Application and interpretation of adjoint-derived sensitivity fields for tropical cyclone steering

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TC Steering Sensitivity

- Given a properly defined response function for TC steering, the adjoint of a NWP model can provide sensitivities of TC steering useful for:

1 Diagnosing synoptic features/processes important for TC steering

2 Providing valuable *a priori* information about regions in the initial conditions where errors could have a large impact on TC steering

TC Steering Sensitivity

R_1 = Zonal steering response function = Average zonal wind in response function box

R_2 = Meridional steering response function = Average meridional wind in response function box

The problem with these response functions is that they are strongly influenced by small changes to the final-time location of the TC in the response function box
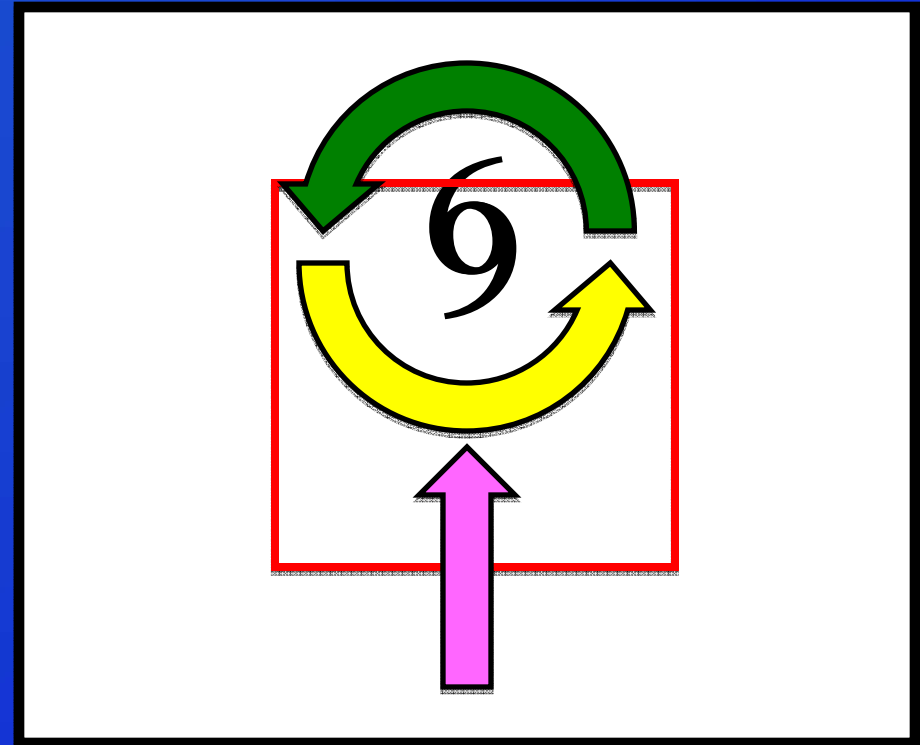
Steering Response Function
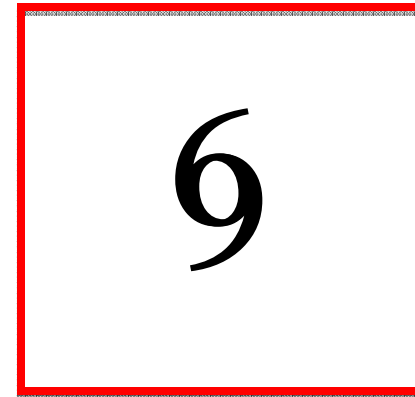
Steering Response Function

Response functions represent the steering of the TC only when the TC is centered in the response function box, with the symmetric circulation around the TC being canceled out
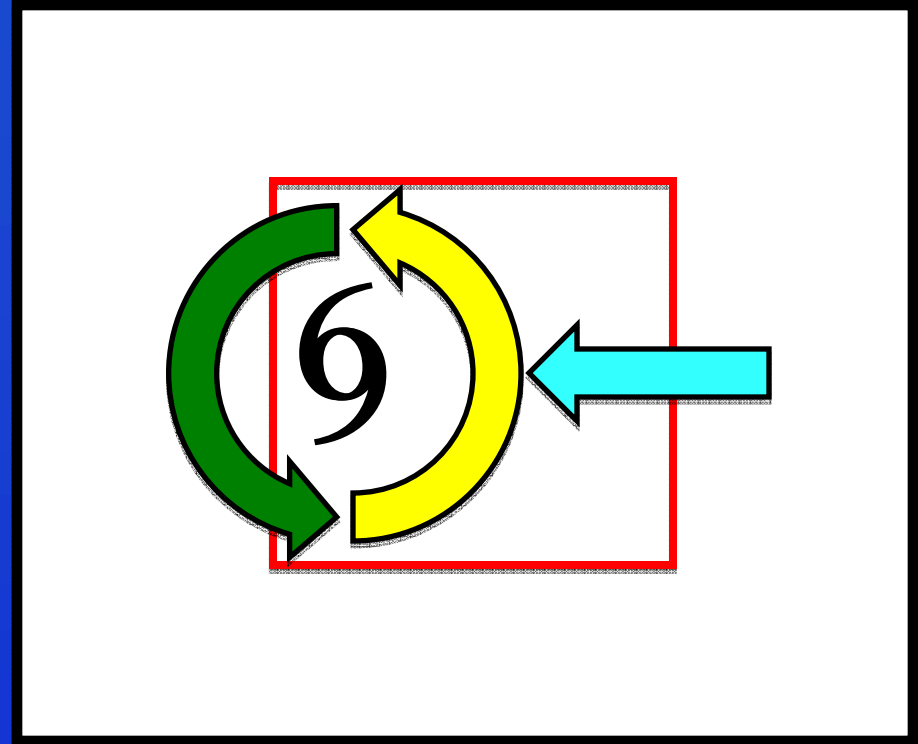
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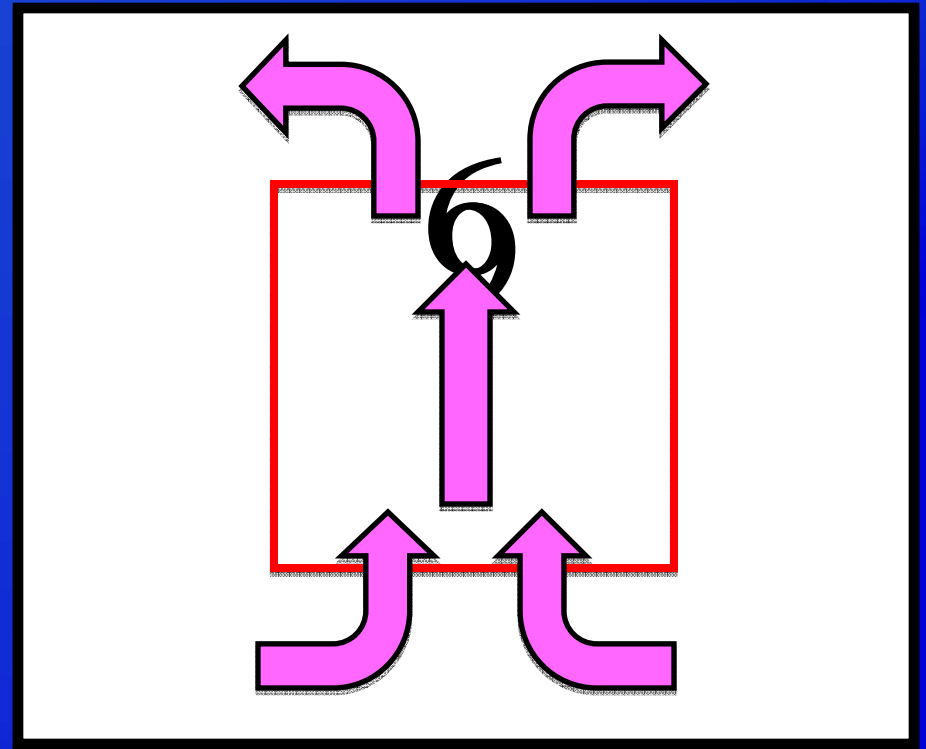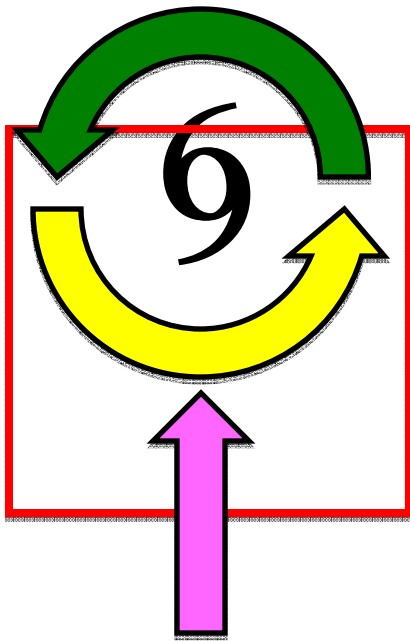A westward displacement of the TC will result in a positive contribution to meridional flow
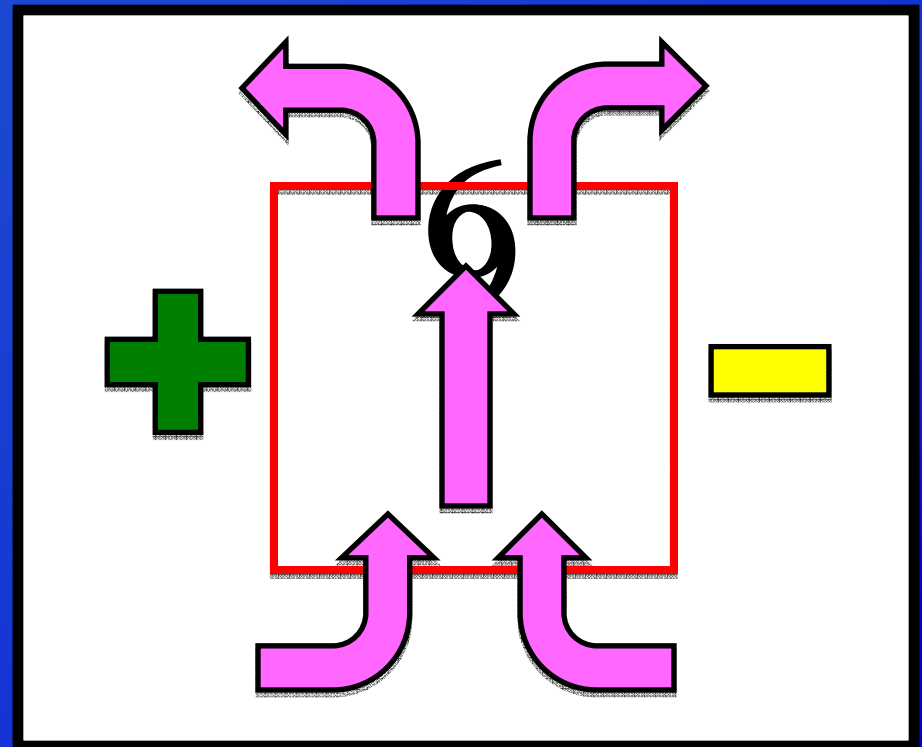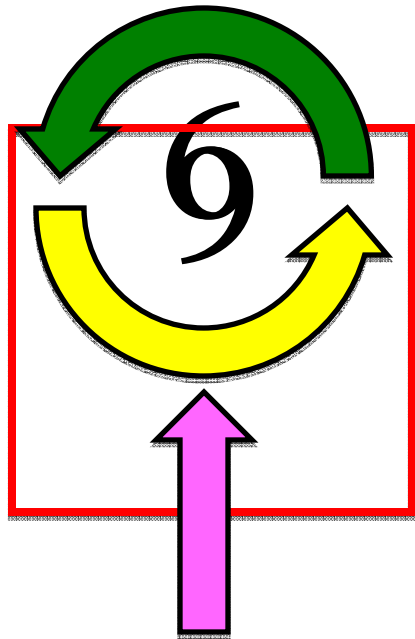
Steering Response Function

