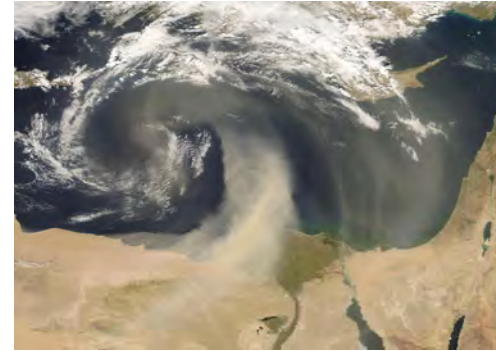
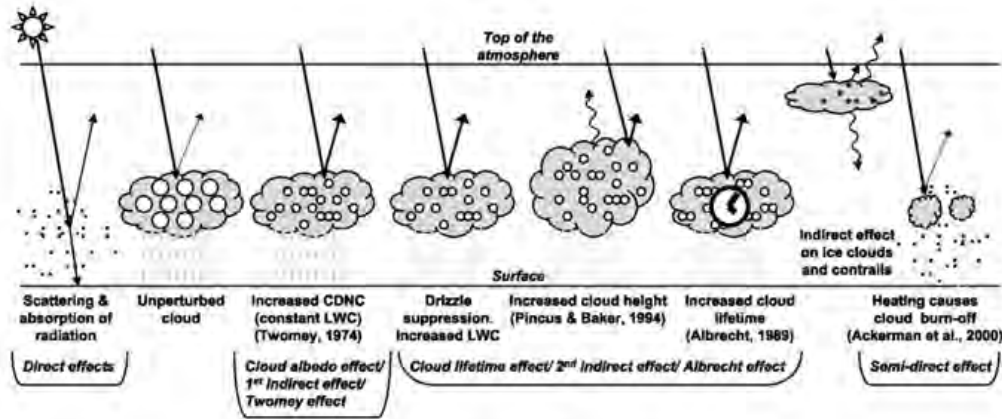


UFS Atmospheric Composition Modeling

Barry D. Baker
NOAA Air Resources Laboratory
March 22, 2022



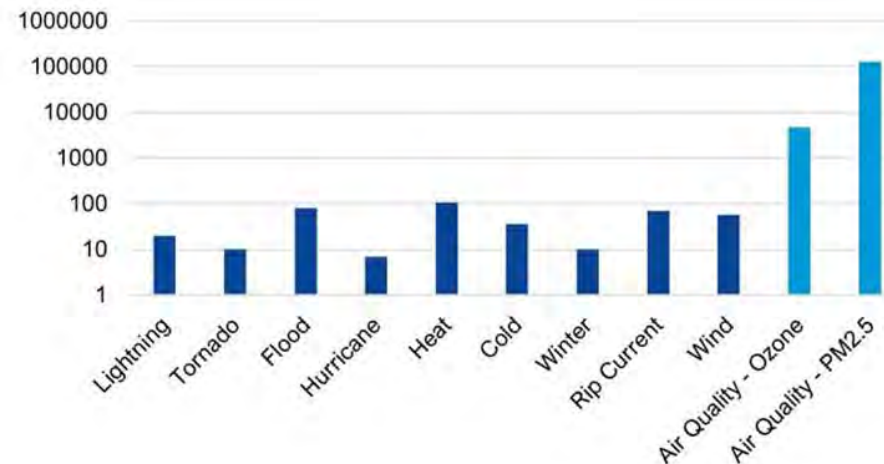
UFS Atmospheric Composition Modeling



- Aerosols and trace gases alter the solar/terrestrial energy balance and cloud physics, affecting meteorology and climate on various timescales.
- Poor air quality has significant societal impacts, including degraded human health and visibility.
- NOAA has numerous legislative, interagency, and international mandates for its research and forecasts of atmospheric composition.



