Evaluating GPP and respiration estimates over northern mid-latitude ecosystems using solar induced fluorescence and atmospheric CO_2 measurements

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Can we constrain large scale CO_2 fluxes?

$$NEE = GPP + Re$$

Net Ecosystem Exchange
Atmospheric CO_2 observations:

- Surface sites (1958 – present)
- SCIAMACHY (2002 – 2012)
- TCCON (2004 – present)
- GOSAT (2009 – present)
- OCO-2 (2014 – present)
- GHGSat (2016 – present)
- TanSat (2016 – present)

Gross Primary Productivity
Solar Induced Florescence (SIF):

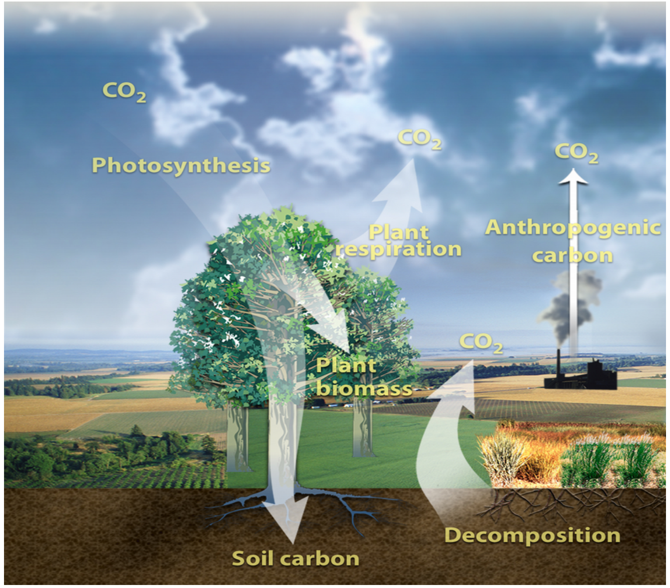
- GOME-2 (2006 – present)
- GOSAT (2009 – present)
- OCO-2 (2014 – present)
- TROPOMI (2017 – present)

(retrieval since ~2011)

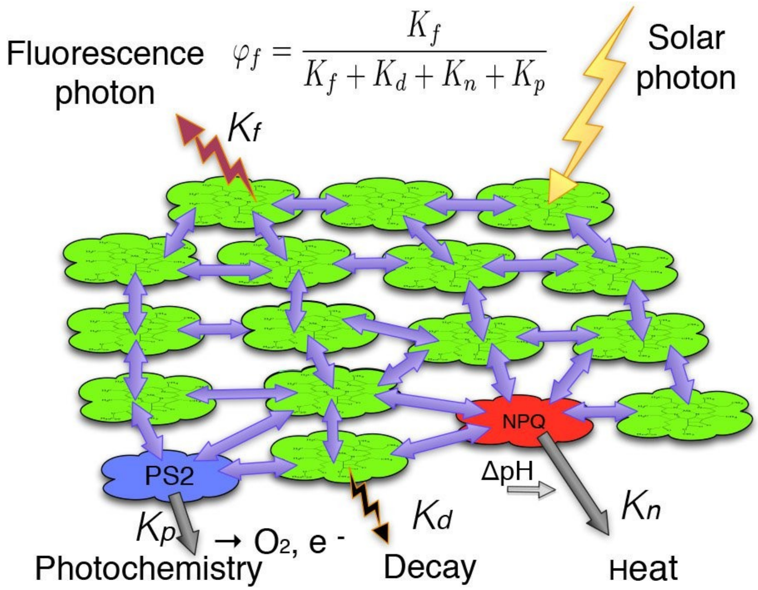
Ecosystem Respiration
No constraints

Objective

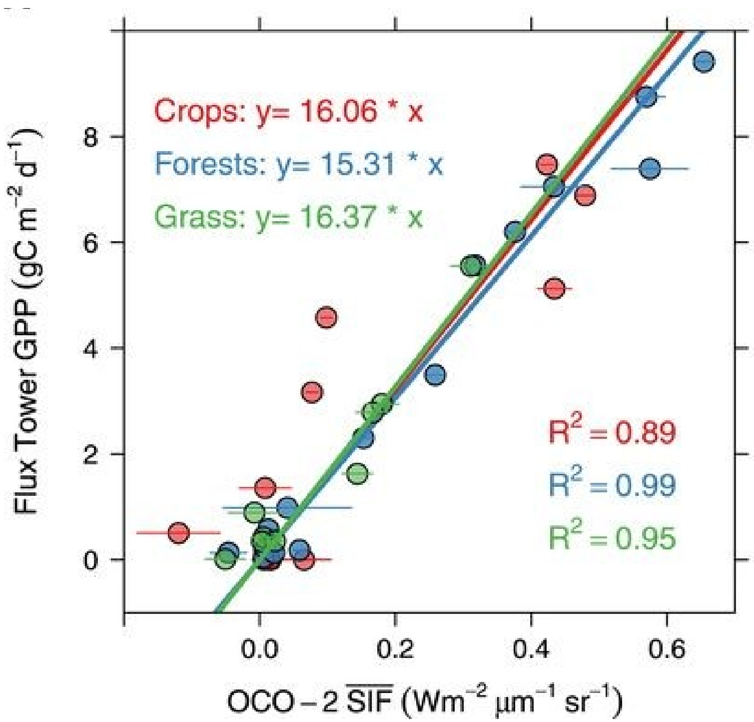
Evaluate seasonal cycle of GPP and Re in terrestrial biosphere models and FLUXCOM using atmospheric CO_2 and Solar Induced Fluorescence (SIF).



