Advances in Tropical Cyclone Vortex-Scale Data Assimilation using NOAA's Hurricane Ensemble Data Assimilation System (HEDAS) and Hurricane WRF (HWRF) Model

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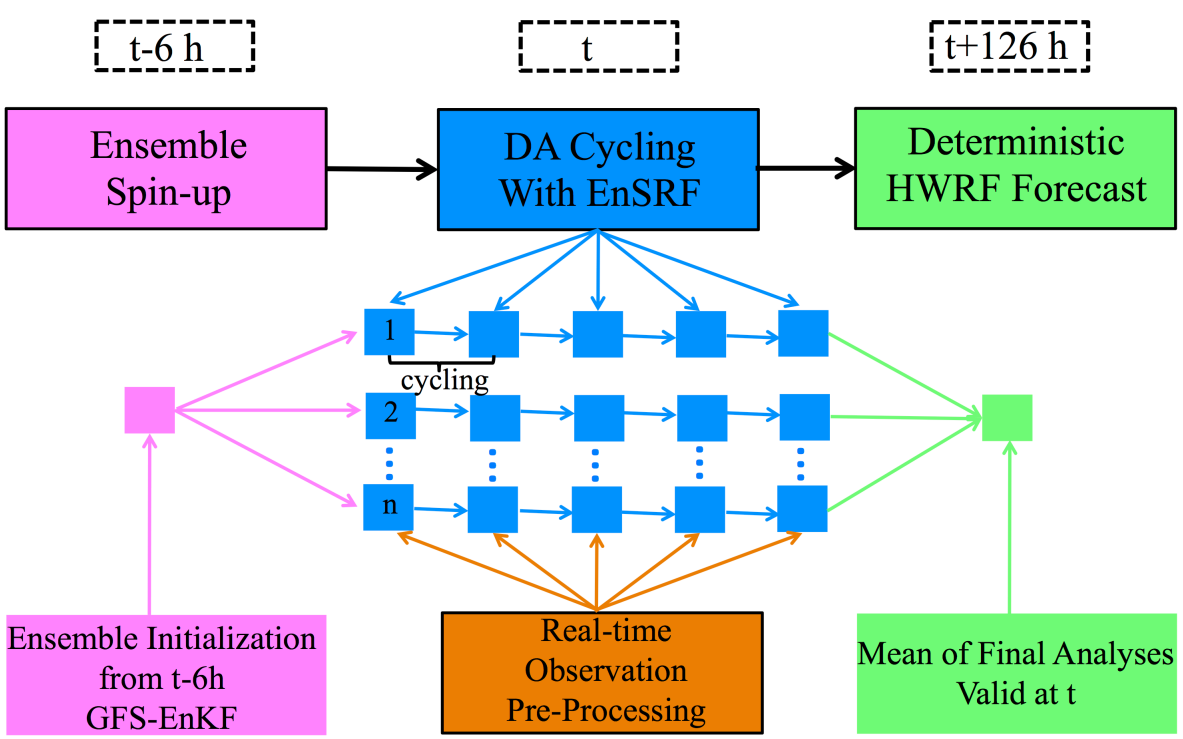
NOAA Hurricane Forecast Improvement Project (HFIP)

Hurricane Ensemble Data Assimilation System (HEDAS)

NOAA/AOML/HRD's Vortex-Scale Data Assimilation System

HEDAS Schematic



HEDAS Characteristics

- Focus on tropical cyclone inner-core data assimilation for high-resolution vortex initialization
- Uses the ensemble square-root Kalman filter (Whitaker and Hamill 2002)
- Storm-relative observation processing capability (Aksoy 2013)
- Interfaced with NOAA's HWRF model
- Deterministic HWRF forecasts initialized with the HEDAS mean vortex analysis

Aircraft/Platforms Processed:

NOAA P-3
NOAA G-IV
Air Force Reserve C-130
NASA Global Hawk
Coyote
Satellite AMVs
AIRS & GPS-RO Retrievals

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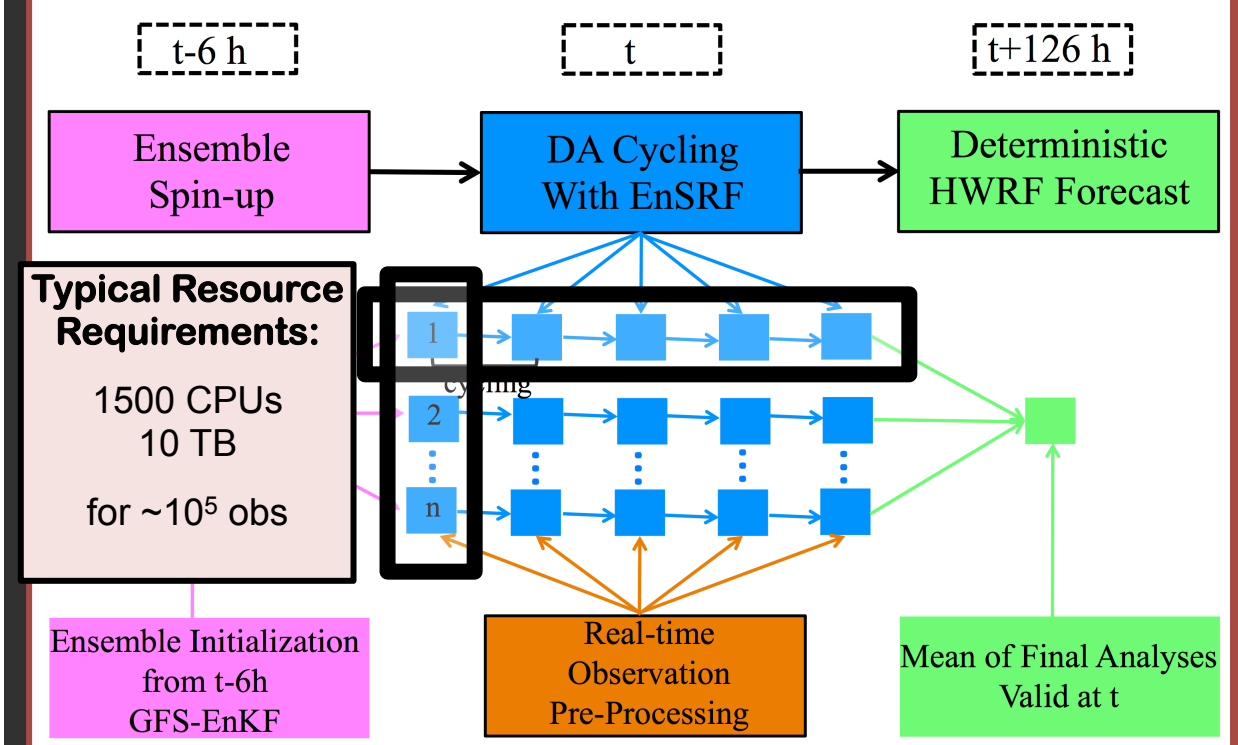

