The AMMA Land surface Models Inter-comparison Project - Microwave Emission Model (ALMIP-MEM)

Microwave and Land Surface Modelling evaluation against AMSR-E data over West Africa

P. de Rosnay, M. Drusch, A. Boone, G. Balsamo T. Pellarin, J.-P. Wigneron,

I – Introduction: ALMIP, ALMIP-MEM and soil moisture remote sensing

II – CMEM forward operator of surface microwave emission

III – Results: C-band ALMIP brightness temperature for 2006

Goal:

Obtain a better understanding of the West African Monsoon (WAM) on daily to inter-annual timescales. AMMA relies on:

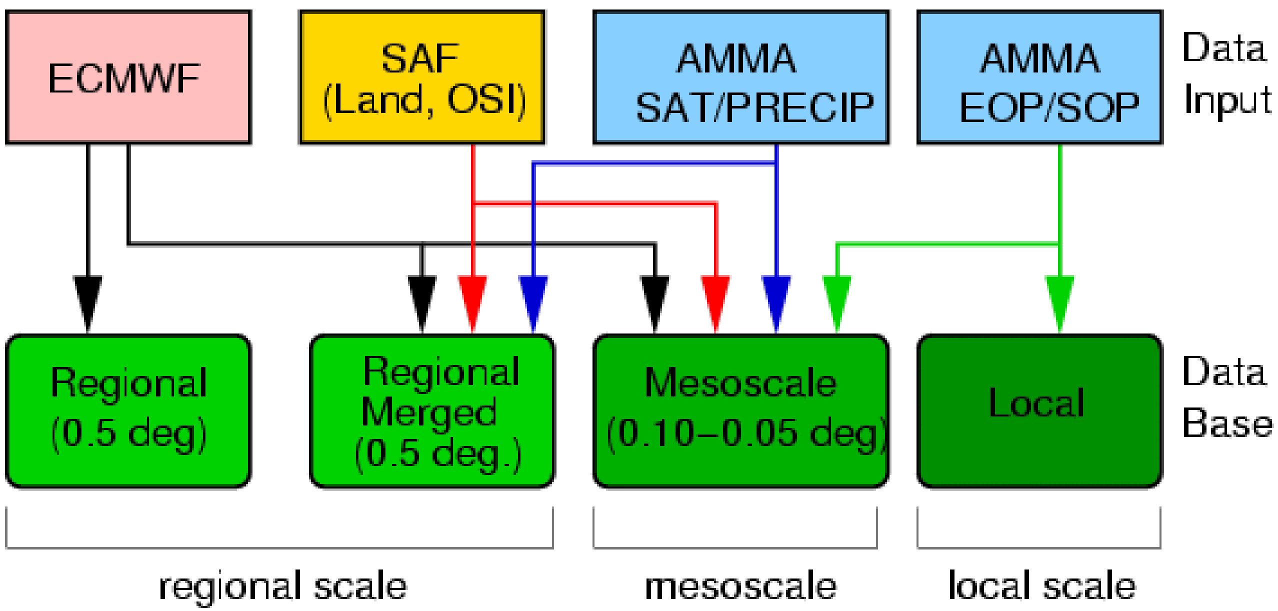
i) the use of extensive observations, notably multi-sensor remote sensing products,
ii) a multi-year field campaign over west Africa, and
iii) a coordinated modeling strategy at different spatial and temporal scales.

ECMWF Forecast Product (EXP1):

- Lowest model level atmospheric variables ➔ Tair, Qair, Wind, PSurf
- Vertically integrated fluxes ➔ SWdown, LWdown, Rainf, CRainf

Merged Forcing (EXP2):

- ECMWF + Satellite based



(Boone and de Rosnay 2007)

ALMIP LSMs

ORCHIDEE (GCM, Hydro)	LMD, Paris, France	J. Polcher, T. Orgeval, P. deRosnay
ISBA (GCM, NWP, MesoM, Hydro)	CNRM / Météo France Toulouse	A. Boone
TESSEL / HTESSEL /CTESSEL (NWP)	ECMWF, Reading, UK	A. Beljaars, G. Balsamo
JULES (GCM, NWP)	CEH, Wallingford, UK	C. Taylor, P. Harris
SETHYS (MM, Rem Sens)	CETP, France	C. Ottlé, S. Saux-Picart
CLSM (GCM, NWP, Hydro)	UPMC, France	A. Ducharne, S. Gascoin
IBIS (GCM)	ISE, Monpellier, France	C. Delire
SWAP (Hydro)	IWP, Moscow, Russia	Y. Gusev, O. Nasonova
SSib (GCM, MesoM)	U. Nantes, France, UCLA, USA	I. Poccard-Leclercq, Y. Xue
MIKE-SHE (Hydro)	U. Copenhagen	A. Norgaard, I. Sandholt
CLM (GCM, …)	NCAR, Boulder, USA	B. Lamptey
NOAH (NWP, MesoM, Hydro)	(NCEP, USA) CETP, France	C. Ottlé, B. Decharme

Validation of ALMIP simulation at regional scale ?
-> Use of soil moisture remote sensing

AMSR-E (**Advanced Microwave Scanning Radiometer on EOS**)

- 2002-present; 25km of spatial resolution, ~1 day
- Brightness Temperature at 6 frequencies, including
- C and X Bands (6.9 & 10.7GHz) for soil moisture remote sensing

SMOS (**Soil Moisture and Ocean Salinity**)

- Launch in Oct 2008 ; 40km of spatial resolution, ~3 day
- Brightness Temperature at L-Band (1.4GHz)
- Specifically designed for soil moisture remote sensing (over land)
- AMMA is an ESA validation site of SMOS for 2009