Annual U.S. premature mortality

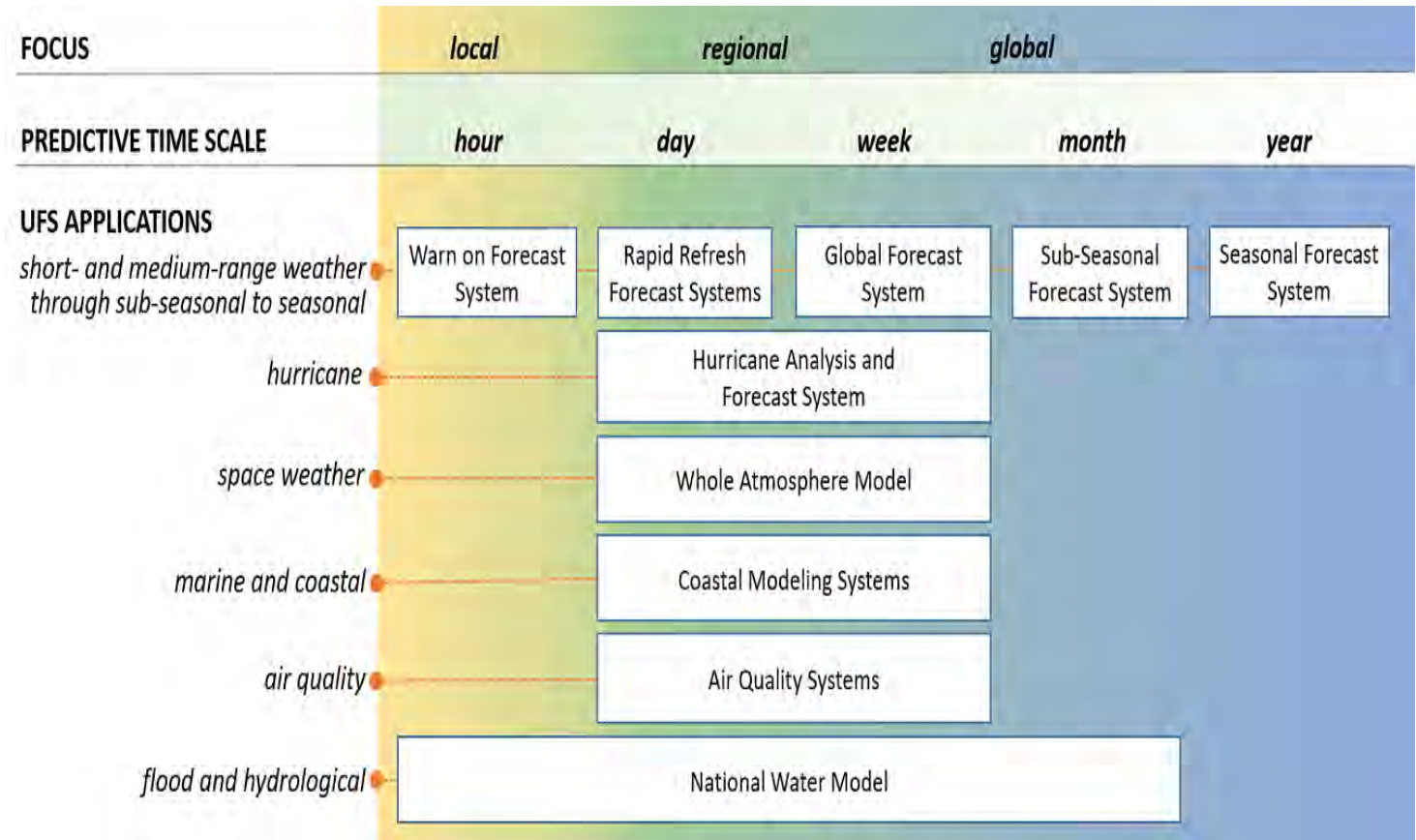


Relevance: UFS Atmospheric Composition Modeling

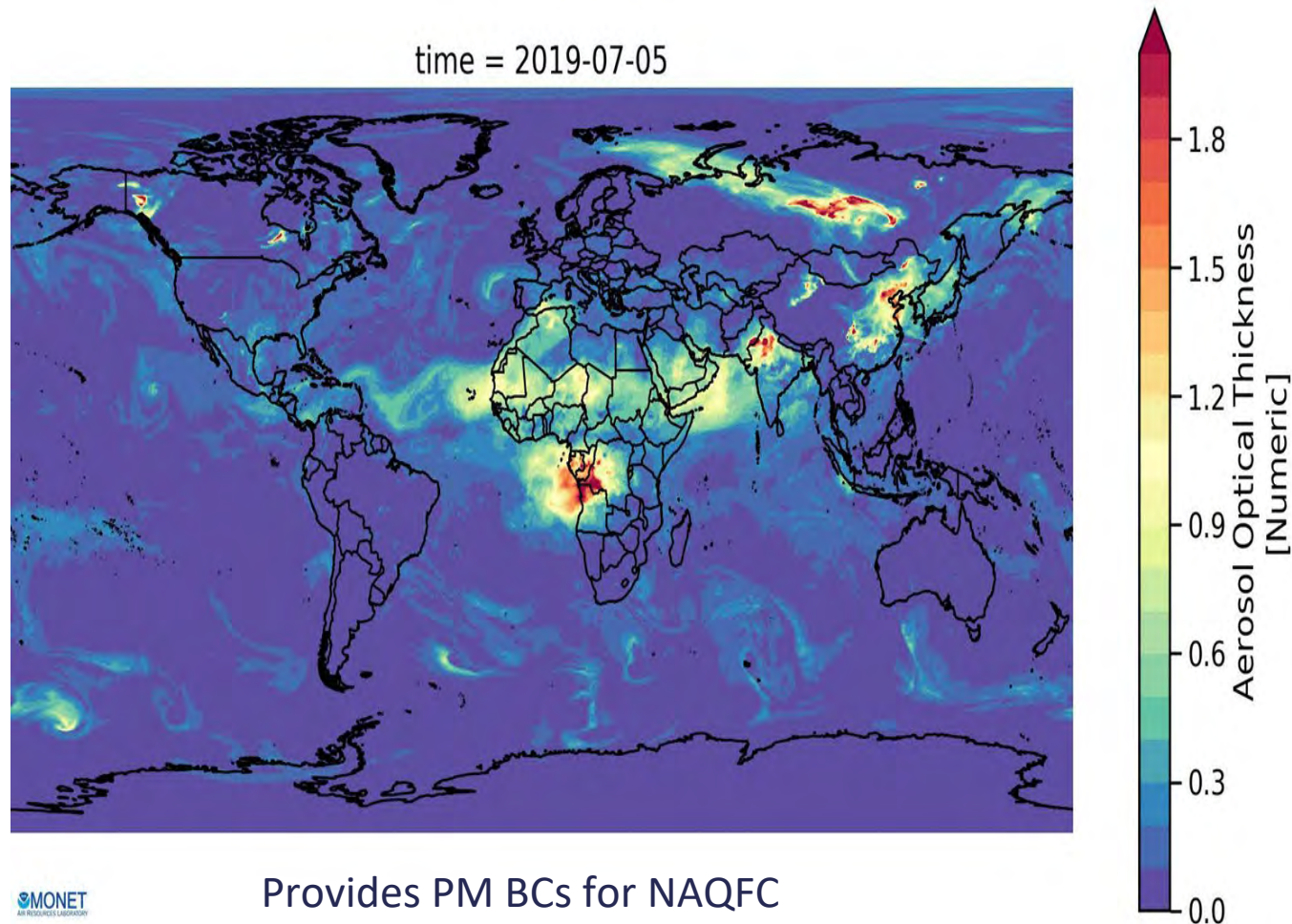


<https://ufscommunity.org>

- Community-based, coupled, comprehensive Earth system modeling
- Applications span local to global domains and predictive time scales from sub-hourly analyses to seasonal predictions
- Designed to support the [Weather Enterprise](#) and be the source system for NOAA's operational numerical weather prediction applications
- Will eventually encompass the full scope of NOAA's operational prediction capabilities that are currently represented by a myriad of separate modeling systems



