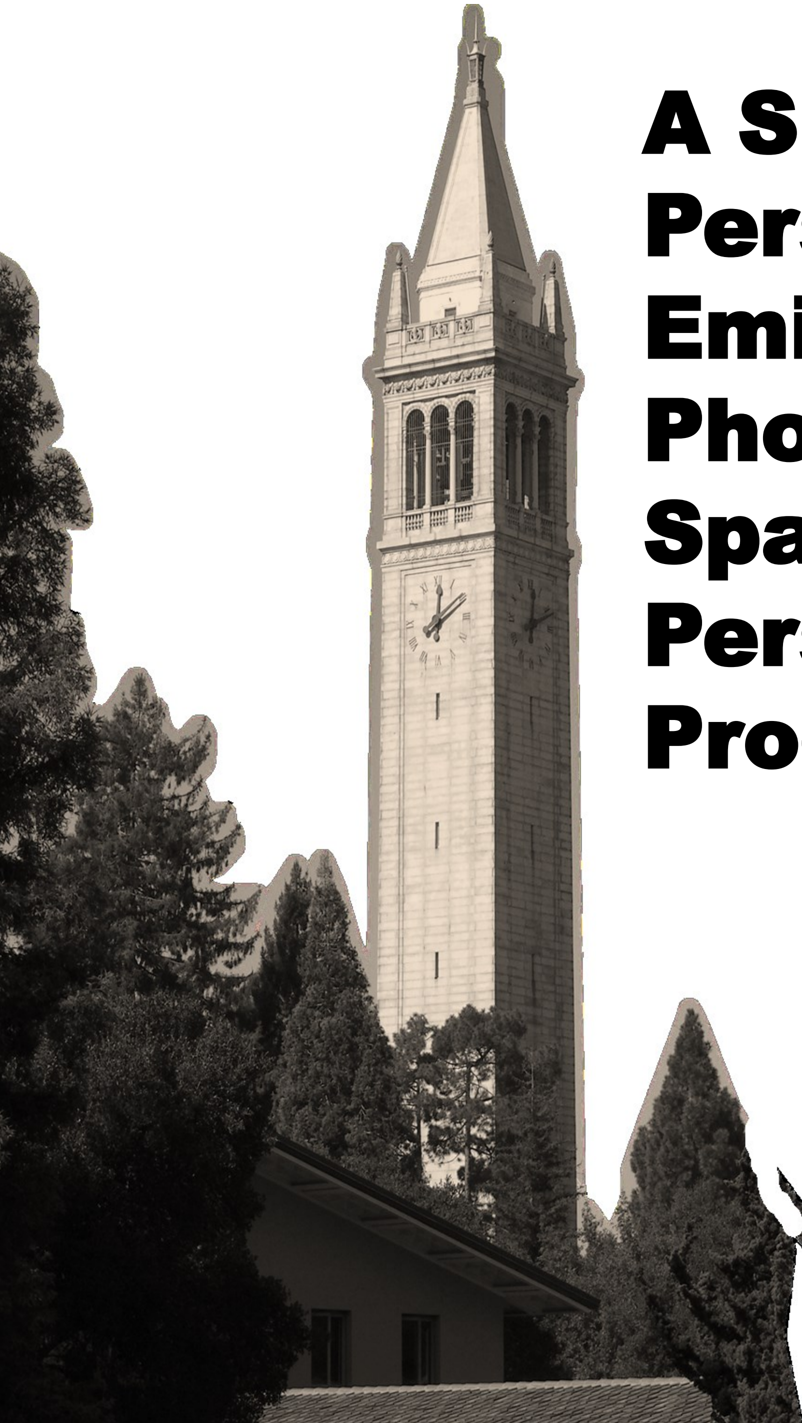
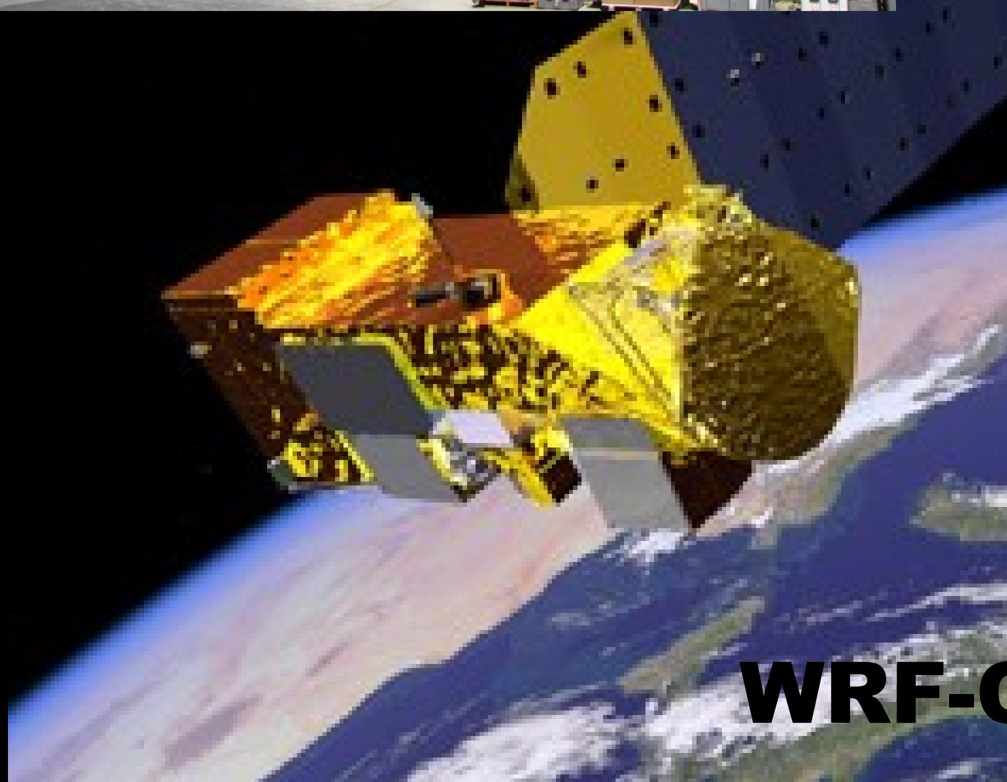
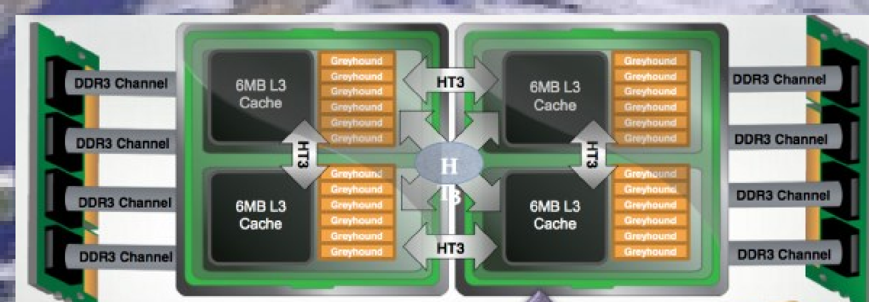


A Space Based Perspective on Urban Emissions and Photochemistry: Winds, Spatial Resolution and Perspectives on Future Progress

Ronald C. Cohen
UC Berkeley

$ NASA

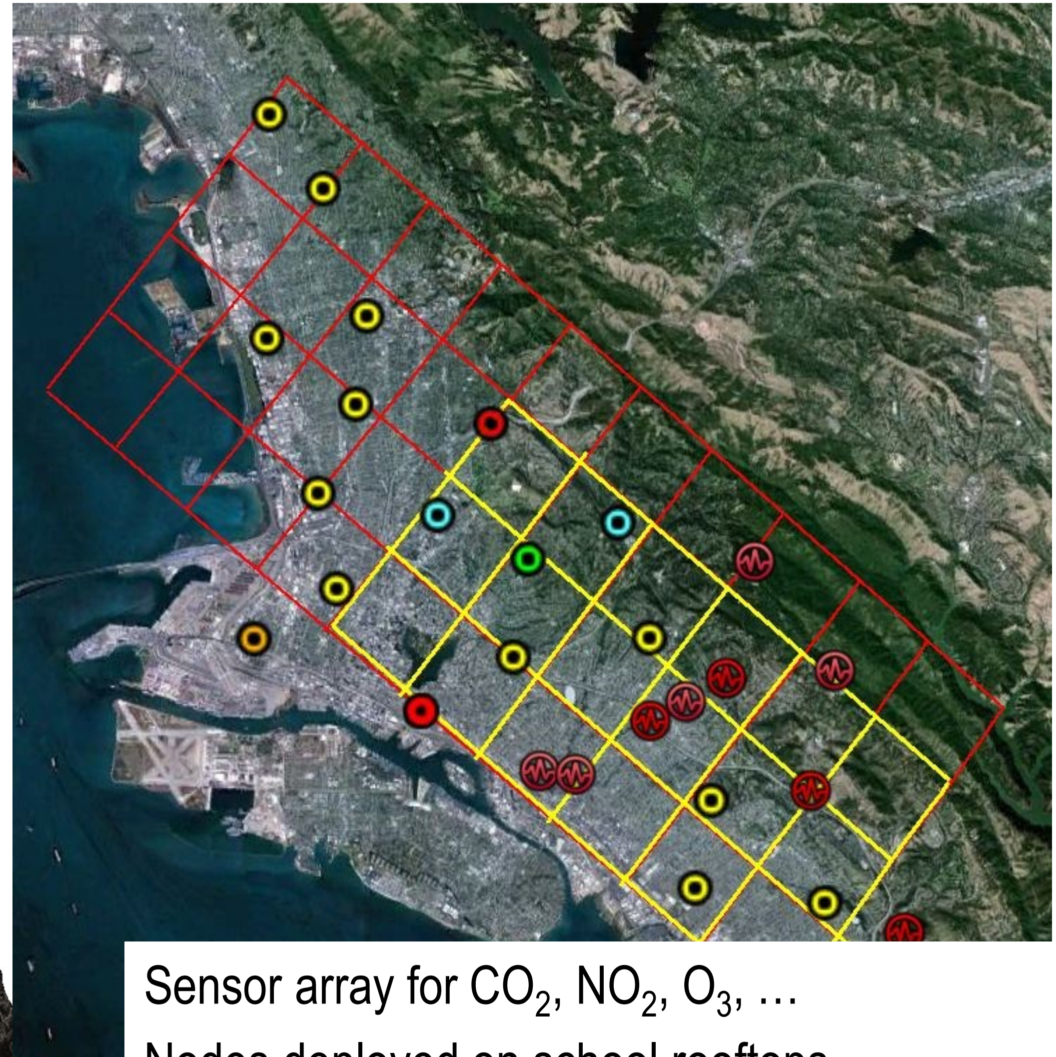




WRF-CHEM/GEOS-CHEM

BEACO$_2$N

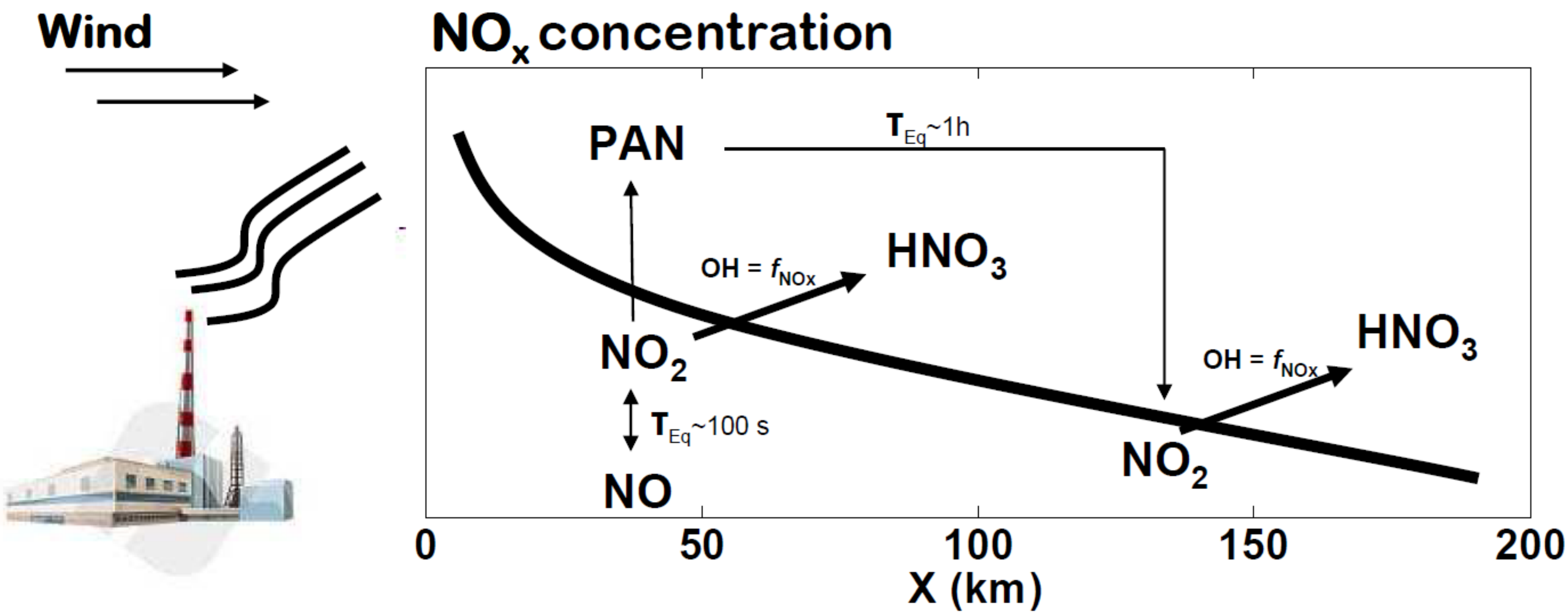
The BErkeley Atmospheric CO$_2$ Observation Network



