Circumventing rain contamination in scatterometer wind observations

Thomas Kilpatrick
Shang-Ping Xie

SCRIPPS INSTITUTION OF OCEANOGRAPHY
UC San Diego

Motivation

The interaction between atmospheric convection and winds is a bottleneck in atmospheric science.

Better observations and understanding of convection-wind coupling could improve the representation of convection in models.

Rain contamination is a long-standing problem in scatterometry (e.g., Weissman et al. 2012), confounding observational study of convection-wind coupling.

Motivation

The interaction between atmospheric convection and winds is a bottleneck in atmospheric science.

Better observations and understanding of convection-wind coupling could improve the representation of convection in models.

Rain contamination is a long-standing problem in scatterometry (e.g., Weissman et al. 2012), confounding observational study of convection-wind coupling.

Can we recover wind signals in rainy areas from existing (Ku-band) scatterometer datasets?

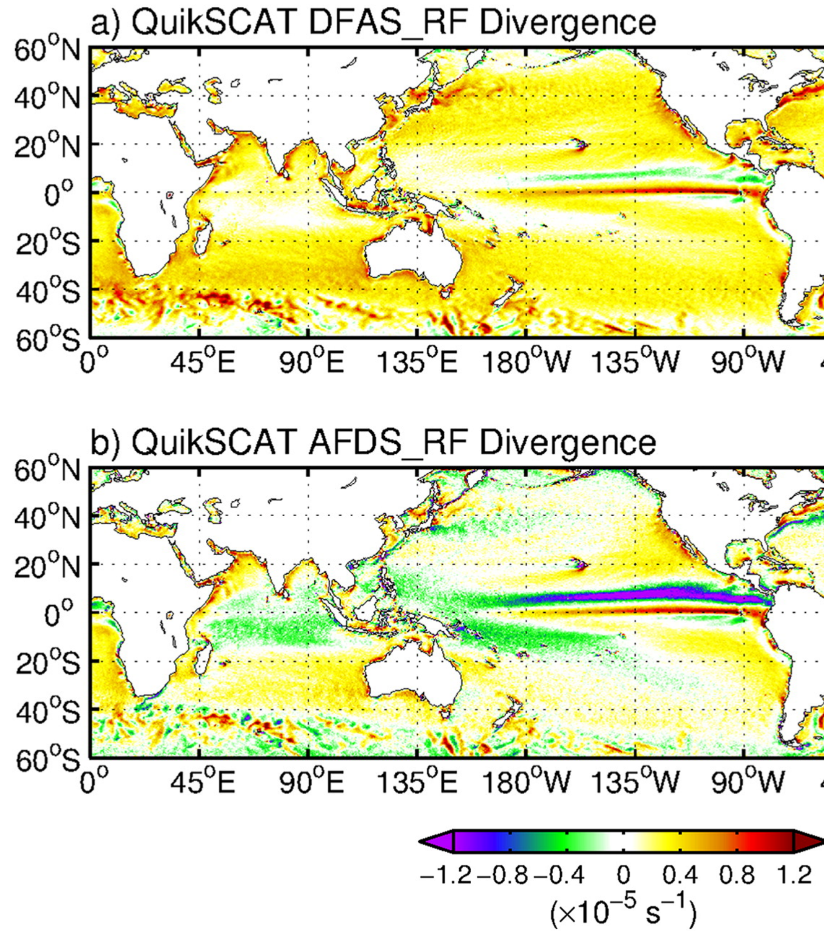
Surface winds in rainy areas have a disproportionate impact on wind climatologies

Divergence computed "in-swath."

"Derivatives first, averages second (DFAS)."

Winds *(u,v)* time-averaged first, then spatial derivatives.

"Averages first, derivatives second (AFDS)."



O'Neill et al. (2015), *J. Climate*

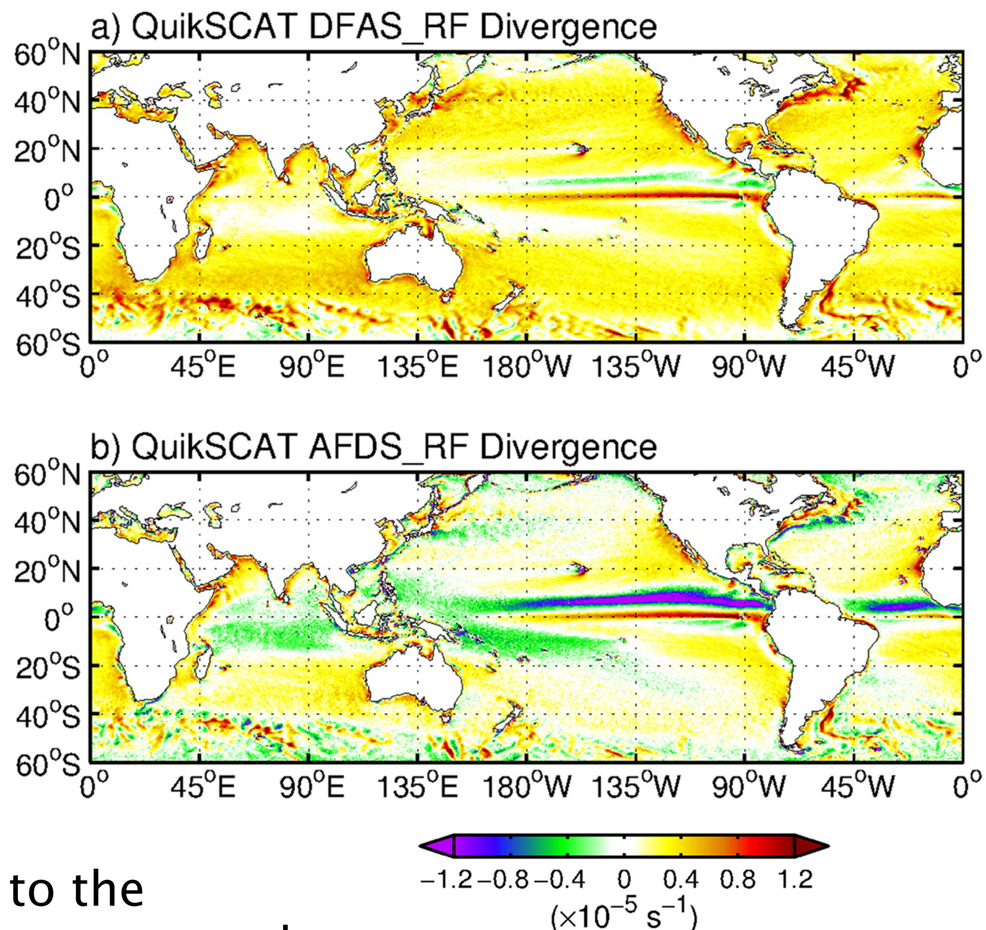
Surface winds in rainy areas have a disproportionate impact on wind climatologies

Divergence computed "in-swath."

