Adjoint-Based Analysis of Observation Impact on Tropical Cyclone Intensity Forecasts

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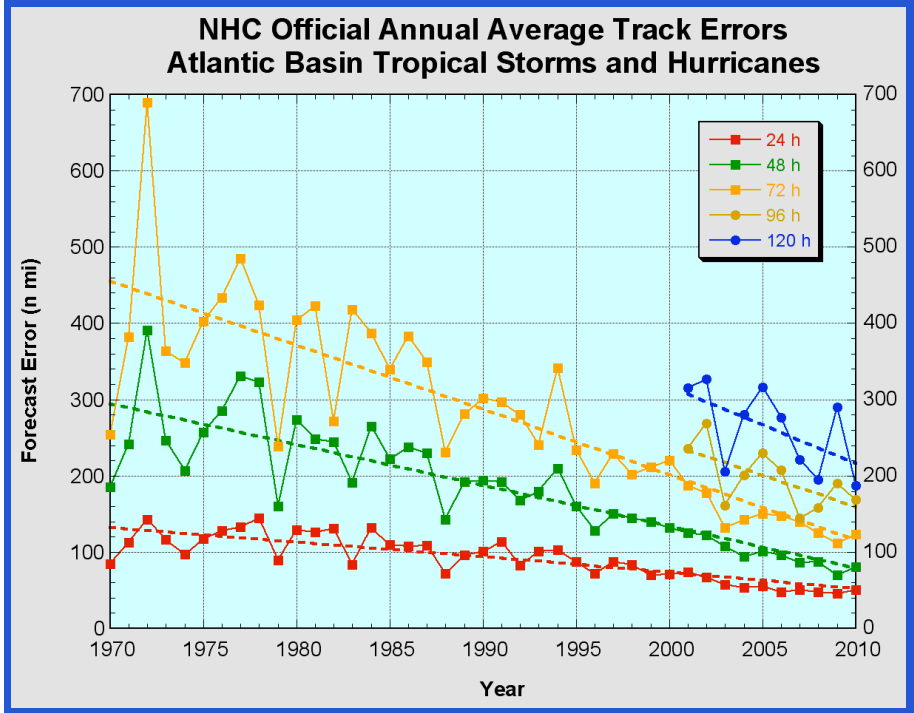
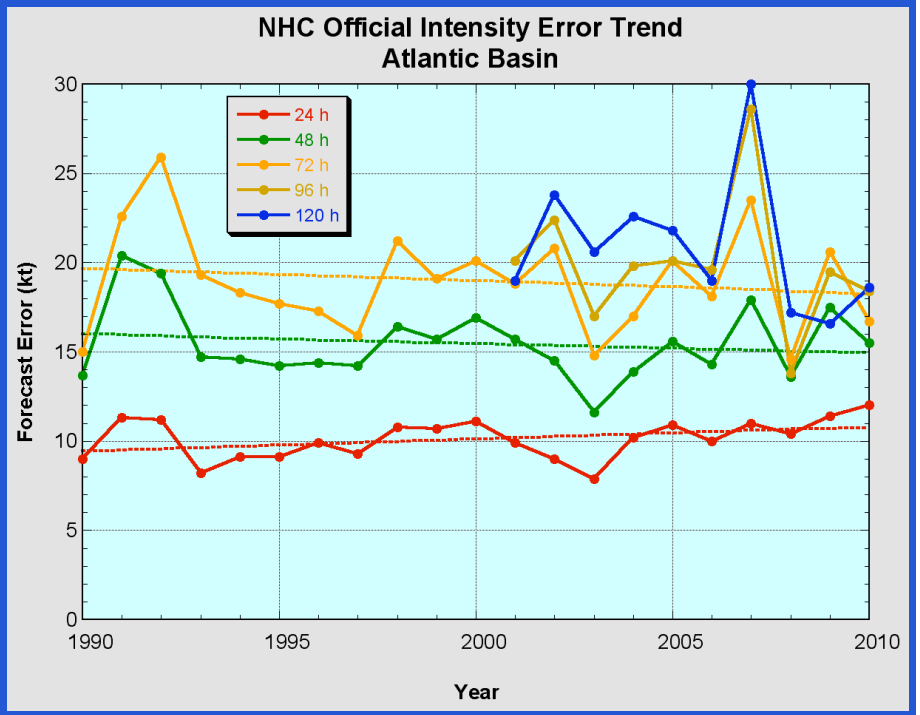
Objective

- In what ways are the TC intensity forecast **sensitive to initial conditions**?
- How do **assimilated observations** impact the TC intensity forecast?
- What differences exist between sensitivity/ob-impact of **24 and 48 hr forecasts**?

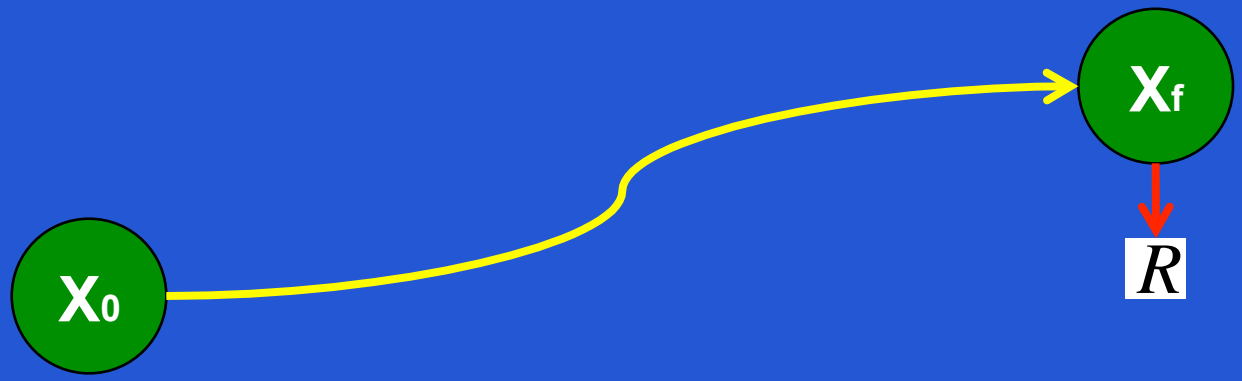




Plots courtesy of http://cliffmass.blogspot.com/2011/08/potential-breakthrough-in-hurricane.html

Adjoint Models

Nonlinear NWP model evolves analysis state ($\mathbf{X}_0$) to forecast state ($\mathbf{X}_f$)
TC intensity forecast can be defined as a function of the final state – R