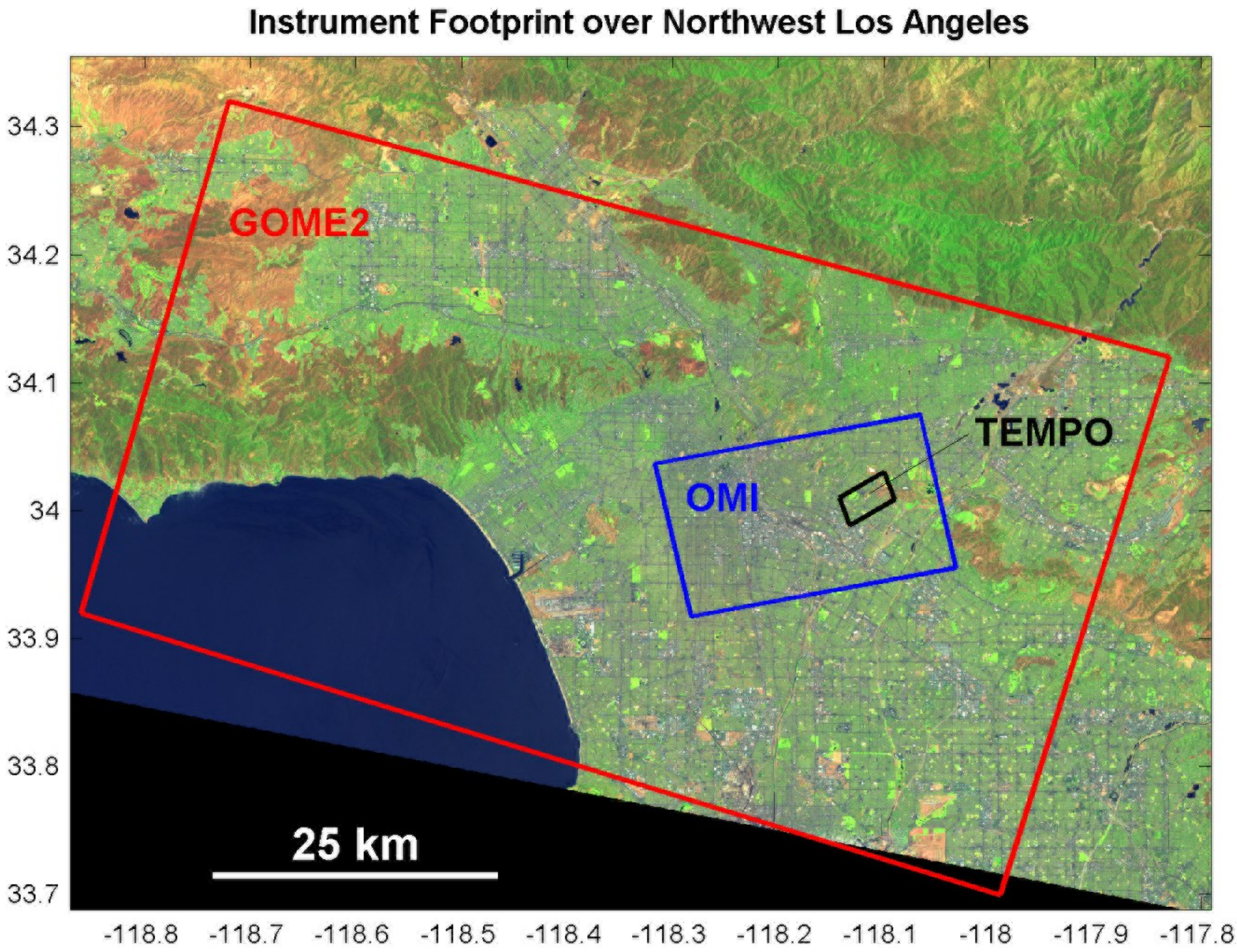
Sensor array for CO_2, NO_2, O_3, …

Nodes deployed on school rooftops

http://beacon.berkeley.edu/



Wind
NOx concentration
PAN
T Eq ~1h
OH = f NOx
HNO3
NO2
T Eq ~100 s
NO
OH = f NOx
HNO3
NO2
0
50
100
150
200
X (km)



Instrument Footprint over Northwest Los Angeles
GOME2
OMI
TEMPO
25 km
34.3
34.2
34.1
34
33.9
33.8
33.7
-118.8
-118.7
-118.6
-118.5
-118.4
-118.3
-118.2
-118.1
-118
-117.9
-117.8

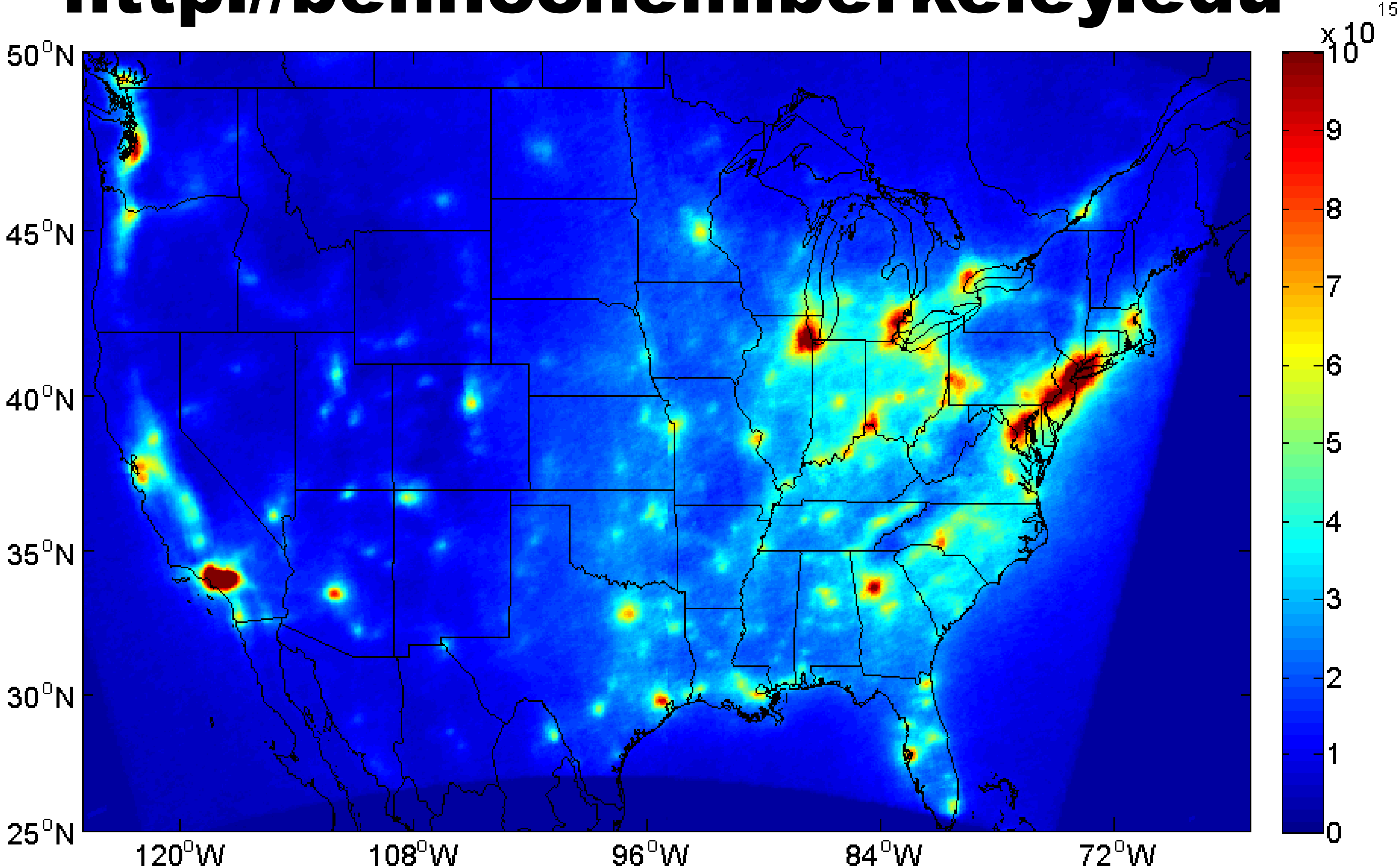
1. We need a retrieval that is accurate at spatial scales of ~10 km

Berkeley High Resolution Retrieval (BEHR)

	NASA standard	BEHR
Terrain pressure	High-res terrain database, center of OMI footprint	High-res terrain database, average over OMI footprint
Terrain reflectivity	Monthly 1° × 1°	MODIS, 8 day 0.05° × 0.05°
NO_2 profile shape	Annually 2° × 2.5°	WRF-Chem, Monthly 4 × 4 km^2 (CA&NV) 12 x 12 km^2 U.S.
Clouds	OMI cloud product	MODIS cloud product

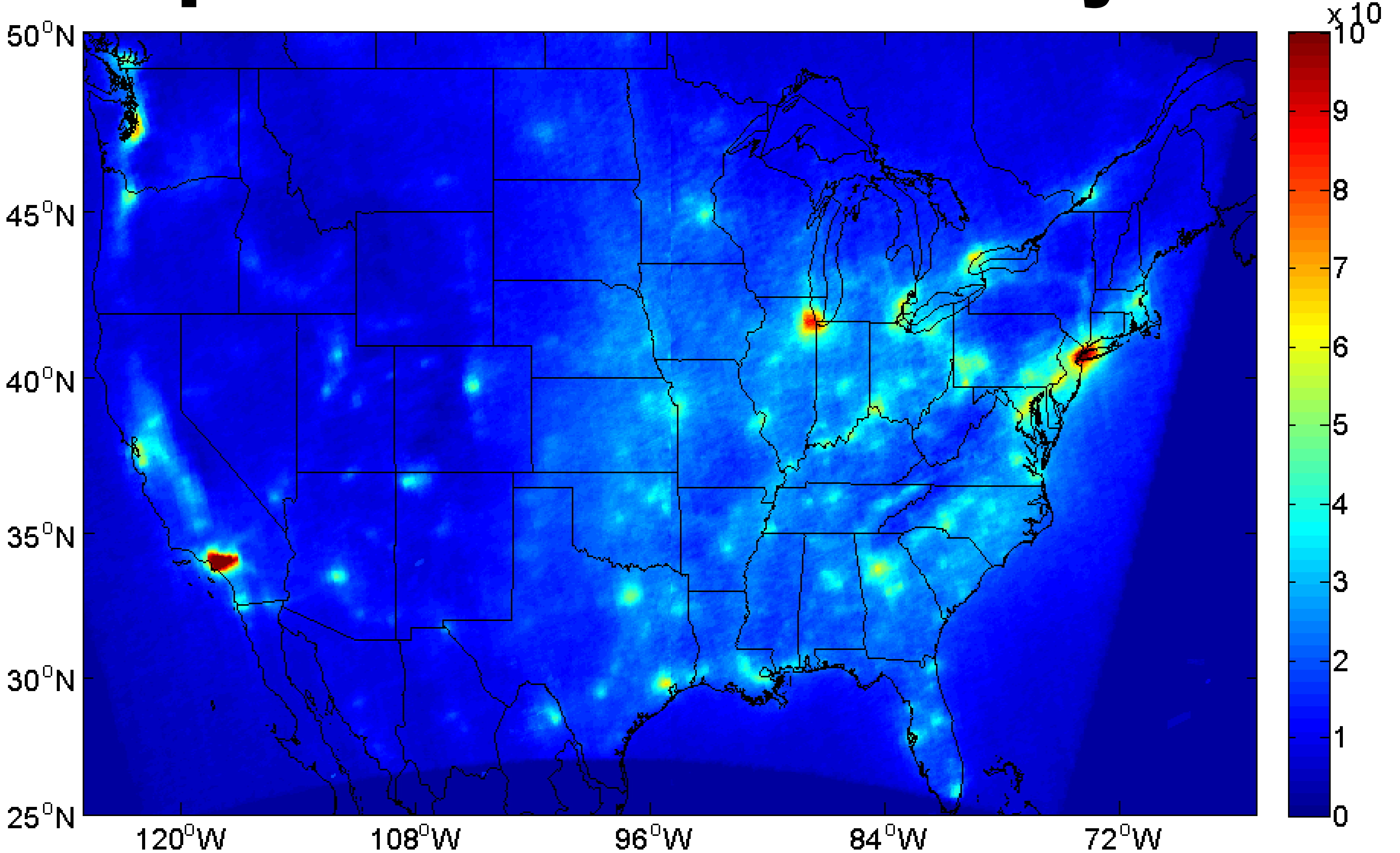
Russell et al., Atmos Chem & Phys **11**, 8543-8554, 2011

