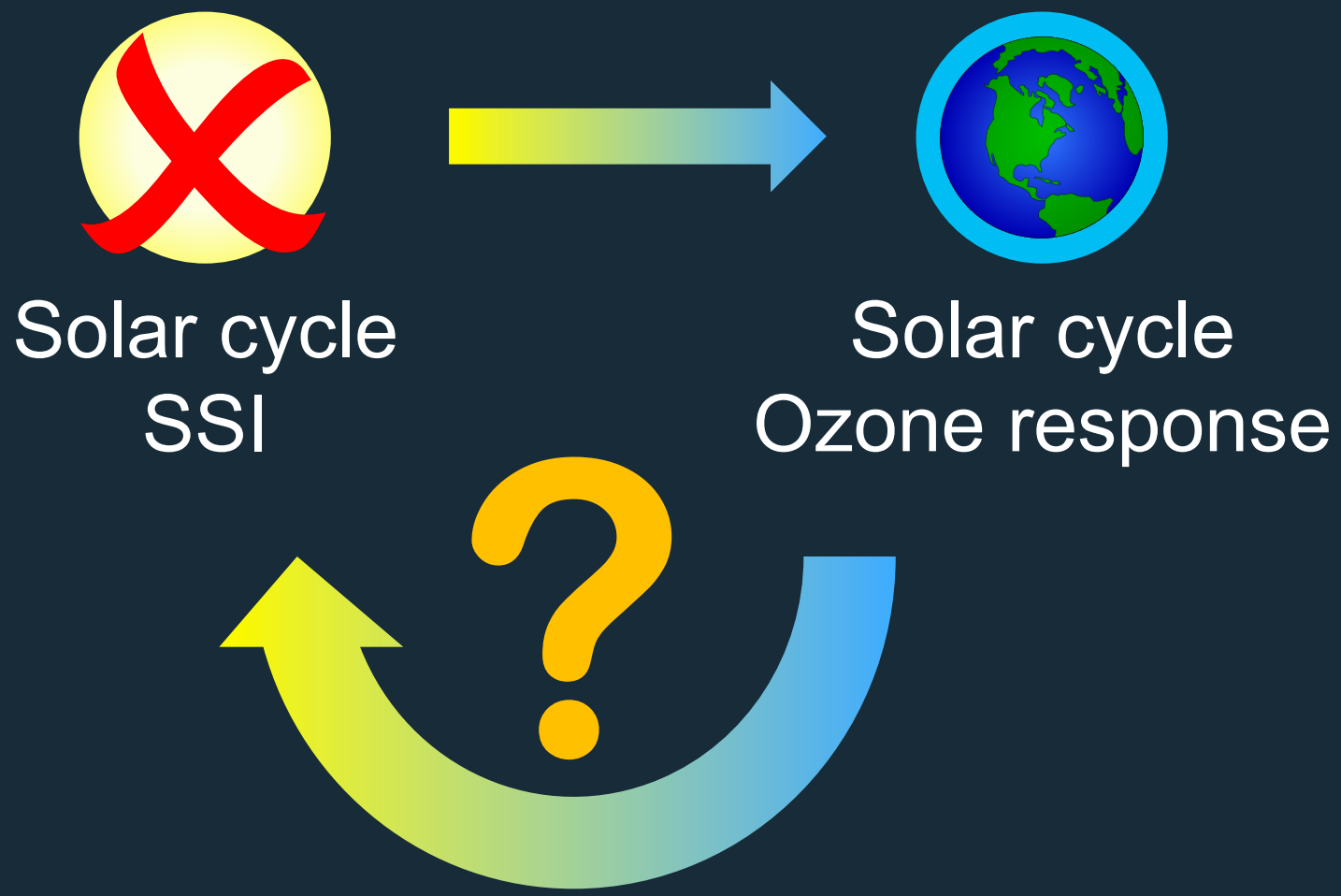
SSI and Stratospheric Ozone:

A new assessment of the relationship using Bayesian Inference

Will Ball
Department of Physics, Imperial College London
Joanna D. Haigh, Daniel Mortlock, Yvonne Unruh, Jack Egerton (Imperial)
Natasha Krivova, Sami Solanki (MPS)


Solar cycle
SSI
Solar cycle
Ozone response

The problem

> solar cycle SSI changes

The background

> how do changes affect our atmosphere?

