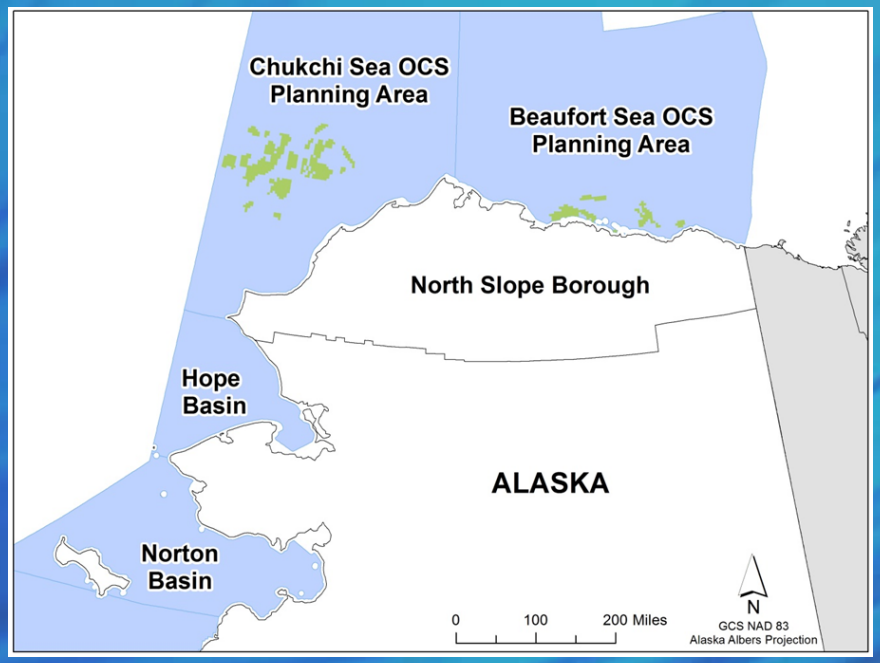
# BOEM PHOTOCHEMICAL MODELING OF OFFSHORE OIL AND GAS DEVELOPMENT IN THE ARCTIC




**Ralph Morris, Ramboll Environ**

**U.S. Canada Northern Oil and Gas Research Forum**

**October 11-13, 2017; Anchorage, Alaska**

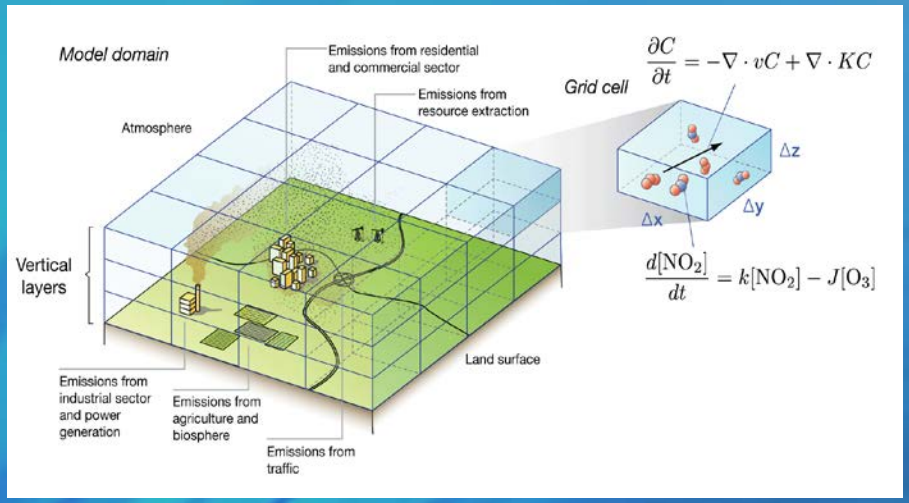
BOEM Bureau of Ocean Energy Management

ERG

RAMBOLL ENVIRON

# Today's Discussion

- Introduction
- Emissions Processing
- Model Performance Evaluation
- Air Quality Impacts
- Sea Salt Sensitivity Analysis
- Summary and Recommendations



# Regional Photochemical Grid Modeling

## Emissions → Impacts

- Baseline: Existing Sources in 2011/2012
  - Oil & Gas (O&G)
  - Other anthropogenic
  - Bio- and Geo-genic
- Future Year Case
  - Potential new OCS O&G
  - Full ULSD usage

- Criteria pollutants
  - $O_3$ and $PM_{2.5}$ NAAQS
  - CO, SO2, NO2, PM10 NAAQS
  - PSD (for informational purposes)
- AQRVs
  - Visibility
  - Acid deposition

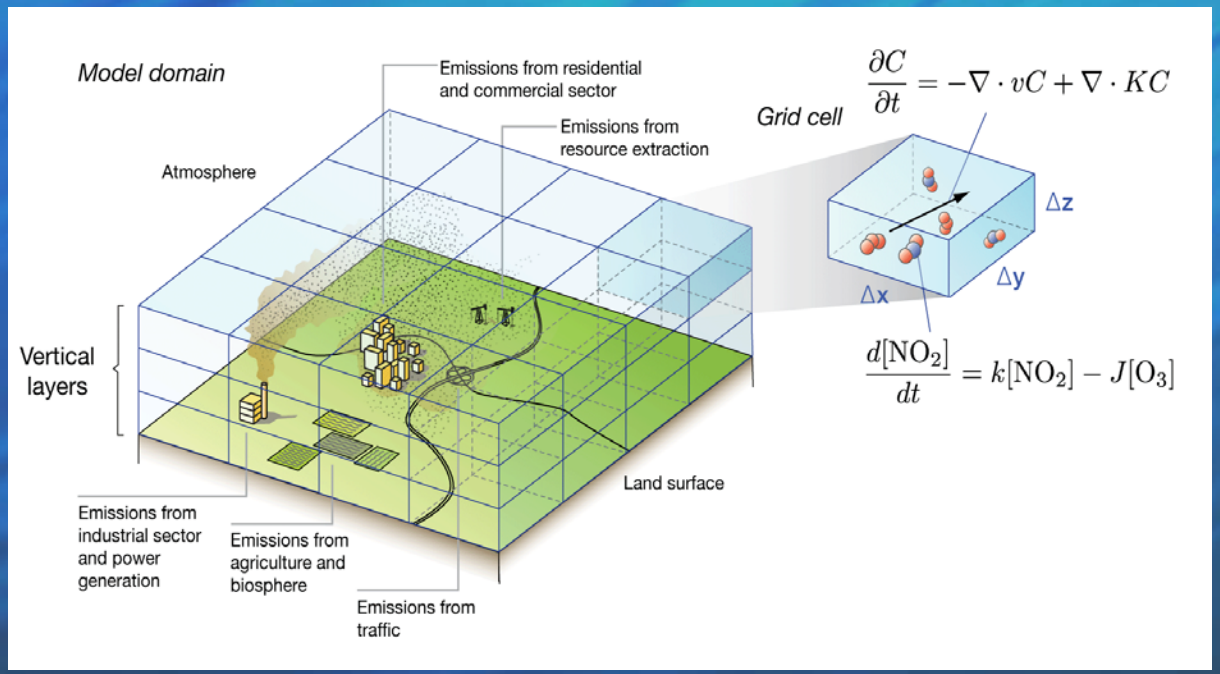
BOEM Bureau of Ocean Energy Management

ERG

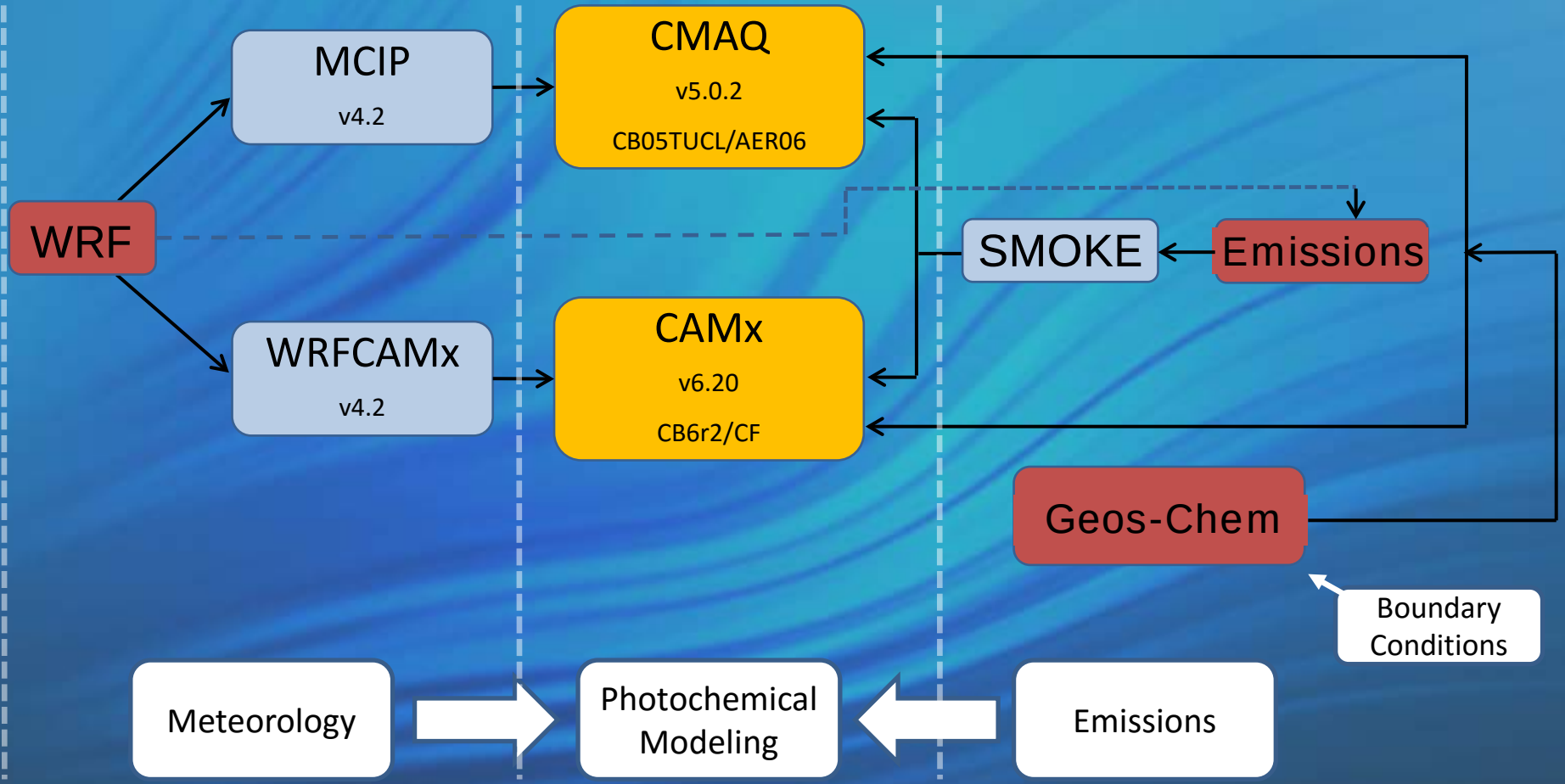
RAMBOLL ENVIRON

# Photochemical Grid Model (PGM)

- Divide modeling domain into 3-D grid cells
- Hourly gridded meteorological inputs (WRF)
- Hourly gridded and point source emission inputs
- Full-Science Chemistry