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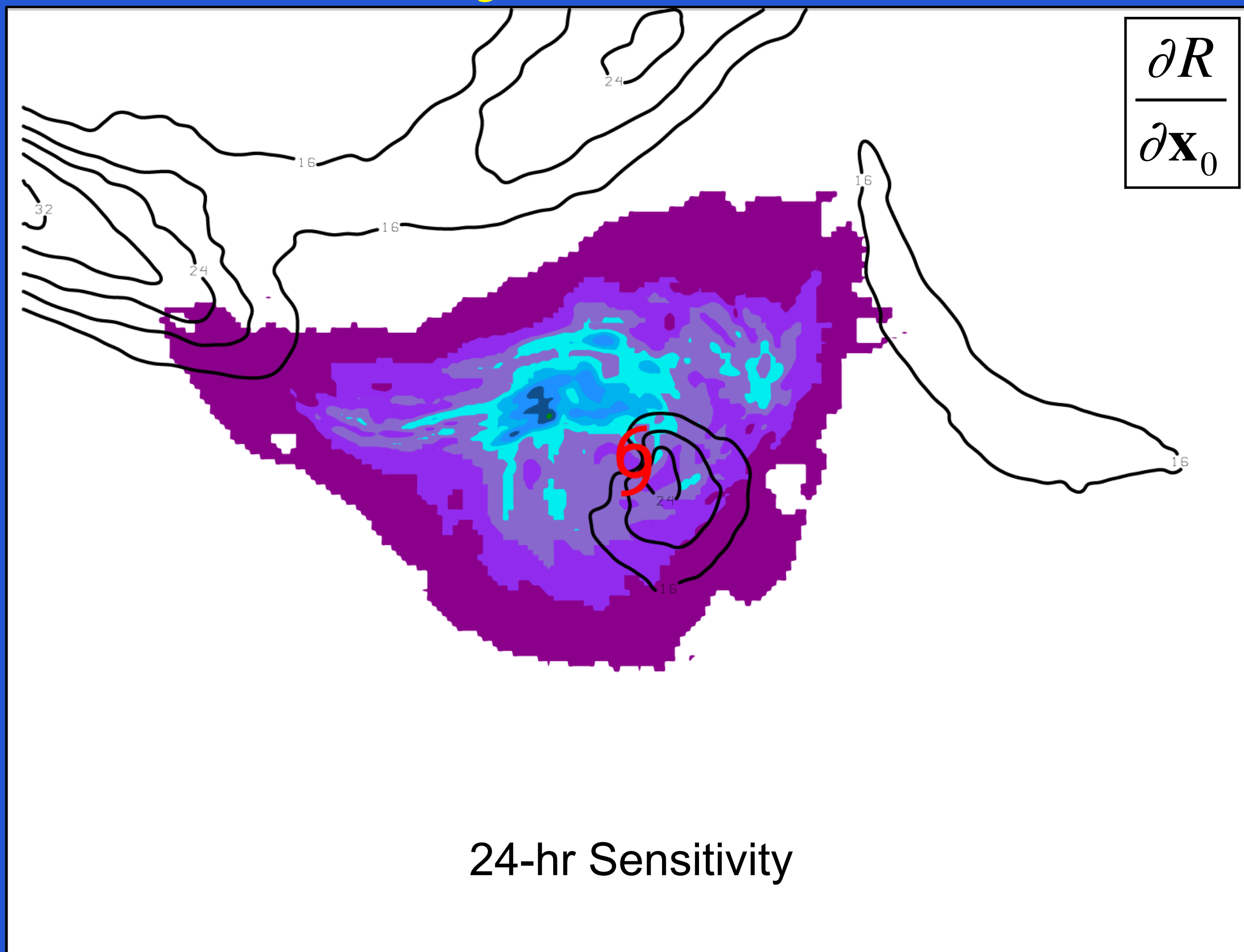
Adjoint model evolves backward along nonlinear NWP trajectory, computing the gradient of some function of the forecast state (R) to perturbations to the initial state – **sensitivity of forecast TC intensity to initial state**

