Assessing the sensitivity of lightning-NO emissions to climate change

ROSES-2008 Modeling, Analysis, and Prediction

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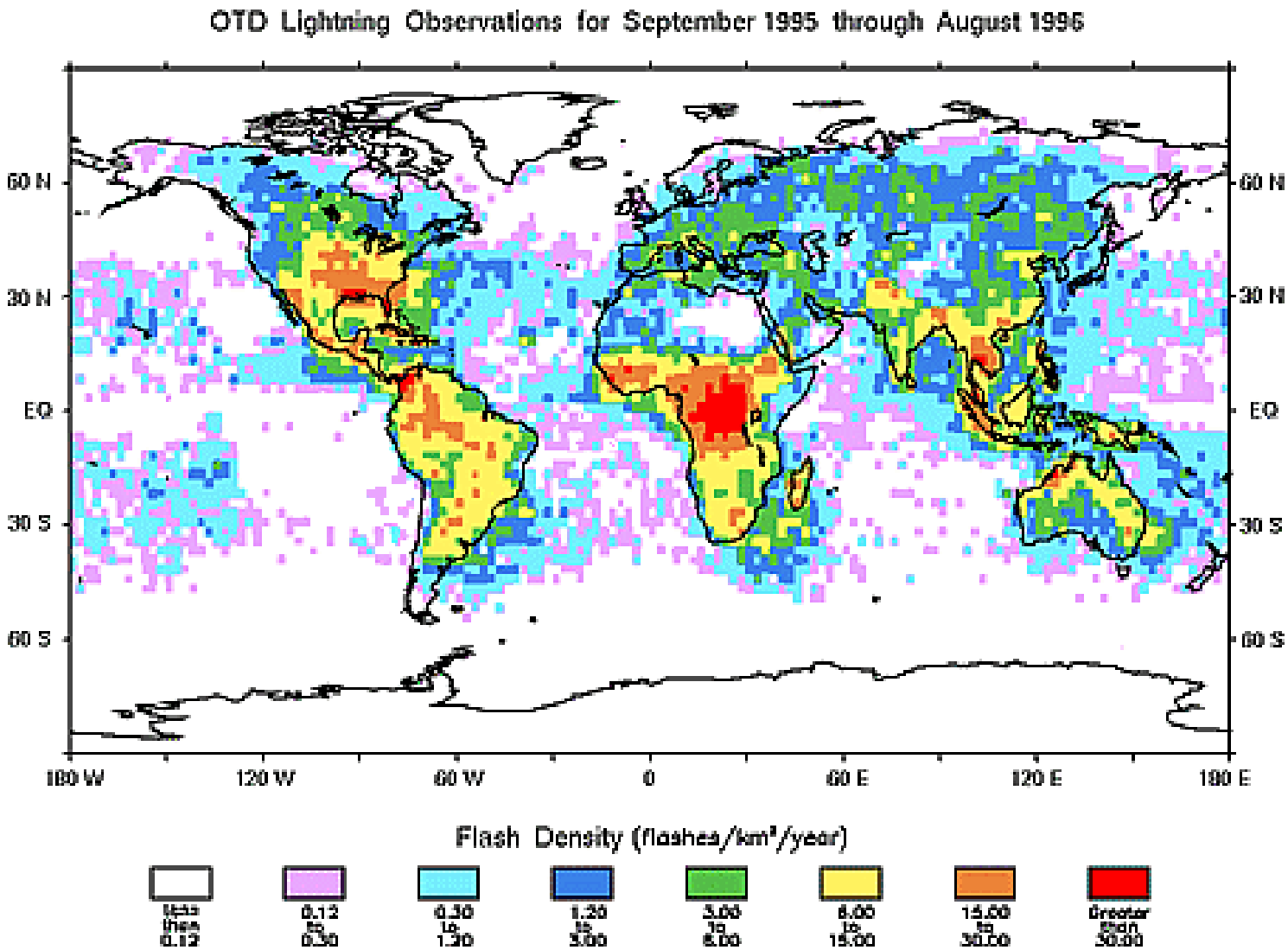
Project Summary