Global Ensemble Forecast System (GEFS)-Aerosol



Provides PM BCs for NAQFC

- Inline aerosol representation based on NASA's GOCART
- GEFS-Aerosol member developed by NOAA's GSL, ARL, CSL, EMC, NESDIS.
- Implemented into operations in September 2020
- Meteorology (based on GFSv15) at C384 (~25 km), 64 levels, to 120 hrs, 4x/day
- Sulfate, Organic Carbon, Black Carbon, Dust, Sea Salt
- Emissions: CEDS-2014 (SO₂, PSO₄, POC, PEC), GBBEPx biomass burning, FENGSHA dust, GEOS-5 sea salt, marine DMS

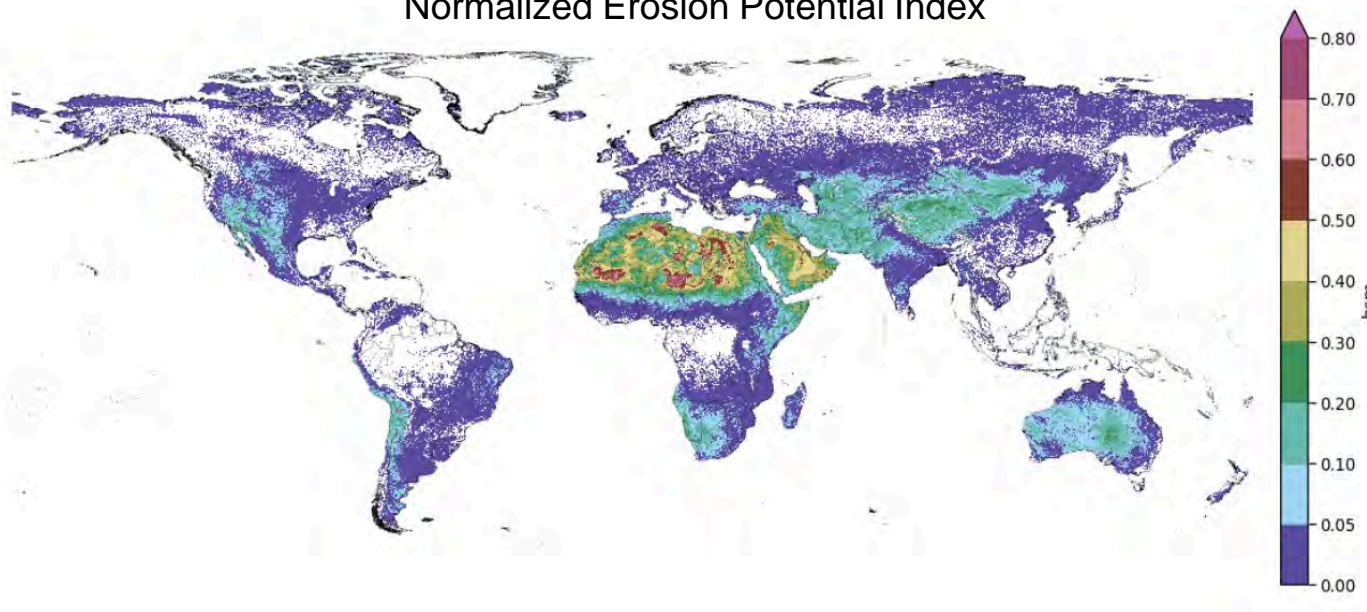


FENGSHA Dust Emission Model

FENGSHA in NWS National Air Quality
Forecast Capability (NAQFC)

