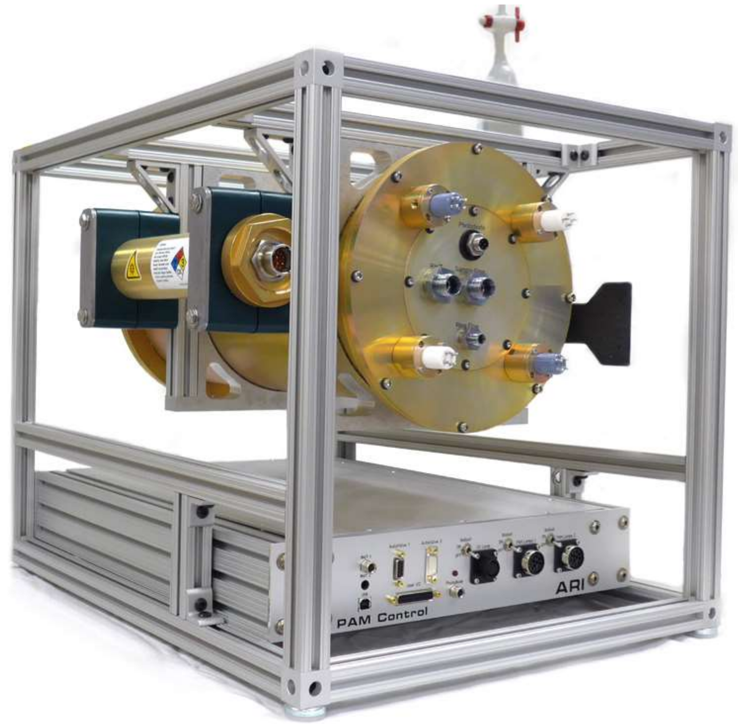
# Updates on Aerodyne Potential Aerosol Mass (PAM) Oxidation Flow Reactor (OFR)
# **PAM**反应器的最新进展




Andy Lambe and Penglin Ye

# Outline 大纲

- Overview （简介）
- Example Applications （应用实例）
- Modeling Tools （计算模拟方法）
- Summary （总结）

Atmos. Chem. Phys., 7, 5727–5744, 2007
www.atmos-chem-phys.net/7/5727/2007/


Atmospheric Chemistry and Physics

**Introducing the concept of Potential Aerosol Mass (PAM)**

E. Kang[1], M. J. Root[1], D. W. Toohey[2], and W. H. Brune[1]

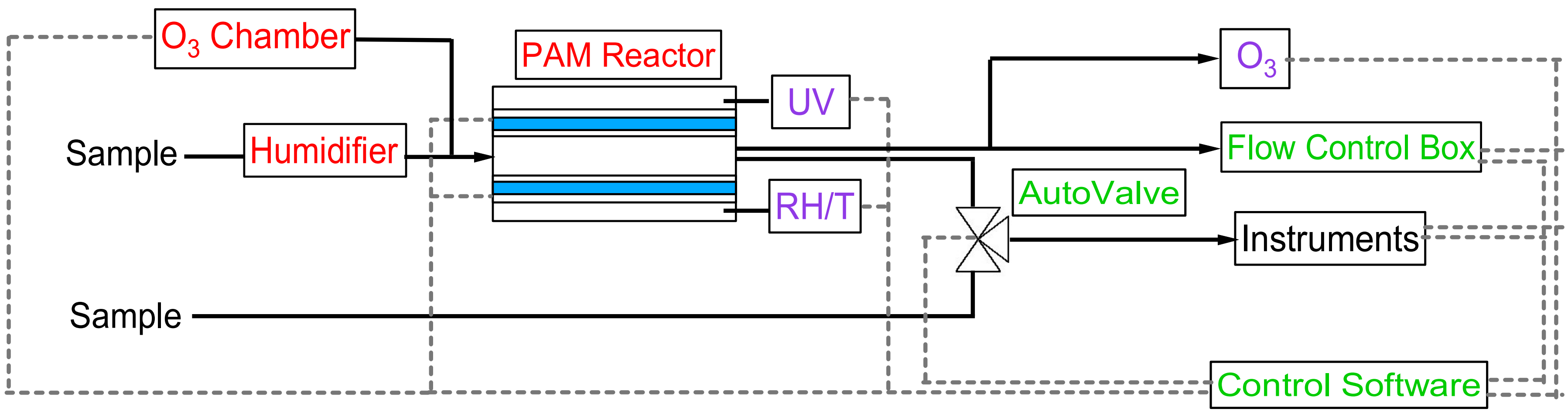
[1]Department of Meteorology, Pennsylvania State University, University Park, PA 16802, USA
[2]Atmospheric and Oceanic Sciences, University of Colorado, CO 80309-0311, USA

Atmos. Meas. Tech., 4, 445–461, 2011
www.atmos-meas-tech.net/4/445/2011/
doi:10.5194/amt-4-445-2011