"Derivatives first, averages second (DFAS)."

Winds *(u,v)* time-averaged first, then spatial derivatives.

"Averages first, derivatives second (AFDS)."



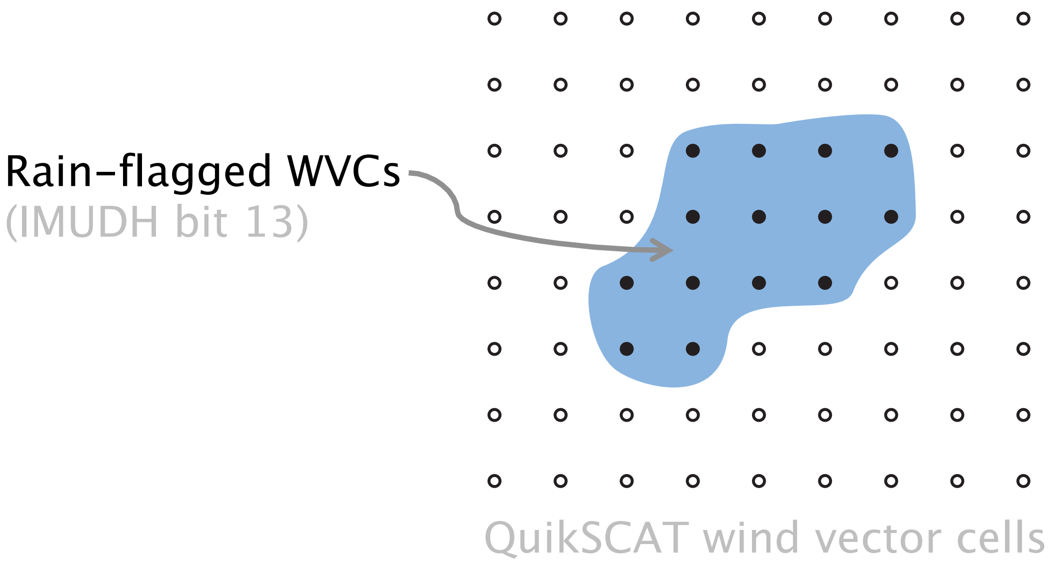
O'Neill et al. (2015), *J. Climate*

The DFAS "divergence bias" is due to the physical link between surface convergence and rainfall, i.e. omitting rain-flagged WVCs results in a sampling bias (O'Neill et al. 2015).

Surface wind climatologies are very sensitive to the method of handling rain-contaminated WVCs

$$\nabla \cdot \mathbf{u} = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$

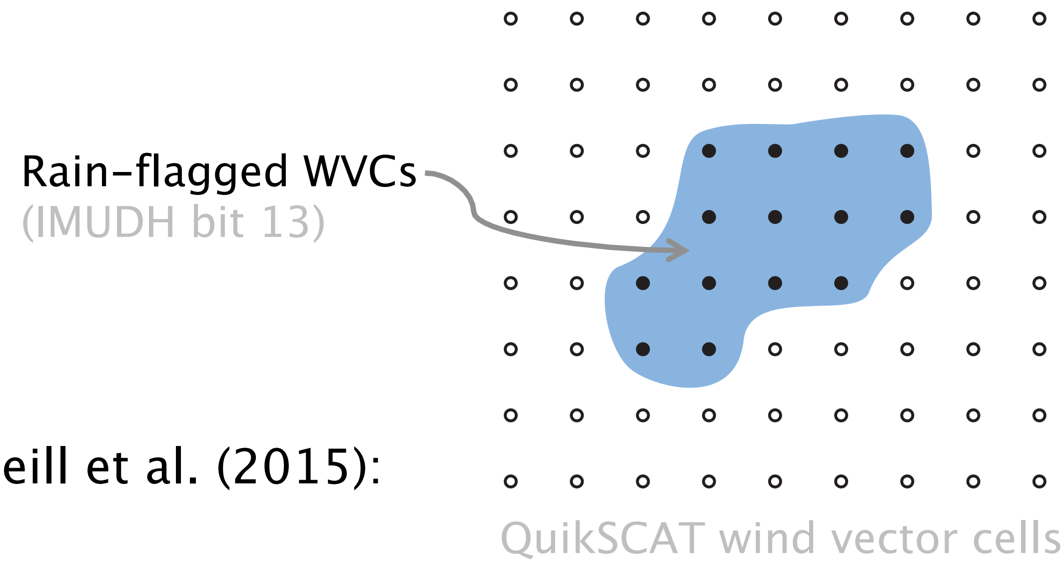
$$\nabla \times \boldsymbol{\tau}_s = \frac{\partial \tau_{sy}}{\partial x} - \frac{\partial \tau_{sx}}{\partial y}$$



Surface wind climatologies are very sensitive to the method of handling rain-contaminated WVCs

$$\nabla \cdot \mathbf{u} = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$

$$\nabla \times \boldsymbol{\tau}_s = \frac{\partial \tau_{sy}}{\partial x} - \frac{\partial \tau_{sx}}{\partial y}$$



Two methods discussed in O'Neill et al. (2015):

DFAS ("derivatives first, averages second")

i.e., taking derivatives "in-swath"

spatial derivatives are not taken at WVCs neighboring rain

AFDS ("averages first, derivatives second")

