# Evaluation of radiative fluxes estimated using Machine learning methods and that from CERES/ERBE
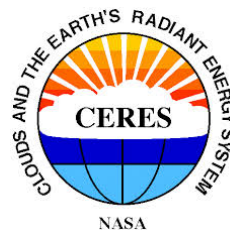
Bijoy Vengasseril Thampi[1], Takmeng Wong[2]

Constantine Lukashin[2]

[1]Science Systems and Applications, Inc., Hampton, VA
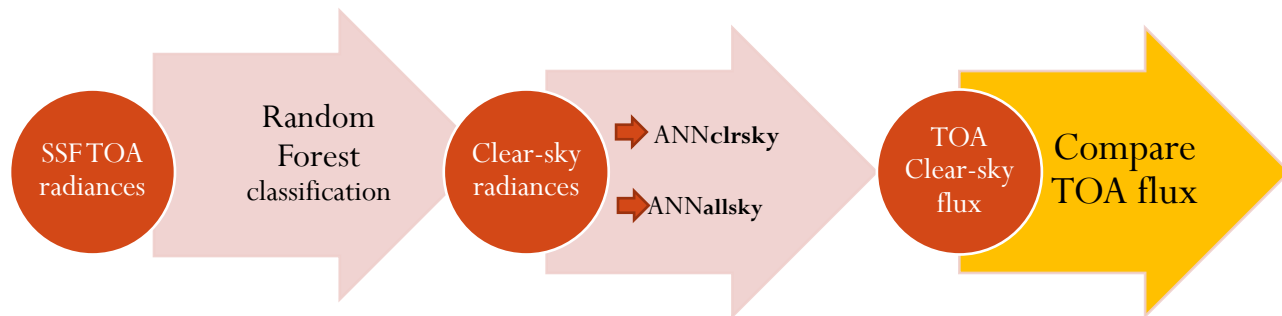[2]NASA Langley Research Center, Hampton, VA
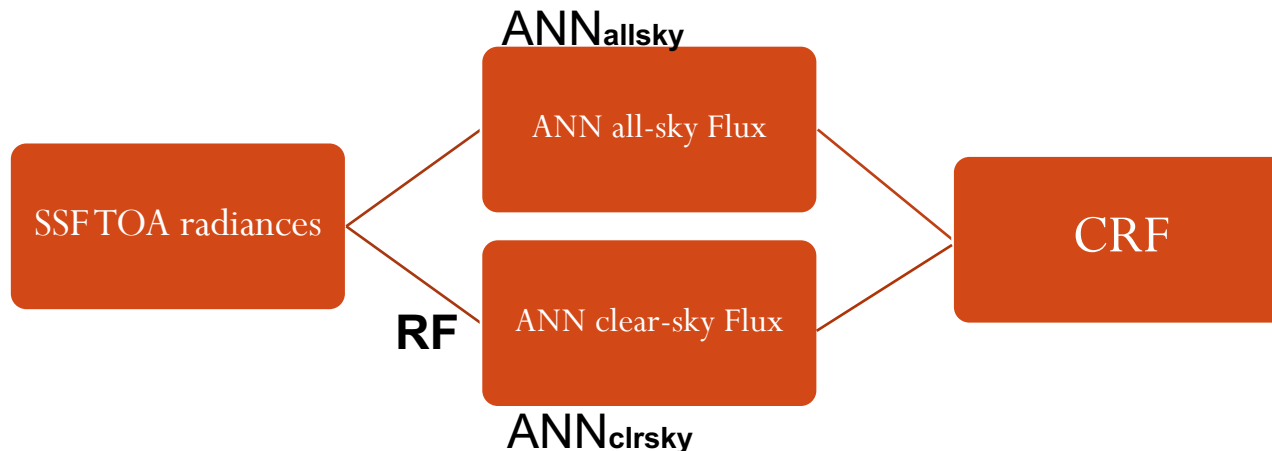
CERES Science Team Meeting, 15-17 May 2018

# Objective

- In this study, our objective is *to compare the TOA radiative fluxes and CRF estimated using the Machine learning methodologies to that with CERES and ERBE-like values.*
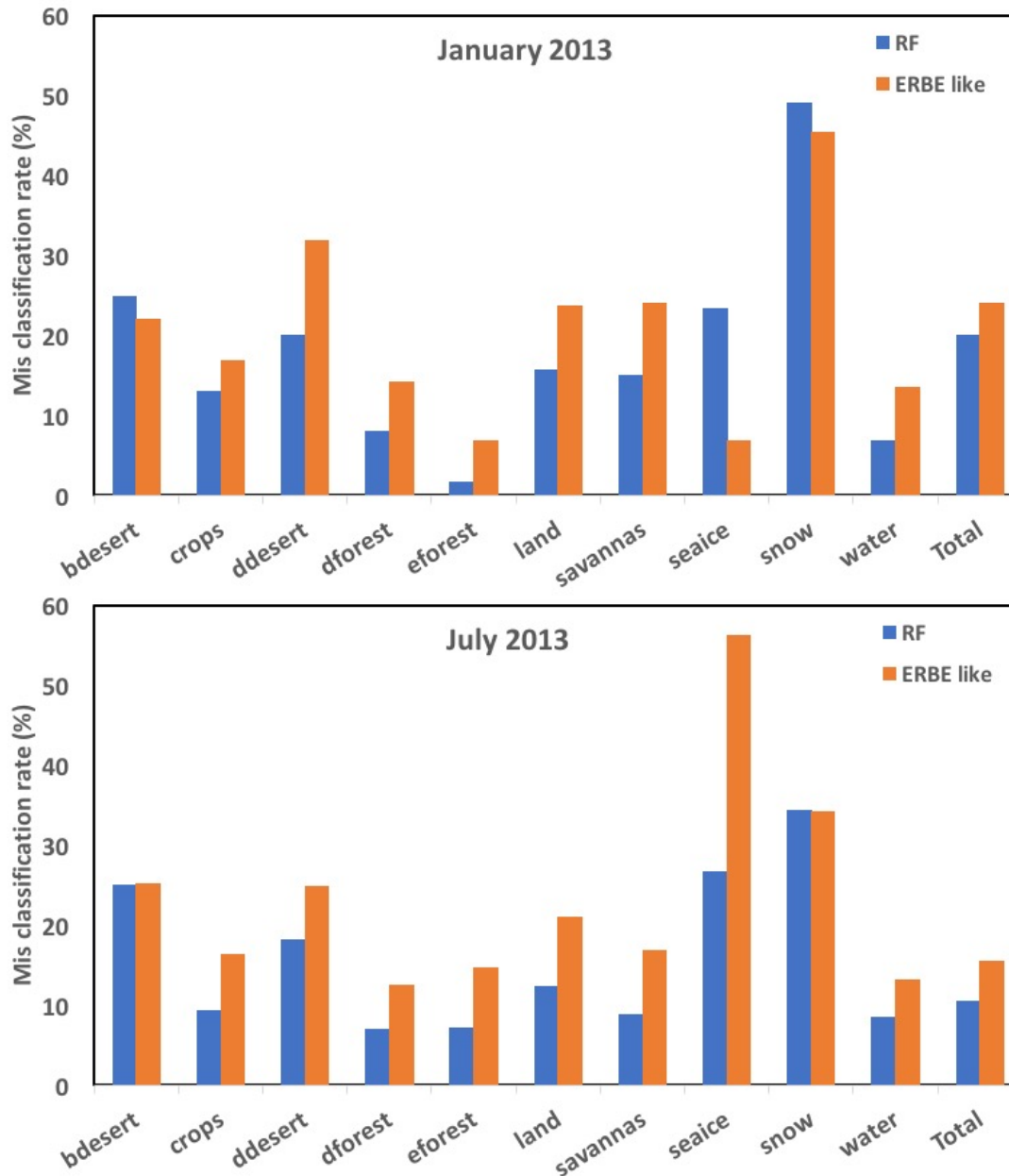


Part I:

SSF TOA radiances → Random Forest classification → Clear-sky radiances → ANNclrsky / ANNallsky → TOA Clear-sky flux → Compare TOA flux

Part II:

SSF TOA radiances → ANNallsky (ANN all-sky Flux) / RF ANNclrsky (ANN clear-sky Flux) → CRF

# Part I: Comparison of ANN methods on TOA Clear-sky Fluxes

## (ANN$_{clrsky}$ vs. ANN$_{allsky}$)

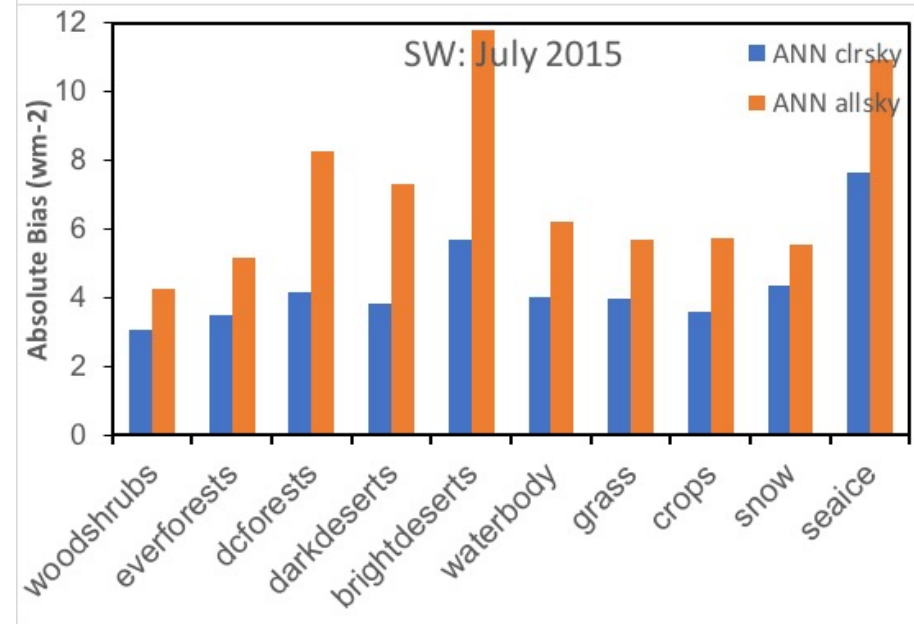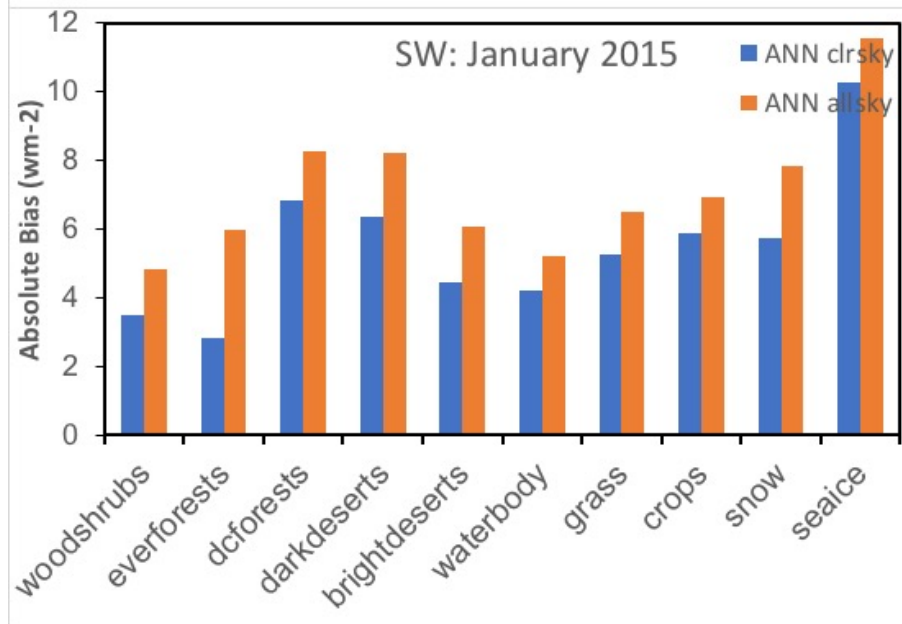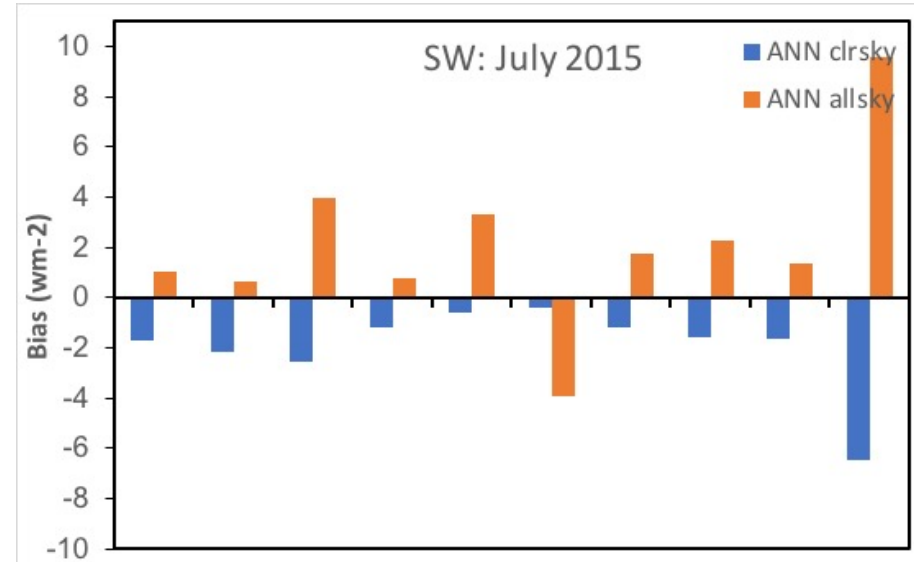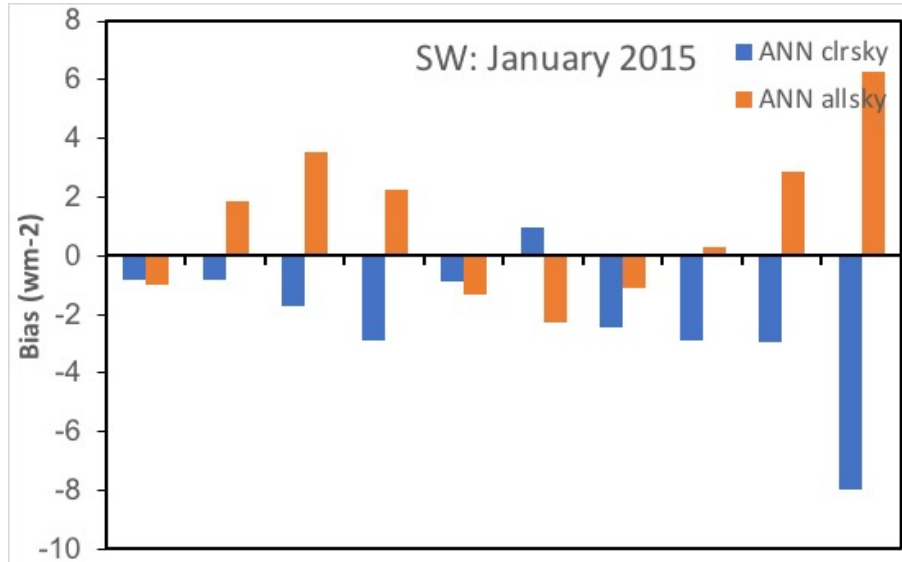# Scene classification: Random Forest vs. ERBE like



