# Wildfire Disturbance in CABLE

## The Fire-Model BLAZE


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# Introduction

Requirements for a fire model:

- operate in concert with vegetation dynamics (POP*)

- go along with inter-annual variations

- cover a changing climate

- without putting too much computational burden

*Haverd et al., “A stand-alone tree demography and landscape structure module for Earth system models”, GRL, 2013

# Outline

1. Introduction
2. The Fire-Model BLAZE
3. Evaluation
4. Simulations
5. Outlook

# The Fire – Model BLAZE

## (BLAZe induced land-atmosphere flux Estimator)

# BLAZE (structure)

| Component | Specifications | Δ t | Input |
|---|---|---|---|
| IGNITION | *SIMFIRE* (Knorr 2014)<br>BA [% grid cell] | m-a | pop. dens., avg. ann. FAPAR, landcover, Nesterov-Index |
| | Observation based data sets (e.g. *GFED*) BA [$m^{-2}$] | d-a | *data set* |
| FIRE characteristics | Compute Fire-Line-Intensity<br>FLI [W/m], Flame-height... | d-a | litter (metb&str), U,T,RH,Precip |
| COMBUSTION | C-Pool turn-over from *FullCAM* combustion tables (Suravski, 2014) | d-a | tabulated $TO_{i,j}$ (FLI)/$g(C)_i$ from pool i -> j |
| | C-Pool turn-over relative to *POP* fire-mortality (Haverd 2014) | a | as above but acc to *POP* C-TO for life pools |

Ignition and combustion can be combined as desired; Δt set accordingly

# Ignition

# SIMFIRE (W. Knorr, Lund University)

Knorr et al.,"Impact of human population density on fire frequency at the global scale", Biogeosciences, 11, 1085–1102, 2014
doi:10.5194/bg-11-1085-2014

SIMple global FIRE model:

$$f_{i,t} = a_d(l_i)F_i^b N_{i,t}^c \exp\left(eP_i\right)$$

| | |
|---|---|
| f | fire "frequency" [frac. area burnt (AB)/a] |
| *t* | *year* |
| *i* | *pixel* |
| *a-e* | *global parameters optimised using PEST* |
| l | dominant land cover type |
| F | multi-year average of annual max. FAPAR (2000-2010) |
| N | max. annual Nesterov index |
| P | population density |

# Fire Characteristics

# Fire characteristics

Byram's Law: $$I = H \cdot w \cdot ROS$$

I Fire-Line Intensity

*H* *heat yield (~ 20MJ/kg; Byram 1959; dep. on Fuel Moisture;*
*constant as in Liedloff 2007)*

*w* *available fuel [kg/m$^2$]*
*use ~60% of litter, PEST optimised*

*ROS* *Rate-of-spread [m/s]*
*computed from U,T,RH,Precip (following McArthur 1967)*

# Fire characteristics

Rate of spread:

$$ROS = const \cdot F(KBDI(DSLR, LR), RH, T, U, AnRain) \cdot w$$

| | |
|---|---|
| F | Mc Arthur Fire Index (Empirical function) |
| KBDI | Keetch-Byram-Drought index (assumes top soil layer water capacity of 200mm and estimates total rainfall needed for saturation) |
| (DS)LR | (Days Since) Last Rainfall (LR(24h)) |
| RH | rel. hum. |
| T | Temperature |
| U | Wind speed |

# Combustion

# Combustion (coupled)

Fire – Disturbance treatment in POP ↔ FireModel

POP uses fire-frequencies ($BA^{-1}$) to distr. around normalized *return-interval / randomize patches burnt*

-Provide Burned Area (BA)

