Comparison of default and convection-based lightning in the GMI model

Kenneth E. Pickering[1] and Dale J. Allen[2]

Bryan N. Duncan[3], Susan E. Strahan[3], Jose M. Rodriguez[1], and Megan Damon[4]

[1]Atmospheric Chem and Dynamics , NASA-GSFC
[2]Dept. of Atmospheric and Oceanic Science, UMCP
[3]UMBC-GEST and NASA-GSFC
[4]Advanced Management Tech. Inc. and NASA-GSFC

GMI Science Team Meeting
Greenbelt, MD
June 13-15, 2007

Motivation/Preview

- **Production of NO by lightning is an important part of the budget of NOx; whose concentration is the rate-limiting factor in O3 production in much of the free troposphere.**

- **The default version of the GMI CTM uses gridded monthly climatological values of lightning NO emission.**

- **Frequently, these model-independent climatological values of lightning NO injection do not match in space or time with the location of model convection.**

- **In this study, we evaluate the effect of this mismatch on upper tropospheric photochemistry in the tropics through analysis of fields from GMI simulations with climatological- and convection-based lightning NO.**

Comparison of lightning algorithms

Default Run

- Horizontal distribution: Climatological based on ISCCP monthly average deep convective cloud top heights
- Vertical distribution: C-shaped (Pickering et al., 1998) using climatological CLDHT
- Flashrate = f(CLDHT, marine/continental; P+R, 1992)
- $P_{CG} = 10\ P_{IC}$ (Price et al., 1997)
- CG fraction based on cold cloud depth (P+R, 1993)
- Scaled to: 5 Tg N/yr

New Run

- Horizontal distribution: Co-located with model-calculated deep convection
- Vertical distribution: C-shaped as before using model-calculated CLDHT
- Flashrate = f(CLDMAS, region)[Allen&Pickering, 2002]
- $P_{CG} = P_{IC}$ (DeCaria et al., Ott et al., Fehr et al.; STERAO, EULINOX, CRYSTAL-FACE)
- CG fraction not needed
- Scaled to 5 Tg N / yr

Implications of the different lightning NO treatments

Default Run

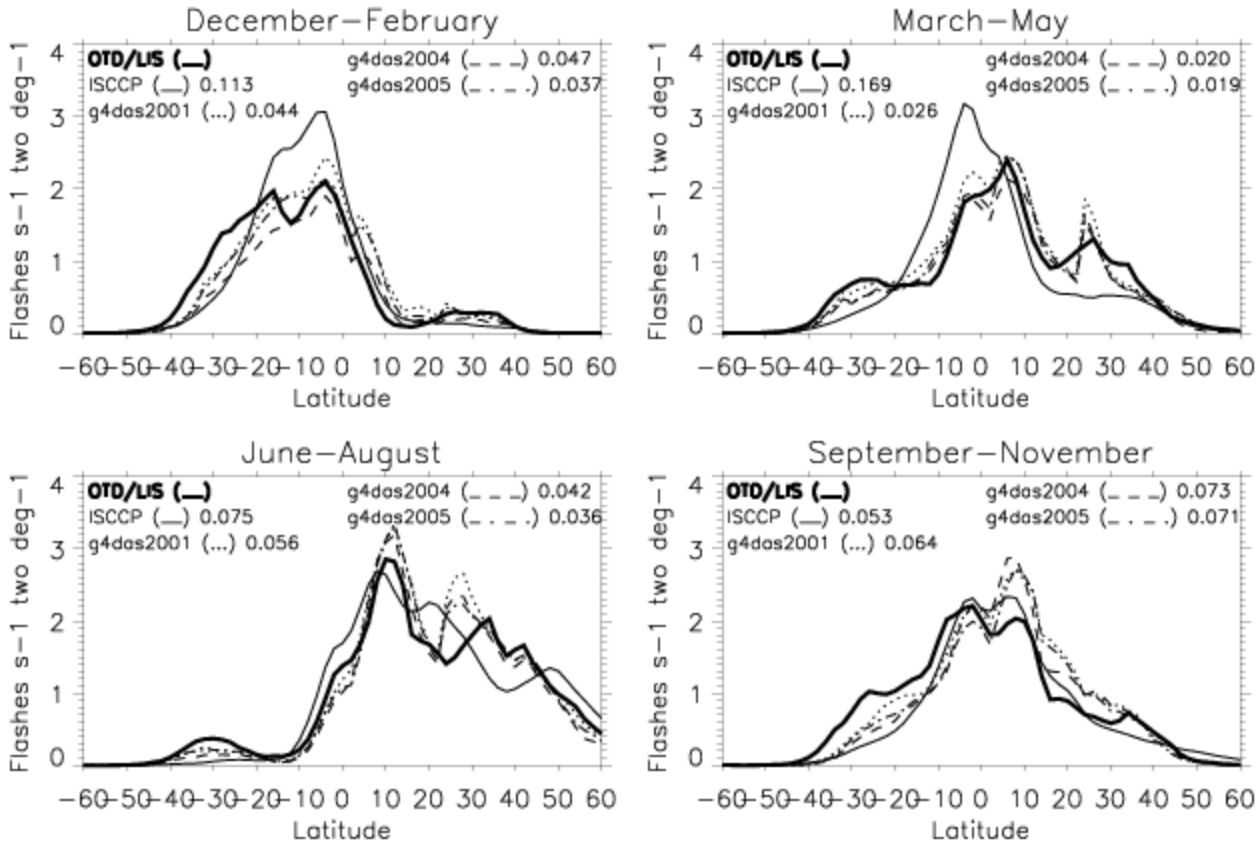
- Convectively-transported precursors (HO_x precursors, NO_x, CO, NMHC) introduced to upper troposphere at different locations than lightning NO
- Lightning NO spigot always open on lowest setting (fuzzy NO_x chemistry)
- Biases in spatial distribution and vertical extent of model convection do not contribute to biases in lightning NO