# Modeling Process



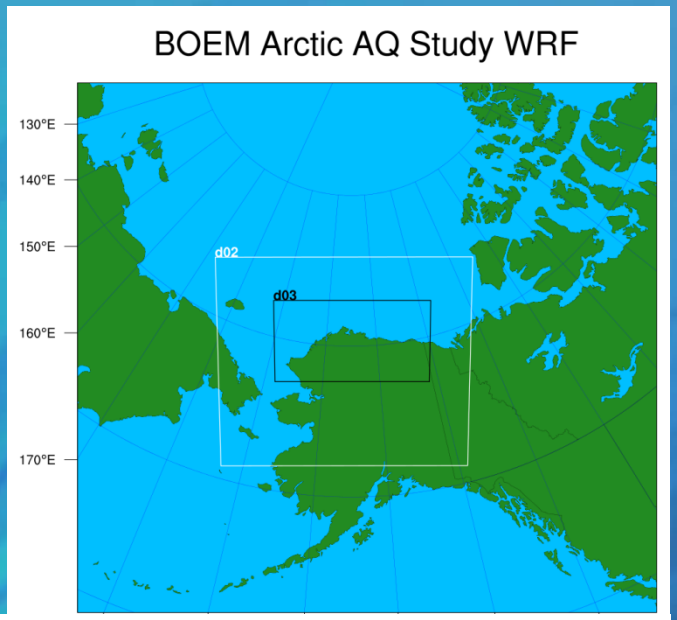

BOEM Bureau of Ocean Energy Management

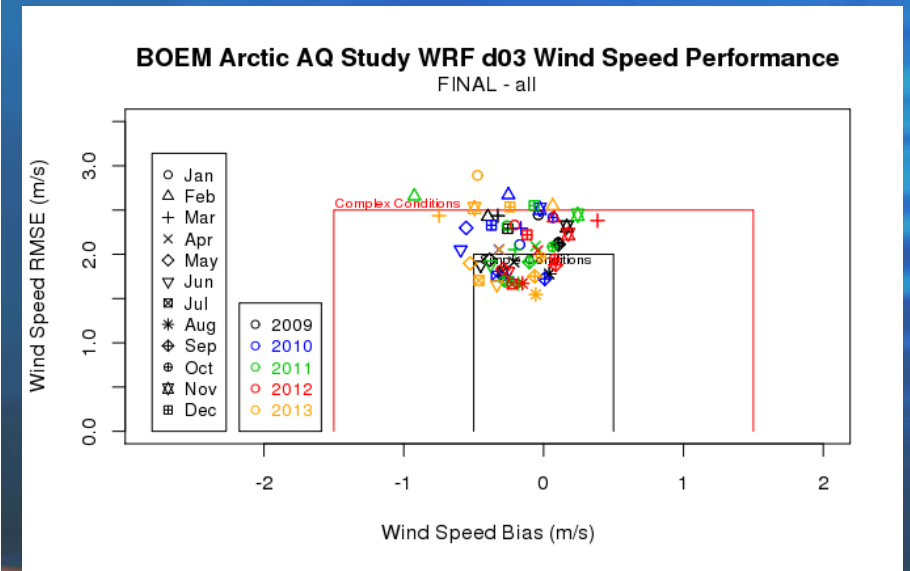
ERG

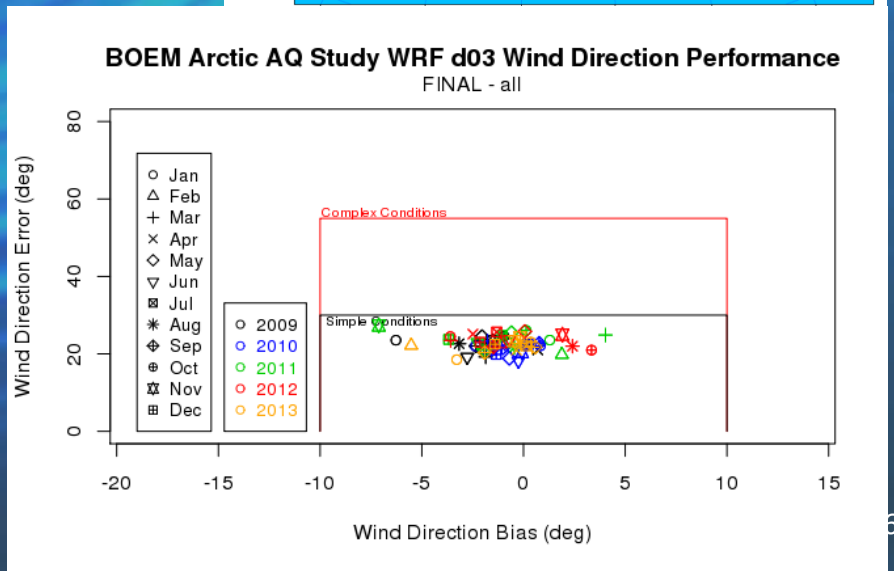
RAMBOLL ENVIRON

# WRF Meteorological Modeling

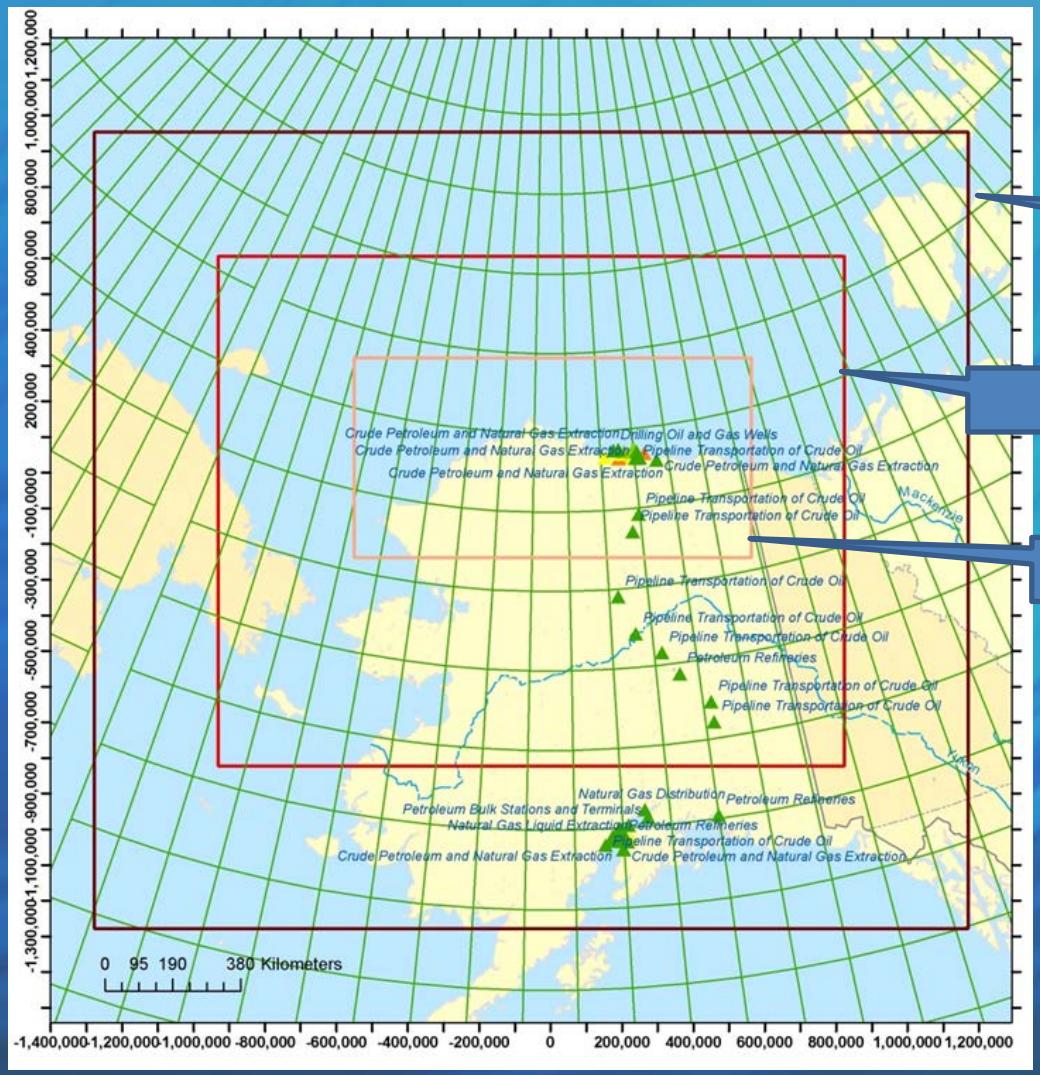
- 5-years of WRF met modeling
  - 2009-2014 (2012 selected for PGM)
  - Evaluation for WS, WD, T, RH and precipitation
  - 5 Sea Surface Temperature (SST) datasets evaluated