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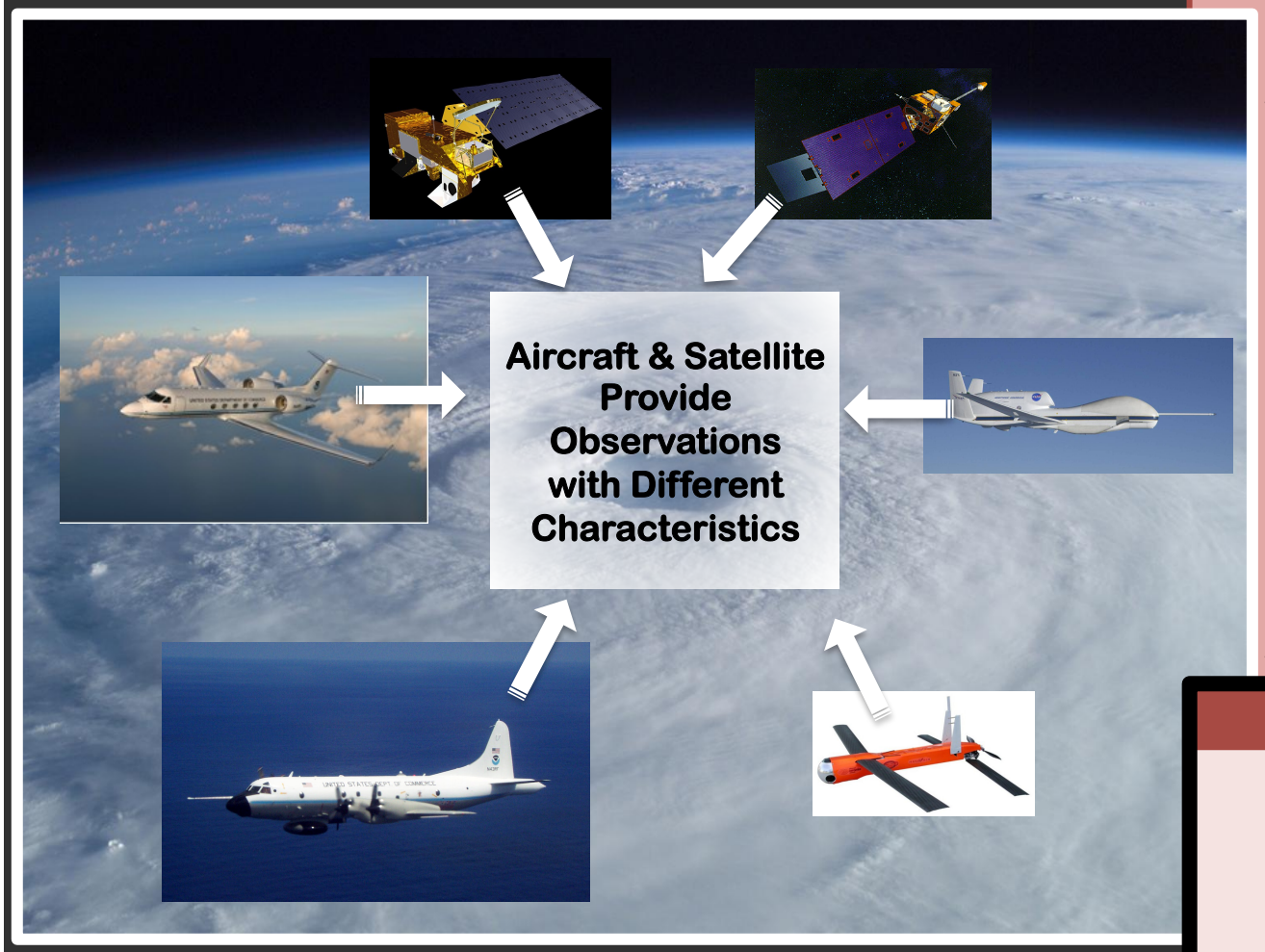
Hurricane Ensemble Data Assimilation System (HEDAS)

Challenges: Observing Platform Inhomogeneity



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Approaches to Observation-Related Issues

Online Quality Control

Most DA Systems: Gaussian Assumption

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Nonlinearity: Suboptimal DA on Distribution Tails

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Need for Online QC: Catch Ob-Model Discrepancies

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Approaches to Observation-Related Issues

Online Quality Control

Most DA Systems: Gaussian Assumption

Nonlinearity: Suboptimal DA on Distribution Tails

Need for Online QC: Catch Ob-Model Discrepancies

Challenging in Mesoscale Applications:

Intensity and Position Differences Often Cause
Large Ob-Model Discrepancies
But Need Many Observations to Correct Them

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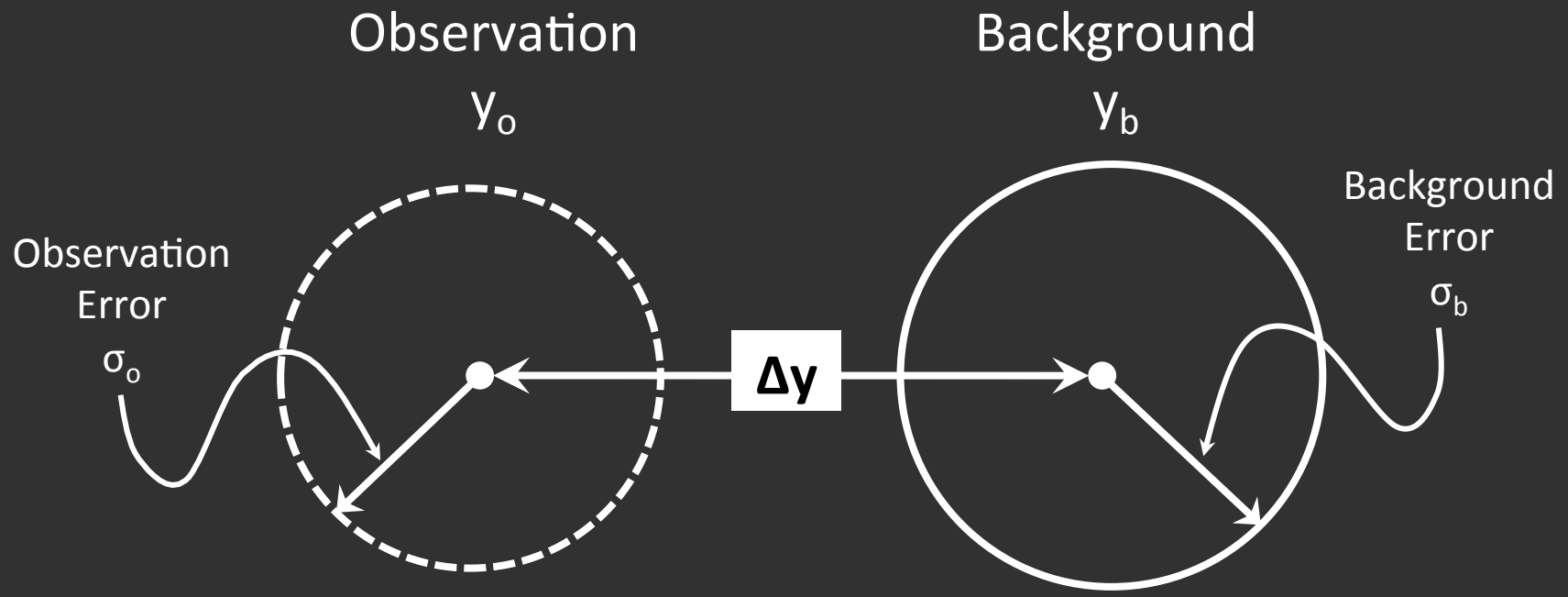
Approaches to Observation-Related Issues

In-line Quality Control: Basics



Compare Departure **Δy**
to Total Expected Distance:

$$\Delta y \propto \sqrt{\sigma_o^2 + \sigma_b^2}$$

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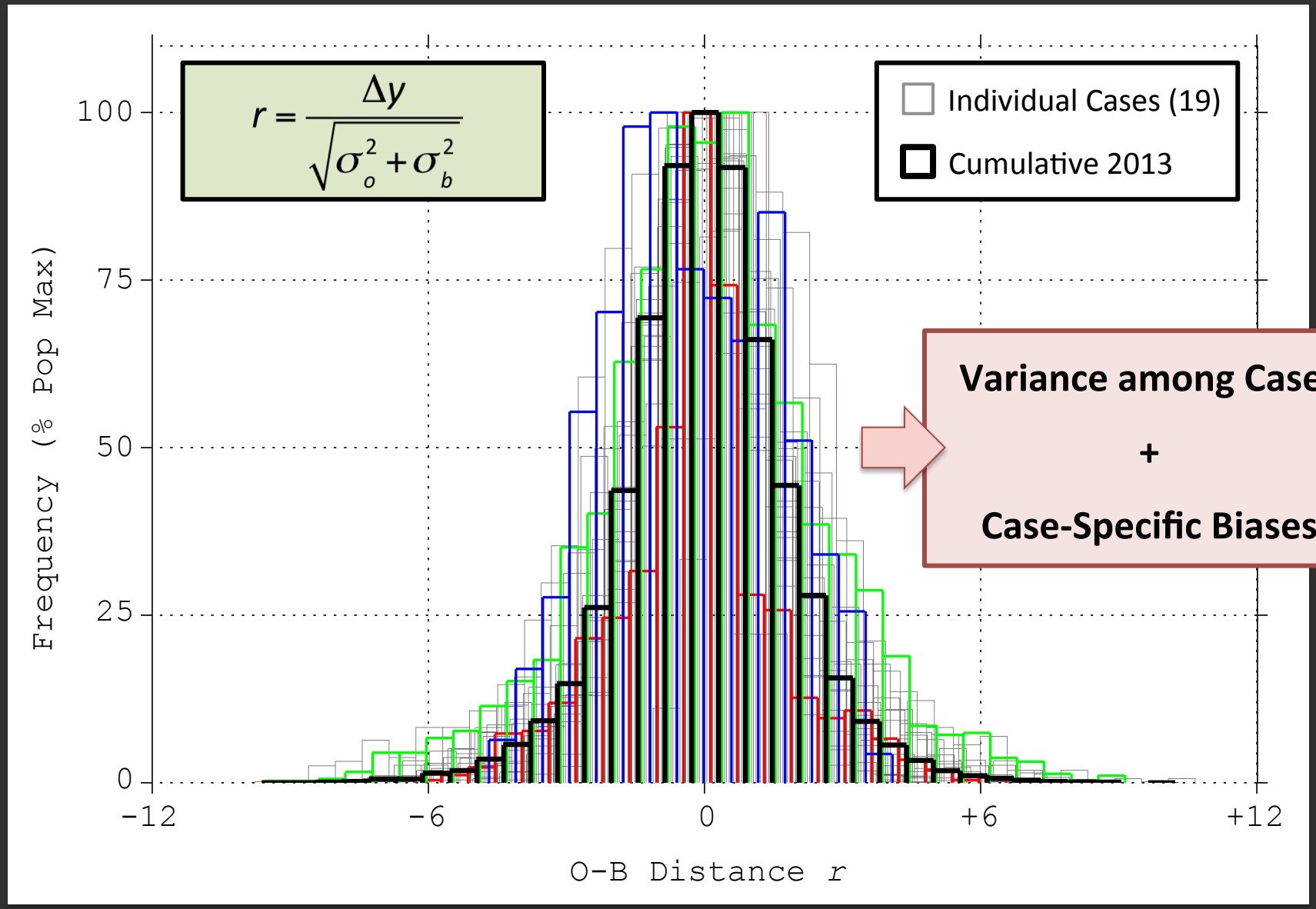
Approaches to Observation-Related Issues