Intercomparison of clear-sky misclassification rate between ERBE-like and RF is carried out.

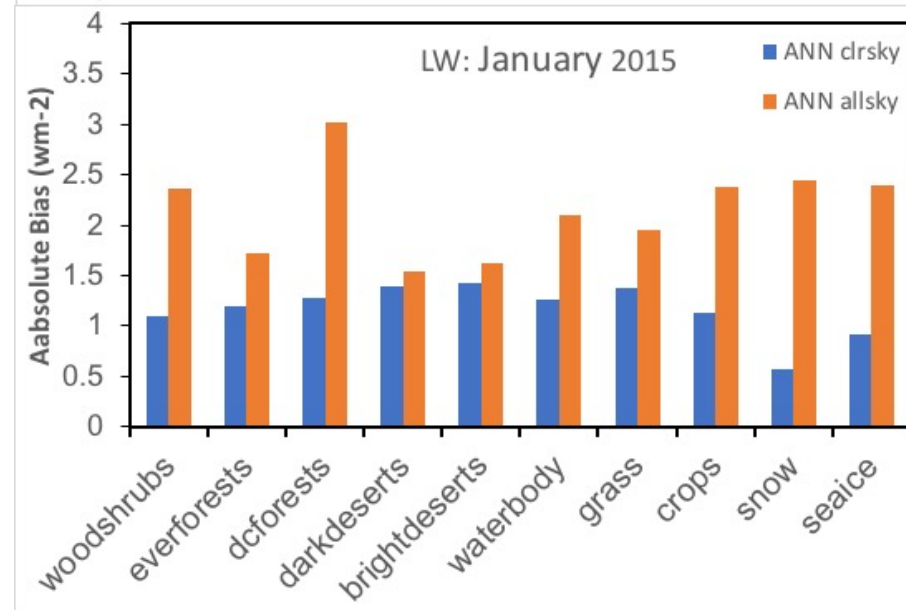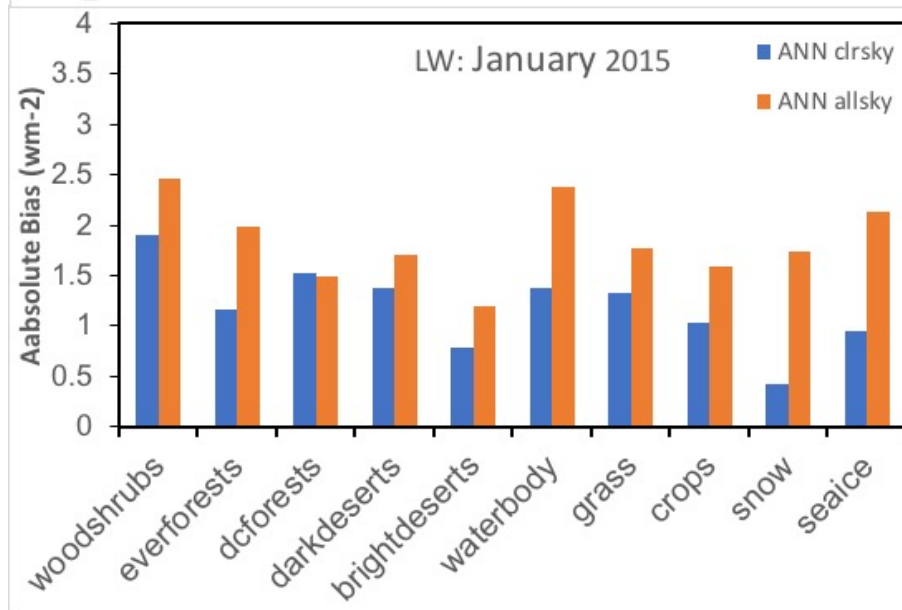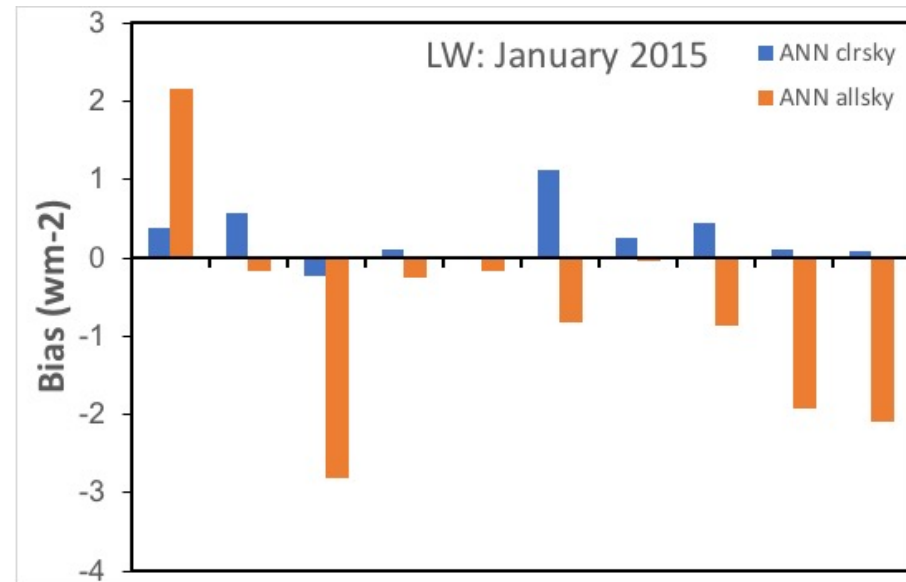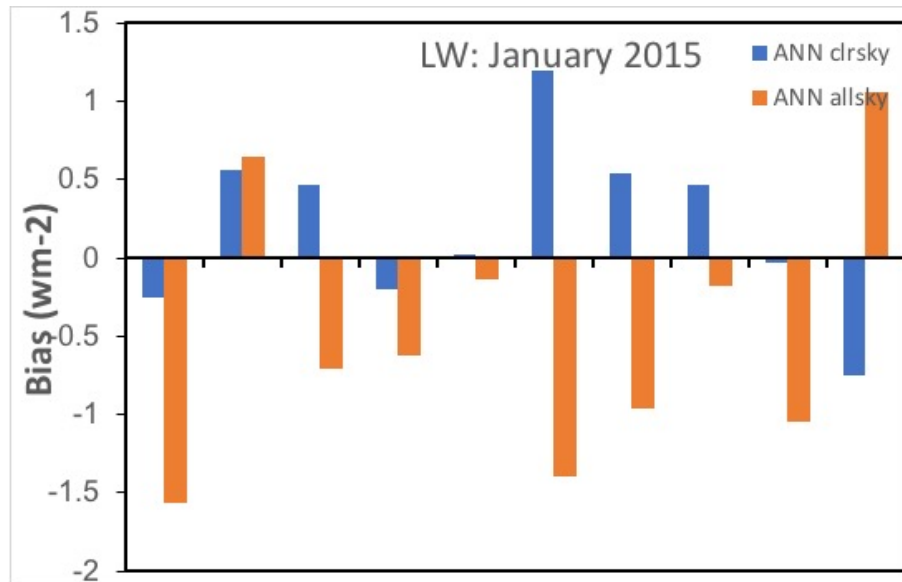RF provides better clear-sky classification for most surface types.

Snow and SeaIce surface types generally show better classification for ERBE-like data

# Bias : Day-time SW Clear-sky Flux



**Bias = SSF Flux- ANN Flux**

# Bias : Day-time LW Clear-sky Flux



**Bias =  SSF Flux- ANN Flux**

# Bias: ANN<sub>clrsky</sub> VS. ANN<sub>allsky</sub>

- Intercomparison of TOA clear-sky flux estimated using **ANN clear-sky** method Vs **ANN all-sky** method is carried out.

- Bias in the ANN estimated TOA clear-sky flux (w.r.t. SSF Flux) is calculated for two methods.

- Table shows the % of clear-sky data with lower bias values when using **ANN clear-sky** method

| Month | SW(%) | LW(%) |
|-------|-------|-------|
| JAN | 60.9 | 78.4 |
| APR | 57.5 | 70.3 |
| JUL | 66.8 | 70.2 |

# Part II: Comparison of TOA Fluxes and CRF

**(SSF vs. ANN vs. ERBE-like)**

# TOA Day-time Clear-sky flux Comparison

- Global Mean(arithmetic) clear-sky TOA flux for different surface types estimated using ANN clear-sky method is compared with that from SSF and ERBE-like method

| Surface Type | Month | SW | | | LW | | |
|---|---|---|---|---|---|---|---|
| | | SSF | ANN-SSF | ERBE-SSF | SSF | ANN-SSF | ERBE-SSF |
| Desert | JAN | 287.5 | 0.6 | -47.5 | 302.9 | -2.0 | 5.5 |
| | APR | 354.0 | 6.0 | -70.1 | 338.2 | 2.3 | -8.8 |
| | JUL | 340.6 | 3.3 | -73.5 | 348.6 | 5.1 | -11.4 |
| Land | JAN | 190.3 | 2.5 | -23.8 | 320.2 | -3.6 | -15.8 |
| | APR | 204.5 | 3.6 | -23.5 | 318.4 | 1.3 | -11.4 |
| | JUL | 170.7 | 3.1 | -19.3 | 316.1 | -4.1 | -16.6 |
| Ocean | JAN | 86.1 | 6.0 | 8.1 | 287.6 | 0.6 | 0.7 |
| | APR | 84.4 | 8.5 | 4.7 | 284.7 | -3.5 | 2.1 |
| | JUL | 79.4 | 8.2 | 7.6 | 284.4 | -2.4 | 2.4 |
| Snow | JAN | 293.7 | -33.9 | 31.8 | 196.0 | -1.3 | -1.0 |
| | APR | 259.7 | -7.3 | -7.5 | 201.3 | -2.5 | 2.3 |
| | JUL | 329.9 | -30.5 | -87.5 | 233.9 | -1.3 | 6.8 |

