Representativeness of CO and O_3 along ATom Transects Derived from GEOS-5 and GMI-CTM Simulations

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Motivation

One major goal for ATom is producing an observation-based chemical climatology to represent the atmospheric heterogeneity.

- Important to assess the representativeness of ATom transects.
- Global atmospheric models can extend the reach of ATom transects by providing a 4D perspective of chemical variations.

Key Questions:

- Can ATom measured CO & O_3 variations be reproduced by models?
- How representative are CO & O_3 variations along the ATom transects relative to the surrounding broader regions (ATom-1 and -2)?

Approach:

An integrated statistical analysis of observation and modeling.

Data and model

Observations:

- QCLS CO from Harvard (obs CO)
- NO_yO_3 from NOAA ESRL (obs O_3)

Models:

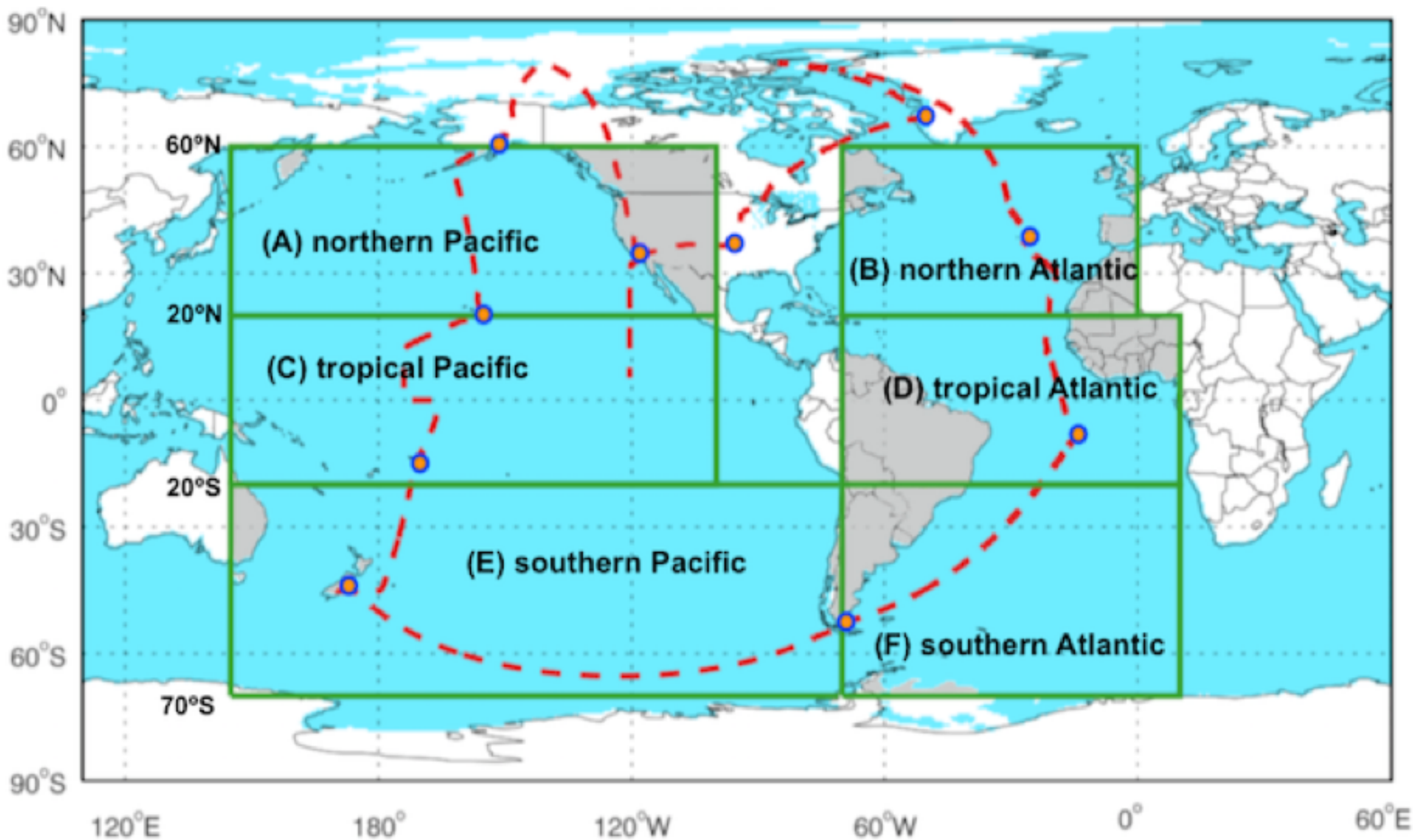
CO from GEOS-5 FP analysis/Forecast (GOCART module)

- Loss – reaction with OH climatology;
- Source – direct emission, oxidation of VOCs through biomass burning (BB) and biogenic activities.
- 0.3125° x 0.25° lon-lat, 3-hr output frequency
- Emissions: HTAP fossil fuel; QFED BB.

O_3 from GMI-CTM hindcast simulation

- NO_X-O_3-VOC-aerosol chemistry
- 1.25°x1° lon-lat, 3-hr output frequency
- Emissions: EDGAR + others FF; QFED BB.

Strategy



1. **Evaluate model performance -** Compare probability density functions (PDFs) of observed and simulated CO & O_3 along the ATom transects.
2. **Assess CO & O_3 representativeness of ATom transects -** Compare PDFs of model simulations sampled along the ATom transects to those over their surrounding broader regions.

