Preliminary 2018 Visibility Projections using WRAP CMAQ Base18a and Plan02a Emission Inventories

WRAP Regional Modeling Center (RMC)

University of California at Riverside

ENVIRON International Corporation

University of North Carolina/Carolina Environmental Program

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ENVIRON UCR UNC CAROLINA ENVIRONMENTAL PROGRAM

2018 Visibility Projections

- 2018 Base18a Emissions Inventory
  - Not all source sectors projected to 2018
  - Some potential errors
- 2002 Plan02a Inventory
  - Typical Fires and EGU Emissions
- 2018 Visibility Projections
  - CMAQ 2018/2002 Simulations
    - CAMx runs TBD
  - EPA Draft Guidance (2001), It Will Change
  - Several Projection Methods Have been Developed

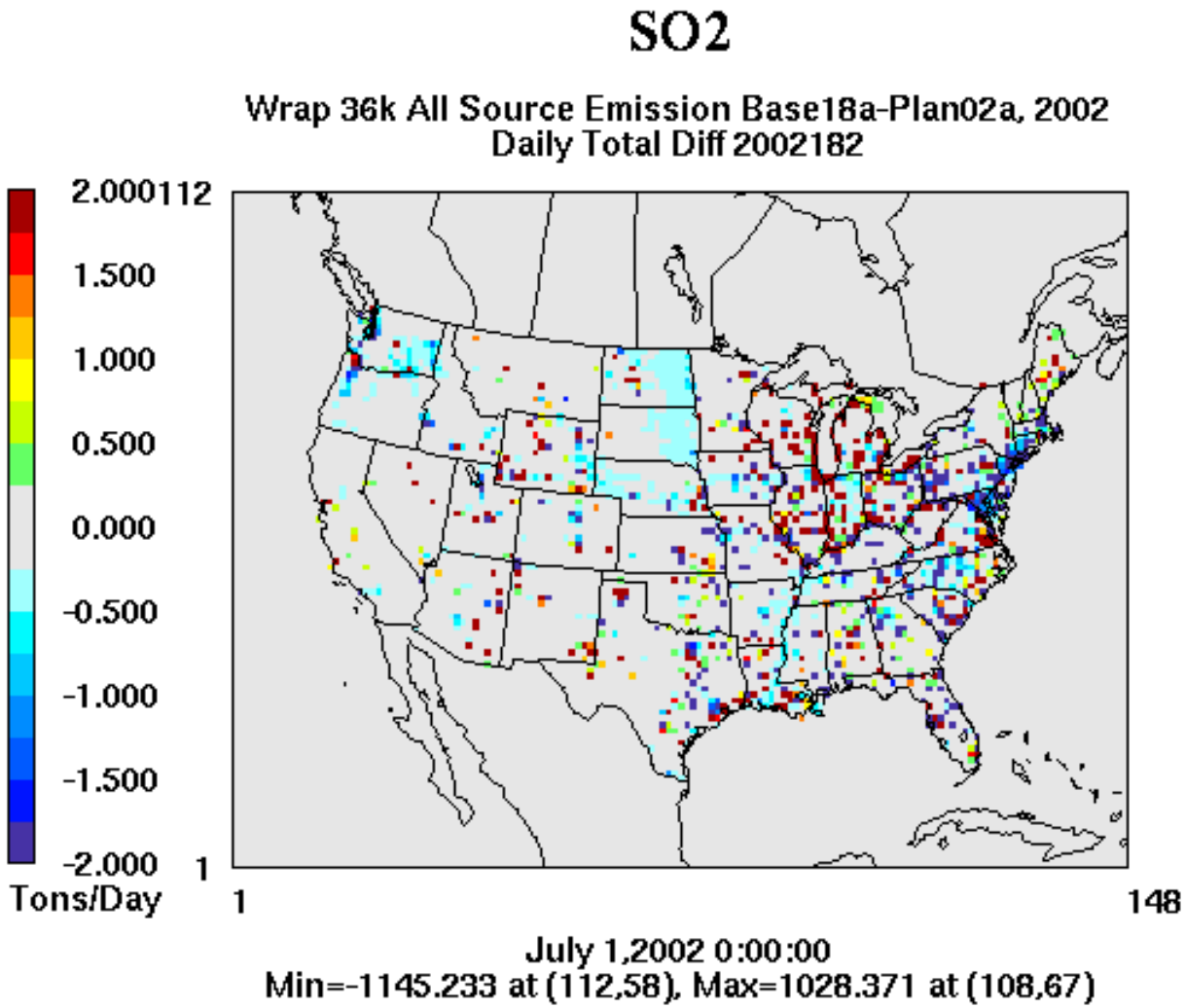
2018 Visibility Projections: Caveats

- Results are preliminary
  - Became available January 2006
  - Minor emission errors in WRAP States identified
  - Other issues identified in Non-WRAP emissions
    - On-Road Mobile Overstated
  - Further QA planned
- The following emissions are held constant
  - Sources outside the U.S. (Canada and Mexico)
  - Ocean-going vessels (off-shore and in-port)
  - Biogenics, Wind Blown dust, and Fires (Wx, Rx, ag)

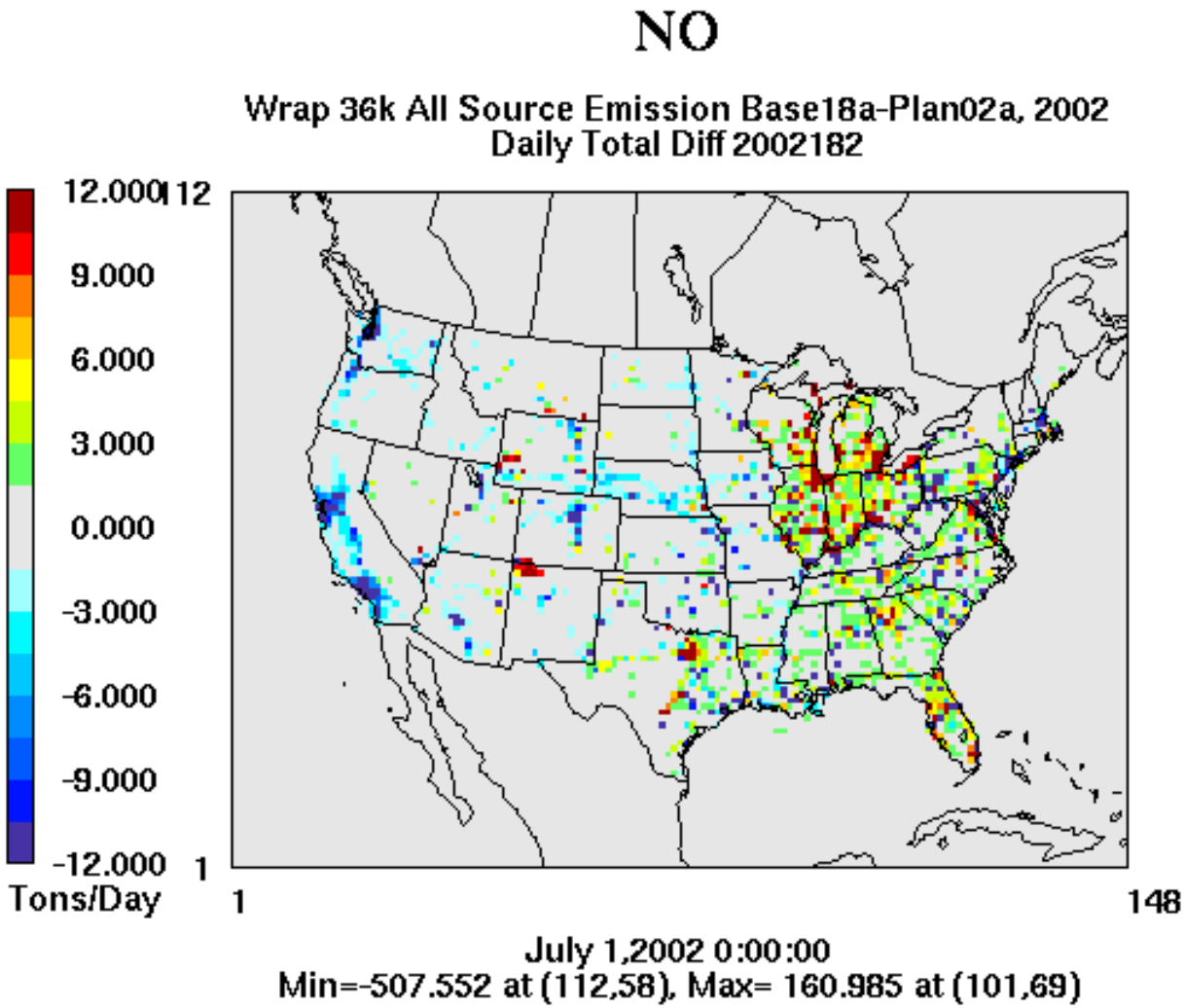
2018 Visibility Projections

- Emission changes limited to known / certain controls on stationary, area, and land-based mobile sources (On-the-Books; OTB). In WRAP region, this equates to annual change of:
  - 51,000 tons of SO2 (-5%)
  - 1,040,000 tons of NOx (-28%)
  - 635,000 tons of PM10 (31%)
  - 424,000 tons of VOC (14%)