New Run

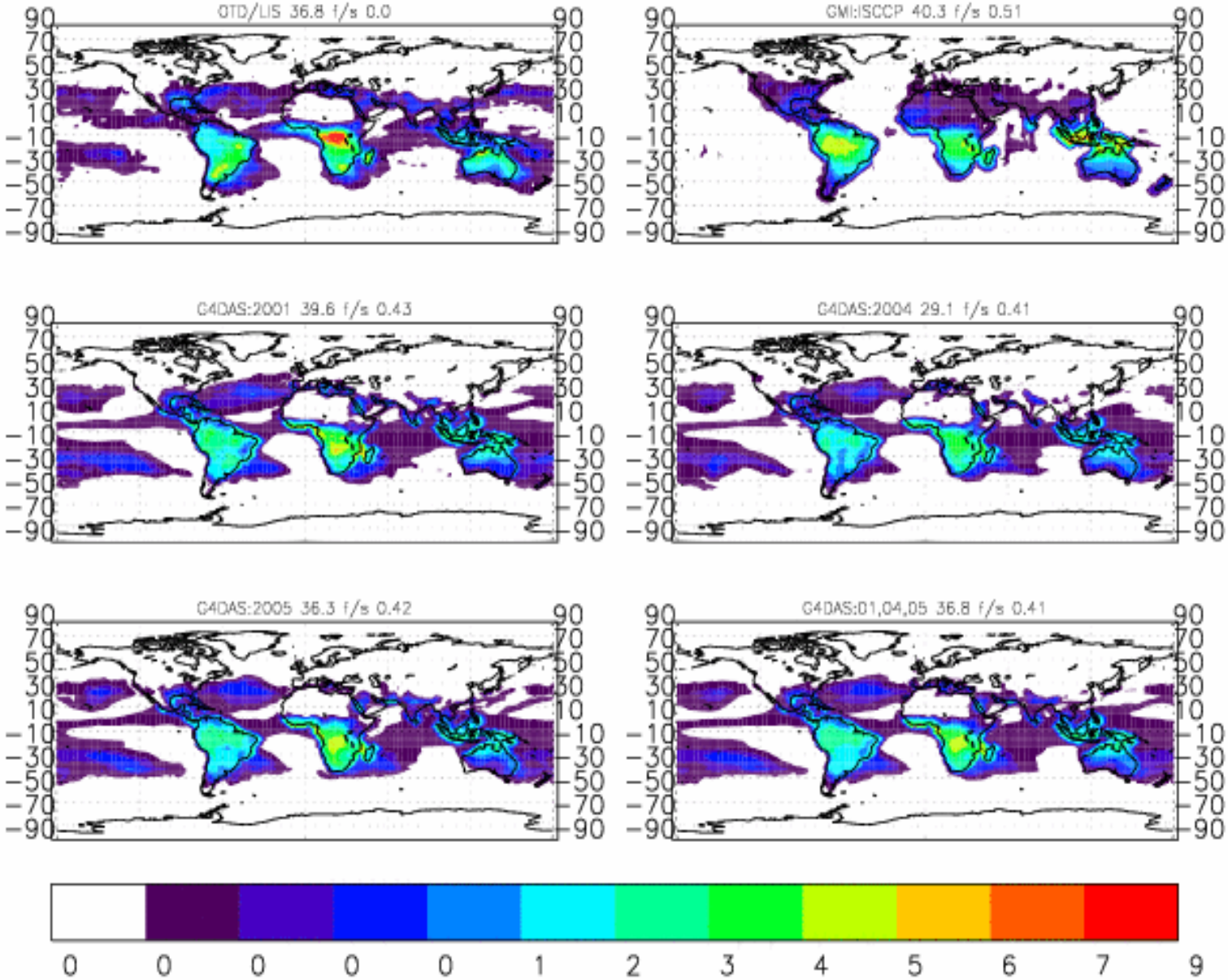
- Convectively-transported precursors introduced to upper troposphere at same locations as lightning NO
- Lightning NO spigot opens when convection occurs; setting determined by CLDMAS and region
- Biases in spatial distribution, vertical extent, and magnitude of model convection contribute to biases in location of lightning NO

Flash rate calculation

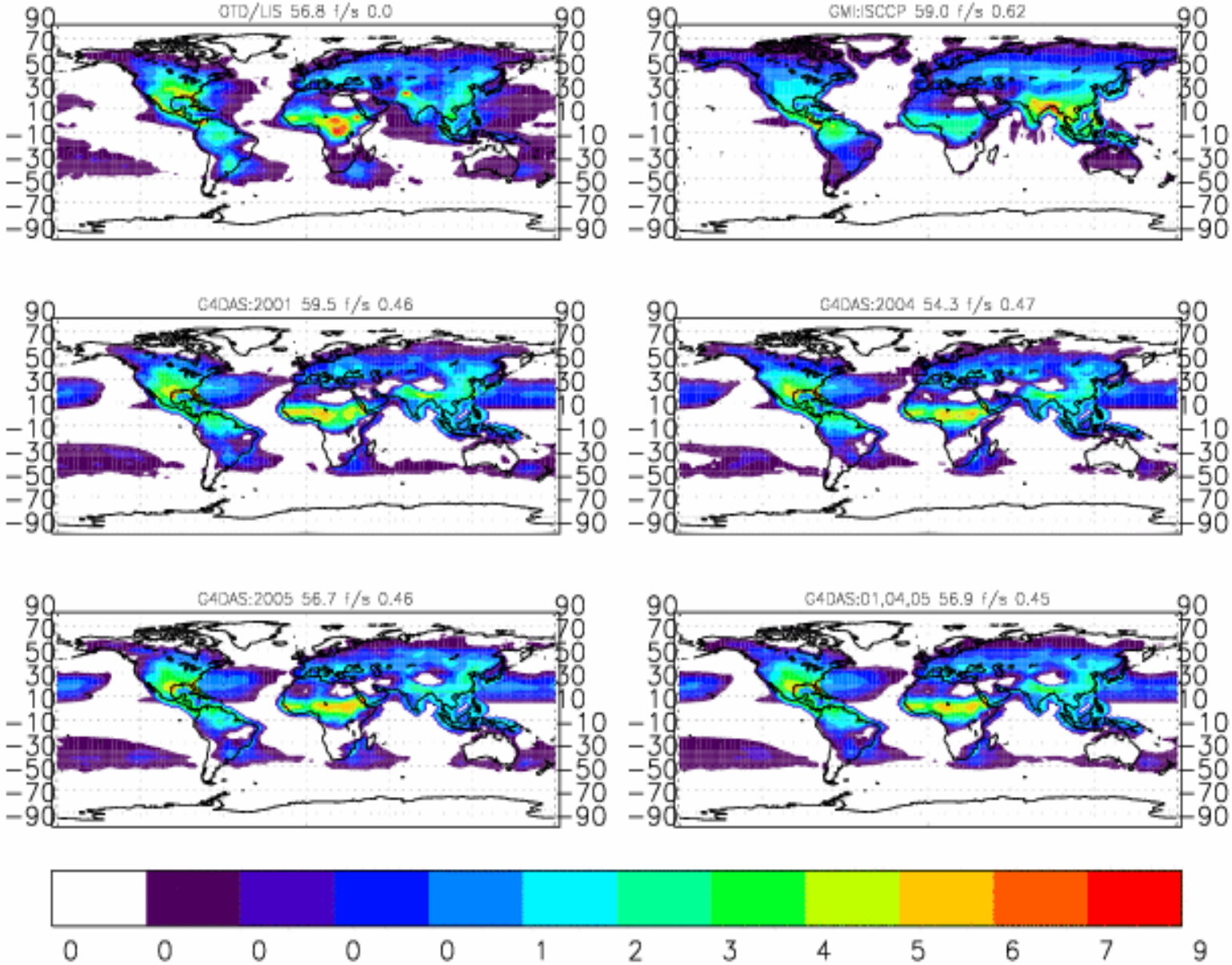
- 1. Construct time series of 3-hr avg 434 hPa zmmu (updraft mass flux) using GEOS-4 AGCM (94-98) and DAS (01,04,05) output
- 2. Set flash rate to nominal value at all locations where zmmu > 0.122(0) kg m-2 min-1 for the GEOS-4 DAS (GCM).
- 3. Scale nominal flash rates so that total global monthly flash rates match v2.2 OTD/LIS climatological flash rates
- 4. Apply regional (tropical marine, African, S American, N American, Southeast Asian, N Asian, coastal, and rest-of-world) adjustments so that regional flash rates match OTD/LIS monthly climatology
- 5. Calculate N production rate (g s-1). (Assume IC and CG flashes produce same amount of NO and scale to get desired global production rate)

