

Application of Advanced Earth Observations & Model Simulations to Improve Air Quality Monitoring in the Hindu-Kush-Himalayan Region

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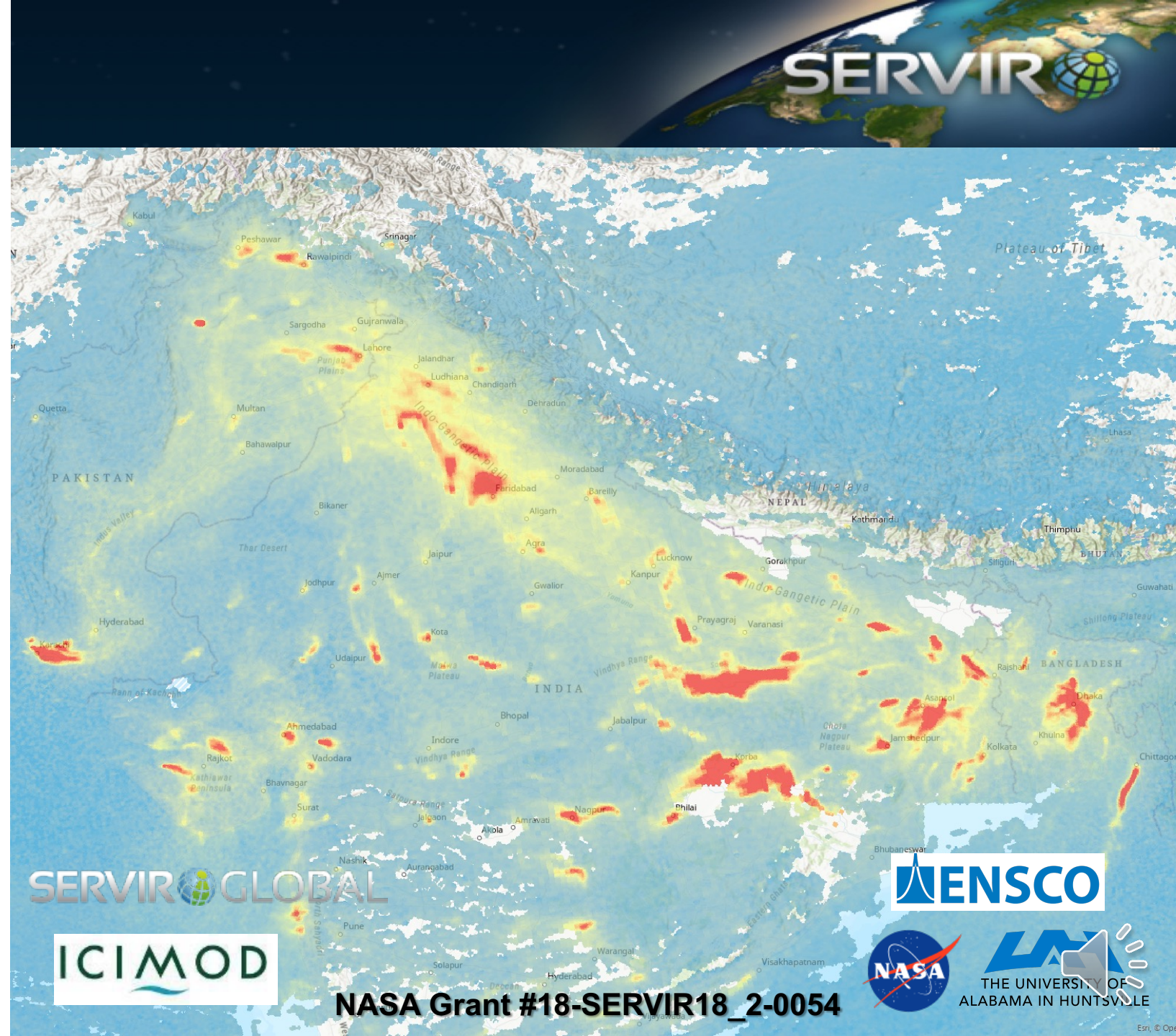
Jonathan Case, ENSCO Inc.

Kevin Fuell, Earth System Science Center, UAH

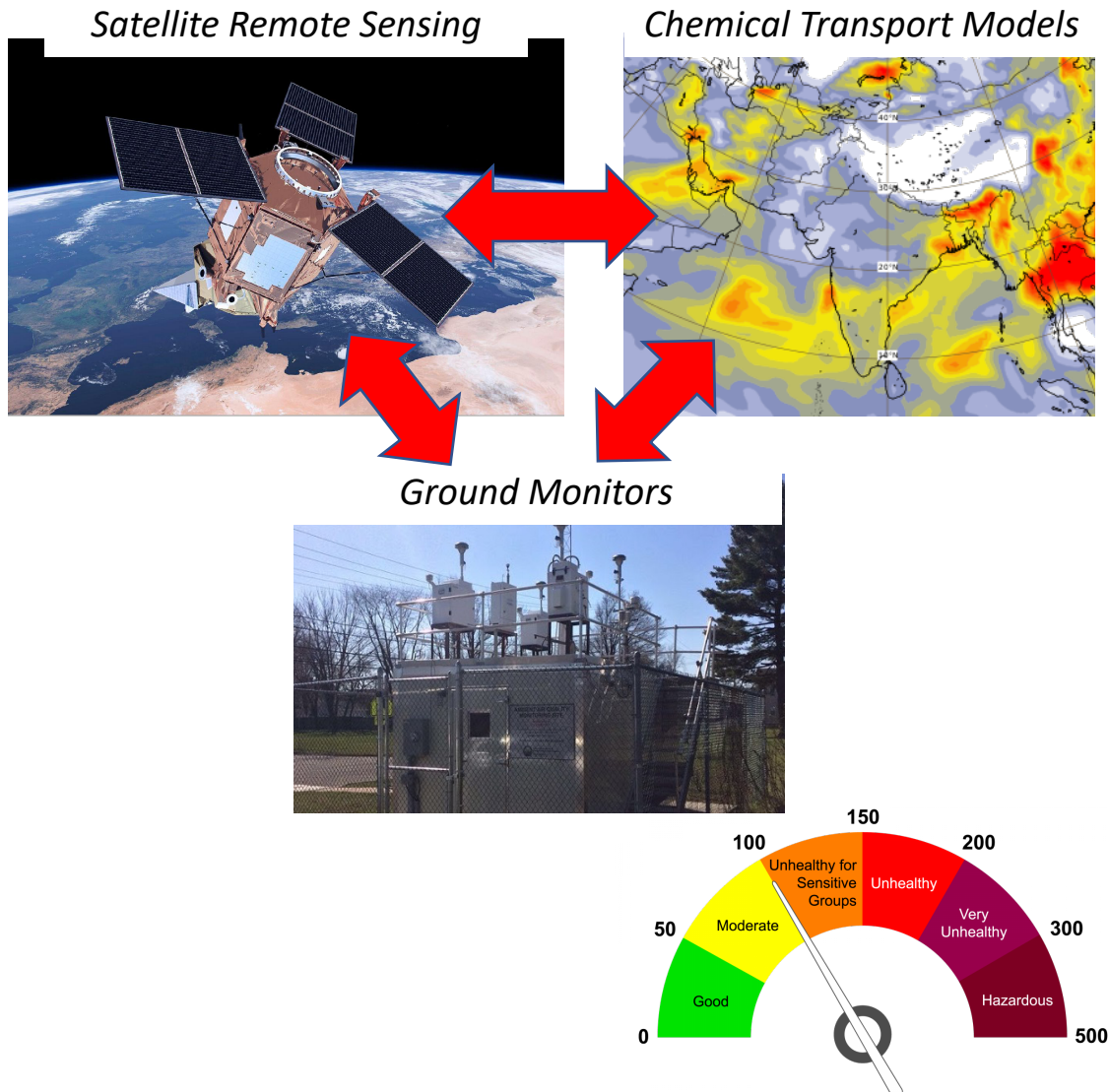
Bhupesh Adhikary; Mir Matin, Birendra Bajracharya, ICIMOD, Kathmandu, Nepal