# 36/12/4 km PGM Domains

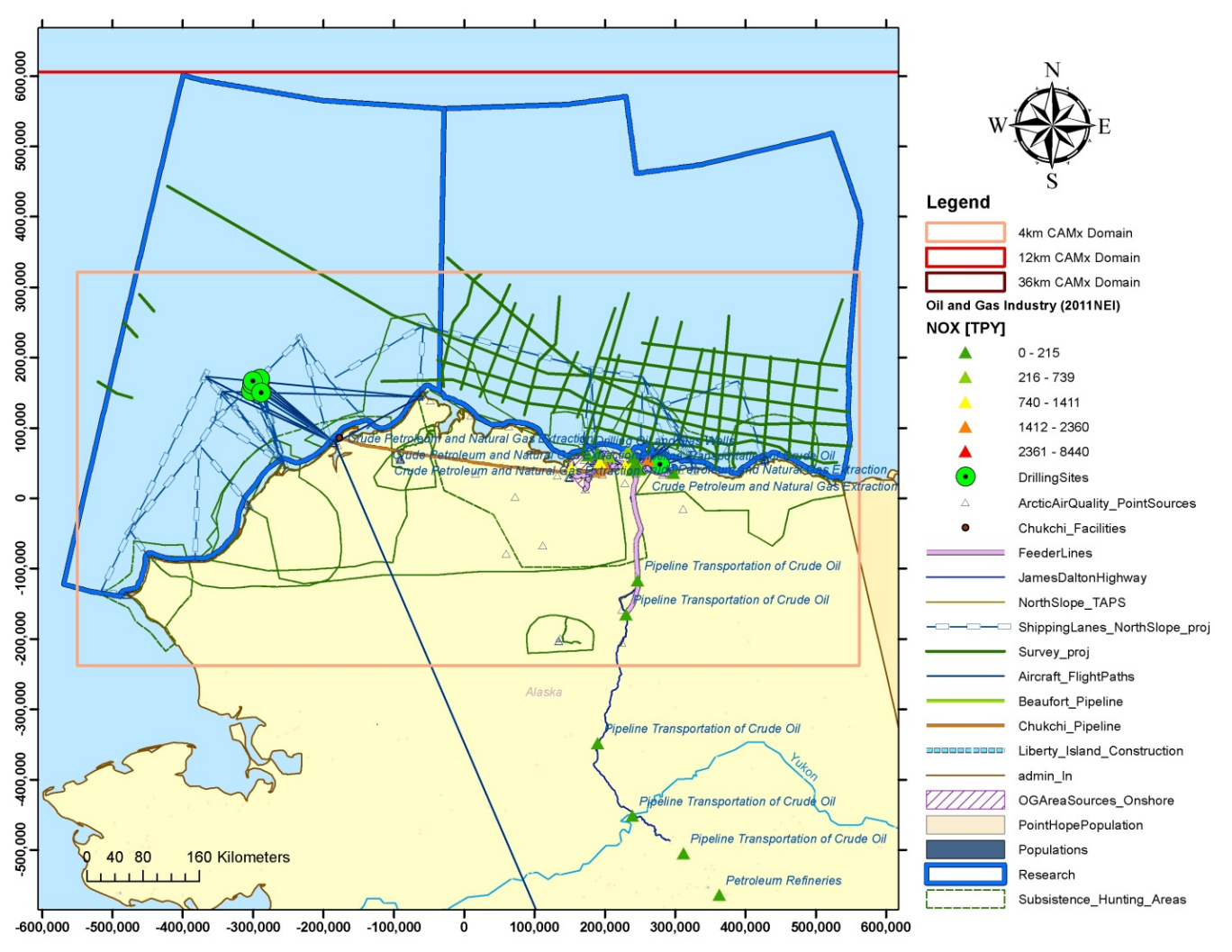



BOEM Bureau of Ocean Energy Management

ERG

RAMBOLL ENVIRON

# PGM 4 km Domain




BOEM Bureau of Ocean Energy Management

ERG

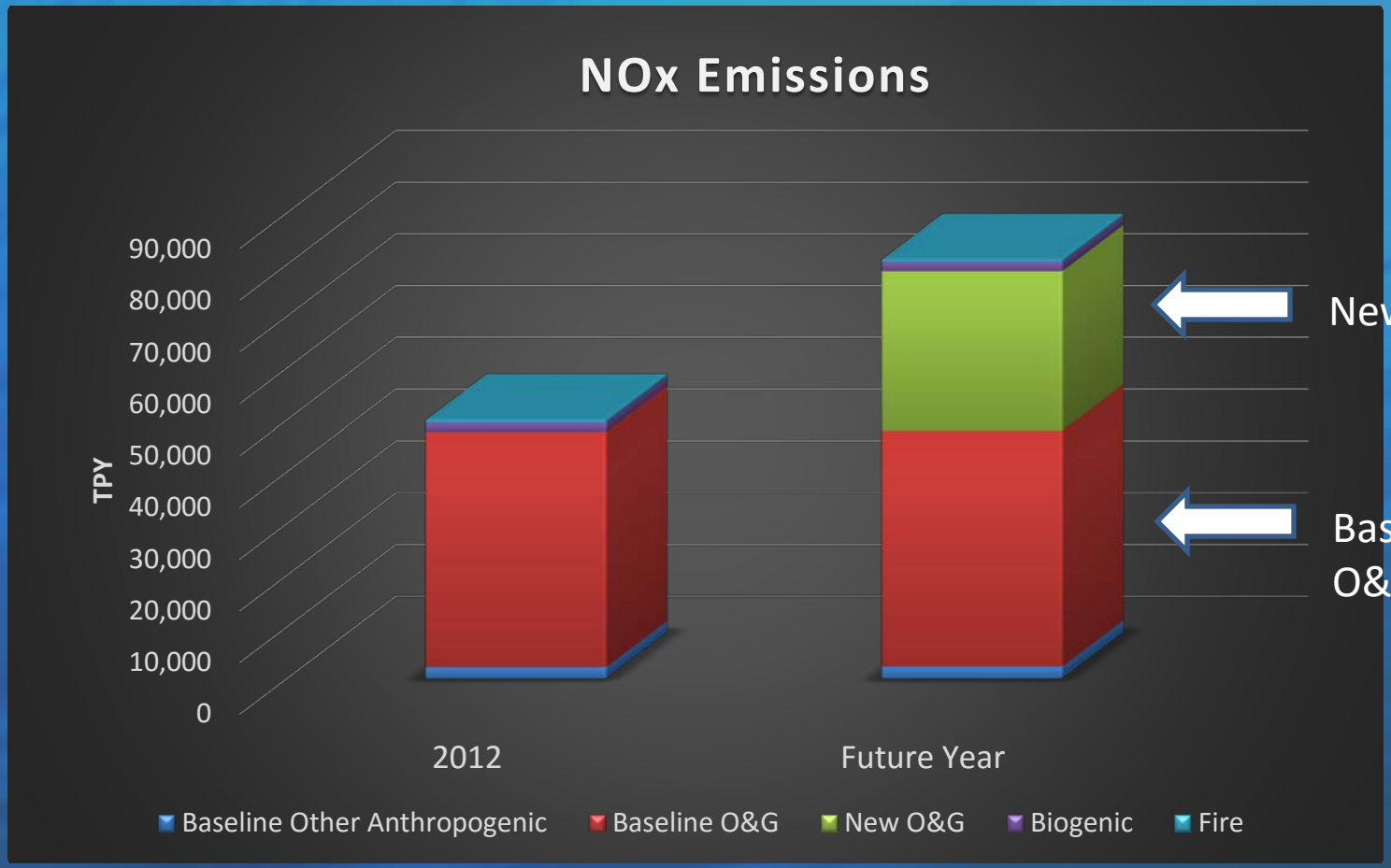
RAMBOLL ENVIRON

# Future Year Modeling Scenario

- 2012 Meteorology (for direct comparison with baseline scenario)
- Hypothetical Future Year Emissions Projections
  - Baseline (2011/2012) sources that do not change
  - Modified sources
    - Exist in baseline but have revised emissions
    - Examples: TAPS (increase), ULSD implementation (decrease)
  - New sources
    - Do not exist in baseline inventory
    - Examples: new OCS O&G, new on-shore production and support facilities

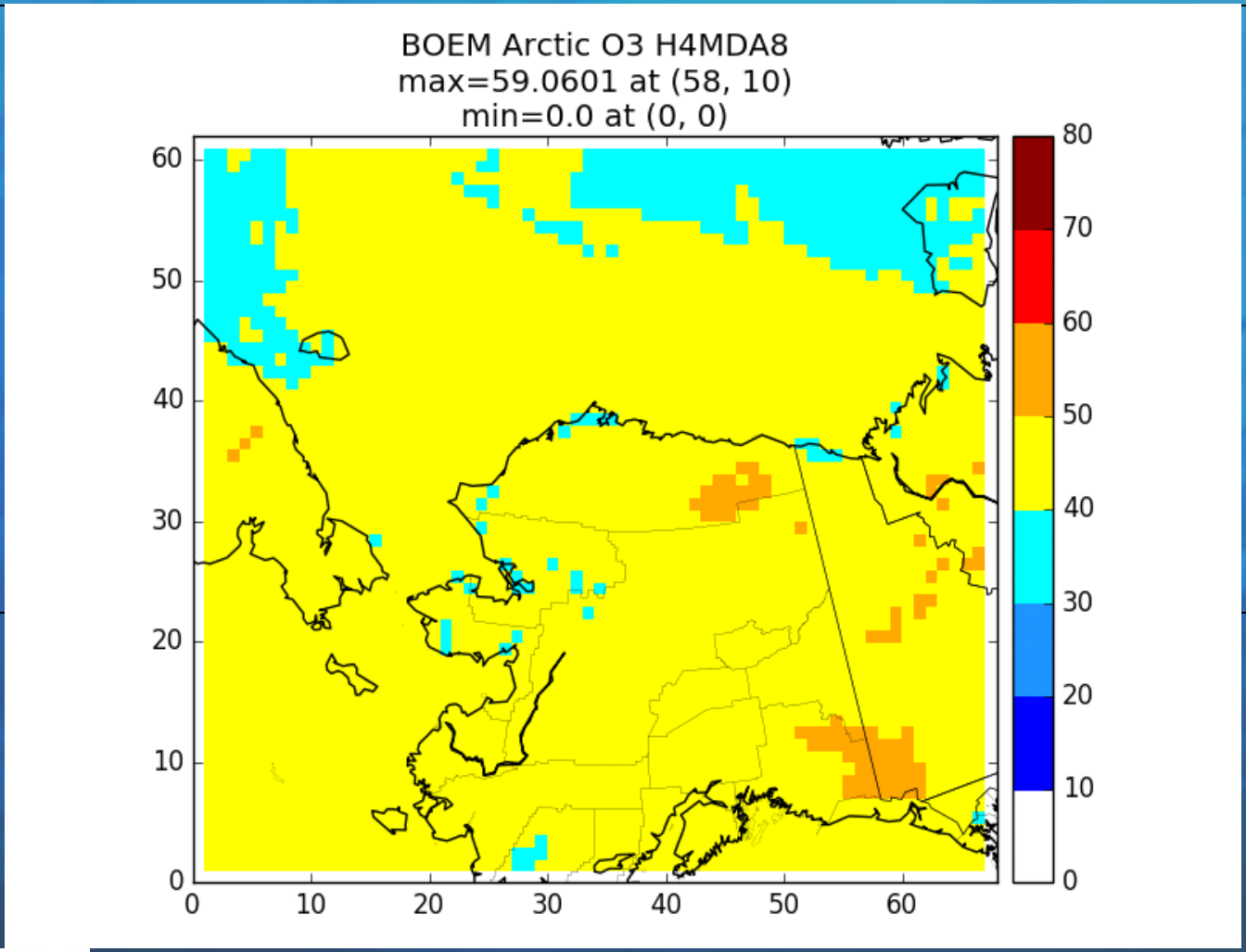
BOEM Bureau of Ocean Energy Management ERG RAMBOLL ENVIRON