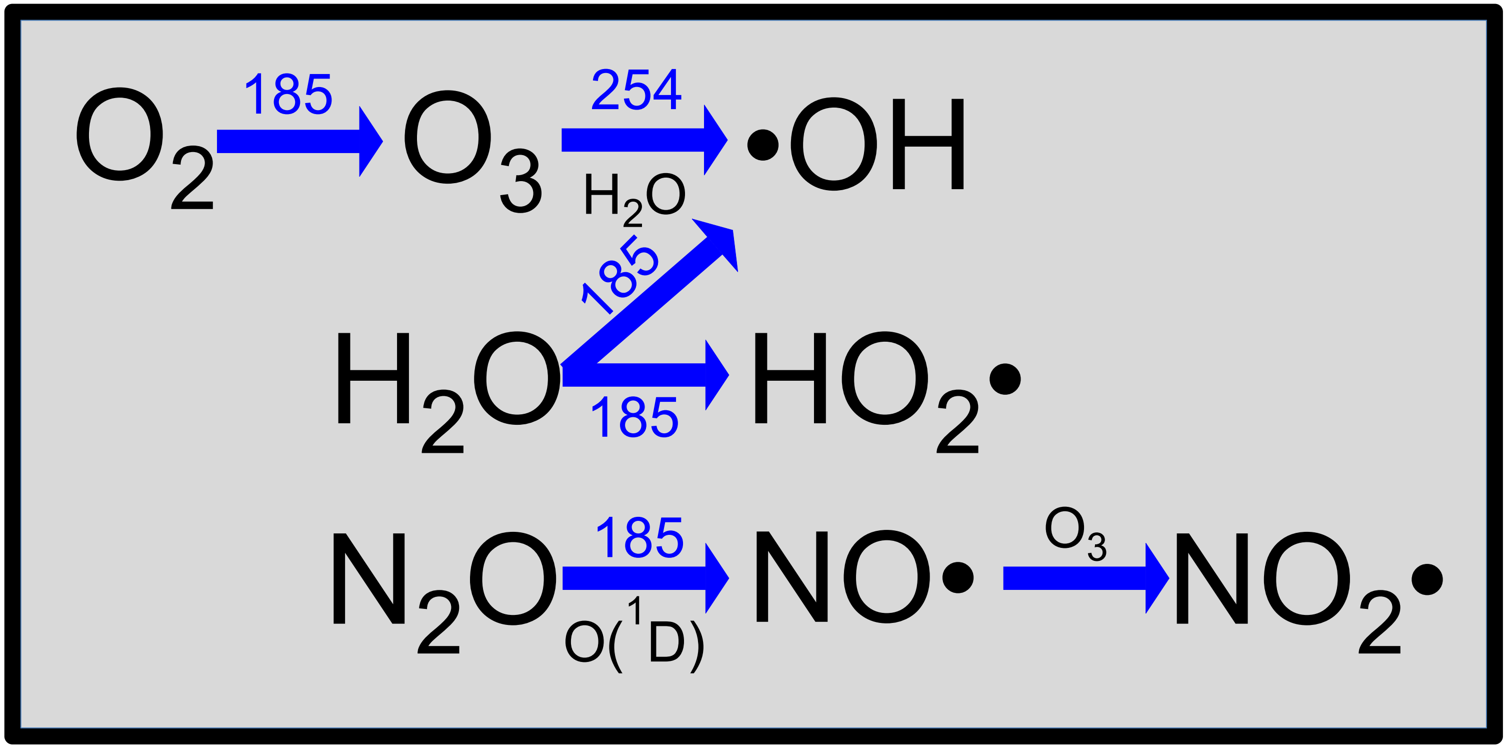

Atmospheric Measurement Techniques

**Characterization of aerosol photooxidation flow reactors: heterogeneous oxidation, secondary organic aerosol formation and cloud condensation nuclei activity measurements**