Evaluating GPP and Re using SIF and CO_2



SIF can provide a constraint on GPP seasonality



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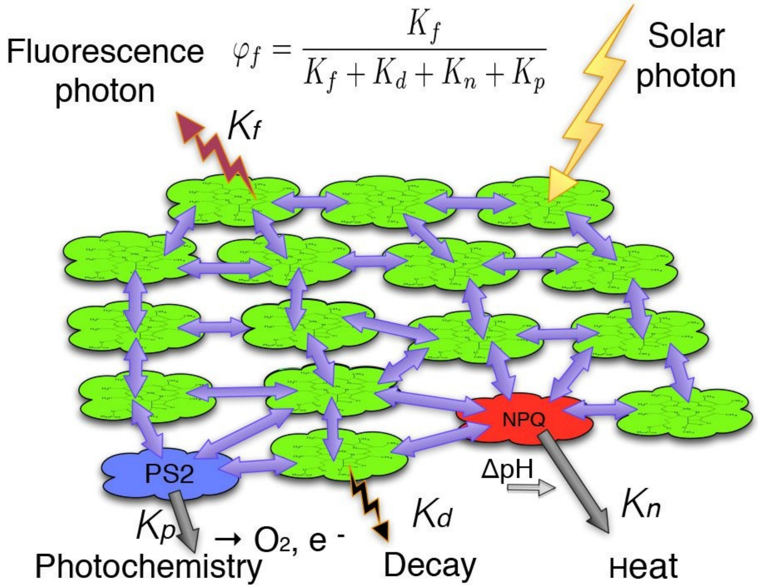
Evaluating GPP and Re using SIF and CO_2



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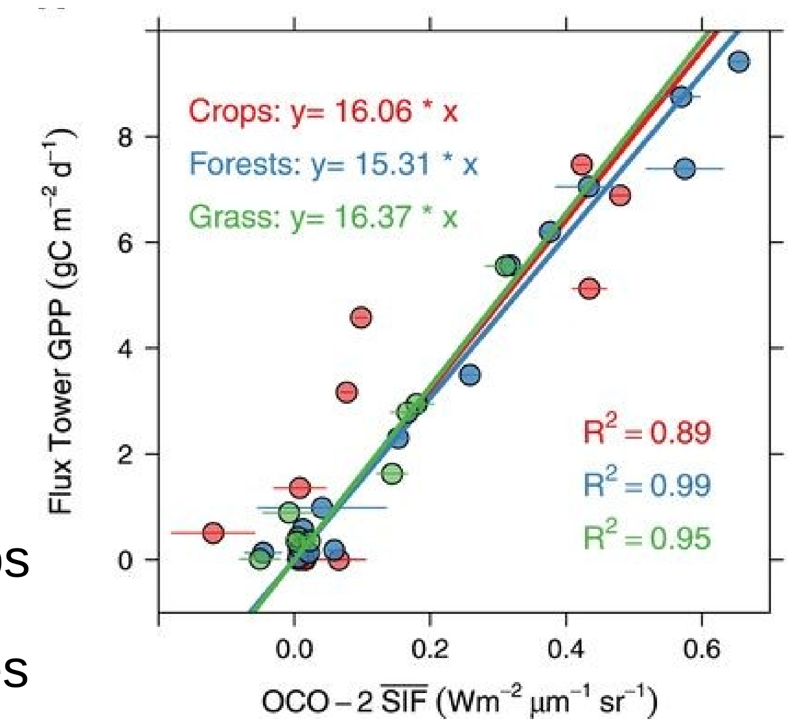

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Approach: Evaluate models with SIF and CO_2 obs

- Mean seasonal cycle in northern mid-latitudes (2007-2012, 39-65 N)
- Evaluate existing GPP and Re estimates from models
  - (a) Use GOME-2 SIF to evaluate model GPP
  - (b) Perform CO_2 flux inversion to obtain NEE
  - (c) Calculate Re (Re = NEE – GPP) with results from (a) and (b)