Adapted for use in the GEFS-Aerosol global model

Normalized Erosion Potential Index



Flux of Dust

Soil Erosion Potential and Source

Surface Friction Velocity

Threshold Velocity

$$F = \alpha A S \frac{\rho_a}{g} u_*^3 \left(1 - \frac{u_{*t}^2}{u_*^2} \right)$$

Vertical to Horizontal Flux Ratio

Areal Coverage

Horizontal Flux (Q)

Outperforms the dust emission model in
the previous NWS operational global
aerosol model, NGAC.



FENGSHA Performance in GEFS-Aerosol

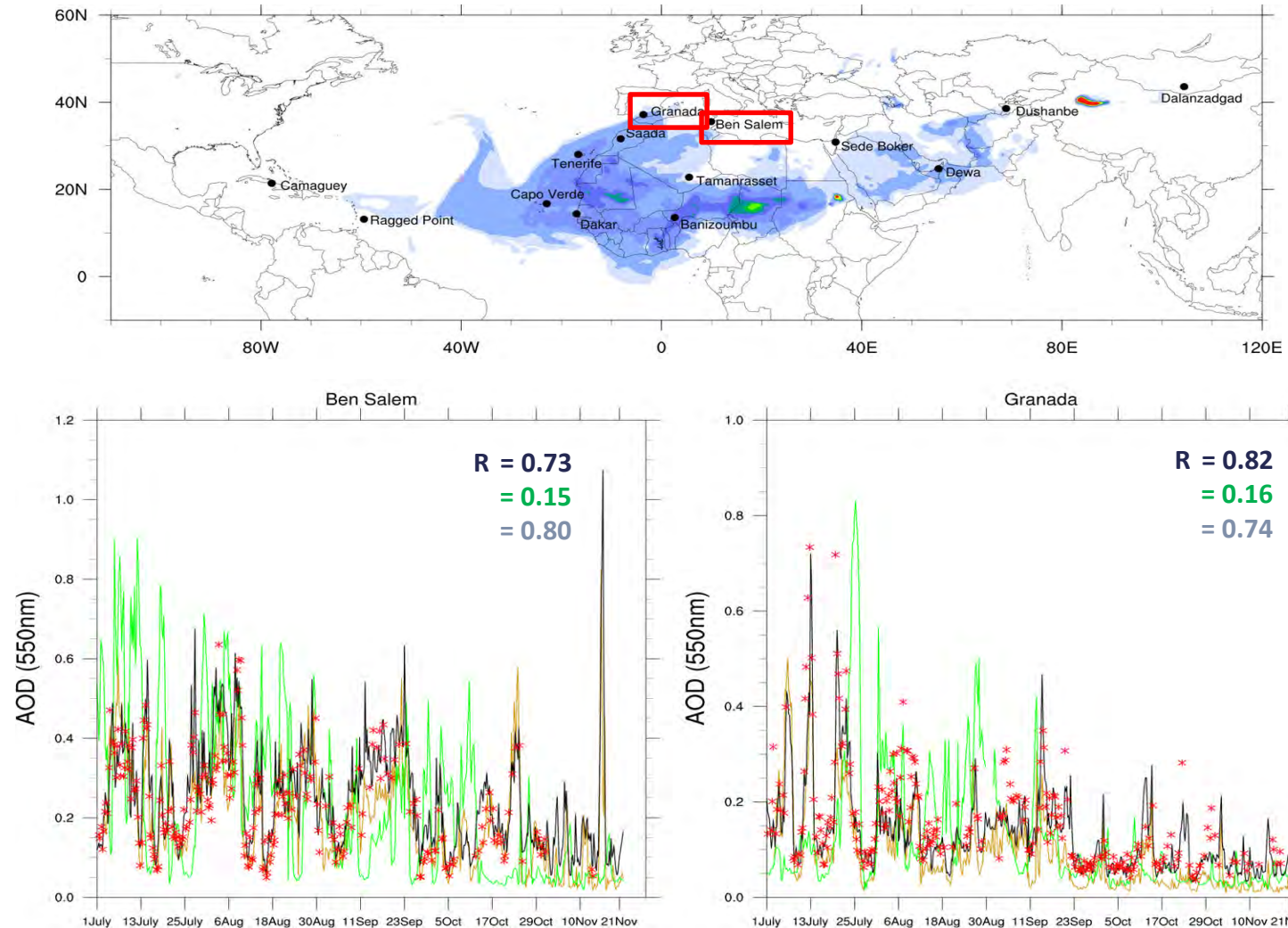