# NSB NOx Emissions



# 4th High MDA8 Ozone (ppb)

## 2015 NAAQS = 70 ppb

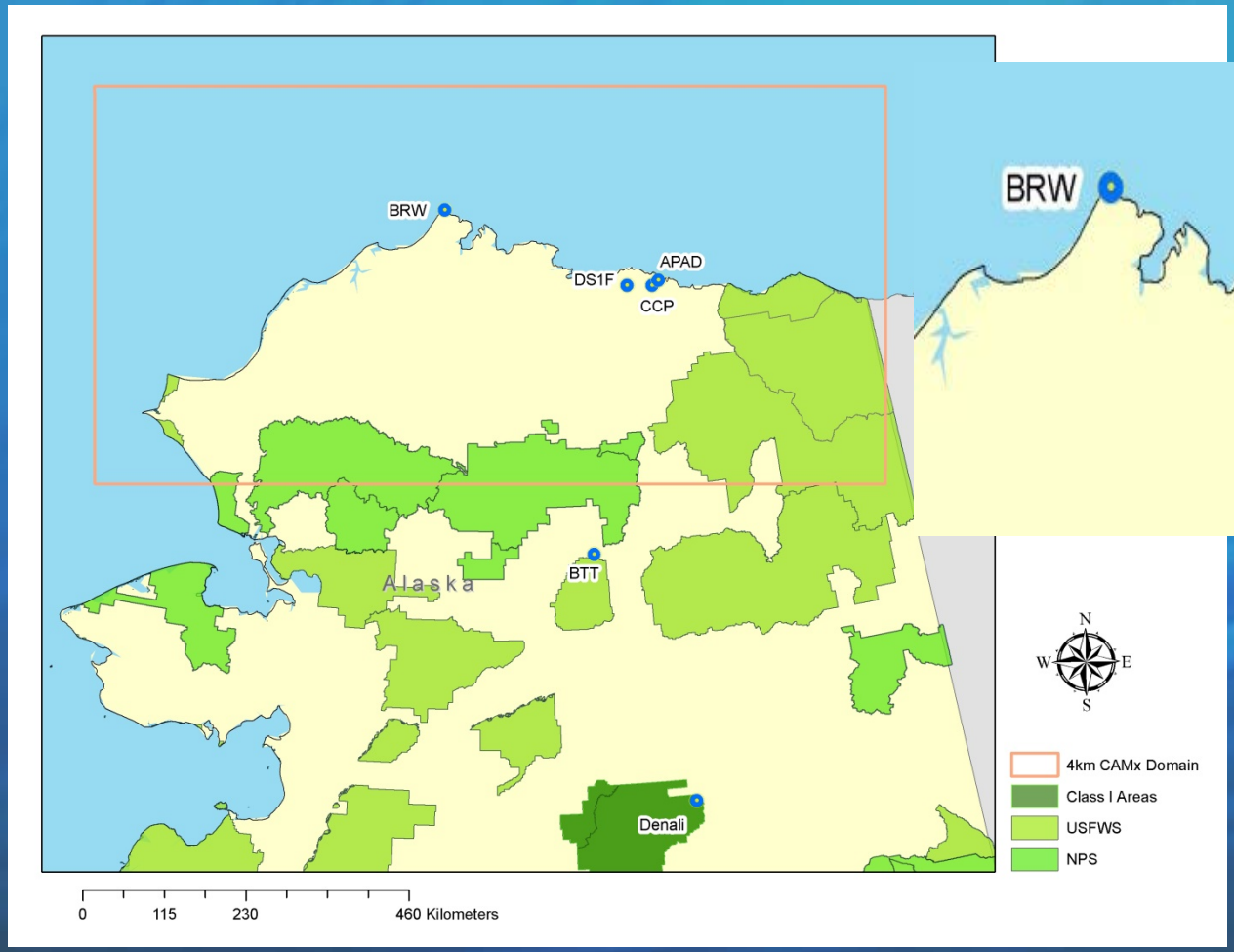



BOEM Bureau of Ocean Energy Management

ERG

RAMBOLL ENVIRON

# Model Performance Evaluation at Ambient Monitoring Sites



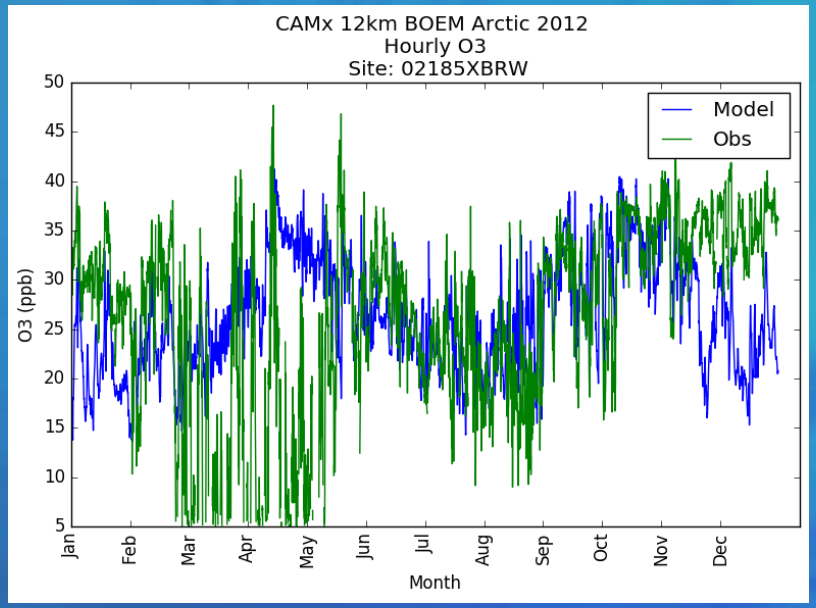


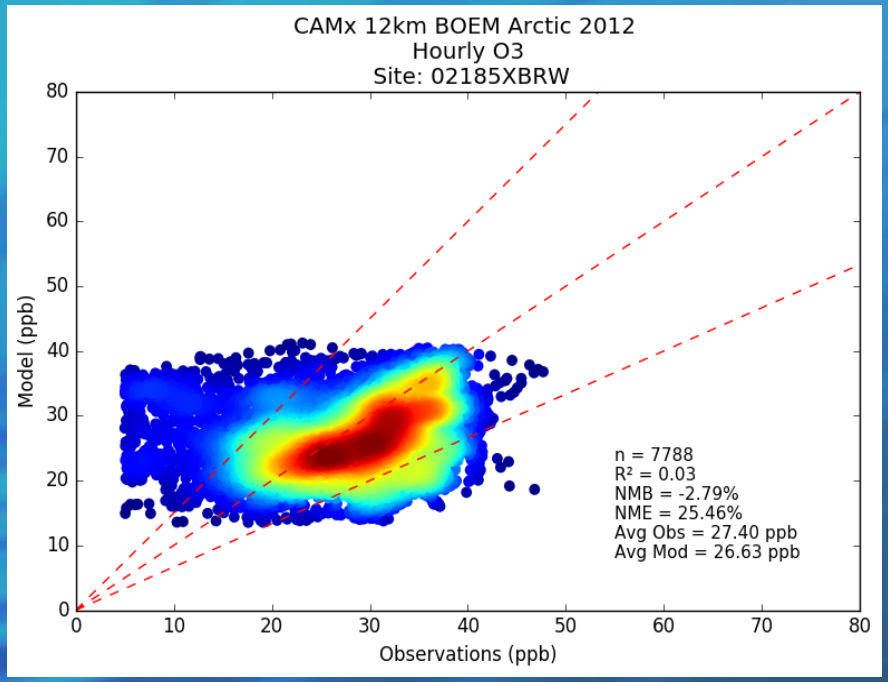
BOEM Bureau of Ocean Energy Management

ERG

RAMBOLL ENVIRON

# Barrow Hourly Ozone




| EPA Ozone Performance Goals | | CAMx Barrow |
|---|---|---|
| NMB | ≤± 15% | -2.8% |
| NME | ≤35% | 25.5% |

