Ubiquity of Stratospheric Influence in Mid-latitude Tropospheric Ozone: Evidence from North American Ozonesondes (IONS, 2004-2008)

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http://croc.gsfc.nasa.gov/arcions

Poster Outline

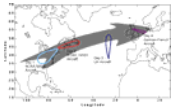
- Sondes – only method with 50-m vertical resolution in UT/LS; consistent location
- Support aircraft campaigns and satellite validation – synergistic measurement
- Highlights of three IONS campaigns
  - **IONS-04:** 2004, mostly eastern No America
  - **IONS-06:** 2006, three phases with 23 sites
  - **ARC-IONS:** 2008, NH Spring, Summer in Canada, US

IONS (2004) Design Strategy

<http:// croc.gsfc.nasa.gov/intex/ions.html>

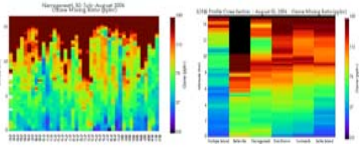
Design (INTEX Ozonesonde Network Study = IONS; INTEX = Intercontinental Transport Expt - NA) to answer:

1. Can O_3 be followed during INTEX? Similar to "Match"
2. TROPOSPHERIC BUDGETS: How much Asian pollution reaches NA? How much O_3 from stratosphere-troposphere exchange (ST), advection (AD), lightning (RCL), local boundary-layer (BL) pollution?
3. Can O_3 pollution be measured from satellite? Predicted?



Ozone Variability in IONS Curtains

~300 Sondes, 6 weeks; Most Sites Daily

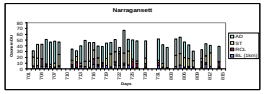


- **Single site variability:** Strong ST influence: Narragansett (left), other NE No American (NENA) sites similar
- **Single day variability:** NENA Sites, 2 Aug 04, low t'pause (ST O_3) with mixed advected (AD) pollution, lightning (right)

4-Term Tropospheric Ozone Budget Computed for *Each* IONS Sounding

- ST O_3 from Rossby Wave (RW); confirm by PV, H_2O
- RCL from Gravity Wave, Lightning Map
- BL integrated to 1 km
- Balance = ADvected O_3
- Method in Thompson et al., *JGR*, 2007a,b

- **Mean IONS-04 Budgets:**
  - 25% from Stratosphere
  - 15% RCL – convection lightning
  - 10% - Boundary layer – local pollution
  - 50% - Advected fresh and aged pollution



IONS-06 for INTEX-B/ Milagro/ Aura (Phase 1, 2) & TEXAQS (Phase 3)

Strategy - Daily Sondes in 4-week Campaigns

March 2006 – Milagro
Is there a Mexico-to-Houston Ozone connection?

April-May 2006 – INTEX-B
Is there an Asia-to-North America Ozone connection?

August 2006 – TEXAQS-06 What is upwind-downwind of Texas?

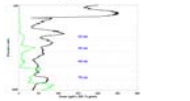
<croc.gsfc.nasa.gov/intexb/ions06>

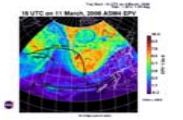
Houston – IONS-06

SPRING – March 2006 during MILAGRO/INTEX-B

Laminar analysis [Thompson et al., 2007] shows frequent Rossby-waves (RW), implies stratosphere influence (ST) in troposphere. 11 Mar 06 Houston ozone/RH (upper)

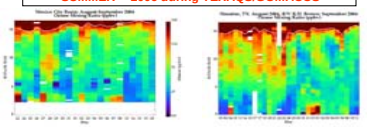
Trajectories from marked levels have differing degree of stratospheric influence, according to intersected pv [Thompson et al., 2008] (lower)



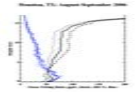


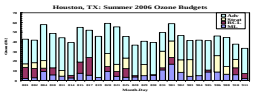
Mexico City & Houston – IONS-06

SUMMER – 2006 during TEXAQS/GOMACCS

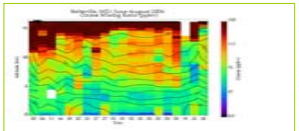


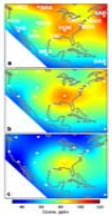
Houston – dashed before, dotted after 25/8. Distinct group. Laminar Identification ("LID") budget – ST increases after 25/8





Major IONS Issue: Sources of UT Ozone. IONS-06 at Beltsville, MD (Wash DC). Contrast "FLEXPART Budget"

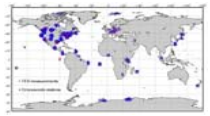


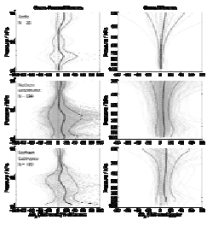


Above – ST influence above 8-9 km (300 hPa). Lightning too?

