NASA grant NNX14AL83G, S.-P. Xie, N. Schneider, T. Kilpatrick

Characterization of the frontal air-sea interaction by transfer functions

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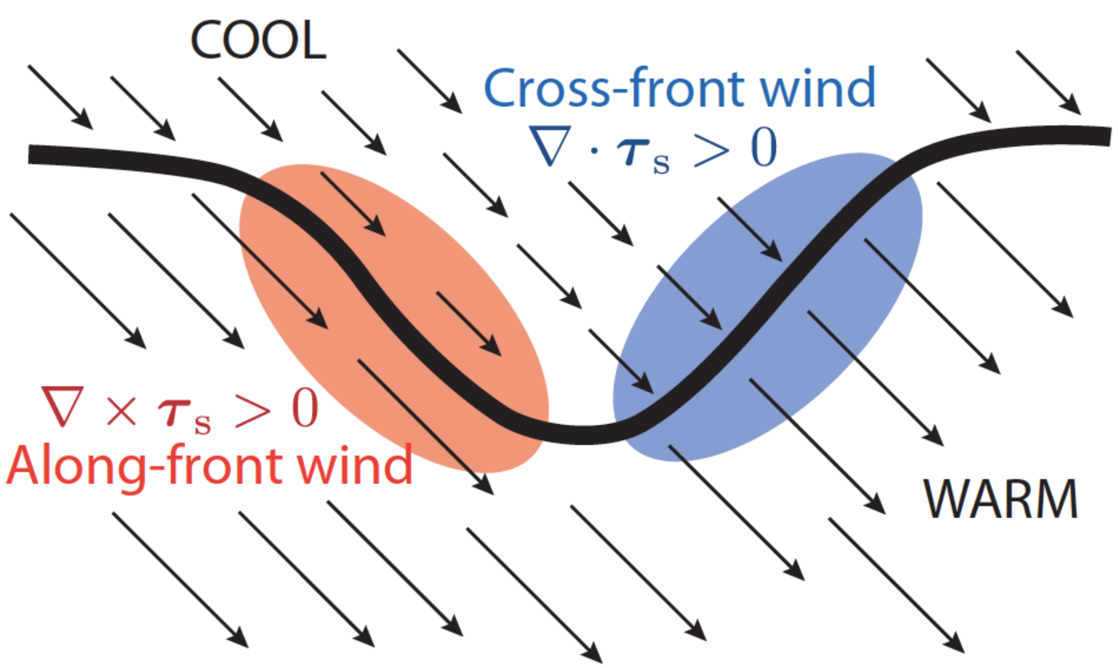
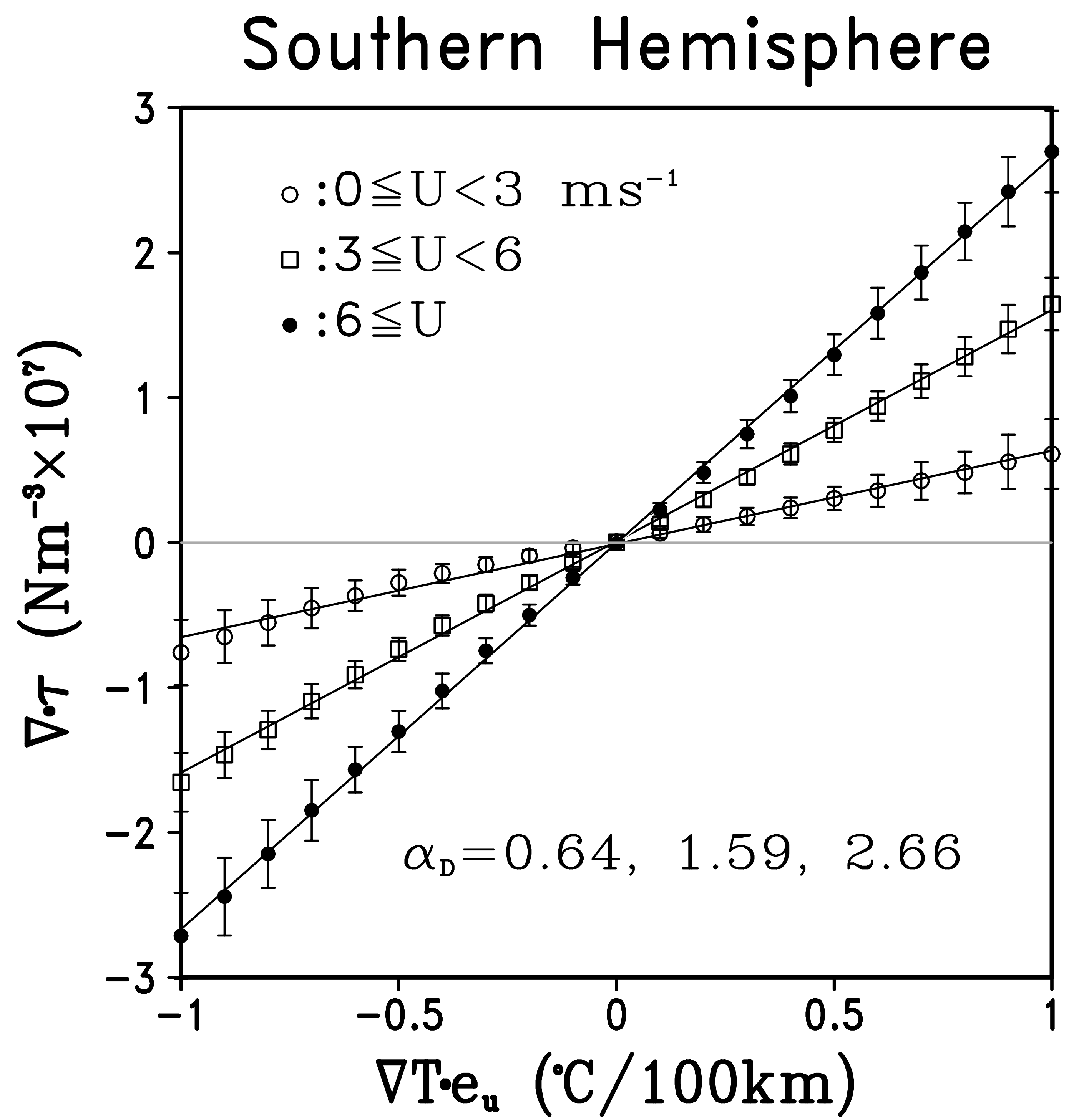