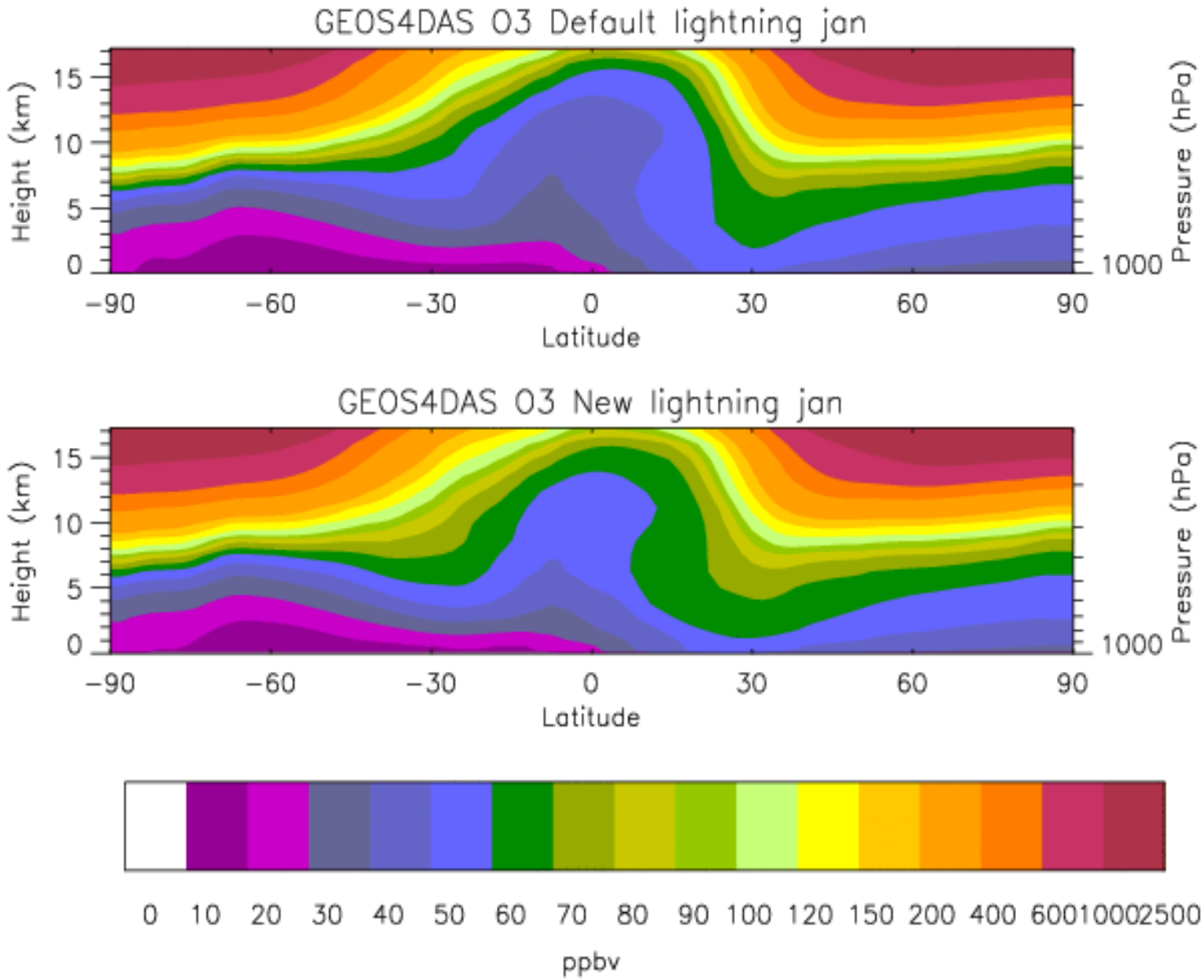

December−February
OTD/LIS (__)
ISCCP (__) 0.113
g4das2001 (...) 0.044
g4das2004 (_ _ _) 0.047
g4das2005 (_ . _ .) 0.037
March−May
OTD/LIS (__)
ISCCP (__) 0.169
g4das2001 (...) 0.026
g4das2004 (_ _ _) 0.020
g4das2005 (_ . _ .) 0.019
June−August
OTD/LIS (__)
ISCCP (__) 0.075
g4das2001 (...) 0.056
g4das2004 (_ _ _) 0.042
g4das2005 (_ . _ .) 0.036
September−November
OTD/LIS (__)
ISCCP (__) 0.053
g4das2001 (...) 0.064
g4das2004 (_ _ _) 0.073
g4das2005 (_ . _ .) 0.071
Flashes s−1 two deg−1
Latitude
0 1 2 3 4
−60 −50 −40 −30 −20 −10 0 10 20 30 40 50 60