Probability density functions (PDFs)

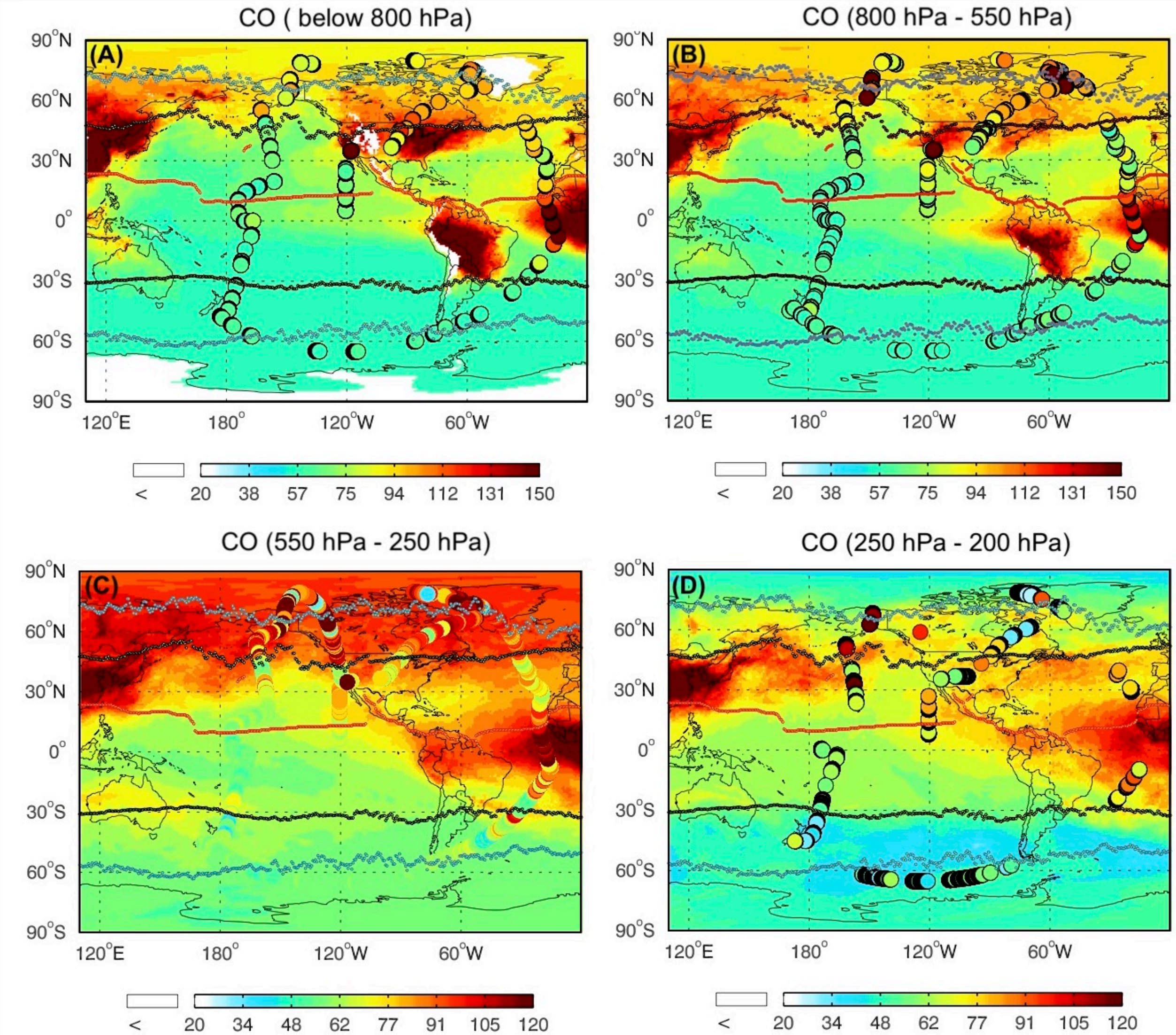
- ***Weighted PDFs:***
  - ATom sampling is biased towards the marine boundary layer (0-2 km) and the cruise level (8-10 km) - Inversely applying sampling weight at each 100-hPa pressure interval to balance the un-uniform sampling.
  - Shape of PDFs
    - Narrowly peaked PDF – uniform air masses.
    - Wide and/or multimodal PDF – heterogeneous air of different origins.

- ***S_{scores}: metric for the overlap of two PDFs***
  - Summing up the minimum PDF from either distribution.
  - S_{score} equals 1.00 when two normalized PDFs are identical.
  - S_{score} goes to 0.00 for separated PDFs.
  - S_{scores} can depend on bin width. We use 2ppb in this study.

GEOS-5 reproduces the global-scale CO patterns observed from ATom-1 (Jul-Aug 2016)

Below 500 hPa: Localized CO max. over continents.

UT: Strong intercontinental transport of polluted air within the jet system.



Map: GEOS-5 CO avg. over flight days and the pressure range.
Circles: observed CO within the pressure range.

Polar Jet (PJ)