FLUXES

(2007-2012, 39-65 N)

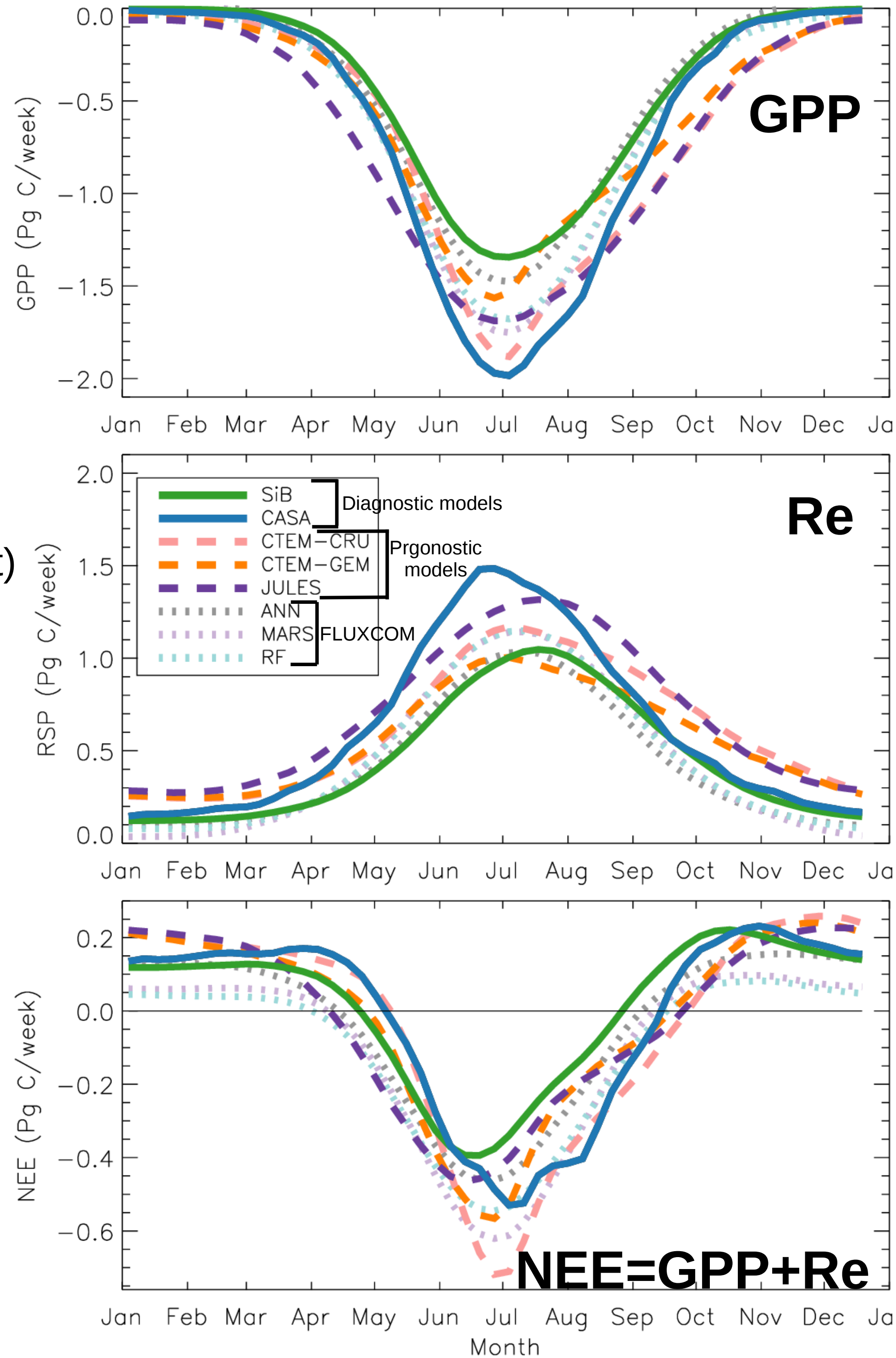
<u>Terrestrial Biosphere models:</u>

- Prognostic models
  - JULES (NCEP-CRU reanalysis)
  - CTEM-CRU (NCEP-CRU reanalysis)
  - CTEM-GEM (GEM-MACH-GHG forecast)
- Diagnostic models (assimilate phenology)
  - CASA (MERRA reanalysis)
  - SiB3 (MERRA, precip scaled to GPCP)