FENGSHA –
windblown dust

**AERONET – Aerosol
Robotic Network,
surface-based AOD**

ICAP – International
Cooperative for
Aerosol Prediction,
ensemble AOD
product

**NGAC – NEMS
GFS Aerosol
Component
(previous NOAA
global aerosol
model)**

GEFS-Aerosol

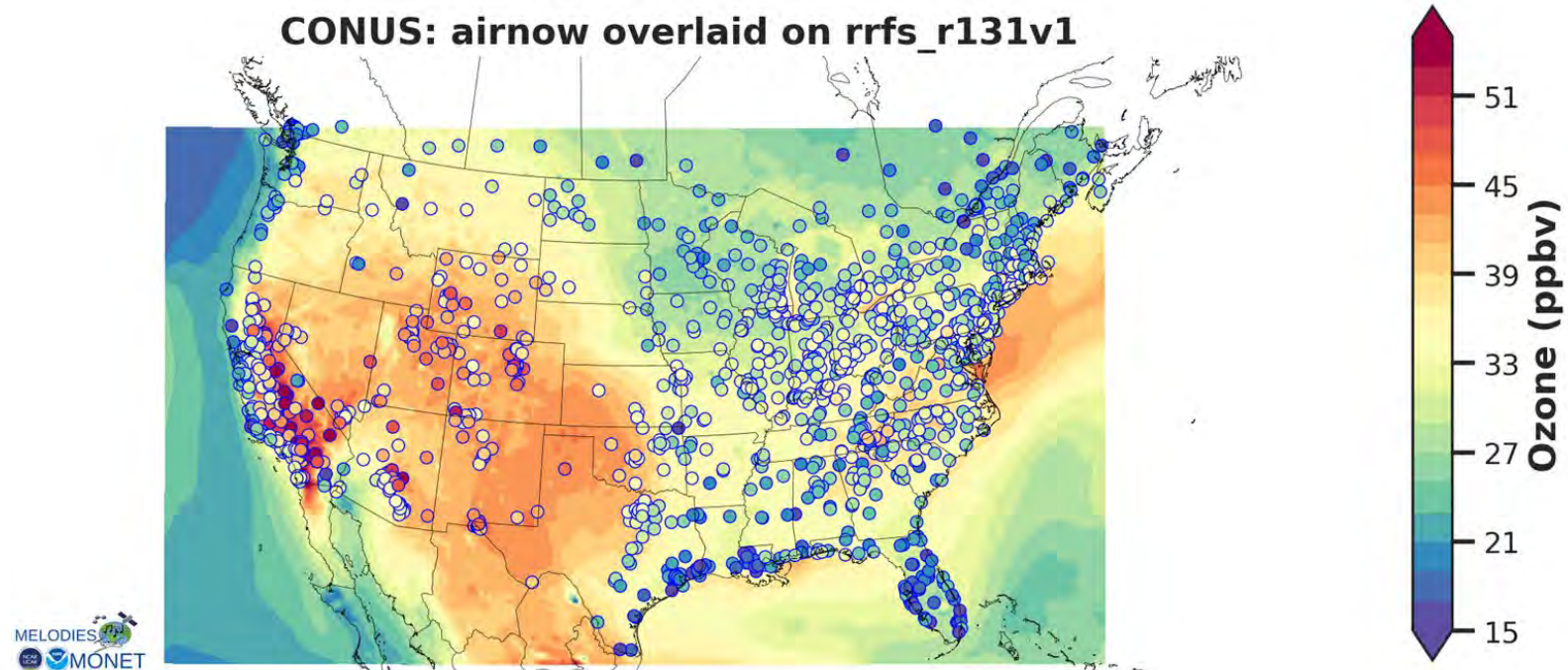


Performance of
FENGSHA
approaches
that of ICAP, a
nine model
ensemble

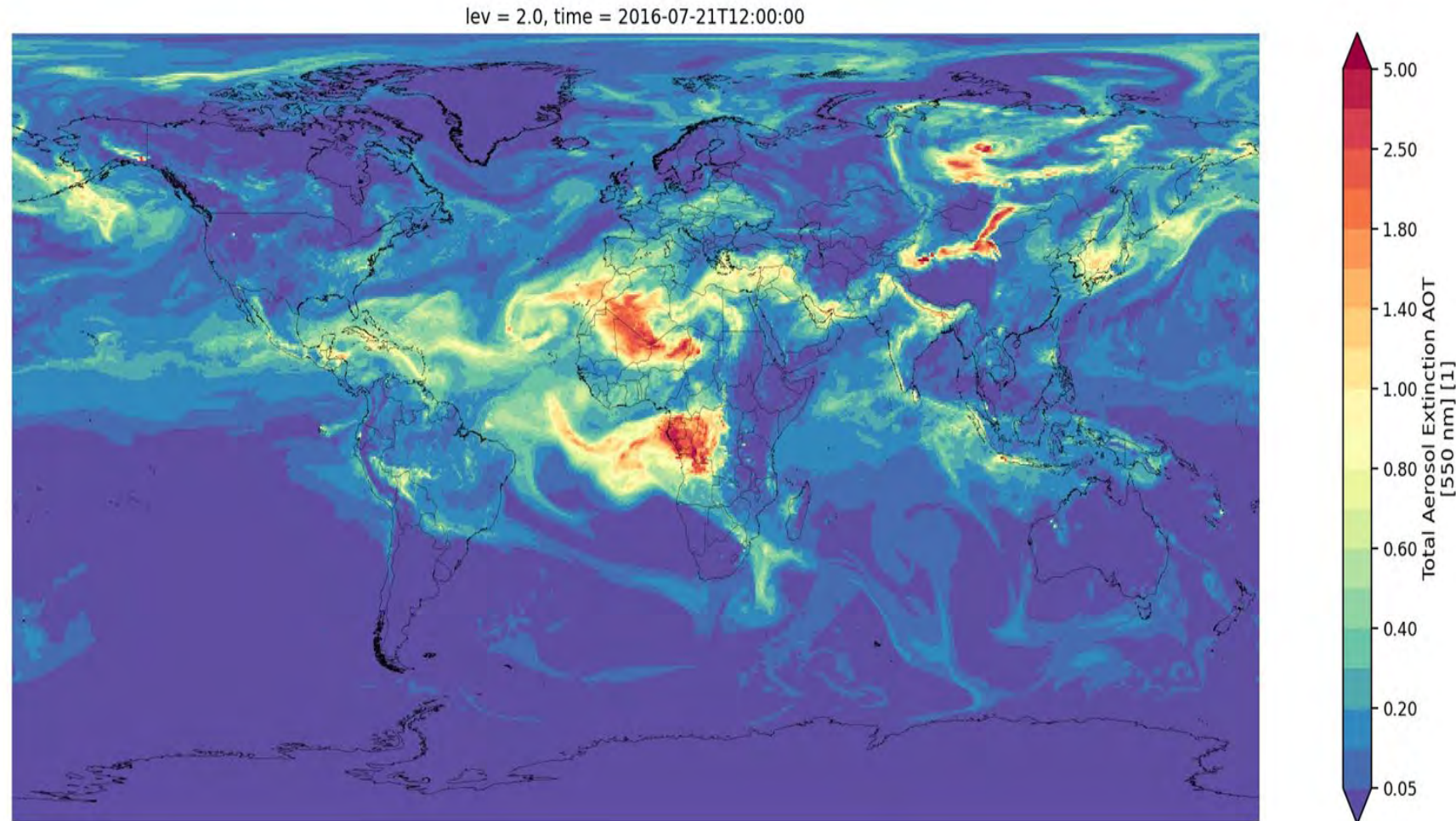


UFS Rapid Refresh Forecast System (RRFS) - CMAQ

- Based on the UFS Rapid Refresh Forecast System (RRFS) - short-term weather application