In-line Quality Control: In Search for a Global Threshold



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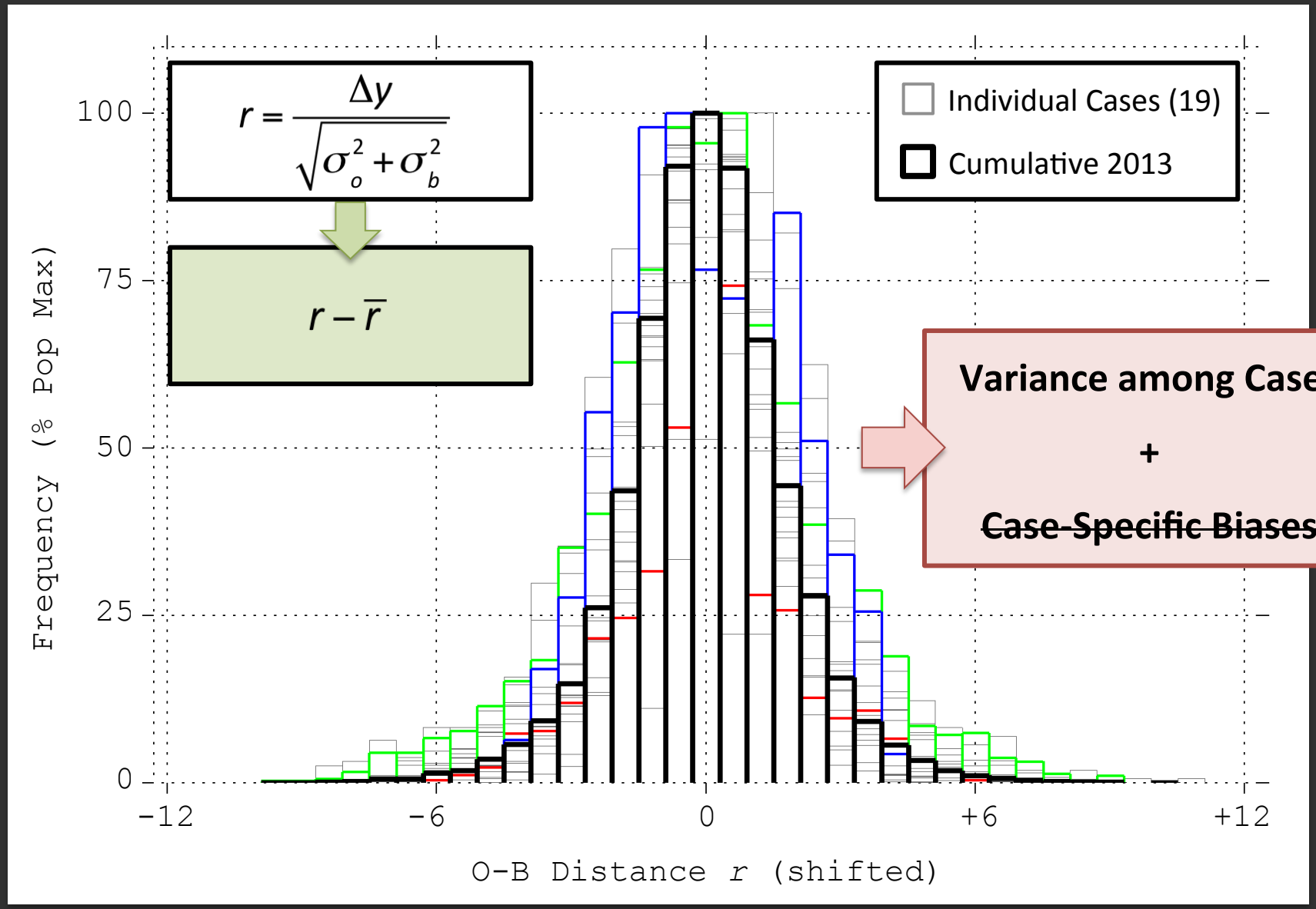