Michael Newchurch, UAH

Emily Berndt, NASA MSFC



Air Quality Monitoring & Forecasting Challenges in HKH



- **Air pollution is a serious threat to human health in HKH, as poor air quality (AQ) is a common occurrence across the region**
- Air pollution is difficult to monitor and predict in HKH due to strong and rapidly evolving emissions
- New generation satellite sensors are capable of significantly advancing AQ monitoring capabilities, especially in areas of highly variable pollution
- New satellite observations are perfectly suited for constraining or assimilating chemical transport models and improving AQ forecasts
- Growing network of ground-based monitors / sensors for complementing satellite & model data

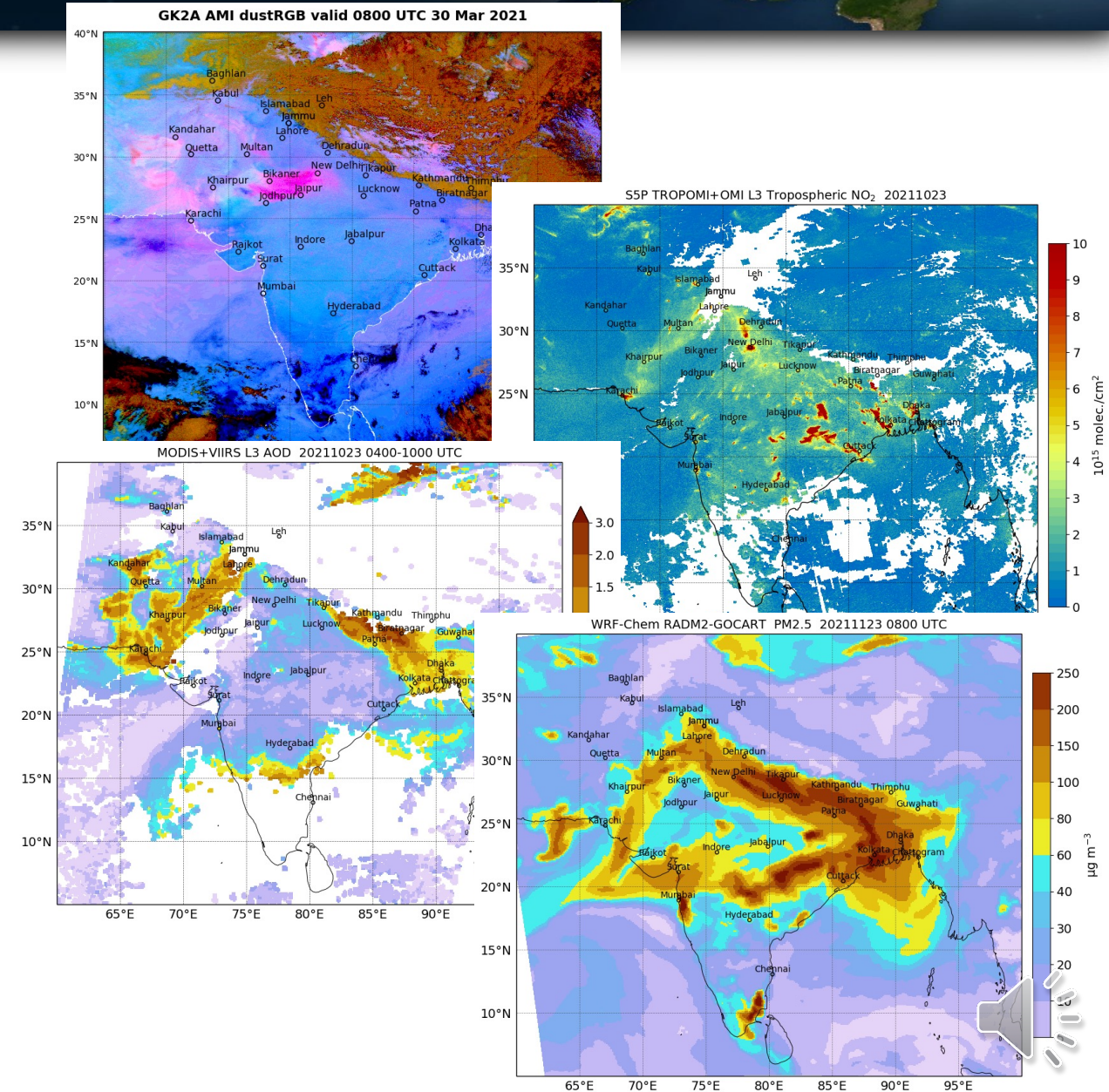
1. Intelligently **fuse information** from state-of-the-art satellite sensors to develop comprehensive products **for advancing real-time air pollution & fog monitoring capabilities**
2. Design a **tailored chemical transport model framework** for providing accurate AQ, fog/smog, and temperature/stability **forecasts**
3. Build a **lagrangian dispersion model** informed by our tailored products **to aid in the rapid response to extreme AQ/disaster events**
4. **Implement the** satellite- and model-based **AQ products into applicable Decision Support Systems**, and develop customized end-user training