- CMAQ chemistry inline
- Goal of 3 km horizontal resolution
- **Machine learning emulator for chemistry being developed by ARL and NASA to speed model execution**
- Coordinated NOAA effort among OAR, EMC, NESDIS-STAR, university partners and NASA/USRA
- **ARL providing emissions, FENGSHA dust scheme and standard evaluation suite**
- Development ongoing with scheduled FY24-25 implementation



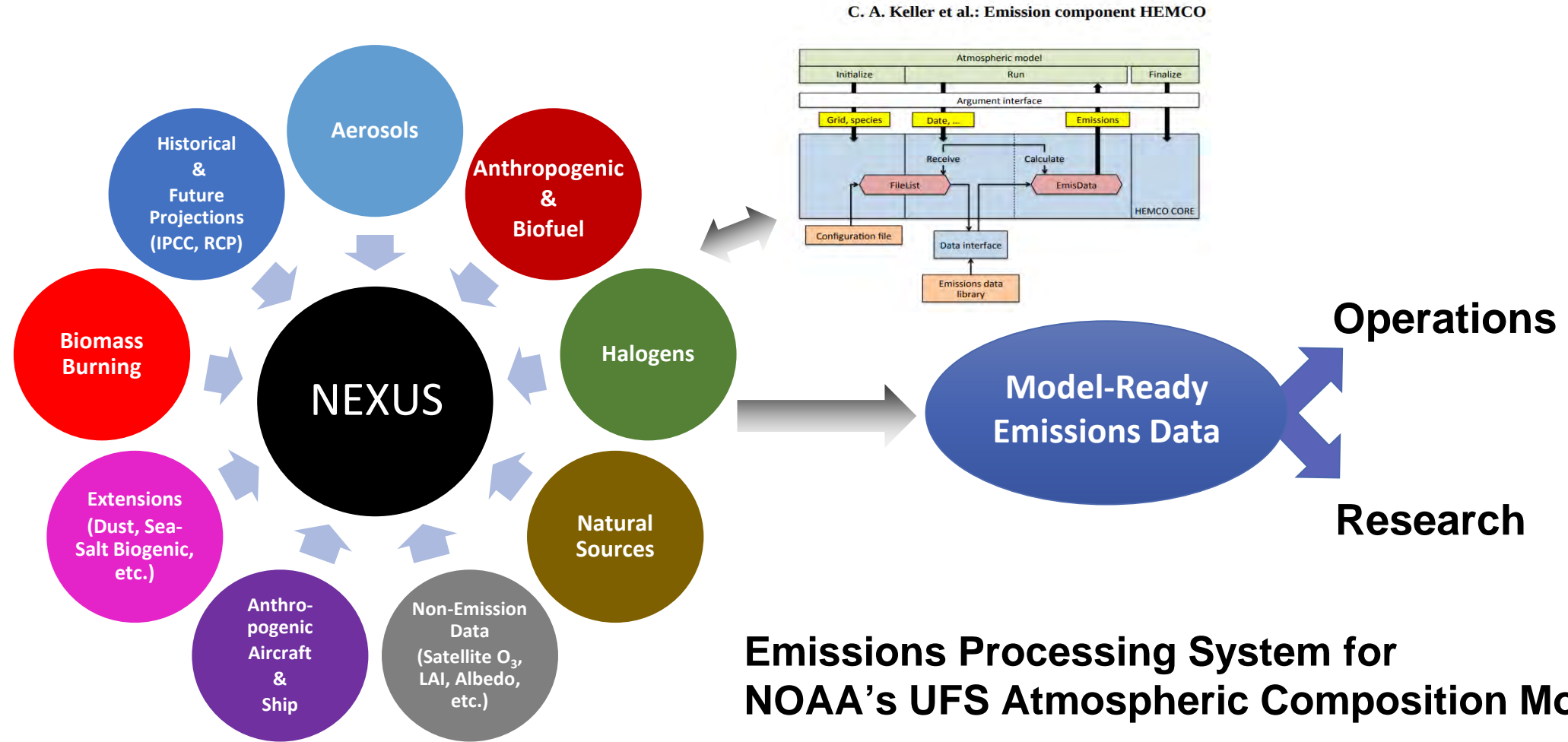
Global Ensemble Forecast System (GEFS)-v13 – UFS-Aerosols



