Aerosol Formation From Oil Vapors Downwind from the Deepwater Horizon Oil Spill

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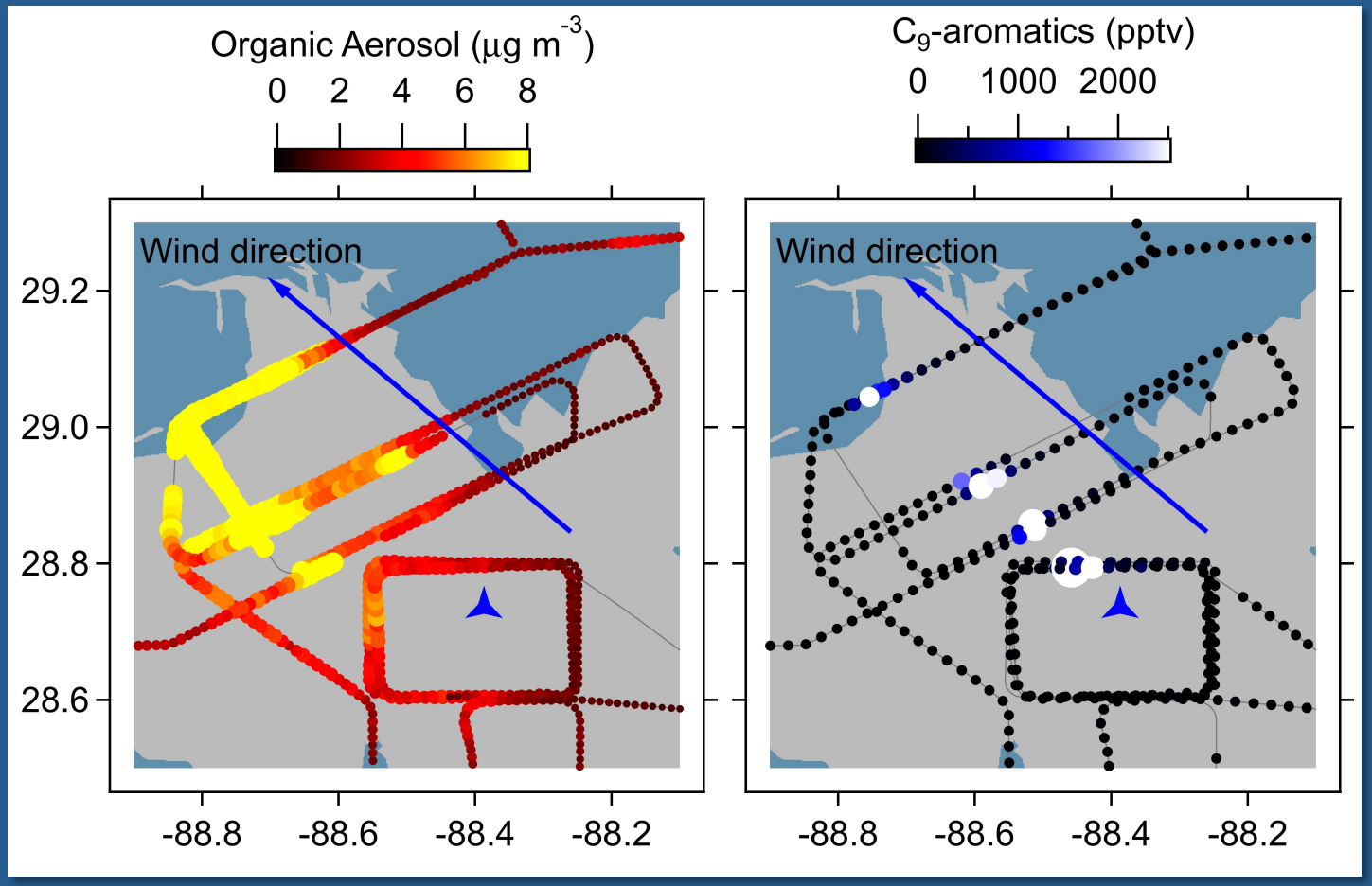
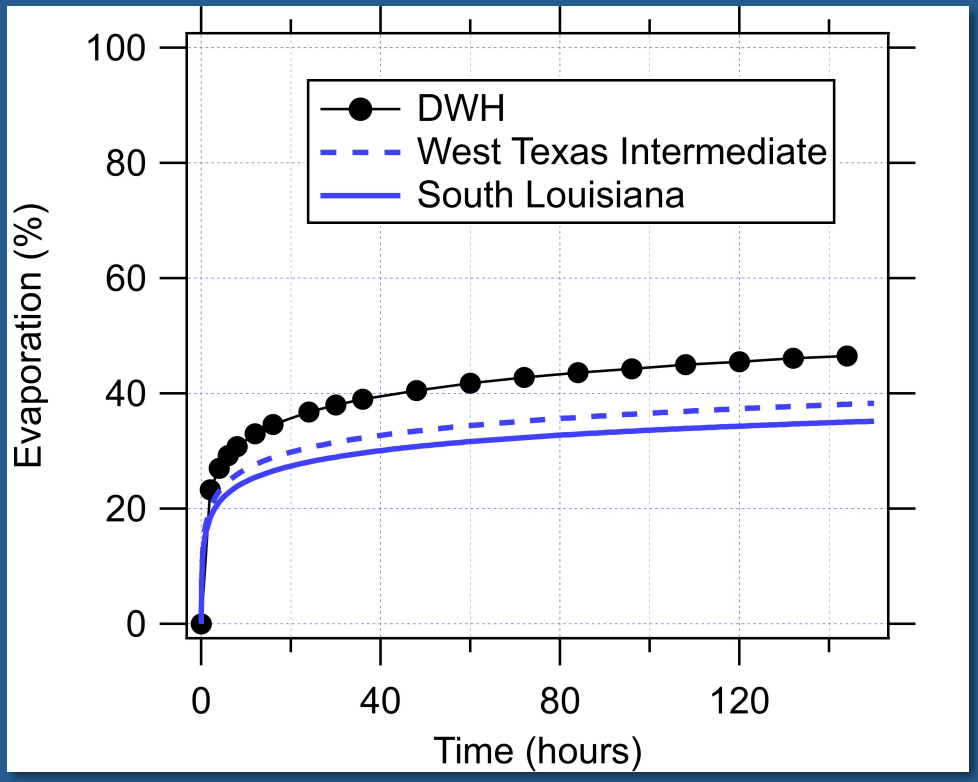
- Based on airborne measurements on June 8 and 10
- Published in *Science* 331, 1295-1299 (2011)

Results from the June 10 Flight



- Narrow plume of volatile organic compounds (VOCs)
  e.g. alkanes, aromatics
- Much wider plume of organic aerosol