- What would this problem look like in the sensitivity gradients?
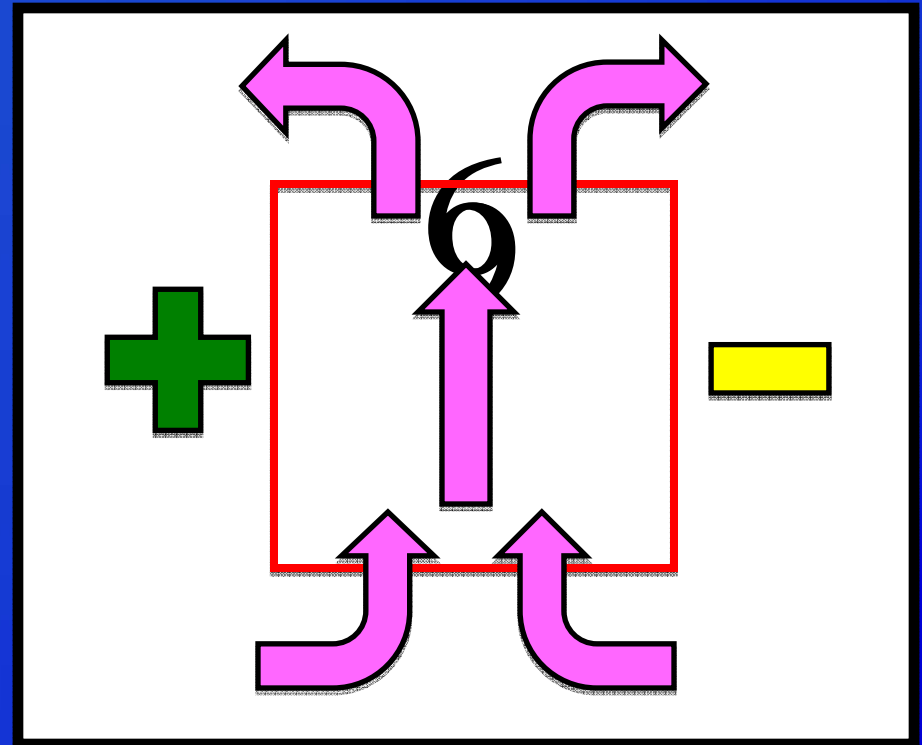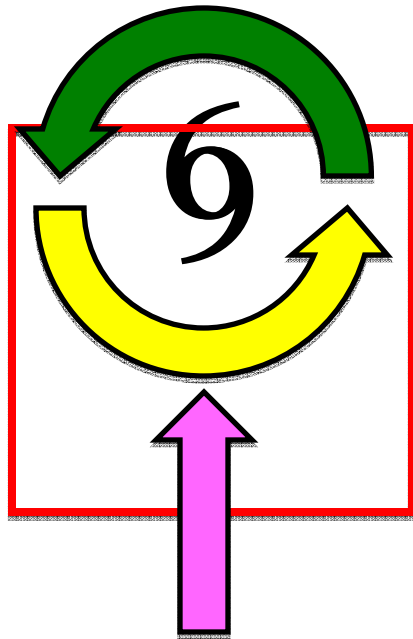
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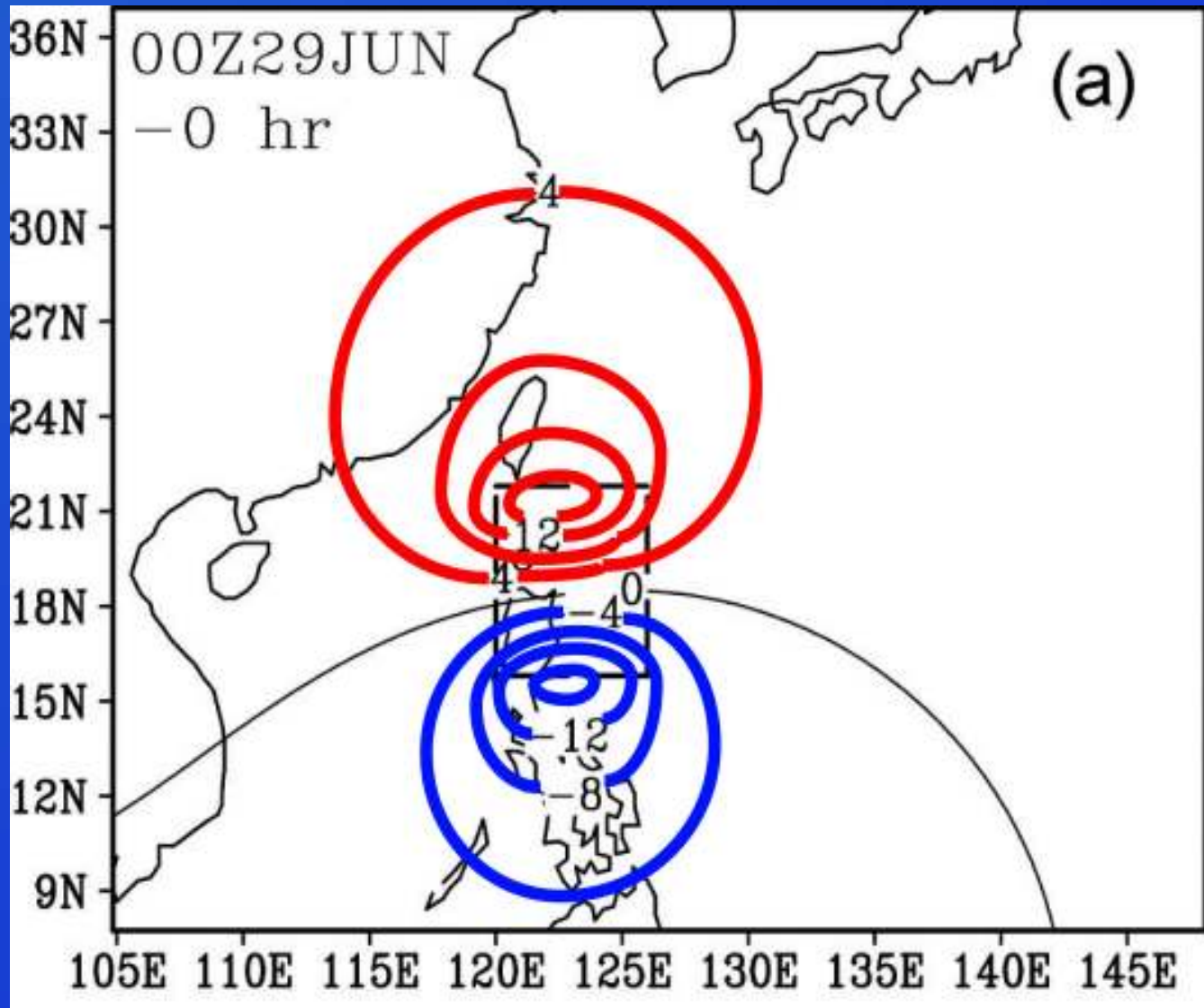
Steering Response Function
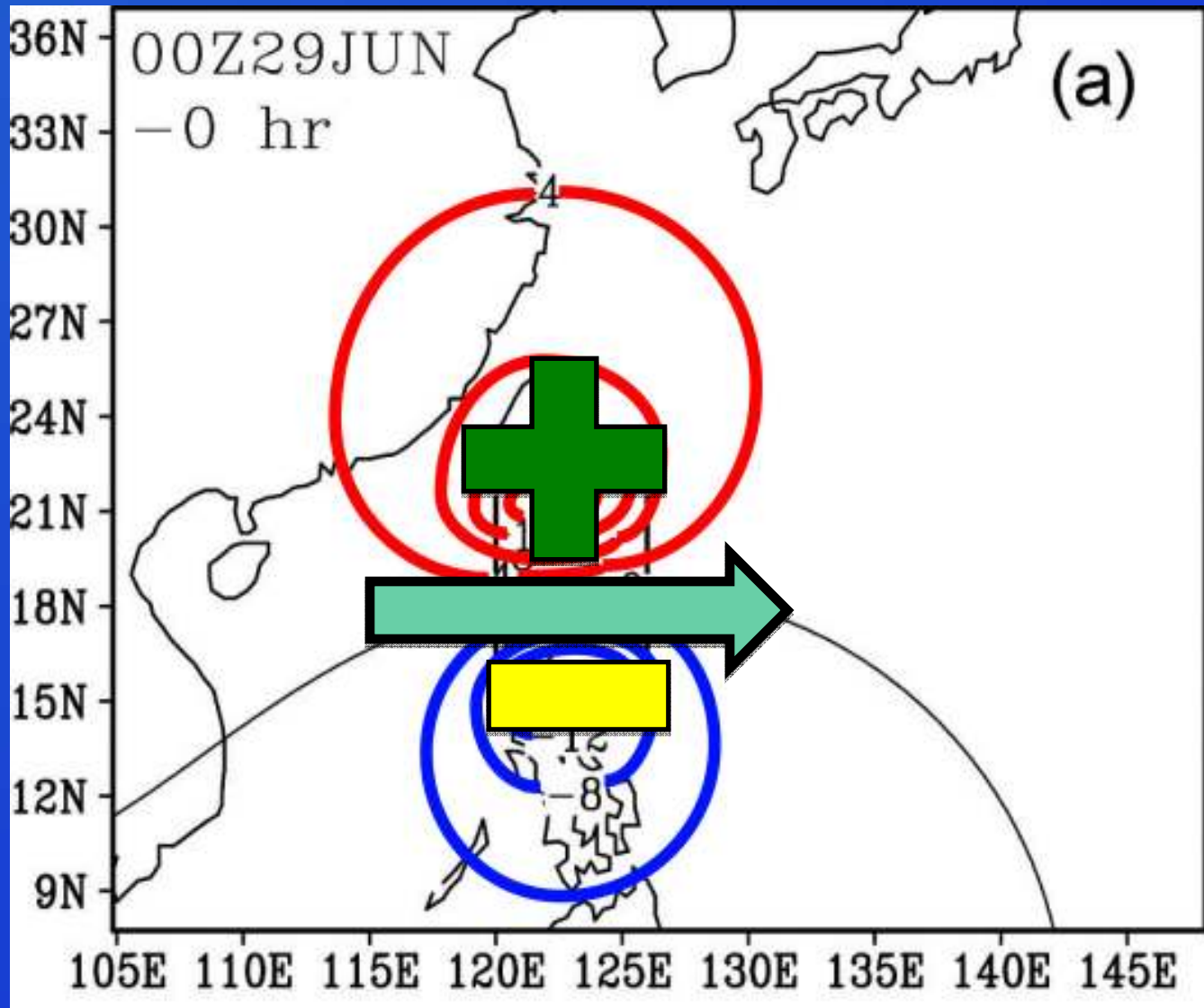
Steering Response Function