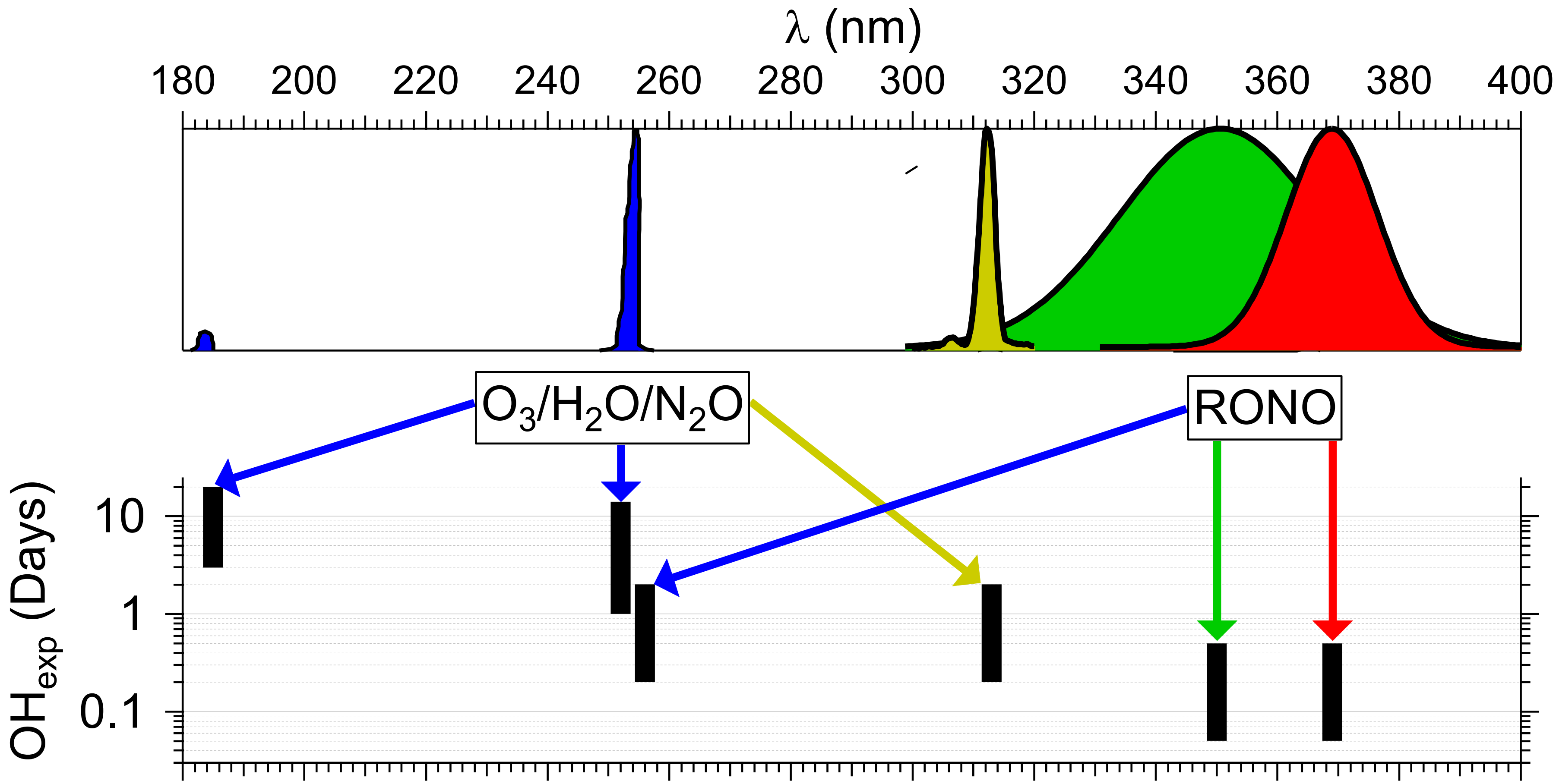
A. T. Lambe[1,2], A. T. Ahern[1,2], L. R. Williams[2], J. G. Slowik[3], J. P. S. Wong[3], J. P. D. Abbatt[3], W. H. Brune[4], N. L. Ng[2], J. P. Wright[1], D. R. Croasdale[1], D. R. Worsnop[2], P. Davidovits[1], and T. B. Onasch[1,2]




- Oxidant generation （氧化剂制备）
- Measurement of photochemical conditions（测量光化学参数）
- Hardware control, data acquisition（硬件控制，数据采集）




- "$OFR_{185}$": Easiest and most efficient method
（最简洁高效的方法）
- "$OFR_{254}$": More flexible method
（比较灵活的方法）