The uncertain solution

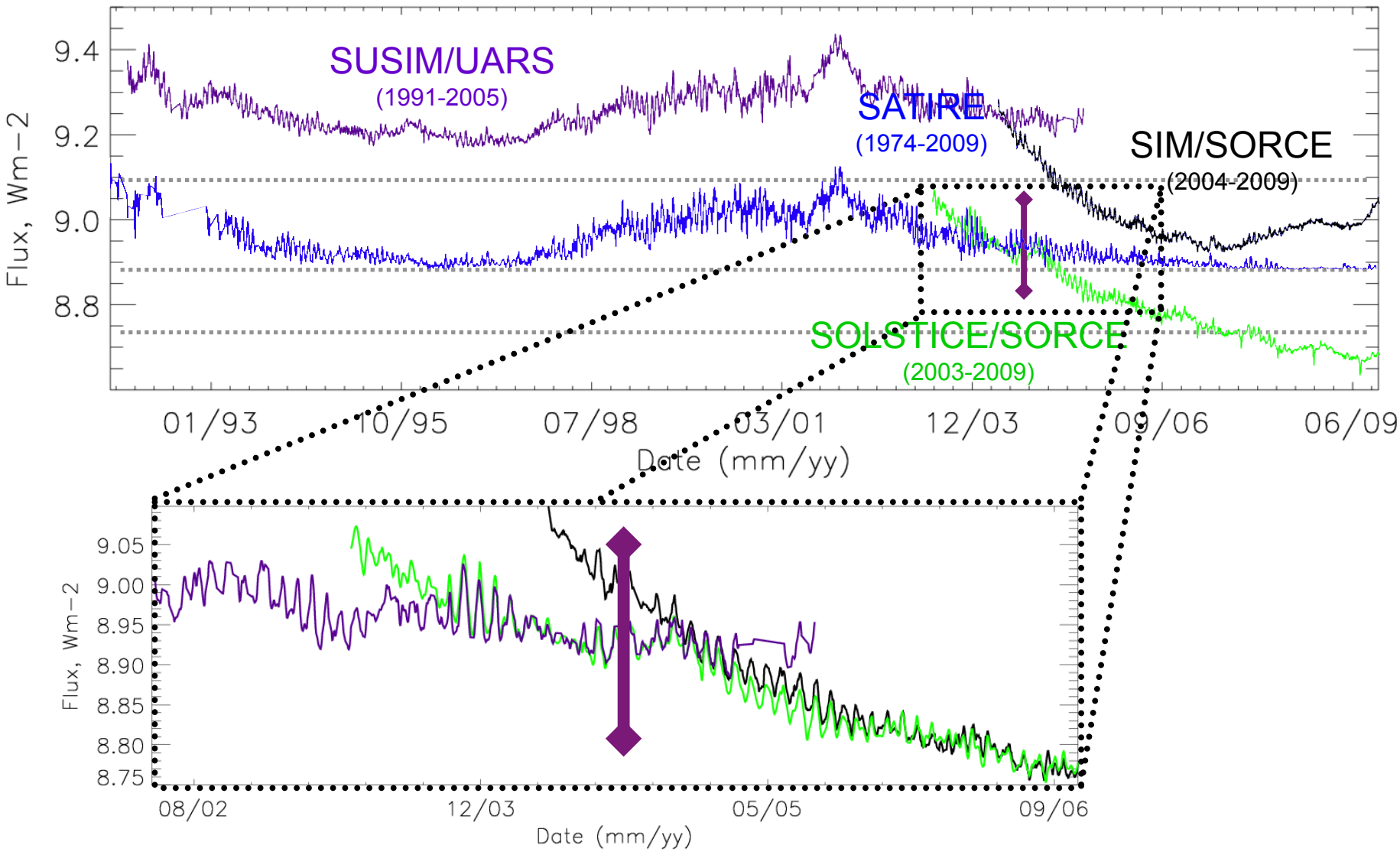
> single profile comparison

> considering knowledge and uncertainty

The problem

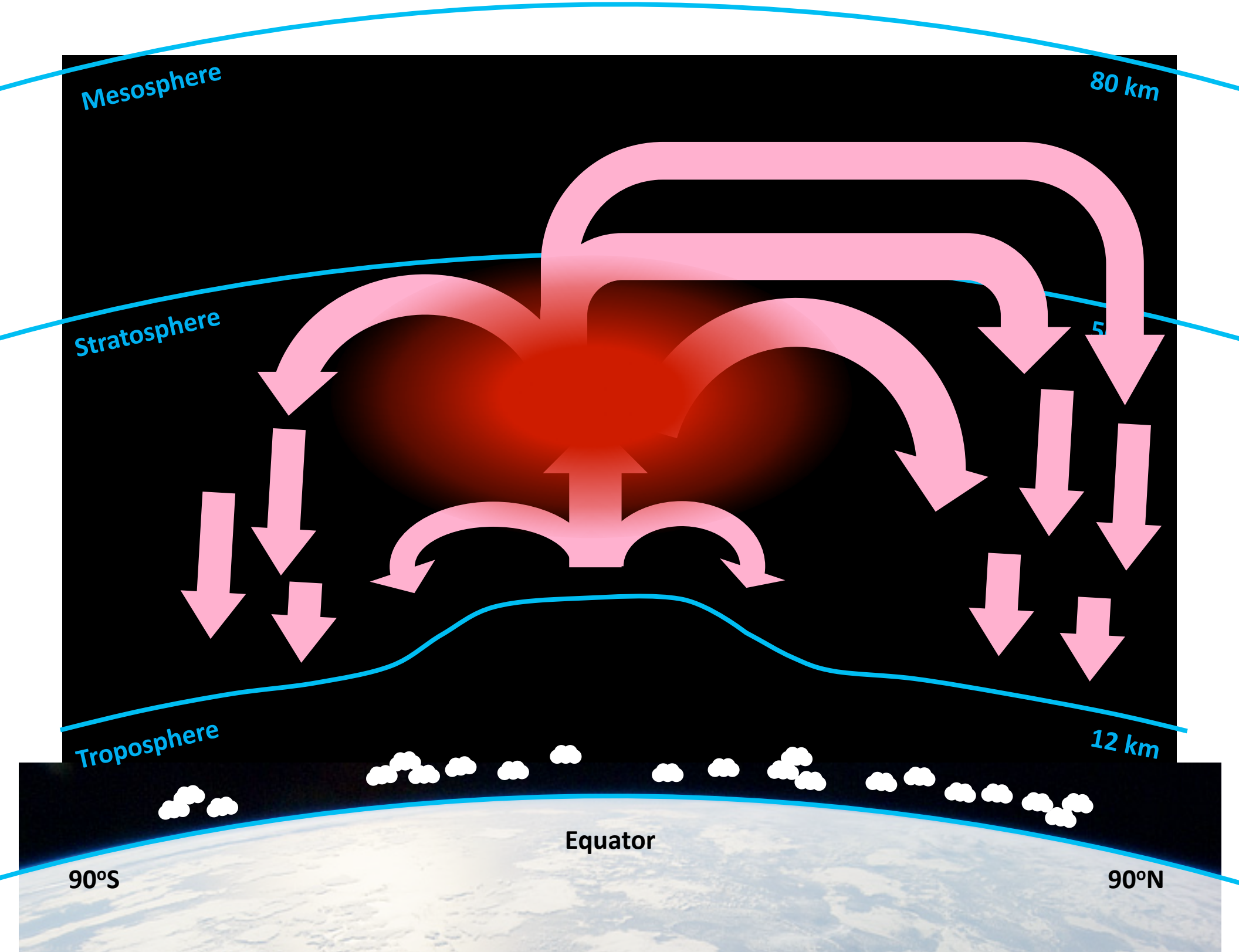
> solar cycle SSI changes

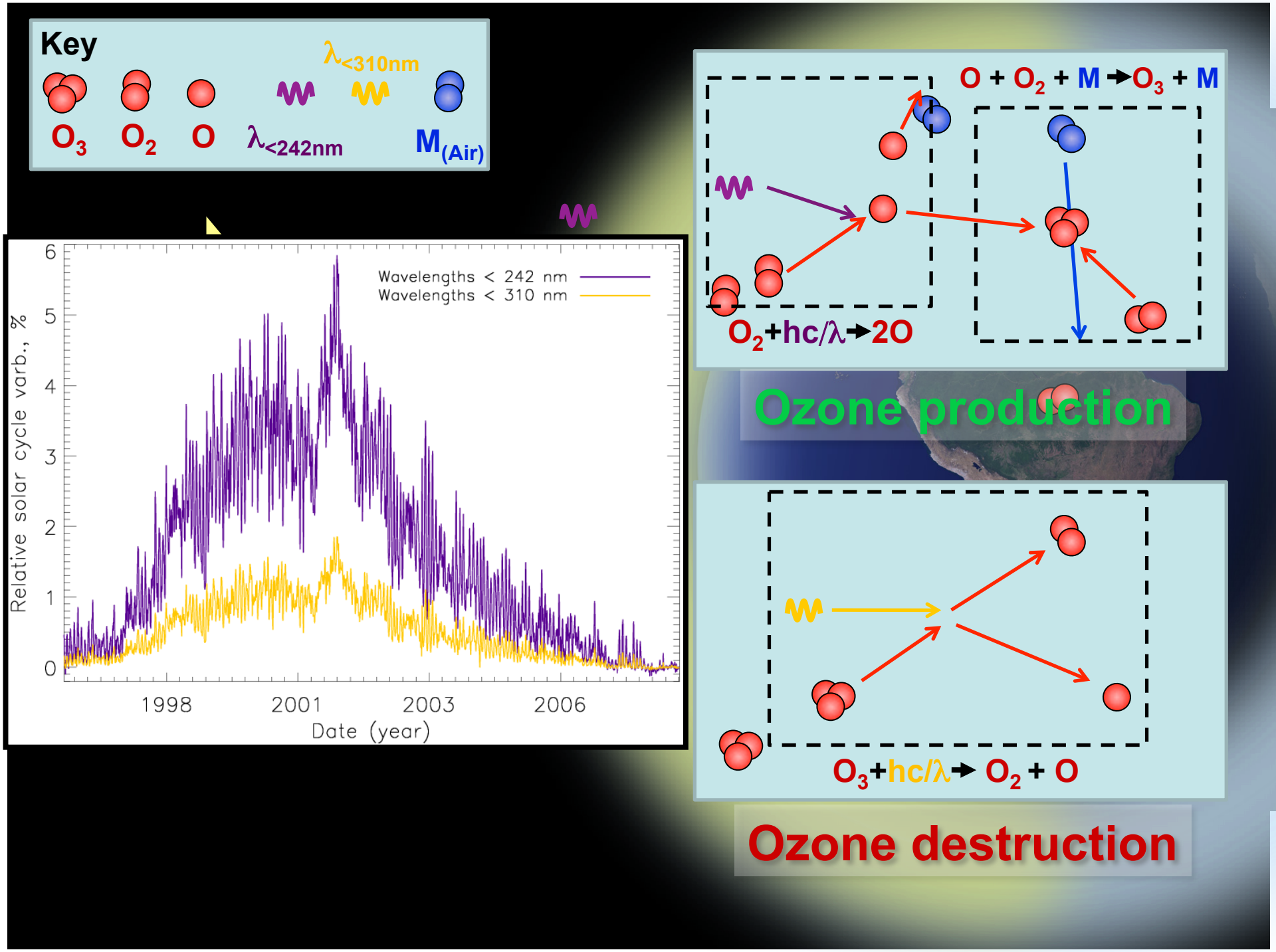
SSI: 200-300 nm



The background

> how do changes affect our atmosphere?


Mesosphere
80 km
Stratosphere
Troposphere
12 km
Equator
90ºS
90ºN


Key
O_3
O_2
O
$\lambda_{<242nm}$
$\lambda_{<310nm}$
$M_{(Air)}$
Wavelengths < 242 nm
Wavelengths < 310 nm
Relative solar cycle varb., %
Date (year)
1998
2001
2003
2006
$O + O_2 + M \rightarrow O_3 + M$
$O_2 + hc/\lambda \rightarrow 2O$
Ozone production
$O_3 + hc/\lambda \rightarrow O_2 + O$
Ozone destruction

176-193 nm

6%
8%
9%

193-205 nm

5%
6%
11%

205-242 nm

3%
3%
9%

242-260 nm

2%
2%
6%

260-290 nm

1.2%
0.8%
3.2%

290-310 nm

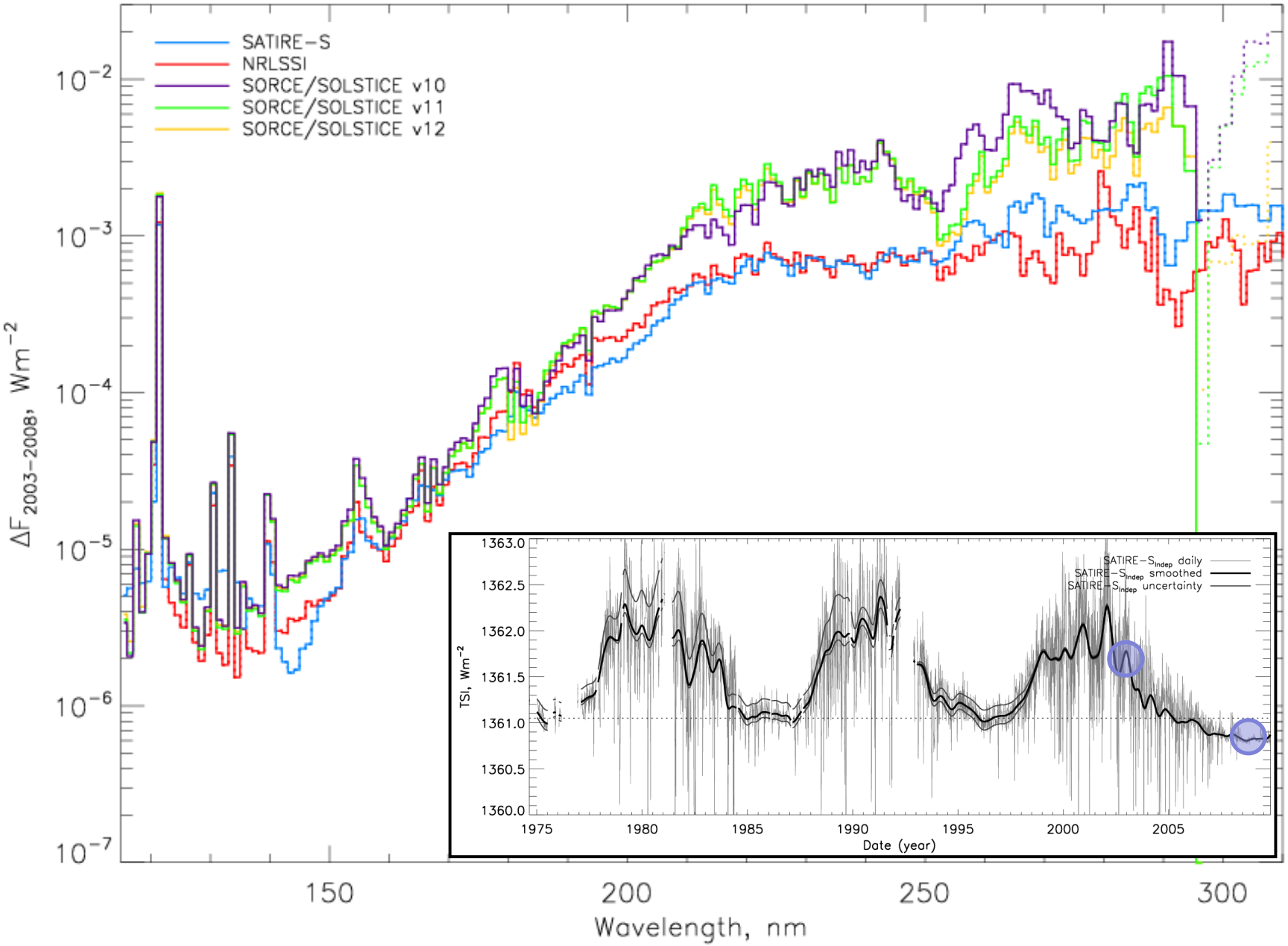
0.7%
0.5%
0.8%

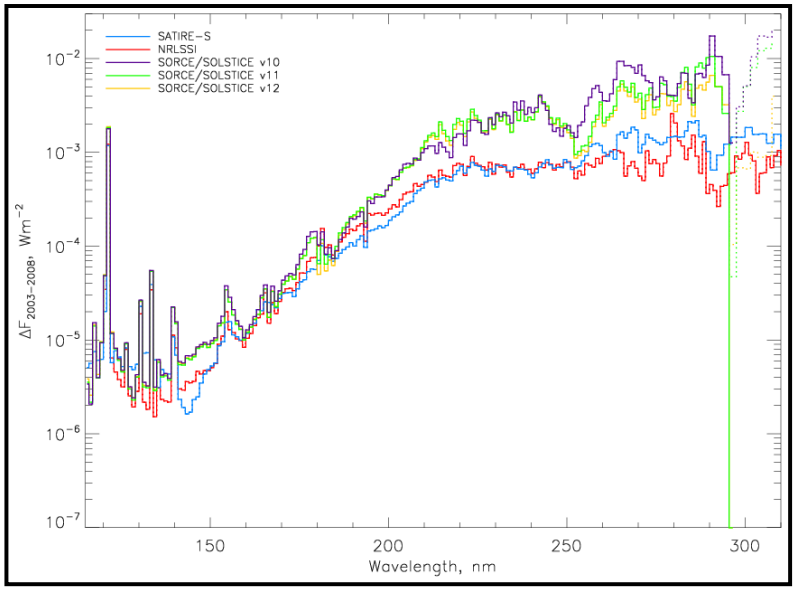
SATIRE-S Model	NRLSSI Model	SORCE/SOLSTICE Observations