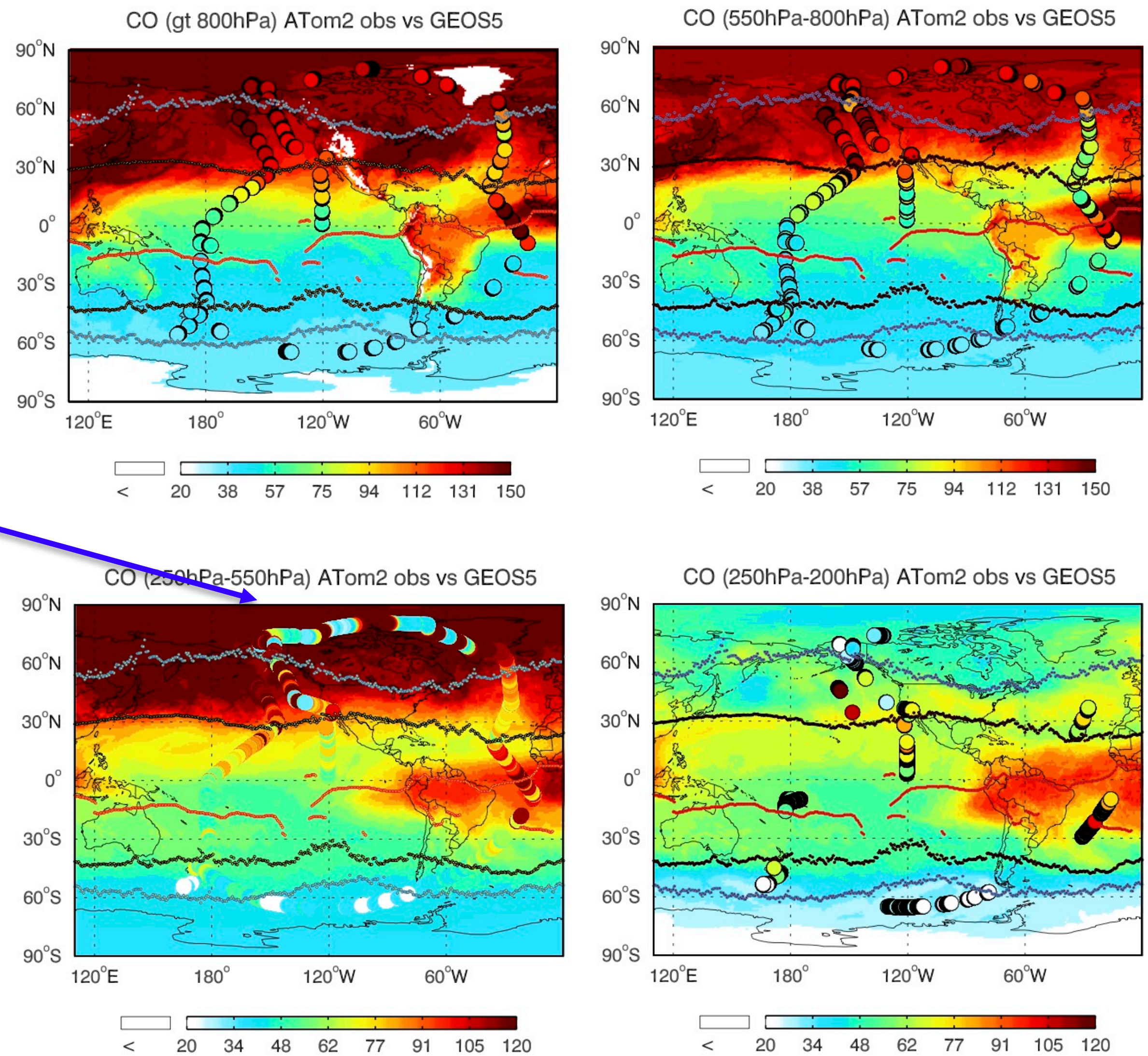
Subtropical Jet (STJ)

ITCZ

Tropical Atlantic CO max.: southern Africa and South America BB.

- **CO mixing ratios are generally greater at mid-latitudes in the northern hemisphere (NH) than the southern hemisphere (SH), in the tropical Atlantic than the tropical Pacific.**

GEOS-5 reproduces the global-scale CO patterns observed from ATom-2 (Jan-Feb 2017)