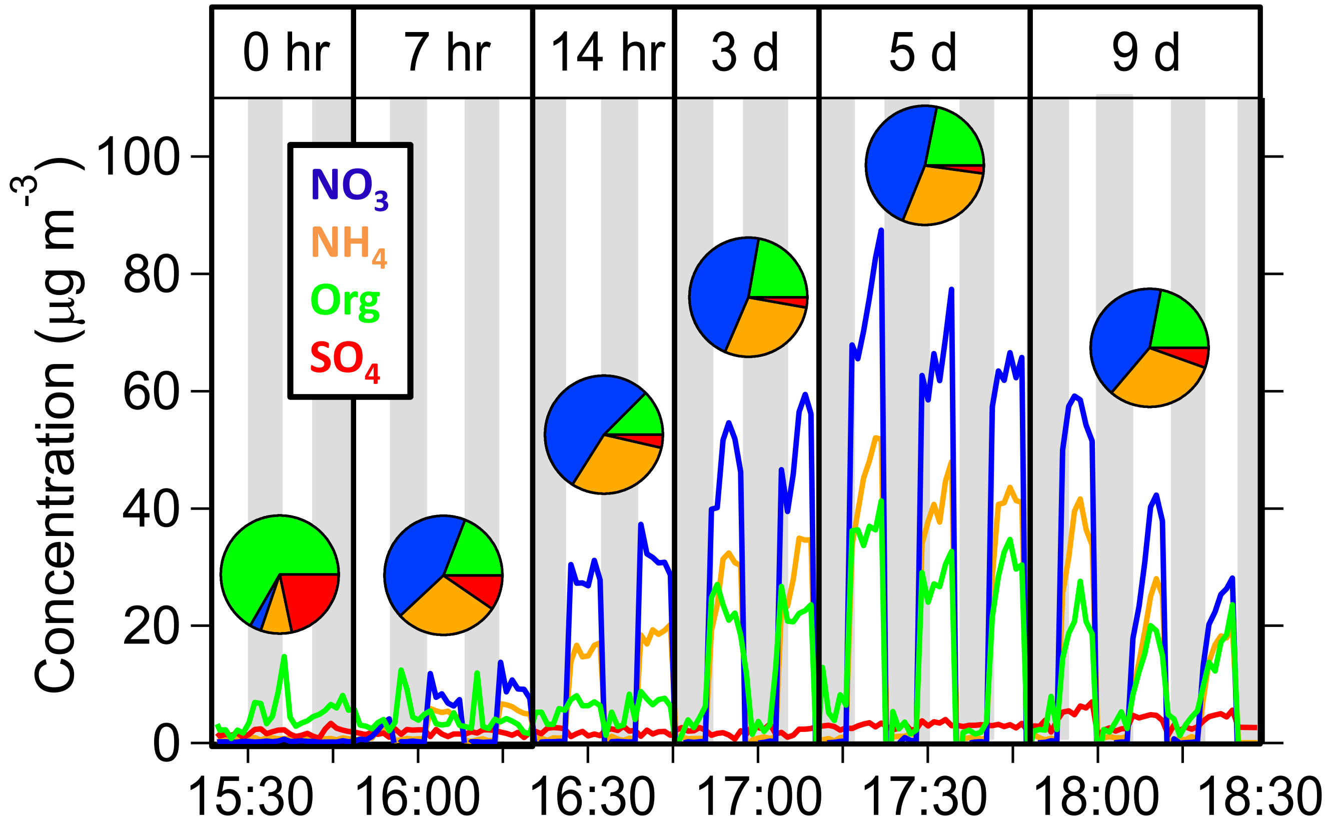


λ (nm)
180
200
220
240
260
280
300
320
340
360
380
400
$O_3/H_2O/N_2O$
RONO
$OH_{exp}$ (Days)
10
1
0.1

Environmental Science & Technology
Article
pubs.acs.org/est

**Secondary Organic Aerosol Formation from in-Use Motor Vehicle Emissions Using a Potential Aerosol Mass Reactor**

Daniel S. Tkacik,[†,¶] Andrew T. Lambe,[‡] Shantanu Jathar,[§] Xiang Li,[¶,∥] Albert A. Presto,[¶,∥] Yunliang Zhao,[¶,∥] Donald Blake,[⊥] Simone Meinardi,[⊥] John T. Jayne,[‡] Philip L. Croteau,[‡] and Allen L. Robinson*[,¶,∥]



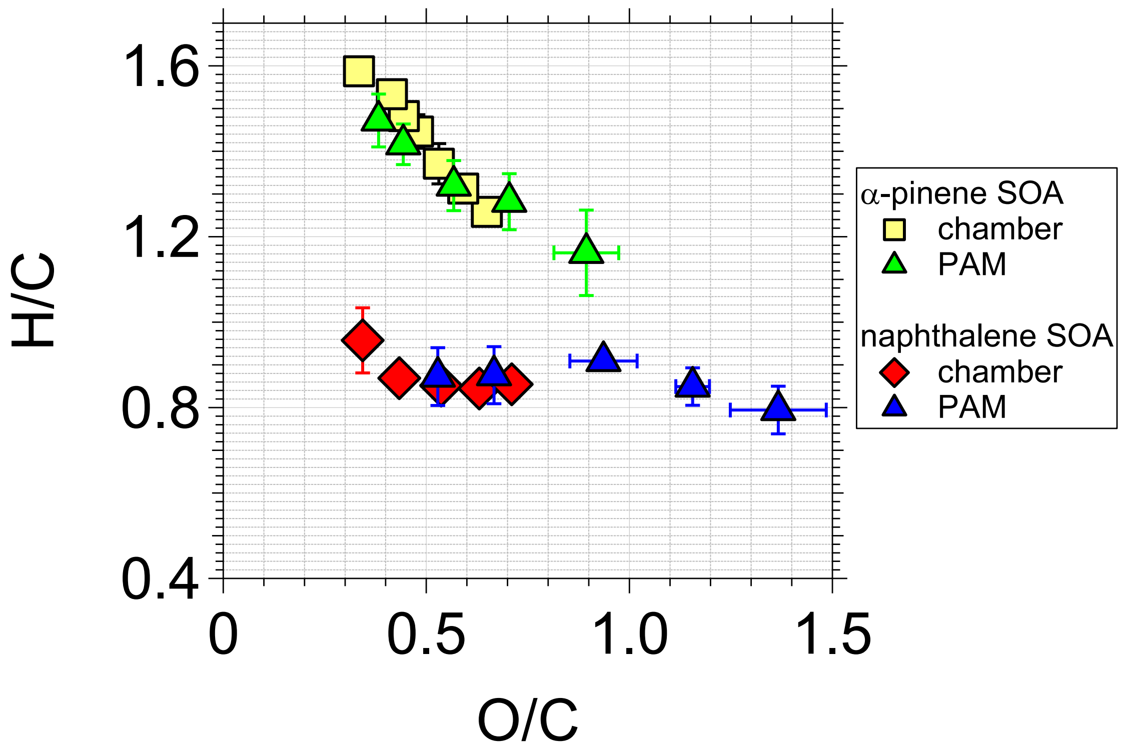

- “Potential Aerosol Mass” of emission sources（来自排放源的潜在气溶胶）
- Transition from “functionalization” to “fragmentation”
（形成官能团到碳链断开的渐变）

Atmos. Chem. Phys., 15, 3063–3075, 2015
www.atmos-chem-phys.net/15/3063/2015/
doi:10.5194/acp-15-3063-2015


Atmospheric Chemistry and Physics

**Effect of oxidant concentration, exposure time, and seed particles on secondary organic aerosol chemical composition and yield**

