Visibility Projection Approaches – Preliminary Results using VISTAS 2018 OTWd Scenario

ENVIRON, Alpine Geophysics and UC Riverside

RPO National Technical Meeting
Modeling Group Meeting
June 10, 2005
Denver, Colorado

Purpose

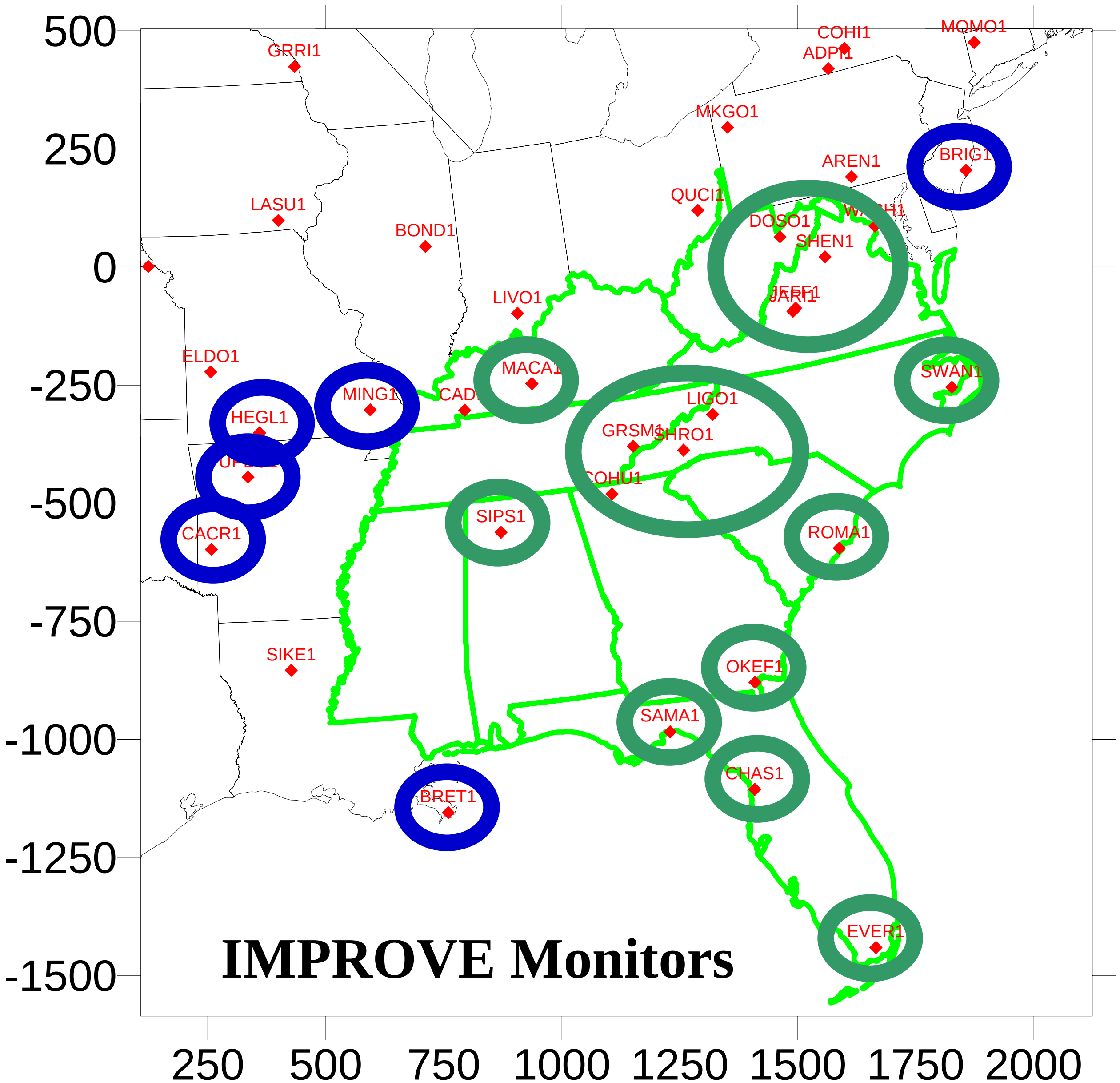
- To test different candidate methods for projecting the observed 2000-2005 visibility baseline to 2018 using modeling results for the 2002 meteorological year and 2002 and 2018 emissions scenarios
- To perform preliminary 2018 visibility projections for VISTAS and nearby Class I areas for comparisons with Reasonable Progress Goal (RPG) using linear Glide Path
- Effects of alternative Natural Conditions and use of alternative aerosol extinction equations on identification of the Worst 20% days not addressed at this time

Content

- Background and Purpose
- Procedures for Calculating Baseline and Tracking Visibility Progress using Observations
- Overview of Procedures for Projection Visibility Changes using Modeling Results
- Example Methods for Projecting Visibility
- Example Results for VISTAS and Nearby Class I Areas

Preliminary Visibility Projections

- For 16 Class I areas in VISTAS states plus 6 nearby Class I areas (CENRAP and MANE-VU)
- Use 2018 36km On-the-Way (OTWd) scenario (on-the-book controls + CAIR) and 2002 36km Typical Run3 CMAQ_SOAmods simulations
- Examine several different methods for visibility projections and variations on the methods
- Compare 2018 visibility projections with goals using EPA default Natural Conditions and linear Glide Path from 2004 to 2064



16 Class I Areas in VISTAS States

Cape Romain, NC
Chassahowitzka, FL
Cohutta, GA
Dolly Sods WV
Everglades, FL
Great Smoky Mtns NC/TN
James River Face, VA
Linville Gorge, NC
Mammoth Cave, KY
Okefenokee, GA
St. Marks, FL
Shenandoah, VA
Sipsey AL
Swanquarter, NC
Shining Rock, NC
Wolf Island, GA

6 Nearby Areas

Breton Is., LA
Brigantine, NJ
Caney Creek, AR
Hercules Glade, MO
Mingo, MO
Upper Buffalo, AR

Regional Haze Rule Requirements

- Protection of visibility at the 156 “mandatory Federal Class I areas” (Sections 169A&B of CAA)
- Visibility goal of “natural conditions” (no man-made impairment) by 2064
- Reasonable progress goals for improving visibility at Class I areas are as follows:
  - Improve visibility for the Worst 20% days
  - No degradation in visibility for the Best 20% days
- First visibility SIP due December 17, 2007 to demonstrate visibility progress in 2018 toward natural conditions

EPA Guidance for Visibility Projections

- Guidance for Demonstrating Attainment of Air Quality Goals for $PM_{2.5}$ and Regional Haze, Draft 2.1 (EPA, 2001)
  - Draft guidance undergoing revision in 2005 – It will change!
- Guidance for Tracking Progress Under the Regional Haze Rule" (EPA, 2003a)
  - Final guidance contains procedures for estimating visibility baseline from IMPROVE measured PM that is the 2004 starting point
- Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Rule" (EPA, 2003b)
  - Provides default "end-point" natural conditions in 2064

→ Default visibility goal in 2018 assumes a linear glide path from the current 2000-2004 baseline to natural conditions in 2064 – not written in stone, can be modified if justified

Visibility at Class I Areas

- Baseline Conditions: Represent average visibility for Worst 20% and Best 20% days. RHR uses 5-years of IMPROVE monitor data for 2000-2004 (EPA, 2003a)
  - Starting point in 2004 for glide path to Natural Conditions in 2064
- Natural Conditions: Estimates of visibility conditions for Best/Worst 20% days in the absence of human-causes impairment (2064 goal)
  - End point in 2064, for now use EPA default values (EPA, 2003b) [topic for June 8 workshop in Denver]

Baseline Conditions (1)

- Use IMPROVE Aerosol Extinction Equation
  - SO4 [assume $(NH_4)_2SO_4$]
  - NO3 [assume NH_4NO_3]
  - Organic Matter [OM or OMC]
  - Elemental Carbon [EC or LAC]
  - Other Fine Particulate [SOIL or IP]
  - Coarse Matter [CM]

IMPROVE RCM	IMPROVE Measured Species
SO_4	1.375 x (3 x S)
NO_3	1.29 x NO3_
OM	1.4*OC1 + 1.4*OC2 + 1.4*OC3 + 1.4*OC4 + 1.4*OP
EC	EC1 + EC2 + EC3 – OP
Soil	2.2*AL + 2.49*SI + 1.63*CA + 2.42*FE + 1.94*TI
CM	MT – MF

Baseline Conditions (2)

- For each Class I area and each 24-h IMPROVE measurement, calculate extinction due to PM:
  - $b_{Sulfate}$ = 3 x f(RH) x $[SO_4]$
  - $b_{Nitrate}$ = 3 x f(RH) x $[NO_3]$
  - b_{EC} = 10 x [EC]
  - b_{OM} = 4 x [OM]
  - b_{Soil} = 1 x [Soil]
  - b_{CM} = 0.6 x [CM]

Monthly and Class I area specific RH adjustment factors [f(RH)] are used

- Total daily extinction (b_{ext}) is sum plus Rayleigh:

$$b_{ext} = b_{Ray} + b_{Sulfate} + b_{Nitrate} + b_{EC} + b_{OM} + b_{Soil} + b_{CM}$$

$$\text{deciview} = dv = 10 \ln(b_{ext}/10)$$

Baseline Conditions (3)

- For each Class I area and year from the Baseline, the daily measured b_{ext}/dv using monthly f(RH) and IMPROVE PM components is ranked and the Worst 20% (Best 20%) days identified (identify Worst 20% visibility days for each year from 2000-2004)
- The annual average visibility for the Worst 20% days for each year is obtained by averaging the daily deciview visibility across the Worst 20% days (averaging in dv across Worst 20% days in each year)
- The Baseline Conditions is obtained by averaging the 5-years of annual average deciview for the Worst 20% days (average 5-years of annual average dv for Worst 20% days)

Visibility Projections (1)

- Use model in a relative sense to scale observed IMPROVE PM concentrations in the Baseline based on the relative change in modeling results from current to future-year
  - Use Relative Reduction Factors (RRFs) defined as the ratio of 2018 to 2002 modeling results
  - SO4(2018) = Observed_SO4(Current) x RRF(SO4)
    - RRF(SO4) = [Model_SO4(2018)]/[Model_SO4(2002)]

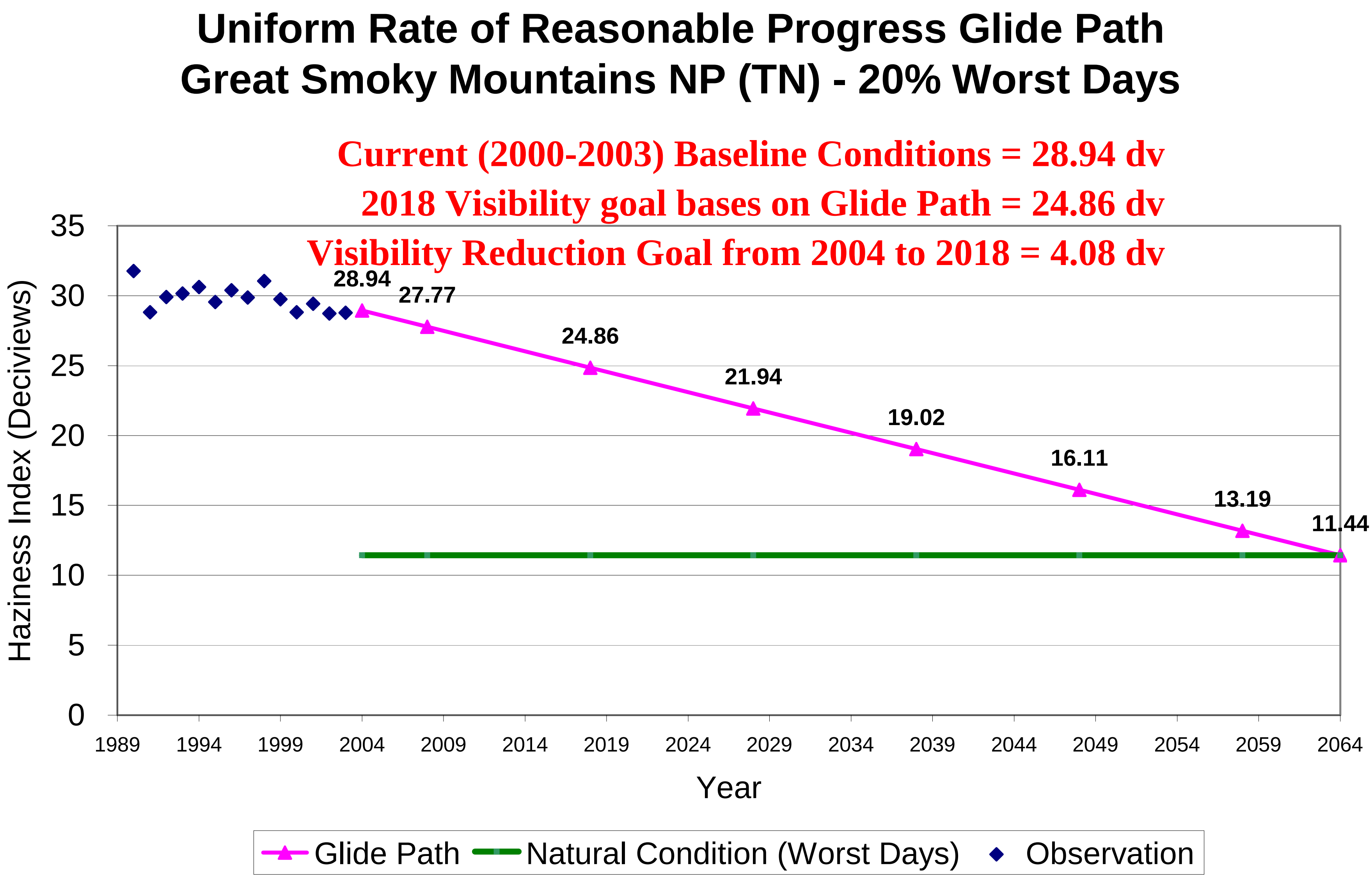
Visibility Projections (2)

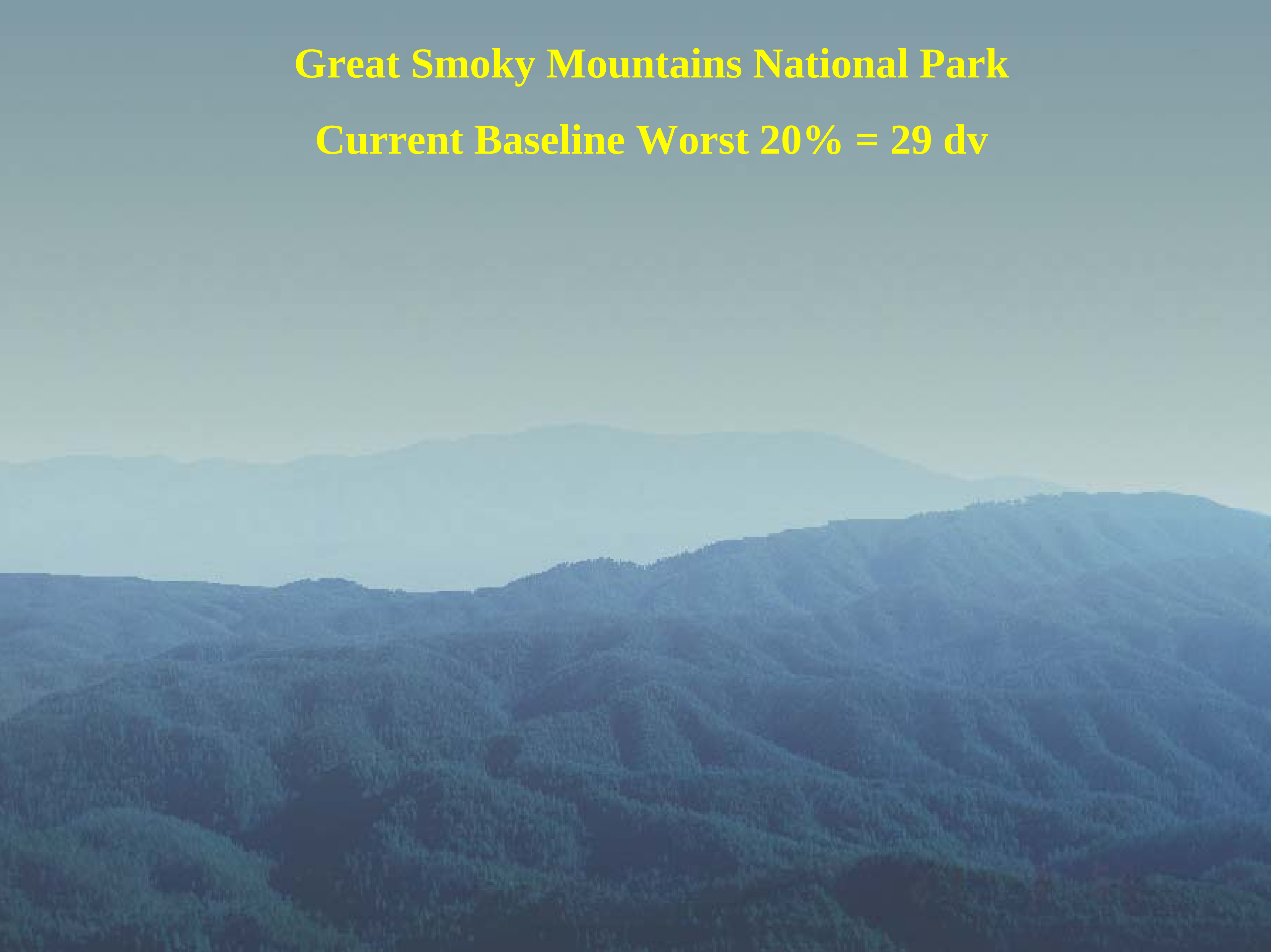
- Use model derived species-specific and Class I area-specific RRFs to scale daily PM components for Worst 20% days in Baseline to obtain 2018 daily PM concentrations for the Worst 20% days
- Calculated daily extinction using projected 2018 24-hr PM species concentrations and IMPROVE aerosol extinction equation then convert to dv
- Average dv across Worst 20% days in each year in Baseline to obtained 5-years of annual dv
- Average annual average dv across 5-years from Baseline to obtain projected 2018 visibility estimates for Worst 20% days
  - (same approach for Best 20% days)

Glide Path to Natural Conditions

- How to define 2018 visibility Reasonable Progress Goal (RPG) to judge visibility progress?
  - Assume linear glide path from the Baseline Conditions (2000-2004) to 2064 Natural Conditions (both in deciview – dv)
    - For now use EPA default Natural Conditions for Worst 20% days
      - States/Tribes can define alternatives if justified
    - States/Tribes can assume different glide paths toward Natural Conditions than linear and justify them in their SIP/TIP

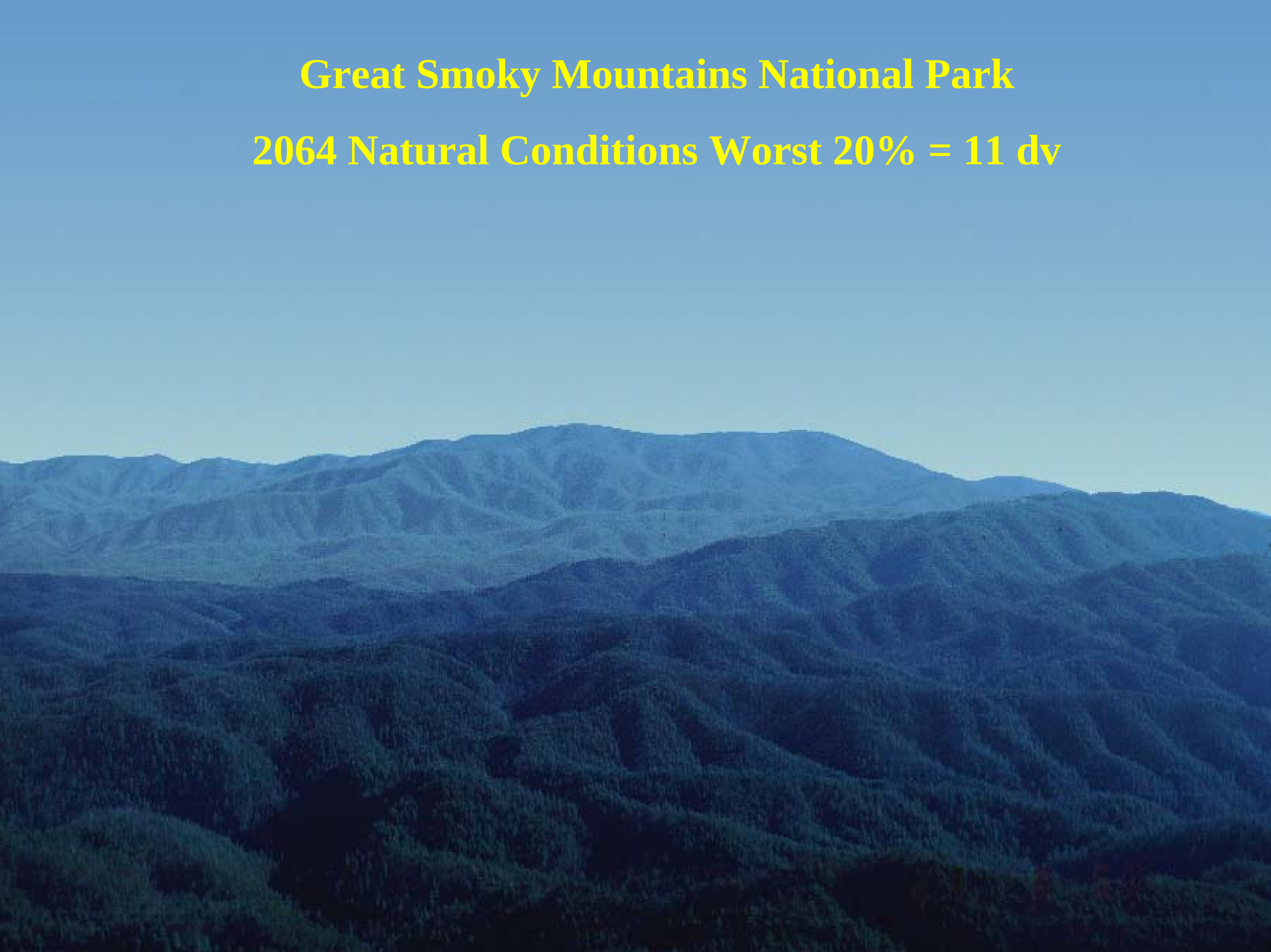
Example Glide Path to Natural Conditions for Great Smokey Mountains and the Worst 20% Days




Great Smoky Mountains National Park
Current Baseline Worst 20% = 29 dv

Great Smoky Mountains National Park

2018 Goal Worst 20% = 25 dv


Great Smoky Mountains National Park
2064 Natural Conditions Worst 20% = 11 dv

Baseline Conditions for Testing Visibility Projection Techniques

- RHR uses 5-year 2000-2004 period to define Baseline Conditions
  - 2004 IMPROVE data not yet available
- For testing, define Two Baseline Conditions

(B) 4-Year Period from Official Baseline (2000-2003)

(C) 2002 Conditions

- ➢ Current modeling year
- ➢ Can use day-specific RRFs as was done in preliminary CAIR

Definition of Terms

- "Regulatory Populations of Days" the ~120 days from 2000-2004 (~20 days/year) that are defined as the Worst 20% days using EPA guidance and monthly average f(RH)
- "Modeled Days" the ~365 days from 2002
- "Modeled Days with Monitoring Data" the ~120 days from 2002 with IMPROVE data
- "Modeled Worst Days" the ~24 Worst 20% days from 2002 modeling year
- CART (Classical Regression Tree)
    - Scheme used to classify days from 2000-2004 into bins based on visibility and meteorological conditions

Visibility Projection Objective

- Use modeling results from 2002 Typical Base Case and 2018 Emission Scenarios for Modeled Days to project PM concentrations from the 2000-2004 Regulatory Population of Days to 2018 to estimate 2018 visibility conditions for comparisons with 2018 visibility goal
- RRFs are used to scale observed PM concentrations for Regulatory Population of Days to 2018 conditions

Approaches for RRFs (1)

- **Method 1: Average RRF Approach**
  - For each Class I area and Observed Worst 20% days from 2002 take the ratio of the average modeled 2018 to 2002 PM species concentrations across Modeled Worst Days

$$RRF_j(SO4) = \frac{\frac{1}{N}\sum_{i=1}^{N} SO4_{ij}(2018)}{\frac{1}{N}\sum_{i=1}^{N} SO4_{ij}(2002)} = \frac{\sum_{i=1}^{N} SO4_{ij}(2018)}{\sum_{i=1}^{N} SO4_{ij}(2002)}$$

  - Applied to observed daily PM components for each day from the Regulatory Population of Days from the Baseline, calculate daily Bext/dv, annual dv and 2018 projected dv same as before (can use Baseline B and C)

Approaches for RRFs (2)

- **Method 2: Average Quarterly RRF Approach**
  - Similar to Average RRF Approach only calculate separate RRFs for each Quarter of the year using the observed Worst/Best 20% days from 2002
  - Allows for seasonal variations in RRFs, has similarities to $PM_{2.5}$ projection approach
  - Can only use with Baseline C based on 2002 observations as other years have Worst 20% days in Quarters not populated by 2002
  - **Have not pursued this technique**

Approaches for RRFs (3)

- **Method 3: Day-Specific RRFs**
  - Class I area and PM species specific RRFs would be developed for each of the the Worst/Best 20% days from 2002
  - Can only be used with Baseline C – 2002 Conditions
  - Approach used in preliminary CAIR modeling

Approaches for RRFs (4)

- **Method 4: Weighted RRF Approach**
  - The goal of Method 4 is to select the Modeled Days, Modeled Days with Monitoring Data or Modeled Worst Days to developed weighted RRFs to be applied to the Regulatory Population Days for projecting 2018 visibility
  - In VISTAS weights are based on CART analysis that has classified days from 2000-2003 into different meteorological bins (types)

Approaches for RRFs (5)

- **Method 4-1: Weighted RRF Approach using Separate RRFs for Each Day**
  - Calculate a separate RRF for each CART bin that occurred during 2002, for bins from 2000-2004 not in 2002 use the most representative bin from 2002
  - Method 4-1.1: Use CART weights for all Modeled Days
  - Method 4-1.2: Use CART weights for Modeled Days with Monitoring Data
  - Method 4-1.3: Use CART weights for Modeled Worst Days
  - Different days from the Regulatory Population of Days may use different RRFs
  - **CART weights for testing Methods 4-1 are not yet available**

Approaches for RRFs (6)

- **Method 4-2: Weighted RRF Approach Average Modeled Days with Monitoring Data**
  - Calculate a weighted average RRF by using CART weights across all Modeled Days with Monitoring Data that best represents the distribution of meteorological regimes that occurred across the Regulatory Population of Days
  - For a given Class I area and PM component, the same RRF is used across all of the Regulatory Population of Days

Approaches for RRFs (7)

- **Method 4-3: Weighted RRF Approach Average Modeled Worst Days**
  - Calculate a weighted average RRF by using CART weights across all Modeled Worst Days that best represents the distribution of meteorological regimes that occurred across the Regulatory Population of Days
  - For a given Class I area and PM component, the same RRF is used across all of the Regulatory Population of Days

Approaches for RRFs (8)

- **Method 5: Average Quarterly RRF Using All Data**
  - Use average of Worst/Best XX% days from each Quarter of the year to develop Quarterly RRFs [e.g., XX%=20% ➔ use ~ 6 days/Quarter]
  - Can be applied for Baselines B and C
  - Similarities to $PM_{2.5}$ projection approach
  - **Involves processing separate sets of data (not done yet)**

Approaches for RRFs (9)

- **Method 6: Averaging of Extinction**
  - Same as Method 1 only the conversion of extinction to deciview occurs at the very end
    - Project 2018 daily PM concentrations for Best/Worst 20% days from Baseline
    - Calculate daily b_{ext} using IMPROVE RCM
    - Calculate annual average b_{ext} for each year from baseline
    - Calculate 5-year average b_{ext} using 5 annual average b_{ext}
    - Convert 5-year average b_{ext} to dv
  - Follow current draft EPA modeling guidance (EPA, 2001)

Approaches for RRFs (10)

- Other RRF Methods Considered
  - **Use of Modeled Worst/Best 20% Days in RRF calculation**
    - Tried this in WRAP Section 309 SIP and model zeroed in on worst performing days (e.g., NO3 over-predictions)
  - **Other Methods????**

Approaches for RRFs (11)

- **Variations/Additional Considerations RRFs**
  - **Using Extinction Based RRFs (<u>ext</u>)**

$$RRF_j(bext) = \frac{\frac{1}{N}\sum_{i=1}^{N} bext_{ij}(2018)}{\frac{1}{N}\sum_{i=1}^{N} bext_{ij}(2002)} = \frac{\sum_{i=1}^{N} bext_{ij}(2018)}{\sum_{i=1}^{N} bext_{ij}(2002)}$$

  - **Bext(2018) = RRF(Bext) x Bext(2000-2004)**
  - **Performed for each day from the Regulatory Population of Days**

Approaches for RRFs (12)

- **Variations/Additional Considerations RRFs**
  - **Accounting for Model Performance (wmpe)**
    - Exclude PM for days from RRF calculation that exhibit poor model performance for a PM component
    - Initial test by excluding PM species on days where the PM components with modeled 2002 and observed PM > factor of 2
  - **Accounting for Model Performance (wmpe2)**
    - Exclude days from RRF calculation that exhibit poor model performance for extinction (b_{ext})
    - Exclude Worst 20% days for all PM components in RRF calculations if observed and predicted b_{ext} differ by over a factor of 2

Approaches for RRFs (13)

Alternative Aerosol Extinction Equations

(a) Standard IMPROVE aerosol extinction equation

3 x f(RH) x 1.375 x 3 x [S] + 3 x f(RH) x 1.29 x [NO3_] + 10 x [EC] + 4 x 1.4 x [OC] + SOIL + 0.6 x [CM]

(b) Alternative with more OC & less SO4 **(alt_b)**

2.2 x f(RH) x 1.375 x 3 x [S] + 3 x f(RH) x 1.29 x [NO3_] + 10 x [EC] + 4 x 1.7 x [OC] + SOIL + 0.6 x [CM]

(c) Extinction equation proposed by EPRI **(alt_c)**

1.62 x f(RH) x (1.375 x 3 x [S] + 1.29 x [NO3_])$^{1.28}$ + 10 x [EC] + 1.71 x (2.0 x [OC])$^{1.42}$ + SOIL + 0.6 x [CM]

→ Testing of alternative equations allows Baseline to change but keep same Worst 20% days based on (a)

How to display Visibility Projections (1)

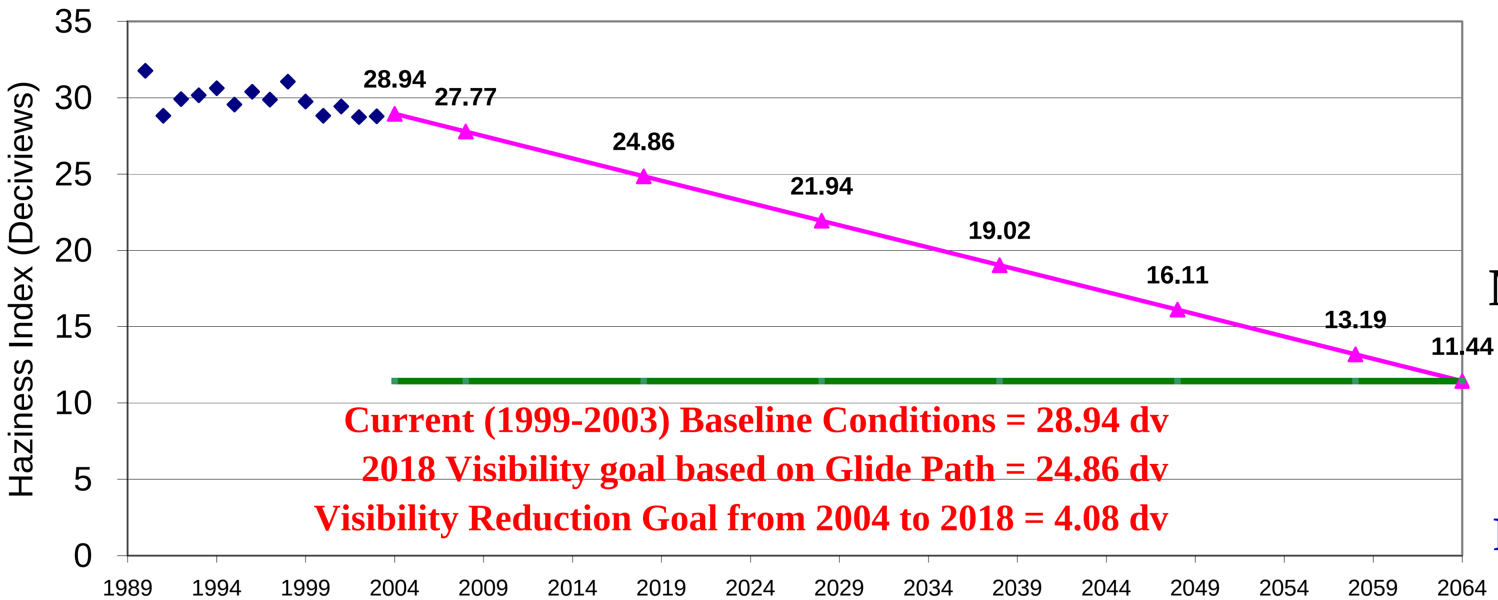
(1) Express different methods as percent toward meeting 2018 visibility goal from Glide Paths using Baselines B and C and EPA default Natural Conditions

(2) Express different methods as changes in percent toward meeting 2018 visibility goal from Method 1B (Average RRF across Modeled Worst Days using 2000-2004 Baseline)

(3) Display projected 2018 visibility on Glide Paths (Method 1B only)

How to display Visibility Projections (2)

Approach (1) as percentage of reaching 2018 goal



Worst 20% Days

Great Smoky Mountains NP Glide Path

Visibility Reduction Goal = 4.08 dv

Suppose modeled dv reduction is 3.0 dv ➔ 100 x 3.0/4.08 = 74% misses 2018 goal by 16%

Suppose modeled dv reduction is 5.0 dv ➔ 100 x 5.0/4.08 = 123% achieves 2018 goal by 23%

Use > 110% as likely meeting RPG, <90% as likely not meeting RPG and 90%<Vis Proj < 110% as may meet goal

Summary of Approaches

Methods

1. **Average RRF Approach for Worst 20% Days**
2. Quarterly Average RRF Approach for Worst 20% (not done)
3. **Day-Specific RRF Approach for Worst 20% 2002 (Baseline C only)**
4. **Weighted RRF Approach (Methods 4-2 and 4-3 only)**
5. Average Quarterly RRF using all Data (not done)
6. **Averaging of Extinction not dv (also changes Baseline)**

Baseline

B. 2000-2003 4-Years in Official Baseline

C. 2002 Meteorological Modeling Year

Considerations

ext = use RRFs based on extinction not PM components

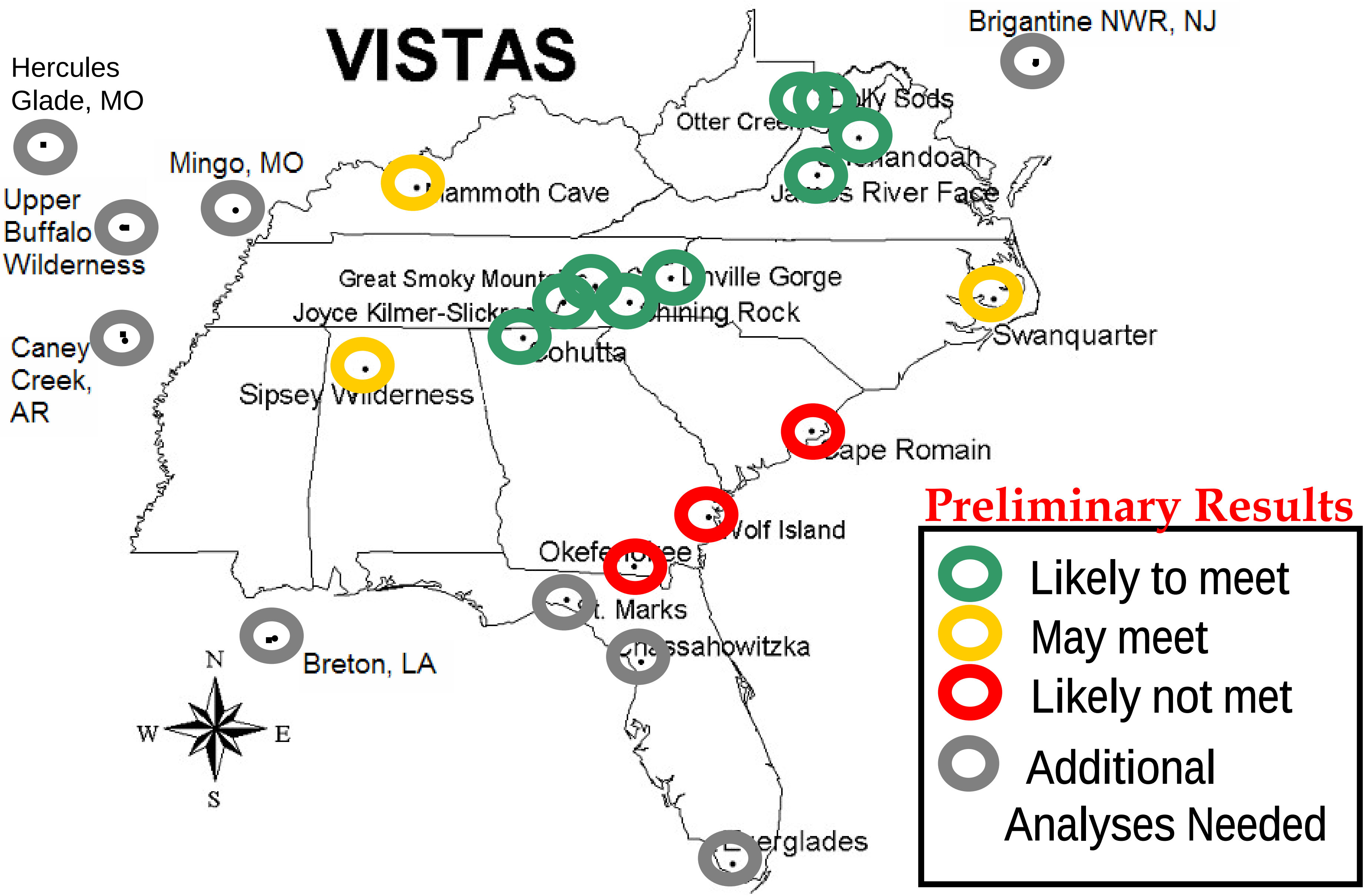
wmpe = do not use a PM component in the RRF on days when the pred/obs PM-species differ by over a factor of 2

wmpe2 = do not use any PM components in RRF on days when pred/obs b_{ext} **> factor of 2**

alt_b = use alt aerosol extinction equation (b) (more OC/less SO4)

alt_c = use EPRI alternative aerosol extinction equation (c)