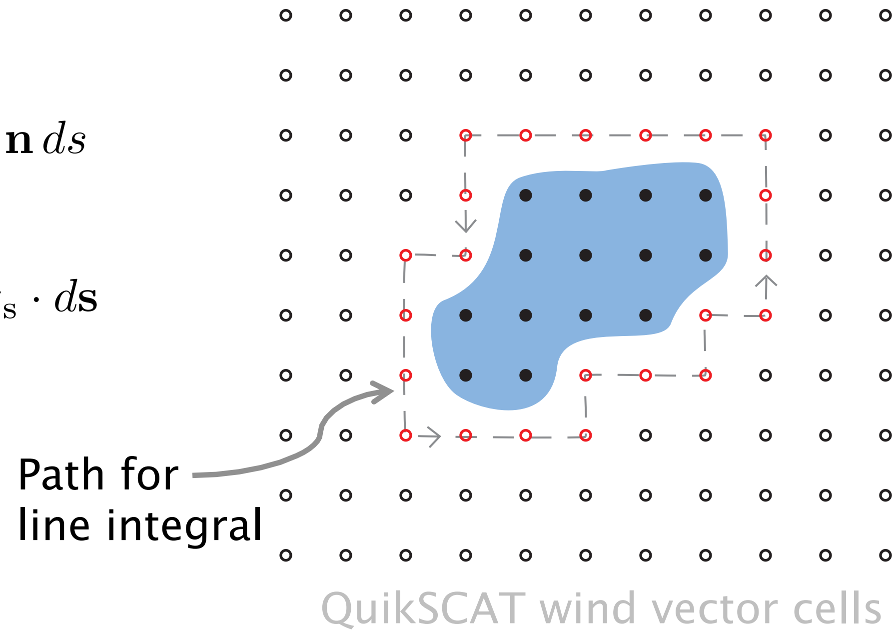
WVCs neighboring rain contribute to time-averaged *(u,v)*

Computing derivatives via line integrals *around* rainy patches recovers critical information about the wind field

$$\mathrm{Div} = A^{-1} \int_A (\nabla \cdot \mathbf{u})\, dA = A^{-1} \oint_S \mathbf{u} \cdot \mathbf{n}\, ds$$

$$\mathrm{WSC} = A^{-1} \int_A (\nabla \times \boldsymbol{\tau}_\mathrm{s})\, dA = A^{-1} \oint_S \boldsymbol{\tau}_\mathrm{s} \cdot d\mathbf{s}$$

Bourassa and McBeth-Ford (2010)
Holbach and Bourassa (2014)

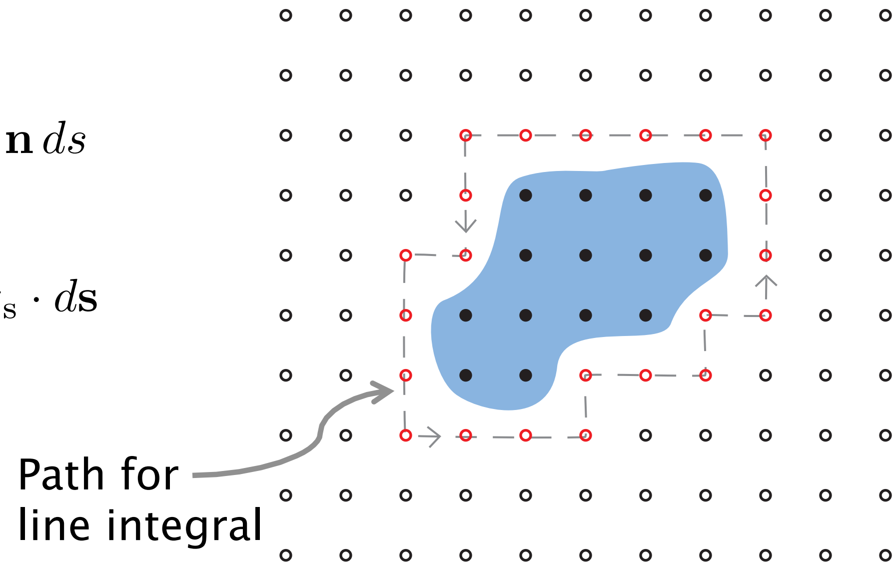


Computing derivatives via line integrals *around* rainy patches recovers critical information about the wind field

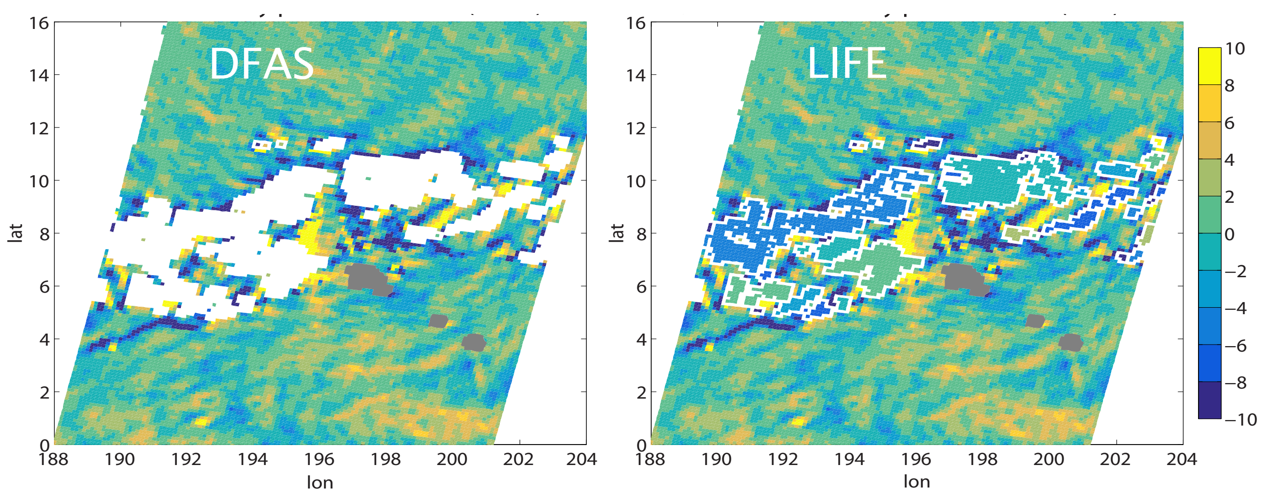
$$\mathrm{Div} = A^{-1}\int_A (\nabla\cdot\mathbf{u})\,dA = A^{-1}\oint_S \mathbf{u}\cdot\mathbf{n}\,ds$$

$$\mathrm{WSC} = A^{-1}\int_A (\nabla\times\boldsymbol{\tau}_\mathrm{s})\,dA = A^{-1}\oint_S \boldsymbol{\tau}_\mathrm{s}\cdot d\mathbf{s}$$

Bourassa and McBeth-Ford (2010)
Holbach and Bourassa (2014)



QuikSCAT wind vector cells



“Line integral, fill holes” (LIFE)

Data and method

JPL QuikSCAT version 3 winds (Nov. 1999–Oct. 2009).