Overarching Project Goal:

Deliver an advanced air quality monitoring & forecasting toolkit for providing accurate and timely alerts/warnings to the public

Key Products & Tools

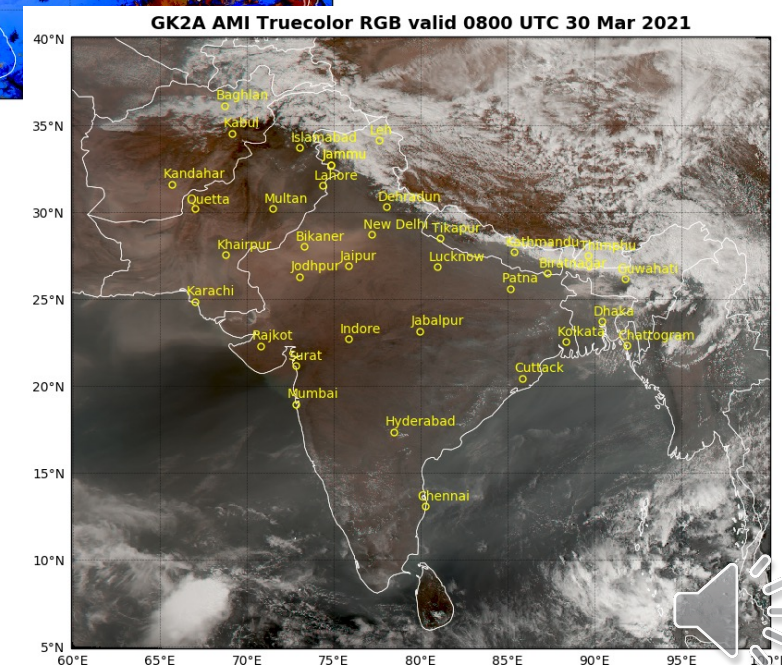
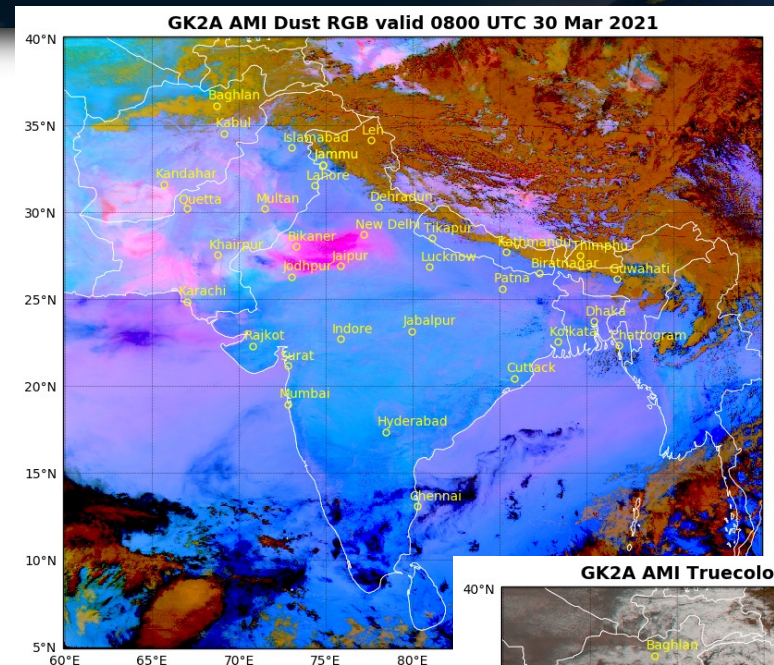
1. **Suite of Red-Green-Blue (RGB) products** from the geostationary Advanced Meteorological Instrument (AMI) for monitoring diurnal evolution of dust, fires, smoke and fog
2. **High-level (L2+) trace gas and aerosol products** developed from composite satellite and model data to track air pollution in the troposphere and surface layer
3. **High-resolution chemical transport model** for accurately predicting AQ in the HKH region and providing timely warnings to the public
4. **Dispersion model designed for efficiently predicting dust pollution** concentrations and enabling rapid response to dust storms



Geostationary AMI RGBs for Dust Monitoring



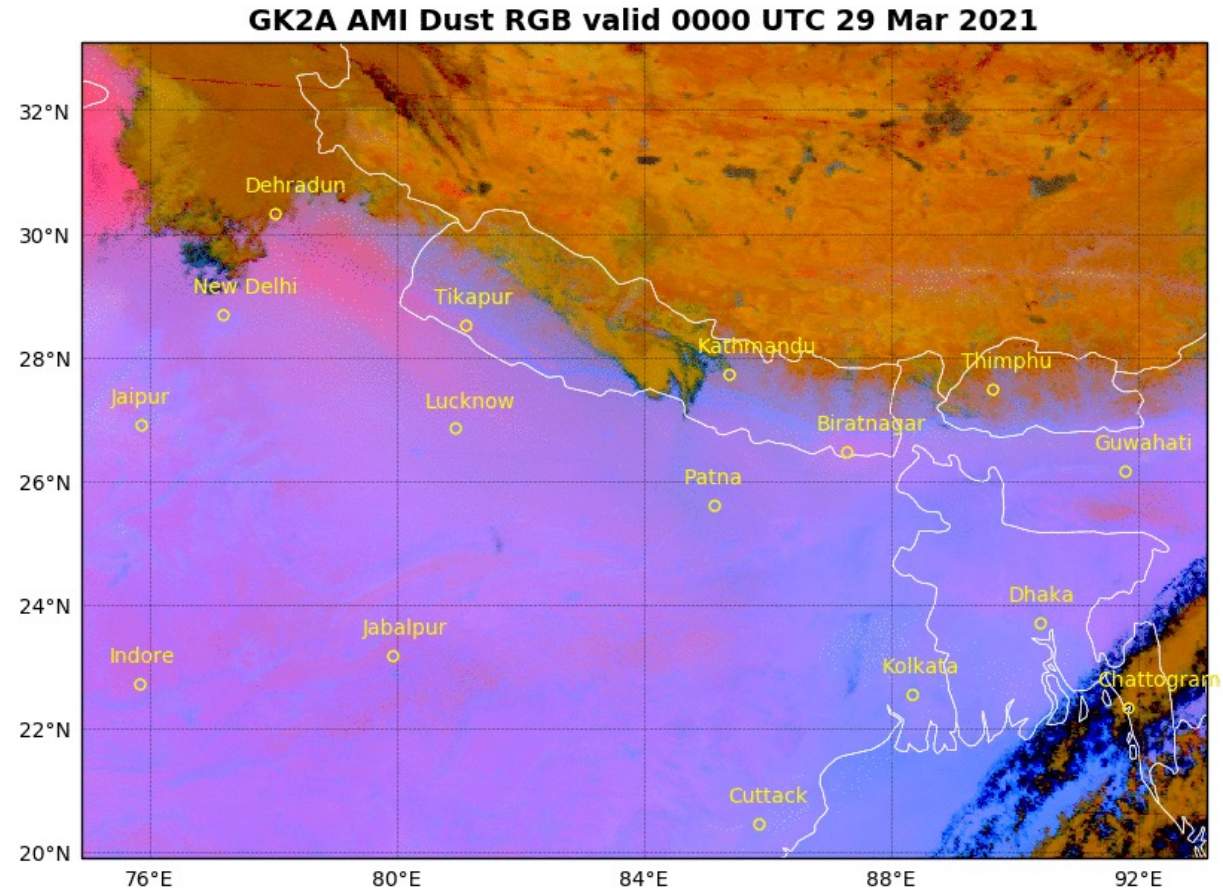
- Dust RGB product uses several IR bands from AMI to depict dust storms in **magenta** colors
 - Individual satellite bands are unable to characterize dust in the atmosphere
 - **Dust RGB valid during the day and night** due to use of IR bands alone
- Rapid 10-minute **Dust RGBs are capable of monitoring the diurnal evolution of dust** emissions and transport
- Effectively identifying dust with the **Dust RGB can aid AQ management and source attribution assessments** (e.g., dust and smoke pollution mixtures over Nepal)