A. T. Lambe[1,2], P. S. Chhabra[2,*], T. B. Onasch[1,2], W. H. Brune[3], J. F. Hunter[4], J. H. Kroll[4], M. J. Cummings[1], J. F. Brogan[1], Y. Parmar[1], D. R. Worsnop[2], C. E. Kolb[2], and P. Davidovits[1]
[1]Chemistry Department, Boston College, Chestnut Hill, MA, USA



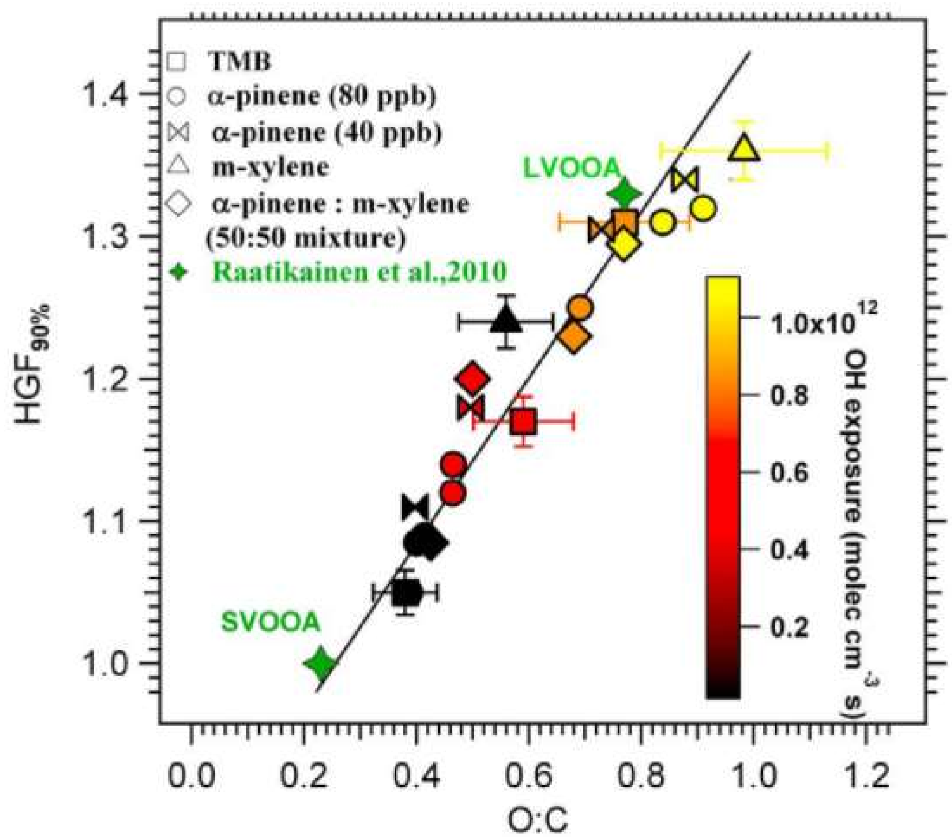

- SOA composition over multigeneration oxidation

（经过多次氧化后的二次气溶胶组成）

GEOPHYSICAL RESEARCH LETTERS, VOL. 37, L24801, doi:10.1029/2010GL045258, 2010

**Relationship between aerosol oxidation level and hygroscopic properties of laboratory generated secondary organic aerosol (SOA) particles**

P. Massoli,[1] A. T. Lambe,[1,2] A. T. Ahern,[1,2] L. R. Williams,[1] M. Ehn,[3] J. Mikkilä,[3] M. R. Canagaratna,[1] W. H. Brune,[4] T. B. Onasch,[1] J. T. Jayne,[1] T. Petäjä,[3] M. Kulmala,[3] A. Laaksonen,[5] C. E. Kolb,[1] P. Davidovits,[2] and D. R. Worsnop[1,3,5]