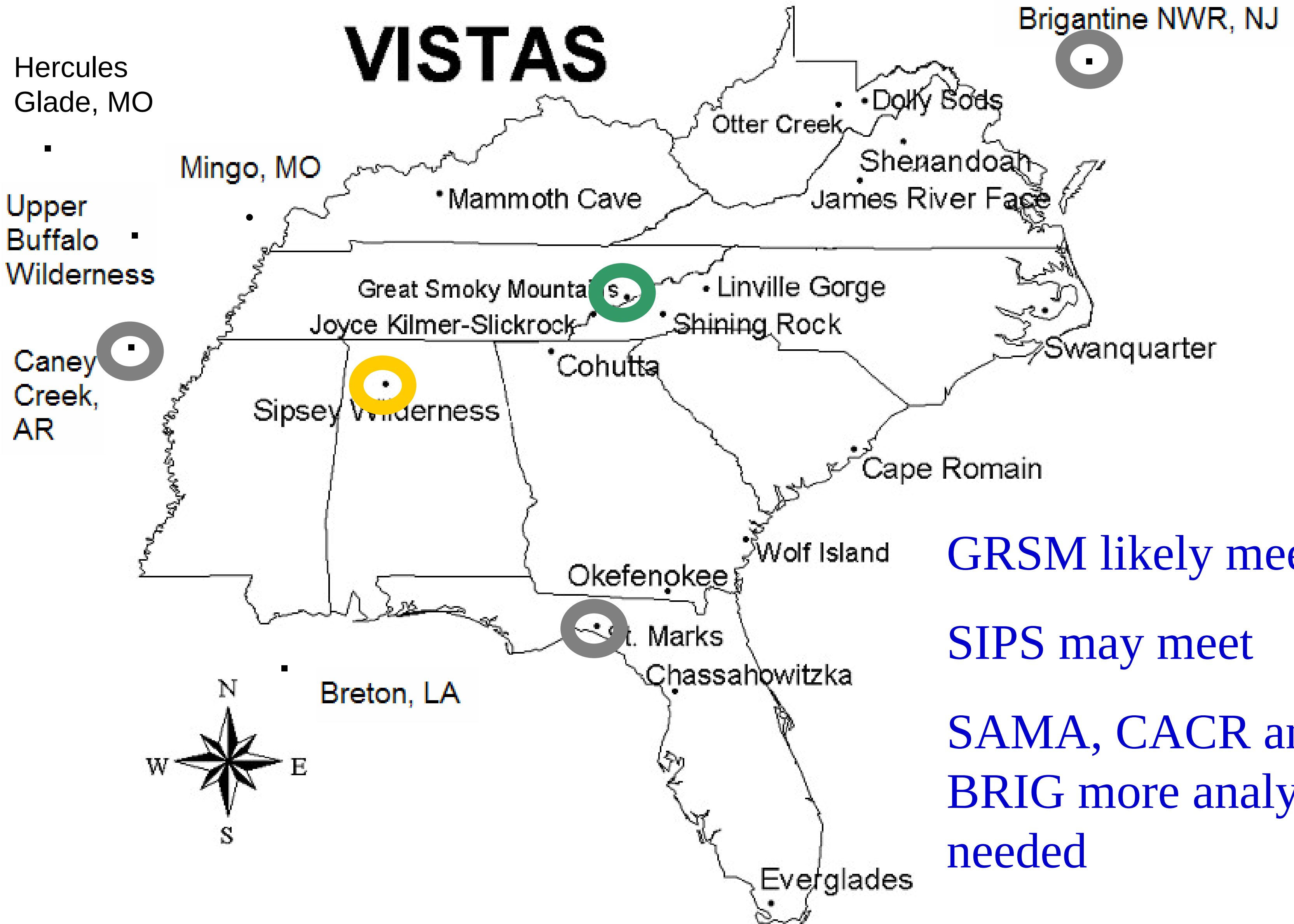
2018 OTWd Annual Reasonable Progress



Visibility Projection Questions

- Does it matter which method is used, do we see consistency across methods or are their outliers and why?
- How should you treat poor performing days?
  - Does the model respond in the same fashion on poor performing days as on other Worst 20% days?
- How should you address extreme events?
  - Fires
  - Windblown dust
  - Other
- Detailed analysis of several Class I areas then summary:
  - GRSM, SIPS, SAMA, CACR, BRIG

Detailed 2018 OTWd Visibility Projections for Five Class I Areas



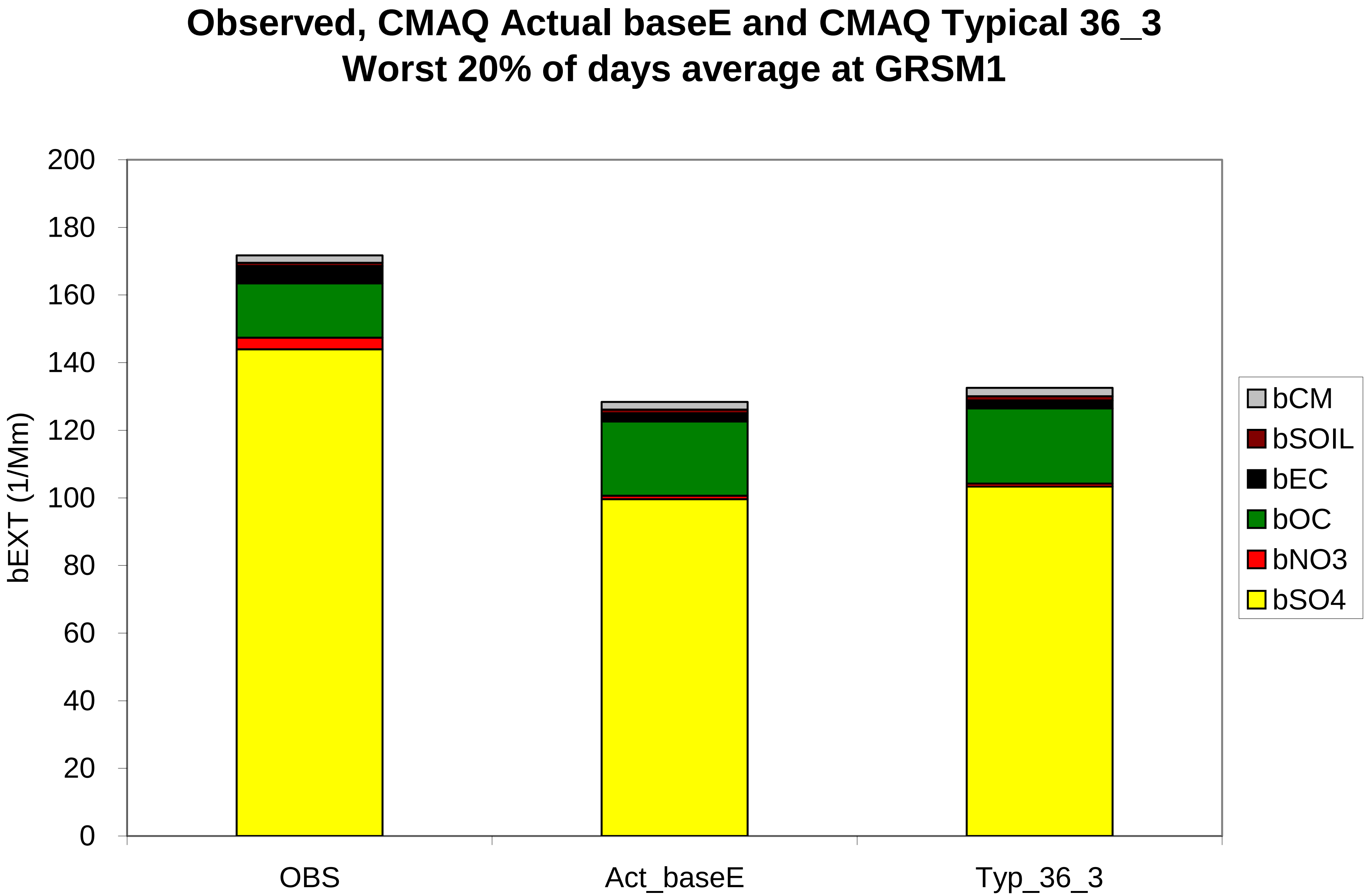
GRSM likely meets

SIPS may meet

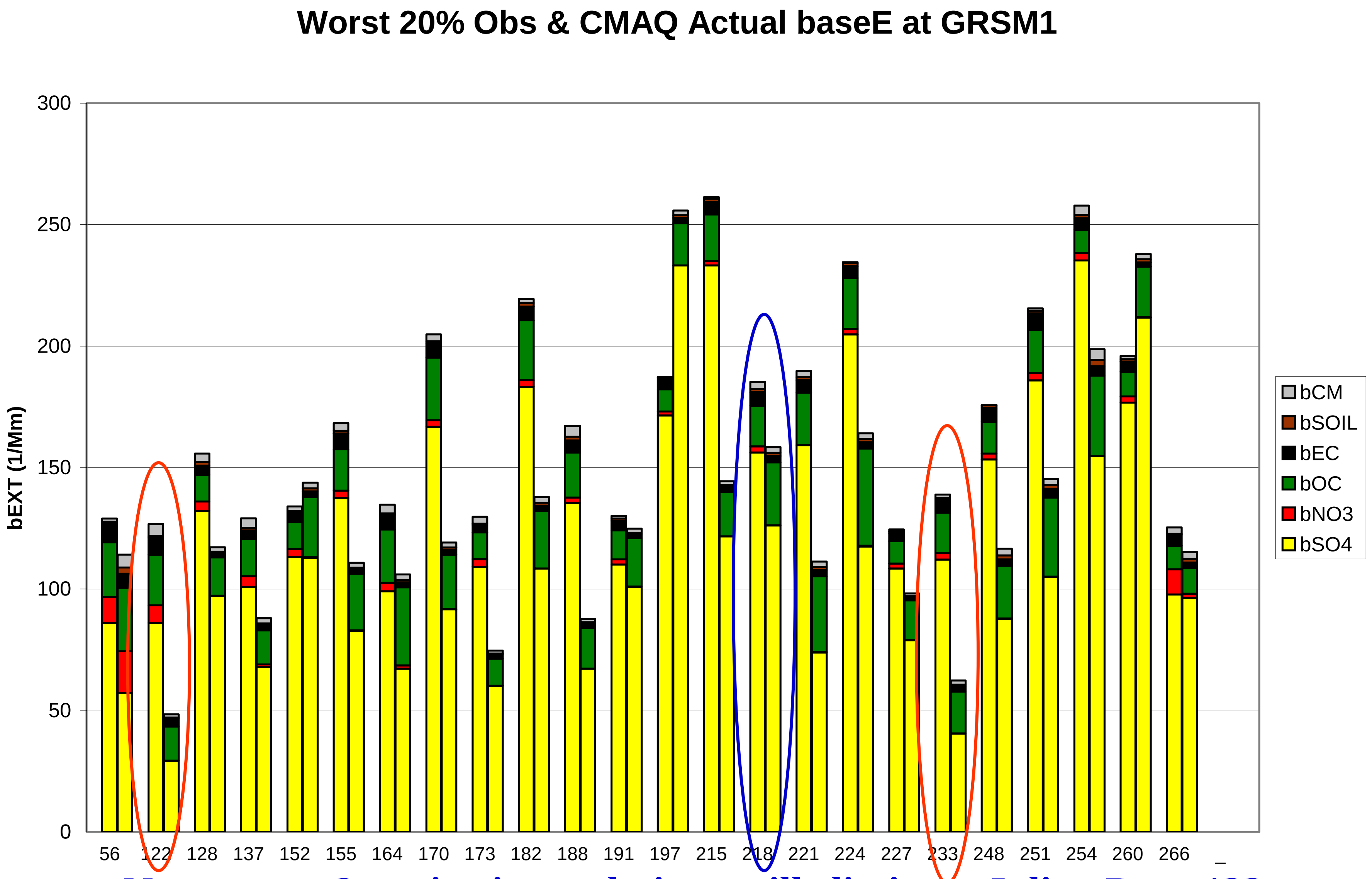
SAMA, CACR and BRIG more analysis needed

Great Smoky Mountains, NC/TN

Observed, 2002 Actual and 2002 Typical average extinction across 2002 Worst 20% days at Great Smoky Mountains, TN/NC

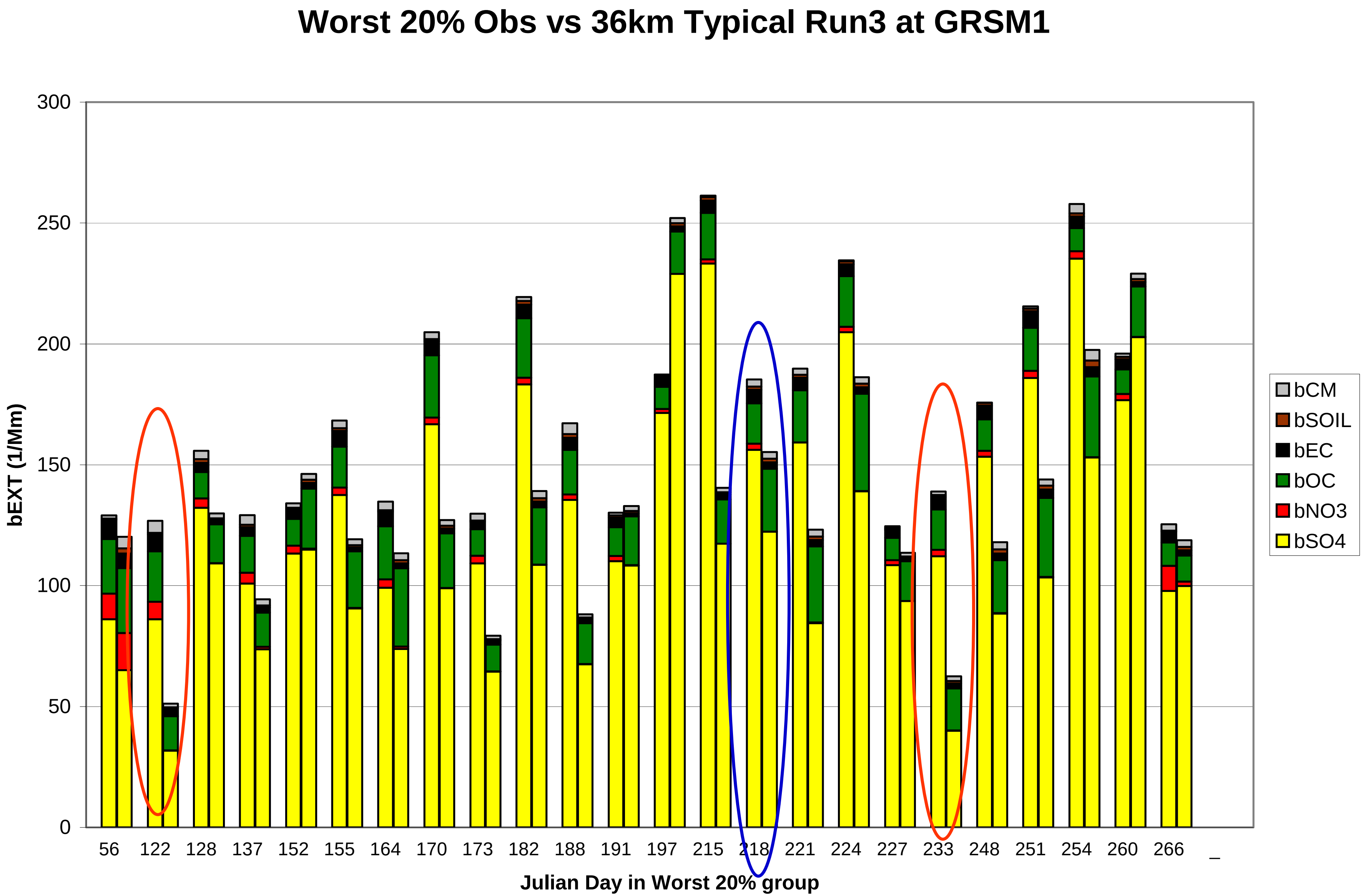


Observed (left) and 2002 Actual (right) daily extinction for Worst 20% days at Great Smoky Mountains, TN/NC

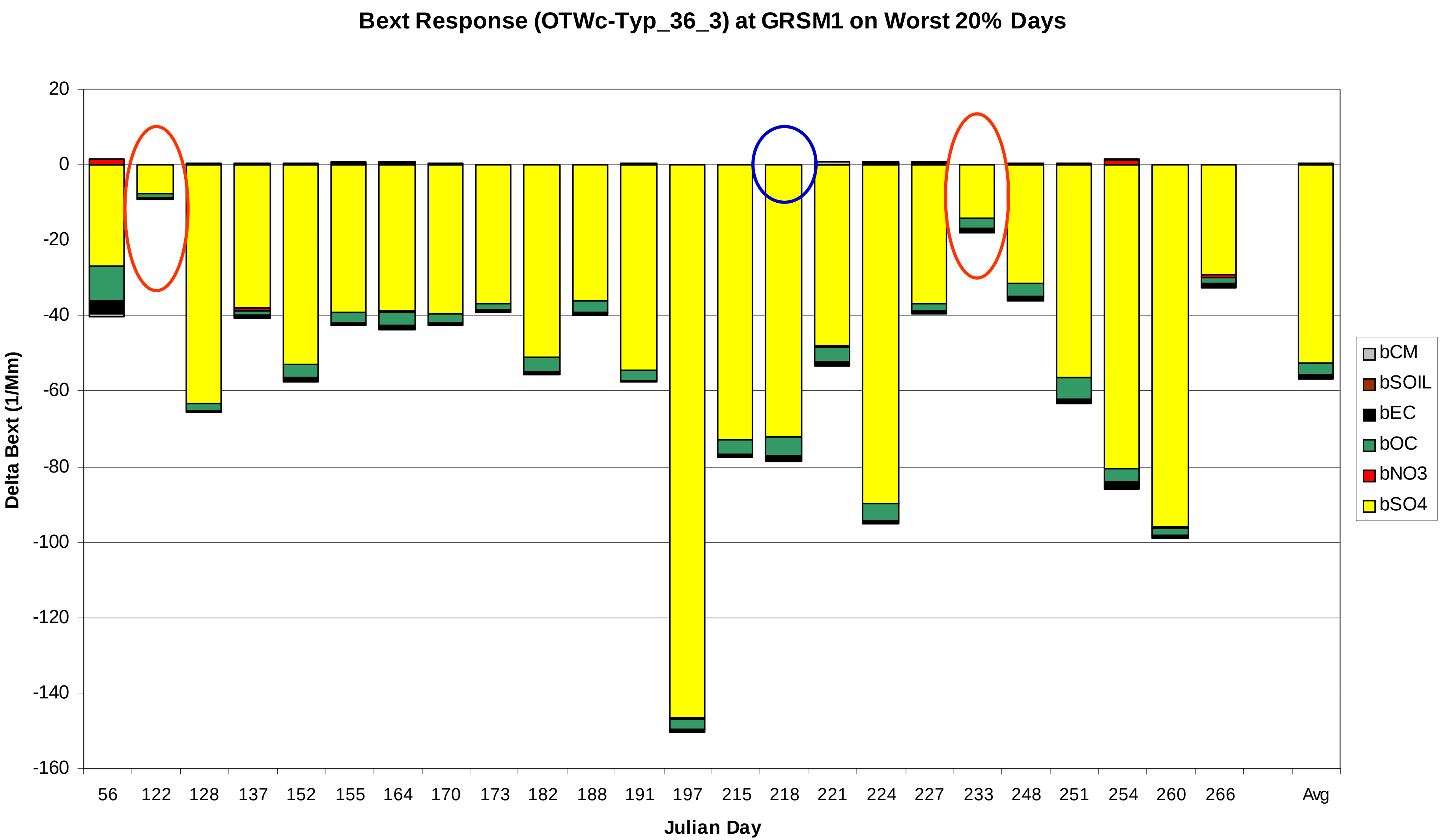


<u>Note</u>: wmpe2 projection technique will eliminate Julian Days 122 and 233 from RRFs

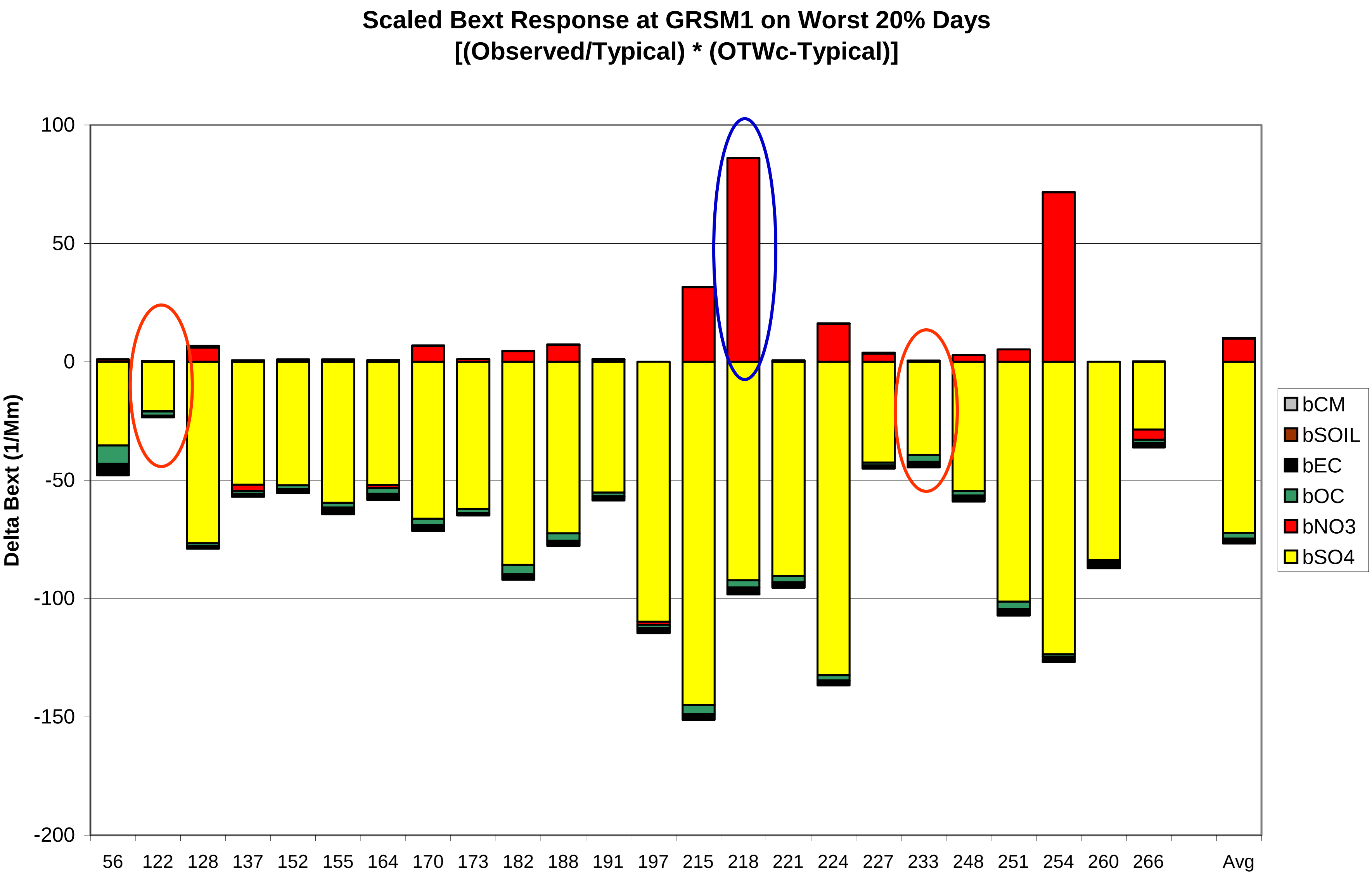
Observed (left) and 2002 Typical (right) daily extinction for Worst 20% days at Great Smoky Mountains, TN/NC



Difference in 2018 OTWd and 2002 Typical daily extinction for Worst 20% days at Great Smoky Mountains, TN/NC

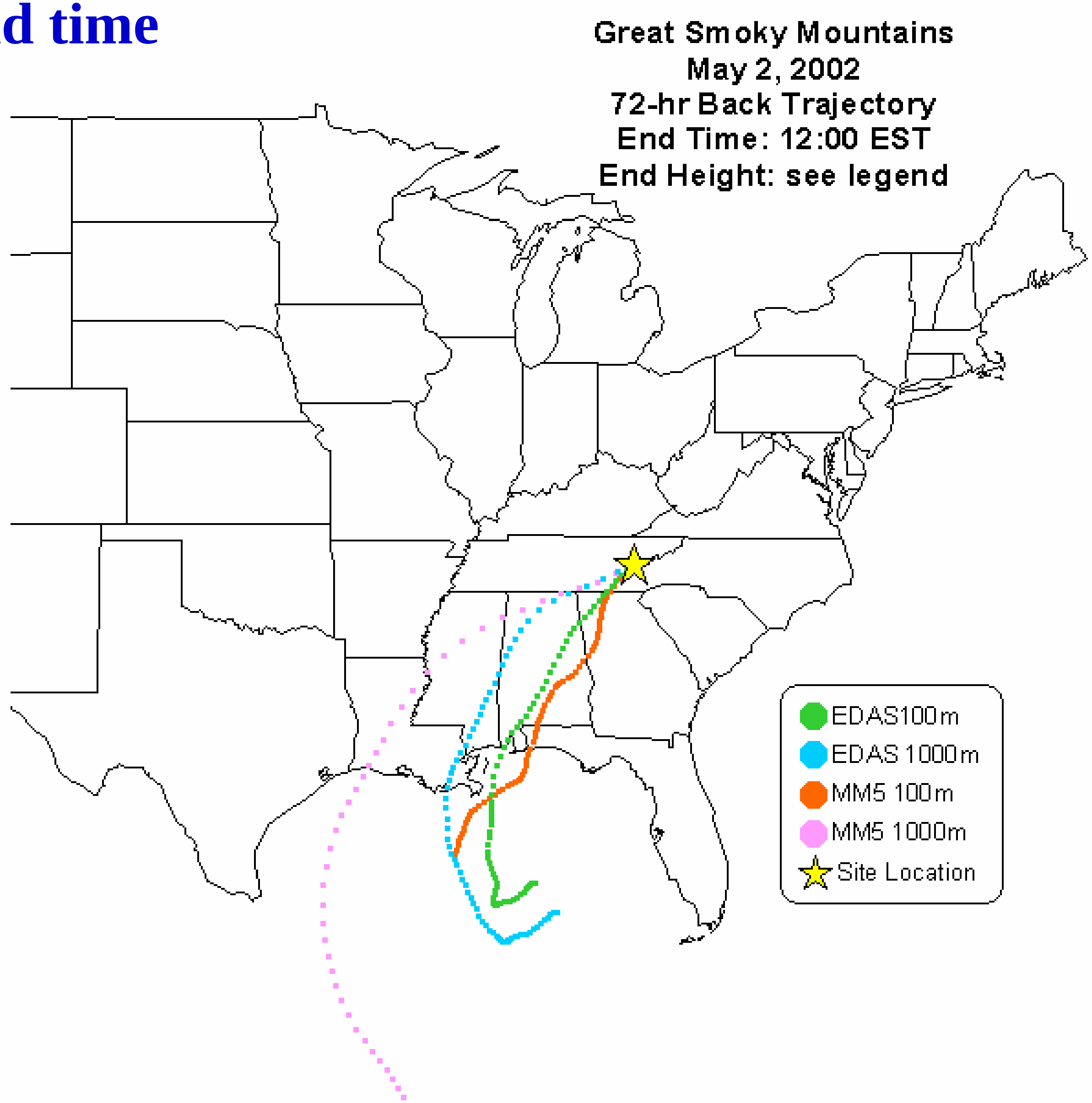


2018 OTWd – 2002 Extinction Differences Scaled by Observations

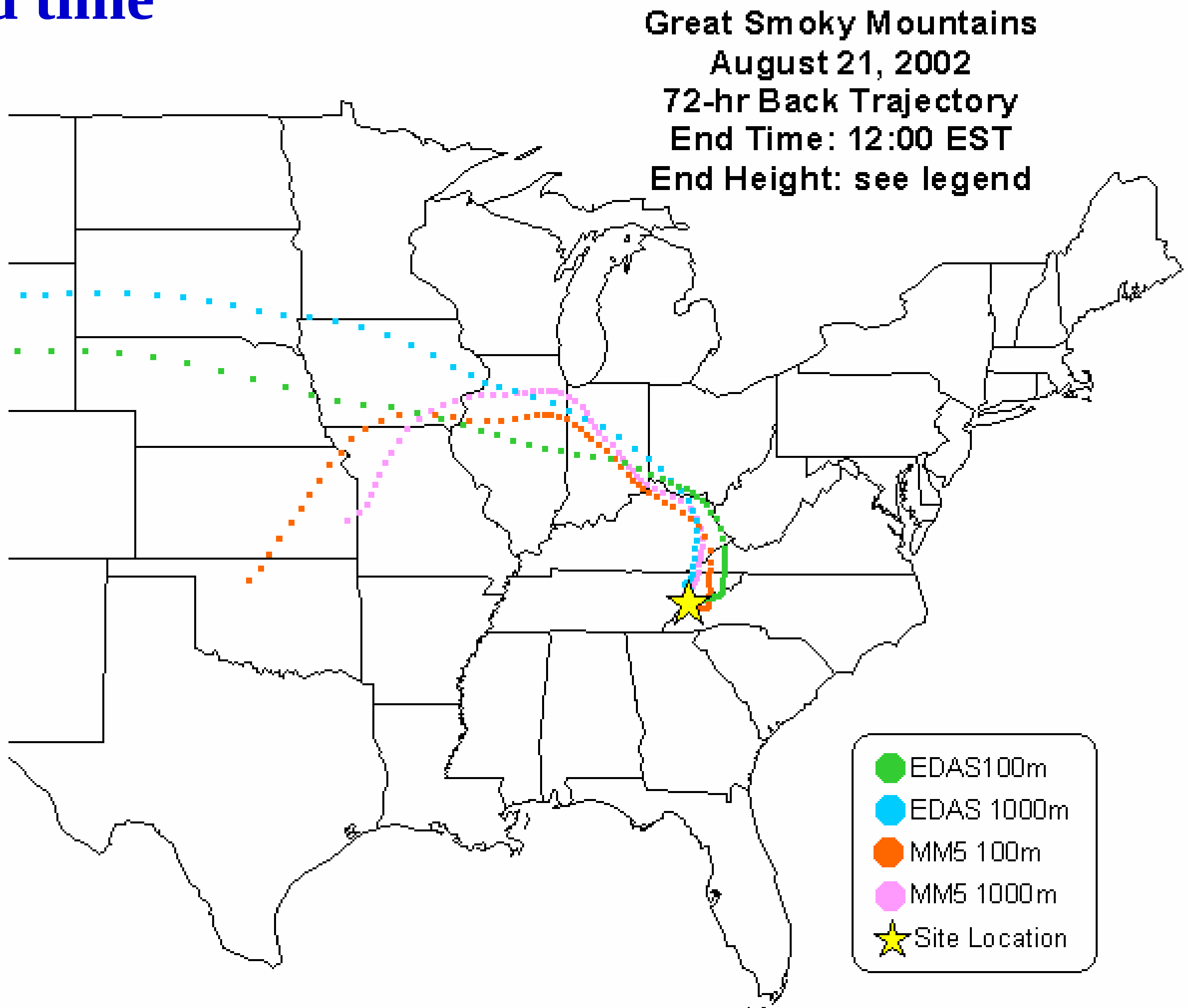


2018/2002 model differences scaled by observations show modeling artifacts for NO3 that affects Method 3 but not other Methods using averaging

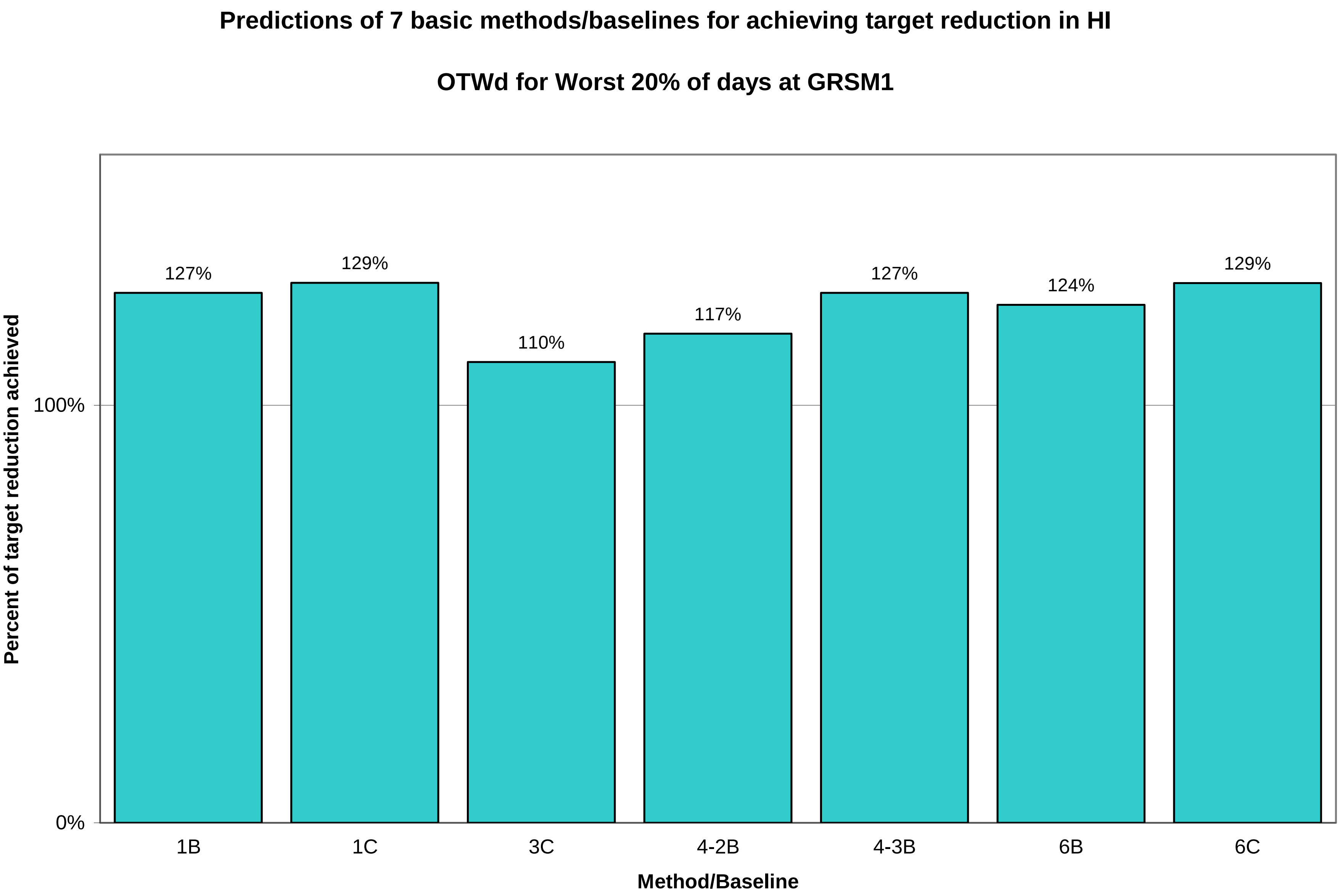
GRSM Julian Day 122, 2002
12:00 end time