http://behr.cchem.berkeley.edu



Summer 2005

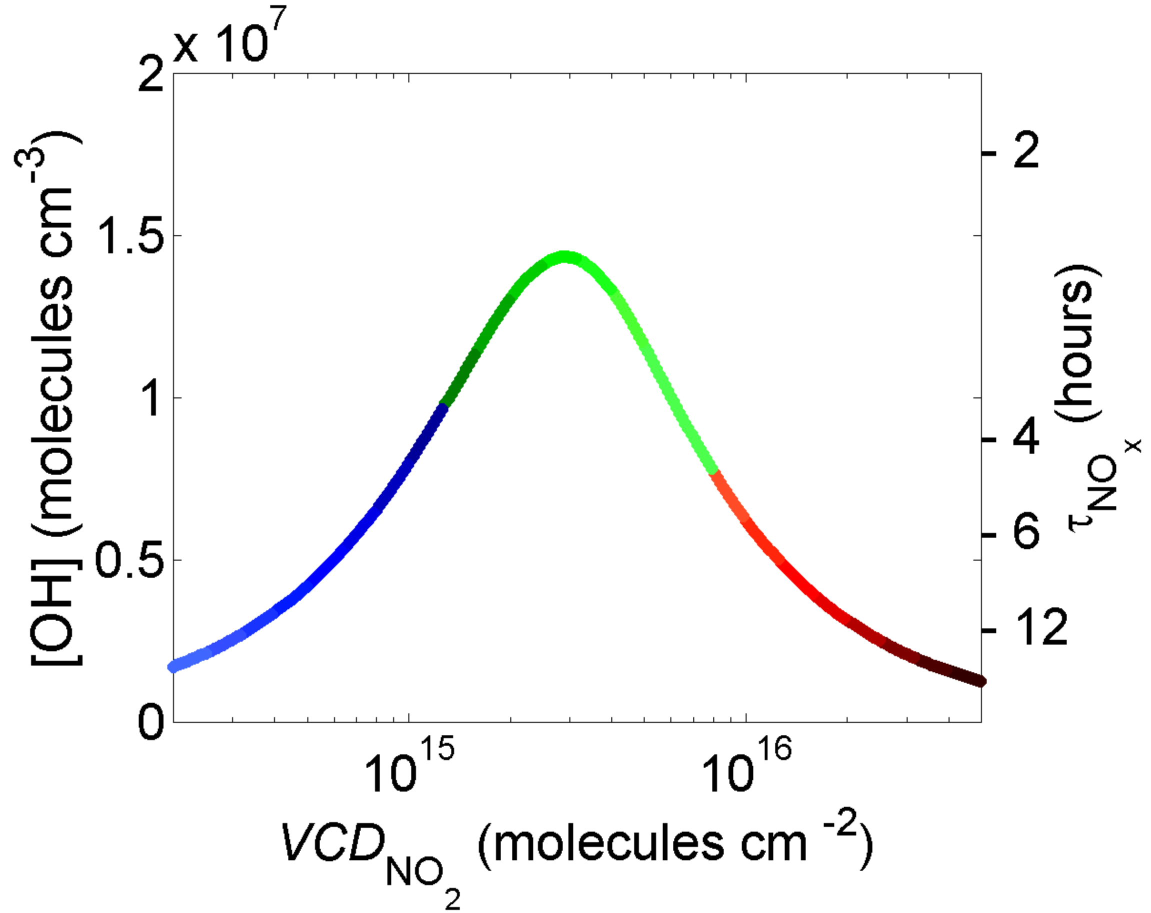
http://behr.cchem.berkeley.edu



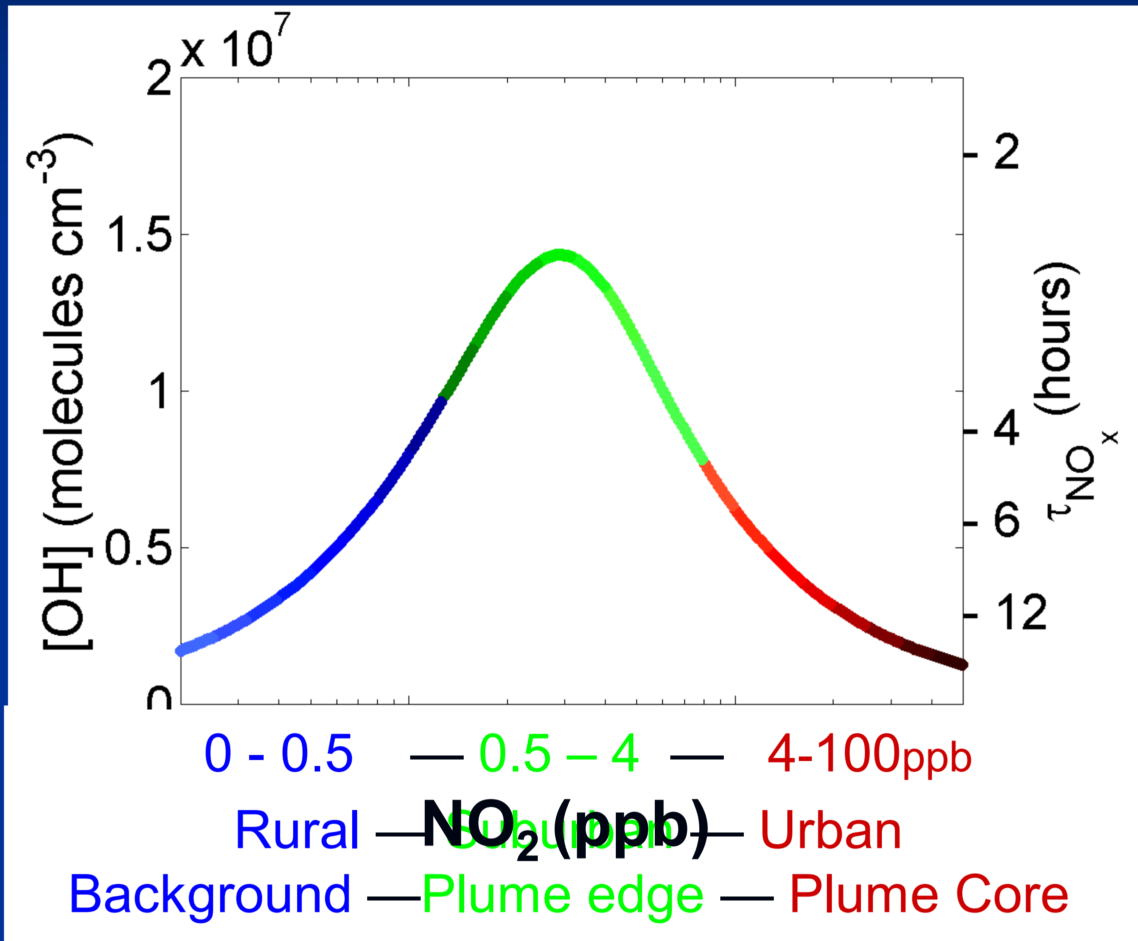
Summer 2011

2. Resolving chemistry and emissions from space

OH is nonlinear with NO_2

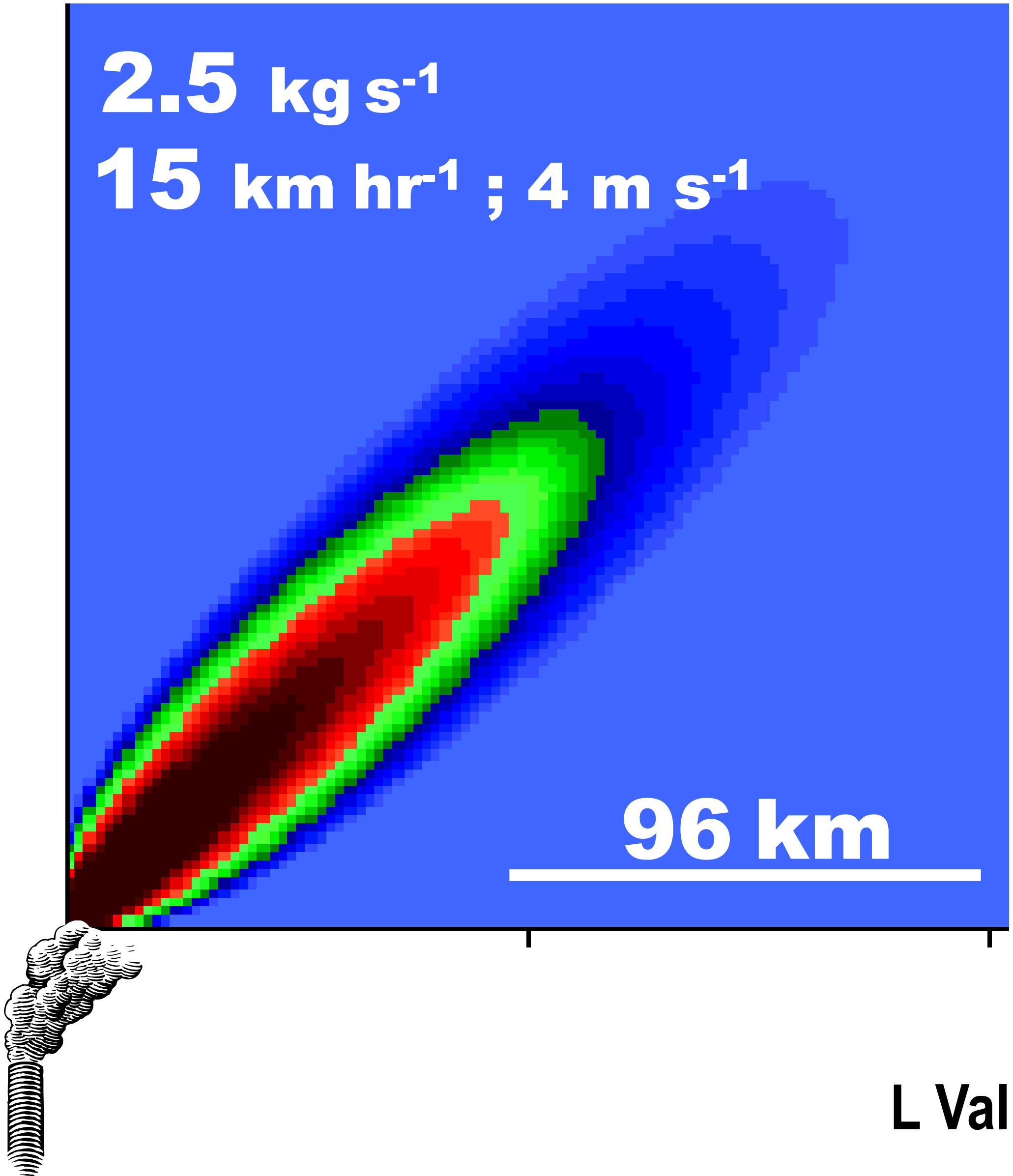


Rural — Suburban — Urban



x 10^7
2
1.5
1
0.5
0
[OH] (molecules cm^-3)
2
4
6
12
τNOx (hours)
0 - 0.5 — 0.5 – 4 — 4-100ppb
NO2 (ppb)
Rural — Suburban — Urban
Background — Plume edge — Plume Core

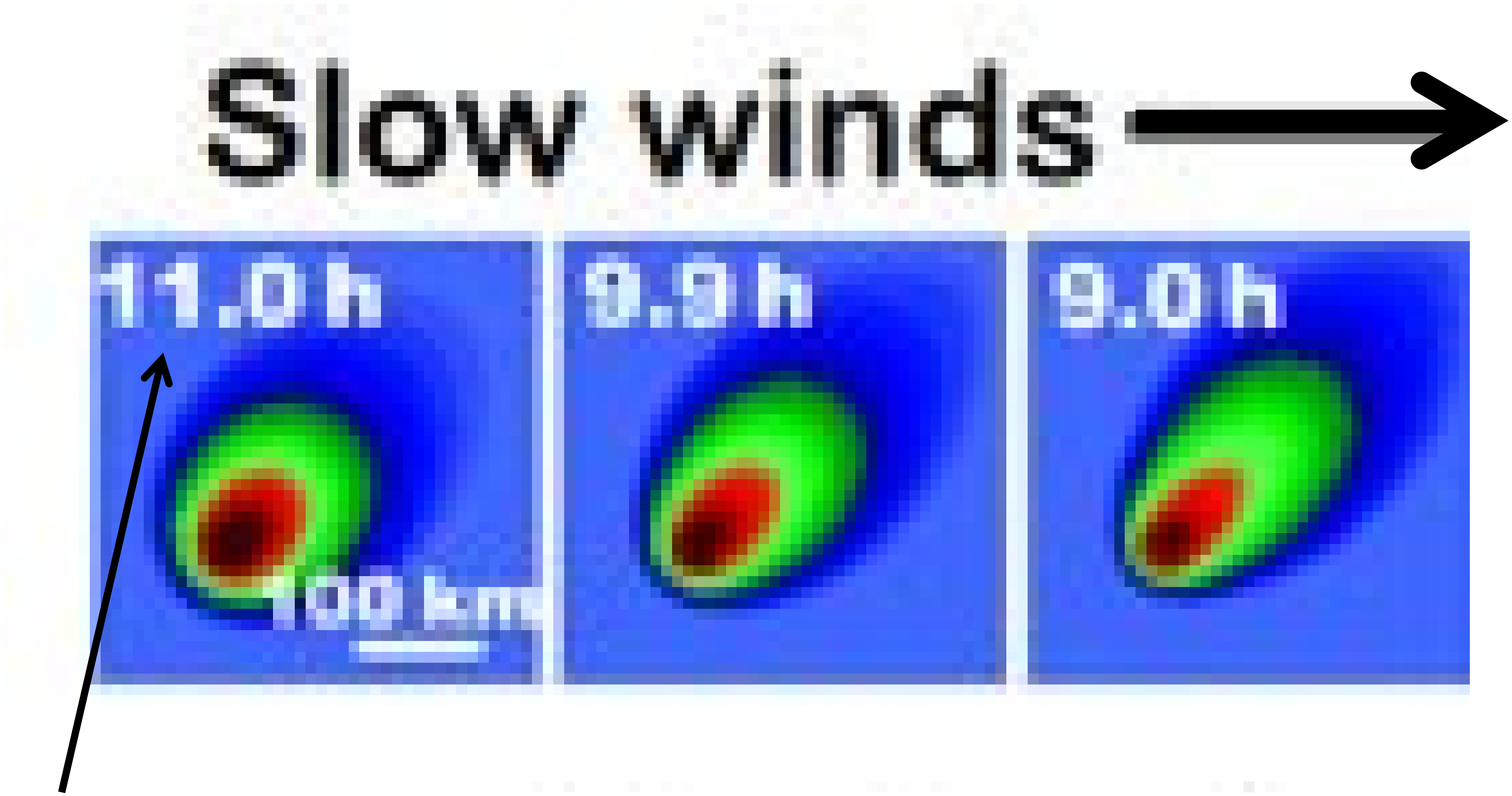
2-d (or 3-d WRF)