<u>Bottom up fluxes:</u>

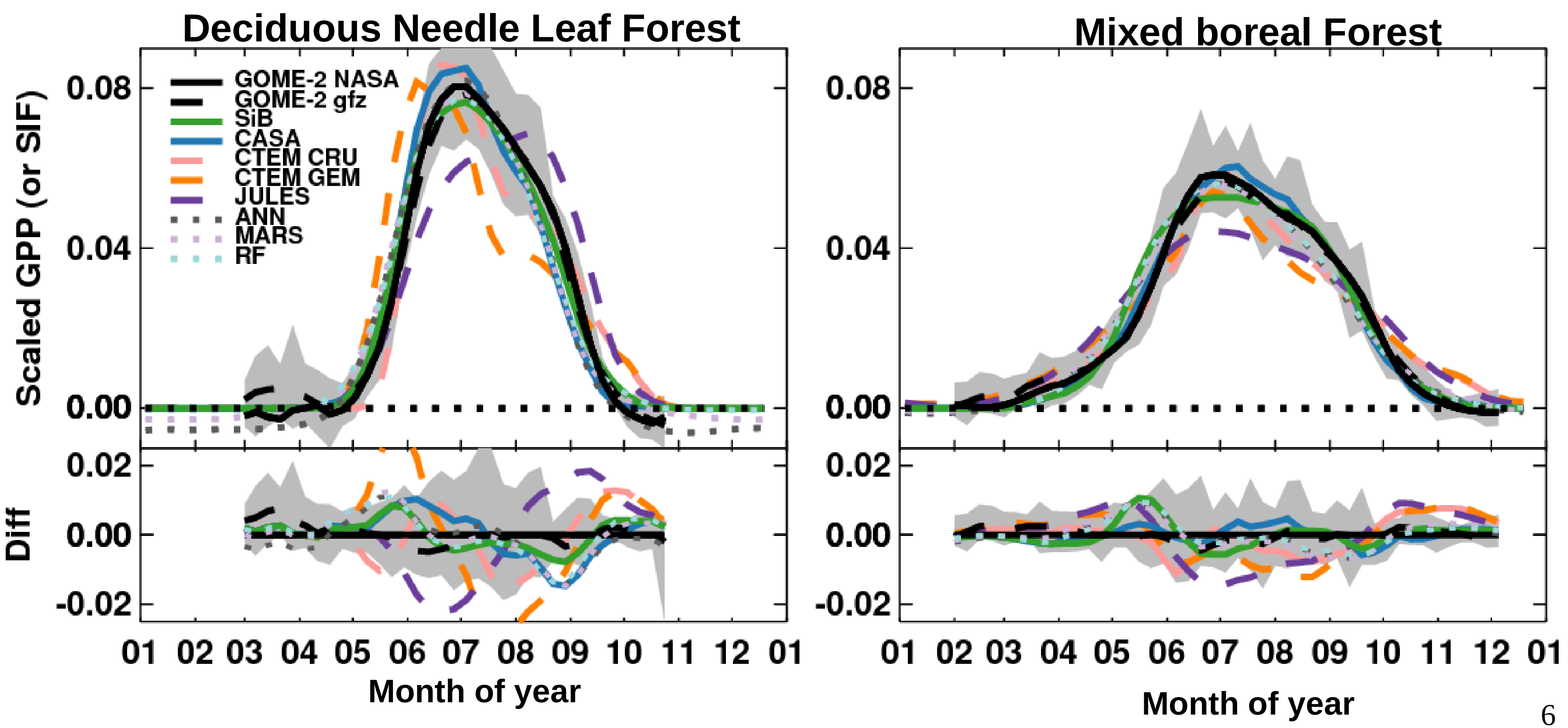
- FLUXCOM
  - ANN, MARS, RF

➔ Large spread in fluxes



(a) Use GOME-2 SIF to evaluate model GPP

- Normalize: divide GPP (or SIF) by annual total
- Results:
  - FLUXCOM and diagnostic models (SiB3, CASA) GPP shows good agreement with SIF
  - Prognostic models (JULES, CTEM CRU, CTEM GEM) show poor agreement

