Impact of Anthropogenic and Natural Emissions on Air Quality in Korea

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National Center for Atmospheric Research

and

the KORUS-AQ science team, including:

Paul Wennberg, John Crounse, et al. – CalTech

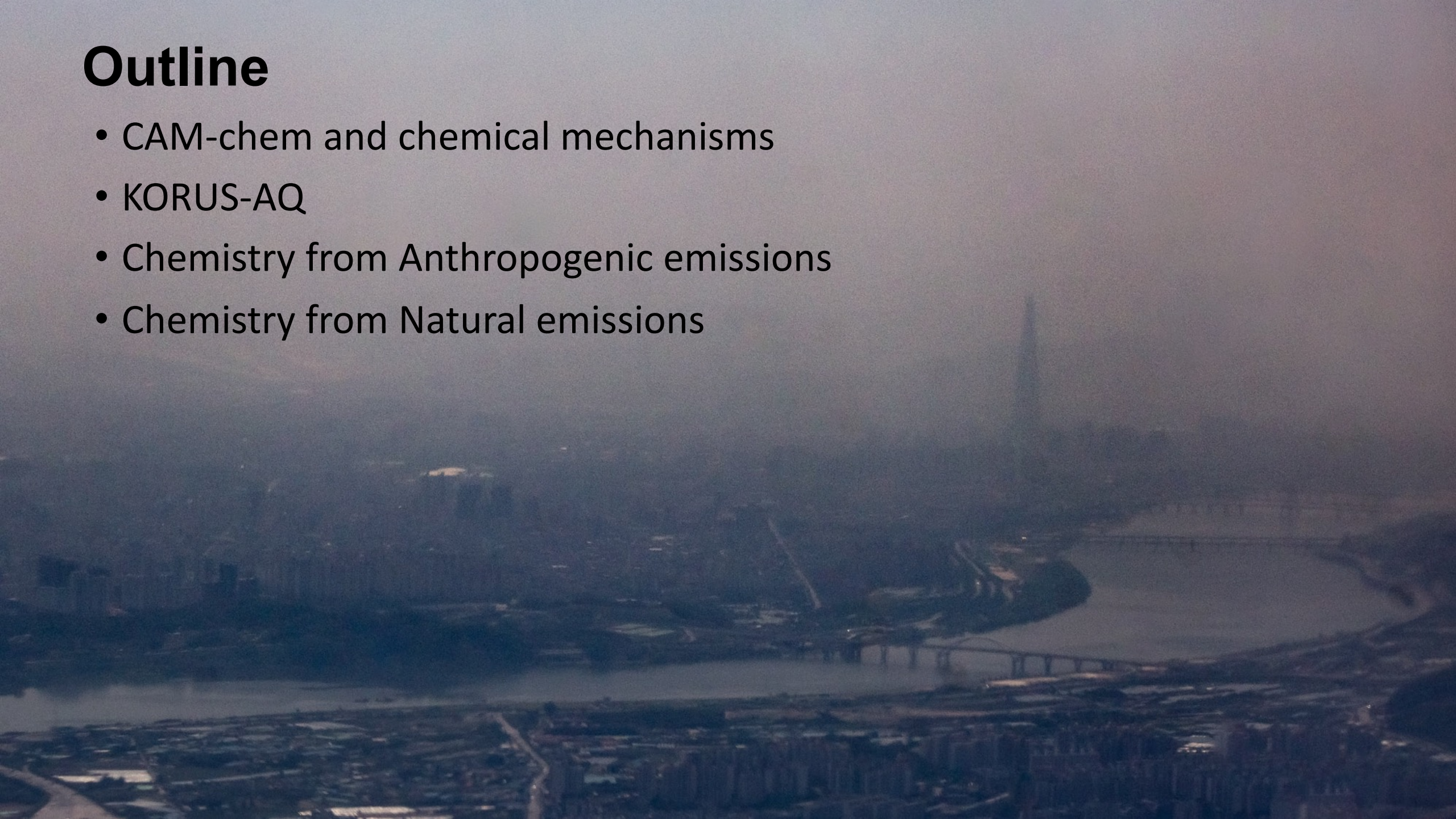
Don Blake, Isobel Simpson et al. – UC-Irvine

Greg Huey – GeorgiaTech

Armin Wisthaler – U.Oslo

Outline

- CAM-chem and chemical mechanisms
- KORUS-AQ
- Chemistry from Anthropogenic emissions
- Chemistry from Natural emissions

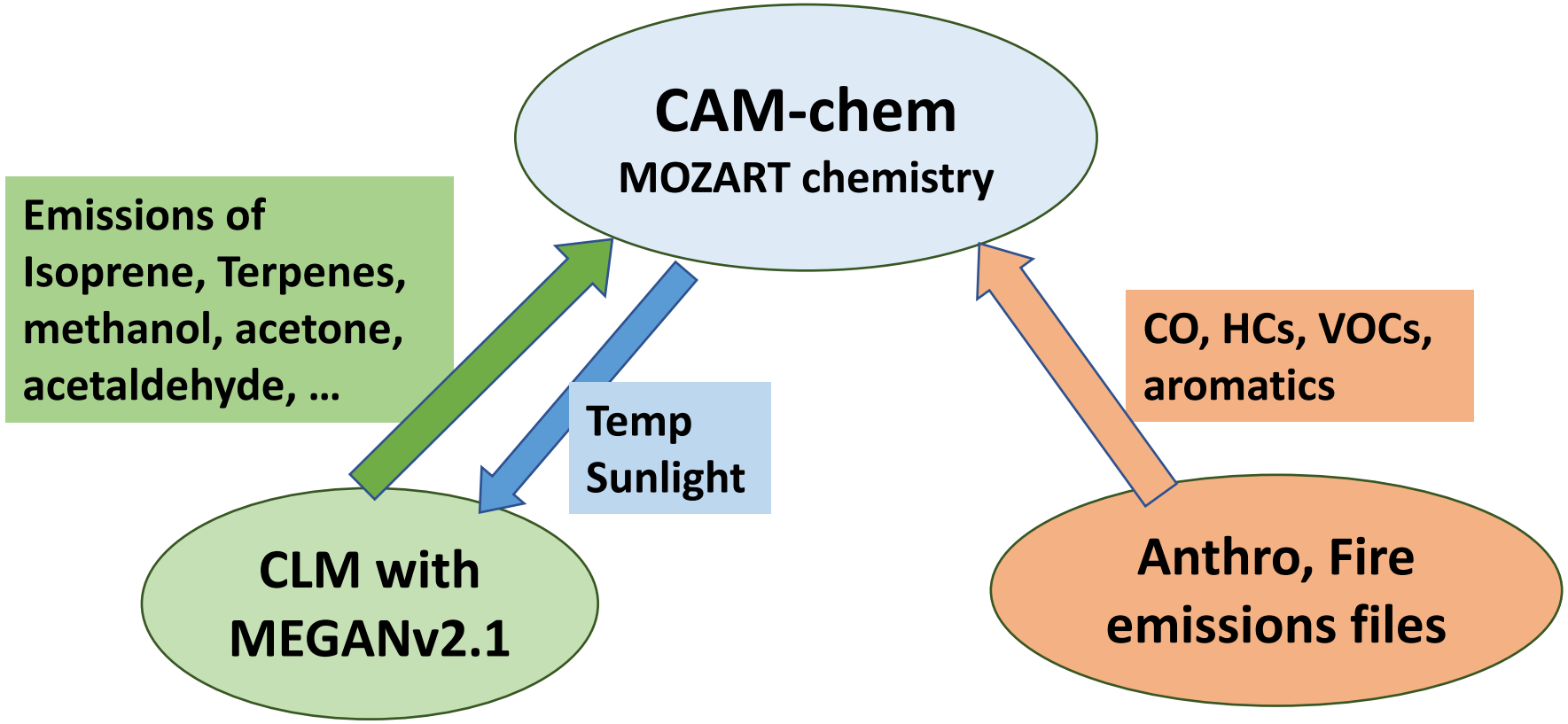


CAM-chem: Community Atmosphere Model with Chemistry

Component of CESM™: Community Earth System Model (NCAR/DOE)

CESM2.0 released last summer – for CMIP6 simulations (for IPCC AR6)

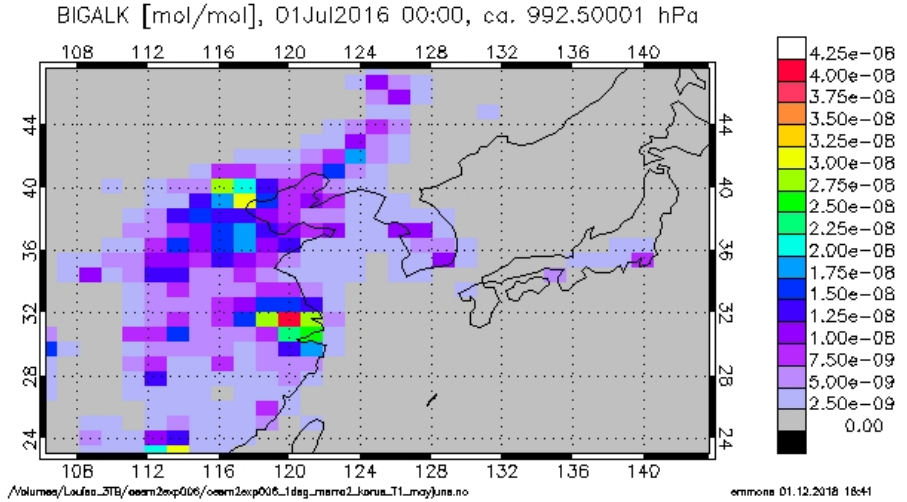
https://wiki.ucar.edu/display/camchem/Home

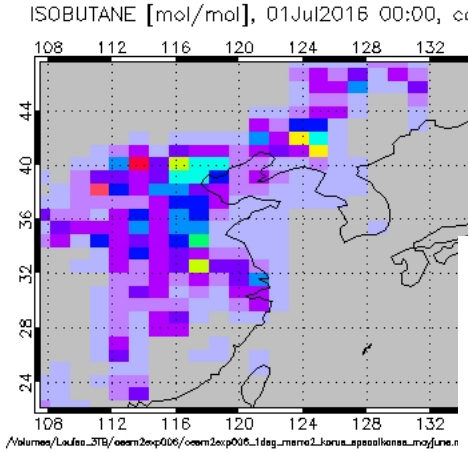


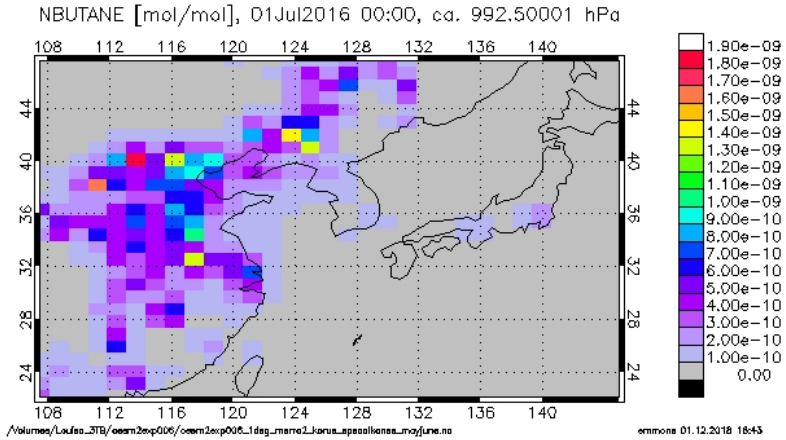
MOZART Chemistry

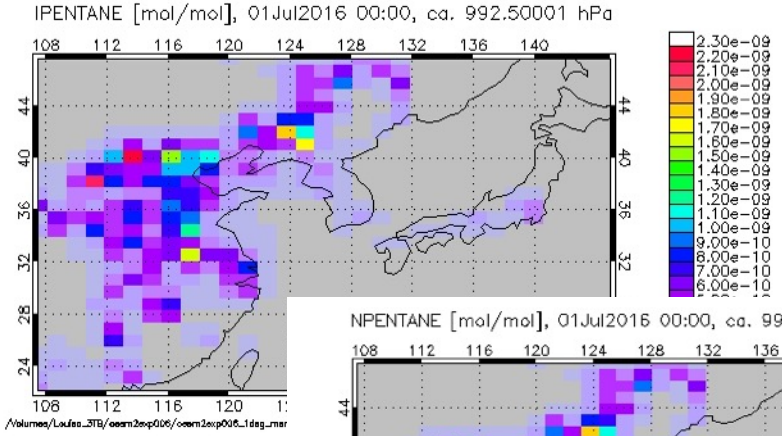
	MOZART-4 (obsolete) [Emmons et al., 2010]	MOZART-T1 (in CESM2) [Emmons et al., in prep.]	MZ-T1+NewAlkanes (in development)
Small HCs	C2H6, C3H8 C2H4, C3H6	C2H6, C3H8 C2H4, C3H6, C2H2	As T1
Larger HCs	BIGALK (C4 and larger alkanes) BIGENE (C4 and larger alkenes)	BIGALK, BIGENE	ISOBUTANE, NBUTANE, IPENTANE, NPENTANE, C6ALKANES, BIGENE, Updated C3H8 oxidation
Aromatics	Lumped aromatics ("TOLUENE")	Benzene, toluene, xylenes with updated oxidation prod.	As T1
Isoprene, terpenes	ISOP, C10H16 (all terpenes) with very simple oxidation products	ISOP and updated oxidation, Speciated terpenes with updated oxidation	As T1
Organic nitrates	ONIT	ALKNIT, NOA, Isoprene nitrates, TERPNIT	PPN

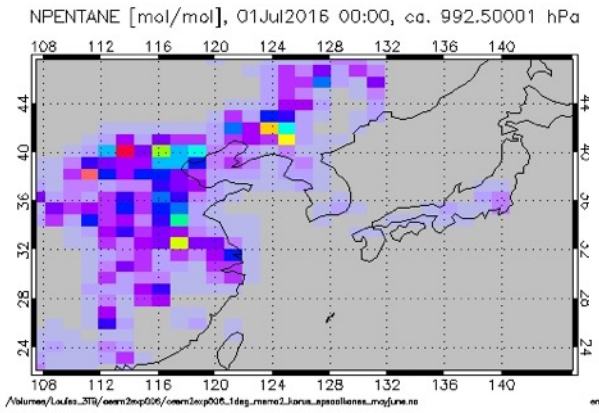
BIGALK replaced with specific butanes, pentanes and lumped C6alkanes

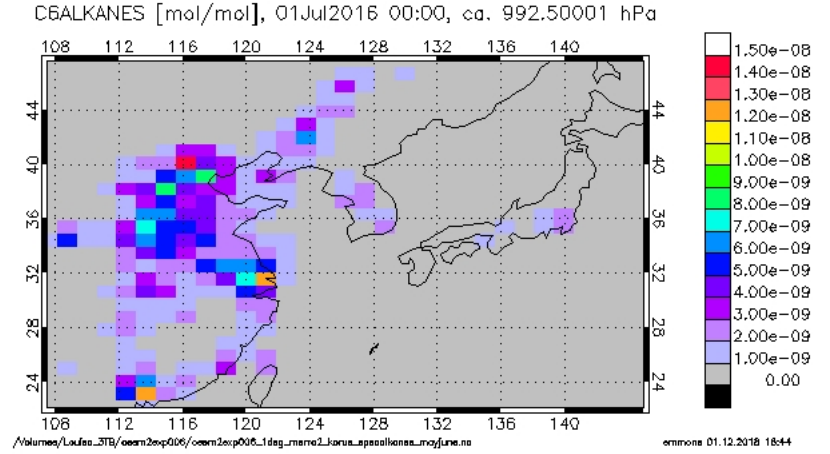












Emissions estimated from CEDS/CMIP6:

NBUTANE = 0.33 * butanes

ISOBUTANE = 0.67 * butanes

NPENTANE = 0.5 * pentanes

IPENTANE = 0.5 * pentanes

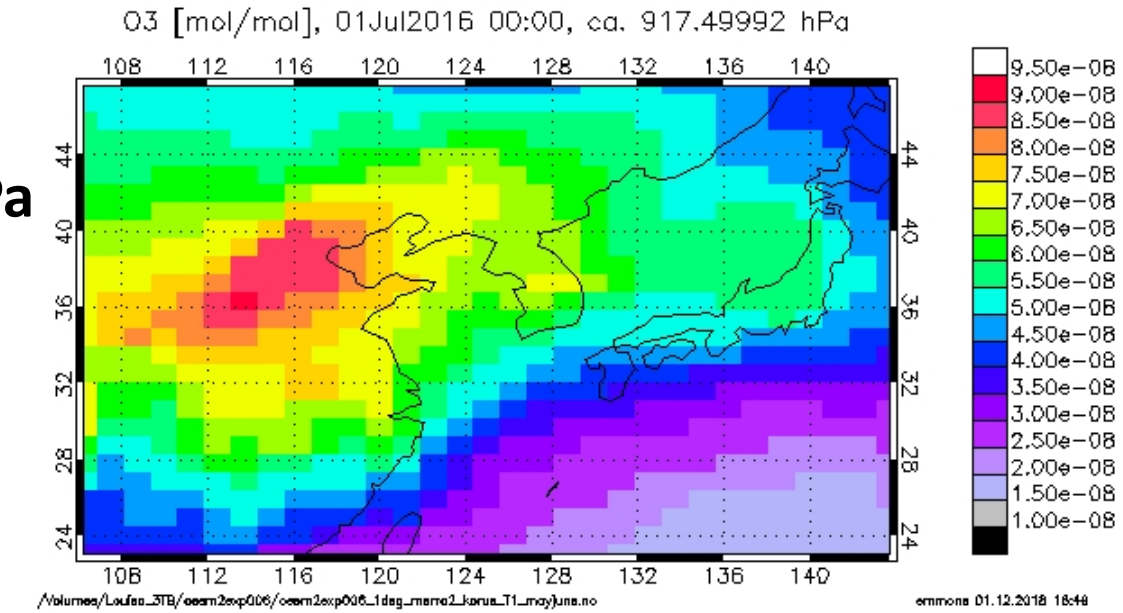
C6ALKANES = hexanes&larger + esters + ethers