- **constant emissions**
- **advection**
- **dilution**
- **chemical feedback.**

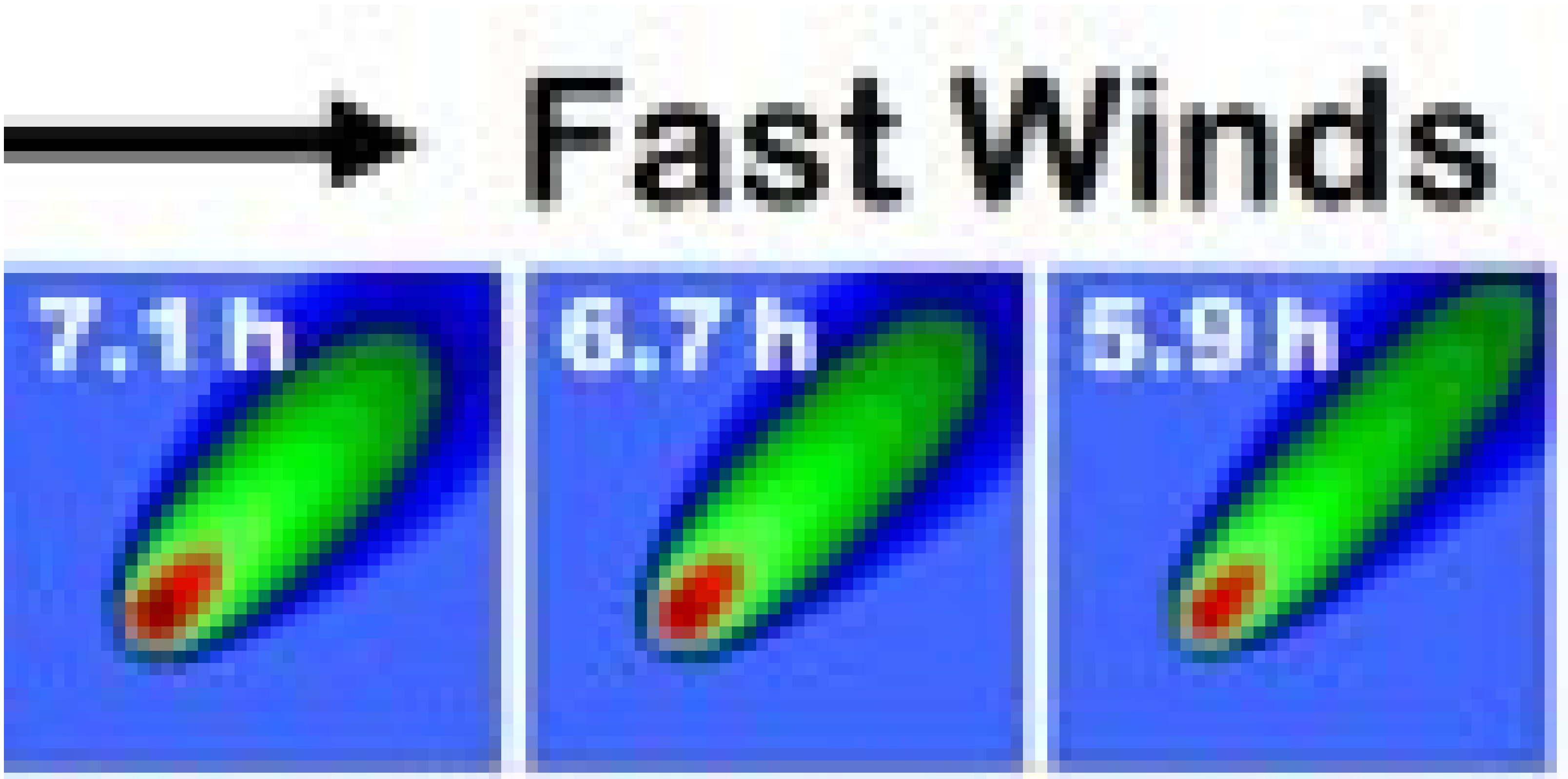
L Valin et al., *Atmos. Chem. Phys.* **2011**

Prediction: lifetime of NO_x depends on wind speed



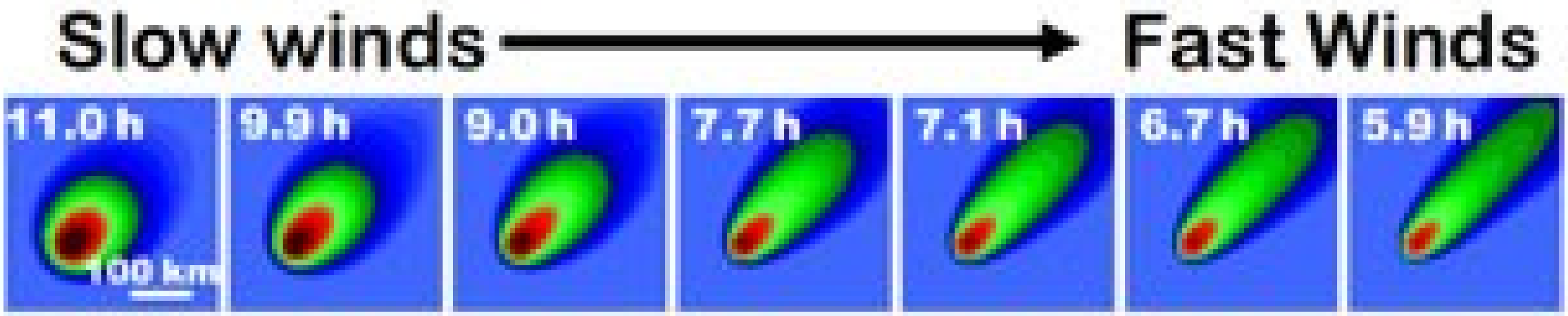
L Valin et al., *GRL* **2013**

Prediction: lifetime of NO_x depends on wind speed.



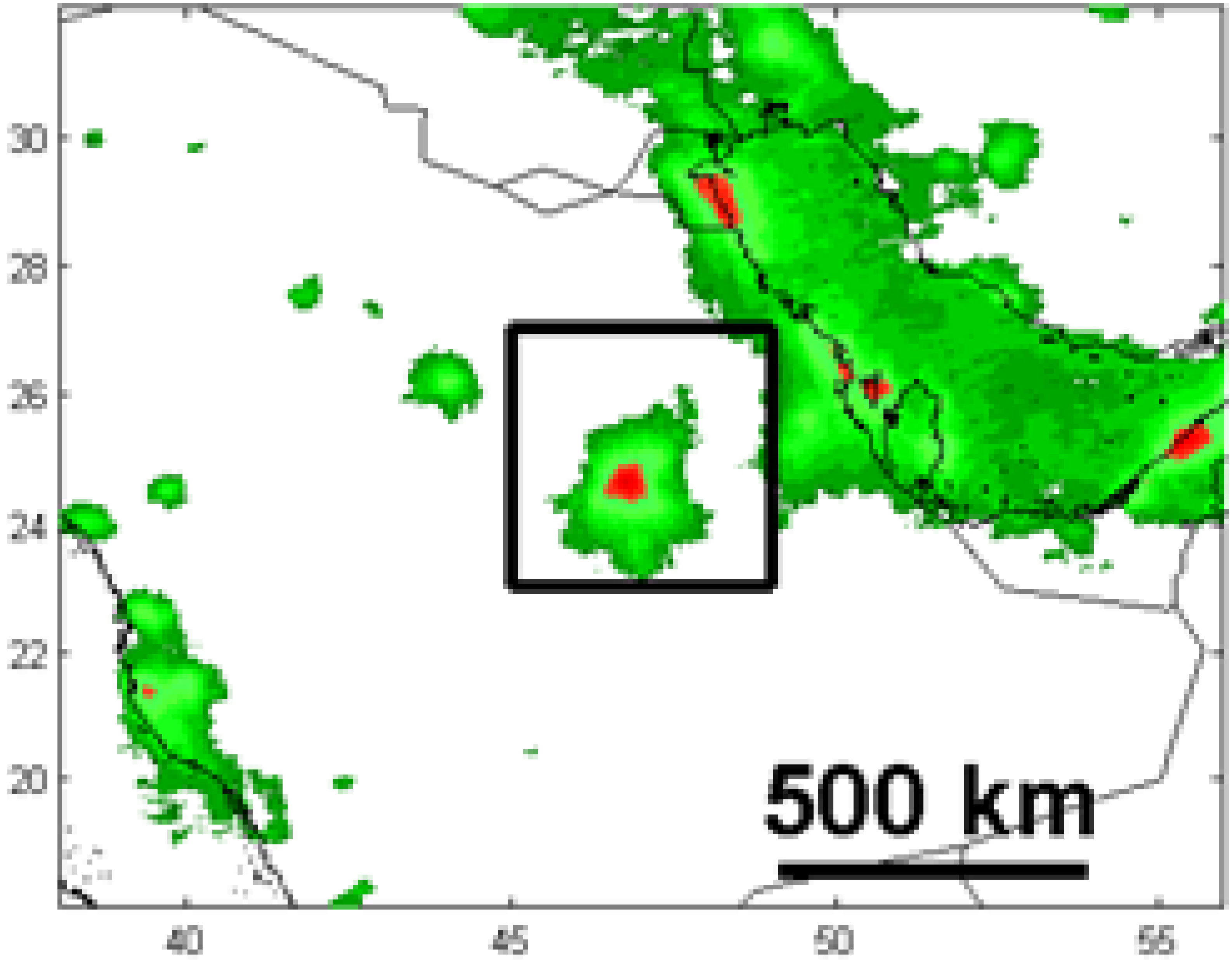
L Valin et al., *GRL* **2013**

Model NO_x lifetime vs. wind speed.