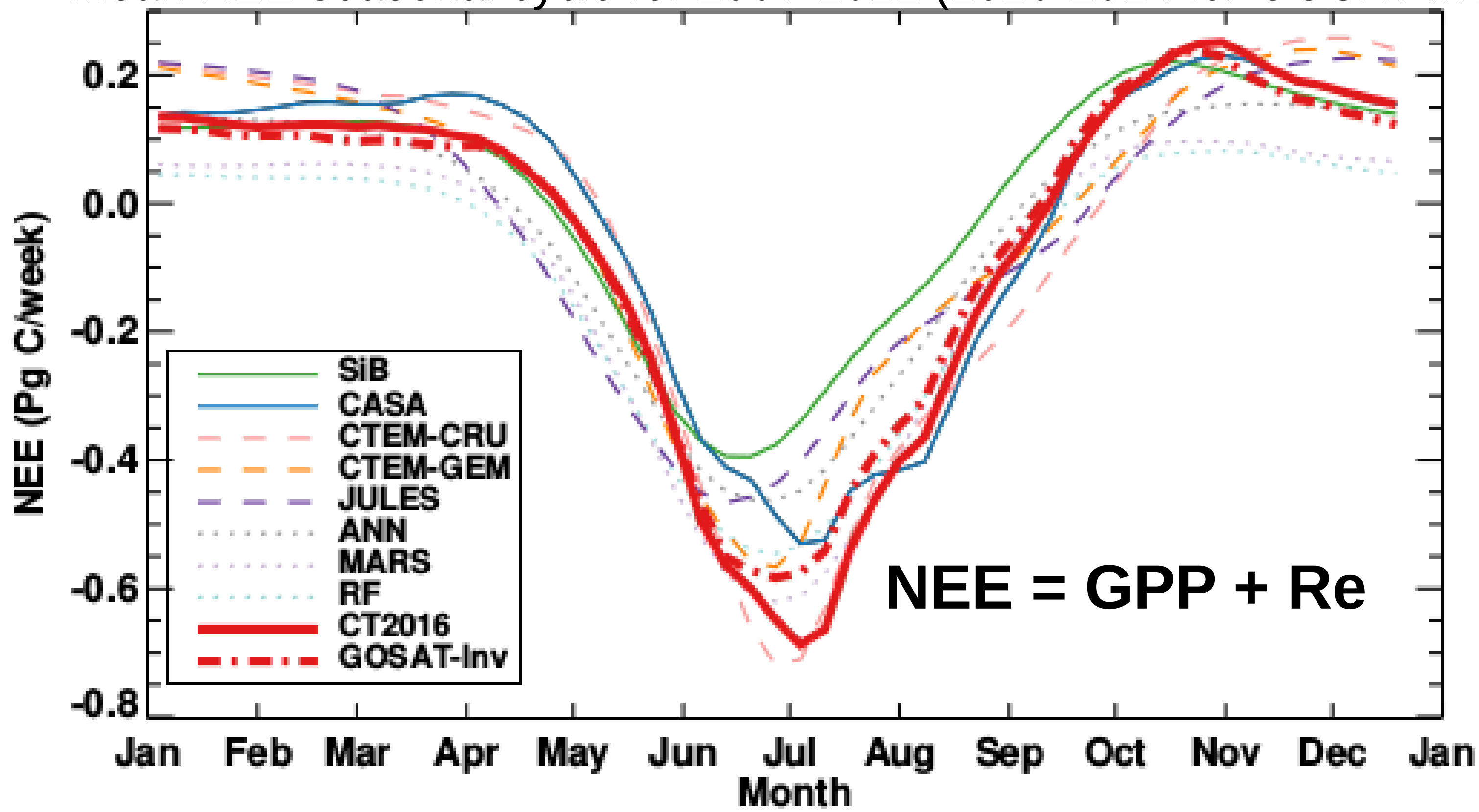


(b) NEE constraint: Flux inversions

Inversion	Observations	Model	Approach	Resolution	Prior NEE
CT2016*	Surface Sites	TM5	EnKF	3x2, 1x1 NA	CASA
GOSAT-Inv	GOSAT	GEOS-Chem	4D-var	4 x 5	CT2016

*CarbonTracker CT2016 results provided by NOAA ESRL, Boulder, Colorado, USA from the website at http://carbontracker.noaa.gov.

Mean NEE seasonal cycle for 2007-2012 (2010-2014 for GOSAT-Inv)