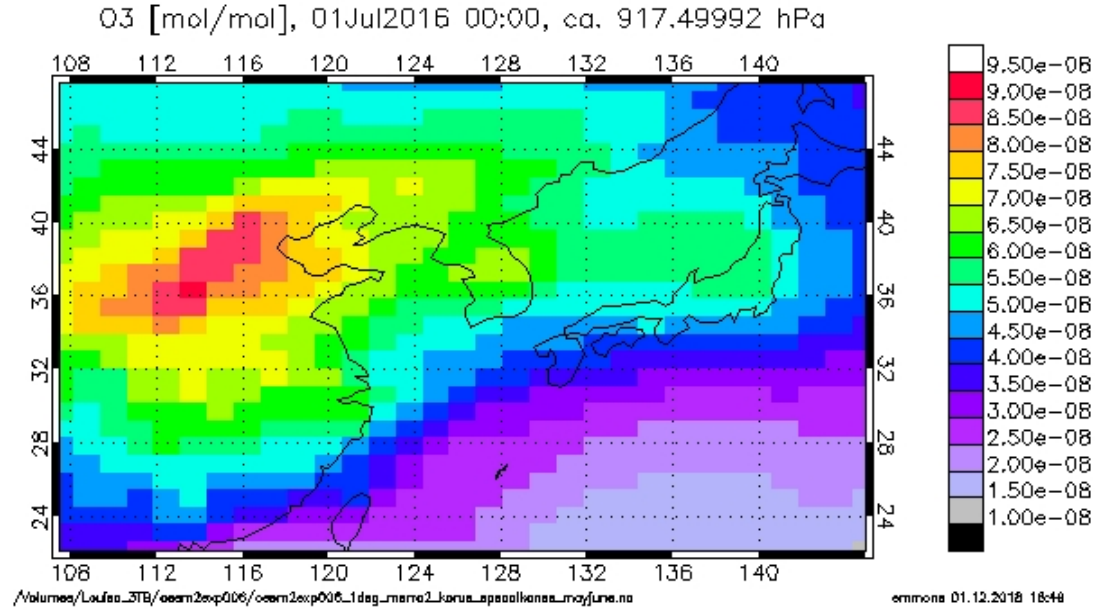
Ozone June 2016

T1

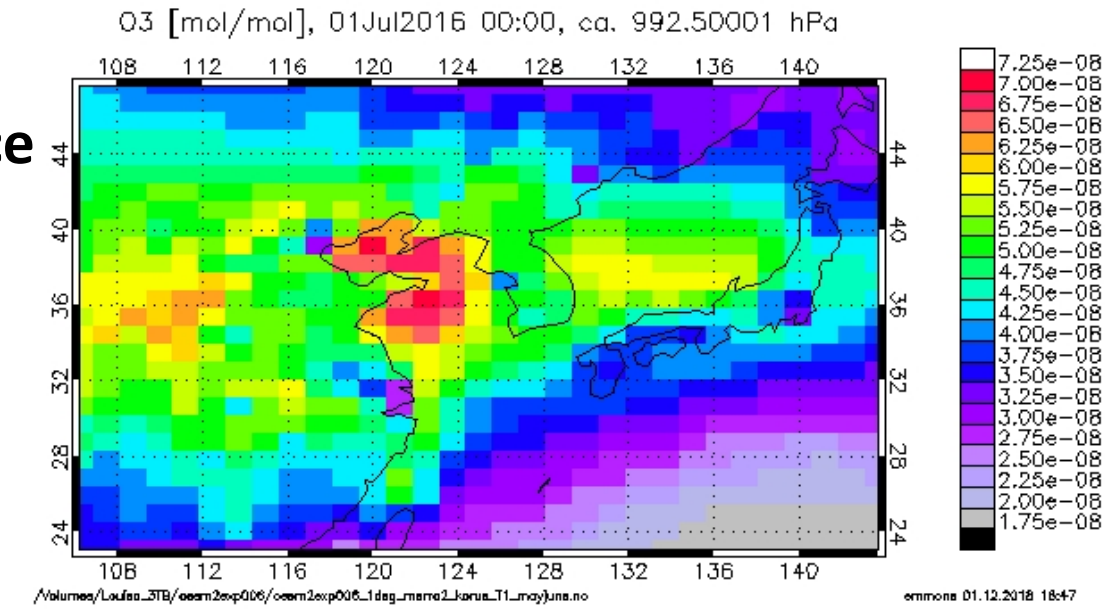
New Alkanes

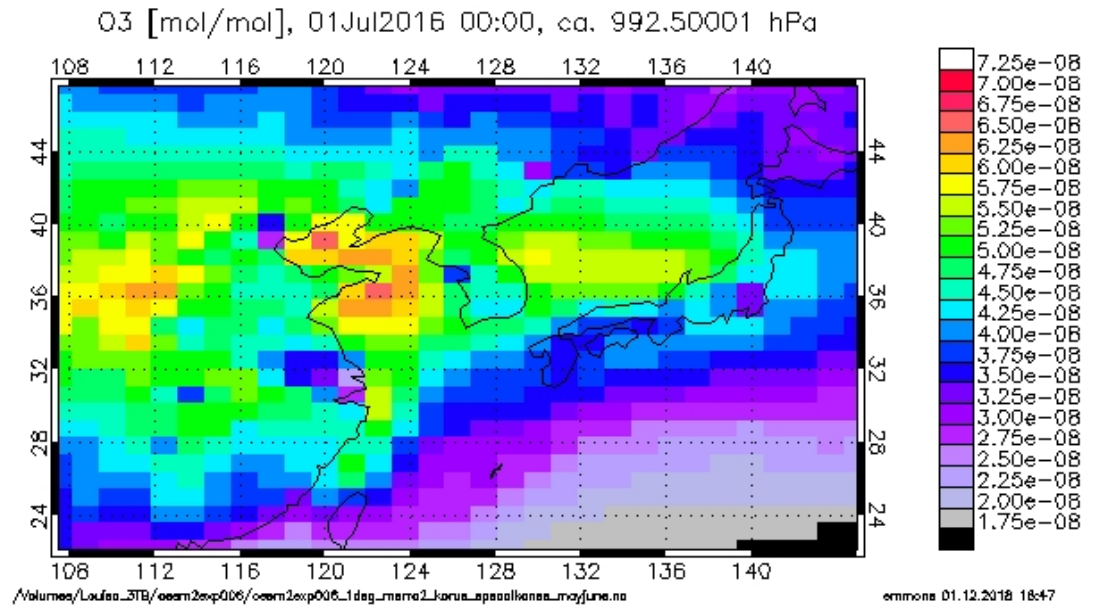
900hPa





Surface





KORUS-AQ

May-June 2016

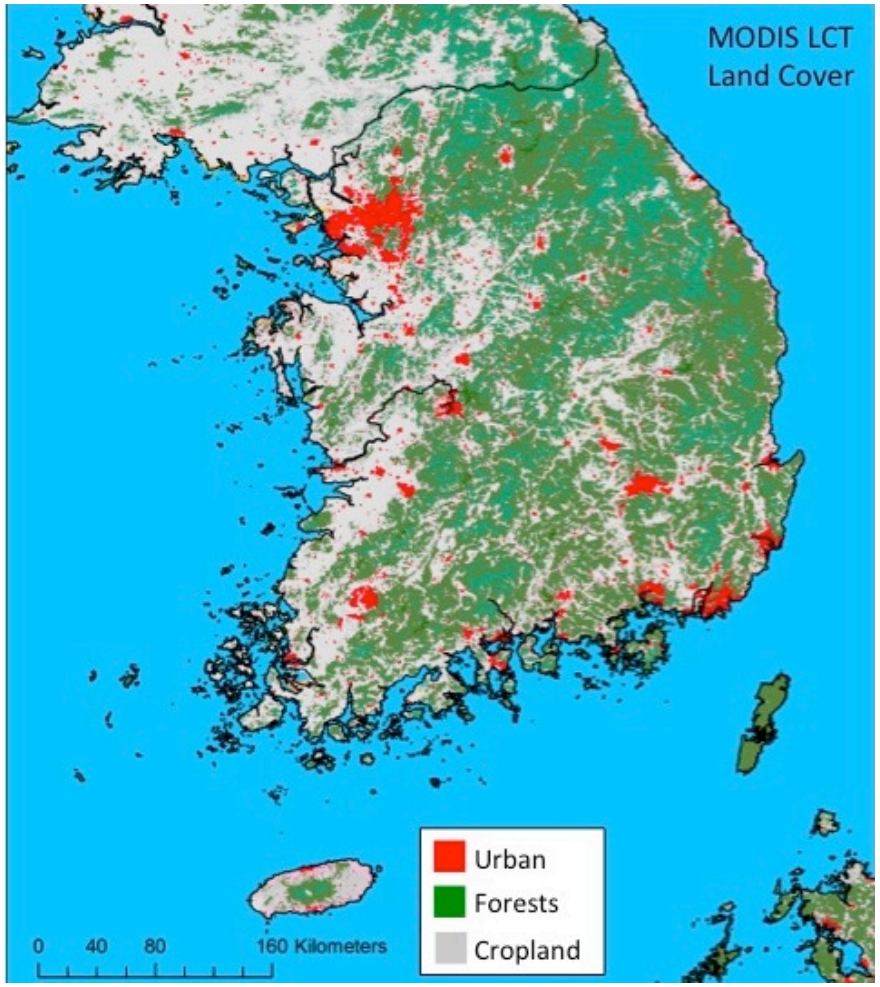
Field campaign led by NASA and NIER

Multiple aircraft, ground sites (in situ and remote sensing), ships

Quantifying drivers of ozone and PM2.5 pollution in Seoul, other regions of Korea, and region

Rapid Science Synthesis Report provided to Korea Ministry of Environment July 2017

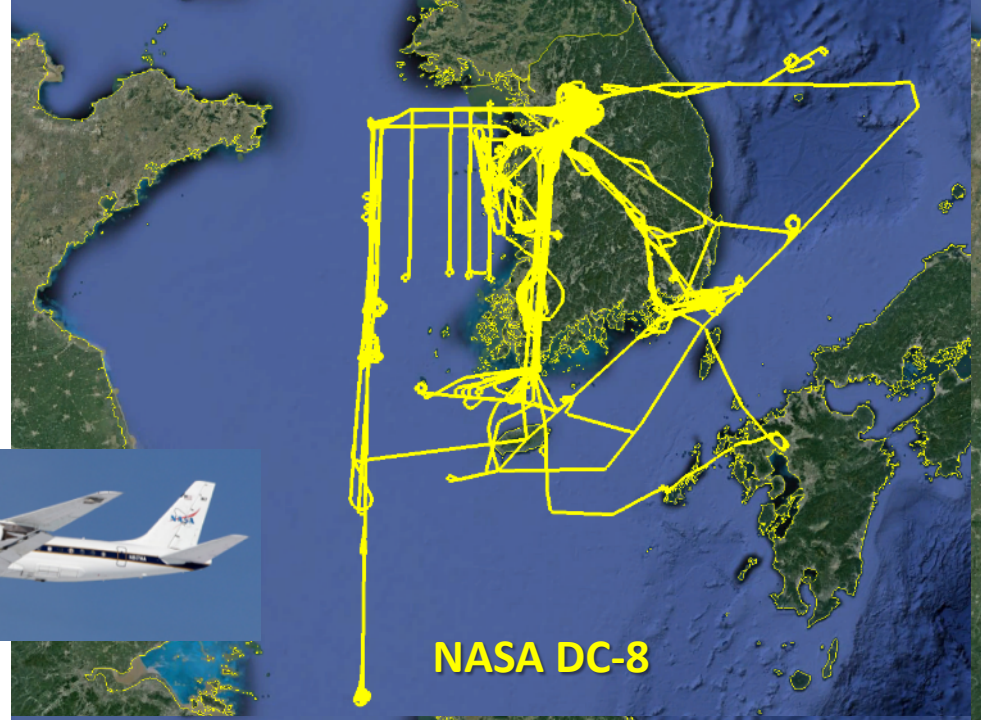
Final report to be written in 2019, providing guidance on improving air quality in Korea



Seoul Metropolitan Area has 25 million inhabitants, half of Korea's population

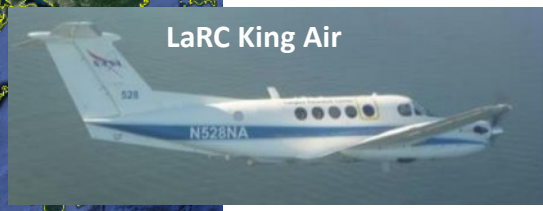
Separation between urban and natural emissions