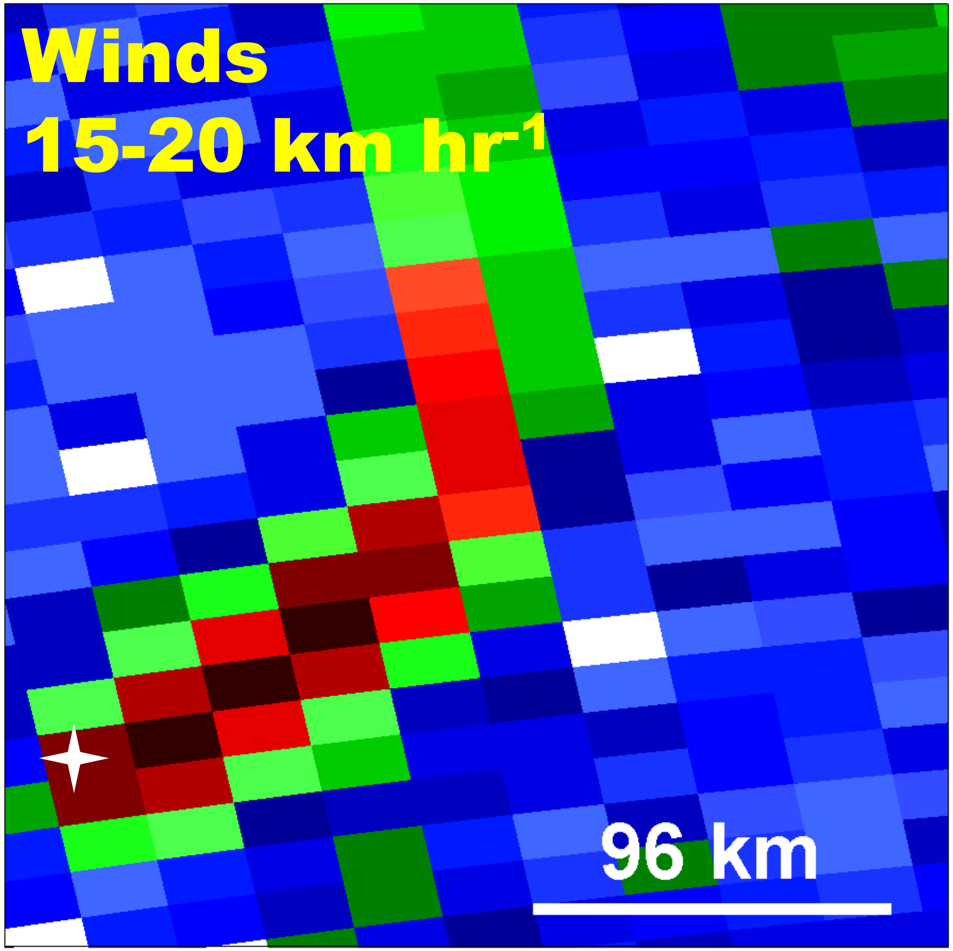
L Valin et al., *GRL* **2013**

Riyadh



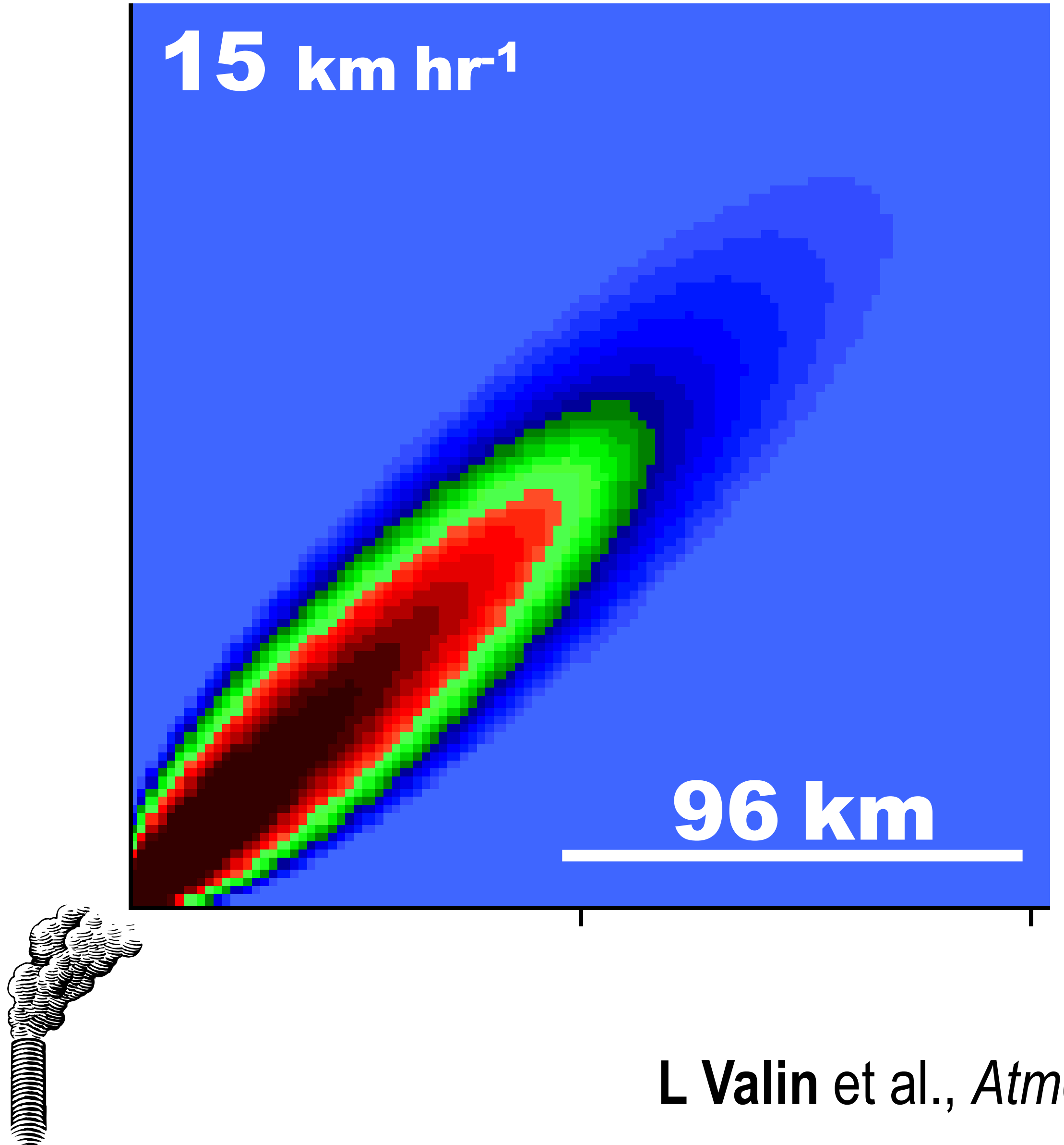
Riyadh urban plume (OMI)