- Based on the UFS-GFSv16 with the latest NASA GOCART aerosol representation
- Coordinated NOAA effort among OAR, EMC, NESDIS-STAR, and university partners
- Fully-coupled model with aerosol-meteorological interactions
- Will provide multi-week weather forecasts as part of GEFSv13
- **ARL provides anthropogenic emissions and FENGSHA dust emissions parameterization**
- Development ongoing
- Scheduled implementation FY24-25



NOAA Emissions and eXchange Unified System (NEXUS)



Quality and Performance

Operational Implementations

- FENGSHA in GEFS-Aerosol (GEFSv12) in September 2020
- FENGSHA in NAQFC in 2018, updated in July 2021

Publications

Lin, H., D. J. Jacob, E. W. Lundgren, M. P. Sulprizio, C. A. Keller, T. M. Fritz, S. D. Eastham, L. K. Emmons, P. C. Campbell, B. Baker, R. D. Saylor, R. Montuoro (2021). Harmonized Emissions Component (HEMCO) 3.0 as a versatile emissions component for atmospheric models: application in the GEOS-Chem, NASA GEOS, WRF-GC, CESM2, NOAA GEFS-Aerosol, and NOAA UFS models, **Geoscientific Model Development**, 14, 5487-5506.

Zhang, L., Montuoro, R., McKeen, S. A., Baker, B., Bhattacharjee, P. S., Grell, G. A., Henderson, J., Pan, L., Frost, G. J., McQueen, J., Saylor, R., Li, H., Ahmadov, R., Wang, J., Stajner, I., Kondragunta, S., Zhang, X., and Li, F.: Development and Evaluation of the Aerosol Forecast Member in NCEP's Global Ensemble Forecast System (GEFS-Aerosols v1), **Geosci. Model Dev. Discuss.** [preprint], <https://doi.org/10.5194/gmd-2021-378>, in review, 2021.

Awards

U. S. Department of Commerce Bronze Medal for Scientific or Engineering Achievement for 2021, *For the development of the Global Ensemble Forecast System – Aerosols (GEFS-Aerosols) model to support air quality alerts and visibility forecasts*, G. Frost, G. Grell, R. Saylor, J. McQueen, I. Stajner, J. Wang, S. Kondragunta



Quality and Performance

Presentations (14)