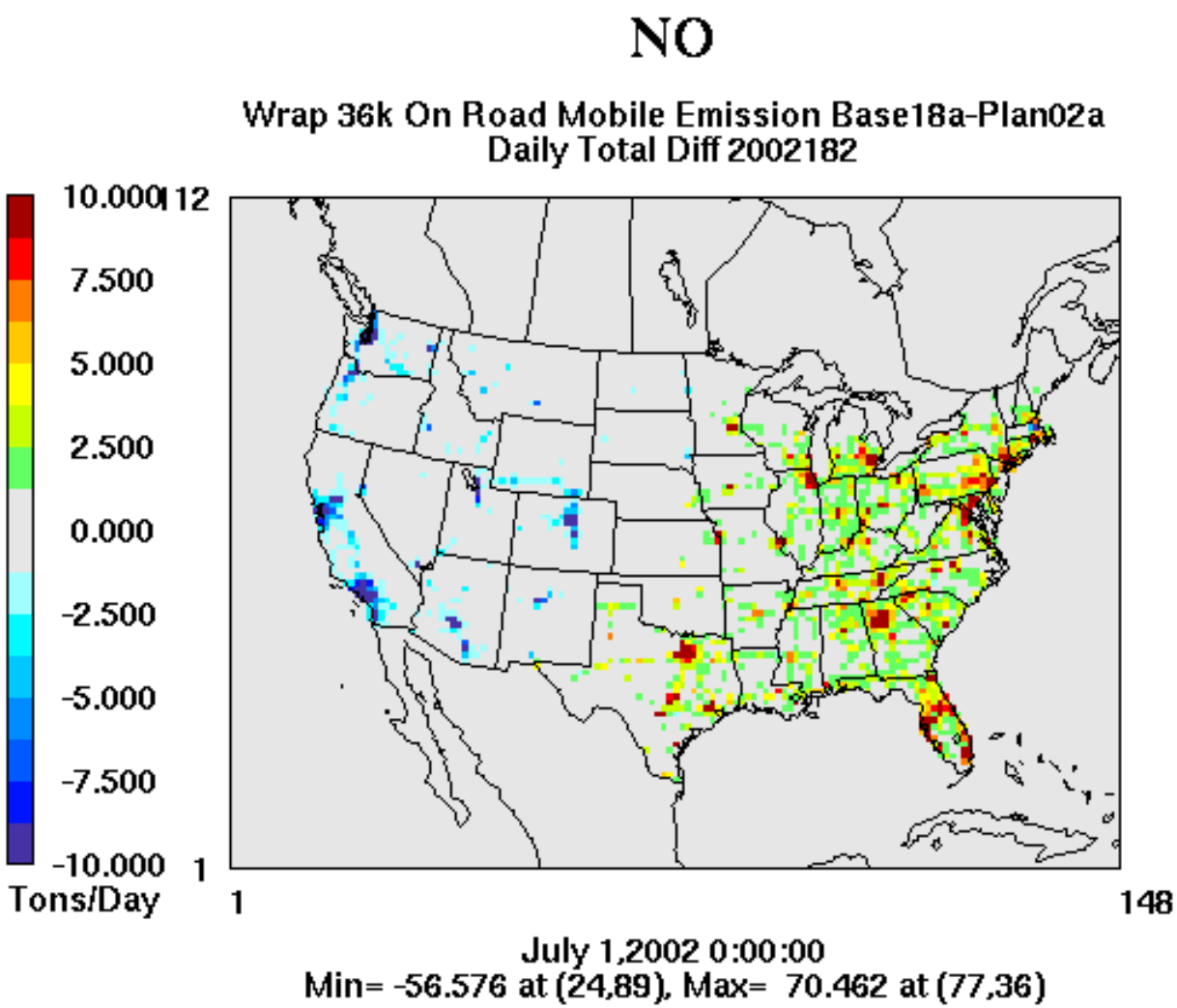
SO2 Total: Base18a – Plan02a



NO Total: Base18a – Plan02a



NO On-Road Mobile: 18a–02a



Projections Procedures

- **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 – Use 2000-2004 5-Year Baseline Period
- **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)

Converting Measured PM to Extinction

- 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

Converting PM to Extinction

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

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

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

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

Haze Index = HI = $10 \ln(b_{ext}/10)$ in deciview (dv)

2000-2004 Visibility Baseline

- 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

- Use model in a relative sense to scale observed IMPROVE PM species 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)]

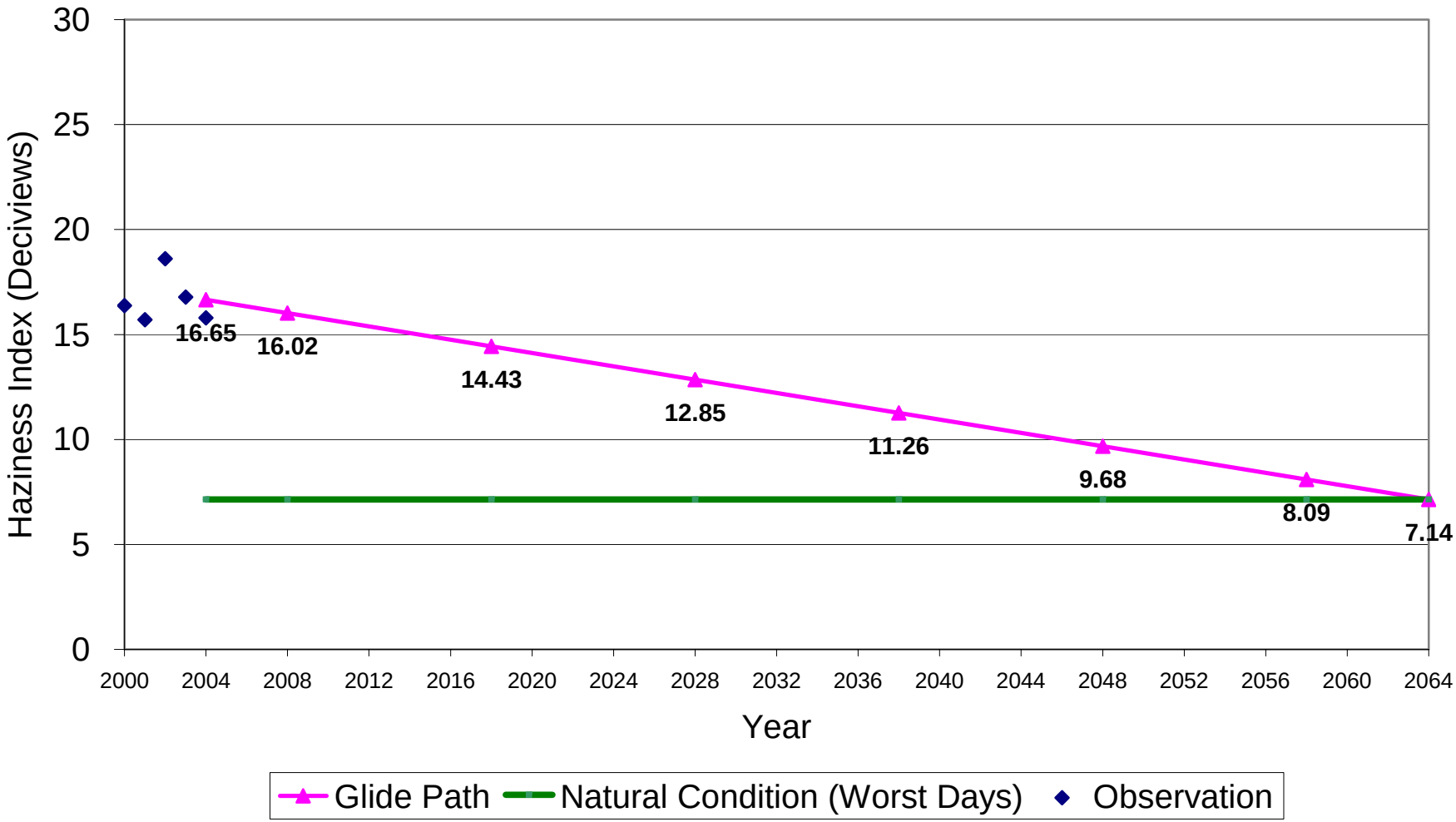
Visibility Projections

- Use model derived species-specific and Class I area-specific RRFs to scale daily observed 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)

Uniform Rate of Progress (URP) 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

Uniform Rate of Reasonable Progress Glide Path
Emigrant Wilderness - 20% Worst Days



Visibility Projections

- Have developed several Methods for Visibility Projections
  - Species and Class I Area specific Relative Reduction Factors (RRFs) are used to scale (project) 24-hour average measured PM concentration for the Worst 20% Days in 2000-2004 to obtain projected 2018 PM concentrations from which extinction and deciview (dv) are obtained

Approaches for RRFs

- **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 the Observed Worst Days from 2002

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

  - Applied to observed daily PM components for each day Worst 20% Days from 2000-2004 to obtained 2018 projected PM components: (1) IMPROVE equation to get Bext; (2) turn into dv; (3) average for each year; and (4) average across 5-years to obtain 2018 HI projection

Summary of Approaches (Method 1 used for WRAP)

Methods

1. Average RRF Approach for Worst 20% Days
2. Quarterly Average RRF Approach for Worst 20%
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
6. Averaging of Extinction not dv (also changes Baseline)