Chelton et al., 2004

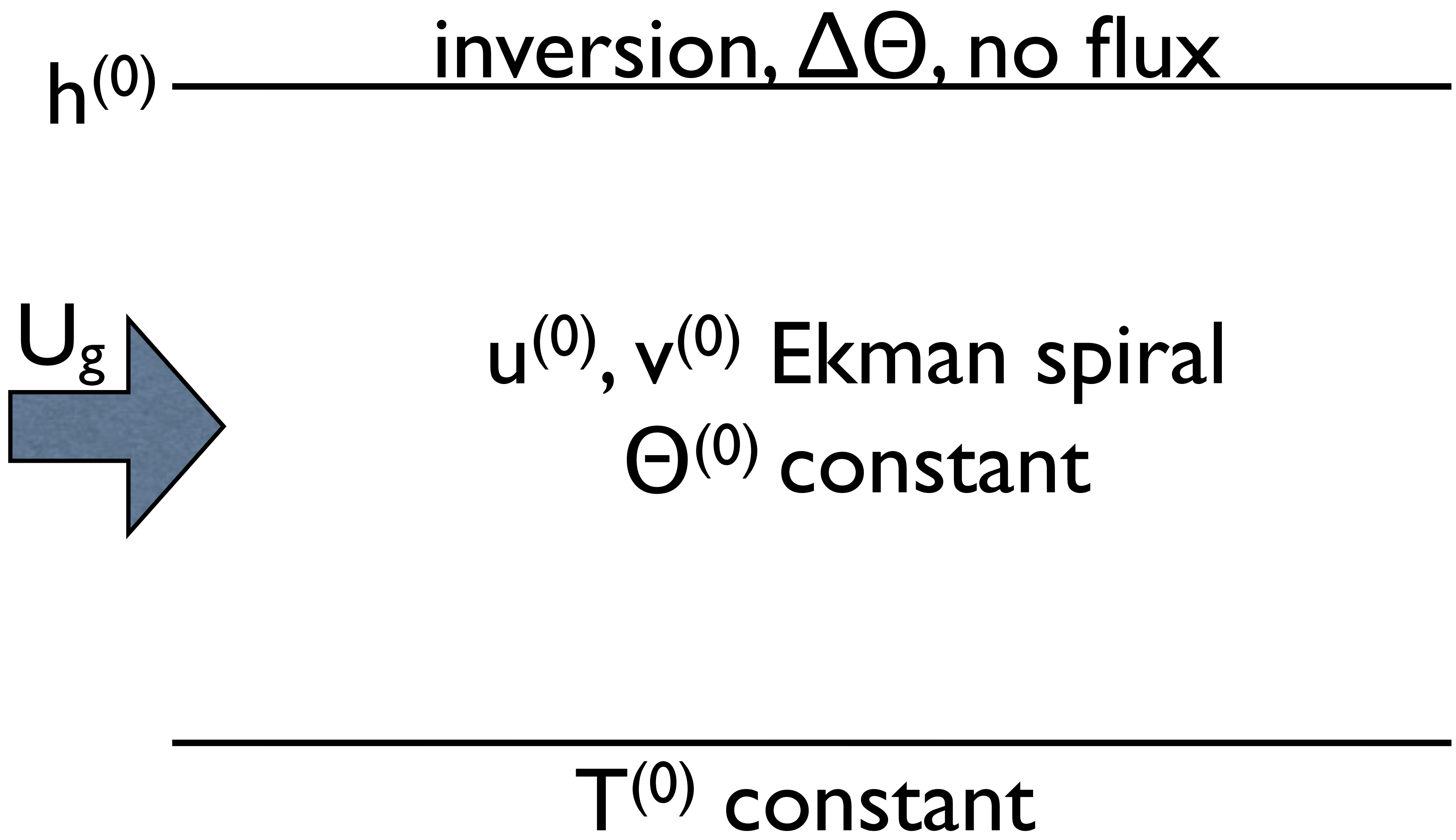


SCOW project:
QuikSCAT wind stress
AVHRR SST
monthly averages

Risien and Chelton 2008

Model for air-sea interaction at SST fronts

- Reduced gravity model capped by sharp inversion
- Forced by barotropic tropospheric pressure gradient
- Background state: SST constant



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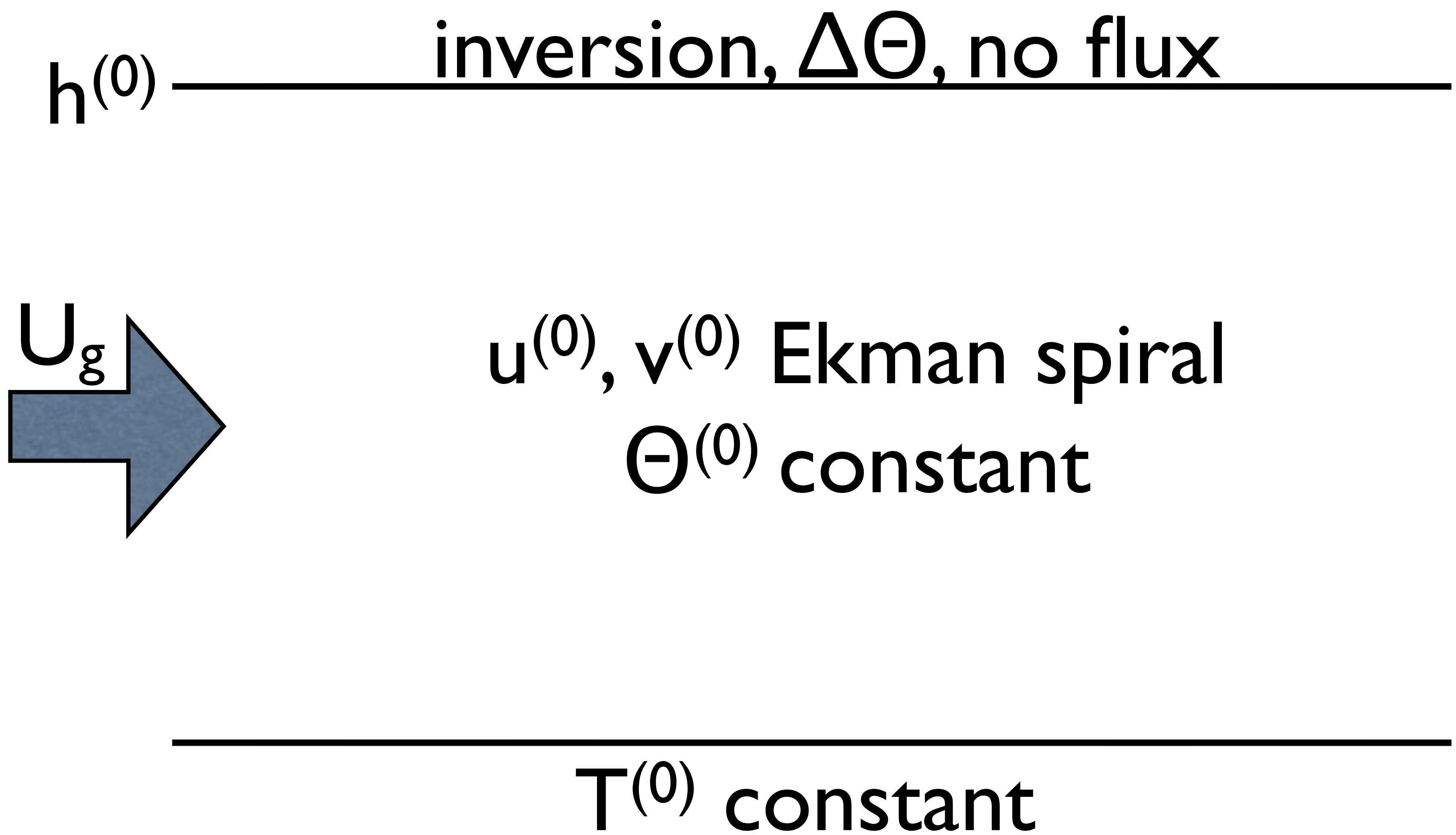

- consider weak front $T^{(0)} + \varepsilon T^{(1)}$, linear response

Air-sea interaction at weak SST front

1st order (linear) response

$$\vec{u}^{(0)} \cdot \nabla\Theta^{(1)} = \gamma \left(T^{(1)} - \Theta^{(1)}\right) + A_h \nabla^2 \Theta^{(1)}$$

nondimensionalized by Rossby radius of deformation, boundary layer height, inversion strength etc.

Schneider, N. and B. Qiu, 2015: The atmospheric response to weak sea surface temperature fronts. *J. Atmos. Sci.*, doi:10.1175/JAS-D-14-0212.1, in press.

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$$\underbrace{\vec{u}^{(0)} \cdot \nabla \vec{u}^{(1)} + w^{\star(1)} \partial_s \vec{u}^{(0)}}_{\text{advection}} + \underbrace{\hat{e_3} \times \vec{u}^{(1)}}_{\text{Coriolis}} + \underbrace{\nabla h^{(1)}}_{\text{back pressure}} - \partial_s \underbrace{E^{(0)} \partial_s \vec{u}^{(1)}}_{\text{background mixing}} = \vec{F}$$

$$\vec{u}^{(0)} \cdot \nabla h^{(1)} + \nabla \cdot \vec{u}^{(1)} + \partial_s w^{\star(1)} = 0$$

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1st order (linear) response

$$\vec{u}^{(0)} \cdot \nabla\Theta^{(1)} = \gamma\left(T^{(1)} - \Theta^{(1)}\right) + A_h \nabla^2 \Theta^{(1)}$$

$\delta^{(1)} = T^{(1)} - \Theta^{(1)}$

air-sea temperature differences modulates vertical eddy viscosity

$$\vec{F} = \nabla \underbrace{\int_s^1 \Theta^{(1)} ds'}_{\text{pressure gradient mechanism}} + \partial_s \left(\underbrace{\delta^{(1)} \left.\frac{\partial E}{\partial \delta}\right|_{\delta^{(0)}} \partial_s \vec{u}^{(0)}}_{\text{vertical mixing mechanism}} \right)$$

$$\underbrace{\vec{u}^{(0)} \cdot \nabla \vec{u}^{(1)} + w^{\star(1)} \partial_s \vec{u}^{(0)}}_{\text{advection}} + \underbrace{\hat{e}_3 \times \vec{u}^{(1)}}_{\text{Coriolis}} + \underbrace{\nabla h^{(1)}}_{\text{back pressure}} - \partial_s \underbrace{E^{(0)} \partial_s \vec{u}^{(1)}}_{\text{background mixing}} = \vec{F}$$