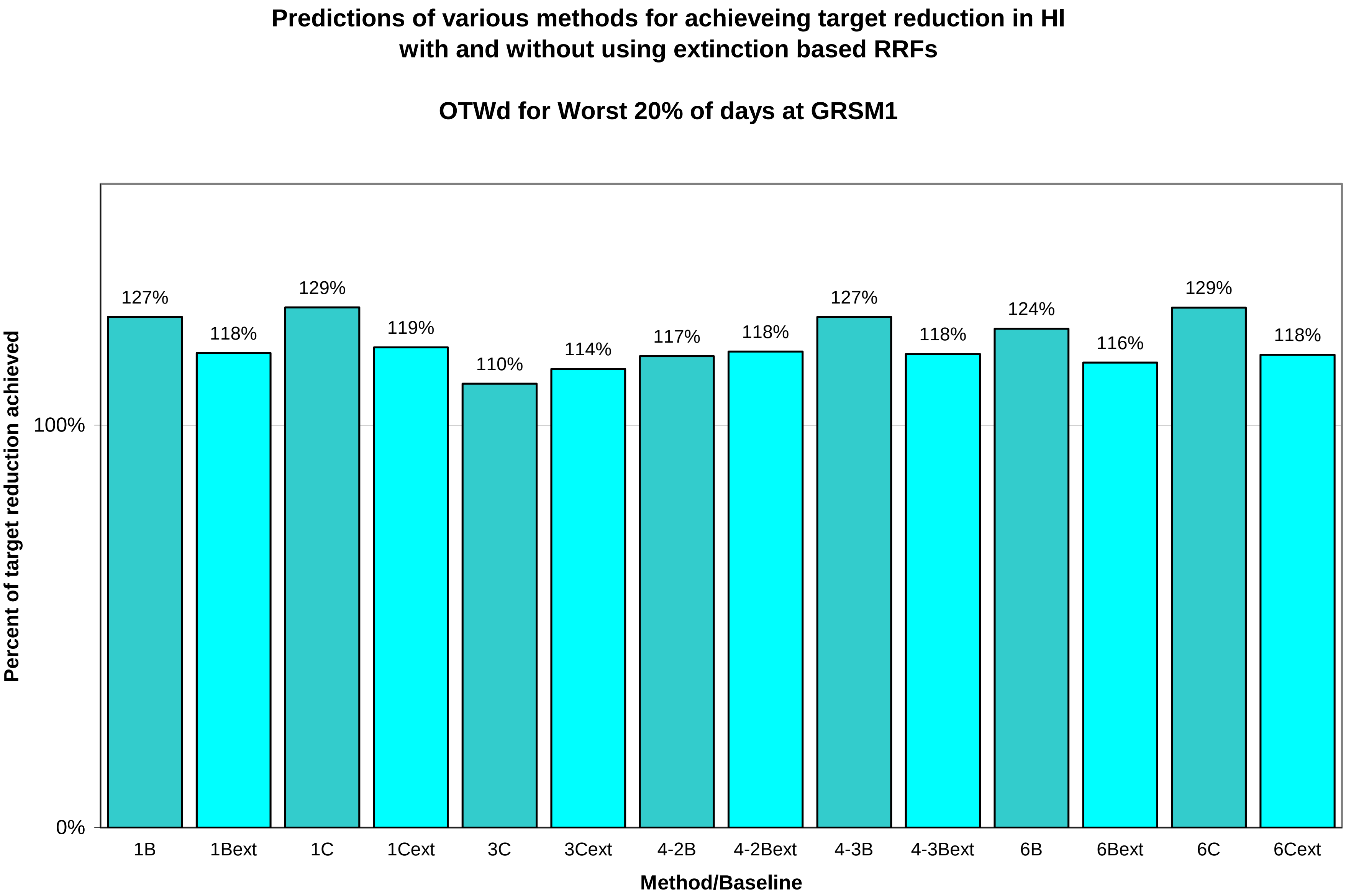
GRSM Julian Day 233, 2002
12:00 end time



GRSM 2018 OTWd Visibility Projections: Basic Methods

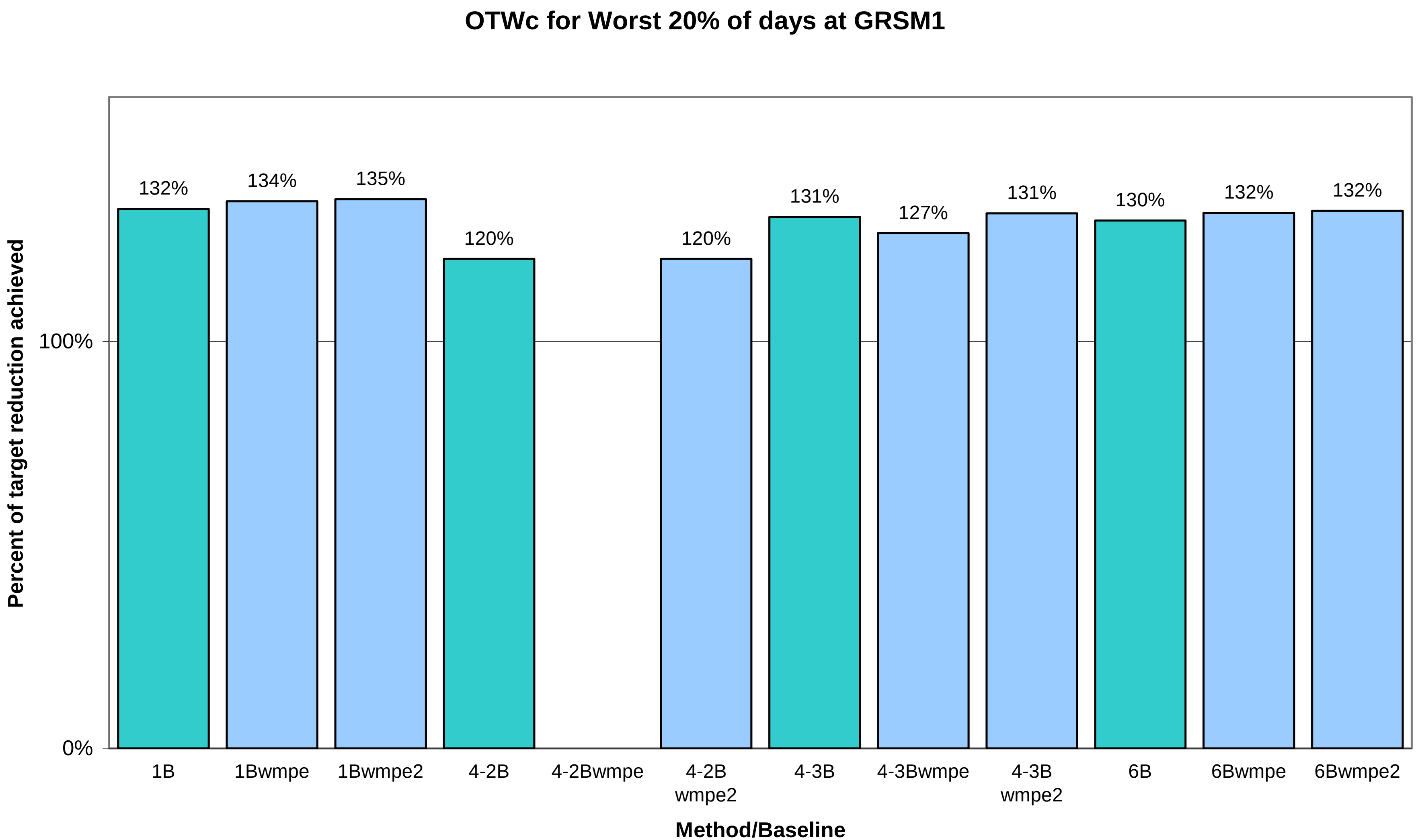


GRSM 2018 OTWd Visibility Projections: Extinction RRFs



GRSM 2018 OTWd Visibility Projections: Accounting for Model Performance

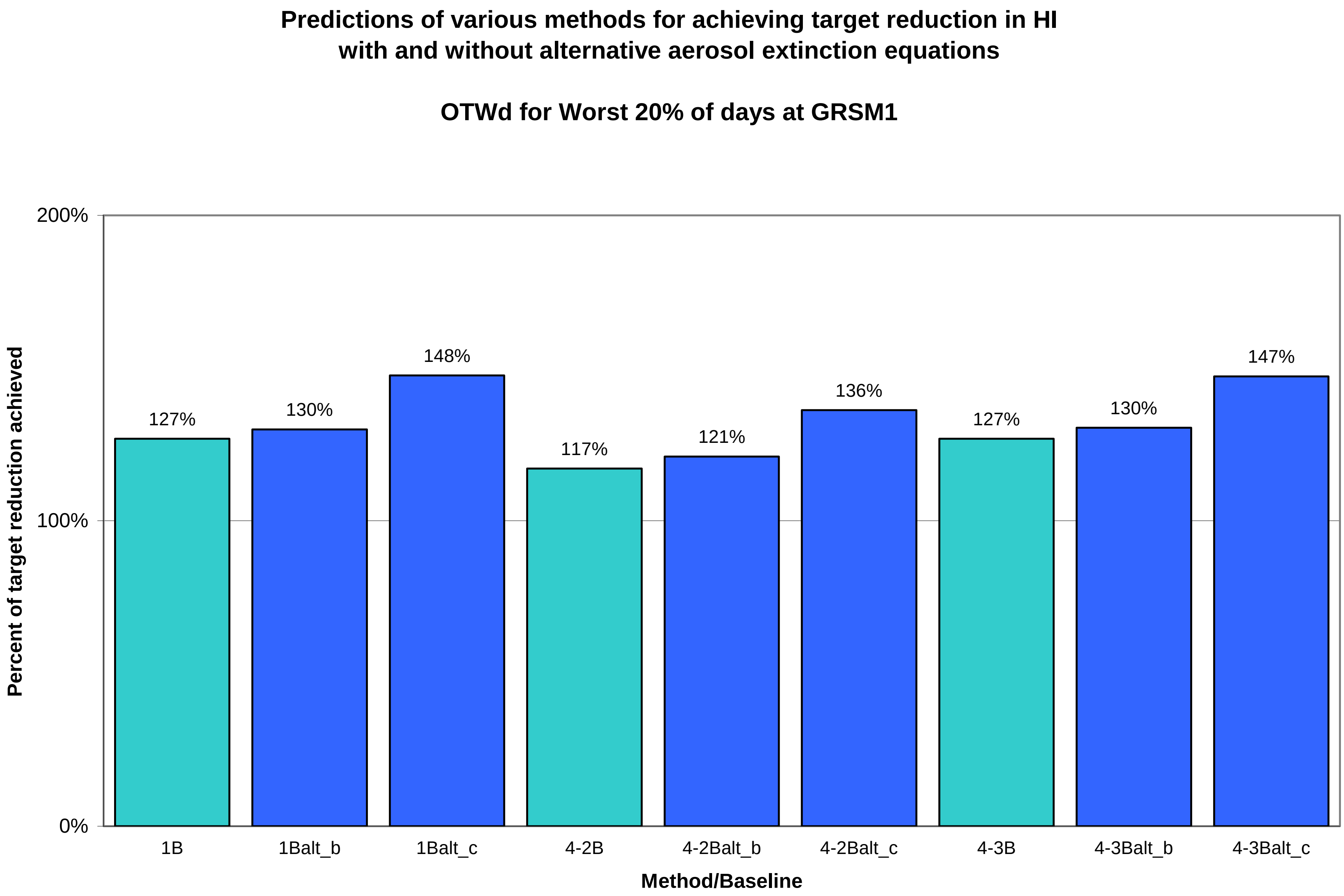
Predictions of various methods for achieving target reduction in HI with and without model performance criteria



Comments on GRSM wmpe Projections

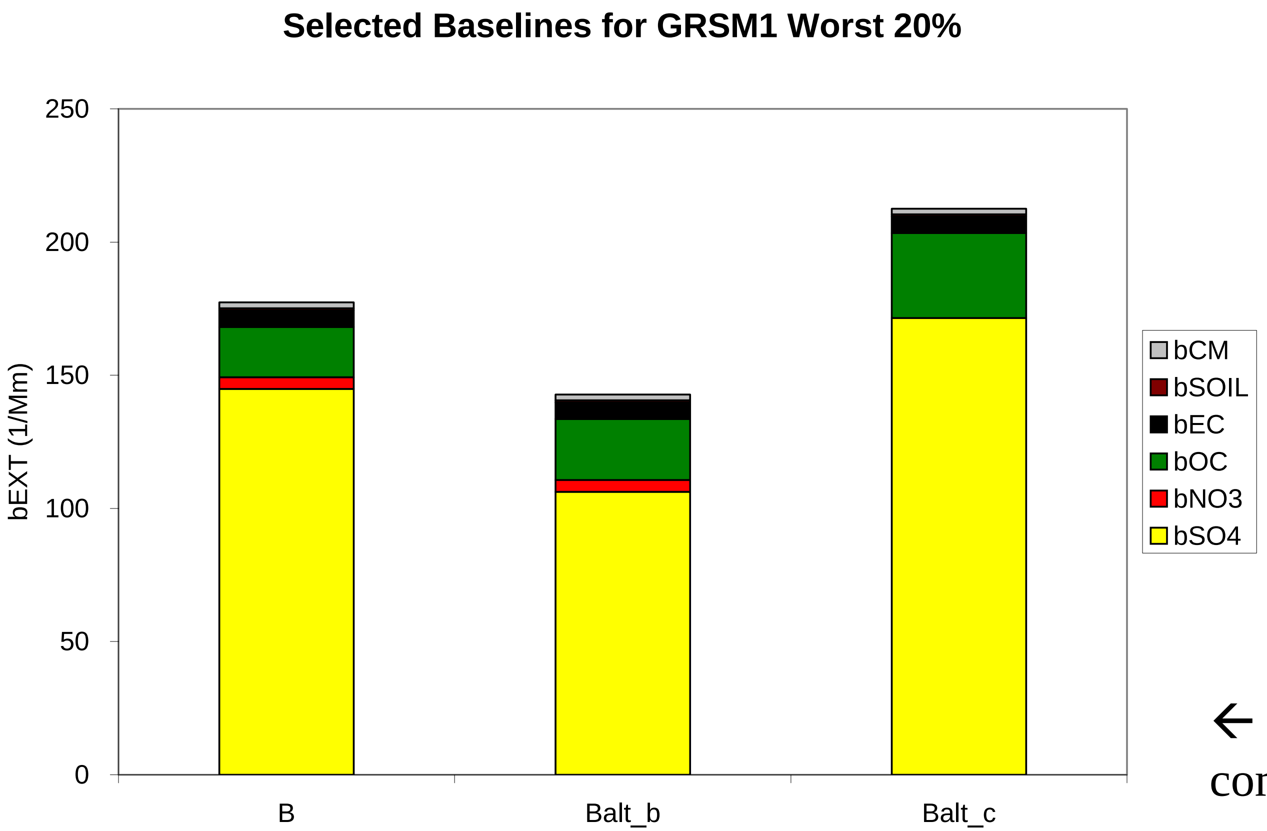
- For GRSM, visibility projections using wmpe and wmpe2 nearly identical (2%-4% different)
- If all days for a PM species fail the wmpe factor of two test can not do projections (Method 4-2B)
- Two poor performing days (122 and 233) eliminated in wmpe2 test, yet essentially no difference
- This is because:
  - low concentration poor performing days have very little influence on RRFs based on average concentrations across Worst 20% days; and
  - SO4 dominates visibility reductions at GRSM and SO4 is best performing species

GRSM 2018 OTWd Visibility Projections: Alternative Equations



Discussion of GRSM alt_b & alt_c

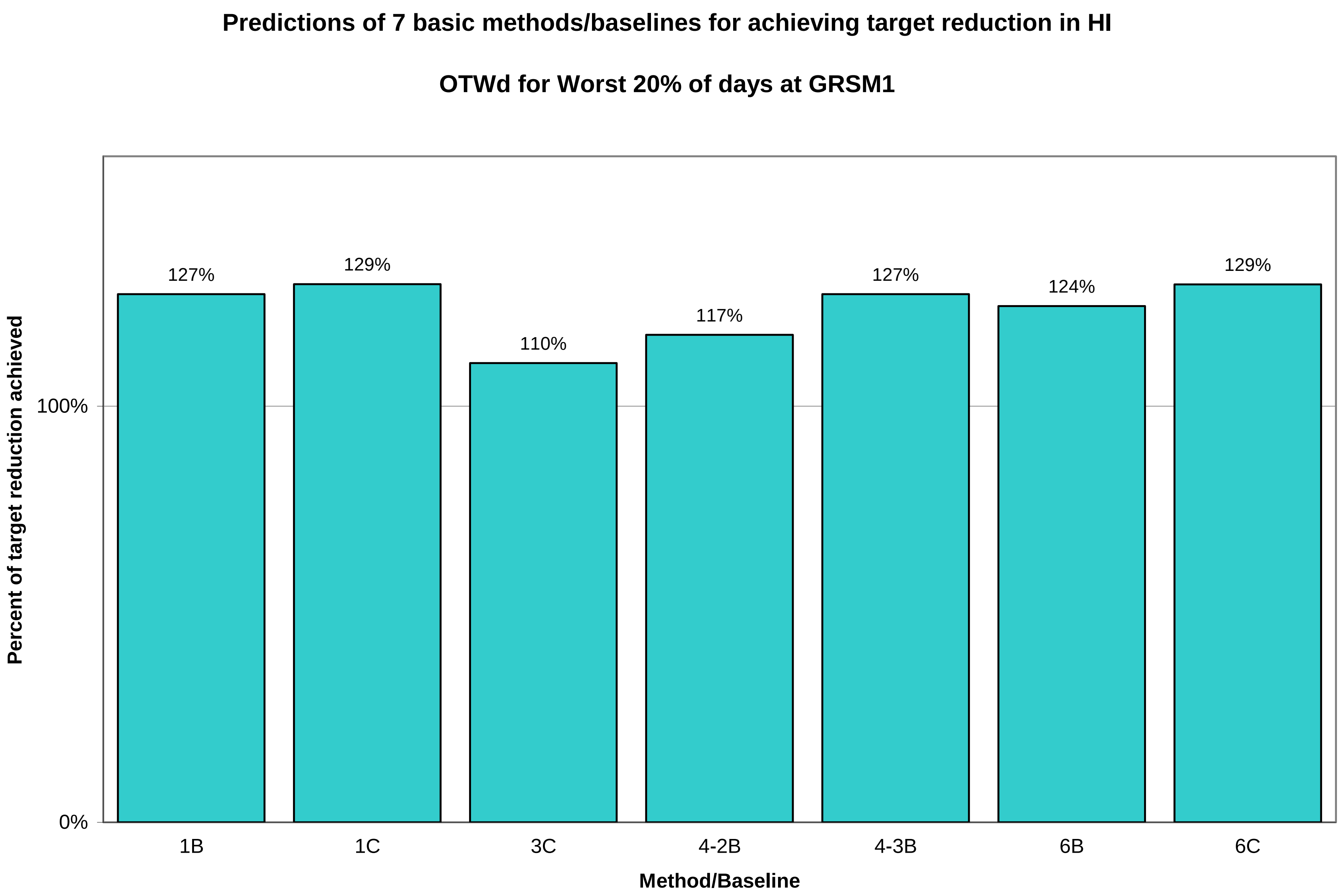
Alternative extinction equations change baseline, 7% lower with alt_b (26.89 dv) and 4% higher with alt_c (30.23 dv) compared to IMPROVE equation (28.95 dv).



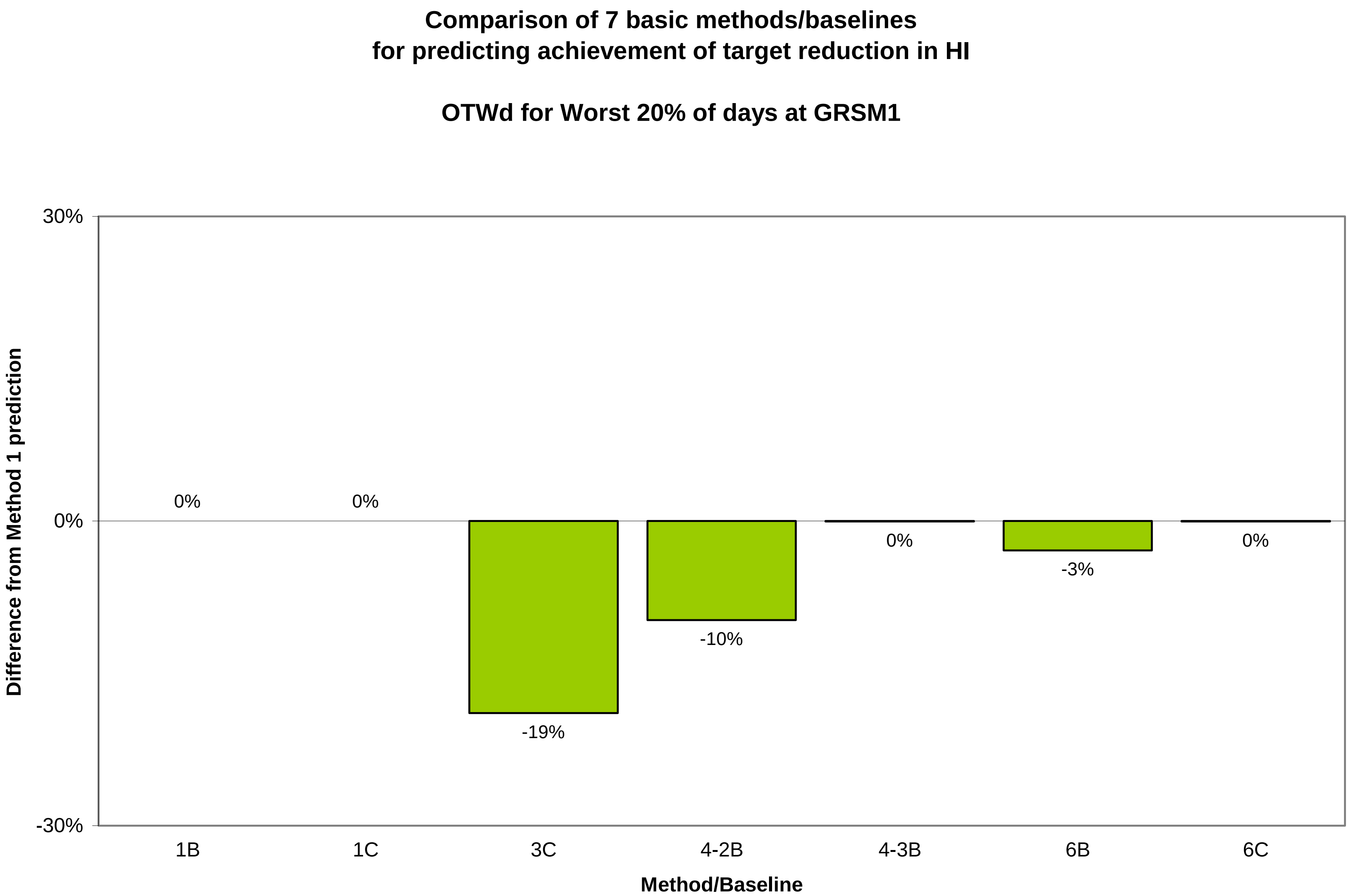
SO4+NO3 contribution for Baseline comparable across equations 72%, 65% and 71% for IMPROVE (a), alt_b and alt_c

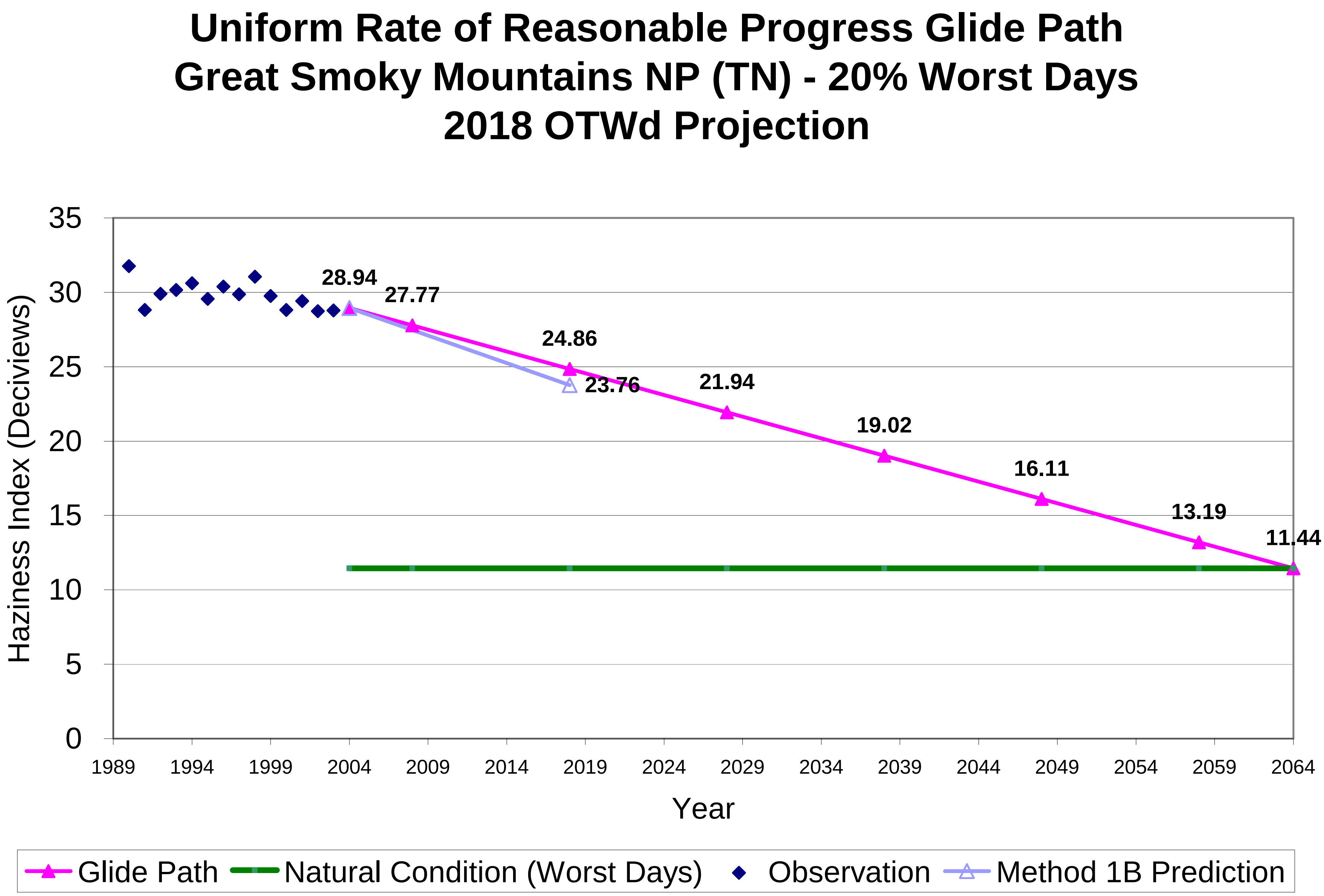
← SO4+NO3 extinction combined for Balt_c

GRSM 2018 OTWd Visibility Projections: Basic Methods



GRSM 2018 OTWd Visibility Projections:
Basic Methods Relative to Method 1B

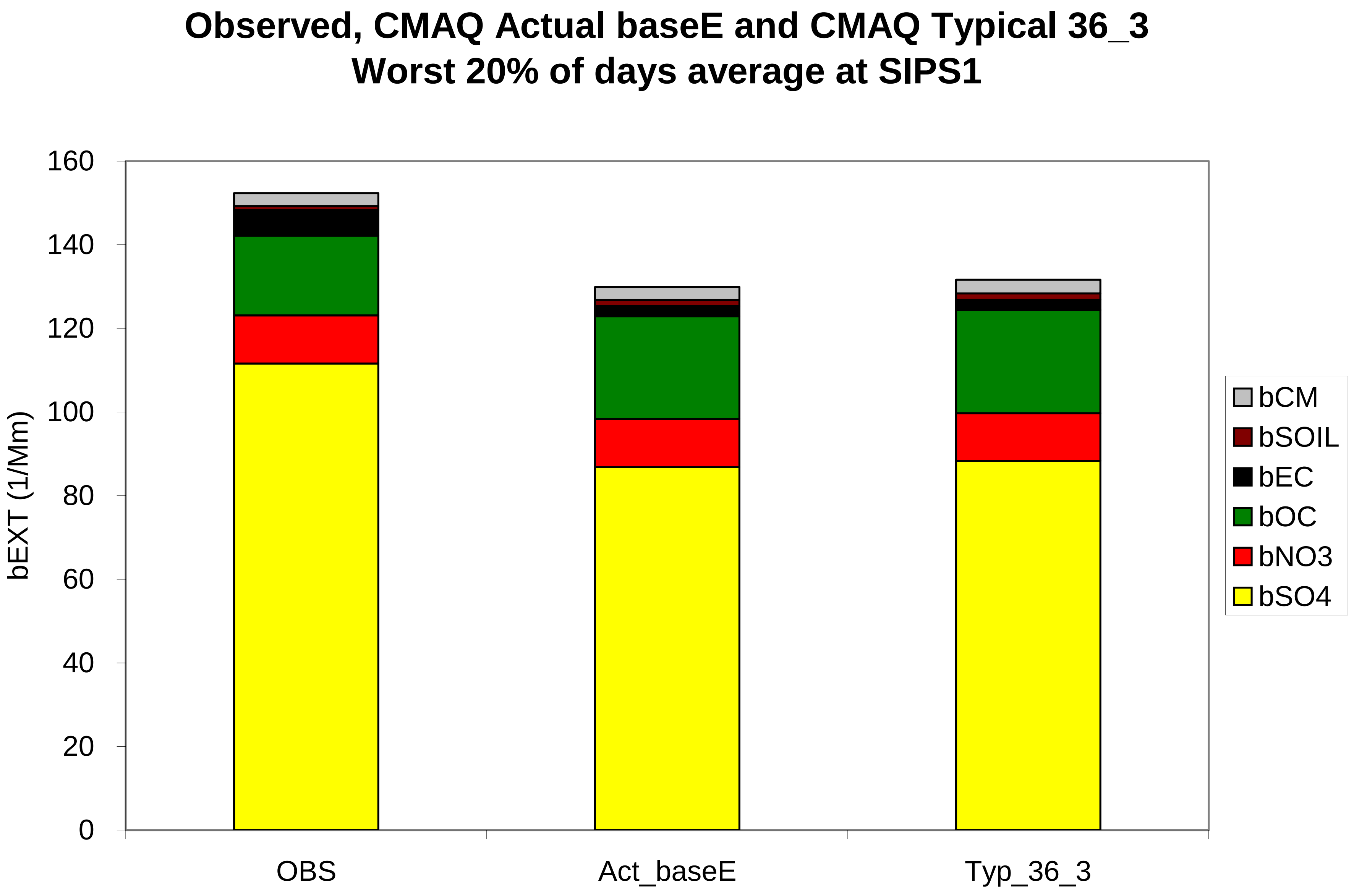




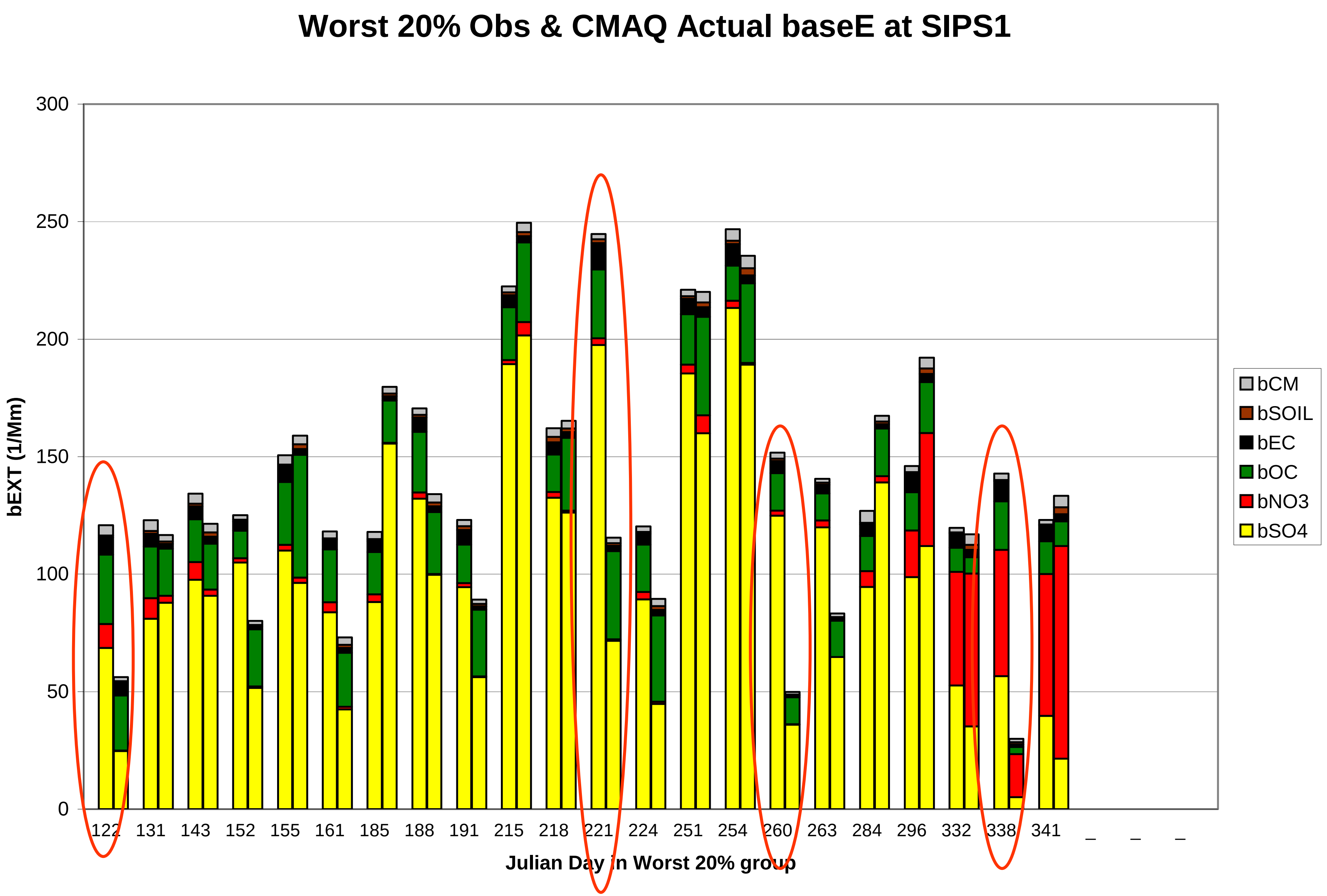
Uniform Rate of Reasonable Progress Glide Path
Great Smoky Mountains NP (TN) - 20% Worst Days
2018 OTWd Projection
Haziness Index (Deciviews)
Year
35
30
25
20
15
10
5
0
1989
1994
1999
2004
2009
2014
2019
2024
2029
2034
2039
2044
2049
2054
2059
2064
28.94
27.77
24.86
23.76
21.94
19.02
16.11
13.19
11.44
Glide Path
Natural Condition (Worst Days)
Observation
Method 1B Prediction

Sipsey Wilderness Area, AL

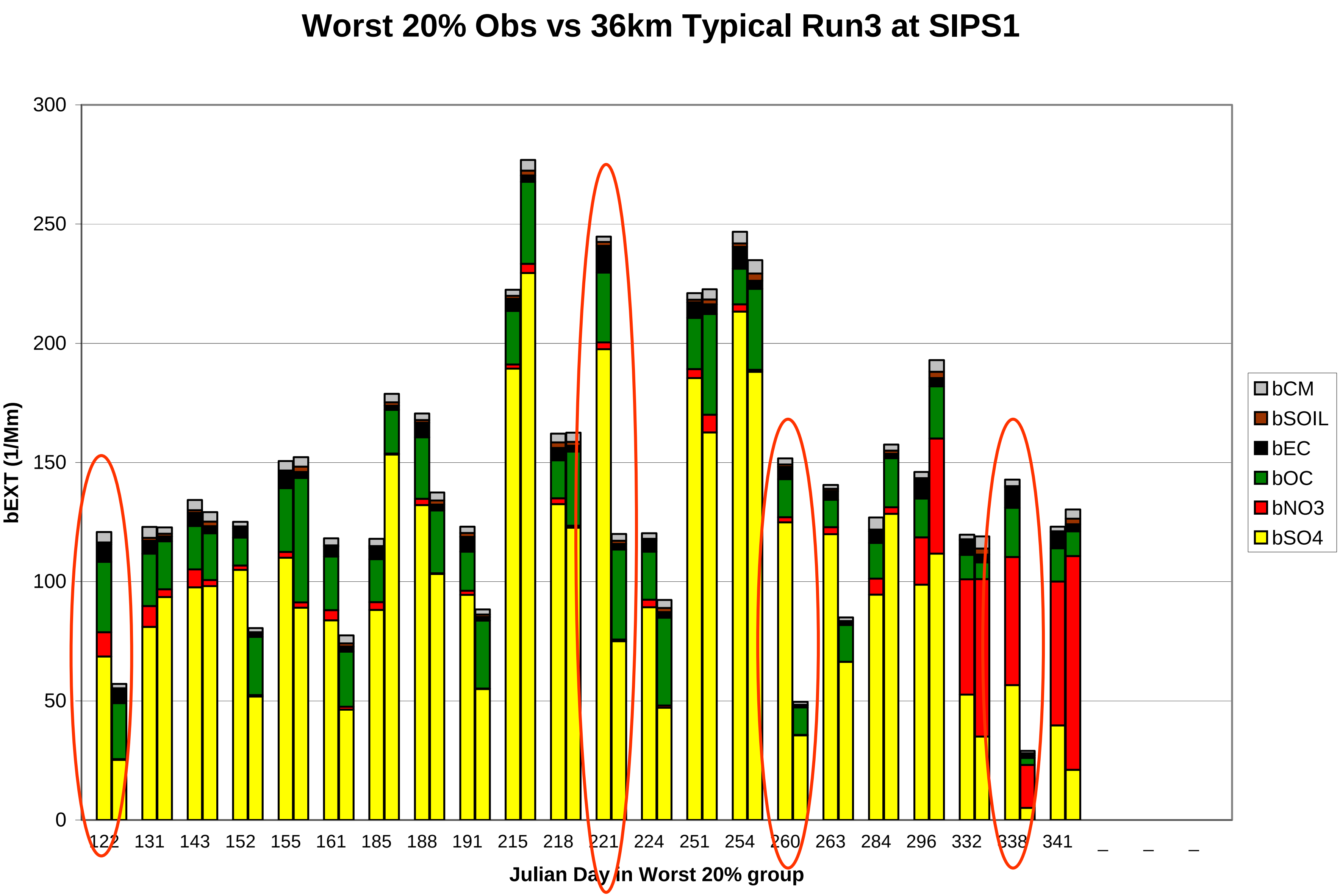
Observed, 2002 Actual and 2002 Typical average extinction across 2002 Worst 20% days at Sipsey, AL