ALMIP-MEM

Concept:

Coupling ALMIP simulations to a Microwave Emission Model (CMEM)

CMEM: simulates C-Band Brightness Temperature as seen by AMSR (at C-band or X-band) or as seen by the future SMOS at L-Band

Validation with AMSR-E TB

Aim:

-> Range of TB simulated by ALMIP LSMs with diff forcing (Exp1-2)

-> Scatter C-band TB simulated by set of LSMs at regional scale

-> Validation of surface soil moisture simulated by LSMs

-> Test and validation of different microwave modelling approaches, with the modular Community Microwave Emission Model, to be used for the future SMOS

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CMEM: Community Microwave Emission Model

- Land surface emission model developed at ECMWF for Numerical Weather Prediction (NWP) applications
- To be used as the forward operator for computing TOA Brightness Temperature in the operational data assimilation scheme
- new highly modular software package providing I/O interfaces for the Numerical Weather Prediction Community
- Conceptually based on physical parameterizations:
    - LMEB (L-Band Emission of the Biosphere), Wigneron et al., 2007,
    - LSMEM (Land Surface Microwave Emission Model), Drusch et al., 2001
- Modular code: combines different parameterizations for computing surface and atmospheric emissions
- Specifically designed for L-band microwave emission for SMOS
- Also applicable for a large range of Freq: 1 GHz to 20 GHz (suitable RTTOV)

CMEM: Modular Model

Allows accounting for different parameterizations for each component:

- **Soil dielectric mixing model**

  (Wang & Schmugge / Dobson / Mironov)

- **Effective temperature model**

  (Choudhurry / Wigneron / Holmes)

- **Soil roughness model**

  (None = Smooth / Choudhurry / Wegmuller / Wigneron 01/07)

- **Smooth surface emissivity model**

  (Fresnel / Wilheit)

SOIL

- **Vegetation opacity model**

  (None / Kirdyashev / Wegmuller / Wigneron / Jackson)

VEGETATION

- **Atmospheric radiative transfer model**

  (None / Pellarin / Liebe / Ulaby)

ATMOSPHERE

In red: options to be tested/validated in ALMIP-MEM

CMEM: flexible portable software

CMEM is coded in Fortran90, according to NWP Centres requirements.

CMEM is flexible for:

- **Input / Output file format:**

  Grib, Ascii, Netcdf

- **Input / output file size and variable dimensions**

  Automatic detection of input size and variable allocations.

- **Portable code, for any Linux and Unix systems**

  Requirements: Grib and Netcdf both compiled with fortran 90

  NWP model routines and libraries are externalized (on going)

CMEM code: 8300 lines of fortran (43 subroutines)

Last tagged version of CMEM version 1.2, March 2008

http://www.ecmwf.int/research/ESA_projects/SMOS/cmem/cmem_index.html

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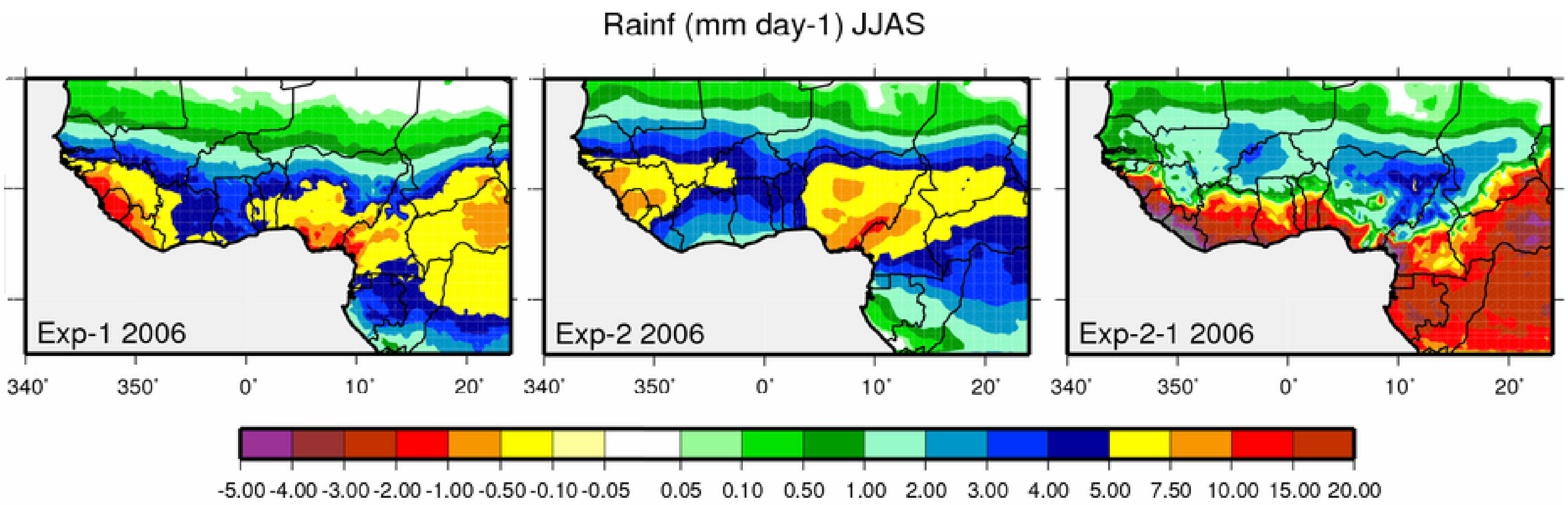