The uncertain solution

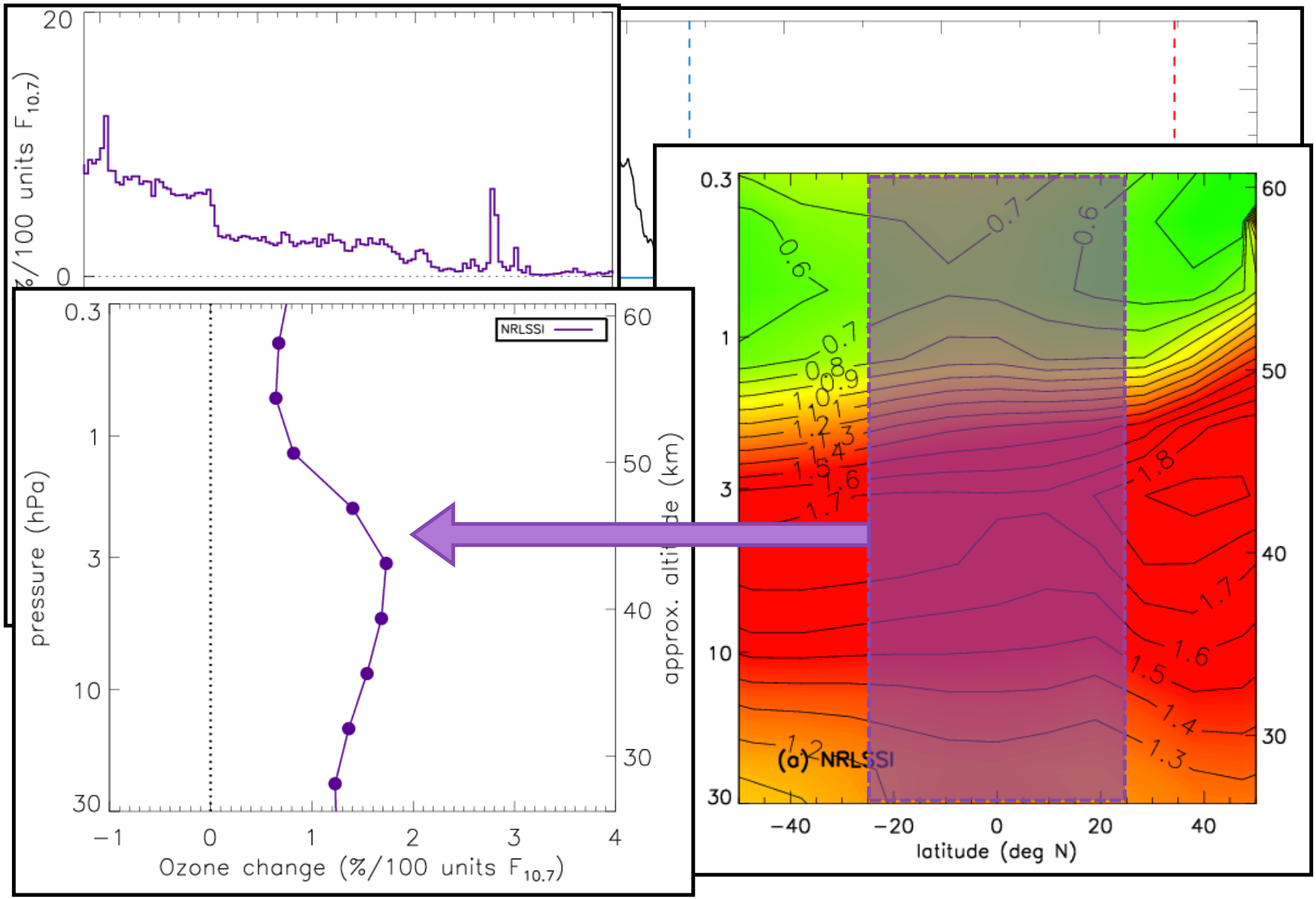
> single profile comparison

Ball et al., 2014a (in review)

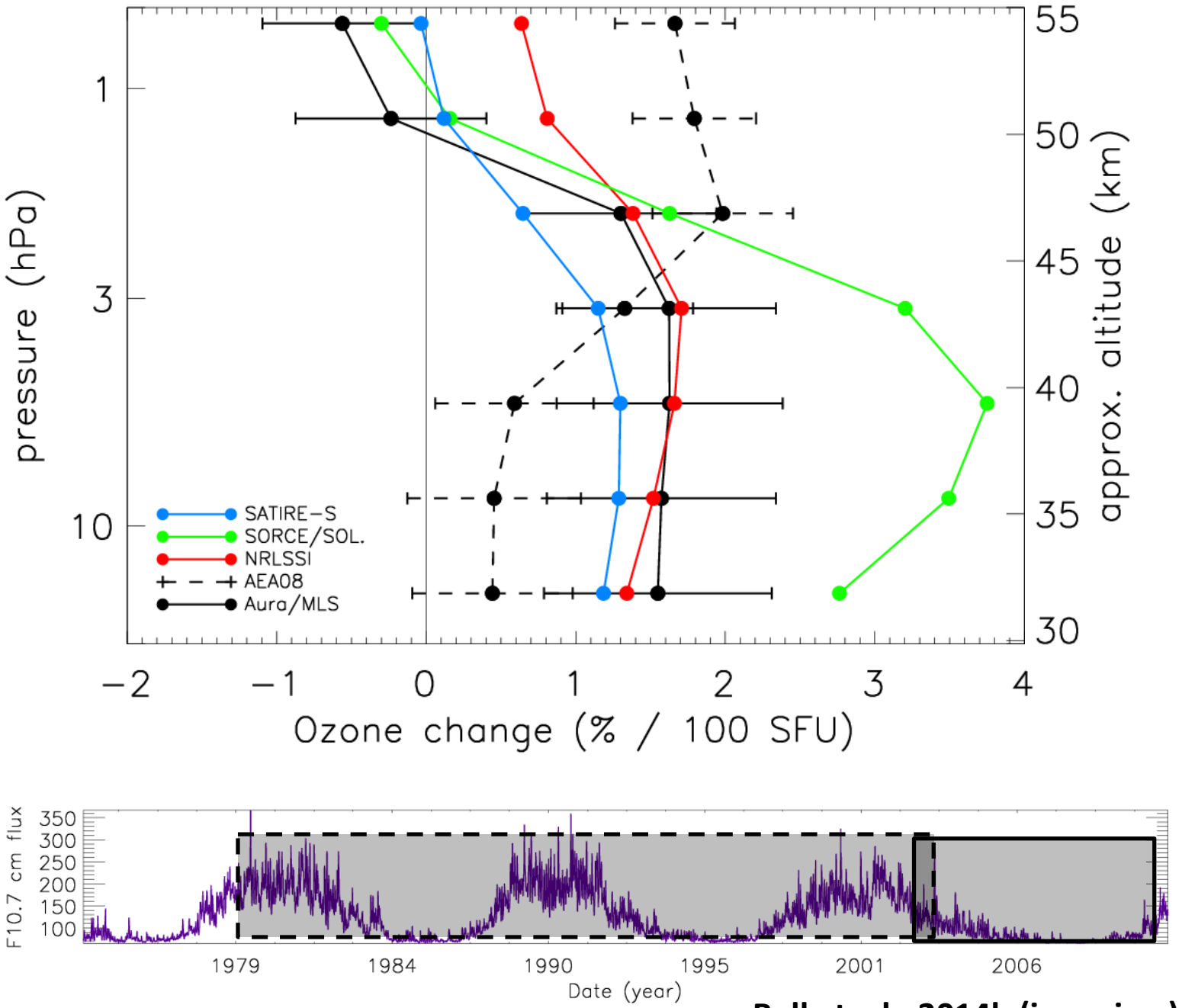




Ball et al., 2014a (in review)

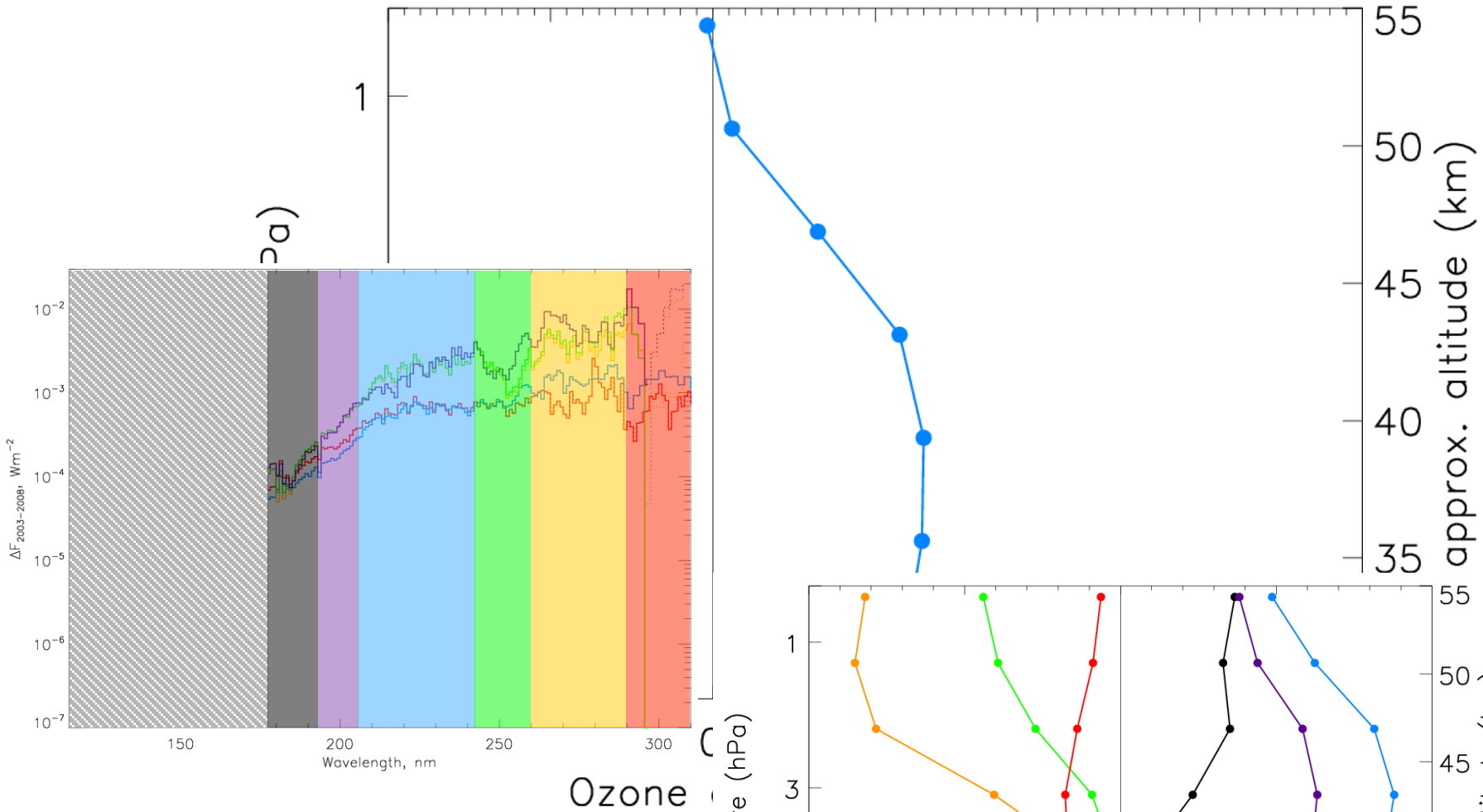


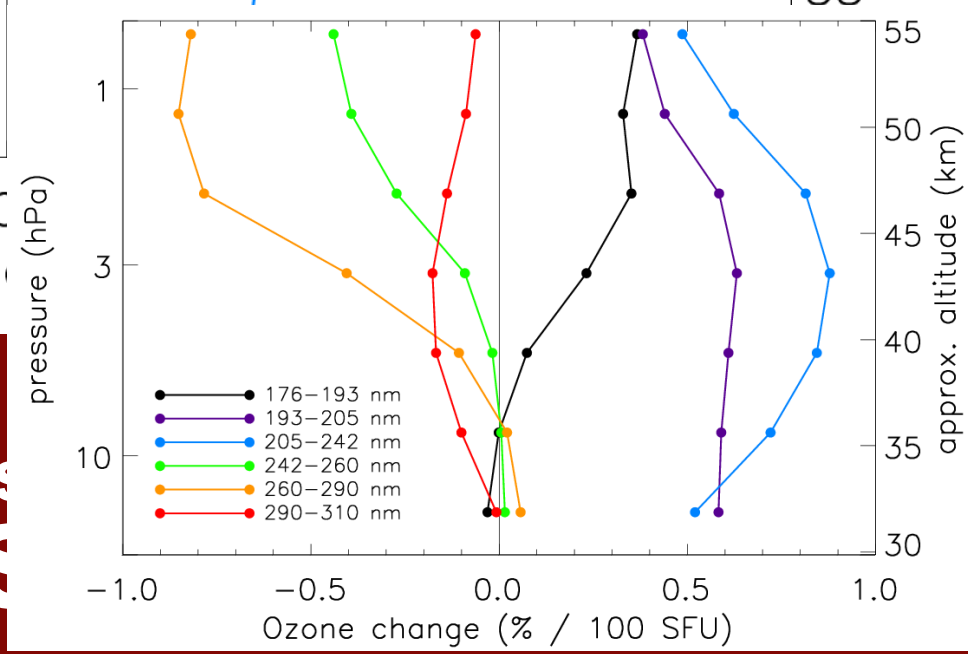
Ball et al., 2014b (in review)



Ball et al., 2014b (in review)