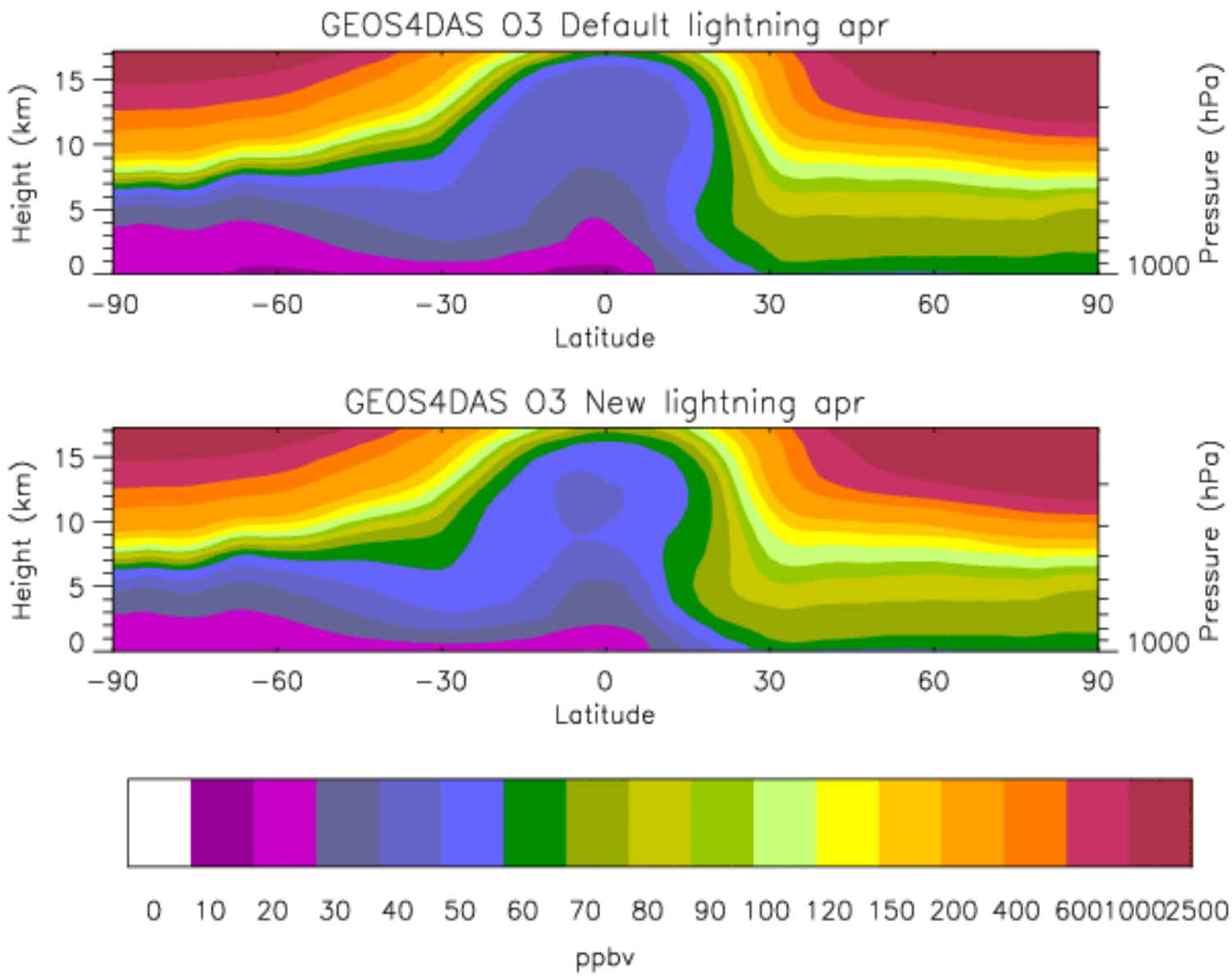
December–February Flash rate

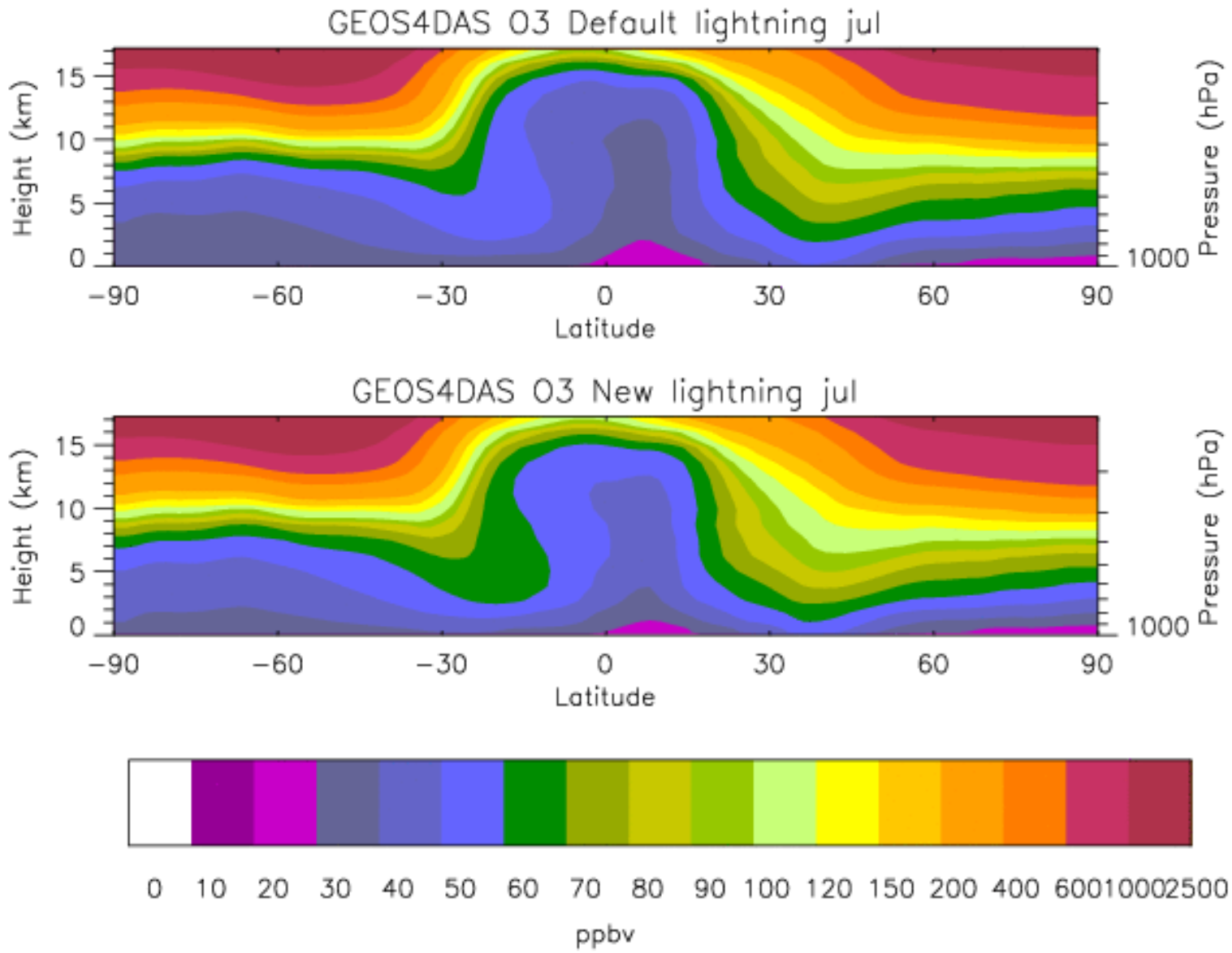


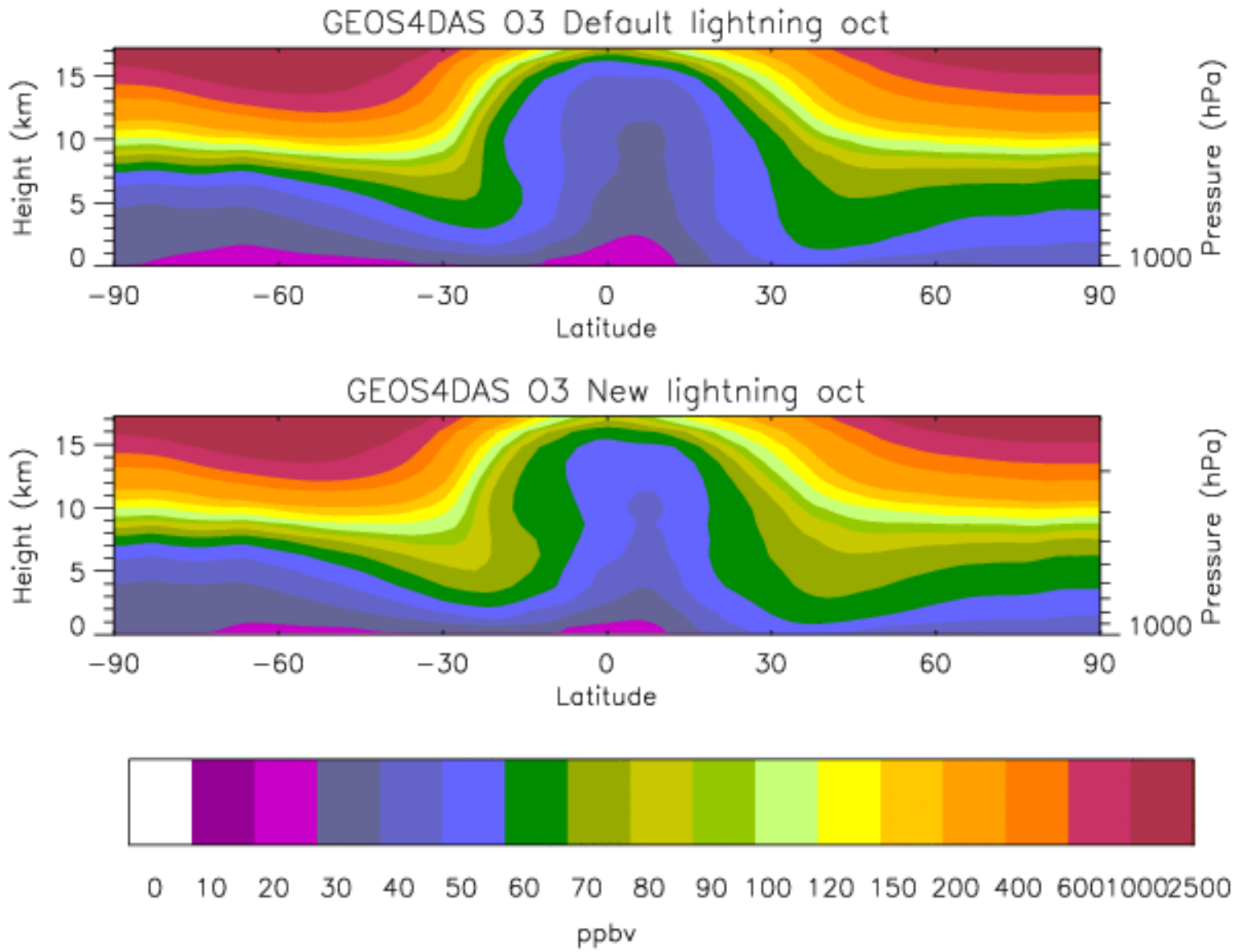
June–August Flash rate

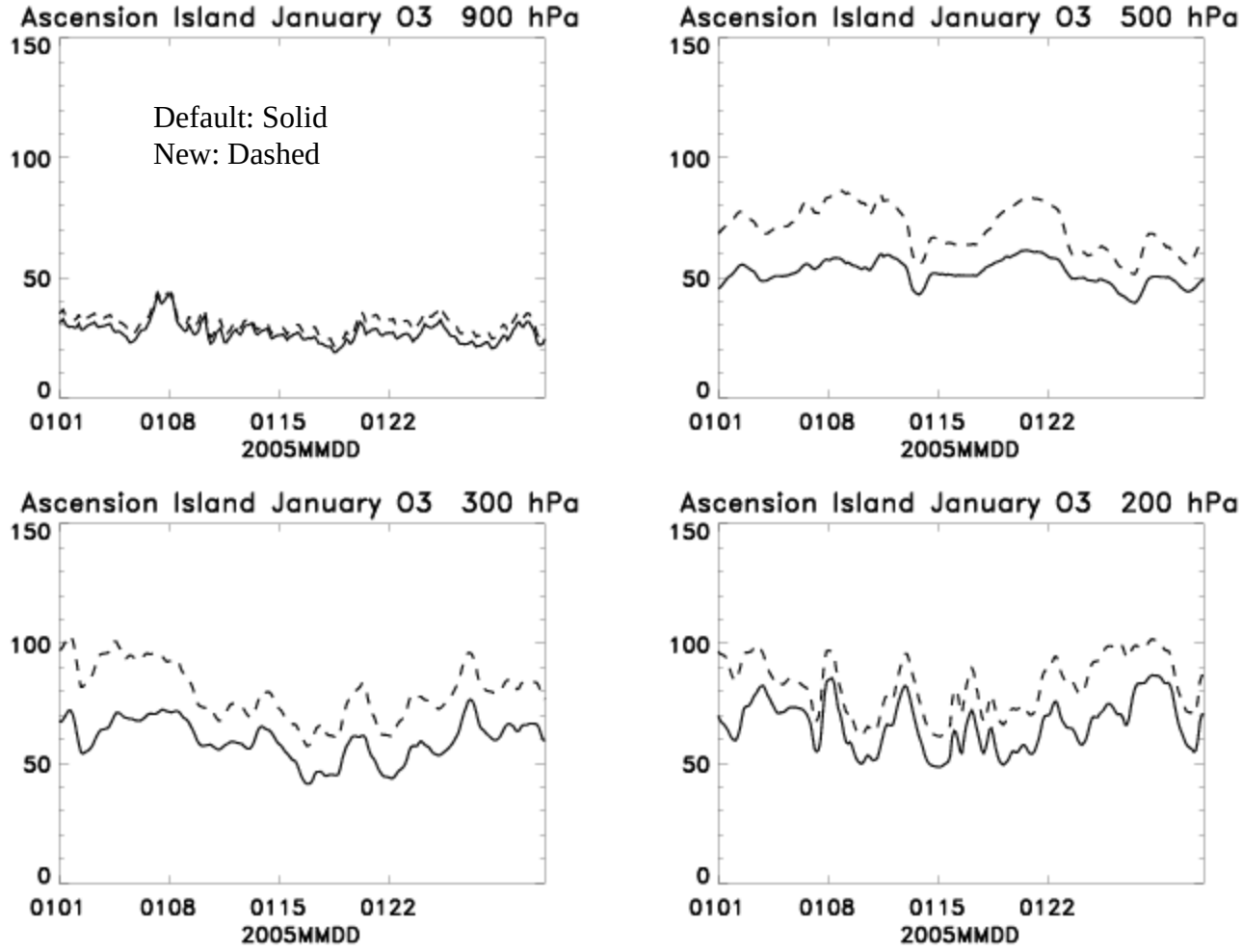


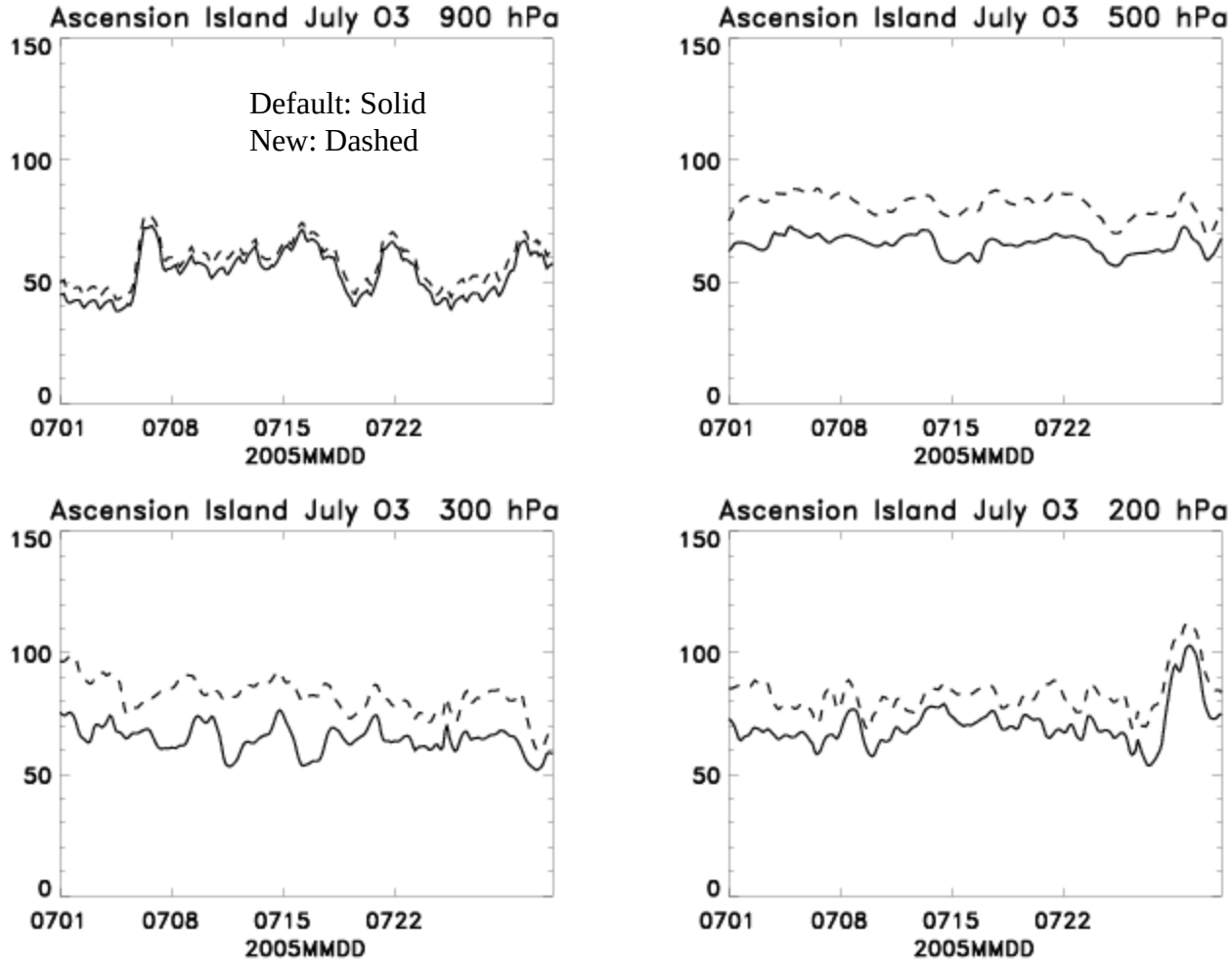

GEOS4DAS O3 Default lightning jan