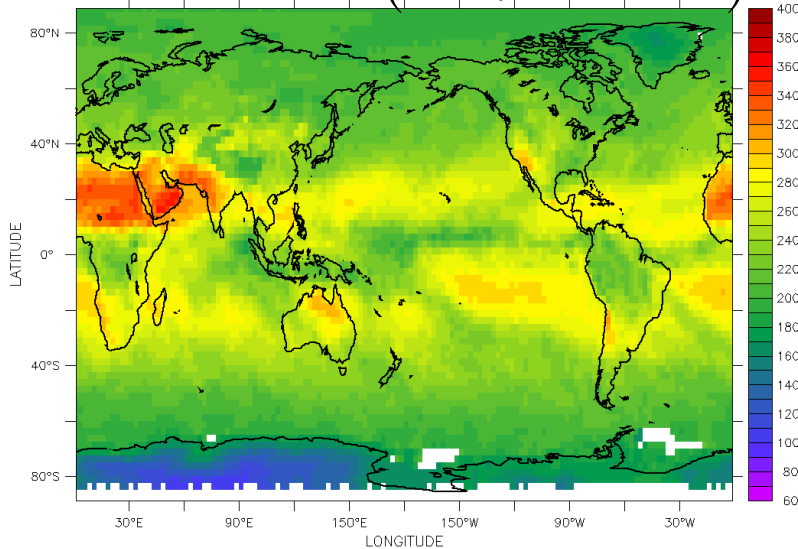# TOA day-time All-sky Flux: SSF vs. ANN (April 2015)
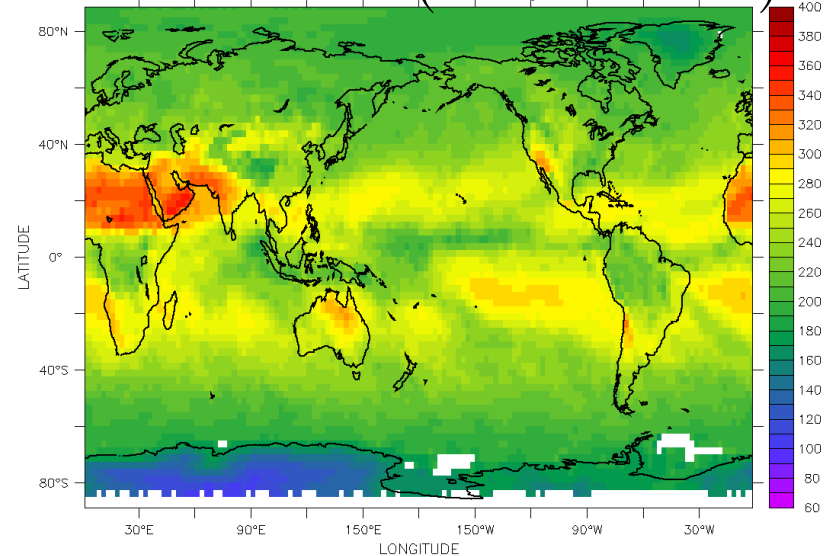


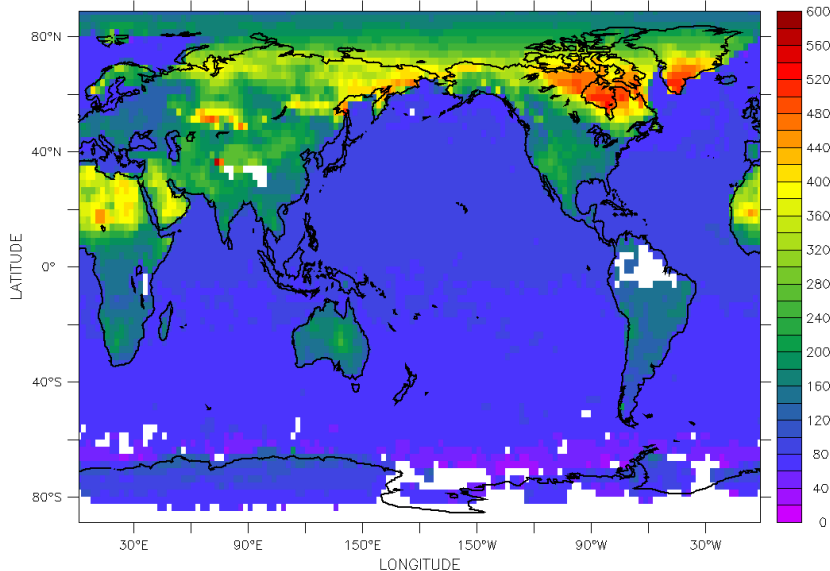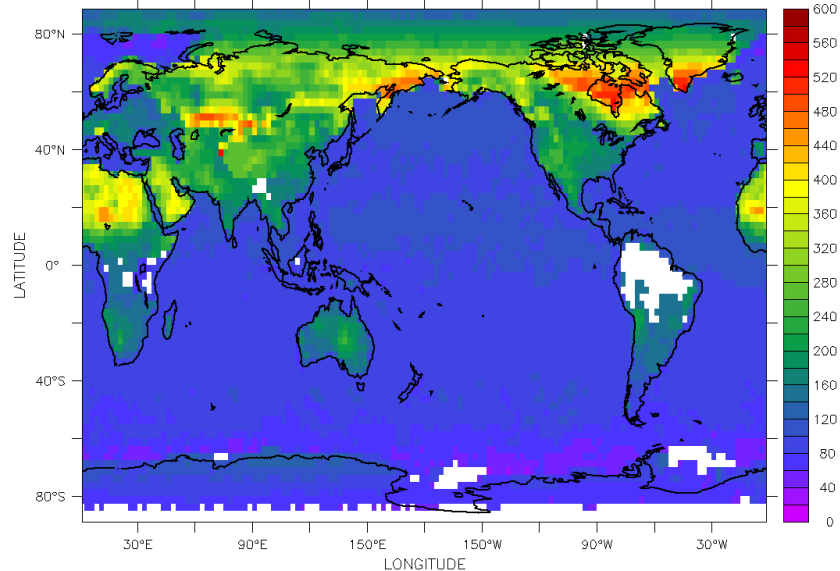SSF (246.2 W/m2)　ANN (246.6 W/m2)

SW

(243.1 W/m2)　(242.5 W/m2)

LW
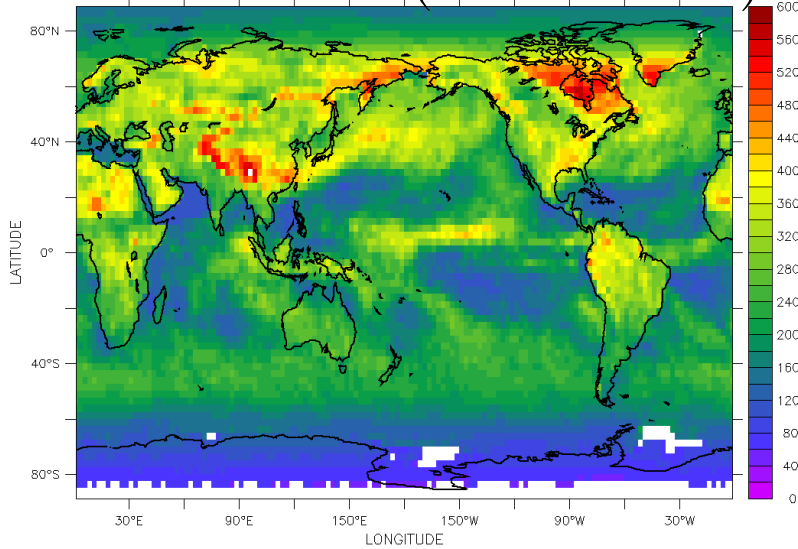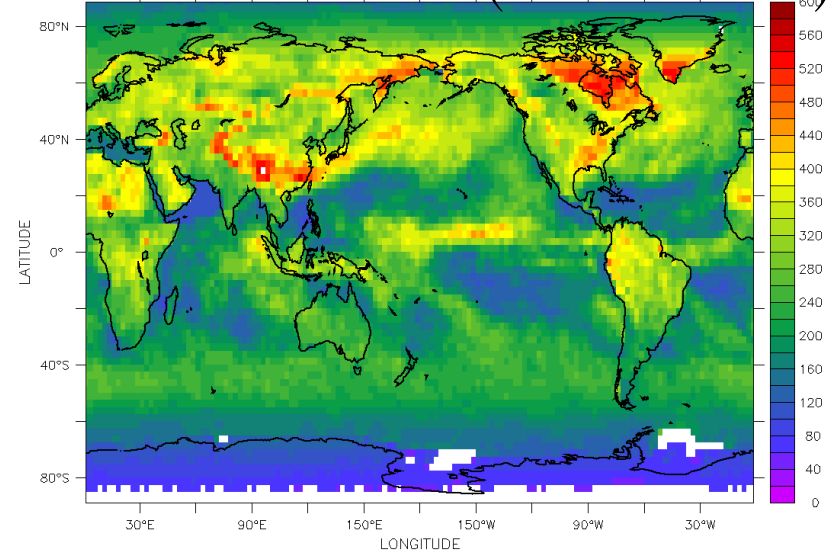
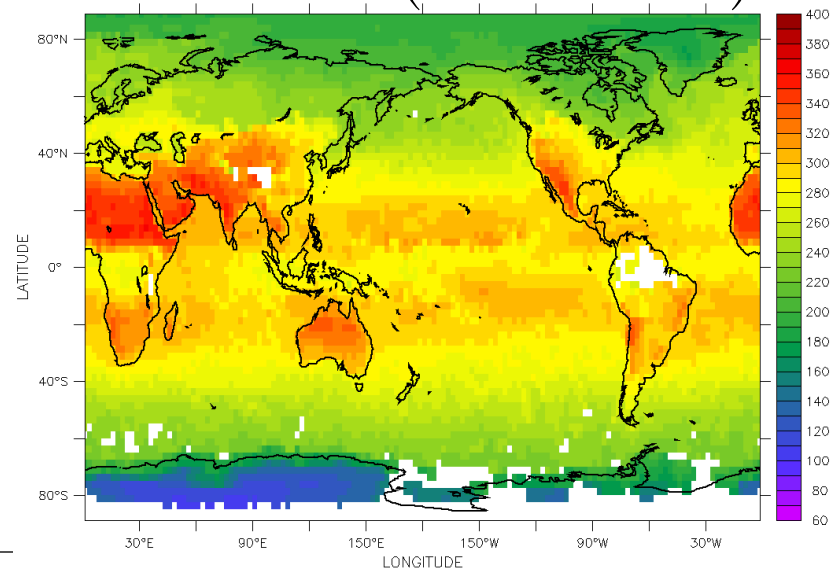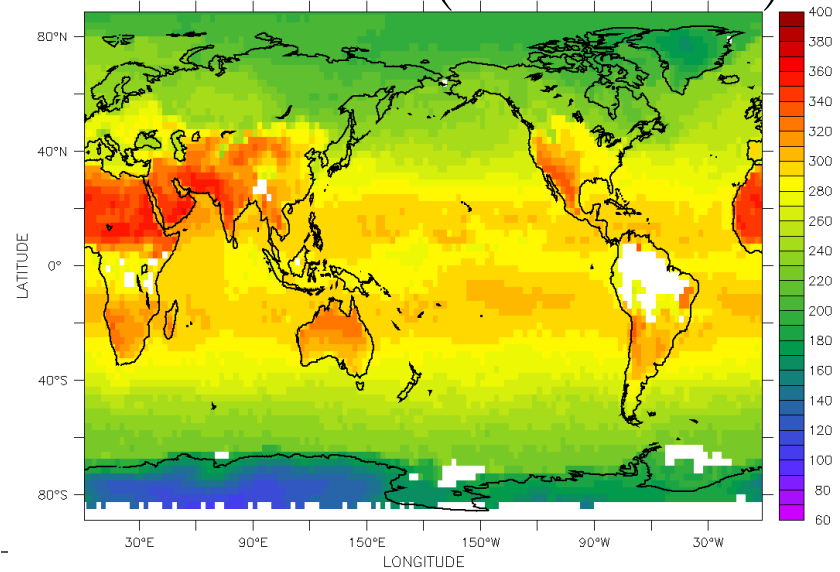# TOA day-time Clear-sky Flux: SSF vs. ANN (April 2015)
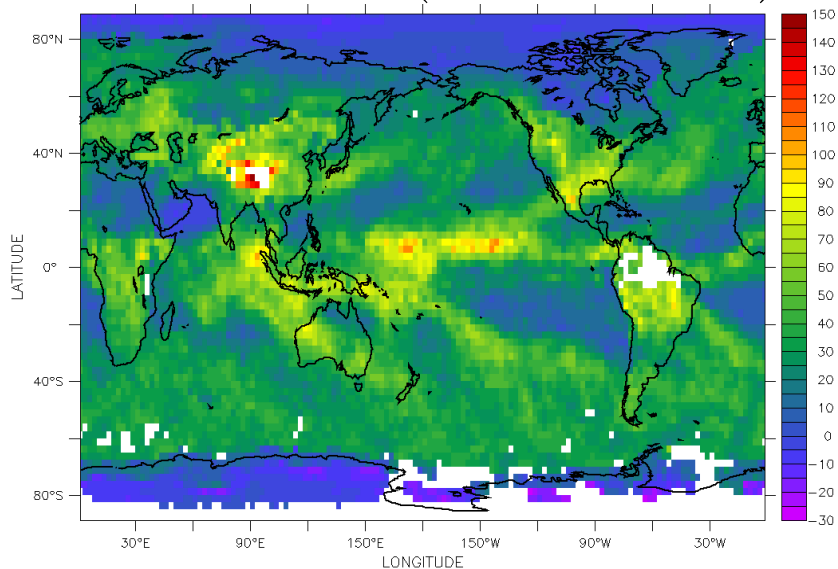
# Day-time TOA flux Comparison

- Global day-time mean (geocentric weighted)TOA flux estimated using ANN method is compared with that from SSF and ERBE-like method.