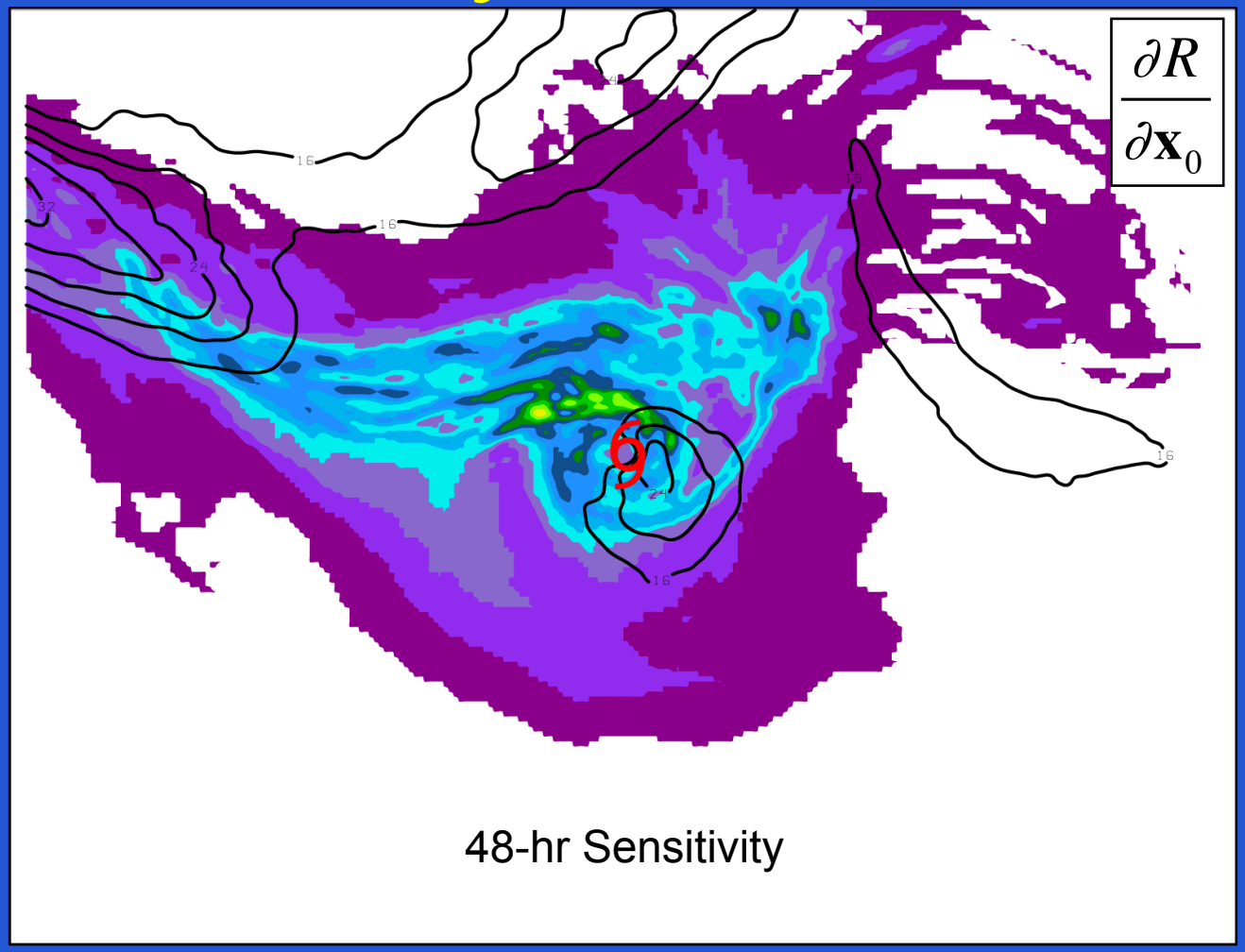
Sensitivity to Initial State



Hurricane Sandy – Storm-centered composites from model initialized 0600 UTC 24 Oct - 1800 UTC 28 Oct 2012

Sensitivity of **24-hr** intensity forecast to **wind perturbations near 500 hPa**

Sensitivity to Initial State



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Sensitivity of **48-hr** intensity forecast to **wind perturbations near 500 hPa**
Higher sensitivity **upstream**, especially **near trough** and **extending into jet**

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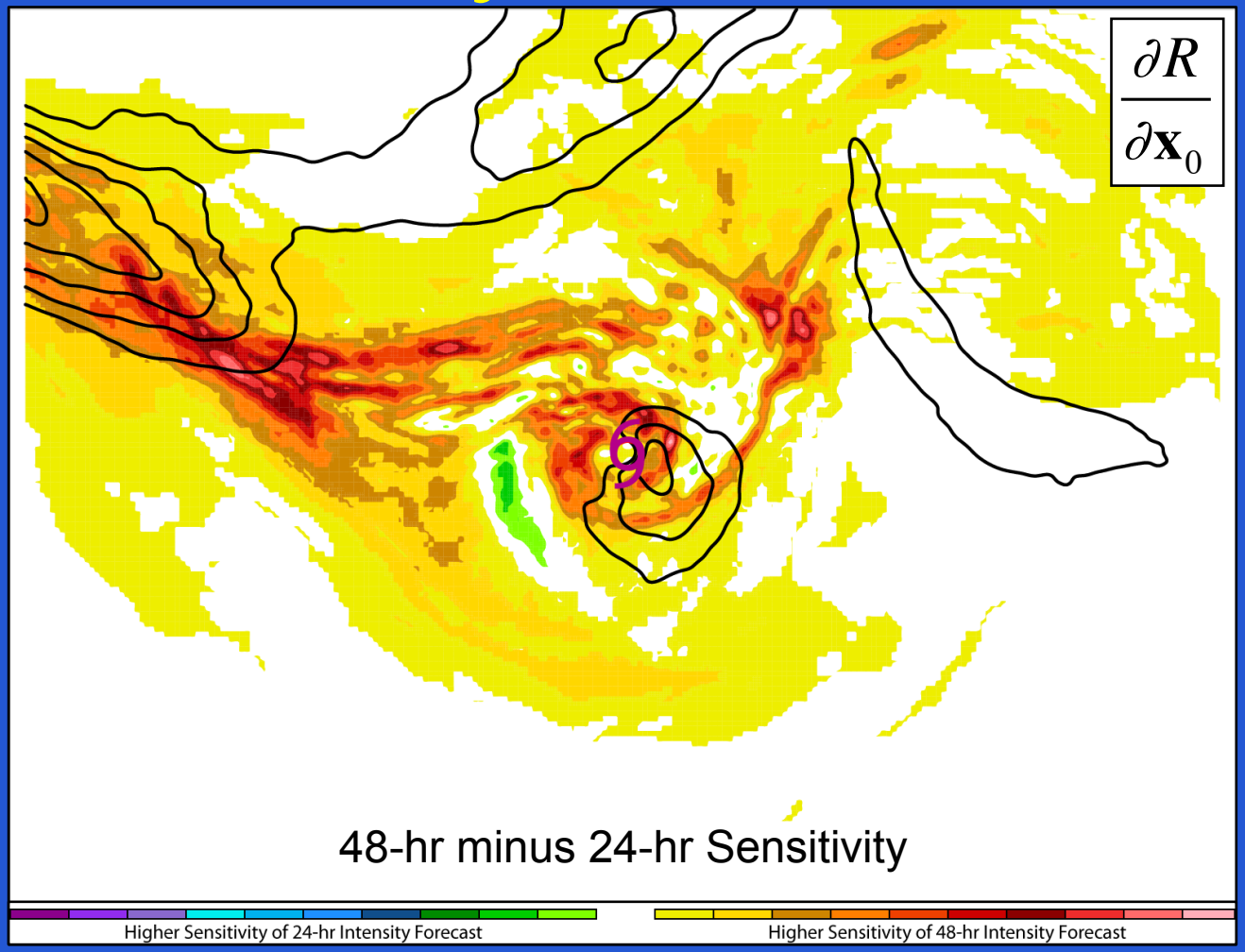