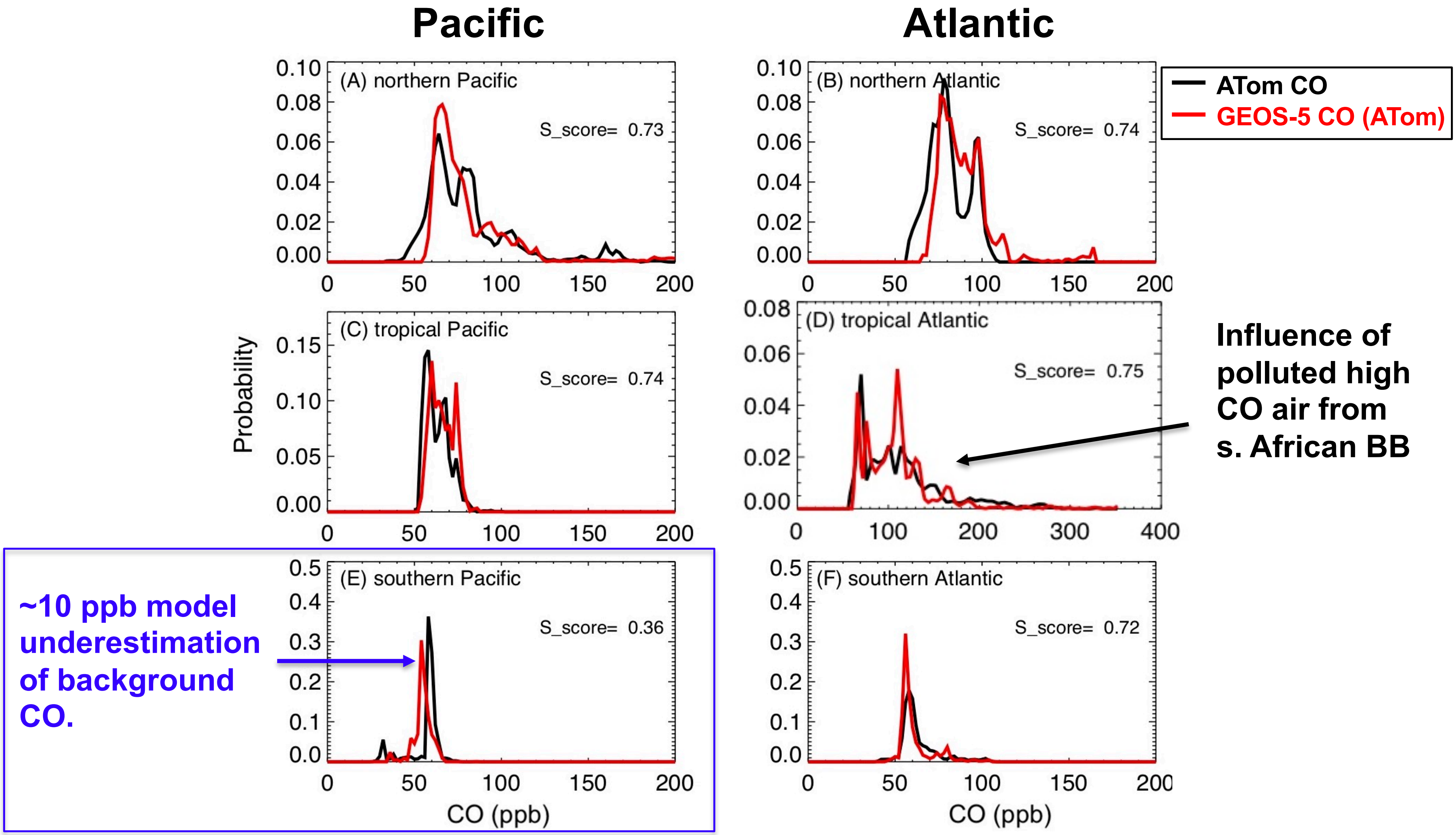


Stratospheric measurements

Trop. Atlantic CO max.: collocation of high CO transported from N. Africa by Harmattan winds in LT & strong vertical mixing near ITCZ.

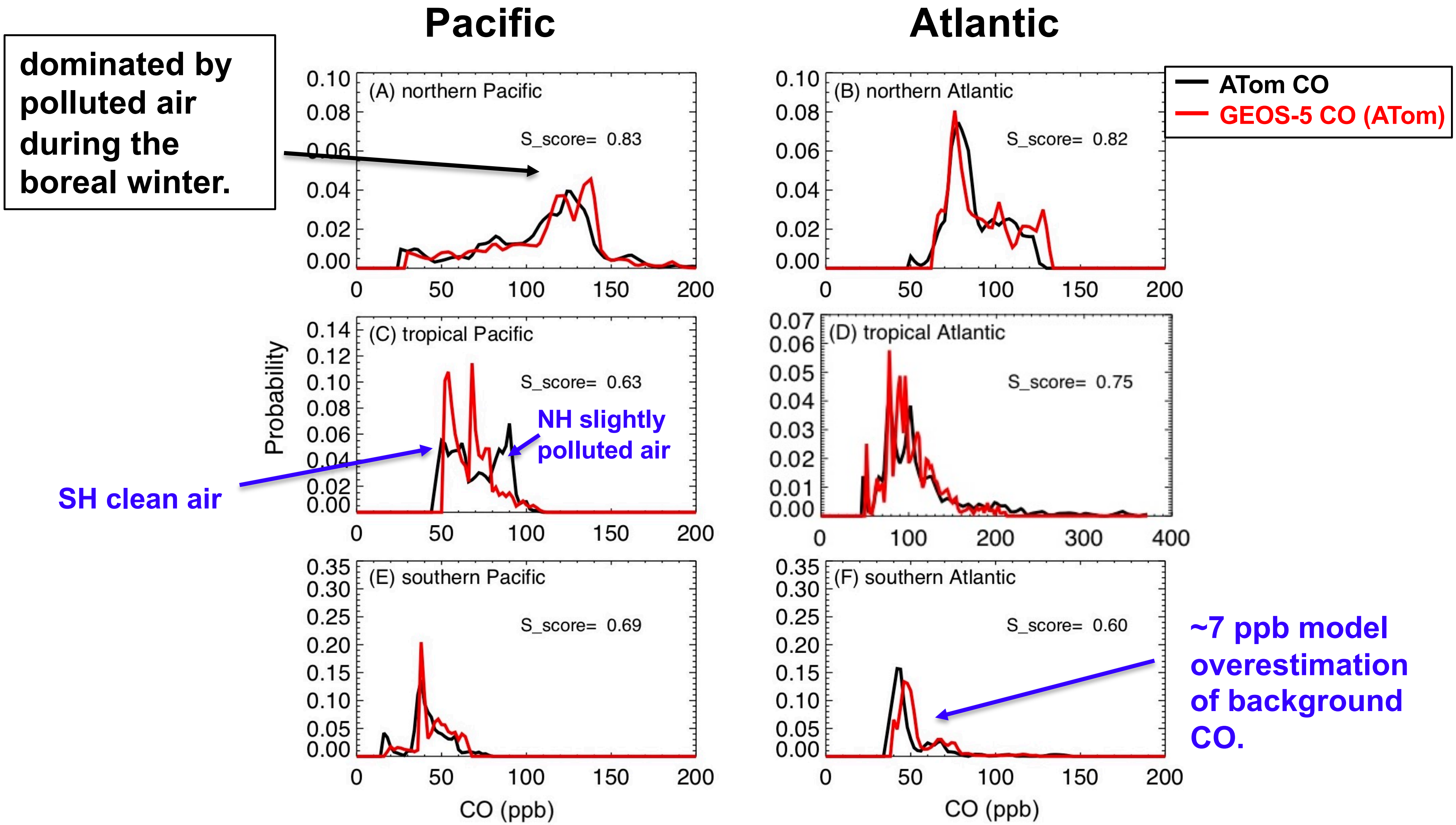
- **Polluted CO-laden air exists from the surface to the free troposphere (300 hPa) north of the NH STJ. CO shows a large latitudinal gradient south of the NH STJ.**
- **SH Background CO is lower in the ATom-2 period than that in the ATom-1 period.**