Riyadh



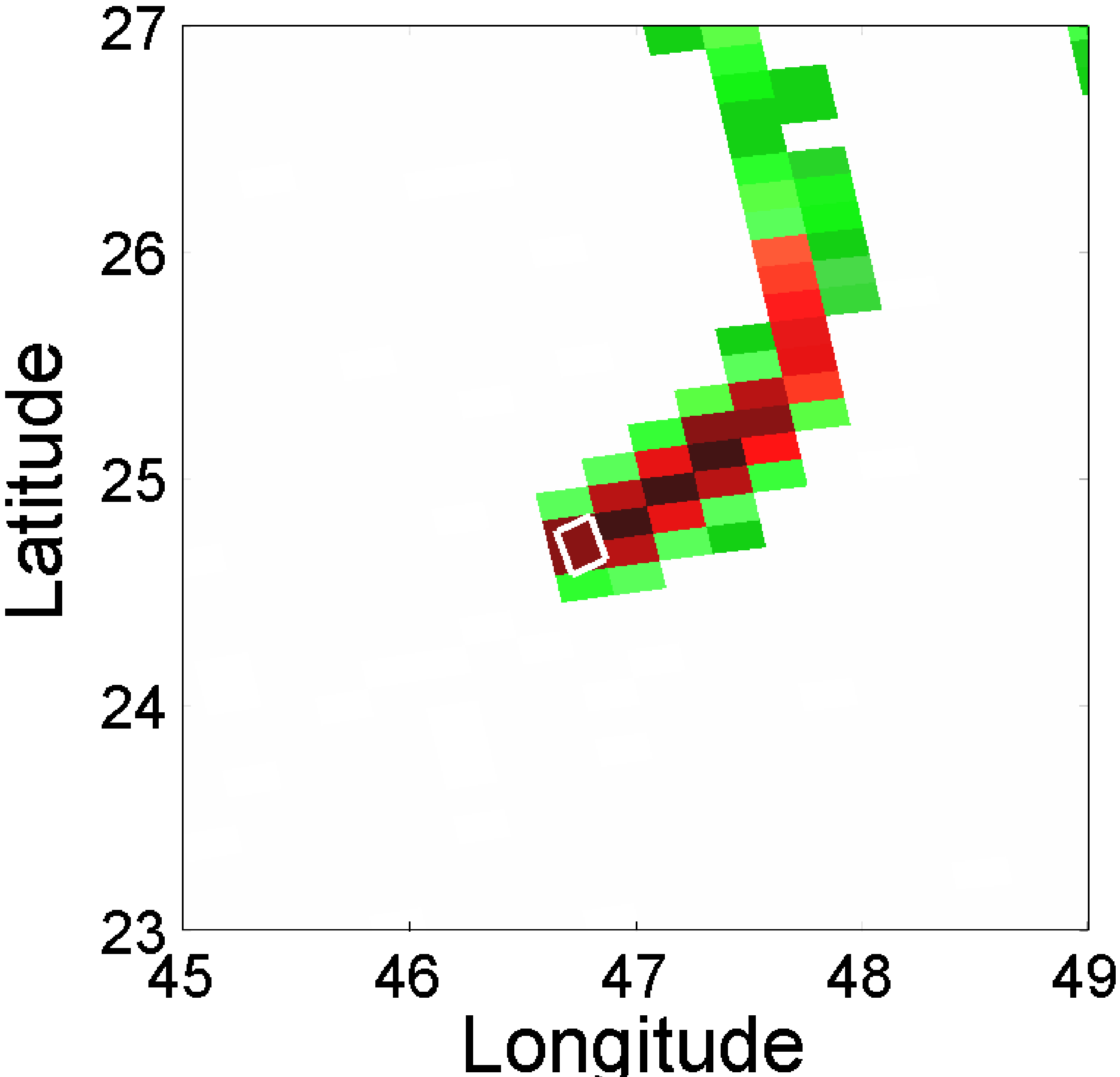
L **Valin** et al., *GRL* **2013**

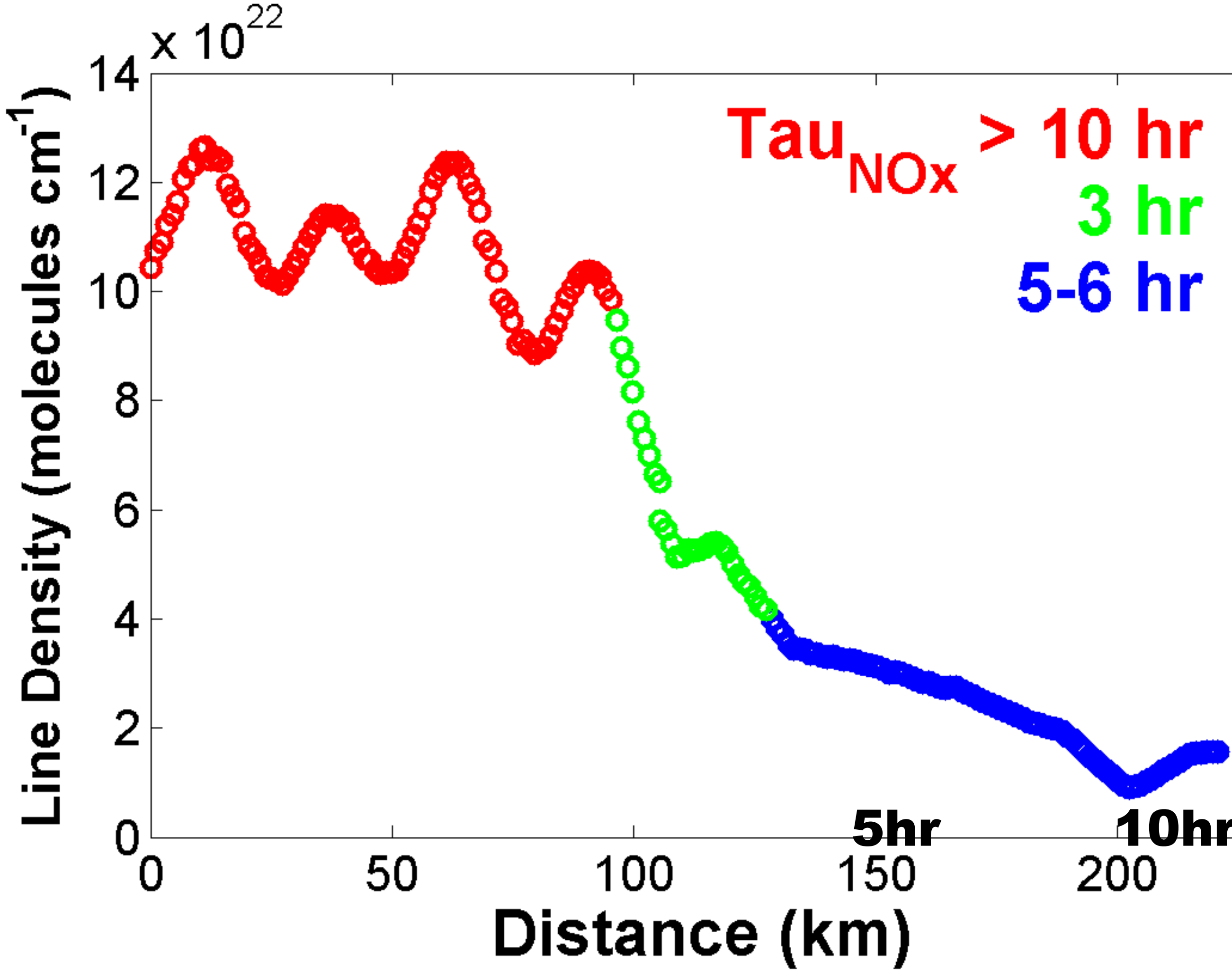
A model plume



L Valin et al., *Atmos. Chem. Phys.* **2011**

L Valin et al., *GRL* **2013**

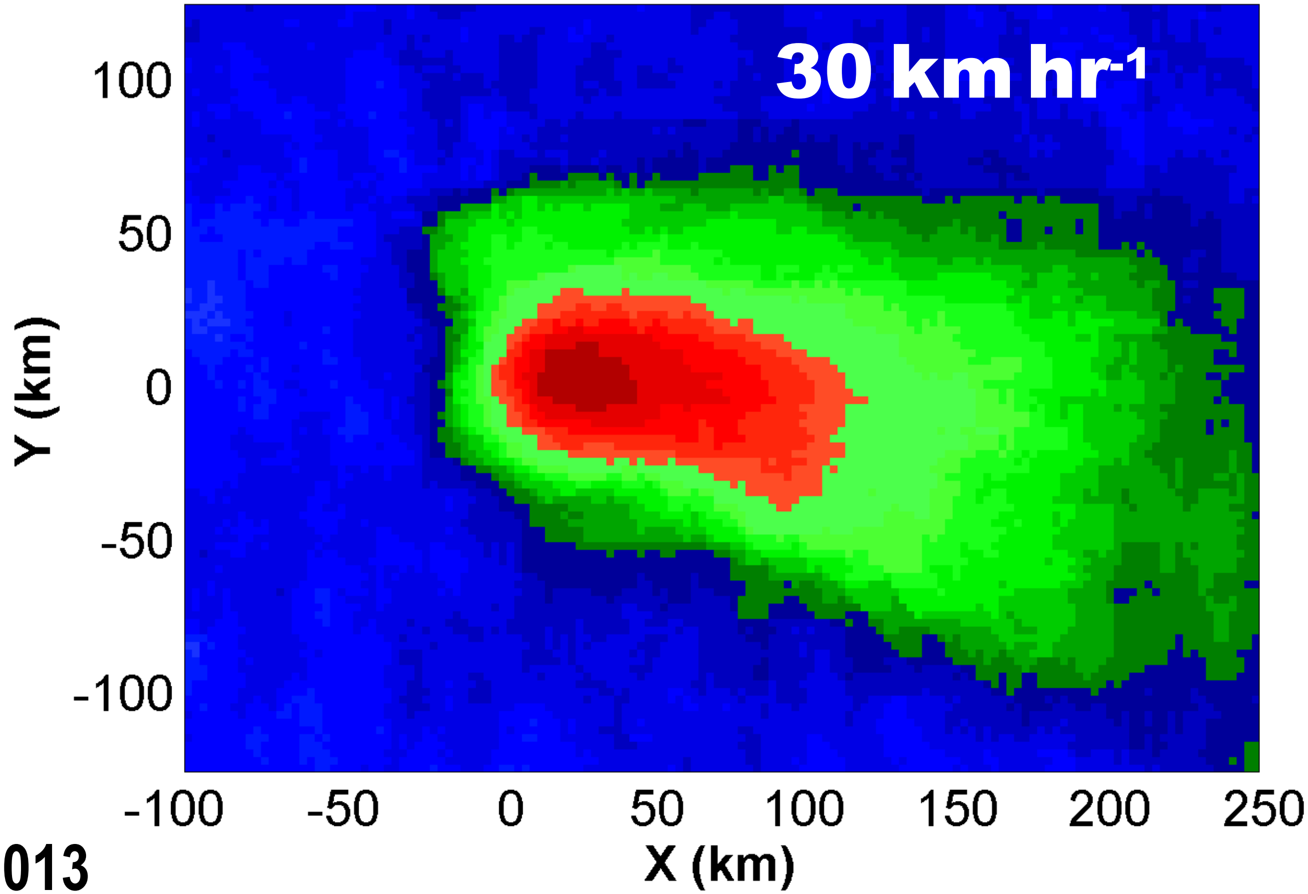




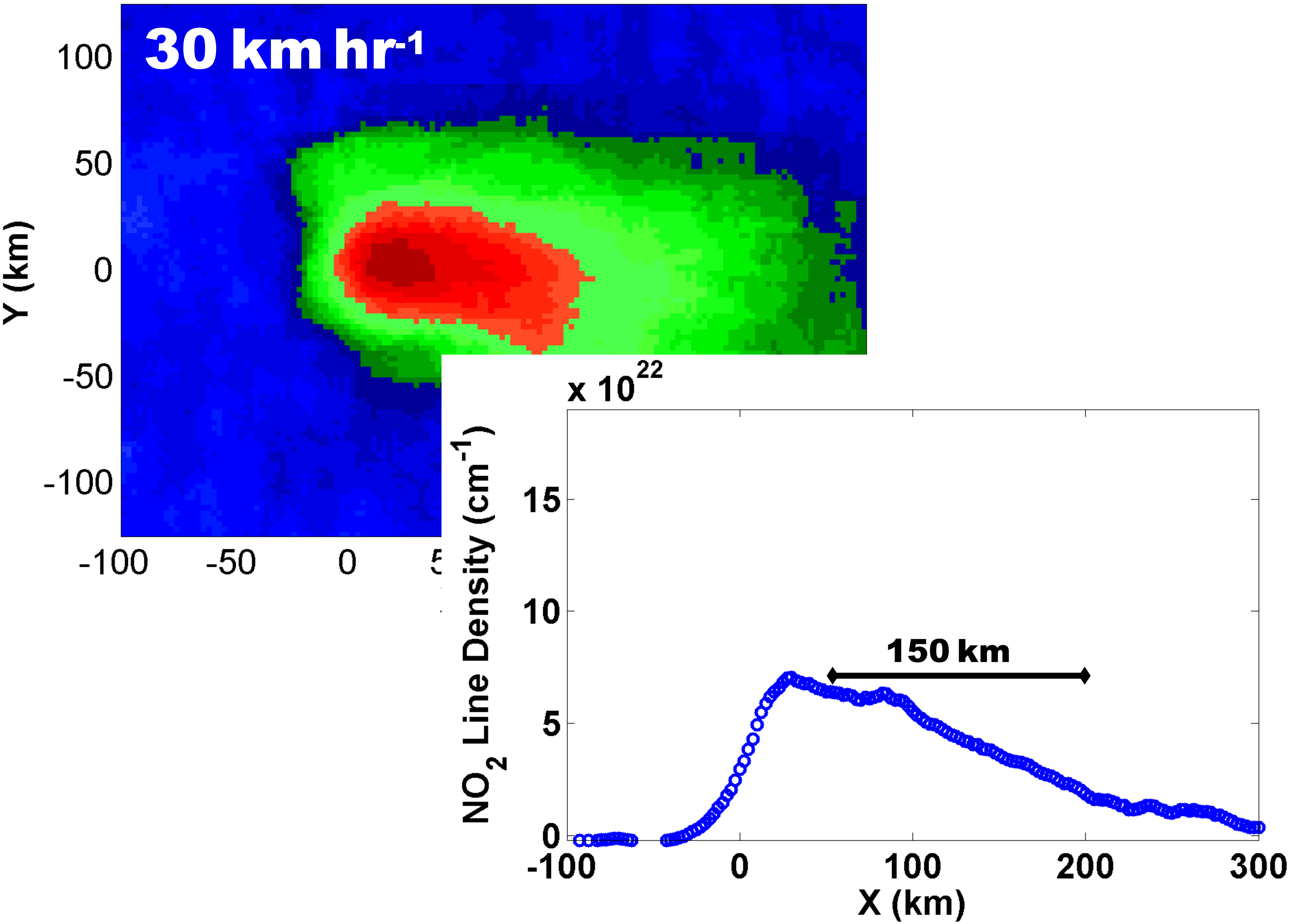
L Valin et al., *GRL* **2013**

Rotate winds to x direction
(see also Beirle et al. Science, 2011)

Sort by wind speed

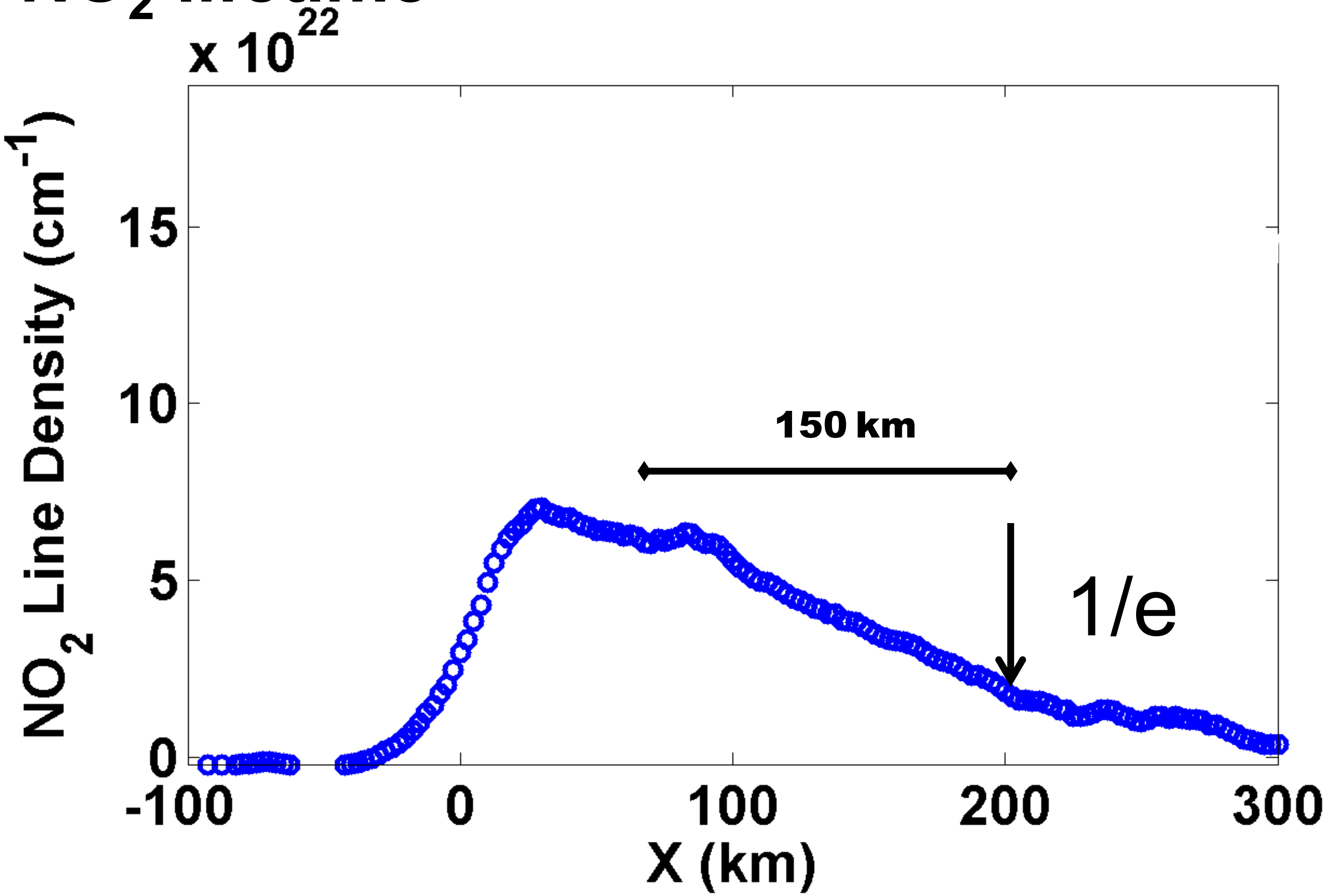


L Valin et al., *GRL* **2013**

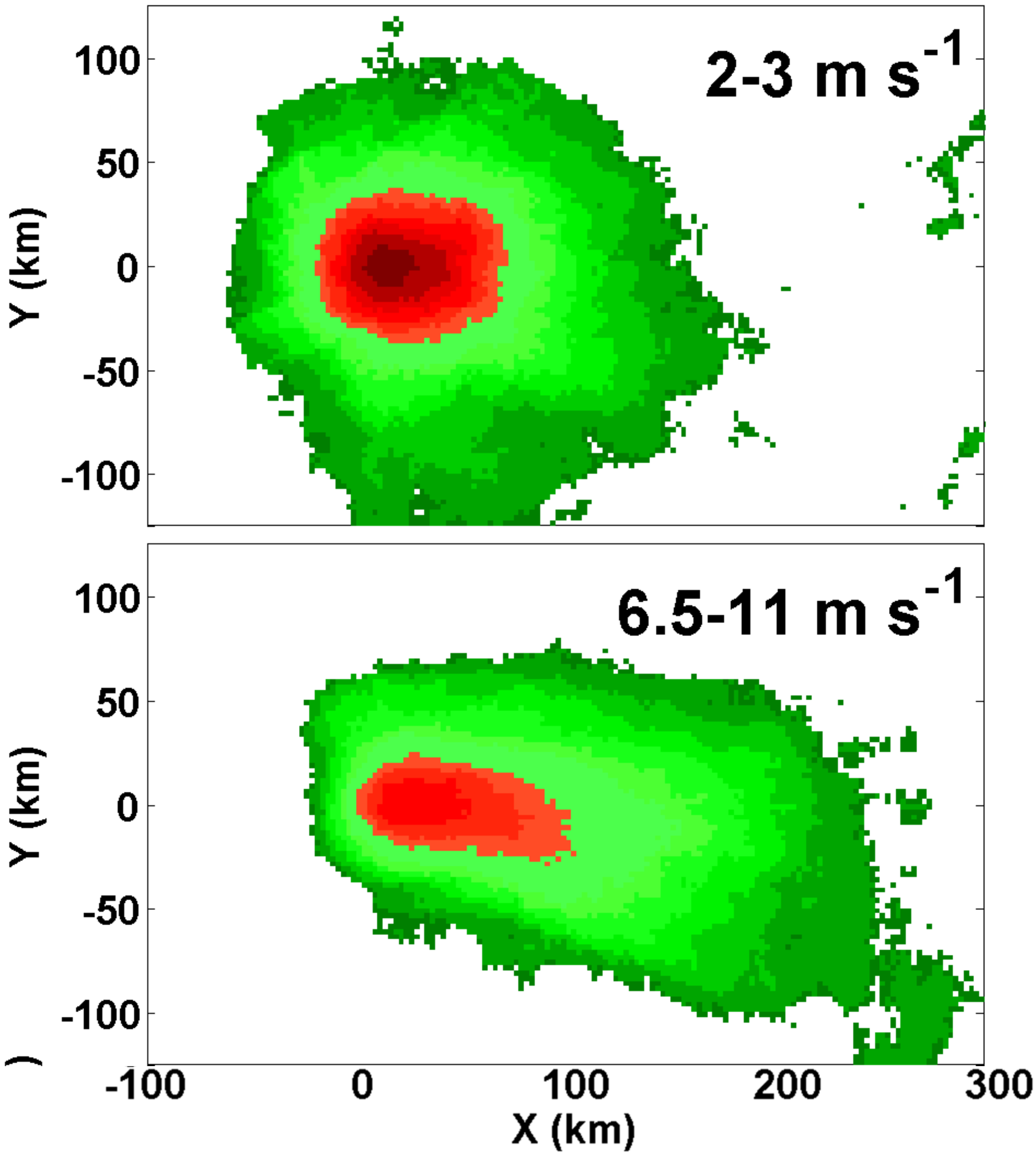


L Valin et al., *GRL 2013*

The NO_2 lifetime

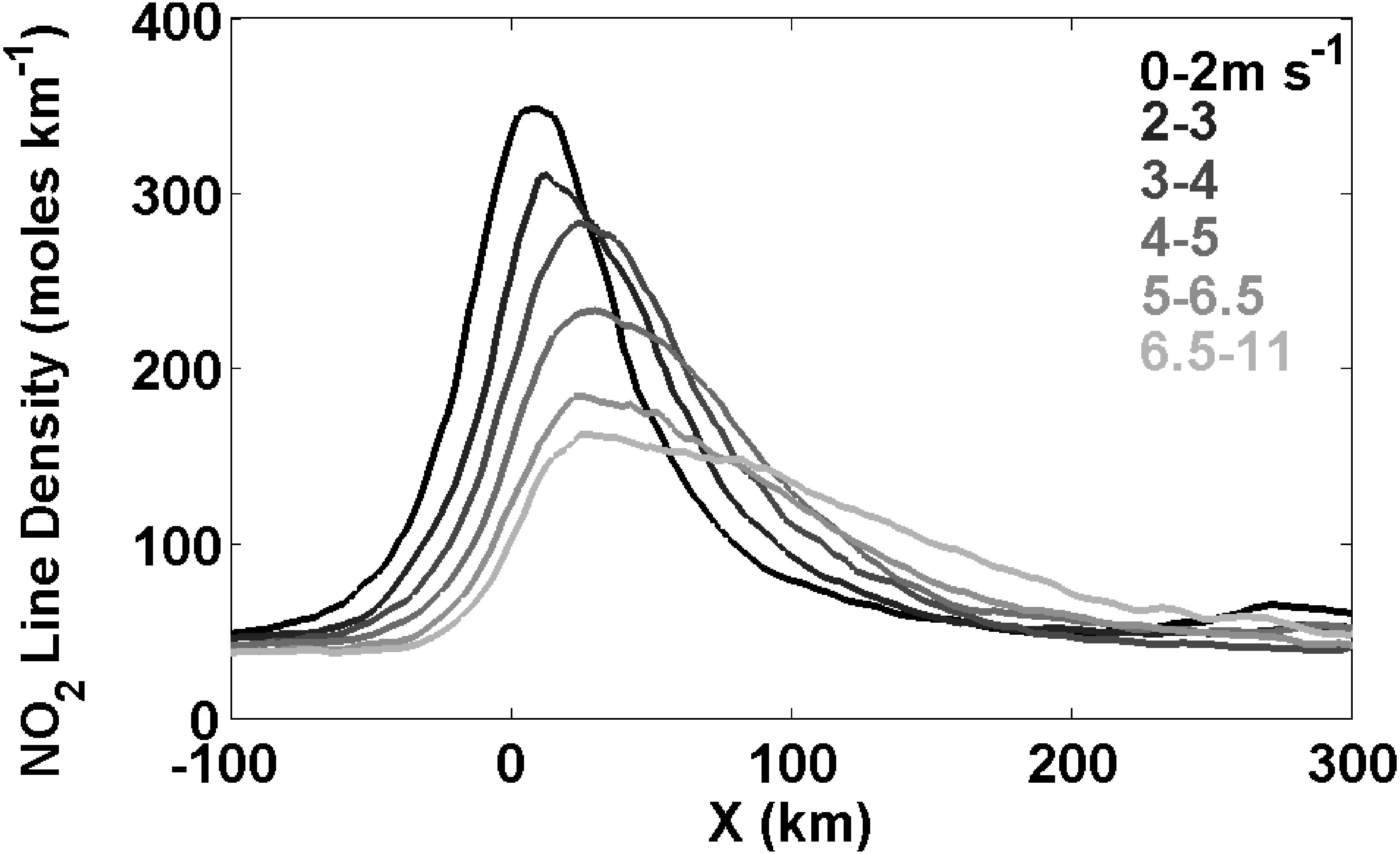


L Valin et al., *GRL 2013*



2-3 m s-1
6.5-11 m s-1
Y (km)
Y (km)
100
50
0
-50
-100
-100
0
100
200
300
X (km)