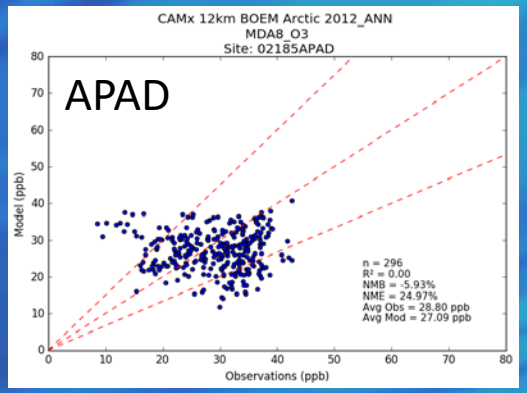
BOEM Bureau of Ocean Energy Management

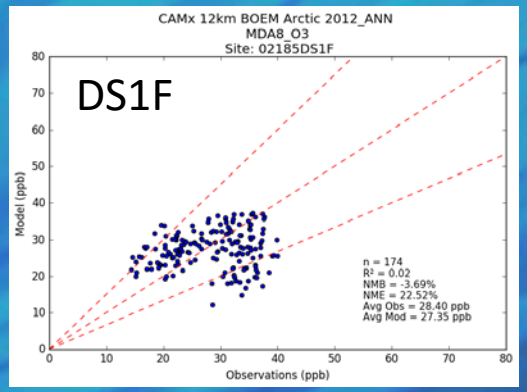
ERG

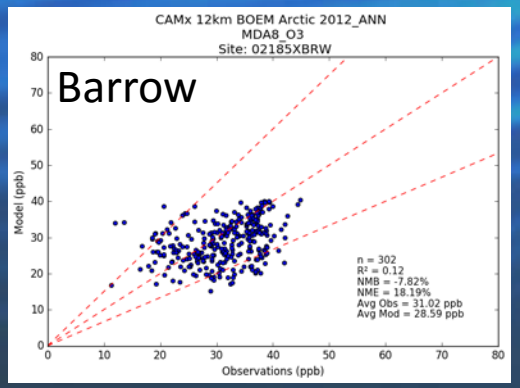
RAMBOLL ENVIRON

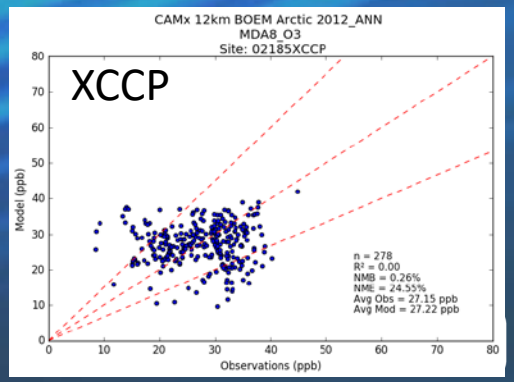
# NSB Daily Max 8-Hour Ozone

| EPA Ozone Performance Goals | | CAMx APAD | CAMx DS1F | CAMx Barrow | CAMx XCCP |
|---|---|---|---|---|---|
| NMB | ≤± 15% | -5.9% | -3.7% | -7.8% | 0.3% |
| NME | ≤35% | 25.0% | 22.5% | 18.2% | 24.6% |



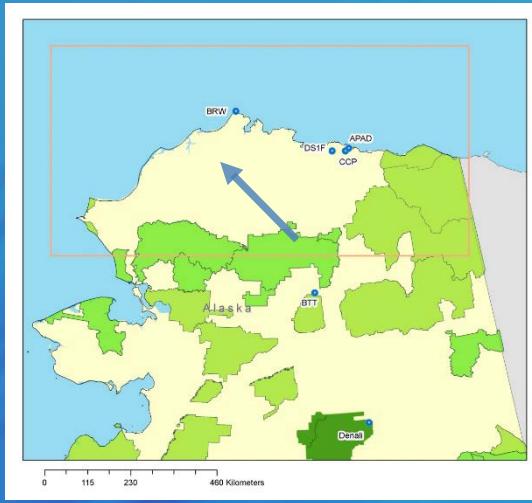



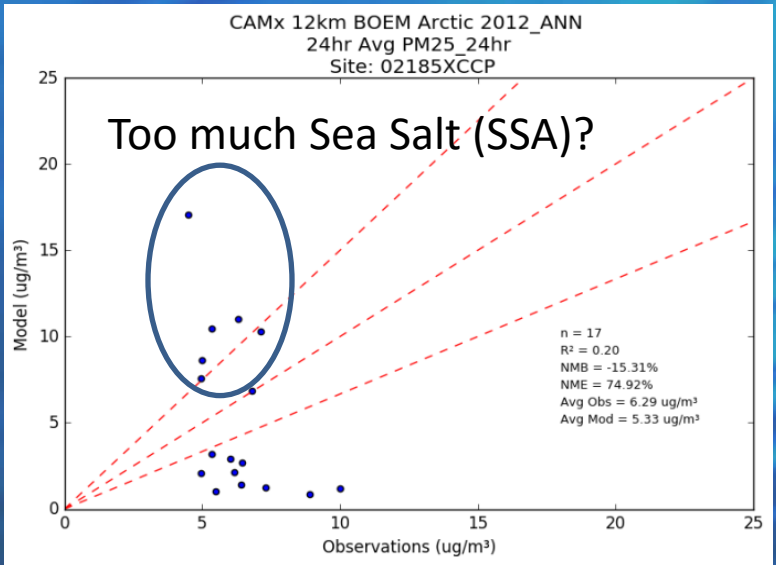

BOEM Bureau of Ocean Energy Management

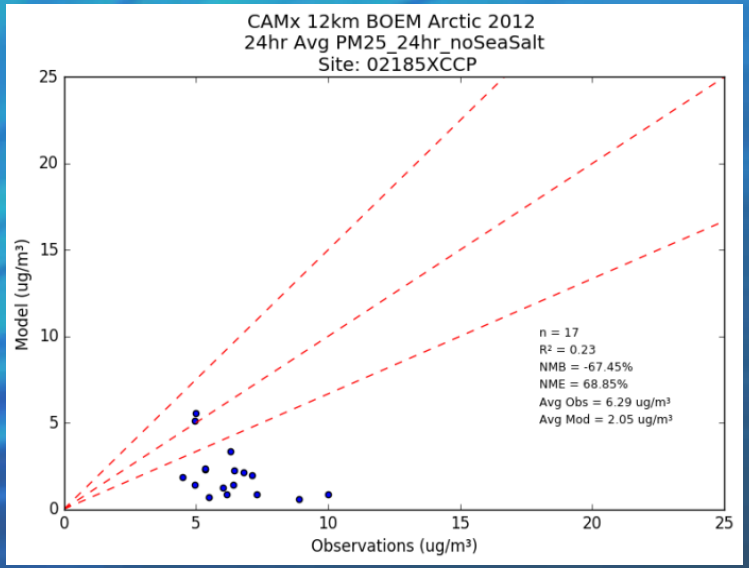
ENVIRON

# 24-Hr PM2.5 at CCP (BAM)




**No SSA Case (remove all NA and PCL)**



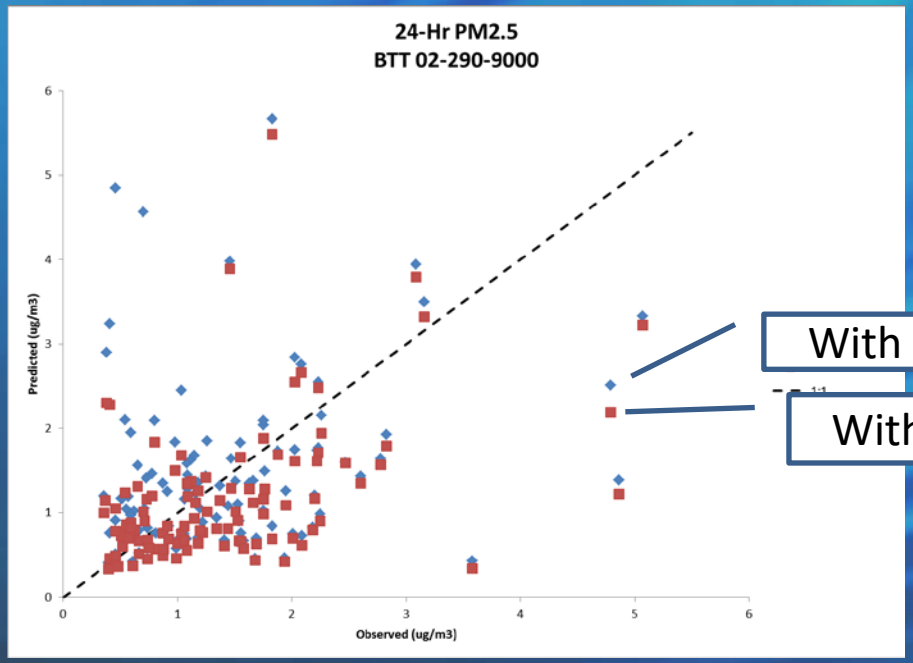

BOEM Bureau of Ocean Energy Management

ERG

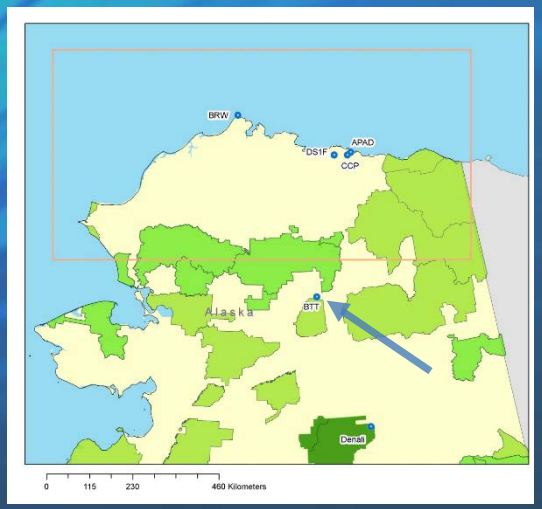
RAMBOLL ENVIRON

# PM2.5 Bettles (BTL)

| PM Performance Goals and Criteria | Goals Good | Criteria Average | CAMx w/ SSA | CAMx w/o SSA |
|---|---|---|---|---|
| NMB | ≤±30% | ≤±60% | 3.9% | -15.7% |
| NME | ≤50% | ≤75% | 55.1% | 46.2% |