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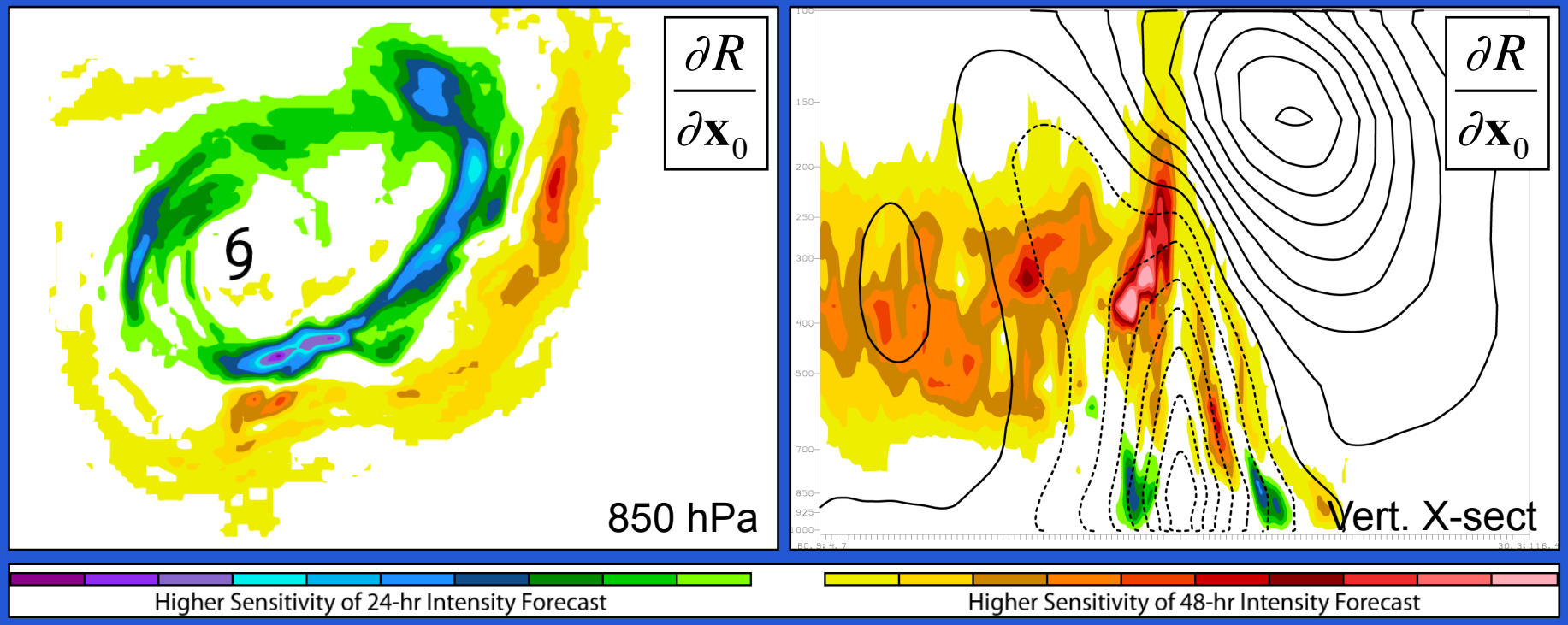
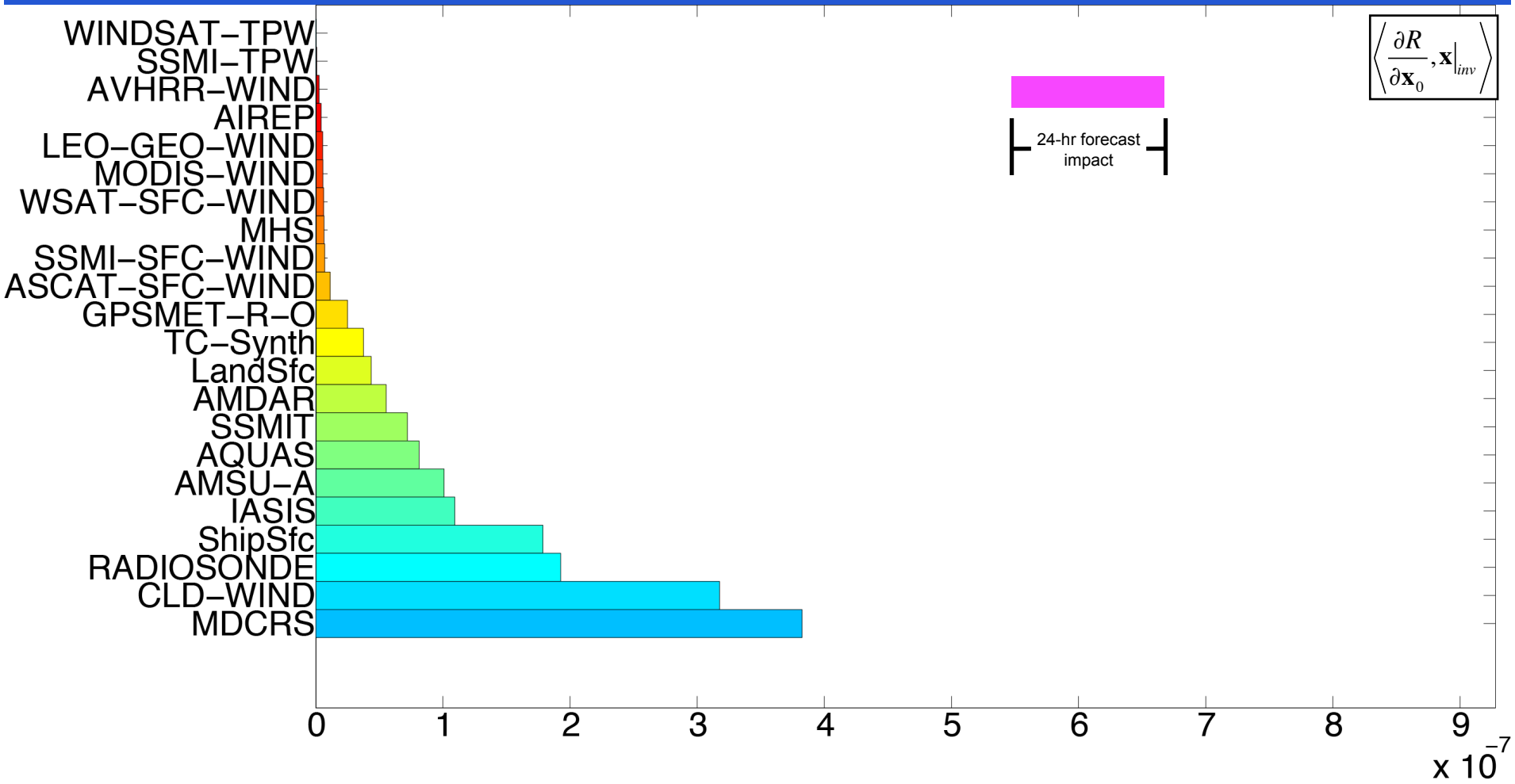


Sensitivity of 48-hr forecast migrates toward **larger radii at low levels** (left) and up to **mid/upper troposophere** toward the **upstream environment** (right), compared to sensitivity at 24-hr