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Transfer function

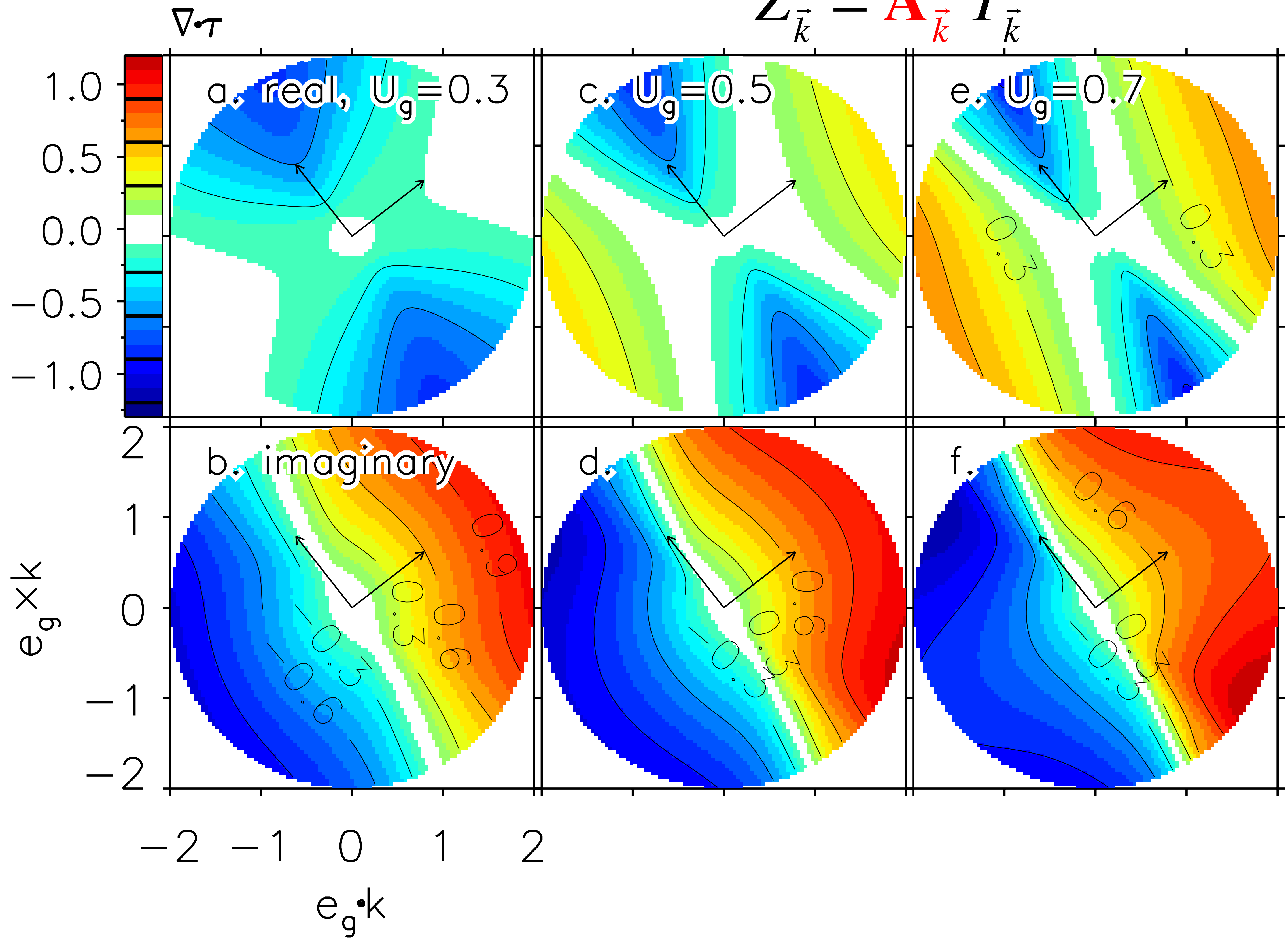
$$\hat{Z}_{\vec{k}} = \hat{\mathbf{A}}_{\vec{k}}\, \hat{T}_{\vec{k}}$$

real part: in phase relationship between Z and T
imaginary part: 90° phase shifted

Transfer function for wind-stress divergence

Linear model

$$\hat{Z}_{\vec{k}} = \hat{\mathbf{A}}_{\vec{k}}\ \hat{T}_{\vec{k}}$$



Transfer function for wind-stress divergence

Linear model

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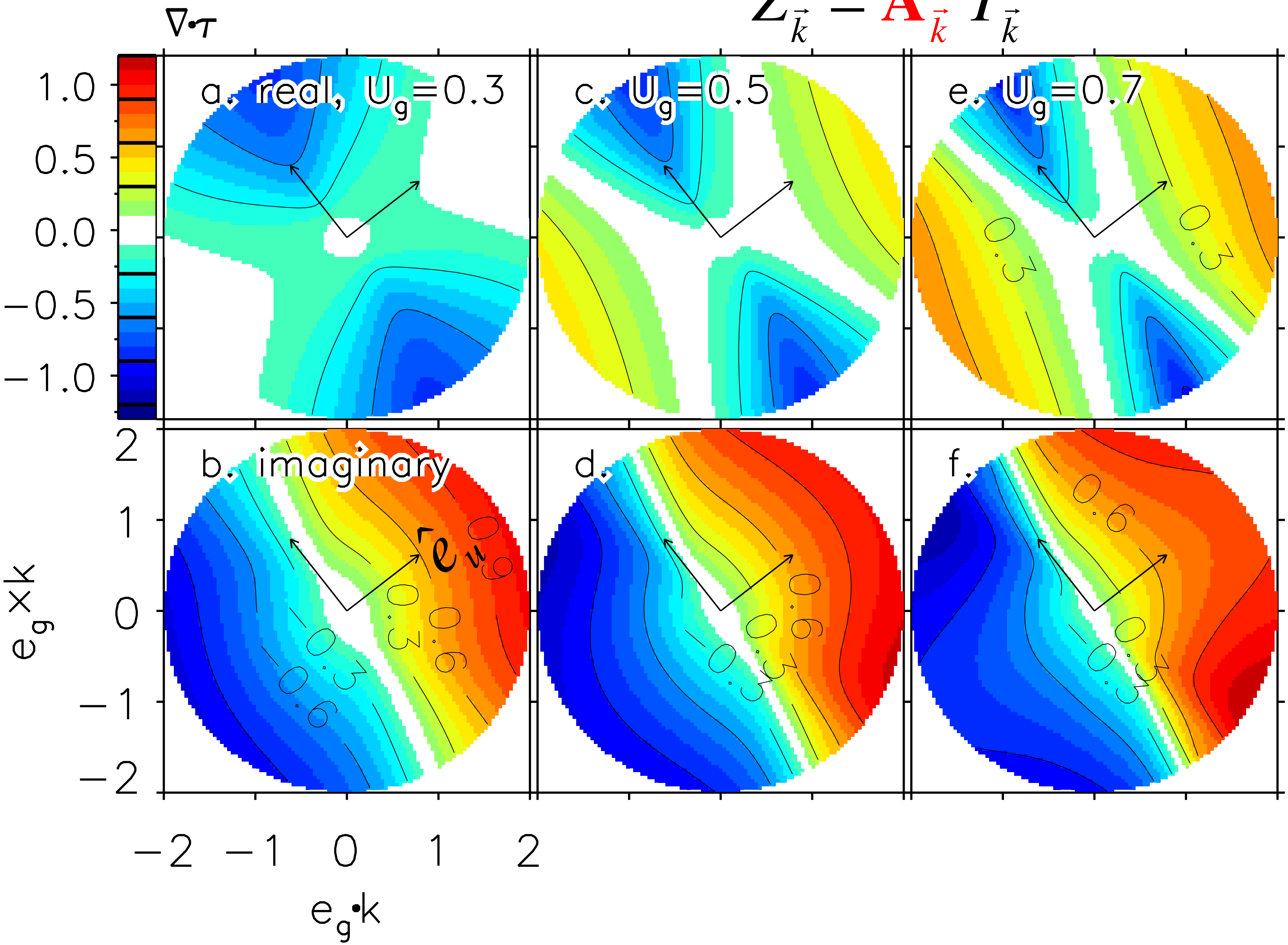