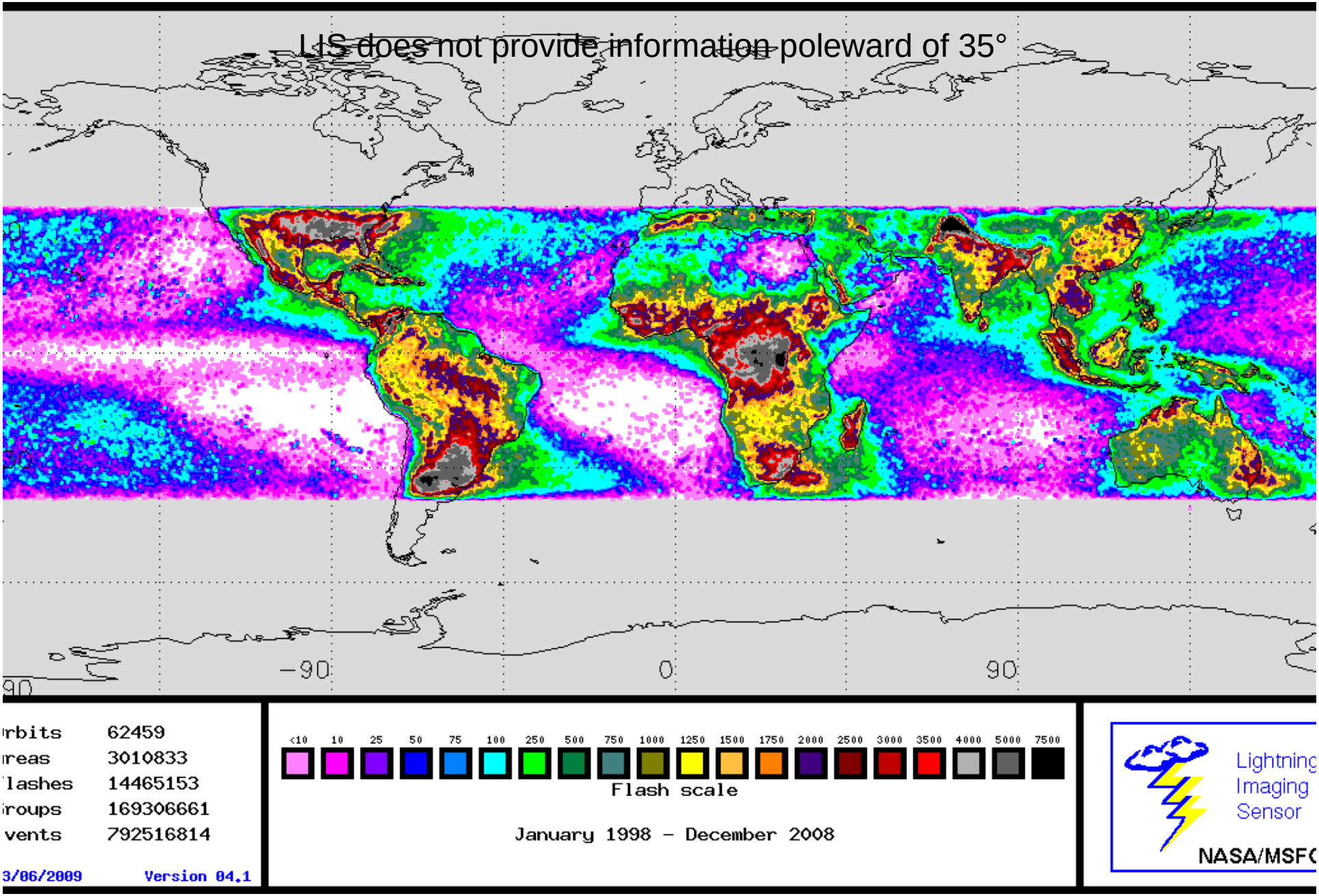
- **Motivation:**
- Lightning-NO emissions are positively correlated with surface temperature.
- Changes in lightning-NO emissions are tied to changes in surface temperature and associated changes in the location and intensity of deep convection.
- Theory and simulations suggest a positive feedback mechanism linking increases in lightning NO emissions with increases in upper tropospheric O_3, which in turn leads to increases in climate forcing. The associated increase in temperature may lead to additional increases in lightning-NO emissions closing the loop.