Height (km)
15
10
5
0
Pressure (hPa)
1000
−90
−60
−30
0
30
60
90
Latitude
GEOS4DAS O3 New lightning jan
Height (km)
15
10
5
0
Pressure (hPa)
1000
−90
−60
−30
0
30
60
90
Latitude
0 10 20 30 40 50 60 70 80 90 100 120 150 200 400 600 1000 2500
ppbv

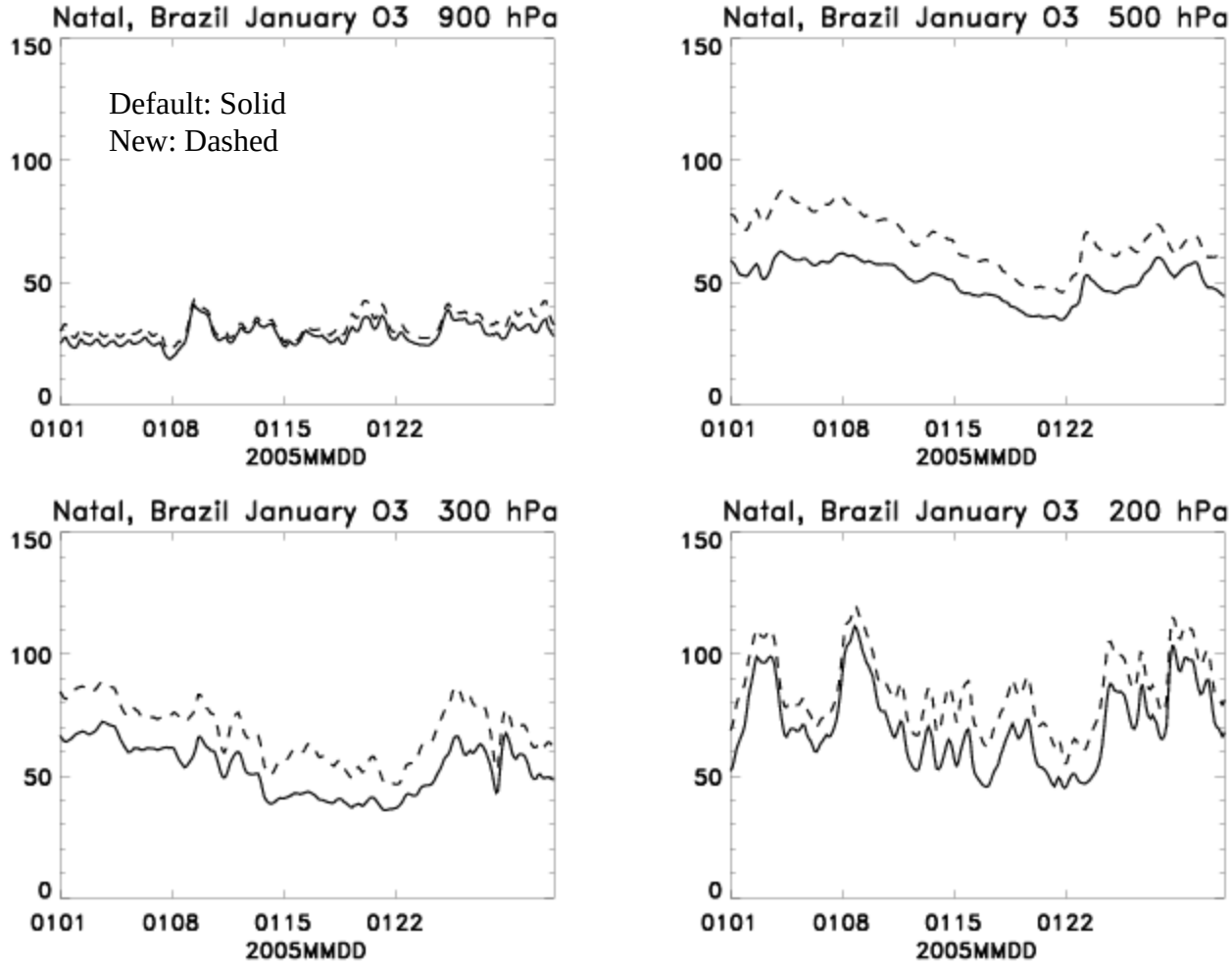

GEOS4DAS O3 Default lightning apr
Height (km)
15
10
5
0
−90
−60
−30
0
30
60
90
Latitude
1000
Pressure (hPa)
GEOS4DAS O3 New lightning apr
Height (km)
15
10
5
0
−90
−60
−30
0
30
60
90
Latitude
1000
Pressure (hPa)
0 10 20 30 40 50 60 70 80 90 100 120 150 200 400 600 1000 2500
ppbv