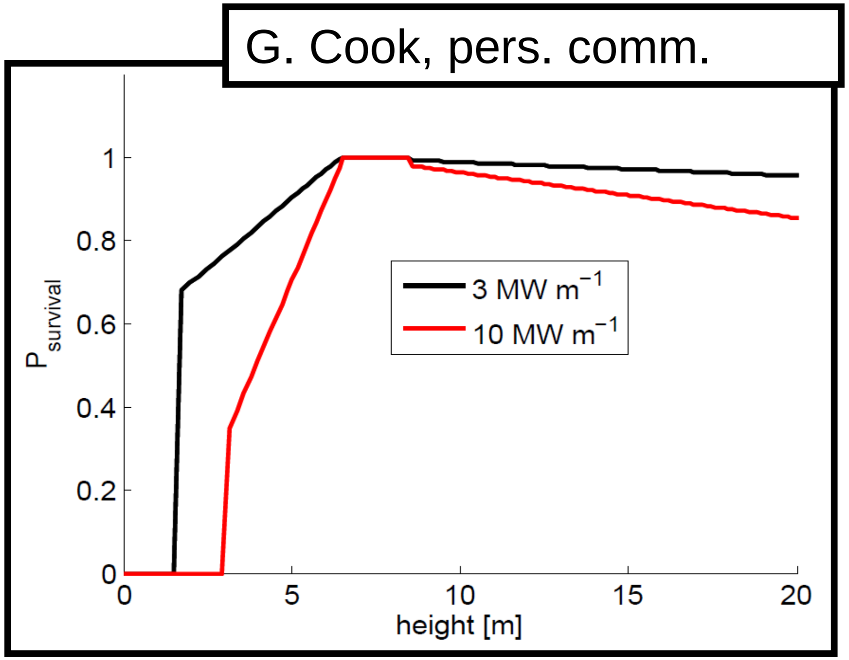
-Compute *Available Fuel* from C-pools

-Determine pot. *Fire-Line Intensity*

-Compute $P_{survival}$

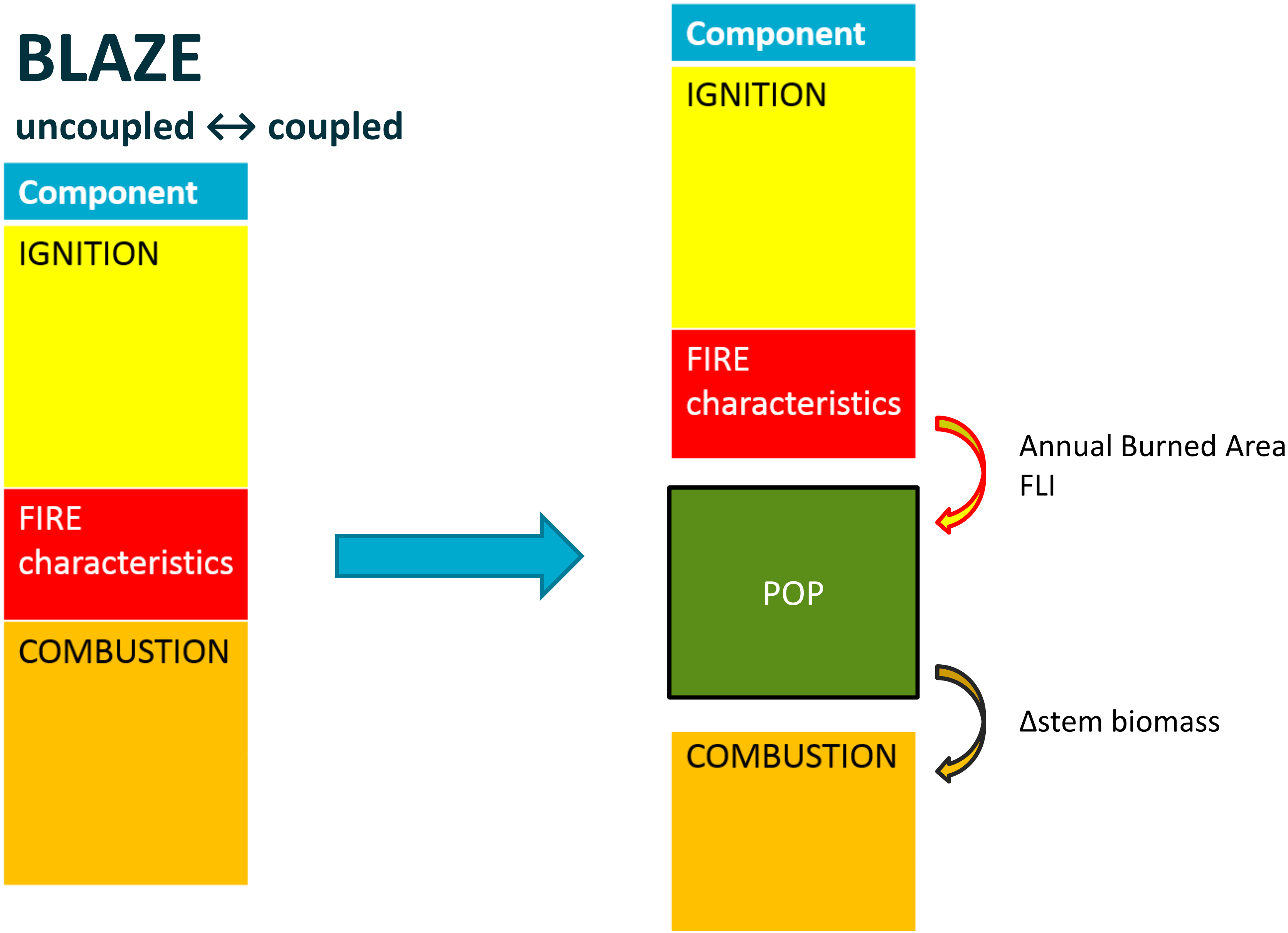
-Reset history

-Update biomass/pools



# BLAZE

## uncoupled ↔ coupled



# C-fluxes

Scale live fluxes by

$$POPflux_i$$

Scale litter fluxes by

$$AB_i$$

Burn grass by

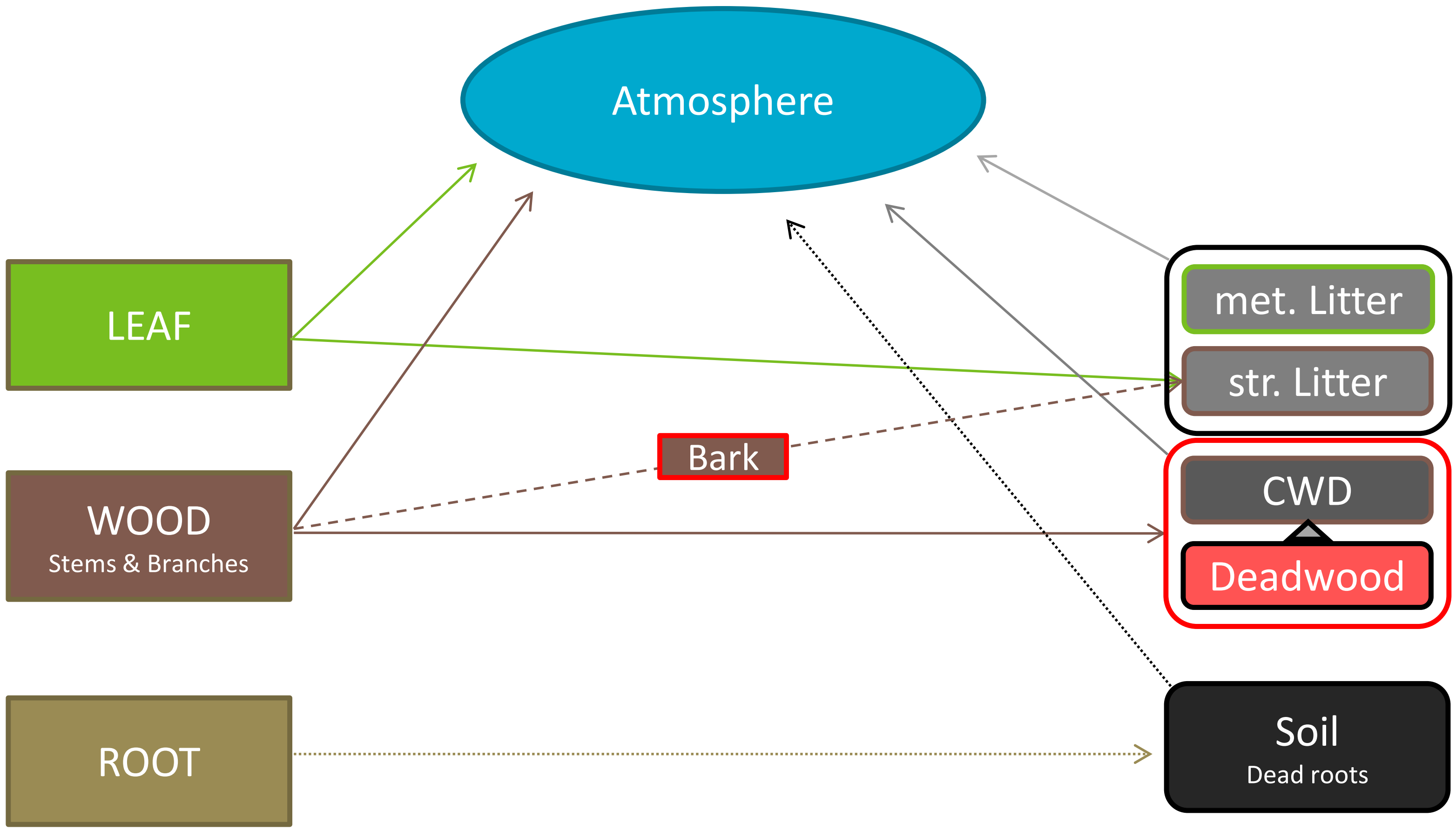
$$AB_i$$

| | Parameter | Event type: Propagating Fireline Intensity < 750 kW/m | 750-3000 kW/m | 3000-7000 kW/m | >7000 kW/m Sprouters | >7000 kW/m Seeders | Post-removal management burn (non-propogating) Hot Burn | Cool Burn |
|---|---|---|---|---|---|---|---|---|
| 1 | Stems to atmosphere | 0 | 0 | 5 | 20 | 20 | - | - |
| | Branches to atmosphere | 0 | 0 | 15 | 20 | 20 | - | - |
| | Bark to atmosphere | 3 if fibrous | 13 if fibrous | 25 if fibrous | 50 if fibrous | 50 if fibrous | - | - |
| | Leaves to atmosphere | 2 | 5 | 10 | 60 | 60 | - | - |
| 5 | Stems to deadwood | 0 | 2 | 7 | 20 | 80 | - | - |
| | Branches to deadwood | 0 | 0 | 5 | 20 | 80 | - | - |
| | Bark to litter | 3 if gum | 13 if gum | 25 if gum | 50 if gum | 50 if gum | - | - |
| | Leaves to litter | 5 | 10 | 15 | 30 | 30 | - | - |
| | Coarse dead roots to atmosphere | - | - | - | - | - | - | - |
| | Coarse roots to dead roots | - | - | - | - | - | - | - |
| | Fine dead roots to atmosphere | 0 | 2 | 2 | 4 | 4 | 4 | 0 |
| | Fine roots to dead roots | - | - | - | - | - | - | - |
| 10 | Deadwood to atmosphere | 50 | 75 | 75 | 80 | 80 | 80 | 65 |
| | Bark litter to atmosphere | 60 | 65 | 85 | 100 | 100 | 75 | 70 |
| | Leaf litter to atmosphere | 60 | 65 | 85 | 100 | 100 | 75 | 65 |

| Flux TO From | ATM | Litter str | CWD |
|---|---|---|---|
| Live Leaf | 4 | 8 | |
| Live Wood | 1-3 | 7 | 5,6 |
| Lit metb | 11 | | |
| Lit str | 12 | | |
| CWD | 10 | | |

Revised FLI-dependent FullCAM parameters, Surawski et al., “Combustion factors in fire affected Australian forests and woodlands: a review on research from 1966-2013”, pers.comm.