Sensitivity of R_1 with respect to vorticity should show positive (negative) sensitivity west (east) of the TC
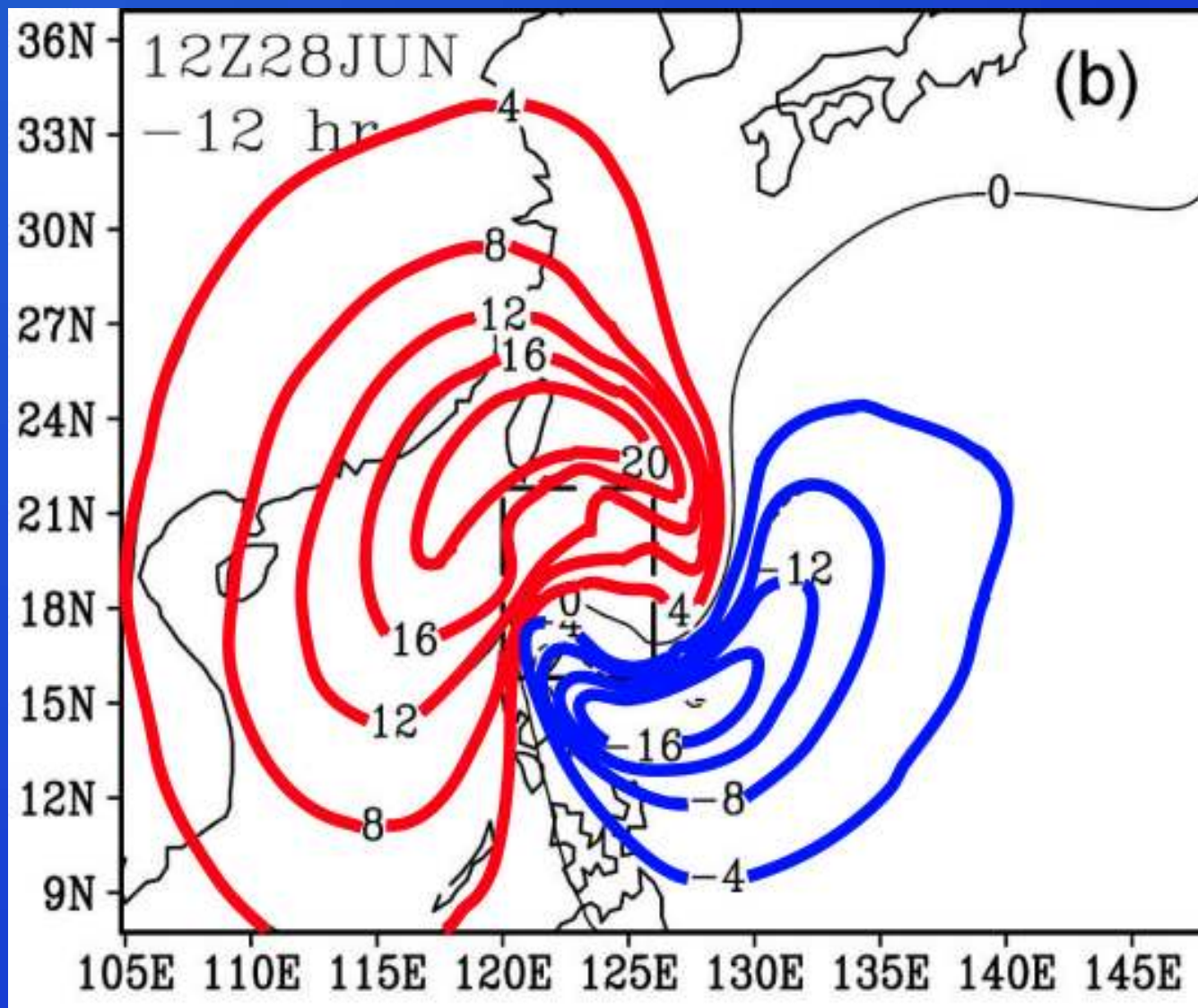