Right – Cooper et al (2007): [a] All median O_3, 10-11 km, Aug 06; [b] pv <1, stratospheric influence removed; [c] trop O_3 less ST O_3 from MPI model = lightning UT O_3 influence

IONS-06: Satellite Overpass Comparisons with Aura/TES Retrievals





- ❑ No Am sites from IONS; European-Asian sites as in Match
- Most SH sites from SHADOZ
- ❑ R Nassar, J Logan et al, *JGR*, 2008. Note UT disagreements between sondes, TES

ARC-IONS (Intensive Ozonesonde Network Study): PSU-NASA-NOAA-Environment Canada Partnership

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- **Builds on IONS-04, IONS-06:**
  - Strategic sonde network to match ARCTAS objectives
  - Aura validation requirements – especially high-lat TES
  - Model evaluation, eg GEOS-CHEM, MOZART, RAQMS, AURAM
- **Optimal plan – two "ARCS"**
  - Spring – north-to-south for STE processes
  - Summer – east-to-west for long-range transport of boreal fire emissions
  - Greenland for POLARCAT link
  - Special launches for Aircraft over Greenland, Canada, Trinidad Head during Spring & Summer phases

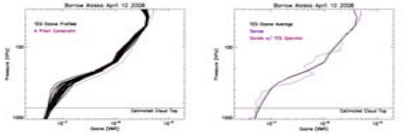
ARC-IONS Highlights

- **Spring Phase, 1-20 April 2008**
  - TES satellite observations promising over colder Arctic
  - Relatively high free tropospheric ozone might indicate pollution during time of "Arctic Haze"
  - Surface ozone depletion, "polar sunrise loss" [Barrie et al., 1988] well-captured over Barrow, Resolute, Churchill
  - Standard ARC-IONS sites plus Barrow
- **Summer Phase, 26 June – 12 July 2008**
  - Standard ARC-IONS sites plus Yellowknife, Goose Bay
  - Fire impacts include mixture of California, Siberian fires and active fires over Saskatchewan sampled by DC-8, P-3, B200

TES "Stare" Mode - 32 Consecutive Observations Compared to Barrow Sonde (ARC-IONS, 10 April 08)

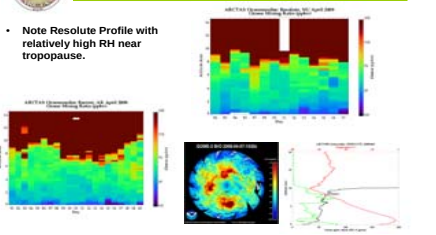
RMS of observed ozone Variability consistent with calculated random errors! TES ozone average agrees to within 10% of sonde after accounting for TES vertical resolution. (Left)

UT/LS segment (Right) shows structure the satellite does not resolve

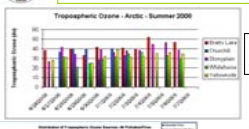


High Ozone in UT – "Pollution?" Depleted Surface Ozone at Resolute, Barrow. See High BrO from GOMEII

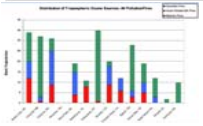
- Note Resolute Profile with relatively high RH near tropopause.

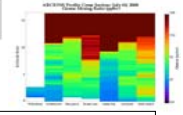


Preliminary Summer ARC-IONS Results: Ozone Increases over Central Canadian Sites after Fire Increase First Week of July



4 July 08 Curtain – Flight 19 over SK, MN – pyrocumulus – fire, Asian, biogenic source mix





ARC-IONS – Fire contributions, determined from trajectories – show impacts on Canadian sondes

Acknowledgments, References

- NASA Aura Validation (M J Kurylo; K W Jucks). NOAA GMD & CSD.
- INTEX (B. Doddridge); ARCTAS (J H Crawford). Environment Canada

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