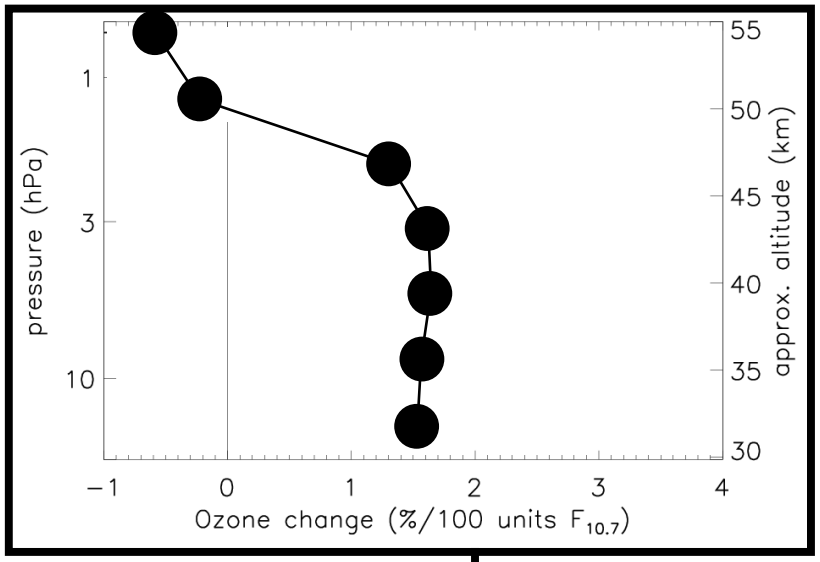
> considering knowledge and uncertainty



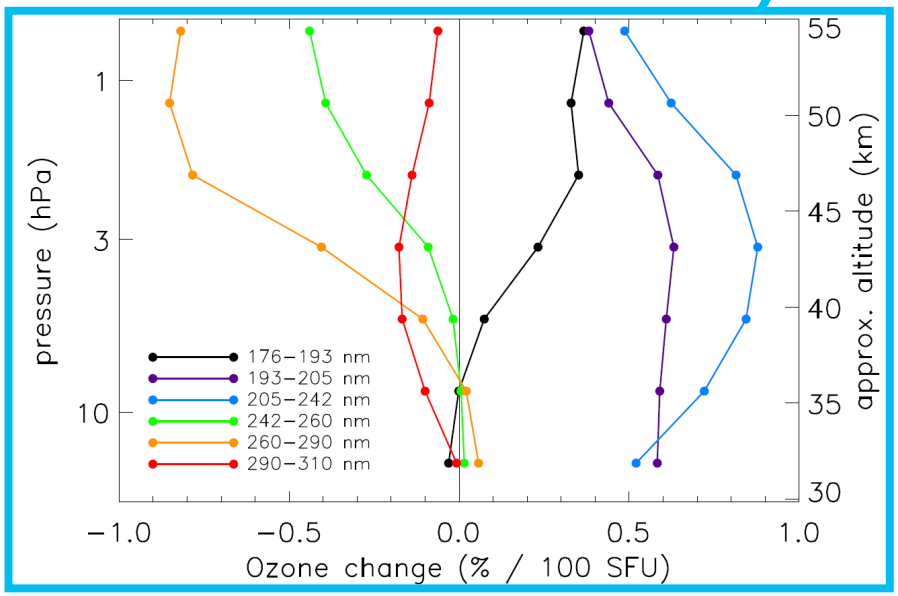


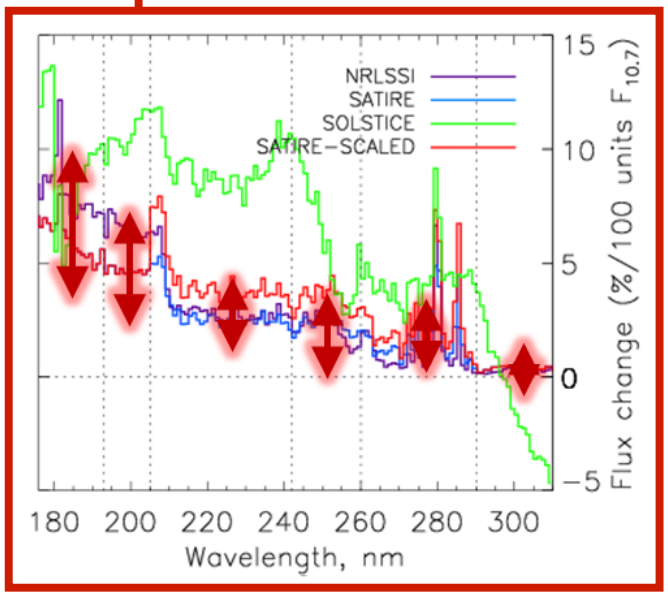
The only difference is

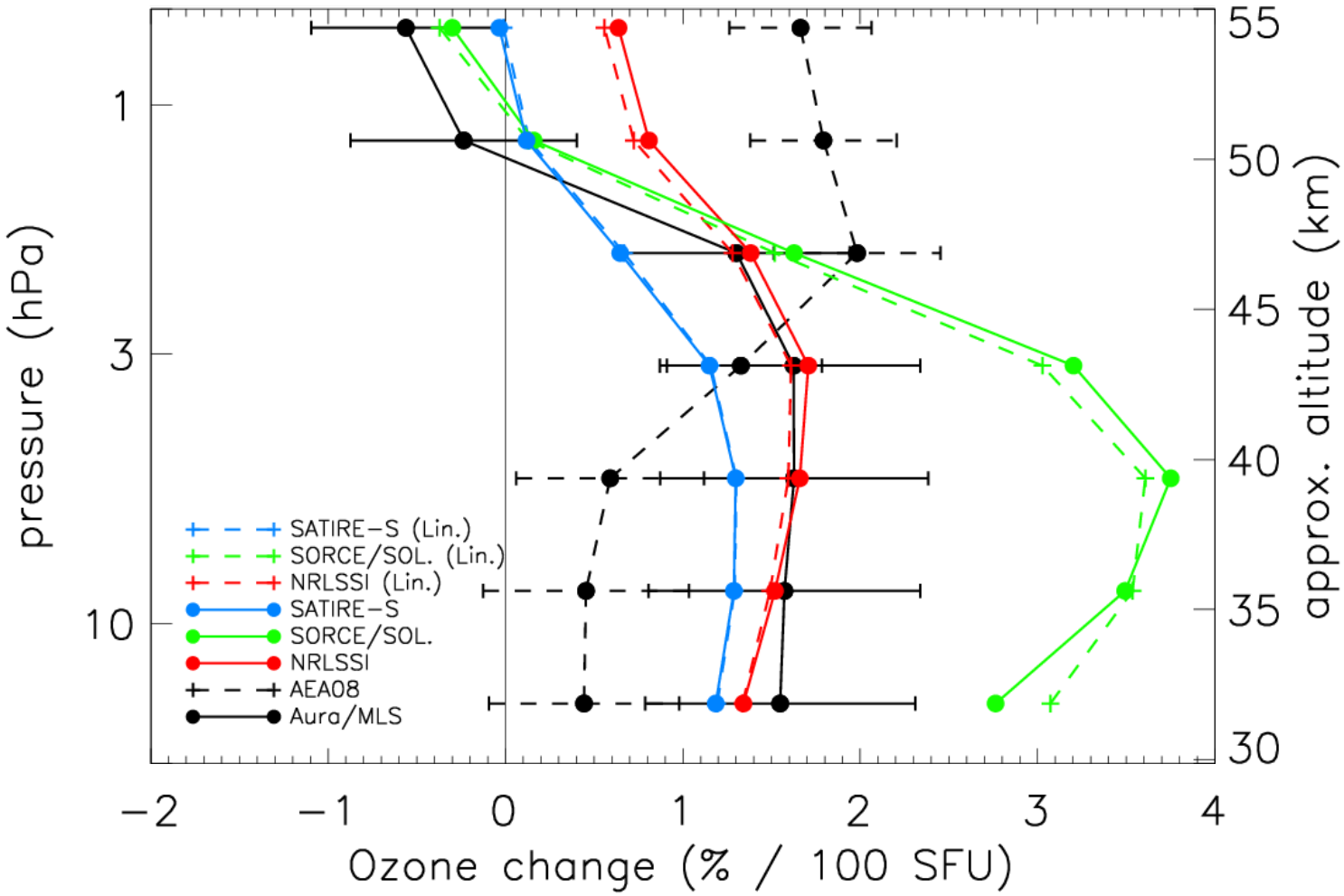
S

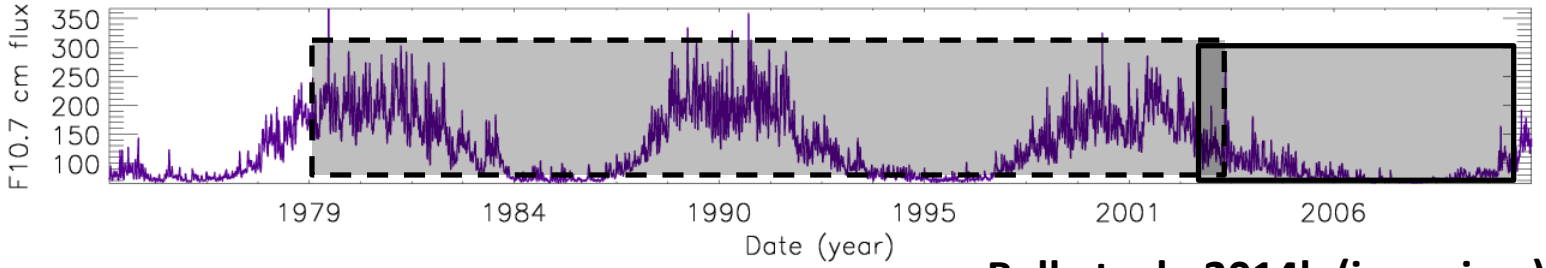


$$\Delta O_3(h) = A(h,\lambda) \times f(\lambda)$$

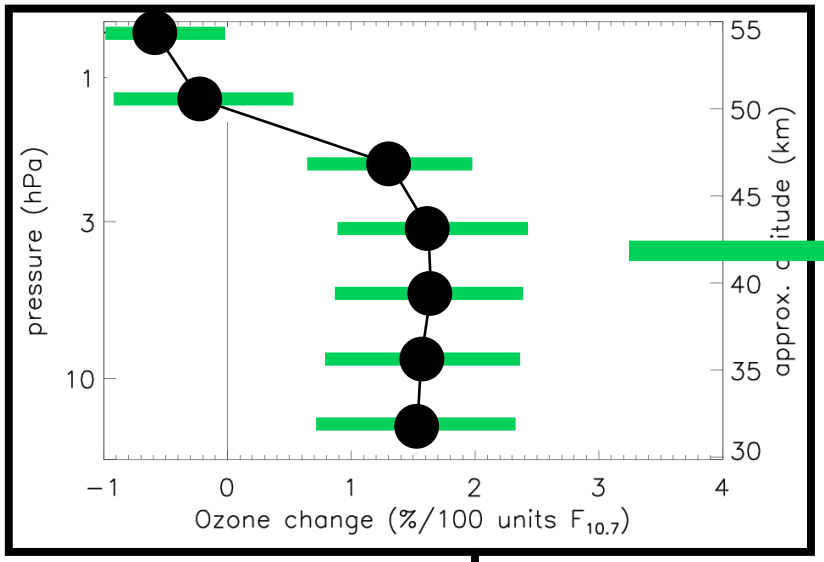


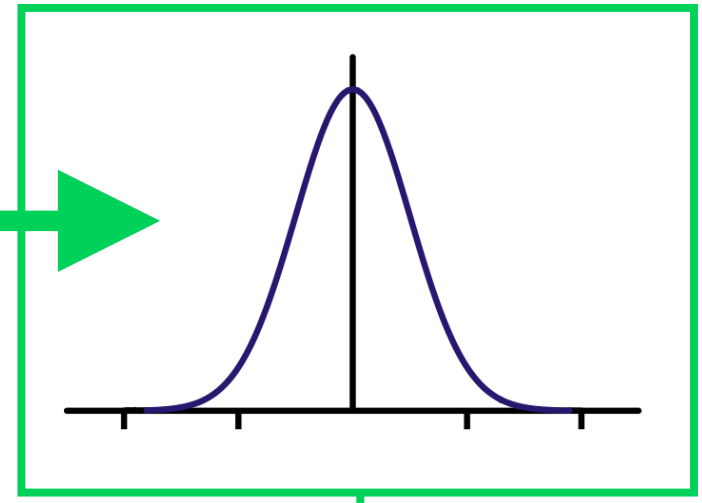




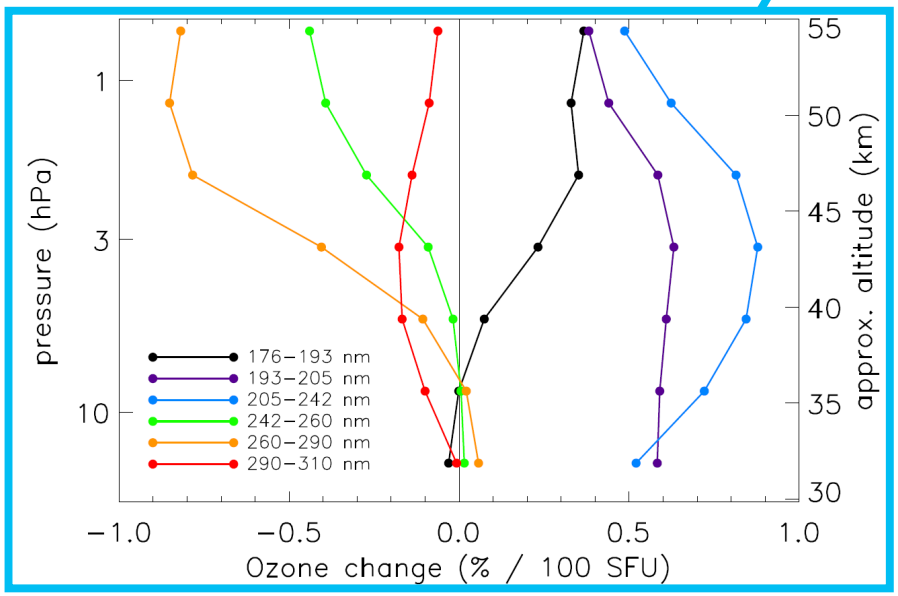


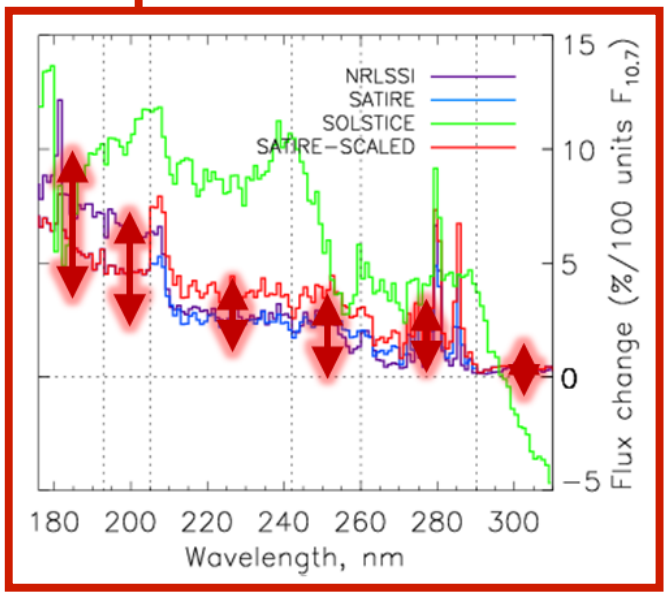
Ball et al., 2014b (in review)





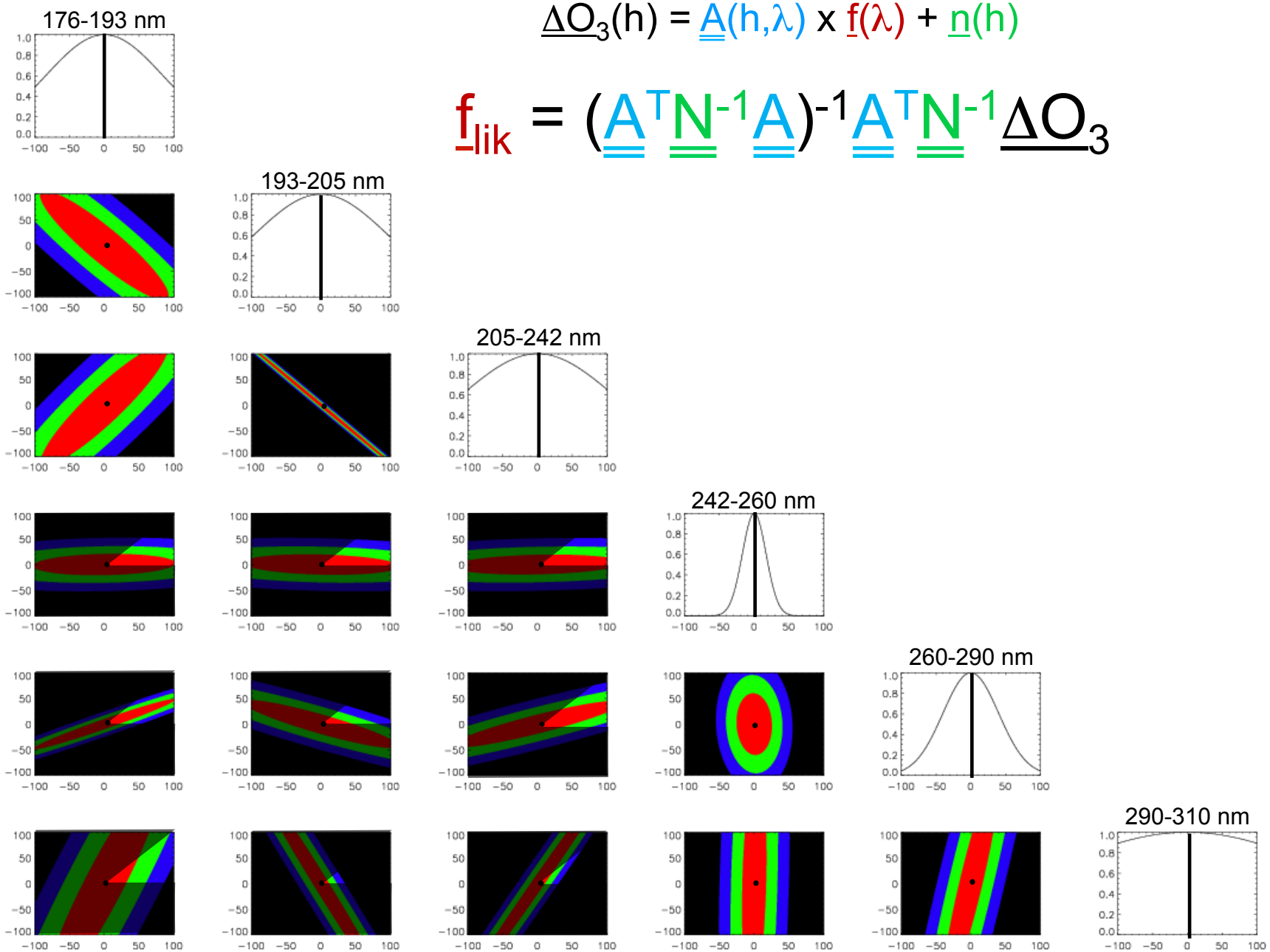
$$\Delta O_3(h) = A(h,\lambda) \times f(\lambda) + n(h)$$