Dust Transport and AQ event from March 29-31, 2021



- Dust RGB monitors transported dust from Pakistan and India, impacting areas of Nepal
- PM2.5 exceeded $250 \mu\text{g m}^{-3}$ at U.S. Embassy monitor site in Kathmandu from March 30-31
- **Dust likely contributed to higher PM2.5 levels in Kathmandu**, in addition to smoke (major contributor) from numerous fires across the region

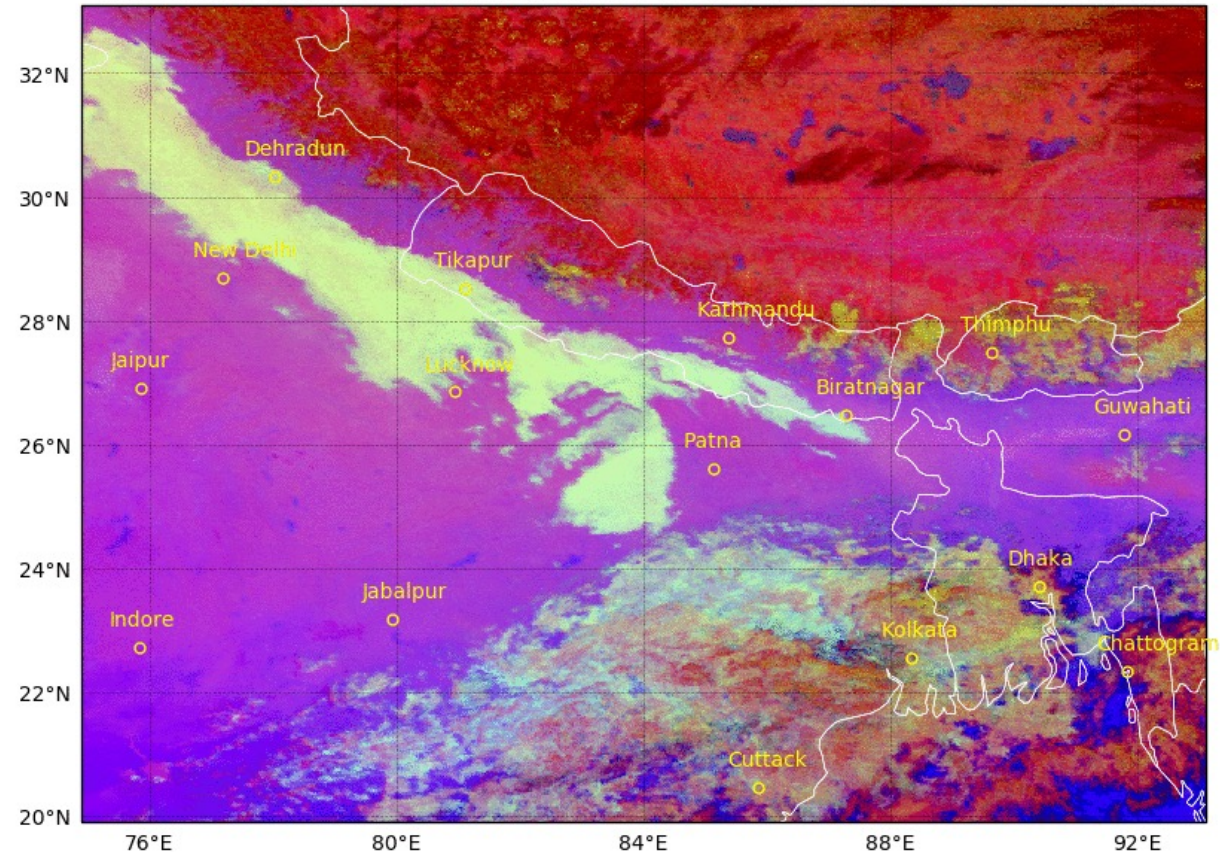


2 km resolution product at 10-minute frequency!



- **AMI Nighttime Microphysics (NtMicro) RGB product monitors** rapidly evolving **low clouds** (bright green) **and fog** (dull aqua) during the nighttime
- **Product can aid in identifying areas of poor visibility** for anticipating hazards to public transit and aviation
- NtMicro RGB can provide guidance on areas of potentially degraded air quality during nighttime
 - Fog and low cloud events are conducive to increased air pollutant levels