Observed (left) and 2002 Actual (right) daily extinction for Worst 20% days at Sipsey, Alabama



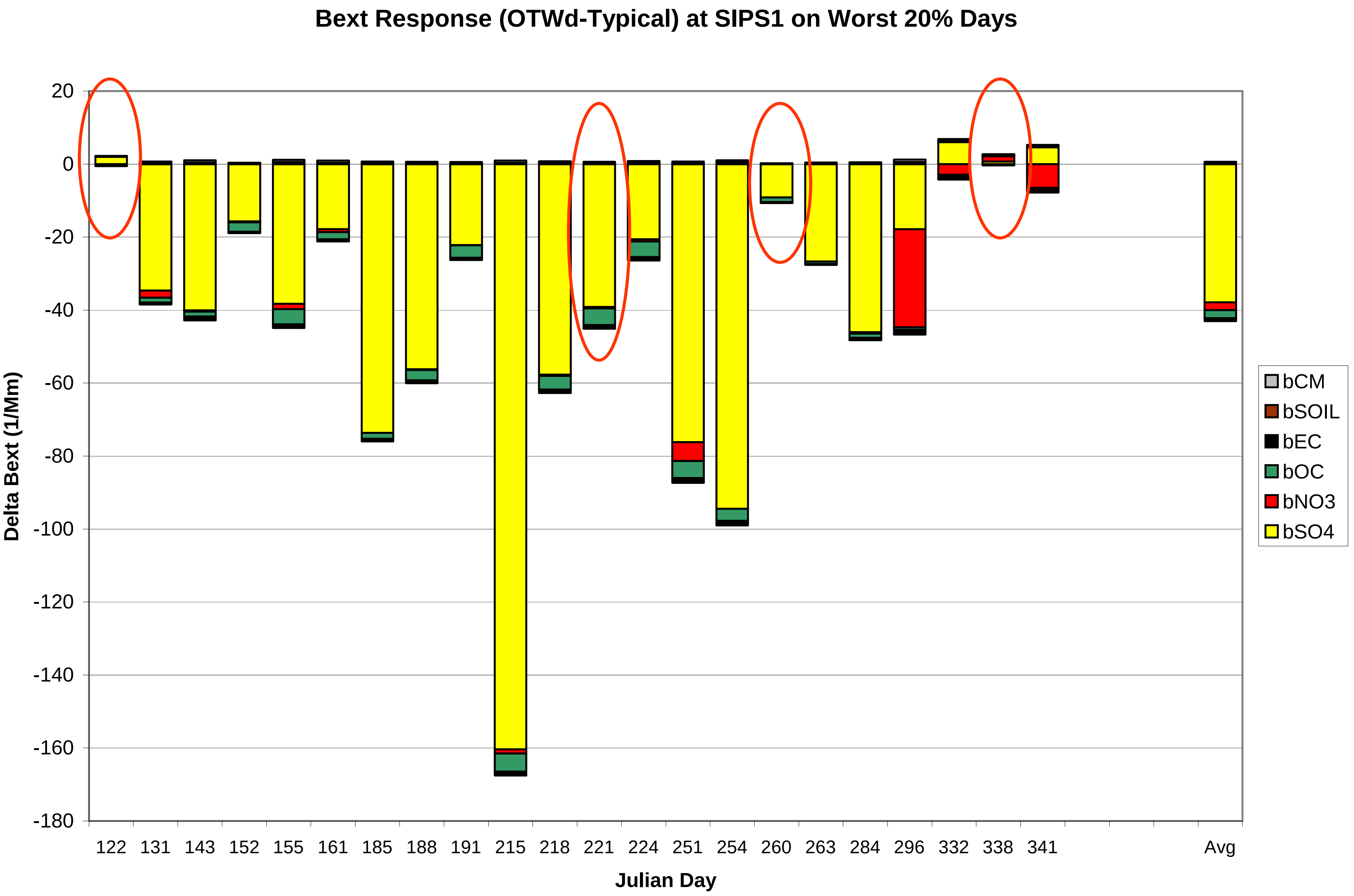
Observed (left) and 2002 Actual (right) daily extinction for Worst 20% days at Sipsey, Alabama



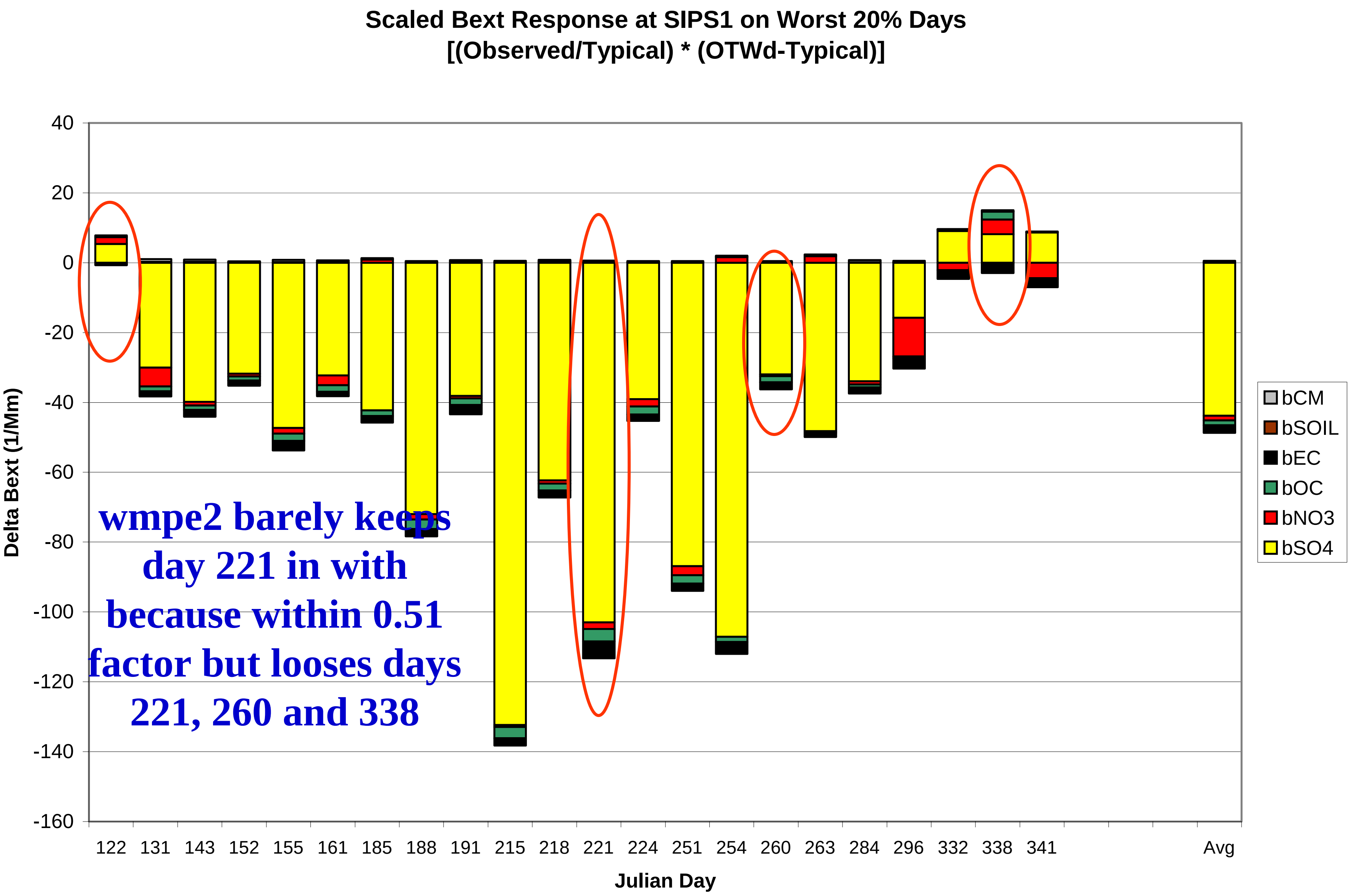
Sipsey, Alabama

- Several days with questionable model performance:
  - May 2, 2002 – Julian Day 122 (SO_4-wmpe)
  - August 9, 2002 – Julian Day 221 (SO_4-wmpe & wmpe2)
  - September 17, 2002 – Julian Day 260 (SO_4-wmpe & wmpe2)
  - December 4, 2004 – Julian Day 338 (SO_4-wmpe & wmpe2)
- Does model respond correctly on these days?
- Why model performance poor?
- When exclude these days from RRF does it make any difference on projections?
  - Tested with <u>wmpe</u> (SO_4 all days) and <u>wmpe2</u> (except Julian Day 122 still included)

Difference in 2018 OTWd and 2002 Typical daily extinction for Worst 20% days at Sipsey, Alabama



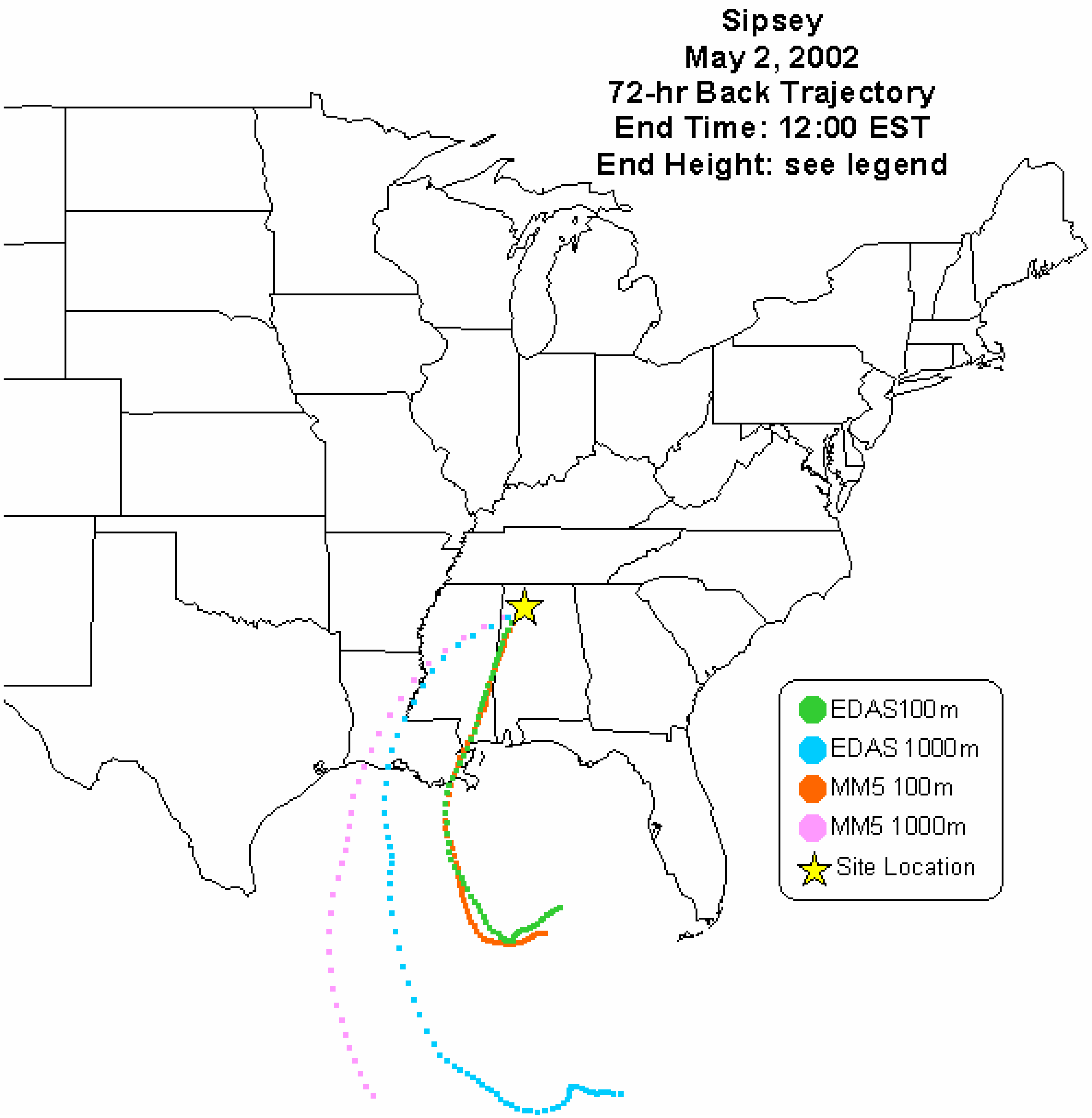
2018 OTWd – 2002 Extinction Differences Scaled by Observations



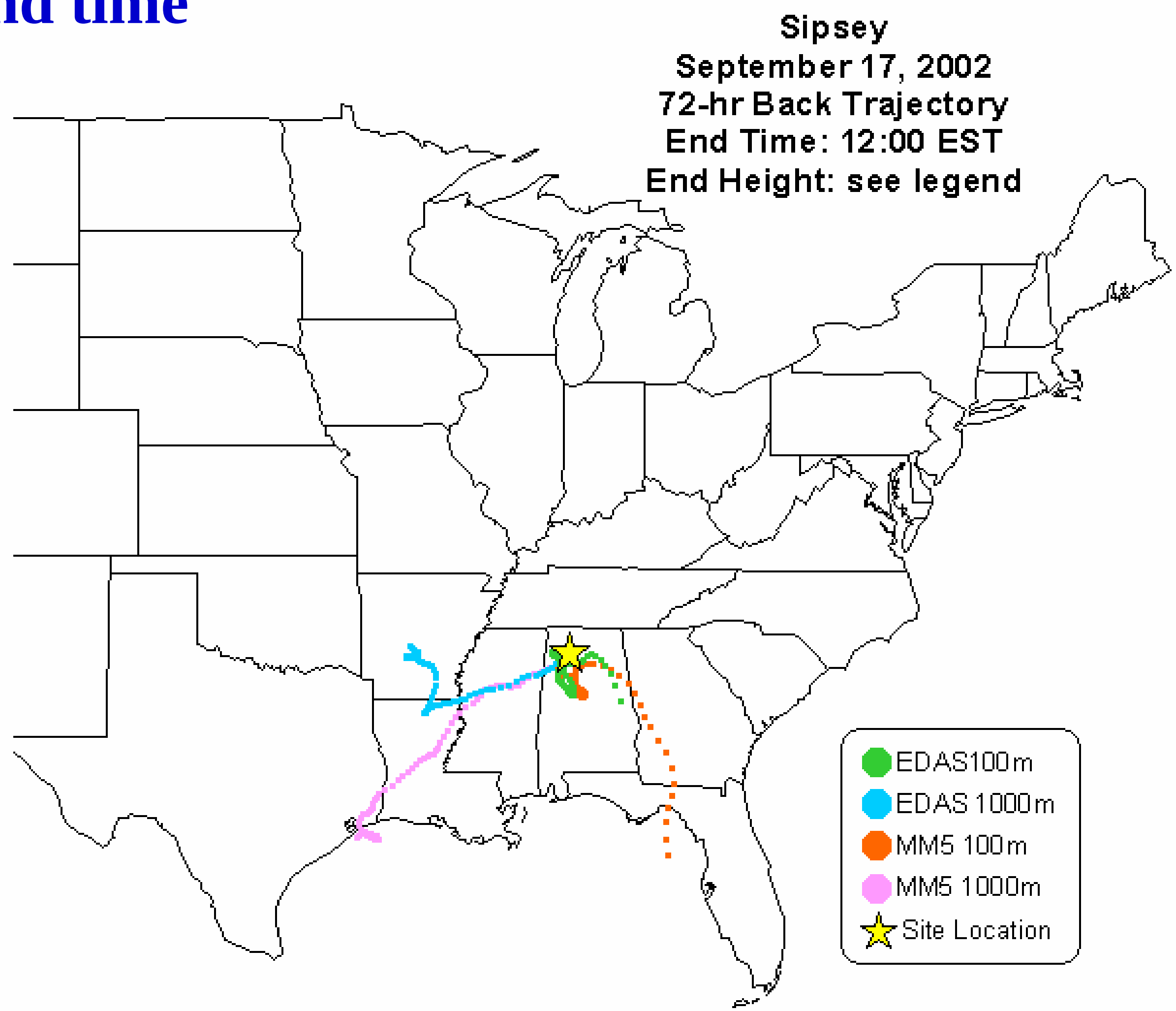
SIPS Julian Day 122, 2002
12:00 end time

Why model underestimation on day 122?

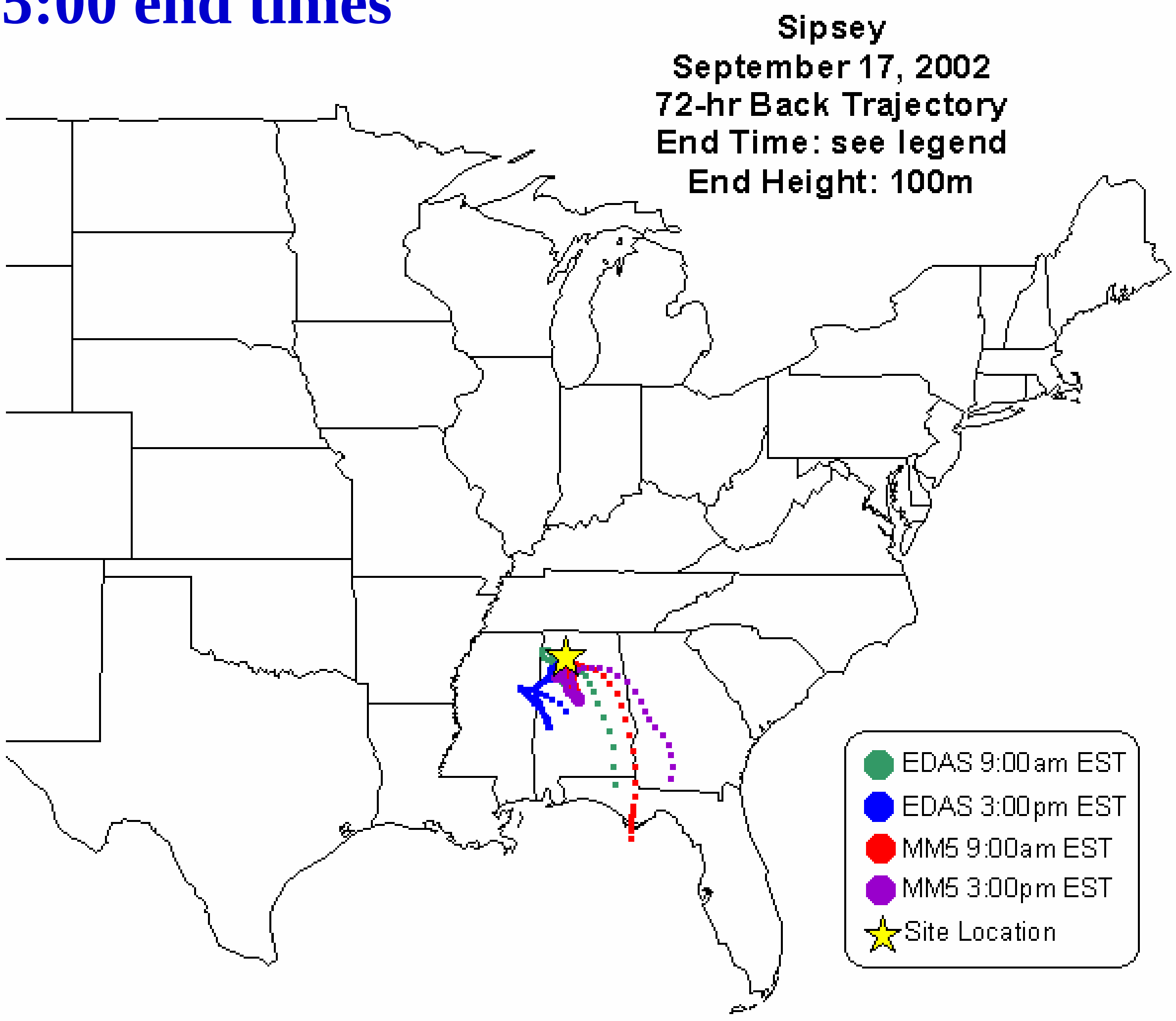
MM5 and EDAS back trajectories both originate in Gulf of Mex. Met problems or missing Caribbean emissions



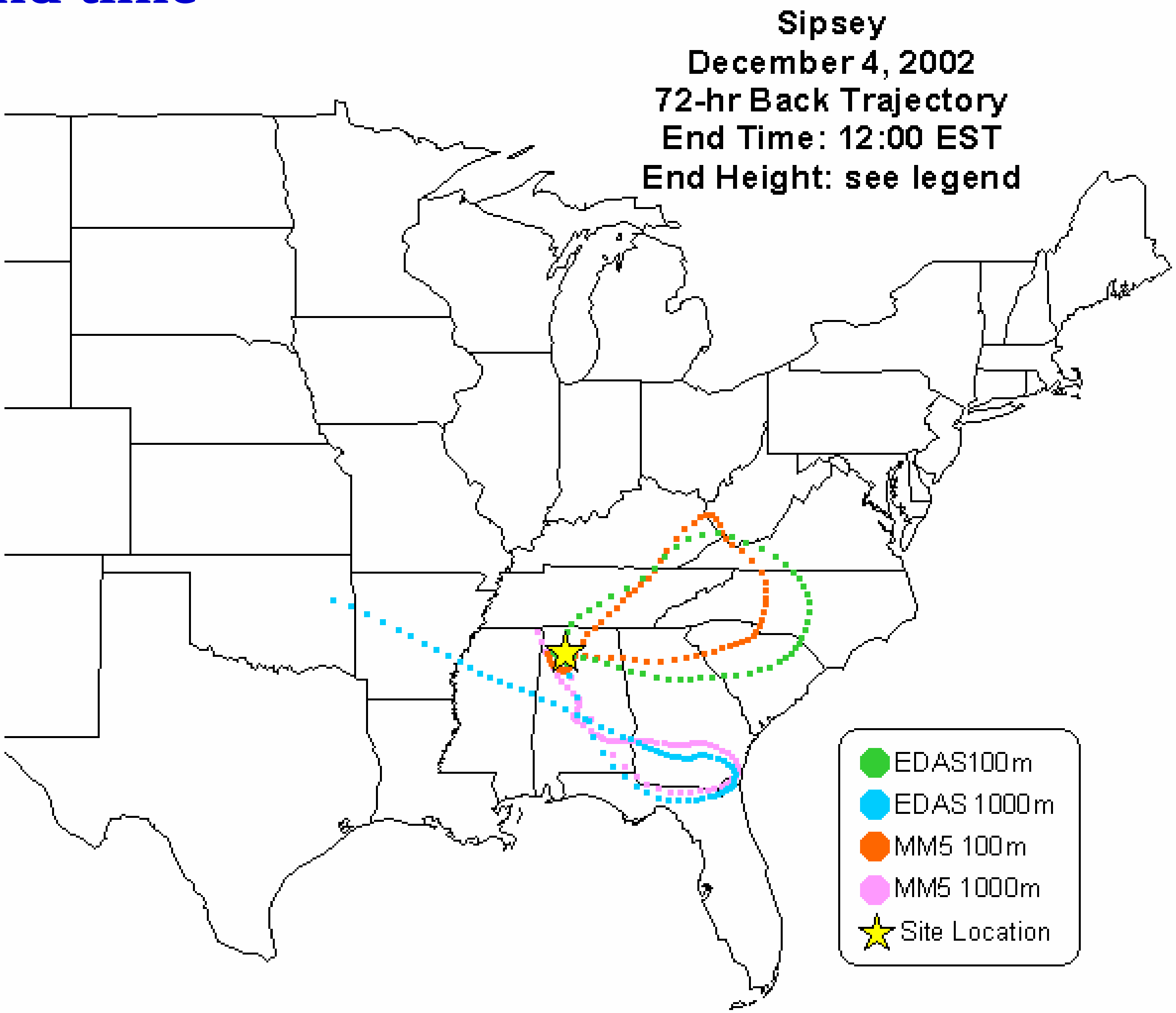
SIPS Julian Day 260, 2002
12:00 end time



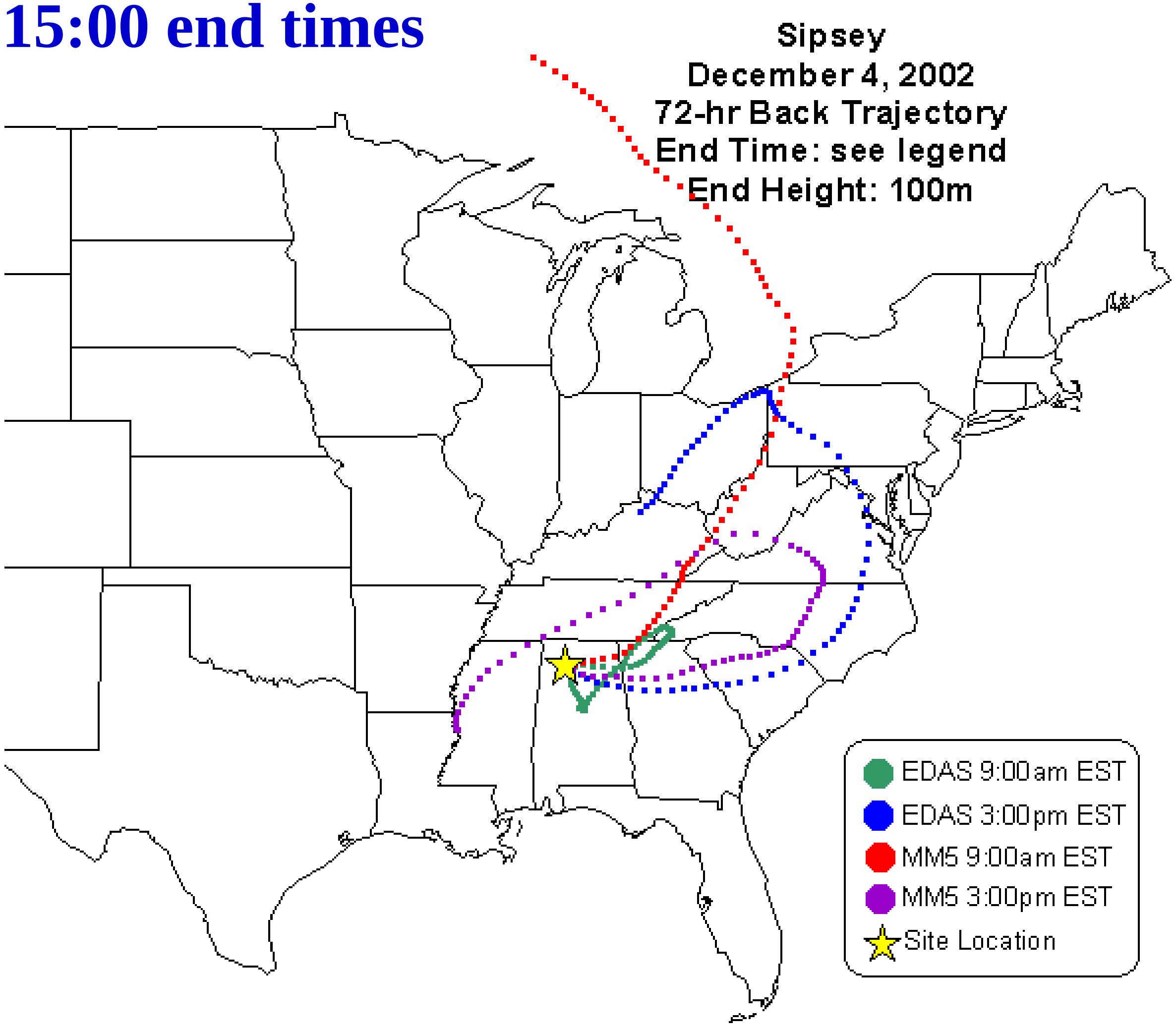
SIPS Julian Day 260, 2002
9:00 & 15:00 end times



SIPS Julian Day 338, 2002
12:00 end time

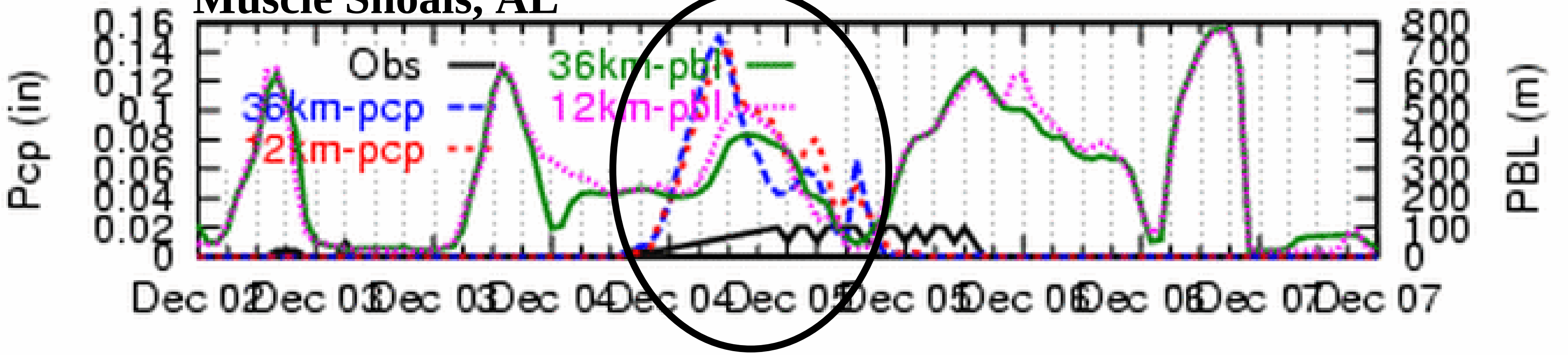


SIPS Julian Day 338, 2002
9:00 and 15:00 end times

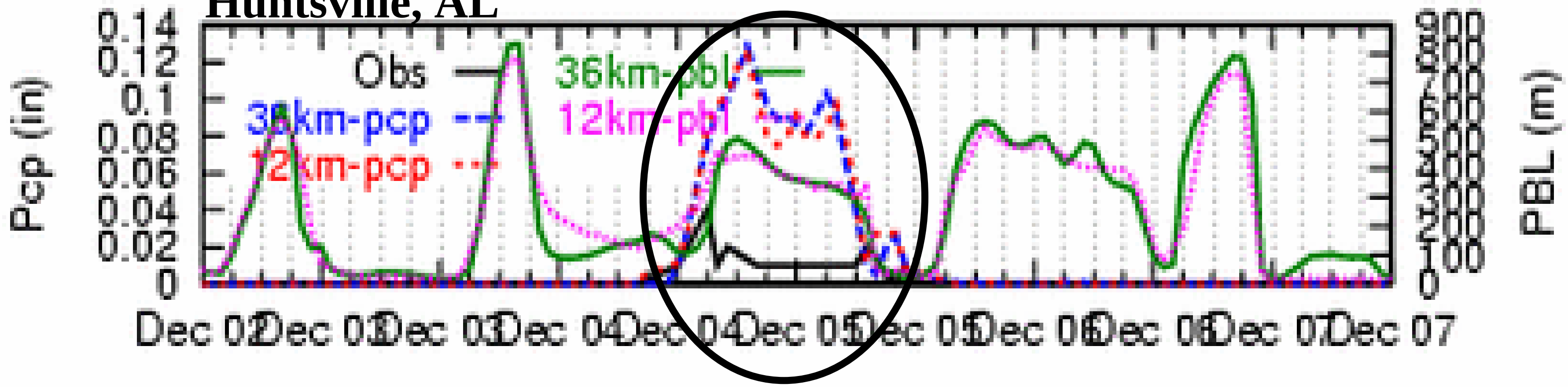


Poor CMAQ model performance on Dec 4th at Sipsey, AL may be partially due to precipitation over-prediction