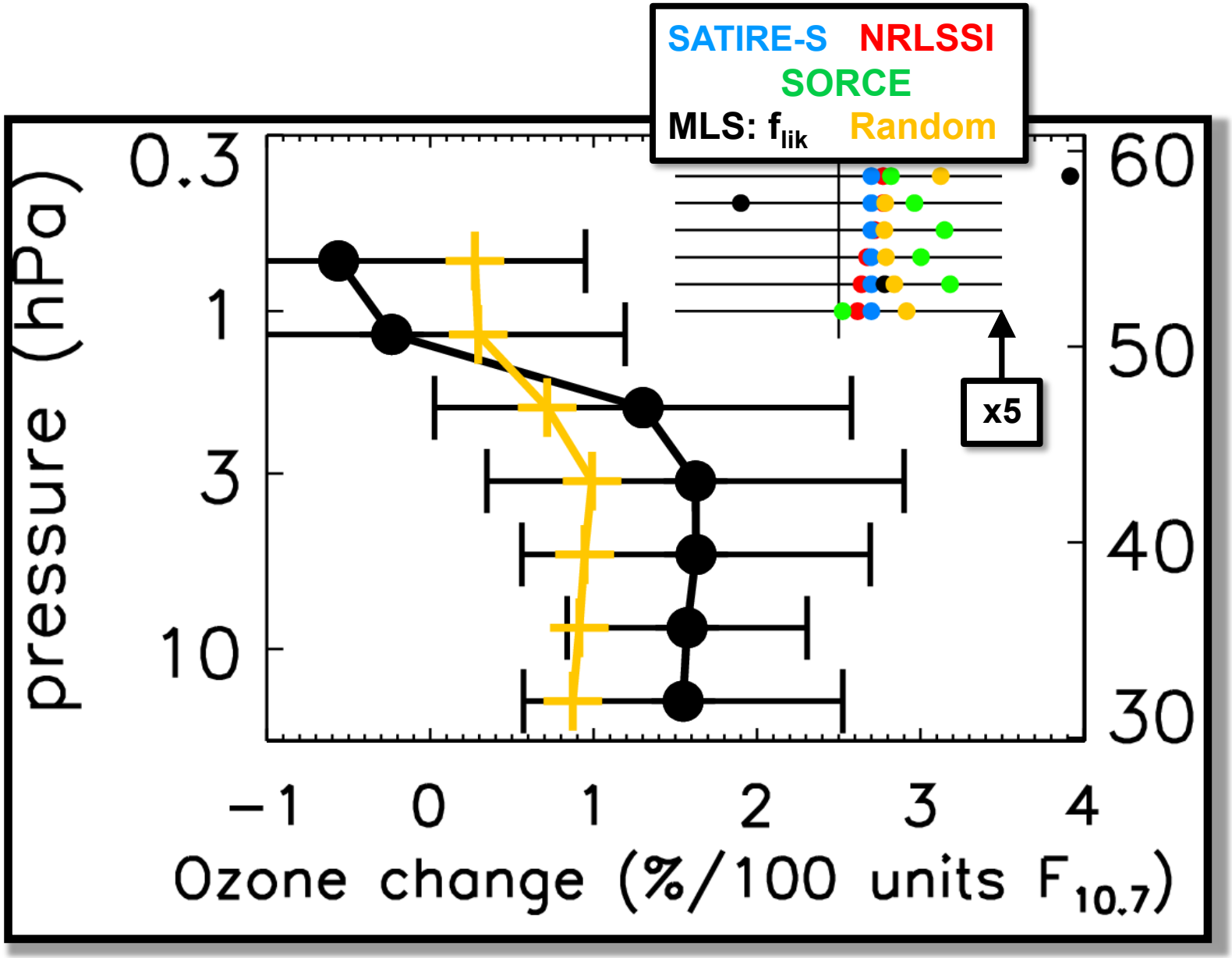


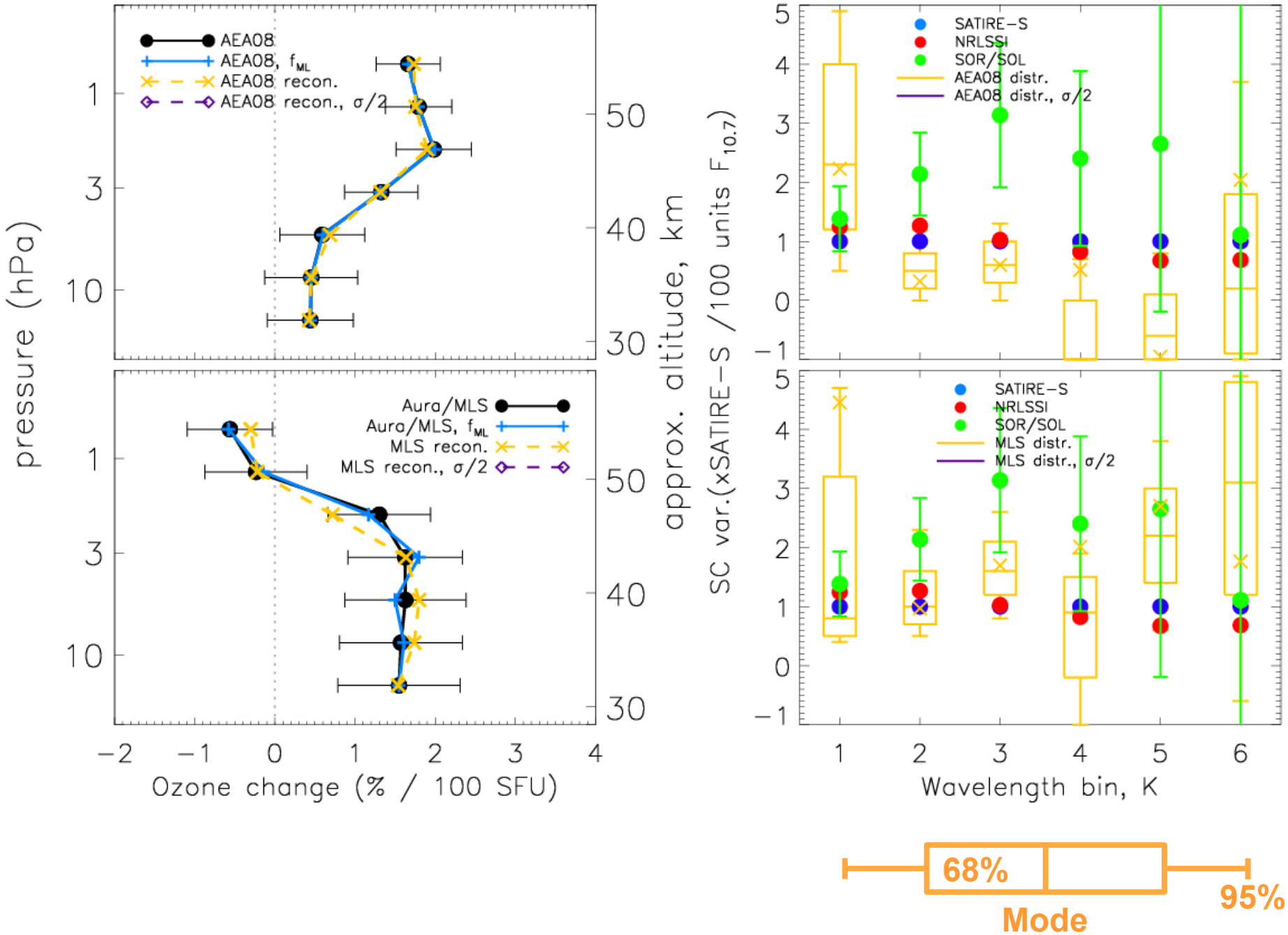


$$\underline{\Delta O_3}(h) = \underline{\underline{A}}(h,\lambda) \times \underline{f}(\lambda) + \underline{n}(h)$$

$$\underline{f}_{lik} = (\underline{\underline{A}}^T \underline{\underline{N}}^{-1} \underline{\underline{A}})^{-1} \underline{\underline{A}}^T \underline{\underline{N}}^{-1} \underline{\Delta O_3}$$




SATIRE-S
NRLSSI
SORCE
MLS: f_{lik}
Random
x5
pressure (hPa)
0.3
1
3
10
60
50
40
30
−1
0
1
2
3
4
Ozone change (%/100 units $F_{10.7}$)



Ball et al., 2014b (in review)

Conclusions

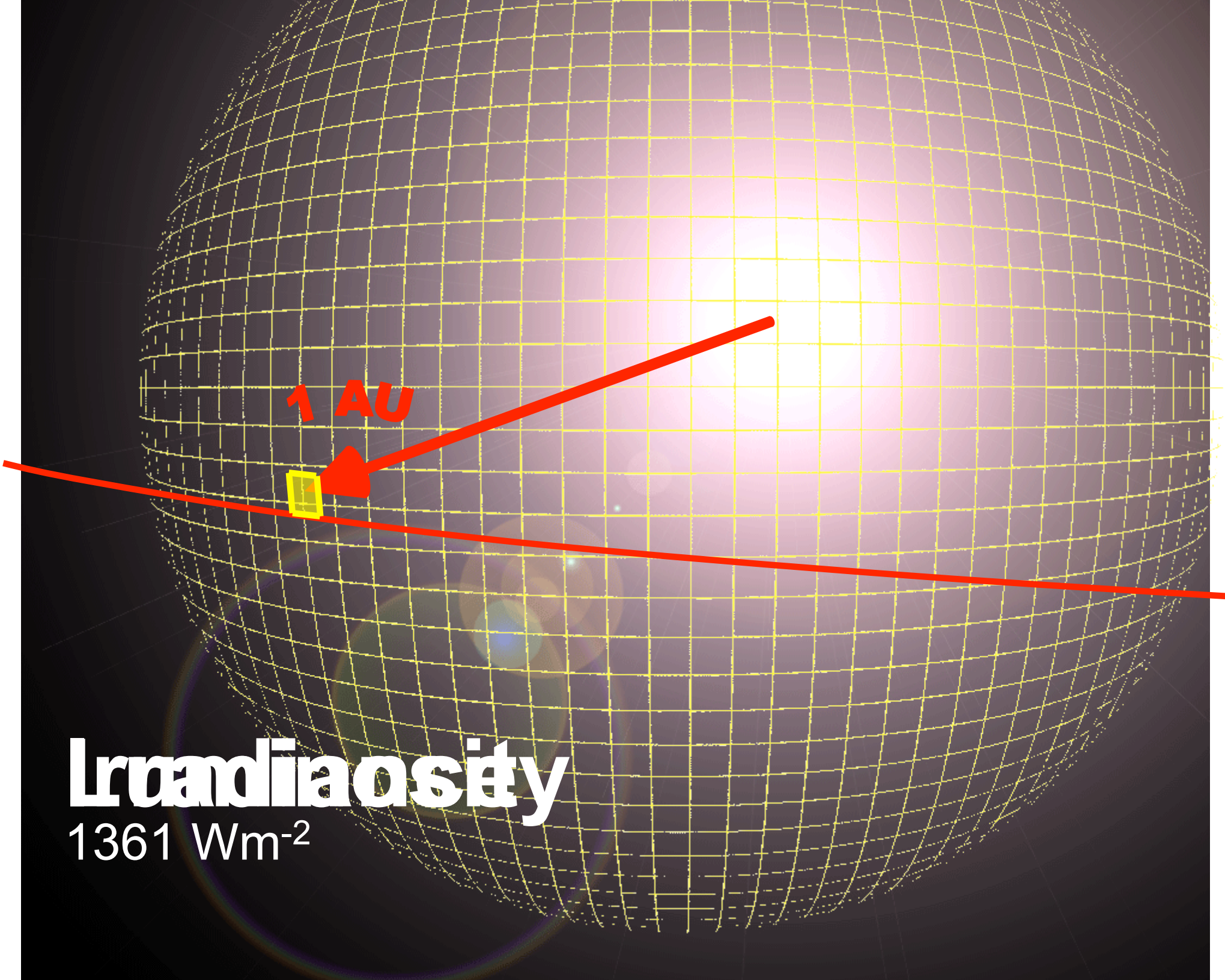
SSI solar cycle changes: poorly constrained

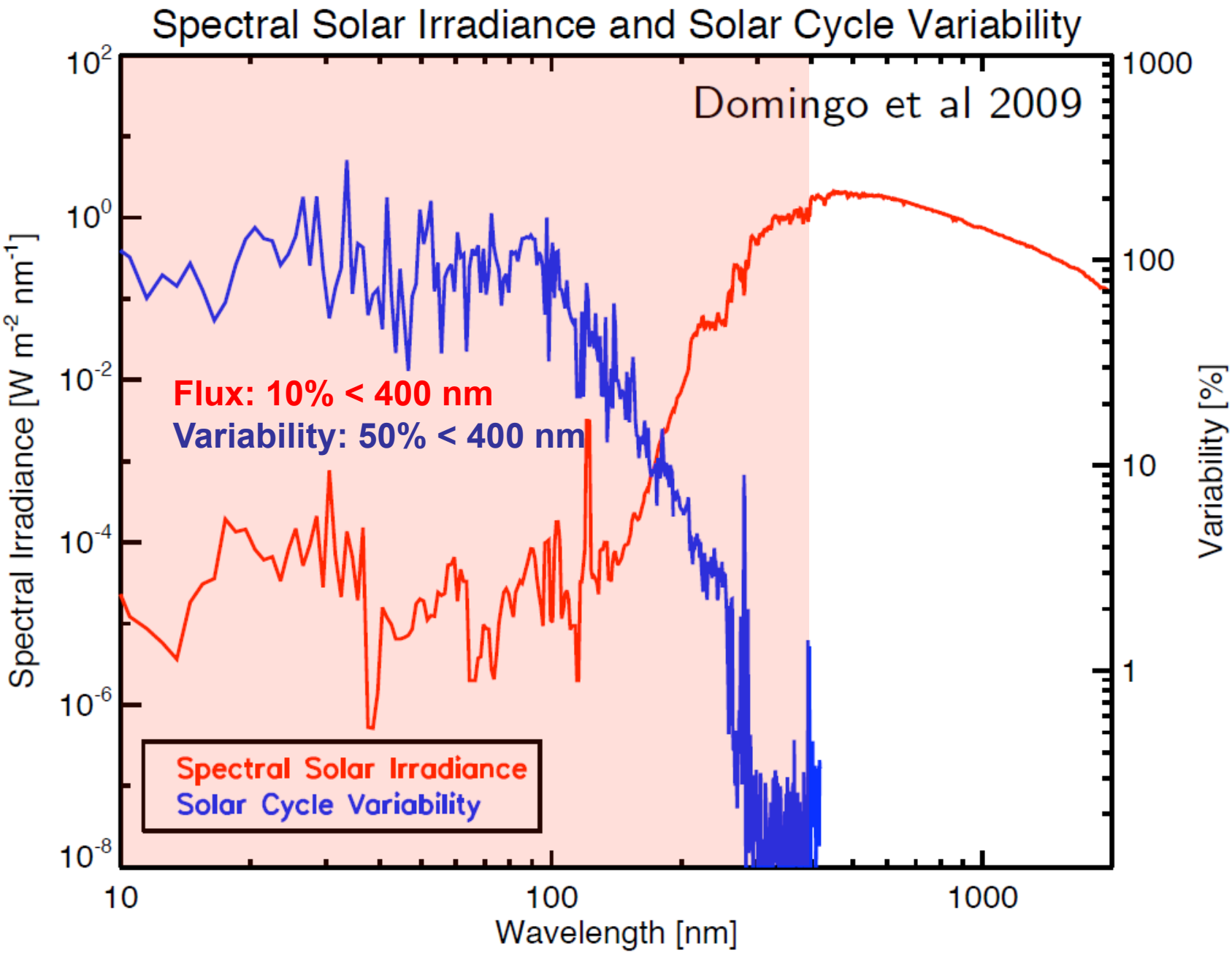
Bayes considers uncertainties; priors are debatable