GK2A AMI Nighttime Microphysics RGB valid 1200 UTC 26 Dec 2019



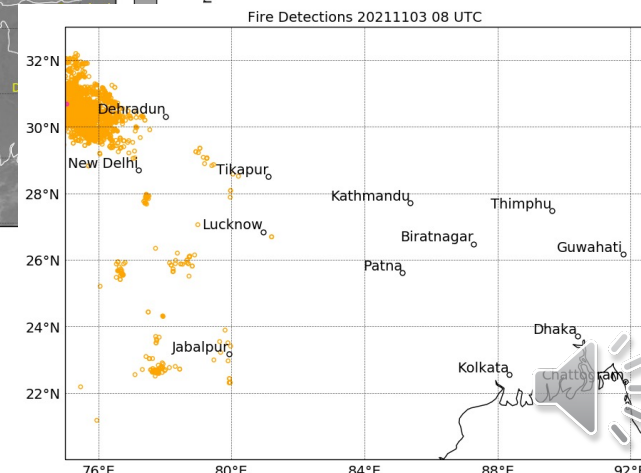
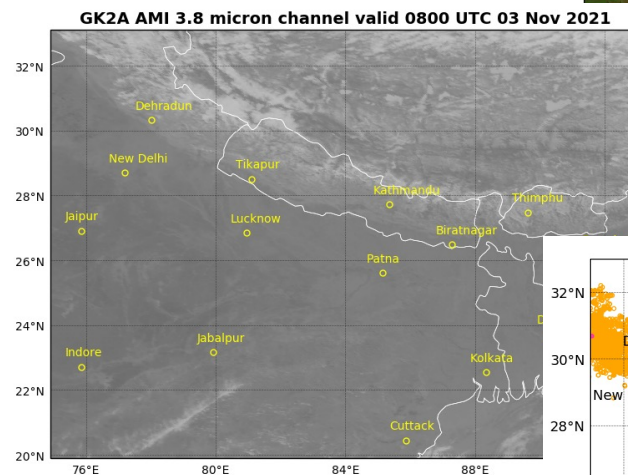
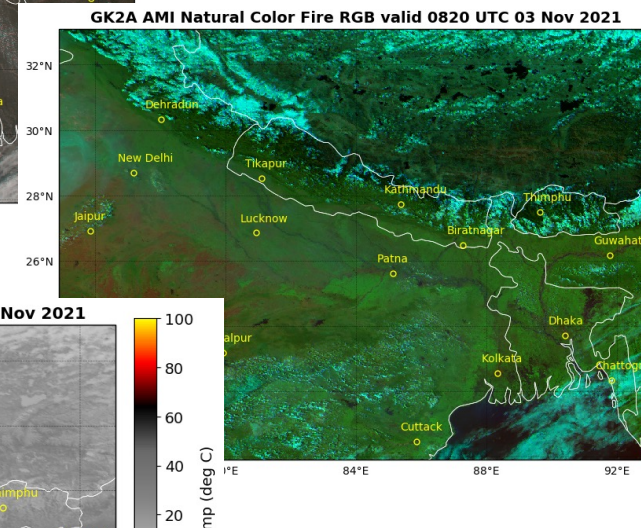
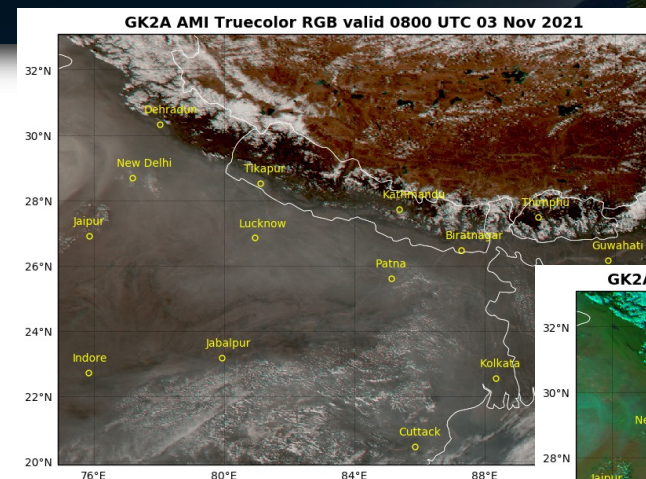
2 km resolution product at 10-minute frequency!



Geostationary AMI for Fire & Smoke Monitoring



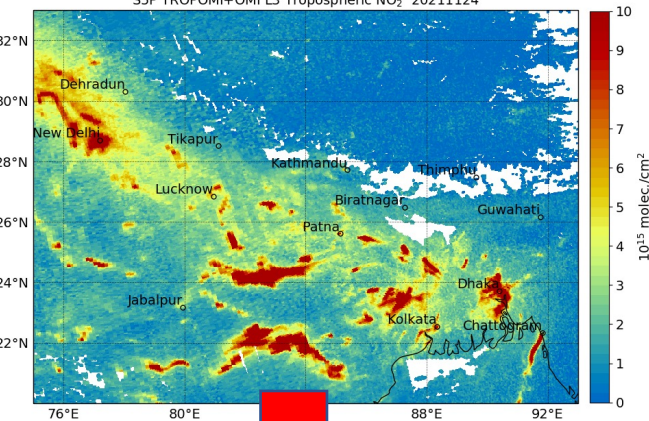
- **Fires are a major source of pollution in HKH** and can lead to extreme pollution events
- Geostationary **AMI can monitor the strong diurnal variation in smoke emissions** from fires
- Our suite of **satellite products for aiding smoke monitoring** include:
 - **AMI True Color RGB**, valid for all pollutants including smoke (1 km resolution every 10 min)
 - **AMI Natural Color Fire RGB** for thick smoke and fires (2 km resolution every 10 min)
 - **AMI 3.8 μm channel for fire detections** (2 km resolution every 10 min)
 - **Merged MODIS, VIIRS, & AMI fire detections** (Hourly & Daily at raw resolution of sensor)