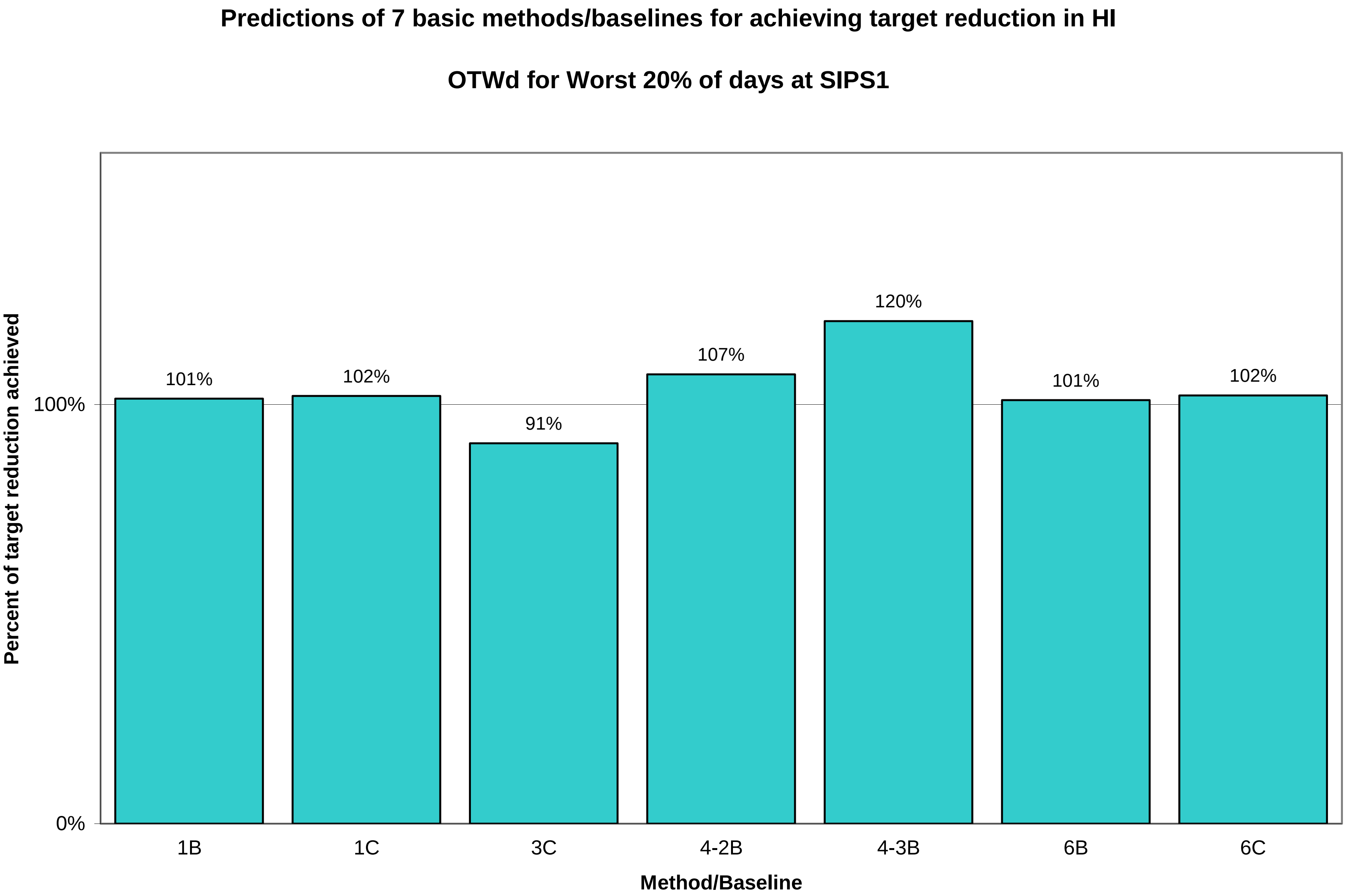
Muscle Shoals, AL



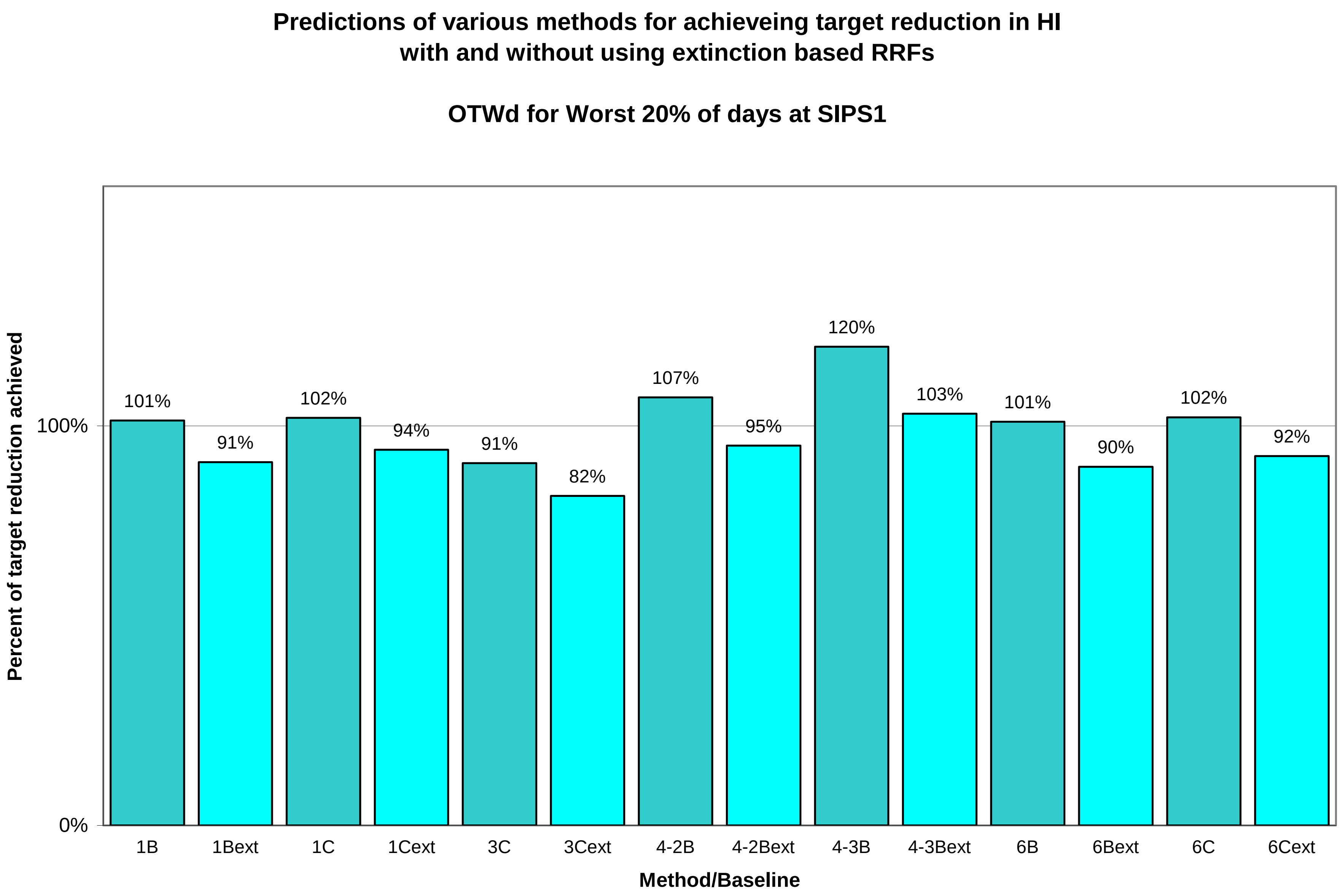
Huntsville, AL



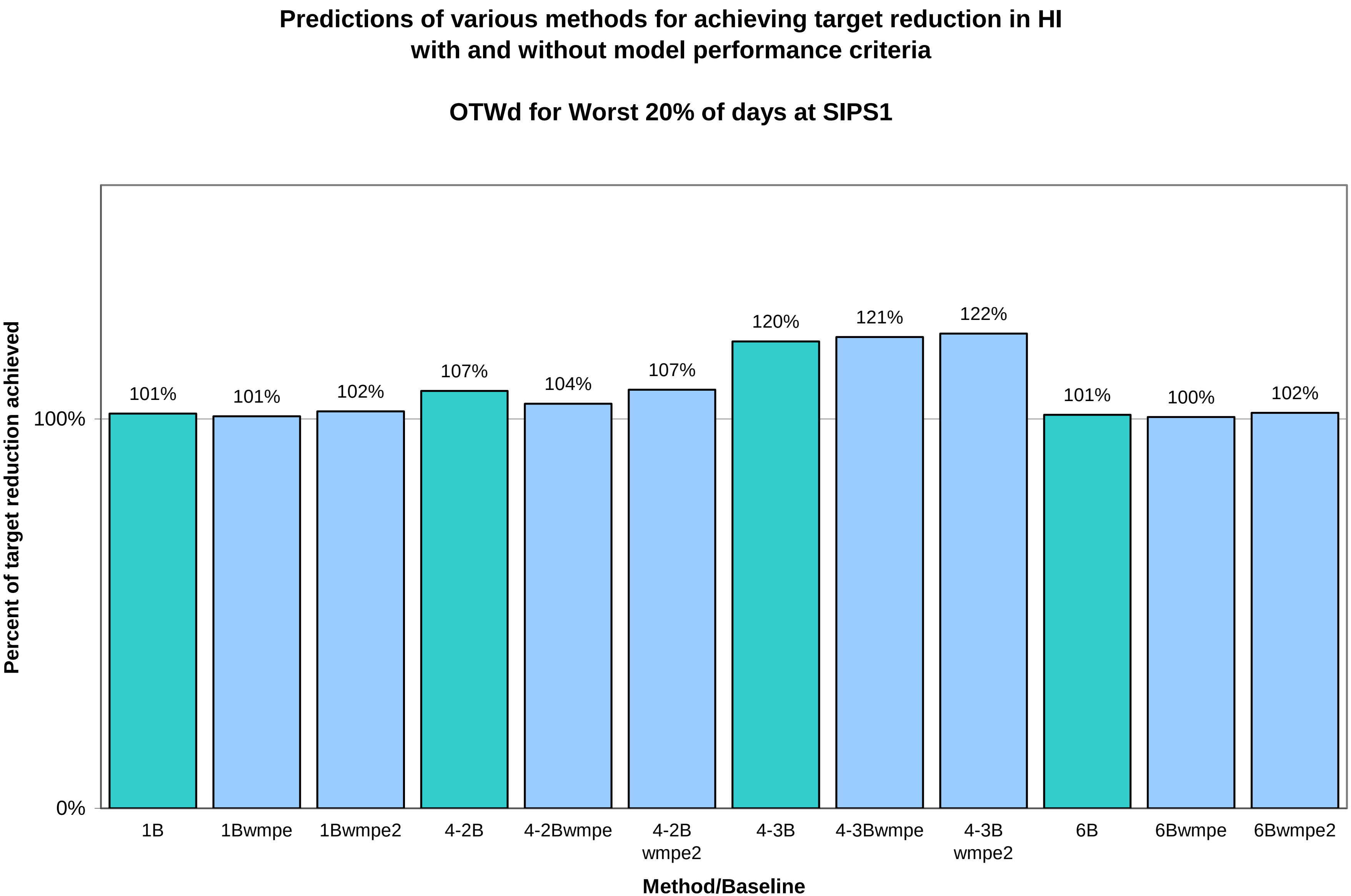
SIPS 2018 OTWd Visibility Projections: Basic Methods



SIPS 2018 OTWd Visibility Projections: Extinction RRFs

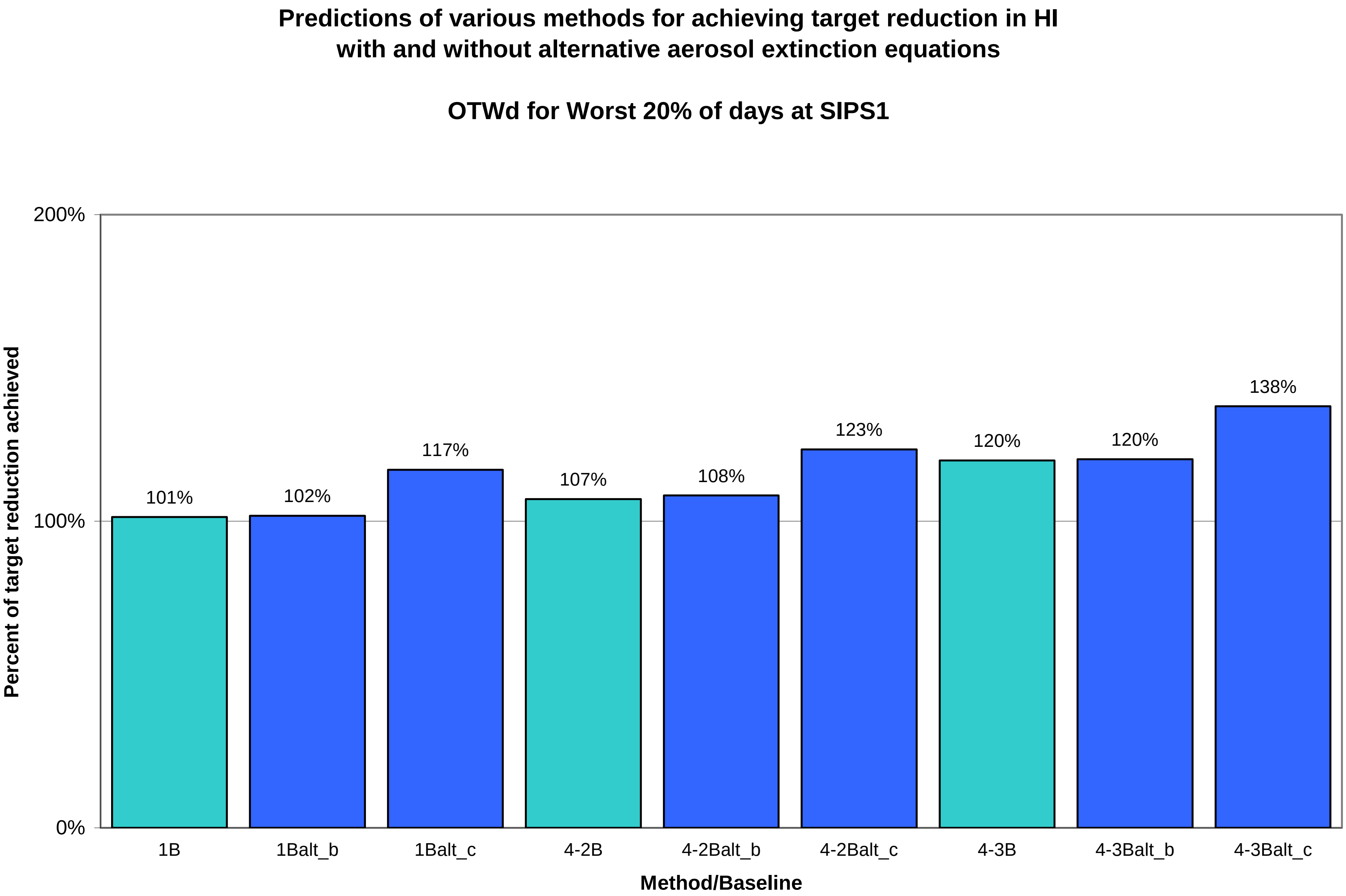


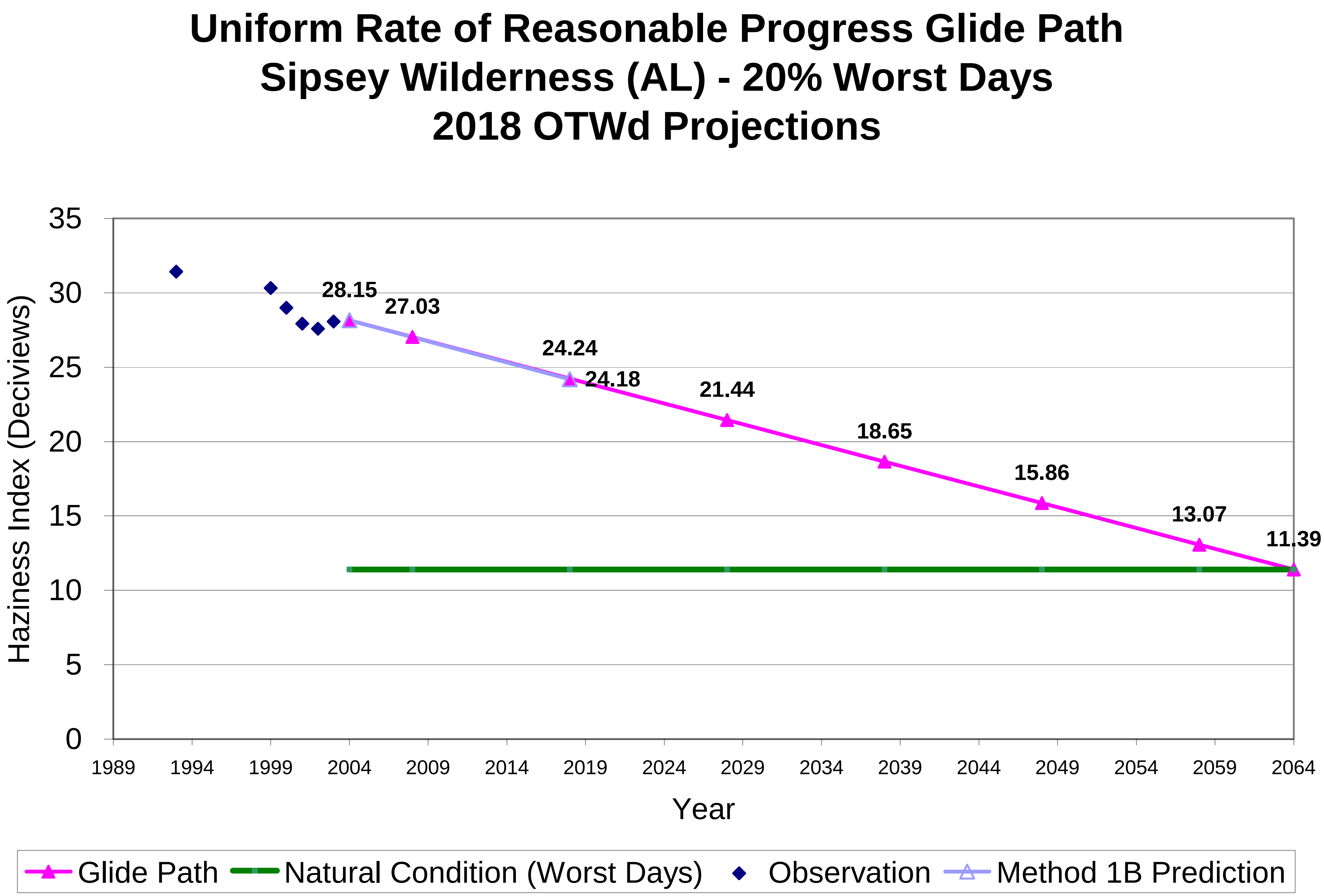
SIPS 2018 OTWd Projections: Accounting for Model Performance



Eliminating poor performing days has little effect on visibility projections

SIPS 2018 OTWd Visibility Projections: Alternative Equations

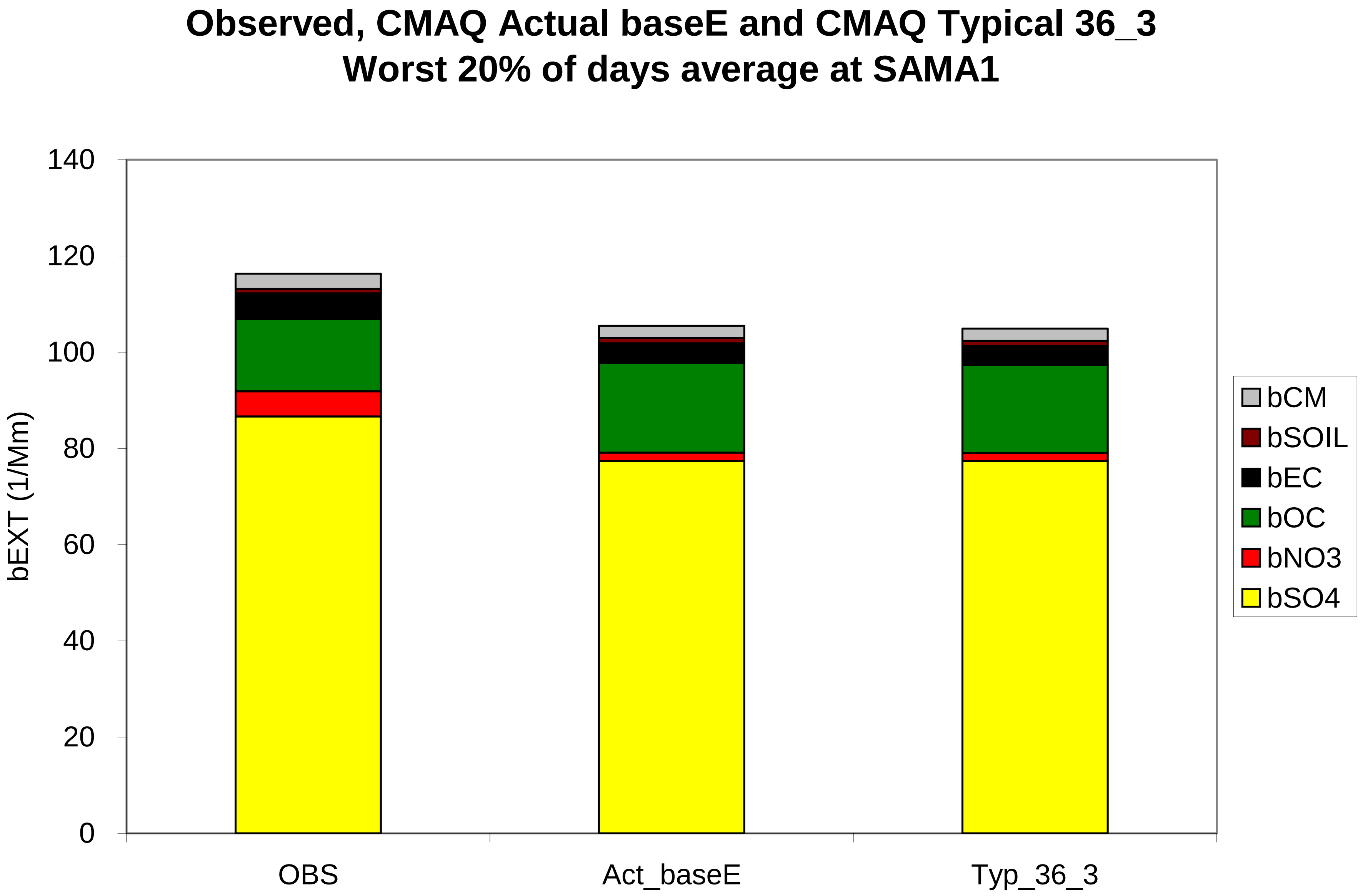




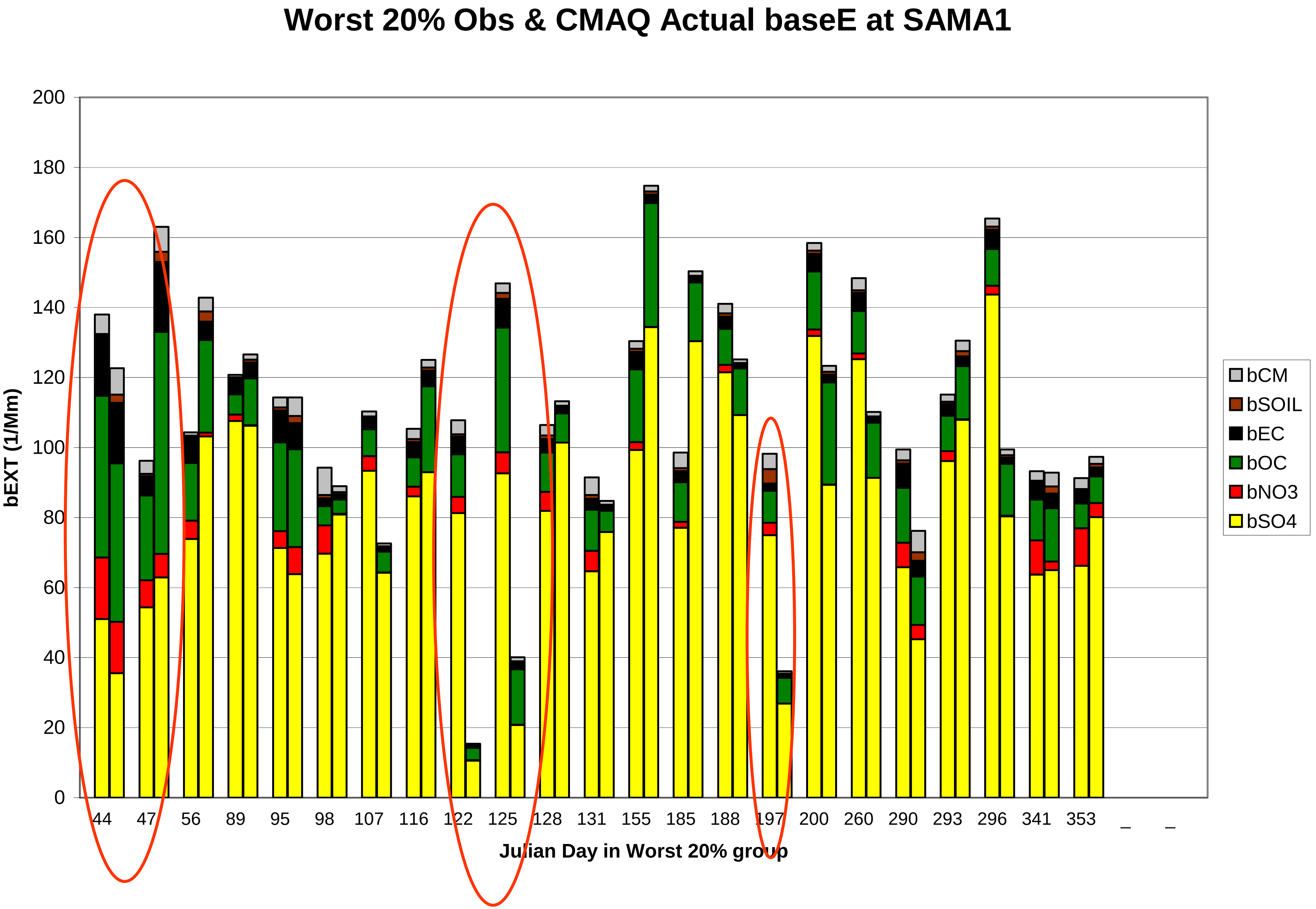
Uniform Rate of Reasonable Progress Glide Path
Sipsey Wilderness (AL) - 20% Worst Days
2018 OTWd Projections
Haziness Index (Deciviews)
35
30
25
20
15
10
5
0
28.15
27.03
24.24
24.18
21.44
18.65
15.86
13.07
11.39
1989
1994
1999
2004
2009
2014
2019
2024
2029
2034
2039
2044
2049
2054
2059
2064
Year
Glide Path
Natural Condition (Worst Days)
Observation
Method 1B Prediction


St. Marks, Florida
© J.F. Hemenway

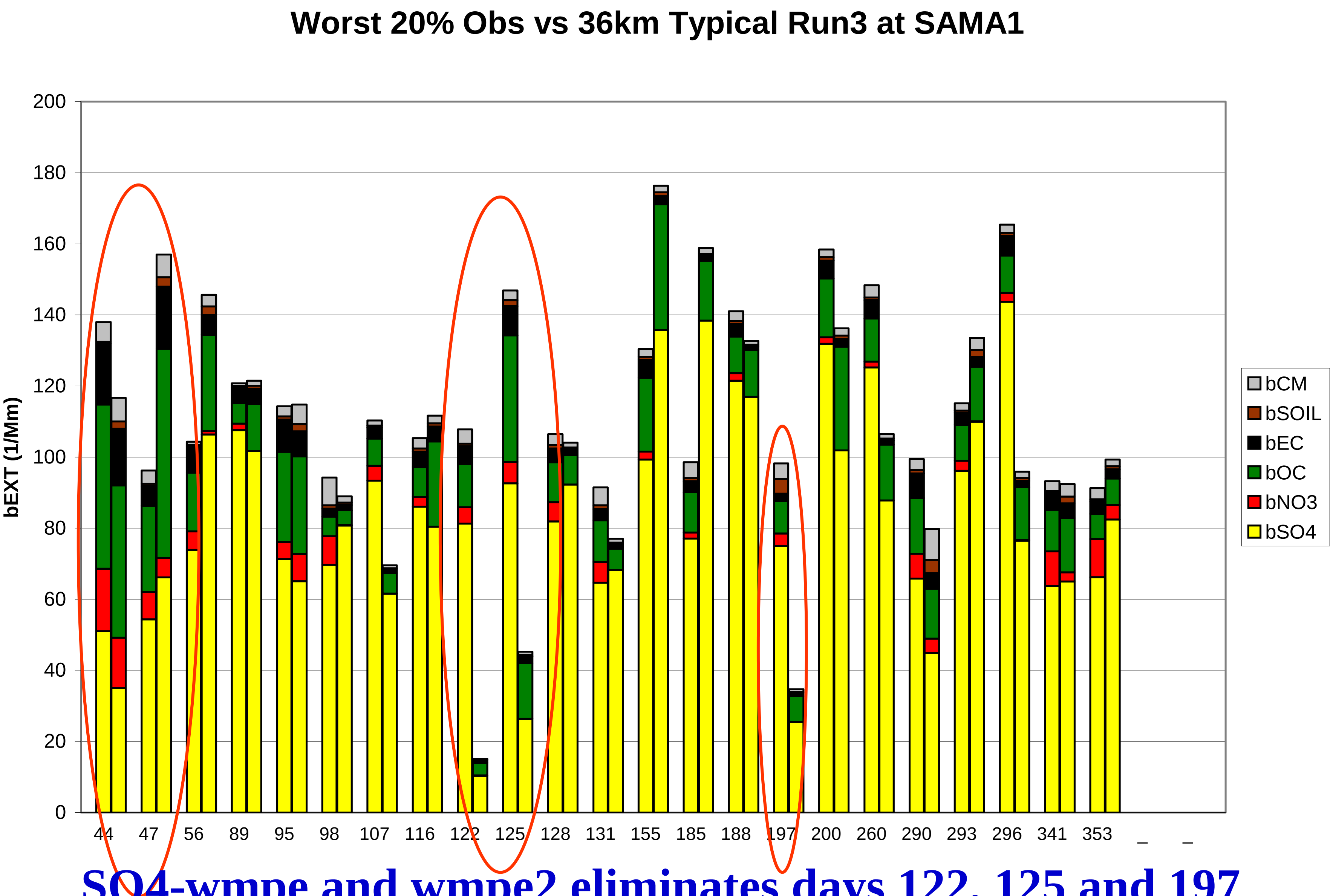
Observed, 2002 Actual and 2002 Typical average extinction across 2002 Worst 20% days at St. Marks, FL



Observed (left) and 2002 Actual (right) daily extinction for Worst 20% days at St. Marks, Florida

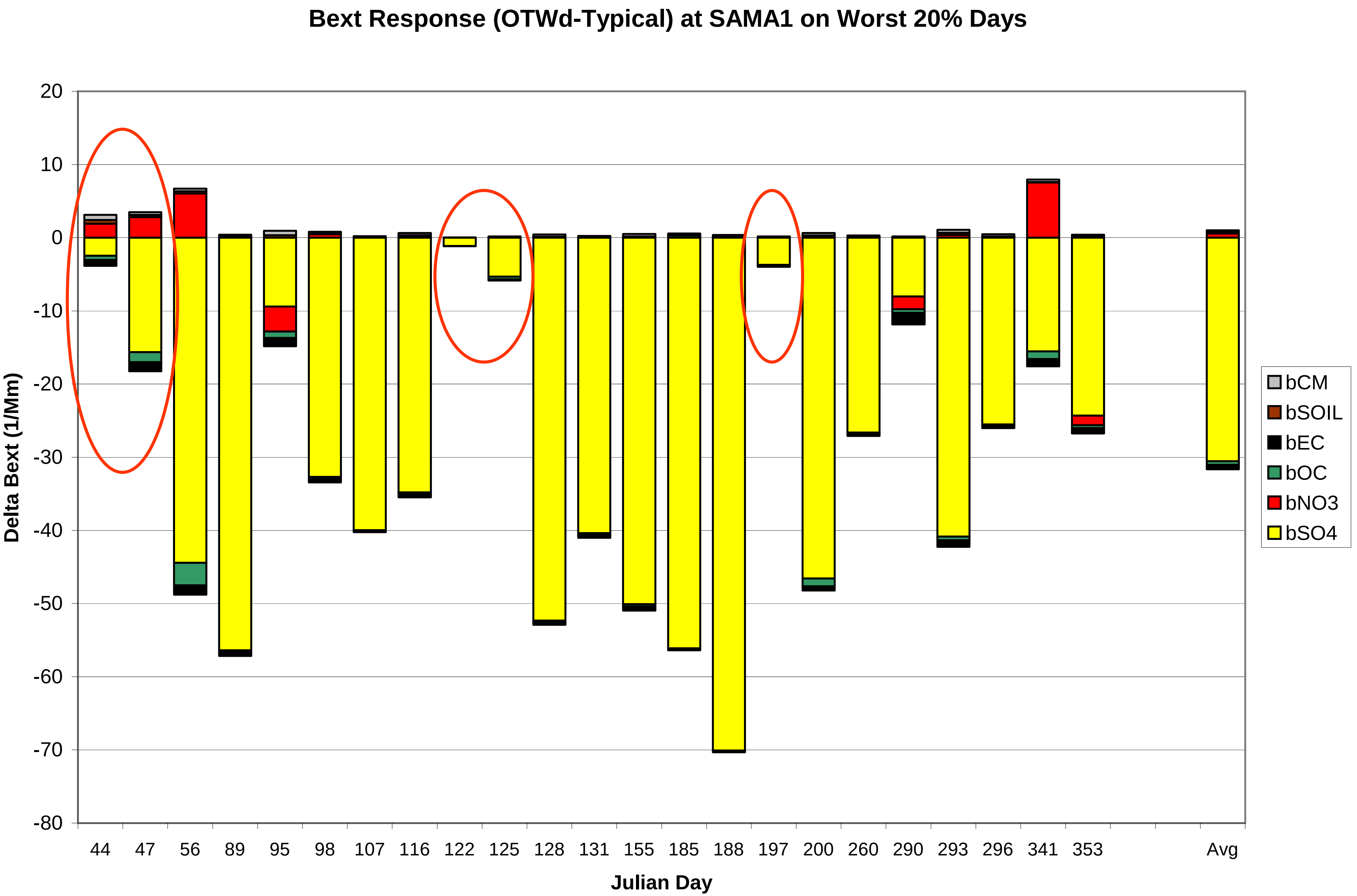


Observed (left) and 2002 Typical (right) daily extinction for Worst 20% days at St. Marks, Florida

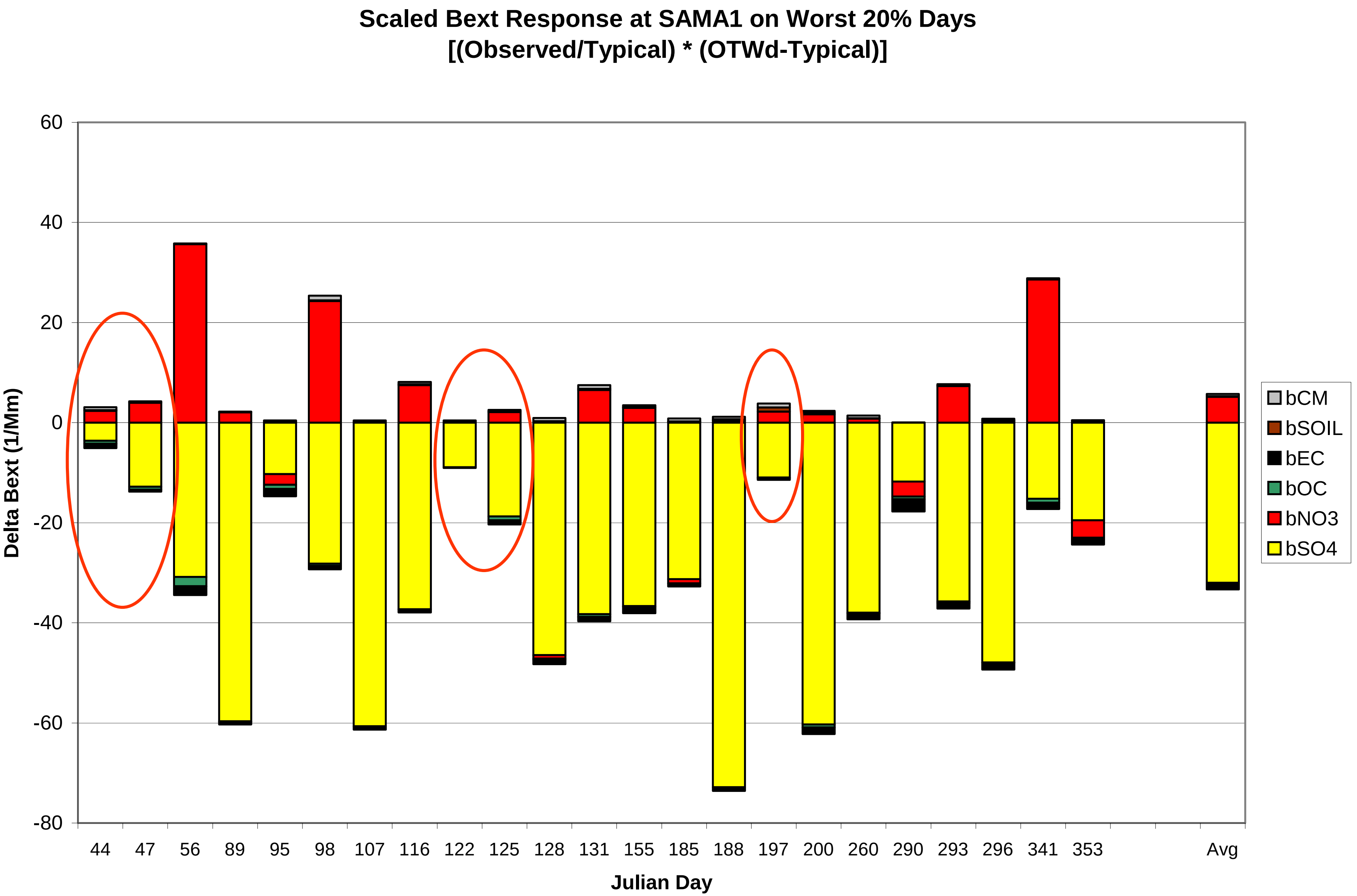


SO4-wmpe and wmpe2 eliminates days 122, 125 and 197

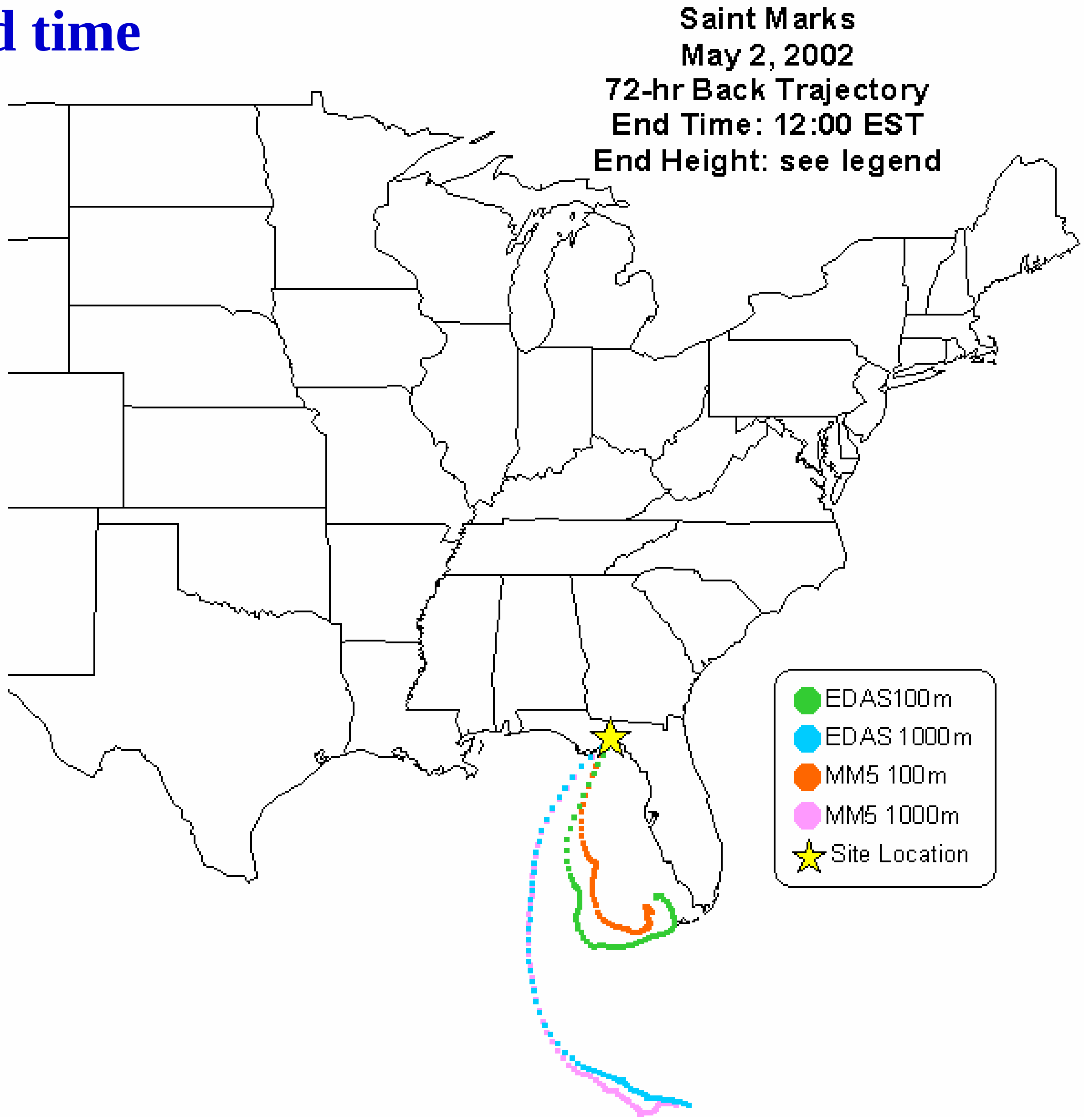
Difference in 2018 OTWd and 2002 Typical daily extinction for Worst 20% days at St. Marks, Florida