Baseline

2000-2004 5-Years in Official Baseline

Considerations

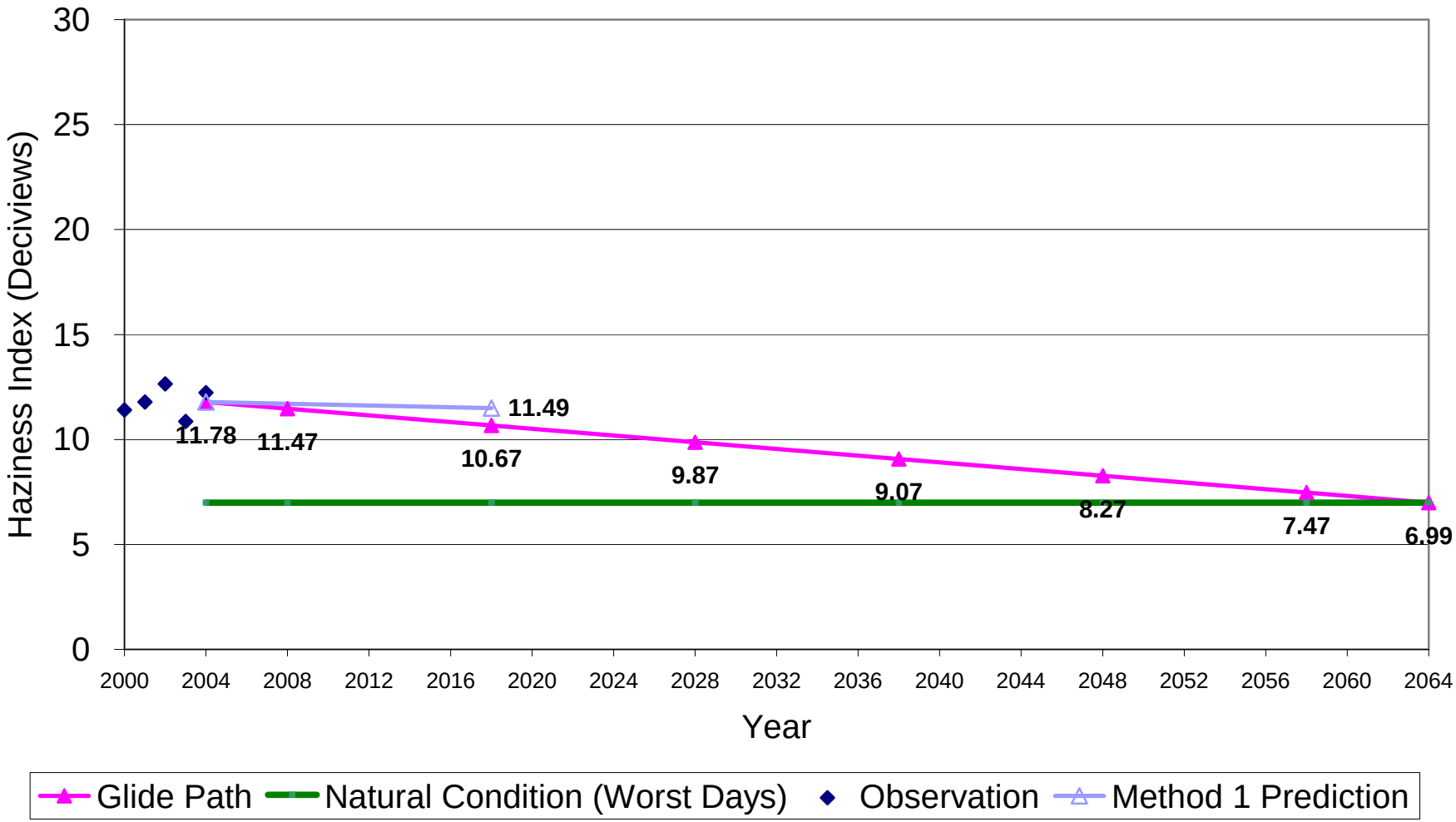
ext = use RRFs based on extinction not PM components

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

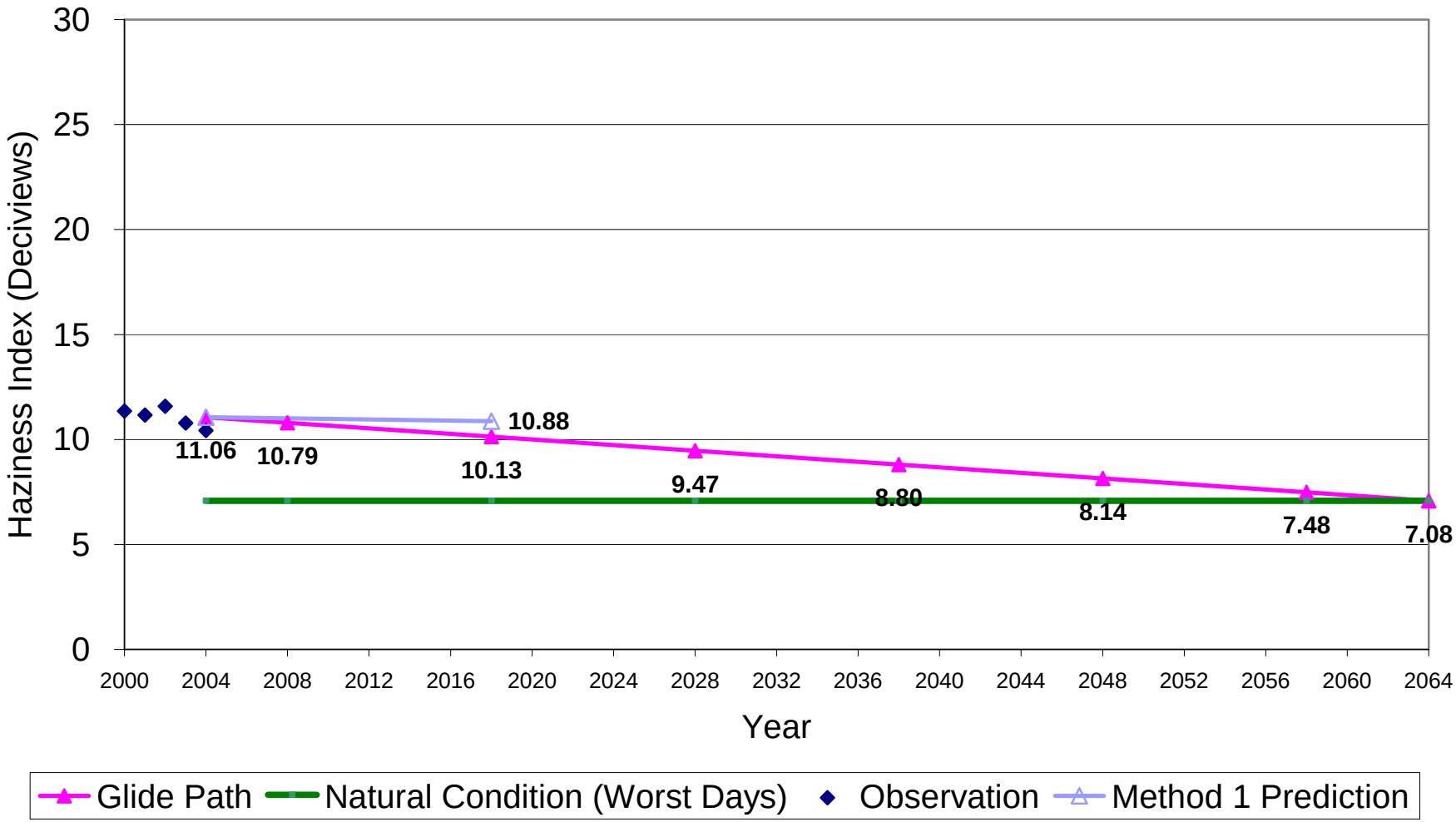
wmpe2 = do not use any PM components in RRF on days when pred/obs b_{ext} > factor of 2

alt_d = use proposed new IMPROVE equation (Big and Little SO4, NO3 and OC)

Uniform Rate of Reasonable Progress Glide Path
Bryce Canyon NP - 20% Worst Days



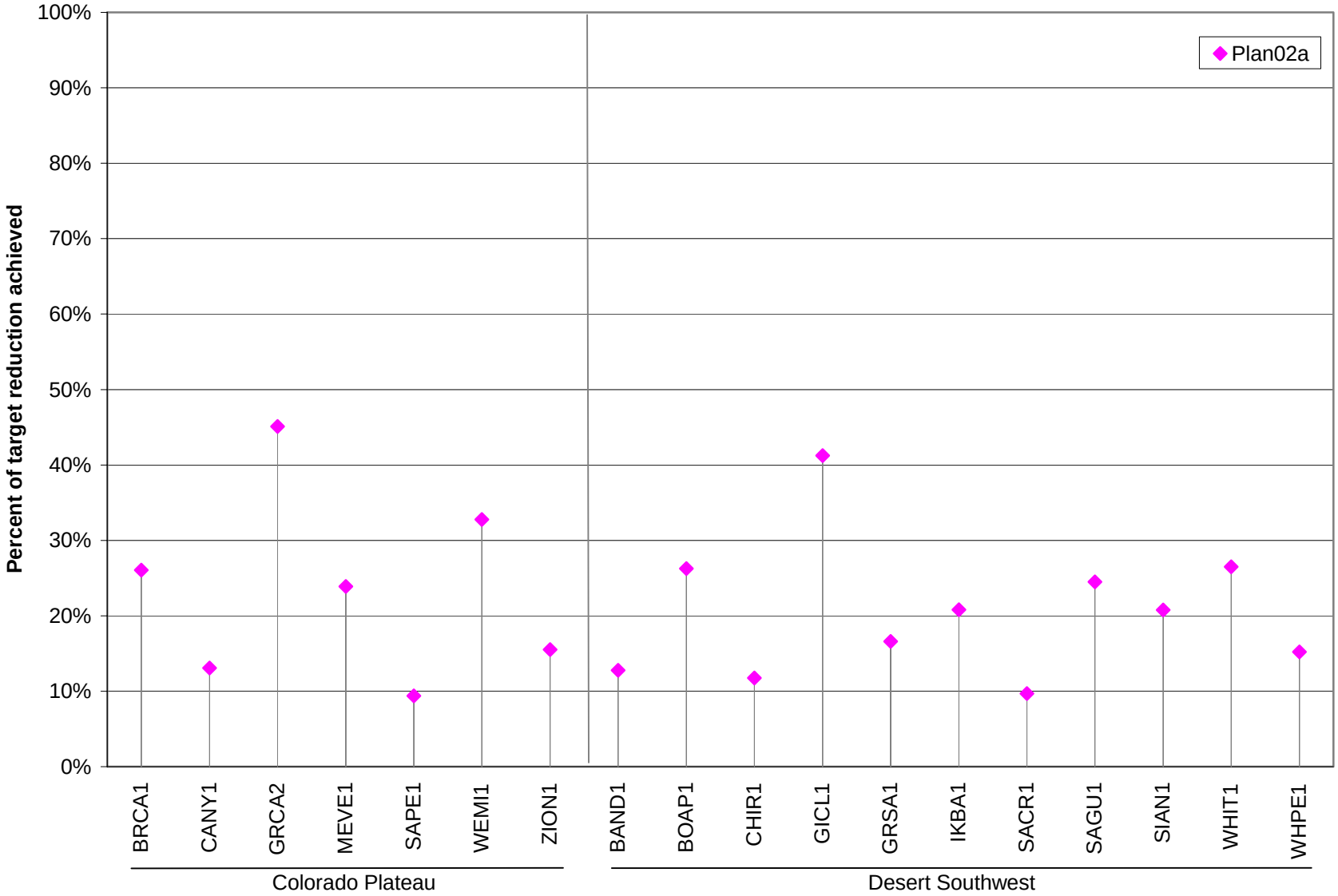
Uniform Rate of Reasonable Progress Glide Path
Fitzpatrick Wilderness - 20% Worst Days