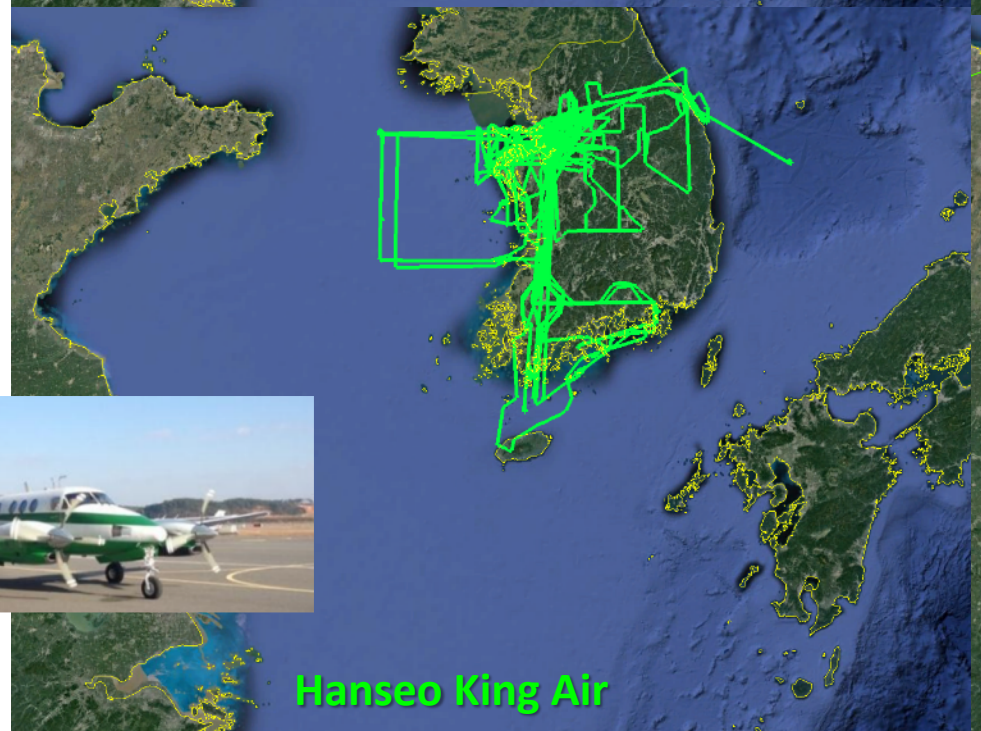
Rural regions are heavily forested

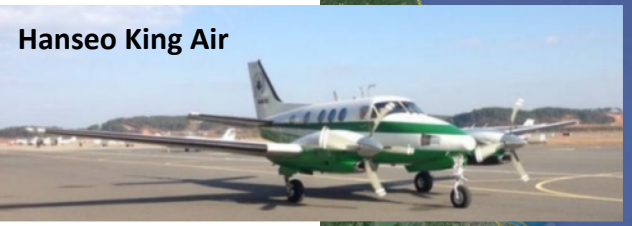

NASA DC-8

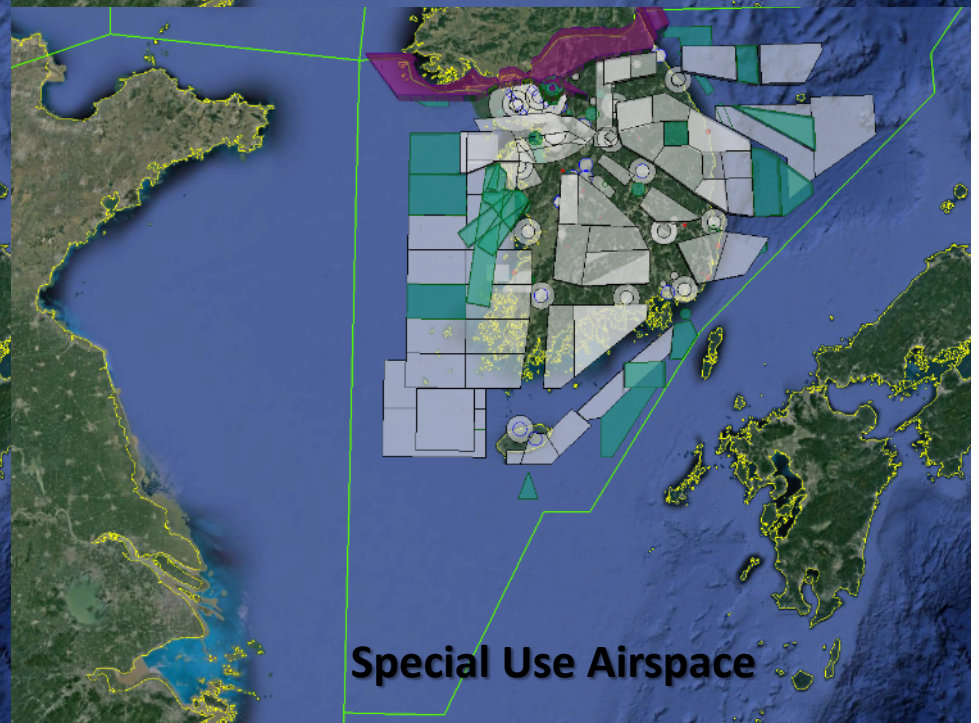

NASA DC-8


NASA King Air


LaRC King Air
N526NA


Hanseo King Air


Hanseo King Air

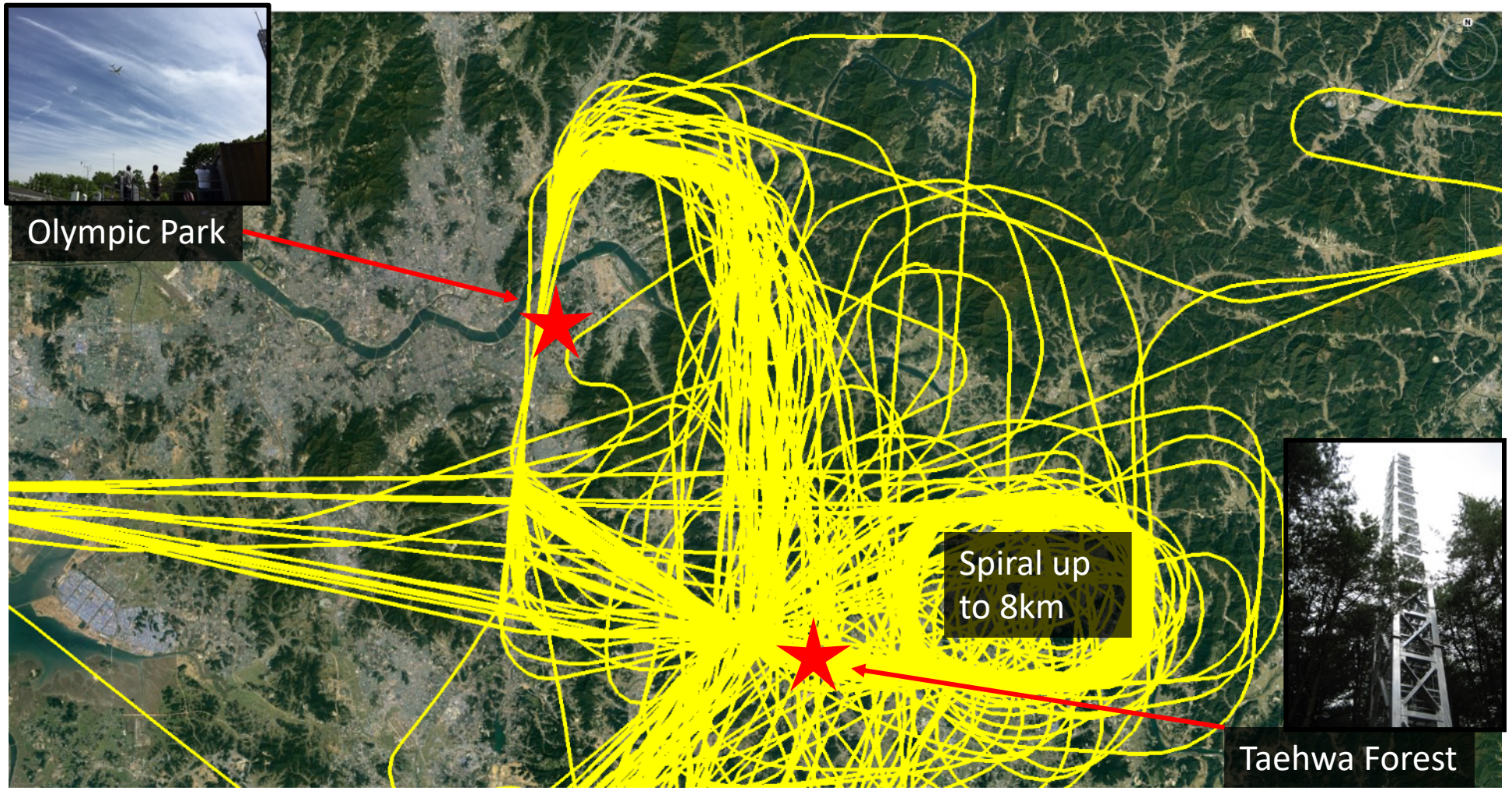

Special Use Airspace

KORUS-AQ

Ministry of Environment
National Institute of Environmental Research

NASA

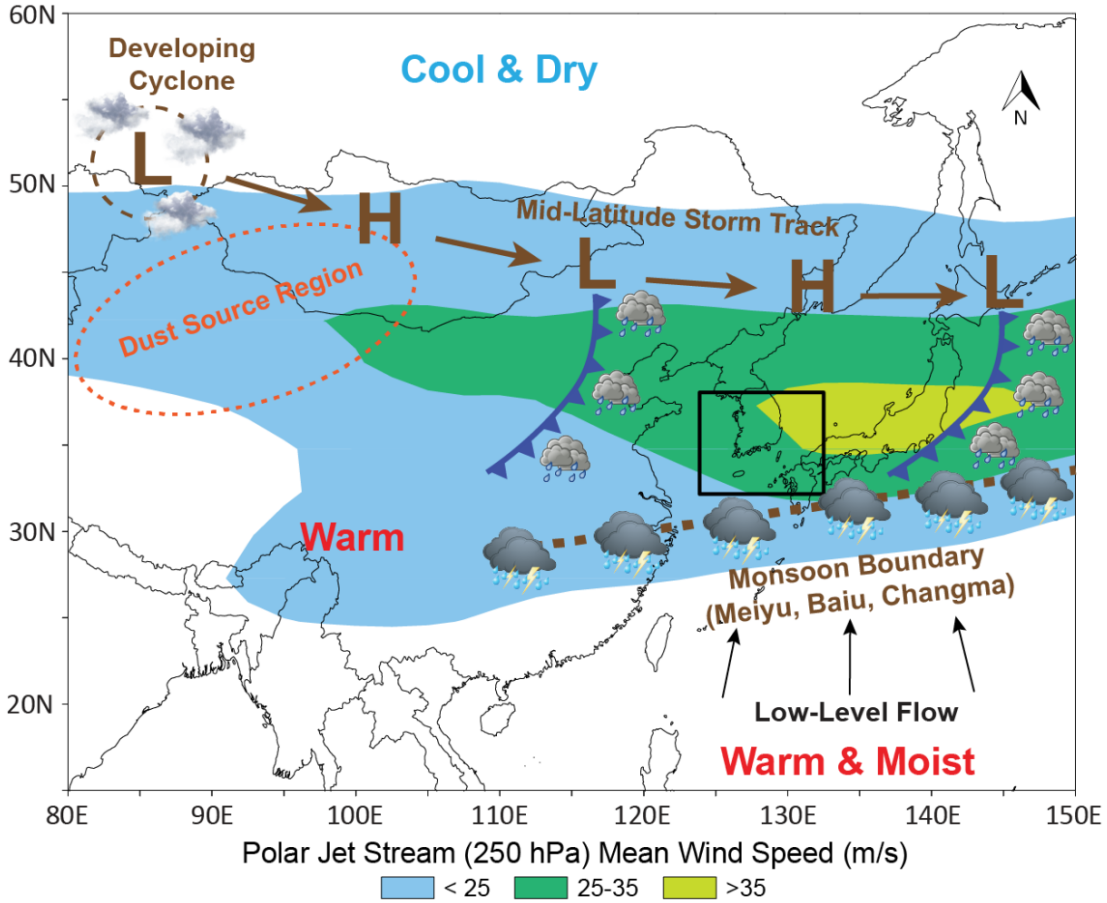
Repetitive sampling by the DC-8 over research sites in Seoul and adjacent rural areas



Photos by J. Crawford

General Meteorology during KORUS-AQ

Meteorology determines pollution impacts!



Mid-Latitude Storm Track:

- Polar jet stream
- Mid-latitude cyclones
- Frontal passages and rain
- Major air mass changes
- Lofting of pollution
- Dust transport
- Smoke transport

Monsoon Boundary:

- Focus of rain/clouds to south
- Slowly migrates north May-June
- Some interaction with fronts

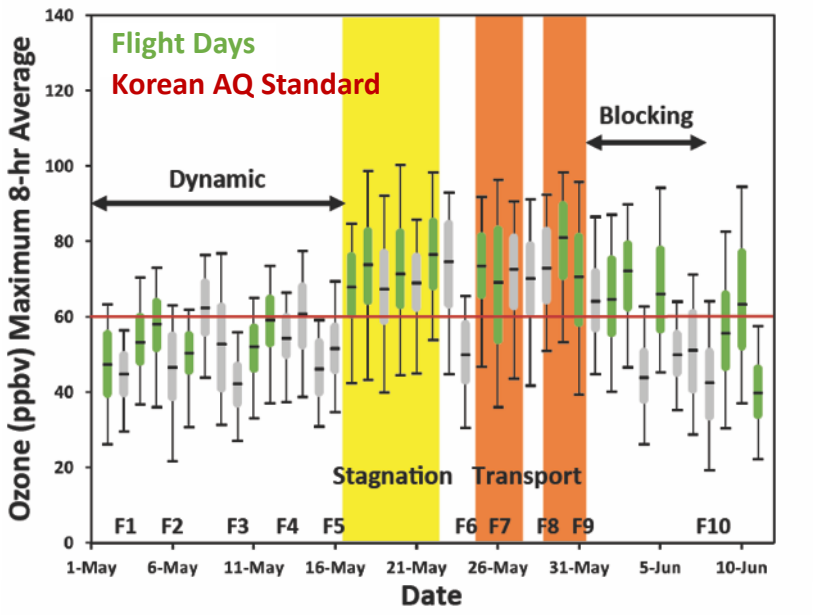
Peterson et al., KORUS-AQ met overview, in prep.

Pollution Regimes driven by Synoptic Meteorology

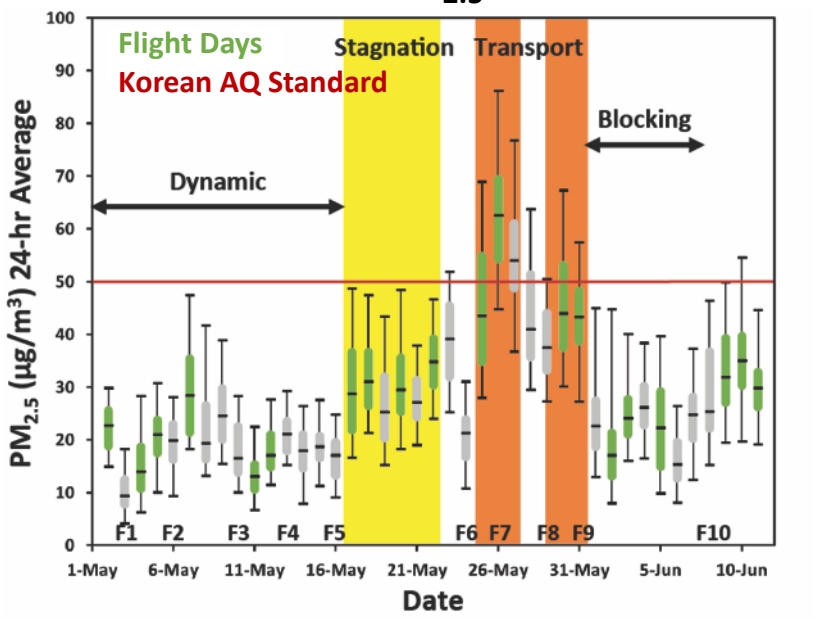
Synoptic meteorology sets the stage for regional and localized pollution regimes

Four distinct research periods during KORUS-AQ…

Ozone



$PM_{2.5}$

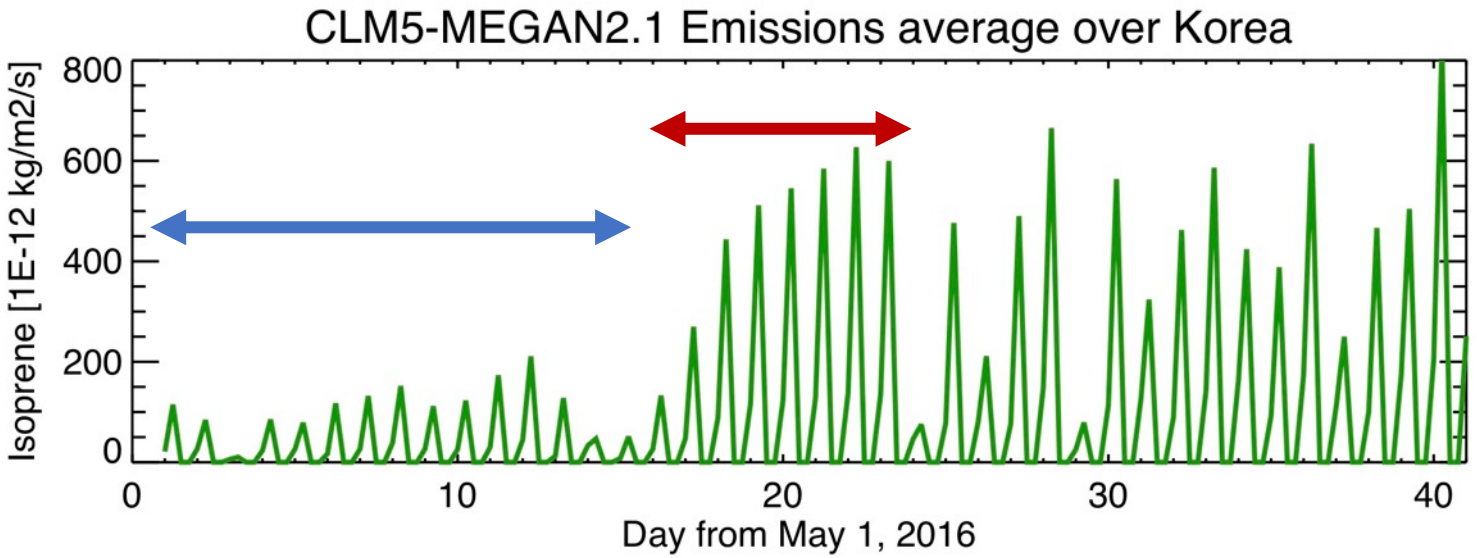


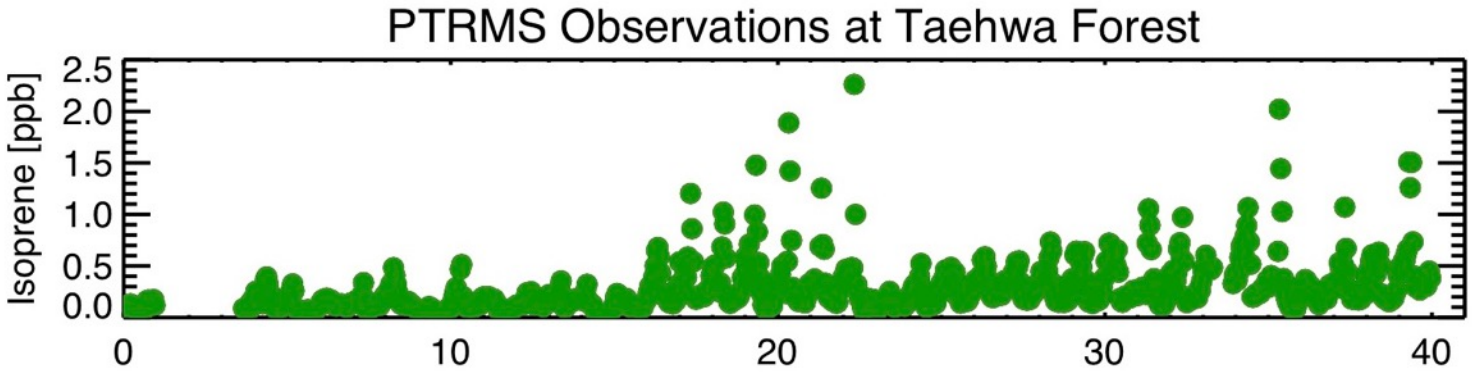
Distributions based on AirKorea surface monitors across South Korea.