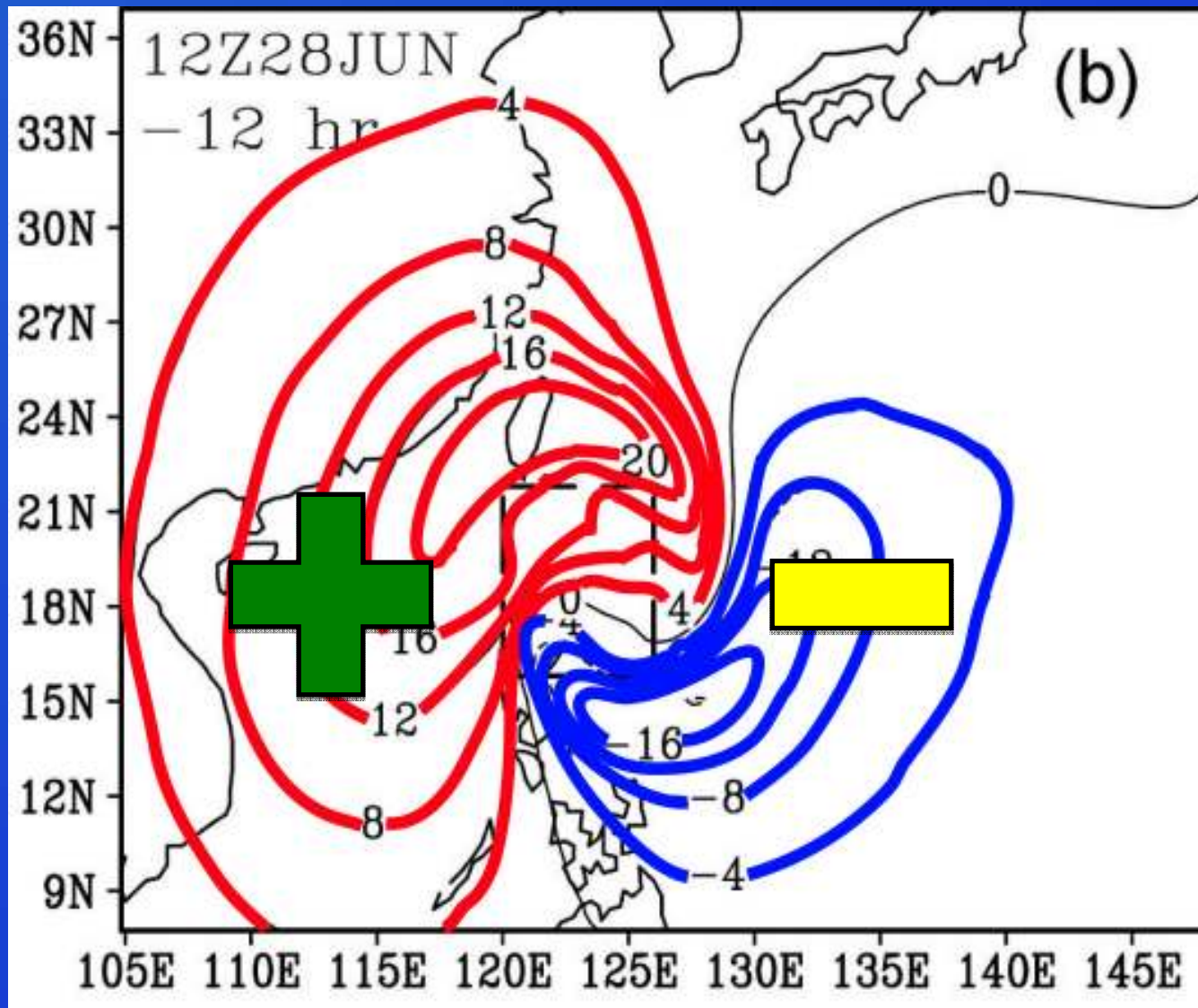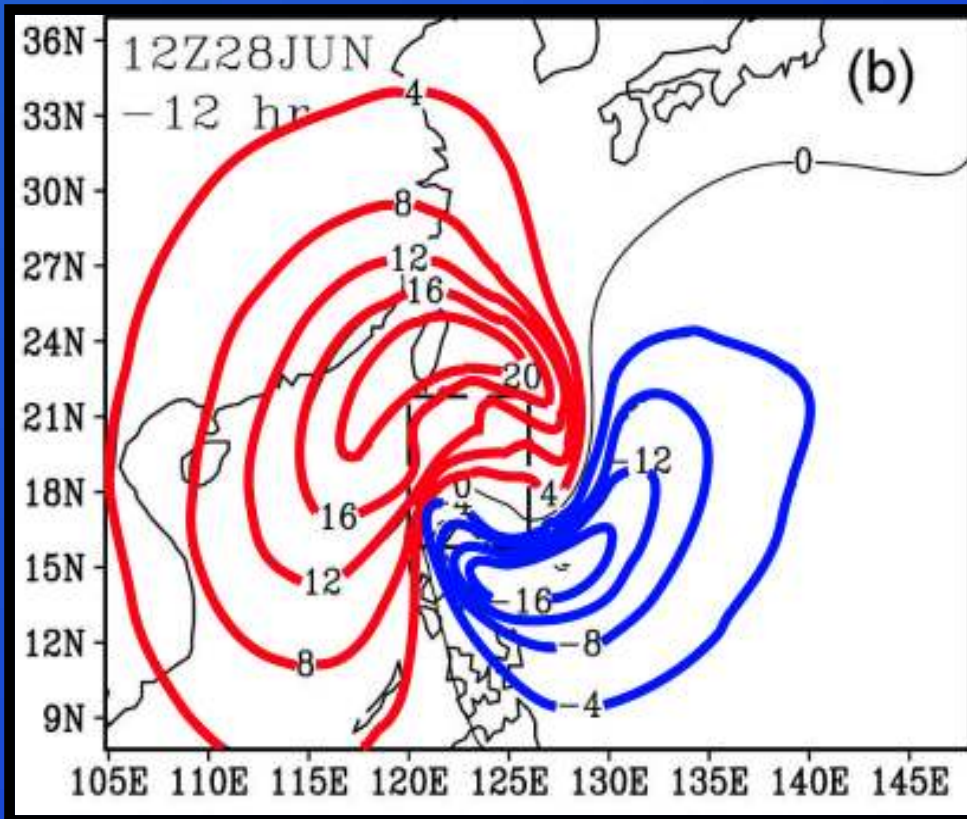
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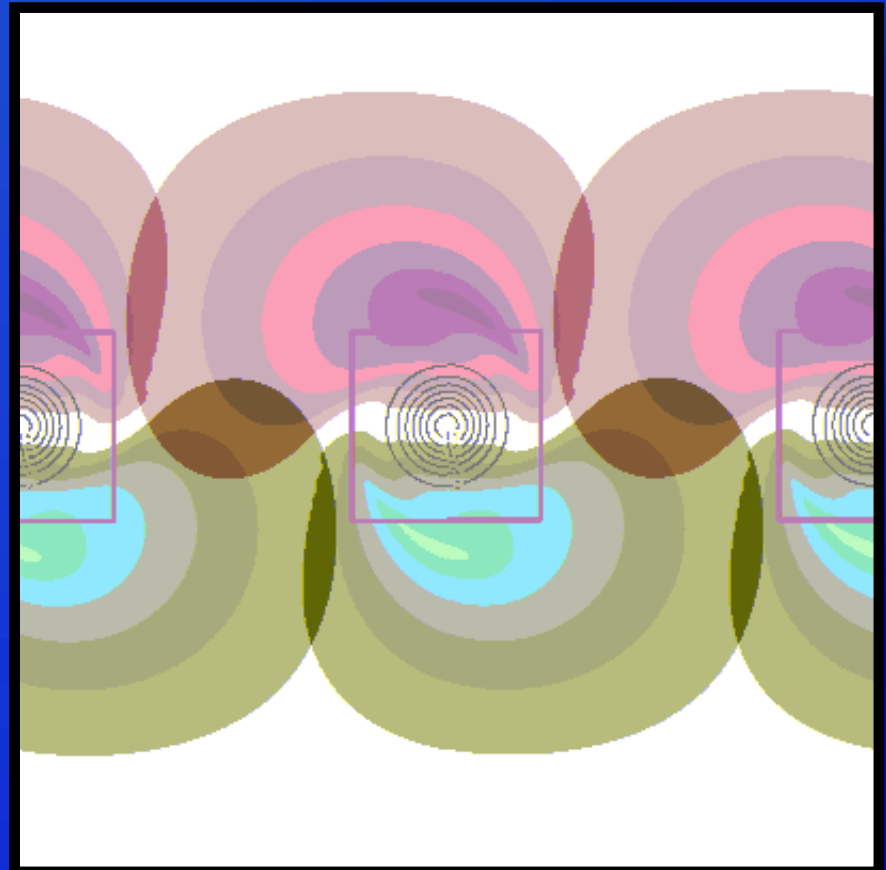
Interpretation