- **Goal:** Develop lightning-NO algorithms for the GEOS-5 CCM that are appropriate for use in a climate setting and to use these algorithms to evaluate the response of lightning-NO emissions and tropospheric chemistry to ENSO-driven and climate-driven changes in surface temperature and convective activity.

Where is lightning most common?

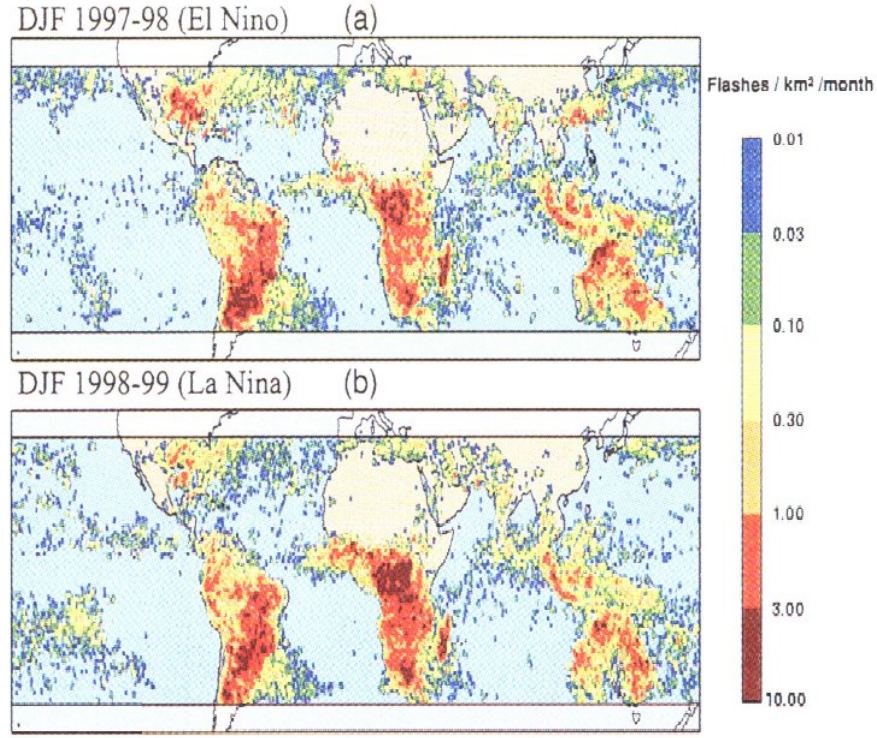


LIS does not provide information poleward of 35°



El Nino

La Nina



More flashes
In Gulf of Mexico, Indonesia, and Argentina

More flashes in Central Africa

Seasonal distribution of December-February lightning during the 1997-1998 El Niño (top panel) and 1998-1999 La Niña (bottom panel) periods. Flash rates derived from the LIS**.** Figure taken from *Goodman et al*. [2000].

Tasks

- Satellite-retrieved estimates of lightning flash rates will be correlated with various meteorological parameters from multi-year GEOS-5 GCM and GEOS-5 DAS simulations.

- Promising lightning-NO emission algorithms will be implemented in the GEOS-5 CCM. Possibilities include convective mass flux based schemes, cloud-top height based schemes (with alternate marine parameterization?), cold-cloud depth based schemes, and/or ice-water content based schemes.

- Cloud-top heights and convective precipitation rates are predicted to increase under a warming climate. Will cold-cloud depths also increase? What impact will these increases have on flash rates?