Good to Average PM2.5 model performance at Bettles

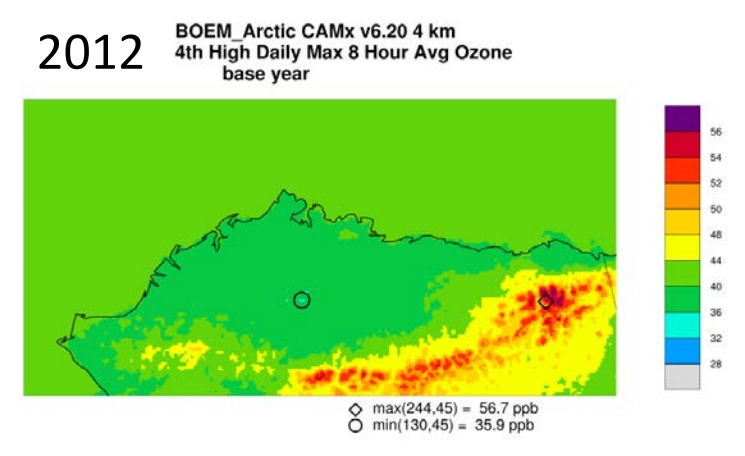


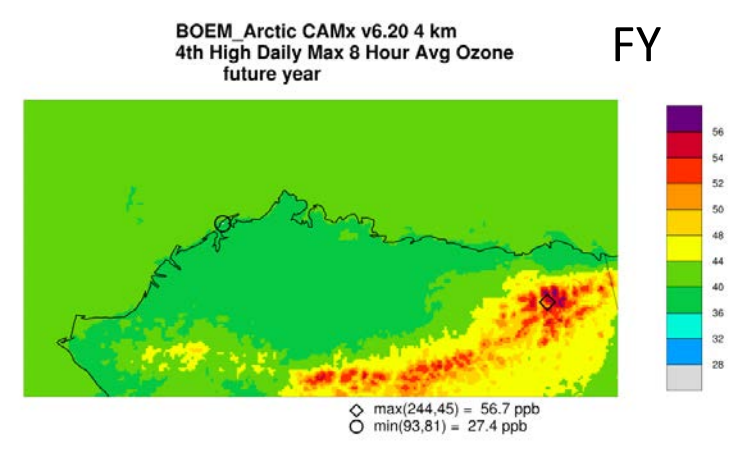

BOEM Bureau of Ocean Energy Management

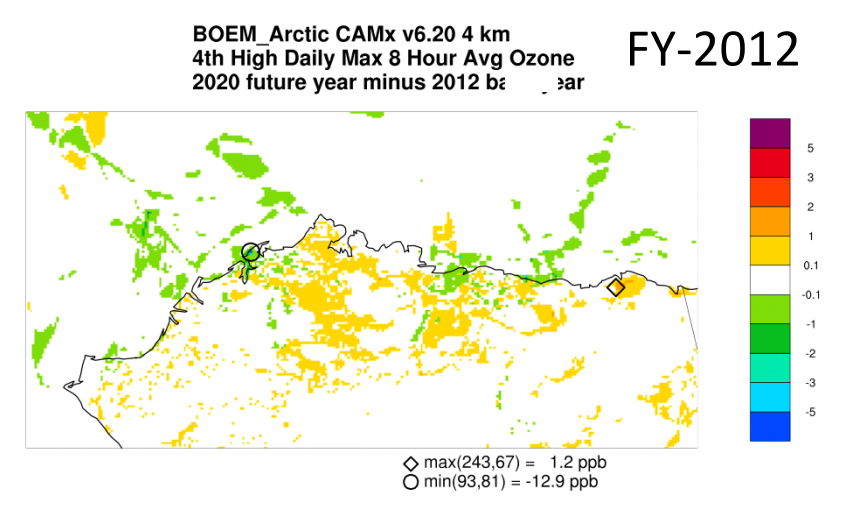
ERG

RAMBOLL ENVIRON

# Change in Ozone Design Values




- O3 increases < 1.2 ppb in future year scenario
- Decreases → O3 formation is VOC limited

BOEM Bureau of Ocean Energy Management

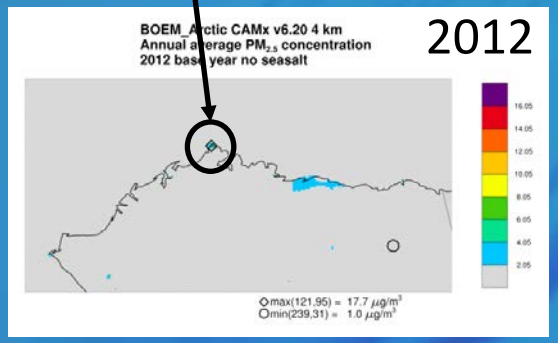
ERG

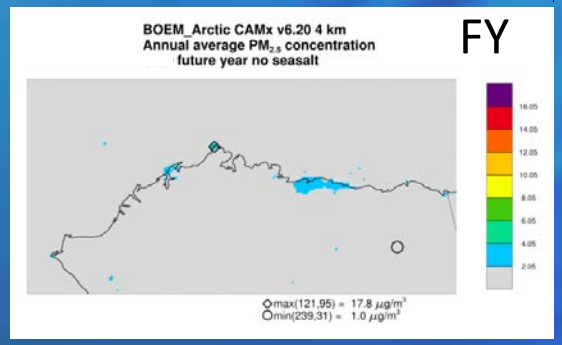
RAMBOLL ENVIRON

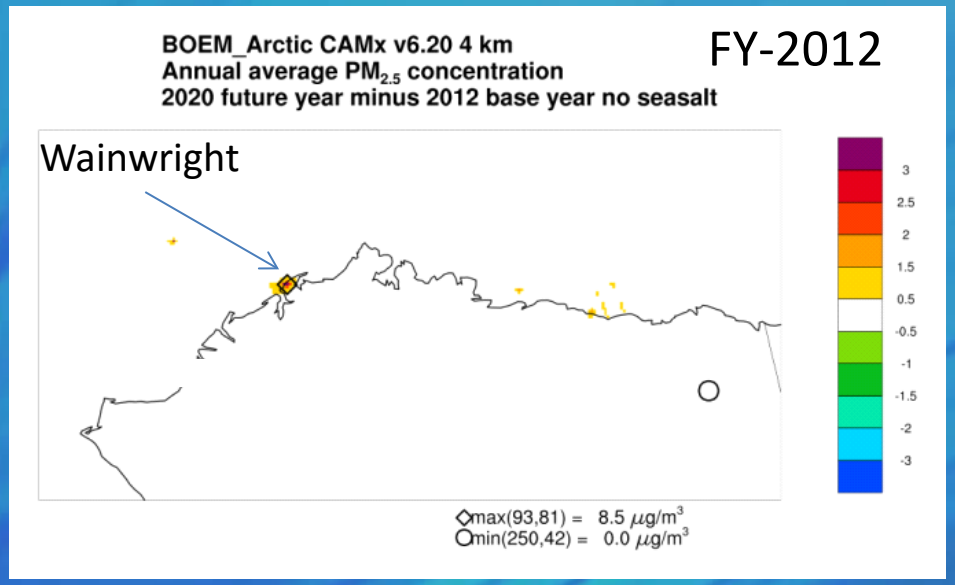
# Annual PM2.5

Road dust in Barrow

"Sea Salt" (NA and PCL) Removed



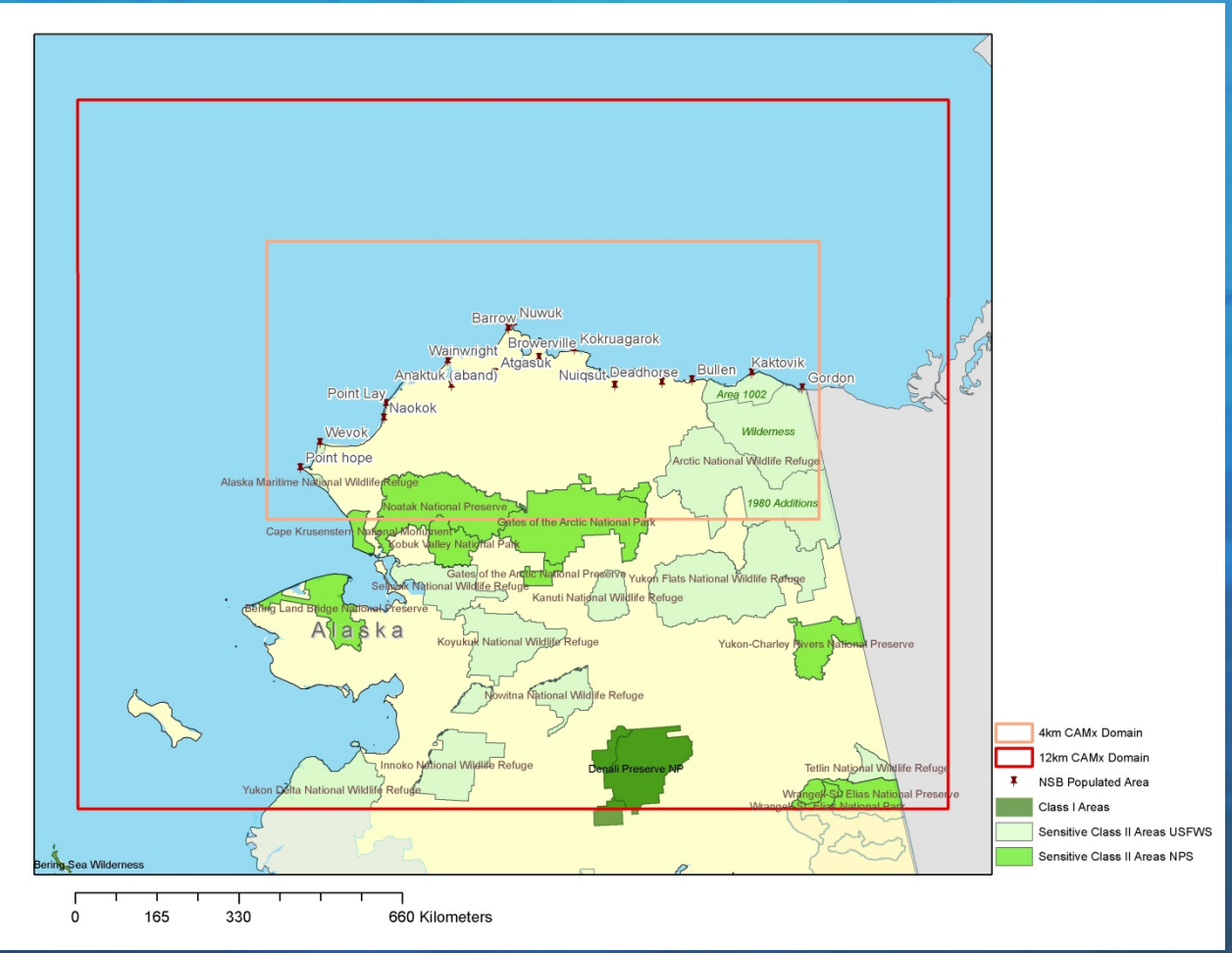

- Values < NAAQS (12 µg/m³) except in Barrow
- 8.5 µg/m³ increase near Wainwright associated with new processing facility