MM5 simulation of Typhoon Minduelle (2004)* (12 hour integration)

2-D barotropic, non-divergent simulation of idealized vortex (24 hour integration)
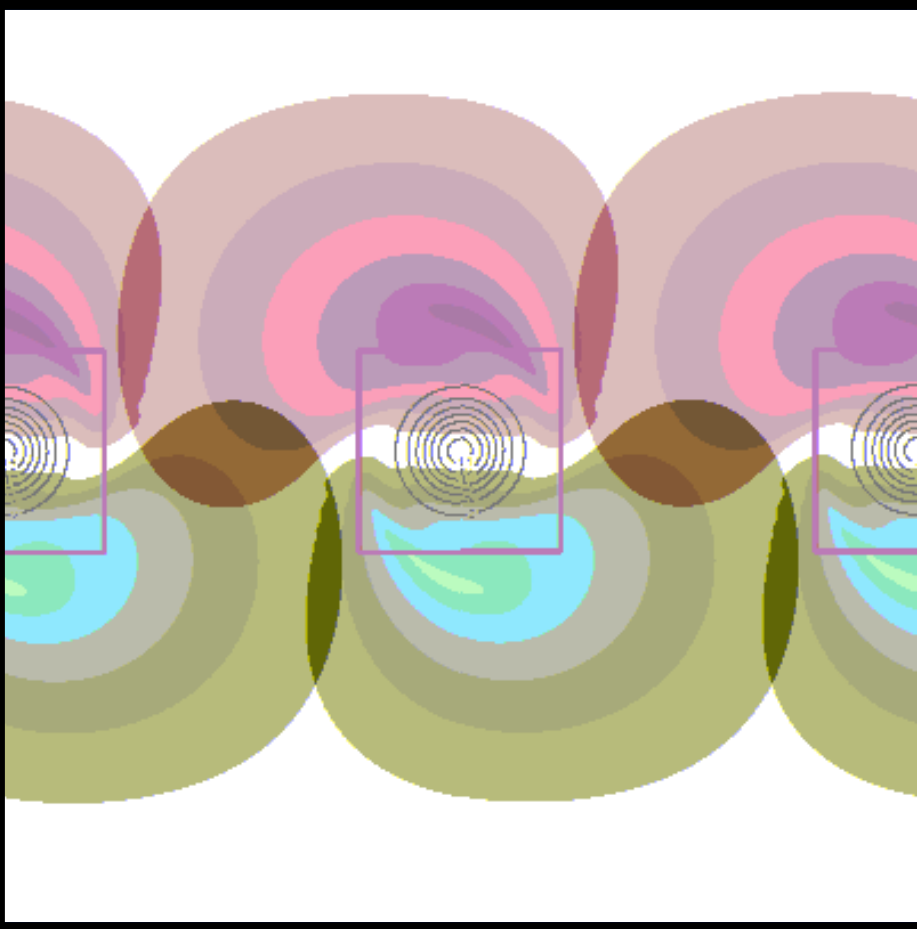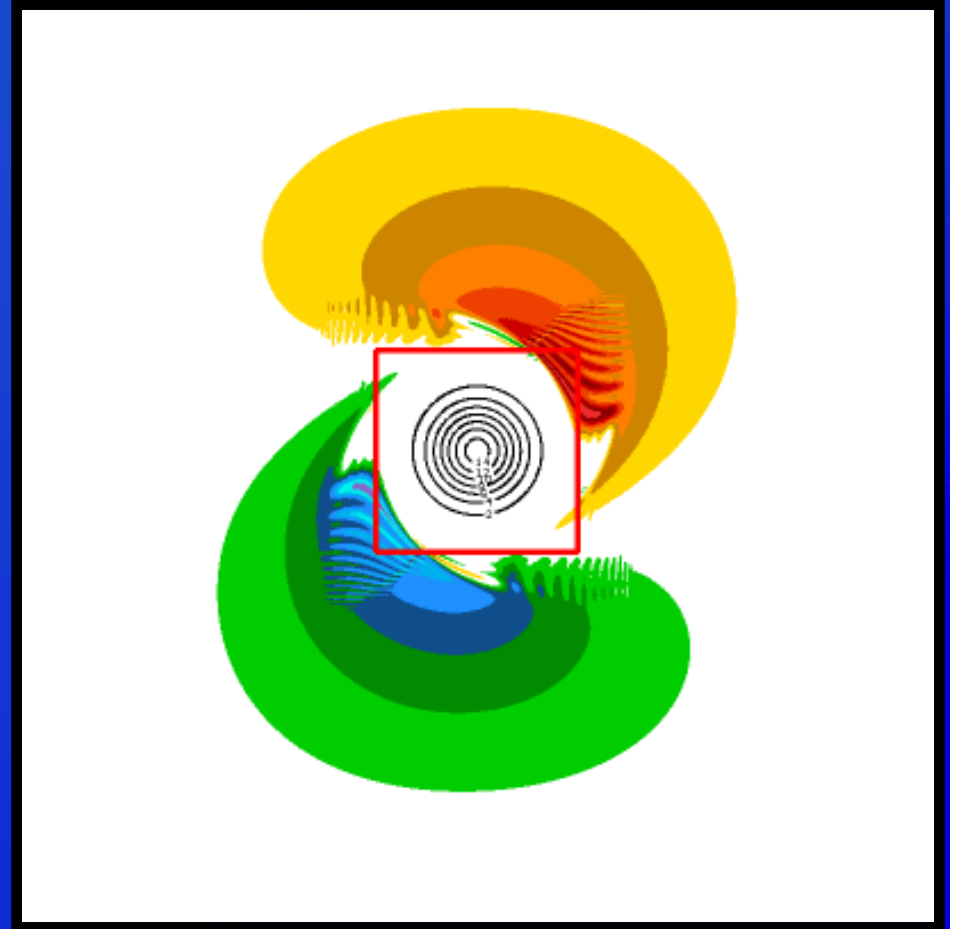
New Steering Response Function

- This problem can be solved if we make a new response function to describe TC steering in a different way:

R_{E1} = Environmental zonal flow in response function box = Zonal flow in box when vorticity/divergence of TC vortex is removed

R_{E2} = Environmental merid. flow in response function box = Merid. flow in box when vorticity/divergence of TC vortex is removed
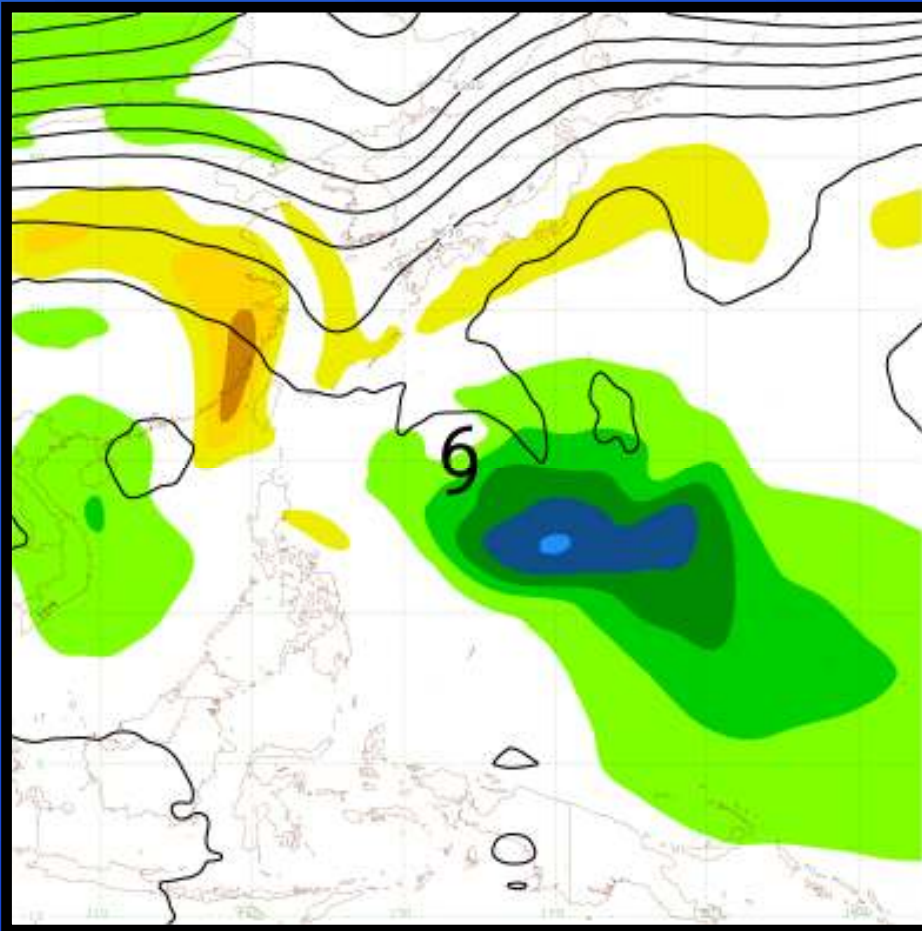
New Steering Response Function