Utilize the IMUDH rain flag (Stiles and Dunbar, 2010; Fore et al., 2014).

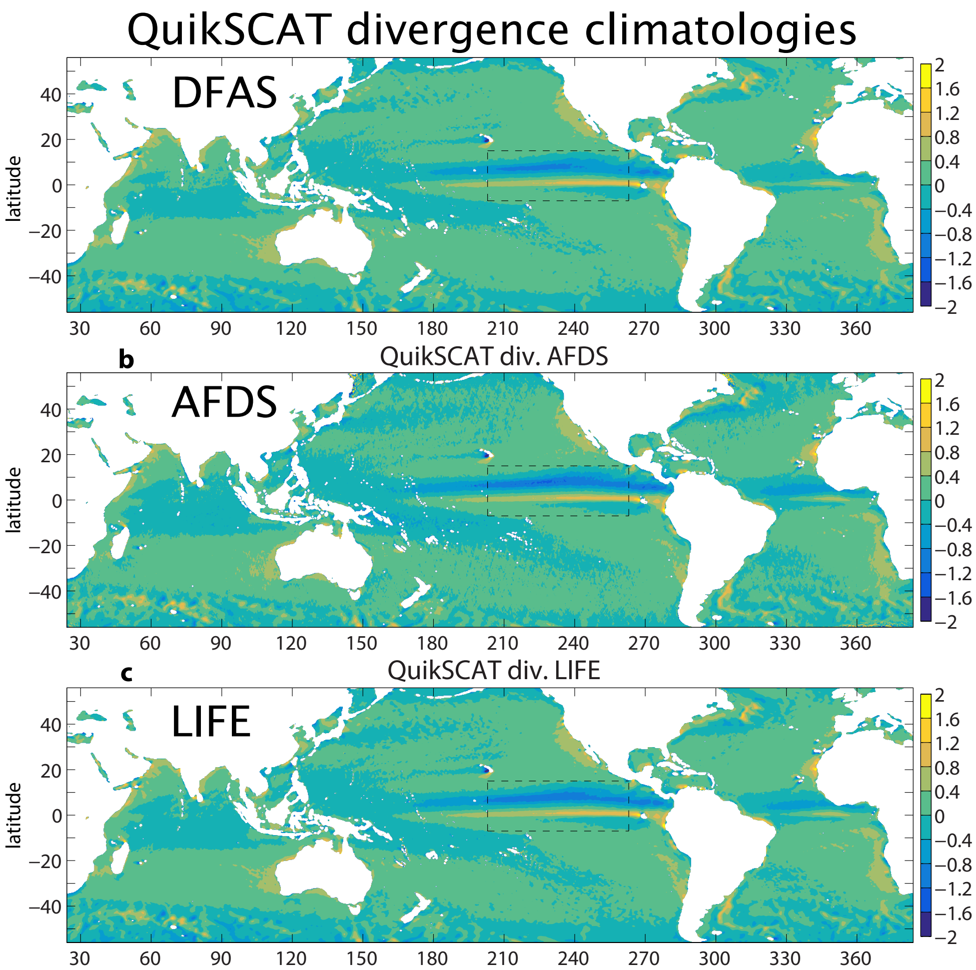
Compare the QuikSCAT divergence and wind stress curl computed via DFAS, AFDS, and LIFE.

Use NCEP's CFSR reanalysis winds as a benchmark.

Error analysis using an explicit-convection numerical model,

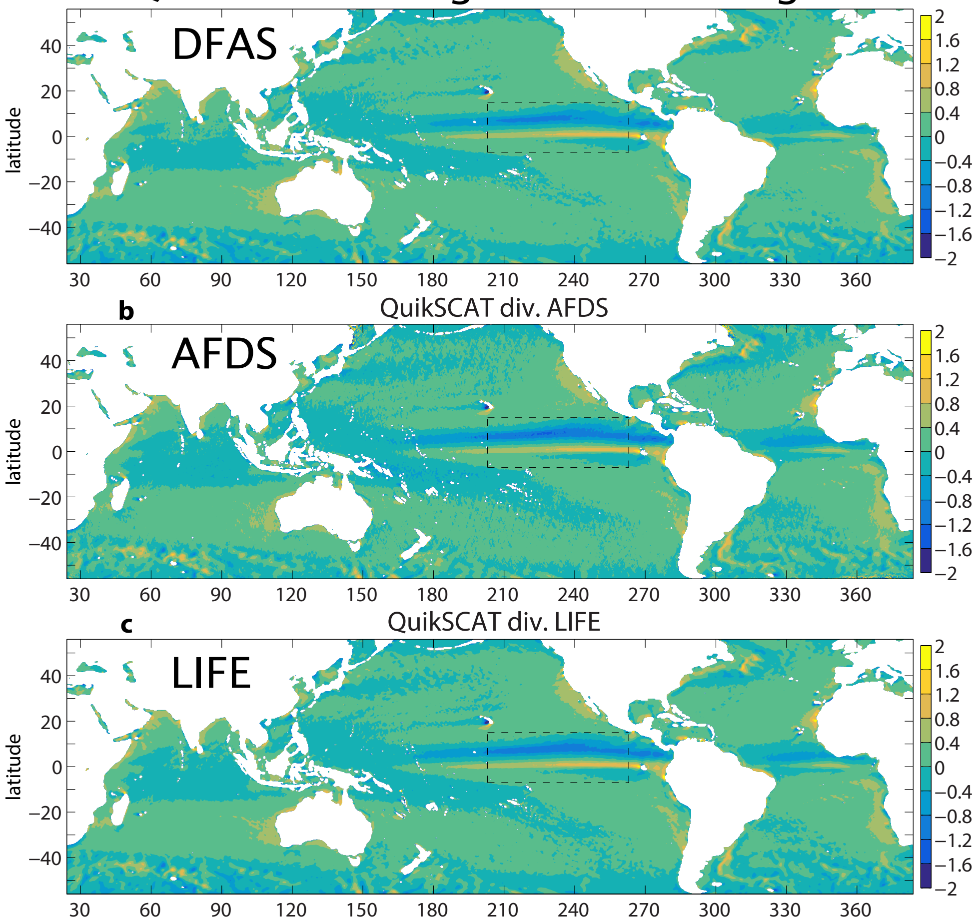
the Non-hydrostatic Icosahedral Atmospheric Model (NICAM).