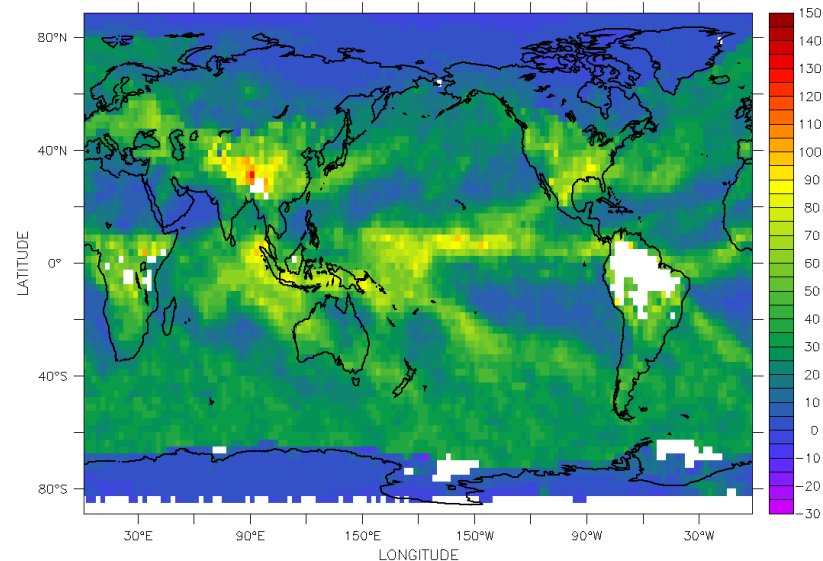|   | Month | All-sky | | | Clear-sky | | |
|---|---|---|---|---|---|---|---|
|   |   | SSF | ANN-SSF | ERBE-SSF | SSF | ANN-SSF | ERBE-SSF |
| SW | JAN | 257.0 | 0.5 | -10.7 | 114.6 | -1.8 | 4.0 |
|   | APR | 246.2 | 0.4 | -10.0 | 119.7 | -2.1 | 3.1 |
|   | JUL | 233.7 | -0.4 | -12.6 | 103.7 | -1.8 | 6.8 |
| LW | JAN | 243.0 | -0.6 | 2.0 | 274.6 | 0.9 | -1.8 |
|   | APR | 243.1 | -0.6 | 1.8 | 276.0 | 1.0 | -1.3 |
|   | JUL | 252.4 | -0.8 | 0.8 | 285.5 | 1.0 | -4.0 |

# TOA Day-time CRF: SSF vs. ANN (April 2015)
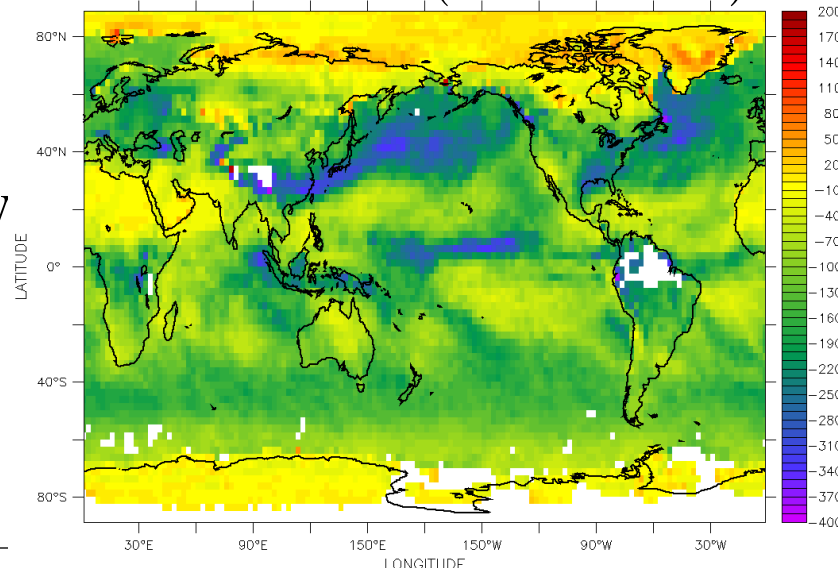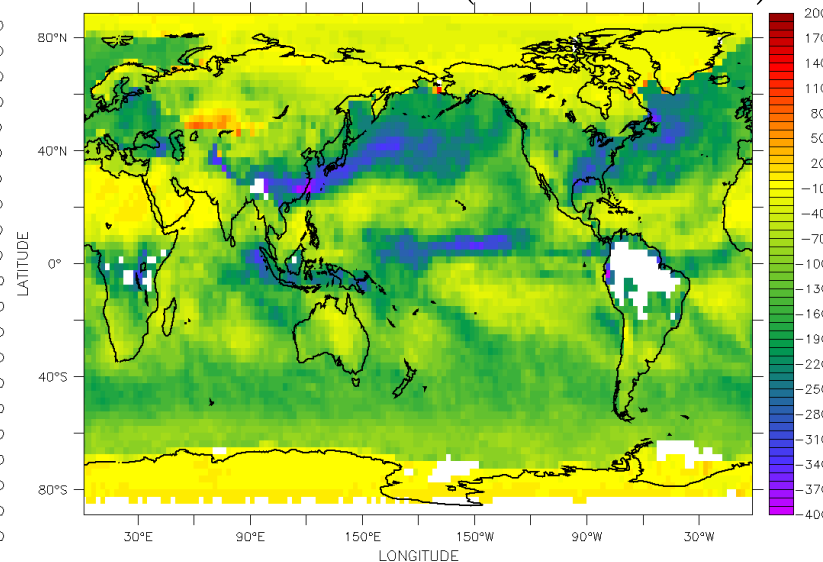


SSF     (-117.7 W/m2)     ANN     (-114.9 W/m2)

SW

(32.6 W/m2)     (29.7 W/m2)
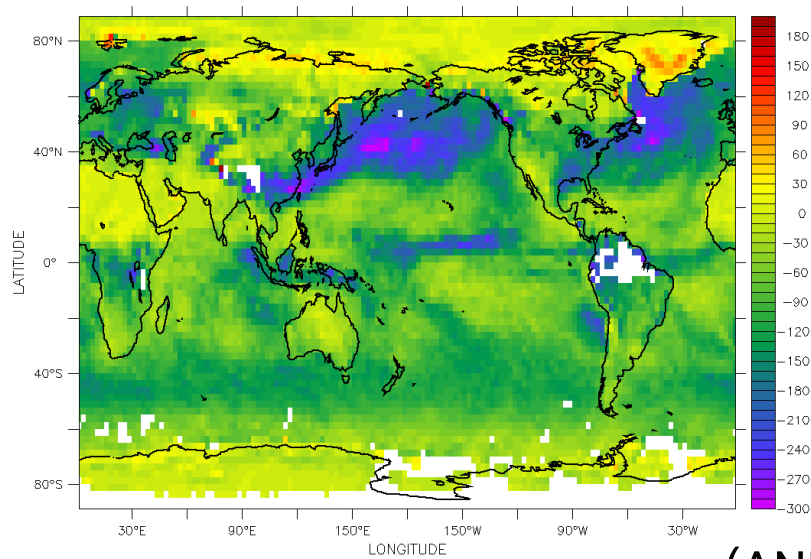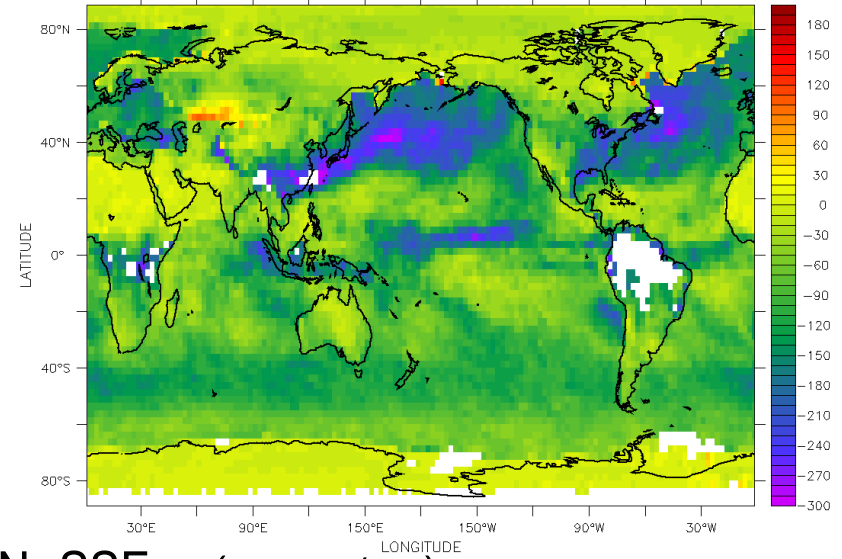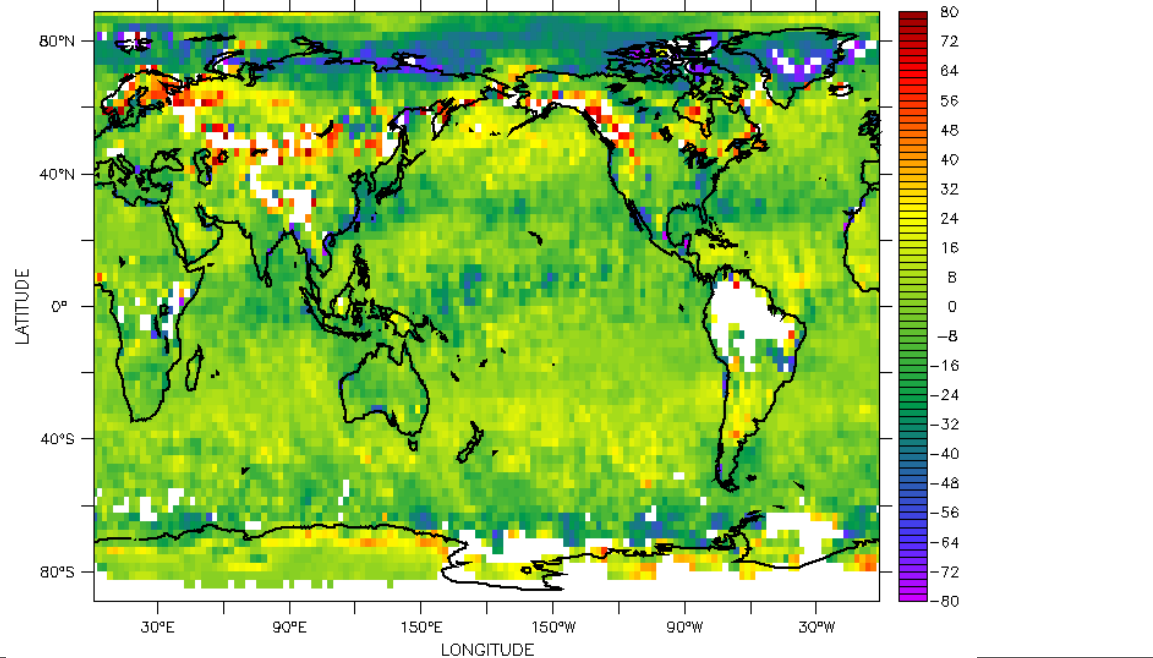
LW

# Mean NETCRF

SSF  (−85.1 W/m2)



(ANN  (−85.2 W/m2)



(ANN−SSF  (−0.1 W/m2)

# Day-time TOA CRF comparison

- Global day-time mean TOA CRF (geocentric mean) estimated using the ANN method is compared with that from SSF and ERBE-like data.

|        | Month | SSF    | ANN-SSF | ERBE-SSF |
|--------|-------|--------|---------|----------|
| SWCRF  | JAN   | -133.1 | -2.5    | 5.3      |
|        | APR   | -117.7 | 2.8     | 4.8      |
|        | JUL   | -120.9 | -0.8    | 9.1      |
| LWCRF  | JAN   | 31.0   | -2.4    | -3.8     |
|        | APR   | 32.6   | -3.0    | -3.5     |
|        | JUL   | 31.8   | -1.6    | -4.1     |
| NETCRF | JAN   | -102.1 | -4.9    | 1.5      |
|        | APR   | -85.1  | -0.1    | 1.3      |
|        | JUL   | -89.1  | -2.4    | 5.0      |

# Summary

- Modified ANN clear-sky method produce more accurate TOA flux values most of the time (>60% of data) compared to all-sky ANN method with relatively lower Bias.

- Global mean (weighted) clear-sky TOA flux estimated using ANN clear-sky method show good comparison with SSF derived Fluxes

- Global mean weighted CRF estimated using ANN method compares well with that with of SSF for different months.