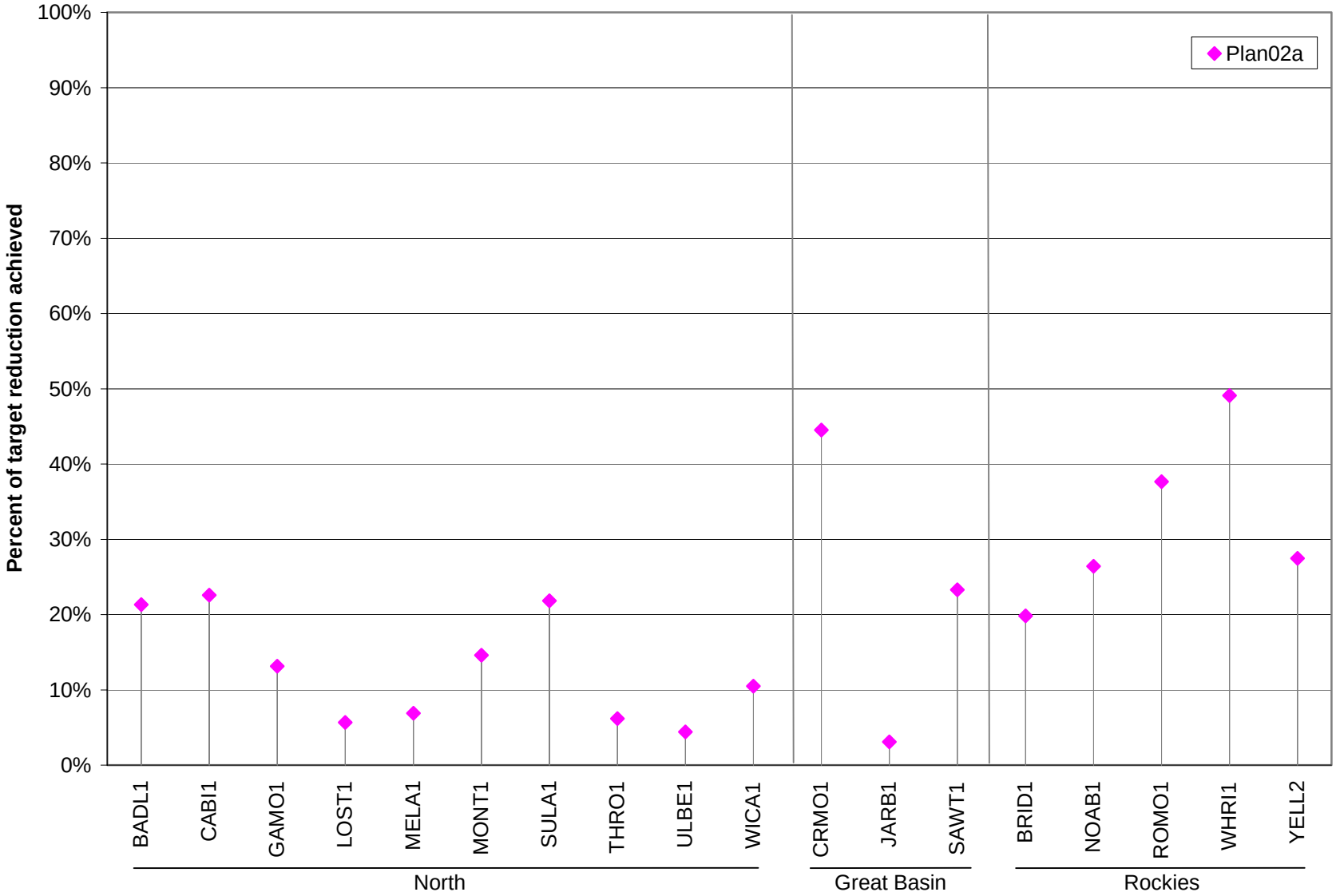
2018 Visibility Projections

- "Dot Plots" are used to display visibility projections for several Class I areas at once using several methods and approaches
  - Express 2018 visibility projections in terms of percentage of achieving the Uniform Rate of Progress (URP) 2018 Goal
    - Not pass/fail type grade, just one component of Reasonable Progress

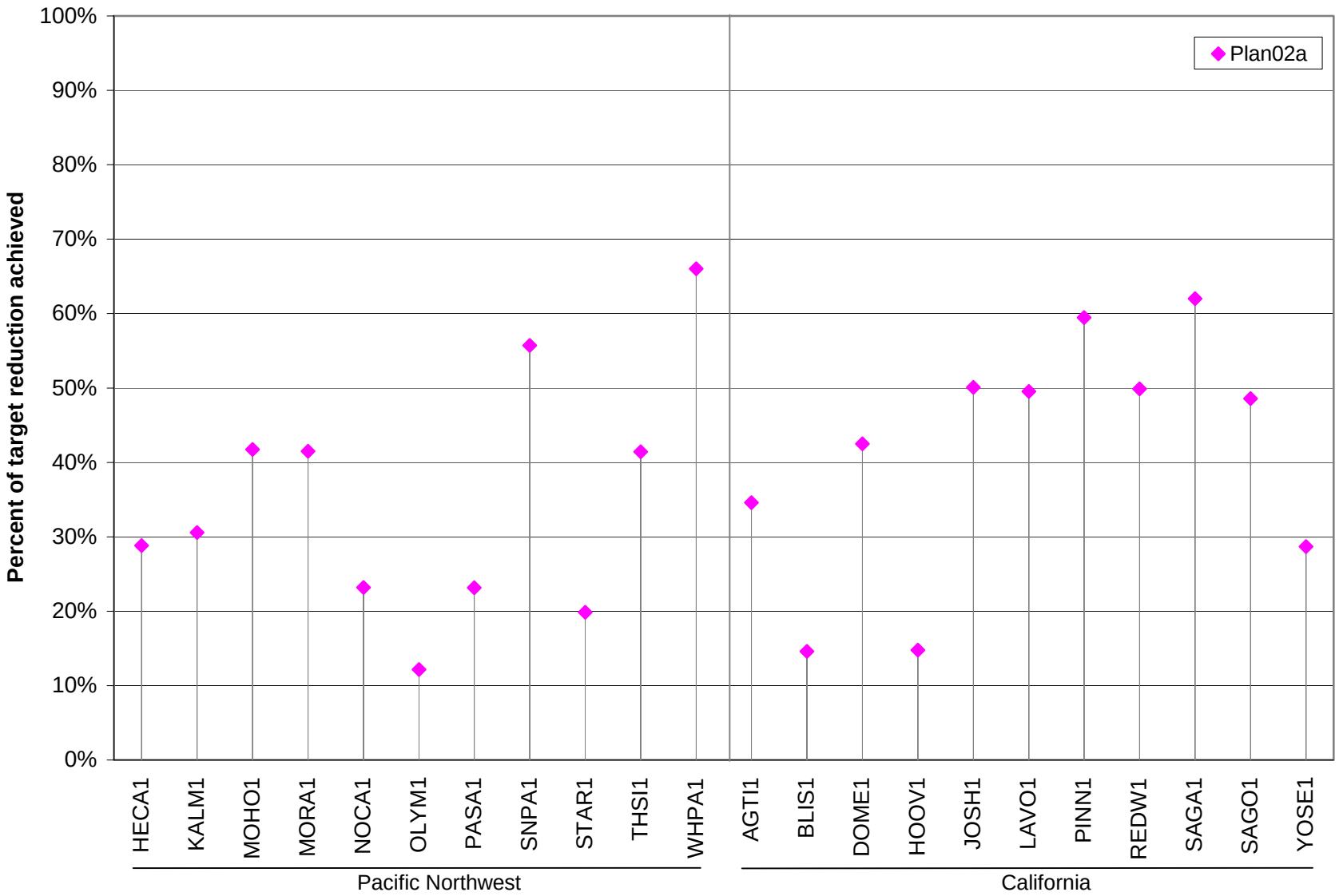
Method 1 predictions for Colorado Plateau and Desert Southwest sites