PDFs of observed and simulated CO along ATom-1 transects



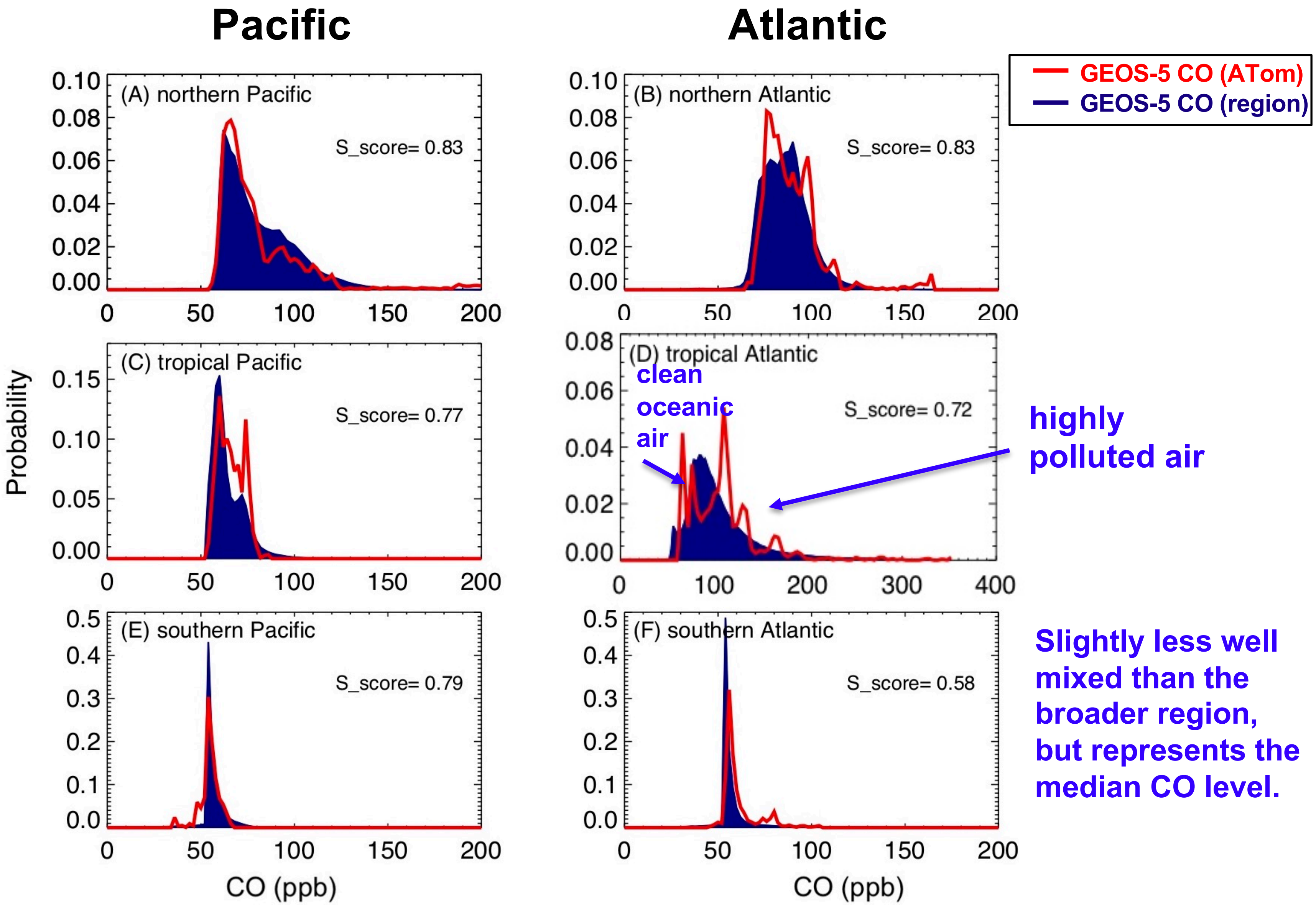
The model captures the observed median CO concentration (peak) and the width of distribution well (S_{score} > 0.7) over most regions, except for the southern Pacific.