Current data insufficient to constrain SSI/ozone

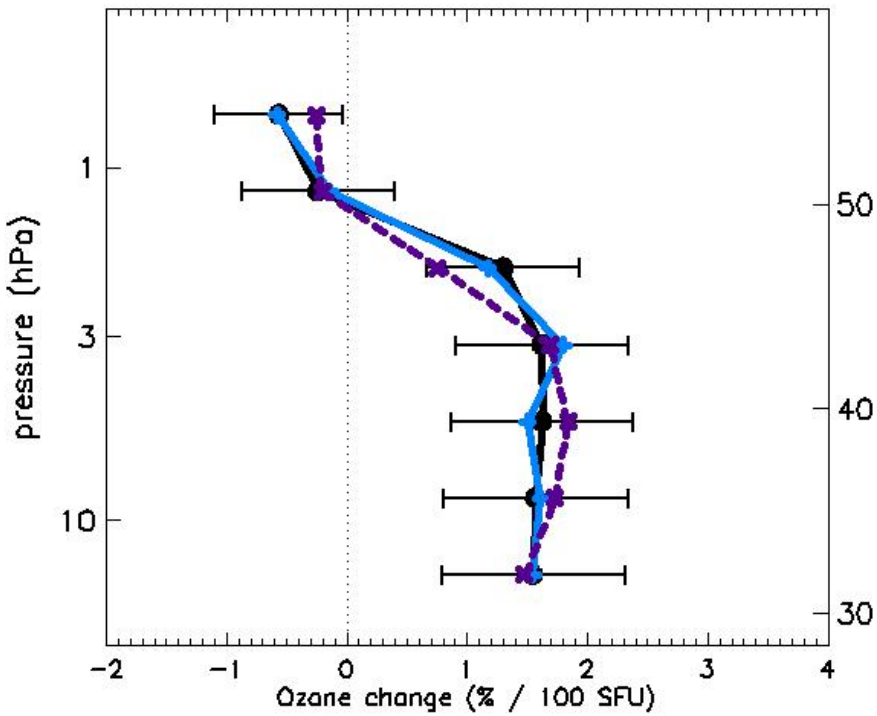
Need to:

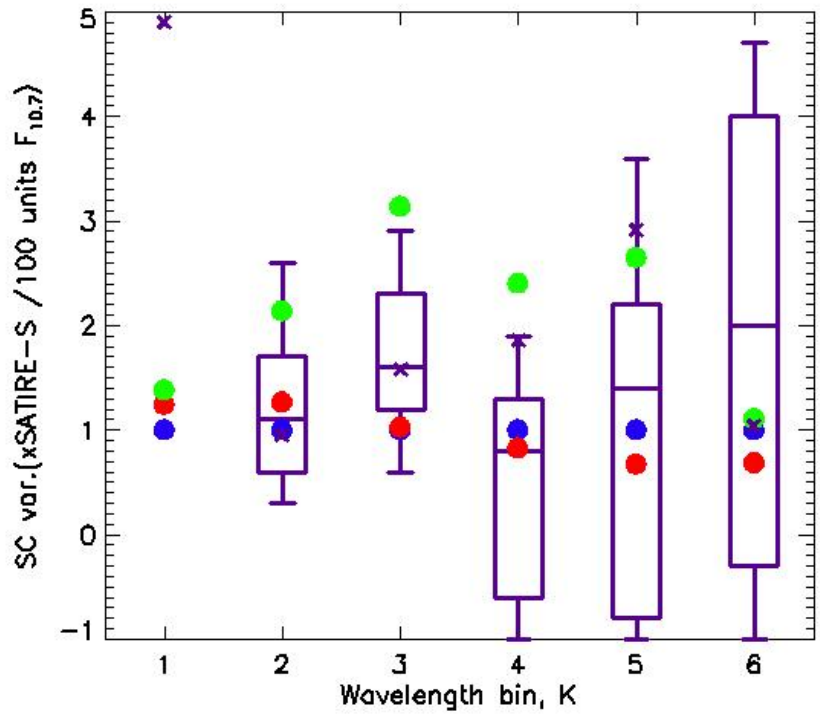
- shrink ozone profile error bars
- have confidence in atmospheric models (3D?)
- include other constraints: temperature, chemicals
- consider new approaches (stellar/models/atmos.)


1 AU
Irradiance
1361 Wm-2


Spectral Solar Irradiance and Solar Cycle Variability
Domingo et al 2009
Flux: 10% < 400 nm
Variability: 50% < 400 nm
Spectral Solar Irradiance
Solar Cycle Variability
Spectral Irradiance [W m-2 nm-1]
Variability [%]
Wavelength [nm]
10
100
1000
1
10
100
1000
10-8
10-6
10-4
10-2
100
102

> how do changes affect our atmosphere?





