







## Monitoring Atmospheric Composition and Long-Range Smoke Transport with NUCAPS Satellite Soundings in Field Campaigns and Operations

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### What are atmospheric sounders?



## Satellite sounders can retrieve temperature, humidity, and trace gases at **100 pressure levels**.

### Soundings support *air quality* applications:

- Fire weather
- Air quality
- Saharan air layer monitoring

#### **Temperature Profiles**



Ozone



Clouds





#### Water Vapor Profiles







**Dust** AIRS vs MODIS AEROSOLS Eastern Mediterranean Dust Storm



Related AMS Talk:

 Characterization and Application of JPSS Products in Biomass Burning Studies Gregory J. Frost, S. A. McKeen, M. Pagowski, G. A. Grell, L. Zhang, R. Ahmadov, C. Francoeur, R. Esmaili, N. Smith, S. Kondragunta, B. Pierce, C. D. Barnet

1/16 11:45 AM



### NUCAPS sounding products in U.S. weather forecasting since 2014



• NUCAPS soundings

supplement radiosondes with wide swaths from the **NOAA-20** and **Suomi NPP** satellites, multiple times during the day.

 Exploring using trace gases in a real-time operational setting including field campaigns



### NOAA-Unique Combined Atmospheric Processing System (NUCAPS)



Cloud-clearing permits retrievals in clear <u>and</u> partly cloudy scenes, day and night



- Supplement imagers by retrieving *through* the clouds
- Small amount of cloud cover can be an obstacle
- We want to minimize the impact of instrumental information content differences on downstream thermodynamic and trace gas products



We do NOT retrieve the thermodynamic environment THROUGH uniform clouds

We can retrieve cloud-cleared thermodynamic environment AROUND transparent holes in clouds

- Sacrifice some of the spatial resolution to dramatically improve yield
  - Combine CrIS+ATMS to stabilize the solution



O NUCAPS retrieval footprint o CrIS measurement area



Case Study: Regional Smoke Composition and Transport of Australian Bushfires



- Nov 6 present
  - 2.7 million acres destroyed
- Causes:
  - Sudden Stratospheric
    Warming (SSW)
  - Decreased rainfall
  - Heatwave



Able to monitor this using IR+MW sounders



SNPP/VIIRS RGB and Active Fire Product Nov 4-11, 2019



## NUCAPS can monitor Sudden Stratospheric Warming (SSW)



- Began Late August 2019
- SSW events associated with wind changes
- Impacts New South Wales and southern Queensland:
  - Temperatures Increases
  - Decreased rainfall
  - Heatwaves
  - Increased fire risk



Courtesy of Tony Reale, NOAA/STAR



# NUCAPS can monitor decreased rainfall, heatwaves







## Combining NUCAPS CO and AOD to monitor smoke transport



### NUCAPS CO (Total Column) from NOAA-20













Information Content (IC):

- Averaging Kernels show where in the vertical column the NUCAPS retrieval differs from the first guess
  - Larger values indicate the retrieval added information
  - Zero indicates no difference from first guess
- IC of retrievals depends primarily on cloud coverage and lapse rates.
- For <u>temperature</u> and <u>moisture</u>, we can examine at all pressure levels







- IC of trace gases peaks: Unlike temperature and moisture, trace gases are only sensitive at <u>specific</u> pressure levels, **not** the entire column.
  - Ozone (O<sub>3</sub>) in lower stratosphere ( above 100mb)
  - Carbon monoxide (CO) and Methane (CH<sub>4</sub>) peak in midtroposphere (~500mb)
  - Skill of  $CO > CH_4$

### Related AMS Talks

- Using Averaging Kernels (AKs) for Validation of IR Sounder EDRs: Application to NUCAPS N. R. Nalli et al. 1/14 11:30 AM
- Validation of the NOAA Unique Combined Atmospheric Sounding System (NUCAPS) N. R. Nalli et al. 1/16

02:30 PM



## Real-Time Case: Kincaid Fires





- Want to look at smaller, more <u>"difficult</u>" fires
- Kincaid Fire: Oct. 23–Nov. 6,
  2019 → 77,758 acres destroyed.
- Real-time monitoring: NUCAPS available w/in 20 mins of overpass
  - Community Satellite Processing Package (CSPP) processes NUCAPS from Direct Broadcast sites



## Kincaid, California: October 27, 2019





• Plume visible in AOD, but not in NUCAPS CO

....did the retrieval fail?



NUCAPS Cloud Top Height (NOAA-20)



NUCAPS Cloud Top Fraction (NOAA-20)



- CO not detected because lower in the atmosphere
- 800 Plume thick enough to
  set off cloud flag in
  retrieval
  - Cloud top height indicates level > 500 mb







## For air quality forecasters/field campaigns

NUCAPS is valuable for:

- Monitor the atmospheric environment to assess hazards during the fire season.
- Tracing long-range smoke transport and composition for **large fires**, when gases advected to the **mid-troposphere**.
- Retrieving plume gases in high-AOD conditions, where VIIRS AOD retrievals have difficulty.
- Nighttime retrievals (which use both IR and MW sounders) have the same skill as daytime.

### NUCAPS is not valuable for:

- AOD (NUCAPS does not retrieve it)
- Knowledge of trace gases in the boundary layer (low sensitivity)
- Trace gases over smaller/moderate sized fires (50 km nadir footprint)

More Information: https://ter.ps/nucaps





### For Researchers

- Averaging kernels give us the ability to understand the IC of the retrieval on a scene-by-scene basis
- Can partition what info came from the background climatology vs. the satellite instruments
- 2019 FIREX-AQ field campaign provides high quality aircraft data for small/medium fire domains.
  - Improve our sensitivity to small/moderate fires
  - Exploring simple ways to convey the NUCAPS information content to users