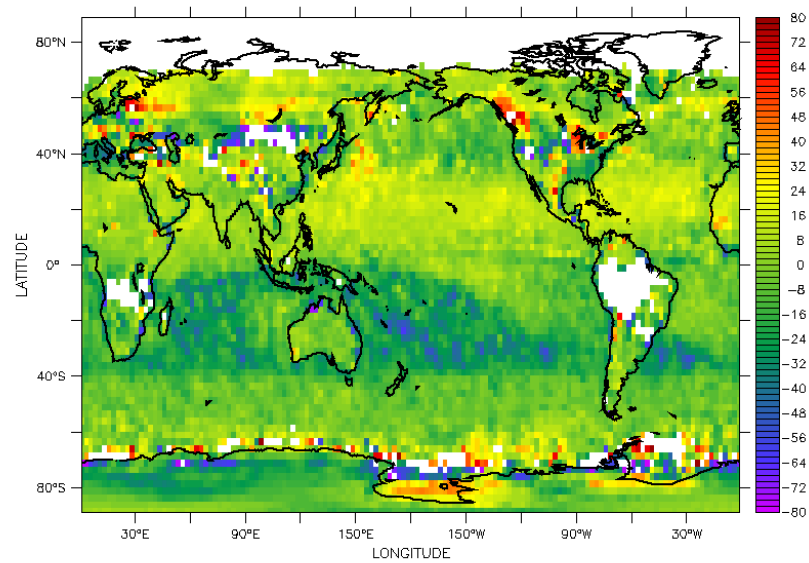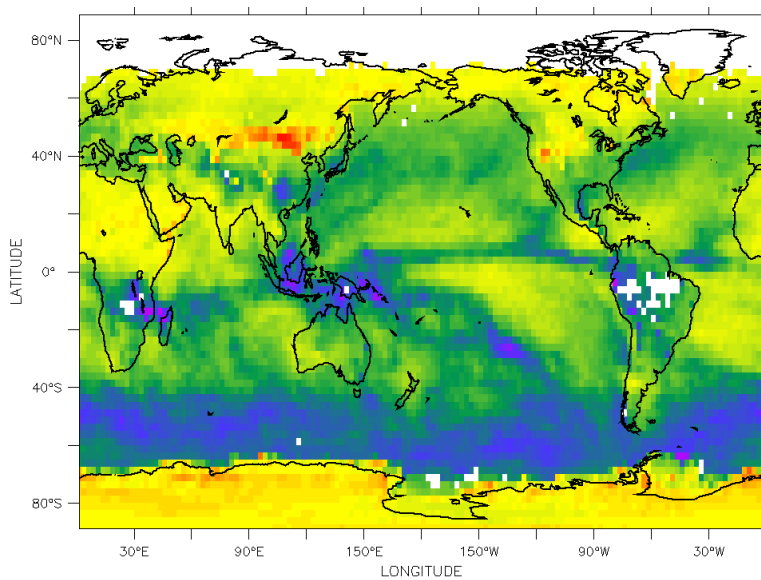- Global mean CRF estimated using the ANN method generally performs better compared to ERBE-like
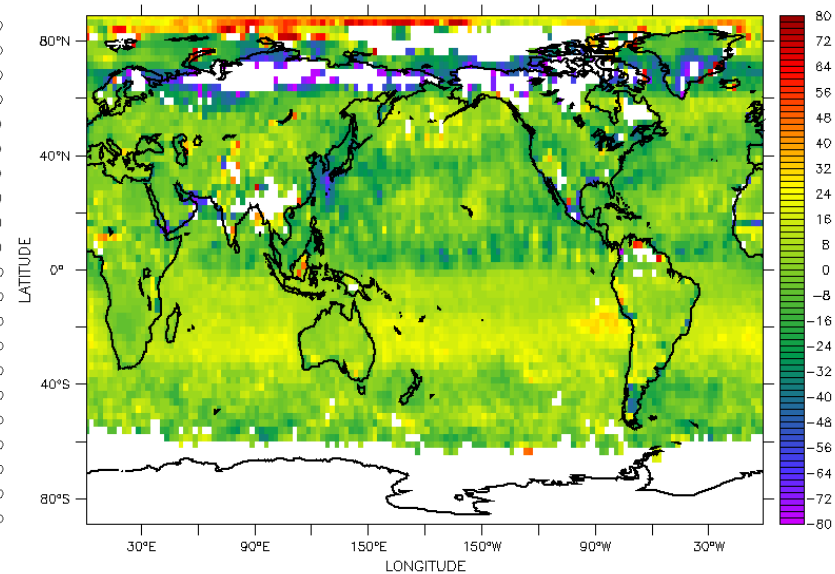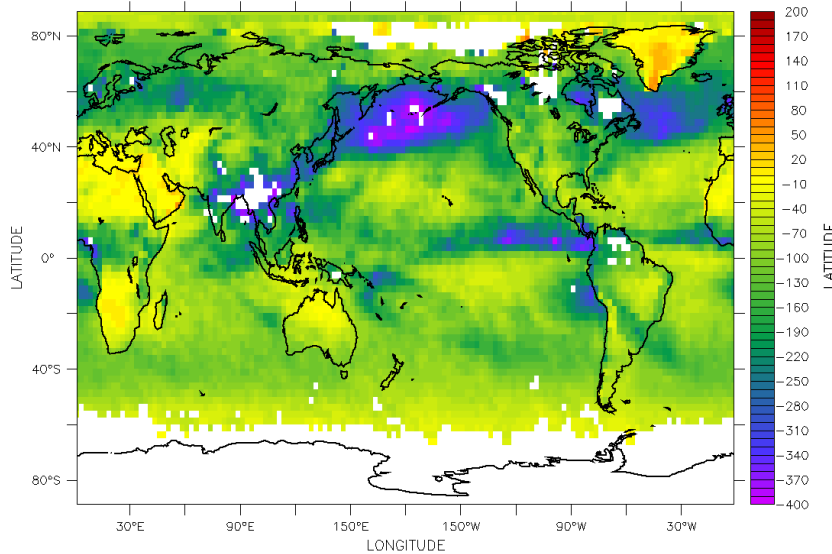
Thank you…

# Mean SWCRF

## CERES

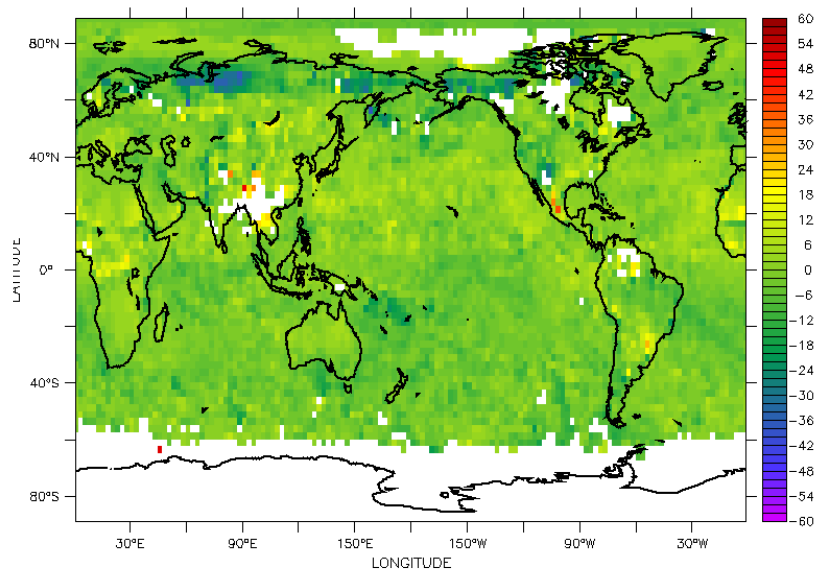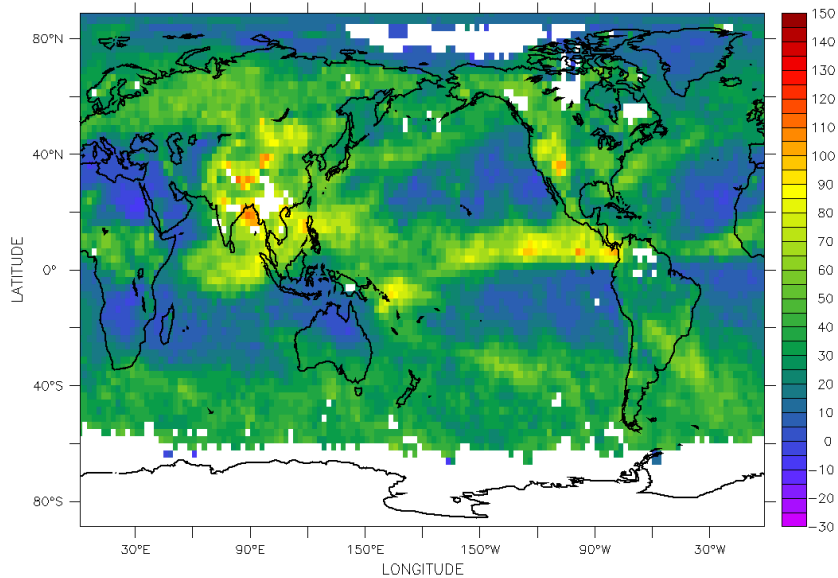## $(SWCRF_{ANN-SSF})$

Jan

Jul

# Mean LWCRF



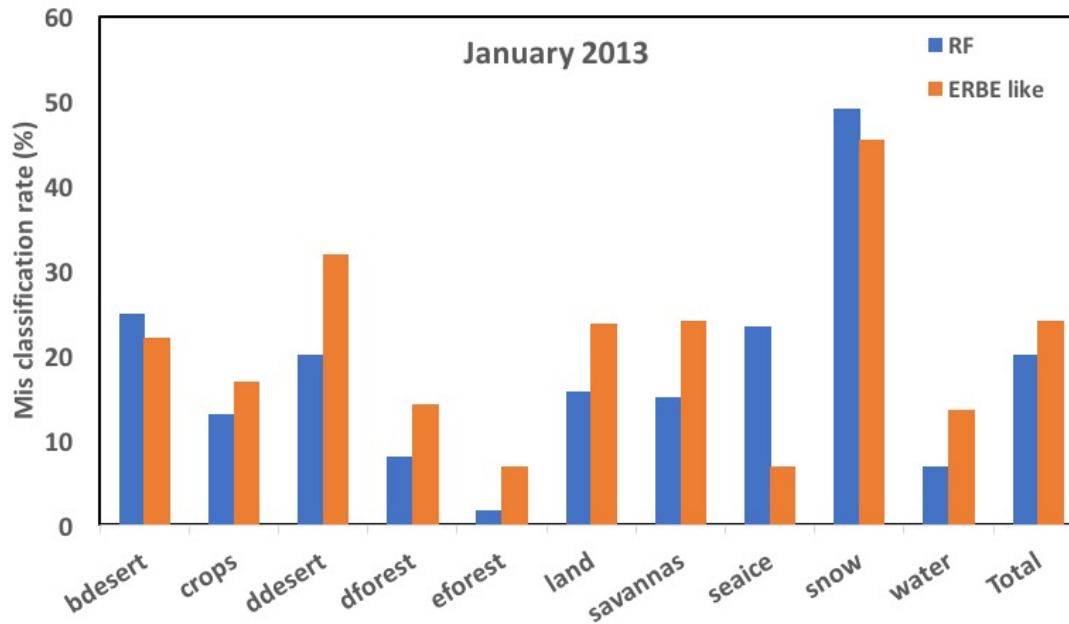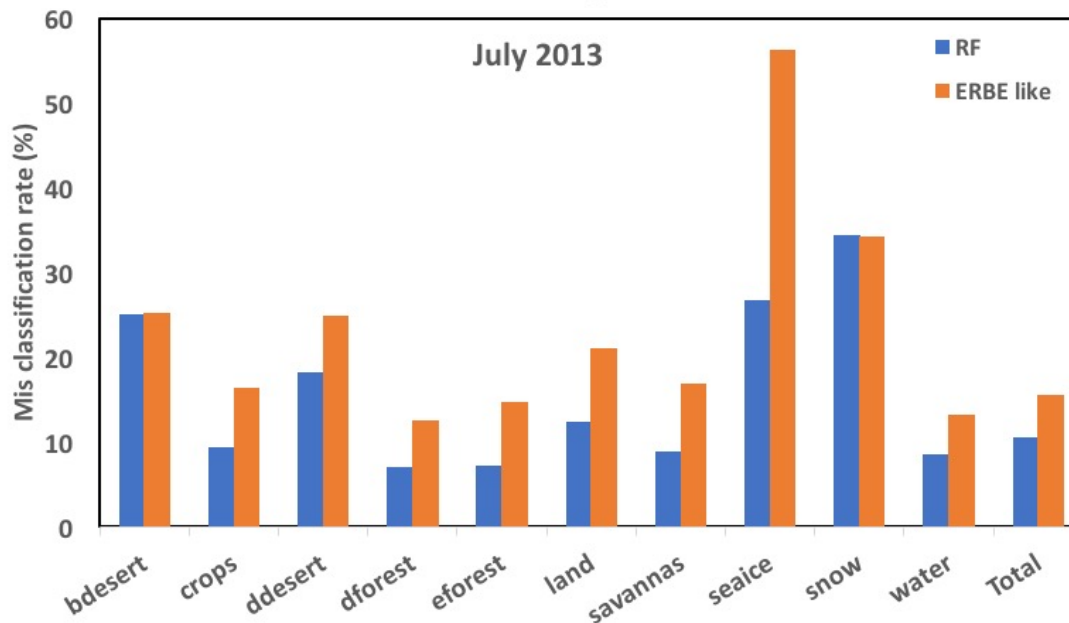CERES      $(LWCRF_{ANN-SSF})$