PDFs of observed and simulated CO along ATom-2 transects



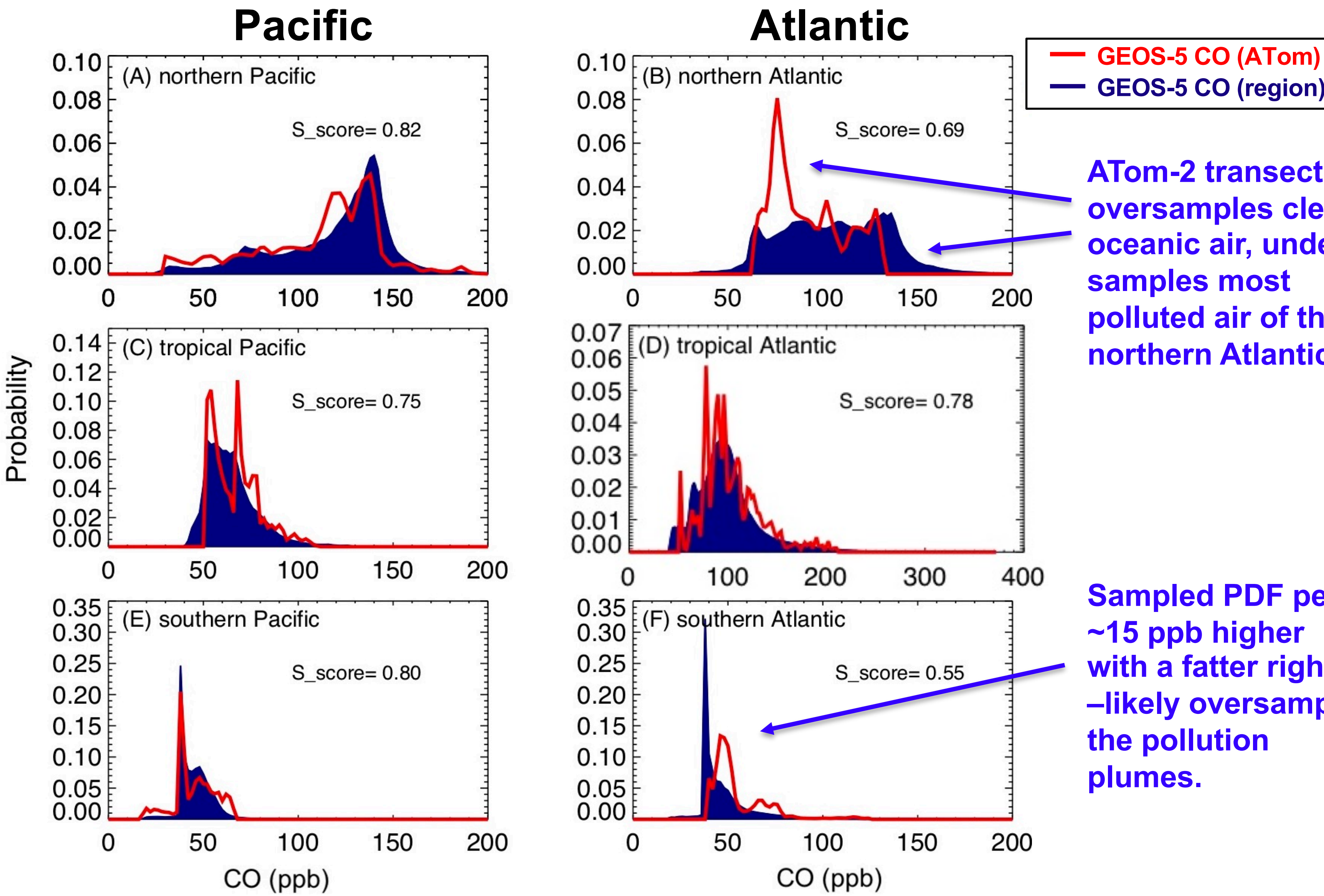
PDFs from both observed and simulated CO along the ATom-2 transect have similar peaks and widths over most regions, except for the tropical Pacific and southern Atlantic.

CO representativeness for ATom-1 (Jul-Aug 2016) transects



CO sampled along the ATom-1 transects is likely representative of typical regional variations over the whole Pacific and the northern Atlantic.

CO representativeness for ATom-2 (Jan-Feb 2017) transects



ATom-2 transect oversamples clean oceanic air, under-samples most polluted air of the northern Atlantic

Sampled PDF peaks ~15 ppb higher with a fatter right tail –likely oversamples the pollution plumes.

CO sampled along the ATom-2 transects is likely representative of typical CO variations over the whole Pacific and the tropical Atlantic.

GMI-CTM simulation reproduce observed global-scale O_3 patterns from ATom-1 (Jul-Aug 2016)

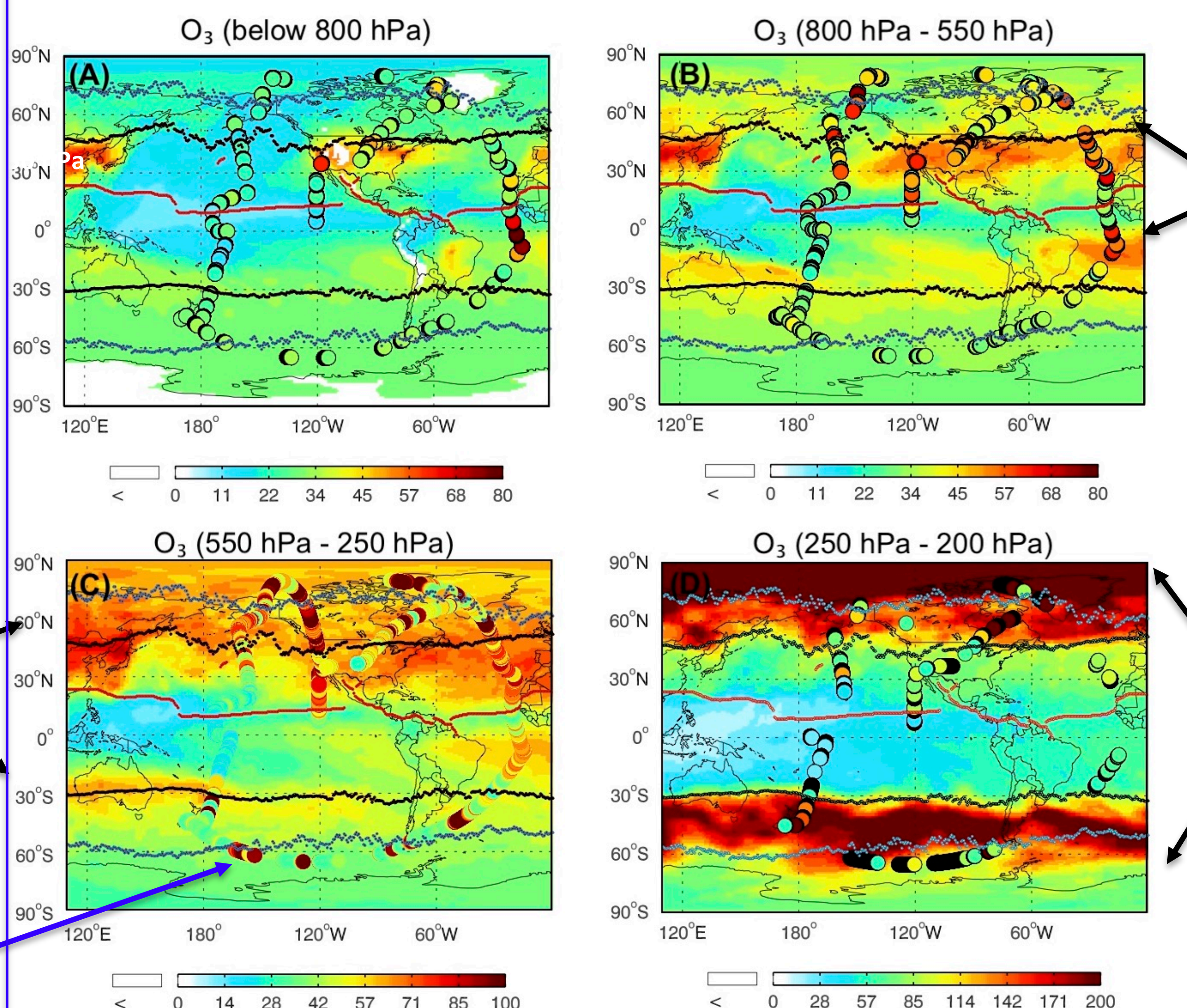
Localized O_3 max. (NH): anthro. emission and July-August 2016 heat waves