Observation Impact



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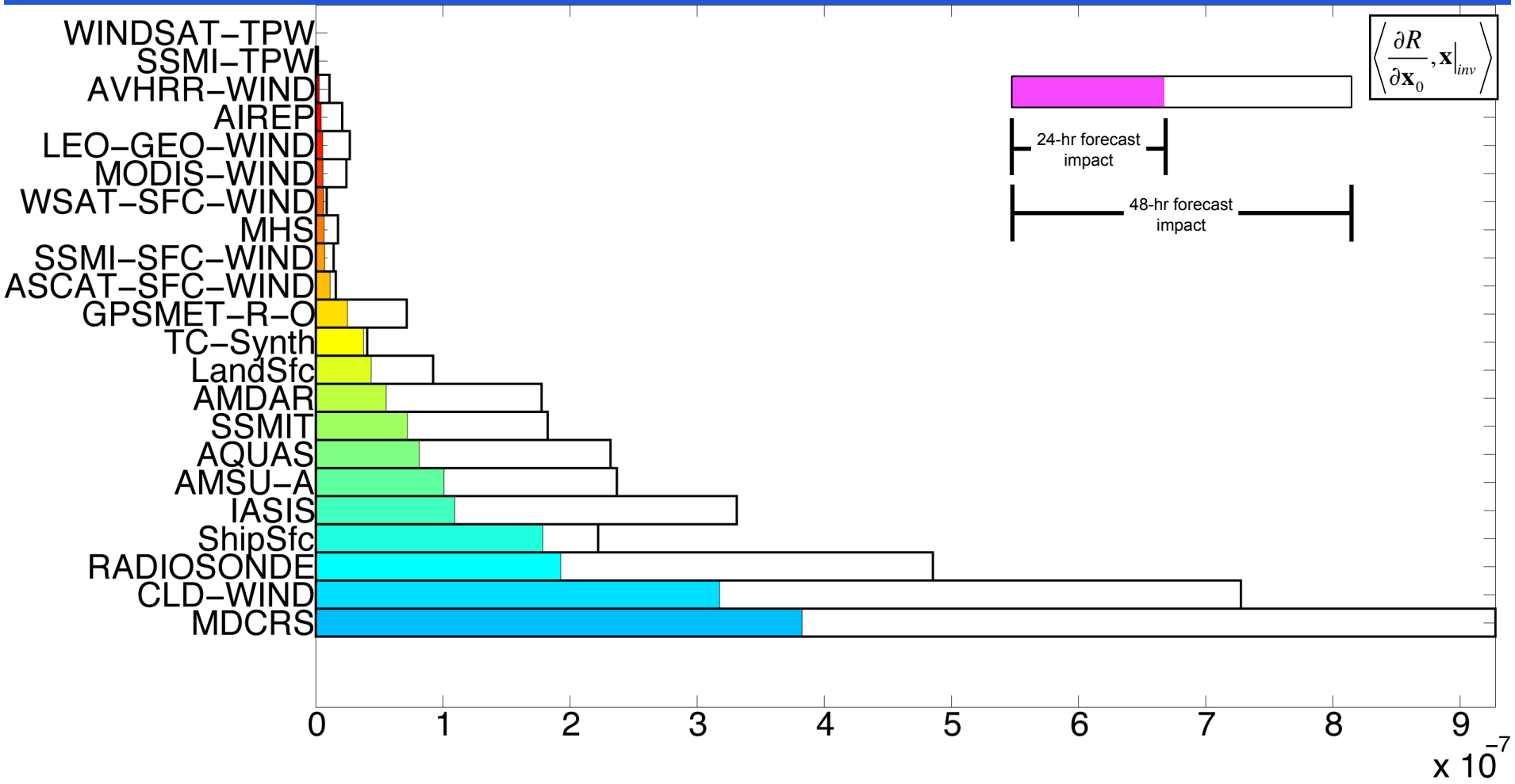
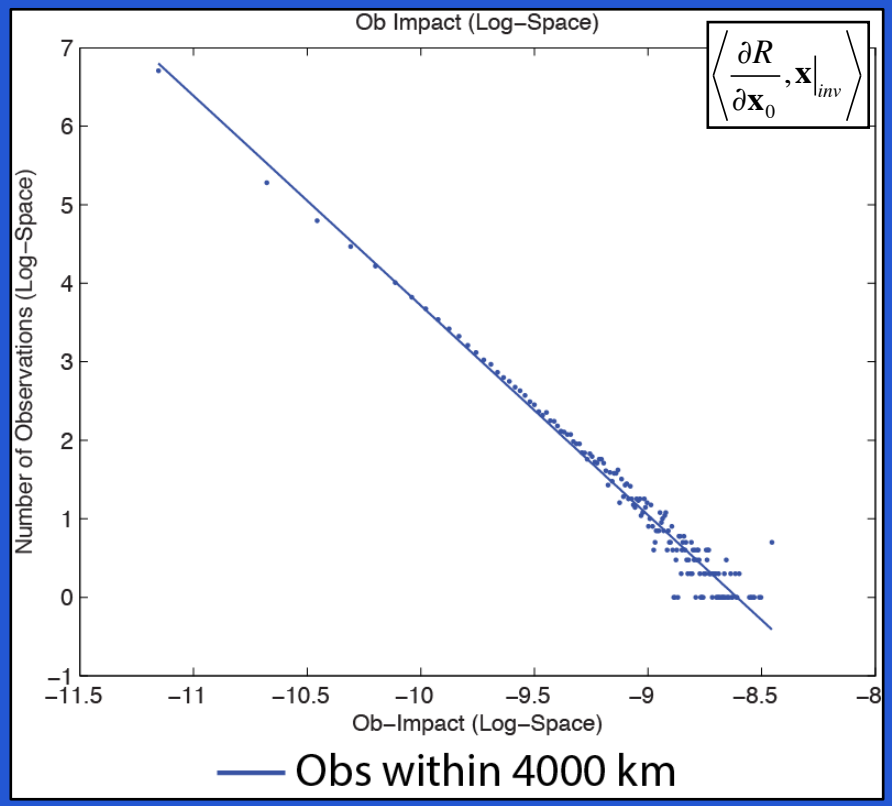
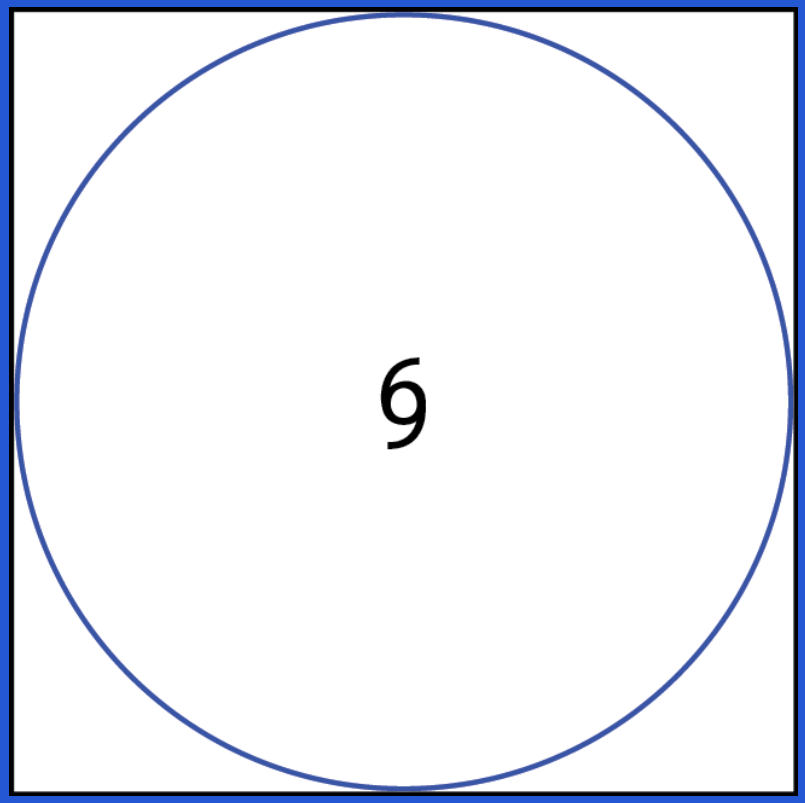