- Correlation of SOA composition and hygroscopicity

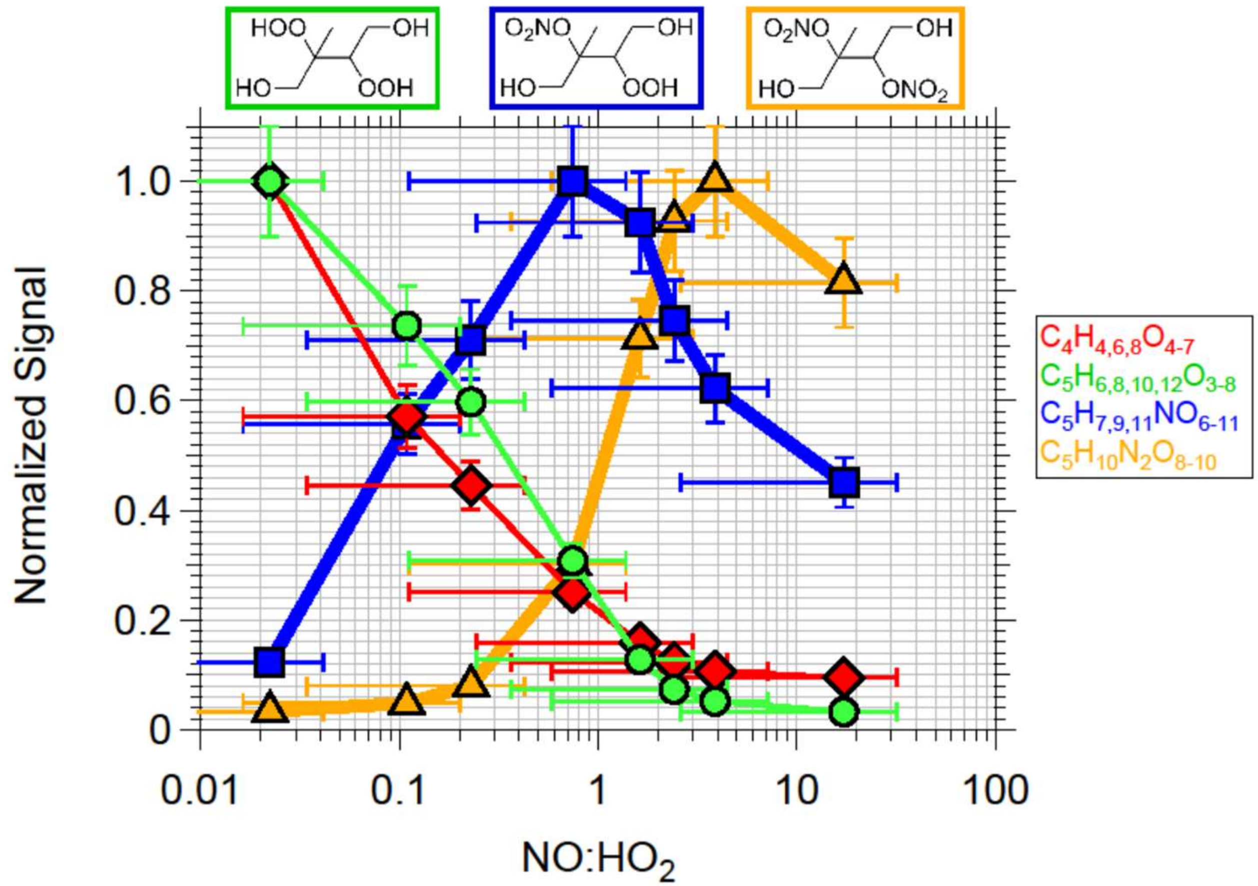
（二次气溶胶组成和吸湿性的相关性）

Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-394, 2017
Manuscript under review for journal Atmos. Meas. Tech.
Published: 6 January 2017


Atmospheric Measurement Techniques Discussions

**Controlled nitric oxide production via $O(^1D)+N_2O$ reactions for use in oxidation flow reactor studies**

Andrew Lambe[1,2], Paola Massoli[1], Xuan Zhang[1], Manjula Canagaratna[1], John Nowak[1,*], Chao Yan[3], Wei Nie[4,3], Timothy Onasch[1,2], John Jayne[1], Charles Kolb[1], Paul Davidovits[2], Douglas Worsnop[1,3], and William Brune[5]




- Molecular tracers for “low-NO” and “high-NO” conditions

（高、低一氧化氮浓度条件下的分子标识物）

## EXAMPLE APPLICATIONS - CIMS

THE JOURNAL OF PHYSICAL CHEMISTRY A
Article
pubs.acs.org/JPCA

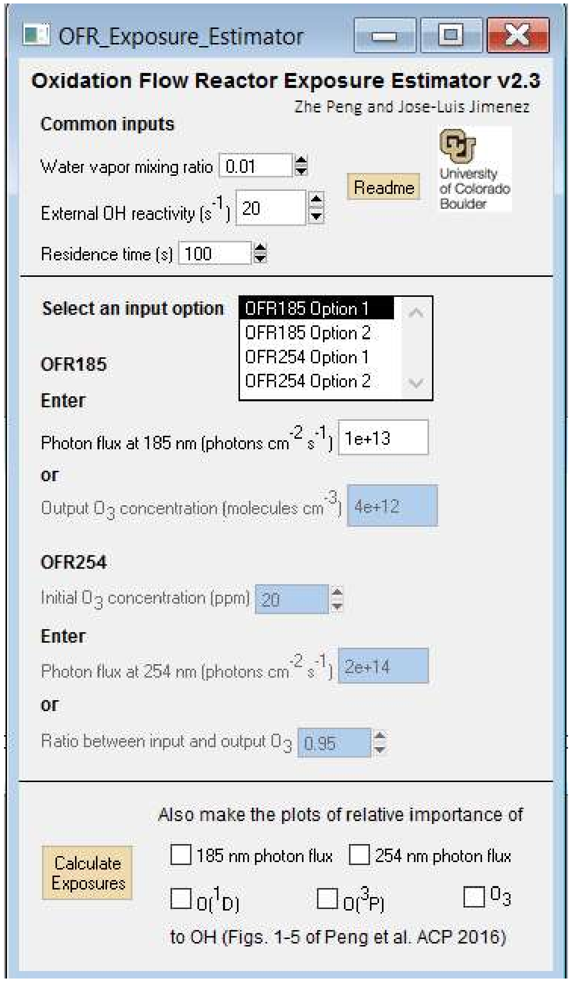
**Modeling the Radical Chemistry in an Oxidation Flow Reactor: Radical Formation and Recycling, Sensitivities, and the OH Exposure Estimation Equation**

Rui Li,[†,‡,§] Brett B. Palm,[‡,∥] Amber M. Ortega,[‡,§] James Hlywiak,[⊥] Weiwei Hu,[‡,∥] Zhe Peng,[‡,∥] Douglas A. Day,[‡,∥] Christoph Knote,[#,∇] William H. Brune,[⊥] Joost A. de Gouw,[†,‡,∥] and Jose L. Jimenez*[,‡,∥]