Rainfall differences between EPSAT-SG (Exp2) less ECMWF (Exp1)

Shift of the active monsoon rain-band to the north

ALMIP-MEM simulations:

- 2 ALMIP Experiments with different precipitation forcing (exp1, exp2)
- 6 LSMs (HTESSEL, CTESSEL, TESSEL, JULES, ISBA, ORCHIDEE)
- 2 observing configurations: C-band and X-band
- 2 orbits per day: desc. Orbit (night) and asc. Orbit (day)
- 12 configurations of the forward model:
    - 3 dielectric models (Dobson, Mironov, Wang)
    - 4 Vegetation models (Kirdyashev, Wigneron, Wegmueller, Jackson)

-> 96 simulations per LSMs

Total of 576 simulations

Each on 101x51x365 grid-cells (lon * lat * day) (1.9 10^6)

For the comparison and to compute background errors:
AMSR-E TB interpolated on the ALMIP grid (0.5 degree)

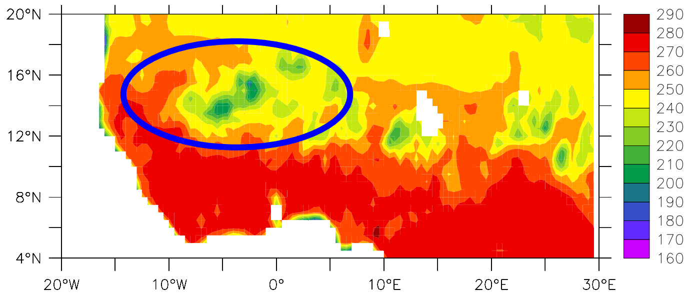
-> CMEM allows evaluating radiative transfer modelling for future SMOS validation

AMSR-E brightness temperature at horizontal Pol (TBH)

Wet Patches Shown by lower TB

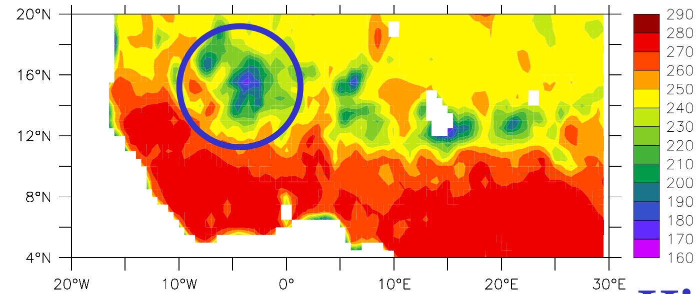
AMSR-E Descending orbit (1am), 2days average

Doy 190-191



AMSR TBH (Desc.) 6.9 GHz 190 2006

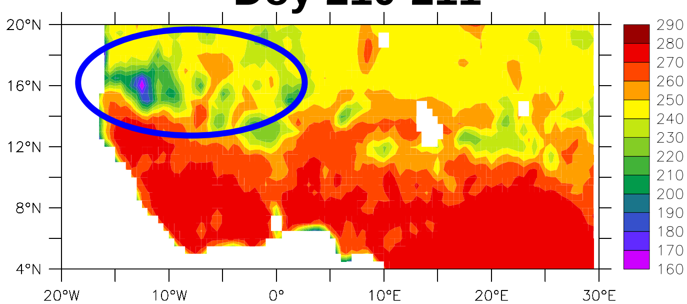
Doy 200-201



AMSR TBH (Desc.) 6.9 GHz 200 2006

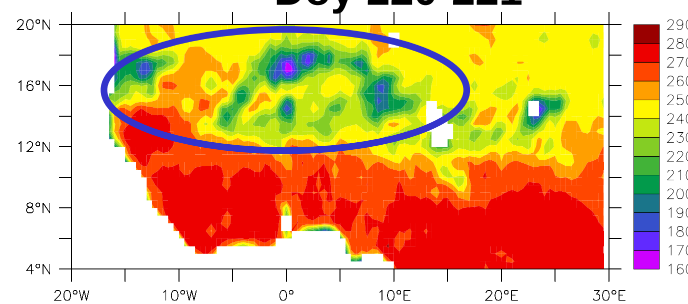
High vegetation with high TB

Doy 210-211



AMSR TBH (desc.) 6.9 GHz 210 2006

Doy 220-221



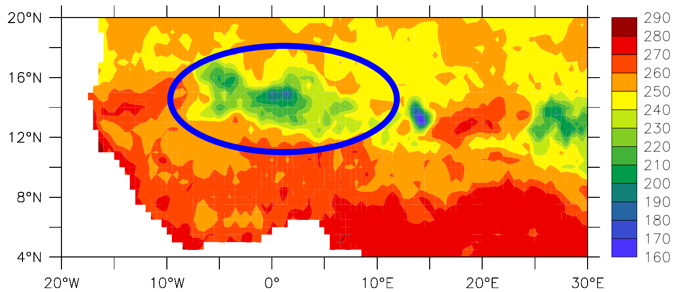
AMSR TBH (Desc.) 6.9 GHz 220 2006

ALMIP-Exp2 brightness temperature at horizontal Pol (TBH)
Four case study in 2006

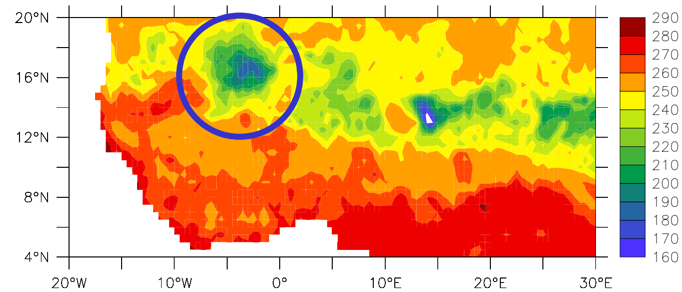
Soil Moisture: EXP2 (PRECIPAMMA forcing), ORCHIDEE-CWRR LSM (at 00.00 UTC, 2d ave)