Highly improved impact from **MDCRS/AMDAR**, **AMVs**, and **Radiosondes** at 48-hrs

Contribution From Large Impact Obs





Observation impact follows a **power-law distribution**: **Significant contribution** of total impact from a **small minority** of **very high-impact obs**

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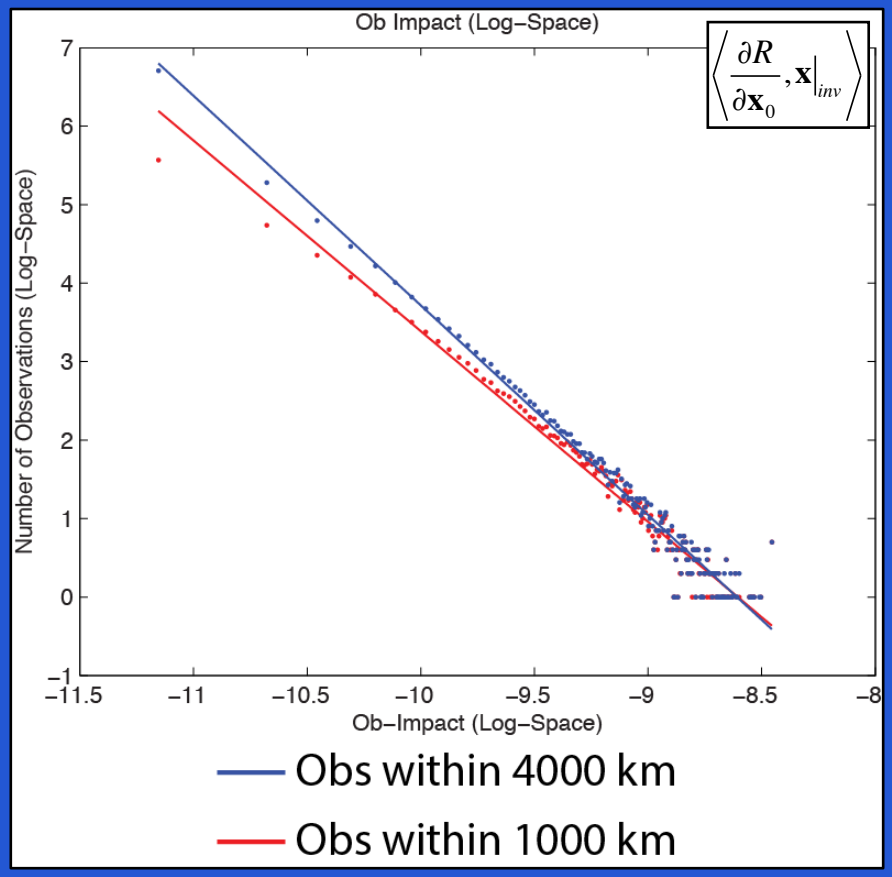

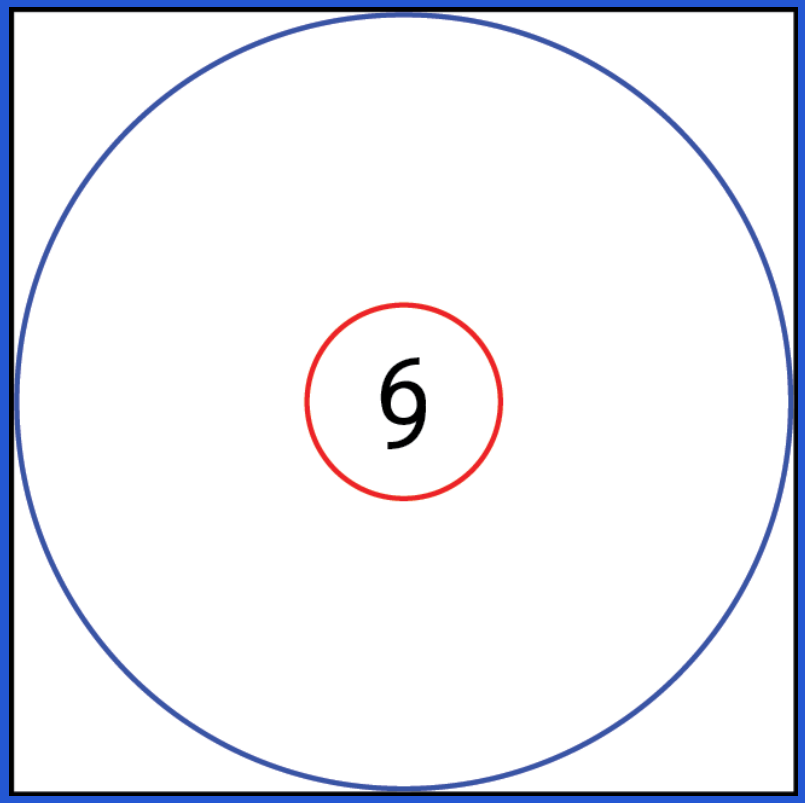

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Relationship is observed for obs **even within small radii** of TC center