# C-fluxes (schematic)

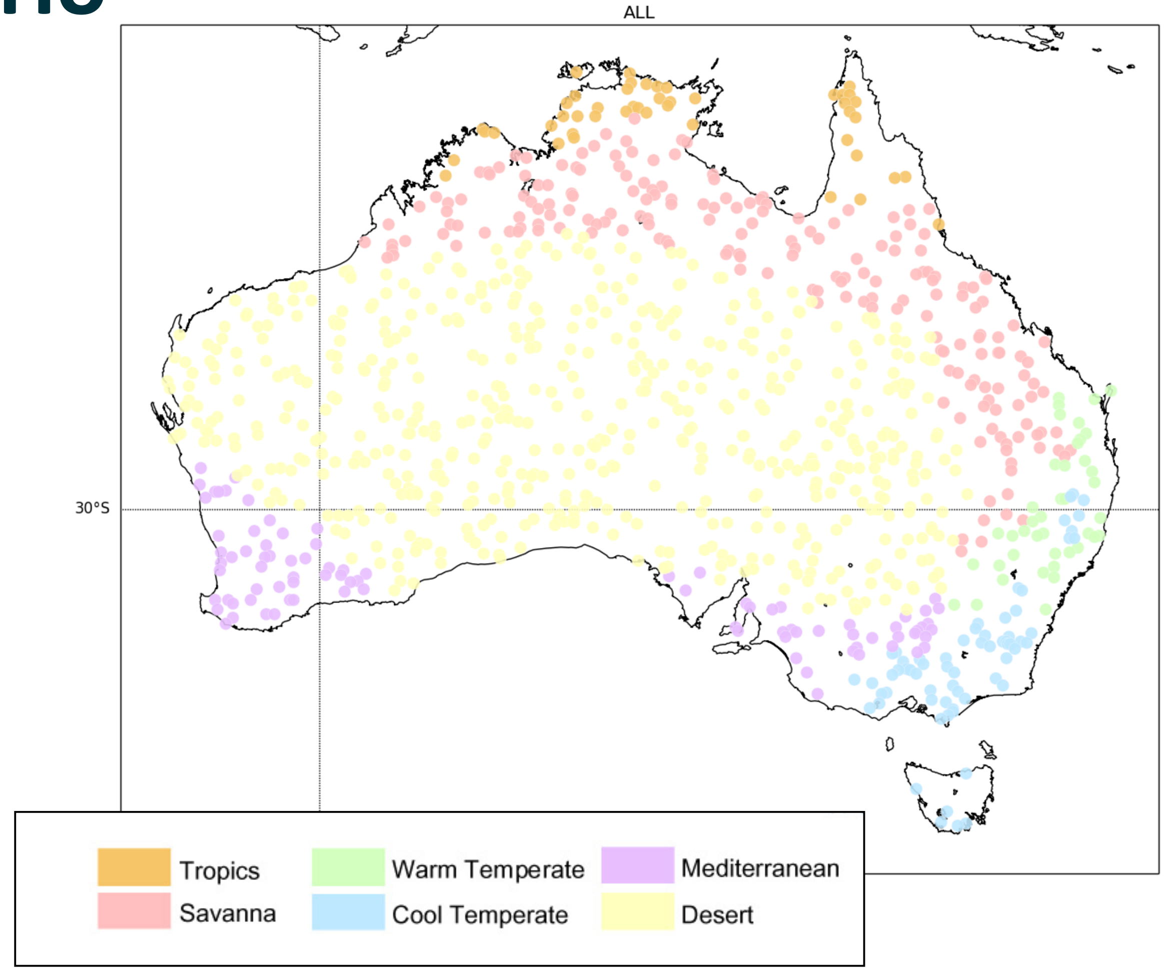


# Evaluation

# RECCAP Scenario

**RECCAP – regions**:

- 1000 random points
- 1997 – 2011
- Rising $CO_2$
- Combustion: BLAZE
- Ignition: GFED 3.1