Transfer function for wind-stress divergence

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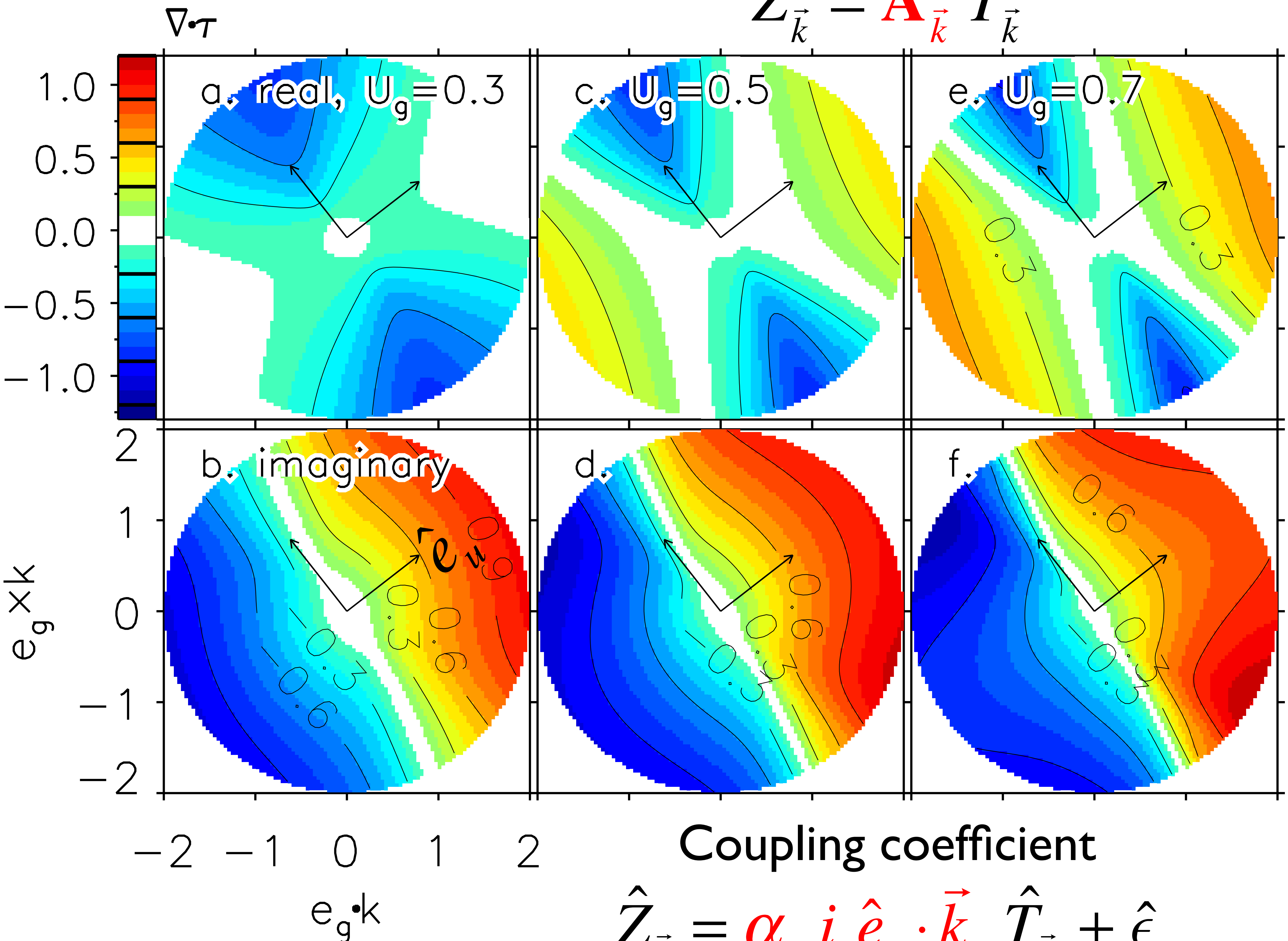


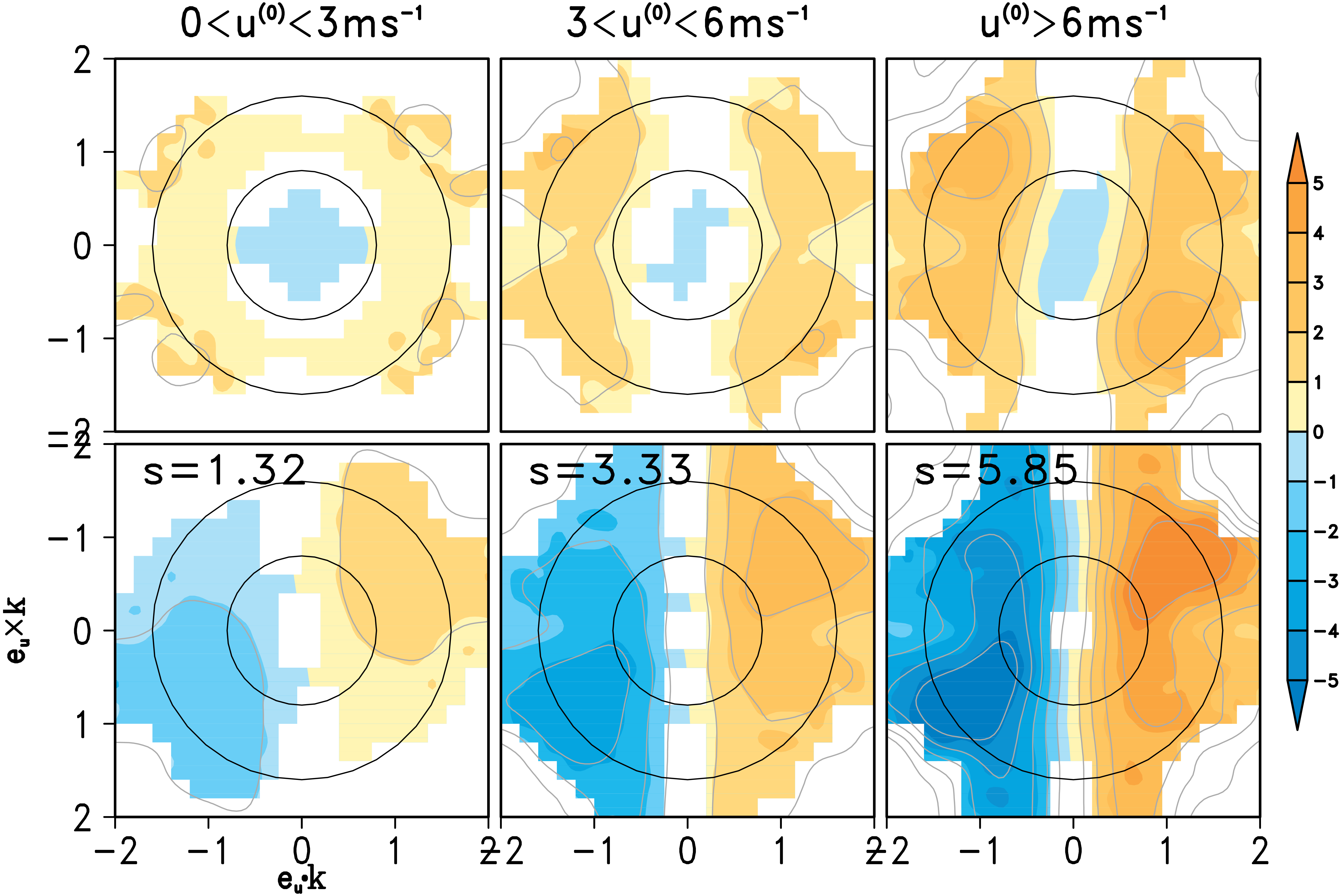
Coupling coefficient

$$\hat{Z}_{\vec{k}} = \alpha\ \ i\ \hat{e}_u \cdot \vec{k}\ \ \hat{T}_{\vec{k}} + \hat{\epsilon}$$

Transfer function for wind-stress divergence

SCOW QuikScat/AVHRR (Risien and Chelton 2008)