Jan
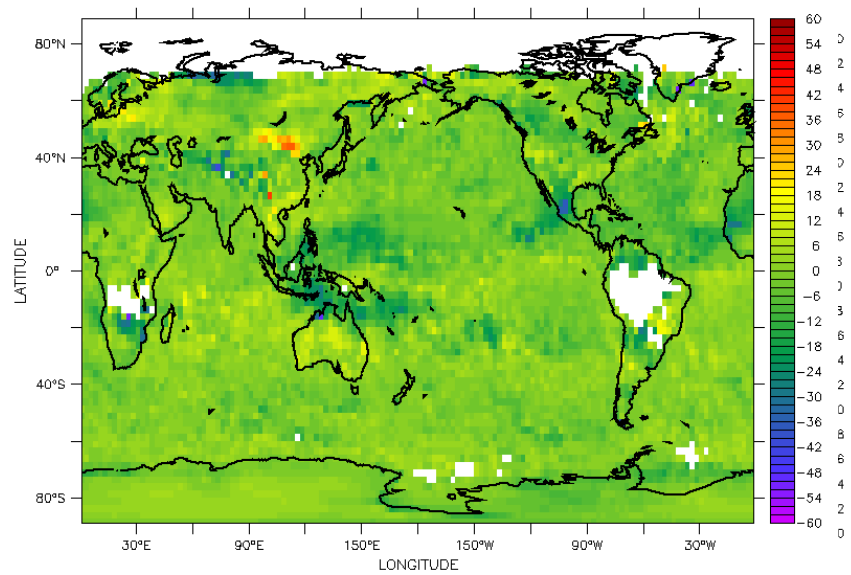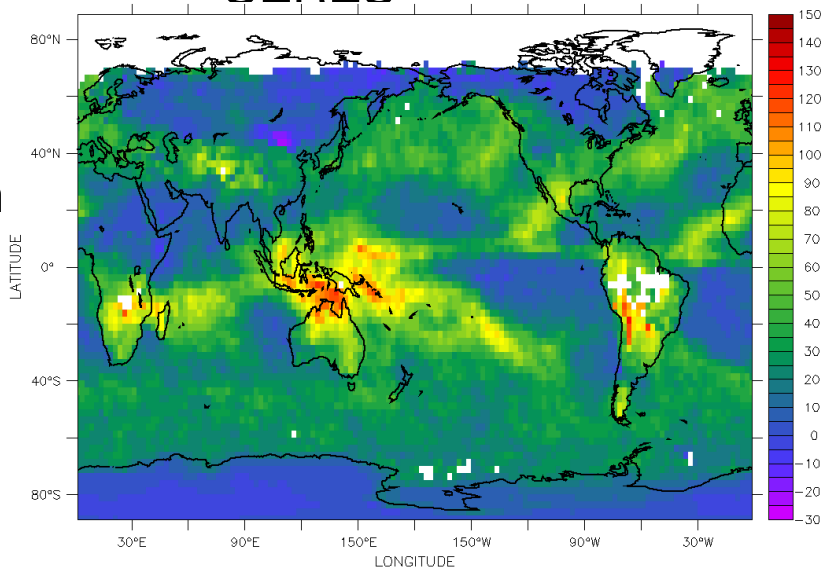
Jul

# Scene classification: RF vs ERBE like



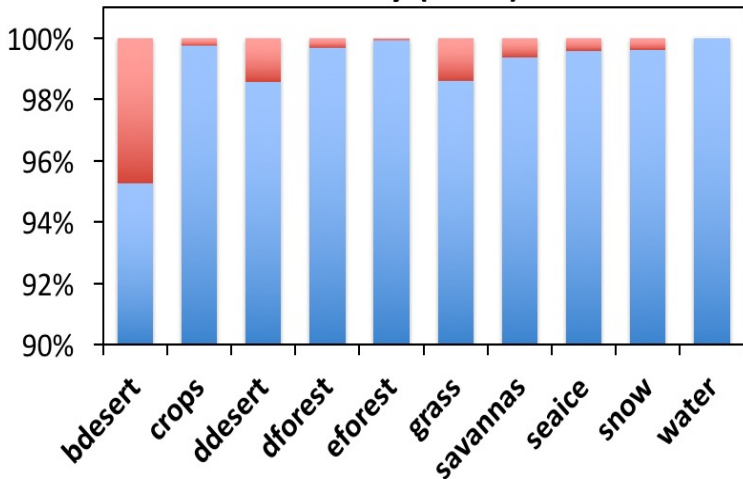Intercomparison of misclassification rate between ERBE-like and RF is carried out.

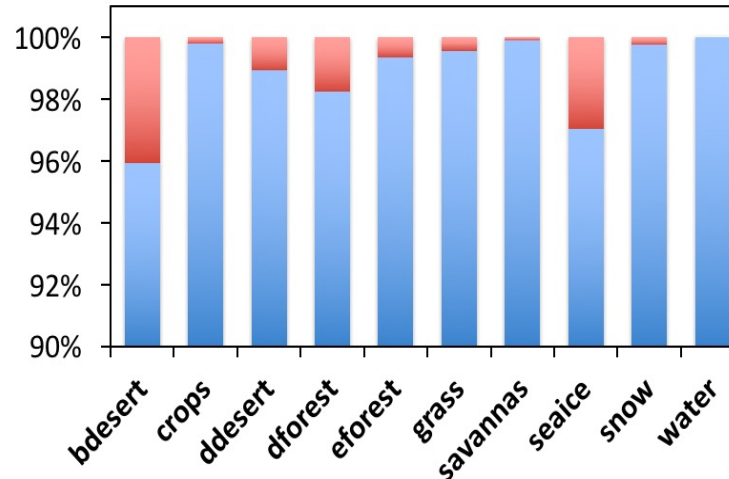RF provides better classification for most surface types.

Snow and SeaIce surface types generally show better classification for ERBE-like data
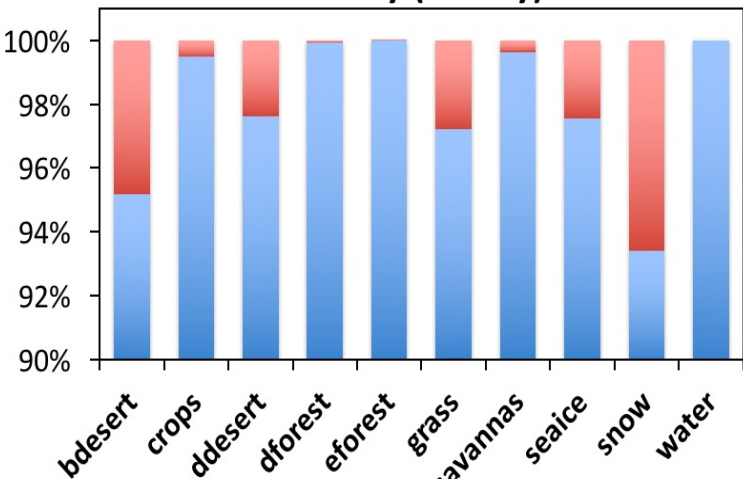
# RF scene classification Results
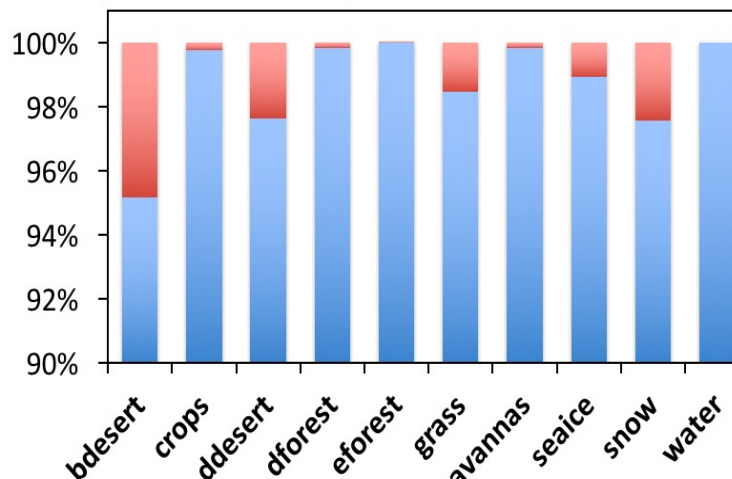


January (Clear)

July (Clear)

**Year : 2015 (Day time)**

**RED** – misclassified data points

January (Cloudy)

July (Cloudy)

- Scene Classification rate in general is > 98% for most of the surface types
- A misclassification rate of 3-6% is observed for surface types like bright deserts, snow and seaice.
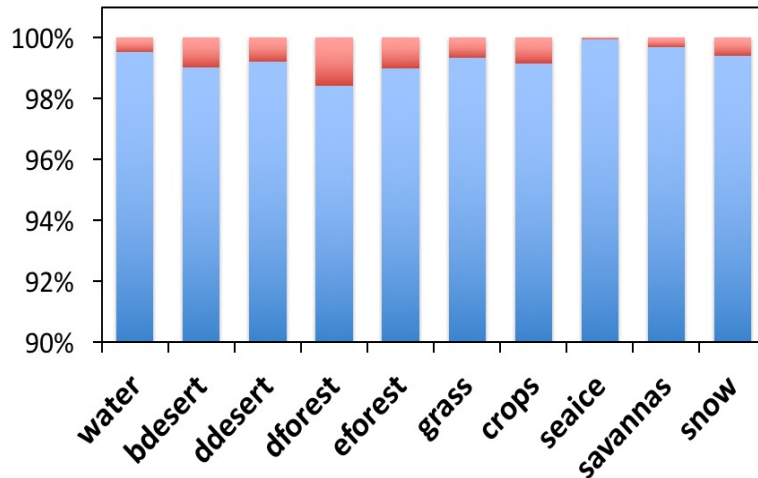
# TOA flux Comparison

- Here the SSF clear-sky flux values are average of the corresponding ANN clr-sky flux in the ANN output file(ANNclrmean.txt). Not monthly mean from SSF output file.
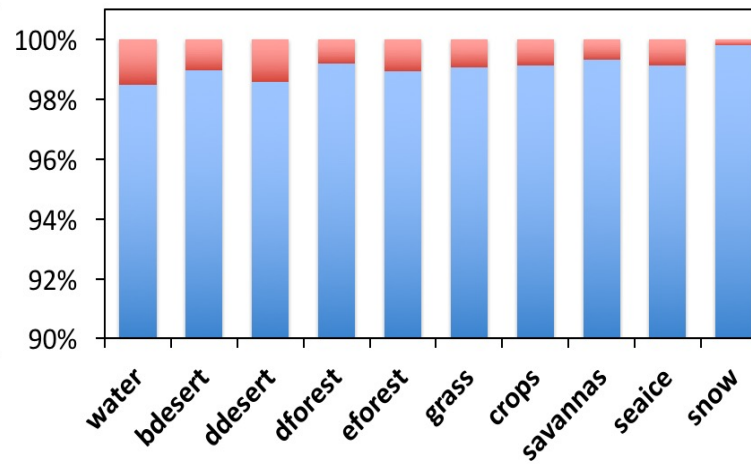
| Month | | All-sky | | Clear-sky | |
|---|---|---|---|---|---|
| | | SW | LW | SW | LW |
| Apr | ANN | 246.58 | 242.49 | 129.97 | 272.44 |
| | SSF | 246.19 | 243.05 | 132.07 | 271.48 |
| | ERBE | 236.18 | 244.8 | 122.81 | 274.66 |
| Jan | ANN | 257.47 | 242.43 | 119.09 | 271.6 |
| | SSF | 257.01 | 243.04 | 120.88 | 270.73 |
| | ERBE | 246.36 | 245.06 | 118.61 | 272.8 |
| Jul | ANN | 233.35 | 251.62 | 110.84 | 282.58 |
| | SSF | 233.72 | 252.38 | 112.63 | 281.56 |
| | ERBE | 221.12 | 253.21 | 110.43 | 281.54 |

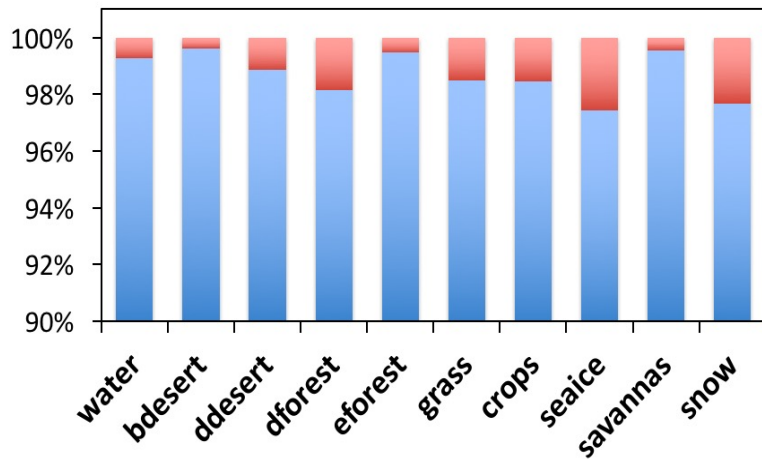# RF scene classification Results
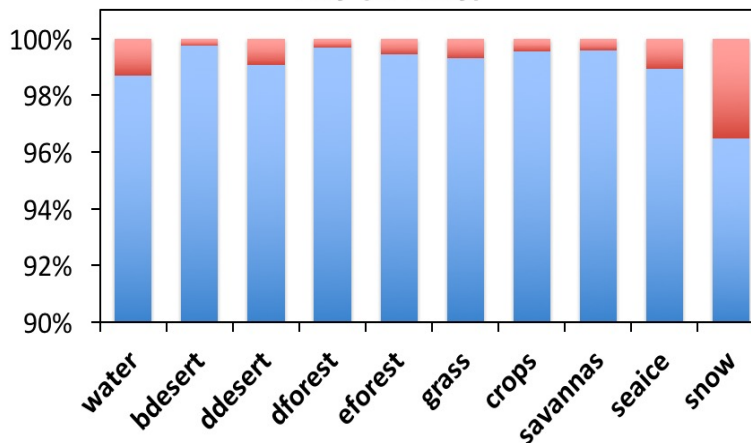