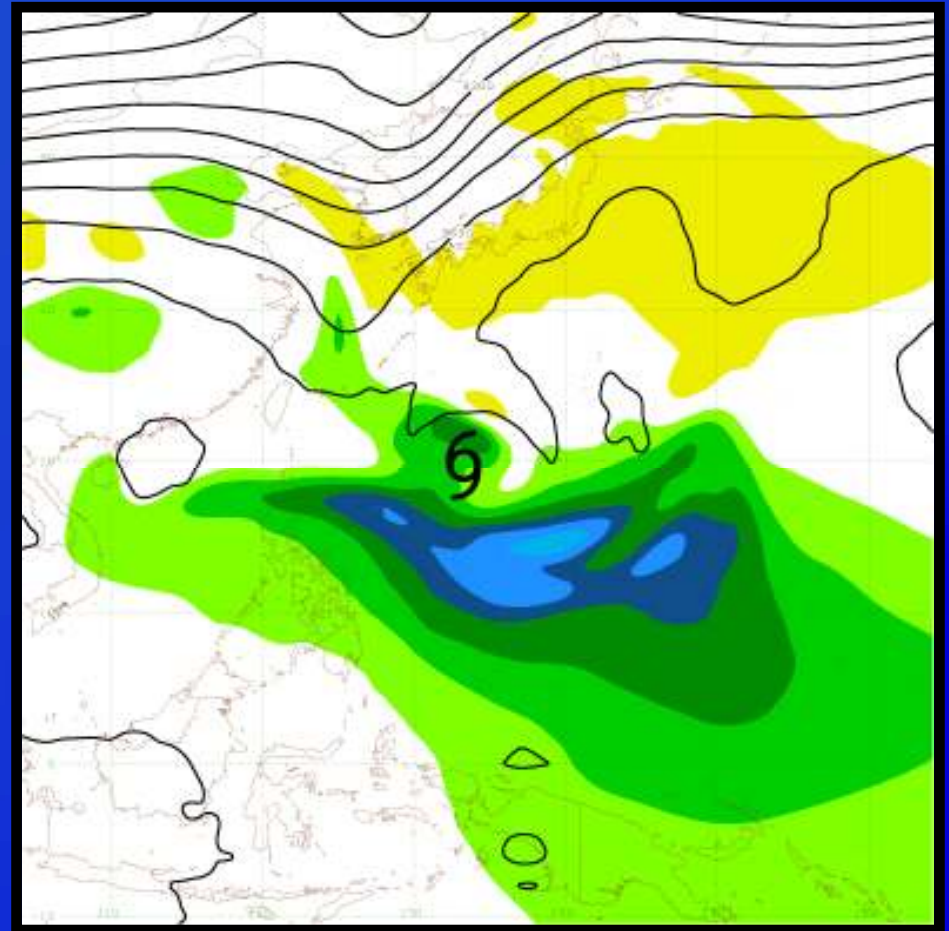Sensitivity of R_1 with respect to vorticity

Sensitivity of R_{E1} with respect to vorticity

New Steering Response Function

at 300 hPa for NOGAPS simulation of Typhoon Meari (2004) (36 hour integration)

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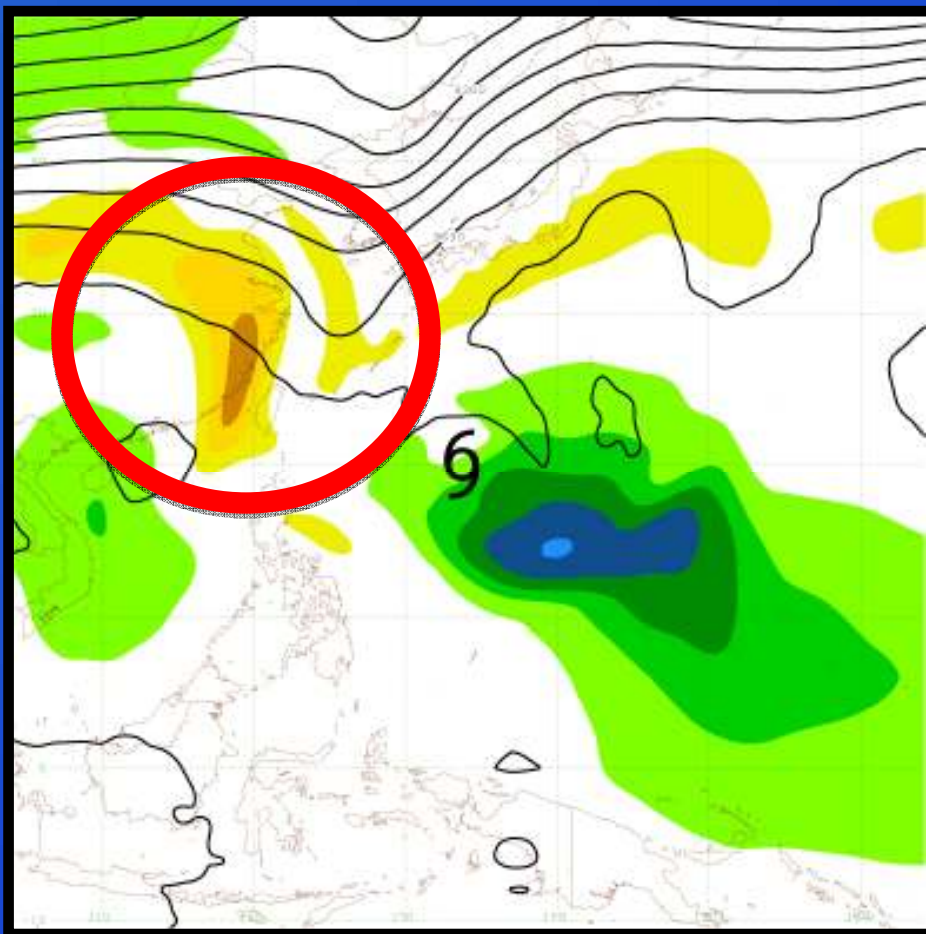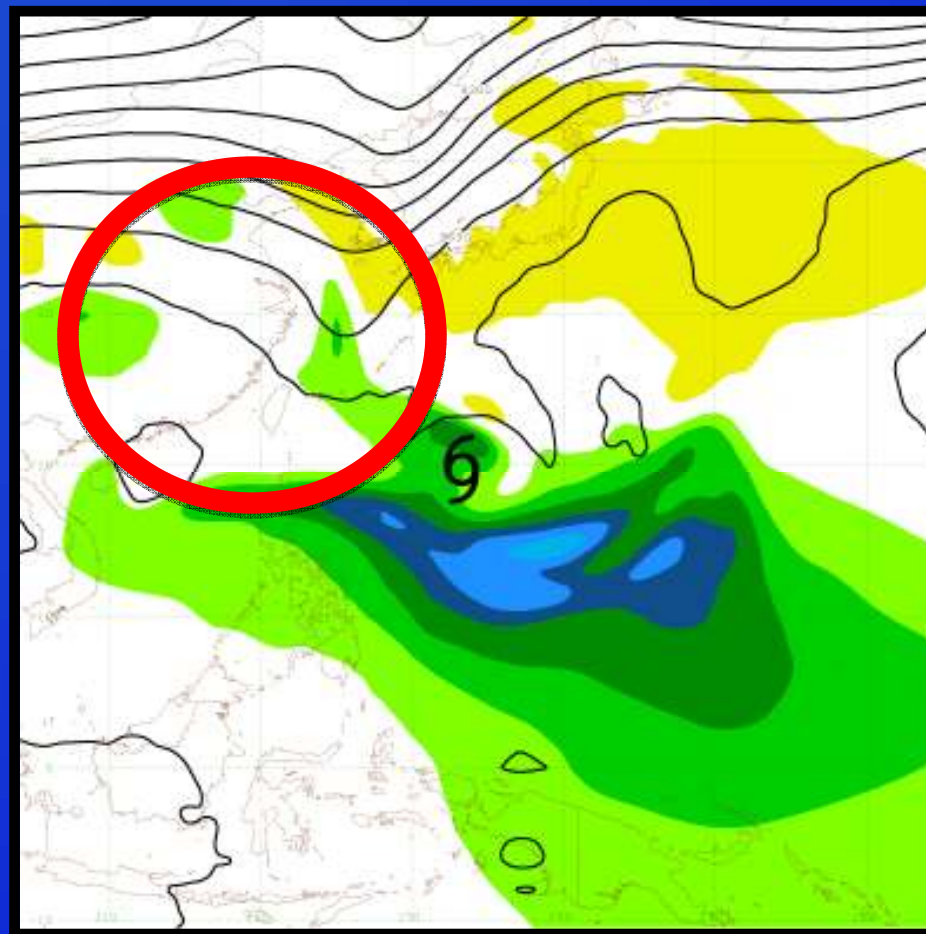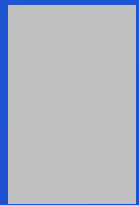

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Comparison

- We expect:

  describes vorticity perturbations that would yield a northward environmental flow
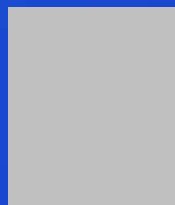
  describes vorticity perturbations that would yield an eastward environmental flow