May 1-15: cool, cloudy weather depressed biogenic emissions

May 16-22: warm, dry weather with stagnant conditions over Korea

Later part of campaign: mixed conditions, warm, but cloudy

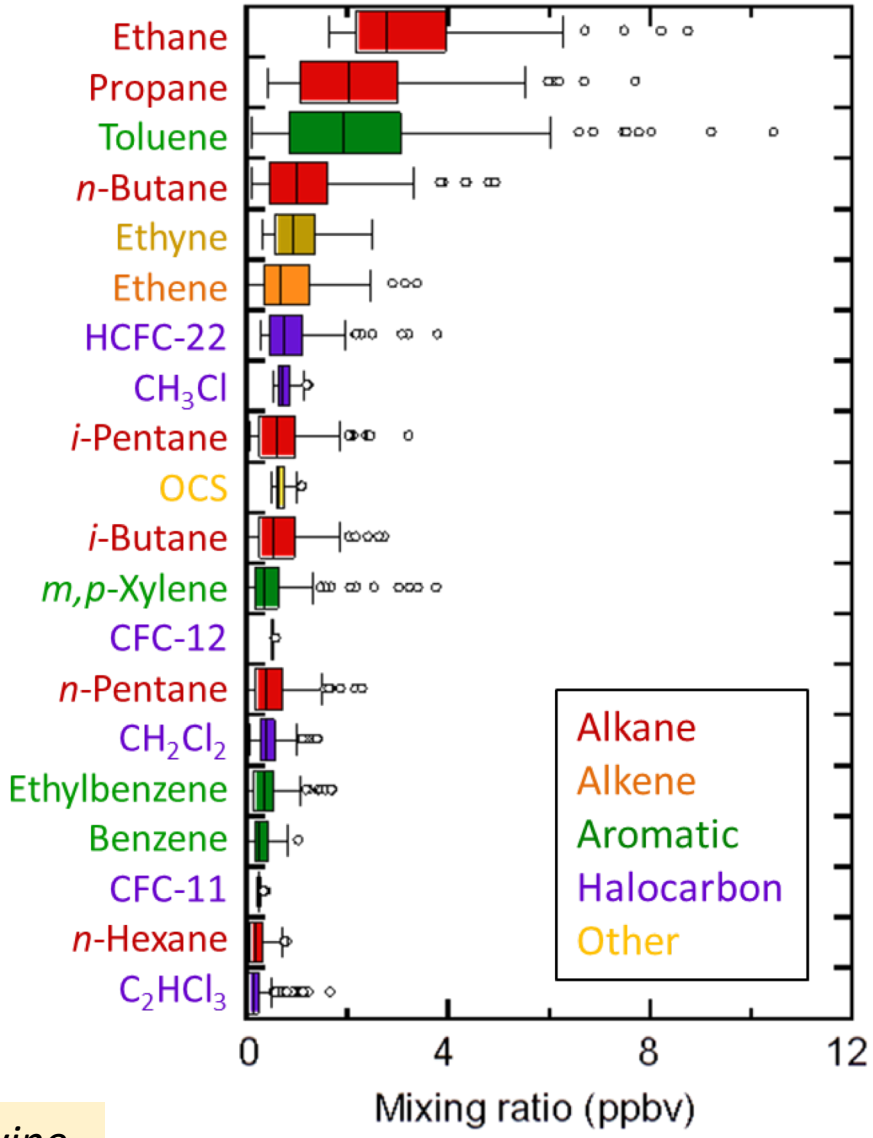




PTRMS observations by S.Kim et al. (UC-Irvine).

Alkanes and Aromatics are very abundant in Seoul

VOC abundance in Seoul



Seoul VOC tracers

CNG
- Ethane
- Propane

LPG:
- Propane (home)
- *n*-Butane (vehicle)

Gas evaporation:
- *i*-Pentane

Vehicle exhaust:
- Ethene
- Propene

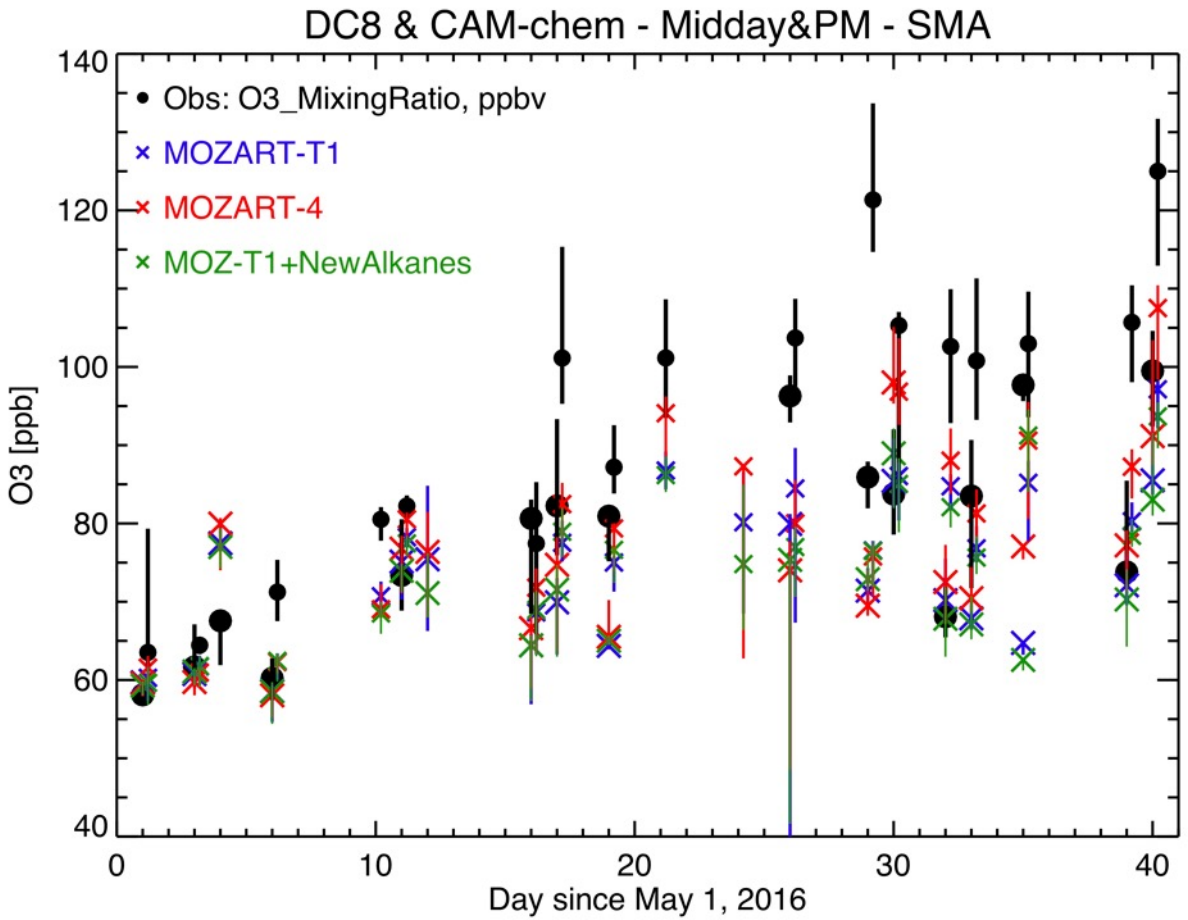
Solvents:
- Toluene
- Xylenes (paint)

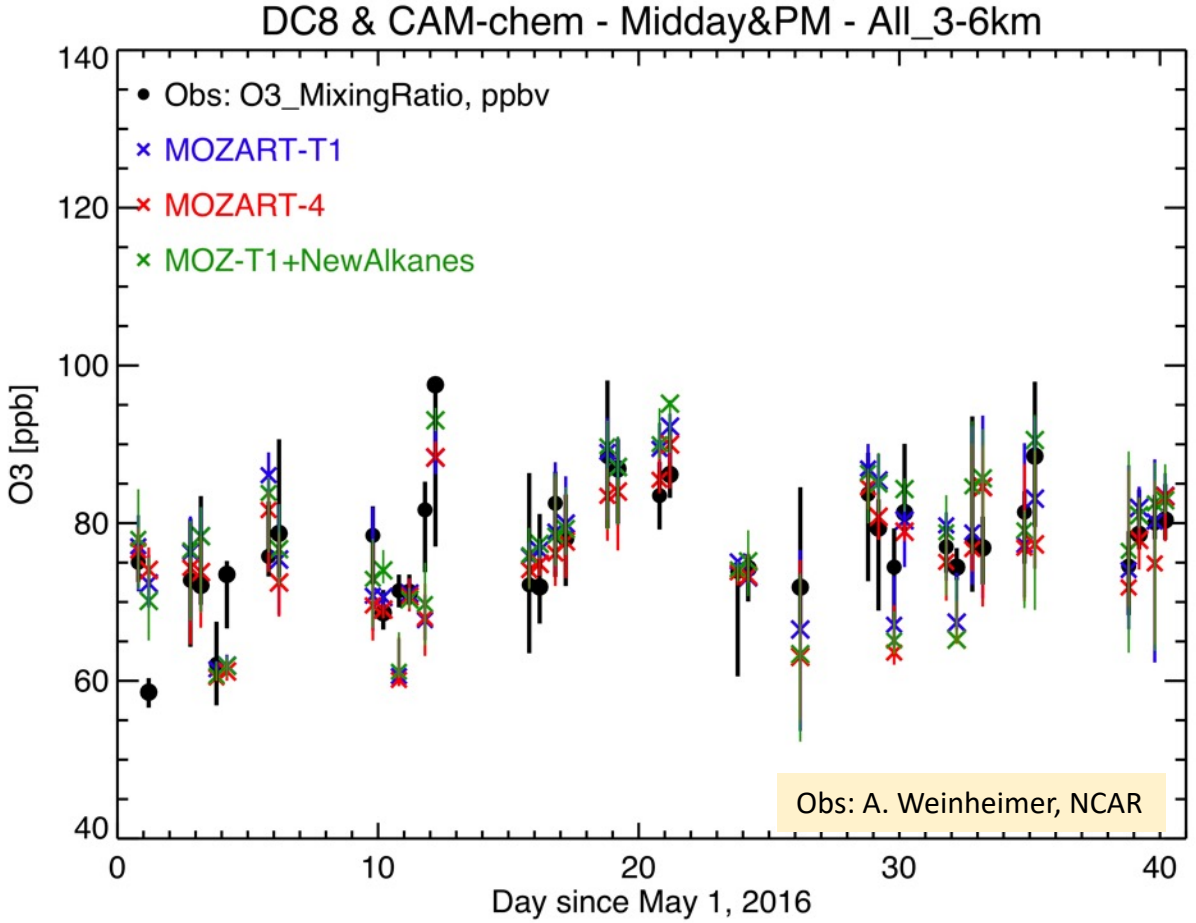
Biogenic:
- Isoprene

CNG = compressed natural gas
LPG = liquefied petroleum gas

I.Simpson, D.Blake, UC-Irvine

Evaluation of CAM-chem MOZART mechanisms with KORUS-AQ DC8 observations

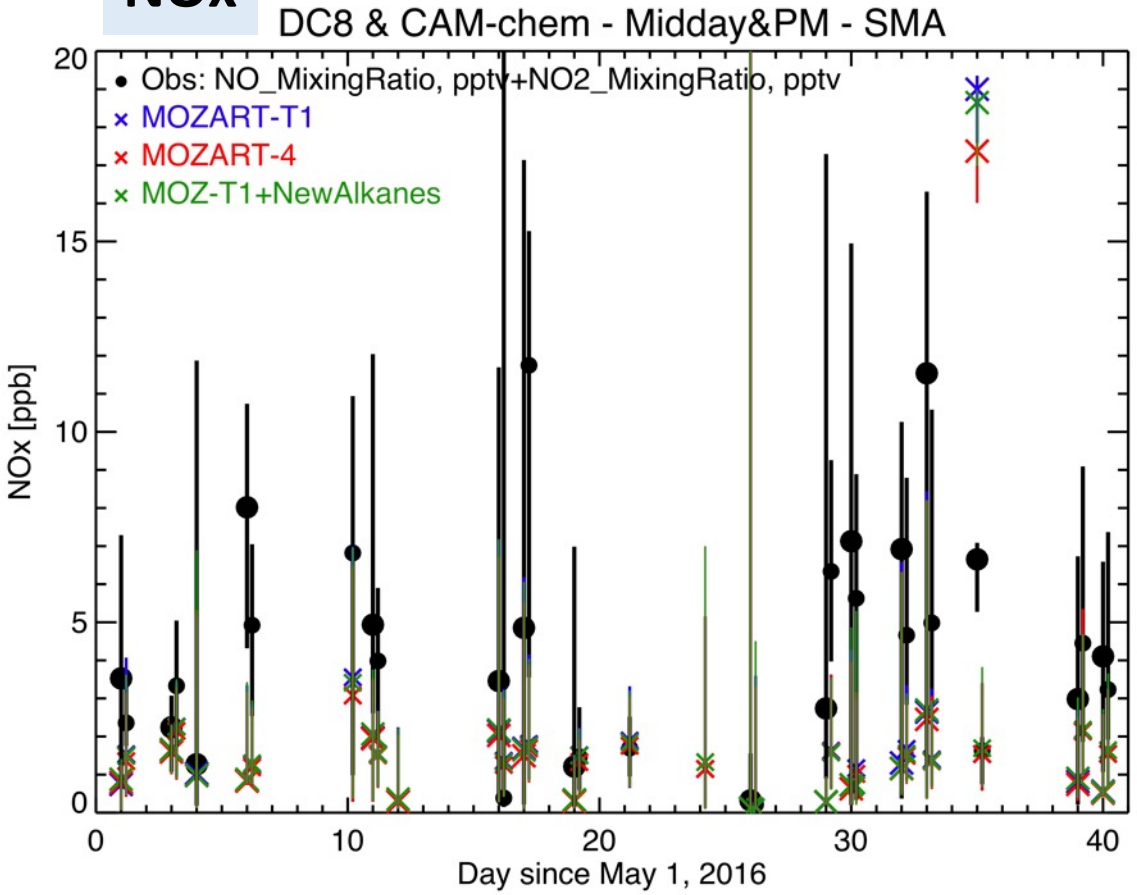




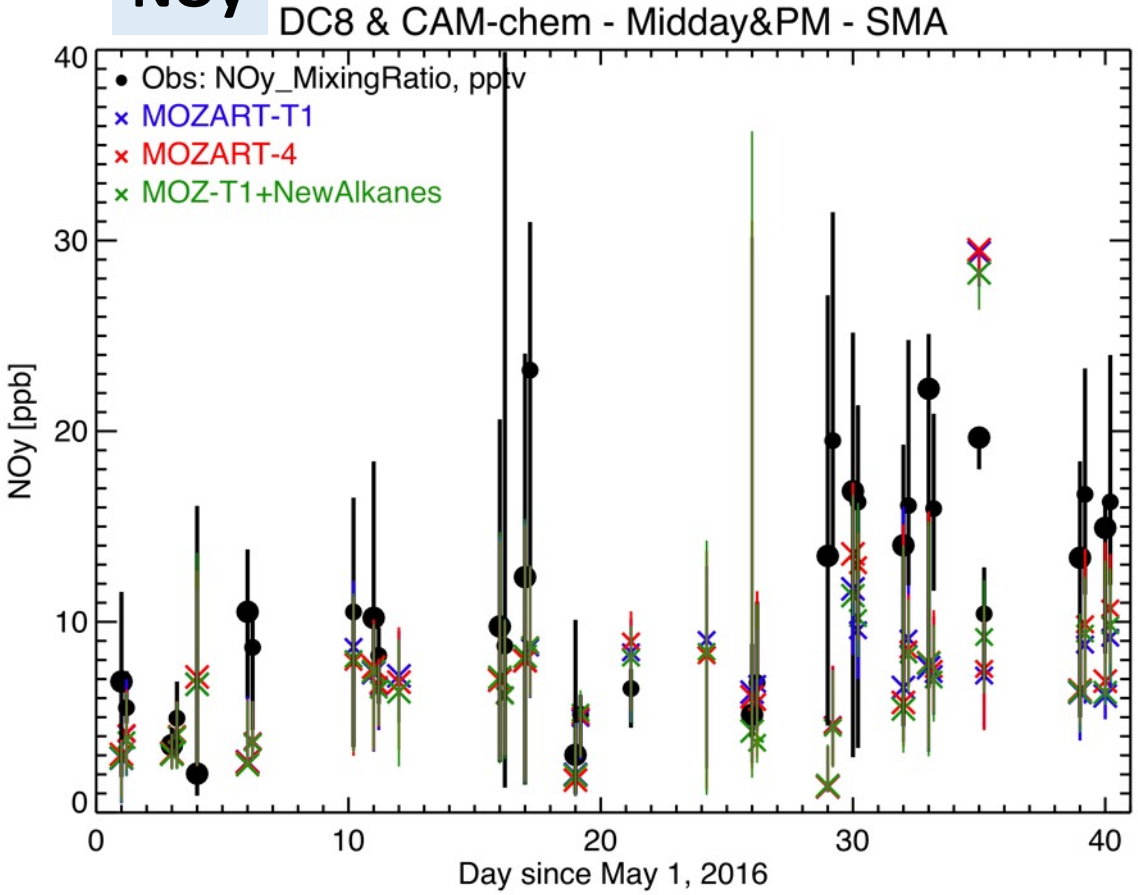
All mechanisms under-estimate ozone in Seoul
Strong seasonal increase