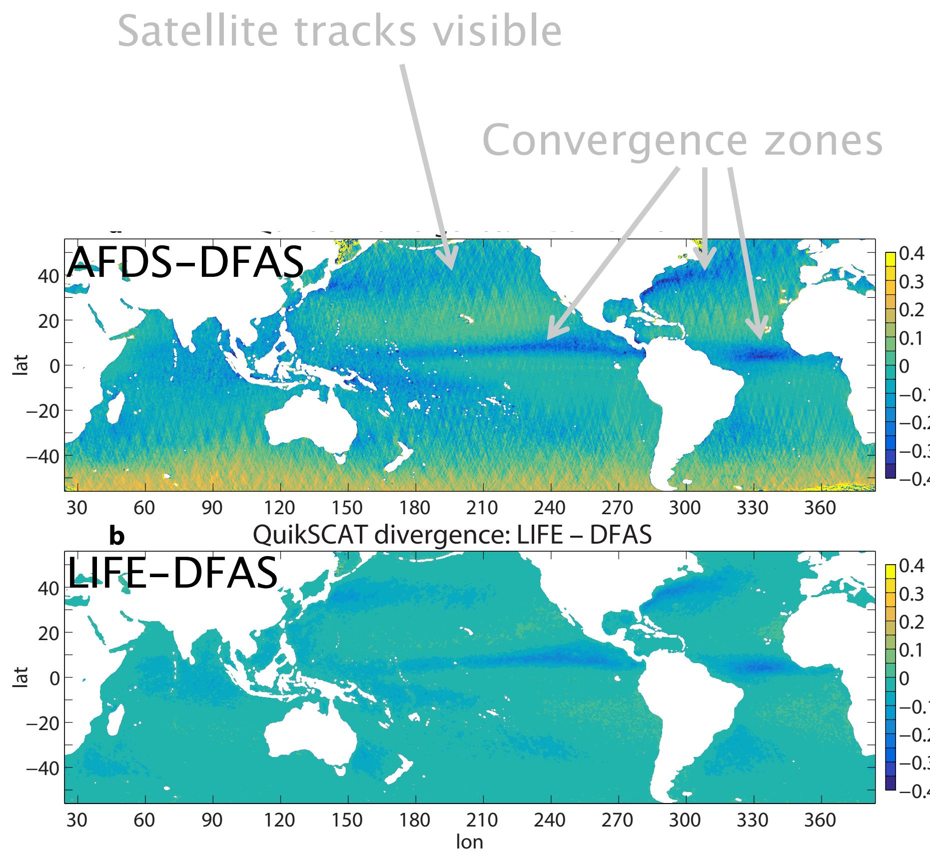
AFDS and LIFE show stronger convergence than DFAS in rainy areas



AFDS and LIFE show stronger convergence than DFAS in rainy areas

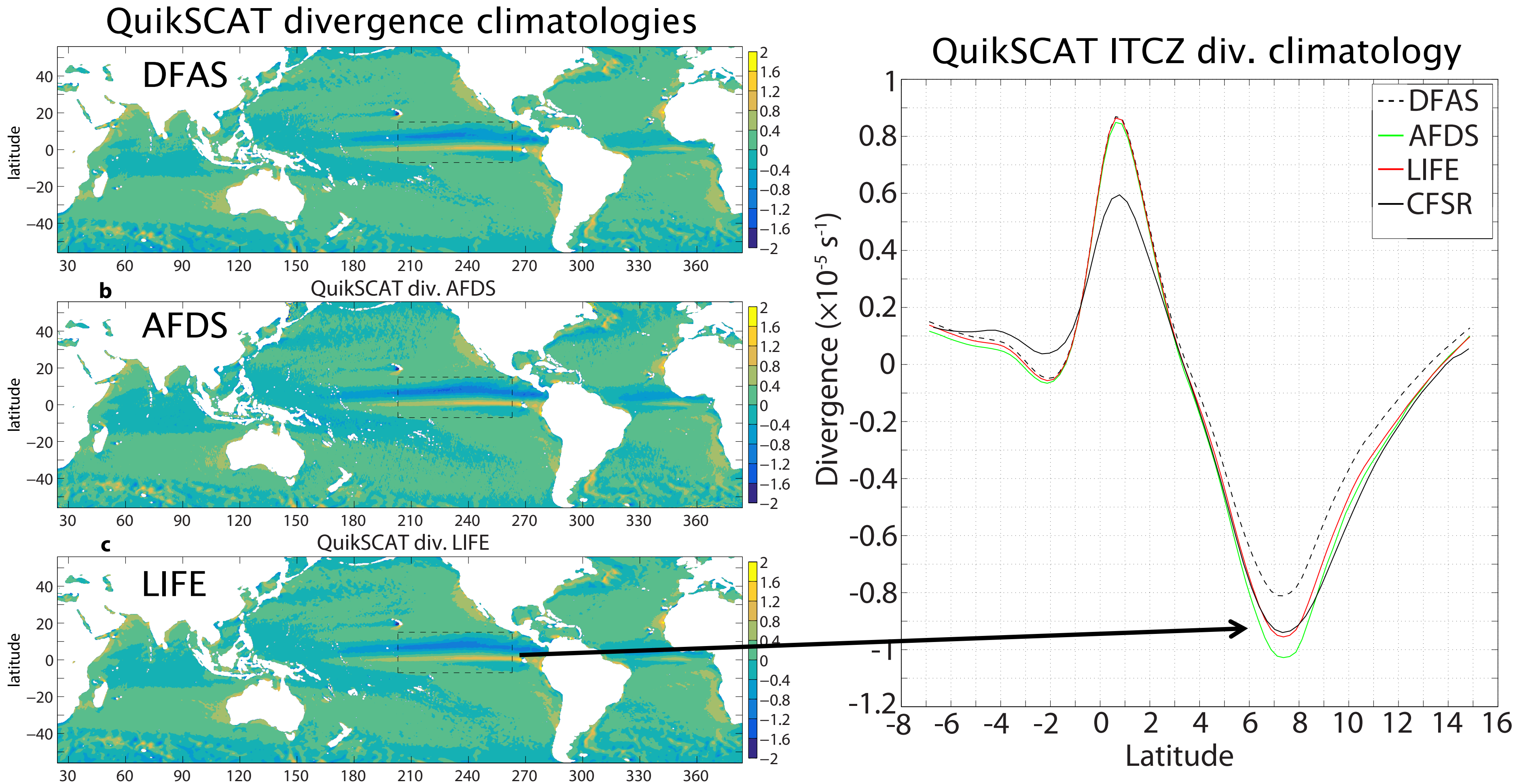
QuikSCAT divergence climatologies





LIFE strengthens the convergence in rainy areas but lacks AFDS's satellite track artifacts.