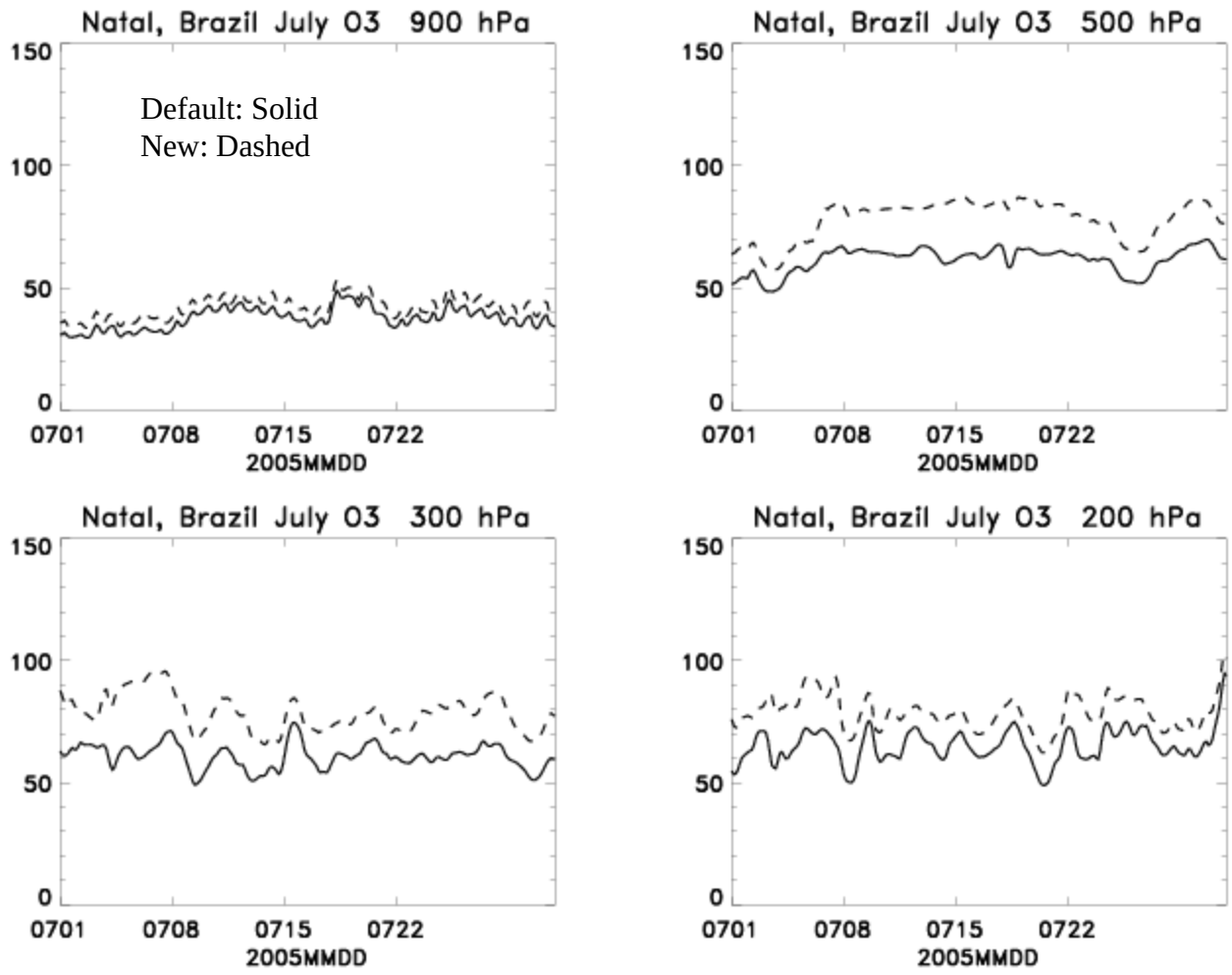

GEOS4DAS O3 Default lightning jul
Height (km)
15
10
5
0
−90
−60
−30
0
30
60
90
Latitude
1000
Pressure (hPa)
GEOS4DAS O3 New lightning jul
Height (km)
15
10
5
0
−90
−60
−30
0
30
60
90
Latitude
1000
Pressure (hPa)
0 10 20 30 40 50 60 70 80 90 100 120 150 200 400 600 1000 2500
ppbv