Microwave module: Mironov dielectric and Kirdyashev opacity

Doy 190-191



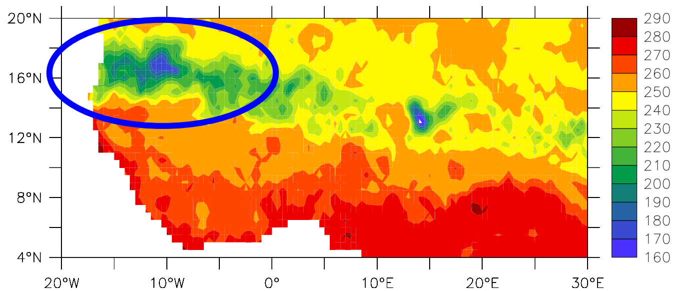
Doy 200-201



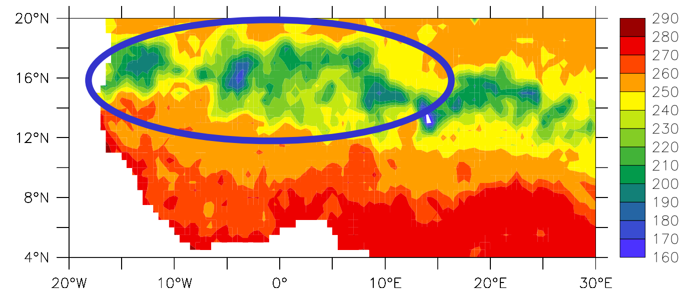
Corr AMSR-E

Doy	R
190	0.60
200	0.66
210	0.55
220	0.72

Doy 210-211



Doy 220-221



Year
R=0.74
B=-1.4K
RMSE=10.1K

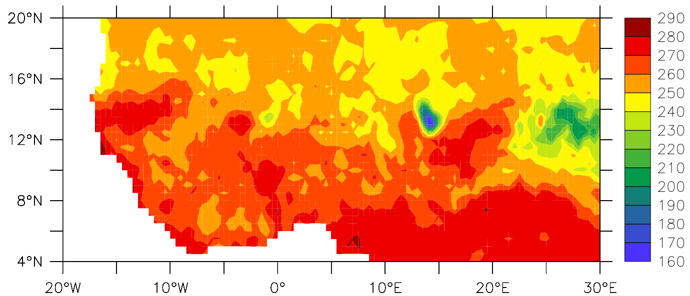
Good agreement between ALMIP-MEM and AMSR-E TBH spatial features

ALMIP-Exp2 brightness temperature at horizontal Pol (TBH)
Four case study in 2006

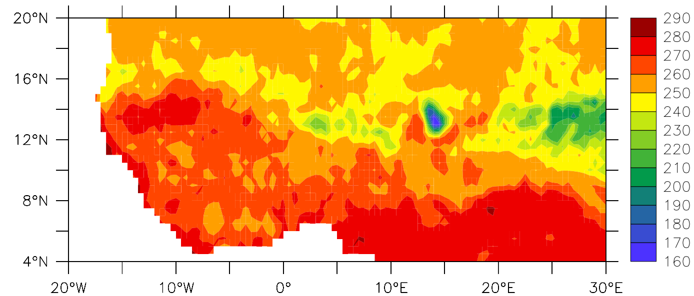
Soil Moisture: EXP1 (ECMWF prcp forcing), ORCHIDEE-CWRR LSM (at 00.00 UTC, 2d ave)