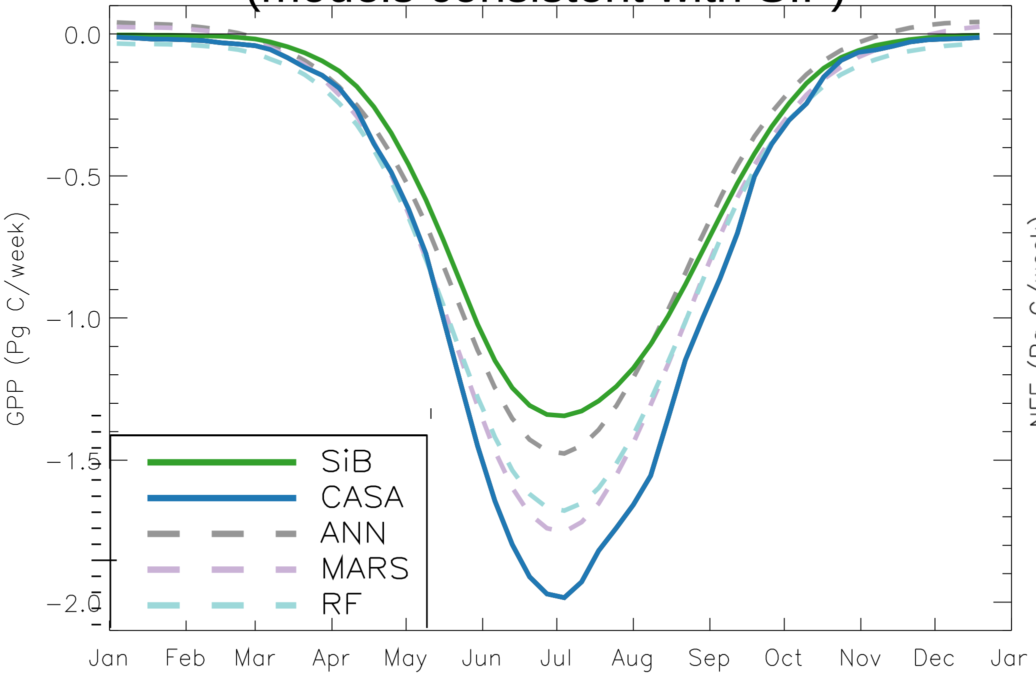


- Flux inversions agree with each other but show differences from models

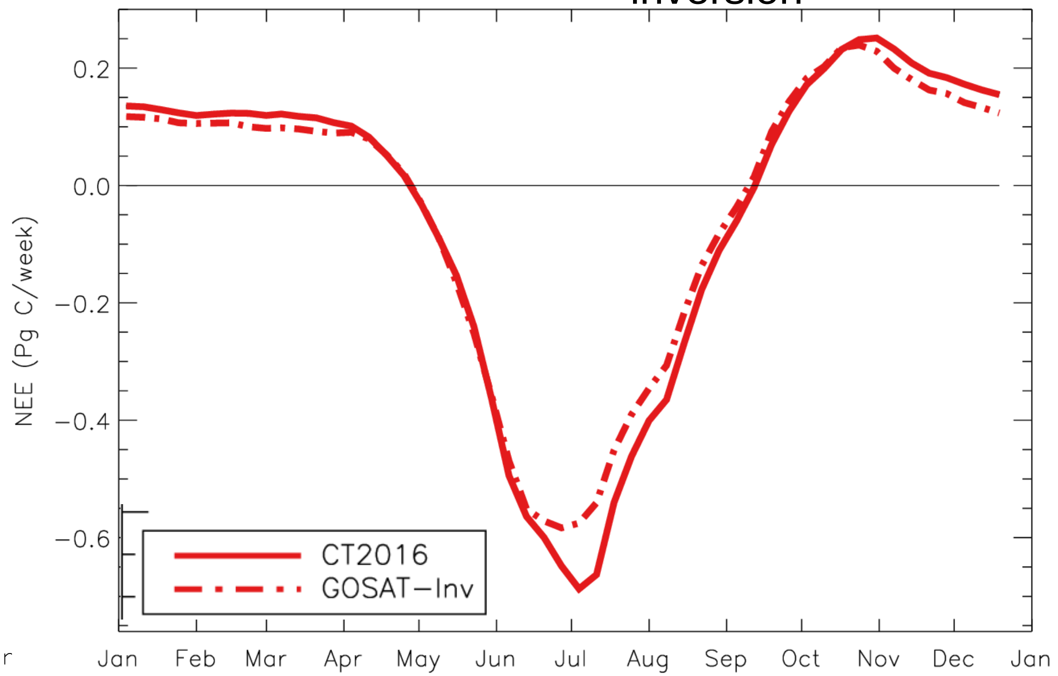
(c) Calculate "optimized" Re

$$\text{Optimized Re}_{\text{inversion-model}} = \text{NEE}_{\text{inversion}} - \text{GPP}_{\text{model}}$$

GPP_{model}
(models consistent with SIF)