Above BL modeled O3 generally agrees with obs.
Constant through late Spring

NOx



NOy

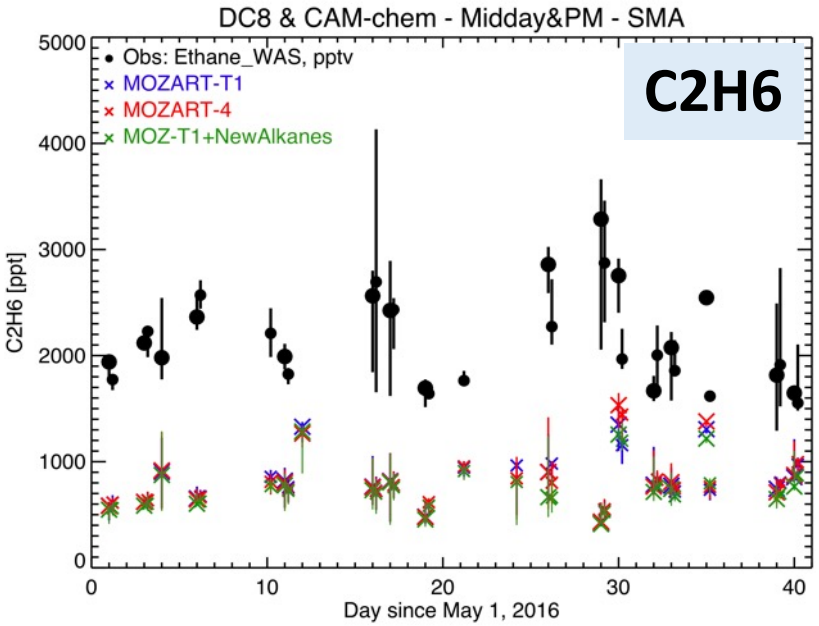


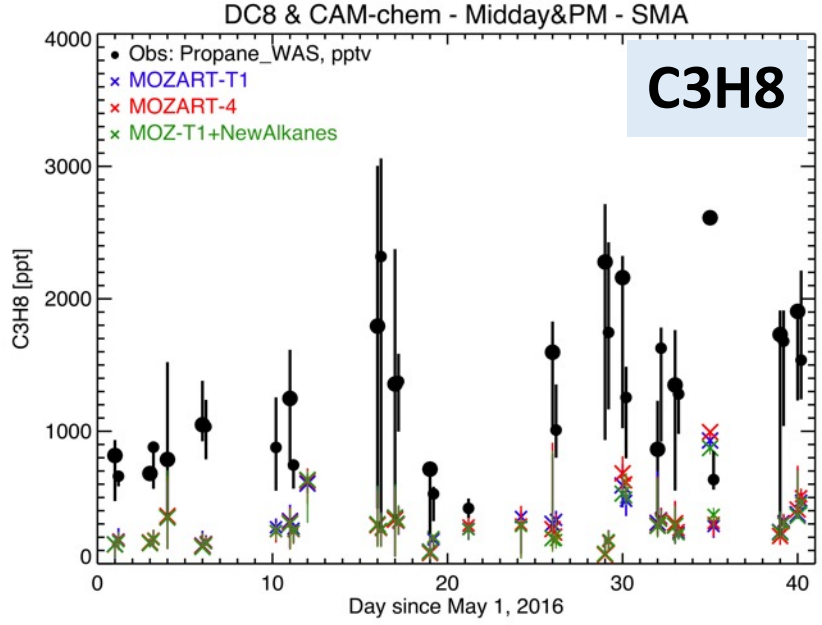
Model underestimates the very high NOx and NOy in Seoul
- probably underestimating traffic emissions

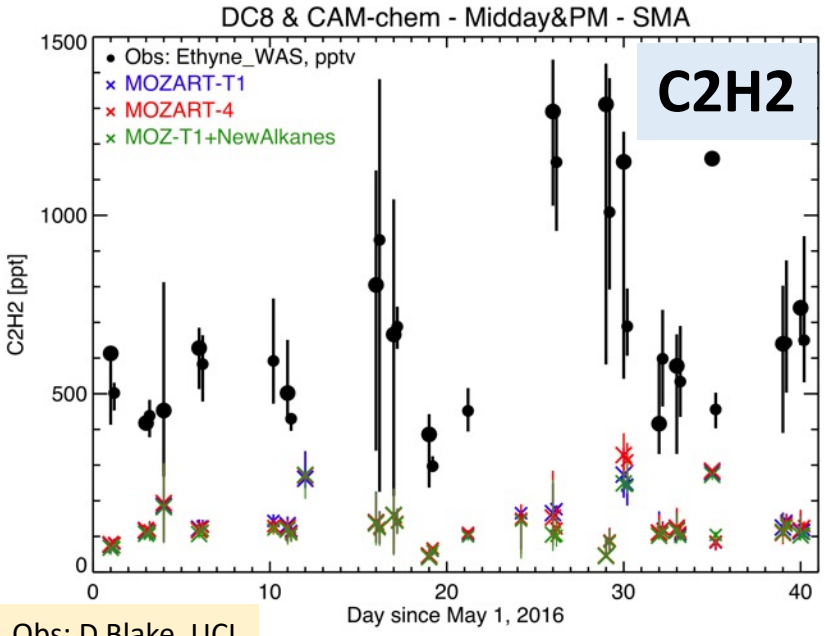
Obs: A. Weinheimer, NCAR

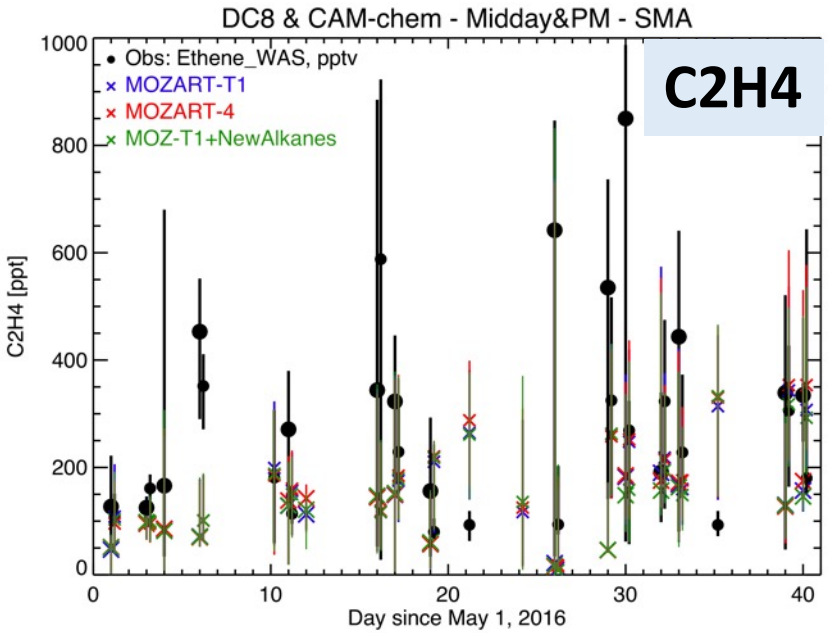
Smaller alkanes, alkenes, ethyne all underestimated

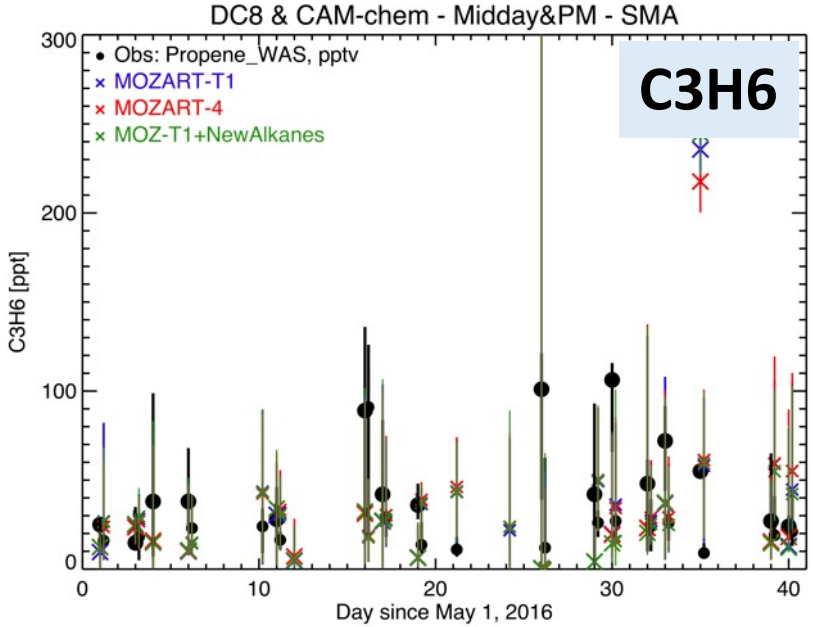
- Emissions likely significantly underestimated
- Too high OH may contribute
- Differences in OH between mechanisms





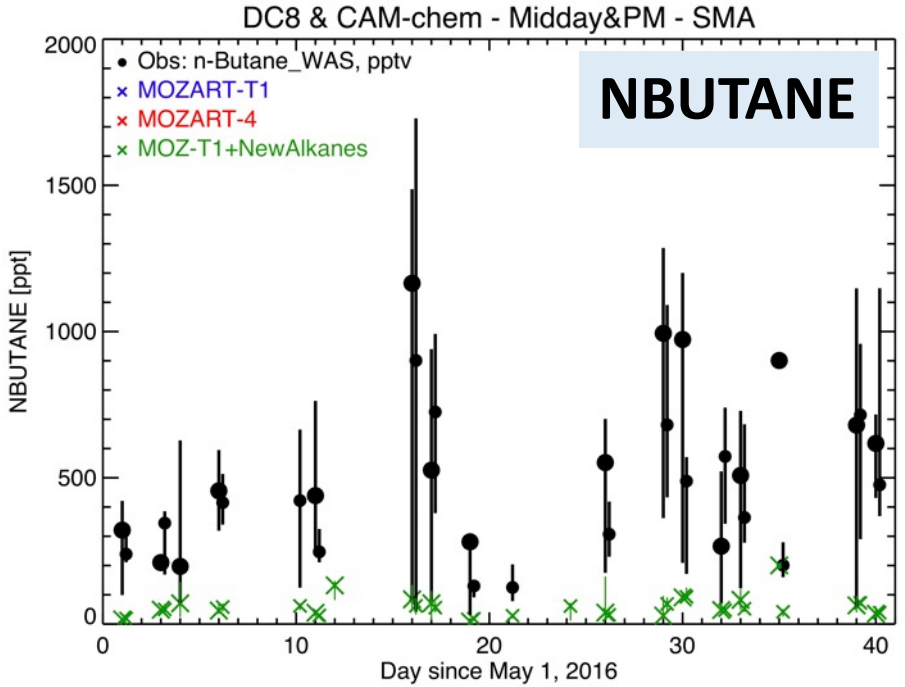


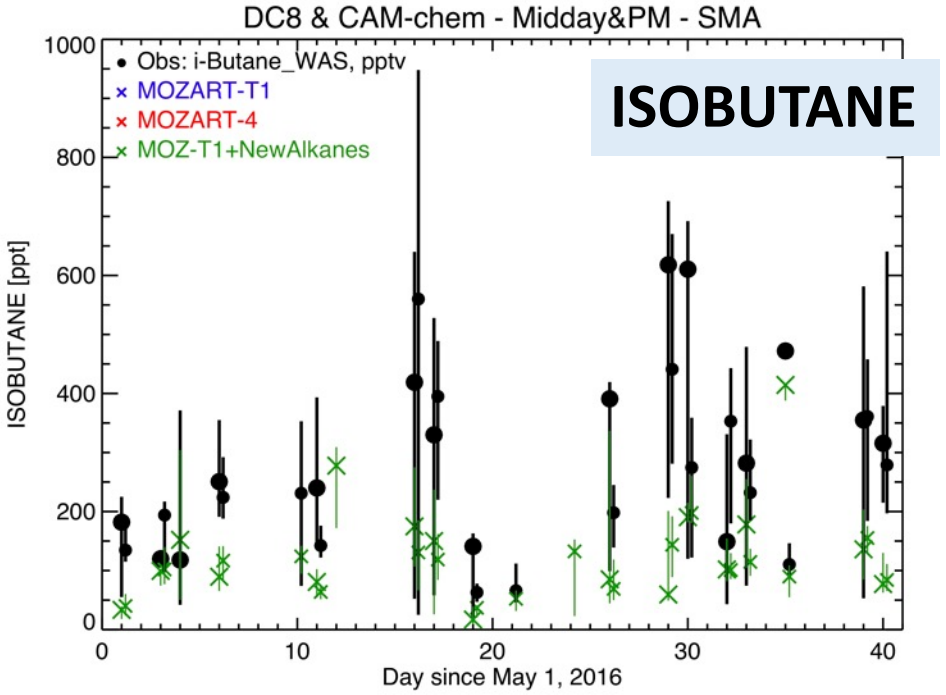


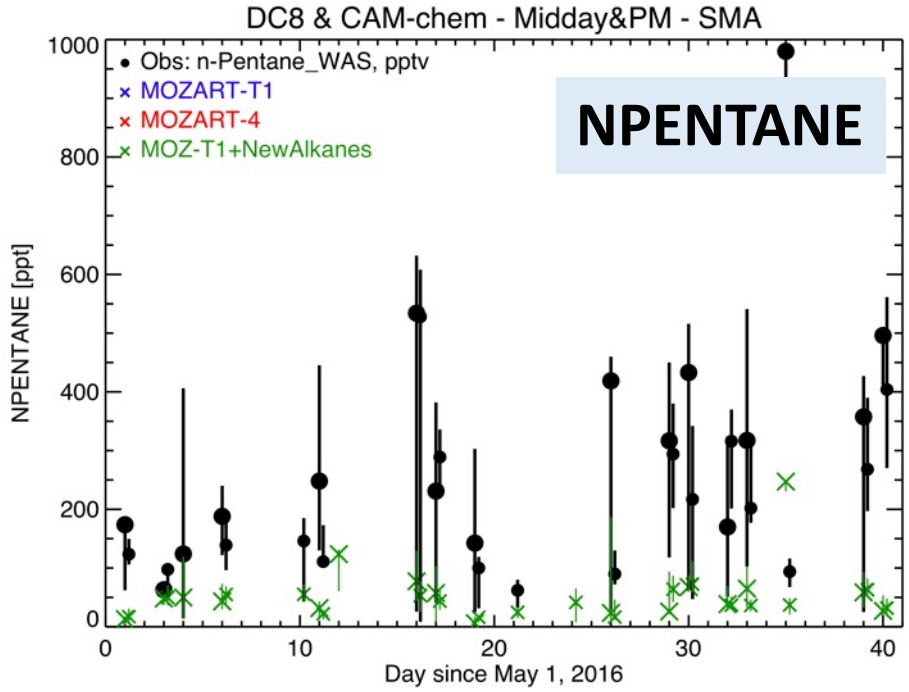


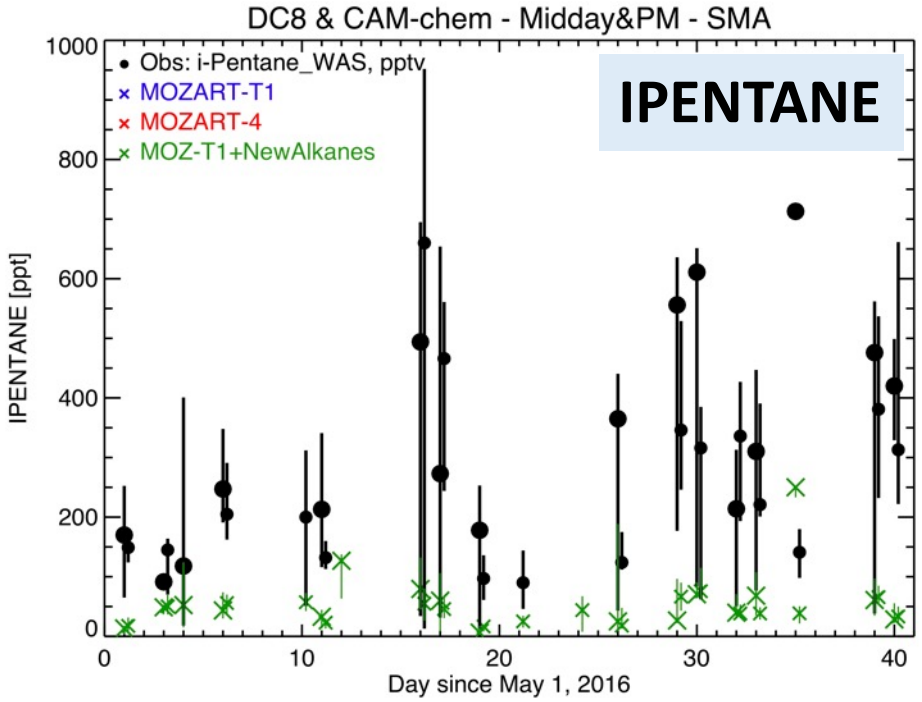
Obs: D.Blake, UCI

Speciated larger alkanes all underestimated by model (low emissions)