Microwave module: Mironov dielectric and Kirdyashev opacity

Doy 190-191



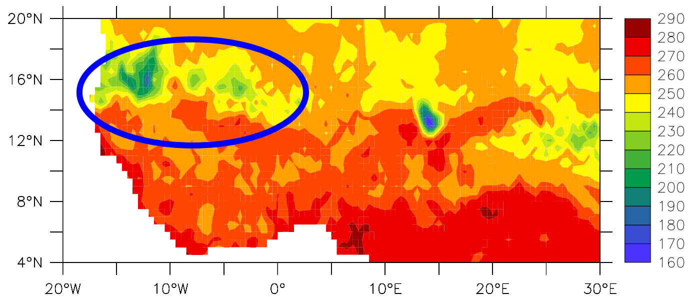
Doy 200-201



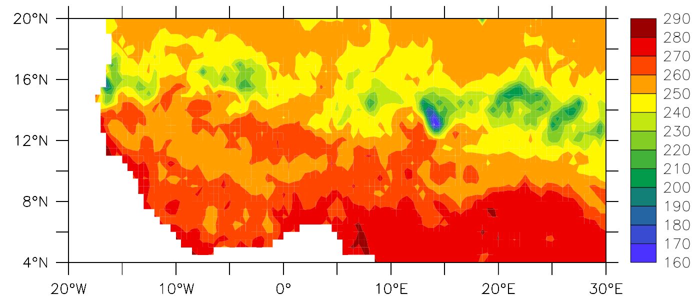
Corr AMSR-E

Doy	R2
190	0.46
200	0.39
210	0.46
220	0.47

Doy 210-211



Doy 220-221

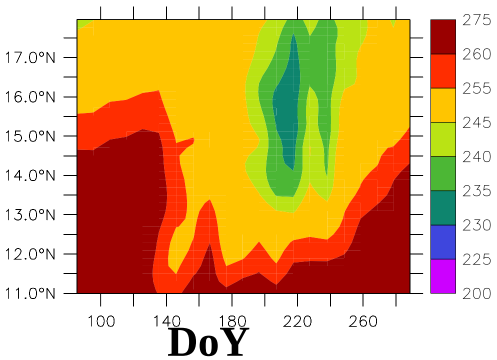


Year
R=0.67
B=1.5K
RMSE=10.6K

Much poorer agreement when simulated SM is obtained from Exp1

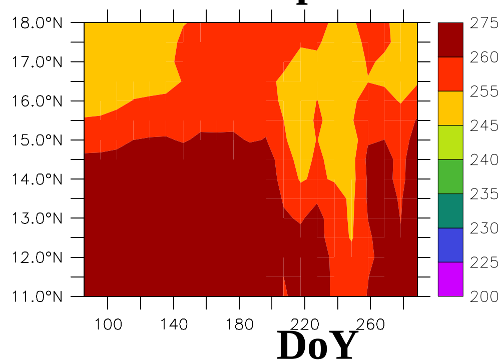
Latitude-Time diagram of TBH for 2006
(10W-10E ave)

AMSR-E

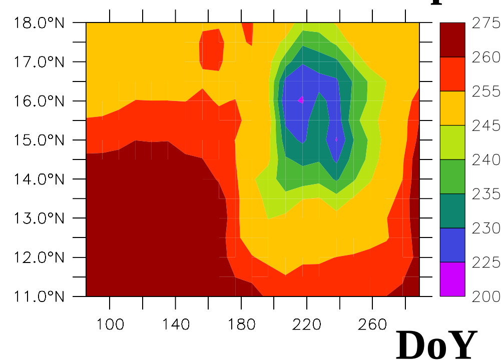


ALMIP (ORCH-CWRR)

Exp1



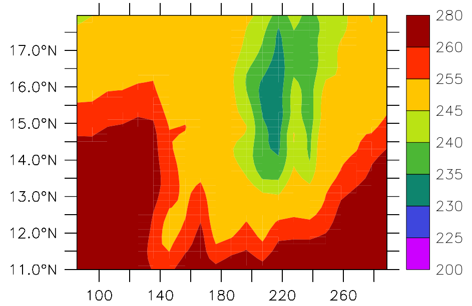
Exp2



- AMSR-E observation of TBH shows a wet patch in Lat-Time, over Sahel in Jul-Aug
- EXP1 (ALMIP simulation with ECMWF forcing) underestimates latitude-time dynamics
- EXP2 (ALMIP with PRECIPAMMA) captures the seasonal latitudinal dynamics of TB, showing that lat-time of soil moisture is captured by this model
- Wet patch over Sahel is slightly over estimated

AMMA

AMSR-E

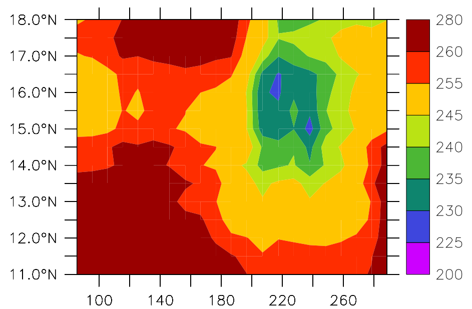


AMSR–E TBH Des. 6.9 GHz

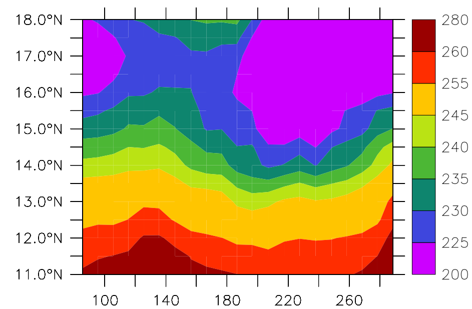
ALMIP AMMA Land Surface Model Intercomparison Project

Latitude-Time diagram of TBH for 2006 (10W-10E ave)

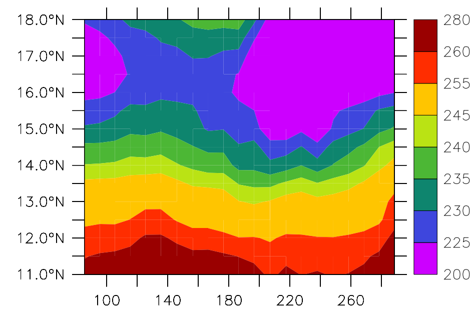
Best configuration for all land surface model: Wang and Kirdyashev or Mironov and Kirdyashev
Consistent with Skylab study (Drusch et al 2008)