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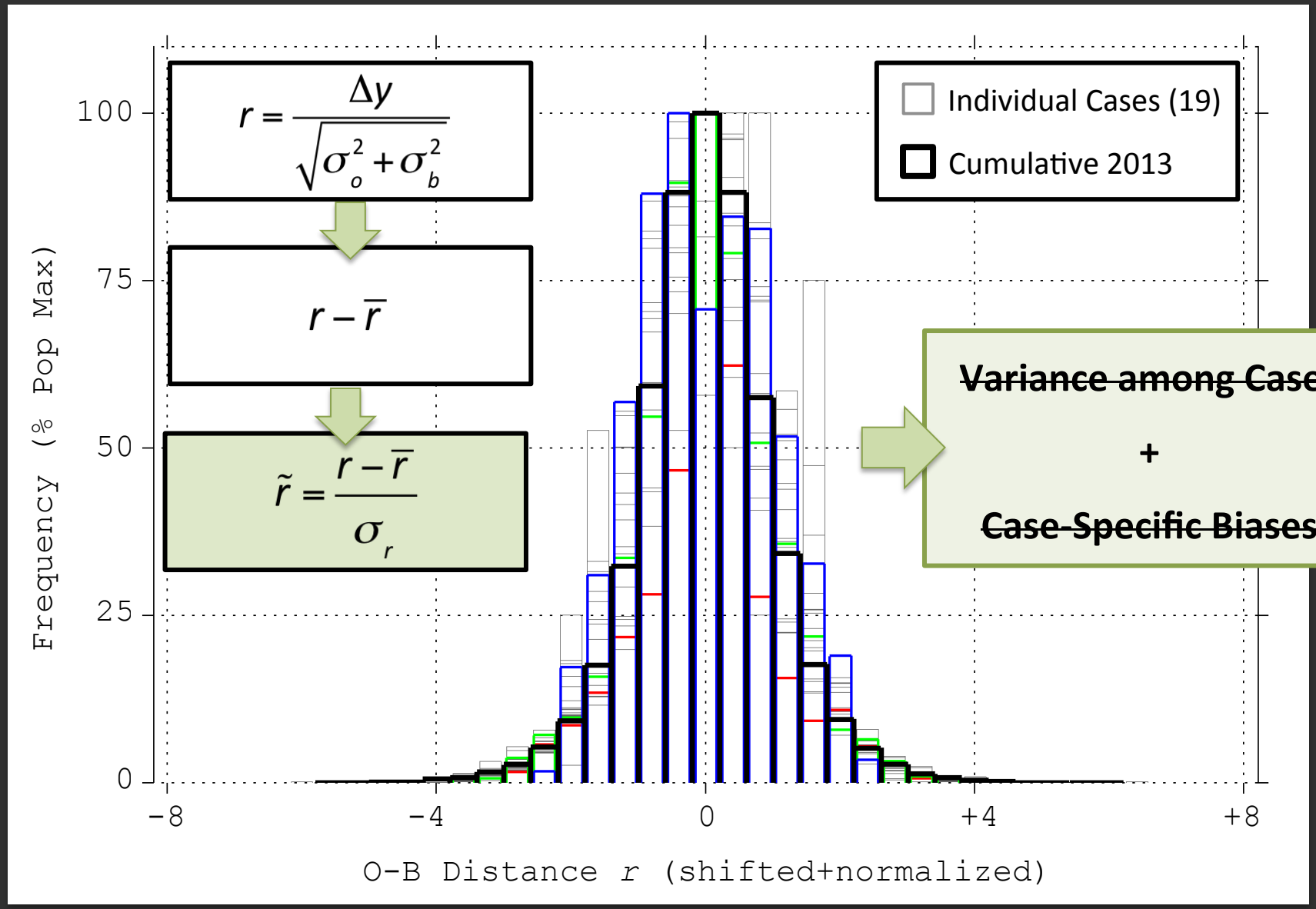

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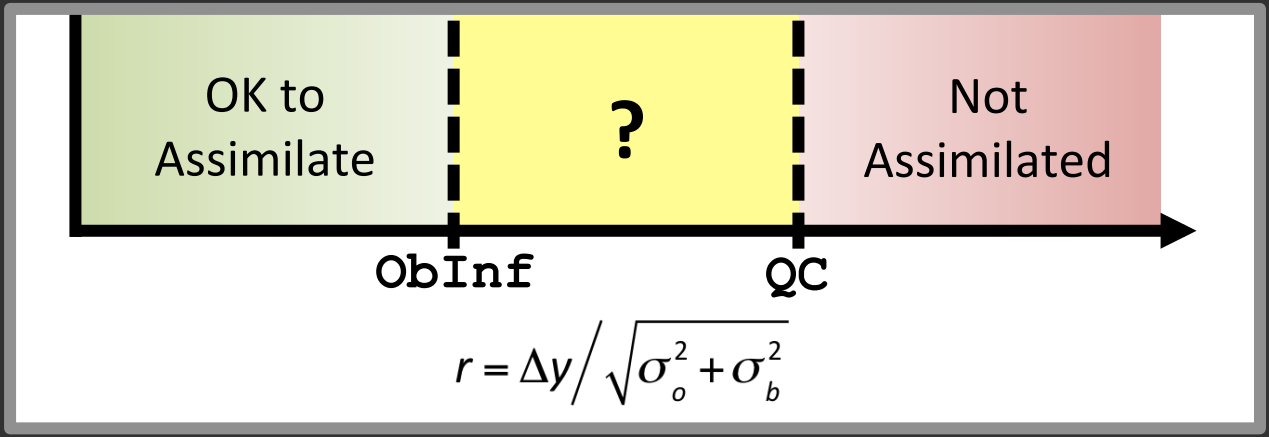
Approaches to Observation-Related Issues