Comparison

500 hPa perturbation environmental winds for optimal perturbations to increase R_1
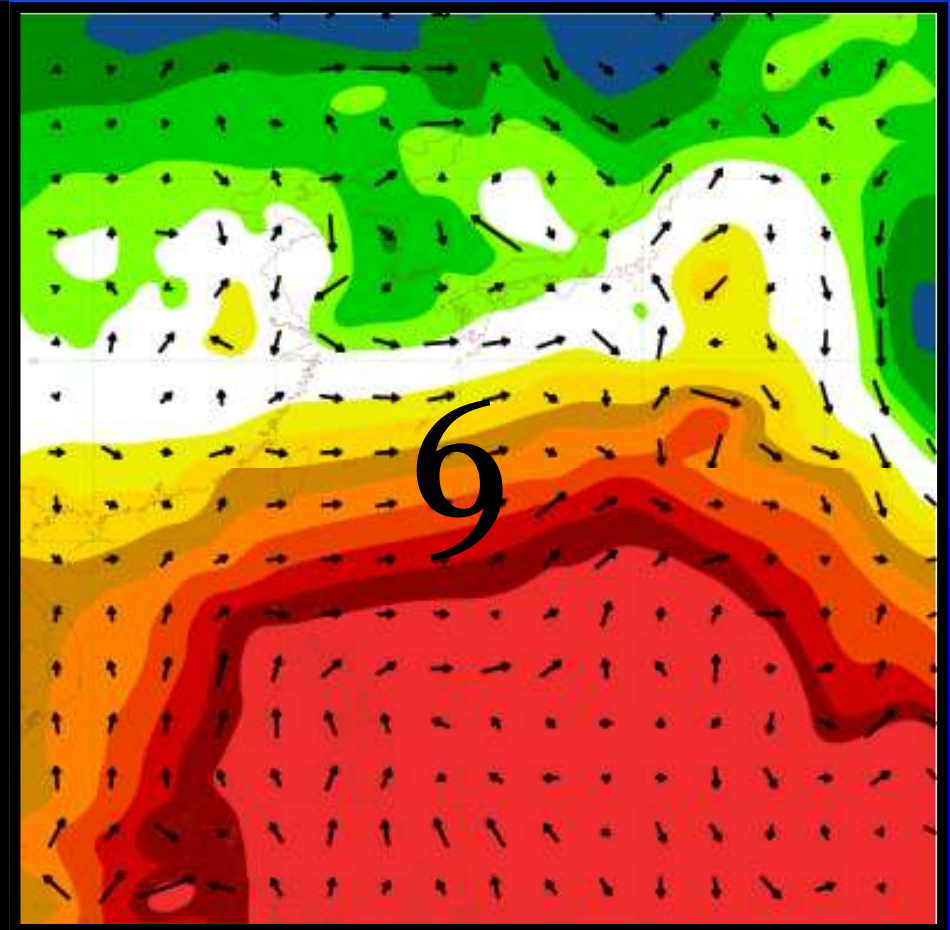
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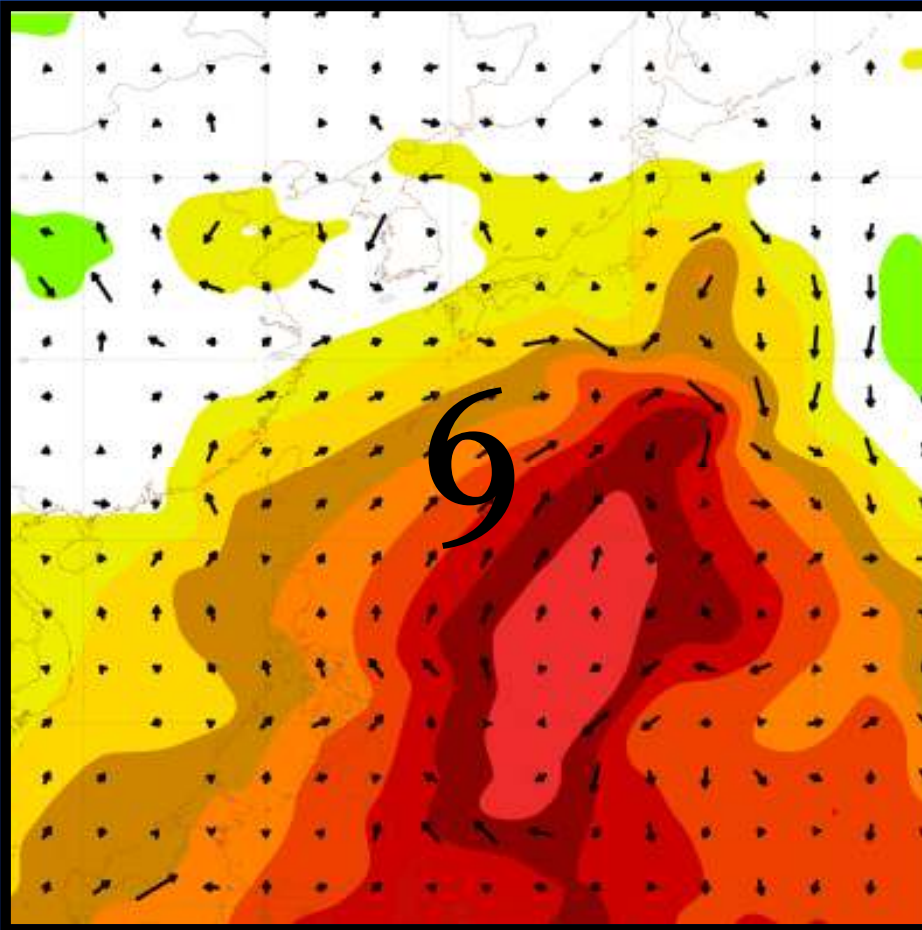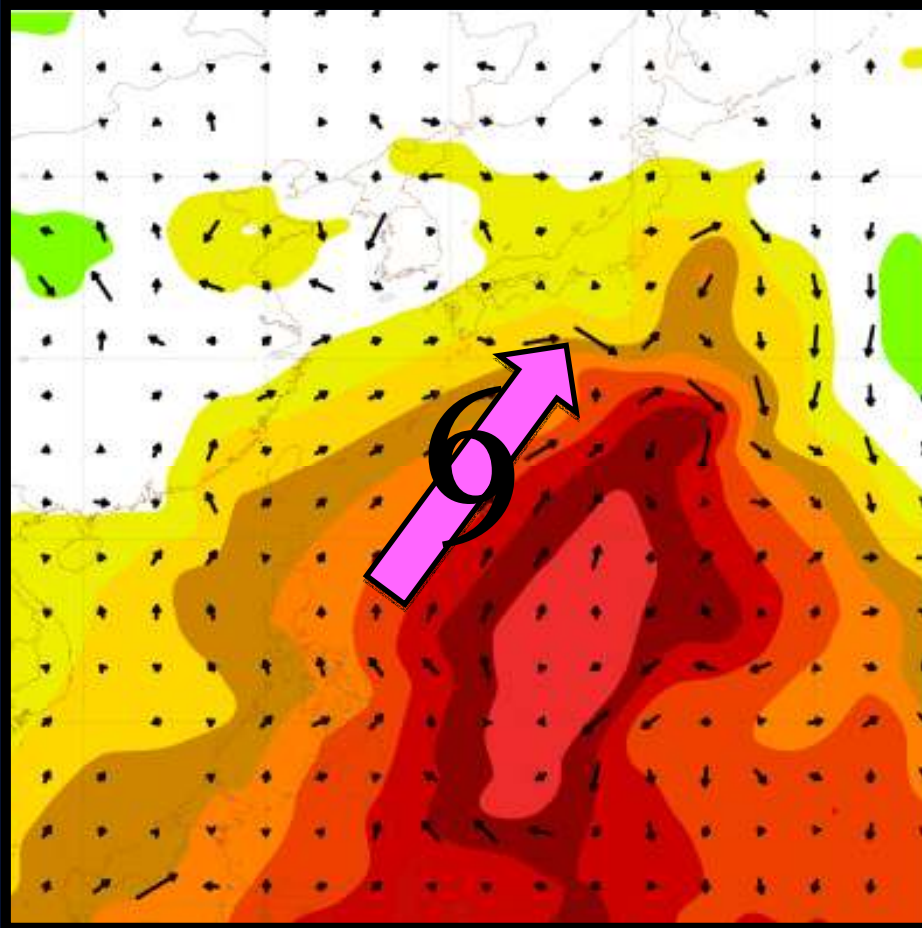500 hPa perturbation environmental winds for optimal perturbations to increase R_1
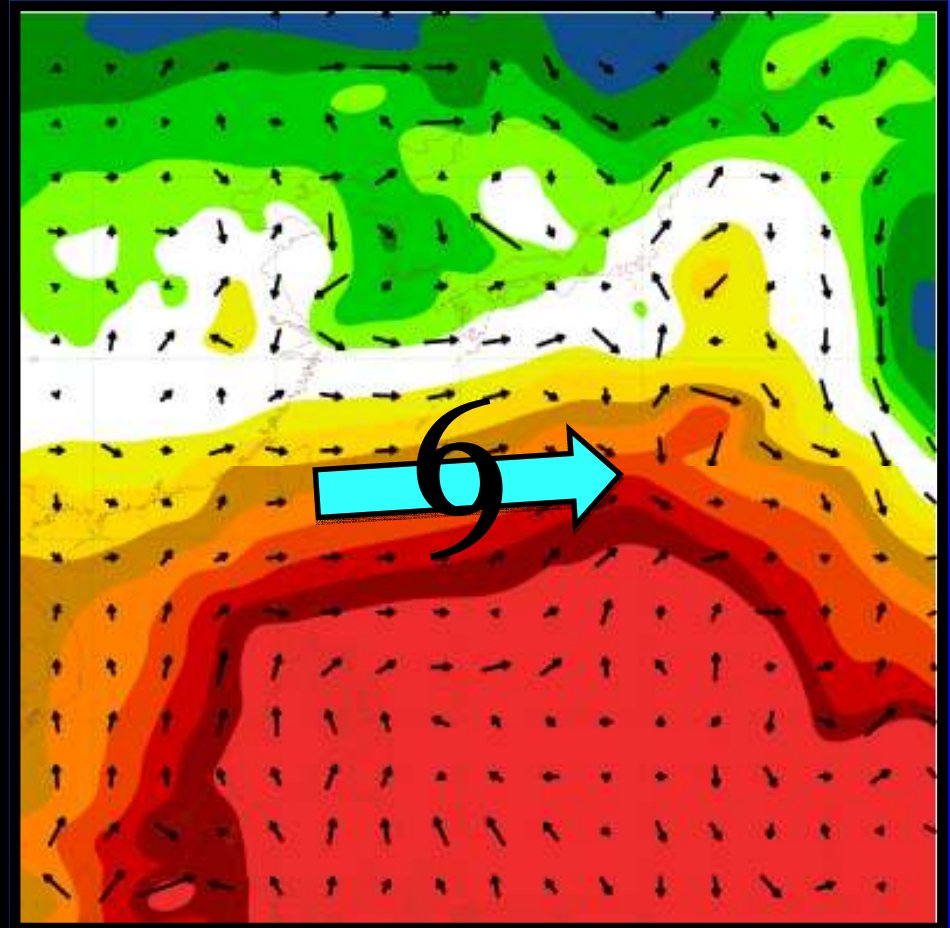
500 hPa perturbation environmental winds for optimal perturbations to increase R_{E1}