Method 1 predictions for North, Great Basin and Rockies sites



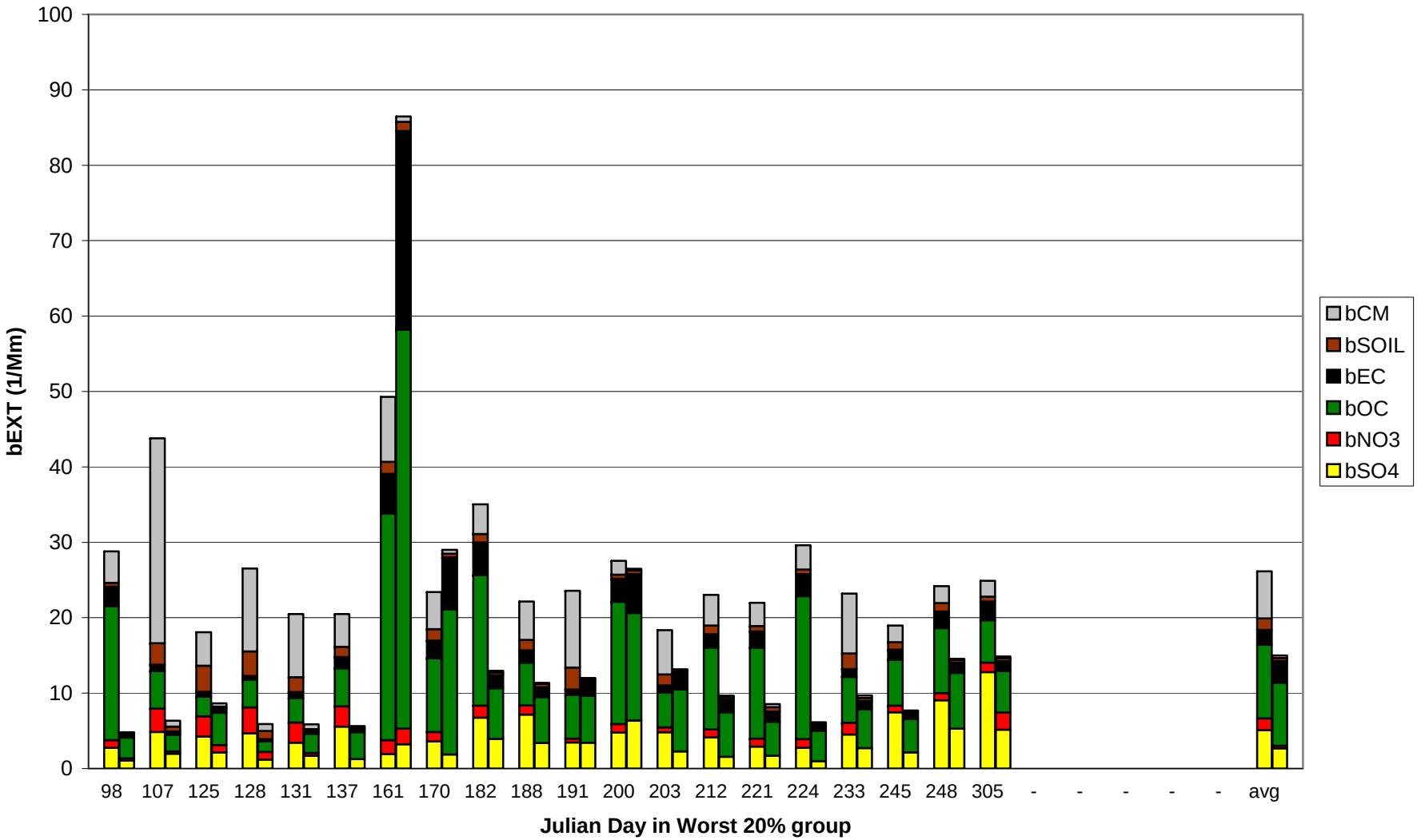
Method 1 predictions for Pacific Northwest and California sites



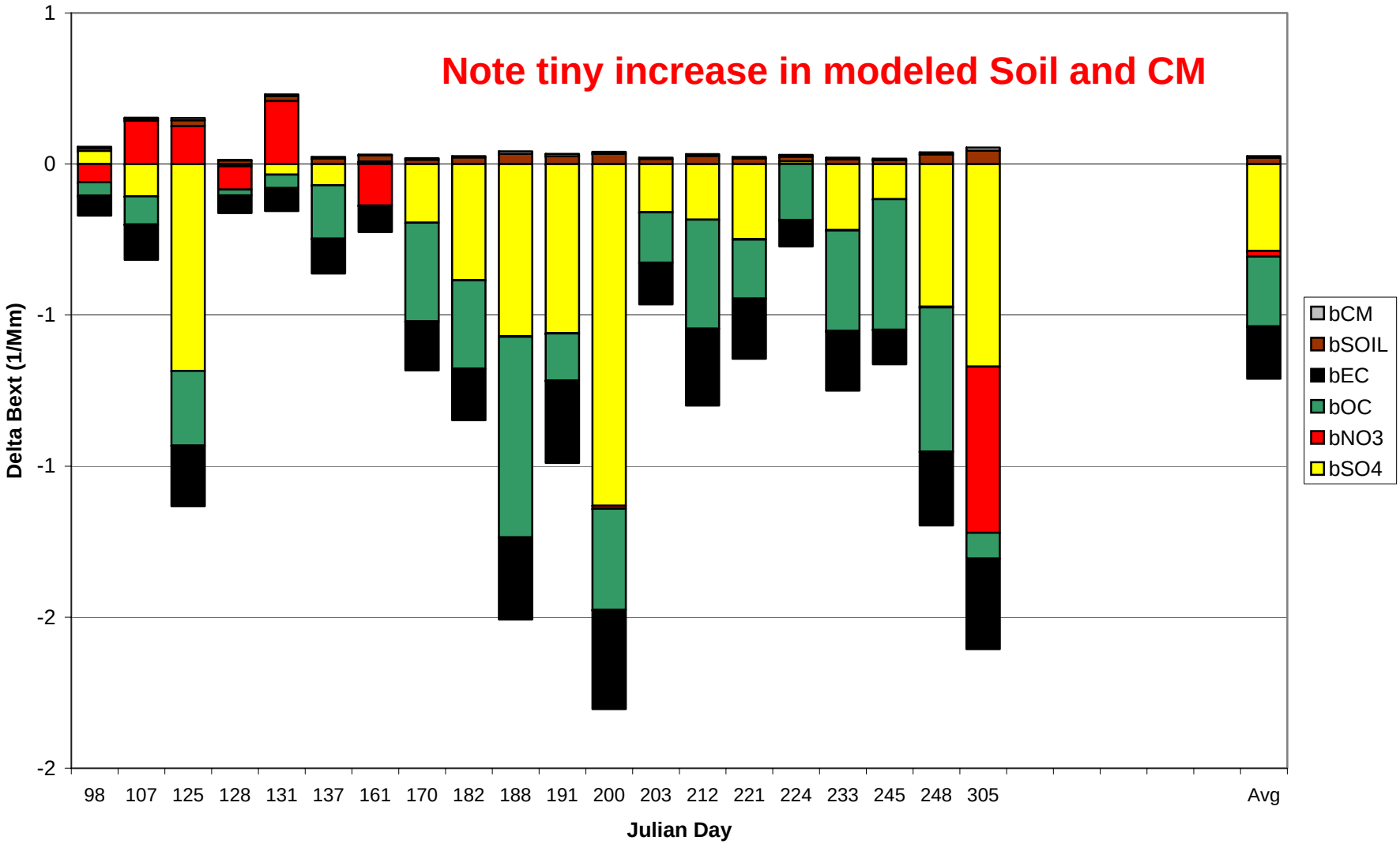
Modeled 2018 URP Goal

- Modeled 2018 URP Goal not met at Western Class I Areas
  - Some 2018 emissions kept constant
  - Large component of uncontrollable PM in Worst 20% Days visibility
    - Fires
    - Dust
    - Biogenic
    - International Transport
    - Unlike Eastern US where Sulfate dominates
  - Need to define WOE "Reasonable Progress"

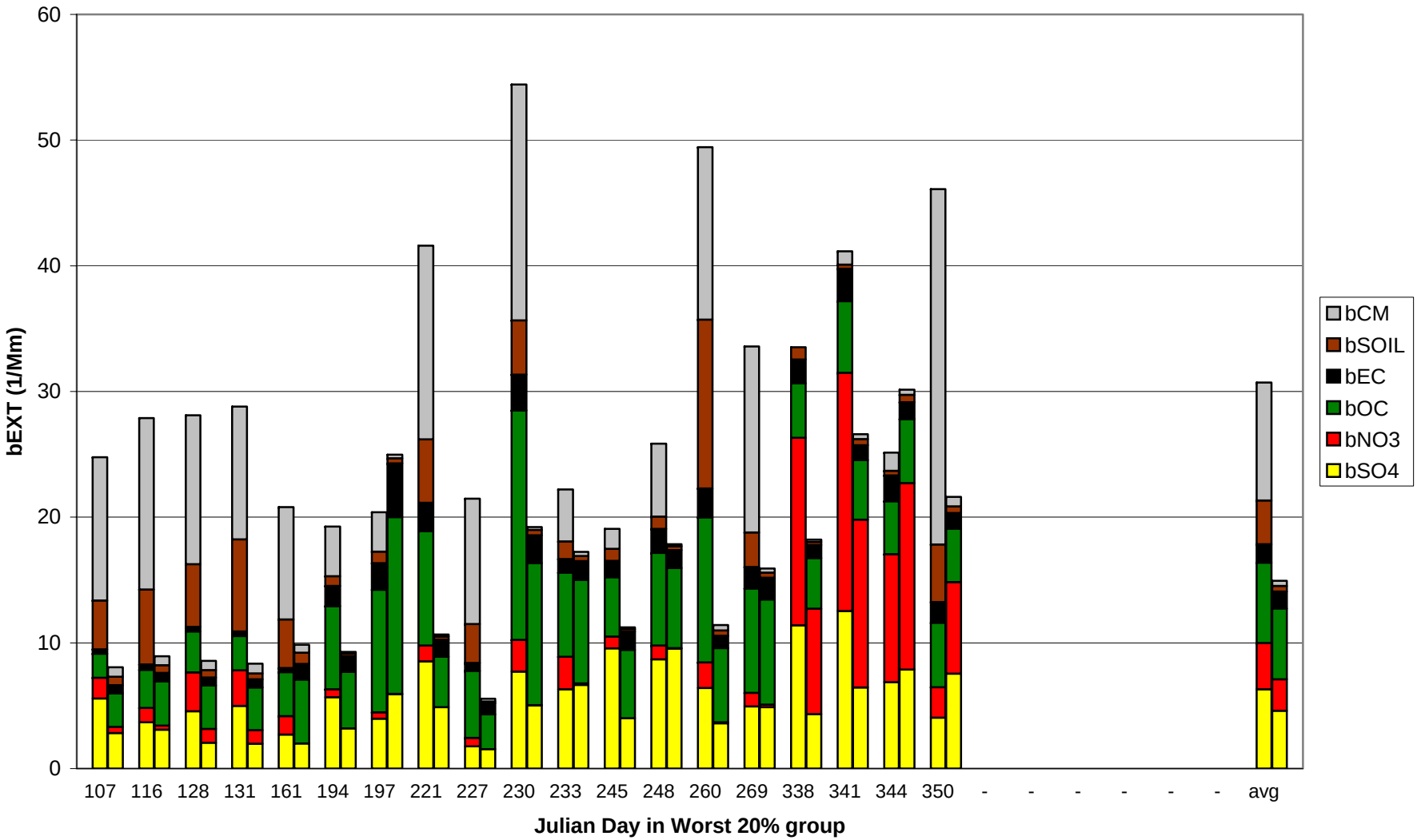
Worst 20% Obs (left) vs Plan02a (right) at BRCA1