Evaporation of Oil Spilled at DWH

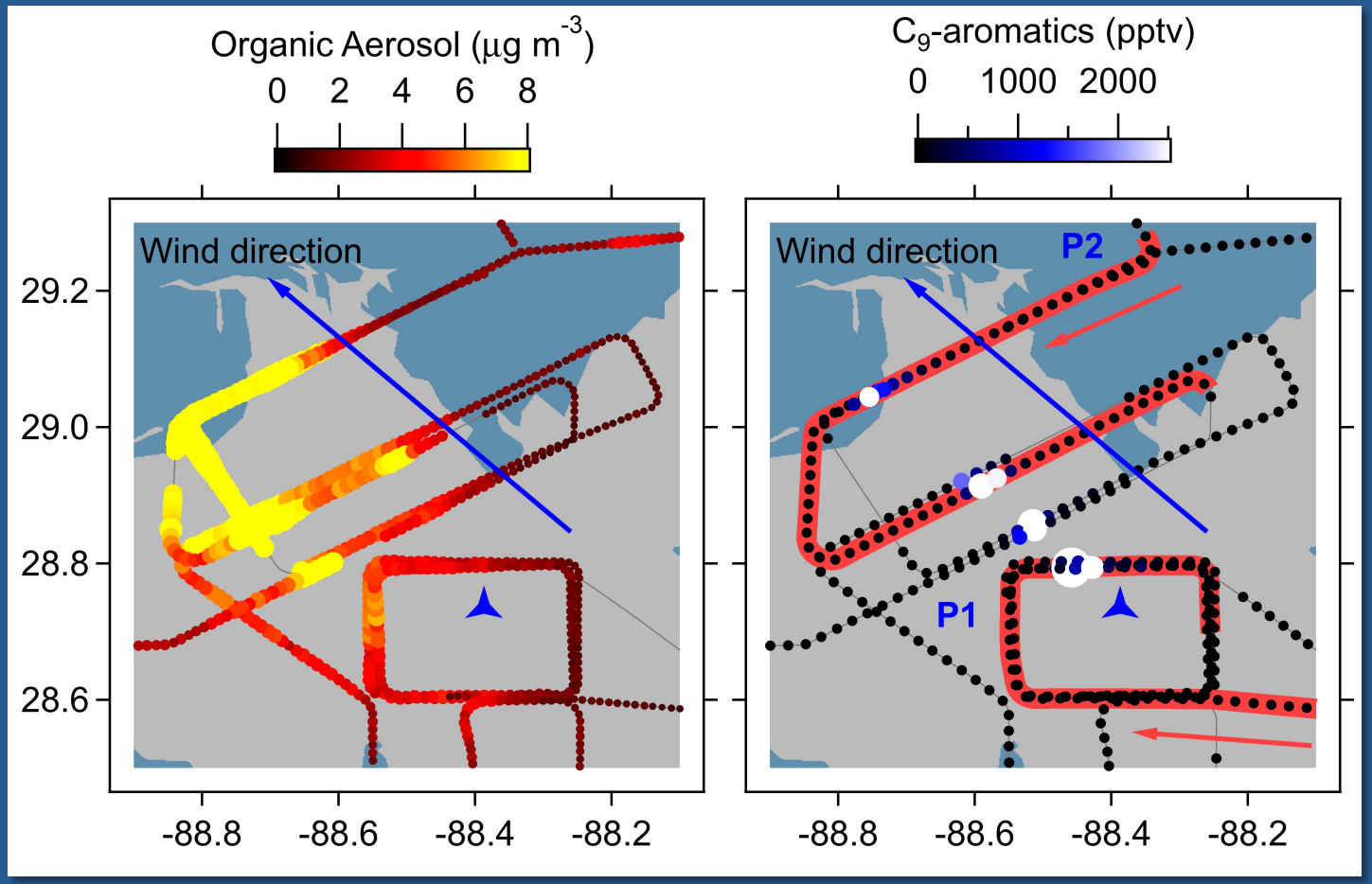


Data:
SL Ross
for BP

Why is the VOC plume so narrow?

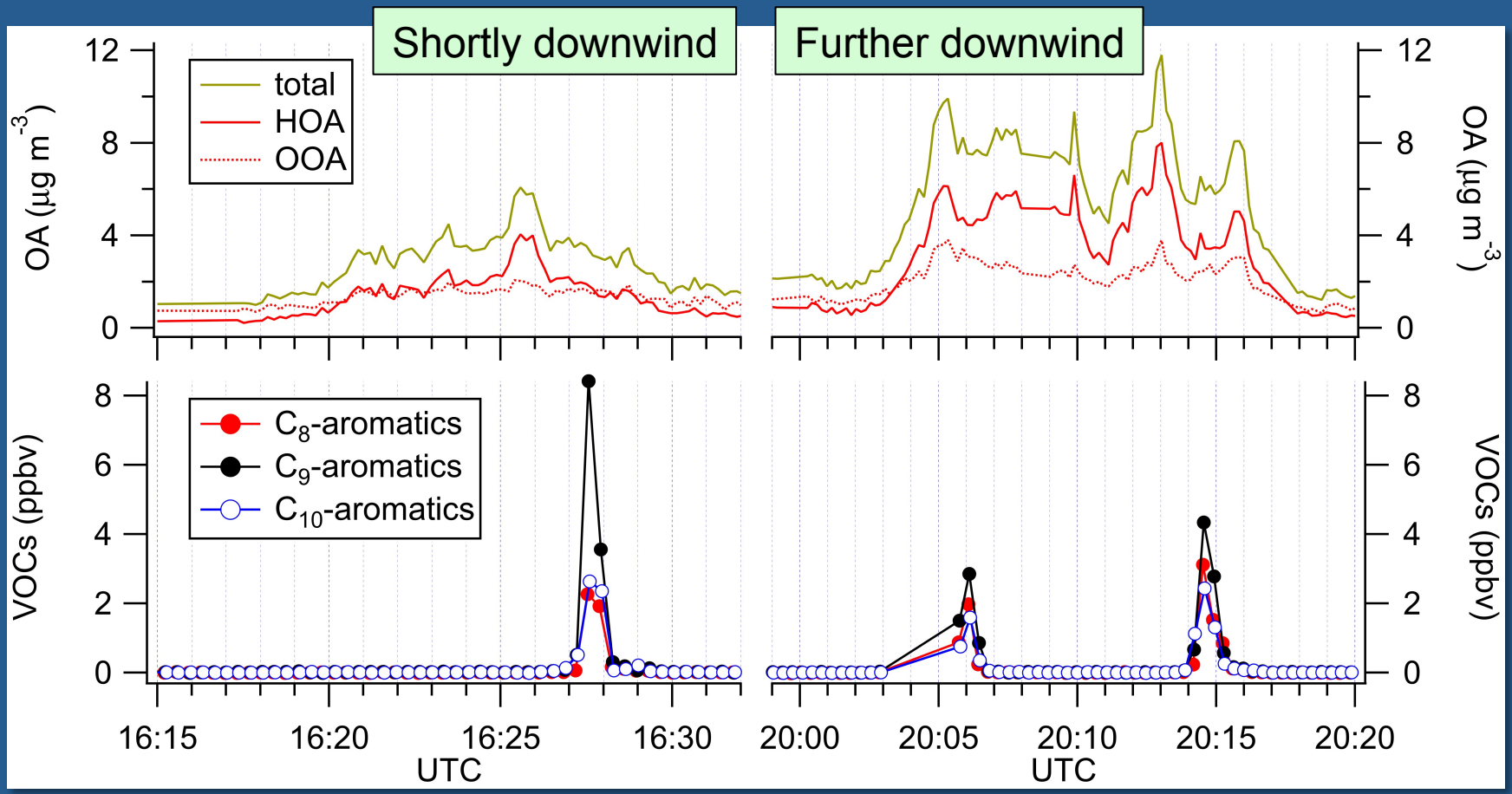
- Oil surfaced in a few km^2
- First 20% of the surfaced oil evaporated in <2 hours
- Surface transport in 2 h is not very far