# ““PAM_chem”模型

| # | reactions | reaction rate constant |
|---|---|---|
| 1 | $O_2 + h\nu$ (185 nm) → $2O(^3P)$ | $1.1 \times 10^{-20} \times flux_{185}{}^{a}$ |
| 2 | $O_3 + h\nu$ (254 nm) → $O_2 + O(^1D)$ | $1.03 \times 10^{-17} \times flux_{254}{}^{b}$ |
| 3 | $H_2O_2 + h\nu$ (185 nm) → $HO_2 + H$ | $1 \times 10^{-19} \times flux_{185}$ |
| 4 | $H_2O_2 + h\nu$ (254 nm) → $2OH$ | $6.7 \times 10^{-20} \times flux_{254}$ |
| 5 | $HO_2 + h\nu$ (254 nm) → $OH+O(^1D)$ | $2.63 \times 10^{-19} \times flux_{254} + 3.68 \times 10^{-18} \times flux_{185}$ |
| 6 | $HO_2 + h\nu$ (185 nm) → $OH + O(^1D)$ | |
| 7 | $H_2O + h\nu$ (185 nm) → $OH + H$ | $6.78 \times 10^{-20} \times flux_{185}$ |
| 8 | $O(^1D) + H_2O \rightarrow 2OH$ | $1.63 \times 10^{-10}e^{60/T}$ |
| 9 | $O(^1D) + N_2 \rightarrow O(^3P)$ | $2.15 \times 10^{-11}e^{110/T}$ |
| 10 | $O(^1D) + O_2 \rightarrow O(^3P)$ | $3.3 \times 10^{-11}e^{55/T}$ |
| 11 | $O(^1D) + CO_2 \rightarrow O(^3P) + CO_2$ | $7.5 \times 10^{-11}e^{115/T}$ |
| 12 | $O(^1D) + O_3 \rightarrow 2O_2$ | $1.20 \times 10^{-10}$ |
| 13 | $O(^1D) + O_3 \rightarrow O_2 + O + O$ | $1.20 \times 10^{-10}$ |
| 14 | $O(^1D) + H_2 \rightarrow OH + H$ | $1.20 \times 10^{-10}$ |
| 15 | $O(^1D) + N_2 + M \rightarrow N_2O$ | $2.8 \times 10^{-36}M(300/T)^{0.9}$ |
| 16 | $O(^1D) + N_2O \rightarrow N_2 + O_2$ or $2NO$ | $1.19 \times 10^{-10}e^{20/T}$ |
| 17 | $O + OH \rightarrow O_2 + H$ | $2.2 \times 10^{-11}e^{180/T}$ |
| 18 | $O + HO_2 \rightarrow OH + O_2$ | $3.0 \times 10^{-11}e^{200/T}$ |
| 19 | $O + H_2O_2 \rightarrow OH + HO_2$ | $1.4 \times 10^{-12}e^{-2000/T}$ |
| 20 | $O + O_3 \rightarrow 2O_2$ | $8.0 \times 10^{-12}e^{-2060/T}$ |
| 21 | $H + O_3 \rightarrow OH + O_2$ | $1.4 \times 10^{-10}e^{-470/T}$ |
| 22 | $OH + O_3 \rightarrow HO_2 + O_2$ | $1.7 \times 10^{-12}e^{-940/T}$ |
| 23 | $HO_2 + NO \rightarrow OH + NO_2$ | $3.5 \times 10^{-12}e^{270/T}$ |
| 24 | $HO_2 + O_3 \rightarrow OH + 2O_2$ | $1.0 \times 10^{-14}e^{-490/T}$ |
| 25 | $OH + HO_2 \rightarrow H_2O + O_2$ | $4.8 \times 10^{-11}e^{250/T}$ |
| 26 | $H + HO_2 \rightarrow 2OH$ | $7.20 \times 10^{-11}$ |
| 27 | $H + HO_2 \rightarrow O + H_2O$ | $1.60 \times 10^{-12}$ |
| 28 | $H + HO_2 \rightarrow O_2 + H_2$ | $6.90 \times 10^{-12}$ |
| 29 | $OH + H_2 \rightarrow H_2O + H$ | $2.8 \times 10^{-12}e^{-1800/T}$ |
| 30 | $OH + OH \rightarrow H_2O + O$ | $1.80 \times 10^{-12}$ |
| 31 | $O + NO_2 \rightarrow NO + O_2$ | $5.1 \times 10^{-12}e^{210/T}$ |
| 32 | $O + NO_2 \rightarrow O_2 + NO_2$ | $1.0 \times 10^{-11}$ |
| 33 | $O + HO_2NO_2 \rightarrow$ products | $7.80 \times 10^{-11}e^{-3400/T}$ |
| 34 | $H + NO_2 \rightarrow OH + NO$ | $4.0 \times 10^{-10}e^{-340/T}$ |
| 35 | $OH + NO_3 \rightarrow HO_2 + NO_2$ | $2.2 \times 10^{-11}$ |
| 36 | $OH + HONO \rightarrow H_2O + NO_2$ | $1.80 \times 10^{-11}e^{-390/T}$ |
| 37 | $HO_2 + NO_3 \rightarrow OH + NO_2 + O_2$ | $3.5 \times 10^{-12}$ |
| 38 | $NO + NO_3 \rightarrow 2NO_2$ | $1.50 \times 10^{-11}e^{170/T}$ |
| 39 | $NO_3 + NO_3 \rightarrow 2NO_2 + O_2$ | $8.5 \times 10^{-13}\ e^{-2450/T}$ |
| 41 | $NO + O_3 \rightarrow NO_2 + O_2$ | $3.0 \times 10^{-12}e^{-1500/T}$ |
| 42 | $NO_2 + O_3 \rightarrow NO_3 + O_2$ | $1.2 \times 10^{-13}e^{-2450/T}$ |
| 43 | $HO_2 + NO_2 + M \rightarrow HONO_2 + M$ | $Eq(1)^{b}$ |
| | $HO_2 + NO_2 + M \rightarrow HOONO + M$ | |
| 44 | $OH + HNO_4 \rightarrow$ products | $1.3 \times 10^{-12}e^{380/T}$ |
| 45 | $OH + H_2O_2 \rightarrow H_2O + HO_2$ | $1.80 \times 10^{-12}$ |
| 46 | $OH + NO_2 + M \rightarrow HNO_3 + M$ | Eq(1) |
| 47 | $O + O_2 + M \rightarrow O_3 + M$ | $6.0 \times 10^{-31}M(300/T)^{2.4}$ |
| 48 | $H + O_2 + M \rightarrow HO_2 + M$ | Eq(1) |
| 49 | $OH + OH + M \rightarrow H_2O_2 + M$ | Eq(1) |
| 50 | $OH + SO_2 + M \rightarrow HOSO_2 + M$ | Eq(1) |
| 51 | $HOSO_2 + O_2 \rightarrow HO_2 + SO_3$ | $1.3^{-12}e^{-330/T}$ |
| 52 | $HO_2 + HO_2 \rightarrow H_2O_2 + O_2$ | $(3.0 \times 10^{-13}e^{460/T} + 2.1 \times 10^{-33}Me^{920/T}) \times (1 + 1.4e^{-21}H_2O \times 10^{2200/T})$ |
| 53 | $O + NO + M \rightarrow NO_2 + M$ | Eq(1) |
| 54 | $O + NO_2 + M \rightarrow NO_3 + M$ | Eq(1) |
| 55 | $NO_2 + NO_3 + M \rightarrow N_2O_5 + M$ | Eq(1) |
| 56 | $OH + CO + M \rightarrow H + CO_2 + M$ | $Eq(2)^{c}$ |
| 57 | $OH + CO + M \rightarrow HOCO + M$ | Eq(1) |
| 58 | $HOCO + O_2 \rightarrow HO_2 + CO_2$ | $1.5 \times 10^{-12}$ |

