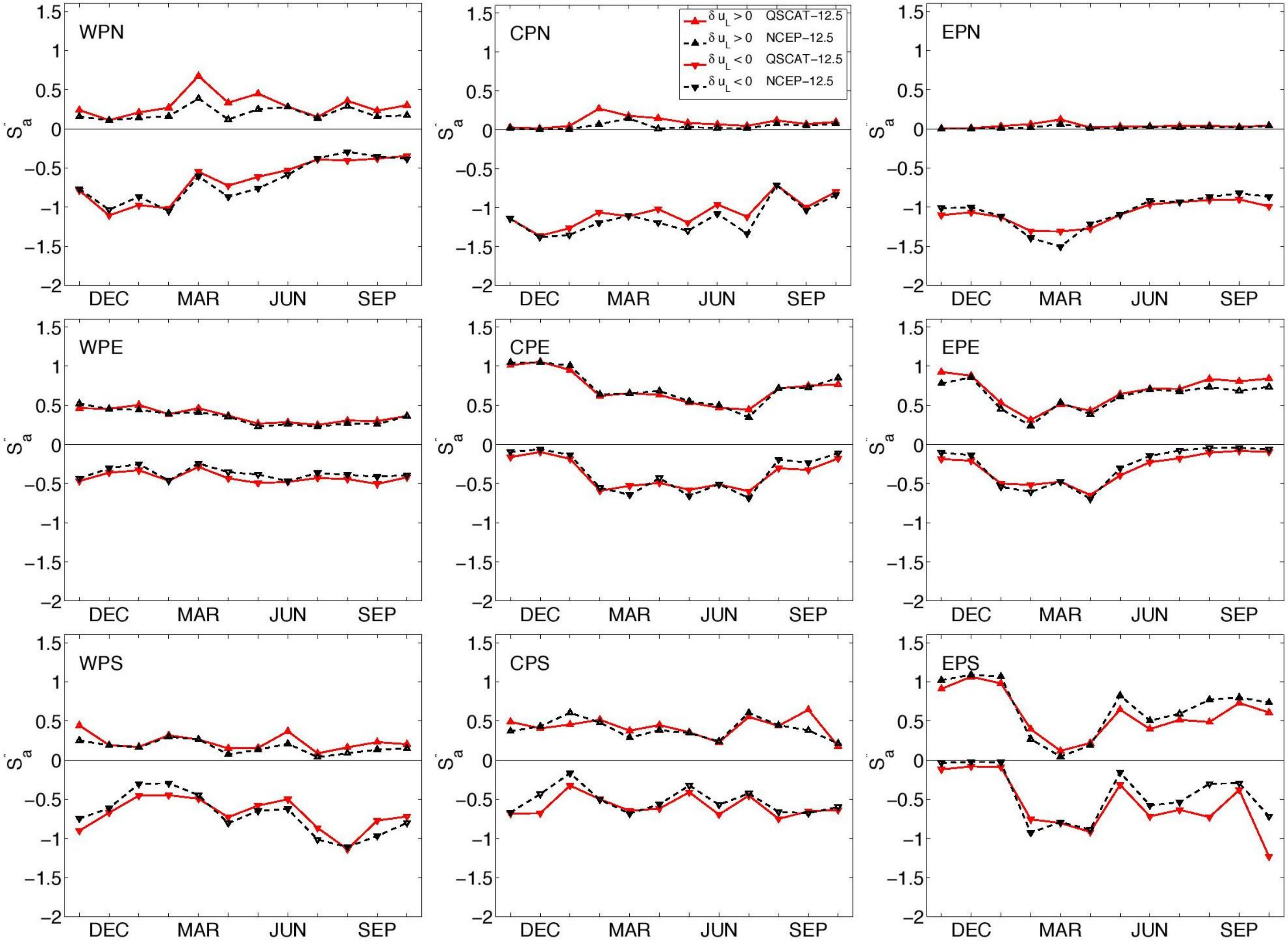
Time series



Time series of skewness at 300 km with SRAD monthly rain rates (grey bars)

Negative skewness correlated with rain

Results



Skewness at 300 km separated into divergent (⇩) and convergent (⇧) contributions for QSCAT-12.5 (red) and NCEP-12.5 (black)

Conclusions

- Product-independent conclusions possible when studying 3rd order structure functions, in particular the skewness (at 300 km):
- Downscale signatures (negative skewness) where and when surface convergence (i.e., deep convection) dominates;
- Upscale signatures (positive skewness) where and when surface divergence dominates;
- Zero skewness where and when near-equal levels of convergence and divergence occur (during averaging period).
- Energy transfer in the atmospheric mesoscales appears both upscale and downscale, with relative magnitudes that vary regionally and seasonally

- So the question whether turbulence is 2D or 3D can be answered with “Yes”