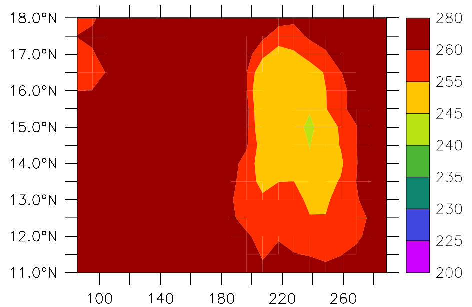
HTESSEL



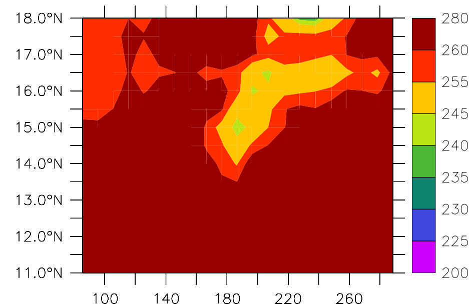
TESSEL



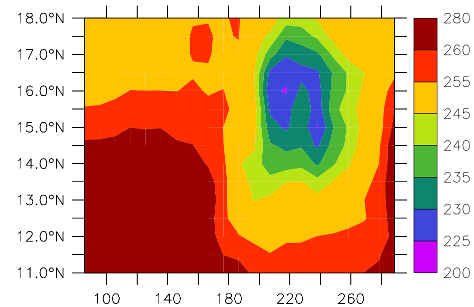
CTESSEL



JULES



ISBA



ORCHIDEE

AMMA

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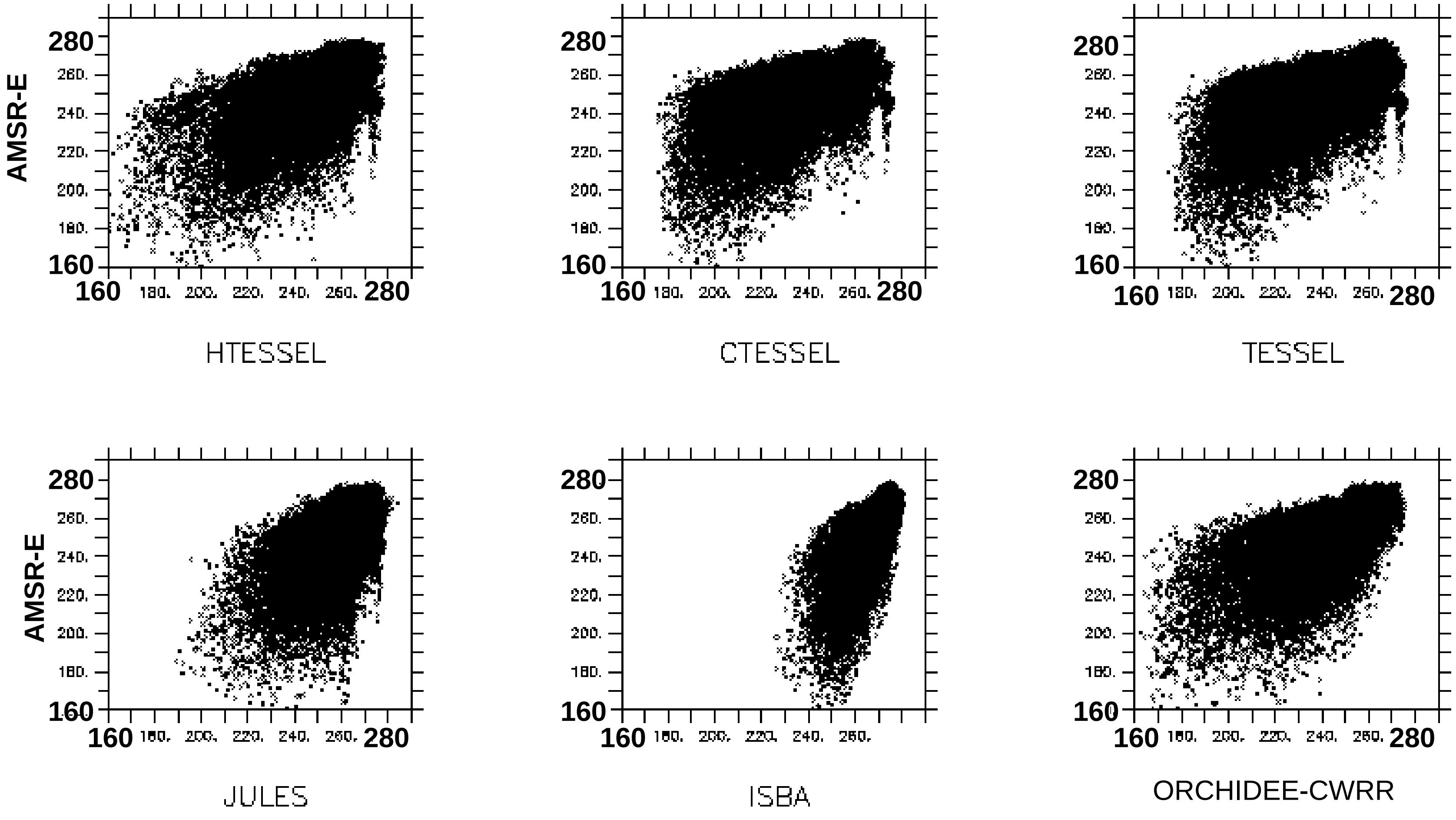
Scatter-plot of TBH (K) for JAS 2006 time series over the region

(Wang and Kirdyashev)



ECMWF

Quantitative comparison between LSMs, all using Wang and Kirdyashev for forward modelling:

Model	Correlation	RMSE	Bias
HTESSEL	0.54	13.4	1.6
TESSEL	0.69	19.2	-13.4
CTESSEL	0.67	19.1	-12.9
JULES	0.63	14.8	10.1
ISBA	0.69	14.2	10.1
ORCHIDEE	0.70	10.1	2
ORCHIDEE	0.74	10.1	-1.4

For all LSMs, Based on 365x2x51x101 Values (3.8 10^6)