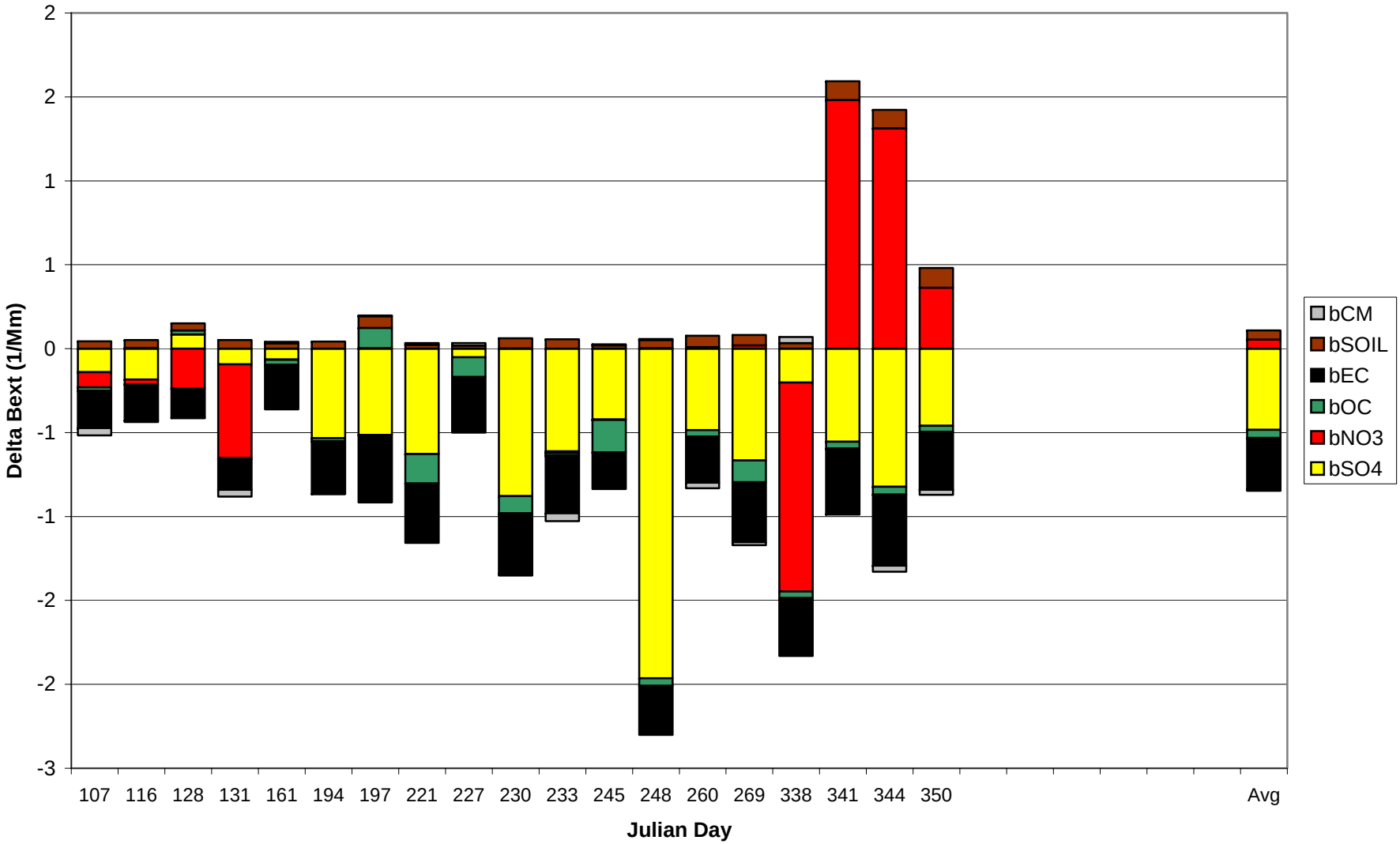
Bext Response (base18a - plan02a) at BRCA1 on Worst 20% Days



Worst 20% Obs (left) vs Plan02a (right) at MEVE1



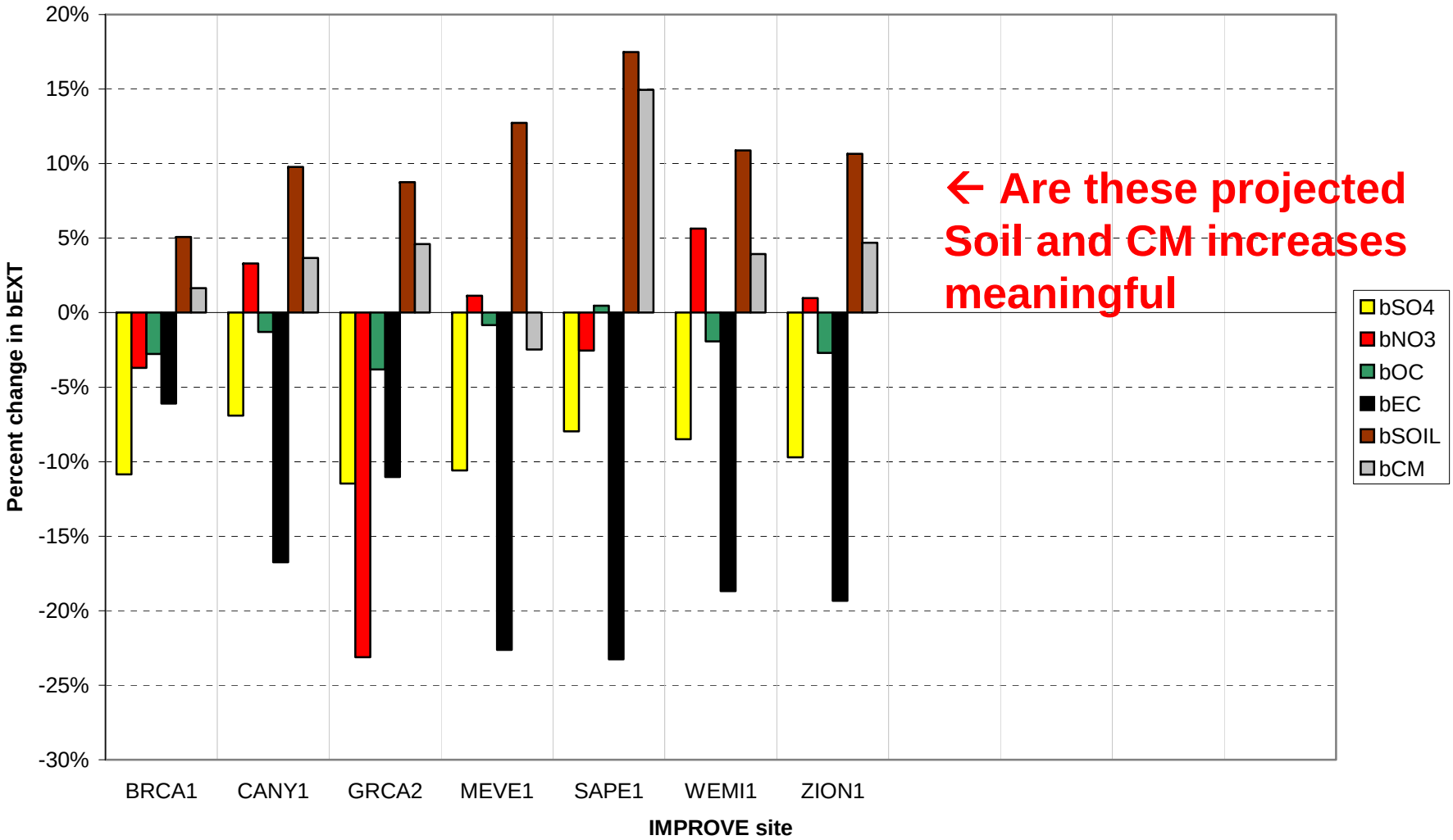
Bext Response (base18a - plan02a) at MEVE1 on Worst 20% Days