BOEM Bureau of Ocean Energy Management

ERG

RAMBOLL ENVIRON

# Class I and Selected Class II Areas




BOEM Bureau of Ocean Energy Management

ERG

RAMBOLL ENVIRON

# Prevention of Significant Deterioration (PSD) Increments

- PSD Pollutants: NO2, PM10, PM2.5 and SO2
- No exceedances of PSD Class I or II concentration increments at any Class I (e.g., Denali National Park) or Class II (e.g., Gates of the Arctic NP) areas due to New OCS O&G and Related Sources
  - Class I Area Max = 0.06 µg/m$^3$ PM10 at Denali National Preserve
    - 3% of the 2.0 µg/m$^3$ PSD Class I area Increment
  - Class II Area Max = 2.8 µg/m$^3$ PM10 at ANWR Area 1002
    - 31% of the 9.0 µg/m$^3$ PSD Class II area Increment
- PSD analysis for informational purposes only, not a formal PSD increment Consumption analysis

BOEM Bureau of Ocean Energy Management ERG RAMBOLL ENVIRON

# Incremental Visibility Impacts* -- New OCS O&G and Related Sources

- CAA offers Class I areas special visibility protection
- Visibility impacts compared against natural background using decivew (dv)
- Overstated SSA will overstate O&G visibility impacts from NOx emissions
  - $NaNO_3$
- No visibility issues at Class I Areas (e.g., Denali)

| Area | Max Δdv | 8th High Δdv | No. Days >1.0 | No. Days >0.5 |
|---|---|---|---|---|
| **Class II Areas** | | | | |
| Alaska Maritime NWR | 7.4 | 6.0 | 160 | 224 |
| ANWR 1980 Additions | 4.9 | 2.3 | 39 | 66 |
| ANWR Area 1002 | 11.5 | 10.3 | 146 | 193 |
| ANWR Wilderness | 10.6 | 5.7 | 95 | 158 |
| Cape Krusenstern NM | 3.1 | 1.4 | 13 | 37 |
| Gates of the Arctic NP | 3.0 | 2.2 | 24 | 48 |
| Gates of the Arctic Npreserve | 2.5 | 1.5 | 13 | 26 |
| Kobuk Valley NP | 12.0 | 0.8 | 4 | 21 |
| Noatak Npreserve | 2.9 | 1.8 | 24 | 55 |
| Yukon Flats NWR | 0.0 | 0.0 | 0 | 0 |

*Results in coastal areas highly sensitive to uncertainties in sea salt (SSA) emissions

BOEM Bureau of Ocean Energy Management ERG RAMBOLL ENVIRON

# Sulfur and Nitrogen Deposition Impact Thresholds

- Sulfur (S) and Nitrogen (N) impacts due to New O&G typically compared against Deposition Analysis Thresholds (DATs)
  - Different DATs for West and East of the Mississippi River
  - No DATs defined for Alaska (Some Critical Loads Defined)
- For Class I Areas:
  - Maximum N deposition is 0.0016 kg/ha/yr that is below the DATs
  - Maximum S deposition is 0.0002 kg/ha/yr that is below the DATs
- For Selected Class II Areas:
  - Nitrogen DAT exceeded (maximum of 0.137 kg/ha/yr at ANWR Area 1002)
  - Sulfur DAT barely exceeded at two Selected Class II Areas (maximum of 0.011 AT Alaska Maritime NWR)

| | Deposition Analysis Threshold (kg/ha/yr) | |
|---|---|---|
| Lower 48 States | Nitrogen | Sulfur |
| East | 0.010 | 0.010 |
| West | 0.005 | 0.005 |

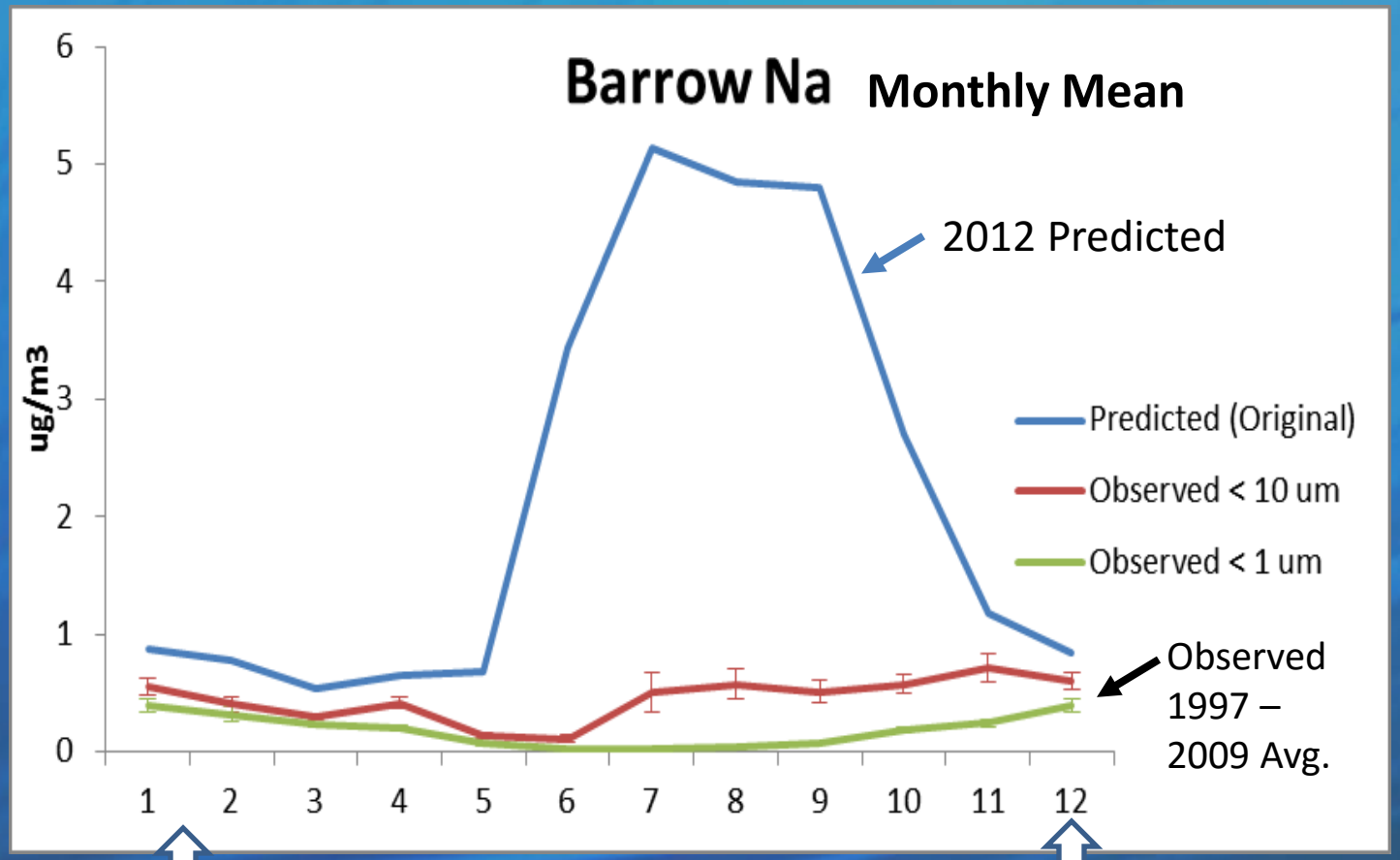
BOEM Bureau of Ocean Energy Management

ERG

RAMBOLL ENVIRON

# SEA SALT SENSITIVITY ANALYSIS

# Apparent SSA Over-Prediction at Barrow based on Historical Obs



# Sea Salt (NaCl) Over Prediction

- Substitution of $Cl^-$ by $NO_3^-$ may result in over prediction of:
  - Particulate $NO_3$ ($NaNO_3$)
  - Total nitrogen deposition
  - Visibility degradation
- Over-prediction of total $PM_{2.5}$ mass due to OCS O&G and related sources
- Sulfate may also be over predicted

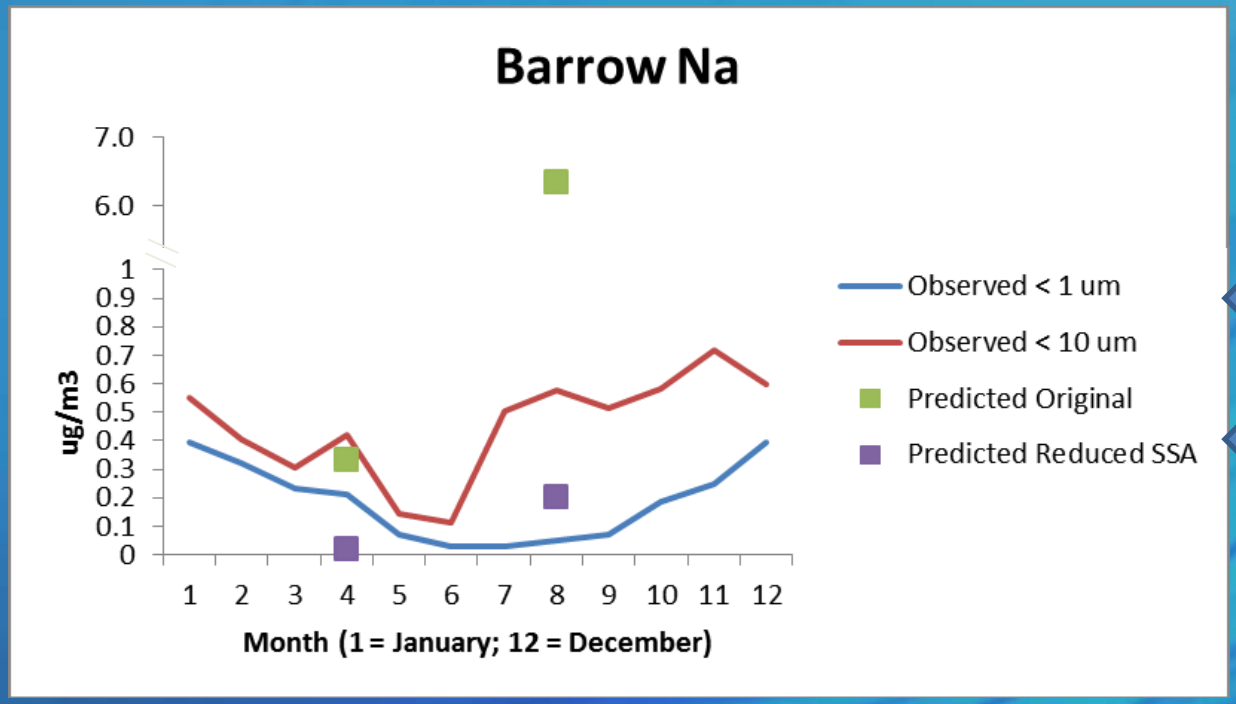
BOEM Bureau of Ocean Energy Management ERG RAMBOLL ENVIRON