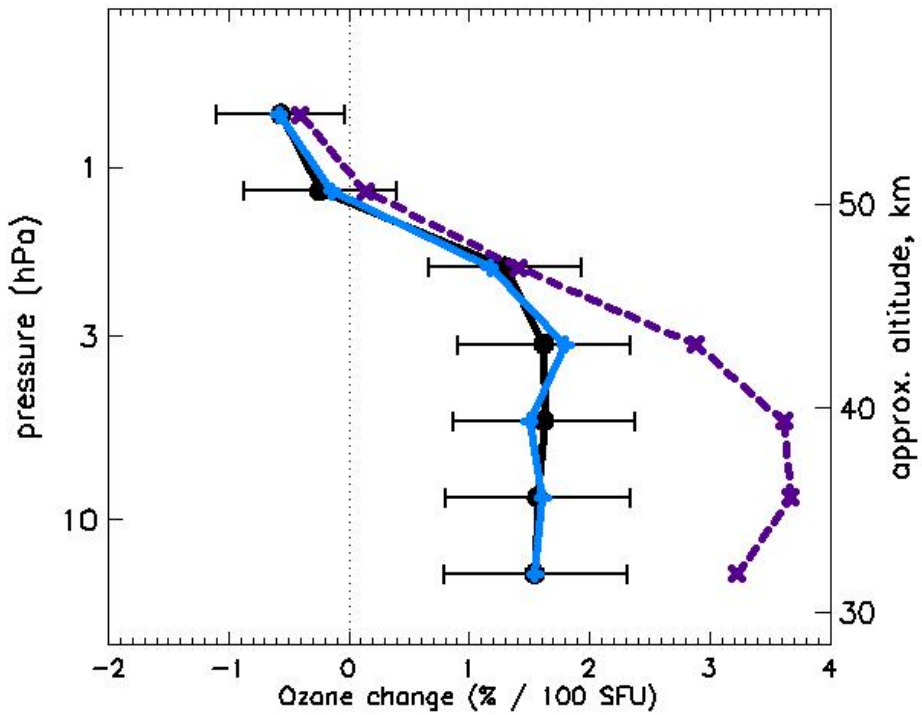
Knowing more about one band

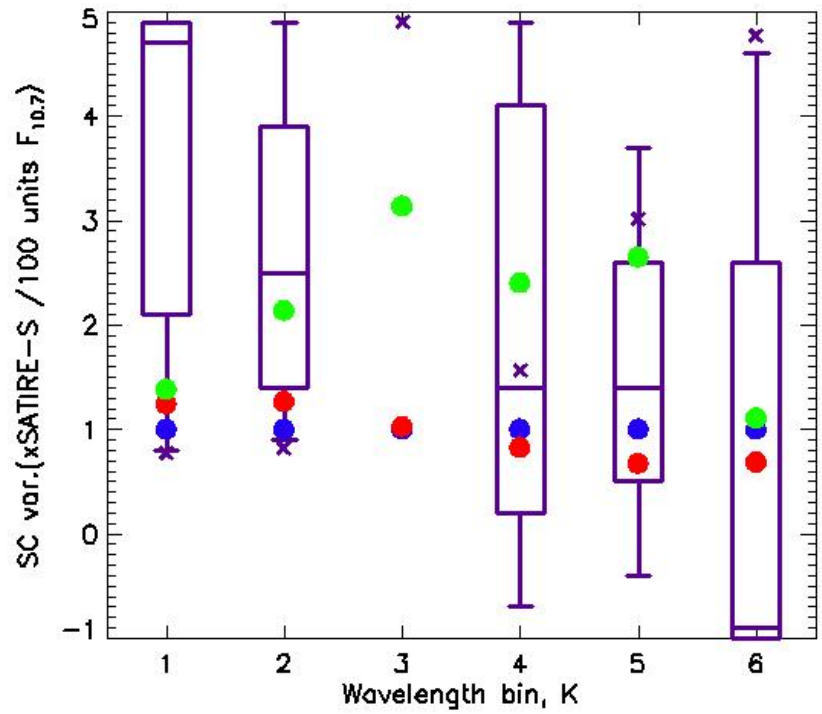
constrains

the others

1

176-193 nm





Knowing more about one band

constrains

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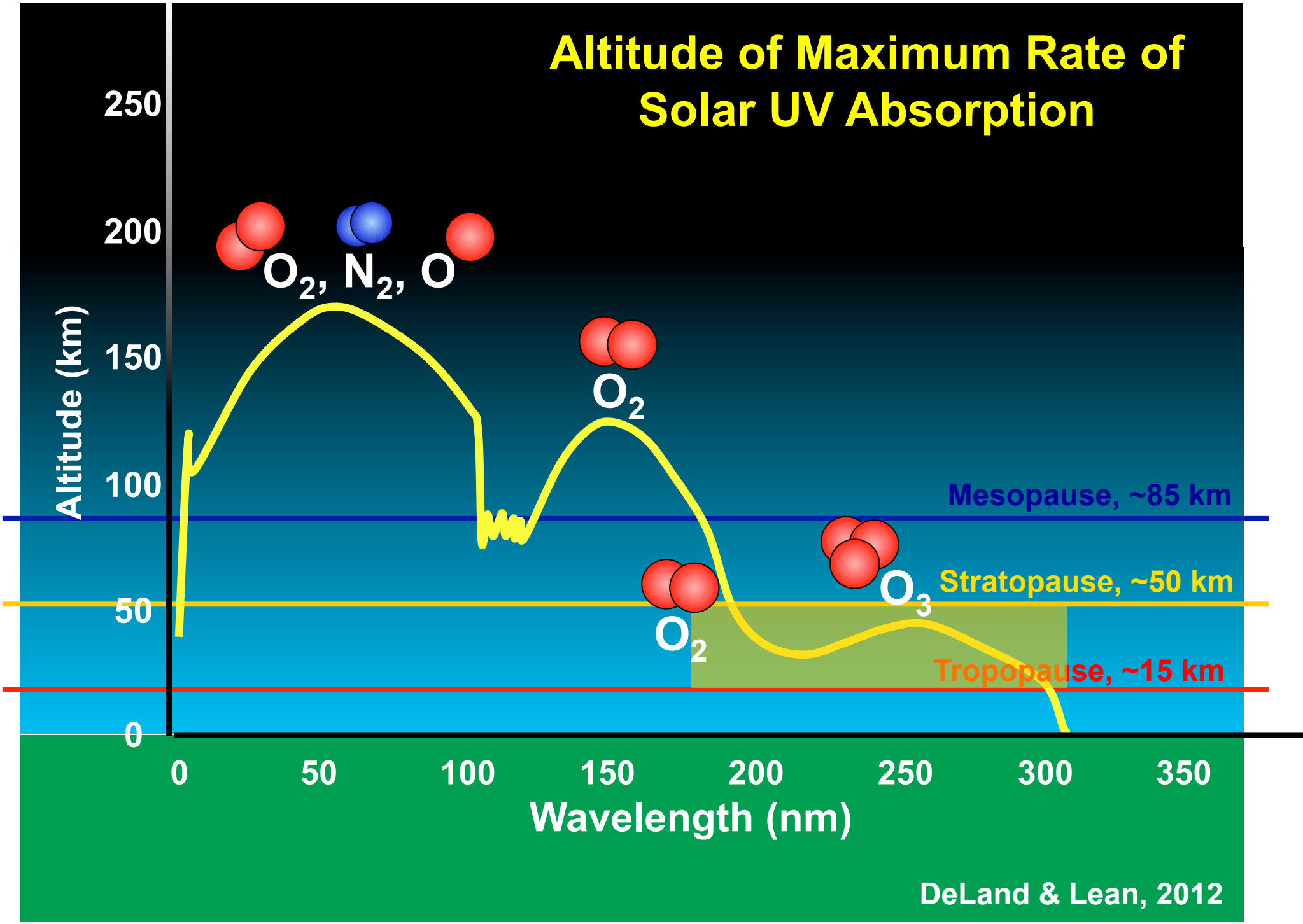
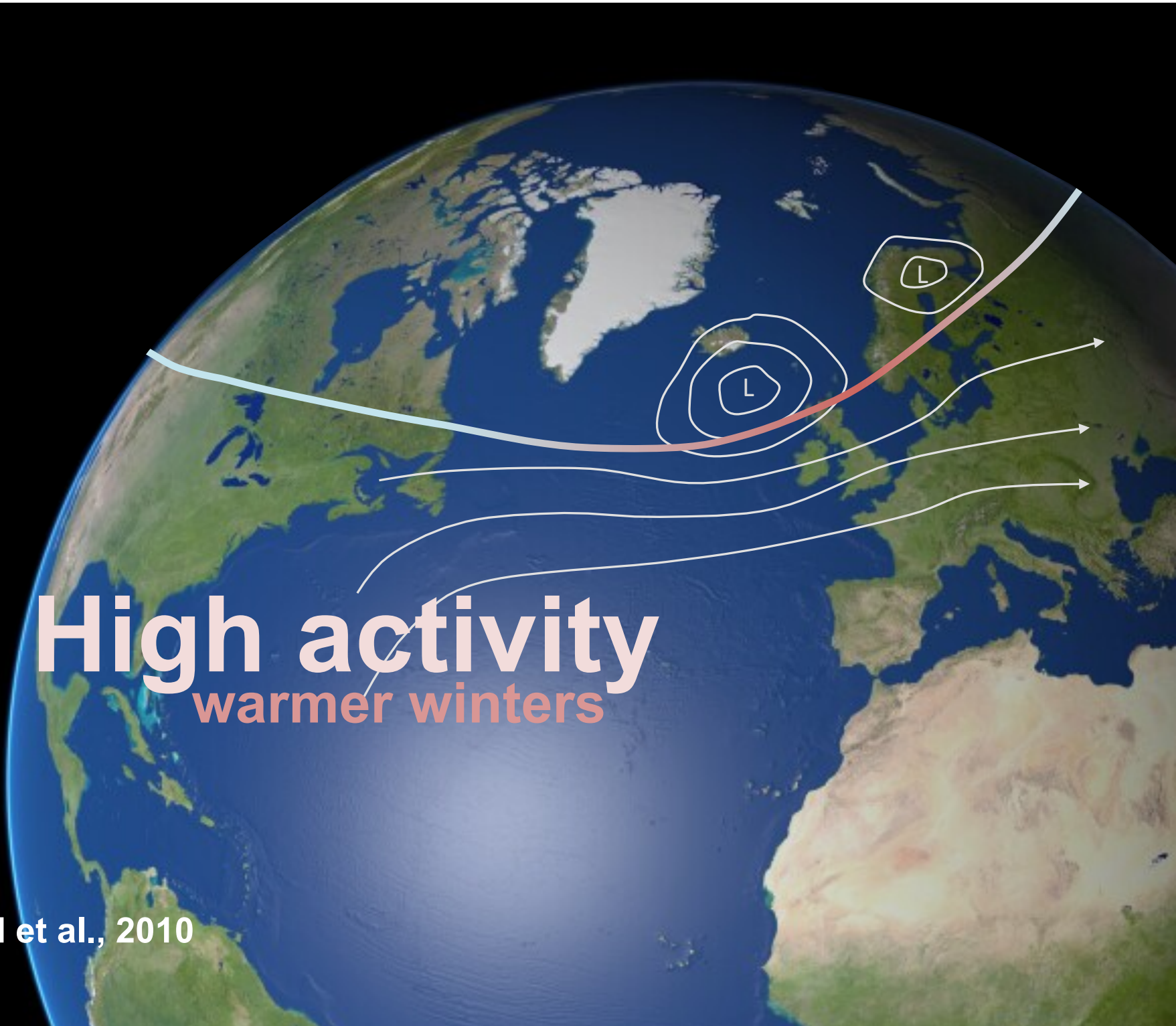
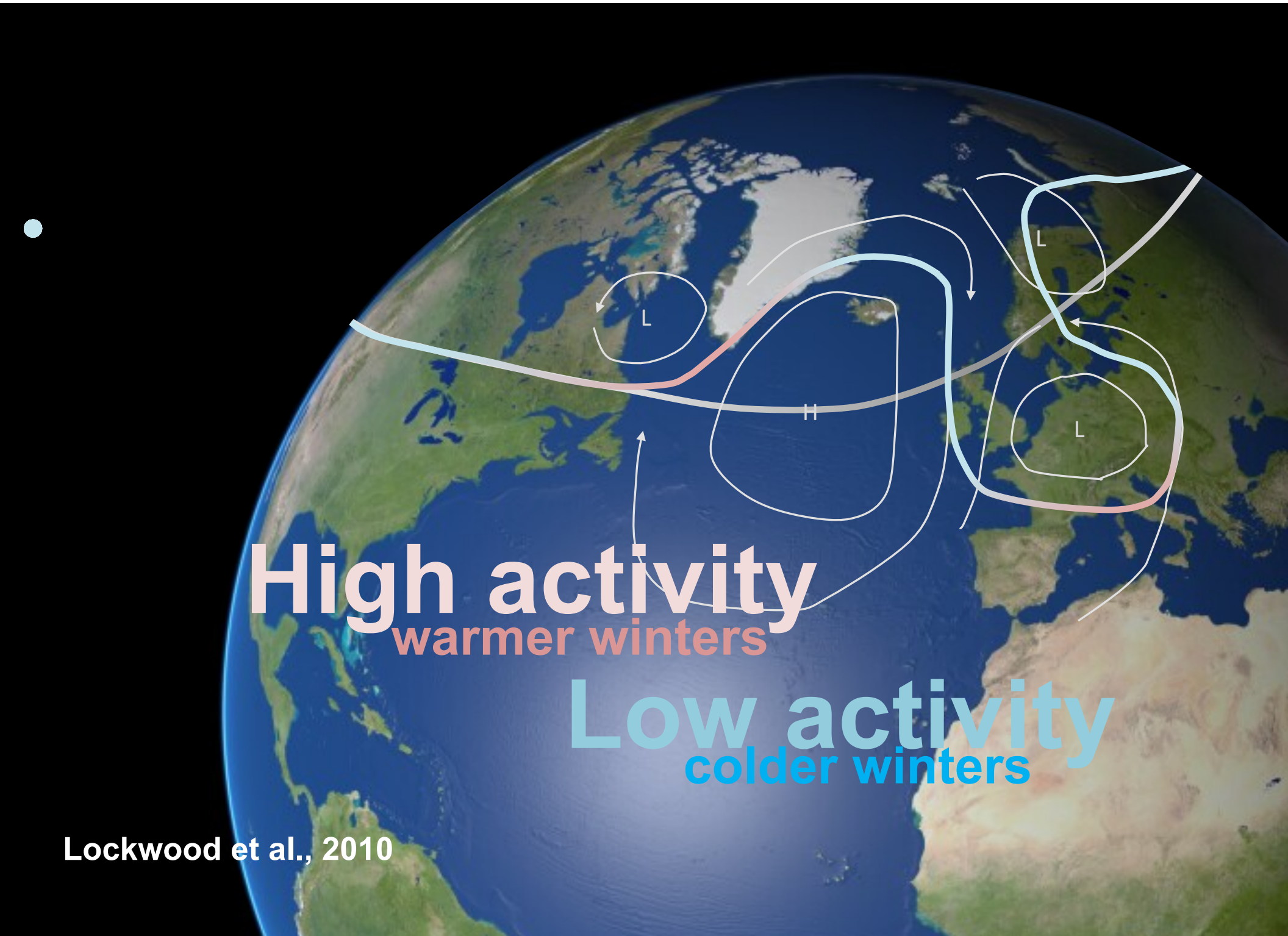