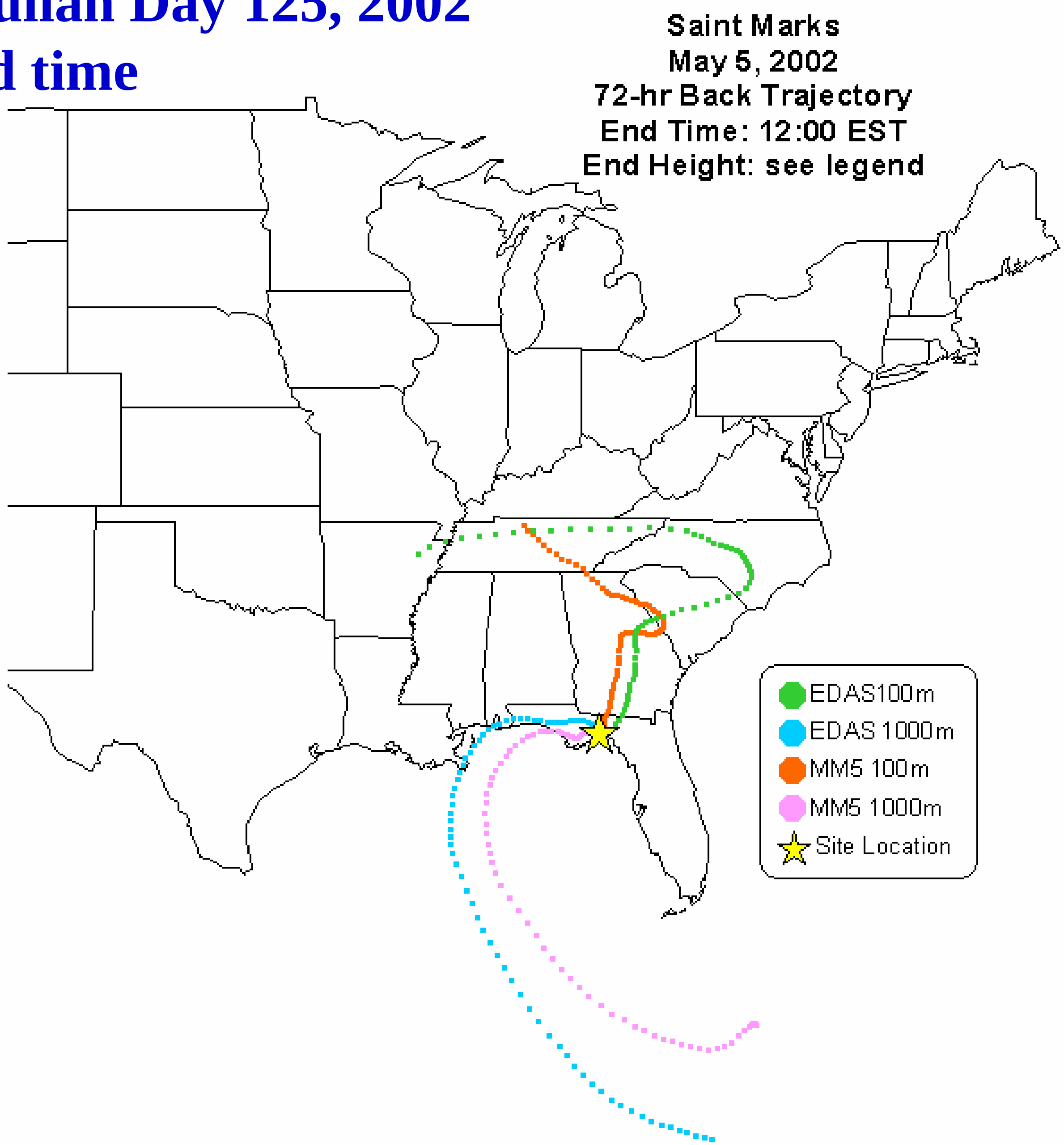
2018 OTWd – 2002 Extinction Differences Scaled by Observations



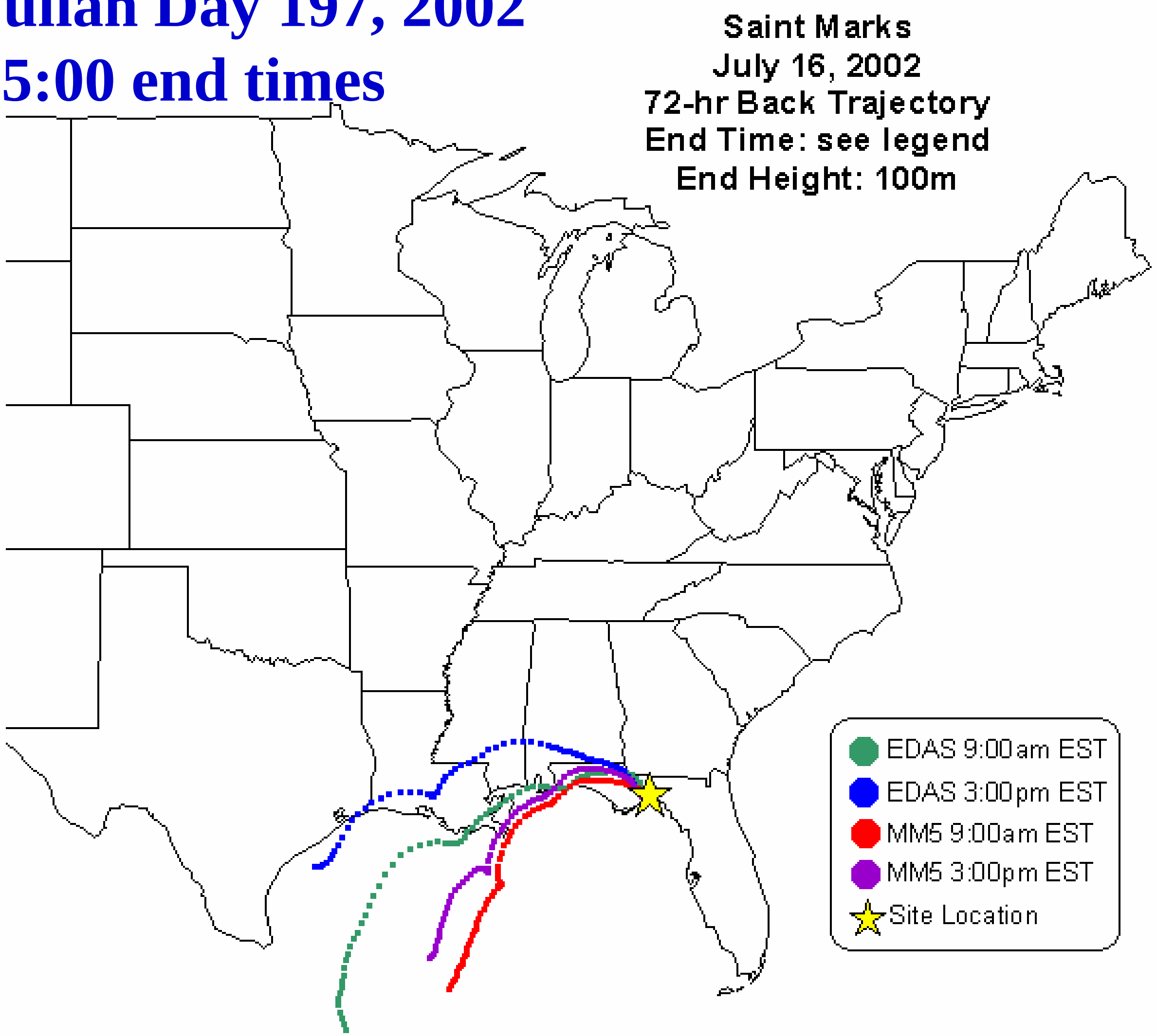
SAMA Julian Day 122, 2002
12:00 end time



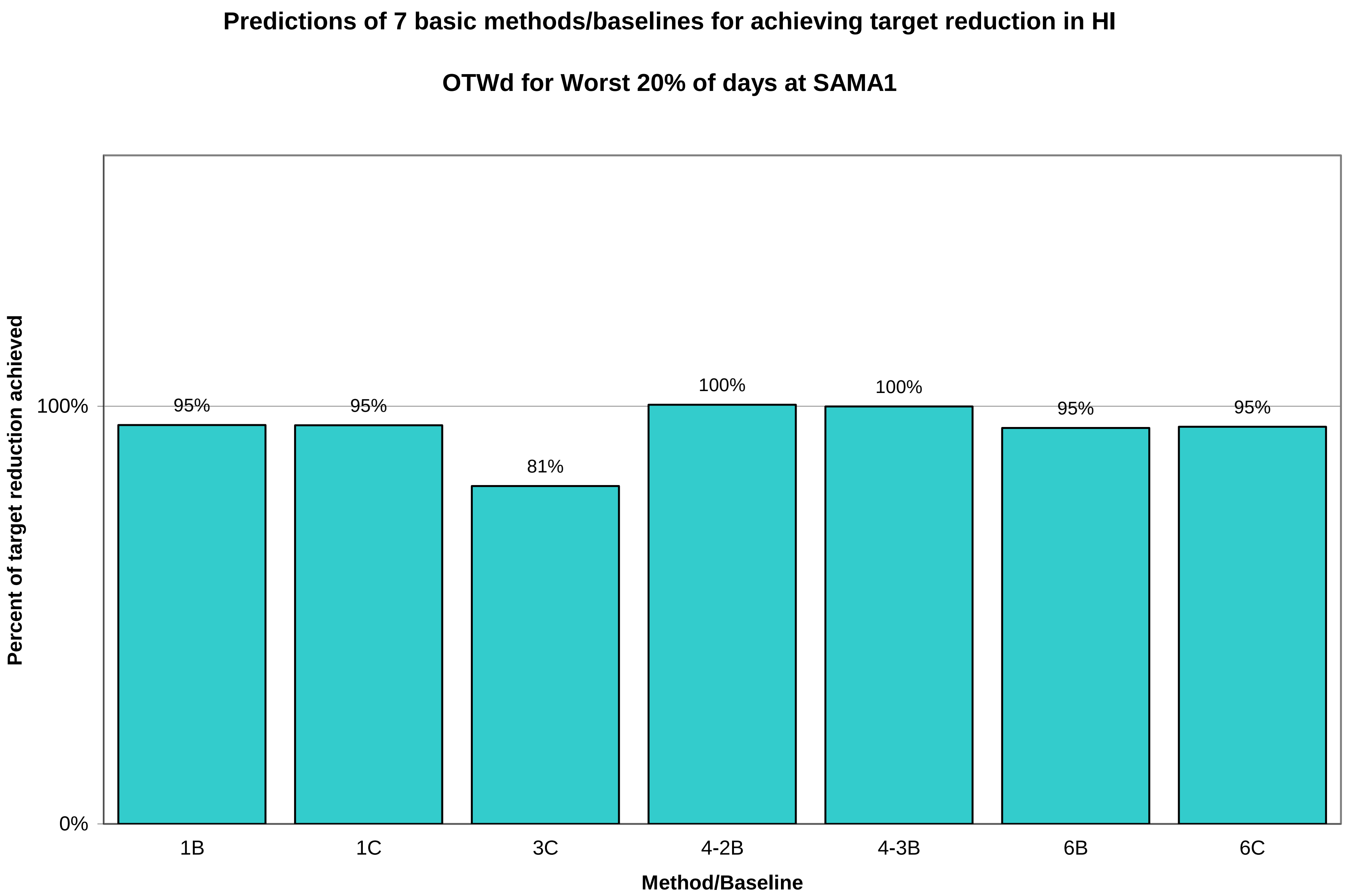
SAMA Julian Day 125, 2002
12:00 end time



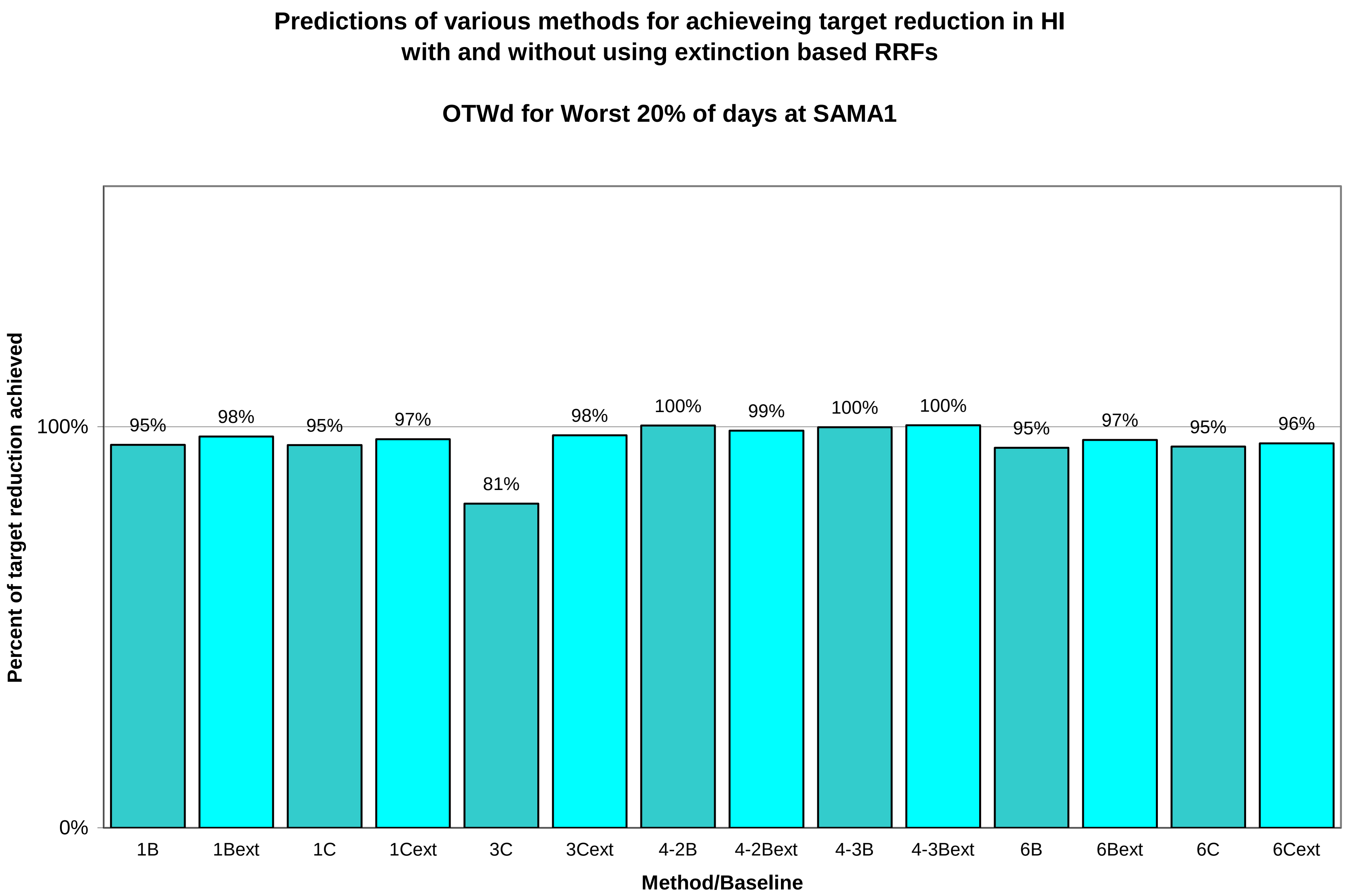
SAMA Julian Day 197, 2002
9:00 & 15:00 end times



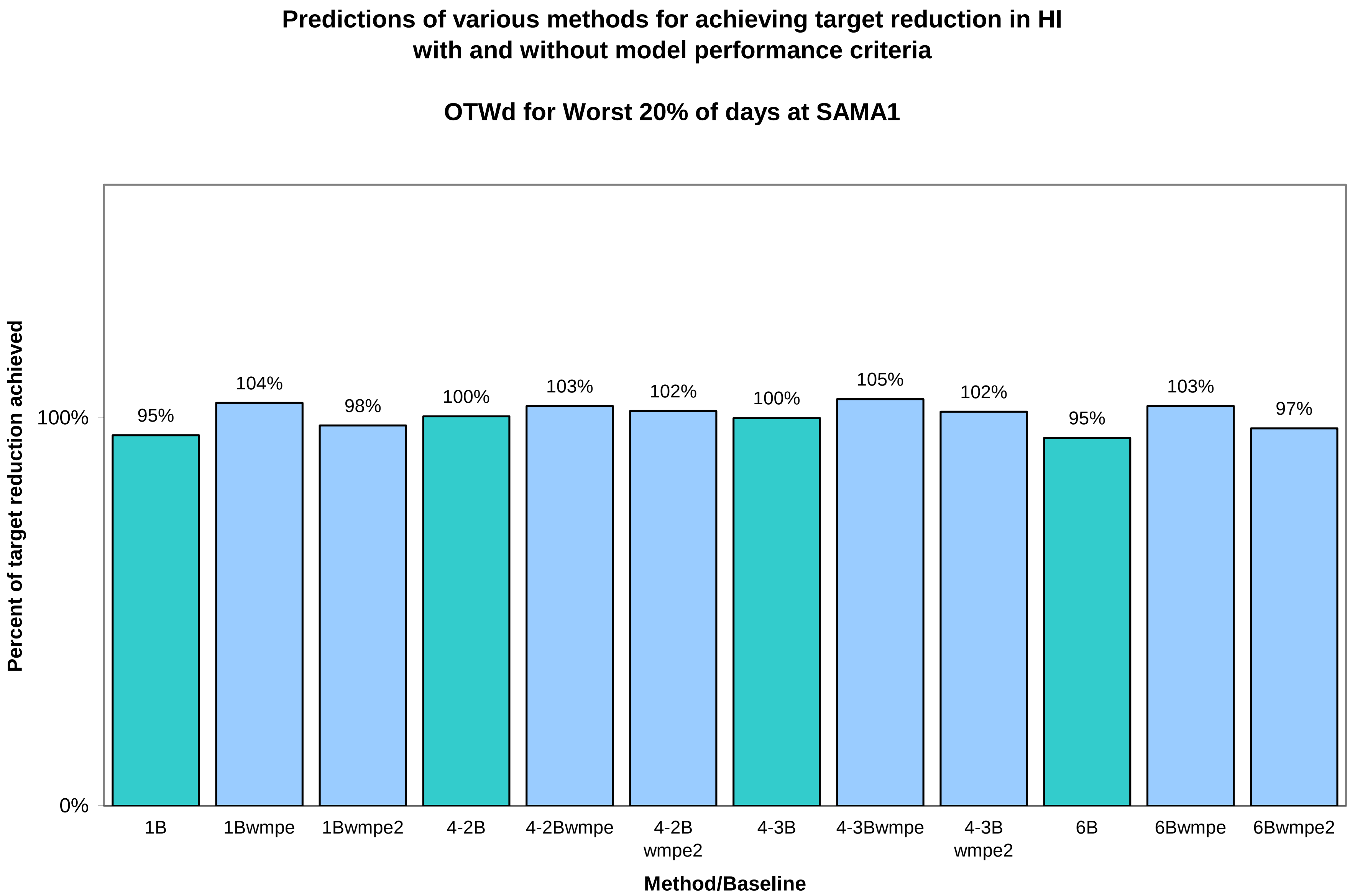
SAMA 2018 OTWd Visibility Projections: Basic Methods



SAMA 2018 OTWd Visibility Projections: Extinction RRFs

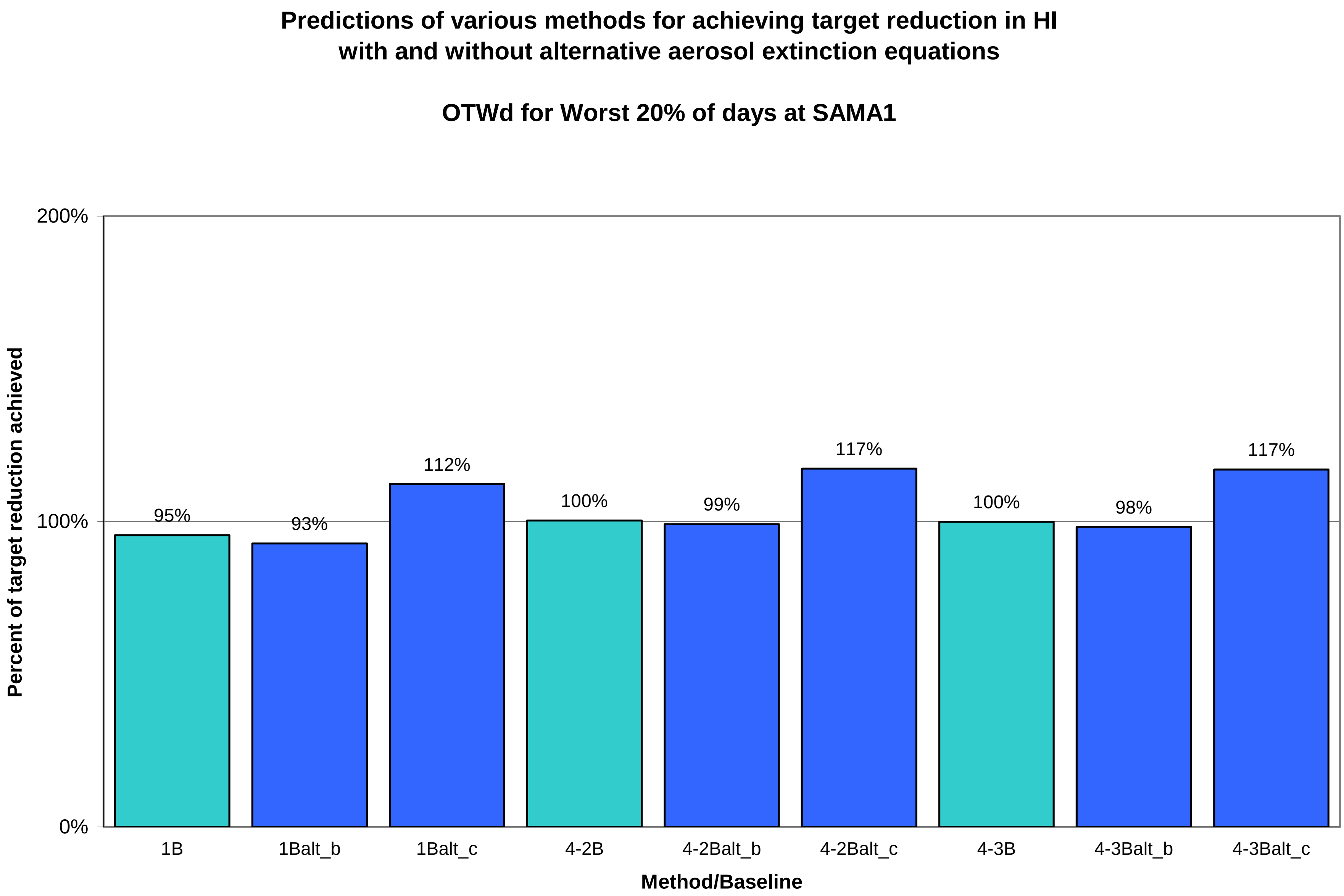


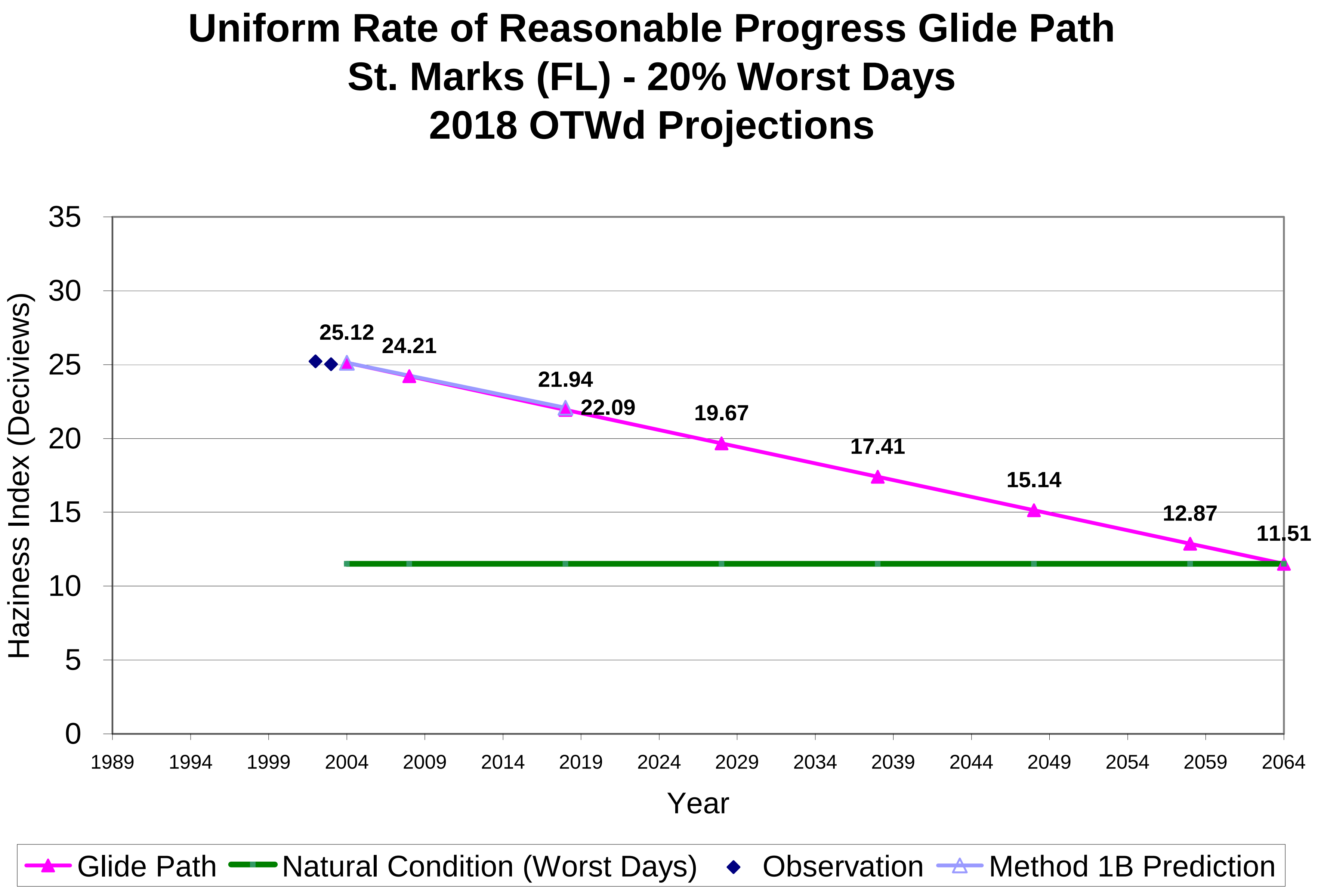
SAMA 2018 OTWd Projections: Accounting for Model Performance



Again, eliminating some poor performing days has little effect on projections

SAMA 2018 OTWd Visibility Projections: Alternative Equations




Uniform Rate of Reasonable Progress Glide Path
St. Marks (FL) - 20% Worst Days
2018 OTWd Projections
Haziness Index (Deciviews)
35
30
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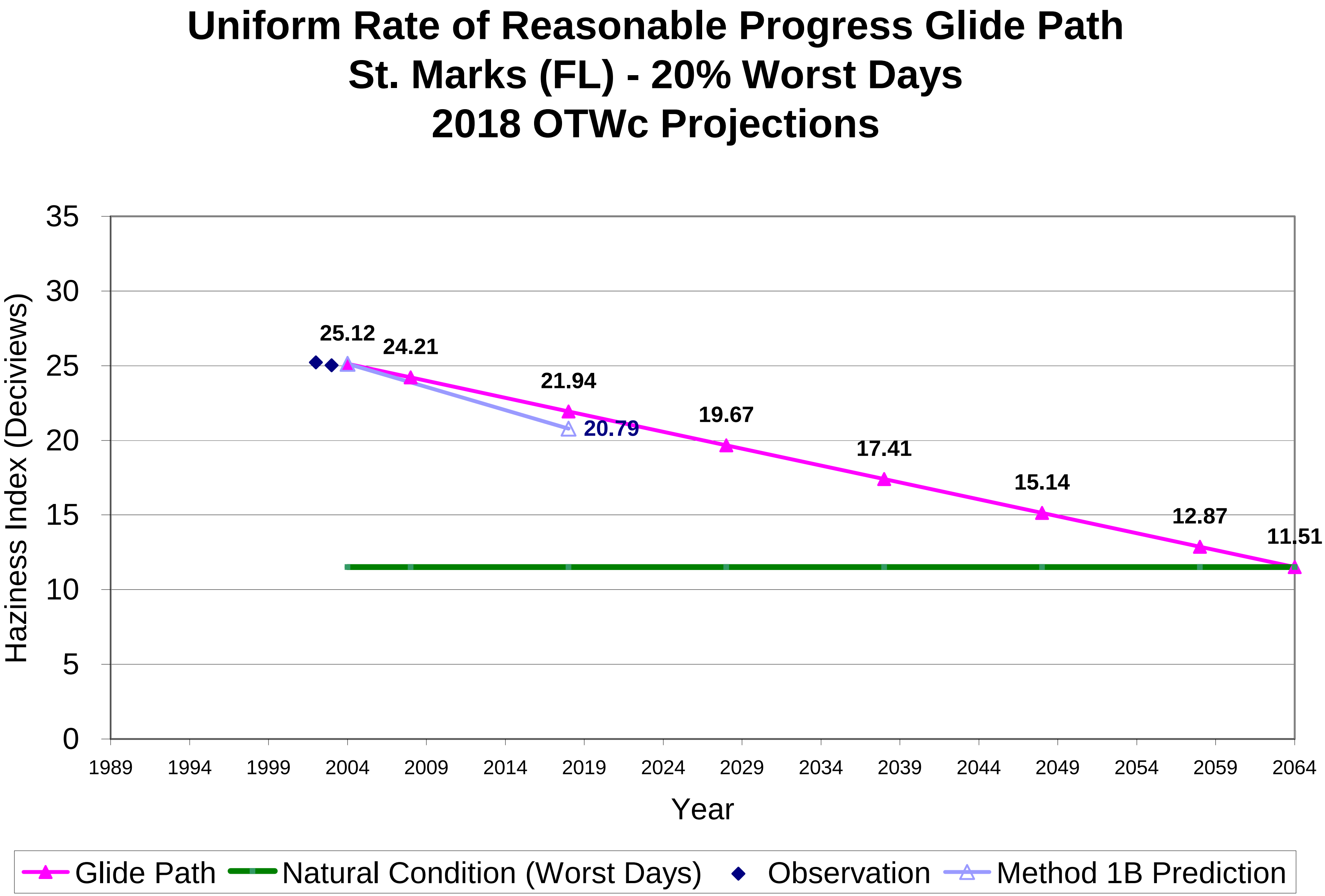
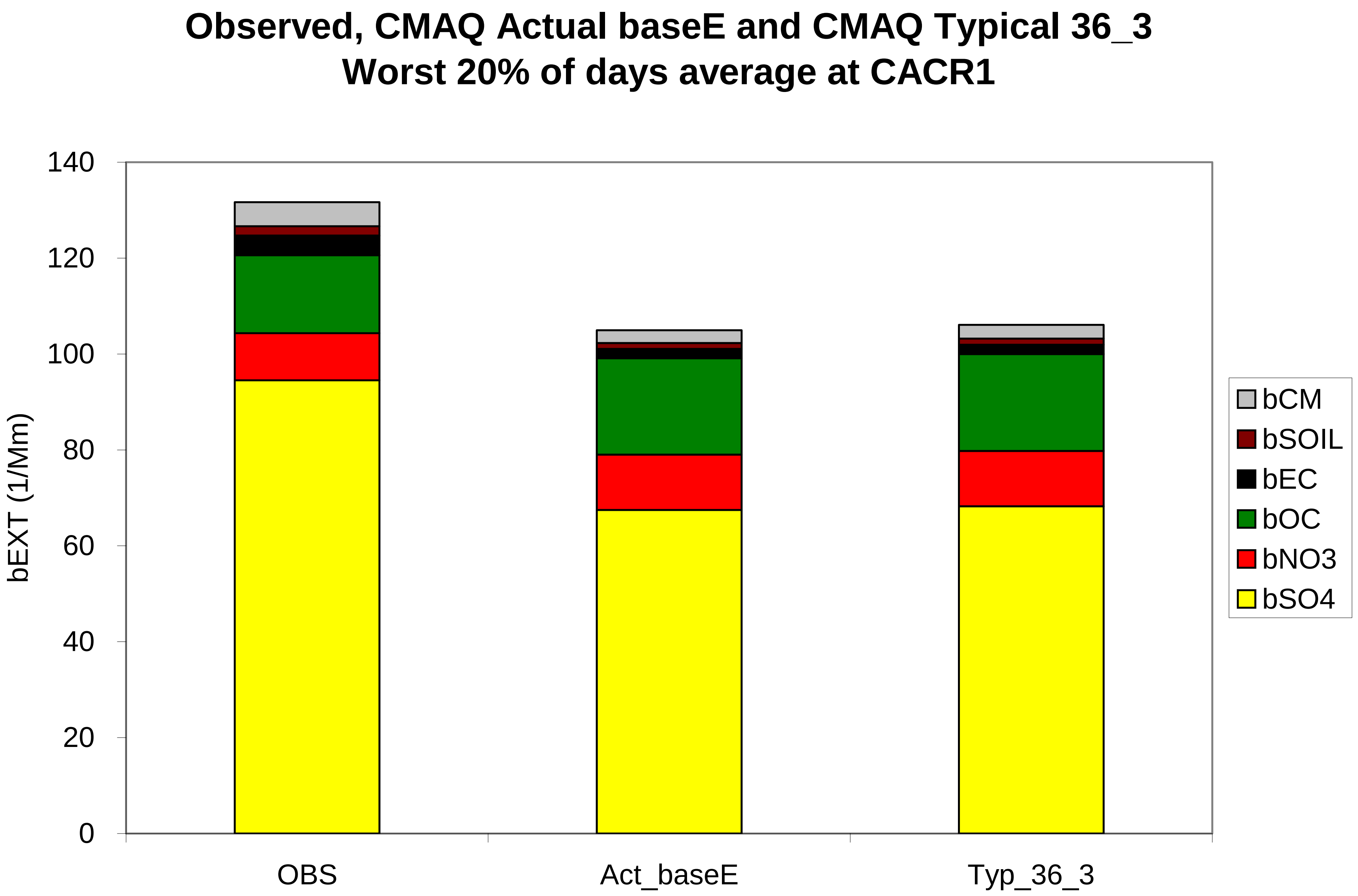
20
15
10
5
0
25.12
24.21
21.94
22.09
19.67
17.41
15.14
12.87
11.51
1989
1994
1999
2004
2009
2014
2019
2024
2029
2034
2039
2044
2049
2054
2059
2064
Year
Glide Path
Natural Condition (Worst Days)
Observation
Method 1B Prediction