Visibility Projections

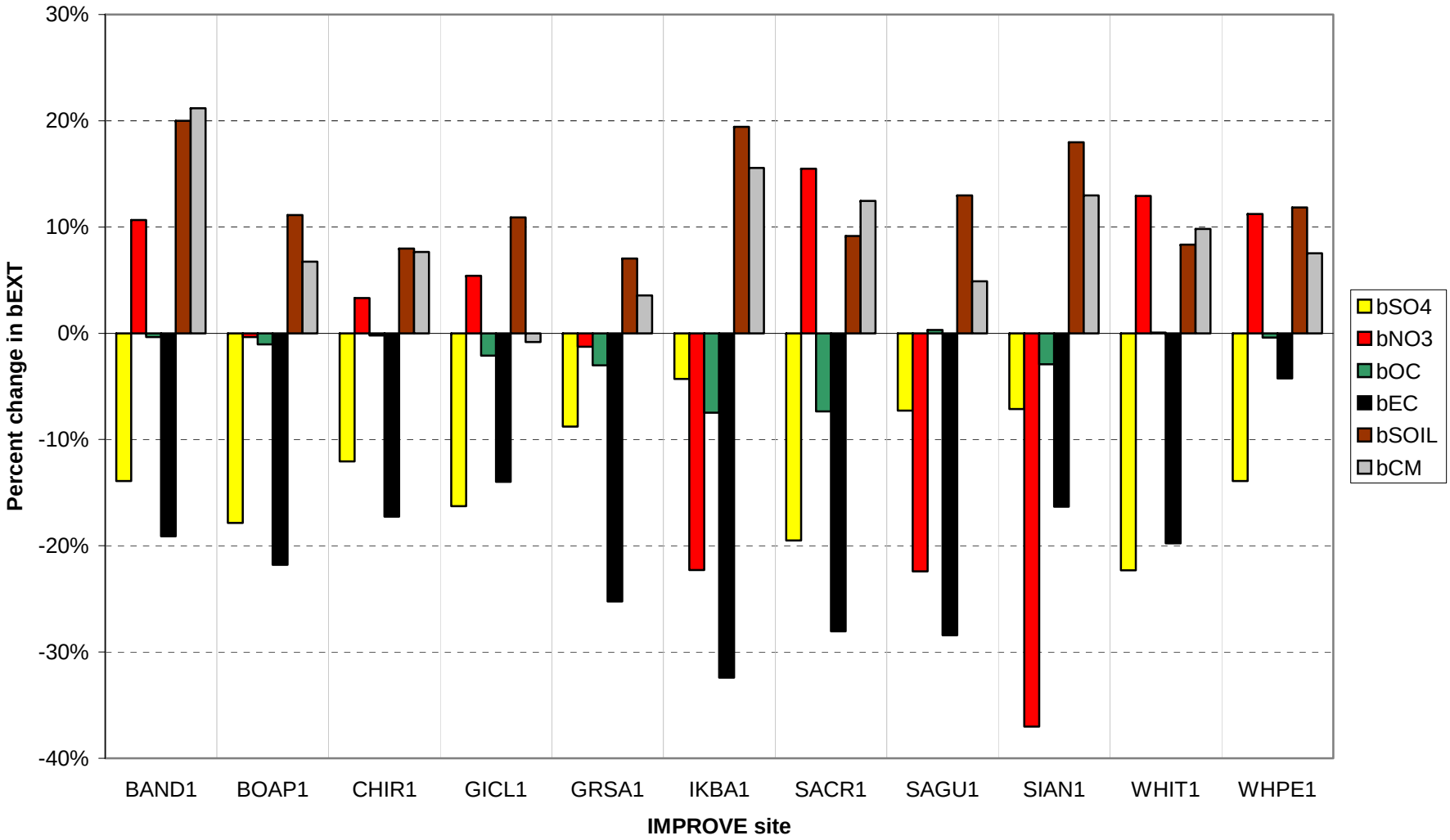
- 2018 Visibility projection has little sensitivity to emissions controls
- Need to examine effects on controllable portion of visibility for the Worst 20% Days
- Use Change in Extinction Between 2000-2004 Baseline to 2018 Projections for Worst 20% Days as indicator

Percent change in extinction components from 2002 baseline to 2018 projected at Colorado Plateau sites using base18a/plan02a RRFs

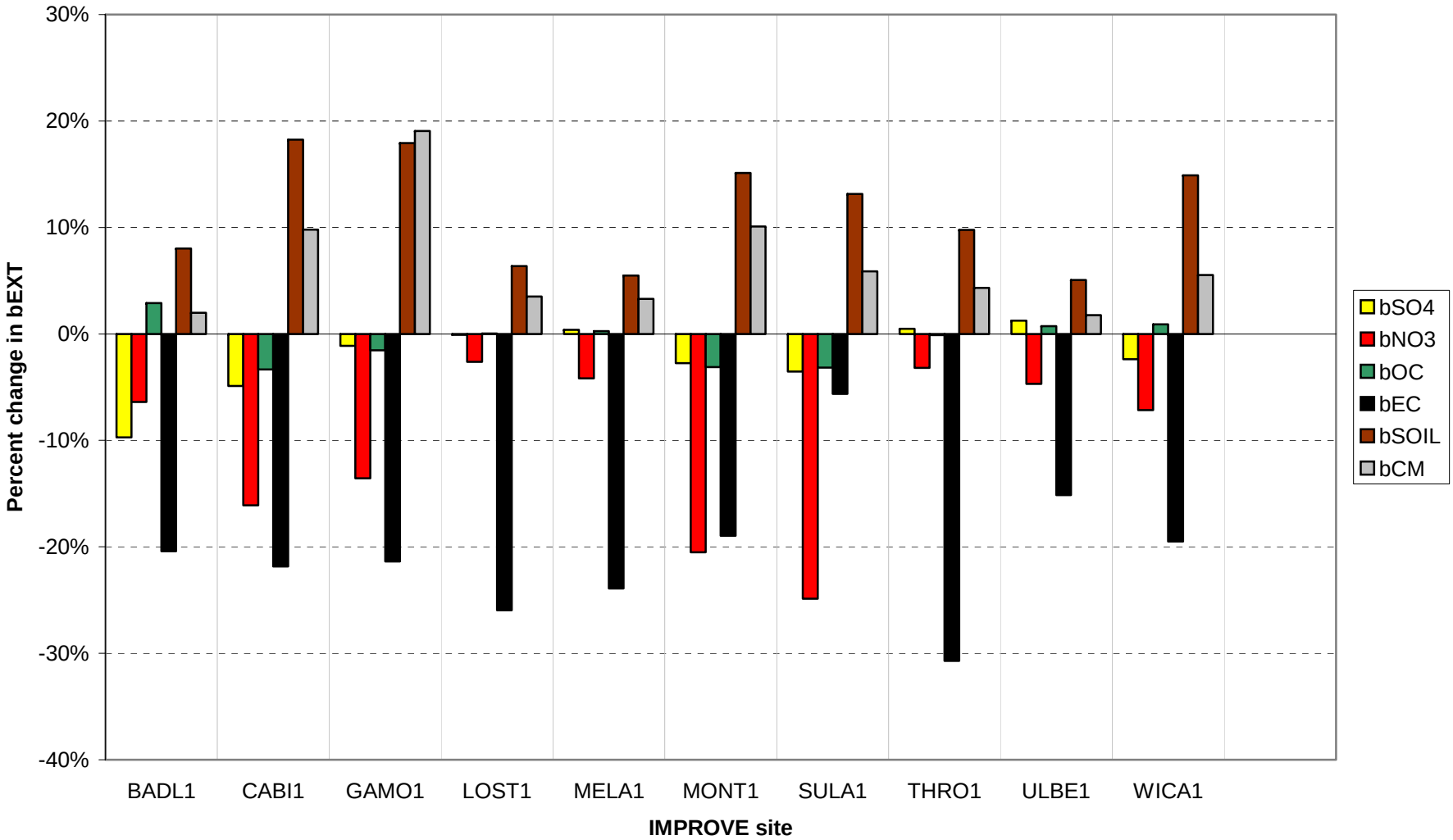


← Are these projected Soil and CM increases meaningful

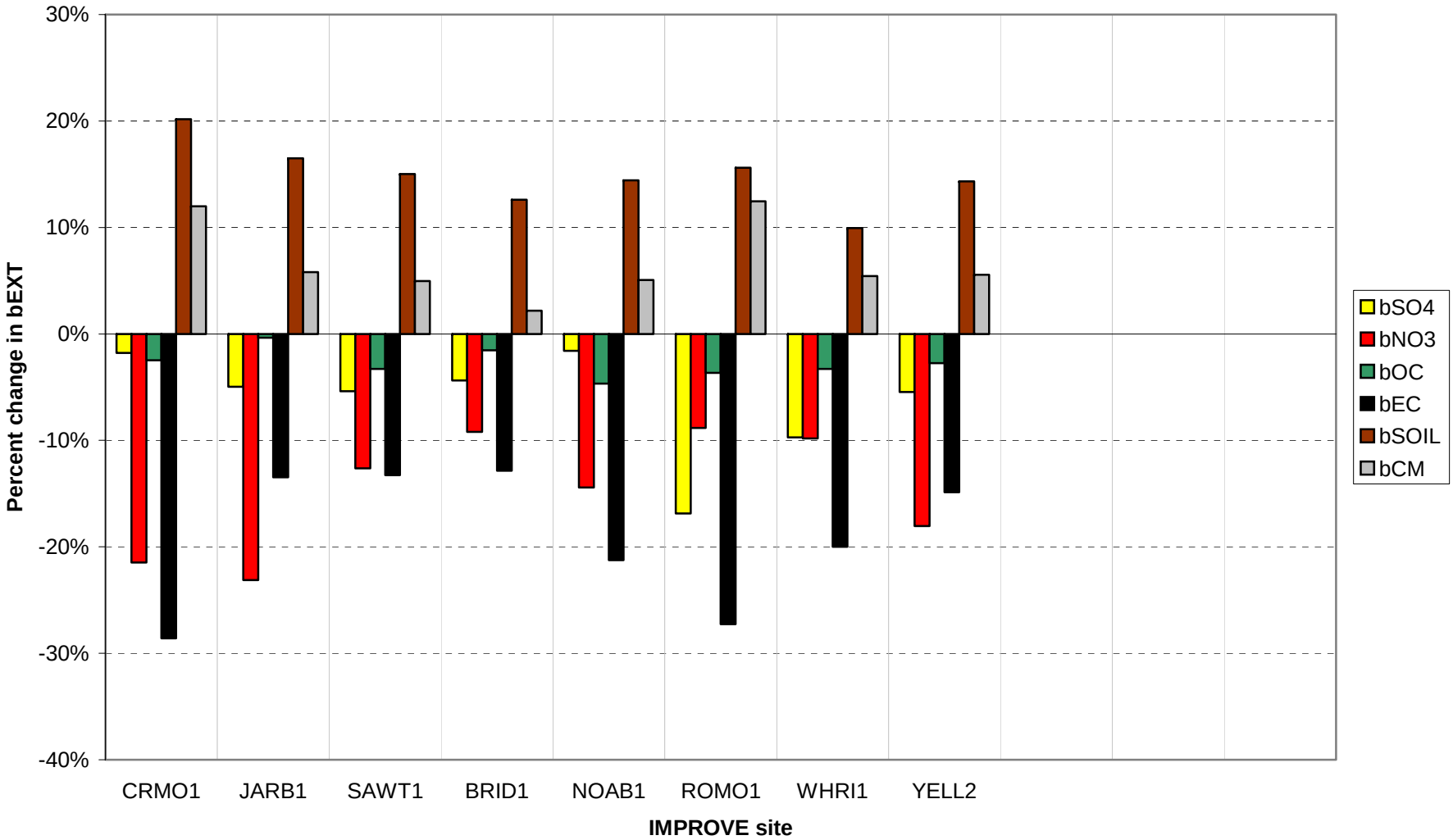
Percent change in extinction components from 2002 baseline to 2018 projected at Desert Southwest sites using base18a/plan02a RRFs