Observation Error Inflation: Tuning Observation Impact



Minamide & Zhang (MWR, 2016):
Inflate Observation Error to Reduce Impact

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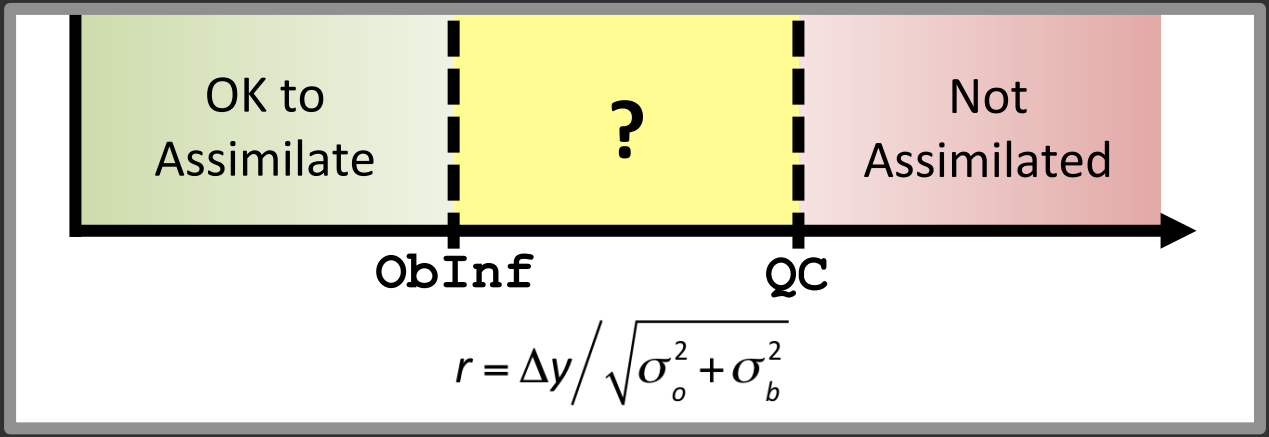

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Adaptive: Increases with Increasing $\tilde{r}$

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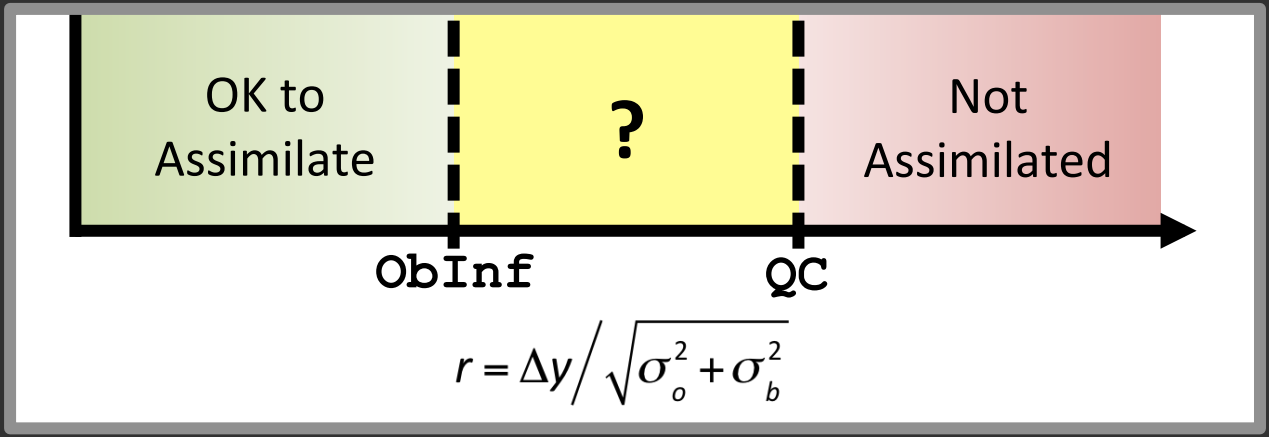

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Adaptive: Increases with Increasing $\tilde{r}$

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New In Our Study:

(1) Mathematical Analysis of Impact
(2) New Tuning to Further Adapt to QC cutoff

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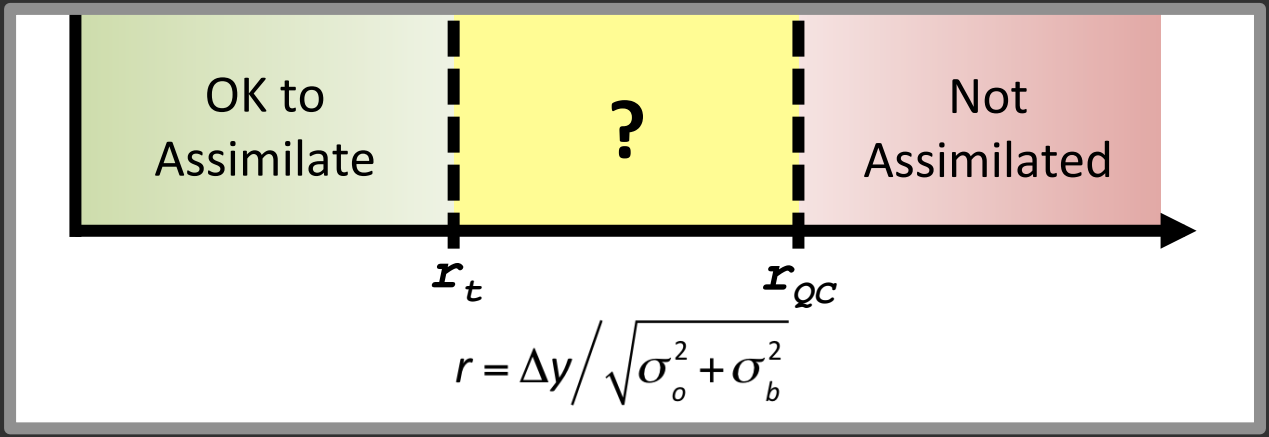