Results from the June 10 Flight



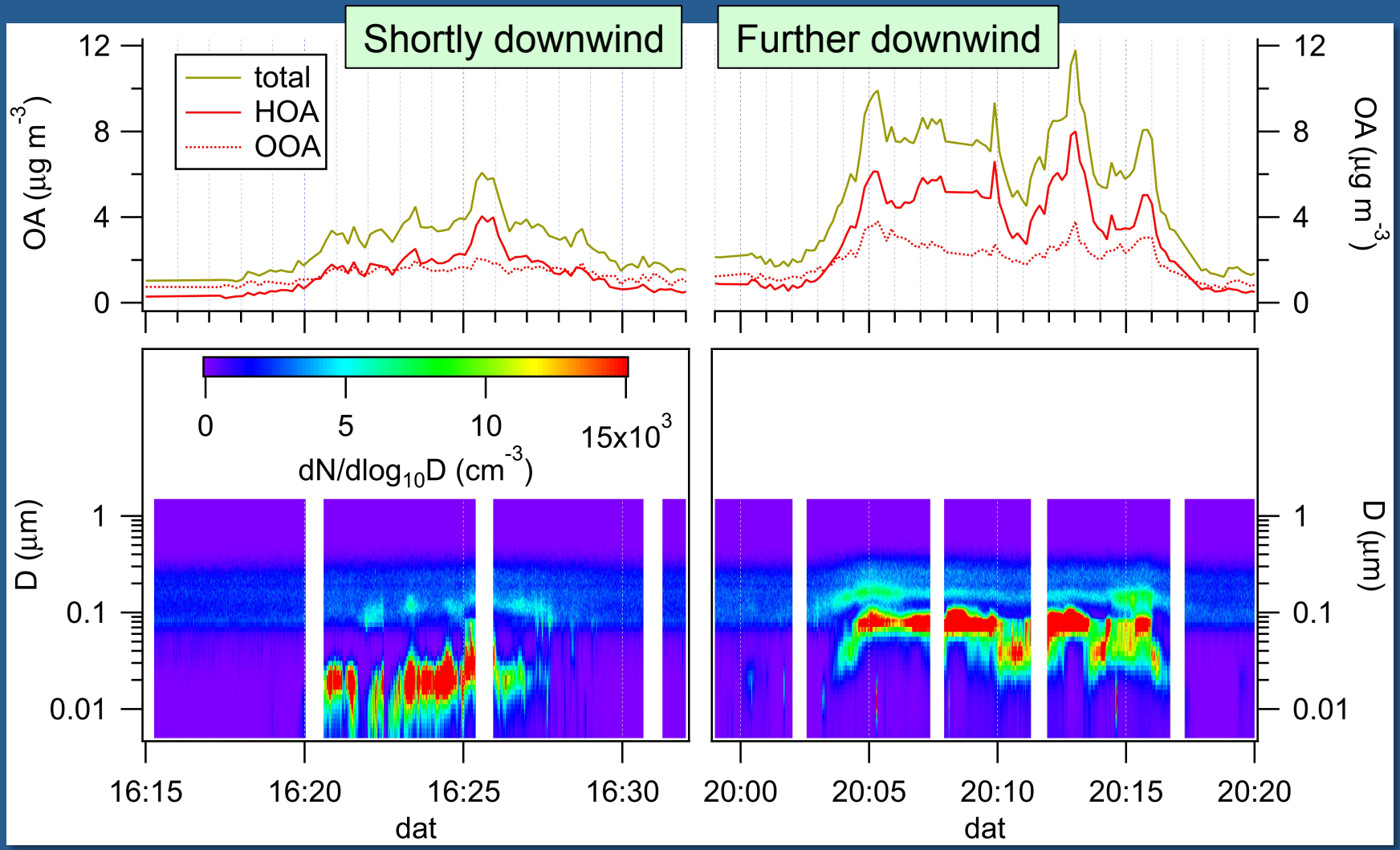
- Rapid evaporation explains narrow plume of VOCs
- Where does the organic aerosol come from?

Results from June 10: What is the Aerosol Source?