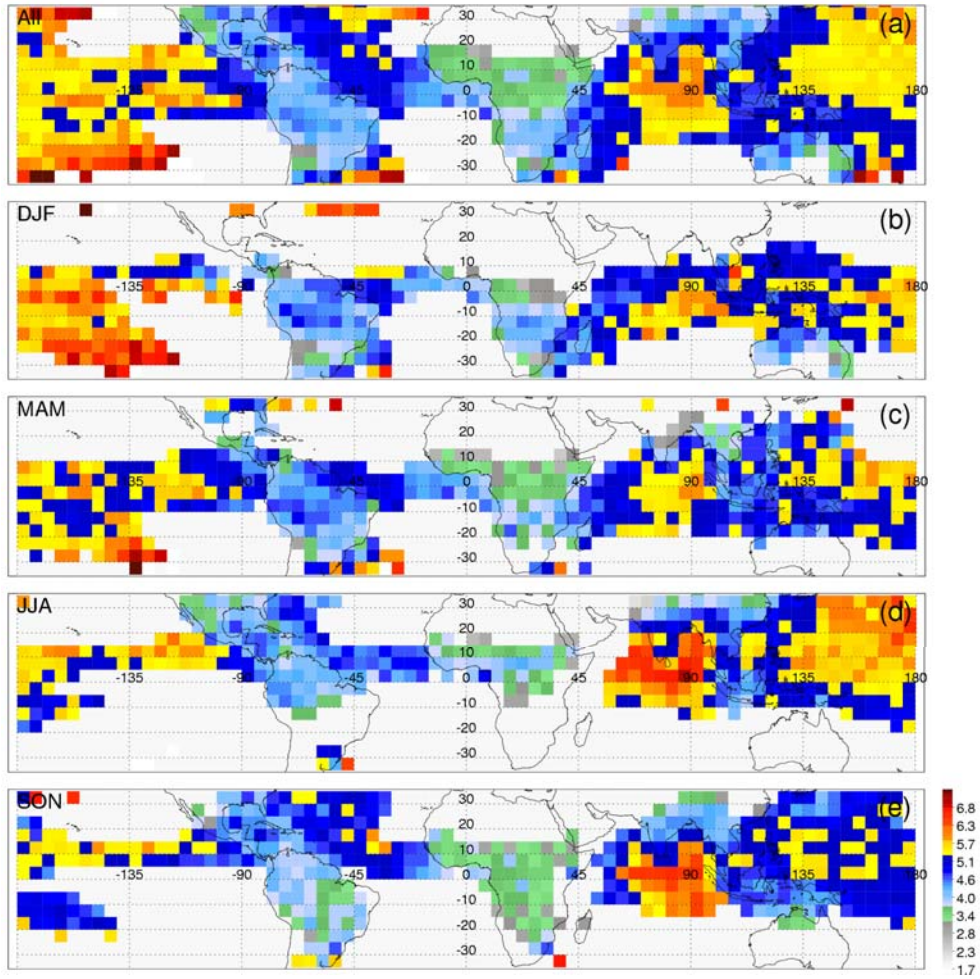
- The sensitivity of flash rates from these schemes to variations in temperature and convection will be evaluated, and contrasts in flash rates between El Niño and La Niña time periods will be examined.

- The implementation of various lightning-NO algorithms into the GEOS-5 CCM will allow us to investigate the uncertainties associated with future lightning-NO emissions.

- CCM simulations will be run for these time periods and the contrast in NO_2 and O_3 during these periods will be compared to contrasts in these species between the Sep 2006 – Feb 2007 El Niño and Sep 2007 – Feb 2008 La Niña periods.

- Can satellite-retrieved cloud top heights lead to improved flash rate parameterizations?
- Flash rates are more closely related to CLDHTs determined using TRMM-PR (which is sensitive to the vertical extent of ice within a cloud) than to CLDHTs determined using the TRMM-VIRS.

TRMM-VIRS CLDHT - TRMM-PR CLDHT (kms)



Annual

DJF

MAM

JJA

SON

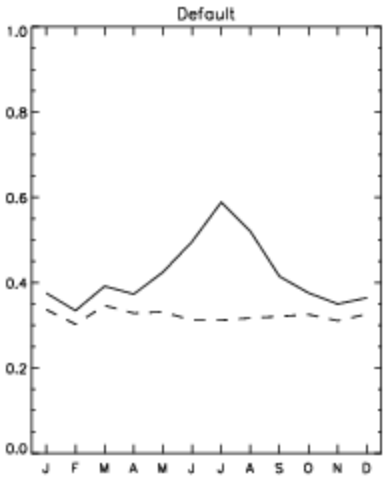
Biases between “VIRS” CLDHTS and “PR” CLDHTS are largest (smallest) over marine locations (central Africa) where CLDHT-based flash rates are overestimated (underestimated) [Plot taken from *Liu et al*., 2007].