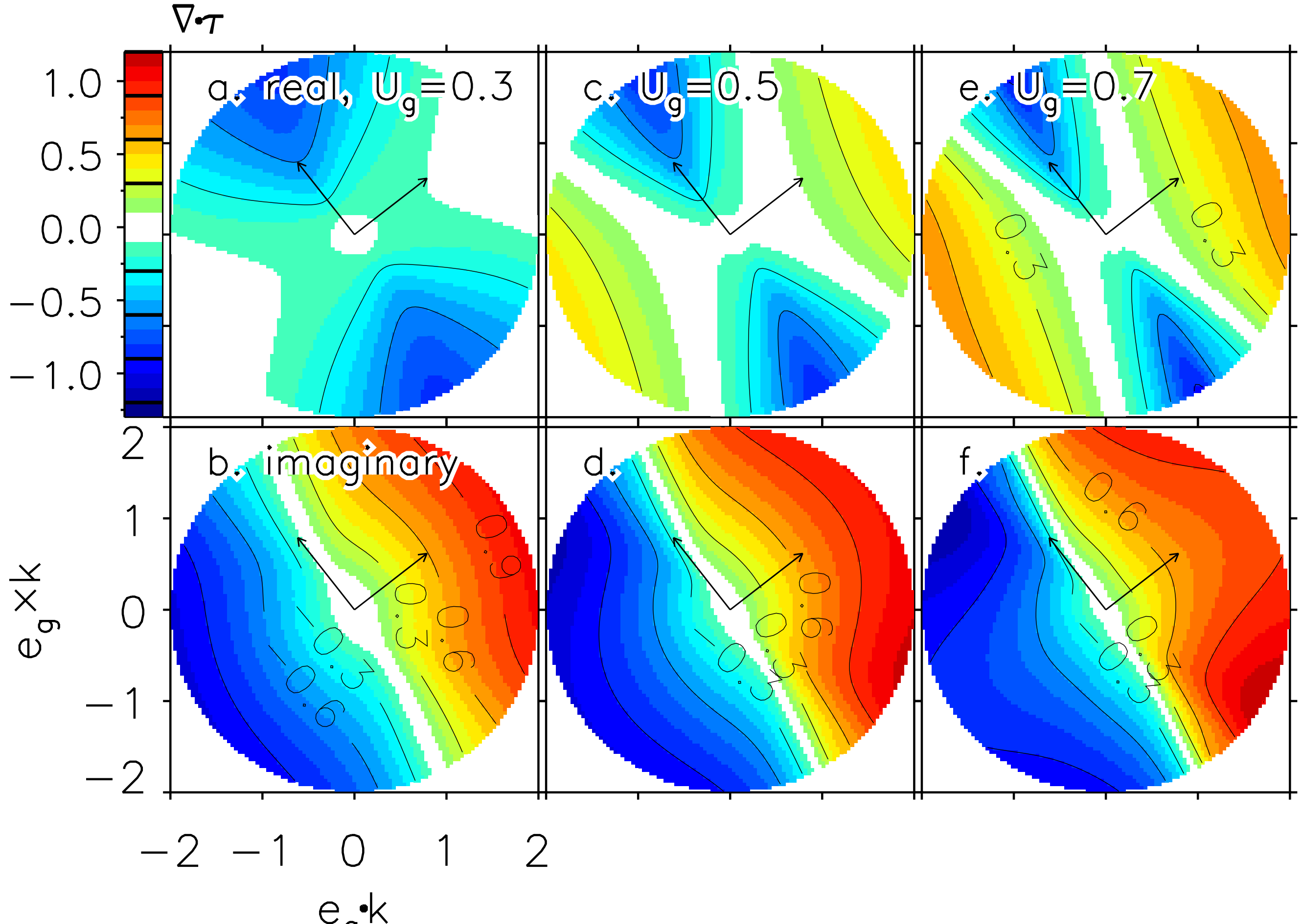
1999-2009 monthly averages, Southern Hemisphere



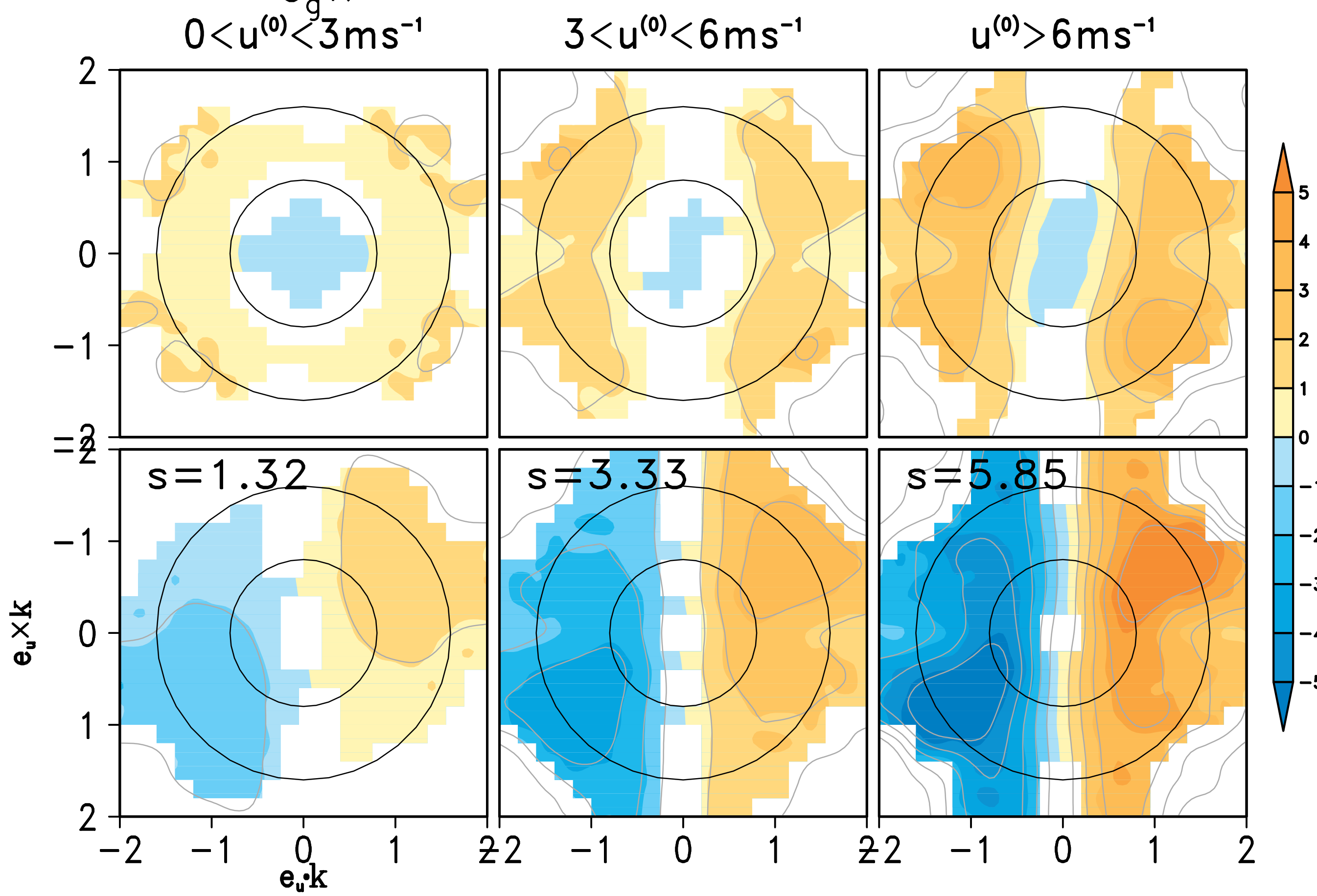
s: least square fit slopes to transfer function for k, l ∈[-1,1]