TROPOMI+OMI Fused High-Level Trace Gas Products

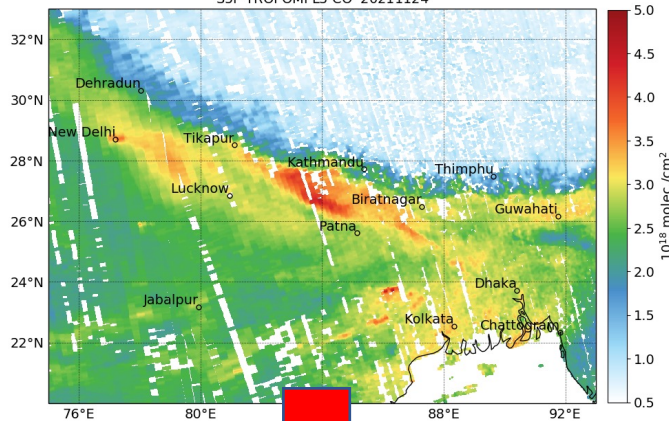
L3 Tropospheric NO₂

S5P TROPOMI+OMI L3 Tropospheric NO₂ 20211124



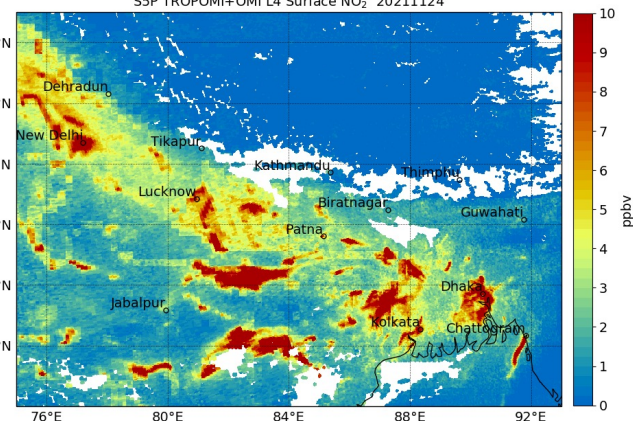
L3 Total Column CO

S5P TROPOMI L3 CO 20211124



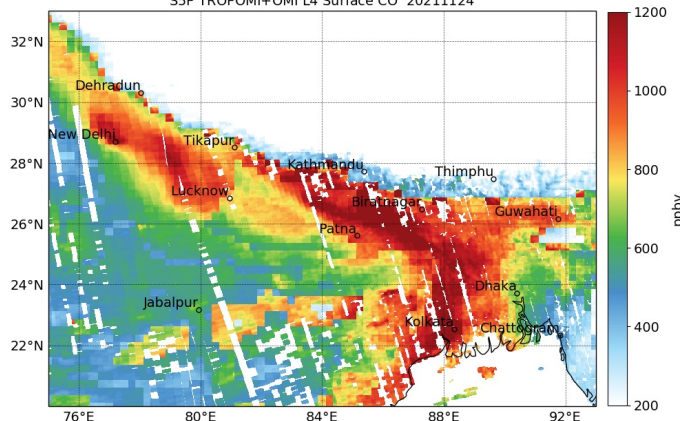
L4 Surface-Layer NO₂

S5P TROPOMI+OMI L4 Surface NO₂ 20211124



L4 Surface-Layer CO

S5P TROPOMI+OMI L4 Surface CO 20211124



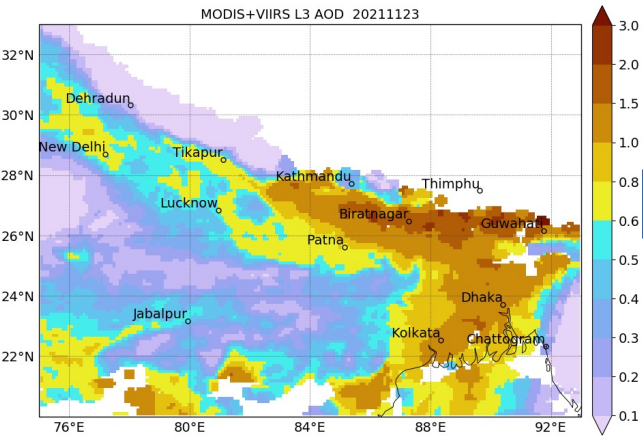
- Suite of high-level (L2+) near-real-time trace gas products for monitoring air pollutants in the troposphere and surface-layer over HKH
- L3 products blend L2 TROPOMI and OMI data using spatial interpolation techniques and quality assurance tests
- **Surface-layer L4 products** fuse L3 TROPOMI+OMI products and model data to **estimate trace gas pollution at the surface where people live!**
- L3 and L4 products are produced once per day on regular 0.02° grid

L2+ Trace Gas Products include: NO₂, HCHO, CO, SO₂, O₃

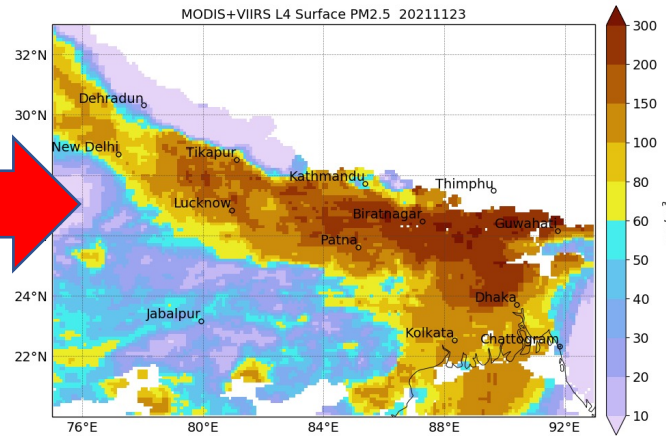
AMI+MODIS+VIIRS High-Level Aerosol Products



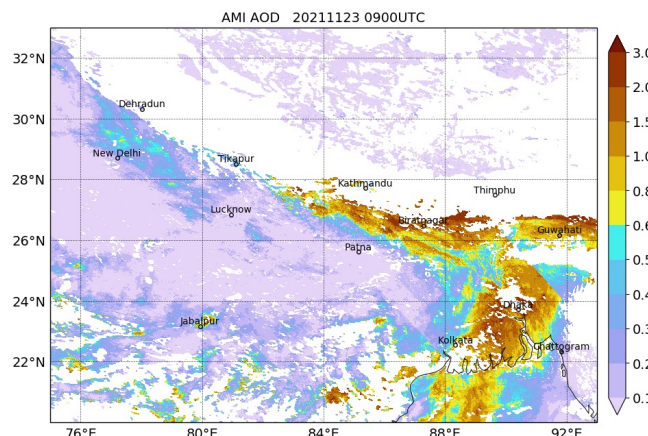
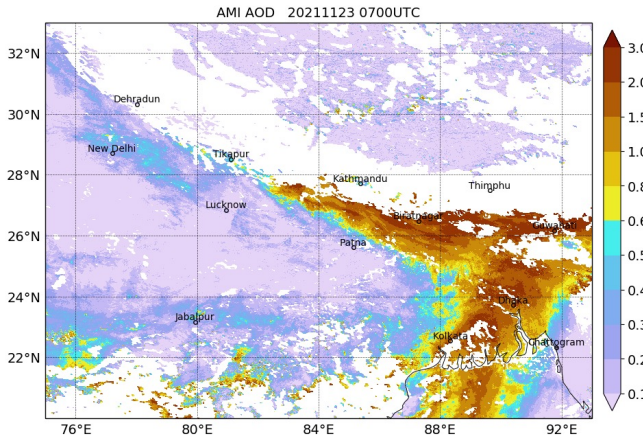
L3 MODIS+VIIRS AOD