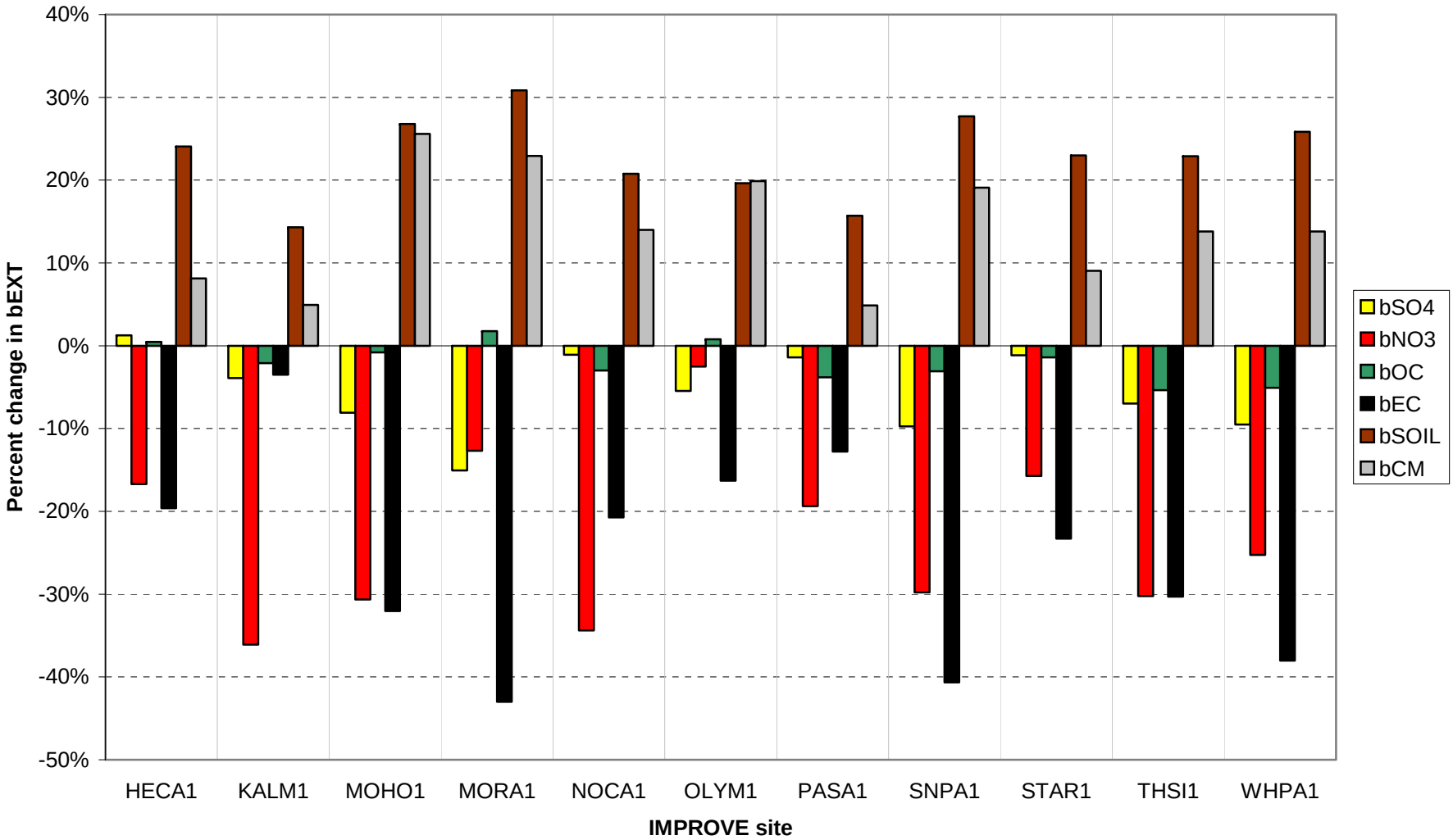
Percent change in extinction components from 2002 baseline to 2018 projected at Northern sites using base18a/plan02a RRFs



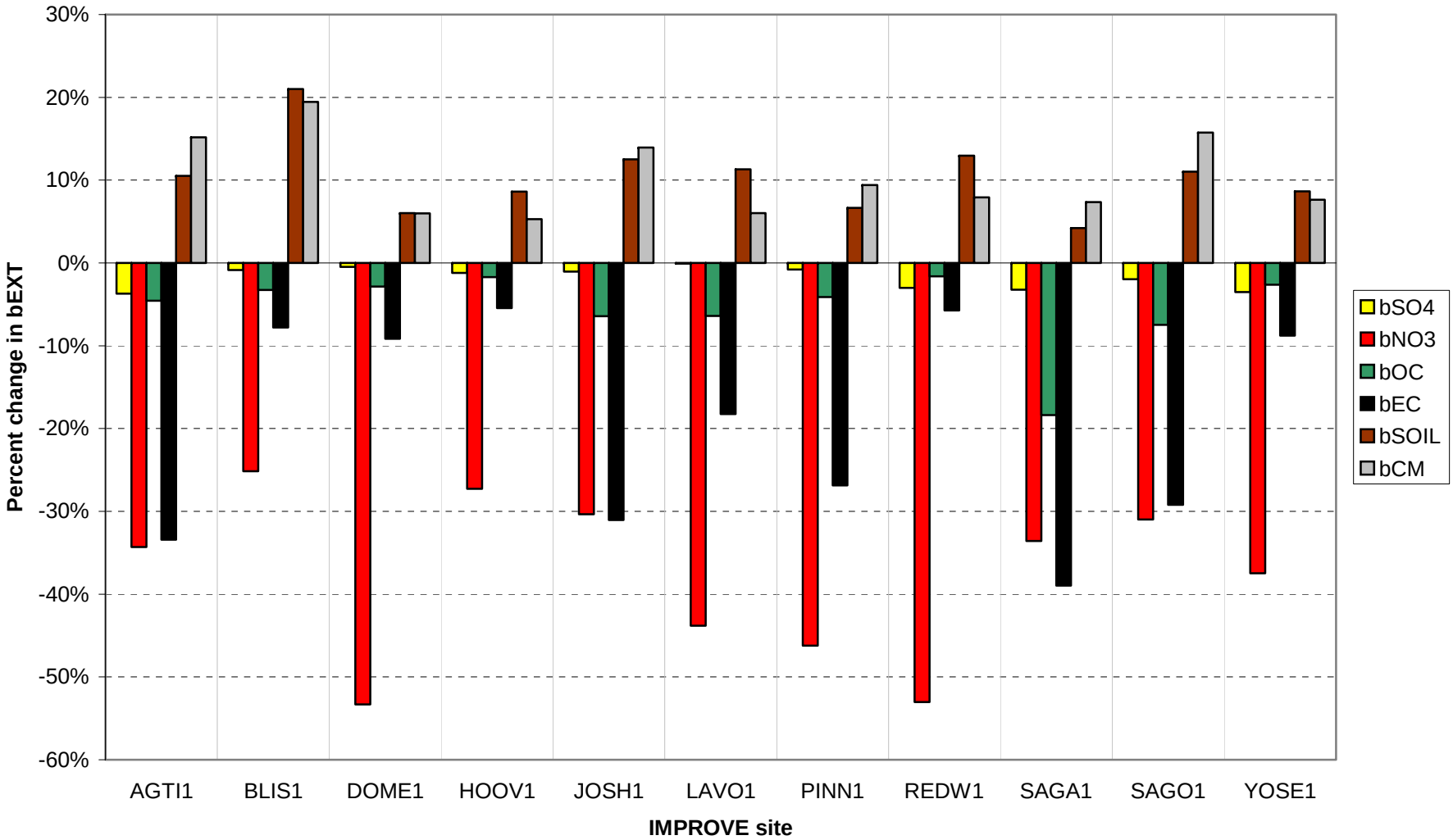
Percent change in extinction components from 2002 baseline to 2018 projected at Great Basin & Rockies sites using base18a/plan02a RRFs



Percent change in extinction components from 2002 baseline to 2018 projected at Pacific Northwest sites using base18a/plan02a RRFs



Percent change in extinction components from 2002 baseline to 2018 projected at California sites using base18a/plan02a RRFs



Next Steps: Visibility Projections

- Update/Corrections to 2018 Emissions
  - Base18b
  - Non-WRAP Mobile Sources
  - Other Corrections
- Proposed New IMPROVE Equation
  - VISTAS Analysis sees Little Effect
- Other Methods (e.g., New IMROVE equ)?
- Should we not use CM and Soil RRFs?
- Define Worst 20% Days in 2002 for IMPROVE Monitors that do not meet EPA's completeness criteria for developing RRFs (~50 sites)