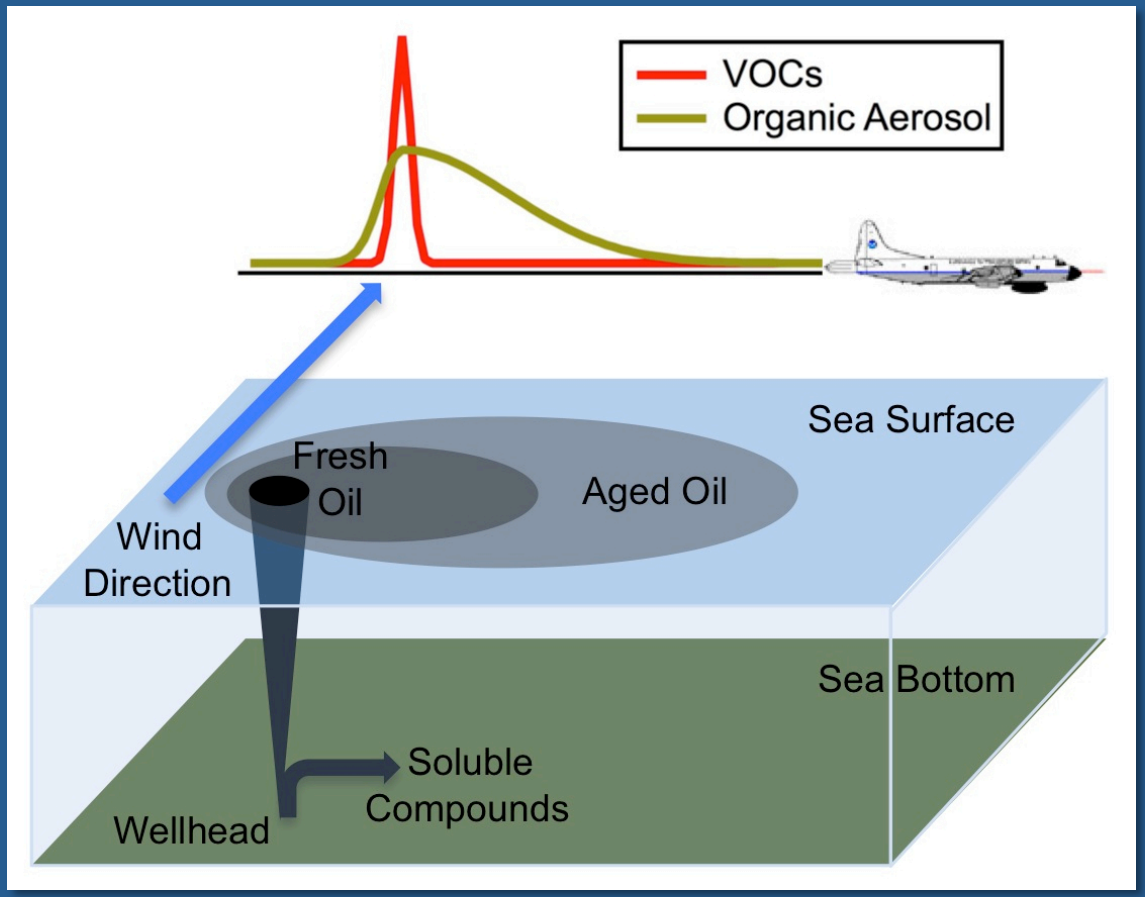
- Organic aerosol mass loadings increased further downwind
- Aerosol was not formed from aromatic VOCs

Results from June 10: What is the Aerosol Source?



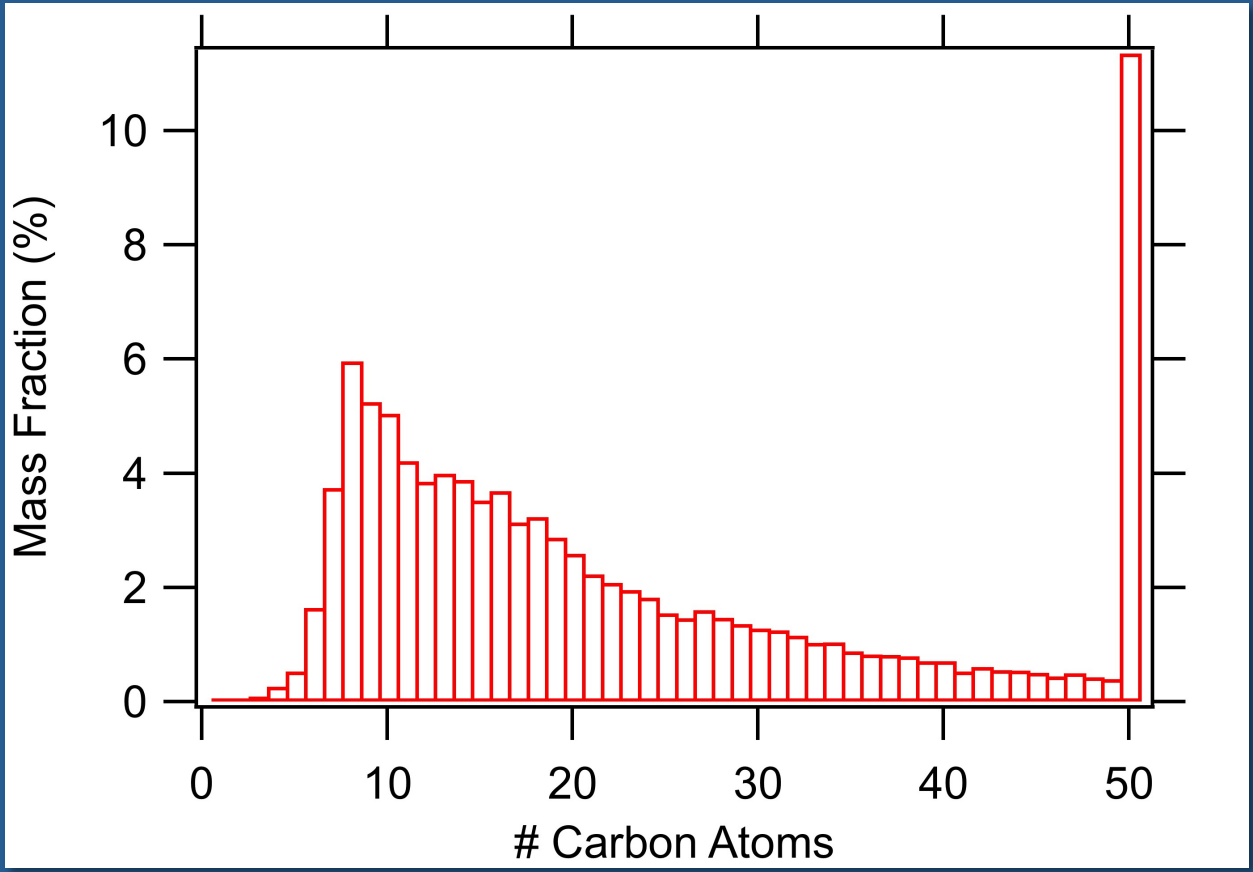
- Aerosol grew in size further downwind
- Aerosol was formed chemically from less volatile oil vapors