L4 Surface-Layer PM2.5



Preliminary L2 AMI AOD



- High-level (L2+) near-real-time aerosol products for monitoring particulate pollution in the atmospheric column and surface-layer over HKH
- L3 aerosol products blend L2 MODIS, VIIRS, and AMI (in development) AOD data using similar retrieval techniques and quality assurance tests
- **Surface-layer L4 products** fuse L3 MODIS, VIIRS, and AMI products and model data to **estimate PM pollution at the surface where people live!**
- L3 and L4 blended aerosol products are on regular 0.1° grid at hourly and daily time scales

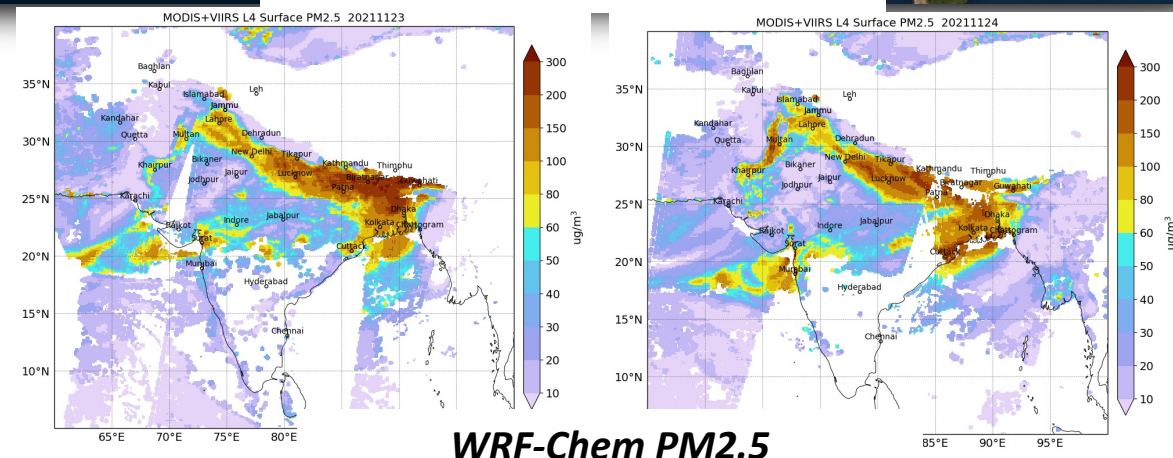
Chemical Transport Model AQ Predictions & Products



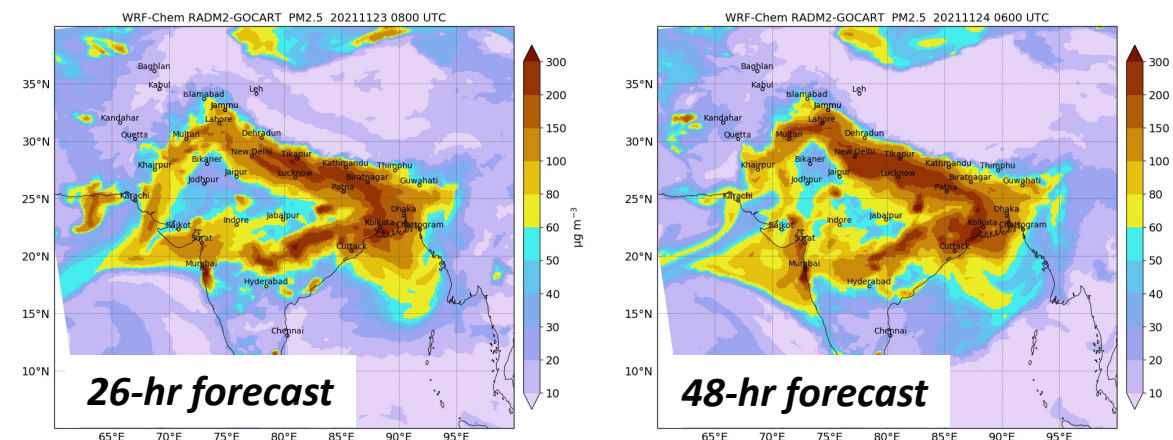
- Uses the Weather Research and Forecast Model coupled with Chemistry (WRF-Chem)
- **12 km grid over HKH region with finer 4 km centered over Nepal**
- **Daily 48-hour forecasts** initialized at 06 UTC
- Global WACCM model for chemical initial & lateral boundary conditions
- Chemical reactions including ozone chemistry predicted via RADM2 mechanism
- **Assimilation of satellite AOD** during initial time window from 03-09 UTC
- Assimilation of TROPOMI NO₂ is in progress