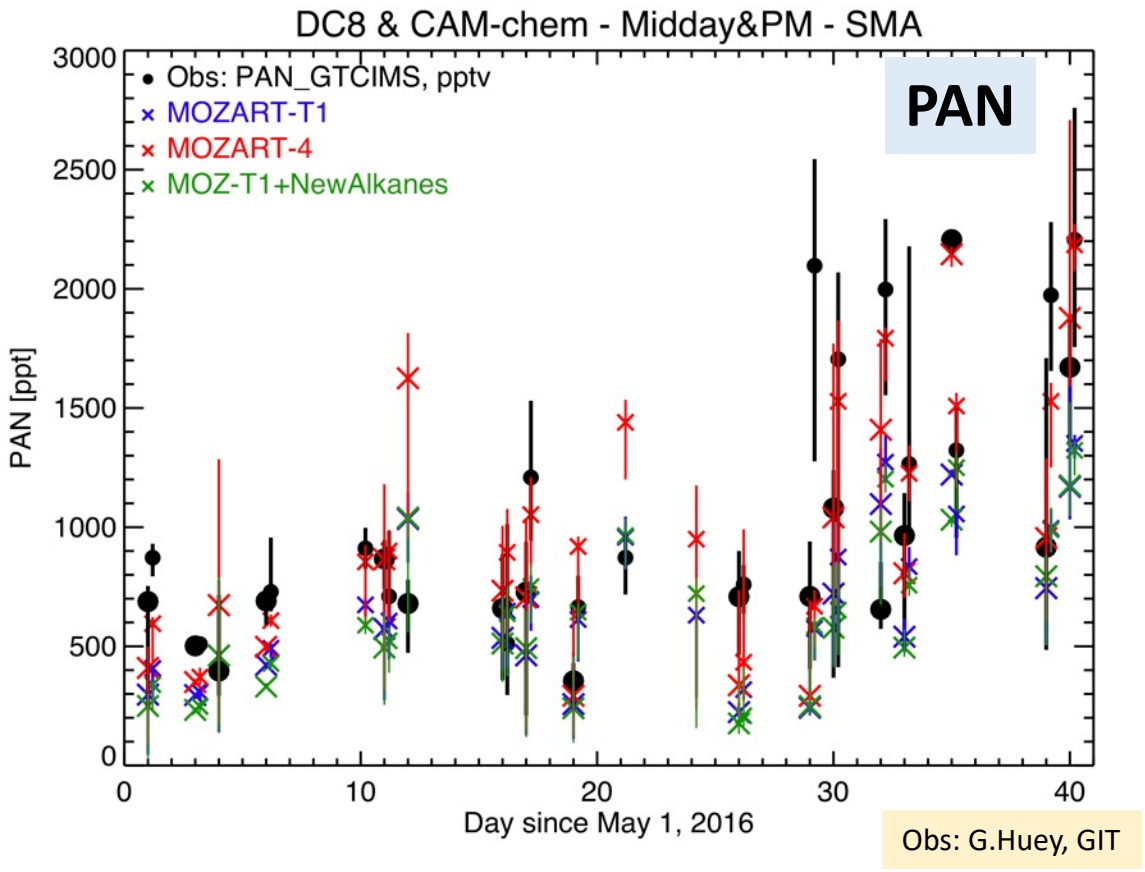


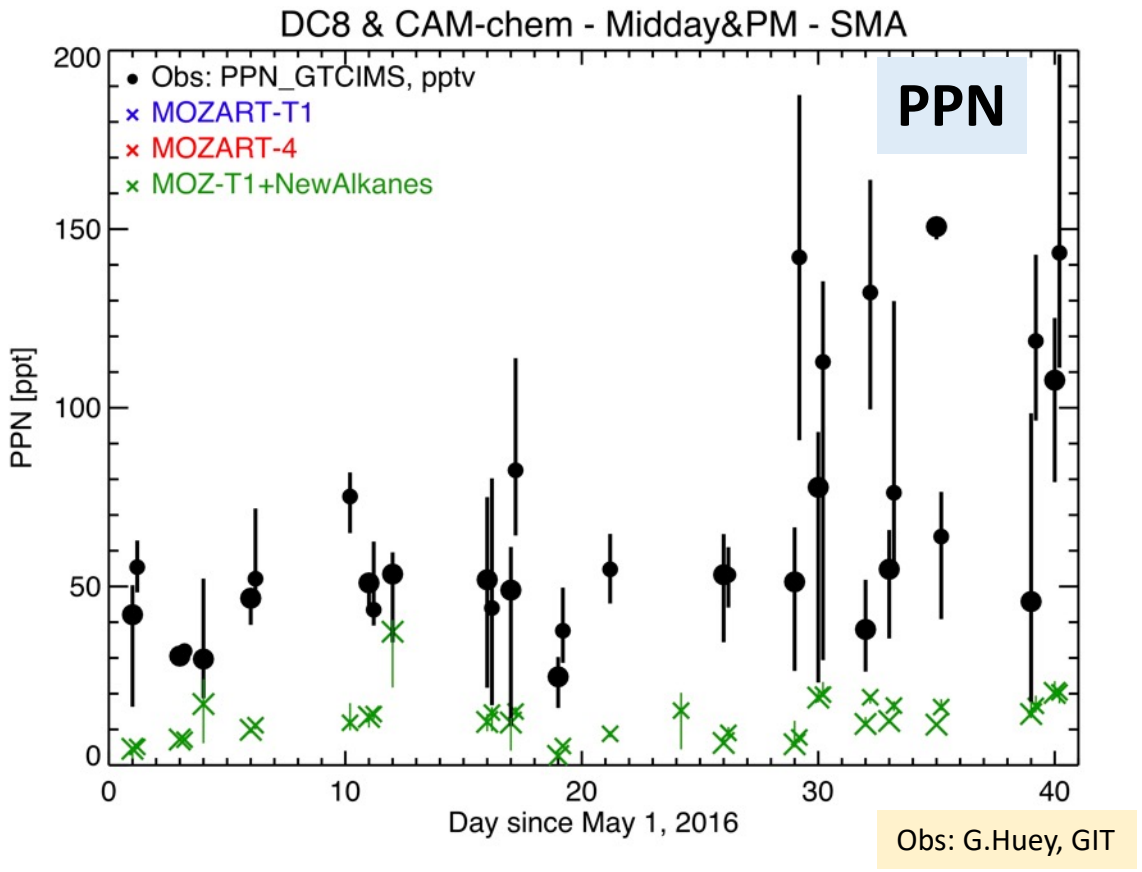




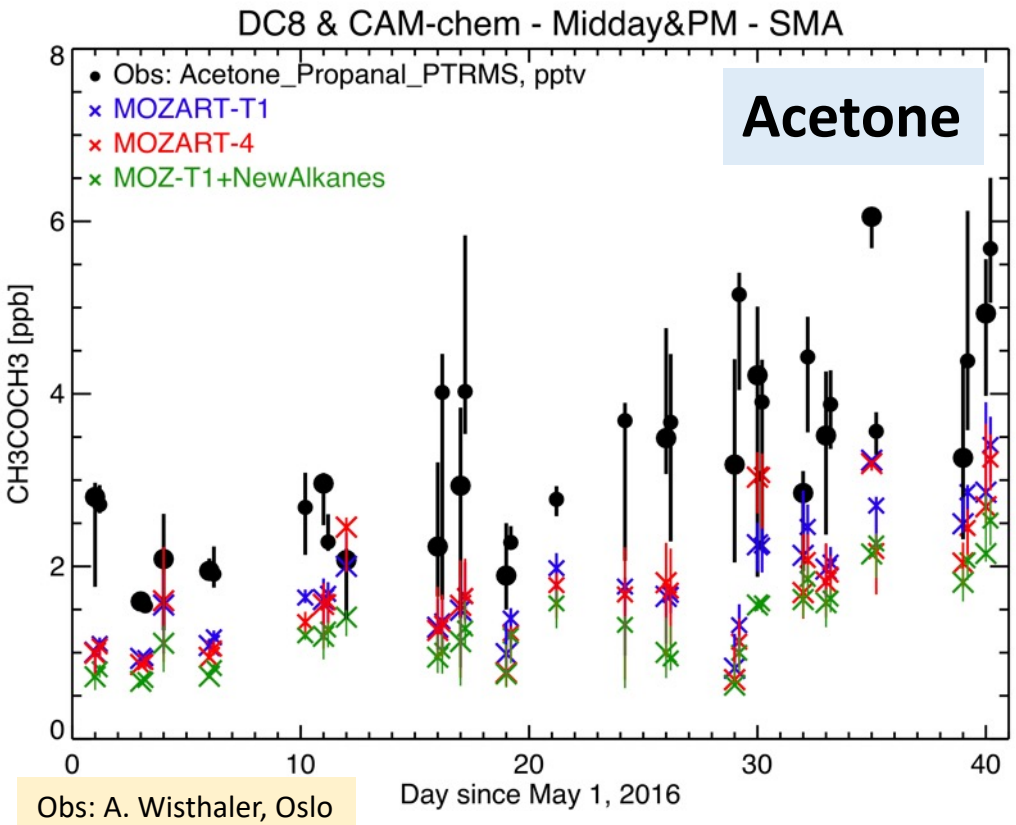


Obs: D.Blake, UCI





Updated propane oxidation includes propanal and PPN
Low modeled PPN consistent with too low C3H8

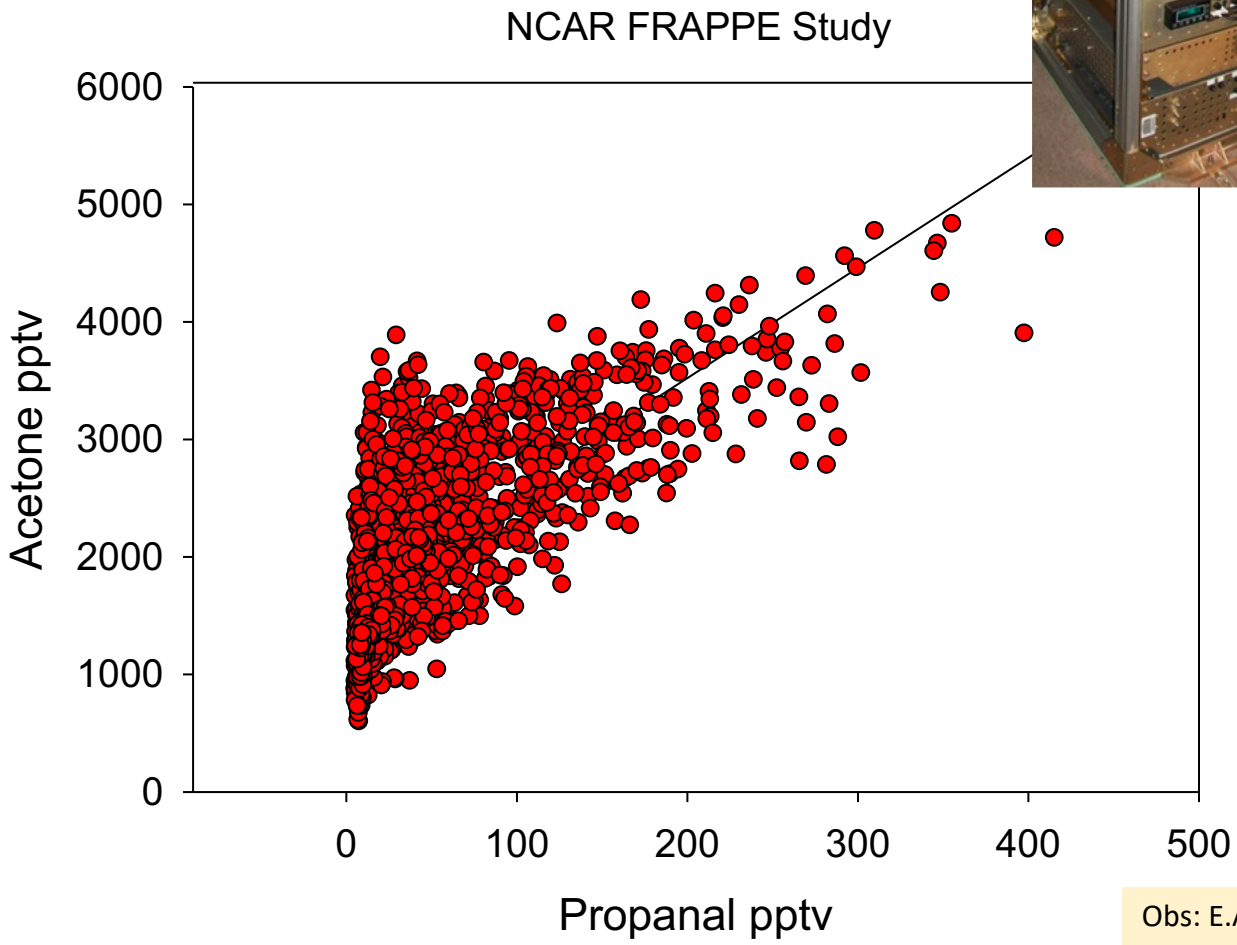


Obs: A. Wisthaler, Oslo

Changes in HC oxidation affect acetone
Ability to model and measure propanal
provides additional test of chemistry

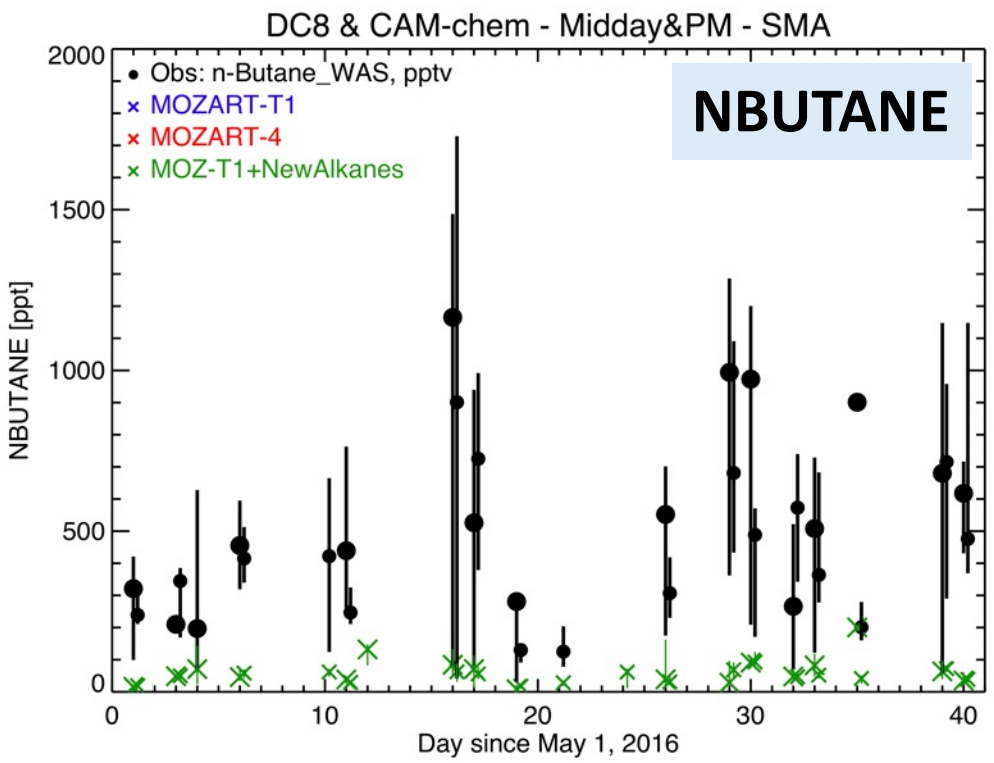
NCAR TOGA instrument

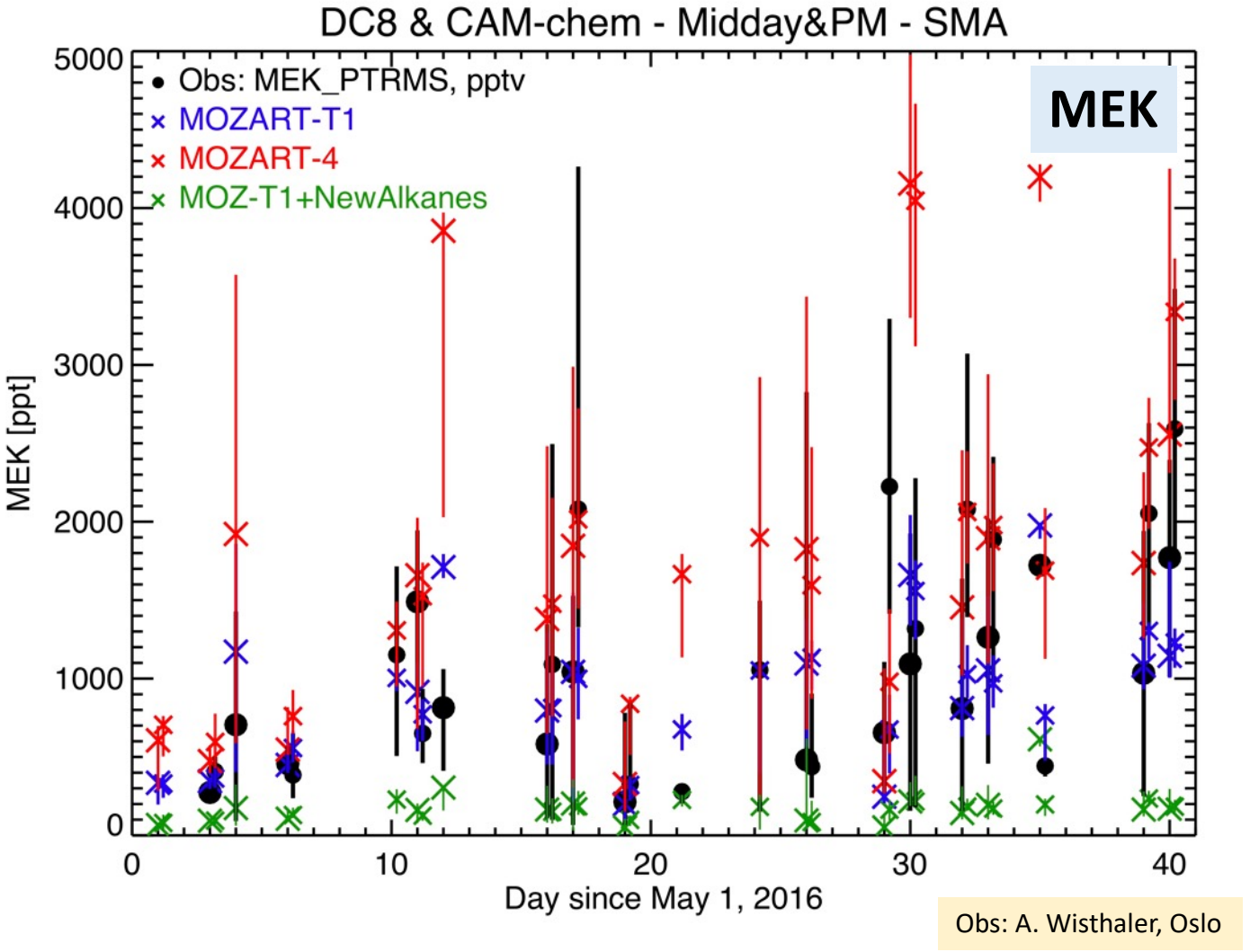
Trace Organic Gas Analyzer
Airborne fast GC-MS
Measures acetone and propanal