**January (Clear)**

**July (Clear)**

**January (Cloudy)**

**July (Cloudy)**

Surface Type

**Year : 2015 (Night time)**

**RED** – misclassified data points

- Both SW radiance and albedo are not included in the night time analysis
- Scene classification rate in general > 98% for most of the surface types
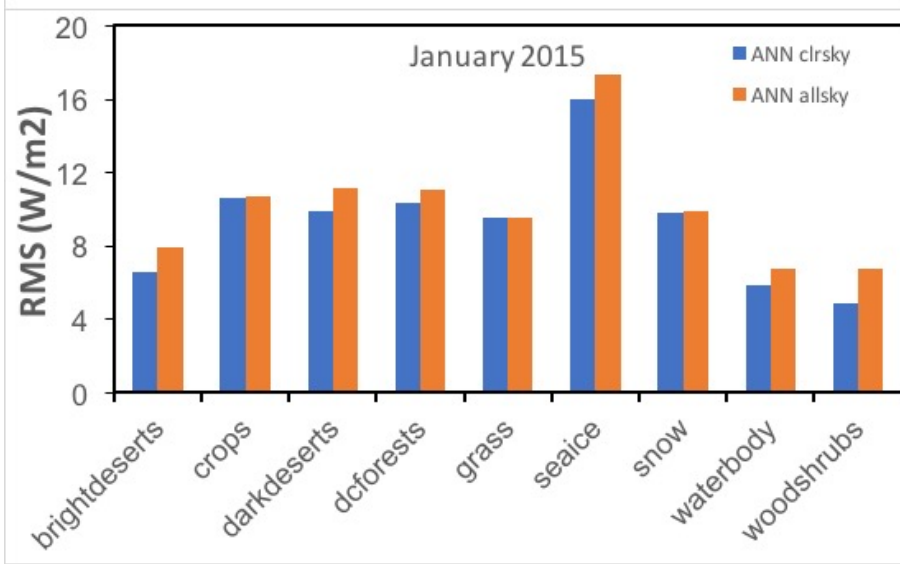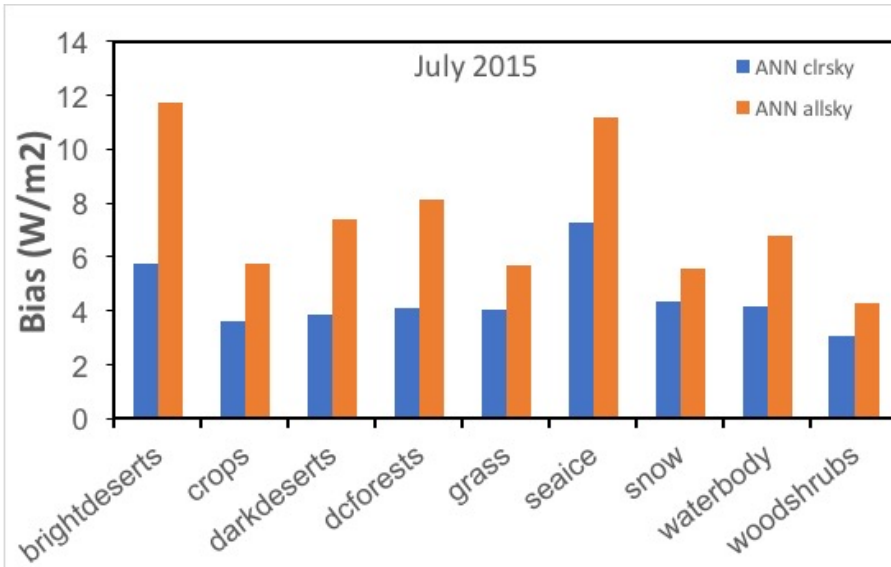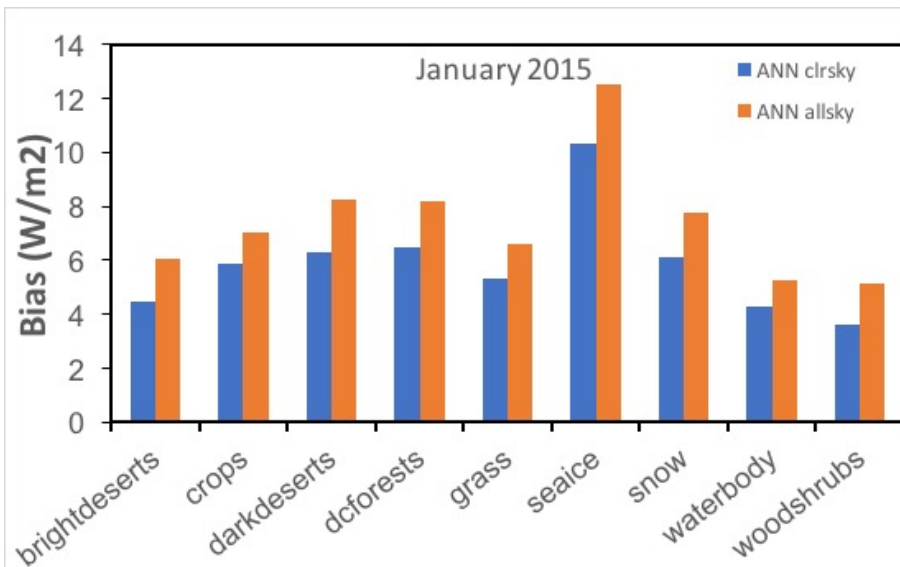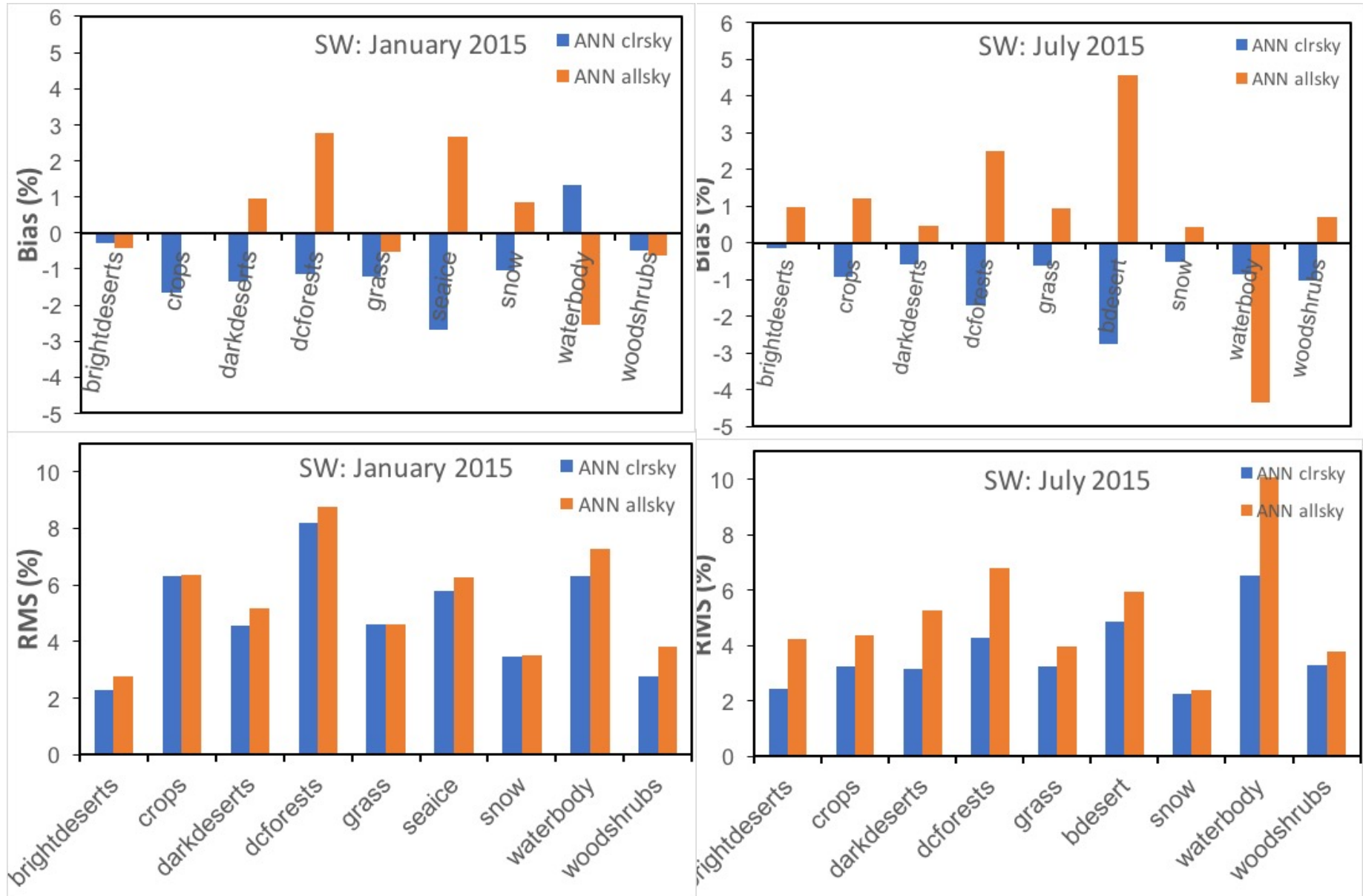- Misclassification rate is relatively high (>3%) for surface types like snow and seaice.