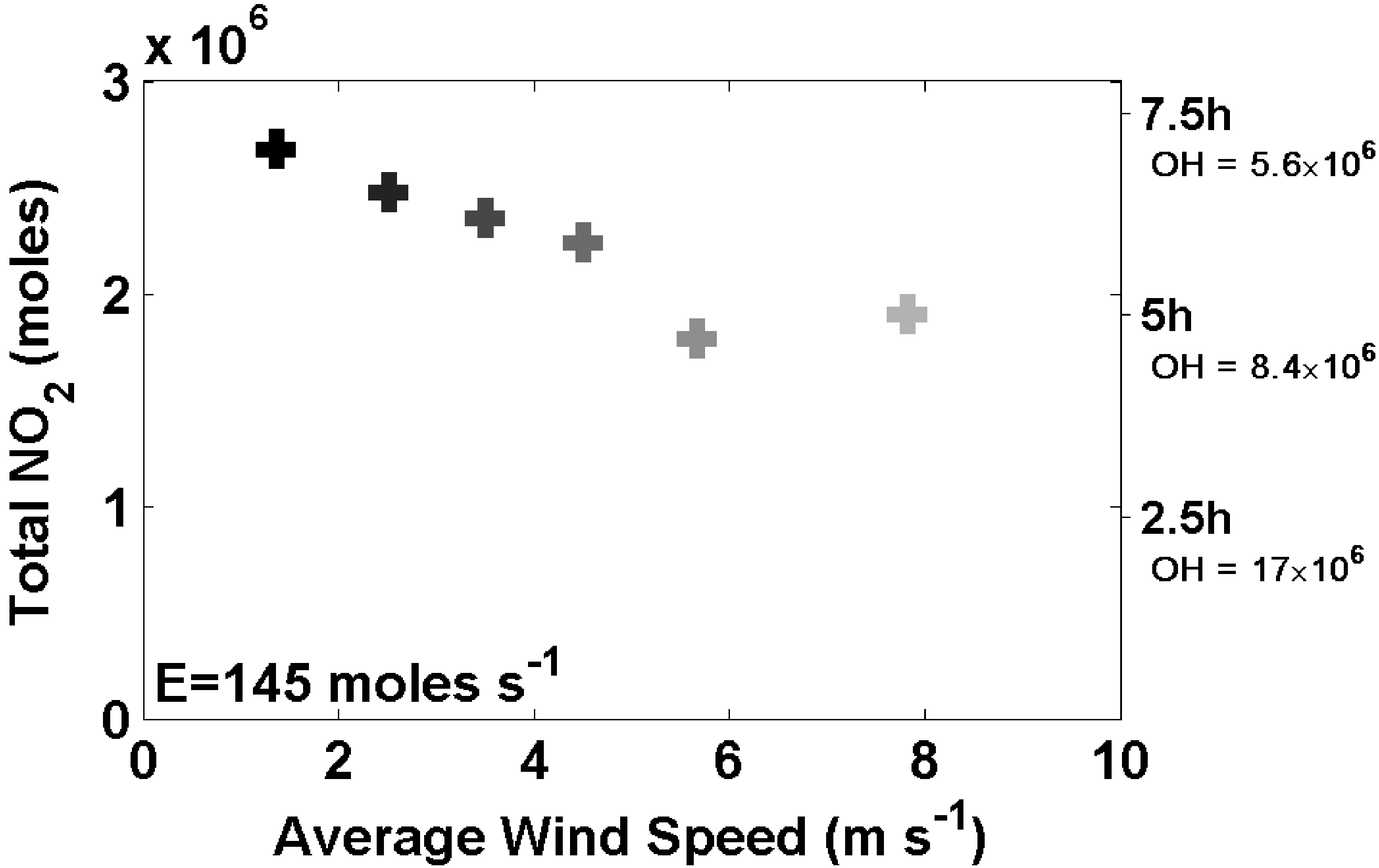
Integral perpendicular to wind



L Valin et al., *GRL* **2013**

Integral of the entire plume

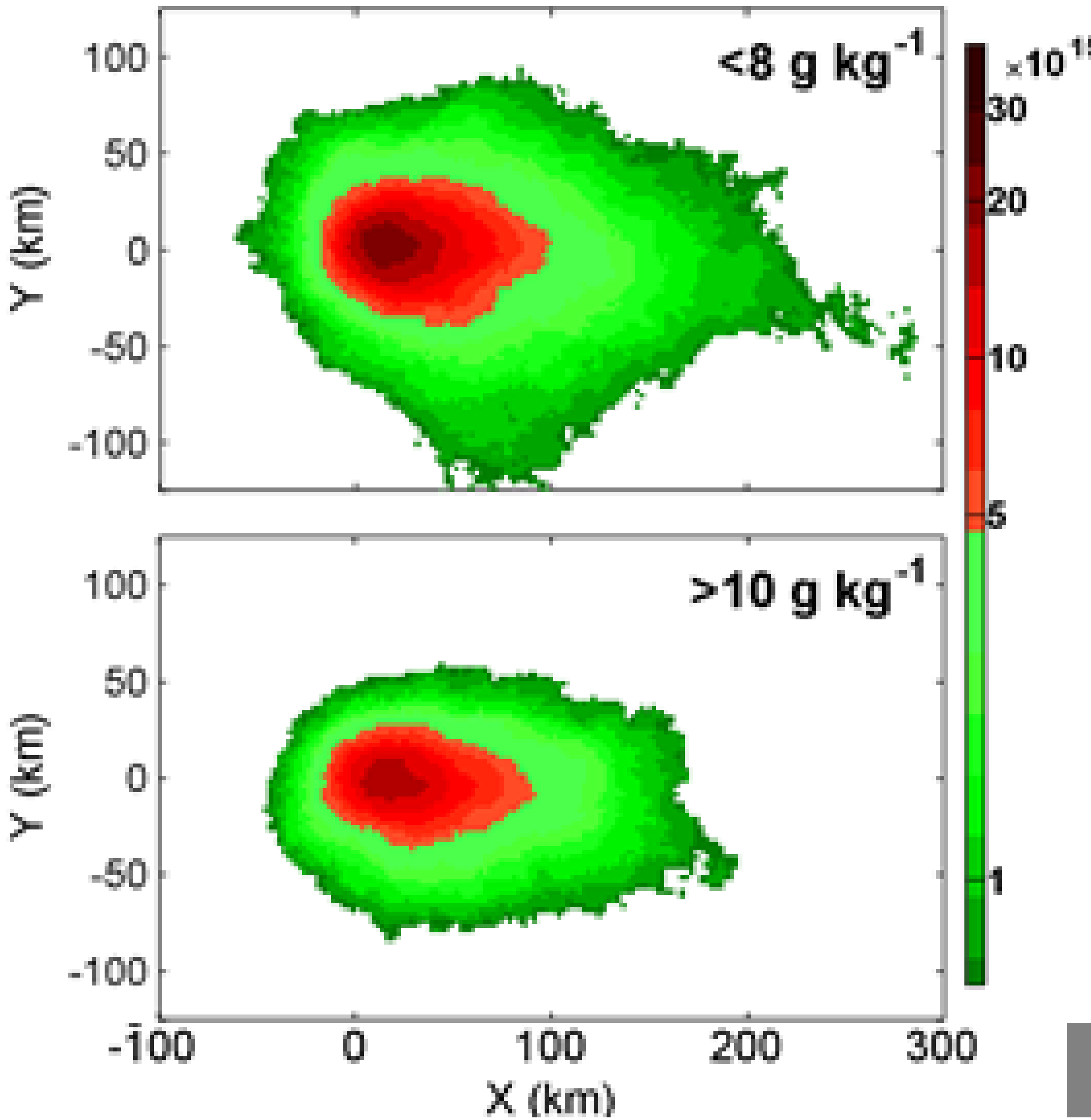
NOx lifetime and $OH_{effective}$



L Valin et al., *GRL* **2013**

The same ideas hold true for variations in H_2O—the source of the OH

H_2O

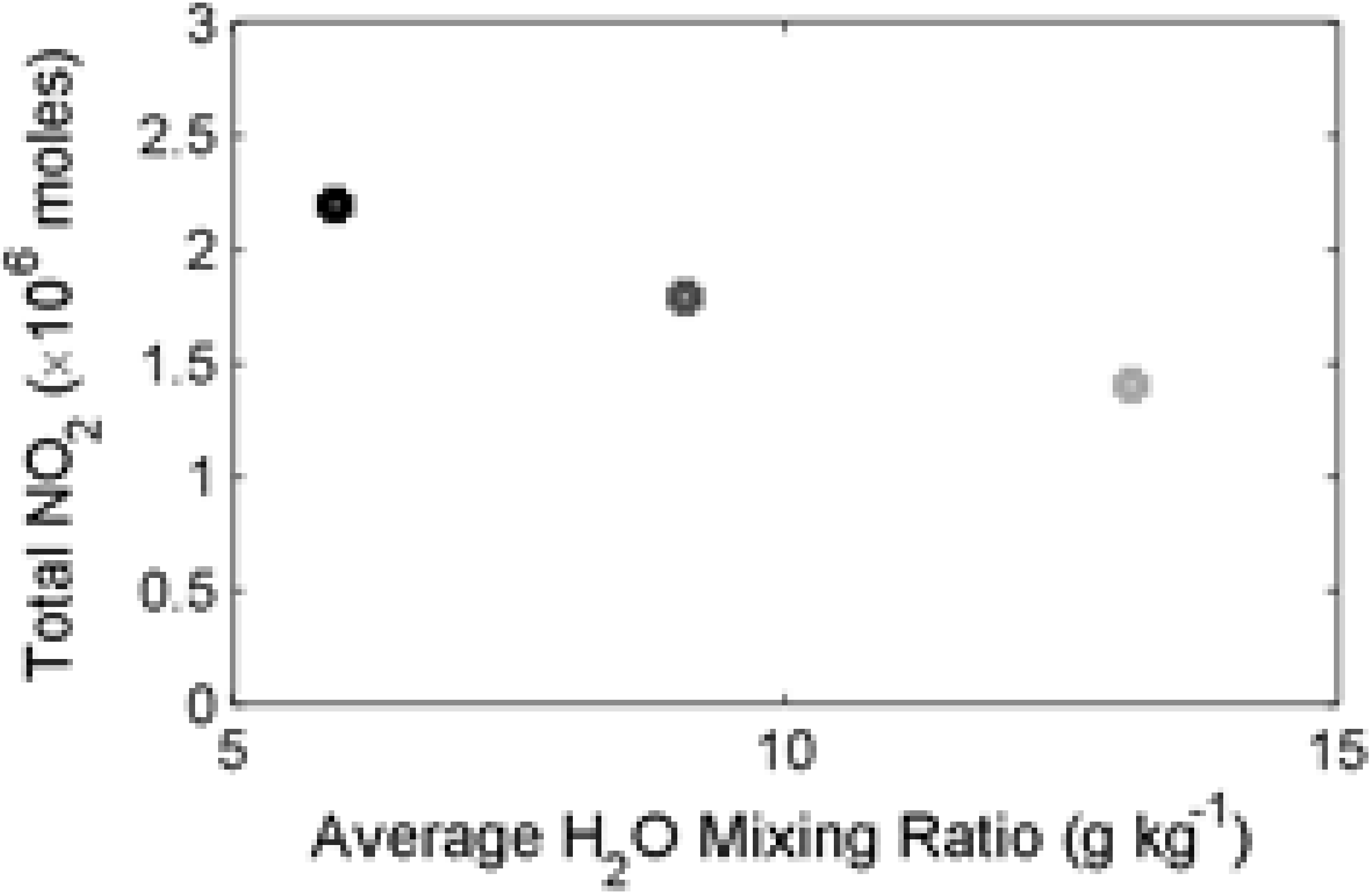


<8 g kg⁻¹
>10 g kg⁻¹
Y (km)
X (km)
100
50
0
-50
-100
-100
0
100
200
300
×10¹⁵
30
20
10
5
1