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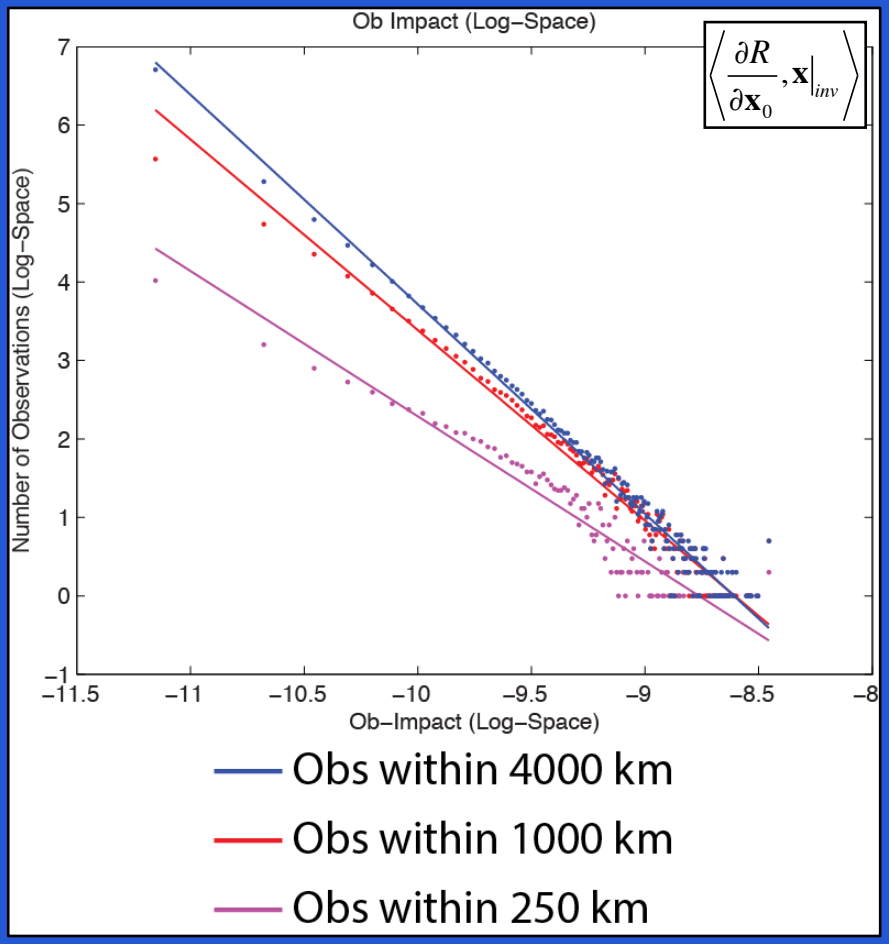