AQ forecasting system can improve AQ warnings / alerts to the public

L4 Surface-Layer PM_{2.5}

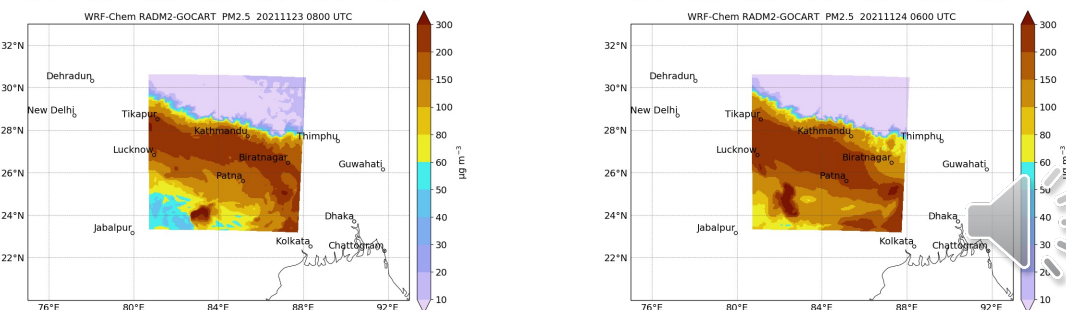


WRF-Chem PM_{2.5}



26-hr forecast

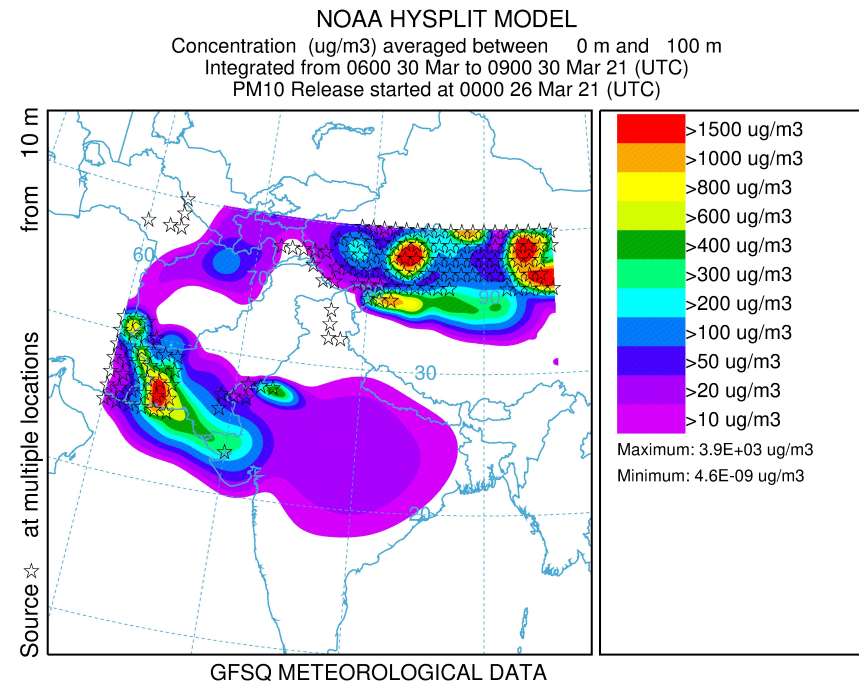
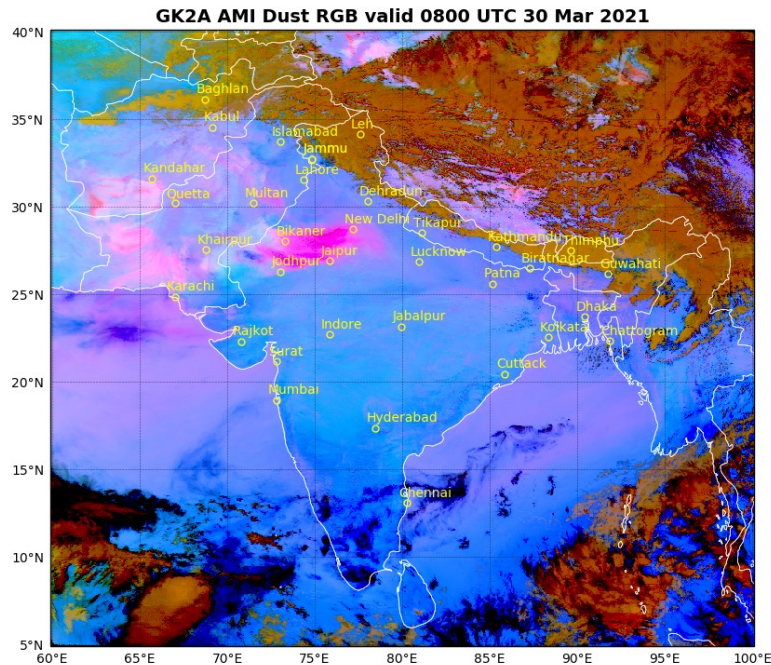
48-hr forecast

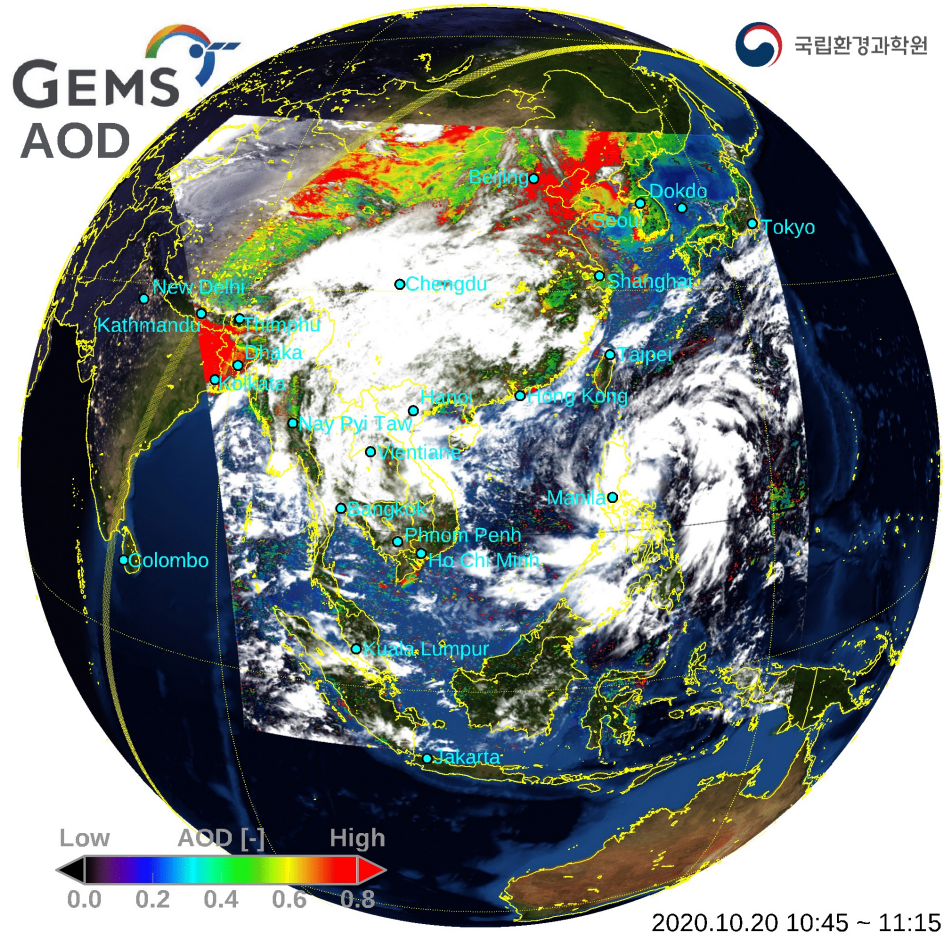


HYSPLIT Dispersion Forecasts for Dust Storms



- Developing an efficient **HYSPLIT dispersion forecasting system** specialized **for rapid response to dust storms** over HKH
- Capable of providing longer term (> 3 day) dust forecasts to provide guidance on transported dust concentrations and impactful AQ events
- Information from dust RGB product provides guidance on dust emission locations in HYSPLIT





Credit: Ministry of Science and Technology Information and Communication-Ministry of Environment-Ministry of Oceans and Fisheries

GEMS – Geostationary Environment Monitoring Spectrometer

- Hourly daytime observations of both trace gases and aerosols
 - Trace gases include: NO₂, HCHO, O₃, SO₂
 - Aerosols include: AOD & Aerosol Effective Height
- GEMS scan coverage moves over the Nepal, East India, Bangladesh, and Bhutan by 0145 UTC
- Fusing GEMS data with satellite-based products and model assimilation techniques

Thank you!