# SSA Sensitivity Runs

- Update Sea Salt emissions processor using latest literature:
  - Account for salinity, size distribution, RH, SST, revised surf zone
- Ran two 10-day periods with new SSA emissions (3 day spin-up; 7 day analysis)
- April and August test periods representative of spring and winter conditions
- Large reduction in predicted Na and Cl due to reduced SSA emissions
  - Large reduction in NaNO3 PM2.5 due to O&G NOx emissions
  - Reduces PM2.5 and visibility impairment due to New OCS O&G sources

BOEM Bureau of Ocean Energy Management ERG RAMBOLL ENVIRON

# SSA Sensitivity Runs




Obs. Monthly avg. 1997-2009

Predicted PNA avg. for 7-day test periods

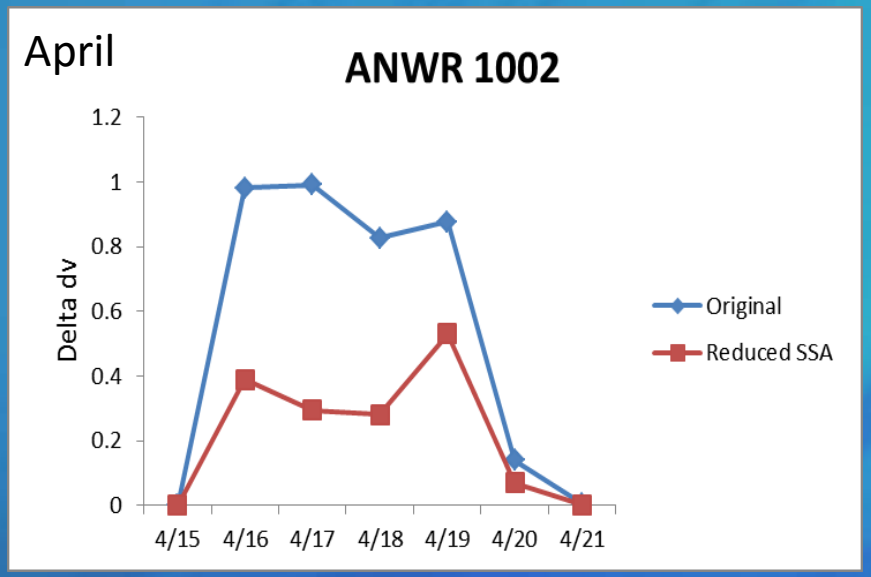
- Reduced SSA predictions eliminate high bias in summer
- Original predicted Na in April due to ice-free patches as diagnosed by WRF
- Under prediction in April may be due to missing sources of SSA (ice flowers; blowing snow); see Huang and Jaeglé (2016)

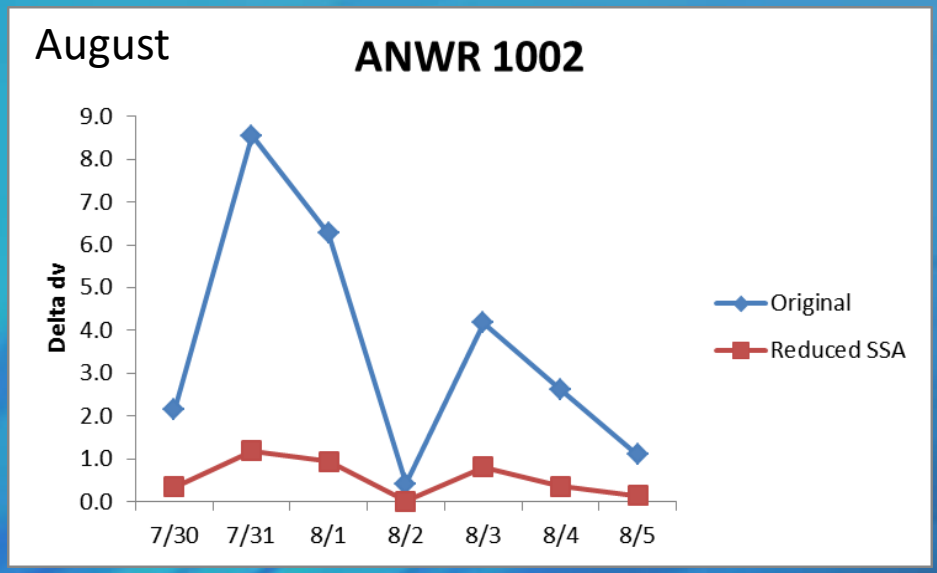
BOEM Bureau of Ocean Energy Management

ERG

RAMBOLL ENVIRON

# SSA Sensitivity: Visibility Impacts Delta dv from New O&G Sources




- Impacts reduced due to PM2.5 NO3 reduction
- Impact still > 1 dv on at least some days
- Visibility  impacts at Gates of the Arctic and Denali all less than 0.02 dv during test periods

BOEM Bureau of Ocean Energy Management

ERG

RAMBOLL ENVIRON

# Summary

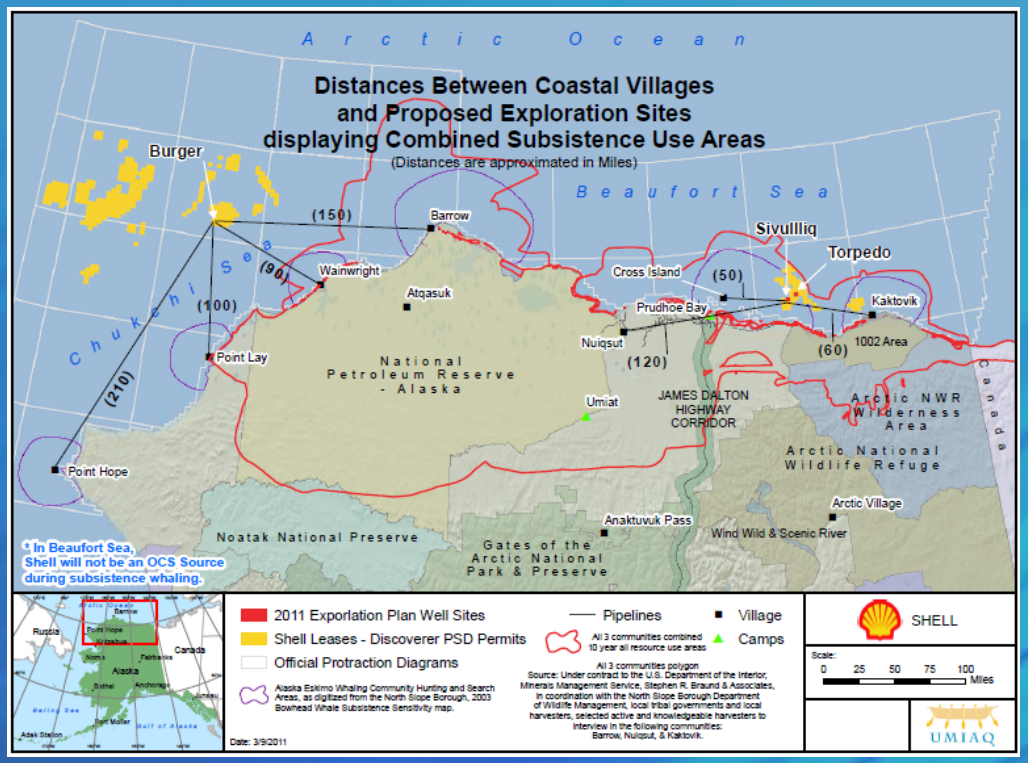
- Hypothetical future year scenario analyzed here represents aggressive expansion of OCS O&G to support analysis of conservatively-high emission levels
  - Total O&G NOx emissions increase by 167%, PM2.5 by 217%, SO2 by 273%, and VOC by 177% in NSB and adjacent waters
- Model performance reasonable aside from sea salt issues but data are very limited
- $NO_3^-$ neutralization is key modeling uncertainty issue
- Visibility impacts from new sources likely exceed 1 dv threshold in coastal Class II areas; impacts further inland are smaller but may exceed 0.5 or 1.0 dv in some locations (but not at Class I Areas)
- N and S deposition analysis suffers from lack of appropriate Alaska benchmarks for comparison
- $O_3$ << NAAQS
- PM: local impacts possible near major new facilities but regional PM difficult to assess along coast due to sea salt uncertainties; road dust impacts may be significant
- PSD increments below Class I/II levels

BOEM Bureau of Ocean Energy Management ERG RAMBOLL ENVIRON

# Potential Recommendations

- Speciated PM monitoring data representative of North Slope communities and nearby selected Class II areas would be valuable
- Improved algorithms to account for winter/spring SSA emissions (ice flowers, blowing snow, etc.)
- Better understand and implement ozone scavenging chemistry that occurs in coastal areas in the spring
- Analyze and quantify $NH_4$ sources
- Derive Critical Load values and suggested Deposition Analysis Thresholds for use in Alaska
- Establish Acid Neutralizing Capacity values for freshwater bodies in Alaska
- Evaluate impacts of current climate trends (e.g., reduced sea ice) on future air quality impacts

# QUESTIONS




## Acknowledgements


**Ramboll Environ: Till Stoeckenius, Jaegun Jung, Bonyoung Koo, Tejas Shah**

**ERG: Paula Fields, Bebhinn Do**

**BOEM: Heather Crowley**


Source:
http://www.epa.gov/region10/pdf/permits/shell/discoverer_supplemental_statement_of_basis_chukchi_and_beaufort_air_permits_070111.pdf

BOEM Bureau of Ocean Energy Management

ERG

RAMBOLL ENVIRON