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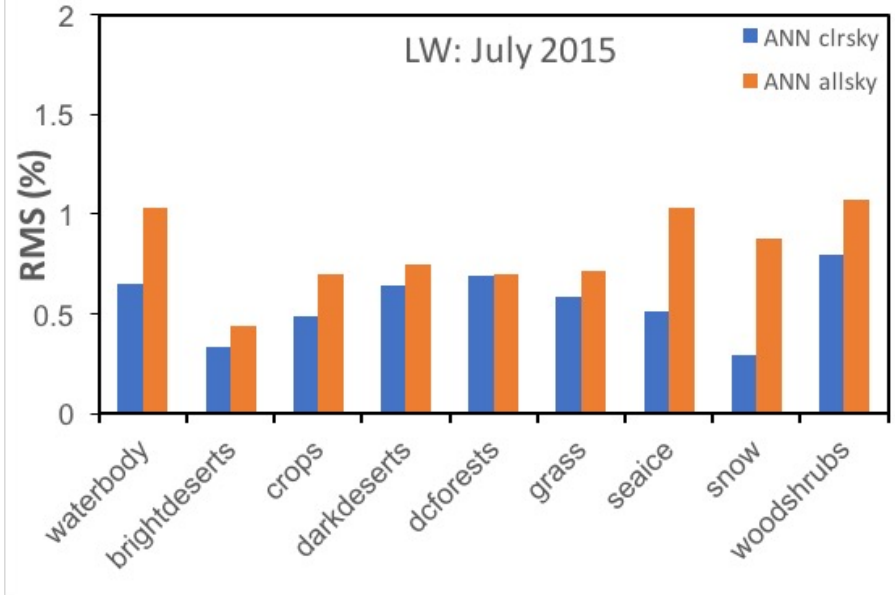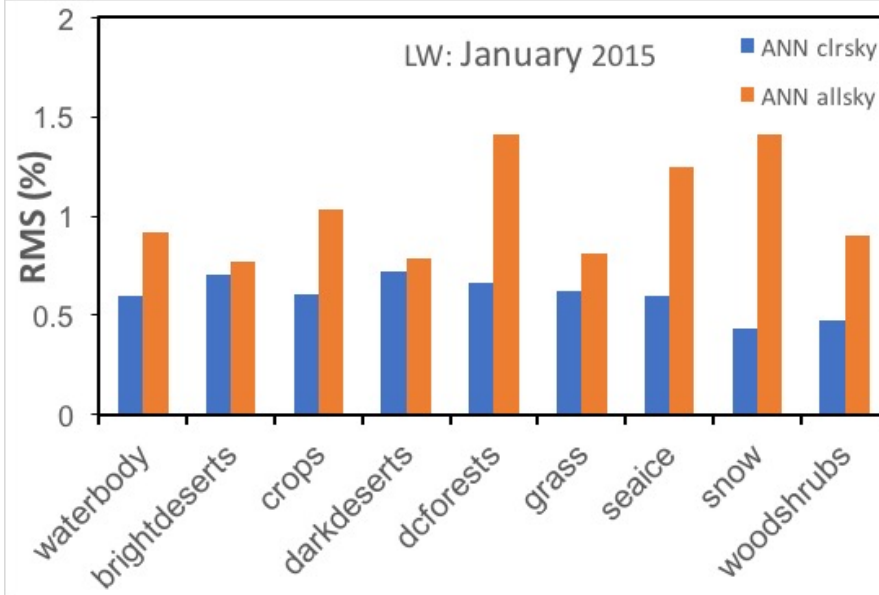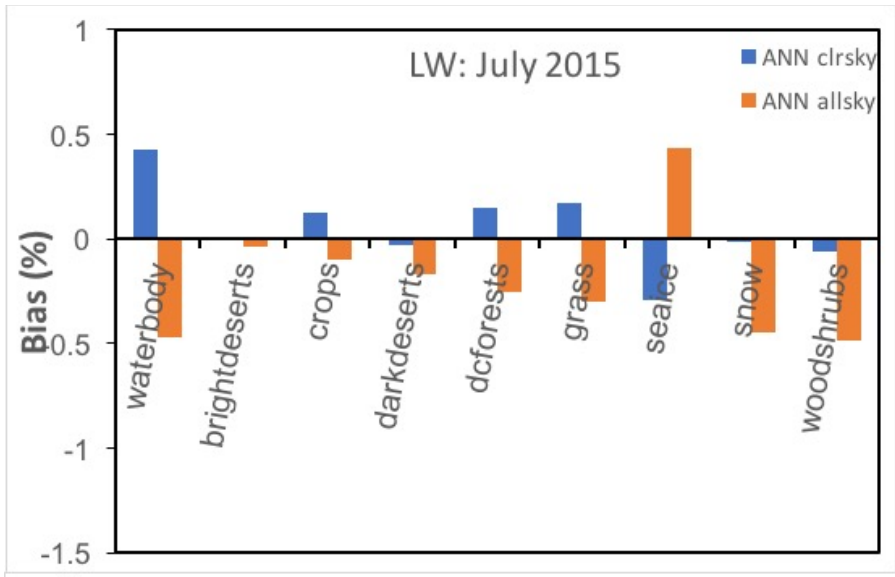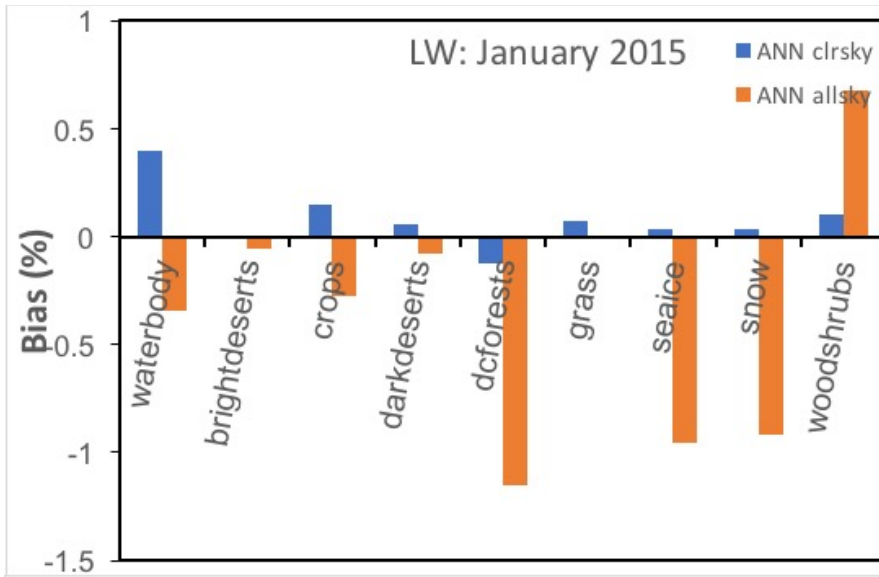# Absolute Bias & RMS : SW clear-sky Flux
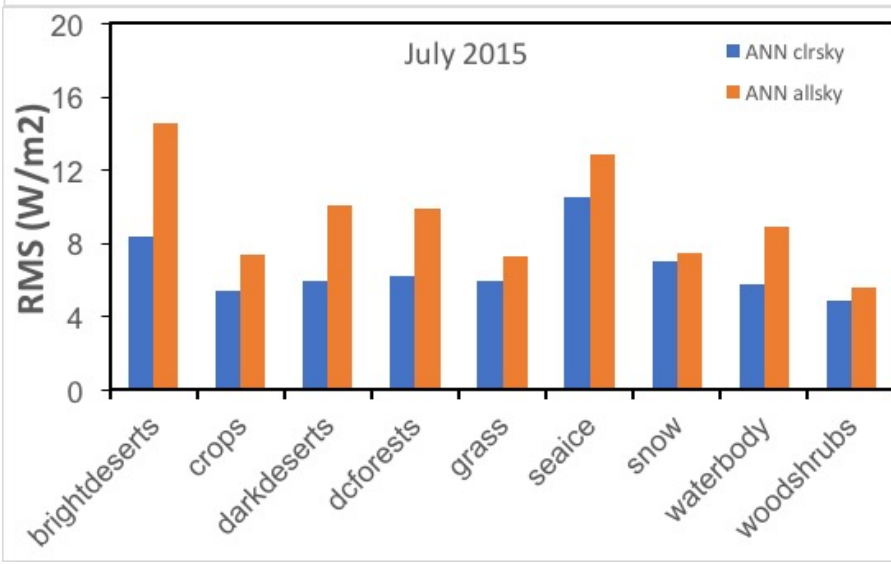


- Mean Bias and RMS is relatively lower for the ANN clear sky method compared to the all sky method estimated for the Clear-sky SW TOA Fluxes.
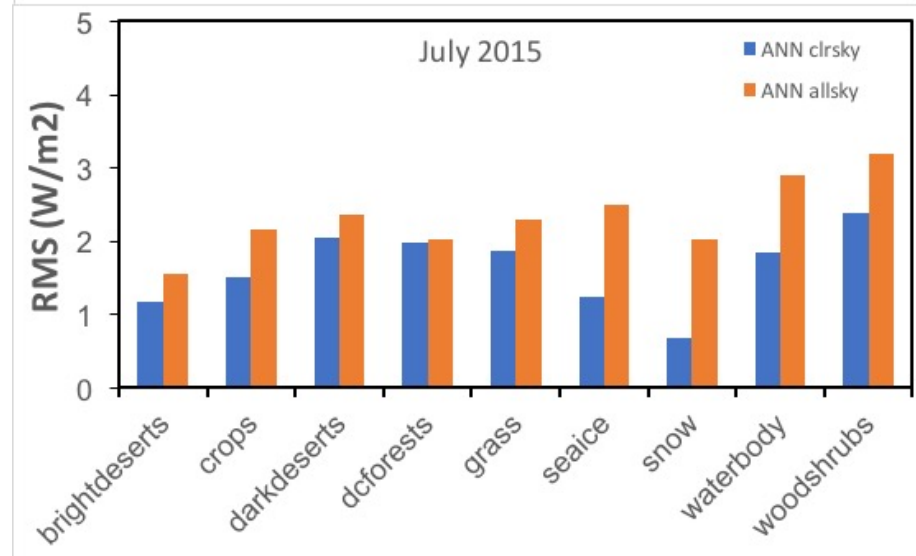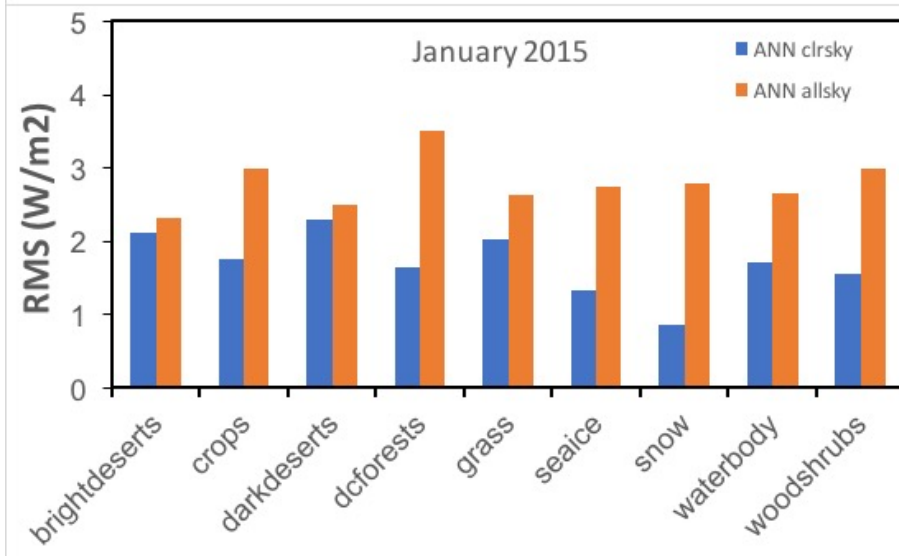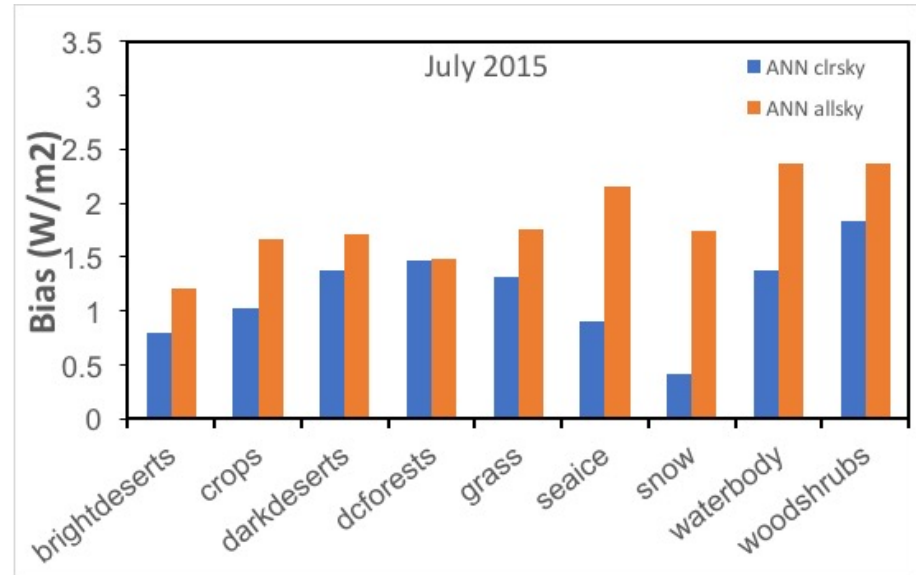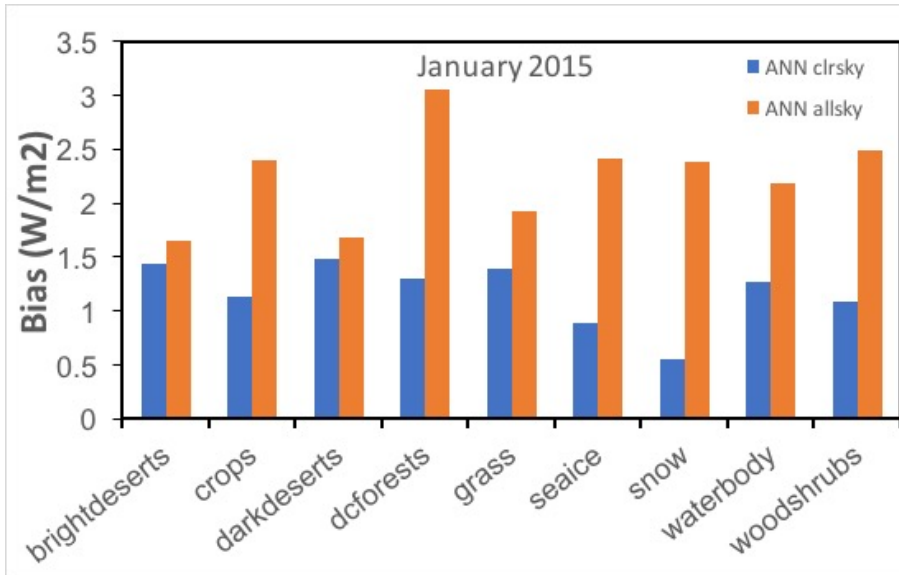
# Bias & RMS : SW Clear-sky Flux

$$\text{Bias} = \text{Flux}_{\text{ANN}} - \text{Flux}_{\text{SSF}}$$

# Bias & RMS : LW Clear-sky Flux

# Absolute Bias & RMS : LW clear-sky Flux

# TOA clear-sky Flux: $ANN_{clear}$ vs $ANN_{allsky}$

- ANN radiance to flux conversion of RF classified data (clear) is conducted using both modified ANN and original ANN method

- Analysis of the ANN derived Flux show that ANN clear sky method produce better results for majority of the cases (>60%) compared to the ANN all sky method.

| SURFACE TYPE | SW | | LW | |
|---|---|---|---|---|
| | JAN (%) | JUL(%) | JAN(%) | JUL(%) |
| bdesert | 64.5 | 67.3 | 84.1 | 63.7 |
| crops | 59.2 | 63.6 | 85.4 | 88.8 |
| ddesert | 57.3 | 64.7 | 82.8 | 77.1 |
| dforest | 65.0 | 68.6 | 63.7 | 59.8 |
| grass | 65.5 | 73.9 | 80.4 | 49.5 |
| savannas | 62.2 | 74.3 | 59.2 | 61.8 |
| seaice | 62.4 | 68.6 | 76.0 | 68.9 |
| snow | 63.5 | 77.4 | 60.9 | 71.2 |
| water | 58.1 | 67.9 | 67.4 | 67.0 |

# TOA clear-sky Flux

- Use **Random Forest** method to classify the CERES TOA radiances in to Clear-sky and Cloudy-sky data.

- TOA clear-sky fluxes estimated for the classified (by Random Forest) clear-sky radiances using ANN clear-sky/all-sky method.

- CERES  SSF Clear and All-sky fluxes

- ERBE-like  instantaneous Clear and All-sky fluxes

- ANN clear-sky method is used only in the estimation of clear-sky Flux in this analysis