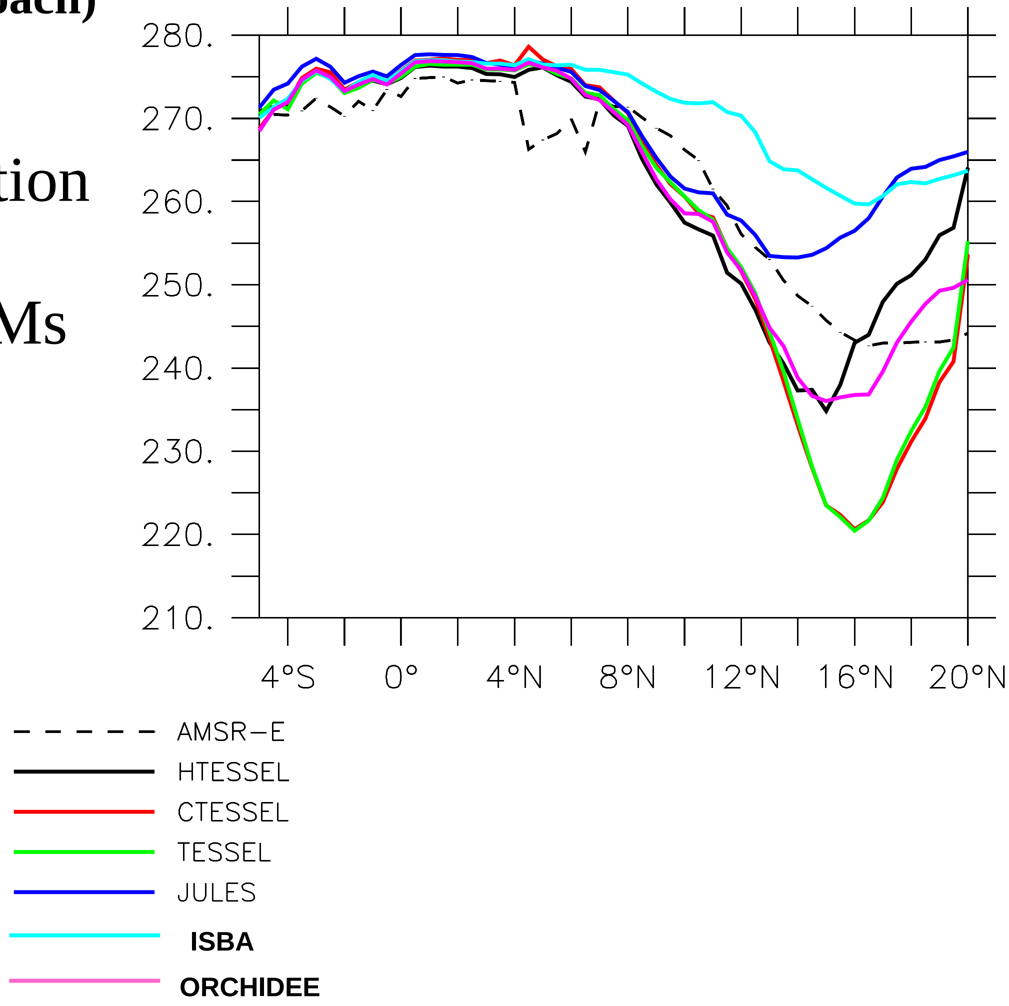
HTESSEL: very low bias suitable for assimilation

(<- orchidee best with Mironov)

Zonal distribution of TBH for all LSM coupled to CMEM Wang and Kirdyashev (different SM, same forward approach)

Scatter in the zonal distribution of TBH due to SM & T differences between the LSMs

-> importance of the LSM (SM & T first guess)



4N-16N: vegetation latitudinal gradient
16N: no more vegetation -> SM effect

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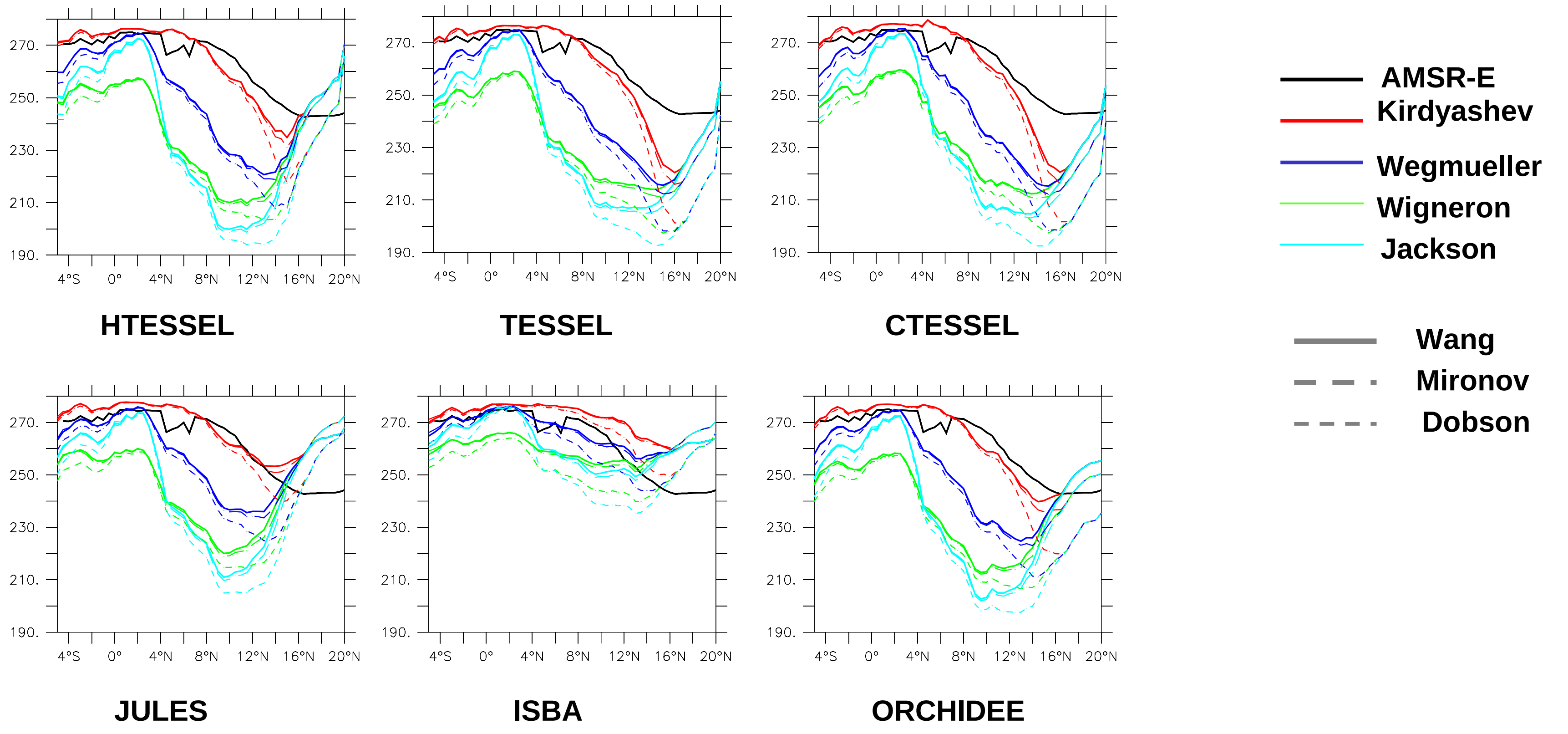
Zonal distribution of TBH for all LSM, all MW model, for JAS (monsoon)