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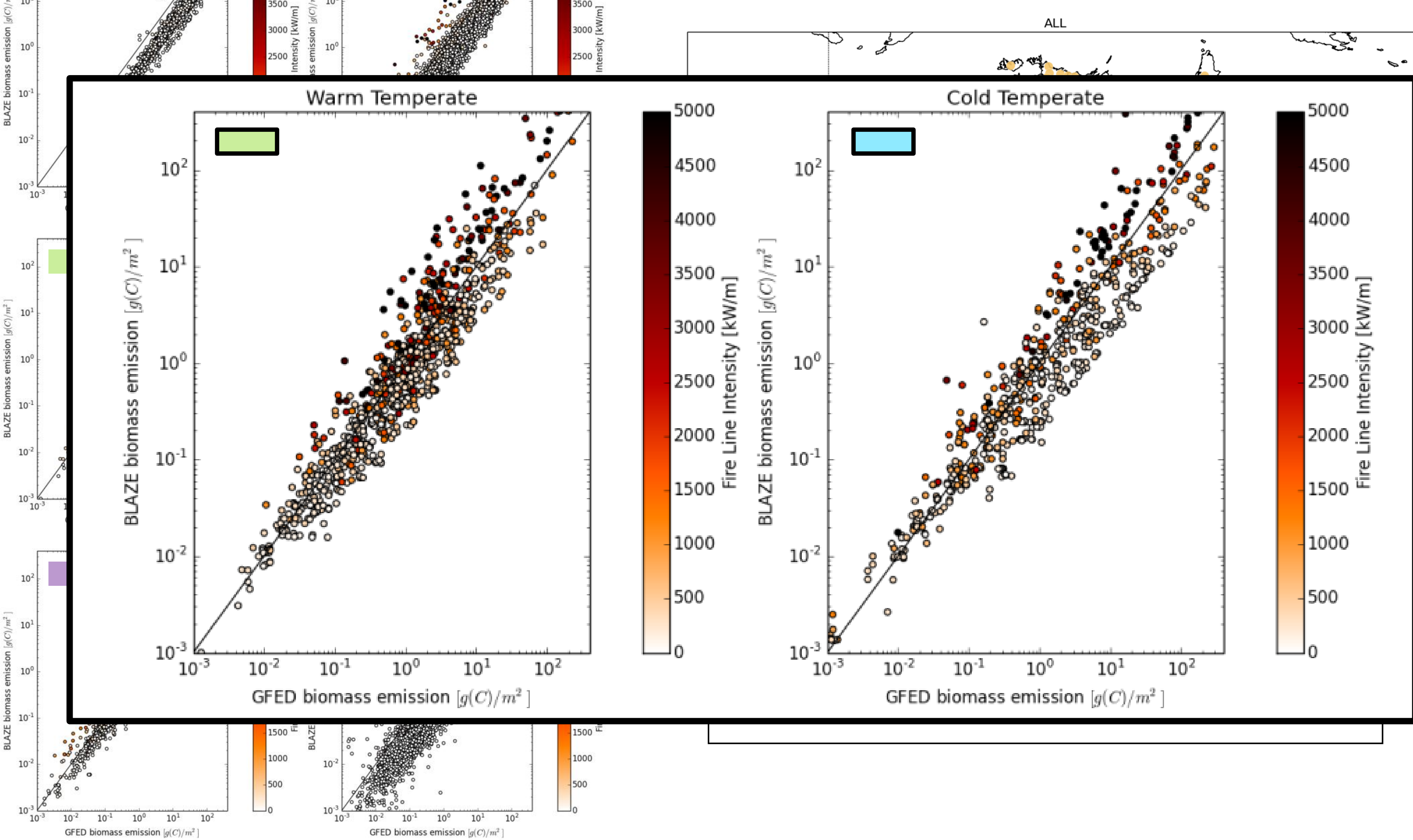
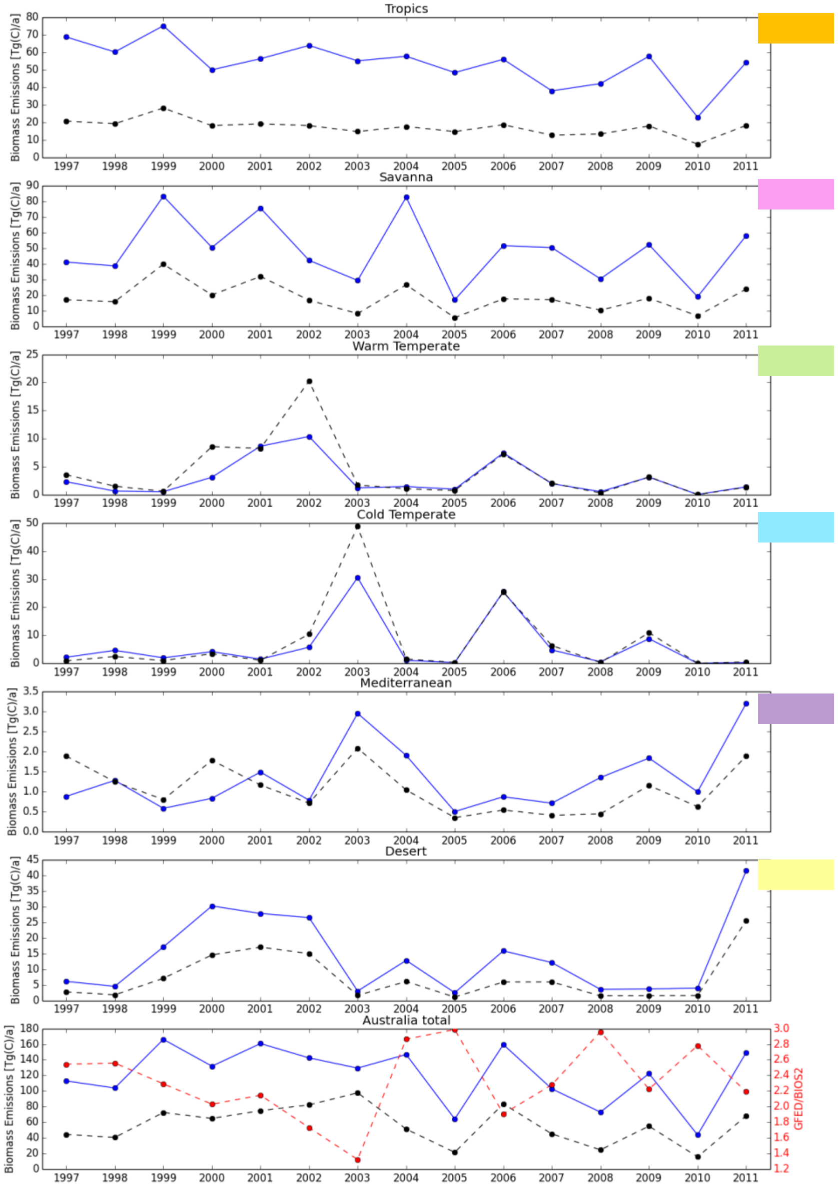
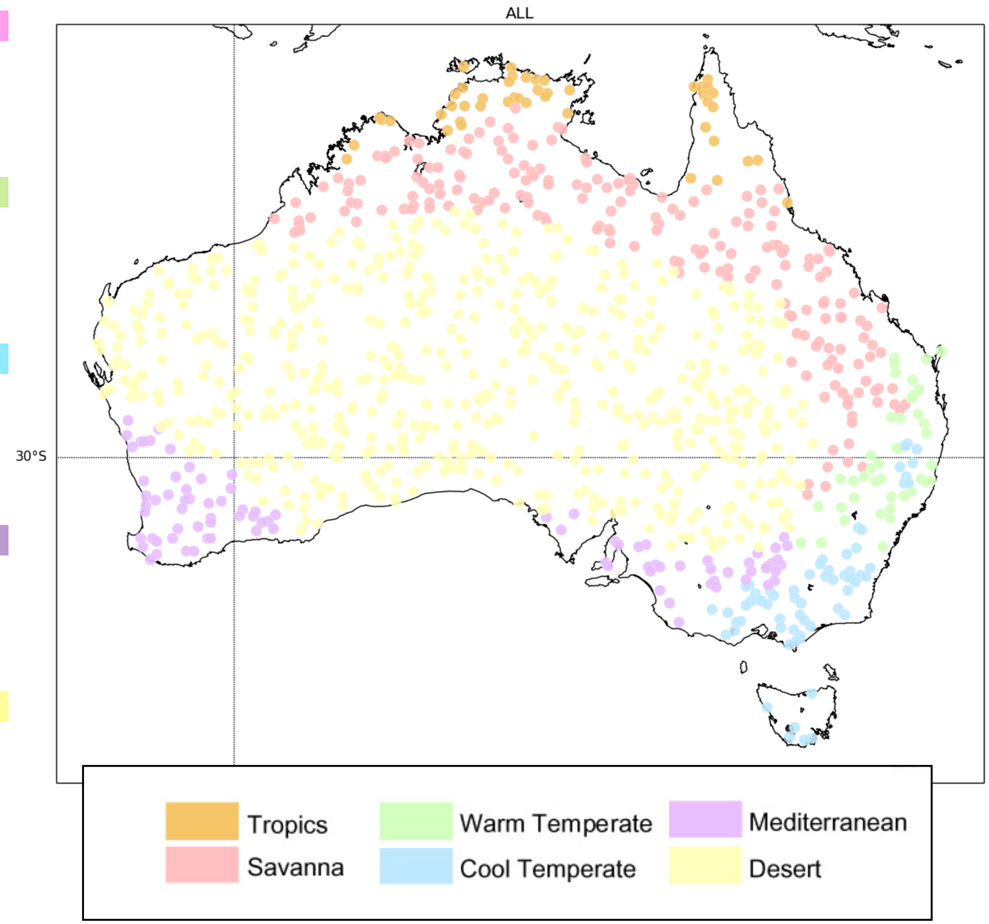