Conceptual Model for Aerosol Formation Downwind DWH



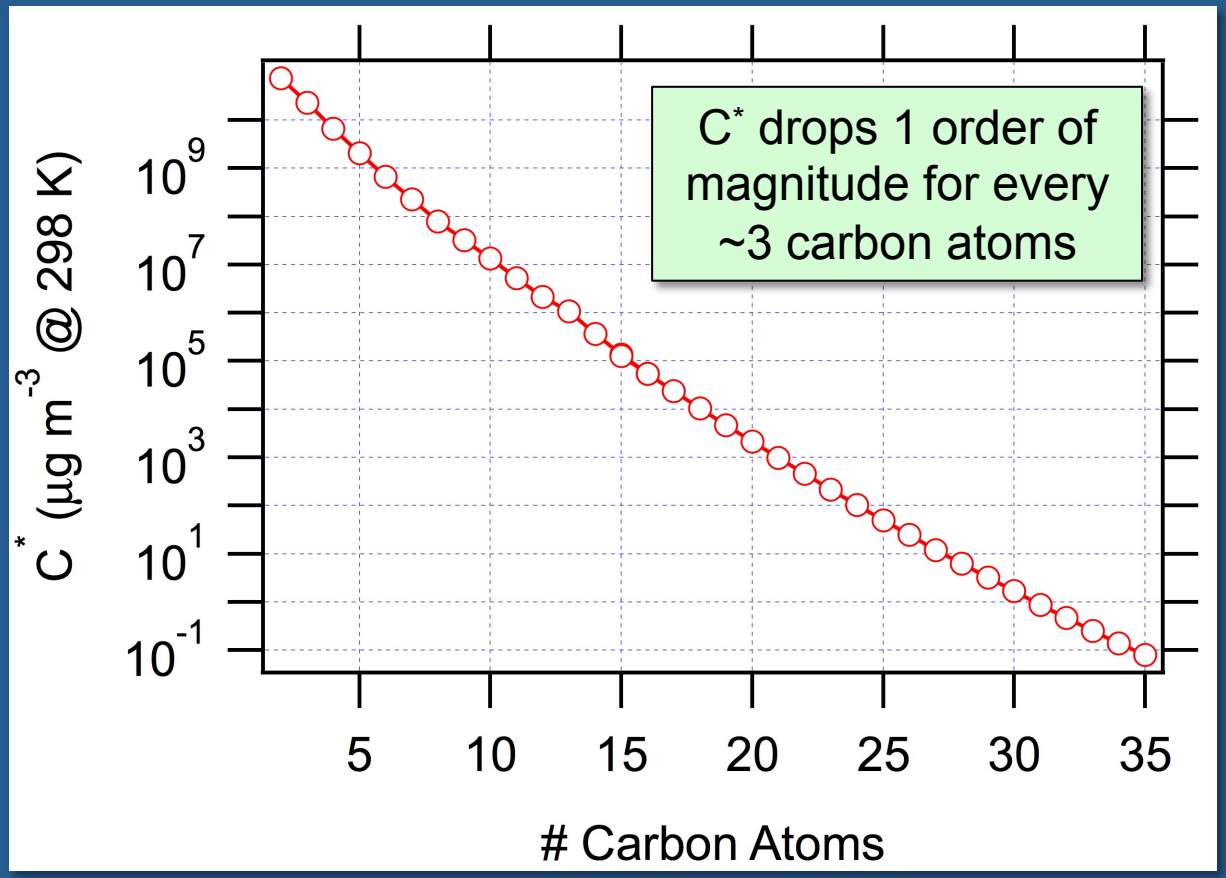
Aerosol was formed from organic compounds of intermediate volatility (IVOCs) that evaporated more slowly and were therefore released from a wider area

From Oil Composition to Volatility Distribution



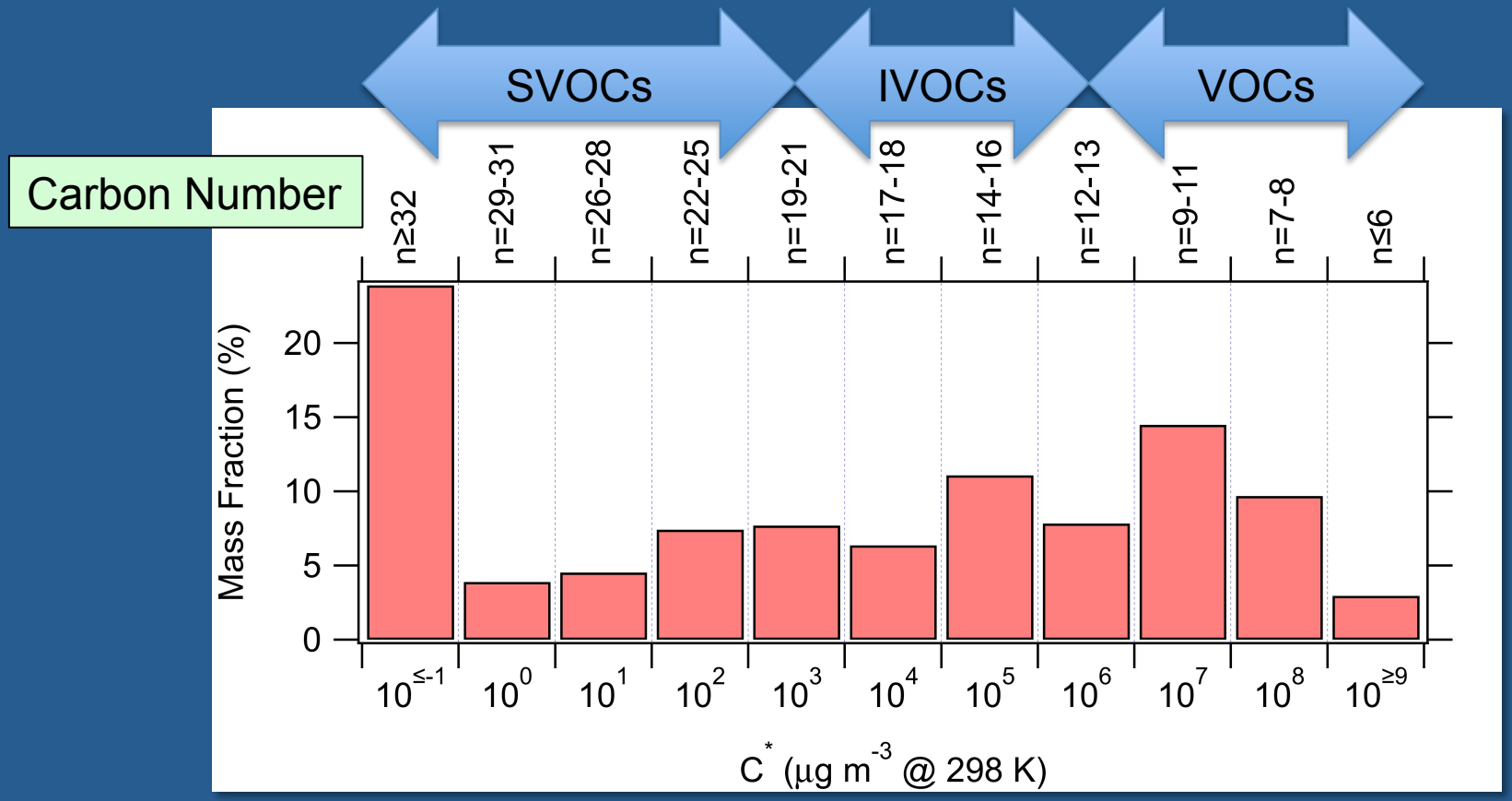
- Composition of the reservoir liquid
- Measured by Pencor for BP