Elevated O_3 along the southern flank of the NH STJ, and over southern tropical Atlantic

Elevated O_3 along the STJs by STE

Lower stratospheric ozone over Antarctica than Arctic

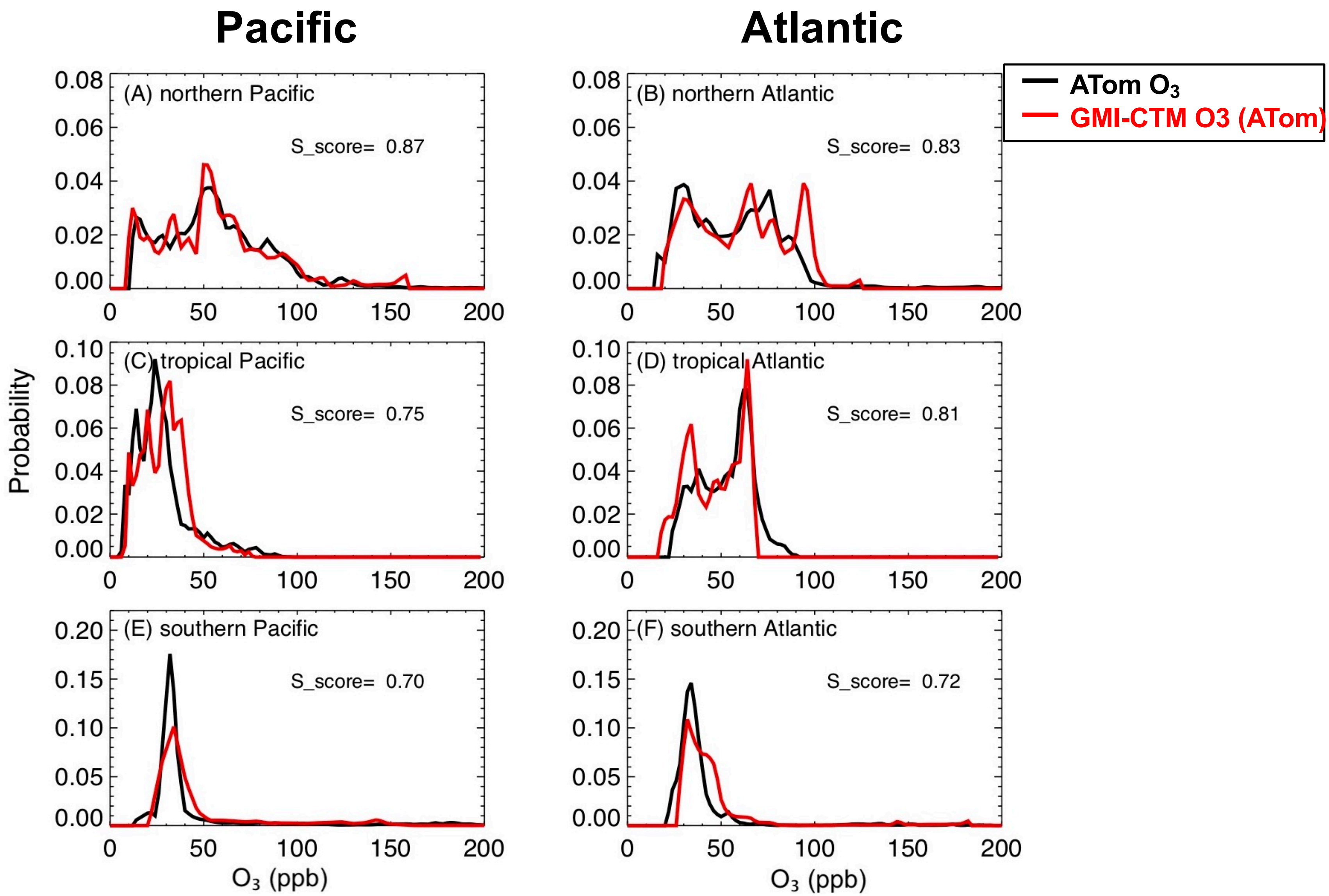
Stratospheric observations



Map: GMI-CTM O_3 avg. over flight days and the pressure range.
Circles: observed O_3 within the pressure range.