Wish list for flash rate pararameterizations?

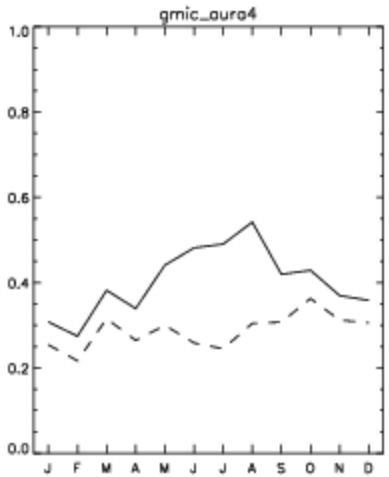
- Convective cloud top heights and/or fractions
- Convective mass fluxes (both in UT and integrated through the cloud depth)
- Convective precipitation rate
- CAPE
- Graupel volume and/or flux
- Precipitation-sized Ice water content integrated through cloud depth and/or its flux (Can detrained ice water content be used as a proxy?)
- Cold-cloud depth (depth of convective cloud above the 0°C isotherm). Temperature distribution needed.
- Vertical wind shear (impacts lightning NO production per flash)

Flash rates as a function of month for various simulations/scenarios

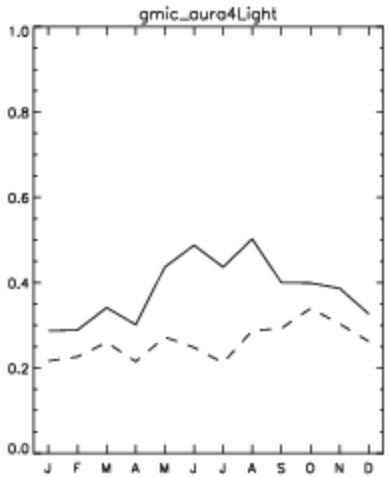
ISCCP climatology

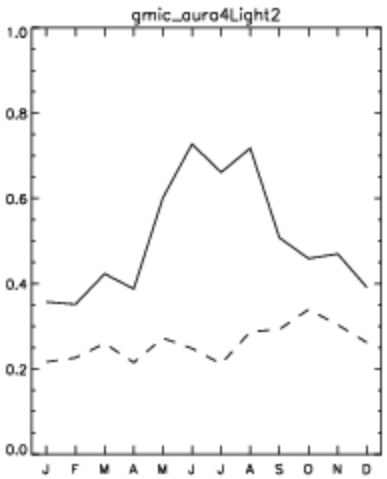


Gmic_aura4

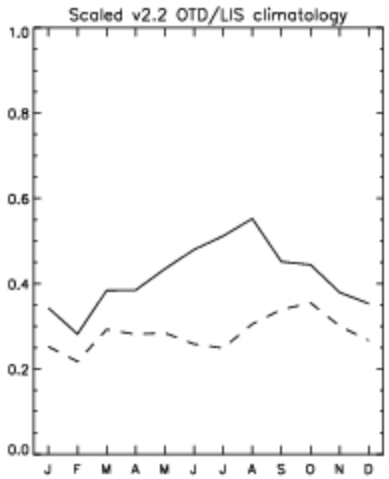


GMIc_aura4Light

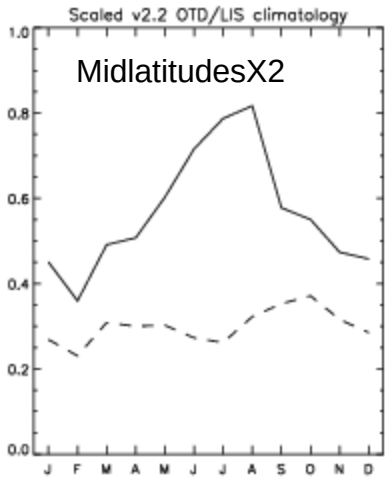




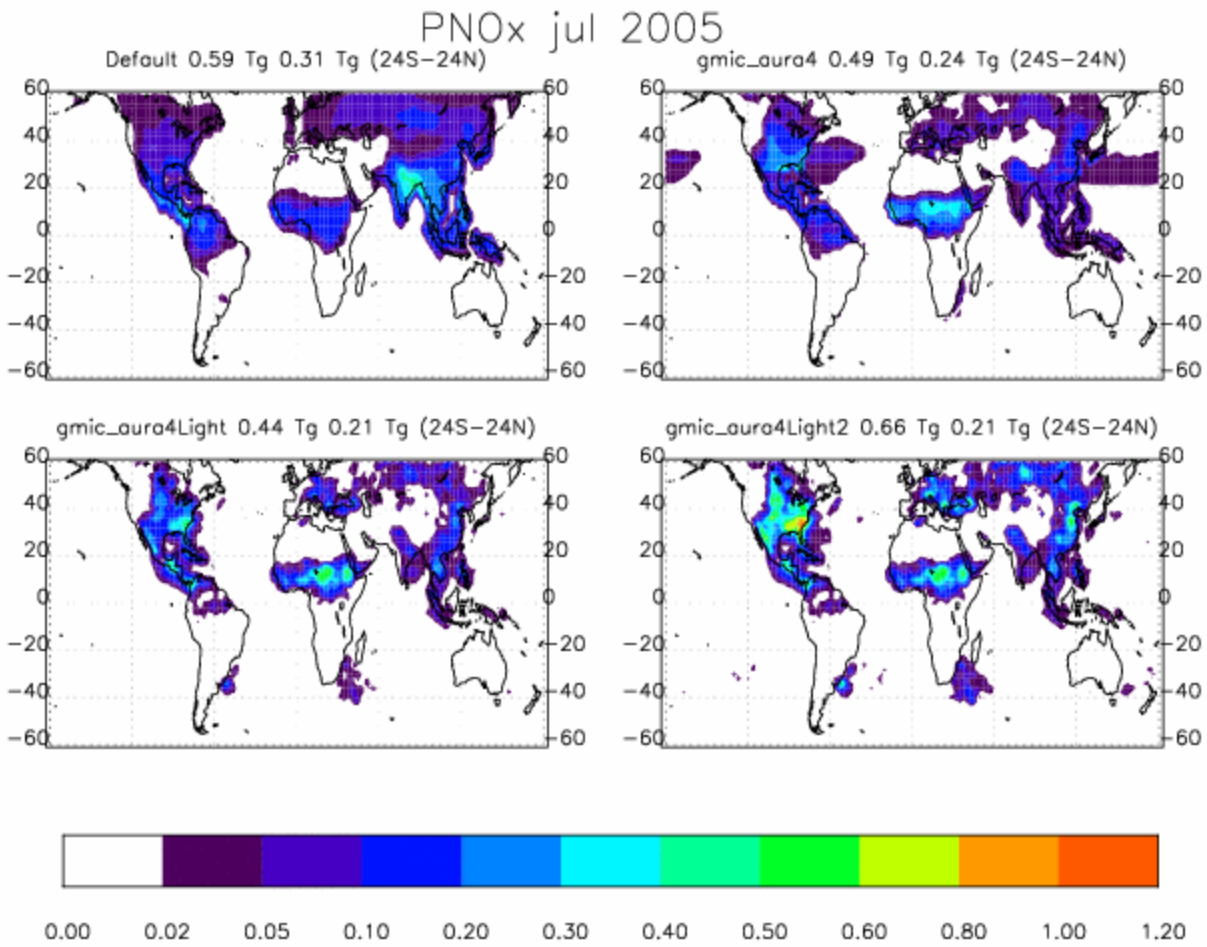
GMIc_aura4Light2



Scaled OTD/LIS



Scaled OTD/LIS


PNOx jul 2005