- Developed by Bill Brune （由**Brune**教授开发）
- Included with delivered PAM systems, compile in Matlab （用**Matlab**写的程序预装在已售的**PAM**中）




Atmos. Meas. Tech., 8, 4863–4890, 2015
www.atmos-meas-tech.net/8/4863/2015/
doi:10.5194/amt-8-4863-2015

Atmospheric Measurement Techniques
Open Access
EGU

**$HO_x$ radical chemistry in oxidation flow reactors with low-pressure mercury lamps systematically examined by modeling**

Z. Peng[1,2], D. A. Day[1,2], H. Stark[1,2,3], R. Li[1,4,5], J. Lee-Taylor[1,2], B. B. Palm[1,2], W. H. Brune[6], and J. L. Jimenez[1,2]

Atmos. Chem. Phys., 16, 4283–4305, 2016
www.atmos-chem-phys.net/16/4283/2016/
doi:10.5194/acp-16-4283-2016

Atmospheric Chemistry and Physics
Open Access
EGU

**Non-OH chemistry in oxidation flow reactors for the study of atmospheric chemistry systematically examined by modeling**

Zhe Peng[1,2], Douglas A. Day[1,2], Amber M. Ortega[1,3,a], Brett B. Palm[1,2], Weiwei Hu[1,2], Harald Stark[1,2,5], Rui Li[1,3,4,b], Kostas Tsigaridis[6], William H. Brune[7], and Jose L. Jimenez[1,2]

- Developed by Zhe Peng and Jose Jimenez（由**Peng Zhe**博士和**Jimenez**教授开发）
- Download from PAM wiki, compile in Igor（用**IGOR**写的程序可以从**PAM wiki**下载）

# Additional Resources 更多资源

- PAMwiki: **https://sites.google.com/site/pamwiki/home**
- Email lists: **pamusers@googlegroups.com, aerodyne-pam-users@aerodyne.com, cacc-support@aerodyne.com**
- **Asian PAM users**:

| Serial # | Institution |
|---|---|
| 005 | Institute of Earth Environment, Chinese Academy of Sciences （中国科学院地球环境研究所） |
| 007 | Hankuk University of Foreign Studies |
| 009 | Peking University （北京大学） |
| 012 | National University of Singapore |
| 014 | Anhui Institute for Optics and Fine Mechanics, Hefei Institutes of Physical Science, Chinese Academy of Sciences （中国科学院安徽光学精密机械研究所，合肥物质科学研究院） |
| 018 | Tsinghua University （清华大学） |

- Please ask me questions during the meeting. （欢迎随时与我讨论）Thank you!