2018 OTWc Fire Sensitivity Test – Zero-Out Elevated Fires

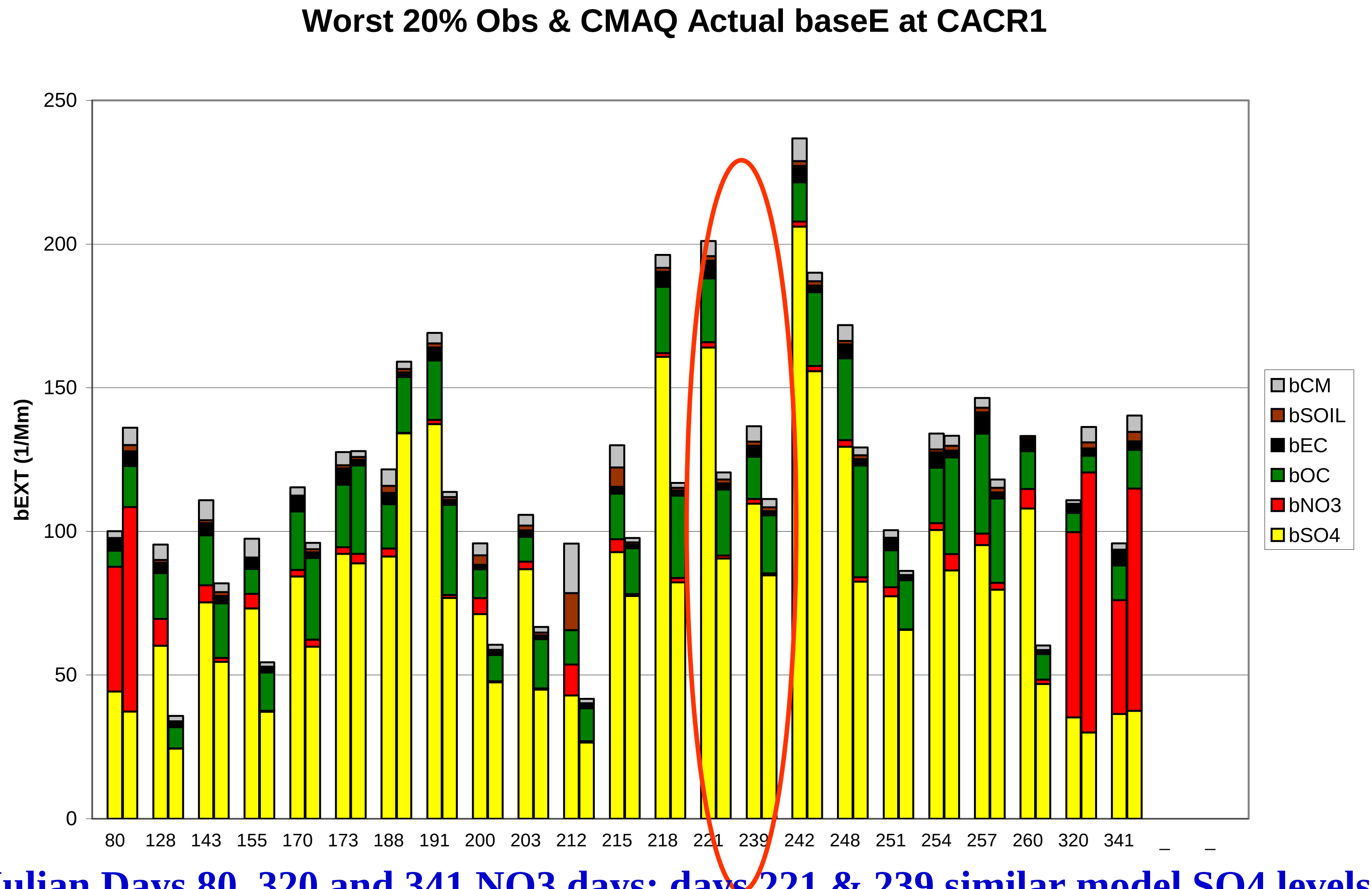


Caney Creek, Arkansas

Observed, 2002 Actual and 2002 Typical average extinction across 2002 Worst 20% days at Caney Creek, Arkansas

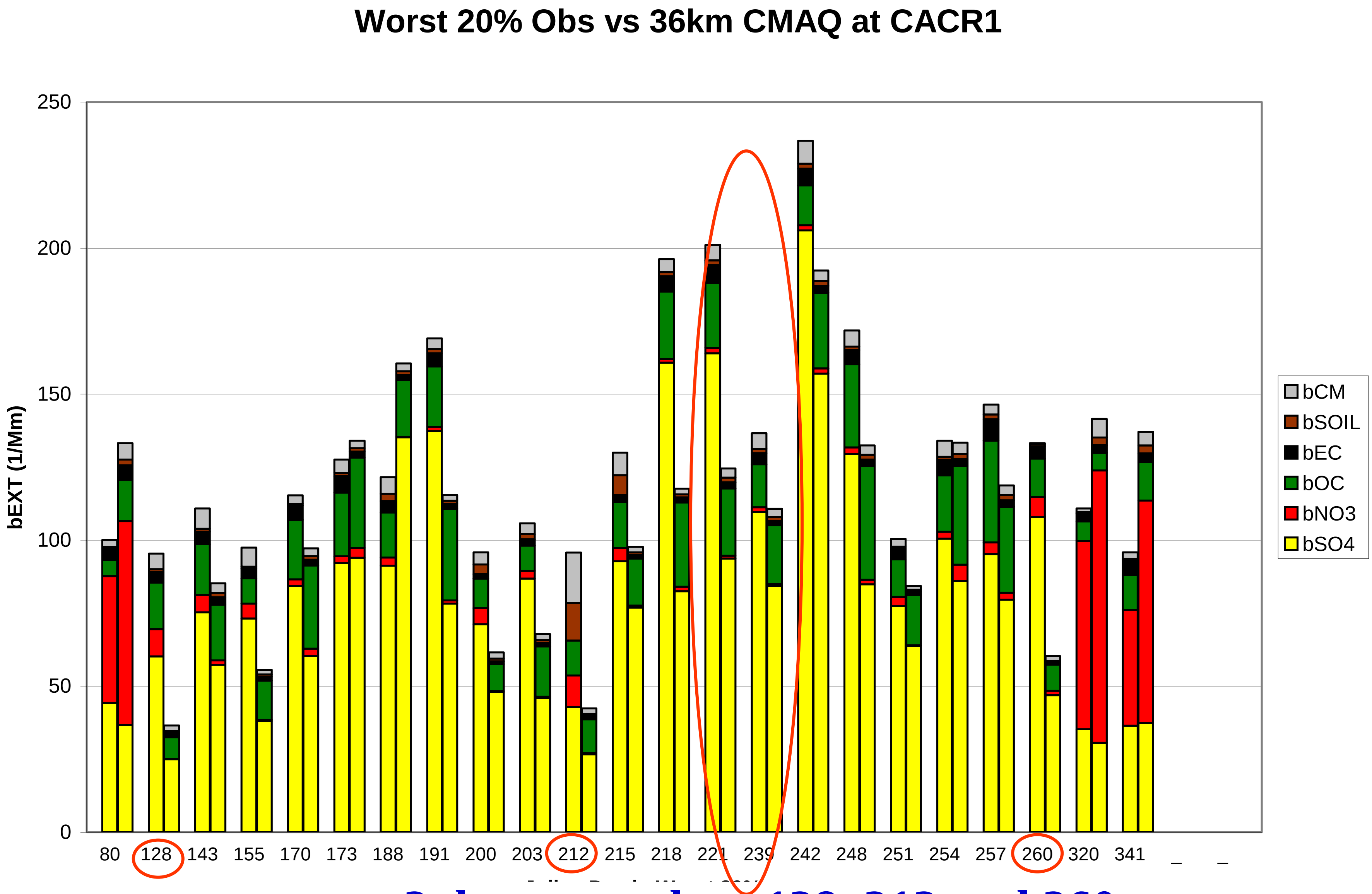


Observed (left) and 2002 Actual (right) daily extinction for Worst 20% days at Great Smoky Mountains, TN/NC



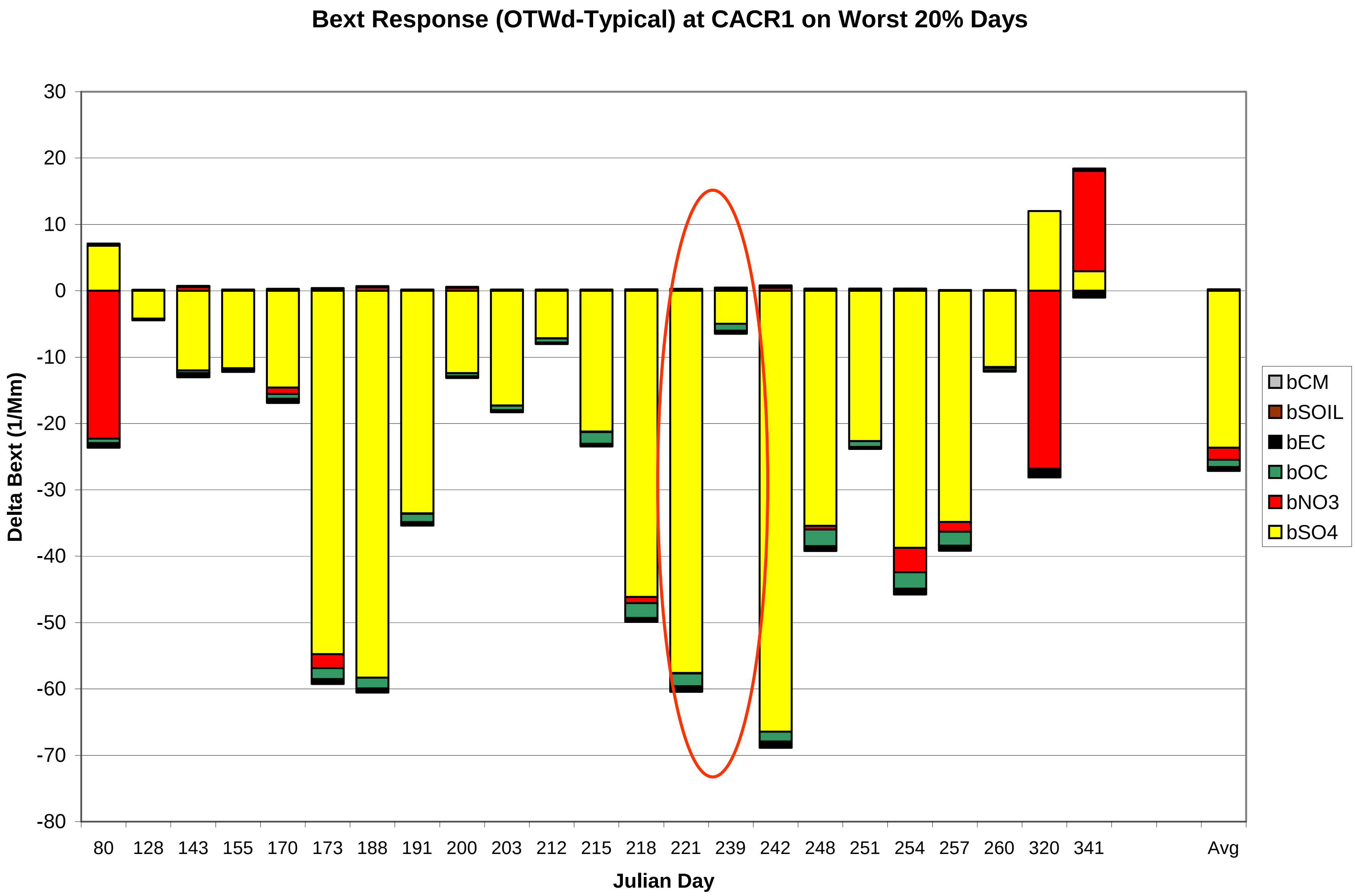
Julian Days 80, 320 and 341 NO3 days; days 221 & 239 similar model SO4 levels

Observed (left) and 2002 Typical (right) daily extinction for Worst 20% days at Caney Creek, Arkansas



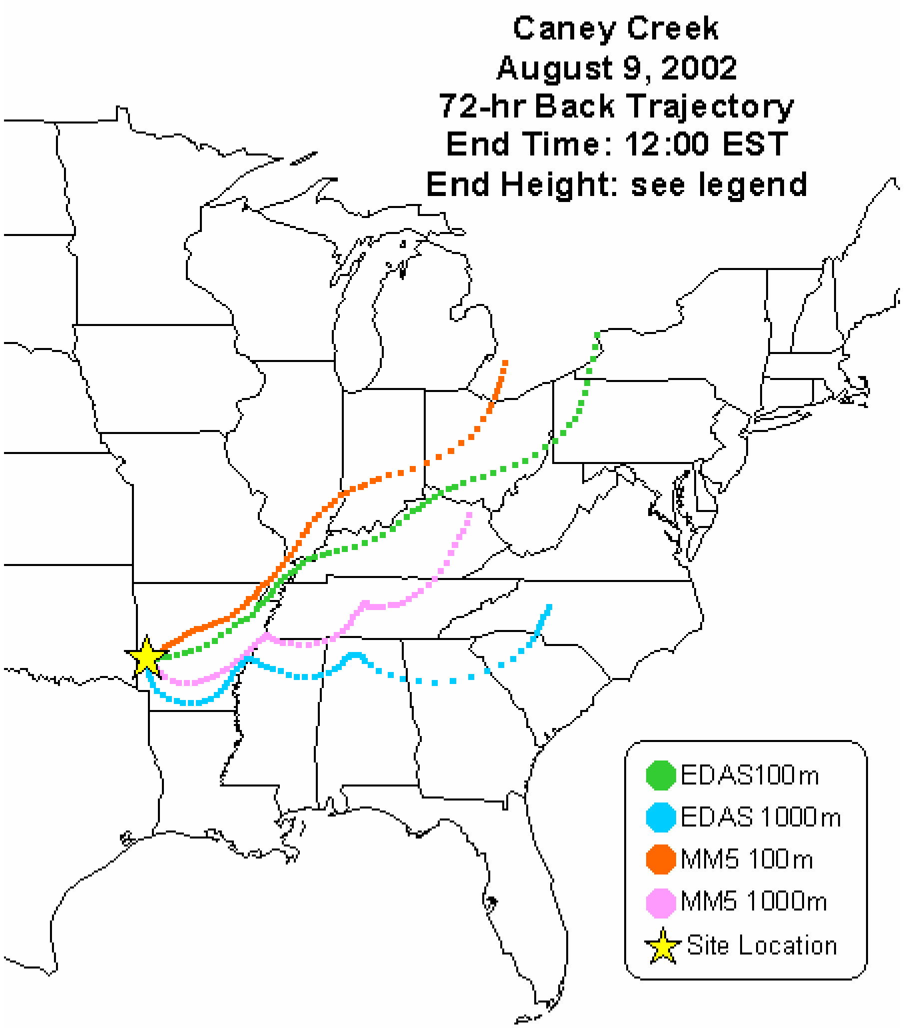
wmpe2 drops out days 128, 212 and 260

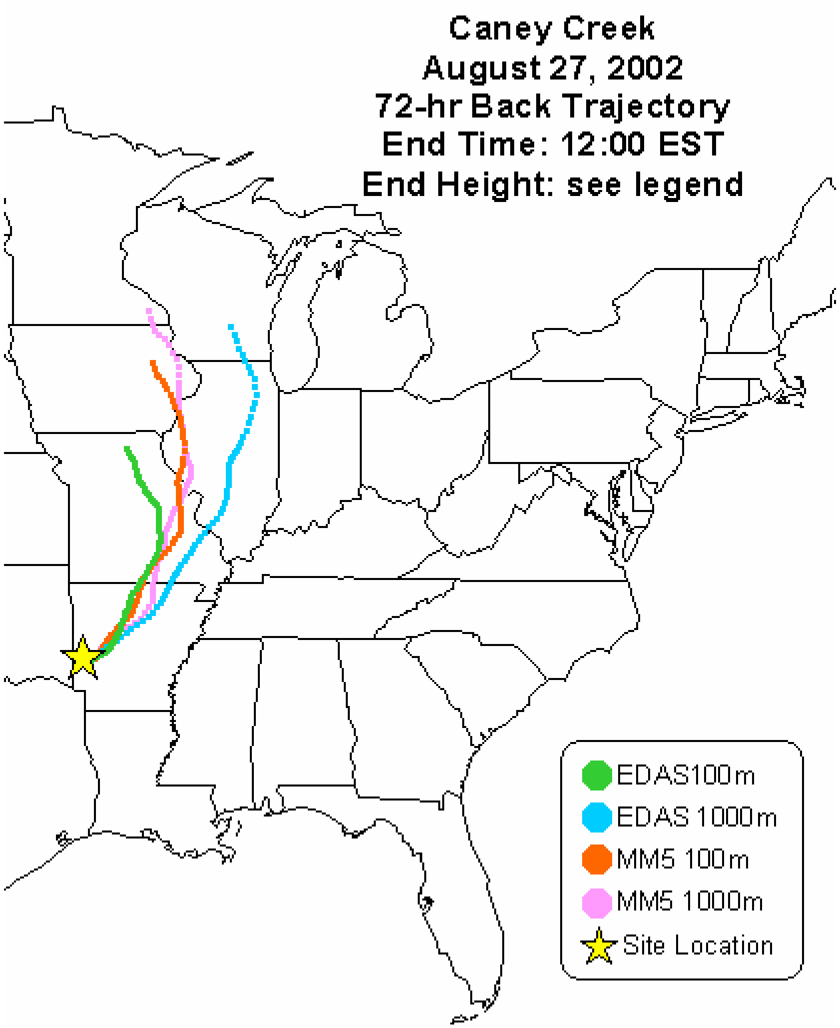
2018 OTWd - 2002 Typical daily extinction at Caney Creek, AR



Julian Days 80, 320 and 341 NO3 days; days 221 & 239 similar model SO4 levels

Caney Creek days 221 and 239 with similar modeled SO4 but very different 2018 OTWd response (<-10 Mm-1 for 239 vs. –60 Mm-1 for 221)

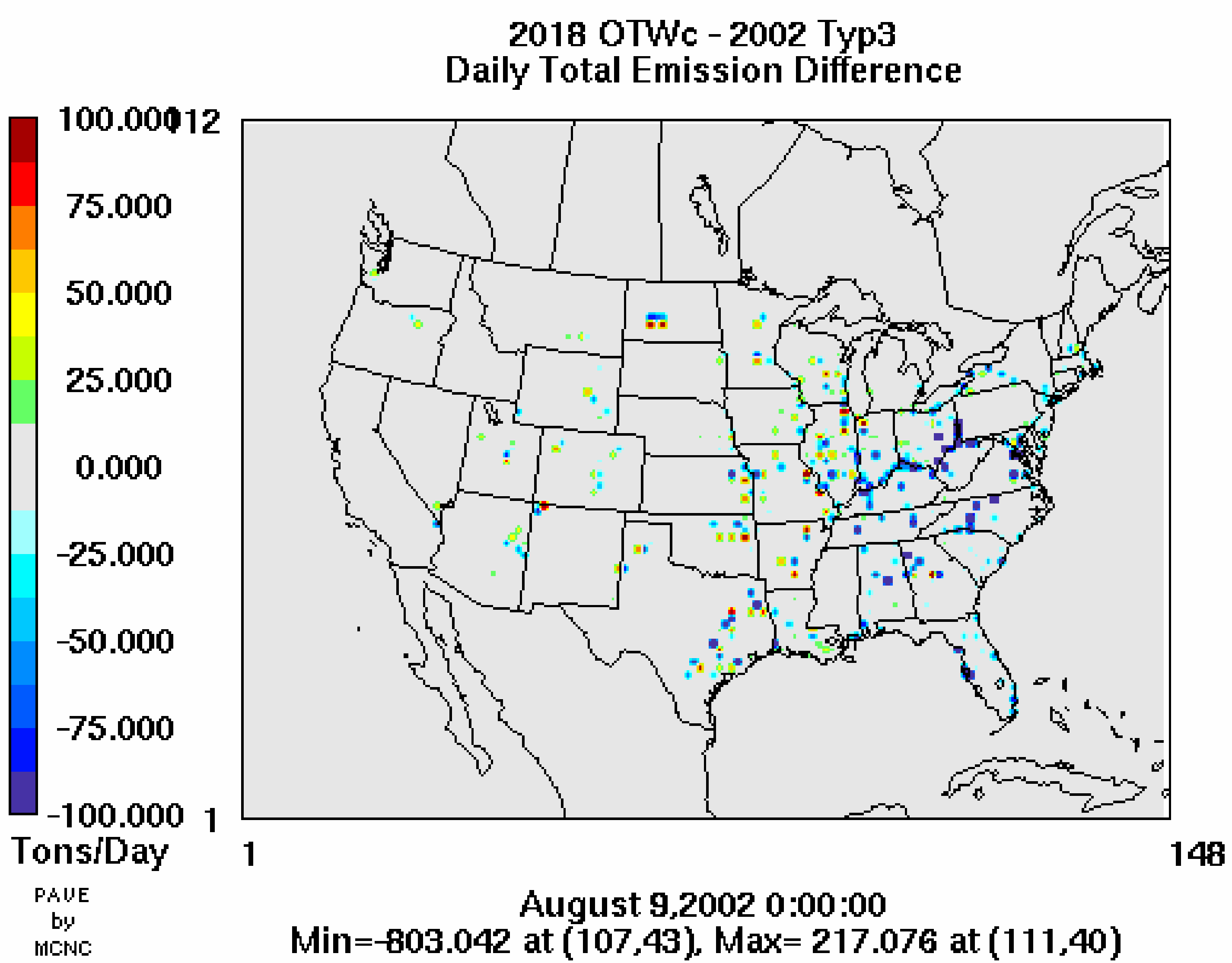




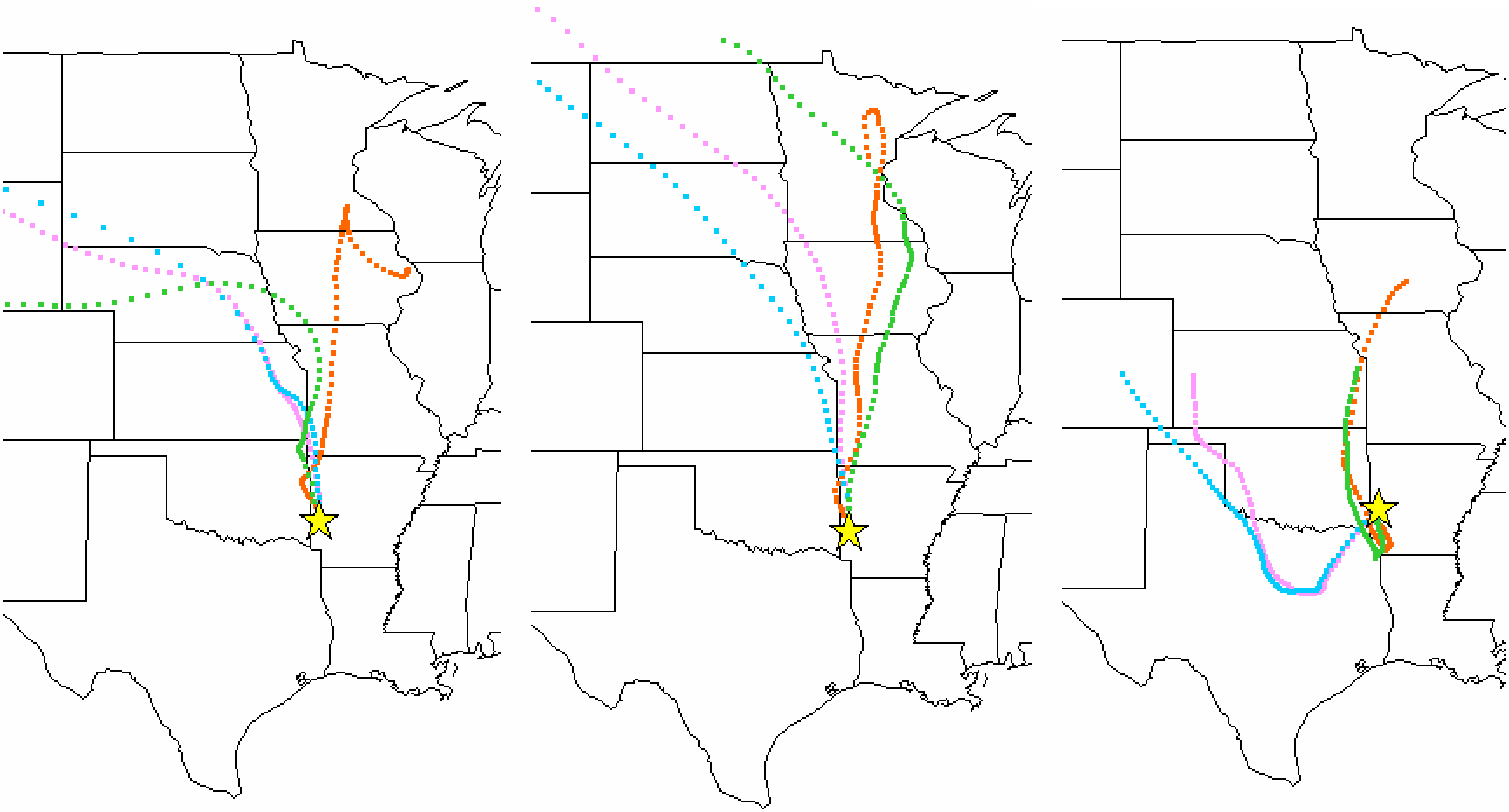
SO2 emission reductions 2018 OTW – 2002 Typical

Day 221 back trajectories through heart of SO2 reductions OH Valley

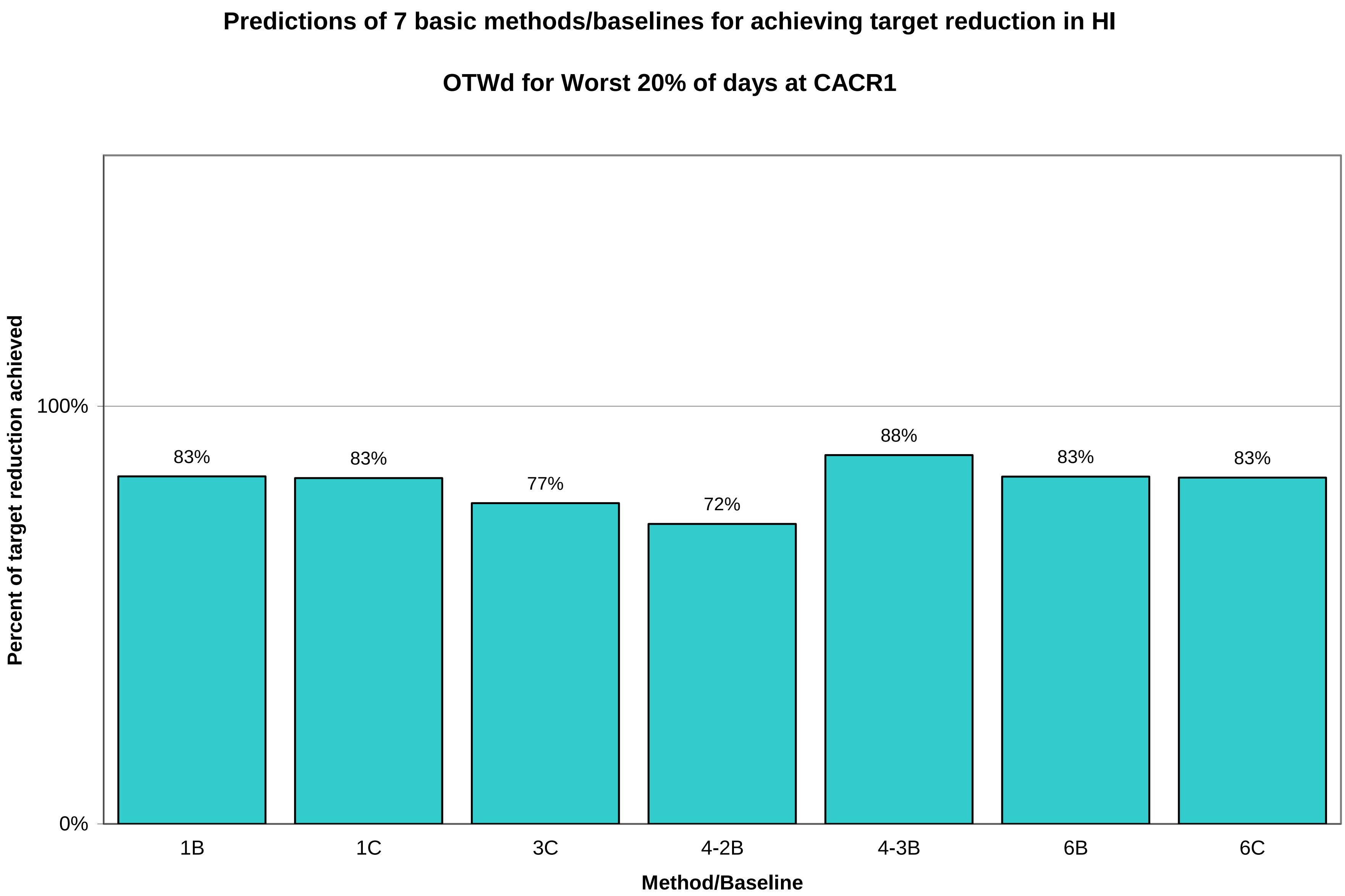
Day 239 back trajectories through AR, MI, IL & IA areas of SO2 increases and decreases



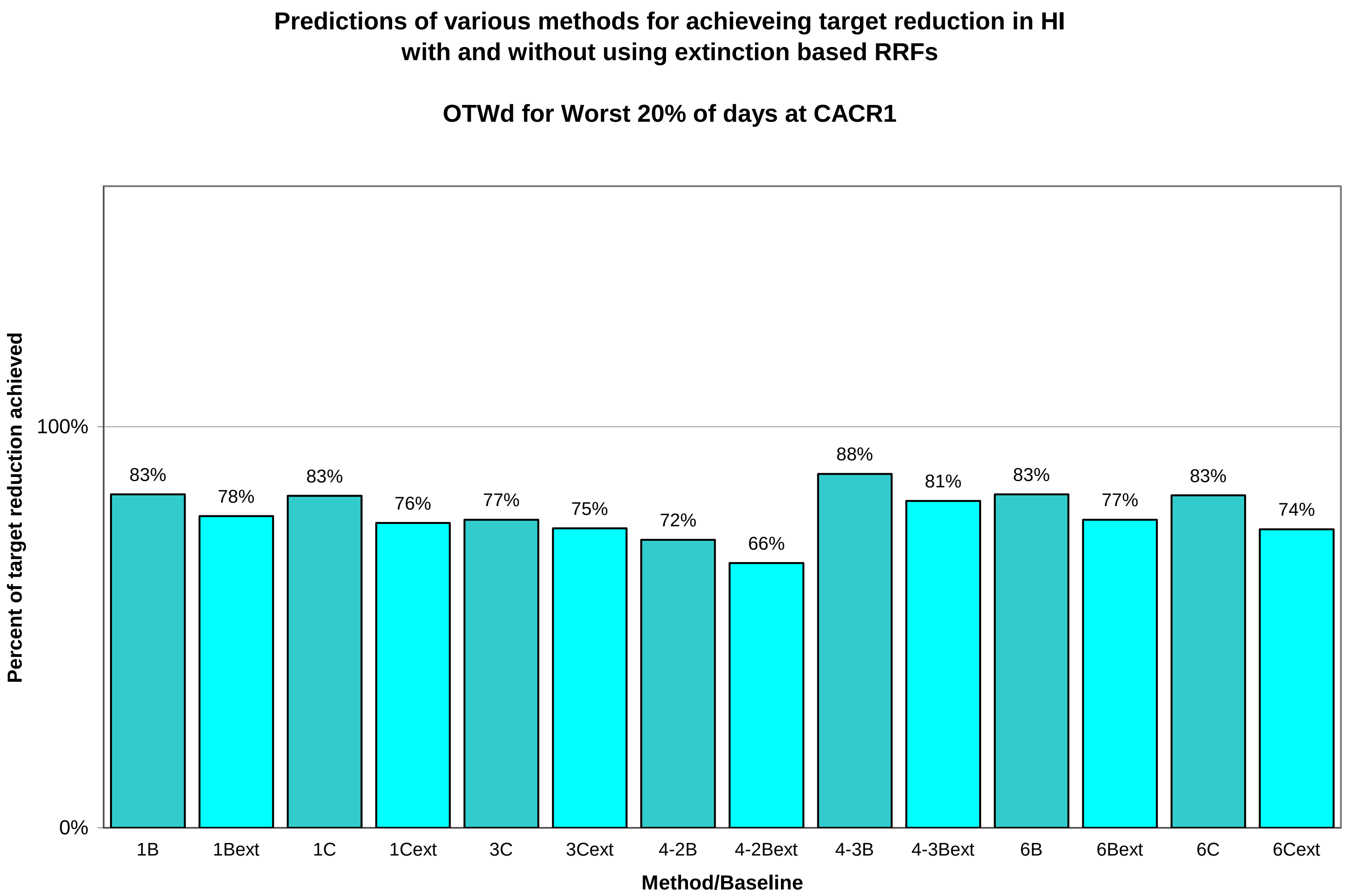
Back trajectories on high nitrate days at Caney Creek, Julian Days 80, 320 and 340



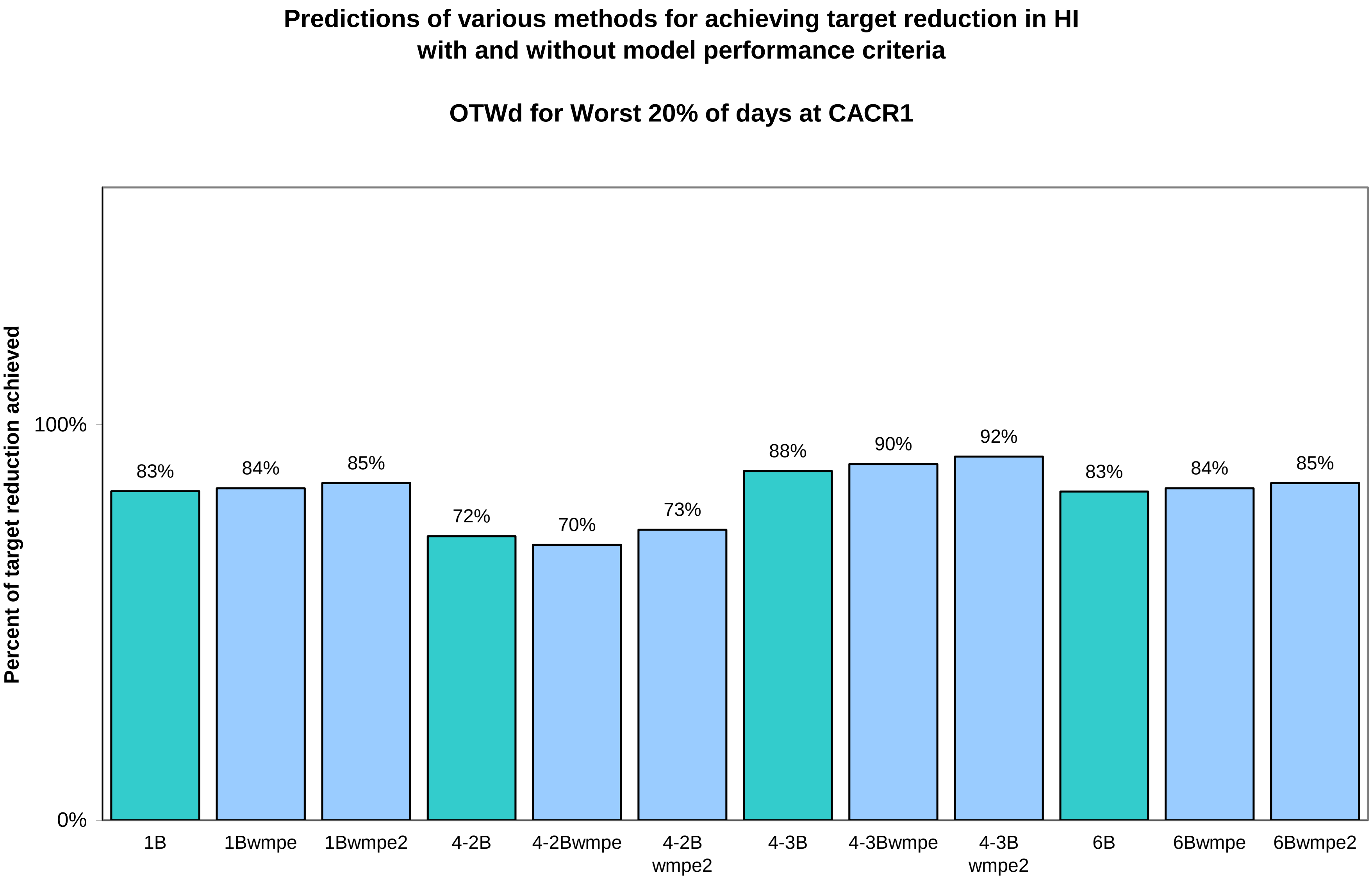
CACR 2018 OTWd Visibility Projections: Basic Methods