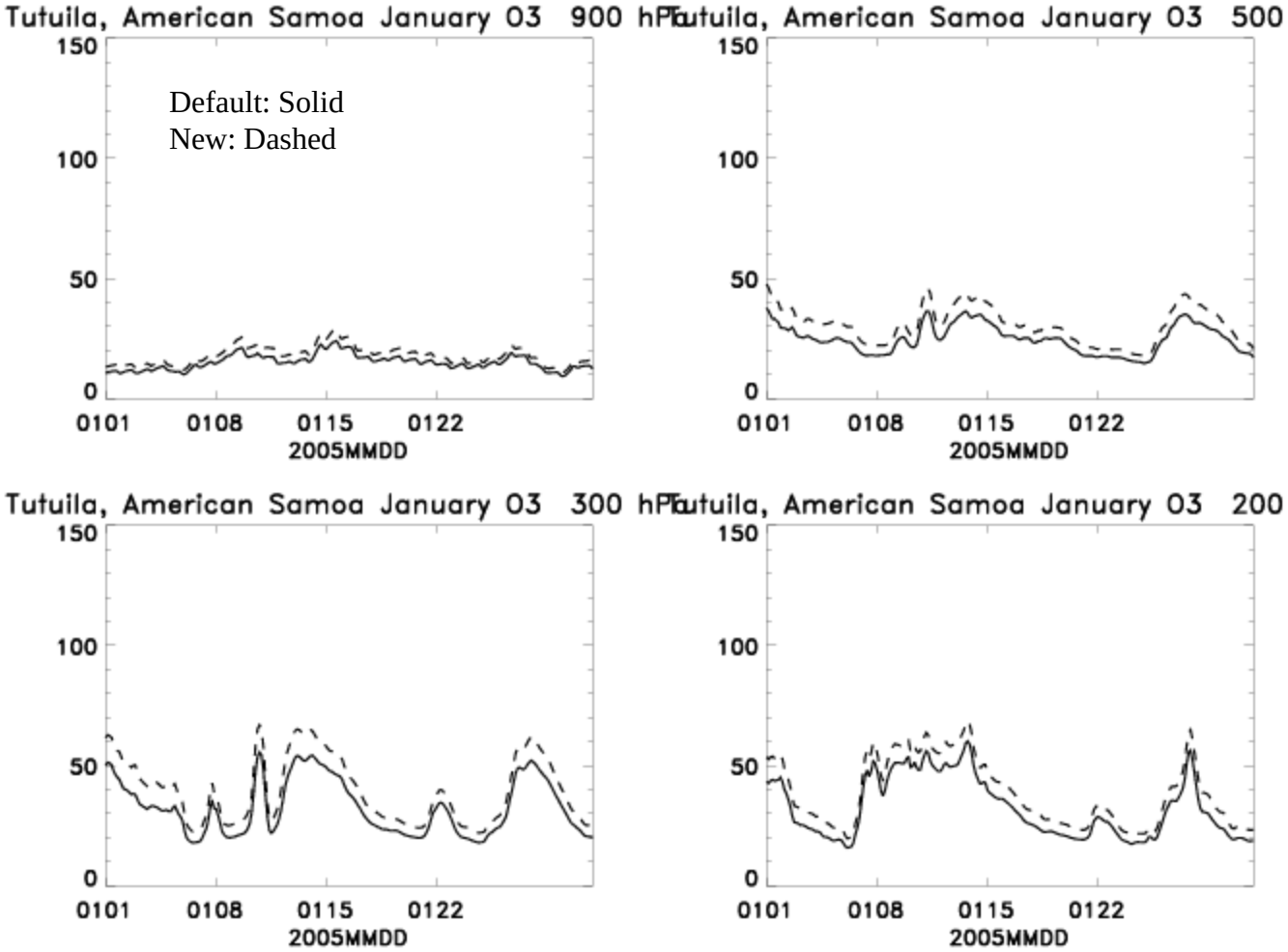

GEOS4DAS O3 Default lightning oct
Height (km)
15
10
5
0
−90
−60
−30
0
30
60
90
Latitude
1000
Pressure (hPa)
GEOS4DAS O3 New lightning oct
Height (km)
15
10
5
0
−90
−60
−30
0
30
60
90
Latitude
1000
Pressure (hPa)
0 10 20 30 40 50 60 70 80 90 100 120 150 200 400 600 1000 2500
ppbv

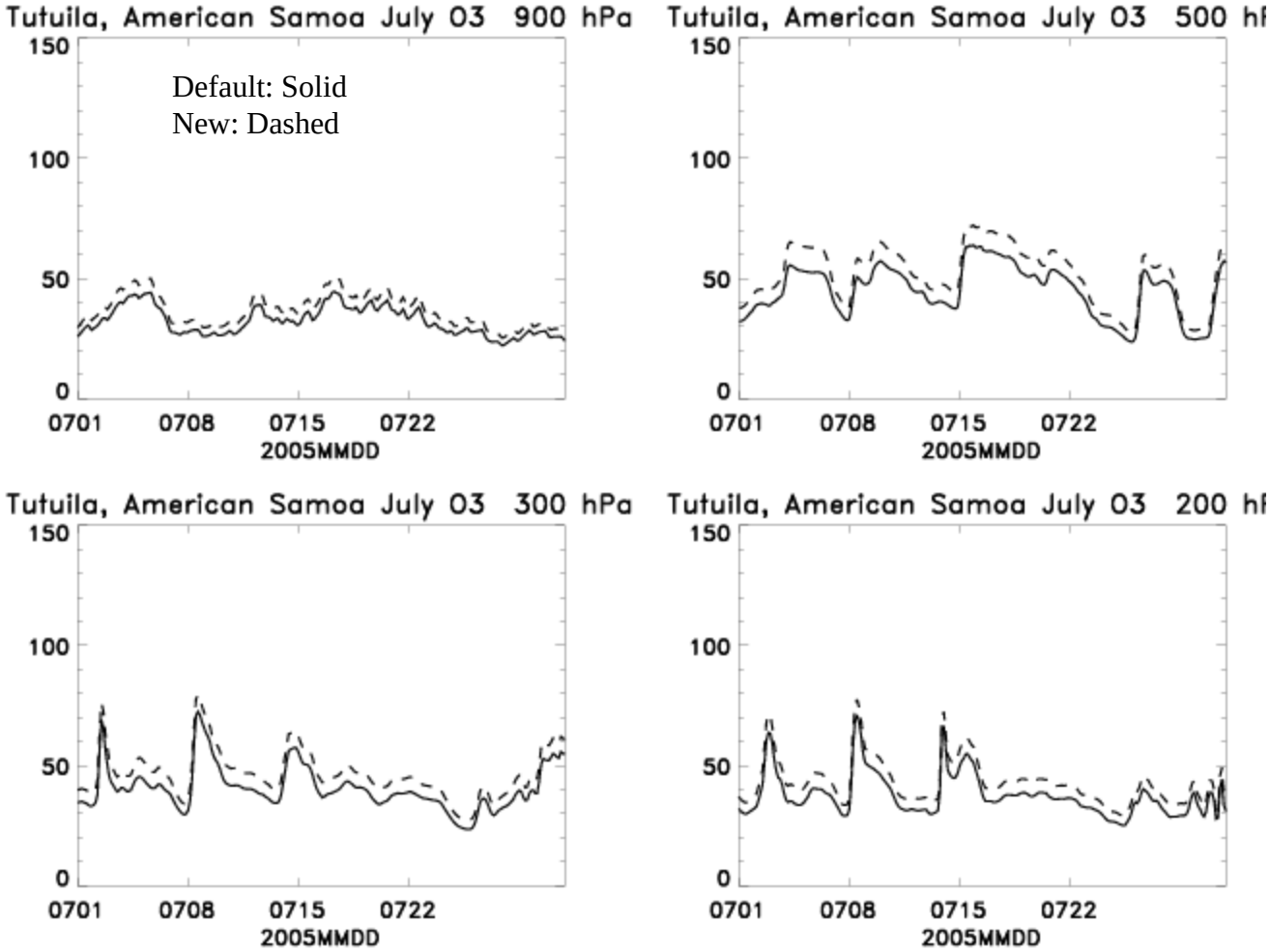

Ascension Island January O3 900 hPa
Default: Solid
New: Dashed
Ascension Island January O3 500 hPa
Ascension Island January O3 300 hPa
Ascension Island January O3 200 hPa
150
100
50
0
0101
0108
0115
0122
2005MMDD


Ascension Island July 03 900 hPa
Default: Solid
New: Dashed
Ascension Island July 03 500 hPa
Ascension Island July 03 300 hPa
Ascension Island July 03 200 hPa
150
100
50
0
0701
0708
0715
0722
2005MMDD


Natal, Brazil January 03 900 hPa
Default: Solid
New: Dashed
Natal, Brazil January 03 500 hPa
Natal, Brazil January 03 300 hPa
Natal, Brazil January 03 200 hPa
150
100
50
0
0101
0108
0115
0122
2005MMDD


Natal, Brazil July 03 900 hPa
Default: Solid
New: Dashed
Natal, Brazil July 03 500 hPa
Natal, Brazil July 03 300 hPa
Natal, Brazil July 03 200 hPa
150
100
50
0
0701
0708
0715
0722
2005MMDD


Tutuila, American Samoa January 03 900 hPa
Tutuila, American Samoa January 03 500
Tutuila, American Samoa January 03 300 hPa
Tutuila, American Samoa January 03 200
Default: Solid
New: Dashed
150
100
50
0
0101
0108
0115
0122
2005MMDD


Tutuila, American Samoa July 03 900 hPa
Default: Solid
New: Dashed
Tutuila, American Samoa July 03 500 hP
Tutuila, American Samoa July 03 300 hPa
Tutuila, American Samoa July 03 200 hP
150
100
50
0
0701
0708
0715
0722
2005MMDD

Near-term Work Plan

- Run 2-year simulation using GEOS-4 GCM using new and default lightning.
- Perform comparisons of ozone using new and default lightning with ozonesondes, aircraft, and satellite (TES, MLS) data.
- Perform case study over SE US, comparing with IONS-04 sondes and ICARTT measurements in 2004 and Aura data and IONS-06 sondes in 2006.
- Test new vertical profiles of LNOx.
- Write paper