- Zhang, L., Grell, G., Montuoro, R., McKeen, S., Bhattacharjee, P. S., Baker, B., Henderson, J., Ahmadov, R., Frost, G., Pan, L., McQueen, J., Saylor, R., Stajner, I., Kondragunta, S., Zhang, X., and Li, F., “Development of Global Aerosol Forecast Model (GEFS-Aerosols) into NOAA’s Unified Forecast System (UFS)”, 101st American Meteorological Society Annual Meeting 2021, January 9-15.
- Baker, B., Grell, G., Tong, D., Bhattacharjee, P. S., Montuoro, R., McKeen, S., Saylor, R., Frost, G., Pan, L., McQueen, J., Stajner, I., and Zhang, L., “The 2020 summer extreme dust event: Effects of the albedo drag partition on the FENGSHA dust emission parameterization in GEFS-Aerosol”, American Geophysical Union Fall Meeting 2020, December 1-17.
- Zhang, L., Grell, G., Montuoro, R., McKeen, S., Bhattacharjee, P. S., Baker, B., Henderson, J., Ahmadov, R., Frost, G., Pan, L., McQueen, J., Saylor, R., Stajner, I., Kondragunta, S., Zhang, X., Li, F., “Capability of NOAA’s Global Aerosol Forecast Model (GEFS-Aerosol) in forecasting hazardous air quality”, American Geophysical Union Fall Meeting 2020, December 1-17.
- Saylor, R., Baker, B., Tong, D., Schepanski, K., and Bhattacharjee, P. S. (2020) Description and evaluation of the FENGSHA dust emission model in FV3GFS-Chem, 100th American Meteorological Society Annual Meeting, Boston, MA, January 12-16.
- Grell, G., Zhang, L., McKeen, S., Montuoro, R., Bhattacharjee, P., Kondragunta, S., Pan, L., Henderson, J., Frost, G., Zhang, X., McQueen, J., Ahmadov, R., Li, F., Wang, J., Baker, B., and Saylor, R. (2020) Development and application of global aerosol forecasts using the online coupled GEFS-Aerosol model, 100th American Meteorological Society Annual Meeting, Boston, MA, January 12-16.
- Campbell, P., Baker, B., Saylor, R., Tong, D., Tang, Y., Lee, P., McKeen, S., Frost, G., and Keller, C. (2020) Initial development of a NOAA Emissions and eXchange Unified System (NEXUS), 100th American Meteorological Society Annual Meeting, Boston, MA, January 12-16.
- Bhattacharjee, P. S., Zhang, L., Grell, G., Pan, L., Baker, B., McQueen, J., Saylor, R., Frost, G., and Stajner, I. (2020) Forecast and evaluation of high aerosol events using Global Forecast model at NOAA/National Weather Service, 100th American Meteorological Society Annual Meeting, Boston, MA, January 12-16.



Quality and Performance

Presentations (continued)

- Baker, B., Schepanski, K., Tong, D., and Saylor, R. (2019) Evaluation of new satellite-derived sediment supply maps within the NOAA GEFS-Aerosol FENGSHA dust model, American Geophysical Union Fall Meeting, San Francisco, CA, Dec 9-13.
- Saylor, R., Grell, G., Zhang, L., Montuoro, R., Frost, G., McKeen, S., Baker, B., Tong, D., McQueen, J., Pan, L., and Bhattacharjee, P. (2019) The NOAA UFS Global Aerosol and Atmospheric Composition Model: Description, Evaluation and Future Directions, New Insights in Atmospheric Science Seminar Series, U. S. Environmental Protection Agency, Research Triangle Park, NC, Dec 5.
- Tong, D., Baker, B., Huang, J., Tang, Y., Lee, P., Campbell, P., Saylor, R., Schepanski, K., Kondragunta, S., Ciren, P., and Murphy, B. (2019) Implementation of new satellite-based source maps in the FENGSHA dust module and initial application with the CMAQ-based NAQFC system, Community Modeling and Analysis Annual [96] Workshop, Chapel Hill, NC, Oct 21.
- Campbell, P., Baker, B., Saylor, R., Tong, D., Tang, Y. and Lee, P. (2019) Initial development of a NOAA Emissions and eXchange Unified System (NEXUS), Community Modeling and Analysis Annual Workshop, Chapel Hill, NC, Oct 22.
- Baker, B., Saylor, R., and Tong, D. (2019) Forecasting dust emissions from regional to global scale using satellite data in NOAA FV3GFS-Chem, Meteorology and Climate Modeling for Air Quality Conference, University of California – Davis, September 11.
- Saylor, R., McQueen, J., Pan, L., Bhattacharjee, P. S., Kain, J., Stajner, I., Grell, G., Zhang, L., Montuoro, R., Frost, G., McKeen, S., Baker, B., and Tong, D. (2019) Update on the NOAA FV3GFS-Chem Global Aerosol Model, International Cooperative for Aerosol Prediction (ICAP) 11th Working Group Meeting, July 22, Tsukuba City, Japan.
- Baker, B., Tong, D., and Saylor, R. (2018) Recent developments of the FENGSHA dust emission module: Implementation into FV3-Chem and Future Developments, 9th International Workshop on Air Quality Forecasting Research (IWAQFR), Boulder, CO, November 7-9.



Future plans

Global Ensemble Forecast System (GEFS) v13 – UFS-Aerosol

- UFS-Aerosol development is ongoing
- Fully-coupled S2S development continues
- Implementation in GFSv17/GEFSv13 scheduled for FY24-25
- NEXUS emissions processing system development ongoing
- Albedo-based sediment supply map and algorithm for FENGSHA dust emissions (regional and global)
- Dynamic global NH_3 emissions

Rapid Refresh Forecast System (RRFS)-CMAQ

- RRFS-CMAQ development continues – Wildfire Supplemental funding
- Machine Learning emulator for CMAQ chemistry under development
- Goal of 3 km horizontal resolution – CONUS domain
- Implementation in NAQFC scheduled for FY24-25
- Near-real-time emissions processing system – ingested satellite and surface data
- Weather-aware emissions – mobile sources, fugitive dust
- Incorporation of canopy effects on chemistry, mixing, emissions and deposition



Saharan Dust Plume - July 2020 - FENGSHA in GEFS-Aerosol