CACR 2018 OTWd Visibility Projections: Extinction RRFs



CACR 2018 OTWd Projections: Accounting for Model Performance

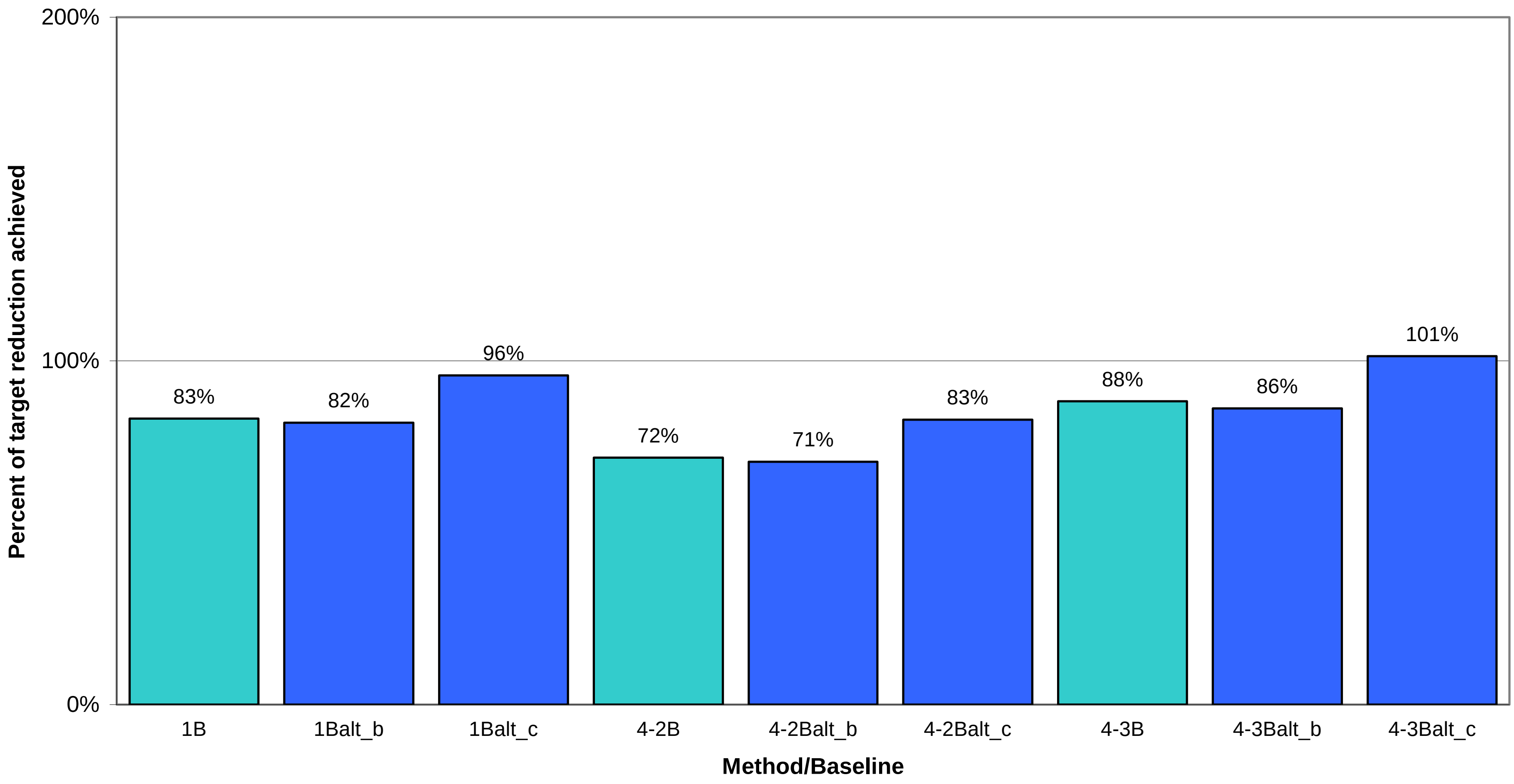


wmpe and wmpe2 don't make large differences, wmpe2 only drops 3 of 24 days

CACR 2018 OTWd Visibility Projections: Alternative Equations

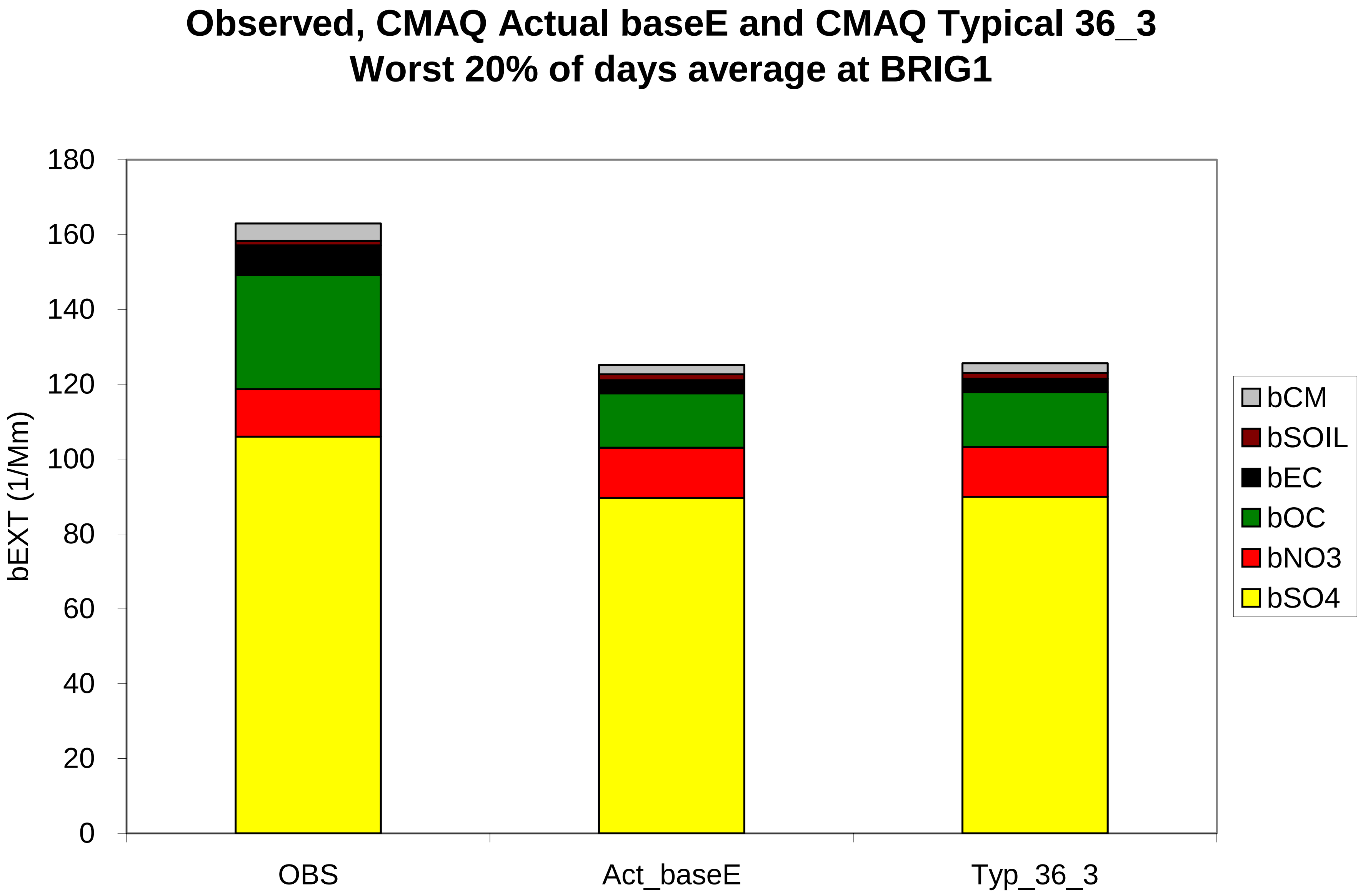
Predictions of various methods for achieving target reduction in HI with and without alternative aerosol extinction equations

OTWd for Worst 20% of days at CACR1

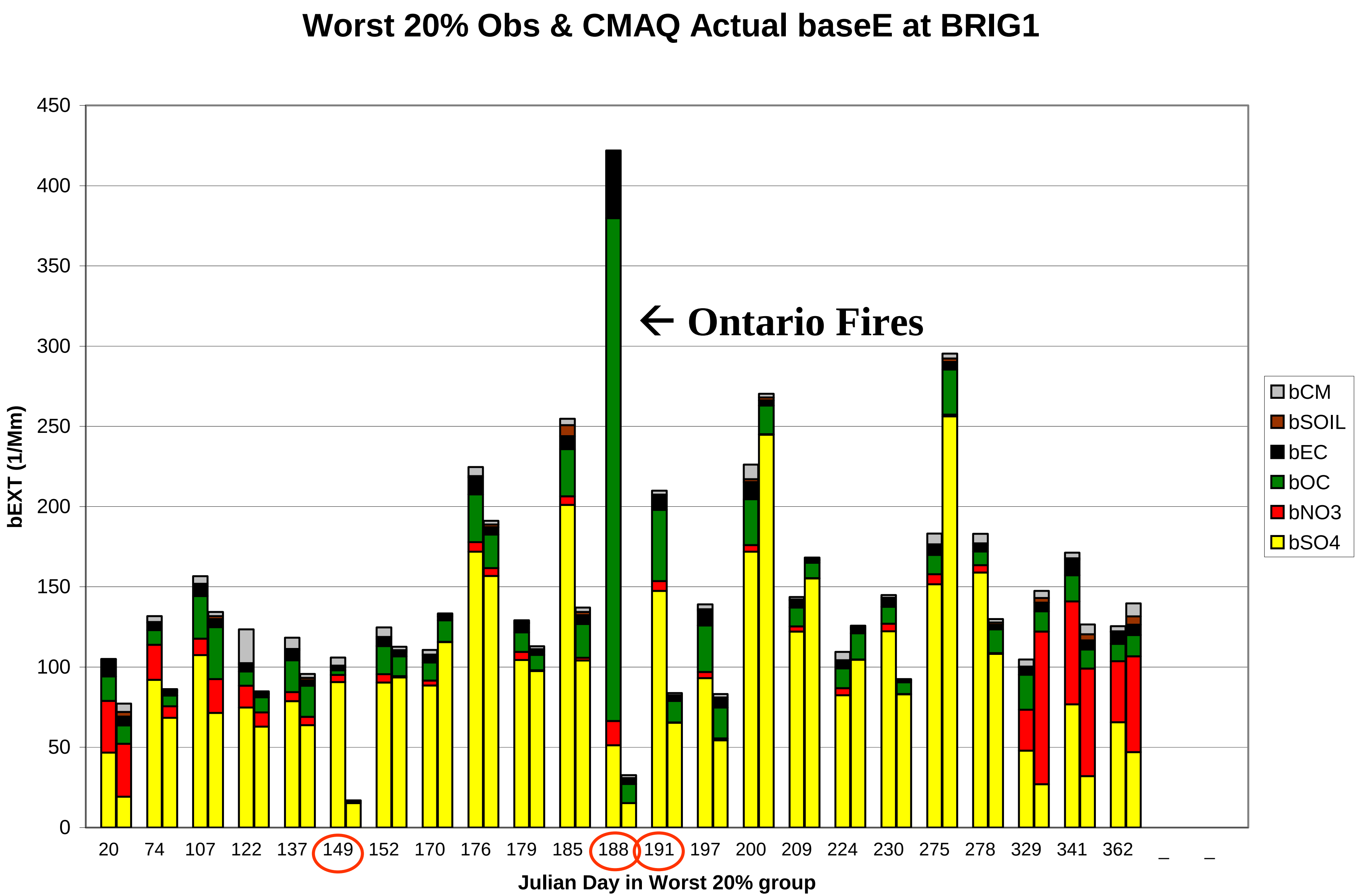


Brigantine, NJ

Observed, 2002 Actual and 2002 Typical average extinction across 2002 Worst 20% days at Brigantine, New Jersey

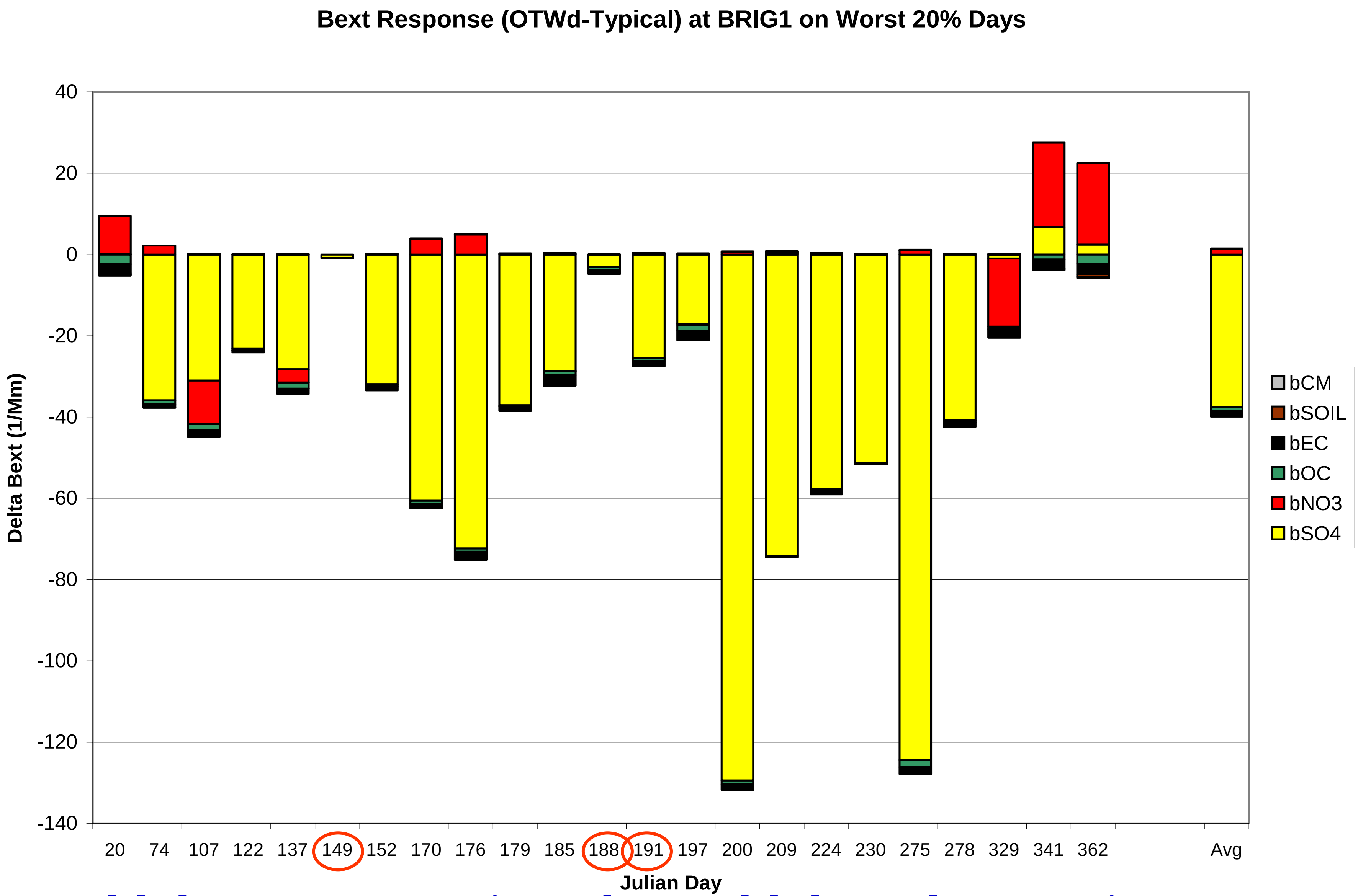


Observed (left) and 2002 Actual (right) daily extinction at BRIG



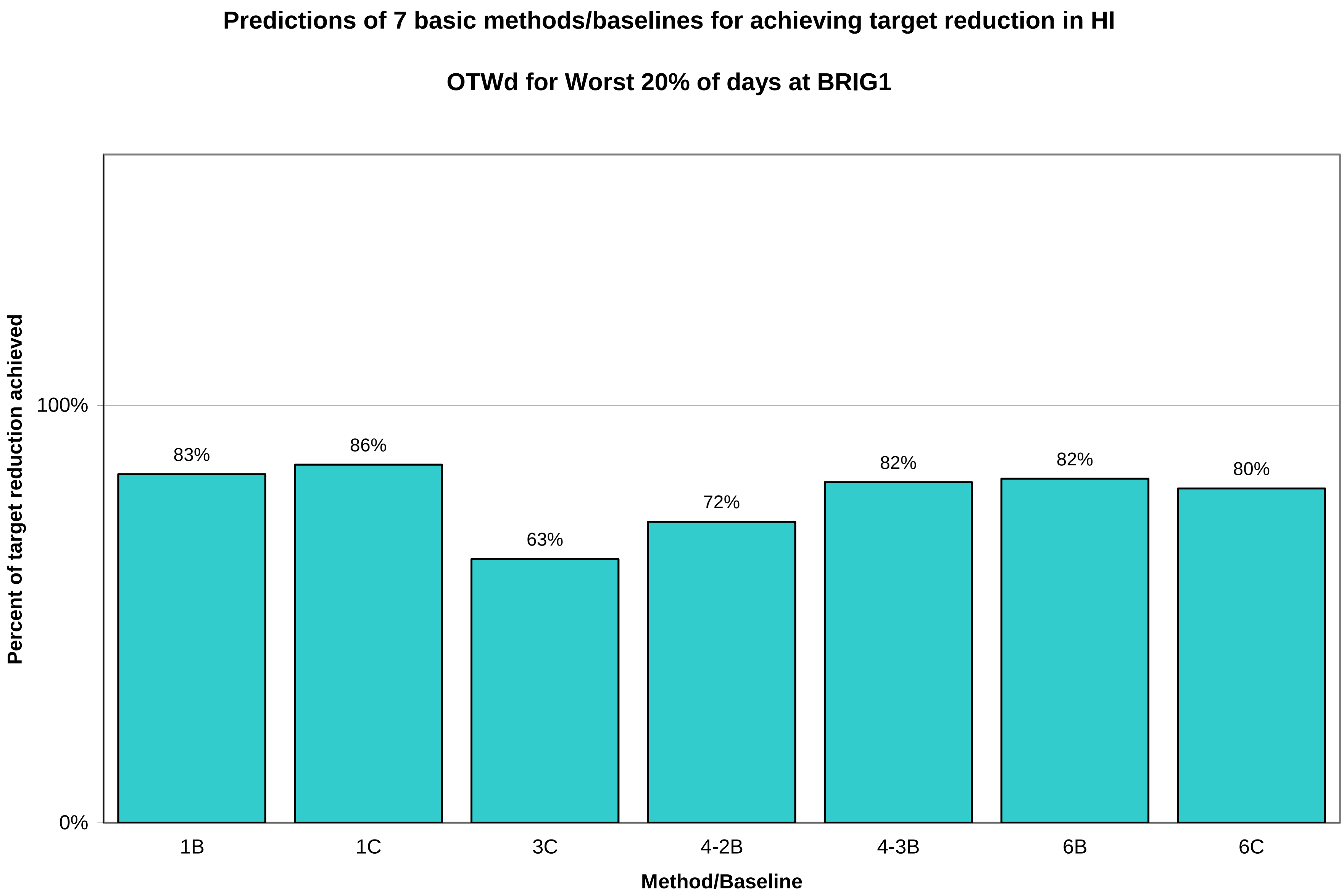
wmpe2 drops out Julian Days 149, 188 and 191

Difference in 2018 OTWd and 2002 Typical at Brigantine, NJ



Modeled Bext not responsive on low modeled SO4 days, Bext increases on NO3 days (nitrate replacement?)

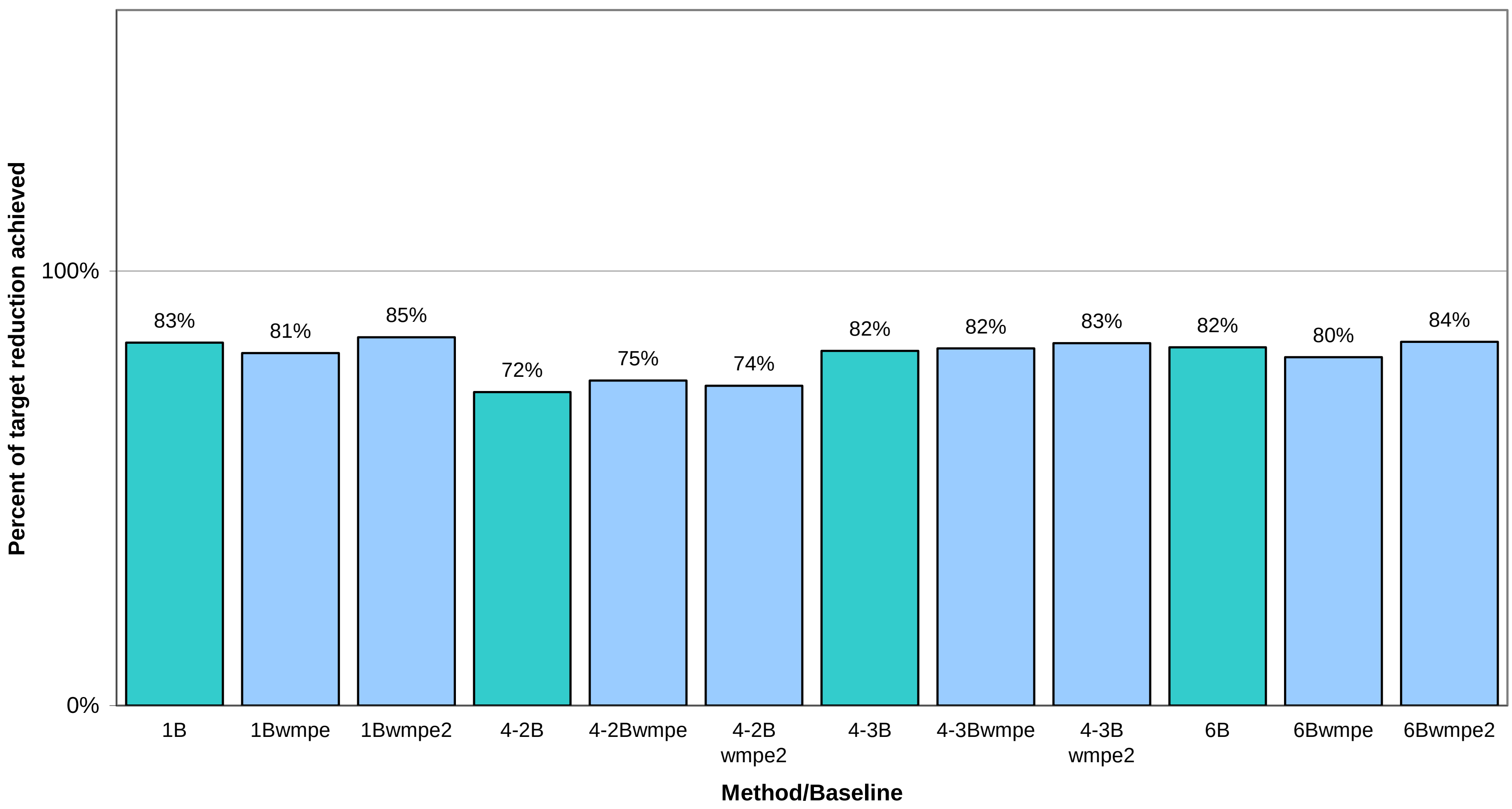
BRIG 2018 OTWd Visibility Projections: Basic Methods



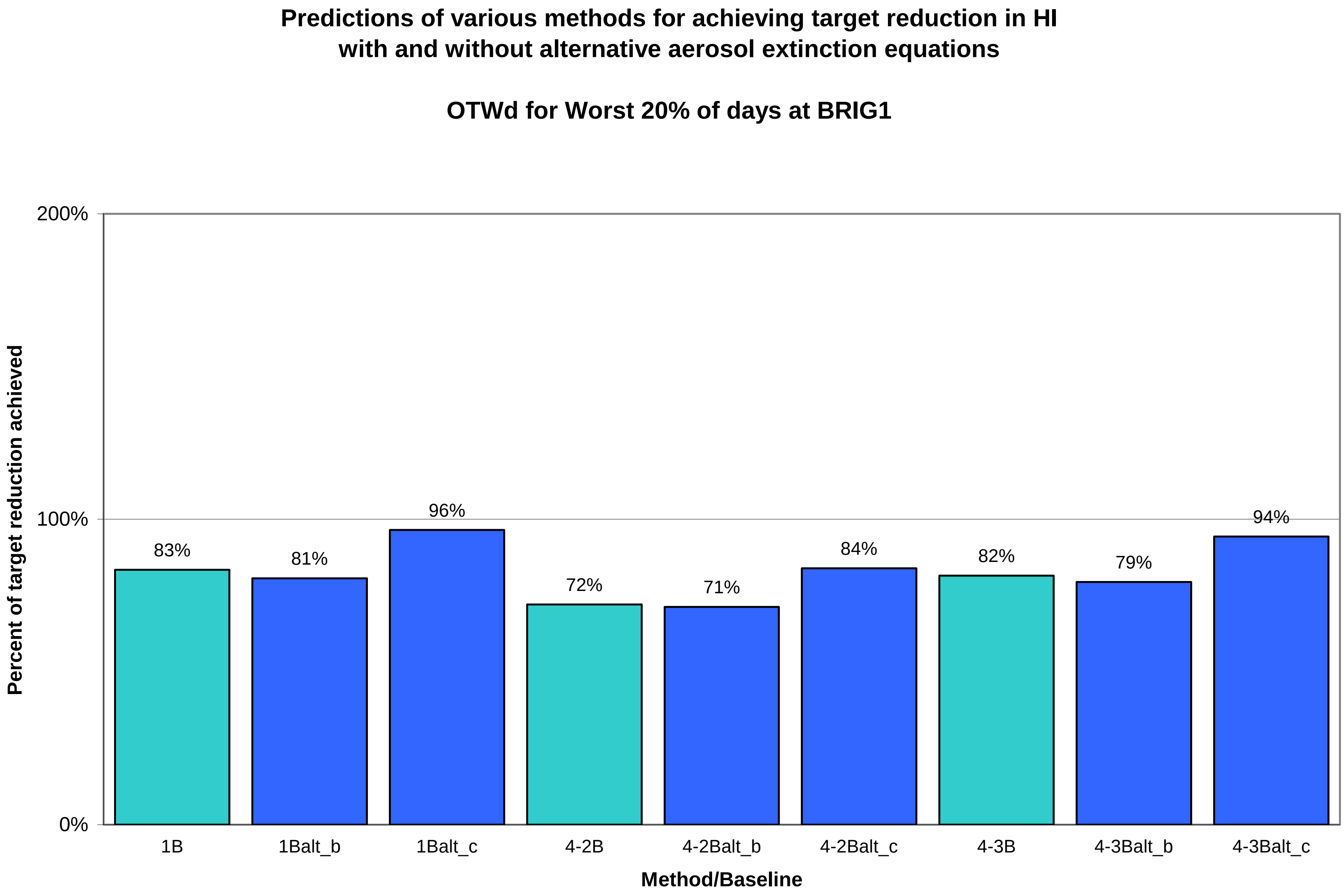
BRIG 2018 OTWd Projections: Accounting for Model Performance

Predictions of various methods for achieving target reduction in HI with and without model performance criteria

OTWd for Worst 20% of days at BRIG1

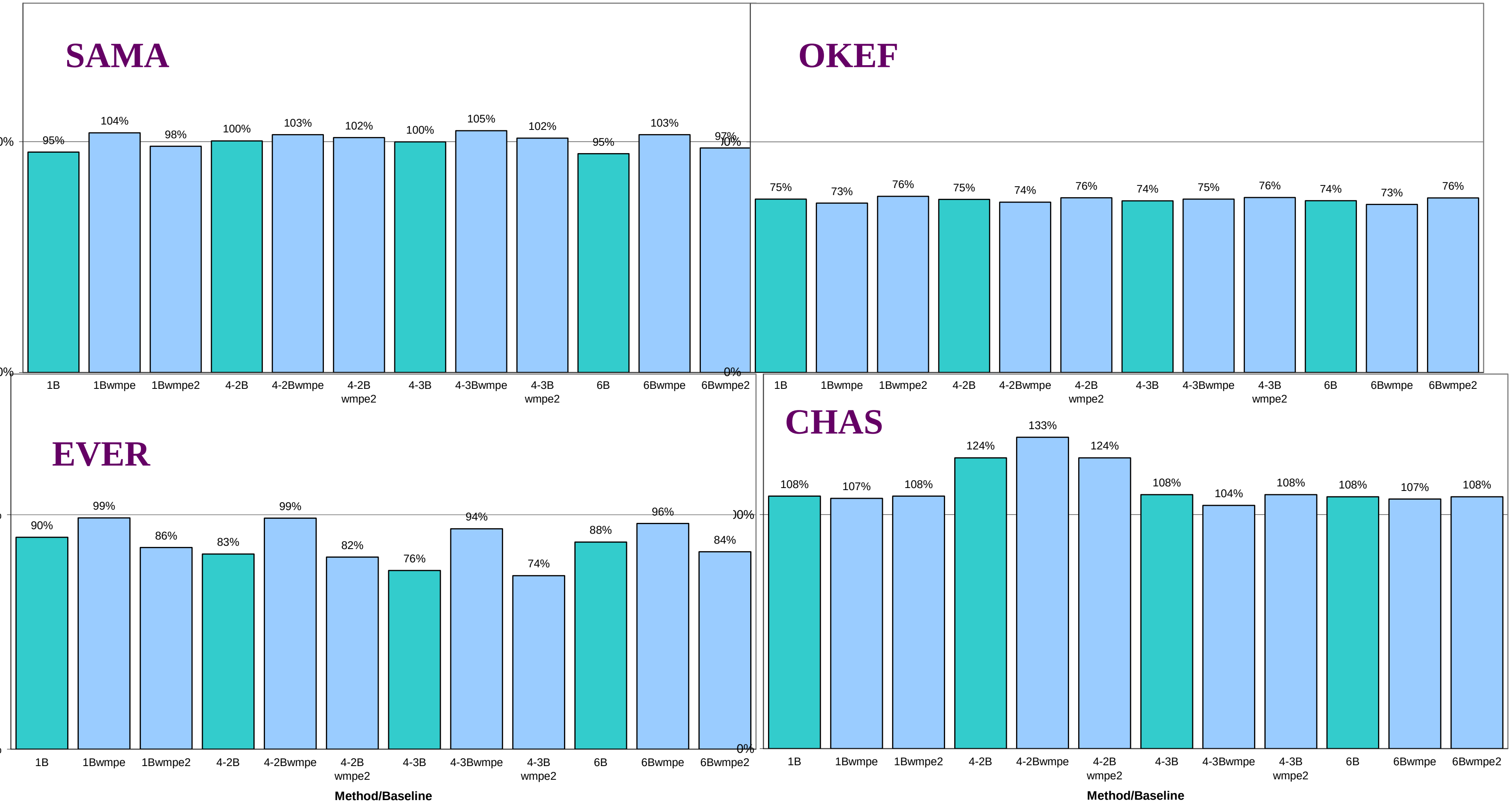


BRIG 2018 OTWd Visibility Projections: Alternative Equations



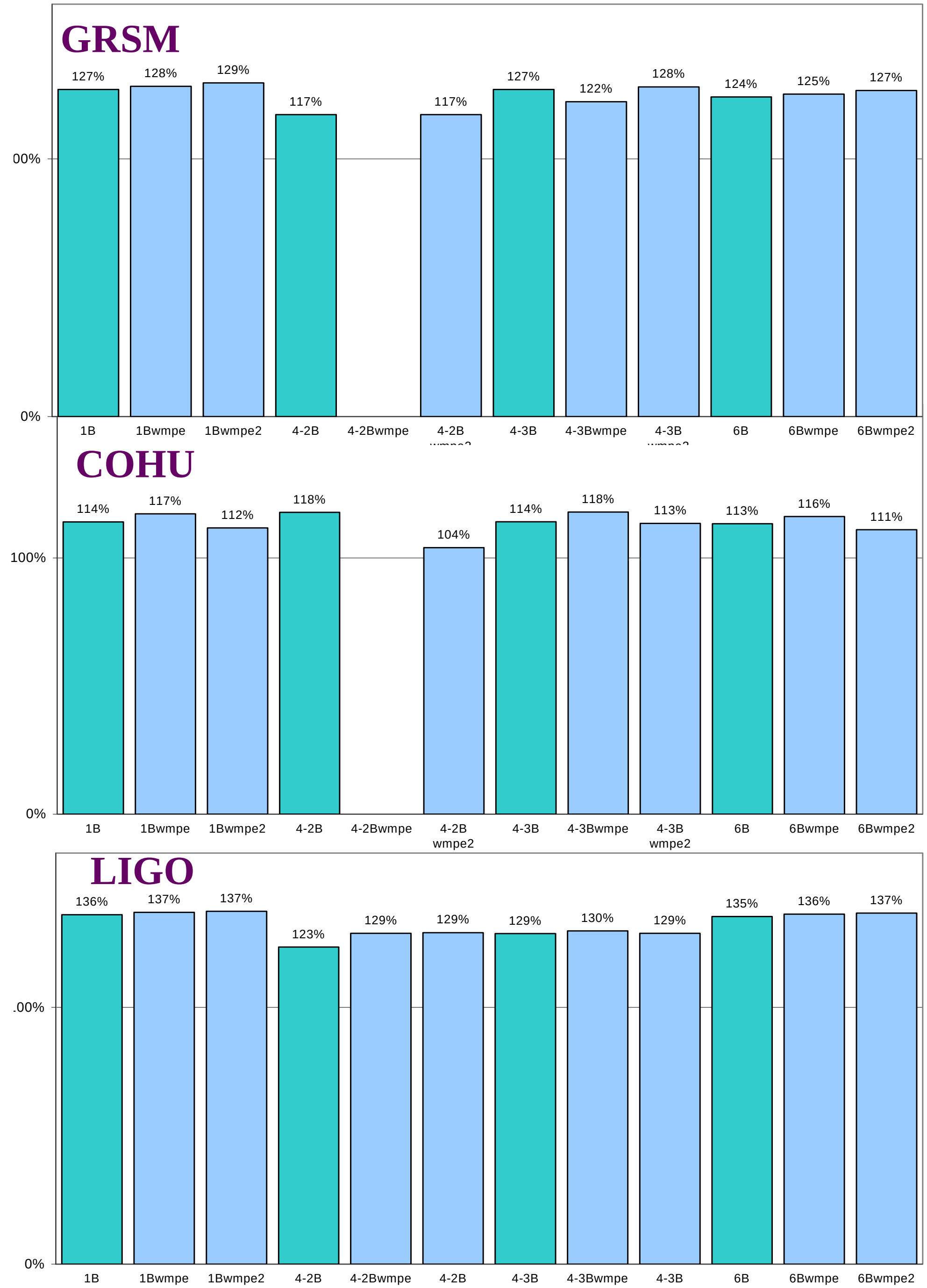
Summary of different Methods and effects of MPE considerations on visibility projections for "Florida" sites

SAMA (95% to 105%) and OKEF (73%-76%) not very sensitive; EVER more sensitive to Method (76%-90%) and wmpe (+8% to +18%); CHAS sensitive to Method (4-2 124% vs. 1 108%) and wmpe (4-2 133%)



Summary of different Methods and effects of MPE considerations on visibility projections for "Coastal" sites

ROMA (75% to 89%), SWAN (97%-107%) and BRIG (72%-85%) not that sensitive to Method or MPE considerations



Summary of different Methods and effects of MPE considerations on visibility projections for Southern Appalachian Mountains sites

More variations seen at Southern Appalachian sites of COHU (104% to 118%), LIGO (123%-137%) and GRSM (117%-127%) but still different Methods and MPE considerations within 15% of each other

Preliminary Conclusions (1)

- Methods: With the exception of Method 3 (day-specific) and sometimes Method 4, there is very little difference in the visibility projections using the different Methods
  - Method 3 appears to be outlier and can have modeling artifacts, as can not use with official 5-year Baseline should we drop it from further consideration?
- Averaging: Averaging daily dv (Method 1) versus averaging daily extinction and then converting to dv (Method 6) has essentially no effect on projections:
  - Drop Method 6 from consideration?
- Bext RRF: Using extinction RRFs (ext) gives similar results as using PM concentrations RRFs
  - Drop ext RRF approach from further consideration?

Preliminary Conclusions (2)

- MPE Considerations: At most sites the wmpe and wmpe2 (model pm components and bext within factor of 2 of observation) model performance considerations had little effect at VISTAS sites (typically < 10% change in projections)
  - Most MPE problems related to underestimation for Worst 20% days so problem days had very little effect using RRFs based on average concentrations
  - More stringent MPE considerations may result in more differences, but may also result in dropping all days
  - Sometimes has desirable result by dropping extreme events (fires & dust)
  - Issue needs further analysis (e.g., western US)

Preliminary Conclusions (3)

- Alternative Extinction Equation: Can potentially have large effect
  - Current analysis fixed Worst 20% days using IMPROVE aerosol extinction equation, **effects of equation on definition of Worst 20% days may also be large** (e.g., switch from SO4 to OC dominated days)
  - Other alternative equations possible
  - More analysis needed

Preliminary Conclusions (4)

- Natural Conditions: Current analysis fixed the Natural Conditions endpoint to EPA's default; changes to Natural Conditions could have more effect that many other parameters studied.
  - Inclusion of sea salt
  - Global and inter-national transport of natural (e.g., dust and fires) and man-made PM
  - Inclusion of other natural emissions (biogenic OC, volcanoes and seeps, wind blown dust, etc.)
  - Doesn't affect model projections, just reasonable progress goal

Preliminary Conclusions (5)

- Data Filling: How to address Class I areas with insufficient IMPROVE data to calculate Baseline using EPA guidance
  - e.g., Breton Island and Shining Rock used data filling from nearby sites in VISTAS for 2002, what about 2000-2004?
- Progress Demonstration: How to decide whether modeling has demonstrated reasonable progress
  - Have been using "10% of 100% RPG as too close to call; > 110% likely meet RPG; < 90% RPG likely not met
  - Modeled demonstration of RPG should be just one component of the RPG demonstration
    - Need corroborative analysis using data, data analysis, receptor modeling, etc., models are just one tool

Preliminary Conclusions (6)

- Caveats: Partial List
  - Examined limited number of sites in Southeast US, issues in western US and elsewhere may be different
  - Examined limited number of Methods and considerations
  - Did not address Natural Conditions
  - Only used 36km results to date, 12 km in future
  - Emissions and modeling results are preliminary
  - Numerous uncertainties, known and unknown
- Encouraging: Different Methods generally gave similar visibility projections
  - Rarely changed conclusions that a Class I area likely meets, likely does not meet or is too close to call for meeting the 2018 visibility goal