Altitude of Maximum Rate of Solar UV Absorption
Altitude (km)
250
200
150
100
50
0
O_2, N_2, O
O_2
O_2
O_3
Mesopause, ~85 km
Stratopause, ~50 km
Tropopause, ~15 km
0
50
100
150
200
250
300
350
Wavelength (nm)
DeLand & Lean, 2012



Lockwood et al., 2010



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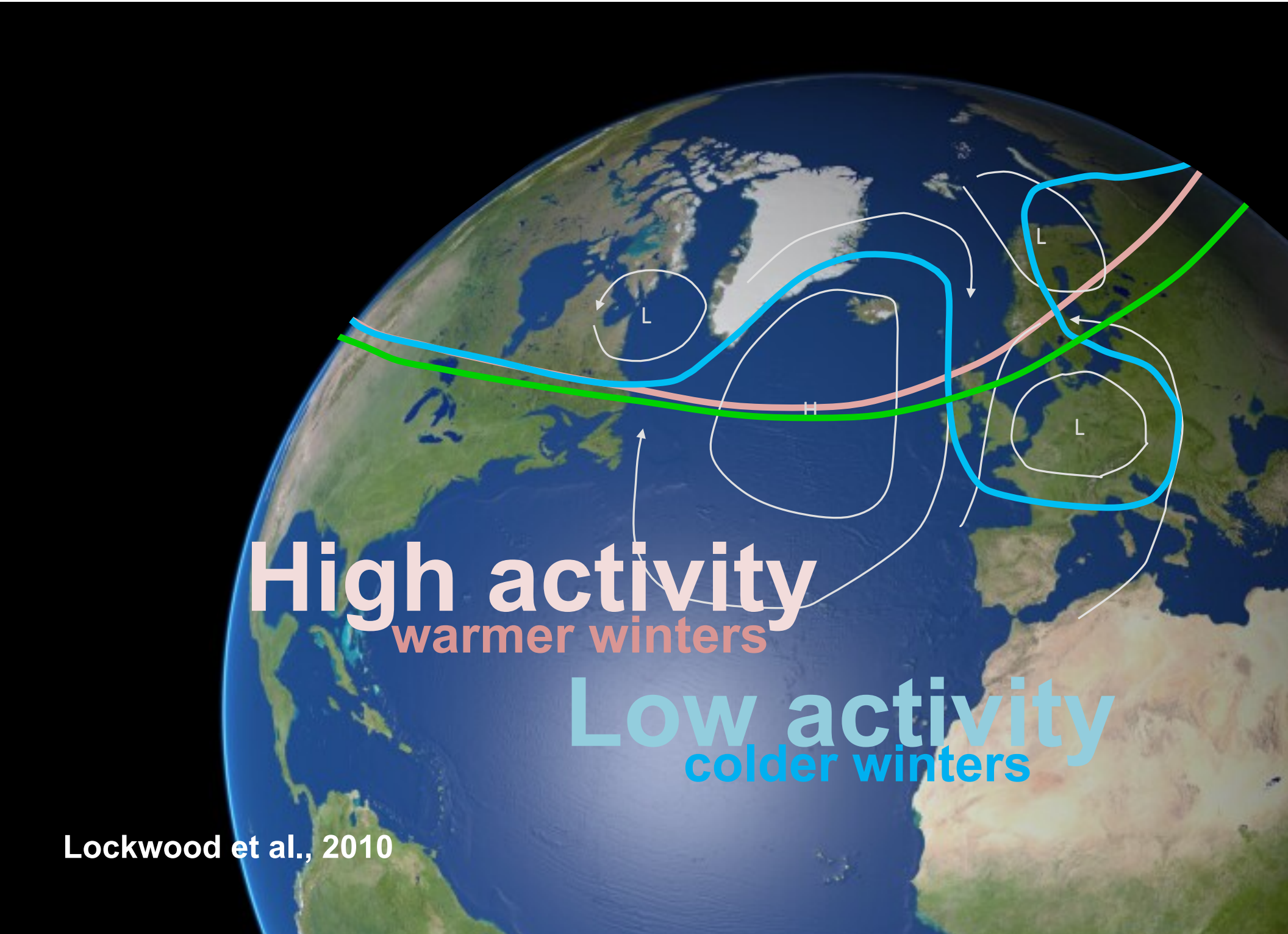

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