# GFED3.1 vs BIOS2-BLAZE C-emissions based on GFED3.1 Burned Area.



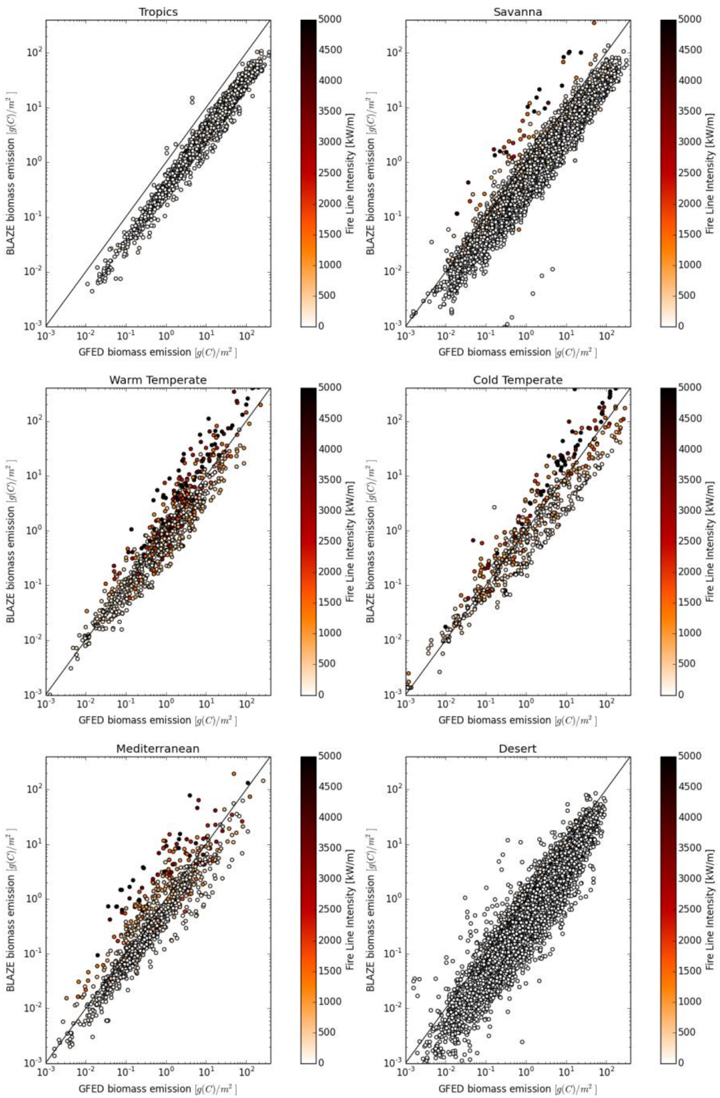
# Total Emissions per region based on GFED BA. Carbon emissions BIOS2 versus GFED3.1