From Oil Composition to Volatility Distribution



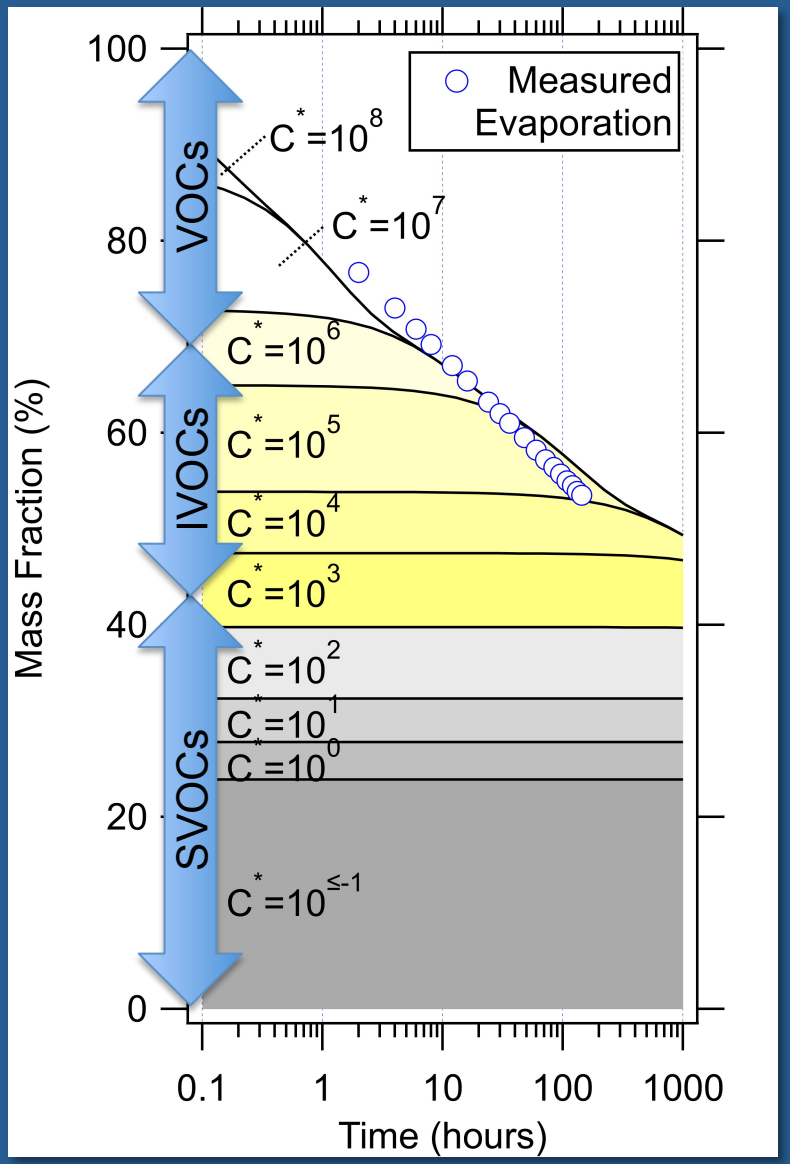
- Effective saturation concentration (C^*) ≅ vapor pressure
- C^* is used for easy comparison with atmospheric data

From Oil Composition to Volatility Distribution



Which volatility classes were the precursors of the SOA?