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gmic_aura4 0.49 Tg 0.24 Tg (24S−24N)
gmic_aura4Light 0.44 Tg 0.21 Tg (24S−24N)
gmic_aura4Light2 0.66 Tg 0.21 Tg (24S−24N)
60
40
20
0
−20
−40
−60
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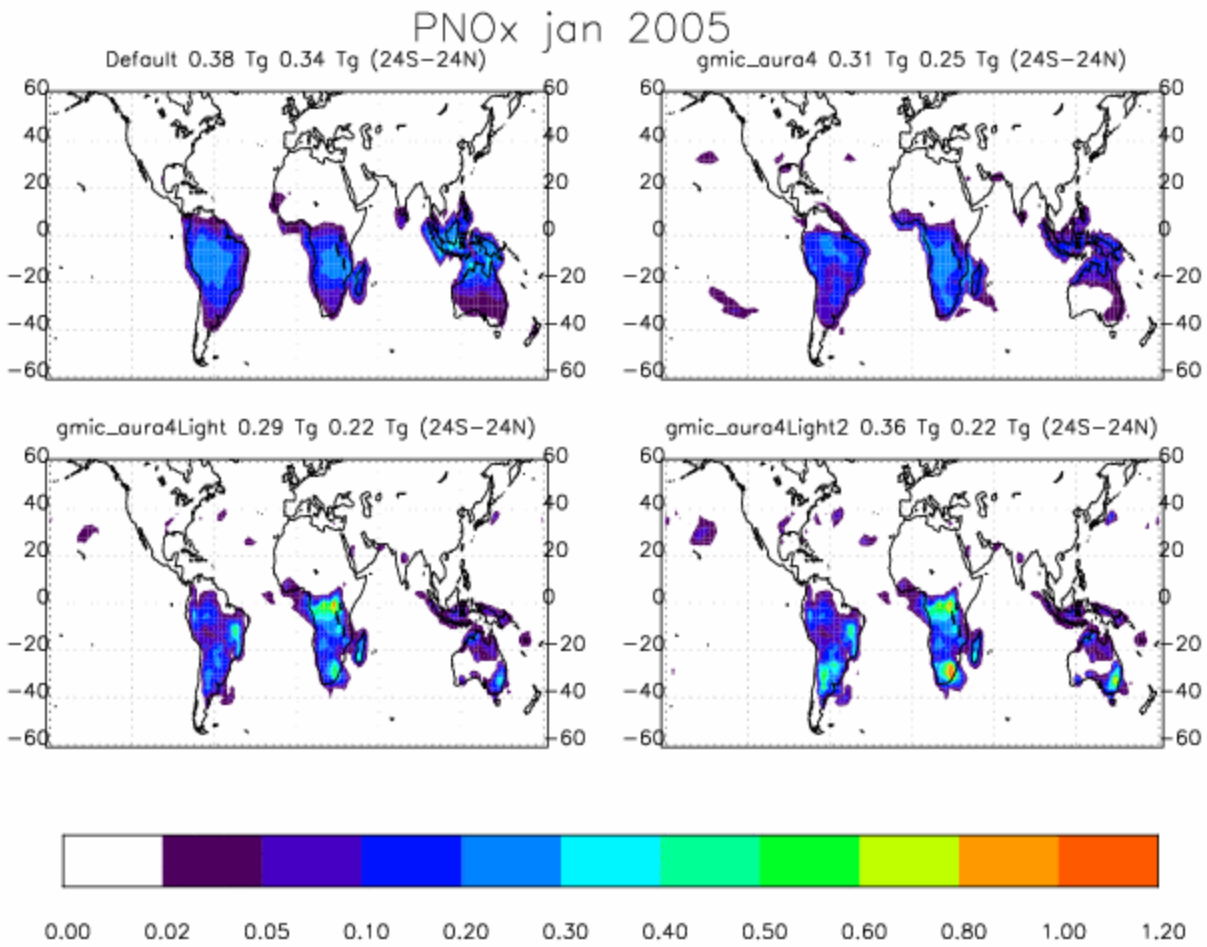
0.20
0.30
0.40
0.50
0.60
0.80
1.00
1.20


PNOx jan 2005
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gmic_aura4Light 0.29 Tg 0.22 Tg (24S−24N)
gmic_aura4Light2 0.36 Tg 0.22 Tg (24S−24N)
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