Choice of vegetation opacity and soil dielectric models
-> scatter more important as that due to differences between LSMs
-> importance of the forward approach



ECMWF

Summary (1/2)

- ALMIP-MEM: Simulate C-Band and X-band TB as seen by AMSR-E Compare different LSMs and different radiative transfer modelling approaches
- Provide an evaluation of both simulated soil moisture and radiative transfer model by comparing with AMSR-E satellite data
- Based on CMEM modular software to compute SMOS microwave emission of land surfaces in NWP models
- Results of TB 6.9GHz simulated by 6 LSMs, in 12 different MW emission configurations. Coupled LSM-CMEM models capture convective system occurrence in Sahel, as well as latitude-time feature of TB
- Better precipitation forcing in EXP2 of ALMIP provides TB in better agreement with AMSR-E measurements

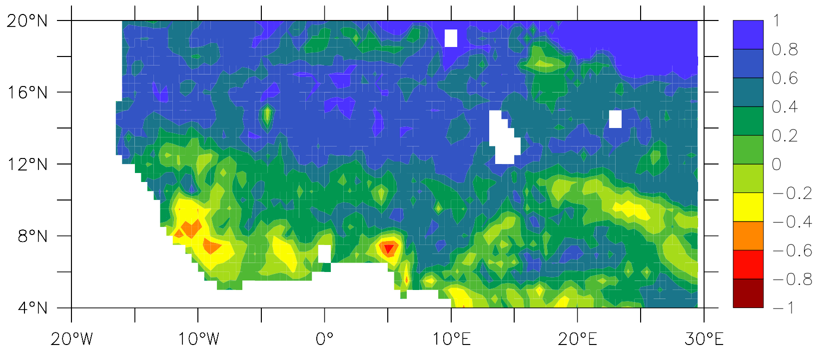
Summary (2/2)

- Different soil moisture and soil temperature 1st guess provides different values of simulated TB and different performances for the various LSMs considered.
- For all LSMs, Kirdyashev opacity model performs best, with lower Background errors compared to AMSR-E measurements

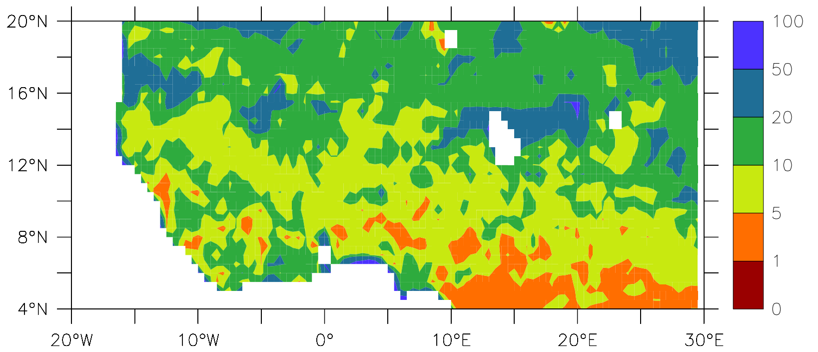
→ Results consistent with those of Skylab study (Drusch et al., 2008), although both incidence angle & frequency are different

- Dielectric models of Wang and Mironov provide the best agreement with AMSR-E C-band TB for any LSM
- Larger scatter in simulated TB due to microwave parameterization than that due to LSM differences
- Larger influence of microwave model than LSM (SM and ST)
- -> high importance of suitable MW modelling approach for SM retrieval and SM assimilation.

Publication ALMIP-MEM: de Rosnay et al. 2008, in prep



Correlation



RMSE (K)

Statistics on time series of TBH for HTESSEL-CMEM EXP2, Wang and Kirdyashev:
- Temporal dynamics very well captured from 5N to 20N
- RMSE very low over forest. Getting larger over Sahel