Time Scales for VOC-IVOC-SVOC Evaporation

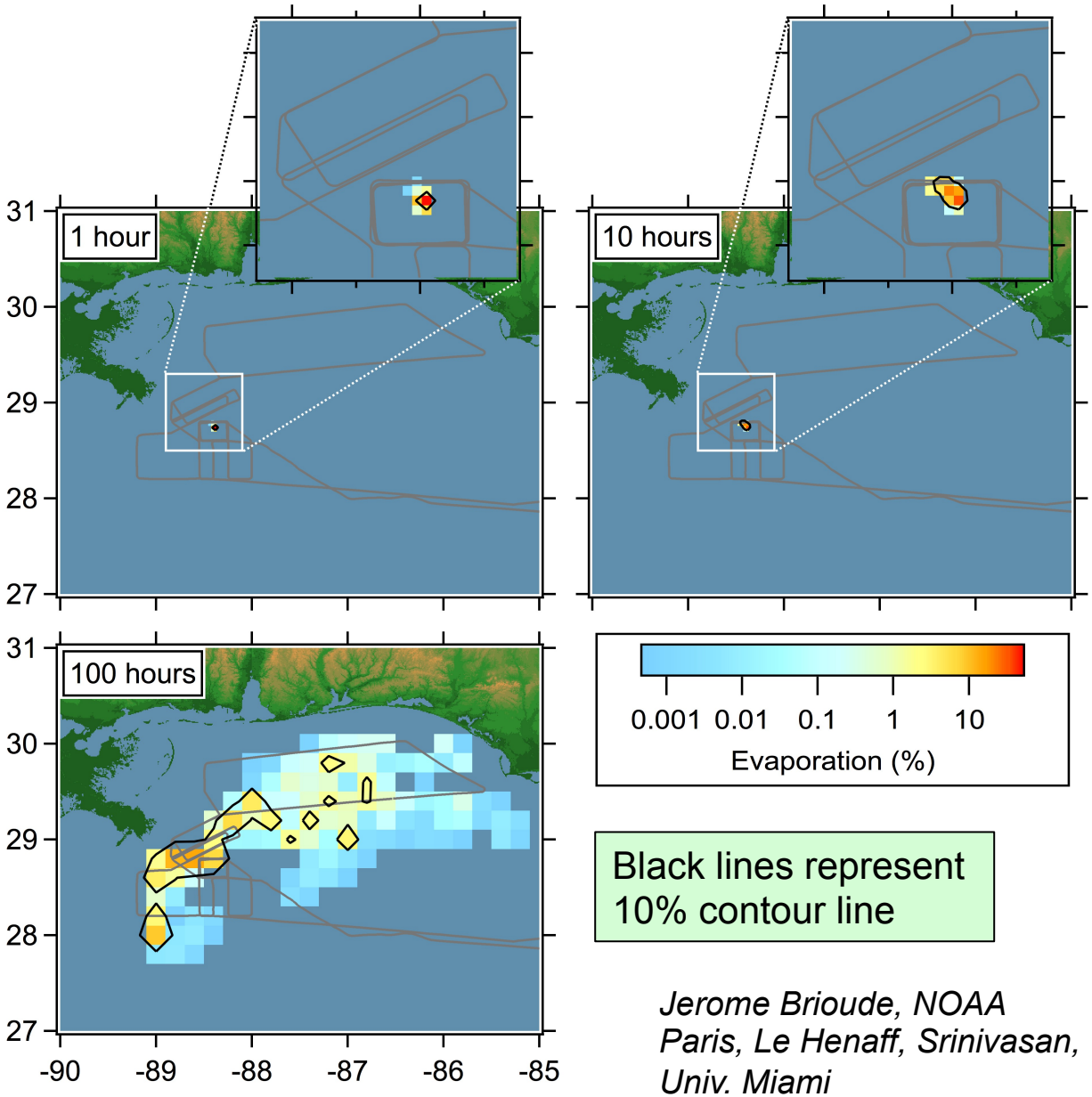


- Measured evaporation is fit using volatility distribution, assuming:

evaporation rate ~ C^*

- VOC evaporation < 10 h
- IVOC evaporation = 10-1000 h
- SVOC evaporation > 1000 h

Time vs. Spatial Scales for Evaporation

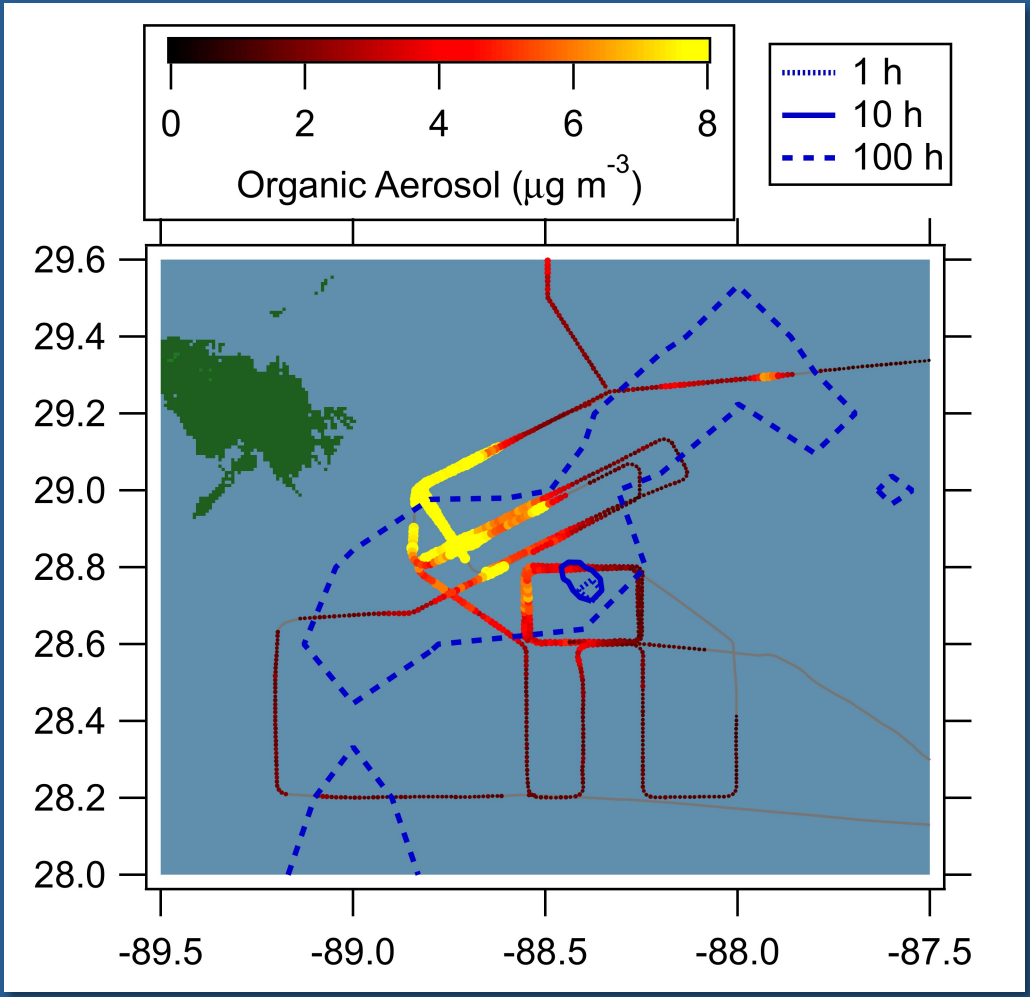


Jerome Brioude, NOAA
Paris, Le Henaff, Srinivasan, Univ. Miami

Modeled oil spreading:

- Model releases oil in a 4×4 km^2 area around DWH
- Lagrangian transport model calculates oil trajectories
- Advection, diffusion and wind drift are accounted for

Spatial Scales for VOC-IVOC-SVOC Evaporation



- Spreading on 10-100 h time scales resembles size of aerosol source area
- IVOCs with $C^{*}=10^{5}$ are most likely SOA precursors

Conclusions

- 20% of the surface oil evaporated in <2 hours and was observed in a narrow plume downwind DWH
- Next 20% evaporated in <2 days and efficiently formed aerosol downwind
- Aerosol formation was:
  ~36% of the most likely IVOC precursors
  ~8% of the surfaced oil
- Aerosols are air pollutants; impact at mass loadings downwind from DWH was limited [*Middlebrook*, PNAS in press]