LIFE brings the ITCZ convergence into best agreement with the CFSR reanalysis

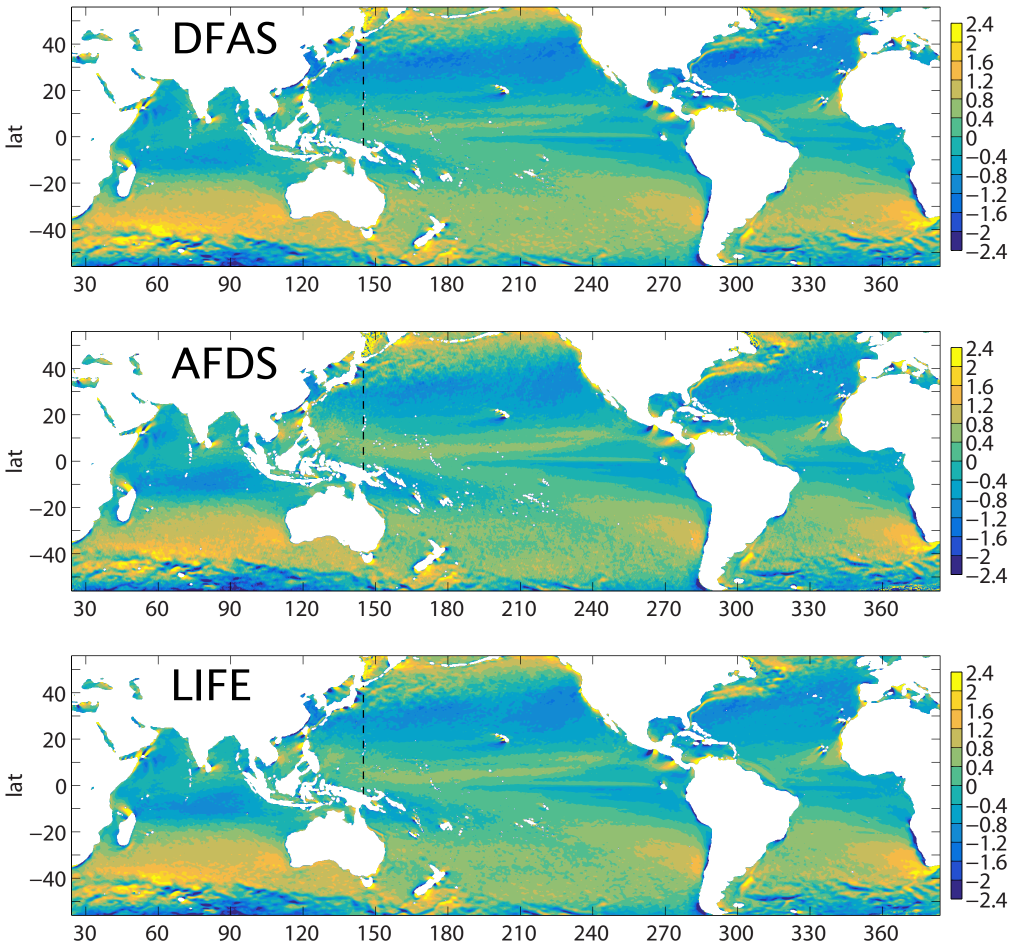


DFAS divergence bias.

AFDS *convergence* bias.

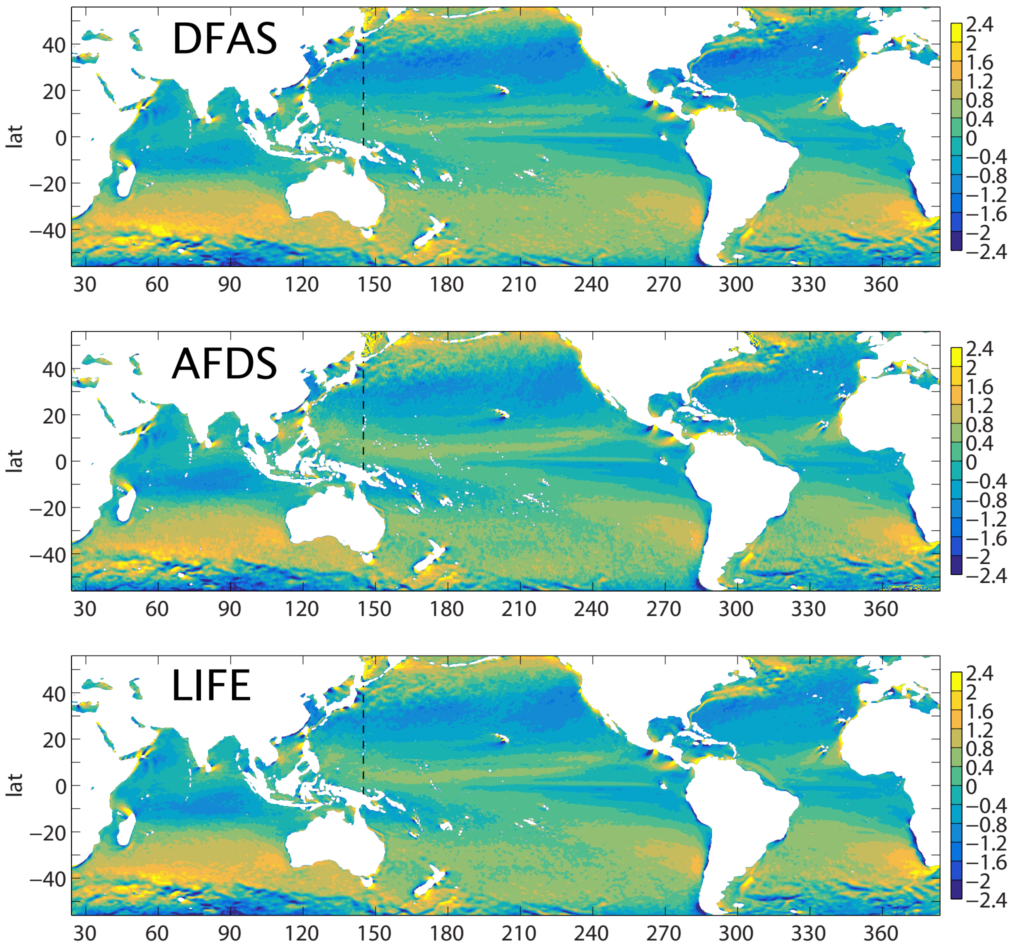
LIFE and AFDS also reduce the DFAS anticyclonic wind stress curl bias