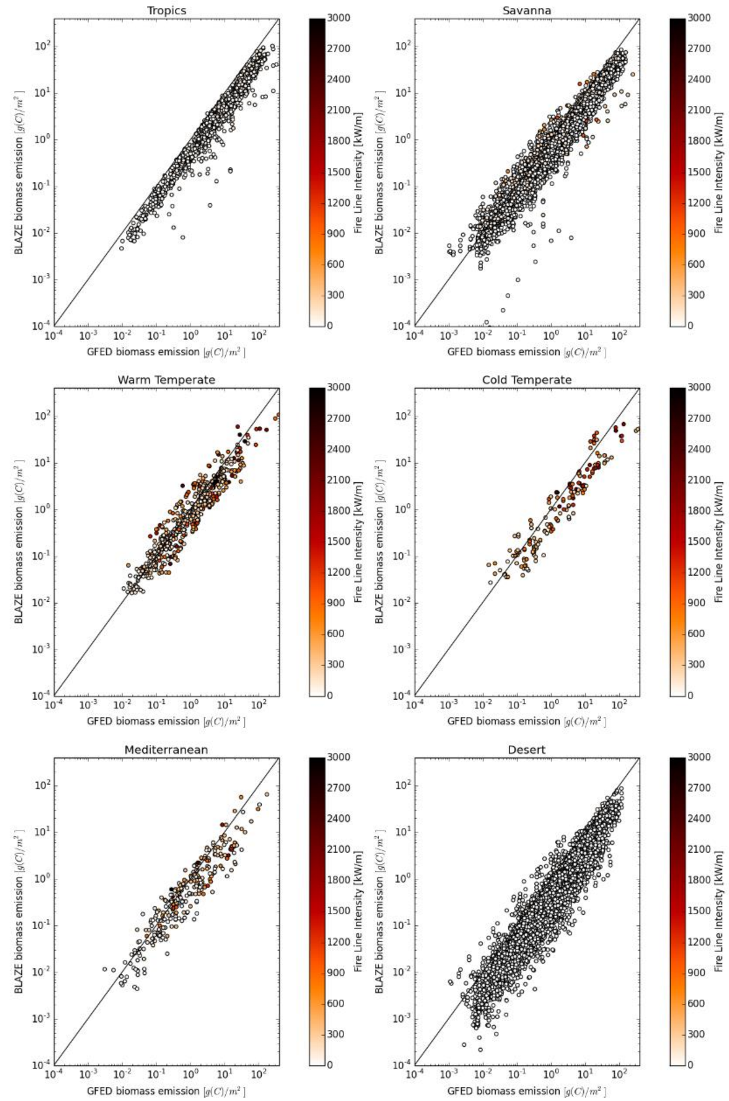




GFED3.1 BIOS2-BLAZE

# GFED3.1 vs BIOS2-BLAZE C-emissions and GFED4.1 vs BLAZE (PRELIMINARY!)

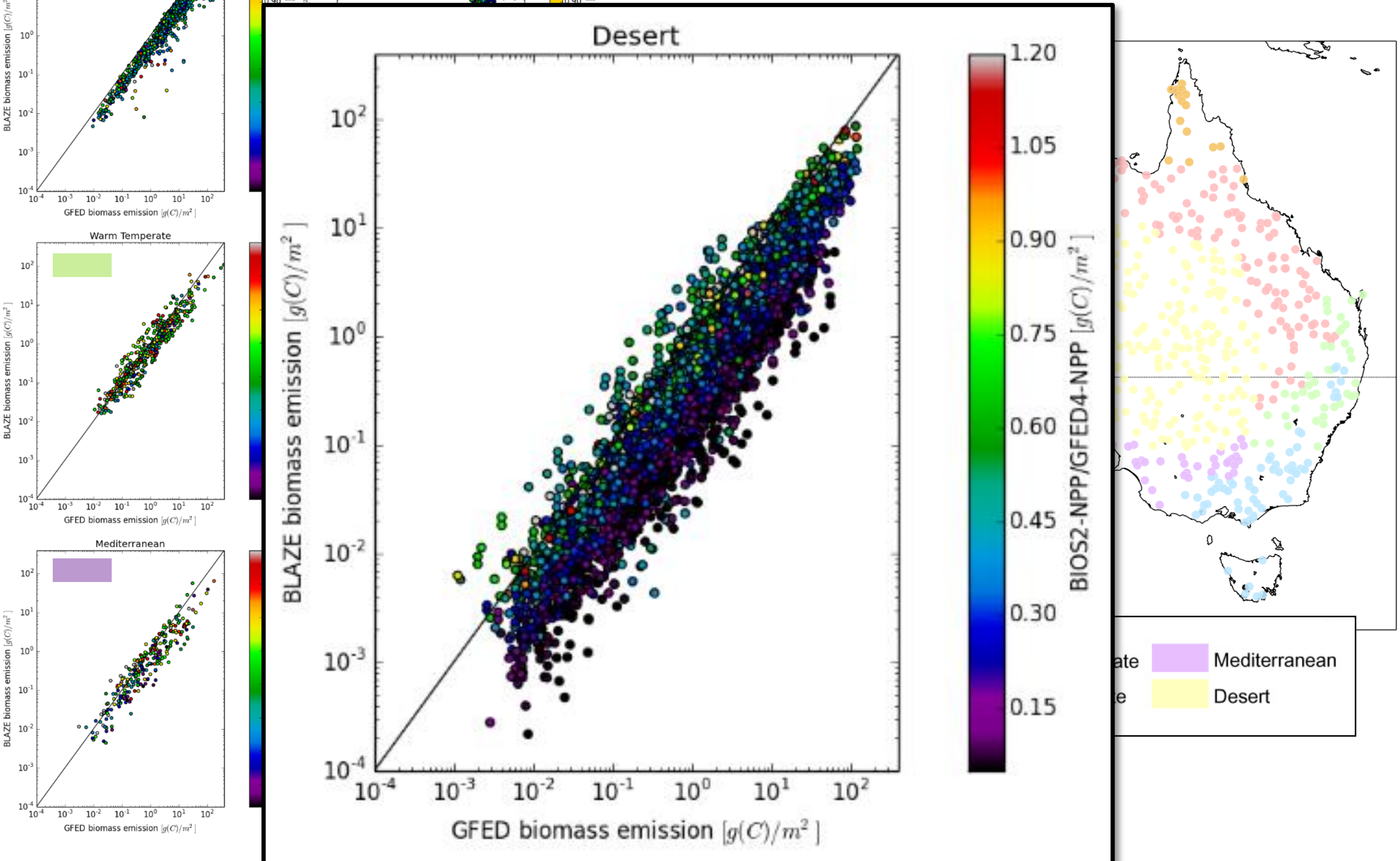



GFED 3.1

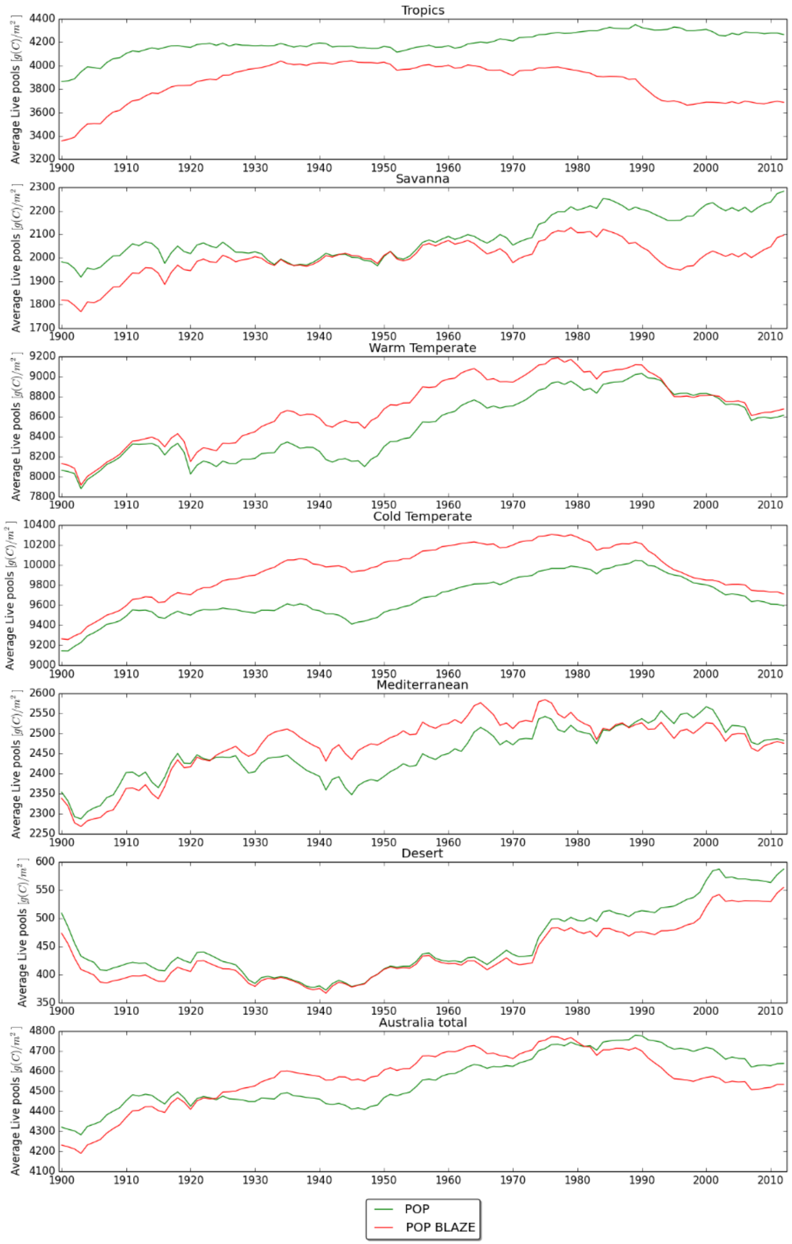



GFED 4.1

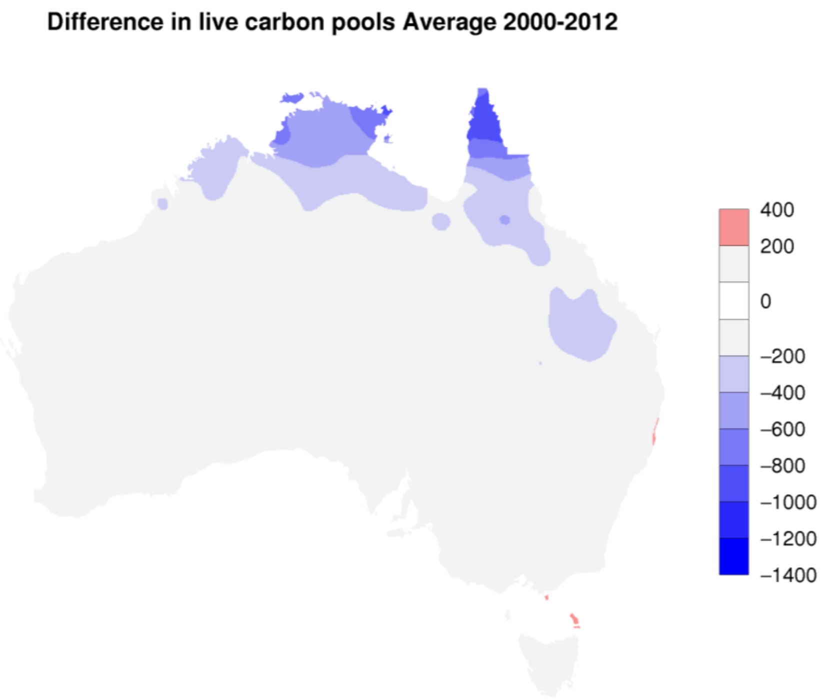
## GFED4.1 vs BIOS2-BLAZE C-emissions based on GFED4.1 Burned Area NPP – overlay(PRELIMINARY)