Current Ratio:

$$r^2 = \frac{\Delta^2 y}{\sigma_o^2 + \sigma_b^2}$$

Target Ratio:

$$r_t^2 = \frac{\Delta^2 y}{z \cdot \sigma_o^2 + \sigma_b^2}$$

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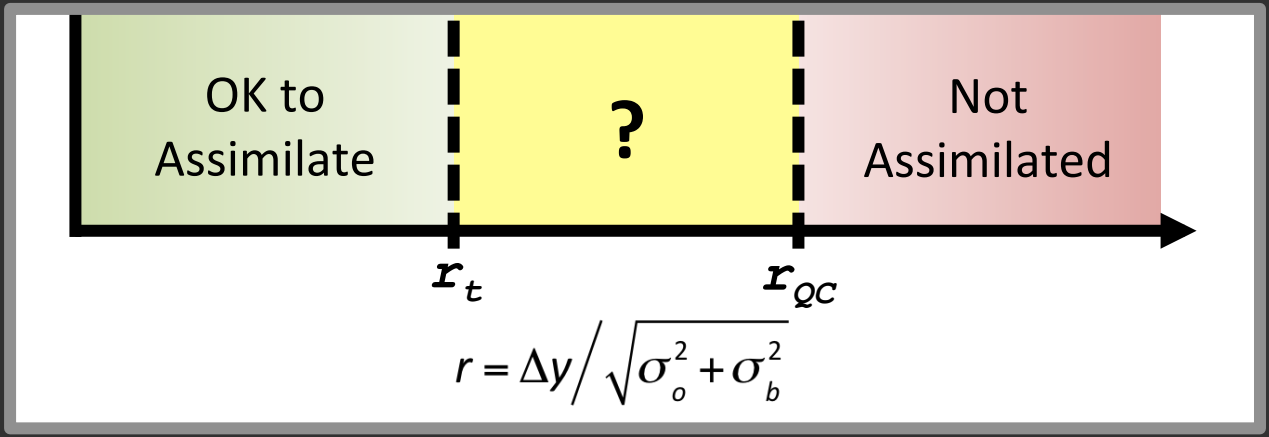

Define:

Current Ratio:

$$r^2 = \frac{\Delta^2 y}{\sigma_o^2 + \sigma_b^2}$$

$$x^2 = \frac{r^2}{r_t^2}$$

Target Ratio:

$$r_t^2 = \frac{\Delta^2 y}{z \cdot \sigma_o^2 + \sigma_b^2}$$

$$y^2 = \frac{\sigma_b^2}{\sigma_o^2}$$

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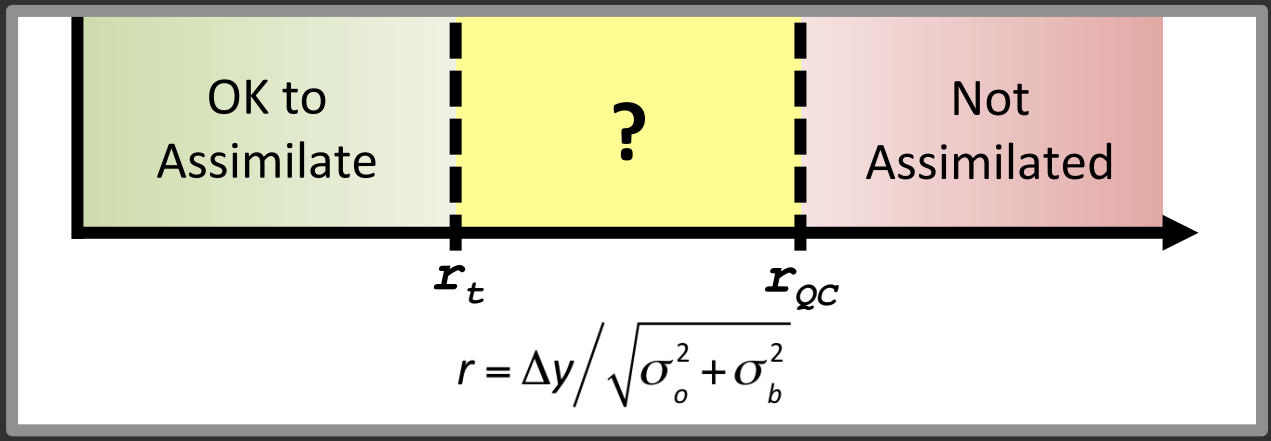
Approaches to Observation-Related Issues

Observation Error Inflation: Tuning Observation Impact



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Target Ratio:

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$$y^2 = \frac{\sigma_b^2}{\sigma_o^2}$$

Inflation Factor:

$$z = x^2 \cdot y + x^2 - y$$

Impact on Gain:

$$k = 1 \Big/ x^2$$

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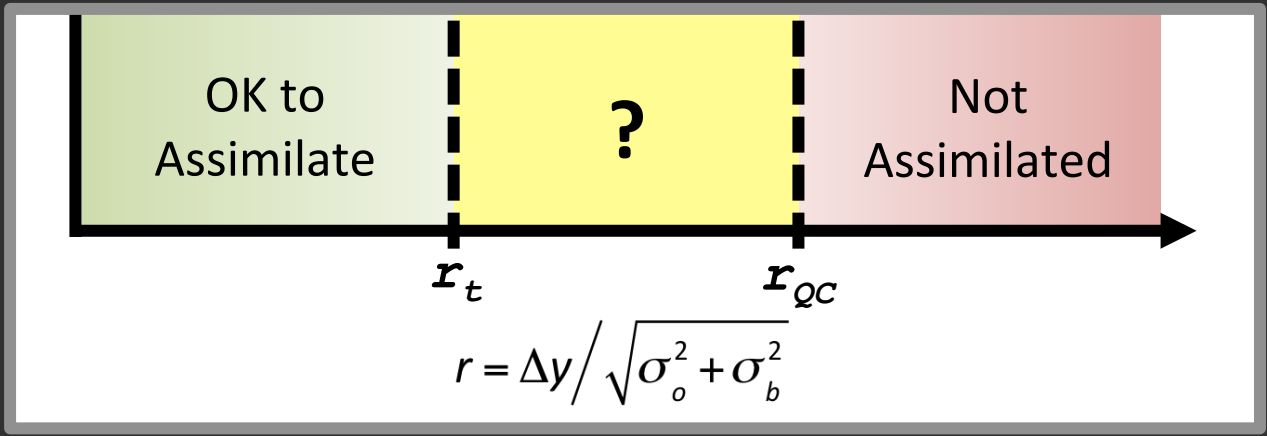