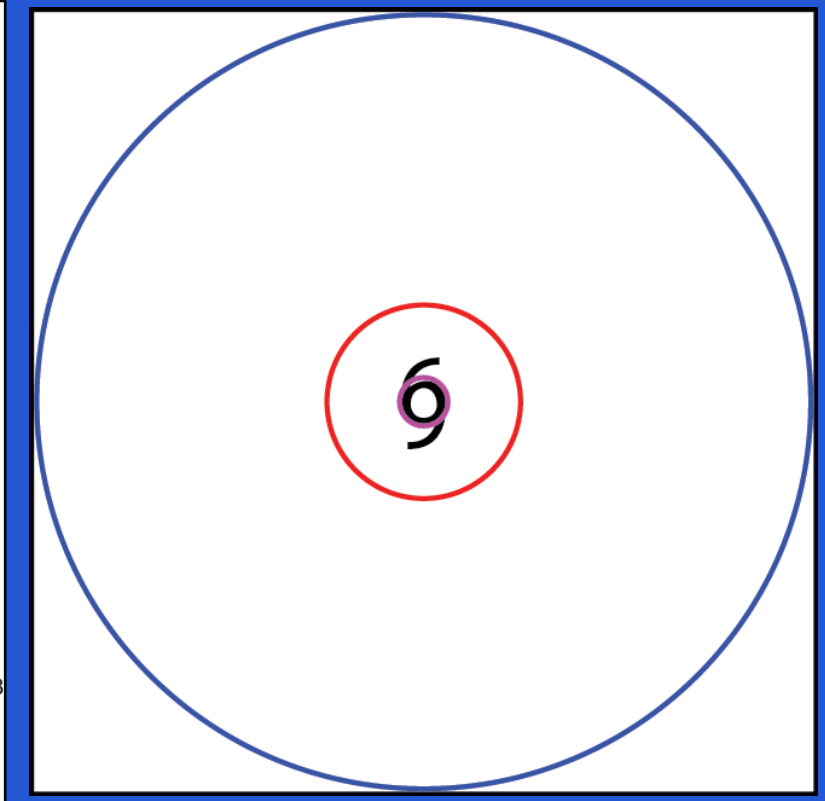

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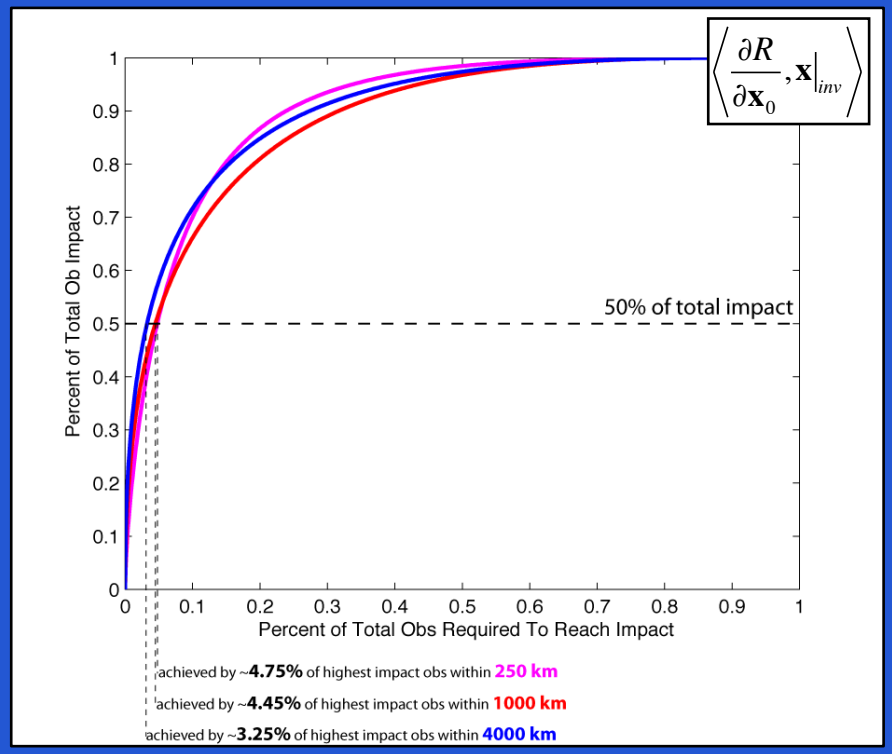
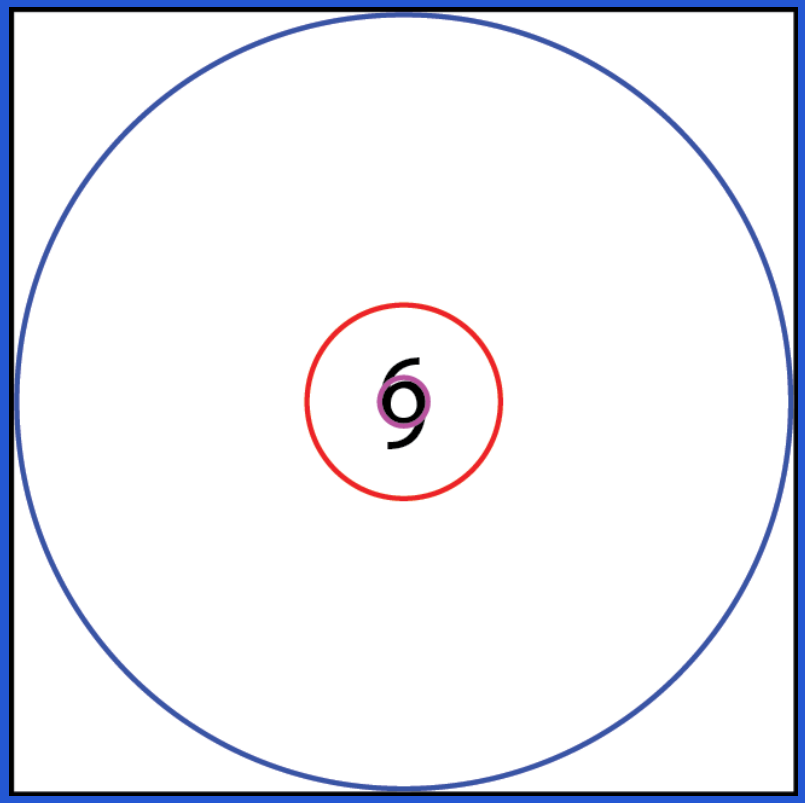
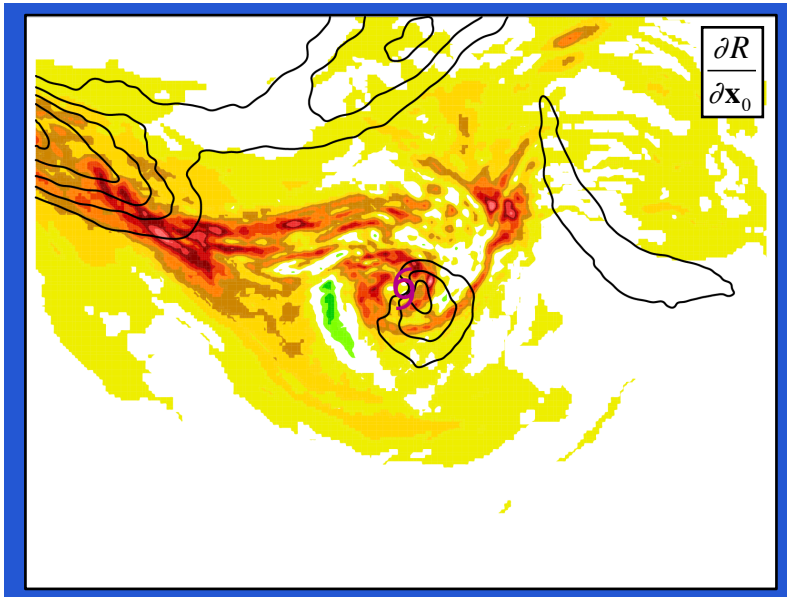
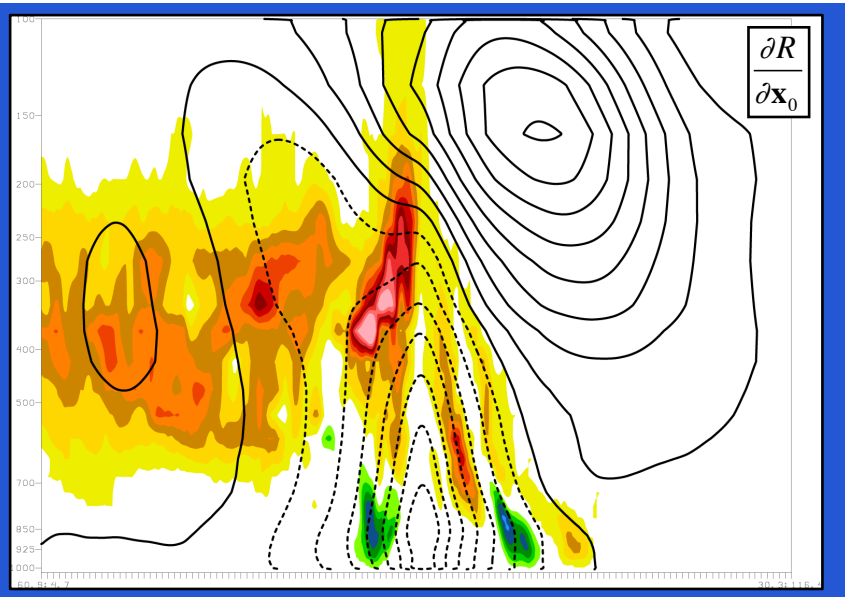




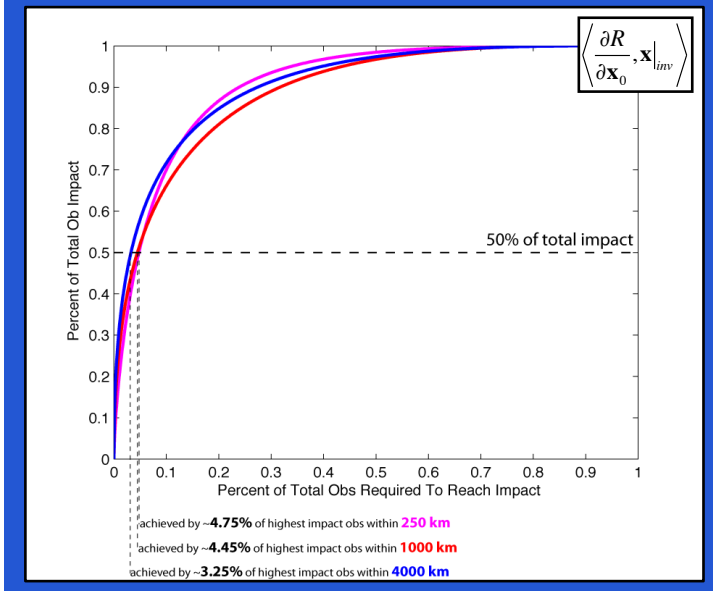
In general, **half** of the total observation impact on TC intensity is contributed by **3-5%** of the total observations! The remaining ~95% of observations contribute the other half.



Sensitivity of intensity forecast **at mid-range** can extend over a **broad region**



Sensitivity **migrates** toward **mid/upper troposphere** and **upstream**



Impact on intensity forecast caused by a **small minority** of total observations

Satellite observations (AMVs, radiances, etc) seem particularly **well-suited** to this task