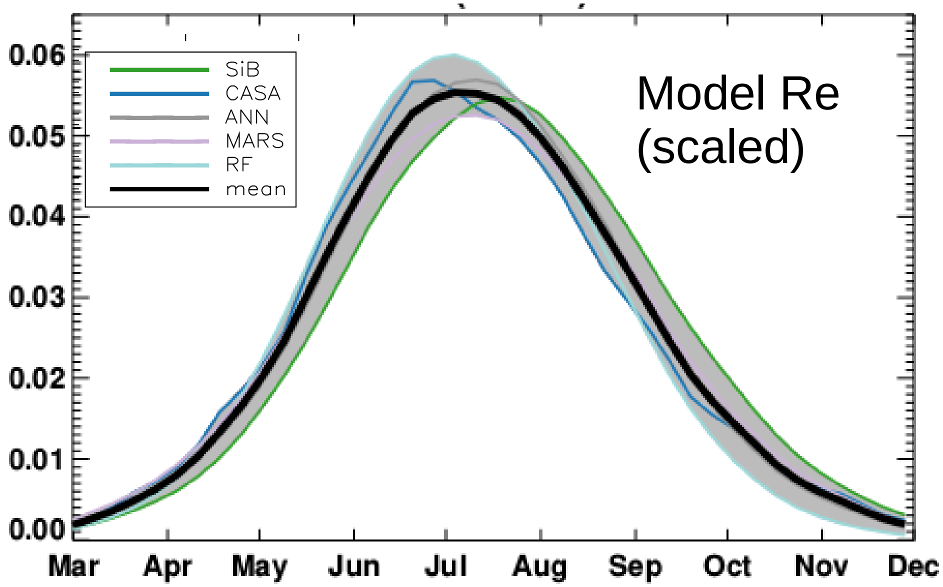


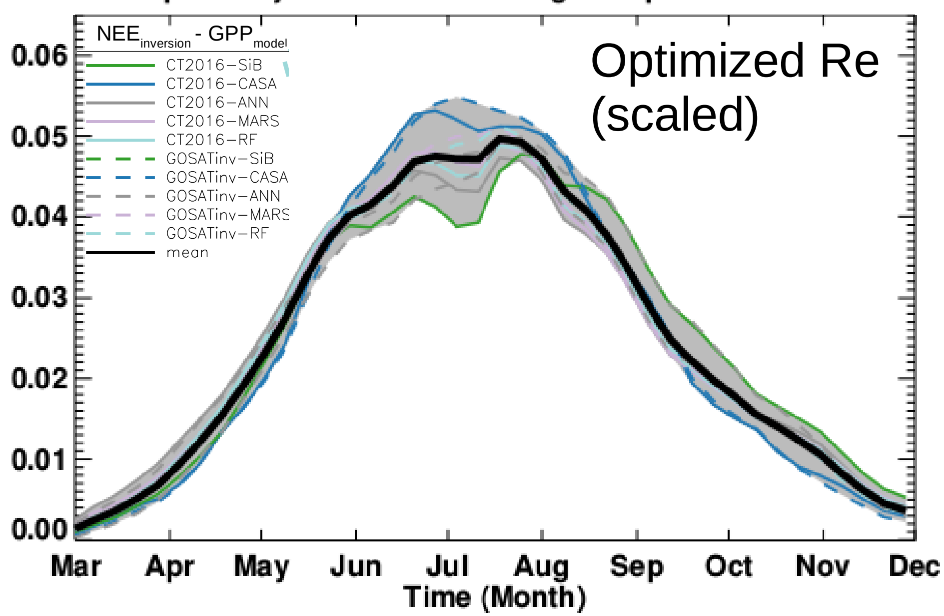
$NEE_{inversion}$

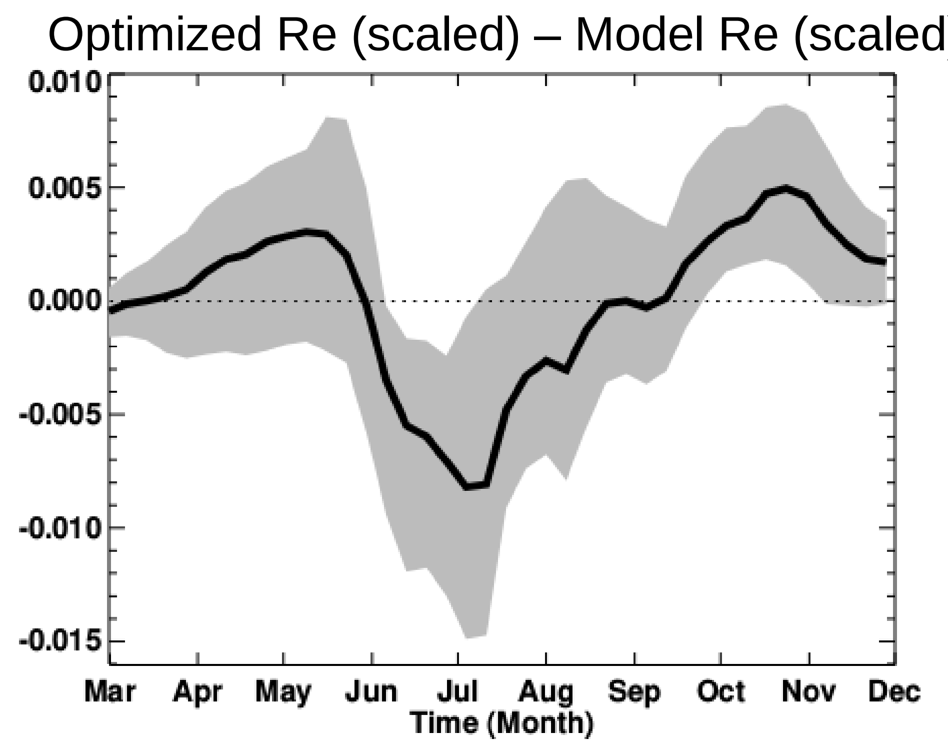


(c) Calculate “optimized” Re (normalized)