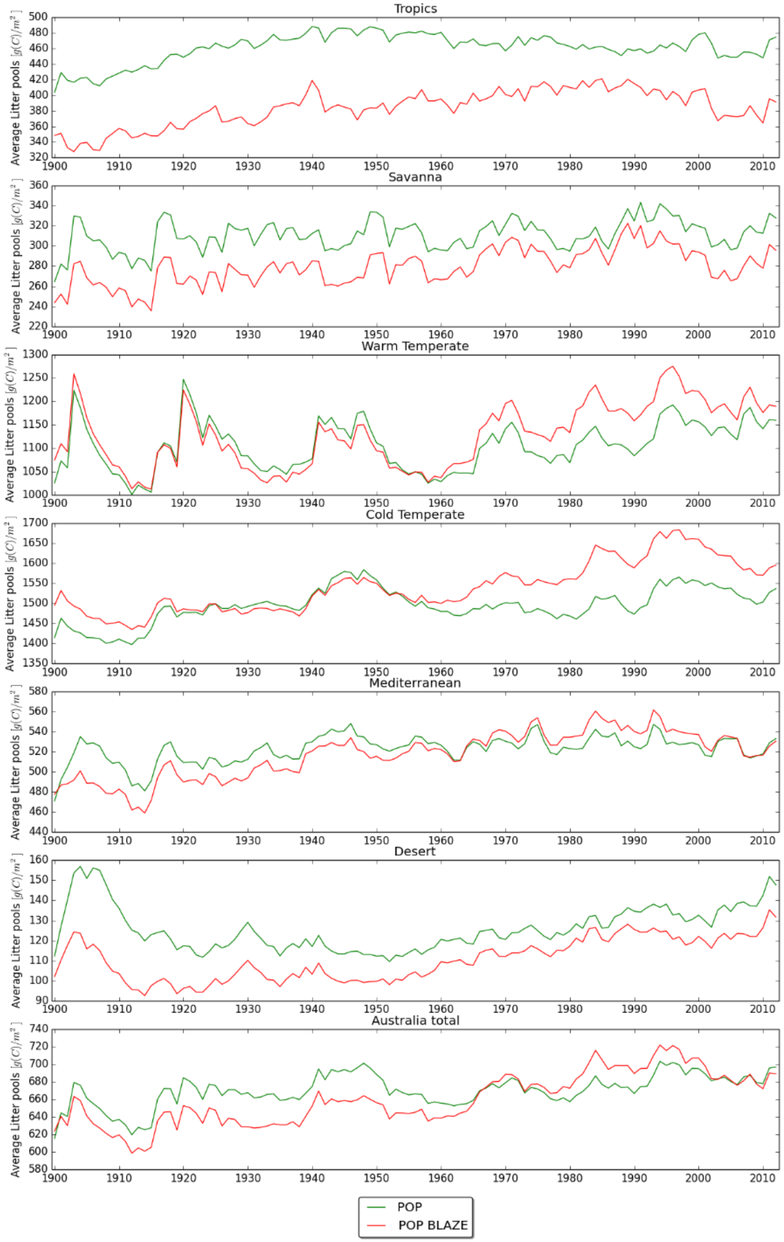
# Simulations

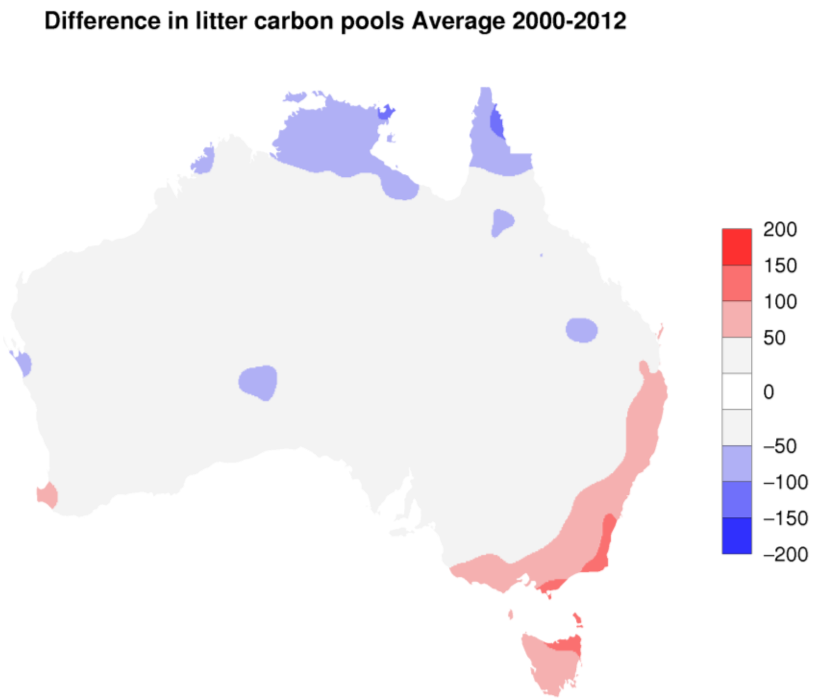


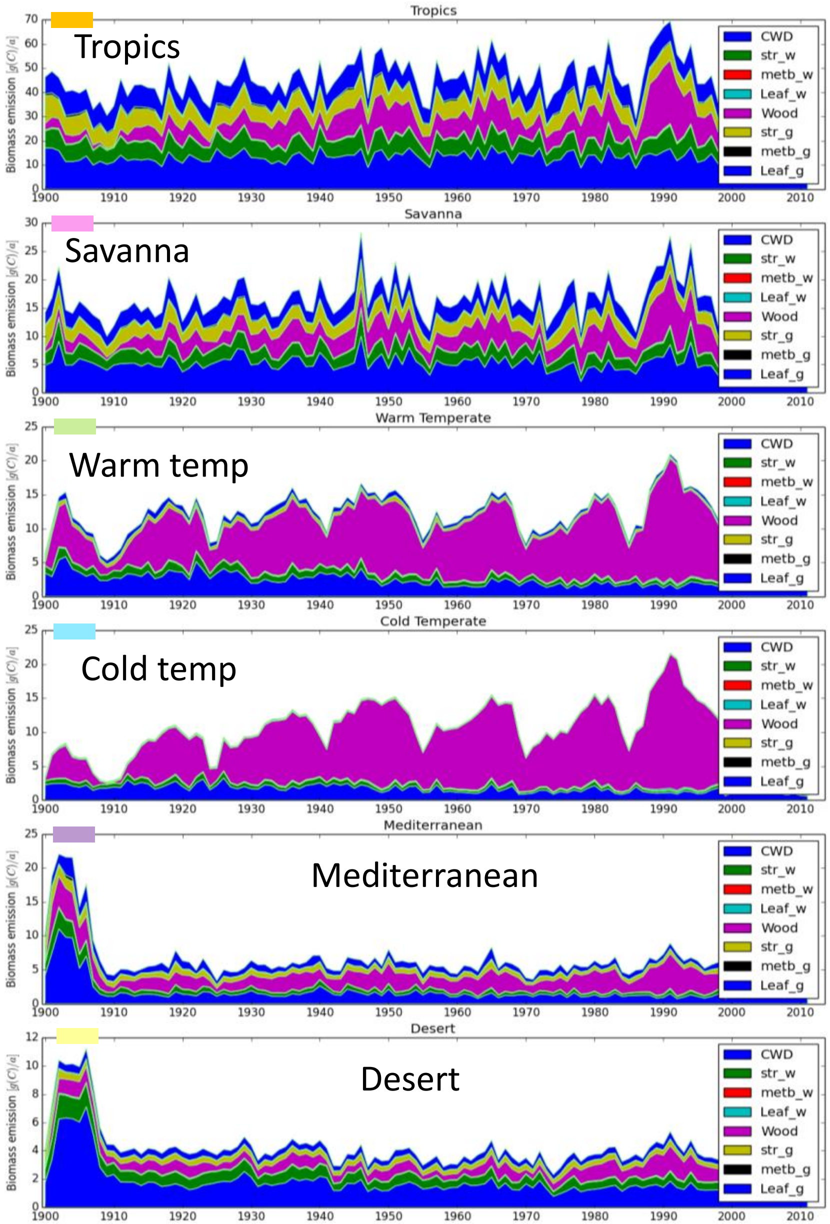
Tropics
Savanna
Warm Temperate
Cold Temperate
Mediterranean
Desert
Australia total
Average Live pools [g(C)/m²]
POP
POP BLAZE

Difference in live carbon pools Average 2000-2012
400
200
0
−200
−400
−600
−800
−1000
−1200
−1400


Tropics
Savanna
Warm Temperate
Cold Temperate
Mediterranean
Desert
Australia total
Average Litter pools [g(C)/m²]
POP
POP BLAZE

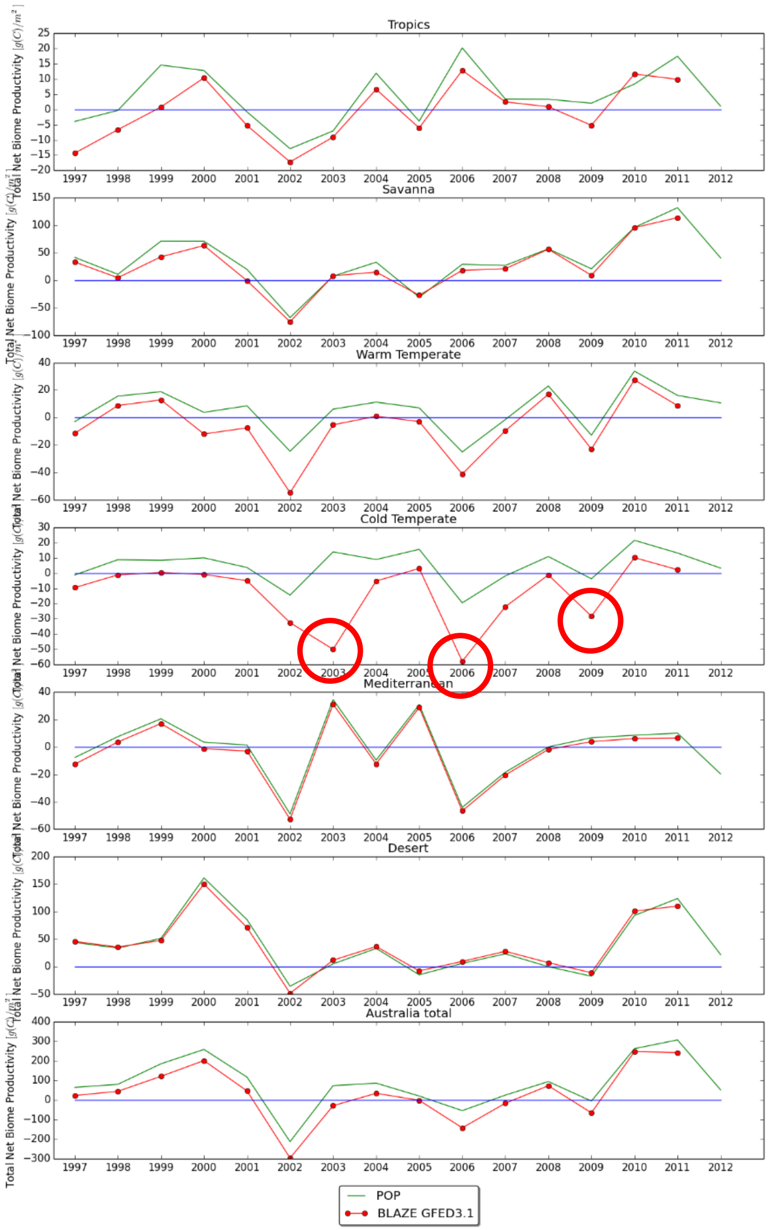

Difference in litter carbon pools Average 2000-2012
200
150
100
50
0
−50
−100
−150
−200




Biomass emissions [g(C )/m$^2$] 1900 – 2011 as fluxes from affected c-pools to atmosphere.

- Tropics and Savanna: slightly dominated by woody litter, grass live and litter play big roles, variability through woody biomass
- Temperate regions dominated by woody biomass
- Mediterranean dominated by wood with a little bit more of a grassy component
- Desert dominated by litter but on a way smaller scale.