QuikSCAT wind stress curl climatologies

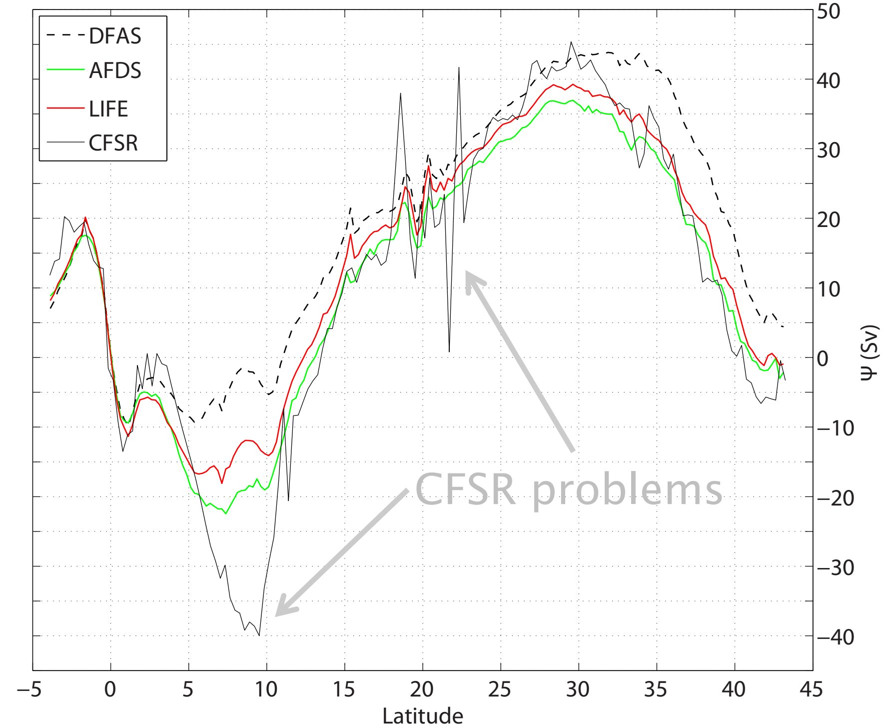


LIFE and AFDS also reduce the DFAS anticyclonic wind stress curl bias

QuikSCAT wind stress curl climatologies

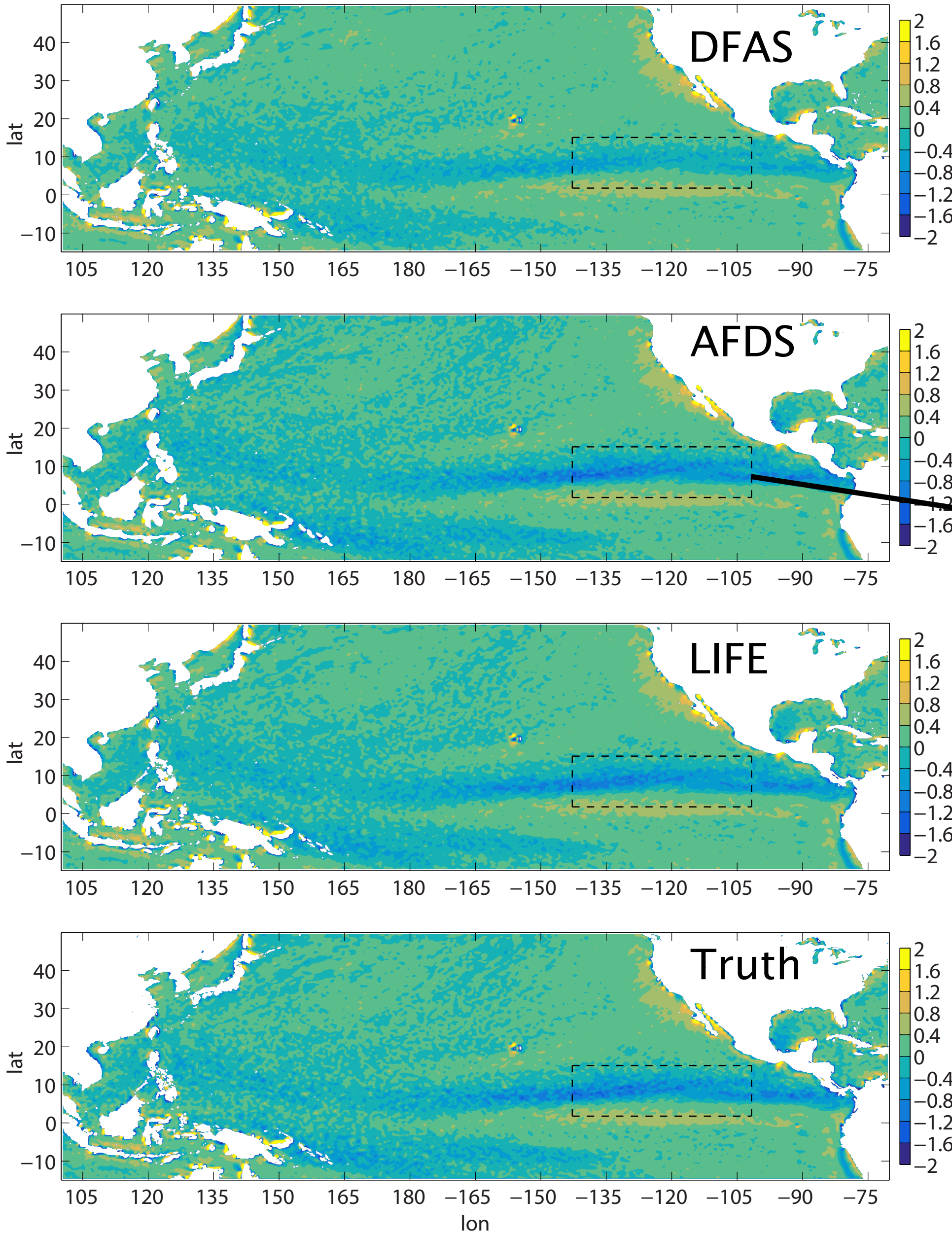


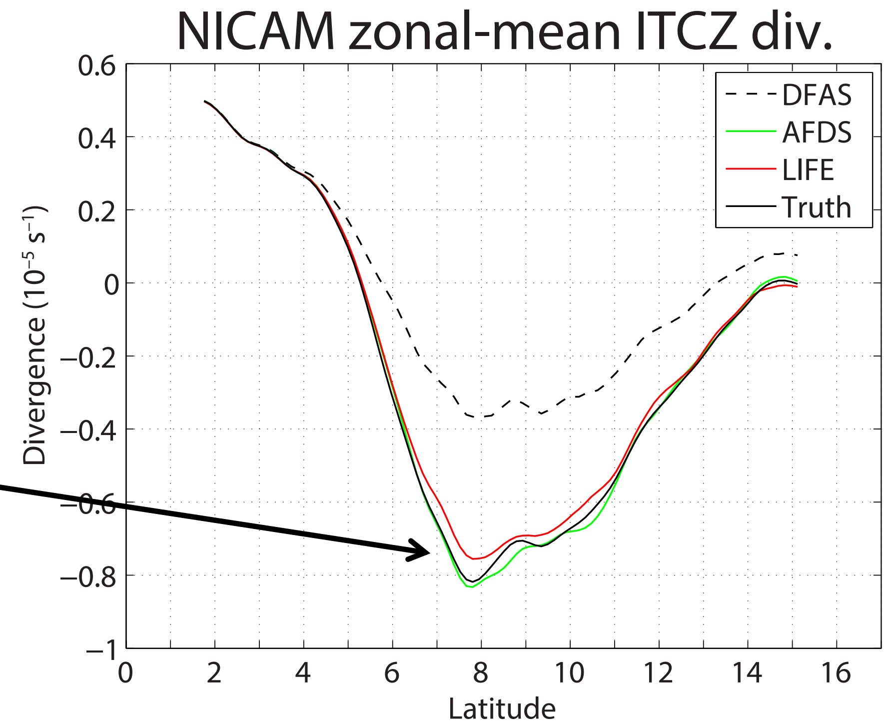
Sverdrup transport ψ at 145°E



LIFE and AFDS both make ψ more negative, but CFSR problems make the comparison inconclusive.

NICAM atmospheric model allows us to validate spatial differencing methods against truth





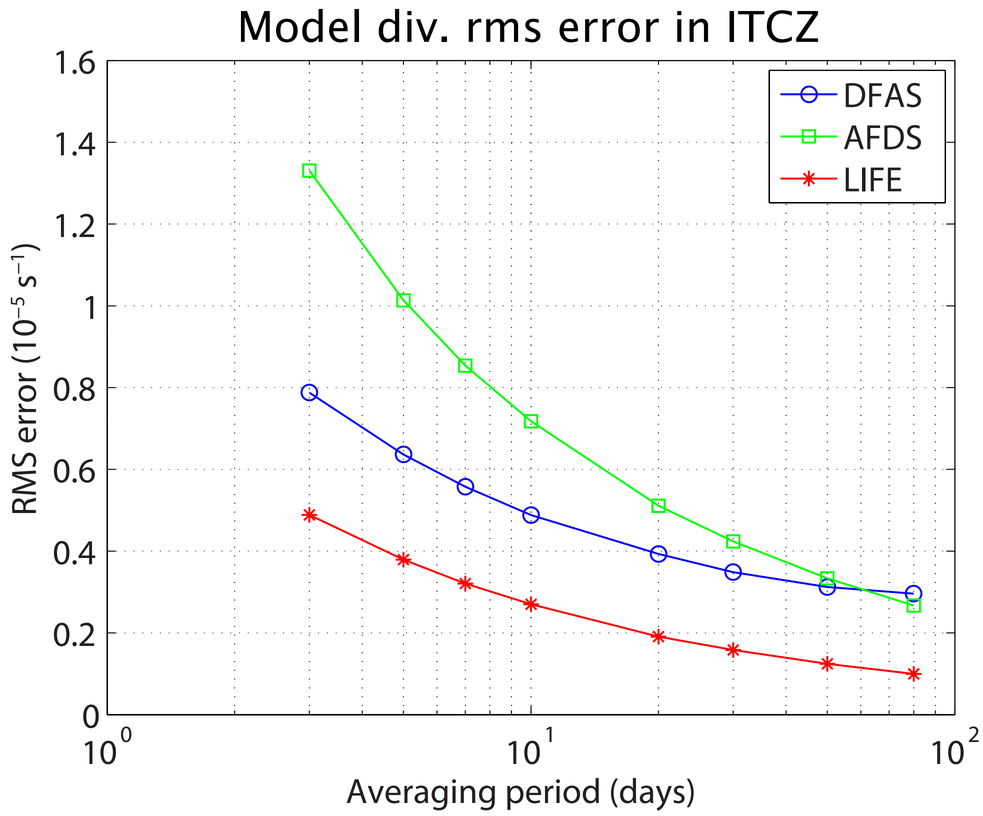
AFDS and LIFE remove most of DFAS's huge divergence bias.

AFDS reproduces the climatology slightly better than LIFE.

Errors for LIFE are consistently smaller than for DFAS and AFDS

LIFE errors in the NICAM model are smallest for all averaging periods, e.g. less than half the AFDS errors.

LIFE's excellent performance validates its ability to recover information about the wind field in rainy areas.



Summary

Computing spatial derivatives via line integrals (LIFE) around rainy patches is an excellent method when balancing our desires for the following:

1. Accurate representation of surface wind climatology.
2. Small rms errors.
3. Minimal artifacts from satellite tracks.
4. Ability to resolve high-frequency wind variability associated with atmospheric convection.

Summary

Computing spatial derivatives via line integrals (LIFE) around rainy patches is an excellent method when balancing our desires for the following:

1. Accurate representation of surface wind climatology.
2. Small rms errors.
3. Minimal artifacts from satellite tracks.
4. Ability to resolve high-frequency wind variability associated with atmospheric convection.

Next:

- convection-wind coupling in the Maritime Continent region
- atmospheric rivers

Reference: Kilpatrick, T., and Xie, S.-P., Circumventing rain contamination in scatterometer wind observations, submitted to *JGR*.


ありがとう!

- 2°N