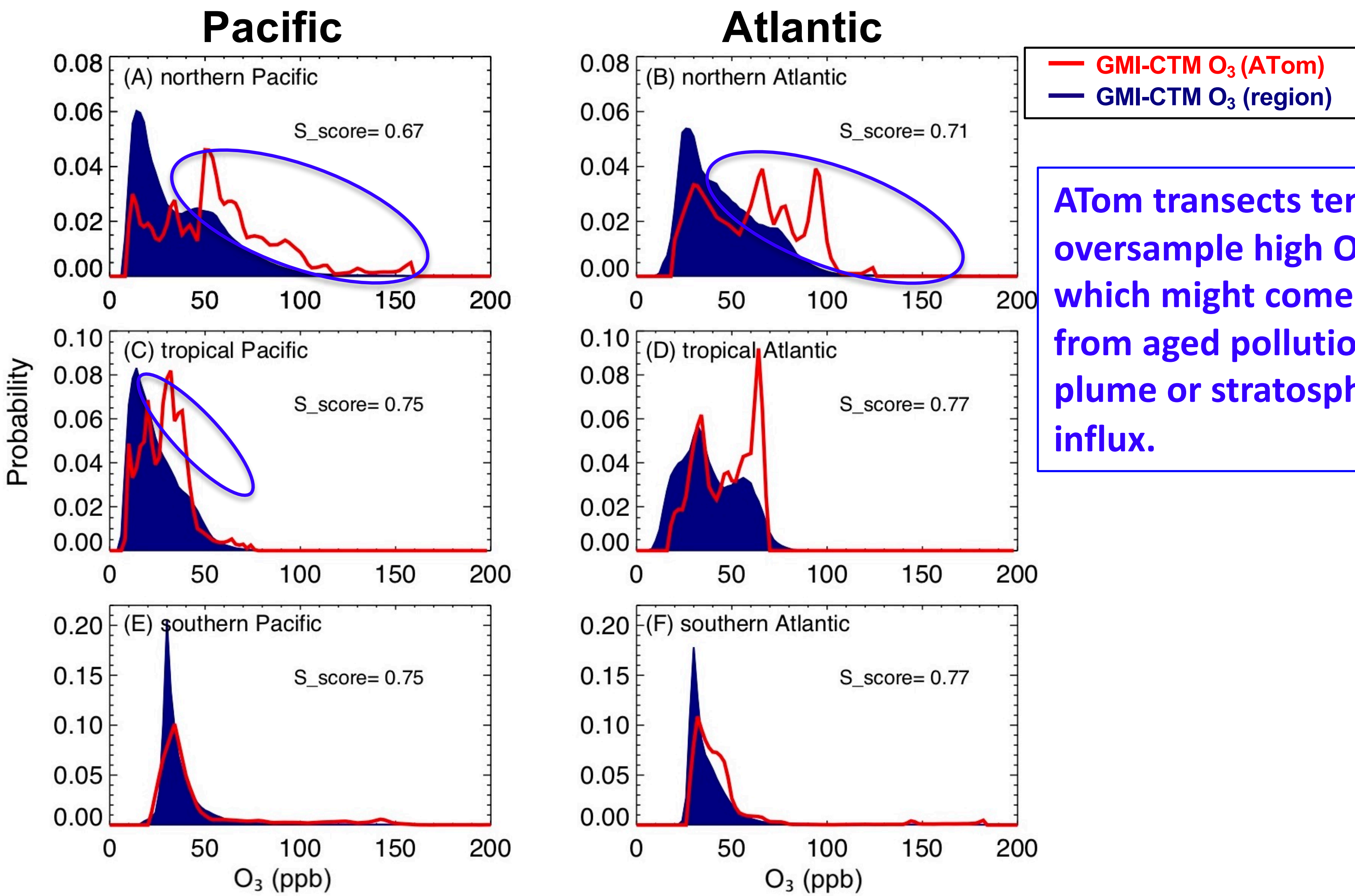
Both model and observations show tropospheric ozone minimum near the west Pacific warm pool

PDFs of observed and simulated O_3 along ATom-1 transects



- The PDFs from simulated O_3 agree well with those from observations with respect to the peaks and the width over all six regions.
- The width of both observed and simulated PDFs decreases from the NH to SH.

O_3 representativeness for ATom-1 (Jul-Aug 2016) transects



ATom transects tend to oversample high O_3 air, which might comes from aged pollution plume or stratospheric influx.

The PDFs from O_3 sampled along ATom transects and over their surrounding regions show fair to good agreements over all six regions ($S_{scores} \geq 0.67$), but they do show discrepancies over some regions.

Conclusion

CO:

- **The GEOS-5 model reproduces the observed CO variations during the ATom-1 (Jul-Aug 2016) and -2 (Jan-Feb 2017) periods.**
- **Representativeness:**
  - The CO variations along the ATom-transect are likely representative of the typical variations over the whole Pacific basin and the northern Atlantic during the ATom-1 period, the whole Pacific basin and the tropical Atlantic in the ATom-2 period.

O_3:

- **The GMI-CTM reproduces the observed O_3 variations.**
- **Representativeness:**
  - The agreements between PDFs of O_3 sampled along the ATom transects and over the broader regions are fair to good over all six regions with notable discrepancies over some regions in the ATom-1 period.
  - Over the northern Pacific, the northern Atlantic and the tropical Pacific, ATom transects tends to oversample high O_3 air, which might come from aged pollution plume or stratospheric influx.