Transfer function comparison

Linear model

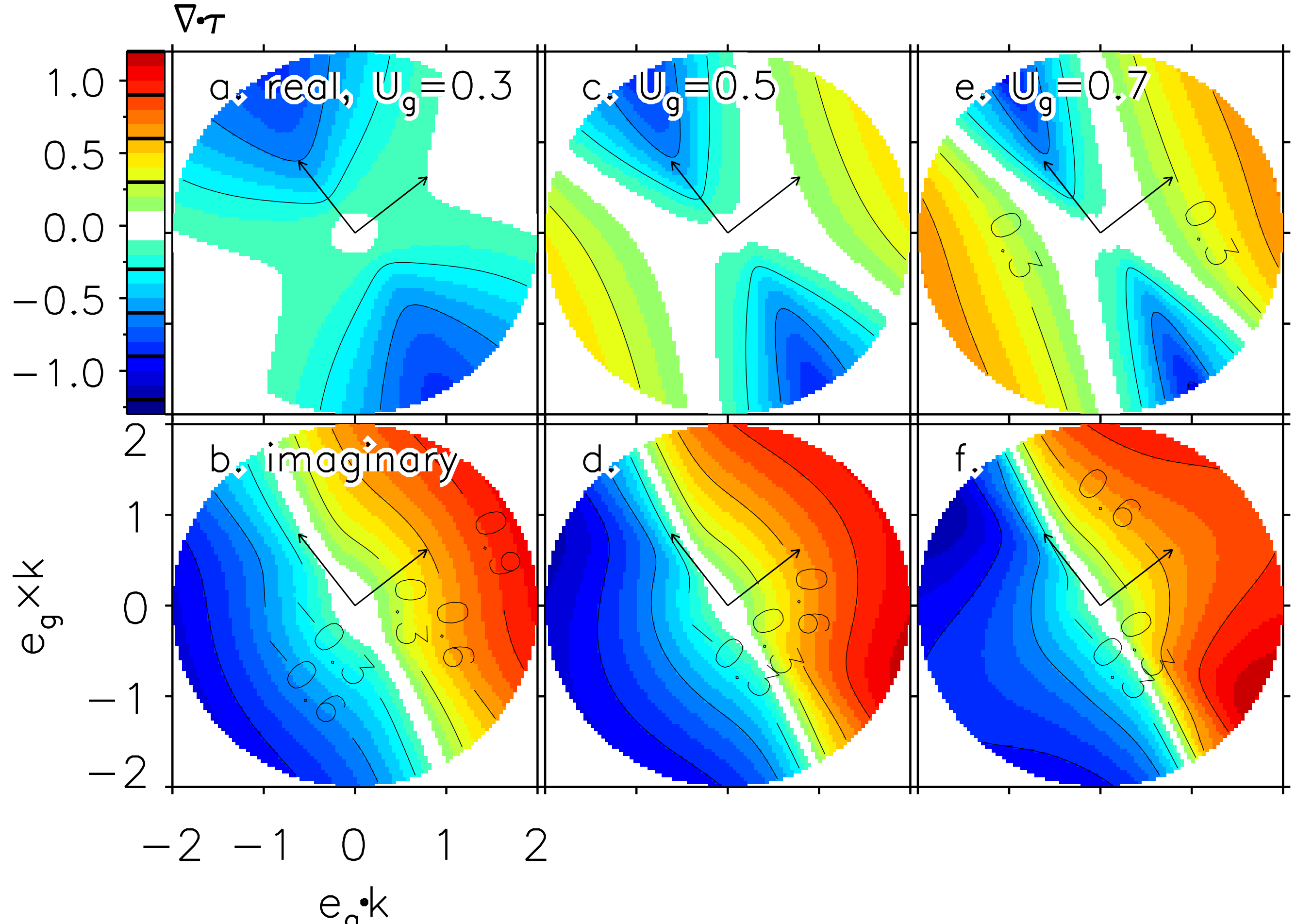


Observations

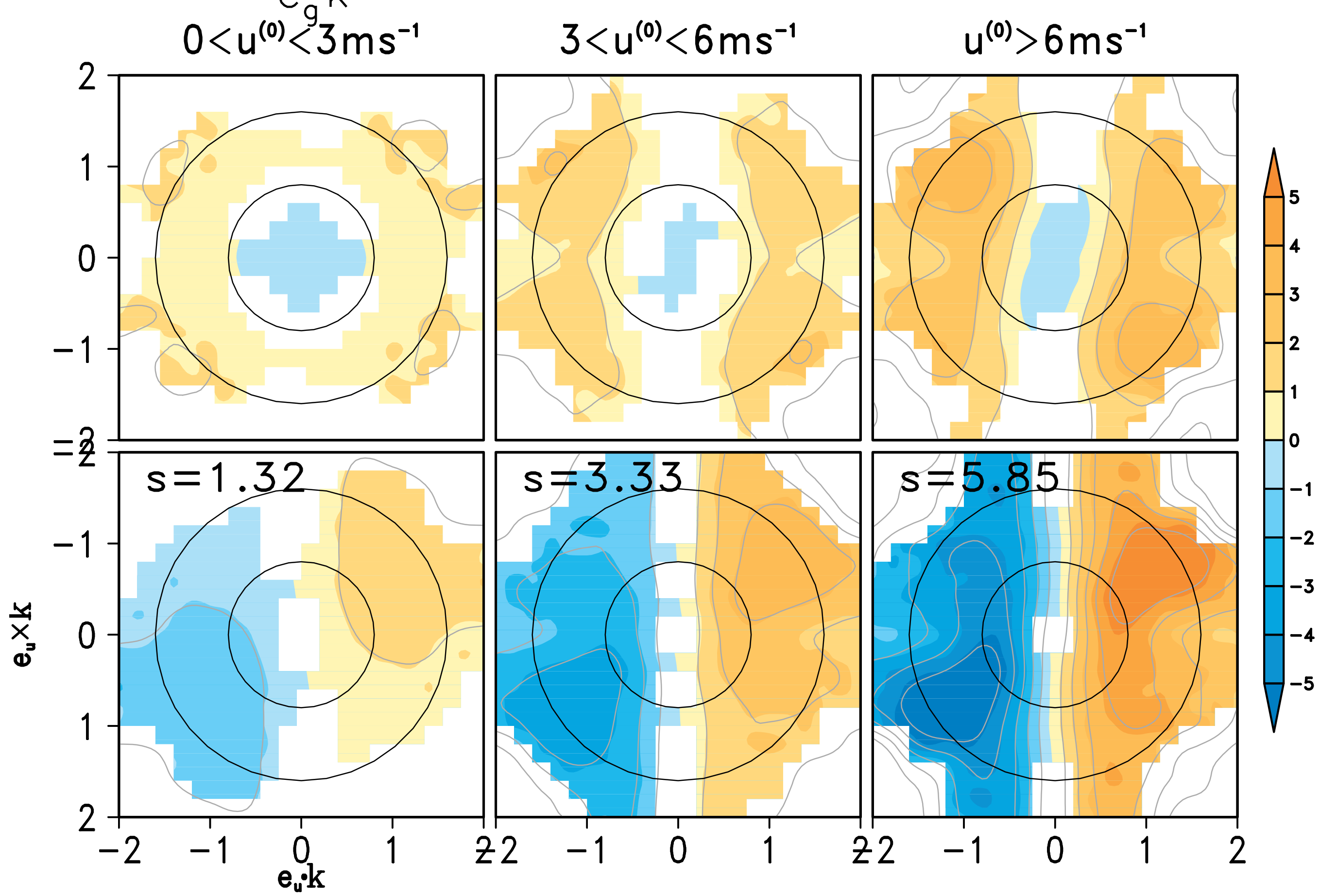


Transfer function comparison

Linear model



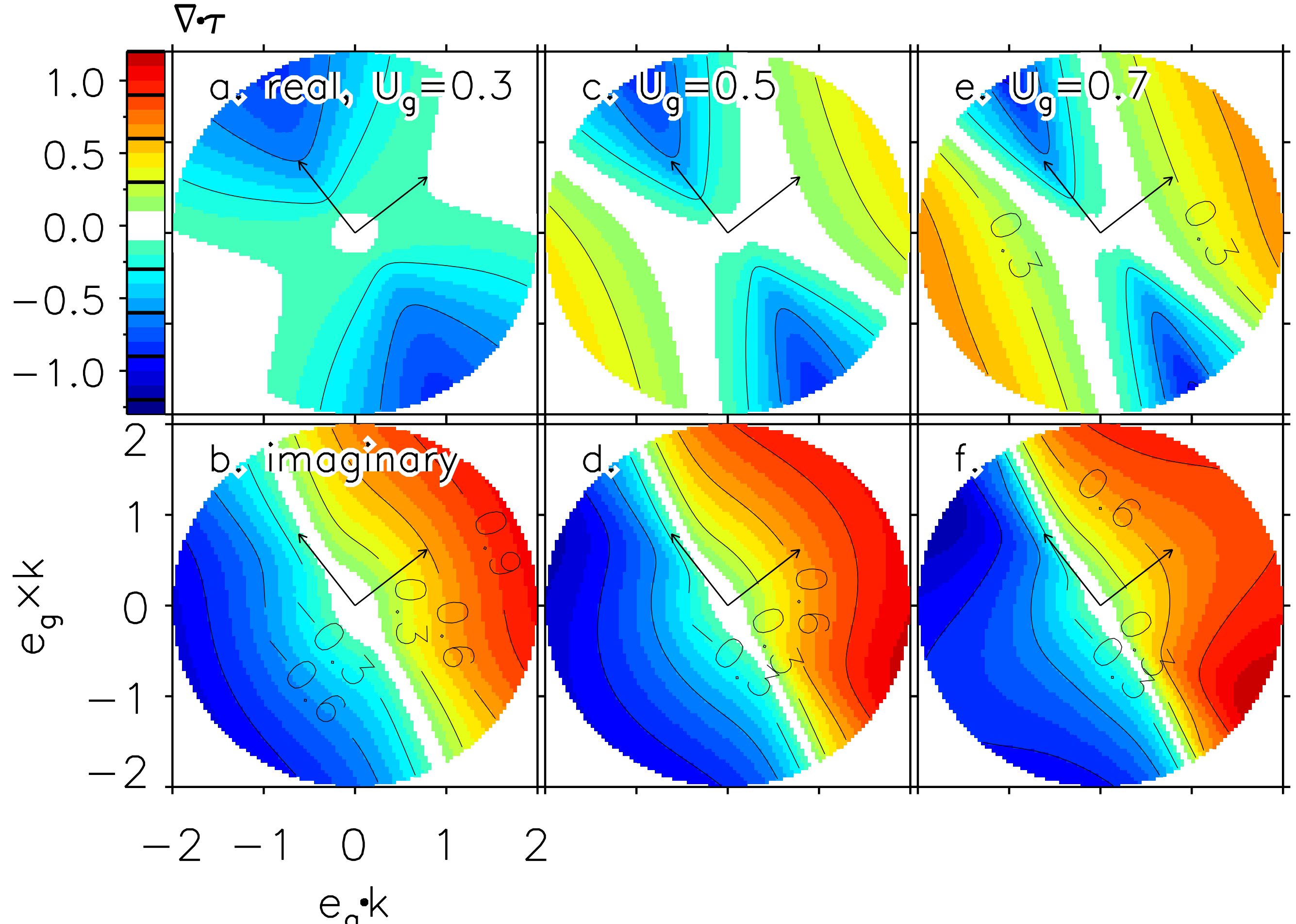
Observations



monthly average

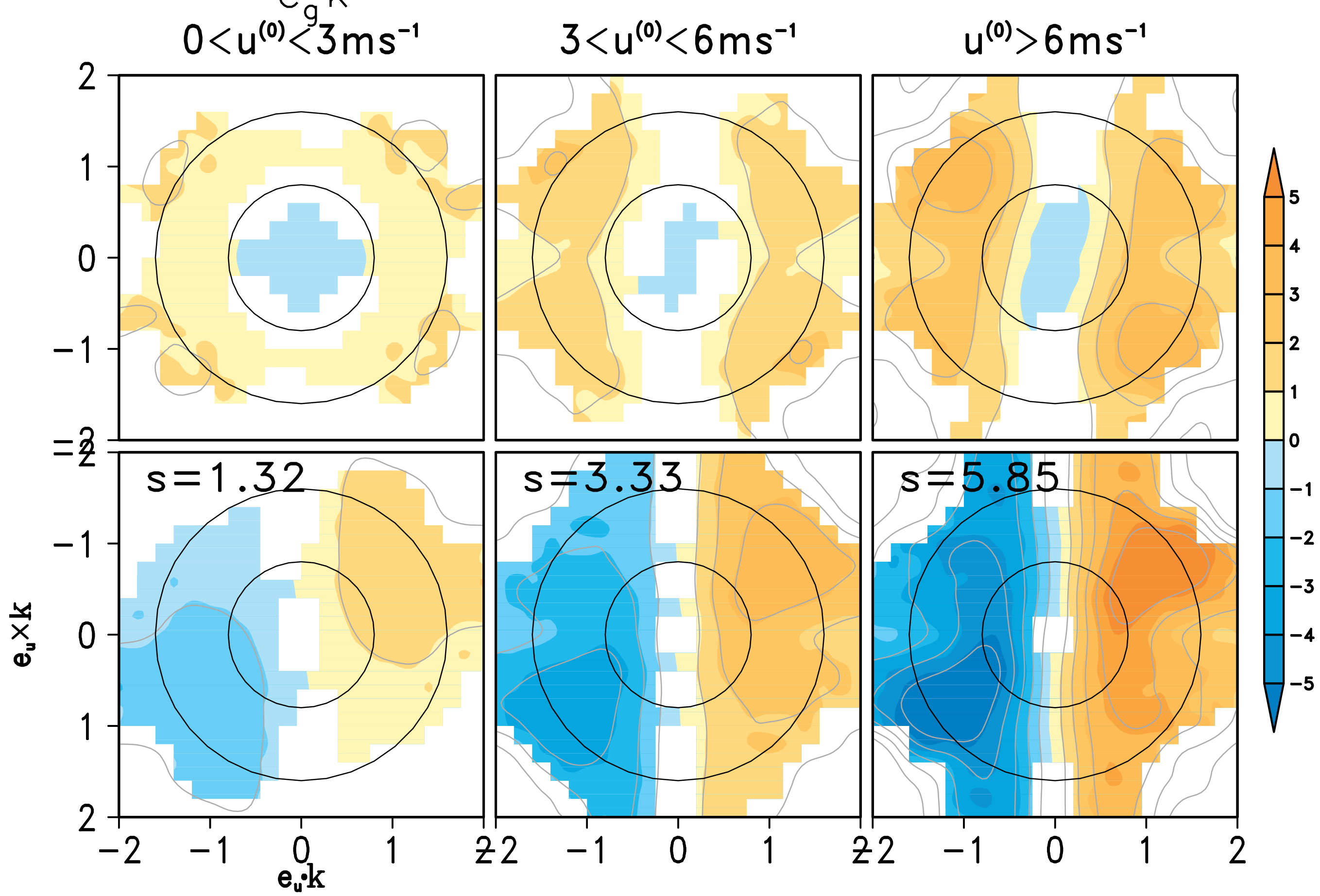
Transfer function comparison

Linear model



few inertial periods

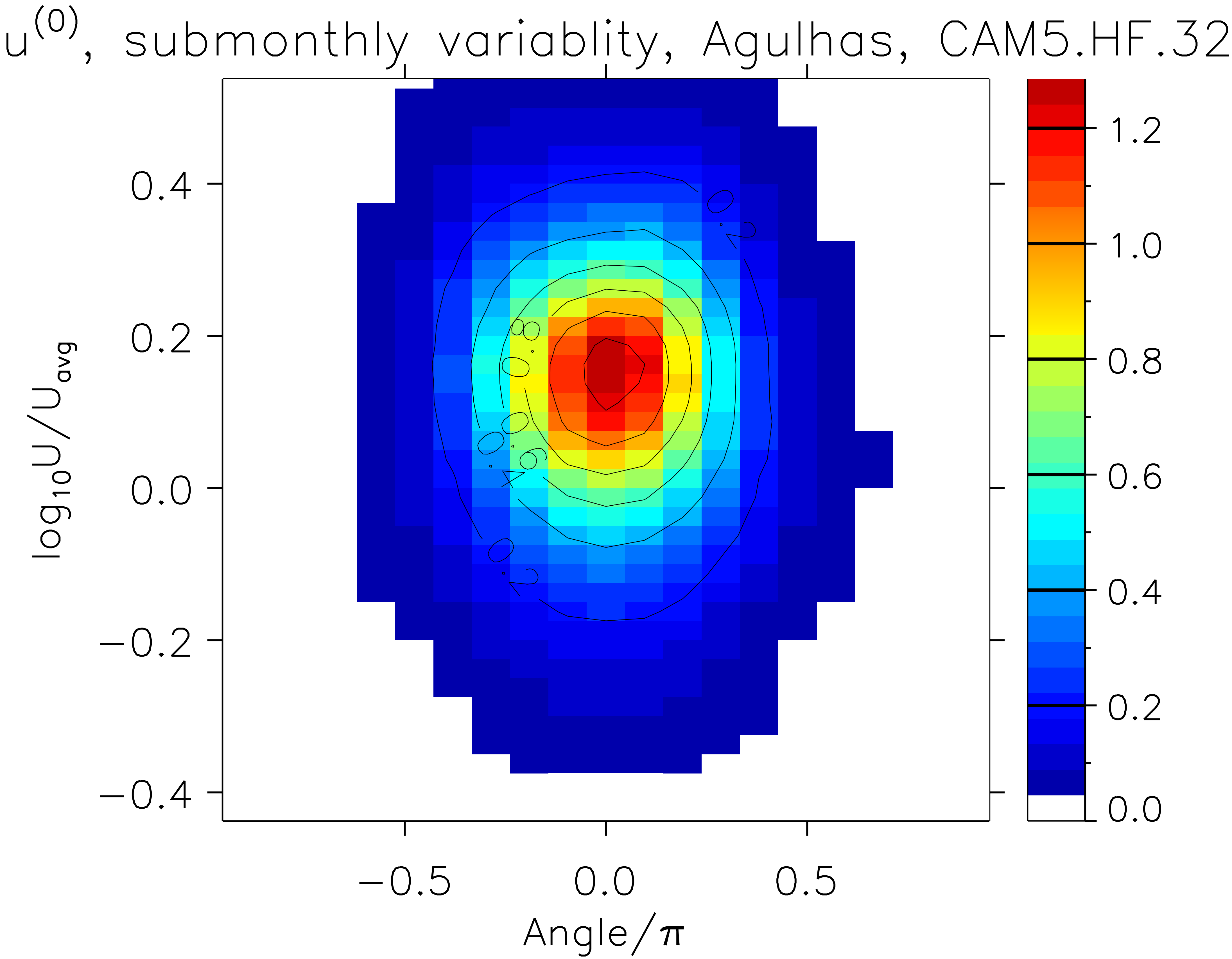
Observations