- Optimized Re curves have broader summer peak than models





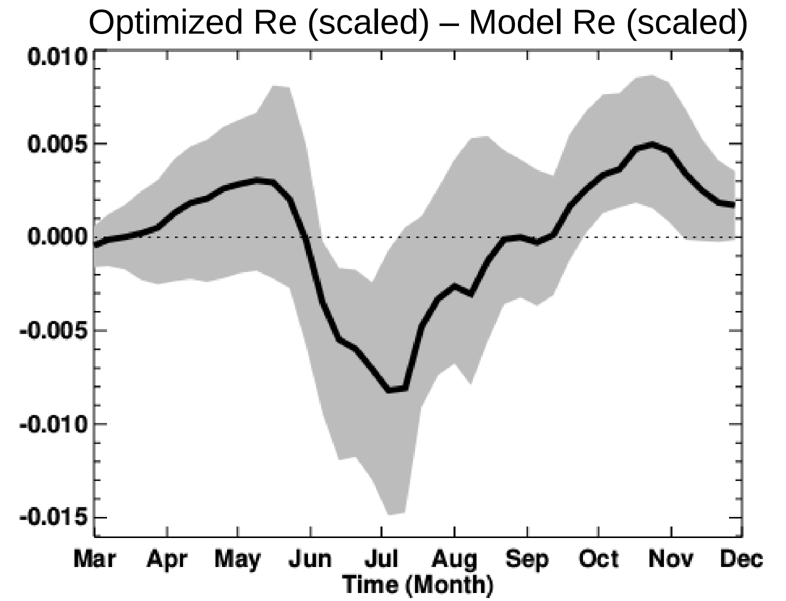


Optimized Re is systematically lower in June

Optimized Re is systematically higher in October

Why the difference?

- Systematic bias in FLUXNET partitioning?
  - Standard methods use a hypothesized response of GPP and Re to light, water, and/or temperature fluxes to do the partitioning.
  - Wehr et al. (2016) use isotopic observations at Harvard forest to show daytime/nighttime ratio is lower in June-July than August-September.
  - Is this true across northern extra-tropical ecosystems?



- Large fall Re at northern latitudes?
  - Commane et al. (2017) find significant Re fluxes from Alaskan tundra during October-December.
  - Could this be true over large boreal and Arctic regions?

Wehr, R., et al. (2016), Seasonality of temperate forest photosynthesis and daytime respiration, Nature, 534(7609), 680.

Commane, et al. (2017), Carbon dioxide sources from Alaska driven by increasing early winter respiration from arctic tundra, P. Natl. A.Sci., 114(21), 5361–5366.

Conclusions

- Evaluated GPP and Re seasonal cycle in northern extra-tropics
  - Re summer peak is systematically broader when constrained by CO_2 and SIF obs.
  - Difference in Re suggests FLUXCOM/models are biased in their seasonal cycle, more research is needed to isolate the cause.

Future Work

- Refine spatial scales
  - Need better understanding of the scales GOSAT and OCO-2 observations can constrain the mean seasonal cycle.

CSA ASC

Canadian Space Agency Agence spatiale canadienne

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- TCCON data were obtained from the TCCON Data Archive, hosted by CaltechDATA [http://tccondata.org].
- NASA and GFZ Potsdam GOME-2 SIF products were obtained from Aura Validation Data Center [http:/avdc.gsfc.nasa.gov] and GFZ-Potsdam FTP [ftp://ftp.gfz-potsdam.de], respectively.
- FLUXCOM products were obtained from the Data Portal of the Max Planck Institute for Biochemistry [https://www.bgc-jena.mpg.de].
- MERRA-2 products were downloaded from MDISC [https://disc.sci.gsfc.nasa.gov], managed by the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC).
- ACOS GOSAT lite files were obtained from the CO2 Virtual Science Data Environment [https://co2.jpl.nasa.gov/#mission=ACOS].

Extra: Re sensitive to GPP magnitude

- Magnitude of GPP is uncertain
- $OptRe_{inversion\text{-}model}$ curves are similar for the same GPP magnitude
- Broad summer maximum in $OptRe_{inversion\text{-}model}$ consistent across GPP range