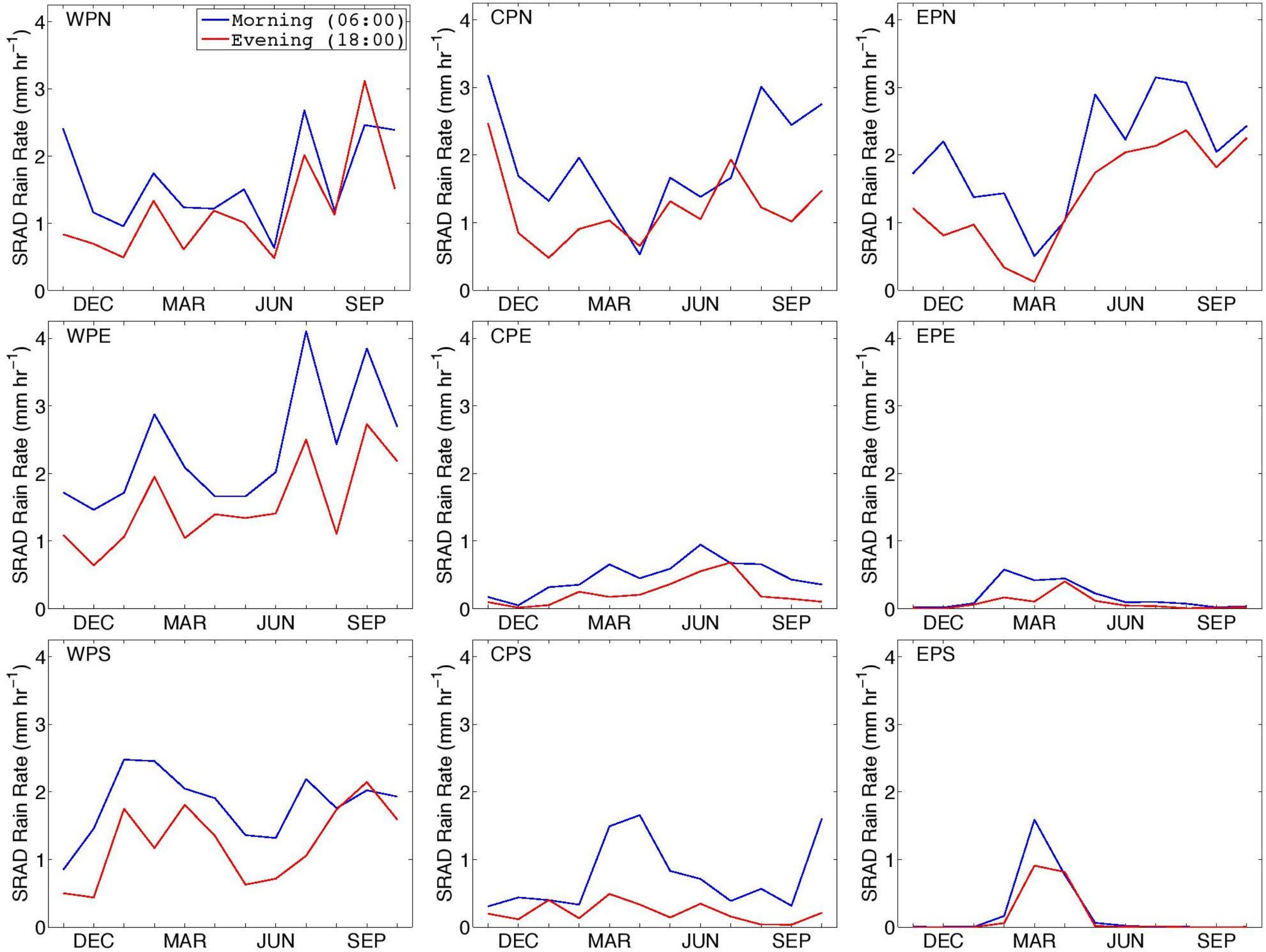
Introduction

- Results from 2nd order structure function analysis on scatterometer wind products derived from QuikSCAT and ASCAT show effects of both instruments/processing and meteorological influences
- Some first results on 3rd order structure functions presented at last years IOVWST by Greg King
- Contents:
- - Study area
- - Data used
- - Structure function definitions
- - Results
- - Conclusions

➢ Analysis now completed; 3rd order structure functions are relatively insensitive to scatterometer instrument and processing effects, but reveal meteorological characteristics

Rain data

SRAD
rain rates
(monthly
averaged)



Winds used

QuikSCAT-NOAA (Operational product @ 25 km grid size)
QuikSCAT-KNMI (Operational product @ 25 km)
ASCAT-25 (Operational product @ 25 km)
ASCAT-12.5 (Operational product @ 12.5 km)
QSCAT-12.5 (Science product @ 12.5 km v.3)

ECMWF
GFS