Acknowledgements

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A. Robinson	SVOC description
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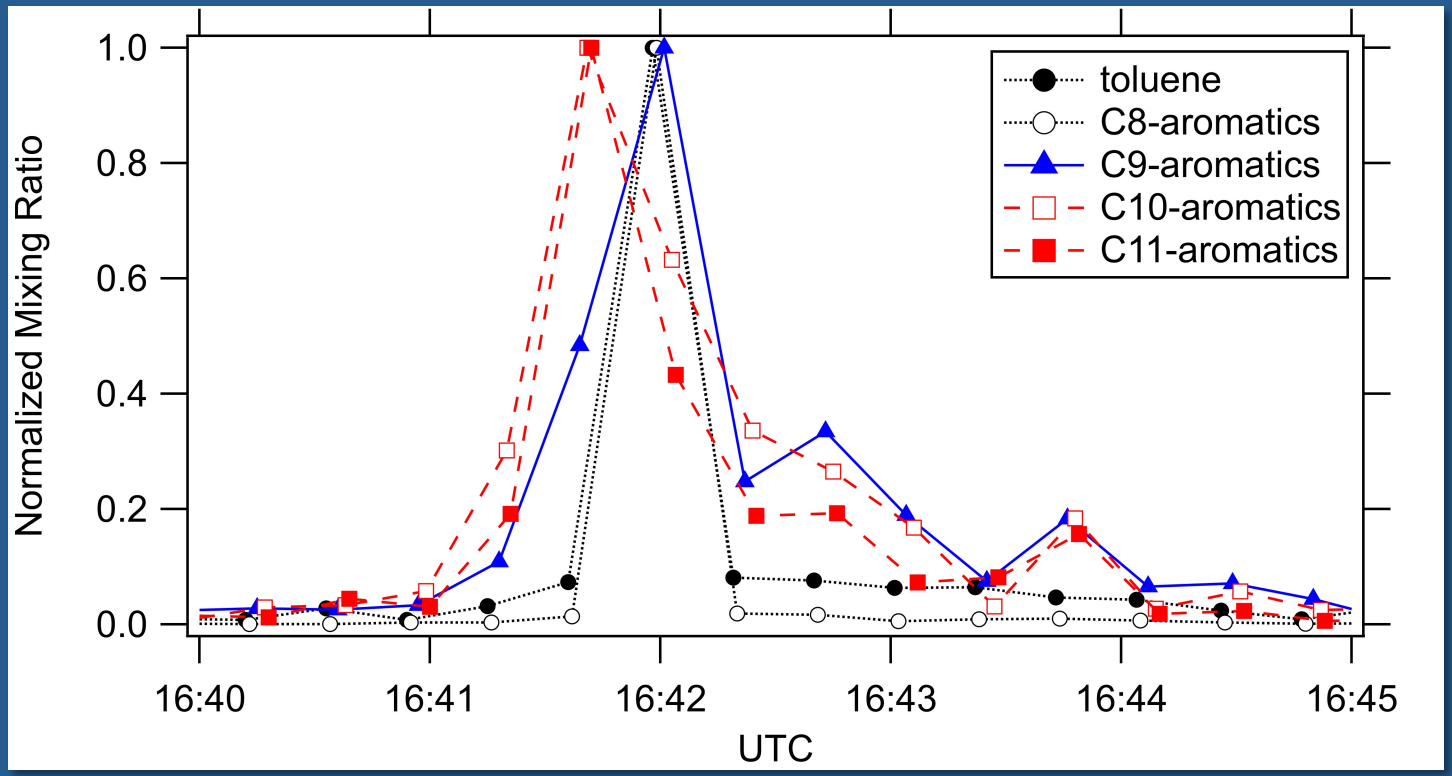
Conceptual Model for Aerosol Formation Downwind DWH

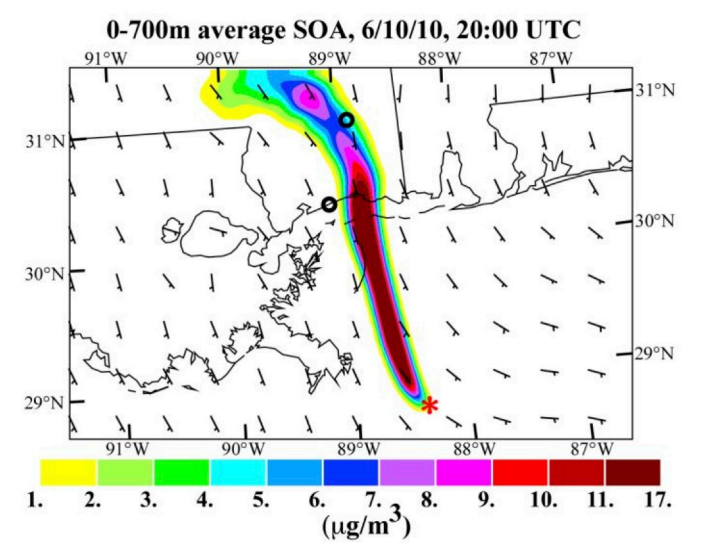


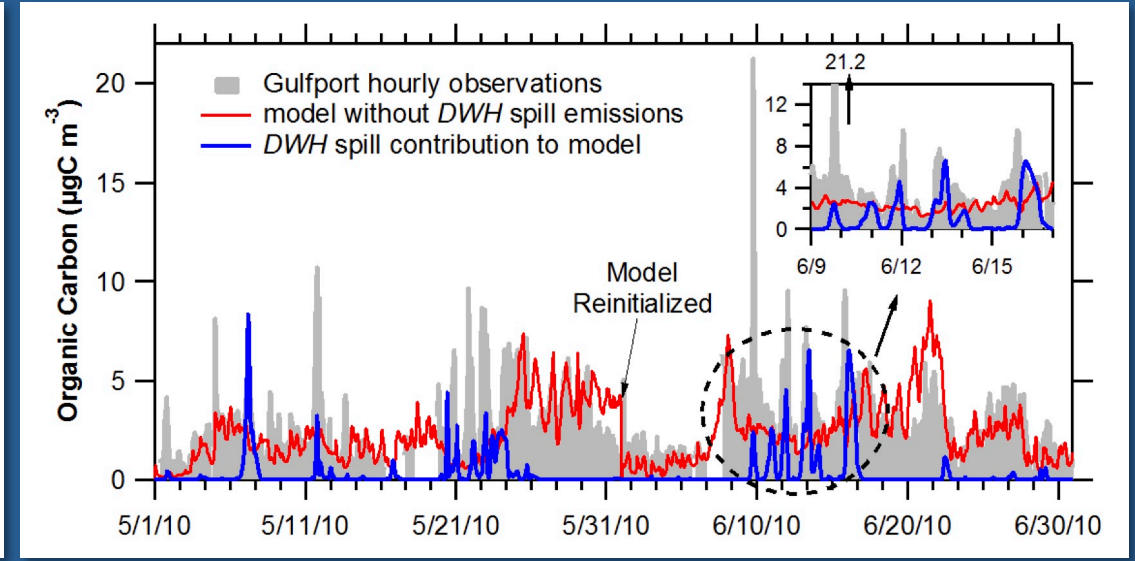
Shortly downwind from DWH:

- Less volatile VOCs are released in wider plumes
- In agreement with conceptual model

WRF-Chem Modeling of Oil Spill SOA

- WRF-Chem run at 4×4 km^2 and 20×20 km^2
- SOA modeled using volatility basis set (VBS) approach
- Emissions: determined directly from measurements





Middlebrook [PNAS in press]

Model evaluation with SEARCH data:

- Model captures some of the variability in OC at Gulfport
- Enhancements in OC downwind from DWH were likely observed at Gulfport