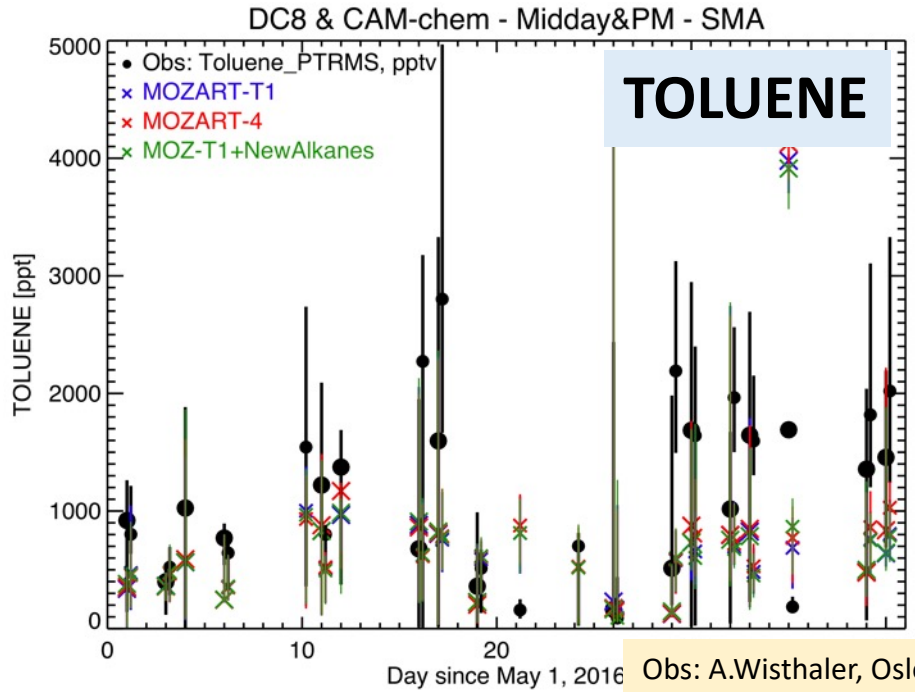
Obs: E.Apel, NCAR

Modeling specific butanes is required to accurately simulate MEK

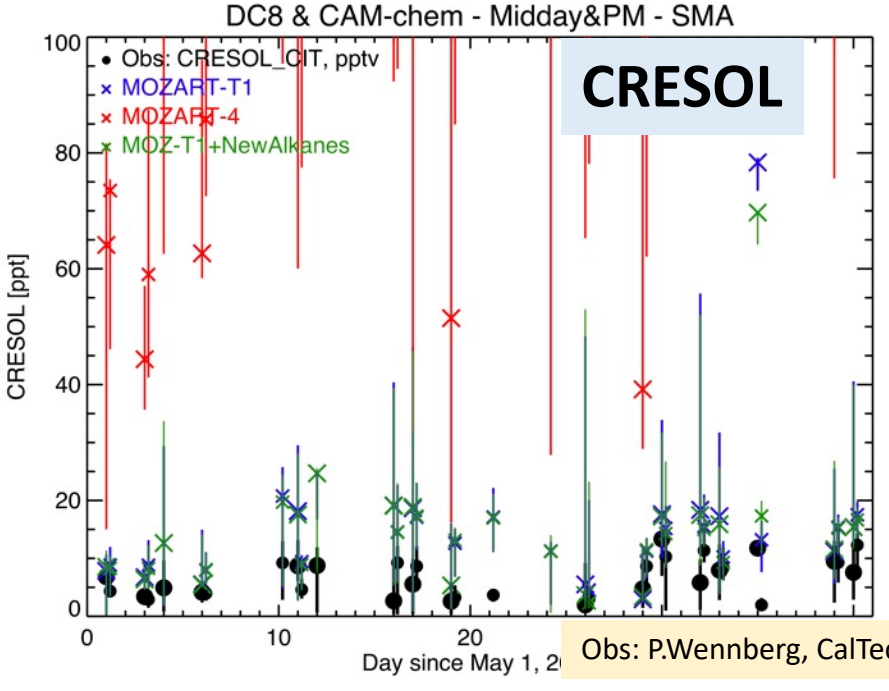




Obs: A. Wisthaler, Oslo



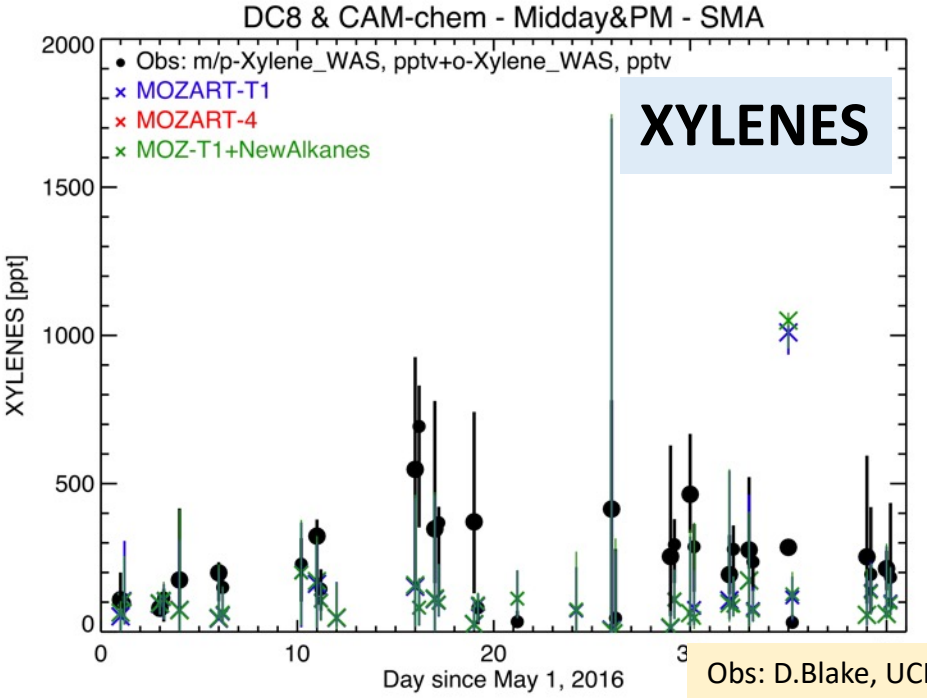
Obs: A.Wisthaler, Oslo



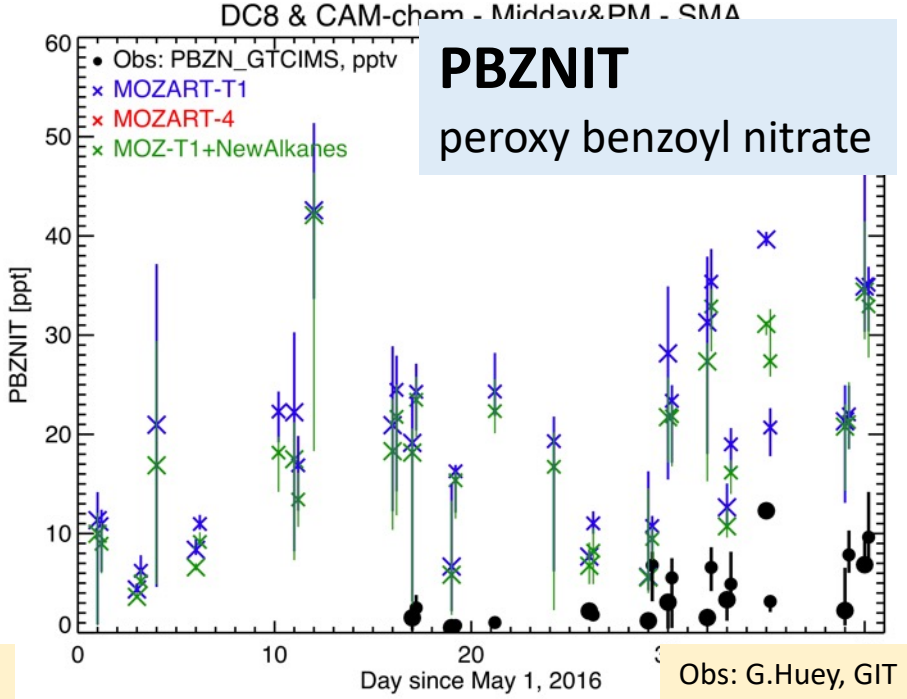
Obs: P.Wennberg, CalTech

MZ4 has higher yield from toluene, slower OH loss

Missing deposition (all mechanisms)



Obs: D.Blake, UCI



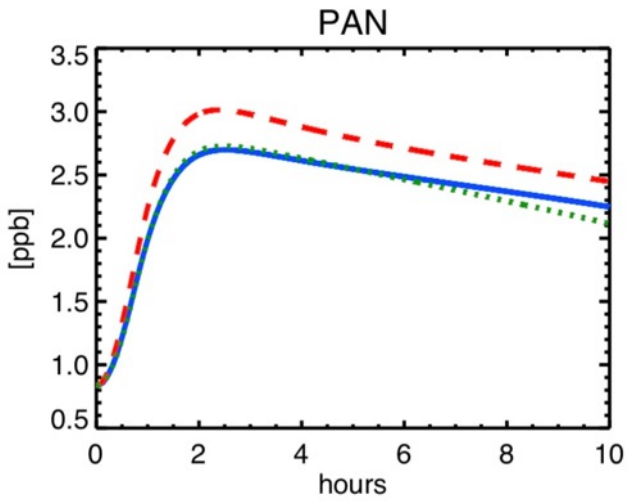
Obs: G.Huey, GIT

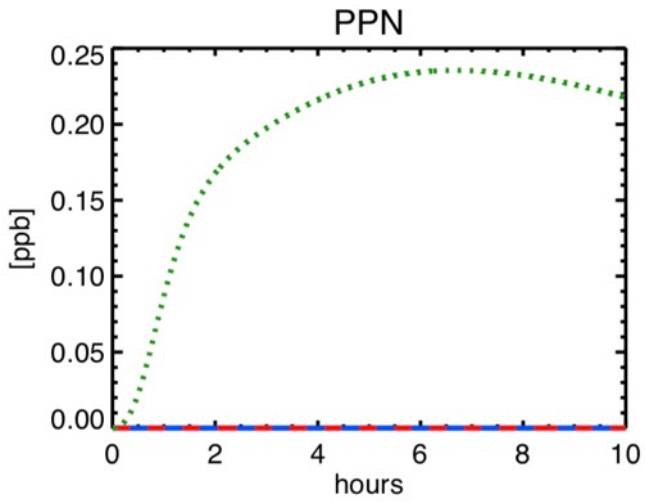
MZ-T1 forms PBZNIT from Toluene and Xylenes

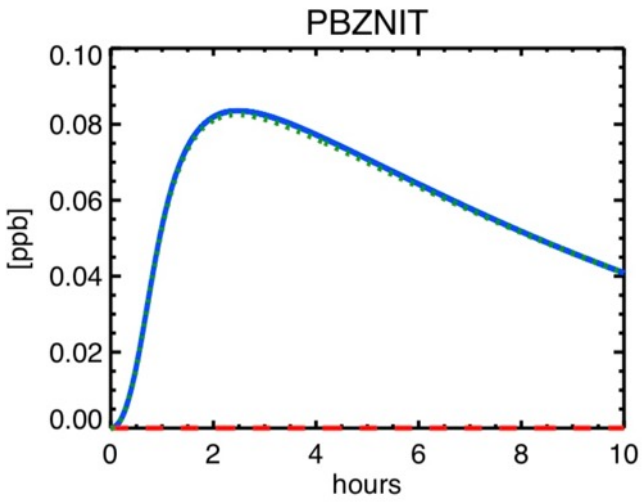
Perhaps also missing a loss

BOXMOX box model runs with 3 MOZART mechanisms

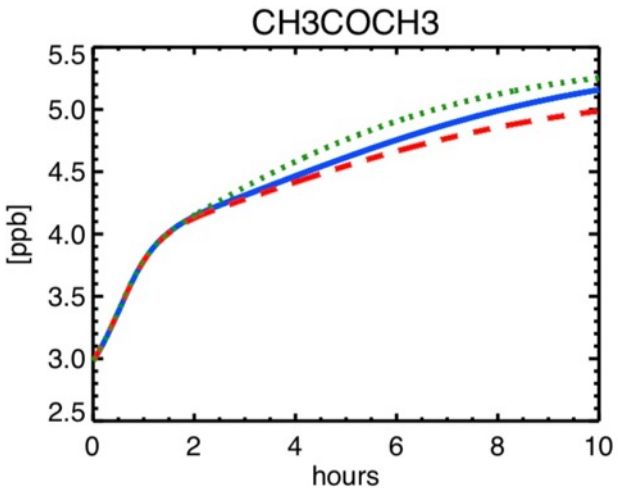
Initial conditions from DC-8 observations over Seoul May 16, identical for all mechanisms