H_2O

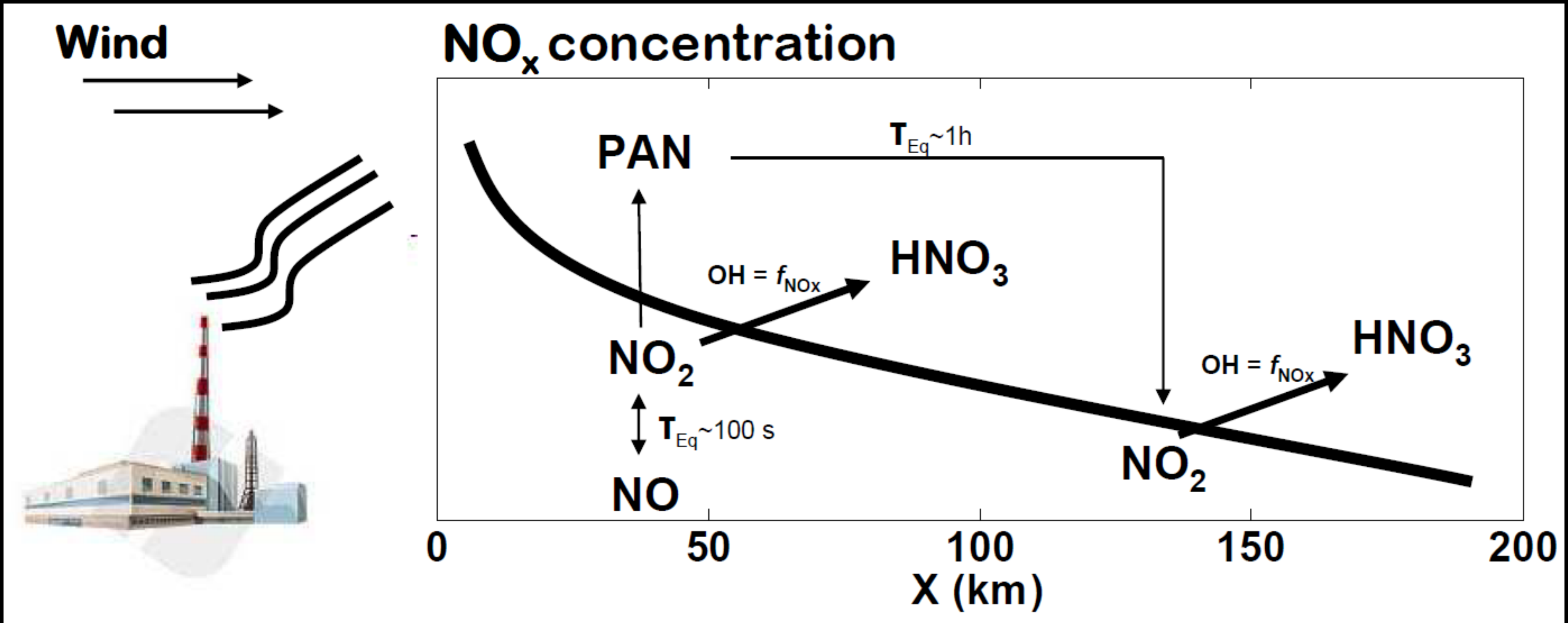
lifetime

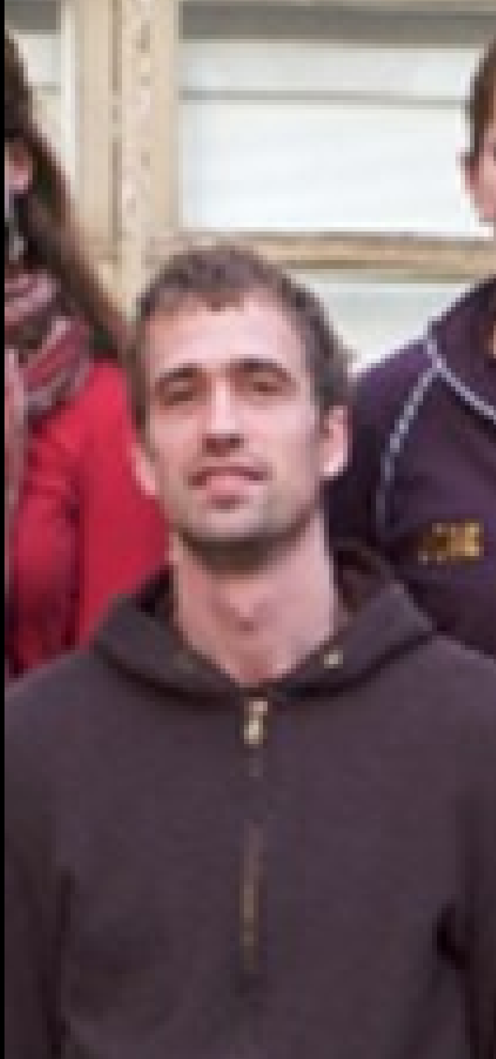
shorter ← longer



Conclusions:

TEMPO, GEOCAPE, TROPOMI, …





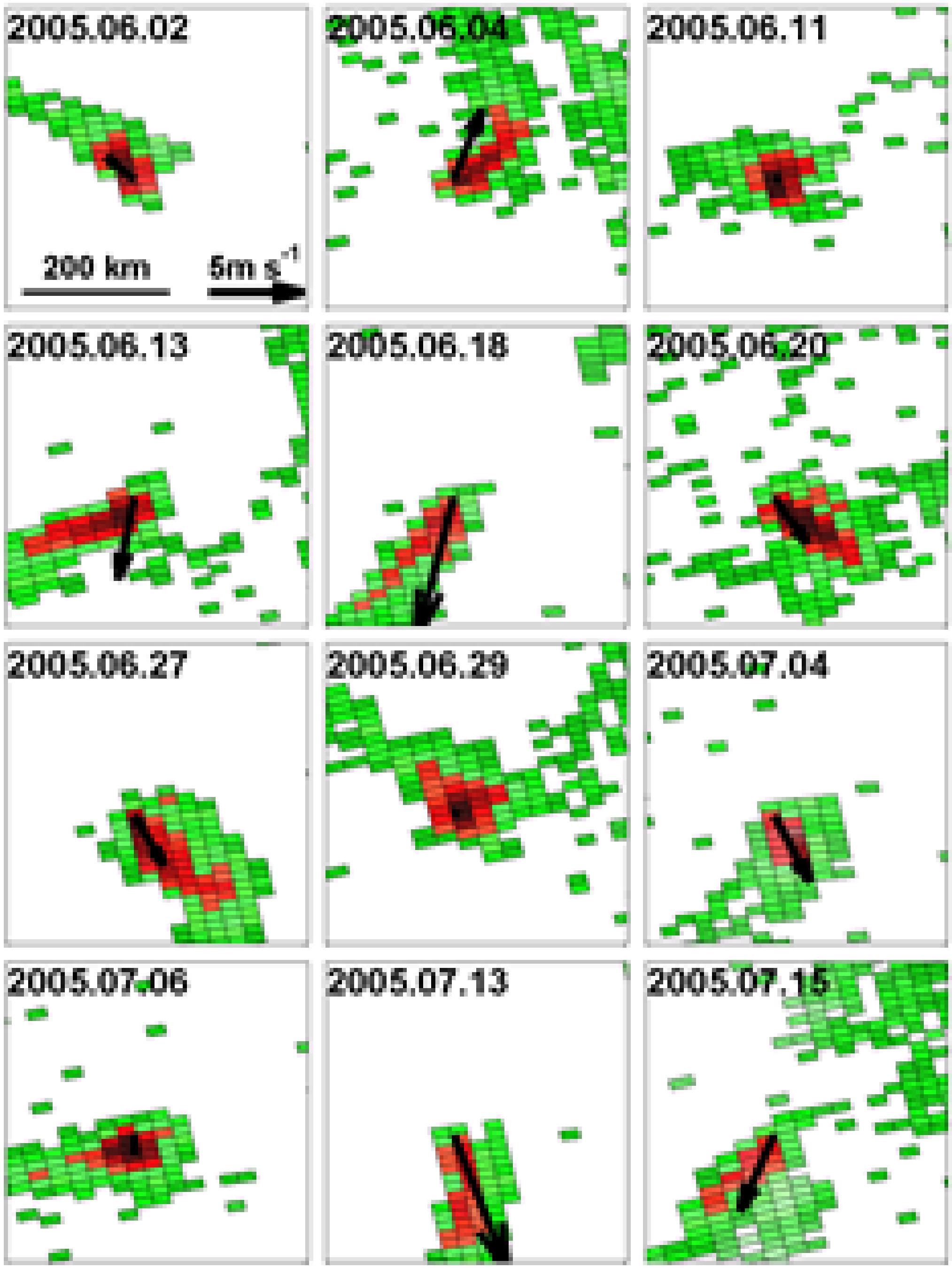
Thank you

Luke Valin
PhD November 2012

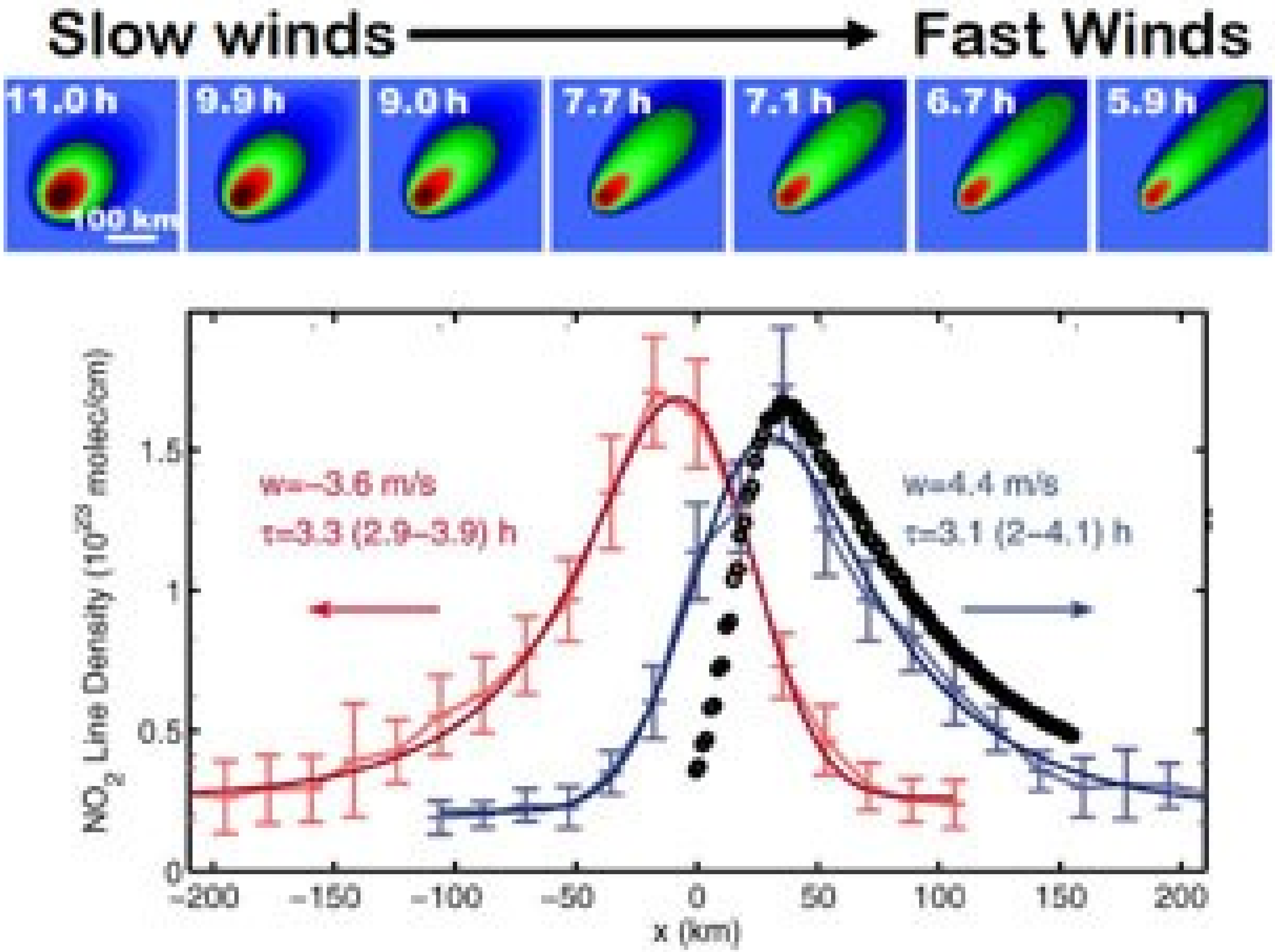
$$ NASA

Thank you

Riyadh



L Valin et al., *GRL* **2013**



Slow winds
Fast Winds
11.0 h
9.9 h
9.0 h
7.7 h
7.1 h
6.7 h
5.9 h
100 km
w=−3.6 m/s
τ=3.3 (2.9–3.9) h
w=4.4 m/s
τ=3.1 (2–4.1) h
NO2 Line Density (10^23 molec/cm)
x (km)
0
0.5
1
1.5
−200
−150
−100
−50
0
50
100
150
200

Steep nonlinear relationships between NO_2 and OH and the associated direct ($OH + NO_2$) and indirect ($OH + VOC + NO_2 \rightarrow PAN$) have the result that

$$<[NO_2]><[OH]> \neq <[NO_2][OH]>$$

Ashley Russell
PhD May 2012
Now at Sonoma Technologies

τ = 150 km / 30 km hr^{-1} = 5.0 hours

→ $OH_{effective} = 8.4\times10^{6}\ cm^{-3}$

→ Emission rate = 145 mole s^{-1}