Grassy Leaf
Grassy Metabolic Litter
Grassy Structural Litter
Woody biomass
Woody Leaf
Woody Metabolic Litter
Woody Structural Litter
Coarse Woody Debris



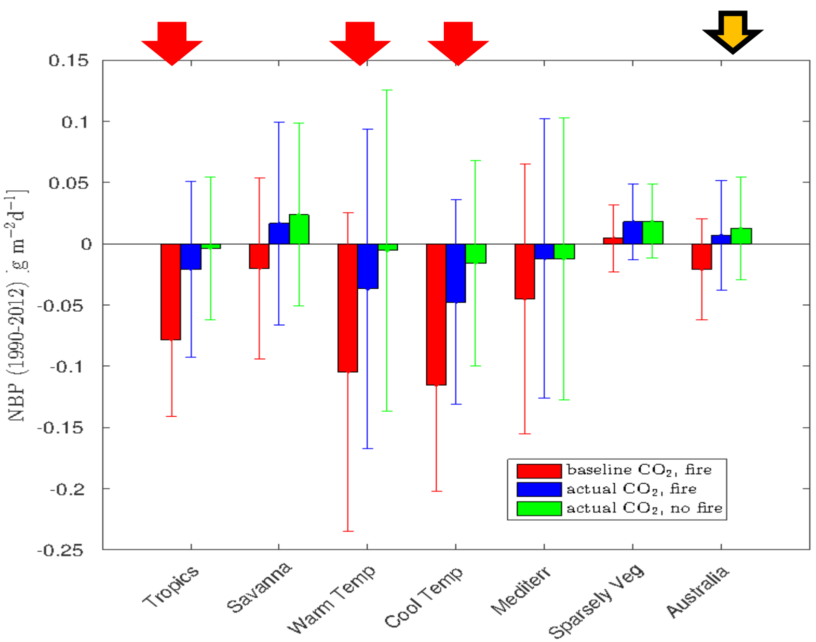

# NBP 1997-2012

- BLAZE-GFED3.1 basically creates offset to no-fire POP
- Large fires in the Cold Temperate region have a significant impact

## Average NBP 1990-2012

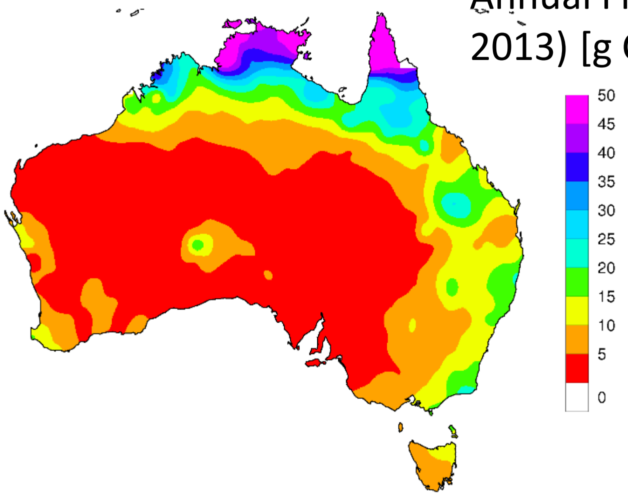
POP-BLAZE with rising and baseline $CO_2$ and POP without fire

- Moderate impact of fire on NBP in Tropics and the temperate regions
- Overall fire halves the continental sink



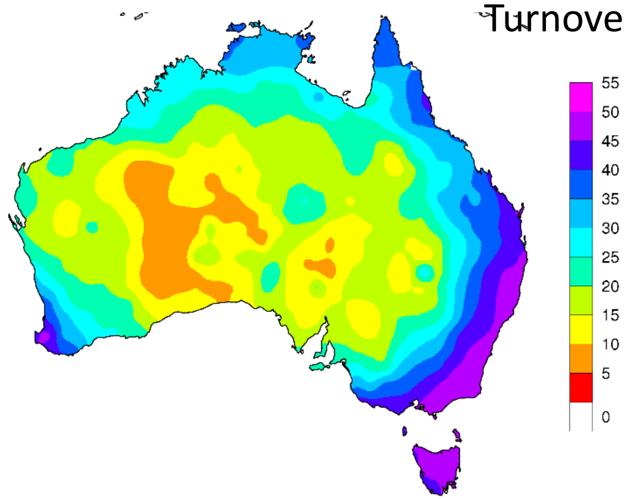
# CABLE-POP-BLAZE: application to Australian Terrestrial Carbon Budget*

Annual Fire Emissions (1990-2013) [g C m$^{-2}$]

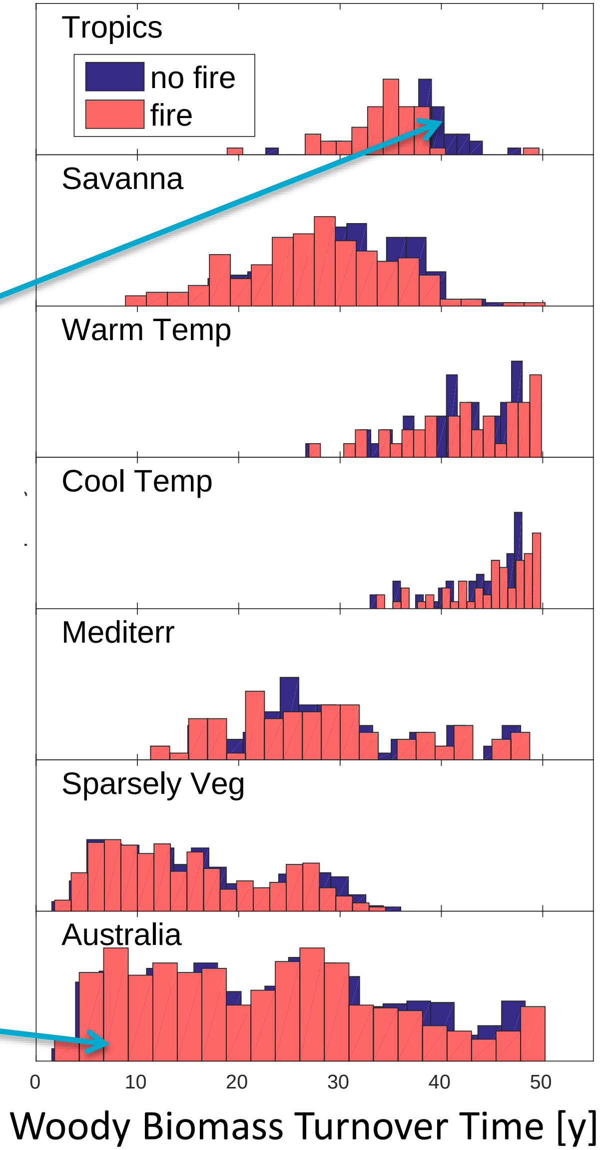



fire decreases turnover time in Tropics

Woody Biomass Turnover Time [y]




Biomass turnover time largely controlled by resource - limitation



# Outlook

- Publication of model description and evaluation in preparation
- Implementation into CABLE is underway
- Global fire mortalities to be added

# Thank you very much

**Acknowledgements:**

**We thank**

- **Wolfgang Knorr for SIMFIRE – Australia**
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# Carbon emissions BIOS2 versus GFED3.1

With the default settings BIOS2 is underestimating GFED3.1 emissions of low burns by a factor of >2 in savannas and the tropics. A known issue is, that GFED is overpredicting Fuel in savanna regions.:

Van Leeuwen et al., 2014, http://www.biogeosciences.net/11/7305/2014/bg-11-7305-2014.html, ("Within the savanna biome GFED3 overestimated the FC field rates by 72 %, and this overestimation was even higher for grassland regions (79 %).")

Roberts et al., 2013, http://www.sciencedirect.com/science/article/pii/S0034425711001167, ("It is difficult to directly validate the derived fuel consumption per unit area (FCA) estimates, since field measures of this parameter are typically only available from fires that are too small to be detected by SEVIRI. The frequency distribution of the FRE-BA derived FCA estimates indicates, however, that they are lower than those found in GFEDv3. ")

# Input

SIMFIRE [initial, running[a]] :

- Average Annual Rainfall (running 5 a mean ; initialisation) [DS,Input]
- Daily precip (Nesterov Index)[-;Input]
- Population density (HYDE3.1) [DS,DS] (future?)
- Average max annual fAPAR (fixed 2000-2010) [DS,?]
- Land Use Information (modis IGBP) [DS,?]

BLAZE[running[d]]:

- RH, T, Precip, U10 (McVicar 1975-2013) -> FLI (max FLI)
- Live C, above ground-Litter C, (soil-moisture for FWI ) -> Accounting ag pools/ Fire Fluxes
- (Fire_mortality) -> Fire Fluxes

TEST:

- GFED3.1, GFED 4