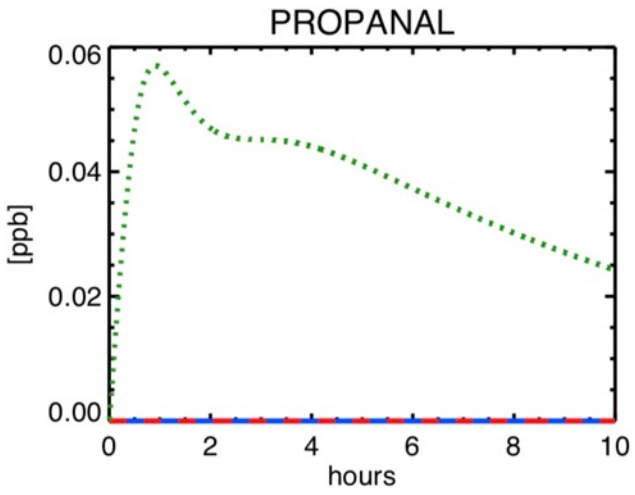


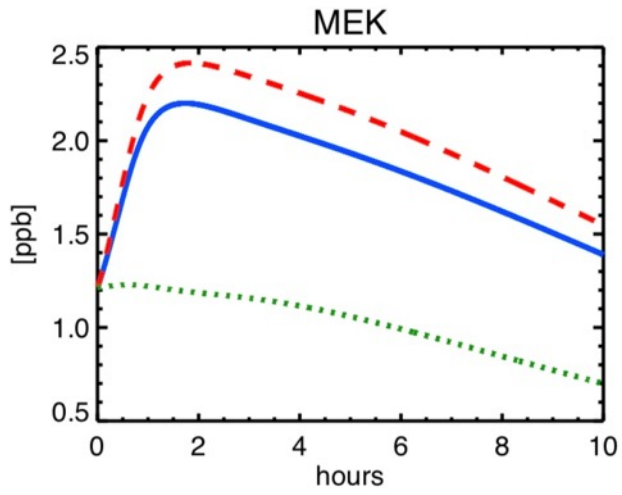


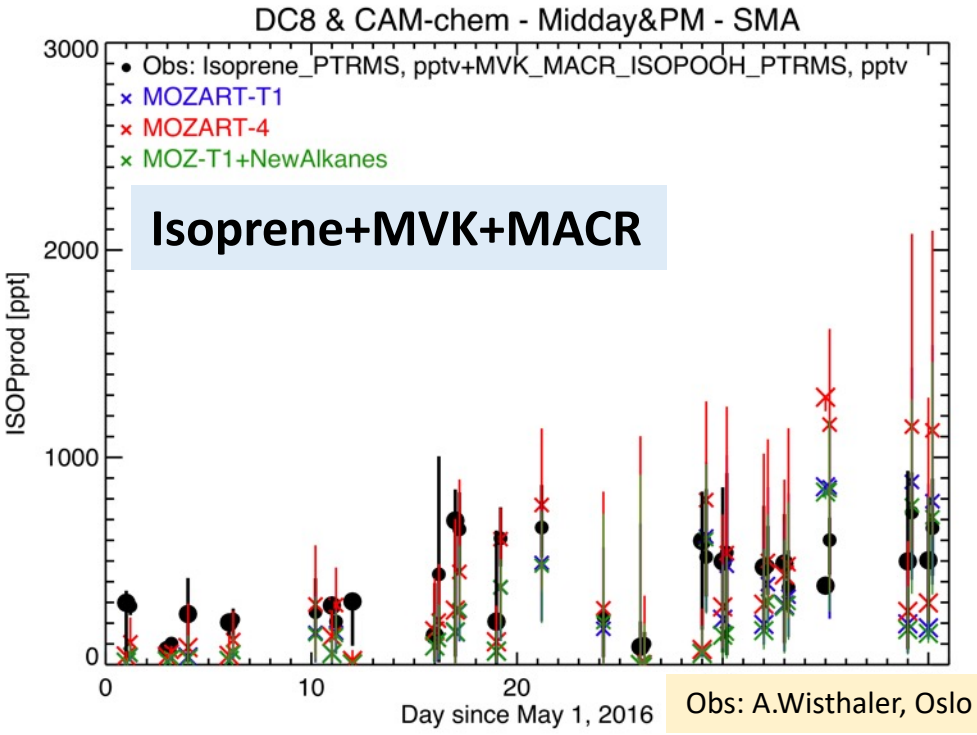


MOZART-4
T1
NewAlkanes

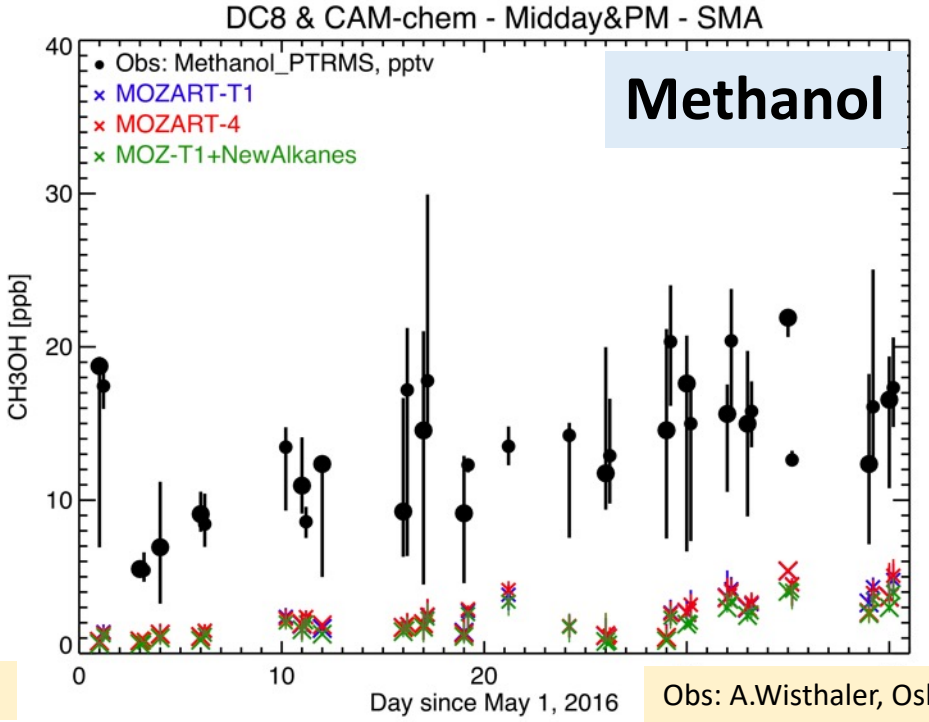






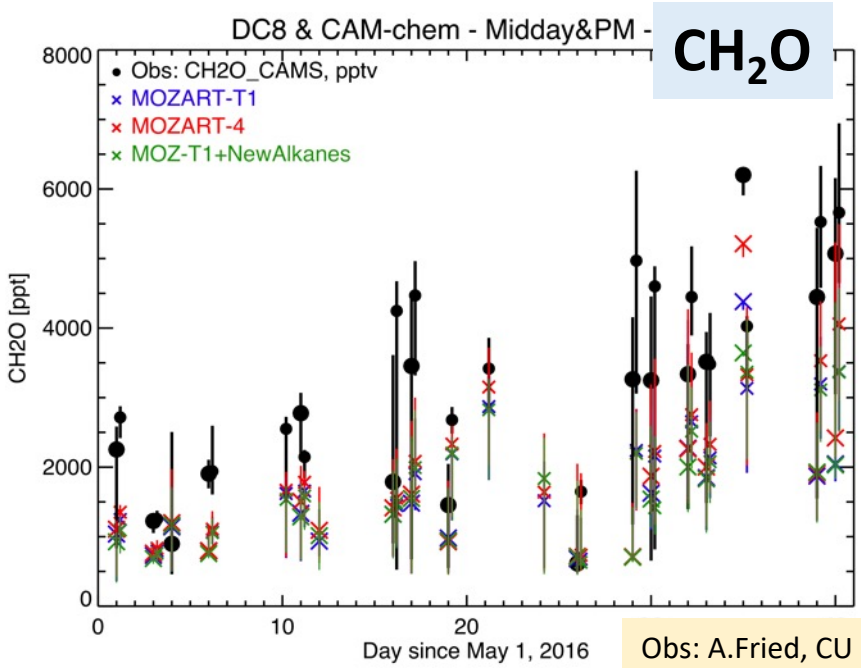


Obs: A.Wisthaler, Oslo



Obs: A.Wisthaler, Oslo

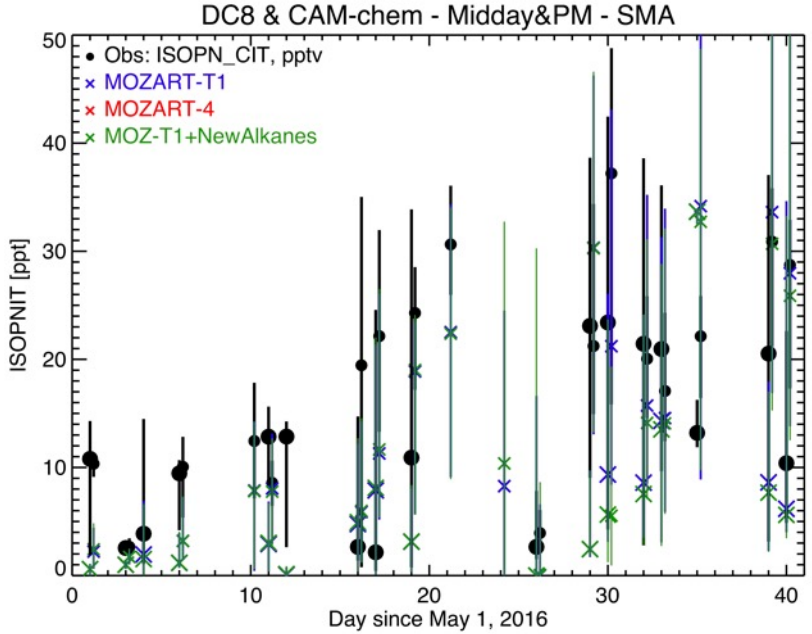
Isoprene + products agrees on average with obs.
CAM-chem methanol very low – missing biogenic emissions? Or anthro emissions?

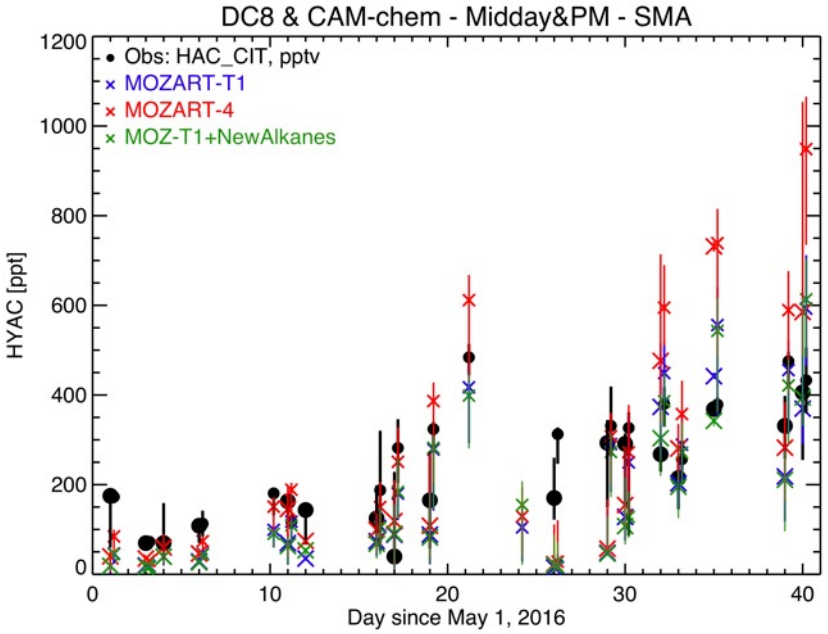


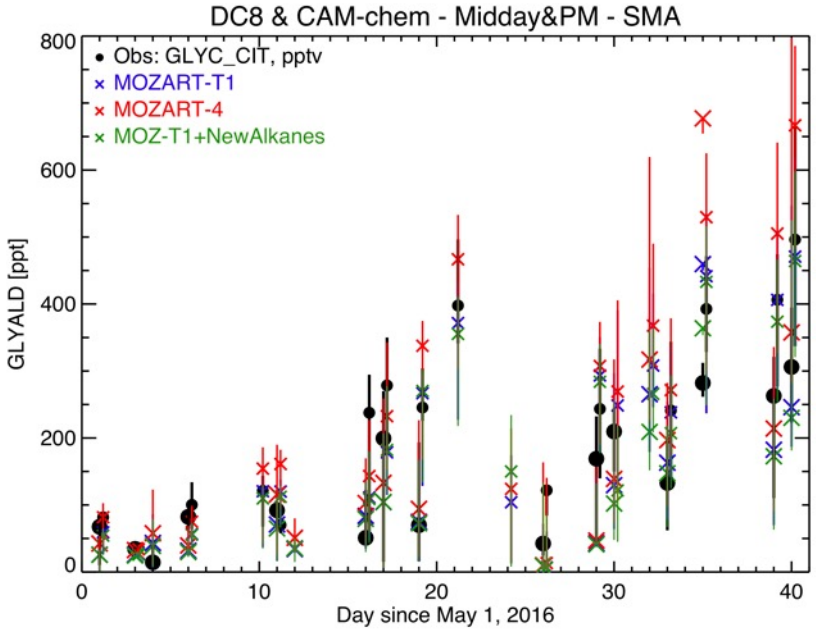
Obs: A.Fried, CU

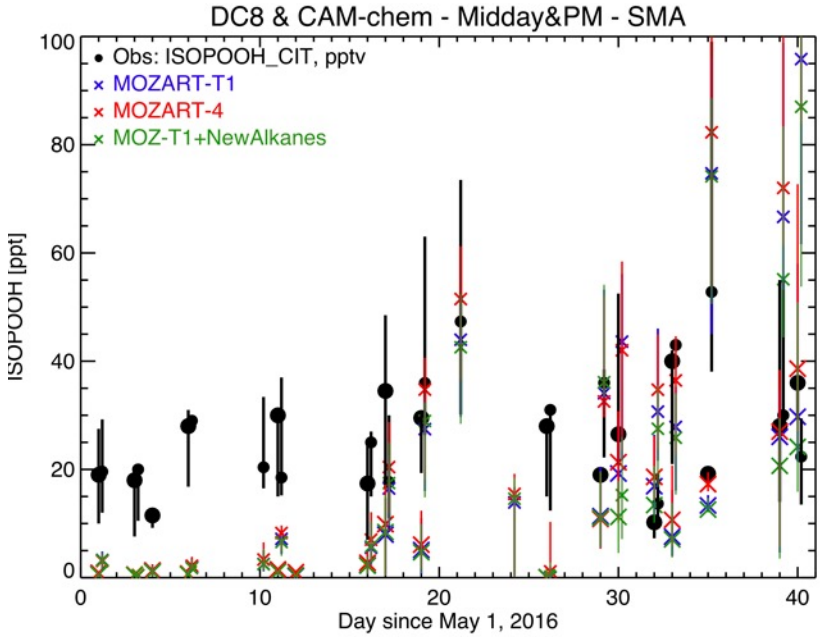
Formaldehyde shows trend of increasing biogenics
Model underestimates generally, consistent with low emissions for many hydrocarbons

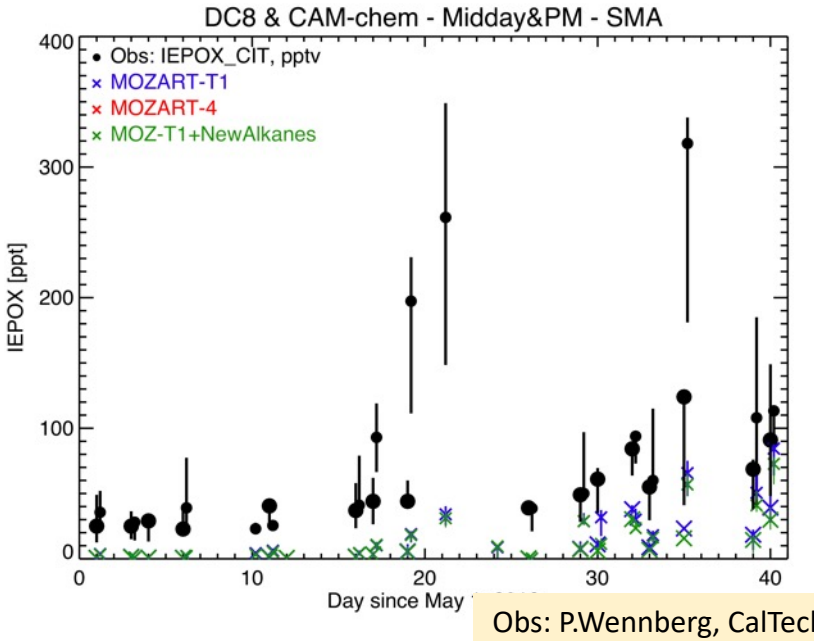
Isoprene oxidation products generally agree with observations





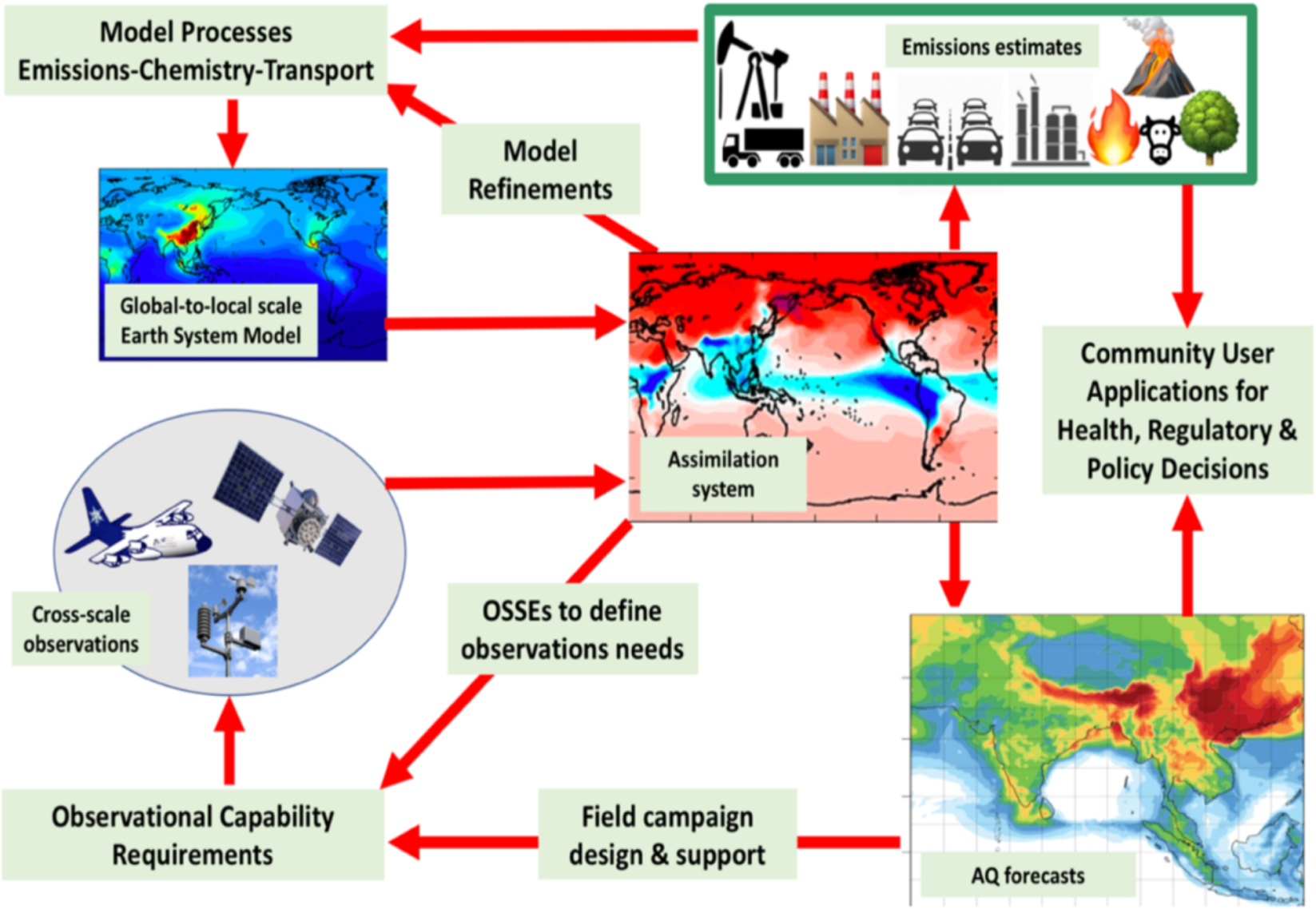






Obs: P.Wennberg, CalTech

Improvement of air quality requires connecting measurements and models and understanding the chemical processes affecting pollution




Thank You!