monthly average

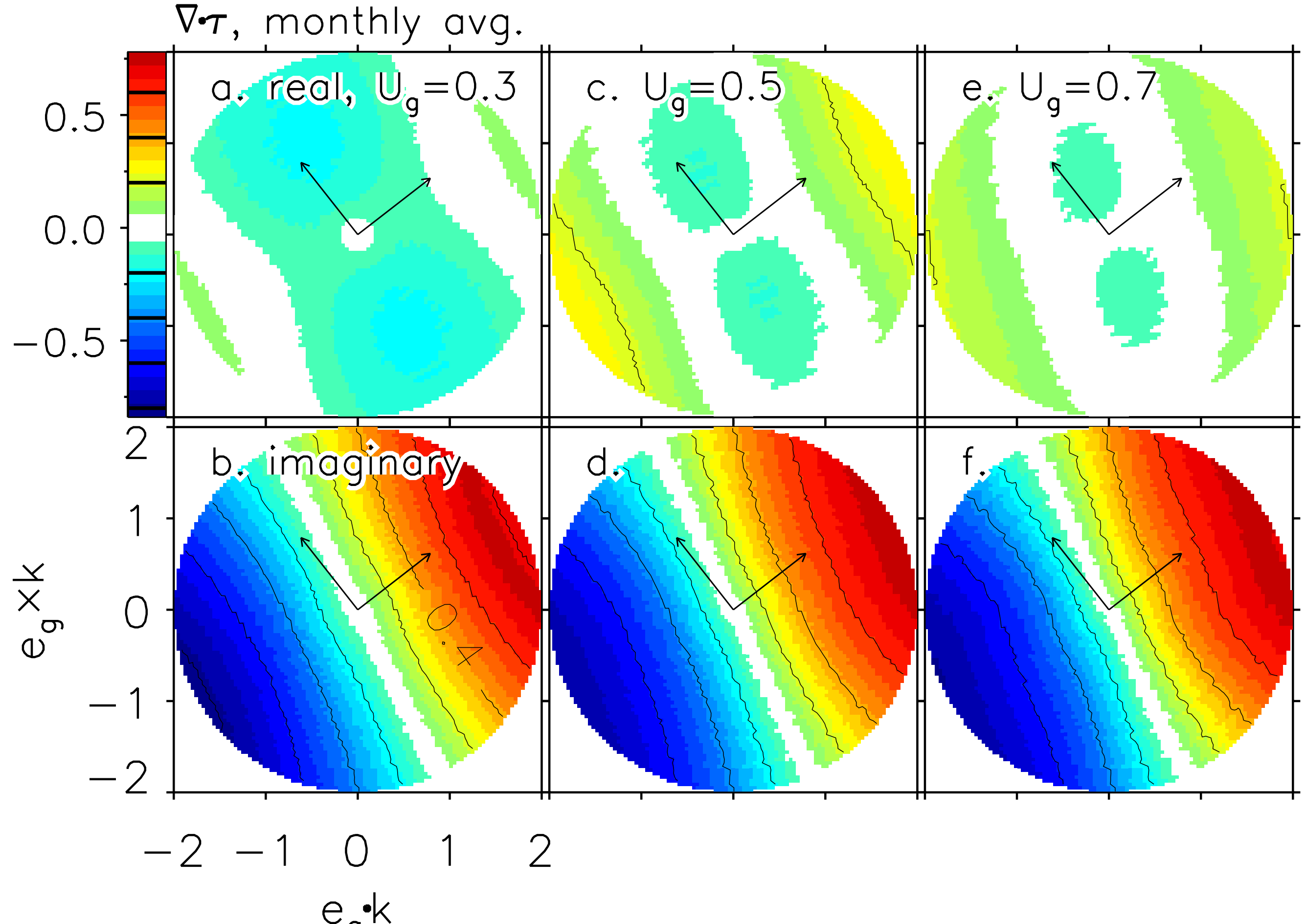
Sub-monthly variations of background wind

CAM5 multi year integration



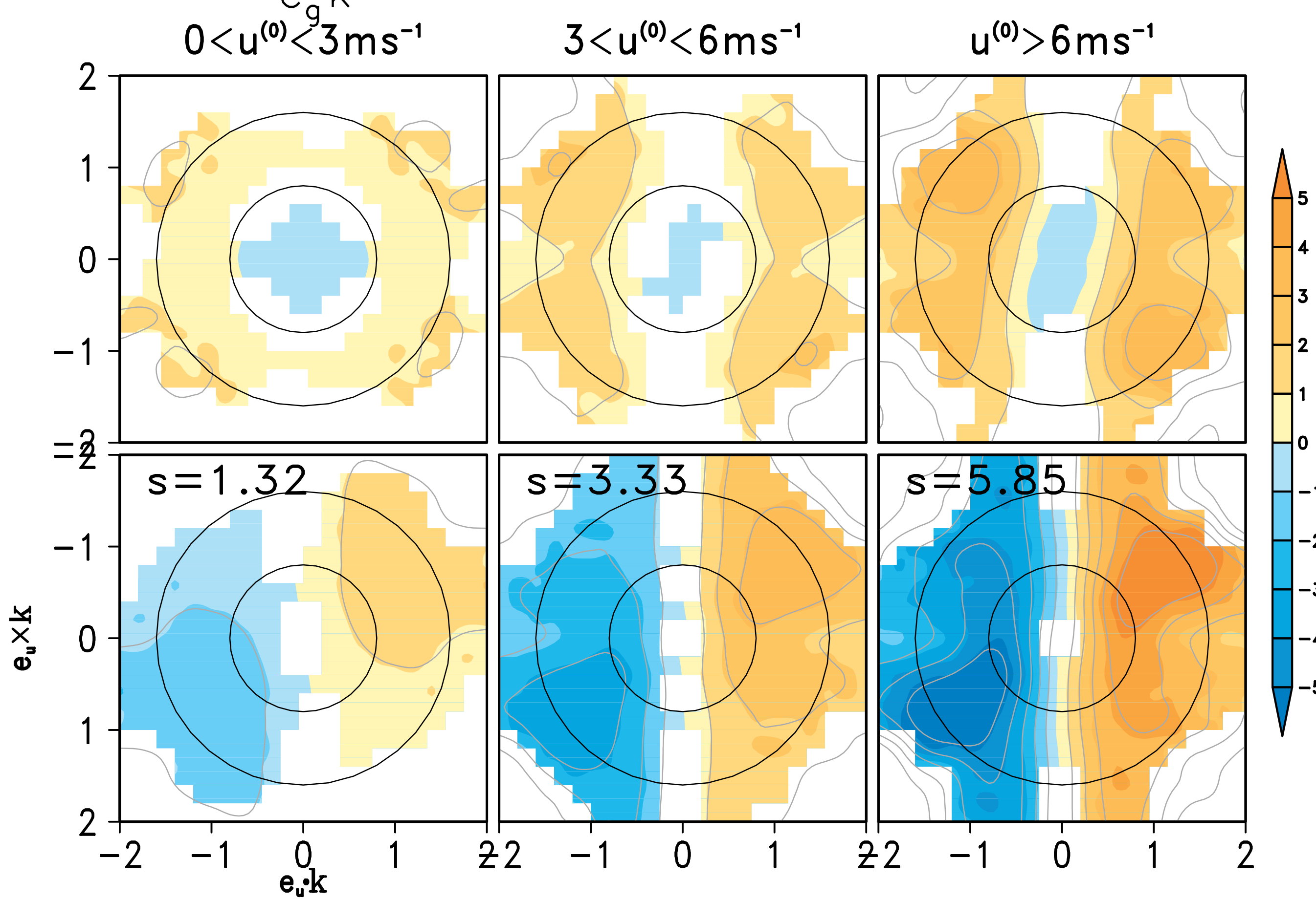
Transfer function comparison

Linear model



smoothed to monthly average

Observations



monthly average

Conclusions

- Transfer functions provide scale-dependent and lagged characterization of atmospheric boundary layer response to mesoscale sea surface temperatures
- Linear model suggests that the transfer function depends on the background wind speed and direction
- Monthly averages smooth out the structure of the transfer function
- Comparison of linear model with estimates of the transfer function is far from perfect but encouraging
- Testing with high resolution AMSR wind and SST products and adjustment of linear model parameters/physics under way