Conclusions

- Response functions traditionally used to define TC steering are flawed:
  - Small meridional (zonal) perturbations of the TC allow the TC's own symmetric circulation to contribute to response function
  - These contributions have nothing to do with the steering of the TC

Conclusions

- New response functions have been created to redefine the steering of the TC and remove this flaw:
  - Focus on "environmental wind" with TC removed instead of averaged full wind
  - Optimal perturbations to increase R_1 result in a southerly environmental flow, while optimal perturbations to increase R_{E1} result in a purely westerly environmental flow
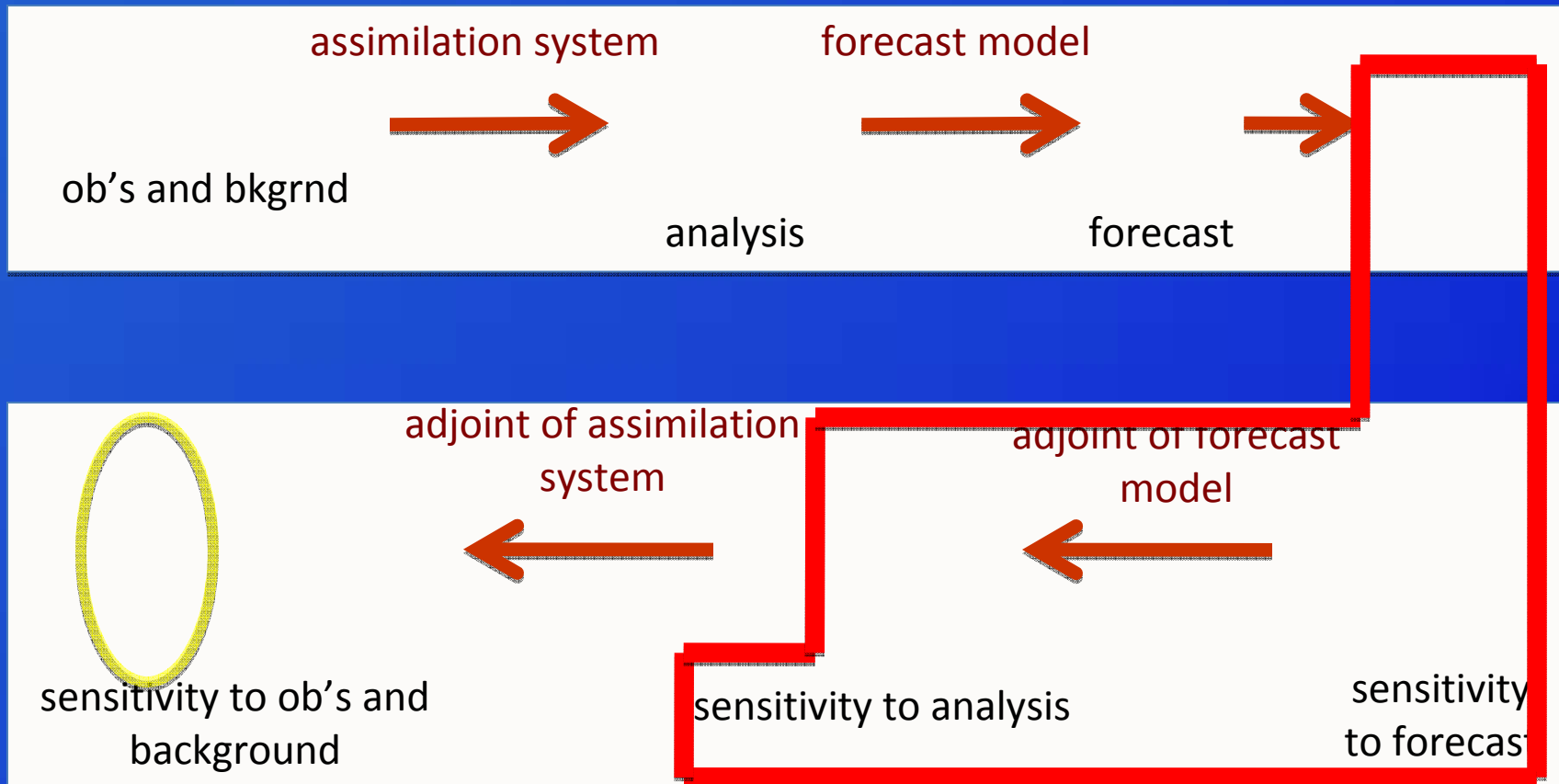
An Adjoint-Based Targeting Strategy
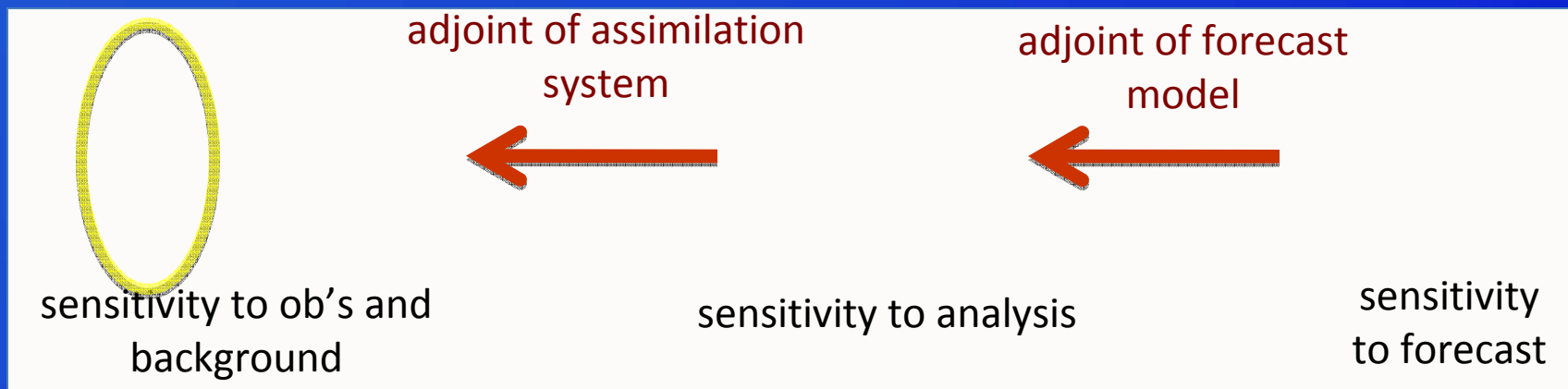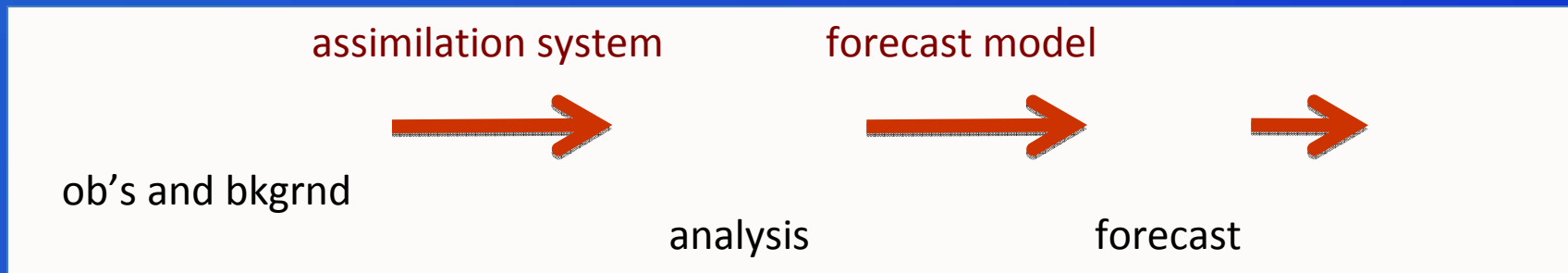
assimilation system   forecast model

ob's and bkgrnd

analysis   forecast

adjoint of assimilation system   adjoint of forecast model

sensitivity to ob's and background   sensitivity to analysis   sensitivity to forecast

Sensitivities of steering to the (potential) observations are informed by the sensitivities to the analysis, the characteristics of the analysis errors, and the nature of the assimilation system.

An Adjoint-Based Targeting Strategy

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