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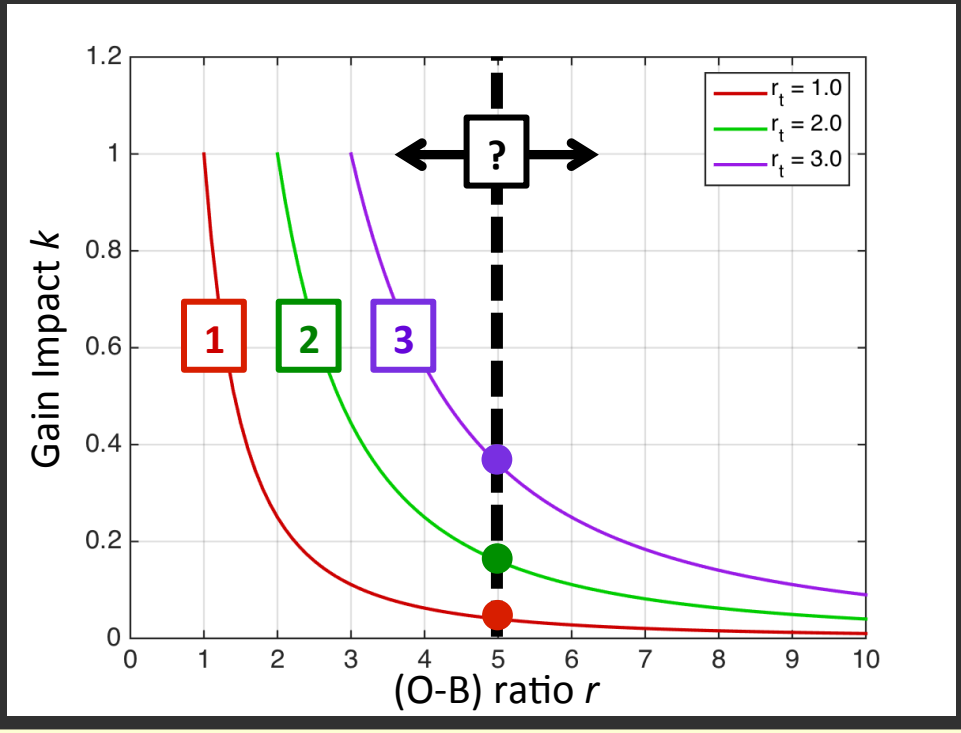

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Approaches to Observation-Related Issues

Joint Impact of Quality Control & Observation Error Inflation

Obs Not Assimilated		
%	QC = 3	QC = 5
No Inf	10	7
Inf = 1	10	7
Inf = 2	10	7

Obs with Inflated Error		
%	QC = 3	QC = 5
No Inf	0	0
Inf = 1	5	9
Inf = 2	0	1

Case: Hurricane Edouard (2014) 15 September 06Z – Global Hawk mission

Approaches to Observation-Related Issues

Joint Impact of Quality Control & Observation Error Inflation

Obs Not Assimilated

%	QC = 3	QC = 5
No Inf	10	7
Inf = 1	10	7
Inf = 2	10	7

Obs with Inflated Error

%	QC = 3	QC = 5
No Inf	0	0
Inf = 1	5	9
Inf = 2	0	1

Dropsde	AIRS	AMV
63	753	1
8	522	1

Dropsde	AIRS	AMV
157	255	16
208	487	17

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Approaches to Observation-Related Issues

Joint Impact of Quality Control & Observation Error Inflation

Net Impact on Frcst Error (Bias + RMSE)
Improvement over No QC/Inf

Dropsonde T

%	QC = 3	QC = 5
No Inf	-3	+1
Inf = 1	+4	+4

AIRS T

%	QC = 3	QC = 5
No Inf	+41	+37
Inf = 1	+45	+45

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Joint Impact of Quality Control & Observation Error Inflation

Net Impact on Frcst Error (Bias + RMSE)
Improvement over No QC/Inf

Dropsonde Q

%	QC = 3	QC = 5
No Inf	+6	+2
Inf = 1	+14	+13

AIRS Q

%	QC = 3	QC = 5
No Inf	+58	+50
Inf = 1	+61	+61

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Joint Impact of Quality Control & Observation Error Inflation

Net Impact on Frcst Error (Bias + RMSE)
Improvement over No QC/Inf

Dropsonde Wind

%	QC = 3	QC = 5
No Inf	-4	+0
Inf = 1	-11	-10

AMV Wind

%	QC = 3	QC = 5
No Inf	+0	+0
Inf = 1	+2	+2

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Summary

- A joint approach is introduced to Quality Control and Observation Error Inflation for Vortex-Scale Data Assimilation

- Tuning may be needed to reach the optimal balance between observations that are discarded versus observations whose impact is reduced by observation error inflation

- Impact is generally positive when QC and inflation are applied together
  - Some slight degradation on wind error – requires further investigation

- Impact varies depending on observation type
  - Further tuning may be necessary specific to different observation types